Storrie Fire Meadow Restoration Prioritization

Report to Lassen National Forest and National Fish and Wildlife Foundation

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Marian E. Vernon, Brent R. Campos, and Ryan D. Burnett

Point Blue Contribution Number 2231

Conservation science for a healthy planet

3820 Cypress Drive, #11 Petaluma, CA 94954

T 707.781.2555 | F 707.765.1685

pointblue.org

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Cover photo: Grizzly Creek 07 meadow. Photo by Ryan Burnett.

Introduction

In 2000, the Storrie Fire burned 27,000 acres within Lassen National Forest (LNF), primarily in the Lower Yellow Creek and Chips Creek watersheds. This fire resulted in alterations to stream conditions (e.g. increased sediment inputs) and wildlife habitat (e.g., loss of mature hardwood cover, stream shading). A large number of wet meadows occur within the upper reaches of these watersheds and many are in a degraded state, further impacting watershed condition and wildlife habitat. Restoring meadows is among the highest priorities for the USFS in the Storrie Fire and across the greater Sierra Nevada (USFS & NFWF 2015; USFS 2017). Restoring meadows in the Storrie Fire nexus will help mitigate the negative impacts of the fire on stream conditions and wildlife habitat by improving water quality, increasing late season base flows, and improving habitat for native birds, amphibians, and cold water fish.

LNF has identified and conducted initial condition assessments on 90 meadows within the Storrie Fire nexus (hereafter "Storrie meadows"). This report describes how we used these condition assessments along with additional data inputs to assess and provide initial recommendations of 21 priority meadows for restoration. Our ultimate goal is to identify 2-5 highest priority meadows for restoration in order to restore the ecological integrity and function of the Storrie Fire nexus watersheds, improve habitat for special status species (e.g., Willow Flycatcher, Cascades Frog), and improve water quality and late season base flows within the restored meadows.

Methods

We used current condition of the meadows and potential resource values to identify restoration priorities. We initially used four data inputs to assess meadow condition and resource values: (1) American Rivers (AR) meadow condition scorecard assessment results for the Storrie meadows (American Rivers 2012), (2) LiDAR data, (3) a climate sensitivity analysis, and (4) application of the Sierra Meadows Partnership (SMP) meadow prioritization tool (hereafter "prioritization tool"). Because of data limitations associated with the LiDAR and climate sensitivity analysis, we made the decision to only use the meadow condition scorecard assessments and prioritization tool in order to identify our 21 priority meadows. A full description of the methods, results, and discussion of data limitations for the LiDAR analysis and climate sensitivity analysis can be found in Appendices A and B, respectively.

Meadow Condition Scorecard Analysis

The LNF Almanor Ranger District Ecology Crew surveyed the 90 Storrie meadows using the Meadow Condition Scorecard (American Rivers 2012) in May-October 2015, June 2016, and August-October 2017. Each meadow was visited once by two or more technicians.

The scorecard is a rapid field assessment method that scores channel and vegetation conditions on a scale of 1-4 to identify impacted meadows (Hunt et al. 2015). It is based on the EPA Physical Habitat Assessment framework (Barbour et al. 1999). The scorecard uses metrics from multiple sources, including the Bureau of Land Management (BLM)'s Multiple Indicators Monitoring (MIM) Protocol (U.S. Department of the Interior 2011), BLM's Proper Function Conditions (PFC) methods (U.S. Department of the Interior et al. 1998), and vegetation indicators developed by Dave Weixelman, former Forest Service Range Ecologist for Region 5 (unpublished data).

Meadow condition was scored using six indicators. Each indicator is given a qualitative score based on quantitative measurements of indicators, such as bank height and percent of conifer encroachment (Hunt et al. 2015). Each indicator receives a score of 1, 2, 3, or 4, with lower scores indicating more impacted condition and higher scores indicating natural condition. The six indicators used in the scorecard are:

1. Bank height in main channel
2. Bank stability (percent of channel that is unstable)
3. Length of gullies and ditches outside of main channel
4. Vegetation cover (ratio of graminoids to forbs)
5. Bare ground (percent of meadow area)
6. Conifer or upland shrub encroachment (percent of meadow area)

The scorecard also includes a checklist of additional observations for which the technician(s) select a value of yes or no, such as evidence of grazing, past restoration efforts, and evidence of different meadow dependent species (American Rivers 2012; Hunt et al. 2015). Technicians also recorded the location of each headcut observed within each meadow on a GPS unit and measured their height, width, length, and slope. Headcuts were also photographed.

We first used the meadow condition indicator scores to identify meadows that were moderately or heavily impacted by three types of stressors: (1) conifer/upland shrub encroachment, (2) degraded channel morphology, and (3) livestock grazing. Meadows were categorized as impacted by encroachment if they received a score of 1 or 2 for conifer/upland shrub encroachment. Meadows were categorized as having degraded channel morphology if they received a score of 1 or 2 for at least one indicator of channel morphology (bank height, bank stability, and length of gullies and ditches). For meadows with more than one channel present, the lower of the two scores for each indicator was used. Meadows were categorized as being impacted by grazing if technicians recorded evidence of grazing, which included dung in or outside channels, trails, low stubble height, cows present in or near the meadow, and/or hoof prints outside of the channel or on banks.

SMP Meadow Prioritization Tool

The SMP's prioritization work group is in the process of developing a tool that will provide a strategic, flexible approach for prioritizing meadows for restoration and protection in order to maximize project benefits and reach desired meadow conditions. This prioritization tool will generate a targeted list of meadows based on the conservation targets of interest to the end user that can complement on-the-ground site assessments and further prioritization efforts on a finer scale; this has been identified as a priority need for the U.S. Forest Service to increase the pace and scale of meadow restoration across national forests in the Sierra Nevada.

The tool, which is currently in development, is housed in an Access database and includes data on a suite of conservation targets and associated indicators for all meadows within the Sierra Nevada Multi-Source Meadow Polygons Compilation version 2.0 (U.C. Davis Center for Watershed Sciences and USDA Forest Service Pacific Southwest Region 2017). The data are based on spatial analyses conducted in ArcGIS. Because the Storrie meadows are not all captured in this meadow polygons layer, we replicated the analyses for the Storrie meadow polygons that we received from LNF staff. We then piloted application of this prioritization tool to the Storrie meadows in order to identify priority meadows across the following conservation targets: (1) biodiversity, (2) carbon storage, (3) climate exposure, (4) water quality, and (5) hydrological importance. Our aim was to identify meadows that had the potential to achieve multiple benefits across these biological and ecological targets. Appendix C includes further information about the indicators associated with each of these conservation target, including rationale for inclusion and the data source.

Biodiversity

We selected five target species for analysis. These species included Chinook salmon, steelhead trout, Cascades frog, Sierra Nevada yellow-legged frog, Southern long-toed salamander, and willow flycatcher. These species were selected because they are species of conservation concern that are meadow-dependent, use meadows for some portion of their life cycle, or depend on cool, clean water emanating from Storrie watersheds. We used range data and indicators of habitat suitability in order to prioritize meadows for each target species. Range data availability varied by species and included current and historic range maps, watersheds with current and historic observations, and recent species inventory surveys (Appendix C). We also identified indicators of habitat suitability for each target species at the meadow and watershed scale based on literature review and discussion with species experts (Appendix C). Some examples of habitat suitability indicators include meadow hydrogeomorphic type, willow/alder cover, and presence of features such as fens, seeps/springs, and perennial streams. The availability of spatial data at a scale relevant to prioritization varied among species, and therefore some species included more indicators than others (Appendix C).

For each species target, we first identified meadows that were located in the species' range based on one or more range indicators. We then took the resulting list of meadows for each species and scored the meadow based on habitat suitability and range indicators. This resulted in a list of meadows with a single score per meadow for each target species, with higher scores indicating that the meadow is a higher priority for the given species. Appendix C provides a complete list of range and habitat suitability indicators used for each target species, the data sources, rationale for inclusion of those indicators for the given species, and how each indicator was scored.

Carbon Storage and Climate Exposure

We were also interested in identifying meadows that could provide climate mitigation and adaptation benefits. We identified indicators for carbon storage and climate exposure and scored meadows according to the values of those indicators. We used three indicators for carbon storage: (1) fen acreage in the meadow, (2) meadow size, and (3) whether a perennial stream was present in the meadow. We focused on fen acreage because fens contain peat soils that have high levels of soil organic carbon, take thousands of years to form, and are susceptible to rapid and irreversible loss if not protected (Drew et al. 2016). We use meadow size as a potential proxy for carbon storage benefits as larger meadows may be able to store more carbon than smaller ones. Finally, we included perennial stream presence as it may indicate meadow wetness, which is correlated with high levels of soil organic carbon in wet meadows (Norton et al. 2011, 2014). We scored each of these indicator on a scale of 0-2 and summed the indicators to generate a single carbon storage score for each meadow.

We evaluated climate exposure based on analyses by the California Integrated Assessment of Watershed Health (U.S. EPA 2013). This assessment calculated the absolute percent change in seven climate indicators from 2010 to 2050 for each National Hydrography Dataset (NHD) catchment in California using the CCSM3-A2 climate model. An NHD catchment is an elevation-based catchment for each flowline in the stream network; the average catchment size for the hydrological region in which California is located is 761 acres. For comparison, the average size of a HUC12 watershed in the same region is 24,286 acres. The indicators used include: (1) snowpack, (2) precipitation, (3) runoff, (4) baseflow, (5) mean temperature, (6) maximum temperature, and (7) minimum temperature (U.S. EPA 2013).

We downloaded a GIS shapefile of the catchments and the associated absolute percent change values for each climate indicator (Conservation Biology Institute 2016; A. Somor, pers. comm.) and did a spatial overlay with the Storrie meadows and their associated catchments. We assigned each Storrie meadow the indicator value for the catchment in which it fell; for meadows that fell into more than one catchment, the mean was used. For each climate exposure indicator, we divided the values into quartiles and assigned scores for each indicator depending on which quartile it fell into, with higher scores indicating lower departure from historic conditions. We gave more weight to hydrological indicators. We summed the indicator scores to come up with a single climate exposure score for each meadow. Higher scores indicate meadows with lower climate exposure. See Appendix C for more details on the carbon storage and climate exposure indicators and how each indicator was scored.

Hydrological Importance and Water Quality Benefits

We were interested in identifying meadows that could provide water quality benefits and were positioned in hydrologically important watersheds. Our indicators of hydrological importance included historic and projected future climate indicators calculated at watershed and catchment scales, respectively, as well as the overall watershed size. Our indicators of historic climate included the historic (1951-1980) mean annual April 1 snowpack, annual precipitation, recharge and runoff, and climatic water deficit from the California Basin Characterization Model (Flint et al. 2014). For each indicator, we calculated the mean value (in mm) for each of the 5 HUC12 watersheds in the Storrie nexus area. We assigned each meadow the historic climate indicator value for the watershed in which it fell. Our indicators of projected future climate included the absolute percent change in snowpack, precipitation, baseflow, and runoff at the NHD catchment scale, as described above under our climate exposure target (U.S. EPA 2013). We assigned each meadow the future climate indicator value for the NHD catchment in which it fell; for meadows that fell into more than one NHD catchment, the mean indicator value was used. This analysis used the hydrological climate indicators from the climate exposure target as described above, but differed from the climate exposure analysis by also considering historic hydrological data at the watershed scale.

Finally, we calculated the acreage of each HUC12 watershed and assigned each meadow the value for the watershed in which it was located. We then summed the hydrologic indicator scores for each meadow to yield a single hydrological importance score for each meadow, with higher scores indicating higher hydrological importance. This resulted in prioritization of meadows located in larger watersheds with historically higher amounts of snowpack, precipitation, recharge, and runoff and lower amounts of climatic water deficit and those meadows located in catchments with lower climate vulnerability for changes in snowpack, precipitation, baseflow, and runoff (see Appendix C).

To prioritize meadows for water quality benefits, we used indicators assessing watershed condition and watershed threats. Our rationale was to prioritize restoration of meadows in watersheds with both high condition and high threat, with the idea that this could help bolster high watershed condition and mitigate against watershed-wide threats. Our indicators for water quality were primarily at the NHD catchment and HUC12 watershed scale. At the NHD catchment scale, we used the Relative Stream Health, Relative Watershed Condition, and Relative Watershed Vulnerability indices from the California Integrated Assessment of Watershed Health (U.S. EPA 2013, see Appendix C). We downloaded a GIS shapefile of the catchments and indicator scores from Databasin (Conservation Biology Institute 2016) and did a spatial overlay with the Storrie meadows to assign each meadow the three index scores of the catchment in which it fell. For meadows that fell into more than one catchment, the mean score was used. Higher scores for stream health and watershed condition indicate better stream health and condition, respectively, while higher scores for watershed vulnerability indicate higher vulnerability relative to the rest of California. We also analyzed the watershed road density (km of roads/km^2) at the HUC12 watershed scale using the TIGER/Line county roads dataset (U.S. Department of Commerce and U.S. Census Bureau 2018) and the U.S. Forest Service's National Forest System Roads shapefile. Each meadow was given the road density value for the HUC12 watershed in which it falls. Finally, we assessed whether the meadow falls in an active grazing allotment.

We used the Relative Watershed Condition Index and Stream Health Index as our indicators of good watershed condition, and used the Relative Watershed Vulnerability Index, watershed road density, and presence of an active grazing allotment as indicators of present or potential future degradation (see Appendix C). We summed the scores for the watershed condition indicators to generate a watershed condition score for each meadow and summed the scores for the watershed threat indicators to generate a threat score for each meadow. Higher scores indicated higher watershed condition and watershed threat, respectively. We then added the two scores to generate a single water quality score per meadow, resulting in higher scores for meadows located in watersheds in good condition that were also vulnerable to future degradation and therefore in need of protection and restoration to mitigate against impacts. See Appendix C for a complete list of water quality and hydrological importance indicators and how each indicator was scored.

Final Scoring

Each meadow received one score for each of the following conservation targets (as described above): (1) fish (Chinook salmon and steelhead trout), (2) Cascades frog, (3) Sierra Nevada yellow-legged frog, (4) southern long-toed salamander, (5) willow flycatcher, (6) carbon storage, (7) climate exposure, (8) hydrological importance, and (9) water quality. Because each of these targets had different numbers of indicators and therefore different total possible scores, we normalized the scores for each target on a scale of 0-1. We then added the resulting normalized scores from the 9 targets to generate a composite final score for each meadow, with the highest possible score being 9. We refer to this score as the "Multiple Benefits Score" as it equally weights our 9 conservation targets.

Integration Method and Sensitivity Analysis

Our goal was to identify a subset of meadows in need of hydrological restoration that could also help achieve multiple benefits to biodiversity, hydrological function, carbon storage, and climate exposure.

To do so, we integrated the results from the meadow prioritization tool's Multiple Benefits Score with additional analyses of the AR Scorecard data, with a specific focus on those meadows that we categorized as having impacted channel morphology.

Beginning with the AR Scorecard data for the full suite of meadows, we examined the number of channel morphology indicators that were moderately or heavily impacted, the number of headcuts, the sum total height of all headcuts, and the height of the largest headcut and used Excel to sort the meadows into a rank-ordered list using the approach described in Table 1. This resulted in a rank-ordered list of meadows from 1 to 90, with meadows at the top of the list having the greatest impacts to channel morphology (inclusive of headcuts).

We then gave each meadow a score for "Hydrological Restoration Need" based on their position in the ranking. Given that there were 90 meadows, we split the meadows into groups of 10, and gave discrete scores for each grouping of 10 meadows in the ranking. We gave meadows that were in the top 10 a score of 8, meadows that were ranked 11-20 a score of 7, and so on, with the final meadows that ranked 81-90 given a score of 0. This resulted in discrete scores for each meadow from 0 to 8. We summed the Hydrological Restoration Needs score and the Multiple Benefits score generated by the prioritization tool into a Final Prioritization Score. This approach gave approximately equal weight to hydrological restoration need and multiple benefits.

Table 1: The meadow condition indicators used to identify meadows with hydrological restoration need.

Sorting	**Meadow Condition Indicator**	**Sorting Criteria**
Sort by:	Number of channel morphology indicators (bank stability, bank height, and gullies/ditches) that are moderately or heavily impacted (score of 1 or 2)	Largest to Smallest
Then by:	Sum total height of all headcuts	Largest to Smallest
Then by:	The height of the largest headcut	Largest to Smallest
Then by:	Number of headcuts	Largest to Smallest

In order to evaluate the sensitivity of our integration method and prioritization tool scoring approach, we also used two additional approaches to identify priority meadows. In the first alternative approach, we used Excel to sort the meadows based on a sequence of the indicators associated with each conservation target in the prioritization tool, giving some indicators greater weight than others. This resulted in nine different ranked lists of meadows (one ranked list per conservation target). Meadows with a rank of 1-10 for a given target received a score of 3; meadows with a rank of 11-20 for a given target received a score of 2; meadows with a rank of 21-30 for a given target received a score of 1; and all other meadows received a score of 0. We then used the ranked list of meadows from the AR Scorecard data as described above and scored meadows in the same method as described previously, giving meadows with a rank of 1-10 a score of 3; meadows with a rank of 11-20 a score of 2; meadows with a rank of 21-30 a score of 1; and all other meadows a score of 0. We then summed the meadow scores from the nine conservation targets and from the AR Scorecard data to generate a single score per meadow, with the highest possible score being 30. Our second alternative approach used the same ranked lists of meadows for each conservation target and for the AR Scorecard data; however, instead of scoring these meadows on a discrete scale from 0-3, we assigned the top 30 meadows in each ranked list a score of 1 and summed these scores to generate a single score per meadow, with the highest possible score being 10.

Results

Below we describe the results of the meadow condition scorecard analysis, prioritization tool application, and method integration used to generate a list of 21 priority meadows.

Meadow Condition Scorecard Analysis

We analyzed which meadows were impacted by three different types of stressors: (1) conifer/upland shrub encroachment, (2) grazing, and (3) impacted channel morphology. Nearly all (93.3%) of the meadows were impacted by one or more stressors (Table 2; Figure 1). 22.2% of meadows were impacted by one stressor, 40% of meadows were impacted by two stressors, and 31.1% of meadows were impacted by all three stressors. Of the six meadows without any stressors, four had total condition scores of 79 or higher; the remaining two meadows were slightly impacted by conifer encroachment, had no evidence of cattle grazing, and either had no channel or had no impacts to channel morphology. Encroachment was the most common type of stressor, followed by grazing and impacted channel morphology, respectively.

Table 2: The number of meadows impacted by one, two, or three stressors.

Number of Stressors	Type of Stressor(s)	Number of Meadows
1	Moderate or heavy impact to the meadow from conifer/upland shrub encroachment	14
	Evidence of grazing	5
	Impacted channel morphology, with one or more channel indicators moderately or heavily impacted	1
2	Conifer/upland shrub encroachment and evidence of grazing	16
	Conifer/upland shrub encroachment and impacted channel morphology	11
	Evidence of grazing and impacted channel morphology	9
3	Impacted channel morphology, evidence of grazing, and conifer/upland shrub encroachment	28
0	Remaining Meadows	6
Total Meadows		**90**

All meadows exhibited some degree of conifer encroachment. The average conifer encroachment score across all 90 meadows was 1.9 out of 4, with 76.7% of all meadows being moderately or heavily impacted (e.g., received a score of 1 or 2 for this indicator). 36 meadows are moderately impacted and 33 meadows are heavily impacted, while 21 meadows are slightly impacted by encroachment.

Encroachment was the primary stressor for 14 meadows and occurred with impacts to channel morphology and/or evidence of grazing, as well (Table 2).

Grazing is the second most common type of stressor after encroachment, with 64.4% of meadows showing evidence of grazing. Of these, 52 meadows have evidence of grazing and are in the Soda Creek/North Butte grazing allotment; the remaining six meadows with evidence of grazing are located in an inactive allotment. The evidence of grazing found in meadows in inactive allotments may be a result of historic grazing impacts or technician error (e.g., mistaking deer browse for livestock browsing). There are four meadows in the Soda Creek/North Butte allotment that have no evidence of grazing. The remaining 28 meadows are outside the active allotment and have no evidence of grazing. Grazing is the primary stressor for five meadows (Table 2), and often occurs alongside conifer encroachment and/or channel morphology impacts.

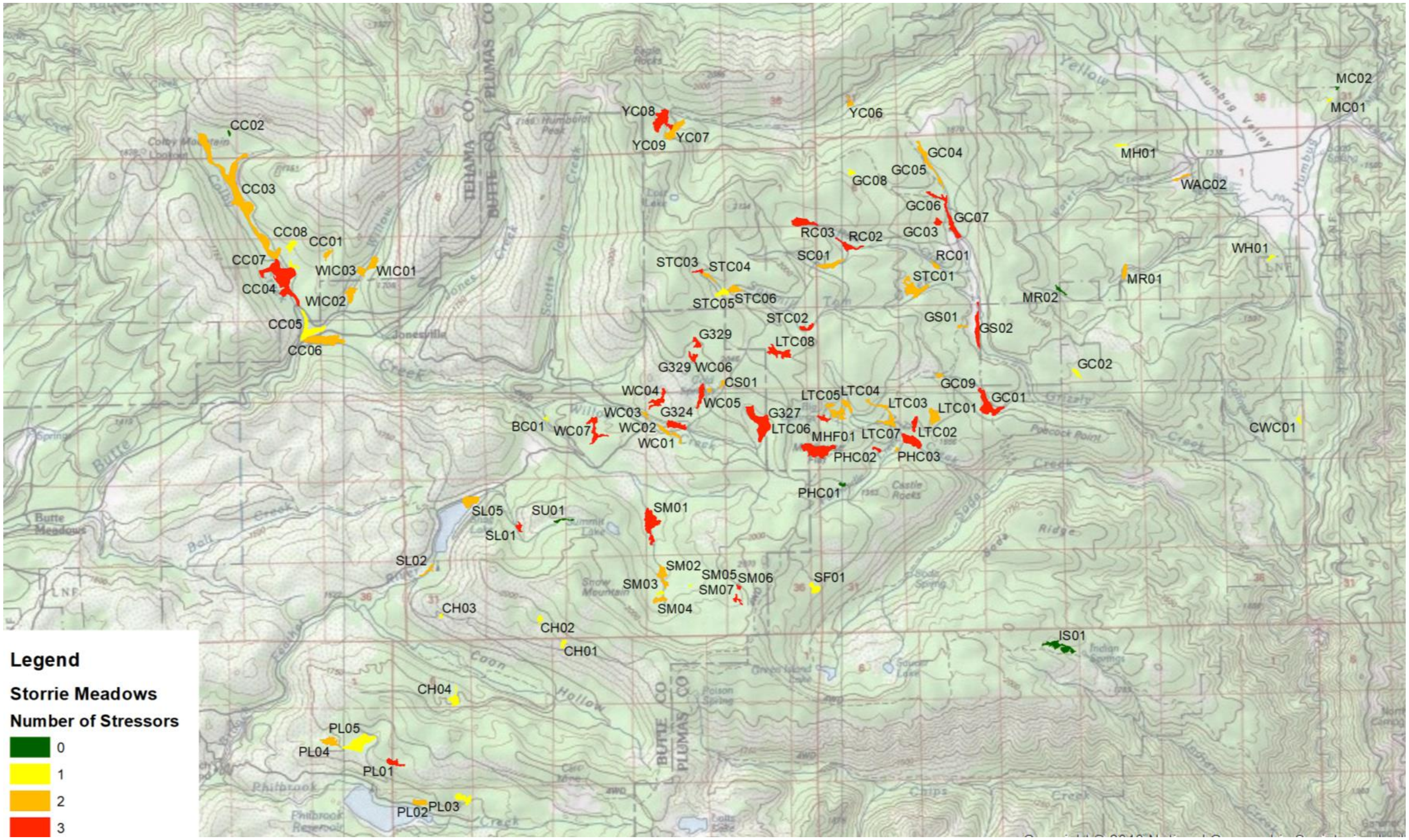

Figure 1: Number of stressors per meadow. Red meadows had 3 stressors, orange meadows had 2 stressors yellow meadows had 1 stressor, and green meadows had no stressors.

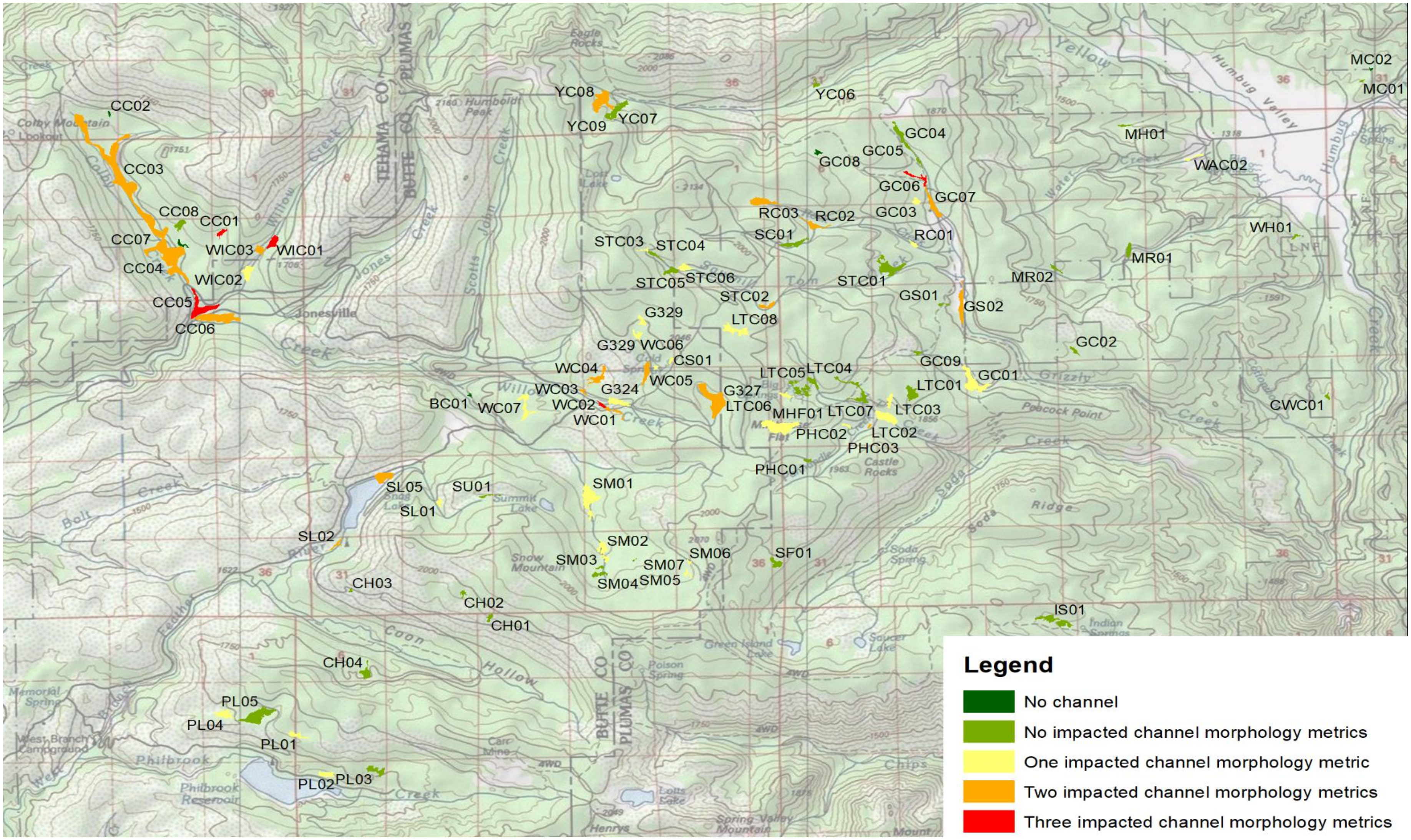

Figure 2: Meadows with impacted channel morphology. Yellow meadows have one impacted channel morphology metric, orange meadows have two impacted metrics, and red meadows have three impacted metrics. Dark green meadows have no channel and light green meadows have channels in natural or slightly impacted condition.

54.4% of meadows have impacted channel morphology, with 49 meadows having one or more channel morphology indicators (bank stability, bank height, and gullies/ditches) that are moderately or heavily impacted (e.g., received a score of 1 or 2, Figure 2). Of these meadows, five received moderately or heavily impacted scores across all three channel morphology indicators, 18 meadows received moderately or heavily impacted scores for two channel morphology indicators, and 26 meadows received moderately or heavily impacted scores for one channel morphology indicator (Figure 2). Thirty-six meadows with a channel present have channel morphology indicators in natural condition or with slight impacts (Figure 2). The remaining five meadows do not have a channel present (Figure 2).

Only one meadow has impacts to channel morphology in the absence of other stressors, with 28 meadows featuring impacts to channel morphology along with evidence of grazing and encroachment (Table 2). Across the 85 meadows with a channel present, the average bank height score is 2.8, the average bank stability score is 2.3, and the average gullies/ditches score is 3.2 (all scores are out of 4). For meadows with a second channel present, the average bank height score is 2.9 and the average bank stability score is 1.8. See Appendix D for a summary of the AR Scorecard data and complete information on types of degradation present in each meadow.

Prioritization Tool Application and Method Integration

We generated three scores using the prioritization tool and integration of AR Scorecard data on meadows with impacted channel morphology that also had headcuts: (1) Multiple Benefits Score, based on equal weighting of 8 conservation target scores representing biodiversity, hydrology, carbon storage, and climate exposure, (2) Hydrological Restoration Need Score, based on channel morphology and headcut data from AR Scorecard results, and (3) Final Score, the sum of the Multiple Benefits Score and Hydrological Restoration Needs Score. We used the Final Score as the basis for our identification of priority meadows that are in need of hydrological restoration (as indicated by the AR Scorecard data) and have the potential to achieve multiple benefits (as indicated by the prioritization tool). See Appendix E for a complete summary of prioritization results for all meadows.

Across all 90 meadows, the average final score was 7.6 (range 2-15.6), with the highest possible score being 17. We made the decision to include all meadows with a score of 10 or higher as priority meadows for field assessments and potential hydrological restoration, resulting in a list of 21 priority meadows. These meadows all have impacted channel morphology, are in need of hydrological restoration, and have the potential to achieve multiple benefits. The decision to use a score of 10 as a cutoff for our list of priority meadows was somewhat arbitrary. Our goal was to identify ~20 meadows to bring to LNF staff, which could then be filtered down to around 15 meadows for site visits. Using a score of 10 as a cutoff let us identify 21 priority meadows (Table 3). Table 3 provides summary data for our 21 priority meadows and Table 4 provides the normalized scores for each conservation target that contributed to the final Multiple Benefits score.

Our priority meadows together demonstrate a relatively good complement of our multiple benefits, capturing meadows with the highest possible scores for six out of the nine conservation targets (carbon storage, Cascades frog, climate exposure, southern long-toed salamander, Sierra Nevada yellow-legged frog, and water quality; Table 4). We did not capture the meadows with the highest scores for fish, hydrological importance, or willow flycatcher, although we often captured meadows with the second highest scores for these targets (Table 4).

Table 3: Priority meadows for hydrological restoration and to achieve multiple benefits.

Rank	ID	Meadow Name	Final Score	Restoration Need Score	Multiple Benefits Score
1	CC04	Colby Creek 04	15.6	8	7.6
2	CC03	Colby Creek 03	15.3	8	7.3
3	CC05	Colby Creek 05	15.0	8	7.0
4	WIC01	Willow Creek West 01	15.0	8	7.0
5	CC06	Colby Creek 06	13.1	7	6.1
6	WIC03	Willow Creek West 03	12.9	6	6.9
7	CC01	Colby Creek 01	12.5	8	4.5
8	WIC02	Willow Creek West 02	12.5	6	6.5
9	RC02	Rock Creek 02	12.2	7	5.2
10	GC06	Grizzly Creek 06	11.2	8	3.2
11	GC07	Grizzly Creek 07	11.1	7	4.1
12	SL05	Snag Lake 05	11.0	7	4.0
13	G327	Grizzly 327	10.9	8	2.9
14	YC08	Yellow Creek 08	10.8	6	4.8
15	LTC02	LT Creek 02	10.7	6	4.7
16	WC02	Willow Creek 02	10.6	8	2.6
17	WC01	Willow Creek 01	10.5	8	2.5
18	STC02	Sawmill Tom Creek 02	10.5	8	2.5
19	PHC03	Panhandle Creek 03	10.3	7	3.3
20	RC03	Rock Creek 03	10.1	7	3.1
21	GS02	Grizzly Spring 02	10.1	7	3.1

All of our priority meadows have impacted channel morphology. Thirteen meadows also have evidence of grazing and 17 are moderately or heavily encroached. Ten meadows are impacted by all three types of degradation (channel morphology, grazing, and encroachment). Our priority meadows represent a fairly good range of climate sensitivity categories, although none of our priority meadows are stressed. Five of the meadows were classified as resilient or resilient and recovering, with the remaining 16 classified as sensitive or sensitive and recovering. Appendix F provides detailed information about each of our priority meadows.

Table 4: Normalized conservation target scores for each meadow that contributed to the Multiple Benefits score. Scores are normalized on a scale of 0 to 1.

Rank	ID	Meadow Name	Multiple Benefits Score	Carbon Storage	Cascades Frog	Climate Exposure	Fish	Hydrological Importance	Sierra Nevada Yellow-Legged Frog	Southern Long-Toed Salamander	Water Quality	Willow Flycatcher
1	CC04	Colby Creek 04	7.6	**1.00**	**1.00**	**1.00**	0.91	0.57	**1.00**	0.67	0.63	0.79
2	CC03	Colby Creek 03	7.3	**1.00**	0.86	**1.00**	0.94	0.60	**1.00**	0.33	0.67	0.86
3	CC05	Colby Creek 05	7.0	**1.00**	**1.00**	0.83	0.91	0.48	**1.00**	0.67	0.24	0.86
4	WIC01	Willow Creek West 01	7.0	0.82	0.93	0.83	0.94	0.44	**1.00**	0.67	0.55	0.79
5	CC06	Colby Creek 06	6.1	0.64	0.71	0.83	0.88	0.45	**1.00**	0.67	0.10	0.86
6	WIC03	Willow Creek West 03	6.9	0.82	**1.00**	0.83	0.82	0.44	**1.00**	0.67	0.55	0.79
7	CC01	Colby Creek 01	4.5	0.36	0.36	**1.00**	0	0.57	0.80	0.33	0.63	0.43
8	WIC02	Willow Creek West 02	6.5	0.55	0.71	0.83	0.94	0.44	**1.00**	0.67	0.55	0.79
9	RC02	Rock Creek 02	5.2	0.82	0.00	0.50	0.34	0.21	0.80	**1.00**	0.84	0.71
10	GC06	Grizzly Creek 06	3.2	0.18	0.00	0.75	0.00	0.32	0.40	0.33	0.76	0.50
11	GC07	Grizzly Creek 07	4.1	0.55	0.00	0.75	0.00	0.32	0.40	0.67	0.76	0.64
12	SL05	Snag Lake 05	4.0	0.27	0.00	0.50	0.00	0.69	**1.00**	0.67	0.22	0.64
13	G327	Grizzly 327	2.9	0.27	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.50
14	YC08	Yellow Creek 08	4.8	0.82	0.00	0.75	0.22	0.00	0.60	0.67	**1.00**	0.71
15	LTC02	LT Creek 02	4.7	**1.00**	0.00	0.08	0.83	0.10	0.60	0.33	0.89	0.86
16	WC02	Willow Creek 02	2.6	0.00	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.50
17	WC01	Willow Creek 01	2.5	0.09	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.29
18	STC02	Sawmill Tom Creek 02	2.5	0.09	0.00	0.25	0.00	0.17	0.40	0.33	0.75	0.50
19	PHC03	Panhandle Creek 03	3.3	0.36	0.00	0.00	0.70	0.06	0.60	0.33	0.89	0.36
20	RC03	Rock Creek 03	3.1	0.27	0.00	0.50	0.00	0.21	0.40	0.33	0.84	0.57
21	GS02	Grizzly Spring 02	3.1	0.27	0.00	0.42	0.00	0.27	0.40	0.33	0.76	0.64

Discussion

We used four data inputs to assess the 90 Storrie meadows and identified 21 priority meadows to be considered for restoration. These meadows were selected because they have degraded channel morphology and have the potential to achieve multiple benefits to biodiversity, carbon storage, climate , and water. In order to evaluate the potential influence of biases in our scoring approach, we analyzed all meadows using two additional approaches and found that the majority of our 21 priority meadows consistently rose to the top as priorities. Specifically, 17 of our 21 priority meadows fell in the top 21 across all three prioritization approaches. Sawmill Tom Creek 01, Snow Mountain 02, Willow Creek 06, and Willow Creek 07 were top priorities across two of the three prioritization approaches, including the final approach described in this report. Thus, we feel confident that these meadows represent a good subset for consideration and the results were not particularly sensitive to our scoring scheme.

Priority Meadows

We identified 21 priority meadows with degraded channel morphology that appear to be in need of hydrological restoration and that may provide multiple benefits. Meadows that are part of the same meadow complex or adjacent to one another often had similar scores for each conservation target. This is likely because some of our target indicators (e.g., species range, climate data) were at a scale (e.g., watershed) that resulted in all adjacent meadows sharing the same score. Additionally, meadows that are part of the same meadow complex often have similar features, such as a perennial stream, fens, or seeps/springs, which were used as indicators for our conservation targets. Some conservation targets (e.g., willow flycatcher, fish) had more indicators associated with them than other targets (e.g., carbon storage, southern long-toed salamander) because of data availability. Below, we describe which of our priority meadows were the highest scoring across the multiple benefit categories of biodiversity protection, carbon storage, climate exposure, hydrological importance, and water quality. See Appendix E for a complete summary of each of our priority meadows.

Our priority meadows for biodiversity are Colby Creek 03, 04, 05, and 06 and Willow Creek West 01, 02, and 03. These meadows are clustered in close proximity to one another (e.g., within 2km distance) and share similar *in situ* features (fens, perennial streams, and seep/springs), which resulted in similar scores for target species, climate exposure, carbon storage, and hydrological importance. Though the Colby Creek and Willow Creek West meadow polygons were delineated as discrete units, they most likely function ecologically as single large meadow complexes, respectively. The Colby Creek meadows are adjacent to one another and represent a meadow complex of over 4km in length. It is likely that these meadows were delineated into separate units for ease of assessments or other reasons. Similarly, Willow Creek West 02 and 03 were delineated as separate meadows because a private inholding covers the middle portion of this large meadow, although from an ecological perspective they are part of the same meadow.

These seven priority meadows for biodiversity are all located within 12km of recently occupied meadows for willow flycatcher. They fall within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog, and also are located in watersheds with historic observations of the frog. They are all important for Cascades frog, as they either have recorded populations of the frog or are located within 1km of these populations. Finally, they scored highly for fish as they all have perennial streams and are located in the Butte Creek watershed. The target species scores have a relatively heavy weighting in the overall multiple benefits score, which is most likely why these meadows had the highest overall multiple benefit scores of our priority meadows.

Our highest scoring priority meadows for carbon storage were Colby Creek 03, 04, and 05, Willow Creek West 01 and 03, Rock Creek 02, Yellow Creek 08, and LT Creek 02. These meadows all feature fens and perennial streams, indicating persistent groundwater and surface water sources that have the potential to keep the meadow saturated throughout the growing season. This water availability may contribute to above and belowground carbon storage in plants and soil. Some of these meadows (Colby Creek 03, 04, and 05, LT Creek 02, and Yellow Creek 08) also fell in the upper quartile for meadow acreage; larger meadows may be able to store large amounts of carbon. Some of these meadows have evidence of cattle grazing, which may cause loss of fragile, irreplaceable peat soils and associated belowground carbon found in fens.

Our climate exposure data was at the catchment scale and therefore meadows in close proximity to one another tended to have the same or similar scores. Our highest scoring priority meadows projected to experience less climate exposure (normalized score of $\geq$0.75) included Colby Creek 01, 03, 04, 05, and 06, Willow Creek West 01, 02, and 03, Grizzly Creek 06 and 07, and Yellow Creek 08. The Colby Creek meadows had the highest overall scores, indicating that they may experience less climate exposure. These meadows are located in catchments projected to experience relatively less change in snowpack, runoff, mean annual temperature, and maximum temperature. Colby Creek 01, 03, and 04 are also located catchments projected to have relatively less change in precipitation compared to meadows in other catchments. The Willow Creek West meadows are located in a catchment projected to experience relatively less change in snowpack, runoff, and annual maximum temperature. Yellow Creek 08 and Grizzly Creek 06 and 07 are located in catchments projected to experience relatively less change in precipitation and baseflow.

Snag Lake 05 is the only one of our priority meadows that scored highly for hydrological importance. This is likely because meadows that did score highly for hydrological importance did not score as highly for our species targets, which contribute more weighting to the final multiple benefits score. This meadow is located in the largest watershed that also has the highest historic snowpack, precipitation, and recharge/runoff. It is located in a catchment projected to undergo relatively less change in snowpack compared to other catchments. Our highest scoring meadows for water quality are LT Creek 02, Panhandle Creek 03, Rock Creek 02 and 03, and Yellow Creek 08. These meadows are all located in watersheds with relatively high threats (e.g., grazing, high watershed road density) and relatively high condition, making them a priority for restoration and protection to improve watershed condition and water quality.

Data Limitations

There were some limitations associated with using some of our data inputs in the prioritization process. As such, we made the decision to limit our prioritization process to the data derived from meadow condition assessments and the SMP tool (see Appendices A and B for discussion of LiDAR and climate sensitivity analyses). We noted some potential inconsistencies with the AR Scorecard data collected. Several small headcuts recorded by technicians may have instead been natural features outside of the main channel; this may have occurred in meadows with a steeper gradient, as well. Additionally, the AR Scorecard does not provide a quantitative score for cattle grazing impacts, and instead just records the presence or absence of grazing based on evidence such as dung, trails, and hoof marks. Some meadows that fell outside of active grazing allotments were listed as having evidence of grazing, which may have been a result of legacy impacts or activity from wild ungulates as opposed to current grazing activity. We see the potential for the AR Scorecard to better incorporate grazing impacts into a quantitative impact scoring scheme.

Conclusion and Recommendations

We identified 21 priority meadows with degraded channel morphology with potential need for hydrological restoration that may also help achieve multiple benefits to biodiversity, carbon storage, climate resiliency, and water. Many of these priority meadows are also impacted by conifer encroachment and/or had qualitative evidence of cattle grazing

Results from the meadow condition assessment revealed that conifer/upland shrub encroachment is the most common stressor across the Storrie meadows, with all meadows exhibiting some degree of encroachment. Over 75% of meadows are moderately or heavily impacted by encroachment. Management actions to remove these upland shrubs and conifers include prescribed burns, tree removal and scattering, and, in cases when conifer encroachment is decades old, active revegetation of native herbaceous meadow cover (Stillwater Sciences 2012).

Nearly two thirds of the Storrie meadows have evidence of grazing. While the meadow condition assessment lacks specific metrics on livestock impacts, qualitative notes indicate that some meadows are degraded from livestock use. These impacts are characterized by trampling and extensive cattle trails, including along stream banks. Technician notes also revealed that several fens within meadows were heavily used by cattle, which may lead to soil compaction and loss of these irreplaceable carbon-rich soils. Fencing implemented by LNF in recent years is a good short term protection of the some of these fens, but long-term grazing management should consider the compatibility of grazing in meadows with fens. Grazing in meadows with sensitive areas (e.g., fens, riparian areas, channels) can be managed through fencing and/or placement of salt blocks and alternative water sources along the forest edge and away from the channel (Stillwater Sciences 2012). We also recommend keeping livestock out of any meadows that undergo hydrological restoration for at least three years after implementation to allow for site recovery (Stillwater Sciences 2012).

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Appendix A: Storrie Fire LiDAR Analysis

Introduction and Methods

We used a LiDAR-derived 1-m digital elevation model (DEM) provided by LNF to model the locations of stream channels and identify potential headcuts in the Storrie meadows. The DEM covered 88 of the 90 Storrie meadows; meadows PL02 and PL03 in the Last Chance Creek–West Branch Feather River HUC12 watershed were not covered and thus excluded from this analysis. We originally proposed to also estimate shrub cover and tree cover in the meadows as estimates of habitat quality and conifer encroachment, however, comprehensive "first-return" data was not available as part of the LiDAR products from LNF, so we were unable to perform those tasks.

We tried two stream channel condition ArcGIS toolsets for this analysis. We first attempted to use a tool called the Valley Bottom Extraction Tool (VBET; Gilbert et al. 2016). VBET was primarily designed for use with National Hyrdrography Dataset and a USGS 10-m DEM, but has been applied to small watersheds using LiDAR data (Gilbert et al. 2016). We found, however, that stream mapping errors in the National Hyrdrography Dataset precluded the utility of VBET at the rather small scales of our interest in this analysis. The second tool we employed was the Stream Channel and Riparian Corridor Toolbox (hereafter, toolbox) developed by Resource Science GIS staff at the Missouri Department of Conservation (Pursell and Wortman 2018). The toolbox is specifically designed to assess and monitor stream channels and riparian corridors using LiDAR data. The toolbox and instruction manual can be downloaded from https://github.com/Rdubya54/Stream-Modeling-Monitoring-Toolbox. This toolbox was a large improvement over VBET because the streams are drawn/modeled using the LiDAR data instead of relying on the stream networks in the National Hydrography Dataset.

We mapped stream networks using the Make Stream Lines tool in the toolbox. Instead of using the 5-m-resolution toolbox-generated flow accumulation and flow direction layers as inputs in the Make Stream Lines tool, we used 1-m-resolution flow accumulation and flow direction layers derived in ArcMap using the standard Flow Accumulation and Flow Direction tools. The distance between stream lines drawn using the 1-m and 5m-pixel input layers was up to 40 m for first-order streams, but was generally less than 5 m for third-order streams. The 1-m pixel streams were overall more accurate, however, because the DEM does not model culverts, the 1-m stream lines had the tendency to be drawn along roads. In areas where a stream followed a road that bisected a meadow or a road that was just upstream of the meadow, the stream was sometimes drawn on the hillslope within part of the meadow polygon, then reconnected to the actual stream channel further downstream in the meadow polygon. The toolbox handbook provides instructions for editing the streams via hand-digitizing streams, but we did not do this step for lack of time and funding. Because this affected a very limited number and small sections of flow paths within meadows, not completing this step had minimal effect on our analysis. All flow paths in the stream networks layers reflect pixels that accumulate surface run-off from an area of ≥100,000 1-m pixels (≥24.7 ac).

We mapped potential headcuts along the modeled stream networks within 25 m of the meadow polygons. To do this, we adapted an experimental ArcGIS Python script developed by the same team at the Missouri Department of Conservation that developed the Stream Channel and Riparian Corridor Toolbox. The script is intended for a tool that is not yet a part of the toolbox, and was downloaded from the GitHub website (link above). The script determines elevation change at sequential points spaced at a user-defined distance interval along the mapped stream channels. We parameterized the script to quantify the change in the minimum elevations within a 10-m radius of sequential 1-m spaced points along each flow path. We then clipped the elevation change data to within 25 m of each meadow polygon. We found 0.7 m (28 in) of elevation change from pixel to pixel along the stream courses to be a decent compromise between identifying potential false positive headcuts and true positives (actual headcuts mapped on the ground by LNF). The headcut script did not distinguish between headcuts and steep slopes where the elevation difference from pixel to pixel along the stream course may be naturally large. In other words, the elevation change was not "detrended" for slope. Hence, for one meadow on a steep slope, CH02, the tool flagged many possible headcuts. We excluded all potential headcuts from CH02. Lastly we compared the number and maximum heights of LiDAR-derived potential headcuts to headcuts > 0.6 m (≥ 24 in) in height recorded by LNF observers in each meadow polygon; we chose 0.6 m for field collected data compared to our 0.7-m threshold for the LiDAR analysis to buffer against measurement error on uneven stream substrates.

Results

We mapped 694 km (431 mi) of water flow paths throughout the five HUC12 watersheds covered by the DEM, 46.1 km (28.7 mi) of which fell inside the 88 meadow polygons (Figure 3). We found 76 potential headcuts along the mapped flow paths within 25 m of the meadows (Figure 3). Of those 76 headcuts, 59 were in the polygon boundaries. Potential headcuts ranged in height from 0.7 to 3.6 m (28 to 142 in). Of the 88 meadow polygons, 38 had at least one potential headcut within 25 m of the meadow. Potential headcuts larger than 1.0 m (39 in), 1.5 m (59 in), and 2.0 m (79 in) in height were found in 21, 10, and 6 meadows, respectively (Figure 3).

The LiDAR analysis found more and larger potential headcuts than those found by LNF observers in the field. LNF observers recorded 26 headcuts > 0.6 m (≥ 24 in) in height compared to 59 potential headcuts in the LiDAR analysis within meadow polygons. The number of headcuts was exactly the same for 52 of the 88 meadows or within a count of one for 78 meadows (Table 5). There were 7 meadows where LNF observers recorded a headcut but none were detected by the LiDAR analysis, compared to 10 meadows where the LiDAR analysis identified potentials headcuts but LNF observers recorded none (Table 5). There were only 10 meadows where the LiDAR analysis and field observations both detected 1 or more headcuts (Table 5). At those 10 meadows, maximum headcut heights from both methods tended to be fairly similar, however, the overall lack of relationship between headcut heights from the two methods suggests the methods would yield very different threat scores (Figure 4). The LiDAR analysis detected 4 potential headcuts > 2 m high in meadows where LNF observers detected no headcuts (Figure 4).

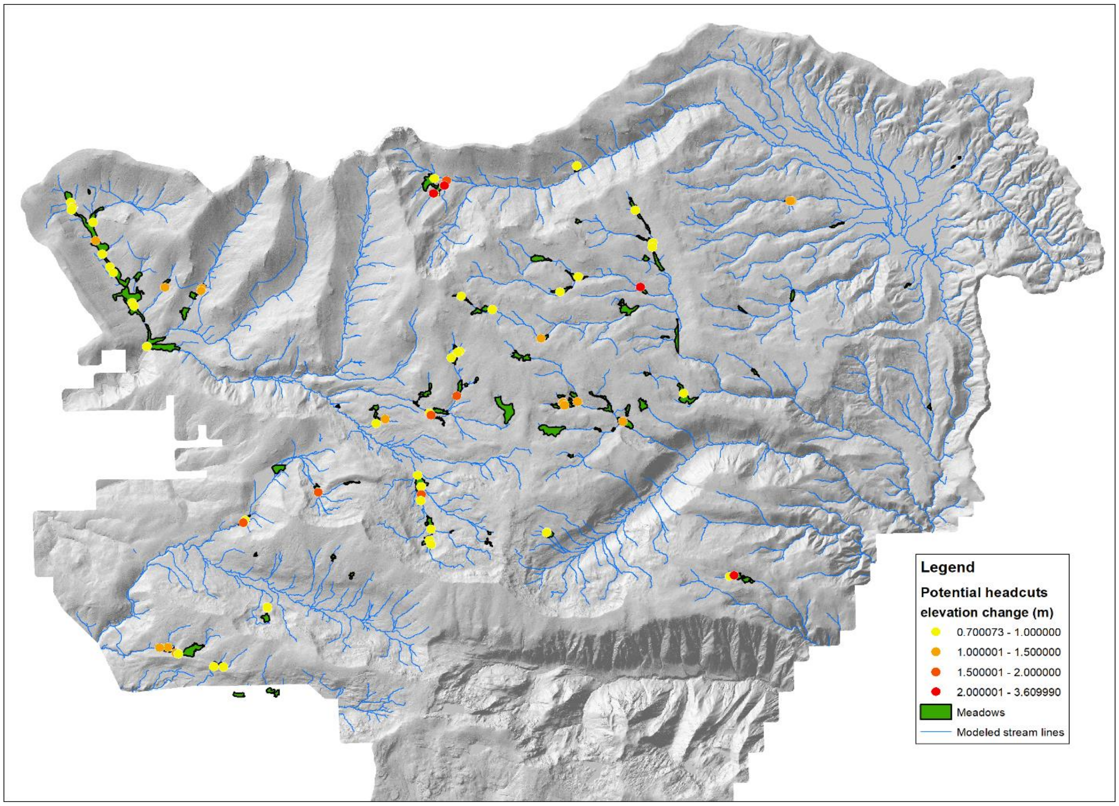

Figure 3. Map of potential headcuts and stream network derived from LiDAR data.

Table 5. Count of headcuts detected by LNF observers and the LiDAR analysis in each of 88 Storrie meadow polygons.

Number of field-detected headcuts	Number of LiDAR-derived headcuts	Number of meadows
Meadows with matching number of headcuts		
0	0	48
1	1	4
2	2	0
>2	>2	0
Meadows with more field-detected headcuts		
1	0	7
2	1	1
2	0	0
>2	0	0
Meadows with more LiDAR-detected headcuts		
0	1	13
0	2	6
0	>2	4
1	2	5
Total Meadows		88

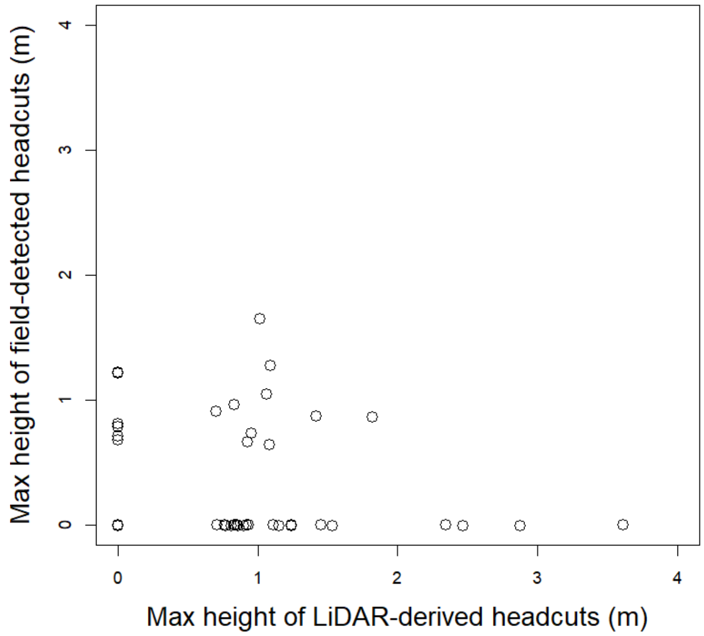

Figure 4. There was little relationship between the maximum heights of LiDAR-derived potential headcuts and headcuts recorded by LNF observers, primarily driven by a lack of headcut detection by each method. Each point represents the maximum headcut height at a single meadow polygon. Points were slightly jittered to better expose overlapping points.

Discussion

Our original intention for the LiDAR analysis was to measure conifer encroachment and shrub cover in addition to channel condition. However, because we were unable to estimate vegetation cover metrics for lack of the first return data, the analysis was less informative for prioritization. The method we used to derive headcut locations and heights is experimental, as it is not yet formally a component of the toolset and has never been applied to meadow ecosystems nor a geography with much topographic relief. There are many reasons why the potential headcuts we mapped may be inaccurate. Many of the headcuts found by LNF in the field were off of mapped channels that flow through the meadows, either on inactive channels or channels from springs emanating from the meadow itself. This tool did not identify headcuts that are away from the main channels, so those headcuts were unaccounted for.

Another drawback to the headcut script was that it did not distinguish between headcuts and steep slopes where the elevation difference from pixel to pixel along the stream course may be naturally large. We removed potential headcuts from meadow CH02 for this reason, but there may be a limited number of other potential headcuts flagged by the tool that are more of a reflection of a steep stream gradient instead of an actual headcut. Other reasons for false positive potential headcuts are intersections of a flow path with a road creating large elevation changes in the DEM, as well as other inaccuracies in the LiDAR-derived DEM. Using the flow accumulation and flow direction layers derived from the toolbox as inputs in the Make Streams Lines tool resulted in a list of potential headcuts containing many more apparent false positives with larger elevation changes. Using the flow accumulation and flow direction layers derived from the 1-m-resolution DEM using the standard ArcGIS Flow Direction and Flow

Accumulation tools reduced false positives and improved the calculation of elevation change, so we highly recommend this method for future applications of this toolset. We did our best to remove obvious false positive headcuts from the final output, but we did err on the side of inclusion. For these reasons, we feel the results of this analysis should be ground-truthed before incorporated into conservation and prioritization decisions. We recommend the River Bathymetric Toolkit (ESSA Technologies and US Forest Service, http://essa.com/tools/rbt) and the Riparian Topography toolkit (Dilts et al. 2010; http://arcscripts.esri.com) also be explored in future applications of LiDAR data to assess stream channel condition on the Lassen National Forest.

The quality of results obtained from LiDAR-based analysis of channel morphology are strongly controlled by the native resolution and accuracy of the LiDAR data and derived products (Faux et al. 2009). A lower resolution data acquisition (expressed as pulse densities for raw LiDAR) may produce different results in terms of how well the DEM represents the channel geometry, with higher resolution data allowing for more detailed analysis (Faux et al. 2009). For example, James et al. (2007) showed that LiDAR data processed at 2-m grid cells were not suitable for detailed morphologic analysis or for subtle change detection in monitoring gullies in headwater streams in South Carolina. We felt the 1-m resolution DEM precluded our ability to derive accurate assessments of stream bank condition in a consistent manner across all meadows in this analysis, as meadow stream channels in this study area can be smaller than 1 m in width. Future LiDAR data collection efforts by LNF in meadows should ensure higher resolution products can be derived.

Appendix B: Climate Sensitivity Analysis

Introduction and Methods

We used Climate Engine (Huntington et al. 2017) to examine meadow sensitivity to climate. For each meadow, we developed two variable analysis plots comparing the median summer (July 1-Sept. 30) Normalized Difference Vegetation Index (NDVI) to total precipitation over the water year (October 1-September 30) on an annual time step for the time period 1984-2017. Climate Engine uses remote sensing LandSat 4/5/7/8 surface reflectance data at a 30m resolution to calculate NDVI and METDATA/gridMET precipitation data on an interpolated surface and at a 4000m resolution to calculate precipitation. NDVI is calculated from the visible and near-infrared light that is reflected by vegetation. Calculations of NDVI result in a value between -1 and 1, with larger values representing greater vegetation vigor. The median summer NDVI in a Sierra meadow is a measure of vegetation vigor (an indicator of biomass), which is strongly correlated with meadow wetness and is sensitive to hydroclimatic conditions, especially snowpack and precipitation (Albano et al, in prep). It can be used to determine how sensitive the meadow is to changes in precipitation as well as whether the meadow may be in a degraded state. For each meadow, we manually delineated the approximate meadow boundaries in Climate Engine based on the Storrie meadow polygons shapefile and aerial imagery. We then generated the two variable analysis plots for each meadow, using data from pixels contained by each meadow polygon, for use in our analysis.

We developed four qualitative categories to describe meadow sensitivity to climate: (1) recovering, (2) resilient, (3) sensitive, and (4) stressed. These categories are not exclusive, and we frequently categorized meadows into more than one category to describe overall trends (e.g., sensitive but recovering, recovering and resilient). We categorized meadows as Resilient when the median summer NDVI tends to be above the mean value even in years with below average precipitation. We categorized meadows as Sensitive when the median summer NDVI is correlated with annual precipitation and therefore sensitive to changes in precipitation. We categorized meadows as Stressed when the median summer NDVI is below the mean value even in years with above average precipitation, which may indicate that the meadow has degraded hydrological function. For each meadow, we made notes about which years exhibited certain conditions (e.g., stressed, resilient) and compared these notes to information about factors that may have influenced the observed results, such as whether the meadow is heavily encroached, if there was a change in grazing allotment status, multi-year droughts, and/or if the meadow fell within the fire footprint for the Storrie and/or Chips fire. We categorized meadows as Recovering when the overall trend of the meadow was moving toward a more resilient state (e.g., from stressed to sensitive or sensitive to resilient). Figure 5 provides representative Storrie meadow examples of each of these four categories.

Two observers (M. Vernon and B. Campos) independently examined the two variable analysis plots for each meadow and categorized each meadow into one or more categories of Resilient, Sensitive, Stressed, and/or Recovering. The two observers then compared their independent categorizations and together examined meadows for which there was disagreement in order to come to a consensus decision.

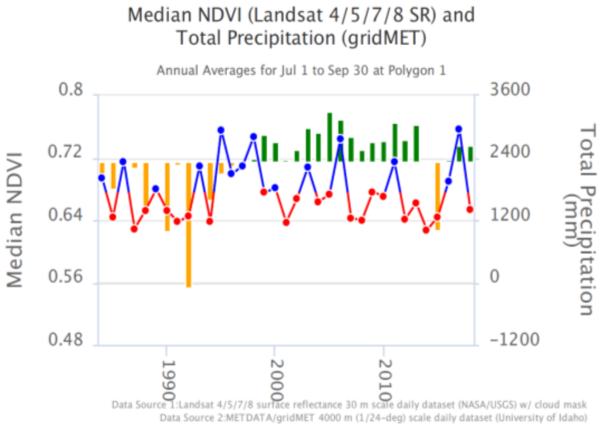

Figure 1a: Colby Creek 02, recovering.

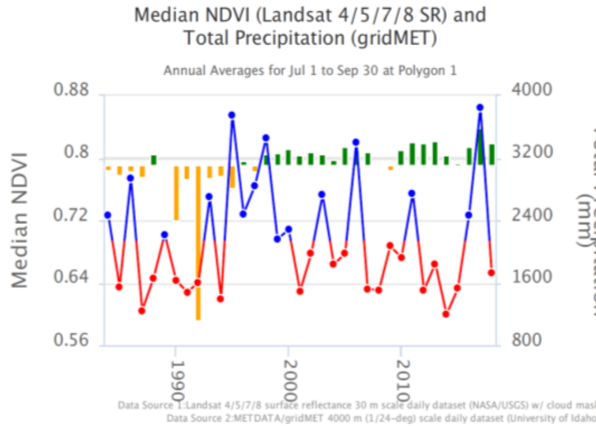

Figure 1b: LT Creek 04, resilient.

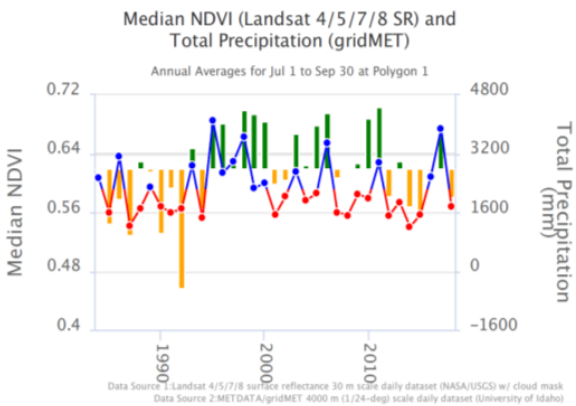

Figure 1c: Grizzly 324, sensitive.

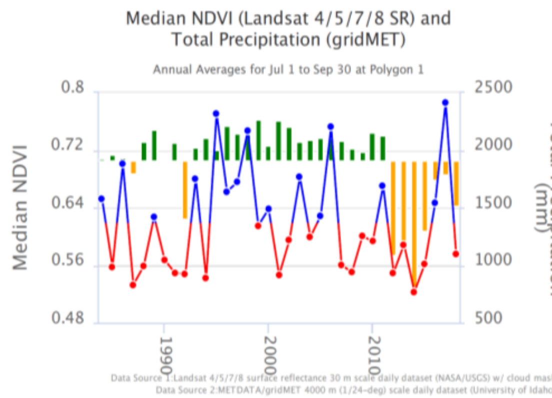

Figure 1d: Grizzly Creek 09, stressed.

Figure 5. Example figures generated by ClimEngine for each meadow, exhibiting the different climate sensitivities. The bars represent the mean NDVI from July 1 to September 30 of each year. Green bars represent years when the annual average NDVI is above the median for the time series, while bars in yellow indicate NDVI values below the median. The lines represent the total precipitation for each year. Blue lines indicate years when the precipitation was above the average precipitation for the time series, while red lines indicate years when the precipitation was below the average precipitation for the time series. Figure 1a shows a recovering meadow, Figure 1b shows a resilient meadow, Figure 1c shows a sensitive meadow, and Figure 1d shows a stressed meadow.

Results

Tables 6-7 and Figure 6 show the results of the NDVI climate sensitivity analysis. Half of the Storrie Fire nexus meadows (50%) show sensitivity in NDVI to precipitation (Table 6). Of the remaining meadows, we categorized 41.1% as resilient and recovering, recovering, or resilient, and 8.9% of meadows are stressed. Of the 12 meadows that we categorized stressed or stressed and sensitive, 10 (83.3%) were also within the burn perimeter of the Chips and/or Storrie fire, compared to 4 (10.8%) of the meadows that are resilient and/or recovering and 4 (9.8%) of meadows that are sensitive and/or recovering. Meadows that are sensitive or sensitive and recovering have an average of 2.3 types of degradation per meadow, while meadows that are resilient and/or recovering have an average of 1.8 types of degradation per meadow as defined in the previous section on meadow condition scorecard analysis. See Appendix B for climate sensitivity results for each meadow.

Table 6: Results of the NDVI climate sensitivity analysis.

Climate Sensitivity	Number of Meadows
Resilient	6
Recovering	2
Resilient and recovering	29
Sensitive	25
Sensitive and recovering	16
Sensitive and stressed	4
Stressed	8

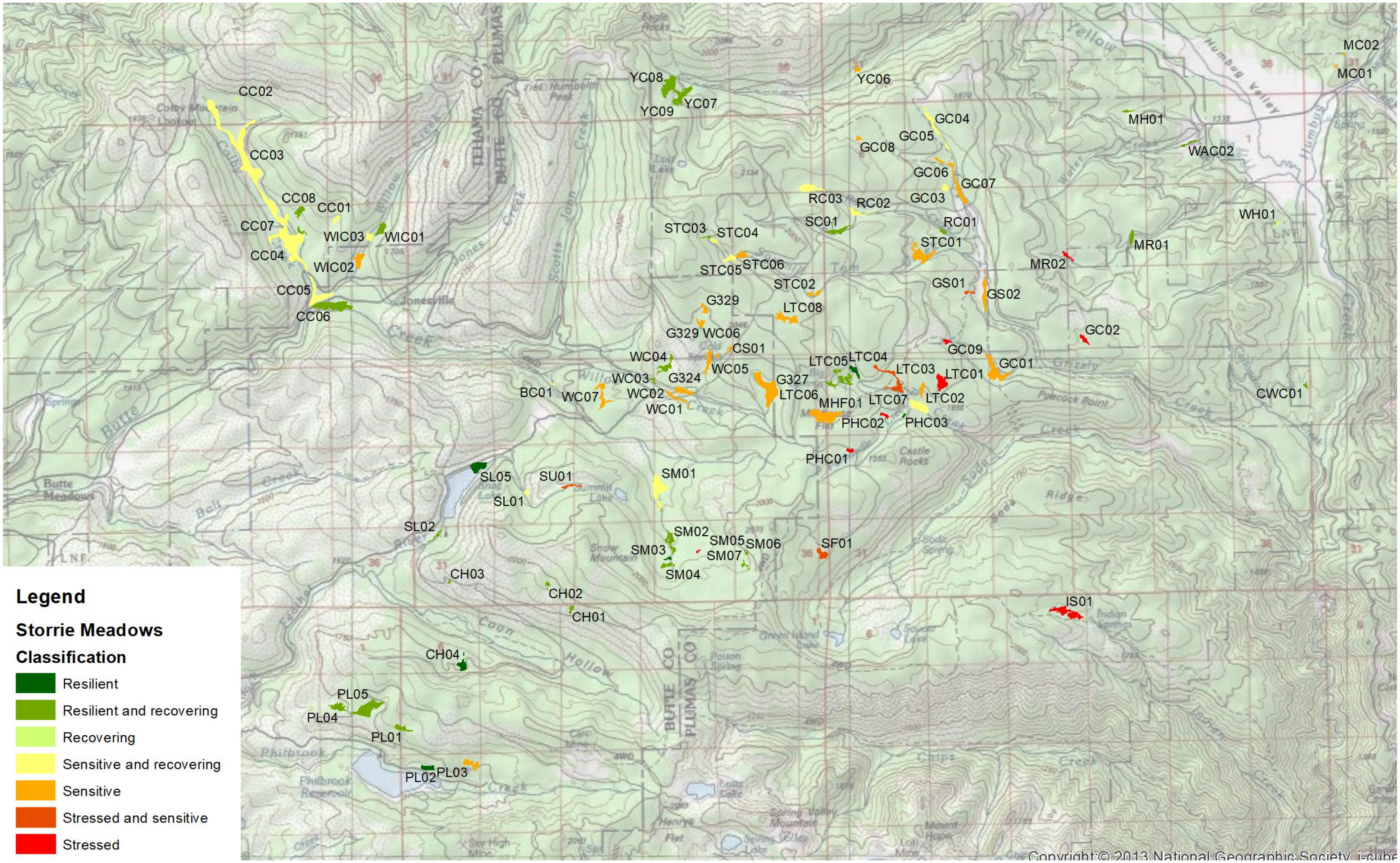

Figure 6: Results of the climate sensitivity analysis for the Storrie meadows.

Table 7: Results of the climate sensitivity analysis for all 90 Storrie meadows.

Meadow ID	Meadow Name	Climate Sensitivity
BC01	Butte Creek 01	Sensitive and recovering
CC01	Colby Creek 01	Sensitive and recovering
CC02	Colby Creek 02	Recovering
CC03	Colby Creek 03	Sensitive and recovering
CC04	Colby Creek 04	Sensitive and recovering
CC05	Colby Creek 05	Sensitive and recovering
CC06	Colby Creek 06	Resilient and recovering
CC07	Colby Creek 07	Resilient and recovering
CC08	Colby Creek 08	Resilient and recovering
CH01	Coon Hollow 01	Resilient and recovering
CH02	Coon Hollow 02	Resilient and recovering
CH03	Coon Hollow 03	Resilient and recovering
CH04	Coon Hollow 04	Resilient
CS01	Cold Springs 01	Sensitive
CWC01	Cottonwood Creek 01	Resilient and recovering
G324	Grizzly 324	Sensitive
G327	Grizzly 327	Sensitive
G329	Grizzly 329	Sensitive
GC01	Grizzly Creek 01	Sensitive
GC02	Grizzly Creek 02	Stressed
GC03	Grizzly Creek 03	Sensitive and recovering
GC04	Grizzly Creek 04	Sensitive and recovering
GC05	Grizzly Creek 05	Sensitive and recovering
GC06	Grizzly Creek 06	Sensitive
GC07	Grizzly Creek 07	Sensitive
GC08	Grizzly Creek 08	Sensitive
GC09	Grizzly Creek 09	Stressed
GS01	Grizzly Spring 01	Stressed and sensitive
GS02	Grizzly Spring 02	Sensitive
IS01	Indian Springs 01	Stressed
LTC01	LT Creek 01	Stressed
LTC02	LT Creek 02	Sensitive and recovering
LTC03	LT Creek 03	Sensitive
LTC04	LT Creek 04	Resilient
LTC05	LT Creek 05	Resilient and recovering
LTC06	LT Creek 06	Resilient and recovering
LTC07	LT Creek 07	Stressed and sensitive
LTC08	LT Creek 08	Sensitive
MC01	Miller Creek 01	Sensitive
MC02	Miller Creek 02	Sensitive
MH01	Mudhole Hollow 01	Resilient and recovering
MHF01	Milkhouse Flat 01	Sensitive
MR01	Miller Ravine 01	Resilient and recovering
MR02	Miller Ravine 02	Stressed
PHC01	Panhandle Creek 01	Stressed
PHC02	Panhandle Creek 02	Stressed
PHC03	Panhandle Creek 03	Resilient

Meadow ID	Meadow Name	Climate Sensitivity
PL01	Philbrook Lake 01	Resilient and recovering
PL02	Philbrook Lake 02	Resilient
PL03	Philbrook Lake 03	Sensitive
PL04	Philbrook Lake 04	Resilient and recovering
PL05	Philbrook Lake 05	Resilient and recovering
RC01	Rock Creek 01	Resilient and recovering
RC02	Rock Creek 02	Sensitive and recovering
RC03	Rock Creek 03	Sensitive and recovering
SC01	Slate Creek 01	Resilient and recovering
SF01	Sunflower Flat 01	Stressed and sensitive
SL01	Snag Lake 01	Sensitive and recovering
SL02	Snag Lake 02	Resilient and recovering
SL05	Snag Lake 05	Resilient
SM01	Snow Mountain 01	Sensitive and recovering
SM02	Snow Mountain 02	Resilient and recovering
SM03	Snow Mountain 03	Resilient
SM04	Snow Mountain 04	Resilient and recovering
SM05	Snow Mountain 05	Stressed
SM06	Snow Mountain 06	Resilient and recovering
SM07	Snow Mountain 07	Resilient and recovering
STC01	Sawmill Tom Creek 01	Sensitive
STC02	Sawmill Tom Creek 02	Sensitive
STC03	Sawmill Tom Creek 03	Resilient and recovering
STC04	Sawmill Tom Creek 04	Sensitive and recovering
STC05	Sawmill Tom Creek 05	Sensitive and recovering
STC06	Sawmill Tom Creek 06	Sensitive
SU01	Summit Lake 01	Stressed and sensitive
WAC02	Water Creek 02	Resilient and recovering
WC01	Willow Creek 01	Sensitive
WC02	Willow Creek 02	Sensitive
WC03	Willow Creek 03	Resilient and recovering
WC04	Willow Creek 04	Resilient and recovering
WC05	Willow Creek 05	Sensitive
WC06	Willow Creek 06	Sensitive
WC07	Willow Creek 07	Sensitive
WH01	Wallack Hollow 01	Recovering
WIC01	Willow Creek West 01	Resilient and recovering
WIC02	Willow Creek West 02	Sensitive
WIC03	Willow Creek West 03	Sensitive and recovering
YC06	Yellow Creek 06	Sensitive
YC07	Yellow Creek 07	Resilient and recovering
YC08	Yellow Creek 08	Resilient and recovering
YC09	Yellow Creek 09	Resilient and recovering

Discussion

We ultimately chose not to use the results of the climate sensitivity analysis in the final prioritization process for multiple reasons. First, there are several ways in which these data could be interpreted for restoration recommendations. For example, we could prioritize meadows for restoration that were categorized as resilient or recovering, which may indicate a persistent groundwater source that can sustain meadow vegetation even during dry years. An alternative option would be to prioritize restoration efforts on meadows that are sensitive or stressed, which may benefit from hydrological restoration to increase groundwater recharge and late-season stream flow.

Second, there were likely other factors besides ground- and surface water availability that contributed to the observed high or low NDVI values for the meadows. It is possible that meadows classified as resilient or recovering may be heavily encroached, and thus the conifers and/or upland shrubs may have contributed to the strong NDVI values observed. Additionally, analysis of small (<1 acre) or narrow meadows may not have had NDVI pixels that fit entirely within the meadow bounds and instead captured conifers along the meadow edge. This may have been why we observed low NDVI values in meadows within the footprint of the Chips and/or Storrie fires, as the NDVI values may have been picking up signals in vegetation biomass from burned conifers along the meadow edge or burned conifers within encroached meadows, especially in meadows that were small and/or narrow. The Chips fire also occurred during the 2012-2017 drought, and thus low NDVI values in meadows within this fire footprint may have been in response to reduced snowpack and precipitation. The climate sensitivity data may be better used as a post-hoc filter and additional data input in the process of identifying the top 2-5 meadows for restoration, with careful attention paid to variables such as meadow size, shape, and encroachment that may impact the observed NDVI.

Appendix C: Prioritization Tool Methods

The following tables list the indicators associated with each conservation target, a brief description of the indicator and its relation to the conservation target, the source data, and how each meadow was scored based on the indicators. For target species, indicators are split into range indicators and habitat suitability indicators. Habitat suitability indicator scores for each meadow are not calculated unless the meadow falls in the range for one or more range indicators.

Target: Chinook salmon and steelhead trout

Range Indicators	**Description and Scoring**	**Source Citation**	**Score**
Colby Creek – Butte Creek watershed	Meadows that have a perennial stream present and fall in the Colby Creek - Butte Creek HUC12 watershed receive a score of 2. Butte Creek is a priority stream for Chinook salmon recovery (Moyle et al. 2017a,b).	USGS National Hydrography Dataset	0 or 2
Steelhead reintroduction strategy	Meadows with a perennial stream present and fall in a watershed with a reintroduction conservation strategy for steelhead trout as listed by the Conservation Success Index receive a score of 2.	Trout Unlimited 2009	0 or 2
Habitat Suitability Indicators	**Description and Scoring**	**Source Citation**	**Score**
Meters of perennial stream	The length of all perennial streams within the meadow in meters, indicating fish habitat. Meadows are ranked based on which quartile they fall in, with Q1=0.5, Q2=1, Q3=1.5, and Q4=2.	USGS National Hydrography Dataset	0.5-2
Habitat integrity for steelhead trout	The Conservation Success Index's habitat integrity scores at the subwatershed scale for steelhead trout based on five indicators: land stewardship, watershed connectivity, watershed conditions, water quality, and flow regime. The scores range from 5-25, with higher scores indicating higher habitat integrity. The meadow is given the score for the subwatershed in which it falls. Storrie meadows had habitat integrity scores of 18 and 19, so for prioritization scoring, we gave meadows with a score of 18 a score of 0.5 and meadows with a score of 19 a score of 1.	Trout Unlimited 2009	0.5-1

Target: Chinook salmon and steelhead trout, cont.

Habitat Suitability Indicators	**Description and Scoring**	**Source Citation**	**Score**
Projected degree change in stream temperature	The degree change in the average August stream temperature from 1993-2011 to 2040 under the A1B climate scenario for meadows with a stream present (and for which NorWest data are available). For meadows with more than one stream present, the average degree change is listed. Data were not available for all meadows. Meadows are scored such that streams with less degree change received higher scores. Scores are based on which quartile they fall in, with Q1=1, Q2=0.75, Q3=0.5, and Q4=0.25. Meadows with no data available received a score of 0.	NorWest (Isaak et al. 2015, 2016)	0-1
Watershed road density (km/km^2)	The density of roads in each HUC12 watershed as km/km^2. Roads data include all primary, secondary, neighborhood, and rural roads, city streets, 4WD vehicular trails, and private roads for service vehicles from the TIGER/Line county roads dataset and all U.S. Forest Service roads not captured in TIGER/Line. Each meadow is given the road density value for the HUC12 watershed in which it falls. Watershed road density can lead to water quality impacts from sedimentation, erosion, and pollutant runoff. Meadows are ranked based on which quartile they fall in, with Q4=0.33, Q2 or Q3=0.66, and Q1=1.	U.S. Department of Commerce and U.S. Census Bureau, 2018 and U.S. Forest Service's National Forest System Roads shapefile.	0.33-1
Final Score			**1.33-9**

Target: Cascades Frog

Range Indicators	Description and Scoring	Source Citation	Score
Current population	The meadow receives a score of 2 if it has a recorded population of Cascades frog.	Karen Pope	0 or 2
1km buffer of current population	The meadow receives a score of 2 if it falls within 1 kilometer of a meadow with a current population of Cascades frog. Excludes meadows with recorded populations.	Karen Pope	0 or 2
Currently occupied watersheds	Whether the meadow falls within a HUC12 watershed with current observations (post 1980) of Cascades frog from the Freshwater Database.	Howard and Klausmeyer 2015.	0 or 1
Habitat Suitability Indicators	**Description and Scoring**	**Source Citation**	**Score**
Fen acres	Meadows without a fen receive a score of 0. Meadows with a fen are scored by quartiles according to the acreage of fens that fall within the meadow, with Q1=0.5, Q2=1, Q3=1.5, and Q4=2. Historic observations of Cascades frog are associated with fens (Pope et al. 2014)	Fen data from LNF	0-2
Presence of a seep/spring	Meadows with a seep/spring present receive a score of 1. Cascades frogs overwinter in springs and are associated with meadows that have consistent groundwater inputs (Pope et al. 2018).	USGS National Hydrography Dataset, LNF Significant Features Shapefile	0 or 1
Perennial stream present	Meadows with a perennial stream present receive a score of 1. Cascades frogs require perennial water and diverse aquatic features (Pope et al. 2018).	USGS National Hydrography Dataset	0 or 1
Pond/lake present	Meadows with a pond or lake present receive a score of 1. Cascades frogs require perennial water and diverse aquatic features (Pope et al. 2018).	USGS National Hydrography Dataset	0 or 1
Final Score			**0 - 10**

Target: Sierra Nevada Yellow-Legged Frog

Range Indicators	**Description and Scoring**	**Source Citation**	**Score**
Historically occupied watersheds	The meadow receives a score of 2 if it falls in a HUC12 watershed with historic observations (pre 1980) of Sierra Nevada yellow-legged frog from the Freshwater Database.	Howard and Klausmeyer 2015	0 or 2
Current range	The meadow receives a score of 2 if it falls within the current range of Sierra Nevada yellow-legged frog.	R. Knapp, pers. Comm.	0 or 2
Habitat Suitability Indicators	**Description and Scoring**	**Source Citation**	**Score**
Perennial stream present	The meadow receives a score of 1 if there is a perennial stream present. The frog requires perennial aquatic habitats for breeding and rearing and are typically found along streams (Vredenburg et al. 2004; Brown et al. 2014).	USGS National Hydrography Dataset	0 or 1
Pond/lake present	The meadow receives a score of 1 if there is a pond/lake present. The frog needs deep lakes as well as shallow lakes and ponds without fish present for egg laying (Vredenburg et al. 2004; Brown et al. 2014).	USGS National Hydrography Dataset	0 or 1
Final Score			**0 - 6**

Target: Southern Long-Toed Salamander

Range Indicators	Description and Scoring	Source Citation	Score
Recently occupied watersheds	If the meadow falls within a HUC12 watershed with current observations (post 1980) of southern long-toed salamander from the Freshwater Database, it receives a score of 2.	Howard and Klausmeyer 2015	0 or 2
Current range	If the meadow falls within the current range for the salamander as defined by the CDFW's California Wildlife Habitat Relationships (CWHR) range data, it receives a score of 2.	California Department of Fish and Wildlife CWHR	0 or 2
Habitat Suitability Indicators	**Description and Scoring**	**Source Citation**	**Score**
Presence of a seep/spring	The meadow receives a score of 1 if there is a seep/spring present. The salamander will breed in spring pools (K. Pope, pers. comm.)	USGS National Hydrography Dataset, LNF Significant Features Shapefile	0 or 1
Presence of a pond/lake	The meadow receives a score of 1 if there is a pond/lake present. The salamander uses ponds and small lakes for breeding (Howard 1997; Viers et al. 2013).	USGS National Hydrography Dataset	0 or 1
Stream present	The meadow receives a score of 1 if there is a stream present. The salamander will use streams, although not for breeding (Howard 1997).	USGS National Hydrography Dataset	0 or 1
Final Score			**0 - 7**

Target: Willow Flycatcher

Range Indicator	Description and Scoring	Source Citation	Score
Meadows within dispersal buffer	The meadow receives a score of 1 if it falls within a 12km buffer of meadows with breeding season detections of willow flycatcher since 2008.	Schofield et al. 2018	0 or 1
Habitat Suitability Indicators	**Description and Scoring**	**Source Citation**	**Score**
Meadow area: perimeter ratio	The meadow's area to perimeter ratio. Larger meadows with greater area to perimeter can support more territories. Meadows were scored by quartiles, with Q1=0.5, Q2=1, Q3=1.5, and Q4=2.	Meadow Condition Scorecard	0.5-2
Perennial stream present	The meadow received a score of 1 if there is a perennial stream present. Willow flycatchers need surface water or saturated soils through all or much of the growing season (Schofield et al. 2018).	USGS National Hydrography Dataset	0 or 1
RIP or DS Hydrogeomorphic type	The meadow received a score of 1 if it has a riparian or discharge slope HGM type. Willow flycatchers need surface water or saturated soils through all or much of the growing season and are associated with riparian and discharge slope meadows (Schofield et al. 2018).	Meadow Condition Scorecard	0 or 1
Willow/alder cover	The percent cover of willows and alders in the meadow. Meadows with 40-45, 45-50, 50-55, or 60-65% cover received a score of 2, meadows with 30-35, 35-40, or 40-45% cover received a score of 1.5, meadows with 15-20, 20-25, or 25-30% cover received a score of 1, and meadows with 1-5, 5-10, or 10-15% cover received a score of 0.5.	Meadow Condition Scorecard	0.5-2
Final Score			**1-7**

Target: Carbon Storage

Indicators	Description and Scoring	Source Citation	Score
Fen acreage	The acreage of fens that fall within the meadow. Fens contain peat soils that have high levels of soil organic carbon, take thousands of years to form, and are susceptible to rapid and irreversible loss if not protected (Drew et al. 2016). Meadows with fens present were scored by quartiles, with Q1=0.5, Q2=1, Q3=1.5, and Q4=2. Meadows without fens received a score of 0.	Data provided by LNF	0-2
Perennial stream present	If the meadow has a perennial stream present, it receives a score of 2. Stream presence may indicate meadow wetness, which is correlated with high levels of soil organic carbon (Norton et al. 2011, 2014).	USGS National Hydrography Dataset	0 or 2
Meadow acreage	The size of the meadow in acres. Larger meadows can store more carbon. Meadows were scored by quartiles, with Q1=0.5, Q2=1, Q3=1.5, and Q4=2.	Meadow Condition Scorecard	0-2
Final Score			**0 - 6**

Target: Climate Resiliency

Indicators	Description and Scoring	Source Citation	Score
Snowpack	The absolute percent change in each indicator from 2010 to 2050 for each NHD catchment in California using the CCSM3-A2 climate model. Each meadow was given the indicator value for the catchment in which it falls. For meadows that fall within more than one catchment, the mean value was used. Each indicator was scored by quartiles. For the hydrological indicators (snowpack, precipitation, runoff, and baseflow), Q1=4, Q2=3, Q3=2, and Q4=1. For the temperature indicators, Q1=2, Q2=1.5, Q3=1, and Q4=0.5. Higher scores indicate less departure from historic conditions and lower projected exposure.	U.S. EPA 2013	1-4
Precipitation			1-4
Runoff			1-4
Baseflow			1-4
Mean temperature			0.5-2
Max temperature			0.5-2
Min temperature			0.5-2
Final Score			**5.5 - 22**

Target: Hydrological Importance

<table>
<tr><th>Indicators</th><th>Description and Scoring</th><th>Source Citation</th><th>Score</th></tr>
<tr><td>Watershed size</td><td>The size of the HUC12 watershed in which the meadow falls. Each meadow receives a score between 0-1 normalized so the scores are relative to all other meadows, with higher scores indicating larger watershed size.</td><td>USGS National Hydrography Dataset</td><td>0-1</td></tr>
<tr><td>Historic annual April 1 snowpack (mm)</td><td rowspan="3">The average annual sum total amount of each indicator calculated for each HUC12 watershed for the period 1951-1980 from the California Basin Characterization Model. Each meadow is given the value of the HUC12 watershed in which it falls. For scoring, each meadow received a score between 0-1 for each indicator. The scores were normalized so the scores are relative to all other meadows, with higher scores indicating higher values for each indicator.</td><td rowspan="3">Flint et al. 2014</td><td rowspan="3">0-1</td></tr>
<tr><td>Historic annual precipitation (mm)</td></tr>
<tr><td>Historic recharge/runoff (mm)</td></tr>
<tr><td>Historic climatic water deficit (mm)</td><td>The average annual sum total amount calculated for each HUC12 watershed for the period 1951-1980 from the California Basin Characterization Model. Each meadow is given the value of the HUC12 watershed in which it falls. For scoring, each meadow received a score between 0-1. The scores were normalized so the scores are relative to all other meadows, with higher scores indicating lower amounts of historic climatic water deficit.</td><td>Flint et al. 2014</td><td>0-1</td></tr>
<tr><td>Projected change in snowpack</td><td rowspan="4">The absolute percent change in each indicator from 2010 to 2050 for each NHD catchment in California using the CCSM3-A2 climate model. Each meadow is given the indicator value for the catchment in which it falls. For meadows that fall within more than one catchment, the mean value is used. For scoring, each meadow received a score between 0-1 for each indicator. The scores were normalized so the scores are relative to all other meadows, with higher scores indicating lower departure from 2010 to 2050 and therefore lower relative exposure.</td><td rowspan="4">U.S. EPA 2013</td><td rowspan="4">0-1</td></tr>
<tr><td>Projected change in precipitation</td></tr>
<tr><td>Projected change in baseflow</td></tr>
<tr><td>Projected change in runoff</td></tr>
<tr><td colspan="3">Final Score</td><td>0 - 4</td></tr>
</table>

Target: Water Quality

Watershed Condition Indicators	Description and Scoring	Source Citation	Score
Relative Stream Health Index	The Relative Stream Health Index is based on the natural attributes of freshwater streams, including physical and biological habitat condition, water quality, and instream biological condition. Relative stream health index scores are at the scale of an NHD catchment and are normalized on a scale of 0 to 1, with higher scores indicating higher relative stream health relative to other catchments with meadows in the Sierra Nevada. Each meadow is given the score of the catchment in which it falls. If the meadow falls into more than one catchment, the mean score is used.	U.S. EPA 2013	0-1
Relative Watershed Condition Index	The Relative Watershed Condition Index is based on the natural attributes of a watershed and its freshwater streams and is characterized by percent natural land cover, percent intact active river area, sedimentation risk, percent artificial drainage area, dam storage ratio, and road crossing density (U.S. EPA 2013). Relative watershed condition index scores are at the scale of an NHD catchment and are normalized on a scale of 0 to 1, with higher scores indicating higher relative watershed condition relative to other catchments with meadows in the Sierra Nevada. Each meadow is given the score of the catchment in which it falls. If the meadow falls into more than one catchment, the mean score is used.	U.S. EPA 2013	0-1
Watershed Threat Indicators	**Description and Scoring**	**Source Citation**	**Score**
Relative Watershed Vulnerability Index	The Relative Watershed Vulnerability Index characterizes the potential for future degradation of watershed processes and aquatic ecosystems based on climate change, projected land cover change, current water demand, and projected change in wildfire severity and fire regime condition class (U.S. EPA 2013). Relative watershed vulnerability index scores are at the scale of an NHD catchment and are normalized on a scale of 0 to 1, with higher scores indicating higher relative watershed vulnerability relative to other catchments with meadows in the Sierra Nevada. Each meadow is given the score of the catchment in which it falls. If the meadow falls into more than one catchment, the mean score is used.	U.S. EPA 2013	0-1

Target: Water Quality, cont.

Watershed Threat Indicators	Description and Scoring	Source Citation	Score
Active grazing allotment	The meadow receives a score of 1 if it has an active grazing allotment and a score of 0 if it does not. Meadows with grazing may have water quality impacts from erosion and sedimentation, increased stream temperatures from removal of riparian shrubs/trees, and water contamination from animal waste.	Meadow Condition Scorecard Database	0 or 1
Watershed road density (km/km^2)	The density of roads in each HUC12 watershed as km/km^2. Roads data include all primary, secondary, neighborhood, and rural roads, city streets, 4WD vehicular trails, and private roads for service vehicles from the TIGER/Line county roads dataset and all U.S. Forest Service roads not captured in TIGER/Line. Watershed road density can lead to water quality impacts from sedimentation, erosion, and pollutant runoff. The road density values for each HUC12 watershed was normalized relative to one another on a scale of 0-1, with higher values indicating higher road density. Each meadow is given the normalized score for the HUC12 watershed in which it falls.	U.S. Department of Commerce and U.S. Census Bureau, 2018 and U.S. Forest Service's National Forest System Roads shapefile.	0-1
Final Scoring	All indicators of watershed condition were summed and normalized so there is one watershed condition score per meadow ranging from 0-1. All indicators of watershed threat were summed and normalized so there is one watershed threat score per meadow ranging from 0-1. The condition and threat scores were then summed and normalized for a final water quality score per meadow on a scale from 0-1. This approach prioritizes meadows with high condition and high threat.	Watershed Condition and Watershed Threat indicators	0-1

Appendix D: American Rivers Meadow Condition Scorecard Analysis

ID	Meadow Name	# of Stressors	Stressor(s)	Count of 1s and 2s	Encroachment Score	Evidence of Grazing	# Headcuts	Max Headcut Height (in)	Sum Headcut Height (in)	Allotment Status
BC01	Butte Creek 01	1	Grazing	N/A	3	Yes	0	0	0	Active
CC01	Colby Creek 01	2	Encroachment, Channel Morphology	3	2	No	2	65	91	Closed
CC02	Colby Creek 02	0	None	N/A	3	No	0	0	0	Closed
CC03	Colby Creek 03	2	Encroachment, Channel Morphology	2	2	No	2	17	31	Closed
CC04	Colby Creek 04	3	Grazing, Encroachment, Channel	2	1	Yes	2	29	47	Closed
CC05	Colby Creek 05	1	Channel Morphology	3	3	No	1	26	26	Closed
CC06	Colby Creek 06	2	Encroachment, Channel Morphology	2	2	No	0	0	0	No Allotment
CC07	Colby Creek 07	1	Encroachment	N/A	1	No	0	0	0	Closed
CC08	Colby Creek 08	1	Encroachment	0	2	No	0	0	0	Closed
CS01	Cold Springs 01	2	Grazing, Channel Morphology	1	3	Yes	0	0	0	Active
CH01	Coon Hollow 01	1	Encroachment	0	2	No	0	0	0	Vacant
CH02	Coon Hollow 02	1	Encroachment	0	1	No	2	0	0	Vacant
CH03	Coon Hollow 03	1	Encroachment	0	2	No	0	0	0	Vacant
CH04	Coon Hollow 04	1	Encroachment	0	2	No	0	0	0	Vacant
CWC01	Cottonwood Creek 01	1	Encroachment	0	1	No	1	48	48	Vacant
G324	Grizzly 324	3	Grazing, Encroachment, Channel	1	1	Yes	8	16	83	Active
G327	Grizzly 327	3	Grazing, Encroachment, Channel	2	1	Yes	9	28	128	Active
G329	Grizzly 329	3	Grazing, Encroachment, Channel	1	1	Yes	0	0	0	Active
GC01	Grizzly Creek 01	3	Grazing, Encroachment, Channel	1	1	Yes	4	36	62	Active
GC02	Grizzly Creek 02	1	Grazing	0	3	Yes	0	0	0	Vacant
GC03	Grizzly Creek 03	3	Grazing, Encroachment, Channel	1	2	Yes	0	0	0	Active
GC04	Grizzly Creek 04	2	Grazing, Encroachment	0	1	Yes	1	27	27	Active
GC05	Grizzly Creek 05	2	Grazing, Encroachment	0	2	Yes	2	17	25	Active
GC06	Grizzly Creek 06	3	Grazing, Encroachment, Channel	3	1	Yes	4	22	47	Active
GC07	Grizzly Creek 07	3	Grazing, Encroachment, Channel	2	1	Yes	0	0	0	Active
GC08	Grizzly Creek 08	1	Encroachment	N/A	2	No	0	0	0	Active
GC09	Grizzly Creek 09	2	Grazing, Encroachment	0	1	Yes	0	0	0	Active
GS01	Grizzly Spring 01	2	Grazing, Encroachment	0	1	Yes	0	0	0	Active
GS02	Grizzly Spring 02	3	Grazing, Encroachment, Channel	2	1	Yes	0	0	0	Active
IS01	Indian Springs 01	0	None	0	3	No	1	12	12	Vacant
LTC01	LT Creek 01	2	Grazing, Encroachment	0	1	Yes	0	0	0	Active
LTC02	LT Creek 02	3	Grazing, Encroachment, Channel	1	1	Yes	1	50	50	Active
LTC03	LT Creek 03	3	Grazing, Encroachment, Channel	1	1	Yes	8	14	85	Active
LTC04	LT Creek 04	2	Grazing, Encroachment	0	2	Yes	0	0	0	Active
LTC05	LT Creek 05	2	Grazing, Encroachment	0	2	Yes	0	0	0	Active
LTC06	LT Creek 06	3	Grazing, Encroachment, Channel	1	1	Yes	1	8	8	Active
LTC07	LT Creek 07	2	Grazing, Encroachment	0	2	Yes	1	14	14	Active
LTC08	LT Creek 08	3	Grazing, Encroachment, Channel	1	1	Yes	1	19	19	Active
MHF01	Milkhouse Flat 01	3	Grazing, Encroachment, Channel	1	2	Yes	0	0	0	Active
MC01	Miller Creek 01	1	Encroachment	0	2	No	2	0	0	Vacant
MC02	Miller Creek 02	0	None	N/A	3	No	0	0	0	Vacant
MR01	Miller Ravine 01	2	Grazing, Encroachment	0	2	Yes	0	0	0	Vacant

Appendix D: American Rivers Meadow Condition Scorecard Analysis

MR02	Miller Ravine 02	0	None	0	3	No	0	0	0	Vacant
MH01	Mudhole Hollow 01	1	Encroachment	0	2	No	0	0	0	Vacant
PHC01	Panhandle Creek 01	0	None	0	3	No	0	0	0	Active
PHC02	Panhandle Creek 02	3	Grazing, Encroachment, Channel	1	2	Yes	1	10	10	Active
PHC03	Panhandle Creek 03	2	Grazing, Channel Morphology	2	3	Yes	0	0	0	Active
PL01	Philbrook Lake 01	3	Grazing, Encroachment, Channel	1	2	Yes	0	0	0	No Allotment
PL02	Philbrook Lake 02	2	Encroachment, Channel Morphology	1	1	No	0	0	0	No Allotment
PL03	Philbrook Lake 03	1	Encroachment	0	1	No	0	0	0	No Allotment
PL04	Philbrook Lake 04	2	Encroachment, Channel Morphology	1	2	No	0	0	0	Vacant
PL05	Philbrook Lake 05	1	Encroachment	0	2	No	1	0	0	Vacant
RC01	Rock Creek 01	2	Grazing, Channel Morphology	1	3	Yes	7	32	116	Active
RC02	Rock Creek 02	3	Grazing, Encroachment, Channel	2	1	Yes	1	11	11	Active
RC03	Rock Creek 03	3	Grazing, Encroachment, Channel	2	1	Yes	0	0	0	Active
STC01	Sawmill Tom Creek 01	2	Grazing, Encroachment	0	1	Yes	1	18	18	Active
STC02	Sawmill Tom Creek 02	3	Grazing, Encroachment, Channel	2	2	Yes	1	25	25	Active
STC03	Sawmill Tom Creek 03	3	Grazing, Encroachment, Channel	1	2	Yes	0	0	0	Active
STC04	Sawmill Tom Creek 04	2	Grazing, Encroachment	0	1	Yes	2	38	56	Active
STC05	Sawmill Tom Creek 05	1	Grazing	0	3	Yes	0	0	0	Active
STC06	Sawmill Tom Creek 06	2	Grazing, Channel Morphology	1	3	Yes	1	19	19	Active
SC01	Slate Creek 01	2	Grazing, Encroachment	0	1	Yes	1	16	16	Active
SL01	Snag Lake 01	3	Grazing, Encroachment, Channel	1	1	Yes	0	0	0	Vacant
SL02	Snag Lake 02	2	Encroachment, Channel Morphology	2	2	No	0	0	0	Vacant
SL05	Snag Lake 05	2	Encroachment, Channel Morphology	2	2	No	0	0	0	Vacant
SM01	Snow Mountain 01	3	Grazing, Encroachment, Channel	1	1	Yes	0	0	0	Active
SM02	Snow Mountain 02	2	Encroachment, Channel Morphology	1	2	No	0	0	0	Active
SM03	Snow Mountain 03	1	Grazing	0	3	Yes	0	0	0	Active
SM04	Snow Mountain 04	2	Grazing, Encroachment	0	1	Yes	0	0	0	Active
SM05	Snow Mountain 05	1	Grazing	0	3	Yes	0	0	0	Active
SM06	Snow Mountain 06	3	Grazing, Encroachment, Channel	1	2	Yes	0	0	0	Active
SM07	Snow Mountain 07	3	Grazing, Encroachment, Channel	1	1	Yes	0	0	0	Active
SU01	Summit Lake 01	0	None	0	3	No	0	0	0	Vacant
SF01	Sunflower Flat 01	1	Encroachment	0	1	No	0	0	0	Active
WH01	Wallack Hollow 01	1	Encroachment	0	1	No	0	0	0	Vacant
WAC02	Water Creek 02	2	Grazing, Channel Morphology	1	3	Yes	0	0	0	Vacant
WC01	Willow Creek 01	2	Grazing, Channel Morphology	2	3	Yes	2	31	52	Active
WC02	Willow Creek 02	2	Grazing, Channel Morphology	3	3	Yes	1	34	34	Active
WC03	Willow Creek 03	2	Grazing, Channel Morphology	2	3	Yes	0	0	0	Active
WC04	Willow Creek 04	3	Grazing, Encroachment, Channel	2	2	Yes	0	0	0	Active
WC05	Willow Creek 05	3	Grazing, Encroachment, Channel	2	2	Yes	0	0	0	Active
WC06	Willow Creek 06	2	Grazing, Channel Morphology	1	3	Yes	1	27	27	Active
WC07	Willow Creek 07	3	Grazing, Encroachment, Channel	1	1	Yes	1	41	41	Active
WIC01	Willow Creek West 01	2	Encroachment, Channel Morphology	3	2	No	1	34	34	Closed
WIC02	Willow Creek West 02	2	Encroachment, Channel Morphology	1	2	No	1	48	48	Closed
WIC03	Willow Creek West 03	2	Encroachment, Channel Morphology	2	2	No	0	0	0	Closed
YC06	Yellow Creek 06	2	Grazing, Encroachment	0	2	Yes	0	0	0	Active
YC07	Yellow Creek 07	2	Grazing, Encroachment	0	2	Yes	0	0	0	Active
YC08	Yellow Creek 08	3	Grazing, Encroachment, Channel	2	2	Yes	0	0	0	Active
YC09	Yellow Creek 09	2	Grazing, Encroachment	0	2	Yes	0	0	0	Active

Appendix E: Prioritization Results Summary

Rank	ID	Final Score	Restoration Need Score	Multiple Benefits Score	Carbon Storage	Cascades Frog	Climate Resiliency	Fish	Hydrological Importance	Sierra Nevada Yellow-Legged Frog	Southern Long-Toed Salamander	Water Quality	Willow Flycatcher
1	CC04	15.6	8	7.6	1.00	1.00	1.00	0.91	0.57	1.00	0.67	0.63	0.79
2	CC03	15.3	8	7.3	1.00	0.86	1.00	0.94	0.60	1.00	0.33	0.67	0.86
3	CC05	15.0	8	7.0	1.00	1.00	0.83	0.91	0.48	1.00	0.67	0.24	0.86
4	WIC01	15.0	8	7.0	0.82	0.93	0.83	0.94	0.44	1.00	0.67	0.55	0.79
5	CC06	13.1	7	6.1	0.64	0.71	0.83	0.88	0.45	1.00	0.67	0.10	0.86
6	WIC03	12.9	6	6.9	0.82	1.00	0.83	0.82	0.44	1.00	0.67	0.55	0.79
7	CC01	12.5	8	4.5	0.36	0.36	1.00	0.00	0.57	0.80	0.33	0.63	0.43
8	WIC02	12.5	6	6.5	0.55	0.71	0.83	0.94	0.44	1.00	0.67	0.55	0.79
9	RC02	12.2	7	5.2	0.82	0.00	0.50	0.34	0.21	0.80	1.00	0.84	0.71
10	GC06	11.2	8	3.2	0.18	0.00	0.75	0.00	0.32	0.40	0.33	0.76	0.50
11	GC07	11.1	7	4.1	0.55	0.00	0.75	0.00	0.32	0.40	0.67	0.76	0.64
12	SL05	11.0	7	4.0	0.27	0.00	0.50	0.00	0.69	1.00	0.67	0.22	0.64
13	G327	10.9	8	2.9	0.27	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.50
14	YC08	10.8	6	4.8	0.82	0.00	0.75	0.22	0.00	0.60	0.67	1.00	0.71
15	LTC02	10.7	6	4.7	1.00	0.00	0.08	0.83	0.10	0.60	0.33	0.89	0.86
16	WC02	10.6	8	2.6	0.00	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.50
17	WC01	10.5	8	2.5	0.09	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.29
18	STC02	10.5	8	2.5	0.09	0.00	0.25	0.00	0.17	0.40	0.33	0.75	0.50
19	PHC03	10.3	7	3.3	0.36	0.00	0.00	0.70	0.06	0.60	0.33	0.89	0.36
20	RC03	10.1	7	3.1	0.27	0.00	0.50	0.00	0.21	0.40	0.33	0.84	0.57
21	GS02	10.1	7	3.1	0.27	0.00	0.42	0.00	0.27	0.40	0.33	0.76	0.64
22	WC04	9.8	7	2.8	0.27	0.21	0.17	0.00	0.16	0.80	0.33	0.54	0.36
23	RC01	9.7	6	3.7	0.45	0.00	0.50	0.31	0.21	0.60	0.33	0.84	0.50
24	WC05	9.4	6	3.4	0.18	0.29	0.17	0.00	0.16	0.80	0.67	0.54	0.57
25	WC03	9.4	7	2.4	0.00	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.21
26	SL02	9.3	7	2.3	0.09	0.00	0.42	0.00	0.70	0.80	0.33	0.00	0.00
27	GC01	9.0	6	3.0	0.27	0.00	0.42	0.00	0.25	0.40	0.33	0.84	0.50
28	LTC06	9.0	5	4.0	0.45	0.00	0.33	0.61	0.13	0.60	0.33	0.82	0.71
29	SM01	8.9	4	4.9	0.64	0.29	0.00	1.00	0.02	1.00	0.33	0.82	0.86
30	G324	8.8	6	2.8	0.18	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.50

Appendix E: Prioritization Results Summary

Rank	ID	Final Score	Restoration Need Score	Multiple Benefits Score	Carbon Storage	Cascades Frog	Climate Resiliency	Fish	Hydrological Importance	Sierra Nevada Yellow-Legged Frog	Southern Long-Toed Salamander	Water Quality	Willow Flycatcher
31	LTC03	8.7	6	2.7	0.18	0.00	0.33	0.00	0.17	0.40	0.00	0.95	0.64
32	PL01	8.6	5	3.6	0.18	0.00	0.92	0.00	0.89	0.80	0.33	0.52	0.00
33	PHC02	8.5	5	3.5	0.55	0.00	0.00	0.61	0.06	0.60	0.33	0.89	0.50
34	WC07	8.4	6	2.4	0.27	0.14	0.08	0.00	0.14	0.80	0.00	0.55	0.43
35	SM02	8.4	4	4.4	0.55	0.29	0.00	0.88	0.02	1.00	0.33	0.82	0.50
36	GC03	8.1	5	3.1	0.27	0.00	0.75	0.00	0.32	0.40	0.00	0.76	0.64
37	LTC08	8.1	5	3.1	0.27	0.00	0.33	0.00	0.13	0.40	0.67	0.82	0.43
38	IS01	7.9	3	4.9	0.64	0.00	0.50	0.61	0.19	1.00	1.00	0.49	0.50
39	G329	7.8	5	2.8	0.18	0.14	0.17	0.00	0.16	0.80	0.33	0.54	0.50
40	WAC02	7.8	4	3.8	0.45	0.00	0.67	0.32	0.11	0.60	0.67	0.48	0.50
41	STC06	7.7	5	2.7	0.18	0.00	0.25	0.00	0.17	0.40	0.33	0.75	0.64
42	WC06	7.7	5	2.7	0.00	0.29	0.17	0.00	0.16	0.80	0.33	0.54	0.43
43	PL02	7.6	4	3.6	0.18	0.00	0.92	0.00	0.89	0.80	0.33	0.52	0.00
44	CC08	7.6	2	5.6	0.55	0.86	1.00	0.00	0.57	0.80	0.67	0.63	0.57
45	MHF01	7.6	5	2.6	0.27	0.00	0.00	0.00	0.06	0.40	0.33	0.89	0.64
46	CS01	7.6	5	2.6	0.00	0.29	0.17	0.00	0.16	0.80	0.33	0.54	0.29
47	STC01	7.6	3	4.6	1.00	0.00	0.25	0.46	0.17	0.60	0.33	0.75	1.00
48	PL04	7.3	4	3.3	0.18	0.00	0.83	0.00	1.00	0.80	0.33	0.19	0.00
49	LTC07	7.3	3	4.3	0.64	0.00	0.33	0.77	0.13	0.60	0.33	0.82	0.64
50	STC04	7.0	4	3.0	0.18	0.00	0.25	0.00	0.17	0.40	0.67	0.75	0.57
51	SL01	6.9	4	2.9	0.09	0.00	0.42	0.00	0.66	0.80	0.33	0.29	0.29
52	SM07	6.8	4	2.8	0.09	0.29	0.00	0.00	0.02	1.00	0.33	0.82	0.21
53	CWC01	6.7	3	3.7	0.36	0.00	0.67	0.22	0.16	0.60	0.33	0.77	0.57
54	STC03	6.7	4	2.7	0.00	0.00	0.25	0.00	0.17	0.40	0.67	0.75	0.43
55	GC04	6.5	3	3.5	0.45	0.00	0.75	0.00	0.32	0.40	0.33	0.76	0.50
56	PL05	6.5	3	3.5	0.36	0.00	0.83	0.00	1.00	0.80	0.33	0.19	0.00
57	GC05	6.5	3	3.5	0.55	0.00	0.75	0.00	0.32	0.40	0.33	0.76	0.36
58	SC01	6.5	3	3.5	0.45	0.00	0.50	0.00	0.21	0.40	0.33	0.84	0.71
59	SM06	6.3	4	2.3	0.00	0.14	0.00	0.00	0.02	0.80	0.33	0.82	0.21

Appendix E: Prioritization Results Summary

Rank	ID	Final Score	Restoration Need Score	Multiple Benefits Score	Carbon Storage	Cascades Frog	Climate Resiliency	Fish	Hydrological Importance	Sierra Nevada Yellow-Legged Frog	Southern Long-Toed Salamander	Water Quality	Willow Flycatcher
60	LTC05	6.0	2	4.0	0.64	0.00	0.33	0.74	0.13	0.60	0.33	0.82	0.43
61	LTC04	6.0	2	4.0	0.55	0.00	0.33	0.74	0.13	0.60	0.33	0.82	0.50
62	CH02	5.8	3	2.8	0.09	0.00	0.58	0.00	0.65	0.80	0.00	0.63	0.00
63	CH04	5.4	2	3.4	0.36	0.00	0.58	0.00	0.65	0.80	0.33	0.63	0.00
64	LTC01	5.3	2	3.3	0.36	0.00	0.17	0.00	0.32	0.40	0.33	1.00	0.71
65	CH01	5.2	2	3.2	0.18	0.00	0.58	0.00	0.65	0.80	0.33	0.63	0.00
66	SM04	5.2	1	4.2	0.45	0.29	0.00	0.82	0.02	1.00	0.33	0.82	0.43
67	MC01	5.0	3	2.0	0.00	0.00	0.75	0.00	0.29	0.00	0.00	0.67	0.29
68	GC09	4.9	2	2.9	0.09	0.00	0.42	0.00	0.25	0.40	0.33	0.84	0.57
69	CH03	4.7	2	2.7	0.00	0.00	0.58	0.00	0.65	0.80	0.00	0.63	0.00
70	GC02	4.6	2	2.6	0.09	0.00	0.50	0.00	0.40	0.40	0.33	0.56	0.29
71	CC07	4.5	0	4.5	0.09	0.57	1.00	0.00	0.57	0.80	0.67	0.63	0.21
72	GS01	4.4	2	2.4	0.00	0.00	0.42	0.00	0.27	0.40	0.33	0.76	0.21
73	SU01	4.3	1	3.3	0.09	0.00	0.42	0.00	0.66	1.00	0.67	0.29	0.21
74	YC07	4.2	0	4.2	0.64	0.00	0.75	0.35	0.00	0.60	0.33	1.00	0.57
75	YC06	4.2	0	4.2	0.64	0.00	0.75	0.19	0.00	0.60	0.33	1.00	0.64
76	YC09	4.1	0	4.1	0.45	0.00	0.75	0.16	0.00	0.60	0.67	1.00	0.50
77	PL03	4.0	1	3.0	0.18	0.00	0.75	0.00	0.79	0.80	0.00	0.50	0.00
78	MR01	3.8	1	2.8	0.09	0.00	0.75	0.00	0.15	0.40	0.33	0.75	0.36
79	STC05	3.8	1	2.8	0.18	0.00	0.25	0.00	0.17	0.40	0.67	0.75	0.36
80	MH01	3.7	1	2.7	0.00	0.00	0.75	0.00	0.29	0.40	0.33	0.67	0.29
81	MR02	3.7	1	2.7	0.27	0.00	0.75	0.00	0.15	0.40	0.00	0.75	0.36
82	CC02	3.3	0	3.3	0.00	0.14	0.92	0.00	0.54	0.80	0.00	0.65	0.29
83	SM05	3.3	1	2.3	0.00	0.14	0.00	0.00	0.02	0.80	0.33	0.82	0.21
84	GC08	3.1	0	3.1	0.00	0.00	0.75	0.00	0.32	0.60	0.33	0.76	0.36
85	SM03	3.1	1	2.1	0.00	0.14	0.00	0.00	0.02	0.80	0.00	0.82	0.29
86	PHC01	3.0	1	2.0	0.00	0.00	0.00	0.00	0.06	0.40	0.33	0.89	0.29
87	BC01	2.8	0	2.8	0.09	0.36	0.17	0.00	0.12	0.80	0.33	0.55	0.36
88	WH01	2.7	0	2.7	0.00	0.00	0.83	0.00	0.22	0.40	0.33	0.59	0.29

Appendix E: Prioritization Results Summary

89	SF01	2.3	0	2.3	0.18	0.00	0.08	0.00	0.06	0.40	0.00	0.98	0.64
90	MC02	2.0	0	2.0	0.00	0.00	0.75	0.00	0.29	0.00	0.00	0.67	0.29

Appendix F: Priority Meadows

Colby Creek 01

This 3.6 acre meadow is degraded by impacted channel morphology and conifer/upland shrub encroachment. It has moderately impacted scores for all three channel morphology indicators, and has two headcuts totaling 91 inches, making it a priority for hydrological restoration. It is also moderately impacted by encroachment. We categorized this meadow as sensitive and recovering based on our climate sensitivity NDVI analysis. The meadow exhibited stressed meadow vegetation from 1984 until 1995, at which point the meadow appears to shift to a more sensitive but recovering state; this shift corresponds with above average precipitation through 2000 and the closure of the grazing allotment over this meadow in 1999. The NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation. This meadow scored highly for climate resiliency, with more moderate scores for hydrological importance, water quality, amphibians, and willow flycatcher. The meadow is located in a watershed with historic observations and is within the current range for Sierra Nevada yellow-legged frog, but lacks additional suitable habitat indicators. The meadow is located in a catchment projected to experience relatively less change in snowpack, runoff, precipitation, mean annual temperature, and maximum temperature, and has relatively low historic climatic water deficit compared to other meadows, which suggests that it might be more resilient to climate change impacts than meadows in other catchments.

Colby Creek 03

This 99.5 acre meadow is degraded by impacted channel morphology and conifer/upland shrub encroachment. It has heavily impacted scores for two channel morphology indicators (bank height and bank stability) and has two headcus totaling 31 inches, making it a priority for hydrological restoration. It is also moderately impacted by encroachment. We categorized this meadow as sensitive and recovering based on our climate sensitivity NDVI analysis. It exhibited stressed meadow vegetation from 1984 until 1999, at which point the meadow appears to shift to a more sensitive but recovering state; this shift corresponds with the closure of the grazing allotment over this meadow in 1999. The NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation.

This meadow had one of the highest scores for multiple benefits. It scored highly for carbon storage, climate resiliency, and all five species targets; it had moderate scores for water quality and hydrological importance. This meadow is one of the largest at 99.5 acres in size, features a perennial stream, and has 26.6 acres of fens present, making it a high priority for protection of existing carbon stocks and restoration to increase carbon storage. Cascades frogs are currently present in the meadow. It is important for fish as it features over 4300 meters of perennial stream in the Butte Creek watershed, among other factors. The meadow is within a watershed with historic observations of Sierra Nevada yellow-legged frog and is within the species' current range; it is also within the range of southern long-toed salamander. It is a riparian/discharge slope meadow with existing willow/alder cover within dispersal distance for recently occupied willow flycatcher meadows, and has a large area to perimeter ratio. The meadow is located in a catchment projected to experience relatively less change in snowpack, runoff, precipitation, mean annual temperature, and maximum temperature compared to other meadows, which suggests that it might be more resilient to climate change impacts than meadows in other catchments.

Colby Creek 04

This 53.9 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and grazing. It has heavily impacted scores for bank height and bank stability, and has two headcuts totaling 47 inches, making it a high priority for hydrological restoration. It is also heavily impacted by encroachment. It is located in an active grazing allotment and has evidence of grazing. We categorized this meadow as sensitive and recovering based on our climate sensitivity NDVI analysis. The meadow exhibited stressed meadow vegetation from 1984 until around 1996, at which point the meadow appears to shift to a more sensitive but recovering state; this shift corresponds with above average precipitation through 2000 and the closure of the grazing allotment over this meadow in 1999. The NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation.

This meadow had the highest score for multiple benefits. It scored highly for carbon storage, climate resiliency, and all five species targets, and had more moderate scores for water quality and hydrological importance. The meadow is important for carbon storage and species targets because of its relatively large size, fens, seep/springs, and perennial stream. It is located within 1km of a current population of Cascades frog. It is important for fish as it features nearly 1100 meters of perennial stream in the Butte Creek watershed, among other factors. It falls within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog, and is located in watersheds with historic observations of the frog. It is a riparian meadow with existing willow/alder cover within dispersal distance for recently occupied willow flycatcher meadows, and has a relatively large area to perimeter ratio. The meadow was one of the highest scoring for potential climate resiliency and scored moderately high for hydrological importance. The meadow is located in a catchment projected to experience relatively less change in snowpack, runoff, precipitation, mean annual temperature, and maximum temperature and has relatively low historic climatic water deficit compared to other meadows, which suggests that it might be more resilient to climate change impacts than meadows in other catchments.

Colby Creek 05

This 19.2 acre meadow is degraded by impacted channel morphology. It has moderately impacted scores for all three channel morphology indicators and has one headcut with a height of 27 inches, making it a high priority for hydrological restoration need. We categorized this meadow as sensitive and recovering based on our climate sensitivity NDVI analysis. The meadow exhibited stressed meadow vegetation from 1984 until 1995, at which point the meadow appears to shift to a more sensitive but recovering state; this shift corresponds with above average precipitation through 2000 and the closure of the grazing allotment over this meadow in 1999. The NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation.

This meadow had one of the highest scores for multiple benefits. It scored highly for carbon storage, climate resiliency, and all five species targets. The meadow is important for carbon storage and species targets because it is relatively large and features fens, seep/spring and perennial stream. It is located within 1km of a current population of Cascades frog. It is important for fish as it features 1258 meters of perennial stream in the Butte Creek watershed, among other factors. It falls within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog, and is located in watersheds with historic observations of the frog. It is a riparian meadow with existing willow/alder cover within dispersal distance for recently occupied willow flycatcher meadows, and has a relatively large area to perimeter ratio. The meadow scored highly for climate resiliency as it is located in a catchment projected to experience relatively less change in snowpack, runoff, mean annual temperature, and maximum temperature compared to other meadows, which suggests that it might be more resilient to climate change impacts than meadows in other catchments.

Colby Creek 06

This 26.5 acre meadow is degraded by impacted channel morphology and conifer/upland shrub encroachment. It has moderately impacted scores for bank height and bank stability and is moderately impacted by encroachment. We categorized this meadow as sensitive and recovering based on our climate sensitivity NDVI analysis. The meadow exhibited stressed meadow vegetation from 1984 until around the early 2000s, at which point the meadow appears to shift to a more sensitive but recovering state; this shift may reflect a delayed response to the closure of the grazing allotment over this meadow in 1999. The NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation.

This meadow scored highly for climate resiliency and our five species targets. It features seep/springs and a perennial stream, which are important for target species. It is located within 1km of a current population of Cascades frog. It is important for fish as it features a perennial stream in the Butte Creek watershed, among other factors. It falls within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog, and is located in watersheds with historic observations of the frog. It is a riparian/discharge slope meadow with existing willow/alder cover within dispersal distance for recently occupied willow flycatcher meadows, and has a relatively large area to perimeter ratio. The meadow scored highly for climate resiliency as it is located in a catchment projected to experience relatively less change in snowpack, runoff, mean annual temperature, and maximum temperature compared to other meadows, which suggests that it might be more resilient to climate change impacts than meadows in other catchments.

Grizzly 327

This 33.6 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of cattle grazing. It is moderately impacted for gullies/ditches and heavily impacted for bank stability, and has nine headcuts totaling 128 inches in height, making it a high priority for hydrological restoration. It is heavily impacted by encroachment. It also has evidence of grazing and is located in an active grazing allotment. We categorized this meadow as sensitive based on our climate sensitivity NDVI analysis, as the NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation.

This meadow had more moderate to low scores across the conservation targets and likely fell in our list of priority meadows because it was one of the highest scoring for hydrological restoration need. The meadow falls within the current range of Cascades frog, Sierra Nevada yellow-legged frog, and southern long-toed salamander and is located in a watershed with historic observations of Sierra Nevada yellow-legged frog, but lacks habitat suitability indicators for these amphibians. It is within dispersal distance of a recently occupied willow flycatcher meadow, features willow/alder cover, and has a relatively large area to perimeter ratio, but has an intermittent, rather than perennial, stream. It has moderately high historic snowpack and low annual historic climatic water deficit, and is projected to have relatively lower change in snowpack in the future compared to meadows in other catchments.

Grizzly Creek 06

This 5.8 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of cattle grazing. It is moderately impacted for bank height and gullies/ditches and is heavily impacted for bank stability. It has four headcuts totaling 47 inches in height, making it a priority for hydrological restoration need. It is heavily impacted by encroachment. It has evidence of grazing and is located in an active grazing allotment, with cattle use prevalent through the entire meadow. We categorized this meadow as sensitive based on our climate sensitivity NDVI analysis, as the NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation. The meadow scored highly for climate resiliency because it is in a watershed projected to experience relatively less change in precipitation and baseflow relative to other meadows' watersheds. It had a moderately high score for water quality and more moderate to low scores for the other conservation targets. This meadow likely fell into our list of priority meadows because it was one of the highest scoring for hydrological restoration need. It is a riparian meadow with some alder/willow cover within the dispersal distance for willow flycatcher, but it has an intermittent, rather than perennial, stream. It is within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog, but lacks suitable habitat indicators for these species. It is located in a watershed with moderately high condition and moderately high threats relative to meadows in other watershed, suggesting possible water quality benefits through conservation and restoration actions.

Grizzly Creek 07

This 11 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of cattle grazing. It has moderately impacted bank height and bank stability, and is heavily impacted by encroachment. It has evidence of grazing and is located in an active grazing allotment, with cattle impacts dispersed throughout the meadow. We categorized this meadow as sensitive based on our climate sensitivity NDVI analysis, as the NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation. This meadow scored relatively highly for climate resiliency and water quality, with moderate to low scores for the other conservation targets. This meadow is located in a catchment projected to experience relatively less change in precipitation and baseflow relative to other meadows. It is 10 acres in size and features a seep/spring, intermittent stream, and a fen, which is important to conserve to prevent loss of carbon stores. It falls within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog. It is a riparian meadow with existing willow/alder cover within the dispersal distance of a recently occupied willow flycatcher meadow, but lacks a perennial stream. It is located in a watershed with moderately high condition and moderately high threats relative to meadows in other watershed, suggesting possible water quality benefits through conservation and restoration actions.

Grizzly Spring 02

This 11.1 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of cattle grazing. It has heavily impacted bank stability and moderately impacted bank height, and is heavily impacted by encroachment. It has evidence of grazing and is located in an active grazing allotment. We categorized this meadow as sensitive, as NDVI is correlated with precipitation, indicating some sensitivity of meadow vegetation to precipitation. This meadow scored highly for water quality, with low to moderate scores for the other conservation targets. It is located in a watershed with moderately high condition and moderately high threats relative to meadows in other watershed, suggesting possible water quality benefits through conservation and restoration actions. It is located within the current range for Sierra Nevada yellow-legged frog and southern long-toed salamander. It has existing willow/alder cover, a relatively high area to perimeter ratio and is located within the dispersal distance of a recently occupied willow flycatcher meadow, but lacks a perennial stream.

LT Creek 02

This 14.8 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of cattle grazing. It has a moderately impacted bank stability and has one headcut totaling 50 inches in height. It is heavily impacted by encroachment. It has evidence of grazing and is located in an active grazing allotment. We categorized this meadow as sensitive and recovering based on our climate sensitivity NDVI analysis. The meadow exhibited some stressed conditions in the late 1980s and early 1990s, but has exhibited some recovery. The NDVI is correlated with precipitation, indicating some sensitivity of meadow vegetation to precipitation.

This meadow scored highly for carbon storage, water quality, and several target species. It is relatively large compared to the other meadows at 14.8 acres in size, features 9.6 acres of fens, and features a perennial stream, making it high priority for carbon storage. It is high priority for fish because it features 525 meters of perennial stream and is located in a watershed with relatively lower road density compared to meadows in other watersheds; its watershed also has a reintroduce strategy listed for steelhead trout. It is located within the current range for Sierra Nevada yellow-legged frog. It is a riparian meadow with existing willow/alder cover and a relatively high area to perimeter ratio within dispersal distance of a recently occupied willow flycatcher meadow. It is located in a watershed in relatively high condition and with relatively high threats compared to meadows in other watersheds, and meadow restoration and conservation actions could potentially address water quality impacts.

Panhandle Creek 03

This is one of the smaller meadows at just under 1 acre in size. It is degraded by impacted channel morphology, with moderately impacted scores for bank height and bank stability. It is located in an active grazing allotment with evidence of cattle grazing and moderate cattle impacts throughout the meadow. We categorized this meadow as resilient based on our NDVI climate sensitivity analysis, as the average NDVI values tend to be near or above the median even in years with below average precipitation, including during the 2012-2016 drought. This may indicate that the meadow has a persistent groundwater source that is able to sustain meadow vegetation even in dry years. This meadow scored highly for fish and water quality and had low to moderate scores for willow flycatcher, southern long-toed salamander, and Sierra Nevada yellow-legged frog. It is located in a watershed in relatively high condition and with relatively high threats compared to meadows in other watersheds, and meadow restoration and conservation actions could potentially address water quality impacts. It scored highly for fish as it has 120m of perennial stream in a watershed with relatively low road density. It is located within 12km dispersal distance of a recently occupied willow flycatcher meadow and has a perennial stream present, although it has a relatively low area to perimeter ratio and higher cover of willow and alders than desirable for willow flycatcher. It is located within the current range of Sierra Nevada yellow-legged frog and southern long-toed salamander. This meadow scored very low for climate resiliency and hydrological importance relative to other meadows, suggesting it may be more vulnerable to climate change.

Rock Creek 02

This 7.2 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of cattle grazing. It has moderately or heavily impacted scores for two channel morphology indicators and has one headcut totaling 11 inches in height. It is also heavily impacted by encroachment. It has evidence of grazing and is located in an active grazing allotment, with cattle impacts dispersed throughout the meadow, mostly in the fen area. We categorized this meadow as sensitive and recovering based on our NDVI climate sensitivity analysis. The meadow exhibited stressed conditions in the late 1980s and early 1990s, at which point the meadow has exhibited some recovery and exhibits some sensitivity. The NDVI is correlated with precipitation, indicating some sensitivity of meadow vegetation to precipitation.

This meadow had relatively high scores for carbon storage, water quality, southern long-toed salamander, Sierra Nevada yellow-legged frog, and willow flycatcher. The meadow is 7 acres in size and features 3.2 acres of fens, a perennial stream, a pond/lake, and a seep/spring, all important habitat suitability indicators for target species. It is important to conserve the meadow's belowground carbon stocks in the fen area, which may be at risk from cattle grazing. It falls within the current range for southern long-toed salamander and Sierra Nevada yellow legged-frog. It is a riparian meadow with existing willow/alder cover within dispersal distance of a recently occupied willow flycatcher meadow. It is located in a watershed in relatively high condition and with relatively high threats compared to meadows in other watersheds, and meadow conservation and restoration actions could potentially address water quality impacts.

Rock Creek 03

This 12.6 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of grazing. It has heavily impacted bank stability and is moderately impacted by encroachment. It is located in an active grazing allotment, with cow trampling that has impacted the channel, causing potholes and ditches. We categorized this meadow as sensitive and recovering based on our climate sensitivity NDVI analysis. The meadow exhibited more stressed conditions until the mid-1990s, at which point the meadow appears to shift to a more sensitive but recovering state. The NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation.This meadow scored highly for water quality and had low to moderate scores for the other conservation targets. It is located in a watershed in relatively high condition and with relatively high threats compared to meadows in other watersheds, and meadow restoration and conservation actions could potentially address water quality impacts. It falls within the current range of southern long-toed salamander and Sierra Nevada yellow-legged frog. It is located within dispersal distance of a recently occupied willow flycatcher meadow with existing willow/alder cover and has a relatively high area to perimeter ratio, although it lacks a perennial stream. It had a moderately high score for climate resiliency, and is located in a catchment projected to experience relatively smaller declines in precipitation, runoff, snowpack, and baseflow in the future compared to other watersheds.

Sawmill Tom Creek 02

This 4.5 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of grazing. It has heavily impacted bank height and bank stability, and is moderately impacted by encroachment. It is located in an active grazing allotment with heavy cattle impacts. Qualitative notes from the AR scorecard assessment indicate that damage to cows is extensive, with the grass grazed to stubble, channels highly eroded from cow trampling, and cow trails heavily beaten into the meadow surface. We categorized this meadow as sensitive based on our climate sensitivity NDVI analysis. The NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation. This meadow scored highly for water quality, with low to moderate scores for the other conservation targets. It is located in a watershed in relatively high condition and with relatively high threats compared to meadows in other watersheds, and meadow restoration and conservation actions could potentially address water quality impacts. This meadow is located within dispersal distance of a recently occupied willow flycatcher meadow with existing willow/alder cover and has a relatively high area to perimeter ratio, although it lacks a perennial stream. It is located within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog.

Snag Lake 05

This 12.5 acre meadow is degraded by impacted channel morphology and conifer/upland shrub encroachment. It has moderately impacted bank height, heavily impacted bank stability, and is moderately impacted by encroachment. We categorized this meadow as resilient based on our climate sensitivity NDVI analysis. It exhibited some stressed conditions in the late 1980s and early 1990s, but shifted to more resilient conditions around 1995. This meadow's NDVI has tended to be close to or above the median, even in years with below average precipitation, although there was a decrease in NDVI below the median during the 2012-2016 drought. This meadow may have a persistent groundwater source that has sustained the meadow vegetation even in years with below average precipitation.

This meadow scored highly for Sierra Nevada yellow-legged frog, southern long-toed salamander, and hydrological importance, with moderate to low scores for the other targets. This meadow is located within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog, and is located within a watershed with historic observations of the frog. It features a pond/lake and intermittent stream, which are habitat indicators for these two species. It is located within the dispersal distance of a recently occupied willow flycatcher meadow, features existing willow/alder cover, has a relatively large area to perimeter ratio, and has a stream, although it is not perennial. This meadow is located in the largest watershed compared to the other meadows and its watershed has relatively higher mean annual historic snowpack, precipitation, and recharge/runoff, although its watershed is projected to experience relatively larger declines in precipitation, baseflow, and runoff in the future compared to other watersheds.

Willow Creek 01

This 4.1 acre meadow is degraded by impacted channel morphology and has evidence of cattle grazing. It has moderately impacted bank height and heavily impacted bank stability as well as two headcuts totaling 52 inches in height, making it one of the highest priorities for hydrological restoration. It is located in an active grazing allotment. Qualitative notes from the AR scorecard assessment indicate that cows have degraded a large portion of the meadow, with stubble, trails, and erosion to the channel from cow use. We categorized this meadow as sensitive based on our climate sensitivity NDVI analysis. The NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation. This meadow had low to moderate scores for the conservation targets and likely fell within the top priority meadows because it was one of the highest scoring for hydrological restoration need. It falls within the current range for Sierra Nevada yellow-legged frog and southern long-toed salamander, and within a watershed with historic observations of the frog. It has an intermittent stream present but lacks other habitat suitability indicators for these amphibians. It falls within the dispersal distance of a recently occupied willow flycatcher meadow but lacks habitat suitability indicators.

Willow Creek 02

This 2.2 acre meadow is degraded by impacted channel morphology and has evidence of cattle grazing. It has moderately or heavily impacted scores for all three channel morphology indicators and has one headcut totaling 34 inches in height, making it one of the highest priorities for hydrological restoration. It has evidence of grazing and is located in an active grazing allotment; cattle have degraded the meadow and have contributed to highly incised, eroded channels. We categorized this meadow as sensitive based on our climate sensitivity NDVI analysis, as the NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation. This meadow had low to moderate scores for the conservation targets and likely fell within our list of priority meadows because it was one of the highest scoring for hydrological restoration need. It falls within the current range for Sierra Nevada yellow-legged frog and southern long-toed salamander, and within a watershed with historic observations of the frog. It has an intermittent stream present but lacks other habitat suitability indicators for these amphibians. It falls within the dispersal distance of a recently occupied willow flycatcher meadow with existing willow/alder cover, but lacks a perennial stream and does not have as large of an area to perimeter ratio as other meadows.

Willow Creek West 01

This 7.7 acre meadow is degraded by impacted channel morphology and conifer/upland shrub encroachment. It has moderately or heavily impacted scores for all three channel morphology indicators and has one headcut totaling 34 inches in height, making it one of the highest priorities for hydrological restoration. We categorized this meadow resilient and recovering based on our climate sensitivity NDVI analysis. The meadow exhibited stressed conditions from 1984 until around 2002, when it indicated signs of recovery and more resilient conditions. This shift may have been in response to the closing of the grazing allotment over the meadow in 1999. In the years since, the average NDVI values are above the median even in years with below average precipitation, including during the 2012-2016 drought. This may indicate that the meadow has a persistent groundwater source that is able to sustain meadow vegetation even in dry years.

This meadow was one of the highest scoring for multiple benefits. It scored highly for all species targets, carbon storage, and climate resiliency. It features fens, a seep/spring, and a perennial stream, which are suitable habitat indicators for several species and are important for carbon storage. The meadow is located within 1km of a current population of Cascades frog. It is high priority for fish because it features 326 meters of perennial stream that is projected to have a relatively smaller change in stream temperature compared to other meadow streams, and is located in the Butte Creek watershed. It falls within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog, and is located in watersheds with historic observations of the frog. It is a discharge slope meadow with existing willow/alder cover, a perennial stream, and a relatively high area to perimeter ratio located within dispersal distance of a recently occupied willow flycatcher meadow. This meadow scored highly for climate resiliency because it is in a catchment projected to experience relatively less change in snowpack, runoff, and mean annual maximum temperature, which suggests that it may be more resilient to climate change impacts compared to meadows in other catchments.

Willow Creek West 02

This 7.7 acre meadow is degraded by impacted channel morphology and conifer/upland shrub encroachment. It has moderately impacted bank height and has one headcut totaling 48 inches in height. It is moderately impacted by encroachment. The meadow is split into two sections because of a parcel of private land in the middle of the meadow, which may be a barrier to restoration. We categorized this meadow as sensitive based on our climate sensitivity NDVI analysis, as the NDVI is correlated with precipitation, indicating some sensitivity to changes in precipitation. This meadow was one of the highest scoring for multiple benefits. It scored highly for several target species and climate resiliency. It features a perennial stream and a seep/spring, which are habitat suitability indicators for several target species. It is high priority for fish because it is located in the Butte Creek watershed, features 327 meters of perennial streams, and is projected to have a relatively smaller change in stream temperature compared to other meadow streams. It is a discharge slope meadow with a perennial stream and a relatively high area to perimeter ratio located within dispersal distance of a recently occupied willow flycatcher meadow. It has a current population of Cascades frog. It is located within the range for southern long-toed salamander and Sierra Nevada yellow-legged frog, and is in a watershed with historic observations of the frog. This meadow scored highly for climate resiliency because it is in a catchment projected to experience relatively less change in snowpack, runoff, and mean annual maximum temperature compared to meadows in other catchments.

Willow Creek West 03

This 5.1 acre meadow is degraded by impacted channel morphology and conifer/upland shrub encroachment. It has moderately impacted scores for bank height and bank stability, and is moderately impacted by encroachment. We categorized this meadow as sensitive and recovering based on our climate sensitivity NDVI analysis. It exhibited some stressed conditions from the late 1980s through late 1990s, at which point it exhibited some recovery and switched to more sensitive conditions. This may have occurred in response to the closing of the grazing allotment of the meadow in 1999. Since then, the NDVI has been more correlated with precipitation, indicating some sensitivity to changes in precipitation. This meadow was one of the highest scoring for multiple benefits. It scored highly for several target species and climate resiliency. It features a perennial stream, a seep/spring, and a fen, which are habitat suitability indicators for several target species and are important for carbon storage. It is a discharge slope meadow with a perennial stream and a relatively high area to perimeter ratio located within dispersal distance of a recently occupied willow flycatcher meadow. It has a current population of Cascades frog. It is located within the range for southern long-toed salamander and Sierra Nevada yellow-legged frog, and is in a watershed with historic observations of the frog. This meadow scored highly for climate resiliency because it is in a catchment projected to experience relatively less change in snowpack, runoff, and mean annual maximum temperature compared to meadows in other catchments.

Yellow Creek 08

This 21.3 acre meadow is degraded by impacted channel morphology, conifer/upland shrub encroachment, and has evidence of grazing. It has moderately impacted bank height and bank stability, and is moderately impacted by encroachment. It has evidence of grazing and is located in an active grazing allotment, with heavy cattle trampling throughout most of the meadow. We categorized this meadow as resilient and recovering based on our climate sensitivity NDVI analysis. It exhibited stressed conditions until around 2000, at which point it exhibited some recovery and switched to more resilient conditions. In the years since, the average NDVI values are above the median even in years with below average precipitation, including during the 2012-2016 drought. This may indicate that the meadow has a persistent groundwater source that is able to sustain meadow vegetation even in dry years.

This meadow scored highly for carbon storage, climate resiliency, and several target species, and was the highest scoring meadow for water quality. It features a seep/spring, perennial stream, and fen, which are habitat suitability indicators for several target species and are important for carbon storage. It falls within the current range for southern long-toed salamander and Sierra Nevada yellow-legged frog. It is a riparian meadow with a perennial stream and a relatively high area to perimeter ratio located within dispersal distance of a recently occupied willow flycatcher meadow. It scored highly for climate resiliency because it is located in a catchment projected to experience relatively less change in precipitation and baseflow compared to other meadows. It was the highest scoring for water quality because it is located in a watershed in relatively high condition and with the highest threats compared to meadows in other watersheds. The meadow is located in a watershed with relatively high stream health compared to other meadows in the Sierra Nevada and has the highest road density relative to the other Storrie meadows; the meadow is also located in an active grazing allotment. These all pose threats to water quality. Meadow conservation and restoration actions might confer water quality benefits.