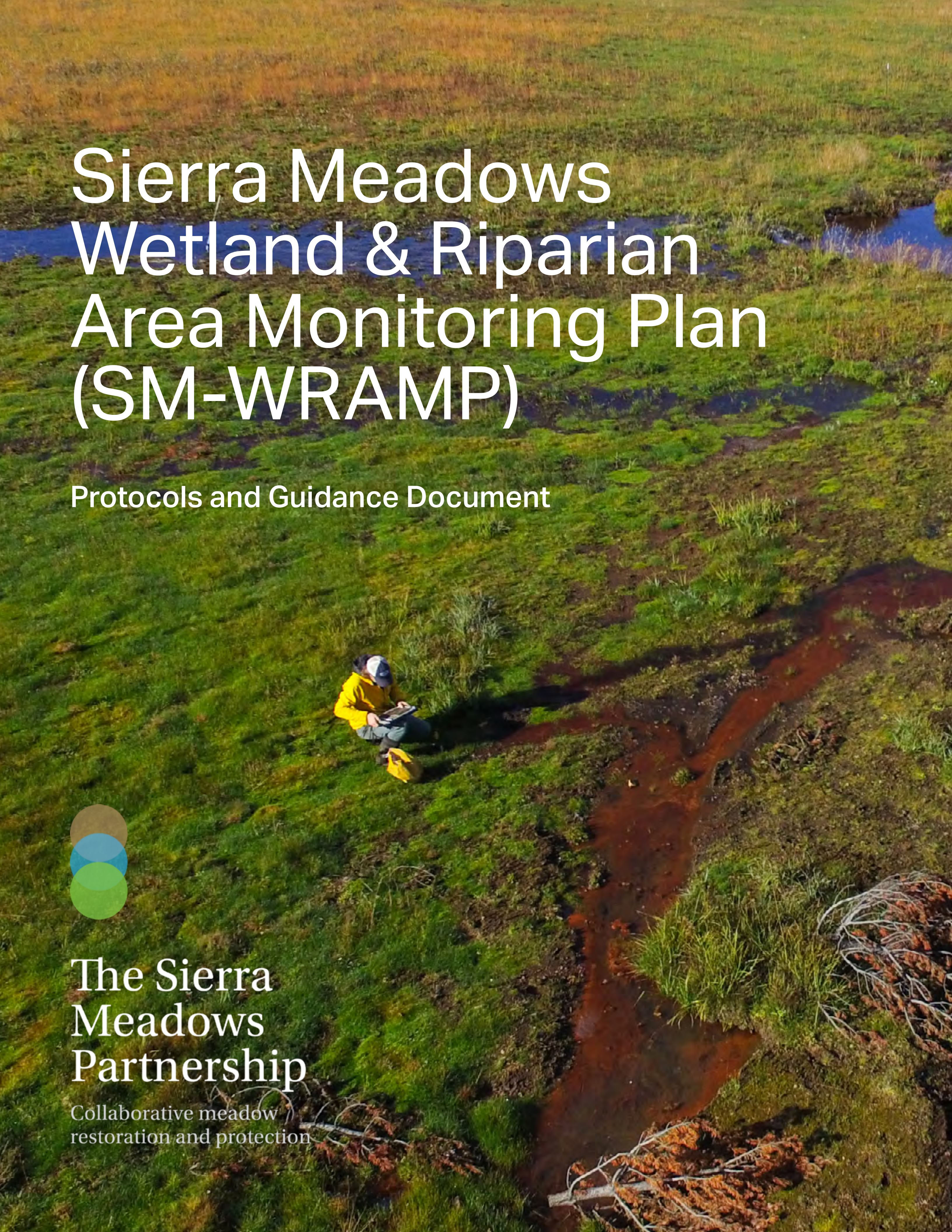
Sierra Meadows Wetland & Riparian Area Monitoring Plan (SM-WRAMP)

Protocols and Guidance Document



The Sierra Meadows Partnership

Collaborative meadow restoration and protection

Pre and post meadow restoration

Sierra Meadows Wetland & Riparian Area Monitoring Plan (SM-WRAMP) Protocols and Guidance Document

Cover photo: Osa Meadow, photo: Mike Wier. Left: Loney Meadow pre- and post-restoration as shown in the recent Technical Report completed on Sierra meadows in which Loney was studied for carbon benefits: Amy G. Merrill, Cody Reed, Ben Sullivan, Stephen C. Hart. 2022. Technical Memo: American C Registry Protocol Justification. Below ground carbon storage in mountain meadows: response to hydrologic restoration. Grant Agreement CalTrout –CDFW No. P1496001.

MODOC PLATEAU
WARNER MOUNTAINS
Redding
CASCADE RANGE
CASCADE FOOTHILLS
N. SIERRA NEVADA RANGE
Sacramento
NEVADA
EASTERN SIERRA NEVADA
WHITE AND INYO MOUNTAINS
N. SIERRA NEVADA FOOTHILLS
San Francisco
C. SIERRA NEVADA RANGE
C. SIERRA NEVADA FOOTHILLS
Fresno
S. SIERRA NEVADA RANGE
S. SIERRA NEVADA FOOTHILLS
Pacific Ocean
Sierra Nevada Meadows
Jepson Geographic Subdivisions
Sierra Meadows Strategy Area
Forest Service
National Park Service
Map Sources
Jepson Geographic Subdivisions: JepsonFlora Project. FederalLands: US National Atlas. Meadows: Fryjoff-Hung & Viers, 2012, UC Davis.
N
0 25 50 100 Kilometers
0 15 30 60 Miles
Stillwater Sciences

Sierra Meadows WRAMP Monitoring Plan

OVERVIEW

The Sierra Meadows Wetland and Riparian Area Monitoring Plan (SM-WRAMP) was developed by the Sierra Meadows Partnership WRAMP Working Group to create a framework to assess pre- and post-restoration conditions in a standardized manner for mountain meadows in the Sierra Nevada.

The goals of this effort are to track the progress and outcomes of meadow restoration and conservation efforts, and to provide information for adaptive management of the Sierra Meadow Strategy *(Sierra Meadows Partnership (SMP) Drew et al, 2016)*.

The monitoring protocols address a goal set out in the SM Strategy under **Approach 1: "Restore and/or protect meadows to achieve desired conditions."**

By developing a common set of monitoring protocols with guidance instructions on how to use them, a body of comparable data will be created from restored and protected meadows in the Sierra Nevada. This comparable data can then be used to assess the success of different restoration approaches across the range.

The two primary objectives of the SM-WRAMP as identified in the 3-Yr Work Plan (SMP, 2018) are to:

1. Serve as a robust, replicable and cost-efficient monitoring plan to track and understand the extent and effectiveness of meadow restoration and conservation actions by utilizing protocols pre- and post-restoration and/or conservation. Use of SM-WRAMP will document efficacy and management of meadow restoration and improve scientific understanding of causal relationships among key meadow functions and restoration actions, allowing for comparison with other management and regulatory programs at regional and statewide scales.

2. Serve as a short, medium and long-term approach to monitoring implementation of the Sierra Meadows Strategy. The Strategy is intended to guide restoration and maintenance of the health of meadows, including assessments, prioritization, project design, permitting, implementation and post-implementation monitoring. The Strategy seeks to increase the pace, scale and efficacy of meadow restoration, targeting 30,000 acres of restored and/or protected meadows by 2030. Data gathered by SM-WRAMP users, stored in a publicly accessible database, will document (a) the abundance, in number and acreage, of meadows protected and/or restored, (b) the diversity and distribution of meadows restored/protected, (c) overall condition of meadows reported, and (d) meadow attributes such as water storage, soil carbon storage, biological abundance, diversity, and distribution, of plants, fish, birds, amphibians, and mammals.

Figure 1. The geographic scope, or Strategy Area, for the Sierra Meadows Strategy includes all of the Sierra Nevada, the Modoc Plateau, and the Southern Cascades, along with the Sierra and Cascade foothills and the Warner Mountains. From the Sierra Meadows Strategy (Sierra Meadows Partnership, Drew et al 2016).

"Meadows of the Sierra Nevada fill an essential role for the ecosystem–they catch winter run-off when the snow melts, they store and release water throughout the year and are a bedrock of biodiversity. They capture carbon in their below-ground root systems and above-ground greenery, they are relatively resistant to wildfire, and they are important wildlife corridors. Given the external threats that meadows face, it's a multi-stakeholder effort to maintain meadows in top shape."

- Dr Sandra Jacobson, PhD, CalTrout Regional Director

Read more on CalTrout Field Notes:
Meadows Matter:
https://caltrout.org/news/field-note-meadows-matter

SM-WRAMP DEVELOPMENT AND TIMELINE

This guidance document contains instructions on how to select and implement SM-WRAMP protocols and how to acquire, process and store data. Draft SM-WRAMP protocols were generated by the SM-WRAMP Advisory Committee (WAC) during spring 2020, building on work of the SM-WRAMP Monitoring Workgroup over the past decade. These protocols assess key meadow attributes/indicators, forming the basis for standardized monitoring of meadows. Protocols were piloted in Horse Meadow on the Sequoia National Forest by two experienced field teams in August 2020. Comments from the WAC, field practitioners and the Monitoring Workgroup were compiled into a Comment Matrix. Draft protocols were further revised by the WAC and Monitoring Workgroup through December 2020, then finalized in March 2021.

Monitoring timeline

SM-WRAMP Monitoring should be performed for at least 15 years (total) pre/post meadow restoration. If funding for monitoring is limited, monitoring should be performed for at least 1 year pre-restoration, then for 2 consecutive years post-restoration, then at 5 and 10 (or 15) years post-restoration.

To reduce costs, restoration objectives may be monitored over the long-term substituting in less costly proxy monitoring protocols (e.g. using vegetation NDVI protocol as proxy for hydrology). Some agencies require access to conduct monitoring and/or to perform adaptive management for 10-25 year periods following project completion as a condition of funding. Monitoring data would need to be acquired according to timelines set forth in funding agency agreements (Appendix A).

Control meadows

BACI (Before-After-Control-Impact) designs are commonly used to evaluate natural and human-caused changes to ecological variables when treatment sites cannot be randomly chosen. The WAC chose not to apply BACI design to Sierra meadows, although some restoration practitioners may opt for this, because control meadows sufficiently similar in all attributes are difficult to identify, and replication is limited by the number of potential restoration sites, cost and logistical factors. Long-term monitoring data from meadows across the Sierra Meadows Partnership Area within areas of comparable elevation, ecosystem type, rainfall, and geology can be used in future analysis to control for annual climatic variation which impacts restoration response metrics (SMP Area, Figure 1).

SM-WRAMP PROTOCOL CLASSES

There are seven SM-WRAMP protocols which include sub-protocols that practitioners can choose from to report on key meadow indicators of geomorphology, hydrology, soils, grazing, vegetation, wildlife and aquatic species. Protocols to be implemented should be chosen based on meadow restoration objectives (Appendix B). Guidance on selection is included in the protocols. Not all protocols need to be implemented for restoration projects.

Training and planning are key elements to performing the correct protocols, acquiring accurate and reliable data, and reporting to public databases. Specialized training may be needed for field crew members implementing certain protocols such as geomorphology, vegetation, wildlife and aquatic species protocols (Appendix C row 8). Some shared equipment is available from SMP partners to reduce cost (e.g. Trimble R2, Smith-Root eDNA backpack unit). CalTrout Sierra regional office staff can be contacted for training guidance and sign-out sheets.

Datasheets provided with each sub-protocol can be used in hard copy, or translated for digital data collection on tablets with desired apps. The data collection and processing system is flexible to allow for personal or organizational preference for data acquisition style, while keeping the data collected and methodology similar across platforms.

Main elements of implementing the SM-WRAMP are covered in this document including: a Process Flow Diagram for the meadow restoration process (Section 5), a decision matrix for protocol selection (Appendix B), a cost matrix for each protocol based on estimates of labor and equipment, and four typical monitoring scenarios based on budget considerations (Appendix C); a matrix of restoration objectives linked to monitoring protocols (Appendix D); a stepwise look at data management, processing and storage (Section 7), a sample QA Plan template (Appendix E), data collection workflow (Appendix F), and Contacts and Collaborators (Section 11).

1. Geomorphology

Christian Braudrick, Stillwater Sciences and collaborators

Long Profile and Cross Section Survey
Assesses channel stability following stream restoration and the extent of lateral migration, channel width adjustment, aggradation and degradation, the degree to which the channel morphology is quasi-stable following restoration. Intended to monitor riparian meadows with stream channels.

Geomorphic Mapping and Grain Size
Assessment Tracks changes in channel morphology including changes to channel width and depth (see cross section and long profile), but also changes in the grain size distribution and pattern of sediment facies on the bed. Intended to monitor riparian meadows with stream channels.

2. Hydrology

Carrie Monohan, The Sierra Fund, and collaborators

Hydrologic Function - Surface Water Flow
Assesses hydrologic function which can be quantified by a meadows ability to retain water on the surface in channels, ponds, and/or depressions, connect in-channel high flows to the floodplain, and maintain higher groundwater levels into the summer season.

Hydrologic Function – Groundwater
Assesses groundwater levels which can be quantified by shallow groundwater wells, piezometers, and vegetation monitoring as a proxy for groundwater level.

3. Soils

Carrie Monohan, The Sierra Fund, and collaborators

Soil – Below Ground Biomass
Assesses below-ground total soil carbon in which subsurface hydrologic conditions of the meadow are expected to change upon restoration and may correlate with water table changes.

4. Vegetation

Shana Gross and Rachel Hutchinson, U.S. Forest Service and collaborators

Summary Vegetation Protocol
Identifies protocol name, primary attributes measured, which protocol should be selected, time required to implement the protocol, and the level of skill needed.

General Vegetation Monitoring Protocol
Assesses whether there is a change in dominant plant species cover and composition by evaluating the change in cover of individual species which allows analysis of cover by wetland indicator status, nativity, lifeform type, and/or locally important species.

NDVI/NDWI Monitoring Protocol
Normalized difference vegetation index (NDVI) is a measure of vegetation vigor. Normalized Difference Water Index (NDWI) is a measure of vegetation water content and indicates wetness of a meadow based on how much water the vegetation is holding. This protocol assesses restoration effectiveness at increasing vegetation vigour/greenness and or vegetation wetness.

R5 Range Monitoring Rooted Frequency
Evaluates the ecological status of the meadow systems based on vegetation as compared to existing long-term plots (established by the USFS – R5 range monitoring program or others). May also be used at locations where restoration activities are expected to result in changes to the plant community structure leading to changes in the ecological status of the meadow system.

Target Species Monitoring
Evaluates change in target plant species distribution and estimated population resulting from restoration activities. Usually used to track special-status plant species or plants that support habitat for special-status species.

Conifer Monitoring Protocol
Assesses the effectiveness of conifer removal from meadows as a restoration treatment and/or the reduction of conifer encroachment following other meadow/channel restoration activities.

5. Grazing

Catherine Schnurrenberger, CS Ecological Surveys and Assessments, and collaborators

Grazing Checklist
Assesses Impacts from current grazing including trampling, shearing, pocking, trailing, hedging/browse of woody vegetation and removal of herbaceous vegetation.

Bank Alteration
Assesses grazing impact to channel banks of trampling, shearing, and trailing from impact of hooves, from current year's grazing on channel banks.

Residual Stubble Height
Assesses grazing impact manifest as removal of key forage species throughout meadow system.

6. Wildlife

Brent Campos, Point Blue and collaborators

Wildlife – Birds
Assesses habitat quality for meadow birds through bird abundance and optionally, habitat measurements.

Wildlife – Beavers
Assesses the number and distribution of beaver dams and lodges/burrows, and by proxy, the extent to which beavers maintain floodplain connectivity.

7. Aquatic Species And Habitat

Lead Natalie Stauffer-Olsen, Trout Unlimited, collaborators

Visual Observation (snorkel survey, electrofishing)
Assesses presence/absence, abundance and types of aquatic species, and physical habitat characteristics of the stream channel and surrounding area.

Environmental DNA (eDNA) Sampling
Assesses presence/absence of aquatic species in a meadow, specifically for fish and amphibians in a non-invasive manner by collecting water samples of DNA shed by aquatic organisms.

Benthic Macroinvertebrate Sampling
Assesses benthic macroinvertebrate abundance, type and distribution in a stream by physically collecting samples from the substrate, sorting and identification to genus and species.

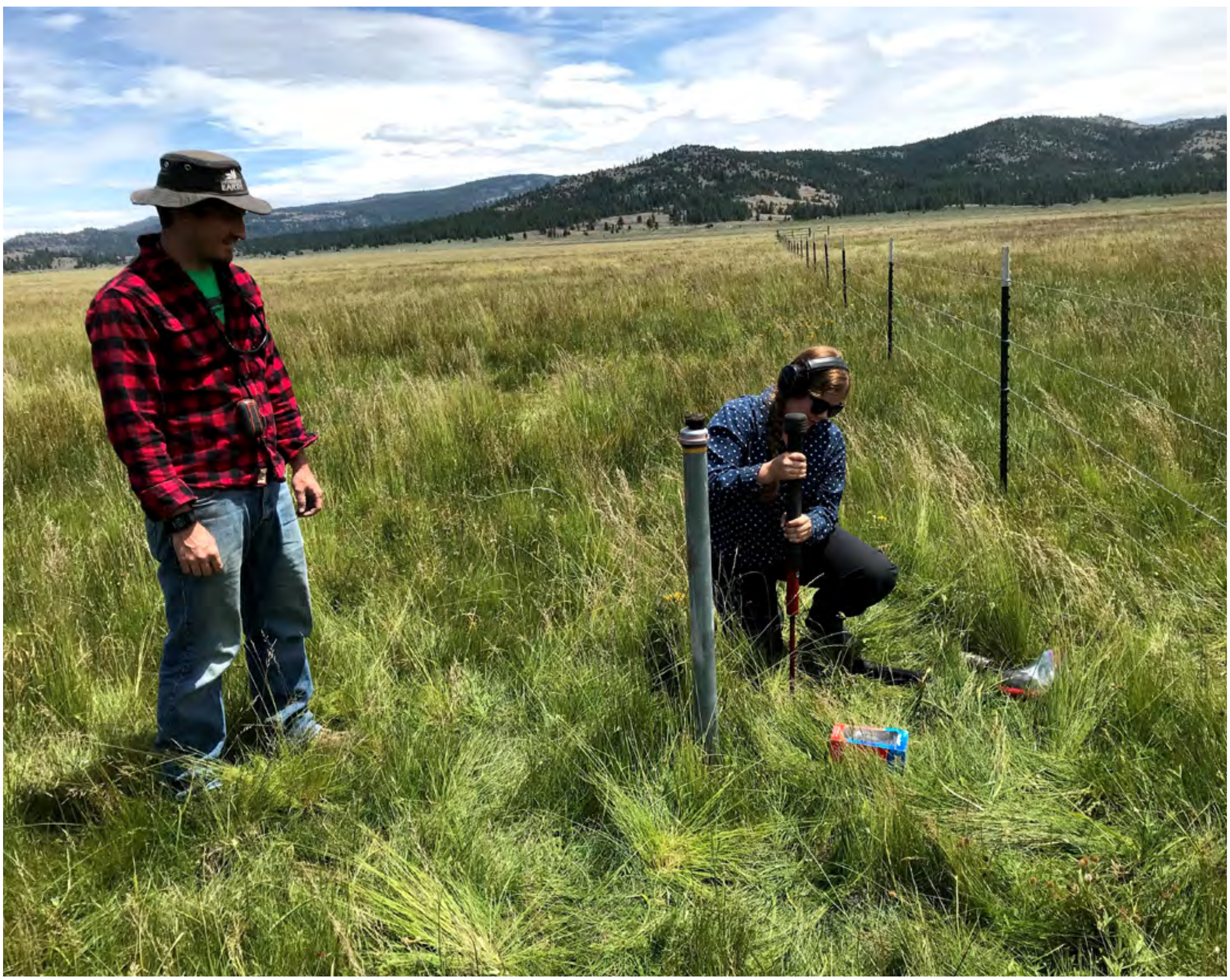
Amphibians
Assesses presence/absence, abundance and types of amphibians.

Aquatic Habitat Assessment
Assesses the physical habitat and characteristics of the stream channel and surrounding area.

SM-WRAMP PROTOCOL REVISIONS

SM-WRAMP Protocol revisions will be done annually by the SM-WRAMP Advisory Committee. Field practitioners who use the protocols and have comments for improvement or questions about application should upload their comments on the SM-WRAMP Contents Form at the USFS Box folder entitled WRAMP Implementation Comments (Appendix H), and into the respective folder.

The lead protocol generator should then be emailed to let them know of the comment. The lead generators are listed above, and contact information for these leads is provided in Section 11. The protocol generator will review and determine if modification to the protocol needs to happen quickly, or whether it can wait until the annual update each January. Updates to the Guidance Document will occur every three years and will be led by the WAC with Workgroup input. Changes to the Guidance Document will meet stringent requirements to preserve continuity of data collection and analysis through a standardized SM-WRAMP monitoring process over time.



Collecting a soil core sample next to a groundwater monitoring well, photo: Monohan 2019.

PROTOCOL TERMINOLOGY AND DEFINITIONS

The goal of the SM-WRAMP process is to standardize data collection for various ecosystem “attributes” so that the resultant “indicators” can be compared across restoration locations. For example, for birds, we generally measure the species composition and quantity of breeding birds (attributes). The actual metrics used to quantify species composition and abundance, such as species richness, relative abundance, occupancy, and diversity are the indicators. Key ecological term definitions are found in Gann et al (2019).

Attribute: qualitative or quantitative characteristic.

Indicator: specific, quantifiable measure of attributes that directly connect longer-term goals and shorter-term objectives. Ecological indicators are variables that are measured to assess changes in the physical (e.g., turbidity units), chemical (e.g., nutrient concentration), or biotic (e.g., species abundance) ecosystem attributes as guided by the reference model.

Metric: unit of measure. Performance metric: the quantitative or qualitative target of restoration efforts.

MEADOW RESTORATION PROCESS FLOW

When a meadow has been selected for restoration based on driving concerns, preliminary restoration objectives are then identified. Driving concerns are attributes characteristic of degraded meadow habitat and hydrologic function that prompt a restoration effort as described in the statewide WRAMP process1.

The process flow diagram below covers the entire process from meadow site selection to implementation and long-term SM-WRAMP monitoring and data storage.

Driving Concerns (DC)
Driving concerns inform meadow restoration objectives which in turn determine which SM-WRAMP protocols are used. Below are examples of five driving concerns that alone or in combination may warrant meadow restoration in the Sierra Nevada.

DC1. Altered hydrologic and geomorphic attributes (ground water level, surface water flow, sediment type and transport, hydrologic disconnect between channel and floodplain, channel incision/erosion, headcut, bank instability)

DC2. Land use impacts (grazing, mining, logging, agriculture, recreation, off-road vehicle use)

DC3. Decreased productivity (vegetation, wildlife), carbon sequestration and/or biodiversity

DC4. Vegetation changes (fire history, invasive species, altered hydrology, soil condition)

DC5. Altered wildlife numbers, types, distribution and usage; decreased habitat quality/quantity. A more detailed description of statewide WRAMP Driving Concerns is at; https://mywaterquality.ca.gov/monitoring_council/wetland_workgroup/wramp/index.html

Monitoring to Inform Design from a Cultural Resilience Perspective

Actions to achieve the desired cultural resilience outcome(s) and the development of monitoring originate from the First Nation’s people on whose ancestral homelands projects are planned. First Nations/Tribes have the agency to guide identification of restoration goals linked to specific actions that remove system constraints. Progress towards these goals is monitored using quantitative and qualitative metrics to evaluate outcomes on ecological function and cultural resilience so that adaptive management activities can be implemented as part of ongoing interaction with the landscape of ancestral homelands.

The approach for developing plans to restore cultural resilience rely on Traditional Ecological Knowledge (TEK) as a basis for understanding the range of restoration opportunity within a system.

The approach for developing plans to restore cultural resilience rely on Traditional Ecological Knowledge (TEK) as a basis for understanding the range of restoration opportunity within a system. In connecting TEK with Western Ecological Knowledge (WEK) to identify desired outcomes for meadow restoration, underlying principles of place-based and regenerative solutions come to the fore, supporting long-term stewardship opportunities and thus adaptive management strategies. Both TEK and WEK “emphasize feedback learning and address uncertainty and unpredictability” - as adaptive management in WEK and traditional resource management with respect to TEK (Zedler and Stevens, 2018).

PROCESS FLOW DIAGRAM FOR MEADOW RESTORATION AND SM-WRAMP IMPLEMENTATION

1. Select meadow for restoration, contact landowner for approval; information
2. Perform WRAMP monitoring as initial pre-restoration assessment; document current conditions; perform limiting factor analysis; consult with tribal nations on restoration objectives; generate site characterization memo; monitoring plan, equipment checklist
3. Determine driving concerns and restoration objectives
4. Perform desktop data collection
5. Field stake (flag) design, hold stakeholder site visit | Perform geomorphic assessment, install water loggers, groundwater wells
6. Generate conceptual design with alternatives analysis; solicit review of design | Generate cost estimate for project and monitoring
7. Perform surveys for CEQA/NEPA | Perform surveys; cultural, wildlife, CRAM, botany, wetland delineation, archeology
8. Proceed through 65% design, get licensed engineering review. Get design review comments from landowner, stakeholders
9. Proceed to 100% design with CEQA/NEPA permitting
10. Implement restoration; as-built studies; adaptive management

PERFORM WRAMP MONITORING → **Write reports, submit data to SMP, state, fed portals**

As desired restoration activities are identified by First Nations, these can be aligned with meadow attributes and indicators that contribute to region-wide understanding of best-practices and support the unique social systems of tribes on ancestral lands. As such, it is possible is to plan for, execute, and adaptively manage a phased program of restoration on ancestral lands that bridges the gap between TEK and Western scientific approaches, and we support this engagement for meadow restoration.

Restoration Objectives Identified in the SM-WRAMP Framework

To determine the effectiveness of meadow restoration projects across a spectrum of meadow conditions, project goals and multi-stakeholder visioning, a collaborative group of experienced restoration practitioners, First Nation/Tribes representatives and scientists from agencies, non-profits, and consultancies should come together in the planning stage of the meadow restoration project to formulate goals and objectives to ensure that visions are addressed. Objectives should be SMART: Specific, Measurable, Achievable, Relevant and Time-bound. Such objectives can provide a framework to determine the success of restoration actions and to trigger adaptive management actions should they prove necessary.

Pre-project Monitoring

SMART objectives derive from current or 'existing' conditions of each meadow. The information gathered for existing conditions will identify limiting factors and opportunities for improving conditions which inform project design. With this information, the 'desired' conditions at each meadow relative to the existing conditions can be discussed, SMART objectives identified, and a clear, well-illuminated path forward can be agreed upon by stakeholders.

A monitoring plan for initial assessment is generated to orient the field team to the sequence of events and resources needed. The monitoring plan should incorporate a list of protocols to be used, an equipment checklist, timeline and field work needed, available desktop data, and a data management plan for data acquisition, analysis, storage and sharing.

An equipment check list (present in each protocol) should be distributed to field team leads two weeks prior to monitoring. If ideal protocols cannot be implemented due to logistics and cost, alternative monitoring scenarios can be considered using proxy indicators and aerial data collection. Examples of monitoring scenarios for budgets are in Appendix C.

If aerial imagery is collected prior to field work, such as drone imagery or LiDAR, a limited amount of equipment should be left in the field as monuments for future monitoring (e.g. have pin flags placed at the corners of permanent plots so that destructive sampling does not take place within those plots; use colored flagging to correlate with transects/GPS coordinates).

Desktop Data Collection

Thorough desktop data collection will make the restoration process more efficient. The list below includes key attributes and indicators that will factor into the restoration process. A responsible party should be identified as lead for this phase, and tasked with following the data management plan, and sharing information with stakeholders and monitoring team members in a timely manner. Information collected for one monitoring protocol, such as hydrology and geomorphology, may be useful for setting up and conducting another protocol, such as vegetation monitoring or wildlife monitoring. The lead for coordinating the desktop data collection should function as the interface of information between monitors.

Design Layout and Site Visit
A site visit should be held with the project team, First Nation/Tribalrepresentativesand other stakeholders to discuss meadow current conditions, desktop knowledge, and restoration approach and objectives. Initial stage field work can be done at this time to stake out design, collect geomorphic data, install water monitoring equipment for surface flow or groundwater wells, and discuss place-based cultural considerations.

Conceptual through Final Design
The standard design sequence is then followed in which conceptual design to 30% is completed with alternatives, reviewedby stakeholders,and then the preferred alternative developed. Surveys needed for CEQA and NEPA permitting should be performed at this stage. These surveys include cultural, archaeological, CRAM, botany, and wetland delineation. The design is then advanced through 65% design and submitted for review and approved by a licensed engineer and agency staff, and the landowner. As the project moves into the implementation stage, the post-implementation SM-WRAMP monitoring plan should be established and funding solidified.

Post-Implementation Monitoring
The success of a restoration should be determined by meeting project goals and objectives. The purpose of post-project monitoring of restored meadows is to assess the status of the recovery trajectory relative to the goals and objectives. Post-

DESKTOP DATA COLLECTION	DATA TYPE	ACQUISITION SOURCE
Project Area Meadow Map	KMZ, Topo, jpg	Google Earth, Topo
Elevation	MSL(ft) NAD83	GIS e.g. Open Topography, USGS National DEM
HGM Type	Class	Weixelman 2011, Brinson 1993
Land Ownership	KMZ	GIS
Management History	Doc	Literature
Current Conditions	Doc, Image, Map, csv	Varied
Previous Restoration	Doc. url	
Survey Records	Doc, csv	Arch, Cultural, Bio, CRAM, WD, Wildlife
Hydrologic Basin Plan Delineation	Doc	Web
Stream Order	Map	GIS
Watershed Area	Map, Report	Web
USGS gages in watershed	Doc	Web
GW well monitoring history	Doc, Report	Project lead
Summer base flow history	Doc, Report	Project lead
Winter snowpack history	Doc, Report	DWR, USFS
Water quality	Doc, Report	Web
Macroinvertebrate istory	Doc, Report	Project Lead
Wildfire history	Doc, Report	CalFire, USFS
Grazing agreement history	Doc, Report	USFS
Google Eart, Drone, LiDAR	kmz, other	Project Lead
Summary of climate projections	Doc, Report	Project Lead

project monitoring runs concurrent with ongoing management and stewardship that assist in ecological recovery. The project lead is responsible for collecting and interpreting monitoring results to assess success. Unintended consequences of restoration should be included inmonitoring results(protocols under development).

PROTOCOL SELECTION

Selection is determined by the meadow restoration objectives, which are in turn determined by the Driving Concerns. Each protocol includes discussion of what attributes the protocol measures and its applicability to specificrestoration objectives. See Appendix C for a decision matrix for SM-WRAMP protocol use. This matrix has parallel construction to the Table of Objectives, Monitoring and Adaptive Management prepared by Trout Unlimited and the SM Partnership for the Sierra 10 Meadow Initiative (Appendix D).

DATA MANAGEMENT AND STORAGE

SM-WRAMP data management involves desktop and field data collection, pre-and post-restoration SM-WRAMP monitoring and adaptive management activities. This section covers specific elements of these processes including QA/QC outline for data collection, data sheets, data processing, storageand upload to the UC-Davis SiteFarm, file types accepted, and a recommended SM-WRAMP data manager role.

Data QA/QC Outline

A Data Management QA/QC Plan is provided as part of the SM-WRAMP collection. The Plan follows the U.S. Fish & Wildlife Service QA/QC Data Management Outlineat:US FWS Data Management Plan Outline at https://www.fws.gov/data/life-cycle/quality

Data quality management is essential to preventdata defects or issues within a dataset that reduce our ability to apply data towards science-based conservation efforts. A sample QA Plan template is in Appendix E. There are two components of data quality management:

Quality Assurance (QA)

Implementing processes that prevent data defects from occurring. For example, writing a detailed protocol for a long-term survey so that the methodology is maintained as new staff come on board.

Best practices include:

- Data collector training and testing
- Scheduled data-quality reviews by informed and qualified reviewers at important points in workflow
- Tracking data changes and implementing a versioning scheme for project data
- Using data quality indicators (e.g. comment fields) to qualify data anomalies.

Quality Control (QC)

Detecting and repairing defects once data is obtained (noticing a negative value in a count field may indicate a data-entry error, which might be fixed by reviewing a field data sheet).

Best practices include:

- Maintaining data-quality metadata and documentation
- Periodically running test data through all processing scripts to verify expected functionality
- Comparing new data to historical values
- Plotting spatial data on a map to verify locations
- Calculating summary statistics for data or display data using common graphs such as boxplots to evaluate for possible anomalies
- Reviewing field notes for unusual occurrences or events that may help explain data anomalies.

Data Management Plan

Key elements of the Data Management Plan are to Plan, Acquire, Maintain, Access, Evaluate and Archiveas describedbelow. A template for constructing a Quality Assurance Plan (CA State Water Quality Control Board) is in Appendix E.

Plan (QA)

Plan formal QA and QC for all of the steps, and make process checklists. (QA) Given the question being addressed, consider information needed and the level of precision and accuracy needed to answer the questions.

Acquire (QA)

Properly train and test field crew on data collection techniques; (QA) Calibrate instruments, determine acceptable precision and accuracy; (QC) Transcribe and check data immediately following field work to identify errors while recollection is still clear.

Maintain (QA)

Schedule backups to protect against file deletion or corruption; (QC) Check data, make sure the correct units are being recorded; (QC) Examine data products, make sure data is being entered into data tables correctly and are formatted properly.

Access (QA)
Establish procedures on sharing data, query and format data properly for stakeholder use; (QA) Provide documentation and metadata to stakeholders for proper interpretation; (QA) Determine accessibility protocols (who, when, why, how).

Evaluate (QA)
Generate preliminary reports to make sure that data management is proceeding as intended; (QA) Define the analytic decision-making process prior to analyzing any data; (QC) Identify and examine outliers; (QC) Define analytical approaches to identify violations of assumptions.

Archive (QA)
Establish policies for how long data will be maintained, who owns it, where is it going to be stored; (QA) Where will electronic data, paper datasheets, etc. be stored; (QA) Prevent data loss; (QA) Archive - Where will the right people be able to find it in the future? What will be saved (data/physical samples)? How will the connection between the two be maintained?

Data sheets
Each protocol has an associated data sheet that has been standardized to the extent possible. Data can be collected in hard copy or electronically, analyzed and converted to standard file format (e.g. open source csv, sql) and uploaded into flat file headers for storage on the UC Davis SMP Database. A process flow diagram for pathways (paper, ArcGIS) is in Appendix F. Data in the form of geodatabase table, feature class, shape file, .dbf file or table view be converted to csv files as described in https://desktop.arcgis.com/en/arcmap/10.3/tools/roads-and-highways-toolbox/convert-table-to-csv-file.htm.

For upload, an output template is provided in the SMP Protocol Data folder to further standardize accessible data and screen for entry and upload errors. Data collected via desktop and field if produced in hard copy will be stored at the project lead location for 10 years, converted into an electronic format as appropriate and/or summarized in reports, and uploaded to the UC Davis site. Contracted field teams should also keep their data in hard and electronic form, and share with the Project Manager within three months.

Data Processing
The processing of tabular and spatial data generated during monitoring is the responsibility of the project lead. For spatial data, CalTrout will hold an ESRI non-profit license and grant sub-licenses to a project lead for a particular meadow. Project leads will work with the SM-WRAMP Data Manager (see below) to gain access and permissions for the organizational structure.

Data storage
Data acquired in the field will remain in hard copy format if paper datasheets were used, and in electronic format if tablet and/or app-based datasheets were used. The field crew lead is responsible for seeing that the data is transcribed into electronic formats, and QA/QC'd according to the Project QA Plan. The project lead is responsible for uploading data to the UC Davis SiteFarm and other relevant state and federal databases. Each meadow will have its own folder on the UC Davis site. Reports, raw data in the standard file format, maps, and shape files will be accepted into storage, and accessible via query in a simple user interface. The project lead is responsible for updating their respective meadows web page. Aerial data such as drone and LiDAR imagery will be accessible via link to an off-site location determined by the project lead.

Data Manager
The SM-WRAMP Data Manager will serve as the technical gatekeeper for data collected as part of meadow restoration efforts of the Sierra Meadows Partnership. The Data Manager may be funded initially through one of the SMP organizations, with long term support budgeted through SMP grant applications utilizing SM-WRAMP monitoring line items, using text as described in Appendix G.

Data Tracking Tools
WRAMP incorporates web-based tools for project siting and design, project tracking, project assessment, aquatic resource mapping, ambient monitoring design, and synthesis and reporting of aquatic resource condition. A list of Project Siting and Design Tools, Project Tracking Tools, Project Impact/Assessment Tools and Aquatic Resources Mapping is in Appendix H.

BUDGET AND PERSONNEL REQUIREMENTS

Cost and technical requirements are important considerations for selecting SM-WRAMP protocols for implementation. The cost of each protocol is estimated in Appendix C. Four typical monitoring scenarios are presented to meet different budget requirements. The geomorphology protocol has the most technical training and costly equipment requirements (e.g. auto level, RTK GPS surveys, drones to generate DEM), and post data collection processing requirements (e.g. Agisoft Metascape, Pix4D).

Example of cost and training considerations are as follows:

- A consultant or staff member with sufficient training and equipment should be contracted early in the process to perform the geomorphology protocol if so indicated.
- Some shared equipment is available from SMP partners to reduce cost (e.g. Trimble R2, Smith-Root eDNA backpack unit). CalTrout Sierra regional office staff can be contacted for training guidance and sign-out sheets.
- Design plan review by a licensed engineer may be needed for grant funding, agency review and landowner approval.
- The vegetation and bird protocols require ecologists trained in vegetation and bird types.
- Proxy monitoring protocols may be used as cost savings in long-term monitoring plans (e.g. vegetation NDVI protocol as proxy for hydrology).

ADAPTIVE MANAGEMENT

Kershner (1997) described adaptive management as: the process whereby management is initiated, evaluated, and refined (Holling 1978, Walters 1986). It differs from traditional management by recognizing and preparing for the uncertainty that underlies resource management decisions. Adaptive management is typically incremental in that it uses information from monitoring and research to continually evaluate and modify management practices. It promotes long-term objectives for ecosystem management and recognizes that the ability to predict results is limited by knowledge of the system. Adaptive management uses information gained from past management experiences to evaluate both success and failure, and to explore new management options.

The success of meadow restoration from a cultural resilience perspective requires consideration of historic and current context as a key component of planning and subsequent implementation. Key to the efficacy of this approach is understanding that cultural and ecological resilience are interwoven. Western meadow practitioners use the term "resilience" to describe the ability of a system to withstand and respond to change. With respect to cultural resilience, the durability of local, climate-adapted social systems are equally important. These complex systems do not differentiate between anthropogenic cultural resources and natural resources – human-environment interactions are interdependent. Traditional ecological knowledge (TEK), and the ability to use and transmit this knowledge, is a qualitative "metric" of the resilience of the tribe's "social system" (Fawzi et al., 2016). Evaluation of success from a cultural resilience perspective relies on quantitative metrics associated with Western ecological knowledge (WEK) in combination with qualitative metrics that can be summarized as access to natural resources that supports the ability to share and perpetuate cultural value systems and lifeways. The desired outcome is a resilient meadow that supports culture self-determination.

Post-project Monitoring and Adaptive Management Plan
Adaptive management actions should be created for each meadow restoration project in a manner similar to the objectives discussed above. The Adaptive Management plan will guide what information is collected through post-project monitoring and how it will be evaluated and used to measure whether restoration actions are successful in reaching the goals and objectives of the project. The Adaptive Management Plan should identify triggers for conditions related to the SMART objectives that, if met, will require further action. The Adaptive Management Plan should list steps to be taken if such triggers are reached. For example, if willow cover does not meet some criteria by 5 years, this could trigger additional planting of willow stakes.

As such, the purpose of an adaptive management program is to inform and improve restoration actions in Sierra meadows and to ensure that completed activities in each meadow achieve the ecological, biological and cultural goals and objectives identified prior to implementation. These objectives should also be used to guide the development of the restoration design in each meadow. In order to be successfully implemented, adaptive management must be linked to measurable goals and monitoring. The SM-WRAMP protocols were designed to be comprehensive enough to provide the information necessary to quantitatively measure progress toward many SMART objectives.

In summary, an effective adaptive management plan should: (1) identify the uncertainty or testable hypothesis in question, (2) quantitatively monitor change in restored meadows according to the specified SMART goals, preferably using SM-WRAMP protocols so collected data will be comparable across Sierra Nevada meadows (3) identify SMART triggers that, if met, would require an additional action or response, (4) define adaptive management actions that would result from monitoring triggers being hit, and (5) incorporate feedback loops that link implementation/adaptive actions to SMART objectives or desired conditions.

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The Sierra Meadows Partnership meeting in Calistoga in February 2016 brought the need and direction for a comprehensive Meadow Strategy into focus.

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Seven Protocol Classes

1 GEOMORPHOLOGY

2 HYDROLOGY

3 SOILS

4 GRAZING

5 VEGETATION

6 WILDLIFE

7 AQUATIC SPECIES

Protocols to be implemented should be chosen based on meadow restoration objectives.
Pickel Meadow, photo Mike Wier

PROTOCOL DECISION FRAMEWORK

APPENDIX B

DRIVING CONCERN	SPECIFIC CONCERN	OBJECTIVE	METRIC	GEO-MORPHOLOGY: LONG PROFILE & CROSS SECTION	GEO-MORPHOLOGY: GM MAPPING & GRAIN SIZE	HYDROLOGY: GROUNDWATER	HYDROLOGY: SURFACE WATER	SOILS: SOILS	GRAZING: GRAZING IMPACTS CHECKLIST	GRAZING: BANK ALTERATION	GRAZING: STUBBLE HEIGHT
DRIVING CONCERN 1: Hydrologic and Geomorphic Attributes	groundwater level	Inc GW table level	meter, time	x		x		x			
	surface water flow	restore natural area/extent surface flow	cfs, depth, time	x	x		x				
	sediment type and transport	restore natural distribution, transport	diam, area	x	x		x	x			
	changes to channel width and depth	natural width/ depth	meter	x	x			x	x	x	
	hydrologic disconnect channel and floodplain	Restore connectivity channel BFH and floodplain	slope (meter), flow (cfs, meter)	x	x	x	x	x	x		
	hydrologic disconnect upstream and downstream	Restore connectivity upstream/ downstream	slope (meter), flow (cfs, meter)	x	x	x	x	x	x		
	lack of continuous slope (headcut, incision, erosion issues)	Restore continuity slope	slope (meter), flow (cfs, meter)	x	x	x	x	x	x	x	
	bank instability	Improve bank stability	meter, diam	x	x			x	x	x	x
DRIVING CONCERN 2: Land Use Impacts (grazing, mining, logging, agriculture, recreation, off-road vehicle use)	alterations to natural processes from anthropogenic causes	Restore meadow attributes favoring native species in pre-impact state	varies depending on type of impact	x	x	x	x	x	x	x	x
	grazing			x	x	x	x	x	x	x	x
	mining					x	x	x			
	logging					x	x	x			
	agriculture					x	x	x			
	recreation							x			
	off-road vehicle use			x	x			x		x	
	high intensity fire					x	x	x			
DRIVING CONCERN 3: Decreased productivity (vegetation, wildlife), carbon sequestration and/or biodiversity	Productivity native species, carbon sequestration, biodiversity	Restore meadow attributes favoring native species in pre-impact state	species # amd type, grams, moles	x	x	x	x	x	x	x	x
DRIVING CONCERN 4: Vegetation changes (fire history, invasive species, altered hydrology, soil condition)	Loss of biodiversity	Restore meadow attributes favoring native species in pre-impact state	# species, distribution (area in meters)	x	x	x	x	x	x	x	x
DRIVING CONCERN 5: Altered wildlife numbers, types, distribution and usage	Loss of biodiversity of sensitive / vulnerable species	Restore meadow attributes favoring native species in pre-impact state	# species, distribution, meters			x	x	x	x	x	x

			VEGETATION					WILDLIFE		AQUATIC SPECIES				
			GENERAL VEGETATION	NDVI / NDWI	R5 RANGE	TARGET SPCIES	CONIFER	BIRDS	BEAVERS	VISUAL OBSERVATION	EDNA	AMPHIBIANS	BMI	PHYSICAL HABITAT
SPECIFIC CONCERN	**OBJECTIVE**	**METRIC**												
groundwater level	Inc GW table level	meter, time	x	x		x								x
surface water flow	restore natural area/extent surface flow	cfs, depth, time											x	
sediment type and transport	restore natural distribution, transport	diam, area							x				x	
changes to channel width and depth	natural width/ depth	meter							x					x
hydrologic disconnect channel and floodplain	Restore connectivity channel BFH and floodplain	slope (meter), flow (cfs, meter)	x	x		x							x	x
hydrologic disconnect upstream and downstream	Restore connectivity upstream/ downstream	slope (meter), flow (cfs, meter)	x	x		x							x	x
lack of continuous slope (headcut, incision, erosion issues)	Restore continuity slope	slope (meter), flow (cfs, meter)	x	x					x				x	x
bank instability	Improve bank stability	meter, diam	x	x					x					x
alterations to natural processes from anthropogenic causes	Restore meadow attributes favoring native species in pre-impact state	varies depending on type of impact	x	x	x	x	x	x	x	x	x	x	x	x
grazing			x	x						x	x		x	x
mining			x	x				x		x	x	x	x	x
logging			x	x	x		x	x						x
agriculture			x			x				x			x	x
recreation			x							x				x
off-road vehicle use			x			x								x
high intensity fire			x	x		x		x		x				x
Productivity native species, carbon sequestration, biodiversity	Restore meadow attributes favoring native species in pre-impact state	species # amd type, grams, moles	x	x	x	x	x	x	x	x	x	x	x	x
Loss of biodiversity	Restore meadow attributes favoring native species in pre-impact state	# species, distribution (area in meters)	x	x	x	x	x	x	x	x	x	x	x	x
Loss of biodiversity of sensitive / vulnerable species	Restore meadow attributes favoring native species in pre-impact state	# species, distribution, meters	x	x				x	x	x	x	x	x	x

> "Given the iconic nature of Sierra meadows and the critical importance of the Sierra Nevada to California's water supply, many state and federal agencies have agreed on the urgent need to increase the pace, scale and efficacy of meadow restoration and protection. The Sierra Meadows Partnership was formed, in part, to address this critical need."
>
> - Sierra Meadows Partnership

1 GEOMORPHOLOGY

In fluvial meadow systems, the channel morphology provides the template for aquatic and riparian habitats.

1.1
GEOMORPHOLOGY

Long Profile & Cross Section

Resource Target
Monitoring channel morphology using cross sections and a long profile

Indicators/Attributes
- Channel slope
- Channel bed elevation
- Bankfull width
- Bankfull depth

INTRODUCTION AND BACKGROUND

Channels can adjust to changes in sediment supply via adjustments in channel dimensions (width and depth), channel slope, and surface grain size. This protocol describes methods to assess the slope and channel dimensions of riparian meadows as well as the changes in those variables through time. The longitudinal profile helps assess spatial variations in bed elevation, while cross sections help to address changes at given locations. These surveys also can provide useful metrics to describe streams such as the bankfull dimensions and channel slope. Both surveys have well-established methods and can be conducted with a variety of surveying equipment.

What goals and/or restorations objectives are being evaluated with the indicators?

In fluvial meadow systems, the channel morphology provides the template for aquatic and riparian habitats. Meadow restoration is often focused on reestablishing a connection between the stream channel and the floodplain. The stream and floodplain often become disconnected due to channel widening and incision, which allows the portion of flood flows carried in the channel to increase. This creates a feedback loop where the more water contained in the channel rather than the floodplain, the higher the shear stresses during floods. Higher stresses lead to increased bed sediment transport (causing incision) and bank erosion leading to channel widening.

Long profile and cross section surveys can be used to assess channel dynamics following stream restoration, including the extent of lateral migration, channel width adjustment, aggradation, and degradation.

When should these indicators be used?

Long profile and channel cross sections should be conducted prior to the restoration action and during subsequent resurveys. The frequency of the resurvey depends on site conditions, but every 1-5 years may be appropriate to track changes to assess the success of the restoration project. The survey interval should be shorter for the first few years following restoration and be spaced more widely with time since restoration. The number and frequency of resurveys required should vary based on available funding, but the longer the time between surveys, the more likely the surveys are to capture the effects and recovery from large, infrequent floods. This protocol is particularly useful in assessing restoration projects designed to arrest channel incision, to explore whether the restoration is meeting its goals, and the degree to which channel dynamism continues.

These surveys will help to assess the dynamics of the channel restoration and also any unintended consequences of the restoration actions, including aggradation or incision. For example, restoration actions that raise the groundwater level through grade control structures could alter sediment continuity leading to changes in aggradation or degradation. Because channel response is often non-linear (Simon et al., 2016), channel adjustments may be small at first, but continued adjustment in one direction (i.e., widening) likely indicates that the channel morphology is unstable and will continue to evolve over time. The results of these surveys need to be evaluated in light of the goals of the restoration project which often include promoting channel dynamics while limiting runaway channel widening or widespread incision. Adjustments that lead to a new equilibrium morphology are expected following many restoration projects.

PLANNING

Data Collection Timing

Surveys can occur any time of year but are easiest when water levels are lower. To assess change, surveys should occur prior to restoration, after restoration implementation, and then 1-5 years after the first year. Depending on budget, subsequent surveys could be tied to high flows, continue annually, or every 5 years for at least 10-15 years after the restoration, if feasible.

Required Resources

Time required per sampling/survey event (# people x hours)
The time required depends on the size of the channel (width and length of the reach), vegetation density near the channel (which affects line of site for the surveys), and whether the channel is wadable. A crew of 2-3 people could survey 3 cross sections and a ~1,000 ft long profile in 1-2 days using a standard auto-level setup, depending on field conditions. More detailed surveys using a Total Station or RTK GPS may take 1-4 days to cover a similar area depending on the size of the restoration reach and the density of survey points.

Equipment costs if new
Survey equipment can be rented from survey supply stores. Auto-levels are the least expensive and rent for approximately $50-$100 per week. Total stations require more survey experience and rent for approximately $1000-$1500 per week. RTK GPS systems rents for approximately $2,000-$3,000 per week.

Level if any special expertise required
Survey experience is required for at least one crew member. Auto-level surveys require less experience and familiarity with a particular device, but familiarity with equipment and experience is necessary for RTK GPS and total station surveys.

Total Costs
Depends on equipment used and labor cost. These surveys likely take 1-2 days for a crew of two people depending on field conditions plus cost of equipment rental (if needed)

DATA ANALYSIS

Data storage

Data should be QA/QC'd and entered into or exported to a spreadsheet. Data storage for meadows is discussed in the guidance document.

Analysis Methods

Cross sections and longitudinal profiles can be assessed through time to evaluate channel changes. Cross sections are more easily compared than long profiles because changes to the position of the thalweg or channel centerline through time make direct comparisons of longitudinal profiles difficult without adjustments such as snapping points to a channel centerline. Without such adjustments, it can be difficult to identify whether changes in elevation represent incision, aggradation due to restoration, or shifts in thalweg position within the channel.

The longitudinal profile can be used to assess the channel slope. Slopes derived from standard 10 m or 30 m DEMs may be inaccurate, particularly for low-slope meadows. Both the channel slope and the valley slope (the channel slope multiplied by the sinuosity) are important metrics to consider. Slope can be derived using a best fit line to the longitudinal profile data if the data are evenly spaced and start and end at hydraulic controls. If this is not the case, the slope may be more accurately represented by fitting a line to the bar top data. Cross section data can be used to assess channel dimensions including the bankfull width and bankfull depth. The bankfull depth and width correspond to the water depth (or width) that just begins to spill onto the floodplain. This typically corresponds to flows that occur every 1.5-2 years, but can occur much less frequently in incised channels. In a channel at equilibrium, where aggradation or degradation is not ongoing, the bankfull elevation is the elevation of the floodplain or meadow surface.

The floodplain elevation may not correspond to the 1.5-2 year flow surface in incised or aggraded channels, but is still probably a reasonable metric for comparison, particularly where the stream is ungaged. Bankfull indicators should also be noted during the survey, and the bankfull width and depth can be calculated using the location of the indicators. In general, bankfull estimation, other than an assumption that bankfull corresponds to the floodplain surface, is highly

1.1 Long Profile & Cross Section

subjective as the indicators depend on recent high flows and other disturbances.

Evaluation Criteria

Successive surveys can be evaluated based on changes to channel width or depth (visible in the cross sections) or changes to the channel slope (visible in the longitudinal profile). Evaluating the implications of these changes in longitudinal and cross-sectional profiles over time requires assessing the degree to which changes reflect initial channel adjustments to the restoration and/or natural channel dynamism in subsequent years rather than widespread changes that suggest the restoration project has not succeeded. It is important to recognize that adjustments to channel width, localized incision, or small headcuts may occur as the channel adjusts through time and are not necessarily indicators of a failure of the restoration. Changes therefore must be evaluated in the context of restoration goals and their implications for aquatic and riparian habitat to evaluate their potential impacts. If the goal of the restoration is to reconnect the channel and the floodplain during frequent (1-2 year events), widening or incision that decreases floodplain inundation to > 5 year flows show that the restoration goals are not being met.

The response of the channel is also likely to change through time following the restoration but the changes depend on the type of restoration. In some cases channel changes are likely to be greatest immediately after restoration because the channel is adjusting to the newly restored channel. In other cases, precautions taken to limit erosion during the first years after restoration may initially limit channel change and suppress channel dynamics.

ADAPTIVE MANAGEMENT

(If evaluation criteria are triggered (see data analysis) what type of actions could occur to improve management. This should be part of the individual restoration project plan as well, but this would specifically help to identify where results are tied to adaptive management. This will be harder for some indicators than others to identify. For example, can you identify interim/maintenance management needed to occur?)

If channel conditions continue to adjust in one direction without trending towards a dynamic equilibrium of limited aggradation or degradation, the channel restoration may be having deleterious effects to aquatic and riparian habitats and should be revisited. For restoration projects with grade control structures, continued aggradation or incision, particularly after the first few years, could indicate an issue with sediment continuity, or a restored channel that is improperly sized.

COORDINATION

Cross sections can be co-located with vegetation transects and groundwater measurements. To accurately represent channel dimensions cross sections should be perpendicular to the channel, which may differ from vegetation and groundwater surveys which are often perpendicular to the valley axis.

CONTACTS

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FIELD DATASHEETS & DATA UPLOAD FORMS

The following forms are available to be downloaded from https://californiatroutinc.box.com/s/u0ua4jr2vxt3ef7sz6g547v3ct157v30

- Geomorphology Cross Section Form
- Long Profile Form

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Long Profile & Cross Section Geomorphology Protocol

1.1

GEOMORPHOLOGY

Print & Carry Field Instructions & Equipment List

What, how, why: Monitoring channel morphology using cross sections and a long profile to compare pre- and post restoration characteristics

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SURVEYING A LONGITUDINAL PROFILE

The longitudinal profile uses elevation surveys of the channel thalweg (the deepest part of the channel) to measure the channel slope and to track topographic changes between cross sections. The channel slope can change due to spatial variations in aggradation and degradation (i.e., deposition on the upstream end of the channel leads to an increased slope) or through changes in sinuosity as either the channel lengthens through migration (and becomes more sinuous) or cuts off. For this reason, it is crucial that the longitudinal profile be assessed in conjunction with aerial photographs or channel maps.

If possible, longitudinal profile surveys should be a minimum of 20-30 channel widths in length to encompass 2 channel wavelengths (or 4 bends/4 bar-pool sequences), and preferably encompass the entire length of the channel in the meadow. If only a portion of the channel in the meadow is being restored, the survey should extend upstream and downstream of the restoration boundaries. The survey should start and end at hydraulic controls (e.g., riffle crests or bar tops) to accurately calculate channel slope. Surveys may extend past these hydraulic controls to track channel changes, but these portions of the profile should not be included in channel slope measurements. If time allows, surveys could also include at least 10-15 channel widths upstream and downstream of the meadow to assess whether restoration affects sediment continuity (i.e., is the restoration halting channel incision in the meadow, but trapping all sediment and destabilizing downstream reaches).

Along the longitudinal profile, collect data points for the channel thalweg elevation. Data survey points should capture major breaks in topography (bar tops, pools, etc.) and transitions to other features that may be of interest (i.e., the boundary between a glide and a pool). Individual survey points should be spaced a maximum of 1 channel width apart, and characteristics of survey points should be noted (channel morphology, bed material, etc.). Depending on the goal of the survey the water surface elevation can be noted as well. Once the survey of the longitudinal profile is collected, the channel slope can be calculated using a best-fit line in Excel or similar software through the entire dataset or through the hydraulic controls (riffle crests) to calculate the slope of the channel thalweg within the meadow. The longitudinal profile should be tied to local benchmarks including rebar or other survey control points.

Longitudinal profiles can be surveyed using a variety of techniques (Auto level, total station), but RTK GPS surveys may be the most efficient in many meadows where the canopy does not block visibility of satellites. Where visibility is obscured, a total station survey can be coupled with the RTK GPS to fill in the survey. Auto levels are widely available and inexpensive relative to the other survey technology, but because the RTK GPS and total stations record the position of the data point in three dimensions, rather than solely the thalweg distance, these data can better help to explain changes in longitudinal profile (including thalweg shifting) and can be used to evaluate any changes in stream planform.

Potential problems:

- For divided channels, survey the main channel that contains the majority of the flow
- Ensure that the survey is at least 20-30 channel widths to accurately represent the channel slope
- Use benchmarks and survey protocols to ensure accurate measurements
- If the thalweg has migrated over years, comparing thalweg points from different years may require correcting the thalweg position to a centerline coordinate to allow for year-to-year direct comparisons of thalweg elevations.

Alternate techniques

This protocol was developed for surveys with an auto-level. More detailed surveys may be required as input to hydraulic models, or if the primary concern is a change in bar and pool morphology. Total stations or RTK GPS surveys may be needed to address these concerns, but require more expensive equipment and more experienced surveyors. Drones can be used to generate a digital elevation model of the meadow where very short vegetation or bare ground exists, and can therefore be used to calculate elevation differences between the upstream and downstream portions of the meadow. These surveys require extensive post-processing using photogrammetry software (Agisoft Metascape or Pix4D), experience with flying drones, and in many cases approval from the FAA as a drone licensed pilot. In addition, because photogrammetry calculates the elevation of the top of the visible surface, which often includes the top of vegetation or a water surface rather than the channel bed, any elevation profiles will be a function of plant height, bare ground, or other surface features. If LiDAR data is available, this can provide a useful basemap to derive slope and other elevation data, but repeat LIDAR surveys are very expensive.

SURVEYING CROSS SECTIONS

Cross section surveys can be used to identify channel dimensions and to track changes to channel morphology with time. Cross sections should extend across the width of the meadow, with less dense measurements on the meadow surface and higher density measurements within channels. Endpoints should be monumented with rebar or other permanent markers, and the endpoint location should be recorded using a GPS. Cross sections should be located in relatively uniform sections of the river such as crossovers between bends where the depth and flow pattern are likely to be relatively uniform. Cross section locations should also be relatively free of wood, if possible. We recommend surveying at least 3 cross sections through each restoration reach, although the number of cross sections may change depending on the size of the restoration project, the size of the meadow, and morphological variability. For very large meadows, LIDAR or photogrammetry surveys will help to document floodplain elevations.

Cross section surveys should capture breaks in slope along the profile and include at least 20 survey points, depending on site complexity and the length of the cross section. At each data point, the survey should include notes on the substrate (e.g., gravel, sand, cobble, etc.), any vegetation present, and topographic markers such as an estimate of the bankfull elevation, edge of water, and bank height. Cross sections should be tied to benchmarks and long profiles. Like all surveys, cross section notes should include a detailed site description, photographs, and maps of the location of end points.

Alternate techniques

An alternative to surveying cross sections is to conduct a detailed topographic survey with a total station or RTK GPS (see similar comments in Surveying a Longitudinal Profile above). This type of detailed survey is more time consuming, but can provide more extensive data than cross sections alone. Similarly, Photogrammetry using drones can be used to supplement surveys of the meadow surface (see discussion in Surveying a Longitudinal Profile above).

Long Profile & Cross Section Geomorphology Protocol

Equipment List

1.1
GEOMORPHOLOGY

Equipment for monitoring morphology

- survey instrument (can use an auto-level with stadia rod and tripod, total station, or RTK GPS)
- GPS to note the location of benchmarks and endpins
- 1-2 100 m tapes if using an auto-level surveys
- Rebar for establishing benchmarks and endpoints of the cross sections (at least 4 ft long)
- Sledge for pounding in rebar
- Rebar Caps
- Flagging
- Camera for documenting benchmarks and endpoints
- Rubber boots and/or waders
- Notebook or field sheets
- Aerial photograph of the site if available
- Kayak or other boat if the stream is too deep to wade

1.2 GEOMORPHOLOGY

Geomorphic Mapping & Grain Size

Resource Target

Geomorphic mapping and bed grain size assessment

Indicators/Attributes

- Changes to grain size metrics (D16, D50, D84)
- Extent of multiple channels (if relevant)
- % Length of unstable channel banks
- Length of incision

Positive feedbacks in meadow systems where bank failure allows more water to enlarge through time (Merrill and Jurjavic 2018)

INTRODUCTION AND BACKGROUND

What goals and/or restorations objectives are being evaluated with the indicators?

To characterize the geomorphology of the channel and the surrounding meadow before and after restoration, it is crucial to track changes in channel morphology. These changes include changes to channel width and depth (see cross section and long profile), but also changes in the grain size distribution and pattern of sediment facies on the channel bed. Any geomorphic changes could be related to systematic disconnect between discharge, sediment supply, channel size, bed material, and bank material, but these changes may also be due to local features such as localized sediment supply, bank failure, or the presence of large woody debris (LWD). This protocol focuses on monitoring of riparian meadows with an active stream channel rather than meadows dominated by groundwater flow.

A geomorphic map of the channel is an extremely useful tool to document the channel condition and how it changes through time. In combination with more quantitative surveys (i.e., longitudinal profiles and cross sections), geomorphic maps can help to document channel evolution after restoration. As part of the geomorphic mapping, the mapper will describe the grain size of the bed, and extent of eroding banks and/or incision. This mapping requires experienced geomorphologists.

Meadow restoration is often focused on reestablishing a connection between the stream channel and the floodplain. The stream and floodplain often become disconnected due to channel incision and net channel degradation, which allows the portion of flood flows carried in the channel to increase. This creates a feedback loop where the more water contained in the channel rather than the floodplain, the higher the shear stresses during floods. Higher stresses lead to increased bed sediment transport and bank erosion leading to further channel incision and degradation over time.

Although generally qualitative, a geomorphic map identifies areas where bank erosion and incision is actively occurring, the relative role of vegetation in stabilizing the channel banks, and the role of large wood in promoting local scour and deposition within the channel.

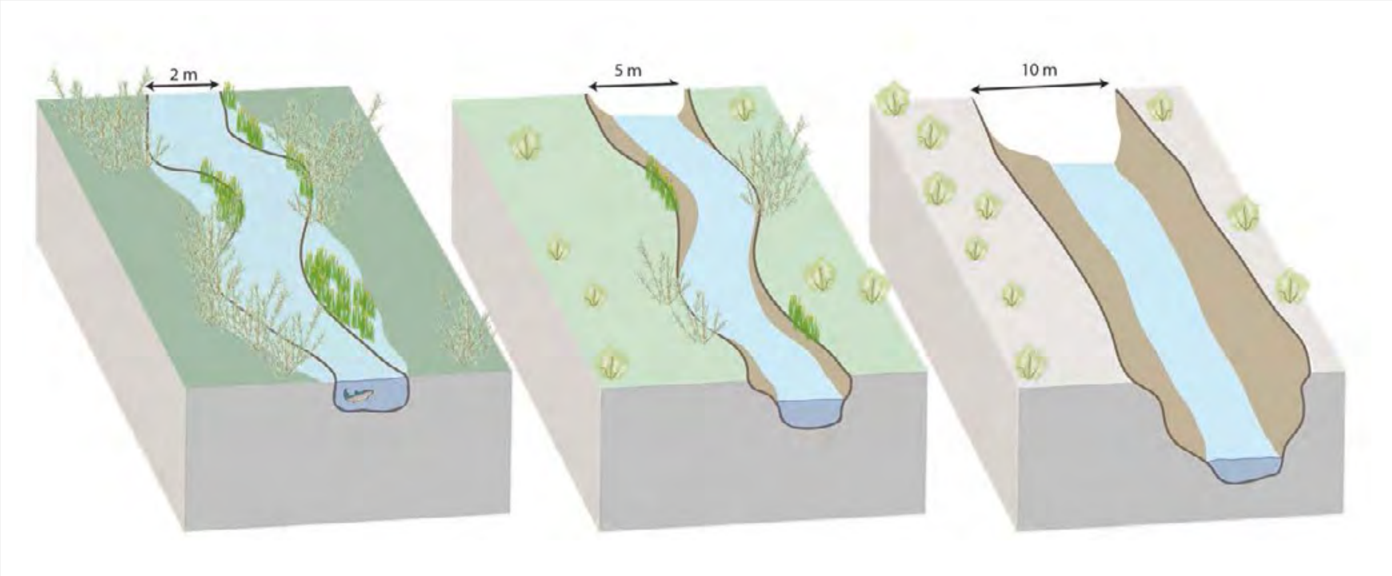

Figure 1. Positive feedbacks in meadow systems where bank failure allows more water to be contained in the channel rather than floodplain and causing the channel to enlarge through time (Merrill and Jurjavic 2018)

When should these indicators be used?

This protocol should be used in riparian meadows prior to the restoration action and during subsequent resurveys. The frequency of the resurvey depends on site conditions, but every 1-5 years may be appropriate to track changes to assess the success of the restoration project. The survey interval should be shorter for the first few years following restoration and be spaced more widely with time since restoration. This protocol is particularly useful in assessing the restoration projects designed to arrest channel incision to explore whether the restoration is meeting its goals and the extent and type of channel dynamism. The degree to which dynamism is expected after restoration is dependent on the type of meadow, the morphology of the stream (meandering and multi-thread channels will be more dynamic than step-pool channels), and the goals of the restoration project.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

Channels can adjust to changes in sediment supply via adjustments in channel dimensions, channel slope, and surface grain size. This protocol describes methods to assess changes in channel morphology and grain size using geomorphic maps and measurements of bed sediment

Geomorphic maps of meadows can be used to assess the condition of meadows before and after restoration. As part of the geomorphic mapping, the mapper will describe the grain size of the bed, channel changes, and the extent of eroding banks and/or incision. Depending on the goal of the project, metrics such as the percent of eroding bank can be harmful or beneficial (i.e., in some cases limiting erosion might be the goal, while in others re-invigorating channel adjustment, migration may be desired).

The grain size measurements allow us to track sediment size distribution changes over time, which can be sensitive to changes in local and regional sediment supply (Buffington and Montgomery 1999a, Dietrich et al. 2005). Because the geomorphic mapping shows the grain size and channel conditions for the entire reach rather than at specific transects, it is better suited than cross sections to determine the mechanisms causing channel response. For example, erosion or deposition could be tied to grazing or LWD jams that occur upstream or downstream of the cross section.

1.2 GM Mapping & Grain Size

PLANNING

Data Collection Timing

All of the surveys described in this protocol are easier at lower flows in the summer or fall.

Required Resources

Time required per sampling/survey event (# people x hours)

Geomorphic Mapping
Depending on the size of the meadow, a geomorphic map could take 1-2 days to complete. These surveys require experienced geomorphologists. Mapping requires 1 person, grain size measurement can require 2-3 people, drone surveys take a few hours in the field depending on conditions.

Equipment costs if new

- These surveys require very little equipment.
- Gravelometer: $60–$70
- Drones rentals $100-$500 per week depending on the drone. Processing software generally costs $3499 for the Agisoft Metashape Professional Edition and Pix4D costs approximately $300 per month. Both software packages have education discounts. Free, open-source software is also available.
- RTK GPS price varies, rental can be $150-$300 per day.
- Laboratory processing of sediment samples costs vary, but range from $50-$100 per sample.

Level if any special expertise required
The geomorphic map should be conducted by an experienced geomorphologist. Pebble counts require some experience but can be readily taught. Drone surveys require extensive post-processing using photogrammetry software (Agisoft Metascape or Pix4D), experience with flying drones, and in many cases approval from the FAA as a drone licensed pilot.

DATA ANALYSIS

Data storage

Maps can be digitized and imported into a GIS or scanned. Grain size data can be saved in a spreadsheet. Data storage is discussed in the guidance document.

Analysis Methods

The geomorphic maps can be digitized and incorporated into a GIS to quantify changes in facies area through time or the extent of erosion and deposition. These results can then be used in conjunction with the geomorphic cross sections and long profile surveys protocol to evaluate channel change. As stated above, channel changes can be harmful or beneficial depending on the goal of the project.

Sediment size measurements are often characterized by the median particle diameter (D50) and the 16th and 84th percentile (D16 and D84, respectively). Characteristics of the particle size distribution such as the skewness and kurtosis can also be evaluated.

Evaluation Criteria

(Based on the data analysis what would trigger a management action; is there a threshold of concern/way to identify success and do these trigger points change over time; For example, when would the project be considered not successful?)

ADAPTIVE MANAGEMENT

(If evaluation criteria are triggered (see data analysis) what type of actions could occur to improve management. This should be part of the individual restoration project plan as well, but this would specifically help to identify where results are tied to adaptive management. This will be harder for some indicators than others to identify. For example, can you identify interim/maintenance management needed to occur?)

COORDINATION

Geomorphic maps and drone imagery should be coordinated with vegetation mapping protocols. The grain size samples can be taken along cross section transects to facilitate hydraulic and sediment transport calculations and to interpret the results of the geomorphic map and cross section and longitudinal profile protocols.

1.2 GM Mapping & Grain Size

RESOURCES AND CONTACTS

Bunte and Abt (2001) provides an exhaustive account of grain size measurement and analysis and should be read by anyone conducting grain size analysis. Kondolf and Lisle (2016) also provides a nice guide on grain size measurement techniques and analysis.

Person(s) who populated the specific protocol
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FIELD DATASHEETS & DATA UPLOAD FORMS

The following dataheet is available to be downloaded from https://californiatroutinc.box.com/s/m54vjj7uh5yc5djiyorzcmfxvn7gi33p

- Pebble Count Datasheet

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(List relevant scientific citations, including any protocols this was built from.)

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1.2
GEOMORPHOLOGY

GM Mapping & Grain Size Geomorphology Protocol

Print & Carry
Field Instructions
& Equipment List

What, how, why: Geomorphic mapping and bed grain size assessment using physical and digital tools to assess bank erosion and incision.

MAPPING GEOMORPHOLOGY AND SEDIMENT FACIES

The geomorphic channel map is meant to document the condition of the restored area and the meadow as a whole. Because restoration can affect downstream reaches of the meadow, it is recommended that the geomorphic mapping extend downstream 10-20 channel widths and extend to areas that are particularly sensitive (low-slope) below the restoration. The mapping should also extend upstream of the restoration site (10-20 channel widths), if possible, to document changes due to the restoration (i.e., backwater conditions or sediment accumulation). . An example geomorphic map is shown in (Figure 5). Aerial photographs can be used as a basemap for the geomorphic map, although some mappers may prefer to map entirely by hand. Meadow characteristics to note during the geomorphic mapping:

- The conditions of the banks including the length of any unstable or recently eroded banks. Unstable banks may occur naturally due to channel migration, but evidence of channel enlargement and incision should also be noted.
- The location of headcuts within the channel
- Facies maps of the channel bed (e.g., Buffington and Montgomery, 1999) including the percentages of silt, sand, and gravel on the bed
- The location of LWD, man-made structures, and local sediment supply
- Sketches of bank stratigraphy including the percentages of silt, sand, and gravel on exposed banks
- Channel planform including location of any floodplain channels and oxbow lakes
- Extent and type of vegetation

Many of these attributes can be entered into a GIS to evaluate changes to attributes through time, such as the extent of eroding banks, the movement of headcuts, and LWD accumulation.

SEDIMENT FACIES

Sediment facies maps identify similar patches of sediment grain size distribution in the active or bankfull channel (Buffington and Montgomery 1999b). Different facies can be identified based on the differing parts of the grain size distribution including dominant and subdominant grain sizes using visual estimates verified by pebble counts. Buffington and Montgomery (1999b) recommend naming the patches based on their dominant and subdominant grain sizes.

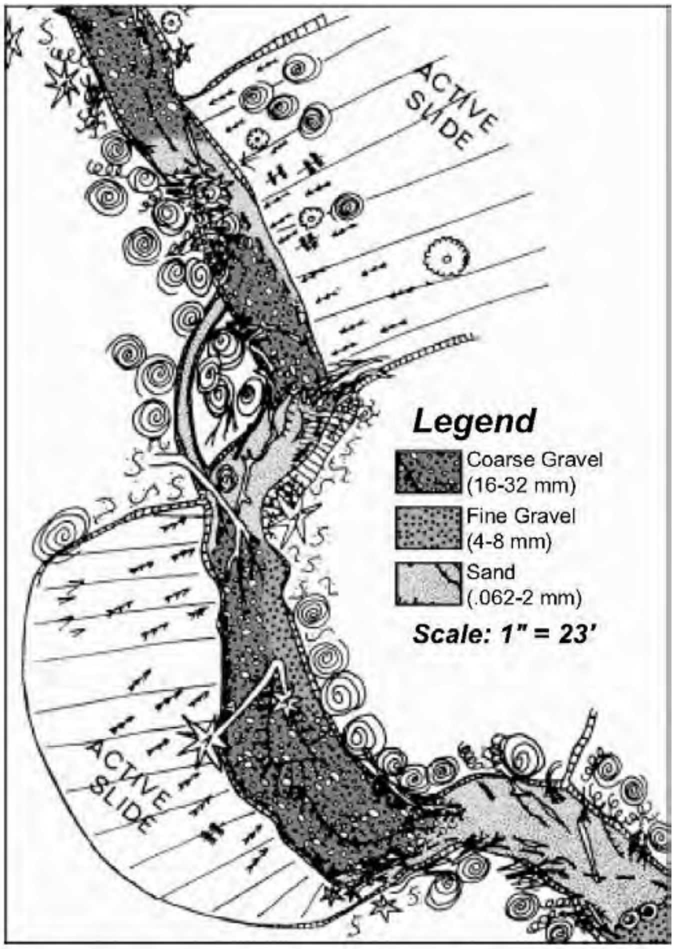


Figure 5. Example channel morphology and facies map from Wildcat Creek, CA (SFEI 2001)

The above classification scheme is applied following Buffington and Montgomery (1999b) to identify textural patches within a study area:

1. Conduct a preliminary reconnaissance of the stream reach, visually identifying textural patches according to grain size metrics (D50, D16, D84).
2. Map surface textural patches including the dominant and up to 2 subdominant facies, providing that the subdominant facies comprise>5% of the bed (Cobble-Gravel-Sand). Patches may repeat within a reach.
3. Check your mapping and naming conventions for several patches of each facies type (i.e., using pebble counts) and compare them with the visually estimated grain-size components of step 1. If there is a discrepancy, reclassify according to the measured grainsize distributions.
4. Group visually similar, but technically dissimilar, textures as equivalent for practical purposes. The imposed classification boundaries should not artificially separate textures that are visually and functionally similar.

The minimum patch size varies depending on the size of the river, the questions of the study (i.e., size of spawning patches), and the amount of time available for the survey.

UNMANNED AERIAL SYSTEMS PHOTOGRAPHY

Unmanned Aerial Systems (UAS) or drone photography is a powerful tool for geomorphic and sediment facies mapping (Figure 6). UAS imagery can be a much higher resolution than other aerial imagery, increasing visible details and readily promoting grain size and geomorphic mapping. Surface reflection, distortion of surface water (on riffles) and shadows can decrease bed visibility. It is best to fly the drone on overcast days or in the middle of the day to reduce shadows. Because drone imagery requires time to orthorectify and overlay the photographs, it is generally best to fly the photographs and map sediment facies on separate trips, although this is not always possible.

Orthorectifying the photos requires surveying ground control points (often using an RTK GPS) which can be identified from the photographs. The number of ground control points depends on the size of the river and length of the reach, but 4-6 points is a reasonable minimum with control points on each side of the river, with more points providing more accurate orthorectification. Benchmarks and cross section endpins can act as control points.

Photographs can be overlaid and rectified using commercial programs such as Agisoft and Pix4D, which identify thousands of common points in the photographs to optimize the overlay. Based on the surveyed ground control points, these programs can also be used to generate topography reflecting the top of visible surfaces (e.g. bare ground, vegetation, etc.). To collect images to map facies in gravel-bed rivers, a pixel size of 5 cm provides a useful balance between speed of the drone survey and image resolution (Ian Pryor personal communication), but finer resolution may be useful for different mapping needs. Recently drones have been developed that collected imagery and elevation through LiDAR. These drones are relatively expensive to rent or purchase and are unable to measure topography below the water surface, but do allow for better resolution of ground topography.

Drone photography can also be used to map vegetation.

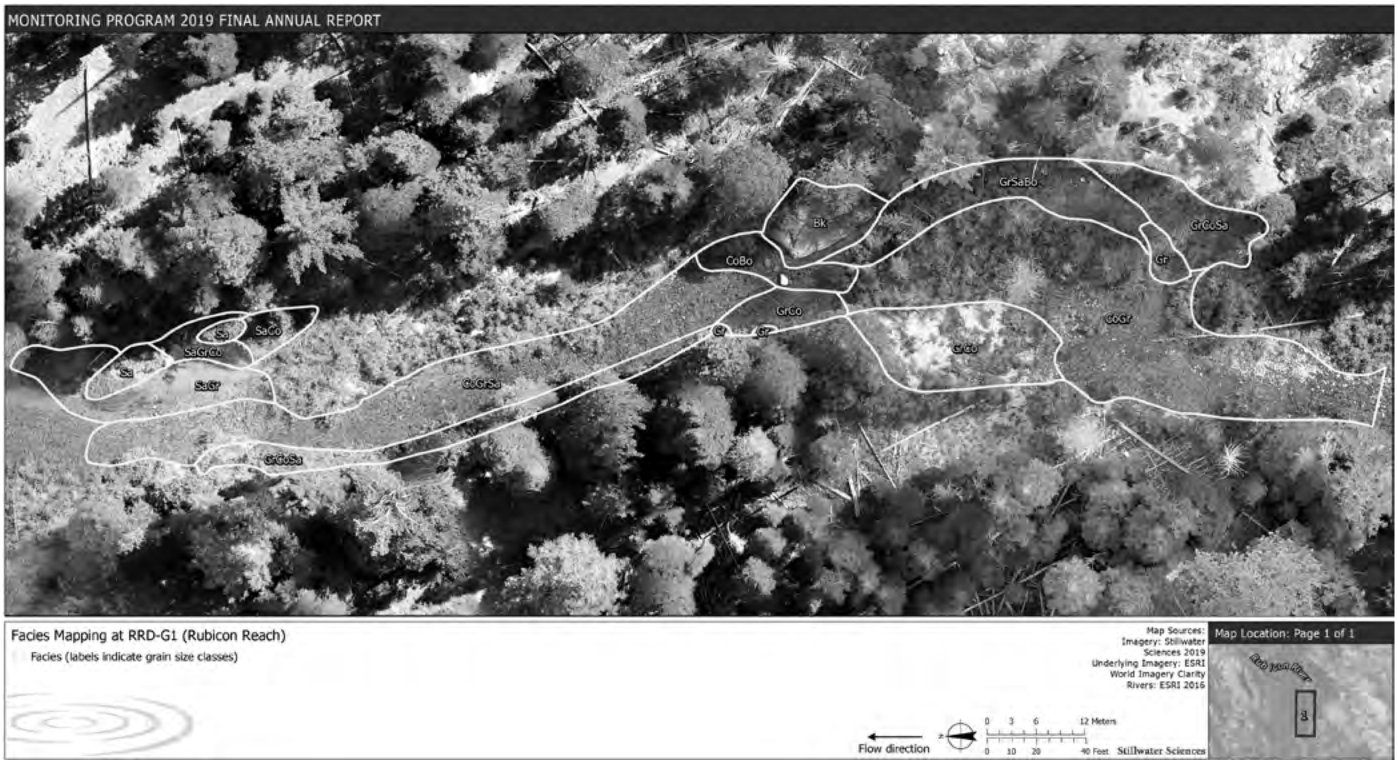


Figure 6. Sediment facies mapped over drone imagery (Stillwater Sciences 2020)

SURFACE GRAIN SIZE MEASUREMENT

If the channel in the meadow has a gravel bed, the standard pebble counts (Wolman, 1954) in each gravel sediment facies (an identifiable patch of similar grain size characteristics, see above) can be used to characterize the channel bed. Pebble counts generally involve measuring the length of intermediate (b) axis of 100 particles. This length can be measured using either a gravelometer (Figure 3) or a ruler. Gravelometers can be faster, but if a gravelometer is not available, a ruler can be used. Whether using a gravelometer or ruler, particles are often placed in 0.5 phi interval bins rather than recording each individual size (phi=-log2(grain size mm) (Table 1 and Figure 4). Particles can be measured using a grid, at intervals along a transect, or a random walk (Bunte and Abt 2001). For the random walk, the measurement should be taken of the particle directly in front of the surveyor's toe indicated by a finger or pencil. If the bed is primarily finer than about 8 mm, measuring the distribution of bed sediment requires taking a bulk sample for sieving because of bias in selecting particles smaller than your finger. Sediment samples can then be sent to a laboratory for processing to determine the grain size distribution of finer sediment.

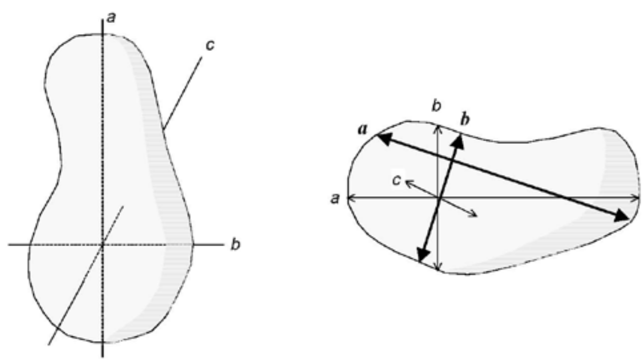


Figure 2. Definition of particle axes (Bunte and Abt 2001)

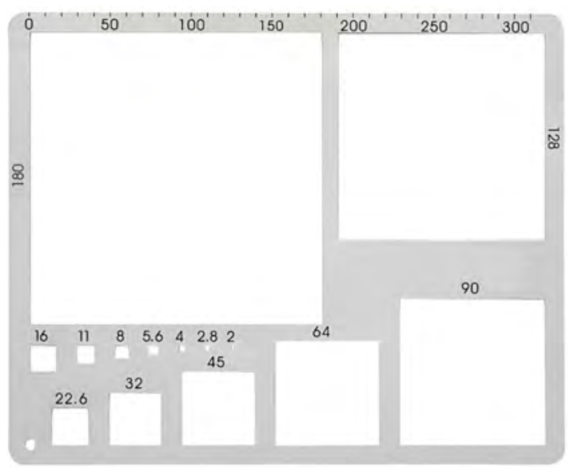


Figure 3. Gravelometer for pebble count measurements from Wildco Inc. Image from Forestry Suppliers Catalog.

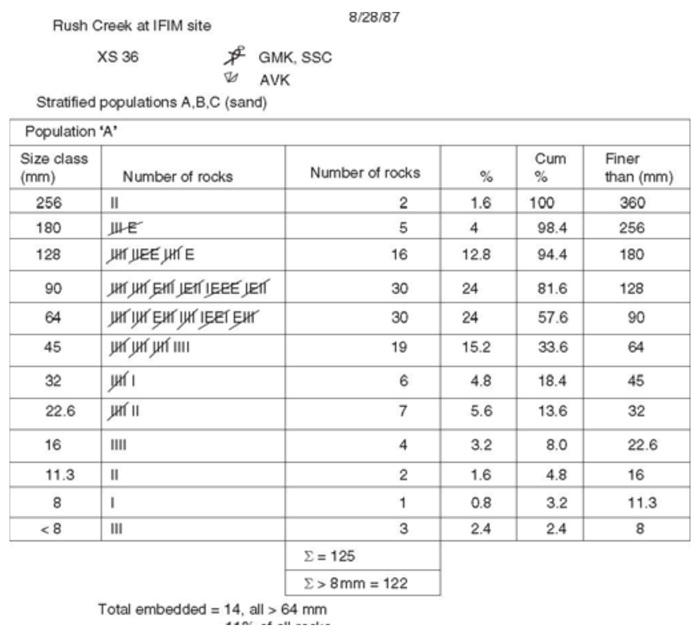
Photographic analysis of bed sediments processed in Matlab or Python is a rapidly growing field, that allows for a large number of bed sediment measurements to be taken in a short amount of time (e.g., Rubin, 2004; Warrick et al., 2009; Buscombe et al., 2010). Testing and calibration of the photographs is crucial prior to collecting field data. These techniques work well in sediment patches that are not highly embedded, but in areas with imbrication or high embeddedness, they can be less accurate that traditional field methods. Under the right conditions (uniform sediment color, lighting, water oc

Description of particle size			ϕ = -log$_2$	mm	ψ = log$_2$
			- 12.0	4096	12.0
	very large		- 11.5	2896	11.5
			- 11.0	2048	11.0
	large		- 10.5	1448	10.5
Boulder			- 10.0	1024	10.0
	Medium		- 9.5	724	9.5
			- 9.0	512	9.0
	small		- 8.5	362	8.5
			- 8.0	**256**	**8.0**
	large		- 7.5	181	7.5
Cobble			- 7.0	128	7.0
	Small		- 6.5	90.5	6.5
			- 6.0	**64**	**6.0**
	very coarse		- 5.5	45.3	5.5
			- 5.0	32	5.0
	coarse		- 4.5	22.6	4.5
		Pebble	- 4.0	16	4.0
Gravel	medium		- 3.5	11.3	3.5
			- 3.0	8	3.0
	fine		- 2.5	5.66	2.5
			- 2.0	4	2.0
	very fine	**Granule**	- 1.5	2.83	1.5
			- 1.0	**2**	**1.0**
	very coarse		- 0.5	1.41	0.5
			0	1	0
	coarse		+ 0.5	0.707	- 0.5
			+ 1.0	0.500	- 1.0
Sand	medium		+ 1.5	0.354	- 1.5
			+ 2.0	0.250	- 2.0
	fine		+ 2.5	0.177	- 1.5
			+ 3.0	0.125	- 3.0
	very fine		+ 3.5	0.088	- 3.5
			+ 4.0	**0.063**	**- 4.0**
Silt					
			+ 8.0	**0.0039**	**- 8.0**
Clay					
			+ 12.0	**0.00024**	**- 12.0**

Table 1. Sediment size gradations for clay to boulders (Bunte and Abt 2001).

SAMPLING LOCATIONS

There are a variety of ways of conducting pebble counts, including on grids, along transects, or as a random walk (within a given area or along a cross section). The techniques and their benefits and shortcomings are discussed in detail in Bunte and Abt (2001) and Kondolf and Lisle (2016), where the best method depends on the objectives of the study. Any sampling method should recognize that particles tend to sort themselves into patches (Dietrich et al. 2005), the particle size distribution often differs between riffles and pools, the distribution can be influenced by obstructions (boulders and LWD), and it can vary based on distance from sediment sources (see Figure 5). It is therefore important to pick representative sites if only a few sites will comprise the grain size measurement.


Rush Creek at IFIM site 8/28/87
XS 36 GMK, SSC
AVK
Stratified populations A,B,C (sand)

Population 'A'					
Size class (mm)	Number of rocks	Number of rocks	%	Cum %	Finer than (mm)
256	II	2	1.6	100	360
180	[illegible]	5	4	98.4	256
128	[illegible]	16	12.8	94.4	180
90	[illegible]	30	24	81.6	128
64	[illegible]	30	24	57.6	90
45	[illegible]	19	15.2	33.6	64
32	[illegible]	6	4.8	18.4	45
22.6	[illegible]	7	5.6	13.6	32
16	IIII	4	3.2	8.0	22.6
11.3	II	2	1.6	4.8	16
8	I	1	0.8	3.2	11.3
< 8	III	3	2.4	2.4	8
		Σ = 125			
		Σ > 8mm = 122			

Total embedded = 14, all > 64 mm

Figure 4. Completed field data sheet for surface grain size measurement (Kondolf and Lislse 2016).

Coupling bed sediment measurements and cross section surveys can be very useful for sediment transport calculations. At a minimum, measuring the grain size distribution at three transects used for cross section surveys will provide sufficient grain size data for hydraulic and sediment transport calculations, and transects allow for the sampling location to be re-occupied more readily. A more complete accounting of the reach would include conducting pebble counts in each mapped sediment facies (see above), but this takes more time than measuring the grain size distribution within the active or bankfull channel along a transect.

BULK SEDIMENT SAMPLING

Bulk Sediment sampling involves sampling and measuring the surface and sometimes subsurface of the channel bed. Bulk sampling is necessary for measuring the grain size distribution of sand (where pebble counts are ineffective) but is not recommended for most gravel and coarser streams. In some cases, bulk measurements may be necessary in gravel streams where infiltration of sand into gravel is impacting aquatic habitat (i.e., spawning gravel for fish).

Because grain size of coarse and fine sediments varies with position on channel bends, it is recommended that bulk samples be collected at straight reaches (i.e., crossovers) rather than at bends and at least two samples be collected at each site to account for spatial variation that may remain.

Bulk samples can be collected by a variety of methods that remove sediment from the armor layer and subsurface to measure the grain size distribution depending on field conditions. In exposed areas, sediment can be collected with a shovel or backhoe. In wadable submerged areas, bulk samples can be collected by driving a McNeil Sampler or other cylinder into the channel bedpreventing finer sediments from moving downstream during sampling, whereas a dredge or ponar sampler can be used in unwadable areas. For sand-bed streams, each sample should be between 0.25 kg-1 kg. For gravel bed rivers, the volume of material required in bulk samples is tremendous. Church et al (1987) recommend that the largest particle should not comprise more than 0.1% of the size distribution. In channel beds coarser than coarse gravel, this 0.1% requirement with a 64 mm particle weighing about 0.69 kg would result in a 700 kg sample.. Church et al. (1987) therefore recommended relaxing this requirement so that particles greater than 32 mm only need make up 1% of the sample. Once collected from the bed, the gravel and coarser material can be sieved on site, but sand and finer sized material generally should be processed in a laboratory.

Alternative methods to track the amount of fine sediment stored in gravel channel beds include using permeability as a proxy for fine sediment storage in the bed (Barnard and McBain 1994). This method is often used to track subsurface flow through spawning gravels and reflects variation based on the amount of sand and finer sediment in the subsurface. Freeze cores can also be used to remove in-tact samples (including vertical stratification) from the channel bed. The edges of freeze cores tend to be irregular and sample sizes are generally too small to meet the Church et al. (1987) standard (Kondolf and Lisle, 2016).

Regardless of sample methodology, statistics of the grain size distribution can be calculated and represented through time. The most common descriptions are D50, D16, and D84 of the bed, representing the median, 16th percentile, and 85th percentile of the cumulative grain size distribution. Other statistical descriptors of the grain size distribution can be used including the standard deviation and skewness.

1.2

GEOMORPHOLOGY

GM Mapping & Grain Size Geomorphology Protocol

Equipment List

- Equipment
- Aerial photographs
- Camera for documenting channel conditions
- Rubber boots
- Waders
- Notebook or field sheets
- Pens and pencils
- Ruler
- Gravelometer
- UAS system (rental)
- RTK GPS (rental)

2 HYDROLOGY

Shallow Groundwater Monitoring Piezometer at The Clover Valley Ranch, photo: Graham 2019

2.1
HYDROLOGY

Groundwater

Resource Target
Groundwater

Indicators/Attributes
Depth to Groundwater, Groundwater Contour Map


4- person piezometer installation track rig

INTRODUCTION AND BACKGROUND

The depth of the water table is perhaps the single most important feature in a meadow that determines both the hydrologic characteristics of a meadow as well as the composition of vegetation communities (Stillwater Sciences, 2012). The most quantitative way to measure the height of the water table is by installing a network of groundwater monitoring wells or piezometers this however can be coupled with or supplemented by vegetation monitoring. The scope of this protocol will focus on the installation, maintenance, and data collection associated with characterizing below ground hydrologic processes, using monitoring wells, piezometers and vegetation monitoring.

Piezometers are defined as a small-diameter, non-pumping well used to measure the elevation of the water table or potentiometric surface (USEPA, 1986). In contrast to monitoring wells where water is allowed through perforations along most of the length of the pipe, piezometers have a defined length along the pipe where water is allowed to enter to assess free water pressure or presence at a specific depth (Figure 1). Piezometers can be installed using track mounted drill rigs, hand augers, or pounded with drive points (WRP, 1993).

Groundwater monitoring equipment such as monitoring wells or piezometers placed in transects from meadows edge to edge spanning stream channels from the upstream to the downstream end of the meadow allows for the groundwater table to be monitored across the width and length of the meadow. The placement of the groundwater monitoring equipment captures the rise and fall of the groundwater table and its proximity to the stream channel in order to characterize below ground hydrologic processes of the meadow.

Depending on the restoration objectives, installation of groundwater monitoring equipment to monitor water table processes may or may not be necessary. There are a number of different methods to characterize groundwater conditions, this protocol will review four separate methods; (1) monitoring wells (2) monitoring with steel or PVC slotted piezometers, (3) Solinst Drive-Point piezometers and (4) vegetation monitoring as an indicator of groundwater table depth using other SM-WRAMP protocols specifically, the Restoration Impact Plant Transect Monitoring Protocol, the R5 Range Monitoring Rooted Frequency, and the Target Species Monitoring Protocol.

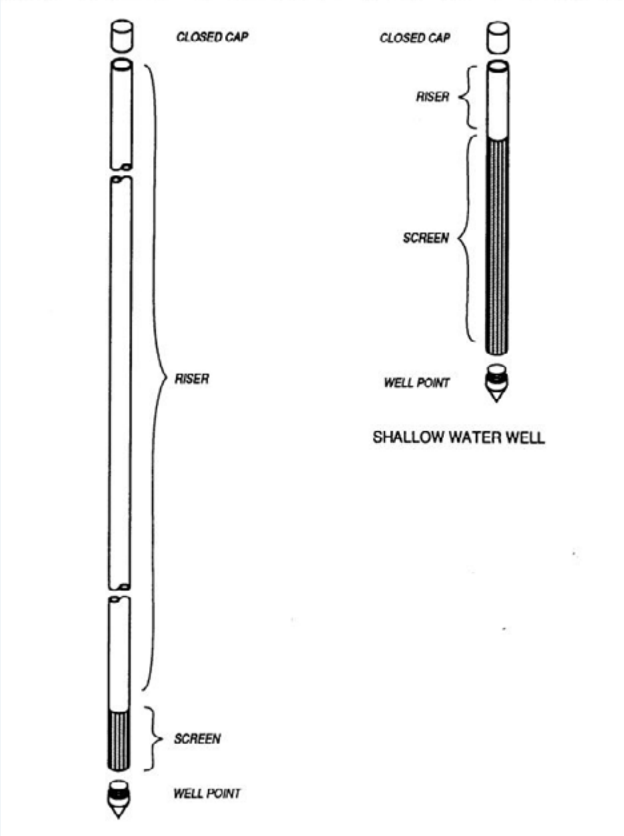


Figure 1. Part of a Piezometer and Monitoring Well, (WRP, 1993).

Certain scenarios may not be conducive to the installation of a piezometer monitoring network such as, limited funding, avoiding the invasive nature of using a track mounted drill rigs or geologic material that may not allow either track mounted or hand drilling of boring holes due to hard pans or other high density geologic layers. In any case a full species list should be monitored when using the vegetation protocols so inferences about the linkages between water table height and vegetation composition can be made for both pre and post restoration conditions.

When should these indicators be used?

These methods for monitoring groundwater characteristics should be conducted when there is an interest in how the groundwater table changes with restoration to assess the recovery or recession in groundwater amount and availability by either the physical measurements of groundwater depths or change in individual vegetation species type or wetland indicator status.

What goals are being evaluated?

The goal of this protocol is to evaluate ground water table recovery and wet meadow characteristics to quantify the change in groundwater with restoration actions.

What restoration objectives does the indicator evaluate?

- groundwater availability
- wetland meadow plant communities

What questions or uncertainties are being answered or addressed?

These methods answer a variety of questions and uncertainties about groundwater availability and how the associated changes affect the habitat as a result of restoration actions and how those changes occur over time.

PLANNING

Level if any special expertise required

Protocol 1: Monitoring Wells
An experienced technician is needed for a drill –rig, but hand auguring can be done by a field crew with limited experience, the data collection can be done by a field crew with limited experience, the data analysis may require an experienced technician.

Protocol 2: Piezometers
An experienced technician is needed for a drill –rig, but hand auguring can be done by a field crew with limited experience, the data collection can be done by a field crew with limited experience, the data analysis may require an experienced technician.

Protocol 3: Solinst Drive-Point Piezometers
A field crew with limited experience can conduct the installation and data collection but a technician should be consulted during data analysis.

Protocol 4: Vegetation Monitoring
Volunteers and/or inexperienced field crews can be used but as all plant species should be identified by a botanist who should be available on and/or off site for identification needs.

2.1 Groundwater

Required Resources

Equipment Costs if New

Protocol 1: Monitoring Wells

- Optional: Rental of track mounted drill rig (~6,000/week)
- Rental of auger with bit/extensions (~60/day)
- 3-1/4" HD Reg Reinforced Auger
- "T" Handle 18" Rubber Coated
- Two 5/8" X 5' Extensions (~$71 for both)
- #3 Sand 50# 72/plt (~$10/50lb bag)
- 2" x 10' SCh 40 PVC .010 Slot Screen F/T (~$24 each)
- 2" PVC Clip Cap ($1 each)
- 2" Female Cap SCh 40 PVC (~$7 each)
- Bentonite (~$20/bag)
- Solinst Kevlar Rope (~$33/100')
- Battery Powered Drill (~$100)
- Solinst Levelogger (~$600/unit)
- Solinst Barologger (~$300/unit)
- Solinst Depth Sounder (~$400)

Protocol 2: Piezometers

- Rental of track mounted drill rig (~6,000/week)
- Rental of 2" hand auger and extensions (~$50/day)
- Screened Drive Well Points (~$150/well)
- 2" x 10' Steel Piping ($30/extension)
- 2" x 10' PVC Piping ($20/extension)
- 2" Steel Coupler (~$5 each)
- 2" PVC Coupler (~$2 each)
- 2" Steel Well Cap (~$5 each)
- 2" PVC Well Cap (~$2 each)
- ≥ 2" Pipe Cutter (~$30)
- Biodegradable cutting oil ($10)
- ≥ 2" Manual Pipe Threader and Die Head (~$250)
- ≥ 2" Pipe Wrench x2 (~$15/each)
- Sand (~$5/50lb bag)
- Bentonite (~$20/bag)
- 1/16" Steel Cable (~$20/100')
- Eyebolts and lock nuts (~$3/well)
- Battery Powered Drill (~$100)
- Solinst Levelogger (~$600/unit)
- Solinst Barologger (~$300/unit)
- Solinst Depth Sounder (~$120)

Protocol 3: Solinst Drive-Point Piezometers

- Manual Slide Hammer (~$150)
- Solinst Drive-Point Piezometer (~$100/well)
- Solinst screened extension (~$115/ft)
- Solinst extensions (~$50/3')
- Couplings (~$15 each)
- Piezometer cap (~$10 each)
- ¾ Pipe Wrench x2 ($15/each)

Protocol 4: Vegetation Monitoring

Restoration Impact Plant Transect Monitoring Protocol:

- GPS unit: $100-6,000
- Meter Tapes: $100
- Compass $20
- Plant Books: $30-200
- Misc. Supplies $200

R5 Range Monitoring Rooted Frequency Protocol

$1000+ depending on quality of equipment. Once equipment is procured, additional meadows/plots will only cost the amount of monumented material (<$20).

Target Species Monitoring Protocol

- GPS Unit (points, polygons, and tracks capabilities): $100-$4000, based on level of accuracy desired
- Camera: $130 – $350
- Mapping software to process in field data collection (GIS: ESRI(Arc), qGIS): qGIS is free while a personal ArcGIS license costs $100/year

Total Costs

Protocol 1: Monitoring Wells

For the installation of 12 monitoring wells it would cost ~$9,500 with Leveloggers/Barologger, and if desired, an additional $6,000 for renting a drill rig.

Protocol 2: Piezometers

For the installation of 12 monitoring wells it would cost ~$9,500 with Leveloggers/Barologger, and if desired, an additional $6,000 for renting a drill rig.

Protocol 3: Solinst Drive-Point Piezometers

For a typical groundwater network consisting of 12 Piezometer's, it would cost ~$7,000.

Protocol 4: Vegetation Monitoring

Restoration Impact Plant Transect Monitoring Protocol:
Total Costs range from $500-7000 depending on meadow size and the number of plots surveyed.

2.1 Groundwater

R5 Range Monitoring Rooted Frequency Protocol: $1000+ depending on quality of equipment. Once equipment is procured, additional meadows/plots will only cost the amount of monumented material (<$20).

Target Species Monitoring Protocol
Costs will be dependent on the number of target species surveyed for, the extent of target species presence within the study area, and the size of the study area.

DATA ANALYSIS

Protocols 1/2/3: Monitoring Wells/Piezometers/ Solinst Drive-Point Piezometers

Like surface water in a watershed, groundwater moves through substrate with flow paths and directions. In order to find the flow direction and whether groundwater is being lost or gained to a stream, groundwater levels can be plotted. Elevations of water levels at different points in a study area, measured through piezometers, are plotted to create a flow map of water table levels. Elevation changes in the water table are shown through contour lines, in equal intervals, where flow direction is from high elevation to low elevation.

In order to create contour maps of the groundwater surface, a level circuit needs to be surveyed to find the relative vertical distances between all piezometers and channel surveying points. To survey piezometers, the top of casing (TOC) on all piezometers are surveyed into local established benchmarks, to be able to relate elevation of each survey well to a common datum. The depth below ground surface can be subtracted from the surveyed elevations to relate the groundwater levels in each piezometer. The fluctuation in groundwater levels can be observed in different seasons for a restored meadow to find interactions between soil, surface water and groundwater. For example, comparing the ground water levels during the dry time of year (Fall) across years, may indicate if the groundwater table is recovering over time.

ArcGIS can be used to create contour maps from Levelogger data and observed depth to groundwater measurements. It is important to remember to calibrate all Levelogger collected data with the complimentary barometric data collected from on site. If implementing the SM-WRAMP Surface water protocol, then the same barometric data collected in that protocol can be used but if not then a Solinst Barologger will need to be deployed in one of the wells or somewhere on site. All piezometers' coordinates along with their collected groundwater elevation can be mapped topographically to show the flow of groundwater. Using the Spatial Analyst and 3D Analyst tools in GIS, groundwater data and flow lines can be created and contoured around the network of piezometers. Hydrology tools can be used to delineate flow paths and compare them between different influxes of water.

When using the Solinst Drive-Point Piezometers the data density of shallow groundwater levels will be limited when compared to implementing pressure transducers within traditional piezometers. General comparisons can still be made when creating and comparing contour maps across seasons, but will be limited to data collections made during site visits and direct observations of the Solinst Drive-Point Piezometers.

Protocol 4: Vegetation Monitoring

Determining the percent of wetland obligate and facultative species following restoration as outlined below, conclusions about the change in hydrologic connectivity and the amount of water available in the root zone pre vs post restoration can be made.

Restoration Impact Plant Transect Monitoring Protocol
The data analysis methods below are both for descriptive and statistical analysis, depending on desired outcomes. Statistical analysis can be conducted in R, and code is provided below but can be tweaked if additional variables are required or other platforms are preferred. There are also several other packages and tools that can be used in R to analyze these data and the framework below is just guidance and does not necessarily have to be used if another method is desired or would be a better fit for the specific analysis you are hoping to conduct.

Example:
Descriptive: use excel to plot up averages of cover for each year by species, lifeform, wetland indicator status, or other variable.

Year to year comparisons of plant data suffer from pseudo replication issues when you start to look at more than two years of data, so a repeated measure or mixed model ANOVA is necessary with paired t tests (does not assume independence between years for the same location):

2.1 Groundwater

Sample R script:

```
output.aov<-aov(cover~Year+Error(type/Year), data=dataset)
Summary(output.aov)
With(dataset, pairwise.t.test(cover, Year, p.adjust.
method="holm", paired=T)
```

1. Change in dominance of Wetland Indicator Status Analysis or Lifeform
   a) Wetland Indicator Identification
      i) Visit USDA Wetland Indicator Status by Species: https://plawnts.usda.gov/core/wetlandSearch
      ii) Enter in the status of each species into your database/datasheet

   b) Lifeform: enter in lifeform status of each species (perennial herb, annual herb, annual graminoid, shrub, tree (can break further by deciduous and coniferous), moss, lichen) and conduct steps c-e

   c) Add up total cover for each type within each plot for each year

   d) If interested in year over year change in cover (dominance) of wetland indicator status or lifeform within plots, run repeated measures ANOVA with t-tests

2. If interested in change in plant species year over year or within a given year:
   a) Alpha Diversity/Richness
      i) Add up all unique species per plot per year to get a count of species per plot (you can also do this with wetland indicator status or lifeform if you are interested in diversity rather than dominance)
         - Compare using excel graphics for descriptive information
         - Run ANOVA (see above) to understand if change is statistically significant. Column headings should include: plot, transect, diversity, any other variables you have collected (groundwater depth, elevation, distance to stream, etc.)

   b) Beta Diversity or plant community change (dissimilarity of species between years or between plots)
      i) Load Vegan Package in R.
      ii) Convert your data to a matrix so that plots are the
         - rows, species are the column headings, and the cover value or presence(1)/absence(0) are the values within the matrix
         - Run vegdist() on your dataset which will return a matrix with Sorensen bray-curtis distance (beta diversity) for plot by plot comparisons. The output matrix will have plots in both the row and columns and the values will be the https://www.rdocumentation.org/packages/vegan/versions/2.4-2/topics/vegdist
         - If you want to look at how environmental variables might be influencing betadiversity, suggest conducting ordination using metaMDS function in vegan.

R5 Range Monitoring Rooted Frequency Protocol

There are a number of metrics that can be evaluated through this monitoring protocol focused on community/environmental analysis. Some metrics that can be evaluated and what change could indicate include:

- Change in plot/meadow diversity: general metric to be interpreted by analyst – an increase in diversity is not necessarily desirable, composition of the diversity that indicates meadow function
- Change in conifer abundance over time, potentially tied to abiotic variables: could indicate a number of things, but in general may suggest that meadow may not persist over time
- Change in invasive and non-native species over time: an increase in non-native and invasive species could suggest decrease in meadow condition
- Change in annuals over time: an increase in annuals could suggest an increase in disturbance
- Change in community composition tied to environmental conditions: provide understanding of the context of the meadow
- Change in wetland species ratios: an increase in upland or facultative species could suggest the meadow is drying and vice versa
- Change in graminoid to forb ratio: suggest that there has been a change in community composition, however it is left up to the analyst to decide if this change is good or not, some assessment methodologies (e.g. CRAM) suggest more graminoids have increased ecosystem function based on rooting properties the decrease bare ground
- Change in plant functional type: similar to metrics above, but specific to meadow PFT groups
- Change due to individual species

2.1 Groundwater

Target Species Monitoring Protocol

The following variables can be compared pre- and post-restoration to determine target species variation from baseline conditions pre-restoration. It is important to note that absence data will be important to collect pre and post – restoration. It will allow you to determine if target species appear in survey area post restoration or if occurrences are no longer detected post restoration.

- Changes in Area of extent (Area of extent = delineated polygon or area described at points).
- Changes in percent cover within area of extent (if the area of extent at an occurrence has not changed).
- Changes in estimated population size within area of extent. This is comparable to previous occurrences even if the area of extent has retracted or expanded.
- Changes in weighted percent cover (this comparison allows for comparison of percent cover changes if the area of extent has decreased or increased upon re-survey).
- Changes in number of occurrences (i.e. total number of points and polygons in study area). Most useful if comparing point data.

Mapping polygons of populations (digitally delineating invasive species populations with a GPS unit) and estimating population size allows for a simple comparison of change in area over time. A software that allows for visual and quantitative comparison like ArcGIS or QGIS (free) will be necessary. Alternatively, population size estimates (number of individuals and percent cover) can be compared from year to year.

ADAPTIVE MANAGEMENT

Protocol 1/2: Monitoring Wells and Piezometers

- For meadows with grazing practices on site, monitoring wells should be protected from cattle by installing ~4ft non-climb fencing attached to 3 t-posts in a triangular fashion. For meadows seeing significant snowpack, remove non-climb fencing over the winter and reinstall in the spring prior to cattle grazing.
- For meadows seeing significant snowpack, consider purchasing robust stainless steel well caps. Snowpack can make removing 2" PVC cap difficult.
- Sediment can over time make its way into the well casing, by monitoring the total depth of the well you can keep a record of depth and monitor any changes. If sediment does make its way into the well then you can either purge the contents with a peristaltic pump or bailer.
- The pressure release hole drilled into the well cap can sometimes become clogged with debris, when this happens it can be difficult to recognize the phenomenon in the data analysis and can appear to just have an offset from surrounding wells. So, common practice is to make sure and clear the opening during each site visit.
- Especially for meadow with grazing practices on site, from time to time, wells can become damaged as cows are naturally curious creatures and the "stick up" portion of the wells make great back scratchers. To protect against this occurrence, consider installing a wire fence around the vicinity of each well.

Protocol 3: Solinst Drive-Point Piezometers

Consult the Solinst Drive-Point Piezometer for any troubleshooting recommendations or contact Solinst customer support directly for any issues.

Protocol 4: Vegetation Monitoring

Restoration Impact Plant Transect Monitoring Protocol:

Over the years and due to changes that might be due to restoration activities, drought, or some unanticipated disturbance, the baseline plot that you established may be in a vegetation "transition" zone and no longer represents what you would consider to be a more or less homogenous vegetation community. If that is the case, you should still continue to document the change in that plot over time. You also have the flexibility to establish a new plot or plots to track the trajectory of the "new" communities that are developing around your baseline plot.

As time goes on, other factors that you did not expect and cannot control may alter your expected outcomes (wildfire, grazing, etc.). Be sure to document changes in land management activities or site conditions as you continue to monitor and incorporate them into your analysis, if necessary or feasible to do so.

R5 Range Monitoring Rooted Frequency Protocol

If evaluation criteria further investigation is triggered, then an evaluation of factors contributing to the negative trend should be evaluated to identify adaptive management.

2.1 Groundwater

Target Species Monitoring Protocol

Trigger: Increased or continued presence of invasive species Potential adaptive management response: invasive species removal. Treatment of invasive species populations will be driven by the status of the land (public/private) and the regulatory framework that applies to the landowner and the goals identified in the project.

Trigger: Decreased presence of rare or culturally significant species.

Potential adaptive management response: Detecting decreases in population would be a concern, but actions will be limited by regulatory framework and funding. Additional management may be needed to improve target species population size, if the restoration suggests that habitat is no longer conducive to supporting the population.

COORDINATION

Protocols 1/2/3; Monitoring Wells/Piezometers/Solinst Drive-Point Piezometers
Piezometer transects should be established transects that can also be vegetation monitoring transects and channel cross section surveys.

Protocol 4: Vegetation Monitoring
Restoration Impact Plant Transect Monitoring Protocol:

This protocol can be coordinated with hydrologic monitoring (groundwater and surface water), geomorphology (cross-section/long profile) and other vegetation data collection (rare plant surveys, invasive plant surveys) to maximize time.

R5 Range Monitoring Rooted Frequency Protocol:
Coordination should occur with the R5 Range monitoring program to identify where plots exist. In addition, this protocol could be coordinated with hydrologic monitoring (groundwater and surface water), geomorphology (cross-section/long profile) and other vegetation data collection (rare plant surveys, invasive plant surveys) to maximize time.

Target Species Monitoring Protocol:
This protocol can be coordinated with hydrologic monitoring (groundwater and surface water), geomorphology (cross-section/long profile) and other vegetation data collection (rare plant surveys, invasive plant surveys) to maximize time.

CONTACTS AND RESOURCES

Monitoring Wells, Piezometers and Solinst Drive-Point Piezometers
- Carrie Monohan Ph.D., Program Director, The Sierra Fund, carrie.monohan@sierrafund.org, 530-265-8454
- Nick Graham, Environmental Scientist, The Sierra Fund, nick.graham@sierrafund.org, 530-265-8454
- Karl Ronning, Hydrologist, The South Yuba River Citizens League, karl@yubariver.org, 530-265-5961

Vegetation Monitoring
Restoration Impact Plant Transect Monitoring Protocol:
- Rachel Hutchinson, East Zone Watershed Program Manager, Tahoe National Forest, Rachel.Hutchinson@usda.gov, 530-562-7517
- Shana Gross, Associate Ecologist Central Sierra Province, USFS, shana.gross@usda.gov 530.543.2752R5

Range Monitoring Rooted Frequency Protocol:
- Shana Gross, Associate Ecologist Central Sierra Province, USFS, shana.gross@usda.gov 530.543.2752
- Thea Chesney, Range Monitoring Program Lead, Pacific Southwest Region, USFS, thea.chesney@usda.gov, 530-478-6843
- Brenda Olson, Assistant USFS Regional Range Program Manager, brenda.olson@usda.gov, 707-562-9164

Target Species Monitoring Protocol:
- Betsy Harbert, Vegetation Ecologist, California Department of Fish and Wildlife Betsy.Bultema@Wildlife.ca.gov

Additional Vegetation Resources:
1. https://www.fs.fed.us/r5/rsl/projects/gis/data/calcovs/NRIS_InvasivePlants_FieldGuide.pdf
2. https://www.cal-ipc.org/solutions/management/edrr/species-id-cards/
3. https://www.cal-ipc.org/resources/library/videos/
4. https://www.cal-ipc.org/resources/library/sites/ Phenomenal and thorough compilation of organizational links to compiled general information about invasive species as well as control methods.
5. Incorporating Climate Resilience into Invasive

2.1 Groundwater

Plant Management Projects: Guidance for Land Managers. California Invasive Plant Council, Berkeley, CA. December 2015. info@cal-ipc.org https://www.cal-ipc.org/docs/ip/climateadaptation/IncorporatingClimateChangeResilience.pdf
6. https://wildlife.ca.gov/Conservation/Plants/Info
7. http://www.rareplants.cnps.org/
8. https://www.calflora.org/
9. Online Jepson Manual: https://ucjeps.berkeley.edu/jepman.html

FIELD DATASHEETS & DATA UPLOAD FORMS

The following datasheet is available to be downloaded from https://californiatroutinc.box.com/s/xfbp1kpqz5j79ycrv2myo6zh7rghurr2

- Hydrology Datasheet

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8. United States Environmental Protection Agency (USEPA), 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, D.D., OSWER-9950.1, 317 pp.
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10. U.S. Army Corps of Engineers. (2005). “Technical standard for water-table monitoring of potential wetland sites,” WRAP Technical Notes Collection (ERDC TN-WRAP-05-2), U. S. Army Engineer Research and Development Center, Vicksburg, MS. (https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/16/nrcs143_020656.pdf)

Vegetation Monitoring

1. Elzinga, C. L., D. W. Salzer & J. W. Willoughby (1998) Measuring & Monitering Plant Populations.
2. Weixelman, D., D. C. Zamudio, and J. A. Lorenzana. 2014 (unpublished). Field Methods for Condition Assessment Using Rooted Frequency and Soil Measurements in Meadows, U.S. Forest Service Pacific Southwest Region, Vallejo, C.
3. Sierra Meadows, Wetland Riparian Area Monitoring Plan (SM-WRAMP) 2021a. DRAFT Sierra Meadows Partnership Monitoring Protocol; Restoration Impact Plant Transect Monitoring.
4. Sierra Meadows, Wetland Riparian Area Monitoring Plan (SM-WRAMP) 2021b. DRAFT Sierra Meadows Partnership Monitoring Protocol; R5 Range Monitoring Rooted Frequency.
5. Sierra Meadows, Wetland Riparian Area Monitoring Plan (SM-WRAMP) 2021c. DRAFT Sierra Meadows Partnership Monitoring Protocol; Target Species Monitoring.

2.1
HYDROLOGY

Groundwater Hydrology Protocol

What, how, why: Groundwater measurements using data loggers to measure depth to groundwater and groundwater contour map.

Print & Carry
Field Instructions
& Equipment List

WHEN SHOULD THIS PROTOCOL BE USED?

Protocol 1: Monitoring Wells
Monitoring wells should be used when restoration objectives are to monitor groundwater table changes over time and/or space pre vs post restoration and when continuous data (eg: hourly) is desired, because a pressure transduce can be placed in each monitoring well. Monitoring wells due to being slotted all the way to the surface allows fluid passage of the water table across all depths for the ideal representation of a shallow groundwater table.

Protocol 1: Piezometers
Piezometers should be used when restoration objectives are such that there is an interest in how the groundwater table changes over time and/or space on a pre vs post restoration basis and when the installation technique and associated costs are warranted and when more continuous data (eg: hourly) is warranted, because a pressure transducer can be placed in each piezometer.

Protocol 2: Solinst Drive-Point Piezometers
Drive-Point piezometers should be used when restoration objectives are such that there is an interest in how the groundwater table changes over time and/or space on a pre vs post restoration basis but the more traditional groundwater monitoring well installation techniques are of concern, and lower frequency groundwater data collection is acceptable (e.g. only when collecting measurements during site visits).

Protocol 4: Vegetation Monitoring
SM-WRAMP vegetation monitoring protocols should be used when restoration objectives are such that there is an interest in how the groundwater table changes over time and/or space on a pre vs post restoration basis but groundwater monitoring well and piezometers installation techniques and associated costs are of concern for the project manager, and vegetation data are a sufficient indicator of groundwater table conditions.

PROTOCOL DESCRIPTION

Monitoring wells and piezometers should be installed to represent the conditions of the meadow. If the meadow is uniform in nature, then a network of at least three transects with a minimum of three piezometers per transect (n=9) is needed to characterize the conditions. Transects should be oriented perpendicular to stream flow and placed to capture the "lower," "middle," and "upper" portions of the meadow (Figure 2). This alignment will provide the data density sufficient to capture the surface and subsurface flow effect on groundwater as it moves from the upstream to downstream ends of the meadow.

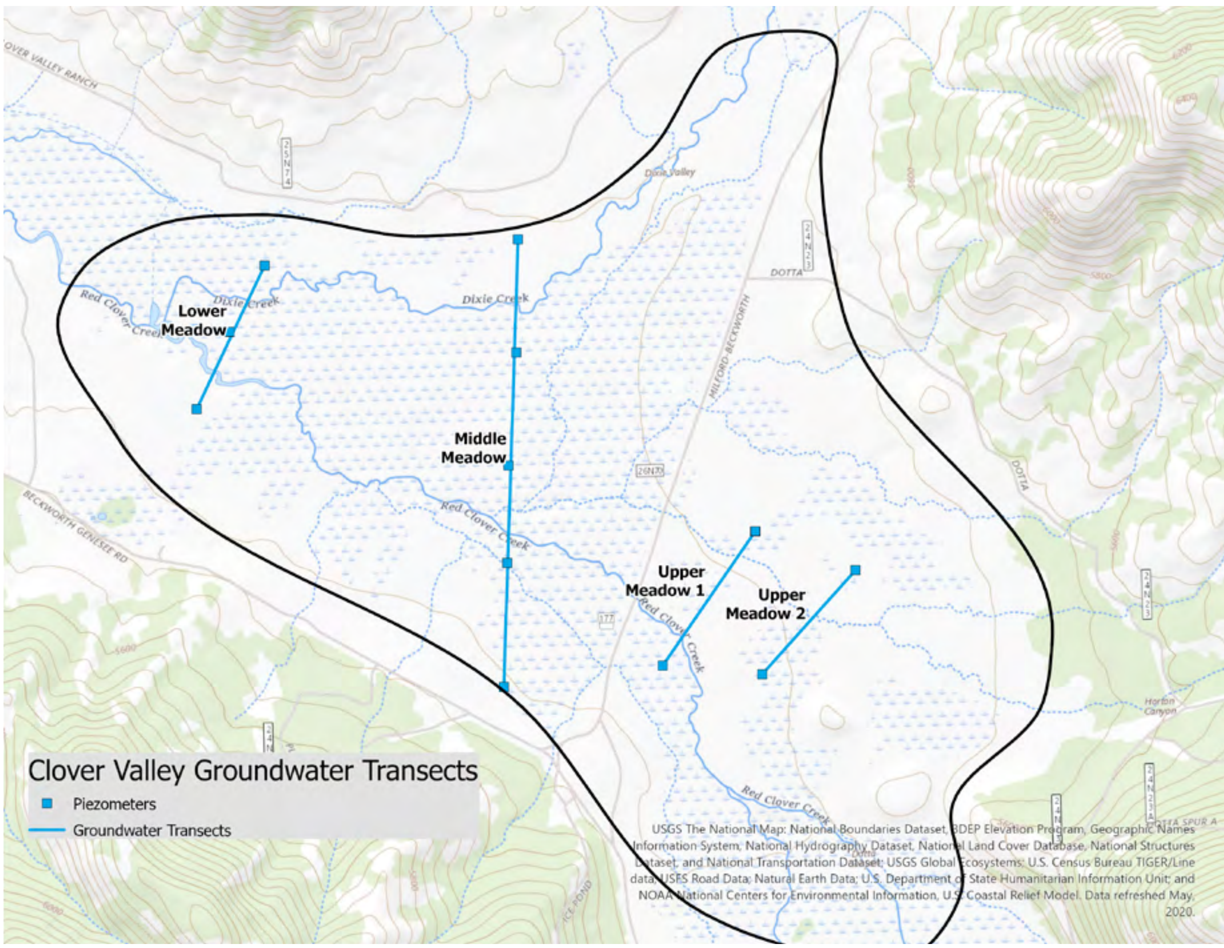

Figure 2. Example Groundwater Transects at The Clover Valley Ranch Restoration Project

Protocol 1: Monitoring Wells

Monitoring well refers to a well that is used to measure or monitor the level, quality, quantity, or movement of subsurface water. Monitoring wells are used to collect groundwater data for scientific studies and to make environmental regulatory decisions. Scientific uses include the collection of water quality and biological samples, water-level measurements and tracer studies. Monitoring wells also provide small windows into the aquifer, which is a habitat that is difficult to study. Sampling efforts using monitoring wells may help refine the known extent and size of populations of groundwater species that inhabit the aquifer.

Monitoring wells (Figure 3) have perforations extending from just below the ground surface to the bottom of the pipe. Water levels inside the pipe result from the integrated water pressures along the entire length of perforations. Piezometers (Figure 3)

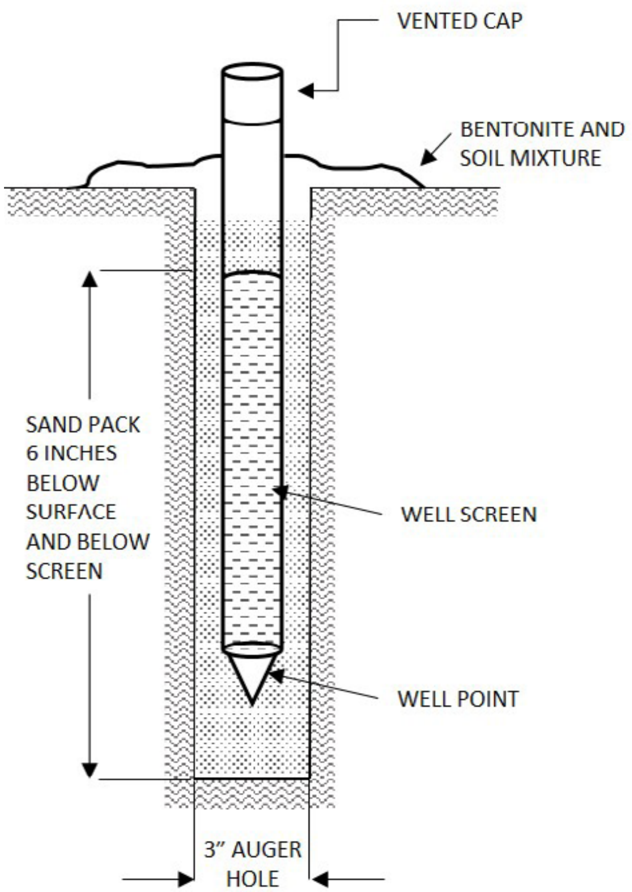

Figure 3. Standard Monitoring Well Installation (The Sierra Fund, 2021).

on the other hand, are perforated only at the bottom of the pipe. They are usually installed with an impermeable bentonite seal above the perforated zone so water cannot flow down the outside of the pipe. Water levels inside the pipe result from the water pressure over the narrow zone of perforation at the bottom of the pipe.

The installation of a monitoring well will be more representative of the shallow groundwater table. Water levels in piezometers do not necessary equate with the actual water table and better represent the water pressure at the well screen location. Subsequently, the well screen location if at different elevations, can have differing water levels despite being in the same body of groundwater. This difference can be significant if the body of groundwater is moving upward or downward. If the groundwater table is moving upward (artesian flow), water pressure is greater at depth and decrease the closer to the groundwater surface. In addition, water levels will be higher in deep pipes than shallow ones (Figure 4: A). Conversely, if the groundwater table is moving downward, water levels are lower in deep pipes and higher in shallow ones (Figure 4: B) (Sprecher 2000).

Protocol 2: Piezometers

Piezometers are a glimpse into the subsurface hydrology and can be used to measure or monitor the level, quantity, or movement of subsurface water. When installing piezometers by either a track mounted drill rig or by using a hand auger, piezometers should be installed during low water periods in the late summer. If they are installed when the water table is low and they are installed deep enough to reach the ground water, then they are less likely to go dry during later periods of summer and fall when groundwater levels are typically at their lowest. Both track mounted rigs and hand auger techniques should anticipate needing to bore a 3" diameter hole to install 10' x 2" diameter steel or PVC pipes. If depths of borings are greater than 10 feet in length, then use 2" couplings to add additional lengths of pipe. When either drilling or using a hand auger, excavate the boring down until you reach the point of which sediment is completely saturated and then continue for an additional 6 – 12 inches to capture late season or drought conditions when the water table will be at its lowest.

When choosing your piezometer material (steel or PVC) keep in mind that there are some disadvantages to using PVC. Although PVC is cheaper than steel, PVC is more susceptible to cracking during freeze-thaw cycles throughout the year, more likely to be damaged by wildlife or grazing cattle and also may become brittle overtime due to UV exposure. However, if you still choose to use PVC, the pipe should be capped and pre-drilled with 2mm holes every inch on four sides of the pipe for the first 6-12 inches of pipe, so that there is a circle of holes for every vertical inch of pipe. If using steel pipe, pre slotted pipe can be purchased and drive-point well heads with screens should be used.

Upon auguring 3" diameter boring;

1. insert the well-point and length of pipe,
2. fill with sand up 6" below the surface,
3. fill top 6" with bentonite and water (Figure 5).

A GPS point of each well should be recorded and wells should be surveyed to the top of the well casing. Repeat for each piezometer within the transect to complete your groundwater monitoring network. It is highly recommended to spray paint the "stick up" portion of your piezometer with a vibrant high visibility color annually so that they are easier to be found.

Prior to installation in the field, technicians should download the Solinst supplied Levelogger software program and configure all Leveloggers and Barologgers. Configuration of pressure transducers means a site ID is identified for each instrument, syncing the internal clocks to a common datum (e.g. PST or PDT), identifying an appropriate logging interval (1-

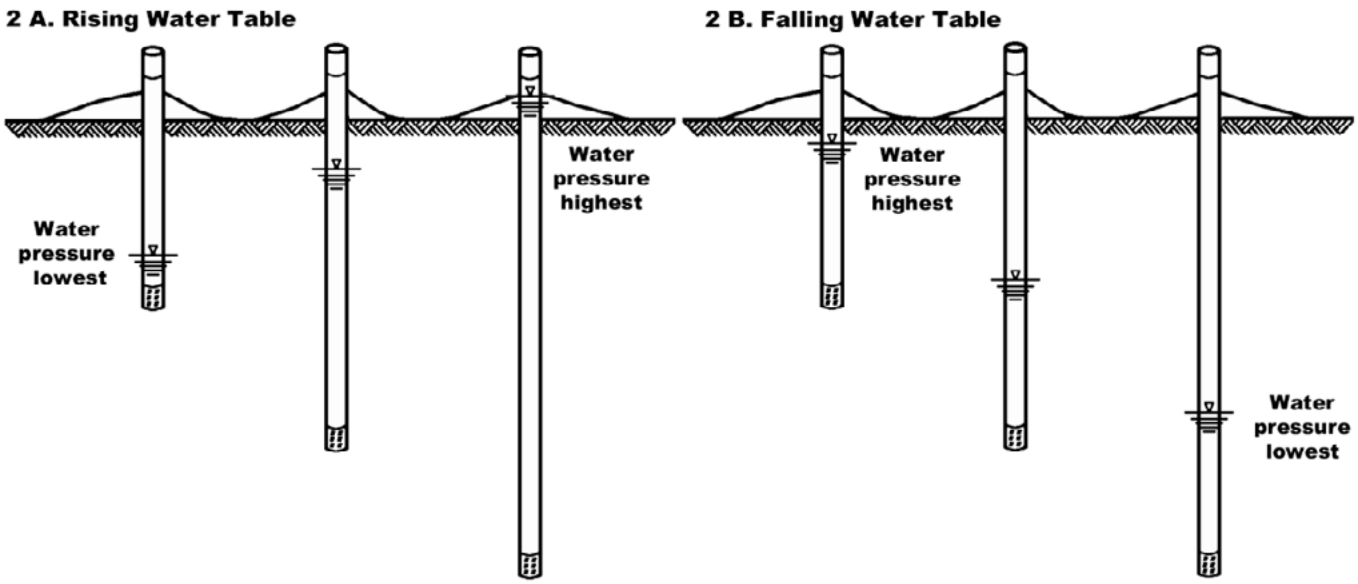

Figure 4. Example of water levels in piezometers. A. Water tables rising from below (artesian or discharge system). B. Water tables dropping from above (recharge system) (Sprecher 2000)

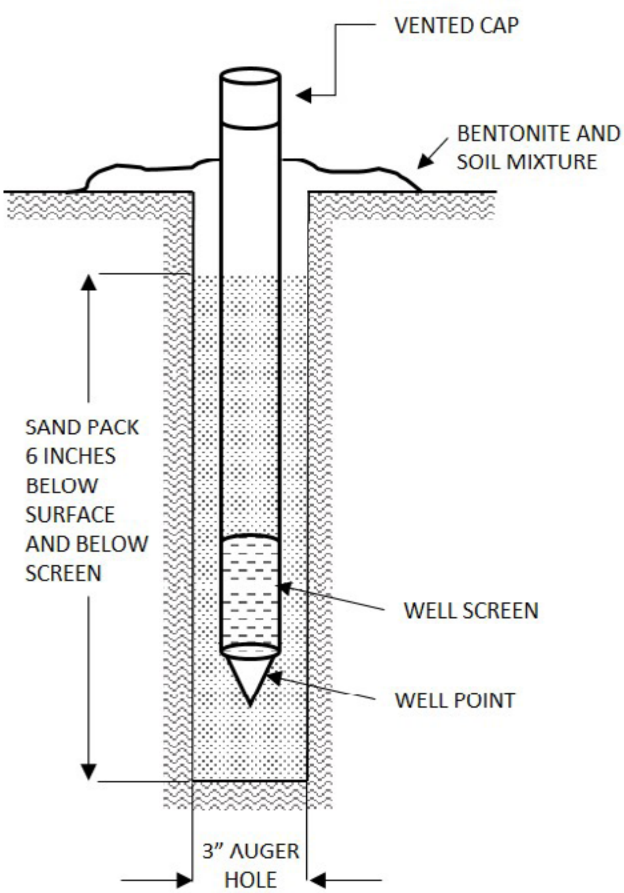

Figure 5. Standard Piezometer Installation (The Sierra Fund, 2021).

hour interval recommended), and establishing a start-time or the time of estimated deployment in the field. Field technicians should also make sure to download the Levelogger software onto all field laptops or tablets prior to entering the field for data downloading and troubleshooting efforts.

Pressure transducers can be installed in each piezometer or a select few depending on the use of the well network and data objectives. To install a pressure transducer in a piezometer, attach a length of steel cable long enough to reach the bottom of the well to either the steel or PVC well cap using an eye bolt. On the other end of the steel cable attach a Solinst Levelogger pressure transducer for continuous depth to groundwater measurements. Additionally, a pressure release hole should be drilled into the cap to equilibrate the environment within the well with atmospheric pressures. Deploy the pressure transduce into the well and secure the well cap.

Solinst Barologger should be installed within the piezometer network account for variations in atmospheric pressure to increase data accuracy. Either secure the Barologger to the same through bolt or eyebolt that the piezometer pressure transducer is attached to within the piping or in a nearby mounted vented PVC housing.

Protocol 3: Solinst Drive-Point Piezometers
Solinst Drive-Point Piezometer Instructions should be followed as recommended by the user manual that accompanies the type and extensions suited for project needs (see Resources Section, Figure 6). Solinst Drive-Point Piezometers are available in 3/4" diameter x 1', 2' and 3' extensions and are installed using a slide hammer rather than auguring. One trade off with using the smaller but less invasive Solinst Drive-Point Piezometers is that they do not allow the collection of continuous data using the Solinst Leveloggers, pressure transducers, as the diameter is smaller than that of the transducer. Solinst Drive-Point Piezometers do however allow the use of depth sounders to collect depth to water measurements by hand. A GPS point of each piezometer should be recorded and surveyed to the top of the well casing. Repeat for each piezometer within the transect to complete your groundwater monitoring network. It is highly recommended to spray paint the "stick up" portion of your piezometer with a vibrant high visibility color annually so that they are easier to be found.

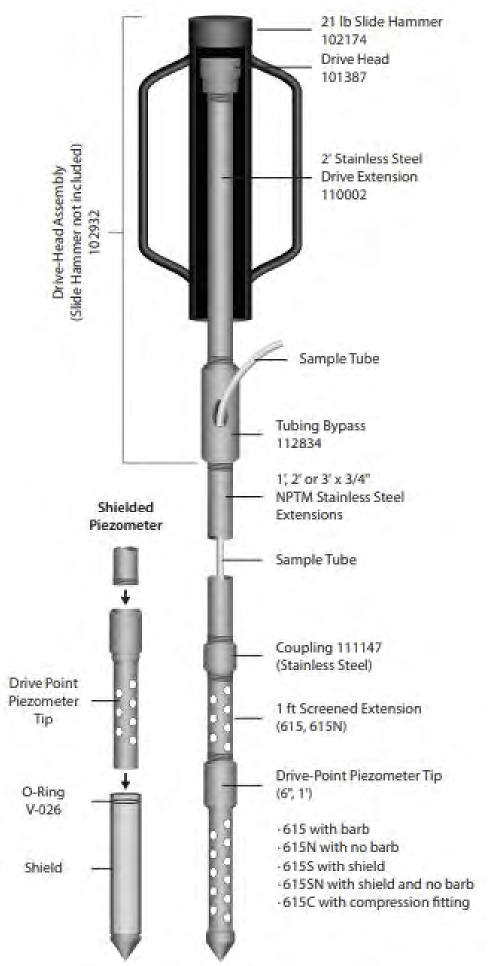

Figure 6. Solinst Drive-Point Piezometer.

Protocol 4: Vegetation Monitoring
Restoration Impact Plant Transect Monitoring Protocol
This method involves establishing transects and subplots across the meadow to identify changes in dominant plant species before and after restoration (SM-WRAMP, 2021a).
R5 Range Monitoring Rooted Frequency Protocol:
Rooted frequency of plant species, ground cover, and rooting depth/density are metrics used to provide a standardized system for determining ecological condition and long-term trend in meadow sites. This report describes field methods for collecting data for rating ecological condition (SM-WRAMP, 2021b).

Target Species Monitoring Protocol
There are three parts to this protocol: desktop analysis, field survey, target plant population documentation, and population revisits. The field survey portion has two levels of effort defined by how systematically the meadow is surveyed for target plant populations. Plan on doing all three steps of this protocol for pre-restoration documentation of spatial location and population size. However, if existing survey data is readily available, it should be utilized to streamline these steps. Once target plant species have been documented plan on implementing the last step, population revisits, to assess target species populations at 1, 3, 5, and ideally 10 years' post-restoration (SM-WRAMP, 2021c).

INSTALLATION

For monitoring well or piezometer installations using a drill rig, a two-person team including a certified operator will be required (Figure 7). The travel time between drilling locations can be significant with a track mounted rig driving through a large meadow and access should be planned for each site accordingly.

Once at a site, depending on the substrate, depth and team experience, it can take 1-4 hours to install a single monitoring well or piezometer. The ~4-hour timeframe includes the drilling, installation, packing and installing a pressure transducer. Cores from this process can be saved in plastic tubes as they are brought up by the drill rig in 4 ft. sections and can be used to create a soil profile to better characterize the subsurface conditions.

Depending on the method of installation the timing and level of effort required to install a monitoring well or piezometer will change. Packing the piezometers with sand and capping with bentonite will be the same regardless of the method used.

Figure 7. Four-person installation of piezometer using a Track Mounted Drill Rig, operator not shown, two helpers that have prepared the pipe and well point and one person who has labeled the soil cores and taken notes on soil conditions as well as taking pictures (Phot Cred. Carrie Monohan).

Protocol 1: Monitoring Wells

The recommended method for installing monitoring wells involves auguring a borehole with an outside diameter 2 in. greater than the well diameter (e.g., 3 in. for a standard 1-in. well) (USACE 2005). The depth of the borehole will change depending on your objectives for groundwater well monitoring. In most cases, a standard monitoring well installed to a depth of 15 in. below the surface should be used to classify wetland types, but installing wells deeper (4-10 ft) is encouraged to help interpret water-table fluctuations and deeper water table information. Deeper wells are not required but, if used, should not penetrate any restrictive soil layers.

Recommended equipment includes a bucket auger/2-man gas powered auger/drill-rig to dig the borehole larger than the diameter of the well being installed, a tamping tool (e.g., wooden or metal rod), bentonite chips, sand, and the constructed monitoring well.

Installation Steps

1. Auger a hole in the ground to a depth approximately 6 in. deeper than the bottom of the well. Be sure the hole is vertical.
2. Scarify the sides of the hole if it was smeared during auguring.
3. Place 4 to 6 in. of sand in the bottom of the hole.
4. For a 15-in. well with 10 in. of well screen, make a permanent mark on the well riser 5 in. above the top of the screen. Insert the well into the hole to the proper depth; the permanent mark on the riser should be even with the soil surface. Do not insert through the sand.
5. Pour and gently tamp more of the same sand in the annular space around the screen and 1 in. above the screen.
6. Pour and gently tamp 4 in. of bentonite chips or soils above the sand to the ground surface. If necessary, add water to cause the bentonite sealant to expand.
7. Form a low mound of a soil/bentonite mixture on the ground surface around the base of the riser to prevent surface water from puddling around the pipe.

Protocol 2: Piezometers

Hand Auger:

For installations using a hand auger, a four-person team is helpful, that way people can take turns auguring and cleaning out the auger (Figure 6). Not including travel time between sites and depending on the conditions of the subsurface material and experience of the team expect to spend ~6-8 hours per piezometer installation. Similar to the drill rig method, the ~6-hour timeframe includes the boring, installation, packing and installation of the pressure transducer. Refer to EPA, 1991, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, for additional information and techniques for hand auguring the bore hole for piezometers.

Figure 8. Hand Auguring of Piezometer Boring at Clover Valley Ranch, 2019. (Photo Cred. Carrie Monohan)

Protocol 3: Solinst Drive-Point Piezometers

Installation of the Solinst Drive-Point Piezometers is a one-person job and does not require packing of sand, cement and bentonite but rather requires the use of a specialized Solinst slide Hammer. Including travel time between sites, expect to spend ~2 hours per piezometer installation. The ~2-hour timeframe includes the assembly of piping and pounding or driving of the piezometer into the ground (Figure 7).

Figure 7. Technician Installing a Solinst Drive-Point Piezometer (Solinst ©).

Protocol 4: Vegetation Monitoring
Plot and transect locations should be selected prior to field work when implementing the SM-WRAMP vegetation protocols as proxies for groundwater conditions. Pre site visit desktop analysis is recommended to identify key features and potential vegetation communities, using aerial imagery, digital elevation models, previously collected vegetation data is applicable or any other digital resources. However, site reconnaissance to select transects that best represent the range of conditions on site are recommended. Similar to the spacing of the piezometer transects, at least three transects are recommended that span the upper, mid and lower portions of the meadow, however the site condition may warrant more, this is discussed in detail in each of the individual protocol documents. If you are coupling a combination of Protocol 1-3, it is recommended that the vegetation transects be "on top of" the groundwater monitoring transects to air in data analysis.

DATA COLLECTION FREQUENCY & TIMING

Protocol 1: Monitoring Wells
Monitoring well data and complimentary barometric pressure readings should be downloaded from the submersed Solinst Levelogger's and Barologger at least twice per year, once following spring thaw when access is permitted and the other at the end of fall just before winter sets in and access is limited. Upon arrival to the monitoring well, remove the cap and retrieve the Levelogger. Using the Solinst supplied optical reader (aka shuttle) and software, download the stored data onto your field laptop or tablet. While the data is downloading inspect the well surrounding for any damages that may have occurred due to weather, wildlife or other elements. Once the data are downloaded from the Levelogger, collect a depth measurement by hand using a depth sounder for instrument calibration.

To measure the water table height, a coaxial water level meter (sounder) or a flat-tape water level meter can be used. The water level meter is used to measure the water level in a well that emits a sound when water is detected. The length of cord/tape that was extended into the well is the distance to the groundwater table. Be sure to measure the depth to groundwater from the same place on the well every time, typically the top of the well casing, and then later subtract the well "stick up" or distance from ground surface to the top of the well casing to get the distance to groundwater table below the ground surface. Also be sure to measure the total depth of the well, to monitor if it is filling in with sediment and if it needs clearing and re-calibration.

Once the measurement is completed, return the Levelogger and Barologger into the piezometer and replace the well cap and hand tighten. It should take one person approximately 10-30 minutes to complete the data download and physical depth the groundwater measurement per monitoring well.

Protocol 2: Piezometers
Piezometer Levelogger data and complimentary barometric pressure readings should be downloaded from the submersed Solinst Levelogger's and Barologger at least twice per year, once following spring thaw when access is permitted and the other at the end of fall just before winter sets in and access is limited. Upon arrival to the piezometer, remove the cap and retrieve the Levelogger. Using the Solinst supplied optical reader (aka shuttle) and software, download the stored data onto your field laptop or tablet. While the data is downloading inspect the well surrounding for any damages that may have occurred due to weather, wildlife or other elements. Once the data are downloaded from the Levelogger, collect a depth measurement by hand using a sounder for instrument calibration.

To measure the water table height, a coaxial water level meter (sounder) or a flat-tape water level meter can be used. The water level meter is used to measure the water level in a well that emits a sound when water is detected. The length of cord/tape that was extended into the well is the distance to the groundwater table. Be sure to measure the depth to groundwater from the same place on the well every time, typically the top of the well casing, and then later subtract the well "stick up" or distance from ground surface to the top of the well casing to get the distance to groundwater table below the ground surface. Also be sure to measure the total depth of the well, to monitor if it is filling in with sediment and if it needs clearing and re-calibration.

Once the measurement is completed, return the Levelogger and Barologger into the piezometer and replace the well cap and hand tighten. It should take one person approximately 10-30 minutes to complete the data download and physical depth the groundwater measurement per monitoring well

Protocol 3: Solinst Drive-Point Piezometers
Because the Solinst Drive-Point Piezometers are not capable of housing a Solinst Levelogger, more frequent site visits are required to collect depth to groundwater data. At a minimum it is recommended to complete at least 4 recordings per year, one per spring, summer, fall, and winter season.

To measure the water table height, a coaxial water level meter (sounder) or a flat-tape water level meter can be used. The water level meter is used to measure the water level in a well that emits a sound when water is detected. The length of cord/tape that was extended into the well is the distance to the groundwater table. Be sure to measure the depth to groundwater from the same place on the well every time, typically the top of the well casing, and then later subtract the well "stick up" or distance from ground surface to the top of the well casing to get the distance to groundwater table below the ground surface. It should take one person approximately 15 minutes to complete the physical depth the groundwater measurement per monitoring well.

Protocol 4: Vegetation Monitoring
Restoration Impact Plant Transect Monitoring Protocol:
This protocol should be conducted during the peak of the growing season in advance of and after restoration implementation. At least one year of pre-restoration transect plot percent vegetation, ground and species cover data should be collected, within one to three years prior to the restoration. The protocol should be repeated at one-year, three-years, five-years, and ten-year post-restoration. Additional data collection efforts can be added (e.g. year 2) if time and resources allow.

Peak growing season at higher elevations is usually in late June-July into August; in the lower elevations it could be as early as May-June (SM-WRAMP, 2021a).

R5 Range Monitoring Rooted Frequency Protocol:
Sampling should occur during peak growing season in order to identify plant species. Rooted Frequency monitoring within established survey plots should occur at a minimum 1-year pre restoration, 1-year post restoration and then every 5 years for a minimum of 10 years total (or 4 sampling periods) depending on project response. If monitoring allows every 5 years in perpetuity great. (Note: R5 Range monitoring plots are currently sampled every 5 years, with the majority of the plots were established between 1999 and 2003) (SM-WRAMP, 2021b).

Target Species Monitoring Protocol:
Season of surveying: timing of surveys pre- and post-restoration depends on the life history of the target species. Because target species may differ in the timing of being identifiable in the field, multiple survey events may be necessary. Utilize CalFlora or USDA plants to determine when the plant is flowering/identifiable to plan the timing of sampling. Depending on the elevation, May through August are typical survey times for plant species in meadows.

Pre-restoration targeted vegetation species monitoring frequency: One visit during the time the plant is identifiable the season before restoration is planned to occur so the most up to date spatial data is available. Surveys for multiple years before the restoration would allow for a clearer distinction of whether variability in population size/cover post-restoration is outside of that detected pre-restoration.

Post-restoration targeted vegetation species monitoring frequency: The frequency of post restoration monitoring will be set by the goals of the restoration as well as the target species of interest and how it is predicted to respond to restoration actions. Annuals, perennials, and shrubs may respond on a different time scale to restoration actions. Multiple re-visits will likely be necessary to determine trends over the years and inform any subsequent adaptive management actions. At a minimum, post-restoration monitoring should occur one, three, five, and ten years following restoration during the flowering season, or appropriate season for identification, of the target species to detect changes in target species populations.

Dramatic increases or decreases in target plant species or an overall trend in target species population size determined through yearly monitoring may trigger additional monitoring or adaptive management strategies (below) (SM-WRAMP, 2021c).

2.1
HYDROLOGY

Groundwater Hydrology Protocol

Equipment List

Print & Carry Field Instructions & Equipment List

Protocol 1: Monitoring Wells

Installation

- Optional: Rental of track mounted drill rig
- Optional: Rental of two man auger with bit/extensions
- 3-1/4" HD Reg Reinforced Auger
- "T" Handle 18" Rubber Coated
- Two 5/8" X 5' Extensions
- #3 Sand 50# 72/plt
- 2" x 10' SCh 40 PVC .010 Slot Screen F/T
- 2" PVC Clip Cap
- 2" Female Cap SCh 40 PVC
- Bentonite
- Solinst Kevlar Rope
- Battery Powered Drill
- Solinst Levelogger
- Solinst Barologger

Monitoring

- Solinst Depth Sounder
- Field Laptop
- Optic Reader
- Datasheets
- Writing utensil
- Key (if you purchased locking well caps)

Protocol 2: Piezometers

Installation

- Track mounted Drill rig or hand auger equipment
- Screened Drive Points
- Steel/PVC Piping
- Steel/PVC Couplers
- Steel/PVC Well caps
- Sand
- Bentonite
- Steel cable
- Eyebolts and lock nuts
- Battery powered Drill and drill bits
- Solinst Leveloggers (one for each well
- Barologger
- ≥ 2" Pipe wrenches (x2)
- ≥ 2" Manual Pipe Threader and Die Head
- ≥ 2" Pipe Cutter
- Biodegradable cutting oil
- Side cutters
- Socket wrench set
- Gloves
- Spray paint
- GPS unit

Monitoring

- 2" Pipe wrench
- Solinst Depth Sounder
- Field laptop or tablet
- Optical reader

Protocol 3: Solinst Drive-Point Piezometers

Installation

- Slide hammer
- Solinst Drive-Point Piezometer
- Solinst screened extensions
- Solinst extensions
- Couplings
- Piezometer caps
- ¾" Pipe wrench x2
- Gloves
- Teflon tape
- GPS Unit

Monitoring

- 3/4" Pipe wrench
- Solinst Depth Sounder
- Field notebook

Protocol 4: Vegetation Monitoring

Refer to the associated SM-WRAMP Vegetation Monitoring Protocol for Equipment lists.

2.2 HYDROLOGY

Surface Water Flow

Resource Target

Hydrologic Function

Indicators/Attributes

Stage, Discharge, Rating Curve, Hydrograph, and Hydrograph Component Analysis for Baseflow, Peak flow, Slope of Rising and Falling Limbs, Flow attenuation, Stormflows

Stream Bank Gaging Station Deployment, Red Clover Valley CA (Photo credit; Monohan 2019).

INTRODUCTION AND BACKGROUND

Monitoring and quantifying surface water hydrology in meadows is critical to characterizing meadow function and health. Degraded meadows with incised streams typically have stream flow that is disconnected from the floodplain (i.e., the floodplain is not inundated during typical 1.5-2-year floods). With successful restoration actions, we expect the stream discharge to reach bankfull more frequently and inundate the floodplain. We also expect the summer baseflow periods to be maintained later in the summer after restoration and that the meadow will provide critical late summer season aquatic habitat.

The surface water hydrology of a meadow is measured by collecting a record of stream flow data over time. The hydrology of the stream is described using stage and discharge. Stage is the height of the water relative to an arbitrary datum or elevation at a specific location. Stage is traditionally measured with a staff plate (vertically installed ruler) and now more often measured with a pressure transducer. Measuring stage by using a pressure transducer in a stilling well (pipe) will allow for pressure measurements to be taken continuously over time. Discharge is the flux of water (volume per time) in the stream at a single location. Discharge is measured using the velocity area method. The relationship between stage and discharge is used to develop a rating curve (Figure 1), so that for any stage the discharge can be estimated.

To develop a stage discharge relationship, or rating curve it is important to measure the discharge over a range of conditions, capturing low flows and high flows (at least 5 measurements are needed). A rating curve is a set of data points for which you have both a stage reading and a discharge measurement. The data are graphed together so that a relationship can be determined to estimate the discharge for any stage within the channel over the range of conditions that have been measured.

The discharge data can be plotted over time to create a hydrograph (Figure 2). A hydrograph is a record of the volume of water movement in the stream over time. You can create annual hydrographs, or daily hydrographs or hydrographs for a single storm. Hydrograph analysis is often broken down into separate components. Key hydrograph components that can be compared over different years include summer base flow, the slope of the rising and falling limbs from storm events, stormflow and peak flow.

Baseflow represents the amount of water that sustains stream flow when no immediate precipitation has occurred and primarily contributed to by groundwater (Price, K., 2011 and Hall, F., 1968). There can be summer base flows and winter base flows. When storm events introduce more water in a system, discharge is added to the baseflow as stormflow (Ward and Tremble, 2003). The rising limb reflects the response to an increase in discharge in a stream typically following a precipitation event, while the falling limb shows the return to baseflow after the increase in discharge. If there is significant interflow, groundwater flow, subsurface drainage or delayed runoff, the receding limb (falling limb) will fall slowly, making it difficult to determine the end of the storm event. The different components of the hydrograph can be compared before and after restoration.

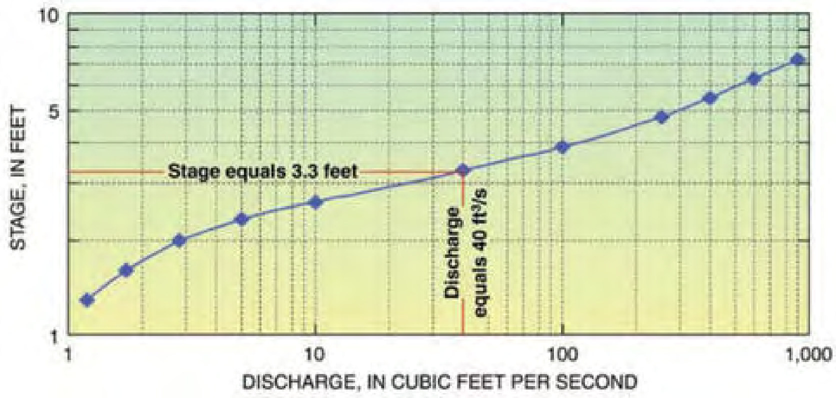

Figure 1 USGS Stage-Discharge Rating Curve Relation Example (USGS, How Streamflow is Measured).

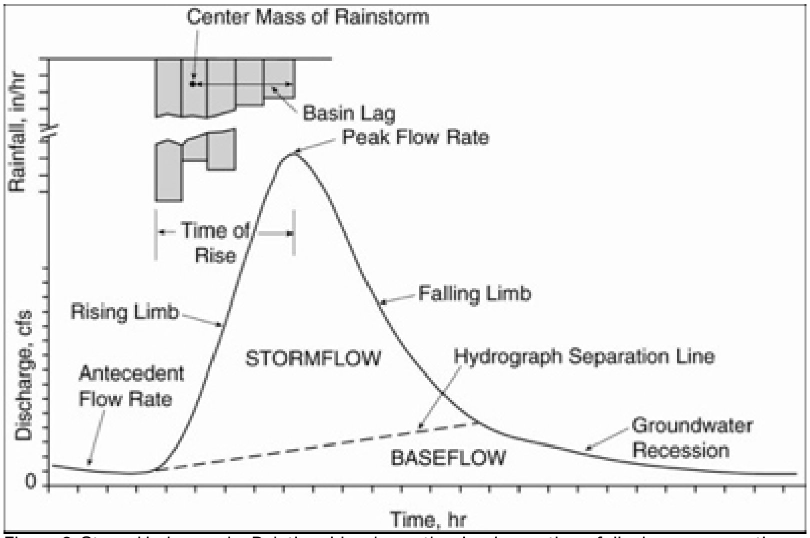

Figure 2. Storm Hydrography Relationship: shows the river's reaction of discharge versus time during a storm event (Ward and Tremble, 2003).

Baseflow separation lines are drawn to show separation of baseflow and stormflow in Figure 1 (Ward and Tremble, 2003), the area above the baseflow separation line is the storm event. Peak flow rate, shown in Figure 1 represents the greatest velocity of discharge during the stormflow. Streamflow responds differently to influxes of flow, with different conditions, such as rainfall intensity, soil infiltration capacities and antecedent soil moisture (Ward and Tremble, 2003).

Each hydrograph component gives a different idea of how the meadow is functioning hydrologically. For restoration with objectives to improve meadow hydrology, a restored meadow would be expected to have a later summer baseflow period than a degraded meadow. Restored meadows would also have a slow rising and falling limb while degraded meadows respond quickly. Restored meadows would have a lower peak flow, compared to pre restoration. These hydrograph components give quantifiable measurements for hydrologic function before and after restoration.

2.2 Surface Water Flow

What goals are being evaluated?

As climate change reduces snowpack on the landscape, meadows play a vital role in the green infrastructure of our headwaters. One common goal of meadow restoration is to restore the meadows hydrologic function. Hydrologic function can be quantified by a meadows ability to retain water on site and connect to the floodplain. Meadows that are spring fed or that do not have a defined channel network may be hydrologically functional and measuring surface water flows would not be feasible with the techniques described here, such environments would benefit from following a groundwater monitoring protocol rather than surface water protocol (See SM-WRAMP Groundwater Protocol). Hydrologically functional meadows in a watershed provide cool water late into the season for many on site and downstream habitats. Hydrologically functional meadows will achieve bankfull conditions and inundate the floodplain regularly or during 1.5-2-year flood events. Floodplain inundation frequency can be measured by the number of times that the stream is at or over bankfull stage.

What restoration objectives does the indicator evaluate?

The restoration objective to reduce or eliminate stream incision is measured by the duration and frequency that stream discharge is at bankfull.

The restoration objective to provide habitat late into the season is measured by the summer baseflow extending late into the season.

The restoration objective of hydrologic function can be measured by increased summer baseflow, decreased peak flows, gradual outflow falling limb post restoration and increased lateral hydrologic connectivity between the channel and the meadow floodplain.

The surface water hydrology indicators help quantify the hydrologic condition of the meadow pre and post restoration, and provide insight into the success of the restoration activity. The indicators of baseflow, falling limb and peak flows characterize the meadows ability to retain, absorb, and slow down/attenuate flow within the site. Quantifying flow attenuation within the meadow represents the meadows capability to buffer stream pulse events and increase water retention time on site.

What questions/uncertainties are being answered/addressed?

Do hydrologically functional meadows attenuate peak flows?

Do hydrologically functional meadows increase water storage?

Do hydrologically functional meadows provide critical late season surface water?

PLANNING

Level of Effort Variations

Variations on the above recommendations can be made for small budgets. If you cannot afford a pressure transducer and a barometric logger which are about $400 each. Then you can install a staff plate instead of a stilling well, the difference is that you have to read the staff plate periodically in order to create a hydrograph and you may miss peak flows as there is only data for when the staff plate is read in this scenario. But this may be sufficient if you only plan to capture summer baseflow conditions. Some scenarios may benefit from installing a wildlife camera positioned towards the staff plate and set up to capture an image on a regular basis to establish a continuous record. Even if you are not setting up a continuous monitoring station with a pressure transducer, you will still need to create a rating curve by vising the site multiple times at a range of flow conditions and measuring discharge using the Velocity-Area method and relating that to a stage reading.

There are also cheaper flow meters. The least expensive meters are mechanical and run for about $800, the trade-off is that they do not detect low velocity conditions very well or at all. In addition, if you do not have a top-setting wading rod, a yard stick can be used to measure the depth of the water and where the velocity meter should be held, 0.6d.

Data Collection Timing

Instream pressure transducers can be set to automatically collect data every 15, 30, 60 minutes and or on a daily basis. The batteries last for 3-5 years depending on the conditions

2.2 Surface Water Flow

they are deployed in and what frequency they collect data. Our pressure transducers collect data every hour year round and we expect them to last 5 years. Stream discharge measurements should be made frequently enough to capture a wide range of stream flow conditions. In order to ensure a well-developed stream discharge rating curve, discharge should be measured at least five times a year spread throughout the water year. It is important to note that both flow and innundation measurements need to be taken during summer and winter baseflows in addition to before, during (peak flows) and after storms so that a range of flow conditions are captured. The rating curve will only be accurate within the range of discharges you measure.

Required Resources

Installing a pressure transducer stream gage is a large effort and will depend on access to the site. Typically, three people in one day per stilling well installation is needed, maybe two stilling wells can be installed in a day if you can get to it with equipment. Installing the stilling well is the hard part, specifically making sure it is secure and that the pressure transducer will be wet under low flow conditions. Ideally the pipe is pre drilled before you go on site. A fence post pounder might help in some situations; other situations might need a hydraulic pounder. If there are large rocks or a bridge abutment you can install the pipe to, then you will need a drill that can install things into concrete or rock. See picture below of a stilling well in a meadow and pressure transducer.

The pressure transducer is held by a cable and deployed inside the stilling well. In Figure 10, the t-posts and other pipe are providing support and can be the most difficult part when installing a gage The support pipe is this picture was installed when heavy equipment was on site and could pound it into the stream bed using a bucket of an excavator or hydraulic pounder for a track mounted drill rig. The bank has receded since this well was installed, and it may blow out in the next winter storm season. Pressure transducers should be downloaded at least twice a year. The typical pressure transducer can last on the factory supplied battery supply for ~5 years with an hour sampling period before replacement.

Two people can complete a discharge measurement and collect data from a pressure transducer in less than an hour per site, under normal weather conditions where access is not a huge issue. This will need to be done at least 5 times per year, at least monthly and during storm events is recommended. Here you see the person with the velocity meter in the water reading the water velocity at 0.6d for each station across the tape. The person on the bank is recording the data into a table on a tablet as it is called out.

Figure 10 Solinst Pressure Transducer (Photo credit; Monohan 2019).

2.2 Surface Water Flow

Figure 11 Image of CSU Chico graduate students and volunteers conducting the Velocity-Area Method for discharge, just upstream of the stream gage. You can see the pipe for the stream gage in the upper left hand corner, this steel pipe has two pressure transducers inside of it, on at the bottom and one at the top. It is secured in place with two t posts set back on the bank, and a support pipe that was pounded into the stream bed (Photo credit; Monohan 2019).

Equipment Costs if New

1. Top-Set Wadding Rod (~$400)
2. Velocity Meter/ flow meter (HACH FH950 ~$7,000) or (Mechanical Price Pygmy ~ $800)
3. Vinyl Tape ($20)
4. Pressure Transducer (Solinst Level Logger model 3001~$600)
5. Barometric Logger (Solinst Barologger model 3001~$300)
6. Data transfer device, shuttle (Solinst Data Transfer Device ($150)
7. Stilling well hardware (~$50/station)
8. 10ft steel pipe, ($20 each) or 10ft of PVC ($10 each)
9. Tools (drill, post pounder, wire cutter…etc.) (~$300)
10. T-posts (~$5 each)
11. Notebook ($20)
12. GPS (~$100)

* Discharge measurement equipment can also be rented from a variety of vendors.

Level of Expertise Required

Introductory level training for field technicians to install monitoring stations and complete discharge measurements and at least 1 year of experience with for identification of inundation extent and hydrologic data analyses for rating curve development.

Total Costs

- Equipment Costs for measuring discharge ~ $1,200-$7,500 (Top-Set Wadding Rod and Flow Meter).
- Estimated Stilling Well Hard Costs ~ $1,500 (Pressure transducers, Data Transfer device, Well piping and hardware).

Installation Labor

$50/hour x 8 hours/station x 2 technicians = ~$800/station
One-time cost

2.2 Surface Water Flow

Monitoring Labor

- $50/hour x 1 hour/station x 2 technicians= ~$100/station. At least monthly for when site is accessible
- $50/hour x 1 hour for every mile of stream length observed during inundation extent and duration evaluation.

Annual Cross Sectional Survey Labor *See SM-WRAMP Geomorphology Protocol*

DATA ANALYSIS

For each gage station a rating curve is developed by inputting the discharge reading and the corresponding instream stage/pressure reading and then doing a best fit curve in a data analysis environment like Excel. The equation for the best fit line is how one can predict/estimate discharge for any stage/pressure reading within the range of measurements that have been made. Thresholds can be established that signify over banking of stream flow signifying inundation periods and frequency. Time series of continuous in stream stage/pressure data requires QA/QC by applying barometric pressure offsets using the Solinst® Barologger corresponding data set. Solinst® provides a data wizard tool that will make barometric offsets for the user. Data wizard software is available for free on the Solinst® website. The corrected stream pressure readings should be used to create the rating curve.

Data Analysis Steps for a Rating Curve and Hydrograph

Step 1: Download the Levelogger and Barologger readings using the shuttle in the Solinst provided software Data Wizard tool.

Step 2: Using the Data Wizard, apply the barometric offsets to the Levelogger data from the Barologger collected readings.

Step 3: Export these corrected readings into Excel.

Step 4: For date and times when discharge was measured, pull out the corresponding corrected pressure and stage readings and create a small table with at least 5 measurements over a range of flows.

Step 5: Use Excel to graph these data on a scatter plot and do a best fit line in Excel and display the stage discharge equation, also called a rating curve.

Step 6: Use the equation for the best fit line to convert all corrected stream pressure readings into a calculated discharge.

Step 7: Graph the calculated discharge over time to make a hydrograph.

Level of Effort

Instream stage/pressure barometric corrections in Solinst Data Wizard requires a low level of effort. Solinst software allows the export of barometrically compensated data in a downloadable excel csv for use in rating curve development. Rating curve development also requires a low level of effort, plotting discharge measurements to corresponding stage/pressure level in excel and finding the best fit is a basic function of excel.

Creating annual hydrographs can be done in Excel for each gage location.

Conducting a Hydrograph Component Analysis is a high level of effort that will need advice and review by someone with hydrology expertise.

ADAPTIVE MANAGEMENT

Following review of data analysis there are a few common trends that the technician may come across. Listed below are some common issues and adaptive management actions to take in response:

1. Inter annual variation in hydrology changes associated with restoration may affect rating curve best fit equation. As a product of restoration activities, stream dynamics may change stage-discharge relationships over time. The technician conducting data analysis can correct this issue by applying the rating curve and associated stage-discharge equations on a yearly basis to increase the best fit relationship.

2. If a phase shift or baseline shift is observed following a large pulse or storm flow, a common issue that can occur is sedimentation within the protective housing of the pressure transducer. This sedimentation essentially

2.2 Surface Water Flow

creates a new baseline or 0, this can be corrected by removing the accumulated sediment in the protective housing, collecting a subset of data, and subtracting the difference. The difference can then be subtracted from the original dataset following the pulse event.

3. In some circumstances the surface water monitoring station can be damaged; Freeze-thaw cycles, large flood events, mounting failures, vandalism, etc... In either case if the surface monitoring station has to be rebuilt, the stage-discharge relationship will have to be renewed from that point on.

4. If floodplain inundation does not increase relative to pre-restoration levels following restoration activities, determine if other non-restoration activities may be influencing lateral floodplain connectivity, such as vegetation extent, water holding capacity of BDAs, or climate conditions. Determine if additional restoration actions are needed to promote floodplain connectivity and inundation, such as increasing the number or size of the BDAs.

Comparison of pre and post restoration surface water monitoring data can provide insight to the evaluation of the effectiveness of restoration efforts. In a successful model of meadow restoration, surface water data analysis would suggest increased flood frequency inundation of the floodplain, an attenuation of stream flow through the project area, increases in water residence time, and later baseflow periods.

If the restoration is completed and there is no evidence that flood inundation has increased, or that baseflows are observed later in the season then addition phases of restoration may be warranted to further attenuate flows, increases sediment aggradation, and dissipate stream power so that stream incision does not occur again.

However, meadow surface water hydrology is notoriously difficult to characterize in isolation due to variables such as annual climatic variability, quantification of overland flow, groundwater influence, and infiltration. Therefore, surface water monitoring should be analyzed in conjunction with additional SM-WRAMP monitoring protocols such as Groundwater and Geomorphology to accurately evaluate restoration effectiveness of project sites.

COORDINATION

Surface water hydrology protocol can facilitate analysis in many other SMP protocols; Vegetation, Soils, Geomorphology, Wildlife, Aquatic Ecology and water quality. Through implementation of the surface water hydrology protocol, pre vs post restoration comparisons can be explained and related to changes in hydrology.

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FIELD DATASHEETS & DATA UPLOAD FORMS

The following datasheet is available to be downloaded from https://californiatroutinc.box.com/s/xfbp1kpqz5j79ycrv2myo6zh7rghurr2

- Groundwater Datasheet

Surface Water Hydrology Protocol

2.2
HYDROLOGY

Measuring stream discharge with the velocity-area method and installing pressure transducers to measure continuous stage continuously, to create hydrographs and analyze them using a hydrograph component analysis pre and post restoration.

Print & Carry Field Instructions & Equipment List

LEVEL OF EFFORT

Implementation of the Surface Water Hydrology Protocol is identified as a medium level of effort. Installing stream gaging stations requires engineering capability to construct stations and field technical experience to select where the stations go and to maintain the stations. Collecting discharge measurements in a range of conditions and regular downloading of data can be done by anyone willing to prepare for stormy weather.

Constructing the rating curve, hydrographs can be done by anyone with experience using excel. Annual cross sectional channel surveys at gage locations are needed for new rating curves or for the continuation of one across multiple years. See Long Profile and Cross Sections Geomorphology Protocol for channel survey methods. Analyzing the data and conducting a hydrograph comparison analysis requires consultation and review by someone with considerable hydrology experience.

The initial effort to install the stream gages is high. The maintenance of stations, collecting the data and organizing the data is a low level of effort. The analysis of the data is a medium to high level of effort because of the expertise needed.

WHEN SHOULD THIS PROTOCOL BE USED?

Ideally, the Surface Water Hydrology protocol should be implemented prior to any restoration activities taking place for projects where restoring hydrologic function is an identified objective and a stream channel is present. Measuring baseline conditions prior to restoration is paramount to assessing the change resulting from restoration efforts. Surface water hydrology should continue to be monitored throughout restoration activities and following completion. Depending on funding and resource availability the Surface Water Hydrology protocol should be used for 3-5 years pre and 5-10 years post restoration to capture the spatial and temporal variability of the system and to be able to make meaningful comparisons.

This protocol can also be used to install stream gages upstream and downstream of the meadow to monitor trends over time prior to, during, and after restoration. If it is only possible to install one stream gage, install it at the downstream end of the meadow and monitor it over time.

PROTOCOL DESCRIPTION

Stream flow dynamics can be characterized by collecting a record of discharge and relating discharge volumes to a stream gage height/pressure over a range of conditions to develop a rating curve for that site. A rating curve must be developed separately for each gage station.

Stream gages should be installed in stream reaches that have an idealized geometry (i.e., relatively straight, with uniform width and depth) and uniform flow to the extent possible, avoid areas with pools, side channels or cross-stream riffle currents. Idealized geometries are naturally found in the crossovers between bars where the depth is relatively uniform. An idealized geometry might be artificially created by a road crossing with a bridge, the area between the two bridge abutments is an example of an idealized geometry because it is uniform and likely won't change much. A traditional survey should be completed at all stream gaging sites to create an accurate channel geometry following protocols outlined in the SM-WRAMP Geomorphology, Long Profile and Cross-Sections Protocol.

Measuring discharge at the gage location over a range of conditions over time increases the strength of the rating curve for as long as the streambed geometry stays constant. The stream gage cross section should be surveyed annually to identify any shifts caused by deposition or erosion of the stream bed which would indicate needing to update or develop a new rating curve for the site. Because a rating curve is used to estimate discharge for a site, a new rating curve can be developed every year for a site but the discharge data can be compared continuously over many years.

Discharge can be monitored using a variety of velocity and depth measurement procedures; this method protocol employs the Velocity-Area method using a HACH FH950 or Marsh-McBirney flowmeter and a Top-Setting Wading Rod. Suitable conditions consist of streams that are safe to wade through (waist deep and below). The Velocity-Area method described below was adapted from the United States Geological Survey (USGS) publication, Discharge Measurements at Gaging Stations (Turnipseed and Sauer, 2010).

Installing a Stilling Well with a Pressure Transducer

1. **Site Reconnaissance**
   Determining the ideal locations for surface water monitoring stations is key to monitoring restoration effects on meadows. Preferably, at least two sites should be selected for surface water monitoring; one at the upstream end of the meadow above the influence of restoration activities and the other on the downstream end of the meadow to capture any anticipated hydrologic changes.

2. **Site Characteristics**
   If possible, the range of flow conditions should be determined prior to installation. Placement of stream monitoring equipment be should such that all flow conditions from summer baseflow to flood events are captured. Ideally, stream gages are placed in the crossovers between bars or the downstream end of a pool where flow is perpendicular to the banks and where the in-stream pressure transducer will be submerged during low flow periods.

3. **Stilling Well/ Protective Housing**
   Depending on site characteristics a PVC, steel stilling well, or protective housing should be installed directly in the streambed or fixed object. For gaging sites where hardscapes such as a road crossings or bridges are present, protective housings should be attached directly to them at a depth that is below summer baseflow periods (Figure 3).

   Protective housings can be mounted using conduit steel straps that are bolted directed to the concrete. Upon selection of your gaging site, drill your bore hole(s) into the concrete with a masonry drill bit (~1/4" deeper than your bolt/screw) and then secure the protective housing with the conduit strap using concrete screws. When hardscapes are not available for deployment, alternatives such as using t-posts along stream banks should be implemented (Figure 4).

Figure 3 Hardscape Gaging Station and Staff Gauge Deployment (American Rivers, 2012).

Figure 4.Stream Bank Gaging Station Deployment, Red Clover Valley CA (Photo credit; Monohan 2019).

Using a post pounder, drive t-posts into the stream bank and bed so that the steel or PVC protective housing can be secured in place. If feasible, an additional pipe should be driven into the stream bed using a post pounder/ sledge hammer for added support that could be hose clamped to the protective housing. Especially recommended in high elevation sites during freeze thaw cycles because the weight of thawing ice moving down stream can dislodge supports. Before deployment, drill 2-3m holes into either the PVC or steel stilling wells to allow water to move freely through the housing. The range of flow conditions and depths will dictate the length of the protective housing that needs to be drilled. Protective housings should be installed slightly above the stream bed to reduce sedimentation within the housing.

Finally, a staff gage should be installed and secured in the immediate proximity of the gaging station (Figure 3) to correlate pressure transducer data with the associated stage height to create the stage-discharge relationship or rating curve. On a length of composite wood (resistant to rot) long enough to capture the full range of expected stream height variability, attach a number plate that spans the entire length of the staff gage with wood screws. Secure the staff gage in a similar fashion as your gaging station (hardscape or streambed), and if possible orient parallel to the direction of flow to limit drag and reduce error when reading stage heights. Stream flow will build on the face of the staff gage if mounted perpendicular to flow and can be misleading while recording stage heights.

4. **Transducer Installation**
This method protocol employs the use of the Solinst® Levelogger, model 3001 for instream pressure data collections and the Solinst® Barologger, model 3001 for barometric pressure readings.

Prior to installation in the field, technicians should download the Solinst supplied Levelogger software program and configure all Leveloggers and Barologgers with the most up-to-date firmware. Configuration of pressure transducers means a site ID is identified for each instrument, syncing the internal clocks to a common datum (e.g. PST or PDT) as Leveloggers and Barologgers do not internally compensate for daylight savings, identifying an appropriate logging interval (≤1-hour interval recommended), and establishing a start-time or the time of estimated deployment in the field.

Field technicians should also make sure to download the Levelogger software onto all field laptops or tablets prior to entering the field for data downloading and troubleshooting efforts.

Suspend and secure the logger to the top of the protective housing through an eye bolt using 1/16 gage stainless steel cable. The cable should be long enough that the transducer will remain under water but not long enough that the transducer touches the bottom of the protective housing or stream bed (Figure 5).

Figure 5. Levelogger Deployment in Stream Bank Gaging Station, Red Clover Valley CA (Photo credit; Monohan 2019).

A Barologger should be installed as close as possible to the instream pressure transducer to account for variations in atmospheric pressure to increase data integrity. One Barologger can be used to compensate all Leveloggers within a 20-mile radius and or 100 feet of elevation change. Either secure the Barologger to the same through bolt or eyebolt that the instream pressure transducer is attached to within the protective housing or in a nearby mounted vented PVC housing. The Barologger should be kept dry.

Measuring Discharge with the Velocity Area Method

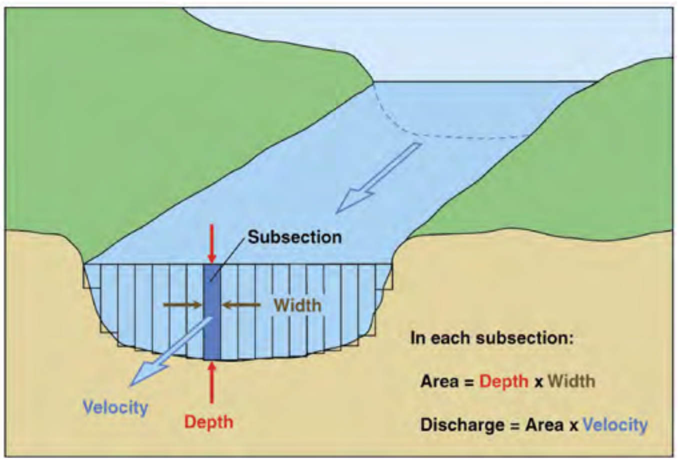

Figure 7. Velocity-Area Method Illustration (USGS, How Streamflow is Measured).

1. In the immediate vicinity of the gaging station, span a vinyl tape measure or tag line across the creek. Hold it taunt and steady perpendicular to the direction of the flow by planting the eye stakes into the ground and wrapping the tape around the stake's loops. Depending on the bank's substrate, you may have to also use rocks or other materials to help keep the stakes in place (Figure 6).

Figure 6. Typical Vinyl Tape Measure Spanning the Stream Width (Photo credit; Monohan 2019).

2. After the tape measure or tag line is in place, record the distance measurement of wetted bank width at both right and left banks. This is the width of the wet stream, not the banks. Note: it is best to read what the tape says and write that down exactly, so you can check your math and your units later. If you are reading your velocity meter in ft/second, then you want a tape in tenths of feet. If you are reading your velocity meter in m/s then you want a metric tape.

3. Divide the width of the stream into equal measurements called "stations," the wider the stream the greater number of stations required. As a guide, a minimum of 1:10 stream width to width of station should be followed. Typically, 15 to 30 stations about 1 foot apart.

4. Record the width, depth at midpoint, and a velocity reading at each station.

   a. Use the tape measure or tag line to find the width reading. The spacing of each station does not have to be perfectly equidistant. For example, if one measurement location ends up on top of a high rock, move slightly along the tape to avoid the feature.

   b. Depth should be measured using the scale on the top-set wadding rod and recorded.

   c. For depths below 2.5 feet, the velocity reading should be taken at 0.6 of the total depth from the water surface to the bed and for wading depths greater than 2.5 feet average the velocities at 0.2 and 0.8 of the total depth to capture vertically integrated velocity measurement (Figure 8).

      Use the top-set wading rod to move the velocity meter to the correct position (Figure 9).

      For example, if the water is 1.3 feet deep, then place the mark in the handle area to 1.3, this automatically sets the velocity meter at 0.6 of the total depth. This is to capture the average velocity of water for that station.

   d. Pivot the velocity meter until it points upstream. To obtain an accurate reading, stand downstream of the meter and not in front of it to prevent velocity bias caused by your presence. Take a velocity reading once the meter equilibrates, even if it is not fully submerged. A piece of flagging can be attached to the wadding rod to help indicate the flow direction and help properly orient the meter.

e. If the velocity measurement is a negative number, turn the flow meter 180° to face downstream to check if it too is a negative number. If both directions are negative record half the minimum detection limit of flowmeter.

5. Multiply the station width (ft) by station depth (ft) and the station velocity at 0.6d (ft/sec) to obtain a volume per time, or discharge (ft3/sec) for each station.

6. Add up the discharge for each station to obtain the total volume of flow per second of the stream (cfs).

7. Note the date and time that you collected this discharge measurement and collect the pressure transducer reading for that time. This is one data point for your rating curve.

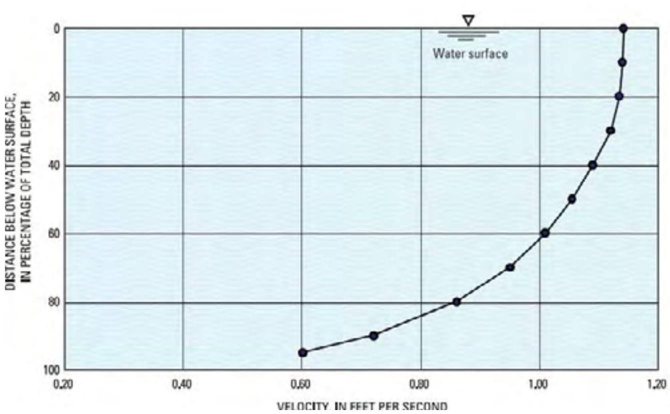

Figure 8. Typical Vertical-Velocity Curve, (Turnipseed and Sauer, 2010)

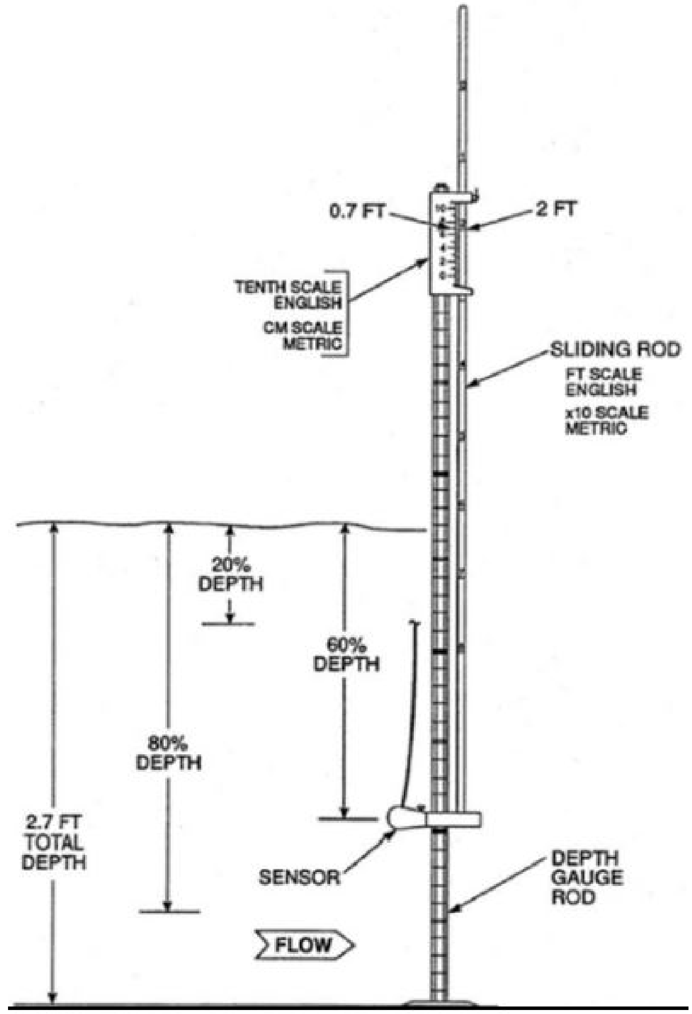

Figure 9. Top-Set Wadding Rod. nps.gov

Developing a Rating Curve

A rating curve is developed by correlating the continuous pressure transducer data with observed stage height recordings from the staff plate and discharge measurements collected during monitoring efforts. The correlated pressure and stage height readings are related to discharge measurements so that for any pressure/stage reading (within the range of conditions measured) you can predict the volume of stream flow or discharge. You create this relationship over time for a single site. If you have two gages on a single stream, you need two different rating curves, one for each gage. Your rating curve will likely be either a linear equation y=mX+b or 2nd order polynomial, y=X2+X+b but if you captured some high flows you may have enough information to generate an asymptotic curve due to overtopping of the bank. Getting flows at bankfull in deeply incised stream can be too dangerous without special equipment, like an Acoustic Doppler Current Profiler (ADCP).

Monitoring Floodplain Inundation

Estimate surface water extent during the spring and late summer using either drone imagery, ground surveys, or time lapse cameras, as determined to be most appropriate. Estimate frequency of floodplain inundation by determining the number of times stream channel depth exceeded bankfull depth at stream gage locations where data loggers are installed. Solinst level loggers record both water depth and temperature at set time intervals. Estimate seasonal duration of floodplain inundation by comparing spring to summer estimates of floodplain extent.

2.2
HYDROLOGY

Surface Water Hydrology Protocol

Equipment List

Equipment for Gage Installation

(note: * designates hardscape specific, ** designates stream bank installations)

Infrastructure

- Solinst® Levelogger
- Solinst® Barologger
- Solinst® Data Transfer Device
- 1/16″ Stainless Steel Cable (25ft/station)
- PVC or Steel Protective Housing (~20′/station)
- T-posts (~4 at 4-6′ lengths/station) **
- Composite wood (~8′/station)
- Number plate (~8′/station)

Tools

- Cordless drill
- Masonry drill bit*
- Metal cutting drill bit
- Post pounder**
- Sledge hammer**
- Wire cutters**

Hardware

- Eyebolt w/nylock nuts (1 set/station)
- 6″ Hose Clamps (~6/station) **
- Bailing wire (~50′/station) **
- Cement screws (6/station) *
- Wood screws (~8/station)

Equipment for Velocity-Area Method

- Top-set wading rod
- Velocity meter (e.g. Hach, Global Water Flow Wand,)
- Vinyl tape measure (>/= 50-ft)
- 2 pins
- Rubber boots/ Waders
- Notebook and or Field Sheets

Equipment for Annual Cross Sectional Survey

See SM-WRAMP Geomorphology Protocol

3
SOILS

Soil core capture from meadow

3.0 SOILS

Soil Carbon

Resource Target

Soil Carbon

Indicators/Attributes

Soil total Carbon (%) and soil bulk density (gcm-3)

Soil core (Photo credit; Monohan 2019).

INTRODUCTION AND BACKGROUND

High elevation wet meadows can store significant amounts of carbon below ground (Reed et al, 2020). Meadow restoration design is often focused on restoring the hydrologic function of the meadow which means reducing stream incision and groundwater table recovery. The groundwater table recover changes the subsurface hydrologic conditions of the meadow which allows for plant community compositions to shift to more wet meadow plans and for more carbon to be stored in soil. Monitoring changes in below ground soil carbon can provide meaningful information about the recovery of the meadow and the restoration effective.

The role that high elevation wet meadows play in carbon sequestration may be an important tool to reduce the impacts of climate change. The ability to determine an individual meadows condition following restoration as well as a regional response to atmospheric carbon sequestration depends on monitoring soil total carbon across the region.

A standardized metric for monitoring soil carbon will allow meadows to be compared to each other as well as regional comparisons to be made. The methods described here are designed to address variability in soil total carbon in an individual meadow by capturing that range of variability in a grid and repeating that method annually so that trends in soil total carbon change can be detected (Merrill et al., 2015).

There are an estimated 300,000 acres of meadows in the Sierra Nevada, and an estimated 70% of these are degraded. In other words, there are approximately 200,000 acres of degraded meadow lands in the Sierra. Degraded meadows do not store water or carbon - they emit it. A restored meadow sequesters an estimated 70 Metric Tons of CO2 equivalent per acre above and below ground (Norton et. al., 2011). This means that there is an estimated 14 Million Metric (70Tc*200,000acres) tons of carbon that can be sequestered from the atmosphere with meadow restoration in the Sierra Nevada. As climate changes continues to apply pressures to industry, agriculture, and recreational practices reliant on year round water supplies, restoring meadows can not only help to improve conditions at an individual meadow but collectively meadow restoration may help to offset carbon emissions.

When should these indicators be used?

Soil total carbon should be monitored to collect baseline conditions prior to meadow restoration, and after meadow restoration to detect change over time. Ideally soil carbon samples are collected for 1-3 years prior to restoration and for as many as 10-20 years following restoration. Soil carbon response, is known to be slow, but significant (Reed et al, 2020).

What goals are being evaluated?

In the face of climate change, high elevation hydrologically functional wet meadows can play a vital role in the sequestration of atmospheric carbon into below ground biomass (Reed et al 2020). One goal of meadow restoration is to restore hydrologic function which can have numerous secondary benefits such as change in vegetation community from dry to wet species and a corresponding increase of below ground root mass and carbon sequestration. Once in the below ground carbon pool, carbon is expected to stay sequestered there for a long time, as long as erosion is limited and the water table remains high without stream incision.

The goal is to determine if:

- There is an increase in soil total carbon with meadow restoration.
- How much soil carbon is sequestered after meadow restoration?
- Root biomass increases with restoration and soil carbon sequestration?
- Groundwater table recovery results in increased soil total carbon?

What restoration objectives does the indicator evaluate?

The restoration objectives to increase belowground total soil carbon sequestration can be a secondary effect of restoring groundwater table, improving floodplain connectivity and reducing stream incision.

Monitoring changes in below ground soil carbon storage due to restoration can help to evaluate carbon storage potential, surface water flow dynamics, groundwater table recovery and vegetation restoration objectives.

What questions/uncertainties are being answered/addressed?

It is difficult to attribute changes in soil carbon sequestration to restoration simply by taking measurements before and after restoration due to spatial and temporal variability in meadows and in weather. In other words, if you take samples for only one year before restoration and it happens to be a dry year, and then you take samples one year after restoration and it happens to be a wet year, you cannot say that the change you detected was because of restoration or because it was a change from a dry year to a wet year. Conducting soil monitoring for a minimum of 5-10 year following restoration actions will increase the probability of observing a change in soil carbon sequestration trends.

This protocol addresses the spatial variability in meadows by recommending a grid sampling protocol that was published by Merrill et al. in 2015, where they looked to capture the variability in meadow soil carbon and designed this approach to capture that variability in repeated samples so that a change in soil carbon could be detected over time or between grids.

Sampling down to the 45 cm depth is recommended in order to capture vertical variability in soil carbon concentrations and bulk density ranges (Merrill and Sullivan, 2015). In the event that your meadow has buried horizons, you may need to sample deeper. Below ground C stocks are highly spatially variable and this variability is often not directly linked to obvious aboveground properties. Sampling intensity should vary with level of precision needed to capture the natural range of variability and detect change from that variability over time.

This protocol addresses temporal variability by recommending that soil carbon be monitored for at least 10 years post restoration so that annual weather trends can be distinguished from long term trends in soil carbon.

3.0 Soils

PLANNING

Level of effort

This should be a low level of planning because it is a protocol that should be added to other sampling efforts, like vegetation transects or groundwater monitoring, in which case the soil core sampling should take place within a grid network that is near the vegetation transects, creating complementary data sets that are layered and integrated.

Data Collection Timing

Soil cores can be collected anytime access is easy to the meadow, not in the dead of winter or early spring. If possible soil cores should be collected annually, if funding is limited the frequency of soil sampling can be reduced as necessary. Ideally 3-5 years of data pre restoration should be collected or at least 1 year of data within three years prior to restoration and 10+ years post restoration. If pre-restoration samples are not possible, then samples should be collected semi-annually for at least10 years post restoration to see a trend in recovery and as a measure of restoration effect. Some meadow systems may take longer for recovery, if not trends observed with the first 10 years then an additional 3-5 years of monitoring should be completed.

Required Resources

Two field technicians should be able to collect soil cores within a soil grid in the meadow in a day (2 people x 8 hours), for all three depths (0-15 cm, 15-30 cm, 30-45 cm).

The time required to prepare samples for total soil carbon and bulk density should take one person one day for 36 samples.

Equipment costs if new
Purchasing a compete slide hammer kit costs about $400. We recommend the AMS 2” x 6” Signature SCS Complete, the kit includes a slide hammer, SCS sampling core cup and cap and three sleeves/liners and caps. Purchasing plastic sleeves/liners and caps for soil cores costs about $150/ grid (n=36 samples). Plastic sleeves/liners can be reused following sample analysis and cleaning.

Analyzing the samples can be done by a lab, the cost is about $100 per sample. ($45 for total C and $45 for bulk density). These estimates were provided by the University of California, Davis Analytical Lab for Fertility (total carbon) utilizing AOAC Official Method 972.43 and bulk density utilizing Blake and Hartge, 1986 Physical and Mineralogical Methods. Additional funding may need to be set aside time and labor for sample processing and preparation for bulk density and total carbon analysis.

Level if any special expertise required
Technicians should be properly trained or supervised by a soil scientist to increase success and reduce error during sampling.

Total Costs
- **Slide hammer,** $400 (onetime expense)
- Plastic Sleeves, $150/sample (onetime expense, reusable)
- **Lab analysis,** $100/sample, 36 samples/grid= $3,600/year (with no reference site)
- **Labor:** $50/hour, two people one day (16 hours)/ sampling grid, $800/day (one day/year)

DATA ANALYSIS

Using the grid network for soil sampling will provide a non-biased location of points that represents both lateral and longitudinal variations in soil properties to compare across pre and post restoration actions. To analyze your soil carbon data, you will have to look at how total soil carbon, and bulk density is distributed across your sampling area. What is the range of soil carbon concentrations and bulk density within the sampling grid? What is the average soil carbon concentration and bulk density? For sites with multiple sampling grids, are there inter-meadow variations? Is there a response in soil carbon concentrations to restoration actions over time? You could create an average concentration of total carbon and bulk density for all the three sampling depths or combine sampling depths for each sampling grid and display your data in bar charts or box plots?

ADAPTIVE MANAGEMENT

Following restoration actions, if no significant changes are observed in soil carbon concentrations or bulk density within the first one to two years, reducing the frequency of sampling to every other year could strengthen the post restoration data collection by extending the period of sampling. Additionally, soil carbon and bulk density changes can take upwards to 10+ years to see significant changes following restoration.

3.0 Soils

Extending the post restoration sampling period will ensure monitoring efforts capture variations in soil properties following restoration and increase the breadth of climate variability captured at the site

When placing the 90 x 150 m grid within the expected restoration footprint, avoid possible future stream and or pond locations. In the event that one or more of your sampling points becomes inundated with water following restoration, that 30 m point should be skipped and an additional point should be added to the row. If there are more than one of these occurrences within a single row, an additional row should be added entirely.

COORDINATION

Ideally soil core sampling is coordinated with vegetation sampling and groundwater monitoring. Any observed soil carbon or bulk density changes following restoration could also be related to or explained by changes in groundwater table recovery, surface water hydrology, specifically the duration of summer baseflow periods. Increased residence time and spatial extent of surface water flows can influence plant species and vigor altering the soil chemical and physical properties.

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- Ben Sullivan, benjaminsullivan@unr.edu
- Cody Reed, coditareed@gmail.com
- Judith Drexler, jdrexler@usgs.gov.

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3.0

SOILS

Soil Carbon Protocol

What, how, why: Soil carbon using coring equipment to determine soil total carbon (%) and soil buk density (gm/cm3).

Print & Carry
Field Instructions
& Equipment List

LEVEL OF EFFORTS

Depending on the size of the meadow, two people should be able to collect soil cores from a meadow in a day, from three depths (0-15 cm, 15-30 cm, 30-45 cm).

The samples can then be processed so that they can be analyzed by a lab for total soil carbon and bulk density, costs are about $100 per sample. Sample processing should take one person one day to do 30-40 samples.

WHEN SHOULD THIS PROTOCOL BE USED?

This protocol should be used when improving soil carbon sequestration is a restoration objective, or is an anticipated benefit to restoring a meadow.

DESCRIPTION OF PROTOCOL

The purpose of this protocol is to characterize the total soil carbon and bulk density conditions of a meadow prior to restoration and evaluate how those conditions change over time post restoration.

The sampling method recommended uses a grid sampling approach outlined in Site Lay Out, Soil and Above Ground Biomass Sampling Protocol for Mountain Meadows (Merrill and Sullivan, 2015) which is a modified approach to soil core sampling recommended by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Soil Survey Field and Laboratory Methods Manual, 2009. In short, a grid location is selected from a location in the meadow where change is expected to occur so that the same area can be sampled in future years. Whenever possible, pairing soil sampling locations alongside, or near other monitoring protocols such as vegetation or groundwater wells will strengthen data analysis and understanding of observations. Note that some clearing of the top layer of vegetation is required to collect the soil core, so it is not recommended that the grip be placed inside vegetation quadrants, but alongside, or near.

PROCEDURE

Sampling Grid

1. Within a 150 x 90 m grid, sampling locations are placed in 30 by 30 m intervals. (Only half of these locations have samples collected from them n=12, see below)

2. The grid should be placed in an area anticipated to respond to restoration, and if desired, in a comparable area outside of the restoration footprint within the same meadow for use as a reference, if desired.

3. Place the long axis of the grid perpendicular to source of the greatest variability i.e. perpendicular to a channel or main meadow slope.

4. The grid should be placed in a fashion that will capture a variety of major plant communities, avoid disturbance from construction activities, not be located within existing stream channel(s), possible future stream channel(s) or ponds, and provide a 15-meter buffer from any stream or pond.

5. Mark the location of each grid with rebar and flagging, record the exact GPS location, and describe the site location on a map.

Preparation

1. Select locations to take soil cores. Within the 150 x 90 m grid soil core samples are collected from every other point. The grid will have 24 locations spaced 30by 30m apart and every other one will be sampled, making a total of 12 sample locations in the grid. Each location will be sampled at three depths, 0-15, 15-30, and 30-45cm. The total number of cores will be 36 (12 locations x 3 depths).

2. Make sure to mark the appropriate depths on the slide hammer (tool used to collect soil samples). Once the slide hammer is in the ground, it is difficult to tell how deep you've dug. Use a sharpie and tape measure to mark 15, 30, and 45 cm depth increments on your slide hammer starting from the end of the beveled tip and extending up the slide hammer.

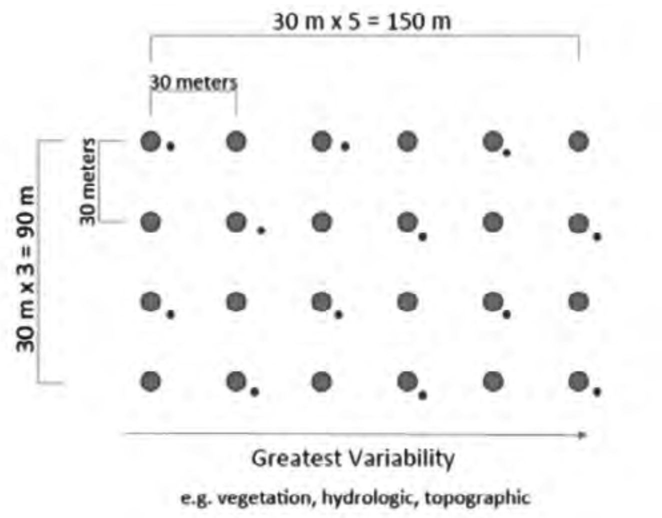

Figure 1. Diagram showing a grid for soil core sampling located 30 x 30 m apart (Merrill et al., 2015).

Sample Collection

1. Clean the slide hammer and soil coring attachment head before starting to take each sample. Pay special attention to the threads where the parts screw together. Any dirt left in the threads can damage the threads during collection. Use a brush to clean the threads between samples.

2. Slide a soil core sleeve into the soil coring attachment head (you can reuse these plastic sleeves).

3. Screw the attachment head onto the slide hammer while wrapping a piece of grass in the threads. The grass will help keep the threads from locking up.

4. Use wrenches to tighten the soil coring attachment head onto the slide hammer. Use one wrench on the slide hammer below the threading and one wrench below the screw. Turn wrenches opposite directions to ensure the soil core attachment head is secured tightly.

5. Put in earplugs or wear earmuffs.

6. Clear vegetation, thatch and other organic material away from soil surface to expose soil. Any organic material on top of the soil core will need to be removed prior to processing.

7. Line up slide hammer vertically to the soil. Begin sliding handle of slide hammer down repeatedly to dig into the soil. *Be careful not to pull handle of slide hammer up too far. This will pull slide hammer up.

8. Once the marked depths on the slide hammer for 15cm (30 or 45 cm) is flush with the soil surface, the slide hammer needs to be pulled out

9. Bend your knees and pull with your legs to make sure you don't injure your back. In general, you should plant your feet under your shoulders and press your pelvis into the slide hammer as you pull up. Proper form will allow you to preserve your strength and protect your body from strain.

10. If the slide hammer is stuck, SLOWLY pull up on the slide hammer handle and tap upwards GENTLY 2-3 times and attempt step 11 again. There is a fine balance between loosening the slide hammer and causing your soil core to fall out of the sleeve.

11. When removing the soil core from the ground, you or a partner should have a plastic bag ready to place your soil core into. Once the slide hammer is completely out of the ground, unscrew the soil core attachment head and remove the soil core sleeve. Cut off clean ends of soil core and place in plastic bag. Any extra soil sticking out of the sleeve is considered waste and should be removed. The waste can be tossed, as it is not part of the soil core. While this soil is technically part of the next core depth, its integrity for bulk density is compromised and therefore cannot be included in the next sample. Note: you do not need to keep the sample in the plastic sleeve, you can get it out of the sleeve into the plastic bag, and you can reuse cleaned sleeves.

12. Mark the plastic bag with the sharpie, writing down the date collected, the depth of the soil core, and the location.

13. Mark a waypoint of the soil core on your GPS or GPS app.

14. Repeat steps 3 through 14 to capture the total 45 cm soil profile. Samples should be bagged and labeled in 15 cm increments. (For example bags labels should look like: Clover Valley Meadow, 0-15cm, 6/11/2020, cm, ng, place label inside the bag on a small piece of paper, as well as written in sharpie on the bag.)

Sample Storage

1. Soil cores should be capped and labeled inside and outside of the plastic sealable bag with the site, date, depth and sampler initials. A piece of paper can be put inside the plastic bag.

2. Soil cores can be stored in a cool dry place until they are shipped.

Sample Processing for Analysis

It is highly recommended to contact a collaborating laboratory prior to soil core analysis, as each lab might have different protocol and availability for receiving soil samples.

Academic laboratories at University of Nevada, Reno (UNR) and University of California, Davis (UCD) both offer services for Bulk Density and Total Soil Carbon analysis but may be limited in availability for sample processing. If samples cannot be shipped as whole soil cores, additional steps for processing such as weighing, drying, sieving, root separation and weighing and grinding. If you are using the UCD lab, you should be follow guidelines found here, https://anlab.ucdavis.edu/Home/SamplingAndPreparation and contact Dr. Ben Sullivan for the UNR lab here, http://sullivanlab.weebly.com/.

When contacting laboratory's, you want to ask the lab:

- Can you analyze soil samples for total soil carbon and bulk density?
- What sample prep is required to do in advance of shipment?
- What is the recommended sample storage procedure and is there a time limit on sample storage?
- How much does it cost per sample?
- How do I get samples to you, is there a chain of custody form?
- How long will it take to get the data back?

Figure 2. Chico State Masters student uses a slide hammer to collect a soil core while Dr. Sullivan observes. She is collecting a sample next to a groundwater monitoring well and wearing protective ear coverings. The vegetation transect also runs along the groundwater table height associated with the samples total soil carbon and bulk density. (Photo credit; Monohan 2019.)

Figure 4. Soil core is inside the sleeve, look at the compaction that occurred, this is normal. This sample will be tapped out of the plastic sleeve, bagged and labeled and kept in a cool dark place until it is sent to a lab for analysis. (Photo credit; Monohan 2019)

Figure 3. Soil core is inside the coring attachment; a plastic bag is held underneath as the attachment is unscrewed from the slide hammer so that no part of the sample is lost. (Photo credit; Monohan 2019).

3.1
SOILS

Soil Carbon Protocol

Equipment List

- 2”x 6” Slide Hammer complete kit (AMS Soil Core Sampling Complete)
- 2”x 6” Soil Core liners and Caps
- Rubber Mallet or Dead Blow
- Crescent Wrenches x2
- Strap Wrench
- Tape Measure
- Plastic Bags (1-qt size) (at least 36)
- Wire Brush
- Field Knife
- GPS or Smartphone
- Sharpie
- Paper for sample labels
- Ear Plugs
- Cooler for sample transport

4
GRAZING

Control plot to assess grazing impact.

4.1
GRAZING

Grazing Impacts Summary

This is a summary of the three grazing impacts protocols included as part of the SMP WRAMP. The table below identifies the protocol name (as named currently), the primary indicators/attributes measured/summarized, when the protocol should be selected (there is additional information regarding protocol use in each protocol this is only a brief summary), the time required to implement the protocol, and the level of skill needed. The decision tree is provided to help determine which protocols may best suit the project needs.

SUMMARY TABLE OF THREE GRAZING PROTOCOLS

NAME OF PROTOCOL	INDICATOR/ ATTRIBUTES	WHEN SHOULD PROTOCOL BE USED	TIME REQUIRED	SKILLS	FREQUENCY MONITORING
Grazing Impacts Checklist	Impacts from current grazing including: trampling, shearing, pocking, trailing, hedging/browse of woody vegetation and removal of herbaceous vegetation.	When these impacts from grazing affect meadow function and imperil the success of proposed projects.	• 1 to 3 hours pre-field (office) • 2 – 6 hours field time • 1 – 3 hours post field (office)	General knowledge of hydrology, riparian plan communities, and meadow function.	Monitoring should be conducted at the end of the grazing season. Pre-project (baseline) monitoring should occur the fall preceding the year other protocols will be applied, 2 years before project implementation. If grazing impacts continue repeat annually. Monitor after a change in grazing management.
Bank Alteration	Trampling, shearing, and trailing from impact of hooves, from current year's grazing on channel banks.	When these impacts from grazing affect channel stability and imperil the success of proposed projects.	• 1 – 3 hours pre-field (office) • 2- 4 hours field time • 2 – 4 hours post field (office)	Ability to identify channel geomorphic features: active channel, floodplain, bankfull and floodprone area.	Monitoring should be conducted at the end of the grazing season. Pre-project (baseline) monitoring should occur the fall preceding the year other protocols will be applied, 2 years before project implementation. If grazing impacts continue repeat annually. Monitor after a change in grazing management.
Stubble Height	Removal of key forage species, throughout meadow system.	When these impacts from grazing affect regeneration and species composition of vegetation, cause erosion, and/or affect meadow function and imperil the success of proposed projects.	• 1- Hour pre-field (office) • 1 – 4 hours field time • 1 – 2 hours post field (office)	Ability to identify key forage species, or at a minimum groups important plants such as sedges, and grasses.	Monitoring should be conducted at the end of the grazing season. Pre-project (baseline) monitoring should occur the fall preceding the year other protocols will be applied, 2 years before project implementation. If grazing impacts continue repeat annually. Monitor after a change in grazing management.

APPLYING MONITORING PROTOCOLS FOR LIVESTOCK GRAZING IMPACTS

Currently the majority of the meadows in the Sierra Nevada, on public and private land are grazed by livestock. Grazing by livestock has impacts on vegetation, hydrology and soils. These impacts may affect the success of stream and meadow restoration projects, and the functionality of the riparian/wetland system. Pre-project (baseline) assessment and ongoing monitoring is required to assess the impacts of livestock grazing, and direct management activities such as: grazing management plans, fencing of key areas, establishment of riparian pastures to aid in controlling livestock impacts.

The following “Decision Tree” is intended to assess the presence/absence impacts from grazing, the potential for affecting the proposed project and monitoring necessary to assess these impacts. If the decision tree indicates that multiple monitoring methods may be needed to accurately assess grazing impacts make sure to combine the protocols in one field visit.

Decision Tree

1. Is livestock grazing present?
   a. No… no further assessment.
   b. Yes… go to step 2.

2. Is there a management plan that includes monitoring of grazing?
   a. Yes… go to step 3.
   b. No… go to step 5.

3. Does the monitoring adequately assess impacts that could affect the area of interest?
   a. Yes… coordinate with all stakeholders to assign monitoring to qualified personnel, with review by project managers. Set schedule (see recommended monitoring schedule).
   b. No… go to step 4

4. Are there elements of the existing monitoring plan that could be incorporated into a relevant and effective monitoring plan?
   a. Yes… extract elements from the existing monitoring plan and add necessary elements from SM-WRAMP grazing monitoring protocols…go to step 5.
   b. No… go to step 5.

5. Perform initial qualitative checklist to determine areas impacted by current grazing. If impacts are minimal, or areas are too small to conduct quantitative monitoring, or time and money limit monitoring limit monitoring to qualitative checklist with supporting photos , if significant aspects of the restoration project, or areas supporting overall meadow function are at risk due to grazing impacts go to step 6.

6. What Type of hydrologic features are present and being considered for restoration?

   a. Channel supported wet meadow (also referred to as Riparian or riverene), i.e. wet meadow hydrology is supported by overbank flows… consider using bank alteration protocol and/or utilization transects along the top of the banks.
   b. No channel present meadow hydrology is supported by dispersed flow/sheetflow from runoff or by local ground water… conduct stubble height monitoring in key areas, document trampling impacts with photos and qualitative monitoring checksheet.

4.2
GRAZING

Bank Alteration

Resource Target
Vegetation, soil, hydrology, geomorphology, aquatic resources (macro-invertebrates and salmonids)

Indicators/Attributes
Disturbed bare ground, trampling, shearing and hoof puncture from livestock.


Grazing can affect bank and channel stability, and the success of restoration efforts.

INTRODUCTION AND BACKGROUND

When should these indicators be used?

This protocol should be used when there is potential for current and future livestock management to affect the success of proposed restoration, the function of the meadow system, and/or the potential condition of the vegetation. This protocol applies specifically to the action of livestock hooves and forage removal on channel banks, altering the natural bank cover and potentially the bank stability.

Currently, the majority of the meadows in the Sierra Nevada, on public and private lands are grazed by livestock. Grazing by livestock has impacts on vegetation, hydrology and soils. These impacts may affect the success of stream and meadow restoration projects, and the functionality of the riparian/ wetland system. Pre-project (baseline) assessment and ongoing monitoring is required to assess the impacts of livestock grazing. Direct management activities such as grazing management plans, fencing of key areas, establishment of riparian pastures may be required to aid in controlling livestock impacts.

The NRCS, USFS and BLM all incorporate utilization monitoring in their grazing programs, utilizing these methods may be useful to meadow restoration projects to identify specific areas of concern. Additional assessment may be necessary prior to considering a meadow for restoration. This protocol outlines a method for baseline monitoring that will assess both the impacts of past grazing and the impacts of current grazing in key areas that are sensitive to grazing impacts, such as channel banks, instream vegetation, wet areas such as seeps, springs, fens and wet meadows.

What goals are being evaluated?

This method will allow one to evaluate if, and to what extent, livestock grazing is limiting meadow function and/or the goals of proposed or existing restoration.

What resto ration objectives does the indicator evaluate?

- Bank and channel stability
- Decrease in ground disturbance
- Increased in vigor of wetland vegetation
- Grazing Management that maintains or increases meadow function

What questions/uncertainties are being answered/addressed?

This method addressed the impacts of grazing on meadow function and the success of restoration. Specifically does the current grazing management impede the intended or existing restoration? Does the current grazing management support meadow function?

PLANNING

Data Collection Timing

This protocol should be conducted at the end of the current year's grazing season. At least one year of pre-restoration data should be collected and it is best to collect this data in the fall preceding the year other monitoring protocols, such as the geomorphic and vegetative protocols, are conducted. The protocol should be repeated at one-year, three-years, five-years, and ten-years post-restoration. Additional data collection efforts should be added if: 1) grazing management changes, 2) actions are taken to redirect grazing such as fencing, off channel water sources, or other physical barriers, 3) there are any other activities that would affect grazing intensity, or an areas sensitivity to grazing (wildfire, drought, water diversion, high use by wildlife). Typically grazing in Sierra Meadows occurs from May through September, but may extend into November in some areas. Most post-grazing monitoring is conducted in October in the middle to higher elevations in the Sierra.

Required Resources

Time required per sampling/survey event (# people x hours)
This can be accomplished by one individual in 5 – 11 hours depending on the length of the stream channel and the degree of alteration/disturbance. This includes pre-field preparation and post-field analysis.

Desktop
It should take one to four hours talking with land managers and/or reviewing grazing management plans and past monitoring data to know if grazing impacts could be significant enough to require this monitoring protocol. It should take a further one to four hours of time to determine which channels you want to sample and how long the banks are.

Establishing the Transect
It should take about 1-2 hours once you have reached your field site to identify your channels, take GPS points, photos, and if desired, install permanent markers.

Monitoring
- Preparation (Office) – It should take 1 – 3 hours to prepare for field monitoring.
- Field time – It should take between 2- 4 hours for one person to sample one meadow.
- Data Entry/Analysis – After the first time monitoring a site it should take on person 2 – 4 hours to upload photos and GIS data, enter data and create a map of the monitoring area. The map only needs to be update in subsequent sampling.

Equipment costs if new
- GPS unit: $100-6,000
- Metric folding ruler (100cm -200 cm long) - $25
- Permanent markers: $10 – 20
- Georeferencing program for phone - $10/year

Total Costs
$400 - 700

DATA ANALYSIS

Data storage

If the landowner or administrator such as the USFS District Range Conservationist who oversees the allotment management has a data file or database, a copy of the data should be provided to them.

Analysis Methods

Data Entry
Datasheets should be reviewed and quality controlled before data entry begins. All data should be entered into an excel spreadsheet or database. Quality control should be conducted by someone other than the person that entered the data to ensure errors are resolved.

Data Analysis
Descriptive – The total distance of altered bank relative to the total length of bank should give a percentage of altered bank. This can be done for the entire meadow, or a portion of

4.2 Grazing Impacts Checklist

interest. This can be done in excel and graphs can be prepared to show the difference and/or trend in subsequent years following adaptive management.

Evaluation Criteria

Most USFS and BLM range management plans use 10% to 25% bank alteration as the maximum allowed (Goss and Roper 2018). These limits were based on research that suggested that channel width to depth ratios increase as bank alteration from livestock increase, and that this relationship starts with as little as 10% bank alteration. The condition, resilience and geomorphology of the channel sampled are factors that determine how sensitive the system is to bank alteration by livestock, still using 10 -15% as a trigger to adjust/adapt grazing management may be a good place to start with this protocol.

ADAPTIVE MANAGEMENT

This monitoring protocol will help determine if grazing management needs to be addressed prior to commencing stream/meadow restoration, or if current grazing is contributing to stream bank instability, erosion, decrease in quality or quantity of bank vegetation, and degradation of salmonid habitat.

COORDINATION

These methods could be coordinated with geomorphic monitoring, collection of vegetation data collection, and/or the wildlife-beaver protocol to save time, however in order to address impacts through the end of the grazing season which may be later than the optimal sampling time for other protocols.

CONTACTS AND RESOURCES

Person(s) who populated the specific protocol
Catherine Schnurrenberger, C.S. Ecological Surveys and Assessment
cschnurrenberger@gmail.com

FIELD DATASHEETS & DATA UPLOAD FORMS

The following datasheet is available to be downloaded from https://californiatroutinc.box.com/s/c2uvtwyjmsfbcuv03rmvmnqvf1kbeazc

- Grazing Bank Alteration Datasheet

REFERENCES

The following are good research documents. The article by Beechie et al. links measures of stubble height and bank alternation to channel stability and salmonid habitat metrics. The Burton et al. references describes a more detailed method of measuring bank alteration using sampling frames along the greenline. Both documents were used in the development of this protocol.

1. Beechie, Timothy & Pollock, Michael & Baker, S.. (2008). Channel incision, evolution and potential recovery in the Walla Walla and Tucannon River basins, northwestern USA. Earth Surface Processes and Landforms. 33. 784 - 800. 10.1002/esp.1578. Available online at: http://www.bioone.org/doi/full/10.3398/064.078.0108
2. Burton, T.A., S.J. Smith, and E.R. Cowley. 2011. Riparian area management: multiple indicator monitoring (MIM) of stream channels and streamside vegetation. Technical Reference BLM/OC/ST-10/003+1737, U.S. Department of the Interior, Bureau of Land Management Denver, CO. 155 pp. Available online at: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd558332.pdf
3. Goss, L.M. and B. B. Roper. 2018. The Relationship Between Measures of Annual Livestock
4. Disturbance in Western Riparian Areas and Stream Conditions Important to Trout, Salmon, and Char. Western North American Naturalist, 78(1):76-91. Available online at: http://www.bioone.org/doi/full/10.3398/064.078.0108

Assessment of Current Grazing Management Impacts

4.2
GRAZING

This protocol uses a transect based method to assess if grazing is impacting channel stability.

Print & Carry Field Instructions & Equipment List

PRE-FIELD/DESKTOP

1. Work with land manager(s) to collect existing range monitoring data and methodology, stocking levels and duration, and any historical information that may be useful.
2. Evaluate if the existing methods and sampling locations adequately evaluate the impacts of current grazing, if so additional monitoring is not needed, however most existing monitoring may not be in the best location to evaluate impacts to proposed restoration.
3. If additional monitoring is required or desired, create a map that identifies areas that will be the most sensitive to impacts from grazing for additional monitoring sites: channels/banks, seeps/springs, areas of concentrated grazing, areas that support plant species/community types of concern.
4. Collect field equipment, datasheets, and map of initial monitoring locations.

MONITORING SITE SELECTION

The monitoring site will be any channels of importance to the meadow, or portion of the meadow being evaluated based on the desktop evaluation and field reconnaissance. The length of each bank can be determined prior to field work by using aerial imagery, if resolution is sufficient to do so. If the transects are pre-determined, load endpoints into a GPS unit or tablet for ease of location. Otherwise the length of the bank can be measured while conducting the sampling by keeping track of the number of paces (steps) walked, measuring the length of your paces and multiplying the number of paces by your pace length. Typically, a step or pace is 2 – 2.5 feet (0.6 - .76 m).

ESTABLISHING THE SAMPLING IN THE FIELD

The transects will be located along the streambanks. The transect will follow the bank, thus it will not be linear, but will meander with the channel. The starting point for the first transect will be the downstream most point of the right bank, when looking downstream, the end point will be the upstream most point of the same bank. The second transect will be placed on the opposite bank in the downstream to upstream direction. At a minimum the start and end point of each transect should be recorded with a GPS unit, and photos should be taken from the end points into the sampling area. Permanent markers such as bent rebar or an 8-10" long galvanized nail with a colored whisker brush could be used to mark transect end points.

ESTABLISHING PLOTS

There are no plots associated with this sampling. The location and length of "altered" or "disturbed" sections of stream bank are recorded along each bank. The "bank" is defined as the water's edge to the highest part of the incised bank, and 0.5 meters beyond that onto the floodplain/riparian corridor. See Figure 1 below for an example of the sampling areas; sample area within red lines on the right bank and between the green lines on the left bank. This measurement will sample the bank below bankfull, which is often impacted by livestock. By extending the measurement to the top of an incised bank trails used to access water will also be captured. It is also important to look at the impact up to 0.5 meters from the top bank because living plant roots are important in stabilizing banks trampled areas where plants have been compromised may be more susceptible to "cavitation" or sloughing at high flows. In addition the weight of cattle, and compaction of soil on the banks can cause erosion and bank alteration.

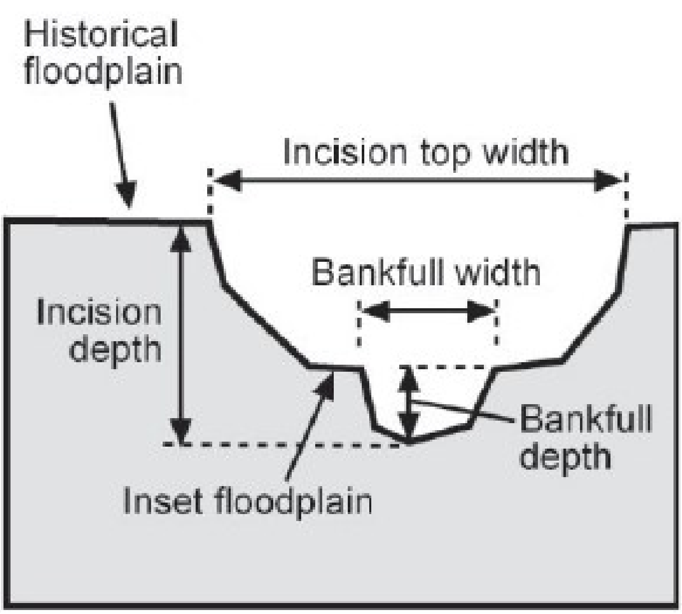

Figure 1. Example of stream channel incision area and location of "sample area" for this protocol in red and green, looking upstream. Beechie et al. 2008

MONITORING

The purpose of this monitoring is to determine if current grazing has altered the function or form of the banks. This will be done by determining what percentage of the banks have been altered by the hooves of grazing animals, usually livestock. To do this the monitor must record the total length of the bank being sampled, and the length of bank altered by ungulates as evidenced by trampling, trailing and/or shearing by the hooves. The impact could be at the water's edge, where livestock stand to access water, or along the top of the incised or upper bank where livestock have created trails, Figure 2. Both of these impacts lead to an increase in bare ground, a decrease in vegetation cover that protects banks from erosion, and therefore make the banks susceptible to erosion at higher flows. Such changes in bank form and function could affect the success of proposed channel restoration. Most land managers set a threshold of 10 – 25% bank alteration by livestock as a limit, if bank alteration is higher than this threshold management actions should be taken to lower the impacts by livestock. If bank restoration is planned it may be best to consider management changes if > 10% of the banks are currently experiencing alteration due to ungulate hooves.

The monitor will walk along the upper most bank of the channel at the level of the adjacent meadow and will stop and recorded areas where impacts from livestock have visibly altered the bank, Figure 2. For this protocol the bank extends from the meadow level to the edge of the low flow channel, Figure 1. Because this protocol is conducted at the end of the grazing season flow should be low, allowing the monitor to view the lower banks. The monitor will count their steps to: 1) measure the entire length of the channel bank, and 2) record the total length of disturbed or altered bank, which allows the monitor to calculate the percent of altered bank, Figure 2. The monitor will stop when impacts by grazing are encountered, assess if the impacts meet one of the alteration types in Table 1, and measure the length of each alteration along the channel. The length of the disturbance or alteration needs to be measured parallel to the bank/channel, not across the bank/channel, Figure 2.

On the datasheet each alteration has a number and a column to enter the length of the alteration, as well as columns for each type of alteration, as described in Table 1 below, and columns for what geomorphic surface the impacts occur on. The monitor just needs to place a check or X in the column for each type of alteration(s) present, and geomorphic surface(s) impacted by the alteration. It is quite possible that more than one type of alteration is present, and that the disturbance or alteration occurs over more than one geomorphic surface. This detail is intended to help determine if proposed restoration features may be at risk, and to direct any management changes in livestock grazing, such as exclusion fences, creating off channel water sources, and changes in timing/intensity of grazing.

The following is an example of what one may encounter during this protocol, the type of alteration/disturbance is black bold type, and the type of geomorphic surface is in red bold type. After walking 10 steps the monitor may encounter a livestock **trail** that follows along the edge of the **upper bank** for 5 steps. That **trail** may then traverse down the incised channel to access forage and water in the **lower floodplain**, for a distance of 3 steps along the paced transect. Where the trail traverses the **upper bank** there may be **shearing**. At the **lower floodplain** there may be both **trampling** in the wetted area, and **shearing** along the **lower/active bank**, this may all occur in the same 3 steps along the transect. If there is no break in this disturbance it would be recorded as one eight step long disturbance over three geomorphic surfaces with three types of impacts.

Though a knowledge of channel geomorphology and hydrology is useful for this protocol, and may result in more accurate identification of which geomorphic features are being impact, the idea here is just to detect impacts that alter any portion of the bank. The percent bank alteration should be similar regardless of the samplers experience with geomorphology, however details in the notes may vary with experience/expertise. Figure 3, located in the appendix with the datasheets, is intended to be used to identify geomorphic features, with the understanding that channels are dynamic systems and not all channels will have each one of these features.

This will be repeated for the opposite bank. Photos should be taken at the start and end of each transect, and at representative locations along the transect. See naming convention for photos.

To aid in identifying types of disturbance and geomorphic features photos of different types of disturbance in Sierra meadows are provided as an attachment. These should be reviewed prior to conducting the monitoring, and if the monitoring team are not familiar with livestock impacts a copy of these photos should be taken in the field as a reference.

TYPE OF UNGULATE ALTERATION	DEFINITION/DESCRIPTION
Shearing	Removal of a portion of the streambank by hooves, leaving a smooth vertical surface and an indentation of a hoof print at the bottom or along the sides.
Trampling	Concentration of hoof prints that overlap and affect the overall surface such that vegetation is crushed, broken or displaced. Soil is also displaced and hooves may have punctured into saturated soil causing water to pool in the hoof prints. The depressions that cause this are usually at least 13 mm deep or cause soil displacement at least 13 mm upwards.
Trailing	Trails/paths and other severe trampling are counted as alteration if there are signs of current year use. Because of compacted soils, trailing counts as disturbance even if hoof prints do not result in a 13 mm depression, because such trails can lead to erosion.

Table 1. Definitions/Descriptions of Ungulate Alteration.

4.2
GRAZING

Grazing Management Impact Protocol: Bank Alteration

Drawings and Photography

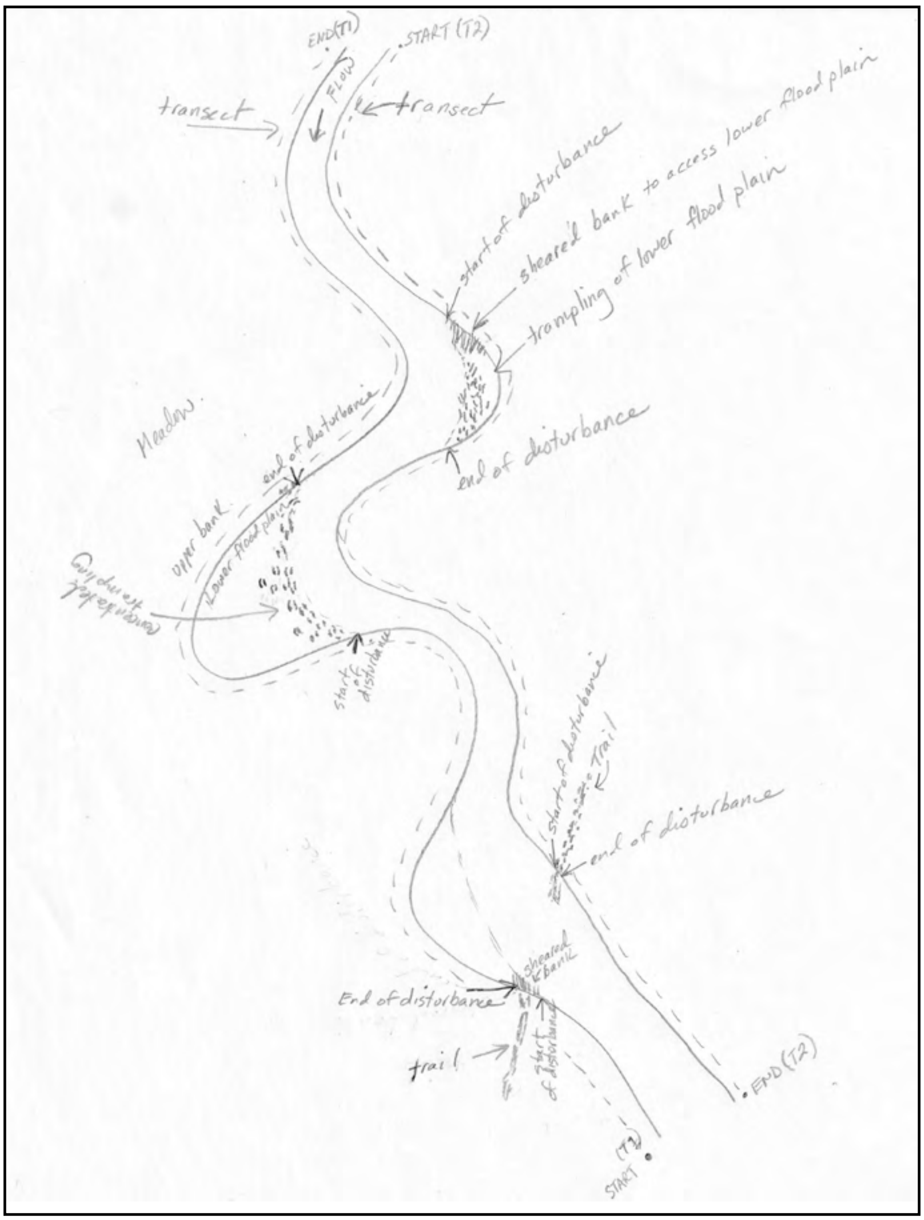

Figure 2. Example of Bank Alteration Monitoring

Photos should be taken at the start and end of each transect. If the channel is narrow and both banks can be seen in the photo only one photo is needed at the upstream and downstream end, if not then take a photo of both banks from the upstream and downstream ends of the channel sampled.

These photos should be labeled as follows:

Meadow_Tnumber_TransectLocation_start/end_upstream/downstream_year (e.g. "Horse_01_LeftBank_Start_downstream_2021")

Additional photos should be taken that represent the extent and type of disturbance encountered. These should be labeled as follows:

Meadow_Tnumber_TransectLocation_distance along transect_year (e.g. "Horse_01_LeftBank_32_2021")
Note: distance can be in paces, i.e. "25 paces upstream".

Example of incised channel with inset low floodplain. Sample from top surface to water's edge.

Example of trampling on: meadow surface, incised bank, active bank and the lower floodplain and channel.

Example of cattle hooves causing "shearing" on upper left bank, and trampling on lower bank and channel.

Example of hoof shear on left bank. Note only measure current year hoof shear.


Example of trampling on upper banks in the meadow and in the channel and of shearing on left bank.


Example of trampling and shearing leading to bank failure.

Close up of hoof shear.


Example of trampling in channel and along bank and of shearing at bank.

Example of trailing.

Example of trailing along the left bank.

Example of trampling and shearing leading to bank damage and incision.

Example of shearing along banks, and trampling adjacent to banks.

Example of concentrated trampling in meadow, on banks and in channel.

Example of trailing along the left bank and trampling in the channel.

4.2

GRAZING

Grazing Impacts Checklist Protocol

Equipment List

- Datasheet
- Clipboard
- Pencils/pens
- Rebar/metal pins
- GPS

DAVID B. HERBST, MICHAEL T. BOGAN, SANDRA K. ROLL AND HUGH D. SAFFORD. 2012. Effects of livestock exclusion on in-stream habitat and benthic invertebrate assemblages in montane streams. Freshwater Biology.

4.3 GRAZING

Residual Stubble Height

Resource Target

Vegetation, soil, hydrology, wildlife habitat and geomorphology impacted by grazing)

Indicators/Attributes

Residual vegetation (stubble height) of key forage species.

Stubble height is an easy, quick and quantitative method to assess how grazed vegetation may meet, or not meet management and restoration objectives. (Photo: CSschnurrenberger)

INTRODUCTION AND BACKGROUND

When should these indicators be used?

This protocol should be used when there is the potential for the current, and anticipated future, livestock utilization to affect the success of proposed restoration, the function of the meadow system, and/or the potential condition of the vegetation. This protocol applies specifically to the removal of key wetland grasses, sedges and rushes by livestock that may have the following effects: decrease in plant vigor, decrease in leaf litter, decrease regeneration and/or growth of woody riparian species, decrease in the ability of vegetation to protect soil, stream banks and wetland features, specifically fens, seeps and springs.

Currently, the majority of the meadows in the Sierra Nevada, on public and private land, are grazed by livestock. Grazing by livestock has a range of diverse impacts on vegetation, hydrology and soils. These impacts may affect the success of stream and meadow restoration projects and the functionality of the riparian/wetland system. Pre-project (baseline) assessment and ongoing monitoring should be used to assess the impacts of livestock grazing and direct management activities such as: adjusting the timing, intensity and location of grazing, fencing key areas, locating water sources outside of riparian areas, and establishment of riparian pastures or exclosures to aid in controlling livestock impacts.

The NRCS, USFS and BLM all incorporate utilization monitoring of key forage species in their grazing programs. SM-WRAMP stubble height monitoring may be conducted in accordance with existing range management plans. Additional assessment areas and transects may be necessary for monitoring specific areas for restoration potential. Baseline or pre-project monitoring will assess the impacts that current grazing management has on key areas within a meadow (such as channel banks, instream vegetation, seeps, springs and fens) to determine if these impacts might affect the efficacy of proposed restoration or meadow function in general. The stubble height method does not assess the impacts of past grazing management, or historical grazing impacts, nor does it track plant succession or meadow condition.

Residual stubble height, the height of vegetation after the grazing season, can affect plant vigor, species composition, retention of sediment and nutrients, bank stability and hydrologic function of seeps, springs and fens (Goss and

Roper 2018, Clary et al. 1996, Clary and Kinney 2002). The leaves of wetland sedges and grasses will bend over and provide a protective layer, reducing erosion in stream channels and floodplains (Clary et al. 1996). Residual vegetation also contributes to the litter or organic matter. The height and density of key forage species, and the litter they provide also creates habitat for local wildlife and may reduce exposure to predation and the elements by providing cover.

PLANNING

This protocol should only be implemented if current grazing management has the potential to adversely affect the success of restoration or meadow function. A review of land management plans, including allotment management plans, grazing management plans, and records of past utilization monitoring in meadow/riparian areas, will help determine if impacts from grazing management should be monitored, and what level of monitoring is needed. Use the decision tree provided in appendix of the "Qualitative Checklist to Assess Grazing Impacts Protocol", to select which monitoring protocol(s) should be used to assess the impacts that grazing has on the project.

Data Collection Timing

Pre-project (baseline) monitoring should be conducted at the end of the grazing season preceding the year other protocols will be applied. This allows for consideration of the need for adjustment in grazing management, use of other methods to limit livestock impacts and allows the assessment team to evaluate the systems' resilience to grazing impacts, i.e. do banks recover and revegetate, does vegetation stabilize trampled areas, do key species have sufficient vigor to recover? If pre-project (baseline) monitoring is conducted over several years this protocol should be repeated each fall prior to other monitoring. The initial year's monitoring may lead to changes in livestock management, and it is important to monitor the effect of these changes.

Post project monitoring should be conducted at the end of the second grazing season, (October), following project construction, and/or the first October following a change in grazing management. The results of this monitoring will determine the need for future monitoring. If grazing impacts are still at levels that "trigger" management changes, then monitoring should occur annually. If grazing impacts decrease significantly, consider only completing the qualitative check list and taking photos.

Required Resources

Time required per sampling/survey event
Stubble height monitoring may be completed by one person in 1 – 4 hours for most meadows. If two people conduct this work the time would be approximately half.

Data Entry, including uploading photos and transect location data to a map is 1 – 2 hours for one person.

Equipment costs if new

- Ruler - $20 – 25
- Daubenmire frame - $10 constructed from PVC (see diagram in appendix)
- Maps or Map App - $10 - 40

Level if any special expertise required
Some knowledge of local plants, hydrology and geomorphology. Knowledge of local grazing management plans, on/off dates for livestock, monitoring locations and minimum stubble height for each area.

Total Costs for Labor
$200 – 500
These costs include the time to conduct the field survey, upload data. Costs for equipment are not included, but an estimate of these costs is mentioned above.

DATA ANALYSIS

Data Storage

The project lead is responsible for storing and processing the original data and for uploading data to the UC-Davis site farm and other relevant state and federal databases as recommended in the SM WRAMP Guidance Document . Copies of all monitoring results should be kept in grazing management files. For the USFS and BLM these will be in the allotment file, for private land owners, including lands held by land trusts and conservation organizations, files or copies may reside with a rangeland manager.

4.3 Residual Stubble Height

Analysis Methods

The goal of this monitoring is to document a level of livestock use that supports the proposed restoration and level of meadow function. At a minimum this would be a residual stubble height of > 6 inches in key areas. The data should be entered into an excel file and stubble height may be tracked from year to year. The date and description of any management changes related to livestock use of the areas should be included in data files, in order to track the effectiveness of such management. This would include: changes in the length, timing or intensity of grazing, installation of fencing, changes in herding practices, development of water sources outside of wetlands and a change in the type of livestock grazing the area.

The data may also be analyzed by species, if the person(s) conducting the protocol can accurately collect that data. This allows for tracking livestock species selection and may be of interest if restoration goals include an increase or decrease in certain species.

Stubble height on the banks and within channels may be related to other monitoring data such as channel form, sediment retention and plant cover and composition, if that level of analysis is of interest. This would require statistical analysis adapted to the project needs.

Evaluation Criteria

A residual stubble height of < 6 inches in key areas could negatively affect the success of restoration and may be used to direct a change in management. If specific wildlife and/or plant species require a higher stubble height, a management decision would be recommended if residual stubble height is clearly less than that level.

ADAPTIVE MANAGEMENT

A minimum stubble height of 6 inches at the end of the grazing season is a common standard objective on many public lands (Clary and Webster 1990 and Goss and Roper 2018). If stubble height is less than 6 inches in key riparian areas this may indicate that restoration activities could be affected by current grazing practices and/or that the function of the meadow system is compromised. This minimum stubble height is significant for several reasons. Stubble height less than 6 inches has been shown to be less effective in retaining sediment, building litter that provides ground cover and contributes to nutrient cycling. Research has shown that when herbaceous species are grazed to 6 inches or less, cattle browse on riparian woody species increases (Clary and Kinney 2002, Swanson et al. 2015 and Pelster et al. 2004).

Presence or potential for a particular wildlife or plant species, or plant species, may require that more plant material is left ungrazed. If restoration goals include providing habitat for such wildlife/plant species, residual stubble height necessary to maintain high quality habitat for that species should be the criteria that indicates project goals are not being met, and management changes may be needed. For example, some studies have shown that residual height of key plant species up to 14 inches (35 cm), on banks, channels and floodplains, improves stream habitat for salmonids (Goss and Roper, 2018). The goals of restoration and preservation for each meadow should be reviewed before conducting this protocol to determine what stubble height would support project goals, and grazing management should be adapted to meet these goals.

COORDINATION

This protocol can be combined with the other grazing impact protocols. It may also be combined with the wildlife – beaver protocol or vegetation protocols, but only if they can be conducted at the end of the grazing and growing season, usually October.

CONTACTS AND RESOURCES

On USFS and BLM lands the range specialist at the District or Forest level should have copies of all allotment management plans. These should include the minimum residual forage standards for the allotment and meadow. Private lands, including those belonging to conservation organizations, may also have grazing management plans. In some cases monitoring may have been conducted by non-profit organizations. For example, on the Stanislaus National Forest the Central Sierra Environmental Resource Center (CSERC) frequently conducts this monitoring. They may be contacted at: https://www.cserc.org/ .

The two technical references listed below, (USDI-BLM 1999. and Burton et al. 2011), provide direction on different methods of

4.3 Residual Stubble Height

utilization monitoring and grazing impact monitoring. Aspects of these documents were used to develop this protocol, and these may be useful to provide background information on the development and use of grazing impact monitoring.

Person(s) who populated the specific protocol
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BURTON, T.A., S.J. SMITH, AND E.R. COWLEY. 2011. Riparian area management: multiple indicator monitoring (MIM) of stream channels and streamside vegetation. Technical Reference BLM/OC/ST-10/003+1737, U.S. Department of the Interior, Bureau of Land Management Denver, CO. 155 pp. Available online at: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd558332.pdf

Research on connection between monitoring metrics and riparian condition

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2. CLARY, W.P., C.I. THORNTON, AND S.R. ABT. 1996. Riparian stubble height and recovery of degraded streambanks. Rangelands 18:137–140.
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APPENDIX

Guide to Applying Residual Stubble Height Protocol

MEADOW TYPE AND PROPOSED RESTORATION	LOCATION OF MONITORING AREAS, AND METHOD OF SAMPLING
Main meadow hydrology is surface water from stream channel, restoration focuses on channel and bank stabilization.	Run transects along each bank, about 0.25 meters from the edge of the bank. Transect will meander along the bank, remaining parallel with the bank.
Meadow has additional sources of hydrology such as hillside seep/springs. Restoration is focused on protecting these areas and restoring hydrologic connection between the seeps and meadow.	Use Daubenmire frames to sample the seeps and areas influenced by the seeps. Randomly toss the Daubenmire frame, try to get at least 25 samples in each area. If the area is really small, < 15 feet by 15 feet, consider just conducting the “qualitative assessment of grazing impacts protocol”.
Meadow does not naturally have a channel but is supported by groundwater. Restoration is focused on protecting saturated areas, susceptible to penetration by hoof puncture.	Cattle will often stay out of seasonally wet areas if sufficient vegetation is available elsewhere, place transects in both drier meadow areas and wetter meadow areas. If the area is less than 100 feet in length use randomly placed Daubenmire frames.
Meadow has multiple tributaries, or braided channels. Restoration is concentrated on headcuts causing channels to incise.	Use transects along banks of longer channels. Use Daubenmire frames to sample non-linear features.
There has been a loss of woody riparian species in the meadow, restoration goals include increasing these species.	Use transects in adjacent herbaceous vegetation to measure stubble height.
There are perennial or seasonal ponds that create habitat for amphibians. Restoration goals focus on protecting these areas.	Use transects in adjacent vegetation to measure stubble height.

4.3

GRAZING

Residual Vegetation - Stubble Height Method

Print & Carry Field Instructions & Equipment List

The purpose of the residual stubble height protocol is to collect data from key areas throughout a meadow system based on measuring the height of the leaves of wetland grasses and sedges remaining at the end of the grazing season (usually October).

GENERAL PROTOCOL DESCRIPTION

The stubble height monitoring protocol is based on the method outlined on pages 51 – 52 of the "Utilization Studies and Residual Measurements, Interagency Technical Reference" (USDI- BLM 1999). These pages are provided in the Appendix. This is a quick "toe point" transect conducted in key areas that gives the stubble height by species, or just by "wetland graminoid", if the sampler cannot identify the species. In small areas, where a transect would not be suitable, a Daubenmire frame may be randomly placed. Both variations of this method are described below.

The main differences between the SM WRAMP protocol and the directions in the USDI-BLM reference are: 1) the SM WRAMP protocol focuses specifically on meadows, riparian areas and wetlands not uplands, and 2) the SM WRAMP protocol is also focused on areas where restoration may occur.

The type of meadow, its hydrologic sources, and proposed restoration will direct where stubble height should be sampled. Table 1 in the appendix section gives examples of where transects or Daubenmire frames would be placed to best assess grazing impacts in each hydrogeomorphic feature and restoration scenario described below. The full protocol may be found in the appendix.

DATA COLLECTION INSTRUCTIONS

Transect Set-up

Locating the transect – Stratify your sampling area using the following steps:

1. Identify areas within the meadow that might be affected by grazing impacts and are either affected by the restoration design or affect the restoration success .Differentiate hydrogeomorphic features and dominant plant communities (i.e. woody riparian, sedge, grass, forb, etc.) to stratify this area for sampling. This step can be done at the office. See guidance table in the appendix for additional information on where to locate monitoring, and how to conduct monitoring.

2. Within each hydrogeomorphic feature and dominant vegetation community, identify areas that are long enough for transects, at a minimum about 100 feet (can be done in the office), and that are in locations that are important to the success of the proposed restoration or overall meadow function.

3. If appropriate, utilize existing stubble height monitoring locations (should be available in grazing management plans) as locations to place transects areas (should be done in the office).

4. Within identified areas, draw transects (100ft minimum) in each hydrogeomorphic feature or important vegetation sources. This will be done in the office, and a map of the sampling areas and transects can be printed or uploaded onto a tablet, GPS unit, or phone.

5. Each meadow will have different hydrologic and vegetative features. One transect may be sufficient to characterize a small stringer meadow. It may take 5 transects, and 5 areas sampled with Daubenmire frames, for a meadow with a main channel, hillside seeps and scattered fens. The objective is to document livestock use as accurately as possible without spending more than about half a day sampling a meadow system.

6. For larger meadows, run transects diagonally across the meadow. To sample along the banks, run transects parallel to the creek (the transect can meander to follow the creek channel). In narrow “stringer” meadows, run transects along the length of the meadow.

7. Load the start point and bearing of the transects into a GPS unit for use in the field, these may be moved but they will give you a starting point for monitoring site selection.

8. Once in the field, check that your map represents what you are seeing. Look for patterns of use in the areas you need to sample. Adjust transect location(s) to capture important hydrologic features in your potential restoration

Sampling the transect

1. A step-toe transect is walked; no tape is needed. Take note of the bearing as you walk and try to maintain a straight line, unless you are walking along a stream channel (see table in appendix).

2. To improve post-restoration sampling efforts, we suggest some combination of the following: documenting the transect end points with a GPS point, monument the transect endpoints with metal or pins (pin flags are commonly consumed by grazing animals are not recommended for long term plot or transect identification), utilizing “witness” trees or rocks that can help with the identification of a transect end point, and the collection of a photo point.

3. The idea is to collect enough samples to be representative of your area of interest. Choose your number of paces to fit the area you have to sample, with the goal of getting at least 50 sample points per transect. For a 100ft transect, a data point is recorded every 2 to 8 paces (steps). Use more paces between points for larger areas.

4. As mentioned above, the transects along the a stream bank will follow the path of the channel and not be straight. If variability is high you may want to investigate if certain patches are grazed more closely, and if those areas are of importance then relocate your transect to sample just that area.

5a. For Transects 100ft or longer:
Toe-Point Sampling: At each sampling point, the sampler records the height of the vegetation at the toe of their boot/shoe at each sampling interval. Use a folding ruler in metric or inches, (the measurement can be converted later), place the ruler at the center of your right toe and look at the vegetation within a 3cm (1 inch) diameter spot at your toe. (continue to Step 6)

5b. For Transects less than 100ft:
Daubenmire Frame Sampling: At each sampling point, use a Daubenmire frame and gently toss it with eyes closed, the idea is to not allow you to “choose” the location of the frame. Record the height of the dominant key forage species in the right lower and left upper corner of the frame, resulting in two sample locations being recorded within the frame. As with toe-point transect sampling look at vegetation within a 3 cm (1 inch) spot at those corners. These areas are often very small so try to get at least 30 total plant heights. A Daubenmire Frame is 25 cm by 50 cm dimensions and can be constructed out of ¾ inch diameter PVC pipe. (Continue to Step 6)

6. You can use the same datasheets for both the Toe-Point and Daubenmire frame protocol (datasheet is attached in the appendix). Record the leaf height (not the stem often these are not eaten by livestock) of the dominant key forage species. A key forage species for a wet meadow in the Sierra Nevada Mountains is usually a sedge, such as Nebraska sedge (Carex nebrascensis), or a wetland grass, such as tufted hairgrass (Deschampsia cespitosa). It may not be possible to identify the species due to grazing, plant phenology or a sampler’s lack of expertise with local botany. If the plant is widespread, and has been significantly grazed, then it is a key forage species. The data sheet has a place for species name, but you can just record “sedge” (Carex sp.), or grass. If you cannot ID the plant, it is still useful data. Often key forage species for specific meadows will be listed in the allotment management plan for each meadow or pasture area.

7. Walk 2 to 8 paces (or as many paces as you had previously determined) and repeat.

If grazing pressure is low, and animals just wandered and selected a few plants, the sampling will show that, and height variability will be high. Areas of different utilization levels should be sampled as independent transects, you don’t want to combine samples of an area that was heavily grazed with an area without much grazing. The purpose of this protocol is to determine if current grazing management could impact restoration and/or meadow function and direct changes in management that allow the selected area to function post restoration, so make sure monitoring meets this purpose.

Throughout the Sierra Nevada the minimum residual stubble height standards at the end of the grazing season for riparian areas is normally 6 inches. The impacts of stubble height are discussed in “Adaptive Management”. In general, if an area is consistently below 6 inches, this would be a red flag and documenting this with monitoring data is important if the area is going to be restored, is an important habitat for wildlife/plant species, and for overall meadow function.

4.3
GRAZING

Stubble Height Protocol
Equipment List

- Daubenmire frame (for non-linear areas)
- Site Maps, or mapping program on phone or tablet
- Folding ruler metric or inches

Grazing Impacts Checklist

4.4

GRAZING

Resource Target

Primary – Vegetation, geomorphology, hydrology
Secondary – Soils, aquatic ecology, wildlife

Indicators/Attributes

Livestock impacts – removal of vegetation, trampling, trailing, shearing of banks and pocking of wetland surface.

INTRODUCTION AND BACKGROUND

This protocol is intended to evaluate if, and to what extent, current grazing will impact meadow restoration and/or function. This protocol should be implemented when grazing, almost always by livestock but potentially by wildlife, is present, and could impede proposed restoration and/or meadow function.

This protocol is only intended to address current grazing impacts, not historical impacts by livestock. This protocol starts by identifying the type of meadow system to be evaluated, channel supported meadow, or non-channel supported meadow. The next steps are determining: 1) if grazing impacts can be identified, and 2) if those impacts will affect the hydrologic function and the health and function of the vegetation communities within the project area.

This protocol is may also be used to determine if more extensive quantitative monitoring of grazing impacts should be conducted, or if this qualitative initial checklist is sufficient to determine the extent of impacts from grazing on the proposed project area.

The results of this monitoring protocol may lead to adjustments in grazing management, construction of protective structures (permanent or temporary fences, log barriers, etc.), and/or location of watering structures out of sensitive areas, or redesign or relocation of restoration activities if grazing impacts will not allow goals to be met.

PLANNING

What level of effort is required?

Moderate to low

This protocol should only be implemented if current grazing management has the potential to adversely affect the success of restoration or meadow function. A review of land management plans, including allotment management plans, grazing management plans, and records of past utilization monitoring in meadow/riparian areas, will help determine if impacts from grazing management should be monitored, and what level of monitoring is needed.

It is important to assess if, and how, current grazing may affect meadow restoration and management.(Photo: CSschnurrenberger)

4.3 Bank Alteration

Data Collection Timing

Pre-project (baseline) monitoring should be conducted at the end of the grazing season preceding the year other protocols will be applied. This allows for adjustment in grazing management, use of other methods to limit livestock impacts, and allows the assessment team to evaluate the system's resilience to grazing impacts, i.e. do banks recover and revegetate, does vegetation still stabilize trampled areas, do key species have sufficient vigor to recover?

Post project monitoring should be conducted at the end of the grazing season, (October), following project construction, and the first October following a change in grazing management. The results of this monitoring will determine the need for future monitoring. If grazing impacts are still at levels that indicate management has not alleviated impacts to the project area then monitoring should continual annually. If grazing impacts decrease significantly consider only completing the qualitative check list and taking photos, every other year to verify that livestock management has been successful and the system is resilient to impacts from grazing. Some level of monitoring should continue as long as livestock grazing occurs in the project area.

Required Resources

Office Work - time required per sampling/survey event (# people x hours)
This protocol will require 1 – 3 hours of office work to research current grazing use and management for one person.

Field Work - time required per sampling/survey event (# people x hours)
This protocol will require 2 – 6 hours of field work to conduct the field work, fill out the checklist, identify impacted areas and take representative photos for one person, reduce by half if two people conduct work.

Post Field Work - time required per sampling/survey event (# people x hours)
This protocol will require 1 – 3 hours of post field work in the office to download photos, organize photos in the template, and produce a map of hydrologic features, and photo locations related to those features for one person.

Equipment costs if new
- Clipboard -$5
- Phone/tablet app for georeferenced photos - $10
- Mapping program for phone or tablet - $30 – 50

Level if any special expertise required
General knowledge of hydrology, geomorphology, meadow vegetation and rangeland management.

Total Costs
$400 – 1,000 depending on person's hourly rate, assume in the range of $50 – 85/hour

DATA ANALYSIS

This is a qualitative monitoring protocol.
If survey is conducted using a program such as Arc Collector, or Arc Survey 123 the actual checkpoint data and notes could also be linked to the location data was collected, along with the photos.

Data storage

The project lead is responsible for storing and processing the original data and for uploading data to the UC-Davis site farm and other relevant state and federal databases as recommended in the SM WRAMP Guidance Document

Analysis Methods

This is a qualitative method. There is no analysis.

Evaluation Criteria

If grazing impacts are determined to significantly impact any hydrologic/hydrogeomorphic feature that is important to the function of the assessment area, as assessed in the checklist datasheet, or by either quantitative monitoring protocol for assessing grazing impacts, grazing management and proposed restoration should be evaluated, and protective measures should be taken. The project would be considered not successful if grazing management continued to impact the function of important hydrologic features such that project goals were not met.

4.3 Bank Alteration

ADAPTIVE MANAGEMENT

If the above evaluation criteria is met adaptive management should focus on alleviating grazing pressure. Management changes may include: changing the season of use so that areas are not grazed when they are wet, reducing the number of animals, shortening the grazing season, active herding to keep animals out of sensitive areas. Structural or physical changes may include: permanent or temporary fencing, repair of existing fencing, construction of physical barriers such as downed logs and locating livestock watering sources and mineral block or feed away from wetlands/hydrologic features.

COORDINATION

This protocol can be conducted with the other two grazing impact protocols: residual stubble height, and bank alteration. This protocol may also be combined with hydrogeomorphic mapping. The beaver protocol can also be conducted at the same time as this protocol. This protocol is conducted too late in the year to be combined with the vegetation protocols, which occur when the majority of the plants are in flower.

CONTACTS AND RESOURCES

The majority of meadows in the Sierra Nevada are managed by the USFS. A number of resources are available that outline management objectives for grazing in riparian areas. These are listed below, with web links where available. These resources may be used in the pre-field research to determine existing monitoring and standards and guidelines for grazing management.

Rangeland Management Resources on USFS Lands

National Level
Rangeland Management Manual – FSM 2200
https://www.fs.fed.us/rangeland-management/aboutus/directives.shtml
Rangeland Management Handbook (FSH 2209.13)
https://www.fs.fed.us/cgi-bin/Directives/get_dirs/fsh?2209.13!..

Forest Level
Land and Resource Management Plan – includes standards and guidelines for the forest as a whole and areas with special considerations, i.e. wilderness areas, protected watersheds etc. Available at individual forest websites.

Allotment Level
- Allotment Management Plan – Available at the Forest supervisors and district offices
- Grazing permit – has terms and conditions of grazing, allotment maps, permitted livestock use
- Annual Operating Instructions – has current resource protection issues

Field References
This reference should be used to aid in identifying and mapping hydrogeomorphic features, "A Field Key - Meadow Hydrogeomorphic Types of the Sierra Nevada and Southern Cascade Ranges in California, R5-TP-034" by Weixelman et al. A link to this reference is provided below in the references section below.

Several pages of photos showing various impacts from livestock to different hydrologic features are provided in the Appendix. It would be useful to upload these to a phone or tablet or print them out to use as a reference in the field.

Person(s) who populated the specific protocol
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REFERENCES

Weixelman, Dave & Hill, Barry & Cooper, D. & Berlow, Eric & Viers, J. & Purdy, S. & Merril, Amy & Gross, S.. (2011). A Field Key to Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges in California. Available online at: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5362593.pdf

APPENDIX

This protocol includes:
1. Protocol instructions (should be printed with datasheets and taken in the field).
2. Datasheets
3. A reference photo sheet with examples of grazing impacts and hydrologic features.

4.4
GRAZING

Qualitative Checklist for Grazing Impacts

Print & Carry
Field Instructions
& Equipment List

This protocol is intended to evaluate if, and to what extent, current grazing will impact meadow restoration and/or function.

FIELD INSTRUCTIONS

This protocol is not based on any existing monitoring reference, but does suggest that the person or people conducting the monitoring use know the difference between channel supported wetlands, and non-channel supported wetlands, and are able to identify key forage areas, based on livestock use patterns, species composition and underlying hydrology. The USDA document, "A Field Key to Meadow Hydrogeomorphic Types of the Sierra Nevada and Southern Cascade Ranges in California", may help the monitor understand the hydrologic function of the meadow system.

Identify if the meadow hydrology is primarily from a channel, or not. Identify key vegetation communities within the meadow system. Answer yes or no questions about the presences and impact of current grazing. Support these answers with notes and photos. One checklist should be sufficient for a project area. The photo sheet is provided as a template, photos should be uploaded to this sheet and submitted with the checklist.

Note: the following protocol directions are also included in the appendix with the field datasheet and should be printed with the datasheet and taken to the field.

Step 1 A - Complete in the office before field assessment – Determine if grazing monitoring is needed

1. Is livestock grazing planned for the project area?
   a. No – continue to question 2.
   b. Yes – Is there a grazing management plan, with a monitoring schedule?
      i. No – read through decision tree, conduct the checklist protocol and consider setting up a monitoring plan and schedule.
      ii. Yes – review existing monitoring schedule, locations and data. Incorporate suitable locations, read through the decision tree and conduct the checklist protocol and consider where additional monitoring will be useful.

2. Is unauthorized (trespass) livestock grazing present and/or anticipated?
   a. No – If no scheduled or trespass livestock grazing is present do not continue with this protocol.
   b. Yes – Is this grazing significant enough to impact the project area?
      i. Yes – read through decision tree, conduct the checklist protocol in the field and consider setting up a monitoring plan and schedule.
      ii. No – do not continue with this protocol.

Step 1B - Complete in the office before field assessment – Set up map for monitoring

1. Is there a map of hydrogeomorphic features?
   a. Yes – make paper copies or upload digital copies to a phone or table to direct field monitoring.
   b. No – Use existing resources, aerial photos, drone imagery, grazing management plans, topo maps etc. to help determine if the meadow is a channel supported meadow or not. Create initial field map of important plant communities, and hydrologic features to monitor, such as channel banks, ground water supported wetlands (seeps, springs, fens), wet and dry meadow vegetation. Take printed aerial photos or upload aerial imagery to phone/tablet for field mapping.

Step 2A - Complete in the field after pre-field assessment – checklist of grazing impacts

1. Is there evidence of grazing – removal of vegetation, trampling, browse of woody riparian species, current season manure?
   a. No – Do not continue with this protocol at this time, but review if grazing management might impact the area in the future, if it will go back to office assessment.
   b. Yes – Use the table below to assess what hydrologic features are present and being impacted by grazing.

Step 2B - Complete in the field after pre-field assessment – Map of hydrogeomorphic features

Take initial maps or imagery from step 1B, use these to identify and delineate the areas you are going to monitor with this protocol. Record all areas monitored and map photo points. This may be done in the field using a mapping program and a GPS (Arc collector, google earth, Gaia), or by using a handheld GPS and uploading GPS locations to the map in the office afterwards. Number each hydrologic feature and use these numbers when naming the photos.

Step 2C – Georeferenced photo points

Take photos of all areas impacted by livestock, and important hydrologic features or vegetation communities within the meadow. Include the number, name and direction of all photos on the checklist. Take photos of areas even if they are not impacted by grazing, this provides a more complete visual database of the overall degree to which the entire project area is impacted by grazing. At each area have one landscape view photo and one close-up of the impact, i.e. grazed vegetation, sheared banks, pocking or hoof puncture in groundwater wetlands (fens, seeps, springs). Consider using a ruler for scale on the close-up photos.

Step 3B - Complete in the Office after field assessment – Complete Map of hydrogeomorphic features

At a minimum finalize a paper map on an aerial photo delineating the channel or groundwater sources that support the meadow and vegetation communities, and mark photo point locations. Alternately digitize the map and save as GIS shape files, convert to a PDF for use in the field and/or reports. If using Arc-collector or a similar program in the field upload all files and compile a complete map, again convert to GIS shape files and also PDF format.

Step 3C – Upload georeferenced photo points to template

Upload georeferenced photos and put them in the template with a description of each photo in the box below the photos. Save as word type document and convert to PDF for use in reports or in the field.

4.4
GRAZING

Grazing Impact Checklist Protocol

Photography

CONVENTION FOR NAMING PHOTOS

Meadow_Project_Hydrologic/vegetation feature_impact_photo #_year

Example: Horse Meadow_Channel restoration_hillslope seep_pocking veg removal_P1 _2020

Because two photos are taken at each hydrologic feature there will be a P1 and P2. Take P1 as the overview, landscape photo and P2 as the close up of the impact – pocking/hoof puncture, trampling, trailing, veg. removal, browse willows.

If at all possible use a photo program such as "context cam" that prints the location, direction of photo and two lines of description on the actual photo.

Photo 1. Example of moderate to light grazing in seasonally wet meadow, note variability in height of key forage species

Photo 2. Heavy use with < 2 inch average stubble height. The cage shows ungrazed sedges and grasses as a reference.

Photo 3. Example of “pocking” or hoof puncture into saturated ground at a hillslope seep. Note also < 2 inch stubble height shows heavy grazing.

Photo 4. Trampling, pocking (hoof puncture) into saturated ground and veg. removal in a spring supported wet meadow.

Photo 5. Heavy grazing in dry meadow in the foreground, and wet meadow at the back left of photo.

Photo 6. Severe use on seep supported wet meadow vegetation < 1” stubble height and trampling, “pocking” of hoof puncture of meadow seep.

Photo 7. Example of severe livestock browse on young willows. All new growth is browsed. Young willows are more susceptible to browse.

Photo 8. Browse on lower branches of mature willows, also called “hedging”. Note moderate - heavy use on dry meadow herbaceous vegetation.

Photo 9. Hillslope seep with heavy grazing < 2" stubble height, severe trampling leading to "pocking" or hoof puncture that affects the function of the seep in supporting wetlands downslope.

Photo 10. Hillslope seep with severe trampling leading to "pocking" or hoof puncture that affects the function of the seep in supporting wetlands downslope. Note hummocks are forming from impact of hooves.

Photo 11. Heavy grazing in spring. Note preferred species grazed to < 2". Trampling has impacted spring hydrology by puncturing into soil reducing the sites ability to retain water.

Photo 12. Fen (peatland wetland), heavy grazing < 2" stubble height and "pocking" or hoof puncture into saturated peat affecting ability of fen to retain water.

Photo 13. Moderate grazing in wet meadow, note patchy nature of remaining forage.

Photo 14. Dry meadow with patchy grazing – heavy to moderate.

Photo 15. Lake shore only moderate grazing, but livestock accessing water caused hoof puncture along saturated shoreline.

Photo 16. Lake shore with moderate to heavy grazing but hoof puncture in wetland vegetation and along shore in background.

Photo 17. Seasonal depressional (pond) wetland only moderate grazing but pocking within pond, reducing function of amphibian habitat.

Photo 18. Concentrated trailing, trampling, and grazing along the edge of perennial depressional wetland (pond).

Photo 19. Marsh with seasonal ponds, ungrazed.

Photo 20. Same marsh lightly grazed, note no evidence of pocking or trampling.

Photo 21. Trailing in riparian meadow with moderate grazing, some browse on willows in background.

Photo 22. Trailing, "pocking" or hoof puncture in wet areas, shearing along wet banks of channel

Photo 23. Heavy grazing < 3" stubble height, trampling and hoof puncture of subsurface supported wet meadow, foreground, and pond in background.

Photo 24. Moderate grazing in foreground, but significant "pocking" or hoof puncture along shore of pond in background, and heavy use on sedges at edge of pond.

Photo 25. Dry meadow with heavy grazing, and concentrated use resulting in trampling and bare ground.

Photo 26. Spring with heavy grazing, trampling, "pocking" of hoof puncture, and shearing leading to loss of vegetation, hummocks, and loss of hydrologic function.

Photo 27. Trampling and shearing on incised banks of channel.

Photo 28. Close up of hoof puncture in a fen, adversely affecting hydrologic function of the fen vegetation and peat.

Photo 29. Trailing on incised bank where cattle accessed the creek causing erosion and bank instability.

Photo 30. Trampling, shearing from hooves on banks of the creek and "pocking" or hoof puncture in channel bottom, also severe grazing.

Photo 31. Shearing by livestock hooves along left bank, and trampling in channel.

Photo 32. Channel with shearing resulting in bank erosion.

Photo 33. Heavy grazing resulting in < 2 inch stubble height in a subsurface wet meadow.

Photo 34. Wet meadow supported by a series of seeps and spring with small channel, on left. Heavy grazing has resulted in trampling and “pocking” leading to loss of vegetation, increase in bare ground and exposed subsurface water and loss of hydrologic function to the system.

The following are examples of how one might map the hydrologic features a meadow. These are taken from * Taken from "A Field Key to Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges in California", Weixelman et al. 2011. The link to this reference is provided in the reference section.

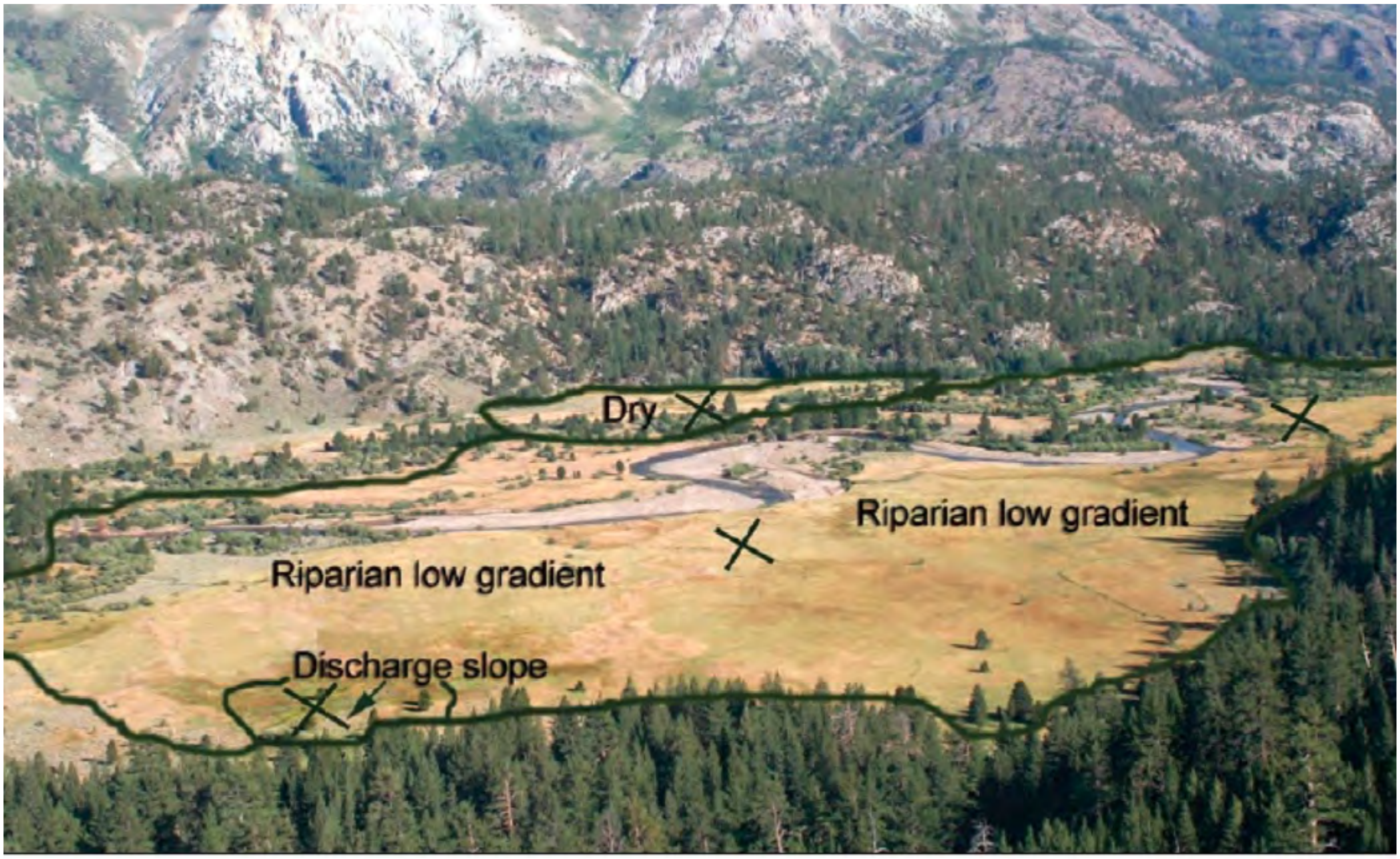


Figure 2. Illustration of a meadow and the component hydrogeomorphic types which make up the meadow. Also shown are the representative locations (marked by X's) where the dichotomous key was used in the field to identify the component hydrogeomorphic types.

Figure 17. Photo of a series of discharge slope meadows occurring on a toeslope above a riparian low gradient meadow system, Modoc National Forest.

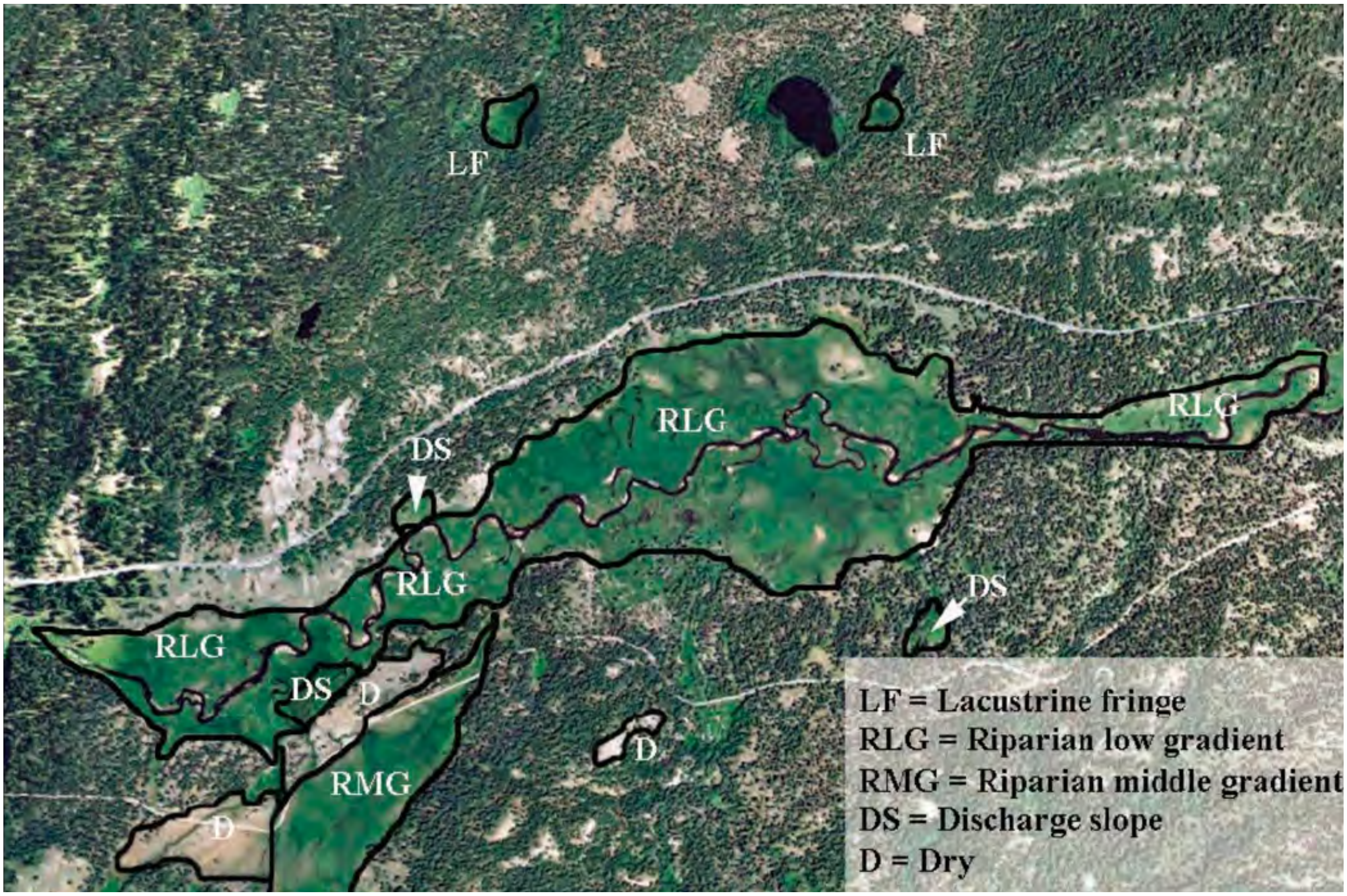


***Figure 31**. Map of hydrogeomorphic meadow types on the Tahoe National Forest.*

4.4
GRAZING

Bank Alteration Protocol

Equipment List

- Daubenmire frame (for non-linear areas)
- Site Maps, or mapping program on phone or tablet
- Folding ruler metric or inches

5
VEGETATION

Monitoring Meadow Vegetation Response to Restoration in the Sierra Nevada Technical Memorandum for American Rivers by Stillwater Sciences 2011.

5.1

VEGETATION

Vegetation Summary

This is a summary of the five vegetation monitoring protocols included as part of the SMP WRAMP. The primary resource target for all of these is Vegetation. The table below identifies the protocol name (as named currently), the primary indicators/attributes measured/summarized, when the protocol should be selected (there is additional information regarding protocol use in each protocol this is only a brief summary), the time required to implement the protocol, and the level of skill needed.

SUMMARY TABLE OF FIVE VEGETATION PROTOCOLS

NAME OF PROTOCOL	INDICATOR/ ATTRIBUTES	WHEN SHOULD PROTOCOL BE USED	TIME REQUIRED	SKILLS	FREQUENCY MONITORING
General Vegetation Monitoring Protocol 6/19/20 + General Vegetation Protocol Datasheet	Dominant plant species Change in plant attributes (e.g. wetland indicator status, nativity, lifeform)	General vegetation protocol if no other vegetation protocol being used and there is interest in understanding how dominant plant species change over time and/or space	1.5-3+ days/meadow depending on intensity of sampling selected and number of species individual knows	Species identification	1-3 years pre-restoration; 1, 3, 5, and 10 years post restoration
NDVI/NDWI Monitoring Protocol	The normalized difference vegetation index (NDVI) is a measure of vegetation vigor. The normalized difference water index (NDWI) is a measure of vegetation water content and indicates wetness of a meadow based on how much water the vegetation is holding.	Anytime restoration includes an objective for vegetation. This protocol should always be used and can be used in combination with other vegetation protocols. Climate Engine provides a simple methodology to process vegetation data which can be tied to climate data and can be informative to understand restoration success.	All of this data can be summarized and reported on in 1-2 hours with one person's time.	Ability to follow instructions on a computer.	5, 10 and 15 years post restoration

SUMMARY TABLE OF FIVE VEGETATION PROTOCOLS CONT.

NAME OF PROTOCOL	INDICATOR/ ATTRIBUTES	WHEN SHOULD PROTOCOL BE USED	TIME REQUIRED	SKILLS	FREQUENCY MONITORING
R5 Range Monitoring Protocol	• Frequency of individual plant species • Percent ground cover • Rooting depth • Depth to saturation • Depth to mottling • Number of conifer seedlings in plot by species • Distance to nearest seedling by species • Distance to nearest seed source by species	If restoration objectives are: increased meadow species, increased wetland species, appropriate biodiversity, grazing management, reduced invasive species **AND/Or** existing range monitoring plots within the meadow, or if want to compare the monitoring to the large USFS R5-Range monitoring plots that are established across CA	1- Hour pre-field (office) 1 – 4 hours field time 1 – 2 hours post field (office)	Species identification	1-year pre restoration, 1-year post restoration and then every 5 years for a minimum of 10 years total (or 4 sampling periods)
Target Species Monitoring Protocol 6/29/20 + Target Species Monitoring Protocol Appendix A	Target species population location and distribution across the area of interest and Weighted percent cover of target species occurrences and/or Estimated number of individuals within populations.	If restoration goals are to change target species populations, this protocol can be utilized to coarsely detect response of target species to meadow restoration actions. It can be used for rare, invasive, culturally significant or other target plant species	16-48 meadow acres/ day/person	Identification of target species and target species habitat	Pre-restoration; 1, 3, 5, and 10 years post restoration
Conifer Monitoring Protocol 6/4/20 + Conifer Monitoring Datasheets	• Conifer density by species, size class, status (live/dead) • Herbaceous cover • Wetland vegetation cover	When conifer removal occurs from meadow	3-5 days/meadow	Basic sampling forest and meadow	1-3 years pre-restoration; 1, 3, 5, and 10 years post restoration

5.2
VEGETATION

General Vegetation

Resource Target

Plant species and distribution

Indicators/Attributes

Dominant plant species and change in plant attributes (e.g. wetland indicator status, nativity, lifeform).

Tracking meadow vegetation plots. Gross and Norman. 2011.
LTBMU 2010/2011 MONITORING PROGRAM ANNUAL MONITORING REPORT

INTRODUCTION AND BACKGROUND

When should these indicators be used?

This method for tracking these indicators should be used when there is an interest in understanding how dominant plant species change over time and/or space (e.g. pre-post restoration or within or between meadows). This method will allow you to assess whether there is a change (an increase or decrease) in dominant plant species by evaluating the change in individual species presence and/or cover which will allow you to perform analysis on wetland indicator status, nativity, lifeform type, etc.

What goals are being evaluated?

This method will allow you to evaluate if plant species are responding to restoration actions.

What restoration objectives does the indicator evaluate?

- Increased wetland/floodplain/meadow plant communities
- Increased wetland species
- Appropriate Biodiversity: if objective is biodiversity, sample all species
- Plant Community: if objective is community composition, sample all species
- Grazing Management
- Reduced Invasive Species (see also target plant species monitoring)
- Reduced upland species invasion (e.g. conifer, sagebrush, etc) (see also Conifer Encroachment Protocol)

What questions/uncertainties are being answered/addressed?

This method answers a variety of questions and uncertainties about how and whether plant species change as a result of restoration activities and how those changes occur over time.

PLANNING

Data Collection Timing

This protocol should be conducted during the peak of the growing season in advance of and after restoration implementation. At least one year of pre-restoration data should be collected, within one to three years prior to the restoration. The protocol should be repeated at one-year, three-years, five-years, and ten-year post-restoration. Additional data collection efforts can be added (e.g. year 2) if time and resources allow. Peak growing season at higher elevations is usually in late June-July into August; in the lower elevations it could be as early as May-June.

Required Resources

Time required per sampling/survey event (# people x hours)
The estimated time per sampling event is dependent on size of meadow and the number of transects and plots you establish in your meadow system.

Desktop
It should take one to four hours of time to determine where you want to put your plots and pull together materials and resources to go in the field.

Establishing the Transect
It should take about 1-2 hours once you have reached your field site to identify your transect end point and establish the first 100 meters. Once established, it should take less than 30 minutes to establish subsequent 100m sections. One person can do this protocol alone or it can be done with multiple people who could sample plots either together or individually. Setting up transects is more efficient with at least two people.

Monitoring the Plots
It should take between 15-45 minutes to establish and monitor a single 10m2 plot, depending on plot diversity and level of skill.

If one person does this protocol alone, setting up three transects and 18 total plots, we estimate it would take between 1.5-3 days to complete, depending on how many species the person already knows. Setting up transects is more efficient with at least two people.

Equipment costs if new

GPS unit:	$100-6,000
Meter Tapes:	$100
Compass	$20
Plant Books:	$30-200
Misc. Supplies	$200

Level if any special expertise required
A botanist should conduct these surveys or train others and be available on and/or off site for identification needs.

Total Costs
$500-7000

DATA ANALYSIS

Data Entry

Datasheets should be reviewed and quality controlled before data entry begins. All data should be entered into an excel spreadsheet or database. Quality control should be conducted by someone other than the person that entered the data to ensure errors are resolved. When a plant cannot be identified a voucher should be made so that it can be identified in future survey years if the plant is found in a different phenological stage.

Data Analysis

The below data analysis methods are both for descriptive and statistical analysis, depending on expertise and desired outcomes. Statistical analysis is recommended to be conducted in R, and code is provided below but can be tweaked if additional variables are required or other platforms are preferred. There are also several other packages and tools that can be used in R to analyze this data and the below framework is here as guidance but does not necessarily have to be used if another method is desired or would be a better fit for the specific analysis you are hoping to conduct.

5.2 General Vegetation Protocol

Examples

Descriptive
Use Excel to plot up averages of cover for each year by species, lifeform, wetland indicator status, or other variable.

Statistics
Note: year to year comparisons of plant data suffer from pseudoreplication issues when you start to look at more than two years of data, so a repeated measure or mixed model ANOVA is necessary with paired t tests (does not assume independence between years for the same location):

1. **Sample r script:**
   output.aov<-aov(cover~Year+Error(type/Year), data=dataset)
   Summary(output.aov)
   With(dataset, pairwise.t.test(cover, Year, p.adjust.method="holm", paired=T)

2. **Change in dominance of Wetland Indicator Status Analysis or Lifeform**
   a. Wetland Indicator Identification
      i. Visit USDA Wetland Indicator Status by Species: https://plants.usda.gov/core/wetlandSearch
      ii. Enter in the status of each species into your database/datasheet
   b. Lifeform: enter in lifeform status of each species (perennial herb, annual herb, annual graminoid, shrub, tree (can break further by deciduous and coniferous), moss, lichen) and conduct steps c-e
   c. Add up total cover for each type within each plot for each year
   d. If interested in year over year change in cover (dominance) of wetland indicator status or lifeform within plots, run repeated measures ANOVA with t-tests

3. **If interested in change in plant species year over year or within a given year:**
   a. Alpha Diversity/Richness
      i. Add up all unique species per plot per year to get a count of species per plot (you can also do this with wetland indicator status or lifeform if you are interested in diversity rather than dominance)
         - Compare using excel graphics for descriptive information
         - Run ANOVA (see above) to understand if change is statistically significant. Column headings should include: plot, transect, diversity, any other variables you have collected (groundwater depth, elevation, distance to stream, etc.)
   b. Beta Diversity or plant community change (dissimilarity of species between years or between plots)
      i. Load Vegan Package in R.
      ii. Convert your data to a matrix so that plots are the rows, species are the column headings, and the cover value or presence(1)/absence(0) are the values within the matrix
         - Run vegdist() on your dataset which will return a matrix with Sorensen bray-curtis distance (beta diversity) for plot by plot comparisons. The output matrix will have plots in both the row and columns and the values will be the https://www.rdocumentation.org/packages/vegan/versions/2.4-2/topics/vegdist
         - If you want to look at how environmental variables might be influencing betadiversity, suggest conducting ordination using metaMDS function in vegan.

ADAPTIVE MANAGEMENT

Over the years and due to changes that might be due to restoration activities, drought, or some unanticipated disturbance, the baseline plot that you established may be in a vegetation "transition" zone and no longer represents what you would consider to be a more or less homogenous vegetation community. If that is the case, you should still continue to document the change in that plot over time. You also have the flexibility to establish a new plot or plots to track the trajectory of the "new" communities that are developing around your baseline plot. As time goes on, other factors that you did not expect and cannot control may alter your expected outcomes (wildfire, grazing, etc.). Be sure to document changes in land management activities or site conditions as you continue to monitor and incorporate them into your analysis, if necessary or feasible to do so.

COORDINATION

These methods can be coordinated with hydrologic monitoring (groundwater and surface water), geomorphology (cross-section/long profile) and other vegetation data

5.2 General Vegetation Protocol

collection (rare plant surveys, invasive plant surveys) to maximize time.

CONTACTS AND RESOURCES

Percent cover diagram
http://www.cnps.org/cnps/vegetation/pdf/percent_cover_diag-cnps.pdf, also attached.

Species Identification Resources
- Calflora: https://www.calflora.org/
- Jepson Manual. Printed or Online Version: http://ucjeps.berkeley.edu/jepman.html)
- Other local plant identification manuals.
- USDA Wetland Indicator Status by Species: https://plants.usda.gov/core/wetlandSearch
- Sensitive Species Resources: https://plants.usda.gov/threat.html (filters by geography and species characteristics)
  California Natural Diversity Database: https://wildlife.ca.gov/Data/CNDDB
- Invasive Species Resources:
  CA State List: https://plants.usda.gov/java/noxious?rptType=State&statefips=06
  CAL-IPC: https://www.cal-ipc.org/
  Sierra Meadows Vulnerability index (CAL-IPC): https://www.cal-ipc.org/solutions/research/sierra_meadows_vul/
  Manual of California Vegetation for vegetation alliance descriptions and classifications. Online version: http://vegetation.cnps.org/

Person(s) who populated the specific protocol
- Rachel Hutchinson, East Zone Watershed Program Manager, Tahoe National Forest, Rachel.Hutchinson@usda.gov and 530-562-7517
- Shana Gross, Associate Ecologist Central Sierra Province, USFS, shana.gross@usda.gov 530.543.2752

FIELD DATASHEETS & DATA UPLOAD FORMS

The following datasheets are available to be downloaded https://californiatroutinc.box.com/s/ndhrzh59k4g6jlbm41sjh8hties6pr5y
- Printable General Vegetation Datasheet
- Digital General Vegetation Datasheet

APPENDIX

Find the General Vegetation Datasheet on the Sierra Meadows Partnership website: https://www.sierrameadows.org/

Species Collection Notebooks
To improve consistency in species identifications in future sampling periods a species notebook may be made. The intent of the specifies notebook is not to have a formal herbarium specimen, but to have a field book that can be brought into the field in future years to compare plant leaves.
- Each time a new species is encountered in the study take a sample and press it. These samples will be turned into a field book for future monitoring so they do not need to be herbarium quality/size. You only need the roots if they are important for identification, include a leaf, flower and seed if available – the leaves will likely be the most important. Make sure you record which transect and plot the sample has come from.

  Do not collect a species unless there are at least 20 individuals of the species present in the area.

- Note the collection on the datasheet in the notes field

.

- Each sample will be glued onto an 8.5x11" piece of paper with herbarium glue and placed in a page protector. Samples will be placed in the freezer after being mounted for 48 hours. They will be alphabetized in a 3 ring binder. During future monitoring these books should be placed in the freezer again after field work is completed.

5.2
VEGETATION

Restoration Impact Plant Transect Monitoring Protocol

Print & Carry
Field Instructions
& Equipment List

This method involves establishing transects and subplots across the meadow to identify changes in dominant plant species before and after restoration.

PRE-FIELD/DESKTOP

Transect and plot locations can be identified by either desktop analysis using GIS or in the field. We encourage a combination. First evaluate the meadow in the office to identify key natural features and potential vegetation communities. If you know where and what restoration activities will be conducted, we suggest utilizing that information to help guide where transects and plots are placed. Second, use a field visit to evaluate if the transect locations are capturing vegetation community variation or intersect with proposed restoration actions. GPS points and transect lines can be created in GIS and adjusted based on field work or can be only identified in the field without a desktop exercise. We recommend that you review aerial imagery, a digital elevation model, vegetation data, and other digital resources as they may be helpful in identifying where transect lines should be placed.

TRANSECT SELECTION

It is important to consider individual site characteristics and level of effort when choosing transect locations to ensure that you are monitoring for your intended outcome/goals. Your pre-restoration data can act as a control or baseline for post-restoration change. Depending on the goals of your project and the availability of adequate “controls” it is optional to establish additional transects in adjacent meadows or in areas not impacted by the restoration project to be used as controls. It is important to understand the limitations associated with identifying appropriate controls in meadow systems and how it impacts your data analysis procedure.

Transect locations (Fig. 1 and Fig. 2) should be placed where:

a. plant response/change is hypothesized to occur, and/or
b. in areas of greatest concern (e.g. special plants or communities that you do not want to change) or
c. by randomly or evenly distributing transects

For example, if you want to document change in dominant plant species as a result of restoration actions you may want to place a higher density of transects in areas where those actions will occur or where you anticipate change (Figure 2f-i).

Meadows are all different and are complex; restoration actions may be designed to address this complexity. If that is the case, you may want to place transects in areas where complexity exists (braided channels, higher/lower elevation zones, swales, fenced areas, glacial deposits, etc.). If possible, transects should be co-located with groundwater wells. Ideally, when co-locating transects with wells both will be established simultaneously in order to meet both hydrologic and vegetation sampling objectives.

A transect is defined as starting at the meadow edge and ending a) halfway across the meadow or b) at the edge of either a channel or feature of interest (e.g. glacial deposit). A minimum of six transects should be established (Fig. 1), however more may be needed depending on the size of your meadow and the questions you as asking (Fig. 2). Transects should be placed on both "sides" of a meadow, where the stream channel(s) or meadow center/feature acts as a dividing line (Fig. 1). Two transects can join together in the center of the meadow so they are continuous across the meadow (Fig. 1d-e or Fig. 2h-i) or transects can be staggered to maximize effort and target specific areas of interest (Fig. 1a-c, f and Fig. 2a-e), restoration impact, or meadow complexity. A transect does not need to extend across the entire meadow if it does not make sense and the key vegetation communities are captured in a shorter transect (Fig 2. 2j). When there is a stream channel present, transects should be placed perpendicular to the stream so that the ends reach the edges of the meadow where it meets the forest (Fig. 1). Transects do not have to be parallel to one another if it is not feasible or if it does not allow you to document restoration results. In long linear meadows it may not make sense to stop the transect at the halfway point, in these cases you may have 6 transects across the meadow (Fig 3).

Note: the minimum number of transects and plots identified in this protocol is based on developing a simple efficient sampling protocol, rather than on a statistical sampling design. Therefore, if the meadows has high variability and there is the capacity for additional sampling we encourage that.

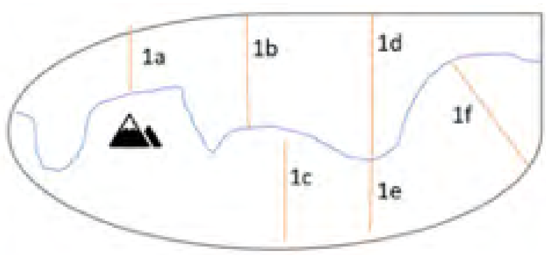


Figure 1. Six transects laid out perpendicular to the channel.

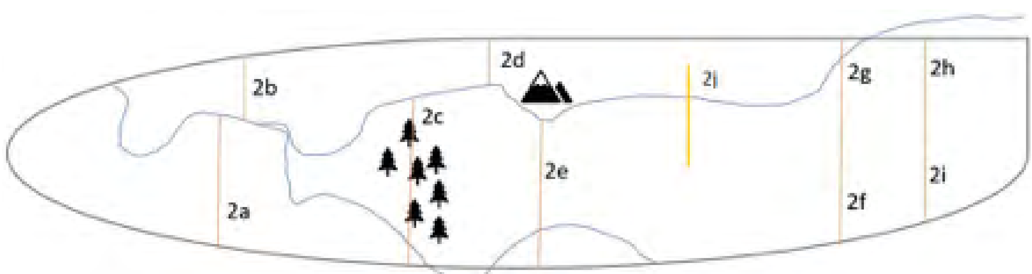


Figure 2. Ten transects in a complex meadow, aligning with key features and streams. Transects are included in areas where there is no stream channel.

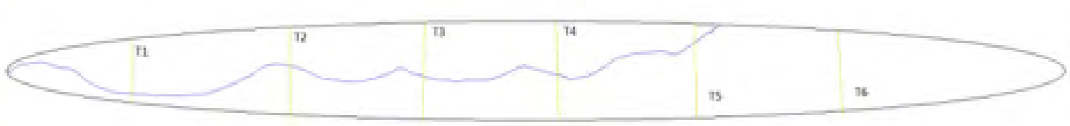


Figure 3. Six transects in a long linear meadow where it makes more sense to extend each transect across the entire meadow rather than splitting half-way across the meadow. Transects are included in areas where there is no stream channel.

ESTABLISHING THE TRANSECT IN THE FIELD

Once in the field, identify the location of your end point with a GPS unit. Mark this end point with transect pins and a permanent marker (rebar, metal pin, etc.) and connect your tape to the pin. If grazing animal hoof damage or theft is not a consideration in your meadow, rebar sticking out of the ground with a PVC cap is helpful in relocating plots and transects. Using the bearing of the transect (determined in the field or office) establish a tape between the start and stop of the transect. If the transect is more than the length of the tape, you will need to continually pull the tape or use multiple tapes connected until you reach the end of the transect. When connecting multiple tapes together, ensure the line is "straight."

ESTABLISHING PLOTS

After the transect has been established walk the transect to determine appropriate plot locations. The goal of the plots is to sample different plant communities that occur/are representative along the transect. The plots should capture the variability of the vegetation along the transect.

At a minimum, three plots should be established per transect line (n=18 per meadow). Prioritize plot placement in locations where you hypothesize plant change will occur over time. Plots will be placed in an area with a homogenous plant community, in order to more easily evaluate changes in plant dominance. Plot location should be documented as the distance along the transect (e.g. start: 102m, end: 107m). Plots should also be GPS'd and the four corners can be marked with a permanent marker (rebar or metal pin) to aid in future monitoring. If GPS accuracy is questionable, consider documenting witness tress/rocks/features to aid in locating plots during future data collection efforts. If grazing animal hoof damage or theft is not a consideration in your meadow, rebar sticking out of the ground with a PVC cap is helpful in relocating plots and transects.

Plots should be 2m x 5m (10m2) in size and centered on the transect, in a configuration that keeps the plot in a homogenous stand of vegetation. Plots should either be parallel to the transect line (with the 2m segment equally splitting the transect, so there is 1m on either side of the line) or can be placed so that the 5-meter length is perpendicular to and equally splitting the transect line. The determining factor for whether or not you place the plot parallel or perpendicular is dependent on the vegetation community you are trying to document; If the plot is placed in a riparian shrub dominated strip that is less than 5m wide along a stream channel you might place it perpendicular vs. at a location in the middle of the meadow where the plant community is homogenous for more than 5 meters.

If a greater level of effort is desired, a plot should be established for every new vegetation community that is encountered along a transect line. In this level of effort, the number of plots that are established will be dependent on the number of plant communities encountered along the transect, your meadow size and transect length, and what goals and objectives you are trying to document.

If you need guidance on determining break points in vegetation communities to establish plots, please refer to the California Native Plant Society protocol for RAs/Releves: https://www.cnps.org/plant-science/field-protocols-guidelines

"A stand is the basic physical unit of vegetation in a landscape. It has no set size. Some vegetation stands are very small, such as a portion of a vernal pool, and some may be several square kilometers in size, such as a forest type. All samples should be in stands that meet the minimum mapping unit of 1 acre for upland and 0.5 acre for special stands such as small wetlands, riparian and serpentine barrens.

A stand is defined by two main unifying characteristics:

1. It has compositional integrity. Throughout the site, the combination of species is similar. The stand is differentiated from adjacent stands by a discernable boundary that may be abrupt or indistinct.
2. It has structural integrity. It has a similar history or environmental setting that affords relatively similar horizontal and vertical spacing of plant species. For example, a hillside forest originally dominated by the same species that burned on the upper part of the slopes but not the lower would be divided into two stands. Likewise, sparse woodland occupying a slope with very shallow rocky soils would be considered a different stand from an adjacent slope with deeper, moister soil and a denser woodland or forest of the same species."

PLOT MONITORING

At the beginning of sampling of any meadow it is beneficial to calibrate cover estimates with all personnel due to the variability of estimating cover between individuals. For cover estimates imagine that you are flying on a magic cover above the plot - estimate percent cover within the plot from this vantage point. Cover within the 10m2 plot: 1% cover = 0. 1m2 or 100cm2, 10% cover = 1m2, 25% cover = 2.5 m2, 50% cover = 5 m2.

Geomorphic Surface should be noted.
Examples of geomorphic surfaces include: gravel bar, swale, floodplain, etc.

Notes should be taken regarding evidence of disturbance at each plot. Disturbance could be a range of things, including but not limited to, evidence of grazing, gopher/rodent mounds, headcut, etc.

VEGETATION-GROWTH FORM COVER

Estimate total vegetative cover within the plot (this will be ≤100%). In addition to total vegetation estimate plot cover of vegetation life forms including grasses, sedges, rushes, forbs, shrubs, and trees. Note that due to overlap of vegetation types (e.g. forbs growing under shrubs) the sum of all vegetation types may be greater than 100% and may not be equal to total vegetative cover. If a life form is present but does not question 1% use 0.5% as trace.

Ground Cover
Estimate total ground cover within the plot for the following ground cover types: Basal area of stems (imagine that every plant is cut at the base and you only have the remaining stem – not basal area is often very low), Bare ground (includes rocks, dirt, sand gravel), Litter, water, and bryophytes and lichens. Ground cover should equal 100%, if the ground cover is present by does not equal 1% use 0.5% as trace.

Species Cover
Identify all species within the plot. Document the species name and cover for each species on the provided datasheet. Estimate cover values for all recorded species, using the CNPS cover guide as a reference for cover estimates. The sum of all the individual plant species cover may be greater than 100%, due to overlap of individual species. When all species are identified in the plot, both species diversity and community analysis can occur.

Optional: If the primary goal of your data collection effort is to identify shifts in dominant plant species, you have the option of only identifying species that are >1% cover within the plot. This will result in a loss of diversity, which is estimated to be between 1 and 5 species per plot. If there are an abundance of species that are ≤1% cover, you may want to consider identifying all species in the plot. In areas with low vegetation cover there may few to no species that meet the minimum cover threshold, in this case record the 3 dominant species and their cover values.

Unknown species should be photographed, labeled, collected in plastic bags, and refrigerated as soon as possible or pressed for identification at a later date. If you do not know a species take a collection and keep a consistent identifying name for that species (e.g. UK Grass #1), you may see it at a later time in flower or in future monitoring. If you do not find it in flower during the field season the sample should be pressed and mounted in the field notebook for use in future years.

A photographic or plant pressed notebook may be used to improve future species identification. This notebook should be kept by the project lead. See appendix: Species Collection Notebooks for additional information on creating a “herbarium” notebook.

PHOTOGRAPHY

- Two photographs will be taken at each transect and one photograph will be taken at each plot.
- Transect photographs should be taken in portrait position (i.e. camera is held vertically), one photo from T0 to the end of the transect and one photo from Tend to T0.
- Plot photographs should be taken in landscape position (i.e. camera is held horizontally), photo should be taken from 1 meter behind the start of the plot.
- Photo number should be recorded, and these should be relabeled once in the office. A common naming convention could be used: Meadow_Tnumber_ TransectLocation/Plotnumber_year.

5.2
VEGETATION

Restoration Impact Plant Transect Monitoring Protocol

Equipment List

- 100m tape to set up transects
- You may want additional tapes depending on how large your meadows is and how you want to extend long transects
- 14m length of tape/rope to set plot areas or 2-1 m pvc pieces
- 6 Transect pins (candy cane pins) or other tool to easily secure measuring tape
- 4-10 Pin flags
- Compass
- Metal detector for re-establishing transects and plots (if rebar/pins were used in first year)
- Plant identification books
- Plastic bags
- Sharpie
- Datasheet
- Clipboard
- Pencils/pens
- Plant press
- Plant notebook to record unknown species and track them through sampling
- Hand lens
- Rebar/metal pins
- GPS
- Percent cover diagram (http://www.cnps.org/cnps/vegetation/pdf/percent_cover_diag-cnps.pdf), also attached.

Hydrologically infused vegetation leads to high species biodiversity.

5.3 VEGETATION

NDVI Protocol

Resource Target
Vegetation

Indicators/Attributes
For the purposes of the Sierra Nevada Partnership at least one metric of vegetation vigor should be selected, however it is recommended that both metrics are evaluated since this tool is simple and rapid. The vegetation metrics will then be compared to climate.

- The Normalized Difference Vegetation Index (NDVI) is a measure of vegetation vigor.
- The normalized difference water index (NDWI) is a measure of vegetation water content and indicates wetness of a meadow based on how much water the vegetation is holding.

NDVI Willow Staking Lower Sardine Meadow

INTRODUCTION AND BACKGROUND

Restoration actions often include goals associated with increasing (or at a minimum maintaining) vegetation vigor. However, climate influences meadows directly through the timing and amount of precipitation and evapotranspiration, which modifies the position of the water table, and indirectly through encouragement or deterrence of episodic tree invasion (Bartolome et al., 1990; Fites-Kaufman et al., 2007). Meadows may also experience declines in groundwater recharge over longer time periods as warmer temperatures and longer growing seasons lead to increased evapotranspiration. Restoration response is therefore influenced by climate.

Climate Engine can be used to assess and monitor meadow conditions and responses to management activities in real time. Timing and amount of precipitation and evapotranspiration impact the position of the water table and warmer temperatures and longer growing seasons may result in a decline in groundwater recharge. Climate Engine is a simple monitoring tool that uses Landsat satellite imagery to compute vegetation and water indices, which can be used to assess restoration effectiveness. This protocol will allow the user to visually display if post restoration vegetation vigor increases irrespective of climate.

Monitoring can be accomplished using either the Normalized Difference Vegetation Index (NDVI) or Normalized Difference Water Index (NDWI), depending on specific objectives. 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 density of green leaves. Hence, mean summer NDVI in a Sierra Nevada Meadow is a measure of greenness and health of the meadow. Similarly, NDWI is a satellite-derived index measuring vegetation water content and indicates the wetness of a meadow. It also can be utilized to assess the well-being of a meadow.

What goals and/or restorations objectives are being evaluated with the indicators?
Anytime restoration includes an objective for vegetation

When should these indicators be used?
Climate Engine provides a simple methodology to process vegetation data which can be tied to climate data and can be informative to understand restoration success.

This method should be used when a simple monitoring tool to assess restoration effectiveness at increasing vegetation vigour/greenness and or vegetation wetness is desired. Ideally due to the simplicity of this monitoring method it will be used at all restoration projects. This method complements on-the-ground field monitoring methods for vegetation.

PLANNING

Data Collection Timing

This data can be pulled at any time; however, a final summary/report should be written 5 years as well as ideally 10- and 15-years post restoration.

Required Resources

Computer with google chrome installed

Time required per sampling/survey event (# people x hours)
All of this data can be summarized and reported on in 1-2 hours with one person's time.

Level if any special expertise required
Ability to use a computer.

Total Costs
The only associated costs are salary costs as long as the person has access to a computer.

DATA ANALYSIS

Summary figures can be assessed and summarized based on the pre and post restoration success. For example: Based solely on NDVI, this project was successful (see figure x). Some of the post-restoration data falls outside of the 95% area of confidence for pre-restoration data, suggesting overall biomass increased in some years relative to pre-restoration biomass. In addition the regression line for post-restoration is higher than for pre-restoration regardless of climate, which suggests that the project successfully increased long-term biomass despite the post-restoration time period capturing the recent extreme drought.

Analysis Methods
See methods above, monitoring and analysis are combined

Evaluation Criteria
A declining trend in NDVI or NDWI five-year post treatment should trigger a field visit to identify what is trigger the decline. [Note the removal of conifers may show a declining trend in NDVI/NDWI]. Note that from previous restoration projects 5 years seems like a good point in time to see success based on NDVI/NDWI.

ADAPTIVE MANAGEMENT

Visit the field site if a declining trend triggers a field visit. It maybe that additional time needs to occur for recovery, or that something is occurring on site.

COORDINATION

Additional vegetation, hydrology, and/or geomorphology may all explain trends occurring in NDVI/NDWI.

CONTACTS AND RESOURCES

At the bottom of the Climate Engine app there is a drop-down for "get help". This includes a tour, tutorials, examples, and the manual for climate engine.

Person(s) who populated the specific protocol
Shana Gross, Associate Ecologist Central Sierra Province, USFS, shana.gross@usda.gov – 530.543.2752

REFERENCES

1. Bartolome, J. W., D. C. Erman, and C. F. Schwarz, 1990, Stability and Change in Minerotrophic Peatlands, Sierra-Nevada of California and Nevada: USDA Forest Service Pacific Southwest Research Station, Research Paper PSW-198.: Berkeley, CA.
2. Fites-Kaufman, J. A., P. Rundel, N. Stephenson, and D. A. Weixelman, 2007, Montane and subalpine vegetation of the Sierra Nevada and Cascade ranges, in M. G. Barbour, T. Keeler-Wolf, and A. A. Schoenherr, eds., Terrestrial Vegetation of California.Third Edition., University of California Press, Berkeley, p. 456-501.

5.3
VEGETATION

NDVI Protocol

The standard method selected for this analysis is collecting data remotely based on Climate Engine. The only equipment that you will need is a computer and good WiFi.

Print & Carry
Field Instructions

OVERVIEW

NDVI/NDWI will be evaluated over the growing season based on either the mean or median. Means are affected by outliers in the data, medians are not. The Median is not stable with small sample sizes. When the sample size is sufficient, in general it is preferred to use the median over the mean to minimize the effect of outliers. However, if a dataset follows Gaussian distribution, the mean is preferred as it can reveal more statistical information. When the data is perfectly normal (Gaussian), the mean, median and mode are identical. Moreover, they all represent the most typical value in the data set. However, as the data becomes skewed the mean loses its ability to provide the best central location for the data because the skewed data is dragging it away from the typical value. Under these conditions, the median best retains its position and is not as strongly influenced by the skewed values.
An important property of the mean is that it includes every value in your data set as part of the calculation. In addition, the mean is the only measure of central tendency where the sum of the deviations of each value from the mean is always zero. So, whether to use the mean or median depends on the properties of the data and the problem at hand.

Go to Climate Engine: https://app.climateengine.org (note: Climate Engine works best in the google chrome browser)

There is a Climate Engine specific web page for Sierra Meadows: https://app.climateengine.org/sierrameadows this specific page has all of the UC Davis meadows uploaded and you can search for meadows by county or UC Davis ID.

METHOD 1

For Comparison: Pre-restoration to Post-restoration

1. Click tab titled Make Graph

2. Region: how you define the area of interest
   a. Use the drop down to select polygon
      i. click the draw shape button and draw a polygon around the meadow (will be shown in upper left of map), make sure to close the polygon by double clicking on starting point of the polygon
      Note: you can enter coordinates for a point to zoom to an area and then switch region to polygon; alternatively, you can use the plus sign to zoom into the area of interest
   b. Use drop down to select CA Sierra Nevada Meadows
      i. Select the county for meadow of interest and zoom in or,
      ii. Select a meadow, which should be tied to UC Davis ID
      iii. The meadow boundaries may be different than your area of interest in which case after visiting the meadow go to A for drawing the meadow. However, if the meadow boundary is acceptable the use of the preloaded boundaries will make it easier to repeat the same analysis in the same location – note can upload KML file

3. Time series calculation
   a. Time series: select - two variable scatter plot

4. Under Variable 1 (See Figure 1 for screen shot to walk through the example).
   Metric of interest is pre and post restoration precipitation (You could also evaluate temperature similar to this method, however since meadows are so heavily tied to water this is the example we are focusing on precipitation. You could also consider using the snow water equivalent data in SNODAS.)
   a. Type: Climate/Hydrology
   b. Dataset: METDATA/gridMET (this data is based on surface meteorological dataset based on PRISM and NLDAS-2)
   c. Variable: Precipitation (PPT)
   d. Units: you have the choice of millimeters or inches
   e. Computation Resolution (Scale): use default (here 4000 m (1/24-deg)
   f. Year Statistic: Total
   g. Time period
      i. Season: Custom Day Range
      ii. Start day: October 1
      iii. End Day: September 30

5. Under Variable 2 (See Figure 2 for screen shot to walk through the example).
   a. Type: Remote Sensing
   b. Dataset: Landsat 4/5/7/8 Surface Reflectance
      i. The Landsat Surface Reflectance dataset is preferred over the Top of Atmosphere dataset since it filters out effects of the atmosphere on the reflectance measurement.
   c. Variable: NDVI or NDWI depending on project objectives (default NDVI)
   d. Computation resolution: use default (30 m)
   e. Year statistic: select Mean or Median (Recommend median)
   f. Time period
      i. Season: JJA (Jun-Aug) which is the peak growing season. You can also customize this to just be end of year growing (such as September)

6. Scatterplot Options
   Compare two-year ranges–this allows you to look at pre and post restoration, or 'Single Year Range' if you do not have post restoration
   a. Target period years: [pre-restoration]
   b. Comparison period years: [post-restoration]
      At a minimum we recommend at least 5 years post restoration before drawing any conclusions.

      Note: if the restoration project has not had the full 5 years you can still evaluate this and then repeat after 5 years

7. Select GET TIME SERIES (green button)

8. Select GET STATISTICS
   In upper left corner of plot there is a 'Get Statistics' button where you can select the statistics you want to compare (See Figure 3)
      i. Select download button to download figure as jpg, png, or as raw data in excel or csv format.

METHOD 2

For Visually Comparing Data

1. Click tab titled Make Graph

2. Region: how you define the area of interest (see above under Method 1)

3. Time series calculation
   a. Time series: select – summary time series
   b. select two variable analysis from the second drop down

4. Under Variable 1
   a. Type: Remote Sensing (see above 'Under Variable 2)

5. Under Variable 2
   a. Type: Climate (See above 'Under Variable 1')

6. Select GET TIME SERIES (green button)

7. In upper left corner of plot there is a Statistics dropdown where you can select the statistics you want to compare *(See Figure 4)*
   a. Select download button to download figure as jpg, png, or as raw data in excel or csv format.

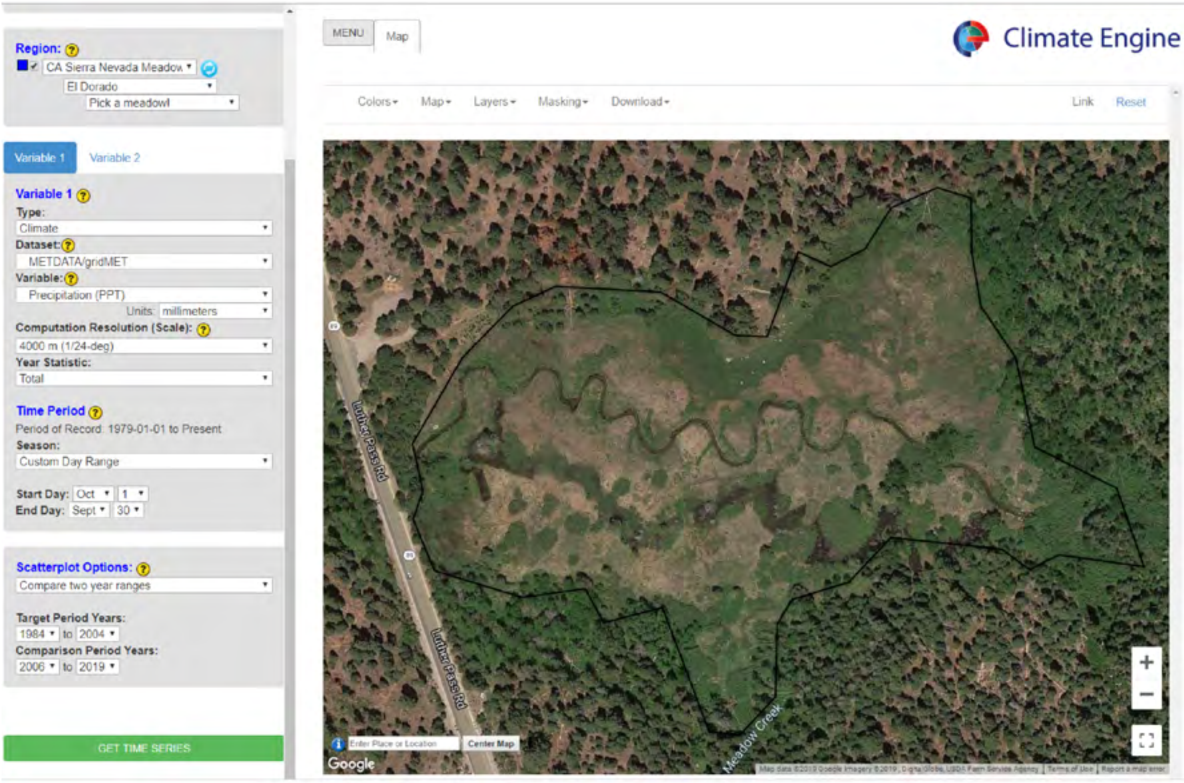


Figure 1: Climate Engine example to pull pre and post precipitation data for a restoration project – selecting target area and data. This example is from Cookhouse Meadow on the Lake Tahoe Basin Management Unit. Project implementation began in 2005 and was completed in 2006. Example shows data for variable 1.

Figure 2: Climate Engine example to pull pre and post precipitation data for a restoration project – selecting target area and data. This example is from Cookhouse Meadow on the Lake Tahoe Basin Management Unit. Project implementation began in 2005 and was completed in 2006. Example shows data for variable 2.

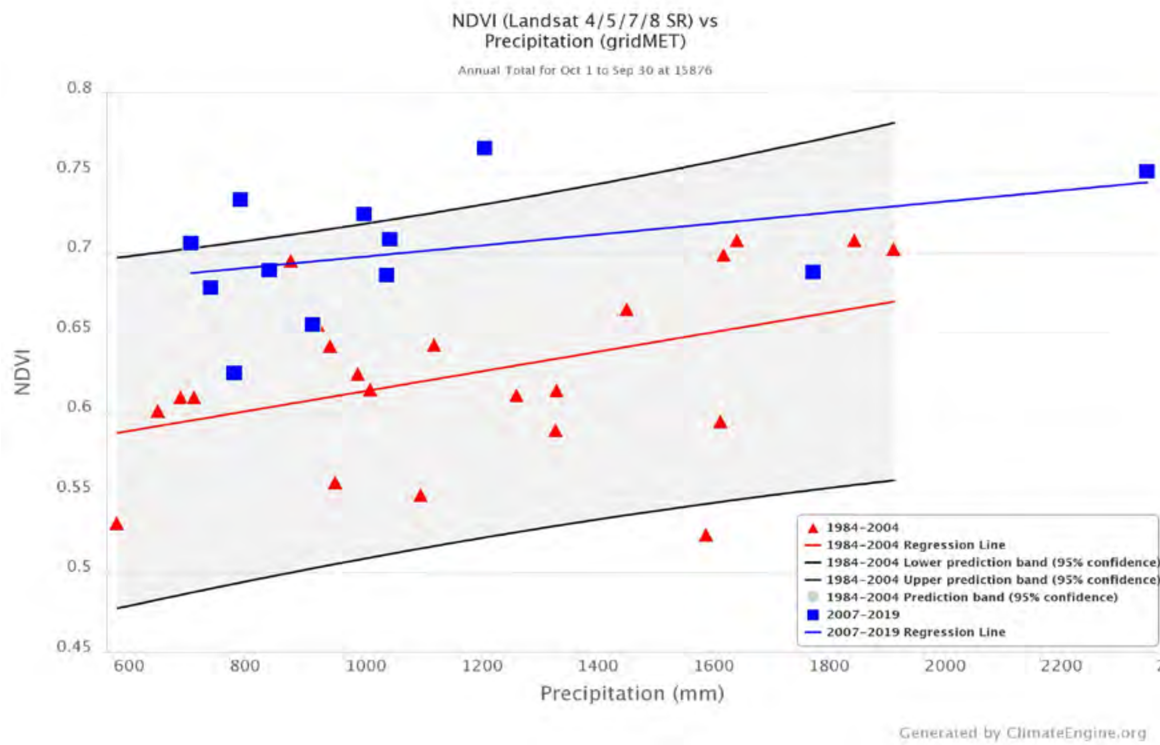


Figure 3: Climate Engine example to pull pre and post precipitation data for a restoration project – after selecting GET TIME SERIES. This example is from Cookhouse Meadow on the Lake Tahoe Basin Management Unit. Project implementation began in 2005 and was completed in 2006, pre-restoration was identified as 1984-2004 and post-restoration was identified as 2007-2019. Some of the post-restoration data falls outside of the 95% area of confidence for pre-restoration, in addition the regression line for post-restoration is higher than for pre-restoration regardless of climate (recent extreme drought is captured in post-restoration data).

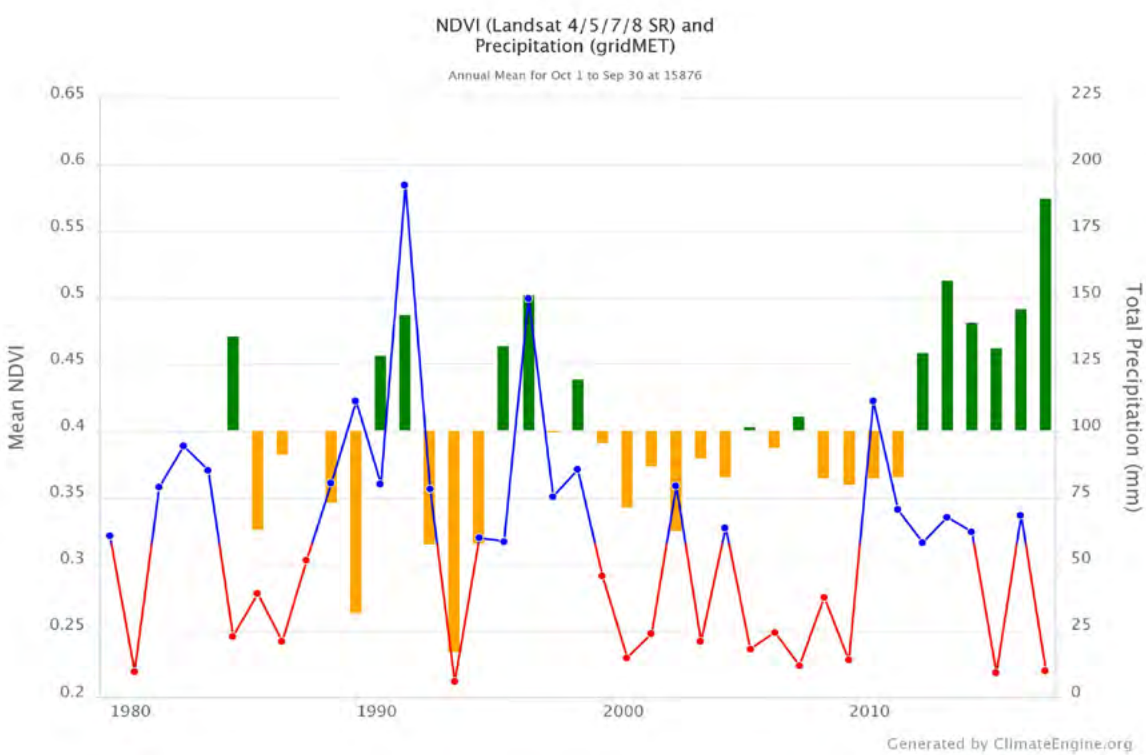


Figure 4: Climate Engine example to look at general NDVI trends compared to precipitation. This example is from Cookhouse Meadow on the Lake Tahoe Basin Management Unit. Project implementation began in 2005 and was completed in 2006. Green bars indicate above average NDVI while yellow bars indicate below average NDVI. Blue lines indicate above average precipitation while red indicate below average precipitation. All above and below averages are based on the individual site and years being evaluated.

5.4 VEGETATION

R5 Range

Resource Target

Vegetation

Indicators/Attributes

- Frequency of individual plant species
- Percent ground cover
- Rooting depth
- Plot photographs
- Depth to saturation
- Depth to mottling
- Number of conifer seedlings in plot by species (optional additional metric)
- Distance to nearest seedling by species (optional additional metric)
- Distance to nearest seed source by species (optional additional metric)

Van Norden Meadow Restoration ProjectTahoe National Forest, SYRCL. Vegetation Monitoring

INTRODUCTION AND BACKGROUND

The USFS R5 currently has approximately 652 plots established in approximately 615 meadows across California. In addition, there are another 82 plots in upland/annual grasslands as well as "reference" plots that have been established in the National Parks. Additionally, plots may already exist in meadows being restored and this is a well-established known protocol that the USFS uses. This protocol was included in the WRAMP protocols to help to utilize the similar methodology across the state.

What goals and/or restorations objectives are being evaluated with the indicators?

The goal of this protocol is to evaluate the ecological status of the meadow systems based on vegetation. This protocol provides the opportunity to evaluate how an individual or group of meadows has changed over time.

When should these indicators be used?

This protocol can be used when restoration objectives are as identified below, or when the goal is to compare to existing long-term plots already established by the USFS – R5 range monitoring program.

- Increased meadow species
- Increased wetland species
- Appropriate Biodiversity
- Grazing Management
- Reduced Invasive Species

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

There are a number of metrics that can be investigated and therefore a number of questions that may change based on type of restoration, number of plots, and desired conditions. See data analysis below for description of trends in meadow condition/status that can be evaluated.

PLANNING

Data Collection Timing

Season
Sampling should occur occur during peak growing season in order to identify plant species.

Frequency
Sampling should occur at a minimum 1-year pre restoration, 1-year post restoration and then every 5 years for a minimum of 10 years total (or 4 sampling periods) depending on project response. If monitoring allows every 5 years into perpetuity great. (Note: R5 Range monitoring plots are currently sampled every 5 years, with the majority of the plots were established between 1999 and 2003).

Required Resources

Time required per sampling/survey event (# people x hours)
1-2(3) plots can be completed per day with a crew of two depending on access time

Equipment costs if new
$1000+ depending on quality of equipment. Once equipment is procured, additional meadows/plots will only cost the amount of monumented material (<$20).

Level if any special expertise required
Plant identification skills are required as all species are identified.

DATA ANAYLSIS

Data storage

The Region 5 range program has an existing database. The format of this database could be followed by USFS partners as well, although margining of the two databases may not be feasible and discussion with the range program would have to occur.

Analysis Methods

There are a number of metrics that can be evaluated through this monitoring protocol focused on community/environmental analysis. Some metrics that can be evaluated and what change could indicate include (note: R code may be available to follow as example for analysis in 2021):

- Change in plot/meadow diversity: general metric to be interpreted by analyst – an increase in diversity is not necessarily desirable, composition of the diversity that indicates meadow function
- Change in conifer abundance over time, potentially tied to abiotic variables: could indicate a number of things, but in general may suggest that meadow may not persist over time
- Change in invasive and non-native species over time: an increase in non-native and invasive species could suggest decrease in meadow condition
- Change in annuals over time: an increase in annuals could suggest an increase in disturbance
- Change in community composition tied to environmental conditions: provide understanding of the context of the meadow
- Change in wetland species ratios: an increase in upland or facultative species could suggest the meadow is drying and vice versa
- Change in graminoid to forb ratio: suggest that there has been a change in community composition, however it is left up to the analyst to decide if this change is good or not, some assessment methodologies (e.g. CRAM) suggest more graminoids have increased ecosystem function based on rooting properties the decrease bare ground
- Change in plant functional type: similar to metrics above, but specific to meadow PFT groups
- Change due to individual species

5.3 R5 Range

Evaluation Criteria

If the trend in the specific metric of interest declines for more than 2 monitoring points (after initial monitoring point) in time, then further investigation should occur to see if the larger meadow is experiencing potential degradation. Because meadows are very heterogeneous both among and within, specific changes to an individual meadow should be evaluated relative to project specific objectives rather than identifying specific objectives across all meadows to detect change.

ADAPTIVE MANAGEMENT

If based on evaluation criteria further investigation is triggered then an evaluation of factors contributing to the negative trend should be evaluated to identify adaptive management.

COORDINATION

Coordination should occur with the R5 Range monitoring program to identify where plots exist. In addition, this protocol could be coordinated with the hydrology protocol for co-occurring monitoring.

CONTACTS

Person(s) who populated the specific protocol
Shana Gross, Associate Ecologist Central Sierra Province, USFS, shana.gross@usda.gov 530.543.2752

Additional contacts for protocol assistance

- Thea Chesney, Range Monitoring Program Lead, Pacific Southwest Region, USFS, thea.chesney@usda.gov, 530-478-6843
- Brenda Olson, Assistant USFS Regional Range Program Manager, brenda.olson@usda.gov, 707-562-9164

REFERENCES

Weixelman, D., D. C. Zamudio, and J. A. Lorenzana. 2014 (unpublished). Field Methods for Condition Assessment Using Rooted Frequency and Soil Measurements in Meadows, U.S. Forest Service Pacific Southwest Region, Vallejo, CA

R5 Range Monitoring Protocol

Based on Weixelman, et al. 2014

5.4
VEGETATION

Print & Carry Field Instructions & Equipment List

A link to the full protocol (detailed methods for sampling) can be found on the Sierra Meadows Partnership website. Below we provide additional information for consideration that is specific to the WRAMP intent for implementation of this protocol.

PLOT SELECTION

Plot locations can be identified by either desktop analysis using GIS or in the field. We encourage a combination. First evaluate the meadow in the office to identify key features and potential vegetation communities, using aerial imagery, a digital elevation model, vegetation data, and other digital resources when available. Overlay vegetation with restoration designs when available to identify areas of change. Second, use a field visit to evaluate desktop analysis to select appropriate plot location. As noted in the original protocol (Weixelman et al 2014), the goal of the protocol is to establish plots in a homogenous vegetation community, which improves one's ability to detect change. In theory this makes sense, in practice it is a bit harder, therefore adjust the plot transects as appropriate. The key is to maintain that the three transects within each macro plot are parallel.

Plot location does not need to be identified randomly as noted in the protocol. These plots may be strategically placed to best represent the goal of the project. Ideally a plot could be established in each of the vegetation types anticipated to be affected by the project. These would be identified by either (a) change is hypothesized to occur, and/or (b) in areas of greatest concern (e.g. special vegetation communities that you do not want to change) or (c) purely by random selection (this option makes more sense if you are limited on the total number of plots). If possible, plots should be co-located with groundwater wells. Ideally, when co-locating transects with wells both will be established simultaneously in order to meet both hydrologic and vegetation sampling objectives.

The number of plots will vary between meadows based on the size and complexity of vegetation type and project. Each plot covers a total of 10 x 25 meters. A minimum of one plot in the dominant vegetation type will still provide information about the project, but additional plots would be better.

PLOT ESTABLISHMENT

The original protocol identifies the need to establish a reference post. In place of a reference post, a witness tree could be established using a tree tag. If a witness tree is used, place the tree tag at the base of the tree (as well as one at eye height) and measure the distance to T1, M0 from the nail at the based of the tree. Note the species and DBH of the tree as well.

Ideally m0 and m25 along all three transects will be marked in addition to the reference post/witness tree. However, if heavy equipment is anticipated rebar may provide safety issues as well as may be dislodged. Therefore, high precision GPS data along with a detailed map may need to be enough for pre-project monitoring.

When laying out transects for the plot walk on the left side of the transect or more than 25 cm from the right side as much as possible to avoid trampling the right side of the transect.

ROOTED FREQUENCY

The protocol identifies that either a 20 cm nested frequency frame or a 10 cm frame can be used. In general, we would recommend the use of the 10 cm frame because it is quicker and easier to analyze. However, if diversity and/or total cover of vegetation is low then the 20 cm frame may be considered. If using the nested frequency frame make sure that the smallest quadrat is placed at the meter mark.

CONIFER DATA

In addition to the information collected in the protocol, it may be beneficial to track conifer encroachment over time because compaction of soil due to restoration activities may increase conifer abundance. While the plots themselves may record evidence of increased conifer, some simple additional measurements can help as well.

- Are there seedlings in the plot (yes/no)?
- Number of seedlings in the plot
- Species of seedlings in the plot
- Distance to nearest seed source from T1MO
- Nearest seed source species

GRAZING INFORMATION

Consider doing a count of cow patties within the plot. While these can last for years they can provide some indication of how many cows are in the area.

Make notes regarding if the plot has been grazed and potentially look to the grazing protocol to evaluate stubble height as well as other potential grazing metrics.

R5 Range Protocol
Equipment List

5.4
VEGETATION

- Rebar – 3/8" x 18" (new plots)
- Rebar caps, yellow – 3/8" (new plots or sometimes older plots)
- T-posts or tree tags (new plots)
- Post pounder or hammer (new plots)
- 3 or 4- 30m tapes
- 6 to 8- chaining pins (candy stripe)
- 10 cm or 20 cm quadrats
- Measuring tape/ruler
- Whiteboard case with board, markers, eraser
- Compass
- Clinometer
- Field computer/data recorder
- Tatum with blank forms
- Metal detector
- Soil auger[1]
- GPS unit
- Radio (fully charged) with frequency booklet
- Folders and map for forest plots
- Laser range finder if collecting conifer data
- Plant ID books/ plant pressed field notebooks
- Plant press
- Camera
- Hand lens
- Work gloves
- Batteries and chargers
- Inverter
- First aid kit
- Insect repellent
- Sunscreen
- Tarp to put soil onto
- Water jug (overnight)
- Tents (overnight)
- Backpacks (overnight)
- Cookstove (overnight)
- Propane (overnight)
- Matches/lighter (overnight)
- Fire starter (overnight)
- Water filter (overnight)
- Jumper cables (overnight)

[1] When augers used for soil cores have either a window into the augur bucket or are hinged to open lengthwise it helps to preserve the soil profile. However, any soil auger will work and as the soil is dumped out, you can recreate the profile, which is easiest when it is dumped onto a tarp.

5.5

VEGETATION

Target Species

Resource Target

Vegetation: monitoring of rare, invasive, culturally significant, or other target plant species populations and their response to restoration activities.

Indicators/Attributes

- Target species population location and distribution across the area of interest and
- Weighted percent cover of target species occurrences and/or
- Estimated number of individuals within populations.

Osa Meadow with incised channel, one of the most common characteristics of a degraded meadow. Photo: L. Keszey

INTRODUCTION AND BACKGROUND

Meadows compose a small portion of acreage of the Sierra Nevada mountains in California, but their unique hydrogeomorphic position supports rare and culturally significant plant species that do not occur in other ecosystems of the Sierra Nevada. Meadows also have a history of anthropogenic disturbance, this disturbance whether purposeful or indirect has led to the destabilization of rare and culturally significant plant populations and the introduction of non-native and invasive plant species. These invasive species often replace native plants, forming large monocultures. As a result, restoration projects may have an objective of managing rare, culturally significant, or invasive plant species, and enacting continued adaptive management.

The purpose of this protocol is to monitor project effectiveness by evaluating change in target plant species distribution and estimated population as a result of restoration activities. Target plant species can include rare, invasive, and culturally significant plant species populations, as well as any individual plant species of interest. Target plant species habitat may be improved or deteriorate because of restoration actions and target plant species populations may respond as a result. While we will not know that the habitat has improved or deteriorated for these target plant species with this protocol, we can measure how the population and distribution of target plant species changes after restoration. Knowledge of their presence and change in distribution over time will be important to determine if objectives around target species populations are met and for developing plans to institute adaptive management after restoration, if necessary.

What goals and/or restorations objectives are being evaluated with the indicators?

Potential restoration goals being evaluated:

- Decrease, eliminate, or prevent the spread of existing invasive species.
- Improvement or maintenance of rare or anthropogenically significant plant species populations.
- Desire to track target species populations if special work was done to improve/manipulate target species population

When should these indicators be used?

This protocol evaluates whether the restoration successfully manipulated existing target plant species populations. If restoration goals are to change target species populations, this protocol can be utilized to coarsely detect response of target species to meadow restoration actions.

For rare or culturally significant species, this may be increasing or maintaining the populations within the area of interest. This protocol can be utilized if a known target species exists in a restoration meadow and there is a desire to know the effect of restoration actions on target species. If you don't know if you have invasive or rare plant species in your meadow, we recommend the medium level of effort protocol if you want to do a pre-survey to assess presence of target plant species. These indicators should be used if a metric for project effectiveness is manipulating or maintaining target species populations. For invasive species, this may be decreasing or eliminating, or at the very least preventing the spread of existing target species populations in the area of interest.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

This method is a coarse way to track species distribution and population size/cover in the area of interest. If increasing rare plant species is a main goal of restoration, a more intensive approach should be used to determine fine scale changes in species population numbers and the environmental variables that might contribute to plant species success (i.e. counting every individual encountered, rather than providing an estimate, sampling population size at an increased frequency before and after restoration, measuring environmental or biotic variables that might impact population size).

This protocol does not directly measure whether restoration conditions have improved habitat, rather, it provides a way to monitor target species over time in order to determine if project objectives of impacting target species populations has been met and can help trigger further adaptive management of target species populations if necessary.

PLANNING

Data Collection Timing

- Season of surveying: timing of surveys pre- and post-restoration depends on the life history of the target species. Because target species may differ in the timing of being identifiable in the field, multiple survey events may be necessary. Utilize CalFlora or USDA plants to determine when the plant is flowering/identifiable to plan the timing of sampling. Depending on the elevation, May through August are typical survey times for plant species in meadows.

- Pre-restoration monitoring frequency: One visit during the time the plant is identifiable the season before restoration is planned to occur so the most up to date spatial data is available. Surveys for multiple years before the restoration would allow for a clearer distinction of whether variability in population size/cover post-restoration is outside of that detected pre-restoration.

- Post-restoration monitoring frequency: The frequency of post restoration monitoring will be set by the goals of the restoration as well as the target species of interest and how it is predicted to respond to restoration actions. Annuals, perennials, and shrubs may respond on a different time scale to restoration actions. Multiple re-visits will likely be necessary to determine trends over the years and inform any subsequent adaptive management actions. At a minimum, post-restoration monitoring should occur one, three, five, and ten years following restoration during the flowering season, or appropriate season for identification, of the target species to detect changes in target species populations.

- Dramatic increases or decreases in target plant species or an overall trend in target species population size determined through yearly monitoring may trigger additional monitoring or adaptive management strategies (see below).

5.5 Target Species

Required Resources

Time required per sampling/survey event (# people x hours)
Time required per sampling or survey event will be determined by the variability of habitat, the number of target species, the size and extent of target species occurrences, the size and experience of the surveying crew, and the size of the meadow. In addition, the number of survey events for the meadow may be greater than one depending on when the target species are identifiable. As an example, a low effort survey for one invasive grass species across a large meadow (>300 acres) with extensive infestation was sampled at the following range of rates: 2-6 acres of meadow/hr./person or 16 - 48 meadow acres/day/person.

Equipment costs if new

- GPS Unit (points, polygons, and tracks capabilities): $100-$4000, based on level of accuracy desired
- Camera: $130 – $350
- Mapping software to process in field data collection (GIS: ESRI(Arc), qGIS): qGIS is free while a personal ArcGIS license costs $100/year

Level if any special expertise required
You may be able to utilize volunteers and/or inexperienced field crews depending on the ease of identification of your target species. Regardless, at least one trained botanist should be leading your field crew. Ideally, those surveying would be trained by the botanist such that they could identify habitats of target species and effectively identify target species and potential look-alikes.

Total Costs
Costs will be dependent on the number of target species surveyed for, the extent of target species presence within the study area, and the size of the study area.

DATA ANALYSIS

Analysis Methods

The following variables can be compared pre- and post-restoration to determine target species variation from baseline conditions pre-restoration. It important to note that absence data will be important to collect pre and post – restoration. It will allow you to determine if target species appear in survey area post restoration or if occurrences are no longer detected post restoration.

- Changes in Area of extent (Area of extent = delineated polygon or area described at points).
- Changes in percent cover within area of extent (if the area of extent at an occurrence has not changed).
- Changes in estimated population size within area of extent. This is comparable to previous occurrences even if the area of extent has retracted or expanded.
- Changes in weighted percent cover (this comparison allows for comparison of percent cover changes if the area of extent has decreased or increased upon re-survey).
- Changes in number of occurrences (i.e. total number of points and polygons in study area). Most useful if comparing point data.

Mapping polygons of populations (digitally delineating invasive species populations with a GPS unit) and estimating population size allows for a simple comparison of change in area over time. A software that allows for visual and quantitative comparison like ArcGIS or QGIS (free) will be necessary. Alternatively, population size estimates (number of individuals and percent cover) can be compared from year to year.

Evaluation Criteria

Triggers for adaptive management action will be different for each target species type.

Invasive species: Depending on the invasive species, an increase in population by a certain percentage or the continued presence of species may be a trigger for adaptive management.

Rare & anthropogenically significant species: Detecting decreases in population would be a concern, but actions will be limited by regulatory framework and funding. At the very least, a detection of decreased population should trigger more intensive quantification of population size over several years to verify trends over time. Additional management may be needed to improve habitat for target species, if the restoration suggests that habitat is no longer conducive to supporting the population.

Potential adaptive management response: Detecting decreases in population would be a concern, but actions will be limited by regulatory framework and funding. Additional management may be needed to improve target species population size, if the restoration suggests that habitat is no longer conducive to supporting the population.

5.5 Target Species

ADAPTIVE MANAGEMENT

Trigger: Increased or continued presence of invasive species Potential adaptive management response: invasive species removal. Treatment of invasive species populations will be driven by the status of the land (public/private) and the regulatory framework that applies to the landowner and the goals identified in the project.

Trigger: Decreased presence of rare or culturally significant species.

Potential adaptive management response: Detecting decreases in population would be a concern, but actions will be limited by regulatory framework and funding. Additional management may be needed to improve target species population size, if the restoration suggests that habitat is no longer conducive to supporting the population.

RESOURCES

1. https://www.fs.fed.us/r5/rsl/projects/gis/data/calcovs/NRIS_InvasivePlants_FieldGuide.pdf
2. https://www.cal-ipc.org/solutions/management/edrr/species-id-cards/
3. https://www.cal-ipc.org/resources/library/videos/
4. https://www.cal-ipc.org/resources/library/sites/ Phenomenal and thorough compilation of organizational links to compiled general information about invasive species as well as control methods.
5. Incorporating Climate Resilience into Invasive Plant Management Projects: Guidance for Land Managers. California Invasive Plant Council, Berkeley, CA. December 2015. info@cal-ipc.org https://www.cal-ipc.org/docs/ip/climateadaptation/IncorporatingClimateChangeResilience.pdf
6. https://wildlife.ca.gov/Conservation/Plants/Info
7. http://www.rareplants.cnps.org/
8. https://www.calflora.org/
9. Online Jepson Manual: https://ucjeps.berkeley.edu/jepman.html

Person(s) who populated the specific protocol
Betsy Harbert, Vegetation Ecologist, California Department of Fish and Wildlife. betsy.Bultema@Wildlife.ca.gov

REFERENCES

Elzinga, C. L., D. W. Salzer & J. W. Willoughby (1998) Measuring & Monitering Plant Populations.

APPENDIX

- Find datasheets at www.sierrameadows.org
- See Target Species Monitoring Protocol_Appendix A. CNDDB form with data sheet addendum

5.5
VEGETATION

Target Species Protocols

Print & Carry
Field Instructions
& Equipment List

The purpose of these protocols is to establish trends in target plant species populations given the uncertainty of species response to restoration.

OVERVIEW

There are three parts to this protocol: desktop analysis, field survey, target plant population documentation, and population revisits. The field survey portion has two levels of effort defined by how systematically the meadow is surveyed for target plant populations. Plan on doing all three steps of this protocol for pre-restoration documentation of spatial location and population size. However, if existing survey data is readily available, it should be utilized to streamline these steps. Once target plant species have been documented plan on implementing the last step, population revisits, to assess target species populations at 1, 3, 5, and ideally 10 years post-restoration.

Level of associated effort

The protocol for describing encountered target plant species populations is the same for both low and medium level of effort described in this protocol. The only difference in these protocols is the systematic surveying across the meadow in the medium level of effort. If you are utilizing skilled botanists who have a good understanding of meadow habitats and target plant species, you might utilize the low level of effort. If it is unknown whether target species occur in your meadow, or if you are utilizing volunteers or people with minimal botanical training, utilize the more systematic survey described in the medium level of effort to insure most of your meadow is visually assessed for target plant species. The area surveyed can also impact whether you utilize the low or medium level of effort. For areas greater than 10 acres, you may want to consider utilizing the low level of effort survey methods.

FIELD INSTRUCTIONS

1. Desktop Analysis

Define survey area and create maps or GIS delineated areas. Ideally, the survey area encompasses the entirety of the meadow footprint. Utilize available resources to identify where target plant species may have historically been identified in your survey area. Research target species habitat preferences within meadows to identify potential habitat in your survey area. Be aware the nature of invasive plants to be generalists, and their location may be driven by disturbance (e.g. trails, roads, powerlines footprints, stream channels), rather than a habitat type. Delineate potential habitat and known species occurrences using GIS to define areas where complete surveys (see definition below) should be conducted. It is important to note that these areas should not limit where complete surveys occur. If field surveyors detect potential habitat in the field, complete surveys should be utilized in these locations as well. Research life history for target species to determine sampling timing.

If target species are not a specific restoration objective/ concern this protocol could still be used to determine if target species are present. In this case, identify potential target species in the region before sampling to determine what species to survey for (CNDDB, CCH, Cal-IPC, D'antonio et al 2002). Research target species habitat preferences within meadows to inform surveying. Research life history for target species to determine sampling timing.

2. Field Survey Methods

We offer two approaches below, a low and a medium level of effort. The low level of effort has 100% visual assessment in areas where it is expected to find the target species and less than 100% visual assessment elsewhere in the study area. The medium level of effort ensures that there is visual assessment of 100% of the study area. Consider applying the medium level of effort if existing survey data is unavailable, you have a number of target species with varying habitat preference throughout your study area or utilizing volunteers or people with minimal botanical training. If you are utilizing skilled botanists who have a good understanding of meadow habitats and target plant species, consider utilizing the low level of effort.

Detect pre-existing distribution of target plant species before restoration.

2.a. Low effort

Intuitive control survey coupled with a complete survey in areas of high likelihood of target species habitat or in areas where target species has been detected historically. Record surveying lines utilizing tracks in a GPS unit.

Please see https://www.blm.gov/or/plans/surveyandmanage/files/sp-sp-va-vascularplants-v2-1998-12.pdf for a detailed description of intuitive control surveys.

Intuitive control survey

From Survey Protocols for Survey & Manage Strategy (Whitaker et al 1998): "This method includes a complete survey in habitats with the highest potential for locating target species. The surveyor traverses through the project area enough to see a representative cross section of all the major habitats and topographic features, looking for the target species while en route between different areas. When the surveyor arrives at an area of high potential habitat (that was defined in the pre-field review or encountered during the field visit), a complete survey for the target species should be made."

Complete survey

A complete survey is defined as "100% visual examination of the survey area" (Whitaker et al 1998) via regularly spaced un-monumented transects. For complete surveys, the distance between transects will be determined by the plant species that the survey is attempting to detect. Ideally you will be maximizing the distance between transects based on the likelihood of surveyors seeing the plant populations between said transects. Thus, a small plant might necessitate closer transects during complete surveys.

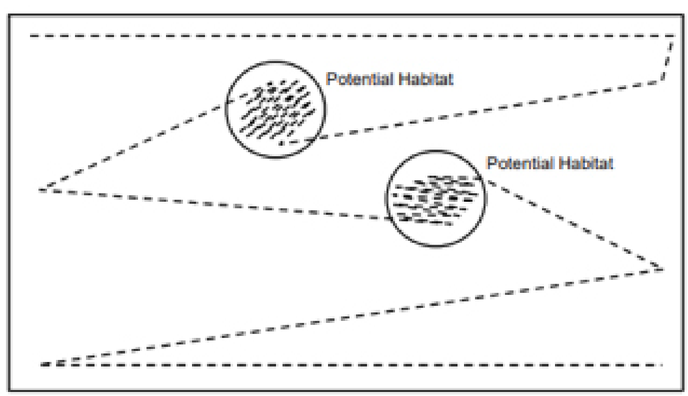


Figure A. Figure from: Survey protocols for survey & manage strategy (Whitaker et al 1998). Intuitive control survey coupled with complete surveys in potential habitat. Complete surveys should be completed within potential habitat and documented historic locations.

2.b. Medium Effort

Systematic survey (transect based) surveys coupled with complete surveys in in areas of target species potential habitat.

Systematic survey
Visual examination at less than 100% via regularly spaced un-monumented transects in habitats with unknown potential for locating target species via regularly spaced un-monumented transects coupled with complete surveys in habitats where there is high likelihood of detecting a target plant species.

Complete survey
100% visual examination of the survey area via regularly spaced un-monumented transects. For complete surveys, the distance between transects will be determined by the plant species that the survey is attempting to detect and the density and height of the vegetation. Ideally you will be maximizing the distance between transects based on the likelihood of surveyors seeing the plant populations between said transects. Thus, a small plant might necessitate closer transects during complete surveys.

Figure B. Example of a systematic survey combined with complete survey methods for assessing targeted species within a meadow. The area in the down-stream section is considered "target habitat" and transects are closer together allowing for 100% visual assessment of the area, while upstream is less suitable habitat for the target species, resulting in transects that are farther apart.

3. Documentation of Target Plant Species Populations

If a target species is not encountered during the field survey step:
Be sure to record the species surveyed for and associated data like the dates of the survey and surveyor ID on the survey form provided below. Save the GIS files generated to document the survey intensity.

If a target plant species is encountered during the field survey step the following data should be collected at a minimum:

- Map species occurrences using points or polygons. An occurrence is all individuals that occur near each other through a visual assessment. You may want to define a buffer between individuals before surveying that helps you determine when a new occurrence occurs, consistency is the goal. If points are used, make sure to record the area of the occurrence.
- Estimate or count the number of individuals and/or assess the percent cover of the target species within the polygon or at the point. If points are used, make sure to record the area of the occurrence.

a. Counting Individuals: Where small populations occur, we highly recommend counting individuals, as this is an accurate way to detect changes in target species population size. Where resources allow, count a minimum of 25 individuals, estimate the number of individuals if larger. Use your best judgement in the context of your particular target species growth habit/ life history when determining whether to assess percent cover, estimate individuals, or counting individuals, you don't have to count species if it doesn't make sense for your species.

b. Determine area of extent and percent cover. If percent cover is used to monitor target species, both the area occupied by the target species at the documented occurrence (area of extent) and the percent cover within that area of extent will need to be recorded.

i. Assess percent cover within a bounded polygon or at a point. When determining the percent cover at a point, it is important to provide a bounded area for each point, determine and record a bounded area for your occurrence, then assess percent cover of the occurrence within this area.

ii. Apply an area weight to percent cover estimates. In accommodating for the potential for target populations to contract or expand and the need to clearly compare target species occurrences from year to year we recommend employing a weighted percent cover to compare year to year variability of a target species occurrence. This will allow area to vary but still make percent cover estimates comparable year to year. To do this, multiply the area of the mapped occurrence polygon (or the recorded area at a point) by the percent cover recorded for that occurrence.

iii. If you have a large polygon, assessing percent cover across it will be a coarse estimate and changes in percent cover will likely need to be significant to be detected. If you would like to monitor finer scale changes, you should likely implement a random sub-sample of the population occurrence. The specificity of this type of protocol is beyond the scope of this document. Guidance can be found in the following resource: Measuring and monitoring plant populations (Elzinga, Salzer and Willoughby 1998)

c. Document occurrence with at least one photograph. Document photo location with GPS unit as well as documenting photo location (UTMs/Lat-Long) and photo direction on survey form.

Details on data to collect for a species encounter and a standard survey form can be found here: https://wildlife.ca.gov/data/CNDDB/submitting-data#44524420-pdf-field-survey-form

Note: This form has a space for # of individuals but would need to be modified to include a place to document:

- Occurrence ID
- Percent cover of population occurrence within area of extent
- Whether the occurrence is a polygon or a point feature
- The area of extent of occurrence (this is the size of the polygon around the detected occurrence or for points, the specific area assessed)
- Calculate a weighted percent cover (mapped area x percent cover). Done in office after data collection in field.
- Photo Id, location, and direction
- For revisits, note whether polygon boundaries have changed and if a remap has occurred and the ID of that polygon.

An addendum to the form with these values is included in Appendix A.

4. Revisit Target Species Populations Post Restoration

Revisit populations at 1, 3, 5, and 10 years after restoration. Utilize the points and polygons created during the previous pre-restoration visit. Each occurrence established pre-restoration should have the minimum data collected for it as noted in step 3 above. In addition, population occurrence areas of extent should be reviewed by assessing the polygon boundaries and points in the field.

- Do an intuitive control survey (low level effort) to detect any new occurrences. If a new occurrence is discovered, document the occurrence as in step 3 above.
- Revisit all previously documented occurrences.
- If a revisited occurrence has expanded or retracted remap the occurrence (draw a new polygon) and assess percent cover and population as in step 3 above. This new polygon is the new baseline occurrence to revisit and assess upon the next re-sample event.
- If your population is present throughout the polygon, do not remap your occurrence (e.g. in cases of decreased percent cover within a mapped population that has not retracted in size). If you determine that population boundaries have significantly expanded or retracted from the previous visit, assess percent cover and/or number of individuals as above in step 3. What you assess will be based on what was recorded historically at the particular occurrence (percent cover and/or number of individuals).
- If revisited occurrences no longer occur, it is important to still fill out a survey data form so that decreases in overall occurrences are measured post-restoration.
- For remapped and re-assessed occurrences calculate the weighted percent cover: area of polygon x percent cover. This will have been done for the occurrence when it was first mapped and will allow for 1:1 comparison to previous percent cover estimates at the occurrence, especially in the instance of expanding or contracting area of extent.
- When determining whether the population has expanded or contracted, be aware of inherent spatial errors from inaccuracy from GPS units that will affect your determination of the boundary when you revisit as well as the boundary when it was first recorded.

5.5
VEGETATION

Target Species Protocols

Equipment List

- GPS Unit (points, polygons, and tracks capabilities)
- Camera
- Paper map of survey area or previously identified locations
- List of potential and known target species present, available resources for determining the identification of target species, identification aids (field guides and dichotomous keys).
- CNDDB datasheet (can be used for invasive, rare and anthropogenically significant species with modification noted above).
- Alternatively, use a field notebook with the following headings: Date, GPS Point/Poly ID, Photo ID, Size of Pop'n, Percent Cover of Pop'n, est. number of individuals,
- Mapping software to process in field data collection (GIS: ESRI(Arc), qGIS)
- CNPS Cover Diagram (https://cnps.org/wp-content/uploads/2018/03/percent_cover_diag-cnps.pdf)

Toiyabe NF with beaver dam remnants by Jason Gregg Point Blue

5.6 VEGETATION

Conifers

Resource Target

Vegetation

Indicators/Attributes

- Conifer density by species, size class, status (live/dead)
- Herbaceous cover
- Wetland vegetation cover

Conifers encroaching on meadow on June Mountain (CalTrout credit).

INTRODUCTION AND BACKGROUND

The intent of this protocol is to determine if removing conifers is an effective restoration tool, and if so where it is it most effective. This protocol is in line with the overall intent of the Sierra Meadow Partnership monitoring in that it is getting at the key questions of, what restoration techniques are successful and where. This protocol is only relevant to use where conifer removal activities are being implemented and/or where detailed assessment of conifer encroachment is desired.

What goals and/or restorations objectives are being evaluated with the indicators?

The goal of this protocol is to monitor the effectiveness of conifer removal from meadows as a restoration treatment. By incorporating data from multiple meadows the intent is to identify meadow types/context where this restoration treatment effective in order to appropriately target meadows with this tool. While this protocol was developed to directly measure effectiveness of conifer removal, it could also be used to track conifer encroachment over time.

When should these indicators be used?

The methods identified here should be implemented anytime conifer removal is occurring as part of a restoration project. In addition, if the meadow is hypothesized to be susceptible to conifer encroachment, the methods presented here could be used to track conifer encroachment over time.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

The key questions being answered as part of this protocol include:

1. How long does the conifer removal treatment effectiveness last? Do conifer seedlings continue to establish after restoration activities? Do follow up treatments need to be conducted in order to maintain low cover of conifers?
2. Does large scale burning of meadows change vegetation community structure (i.e. changing community from graminoid dominate to herbaceous dominate)?

Additional questions can be answered with additional data collection, these include:

3. Does removal of conifers and/or introduction of fire change the ratio of wetland species (i.e. obligate, facultative, upland, etc)?

PLANNING

Data Collection Timing

Repeated measurements will be taken at the following intervals: 1-3 years pre-treatment, 1-year post treatment, 3 years post treatment, 5 years, and 10 years post treatment. After 10 years future monitoring will be reevaluated, in order to evaluate the effectiveness of treatments long term monitoring is ideal. Data will be collected in summer to early fall to capture the peak growing season for herbaceous cover component.

Required Resources

Time required per sampling/survey event (# people x hours) For a trained crew of two it will take between 3-5 days depending on approach time to sample a meadow.

Equipment costs if new
<$100 for tree tags, rebar; all other equipment is normal field equipment; except for question 4 which requires the purchase of data loggers (~$600/ET logger)

Level if any special expertise required
If species level data is going to be collected to address question 3 than someone trained in plant identification is important. Otherwise experience with tree identification measuring DBH. This protocol has been successfully implemented with volunteer groups.

DATA ANALYSIS

Analysis Methods

This protocol was first implemented in 2017, a detailed analysis methodology with accompanying R code will be available late 2020/early 2021. The intent of the protocol is to evaluate the change in conifer density and wetland species cover over time.

In order to evaluate effectiveness, analysis should occur at both the individual meadow, as well as across multiple meadows.

Evaluation Criteria

The density of seedlings following treatment could trigger adaptive management, see below.

ADAPTIVE MANAGEMENT

If small conifers remain after treatment, or if new conifer seedlings become established and are present for more than one-year post treatment then management should consider either pulling/cutting small conifers or implementing prescribed fire to kill small seedlings.

COORDINATION

One component of this protocol involves detailed evapotranspiration data collection to evaluate question 4, which could compliment wells being installed by the hydrology group.

CONTACTS

Person(s) who populated the specific protocol
Shana Gross, Associate Ecologist Central Sierra Province, USFS, shana.gross@usda.gov – 530.543.2752

5.6 VEGETATION

Conifers Protocol

This protocol was developed by the Region 5 Ecology Program of the USFS.

Print & Carry
Field Instructions
& Equipment List

OVERVIEW

Ten permanent plots will be established in each meadow (a plot consists of 40-meter belt transect and 1-2 8-m radius circular plots). If the meadow will have more than 1 treatment type separated spatially then it would be ideal to have 10 plots per treatment type. Specific details on how to collect the data at each plot is included in the appendix with full protocol.

Ecological Effectiveness of Conifer Removal in Meadows (updated 11/17/20)

This protocol was developed to be used in conjunction with the Aspen effectiveness monitoring that was originally adapted from: Jones, B.E., D. Burton, and K.W. Tate. 2005. Effectiveness Monitoring of Aspen Regeneration on Managed Rangelands. A monitoring method for determining if management objectives are being met in aspen communities. USDA Forest Service, PSW Region. These two protocols can then be used to monitor both the effectiveness of conifer removal from Aspen and Meadows.

Key Questions:

1. How long does the conifer removal treatment effectiveness last? Do conifer seedlings continue to establish after restoration activities? Do follow up treatments need to be conducted in order to maintain low cover of conifers?
2. Does large scale burning of meadows change vegetation community structure (i.e. changing community from graminoid dominate to herbaceous dominate)?

Additional questions depending on the intensity of data collection:

3. Does removal of conifers and/or introduction of fire change the ratio of wetland species (i.e. obligate, facultative, upland, etc)?
4. Will removal of lodgepole pine in meadows increase groundwater level and meadow wetness?

METHODS

Monitoring Plots

Ten permanent plots will be established in each meadow (a plot consists of 40 meter belt transect and one to two 8-m radius circular plots). If the meadow will have more than 1 treatment type separated spatially then it would be ideal to have 10 plots per treatment type.

Repeated measurements will be taken at the following intervals: 1 year post treatment, 3 years post treatment, 5 years, and 10 years post treatment. If the project uses multiple tools that are implemented at different times (e.g. thinning and then burning) we recommend evaluating 1 year post following the use of each tool and then start the 3, 5 and 10 year intervals. This would provide insight into the effectiveness of each tool. After 10 years future monitoring will be reevaluated, in order to evaluate the effectiveness of treatments long term monitoring is ideal. Data will be collected in summer to early fall to capture the peak growing season for the herbaceous cover component.

Plot Design

Plot locations will be selected in GIS. Twenty plot locations will be identified around the meadow at equal spacing. Ten of these will be identified randomly as priority, if one of the locations does not work than a secondary plot will be selected. Transects should run through areas where conifer removal will occur. Transects should avoid running through dense willow stands.

Transects will run perpendicular to meadow edge (be sure to record the azmuth). The objective of each transect is to capture areas that will be treated, if a plot does not fall in an area that will noticeably receive treatment then it should be dropped. Belt transects will be established with one 8-m radius plots. Starting points will extend 30 meters into the meadow and 10 meters into the surrounding forest. If the transect crosses a channel, extend the transect to accommodate the distance of the channel (e.g. if the transect crosses from meter 23 to meter 25, extend the transect to 42 meters total). Meter 0 will start on the forest end (0-10 meters transect through forest, 10-40 m plot through the meadow). An 8-m radius plot will be established at meter 0 and occasionally at an additional transect location along the transect. The intent of the meter 0 radius plot will be to evaluate how surrounding forest structure influences the effectiveness of conifer removal (e.g. do denser forests reduce effectiveness of treatments).

Transect Design

Transects will be 40m belt transects with 1 meter on each side of the center line (2 meters wide). The transect start location will be 10 meters from the edge of meadow in the forest ecotone and move towards the meadow.

At each transect location, place a piece of rebar with a cap at each end of the transect, the rebar should be 40 meters apart. Label cap with transect number. Stretch a meter tape from end to the other so that the tape is tight and straight, secure with range stakes.

Plot Data

Record the plot number: The plot number will be meadow unit number sequential plot numbers (e.g. BW_1_P1).

- Transect bearing
- Slope
- Transect distance
- Distance to nearest seed tree from meter 0.
- Length of Channel (if applicable)
- If sampling is post treatment note if seedlings were pulled as they were found.
- Location of piezometer plot if one is established in a location different than meter 0
- GPS location (this is a backup in case the Javad point does not process)
- Establish witness trees on the two closest trees at both ends of the transect, nail an aluminum tag at the base identifying the plot number. Record the tree species and the distance and azimuth from this tag to meter 0 or 40 respectively. If there are not two trees available then tag at least one.

Javad GPS Coordinates

The Javad receiver should be used to measure a point at each end of the transect. Each point should be recorded at 5 sec intervals for 15 minutes.

Photo Documentation

Take 5 photos of the plot:

1. Photo of plot number
2. Photo from 1 meter behind meter 0 to meter 40
3. Photo meter 0 towards the forest – looking towards circular plot away from transect
4. Photo from 1 meter behind meter 40 to meter 0
5. Photo meter 40 towards the meadow – looking away from transect

Each photo should be renamed as follows: Plot number (for each photo) followed by: _0m (for meter 0 to meter 40), _Forest (for meter 0 towards the forest), _40m (for meter 40 to meter 0), and _Meadow (for meter 40 towards the meadow). For example: BW_1_0m.

Conifer Density

All conifers stems within 1 meter of each side of the transect are counted and recorded by live or dead and by species in the following size classes: 1 (seedling <1.37 m tall), 2 (sapling >1.37 m tall and 7.6 cm dbh), 3 (tree >7.6-25.4 cm dbh (3.0-10")), 4 (tree >25.5-45.7 cm dbh (>10-18")), 5 (tree >45.8 cm dbh). Use a measuring pole at ground level to determine if each conifer stem is in or out of the 2 meter belt. A tree is considered in if the pith is within the transect belt. The number of stems by size class is recorded in 4m segments along the transect.

For the seedling category (<1.37 m tall) categorize all seedlings into one of the two age classes. 1) If under 3 years then enter the age of the seedling in years (0 to 3, where 0 is present year seedling) (see figure 1 to determine how to age a seedling); 2) If seedling is >3 then identify as >3.

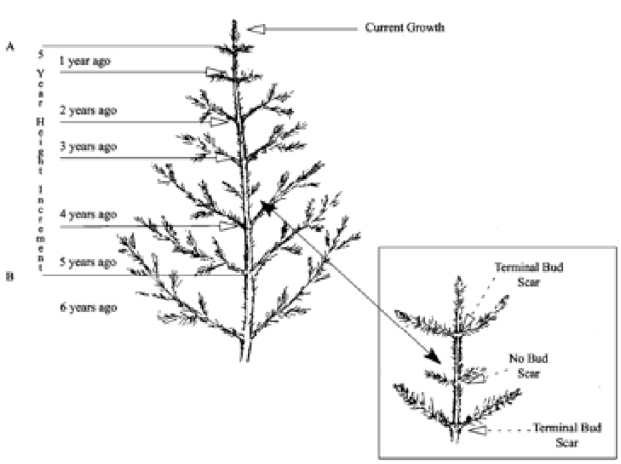


Figure 1: How to count branch whorls to age a seedling

Key to seedling species identification

- Cotyledons needle-like, isosceles triangle, glaucus above (except PICA)
  - Glaucus above
    - 3-4 (~7) cotyledons, 16-30 mm .... PICO
    - 6-10 (usu 7-8) cotyledons, 16-30 mm .... PIMO
    - 7-13 cotyledons, 40-80 mm, ±serrulate near base .... PIJE
  - Not glaucus above
- Cotyledons linear, obtuse triangle
    - >10 mm long cotyledons <--> <10 mm, 3-4 cotyledons, glaucus above .... TSME
    - Outer bud scales elongate and free, not resinous, light red-brown, 6-13 cotyledons, 30-45 mm .... ABMA
    - Outer bud scales not elongated or free, resinous, dark brown, 5-8 cotyledons, 20-30 mm .... ABCO
    - Young needles with acute end, tiny bristle, not glaucus, reddish scales, 5-8 (~10) cotyledons, 12-25 mm .... PSMA

Cover Data

A one meter square quadrat will be placed every 4 meters starting at 0 meters. The plot at 0 meters should be read on the right side of the transect (as look towards 40 meters) and then the plots should be alternated left-right-left. You should have a minimum of 10 plots per conifer treated area. Within the 1 m2 plot frame, estimate total cover of vegetation. Estimate the cover for the following growth forms: forbs, graminoids (grasses, sedges, rushes), cryptograms, shrubs, conifers, hardwood, and invasive species.

Only include canopy cover of trees rooted in the plot under conifers. If there is canopy cover in the plot from a tree not rooted in the plot, record the cover in the notes. The sum of all the individual growth form cover in the plot may be greater than the total cover because of overlapping values but should not add to less than the total cover. Record the dominant shrub species. If invasive species are identified note the species found. Record if plot is dominated by upland(forest) or meadow vegetation or in a transition zone.

Estimate percent ground cover (below vegetation) which will add to 100%. Ground cover categories include: bare ground, rock, fine woody debris (1, 10, and 100 hour fuels), course woody debris (1000 hour fuels), litter, basal vegetation, dead basal vegetation, water, piles (unburned only if burned then should be part of woody debris), and stumps.

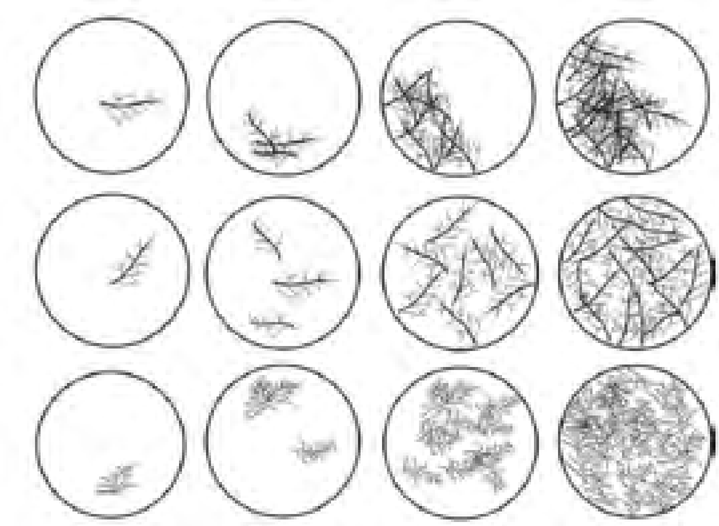
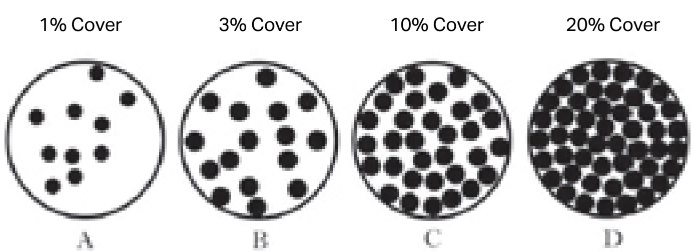


Figure 1. Percent cover examples. Each circle represents a 6-ft diameter sampling area. Thick lines represent 1" diameter pieces and thin lines represent 0.25" diameter pieces



Wetland Veg Cover

This component will only be evaluated if the following question is being addressed: Does removal of conifers and/or introduction of fire change the ratio of wetland species (i.e. obligate, facultative, upland, etc)? Due to time constraints this metric is not currently being evaluated. If desired the methods should be evaluated. Identify and record cover of each individual species in the 1 m square plots.

Eight Meter Radius plots

Both tree and cover data will be collected in the radius plots.

- The center of the forested plot should be at meter 0 and will be called A (e.g. BW_1_P1A).
- The piezometer plots will be targeted in areas specifically where there is noticeable conifer removal that will occur – these can be established along the transect or 8 meters from end of the transect. These do not need to be random because the key is to evaluate the response of conifer removal on ET trends.

Plots should be established where:

a. There is a noticeable stand where removal activities will remove a large portion of the stand.
b. The stand is at least 10 meters from flowing water and ideally does not have standing water in the stand during peak growing season.

1. The cover data will be collected as noted above but for the full 8-m radius plot rather than 1-m plot. In addition, cover of conifer seedlings will be separated from conifer tree and sapling cover.

2. Count saplings by status (live/dead) and species (all tree species not just conifers) (note: do not include cut trees as dead).

3. For each tree (all tree species not just conifers) record:
   a. Species
   b. Status (Live/dead)
   c. DBH

4. Within the 8 m radius plot establish a smaller 4.37 m radius plot to count seedlings by species. For the seedling category (<1.37 m tall) categorize all seedlings into one of the two age classes. 1) If under 5 years then enter the age of the seedling in years (0 to 4, where 0 is present year seedling); 2) If seedling is >3 then identify as >3

.

5. When a piezometer is installed a polygon will be drawn around the stand that the piezometer is in. The stand will be identified as the area with similar vegetation/topography. (See appendix B.)

APPENDIX A

Detailed Instructions ArcGIS for selecting meadow plots

1. Turn polygon into line feature: Toolbox -> Data Management Tools -> Features -> Polygon to Line -> uncheck box
2. Make new point feature to store points in
3. Evenly space points along meadow edge – aka line feature
   a. Click the Edit tool on the Editor toolbar – edit point file
   b. Click the line feature using along which you want to generate points.
   c. Click the Editor menu and click Construct Points.
   d. Choose the target in which the new feature will be created.
   e. If you have feature templates for the layers in your map, click the Template button and click the template to use to create the new feature. You can also double-click the preview of the template to choose a different template.
   e. If you do not have feature templates, click the layer in which to create the feature.
4. Choose how you want the points to be created.

Number of points	Creates a specific number of points that are spaced evenly along the line. Click this option and type the number of points to create.
Distance	Creates points at a specific interval in map units. Click this option, type the interval, then click whether the points should originate from the start or end of the line. Arrows are drawn on the map to indicate the direction of the line.
By measures (m-values)	Creates points at a specific interval based on m-values along the line. Click this option, type the interval, then click whether the points should originate from the start or end of the line. Arrows are drawn on the map to indicate the direction of the line.

5.6

VEGETATION

Conifers Protocol

Equipment List

- 50 m tape measure
- 2 Chaining Pins
- 1 meter PVC square
- DBH tape
- 2 meter distance measuring pole, tape measure or Biltmore stick
- Rebar (two for each transect, for a total of up to 20 per treatment area) and 2 plus rebar caps (write plot number on cap)
- Sharpie
- Four tree tags and four nails for witness trees per transect
- Hammer
- GPS
- Camera
- Compass
- Data Sheets/Data recorder
- Metal detector for post effectiveness monitoring
- Trimble when installing piezometer

Datasheets Electronic datasheets have also been developed in Excel or in Survey 1,2,3 (contact Shana Gross, shana.gross@usda.gov for access to these)

Visit the Sierra Meadows Partnership website to download pdf conifer monitoring datasheets

6 WILDLIFE

Yellow Warbler Nest at Van Norden Meadow by Jenny Rieke Point Blue

6.1 WILDLIFE

Birds

Resource Target
Wildlife - Birds

Indicators/Attributes

Attributes
Species composition and abundance of the bird community.

Indicators/Metrics
Species relative abundance, species density, species presence, species occupancy probability, community diversity.

Yellow Warbler by Tom Grey

INTRODUCTION AND BACKGROUND

What goals and/or restorations objectives are being evaluated with the indicators?

Applicable objectives:
- Improve habitat quality for meadow birds.
- Increase the abundance of meadow birds.
- Increase habitat quality for a particular species of meadow bird.
- Increase the abundance of a particular species of meadow bird.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

One way to evaluate the ecological success of meadow restoration projects is to monitor the responses of bird populations that inhabit the meadow. This protocol can be used to sample a large segment of the bird community. The data can be used to derive the presence of bird species, their relative abundance, and, depending on the analysis method and the amount of data collected, the protocol can also be used to derive absolute density, occupancy, and diversity of bird species. These are secondary population parameters that are intended to index habitat quality. This protocol does not measure primary population parameters such as survival, productivity, and population growth.

Level of Effort

- Point counts only: Low Effort
- Point counts combined with relevé-style vegetation surveys at each point count station: Moderate Effort

PLANNING

Data Collection Timing
Ideally, bird monitoring should be completed for at least 1-3 years before the onset of restoration activities and for at least 10 years after the onset restoration activities. However, restoration managers or researchers may face constraints on the resources they can allocate to bird monitoring or may have other competing project goals. Although this protocol recommends multi-year monitoring and the inclusion of one or more reference sites, it can easily be adjusted to accommodate

constraints or serve other goals, including sampling the bird community at a single point in time at a single meadow at any point in time relative to restoration activities.

Required Resources

Time required per sampling/survey event (# people x hours)
Point count surveys: 1 day (survey morning) per 10-18 survey locations depending on observer experience and ease of navigation within the meadow between points. The number of survey locations will vary as a function of meadow size, butshould not exceed 18 points (spaced 200-250 m apart) to complete in one morning. Surveys should be completed within 4 hours of sunrise ideally between June 1 and 30, but no earlier than May 25th and no later than July 7th. Two complete surveys are recommended per season. The best practice would be to keep surveys over different years within a couple weeks of the same annual calendar dates.

Equipment costs if new
$800–$2,000

Level if any special expertise required
Observers require a high level of training to accurately identify and count all bird species that occur in Sierra Nevada meadows, as well as estimate distance to birds. Given the high level of experience required for bird monitoring, we recommend reaching out to the technical experts listed at the end of this document for assistance establishing bird monitoring.

DATA ANALYSIS

Analysis Methods

See the full protocol for a description of data analysis options and methods.

Evaluation Criteria

Campos et al. (2014) recommends meadow restoration targets of 1.0 focal species per acre and 0.54 Yellow Warbler per acre. The focal species include Wilson's Snipe (Gallinago delicata), Red-breasted Sapsucker (Sphyrapicus ruber), Calliope Hummingbird (Selasphorus calliope), Willow Flycatcher (Empidonax traillii), Swainson's Thrush (Catharus ustulatus), Warbling Vireo (Vireo gilvus), Wilson's Warbler (Cardellina pusilla), Yellow Warbler (Setophaga petechia), MacGillivray's Warbler (Geothlypis tolmiei), Song Sparrow (Melospiza melodia), Lincoln's Sparrow (Melospiza lincolnii), Mountain West White-crowned Sparrow (Zonotrichia leucophrys oriantha), and Black-headed Grosbeak (Pheucticus melanocephalus). See Campos et al. 2014 and Campos et al. 2020 for more details on the focal species.

The focal species target applies to all meadows. The Yellow Warbler target applies to meadow restoration sites withinthe elevation range of Yellow Warbler: below 5,500 and 6,500 ft in the northern and southern Sierra, respectively. Yellow Warblers are closely aligned with riparian deciduous shrubs such as willows, which are an essential habitat component for the endangered Willow Flycatcher. Willow Flycatchers are often a primary target of meadow restoration efforts in the Sierra Nevada, however, they may not respond to restoration given severe restrictions in their range and population size over the last century. We provide a target for Yellow Warbler as a proxy for Willow Flycatcher habitat. If the focal species and Yellow Warbler targets are not met within 10 years, adaptive management action is warranted.

ADAPTIVE MANAGEMENT

If the restoration targets are not achieved, evaluate whether vegetation and hydrology attributes (i.e. cover of riparian deciduous shrubs and trees, herbaceous cover and height, and water cover) are providing suitable bird habitat. Simple ocular estimates of cover within 50 m of each point count sample location, as described in Appendix G of the full protocol, can provide this information is not otherwise available for the meadow.

Habitat suitability can be evaluated by comparing cover estimates at the restoration site to a reference site or through expert opinion. If habitat attributes are within the range of suitability, no action is warranted. In this case, the target in this objective may have been too high and may need to be lowered. If structural habitat attributes do not meet thresholds for suitable habitat, evaluate whether other factors (e.g. grazing, floodplain connectivity, groundwater elevation) may be limiting habitat suitability. If the underlying processes that drive biotic responses have been restored and maintained at a restoration site, yet the site is not trending toward high suitability habitat for birds, consider taking other actions to improve habitat suitability for birds, such as increased revegetation of deciduous shrubs and trees.

6.1 Birds Protocol

Deciduous shrubs and trees are the primary driver of the abundance of most meadow bird focal species (Campos et al. 2014, Campos et al. 2020). Woody deciduous vegetation provides important nesting and foraging structure for meadow birds. If the evaluation criteria above indicate adaptive management is needed to boostbird abundances, meadow managers can accelerate the establishment of riparian deciduous vegetation by planting a diversity of meadow shrubs and trees that are appropriate for the restoration site, as well as forbs that provide nectar resources (see Vernonet al. 2020). In meadows that arenaturally herbaceous dominated, managers may want to focus on planting on the meadow edges.

COORDINATION

This protocol is not easily coordinated with others for the efficiency of data collection efforts. However point count surveys last less than 4 hours per morning, which may leave time in the day to complete other monitoring.

CONTACTS AND RESOURCES

Technical experts:

- Brent Campos, Point Blue Conservation Science, bcampos@pointblue.org, office: 530-665-6413, mobile: 530-902-7515
- Helen Loffland, The Institute for Bird Populations, hloffland@birdpop.org, 209-283-4028

Person(s) who populated the specific protocol

- Brent Campos, Point Blue Conservation Science, bcampos@pointblue.org, office: 530-665-6413, mobile: 530-902-7515
- Helen Loffland, The Institute for Bird Populations, hloffland@birdpop.org, 209-283-4028

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2. Campos, B.R., Burnett, R.D., Loffland, H.L., Siegel, R.B. 2020. Bird response to hydrologic restoration of montane riparian meadows. Restoration Ecology. https:// doi.org/10.1111/rec.13212
3. Loffland, H. L, R. B. Siegel, and R. L. Wilkerson. 2011. Avian Monitoring Protocol for Sierra Nevada Meadows: A tool for assessing the effects of meadow restoration on birds. Version 1.0. The Institute for Bird Populations, Point Reyes Station, CA.
4. Vernon, M. E., Burnett, R. D., and Campos, B. R. 2020. Sierra Meadow Planting Palette Tool User Guide. Point Blue Conservation Science, Petaluma, CA.

APPENDIX

Full Protocol and Datasheets

Link to full protocol:
https://www.birdpop.org/docs/pubs/ Loffland_et_al_Avian_ Monitoring_Protocols_for_Meadows.pdf

Avian monitoring protocol for Sierra Nevada meadows

6.1
WILDLIFE

A tool for assessing the effects of meadow restoration on birds. Version 1.0. (Loffland et al. 2011)

Print & Carry
Field Instructions
& Equipment List

OVERVIEW

This protocol provides methods for monitoring birds at meadow restoration sites in the Sierra Nevada. It was developed by The Institute for Bird Populations with funding from the National Fish and Wildlife Foundation's Sierra Nevada Meadows Initiative, in a process that included review of existing methodologies, collaborative discussion, and peer review.

The protocol reflects widely used methodologies (i.e. point counts, broadcast surveys) for surveying breeding birds in a variety of habitat types. Point counts and observed conditions at the restoration site at time of point count surveys are the required minimum for bird monitoring (Appendices B-C in full protocol). Appendix A in the full protocol outlines the steps for establishing the point count survey locations.

We also recommend relevé-style vegetation surveys centered on point count locations to help with interpretation of the bird data and to inform management actions (Appendix G in full protocol). Other components of the full protocol, including broadcast surveys (Appendix D in full protocol) and area searches (Appendix E in full protocol) are for targeting species (depending on restoration objectives) that are not well sampled with the point count method (e.g. Great Gray Owl, Sandhill Crane) or you want to completely census a species' population at a meadow (e.g. Willow Flycatcher); these latter components of the full protocol are project- and context-specific and not a part of SM-WRAMP activities.

6.1
WILDLIFE

BirdsProtocol Checklist

Equipment List

- Binoculars ($300 – $800)
- Watch with stopwatch function ($25 – $50)
- Field guide to Western Birds ($30)
- Clipboard
- Data forms
- Pens
- Maps and aerial photos of site
- UTM coordinates of survey stations
- GPS unit ($200-400)
- Laser rangefinder ($150 – $400)
- Rubber boots with waterproof pants ($100 – $150) or waders ($150 – $300)

Yuba River at Van Norden Meadow by Jenny Rieke Point Blue

6.2 WILDLIFE

Beavers

Resource Target

Wildlife - Beavers

Indicators/Attributes

Attributes

Distribution, number, and maintenance status of beaver dams, lodges and bank burrows

Derived Indicators/Metrics

Beaver dam density or presence, beaver lodge/burrow density or presence

Beaver Dam at Childs Meadow by Jenny Rieke Point Blue

INTRODUCTION AND BACKGROUND

This protocol is intended to provide a common method for monitoring beaver activity in montane meadows of California. This protocol is designed to provide data on the location and sizes of beaver dams and lodges/burrows. This information can be used to calculate beaver dam density, identify areas of concentrated beaver activity (e.g. lodge/burrow location), or calculate other indices of beaver activity based on the location and dimensions of dams and lodges. These indices are intended to represent the extent to which beavers have modified a meadow stream and its ecology and hydrology. These effects can be tracked through time with repeated measures before and at multiple intervals after the onset of restoration activities.

Data collection for this protocol involves a complete area search for dams and lodges/burrows as well as dam measurements. Ideally the entire perennial network of streams in the meadow or project area will be censused, but the scale of the search area depends on the area of monitoring interest.

Data collection efforts can be reduced by only recording data for active dams and lodges/burrows and by not collecting dam height and length measurements. This may be warranted for search areas in years following full data collection on all active and inactive dams and lodges/burrows.

An earlier version of the protocol was used for a study of the relationship between beaver activity and Willow Flycatchers in the Truckee and Carson River watersheds (Campos et al. 2019). The variables in this protocol were adopted from products developed by Josh Wheaton's Lab at Utah State University. The Wheaton Lab does not currently (as of June 2020) have an area search protocol for beaver activity, though they are developing one (personal communication with Wally MacFarlane, June 2020)

What goals and/or restorations objectives are being evaluated with the indicators?

Applicable goals:

- Promote beaver occupancy and dam building activity.
- Use beavers to maintain floodplain connectivity at a restoration site.
- Increase habitat heterogeneity at a restoration site through space and time with beaver activity.

When should these indicators be used?

This protocol should be used primarily for effectiveness monitoring of restoration projects where an objective of restoration is to promote beaver occupation and activity. This protocol may be useful for ambient monitoring applications as well, if there is interest in tracking beaver activity across a watershed or region.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

This protocol can be used to calculate beaver dam density, identify areas of concentrated beaver activity (e.g. lodge location), or calculate other indicators of beaver activity based on the location, dimensions, and integrity of beaver dams, and the location and status of beaver lodges, as well as changes through time. The beaver dam density indicator is intended to index the extent to which beavers have modified a meadow stream and its ecology and hydrology, even though many attributes of beaver activities and habitat modification go unmeasured (e.g. the beaver canal network and vegetation modifications). The indicators derived from this protocol may be useful for relating to measures/indicators of hydrology, vegetation, and other wildlife. The protocol does not measure beaver population abundance or population dynamics.

Level of Effort

Low – No or low beaver activity and/or small search area.
Moderate – Low to moderate beaver activity and/or large search area.

High – High beaver activity and/or very large search area.

While the protocol recommends a complete census of the meadow, this is not absolutely necessary. A more detailed approximation of survey effort is provided in the time required section.

PLANNING

Data Collection Timing

Season:
May through September

Frequency:
Pre-restoration and post-restoration. Can be done annually or less depending on the project monitoring questions and project objectives. For sites that have no beavers and do not have a source population close to the project area, beaver occupancy may take many years or decades even. Reintroduction may be the only option, though in most circumstances it is not currently allowed in California.

Required Resources

Time required per sampling/survey event (# people x hours)
Approximately 0.25 to 2.5 person-hours per kilometer of stream channel depending on dam density, shrub cover, and general ease of navigability of meadow.

Equipment costs if new
(See below for equipment list)
$600 - $1300

Level if any special expertise required
Data collectors need to know how to identify beaver dams, lodges, and bank burrows. Observers can be trained in a half day or less. For observers familiar with stream channels and signs of beaver activity, no training is required.

DATA ANALYSIS

Analysis Methods

To calculate **Dam Density**, divide the number of dams by area of the search area in a GIS framework. In the case of very large search areas, it may be helpful to divide it into multiple areas to provide multiple values for dam density across the meadow at scales relevant to the ecology of the system. The analyst can filter dams by status (intact, breached, blown out) prior to

6.2 Beavers

calculating this metric, or include all dams regardless of status.
For **Beaver Dam Presence**, proceed as for Dam Density, then distill this number into a binary 0 (for 0 dams) or 1 (for >0 dams).
For **Lodge/Burrow Density**, proceed as for Dam Density, but with lodges/burrows instead of dams.
For **Lodge/Burrow Presence**, proceed as for Lodge/Burrow Density, then distill this number into a binary 0 (for 0 lodges/burrows) or 1 (for >0 lodges/burrows).

Evaluation Criteria

- Beavers occupy the site within 5 years.
- Beavers occupy the site within 10 years.
- More than a 50% reduction in active beaver dams in the second year following a major disturbance (e.g. ≥10-year flood event).

ADAPTIVE MANAGEMENT

If beavers have not occupied the site within 5 years, site managers should evaluate the habitat's suitability for beavers and take action (e.g. revegetate with more beaver food and building materials, such as willow, cottonwood, and aspen) if the site is not trending toward high-quality habitat. If beavers have not occupied the site within 10 years, managers may want to reconsider the objective, or, if reintroduction is an option, reintroduction should be considered.

Habitat suitability for beavers depends on several factors. Beavers need ample food, perennial flow, adequate water depths to escape predators and to cache food in the winter, as well as dam-building building resources to colonize and persist in a meadow. If beavers have not colonized a site even though they are known to be present nearby, managers can use a habitat suitability scorecard to evaluate the site's suitability for beavers. See the Methow Beaver Project scorecard and the field evaluation forms from the Beaver Restoration Assessment Tool from Joe Wheaton's lab at Utah State University.

Where BDAs are used to mimic beaver activity and a major objective of the restoration project is for beavers to occupy the stream reaches with BDA structures, the BDAs will likely need to be maintained once or more per year to maintain deep enough water levels that provide refuge for beavers from predation so they can more easily occupy the restoration site.

After beavers occupy a site, if intact beaver dam density declines and does not recover within 2 years following major disturbances, managers should consider interventions such as re-building and maintaining BDAs and evaluate the need for a ban on depredation by working with the proper authorities (e.g. California Department of Fish and Wildlife).

COORDINATION

The protocol is relatively simple and could be added to a field day, potentially without much additional time depending on the search area and the amount of beaver activity. Depending on field conditions, the protocol may be coordinated and completed with others for the efficiency of data collection efforts.

CONTACTS AND RESOURCES

Pollock, M., Lewallen, G., Woodruff, K., Jordan, C., Castro, J., 2015. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 1.0. United States Fish and Wildlife Service, Portland, Oregon.

Person(s) who populated the specific protocol
Brent Campos, Point Blue Conservation Science, bcampos@pointblue.org, office: 530-665-6413, mobile: 530-902-7515

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A Protocol for Monitoring Beaver Activity in Meadows

6.2
WILDLIFE

Version 1.0 - Brent Campos, Point Blue Conservation Science

Print & Carry Field Instructions & Equipment List

COMPLETING THE AREA SEARCH

Always start the area search on the downstream end of your search area. Walk the entire downstream edge of the search area boundary to identify all channels exiting the search area. From each stream channel exit point, walk upstream looking for dams and lodges, doing your best to stay inside the stream channel at all times while walking. At each branch/fork in the stream channel, mark a waypoint in your GPS, then choose one of the channels to continue walking up.

Follow the channel to its entrance point into the search area boundary, to its spring source with the search area boundary, or, in the case of secondary channels, to where the channel returns to the primary channel. If you marked any waypoints, return to the last marked waypoint and continue your search upstream in the other stream channel. Repeat this process until you have searched the entire length of every stream channel in the project area, including dry channels.

When you encounter a dam or lodge, record your measurements and data in the fields on the datasheet, as outlined below. (Note: The waypoints at each channel confluence can be saved and used to calculate the number and density of stream channel segments, a powerful indicator of meadow aquatic and floodplain complexity.)

DATA FORM FIELDS

Header

Search Area ID: An alphanumeric code to identify the search area (e.g. B09, SWAIN, CHME05). Also referred to as a Site ID.
Date: The date you are collecting the data.
Observers: The names and three-letter initials for all observers aiding in data collection.
GPS Datum: The datum your GPS is in that you will record coordinates with.

Observations

Active/Inactive: Indicate whether the recorded data includes just active dams by circling active, or both active and inactive dams by circling both active and inactive. Active dams have fresh cuttings on the lodge.
Beavers/BDAs: Indicate whether the recorded data includes just beaver dams by circling beavers, or both beaver dams and BDAs by circling both beavers and BDAs.

Dams

Dam ID: Assign a beaver dam ID based on the search area ID and the order in which you encounter the dam. For the first dam, the ID will be the search area ID followed by the letter D, and the number 1 (e.g., B09D1).

BDA: If the dam is actually a beaver dam analogue (BDA), or was a BDA that has been adopted by beavers, record Y, otherwise N.
Posts: If the dam has been post-assisted, record Y, otherwise N. BDAs typically have posts, so if you record Y for BDA, you will likely record Y for Posts.
Easting, Northing: Record the coordinates for the location of the beaver dam. Use the average function when marking the waypoint until the measurement count reaches at least 15.
Active: Indicate whether the dam is actively being maintained or inactive. Active dams have fresh cuttings and pool water close to the full height of the dam.
Dam Status: Record the status of the dam by circling intact, breach (for breached), or blown (for blown-out). Breached dams have a large notch in them, but the breach is not the full height of the dam. Blown-out dams are breached through the full height of the dam. All blown-out dams may not be detectable depending on the time passed since dam failure.
Max Height: Measure the maximum height of the dam from the lowest point in the channel just downstream of the dam to the top of the dam. If the downstream channel is not well defined or readily visible, walk the length of the dam to find the tallest point relative to the downstream side.
Length: Use a rangefinder or dam measurement stick to measure the length of the dam in meters. For arched dams, measure the chord length: the straight-line distance from the dam's two end points.
Photo(s): Take a photo from below each dam, looking upstream toward the dam. Ideally the entire height of the dam and the ponded water surface behind the dam should be visible in the photo. Take a photo from above the dam if you feel it would show more of the dam width and pond. Before taking a photo of the dam, take a photo of the dam records section of the datasheet so the dam ID can be attributed to subsequent photos of the dam after uploading photos to a computer. Fill out all other fields for the dam record before taking a photo of the datasheet and dam.

Lodges

Lodge ID: Assign a beaver lodge ID based on the search area ID and the order in which you encounter the lodge. For the first lodge, the ID will be the search area ID followed by the letter L, and the number 1 (e.g., B09L1).
Coordinates: Record the coordinates for the location of the beaver lodge. Use the average function when marking the waypoint until the measurement count reaches at least 15.
Active: Indicate whether the lodge is actively being maintained or inactive. Active lodges often have fresh cuttings on the lodge.

Other Information (Optional)

Other signs of beaver activity: Circle whether you observe cut stems, tracks, skid trails, felled trees, or "corn cobs" in the search area. Circle none if none are detected. Also record the age of the activity if it can be determined. For cut stems, corn cobs, and felled trees, old is gray-colored, otherwise it is fresh.

6.2
WILDLIFE

Beavers Protocol

Equipment List

- waders with wading boots (recommended) or amphibious footwear: $150-300
- GPS unit w polygons outlining the search areas: $200-400
- dam height measurement stick: a 48" long, ¾" dia. wooden dowel ringed with black marker at 10 cm intervals: $5
- laser rangefinder: $150-$400
- camera: $100-200
- map(s) of meadow(s) or reach(es)
- data forms
- pens
- clipboard

7
AQUATIC SPECIES

NEED CAPTION???

7.1

AQUATIC SPECIES

Fish & Aquatic Habitat

Resource Target

Aquatic Species-Fish and aquatic habitat

Indicators/Attributes

- Fish presence (species, number)
- Habitat type
- Hydrogeomorphic measurements

Snorkeling to gather data on aquatic species. Monitoring by snorkel survey is an effective method to visualize aquatic species in their habitat for abundance and distribution monitoring.

INTRODUCTION AND BACKGROUND

Sierra Nevadan meadows provide essential habitat to aquatic species. Meadow restoration actions are expected to improve habitat quality, and thus to increase the distribution and abundance of native fish and amphibians as well as increase the food availability for these species. Monitoring how the biology and aquatic habitat of meadows respond to restoration actions indicates the success of the restoration effort and informs how actions might be altered in the future for increased effectiveness.

What goals and/or restorations objectives are being evaluated with the indicators?

The species and numbers of fish found in a consistently sampled reach before and after a restoration project informs whether the restoration project appeared to support a change in the fish populations around the project site. In addition, the collection of aquatic habitat parameters determines the extent to which the restoration actions altered the stream condition/ physical aquatic habitat of the area of interest.

When should these indicators be used?

When the goals and/or objectives of the restoration include an increase in the amount and/or heterogeneity of aquatic habitat and fish abundance and/or distribution, this protocol should be used prior to project implementation and during subsequent resurveys, which should take place between every 1-5 years for up to 20 years post implementation. At a minimum, this protocol should be completed once before project implementation, the year after implementation and again between one and five years later.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

This protocol addresses whether fish populations, as well as aquatic habitat quantity and quality, have changed before and after restoration implementation. The changes can be correlated with restoration and other monitoring activities, but causation for changes in fish populations cannot be concluded with certainty.

PLANNING

Data Collection Timing

Samples should be taken prior to project implementation and during subsequent resurveys, which should take place between every 1-5 years for up to 20 years post implementation. At a minimum, samples should be collected once before project implementation, the year after implementation and again between one and five years later. If possible, monitoring should be done in the same month every year that it is done.

Required Resources

Time required per sampling/survey event (# people x: hours)
Data collection in the field – 2-4 hours with a 2+ person team, plus travel time.

Equipment costs if new
Field notebook - $5
Equipment decontamination supplies - $50
Waders - $100
Thermometer - $10
pH meter - $200
Water quality meter - $200
Digital camera - $100
GPS - $100
Stopwatch - $5
Spare batteries, parts for meters etc. - $20
Measuring tape - $5
Flags to mark transects - $5
Meter stick - $40
Clinometer - $50
Autolevel and tripod - $100
Current velocity meter and top setting rod - $500
Flagging tape - $5
Densiometer - $100
Wet or dry suit -$200
Fins or wading boots - $50
Snorkel - $20
Plastic slate board - $25
Mask - $40
Waterproof felt pen - $5

Level if any special expertise required
Those observing fish need to be able to quickly identify species and estimate numbers and size. Some experience would certainly be helpful in getting more accurate information. Experienced divers can learn to identify, count, and record fish in a relatively short time.

Total Costs
Field equipment-$1,500-$1,700

DATA ANALYSIS

Data storage

Once data is collected in the field, information recorded will need to be added to a digital data library. All data should be uploaded to the meadows clearing house.

Analysis Methods

Standard statistics can be used to determine if population abundances and/or diversity changed before and after restoration implementation.

Evaluation Criteria

If the indicators of interest have not improved and they were expected to, it is suggested that stakeholders discuss potential hypotheses for the species' distribution not changing and possible next steps.

ADAPTIVE MANAGEMENT

If the indicators of interest have not improved post restoration, habitat quantity and quality as indicated by the results of other SM-WRAMP protocols should be reviewed. If habitat has not improved, additional restoration or on-going stewardship actions should be decided upon and taken.

COORDINATION

All of the aquatic species protocols can be done using the same transect layout and habitat typing data.
Person(s) who populated the specific protocol
Natalie Stauffer-Olsen, nstauffer-olsen@tu.org, (707) 696-9839

FIELD DATASHEETS & DATA UPLOAD FORMS

The following datasheets are available to be downloaded from https://californiatroutinc.box.com/s/itpw9qd6utmaka5s8370nmg1c715a539

- PHab Protocol Datasheet
- Fish Survey Datasheet

7.1
AQUATIC SPECIES

Fish Observation and Aquatic Habitat Protocol

Print & Carry
Field Instructions
& Equipment List

This protocol is developed from the California Salmonid Stream Habitat Restoration Manual, which has additional details about fish collection methods, including both capture (electrofishing) and non-capture (snorkeling, above water observation), explained below.

PROTOCOL DESCRIPTION

Physical habitat methods proposed here are adapted from the document "Standard Operating Procedures (SOP) for the Collection of Field Data for Bioassessments of California Wadeable Streams: Benthic Macroinvertebrates, Algae, and Physical Habitat", also called the Surface Water Ambient Water Monitoring (SWAMP) protocol, which is available here. Alternatively, practitioners can choose to use the Stream Condition Inventory to monitor aquatic habitat.

Work described in this protocol can be done in the same sampling area as the stream habitat characterization for physical habitat (PHab). The effectiveness of this work can be improved when combined with electrofishing or eDNA.

The number of transects and replicates laid out for physical habitat data collection will depend on the scope, goals, objectives, and funding of a project. Here, we recommend as a minimum 11 duplicate samples collected at 11 transects spread out over a randomly chosen 150m reach within the area most likely to display change based on analyses of channel morphology, biological communities and processes, and existing or proposed management activities. If the management activities are to be carried out across a large meadow or are expected to have measurable impacts to a large section of a meadow, we encourage practitioners to choose multiple 150m reaches or to extend the reach as necessary. Another method for determining the study reach is available in the Stream Condition Inventory.

In order to describe fish populations, the following data should be gathered and/or noted:
Species composition

- Juvenile rearing areas or general distribution
- Spawning areas or general distribution
- Sizes (lengths) of adults and juveniles
- Age classes of juveniles (based on lengths)
- Relative abundance in selected areas
- Biomass (weight per unit volume)
- Habitat utilization
- Timing of spawning activity if observed

The above information provides a general assessment of fish presence, distribution and habitat utilization within a meadow stream. It is essential to know what fish species exist within a meadow stream and particularly the status of species of special interest. The amount of habitat being utilized or not being utilized by adults and juveniles is useful information for determining how fish are responding to restoration actions.

The California Salmonid Stream Habitat Restoration Manual states “most general fishery information can be obtained using non-capture techniques. In some instances, specialized capture techniques of trapping or electrofishing may be useful to obtain length, weight, and positive species identification data. However, most fish capture methods, including trapping and electrofishing, have a high potential for causing fish mortality if used improperly. It is highly recommended that fish capture be avoided whenever possible, and that observation techniques be employed to collect the general fishery information required for the level of habitat assessment described in this manual.” As such, this protocol focuses on non-capture techniques: stream bank or above water observation and direct or underwater observation. For information on electrofishing and other capture techniques, please refer to the California Salmonid Stream Habitat Restoration Manual.

BEFORE GOING OUT INTO THE FIELD

1. To eliminate bias, target coordinates for transect locations should be determined at random from the reach within the area most likely to display change based on analyses of channel morphology, biological communities and processes, and existing or proposed management activities before going out into the field. Target coordinates should be placed on a map (paper or digital) for visual orientation in case the GPS is not functioning in the field. If practitioners prefer to pre-determine the study reach, which is especially suitable if a reach or reaches longer than 150m will be surveyed, that is also acceptable.

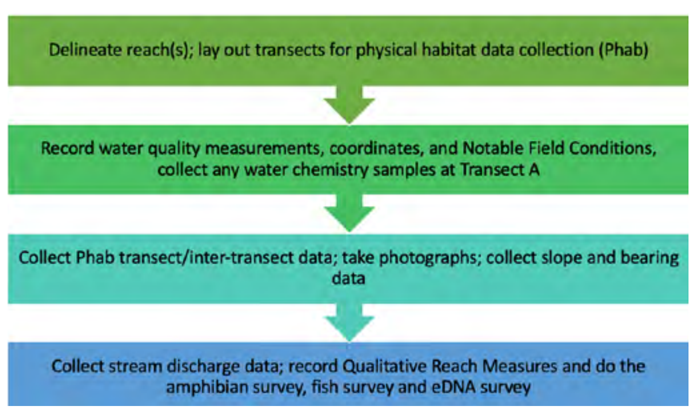
2. Gather sampling equipment
   - Map of pre-chosen transect location
   - Print out of this document
   - Equipment decontamination supplies
   - Waders
   - Thermometer
   - pH meter
   - Water quality meter
   - Calibration standards
   - Digital camera
   - GPS
   - Stopwatch
   - Spare batteries, parts for meters etc.
   - Measuring tape
   - Flags to mark transects
   - Meter stick
   - Clinometer
   - Autolevel and tripod
   - Current velocity meter and top setting rod
   - Flagging tape
   - Densiometer
   - Pencil
   - Physical Habitat (PHab) field forms
   - Fish sampling datasheets
   - Field notebook

   For underwater observation
   - Wet or dry suit
   - Fins or wading boots
   - Snorkel
   - Plastic slate board
   - Mask
   - Waterproof felt pen

3. Learn how to identify fish species that might be present in the meadow to be monitored.

IN THE FIELD

Suggested Work-Flow Diagram



Upon arrival at the site, fill out the “Reach Documentation” section of the PHab field form. Record the geographic coordinates of the downstream end (Transect A) of the reach with a GPS receiver and record the datum setting (preferably NAD83) of the unit. Sampling locations can be moved up or downstream as much as 300 m from the predetermined target location for reasons such as avoiding obstacles, mitigating issues regarding safety or permission to access, and GPS error. Because GIS information about stream locations is imperfect, the target coordinates may not fall exactly on a streambed, but rather nearby, requiring a shift in order to correspond to the nearest aquatic habitat. The potential discrepancy between the target coordinates and where sampling actually occurs makes it essential to record the actual field coordinates on the field sheet.

To delineate the monitoring reach, first scout it to ensure it is of adequate length for sampling biota. Delineate a 150 m reach for sampling. Again, if the practitioner has the resources to survey a longer reach or multiple reaches likely to display change we encourage them to do so. The 150 m reach discussed here is a minimum.

Use markers (e.g., wire-stemmed flags) to indicate locations of transects and intertransects. The standard sampling layout consists of 11 “main” transects (A-K) interspersed with 10 ”inter-transects”, all of which are placed at equal distances from one to the next (7.5m). The first flag should be installed at water’s edge on one bank at the downstream limit of the sampling reach to indicate the first main transect (“A”). The positions of the remaining transects and inter-transects are then established by heading upstream along the bank and using the transect tape or a segment of rope of appropriate length to measure off successive segments of 7.5m, or more if fewer transects are being used.

Physical Habitat (PHab) Transect-Based Field Measurements

For a detailed explanation of how to collect PHab data, please see the “SWAMP Bioassessment Procedures” (2016) document available here. The following “Basic” list of PHab measurements reflects the minimum amount of physical and chemical data that should be taken along with any biological samples. In addition, several hydrogeomorphic variables that measure connection to the floodplain and amount of incision are included.

- Layout of reach, marking transects, recording GPS coordinates
- Temperature, pH, specific conductance, salinity, DO, alkalinity
- Notable field conditions
- Wetted width
- Stream shading
- Bank stability and entrenchment
- Percent algal cover
- Flow habitat delineation
- Slope (%) of 150m reach
- Photo documentation
- Habitat type and length (Practitioners can either follow the habitat typing protocol described in the SWAMP, or the Stream Conditions Inventory (SCI). The worksheet for data collection associated with the protocol has spaces for both or/or either method. Instructions on how to determine habitat typing following the SCI protocol can be found in the Stream Condition Inventory on page 31). Briefly, channel geomorphic units are divided into fast or slow water habitats. Fast water habitats can be further divided into turbulent and non-turbulent habitats, which subsequently can be divided into falls, ripples, cascades, rapids, shoots (turbulent) and sheets and runs (non-turbulent), respectively. Slow water habitats can be further divided into scour pools or dammed pools, which subsequently can be divided into eddy, trench, lateral, mid-channel, plunge, or convergence (scour) pools, and debris, landslide, beaver, backwater, and abandoned channel (dammed) pools respectively. We suggest surveying a minimum of 12-15 habitat units (or 150 meters, whichever is more) and if the habitat typing is longer than 150 m, we leave it to the practitioner to determine which other attributes to collect in that extra length of channel.
- Floodplain width- distance from terrace to terrace (to inform floodplain accessibility) at each habitat type segment or transect
- Height of current bankfull, and where it is in relation to the height of the historic floodplain terrace at each habitat type segment or transect

Stream Bank Observation

Observation of fish from the stream bank or other vantage point is a commonly used technique to determine presence or absence of fish. It also provides “gross” estimates of fish numbers in sampled habitats (e.g., 10-20 young-of-year steelhead). This method can be accomplished quickly and the only equipment required are polarized glasses and record forms or notebook.

The primary drawback to bank observation is difficulty with species identification. Observation experience associated with species confirmation techniques (electrofishing or trapping) can improve species identification skills. Numbers of fish observed are very rough estimates of relative abundance in selected habitats or stream reaches and should be used with caution. However, this type of information has many uses in describing existing conditions and comparing observations over several years. Useful data stems from observer consistency and careful attention to accuracy. Opportunities for observation are usually best in pools and runs where visibility is better than in riffles.

Habitats to be observed should be approached slowly and quietly from downstream; most fish orient themselves heading upstream when feeding. Patience is required to adjust the observer's eyes to the light conditions and to allow the fish to recover from any fright response caused by the observer's approach. Juvenile salmonids should be placed in general age categories according to length:

- 0+ young-of-year (YOY), 3 inches or less,
- 1+ 3 to 6 inches,
- 2+ 6 inches or greater.

These lengths are approximate and depend on stream systems and time of year. Generally, these size categories are obvious when groups are observed together. In most cases, the smaller size group will be more numerous. We suggest that observation takes place at least along the entire 150m sampling area. However, if resources permit, observing additional stream would provide more robust information. If fish are observed beyond the sampling area, please make a note of that as well in the supplied datasheet.

Underwater observation

This is a cost-effective method to determine fish distribution and species composition as well as fish behavior and habitat utilization. One or more divers, equipped with a mask, snorkel, and wet or dry suit, enter a sampling area at the downstream end and swim or crawl to the upstream end, counting, identifying, and recording all the fish they see. In small streams, a single, experienced diver can effectively count and identify all fish in a single pass. In larger streams or complex habitatss, a combination of divers working together systematically may be necessary to determine fish numbers. Since it is difficult to dive and count fish in riffles, underwater observation is usually only conducted on sample pool and run units.

Instructions for Completing the Stream Bank or Underwater Observation Field Form (supplied with this protocol)

1. Form No. - Enter in the form number.
2. Date
3. Stream Name
4. T-R-S - Enter the township, range, and section at the mouth of the stream.
5. Drainage - Enter the name of the drainage.
6. Lat - Record the latitude of the sampling location
7. Long - Record the longitude of the sampling location
8. Quad - Record the name of the USGS quadrangle of the sampling location
9. Observer(s) - Enter the names of the observers.
10. Time - Enter the time the survey began
11. Air Temperature
12. Water Temperature
13. Habitat Type - Enter the number or abbreviation for the individual habitat type being sampled. This should correlate with the PHab datasheets.
14. Reference Point - Stream confluence, a tributary, a road crossing, or any other permanent feature
15. Distance from the Confluence or other Known Location - Enter the distance in feet from the reference point.
16. Length of Stream Sampled in Feet
17. Observation Method - Put a check by the sampling method used in the survey.

7.1

AQUATIC SPECIES

Fish Observation & Aquatic Habitat Protocol

Equipment List

- Map of pre-chosen transect location
- Print out of this document
- Equipment decontamination supplies
- Waders
- Thermometer
- pH meter
- Water quality meter
- Calibration standards
- Digital camera
- GPS
- Stopwatch
- Spare batteries, parts for meters etc.
- Measuring tape
- Flags to mark transects
- Meter stick
- Clinometer
- Autolevel and tripod
- Current velocity meter and top setting rod
- Flagging tape
- Densiometer
- Pencil
- Physical Habitat (PHab) field forms
- Fish sampling datasheets
- Field notebook

For underwater observation

- Wet or dry suit
- Fins or wading boots
- Snorkel
- Plastic slate board
- Mask
- Waterproof felt pen

Collecting meadow aquatic habitat data

7.2 AQUATIC SPECIES

eDNA

Resource Target

Aquatic Species-eDNA and aquatic habitat

Indicators/Attributes

- Presence/absence of eDNA of target species
- Habitat type
- Hydrogeomorphic measurements

eDNA can be used instead of fish capture to identify presence/absence of fish species.

INTRODUCTION AND BACKGROUND

Sierra Nevadan meadows provide essential habitat to aquatic species. Meadow restoration actions are expected to improve habitat quality, and thus to increase the distribution and abundance of native fish and amphibians. Monitoring how the native biology and aquatic habitat of meadows respond to restoration actions indicates the success of the restoration effort and informs how actions might be altered in the future for increased effectiveness. Traditional sampling methods such as electrofishing can be deleterious to fish, so we encourage eDNA supplemented with fish observation surveys to determine the effects of meadow habitat restoration on fish assemblages.

What goals and/or restorations objectives are being evaluated with the indicators?

These indicators evaluate whether the restoration project resulted in an increase or a decrease in desired species distribution and/or abundance around the project area. In addition, the collection of aquatic habitat parameters determines the extent to which the restoration actions altered the stream condition/physical aquatic habitat of the area of interest.

When should these indicators be used?

When the goals and or objectives of the restoration include an increase in the amount and/or heterogeneity of aquatic habitat or desired species distribution or abundance, this protocol should be used prior to project implementation and during subsequent resurveys, which should take place between every 1-5 years for up to 20 years post implementation. At a minimum, this protocol should be completed once before project implementation, the year after implementation and again between one and five years later.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

This protocol addresses whether aquatic species distribution and potentially abundance, as well as aquatic habitat quantity and quality, has changed before and after meadow restoration implementation. The changes in species presence and composition can be correlated with restoration and other monitoring activities, but causation for changes in aquatic species cannot be concluded with certainty.

PLANNING

The methods used to collect and analyze eDNA are new and evolving, thus there is currently no one size fits all sampling protocol that can be used in the SM-WRAMP. The desired detection probability and available funding together will dictate the sampling protocol, which, in order to determine a detection probability, will need to be developed by using the R package Artemis, which is available here.

To determine the most suitable collection plan, contact the lab that will be analyzing the eDNA samples. Artemis can be used by a geneticist at Genidaqs ($150/hour and plan for 4 hours) or it can be done by an SMP representative, or the restoration practitioner (which might require more time, but cost less per hour) and will need to be done before field work.

Artemis was created to aid in the design and analysis of eDNA survey studies by offering a custom suite of models for eDNA sampling and qPCR data. The lab Genidaqs, located in Sacramento, California, can run Artemis to help teams come up with suitable sampling protocols. The number of samples collected, the distance between each sample, the amount of water filtered per sample, and the number of lab analyses of each sample will all be dictated by environmental conditions, characteristics of the species of interest, and the desired detection probability. For example, if a 50% detection probability is desired, then fewer samples will need to be collected and analyzed than if a 95% detection probability is desired. However, if the above steps are outside the scope of your eDNA sampling level of commitment, we recommend at least 7 samples are taken and analyzed in replicate at different transects that span the sampling area.

Data Collection Timing

Collection of eDNA data should occur during the low flow period prior to project implementation and during subsequent resurveys, which should take place between every 1-5 years for up to 20 years post implementation. At a minimum, this protocol should be completed once before project implementation, the year after implementation and again between one and five years later.

Required Resources

To determine the suitable collection plan using Artemis -

- 4 hours for Genidaqs geneticist @ $150/hour - $600; or approximately 8 hours for coordination with Rocky Mountain Research Station @$50/hour - $400
- Field planning and coordination – 4 hours @ $50/hour - $200
- Data collection in the field - 15 minutes/sample plus travel time; estimated 1 hour/sample for first 5 samples, 15 minutes for additional samples @$50/hour
- Getting data to lab for analysis - 1 hour @ $50/hour - $100
- Data post-processing and coordination - 4 hours @ $50/hour - $200
- eDNA Quantitative PCR analysis from Genidaqs lab - $150/sample for 1 species, additional species are $20/each; from Rocky Mountain Research station - $125/sample for 1 species, additional species are $20/each.

Time required per sampling/survey event (# people x: hours)
One person approximately 15 minutes from arrival to departure to collect and catalog each sample.

Equipment costs if new
Single use filter packs for use with Smith-Root backpack sampling unit (approximately $15/each)
Sampling equipment listed below if not using the Smith-Root backpack sampling unit - $200
Random (gloves, bags, pens, etc.) - $20

Level if any special expertise required
If the person/people collecting eDNA data do the required homework (read this document, contact Sandra Jacobson and Genidaqs or the Rocky Mountain Research Station, complete field planning, and create a sampling plan) ahead of data collection, they should be equipped to collect this data accurately and easily

Total Costs

For eDNA sampling from Genidaqs

- 5 samples, 1 species - $1100 set-up + $250 field collection + $750 lab analysis = $2,100
- 5 samples, 3 species - $1100 set-up + $250 field collection + $950 lab analysis = $2,300
- 10 samples, 1 species - $1100 set-up + $300 field collection + $1500 lab analysis = $2,900
- 10 samples, 3 species - $1100 set-up + $300 field collection + $1900 lab analysis = $3,300
- 20 samples, 1 species - $1100 set-up + $500 field collection + $3000 lab analysis = $4,600

7.2 eDNA Protocol

- 20 samples, 3 species - $1100 set-up + $500 field collection + $3800 lab analysis = $5,400
- (estimates do not include equipment costs)

Please see above for information on costs for analysis at the Rocky Mountain Research Station, which has assays for fewer potential species of interest as of the time that this document was created but a slightly less expensive cost to analyze species with assays already developed.

DATA ANALYSIS

Data storage

Once data is collected in the field, information recorded for each sample including the: sample ID, volume of water filtered, date, location description, GIS latitude and longitude, and notes/observations will need to be added to a digital data library.

All data should be uploaded to the meadows clearing house. If 50 or more eNA samples were collected and if funding permits, we suggest that data also be included in the eDNAtlas database from the USFS National Genomics Center for Wildlife and Fish Conservation (NGC). Contact information for the NGC can be found here.

Analysis Methods

Lab results will be given in an excel document with an explanation of data and conclusions related to hypotheses (namely, if the species of interest was/were present or not) from Genidaqs or the Rocky Mountain Research Station. If time and funding permit, occupancy models (which require the collection of several independent samples at each site) can be used to estimate the likelihood that an organism is present but is not detected with eDNA-based surveys (e.g., Erickson et al. 2017; Smith and Goldberg 2020). Occupancy models are most useful when there is a significant chance of false negative detection (missing a target individual that is present), which is possible with the type of monitoring that will be done by SM-WRAMP practitioners.

Evaluation Criteria

If the species of interest have not moved into the restored area and they were expected to, it is suggested that stakeholders discuss potential hypotheses for the species' distribution not changing and possible next steps.

ADAPTIVE MANAGEMENT

If the species of interest have not moved into the restored area, the habitat quantity and quality as indicated by the results of other SM-WRAMP protocols should be reviewed. If suitable habitat is available during the right time and at the desired location, additional eDNA sampling can be done to check previous results and provide further information.

COORDINATION

eDNA sampling sites can occur at any flat, stable area with medium flow, which could overlap with data collection sites from any of the other SM-WRAMP protocols.

Person(s) who populated the specific protocol

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FIELD DATASHEETS & DATA UPLOAD FORMS

The following form is available to be downloaded from https://californiatroutinc.box.com/s/u0ua4jr2vxt3ef7sz6g547v3ct157v30

- Cramer Fish Sciences eDNA Sample Submission Form

REFERENCES

1. Blankenship, S.M. and G. Schumer. 2017. Field Collection Procedure for Aquatic Environmental DNA sample collection and analysis. Cramer Fish Sciences Genidaqs, Sacramento, California.
2. Carim, K. J., K. S. McKelvey, M. K. Young, T. M. Wilcox, and M. K. Schwartz. 2016b. A protocol for collecting environmental DNA samples from streams. U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.
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4. Smith, M. M., and C. S. Goldberg. 2020. Occupancy in dynamic systems: accounting for multiple scales and false positives using environmental DNA to inform monitoring. Ecography 43:376–386.

eDNA & Aquatic Habitat Protocol

7.2
AQUATIC SPECIES

This protocol details how to determine if species of interest are in the project area before and/or after the project using eDNA, snorkel surveys, or amphibian surveys.

Print & Carry Field Instructions & Equipment List

PROTOCOL DESCRIPTION

If possible, eDNA should be used in collaboration with fish collection for more accurate information. Non-capture methods are detailed in an accompanying protocol we developed. For information on fish capture methods such as electrofishing, please see the “California Salmonid Stream Habitat Restoration Manual” here.

The methods used to collect and analyze eDNA are new and evolving, thus there is currently no model available for estimating the ideal sampling interval for a particular system that can be used in the SM-WRAMP, especially because it is likely that target species are present in low abundance and habitat in meadows can be highly heterogeneous.

However, a species’ distribution can be used to increase detection efficiency by targeting sampling when and where individuals are most likely to be present. In addition, to control for habitat heterogeneity throughout a given stream and to maintain objectivity in study design, it is recommended that eDNA sampling occurs at a consistent spatial interval throughout the study area while allowing some flexibility to add or slightly move sampling locations to further increase the probability of detection based on prior knowledge of the habitat or species distributions in a particular area.

Furthermore, sampling during base flow conditions will increase the probability of detecting a target species, particularly at low densities and on a fine spatial scale, such as what will be most common in projects that use the SM-WRAMP.

BEFORE GOING OUT INTO THE FIELD

1. Become familiar with how to use the Smith-Root backpack sampling unit.

2. Coordinate with Sandra Jacobson (sjacobson@caltrout.org) to schedule getting and using the Smith-Root backpack sampling unit for eDNA sample collection.

3. Contact the lab that will be doing the eDNA processing (we recommend Genidaqs, a private lab located in Sacramento; genidaqs@fishsciences.net and the Rocky Mountain Research Station, a US Forest Service lab, see https://www.fs.usda.gov/rmrs/ngc/edna for more information) to inform them about the project, decide upon an eDNA sampling strategy, and create a plan for getting them the samples after collection.

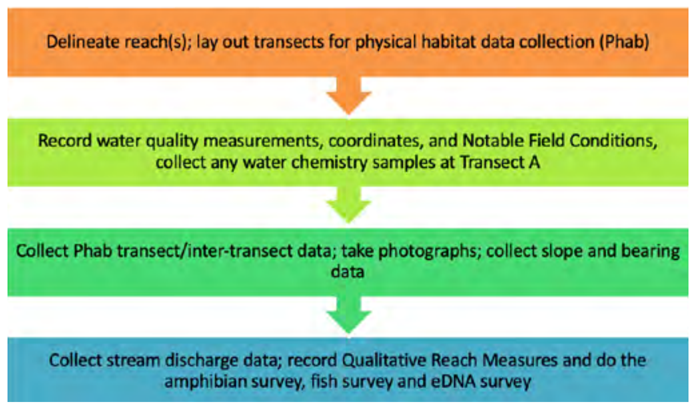
4. To eliminate bias, target coordinates for transect locations should be determined at random from the reach within the area most likely to display change based on analyses of channel morphology, biological communities and processes, and existing or proposed management activities before going out into the field. Target coordinates should be placed on a map (paper or digital) for visual orientation in case the GPS is not functioning in the field. If practitioners prefer to pre-determine the study reach, which is especially suitable if a reach or reaches longer than 150m will be surveyed, that is also acceptable.

5. Gather sampling equipment

- Map of pre-chosen transect location
- Print out of this document
- Equipment decontamination supplies
- Waders
- Thermometer
- pH meter
- Water quality meter
- Calibration standards
- Digital camera
- GPS
- Stopwatch
- Spare batteries, parts for meters etc.
- Measuring tape
- Flags to mark transects
- Meter stick
- Clinometer
- Autolevel and tripod
- Current velocity meter and top setting rod
- Flagging tape
- Densiometer
- Pencil
- Physical Habitat (PHab) field forms
- Fish sampling datasheets
- Field notebook
- Smith-Root backpack unit and accessories
- Single-use filter packs for each planned collection site, plus several extras
- Nitrile gloves (non-powdered)
- Ziploc bags
- Permanent markers

IN THE FIELD

Suggested Work-Flow Diagram



Upon arrival at the site, fill out the "Reach Documentation" section of the PHab field form. Record the geographic coordinates of the downstream end (Transect A) of the reach with a GPS receiver and record the datum setting (preferably NAD83) of the unit. Sampling locations can be moved up or downstream as much as 300 m from the predetermined target location for reasons such as avoiding obstacles, mitigating issues regarding safety or permission to access, and GPS error. Because GIS information about stream locations is imperfect, the target coordinates may not fall exactly on a streambed, but rather nearby, requiring a shift in order to correspond to the nearest aquatic habitat. The potential discrepancy between the target coordinates and where sampling actually occurs makes it essential to record the actual field coordinates on the field sheet.

To delineate the monitoring reach, first scout it to ensure it is of adequate length for sampling biota. Delineate a 150 m reach for sampling. Again, if the practitioner has the resources to survey a longer reach or multiple reaches likely to display change we encourage them to do so. The 150 m reach discussed here is a minimum.

Use markers (e.g., wire-stemmed flags) to indicate locations of transects and intertransects. The standard sampling layout consists of 11 “main” transects (A-K) interspersed with 10 “inter-transects”, all of which are placed at equal distances from one to the next (7.5m). The first flag should be installed at water’s edge on one bank at the downstream limit of the sampling reach to indicate the first main transect (“A”). The positions of the remaining transects and inter-transects are then established by heading upstream along the bank and using the transect tape or a segment of rope of appropriate length to measure off successive segments of 7.5m, or more if fewer transects are being used.

Physical Habitat (PHab) Transect-Based Field Measurements

For a detailed explanation of how to collect PHab data, please see the “SWAMP Bioassessment Procedures” (2016) document available here. The following “Basic” list of PHab measurements reflects the minimum amount of physical and chemical data that should be taken along with any biological samples. In addition, several hydrogeomorphic variables that measure connection to the floodplain and amount of incision are included.

- Layout of reach, marking transects, recording GPS coordinates
- Temperature, pH, specific conductance, salinity, DO, alkalinity
- Notable field conditions
- Wetted width
- Stream shading
- Bank stability and entrenchment
- Percent algal cover
- Flow habitat delineation
- Slope (%) of 150m reach
- Photo documentation
- Habitat type and length (Practitioners can either follow the habitat typing protocol described in the SWAMP, or the Stream Conditions Inventory (SCI). The worksheet for data collection associated with the protocol has spaces for both or/or either method. Instructions on how to determine habitat typing following the SCI protocol can be found in the Stream Condition Inventory on page 31. Briefly, channel geomorphic units are divided into fast or slow water habitats. Fast water habitats can be further divided into turbulent and non-turbulent habitats, which subsequently can be divided into falls, ripples, cascades, rapids, shoots (turbulent) and sheets and runs (non-turbulent), respectively. Slow water habitats can be further divided into scour pools or dammed pools, which subsequently can be divided into eddy, trench, lateral, mid-channel, plunge, or convergence (scour) pools, and debris, landslide, beaver, backwater, and abandoned channel (dammed) pools respectively. We suggest surveying a minimum of 12-15 habitat units (or 150 meters, whichever is more) and if the habitat typing is longer than 150 m, we leave it to the practitioner to determine which other attributes to collect in that extra length of channel.
- Floodplain width- distance from terrace to terrace (to inform floodplain accessibility) at each habitat type segment or transect
- Height of current bankfull, and where it is in relation to the height of the historic floodplain terrace at each habitat type segment or transect

PREFERRED METHOD
eDNA sampling with Smith-Root backpack sampler

The Smith-Root backpack unit, acquired by CalTrout will monitor and regulate flow and pressure across your filter to provide maximum DNA yield per volume of water and to standardize the amount of water filtered. If possible, watch this short video about how to set up the unit here.

Note: Sample contamination is one of the main concerns with eDNA collection. Making sure that all items used in sample collection are either sterilized or single use, and not entering the water (or entering downstream of the sampling site, if necessary) can decrease the chance of sample contamination with DNA that is not from the species of interest.

eDNA water sample collection

System set-up

1. Find a stable spot to place backpack and bipod
2. Extend first pole segment
3. Run long tubing up through eyelets
4. Connect other end to “In” port on side of backpack
5. Connect short tubing to “out” port on other side of backpack
6. Open a new eDNA filter packet
7. Carefully remove filter housing and attach to tubing extension/snorkel tube (while still in the bag)
8. Place filter housing in clamp at the end of the tripod and tighten (do not overtighten)
9. Attach end of tubing threaded through eyelets to end of filter housing
10. Power on the remote

Water filtration sampling

1. Extend bipod legs by depressing button at the top of legs *Do not twist bipod legs*
2. Extend pole to needed length
3. Dip the filter housing into the water, holding at the other end (will be like a fishing pole with no line)
4. Select mode on the remote and start pump. Water will come up through the tubing, the remote will measure how much water has been filtered (5 L is standard)
5. When you hear two beeps, quickly invert the tubing by twisting the extended first pole segment and then take the pole out of water and elevate to assist the tube clearing the water
6. Stop the pump when the tube is cleared

Sample (eDNA) Preservation

1. Retract pole to retrieve sample
2. Remove the filter housing from the bag (contents in this bag are all single use)
3. With gloves on and clean forceps, grab the filter paper. Use the snorkel tube to assist in folding it several times, so it will fit in the sample tube
4. Place folded filter paper into 95% ethanol
5. Place preserved samples in backpack storage. Record the: sample ID, volume of water filtered, date, location description, GIS latitude and longitude, and notes/ observations.
6. Pack up everything to prepare for the next sampling location (tubing can be left rigged in the pole if desired)

OPTIONAL METHOD

eDNA water sample collection (does not use extender arm of Smith-Root backpack; can be used with any pump)

1. Use sterilized wide mouth bottle to collect water near surface of target area
2. Connect long tubing to “In” port on side of backpack
3. Connect short tubing to “out” port on other side of backpack
4. Open a new eDNA filter packet
5. Carefully remove filter housing and attach to tubing extension/snorkel tube (while still in the bag)
6. Power on the remote and start pump
7. Use backpack, or whatever pump is available, to pass water through filter (don’t use the extender arm for sampling).
8. Remove the filter housing from the bag (contents in this bag are all single use)
9. With gloves on and clean forceps, grab the filter paper and fold
10. Place folded filter paper into 95% ethanol
11. Record the: sample ID, volume of water filtered, date, location description, GIS latitude and longitude, and notes/ observations
12. Place preserved samples in cold, dry and dark storage (cooler with blue ice packs would be ideal)
13. Pack up everything to prepare for the next sampling location

eDNA sampling without Smith-Root backpack sampler

If you plan to use Genidaq to process eDNA samples, please follow Genidaq’s eDNA sampling procedure available here. Once back from the field, samples should be dropped off or sent to the Genidaqs lab in Sacramento as quickly as possible with the submission form.

If you plan to use the Rocky Mountain Research Station to process eDNA samples, please follow their eDNA sampling procedure available here. Once back from the field, samples should be sent to the Rocky Mountain Research Station lab as quickly as possible with the submission form which can be obtained by contacting the lab at ngc@usda.gov.

eDNA Protocol Checklist

Equipment List

7.2

AQUATIC SPECIES

With Smith-Root backpack unit (preferred method)

- Smith-Root backpack unit and accessories
- Single-use filter packs for each planned collection site, plus several extras
- Nitrile gloves (non-powdered)
- Ziploc bags
- Permanent markers
- GPS with extra batteries

Without Smith-Root backpack unit (as listed in alternative Genidaqs protocol)

- Cordless drill (brushless)
- Pump driver bit (1/2 inch spade)
- Backup drill battery and battery charger
- Cole Parmer Peristaltic Pump MasterFlex Easy Loader II Model#77200-52
- USEPA approved Millipore Sterivex™0.45 µm sterile filter units (EPA# 90260-ITA-001)
- Masterflex spooled peroxide-cured silicon tubing, L/S 15
- Tube adaptor (Cole Parmer 30800-22)8) Inlet caps (Qiagen Mat. No. 1104193)
- Outlet caps (Qiagen Mat. No. 1104194)
- Graduated beaker
- Nitrile gloves (non-powdered)
- Ziploc bags
- Permanent markers
- Backpack and chestpack
- GPS with extra batteries
- Cooler with blue ice pack
- Ice chest with blue ice packs
- Garbage bags

7.3 AQUATIC SPECIES

BMI

Resource Target

Aquatic Species-Benthic Macroinvertebrates (BMI) and aquatic habitat

Indicators/Attributes

- Aquatic invertebrate assemblages collected at transects
- Habitat type
- Hydrogeomorphic measurements

Benthic macroinvertebrate sampling

INTRODUCTION AND BACKGROUND

Sierra Nevadan meadows provide essential habitat to aquatic species. Meadow restoration actions are expected to improve habitat quality, and thus to increase the distribution and abundance of native fish and amphibians as well as increase the food availability for these species. Monitoring how the biology and aquatic habitat of meadows respond to restoration actions indicates the success of the restoration effort and informs how actions might be altered in the future for increased effectiveness.

What goals and/or restorations objectives are being evaluated with the indicators?

These indicators evaluate whether the restoration project resulted in physical and biological responses, in terms of invertebrates, to restoration implementation and indicates the food availability for other aquatic species such as fish and amphibians. Because benthic invertebrates are sensitive to environmental changes and can respond quickly and with greater clarity (for example, higher numbers) than other biological indicators like fish, they are often used in bioassessment and biomonitoring programs. Depending on what the specific goals of the project are, the types of metrics calculated from collected benthic invertebrate data will vary. Generally, for BACI projects, an increase in invertebrate diversity, and an increase in sensitive taxa (mayflies-Ephemeroptera, caddisflies-Trichoptera, and stoneflies-Plecoptera) might reflect increased habitat complexity (which is a good thing in meadows) or improved water quality conditions, respectively.

When should these indicators be used?

When the goals and/or objectives of the restoration include an increase in the amount and/or heterogeneity of aquatic habitat, food availability for fish and/or amphibians, or an increase in overall biodiversity or stream productivity, this protocol should be used prior to project implementation and during subsequent resurveys, which should take place between every 1-5 years for up to 20 years post implementation. At a minimum, this protocol should be completed once before project implementation, the year after implementation and again between one and five years later.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

This protocol addresses whether benthic invertebrate biodiversity, assemblage structure and/or biomass, as well as aquatic habitat quantity and quality has changed before and after restoration implementation. The changes can be correlated with restoration and other monitoring activities, but causation for changes in aquatic habitat and species cannot be concluded with certainty.

PLANNING

Data Collection Timing

Samples should be taken prior to project implementation and during subsequent resurveys, which should take place between every 1-5 years for up to 20 years post implementation. At a minimum, samples should be collected once before project implementation, the year after implementation and again between one and five years later. For accurate results, samples should be taken in replicate, with three replicates being preferred.

Required Resources

Data collection in the field: 6-12 hours plus traveling time. Lab analyses: 1-4 hours per sample, or $30-$100 per sample if sent to Utah State University's BugLab.

Time required per sampling/survey event (# people x: hours)
A crew of 2+ people should be able to complete this protocol in 2-6 hours, not including travel time.

Equipment costs if new

- Dnet or some 500 μm net - $40
- 95% alcohol to preserve samples - $20
- Wide-mouthed sealable jars to put samples - $20
- Permanent markers for labeling - $5
- Pencil and paper for labels placed inside samples - $5
- Field notebook - $5
- Equipment decontamination supplies - $50
- Waders - $100
- Thermometer - $10
- pH meter - $200
- Water quality meter - $200
- Digital camera - $100
- GPS - $100
- Stopwatch - $5
- Spare batteries, parts for meters etc. - $20
- Measuring tape - $5
- Flags to mark transects - $5
- Meter stick - $40
- Clinometer - $50
- Autolevel and tripod - $100
- Current velocity meter and top setting rod $500
- Flagging tape - $5
- Densiometer - $100
- Sieve with 500 μm mesh (#35) - $60
- Pipettes - $10
- Forceps - $10
- Preprinted waterproof labels - $10
- Large spill tray - $20

Level if any special expertise required
If the person/people collecting invertebrates will be doing it for the first time, it is suggested that they watch a collection videos. One helpful video can be found here. There is also substantial information available on the Utah State University's BugLab website here.

An individual or group with substantial experience in invertebrate sorting and identification will need to lead lab analyses if they are done in house.

Total Costs

- Field equipment-$1,700-$2,000
- Sample analyses-$30-$200/sample depending on analysis methods

DATA ANALYSIS

Data storage

Once data is collected in the field, information recorded for each sample including the: sample ID, volume of water filtered, date, location description, GIS latitude and longitude, and notes/observations will need to be added to a digital data library. All data should be uploaded to the meadows clearing house.

Analysis Methods

As discussed above, for information on the overall biological diversity of the system before and after restoration, invertebrates should be picked from the collected sample in the laboratory and identified to species if possible, and

7.3 BMI Protocol

otherwise to the lowest taxonomic group given budget and/or personnel constraints. If the space sampled and sampling time are consistent, results can be compared before and after restoration to see if the number of species have changed. Replicate samples will improve the power of statistical results.

For information on how the biology of a site is responding to water and habitat quality, invertebrates should be picked from the collected sample in the laboratory and identified to order or family. The proportion of sensitive stream insects (Ephemeroptera, Plecoptera and Trichoptera, or EPT, which generally have lower tolerance to water pollution and warmer temperatures) to more tolerant insects should be measured and compared before and after restoration implementation.

To calculate biomass of BMI, we suggest the ash-free dry mass method. To calculate ash-free dry mass, picked invertebrates should be dried at 50 °C for 48 hours, weighed, ashed at 500 °C for 2 hours, and re-weighed (Wissinger et al. 2006). Additional sampling strategies can be found in (Carter and Resh 2001, 2013).

Evaluation Criteria

If the indicators of interest have not improved and they were expected to, it is suggested that stakeholders discuss potential hypotheses for the species' distribution not changing and possible next steps.

ADAPTIVE MANAGEMENT

If the indicators of interest have not improved post restoration, habitat quantity and quality as indicated by the results of other SM-WRAMP protocols should be reviewed. If habitat has not improved, additional restoration or on-going stewardship actions should be decided upon and taken.

COORDINATION

Sampling can overlap both spatially and temporally with data collection from any of the other SM-WRAMP protocols, such as hydrology or geomorphology.

Person(s) who populated the specific protocol

Natalie Stauffer-Olsen, nstauffer-olsen@tu.org, (707) 696-9839

REFERENCES

1. Carter, J. L., and V. H. Resh. 2001. After site selection and before data analysis : sampling , sorting , and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies. Journal of the North American Benthological Society 20:658–682.
2. Carter, J. L., and V. H. Resh. 2013. Analytical Approaches Used in Stream Benthic Macroinvertebrate Biomonitoring Programs of State Agencies in the United States.
3. Wissinger, S. A., A. R. Mcintosh, and H. S. Greig. 2006. Impacts of introduced brown and rainbow trout on benthic invertebrate communities in shallow New Zealand lakes. Freshwater Biology 51:2009–2028.

Aquatic Invertebrate Species and Habitat Protocol

7.3
AQUATIC SPECIES

This protocol details how to collect aquatic invertebrate samples and aquatic habitat typing data based on a transect layout to determine if invertebrate biodiversity, assemblage structure and/or biomass has changed after restoration actions.

Print & Carry Field Instructions & Equipment List

PROTOCOL DESCRIPTION

The methods proposed here are adapted from the document "Standard Operating Procedures (SOP) for the Collection of Field Data for Bioassessments of California Wadeable Streams: Benthic Macroinvertebrates, Algae, and Physical Habitat", also called the Surface Water Ambient Water Monitoring (SWAMP) protocol, which is available here. Alternatively, practitioners can choose to use the Stream Condition Inventory to monitor aquatic habitat.

The number of transects and replicates will depend on the scope, goals, objectives, and funding of a project. Here, we recommend as a minimum 11 duplicate samples collected at 11 transects spread out over a randomly chosen 150m reach within the area most likely to display change based on analyses of channel morphology, biological communities and processes, and existing or proposed management activities. If the management activities are to be carried out across a large meadow or are expected to have measurable impacts to a large section of a meadow, we encourage practitioners to choose multiple 150m reaches or to extend the reach as necessary. Another method for determining the study reach is available in the Stream Condition Inventory.

Replicates of the 11 subsamples are then combined into two replicate composite samples that should capture much of the natural variability in the invertebrate biology of the site. In order for this protocol to be useful, we recommend a minimum of 5 transects be laid out and all the associated data collected. BACI invertebrate sampling should occur at the same time of year in order to ensure that invertebrate assemblages are as comparable as possible. Sampling should occur above, within and downstream of the project area, and ideally BMI and aquatic habitat data would also be collected from two additional transect layouts near where the stream enters the meadow and near where the stream exits the meadow.

Lab analyses will be dictated by the objectives of the monitoring effort. For example, if information on the overall biological diversity of the system before and after restoration is desired, then analysis of collected samples will focus on species identification and the overall number of species or taxonomic groups (order, family, genus, etc.) of collected samples. If information on how biology is responding to water and habitat quality, the proportion of sensitive stream insects (ie those that generally have low tolerance to water pollution and warmer water temperatures such as Ephemeroptera, Plecoptera and

Trichoptera, or EPT) to more tolerant insects should be measured. If the food availability for salmonids is of interest, then analysis of collected samples should measure the biomass before and after restoration implementation. Please see below for more information.

BEFORE GOING OUT INTO THE FIELD

1. To eliminate bias, target coordinates for transect locations should be determined at random from the reach within the area most likely to display change based on analyses of channel morphology, biological communities and processes, and existing or proposed management activities before going out into the field. Target coordinates should be placed on a map (paper or digital) for visual orientation in case the GPS is not functioning in the field. If practitioners prefer to pre-determine the study reach, which is especially suitable if a reach or reaches longer than 150m will be surveyed, that is also acceptable.

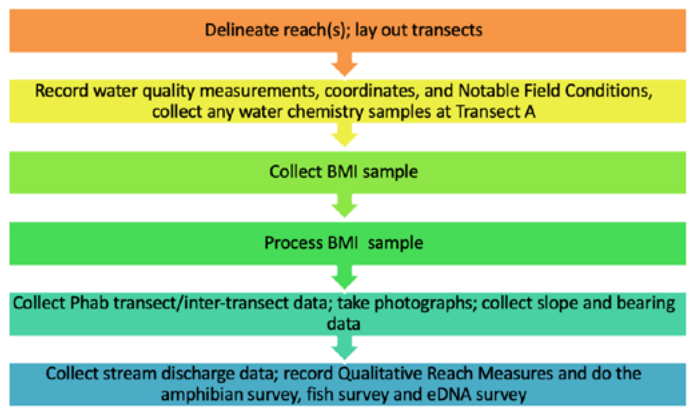
2. Gather sampling equipment

- Map of pre-chosen transect location
- Print out of this document
- Equipment decontamination supplies
- Waders
- Thermometer
- pH meter
- Water quality meter
- Calibration standards
- Digital camera
- GPS
- Stopwatch
- Spare batteries, parts for meters etc.
- Measuring tape
- Flags to mark transects
- Meter stick
- Clinometer
- Autolevel and tripod
- Current velocity meter and top setting rod
- Flagging tage
- Densiometer
- Dnet or some 500 μm net
- 95% alcohol to preserve samples
- Wide-mouthed sealable jars to put samples-several per sampling site
- Permanent markers for labeling
- Pencil and paper for labels placed inside samples
- Physical Habitat (PHab) field forms
- Field notebook
- Sieve with 500 μm mesh
- Pipettes
- Forceps
- Preprinted waterproof labels
- Large spill tray

3. Contact Utah State University's BugLab (trip.armstrong@usu.edu) to request a quote if samples will be analyzed out of house and to confirm the sample submission process.

IN THE FIELD

Suggested Work-Flow Diagram



Upon arrival at the site, fill out the "Reach Documentation" section of the PHab field form. Record the geographic coordinates of the downstream end (Transect A) of the reach with a GPS receiver and record the datum setting (preferably NAD83) of the unit. Sampling locations can be moved up or downstream as much as 300 m from the predetermined target location for reasons such as avoiding obstacles, mitigating issues regarding safety or permission to access, and GPS error. Because GIS information about stream locations is imperfect, the target coordinates may not fall exactly on a streambed, but rather nearby, requiring a shift in order to correspond to the nearest aquatic habitat. The potential discrepancy between the target coordinates and where sampling actually occurs makes it essential to record the actual field coordinates on the field sheet.

To delineate the monitoring reach, first scout it to ensure it is of adequate length for sampling biota. Delineate a 150 m reach for sampling. Again, if the practitioner has the resources to survey a longer reach or multiple reaches likely to display change we encourage them to do so. The 150 m reach discussed here is a minimum.

Use markers (e.g., wire-stemmed flags) to indicate locations of transects and intertransects. The standard sampling layout consists of 11 “main” transects (A-K) interspersed with 10 “inter-transects”, all of which are placed at equal distances from one to the next (7.5m). The first flag should be installed at water’s edge on one bank at the downstream limit of the sampling reach to indicate the first main transect (“A”). The positions of the remaining transects and inter-transects are then established by heading upstream along the bank and using the transect tape or a segment of rope of appropriate length to measure off successive segments of 7.5m, or more if fewer transects are being used.

Invertebrate Collection

Step 1. Invertebrate collection position alternates between left, center, and right portions of the main transects, as one proceeds upstream from one transect to the next. These sampling locations are defined as the points at 0% (left bank) 25% (“left”), 50% (“center”), 75% (“right”) and 100% (right back) across the wetted width in most systems. The left and right sides of the stream are determined when facing downstream. Two invertebrate samples should be collected at each transect. The second sample should be to the right of the previous position (for example, 0% then 25% or 75% and then 100%).

Step 2. Once the sampling spot is identified, place the 500-µm D-frame net in the water 5-10 cm downstream of the sampling location, depending on flow. Determine net placement based on where disturbed sediment is flowing; you want disturbed sediment to flow easily into the net. Position the net so its mouth is perpendicular to, and facing into, the flow of the water.

Step 3. Holding the net in position on the substrate, visually define a square shape (a “sampling plot”) on the stream bottom upstream of the net opening, approximately one net-width wide and one net-width long. Because standard D-nets are 12 inches wide, the area within this plot is 1ft2 (0.09 m2). Restrict sampling to within that area.

Step 4. Working backward from the upstream edge of the sampling plot, check the sampling plot for heavy organisms such as mussels, caddis cases, and snails. Remove these organisms from the substrate by hand and place them into the net. Carefully pick up and rub stones directly in front of the net to remove attached animals. Pick up and clean all of the large rocks within the sampling plot such that all the organisms attached to them are washed downstream into the net. Set these rocks outside the sampling plot after they have been cleaned. Large rocks that protrude less than halfway into the sampling area should be pushed aside. If the substrate is consolidated, bedrock, or comprised of large, heavy rocks, kick and dislodge the substrate (with the feet) to displace BMIs into the net. If a rock cannot be removed from the stream bottom, rub it with your hands or feet (concentrating on cracks or indentations), thereby loosening any attached insects. While disturbing the plot, let the water current carry all loosened material into the net. Do not use a brush to dislodge organisms from substrates.

Step 5. Once the coarser substrates have been removed from the sampling plot, dig through the remaining underlying material with fingers or a digging tool (e.g., rebar or an abalone iron) to a depth of 1-10 cm (less in sandy streams), where gravels and finer particles are often dominant. Thoroughly manipulate the substrates in the plot to encourage flow to dislodge any resistant organisms. To the extent practical, reduce the amount of sand particles in the net, as they damage organisms and degrade taxonomic data quality.

For slack-water habitats, vigorously kick the remaining finer substrate within the plot using the feet while dragging the net repeatedly through the disturbed area just above the bottom. Keep moving the net so that the organisms trapped in the net will not escape. Continue kicking the substrate and moving the net. For vegetation-choked sampling points, sweep the net through the vegetation. When finished, remove the net from the water with a quick, upward motion to wash the organisms to the bottom of the net.

Notes:

- The sampler may spend as much time as necessary to inspect and clean larger substrates (Step 4), but should take a standard time for the disturbance portion of this protocol (Step 5). We suggest that 3 minutes in fast water units and 5 minutes in slow-water units should be appropriate time periods for Step 5. Make sure to note how long each sample was collected for. This will help standardize samples within and among sites.
- If possible, choose sampling sites where the surface of the water flows into the net area when the net is on the bottom substrate so that invertebrates drifting in the water column are also collected.

Step 6. Let the water run clear before carefully lifting the net. Dip the lower portion of net in the stream several times to remove fine sediments and to concentrate organisms into the end of the net, while being careful to prevent water or foreign material from entering the mouth of the net. Be particularly careful to avoid “backflow” situations, in which collected material restricts flow through the net and the resulting turbulent flow causes collected material to escape the net; this is a major potential source of loss of BMIs during sampling.

Step 7. Collect the duplicate sample at the position to the right (when looking downstream) of the first sample. For example, at Transect A, BMI samples are collected at 0% (ie left bank) and 25% of the wetted width. At Transect B, samples are collected at 50% and 75% of the wetted width. At Transect C, samples are collected at 100% (ie right bank) and 0% of the wetted width. At Transect D, samples are collected at 25% and 50% of the wetted width.

Step 8. Move on to the next transect to repeat the sampling process across all 11 main transects. For BMIs, crews should skip the dry transects and make a note of how many subsamples were ultimately collected (i.e., some number < 11).

Step 9. Each of the 11 samples from the 11 transects should be combined to create two replicate composite samples. Fill sampling jar(s) (no more than half full) with 95% ethanol and label outside with permanent marker. Include: sample ID, date, location name, GPS coordinates, and collector. With pencil, write sampling information on a piece of paper and place in the jar with the sample. Double labeling like this ensures that collection information will be accurate even if the outside label smears.

Step 10. Turn net upside down into sampling jar and place sample into the jar. Dip net in water to again concentrate the remaining part of the sample in the bottom of the net, and turn the net upside down again into the jar to make sure that all invertebrates in the net are captured in the sampling jar. Make sure that ethanol covers the entire sample. Swirl sample to gently mix ethanol into the entire sample.

Step 11. Repeat at other sampling locations, if there are additional transect layouts to sample (ie at the top or bottom of the meadow).

Step 12. Once samples are collected, transport to the lab for analysis and identification or send to Utah State University's BugLab as detailed here.

Step 13. Check invertebrate samples every 6 months after collection and refill with 95% alcohol as even tightly sealed jars will slowly evaporate with time and samples could dry out.

Physical Habitat (PHab) Transect-Based Field Measurements

For a detailed explanation of how to collect PHab data, please see the "SWAMP Bioassessment Procedures" (2016) document available here. The following "Basic" list of PHab measurements reflects the minimum amount of physical and chemical data that should be taken along with any biological samples. In addition, several hydrogeomorphic variables that measure connection to the floodplain and amount of incision are included.

- Layout of reach, marking transects, recording GPS coordinates
- Temperature, pH, specific conductance, salinity, DO, alkalinity
- Notable field conditions
- Wetted width
- Stream shading
- Bank stability and entrenchment
- Percent algal cover
- Flow habitat delineation
- Slope (%) of 150m reach
- Photo documentation
- Habitat type and length (Practitioners can either follow the habitat typing protocol described in the SWAMP, or the Stream Conditions Inventory (SCI). The worksheet for data collection associated with the protocol has spaces for both or/or either method. Instructions on how to determine habitat typing following the SCI protocol can be found in the Stream Condition Inventory on page 31). Briefly, channel geomorphic units are divided into fast or slow water habitats. Fast water habitats can be further divided into turbulent and non-turbulent habitats, which subsequently can be divided into falls, ripples, cascades, rapids, shoots (turbulent) and sheets and runs (non-turbulent), respectively. Slow water habitats can be further divided into scour pools or dammed pools, which subsequently can be divided into eddy, trench, lateral, mid-channel, plunge, or convergence (scour) pools, and debris, landslide, beaver, backwater, and abandoned channel (dammed) pools respectively.
  We suggest surveying a minimum of 12-15 habitat units (or 150 meters, whichever is more) and if the habitat typing is longer than 150 m, we leave it to the practitioner to determine which other attributes to collect in that extra length of channel.
- Floodplain width- distance from terrace to terrace (to inform floodplain accessibility) at each habitat type segment or transect
- Height of current bankfull, and where it is in relation to the height of the historic floodplain terrace at each habitat type segment or transect

Lab Analyses

Utah State University's BugLab is an excellent place to send samples for analyses. Substantial collection information including sample submission and analyses options can be found on their website here.

For information on the overall biological diversity of the system before and after restoration, invertebrates should be picked from the collected sample in the laboratory and identified to species if possible, and otherwise to the lowest taxonomic group given budget and/or personnel constraints. If the space sampled and sampling time are consistent, results can be compared before and after restoration to see if the number of species have changed. Replicate samples will improve the power of statistical results.

For information on how the biology of a site is responding to water and habitat quality, invertebrates should be picked from the collected sample in the laboratory and identified to order or family. The proportion of sensitive stream insects (Ephemeroptera, Plecoptera and Trichoptera, or EPT, which generally have lower tolerance to water pollution and warmer temperatures) to more tolerant insects should be measured and compared before and after restoration implementation.

To calculate biomass of BMI, we suggest the ash-free dry mass method. To calculate ash-free dry mass, picked invertebrates should be dried at 50 °C for 48 hours, weighed, ashed at 500 °C for 2 hours, and re-weighed (Wissinger et al. 2006). Additional sampling strategies can be found in (Carter and Resh 2001, 2013).

Notes:
If time and/or funding is limited, composite sample can be subsampled. To do this, we suggest that the sample is poured into a tray in the lab and divided by eye in half, or some other fraction-just make sure to take good notes and alter later calculations accurately.

BMI Protocol

Equipment List

7.3
AQUATIC SPECIES

- Map of pre-chosen transect location
- Print out of this document
- Equipment decontamination supplies
- Waders
- Thermometer
- pH meter
- Water quality meter
- Calibration standards
- Digital camera
- GPS
- Stopwatch
- Spare batteries, parts for meters etc.
- Measuring tape
- Flags to mark transects
- Meter stick
- Clinometer
- Autolevel and tripod
- Current velocity meter and top setting rod
- Flagging tape
- Densiometer
- Dnet or some 500 μm net
- 95% alcohol to preserve samples
- Wide-mouthed sealable jars to put samples-several per sampling site
- Permanent markers for labeling
- Pencil and paper for labels placed inside samples
- Physical Habitat (PHab) field forms
- Field notebook
- Sieve with 500 μm mesh
- Pipettes
- Forceps
- Preprinted waterproof labels
- Large spill tray

7.4 AQUATIC SPECIES

Amphibians

Resource Target

Aquatic Species-Amphibians and aquatic habitat

Indicators/Attributes

- Amphibian presence (species, number)
- Habitat type
- Hydrogeomorphic measurements

The Sierra Nevada yellow-legged frog, which once swam in fishless waters, is predated on by non-native fish.

INTRODUCTION AND BACKGROUND

Sierra Nevadan meadows provide essential habitat to aquatic species including amphibians. Some meadow restoration actions are expected to improve habitat quality and/or quanity, and thus to increase the distribution and abundance of native amphibian populations. Monitoring how amphibian populations and aquatic habitat respond to restoration actions indicates the success of the restoration effort and informs how actions might be altered in the future for increased effectiveness.

What goals and/or restorations objectives are being evaluated with the indicators?

The species and numbers of amphibians found on a consistent transect layout before and after a restoration project informs whether the restoration project appeared to support a change in the population around the project site. In addition, the collection of aquatic habitat parameters determines the extent to which the restoration actions altered the stream condition/ physical aquatic habitat of the area of interest.

When should these indicators be used?

When the goals and/or objectives of the restoration include an increase in the amount and/or heterogeneity of aquatic habitat and/or amphibians, this protocol should be used prior to project implementation and during subsequent resurveys, which should take place between every 1-5 years for up to 20 years post implementation. At a minimum, this protocol should be completed once before project implementation, the year after implementation and again between one and five years later.

What questions/uncertainties are being answered/addressed and what is not being addressed by the measured indicators?

This protocol addresses whether amphibian populations, as well as aquatic habitat quantity and quality, have changed before and after restoration implementation. The changes can be correlated with restoration and other monitoring activities, but causation for changes in amphibian populations cannot be concluded with certainty.

PLANNING

Data Collection Timing

Amphibian monitoring should be done prior to project implementation and during subsequent resurveys, which should take place between every 1-5 years for up to 20 years post implementation. At a minimum, surveys should be completed once before project implementation, the year after implementation and again between one and five years later. If possible, monitoring should be done in the same month every year that it is done.

Required Resources

Data collection in the field – 2-4 hours with a 2+ person team, plus travel time.

Equipment costs if new
- Field notebook - $5
- Equipment decontamination supplies - $50
- Waders - $100
- Thermometer - $10
- pH meter - $200
- Water quality meter - $200
- Digital camera - $100
- GPS - $100
- Stopwatch - $5
- Spare batteries, parts for meters etc. - $20
- Measuring tape - $5
- Flags to mark transects - $5
- Meter stick - $40
- Clinometer - $50
- Autolevel and tripod - $100
- Current velocity meter and top setting rod $500
- Flagging tape - $5
- Densiometer - $100

Level if any special expertise required
If the person/people collecting invertebrates will be doing it for the first time, it is suggested that they familiarize themselves with the amphibian species that might occur in the meadow of interest.

Total Costs
Field equipment-$1,300-$1,700

DATA ANALYSIS

Data storage

Once data is collected in the field, information recorded will need to be added to a digital data library. All data should be uploaded to the meadows clearing house.

Analysis Methods

Standard statistics can be used to determine if population abundances and/or diversity changed before and after restoration implementation.

Evaluation Criteria

If the indicators of interest have not improved and they were expected to, it is suggested that stakeholders discuss potential hypotheses for the species' distribution not changing and possible next steps.

ADAPTIVE MANAGEMENT

If the indicators of interest have not improved post restoration, habitat quantity and quality as indicated by the results of other SM-WRAMP protocols should be reviewed. If habitat has not improved, additional restoration or on-going stewardship actions should be decided upon and taken.

CONTACTS AND RESOURCES

All of the aquatic species protocols can be done using the same transect layout and habitat typing data.

Person(s) who populated the specific protocol
Natalie Stauffer-Olsen, nstauffer-olsen@tu.org,
(707) 696-9839

FIELD DATASHEETS & DATA UPLOAD FORMS

The following datasheet is available to be downloaded from https://californiatroutinc.box.com/s/itpw9qd6utmaka5s8370nmg1c715a539
- Amphibian Survey Datasheet

7.4
AQUATIC SPECIES

Aquatic Species & Habitat Protocol: Amphibians

Print & Carry Field Instructions & Equipment List

This protocol details how to collect quantitative information on native amphibian populations to determine if they have changed (presumably increased) after restoration actions.

PROTOCOL DESCRIPTION

Physical habitat methods proposed here are adapted from the document "Standard Operating Procedures (SOP) for the Collection of Field Data for Bioassessments of California Wadeable Streams: Benthic Macroinvertebrates, Algae, and Physical Habitat", also called the Surface Water Ambient Water Monitoring (SWAMP) protocol, which is available here. Alternatively, practitioners can choose to use the Stream Condition Inventory to monitor aquatic habitat.

Work described in this protocol can be done in the same sampling area as the stream habitat characterization for physical habitat (PHab). The effectiveness of this work can be improved when combined with electrofishing or eDNA.

The number of transects and replicates will depend on the scope, goals, objectives, and funding of a project. Here, we recommend surveying at least a 150 m reach of channel and 100 meters on both sides of the main stream channel at 11 transects perpendicular to the stream flow that are spread out over the randomly chosen sampling reach. In order for this protocol to be useful, we recommend a minimum of 5 transects be laid out and all the associated data collected. If the management activities are to be carried out across a large meadow or are expected to have measurable impacts to a large section of a meadow, we encourage practitioners to choose multiple 150m reaches or to extend the reach as necessary. Another method for determining the study reach is available in the Stream Condition Inventory.

Amphibian monitoring should occur at the same time of year for each sampling event in order to ensure that populations are as comparable as possible. Sampling should occur within and/or downstream of the project area, and ideally amphibians would be monitored from two additional transect layouts near where the stream enters the meadow and near where the stream exits the meadow. This protocol can easily be done in addition to the other aquatic species protocols as they use the same habitat typing method and transects.

BEFORE GOING OUT INTO THE FIELD

1. To eliminate bias, target coordinates for transect locations should be determined at random from the reach within the area most likely to display change based on analyses of channel morphology, biological communities and processes, and existing or proposed management activities before going out into the field. Target coordinates should be placed on a map (paper or digital) for visual orientation in case the GPS is not functioning in the field. If practitioners prefer to pre-determine the study reach, which is especially suitable if a reach or reaches longer than 150m will be surveyed, that is also acceptable.

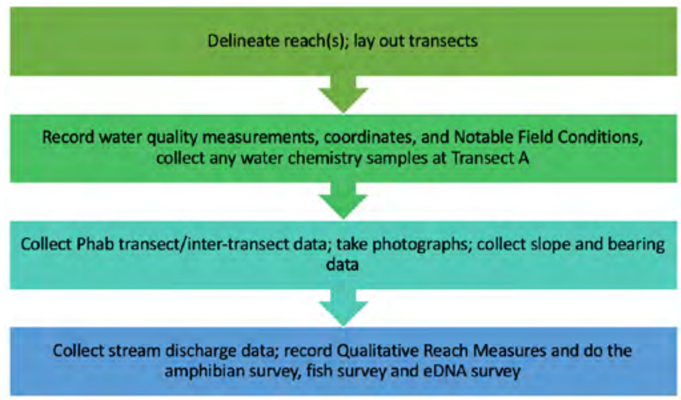
2. Gather sampling equipment

- Map of pre-chosen transect location
- Print out of this document
- Equipment decontamination supplies
- Waders
- Thermometer
- pH meter
- Water quality meter
- Calibration standards
- Digital camera
- GPS
- Stopwatch
- Spare batteries, parts for meters etc.
- Measuring tape
- Flags to mark transects
- Meter stick
- Clinometer
- Autolevel and tripod
- Current velocity meter and top setting rod
- Flagging tape
- Densiometer
- Pencil
- Physical Habitat (PHab) field forms
- Amphibian visual encounter survey datasheets
- Field notebook

3. Learn how to identify amphibian species (adults and juveniles) that might be present in the meadow to be monitored.

IN THE FIELD

Suggested Work-Flow Diagram



Upon arrival at the site, fill out the "Reach Documentation" section of the PHab field form. Record the geographic coordinates of the downstream end (Transect A) of the reach with a GPS receiver and record the datum setting (preferably NAD83) of the unit. Sampling locations can be moved up or downstream as much as 300 m from the predetermined target location for reasons such as avoiding obstacles, mitigating issues regarding safety or permission to access, and GPS error. Because GIS information about stream locations is imperfect, the target coordinates may not fall exactly on a streambed, but rather nearby, requiring a shift in order to correspond to the nearest aquatic habitat. The potential discrepancy between the target coordinates and where sampling actually occurs makes it essential to record the actual field coordinates on the field sheet.

To delineate the monitoring reach, first scout it to ensure it is of adequate length for sampling biota. Delineate a 150 m reach for sampling. Again, if the practitioner has the resources to survey a longer reach or multiple reaches likely to display change we encourage them to do so. The 150 m reach discussed here is a minimum.

Use markers (e.g., wire-stemmed flags) to indicate locations of transects and intertransects. The standard sampling layout consists of 11 "main" transects (A-K) interspersed with 10 "inter-transects", all of which are placed at equal distances from one to the next (7.5m). The first flag should be installed at water's edge on one bank at the downstream limit of the sampling reach to indicate the first main transect ("A").

The positions of the remaining transects and inter-transects are then established by heading upstream along the bank and using the transect tape or a segment of rope of appropriate length to measure off successive segments of 7.5m, or more if fewer transects are being used.

Physical Habitat (PHab) Transect-Based Field Measurements

For a detailed explanation of how to collect PHab data, please see the "SWAMP Bioassessment Procedures" (2016) document available here. The following "Basic" list of PHab measurements reflects the minimum amount of physical and chemical data that should be taken along with any biological samples. In addition, several hydrogeomorphic variables that measure connection to the floodplain and amount of incision are included.

- Layout of reach, marking transects, recording GPS coordinates
- Temperature, pH, specific conductance, salinity, DO, alkalinity
- Notable field conditions
- Wetted width
- Stream shading
- Bank stability and entrenchment
- Percent algal cover
- Flow habitat delineation
- Slope (%) of 150m reach
- Photo documentation
- Habitat type and length (Practitioners can either follow the habitat typing protocol described in the SWAMP, or the Stream Conditions Inventory (SCI). The worksheet for data collection associated with the protocol has spaces for both or/or either method. Instructions on how to determine habitat typing following the SCI protocol can be found in the Stream Condition Inventory on page 31). Briefly, channel geomorphic units are divided into fast or slow water habitats. Fast water habitats can be further divided into turbulent and non-turbulent habitats, which subsequently can be divided into falls, ripples, cascades, rapids, shoots (turbulent) and sheets and runs (non-turbulent), respectively. Slow water habitats can be further divided into scour pools or dammed pools, which subsequently can be divided into eddy, trench, lateral, mid-channel, plunge, or convergence (scour) pools, and debris, landslide, beaver, backwater, and abandoned channel (dammed) pools respectively. We suggest surveying a minimum of 12-15 habitat units (or 150 meters, whichever is more) and if the habitat typing is longer than 150 m, we leave it to the practitioner to determine which other attributes to collect in that extra length of channel.
- Floodplain width- distance from terrace to terrace (to inform floodplain accessibility) at each habitat type segment or transect
- Height of current bankfull, and where it is in relation to the height of the historic floodplain terrace at each habitat type segment or transect

Amphibian Survey

Carefully walk the 150 m survey reach, upstream on the left side of the channel and downstream on the right side of the channel and make note of any amphibians observed using the visual encounter survey datasheets provided. Then, walk 100 m perpendicular to and on both sides of the stream channel at each of the 11 transects and make note of any amphibians observed. If any amphibians are surveyed at all while the team is in the field, please make note of it, even if the amphibian was not observed at the sampling site or while walking the transects.

Aquatic Species & Habitat Protocol
Amphibians:

Equipment List

7.4
AMPHIBIANS

- Map of pre-chosen transect location
- Print out of this document
- Equipment decontamination supplies
- Waders
- Thermometer
- pH meter
- Water quality meter
- Calibration standards
- Digital camera
- GPS
- Stopwatch
- Spare batteries, parts for meters etc.
- Measuring tape
- Flags to mark transects
- Meter stick
- Clinometer
- Autolevel and tripod
- Current velocity meter and top setting rod
- Flagging tage
- Densiometer
- Pencil
- Physical Habitat (PHab) field forms
- Amphibian visual encounter survey datasheets
- Field notebook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