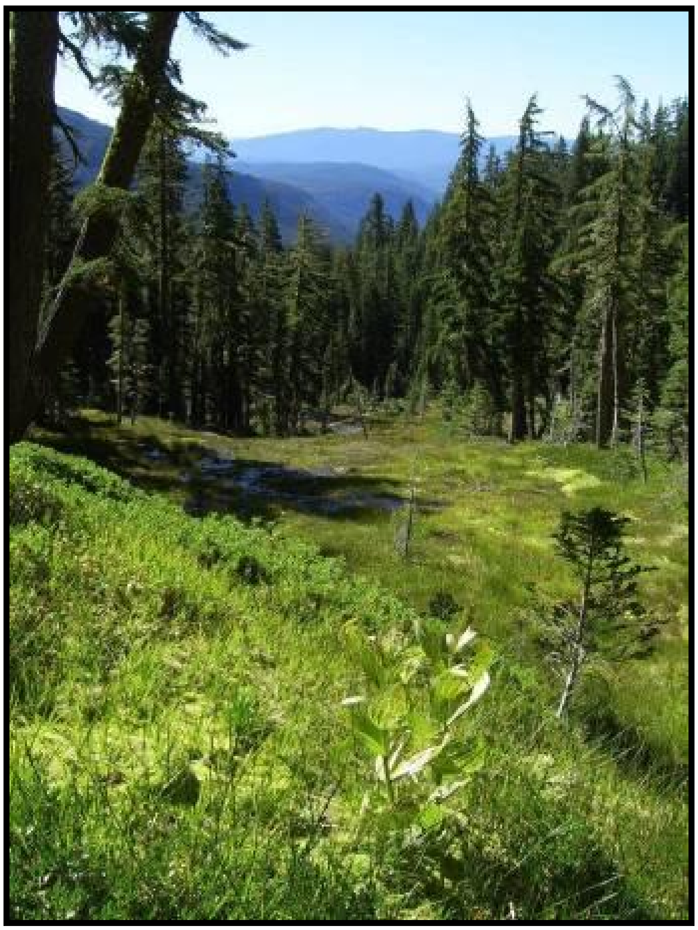
National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Wetlands of Lassen Volcanic National Park: *An Assessment of Vegetation, Ecological Services, and Condition*

Natural Resource Technical Report NPS/KLMN/NRTR—2008/113



ON THE COVER
A wetland in Lassen Volcanic National Park.
Photograph by: Cheryl Bartlett

Wetlands of Lassen Volcanic National Park: An Assessment of Vegetation, Ecological Services, and Condition

Natural Resource Technical Report NPS/KLMN/NRTR—2008/113

Paul R. Adamus, PhD
College of Oceanic and Atmospheric Sciences
Oregon State University
104 COAS Administrative Bldg
Corvallis, OR 97331-5503

Cheryl L. Bartlett
Department of Botany and Plant Pathology
Oregon State University
2082 Cordley Hall
Corvallis, OR 97331-2902

March 2008

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The Natural Resource Publication series addresses natural resource topics that are of interest and applicability to a broad readership in the National Park Service and to others in the management of natural resources, including the scientific community, the public, and the NPS conservation and environmental constituencies. Manuscripts are peer-reviewed to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and is designed and published in a professional manner.

The Natural Resource Technical Reports series is used to disseminate the peer-reviewed results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service's mission. The reports provide contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations. Current examples of such reports include the results of research that addresses natural resource management issues; natural resource inventory and monitoring activities; resource assessment reports; scientific literature reviews; and peer reviewed proceedings of technical workshops, conferences, or symposia.

Printed copies of reports in these series may be produced in a limited quantity and they are only available as long as the supply lasts. This report is also available from the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/NRPM) on the Internet or by sending a request to the address on the back cover.

Please cite this publication as:

Adamus, P. R., and C. L. Bartlett. 2008. Wetlands of Lassen Volcanic National Park: An assessment of vegetation, ecological services, and condition. Natural Resource Technical Report NPS/KLMN/NRTR—2008/113. National Park Service, Fort Collins, Colorado.

NPS D-163, March 2008

Contents

Appendixes

Figures

Tables

Summary

During 2005, we visited and assessed the health of 68 wetlands throughout Lassen Volcanic National Park (LAVO), covering an area equal to 39% of the park's wetland area. Of the wetlands visited, 47 were selected using a statistical procedure that drew a spatially-balanced randomized sample from an existing map of LAVO wetlands. Among the visited wetlands, we surveyed a total of 78 plots dominated by herbaceous wetland vegetation and 15 plots dominated by wetland shrubs or trees. We also characterized soil profiles and observed hydrologic conditions. Before beginning the field work, we used GIS and a variety of existing spatial data layers to quantitatively characterize all mapped LAVO wetlands.

Wetlands in LAVO occur in a variety of settings, including stream riparian areas, pond margins, alder-covered slopes, springs, montane meadows, and snowmelt depressions. Based on the hydrogeomorphic (HGM) classification system, about 45% of the wetlands are Depressions or Flats, 38% are Slope wetlands, 7% are Riverine, and 1% are Lacustrine Fringe. Based on the Cowardin classification system, 34% of the LAVO wetlands area is emergent vegetation, 24% is scrub-shrub, 7% is forested, and the remainder is open water or aquatic bed. Slightly fewer than one-third of the wetlands retain some surface water year-round. At least one plant species characteristic of fens (an uncommon type of mossy groundwater-fed wetland) was found in 23 of the wetlands, but soil profiles provided definitive evidence of fen conditions in only two of the visited wetlands. We discovered three wetlands that appear to be a type – acid geothermal fen – that is rare globally and apparently had not been documented previously in the Sierra-Cascade system.

Many factors define wetland health (or integrity), including contaminants in air, soil, vegetation, and water that were not measured by this study. Few indicators of wetland health can be estimated rapidly and at reasonable cost across a large number of wetlands. When health is defined solely by the prevalence of native plant species and scores from the California Rapid Assessment Method (CRAM), most LAVO wetlands appear to be relatively healthy. We found 19 disturbance-associated plant species (6% of all species we encountered) among 44 of the 68 wetlands we visited. From zero to six such species were found per wetland, but never dominated the vegetation cover. They were more frequent near roads but not trails.

Our sample of just 68 wetlands detected 51% of LAVO's known wetland flora, and added six species to the LAVO plant list. Among the 338 plant taxa (both wetland and upland) we found in the visited wetlands were at least two that are listed by the California Native Plant Society as rare or having limited distribution. In most wetlands, more than 30 plant species were found, and most of the 100 m^2 herbaceous plots we surveyed had more than 13, with a maximum of 43. The plant species composition tended to be more unique in wetlands that were dominated by emergent (herbaceous) vegetation, not on lakeshores, at lower elevations, and intercepted by streams.

Wetlands in LAVO perform a variety of ecological services. In each visited wetland, we visually assessed presumed indicators of nine of the most common ecological services (functions). Based on that, we found that more of LAVO's wetlands are likely to support native invertebrates, birds, and mammals at a high capacity than are likely to effectively support fish, filter suspended sediments, or maintain surface water temperatures.

Although major objectives of this project did not include mapping wetland boundaries or comprehensively identifying previously unmapped wetlands, we did incidentally discover 87 unmapped wetlands and found that the spatial extent of many mapped wetlands had been underestimated. All visited sites that had been previously mapped as wetlands were found by our field inspection to be wetlands. Attempts to develop spatial models for predicting occurrence of unmapped wetlands were only partially successful, due mainly to limitations of existing spatial data layers.

Acknowledgments

The need for this project was identified by Dr. Daniel Sarr, I & M Coordinator, Klamath Network, National Park Service. His support and feedback throughout the project was absolutely crucial to its success. Dr. Jim Good at Oregon State University administered the agreement (Cooperative Agreement #CA9088A0008). At Lassen Volcanic National Park (Figure 1), the thoughtful administrative support from Nancy Nordensten (Biologist) and Louise Johnson (Chief of Resources Management) helped our field work go smoothly. Field assessments of wetland soils were done by Nick Pacini, and John Beickel helped with a variety of field tasks. Early in the project, Andrew Duff (then at Southern Oregon University) used GIS to identify and compile the most important spatial data layers for LAVO. Expert assistance with identification of sedges was provided by Dr. Laurence Janeway at Chico State University. Dr. David Cooper of Colorado State University generously shared his knowledge of Sierra fens. Jennifer Larsen and Rebecca Tully, graduate students advised by the author at Oregon State University, assisted with the GIS tasks and data entry tasks, respectively.

Figure 1. The rugged high-elevation landscape of Lassen Volcanic National Park.

1.0 Introduction

1.1 Study Background and Objectives

Wetlands include portions of features as varied as springs, seeps, alder swales, montane meadows, cottonwood stands, ponds, beaver impoundments, snowmelt pools, marshes, bogs, and fens. As water-gathering foci in watersheds, wetlands are especially vulnerable to impacts at landscape and local scales. They also are an excellent indicator of the overall ecological health of the watersheds within which they occur. Wetlands in Lassen Volcanic National Park (LAVO) are potentially vulnerable to a range of cumulative impacts, including non-native species invasions, air-borne or water-borne pollutants, hydrologic alterations, and excessive traffic. Some of them may be experiencing lingering effects of grazing, drainage, and logging that occurred historically, as well as the volcanic eruptions of 1914-1915.

Like a similar project in Crater Lake National Park (Adamus and Bartlett 2008), this project sought to address three main questions:

- What is the general accuracy of the existing National Wetlands Inventory (NWI) maps of LAVO wetlands?
- What is the relative ecological health of LAVO wetlands?
- What is the most consistent and logical scheme for defining plant species assemblages (communities) of LAVO wetlands?

These objectives are consistent with the park enabling legislation, the national goals of the Inventory and Monitoring Program (including Vital Signs Monitoring), and future park management. This project was not intended to be either a research study (in the sense of testing specific hypotheses) or a comprehensive resource *inventory* of wetlands or plant species. Rather, it is a resource *assessment*, characterizing the overall distribution, health, ecological services, and types of wetlands within the park. Such an assessment is necessary to provide a baseline against which future changes may be monitored – and their causes sought and where necessary, remedied (Bedford 1996). Data compiled and analyzed by this assessment also support quantitative reference standards for ongoing wetland management and restoration activities. Currently, managers are hindered in assessing the severity of possible impacts to wetlands because there are no systematic data that quantify what unaltered wetlands of each major type "should" look like, in terms of the range of plant diversity, species composition, and ecological services.

1.2 Wetland Health and Its Indicators

Whether discussing wetlands (Figure 2), forests, or rangelands, the terms, "ecological condition," "health," "integrity," and "quality" are often used interchangeably. As noted above, a major objective of this project was to estimate the proportion of LAVO wetlands that are "healthy." However, although scientists and policy makers have long struggled with the question of how to define wetland health or ecological condition, *no consensus on a definition of wetland health – let alone an accepted procedure for measuring it comprehensively – currently exists* (Young and Sanzone 2002). To some, health is synonymous with the "naturalness" of a wetland's biological communities and hydrologic regime. For example, by such criteria, wetlands that support only native species, and especially native species that are intolerant of pollution and other human disturbance, are considered to be the healthiest. To other scientists and policy makers, wetland health means the degree to which a wetland performs various ecological services – such as storing water, retaining sediments, and providing habitat. Still other professionals believe that wetland health should reflect not only the performance of these ecological services (sometimes called "functions"), but also the *value* of the services that are provided to society in specific local settings. These three perspectives are not synonymous, interchangeable, or inevitably correlated, at least not when using only data that can be assessed rapidly (Hruby 1997, 1999, 2001). Alternatively, some have suggested use of the phrase, "proper functioning condition" to describe ecosystem health and have suggested qualitative indicators and a "condition checklist" for its assessment in fen wetlands (see below) and freshwater wetlands of the arid West (Pritchard 1994, Rocchio 2005). However, such checklists or scorecards require considerable judgment on the part of the user, tend not to generate consistent results among users and across a variety of wetland types in different regions, and are often not sensitive to important differences between wetlands. The visually-based estimates they provide have seldom been tested for correlation with meaningful measured data. Finally, the term "desired future condition" has been suggested. Although this term makes explicit the value judgments involved, the term can be defined by managers in almost any manner, which confounds the interpretation of results from broadscale comparative assessments.

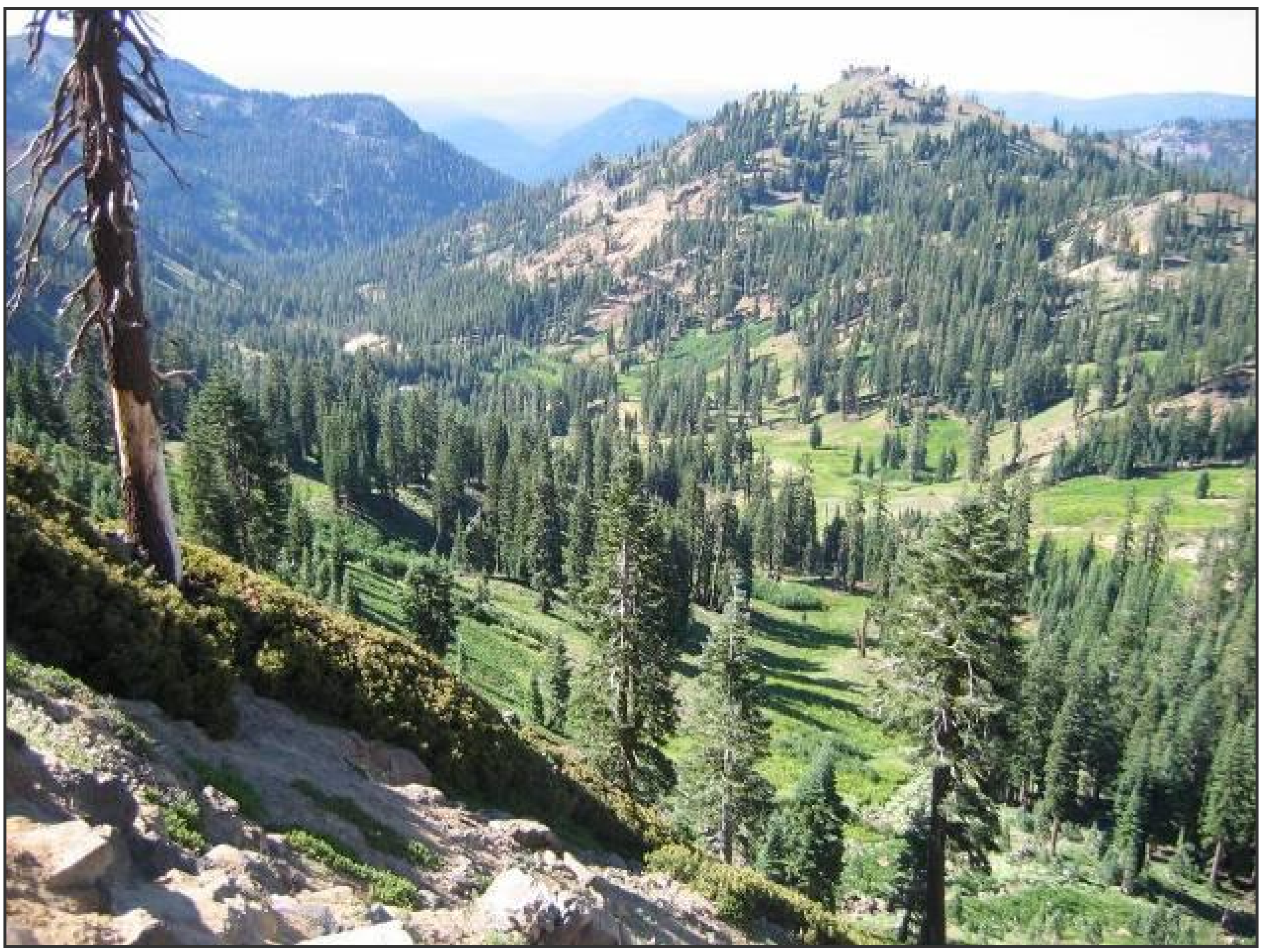


Figure 2. Groundwater-fed wetlands in LAVO often occur in meadows at the toe of steep slopes.

Attempts to define wetland health become further confused when the simple presence of activities or features that have the *potential* to disturb wetland biological communities, ecological services, and values are *assumed* without site-specific evidence to have had that effect, and the alteration is assumed to inevitably be “negative” from a human perspective. For example, a trail adjoining a small, sensitive wetland has the potential to introduce sediment into the wetland during periods of high runoff. But without further evidence, this cannot be assumed to occur, because many trails are on soils highly resistant to erosion. Even if sediment enters the wetland, the effect on wetland services, values, and health cannot be assumed to necessarily be negative.

A major challenge has always been to find *indicators* of the key ecological attributes and processes – as well as for wetland health, ecological condition, naturalness, ecological services, and value – that are both highly repeatable (among different users) and practical to apply. Many features that could yield the most information for judging ecological services and health cannot be measured without a considerable monitoring investment in each wetland over long periods of time. Examples include the duration and frequency of flooding, proportionate contributions of various sources of water, soil organic content and buildup rates, functional diversity of microbes and invertebrates, contamination of sediments, seed germination rates, and wildlife productivity and consistency of use. Often the most rapid and objective (but not comprehensive) approach for estimating the health of wetlands is to identify their plants. Many plant species can serve as excellent indicators of wetland health (Adamus and Brandt 1990, Adamus et al. 2001); see also: http://www.epa.gov/waterscience/criteria/wetlands/. In some regions, a “floristic quality index” has been developed and applied to assess wetland health, but such a metric has not been developed for this region. It requires a considerable amount of basic information on tolerances of wetland species to various types of disturbances.

1.3 General Description of LAVO

The following is paraphrased from existing LAVO reports by the NPS:

> **Water Bodies and Alterations**. The 106,372-acre park contains over 200 lakes and ponds and 15 perennial streams. Some lakes have been significantly modified by stocking of non-native sport fish, a practice that ended in 1980. Some of the natural drainage systems in the park have been altered. The most obvious of these are Manzanita and Reflection Lakes in the park’s northwest corner, and Dream Lake in Warner Valley. Manzanita Lake was created from the Chaos Crags rockfall avalanche 300 years ago and was enlarged with a dam in 1911 for a small hydropower operation. Water was also diverted from Manzanita Creek to Reflection Lake, originally a closed basin lake, to provide water power and to improve fish production. Dream Lake was impounded as a recreational and scenic feature for the Drakesbad resort. Natural drainage patterns in Warner Valley were also altered by early ranchers to more evenly distribute water in the meadow for livestock grazing. The park contains 42 miles of paved roads, 15 miles of unpaved roads, five small bridges, and 146 miles of trails.
>
> **Soils**. The soils are generally rocky, shallow, rapidly drained and strongly acidic. They are almost exclusively volcanic in origin. Depths vary from several feet in limited lower elevation meadows to thin or nonexistent on the higher elevations.
>
> **Vegetation.** As a result of the park being located near the junction of two great mountain ranges, the Cascades and the Sierra Nevada, and intersecting with the Great Basin, there is an overlap of floral species commonly specific to one of these provinces. The diversity of geologic formations and chemical and textural compositions of lava have resulted in a wide diversity of plants in these communities and many anomalies to the altitudinal life zones. Four major plant communities are found within the park: yellow pine forest, red fir forest, subalpine forest, and

alpine fell fields. These correspond roughly to the four life zones: Transition, Canadian, Hudsonian, and Arctic-alpine. The yellow pine forest, found at elevations below 6,000 feet, typically consists of sugar pine, Jeffrey pine, white fir, and incense cedar. The widespread red fir forests at elevations between 6,000 and 8,500 feet consist of lodgepole pine, Jeffrey pine, western white pine, red fir and mountain hemlock. The subalpine forest, at the upper limit of the coniferous forest, is characterized by the whitebark pine, a highly weather-resistant plant that grows at elevations as high as 10,000 feet. Above timberline are the alpine meadows and fell fields. Brushland covers approximately 10% of the park, consisting primarily of greenleaf manzanita, pinemat manzanita, and snowbrush ceanothus. Other common shrubs are currant, gooseberry, serviceberry, bitter cherry, and California chinquapin. Much of the park is rocky, exposed, and relatively devoid of forest vegetation. Volcanic eruptions of Lassen Peak in 1914 to 1915 destroyed over 7 square miles of forestland. Pioneering lodgepole pines are now succeeding in many areas to the other pines and firs. Historically, human activities within the park included the grazing of horses, sheep, and cattle; the treatment of insect-infected trees; and the suppression of virtually every wildfire for almost 90 years.

1.4 Previous and Ongoing Studies Related to the Park's Wetlands

Wetlands of LAVO have not previously been studied in a holistic and statistically-rigorous manner. Botanists had previously visited many of the park's wetlands (as well as all other habitat types) non-systematically, as reflected in publications on the park's vascular plants (Gillett et al. 1961) and mosses (Showers 1982). Their published data are of limited use in assessing wetland health because they were not referenced to precise geographic locations. One large, partially-restored wetland along the southern edge of the park – Drakesbad Meadow – has been the object of an intensive study of its hydrology, soils, and vegetation (Patterson 2005). Lichens have been monitored systematically since 1996 along transects in nearby Lassen National Forest, as indicators of air quality. Although not specific to wetlands, NPS-sponsored efforts are currently underway to develop and apply a classification scheme to vegetation of LAVO and other parks in the region, building upon an earlier effort by White et al. (1995).

Amphibians, reptiles, and fish were the objects of a rapid visual survey of 365 LAVO ponds (Figure 3), lakes, and meadows in 2004 by researchers from the USDA Forest Service (Dr. Hartwell Welsh) and Southern Oregon University (Dr. Michael Parker) (Stead et al. 2005). Habitat characteristics of those sites were also rapidly assessed, and all data were geographically referenced. For the present study, we surveyed plants, soils, and structural indicators of wetland ecological services at many of the same sites. Also, park biologists and interns have surveyed some ponds and wetlands for particular wildlife species, such as nesting bufflehead (a duck species that reaches the southern limit of its breeding range near the park). Invertebrate samples were collected in 2004 from many LAVO ponds and wetlands, and a report summarizing the data has been prepared by Dr. Michael Parker of Southern Oregon University.

Information on the distribution of soil types within the park is limited, but a comprehensive survey is currently underway. Water quality has been measured in various streams, lakes, and in a few springs, but not from wetlands (NPS-WRD 1999). Some of the results are summarized in Table 1. Water quality in wetlands is determined not only by proximity to pollutant-generating human activities, but also by water source (groundwater vs. surface water runoff), residence time (flow rate), location (high or low in watershed and east or west side of park, which correlate with precipitation), and soil type.

Microbial and algal diversity in LAVO hot springs also has been characterized (e.g., Brown and Wolfe 2006).

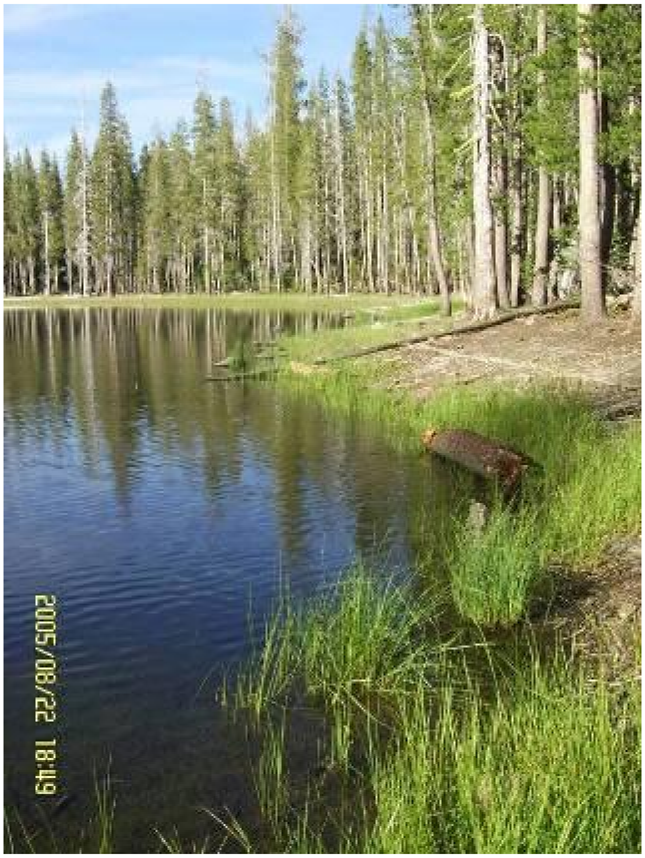


Figure 3. Wetland on the fringe of a pond.

Outside the park, several publications discuss the ecological condition and threats to wetlands and other aquatic habitats in the northern Sierra – southern Cascade region (e.g., Moyle and Randall 1998). Quaking aspen stands and montane meadows of the Sierras, many of which are wetlands, are the focus of a regional wildlife and vegetation study by Dr. Mike Morrison and others from UC Davis. A statistical classification of vegetation communities of one of the region's montane wetland types – fens – was published recently by Cooper and Wolf (2006) and a vegetation classification has been attempted for the region's riparian areas (Smith 1998). A qualitative method for assessing the ecological condition of fen wetlands of the Sierras and southern Cascades was proposed by Weixelman et al. (2007), following generally the "Proper Functioning Condition" (PFC) approach used widely by some federal agencies (Pritchard 1994). A qualitative method for assessing the ecological condition of all major types of California wetlands (California Rapid Assessment Method, termed CRAM) was published by Collins et al. (2006). We applied it to the LAVO wetlands we visited.

Table 1. Summary of past water quality exceedences in LAVO water bodies.

Parameter	% and # of sampled stations* with any exceedence	Examples of Exceedence Locations*
Dissolved Oxygen	5% (19)	Reflection Lake, Horseshoe Lake Butte Lake, Boiling Springs Lake
pH	38% (85)	Growler & Morgan Hot Springs (high), Bumpass Hell spring (low)
Turbidity	3% (1)	Reflection Lake
Chloride	11% (15)	Growler & Morgan Hot Springs
Sulfate	13% (16)	Sulfur Works
Arsenic	50% (8)	Growler & Morgan Hot Springs
Barium	37% (7)	Growler & Morgan Hot Springs, Little Hot Springs Valley, Sulphur Works

* "Exceedence" refers to exceedence of national (USEPA) water quality criteria for freshwater as interpreted by NPS-WRD (1999). LAVO waters have not been sampled comprehensively and the sampling stations are not a representative statistical sample of LAVO waters.

2.0 Methods

We used three complementary strategies for characterizing the wetlands of LAVO:

1. **GIS Strategy**. This involves summarizing available information on every known wetland within the park. By measuring the entire wetland population using digital spatial data and GIS, it avoids having to extrapolate data collected from a limited number of sites whose representativeness and scope can be challenged. However, the merits of this comprehensive strategy can be offset if spatial data are unavailable for themes relevant to wetlands, or if spatial data are inaccurate or spatially imprecise.
2. **On-site Sampling, Randomized**. This involves measuring only a limited number of wetlands, but has the advantage of allowing collection of more detailed and accurate information during actual site visits. Selecting sites in a statistically random manner for those on-site visits allows inference to the entire population. However, it is seldom feasible to sample enough of a park's wetlands during a single field season to allow reliable extrapolation of all the measured wetland features.
3. **On-site Sampling, Selective**. This involves augmenting (not replacing) the randomly-selected wetlands with ones that have complementary features not included in the random sample, such as greater levels of environmental threat, rare soil types, and extreme elevations.

These strategies are now described in more detail.

2.1 Initial Site Characterization

We began this project by obtaining just-completed wetlands maps for LAVO from the National Wetlands Inventory. Those digital maps had been based solely on recent aerial imagery and had not been checked in the field for accuracy. The maps show gross cover types (emergent, shrub, forested, etc.) as distinct polygons (shapes). Where these are contiguous, they had not been digitally joined to create a hydrologically "whole" wetland, so this was done by a graduate student at Oregon State University (Jennifer Larsen) supervised by the project scientist (Dr. Paul Adamus). Ms. Larsen overlaid the resulting wetland polygons with digital maps of various other natural resource themes that had been prepared for LAVO over previous years, as identified and compiled in an inventory by Andrew Duff, formerly on the faculty of Southern Oregon University. The result was a database describing multiple attributes of each wetland polygon. Dr. Adamus organized and queried the database to yield several cross-tabulations useful for defining reference conditions and the range of natural variability. The resulting statistical profile of LAVO wetlands is provided in Section 3.2.

2.2 Wetland Inventory

This project was not intended to provide a complete inventory of wetlands in all or any part of LAVO, nor to delineate with high precision the boundaries of any of the park's wetlands. Rather, a primary objective was to determine what proportion of areas mapped by the National Wetlands Inventory (NWI) as wetlands are actually not wetlands (i.e., "commission errors"). This was accomplished by our field inspections, as described in Section 2.4.

A secondary objective was to estimate the extent to which areas not mapped as wetlands may actually contain wetlands (i.e., "omission errors"). This was attempted using statistical modeling and follow-up field inspections. Specifically, to estimate the omission error rates, we first selected approximately 1000 points mapped as palustrine wetland by NWI and 1000 non-wetland points. The points in each group were selected as a spatially-distributed random sample using the GRTS[1] algorithm (see next section). The wetland points were selected only in palustrine wetlands because locations of such wetlands were anticipated to be the least difficult to predict using spatial modeling of existing park data layers. Using the GIS, at each point we determined the geologic type, elevation, annual precipitation, stream presence/absence, and several topographic variables (slope, compound topographic index, curvature, plan curvature, profile curvature). Operating under a temporary hypothesis that the NWI digital map contained no errors of omission or commission, we used two approaches to develop models for predicting wetland presence/absence in LAVO. One approach employed Logistic Regression and the other used a recursive-partitioning ("tree") algorithm called CHAID (Chi-square Automatic Interaction Detection). For Lassen Volcanic National Park, both yielded models that explained 70-80% of the variance, but the CHAID model was far more informative. It yielded a series of 16 decision rules that were easily converted to GIS queries of the spatial data. For example, one of the 16 rules stated the following:

> "If SLOPE is greater than or equal to 0 and is less than 0.93 and ANNUAL PRECIPITATION is greater than or equal to 1171 and is less than or equal to 3164 then there is a 92 percent chance that the point is a WETLAND."

2.3 Field Site Selection

We estimated that we would be able to assess an average of about one wetland per day, allowing for variations in wetland accessibility, size, and other contingencies. Given a single field season of about 60 days (late June through September), we estimated that approximately 60 wetlands could be visited once, using one crew of two persons. Wetlands to be assessed in the field (Table 2, Figure 4) were chosen using two strategies, one random and the other non-random (selective). The random strategy featured the use of GRTS (Stevens 1997, Stevens and Olsen 1999, 2003, 2004, Stevens and Jensen 2007), a state-of-the-art statistical algorithm being used by several state and federal resource agencies, and applied to our data by its developer, Dr. Donald Stevens at Oregon State University. GRTS selected a statistically-random sample of spatially-distributed points. That is, wetland sample points were selected randomly in a manner that gave equal weight to all parts of the park that have wetlands. Use of GRTS minimizes problems associated with spatial autocorrelation, which otherwise limits making valid statistical inferences from site-level data to an entire park. The GRTS application resulted in a list of 939 points, one for each NWI wetland polygon. Of course, not all wetlands (points) could be visited during the single season available for field work, so only the first 48 specified by the GRTS application were visited, and 20 additional wetlands were selected judgmentally. Selecting points in their GRTS sequence was necessary to achieve geographic spread and maintain statistical integrity of the sample. One of the 48 points (K38) had been mapped by NWI as wetland but our field data suggests it may not be.

An additional 57 points not prioritized as highly by the GRTS application were visited but not fully assessed. Of those, 14 were in areas mapped as wetlands and were selected to include major features not present among the 48 randomly-selected GRTS wetlands. One of those points (NR689) turned out to not be a wetland. To select those points, we first used GIS to extract and compare attributes of the 48 GRTS-selected wetland points with attributes of the remaining 900+ points in wetlands that GRTS

[1] Generalized Random Tessellation Stratified (Stevens 1997, Stevens & Olsen 1999, 2003, 2004)

had assigned lower priority for a site visit. For example, a few geologic types were found to be lacking among the GRTS-selected wetlands we had planned to visit, so the first one of the non-GRTS wetlands that had the missing type was added to the list of wetlands to be visited. We then ran a cluster analysis on the complete GRTS wetland dataset to determine if wetlands having unusual *combinations* of attributes were lacking among the 48 wetlands we planned to visit. Attributes used in the cluster analysis were the same used in the modeling to predict wetland presence: geologic type, elevation, annual precipitation, stream presence/absence, slope, compound topographic index, curvature, plan curvature, and profile curvature – all of which could be determined from existing spatial data. Also, we hand-picked two sites that appeared to have high potential exposure to human disturbances (e.g., are near campgrounds). Thus, the cluster analysis, together with the queries of single attributes and consideration of wetlands most likely to be impacted, was used to identify the 14 additional wetlands to be assessed and these "non-random" (NR) wetlands were added to the agenda for the field season.

Among the 57 points added to the plans for field inspection were 21 points predicted to be wetlands but not mapped as such by NWI (as described previously in Section 2.2) and 21 points neither mapped nor predicted to be wetlands. Of these, four of the predicted points (NW7, NW28, NW51, NW56) and one of the non-predicted points (T22) were found to be in a wetland. Also, 79 unmapped and unpredicted wetlands were discovered while traveling to designated assessment sites. One of these (NRF1) was assessed fully, whereas for the others we recorded only their GPS coordinates and dominant plant species. In all, a total of 105 points were visited, 68 wetlands were assessed fully, and plant species composition was quantified in 78 herb plots (100 m^2 each) and 15 shrub plots (400 m^2 each).

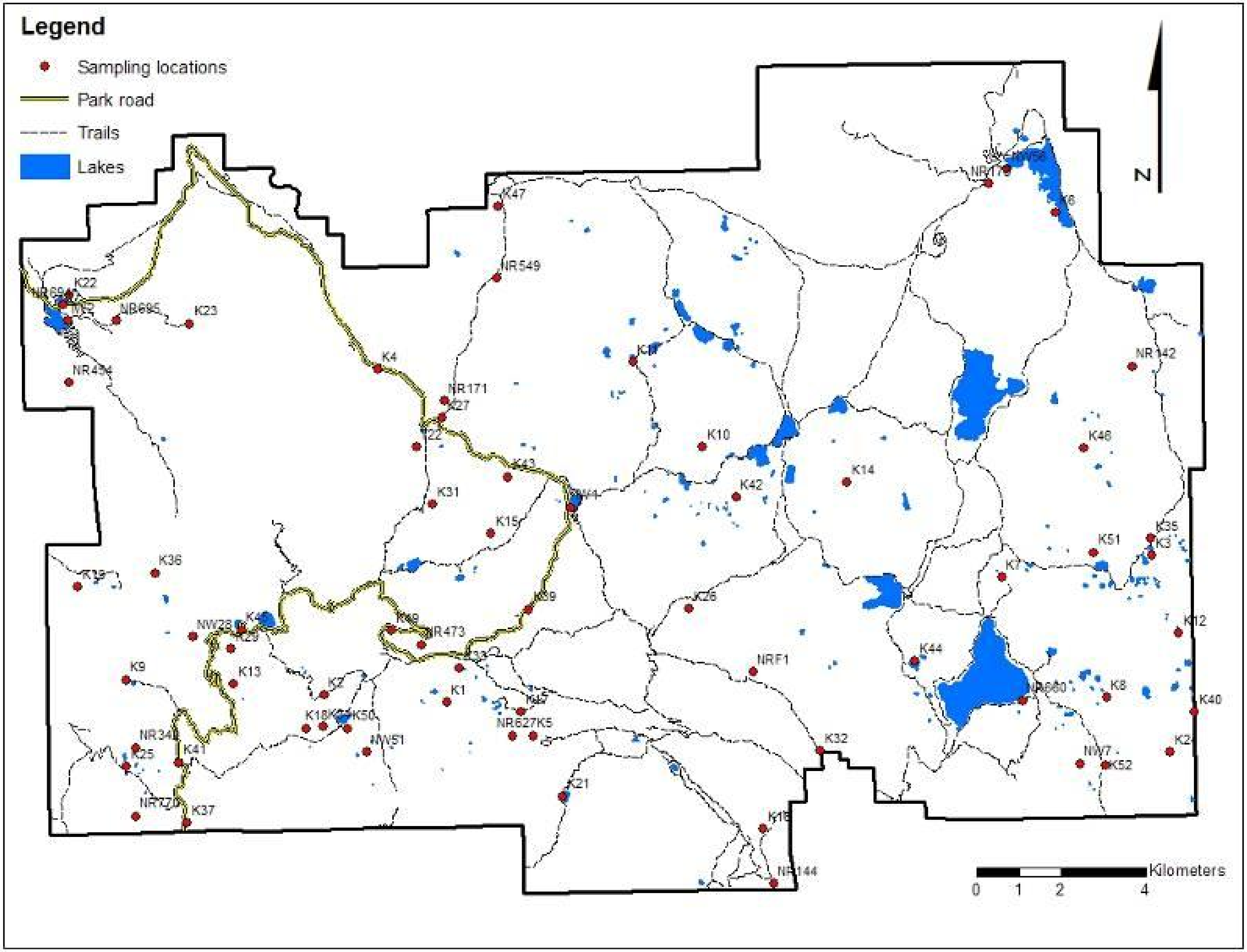


Figure 4. Map of LAVO wetlands visited and assessed during 2005.

Table 2. GPS coordinates and general descriptive information on the assessed wetlands.

Stratum	Site ID	Point	UTM north	UTM east	Site Name Given	Date Visited	Acres NWI Mapped	Acres Covered	Elevation (m)
0	IW1	L757	633510	4483508	Summit Lake CG	08/19/05	2.67	19.31	2035
0	IW2	L916	621556	4487925	Manzanita Lake	08/19/05	1.63	54.97	1786
1	K1	L284	630561	4478876	West Sifford Lakes	08/24/05	0.22	14.84	2176
1	K10	L817	636625	4484934	Echo Lake Slope	08/22/05	0.03	0.20	2152
1	K11	L884	634969	4486956	Little Bear Lake	08/22/05	0.39	4.89	2069
1	K12	L484	647935	4480515	Thunder	08/14/05	0.05	0.20	2178
1	K13	L371	625490	4479315	Middle Little Hot Springs Valley	09/22/05	1.32	1.54	2165
1	K14	L770	640063	4484091	Crater Butte	08/23/05	0.05	0.51	2108
1	K15	L687	631594	4482884	Cliff Creek	08/02/05	0.26	0.30	2193
1	K16	L24	638065	4475879	Terminal Geyser	06/24/05	0.07	2.16	1779
1	K17	L254	632333	4478641	East Sifford Lakes	09/01/05	0.17	1.62	2140
1	K18	L220	627207	4478253	Bumpass Creek East	09/08/05	0.05	2.72	2220
1	K19	L571	621800	4481611	Talus	08/03/05	0.05	1.51	2081
1	K2	L307	627644	4479043	NW Crumbaugh Lake	09/02/05	0.01	2.83	2380
1	K21	L75	633314	4476645	Drake Lake	07/28/05	1.04	10.88	1982
1	K22	L929	621588	4488535	Lily Pond	06/16/05	0.53	2.95	1801
1	K23	L908	624449	4487861	Crags Lake	07/25/05	0.03	0.21	2039
1	K24	L158	647725	4477696	Bonte Peak SE	08/11/05	0.16	2.31	2057
1	K25	L122	622963	4477342	Forest Lake Drainage	08/31/05	0.20	1.55	2261
1	K26	L534	636304	4481099	Grassy Swale	07/03/05	0.26	0.78	1915
1	K27	L834	630462	4485622	Mat Creek	07/08/05	0.02	4.21	1950
1	K29	L452	625431	4480140	Upper Little Hot Springs Valley	09/22/05	0.01	3.32	2292
1	K3	L629	647281	4482365	Dry Hole	08/18/05	0.01	0.33	2182
1	K31	L735	630220	4483576	Paradise Meadow	07/26/05	0.10	0.73	2138
1	K32	L159	639408	4477722	Kings Creek	06/23/05	0.02	0.23	1579
1	K33	L405	630854	4479682	Hemlock Lake	08/01/05	0.33	6.20	2204
1	K34	L238	627630	4478302	Crumbaugh Lake West	09/08/05	0.37	3.80	2239
1	K35	L682	647265	4482772	Jakey Lake NE	08/17/05	0.01	0.11	2192
1	K36	L605	623632	4481950	Vulcans Castle	08/04/05	0.01	22.92	2270
1	K37	L47	624397	4476030	Bert	07/09/05	1.20	6.34	1917
1	K39	L530	632508	4481085	Tiny	08/02/05	0.03	0.13	2185
1	K4	L876	628928	4486776	Old Boundary Spring	06/18/05	0.07	2.74	1914
1	K40	L252	648287	4478640	Boundary	08/08/05	0.02	0.20	2103
1	K41	L134	624193	4477445	Southwest entrance	07/27/05	0.26	14.38	2075
1	K42	L748	637416	4483740	East Echo Lake	09/21/05	0.11	1.55	2131
1	K43	L786	632009	4484226	Dersh Meadow	07/21/05	0.06	1.49	2022
1	K44	L419	641670	4479862	Indian Lake	08/10/05	0.81	11.16	2128
1	K45	L507	625679	4480589	Emerald Lake	08/30/05	0.13	1.63	2470
1	K46	L816	645672	4484910	Mt. Hoffman	08/17/05	0.05	0.63	2169
1	K47	L968	631770	4490637	Lower Hat Creek	07/13/05	0.10	3.19	1868
1	K49	L503	629247	4480577	Kings Upper Meadow	08/11/05	1.23	20.23	2277
1	K5	L205	632623	4478086	Devils Kitchen	07/05/05	0.03	0.73	1881
1	K50	L217	628196	4478258	Crumbaugh Lake	09/07/05	0.01	1.87	2206
1	K51	L653	645899	4482442	Mallard	08/18/05	0.11	0.58	2138
1	K52	L225	646177	4477392	Borite Creek	08/09/05	0.93	5.19	2037
1	K6	L965	645001	4490503	Lava bed	07/22/05	0.02	0.63	1844

Table 2. GPS coordinates and general descriptive information on the assessed wetlands (continued).

Stratum	Site ID	Point	UTM north	UTM east	Site Name Given	Date Visited	Acres NWI Mapped	Acres Covered	Eleva-tion (m)
1	K7	L598	643733	4481851	Inspiration Point	08/10/05	0.01	0.15	2131
1	K8	L308	646220	4478988	Glen Lake SE	08/08/05	0.04	0.65	2116
1	K9	L374	622956	4479413	Ridge Lakes	08/30/05	0.60	6.74	2435
0	NR142	L877	646831	4486846	Ash Butte	08/17/05	0.04	0.63	2184
0	NR144	L6	638324	4474572	Willow Lake	07/04/05	9.59	13.68	1650
0	NR171	L850	630499	4486027	Aspen	07/08/05	0.08	0.42	1941
0	NR178	L980	643415	4491191	Cold Spring	07/11/05	0.01	0.18	1859
0	NR342	L170	623175	4477798	Sphagnum EEN	08/31/05	0.22	2.80	2265
0	NR454	L866	621603	4486468	North Means South	06/17/05	0.03	0.16	1865
0	NR473	L467	629950	4480246	West King Creek MDW	09/06/05	2.64	31.52	2231
0	NR549	L939	631746	4488930	Giuseppe	07/25/05	10.80	23.85	1893
0	NR627	L223	632107	4478082	Hotspring Creek	08/10/05	4.20	0.63	1969
0	NR660	L303	644233	4478916	Juniper Lake	08/09/05	0.24	1.31	2054
0	NR694	L923	621442	4488314	Reflection Lake	06/19/05	0.83	10.30	1795
0	NR695	L911	622725	4487933	Manzanita Spring	06/17/05	0.04	0.37	1852
0	NR770	L45	623174	4476181	Brokeoff trail pond	08/09/05	0.01	0.25	2316
0	NRF1	L392	637829	4479598	Lost	07/01/05	0.54	2.46	1691
0	NW28	L500	624530	4480438	Pilot Pinnacle Thermal Wetland	09/07/05	1.12	5.81	2462
0	NW51	L155	628656	4477699	Reading Peak	09/23/05	0.02	2.51	2144
0	NW56	L984	643868	4491527	Butte Lake North	07/11/05		1.46	1852
0	NW7		645578	4477420	W Bonte Peak	08/11/05		0.03	
0	T22	L923	629841	4484933	Hat Lake	07/21/05		1.51	1795

2.4 Field Data Collection

Over 700 variables were assessed in each of the 68 wetlands visited. This included variables measured from existing data layers using GIS, variables from the CRAM rapid assessment method that were estimated visually in the field, other variables pertaining to wetland plant community composition and richness, and variables potentially important to wetland health and ecological services but not represented by the aforementioned (Figure 5). The number of variables was undoubtedly more than some minimum necessary to estimate wetland health and ecological services. The additional variables were assessed because knowledge of indicators of wetland ecological services and health is rapidly evolving; what seems superfluous to measure today may very well be recognized as a critical indicator at a future time. Therefore, decisions about whether to include a variable were based largely on how rapidly it could be assessed, also taking into consideration its repeatability and anticipated relevance. The main consideration was to ensure that all variables together could be assessed in less than six hours per wetland. All variables included in the database files resulting from this project are listed in the Data Dictionary (Appendix A), which is cross-referenced to specific items in the field forms (Appendix B) and their supporting protocols (Appendix C).

Figure 5. Assessing soils in a LAVO wetland.

The field crew was trained in protocols specific to this project by the protocol author, Dr. Adamus. The crew consisted of an experienced botanist (Cheryl Bartlett) and a soils technician who had just graduated from college (Nick Pacini). In addition, a student (John Beickel) from Southern Oregon University assisted the crew for part of the summer and Drs. Marie Denn and Joel Wagner of the National Park Service (NPS) spent two days observing the field data collection process. Dr. Adamus helped the crew collect data during three of the 14 weeks of the field season.

As noted in Section 2.2, two types of areas were visited: areas identified as wetlands (from existing NWI maps) and areas identified as "possible wetlands" by our statistical models. Depending on the indicator being assessed, field estimates of indicators were made at the scale of centerpoint, plot, polygon (site), and/or polygon buffer:

- A ***polygon*** is the entire contiguous wetland, usually separated from similar polygons by upland or deepwater (>6 ft deep) or by major constrictions in sheet flow patterns. Recognizable wetland vegetation forms or communities were not used to delineate separate polygons.
- A ***centerpoint*** is the point that represented the polygon during the site selection process and has specific coordinates which have a precision of less than 40 ft. It was not necessarily located in the center of a wetland polygon. This point is the target location for the first plot completed at each wetland.
- A ***plot*** is a releve plot of variable dimensions but standard area in which detailed vegetation data were collected.
- A ***buffer*** is the upland zone extending upslope a specified distance from the polygon's outer edge.

Basic tasks that were accomplished during each site assessment were:

- Navigated to and from the centerpoint of a wetland that was targeted for assessment (those with a "K" prefix in the parkwide map of sample points).
- Determined if the site is a wetland.
- If the site was found to be a wetland, one marker (***benchmark***) was placed at a measured distance and direction from the centerpoint. The marker was a round, numbered metal tag nailed into a live tree at eye level, with at least 0.5 inch protruding. Locations of most data collected in the wetland were referenced to this benchmark. It could serve as a basis for linking our data to future "vital signs" and trends monitoring data.

- Recorded data from the following tasks:
  - Dug at least three 12-inch deep pits, GPS'd them, evaluated soil indicators and vegetation, and then replaced soil.
  - Identified plants and estimated their cover classes in a standard-sized plot, as well as while walking as much of the wetland as time and physical access allowed.
  - Observed and assessed vegetation structure, distribution of water, signs of human presence, and other indicators of wetland ecological service and health as shown in the data forms (Appendix B)[2].
  - Took one series of panoramic shots from a fixed point with a digital camera (documented the location and direction by including a labeled whiteboard in the picture).
  - Delineated the approximate wetland boundary (polygon perimeter) using a hand-held GPS unit. At times the boundaries between the assessment wetland and nearby wetlands were indistinct and erratically contiguous (e.g., connected by a channel containing a very narrow band of wetland vegetation). In those situations, judgment was exercised in deciding where to draw the boundary. Constrictions in surface runoff patterns were used predominantly, while in larger wetlands an additional consideration in limiting the boundary was the extent of wetland that was feasible to walk in about an hour while actively identifying plants.

To maintain consistency, all plants except some difficult sedges were identified by Cheryl Bartlett. The difficult sedge species were referred to an expert, Dr. Laurence Janeway at Chico State University, who kindly identified them. We preserved voucher specimens of about 75% of the plant species we identified and also photographed many species. With NPS permission, our pressed specimens have been placed in permanent repository at the herbarium of either Chico State University or LAVO.

This study was not intended to comprehensively survey the flora of any wetland visited, nor estimate precisely the overall percent cover (throughout a wetland, not just in plots) of any plant species. It also is important to understand that the detectability and identifiability of plants was greatest in mid-season, and consequently there probably was a tendency to discover more species per plot and per wetland among sites visited at that time. Early and late in the season, some plant species were not evident or, because they were not flowering and/or were senescing, were not reliably identified[3].

2.5 Data Analysis

In light of the conceptual challenges described in Section 1.2, our strategy for assessing the health of LAVO wetlands involved the use of three approaches:

1. Analysis of plant community composition and richness.

---

[2] These were initially derived partly from data forms used previously by the author (WET, HGM), in other NPS projects (Pt. Reyes, CRAM), and officially by the California Native Plant Society (releve procedure). However, this form is intended to describe wetlands with much greater detail than existing methods, with regard to structural components important to wetland ecological service and ecological integrity. This greater level of detail is needed to provide the sensitivity necessary to distinguish ecological serviceally significant differences among wetlands of which most are expected to be in nearly-pristine condition.

[3] By intent, higher-elevation sites were surveyed later in the season. Their plots tended to contain fewer species. Based on the correlation analyses, the species found at sites visited earlier in the season tended to be more ubiquitous among all sites visited, and were more likely to be species associated with disturbance.

2. Use of a rapid assessment method (CRAM) that claims to represent wetland ecological condition.
3. Consideration of wetland ecological services valued by society, through use of some rapid indicators and heuristic models.

These approaches overlap to some degree but in other ways may be complementary. Given the uncertainties in defining wetland health, and the budget and time limitations of this project, it seemed most prudent to use this multi-strategy approach rather than relying on just one.

All data files have been provided in Excel format to the NPS Klamath Network Office, along with a data dictionary and metadata.

From the raw data, we calculated several metrics at plot and/or polygon scales. These included (for example) plant species richness, number of dominant species, number of non-native species, frequency index, and prevalence index[4]. We then computed a variety of summary statistics (means, etc.) for these metrics and all other major variables, in some cases reporting them by wetland type, vegetation layer (herbaceous vs. shrub/tree plots), and other categorical variables. Using database queries, we also interpreted our data with respect to wetland ecological condition as represented by CRAM scores and with respect to wetland ecological services as represented by scores from our own heuristic models. We screened for Spearman rank correlations ($p<0.01$) among pairs of variables, and analyzed partial correlations among selected variables in instances where particular co-variables were known to be both statistically and ecologically significant. As of this writing, correlations at the plot scale have not been thoroughly examined; we made most paired comparisons at the wetlands scale and did not examine correlates of individual plant species.

The preliminary statistical classification of wetland vegetation was conducted by Cheryl Bartlett. All unidentified species were removed from the datasets used in the analysis, except for two species that had high cover values. Two sites (NR454 and K23) were completely excluded from the analysis because their proportion of unidentified species was large (NR454) or overall cover was very low (K23). An agglomerative cluster analysis was then used to determine the groups (classes or "communities"), and then an indicator species analysis procedure was used to determine the optimal number of groups and indicator species for each group. Finally, the procedure, MRPP (Multi-response Permutation Procedure), was used to test the null hypothesis of no difference between groups (null hypothesis rejected). The computer program PC-ORD was used for these analyses, and the program NCSS was used for statistical summaries and correlation analyses.

[4] See section 3.3.2 for definitions of these metrics

3.0 Results

3.1 Wetland Inventory

3.1.1 Rates for Errors of Commission

Wetlands are defined partly by having a prevalence of plant species that characteristically are hydrophytic (i.e., grow in water or in soils that are periodically saturated). “Prevalence” is commonly quantified with a “Prevalence Index.” In its simplest form, the predetermined, published “indicator status” scores of all species present in an area are averaged. If the average is greater than or equal to 5, the area is considered a wetland, contingent as well on soil and water conditions[5]. All of the NWI-mapped wetlands had Prevalence Index values indicating they are, indeed, wetlands. However, that was true only when 25% (on average) of the species at each site were excluded from the calculation. Those were species for which NWI has not assigned an indicator score. If those species had all been included under the assumption (used by wetland regulatory agencies) that they are most likely to be non-wetland species, as many as one-quarter of the sites would not have qualified as wetlands. Thus, the lack of information on the hydrophytic tendencies of many species limits broad conclusions about the accuracy of the NWI maps, but in general our field inspections suggested the areas shown to be wetlands are, indeed, wetlands.

3.1.2 Rates for Errors of Omission

To what extent do the existing NWI maps for LAVO fail to show wetlands? Given the fact that (a) development of those maps relied entirely on NWI’s interpretation of aerial imagery (not field inspections), and (b) many small wetlands are partially concealed by a forest canopy, it can be expected that some wetlands are not shown on NWI maps. As described in Section 2.2, we used a statistical modeling approach to identify such possible wetlands. A total of 1981 points not currently included within polygons mapped as wetlands were predicted to be wetlands. Due to time constraints, we were able to visit only 21 of these. Of those 21 points, our field inspection determined that only four (19%) of the points predicted to be wetlands were indeed wetlands. We also visited 21 points that were predicted to not be wetlands, and determined that one (T22) actually was a wetland, although only marginally so. There are several possible interpretations for why the statistical modeling was relatively unsuccessful: (a) the NWI maps contain few errors of omission, (b) attributes of unmapped wetlands are drastically different from those of mapped wetlands, and/or (c) quality and precision of some of the digital spatial data used to characterize both the mapped and unmapped wetland points (e.g., soils data, topographic data) in LAVO are insufficient to predict wetland occurrence consistently. Our experience leans towards (b) and (c) as the most likely reasons.

In addition to the statistical modeling approach, we noted the locations of unmapped wetlands that we discovered incidental to our other field activities, i.e., walking to and from wetlands we had targeted as part of our statistical sample. We discovered 87 such areas. We recorded their coordinates, dominant vegetation species, and geomorphic setting. Because we did not examine their soils, make a formal wetland determination, or delineate boundaries, it is likely some are technically not wetlands. And

[5] When calculating the Prevalence Index, obligate (OBL) species are scored 0, upland species are scored 5, facultative (FAC) species are scored 3, etc. Species not on the official indicator list (NOL or NOLW) are assumed to most likely be upland species and are thus assigned a 5. The preferred (weighted) form of the Prevalence Index multiplies the indicator score for each species by the percent cover of the species, and then the products are summed among all species and divided by the sum of the percent covers. When cover estimates are not available, the average of the species indicator scores is taken.

because they were not searched for systematically (e.g., along random transects), we cannot infer omission rates for LAVO generally from this information.

Although not a significant focus of this project, another question concerns the precision of boundaries of wetlands that NWI did map. Our field inspections found many instances where wetlands were actually much larger than shown on maps (Table 2).

3.2 Wetlands Profile

3.2.1 Geomorphic Classification

Under the national hydrogeomorphic (HGM) classification for wetlands (Brinson 1993), LAVO's wetlands might be categorized as shown in Table 3. These results are based on topographic conditions assumed to be associated with these types (see footnotes to the table). The validity of the specific thresholds (e.g., for slope) that we used to define the HGM types was not field-verified. The tallies were based on queries of the digital topographic data.

Table 3. Number and area of LAVO wetlands by hydrogeomorphic (HGM) class, as estimated using two methods (comprehensive GIS-based vs. field-checked sites).

	From GIS Analysis of NWI Maps			From Field Visits to Statistical Sample of 47 Wetlands			
Tentatively Assigned Class	# of Wetlands	% of Wetlands	% of Total Wetland Area in LAVO	# of Wetlands	% of Wetlands	Acres	% of Total Wetland Area in LAVO
Riverine	182	18	59	8	17	12	7
Slope	337	34	9	17	38	90	52
Depression or Flat	464	47	26	21	45	65	38
Lacustrine Fringe	6	1	6	1	<1	7	4

Notes:

- The "Riverine" class as defined by HGM is not the same as the Cowardin et al. (1979) "Riverine" class.
- Most wetlands contain multiple HGM classes but in this table each wetland polygon was assigned to only one HGM class.
- The HGM classifications based on the comprehensive GIS analysis of NWI maps are much less accurate (especially with regard to distinguishing Riverine vs. Slope) than those based on the field-checked sites. The GIS query used to assign these HGM classes to NWI-mapped wetlands was implemented in the following sequence:
  1. If NWI system = Lacustrine (any amount within the polygon), then HGM= Lacustrine Fringe
  2. If not #1 AND located less than 60 ft from a seep/spring, then HGM= Slope.
  3. If above criteria not met AND (NWI system = Riverine OR if a mapped stream is within 10 ft), then HGM= Riverine UNLESS geologic code = lake OR NWI class = aquatic bed or unconsolidated bottom, in which case convert to Depression/Flat
  4. If none of above AND minimum slope is >2.29% (the median of all wetlands was 2.3) then HGM = Slope.
  5. If none of the above, then HGM= Depression/Flat.

3.2.2 Cowardin Classification

Under the contrasting Cowardin classification (system level), LAVO's wetlands have been categorized on NWI maps as shown in Table 4.

Table 4. Number and area of LAVO wetlands summarized by Cowardin classification shown on NWI maps.

Cowardin Classification Level	Classifier	Number of Wetlands Containing Any	Percent of Wetlands Containing Any	Acres	Percent of Total Wetland Area in LAVO
System	Riverine	20	1.80	18	2.03
	Lacustrine	27	20.95	207	23.68
	Palustrine	989	65.68	650	74.24
Class	Open Water*	372	28.98	287	32.75
	Aquatic Bed	159	2.31	23	2.62
	Emergent	670	29.65	293	33.51
	Scrub-shrub	339	20.88	207	23.60
	Forested	152	6.61	65	7.47
Hydroperiod	Saturated	3	0.12	1	0.14
	Temporarily Flooded	49	0.58	6	0.65
	Seasonally Flooded	807	58.48	578	66.10
	Semipermanently Flooded	234	1.91	19	2.16
	Permanently Flooded	362	27.34	270	30.91

* mapped as Unconsolidated Bottom or Unconsolidated Shore

3.2.3 Classification Based on Wetland Vegetation

We noted several repetitive assemblages of plant species during our field work. In colloquial terms, the following seem intuitively to comprise the most commonly recurring and distinctive assemblages of wetland plants that we saw.

Veratrum californicum var. californicum dominated meadows: This type is found in moist (but not wet) areas of meadows. Other species commonly found in this type include *Senecio triangularis, Lupinus polyphyllus var. burkei, Calamagrostis canadensis, Glyceria elata,* and various spp. of *Carex.* It is a very species-rich type.

Graminoid dominated meadows: This type is found in wet to inundated areas of meadows and species composition was somewhat variable. Common species include *Carex vesicaria, Carex utriculata, Carex angustata, Juncus mertensianus, Juncus nevadensis, Calamagrostis canadensis, Glyceria elata, Deschampsia caespitosa,* and *Agrostis thurberiana*.

Wet depressions: These are particularly common on the east side of the park. They are typically dominated by graminoids including *Eleocharis acicularis, Juncus mertensianus, Deschampsia caespitosa, Carex vesicaria,* and *Juncus balticus*.

Pond and pond margins: This type has a species composition similar to wet depression type, but densities of plants are most often lower. In areas where standing water persists in most years, an aquatic bed community usually exists and is dominated by *Isoetes bolanderi. Sparganium angustfolium, Eleocharis acicularis. Ranunculus flamula* are also sometimes present.

Alnus incana var. tenuifolia dominated shrublands: This is found on steep to gentle slopes and often is associated with a drainage channel or creek. Herbaceous understory is sparse to dense and often rich in species.

A more rigorously-derived community classification, based on statistical analyses of the data, is presented in Table 5, and photographs of each class are presented in Appendix J. This classification should be considered as a preliminary attempt at designating wetland community types in LAVO. Additional data were collected in 2007 but have not been analyzed, so group membership and indicator species may differ once those data are added to the analysis.

The initial results indicate that wetland community types present in LAVO are similar but not entirely identical to types described by previous classification efforts in the region, including types documented from the Sierra Nevada (Cooper and Wolf 2006, Potter 2005) and the Humboldt and Toiyabe National Forests of Nevada and Eastern California (Manning and Padgett 1995). Also, a brief examination of Oregon wetland community names (Kagan et al. 2000) indicates that several of LAVO's wetland communities at the very least share dominant species with recognized wetland communities found to the north in the Oregon Cascades.

Table 5. Preliminary vegetation-based wetland communities of LAVO derived by statistical processing of data from 78 wetland plots.

These classes may change as a result of unanalyzed data that were collected by C. Bartlett in 2007, so should not be considered definitive at this time. Characteristic species are listed in decreasing order of importance, with indicator values in parenthesis for species found to be significant indicators ($p < .05$) of the community type. Indicator values can range from 0 to 100 and do not necessarily indicate dominance of a particular species within a group; rather they are a measure of a species faithfulness to a particular group (consistency) and relative abundance when compared to other groups.

Class ID	Wetland plots included in the class (w= shrub plot)	Characteristic Species	Foot-note #
1	K37b-1, K34-1w, NW51-1w, IW1-1, K24-1, K26-1, K27-1, K31-1	Veratrum californicum (29), Ranunculus alismifolius (62.9), Perideridia parishii (27.9), Trifolium longipes (25.4), Senecio triangularis, Carex luzulifolia (34.4)	
2	IW1-2, K36-1, K39-1, NR342-1, NW28-1, K49-1w, K49-3w	Juncus nevadensis (39.1), Carex scopulorum (58.9), Aster alpigenus, Dodecatheon alpinum (39.8)	
3	IW2-1, K16-1	Mimulus primuloides (36.6), Juncus balticus, Cirsium vulgare (81.8), Veronica serpyllifolia (41.6)	
4	K10-1, K11-1, K14-1	Eleocharis acicularis (46.2), Carex leporinella	1
5	K45-1, K50-1, K9-1, K1-1w, K33a-1w, K49-2w	Potentilla flabellifolia (66.7), Aster alpigenus (58.9), Juncus drummondii (58.5), Kalmia polifolia (54.9), Carex nigricans (50), Phyllodoce breweri (50), Tsuga mertensiana-short (33.3)	6
7	K12-1, K3-1, NR142-1	Carex leporinella, Juncus nevadensis, Eleocharis acicularis, Juncus balticus, Juncus drummondii	
8	K13-1, NR144-1, NR695-1	Glyceria elata (53), Carex angustata, Scirpus microcarpus (39.5), Equisetum arvense, Mimulus moschatus, Veronica americana (58.3)	
10	K15-1, K2-1, K29-1, K18-1w	Lupinus polyphyllus (55.6), Senecio triangularis (35), Veratrum californicum, Hackelia micrantha (47.7), Aster eatonii (40)	2
12	K17-1, K33b-1, K42-2, K44-1	Isoetes bolanderi (78.9), Sparganium angustifolium (100)	3
14	K19-1w	Acer glabrum, Ageratina occidentalis, Hackelia micrantha	
16	K21-1, K42-1, NR770-1	Deschampsia cespitosa (39.6), Carex vesicaria	
17	K2-2, NR178-1, NW56a-1	Juncus balticus (33), Muhlenbergia filiformis (38.1), Achnatherum occidentalis (66.7), Gayophytum racemosum (48.5), Linanthus harknessii (66.7), Penstemon heterodoxus (53.3)	
18	K22-2, NR694-1	Carex angustata (46.9), Pinus contorta – tall (36.1), Viola macloskeyi (31.1), Fragaria virginiana (60)	
20	K25-1, K41b-1	Carex lenticularis (73.4), Epilobium hornemannii (48.6), Senecio triangularis	
26	K32-1, NR627-1, NRF1-1, K37a-1w, K41a-1w, K43-1w, K5-1w	Alnus incana - medium (56.7), Viola glabella (67.3), Senecio triangularis, Alnus incana - low (55.7), Mimulus moschatus, Carex nervina, Veratrum californicum, Stachys ajugoides, Dicentra formosa (57.1), Circaea alpina (42.9), Cirsium douglasii (42.9), Osmorhiza occidentalis (42.3), Heracleum lanatum (42.9), Ribes roezlii – low (42.9)	1
30	K35-1, K40-1, K51-1, K7-1, K8-1, NR660-1	Carex vesicaria (57.2), Carex leporinella	
36	K4-1, K6-1	Salix lemmonii – medium (72.7)	4
44	K46-1, NR473-1	Carex utriculata (53.8)	

Table 5. Preliminary vegetation-based wetland communities of LAVO derived by statistical processing of data from 78 wetland plots (continued).

Class ID	Wetland plots included in the class (w= shrub plot)	Characteristic Species	Foot-note #
45	K47a-1, NR171-1, T22-1, K47b-1w, NR549-1w, NW56b-1w	Pinus contorta – medium (32.5), Salix lemmonii - medium, Populus tremuloides - tall, Achillea millefolium (26.7), Trifolium longipes, Carex abrupta, Bromus carinatus (33.3), Stellaria longipes (50), Osmorhiza chilensis (46.7), Elymus glaucus (45.6)	5
53	K52-1	(Mixed meadow)	
55	K6-2	Carex subfusca, Penstemon heterodoxus, Agrostis variabilis	
56	K6-3	Polygonum amphibium, Myriophyllum sibiricum	
77	NW7-1	Juncus parryi, Penstemon gracilentus	

Footnote 1. Similar to communities described by Potter (2005) and Manning and Padgett (1995). However, the subordinate species that were found to have 100% consistency and high indicator values for each of these communities in LAVO – *Ranunculus alismifolius* for group 1 and *Viola glabella* for group 26 – were either absent or of much less importance in types described by the riparian community classifications cited.

Footnote 2. A very similar community type (*Lupinus polyphyllus* - *Senecio triangularis* community type) was described from the eastern Sierra Nevada, although the subordinate species are somewhat different. Communities from the west slope of the Sierras (Potter 2005) have been described which are also similar, but *L. polyphyllus* is replaced by *Lupinus latifolius* in these more southern wetlands.

Footnote 3. Similar to communities known to occur in Oregon, but are not described in either the California or Nevada classifications.

Footnote 4. This is a minor type which was found growing in extremely wet sites (shrubs growing in standing or flowing water) along lake or stream margins with very high cover of *S. lemmonii* and a sparse understory. This type is similar to the *Salix lemmonii*/ Bench community type described from the eastern Sierra Nevada (Manning and Padgett 1995), but is not specifically described by Potter from the west slope of the Sierra Nevada.

Footnote 5. This group represents the more common *S. lemmonii* community in LAVO, and can occasionally be found under a canopy of *Populus tremuloides* and/or mixed with medium height *Pinus contorta*. Manning and Padgett (1995) describe a *Salix lemmonii/Carex scopulorum* community that can include scattered trees of both of these species "which can colonize these sites when conditions are dry for one or more growing seasons". *C. scopulorum*, a species more characteristic of wetter sites, was not found in any of the *S. lemmonii* sites sampled at LAVO. Rather, species more indicative of drier growing conditions, such as *Achillea millefolium, Trifolium longipes,* and *Carex abrupta,* were the most common understory species. Potter's classification lumps all *S. lemmonii* communities into a single group, and does not mention the occasional presence of *P. contorta* or *P. tremuloides*. Common understory species mentioned also tend to occur on wetter sites than those found in the group 45 *S. lemmonii* community type in LAVO.

Footnote 6. This describes a community with *Potentilla flabellifolia, Aster alpigenus, Juncus drummondii, Kalmia polifolia, Carex nigricans, Phyllodoce breweri,* and low growing *Tsuga mertensiana* as important species. Two of these – *K. polifolia* and *P. breweri* – are Ericaceous dwarf shrubs. A somewhat similar *Phyllodoce breweri – Vaccinium caespitosum* community is described by Potter as occurring at high elevations (>9000 ft) in the central and southern portions of the Sierra Nevada; all LAVO plots of this type were located at less extreme elevations, but were among some of the highest elevation locations sampled within the park (but <8500 ft). Although this more southern community has a dominant (*V. caespitosum*) which was found in trace amounts once in the LAVO plots, it does share several of the important herbaceous species, including *A. alpigenus, J. drummondii* and *C. nigricans*, with the communities sampled from Lassen. Although poor fen communities with *K. polifolia* as a dominant species have been described (Cooper and Wolf 2006), their relationship to the communities discussed here is unknown.

Table 6. Botanical metrics for herb plots, by community class.

mean (top number in cell), minimum-maximum (bottom numbers)

Class	n	Elevation (m)	Number of species	% of spp. <1% cover	% of spp. 1-25% cover	% of spp. 25-60% cover	% of spp. >60% cover
1	8	2050 1915-2239	20 12-34	58 28-77	35 16-57	5 0-25	1 0-5
2	7	2292 2185-2462	16 8-26	65 52-75	27 12-43	4 0-12	3 0-8
3	2	1783 1779-1786	20 19-21	66 47-84	31 15-47	2 0-4	0
4	3	2110 2069-2152	5 3-6	41 33-50	46 33-66	12 0-20	0
5	6	2298 2176-2470	17 10-27	63 40-78	31 18-50	5 0-11	0
7	3	2181 2178-2184	4 3-4	50 0-100	30 0-66	0	19 0-33
8	3	1889 1650-2165	18 11-22	65 54-72	28 22-36	6 4-9	0
10	4	2271 2193-2380	23 14-32	72 64-81	24 15-30	3 4-9	0
12	4	2.57 2128-2380	3	44 33-66	44 33-66	11 0-33	0
14	1	2081	22	63	31	4	0
16	3	2143 1982-2316	3 2-4	46 40-50	46 40-50	6 0-20	0
17	3	1859	11 10-12	64 58-70	22 20-25	8 0-16	5 0-10
18	2	1801	13 12-14	69 64-75	22 16-28	0	7 7-8
20	2	2168 2075-2261	12 11-13	66 63-69	25 23-27	0	8 7-9
26	7	1876 1579-2075	26 16-39	72 52-91	24 1-42	1 0-5	2 0-5
30	6	2122 2054-2192	4 2-7	25 0-57	43 25-60	20 0-50	10 0-50
36	2	1879 1844-1914	11 5-16	50	21 0-43	0	28 6-50
44	2	2200 2169-2231	3 2-3	0	41 33-50	33 0-66	25 0-50
45	6	1873 1785-1941	27 15-43	71 63-80	23 15-31	5 0-11	0
53	1	2037	24	75	25	0	0

3.2.4 Unusual Wetland Plant Communities

Wetland scientists classify some wetlands as “fens,” which are defined as wetlands having substantial accumulations of peat, characteristic flora, and significant influxes of groundwater (Bedford and Godwin 2003). Groundwater chemistry is fundamental in determining the plant communities that occur in fens, and consequently is used to classify them. During our 2005 survey, we visited an odd-looking wetland, which from our vegetation description alone was later identified by Dr. David Cooper of Colorado State University as probably being an **acid geothermal fen**. Acid geothermal fens, and similar iron fens, are globally and regionally very rare, and have been found in the Warner Mts. in northeastern California, as well as in Colorado, Wyoming (Yellowstone National Park), South Dakota (Black Hills), Alaska, and the Peruvian Andes. *They have never been documented in the Sierra-*

Cascade system (D. Cooper, personal communication). Their occurrence in LAVO is not surprising, given their association with geothermal situations that are a hallmark of LAVO. Acid geothermal fens are characterized by very low pH (3.0 – 4.5), which is the result of sulfide gas from geothermal vents oxidizing to form sulfuric acid in areas where water and gas combine near the soil surface (D. Cooper, personal communication). Iron fens, which are not found at Lassen, are similar except that the sulfuric acid source in iron fens is iron pyrite rich bedrock and talus (Cooper et al. 2005). The pool morphology of these wetlands is also distinctive, and *Sphagnum* spp. and Ericaceous sub-shrubs are often, but not always, present (D. Cooper, personal communication).

The wetland identified as probably being an acid geothermal fen is Site NR342, in the Forest Lake area in the southwestern portion of the Park (UTM 623176E 4477799N, NAD 83 - zone 10T). Although we did not measure pH, the vegetation and soil characteristics (Figure 6) are highly suggestive.

Figure 6. Site NR342, a probable acid geothermal fen. Note the pool morphology and abundant *Sphagnum* moss that are typical.

Upon learning of the scarcity of this wetland type, we made a limited effort to identify other acid geothermal fens in LAVO during summer 2007. Two more were identified. One is approximately 0.5 km east of Ridge Lakes on a moderate to steep, south facing slope (UTM 623609E 4479479N, NAD 83 - zone 10T). It is much larger than the Forest Lake site and consists of a long narrow area of diffuse shallow pools, with abundant *Sphagnum* spp. and other mosses (report cover photo). *Ledum* *glandulosum* and *Kalmia polifolia* are common, and in several areas, dense colonies of *Drosera rotundifolia* were observed. The pH was measured at 3.9 in one of the pools. The second possible acid geothermal fen is located immediately adjacent to Bumpass Hell (UTM 627192E 4479576N, NAD 83-zone 10T), the largest geothermal feature in LAVO (Figure 7). This is a moderately sized fen with several small terraced arms that stretch into the surrounding forest. Pools of varied sizes and depths are interspersed throughout, and gas can be seen bubbling up in some of the larger pools. Although moss is abundant at this site, *Sphagnum* spp. were not observed, but *Kalmia polifolia* and *Phyllodoce breweri* were both common. The pH was not measured.

Figure 7. Bumpass Hell acid geothermal fen. Bumpass Hell is just below the exposed whitish hillside in the background of the photo; the large pool at the terminus of the wetland can be seen in immediately in front of that hillside.

Further survey efforts would likely yield more occurrences of this unique community type within LAVO, particularly in higher elevation drainages influenced by geothermal areas (Sulphur Works, in particular). Because of the unusual water chemistry and rarity of acid geothermal fens, these communities would be excellent candidates for monitoring and/or inventories of other understudied taxa.

In addition, in 2005 we visited eight wetlands that appear to be fens, although not of the acid geothermal type. These contained three or more plant species characteristic of fens, and an additional 14 wetlands (which may or may not be fens) contained one or two. We did not attempt to identify which particular class (Cooper and Wolf 2006) each fen belonged to. The communities we defined as being dominated by the possibly fen-associated sedges *Carex scopulorum* and *Carex utriculata* (group 2 and 44, in Table 5) are similar to riparian communities described from the west slope of the central and southern Sierra Nevada (Potter 2005) and Nevada and eastern California (Manning and Padgett 1995), but neither of those sources describes them as fen communities. Drakesbad Meadow in southern LAVO has been termed a fen, and Patterson (2005) used statistical clustering to define four plant communities there. She noted:

> Areas with a late July water table within 20 cm from the soil surface are dominated by the peat forming species *Carex simulata* and *Carex utriculata*. Areas dominated by *Carex nebraskensis* and *Deschampsia cespitosa* occur between the two major flowpaths and down slope from the drainage ditch. These are also areas with organic horizons >20 cm thick, but water table depths deeper than 20 cm. Communities dominated by *Poa pratensis* and *Hordeum brachyantherum* occur on the margins.

3.2.5 Other Structural Attributes for Defining Reference Conditions

Lassen wetlands also were characterized using GIS and available geospatial data (Table 7). Although wetlands in the park are fairly numerous (988 mostly-discrete polygons), those that have been mapped total only about 875 acres, or about 0.83% of the park's area. They range in size from a few square feet to 163 acres, with a median size of only 0.11 acres. Their median elevation is 6968 ft, most are in areas receiving more than 57 inches of annual precipitation, and they occur mainly on slopes of less than 2.5%. Geologically, they occur mostly on substrates of the Sheld-Yallani-Inville geologic group.

Most LAVO wetlands are more than 281 ft from roads. Only 180 (18%) of the wetlands are shown on maps as being connected to streams, and for those that are not, their median distance from streams is 504 ft. A series of 500 random points were placed – half of them within mapped wetlands and half outside of mapped wetlands. This indicated (unsurprisingly) that slope is significantly flatter and potential water accumulation (as represented by the Compound Topographic Index, CTI) is significantly greater at points mapped as wetlands.

Statistical associations of mapped wetland characteristics with mapped geomorphic attributes were examined, and the following statistically-significant associations were identified using the Spearman rank-correlation test:

- Emergent wetlands (i.e., the proportion of a wetland's area mapped as "emergent") tended to increase with increasing elevation, slope, locally drier environments (as implied by decreasing values of the compound topographic index, CTI) and/or the proportion of the wetland whose hydroperiod was mapped as temporarily or seasonally flooded. They also were closer to seeps and/or were frequently associated with wetlands with a greater proportion of seasonally or permanently flooded conditions
- Scrub-shrub wetlands tended to be larger wetlands, on steeper slopes, at lower elevations, in locally drier environments (as implied by the CTI). They typically were farther from streams, seeps, and roads.
- Forested wetlands, when mapped, tended to be relatively large, associated with seasonally flooded hydroperiods, flat or gentle slopes, drier environments (as implied by the CTI), and/or lower elevations.

Also, field measurements suggested that conductivity of flowing and standing water was greater in slope wetlands and wetlands at the toe of slopes.

Table 7. Statistical summaries for LAVO wetland polygons as derived from existing geospatial data. The first number in each vertical pair is for the wetlands in our statistical sample, the second is for all LAVO wetlands mapped by the NWI.

Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Area (sq.ft)	507	788	2110	7648	30210
	541	1384	3896	15490	53550
Perimeter (ft)	85	107	185	448	1148
	86	146	264	730	2290
% Scrub-shrubWet	0	0	0	22.74	100
	0	0	0	26.09	100
% Open Water	0	0	0	1.06	100
	0	0	0	0	100
% EmergentWet	0	0	12.64	100	100
	0	0	52.93	100	100
% ForestedWet	0	0	0	0	0
	0	0	0	0	26.49
% AquaticBed	0	0	0	0	0
	0	0	0	0	2.24
% Saturated	0	0	0	0	0
	0	0	0	0	0
% Temporarily Flooded	0	0	0	0	0
	0	0	0	0	0
% Seasonally Flooded	0	0	100	100	100
	0	52.80	100	100	100
% Semipermanently Flooded	0	0	0	0	0
	0	0	0	0	17.10
% Permanently Flooded	0	0	0	0	100
	0	0	0	0	100
CTI mean	7.86	8.75	9.87	10.94	12.74
	7.91	8.81	10.19	11.63	13.18
CTI min	5.49	6.07	7.11	8.08	8.92
	5.41	6.04	6.85	7.70	8.54
CTI max	8.92	10.62	13.60	17.37	20.98
	9.78	11.09	15.60	18.46	22.04
Elevation Mean (ft)	6087	6544	6969	7230	7577
	6052	6310	6962	7194	7468
Elevation Min	6072	6509	6959	7210	7535
	5996	6268	6958	7184	7442
Elevation Max	6109	6560	6986	7257	7643
	6069	6400	6967	7234	7522
Slope Mean (%)	0.90	2.00	4.66	11.28	20.11
	1.26	1.90	3.68	9.39	17.09
Slope Min	0.00	0.40	2.50	6.23	13.72
	0.00	0.03	1.64	4.44	12.08
Slope Max	2.08	4.27	10.02	22.45	30.59
	2.69	4.70	14.02	22.62	29.43
Distance* to Stream (ft)	0	47	353	1102	2422
	0	2	250	945	2028
Distance* to Seep (ft)	666	1496	2411	3810	4948
	680	1648	2211	3946	5000
Distance* to Road (ft)	3	61	281	633	1149
	0	12	117	306	1350

Table 8. Statistical summaries for LAVO wetland polygons as derived from existing geospatial data. The first number in each vertical pair is for the wetlands in our statistical sample, the second is for all LAVO wetlands mapped by the NWI (continued).

Parameter	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Precipitation Annual_mm	1169	1295	1462	2706	2949
	1176	1300	1531	2576	2807

* Distance percentiles are underestimates because any distance greater than 5000 ft was represented as 5000 in the dataset.

3.3 Wetland Health

3.3.1 Risks to Wetland Health as Implied by Exposure to Human-related Factors

Within LAVO, human-associated surface disturbances that have occurred and that have the potential to impair wetland health include roads (Figure 8), gravel pits, rock quarries, buildings, dumps, dams, channel modifications, and ditches (Ziegenbein and Wagner 2000). As a prelude to assessing each visited wetland's health, we inventoried these and other human-related features in each. We also assessed features (e.g., fire rings) that, although not usually capable of harming wetlands directly, imply the possible occurrence of unmeasured accompanying factors or uses that could harm a wetland.

Overall, 36% of LAVO's wetlands show signs of human visitation, with the most frequent alteration being man-made trails (23% of wetlands) (Table 9). Severely disturbing factors such as fill or ditching were not documented in any of the visited wetlands, and excavation was noted in only 2%. Table 10 ranks the visited wetlands according to the number, extent, and recentness of risk factors that were noticed and evaluated. Two wetlands (IW1 Summit Lake Campground, and IW2 Manzanita Lake) were selected and assessed specifically because they were anticipated to have experienced the largest human impacts. Alteration also has been extensive in Drakesbad Meadow, a 90-acre wetland exposed to grazing and ditching over many decades. Restoration of part of this wetland is ongoing and monitoring results are reported by Patterson (2005).

Table 9. Frequency of artificial features noted in or near LAVO wetlands.

Feature	All Visited Wetlands (n= 68)	Only the Visited Wetlands Comprising the Statistical Sample (n= 47)
Bridge	12%	9%
Building	1%	0%
Excavation	1%	2%
Ditch	0%	0%
Fence	1%	0%
Fill	0%	0%
Fire Ring	6%	4%
Firefighting Gear	0%	0%
Fish Hooks	3%	0%
Flagging, Markers	10%	9%
Trail	28%	23%
Livestock Grazing Evidence	0%	0%
Gullying	1%	0%
Saw Marks	6%	2%
Tire Marks	4%	0%
Trash	9%	9%
Any of Above	40%	36%

Figure 8. Wetland vegetation along shoreline that has been impacted by excessive off-trail foot traffic.

Table 10. Artificial features found in visited wetlands.

Visited wetlands not shown on this list appeared to lack any artificial features. None of the identified artificial features were of severe ongoing ecological concern. Many potential risk factors (e.g., contaminant exposure) could not be assessed during these site visits.

Code	Wetland Name	Artificial features
IW1	Summit Lake Campground	trails, bridge, tire marks
NW56	Butte Lake North	tire tracks, fire ring, trails
NR694	Reflection Lake	saw marks, tire tracks, trails, trash, bridge, fish hooks
K33	Hemlock Lake	trails
NR549	Guiseppe	building, bridge, fish hooks, flagging, trails, saw marks
K41	Southwest entrance	flagging, trail, bridge, saw marks, trash
NR144	Willow Lake	fencing, trails
K25	Forest Lake Drainage	trails, trash
NR178	Cold Spring	trails, trash
K9	Ridge Lake	trails, fire ring
K17	Sifford Lake	trails
K2	NW Crumbaugh Lake	trails
K23	Crags Lake	trails
K34	Crumbaugh West Lake	trails
NR473	Wet Kings Creek MDW	bridge

Table 9. Artificial features found in visited wetlands (continued).

Code	Wetland Name	Artificial features
IW2	Manzanita Lake	trails, bridge, flagging, trash, hydrologic alteration
K44	Indian Lake	trails, trash
K21	Drake Lake	fire rings
K45	Emerald Lake	bridge
NR342	Sphagnum fen	flagging
NR660	Juniper Lake	trails
K37	Bert	bridge
K52	Borite Creek	excavation
K36	Vulcans Castle	trails
NW28	Pilot Pinnacle Thermal Wetland	trails
K16	Terminal Geyser	flagging
K5	Devils Kitchen	flagging

Before LAVO was created in 1916, parts of the park were mined and extensively logged and grazed, with accompanying fires and sedimentation of surface waters. Although small in comparison to the changes wrought by the eruption in 1915-1916, these activities undoubtedly had a significant local impact on the water quality, vegetation, and wildlife of wetlands. The permanency of those impacts is uncertain (Figure 9), and extensive recovery of vegetation from both the eruption and the preceding human activities is evident. Until 1980, some of the park's waters were annually stocked with fish, and recent studies have suggested negative impacts on native amphibians as a result of this practice (Stead et al. 2005). Campgrounds and heavily-used trails located near some of the park's waters have the potential to affect those water bodies. For example, a study of ponds in Kings Canyon National Park, California, found greater aquatic plant cover (mainly *Nitella* and *Isoetes*) when campgrounds and trails were present nearby, even in cases where those had been abandoned for several years (Taylor and Erman 1979).

Figure 9. Remnants of more intensive land uses during historic times in LAVO.

Decades of fire suppression also have affected LAVO vegetation because some types of fires are important in shaping vegetation communities (Taylor 2000). However, intense fires and the use of heavy equipment and flame retardants used in fire fighting can potentially harm wetlands. Recognizing the importance of fire as a natural shaper of ecological communities, current policies allow fires that start naturally in many parts of LAVO to burn with only limited control efforts. NPS staff also conduct controlled burns in selected areas of the park. Many of LAVO's montane meadows are wetlands. As a result of decades of fire suppression, prolonged drought, and/or other factors, many montane meadows are gradually being invaded by trees, with consequent impacts on herbaceous plants and some wildlife species (Berlow and D'Antonio 2002). Other natural factors that are likely to have influenced the occurrence and characteristics of the park's wetlands and their vegetation include landslides, seismic and volcanic activity, springs, beaver, insect and plant disease outbreaks, wind storms, and annual changes in temperature and precipitation (snow amount, date of complete meltdown in each wetland, occurrence of summer rains, timing and duration of freezing). Global climate change can alter the frequency and intensity of these natural disturbances, thus posing an increasing threat to the park's wetlands and their biological communities.

Although relatively few pollution sources remain within the park, long-distance airborne transport of contaminants poses a potential threat. A recent study found evidence for nutrient enrichment of high-elevation lakes in the Sierra Nevada (Sickman et al. 2003), and it has been suggested that the source might be increased levels of atmospheric nitrogen, phosphorous, and pesticides in dust and soil aerially transported from the Central Valley of California or Asia. The Western Airborne Contaminants Assessment Project (Landers et al. 2008) determined that lichens and conifers sampled at five sites in LAVO were contaminated with several pesticides currently used outside the park, especially endosulfans and dacthal, but also chropyrifos and g-HCH (lindane) and historically-used DDT, hexachlorobenzene, chlordanes, dieldrin, and PCB. Lichens and/or conifers also had relatively high levels of PAHs (combustion by-products). These contaminants were also present in air samples at levels mostly greater than found in other western parks. Concentrations increased with elevation within the park. Also present in air samples at above-median concentrations were triuralin (an herbicide) and the historically-used pesticides chlordane, DDT, HCB, and a-HCH (alpha hexachlorocyclohexane). Nitrogen deposition was not elevated compared with other western parks. In other parts of the Sierras, long distance transport of airborne pesticides has been noted (Zabik and Seiber 1993) with possible damage to amphibian populations (Davidson 2004).

3.3.2 Wetland Health as Indicated by Plants

Biodiversity and Reference Conditions: Through our wetland survey efforts, six species that were previously unknown in the park have been added to the park's flora. These are as follows (parenthesized codes are their wetland indicator status, see Table 11):

- *Sisyrinchium elmeri.* (OBL). Found at Upper Meadow in the Kings Creek drainage within sight of the park road (site NR473). Plants were found growing near a seep on the eastern edge of the meadow in full sun. This population may represent the first documented collection of this plant in Shasta County, although it has been collected just south of the park in Tehama County.
- *Danthonia intermedia.* (FACU+). Found at several locations in the park. The absence of this plant from the park's flora may be the result of differing classifications; the key in the Lassen Flora by Gillett et al. results in a different identification from the key in the Jepson Manual (Hickman 1993).
- *Elodea canadensis.* (OBL). Found in Manzanita Lake. The nativity of this plant to the park is unknown. There is a possibility that this plant may have been introduced incidentally by fishermen, although it is native to the region and has previously been documented at locations

relatively close to the park. However, it seems odd that this plant has not been documented in the lake previously when there are records of other aquatic plants from this well botanized wetland.

- *Hesperochiron pumilis.* (FAC). Collected very early in the season (late June) in a meadow northeast of Terminal Geyser (site K16). This plant has previously been collected to the south of the park; likely it had not been found within the boundaries prior to this since it is a very early bloomer.
- *Carex douglasii.* (FAC-). Collected at Butte Lake at the edge of a dry meadow bordered on three sides by lava flows (site NW56). This species is fairly common to the east and south of the park.
- *Agrostis stolonifera.* (FACW). Collected on the northwest shore of Manzanita Lake. This is a non-native plant. Due to the difficulty in separating this plant from *A. gigantea*, a subject matter expert should examine this specimen before adding this plant to the flora.

Our surveys of just 68 wetlands (7% of the total number of mapped LAVO wetlands, or about 16% by acreage) detected 338 species, representing about 41% of the park's vascular plant species. Considering just the 434 plant species that occur characteristically in wetlands and have been reported previously in LAVO, we detected 221, or 51% of the park's wetland flora (Table 11). Plant species reported previously from LAVO, and which typically occur in wetlands but which our wetland surveys did not find, are denoted in the table in Appendix D. The potential reasons for not finding the 49% of the wetland species that had previously been reported from the park are numerous, and include (a) the fact that we could survey only 7% of the park's wetlands, and those during only one time of the season, (b) difficulty in noting diagnostic features of some species during a single wetland visit, thus prohibiting definitive identification, (c) inaccessibility of some aquatic species that occur in deeper-water areas of ponds, (d) temporary dormancy during 2005 of some species which might still be represented in the wetland seed bank, (e) potential misidentifications in the historical reports, and (f) long-term disappearance of the species from park wetlands as a result of natural succession, other natural phenomena, or human influences. For individual wetlands, about 60% (range: 4 to 100%) of the species list for the entire wetland was found within the herb and shrub plots.

Among the 338 plant taxa (both wetland and upland) we found in the visited wetlands, there are at least two that are listed by the California Native Plant Society (CNPS 2007) as rare or having limited distribution. We found *Potamogeton praelongus* (white-stemmed pondweed) in just one wetland (site IW2) and *Stellaria obtusa* (obtuse starwort) in just one other wetland (K41). Both species are considered "rare in California but more common elsewhere." In addition, we encountered *Dicentra formosa* in four wetlands, *Penstemon heterodoxus* var. *shastensis* in three wetlands, *Corydalis caseana* ssp. *caseana* in two wetlands, and *Eriogonum nudum* in two wetlands. These subspecies or varieties have particularly limited statewide distributions according to the CNPS, and those subspecies and varieties have been documented previously from LAVO. We did not determine if the individual plants we found of these species were in all cases those particular subspecies or varieties. Although most of the park's thermal and non-thermal springs (most classified as wetlands) have unusual water quality and thermal regimes, apparently no plant species in LAVO are restricted to such habitats, although one variety (*Dichanthelium acuminatum* var. *thermale*) is, according to Gillett et al. (1961).

Table 11. Survey effectiveness for detecting wetland indicator plant species known to occur in LAVO.

Wetland Indicator Status	# of Wetland Species Reported Previously from LAVO	# of Wetland Species Found During 2005 (% of total in that status category)
OBL	118	50 (42%)
FACW+	30	21 (70%)
FACW	63	40 (63%)
FACW-	25	13 (52%)
FAC+	17	13 (76%)
FAC	78	40 (51%)
NOLW	103	44 (43%)
total	331-434*	221 (51%)

*Depending on whether certain NOL species are counted as NOLW (i.e., "wetland") species. Wetland species together comprise 38-49% of the LAVO flora, a relatively high percentage for a park in which known wetlands occupy less than 1% of the park's area. For comparison, 38% of Yellowstone National Park's plant species are associated with wetlands (Elliott and Hektner 2000). OBL (Obligate wetland species): occur almost always under natural conditions in wetlands (more than 99 percent of the time). FACW (Facultative wetland species): occur in wetlands 67-99 percent of the time but are occasionally found in non-wetlands. FAC (Facultative species): are equally likely to occur in wetlands (34-66 percent of the time) or non-wetlands. FACU (Facultative upland species): more likely to occur in non-wetlands, but may occur in wetlands. (+) tending to the wetter end; (-) tending to the drier end. NOLW= no indicator status has been assigned by NWI, but anecdotal information suggests wetland association.

Botanical Uniqueness of Individual Wetlands: Of the 221 wetland plant species we encountered in 68 wetlands, we found almost half (45%) in only a single visited wetland. These species are listed in Appendix D and their location can be determined from the accompanying database files. Figure 10 shows the overall frequency distribution of wetland plant species among the sites we visited. The large proportion of species occurring in only one or a few wetlands suggests (a) relatively low rates of population dispersal and mixing, as is often the case in undisturbed landscapes, and/or (b) short seasonal detection periods for some species, and/or (c) high spatial variation among the visited wetlands with regard to their natural physical conditions (hydrology, soils, microclimate). A statistical analysis of the environmental correlates of each of the plant communities will be presented in a separate document (Cheryl Bartlett, thesis in progress, Oregon State University).

One way of expressing the uniqueness of a particular wetland is the number and proportion of its species (total, and just wetland species) that were found at no other sites, or just a few other sites. This can be expressed as a "frequency index" in which each species has a coefficient, that being the number of wetlands in which it was found. These coefficients are averaged among all species found in a wetland. Higher values indicate a prevalence of species that are more ubiquitous (frequent) among the visited LAVO wetlands.

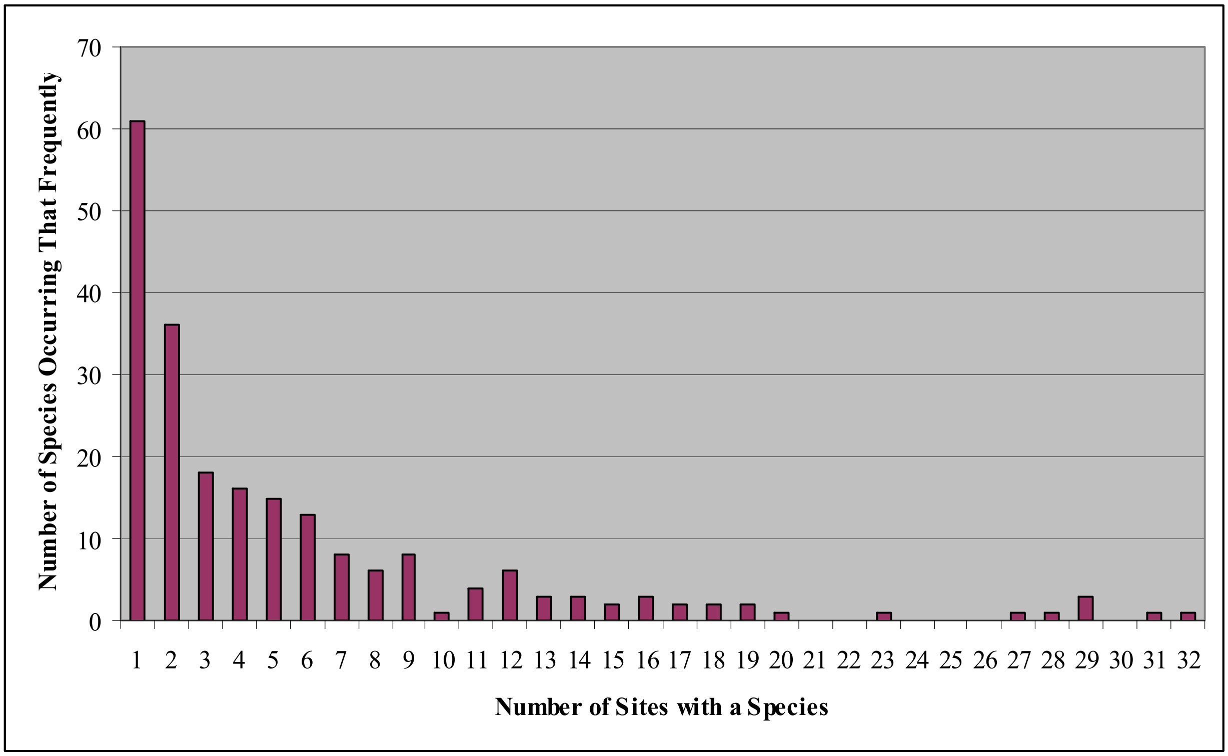


Figure 10. Site frequency distribution for wetland-associated plant species of LAVO.

Based on this index as calculated from data in Appendix E, among the visited wetlands, the ones with most unusual floras were (from most to least unique) K31, K43, K26, NR549, K27, K2, K37, K19, and K52. However, because larger wetlands contained a larger search area, there was a bias towards encountering a larger proportion of unusual species in larger wetlands. To compensate for this, we compared wetlands using the frequency index just from the standard-sized herbaceous vegetation plot (one per wetland). The results also suggest that, among the visited wetlands, the ones with most unusual floras were (from most to least unique) NW7, K23, K46, K6, NR473, NW56, K11, NRF1, NR178, K21, K19, and K42. Floras tended to be less typical in wetlands that were dominated by emergent (herbaceous) vegetation, intercepted by streams, at lower elevations, and not on lakeshores. At a plot scale, floras with restricted occurrence were found more often in plots dominated by emergent vegetation in flat terrain with a relatively large amount of downed wood. Plots whose most-restricted species were relatively ubiquitous within the park tended to be generally wet (based on indicator status of their flora), isolated from other wetlands and streams, in flatter terrain, and in the more easterly parts of the park.

Another way of identifying the most botanically unique wetlands is by doing a statistical cluster analysis of the species composition data. As expected, those results were similar to those using the frequency index, identifying wetlands K6, K19, and NW7 as distinctive, and additionally identifying wetland K52 as botanically unique.

Species Composition Metrics: Wetland ecologists have proposed a variety of indices or metrics for representing wetland health (Cronk and Fennessey 2001), but few have been validated experimentally by correlation with various types of wetland disturbances. Because they are used most commonly, we used the following metrics to summarize our data at both the wetland (plot + polygon) and plot scale, as shown in Table 12.

Number of Species or Families: Other factors being equal, wetlands with greater species richness are sometimes considered to be healthier. However, this becomes harder to interpret if most of the species are ones that are common and widespread in the region. Also, both human-related and natural disturbances can temporarily increase species richness in wetlands. And to make fair comparisons among wetlands, equal-sized plots must be compared because richness always increases with increasing wetland area (Figure 11). In the 100 m^2 herbaceous plots, the median number of species was 14 and the median number of families was nine. In the 400 m^2 shrub plots, the median number of species was 28 and the median number of families was 15. For entire wetlands, the median number of species was 30. For comparison, in Drakesbad Meadow, Patterson (2005) found two to 18 vascular plant species per 10 m^2 plot.

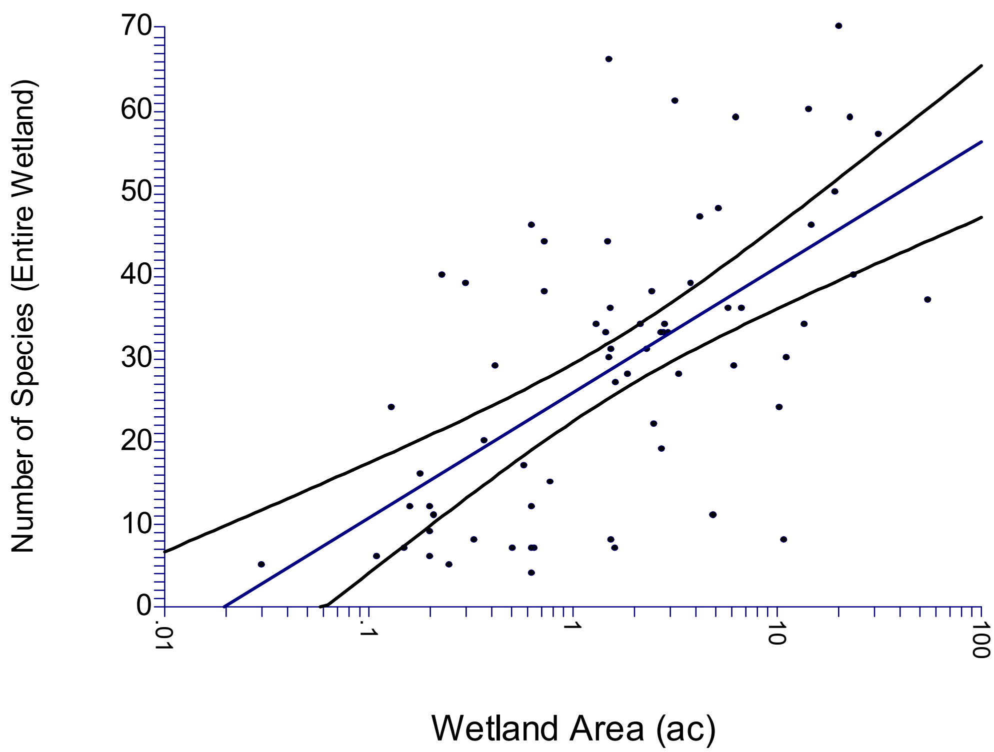


Figure 11. Plant species-area relationship among all wetlands surveyed in LAVO.

At both a wetland polygon scale and at a plot scale (the preferred scale for comparing richness), correlation analysis showed that the most species-rich wetlands were large, not strongly dominated by any species, at least partly wooded (forest or shrub), sloping, relatively dry but intersected by streams with relatively high conductivity, near other wetlands and roads, and in the wetter western parts of the park. Their floras tended to include many species with limited distribution in the park. The number of plant families in a plot was greater in higher elevation (higher precipitation) sloping wetlands, especially those intersected by streams. It was less in plots associated with drier wetlands, with more shrub cover and less year-round water.

Number of Vegetation Forms: Other factors being equal, wetlands with a greater variety of vegetation forms (trees, shrubs, forbs, grasses, aquatic plants) are sometimes considered to be healthier. But again, both human-related and natural disturbances can temporarily increase form diversity in wetlands, and ideally, comparisons should be made only among equal-sized plots. Environmental correlates were found to be similar to those described above for species richness.

Frequency Index: To calculate this, each species found in a wetland is assigned a coefficient, that being the number of visited wetlands in which it was found. These coefficients are averaged among all species found in a wetland. Higher values indicate the wetland's species list is dominated numerically by species that are more ubiquitous among the visited LAVO wetlands. Other factors being equal[6], lower values may suggest wetland health is greater, assuming this is indicated by proportionally more species with narrow tolerances. Although based on species distributional data from only LAVO, this index is similar to the "coefficient of conservatism" that is a component of widely-used Floristic Quality indices. Environmental correlates are described on page 34.

Number and Percent of Fen Species: "Fen species" are plants that characteristically thrive in fens (wetlands with peat soils and substantial inputs of groundwater), although most occur in other habitat types as well. The *Fen Condition Checklist* for the Sierras (Weixelman et al. 2007) lists 33 such species, and we found 10 of these among 23 of the visited LAVO wetlands (see Appendix D). The number of fen species also can be expressed as a percent of all plant species found in a wetland, although this makes it susceptible to the biases inherent in species richness estimation that were noted above. In LAVO, we found the highest number of fen species in larger, wetter wetlands associated with streams and other water bodies in the eastern part of the park.

Moss Cover: The percent of a wetland's vegetated area that is covered by mosses might be used as an indicator of relatively undisturbed conditions in some wetland types, e.g., fens. Most mosses grow slowly and are major contributors to accumulation of peat, thus sequestering carbon for long periods.

Number and Percent of Disturbance Species: Disturbance species include all non-native plants plus a few native species (*Aster alpigenus*, *Hypericum anagalloides*, *Mimulus primuloides*) believed by Cooper and Wolf (2006) to become increasingly dominant in significantly disturbed wetlands of the Sierras. The number of such species also can be expressed as a percent of all plant species found in a wetland, although this makes it susceptible to the biases inherent in species richness estimation that were noted above. In the 100 m^2 herbaceous plots, the median number of disturbance species was zero. In the 400 m^2 shrub plots, the median number of disturbance species was seven. For entire wetlands, the median number of disturbance species among all wetlands was two.

We found 19 disturbance species (6% of all species we encountered) among 44 of the 68 wetlands we visited. The number of disturbance species was greatest in large, sloping, relatively wet shrub and forested wetlands intersected by streams with higher conductivity and in the western part of the park. Of note, we found that the number of disturbance species, as well as the percent of a wetland's species list that was comprised of disturbance species, increased the closer a wetland was to roads (Figure 12). However, the percentage decreased with proximity to *trails*. The total number of species also increased significantly closer to roads.

[6] The value for the frequency index was not significantly correlated with wetland size, but was larger for wetlands surveyed later in the season and those at higher elevations.

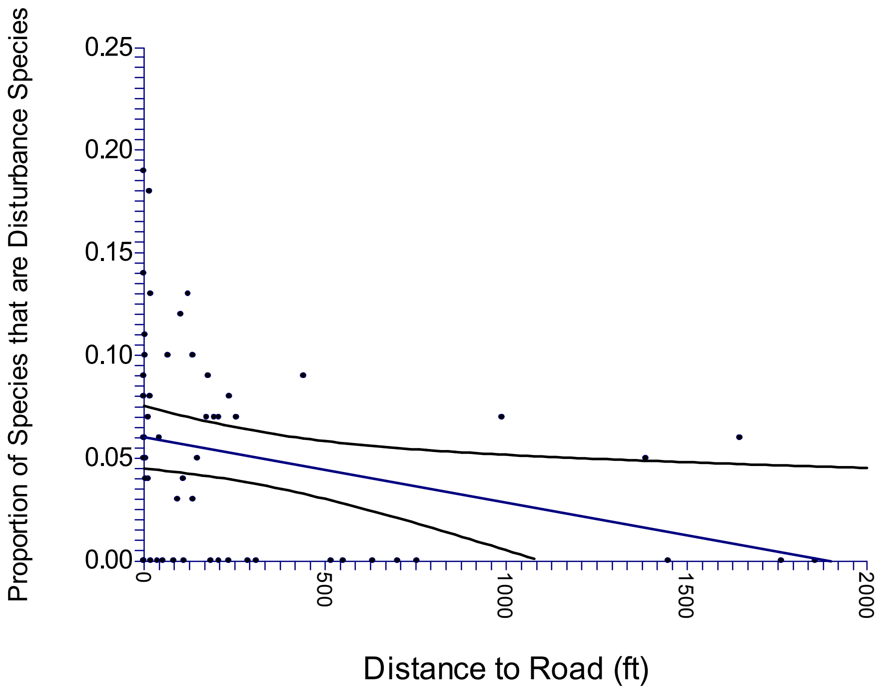


Figure 12. Statistically significant relationship in LAVO wetlands between proportion of species that are disturbance species and wetland distance from a road.

Dominance: Degraded wetlands are often characterized by a very few species comprising nearly all the vegetative cover, whereas healthy wetlands are often characterized by many species, none of which cover a significant proportion of the vegetated part of the wetland. Thus, the number and proportion of the species that comprise more than 60% of the cover (CC4, cover class 4) can be used to indicate disturbance. However, strong species dominance or co-dominance also can occur as a result of natural disturbances as well. In just 22% of the herb plots, one herb species clearly dominated, comprising more than 60% cover. These dominants were varied: *Carex angustata, Carex lenticularis, Carex vesicaria, Juncus balticus*, and *Veratrum californicum* – none dominating in more than two of the 72 plots. Co-dominants (herb species comprising 25-60% of the cover) were present in about half of the herb plots. In six of the 11 shrub plots, one species comprised more than 60% cover, and in five of the shrub plots, one or more species comprised 25-60% of the cover. Dominance was greater in smaller wetlands, those in more southerly parts of the park, and those known to have had fires in their vicinity. Unexpectedly, dominance was less in wetlands closer to roads than those farther away.

Prevalence Index: In some cases, wetlands whose species list and cover is dominated by "true" wetland species (those least tolerant of drier upland conditions) might be considered healthier, because upland species tend to invade wetlands that have been partially filled or whose water table has been artificially drawn down. Such wetlands have larger values for their Prevalence Index. However, natural periods of drought can have the same effect, and many healthy seasonal wetlands are somewhat dry naturally, so this index is not consistently reliable as an indicator of human disturbance. In the 100 m^2 herbaceous plots, the median Prevalence Index value (unweighted by cover class) was 2.04, whereas in the 400 m^2 shrub plots, it was 2.26, indicating drier conditions (as expected). At a wetland scale, the median value (unweighted by percent cover) was 2.10 and tended to be lower in wetlands in flat terrain farther from streams, that have less shrub cover and are (logically) classified on NWI maps as being permanently or semipermanently flooded. At a plot scale, the value weighted by species cover was less (i.e., indicating wetter conditions) in wetland plots at higher elevation, distant from streams, associated with permanent inundation (e.g., ponds), in more easterly parts of the park.

Table 12. Statistical summaries of botanical metrics for pooled polygon and plot data.

	Wetland Polygon Including Plots (all sites, n= 68)						Wetland Polygon Including Plots (random sites only, n= 47)					
Metric	mean	S.D.	median	range	25th	75th	mean	S.D.	median	range	25th	75th
# of species	29.06	2.1	30.5	66	12	39	28.34	2.59	30	66	11	39
Prevalence Index, unweighted	2.13	0.29	2.10		1.94	2.34	2.13	0.31	2.09		1.92	2.38
# of Fen spp.	0.73	0.16	0	6	0	1	0.55	1.10	0	6	0	1
Fen species as % of Total	2.37	4.69	0	0.25	0	3.01	2.37	4.69	0	0	3.01	0.25
# of disturbance spp.	1.91	1.78	2	7	0	3	1.53	1.56	2	6	0	3
Disturbance spp. as % of Total	5.57	5.48	5.41	0.21	0	8.82	4.26	4.44	4.29	0	6.90	0.18
Frequency index	6.46	1.62	6.41	8.49	5.61	7.17	6.65	1.39	6.5	5.83	7.29	7.15

Table 13. Statistical summaries of botanical metrics at plot scale (herb plots only).

	Herb Plots (all sites and plots, n= 72)				Herb Plots (random sites only, n= 47)			
	mean	median	25th	75th	mean	median	25th	75th
# of spp.	14.62	14	5	21	14.21	15	4	21
Prevalence Index, weighted	1.99	2.04	1.72	2.31	2.01	1.75	2.05	2.33
# of Fen spp.	0.26	0	0	0	0.15	0	0	0
Fen spp. as % of Total	3.53	0	0	0	1.89	0	0	0
# of Non-native spp	2.06	2	1	3	2.17	2.5	1	3
Non-native spp. as % of Total	1.93	0	0	0	1.05	0	0	0
# of Disturbance spp.	1.01	0	0	2	0.96	0	0	2
Disturbance spp. as % of Total	5.19	0	0	9	4.70	0	0	8
Frequency index	13.00	13.23	11	16	13.53	13.27	11.30	16.05
% of spp. <1% cover	58	64	50	73	55	62	40	73
% of spp. 1-25%	32	29	22	42	34	32	23	48
% of spp. 25-60%	6	0	0	6	6	0	0	5
% of spp. > 60%	4	0	0	4	5	0	0	4

Table 14. Statistical summaries, by HGM class, of botanical metrics at plot scale.

Calculated for all sites and plots combined, not just for random ones.

	Depressional Wetlands (n=30)				Slope Wetlands (n= 27)				Riverine Wetlands (n= 12)			
	mean	median	25th	75th	mean	median	25th	75th	mean	median	25th	75th
# of spp.	9.70	5	3	15	16.41	16	12	20	25.00	24.50	13	37
# of Fen spp.	0.33	0	0	0	0.29	0	0	0	0	0	0	0
Fen spp. as % of Total	4.24	0	0	0	4.34	0	0	0	0	0	0	0
# of Non-native spp	2.00	2	1	3	1.50	1.50	1	2	2.42	3	1	3
Non-native spp. as % of Total	1.49	0	0	0	1.43	0	0	0	4.65	2.91	0	8
# of Disturbance spp.	0.73	0	0	1	1.04	1	0	2	1.83	1	0	4
Disturbance spp. as % of Total	4.09	0	0	0	6.03	5.88	0	9	6.52	5.30	1	10
Frequency index	12.33	12.75	10.49	14.50	14.41	14.82	12.25	17.21	12.63	12.11	9.99	14.31
% of spp. <1% cover	52	51	33	74	63	64	57	70	63	72	48	79
% of spp. 1-25%	33	33	22	50	28	29	23	33	30	24	16	45
% of spp. 25-60%	7	0	0	8	6	0	0	5	5	3	0	10
% of spp. > 60%	6	0	0	0	3	0	0	6	1	0	0	0

Table 15. Statistical summaries of botanical metrics at plot scale (shrub/forest plots only).

	Shrub/forest (all sites, n= 11)						Shrub/forest (random sites only, n=8)					
	mean	S.D.	median	range	25th	75th	mean	S.D.	median	range	25th	75th
# of spp.	26.27	2.29	26	27	21	33	28.75	2.4	27.5	22	24.5	33.75
# of Families	14.82	1.39	14	17	12	18	16.38	1.39	15	11	13.25	20.25
# of veg forms	3.73	0.27	4	3	3	4	3.75	0.37	4	3	3	4.75
# of disturbance spp.	2.22	0.4	2	3	1	3.5	2.67	0.49	2.5	3	1.75	4
Prevalence Index (weighted)	2.25	0.23	2.26		2.08	2.42	2.21	0.23	2.16		2.03	2.40
Disturbance spp. as % of Total	6.8	4.68	7.14	15	4	10	6.71	5.38	6.51	15.38	1.04	10.83
Frequency index	7.25	1.74	6.5	6.27	8.69	5.24	7.18	1.47	1.54	4.05	6.31	8.17
% of spp. <1% cover	80.84	14.77	64.29	100	48.15	114.29	60.87	9.86	56.64	87.5	38	70.45
% of spp. 1-25%	35.53	8.77	33.33	100	20	44.44	27.76	4.92	29.17	35.62	12.86	41.99
% of spp. 25-60%	2.78	1.17	0	12	0	5.56	2.33	0.93	1.52	5.88	0	5.21
% of spp. > 60%	2.03	0.8	0	7.69	0	3.85	1.24	0.62	0	3.85	0	3.3

3.3.3 Wetland Health as Assessed Using CRAM

Although mostly calibrated against more robust measurements of ecological health, the California Rapid Assessment Method (CRAM) states that its objective is to provide a standardized, cost-effective tool for assessing the health of wetlands and riparian habitats. Within each HGM class, the maximum points a wetland can score is 100. That score is a composite of the scores of 16 variables that are estimated visually in a wetland and its surrounding landscape. Each variable is scored A (12 points), B (nine points), C (six points), or D (three points).

CRAM scores for the individual wetlands we visited are shown in Appendix F, and summarized below in Table 16. The median score was 78 in a scale of 0 to 100, suggesting that LAVO's wetlands are in relatively good condition. This is confirmed by comparison with scores from 14 non-randomly selected Riverine High (i.e., Riverine Confined) wetlands assessed by other investigators in other parts of California. The median CRAM score for those was just 46 and the maximum was only 53.

CRAM uses rudimentary botanical data for some of its input variables, so correlations with botanical metrics (such as number of weedy species) would be circular and meaningless. Wetlands intercepted by streams (especially streams with high conductivity) tended to have higher CRAM scores, and those with a low Prevalence Index (suggesting wetter conditions) and isolated ones dominated by emergent vegetation in the eastern part of the park scored lower. CRAM scores for LAVO wetlands were not correlated significantly with any of the independent measures of potential risks to wetland ecological condition (e.g., proximity to roads and trails, visual evidence of human visitation).

Table 16. CRAM scores from visited LAVO wetlands: summary statistics.

HGM Type	Statistical Sample of Wetlands (n= 47)				All Visited Wetlands (n= 68)			
	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum
Riverine Confined	8	79.95	75.39	88.67	11	80.08	75.39	88.67
Depressional	21	76.95	66.02	87.89	30	78.72	65.63	87.89
Vernal Pool	1	69.92	69.92	69.92	2	70.90	69.92	71.88
Slope	17	78.52	66.41	93.75	25	78.52	66.41	93.75
ALL	47	78.52	66.02	93.75	68	79.30	65.63	93.75

3.3.4 Wetland Health as Assessed Using the Fen Condition Checklist

Another qualitative method (checklist) for assessing wetland health was proposed for fen wetlands of the Sierras and southern Cascades by Weixelman et al. (2007). It follows generally the "Proper Functioning Condition" (PFC) approach used widely by some federal agencies (Pritchard 1994). The presence or absence of 11 conditions believed to indicate healthy fens is evaluated visually. Unlike CRAM, no standardized protocol is provided to synthesize the information on the 10 conditions into one overall assessment of a wetland's health. Although only a few of the wetlands we visited would be considered fens, we evaluated the wetlands as a whole (not individually) as shown in Table 17 using the draft *Fen Condition Checklist*.

Table 17. Health assessment of visited LAVO wetlands based on the draft *Fen Condition Checklist*.

Proper Functioning Condition	Application to the Visited LAVO Wetlands
1) Water table depth is <20 cm from surface in July-August.	A well-defined peat layer was lacking from many wetlands, but in nearly all cases this appeared to be more likely due to natural factors (fire, low precipitation, young soils) than to human alteration.
2) Potential extent of the fen, i.e. fen is enlarging or has achieved potential extent.	True of most visited wetlands.
3) Upland watershed is not contributing to fen degradation.	True of nearly all visited wetlands.
4) Natural surface or subsurface flow patterns are not altered by disturbance (i.e., dams, dikes, trails, hoof action, roads, rills, gullies, drilling activities).	True of nearly all visited wetlands.
5) Vegetation has a high percentage of native plant species.	True of nearly all visited wetlands.
6) Vegetation has a high percentage of peat-forming plant species (either vascular or non-vascular).	Two wetlands (K25, NR342) were dominantly moss-covered, suggesting potential for peat formation. No other wetlands had appreciable cover of moss. 34% of the wetlands had fen species that help form peat.
7) Plant species indicate maintenance of fen soil moisture characteristics.	True in 34% of visited wetlands.
8) Fen indicator species are present and well represented. (Generally applicable to poor fens, transitional fens, and rich fens).	"Well represented" in 12% of visited wetlands.
9) Amount of bare soil and bare peat is within guidelines (generally, <20%) for healthy fen systems.	True in all visited wetlands.
10) No surface disturbances significantly expose peat or cause fragmentation of the vegetative cover, e.g., as possibly caused by hoof punching due to livestock, or recreational vehicles.	True. None found in any visited wetlands.
11) Fen-wetland is in balance with the water and sediment being supplied by the watershed (i.e., neither erosion nor deposition are excessive)	True.

3.4 Valued Ecological Services of Wetlands: Estimates Based on Heuristic Models

"Ecological services" are the things that wetlands do, such as intercept and store water. Wetlands perform dozens of ecological services recognized as directly useful to society. Just nine (Table 27) are addressed in this document. These are described below.

The degree to which a wetland performs many ecological services often has less to do with the wetland's health (ecological condition or naturalness) than with intrinsic features, such as underlying soil, elevation, size, and native vegetation communities that are adapted naturally to the site. For each wetland, this document describes our assessments of both wetland health and ecological services. In both cases, because it was not feasible to measure health or ecological services directly, we used rapidly-estimable features that scientists believe, to varying degrees, can be used as indicators of *relative* health or capacity to support ecological services. We found that the levels of *none* of the nine ecological services, as estimated, were correlated with indicators of risk (e.g., distance to roads and trails, visual evidence of human presence).

To arrive at an estimate for each of a wetland's ecological services and its overall ecological condition, the rapid indicators were integrated using heuristic models, also known as "criteria" or narrative "rules-of-thumb." They were tailored to the environmental conditions and data sources specific to

LAVO, and include many of those identified, documented, and applied previously by the principal investigator (Adamus and Field 2001) and many other scientists (Bartoldus 1998, Fennessey et al. 2004). The rationale for each indicator is not repeated here; readers should consult the document by Adamus et al. (1992) for such documentation.

The following estimates of wetland ecological services are relative, not absolute. That is, just because a wetland is rated (for example) "Low" with regard to its capacity for an ecological service – such as Supporting Native Amphibians – it does not mean that the wetland is absolutely useless as habitat for any native amphibian species. Rather, compared to other wetlands, its suitability or usefulness is more limited. Ideally, when assessing ecological services, individual wetlands should be compared just with others of the same type (however "type" is defined). This limitation was not imposed in our data analysis because of the relatively small sample size (68 wetlands).

3.4.1 Natural Water Storage and Slowing of Infiltration

This ecological service concerns the capacity of a wetland or riparian area to store or delay the downslope movement of surface water for long or short periods, and in doing so to potentially influence the height, timing, duration, and frequency of inundation in downstream or downslope areas. This usually has positive economic, social, and ecological implications for the affected areas downstream or downslope. In some cases, water stored by wetlands early in the growing season can help maintain local water tables and in doing so, may sometimes sustain streamflow for longer into the summer, increasing habitat available to fish, amphibians, and aquatic plants.

Table 18. Model for describing relative capacity of LAVO wetlands for natural water storage and slowing of infiltration.

Rating is	Heuristic Model*
HIGH if	(wetland is along a lake/pond *or* classified as Depressional or Vernal Pool) *and* (≤20% of the wetland has obvious slope) *and* (<30% of the wetland is flooded year-round)]
LOW if	riverine *or* [(>50% of the wetland is sloping) *and* (>30% of the wetland is flooded year-round)]
INTERMEDIATE if	neither of above

*In each of the ecological services in this section, wetlands are screened first using the model for HIGH, then using the model in the next box down (usually LOW) only if the criteria in the first box were unmet, etc. Also, within each box, parentheses and brackets indicate the required order of operations.

Application of this model (Table 18) resulted in 33/34% of the visited wetlands being rated HIGH, 22/25% rated LOW, and the remainder rated INTERMEDIATE. (The first number is for the statistical sample of 47 wetlands, the second is for all 68 visited wetlands).

Figure 13. Note the bands on the rock in the foreground, indicating changing water levels which are evidence of water being stored seasonally in this LAVO wetland.

3.4.2 Intercepting and Stabilizing Suspended Sediments

This concerns the capacity of a wetland to intercept suspended inorganic sediments, reduce current velocity, resist erosion of underlying sediments, and/or minimize downstream or downslope erosion that otherwise would result from direct rainfall, sheet flow, flow in degrading channels, or wave action. This ecological service is of economic and social interest because excessive suspended sediment (turbidity) in water is usually considered to be a pollutant, partly because unnatural rates of bank erosion can adversely affect survival of aquatic life, vegetation, and property. However, excessive rates of sediment retention can eventually eliminate the wetland that is doing the retaining.

Table 19. Model for describing relative capacity of LAVO wetlands for intercepting and stabilizing suspended sediments.

Rating is	Heuristic Model
HIGH if	Water Storage was rated HIGH
LOW if	(Water Storage was rated LOW) *and* (classified as a Slope wetland) *and* (few internal depressions*)
INTERMEDIATE if	neither of above

*CRAM score for Topographic Complexity was <12

Application of the model (Table 19) resulted in 33/34% of the visited wetlands being rated HIGH, 51/50% rated LOW, and the remainder rated INTERMEDIATE. (The first number is for the statistical sample of 47 wetlands; the second is for all 68 visited wetlands.)

3.4.3 Processing Nutrients, Metals, and Other Substances

This describes the capacity of a wetland to retain and/or remove any forms of phosphorus, nitrate, metals, pesticides, oil, or other substances considered in excess to be pollutants. This ecological service is valued because these substances otherwise can adversely affect aquatic life located in water bodies to which the wetland drains. However, excessive retention of some substances can harm aquatic life within the wetland doing the retaining. Also, the capacity of wetlands to process some substances effectively for years and decades may be finite. In contrast, the capacity of most wetlands to remove excessive nitrate (by converting it to nitrogen gas) appears to be almost unlimited.

Application of the model (Table 20) resulted in 40/45% of the visited wetlands being rated HIGH, 40/36% rated LOW, and the remainder rated INTERMEDIATE. (The first number is for the statistical sample of wetlands; the second is for all visited wetlands.)

Table 20. Model for describing relative capacity of LAVO wetlands for processing nutrients, metals, and other substances.

Rating is	Heuristic Model
HIGH if	(Water Storage was rated HIGH) *or*{(Water Storage was rated INTERMEDIATE) *and either* [(>30% of the wetland is flooded year-round) *or* (soils are relatively organic*)] *and* (alder comprises <20% cover)}
INTERMEDIATE if	(Water Storage was rated INTERMEDIATE) *and* [(>5% of wetland is flooded only seasonally) *or* (soils are relatively organic*)]
LOW if	(Water Storage was rated LOW or INTERMEDIATE) AND (<30% of wetland is flooded only seasonally) *and* (soils are mostly not organic)

*more than one “fen indicator” plant species was present, and/or soils in at least one test pit were peat or muck or had redox mottles

3.4.4 Sequestering Carbon

This describes the capacity of a wetland to remove and store on a net basis for long periods (100+ years) carbon from the atmosphere, such as by photosynthesis. This ecological service is valued because gaseous carbon can otherwise contribute to global climate change. Carbon fixed through photosynthesis also is vital to food webs.

Application of the model (Table 21) resulted in 34/33% of the visited wetlands being rated HIGH, 11/18% rated LOW, and the remainder rated INTERMEDIATE. (The first number is for the statistical sample of wetlands; the second is for all visited wetlands.)

Table 21. Model for describing relative capacity of LAVO wetlands for sequestering carbon.

Rating is	Heuristic Model
HIGH if	[(veg cover is ≤10% underwater) *or* (elevation is high*)] *and either* [(soils are relatively organic) *or* (tree cover is ≥5%)]
LOW if	(soils are mostly not organic) *and* (riverine *or* low elevation*)
INTERMEDIATE if	neither of above

* for LAVO, low elevation defined as <2000 m, high elevation defined as >2200 m

3.4.5 Maintaining Surface Water Temperatures

This describes the capacity of a wetland to maintain ambient temperatures of surface waters and ground-level microclimate by acting as a conduit for discharge of usually-cooler ground waters or by providing shade from sun and shelter from severe winds. This ecological service is valued because many fish, amphibians, and aquatic invertebrates are highly sensitive to temperature and soil moisture extremes as well as to too-frequent fluctuations in these factors.

Application of the model (Table 22) resulted in 28/31% of the visited wetlands being rated HIGH, 40/45% rated LOW, and the remainder rated INTERMEDIATE. (The first number is for the statistical sample of wetlands; the second is for all visited wetlands.) The model does not account for important differences among wetlands with regard to their aspect (south-facing being less effective for maintaining temperature in receiving waters) and contributing area (wetlands with large contributing areas being less effective) (Welsh et al. 2005).

Table 22. Model for describing relative capacity of LAVO wetlands for maintaining surface water temperatures.

Rating is	Heuristic Model
HIGH if	(>5% of wetland contains water year-round) *and either* [(a non-thermal spring is present) *or* (>30% of the water surface is shaded in summer)]
LOW if	no surface water persists year-round
INTERMEDIATE if	neither of above

3.4.6 Supporting Native Invertebrate Diversity

This describes the capacity of a wetland to support the life requirements of many invertebrate species characteristic of wetlands in this region, for example, midges, freshwater shrimp, some caddisflies, some mayflies, some butterflies, water beetles, shore bugs, snails, and aquatic worms. Such organisms contribute importantly to regional biodiversity, and are essential as food for fish, amphibians, and birds. The 2004 survey of 365 wetlands and ponds found fairy shrimp (most presumed to be *Streptocephalus sealii*) in 15% of those (Stead et al. 2005).

Application of the model (Table 23) resulted in 55/58% of the visited wetlands being rated HIGH, 34/30% rated LOW, and the remainder rated INTERMEDIATE. (The first number is for the statistical sample of wetlands; the second is for all visited wetlands.)

Table 23. Model for describing relative capacity of LAVO wetlands for supporting native invertebrate diversity.

Rating is:	Heuristic Model
HIGH if	a). (>5% of wetland contains underwater vegetation) *or* b). [(>5% of wetland contains water year-round) *and either* (>20% of wetland contains water only seasonally) *or* (contains several widely dispersed pools[1]) *or* (abundant internal depressions[2])] *or* c). [multiple veg layers[3] *or* high plant richness[4] *or* high plant ubiquity[5]]
LOW if	no surface water persists year-round *and not* a non-thermal spring *and* alder cover is <1%
INTERMEDIATE if	neither of above

1. Categories E-K on Data Form F that we used
2. CRAM score of 12 for Topographic Complexity
3. CRAM score of 12 for Number of Plant Layers
4. More than 50 native species
5. Most species found in wetland were present at 5 or fewer other visited wetlands (<7% of all visited wetlands)

Figure 14. Upturned trees (right) are a sign of increasing water levels in some wetlands; the resulting pools create habitat for aquatic invertebrates and amphibians.

3.4.7 Supporting Native Fish

This describes the capacity of a wetland to support the life requirements of fish species characteristic of wetlands or their receiving waters in this park. The 2004 survey of 365 wetlands, lakes, and ponds found fish in 6% of those (Stead et al. 2005). Fish-supporting waters were mostly lakes and large ponds at low elevation with multiple inlets. Species found by that survey were brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), tui chub (*Gila bicolor*), golden shiner (*Notemigonus crysoleucas*), fathead minnow (*Pimephales promelas*), speckled dace (*Rhinichthys osculus*), Lahontan redside (*Richardsonius egregious*), and Tahoe sucker (*Catostomus tahoensis*). These species contribute importantly to regional biodiversity, and are essential as food for some other fish, birds, and mammals.

Application of the model (
Table 24) resulted in 17/24% of the visited wetlands being rated HIGH, 49/46 rated LOW, and 34/31% rated INTERMEDIATE. (The first number is for the statistical sample of wetlands, the second is for all visited wetlands.) The model does not account for important differences among wetlands, regarding the physical accessibility of their connecting streams to fish.

Table 24. Model for describing relative capacity of LAVO wetlands for supporting native fish.

Rating is	Heuristic Model
HIGH if	(≥5% of wetland is flooded year-round *and* fish were noticed by this study or found by the SOU/USFS survey) *or* (≥20% of wetland is flooded year-round *and* wetland is classified as riverine or depressional)
LOW if	<50% of wetland contains surface water year-round *and* classified as a Slope wetland *and* if

	surveyed by SOU/USFS and no fish were found
INTERMEDIATE if	neither of above

3.4.8 Supporting Native Amphibians and Reptiles

This concerns the capacity of a wetland to support the life requirements of several species of amphibians and reptiles that inhabit the park. These species contribute importantly to regional biodiversity, as well as helping cycle energy within and between aquatic and terrestrial ecosystems. The 2004 survey of 365 wetlands and ponds found at least one amphibian species in 61% of those (Stead et al. 2005). Amphibians were found in 90% of the surveyed lakes, 73% of the wet meadows, 64% of the permanent ponds, and 47% of the temporary ponds. The most widespread species was Pacific treefrog (*Hyla regilla*) at 59% of the sites, followed by long-toed salamander (*Ambystoma macrodactylum*) at 10% of the sites, western toad (*Bufo boreas*) at 8%, and Cascades frog (*Rana cascadae*) and rough-skinned newt (*Taricha granulosa*) at just 1% each. Among reptiles, western terrestrial garter snake (*Thamnophis elegans*) and the common garter snake (*T. sirtalis*) were found most often, and either or both were found at 26% of the sites.

Application of the model (Table 25) resulted in 26/24% of the visited wetlands being rated HIGH, 2/3% rated LOW, and 72/74% rated INTERMEDIATE. (The first number is for the statistical sample of wetlands, the second is for all visited wetlands).

Table 25. Model for describing the relative capacity of LAVO wetlands for supporting native amphibians and reptiles.

Rating is	Heuristic Model
HIGH if	any uncommon herps[1] were found by the SOU/USFS survey *or* [(habitat connectivity is relatively good)[2] *and* >5% of wetland is flooded year-round *and* downed woody debris is extensive and/or diverse[3]
LOW if	no herps were found by either the SOU/USFS survey or incidental to our field work *and* habitat connectivity is relatively poor[2] *and* ≤5% of wetland contains water year-round
INTERMEDIATE if	neither of above

1. Any native species other than Pacific treefrog
2. CRAM score of 12(=HIGH); or 3 or 6 (= LOW)
3. From our Data Form F, multiple decay categories and/or diameter classes

Figure 15. Large pieces of downed wood provide essential habitat for many LAVO wildlife species.

3.4.9 Supporting Native Birds and Mammals

This concerns the capacity of a wetland to support the life requirements of a variety of birds and mammals that inhabit the park. Those that are known to be most dependent on wetlands are listed in Appendix H and Appendix I. These species contribute importantly to regional biodiversity, as well as helping cycle energy within and between aquatic and terrestrial ecosystems.

Application of the model (Table 26) resulted in 49/47% of the visited wetlands being rated HIGH, 6/9% rated LOW, and 45% rated INTERMEDIATE. (The first number is for the statistical sample of wetlands, the second is for all visited wetlands). Bufflehead is a species of diving duck that reaches, near LAVO, the southern limit of its North American breeding range, and thus is given special recognition in this model. Park biologists report that during 2005, Bufflehead broods were found in 18 lakes, ponds, and wetlands within the park, and adults were seen in an additional 24. Park biologists had previously noted Buffleheads in nine of the 47 wetlands and water bodies in our statistical sample, and one that we visited but which was not in our statistical sample. We noted previously unreported pairs in one wetland (K24) in our statistical sample and one wetland not in our sample (IW1).

Table 26. Model for describing the relative capacity of LAVO wetlands for supporting native birds and mammals.

Rating is	Heuristic Model
HIGH if	Bufflehead reported *or* (habitat connectivity is relatively good)[1] *and* either (>5% of wetland is flooded year-round) or (high veg type interspersion[2] or several veg layers[3] *or* high plant richness[4] *or* downed woody debris is extensive and/or diverse[5] *or* snags are extensive and/or diverse[6])
LOW if	(habitat connectivity is relatively fair or poor[1]) *and* [(few veg layers[3] *or* low plant richness[4]) *or* (downed woody debris is scarce[5] *or* snags are scarce[6])] *and* no Bufflehead reported
INTERMEDIATE if	neither of above

1. CRAM score of 12 (=High) or 3 or 6 (=Low)
2. CRAM score of 12 for Veg Interspersion and Zonation
3. CRAM score for Number of Plant Layers: 12= HIGH; 3 or 6 = LOW
4. More than 50 native species = HIGH; fewer than 20 native species= LOW
5. From our Data Form F, multiple decay categories and/or diameter classes
6. From our Data Form F, multiple decay categories and/or diameter classes

3.4.10 Summary of Ecological Services of LAVO Wetlands

Based on applying the above models to the statistical sample of wetlands we visited, the numbers and percentages of LAVO wetlands having relatively high, intermediate, and low capacity to perform each of nine ecological services is shown in Table 27. Ratings for the individual wetlands are given in Appendix F.

Table 27. Number (percent) of wetlands capable of performing selected ecological services, for just the visited wetlands that comprised the statistical sample.

See preceding section for descriptions of models used to compute these.

Ecological Service:	Relatively HIGH Capacity	Relatively LOW Capacity	Intermediate Capacity
Natural Water Storage & Slow Infiltration	15 (32%)	10 (21%)	22 (47%)
Intercepting and Stabilizing Suspended Sediments	15 (32%)	24 (51%)	8 (17%)
Processing Nutrients, Metals, and Other Substances	19 (40%)	19 (40%)	9 (19%)
Sequestering Carbon	16 (34%)	5 (11%)	26 (55%)
Maintaining Surface Water Temperatures	13 (28%)	19 (40%)	15 (32%)

Table 28. Number (percent) of wetlands capable of performing selected ecological services, for just the visited wetlands that comprised the statistical sample (continued).

Ecological Service:	Relatively HIGH Capacity	Relatively LOW Capacity	Intermediate Capacity
Supporting Native Invertebrate Diversity	26 (55%)	16 (34%)	5 (11%)
Supporting Native Fish	8 (17%)	23 (49%)	16 (34%)
Supporting Native Amphibians	12 (26%)	1 (2%)	34 (72%)
Supporting Native Birds and Mammals	23 (49%)	3 (6%)	21 (45%)

Although these ratings are based on standardized but non-validated models, they suggest that perhaps more LAVO wetlands are likely to support native invertebrates, birds, and mammals at a high level, than are likely to effectively support fish, filter suspended sediments, or maintain surface water temperatures.

4.0 Discussion

4.1 Implications for Wetlands Management in LAVO

The results of this study have several practical applications to routine operations at LAVO and beyond:

4.1.1 Avoidance of Impacts

From the diversity of wetland types present in LAVO, types that are least common have now been described in this report, as defined primarily by their plant communities and species. Where warranted, greater consideration may be given in the future to minimizing potentially harmful activities near these types, e.g., by managing visitor use patterns, relocating structures or trails, and ensuring that any fire control activities do not cause undue disturbance. Specifically, disturbance should be minimized to the greatest degree near wetlands *that are the most sensitive, have the healthiest or most unusual vegetation communities, and/or which appear to provide the highest levels of ecosystem services*. Among the wetlands visited in 2005, these are the following:

NR342 (Sphagnum): A probable acid geothermal fen with several fen species and no non-native plants.
NW28 (Pilot Pinnacle thermal wetland): A high-elevation wetland with several fen species and no non-native plants.
K9 (Ridge Lake): This wetland closely resembles a subalpine meadow, being at treeline at the base of a small cirque. It is the only site where we found *Carex vernacula.*
K6 (Lava Bed): A small depressional wetland surrounded by lava and having plant species with low frequencies of occurrence in LAVO. This type is undoubtedly very rare in the region.
NR473 (West Kings Creek): A species-rich wetland with several fen species and others with low frequencies of occurrence in LAVO, including the only known LAVO occurrence of *Sisyrinchium elmeri.*
K33 (Hemlock Lake): A depressional wetland with many fen species and potential for providing several ecological services at a high level.
NR770 (Brokeoff Trail Pond): A high-elevation depressional wetland with no disturbance-associated plant species.
K41 (Southwest Entrance): A species-rich wetland with the only known LAVO occurrence of *Stellaria obtusa.* This wetland has a good example of the *Alnus incana* type, as well as a large wet meadow.
K46 (Mt. Hoffman): A small depressional wetland, one of very few in this remote part of the park, having plant species with low frequencies of occurrence in LAVO.
K36 (Vulcans Castle): This wetland is located in upper Blue Lake Canyon near the headwaters of Bailey Creek. It is large and complex, with both shrub (*Salix boothii*) communities and a heterogeneous mix of herb dominated communities, with scattered large conifers and snags. There are also several seeps and a network of small perennial creeks.
K16 (Terminal Geyser): A wetland with the only known LAVO occurrence of *Hesperochiron pumilis*.

To a lesser degree, the following visited wetlands meet the criteria described above:
K1, K2, K3, K8, K11, K12, K14, K17, K22, K23, K29, K35, K36, K42, K43, K44, K45, K49, K50, K51, IW2, NR142, NW51, T22.

Additional efforts should be made to identify other acid geothermal fens in LAVO and to confirm, by measurement of pH and other parameters, the status of the one already found (NR342) and a possible one (K25). Other wetlands that deserve heightened protection due to their sensitivity include those supporting uncommon wildlife species or communities, and other high-elevation depressional wetlands.

4.1.2 Monitoring of Change

A statistically-valid, quantitative baseline has now been established for LAVO wetlands, mainly using vegetation. This serves as one indicator of the health or condition of the wetlands. Future changes in LAVO wetlands in general can be quantified by revisiting all of the same wetlands at least once every 20 years, relocating the markers and sample plots we georeferenced and photographed, and reassessing their vegetation and other characteristics using the exact protocols described in this report (especially in Appendixes B and C). A subset of the wetlands we assessed should be reassessed if new incidents (e.g., fire, new road or trail construction, restoration) suggest the potential for changes to specific wetlands, or where anecdotal observations suggest something may be changing. Whether arising from factors originating within LAVO or externally, changes that may be detected in wetland vegetation can alert managers of potentially impacting disturbances, such as altered drainage in the wetland's contributing basin. Interpretation of which changes are significant, and the diagnoses of their causes, must take into account the fact that the species composition of vegetation in wetlands is to some degree naturally dynamic.

4.1.3 Education

Part of the Park Service's mission is to help educate visitors about the natural world and to instill an appreciation for the public resources of the nation's parks. This study has assisted that mission by providing a detailed characterization of LAVO's wetlands and their functions based on systematically-collected data. This new information may be excerpted for use in interpretive signs and brochures, and incorporated into Internet (web) material and public presentations by park staff. For example, because one of the rarest wetland types (acid geothermal fen) is in a highly visible area adjacent to one of the most popular features in the park (Bumpass Hell), it presents an opportunity for inclusion in an interpretive program.

4.1.4 Restoration

We noted past disturbances by humans in very few visited wetlands, and those wetlands appeared to be recovering or adapting to the mostly-minor disturbances quite well, so hands-on restoration is not urgently needed. If unforseen future events or activities cause additional disturbances that require restoration, then the "reference wetland" information from this study (e.g., Table 29) can be used to help establish performance standards useful for monitoring the progress of the restoration. Specifically, this study has defined 23 wetland plant communities (Table 5) that should be the targets of restoration, wherever any future need for restoring LAVO wetlands is noted.

4.2 Broader Applications

4.2.1 Regional Wetland Benchmarks

In the past two centuries, California has lost more wetlands than any other state, and the condition of many remaining wetlands is questionable. Resolving questions about the condition of those wetlands requires comparing them to wetlands of the same type that are known or expected to be the least-altered. For comparisons among wetlands in the northern Sierras, the relatively undisturbed wetlands of LAVO can serve as excellent reference points. For example, when the California Rapid Assessment Method (CRAM) is used to assess the condition of depressional or small riverine wetlands elsewhere in this region, the high CRAM scores we computed for those types of LAVO wetlands can be used as a comparative standard.

4.1.2 Sampling Approach
For the first time in any national park, this study has demonstrated the practicality and efficiency of park-wide use of a new spatially-balanced probabilistic sampling design for assessing wetlands – the GRTS algorithm. This allows valid statements to be made about the condition of a resource throughout a park, rather than just individual sites that may or may not be assumed to be representative. Moreover, in situations where field efforts are significantly constrained by time and resources, this study uniquely demonstrates how a GIS-based cluster analysis procedure can be used to augment and complement the GRTS approach for selecting sites to visit and assess.

4.1.3 Estimates of Ecosystem Services
This study represents one of only a few instances where the relative levels of ecological services (functions) provided by wetlands have been estimated throughout a national park. The heuristic scoring models used to do this could be modified slightly for use in similar assessments of wetlands elsewhere.

Table 29. Normative ranges for ecological service and health metrics in wetlands of LAVO (all HGM classes combined).

Note: See other report sections for definitions of these indicators. “Plot-herb” refers to measurement of the indicator in a 100m^2 plot. “Plot-shrub” is for a 400 m^2 plot that is primarily wetland trees and shrubs. The three normative categories are based simply on the division of our data into three categories (defined by the 30th and 70th percentiles), with number of wetlands in each category being about the same. “Above Norm” generally reflects a healthier condition, and “Below Norm” the opposite. However, the categories do not necessarily reflect impacts from humans, or needs for any corrective actions. They should not be considered synonymous with “Proper Functioning Condition.” They are intended for use as reference points only in comparisons involving other wetlands within LAVO specifically. The bounds of these categories might just as easily be the result of natural constraints of geology, climate, and other factors – this could not be determined from our data, and cannot be accounted for by hydrogeomorphic (HGM) class alone. Due to these natural constraints, no wetland should be expected to be Above Norm for all metrics. Ideally, with additional data (larger sample sizes) in the future these ranges could be customized to particular wetland types, elevations, and other settings.

Metric	Scale	Above Norm	Normative for LAVO	Below Norm
CRAM total score	wetland	>82	75-82	<75
Ecological Service Rating (each of 9 services)	wetland	High	Intermediate	Low
Botanical Metrics:				
Total number of species (species richness)	wetland*	>38	13-38	<13
	plot - herb	>21	4-21	<4
	plot- shrub	>34	24-34	<24
Number of plant families	plot - herb	>12	3-12	<3
	plot- shrub	>18	13-18	<13
# of Disturbance species	wetland*	0	1 - 3	>3
	plot - herb	0	1 or 2	>2
	plot- shrub	<2	2 or 3	>3
Disturbance species as % of Total	wetland	0%	1-7%	>7%
	plot - herb	0%	1-8%	>8%
	plot- shrub	0%	1-10%	>10%
Frequency index (among sites)	wetland	<5.83	5.83-7.00	>7.00
	plot - herb	<6.20	6.20-8.62	>8.62
	plot- shrub	<6.41	6.41-6.61	>6.61
Dominance (% of species comprising 25-60% of cover)	plot - herb	0	1-15%	>15%
	plot- shrub	0	1-6%	>6%
Dominance (% of species comprising >60% of cover)	plot - herb	0	1%	>1%
	plot- shrub	0	1-3%	>3%
Prevalence (Moisture) Index, weighted	plot - herb	<1.80	1.80-2.25	>2.25

*Potentially biased by a wetland’s acreage.

5.0 Literature Cited

Adamus, P. R., and C. L. Bartlett. 2008. Wetlands of Crater Lake National Park: An assessment of their ecological condition. Natural Resource Technical Report NPS/KLMN/NRTR—2008/115. National Park Service, Fort Collins, CO.

Adamus, P. R., and K. Brandt. 1990. Impacts on quality of inland wetlands of the United States: A survey of indicators, techniques, and applications of community level biomonitoring data. EPA/600/3-90/073 (NTIS PB 113 837/AS). USEPA Environmental Research Lab, Corvallis, OR. Online. (http://www.epa.gov/owow/wetlands/wqual/introweb.html). Accessed 17 April 2008.

Adamus, P. R., and D. Field. 2001. Guidebook for hydrogeomorphic (HGM)–based assessment of Oregon wetland and riparian sites. I. Willamette Valley Ecoregion, riverine impounding and slope/flat subclasses. Volume IA: Assessment Methods. Oregon Division of State Lands, Salem, OR.

Adamus, P. R, T. J. Danielson, and A. Gonyaw. 2001. Indicators for monitoring biological integrity of inland, freshwater wetlands: A survey of North American technical literature (1990-2000). EPA843-R-01. Online. (http://www.epa.gov/owow/wetlands/bawwg/monindicators.pdf). Accessed 17 April 2008.

Adamus, P. R., L. T. Stockwell, E. J. Clairain, Jr., M. E. Morrow, L. T. Rozas, and R. D. Smith. 1992. Wetland evaluation technique (WET). Vol. I: Literature review and evaluation rationale. Wetlands Research Program Technical Report WRP-DE-2. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Bartoldus, C. 1998. A comprehensive review of wetland assessment procedures: A guide for wetland practitioners. Environmental Concern, Inc., Edgewater, MD.

Bedford, B. L. 1996. The need to define hydrologic equivalence at the landscape scale for freshwater wetland mitigation. Ecological Applications **6**:57-68.

Bedford, B. L., and K. S. Godwin. 2003. Fens of the United States: Distribution, characteristics, and scientific connection verses legal isolation. Wetlands **23**:608-629.

Berlow, E. L., and C. M. D'Antonio. 2002. Shrub expansion in montane meadows: the interaction of local-scale disturbance and site aridity. Ecological Applications **12**:1103-1118.

Brinson, M. M. 1993. A hydrogeomorphic classification of wetlands. Technical Report. WRP-DE-4. U.S. Army Corps of Engineers Waterways Expermental Station, Vicksburg, MS.

Brown, P. B., and G. V. Wolfe. 2006. Protist genetic diversity in the acidic hydrothermal environments of Lassen Volcanic National Park, USA. The Journal of Eukaryotic Microbiology **53**:420-431.

California Native Plant Society. 2007. Online inventory of rare and endangered plants. Online. (http://cnps.web.aplus.net/cgi-bin/inv/inventory.cgi/Search?search={CNPS_LIST}%20=~%20m/./i). Accessed 17 April 2008.

Collins, J. N., E. D. Stein, M. Sutula, R. Clark, A. E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2006. California rapid assessment method (CRAM) for wetlands and riparian areas. Version 4.2.3. Online. (www.cramwetlands.org). Accessed 17 April 2008.

Cooper, D. J., and E. C. Wolf. 2006. Fens of the Sierra Nevada, California. Department of Forest, Rangeland and Watershed Stewardship. Colorado State University, Ft. Collins, CO.

Cooper, D. J., R. A. Chimner, and K. Tate. 2005. Improving sustainable management of montane meadows in the Sierra Nevadas, California. Unpublished report on file: U.S. Forest Service. Tahoe National Forest. Nevada City, CA.

Cowardin, L., F. Golet, and V. Carter. 1979. Classification of wetlands and deepwater habitats of the United States, U.S. Fish and Wildlife Service Publication FWS/OBS-79/31, Washington, D.C.

Cronk, J., and M. S. Fennessy. 2001. Wetland plants: Biology and ecology. Lewis Publishers, Boca Raton, FL.

Davidson, C. 2004. Declining downwind: Amphibian population declines in California and historical pesticide use. Ecological Applications **14**(6):1892-1902.

Elliott, C. R., and M. M. Hektner. 2000 . Wetland resources of Yellowstone National Park. National Park Service, Yellowstone National Park, WY.

Fennessy, M. S., A. D. Jacobs, and M. E. Kentula. 2004. Review of methods for assessing wetland condition. EPA/620/R-04/009. U.S. Environmental Protection Agency, Washington, D.C.

Gillett, G. W., J. T. Howell, and H. Leschke. 1961. A flora of Lassen Volcanic National Park. Wasmann Journal of Biology **19**(1):1-185. Revised and expanded edition by V. Oswald, D. Showers, and M. Showers. 1995. California Native Plant Society, Sacramento, CA.

Hruby, T. 1997. Continuing the discussion: Scientific and technical issues regarding the hydrogeomorphic approach to function assessment of wetlands. National Wetlands Newsletter, September 1997:23-24.

Hruby, T. 1999. Assessments of wetland functions: What they are and what they are not. Environmental Management **23**:75-85.

Hruby, T. 2001. Testing the basic assumption of the hydrogeomorphic approach to assessing wetland functions. Environmental Management **27**:749-761.

Kagan, J.S., J.A. Christy, M.M. Murray, and J.A. Titus. 2000. Classification of native vegetation of Oregon. Oregon Natural Heritage Program.

Landers, D. H., S L. Simonich, D. A. Jaffe, L. H. Geiser, D. H. Campbell, A. R. Schwindt, C. B. Schreck, M. L. Kent, W. D. Hafner, H. E. Taylor, *and others*. 2008. The fate, transport, and ecological impacts of airborne contaminants in western National Parks (USA). EPA/600/R-07/138. US Environmental Protection Agency, Western Ecology Division, Corvallis, OR.

Manning, M. E. and W.G. Padgett. 1995. Riparian community type classification for Humboldt and Toiyabe National Forests, Nevada and Eastern California. R4-Ecol-95-01. Intermountain Region, USDA Forest Service, Ogden, UT.

Moyle, P. B., and P. J. Randall. 1998. Evaluating the biotic integrity of watersheds in the Sierra Nevada, California. Conservation Biology **12**:1318-1326.

National Park Service, Water Resources Division (NPS-WRD). 1999. Baseline water quality data inventory and analysis: Lassen Volcanic National Park. National Park Service, Water Resources Division, Fort Collins, CO.

Patterson, L. S. 2005. Hydrologic characterization and restoration of a mountain fen-complex, Drakesbad Meadow, Lassen Volcanic National Park, Cascade Range, California. Thesis, Colorado State University, Ft. Collins, CO.

Potter, D. A. 2005. Riparian plant community classification: West slope, central and southern Sierra Nevada, California. R5-TP-022. Pacific Southwest Region, USDA Forest Service, Vallejo, CA.

Pritchard, D. (work group leader). 1994. Process for assessing proper functioninging condition for lentic riparian-wetland areas. TR 1737-11. USDI Bureau of Land Management, Denver, CO.

Rocchio, J. 2005. Rocky Mountain subalpine-montane fen ecological system: Ecological integrity assessment. Colorado Natural Heritage Program (CNHP). Colorado State University. Fort Collins, CO.

Showers, D. W. 1982. The mosses of Lassen Volcanic National Park, California. The Bryologist **85**(3):324-328.

Sickman, J. O., J. M. Melack, and D. W. Clow. 2003. Evidence for nutrient enrichment of high elevation lakes in the Sierra Nevada, California. Limnology and Oceanography. **48**(5):1885-1892.

Smith, S. 1998. Riparian community type classification for national forests in northeastern California: A first approximation. Draft. USDA Forest Service, Alturas, CA.

Stead, J. E., H. H. Welsh, and K. L. Pope. 2005. Census of amphibians and fishes in lentic habitats of Lassen Volcanic National Park. Report to the National Park Service, LAVO Study Number: LAVO-00717. USDA Forest Service Pacific Southwest Research Station, Arcata, CA.

Stevens, D. L., Jr. 1997. Variable density grid-based sampling designs for continuous spatial populations. Environmetrics **8**:167-195.

Stevens, D. L., Jr., and S. F. Jensen. 2007. Sample design, execution, and analysis for wetland assessment. Wetlands **27**:515-523.

Stevens, D. L., Jr., and A. R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics **4**:415-428.

Stevens, D. L., Jr., and A. R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. Environmetrics **14**:593-610.

Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially-balanced sampling of natural resources. Journal of American Statistical Association **99**:262-278.

Taylor, A. H. 2000. Fire regimes and forest changes in mid and upper montane forests in the southern Cascades, Lassen Volcanic National Park, California, USA. Journal of Biogeography **27**:87-104.

Taylor, T. P., and D. C. Erman. 1979. The response of benthic plants to past levels of human use in high mountain lakes in Kings Canyon National Park, California. Journal of Environmental Management **9**:271-278.

Weixelman, D., S. Weis, and F. Linton. 2007. Condition checklist for fens in the Montane and Subalpine zone of the Sierra Nevada and Southern Cascade Ranges, California. Draft.

Welsh, H. H., G. R. Hodgson, and N. E. Karraker. 2005. Influences of the vegetation mosaic on riparian and stream environments in a mixed forest-grassland landscape in “Mediterranean” northwestern California. Ecography **28**:537-551.

White, J. D., G. C. Kroh, and J. E. Pinder III. 1995. Forest mapping at Lassen Volcanic National Park, California, using Landsat TM Data and a geographical information system. Photogrammetric Engineering & Remote Sensing **61**(3):299-305.

Young, T. F., and S. Sanzone (editors). 2002. A framework for assessing and reporting on ecological condition. EPA-SAB-EPEC-02-009. Science Advisory Board, USEPA, Washington, DC. Online. (http://www.epa.gov/sab/pdf/epec02009.pdf). Accessed 17 April 2008.

Zabik, J. N., and J. N. Seiber. 1993. Atmospheric transport of organophosphate pesticides from California's Central Valley to the Sierra Nevada mountains. Journal of Environmental Quality. **22**:80-90.

Ziegenbein, M. S., and J. Wagner 2000. Trip report – Lassen Volcanic National Park, Disturbed land inventory and recommendations. Memorandum to Superintendent, Lassen Volcanic National Park.

Appendix A. Data Dictionary Introduction

The following files have been created in Excel and are provided separately on electronic media. Most can be linked or joined using the field, "SiteID." A full listing of the variables each contains is provided by the DataDictionary.doc file on the accompanying electronic media. In addition, we have provided to the National Park Service (Klamath Network Office, Ashland, OR) a shapefile containing all joined NWI wetland polygons, revised wetland boundaries based on field visits to the wetlands, and point data for benchmarks and plots in wetlands. Also available from the Network Office are georeferenced panoramic photographs we took at each site, and a sketch map of each site showing key features.

Name	Description
Benchmark	Narrative description of the location of the tagged benchmark in each visited wetland, plus its GPS coordinates, precision, etc.
bmetrix_herb_plot_all	Botanical metrics (species richness etc.) by site and plot computed for all herb plots (multiple plots per site at some sites).
bmetrix_herb_plot1	Botanical metrics by site and plot computed for just one herb plot per site (the one assessed first)
bmetrix_shrub	Botanical metrics by site computed for just the one shrub/forested plot
bmetrixPoly	Botanical metrics by site computed using all data from a wetland polygon (all plots plus walk-around identifications)
SettingsAllPlots	General characteristics of all the herb and shrub plots, by site and plot. (e.g., canopy cover, landscape setting, etc.)
Bspp_combo	Plant species data by site using all data from wetland polygon (all plots plus walk-around identifications)
Bspp_poly	Plant species data by site using only the data from the walk-around
BsppPlot	Plant species data by site and plot (both herbaceous and woody plots)
CRAM_calc	Ratings, by site, for variables used in the calculation of the wetland condition scores of the California Rapid Assessment Method
DataForCorrelations	A combination of site data from other databases listed here, that was used in the correlation analysis
FunctionCalcs	Information used to compute ratings for 9 wetland ecological services for each wetland site, and the ratings themselves.
NonWetlands	Descriptions of random points visited that turned out to not be wetlands
NWIwetlandsAll	Data on wetland attributes, by site, from NWI data and GIS querying of several spatial data layers (e.g., topography, soils)
PhysChar	Physical characteristics of wetland polygons as estimated in the field
PlotDescrip	Narrative description of the herb and/or shrub plot at each site
Significant_Correlations	Correlations among pairs of variables that were found to be significant at the $p<0.05$ level
SoilsForm	Soil profile data (generally 3-5 pits per wetland site)
Stressors	Data on observed human-associated features in each wetland, as well as natural disturbances and incidental wildlife observations
UnmappedWetlands	GPS coordinates, dominant vegetation, and other notes on chance encounters with wetland-like areas not currently mapped as wetlands by NWI
VegForm_allHerbPlots	Vegetation form data by site and plot from all herb plots within each wetland polygon
VegForm_oneHerbPlotOnly	Vegetation form data by site and plot from just one herb plot per site (the one assessed first)

Appendix B. Field Datasheets

Form C. Collective Assessment Data Form
Wetland Assessment - Lassen Volcanic National Park 2005
file= Stressors. Red #'s refer to variable numbers in the Data Dictionary

Point Code:__1,2___ Wetland Polygon Code: ___3____ Polygon Name: _______________4_____
Date: _________5___ Time Begin: ____6_____ a.m. p.m.

1. Signs of Human Presence:

Indicate: 1= minor 2= extensive	On-site recent	On-site old	Off-site recent	Off-site old	Closest Distance & Direction to Centerpoint
Bridge/ culvert	7				26
Building	8				27
Cairn/ tailings	9				28
Dig	10				29
Ditch	11				30
Fence	12				31
Fill	13				32
Fire ring	14				33
Firefighting paraphernalia	15				34
Fish hooks/ line	16				35
Flagging. other markers	17				36
Footprints/ trail	18				37
Grazing: browsed veg	19				38
Grazing: cattle present	20				39
Grazing: gullies, headcuts	21				40
Plantings	22				41
Saw/ axe mark	23				42
Tiremark/ compaction*	24				43
Trash	25				44

* increase in soil bulk density of >15% or macropore reduction of >50%

2. Major Natural Disturbances:

Indicate: 1= minor 2= extensive	On-site recent	On-site old	Off-site recent	Off-site old
Insect/ disease damage to veg	45			
Rockfall	46			
Landslide/ sedimentation	47			
Avalanche damage	48			
Fire	49			
Flooding, beaver-related	50			
Flooding, storm events	51			
Wind damage	52			
Other: __________________	53			

3. Signs of possible damage. If uncertain, photograph these for later diagnosis.

54_Unnaturally incised or headcut channel
55_Hydrophytes with blotched/discolored foliage
56_Sediment or oil coatings on foliage
57_Severe growths of aquatic algae
58_Unnatural water color or odor (H_2S)
59 Very high water marks despite small contributing area
60 Extensive mud, suggesting recent sudden drawdown
61 Extensive blowdown/ windthrow of trees
62 Non-rocky soils very difficult to penetrate
63 Soils with reddish upper horizons due to hot burn

4. Review the file of polygon characteristics derived from existing spatial data layers.
Do your observations contradict anything reported? Explain: ___________________________
____
____
____

5. Review the 1988 natural-color airphoto. Do your observations contradict anything apparent? In particular:
percent-expansion of conifers into the wetland: ______%
percent-expansion of all woody vegetation into the wetland: ______%
evidence of human disturbance not currently present? ____________________________
other (explain): ____

6. What else distinguishes this wetland from others you've seen so far in this Park?
____
____

7. Condition. Relative to other Lassen wetlands, how would you rate its overall ecological integrity?
(*just a gut feeling – this will not supercede future results from models and data analysis*) **64**

1	**2**	**3**	**4**	**5**
less-functional		→		more functional

8. Incidental Observations or Signs

Indicate Type of Detection

x= observed	L= claw
A= auditory	N= nest
B= burrow/ tree cavity	S= scat
C= carcass, kill	T= track
D= den, lodge, dam	

65 Deer	74 **Frog**	83 Duck (note if **Bufflehead**)
66 Bear	75 Newt, Rough-skinned	84 Heron/ Bittern
67 Beaver	76 Salamander, Long-toed	85 Sandpiper/ Dipper
68 Coyote/ dog	77 Snake	86 Kingfisher
69 Otter	78 Lizard	87 **Eagle, Bald**
70 Bat	79 Toad, Western	88 Hawk
71 Raccoon	80 Fish	89 **Flycatcher, Willow**
72 Rabbit	81 Ant hill	**90** Dragonfly
73 Muskrat	82 Gopher Mound	**91** Butterfly

List other identifiable animal species & type of detection:

Time End: ___________________________**92**__________________

Form F. Physical Features Data Form
Wetland Assessment - Lassen Volcanic National Park 2005
file= PhysChar. Red #'s refer to variable numbers in the Data Dictionary

Point Code:___1_& 2_ Wetland Polygon Code: ____3___ Polygon Name: _______4_____________
Date: _______5_______ Time Begin: ______6____ a.m. p.m. Quad Sheet: ______________________
Size (*from database*): ______acres Crew: _________7___________________

Point locations	Latitude	Longitude	Direction to CP	Distance to CP	Offset Direction from CP	Offset Distance from CP
Target Center Point	9	10			11	12
Actual Center Point (CP)	13	14				
Photo Point	15	16	17	18		
Benchmark. Tag #: ___8__	19	20	21	22		
Main Xsec	23	24	25	26		
Releve Plot !	27	28	29	30		
Releve Plot 2	31	32	33	34		
Releve Plot 3	35	36	37	38		

Mark approximate locations of these on the sketch map and airphoto.

Detailed description of benchmark location (height, facing direction, type of tree, etc.):

____

1. Landscape Position (of most of the wetland polygon; multiple entries are allowed)
39__ midslope 40___toe slope 41 __lake fringe 42___floodplain 43___ interfluve 44___depression/flat

2. Hydrologic Connectivity: (check all that apply)
45__ No inlet, no outlet
46__ Outlet channel, flowing
47__ Outlet channel, currently no flow
48__ Inlet channel, flowing
49__ Inlet channel, currently no flow

Is this a *source wetland*? (i.e., outflow-only)50 ___ yes ___no
If yes, is the channel *head* (initiation point) an abrupt vertical break? 51 ___ yes ___no

3. Outlet Blockage
52__ none 53__ beaver-impounded _54__ slide-impounded _55__ natural debris impounded (log etc.)
56 __natural constriction _57 __artificial

4. Channel Patterns
58__ no channel 59 __% confined entrenched 60 __% confined meander _61__% braided 62 ___% diffuse

5. Stream Order (maximum, include only channels with permanent water): ___63______

6. Indicate height of **water marks** above today's wetted edge, if any found:

	in channel	outside channel
Type of indicator*	**64**	**65**
Maximum height above today's wetted edge	**66**	**67**

*Debris, Stain, Ice abrasion, Algae

7. Estimate the **maximum depth** of surface water (<6 ft deep) as it would exist:

	During wettest 2 weeks annually	During driest 2 weeks annually
Standing water	**68**	**69**
Flowing water	**70**	**71**

* do so by considering the basin or channel morphology, elevation, contributing area, and today's water depth

8. Percent of wetland polygon that is*:

Inundated continuously only for 2-4 weeks per year	_**72**_____%	___**76**____m^2
Inundated longer but not continuously year-round	_**73**_____%	___**77**____m^2
Inundated year-round without interruption	_**74**_____%	___**78**____m^2
Almost never, but soil is saturated for >2 weeks/yr	_**75**_____%	___**79**____m^2
	100 %	

* estimate area (m^2) of the zone only if it occupies <100 m^2

9. Are there defined channels that convey water **less often than once per year**? **80** ___ yes ____no

10. Springs/ Seeps (report whether thermal or non-thermal and describe evidence: temperature, conductivity, rust deposits, colored precipitates, dispersible oil sheen, "boils," shallow pools not supported by recent rain or snowmelt, etc.)
___________**81**___________________________________

11. Estimated Water Sources (late summer):

_**82**____% Subsurface Inflow (springs etc.)
_**83**____% Surface Inflow (channels, overland runoff)
_**84**____% Detained Direct Precipitation
100%

12. Overall Wetland Gradient (as percent of vegetated part of polygon):
no observable gradient: _**85**____% slight (1-5%):_**86**___% very obvious (>5%)_**87**____%

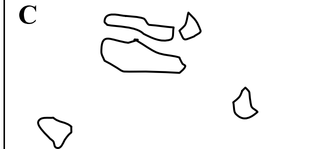
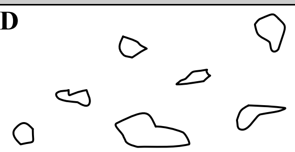
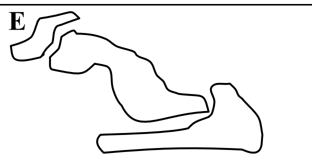
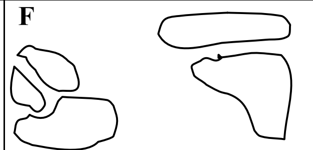
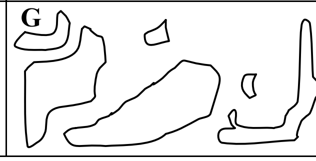
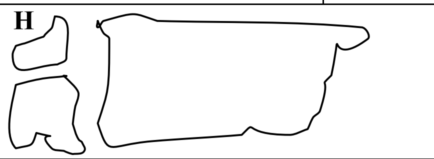
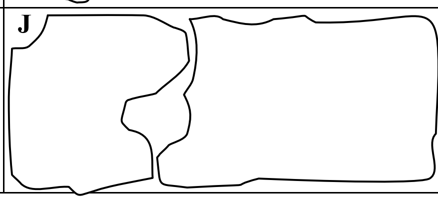
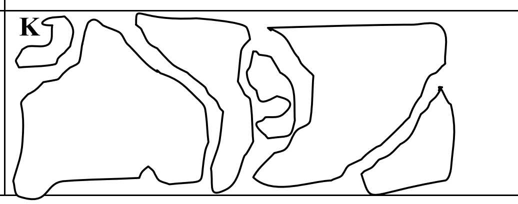
13. Predominant Aspect (circle one): **88** N NE E SE S SW W NW

14. Terrain Microtopography (excluding logs and temporary objects) **89**

1	2	3	4	5
minimal	→			extensive

15. Percent that is shaded at mid-day:
__**90**______% of standing water _____**91**____% of flowing water

16. Standing Water Interspersion -- water with vegetation: **92**

Percent & distribution of pools			
	Pools are few & are mostly clumped together	Pools somewhat scattered, more common	Pools numerous, scattered evenly, & highly intermixed with vegetation
None **A**			
1-30% of polygon is pools	**B** 	**C** 	**D** 
30-60% of polygon is pools	**E** 	**F** 	**G** 
60-90% of polygon is pools	**H** 		**I** 
>90% of polygon is pools	**J** 		**K** 

17. Snags within wetland

Estimated number: #: 0= none; Rare= 1 to 10; Uncommon= 11-20; Abundant= >20

	barked	hard	soft
4-12"	**93**	**97**	
12-18"	**94**	**98**	
18-24"	**95**	**99**	
>24"	**96**	**100**	

minimum height = 10 ft.

dispersion: **1** concentrated **2** **3** → **4** **5** **101** dispersed

18. Downed Wood: size and decay class

Categorical # of pieces: 0= none; Rare= 1 to 10; Common = >10

	barked	hard	soft
4-8"	**102**	**106**	
9-14"	**103**	**107**	
15-30"	**104**	**108**	
>30"	**105**	**109**	

minimum length = 6 ft.

dispersion: **1** concentrated **2** **3** → **4** **5** **110** dispersed

19. Channel Dimensions. Locate the largest wadeable channel within the polygon. Measure 3 cross-sections, beginning at the widest point and 1 each at a distance upstream and downstream equal to 10 times this width.

	Distance from widest	Wetted Width (today)	Bankfull Width	Floodprone Width (estimated)	Water Depth (today)	Bank Height	Flood Height (estimated.)
Widest	----	**111**	**112**	**113**	**114**	**115**	**116**
Upstream	**117**	**118**	**119**	**120**	**121**	**122**	**123**
Downstream	**124**	**125**	**126**	**127**	**128**	**129**	**130**

20. Channel Bank Characteristics.
Percent of the polygon's channel network with channel banks that are:
(Each row must add to 100%. Combine both sides of the channel)

undercut:_**131**___% steep (>30% slope): **132**_____% gradual: **133**____%

bare rock: **134**____% bare soil_**135**__% alder:_**136**___% other vegetated/ downed wood:_ **137**___%
no distinct bank: _**138**__% benched **139**_____% naturally leveed **140**_____%

21. Specific Conductance and Temperature.

	Standing Water	Flowing Water
Specific Conductance (µS/cm)	**141**	**142**
Water Temperature (C)	**143**	**144**
Air Temperature (C)	**145**	**146**

Ending Time: ____**147**________________ a.m. p.m.

Form S. Soil Assessment Sheet
Wetland Assessment - Lassen Volcanic National Park 2005
file= SoilsForm. Red #'s refer to variable numbers in the Data Dictionary

Pit #1 Pit Type ___5
Location relative to benchmark: Direction: ___6__ ° Distance: _____7__
Distance to surface water if any: _______ Slope: ____________
Dominant Veg.(50-20 rule):_______8______________________________________
Texture & Indicators by depth:

	Color	Texture	Saturation	Indicators**
depth1: 9 - 10	11	12	13	14
depth2: 15 - 16	17	18	19	20
depth3: 21 -22	23	24	25	26
depth4: 27 -28	29	30	31	32

** **M**ottled, **G**leyed, **C**hroma 1-2, **O**rganic streaks in sandy soils, **S**ulfidic odor, **SW**= shrink-swell cracks
Also indicate any charred layer (**B**) or hardpan/ spodic horizon (**H**)

Pit #2 Pit Type ___33
Location relative to benchmark: Direction: ___34__ ° Distance: _____35__
Distance to surface water if any: _______ Slope: ____________
Dominant Veg.(50-20 rule):_______36______________________________________Location relative to benchmark: Direction: _____ ° Distance: _______
Distance to surface water if any: _______ Slope: ____________
Dominant Veg.50-20 rule:_____________________
Texture & Indicators by depth:

	Color	Texture	Saturation	Indicators
depth1: 37 - 38	39	40	41	42
depth2: 43 - 44	45	46	47	48
depth3: 49 -50	51	52	53	54
depth4: 55 - 61	57	58	59	60

Pit #3 Pit Type ___61
Location relative to benchmark: Direction: ___62__ Distance: _____63__
Distance to surface water if any: _______ Slope: ____________
Dominant Veg.(50-20 rule):_______64______________________________________
Location relative to benchmark: Direction: _____ ° Distance: _______
Distance to surface water if any: _______ Slope: ____________
Dominant Veg.50-20 rule:_____________________
Texture & Indicators by depth:

	Color	Texture	Saturation	Indicators
depth1: 65 - 66	67	68	69	70
depth2: 71 - 72	73	74	75	76
depth3: 77 -78	79	80	81	82
depth4: 83 - 84	85	86	87	88

Pit #4 Pit Type ___**89**
Location relative to benchmark: Direction: ___**90**__ Distance: _____**91**__
Distance to surface water if any: _______ Slope: ____________
Dominant Veg.(50-20 rule):_______**92**______________________________________
Location relative to benchmark: Direction: _____° Distance: _______
Distance to surface water if any: _______ Slope: ____________
Dominant Veg.50-20 rule:_____________________
Texture & Indicators by depth:

	Color	Texture	Saturation	Indicators
depth1: **93** - **94**	**95**	**96**	**97**	**98**
depth2: **99** - **100**	**101**	**102**	**103**	**104**
depth3: **105** -**106**	**107**	**108**	**109**	**110**
depth4: **111 - 112**	**113**	**114**	**115**	**116**

etc. for Pit #5, #6

Form B. Botanical Data Form
files= SettingsAllPlots and VegFormHerb. Red #'s refer to variable numbers in the Data Dictionary; similar data with different variable #'s [1-94] were collected for the polygon as well)
Wetland Assessment - Lassen Volcanic National Park 2005

Point Code:_**1&2**____ Wetland Polygon Code: __**5**_____ Polygon Name: _______**6**____________
Date: _____**6**_______ Time Begin: _______**8**__ a.m. p.m. Releve Plot #: ___**3**________

PART A: Releve Plot Data

A1. Type of Releve Plot *(check dominant one)* 4
Moss__**9**__ Herb (<0.5 m)__**10**__ Shrub (0.5-4m)__**11**__ Tree (>4m)__**12**__

A2. Plot Dimensions
Length____**13**__ Width_**14**_____ Long axis bearing__**15**___ Short axis bearing____**16**_
Aspect (circle one): **17** N NE E SE S SW W NW none (flat)

A3. Landscape Position of the Plot
__**18**_ interfluve _**19**_ midslope _**20** __toe slope _**21** __depression/flat **22** ___floodplain **23** __lake fringe

A4. Percent of plot that (during most years) is:
Inundated continuously only for 2-4 weeks per year ___**24**___%
Inundated longer but not continuously year-round ___**25**___%
Inundated year-round without interruption ___**26**___%
Almost never, but soil is saturated for >2 weeks/yr ___**27**___%
100 %

A5. Plot Cover & Dispersion
(*for each, indicate:* **A**: <1%, **B**: 1-5%, **C**: 5-25%, **D**: 25-50%, **E**: >50% as ground cover):
Herb_**28**__ Moss:_**29**__ Fern:_**30**__ Litter_**31**__ Wood:_**32**__ Rock:_**33**__ Other Bare:_**34**__

(*for each, indicate:* ***C****ontinuous,* ***S****parse/Scattered, or* ***N****one*)
Tree (>4m)_**35**___ Shrub (0.5-4m)__**36**__ Herb (<0.5 m)__**37**_ _ Moss_**38**___ Bare_**39**______

Canopy Shade (densiometer, record # of dots per quadrant if plot is mainly shrub/tree):

	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
Point 1	40	43	46	49
Point 2	41	44	47	50
Point 3	42	45	48	51

A6. Detailed Height Strata in the Plot (indicate cover class: **1** (<1%), **2** (1-25%), **3** (25-60%), **4** (>60%)

Height	**Name**	**% Cover**	**Main Species.** Measure **max. diameter** of main tree species.
0-.25m	Moss/Lichen	52 %	62
0-.25m	Low Herb.	53 %	63
.25-.50m	Medium Herb	54 %	64
.50-1m	Low Shrub	55 %	65
1-2m	Herb/ Medium Shrub	56 %	66
2-5m	High Shrub	57 %	67
5-10m	Low Tree	58 %	68
10-20m	Medium Low Tree	59 %	69
20-30m	Medium High Tree	60 %	70
>30m	High Tree	61 %	71

A7. Full Species List for Plot (one row for each combination of species-height-cover class)
Height classes: **L**: <0.5m tall, **M**: 0.5-4m, **T**: >4m **BsppPlot file**
Cover classes**: 1** (<1%), **2** (1-25%), **3** (25-60%), **4** (>60%)

Circle any dominant **non**-wetland species (50-20 rule) if it's at a spot appearing to have prolonged (>2 wks) inundation or hydric soil indicators. Denote photographed species with *

SpCode	HtCl	CovCl

SpCode	HtCl	CovCl	FieldID	Coll. #

PART B: Overall Polygon Vegetation

B1a) Emergent Vegetation (Em) & moss

Em as % of polygon area:_______**72**___%

Em as % of:

permanently-inundated standing water area:_____**73**___%
seasonally-inundated standing water area:__**74**______%
permanently-inundated flowing water area:____**75**____%
seasonally-inundated flowing water area:____**76**____%
saturated-only area:____**77**_____%

Em cumulative edge-length with flowing permanent water (estimated): ___**78**____

Invasives as % of Em area: __**79**___%

Sphagnum moss as % of Em area: __**80**__%

Top 5 EM species	% of EM area	Depth Max.
81	**82**	**83**
84	**85**	**86**
87	**88**	**89**
90	**91**	**92**
93	**94**	**95**

Area threshold: 1% of EM zone or 9 m^2, whichever smaller

B1b) Underwater Herbaceous Vegetation (UHV):

UHV as % of standing permanent water area <2 m deep: ______**96**______%

Area (approx.) of standing permanent water area <2 m deep in polygon: __**97**______sq. m.

Top 5 UNV species	% of UHV area
98	**99**
100	**101**
102	**103**
104	**105**
106	**107**

Area threshold: 1% of EM zone or 9 m^2, whichever smaller

B1c) Shrubs, Seedlings, and Saplings (SS)
SS as % of polygon: ____**108**________________
SS as % of: permanently-inundated standing water area:___**109**_____%
seasonally-inundated standing water area:_____**110**_____%
permanently-inundated flowing water area:_____**111**_____%
seasonally-inundated flowing water area:_____**112**______%
saturated-only area: _____**113**______%
Shrub cumulative edge-length with permanent water (estimated): ___**114**____m
Maximum width of shrub patch, perpendicular to permanent* water: __**115**_____m
* if no permanent water, use max. dimension of largest shrub patch
Invasive shrubs as % of shrub canopy: __**116**___%
Percent of stems dead (circle one): **117** <1% 1-25% >25%

What is under the shrub drip line?

	% of shrub understory
herbaceous	**118**
water – flowing	**119**
water – lentic	**120**
bare	**121**

Top 5 shrub species	% of shrub area
122	**123**
124	**125**
126	**127**
128	**129**
130	**131**

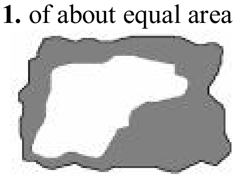
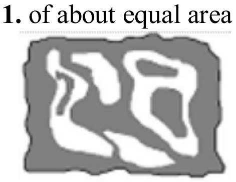
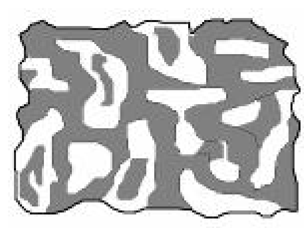
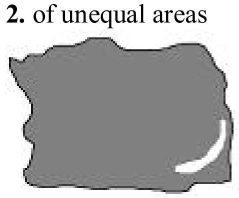
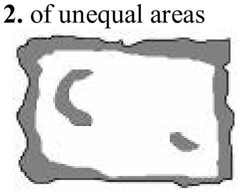
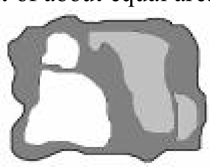
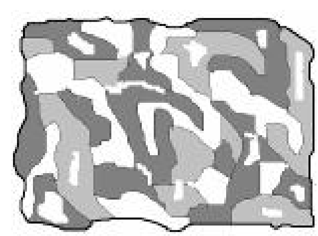
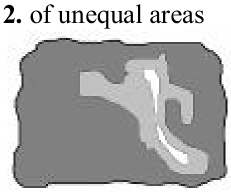
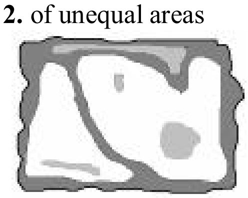
B1d) Trees (T)
Trees as % of polygon: __________**132**__________
Tree cumulative edge-length with permanent water (estimated): __**133**_____m
Maximum width of tree patch, perpendicular to permanent* water: __**134**_____m
* if no permanent water, use max. dimension of largest shrub patch
Invasive tree species as % of tree canopy: _**135**____%
Percent of trees dead or severely stressed (approx.) _**136**____%
What is under tree drip line?

	% of subcanopy
shrubs	**137**
herbaceous	**138**
water – flowing	**139**
water – lentic	**140**
bare	**141**

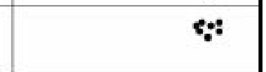
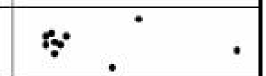
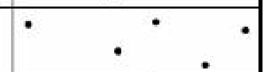
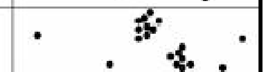
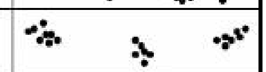
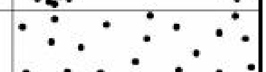
Top 5 tree species-height classes	height class	% of treed area
142	**143**	**144**
145	**146**	**147**
148	**149**	**150**
151	**152**	**153**
154	**155**	**156**

height classes: SA= sapling (<6"), P= pole (6-11"), ST= small tree (11-24"), LT= large tree (>24")
Area threshold: 1% of EM zone or 9 m^2, whichever smaller

B2. Overall Vegetation Pattern/ Zonation: 157

Number & distribution of vegetation forms **Forms**= herb, shrub, tree.			
	Veg forms are mostly in discrete, quite homogeneous zones or patches:	Zones/patches are recognizable but not homogeneous, and are:	Forms are highly intermixed; zones are mostly not recognizable; no patch >20% of polygon
Only ONE vegetation form = A			
Two forms …	**B 1.** of about equal area 	**C 1.** of about equal area 	**D** 
	B 2. of unequal areas 	**C 2.** of unequal areas 	
ll three forms …	**E 1.** of about equal area 	**F 1.** of about equal area 	**G** 
	E 2. of unequal areas 	**F 2.** of unequal areas 	

B3. Invasive vegetation pattern (circle one) 158

CLASS	DESCRIPTION OF ABUNDANCE	DISTRIBUTION PATTERN
0	No invasive plants on the polygon	
1	Rare occurrence	
2	A few sporadically occurring individual plants	
3	A single patch	
4	A single patch plus a few sporadically occurring plants	
5	Several sporadically occurring plants	
6	A single patch plus several sporadically occurring plants	
7	A few patches	
8	A few patches plus several sporadically occurring plants	
9	Several well spaced patches	
10	Continuous uniform occurrence of well spaced plants	
11	Continuous occurrence of plants with a few gaps in the distribution	
12	Continuous dense occurrence of plants	
13	Continuous occurrence of plants associated with a wetter or drier zone within the polygon.	

Names of Non-native Species: 159

B4. Plot General Description (continue on back if necessary):

____

____

____

____

____

B5. In hindsight, how **representative** do you feel the releve plot was of the entire polygon? 160

1	**2**	**3**	**4**	**5**
unique		→		similar

Ending Time: _______161_____________ a.m. p.m.

B5. Plant species found only outside the plot(s) BsppPoly file

Circle any dominant non-wetland species ("50-20 rule") if it's at a spot appearing to have prolonged inundation or hydric soil. Determine GPS coordinates of any rare species. Denote with * if photographed.
Height Class: **L**: <0.5m tall **M**: 0.5-4m **T**: >4m
Relative Extent: **R**are= only 1 plant noticed; **U**ncommon= a few; **C**ommon= extensive; **A**bundant= one of the "50-20 rule" species

SpCode	HtCl	CovCl

SpCode	HtCl	CovCl	FieldID	Coll. #

Appendix C. Field Data Collection Protocols

Wetland Field Data Collection Protocol
June 14, 2005 revised version

Two types of areas will be visited: areas identified as wetlands from existing NWI maps (coded "K") and areas identified as "possible wetlands" based on terrain analysis modeling (coded "NW"). Depending on the indicator being assessed, field estimates of indicators will be made at the scale of centerpoint, plot, polygon (site), and/or polygon buffer:

- A ***polygon*** is the entire contiguous wetland, usually separated from similar polygons by upland or deepwater (>6 ft deep).
- A ***centerpoint*** is the point that represented the polygon during the site selection process and has specific coordinates which have a precision of about 40 ft. It is not necessarily located in the center of a wetland polygon.
- A ***plot*** is a releve plot of variable dimensions but standard area in which detailed vegetation data may be collected.
- A ***buffer*** is the upland (non-wetland) zone mostly extending 50m upslope from the polygon's outer edge. This distance is doubled up any polygon tributaries, and may be contracted if an impervious runoff barrier (e.g., tall berm or levee) is present before the 50m distance is reached.

Basic tasks that must be accomplished each day are:

- Navigate to and from the centerpoint of a wetland that's been targeted for assessment (those with a "K" prefix in the parkwide map of sample points)
- Determine if the site is a wetland.
- If the site is a wetland, place one unobtrusive marker (***benchmark***) at or within a measured distance and direction of the centerpoint. The marker will be an unflagged nail driven into a tree at eye level, with at least 0.5 inch protruding. No other permanent markers or lasting evidence of our visit will remain in any wetland. Locations of most data collected in the wetland will be referenced to this benchmark. It could serve as a basis for linking our data to future "vital signs" data and trends monitoring.

Record data from the following tasks

- Dig at least four 12-inch (30 cm) deep pits, GPS them, and evaluate soil indicators and vegetation. Replace soil. If the wetland is smaller than 100 square meters, a smaller number of pits may be used.
- Survey plants in a standard-sized plot, as well as while walking as much of the wetland as time and physical access allow.
- Observe and assess vegetation structure, distribution of water, signs of human presence, and other indicators of ecological services and condition as shown in the data forms (Appendix B).
- Take one series of panoramic shots from a fixed point with a digital camera (document the location and direction by including a labeled whiteboard in the picture). For consistency, shoot the photos from left to right (clockwise).
- On an airphoto or grid sheet, sketch the approximate polygon boundary and key points.

On a given day, field tasks will proceed in approximately the following order. Tasks will be conducted by the Plant Scientist (**PS**), Soil Scientist (**SS**), or both together (Both). Tasks performed simultaneously but independently by the PS and SS have an a, b suffix below. Even when the PS and SS are operating independently in different parts of a wetland, they may stay in touch through use of their walkie-talkies.

1. **Person PS**. Before leaving camp:

- Review the checklist (Appendix A) to ensure all needed supplies are packed.
- Decide which centerpoint to visit and plan the route. Identify alternative wetlands or survey points that may be visited if the primary target is unsuitable or inaccessible, or if sufficient time remains in the day to assess these after assessing the primary target. Set waypoints on the GPS unit as necessary.
- Be sure all electronics are charged

2. **(Both persons).** Upon arriving at the **centerpoint**, determine if the point is a wetland by virtue of its indicators related to vegetation, soil, and/or hydrology (>14 continuous days of saturation). For this project, channels that lack a predominance of wetland vegetation should be considered wetlands if they convey flow at least once annually. If the point is a wetland, proceed to #3. If not, spend 20 minutes searching (mainly in a downhill direction) for such wetland indicators. If found, establish a centerpoint and record the GPS coordinates (decimal degrees, NAD 83). Continue with #3. If none found, proceed to the alternative point selected for today.

3a. **Person PS**. Establish the **benchmark** at or near the centerpoint. Reference its exact location by measuring distance and direction from the centerpoint, as well as with GPS and by marking on the airphoto or grid sheet. Provide a detailed description.

3b. **Person SS.** At the **centerpoint** or in the **plot** (see below), dig one shallow pit (shovel width) and assess soil and vegetation features as requested in the field sheet (Data Form S). Measure the minimum depths to indicators such as gleying, mottles, changes in texture or color, and note the dominant vegetation. If subsurface water is encountered, record the depth and do not dig any deeper. Do not attempt to dig a pit where water, waterlogged soils, or hard rock is apparent at the surface, or where rare plants or archaeological relicts are noted. In such cases, move the point to the closest location where conditions permit digging a 12-inch (30 cm) deep pit. Measure and record the pit's distance and direction to the centerpoint. Also take panoramic series of photos from the centerpoint, or from a point referenced to the centerpoint. Additional photos should be taken of any human-related site disturbances that are noted. If archaeological relicts are discovered record their location with GPS and on the sketch map, and leave them in place.

4. **(Both).** Using the meter tape, lay out the boundaries of the **plot**, which will be square or rectangular with one corner anchored at the centerpoint[7]. Lay out the plot in a configuration that more or less conforms with the topography and appears to provide the most homogeneity of vegetation form, e.g., doesn't mix large patches of shrubs within a herbaceous plot or vice versa. For plots that are primarily **herbaceous, the contiguous area must be exactly 100 square meters** (e.g., 10m x 10m, or 20m x 5m, etc.). For plots that are primarily **shrub or tree, the plot must cover exactly 400 square meters**. Every shrub/tree plot **must** contain a 100 square meter herb plot within its boundaries, but not every herb plot will conversely include a shrub/tree plot.

To the extent such areas can be avoided, the plots should be configured to exclude unvegetated water areas (e.g., deep streams and ponds), bare rock, and areas dominated by non-wetland plant species, i.e., upland. **If a wetland is too small to contain a plot of 100 square meters**, measure its exact dimensions and survey whatever plants and soils are within it.

5a. **Person PS**:

- Conduct a complete releve-style survey within the plot. Identify all species possible and assign cover class to each within each height stratum. Photograph and place the few unknowns in a baggie with label. As needed, consult the list of plants known to occur in LAVO. Record data in part A of Data Form B, using the approved codes.
- Lay out and survey a second releve plot if necessary (i.e., if shrubs are a major component of the polygon but the first plot was herb-focused, or vice versa). In very large and diverse wetlands, survey additional plots as time allows. Locate any additional releve plots based on (a) whether it is dominated by a plant association not encountered up to this point in the field season, and secondarily, (b) its perceived representativeness of the wetland in which it is located. For shrub/tree plots, use the spherical densiometer to estimate canopy shade at 3 representative points within the plot.
- After completing the above, walk the remainder of the polygon (wetland), visiting all microhabitats while you build a cumulative list of any plant species not found in the plot(s). Continue as time allows or until species-accumulation curve seems to level off. Record time spent. As you walk around, also fill out part B of Data Form B.
- Identify all species possible. Photograph all species once during the field season, i.e., "voucher photo." Include the whiteboard in the picture to label what you're calling the plant in the image. Take multiple images if necessary to illustrate key diagnostic features. Then check off on the master list to indicate the species has been photographed, and denote the date and location. Be especially sure to photograph and label any unknowns, and place them in a baggie with label to work on back at camp or under the dissecting scope.

5b. **Person SS**. Walk the remainder of the polygon (as much as time allows). During this time:

- Evaluate soils in a minimum of 2 more pits (and no more than 12) located to represent different geomorphic and/or vegetation associations within the polygon. Assess at least one pit in the adjoining upland for sake of reference. Record the data in Data Form S.
- If a channel is present, measure 3 cross-sections as prescribed on Data Form F, and measure specific conductance (electrical connectivity).
- Fill out all remaining sections of Data Form F, which deals with hydrologic features.
- Sketch the approximate wetland boundary on the gridded sheet (Form G) and airphoto.

[7] But if the centerpoint is in a plant association that already was surveyed as a releve plot in another wetland on a previous day, you may shift the centerpoint such that the plot will cover a new association. Be sure to explain this.

- Photograph the channel cross-section (upstream, down) and any signs of prior human activity there or elsewhere in the polygon.

6. **(Both).** Before leaving the polygon, review each others' data sheets, add any species or features overlooked by the partner, and resolve any differing interpretations.

7. **Person PS:** Upon completing the day's field work:
   - Transfer the day's digital photos to a computer. After checking to be sure they've been saved, erase them from the camera's memory.
   - Charge batteries (radio, GPS). If you'll be away from a power source for more than a day (i.e., packing in overnight), be sure to bring along extra charged-up batteries.
   - Identify or press unidentified plants
   - Check weather and plan route for next day
   - On a semi-daily basis, fax or mail me copies of all completed data forms. Please be sure they're legible and complete.
   - At least once every 2 weeks, burn a CD with the digital photos and send it to me.

Supplemental Guidance

Locating the Centerpoint

1. Don't rely on the printed map or airphoto to locate the centerpoint -- their precision is not great. Instead rely on the GPS, assuming an adequate signal is obtained.
2. If you can't obtain an adequate GPS signal initially, search for the point in the approximate area indicated by the map and airphoto, while constantly looking for wetland plant species to narrow the search area, and repeatedly checking the GPS to see if signal interception has improved. Once the GPS signal is adequate, collect required data at that point, and separately note the occurrence and GPS coordinates (if available) of wetland plants you found elsewhere while searching if their distribution is not contiguous to the survey point. If no adequate GPS signal is obtained after about 20 minutes, and if you've found no predominance of wetland plants while searching in the vicinity, proceed to the next survey point.

Deciding When to Do Additional Releves at a Site

1. First priority: Do a releve at the designated sample point IF it is a wetland. If not, see above.
2. Second priority: Do one in the same wetland if it represents a different vegetation form than found elsewhere onsite, or if it is a different plant association than found at any other wetland that's been assessed up to this point in the field season.
3. Third priority – ONLY if time allows. Do one where there has been a major localized human disturbance, e.g., road crossing, or if you see a wetland plant association not encountered at any other site you visited up to this point in the field season.

Priorities for Field Surveys

Priority 1. Points labeled "K" (random points mapped as wetlands by NWI). Must survey all 50 before end of field season. All other considerations being equal, survey the lower-numbered K points first and proceed upwards in numeric sequence. Be sure the highest-elevation points are covered before autumn snowfall

Priority 2. Points labeled "NW" (random points predicted to be wetlands but not mapped as such). Survey these only during "remainder of day" after surveying one "K" point and there is not enough time to survey a second "K" point during that day. And/or survey these late in the season after all 50 "K" points have been surveyed. The goal is to survey 25 NW's and 25 T's before end of the season.

Priority 3. Points labeled "T" (random points predicted to be terrestrial). The goal is to survey 25 T's before end of the season.

Priority 4. Points labeled "NRS" (points mapped as wetlands by NWI but selected *non-randomly* to encompass geomorphic or stressor conditions not covered by the randomly-selected sites). The goal is to survey as many as possible before end of the season, without compromising any of the above priority goals. It's likely that I will select additional NR points during the first month of field work, and substitute for ones that haven't been covered as of that time.

If time remains in a day and it is equally convenient to survey either of two NW or T points, survey the one with the lower number first. The NR points may be surveyed in any order, but at a lower priority than K, NW, and T points.

Worst Case: If you arrive at a point and find (a) no wetland there, or you cannot safely access the wetland, and (b) there are no unsurveyed points anywhere in the vicinity, and (c) your chances are slim of being able to get to other unsurveyed points with enough time to survey adequately before dark, THEN survey whatever undesignated wetland(s) you can find in the vicinity or along the way back, so the day is not a total waste. Give each undesignated wetland a unique number preceded by the prefix “NRF” (non-random found, as opposed to non-random selected).

When such unmapped “NRF” wetlands are encountered opportunistically (e.g., while hiking to designated points), note their GPS coordinates (just one point) and record their predominant plant species in each vertical stratum, but do not allow this to hinder accomplishment of the above priorities.

While Traveling To and From Target Wetlands:

If the most efficient route to the target wetland intercepts another *mapped but unvisited wetland*, as you pass it by, briefly record its apparently dominant vegetation, Cowardin type, and HGM type (and identify it by its polygon code on our map). While en route to a target wetland IF you notice:

(a) a very rare wetland plant species or association not encountered previously in your surveys,
(b) a channel, or
(c) an unmapped wetland, i.e., an area of any size dominated by wetland indicator species, or
(d) surface water occupied by plants, even if the dominant species are not on the list of those officially designated as wetland indicators,
THEN: get a GPS reading and note the lat-long, along with the date and the dominant species. If it’s a rare plant, also take photographs and estimate the number of individuals.

Appendix D. Wetland Plant Species of LAVO, including Both Wetland and Non-wetland Species Found in LAVO Wetlands in 2005

Found: Y= species was found by this study. Species occurrence in number of wetland sites and number of plots within all sites are noted. Native: Y= native to California (0= not). Wet Score= wetland indicator status. Higher numbers indicate greater dependency on wetlands (10= obligate, 0= upland species), with scores equal or greater than 5 denoting wetland species. Blanks indicate that no indicator status has been assigned by the USFWS and Corps of Engineers. These scores are used in computing the Prevalence Index. Fen Sp?= considered to be an indicator of fens (a distinctive wetland type) by Cooper (2005) as summarized by Weixelman et al. (2007). Disturb Sp?= when dominating in fen wetlands, this species is considered to be an indicator of overgrazing or artificial drainage according to Weixelman et al. (2007). Only native species are included.

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Abies concolor	7	7	Y	0		
Y	Abies magnifica	5	5	Y	0		
Y	Acer glabrum	1	2	Y	2		
Y	Achillea millefolium	14	16	Y	2		
Y	Achnatherum nelsonii	4	4	Y			
Y	Achantherum lemmonii	1	1	Y			
Y	Achnatherum occidentalis	2	2	Y			
Y	Aconitum columbianum	3	3	Y	8		
Y	Actaea rubra	1	0	Y	8		
	Adiantum aleuticum	0	0	Y	5		
Y	Ageratina occidentalis	1	2	Y	0		
Y	Agoseris aurantiaca	1	1	Y	2		
Y	Agrostis exarata	1	1	Y	2		
Y	Agrostis gigantea	2	3	0	8		
Y	Agrostis idahoensis	0	0	Y	8		
	Agrostis oregonensis	0	0	Y	5		
Y	Agrostis scabra	1	1	Y	8		
Y	Agrostis stolonifera	1	0	0	5		
Y	Agrostis thurberiana	11	11	Y	8		
Y	Agrostis variabilis	6	6	Y	8		
Y	Allium campanulatum	1	0	Y			
Y	Allium validum	0	0	Y	10		
Y	Allophyllum integrifolium	1	0	Y	10		
Y	Alnus incana	10	10	Y	8		
	Alopecurus aequalis	0	0	Y	10		
	Alopecurus geniculatus	0	0	Y	10		
	Alopecurus pratensis	0	0	0	8		
	Amaranthus blitoides	0	0	0	8		
Y	Amelanchier utahensis	1	1	Y	8		
Y	Anaphalis margaretacea	1	1	Y			
	Antennaria corymbosa	0	0	Y	5		
Y	Antennaria media	2	0	Y	0		
Y	Antennaria rosea	1	1	Y	0		
Y	Aquilegia formosa	4	4	Y	5		
Y	Arabis glabra	1	1	Y			
Y	Arabis lemmonii	1	1	Y	1		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Arabis platysperma	1	0	Y	1		
	Arnica chamissonis	0	0	Y	8		
Y	Arnica longifolia	2	0	Y	8		
Y	Arnica mollis	3	0	Y	8		
Y	Artemisia douglasiana	3	3	Y	5		
	Asclepias speciosa	0	0	Y	6		
Y	Aster alpigenus	9	11	Y	8		Y
Y	Aster eatonii	4	4	Y	6		
	Aster foliaceus	0	0	Y	7		
	Aster frondosus	0	0	Y	9		
Y	Aster integrifolius	4	4	Y	6		
Y	Aster occidentalis	1	1	Y	5		
Y	Asteraceae sp.	0	0				
Y	Athyrium filix-femina	3	4	Y	5		
Y	Balsamorhiza sagittata	2	0	Y			
Y	Barbarea orthoceras	4	4	Y	9		
	Betula glandulosa	0	0	Y	10		
	Bidens cernua	0	0	Y	9		
Y	Botrychium multifidum	3	0	Y	9		
Y	Botrychium simplex	1	1	Y	2		
	Brasenia schreberi	0	0	0	10		
	Brodiaea coronaria	0	0	Y	5		
Y	Bromus carinatus	1	1	Y			
	Bromus ciliatus	0	0	Y	5		
Y	Bromus inermis	2	2	0	5		
Y	Bromus suksdorfii	4	4	Y	5		
Y	Calamagrostis canadensis	5	7	Y	9		
Y	Callitriche verna	1	0	Y	9		
Y	Calocedrus decurrens	3	3	Y			
Y	Calochortus nudus	2	2	Y	5		
Y	Caltha leptosepala	6	7	Y	5		
Y	Calyptridium umbellatum	1	1	Y	10		
Y	Camassia quamash	2	0	Y	8		
	Camissonia subacaulis	0	0	Y	7		
Y	Cardamine breweri	1	1	Y	8		
Y	Carex abrupta	7	7	Y	0		
	Carex amplifolia	0	0	Y	9		
Y	Carex angustata	9	10	Y	0		
Y	Carex athrostachya	1	1	Y	8		
Y	Carex aurea	2	2	Y	9		
Y	Carex bolanderi	1	1	Y	8		
	Carex canescens	0	0	Y	9		
	Carex capitata	0	0	Y	5		
	Carex cusickii	0	0	Y	10		
Y	Carex douglasii	1	0	Y	2		
	Carex echinata	0	0	Y	10		
	Carex feta	0	0	Y	8		
Y	Carex fracta	1	1	Y			
	Carex hassei	0	0	0	8		
Y	Carex heteroneura	7	7	Y	5		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Carex hoodii	1	1	Y	5		
Y	Carex illota	1	0	Y	5	Y	
Y	Carex integra	6	6	Y	5		
Y	Carex jonesii	1	1	Y	9		
Y	Carex lanuginosa	1	1	Y	9		
	Carex lasiocarpa	0	0	Y	10		
	Carex lemmonii	0	0	Y	10		
Y	Carex lenticularis	5	5	Y	8		
Y	Carex leporinella	8	8	Y	9		
	Carex limosa	0	0	Y	10		
Y	Carex luzulifolia	7	7	Y			
Y	Carex luzulina	5	5	Y	10		
Y	Carex microptera	2	3	Y	6		
Y	Carex multicostata	1	1	Y	6		
Y	Carex nebrascensis	1	0	Y	10		
Y	Carex nervina	12	13	Y	10		
Y	Carex nigricans	4	4	Y	7		
Y	Carex pachystachya	3	3	Y	5		
	Carex praeceptorium	0	0	Y	10		
Y	Carex raynoldsii	3	3	Y	8		
Y	Carex rossii	2	2	Y	2		
Y	Carex scopulorum	4	5	Y	8		
	Carex senta	0	0	Y	10		
Y	Carex simulata	3	3	Y	10	Y	
Y	Carex specifica	1	0	Y	10		
Y	Carex spectabilis	9	1	Y	8		
Y	Carex straminiformis	1	1	Y			
Y	Carex subfusca	3	3	Y	4		
Y	Carex utriculata	4	1	Y	10	Y	
Y	Carex vernacula	1	1	Y	5		
Y	Carex vesicaria	10	11	Y	10		
Y	Caryophyllaceae sp.	0	0	Y			
Y	Castilleja lemmonii	1	1	Y	10		
Y	Castilleja miniata	2	3	Y	2		
Y	Castilleja tenuis	1	0	Y	2		
Y	Cerastium fontanum	1	0	0	1		
	Ceratophyllum demersum	0	0	Y	10		
	Chenopodium album	0	0	0	5		
Y	Chenopodium atrovirens	1	0	Y	2		
Y	Chimaphila menziesii	2	2	Y			
Y	Chimaphila umbellata	1	1	Y			
Y	Chrysothamnus nauseosus	1	1	Y			
Y	Cicuta douglasii	1	2	Y	10		
	Cinna latifolia	0	0	Y	8		
Y	Circaea alpina	2	2	Y	10		
Y	Circium sp.	0	0				
Y	Cirsium douglasii	1	1	Y	5		
Y	Cirsium scariosum	1	2	Y	10		
Y	Cirsium vulgare	2	2	0	0		
Y	Claytonia nevadensis	1	1	Y	5		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Collinsia torreyi	2	2	Y	2		
Y	Collomia tinctoria	1	1	Y			
Y	Corallorrhiza maculata	1	0	Y	4		
	Cornus sericea	0	0	Y	8		
Y	Corydalis caseana	2	0	Y	8		
	Crypsis schoenoides	0	0	0	10		
Y	Cryptantha sp.	0	0	Y			
Y	Cryptantha torreyana	1	1	Y	9		
	Cyperus squarrosus	0	0	Y	10		
Y	Cystopteris fragilis	2	3	Y	2		
Y	Danthonia californica	2	2	Y	2		
Y	Danthonia intermedia	1	1	Y	2		
Y	Danthonia unispicata	2	0	Y			
Y	Delphinium depauperatum	2	0	Y			
Y	Deschampsia cespitosa	12	13	Y	8		
	Deschampsia danthonioides	0	0	Y	7		
Y	Deschampsia elongata	2	2	Y	8		
Y	Dicentra formosa	4	5	Y	7		
Y	Dicentra uniflora	1	1	Y	2		
	Dichanthelium acuminatum	0	0	Y	5		
Y	Dodecatheon alpinum	5	5	Y	9		
	Downingia yina	0	0	Y	10		
Y	Draba albertina	1	1	Y	9		
	Drosera anglica	0	0	Y	10		
	Drosera rotundifolia	0	0	Y	10		
	Dulichium arundinaceum	0	0	Y	10		
Y	Eleocharis acicularis	5	5	Y	10		
Y	Eleocharis macrostachya	1	2	Y	10		
Y	Eleocharis pauciflora	4	4	Y	10	Y	
Y	Eleocharis sp.	0	0	Y			
Y	Elodea canadensis	1	0	Y	10		
Y	Elymus elymoides	2	2	Y	1		
Y	Elymus glaucus	7	9	Y	1		
	Elymus trachycaulus	0	0	Y	5		
Y	Epilobium anagallidifolium	1	0	Y	2		
	Epilobium canum	0	0	Y	7		
Y	Epilobium ciliatum	3	3	Y	1		
	Epilobium densiflorum	0	0	Y	7		
Y	Epilobium glaberrimum	2	2	Y	7		
Y	Epilobium halleanum	3	3	Y	8		
Y	Epilobium hornemannii	8	8	Y	8		
Y	Epilobium oregonense	1	1	Y	7		
Y	Epilobium sp.	0	0	Y			
Y	Equisetum arvense	4	1	Y	5		
	Equisetum laevigatum	0	0	Y	8		
	Erigeron acris	0	0	Y	5		
Y	Erigeron coulteri	2	0	Y	8		
Y	Erigeron peregrinus	1	0	Y	8		
Y	Erigeron sp.	0	0	Y			
Y	Eriogonum nudum	2	2	Y	8		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
	Eriophorum gracile	0	0	Y	10		
	Eryngium alismifolium	0	0	0	8		
Y	Erythronium purpurascens	6	6	Y			
Y	Festuca pratensis	1	1	0	2		
	Festuca rubra	0	0	0	6		
Y	Floerkea proserpinacoides	2	3	Y	8		
Y	Fragaria virginiana	2	2	Y	8		
Y	Galium aparine	1	1	Y			
Y	Galium bifolium	1	1	Y	2		
Y	Galium sp.	0	0	Y			
Y	Galium trifidum	2	2	Y	8		
Y	Galium triflorum	5	5	Y	2		
Y	Gaultheria humifusa	1	0	Y	8		
Y	Gayophytum diffusum	1	1	Y	8		
Y	Gayophytum humile	2	2	Y	0		
Y	Gayophytum racemosum	2	2	Y	0		
Y	Gentiana newberryi	2	2	Y	0		
	Gentianella amarella	0	0	Y	7		
Y	Gentianopsis simplex	1	0	Y	0		
Y	Geum macrophyllum	1	1	Y	8		
Y	Gilia capilaris	1	1	Y	6		
Y	Glyceria borealis	1	0	Y	10		
Y	Glyceria elata	5	6	Y	9		
	Gnaphalium luteoalbum	0	0	0	7		
Y	Gnaphalium palustre	2	2	Y	6		
	Gratiola ebracteata	0	0	Y	10		
Y	Hackelia californica	1	1	Y	6		
Y	Hackelia micrantha	7	8	Y	0		
Y	Hackelia nervosa	1	1	Y	0		
	Hastingsia alba	0	0	0	10		
	Helenium bigelovii	0	0	Y	9		
	Helianthus bolanderi	0	0	Y	5		
Y	Heracleum lanatum	3	4	Y	2		
Y	Hesperochiron pumilis	1	0	Y	2		
	Heterocodon rariflorum	0	0	Y	8		
Y	Hieracium albiflorum	1	0	Y			
Y	Hieracium gracile	2	2	Y	0		
	Hippuris vulgaris	0	0	Y	10		
Y	Holcus lanatus	1	0	0	0		
Y	Holodiscus microphyllus	2	3	Y	5		
Y	Hordeum brachyantherum	5	5	Y	7		
Y	Hydrophyllum occidentale	3	0	Y	7		
Y	Hypericum anagalloides	14	14	Y	8		Y
Y	Hypericum formosum	1	1	Y			
Y	Isoetes bolanderi	5	5	Y	10		
	Isoetes echinospora	0	0	Y	10		
	Isoetes nuttallii	0	0	Y	10		
Y	Juncus balticus	15	16	Y	10		
	Juncus bufonius	0	0	Y	8		
Y	Juncus drummondii	8	8	Y	10		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Juncus effusus	1	0	Y	7		
	Juncus ensifolius	0	0	Y	8		
Y	Juncus hemiendytus	1	1	Y	10		
Y	Juncus howellii	1	1	Y	9		
Y	Juncus mertensianus	8	8	Y	10		
Y	Juncus nevadensis	8	9	Y	8		
	Juncus orthophyllus	0	0	Y	8		
Y	Juncus parryi	5	1	Y	6		
	Juncus patens	0	0	Y	8		
Y	Juncus sp.	0	0	Y			
Y	Kalmia polifolia	5	5	Y	6	Y	
Y	Kelloggia galioides	1	0	Y	10		
Y	Ledum glandulosum	3	0	Y	9		
Y	Lemna sp.	0	0	Y			
	Lemna trisulca	0	0	Y	10		
Y	Lemna turionifera	1	1	Y	9		
	Leucothoe davisiae	0	0	Y	8		
Y	Lewisia nevadensis	2	2	Y	0		
Y	Lewisia sp.	0	0	Y			
Y	Lewisia triphylla	2	2	Y	0		
Y	Ligusticum grayi	8	10	Y	0		
Y	Lilium pardalinum	3	3	Y	0		
	Limosella acaulis	0	0	Y	10		
Y	Linanthus harknessii	2	2	Y	10		
Y	Listera convallarioides	1	1	Y	5		
Y	Lithophragma glabrum	1	0	Y	5		
	Lolium perenne	0	0	0	5		
	Lonicera cauriana	0	0	Y	8		
	Lonicera conjugialis	0	0	Y	5		
Y	Lonicera involucrata	2	0	Y	6		
	Lotus corniculatus	0	0	0	5		
Y	Lotus oblongifolius	1	0	Y	6		
Y	Lotus purshianus	1	0	Y	10		
	Ludwigia palustris	0	0	Y	10		
Y	Lupinus angustiflorus	1	0	Y			
Y	Lupinus arbustus	1	1	Y			
Y	Lupinus lepidus	3	3	Y			
Y	Lupinus obtusilobus	2	0	Y			
Y	Lupinus polyphyllus	10	13	Y	6		
Y	Lupinus sp.	0	0	Y			
Y	Luzula comosa	5	5	Y	0		
Y	Luzula divaricata	2	0	Y	0		
Y	Luzula sp.	0	0	Y			
Y	Luzula subcongesta	5	5	Y	0		
	Lycopus uniflorus	0	0	Y	10		
	Lysimachia thyrsiflora	0	0	0	10		
	Lythrum hyssopifolia	0	0	0	10		
	Marsilea oligospora	0	0	0	10		
Y	Melica subulata	1	1	Y	0		
	Mentha arvensis	0	0	Y	5		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Mentzelia dispersa	1	0	Y			
	Menyanthes trifoliata	0	0	Y	10		
Y	Microseris nutans	1	0	Y			
Y	Mimulus breweri	2	2	Y	0		
	Mimulus dentatus	0	0	Y	10		
Y	Mimulus guttatus	12	14	Y	10		
	Mimulus lewisii	0	0	Y	9		
Y	Mimulus moschatus	13	14	Y	10		
Y	Mimulus primuloides	17	19	Y	9		Y
Y	Mimulus sp.	0	0	Y			
Y	Mimulus tilingii	3	3	Y	9		
Y	Mitella pentandra	2	2	Y	10		
Y	Monardella odoratissima	2	2	Y	5		
Y	Montia chamissoi	1	1	Y	1		
	Montia fontana	0	0	Y	10		
	Muhlenbergia andina	0	0	Y	5		
Y	Muhlenbergia filiformis	3	3	Y	7		
Y	Muhlenbergia richardsonis	4	5	Y	7		
	Myriophyllum hippuroides	0	0	Y	10		
Y	Myriophyllum sibiricum	1	1	Y	5		
	Najas flexilis	0	0	Y	10		
	Navarretia intertexta	0	0	0	5		
	Navarretia leucocephala	0	0	Y	5		
Y	Nemophila pedunculata	1	0	Y	10		
Y	Nuphar lutea	1	1	Y	5		
Y	Nuphar polysepala	0	0		10		
	Oenothera elata	0	0	Y	7		
Y	Orobanche uniflora	1	1	Y			
Y	Orthilia secunda	2	0	Y	2		
Y	Osmorhiza chilensis	3	4	Y	2		
Y	Osmorhiza occidentalis	4	5	Y			
	Oxypolis occidentalis	0	0	Y	10		
	Panicum acuminatum	0	0	Y	5		
Y	Panicum capillare	1	0	Y	3		
Y	Parnassia californica	1	0	Y	3		
Y	Pedicularis attollens	4	0	Y	0		
Y	Pedicularis groenlandica	2	3	Y	10		
Y	Pedicularis semibarbata	1	1	Y	10		
Y	Penstemon gracilientus	1	1	Y			
Y	Penstemon heterodoxus	3	3	Y			
Y	Penstemon rydbergii	1	0	Y	2		
Y	Penstemon sp.	0	0	Y			
Y	Perideridia bolanderi	1	0	Y	2		
	Perideridia gairdneri	0	0	Y	5		
	Perideridia howellii	0	0	Y	8		
Y	Perideridia lemmonii	1	1	Y	0		
Y	Perideridia parishii	16	17	Y	8		
Y	Phacelia mutabilis	1	1	Y	8		
Y	Phacelia procera	1	2	Y	6		
Y	Phacelia sp.	0	0	Y			

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Phleum alpinum	5	7	Y	6		
Y	Phleum pratense	1	0	0	6		
Y	Phyllodoce breweri	4	4	Y	4		
Y	Pinus contorta	14	16	Y	2		
Y	Pinus lambertiana	1	1	Y			
Y	Pinus jeffreyi	1	1	Y			
Y	Pinus monticola	3	3	Y	2		
Y	Pinus ponderosa	2	2	Y	2		
	Piperia unalascensis	0	0	Y	5		
Y	Plantago major	1	1	0	1		
Y	Platanthera leucostachys	7	7	Y	5		
Y	Platanthera sparsiflora	2	3	Y	0		
Y	Poa annua	1	1	0	8		
	Poa palustris	0	0	0	5		
Y	Poa pratensis	5	6	0	5		
Y	Poaceae sp.	0	0				
Y	Polemonium californicum	3	1	Y	5		
Y	Polygonum amphibium	1	1	Y	10		
Y	Polygonum bistortoides	1	1	Y	10		
Y	Polygonum douglasii	1	1	Y	8		
	Polygonum lapathifolium	0	0	Y	8		
Y	Polygonum phytolaccifolium	1	2	Y	2		
Y	Polygonum polygaloides	3	3	Y	0		
Y	Populus balsamifera	2	2	Y	5		
Y	Populus tremuloides	2	3	Y	5		
	Populus trichocarpa	0	0	Y	5		
Y	Porterella carnosula	1	1	Y	6		
Y	Potamogeton amplifolius	1	0	Y	10		
	Potamogeton foliosus	0	0	Y	10		
	Potamogeton gramineus	0	0	Y	10		
	Potamogeton natans	0	0	Y	10		
	Potamogeton nodosus	0	0	Y	10		
Y	Potamogeton praelongus	1	0	Y	10		
	Potamogeton pusillus	0	0	Y	10		
	Potamogeton richardsonii	0	0	Y	10		
	Potamogeton robbinsii	0	0	Y	10		
Y	Potentilla drummondii	1	1	Y	5		
Y	Potentilla flabellifolia	4	4	Y	10		
Y	Potentilla glandulosa	2	2	Y	4		
Y	Potentilla gracilis	3	1	Y	4		
	Potentilla palustris	0	0	Y	10		
Y	Potentilla sp.	0	0	Y			
Y	Pteridium aquilinum	1	1	Y	2		
	Pyrola asarifolia	0	0	Y	7		
Y	Ranunculus alismifolius	11	11	Y	2		
Y	Ranunculus aquatilis	2	0	Y	10		
Y	Ranunculus flammula	3	3	Y	10		
	Ranunculus occidentalis	0	0	Y	5		
Y	Ranunculus orthoryhnchus	1	1	Y	8		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
	Ranunculus populago	0	0	Y	8		
	Ranunculus uncinatus	0	0	Y	5		
	Rhynchospora alba	0	0	0	10		
Y	Ribes cereum	1	0	Y	8		
Y	Ribes inerme	2	2	Y	5		
Y	Ribes montigenum	2	2	Y	5		
Y	Ribes roezlii	2	2	Y			
	Ribes viscosissimum	0	0	Y	5		
Y	Rorippa curvisiliqua	5	5	Y	10		
Y	Rubus leucodermis	2	1	Y	0		
Y	Rumex acetosella	1	0	0	0		
Y	Rumex crispus	1	0	0	6		
	Rumex occidentalis	0	0	Y	9		
Y	Rumex salicifolius	1	1	Y	6		
	Rumex triangulivalvis	0	0	Y	5		
Y	Sagina saginoides	2	3	Y	8		
Y	Sagittaria cuneata	1	0	Y	7		
	Salix arctica	0	0	Y	5		
Y	Salix boothii	1	2	Y	10		
	Salix jepsonii	0	0	Y	10		
	Salix lasiandra	0	0	Y	10		
Y	Salix lemmonii	5	6	Y	9		
Y	Salix lucida	2	2	Y	9		
	Salix melanopsis	0	0	Y	10		
	Salix scouleriana	0	0	Y	5		
Y	Sambucus racemosa	1	1	Y	9		
Y	Sarcodes sanguinea	3	0	Y	2		
Y	Saxifraga aprica	1	1	Y	5		
Y	Saxifraga bryophora	1	1	Y			
Y	Saxifraga nidifica	1	0	Y	8		
Y	Saxifraga odontoloma	1	1	Y	8		
Y	Saxifraga oregana	1	0	Y	9		
Y	Saxifraga sp.	0	0	Y			
	Scheuchzeria palustris	0	0	Y	10		
	Scirpus acutus	0	0	Y	10		
	Scirpus americanus	0	0	Y	10		
Y	Scirpus congdonii	5	6	Y	9		
Y	Scirpus microcarpus	4	4	Y	8	Y	
	Scirpus subterminalis	0	0	Y	10		
	Senecio pauciflorus	0	0	Y	5		
Y	Senecio triangularis	18	23	Y	10		
Y	Senecio hydrophilus	1	1	Y	9		
Y	Senecio scorzonella	5	5	Y	5		
Y	Sibbaldia procumbens	5	5	Y	0		
Y	Sidalcea oregana	2	2	Y	0		
Y	Silene douglasii	1	1	Y			
Y	Sisyrhinchium sp.	0	0	Y			
Y	Sisyrinchium bellum	1	0	Y	7		
Y	Sisyrinchium elmeri	1	0	Y	7		
Y	Sisyrinchium idahoense	1	0	Y	8		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Sium suave	1	1	Y	8		
Y	Smilacina racemosa	1	2	Y	10		
Y	Smilacina stellata	3	3	Y	5		
Y	Solidago canadensis	1	2	Y	5		
Y	Sparganium angustifolium	4	4	Y	2		
Y	Sparganium emersum	1	1	Y	10		
	Sparganium natans	0	0	Y	10		
Y	Sphenosciadium capitellatum	1	0	Y	10		
Y	Spiraea densiflora	6	0	Y	8		
Y	Spiraea douglasii	1	0	Y	8		
Y	Spiranthes porrifolia	1	0	Y	8		
	Spirodela punctata	0	0	Y	10		
Y	Stachys ajugoides	4	4	Y	10		
Y	Stachys sp.	0	0	Y			
	Stellaria borealis	0	0	Y	7		
Y	Stellaria calycantha	2	0	Y	8		
Y	Stellaria crispa	1	1	Y	8		
Y	Stellaria longipes	2	3	Y	6		
Y	Stellaria obtusa	1	1	Y	8		
Y	Stellaria sp.	0	0	Y			
Y	Streptopus amplexifolius	1	1	Y	8		
	Subularia aquatica	0	0	Y	10		
Y	Taraxacum officinale	6	8	0	4		
Y	Thalictrum fendleri	1	1	Y	2		
Y	Thalictrum sparsiflorum	2	4	Y	5		
Y	Tofieldia occidentalis	3	3	Y	5	Y	
Y	Torreyochloa erecta	1	1	Y	10		
Y	Torreyochloa pallida	1	1	Y	10		
Y	Tragopogon dubius	1	2	0	10		
	Trautvetteria caroliniensis	0	0	Y	5		
Y	Trifolium cyathiferum	1	0	Y	5		
	Trifolium hybridum	0	0	0	5		
Y	Trifolium kingii	2	0	Y	5		
Y	Trifolium longipes	16	19	Y	4		
	Trifolium microcephalum	0	0	Y	5		
Y	Trifolium monanthum	1	2	Y	8		
Y	Trifolium sp.	0	0				
	Trifolium variegatum	0	0	Y	5		
	Trifolium wormskioldii	0	0	Y	9		
	Triglochin maritima	0	0	0	10		
	Trimorpha acris	0	0	Y	5		
Y	Trisetum canescens	1	1	Y			
Y	Trisetum wolfii	5	6	Y	2		
Y	Tsuga mertensiana	6	6	Y	2		
Y	Typha latifolia	1	1	Y	10		
	Urtica dioica	0	0	Y	6		
	Utricularia intermedia	0	0	Y	10		
	Utricularia minor	0	0	Y	10		
	Utricularia vulgaris	0	0	Y	10		

Found	Scientific Name	# of Sites	# of Plots	Native ?	Wet Score	Fen Sp.?	Disturb Sp.?
Y	Vaccinium caespitosum	1	1	Y	10		
Y	Vaccinium ulignosum	1	0	Y	8	Y	
	Valeriana californica	0	0	Y	10		
Y	Veratrum californicum	20	24	Y	8		
Y	Verbascum thapsus	1	1	0	10		
Y	Veronica americana	3	3	Y	0		
	Veronica peregrina	0	0	Y	10		
	Veronica scutellata	0	0	Y	10		
Y	Veronica serpyllifolia	9	9	Y	10		
Y	Veronica wormskjoldii	2	2	Y	5		
	Vicia americana	0	0	Y	5		
Y	Viola adunca	4	4	Y	7		
Y	Viola bakeri	1	0	Y	7		
Y	Viola glabella	7	8	Y	5		
Y	Viola macloskeyi	10	11	Y	5		
Y	Viola sp.	0	0	Y			
Y	Zigadenus venenosus	1	0	Y	10		

Appendix E. Plant Metrics for Individual Visited Wetlands

Table E-1. Plant metrics for shrub/tree plots (400 m^2).

Legend:
Stratum: 0= hand-picked site; 1= random site. See Figure 4, Table 2, or supporting digital spatial data for site locations.
See section 3.3.2 for definitions of plant metrics in this table.

Stratum	Site ID	# of spp.	# of Families	# of veg forms	# of Fen species	# of disturbance species	Frequency, mean of spp	Frequency, min. of spp.	# of spp. w. <1% cover	# spp. w. 1-25%	# spp. w. 25-60%	# spp. w. >60%
1	K1	34	18	4	1	2	6.41	1	21	3	2	0
1	K34	27	12	2		3	10.24	2	13	12	0	0
1	K37	18	15	4			6.19	1	6	8	1	0
1	K41	24	15	3		1	6.57	1	29	6	1	0
1	K43	33	21	5			6.27	1	17	11	1	0
1	K47	26	14	4		4	6.5	1	9	9	0	1
1	K49	28	13	3		2	8.69	1	18	6	0	1
1	K5	40	23	5	1	4	6.61	1	29	4	0	1
0	NR549	25	14	4		1	6.48	1	22	5	3	0
0	NW51	21	12	3		2	10.55	1	24	7	0	1
0	NW56	13	6	4	1	1	5.31	1	26	15	0	1

Table E-2. Plant metrics for 100 m^2 herb plots, one plot per site.

<u>Legend</u>:
Stratum: 0= hand-picked site; 1= random site. For site locations see Figure 4and Table 2, or supporting digital spatial data.
See section 3.3.2 for definitions of plant metrics in this table.

Site ID	# of spp.	# of Fams.	# of veg forms	# of Fen species	# of disturbance species	Frequency, mean of spp	Frequency, min. of spp.	# of spp. w. <1% cover	# spp. w. 1-25%	# spp. w. 25-60%	# spp. w. >60%
IW1	19	12	3	1	5	6.67	1	16	3	0	0
K1	28	17	4	1	2	6.69	1	24	5	1	0
K10	6	3	2			7.00	3	3	2	1	0
K11	3	2	1			4.00	3	1	2	0	0
K12	3	2	1			10.00	5	0	2	0	1
K13	20	12	3	1		8.58	1	15	5	1	0
K14	6	2	1			7.83	1	3	2	1	0
K15	32	14	3		2	7.39	1	27	5	1	0
K16	21	13	4	1	4	7.55	1	10	10	2	0
K17	3	3	2			6.33	4	4	2	0	0
K18	27	12	3		1	8.00	1	21	7	1	0
K19	22	13	4		2	4.95	1	14	7	1	0
K2	14	9	2			8.36	1	9	4	1	0
K21	4	4	2			6.50	1	2	2	0	0
K22	13	11	3		1	7.64	1	11	2	0	1
K23	7	7	3			2.33	1	7	1	0	0
K24	17	13	3		2	11.57	2	13	3	3	0
K25	13	9	2			6.50	1	9	4	0	1
K26	12	9	4		1	10.30	1	3	4	1	0
K27	18	11	3		1	10.56	2	14	3	0	1
K29	21	11	3			6.20	1	14	8	0	0
K3	4	3	1			8.00	8	4	0	0	0
K31	25	15	3		2	9.48	1	19	8	0	1
K32	39	23	4		3	4.94	1	31	12	2	0
K33	16	9	4	2	1	5.57	1	9	8	2	0
K34	23	11	2		2	10.52	2	16	8	1	0
K35	2	1	1			9.00	8	0	2	0	1
K36	25	15	2		2	9.45	1	18	7	1	0

Site ID	# of spp.	# of Fams.	# of veg forms	# of Fen species	# of disturbance species	Frequency, mean of spp	Frequency, min. of spp.	# of spp. w. <1% cover	# spp. w. 1-25%	# spp. w. 25-60%	# spp. w. >60%
K37	34	23	5		2	8.22	1	23	13	0	0
K39	16	12	3		3	8.94	1	9	6	0	1
K4	16	12	4			5.45	2	10	7	0	1
K40	2	1	1			9.00	8	0	1	1	0
K41	11	9	2	1		8.27	2	7	3	0	1
K42	5	3	2			5.00	1	3	2	1	0
K44	3	3	2			8.00	4	2	1	0	0
K45	19	10	3	2	3	6.94	1	14	6	0	0
K46	2	2	2	1		2.50	1	0	1	0	1
K47	43	21	4		5	5.88	1	34	8	0	0
K50	13	8	3		2	6.77	2	11	3	0	0
K51	2	1	1			9.00	8	2	1	0	0
K52	24	16	3		1	6.18	1	18	6	0	0
K6	5	4	2			3.00	1	2	1	2	0
K7	4	2	2			12.50	10	1	1	2	0
K8	5	3	1			10.50	5	1	3	1	0
K9	10	7	3	1	1	5.90	1	5	5	1	0
NR142	4	2	1			9.00	5	2	2	0	1
NR144	22	17	3	3		5.10	1	16	6	1	0
NR171	19	12	4			7.56	1	13	7	1	0
NR178	10	9	2		1	4.90	1	7	2	0	1
NR342	8	6	3	2		8.25	3	7	1	1	0
NR454	12	10	3			9.50	7	7	5	0	0
NR473	2	1	1	2		3.50	3	0	1	1	0
NR627	37	23	4		1	5.22	1	31	3	0	0
NR660	7	4	2			8.33	3	4	2	0	1
NR694	14	11	4		2	6.07	1	9	4	0	1
NR695	11	8	3		2	7.56	1	6	4	1	0
NR770	2	1	1			8.00	4	2	1	0	0
NRF1	35	23	5		1	4.76	1	25	9	1	1
NW28	12	9	2	1	1	7.40	1	9	3	0	1
NW56	12	9	3		1	3.50	1	7	3	2	0
NW7	5	5	2			1.80	1	4	1	0	0
T22	31	17	4		3	5.90	1	22	9	1	0

Table E-3. Plant metrics from pooling of plot and polygon data.

Legend:
Stratum: 0= hand-picked site; 1= random site. For site locations see Figure 4 and Table 2. See section 3.3.2 for definitions of plant metrics in this table.

Stratum	Site ID	# of spp.	# of native species	# of Fen species	# of disturbance species	Frequency, mean of spp	Frequency, min. of spp.
0	IW1	50	45	3	7	5.60	1
0	IW2	37	31	3	7	4.83	1
1	K1	46	44	2	3	6.41	1
1	K10	6	5	0	0	6.60	3
1	K11	11	10	0	2	9.90	1
1	K12	9	7	0	0	6.86	2
1	K13	36	35	1	1	7.00	1
1	K14	7	7	0	0	7.43	1
1	K15	39	38	0	3	7.16	1
1	K16	34	30	1	4	5.85	1
1	K17	7	7	0	0	5.71	3
1	K18	33	33	0	1	7.22	1
1	K19	30	28	0	2	5.17	1
1	K2	34	34	0	0	5.50	1
1	K21	8	6	0	0	5.83	1
1	K22	33	29	2	2	6.07	1
1	K23	11	9	0	0	3.75	1
1	K24	31	29	0	2	8.04	1
1	K25	31	30	2	0	6.50	1
1	K26	15	14	0	1	9.38	1
1	K27	47	42	0	2	7.00	1
1	K29	28	28	0	0	5.81	1
1	K3	8	7	0	0	7.29	1
1	K31	38	37	0	2	8.00	1
1	K32	40	35	0	3	4.88	1
1	K33	29	27	6	2	5.48	1
1	K34	39	39	0	3	8.68	1
1	K35	6	6	0	0	8.33	5
1	K36	59	57	1	3	6.09	1
1	K37	59	54	0	3	5.98	1

Stratum	Site ID	# of spp.	# of native species	# of Fen species	# of disturbance species	Frequency, mean of spp	Frequency, min. of spp.
1	K39	24	24	0	3	8.52	1
1	K4	19	16	0	0	6.08	1
1	K40	12	12	0	0	6.36	1
1	K41	60	54	1	4	5.78	1
1	K42	8	7	0	0	6.43	1
1	K43	44	41	0	0	5.65	1
1	K44	30	30	0	3	7.48	1
1	K45	27	26	2	3	6.81	1
1	K46	4	4	1	0	5.25	1
1	K47	61	57	0	6	5.84	1
1	K49	70	68	3	3	6.38	1
1	K5	44	40	1	4	6.60	1
1	K50	28	27	1	2	6.74	1
1	K51	17	17	1	0	6.69	1
1	K52	48	45	0	3	6.50	1
1	K6	12	12	0	0	2.75	1
1	K7	7	7	0	0	9.40	2
1	K8	7	6	0	0	9.00	4
1	K9	36	36	1	2	6.25	1
0	NR142	7	7	0	0	10.29	5
0	NR144	34	32	3	3	5.03	1
0	NR171	29	25	0	3	6.92	1
0	NR178	16	15	0	2	4.19	1
0	NR342	33	33	4	3	6.94	1
0	NR454	12	9	0	0	7.17	2
0	NR473	57	57	5	2	5.69	1
0	NR549	40	39	0	2	6.05	1
0	NR627	46	45	0	1	4.43	1
0	NR660	34	33	0	3	8.55	1
0	NR694	24	19	2	5	5.23	1
0	NR695	20	17	0	4	6.41	1
0	NR770	5	5	0	0	6.80	4
0	NRF1	38	36	0	3	4.41	1
0	NW28	36	36	3	3	6.94	1
0	NW51	22	22	0	3	10.27	1

Stratum	Site ID	# of spp.	# of native species	# of Fen species	# of disturbance species	Frequency, mean of spp	Frequency, min. of spp.
0	NW56	33	30	1	3	3.74	1
0	NW7	5	5	0	0	1.80	1
0	T22	66	63	0	4	5.57	1

Appendix F. CRAM Scores and Ecological Service Ratings of Visited LAVO Wetlands

<u>Legend</u>:
Stratum: 0= hand-picked site; 1= random site. For site locations see Figure 4 and Table 2
See section 3.3.2 for definitions of plant metrics in this table. HGM type: D= depresssional, S= slope, CR= riverine confined, VP= vernal pool

				Biogeochemical Services					Habitat Support Services			
Stratum	Site ID	CRAM total score	HGM type	Water Storage & Slow Infiltration	Intercepting, Stabilizing Suspended Sediments	Processing Nutrients, Metals	Sequestering Carbon	Maintaining Surface Water Temperatures	Native Invertebrate Diversity	Native Fish	Amphibians & Reptiles	Birds & Mammals
0	IW1	79.30	D	High	High	High	High	High	High	High	High	High
0	IW2	84.38	D	Intermediate	Intermediate	High	Intermediate	Intermediate	High	High	High	High
1	K1	87.89	D	High	High	High	High	Low	Low	Intermediate	High	High
1	K10	75.39	CR	Low	Low	Intermediate	Intermediate	Intermediate	High	High	High	Intermediate
1	K11	78.52	D	High	High	High	Intermediate	Low	High	Intermediate	High	High
1	K12	69.92	VP	High	High	High	High	Low	Low	Low	Intermediate	Intermediate
1	K13	81.64	S	Intermediate	Low	Intermediate	Intermediate	High	Intermediate	Low	Intermediate	Intermediate
1	K14	69.92	D	High	High	High	Intermediate	Low	Low	Intermediate	Intermediate	Low
1	K15	79.69	CR	Low	Low	Low	Intermediate	High	High	Intermediate	Intermediate	Intermediate
1	K16	78.13	CR	Low	Low	Intermediate	Low	High	Low	Intermediate	Intermediate	Intermediate
1	K17	75.00	D	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	High	Intermediate	Intermediate	High
1	K18	79.82	CR	Low	Low	Low	Intermediate	Low	Low	Intermediate	Intermediate	Intermediate
1	K19	82.81	S	Intermediate	Low	Low	Intermediate	Low	Low	Low	Intermediate	Intermediate
1	K2	77.34	S	Intermediate	Low	Low	Intermediate	Low	Intermediate	Low	Intermediate	Intermediate
1	K21	69.53	D	High	High	High	Intermediate	Intermediate	High	Low	Intermediate	High
1	K22	86.72	D	High	High	High	High	Low	High	Intermediate	High	High
1	K23	70.83	D	High	High	High	Intermediate	Intermediate	High	Intermediate	Intermediate	Low
1	K24	66.41	S	Intermediate	Low	Intermediate	Intermediate	Intermediate	Low	Low	High	High
1	K25	85.16	S	Low	Low	Intermediate	High	High	High	Low	Intermediate	High
1	K26	82.03	CR	Low	Intermediate	Low	Low	High	High	High	High	High
1	K27	81.64	S	Intermediate	Low	Low	Low	Intermediate	Low	Low	Intermediate	Intermediate
1	K29	78.52	S	Intermediate	Low	Low	Intermediate	Low	Low	Low	Intermediate	Intermediate
1	K3	78.91	D	High	High	High	High	Low	Low	Low	Intermediate	Intermediate
1	K31	72.27	S	Intermediate	Low	Low	Intermediate	Low	Intermediate	Low	Intermediate	Intermediate
1	K32	88.67	CR	Low	Low	Low	High	Low	High	Intermediate	Intermediate	Intermediate

Stratum	Site ID	CRAM total score	HGM type	Biogeochemical Services					Habitat Support Services			
				Water Storage & Slow Infiltration	Intercepting, Stabilizing Suspended Sediments	Processing Nutrients, Metals	Sequestering Carbon	Maintaining Surface Water Temperatures	Native Invertebrate Diversity	Native Fish	Amphibians & Reptiles	Birds & Mammals
1	K33	82.03	D	Intermediate	Intermediate	High	High	High	High	Intermediate	Intermediate	High
1	K34	82.42	S	Intermediate	Low	Low	Intermediate	Low	High	Low	Intermediate	Intermediate
1	K35	76.69	D	High	High	High	High	Intermediate	High	Intermediate	Intermediate	High
1	K36	83.98	S	Intermediate	Low	Low	Intermediate	High	High	Low	High	High
1	K37	74.22	S	Intermediate	Low	Low	Intermediate	Low	High	Low	Low	Intermediate
1	K39	74.35	S	Intermediate	Low	Low	Intermediate	High	Intermediate	Low	Intermediate	Intermediate
1	K4	80.08	CR	Low	Low	Low	Low	Low	Low	Intermediate	Intermediate	Intermediate
1	K40	75.39	D	High	High	High	High	Intermediate	Low	High	High	High
1	K41	70.70	S	Intermediate	Low	Intermediate	High	High	High	Low	Intermediate	Intermediate
1	K42	76.95	D	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	High	High	Intermediate	High
1	K43	86.33	S	Intermediate	Low	Low	Intermediate	Low	Intermediate	Low	Intermediate	High
1	K44	84.38	D	Intermediate	Intermediate	Low	Intermediate	Intermediate	High	High	High	High
1	K45	75.39	S	Intermediate	Low	Intermediate	High	Low	High	Low	High	High
1	K46	66.02	D	Intermediate	Intermediate	High	High	Intermediate	Low	High	High	Intermediate
1	K47	82.42	CR	Low	Low	Low	Low	Intermediate	High	Intermediate	High	High
1	K49	93.75	S	Intermediate	Low	High	High	High	High	Low	Intermediate	High
1	K5	75.78	S	Low	Low	Low	High	High	High	Low	Intermediate	High
1	K50	82.42	D	High	High	High	Intermediate	Low	Low	Low	Intermediate	High
1	K51	82.03	D	Intermediate	Intermediate	High	High	Intermediate	High	High	High	High
1	K52	81.64	D	High	High	High	High	Low	Low	Intermediate	Intermediate	High
1	K6	80.47	D	High	High	High	Intermediate	High	High	High	Intermediate	High
1	K7	70.31	D	High	High	High	Intermediate	Intermediate	Low	Low	Intermediate	Intermediate
1	K8	76.56	D	High	High	High	Intermediate	Intermediate	High	Intermediate	Intermediate	Intermediate
1	K9	67.19	S	Intermediate	Intermediate	Low	Intermediate	High	High	Low	Intermediate	Low
0	NR142	72.27	D	High	High	High	Intermediate	Low	High	Low	Intermediate	Intermediate
0	NR144	81.64	D	Low	Low	Intermediate	High	High	High	High	Intermediate	High
0	NR171	77.34	S	Intermediate	Low	High	Low	Low	Intermediate	Low	Intermediate	Intermediate
0	NR178	73.05	S	Low	Intermediate	Low	Low	Low	High	Low	Intermediate	Low
0	NR342	81.64	S	Low	Low	Intermediate	High	High	Intermediate	Low	Intermediate	High
0	NR454	81.64	CR	Low	Low	Intermediate	Intermediate	Low	Low	Intermediate	Intermediate	Intermediate
0	NR473	76.56	S	High	High	High	High	High	High	High	Intermediate	High

				Biogeochemical Services					Habitat Support Services			
Stratum	Site ID	CRAM total score	HGM type	Water Storage & Slow Infiltration	Intercepting, Stabilizing Suspended Sediments	Processing Nutrients, Metals	Sequestering Carbon	Maintaining Surface Water Temperatures	Native Invertebrate Diversity	Native Fish	Amphibians & Reptiles	Birds & Mammals
0	NR549	76.95	D	High	High	High	Low	Low	Low	High	High	High
0	NR627	80.08	CR	Low	Low	Intermediate	Low	Low	High	Intermediate	Intermediate	Intermediate
0	NR660	82.03	S	Intermediate	Low	Low	Intermediate	High	Intermediate	High	Intermediate	Intermediate
0	NR694	82.81	D	High	High	High	Intermediate	Low	High	High	High	High
0	NR695	80.08	S	Intermediate	Low	Low	High	Low	Intermediate	Low	Intermediate	Intermediate
0	NR770	65.63	D	Intermediate	Intermediate	Low	Intermediate	Intermediate	Low	High	Intermediate	Low
0	NRF1	82.81	CR	Low	Low	Low	Low	High	High	Intermediate	Intermediate	High
0	NW28	73.83	S	Intermediate	Low	High	High	High	High	Low	Intermediate	Intermediate
0	NW51	83.59	D	High	High	High	Intermediate	Low	Low	Intermediate	Intermediate	Intermediate
0	NW56	79.30	S	Low	Low	Intermediate	Low	High	High	Low	Intermediate	High
0	NW7	71.88	VP	High	High	High	Intermediate	Low	High	Low	Low	Low
0	T22	79.30	D	High	High	High	Low	Low	High	Intermediate	Intermediate	Intermediate

Appendix G. Amphibians, Reptiles, Fish, and Fairy Shrimp Noted in or near LAVO Wetlands by this Study or Stead et al. (2005)

<u>Legend:</u>
1= noted within the wetland by this study (incidental observations only)
2= noted within the wetland <u>*or*</u> *in wet areas within 500m* of it by Stead et al. (2005) using a focused search
Wetland ID's in **bold** indicate wetlands checked only by this study, which was not intended to actively survey these species

Site ID	Fathead Minnow	Speckled Dace	Golden Shiner	Brook Trout	Brown Trout	Rainbow Trout	unknown trout	unknown fish	Fairy Shrimp	Western Toad	Pacific Treefrog	Cascades Frog	unidentified Anuran	Long-toed Salamander	N. Alligator Lizard	Sagebrush Lizard	unidentified Lizard	W. Terrestrial Garter Snake	Common Garter Snake	unidentified snake
IW1	0	0	0	2	0	0	0	0	2	2	2	0	0	2	0	0	0	0	2	0
IW2	0	2	2	2	2	2	0	0	0	0	0	0	2	0	2	2	2	2	2	0
K1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1
K11	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K12	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K13	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K14	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
K17	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K18	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K21	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	2	0
K22	2	0	2	0	0	0	0	0	2	2	2	0	0	2	0	0	0	2	2	0
K23	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	1
K24	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
K25	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K27	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K3	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0
K32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
K33	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
K34	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
K35	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0
K40	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
K42	0	0	0	0	0	0	0	2	2	0	2	0	0	2	0	0	0	0	2	0
K44	0	0	0	0	0	0	0	0	2	2	2	0	0	2	0	0	0	0	2	0

Site ID	Fathead Minnow	Speckled Dace	Golden Shiner	Brook Trout	Brown Trout	Rainbow Trout	unknown trout	unknown fish	Fairy Shrimp	Western Toad	Pacific Treefrog	Cascades Frog	unidentified Anuran	Long-toed Salamander	N. Alligator Lizard	Sagebrush Lizard	unidentified Lizard	W. Terrestrial Garter Snake	Common Garter Snake	unidentified snake
K45	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0
K46	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0
K49	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
K50	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	0
K51	0	0	0	0	0	0	0	0	2	0	2	0	0	2	0	0	0	0	2	0
K52	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
K6	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K7	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
K8	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0
K9	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
NR142	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
NR342	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
NR473	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0
NR549	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
NR660	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	1
NR694	2	0	2	0	0	0	0	0	2	0	2	0	0	2	0	0	0	2	2	0
NW51	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	0
NW56	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0

Appendix H. Bird Species Regularly Present in Summer in LAVO and That Are Associated Strongly with Wetlands and Water Bodies

Habitat ratings are based on technical literature and the author's experience in the western U.S. generally, not on field data from this study.

	Wetland or Water Body (Habitat) Type (1= primary, 2= secondary use)					Occurrence Rates (from Breeding Bird Survey that includes part of LAVO, 1972-2004)				
	Pond/ Lake	Perennial Stream	Seasonal Marsh/ Meadow	Seasonal/ Riparian Shrub	Seasonal/ Riparian Tree	Route-Years	Stops/ Route/ Year	Max Stops	Indivuals/ Route/ Year	Max Indiv
Pied-billed Grebe	1		2			1	1.00	1	1.00	1
Great Blue Heron	1		2			1	1.00	1	1.00	1
Mallard	1	2	2			7	1.14	2	2.43	6
Ring-necked Duck	1		2			0				
Canada Goose	1		2			0				
Bufflehead	1		2		2	0				
Common Merganser	1	2				0				
Bald Eagle	1					0				
Osprey	1	2				0				
American Coot	1		2			1	1.00	1	3.00	3
Sandhill Crane			1			1	1.00	1	2.00	2
Spotted Sandpiper	1	2	2			2	1.00	1	1.00	1
Wilson's Snipe			1	2		0	1.33	2	1.67	3
White-throated Swift			1			4	1.25	2	1.25	2
Vaux's Swift			2	2	1	0				
Belted Kingfisher	1	2		2		0				
Downy Woodpecker				2	1	7	1.43	4	1.43	4
Red-breasted Sapsucker					1	20	2.10	5	2.15	5
Williamson's Sapsucker					1	1	1.00	1	1.00	1
Red-naped Sapsucker					1	0				
Pacific-slope Flycatcher					1	6	2.33	6	2.50	6

	Wetland or Water Body (Habitat) Type (1= primary, 2= secondary use)					Occurrence Rates (from Breeding Bird Survey that includes part of LAVO, 1972-2004)				
	Pond/ Lake	Perennial Stream	Seasonal Marsh/ Meadow	Seasonal/ Riparian Shrub	Seasonal/ Riparian Tree	Route-Years	Stops/ Route/ Year	Max Stops	Indivuals/ Route/ Year	Max Indiv
Dusky Flycatcher				2	1	20	4.50	14	6.10	21
Willow Flycatcher			2	1		1	1.00	1	1.00	1
Tree Swallow	2	2	1	2	2	14	1.14	2	3.00	14
Violet-green Swallow	2	2				2	1.00	1	1.50	2
N. Rough-winged Swallow	2	2	1	2		0				
House Wren				1		1	1.00	1	1.00	1
Winter Wren					1	1	1.00	1	1.00	1
American Dipper	2	1				2	1.00	1	1.00	1
Mountain Bluebird				2	1	5	1.20	2	1.20	2
Western Bluebird				2	1	4	1.25	2	1.50	3
American Robin			2	1	2	31	21.58	36	33.90	63
American Pipit			1			0				
Warbling Vireo				2	1	24	4.25	14	5.33	15
Red-winged Blackbird			1	2		16	1.00	1	1.38	3
Orange-crowned Warbler				1		9	1.44	3	2.11	5
Nashville Warbler				1	2	5	3.00	5	3.80	5
Wilson's Warbler				1	2	6	2.00	4	2.33	5
Yellow Warbler				1	2	31	2.81	11	3.39	16
MacGillivray's Warbler				1	2	5	1.80	3	2.60	5
Lazuli Bunting				1	2	2	1.00	1	1.00	1
Black-headed Grosbeak				2	1	11	3.36	8	4.18	11
Chipping Sparrow				1	2	24	7.29	18	10.04	26
Dark-eyed Junco			2	1		31	24.97	35	40.03	67
Lincoln's Sparrow			1	2		5	1.20	2	1.20	2
Song Sparrow			2	1		6	1.33	2	1.50	2
White-crowned Sparrow			2	1	2	2	1.00	1	1.00	1
Cassin's Finch				2	1	21	6.10	13	7.43	22
Purple Finch				2	1	11	7.55	17	16.27	42

Appendix I. Mammals of LAVO That Are Probably the Most Dependent on Wetlands and Water Bodies

Not based on data from this study.

Scientific Name	Common Name
Sorex palustris	Northern water shrew
Zapus princeps	Western jumping mouse
Procyon lotor	Raccoon
Lontra canadensis	River otter
Mustela vison	Mink
Aplodontia rufa	Mountain beaver
Castor canadensis	Beaver
Ondatra zibethicus	Muskrat

Appendix J. Photographs of the Defined Wetland Plant Communities

Class 1
Typical components: *Veratrum californicum, Ranunculus alismifolius, Perideridia parishii, Trifolium longipes, Senecio triangularis, Carex luzulifolia*. Photo of Site K34.

Class 1 (continued). Photos: *Ranunculus alismifolius*, *Veratrum californicum*

Class 2
Typical components: *Juncus nevadensis, Carex scopulorum, Aster alpigenus, Dodecatheon alpinum.* Photos: Site K49, *Dodecatheon alpinum.*

Class 3
Typical components: *Mimulus primuloides, Juncus balticus, Cirsium vulgare, Veronica serpyllifolia.* Photo: Site IW2, *Mimulus primuloides*

Class 4
Typical components: *Eleocharis acicularis, Carex leporinella.* Photos: Sites K10, K14.


Class 5
Typical components: *Potentilla flabellifolia, Aster alpigenus, Juncus drummondii, Kalmia polifolia, Carex nigricans, Phyllodoce breweri, Tsuga mertensiana* (short). Photos: Site K45, *Phyllodoce breweri.*


Class 5 (continued). Photos: *Potentilla flabellifolia, Kalmia polifolia*


Class 7
Typical components: *Carex leporinella, Juncus nevadensis, Eleocharis acicularis, Juncus balticus, Juncus drummondii.* Photos: Sites K12, NR142.

Class 8

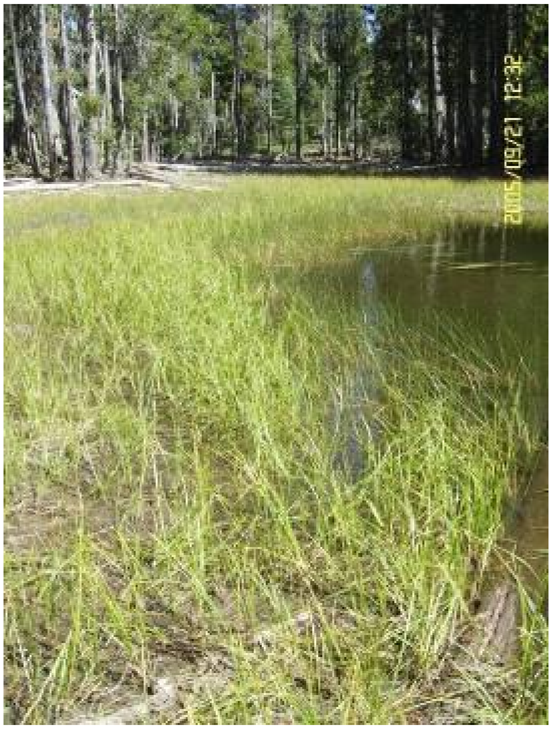
Typical components: *Glyceria elata, Carex angustata, Scirpus microcarpus, Equisetum arvense, Mimulus moschatus, Veronica americana*. Photo: Site K13.

Class 10

Typical components: *Lupinus polyphyllus, Senecio triangularis, Veratrum californicum, Hackelia micrantha, Aster eatonii*. Photos: Site K18, *Lupinus polyphyllus.*

Class 12
Typical components: *Isoetes bolanderi, Sparganium angustifolium*. Photos: Site K12.


Class 14
Typical components: *Acer glabrum, Ageratina occidentalis, Hackelia micrantha.* Photos: Site K19.



Class 16
Typical components: *Deschampsia cespitosa, Carex vesicaria*. Photo: Site K42.

Class 17
Typical components: *Juncus balticus, Muhlenbergia filiformis, Achnatherum occidentalis, Gayophytum racemosum, Linanthus harknessii, Penstemon heterodoxus.* Photos: Site K2, *Penstemon heterodoxus.*


Class 18
Typical components: *Pinus contorta* (tall), *Carex angustata, Viola macloskeyi, Fragaria virginiana.* Photos: Site K22, *Viola macloskeyi.*


Class 20
Typical components: *Carex lenticularis, Epilobium hornemannii, Senecio triangularis.* Photos: Site K25, *Carex lenticularis.*

Class 26
Typical components: *Alnus incana* (medium height), *Viola glabella, Senecio triangularis, Alnus incana - short, Mimulus moschatus, Carex nervina, Veratrum californicum, Stachys ajugoides, Dicentra formosa, Circaea alpina, Cirsium douglasii, Osmorhiza occidentalis, Heracleum lanatum, Ribes roezlii* (short). Photos: Site K43, *Dicentra formosa.*

Class 30
Typical components: *Carex vesicaria, Carex leporinella.* Photo: Site K7.

Class 30 (continued) Site K42, *Carex vesicaria.*


Class 36
Typical components: *Salix lemmonii* (medium height). Photos: *Salix lemmonii* at Site K6.

Class 44
Typical component: *Carex utriculata*. Photos: Sites NR473, K46.

Class 45
Typical components: *Pinus contorta* – medium height, *Salix lemmonii* – medium height, *Populus tremuloides* - tall, *Achillea millefolium, Trifolium longipes, Carex abrupta, Bromus carinatus, Stellaria longipes, Osmorhiza chilensis, Elymus glaucus*. Photos: Site NR171, *Achillea millefolium.*

Class 53
Typical components: No single species dominates. Includes *Hordeum brachyantherum, Trifolium longipe*s. Photo: Site K52.

Class 55
Typical components: *Carex subfusca, Penstemon heterodoxus, Agrostis variabilis*. Photo: Site K6.

Class 56
Typical components: *Polygonum amphibium, Myriophyllum sibiricum.* Photos: Site K6.

NPS D-163, March 2008

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA ™