JANUARY 2023

KERN PLATEAU MEADOWS PROJECT

FINAL DESIGN

LOW-TECH PROCESS-BASED RESTORATION

PREPARED FOR & EDITED BY:
Trout Unlimited

PREPARED BY:
Nick Bouwes, Sabra Purdy

ANABRANCH SOLUTIONS
PO Box 577 Providence, UT 84332
info@anabranchsolutions.com

KERN PLATEAU MEADOWS

LOW-TECH PROCESS-BASED RESTORATION FINAL DESIGN

January 2023

Prepared by:

Nick Bouwes and Sabra Purdy

Anabranch Solutions, LLC.

PO BOX 577, Providence, UT 84332

Prepared for and edited by:

Trout Unlimited

DESIGN SUMMARY

As part of T*he Golden Trout Wilderness – Kern Plateau Meadows Restoration Planning Project* sponsored by Trout Unlimited and funded under the California Department of Fish and Wildlife Watershed Restoration Grant Program, this final design document describes the basis of design, project objectives and provides the restoration design for 15 degraded meadow complexes. The overall goal of the project is to restore natural hydrological, biological, and geomorphic processes to increase resilience and improve aquatic, riparian, and floodplain habitats thus improving ecosystem function and services provided by meadows across the headwaters of the Kern Plateau.

The restoration approach selected to restore the degraded meadow project sites is founded on low-tech process-based restoration (LTPBR) techniques. The LTBPR approach described herein is based on an extensively researched and field-tested methodology that is rapidly gaining interest and application across diverse riverscapes. It provides a sensitive and nuanced application of techniques that utilize the specific site characteristics and system ecological, hydrological, and geomorphic processes to create a low-risk treatment regime to improve and enhance ecological conditions. Meadow ecosystems throughout the Sierra Nevada have suffered enormous losses of soils and floodplain connectivity driving a shift in community structure and ecosystem function, resulting in a significant reduction in functioning wet meadow habitat. The restoration approach detailed here is intended to improve conditions in 15 meadow complexes located within the Inyo National Forest on the Kern Plateau by enabling and enhancing the processes of aggradation and erosion that can lead to incision recovery and reconnection to the floodplain (or expansion of an inset floodplain). The LTPBR design presented here does not assume that the project goal is to achieve historic reference conditions of all the meadows. The design also recognizes that each meadow may have had several reference states such as subsurface meadow, riparian meadow, and beaver dominated states. Restoring hydrologic and geomorphic functions in a process-based context ensures that restoration actions are consistent with the site potential and current process rates that may be altered as the climate changes. Furthermore, a process-based approach limits the risks associated with restoration by its explicit reliance on an adaptive management framework. The LTPBR design relies on strategic low-tech restoration structures, such as beaver dam analogues, post-assisted log structures, and sedge plugs to initiate and accentuate hydrologic and geomorphic processes to restore ecological function. Specific restoration is based on a reach-scale condition assessment and includes: increasing lateral connectivity to both inset and original floodplain surfaces, expanding inset floodplain development through channel widening, and forcing aggradation of the incised channel to raise water tables and promote eventual reconnection to the original floodplain in portions of each meadow. Additionally, repairing or arresting headcuts that threaten current meadows will also be addressed.

LTPBR relies on multiple restoration phases to meet restoration objectives. Harnessing the existing ecological and hydrologic processes at the site to meet those objectives. It is unknown how many phases will be required to meet long-term project goals; however, an adaptive management framework that will be developed as part of project will aid managers in monitoring progress towards phase objectives and determine when new implementation phases are required. The benefits of the phased LTPBR efforts outlined here include a wilderness-appropriate treatment approach that maintains and enhances existing meadow ecological value, and provides a low-risk, scalable tool for successful restoration that can be implemented by a range of groups and organizations. This approach has many benefits and has been utilized with great success in many areas of the U.S. but has not yet been applied at a large scale in meadow restoration in the Sierra Nevada. Due to the Wilderness Area designation of many of the meadows in our project, this is one of the few feasible approaches for addressing significant long-term habitat impacts and losses in these large, critically important Kern Plateau meadows. – January 15, 2023

CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The *Golden Trout Wilderness – Kern Plateau Meadows Restoration Project* (hereafter, Kern Plateau Meadows Project) entails restoring 15 degraded meadow complexes located in the headwaters of Owens River watershed (Horseshoe, Round Valley, Poison, and Dutch Meadows), the South Fork Kern River watershed (Bullfrog, Mulkey, Brown, Strawberry, Fat Cow, Schaefer, Kingfisher, Soda Creek, Round Mountain, Snake and Casa Vieja Meadows) located on the Kern Plateau of the Inyo National Forest (INF) (Figure 1). In 2012, the National Fish and Wildlife Foundation funded a partnership between CalTrout, Trout Unlimited, and American Rivers to evaluate and prioritize meadow sites for restoration on the Kern Plateau. Over the last five years, the INF has identified and began conducting initial surveys on a subset of those meadows. The selected meadows for this project were identified as the “best candidates” for initiating restoration implementation planning based on critical need of repair or potential to support two sensitive species, California Golden Trout and Mountain Yellow-legged Frog.

This project is driven by a diverse and strong partnership including Trout Unlimited, the INF, consulting stream-meadow restoration practitioners, engineers, geomorphologists, and ecologists. The California Department of Fish & Wildlife (CDFW) Proposition 1 funds are currently providing for project design, environmental compliance, permitting, and baseline monitoring to move all proposed meadows into implementation phase by 2024. Restoration design will include a combination of techniques to reconnect incised stream channels with the meadow floodplain focused on restoring the hydrologic function of the meadow ecosystems and restoring diverse instream habitat components that benefit fish and other aquatic organisms. Project co-benefits include improving habitat diversity and connectivity, improving climate change resilience associated with drought, floods, and fire, increasing greenhouse gas sequestration capacity, reducing water temperatures, improving water quality and late-season water availability for aquatic and meadow-associated species.

The goal of the Kern Plateau Meadows Project is to restore natural hydrological, biological, and geomorphic processes throughout the meadow complexes to increase resilience, ecosystem services, and improve aquatic, riparian, and floodplain habitats. Sierra Nevada meadow ecosystems have seen over a century of anthropogenic impacts, primarily from unregulated grazing in the late 1800s, resulting in degraded condition, loss of wet meadow habitat, and reduced resilience to climate change. All meadow project sites include active or historic gullied stream channels that have resulted in the loss of meadow habitats, simplification of instream habitats, and disconnection and loss of floodplain processes. The resulting vegetation community in a large portion of these meadows is currently trending towards conversion to upland and dry community types. This trend is concurrent with active headcutting, channel down-cutting, soil erosion, diminished vegetative productivity and diversity, reduced groundwater recharge and water table elevation, and decreased fish and wildlife habitat.

The current dysfunctional processes in these meadows have developed a self-reinforcing degradational cycle. Implementation of the Kern Plateau Meadows Project would halt degradation and improve ecosystem resiliency and hydrologic processes primarily by increasing stream channel connection to the meadow floodplain. This would result in greater frequency of flooding, similar to pre-degradational conditions. A more frequently inundated floodplain would:

- increase the wetted aerial extent of the meadow
- reduce peak flood flows
- increase/extend summer base flows
- increase in-stream cover and shading
- enhance aquatic and terrestrial habitat value
- improve water quality (reduce sedimentation and lower summer water temperatures)

- raise groundwater elevations
- reduce soil erosion
- improve infiltration of precipitation
- increase vegetative productivity

To achieve full floodplain function and associated ecosystem benefits, the meadow drainage system would have to be restored to historic floodplain elevation to allow frequent dispersal of flood flows over the meadow. In several locations, channel incision is so deep that historic floodplain connectivity may not be practical or possible. However, increased inundation of inset floodplains can also enhance riparian production improving overall meadow health.

Restoration of project site meadows will largely rely on low-tech process-based restoration (LTPBR) techniques (Wheaton et al. 2019) to address meadow impairments such as headcutting and channel incision. LTPBR relies heavily on using hand-built structures to amplify hydraulics to initiate geomorphic processes of erosion and deposition as well as that increase vertical and lateral hydrologic connectivity. The structures use local natural material, are hand-built (necessary for implementation in designated Wilderness Areas), relatively inexpensive, and provide low risk to the physical and biological meadow ecosystems. Although similar restoration techniques have been used for nearly a century in Sierra Nevada meadows (Kraebel and Pillsbury 1934), they are far less common than more traditional engineered approaches for larger meadow restoration efforts. While LTPBR approaches are gaining greater popularity in California, examples of large meadows utilizing LTPBR designs are not common.

This document presents the final design for 15 meadow complexes for CDFW and other agency partners, project stakeholders and restoration practitioners. The final design is based on observations from multiple field visits by restoration practitioners and meadow ecologists, hydrologist and geomorphologists, LiDAR data, publicly available GIS data, and aerial imagery.

LOCATION AND SETTING

The Kern Plateau is one of the most valuable and unique areas in the Sierra Nevada supporting an expansive suite of mountain meadows and providing habitat for sensitive native species, including the California Golden trout (*Oncorhynchus mykiss aguabonita*) and mountain yellow-legged frog (*Rana muscosa*). The Kern Plateau is situated in the southern end of the Sierra Nevada and includes the Golden Trout Wilderness (GTW) (Figure 1). Meadow streams of the Golden Trout Wilderness Area of the INF and surrounding areas of the Kern Plateau are also a primary draw for anglers and other recreationalists. These same headwater areas are critical sources of domestic and agricultural water supplies for downstream users.

The project meadows are located in the headwaters of the Owens River watershed and the South Fork Kern River watershed of the Inyo National Forest. The highest elevation meadow project site is Poison Meadow at 3,255 m (10,680 ft) with Snake Creek Meadow at the lowest elevation of 2,392 m (7,848 ft). PRISM information suggests the mean annual, maximum mean daily, and minimum mean daily temperature at Mulkey Meadow (the largest meadow in the project at 2,840 m) is 3.4°C (38°F), 11°C (51.8°F), -4 °C (24.8°F), respectively. The annual precipitation is 540 mm (21.3”).

Kern Plateau Meadow Restoration Project

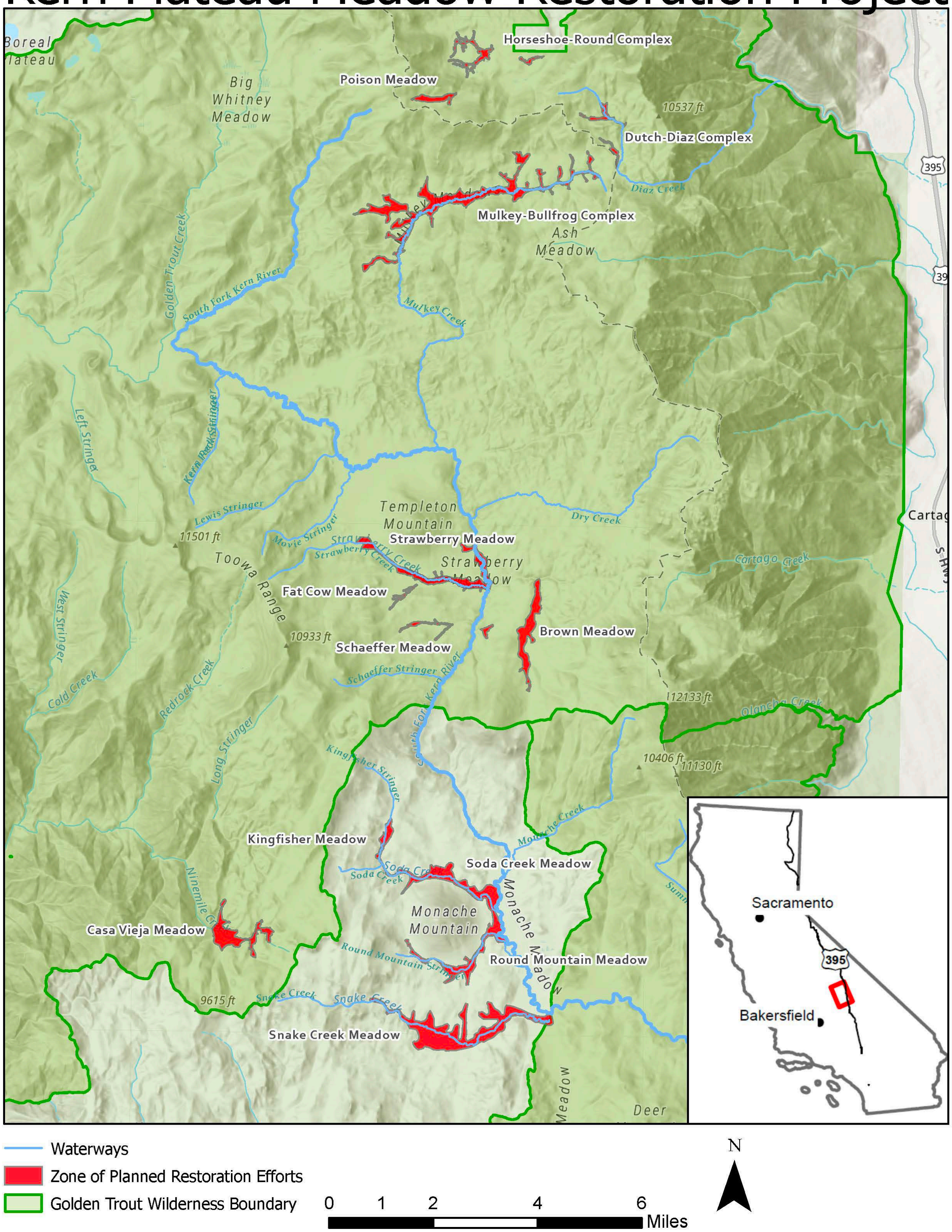

Figure 1. Kern Plateau Meadows Project – project site meadow locations

MEADOW IMPAIRMENTS AND EXISTING CONDITION

CURRENT CONDITIONS

Kern Plateau meadows and streams have been highly impacted by historic land uses, including the construction of water diversions (notably in Strawberry Meadow) (Pister 2008), and grazing by sheep and cattle. These impacts have triggered restoration actions dating to the 1930s, when the INF began armoring headcuts (Pister 2008). Throughout the Kern Plateau, many riparian meadow areas remain confined to inset floodplains within incised stream gullies. The historic floodplain is generally disconnected from the stream channel, and much of the historic meadow has been converted to sagebrush steppe and other upland species with a loss of meadow species and peat forming conditions. In general, the stream channels within project meadows remain moderately to severely incised but active erosion has largely been arrested in part due to previous restoration efforts and changes in grazing management. The existing stream channel banks are largely stable and well-vegetated though disconnected from the historic floodplain in a larger entrenched channel. Areas of thick peat often bear the impacts of grazing through hoof pocking and livestock trailing that punctures the sod and compresses soft peat soils, forming elevated hummocks. Throughout the meadow project sites there are multiple meadow types as described by Weixelman et al. (2011), including discharge peatlands, mound peatlands, discharge slopes and subsurface meadows. These meadow types show extensive hummocking and trampling evidence that is likely a residual of legacy grazing impacts but can be exacerbated by contemporary grazing in sensitive areas. These incised channels and compacted soils decrease the water table elevation and limit the water storage abilities of degraded meadows.

Degraded hydrologic function and geomorphic conditions have negatively impacted aquatic and meadow-dependent species across the Kern Plateau including wet meadow vegetation, fish and macroinvertebrates, and riparian-associated birds. The loss of meadow water storage decreases summer base flows that are critical for fish and other aquatic species survival during vulnerable life history stages. Additionally, simplified planar channels and the loss of deep-water habitat and cover lowers habitat quality and limits fish refugia. CA Golden trout prefer pools, undercut banks, and aquatic vegetation (sedge) habitat types, and these habitat features are often reduced or lacking which impacts fish distribution and abundance (Knapp et al 1996a and 1996b). Many stream reaches throughout the project meadow sites have high stream width to depth ratios, eroded stream banks or formed a reduced inset floodplain, and limited riparian overstory vegetation. This has resulted in a reduction in benthic macroinvertebrate biodiversity and biomass, and led to reduced invertebrate food resources available for Golden trout potentially limiting growth rates (Knapp et al 1996, Herbst et al 2012).

Loss or lack of riparian cover, particularly willow (*Salix spp*.) in some areas, has resulted in increased stream temperatures, further impacting aquatic habitat condition (Nussell et al 2015). Reduced riparian vegetation and loss of surface water cover (ponding) has also impacted meadow-associated bird diversity and abundance. In much of the project site meadows, the percentage cover and heights of willows are considered insufficient to support high abundances and richness of meadow birds (Campos unpublished baseline site condition report 2022). There is a natural mosaic of willow presence and recruitment across and within the meadows that is strongly associated with hydrogeomorphic conditions. Areas of steeper gradient with alluvial soils (i.e., larger average substrate size and better drainage) tend to have higher levels of willow recruitment than areas of very fine and highly saturated soils (e.g., peatlands). While some of these areas naturally support less dense riparian shrub cover due to soils or other factors, some areas have the potential for better willow recruitment with restoration treatments.

Grazing management has improved markedly over the past century and has been reevaluated and refined several times in the last 40 years. The INF closed two of the four grazing allotments that span the Golden Trout Wilderness Area of the Kern Plateau (Templeton and Whitney) in 2000, but the Mulkey and Monache allotments remain active. Our meadow project sites span both the open and closed allotments. Some work has been done to quantify meadow properly functioning condition in grazed and ungrazed areas. Some level of comparison will be a component of the project monitoring program and may be helpful in future grazing management discussions.

HISTORICAL LAND USE

Data shows that humans have occupied the Kern Plateau for the past 6,000 years. Before settlement nomad sheep roamed and grazed the plateau beginning in the 1800's (USDA 1982). Prior to the California Gold Rush, which brought millions of settlers to California in the 1850s, the Kern was the province of numerous Indigenous cultures including the Paiute Shoshone Tribe and others. From the mid-1800's to the 1920's thousands of sheep and cattle grazed the Kern Plateau causing erosion and degradation (USDA 1961). By the late 1800's grazing in the Kern Plateau was over carrying capacity, despite the creation of the Great Sierra Forest Preserve, and their efforts to prohibit sheep grazing. Cattle grazing was still very prevalent, with ranchers, pack trips, tourists, and rangers occupying the plateau every season. This caused damage to the meadow and riparian systems of the plateau. The result of such heavy and unregulated grazing was a disastrous reduction in the wet meadow vegetation cover. Massive erosion events converted the broad depositional wet meadow floodplains to narrow, incised single-thread channels in gullies disconnected from the floodplain and drastically reduced the area of wet meadow riparian habitats to the inset floodplain of the gullies that persists today (Stephens et al. 2004).

BEAVERS

Beavers (*Castor canadensis*) have a complicated history in the Sierra Nevada. For much of the 20th century, they were considered a non-native to the Sierra Nevada range but were introduced in the 1930's and 1940's with the intention of combatting erosion. More recent studies of Indigenous languages and history, fur trapper's records, and physical evidence of pre-settlement beaver dams being found in numerous meadows in the Sierra Nevada indicate that beavers were likely widespread throughout the range. Lanman et al. 2012 and Lanman and James 2012 provide a thorough investigation into the historical range of beavers in the Sierra Nevada and demonstrated they were almost certainly historically present in the Golden Trout Wilderness and Kern Plateau. Heavy fur trapping in California from around 1820 to 1840 decimated native beaver populations altering nearly every stream in the Sierra Nevada. This was followed by the equally devastating dredging and placer mining endeavors of the Gold Rush, beginning in 1849. The heavy livestock grazing from ~1865 to 1930 meant that there was little available food or building material for beavers in the Kern Plateau meadows and greater Sierra Nevada, making them vulnerable to predation. At that point in time, beavers in California became confined primarily to the Central Valley. Beaver reintroduction occurred throughout the Sierra Nevada in the 1930's and 1940's and they became widespread. However, beginning in the 1970's and continuing to the present day, eradication programs were instituted to rid these "non-native" nuisance species. The loss of beavers in meadow ecosystems, which they helped form and maintain, coupled with unregulated livestock grazing led to massive uncontrolled erosion in meadows and depositional landscapes. The current reversal in understanding of the role of beavers could usher in a new era of beaver reintroduction and use them as valued partners in restoration efforts in many ecosystems.

CURRENT LAND USE

Today, in the Golden Trout Wilderness Area meadows, only activities such as backpacking, hiking, mountaineering, skiing, and horse camping are allowed. The use of motorized or mechanical equipment is prohibited. The Golden Trout Wilderness has maintained trails but there are no developed campground facilities. Stock users and hikers can access the Golden Trout Wilderness through Cottonwood Lakes trail, Olancha Pass, Black Rock trail, and the Pacific Crest trail. Cottonwood Lakes trail is a loop that encompasses Horseshoe and Poison meadow. The trail crosses through the southernmost portion of Poison meadow. An extension of the trail that goes from one end of the loop to the other, Cottonwood Pass, crosses through the northern most portion of Horseshoe meadow. Olancha Pass does not cross through any of the meadows within the project area. Blackrock Trail is an out and back trail that borders and passes through the eastern portion of Casa Vieja meadow. The Pacific Crest Trail runs through the northern cohort of meadows and continues along the eastern side of the central and southern cohorts (USDA 2017). Additional land use activities include grazing as mentioned above, with Mulkey and Monache allotments being open to cattle grazing.

For project meadows located outside of Golden Trout Wilderness Area, they are subject to the effects of roads, off-highway vehicle use, and dispersed camping. All non-wilderness meadows are adjacent to the larger Monache Meadows area, accessible only via the Monache Jeep trail. This is a high clearance 4WD trail, which does limit the number of users in these non-wilderness meadow systems.

RESTORATION EFFORTS

Meadow conservation efforts in the Kern Plateau to arrest headcutting and prevent gully erosion began in the 1930's (Pister 2008). In fact, Kraebel and Pillsbury (1934) published a USFS manual for Sierra Meadows, describing similar restoration and erosion techniques to those described in this report. Since that time, hundreds of headcuts have been armored, and the INF continues to map, monitor, and repair headcuts. Meadow conservation efforts have primarily focused on protecting the meadow that remains in the inset floodplain through a combination of grazing management and structure building. Headcut treatments have typically been made of a combination of rock and wood, sometimes with jute or other material. Log check dams have been used extensively throughout the Golden Trout Wilderness but most concentrated in Casa Vieja, Soda Creek, Brown, and Schaeffer Meadows. Outside of the current project, Groundhog Meadow has received extensive check dam installation beginning in the 1930’s. Across the project area gully treatment efforts (most commonly check dams, but also some rock gabion structures) were instituted in the 1930’s, 1950’s, 1980’s, and again in the late 1990’s through 2013.

RECENT GRAZING EXPERIMENTS

The INF constructed grazing enclosures in several Golden Trout Wilderness Area meadows in 1983 and 1991, and these have provided comparison plots for several studies that show increased bank stability, stream shading, and Golden trout abundance within the grazing enclosures (Knapp and Mathews 1996, Sarr 1996, Herbst et al. 2012).

In 2001, grazing was suspended on two of the main allotments (Templeton and Whitney), and three studies have evaluated the meadow and riparian responses to rest from grazing. Herbst et al. (2012) observed that the rested allotments had significantly more bank stability, more bank vegetation and riparian cover, lower width-to-depth ratios, coarser sediment, and greater richness of aquatic macro-invertebrates. Wiexelman (2011) compared 10-year vegetation trends and bank stability (greenline) estimates of desired condition on all four allotments and concluded that ungrazed allotments have responded positively to rest from grazing. In addition, Weixelman (2011) concluded that greenline estimates of desired condition responded more quickly to changes in grazing management than did desired condition estimates based on meadow vegetation condition. Neither Weixelman (2011) nor Freitas et al. (2014) were able to detect changes in desired condition based on analyses of meadow vegetation alone.

At both the enclosure and allotment scale, rest from grazing improved riparian and in-stream habitat. Rested allotments also had more diverse communities of aquatic invertebrates and Golden trout abundance increased in areas where cattle were excluded. Farther from the channel, meadow vegetation condition did not vary appreciably across grazed and ungrazed allotments.

MEADOW SPECIFIC CONDITIONS

While incision is the main impairment affecting all meadows in this project, each meadow does have subtle differences that can influence how restoration is designed and implemented. Here we describe meadow specific characteristic and conditions (Table 1).

Table 1. Characteristics of meadows within Golden Trout Wilderness – Kern Plateau Meadows Restoration Planning Project.

Meadow Name	Total Meadow Size (acres)	Watershed Name	Within Wilderness	Currently Grazed	Stream Miles	Golden trout Native Range, Occupied or Unoccupied	Mountain Yellow-legged Frog Native Range, Occupied or Unoccupied
Horseshoe	299	Upper Cottonwood Creek	Y	Y	4.1	N, O	Y, U
Round	112	Upper Cottonwood Creek	Y	Y	1.5	N, O	Y, U
Poison	37	Upper Cottonwood Creek	Y	Y	1.5	N, U	Y, U
Dutch	28	Lower Cottonwood Creek	Y	Y	1.7	N, O	Y, U
Mulkey	571	Mulkey Creek-South Fork Kern River	Y	Y	5.8	N, O	Y, O
Bullfrog	126	Mulkey Creek-South Fork Kern River	Y	Y	3.1	Y, O	Y, O
Strawberry	166	Soda Creek-South Fork Kern River	Y	N	5.4	Y, O	Y, U
Fat Cow	37	Soda Creek-South Fork Kern River	Y	N	0.7	Y, O	Y, U
Schaeffer	52	Soda Creek-South Fork Kern River	Y	N	1.6	Y, O	Y, U
Brown	109	Soda Creek-South Fork Kern River	Y	N	4.2	Y, U	Y, U
Kingfisher	14	Soda Creek-South Fork Kern River	N	Y	1	Y, O	Y, U
Soda	101	Soda Creek-South Fork Kern River	N	Y	4.8	Y, O	Y, U
Round Mountain	80	Soda Creek-South Fork Kern River	N	Y	3.7	Y, O	Y, U
Snake	341	Snake Creek-South Fork Kern River	N	Y	6	Y, O	Y, U
Casa Vieja	119	Ninemile Creek	Y	Y	4.5	N, O	Y, U

HORSESHOE MEADOW

Horseshoe Meadow is a large meadow complex that drains easterly into Cottonwood Creek and eventually the Owens Valley. The meadow is fed by several small streams and numerous springs and groundwater upwelling areas, the largest being Poison Creek from the southwest. The meadow is located just south of Cirque Peak and represents the southernmost limit of glaciation in the Sierra Nevada range. Shaped like a large "horseshoe," two distinct lobes are separated by an elevated area of glacial moraine that come together in a confluence, then pass through a narrow and confined area between two moraines, prior to joining the stream draining nearby Round

Figure 2. Horseshoe Meadow, Southern Lobe. Hoof pocking in the riparian meadow (note the small elevational difference between the inset floodplain the historic floodplain now occupied by upland vegetation.

Meadow to the southeast. This creek then joins Cottonwood Creek to flow down the eastern flank of the Sierra to Owens Lake. While this site is one of the closest in terms of motor vehicle access, it is within Golden Trout Wilderness, although a portion of it is owned by Los Angeles Department of Power and Water (LADPW).

Horseshoe is part of the active Mulkey Grazing Allotment which also includes, Round, Poison, Dutch, Diaz, Mulkey, and Bullfrog Meadows. The relic unregulated grazing activity resulting in channel incision created an isolated floodplain that converted from wet meadow habitat to sagebrush steppe with some dry meadow species interspersed. Active headcuts exist in some of the stream channels, but others have filled in with sediment deposition from sources outside the meadow. Substantial active sediment deposition can be found in the dominant channel in the northern lobe and below the confluence with the southern lobe. There are several areas of mound peatlands at the northern margin of the northern lobe. Discharge slope/discharge peatlands are also present at the western margins. Much of the historic riparian floodplain has been converted to subsurface meadow due to channel incision and rarely, if ever, has active flooding. These areas show a more mesic vegetation community structure dominated by grasses and mesic forbs in non-saturated soils. The ground water table is likely within 1 m of the meadow surface, but this meadow is vulnerable to conversion to sagebrush/upland with persistent drought and drier, hotter climatic conditions. The southern lobe has a wider inset floodplain that contains wet riparian meadow habitat that is generally in good condition. However, it is disconnected from the adjacent historic floodplain surface, which is mixed sagebrush steppe and dry meadow habitat that is on the verge of full conversion in many locations (Figure 2). The multiple tributaries entering the meadow come together into a single threaded channel confined by moraines below the confluence. The channel is confined and entrenched, but mostly stable and highly sinuous.

ROUND VALLEY MEADOW

Round Valley Meadow is located at the southeastern lobe of the Horseshoe Meadow Complex. It is also within Golden Trout Wilderness area with a portion owned by LADPW. The upper end of the meadow (the widest, largest area) is predominantly subsurface low gradient meadow with no defined stream channels. Several tributary streams enter the meadow on the south and west sides that provide both surface flow and abundant sediment (Figure 4), though these have largely incised and cannot access the historic floodplain surface. A large many-lobed headcut marks the zone between the subsurface meadow and the incised riparian channel below. The headcuts have been treated using wood, rock, and cloth (~2010) and have largely arrested the active headcutting into the upper meadow, though some minor repairs are needed. Below the large headcut repair area, the channel becomes deeply incised (1.5-2.5 m) with sagebrush conversion at the margins and a healthy but highly reduced inset floodplain channel of riparian wet meadow. Several areas of subsurface meadow and discharge slopes and peatlands are in the higher ground, particularly in the areas on the south side of the channel. The exposed banks in this section show deep peat layers proving that the meadow surface was significantly higher pre-settlement with a much larger wetland area. The edge of the historic terrace is actively eroding in some areas and has little to no vegetation with large chunks of peat sloughing into the channel below.

Figure 3. Round Valley Meadow. A gully supplies sediment to potentially aggrade the highly incised main channel.

POISON MEADOW

Poison Meadow is a tributary to Horseshoe Meadow located to its southwest 225 m upstream. A mix of several small tributary channels at the upper end cut through a transverse sediment splay with sagebrush on the high surface. Several discharge slope springs drain onto the north side of the meadow. Below that area, the multiple channels become subsurface low gradient meadow with dense sedges and a water table depth of less than 1 m. At the eastern end of the subsurface meadow there is an abrupt shift in gradient and an actively headcutting single-thread channel forms (Figure 5). On the south side of this section there is a small subsurface meadow that is becoming very dry, and the peat soil is actively drying, crumbling, and oxidizing. As the channel continues down the valley, the gradient increases and substrate size increases and willow cover increases commensurately. Hummocking occurs on the left bank of the channel, and the valley width becomes increasingly narrow before spilling over the edge into a continuous steep cascade through dense willow shrubfields.

Figure 4. Poison Meadow. View of the low gradient subsurface meadow that is vulnerable to incision if the headcut at the lower progresses upward.

DUTCH MEADOWS

Dutch Meadow is the headwater meadow of Diaz Creek and is part of the active Mulkey Grazing Allotment within Golden Trout Wilderness. The northern lobe contains two main tributary drainages that converge in a small area of intact subsurface and riparian middle gradient meadow that has willow cover and conifers at the margins. The western lobe contains a small riparian channel and subsurface low gradient meadow at the upstream end with discharge slope peatlands at the western margin. Both lobes quickly deteriorate into incised channels due to historic channel incision that has resulted in a narrow, inset floodplain 1-3 m below the historic meadow surface in both lobes with sagebrush encroachment on the historic floodplain (Figure 6). Most of the active headcuts have been arrested through several historic efforts by the INF throughout the last 70 years, but the gully remains. In the western lobe, erosion has revealed alternating layers of peat and sand and gravel. The pattern of peat build-up from organic materials (mostly saturated sedge and bryophytes), and thick layers of decomposed granite from the bare uplands, suggests high deposition across the meadow surface in times of high runoff, likely from intense summer storms that can occur on the Kern Plateau. The episodic nature of sediment mobilizing events that aggrade the valley bottoms is at the core of the restoration design strategy for this project and Dutch Meadow is an excellent example of that process. The northern lobe has a larger drainage basin and thus sees higher flows. The inset floodplain is both wider and deeper here. Both lobes have a very healthy riparian wet meadow system within the inset floodplain, but most of the meadow has been converted to sagebrush upland. Below the confluence of the two lobes, the gradient becomes steeper with multiple discharge slope peatlands near the margins before it narrows rapidly as it enters the steep canyon between Dutch and Diaz Meadow ~0.66 miles (1.05 km) below.

Figure 5. The primary channel in Dutch Meadow shows the typical pattern of incision followed by widening and stabilization and development of high-quality meadow habitat within the much smaller footprint of the inset floodplain. All connectivity to the historical floodplain surface has been lost.

MULKEY MEADOW

Mulkey Meadow is the largest single meadow in the project area at 7 km in length and is highly heterogeneous. It contains ~20 tributary drainages and scores of springs. It is the core of the Mulkey Grazing Allotment and Mulkey Cow Camp is located on the north side of the meadow in a large stringer meadow. It contains several distinct habitat zones that are markedly different from each other and will respond slightly differently to treatment. The lower end of the meadow is confined by a rocky canyon that acts as grade control which is thought to have historically been a barrier to fish. Shepherds and others commonly moved fish into fishless waters throughout the Sierra Nevada, and Mulkey Meadow now boasts one of the most robust populations of Golden trout on the Kern Plateau. The meadow begins fairly narrow and quickly widens to a valley width of approximately 65 m with a small amount of channel incision and widening from the historic floodplain position (incision ranges from 0.4 to 0.7 m below historic elevations in this zone). The floodplain that can become inundated during higher flow events and supports a mesic meadow plant community with dense stands of multiple-seral stage willow, sedges, rushes, grasses, and forbs (Figure 7). The inner riparian zone supports lush hydric meadow species, particularly emergent sedge marshes below bankfull elevation. The channel here is largely in good condition with minimal bank instability. Slight increases in surface elevation result in sagebrush encroachment onto the historic meadow surface. The sloping valley sides at the margins of the meadow support sagebrush upland. Groundwater from the surrounding hillslopes supports meadow function, and the area is a mix of riparian and subsurface meadow hydrogeomorphic types. Evidence of historic beaver activity is found throughout this area with geomorphological evidence of beaver dams shown in bar development, dam remnants, willow growth patterns, and bank shape. This area continues past the confluence with Bullfrog Creek up to approximately the lower third of the meadow near the connection to Trail Pass.

At this juncture, the gradient decreases due to the sediment inputs of several large tributaries. The channel is greatly incised here, with historic floodplain and fan elevations ranging from 1-3 meters above current bankfull that have converted from meadow types to sagebrush steppe with some grasses intermixed. Peat layers at the historic floodplain elevation throughout indicate that both the valley bottom and the fans were covered in sod-forming hydric and mesic meadow vegetation with moist and saturated soils. Historic meander channels on the old floodplain terrace also show that much of the valley bottom and tributary fans supported complex, multi-thread networks of channels with a high water table and hydric vegetation. This conversion has occurred across most of the meadow and the inset floodplain is the only remaining meadow habitat. Some areas have a widened inset floodplain that is highly active and supports hydric meadow vegetation, but other areas have a narrow valley bottom confined by fans from tributary channels. The current active inset riparian zone averages 20-30 m across whereas historical indicators such as peat layers and meander channels show that meadow habitat averaged 100-300 m across depending on fan and hillslope topography, a huge loss in functional meadow habitat and one that has been recognized as an urgent issue since the 1930s (Kraebel and Pillsbury, 1934).

In the central lower zone of Mulkey Meadow, there is a sudden decrease in the density and recruitment of willows. This is also the upper end of an enclosure, thus a loss due to grazing is thought to be responsible for the decrease in willow. However, grazing does not fully explain the shift since there are very dense stands of willow that were not excluded by the exclosure. Two additional factors likely explain willow distribution throughout the Golden Trout Wilderness. Decreases in slope in this area result in much finer soils and channels with inundated sedge. Willow germination and growth occurs best on fresh sand and gravel bar deposits rather than in anoxic mucky silt. Secondarily, this area of Mulkey has been identified as a cold sink by Forest Service personnel indicated by the presence of cryosols (soils marked by indications of freezing and thawing) according to the Weixelman botanical surveys in the area (Lisa Sims, pers. comm.). The sparse and often stunted willows in this area show signs of frostbite (dead branches, coppicing), rather than removal of material due to active livestock grazing, and recruitment is very limited though sedge and grass species appear to be untouched by the cold. Several areas of Mulkey and other meadows in the region appear to have significant mortality of sagebrush, small conifers, and willows due to frostbite within the last 10-20 years. This is likely a result of lack of snow cover in winter due to numerous prolonged droughts and changing climatic conditions. The exposed plants suffer from frostbite damage or mortality during periods of extreme cold during the winter season. Microclimates within Mulkey Meadow and patterns of sagebrush mortality and willow recruitment lend credence to this hypothesis.

The central portion of Mulkey Meadow between Mulkey Cow Camp and Trail Pass is generally extremely low gradient with large sloping alluvial fans entering laterally and protruding across the valley to form a narrow valley bottom. The narrow, inset floodplain is deeply incised (0.7-3 m below historic floodplain elevation; Figure 7). The historic floodplain has, in most areas, converted to sagebrush steppe except for subsurface meadow areas that are supported by groundwater flows or discharge slope springs that contribute surface water from upland areas to the valley bottom. In some areas, the stream channel cuts deeply into the hillslopes adjacent resulting in steep eroding cutbanks 10-15 m high that provide an enormous sediment input into the channel. Near Mulkey Cow Camp, several significant tributaries enter the mainstem from both sides of the valley.

Above this zone, the channel is much smaller and the gradient increases significantly. Many springs, discharge slope peatlands, and tributaries in this area contribute to the mainstem. This area was occupied by beavers until the 1970s when they were removed under the perception that they were a non-native nuisance species (Figure 9). This zone remains rife with remnant beaver dams, willow row-crops on old dams, and multiple flow paths. The steepness of the gradient drives a diverse pool-drop habitat. This is the zone of Mulkey Meadows that supports one of the few populations of the state and federally endangered *Rana muscosa* (Mountain Yellow-Legged Frog). This species has experienced precipitous decline due to impacts from non-native fish introductions, deadly chytrid fungus, and a suite of other anthropogenic impacts that have resulted in near extinction throughout its range. A relatively stable population of several hundred individuals live in upper Mulkey Meadow where their range precisely overlaps recent beaver occupation zones. The complexity and type of habitat generated by beaver dams provides a full range of habitats that are useful for supporting *R. muscosa*'s life history cycle (including three full seasons as a tadpole prior to transformation) ranging from breeding and rearing habitat (shallower, warmer water) and overwintering habitat (deep water below the ice). Recent conservation efforts include transplanting a small number of individuals to nearby Ramshaw Meadow, the only known meadow in the Golden Trout Wilderness that supports an active beaver population. A small but less well-understood population of frogs also reside at Bullfrog Meadow.

Figure 6. Lower Mulkey Meadow where floodplain surfaces are relatively close to the surface water and the riparian area supports sedges and willow.

Figure 7. Middle Mulkey Meadow depicting a deeply incised channel with inset floodplains supporting sedges.

Figure 8. Upper Mulkey Meadow where a beaver complex active in 1970 has created habitat suitable for supporting Yellow-Legged frogs.

BULLFROG MEADOW

Bullfrog meadow is essentially the western wing of Mulkey Meadow and is a part of the Mulkey Grazing Allotment. The Bullfrog tributary connects in the lower zone of Mulkey and goes up through a series of sinuous, deep pools and steepens through a rocky section of confined channel with plunge pools. Above this is a large, gently sloping meadow with numerous mound peatlands interspersed with sagebrush patches and subsurface meadow habitat. The stream here becomes deeply incised with a verdant inset floodplain surrounded by encroaching sagebrush at the margins. Numerous channels headcut toward the intact meadow and have been treated in the past with rock, cloth, and wood structures that have largely been successful at arresting headcuts, though one large headcut in the primary channel remains active. Above the large headcut, the stream channel is much less incised and is almost at its historic elevation with a few older structures in place where headcutting occurred in the past that have successfully maintained the channel elevation.

The upper section of Bullfrog meadow has a large drainage entering from the north that has continuously splayed gravel and sand across the meadow creating a raised hump that has some sagebrush encroachment but also supports a high groundwater table with sedges. West of this drainage, there is a section of dense mound peatlands and discharge slopes that is incredibly wet with complex channels and sheetflow connections throughout supporting dense hydric sedges that come together to the main channel on the south edge of the meadow. A dry riparian channel continues to the west and an area of subsurface meadow and riparian middle gradient meadow comes down from the south arm. This meadow is quite large and contains proportionately much more intact meadow habitat than neighboring Mulkey. It is very diverse in both meadow and in-channel habitat types and soil moisture, ranging from fully saturated to dry sagebrush steppe. There is a small population of Mountain Yellow Legged Frogs in this meadow, particularly in the steeper pool/drop section near the downstream end though they are not as well understood as the upper Mulkey population (Figure 10). The two habitats are strikingly similar in that there are many boulders, pools, fast moving water, and cover. It is not clear where the breeding habitat for this population is, but it is likely in the extremely wet zone of mound peatlands at the upstream end of the meadow that is covered in such dense, tall sedges that detecting tadpoles would be virtually impossible there. This population coexists with Golden trout in this habitat but likely the eggs and tadpoles would be extremely vulnerable to predation in this reach and likely are only successful in the area above where trout commonly occur. Any additional structure would likely benefit frogs by diversifying habitats and making deeper pools, a critical overwintering habitat.

Figure 9. Lower Bullfrog Meadow where a yellow-Legged frog was observed in this pool.

STRAWBERRY MEADOW

Strawberry Meadow is located at the confluence of the South Fork Kern River and Strawberry Creek deep in the Golden Trout Wilderness on the southern side of Templeton Mountain. Like most of the meadows in the Golden Trout Wilderness area, it is a long narrow meadow occupying the valley bottom between barren upland areas that have sparse understory cover over highly erosible decomposing granite soils. It is part of the closed Templeton Grazing Allotment that ceased grazing in 2001. The gradient is consistently low and contains small tributaries from discharge slope springs, the largest of which enters Strawberry Creek from the north and whose confluence creates the widest zone of the meadow. The meadow is consistently slightly to moderately incised throughout and a minimal lifting of water table elevation would allow regular connectivity to most of the historic floodplain. Fat Cow Stringer enters from the southwest and this confluence is the most incised, poorest condition part of the channel. The confluence with the South Fork Kern River has an extremely mobile streambed with minimal structure. There is good willow recruitment throughout the meadow (Figure 10) with sagebrush at the sloping meadow margins and encroaching onto the historic floodplain in areas with deeper channel incision. Overall, the incision ranges from ~0.3 to 0.6 m below the historical floodplain elevation. This allows the meadow to persist with mesic and dry meadow species on the historic floodplain surface. Hydric (obligate and facultative wetland species) vegetation is primarily limited to inset floodplain areas and low-lying floodplain surfaces with good surface or groundwater connectivity.

Figure 10. Lower Strawberry Meadow near the confluence with the South Fork Kern River. Willow and sedges are supported throughout much of the riparian corridor.

FAT COW STRINGER MEADOW

Fat Cow Stringer is a small, moderate gradient tributary drainage to Strawberry Meadow and is part of the Templeton Grazing Allotment that has been closed to grazing for 2 decades. A sinuous channel of small scour pools with rocky riffles between goes through the middle of the meadow. The stream is ephemeral; likely flowing only early in the season and during heavy precipitation events in the summer months. The dry conditions and earlier livestock use contribute to fractured sod with some eroding cutbank edges. However, these are typical of dry channels in higher gradient systems and may be infeasible to recover hydric and mesic meadow species cover here under current and future climatic conditions. The upper portion of Fat Cow Stringer has increased groundwater support and a few discharge slope springs that support meadow vegetation. The channel contains a few active headcuts that should be treated to protect the wetter, more intact areas of Fat Cow. Overall, its condition is typical of its hydrology and gradient, and it is doubtful that treatment will result in a significant increase in meadow cover, but it will help protect existing meadow habitat and buffer against increasingly dry and hot climatic conditions (Figure 11).

Figure 11. The middle portion of Fat Cow Stringer with some mesic and hydric plants species within a lot of upland species

SCHAEFFER MEADOW

Figure 12.Upper Schaffer Meadow that is relatively intact.

Schaeffer Meadow is a long, narrow, high-gradient meadow that is one drainage to the south of Strawberry Creek, and is a tributary to the South Fork Kern River. As part of the now-closed Templeton Grazing Allotment, the meadow has been rested from grazing for two decades. The ephemeral stream is dry most years. Its high gradient and often dry conditions make it very vulnerable to headcutting, and it contains numerous active and arrested (through checkdams and wood installations) headcuts throughout. The channels in the meadow tend to be moderately to significantly incised but there are some areas (generally lower gradient), where the channel elevation is much closer to the historical floodplain surface and the vegetation responds accordingly to support more mesic and hydric meadow species (Figure 12). However, major legacy channel incision (likely between 1860 and 1930) has resulted in an incised channel with a small inset floodplain supporting meadow plant species with sagebrush encroachment on the adjacent terrace that was the historic meadow surface. The potential to aggrade the channel to this historic surface may be limited or take a very long time, but treatment of headcuts and introduction of structures in the inset floodplain may help accelerate the aggradation process. Lack of consistent stream flow and very dry sod make this a difficult system to predict the timeline of treatment outcomes, but sediment movement will be linked to large episodic events, particularly the violent summer rainstorms that sometimes affect the Kern Plateau mobilizing large amounts of sediment and upland materials into the meadows. All of the check dams and wood installations that were installed in Schaeffer Meadow between the 1980s and the early 2000s have filled to capacity with sediment, providing a good indicator that channel aggradation is possible even in ephemeral channels such as this.

BROWN MEADOW

Brown Meadow is a very long, narrow moderate to high gradient meadow that is located east of the South Fork Kern canyon and flows north into the stream that drains Gomez Meadow which then confluences with the South Fork Kern River just upstream of the confluence with Strawberry Creek. It is part of the Templeton Grazing

Allotment that has been closed to grazing since 2002. Brown's headwater zone is typical of the higher gradient upper reaches of many of the meadows in this area with an indistinct channel through a subsurface high gradient meadow type supporting mesic and hydric meadow vegetation. There is a small cluster of willows near the top indicating some sort of groundwater upwelling zone. This section likely has sheet flow during periods of high runoff but soon concentrates into a distinct channel that has had numerous headcuts. These have mostly been treated by the USFS with a combination of rock, cloth, and wood. These treatments have largely been successful at arresting headcuts, but some need minor maintenance for optimal continued performance. As the stream descends, the channel becomes increasingly incised and becomes a narrow inset floodplain with sagebrush and upland species encroachment on the adjacent terrace (former meadow surface). It travels through a steeper pinch point with through conifer forest and incises further.

The middle of Brown Meadow enters the broader, lower gradient valley at the Brown Cow Camp. Throughout this zone the channel is incised ~2.5-3 meters below the historic floodplain surface leaving a narrow inset floodplain channel that supports hydric meadow species but has no connectivity to its historic floodplain. Several significant tributaries enter this section of the meadow from the east forming a sloping alluvial fan perpendicular to the valley gradient that also contains a significantly incised channel. A second tributary just south of this fan has a very large, active headcut that threatens high quality habitat above that urgently needs treatment. There are several log check dam installations in this section of meadow that have all filled with sediment suggesting structures promote aggradation and that, despite the typical low flows on Brown Creek (Figure 13). Large amounts of sediment can be mobilized during episodic events with high flows and runoff from the surrounding decomposing granite upland and exposed erodible channel banks. Numerous springs and discharge slopes provide additional surface and subsurface flows and support a variety of meadow hydrogeomorphic types including subsurface, discharge slope peatlands, and riparian meadow types. The groundwater flowing through from the alluvial fan as well as springs helps to maintain areas of intact meadow on the historic surface, but the deep channel incision creates a drain on groundwater leaving the margins of the channel dry and covered in encroaching sagebrush.

Below the Cow Camp, the channel becomes confined and forested for a short time with an increased gradient and larger diameter substrate with much more cobble and boulder than the fine sediments and gravels found in the depositional zones above. Below this second pinch point the meadow opens up again with numerous significant discharge slope springs supplying surface and ground water throughput down high gradient slopes into the somewhat confined riparian zone. This lower section of Brown Meadow is generally much less incised than the Cow Camp area but is still entrenched 0.7 to 2 m below the historic valley bottom surface with sagebrush encroachment at the terrace margins and a lush but confined inset floodplain. As the stream descends further, it becomes decreasingly incised and near the bottom of the meadow where large rock formations maintain gradient control, is barely incised (~0.1 – 0.4 m below the historic floodplain surface). The habitat here has dense stands of willow and hydric meadow vegetation throughout the active floodplain zone. The hillslopes confining the meadow to the west are relatively barren with only sparse conifers and tiny annual forbs holding the unconsolidated decomposing granite material. This highly mobile sediment readily erodes during small alluvial fans into the mainstem of Brown Creek. This ready source of sediment is exceedingly valuable to the restoration process both here and in all the meadows on the Kern Plateau where one of the primary issues is loss of structure (beavers, sedge, wood, riparian vegetation) to help catch and retain the sediment inputs from the upland and incised banks. With a replacement of structural elements, there should be adequate material to aggrade incised channels over time.

Figure 13. Middle Brown Meadow above a structure installed by the USFS around 2000. This structure is approximately 1.5 m high and has completely aggrade the channel to the structure elevation. This surface has colonized with sedges. This response to the structure provides evidence that restoration approach proposed here can meet the project objectives.

KINGFISHER STRINGER MEADOW

Kingfisher Stringer is located to the northwest of Monache Mountain and is a tributary of Soda Creek. The small meadow has two main tributaries flowing in. The western tributary enters the meadow midway down its western flank and has flow paths which are essentially intact with full floodplain access. The eastern tributary is the dominant flow path and is therefore significantly more impacted. The eastern tributary has incised 0.5 to 1m below the historic floodplain surface and has formed the typical inset floodplain channel with encroaching sagebrush along the terrace margins where groundwater dives well below the surface to drain into the incised channel forcing a conversion to upland vegetation. Within the incised channel, the ephemeral stream has created a series of scour pools with crests 0.1-0.3 m below the inset floodplain surface. The edges of the pools are notably ragged with a sod layer that is drying out and vulnerable to sloughing and fracturing when cattle cross or use the channel as a trail. At the upstream end of the meadow, the channel is very shallow and fully vegetated and becomes progressively deeper and more eroded as it proceeds downstream. The two channels come together and become more deeply entrenched downstream of the confluence. Here the channel is hard against the forested western margin of the meadow and there are many downed trees falling into the channel (Figure 14). The eastern flank of the channel is a sagebrush terrace ~1.5 m above the inset channel. There is an old two-track road crossing the meadow below and the tire tracks have sunk deeply into the meadow. Below this, the valley narrows abruptly and begins to become a much steeper gradient with a rocky stream that seems to hold water for much of the year thanks to a number of discharge slope springs on both sides contributing to flow. As it continues down canyon, it becomes increasingly narrow until it becomes a forested drainage. In this section there are numerous geomorphic surfaces that are consistent with the shapes created by old beaver dams. We found one apparent dam remnant with what appeared to be an old chewed beaver stick in 2020 but further excavation of the dam did not uncover more chewed sticks that would definitively mark it as a beaver dam as opposed to just a woody debris jam that created similar habitat. As with Snake Creek, definitive carbon dating of beaver sign in the area will help guide beaver management and potentially eventual reintroduction to the area as an essential ecosystem component.

Figure 14. Kingfisher Meadow below the confluence of the two upper tributaries. Note the presence of wood and boulders.

SODA CREEK MEADOW

Soda Creek Meadow is part of the immense Monache Meadow Complex centered on Monache Mountain located on the north side of Monache Mountain just south of Bake Oven Dune. It is part of the active Monache Grazing Allotment. The channel is low-gradient but significantly incised. It has a road crossing near the downstream end of the meadow to allow access to the Cow Camp and former USFS Ranger Station located on the slope of Monache Mountain which also acts as grade control for the stream above the road crossing. The channel has been treated with numerous log check dams by the USFS that are intact have been successful at aggrading the channel to the structure elevation. However, this elevation is still below the historic surface of the meadow (0.5-1 m incised).

There are several discharge slope springs coming from the margin of the meadow on the toe slope of Monache Mountain that provide surface and groundwater throughput into the riparian channel. The historic floodplain surface north of the channel has a lot of sagebrush encroachment due to the channel incision draining groundwater and then gradually returns to subsurface meadow type supported by a small tributary (usually dry) entering from the northern edge of the meadow. The inset floodplain and channel support hydric meadow vegetation, but in most areas, the channel is too deeply incised to activate the floodplain in most high flow events. Treatment of this reach will build on the successful earlier effort to increase water table elevations and aggrade sediment (Figure 15). The floodplain is likely able to be reconnected with structures ~0.5 to 1 m tall which has excellent potential to regain a large amount of meadow that has been converted to sagebrush and upland species.

Figure 15. A filled in structure in Soda Creek Meadow, another example of structurally forced aggradation.

ROUND MOUNTAIN MEADOW

Round Mountain Stringer is located on the south side of Monache Mountain and is part of the active Monache Grazing Allotment. It is a relatively small meadow that is mostly subsurface meadow with sheetflow and swale type habitat with some areas of riparian channel where flows have concentrated. The flow is ephemeral and the channel and meadow are dry throughout most of the year. The areas that are most in need of treatment are (similar to Snake Creek Meadow) places that are deep, wide, generally straight channels that may originally have been livestock trails that got captured by the stream channel and began to incise and widen as stock persistently use the same trail and the deeper pools hold water longer than any other area of the meadow (Figure 16). There is a road crossing at the downstream end of the meadow that has received a rock dam treatment to prevent headcutting up the meadow and this has been successful.

Figure 16. Round Mountain Meadow channel that is used by cattle for trails.

SNAKE CREEK MEADOW

Snake Creek is located south of Monache Mountain and is one of the last significant tributaries to flow into the South Fork Kern River in the Monache Meadow Complex. It begins near the Snake Creek bridge and the channel is incised 1.5 – 2.5 m below the historical meadow surface with the attendant sagebrush encroachment at the terrace margins and a confined narrow inset channel and floodplain that has become an alternative stable state disconnected from the full valley bottom. As the stream continues through the meadow it becomes much less incised and in many places is within 0.5 to 1 m from the historical floodplain surface. The valley gradient is very low and historically this channel would likely have been indistinct in many areas with sheetflow and swale-type channel during times of runoff. It is currently ephemeral though it likely flowed more perennially in previous centuries (a combination of better meadow conditions and wetter climatic conditions). The channel may actually be a captured livestock trail that continues to become wider and deeper as livestock walk through and across it (Figure 17). This forms a positive feedback loop because these deeper pools hold water longer in the season, stock tend to converge on them and the trampling becomes concentrated in the already entrenched channel. Deterring livestock from walking in the channel will help reduce the widening and deepening and may allow aggradation to occur and revegetate and fill the channel back in over time.

Figure 17. Snake Creek Meadow. The ephemeral creek has become a trail for cattle.

Upstream of the Snake Creek Bridge there is a large aspen stand that has extensive evidence of beavers including downed mature aspens and remnant dams. This adds another area of confirmed beaver occupation to the Golden Trout Wilderness/Kern Plateau. If confirmed to be older than the late 1930s/early 1940s (i.e., prior to reintroduction of beavers Sierra-wide to help with widespread erosion problems from historic livestock grazing practices), this will provide more physical evidence that beavers were historically present in the system.

CASA VIEJA MEADOW

Casa Vieja Meadow is the southwestern limit of the project and is the headwaters of Ninemile Creek which flows into the mainstem Kern River. It is part of the active Monache Grazing Allotment but has a large area at the center of the main meadow that is fenced and generally off limits to livestock but sometimes experiences some trespass from wily bovines. The headwaters of the meadow start in two wings at the eastern end of the meadow with a northerly (the larger) and southerly wing that have many discharge slope springs and seeps. Each wing has a small, moderate to high gradient channel which come together then turn west down a confined pinch point that then opens up into the larger main meadow at Casa Vieja. Here, numerous discharge slope springs and large areas of groundwater-mediated subsurface meadows feed the main channel, which decreases from moderate to low gradient as it travels downstream and enters the cattle exclosure areas. A significant tributary enters from the northern edge of the meadow and joins the mainstem just before it goes into the steep canyon west of the meadow.

Casa Vieja has been the site of many decades of effort controlling erosion and restoring the channel dating back to the 1930s. The primary tool has been log and rock check dams and rock gabion structures which have generally worked very well to capture sediment, aggrade the channel, reduce erosion, and arrest headcuts. The numerous tributary channels on all sides of the meadow nearly all have at least a few old structures still visible that have done an excellent job of reversing the trajectory of erosion and soil loss from the system. Many of these structures have become completely integrated with the meadow (particularly in channels with perennial flow) and have been colonized with hydric sedges and bryophytes. There have been multiple rounds of treatment in Casa Vieja Meadow with major efforts in the 1930s, 1950s, 1980s, and late 1990s/early 2000s. These iterative efforts over time have allowed significant resource recovery and reversed the trajectory of degradation at the site. The most significant structure is a large rock gabion/check dam structure at the eastern end of the main meadow that arrested a massive headcut and created a large emergent marsh/sheetflow area above it that has several flow paths onto the meadow surface below. Below this grade control structure, smaller check dams and rock structures are along the main channel.

This section of stream channel displays a frequently encountered phenomenon on small moderate and high gradient headwaters meadow streams in the area where flows that overtop the adjacent stream banks deposit fine sediment next to the channel. Over time, these deposits and the streambed elevation increase together forming a perched stream channel that is actually higher than the surrounding floodplain. Below this section the stream becomes even larger through a combination of riparian surface tributaries and groundwater inputs as it goes into the cattle exclosure area (Figure 18). In this section, the stream channel is minorly entrenched with numerous old log and rock check dam structures that are well-integrated with the meadow but are not quite to the historic meadow surface, so the active floodplain remains confined and limited to the immediate vicinity of the channel.

Figure 18. Gully in the middle of the main Casa Vieja Meadow outside of the exclosure.

PROJECT GOALS AND OBJECTIVES

The long-term, overarching goal of the Kern Plateau Meadows Project is to restore natural geomorphic, hydrologic, and biotic processes throughout the meadow complex to increase resilience, ecosystem services, and improve aquatic, riparian, and floodplain habitats for species of concern.

Restoration objectives were developed according to hypotheses that articulate expectations for geomorphic, hydrologic, and biotic process creation and enhancement in response to treatments within the restoration design. **Restoration objectives for the Kern Plateau Meadows Project are as follows:**

PRIMARY GOAL 1: Restore natural geomorphic, hydrologic, and biotic processes throughout meadow sites.

- **Objective 1-1:** Arrest and mitigate headcuts
- **Objective 1-2*:*** Increase channel aggradation
- **Objective 1-3***:* Increase structurally forced channel widening
- **Objective 1-4*:*** Increase channel length and complexity
- **Objective 1-5:** Increase water surface elevation (vertical connectivity)
- **Objective 1-6*:*** Increase ground water table elevation (vertical connectivity)
- **Objective 1-7*:*** Maximize active channel and floodplain proportion of the valley bottom (lateral connectivity)
- **Objective 1-8:** Reverse riverscape structural starvation
- **Objective 1-9:** Increase meadow soil water saturation extent and elevation
- **Objectiv*e 1*-10:** Increase carbon storage
- **Objective *1-11:*** Increase riparian and wet meadow vegetation extent and production

PRIMARY GOAL 2: Improve aquatic, riparian, and floodplain habitats to create ecological benefits to fish, wildlife, and native vegetation.

- **Objective 2-1:** Increase meadow-associated bird habitat quantity and quality
- **Objective 2-*2:*** Increase meadow bird abundance and richness
- **Objective 2-3:** Increase benthic macroinvertebrate biomass and richness
- **Objective 2-4:** Expand the quantity and extent of off-channel deep pool habitat for MYLF
- **Objective 2-5:** Increase MYLF distribution and abundance
- **Objective 2-6*:*** Improve aquatic habitat quality through improved stream temperature regulation
- **Objective 2-*7:*** Increase CA Golden trout habitat quantity
- **Objective 2-8*:*** Increase CA Golden trout habitat complexity
- **Objective 2-9**: Increase CA Golden trout distribution and abundance

Based on our overarching project goal, hypotheses were developed on expected meadow-wide and localized response to our proposed structural treatments selected to address the identified driving concerns. Our overarching response hypothesis is that mimicking natural structures will promote processes that will lead to recovery of self-sustaining meadow systems. Structures (beaver dam analogs, post-assisted log structures and sod (primarily made of sedges) plugs) create hydraulic diversity that amplifies geomorphic processes of deposition and erosion. Structures raise water surface elevations and increase geomorphic unit diversity. Water of different velocities carry different size sediment resulting in depositional patterns varying by velocity often referred to as "sediment sorting." This can create patches of suitable gravel for trout spawning and concealment that might otherwise be more limiting in simple planar flow channels. The structures slow and raise water that creates dam pools above and eddy pools below that provide flow refugia for fish during high flows and locations to rest and forage. The raised water elevation increases the likelihood that floodplains will be inundated, promoting greater water storage and hyporheic exchange. These processes also have the potential to cool water. Additionally, aggradation will occur from the decrease in water velocity, which we expect will lead further to floodplain connectivity. As water tables rise and floodplains are connected, a greater proportion of the valley bottom will become hydrologically connected, leading to an increase in active channels (including multithreaded channels) and off channel habitat. The former leads to a greater quantity of fish habitat and the latter to an increase in frog habitat. Also increased fluvially active valley bottom leads to an increase in soil moisture and hydric vegetation, which will increase in vigor and extent. This increase in vegetation production can also support increases in bird and other wildlife habitat. The assemblage of hydrogeomorphic meadows following restoration might start to revert from the current degraded state to what was present historically, which were important carbon sinks rather than carbon sources they have been shown to become following degradation. The conditions in project meadows after restoration will likely lead to a more historic vegetation community dominated by sedges. Root mats from sedges are the major form of structure that has been lost from the system. As discussed above, these sedges can be the self-sustaining structure that maintains this new stable state meadow complex that was similar to historic conditions but scaled to the current climatic regime. If beaver were to passively or actively reintroduced into the meadow, these processes would likely engage quicker and more intensely (Figure 19).

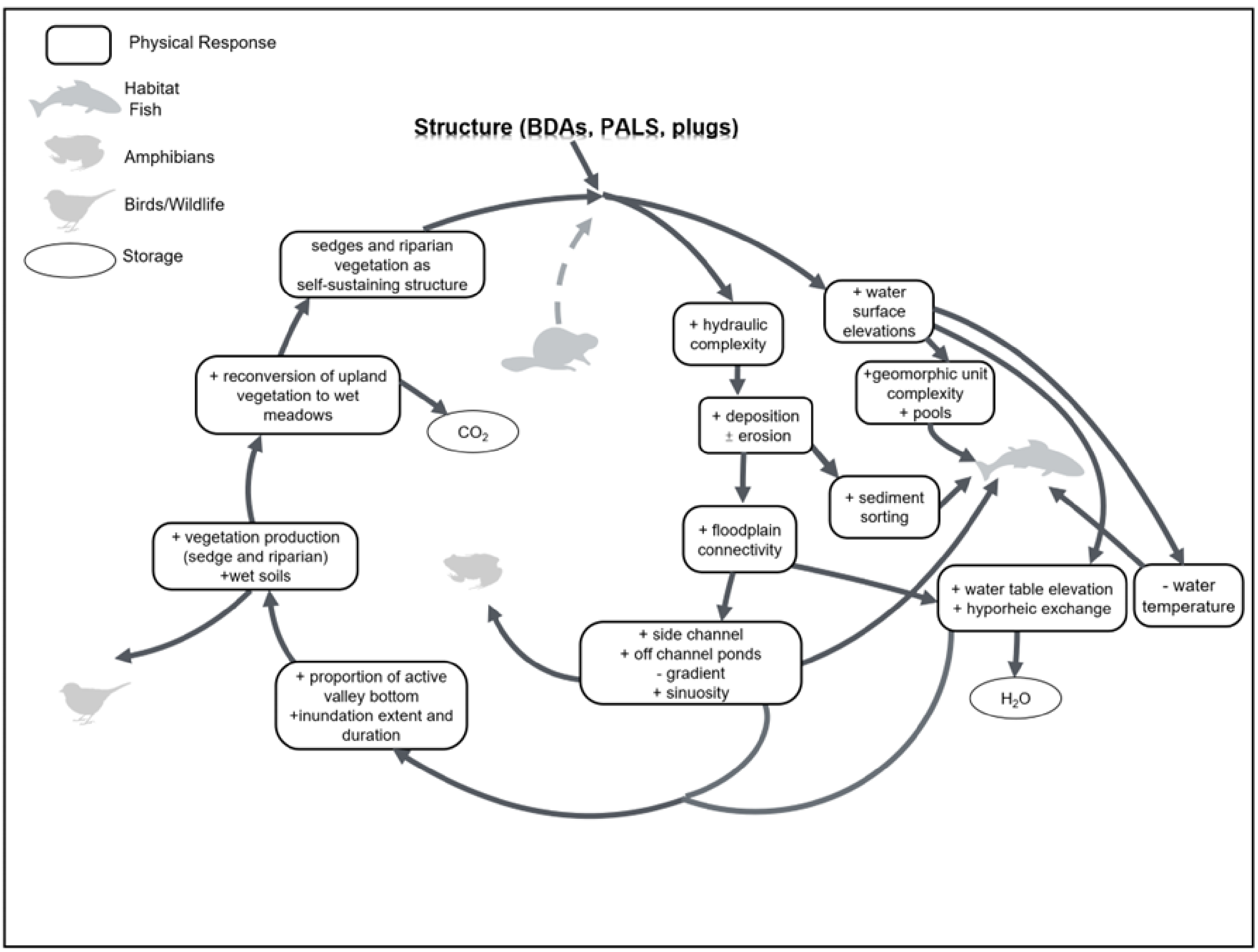

Figure 19. Conceptual model depicting our response hypotheses related to the addition of structure to a meadow system.

PROJECT CONSTRAINTS AND OPPORTUNITIES

Implementation of the Kern Plateau Meadows Project will help inform future efforts about the ability to, not just meet project objectives, but to identify the challenges, constraints, and opportunities of LTPBR to restore meadows, especially in wilderness areas.

Sierra Nevada meadow restoration efforts have been ongoing for nearly a century. In recent decades, this restoration has been dominated by engineered approaches using heavy machinery such as pond and plug and channel-fill techniques. Discussions about relative restoration effectiveness and costs aside, these approaches are simply not available for restoration in wilderness areas where mechanized and motorized equipment (this includes even a wheelbarrow) is prohibited. Hand-built techniques using simple tools (e.g., shovels, saws, axes, loopers, etc.) are the only active restoration approaches that can be used in designated wilderness area. Similar, perhaps more labor intensive, techniques were applied across the Kern Plateau starting in the early 1900s (Kraebel and Pillsbury, 1934). While hand-built approaches are doable, the manual labor is strenuous and poses a constraint on the project. Coupled with the difficulty of travel in extremely rugged terrain, carrying not only this equipment but camping gear can be a major challenge. The use of pack animals to help carry equipment likely may be necessary in several locations.

A perceived constraint of using LTPBR in meadow restoration is the inability to aggrade channels sufficiently to reconnect floodplains in systems that have lost so much sediment, since degradation occurred over a century ago. It is true that many of these meadows do not consistently have predictably high flow events that mobilize large amounts of sediment needed to fill incised channels. Some of the meadows are located near the top of the watershed without much sediment input even in high flow events. However, observations of past constructed and natural structures in these meadows suggest significant deposition would occur behind the proposed structures. With increasing temperatures and decreasing precipitation, spring runoff events are becoming more diminished due to climate change. However, episodic summer intense rain events, which likely brings in the majority of hillslope material critical for channel fill, have become more extreme as a function of climate change.

Another constraint to this project is that a primary stressor to these fragile systems that is also in large part responsible for the degradation is still imposed on the system. Grazing still occurs in several of these meadows, albeit at a much lower animal density than historically. While the reduction in grazing intensity has allowed some recovery, the impacts are still observable, documented, and had instigated actions to preserve sensitive areas. Thus, the restoration will have to not only reverse past impacts but overcome continuing impacts.

Another challenge is the discrepancy between funding and permitting cycles, and the timeframe over which this restoration approach occurs. LTPBR is not a one-and-done action but rather harnesses the power of water to do much of the work. The work done is not measured in years but rather in large flow events. The amount of sediment to be delivered to fill these channels will take several large flow events. Maintenance and multiple phases of restoration will be needed to achieve ultimate project objectives. Under the current processes necessary to implement restoration, this might require multiple reapplications for grants and permits adding to the costs and uncertainty in completing the project.

While these challenges and constraints are daunting for such a large project, they can be surmounted. Additionally, meadows provide opportunities for these approaches to be highly effective and extremely valuable. First, these systems are depositional geomorphic features on the landscape. The highly erosive and often exposed decomposed granite in steep uplands is constantly being delivered to these low gradient areas. Additionally, large episodic rain events do happen frequently and can mobilize a tremendous amount of sediment. The perception that LTPBR approaches cannot aggrade these highly incised systems is far from universal, with several lines of evidence that hand-built structures can be highly efficient and effective at reconnecting floodplains. Several large structures, including very large gabions, that have been installed in these meadows have largely filled the channel behind them (as much as 2m deep). Large trees that have fallen on subsurface meadows show a step increase in elevation on the upslope side suggesting sediment deposition is occurring even with sheetflow. This project will test the ability for the structures to reconnect floodplains with relatively low investment.

Additionally, while these meadows do not store as much water as historically, they still have a relatively high water table and several springs systems. This wet landscape supports a lot of wet meadow vegetation that has dense root mats and greatly increases surface roughness to capture sediment and prevent incision. Many of the incised channels have widened and aggraded enough to create inset floodplains where this vegetation is most abundant and accelerating the aggradation process.

The main opportunity with this project is the potential to recover these extremely valuable ecosystems. The ability of meadows to sequester carbon is on par with, or higher than, tropical rainforests (Reed et al. 2020). The ability to store and slowly release water during the dry season provides extremely valuable increases in baseflow for downstream uses. Meadows keep sediment and nutrients up in these headwater systems that could otherwise overwhelm systems downstream. Increasing the resiliency to drought, floods, and fires affects the entire watershed. Additionally, these systems provide critical habitat for several species of flora and fauna. For a relatively small investment the opportunity to provide large benefits cannot be overstated.

PROJECT ASSESSMENTS AND ANALYSES

The design was informed by field visits, desktop analyses, and previous studies and insights from personnel that have decades of experience in management, restoration, and monitoring of the Golden Trout Wilderness area meadows. A hydrogeomorphic analysis reports is included as Appendix A that describes some of the information used to inform this design and supplement the meadow descriptions supplied above. Information in Geomorphic and Hydrological Studies report includes hydrogeomorphic meadow typing, meadow potential responses to restored conditions, and meadow topography from the lidar demonstrating channel incision.

FIELD VISITS

On August 2-7th, 2020 several of the collaborators including TU and INF USFS personnel, and consultants visited meadows in the southern half of the project area. The INF personnel showed the group impaired areas and past restoration locations. A vast amount of knowledge from the multi-disciplinary team about meadow ecosystems, geology, geomorphology, hydrology, ecology, management, and restoration was shared and discussed. This created a common understanding and perspective that was essential for developing shared project goals and objectives for future planning, design, monitoring, and adaptive management.

Another meeting to tour the northern project meadows was planned for the end of August 2020 but was cancelled due to fire and smoke hazards. This meeting was rescheduled and occurred on June 7-9th and included additional INF personnel, CDFW, and other project partners. Additional time was spent by consultants on design and monitoring June 10-11th.

Another trip occurred in July 12-16th 2021 for design and mapping of meadow type and condition in the southern project meadows. The northern project meadows design and meadow mapping trip occurred June 13-17th 2022. A final trip to complete design and meadow mapping occurred August 24-29th 2022.

During the design and meadow mapping field visits, locations of complexes, structure types and size, and restoration opportunities and strategies were determined and recorded on a tablet in a QGIS application, and thus all information gathered was spatially explicit. In this same QGIS application, polygons of meadow hydrogeomorphic meadow type based on hydrology, geomorphology, and vegetation characteristics were recorded. This information is all stored in a geodatabase.

DESKTOP ANALYSES

Several types of publicly available GIS data exist (e.g., 10 DEM, vegetation classifications, National Hydrography Data) that have been summarized or synthesized to provide information of the project areas to support analyses and mapping products. Output from many of the tools developed as part of the Riverscape Consortium (https://riverscapes.xyz/Tools/) were summarized for the South Fork Kern (HUC8) for almost no expense. The tools used to produce information for the project area includes Riverscape context , valley bottom extraction tool (VBET), Terrain analysis using digital elevation models (TAUDEM), and the beaver restoration assessment tool (BRAT) (Table 2).

Because LiDAR (2m DEM resolution) is available for the project area, we used this information in TAUDEM in place of the publicly available 10m DEM to provide much more accurate topographic analyses. This higher resolution data was used to delineate the channel and ZOI.

Table 2. Riverscape GIS information compiled from publicly available data and Riverscape Tools model output.

Riverscape Context		**Valley Bottom Extraction Tool (VBET)**	**Terrain Analysis Using DEMs (TAUDEM)**	**Beaver Restoration Assessment Tool (BRAT)**
Ecoregions (EPA)	Level 1, 2, and 3	Valley Bottom Extent	Pit-filled DEM	Current Beaver Dam Capacity
LANDFIRE vegetation	Existing vegetation	Probability of Valley Bottom	D-infinity Flow Direction	Historic Beaver Dam Capacity
	Historic vegetation	Active Channel	D-infinity Contributing Area	Capacity Veg Limited Only
Topography (DEM)	Slope	Estimated Active Floodplain	Topographic Wetness Index	Limiting Factors
	Flow Accumulation	Estimated Inactive Floodplain	D-infinity Slope (%)	Restoration Conservation Opportunities
	Drainage area	Slope	D-8 slope (degrees)	Risk of Conflict
	Detrended DEM	Relative DEM (HAND)	Relative DEM (HAND)	Current Riparian Vegetation
	Hillshades for context	Topographic Wetness Index	Delineated Channel	Historic Riparian Vegetation
Hydrology	Hydrography (NHD HR+)	Channel Area		
	Watershed boundaries			
Land Management	Land ownership/agency			
	Fair market value			

Climate (PRISM)	Mean Annual Precipitation Mean Annual Temperature Min Temperature Max Temperature Avg Dewpoint Temperature Min Vapor Pressure Deficit Max Vapor Pressure Deficit
Transportation	Roads

Complex and Structure Information

Using the field-collected and GIS data described above, complex relief, gradient, and length was calculated for each complex. Structure height and width was determined based on the assumption that a channel spanning structure would be built to bank-full height, so average channel width and depth was estimated in the field.

Structure height, when combined complex relief and length, was used to calculate the total number of structures required for the backwater of an individual structure to extend upstream to 50% of the next restoration structure. As such, this design reflects the upper bound of possible restoration structures.

Channel Delineation

An accurate delineation of the channel is important for deriving inundation extents used in developing ZOI (see below). The channels provided by the National Hydrography Data are often not accurate as they are derived from the 10m DEM. Therefore, a new channel network was derived from LiDAR data available for the project areas. The channel delineation of the watershed using a LiDAR-derived DEM was performed using the latest available release of TauDEM (5.3.7). Following the standard workflow provided by the TauDEM developers, the DEM was first hydrologically conditioned to remove pits (PitRemove), followed by calculating the flow direction (D8FlowDir) and contributing flow area (AreaD8). Next, several intermediate outputs were generated using the Gridnet tool including (1) the longest flow path along D8 flow directions to each grid cell, (2) the total length of all flow paths that end at each grid cell, and (3) the grid network order. A stream skeleton was derived, from which a weighted flow accumulation grid was derived (AreaD8, with watershed outlet point specified). The DropAnalysis command was used to identify the ideal threshold value for capturing the stream network from the weighted area grid. As the LiDAR-derived DEM is higher resolution than the typical DEM used in TauDEM analysis, the range for the Drop analysis was increased to 500-50000. Finally, the threshold was applied to the weighted area grid (Threshold) and the stream network was vectorized (StreamNetwork).

Detrended Digital Elevation Model

Estimation of floodplain connectivity largely depended on the use of LiDAR topographic surfaces that have been detrended. Conceptually, the process of detrending topographic data consists of removing elevational changes due to the valley gradient, thereby allowing the elevation of valley bottom features (i.e., channels, floodplains, etc.) to be directly comparable (Figure 3). The resulting relative elevation model can provide an estimate of inundation at different heights above the channel bottom. Detrending of the Kern Meadow Project LiDAR data was implemented using the height above nearest drainage (HAND) approach and implemented within the TAUDEM suite of topographic analysis tools. The HAND method starts with the identification of a drainage pathway for the channel network, the DEM surface is then "detrended" by differencing the elevation of each cell in the raster by the elevation if its nearest drainage cell (Liu et al. 2018).

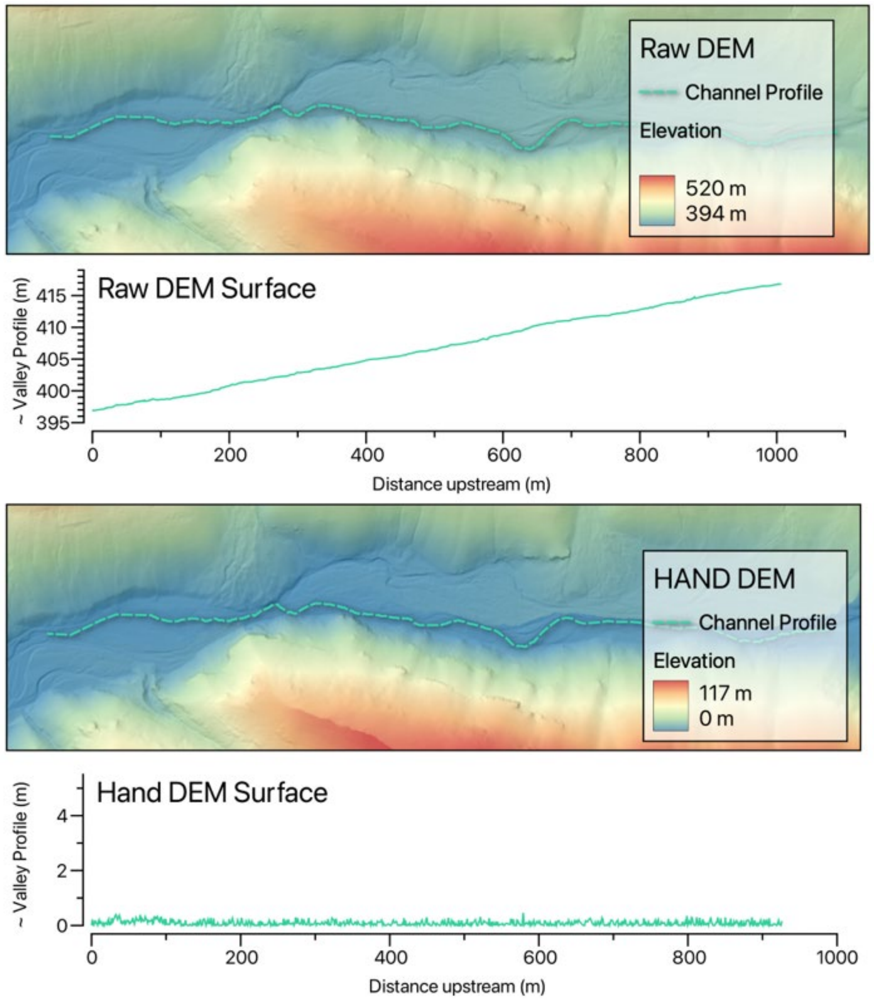

Figure 20. Profile comparison of a digital elevation model and a detrended digital elevation model using HAND.

Zone of Influence

We identify the complex zone of influence (ZOI), which is the area that a complex (i.e., group of structures) can provide geomorphic and hydrological impacts. The ZOI of a complex designed to force overbank flows may occur within an expected lateral extent with a given increase in surface elevation provided by the structure height. The hydrological ZOI on vegetation can extend further by increasing the water table elevations within the riparian area that roots can access below the ground surface. The ZOI can extend further yet (sometimes 100s m) if overbank flows propagate down the floodplain or into paleochannels. Here we include a conservative ZOI that includes the extent of lateral overbank flows and increased access of the elevated water table to riparian vegetation. We recognize that further longitudinal extent is likely to occur in situations where overbank flows continue downstream in the active floodplain which can be mapped after the as-built design demonstrates this response.

Here, we assume that structures will likely be able to increase water surface levels by up to 1 m over the channel bottom given the channel in most instances is between 0.3-1.0 m deep. We also assume that this increase in water surface will increase water table elevations influencing vegetation up to 3 m above the channel bottom, thus we use inundation elevations of 1.0-3.0 m to describe hydrological benefits to riparian vegetation.

RESTORATION APPROACH

LOW-TECH PROCESS-BASED RESTORATION

LTPBR is based on an understanding of what constitutes healthy riverscapes, and how restoration actions lead to restoring riverscape health and resilience. Riverscapes are composed of channel and floodplain habitats and their associated biotic communities that are maintained by physical and biological processes that vary across spatial and temporal scales (Ward, 1998). Structural starvation (i.e., the absence of wood, beaver dams, and/or dense vegetation) in riverscapes is one of the most common impairments affecting riverscape health. Generally, a riverscape starved of structure drains too quickly, has lower lateral connectivity, is more prone to incision, and has simpler more homogenous habitat. By contrast, a riverscape system with an appropriate amount of structure provides obstructions to flow. What follows in the wake of structurally-forced hydraulic diversity are more complicated geomorphic processes that result in far more diverse habitat, resilience, and a rich suite of associated ecosystem services. The specific restoration structures used (e.g., beaver dam analogues (BDAs), post-assisted log structures (PALS), sedge plugs) are the tools used on-the-ground, however, ultimately they are based on riverscape and restoration principles (Wheaton et al. 2019b).

An important component of all restoration is attempting to establish a target condition that restoration seeks to attain. This condition may be: the single historic condition (i.e., generally considered as “pre-European settlement”); a set of two or more historic conditions based on “stages” or alternate reference conditions based on the natural evolution of riverscapes; a new condition supported by contemporary hydrologic and climatic processes; or a new and novel condition that can be encouraged by management actions (i.e., not ‘natural’) and to provide priority ecological benefits. The LTPBR approach only requires that we establish *potential* historic conditions to help define what are possible outcomes from structural additions (or beaver relocation). Also, this approach implicitly recognizes the possibility of multiple reference conditions. In these meadows, these may include a riverscape characterized by multiple channels, high channel-floodplain connectivity, seasonal and perennial overbank flow, as well as perennial channelized flows. Alternatively, the riverscape could be characterized by an absence of channels, or of discontinuous channels and dominated by sheetflow and subsurface flow, rather than channelized flow. Or perhaps the restored riverscape may include beaver that were almost certainly present historically (James and Lanman 2012, Lanman et al. 2012), where multiple beaver dam complexes create large inundation extents and wetlands. In other words, the immediate restoration treatments (e.g., beaver dam analogues) do not necessarily lead towards a single restoration target condition, rather they are intended to promote geomorphic, hydrologic, and biotic processes that will shape the target system using contemporary conditions and inputs. In the context of unknown process rates and changes to the natural disturbance regime (e.g., fire, snowpack, changes from snow- to rain-dominated hydrology) giving the system the tools it needs (i.e., structure), rather than imposing a specific form ensures that the outcomes of restoration, are sustainable under the current climatic regime, rather than designed for historic conditions that may no longer persist.

This stream evolution model from Cluer and Thorne (2014) is a modification of previous stream evolution models in that it recognizes that the historic reference condition is not always the single threaded channel (Stage 1) often assumed, but rather a highly dynamic multi-threaded system (Stage 0). Streams can go through a rapid change of incision (Stage 2-3) if pushed by both anthropogenic and natural disturbances, resulting in a degraded state that does not support a diversity of habitats and biota and loss of ecosystems services. The natural recovery of channel incision is channel widening (Stage 4) and aggradation (Stages 5-7). Eventually, multiple channels will form (Stage

8) until the stream is reconnected to the floodplain retaining the reference condition. Structure is necessary to maintain the refence condition and to accelerate the recovery from centuries to decades.

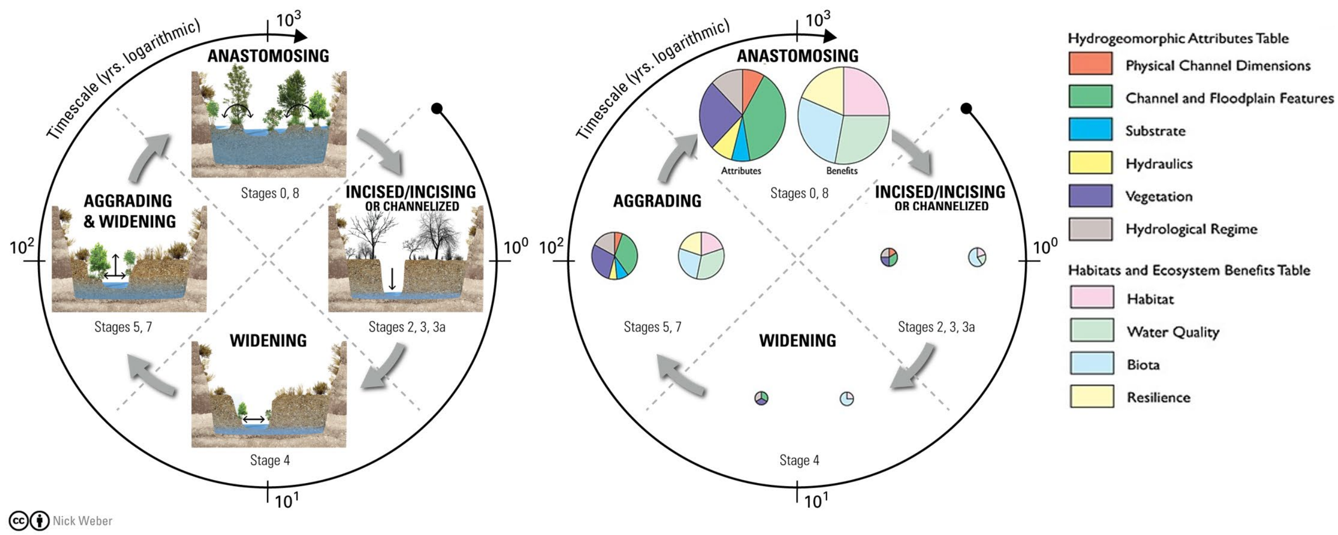

Figure 21. Simplified version stream evolution model (SEM) proposed by Cluer and Thorne (2014) in Wheaton et al. (2019).

The LTPBR approach focuses on harnessing existing hydrological, geomorphological, and ecological processes that have been interrupted or extirpated due to anthropogenic changes. For example, historic grazing-driven channelization that shifted what was historically a depositional meadow habitat into an eroding transport reach that lacks the structure and the function of accreting and retaining the sediment that is generated both upstream of and within the meadow stream channel itself. The primary methods used include using wood, conifer branches, sagebrush, willow, and sedge mats to simulate natural beaver dams, woody debris jams, and other in-stream structure to slow, split, and spread stream flows, promote inset floodplain development, raise water tables, and aggrade stream channels to increase floodplain connectivity (Pollock et al. 2015, Wheaton et al. 2019a). The approach mimics structure that promotes processes that accelerates the evolution of the system from an incised channel to one that is highly connected to the floodplain within years-decades rather than centuries-millennia (Cluer and Thorne 2014, Pollock et al. 2014), resulting in a system that is self-sustaining (Figure 21).

The LTPBR approach is iterative and begins within the inset channel and works to simultaneously widen and aggrade the channel bed. Structures can be used to both shunt flows and erode banks to widen the channel and create inset floodplains. Structures can also be designed to create low-velocity dam pools, in which sediment is deposited, aggrading the stream channel, increasing channel-floodplain connectivity. Structures create hydraulic diversity that amplifies geomorphic processes, leading to a greater complexity of geomorphic units and sediment sorting. In meadow systems, newly formed surfaces of fine sediments and raised water tables increase the recruitment of mainly sedges and other aquatic and emergent plant species, producing dense networks of root mats. Fresh sediment surfaces, especially those dominated by gravels, can recruit willow and other woody riparian vegetation, important habitat for willow flycatchers and other bird species. This vegetative structure leads to a feedback where stems increase surface roughness, promoting further sediment deposition that becomes locked into the root matrix and is highly resistant to erosion. Shallow water tables, highly connected floodplains that dissipate flow energy, and resistant surfaces create a system resilient to drought, floods, and fire that are likely to increase in a warming climate.

LTPBR involves no earthmoving or heavy equipment in the channel or adjacent floodplain. This equipment is also not allowed in the Golden Trout Wilderness. The habitat that is generated comes at the pace and scale of the site's delivery of flow, sediment, and natural recruitment of aquatic and riparian vegetation and will respond most to episodic events that will provide higher than average influxes of flow and sediment. The existing vegetation community that is present at the site provides the source of seed and clonal material to propagate on new surfaces. With the relative lack of disturbance during restoration at the site, there is considerably less risk of weedy, non-native invasive vegetation to become established as well as little danger of catastrophic structure failure that might negatively impact the site. Current habitat that is supporting at-risk species will likely not only be preserved but enhanced. Intact wetland areas will be protected and enhanced by strategically placing structures to treat and reduce the impacts of headcutting and gully formation. Overall, water tables will begin to rise with the first phase of structures being installed.

Willow harvest at a sustainable level for the site may be used for material, although in most cases upland vegetation such as conifer branches and sage brush will be used that, with their small needles and leaves, are effective at ponding water. Willow and other riparian species regeneration is encouraged by LTPBR due to the mixture of sediment recruitment and deposition. This is the ideal recruitment environment for willows because they require fresh, moist gravel sediment deposits for sprouting. Structures encourage the settling of fine sediments and silt which is essential for recruitment of sedges and other desirable hydric herbaceous species. These species help provide organic matter to the soil which helps with sod building and retention of soil carbon and nutrients. Structures will be strategically placed within the project footprint to encourage sediment harvest at appropriate locations while providing the structure to catch and prevent sediment losses from the system thus benefitting willow and riparian plant recruitment and minimizing impacts to intact stands of willows. If willows should become entrained into the channel, they will become a welcome part of the in-channel structure and will likely take root.

Because LTPBR defers decision making to the system itself, the approach relies on stream power to do most of the work, is not highly invasive, destructive, or risky, and the likelihood of causing harm to the system is minimal. Material gathered on site is a mix of upland foliage and dead and downed wood (which has the ancillary benefit of reducing fuels and sequestering carbon) and riparian foliage. Riparian woody species used in BDAs and PALs often take root establishing additional desired vegetation stands. Additionally, monitoring and evaluation between phases as part of the adaptive management framework is used to observe, and if necessary, alter non-desirable trajectories. The removal of hand-built structures is not difficult in the unlikely event this restoration approach is leading to harm. The risks mainly come from the loss of time and money. Given the relatively low investment compared to more traditional engineered approaches, even this risk is minimized.

Because the LTPBR approach relies mainly on hand-built techniques to promote processes, this approach is possible in wilderness areas where limited mechanical equipment is allowed. Implementation does not require highly specialized and expensive equipment or a dedicated career of restoration training. Thus, the community of practitioners for LTPBR is much broader with diverse backgrounds than highly engineered approaches. The thousands of people from all over the world with very different backgrounds that participated in a recent LTPBR workshops we presented is testament to this statement. A rapidly growing community of LTPBR practitioners demonstrates both how desirable and adoptable this approach is.

BEAVERS- ECOSYSTEM ENGINEERS

Beavers can significantly amplify the processes described above because of their tireless building and maintenance of dams that are far more capable of ponding water than hand-built structures. It is entirely possible that extant populations in the area could re-occupy areas that currently do not have active populations as habitat improves and populations increase. While active relocation of beavers was not permitted under California state regulations at the onset of this project, recently a new Beaver Restoration Program at the CDFW will be enacted. Thus, relocation of beavers into the project area might be a restoration option if implementation is approved. If so, the addition of structures would improve the likelihood that beaver could be reestablished in the Kern Plateau. If beaver are passively or actively introduced into the system, the proportion of the inactive valley bottom that becomes active across all seasons will likely greatly increase.

LOW-TECH RESTORATION STRUCTURES

As mentioned above, LTPBR practices often rely on the strategic implementation of structural elements that include beaver dam analogs (BDAs), which mimic beaver dams, post-assisted log structures (PALS), which mimic woody debris accumulations, and sedge plugs, which mimic sedge surfaces common in meadows. These structures are not intended to be permanent. They are specifically intended to first mimic, then promote, and natural processes of beaver dam activity, wood accumulation, and most importantly, the production of sedge and other riparian species root masses sustain the system and drive other important hydrologic and geomorphic processes that characterize healthy riverine ecosystems. As such, both BDAs and PALS may require maintenance and/or replacement until natural processes take over.

BDA – Beaver Dam Analog

BDAs mimic natural beaver dams in form (Figure 22) and in function where they can pond water during high and low flows. They utilize a mixture of woody material harvested on site such as woody conifer branches and sage brush, sediment, and may use untreated wooden posts driven into the bed to secure the structure, to form an upstream pond. They can be used to create immediate pond habitat, increase lateral connectivity, promote channel aggradation, and raise surface water and water tables. Examples of post and postless BDAs can be found in Figure 23.

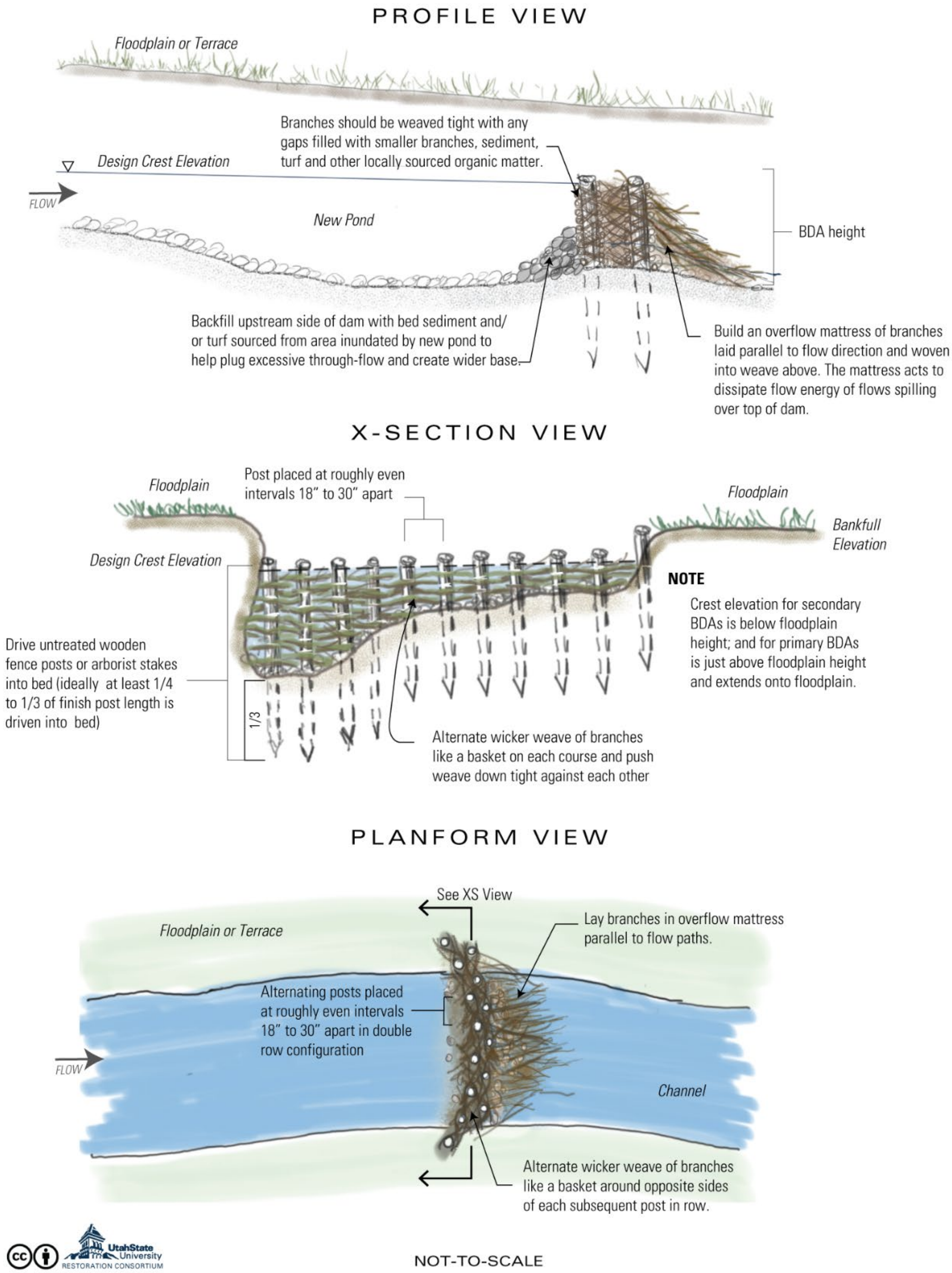

Figure 22. Planform view depicting typical design of a postless BDA structure that induce pond creation and frequency, duration, and extent of floodplain inundation.

Figure 23. Examples of BDAs built in a range of settings, using a variety of materials, and with or without untreated wooden posts for additional temporary stability.

PALS – Post-Assisted Log Structure

Similar to BDAs, PALS (Figure 24) are hand-built structures composed of woody material. Unlike BDAs, PALS are not intended to create an immediate upstream pond although they may serve this purpose at high flows. Often an advantage of PALS is that they can built with generally less effort than BDAs allowing for more PALS built for the same effort. PALS can be used to force specific geomorphic processes, such as channel widening and aggradation or increase lateral connectivity during high flow events. They may use untreated wooden posts to increase their temporary stability. PALS can be bank-attached (Figure 25), to force convergent flow and promote channel scour and pool formation or widening and increased sinuosity; mid-channel to promote flow divergence, and bar or island formation; or channel-spanning to promote aggradation (Figure 26).

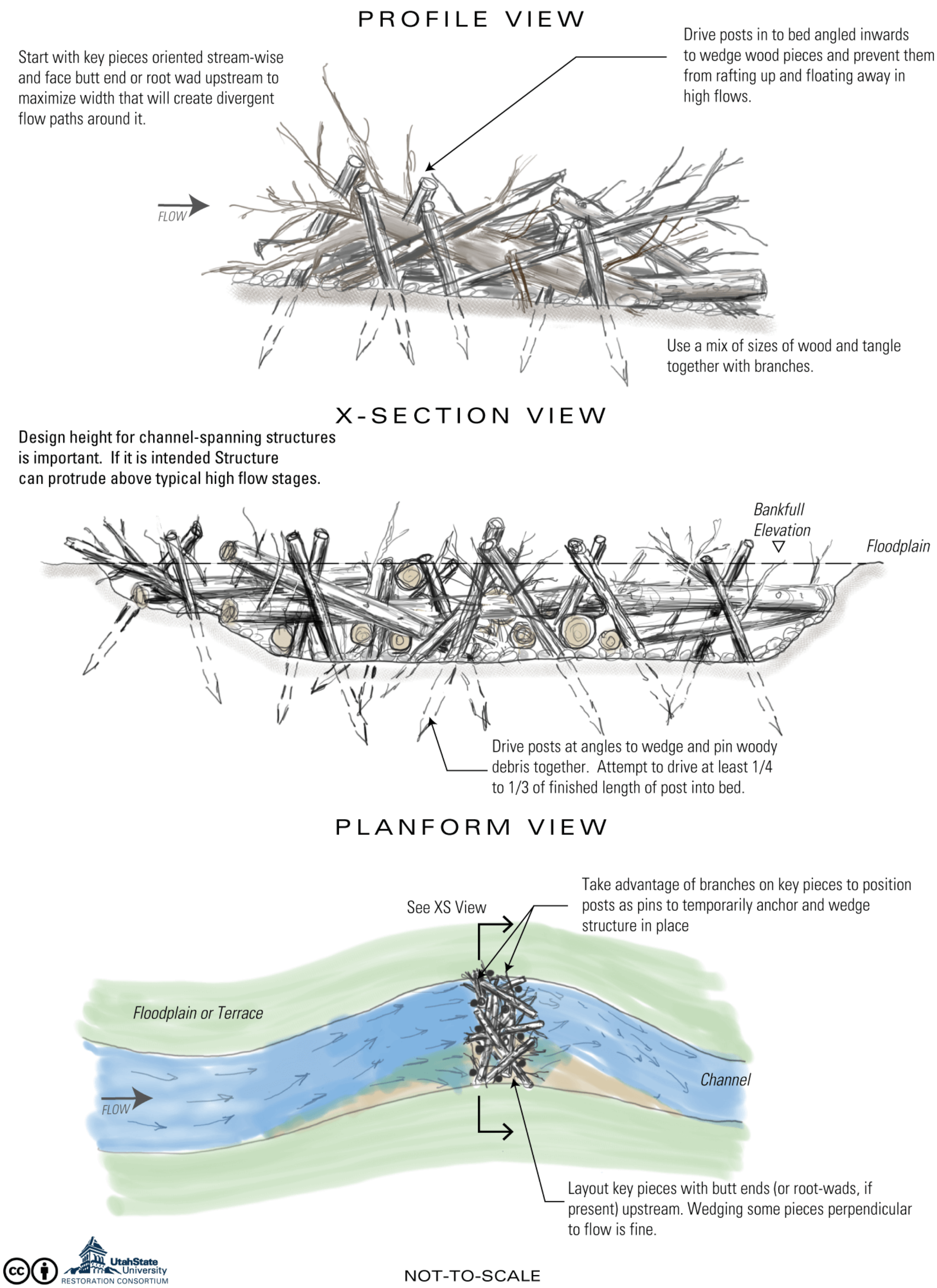

Figure 24. Profile, cross-sectional, and planform views of typical channel spanning Post-Assisted Log-Structure (PALS) (from Wheaton et al. 2019).

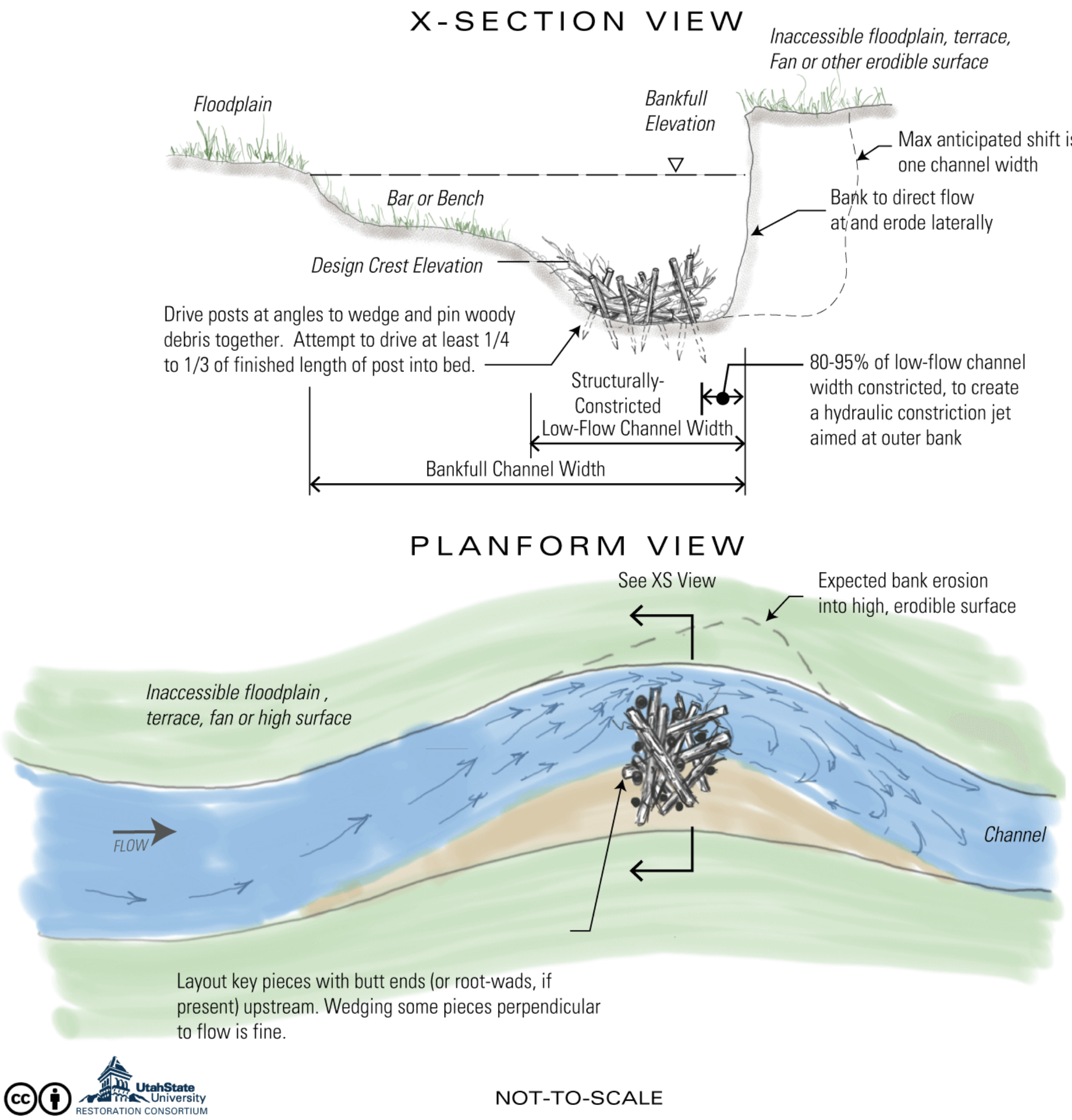

Figure 25. Cross-sectional, and planform views of typical bank-attached Post-Assisted Log-Structure (PALS) (from Wheaton et al. 2019).

Figure 26. Examples of different types of PALS, designed to achieve specific objectives. PALS can be bank-attached, mid-channel or channel-spanning.

Sedge Plugs

Sedge plugs are simply sedge mats harvested directly from the surrounding meadows and transplanted within the channel, preferably on a shallow channel-spanning bar that already is recruiting sedges. Because of the matrix created by the root mass, sedge mats hold together fine sediments and organic material that greatly restricts flow allowing for the immediate ponding of water (Figure 27). The live sedge plugs are expected to take root and grow quickly to integrate with the channel bottom. If harvest is dedicated to certain locations, they may form off channel habitat for amphibians.

Figure 27. Sedge plugs transplanted into a small shallow channel (arrow) to raise surface water levels spilling water onto the floodplain creating an upstream pool. The small off-channel pond is expected to provide frog habitat as it fills as water levels rise.

RESTORATION DESIGN

The design is organized with respect to the concept of structure complexes (i.e., groups of LTPBR restoration structures), that have individual designs, objectives, and process-based response hypotheses. We have created designs for each of the 15 meadows. While the complex details and locations are provided, they should be interpreted as guidelines rather than an exact prescription. The final layout of structures occurs during implementation where subtle site-specific features are incorporated into the design taking advantage of opportunities that only become apparent as water routing responses are observed. Therefore, the design here will approximate the as-built design.

LAYOUT OF COMPLEXES

We delineated complexes that we believe will cause the greatest uplift or preservation of existing meadows for the least amount of effort. Some locations are close enough to intact conditions that restoration efforts were not deemed necessary. Conversely, other locations were so far degraded that the effort to restore to historic conditions seemed infeasible, such as areas where the channel gullying was severe. These gullies supported inset floodplains with healthy sedge communities and thus providing meadow functions as best that can be expected in the foreseeable future. Although the main objective is to aggrade incised channels and arrest problematic headcuts, the complexes will address slightly different issues within variations of channel morphology.

COMPLEX-SCALE OBJECTIVES

Complex-scale objectives differ from project objectives in that they specifically describe the geomorphic or hydrologic response a group of structures is designed to force. An example of a complex-scale objective is to force flows overbank to increase lateral connectivity or to aggrade the channel, both of which contribute to the larger goal of restoring and increasing wetland area. We differentiate between three different settings in the project area. We based our valley bottom segmentation on setting, gradient and geomorphic condition of the mainstem channel. However, throughout the valley there are numerous headcuts that feed the mainstem. While the specific objectives at the complex-scale differ among areas of the valley bottom, the strategy for addressing headcuts remains the same regardless of their location. As such, we address them separately, and as distinct from mainstem reach objectives. We then outline the common objectives along the mainstem channel at the reach scale which include sediment recruitment, aggradation, and increased lateral connectivity.

Note that all areas are likely to benefit from structures by increased hydraulic diversity and geomorphic complexity as structures influence flow paths and the processes of erosion and deposition. As such, we do not list it as a specific reach-scale objective here.

Headcuts

We have identified the location of numerous headcuts across all meadow project sites. Some appear to be fed by the mainstem channel, swales on the floodplain, or sheetflow. Given the importance of groundwater contributions in these meadows, headcuts may be propagating by a combination of both surface and subsurface flows. Where flow is already channelized before reaching a headcut, we plan on using BDAS to disperse flows before they reach the headcut. In areas where flows to a headcut are characterized by sheetflow and where it is channelized below, we plan on 1) adding cobble at the base of the headcut to prevent scour and 2) building a BDA within the downstream channel to back water up to headcut to further dissipate plunging flows 3) filling the BDA created backwater with woody material to further disrupt and create multiple lower energy flow paths and 4) using multiple BDAs/PALS to capture sediment and aggrade the channel further downstream.

Discontinuous Channels

Within the project area, there are channels that emerge from upstream drainages and terminate on the perimeter of the meadow. Along these sections we will use channel-spanning structures to promote aggradation of the channel and force the dispersal of flows onto the meadow. Unlike the mainstem channel, the objective in these areas is only channel aggradation and associated dispersal of flows.

Mainstem Channel Complex-Scale Objectives

Complex-scale restoration objectives on the mainstem channel are directly related to the existing conditions. Our approach to restoration is to promote complex-appropriate processes by strategic use of instream low-tech structures.

Sediment Recruitment

Channel widening is part of natural cycle of recovery of incised channels. In more confined valley settings, bank-attached PALS will be used to force channel widening and create a local source of sediment to deliver to downstream reaches to promote channel aggradation. These segments are characterized by higher channel gradients than downstream sections.

Aggradation

Aggradation is also part of natural cycle of recovery of incised channels. While stream evolution models generally suggest that aggradation naturally occurs after the process of widening, structures can short-circuit this cycle by immediately capturing sediment. BDAs and channel-spanning PALS are intended to capture sediment and aggrade the channel bed. In less severe cases of incision, aggradation may occur quickly enough that sustained floodplain connection can be obtained within the life of these structures. Moderate cases may require buildup of structures in multiple stages. Severe cases might initiate widening (above) before attempting aggradation. Aggradation is a common objective in all meadows.

Increase Lateral Connectivity

In areas where the original floodplain remains accessible, or where the channel has widened and created an inset floodplain, we rely on channel-spanning structures (e.g., BDAs, channel-spanning PALS) to force connectivity to adjacent surfaces. Depending on the local channel geometry (i.e., bank height) lateral connectivity may be achieved at baseflow conditions, or only during high flow conditions. In the short term, connectivity depends on the structural forcing of flows out of the channel. The increase in lateral connectively is a common objective in all meadows as many surfaces can be inundated by building structures the depth of the channel, which will not be difficult given the average size of many channels.

Pool Habitat

The use of channel-spanning structures also forces the creation of inundated aquatic habitat (i.e., ponds and shallow backwaters). BDAs are specifically designed to force and maintain ponds during all flow conditions, while channel-spanning PALS are more likely to force ponds during high flow conditions. If PALS fill with sediment, they may also force ponds during baseflow conditions. Additionally, particularly in Mulkey Meadow, off-channel pool habitat to provide a fishless refuge for Mountain Yellow-Legged Frogs will be created by harvesting sedge plugs (use as structure fill in the channel) in dedicated locations.

COMPLEX SPECIFICATIONS

To determine the expected number of structures to build for the project to fulfill permit requirements and help estimate budgets, we use topographic data collected via LiDAR and field visits to obtain average depth and widths of the channel for each complex. We define a generalized structure height as equivalent to the channel depth or the max structure height of 1 m, whichever is less. The structure width is equivalent to the channel width, and structure length (upstream to downstream) of 1 m at the base and 0.5 m at the top (typical of LTPBR structures). Based on the complex relief (i.e., the elevational difference between the top and the bottom of a complex), and the height of the structure, we can estimate the maximum number of structures that will lead to redundancy (i.e., where water of the downstream structure inundates to upstream structure). We plan on having a downstream structure inundate to 50% of the height of the structure upstream to both protect the upstream structure from scour as water plunges over the structure and to reduce the elevation required to inundate the adjacent floodplain during high flows (Figure 28). Thus, the number of structures for complex is the relief/(structure height*0.5). We always rounded up and assume the field fitted number will be within 30% of this estimate. The number of structures divided by the complex length gives the average spacing between structures, although this will be field fitted to deal with variations within the channel and structure specific objectives. Assuming the structure is trapezoidal in shape, volume was estimates as ½ * (1+0.5)* height* width of the structure. A conservative estimate of total fill was calculated as the number of structures*30%. Structures are made of both woody material and sediment. For a BDA, we assume that 85% of the material of the structure is woody and the rest is sediment, or sod/sedge mat. For a PALS, 100% of the fill is woody material. For sedge plug 100% is sod or sedge mat. This information will be provided and include the range of material volume that will be needed to implement the restoration design in each meadow for permitting purposes.

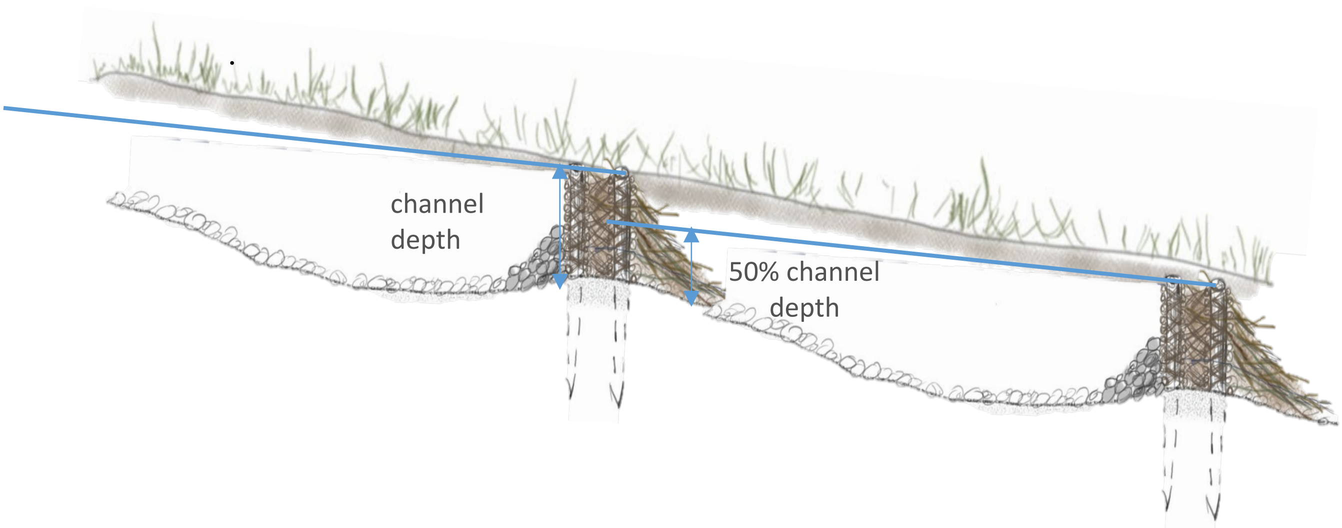

*Figure 28. To determine the number of structures in a complex, the relief is divided by the structure height (channel depth) * 50% downstream inundation height.*

FINAL MEADOW DESIGNS

We have identified the location of 174 complexes, totaling approximately 30 km of stream channel, throughout the project meadows (Table 3). In most meadows, primary and secondary objectives include increased lateral connectivity and aggradation. In meadows with Golden trout and Mountain Yellow-legged frogs, an emphasis on using these structures to also create deeper pools will be important. Headcut mitigation also occurs in most meadows. While we have identified several headcuts that need to be addressed, headcuts will be evaluated during implementation whether new headcuts need attention or existing headcut structures need to be repaired. Sediment recruitment and channel widening through directed bank erosion is planned in only a few locations.

Table 3. Complex count, complex length, number of structures, (±) potential difference between field fit design and proposed design, structure volume (fill), footprint of structures, and ZOI.

Meadow	No. Complexes	Complex Length (km)	No. Structures	±	Structure Volume (m3)	Structure Area (m^2)	ZOI (ac)
Total	174	30	1525	577	2270	4896	188
Horseshoe Meadow	22	4.36	167	61	144.6	499	37.3
Round Valley	10	1.37	44	22	115.4	206.5	4.1
Poison Meadow	7	0.53	84	32	93.2	297	1.8
Dutch Meadow	10	1.42	75	32	465.2	635	3.8
Mulkey Meadow	53	9.73	414	153	616.5	1375.8	63.4
Bullfrog Meadow	4	0.30	24	9	25.2	56	1.2
Strawberry Meadow	13	2.26	129	50	155.8	366.5	15.0
Fat Cow Meadow	3	0.15	28	10	8.9	32.5	0.4
Schaeffer Meadow	2	0.20	20	7	37.8	50.2	1.0
Brown Meadow	18	2.50	197	75	222.1	527.4	9.0
Kingfisher Meadow	4	0.60	31	13	44.3	118	2.3
Soda Creek Meadow	8	1.61	34	11	64.4	106	12.3
Round Mountain Meadow	1	1.08	22	8	33.8	90	15.1
Snake Meadow	2	1.28	34	12	126.8	172	8.3
Casa Vieja Meadow	17	2.56	234	84	140.2	395.5	13.4

HORSESHOE MEADOW

Horseshoe meadow has high floodplain reconnection potential with relatively minimal uplift. As with most meadows, the main objective in Horseshoe meadow is to aggrade the channel or raise water surface elevation enough to reconnect floodplains (Figure 29). We expect to install 167 structures in 22 complexes spanning over 4 km of stream (Table 3). Most of the structures used in these complexes are relatively small (height of 0.25-0.5 m) (Table 4) but will still likely raise water surface elevations sufficiently to inundate inset floodplains and in some instances old side-channels. Several inset floodplains within the incised trench have well establised sedges. The increase surface roughness from sedges will lead to perhaps the most rapid aggradation, and thus no active restoration is planned (i.e., upstream of HS13- flow is from west to east). We will bring in some woody materials in these locations to test if a structure can further accelrate aggradation. Because this meadow is expected to respond quickly to restoration, most of the restoration here will occur in Phase 1. Some complexes encompass more incised channels and will likely require structures to be enhanced or added in Phase 2.

ROUND VALLEY MEADOW

The upper Round Valley meadow contains subsurface and riparian meadows; however, massive headcuts in the middle portion of the meadow has reduced upper meadow water storage capacity likely resulting in converted upland. A total of 44 structures in 10 complexes over nearly 1.4 km are planned for this meadow (Table 3). Headcuts have largely been arrested through mitigation but do need to be repaired and enhanced. This area is a prime focus for treatment using BDAs and PALS to increase the water table elevation, capture incoming sediment, aggrade the stream bed, and stabilize eroding banks. Due to the depth of the incision downstream of the headcut, most of the restoration will likely enhance only the inset floodplain in the near term. However, some tributaries are delievering a relatively high amount of sediment from hillslopes, and so an attempt will be made to capture this sediment for aggradation to eventually reconnect to the historic floodplain over several phases (Figure 29). Approximately 75% of the structures will be built in Phase 1. Phase 2 structures will increase the height of exisiting structures or add more structures in the highly incised areas (Table 5).

POISON MEADOW

Approximately 80 structures within 7 complexes over 0.5 km of stream is planned for Poison Meadow (Table 3). The upper portion of Poison Meadow has multiple small channels that BDAs could quickly aggrade and spill water to floodplain surfaces. Just below these small channels, two large headcuts created about two 150 m long deeply incised channels with well-developed inset floodplains. Given the depth of the incision and the relatively short length, no restoration is planned in these channels. The meadow largely turns into subsurface meadow until it reaches some headcuts that have received past mitigation. Flows will be dispersed just below these headcuts to increase inundation in complexes PN04 and PN05 (Figure 30). The channel just downstream will receive some structures to increase aggradation. Willow eventually becomes the dominant riparian vegetation which have become established both in and out of the channel. The high stem density and root systems (i.e., this section is not structurally starved) will likely lead to aggradation, and thus this area will not receive many structures accept to arrest some headcuts (Table 6). Approximately 75% of the structures will be installed in Phase 1. Structures will be added in Phase 2 to continue the trajectories that have been initiated in Phase 1.

Table 4. Horseshoe Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**4364.2**					**37.3**	**165**	**60**	**2**	**1**			**144.6**	**499**	
HS01	LC, AG	92.6	0.75	3	1	1.08%	0.52	3	1	0	0	70/30/0	30.9	6.8	12	Look for opportunities for lateral connectivity
HS02	AG	99.9	0.5	2	0.7	0.70%	0.49	3	1	0	0	100/0/0	33.3	3.0	8	Mid-size BDAs to act as grade control
HS03	LC, AG	746.2	0.5	2	2.7	0.36%	6.36	11	4	0	0	50/0/50	67.8	11.3	30	Sedge plugs and BDAs on riffles to increase lateral connectivity, activate channel on river right
HS04	LC, AG	56.1	0.3	2	0.2	0.36%	0.73	4	2	0	0	40/50/10	14.0	2.7	12	Bank attached PALS to accentuate point bars. Also use a couple BDAs, sedge plugs
HS05	LC, AG	134.5	0.5	2	0.7	0.52%	1.20	3	1	0	0	50/50/0	44.8	3.0	8	Less opportunity than downstream reach but pockets of inset floodplain. PALS and BDAs
HS06	LC, AG, PH	278.6	0.75	2.5	2	0.72%	3.30	5	2	2	1	100/0/0	46.4	14.1	25	Use BDA at top to push water to river left channel. BDAs throughout main channel. If side channel gets activated put a BDA in it to keep water running channel left.
HS07	LC, AG, PH	249.3	1	3	1.2	0.48%	3.07	3	1	0	0	100/0/0	83.1	9.0	12	Look for areas to inundate floodplain on river right. Might require a few large BDAs, might take a couple phases.
HS08	LC, AG, PH	447.7	0.75	3	2.1	0.47%	4.17	6	2	0	0	100/0/0	74.6	13.5	24	Look for opportunities to raise surface water elevation high enough to activate old side channels, using 0.5 to 1 m BDAs

HS09	AG, LC	75.4	0.3	1.5	0.3	0.40%	0.27	2	1	0	0	100/0/0	37.7	1.0	4.5	Use BDAs to reconnect small floodplain pockets
HS10	LC	56.1	0.25	2	0.4	0.71%	0.40	4	2	0	0	80/0/20	14.0	2.3	12	Small BDAs, raise water surface elevation to hydrological influence vegetation
HS11	LC	61.5	0.25	1	0.3	0.49%	0.32	3	1	0	0	0/0/100	20.5	0.8	4	Use sedge plugs to raise water surface elevation and spread flows
HS12	AG, LC	120.4	0.2	1	0.4	0.33%	0.67	4	2	0	0	0/50/50	30.1	0.9	6	Look for opportunities to aggrade both the channel and the inset floodplain. Small BDAs and sedge plugs
HS13	AG, LC	133.8	0.2	1.5	1.4	1.05%	1.13	14	5	0	0	30/20/5 0	9.6	4.3	28.5	Small BDAs and sedge plugs. Less than 0.25 m. Try to mitigate small headcuts throughout the complex
HS14	HM	11.1	0.5	1	0.4	3.6%	0.01	2	1	0	0	100/0/0	5.6	1.1	3	Arrest Headcut
HS15	AG, LC	120.1	0.5	2.5	0.9	0.75%	0.75	4	2	0	0	100/0/0	30.0	5.6	15	A couple BDAs to aggrade channel and activate small floodplain pockets
HS16	LC	363	0.25	2	2	0.55%	3.24	16	5	0	0	80/10/1 0	22.7	7.9	42	Small BDAs to inundate floodplains
HS17	AG, LC	183.5	0.4	3	1.2	0.65%	1.10	6	2	0	0	90/10/0	30.6	7.2	24	Reconnect occasional floodplain pockets. 0.25 to 0.5 m BDA size
HS18	LC	380.3	0.25	2	2.9	0.76%	1.97	24	8	0	0	80/20/0	15.8	12.0	64	Several small BDAs to force water on the floodplains
HS19	AG, LC	255.5	0.3	2	2.6	1.02%	1.36	18	6	0	0	60/30/1 0	14.2	10.8	48	Reconnect occasional floodplain pockets
HS20	AG	423.8	0.25	3	3.1	0.73%	5.83	25	8	0	0	50/50/0	17.0	18.6	99	Combination of small BDAs and PALS. 0.25 m
HS21	AG	68.7	0.5	2	0.9	1.31%	0.42	4	2	0	0	80/20/0	17.2	4.5	12	Aggrade channel
HS22	HM	6.1	1	3	0.5	8.2%	0.00	1	1	0	0	100/0/0	6.1	4.5	6	Big BDA to back water up to headcut and divert flows around headcut. Put rocks at the base

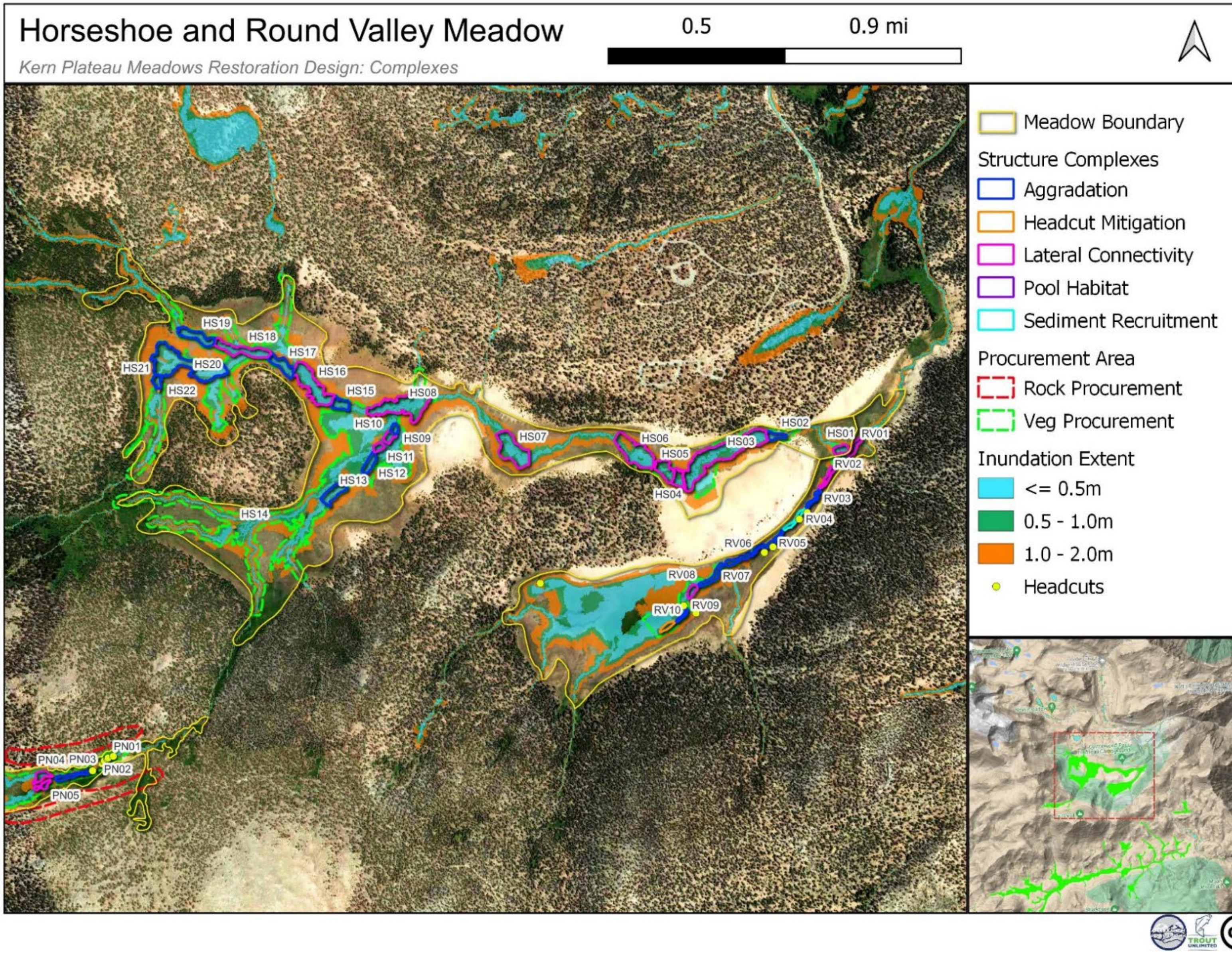

Figure 29. Horseshoe and Round Valley Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

Table 5. Round Valley Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Round Valley																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		1371.9					4.1	31	13	13	8			115.4	206.5	
RV01	LC. AG	125.2	0.75	3	0.8	0.64%	0.43	3	1	0	0	0/100/0	41.7	6.8	12	Improve laterally connectivity with PALS
RV02	LC. AG	136.6	0.5	3	1.9	1.39%	0.39	7	3	2	1	70/30/0	17.1	14.6	39	Reconnect inset floodplains, look for opportunities for channel widening. Take down to confluence. Small BDAs
RV03	AG, LC, PH	125.5	0.75	3.5	0.9	0.72%	0.30	3	1	1	1	100/0/0	41.8	11.8	21	BDAs to aggrade, new source of sediment recruitment from gully at top of complex
RV04	SR, CW, AG	162.1	0.75	4	1.2	0.74%	0.43	4	2	1	1	50/50/0	40.5	18.0	32	Mix BDAs and PALS, look for opportunities for sediment recruitment
RV05	AG, LC, PH	198.1	1	4	1.2	0.61%	0.53	3	1	1	1	70/30/0	66.0	18.0	24	Use BDAs at pinch points to aggrade inset floodplain.
RV06	AG, LC	187.4	1	5	2.1	1.12%	0.53	4	2	1	1	20/80/0	37.5	30.0	40	Use only a few PALS to see if aggradation can be accelerated
RV07	AG, LC, HM	190.2	1	4	0.7	0.37%	0.60	2	1	0	0	40/60/0	95.1	9.0	12	PALS and BDA, protect headcuts and banks with wood from cattle
RV08	LC, AG	84.1	0.25	3	0.2	0.24%	0.39	2	1	0	0	70/30/0	42.1	1.7	9	Reconnect inset floodplain
RV09	AG, LC	81.4	0.25	0.5	0.8	0.98%	0.18	0	0	7	3	60/30/10	11.6	1.0	5.5	Phase 2, eventually recruit sedges if downstream base level is increased
RV10	HM	81.3	0.5	3	0.6	0.7%	0.30	3	1	0	0	0/100/0	27.1	4.5	12	Put out wood on trails to discourage cattle use

Table 6. Poison Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for

Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Poison Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**531.4**					**1.8**	**64**	**24**	**20**	**8**			**93.2**	**297.0**	
PN01	HM, AG	102.5	0.4	2	6.6	6.4%	0.24	14	5	6	2	50/50/0	5.1	16.2	54	Multiple head cuts in this area. Repair or arrest. Many boulders and willows that act as structure.
PN02	HM, AG	21	0.6	3	1.5	7.1%	0.05	5	2	0	0	80/20/0	4.2	9.5	21	Headcut that needs to be arrested. Try to aggrade a bit below to step it down
PN03	AG, HM	181	0.5	2	6.3	3.48%	0.57	19	6	8	3	70/30/0	7.0	27.0	72	BDAs to step down gradient
PN04	LC	91.5	0.25	3	1.6	1.75%	0.52	7	3	2	1	20/60/20	11.4	7.3	39	A couple of structures could keep water on floodplain longer before dropping down into headcut.
PN05	LC	88.2	0.25	3	2.3	2.61%	0.31	7	3	2	1	20/60/20	11.0	7.3	39	A couple of structures could keep water on floodplain longer before dropping down into headcut.
PN06	LC. AG	36.5	0.5	5	1.8	4.93%	0.11	7	3	2	1	40/60/0	4.6	24.4	65	Structures can increase lateral connection but trench is likely too deep to ever fill. Use PALS
PN07	HM	10.7	0.3	1	0.7	6.5%	0.02	5	2	0	0	0/100/0	2.1	1.6	7	Repair headcut structure

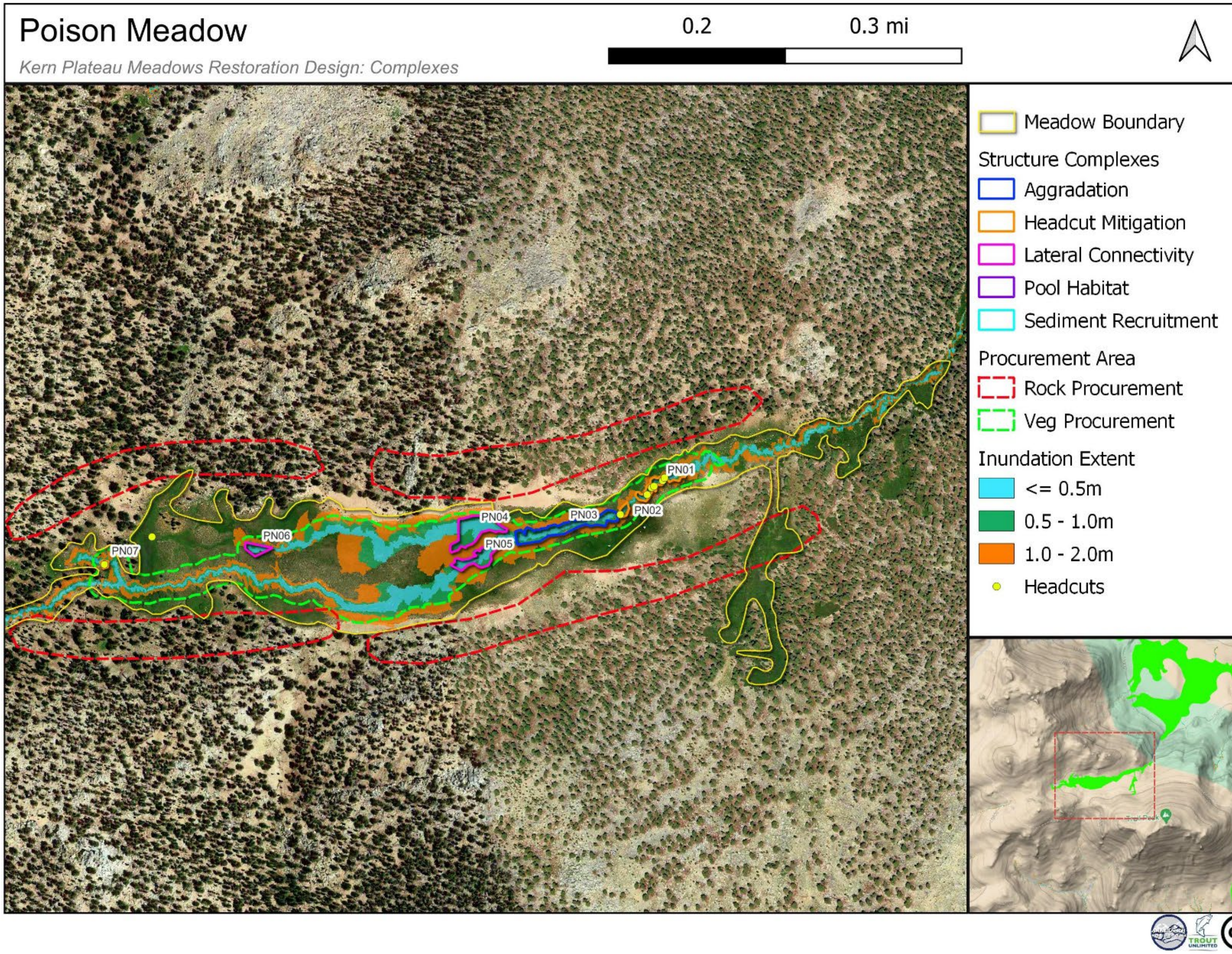

Figure 30. Poison Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

DUTCH MEADOW

Dutch Meadow has been greatly incised leaving many historic meadow surfaces converted to upland vegetation. Seventy-five structures in 10 complexes are planned for restoration treating approximately 1.4 km of stream (Table 3). Apart from some upstream headcut treatments, most complexes have a primary objective to aggrade the incised trench (Table 7). We plan to build some large BDAs to completely span the trench that is up to 10 m wide is someplace (Figure 31). Sediment input from the hillslope seems highly likely given the sparse vegetation. While there may be several years where little sediment accumulates, large, episodic runoff events will rapidly aggrade the channel if structure is present to help disperse flows and retain the sediment within the meadow system. Because of large size of the planned structures and the necessity to build up the lower meadow as base-level control, more structures are planned for Phase 2 than in Phase 1. In Phase 2, as the large structures fill in they will have to be built up to maintain their trajectory. This relatively small but highly incised meadow appears to be a good candidate to test the ability to rapidly aggrade the channel with large structures. If aggradation is fairly rapid, then Phases 3 and beyond might be needed to reconnect this meadow to its historic floodplain.

MULKEY MEADOW

Mulkey meadow is the largest meadow in the Kern Plateau Meadows Project. The meadow is diverse in both hydrogeomorphic meadow types and meadow conditions containing several tributary meadow complexes. The design is for over 400 structures in 53 complexes in both the mainstem and tributaries spanning nearly 10 kms of treated channel (Table 3). Several complexes in the lower portion of the meadow could laterally connect large areas with the addition of 0.5-1 m high structures in Phase 1(Figure 32). This area is very low gradient, thus few structures are need to back water up through the complex (Table 8). This zone shows the most promise for reconnection of the full historic floodplain with ample material for building available. This would ultimately be an excellent area to reintroduce beavers and has all of the key habitat, forage, and material components to support a population once initial restoration work creates appropriate habitat for cover and protection. Other areas might need to achieve some aggradation in Phase 1 and then look to inundate similar size areas in Phase 2 (Figure 32). The tributary upstream from Bullfrog on river right contributes a large amount of sediment, that has decreased the gradient of the valley bottom upstream of the confluence (MK11). Here, smaller BDAs (0.25 m) can inundate large areas. Another tributary upstream from here also brings in a large amount of sediment, thus the lower portion of Mulkey has a good sediment supply coupled with modest amounts aggradation needed to inundate large areas making this area likely to achieve large benefits as a result of LTPBR.

In the middle portion of Mulkey, the incision depth becomes more significant until it is several meters deep. Two similar size channels, both highly incised, meet to form the mainstem (Figure 33). Massive areas of historic meadow are now converted uplands. In the north tributary there is large rock/gabion structures that are near the height (>2 m) of the incision depth built in the mid-1980s. These structures have completely backfilled suggesting that aggradation rates are rapid and given enough time even huge, incised trenches can fill in. However, much of the complex responses are going to be within the inset floodplain. Here modest gains could be made by raising water surface elevations to frequently inundate and aggrade the inset floodplain. In a few locations, some large BDAs will be installed for experimental purposes that will be outlined in the adaptive management plan. While the needed lift to convert any upland vegetation on terraces to wet meadow vegetation in the current climatic regime seems unlikely, we do not want to rule out the possibility.

The lower end of the upper portion of Mulkey is fairly confined with several contributing stringer meadows (Figure 34). The channel is less incised in the confined portion with heavy beaver influences. Based on carbon dating of sticks of relic dams, beavers were active here in the early 1970s (R. Knapp personal communication). Nearly all the Mulkey population of ESA-listed yellow legged frogs are found here (MK33). This areas is charcterized as having deep and complex habitat, isolated off-channel ponds, and healthy willow stands. The relic beaver dams are still providing some structural forcing of hydraulics to create this complexity. This area may act as a reference condition and provides evidence that BDAs have the potential to improve amphibian and riparian habitat in more degraded locations. The design here is to harvest sedge plugs to create off-channel pools that act as habitat free of trout that prey on eggs and tadpoles. These plugs will be used in the channel to force water out into the floodplain and inundate the off-channel pools.

In the upper portion of the meadow, complex objectives are to increase aggradation of the inset floodplain as channel incision gets fairly deep in some locations. However, reconnection to historic surfaces maybe achieveable after a couple phases of restoration (**Error! Reference source not found.**). Many of these complexes will be the focus of Phase 2.

Several of the stringer meadows complexes will address headcuts. Some of the channels in these stringer meadows have incised, but their small size and incision depth should be fairly straight forward to mitigate with small BDAs and sedge plugs.

BULLFROG MEADOW

Bullfrog Meadow is connected to Mulkey and has intact subsurface and riparian meadows with headcuts mainly found in the lower portion of the meadow (Figure 32). Only 4 complexes containing 24 structures are planned in Bullfrog (Table 3). The restoration will be to mitigate headcuts to prevent further upstream migration and to increase the elevation of the meadow base-level control to conserve the existing meadows. The area near BF02 is one of the other locations (the other being middle Mulkey) where Mountain Yellow-Legged Frogs can be found. As in Mulkey, the design here is to harvest sedge plugs to create off-channel pools that act as habitat free of trout that prey on eggs and tadpoles. These plugs will be used in the channel to force water out into the floodplain and inundate the off-channel pools (Table 9).

STRAWBERRY MEADOW

Strawberry Meadow has several locations where the meadow is in relatively good condition that will benefit immediately from addition of structures. The design includes 13 complexes with approximately 130 structures treating 2.26 km of stream channel (Table 3). In the lower portion of Strawberry Meadow, the inundation potential of accessible floodplain and side channels is high with relatively small structures (e.g., 0.5 m high BDAs; Table 10). In this area, willow is common, but willow production could be enhanced if the floodplain was more frequently inundated. Thus, the primary objective for the lower complexes is to increase lateral connectivity (Figure 35). Installation of structures will help buffer the meadow against further conversion to dry or upland conditions and will likely increase the coverage and robustness of the hydric species.

In the upper portion, much of the channel is high gradient and confined and in good condition. The very upper portion of Strawberry is characterized by moderate channel incision. BDAs would be used to aggrade the channel likely over a couple phases (Figure 36).

Table 7. Dutch Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Dutch Meadow																	
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**1418**					**3.8**	**29**	**12**	**46**	**15**			**465.2**	**635**	
DH01	AG, LC	116.8	1	10	1.9	1.63 %	0.38	4	2	0	0	70/30/0	29.2	45.0	60	Attempt to raise base level control with large BDAs and PALS (upstream of BDAs).
DH02	AG, LC	228.8	1	10	3.2	1.40 %	0.76	7	3	0	0	70/30/0	32.7	75.0	100	If we can achieve aggradation to height of the structures in phase 1, continue trajectory in Phase 2
DH03	AG, LC	350.9	1	6	9.7	2.76 %	0.82	0	0	20	6	70/30/0	17.5	121.5	162	Phase 2. Make structure height equal to amount of aggradation achieved in lower complex in Phase 1
DH04	HM	50.7	0.4	1	1.8	3.6%	0.06	0	0	9	3	50/0/50	5.6	3.9	13	Plug channel with sedge plugs and small BDAs
DH05	AG, LC	284.3	1	10	4.3	1.51 %	0.96	9	3	0	0	70/30/0	31.6	90.0	120	If we can achieve aggradation to the height of the structures in phase 1, then implement Phase 2 at a similar increase in elevation
DH06	AG, LC	79.8	1	8	1.3	1.63 %	0.19	0	0	3	1	70/30/0	26.6	30.0	40	Phase 2 aggradation, aggrade up to levels achieved in phase 1
DH07	AG, LC	83.1	1	6	2.6	3.13 %	0.20	0	0	6	2	70/30/0	13.9	40.5	54	Phase 2. Goal is to achieve same amount of aggradation as phase 1 in complex below.
DH08	AG, LC	5.5	0.5	1.5	0.2	3.6%	0.32	1	1	0	0	50/50/0	5.5	1.1	3	Arrest headcut
DH09	HM	153.1	1	6	3.9	2.55 %	0.01	0	0	8	3	70/30/0	19.1	54.0	72	Phase 2. Goal aggrade to aggradation achieved in phase 1 in complex below.
DH10	HM	65	0.5	1	4.7	7.2%	0.07	8	3	0	0	50/50/0	8.1	4.1	11	Repair headcut.

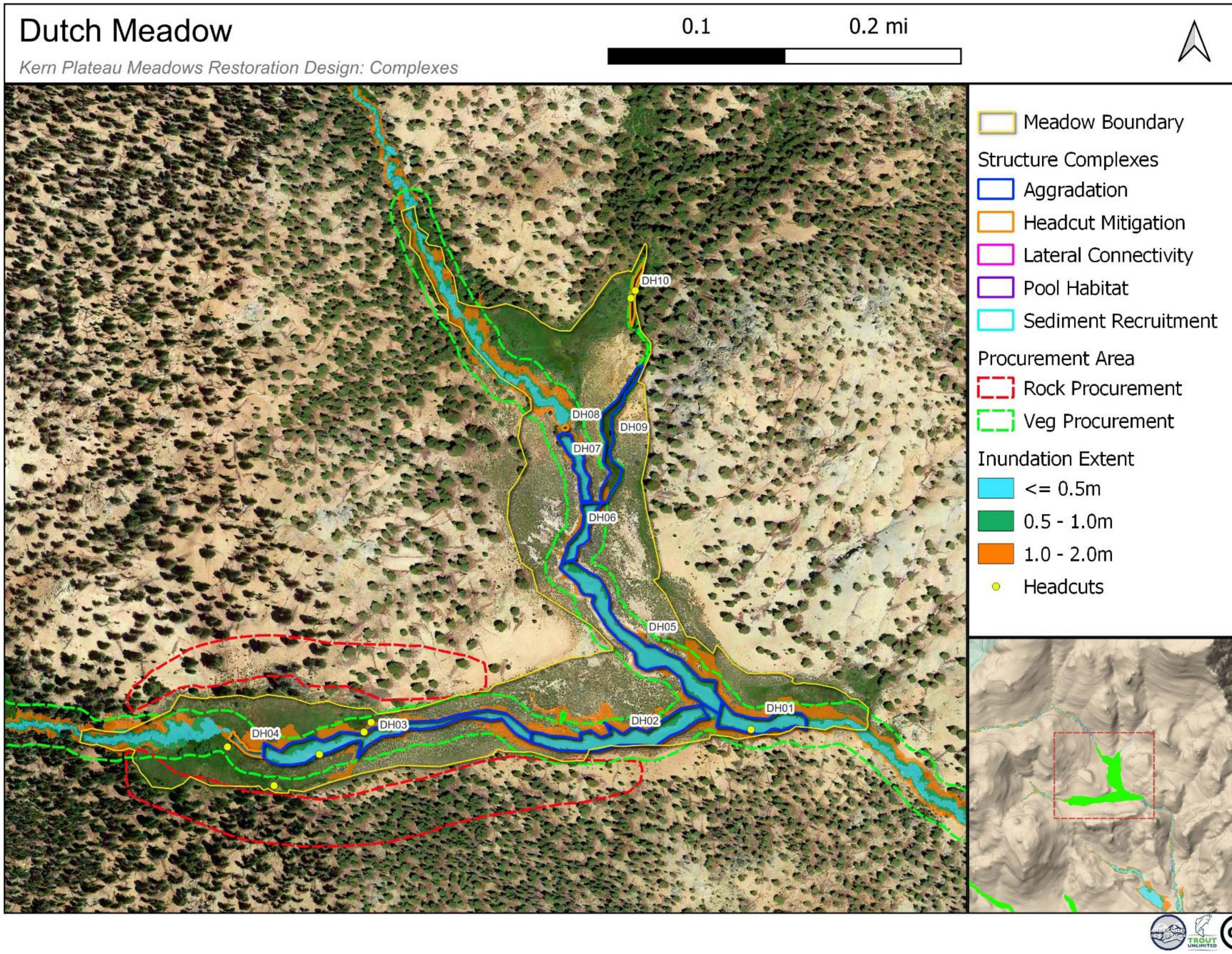

Figure 31. Dutch Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

Table 8. Mulkey Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Mulkey Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol	Str. Area	Description
Total		9731.8					63.4	293	109	121	44			616.5	1375.8	
MK01	AG	50.8	0.75	3	0.1	0.2%	0.23	2	1	0	0	50/50/0	25.4	5.1	9	This Complex is the transition from meadow to stream and will be used to increase base level elevations for the meadow. Structures need to be robust, consider posts and key wood into banks
MK02	AG, LC, PH	678.4	0.75	3	2.3	0.34%	5.37	7	3	0	0	50/50/0	96.9	16.9	30	Potential for increasing inundation of floodplains much more frequently. Aggradation can be fairly rapid here because of inputs from tributary on river left. Consider front end loading with PALS and. Back end with BDAs to distribute sediment better.
MK03	LC, AG, PH	374.1	0.75	3	1.1	0.29%	3.79	3	1	0	0	100/0/0	124.7	6.8	12	Mostly BDAs potential area of inundation is enormous on river left. Several paleo channels can be connected
MK04	LC, AG, PH	380.4	0.75	3	1.3	0.34%	2.84	4	2	0	0	70/30/0	95.1	10.1	18	0.5 to 1 m BDAs and PALS. Upper part of complex has high potential to reactivate old channels and frequently inundate floodplain. Lower part of complex will require larger BDAs to aggrade.
MK05	AG, LC, PH	422.3	1.25	4	1.2	0.28%	2.98	3	1	0	0	100/0/0	140.8	15.0	16	BDAs 1 to 1.5 m Focus in phase 1 will be aggradation. In phase 2, consider lateral connectivity to connect riparian area to upland meadow.
MK06	HM	9.6	0.5	1	0.3	3.1%	0.01	2	1	0	0	100/0/0	4.8	1.1	3	Use rocks to mitigate headcut
MK07	LC, AG, PH	149.9	0.5	3	0.4	0.27%	1.55	2	1	0	0	70/30/0	75.0	3.4	9	Potential for inundation is high. BDAs and PALS, 0.5m

MK08	LC, AG, PH	91.9	0.75	3	0.2	0.2%	0.44	2	1	0	0	100/0/0	46.0	5.1	9	BDAs 0.5 to 1 , try to activate floodplain on river left.
MK09	AG, LC	39.3	0.3	2	0.1	0.25%	0.48	1	1	0	0	100/0/0	39.3	0.9	4	Small BDAs, try to inundate area between here and main stem. Mitigate for small headcut moving into bullfrog
MK10	AG, LC, PH	745.4	0.75	3	2.3	0.31%	6.17	6	2	2	1	70/30/0	106.5	18.6	33	BDAs and PALS 0.5 to 1m. Phase 1 aggradation, phase 2 opportunities to inundate floodplain. Similar to below complex
MK11	LC, AG	457.2	0.25	4	1.3	0.28%	4.13	9	3	3	1	40/40/20	41.6	12.0	64	Occasional small BDAs and PALS. Will likely push water onto large floodplains. Has very low gradient due to sediment inputs from river right
MK12	LC, AG	407.8	0.25	4	1	0.25%	2.06	7	3	2	1	40/40/20	51.0	9.8	52	0.25m structures, could easily frequently inundate large floodplains. Floodplains are too wide to consider lifting to historic levels, but could consider one location as a pilot
MK13	HM	149.6	1	3	0.8	0.5%	0.71	2	1	0	0	50/50/0	74.8	6.8	9	Repair headcut structure and gradually step it down with BDAs and PALS to the next complex. Mostly small BDAs but a couple large BDAs
MK14	AG, LC, PH	145.5	1	3	1	0.69%	0.66	2	1	0	0	100/0/0	72.8	6.8	9	1m BDAs, may take 2 phases to aggrade. However, tributary on river right is bringing in a lot of sediment
MK15	AG, LC	165.9	0.25	2	1.6	0.96%	0.61	0	0	13	4	50/30/20	12.8	6.4	34	Use 0.25 m structures to capture large amount of sediment coming down and activate river left floodplain. Do this after downstream section on main stem is aggraded, phase 2. For now, this is sediment source for main stem
MK16	HM	171.2	1	3	1.7	1.0%	1.08	4	2	0	0	100/0/0	42.8	13.5	18	Big BDA up top and smaller BDAs stepping down
MK17	LC	123.7	0.25	2	0.4	0.32%	1.24	4	2	0	0	50/30/20	30.9	2.3	12	Small structures to frequently inundate floodplains. 0.25m structures
MK18	HM	24	0.25	2	0.7	2.917%	0.15	6	2	0	0	70/30/0	4.0	3.0	16	Small BDAs

MK19	AG, LC, PH	750.9	0.4	3	2.4	0.32%	6.20	9	3	4	2	70/30/0	62.6	16.2	54	Phase 1 aggradation. Phase 2 lateral connectivity.
MK20	LC, AG, PH	162.8	0.25	3	0.7	0.43%	0.78	6	2	0	0	70/0/30	27.1	4.5	24	BDAs and sedge plugs
MK21	LC, AG, PH	94.9	1.5	4	0.3	0.32%	0.51	3	1	0	0	100/0/0	31.6	18.0	16	One large BDA will back water up to the top of the complex. Step down the large BDA with smaller BDAs until the end of the complex
MK22	LC, AG, PH	293.2	1	3	0.9	0.31%	1.31	2	1	0	0	100/0/0	146.6	6.8	9	Large and small BDAs to inundate floodplain
MK23	AG, LC, PH	34	1.5	4	0.1	0.29%	0.10	2	1	0	0	100/0/0	17.0	13.5	12	2 large BDAs, take advantage of large sediment input on river right
MK24	AG, LC, PH	97.1	1	8	0.4	0.41%	0.28	2	1	0	0	100/0/0	48.6	18.0	24	2 large BDAs (w/posts), trying to raise entire inset floodplain to see how feasible this will be. Do 1 m at a time 2-3 phases
MK25	AG, LC, PH	75.7	0.5	3	0.4	0.53%	0.17	2	1	0	0	100/0/0	37.9	3.4	9	0.25 to 0.5 m BDAs, with lots of sloped hillsides expect aggradation to be quick
MK26	AG, LC, PH	70.6	0.5	4	0.3	0.42%	0.23	2	1	0	0	100/0/0	35.3	4.5	12	BDAs to capture sediment coming in from river right
MK27	AG, LC, PH	53	0.5	10	1.34	2.5%	0.14	6	2	0	0	70/30/0	8.8	30.0	80	Aggrade entire inset floodplain
MK28	AG, LC, PH	139.4	1	6	2	1.43%	0.53	4	2	0	0	100/0/0	34.9	27.0	36	Large BDAs to aggrade and eventually inundate much more meadow area
MK29	HM	17.5	1.5	3	0.8	4.6%	0.03	2	1	0	0	50/50/0	8.8	10.1	9	Large headcut needs to be arrested.
MK30	LC, AG	239	0.35	3	1.2	0.50%	0.75	6	2	2	1	50/30/20	34.1	8.7	33	Try to increase frequency of inset floodplain inundation. 0.25 to 0.5m BDAs
MK31	AG, LC, PH	117.8	0.75	10	0.3	0.25%	0.48	2	1	0	0	100/0/0	58.9	16.9	30	Aggrading the whole inset floodplain. This will require very large BDAs in multiple Phases.
MK32	SR, CW, AG	514.3	0.5	8	3.5	0.68%	1.32	10	3	5	2	0/100/0	36.7	60.0	160	Use bank blasters PALS to recruit sediment and widen inset floodplain. WIll need to use posts
MK33	PH	524.9	0.5	1	7.7	1.47%	9.48	22	7	10	3	50/0/50	16.9	15.8	42	Use sedge plugs harvested from off-channel location to create MYLF habitat. Accentuate current pools and create new deep water pools in the channel.
MK34	HM	10	0.25	1	0.3	3.00%	0.03	3	1	0	0	0/100/0	3.3	0.8	4	Use branches and fill at base to level off

MK35	LC	51.9	0.25	0.5	1.8	3.47%	0.15	15	5	0	0	20/0/80	3.5	1.9	10	Use sedge plugs to fill up channel
MK36	HM	41.8	0.25	0.5	2	4.8%	0.15	16	5	0	0	60/0/40	2.6	2.0	10.5	Step down headcuts with a few small BDAs
MK37	HM	59.9	0.25	0.5	2.9	4.8%	0.16	24	8	0	0	50/0/50	2.5	3.0	16	Small BDAs to fill in headcuts. Sedge plugs
MK38	LC	106.4	0.25	0.5	4.4	4.14%	0.30	36	11	0	0	0/0/100	3.0	4.4	23.5	Sedge plugs to address minor headcuts and to spread out flows in multiple channels
MK39	HM	7.2	0.25	0.5	0.4	5.56%	0.01	4	2	0	0	40/30/30	1.8	0.6	3	Minor repairs on headcut
MK40	LC	174.1	0.5	1	3	1.72%	0.65	6	2	6	2	60/20/20	14.5	6.0	16	Fairly intact area but look for opportunities to push water into old channels with BDA
MK41	AG	65.5	0.5	1	2.8	4.27%	0.14	6	2	6	2	80/10/10	5.5	6.0	16	A few small bdas could aggrade channel
MK44	AG, LC, PH	138.9	0.75	2	1.4	1.01%	0.39	0	0	4	2	50/30/20	34.7	6.8	12	Small BDAs and PALS. Lower end of complex, small inset floodplains can be reconnected
MK45	AG, LC, PH	480.6	1	3	9.7	2.02%	1.69	8	3	12	4	20/80/0	24.0	60.8	81	Highly incised channel. Aggrade and slow down water. Use mostly PALS
MK46	AG, LC, PH	308.4	1	5	4.4	1.43%	1.30	2	1	8	3	20/80/0	34.3	52.5	70	Channel is incised and the inset floodplain is functioning riparian meadow. It is possible we could aggrade it more quickly with large wood. Test in phase 1
MK47	AG, LC	36.2	0.25	1	0.6	1.66%	0.10	3	1	3	1	0/0/100	7.2	1.5	8	Couple of sedge plugs
MK48	AG, LC	78.5	0.3	1.5	1.9	2.42%	0.19	3	1	11	4	60/0/40	6.0	6.4	28.5	small BDAs
MK49	HM	5.8	0.25	0.5	0.3	5.2%	0.01	3	1	0	0	0/0/100	1.9	0.4	2	Sedge plug structure in small side channel
MK50	AG, HM	61.9	0.4	2	1.5	2.42%	0.18	4	2	4	2	80/0/20	7.7	7.2	24	Use BDAs, 0.25 to 0.5m. Last structure in the complex will be used to arrest a headcut
MK51	AG, HM	35.5	0.5	4	1	2.82%	0.08	2	1	2	1	100/0/0	8.9	9.0	24	Step down headcut structure. Aggrade with BDAs
MK52	HM	3.5	0.5	20	0.3	8.6%	0.00	2	1	0	0	0/100/0	1.8	22.5	60	Protect spring with wood.
MK53	AG, HM	104.9	0.75	2	3.6	3.43%	0.28	2	1	8	3	70/30/0	10.5	15.8	28	Incised channel Use BDAs and PALS. Will help repair headcut structures
MK54	AG, LC	176.6	0.25	0.75	5.3	3.00%	0.71	4	2	16	5	60/0/40	8.8	3.8	20.25	Small BDAs and sedge plugs to encourage aggradation and over bank flows
MK55	HM	12.1	1	2	2	16.5%	0.01	4	2	0	0	50/50/0	3.0	9.0	12	1Big headcut

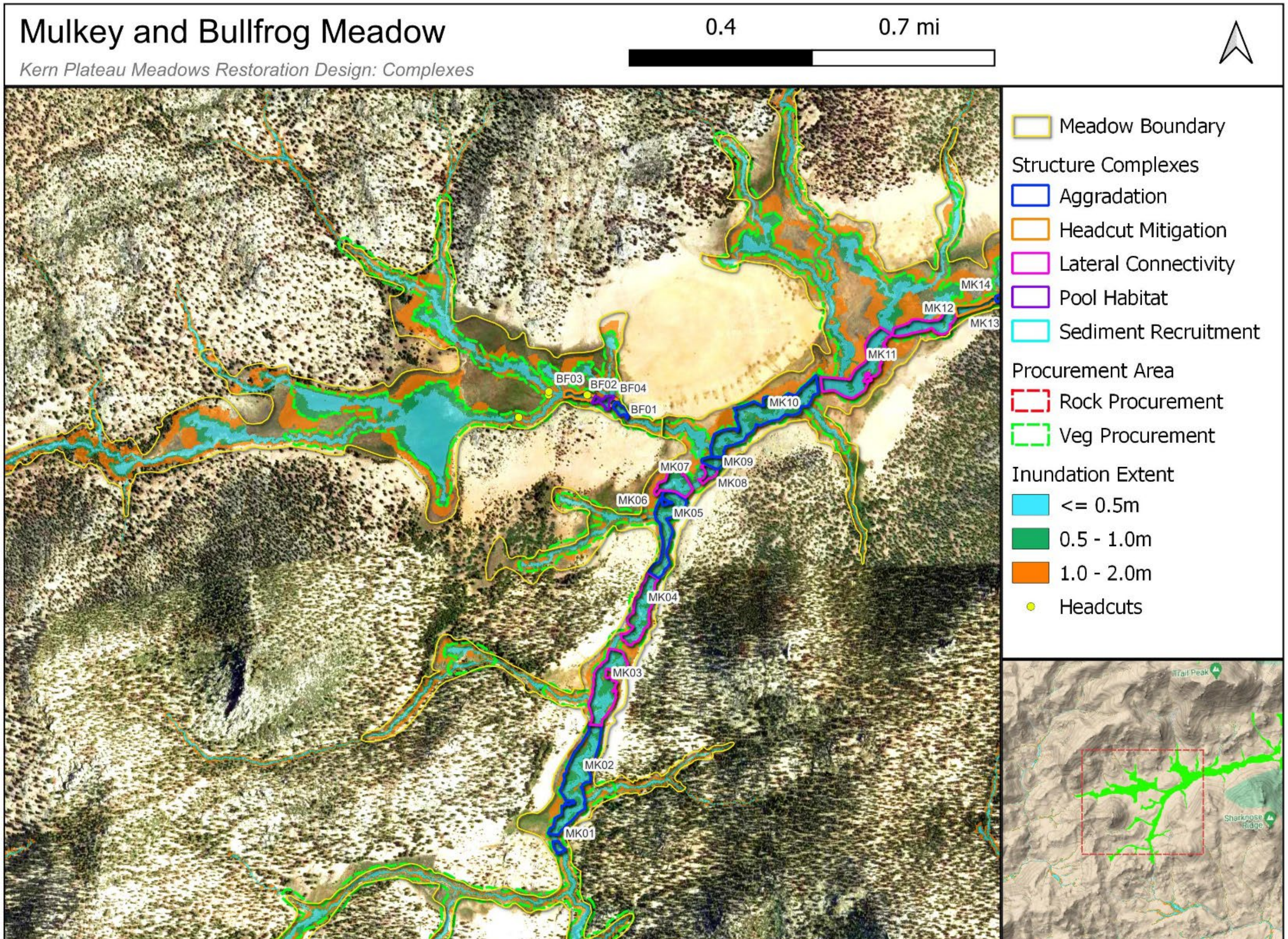

Figure 32.Lower Mulkey and Bullfrog Meadows complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

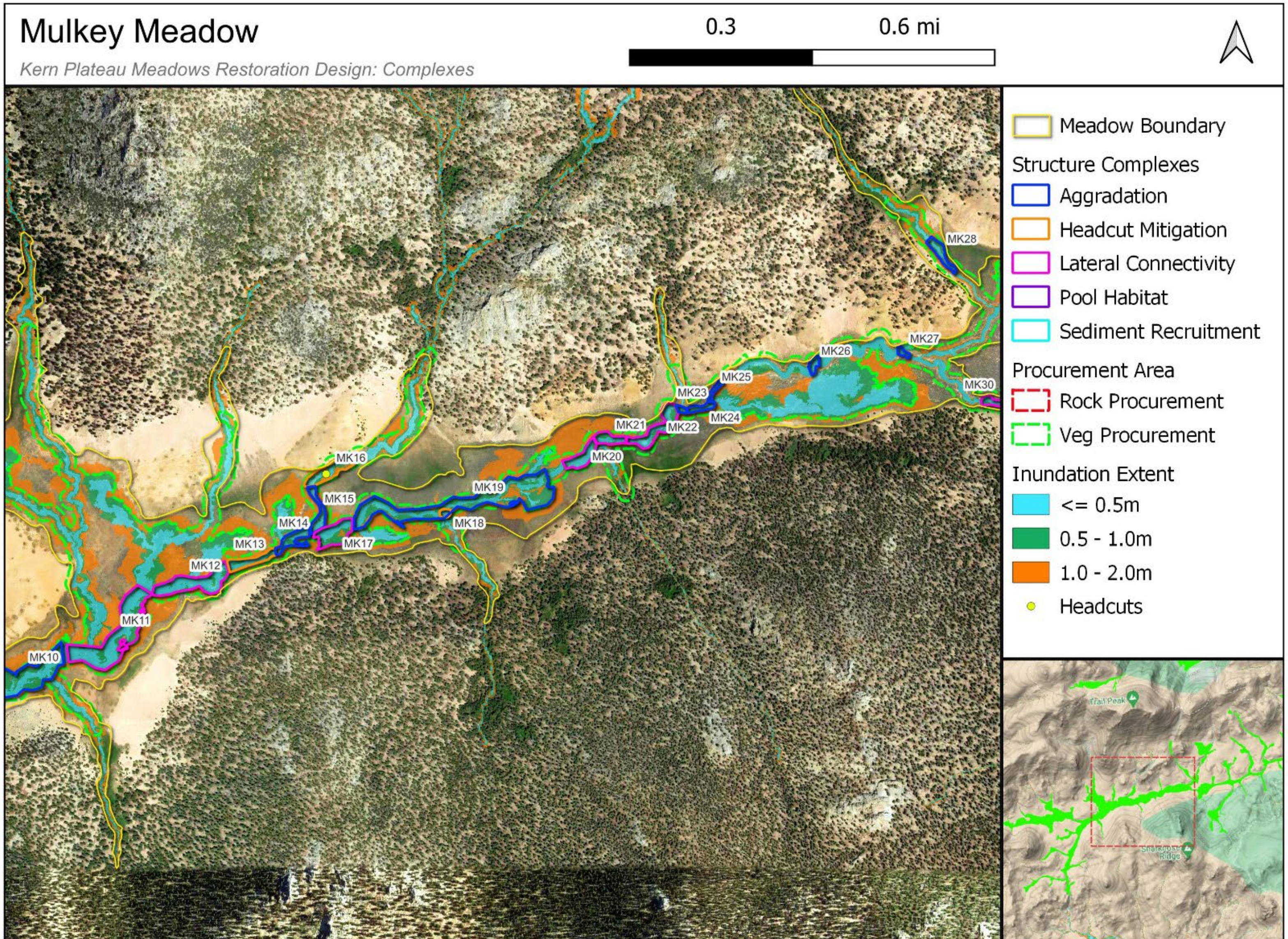

Figure 33. Middle Mulkey Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

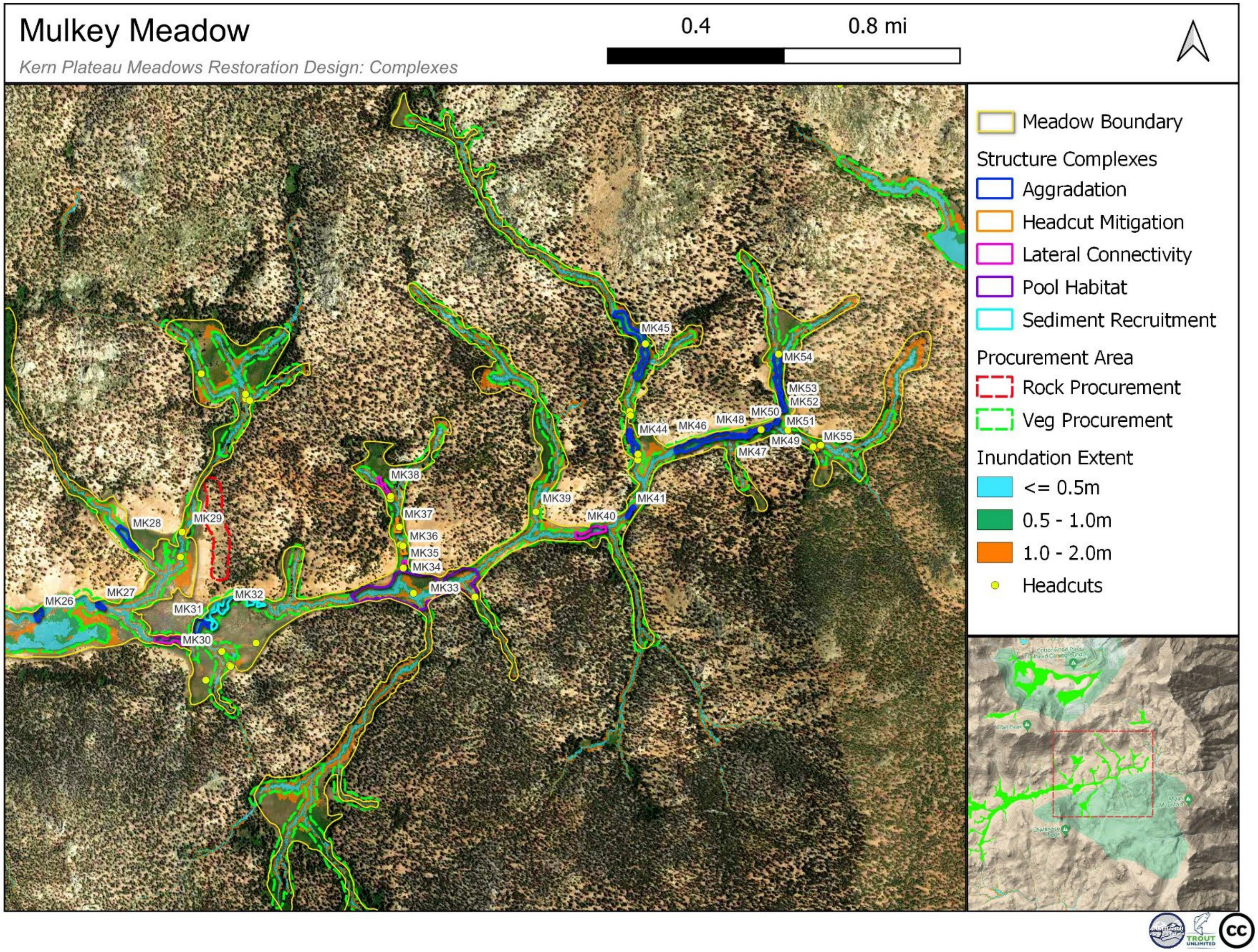

Figure 34. Upper Mulkey Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

Table 9. Bullfrog Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Bullfrog Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**302**					**1.2**	**22**	**8**	**2**	**1**			**25.2**	**56**	
BF01	AG, LC	100.3	0.7	2	2.4	2.39%	0.31	6	2	2	1	70/30/0	14.3	11.6	22	aggrade and spill to floodplain surface
BF02	PH	52.2	0.7	1.5	1.3	2.49%	0.35	6	2	0	0	50/0/50	8.7	6.3	12	Create off-channel pools from sedge plugs harvest away from the channel. Use sedge plugs in the channel to create deepwater habitat.
BF03	HM	113.1	0.5	2	1.5	1.3%	0.47	6	2	0	0	100/0/0	18.9	6.0	16	Aggrade channel 0.5 m and inundate current headcut
BF04	HM	36.4	0.3	1	0.5	1.4%	0.10	4	2	0	0	100/0/0	9.1	1.4	6	Prevent headcutting up small channels on river left. At bottom of reach, try to force water onto river left floodplain. Small BDAs

Table 10. Strawberry Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Strawberry Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**2255.1**					**15.0**	**88**	**35**	**41**	**15**			**155.8**	**366.5**	
SB01	LC, AG, PH	71.9	0.6	5	1.1	1.53%	0.31	4	2	0	0	70/30/0	18.0	13.5	30	Delta of strawberry creek. Build up and connect multiple channels
SB02	LC, AG, PH	61.7	0.8	3	0.6	0.97%	0.65	2	1	0	0	100/0/0	30.9	5.4	9	Section that can activate old side channel. Possibly dig a small channel to connect relic side channel to main channel.
SB03	LC, AG, PH	57.5	0.6	2	0.4	0.70%	0.42	2	1	0	0	100/0/0	28.8	2.7	6	Structures will inundate floodplain on the right
SB04	LC, AG, PH	41.1	0.4	1.5	0.3	0.73%	0.26	2	1	0	0	100/0/0	20.6	1.4	4.5	Structures will inundate side channels. Observations indicate these channels are inundated more frequently
SB05	LC, AG, PH	261.6	0.6	1.5	2.2	0.84%	2.70	7	3	2	1	60/40/0	32.7	8.8	19.5	Potential to inundate a lot of old floodplain.
SB06	LC, AG, PH	219.7	0.5	1.5	1.9	0.86%	0.96	7	3	2	1	60/40/0	27.5	7.3	19.5	Potential for a lot of inundation
SB07	LC, AG, PH	35.3	0.5	2	0.2	0.57%	0.13	1	1	0	0	100/0/0	35.3	1.5	4	Structures in side channel to help inundate more floodplain
SB08	LC, AG, PH	310.5	0.5	2	2.1	0.68%	2.19	7	3	3	1	70/30/0	34.5	10.5	28	Area of inundation relatively large for uplift
SB09	LC, AG, PH	40.4	0.3	1.5	0.8	1.98%	0.10	5	2	2	1	70/30/0	6.7	3.4	15	Inundate inside bend, might lead to significant inundation
SB10	HM	63.8	0.6	3	1.4	2.2%	0.26	5	2	0	0	80/20/0	12.8	9.5	21	Double lobe headcut from confluence of Strawberry and Fat cow.
SB11	LC	187.4	0.5	2	2.7	1.44%	1.27	7	3	5	2	70/30/0	17.0	12.8	34	Force water on to floodplain
SB12	AG, LC	507.9	0.6	2	6.9	1.36%	3.81	14	5	10	3	70/30/0	22.1	28.8	64	Incised channel, use PALS and BDAs to aggrade
SB13	AG, LC	396.3	0.6	2	12.3	3.10%	1.96	25	8	17	6	70/30/0	9.7	50.4	112	Incised channel, use PALS and BDAs to aggrade

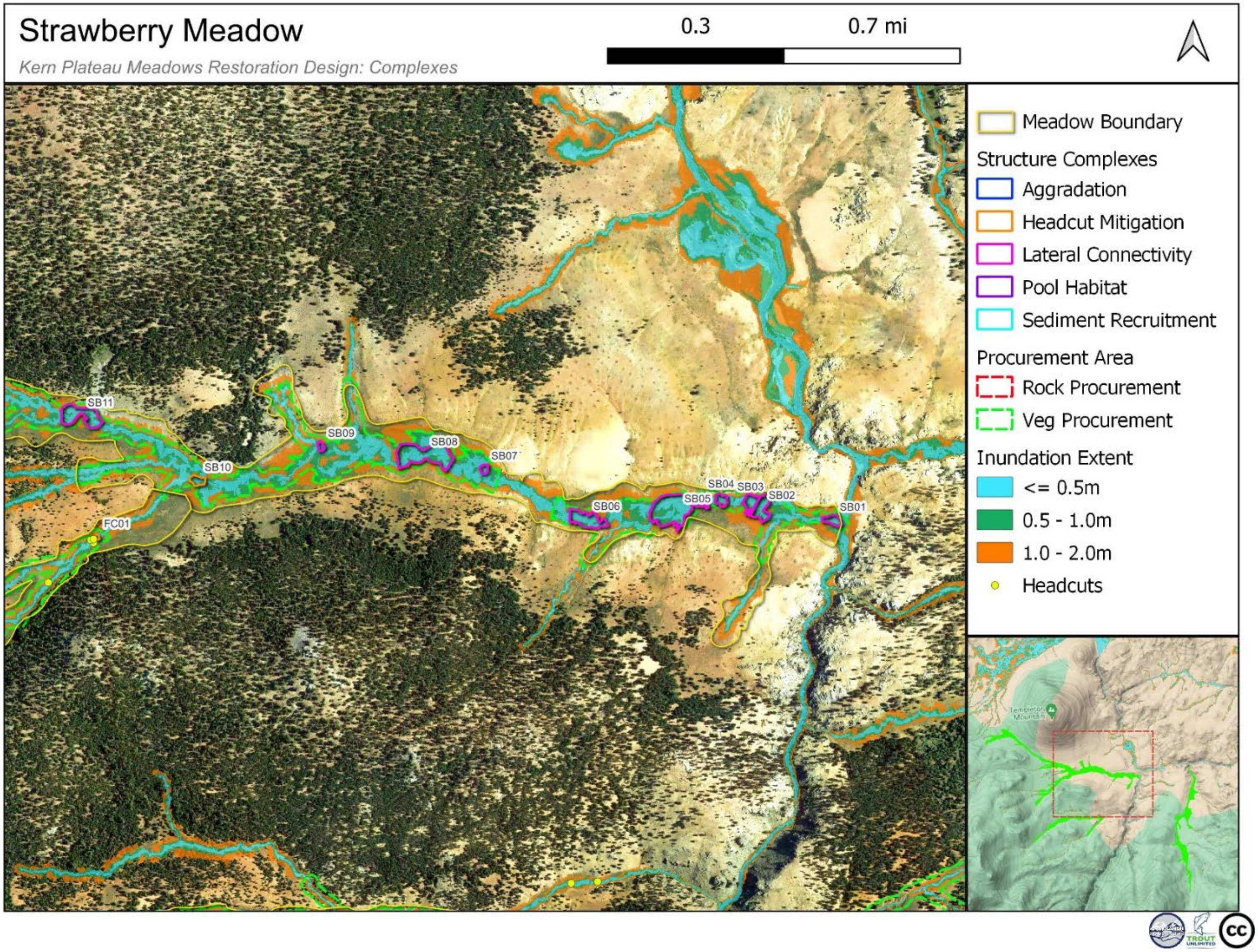

Figure 35. Lower Strawberry Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) are defined by dashed lines.

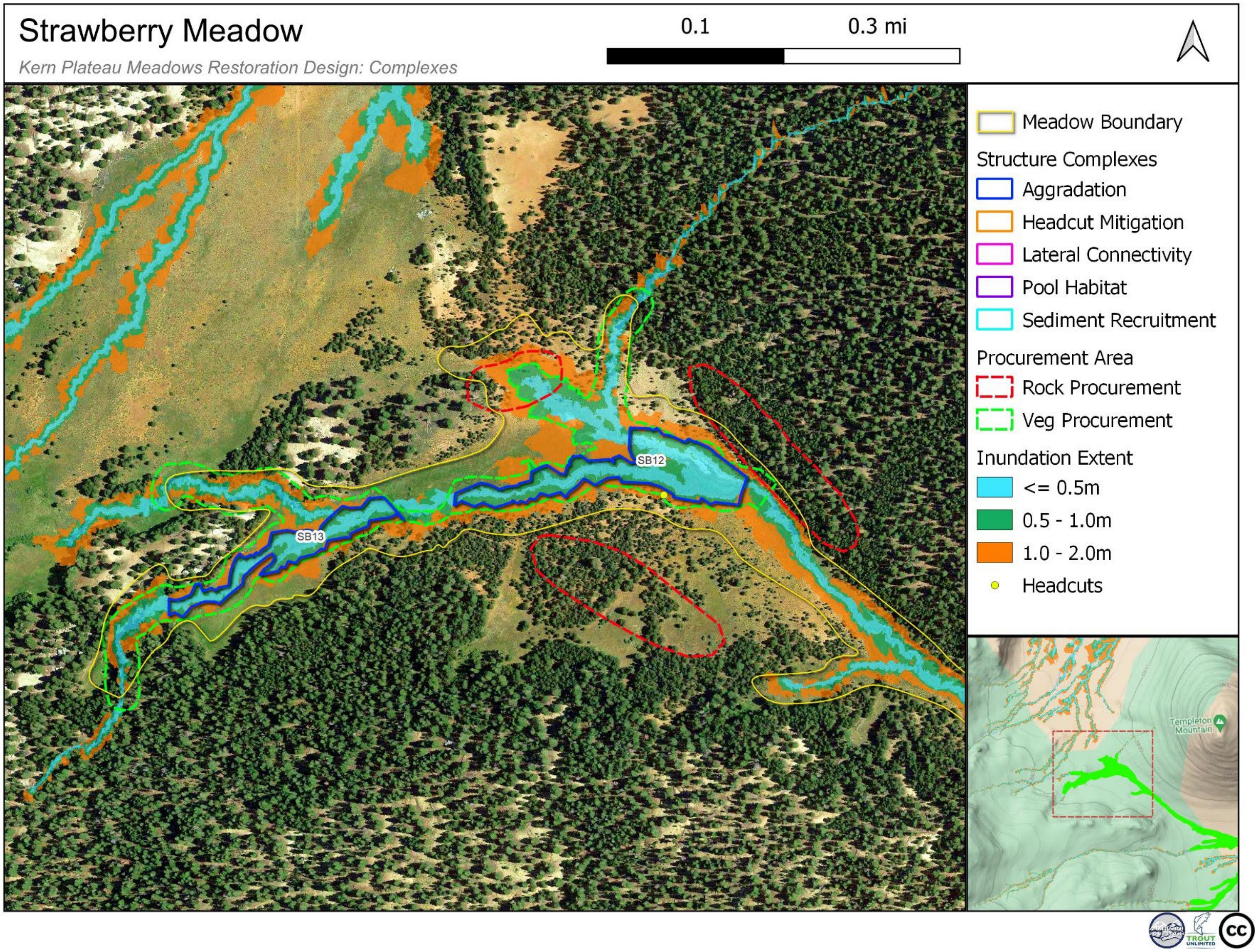

Figure 36. Upper Strawberry Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

FAT COW MEADOW

Fat Cow Stringer is a tributary to Strawberry Meadow. The lower portion of Fat Cow Stringer has a deeply incised and wide trench. Given the minimal flows (i.e., no water observed in the two visits to this meadow), the ability to achieve much uplift is likely low (Figure 37). Headcut mitigation in a few locations could preserve some of the riparian and subsurface meadows found in the middle and upper portion (Table 11). In the upper meadow, flows could be deflected immediately onto floodplain surfaces that would propagate a long-distance downslope.

SCHAEFFER MEADOW

Schaeffer Meadow is similar to Fat Cow, in that the lower half is greatly incised and unlikely to achieve much uplift from structures given the ephemeral flow regime. The upper half has several areas of channel incision and headcuts, but also relatively intact subsurface meadows. Headcut mitigation can preserve these meadows (Table 12). Aggradation might lead to a channel that is eventually connected to its floodplain (Figure 38). Past restoration structures here have backfilled with sediment suggesting this is potentially feasible.

BROWN MEADOW

Brown Meadow has a diversity of meadows in different conditions. The design consists of 18 complexes with nearly 200 structures is planned to treat 2.5 km of stream (Table 3). In Brown Meadow, current conditions are generally good in the lower third of the meadow where structures could provide immediate floodplain reconnection and requiring a modest amount of aggradation to ensure this occurs during even low flow years (Figure 39). Because of the low uplift required to improve meadow function in this section, most structures would be installed in Phase 1, with a few more structures to ensure the trajectory to self-maintained processes (mainly an increase in sedge production) added in Phase 2 (Table 13).

The middle third of the meadow, near the historic Brown cow camp, is in much worse condition with channels that are highly incised and limited inset floodplain area inundated at baseflow (Figure 40). This section was likely eroded by large headcuts moving quickly through the system at a time with limited vegetation cover resulting in a highly degraded channel. Here the main treatments are to arrest headcuts to protect meadows that are currently present, to create inset floodplains through channel widening, and to recruit sediment to aggrade the channel where possible. This section will require several structures in Phases 1 and 2 and likely more phases and will be most responsive during high flow episodic events. A large structure from past restoration has completely back-filled suggesting aggradation following the addition of structures is likely.

The upper third of the meadow is mostly in good condition but will require headcut mitigation in a few locations (Figure 40). This section will also benefit from trees felled into the meadow to try to dissipate and slow flows for further sedge development as well as carbon sequestration and nurse log function.

Table 11. Fat Cow Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Fat Cow Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**154.2**					**0.4**	**22**	**8**	**6**	**2**			**8.9**	**32.5**	
FC01	HM.AG	13.8	0.4	0.5	0.4	2.9%	0.04	2	1	0	0	50/50/0	6.9	0.5	1.5	Small Headcut
FC02	HM	46.1	0.8	0.5	2.2	4.8%	0.13	6	2	0	0	80/20/0	7.7	2.4	4	Series headcut
FC03	LC	94.3	0.3	1	5.9	6.26%	0.19	14	5	6	2	50/30/20	4.7	6.1	27	Good area to inundate a large floodplain downstream

Table 12. Schaeffer Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m^3, area = m^2.

Schaeffer Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**201.1**					**1.0**	**17**	**6**	**3**	**1**			**50.45**	**37.8**	
SF01	LC	60	0.5	0.8	2.2	3.67%	0.15	7	3	3	1	70/30/0	6.7	5.6	4.2	Opportunity to push water into center of meadow out of incised channel
SF02	HM, AG	141.1	1.15	3	9.1	6.4%	0.84	10	3	0	0	70/30/0	14.1	44.85	33.6	Several headcuts should be addressed

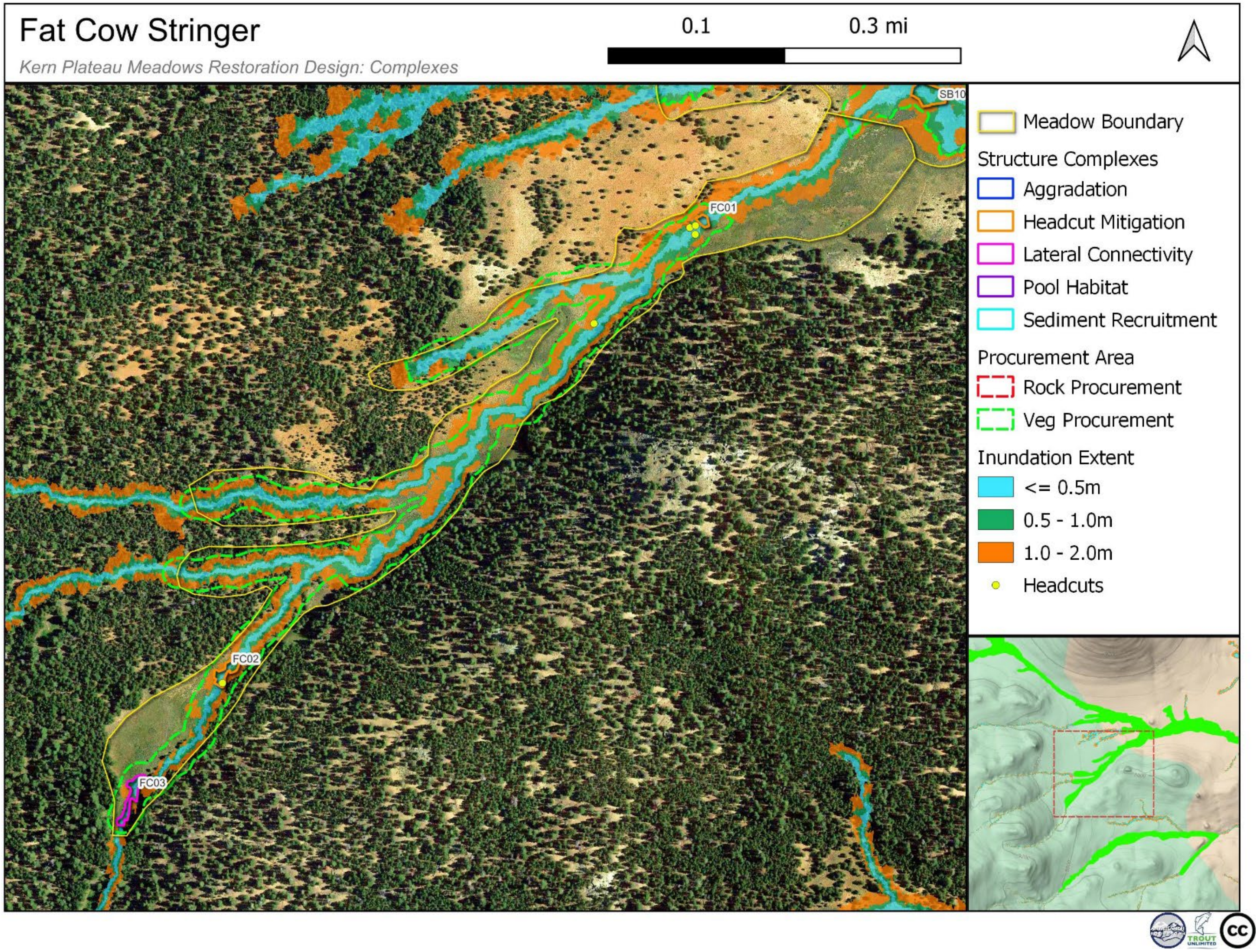

Figure 37. Fat cow meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

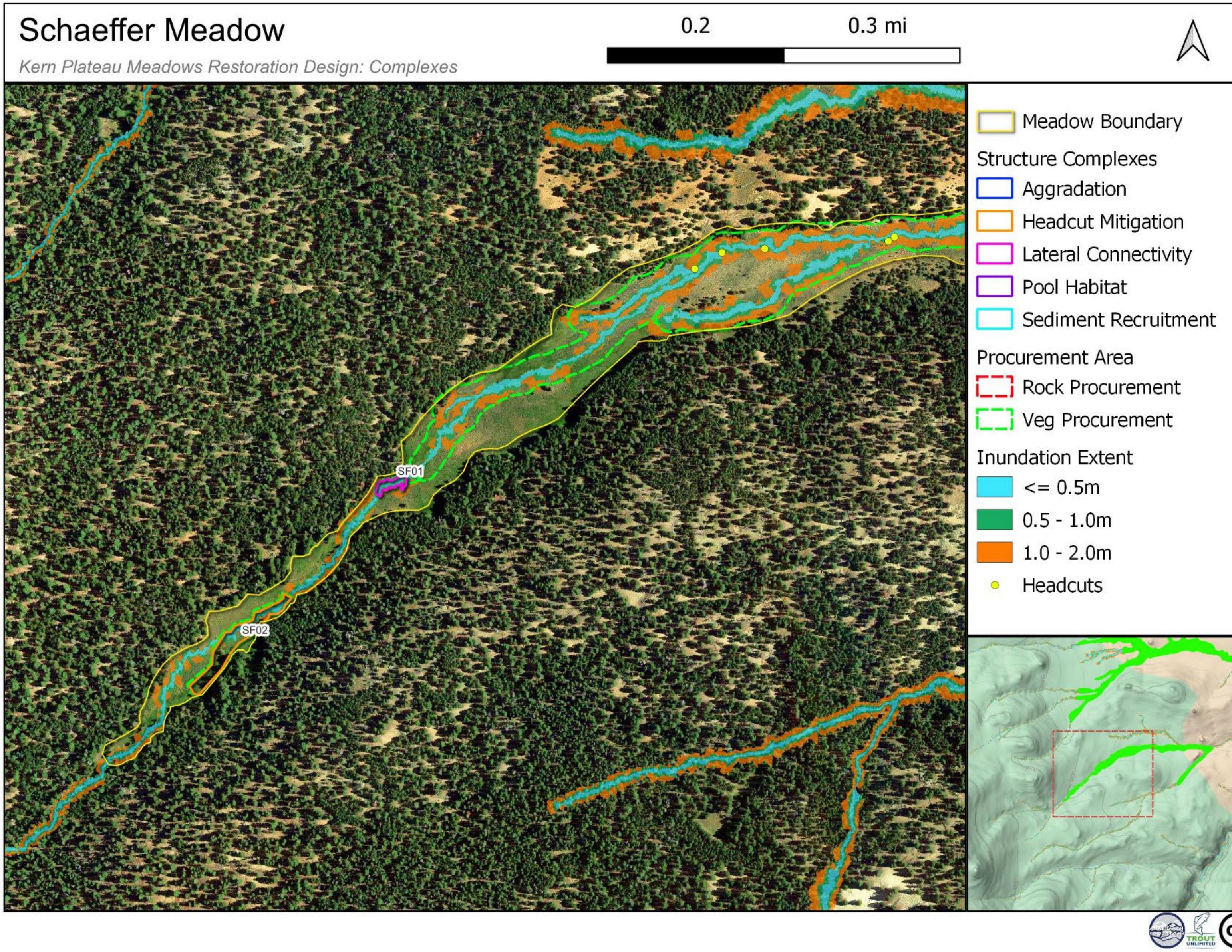

Figure 38. Schaeffer Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

Table 13. Brown Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Brown Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**2503**					**9.0**	**134**	**50**	**63**	**25**			**222.1**	**527.4**	
BR01	AG	200.4	0.6	2	3.9	1.95%	0.72	10	3	4	2	70/30/0	15.4	17.1	38	Narrow Valley with vertical accretion and incised channel in lower 1/2. Moderate incision, widening in some places. Floodplain could be activated. Also will improve LC and PH
BR02	AG	224.4	0.5	1	2.4	1.07%	1.07	7	3	3	1	70/30/0	22.4	5.3	14	Recover some incision increase lateral connectivity
BR03	LC, AG, PH	201.6	0.3	2	3.4	1.69%	0.69	17	6	7	3	30/20/50	8.8	14.9	66	Sedge plugs to build up riffle in pool-riffle complex
BR04	LC, AG, PH	305.9	0.5	1	5.4	1.77%	1.09	16	5	7	3	40/30/30	13.9	11.6	31	Mixture sod plugs, PALS (lower in reach), BDAs (upper)
BR05	AG,LC	349.7	0.4	3	5.8	1.66%	1.25	21	7	9	3	50/30/20	12.1	36.0	120	Aggrade with mixture BDA and PALS
BR06	HM, AG, LC	47.9	0.3	3	1.3	2.7%	0.17	9	3	0	0	80/20/0	5.3	8.1	36	Force water out of channel upstream end to dissipate energy, BDAs to aggrade and arrest headcuts. BDAs in right channel to step down some of the drops.
BR07	LC	52.8	0.5	1	0.8	1.52%	0.32	4	2	0	0	100/0/0	13.2	2.3	6	Push water down river right use BDAs
BR08	AG, LC	190.4	0.5	1	3	1.58%	0.74	9	3	4	2	80/20/0	15.9	6.8	18	Channel incised, needs to aggrade, use BDAs
BR09	AG, PH	207.2	0.75	1.5	4.9	2.36%	0.65	7	3	7	3	80/20/0	14.8	16.9	30	Deep incision in confined reach. BDAs to help fill channel. One PAL to help erode bank

BR10	LC, AG, PH	158.8	0.9	5	2.3	1.45%	0.74	6	2	0	0	50/50/0	26.5	27.0	40	Large Confluence with tributary from river right. Incised to mainstem grade but improves as you go up the tributary fan. Lots of willow. Want to make several floodplain spanning structures. Mix BDAs PALS
BR11	HM, AG	39.8	1.25	3	1.9	4.8%	0.11	4	2	0	0	50/50/0	10.0	16.9	18	Arrest massive headcut. Hard structrure at base, back up with BDAs, step down this BDA. Can divert some water around as well. Fill pool with branches
BR12	HM, AG	204.5	0.5	2	4.6	2.2%	0.65	8	3	12	4	50/50/0	10.8	20.3	54	Treat headcut and fill channel with BDAs or PALS. Arrest headcut Phase 1, fill Phase 2
BR13	AG, HM	55.2	1	4	1.5	2.72%	0.10	3	1	0	0	70/30/0	18.4	12.0	16	Structures can potentially arrest headcut above, aggrade incised channel to change base level for headcut mitigation
BR14	HM	15.2	0.5	1	0.55	3.6%	0.01	3	1	0	0	70/30/0	5.1	1.5	4	Structures to arrest headcut
BR15	AG, LC	57.1	1	3	0.8	1.40%	0.15	0	1	2	1	40/30/30	28.6	9.0	12	This was the large structure that has filled in. Add to the height of it and step it down.
BR16	HM, AG	24.4	0.75	1.5	1.5	6.1%	0.07	4	2	0	0	100/0/0	6.1	5.1	9	Use approximately 4 BDAs to arrest headcuts
BR17	LC	45.8	0.3	0.75	1.1	2.40%	0.20	6	2	3	1	40/30/30	5.7	2.0	9	Small structures might force water out for a large ZOI
BR18	AG	121.9	2	0.8	2.2	1.80%	0.26	0	1	5	2	50/50/0	24.4	9.6	6.4	Deep incision. Consider doing later phases so not starving downstream sedimentside

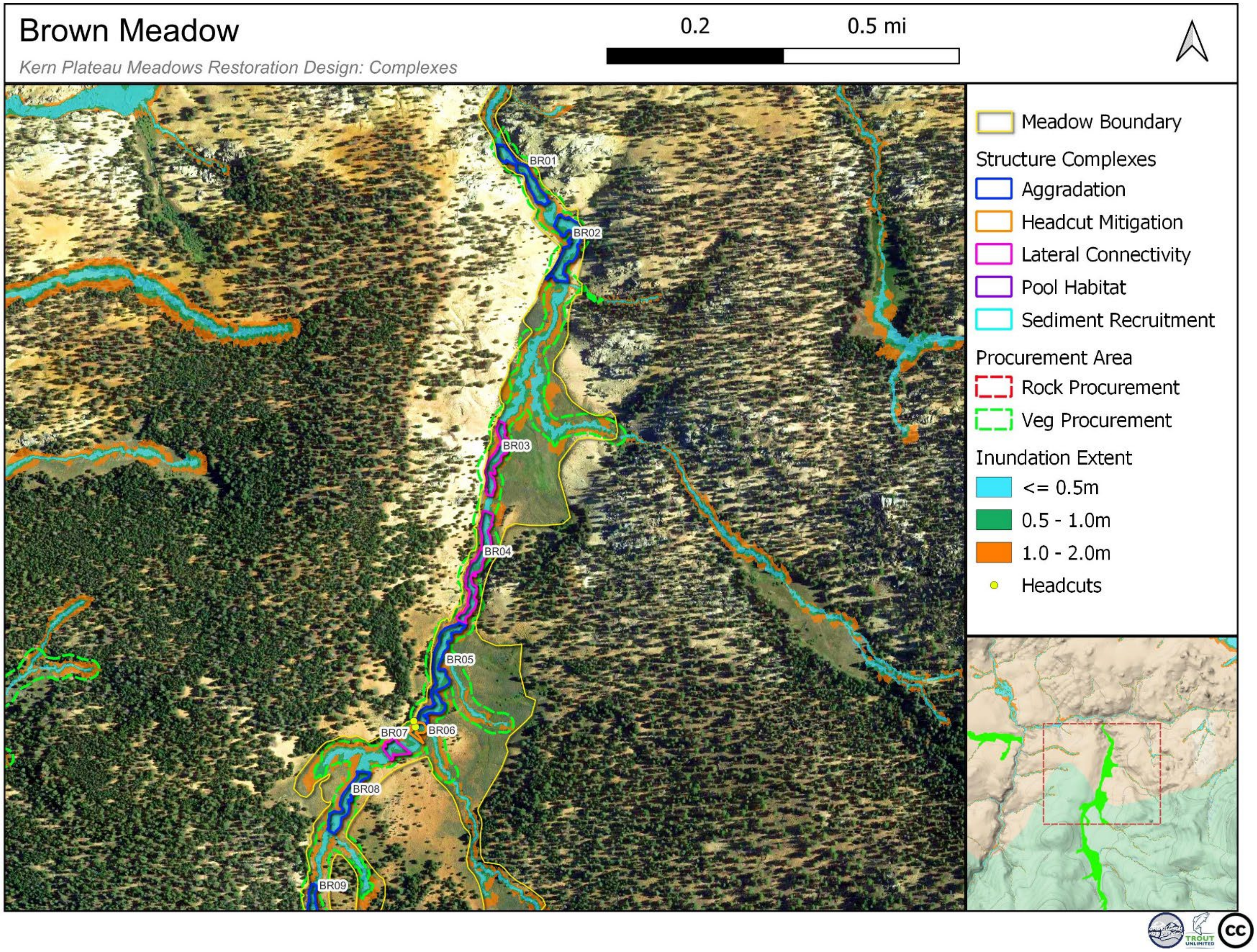

Figure 39. Lower Brown Meadow complexes complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

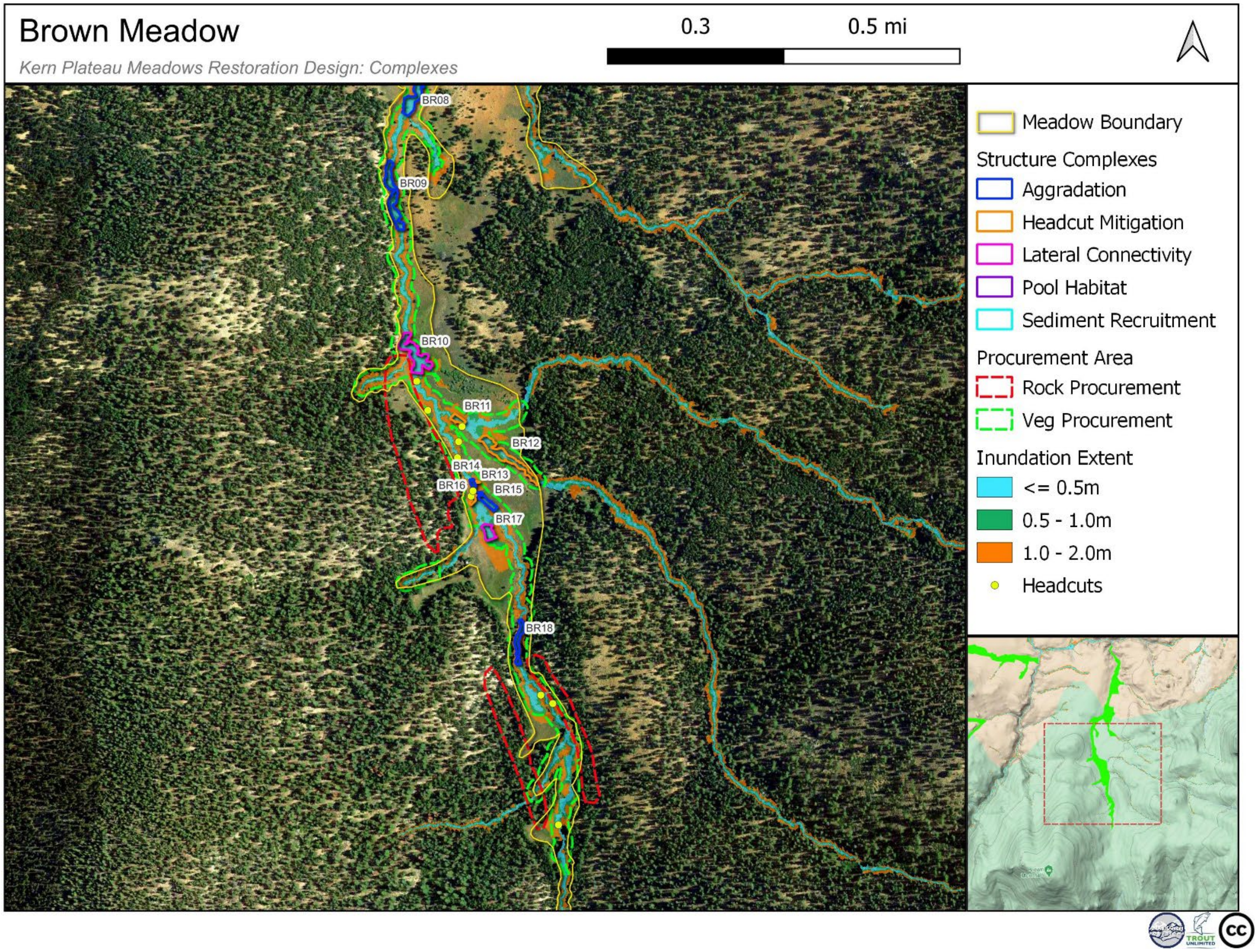

Figure 40. Upper Brown Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

KINGFISHER MEADOW

The lower portion of Kingfisher Meadow is highly incised below the confluence of two tributaries (Figure 41). Aggradation of this lower portion would increase the base-level control elevation and help with the incision in both tributaries. At the bottom of each tributary the incised trench would also be raised to increase water storage in the upper meadows. The furthest upper complex is simply adding large woody material to discourage cattle from creating trails in the intact sedges in the inset floodplain. The design contains 4 complexes with over 30 structures in this meadow (Table 14).

SODA CREEK MEADOW

Soda Creek was highly incised but structures installed by the USFS several decades ago have greatly aggraded the channel and created productive inset floodplains (Figure 42). Theses structures are somewhat similar to the LTPBR structures described here, albeit more labor intensive. The response to these structure provides strong evidence that aggradation is highly likely as all structure completely backfilled with sediment. The only issue with these structures is that Phase 2 or 3 was not implemented. Again, LTPBR is not a one-and-done process but will require structure enhancement and additions. The restoration plan for Soda Creek is mainly to enhance the excellent work done previously to keep the creek on the trajectory to complete floodplain connection. Large opprotunities exist downstream to quickly aggrade so that lateral connectivity is self-sustaning (Table 15). Also, headcut mitigation structures will be added to protect the northern portion of the meadow. The design consists of 8 complexes with 34 structures all in Phase 1.

ROUND MOUNTAIN MEADOW

Round Mountain Meadow is dry most of the year. The potential to recover some of the incised channel in this meadow is low because of the lack of flow (Figure 43). Cattle traverse this meadow using the same trails. Thus, the only treatment here is to use brush and downed wood in the artificially enlarged pools and channel to deter livestock from continuously using that path and exacerbating the problem. The structure will likely have to be moved or added frequently to disperse cattle over whole meadow to allow any recovery (Table 16).

SNAKE CREEK MEADOW

Snake Creek straddles the border of Inyo and Sequoia National Forest. Most of the meadow is actually in the Sequoia National Forest and is thus not part of the Kern Plateau Meadows Project. However, the main channel is found in the Inyo. The middle portion of the meadow has a moderately incised channel that if aggraded would result in very large areas of inundated floodplain. Cattle appear to use the main channel, that is often dry, in this area. PALS could be placed in high frequency that would discourage cattle trailing and allow sedges to become more established. The combination of more sedges and PALS could lead to aggradation (Table 17, Figure 44). Because the water delivery appears intermittent or ephemeral and therefore less certain to deliver enough sediment to aggrade the channel, less investments should be given in Phase 1, making PALS an excellent choice to achieve objectives. In the adaptive management plan, a process will be described on observing responses and potentially change the structure type in Phase 2. The upper portion is more confined, stream-like and moderate to good condition. Mitigation of a couple headcuts will be the only action here.

CASA VIEJA MEADOW

Casa Vieja has been treated by several restoration actions over the decades. Like Soda Creek, these structures achieved what could be expected but need further phases to conitue the trajectory to achieve maximum lateral connectivity. The design for future work includes over 230 structures in 18 complexes covering 2.5 km of stream (Table 3l). In the upper reaches, flows can immediately be directed on the to floodplain surfaces with very little uplift, likely achieved with sedge plugs (Figure 45). As the two branches converege the channels are more incised and will need to have larger BDAs and PALS to aggrade the channel. At the upper part of the lower meadow, the USFS installed a massive headcut struture that has completely backfilled and is forcing water out onto the floodplain downstream, again providing evidence that structures capture sediment and have the ability to reconnect floodplains. The channel below has some incision and likely can easily be aggraded or force water surfaces out onto the floodplain. In the lower portion of the meadow, we will add structure to build off responses from older structures (Table 18).

In September of 2021, with Trout Unlimited endowment funds and in collaboration with the USFS, we initiated a pilot project to maintain and enhance existing structures and put in additional structures which included BDAs, PALS, sedge plugs, and woody debris installations of various configurations. These installations differ from previous styles of structure building in that they are much faster to build (10 minutes to 1 hour per structure after gathering materials versus 3 days for a log check dam and up to 10 days for a rock gabion structure). We put installations in two reaches in the main meadow (the western reach within the cattle exclosure and the steeper reach just downstream of the large rock gabion in the eastern portion of the main meadow). In addition, we installed structures in both wings of the upper meadows. This provided good coverage of the range of the flow, channel geomorphology, and habitat conditions that exist within Casa Vieja (and a good surrogate for most other meadows within the project). Summer of 2022 provided an excellent test as major monsoon storms hit the area in July through August creating high flow conditions and mobilizing large amounts of sediment. All new structures and enhancements built in Casa Vieja survived the storm cycles well with limited changes or impact. We did observe that the green conifer material used in building the BDAs compressed or sloughed downstream slightly in the high flows. This provided useful information for future building knowing that anchoring structures with posts may help keep them in place, particularly in high gradient area. Because material compression is likely to occur building structures slightly higher in anticipation of this should mitigate any issues.

Table 14. Kingfisher Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Kingfisher Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**599.6**					**2.3**	**13**	**6**	**18**	**7**			**44.3**	**118**	
KF01	AG	128.1	0.5	3	1.1	0.86%	0.40	4	2	2	1	20/80/0	25.6	10.1	27	Complex through most incised part of meadow below confluence. Lots of wood available from upland and already some in channel that can be used in structures.
KF02	AG, LC	87.1	0.5	2	1.5	1.72%	0.59	5	2	2	1	20/80/0	14.5	7.5	20	Small structures and brush piles to encourage deposition and discourage livestock from walking in channel
KF03	AG, LC	140.8	0.5	2.5	1	0.71%	0.57	1	1	4	2	40/60/0	35.2	7.5	20	Build a series of structures in this incision zone to help slow flow and reduce erosion while promoting lateral connectivity and aggradation
KF04	HM, AG	243.6	0.5	3	2.9	1.19%	0.76	3	1	10	3	20/80/0	20.3	19.1	51	Series of structures and brush fence to discourage livestock from walking in the channel

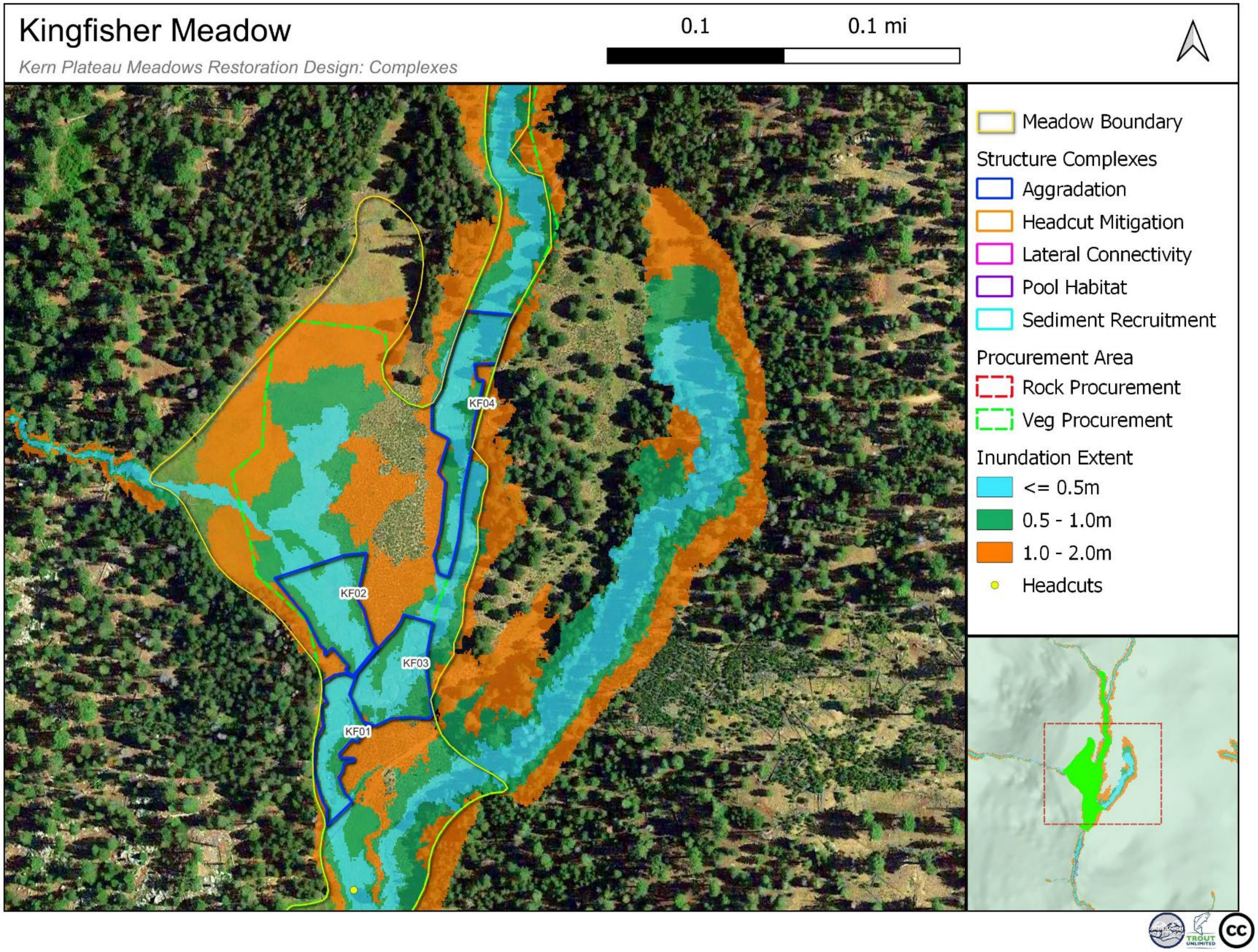

Figure 41. Kingfisher Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

Table 15. Soda Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Soda Creek Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**1610.2**					**12.3**	**34**	**11**	**0**	**0**			**64.4**	**106.0**	
SC01	AG, LC	362.7	0.5	3	1.3	0.36%	4.98	6	2	0	0	60/20/20	60.5	9.0	24	High probability of reconnecting large floodplain if aggradation occurs
SC02	LC, AG	139.4	1	2	0.8	0.57%	0.49	3	1	0	0	60/20/20	46.5	6.0	8	Try to connect to inset floodplain. Use gradient for structure number
SC03	AG, LC, PH	150.6	1	1.5	1.1	0.73%	0.76	3	1	0	0	100/0/0	50.2	4.5	6	Increase aggradation to also prevent headcutting of tribs
SC04	AG, LC, PH	192	1	3	1.3	0.68%	1.91	3	1	0	0	70/30/0	64.0	9.0	12	Use gradient to figure structure number. Huge potential
SC05	AG, LC, PH	398.6	0.75	2	3.5	0.88%	2.26	10	3	0	0	60/20/20	39.9	14.6	26	build up existing structure and add more
SC06	AG, LC, PH	296	1	3.5	2.7	0.91%	1.03	6	2	0	0	60/20/20	49.3	21.0	28	Build up current structure, add a couple more BDAs
SC07	HM	70.9	0.2	0.5	0.3	0.4%	0.84	3	1	0	0	80/20/0	23.6	0.3	2	Large wallow with small but active headcut at upstream end and widening from livestock
SC08	HM	85.4	0.5	0.75	0.7	0.8%	0.37	3	1	0	0	60/40/0	28.5	1.1	3	Small headcut on trib- push water to floodplain. Flow path from tributary may have been captured by livestock trail, could use some wood for deflection

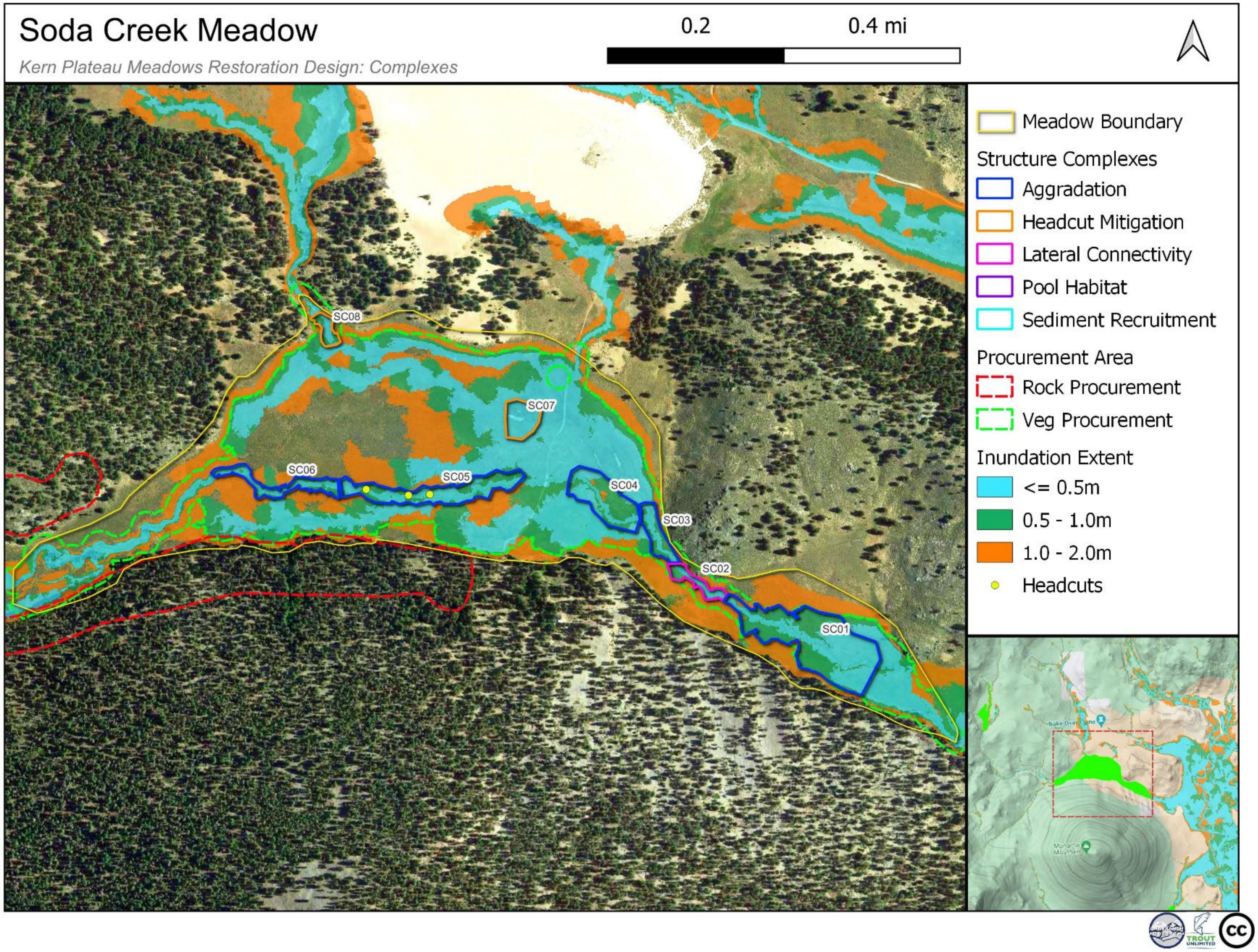

Figure 42. Soda Creek Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

Table 16. Round Mountain Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Round Mountain Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**1082.6**					**15.1**	**11**	**4**	**11**	**4**			**33.8**	**90**	
RM01	HM	1082.6	0.5	3	5.3	0.5%	15.10	11	4	11	4	0/100/0	49.2	33.8	90	The main treatment here is to place wood to keep cattle from establishing trails

Table 17. Snake Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m^3, area = m^2.

Snake Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**1278.8**					**8.282**	**25**	**9**	**9**	**3**			**126.8**	**172**	
SN01	AG	1175	1	4	3.4	0.29%	7.97	21	7	9	3	0/100/0	39.2	120.0	160	Dense PALS can be used to discourage cattle use and increase aggradation
SN02	HM	103.8	0.75	2	1.3	1.3%	0.31	4	2	0	0	80/20/0	26.0	6.8	12	Arrest 3 headcut

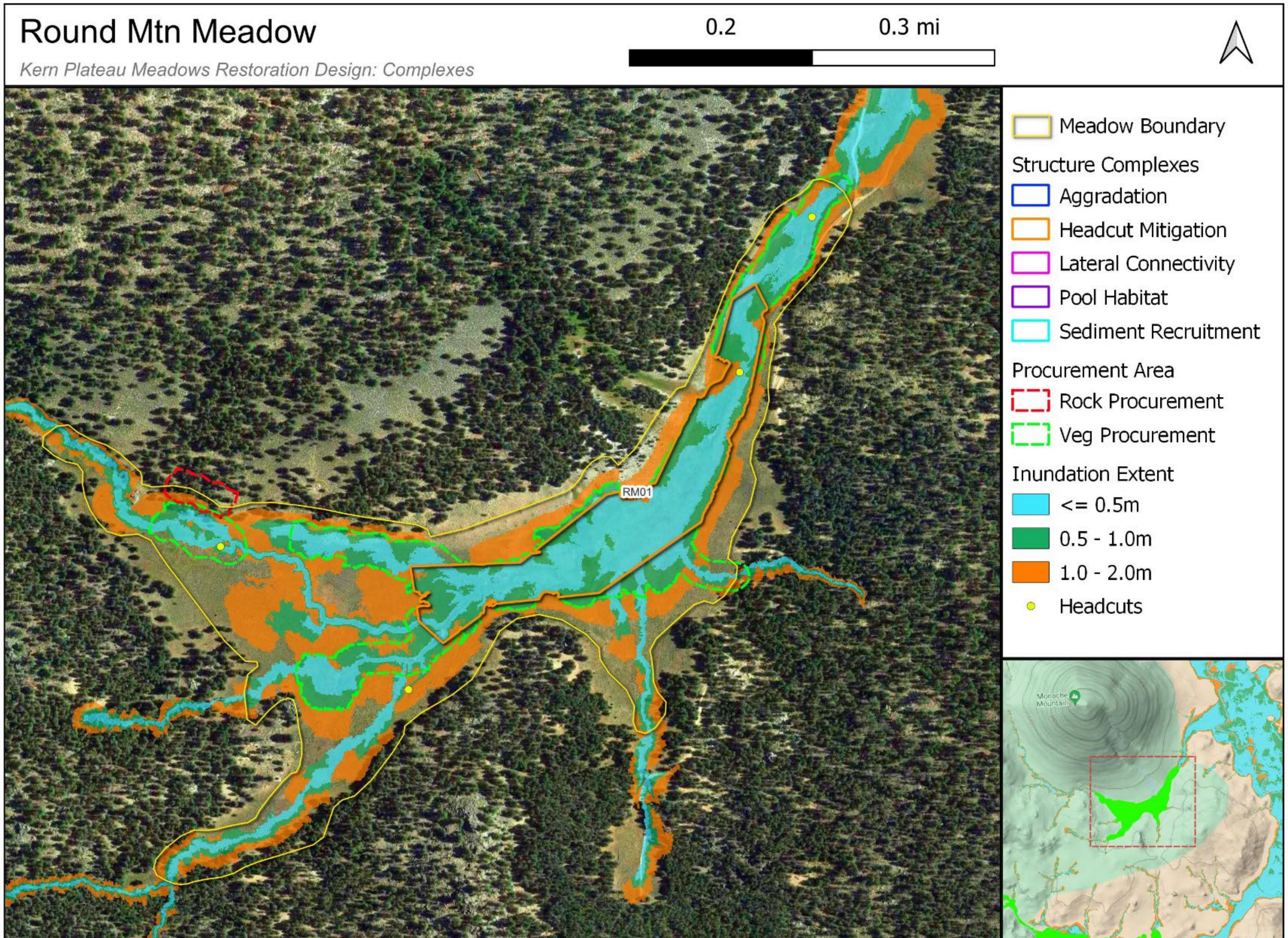

Figure 43. Round Mountain meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

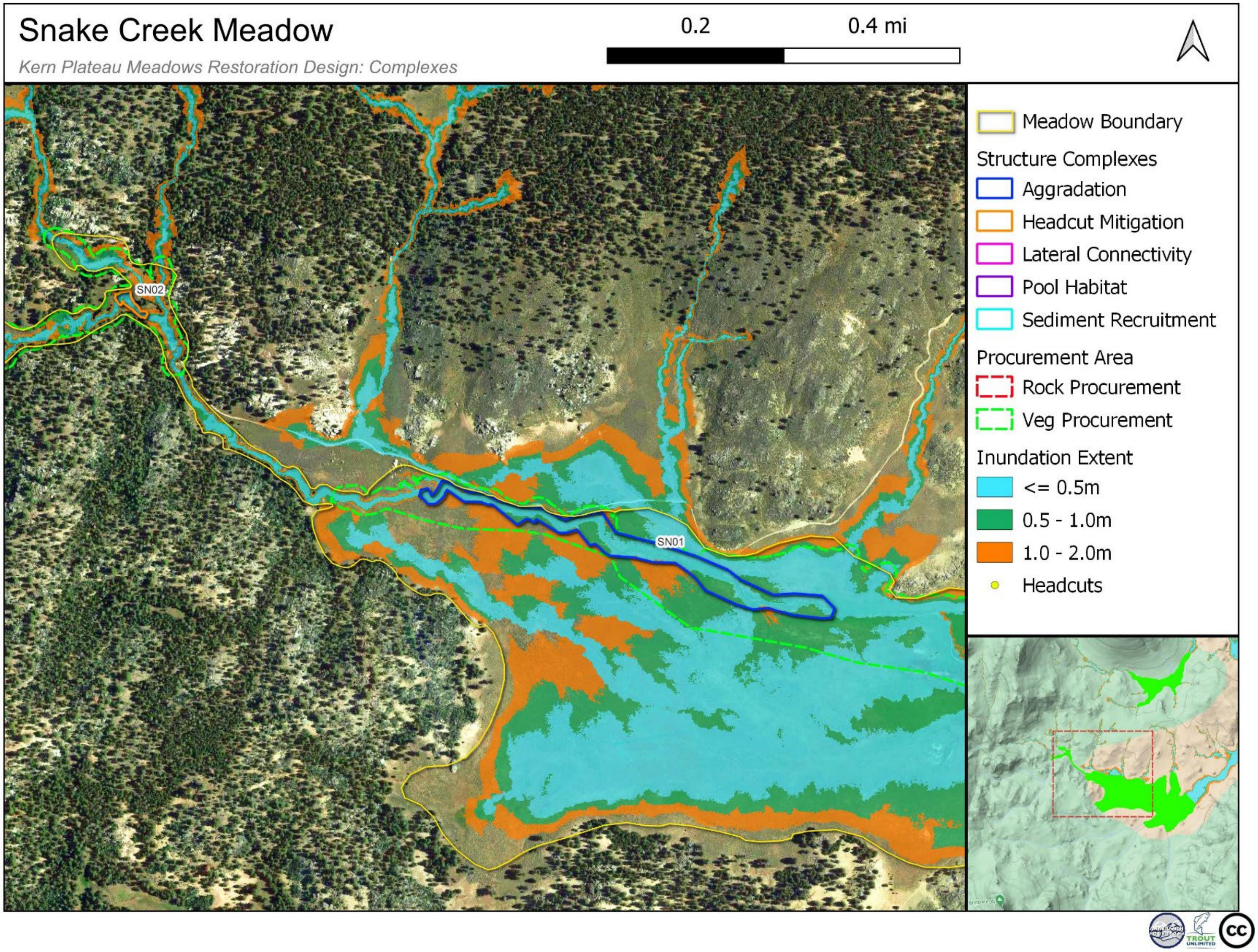

Figure 44. Snake Creek Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

Table 18. Casa Vieja Meadow Complexes. Complex objectives (AG=Aggradation, LC=Lateral Connectivity, SR=Sediment Recruitment, SR=Sediment Recruitment, PH=Pool Habitat) with the primary objective listed first, channel length and average dimensions, relief, gradient, and Zone of Influence (ZOI: in acres). The estimated number of structures (± 30%) for Phases 1 and 2, with percent structure type (BDAs/PALS/SP), average spacing, and size of average channel spanning structure, and description. Length, depth, width, relief units=m, volume = m3, area = m2.

Casa Vieja Meadow																
Complex ID	Complex Obj.	Complex Length	Channel Depth	Channel Width	Relief	Grad.	ZOI (ac)	No. Str. (Ph1)	±	No. Str. (Ph2)	±	% Type	Spacing	Str. Vol.	Str. Area	Description
Total		**2562.7**					**13.4**	**144**	**52**	**90**	**32**			**140.2**	**395.5**	
CV01	LC	251.7	0.5	2	2.1	0.83%	1.76	8	3	2	1	100/0/0	28.0	10.5	28	Large inundation possible with relatively little uplift. Use BDAs
CV02	HM	17.6	0.5	1	0.6	3.4%	0.09	3	1	0	0	70/30/0	5.9	1.5	4	Repair headcut structure
CV03	HM	21.6	0.5	1	0.7	3.2%	0.06	3	1	0	0	70/30/0	7.2	1.5	4	Repair headcut structure
CV04	AG, LC	140.4	0.25	1	3.5	2.49%	0.67	14	5	6	2	50/20/30	7.0	5.1	27	Small channel can quickly be filled using BDAs
CV05	AG, LC	177.1	0.25	1	3.1	1.75%	0.91	11	4	5	2	50/20/30	11.8	4.1	22	Small channel can quickly be filled using BDAs
CV06	LC, AG	222.4	1	2	1.8	0.81%	3.01	4	2	0	0	100/0/0	55.6	9.0	12	Large inundation possible with relatively little uplift. Use BDAs
CV07	AG, LC	205.7	1	2.5	3.4	1.65%	1.32	7	3	0	0	80/20/0	29.4	18.8	25	Aggrade incised channel
CV08	AG, LC	146.1	0.75	2	2.9	1.98%	1.05	8	3	0	0	80/20/0	18.3	12.4	22	Aggrade incised channel
CV09	LC	123.5	0.5	1	3.7	3.00%	0.65	15	5	0	0	80/20/0	8.2	7.5	20	Small channel has built natural levees that is keeping water in the channel. Can connect to floodplain easily with small BDAs, use levee material for fill

CV10	AG, LC, PH	240	0.7	1.5	5.6	2.33%	0.49	13	4	4	2	80/20/0	15.0	18.1	34.5	Water can connect immediately to floodplain with BDAs but aggrading incised channel would ensure this happens frequently
CV11	AG, LC,PH	327.1	0.5	1	12.6	3.85%	0.98	18	6	18	6	20/80/0	9.3	18.0	48	Small channel is incised. Repair old structures and use PALS to aggrade
CV12	LC	38.9	0.2	1	0.8	2.06%	0.07	7	3	2	1	30/0/70	4.9	2.0	13	Upper portion has sheet flow, but then small channel forming near for margin. Push water away from channel to meadow on the right with sedge plugs
CV14	LC	217.8	0.3	0.75	3.9	1.79%	1.32	8	3	19	6	30/30/40	8.4	6.1	27	Small structures or sedge plugs could keep water spread out over the meadow
CV15	AG	175.6	0.3	3	7	3.99%	0.50	6	2	9	3	10/40/50	11.7	13.5	60	Aggrade inset floodplain that is mostly sheet flow and full of sedges. Use sedge plugs or full trees (branches clipped on channel surface side)
CV16	AG	81	0.25	0.5	3.3	4.07%	0.13	8	3	8	3	50/50/0	5.4	2.1	11	Use PALS and small BDAs to fill in this channel that is turning into a gully
CV17	LC	86.4	0.5	1	3.5	4.05%	0.20	6	2	9	3	40/30/30	6.2	7.5	20	Small channel can easily use structures to force water to the floodplain (subsurface meadow)
CV18	LC	89.8	0.2	1	4.8	5.35%	0.16	5	2	8	3	40/30/30	7.5	2.7	18	Sedge plugs and small structures can easily force water to floodplain (subsurface meadow)

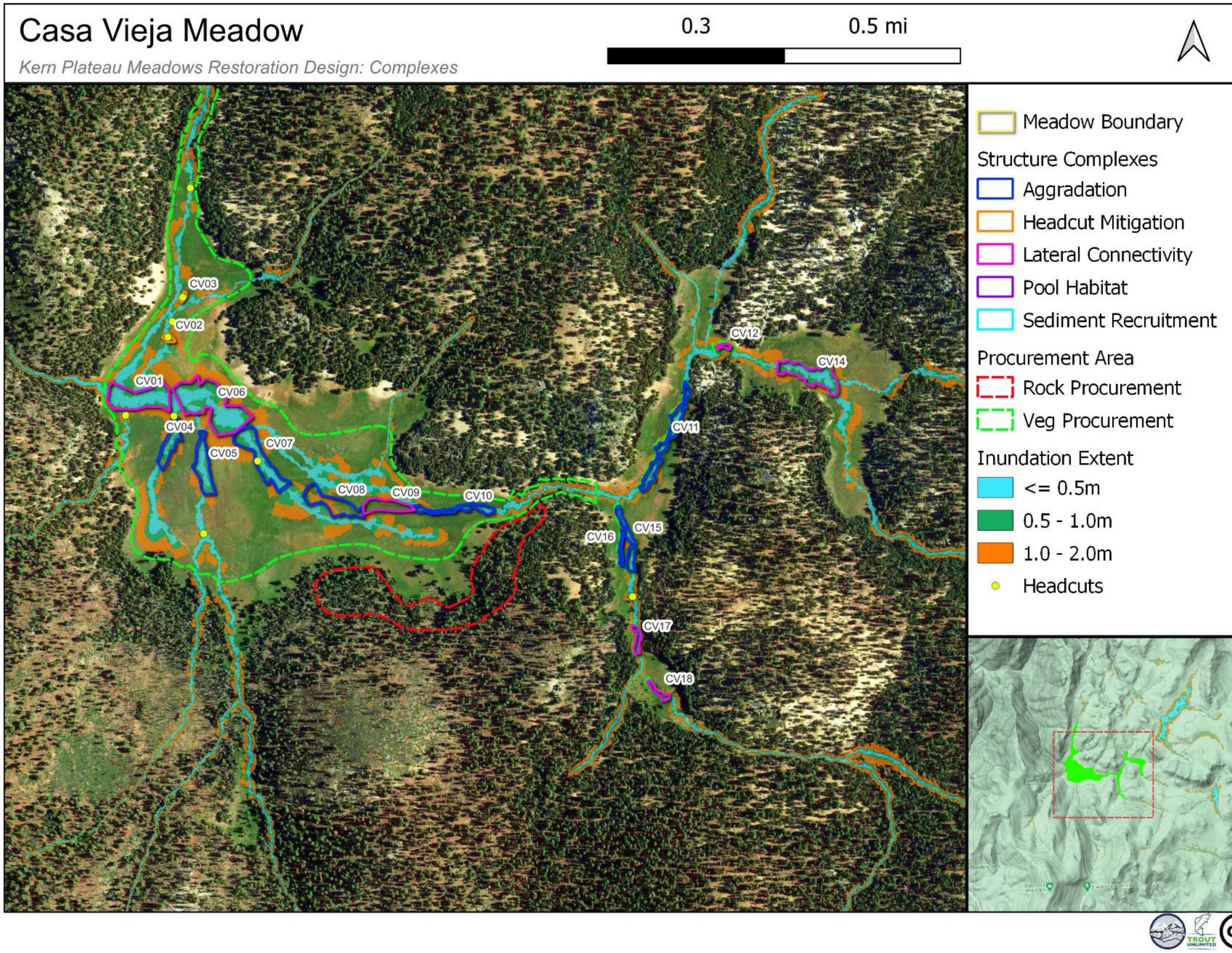

Figure 45. Casa Vieja Meadow complexes coded by the primary complex objective. Inundation areas 0.5 m (blue), the 1 m (green) used to define the complex lateral ZOI, and 2 m (orange) potential water table influence on riparian vegetation. Rock (red) and vegetation (green) procurement boundaries are defined by dashed lines.

RESTORATION IMPLEMENTATION

IMPLEMENTATION LOGISTICS

While LTPBR is relatively inexpensive compared to more engineer approaches using large machinery, this project will require a significant budget for several reasons. The project is large and ambitious requiring hard manual labor in a challenging setting. The southern Sierras are quite remote and labor will likely have to mobilize from their central location several hours away. Several meadows are in wilderness areas and thus any mechanical assistance is not available. Access to some meadows requires hiking in several miles and traversing passes greater than 11,000 ft elevation requiring at least a day, sometimes two, to hike to while carrying both camping and restoration equipment. In remote wilderness locations, pack animals will be used to carry gear and supplies.

We expect to source sod or sediment as fill material from regions that will be inundated by the structures themselves. We anticipate sourcing all woody material from the procurement areas defined in preceding maps as determined as part of the NEPA process. Construction of structures would be performed by hand using loppers, hand and bow saws, axes, shovels, and sledgehammers.

To provide some context of the labor needs required, we can use experience from two pilot projects that occurred in Casa Vieja, Horseshoe, and Round Meadow ancillary to this project in 2021 and 2022. Approximately 5 hours on average was needed to build a structure (5 people would take 1 hour). In Horseshoe and Round Valley Meadow, we assume 2 hours per person to carry in gear and prepare construction, 2 hours back. In Casa Vieja Meadow, an additional 2 hours was required to hike in. Some meadows will take over 8 hours. We assume for every 8-day hitch (eight 10 hr days), workers traveled 8 hrs each way to the Sierras. We also assume 0.5 hrs of labor needed on 30% of the structures for maintenance. Hiking and gear prep time was similar but travel was greatly reduced as several meadows will be visited at a time for maintenance. We estimated the time required for both phases of structures (Table 19). Structure count included the high end of the buffer (±) around the point estimate to be conservative.

Table 19. Estimate of the total number of hours required to implement the design. Hours includes travel to the Sierras, staging and travel within the Sierras, installation of structures (assumes structure count plus max ± buffer), and maintenance of structures for Phase 1 and 2.

Meadow	Phase 1	Maintenance	Phase 2	Maintenance	Total Phase 1	Total Phase 2	Total
Total	10777	825	5753	677	11602	6429	18031
Horseshoe and Round Valley	1552	77	280	48	1629	328	1957
Dutch and Poison	933	55	733	58	988	791	1779
Mulkey Meadow	2987	132	1401	114	3119	1515	4634
Strawberry, Fat Cow, Schaeffer	1443	110	903	195	1553	1098	2651
Brown Meadow	1489	195	1019	115	1684	1133	2817
Kingfisher, Soda, Round Mtn, Snake	1056	121	468	66	1176	534	1710
Casa Vieja Meadow	1319	133	949	80	1453	1030	2482

MAINTENANCE AND PHASED RESTORATION

LTPBR projects are not intended to be 'one-and-done' projects. They are intended to be implemented within an adaptive management framework that can adjust restoration decisions based on the outcomes of previous Phases given pre-defined decision criteria. LTPBR relies on streamflow to 'do the work' of restoration. Different restoration objectives and outcomes are more likely to be realized by different flow conditions. For example, BDAs can form immediate pond habitat and lateral connectivity during baseflow conditions, while bank-attached PALS designed to promote channel widening and recruit sediment require high flow conditions. Years of low flows (e.g., 2021) are not likely to result in much change, thus expected responses should not be in years but in the number of typical to large flow events. The most work will be done during large episodic storm events that are known to occur in the area. During these events, a considerable amount of decomposed granite can be recruited into the channel from off the surrounding hillslopes. This process is also affected by the widespread fires that have occurred in the area and may provide additional material depending on the severity of the burn and proximity to stream channels. During these events structures can be damaged or fill material can be mobilized. Generally, to repair these structures that have minimal impact can be very rapid (e.g., 10 minutes per structures) and greatly increase their effectiveness. Thus, this maintenance is recommended every year to ensure that structures are most effective until the next phase of restoration.

Phase 1 typically involves the largest number of structures with fewer structures necessary in subsequent phases. We suggest that Phase 1 objectives are likely to be met following 2-4 typical high flows and one higher flow event. Subsequent treatments will likely follow a similar timeframe. The decision of phases will be based on multiple criteria that will be described more fully in subsequent design, monitoring, and adaptive management documents. The phase during which a complex will be implemented will be determined through several considerations. For example, the location of the complex relative to sediment inputs is important for channel aggradation to be achieved. The structures are purposely leaky, allowing downstream movement of sediment. Still, enough upstream structures could capture most sediment, starving downstream structures. Therefore, downstream structures should be implemented in the first phase with upstream structures implemented in later phases unless sediment inputs (i.e., tributaries and gullies) are located in between complexes, or structures can be designed to recruit sediment from the banks. Also, the depth of channel incision is dependent on base-level controls. Again, downstream complexes can raise the base-level for upstream complexes and thus should be given higher priority. Complexes that can achieve objectives relatively quickly will also be given priority. Some complexes will require multiple phases to achieve objectives, such as areas that are deeply incised. Another consideration is the experimental design to maximize temporal (e.g., before vs after restoration) and spatial (e.g., treatment vs control reaches) contrast to document restoration effectiveness that will be addressed in the monitoring and adaptive management strategies.

DESIGN CRITERIA

The project will follow the standards and guidelines in the Inyo National Forest LMP. Additional specific resource guidelines, laws, regulations, and/or policy will be included as part of restoring the project site meadows. These include, but are not limited to, Endangered Species Act consultation with US Fish and Wildlife Service (USFWS), adherence to the National Historic Preservation Act to protect cultural and historic resources, and National Best Management Practices.

Design criteria for the project are listed below, by resource:

Hydrology and Soils

- Implement watershed Best Management Practices to minimize sediment entry into project streams. Practices include various erosion control measures during and post-project implementation. (WTR-FW-STD-01).
- The project would be completed during low water periods and when the chance of runoff producing rain is less likely to protect water quality (minimize erosion and sedimentation). Project activities would be completed with the minimal amount of vegetation and ground disturbance as possible. The project would include planting sod plugs and willow stems to encourage more rapid establishment of vegetation to improve soil stability and minimize erosion. The following Best Management Practices (BMP) would be implemented: AqEco-2 Operations in Aquatic Ecosystems, AqEco-03 Ponds and Wetlands, and AqEco-4 Stream Channels and Shorelines (From Forest Service National Core BMP Technical Guide, FS-990a, 2012).
- To discourage livestock access to headcut treatment structures utilize tree branches around the treatment sites.

Wilderness

- The project will be completed utilizing primitive hand tools (i.e., cross-cut saws, shovels, pulaskis, etc.). Chainsaws and wheelbarrows may be used outside of wilderness.
- For most of the project sites, trees will need to be utilized for constructing headcut and grade stabilization structures. Trees up to 12 inches dbh would be cut with cross-cut saws and moved by hand to the project site. Trees would be selected randomly around the project sites to not impact the visual quality and wilderness character. Trees that are visible from trails or campsites would not be removed. Where feasible, standing dead and down logs may be used. Stumps from cut trees would be flush cut and disguised so as not to affect wilderness character.
- Visible tracks created by the project will be raked out and disguised.

Botanical Resources

- Disturbance to the plant sensitive plant populations will be minimized or avoided. Foot traffic across the sand flats and immediately adjacent areas would be minimized to protect potential sensitive plant habitat.
- To prevent the spread of noxious weeds, the tools will be cleaned before being transported to the project site.

Wildlife

- Treatments where risk assessments show greatest level of concern (potential occurrence, breeding habitat) for federally endangered mountain yellow-legged frog (MYLF) requires USFWS permitted Forest biologist involvement in project planning and/or implementation. The following apply:
  - Amphibian DC-1 - In suitable habitat and critical habitat the following restrictions apply:
    - The USFWS permitted Forest biologist will review treatment sites that are within MYLF designated critical habitat or within suitable habitat with high likelihood for occurrences. Treatment strategies in these areas, including applying buffers, limited operating periods, and relocating individual amphibians, will be developed collaboratively to ensure treatment efforts minimize impacts to frog populations and suitable habitat.
  - Amphibian DC-2 - In occupied habitat the following restrictions apply:
    - Immediately prior to any treatment activities, a USFWS permitted Forest biologist who is trained in identifying and handling rare amphibians will survey the area for MYLF. If individuals are found, they will be relocated to a safe location that is nearby but out of potential harm's way from treatment activities. In most cases this will be less than 100 feet from the original location of the amphibian.
- Treatments in Monache where risk assessments show greatest level of concern (potential occurrence, denning habitat) for federally threatened Pacific fisher requires USFS Wildlife Biologist assessment of disturbance. In some cases, the activities may be exempt from the following LOP restrictions if they are carefully designed and implemented to mitigate risk. The following apply:
    - March 1 to June 30 - prohibiting noise disturbance from mechanical treatment activities (machinery, chainsaws,)
- To reduce likelihood of direct mortality to pollinators and wildlife, particularly butterflies and nocturnal animals, when driving and working in Monache the following apply:
  - Maximum speed is 10 mph and does not create dust clouds training behind vehicles.
  - Driving shall take place between sunrise and sunset.
- Any Inyo NF At-risk species occurrences discovered prior to or during implementation would be evaluated for protection measures by a USFS Wildlife Biologist (in compliance with SPEC-FW-STD 01).
- Prior to project implementation each year, conduct relevant aquatic and terrestrial wildlife surveys, in and immediately adjacent to project area. If indications of breeding behavior such as nesting, fawning, and rearing are detected, a USFS Wildlife Biologist will be consulted and will recommend appropriate mitigations (in accordance with SPEC-FW-GDL 01).
- During implementation, incidental observations of local and neotropical migratory bird nesting behaviors will be flagged and avoided if active. Disturbance to nesting birds will be avoided or mitigated, to the extent possible to meet project objectives (in accordance with SPEC-FW-GDL 01).

- All project generated garbage and other waste will be secured and/or removed from the site daily, plus litter and debris on a regular basis.

Heritage Resources

- Specific methods to avoid adverse effects to historic properties in the area of potential effect enumerated. Project work was modified to avoid cultural sites.
- If any previously unknown cultural sites are found work will stop in that area, they will be located on a map and a Heritage Resource person will be notified.

EFFECTS ANALYSIS

Definitions

Direct effects include immediate changes in habitat conditions and potential disturbance to individuals during project activities. Indirect effects include effects that occur later in time or may affect such things as prey species and their habitats. Cumulative effects are the impact on the environment resulting from the incremental impact of the action in the context of other past, present, and foreseeable future actions.

General Environmental Effects

The 2192-acre project area can be divided into three affected areas: (1) "Complex Locations" (biogenic habitat structure placement areas) and (2) "Inundation Areas" (vegetation procurement areas) and (3) Upland Procurement Areas (rock and branch procurement areas)

Direct Effects

The direct effects of the three area types are as follows:

Complex Location Areas: Direct effects are the result of the installation of instream biogenic habitat structures (i.e., BDA's and PAL's), which includes the placement of "fill" (i.e., locally sourced vegetation, native river sediments "soil," and river rock/cobble) into the streambed and bank covering a total of X acres of surface area within the stream channel. These structures will impound water to varying degrees, thus raising the water table. Dewatering is not necessary for construction, and construction should have very short duration impacts on water quality (i.e., turbidity) and aquatic life (i.e., short-term displacement of aquatic macroinvertebrates and fish). Fish will scatter at the onset of human disturbance thus no impact is expected. Stream beds will be surveyed immediately prior to construction for spawning redds, and if found, will be flagged and avoided. Sensitive aquatic species surveys will be completed in accordance with project design criteria. A qualified biologist will be present during construction to ensure that no species are harmed due to project activities.

Inundation Areas: Vegetation for instream biogenic habitat structure construction will be procured from Inundation Area boundaries. Conifers that have encroached into the meadow floodplain will be directly affected by either their complete removal (small conifers, less than eight inches DBH and less than 10 feet in height) or with larger conifers, branch removal. For whole conifer removal, trees will be cut as close to the tree base as possible. Sagebrush and willows will be directly affected by the removal of up to 25% of the stems of an individual plant. Vegetation will be clipped, not pulled from the ground. Therefor no ground disturbance will occur in these areas. Prior to implementation, incidental observations of local and neotropical migratory bird nesting behaviors will be flagged and avoided if active. Disturbance to nesting birds will be avoided or mitigated, to the extent possible to meet project objectives.

Birds that utilize sagebrush and meadows with willow for nesting, foraging, and cover may be impacted by vegetation procurement. Studies indicate that sagebrush nesting birds prefer habitats with minimum 20% ground cover and willow nesting birds prefer habitats with 20-40% willow cover. Vegetation measurements taken by Point Blue Conservation in 2021 and 2022 indicate that project site meadows have well over 50% ground cover. It was also found that willow cover at project area meadows ranges from 0-13%, below preferred habitat requirements, resulting in low meadow-associated bird abundance. Therefore, willow will be selectively utilized in relation to its relative local site abundance. A maximum utilization standard of 20% within a $10m^2$ area has been set to preserve the required community characteristics for sagebrush and willow associated bird species.

Upland Procurement Areas: Rock and downed branches will be procured from Upland Procurement Area boundaries. Rock collection may create small ground disturbance. Very few rock treatments are planned and little to no direct impacts are expected. Downed branches collected will not be larger than 8-inch (20.3 cm) DBH or greater than 6 feet (1.8 m) tall. They will also be hardened material (so recently downed) versus softened older material. Given the small size and hardened nature of proposed branches for collection, we anticipate little to no utilization by cavity nesting birds. As a precautionary measure, prior to collection, all branches to be collected will be surveyed for cavity nests. Branches with nests will be flagged and avoided. Pacific fisher utilize snags great than 15 inch (38 cm) and 6.6 feet (2m) tall. Therefor we will be collecting material below typical thresholds for snag habitat utilization and no direct impacts are expected.

Indirect and Cumulative Effects:

The direct effects of the three area types are as follows:

Complex Locations: Indirect effects of constructed instream biogenic structures in the Complex Location Areas may include the artificial obstruction that precludes or prevents the migration of fish. California Golden trout and CA Golden trout x Rainbow trout hybrid species currently occupy some of the project treatment reaches. This project proposes installing PAL structures and BDA structures. The PAL structures are composed of large diameter wood with large interstitial spacing, and therefor not considered a potential fish passage barrier. The BDA structures will be channel spanning structures comprised of organic materials and with a porous organic material weave between untreated posts built to mimic a natural beaver dam. The “porous organic material weave” means loose configuration that allows passage of water through interstitial spaces. The proposed structures will not be over-engineered, hardened, persistent structures that do not resemble a natural beaver dam or interfere with natural instream and floodplain processes. The fish that inhabit the project area are a small non-migratory salmonid species, growing up to 1.7 inches in year one, 4.7 inches in year 2 and 7.5 inches in year three, this also being their maximum size. California Golden trout on the Kern Plateau are documented to have a small average home range of 60 to 225 feet, and a strong preference for pool habitat. Given these species traits and the permeable nature of our proposed BDA structures, it is very unlikely they will act as an artificial obstruction. It is more likely that the BDA structures will increase water permanence in this intermittent system, potentially resulting in an increase in fish movement. Detailed life history studies of CA Golden trout across the Kern Plateau were completed in 1980-90's. These studies found that spawning in the project area typically begins mid to late May (when maximum daily water temperature consistently exceeds 15C and the average daily temperature exceeds 8C) and is complete by the first week of June (Knapp and Dudley 1990; Knapp et al. 1998; Knapp and Vredenburg 1996). Project implementation will not initiate until June 15th of every year, with that being the earliest possible start date. Depending on water year, snowpack and access, start dates will likely be later in the summer seasons. Therefor no impact is expected on trout spawning. Fry emerge approximately a month and a half to three months later, thus redd surveys will be completed, flagged and avoided prior to construction. Instream aquatic invertebrates will likely benefit from the project as a result of increased water permanence and habitat diversity.

Inundation Areas: Indirect effects within the Inundation Areas include increased soil moisture in the adjacent riparian/meadow floodplain. Within this area, we would expect increased stream channel-floodplain connectivity, a reduction in mesic meadow vegetation/increase in hydric species, increased vegetation productivity, and increased soil carbon sequestration capacity. Vegetation procurement may result in altered vegetation and foraging habitat and/or nesting habitat for riparian-associated bird communities. Those potential effects are presented by vegetation type to be procured as follows:

- **Conifer:** Conifers proposed for utilization will be those that have encroached the meadow floodplain due to its unnaturally dry degraded state. Only small whole conifers less than 10 feet tall and maximum eight-inch DBH will be used. Due to their smaller stature, there would be no effect on raptors (including owls) and a negligible effect on other bird species that may utilize them. Raptors in the area generally use trees in the 30 – 100-foot range, and most prefer trees that are taller than surrounding trees. The project is expected to have a long-term effect of transitioning valley bottoms with conifers that were historically wetlands back to wetlands that will no longer support conifers; hence, conifer procurement in these areas will only be an acceleration of an effect that would eventually manifest.

- **Sagebrush:** Sagebrush grows in excess within the project meadow floodplain due to its unnatural dry degraded state. Vegetation surveys completed in 2021 and 2022 by Point Blue Conservation denoted sagebrush shrub cover ranging between 21-39% at project site meadows, outside of Casa Vieja Meadow which is only 1% sagebrush. The historic floodplains in the project area meadows are in an unnaturally dry state that supports sagebrush and dry grassland habitats and their associated avifauna in excess relative to the historic natural condition. Bird species that use sagebrush and dry grasslands for nesting, foraging, and cover include Vesper Sparrow, Brewer's Sparrow, Green-tailed Towhee, Horned Lark, Western Meadowlark, Brewer's Blackbird, and Savannah Sparrow. Where the project is successful in returning sagebrush and dry grasslands to wetland conditions, these species will be displaced as the habitat transition occurs. However, given the overabundance of this habitat type and slow rate of potential reconversion to wet meadow (5 plus years), these species will have sufficient time to relocate. The project is expected to have a long-term effect of transitioning valley bottoms with sagebrush habitat that were historically wetlands back to wetlands that will no longer support extensive sagebrush; hence, sagebrush procurement in these areas will only be an acceleration of an effect that would eventually manifest.
- **Willow:** Birds that utilize willows for nesting, foraging, and cover may be impacted from willow procurement. Willow cover at project area meadows ranges from 0-13% (2021 and 2022 surveys, Point Blue Conservation). At all surveyed meadows, the average percent cover of willows was well below the 20–40% cover that maximize the abundance and richness of most meadow-associated bird species. Only at half the meadows did willow heights attain the >2 m threshold that is most attractive to most meadow-associated bird species (Campos et al. 2014). In most areas of all the meadows, the percentage cover and heights of willows were insufficient to support high abundances and richness of meadow birds. However, birds that utilize willows for nesting, foraging, and cover may be impacted from willow procurement. Though there is one sensitive bird species that may utilize willow within the project area, willow flycatcher, the project area

currently does not contain suitable habitat for willow flycatcher due to the high elevation of the project area, the smaller sizes of some meadows, and especially lack of abundant willow. Bird surveys completed in 2021 and 2022 also did not detect willow flycatcher. To protect the limited existing willow stands and the bird species that may utilize them, only 25% of stems from each plant will be harvested. Additionally, a maximum total utilization standard of 20% within a $10m^2$ area has been set to preserve the required community characteristics for associated species. These effects are expected to be short lived as willows grow quickly after pruning and willow cuttings used in biogenic structures often take root and eventually grow into new mature bushes, self-mitigating project impacts.

Upland Procurement Areas: There are no indirect effects from rock procurement in the Upland Procurement Areas. Indirect effects of procuring small, downed conifer branch (8-inch (20.3 cm) DBH and no greater than 6 feet (1.8 m) tall) are anticipated to be negligible to non-existent considering its below typical usage thresholds for cavity nesting birds and Pacific fisher.

CONCLUSION

The final design describes meadow impairments that will be addressed by LTPBR restoration. The methods of LTPBR are one of the few active approaches available to meadow restoration in wilderness areas where most of these meadows are found. Another alternative would be beaver reintroduction that, until recently, was not an option. But this year CDFW is investing into beaver relocation approaches for the first time, and thus beaver mediated restoration could eventually complement restoration described here.

The final design revolves around the location of complexes which will be composed of groups of structures. Further details about complexes and structures will be provided in subsequent drafts. Here, we used complexes to summarize several field visits, observations, GIS, and LiDAR information to describe the locations and general objectives where restoration is predicable, achievable, and feasible.

REFERENCES

Allen Diaz, B. H. 1991. Water-Table and Plant-Species Relationships in Sierra-Nevada Meadows. American Midland Naturalist 126(1): 30-43.

Bouwes, N., S. Bennett, and J. Wheaton. 2016. Adapting Adaptive Management for Testing the Effectiveness of Stream Restoration: An Intensively Monitored Watershed Example. Fisheries 41:84-91.

Cluer, B., and C. Thorne. 2014. A stream evolution model integrating habitat and ecosystem benefits. River research and applications 30:135-154.

Darrouzet-Nardi, A., C. D'Antonio, and E. Berlow. 2003. The effects of invading young sagebrush (*Artemisia rothrockii*) on the water status of an herbaceous montane meadow in the Eastern Sierra Nevada. Ecological Society of America Annual Meeting Abstracts 88: 80.

Herbst, D. B. and S. D. Cooper. 2010. Before and after the deluge: rain-on-snow flooding effects on aquatic invertebrate communities of small streams in the Sierra Nevada, California. Journal of the North American Benthological Society. 29(4): 1354-1366.

Herbst, D. B., M. T. Bogan, S. K. Roll, and H. D. Safford. 2012. Effects of Livestock Exclusion on in-Stream Habitat and Benthic Invertebrate Assemblages in Montane Streams. Freshwater Biology 57 (1): 204–17.

James, C. B., and R. B. Lanman. 2012. Novel physical evidence that beaver were historically native to the Sierra Nevada. California Fish and Game 98:129-132.

Knapp, R. A., and K. R. Matthews. 1996. Livestock Grazing, Golden trout, and Streams in the Golden Trout Wilderness, California: Impacts and Management Implications. North American Journal of Fisheries Management 16 (4): 805–20.

Kattelmann, R. and Embury, M. 1996. Riparian Areas and Wetlands. Sierra Nevada Ecosystem Project: Final Report to Congress, vol. III, Assessments and scientific basis for management options. University of California, Davis, Centers for Water and Wildland Resources.

Kiernan, J. D. and P. B. Moyle. 2012. Flows, droughts, and aliens: factors affecting the fish assemblage in a Sierra Nevada, California, stream. Ecological Applications 22(4): pp. 1146-1161.

Kraebel, C. and Pillsbury, A.F., 1934. Guideline for watershed improvement measures: Handbook of erosion control in Mountain Meadows. 1-69

Lanman, R. B., H. Perryman, B. Dolman, and C. D. James. 2012. The historical range of beaver in the Sierra Nevada of California and Nevada: a review of the evidence. 98:65-80. California Fish and Game

Liu, Y. Y., Maidment, D. R., Tarboton, D. G., Zheng, X., and Wang, S. 2018. A CyberGIS Integration and Computation Framework for High-Resolution Continental-Scale Flood Inundation Mapping, J. Am. Water Resour. Assoc.

Loheide, S. P., Deitchman, R. S., Cooper, D. J., Wolf, E. C., Hammersmark, C. T., Lundquist, J. D. 2009. A framework for understanding the hydroecology of impacted wet meadows in the Sierra Nevada and Cascade Ranges, California, USA. Hydrogeology Journal 17(1): 229-246.

Lytle, D. A. and N. L. Poff. 2004. Adaptation to natural flow regimes. Trends in Ecology & Evolution 19(2): 94-100.

McCullough, D. A., J. M. Bartholow, et al. 2009. Research in Thermal Biology: Burning Questions for Coldwater Stream Fishes. Reviews in Fisheries Science 17(1): 90-115.

Micheli, E. R. and J. W. Kirchner. 2002. Effects of wet meadow riparian vegetation on streambank erosion. 2. Measurements of vegetated bank strength and consequences for failure mechanics. Earth Surface Processes and Landforms 27(7): 687-697.

Morton, M. L. and M. E. Pereyra. 2010. Habitat Use by Yosemite Toads: Life History Traits and Implications for Conservation. Herpetological Conservation and Biology 5(3): 388-394.

Moyle, P.B., Israel, J.A., and Purdy, S.E. 2008. Salmon, steelhead, and trout in California: status of an emblematic fauna. California Trout, San Francisco, p 316NFWF 2009

Null, S.E., J.H. Viers, and J.F. Mount. 2010. Hydrologic Response and Watershed Sensitivity to Climate Warming in California's Sierra Nevada. Plos One 5(3).

Patton, D. R. and B. I. Judd. 1970. Role of Wet Meadows as Wildlife Habitat in the Southwest. Journal of Range Management 23(4): 272

Pister, E.P. 2008. Restoration of the California Golden trout in the South Fork Kern River, Kern Plateau, Tulare County, California, 1966-2004, with Reference to Golden Trout Creek. California Department of Fish and Game, Central Region. Administrative Report No. 2008-1. 122 pp.

Pollock, M. M., T. J. Beechie, J. M. Wheaton, C. E. Jordan, N. Bouwes, N. Weber, and C. Volk. 2014. Using beaver dams to restore incised stream ecosystems. BioScience 64:279-290.

Pollock, M. M., G. Lewallen, K. Woodruff, C. E. Jordan, and J. M. Castro. 2015. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Page 189 pp in U. S. F. a. W. Service, editor., Portland, Oregon.

Potter, K.W.1994. Estimating potential flood reduction benefits of restored wetlands. Water Resource Update 97: 34–38.

Povirk, K.L., J.M. Welker, et al. 2001. Carbon sequestration in Arctic and Alpine Tundra and Mountain Meadow Ecosystems In: The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect., Follett, R.F., Kimble, J.M., and R. Lal, Eds. CRC Press.

Purdy, S.E., P.B. Moyle, and K.W. Tate. 2012. Montane meadows in the Sierra Nevada: comparing terrestrial and aquatic assessment methods. Environmental Monitoring and Assesment 184(11): pp. 6967-6986.

Reed, C. C., A. G. Merrill, W. M. Drew, B. Christman, R. A. Hutchinson, L. Keszey, M. Odell, S. Swanson, P. S. J. Verburg, J. Wilcox, S. C. Hart, and B. W. Sullivan. 2020. Montane Meadows: A Soil Carbon Sink or Source? Ecosystems.

Sarr, D. A. 2002. Riparian Livestock Exclosure Research in the Western United States: A Critique and Some Recommendations. Environmental Management 30 (4): 516–26.

Saleska, S.R., J. Harte, and M.S. Torn. 1999. The effect of experimental ecosystem warming on CO2 fluxes in a montane meadow. Global Change Biology 5(2): 125-141.

Stephens, S.J, C. McGuire, and L. Simms. 2004. Conservation Assessment and Strategy for the California Golden Trout (*Oncorhynchus mykiss aguabonita*) Tulare County, California. California Department of Fish and Game, USDA Forest Service, and U. S. Fish and Wildlife Service.

Trowbridge, W., J. Chambers, and D. Germanoski. 2007. Establishing priorities for restoration of riparian streams and meadows. Ecological Society of America Annual Meeting Abstracts.

Viers, J. H., S. E. Purdy, et al. 2013. Montane Meadows in the Sierra Nevada: Changing Hydroclimatic Conditions and Concepts for Vulnerability Assessment. Center for Watershed Sciences Technical Report (CWS-2013-01), University of California, Davis. 63 pp.

Weixelman, D. A., B. A. Hill, D.J. Cooper, E.L. Berlow, J.H. Viers, S.E. Purdy, A.G. Merrill, S.E. Gross. 2011. A Field Key to Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges in California. Gen. Tech. Rep. R5-TP-034, Vallejo, Ca, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region: 34.

Wheaton, J.M., Bennett, S.N., Bouwes, N., Camp, R., Maestas, J.D. and Shahverdian, S.M., 2019. Chapter 2 – Principles of Low-Tech Process-Based Restoration. In: J.M. Wheaton, S.N. Bennett, N. Bouwes, J.D. Maestas and S.M. Shahverdian (Editors), Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Utah State University Restoration Consortium, Logan, Utah. 286 pp. DOI: 10.13140/RG.2.2.19590.63049/1.

Wright, J.M., and J. C. Chambers. 2002. Restoring riparian meadows currently dominated by Artemisa using alternative state concepts - above-ground vegetation response. Applied Vegetation Science 5(2): 237-246.

APPENDIX A: GEOMORPHIC AND HYDROLOGIC STUDIES FOR THE KERN PLATEAU RESTORATION DESIGN

The Kern Plateau Meadows Final Design provides the details of the restoration plan of 15 degraded meadows located in the headwaters of Owens River watershed the South Fork Kern River watershed located on the Kern Plateau of the Inyo National Forest. The goal of the Kern Plateau Meadows Project is to restore natural hydrological, biological, and geomorphic processes throughout the meadow complexes to increase resilience, ecosystem services, and improve aquatic, riparian, and floodplain habitats. To develop a design to restore these processes, identification of how, where, and scope of the degradation is required. Much of the setting and current condition has already been described in the main final design report (see Meadow Impairments and Existing Condition). Here we describe other supporting geomorphic and hydrological studies based on observations from multiple field visits and GIS data including LiDAR, aerial, and satellite imagery.

GENERAL MEADOW IMPAIRMENTS

Throughout the Kern Plateau, many riparian meadow areas remain confined to inset floodplains within incised stream gullies. The historic floodplain is generally disconnected from the stream channel and much of the historic meadow has been converted to sagebrush steppe and other upland species with a loss of meadow species and peat forming conditions. In general, the stream channels within project meadows remain moderately to severely incised but active erosion has largely been arrested in part due to previous restoration efforts and changes in grazing management. The existing stream channel banks are largely stable and well-vegetated though disconnected from the historic floodplain in a larger entrenched channel. These riparian meadow type will be the focus of restoration efforts because the sediment transport capabilities of flowing water allow for aggradation and deposition behind treatment structures. Other areas within the meadows do not have many active treatment options other than import of fill material with heavy equipment (in non-wilderness meadows). Throughout the meadow project sites there are multiple meadow types as described by Weixelman et al. (2011), including riparian, discharge peatlands, mound peatlands, discharge slopes and subsurface meadows.

HYDROGEOMORPHIC MEADOW TYPING

Meadows are characterized by a shallow water table and fine-textured surficial soils that support hydric and mesic herbaceous vegetation and limits the establishment of many trees and shrubs. Hydrological processes and geomorphology control the formation of the meadows in Sierra Nevada mountains. The variability in the range hydrological and geomorphic conditions forming meadows results in a diversity of meadow types. Hydrological characteristics include the timing, amount, source, location, and duration of water in the meadow. Different combinations of precipitation, groundwater, or surface flows will produce different meadow types. Discharge from the base of hillsides and alluvial fans, springs or seeps, or in stream channels are affected by geomorphology (landforms) influencing where in the landscape meadows of different types form. The presences of sheetflow, channelized flow, and subsurface flow are determined by gradient, swales, and floodplain connectivity.

We used the Weixelman et al. (2011) Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges in California classification system to identify and delineate meadows types for all 15 meadows with project area. The hydrogeomorphic meadow (HGM) classification relies on the characteristics of soils, peat, groundwater influence, topography, and vegetation to identify meadow types. The meadow types encountered in this project include basin peatland, mound peatland, discharge slope peatland, discharge slope, depressional seasonal, dry, riparian (low, medium, high gradient), subsurface (low, medium, high gradient). To simplify the meadow type for illustration and for comparison to multispectral imagery, we do not distinguish between the gradient variants in the riparian and subsurface meadow types. We also display the upland areas within the meadow complex.

Peatland type meadows have at least 20 cm of organic soils within the top 40 cm of soil and the water table with 20 cm of the surface during the summer. These meadows support obligate and facultative wetland graminoid and moss peat forming vegetation. If topography is a concavity with no inlets and outlets the meadow type is basin peatland. Peat that has accumulated and formed a convexity is referred to as mound peatland meadow type. This meadow types is found where there is strong upwelling of groundwater. Discharge slope peatland are planar meadows that occur on hillslopes, toeslopes, and the base of alluvial fans where groundwater discharges to the surface creating sheetflow.

Discharge slope meadows do not form peat but are also planar meadows that occur on hillslopes, toeslopes, and the base of alluvial fans where groundwater discharges as springs and seepage areas creating sheetflow or sometimes in very small channels. The dominant vegetation is hydric meadow obligate and facultative graminoid species with occasional shrubs such as willow.

Depressional meadow types are formed in a concavity that is fed by surface flow and is characterized by less than 20 cm of organic soils within the top 40 cm of soil. Water table is within 20 cm of the surface. Seasonal depressional meadows dry up generally by mid-summer whereas perennial depressional meadows tend to maintain some water throughout the summer. They support a diverse community of herbaceous plants.

The dry meadow type typically has a water table a least a 1 m below the surface and soil surface are dry by mid-summer occurring across of diversity of topographies. Dry meadows are dominated by perennial dryland grasses, dryland sedges, or herbaceous dicots.

Riparian meadows contain a one or more channels throughout most of the length of the meadow which occurs on the floodplain. Weixelman et al. (2011) distinguishes between low (<2%), medium (2-4%), and high (>4%) gradient riparian meadows. The dominant vegetation is hydric meadow obligate and facultative graminoid species often with shrubs such as willow and alder present.

Subsurface meadows are fed by a channel and have a channel exiting the meadow, but a channel is not present in the generally wide planer surface. Groundwater may also enter from the base of hillslopes. Water is dispersed throughout the meadow at the surface or just below the surface as sheetflow. The dominant vegetation is hydric meadow obligate and facultative graminoid species often with shrubs such as willow present.

The increase in vegetation extent and production is a major project objective (see Objective 1-11) as many of the ecological benefits of the restoration efforts are through vegetation responses. A tight coupling exists between the different HGM types and vegetation production and community types. As such, vegetation will be used a response variable to evaluate project effectiveness (see Kern Plateau Meadows Project Monitoring Plan). The vegetation response will be monitored via on the ground vegetation surveys and through multispectral satellite imagery. The hydrogeomorphic meadow type will be used to provide context to these changes (Figure A-1).

Aside from providing structure to protect springs and discourage trailing by cattle, the restoration actions focus on reconnecting stream channels to their floodplain through the addition of structures as that is the main practical action that can be taken, other than a change in grazing management. The riparian meadow type is associated with stream channels. While the riparian meadow portion of the meadow complex may be relatively small, increased sedge production and recruitment of woody species can provide the needed structure to repair and prevent further degradation of the meadow complex while providing important habitat for fauna. Evaluating differences between pre- and post-restoration within the riparian polygon rather than the entire meadow complex will likely demonstrate much larger relative changes, and hence the need for the HGM context.

Additionally, we mapped upland vegetation. While not a meadow type, the main degradation to many of these meadows is channel incision that happened perhaps a century ago where the floodplain has been disconnected, and the abandoned surface now supports a drier vegetation community including upland species. Thus, we include this category to not only describe the degradation but also the opportunity to reclaim this in a wet meadow vegetation community. We have tried to distinguish between upland (naturally support under intact conditions) and converted upland; however, to simplify the following maps and because it is difficult to truly know, we do not distinguish between the two and refer to natural and converted uplands to upland. While we expect an increase in vegetation production within the riparian meadow type in response to the restoration actions, change from one meadow type to another might be less common. However, in locations where inundation out into the floodplain that now contains dryer conditions supporting upland vegetation and dry meadows, we might also see a change in meadow type occur through addition of structures. Thus, the meadow type mapping might also serve a response variable to restoration effectiveness.

Riparian meadow types provide the highest vegetation production and species and habitat diversity of the all the meadow types. To evaluate the restoration potential in converting these different vegetation communities to a riparian community we overlayed the delineated riparian meadow type over multiple inundation extents that might occur if the floodplain were reconnected and channel incision reversed to some degree.

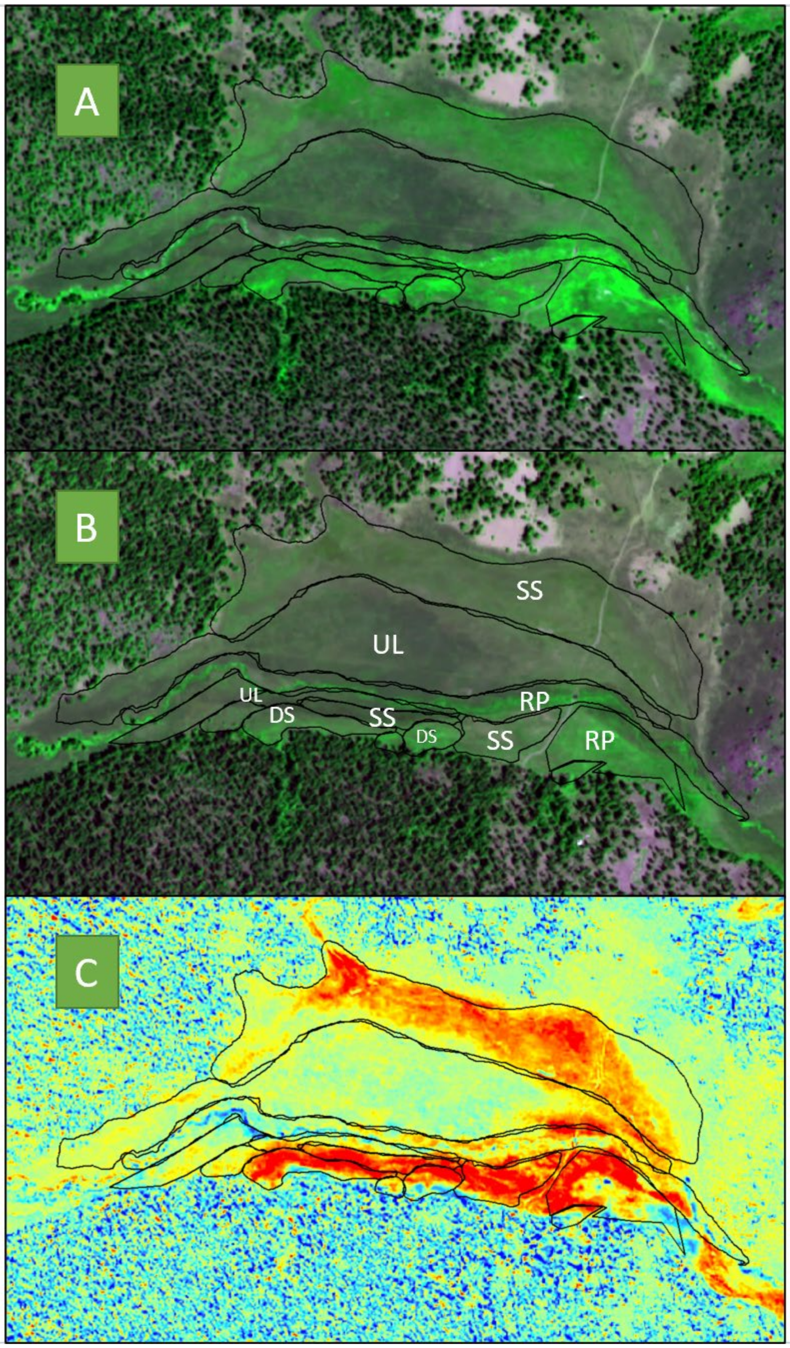

Figure A-1. Outlines of different hydrogeomorphic meadow types (SS=Subsurface, UL=Upland, RP=Riparian, DS=Discharge Slope) are overlaid on multispectral signatures (i.e. Normalized Difference Vegetation Index or NDVI) from Pleiades-1 satellite remote sensing data. A) NDVI imagery from June 2022. B) NDVI imagery from September 2022. C) NDVI difference of June from September where red indicates vegetation is less productive in September than June, blue represents the opposite. Note that SS, DS, and the RP that is disconnected (lower right) are very productive in June and less productive in September (i.e., red in C) as the meadow become drier. The RP that is connected (long narrow band immediately adjacent to the channel) becomes more productive as this vegetation stays wet and has a longer growing season (i.e., dark blue in C). UL is generally always less productive and dry (i.e., mix of light yellow and light blue).

Below, we present HGM information on a meadow-by-meadow basis. We first show the delineation and distribution of HGM types and upland communities. The restoration actions are meant to increase the water surface elevation and reconnect floodplains. We built inundation extents based off of DEMs created from LiDAR information to provide a conservative estimate of where water might spill to assuming current stream surface levels were raised 0.5, 1.0, 2.0 m (see Detrended Digital Elevation Model and Zone of Influence sections of main report for further information). Given that incision depth is often between 0.3 and 1.0 m, these first two elevations seem reasonable. We include 2.0 m to capture what might be possible if water can be diverted onto the floodplain at a low point remaining on the surface to exit further downstream at a much higher elevational difference between channel bottom and floodplain. Additionally, through capillary action and the extension of roots, a raised ground water elevation of 1 m, might cause hydrological influence of vegetation 1 m from the surface, equivalent to a 2 m inundation extent. In addition to the HGM types, we then provide another map that collapses upland and all meadow types, except riparian, into one meadow type. To demonstrate what conversion might be possible following restoration, we overlay the inundation extent over the current riparian extent and consolidated meadows. We provide the 3 inundation elevations to provide a range of the potential riparian meadow expansion, assuming inundation will convert other meadow types to riparian meadow type.

GEOMORPHIC SETTING

Channel incision is the main degradation and threat to the meadows in the project area. Reversing incision through addition of structures that capture sediment and aggrade the channel is the main strategy of this restoration project. While the increase in water surface elevations following the addition of structures provides immediate benefits, the ability to aggrade the channel sufficient enough to allow typical floods to inundate the floodplain is needed to engage the processes that sustain a healthy meadow. However, in some cases, the incision is so great that reconnecting the floodplain may not be a feasible option and making these areas potentially lower priority. However, extending the inset floodplain by eroding banks (channel widening), frequently inundating this floodplain while preventing further downcutting can still provide substantial ecological benefits. Identifying and delineating the degree of channel incision can help in prioritization and developing relevant restoration strategies.

To characterize the geomorphic setting and provide an index of channel incision we conducted several analyses based on the topographic data collected via LiDAR. Because LiDAR (2m DEM resolution) is available for the project area, we used this information in TAUDEM in place of the publicly available 10m DEM to provide much accurate topographic analyses (see Detrended DEM section of the main report for more information). An accurate delineation of the channel is important for estimating channel gradient, sinuosity, and deriving inundation extents (see Detrended DEM section of the main report for more information). The channels provided by the National Hydrography Data are often not accurate as they are derived from the 10m DEM. Therefore, a new channel network was derived from LiDAR data available for the project areas. The channel delineation of the watershed using a LiDAR-derived DEM was performed using the latest available release of TauDEM (5.3.7). As stated in the previous section, we also estimated inundation extents also using TauDEM (see Detrended Digital Elevation Model and Zone of Influence in main report for further information).

All meadows were delineated using reach breaks which separated areas of the meadow with different geomorphic characteristics, mainly valley width of the main channel and valley of the meadow, and input from tributaries/stringer meadows in the valley bottom (for example see Figure 23). A center valley line was drawn through all mainstem reaches throughout the meadow. We compared the area of the inundation extent of 0.5, 1, and 2 m surface elevations surrounding the main channel. Additionally, we estimated the proportion of the 0.5 m and 1 m aerial extent of the 2 m aerial extent. The absolute area of inundation for each extent provides useful information about the potential benefit of the restoration efforts as described above. However, the relative differences in the extents can also provide an index of channel incision. If the 2 m extent was far greater than 0.5 or 1 m, this would suggest a channel incised between 1-<2 m. If the 1 m was far greater than the 0.5 m extent, then incision would be between 0.5-<1 m. If there was little difference between all 3 extents then the channel is in a highly confined area or is greatly incised suggesting restoration might not provide much benefit in these locations. Alternatively, little difference between the 3 extents might suggest little to no incision as very little increase in water surface elevation might spill out over the whole floodplain. Thus, it is important to look at proportions in the context of the absolute areas.

Additionally, to summarize the inundation information, we created an average width of each level of inundation extent. This was calculated as polygon area divided by the length. We used this metric as the area is normalized by the length of geomorphic reach. Cross-sections are commonly used to help identify and quantify the area of channel incision. However, a tremendous amount of variability exists in these meadows as to the degree of channel incision. To capture a reasonable average incision value per geomorphic reach would require the creation and interpretation of a tremendous amount of cross-sections. The advantage of the approach laid out here is that the values provided are widths integrated across the entire polygon. Below we summarize this information in maps and graphs only for the mainstem channel for each meadow.

HORSESHOE MEADOW

Horseshoe meadow is a large meadow complex that drains easterly into Cottonwood Creek and eventually the Owens Valley. The meadow is fed by several small streams and numerous springs and groundwater upwelling areas, the largest being Poison Creek from the southwest. The relic unregulated grazing activity resulting in channel incision created an isolated floodplain that converted from wet meadow habitat to upland with some dry meadow species interspersed which comprises the majority of the meadow types (Table 1). Active headcuts exist in some of the stream channels, but others have filled in with sediment deposition from sources outside the meadow. There are several areas of mound peatlands at the northern margin of the northern lobe. Discharge slope/discharge peatlands are also present at the western margins (Figure 3). Much of the historic riparian floodplain has been converted to subsurface meadow due to channel incision and rarely, if ever, has active flooding. These areas show a more mesic vegetation community structure dominated by grasses and mesic forbs in non-saturated soils. The ground water table is likely within 1 m of the meadow surface, but this meadow is vulnerable to conversion to sagebrush/upland with persistent drought and drier, hotter climatic conditions. The southern lobe has a wider inset floodplain that contains wet riparian meadow habitat that is generally in good condition. However, it is disconnected from the adjacent historic floodplain surface, which is mixed sagebrush steppe and dry meadow habitat that is on the verge of full conversion in many locations. This area has high riparian meadow potential (Figure 4). The multiple tributaries entering the meadow come together into a single threaded channel confined by moraines below the confluence. The channel is confined and entrenched, but mostly stable and highly sinuous (Figure 5 & Figure 6); with below reach 1 needing 2 m elevation gain to average approximately 100 m floodplain width (Figure 1).

Table 1. Acres and percent of total for each meadow type found in Horseshoe Meadow.

Meadow	Acres	% Total
Horseshoe	**282.6**	**100%**
Discharge Slope - Peatland	0.2	0%
Dry	112.0	40%
Riparian	43.9	16%
Subsurface	39.4	14%
Upland	87.1	31%

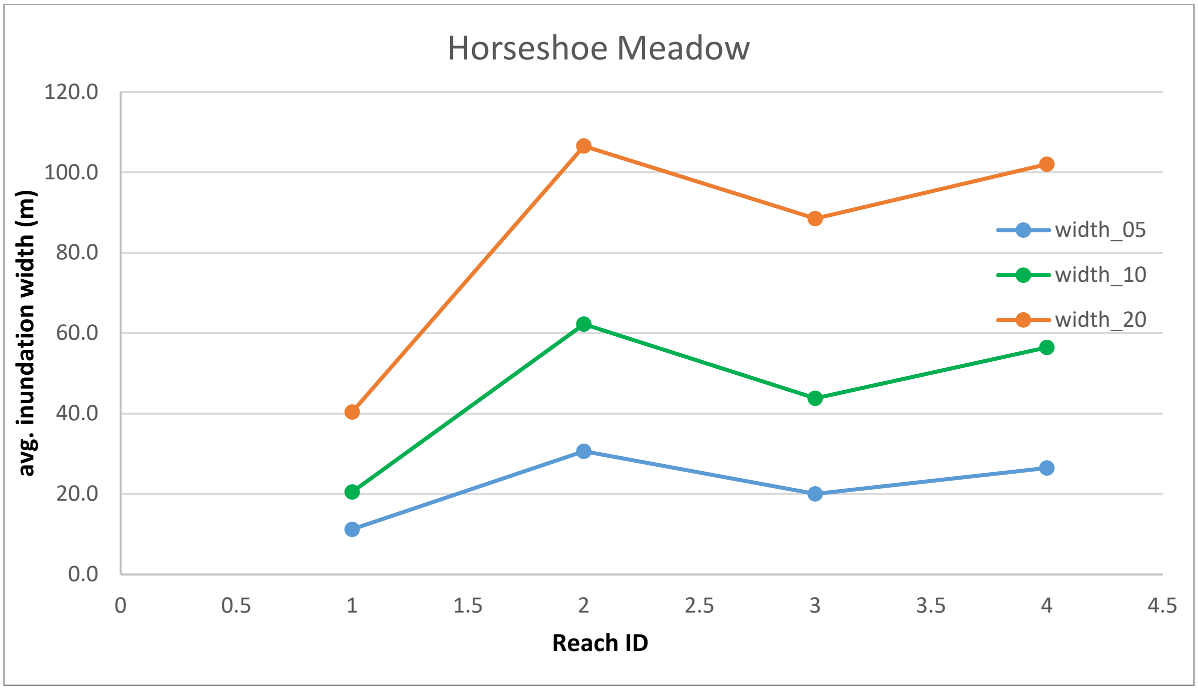

Figure 1. Horseshoe Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

ROUND VALLEY MEADOW

Round Valley Meadow is located at the southeastern lobe of the Horseshoe Meadow Complex. The upper end of the meadow (the widest, largest area; Figure 2) is predominantly subsurface low gradient meadow (Table 2. Acres and percent of total for each meadow type found in Round Valley Meadow.) with no defined stream channels (Figure 3). Several tributary streams enter the meadow on the south and west sides that provide both surface flow and abundant sediment, though these have largely incised and cannot access the historic floodplain surface. A large many-lobed headcut marks the zone between the subsurface meadow and the incised riparian channel below has largely been arrested through past restoration efforts. Below the large headcut repair area, the channel becomes deeply incised (> 2 m) with sagebrush conversion at the margins and a healthy but highly reduced inset floodplain channel of riparian wet meadow (Figure 6). Several areas of subsurface meadow and discharge slopes and peatlands are in the higher ground, particularly in the areas on the south side of the channel. The exposed banks in this section show deep peat layers proving that the meadow surface was significantly higher pre-settlement with a much larger wetland area. The edge of the historic terrace is actively eroding in some areas and has little to no vegetation with large chunks of peat sloughing into the channel below.

Table 2. Acres and percentage of total for each meadow type found in Round Valley Meadow.

Round_Valley	106.3	100%
Depressional - Seasonal	1.6	1%
Discharge Slope - Peatland	0.1	0%
Dry	7.3	7%
Riparian	8.2	8%
Subsurface	54.0	51%
Upland	34.8	33%

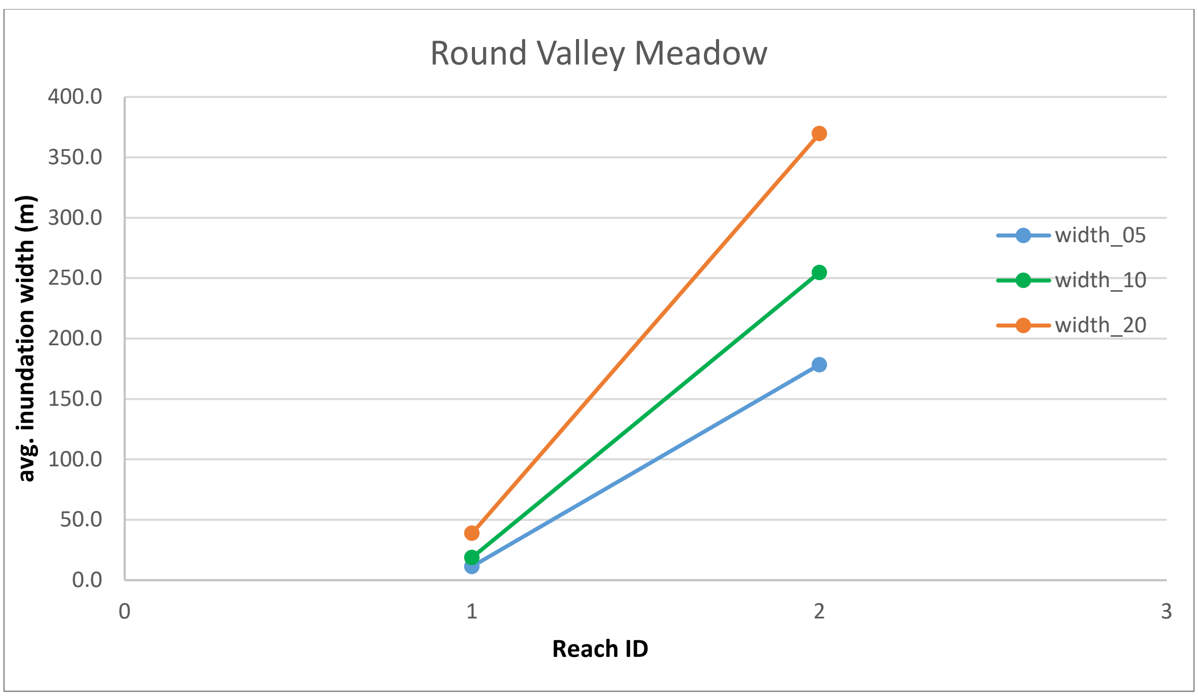

Figure 2. Round Valley Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

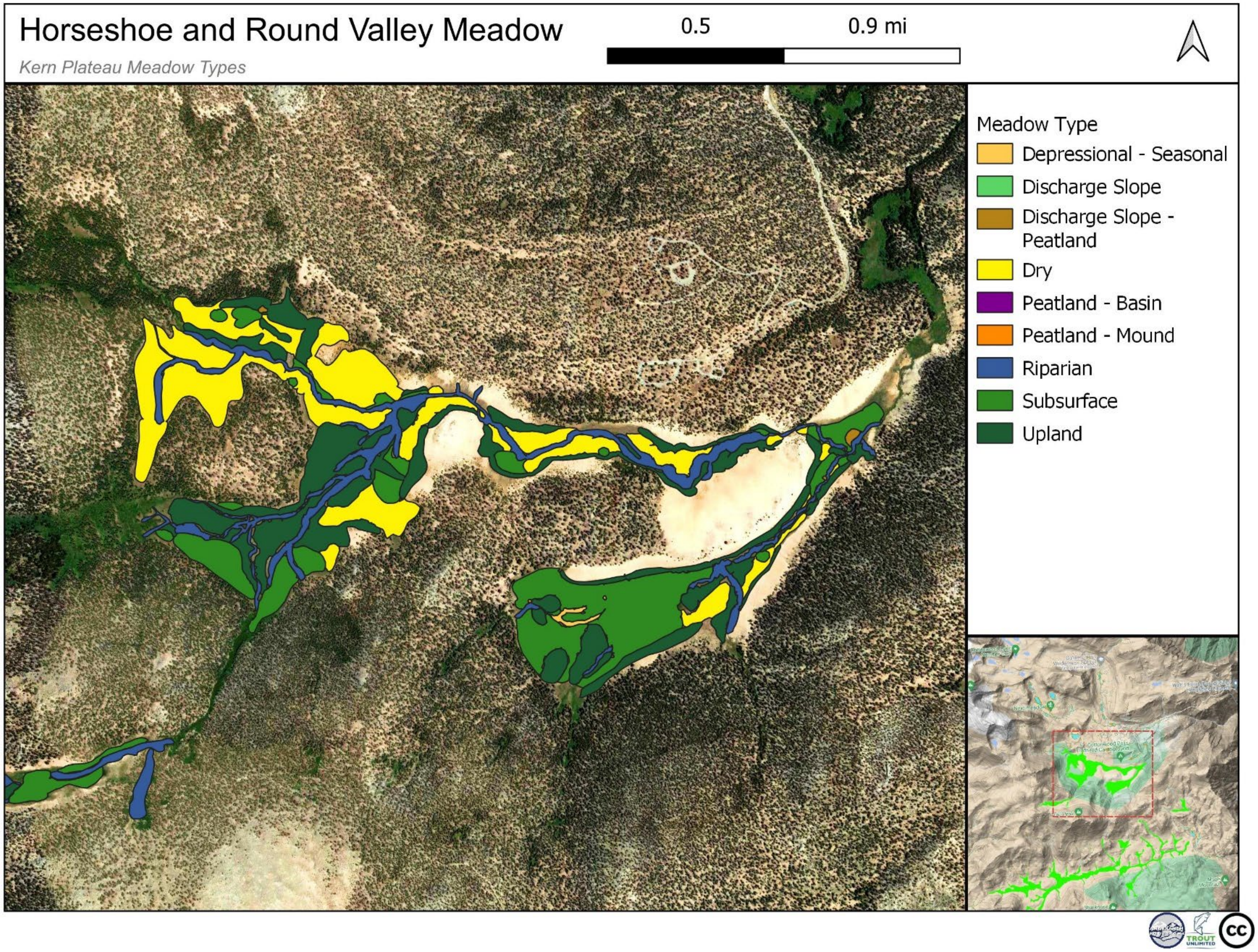

Figure 3. Distribution of meadow types in Horseshoe and Round Valley Meadows.

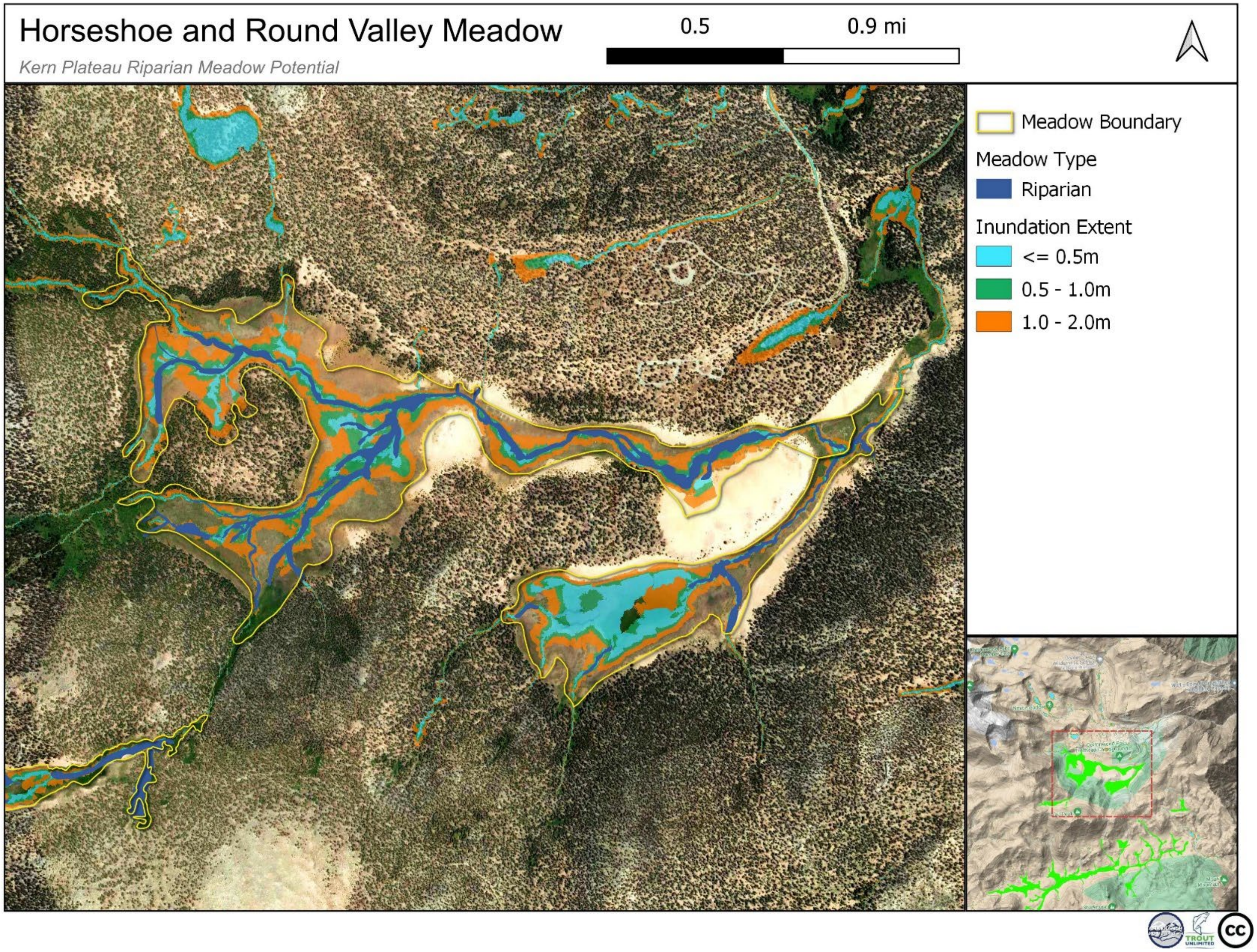

Figure 4. Dark blue represents the current riparian meadow in Horseshoe and Round Valley. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

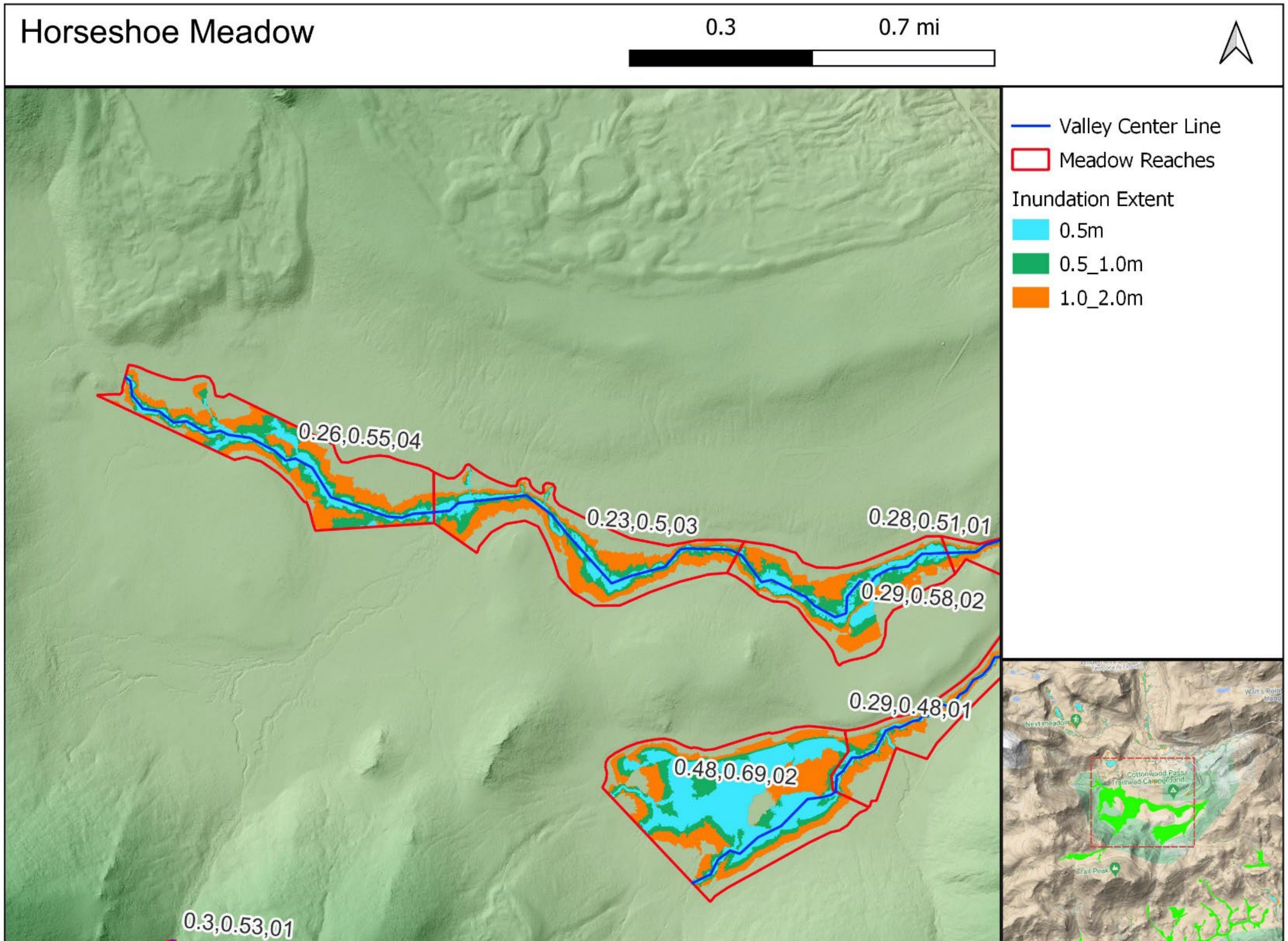

Figure 5. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in upper Horseshoe and Round Valley Meadows. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

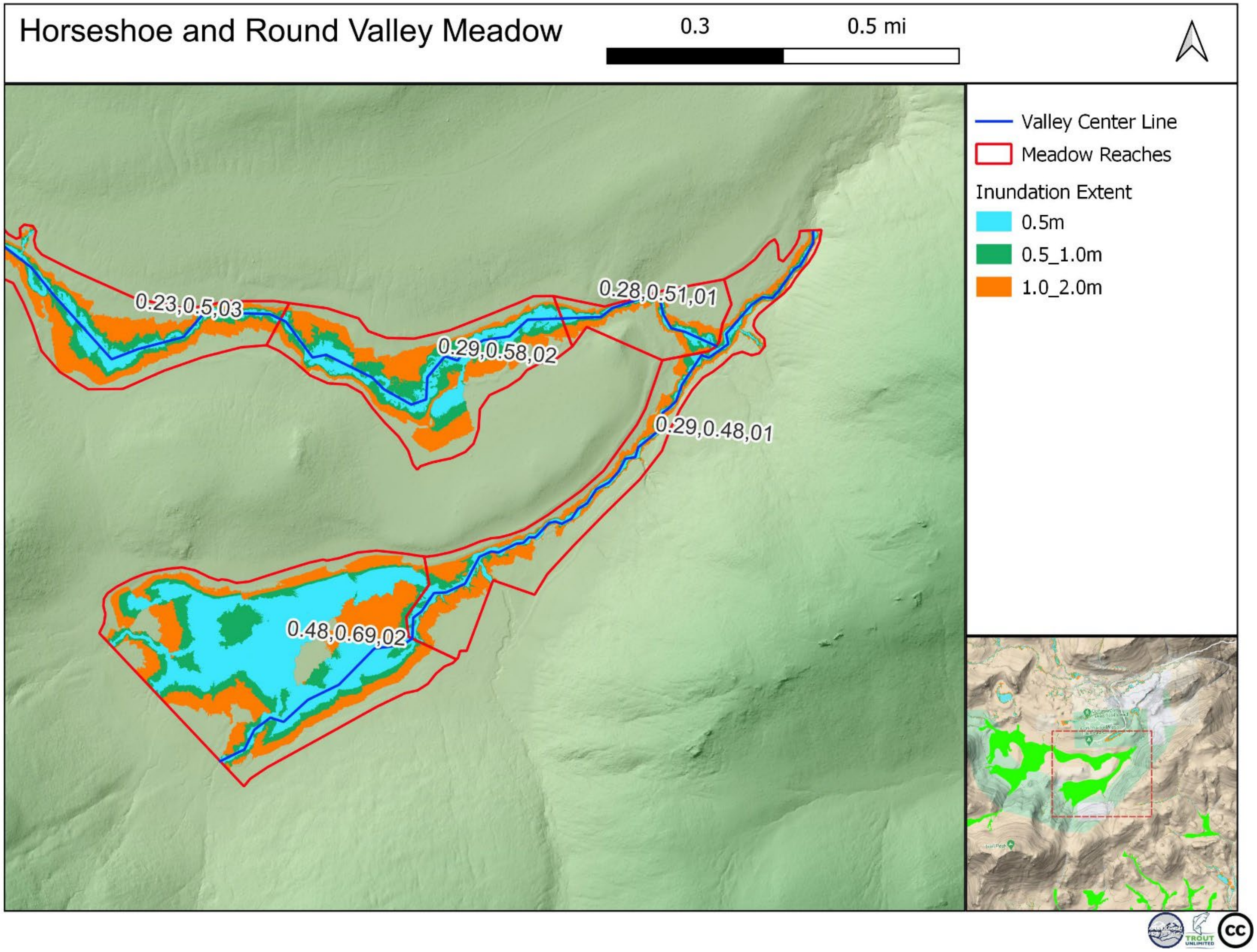

Figure 6. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in lower Horseshoe and Round Valley Meadows. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

POISON MEADOW

Poison Meadow is a tributary to Horseshoe Meadow. The majority of the meadow is riparian or subsurface, with upland making up only 8% of the meadow area (Table 3). A mix of several small tributary channels at the upper end cut through a transverse sediment splay with sagebrush on the high surface. Several discharge slope springs drain onto the north side of the meadow (Figure 8). Below that area, the multiple channels become subsurface low gradient meadow with dense sedges and a water table depth of less than 1 m. This is the widest portion of the meadow (Figure 7). At the eastern end of the subsurface meadow there is an abrupt shift in gradient and an actively headcutting single-thread channel forms. On the south side of this section there is a small subsurface meadow that is becoming very dry, and the peat soil is actively drying, crumbling, and oxidizing. As the channel continues down the valley, the gradient increases and substrate size increases and willow cover increases commensurately. Because of the confinement of the riparian meadows, the potential to convert to other meadow types is low (Figure 10 & Figure 11).

Table 3. Acres and percent of total for each meadow type found in Poison Meadow.

Meadow	Acres	% Total
Poison	**29.0**	**100%**
Discharge Slope	4.4	15%
Discharge Slope - Peatland	0.9	3%
Riparian	12.0	41%
Subsurface	9.5	33%
Upland	2.3	8%

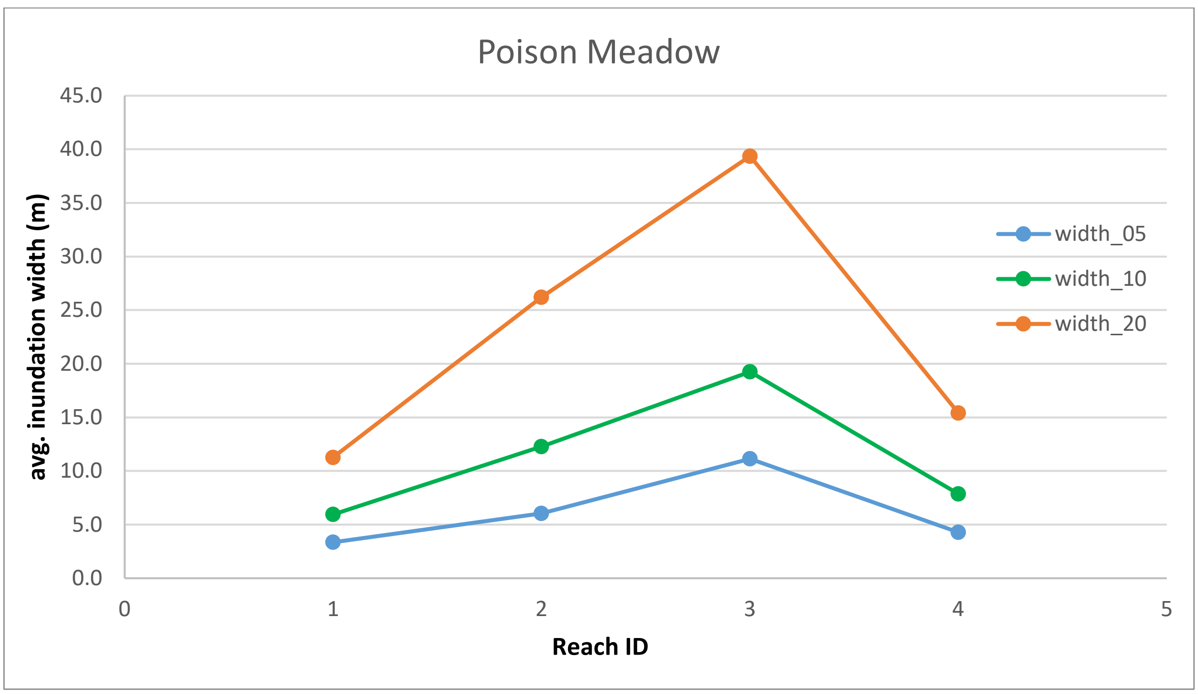

Figure 7. Poison Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

DUTCH MEADOW

Dutch Meadow is the headwater meadow of Diaz Creek and is part of the active Mulkey Grazing Allotment within Golden Trout Wilderness. The northern lobe contains two main tributary drainages that converge in a small area of intact subsurface and riparian middle gradient meadow that has willow cover and conifers at the margins. The western lobe contains a small riparian channel and subsurface low gradient meadow at the upstream end with discharge slope peatlands at the western margin (Figure 12). Both lobes quickly deteriorate into incised channels due to historic channel incision that has resulted in a narrow, inset floodplain 3 m below the historic meadow surface in both lobes with upland encroachment on the historic floodplain now comprising the majority of the meadow (Table 4). Major aggradation would be necessary to increase the floodplain width in order for upland to be converted to riparian meadow (Figure 13). In the western lobe, erosion has revealed alternating layers of peat and sand and gravel. The pattern of peat build-up from organic materials (mostly saturated sedge and bryophytes), and thick layers of decomposed granite from the bare uplands, suggests high deposition across the meadow surface in times of high runoff, likely from intense summer storms that can occur on the Kern Plateau. The northern lobe has a larger drainage basin and thus sees higher flows. The inset floodplain is both wider and deeper here (Figure 8 & Figure 14). Both lobes have a very healthy riparian wet meadow system within the inset floodplain, but most of the meadow has been converted to sagebrush upland. Below the confluence of the two lobes, the gradient becomes steeper with multiple discharge slope peatlands near the margins.

Table 4. Acres and percent of total for each meadow type found in Dutch Meadow.

Meadow	Acres	% Total
Dutch	**27.4**	**100%**
Discharge Slope - Peatland	0.1	0%
Riparian	6.6	24%
Subsurface	5.9	22%
Upland	14.8	54%

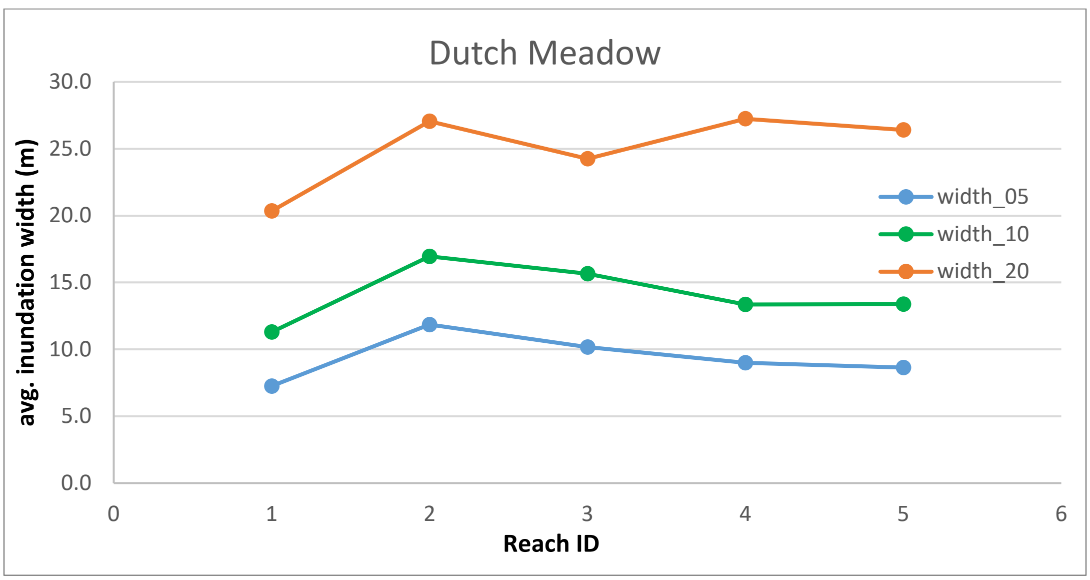

Figure 8.Dutch Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

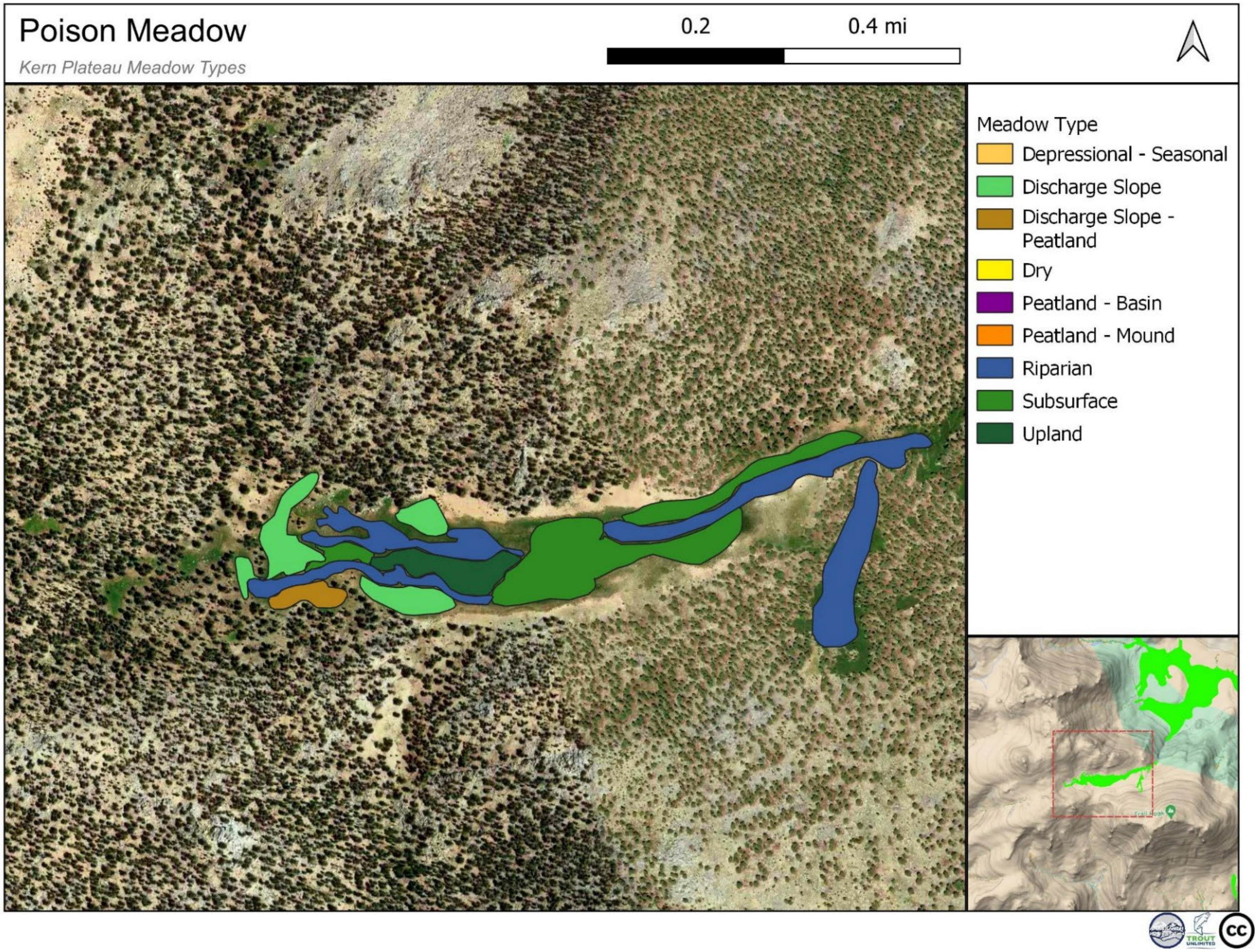

Figure 9. Distribution of meadow types in Poison Meadow.

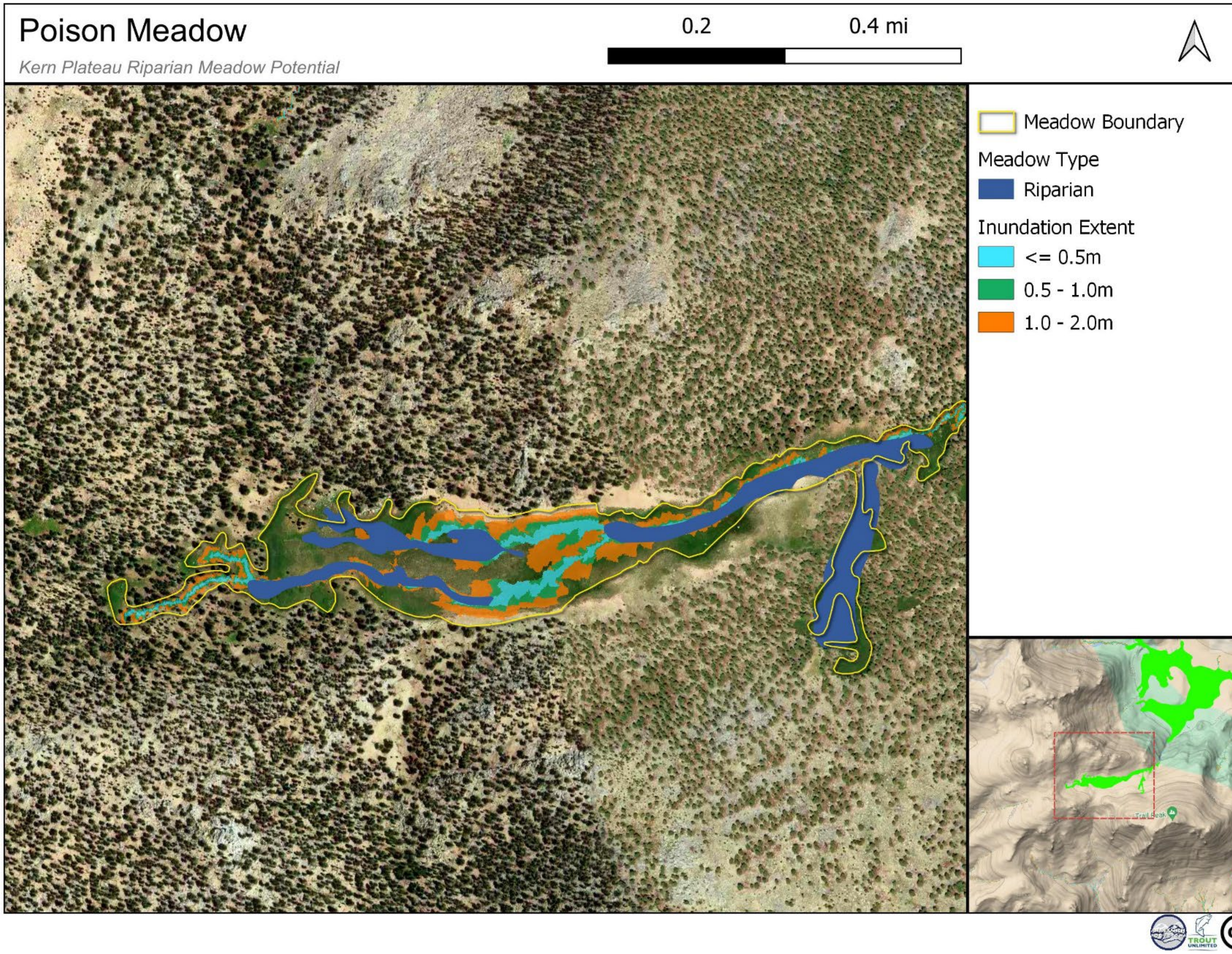

Figure 10. Dark blue represents the current riparian meadow in Poison Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

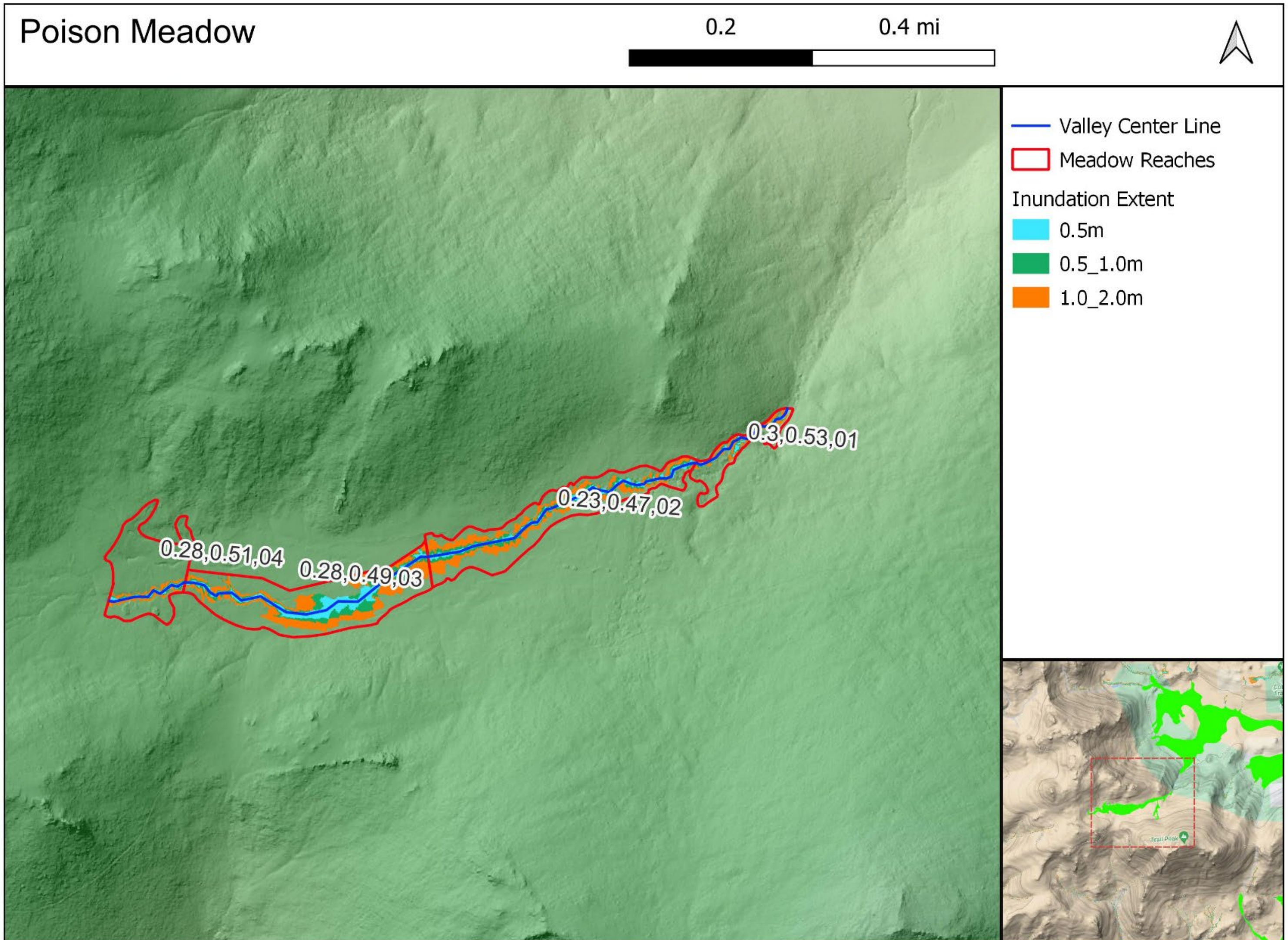

Figure 11. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Poison Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

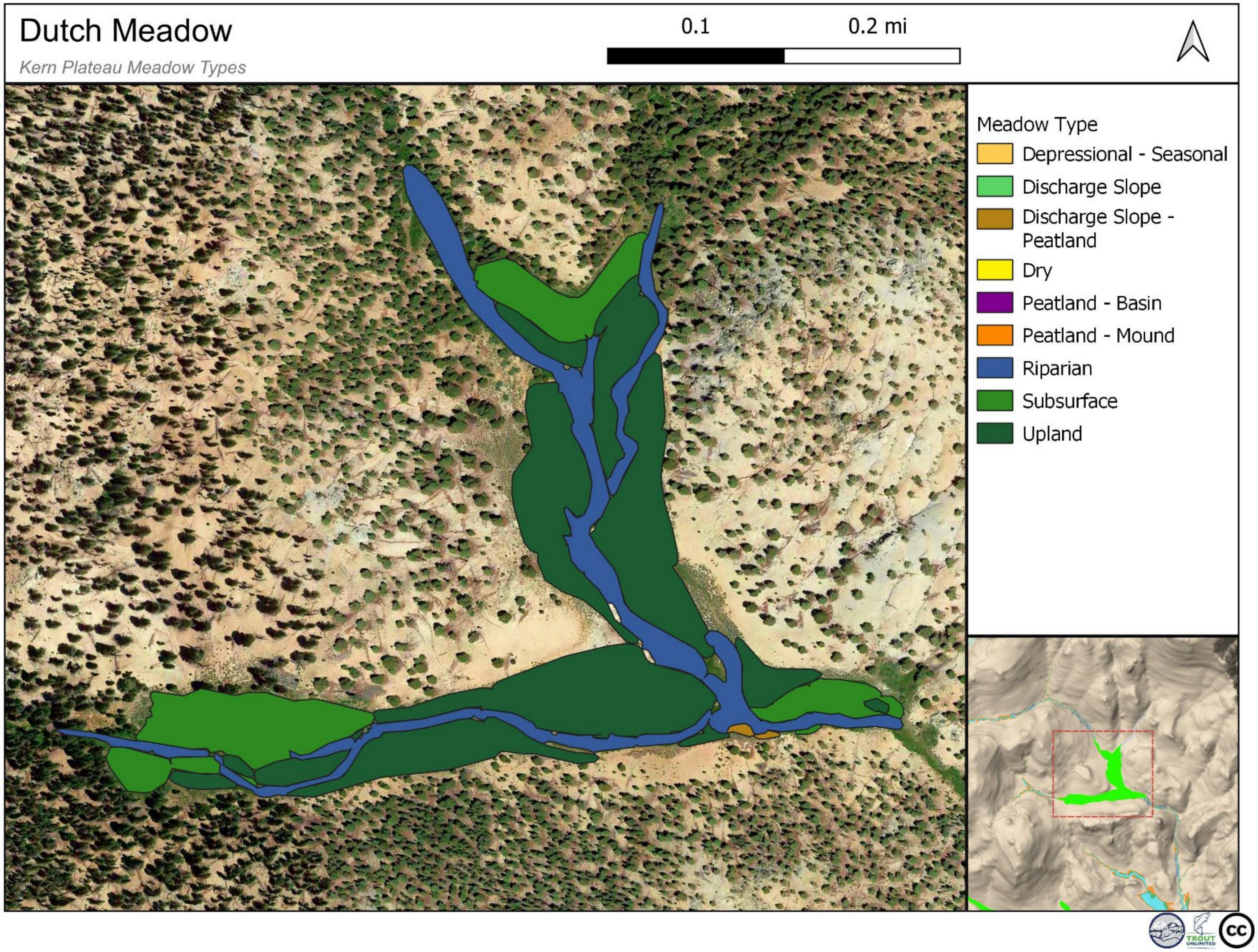

Figure 12. Distribution of meadow types in Dutch Meadow.

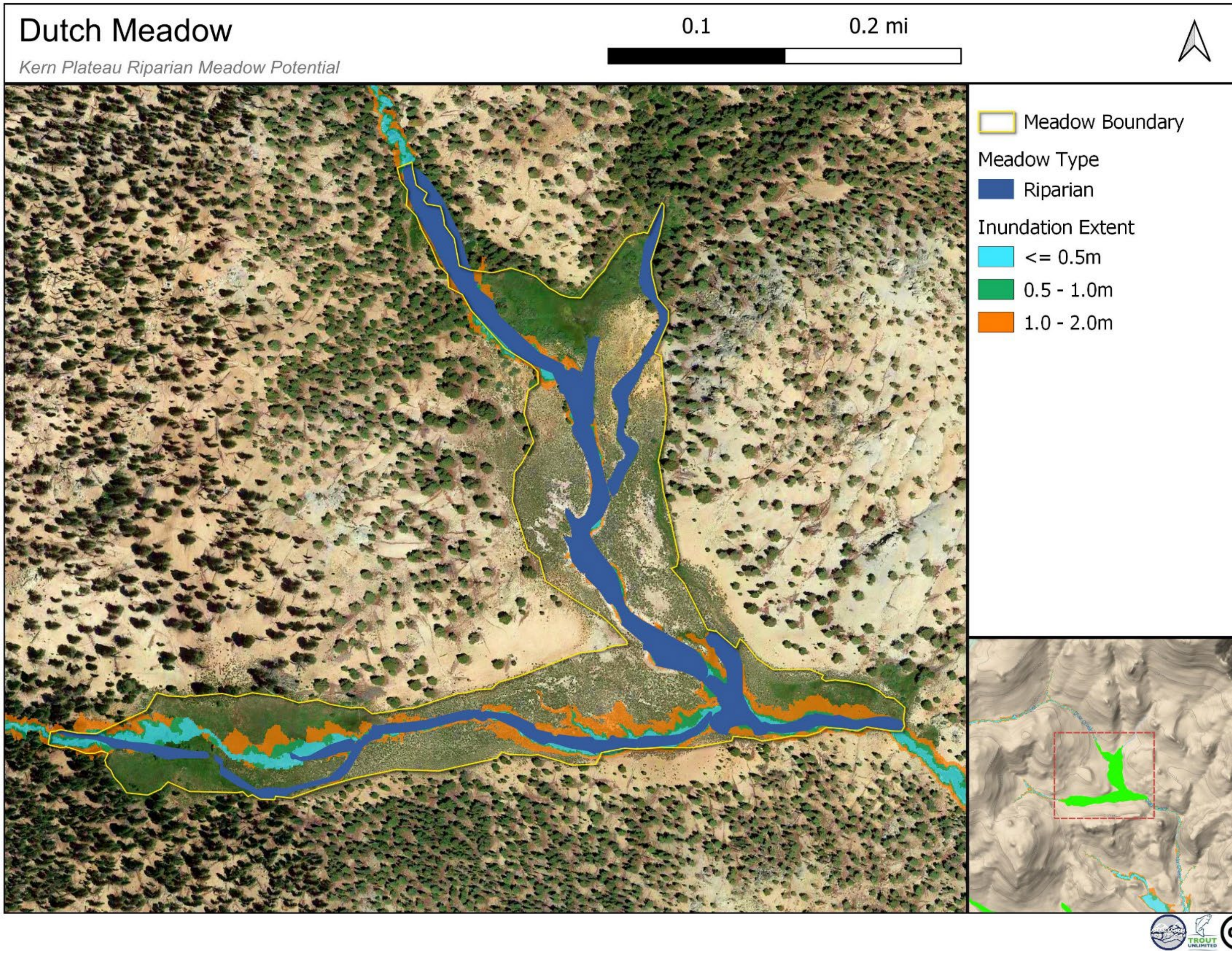

Figure 13. Dark blue represents the current riparian meadow in Dutch Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

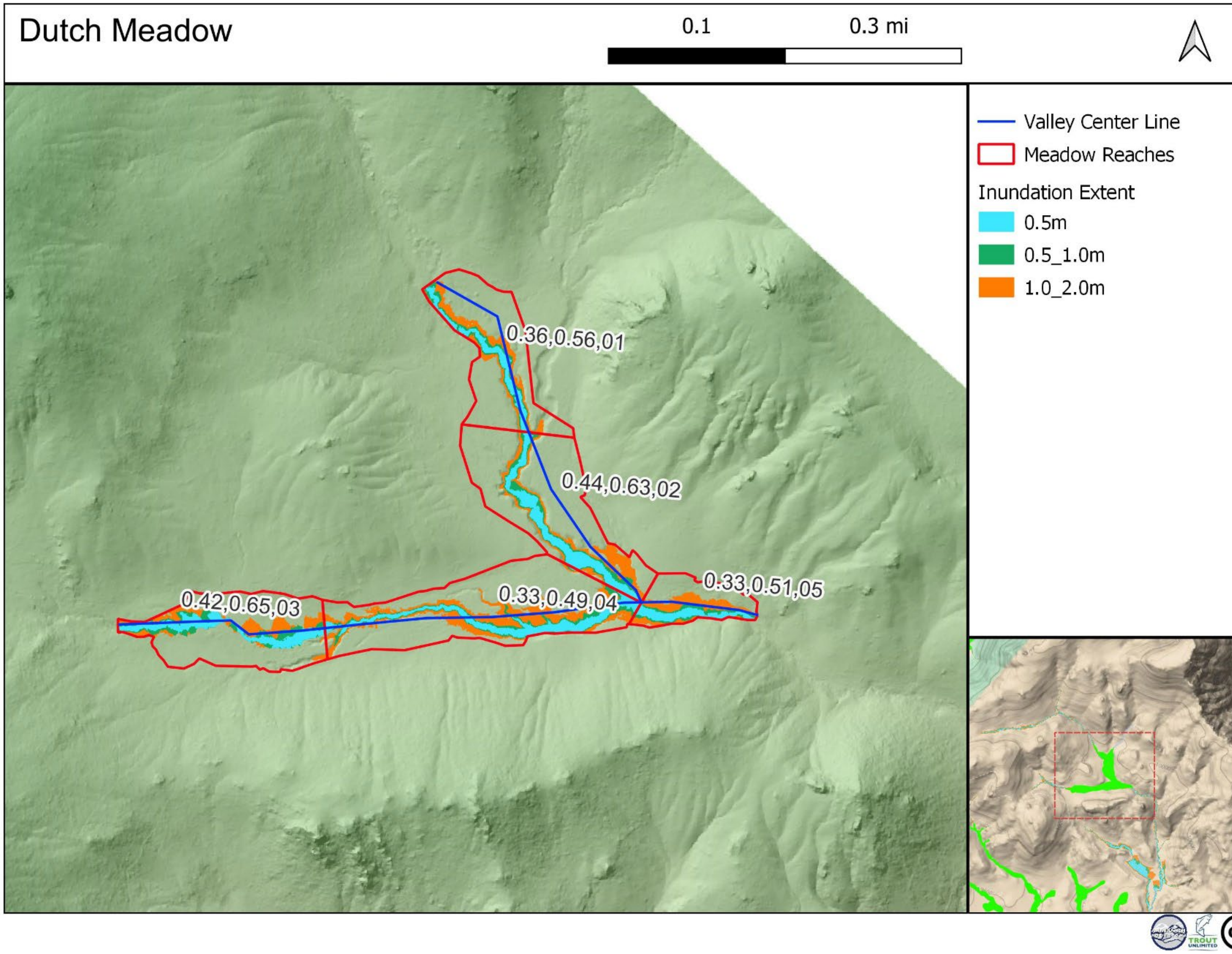

Figure 14. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Dutch Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

MULKEY MEADOW

Mulkey Meadow is the largest single meadow in the project area at 7 km in length and is highly heterogeneous. It contains ~20 tributary drainages and scores of springs. The meadow begins fairly narrow and quickly widens to a valley width of approximately 65 m (Figure 15) with a small amount of channel incision and high potential for floodplain inundation (Figure 23; MK01). Above this, incision ranges from 0.4 to 0.7 m below historic elevations in this zone in a low gradient section. The floodplain that can become inundated during higher flow events and supports a mesic meadow plant community with dense stands of multiple-seral stage willow, sedges, rushes, grasses, and forbs. The inner riparian zone supports lush hydric meadow species, particularly emergent sedge marshes below bankfull elevation (Figure 17). Slight increases in surface elevation result in sagebrush encroachment onto the historic meadow surface. The sloping valley sides at the margins of the meadow support sagebrush upland. Groundwater from the surrounding hillslopes supports meadow function and the area is a mix of riparian and subsurface meadow hydrogeomorphic types. This area continues with the confluence Bullfrog Creek where channel incision is between 0.5-1.0 m , with above 1.0 m able to inundate over 60% of the wide 2 m inundation area which is over 100 m across (Figure 15 & Figure 24). Above this, the channel is greatly incised here, with historic floodplain and fan elevations ranging from 3 m above current bankfull that have converted from meadow types to sagebrush steppe with some grasses intermixed. Peat layers at the historic floodplain elevation throughout indicate that both the valley bottom and the fans were covered in sod-forming hydric and mesic meadow vegetation with moist and saturated soils. Historic meander channels on the old floodplain terrace also show that much of the valley bottom and tributary fans supported complex, multi-thread networks of channels with a high water table and hydric vegetation. This conversion has occurred across most of the meadow and the inset floodplain is the only remaining meadow habitat. However, this inset floodplain is relatively wide and has potential to become all riparian meadow (Figure 23 & Figure 24).

The upper portion of Mulkey Meadow has a narrow, inset floodplain and reach 8 being deeply incised 3 m below historic floodplain elevation (Figure 15 & Figure 26 i.e., the 0.5 m inundation is the same as the 2 m). The historic floodplain has, in most areas, converted to sagebrush steppe except for subsurface meadow areas that are supported by groundwater flows or discharge slope springs that contribute surface water from upland areas to the valley bottom. Above this zone, the channel is much smaller in a confined valley and the gradient increases significantly, (Figure 27).

Table 5. Acres and percent of total for each meadow type found in Mulkey/Bullfrog Meadows.

Meadow	Acres	% Total
Mulkey_Bullfrog	**441.8**	**100%**
Depressional - Seasonal	0.6	0%
Discharge Slope	5.7	1%
Discharge Slope - Peatland	19.6	4%
Dry	11.2	3%
Peatland - Basin	0.5	0%
Peatland - Mound	2.4	1%
Riparian	118.7	27%
Subsurface	71.2	16%
Upland	211.8	48%

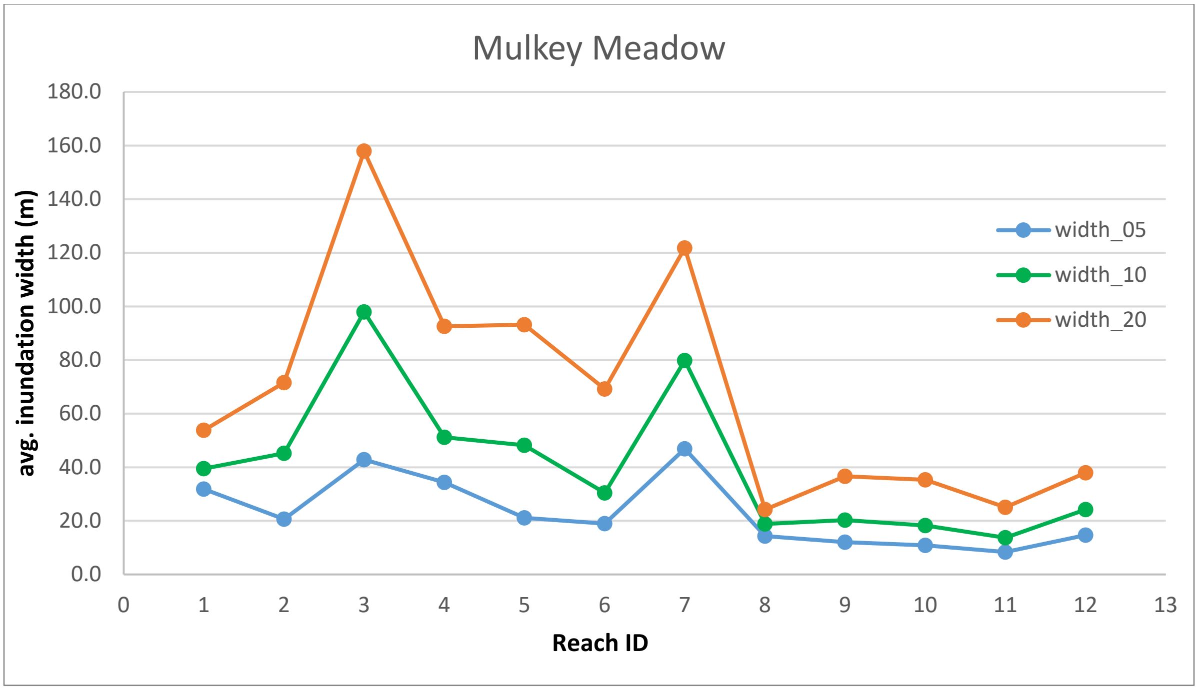

Figure 15. Mulkey Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

BULLFROG MEADOW

Bullfrog meadow is essentially the western wing of Mulkey Meadow and goes up through a series of sinuous, deep pools and steepens through a rocky section of confined channel and floodplain just above the confluence (Figure 16). Above this is a large, gently sloping meadow with numerous mound peatlands interspersed with sagebrush patches and subsurface meadow habitat (Figure 17). The stream here becomes deeply incised with a verdant inset floodplain surrounded by encroaching sagebrush at the margins. Numerous channels headcut toward the intact meadow and have been treated in the past with rock, cloth, and wood structures that have largely been successful at arresting headcuts, though one large headcut in the primary channel remains active. Above the large headcut, the stream channel is much less incised and is almost at its historic elevation with a few older structures in place where headcutting occurred in the past that have successfully maintained the channel elevation.

The upper section of Bullfrog meadow has a large drainage entering from the north that has continuously splayed gravel and sand across the meadow creating a raised hump that has some sagebrush encroachment but also supports a high groundwater table with sedges. This hump has the potential to act as a massive structure slow and spread flows (NF04) (Figure 16 & Figure 20 & Figure 28). West of this drainage, there is a section of dense mound peatlands and discharge slopes that is incredibly wet with complex channels and sheetflow connections throughout supporting dense hydric sedges that come together to the main channel on the south edge of the meadow. A dry riparian channel continues to the west and an area of subsurface meadow and riparian middle gradient meadow comes down from the south arm. This meadow is quite large and contains proportionately much more intact meadow habitat than neighboring Mulkey. It is very diverse in both meadow and in-channel habitat types and soil moisture, ranging from fully saturated to dry sagebrush steppe.

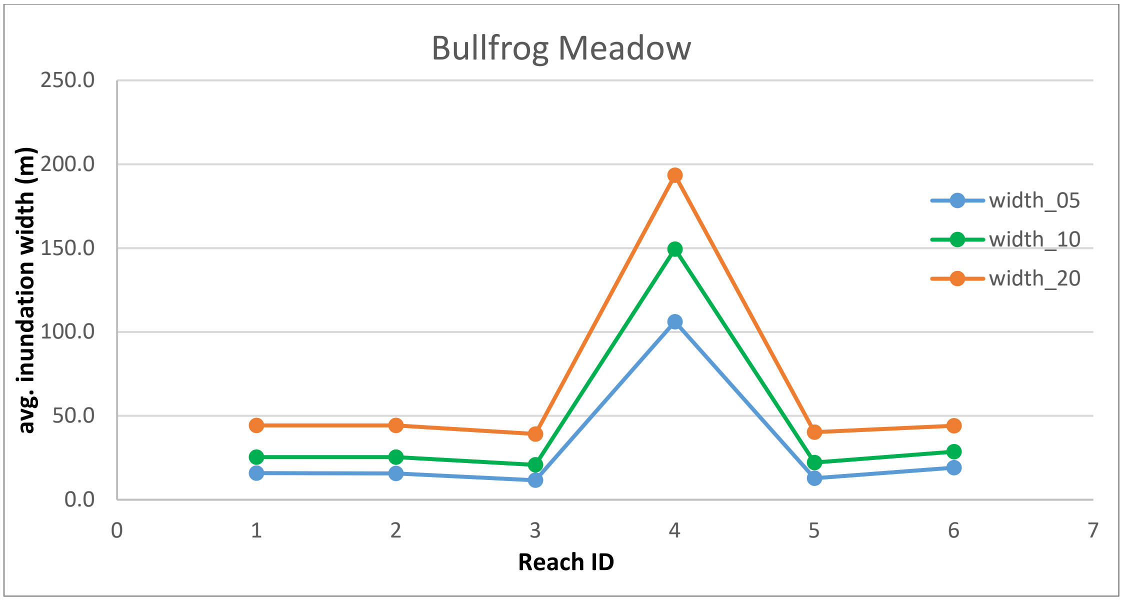

Figure 16. Bullfrog Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

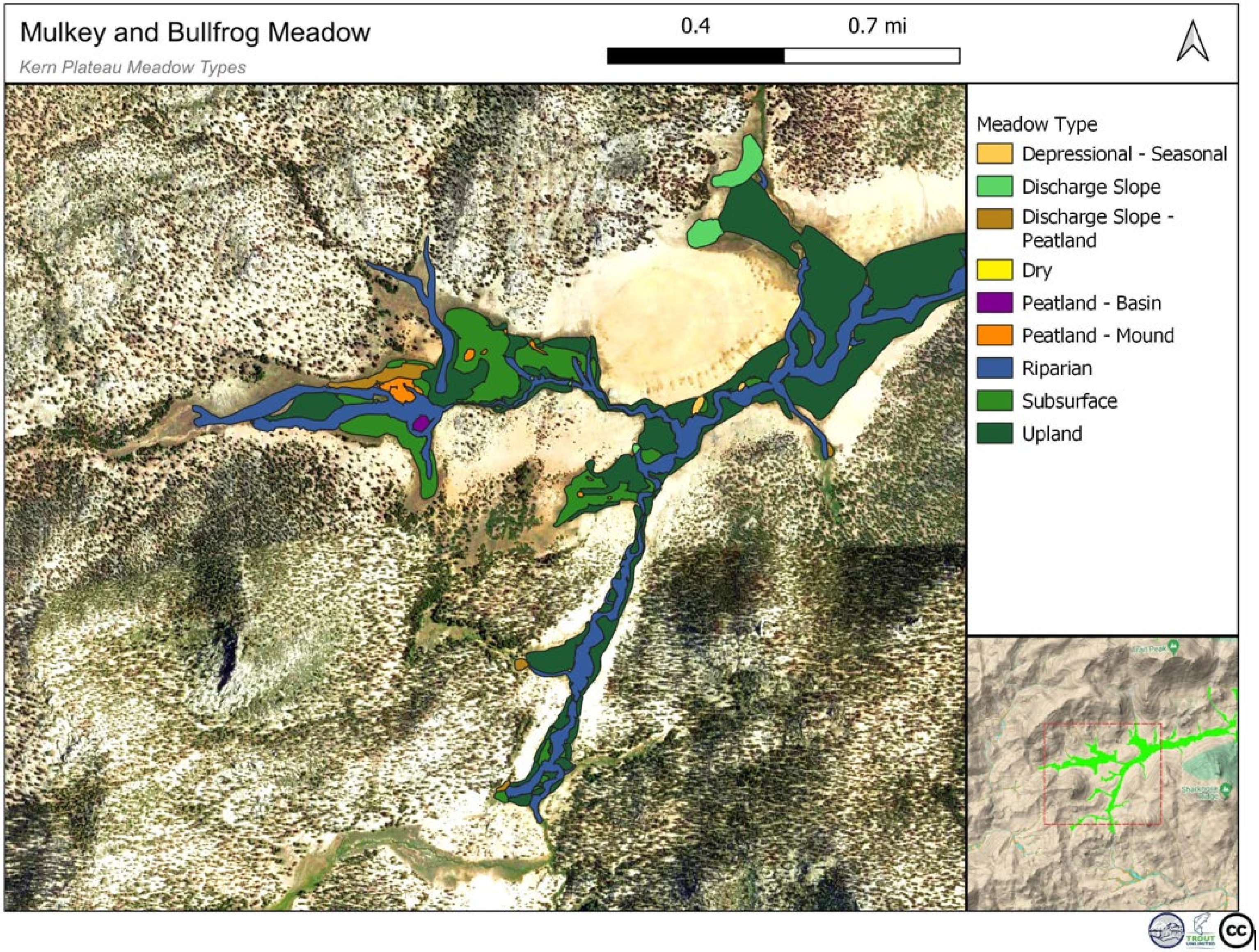

Figure 17. Distribution of meadow types in lower Mulkey and Bullfrog Meadows.

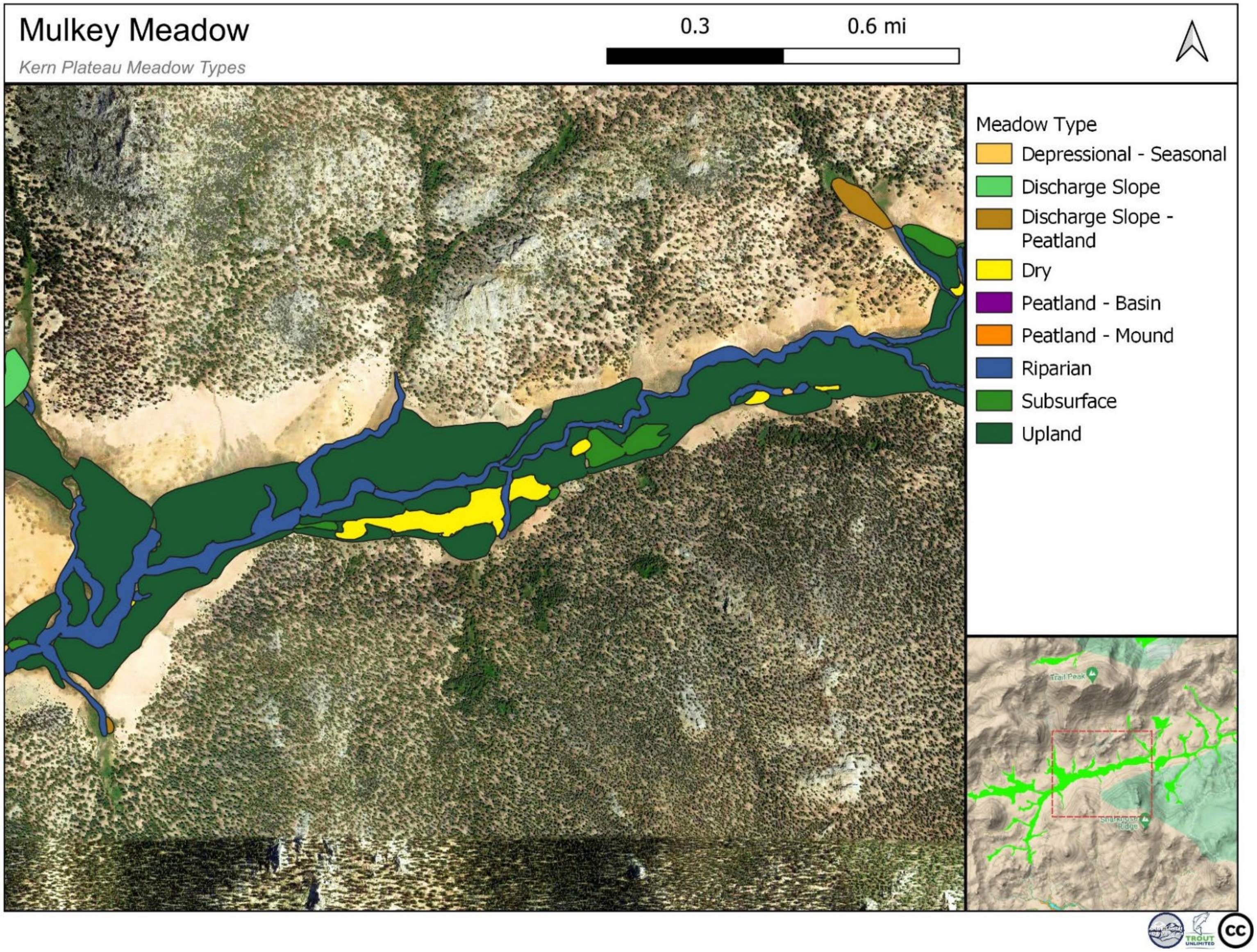

Figure 18. Distribution of meadow types in middle Mulkey.

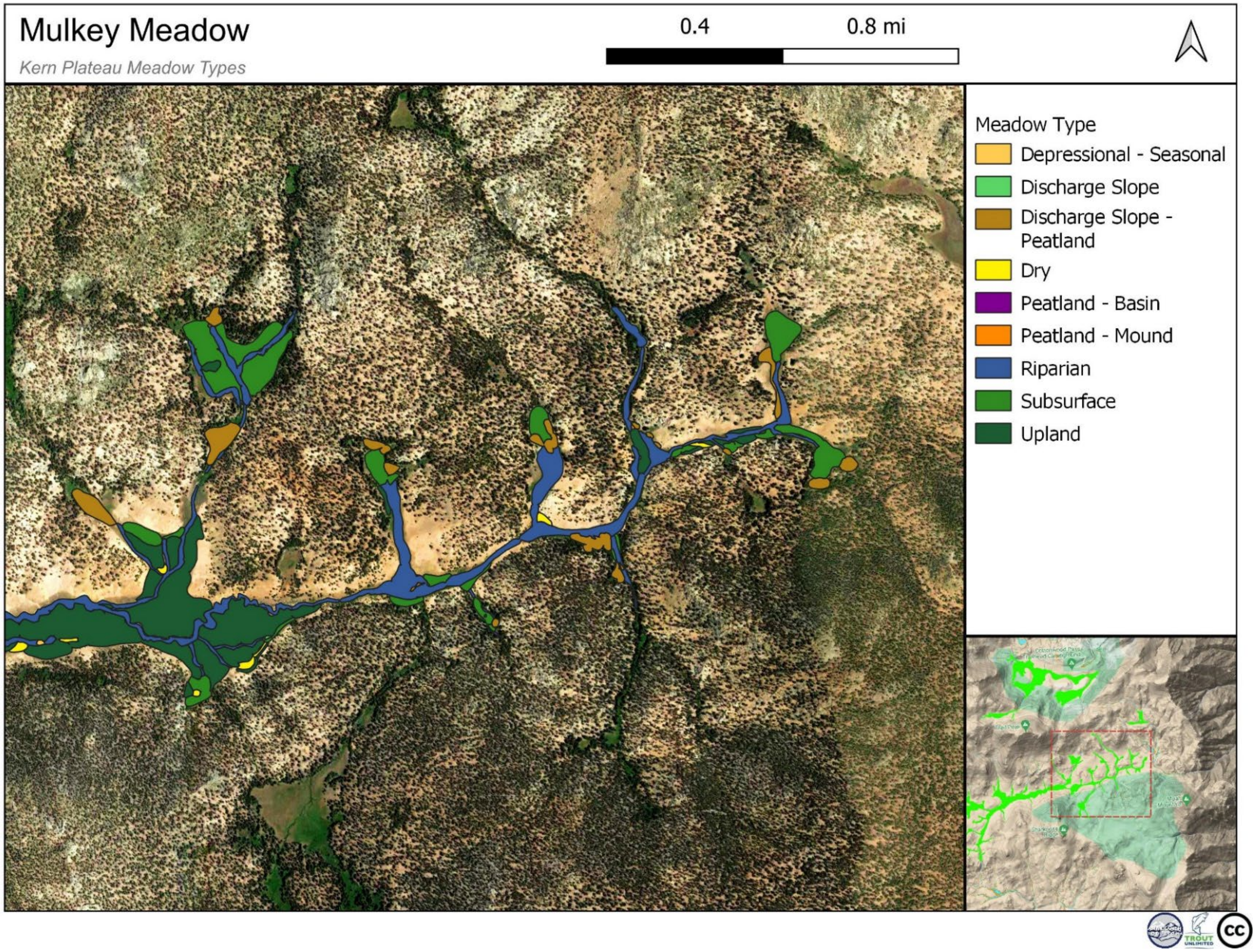

Figure 19. Distribution of meadow types in upper Mulkey Meadow.

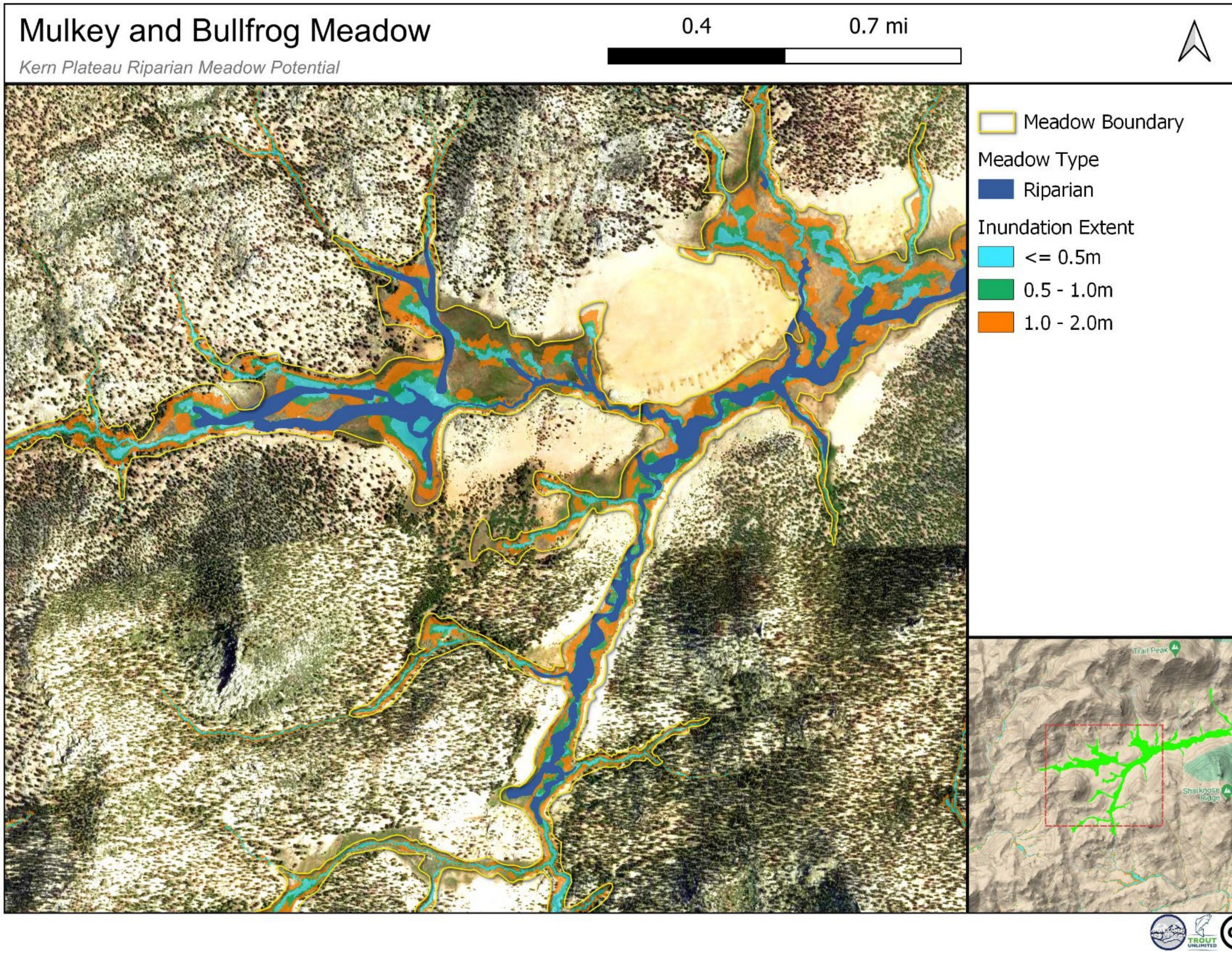

Figure 20. Dark blue represents the current riparian meadow in lower Mulkey and Bullfrog Meadows. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

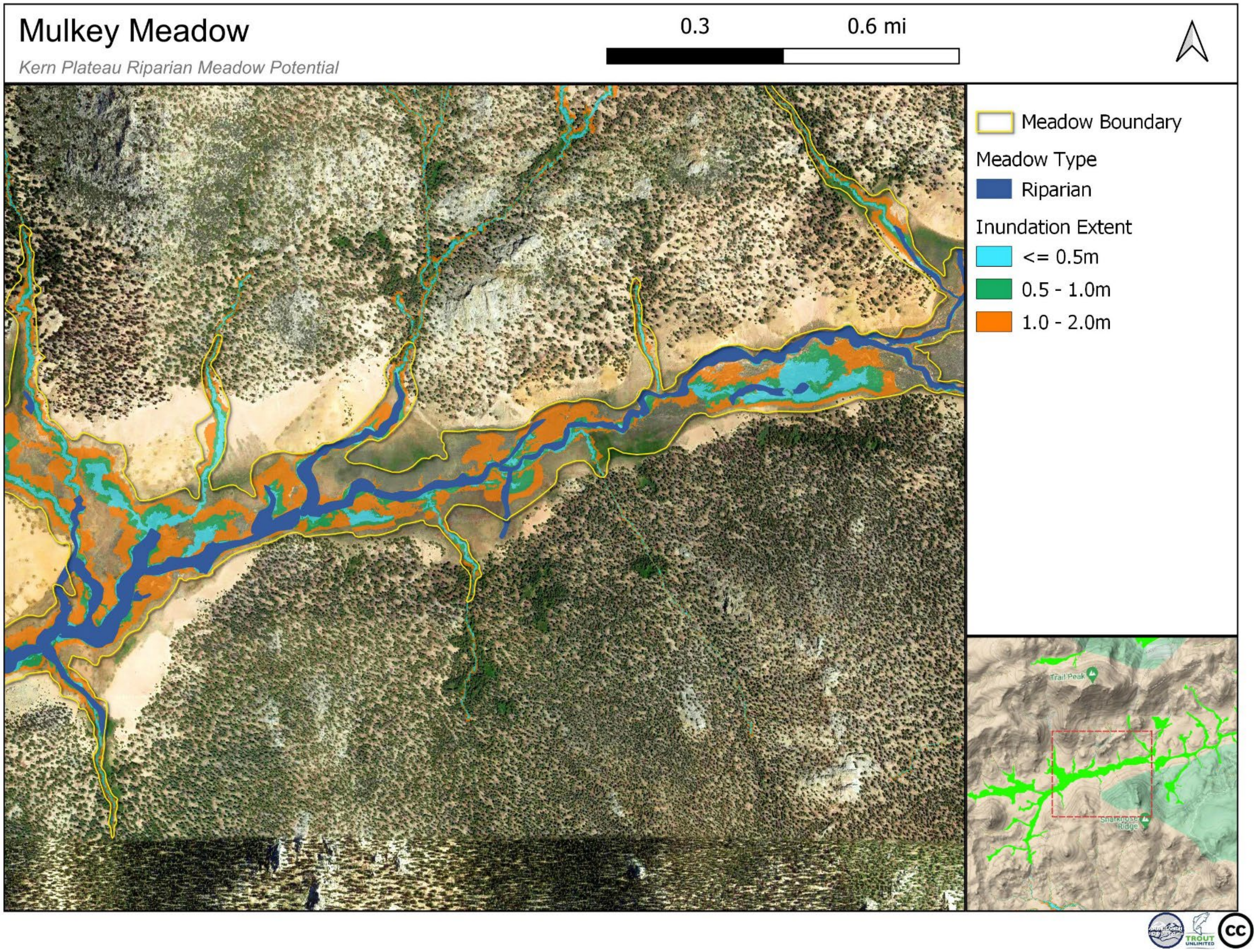

Figure 21. Dark blue represents the current riparian meadow in middle Mulkey Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

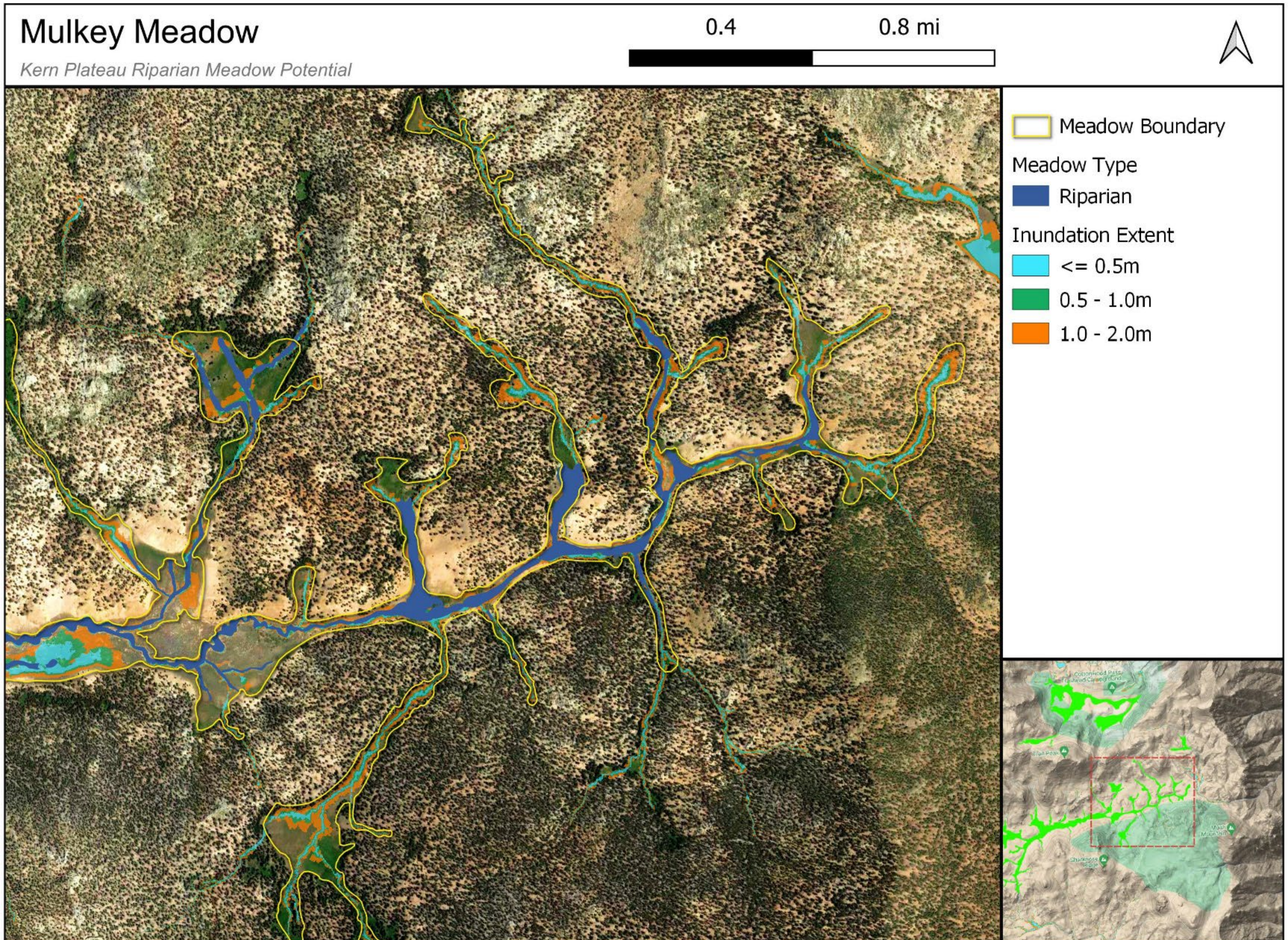

Figure 22. Dark blue represents the current riparian meadow in upper Mulkey Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

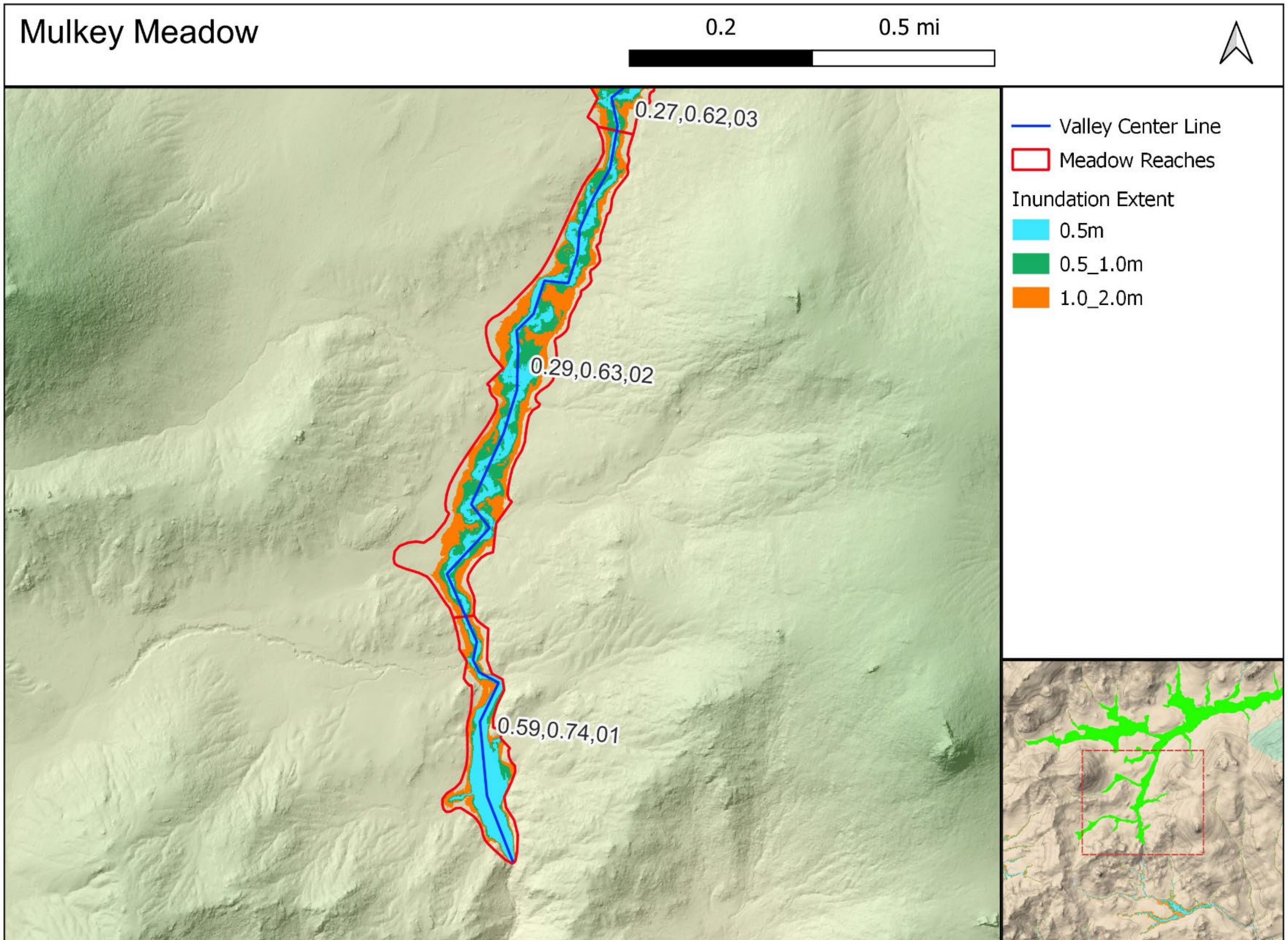

Figure 23. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 1&2 of Mulkey Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

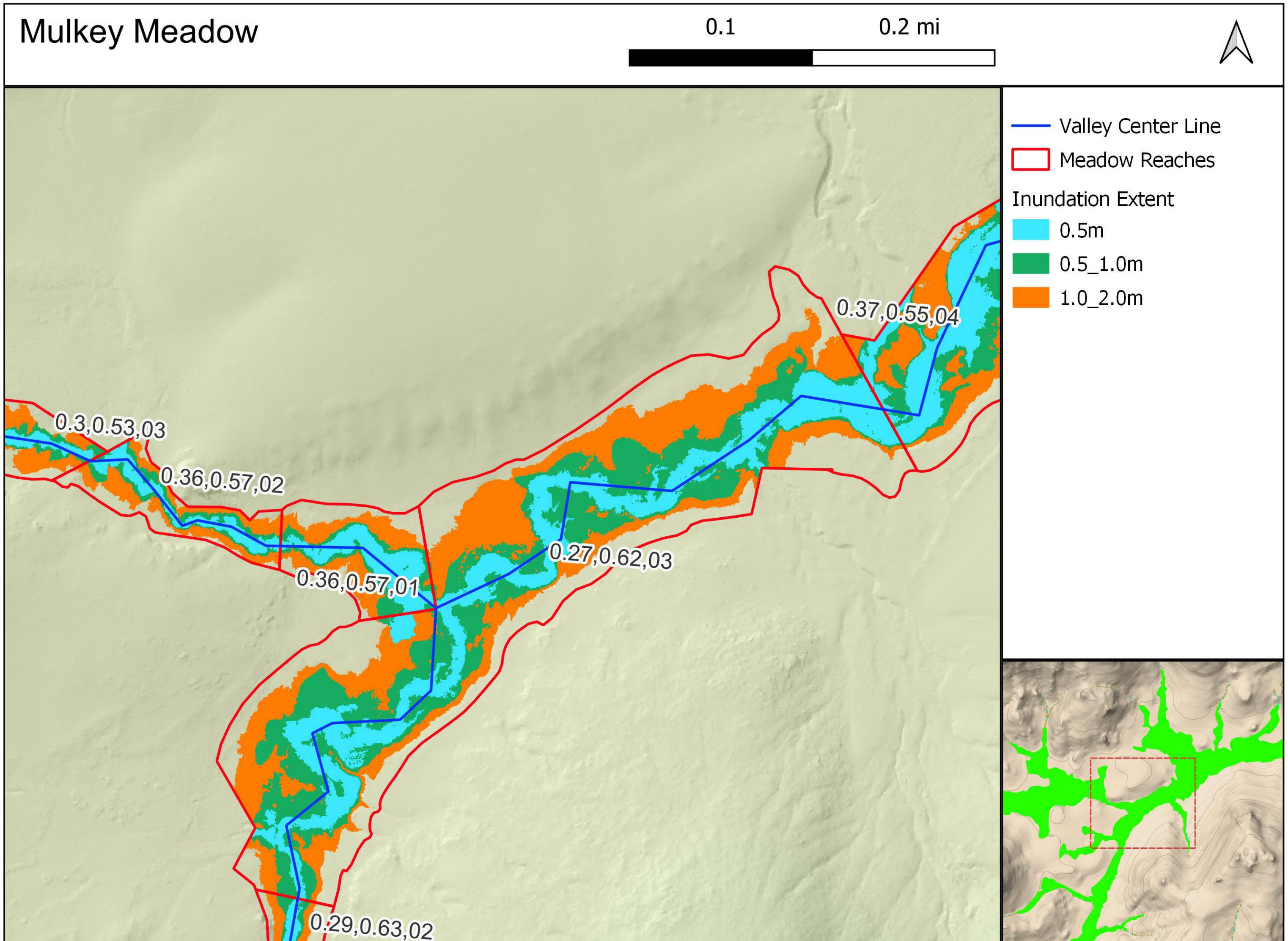

Figure 24. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reach 3 of Mulkey Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

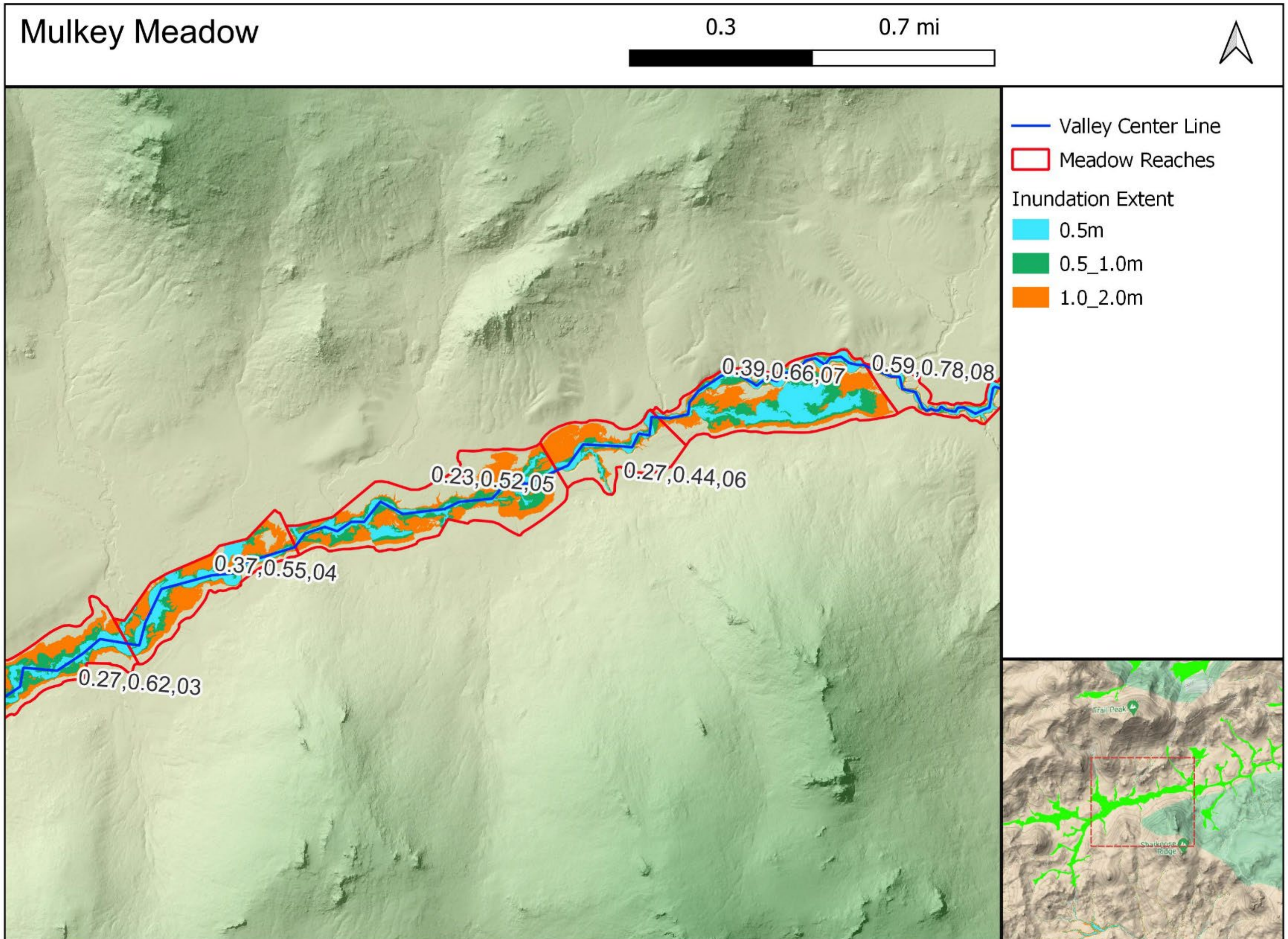

Figure 25. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 4-7 of Mulkey Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

Figure 26. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 8 & 9 of Mulkey Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

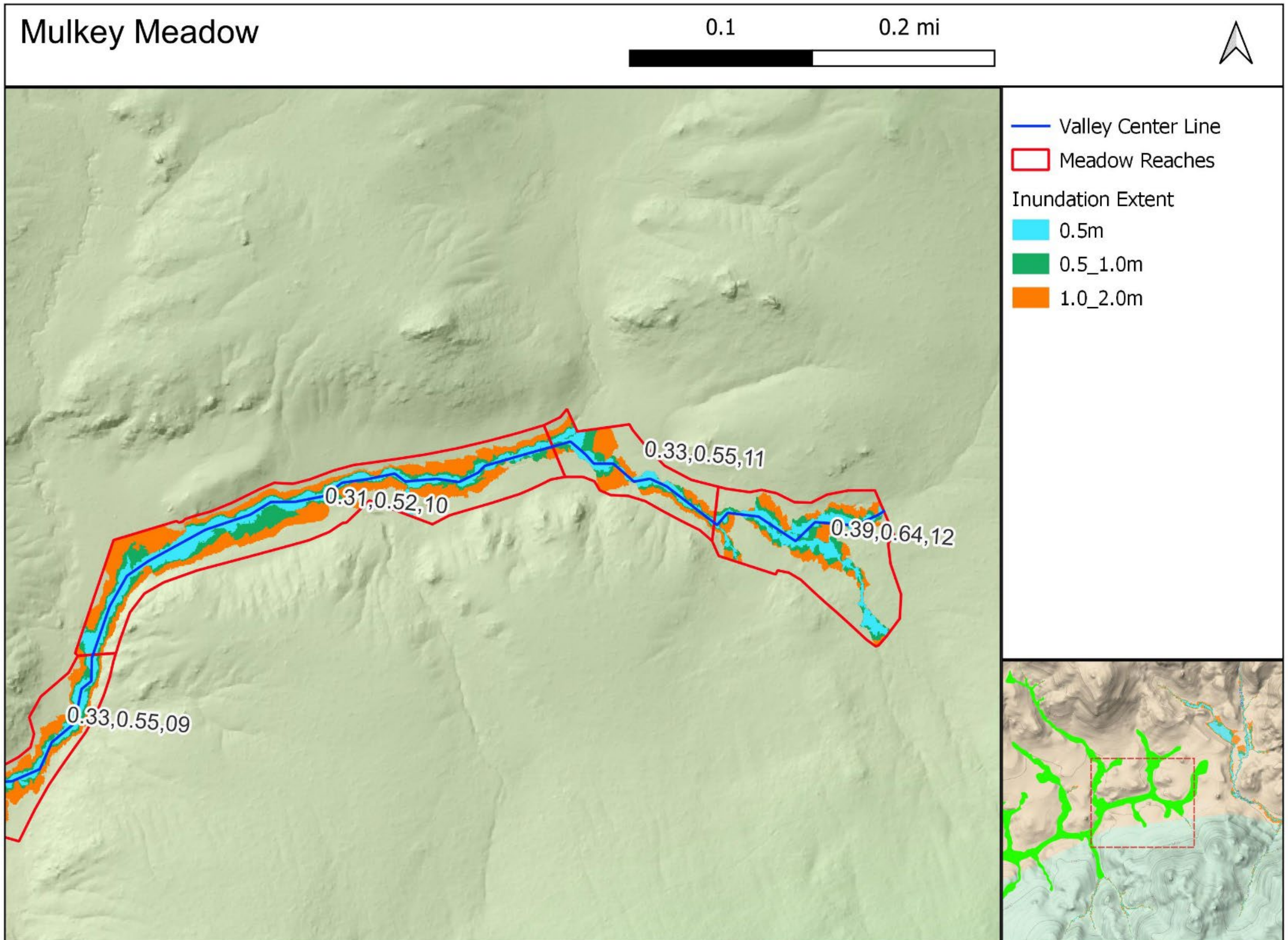

Figure 27. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 10-12 of Mulkey Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

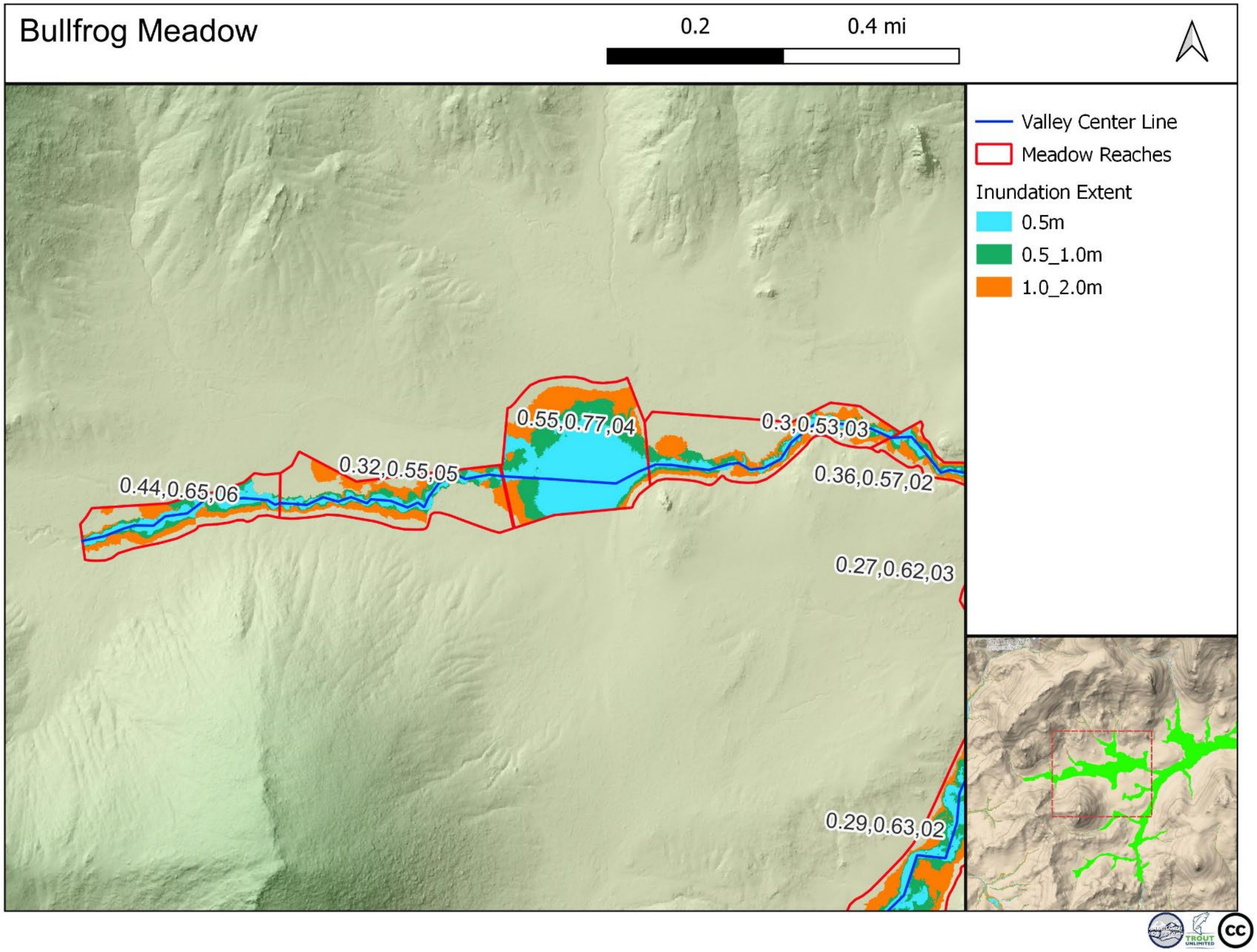

Figure 28. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic of Bullfrog Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

STRAWBERRY MEADOW

Strawberry Meadow is located at the confluence of the South Fork Kern River and Strawberry Creek. The gradient is consistently low and there are a few small tributaries from discharge slope springs, the largest of which enters Strawberry Creek from the north and whose confluence creates the widest zone (BF03) of the meadow (Figure 29). The lower reaches of the meadow are consistently slightly to moderately incised throughout and a minimal lifting of water table elevation would allow regular connectivity to most of the historic floodplain making the riparian meadow type the most common (Table 6 & Figure 32). There is good willow recruitment throughout the meadow with sagebrush at the sloping meadow margins and encroaching onto the historic floodplain in areas with deeper channel incision. Overall, the incision ranges from ~0.3 to 0.6 m below the historical floodplain elevation. This allows the meadow to persist with mesic and dry meadow species on the historic floodplain surface. Hydric (obligate and facultative wetland species) vegetation is primarily limited to inset floodplain areas and low-lying floodplain surfaces with good surface or groundwater connectivity. Aggradation of 1 m in the lower part of the meadow has the potential to greatly increase the riparian meadow extent as historic channels would get filled frequently (Figure 33). The upper part of the meadow is more confined with less inundation potential (Figure 35).

Table 6. Acres and percent of total for each meadow type found in Strawberry Meadow.

Meadow	Acres	% Total
Strawberry	**33.7**	**100%**
Discharge Slope	0.7	2%
Discharge Slope - Peatland	0.1	0%
Dry	2.0	6%
Riparian	23.0	68%
Subsurface	1.1	3%
Upland	6.9	20%

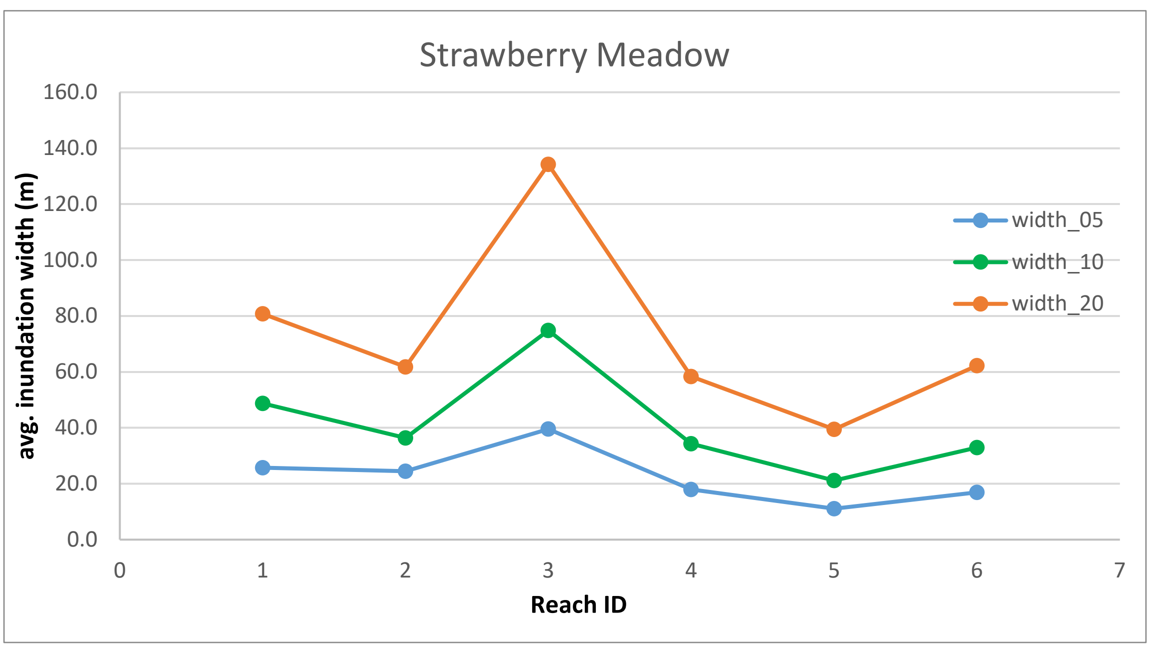

Figure 29. Strawberry Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

FAT COW STRINGER MEADOW

Fat Cow Stringer is a small, moderate gradient tributary drainage to Strawberry Meadow. A sinuous channel of small scour pools with rocky riffles between goes through the middle of the meadow. The stream is ephemeral; likely flowing only early in the season and during heavy precipitation events in the summer months. The dry conditions and earlier livestock use contribute to fractured sod with some eroding cutbank edges. However, these are typical of dry channels in higher gradient systems. Despite a majority of the meadow classified as riparian or subsurface (Table 7 & Figure 32), it may not be feasible to increase the production of hydric and mesic meadow species cover here under current and future climatic conditions. The upper portion of Fat Cow Stringer has increased groundwater support and a few discharge slope springs that support meadow vegetation. Overall, its condition is typical of its hydrology and gradient, and it is doubtful that treatment will result in a significant increase in meadow cover, but it will help protect existing meadow habitat and buffer against increasingly dry and hot climatic conditions.

Table 7. Acres and percent of total for each meadow type found in Fat Cow Stringer.

Meadow	Acres	% Total
Fat_Cow	**12.7**	**100%**
Discharge Slope	0.2	2%
Discharge Slope - Peatland	1.1	8%
Peatland - Mound	0.7	5%
Riparian	6.4	50%
Subsurface	3.7	29%
Upland	0.7	6%

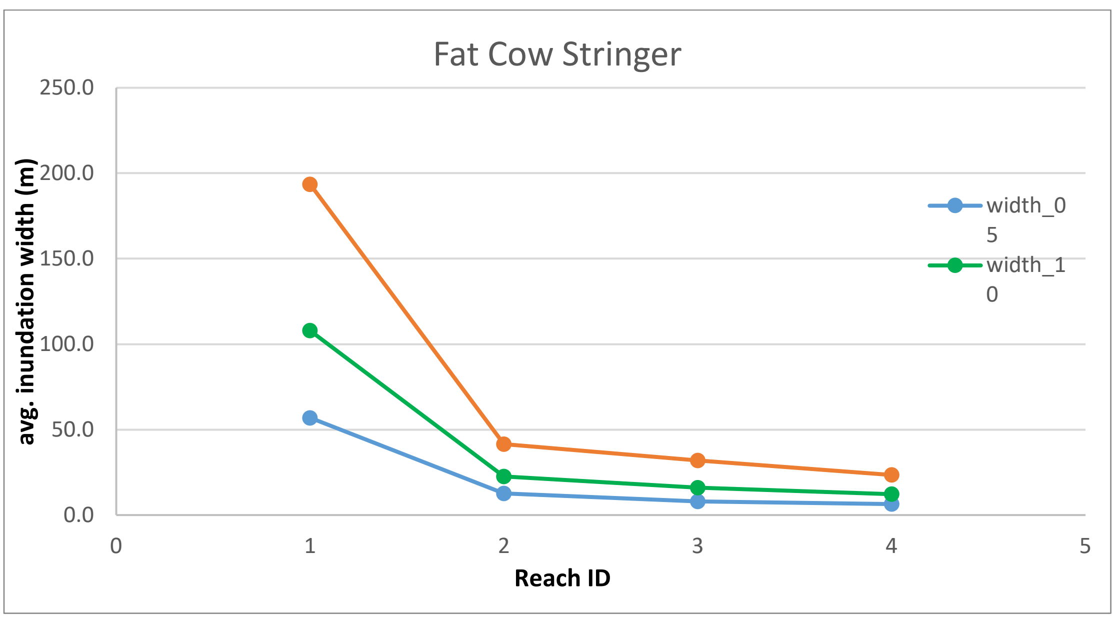

Figure 30. Fat Cow Stringer integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

SCHAEFFER MEADOW

Schaeffer Meadow is a long, narrow, high-gradient meadow that is one drainage to the south of Strawberry Creek, and is a tributary to the South Fork Kern River. The ephemeral stream is dry in most years. Its high gradient and often dry conditions make it very vulnerable to headcutting, and it contains numerous active and arrested (through checkdams and wood installations) headcuts throughout. The channels in the meadow tend to be moderately to significantly incised but there are some areas (generally lower gradient), where the channel elevation is much closer to the historical floodplain surface and the vegetation responds accordingly to support more mesic and hydric meadow species (Figure 39). However, major legacy channel incision (likely between 1860 and 1930) has resulted in an incised channel with a small inset floodplain supporting meadow plant species with sagebrush encroachment on the adjacent terrace that was the historic meadow surface. The potential to aggrade the channel to this historic surface may be limited or take a very long time, but treatment of headcuts and introduction of structures in the inset floodplain may help accelerate the aggradation process. Like Fat Cow, despite the majority of the meadow being riparian or subsurface (Table 8), the lack of consistent stream flow and very dry sod make these meadows rather unproductive.

Table 8. Acres and percent of total for each meadow type found in Shcaeffer Meadow.

Meadow	Acres	% Total
Schaeffer	**19.5**	**100%**
Discharge Slope	0.3	1%
Riparian	7.4	38%
Subsurface	7.4	38%
Upland	4.4	23%

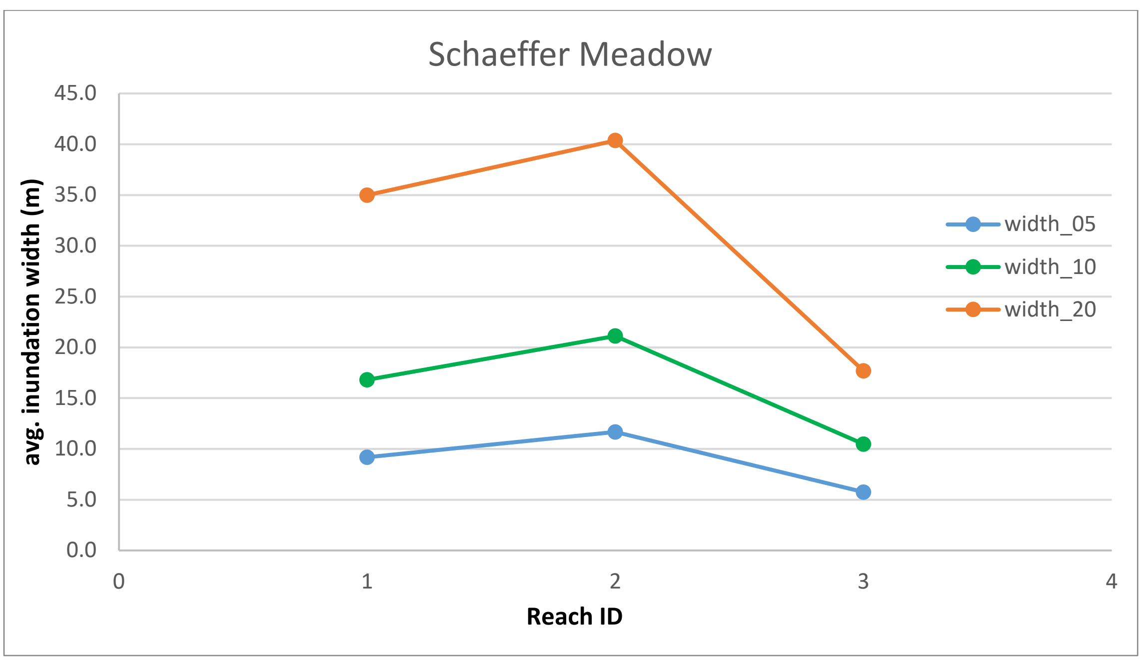

Figure 31. Schaeffer Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

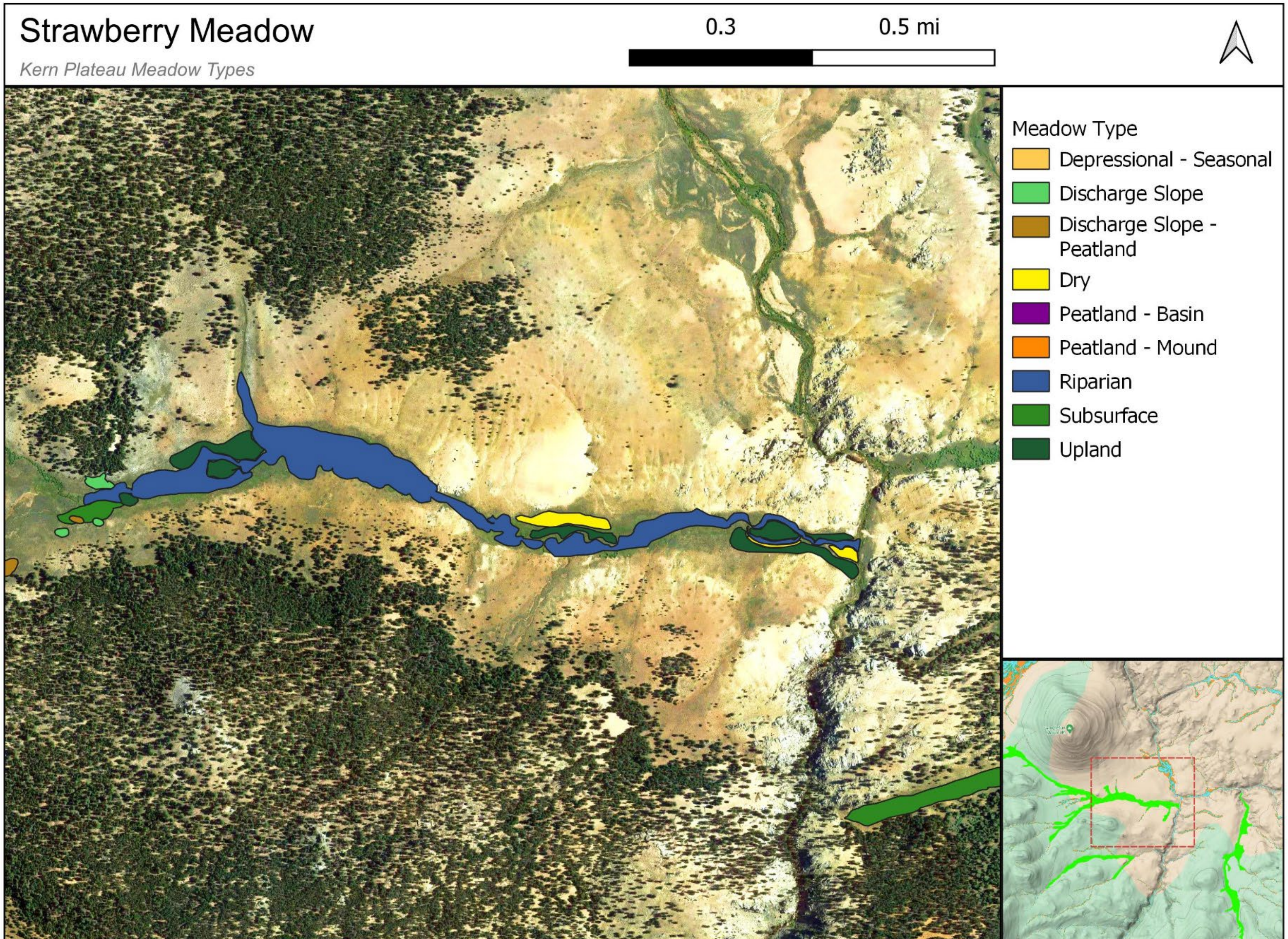

Figure 32.Distribution of meadow types in Strawberry Meadow.

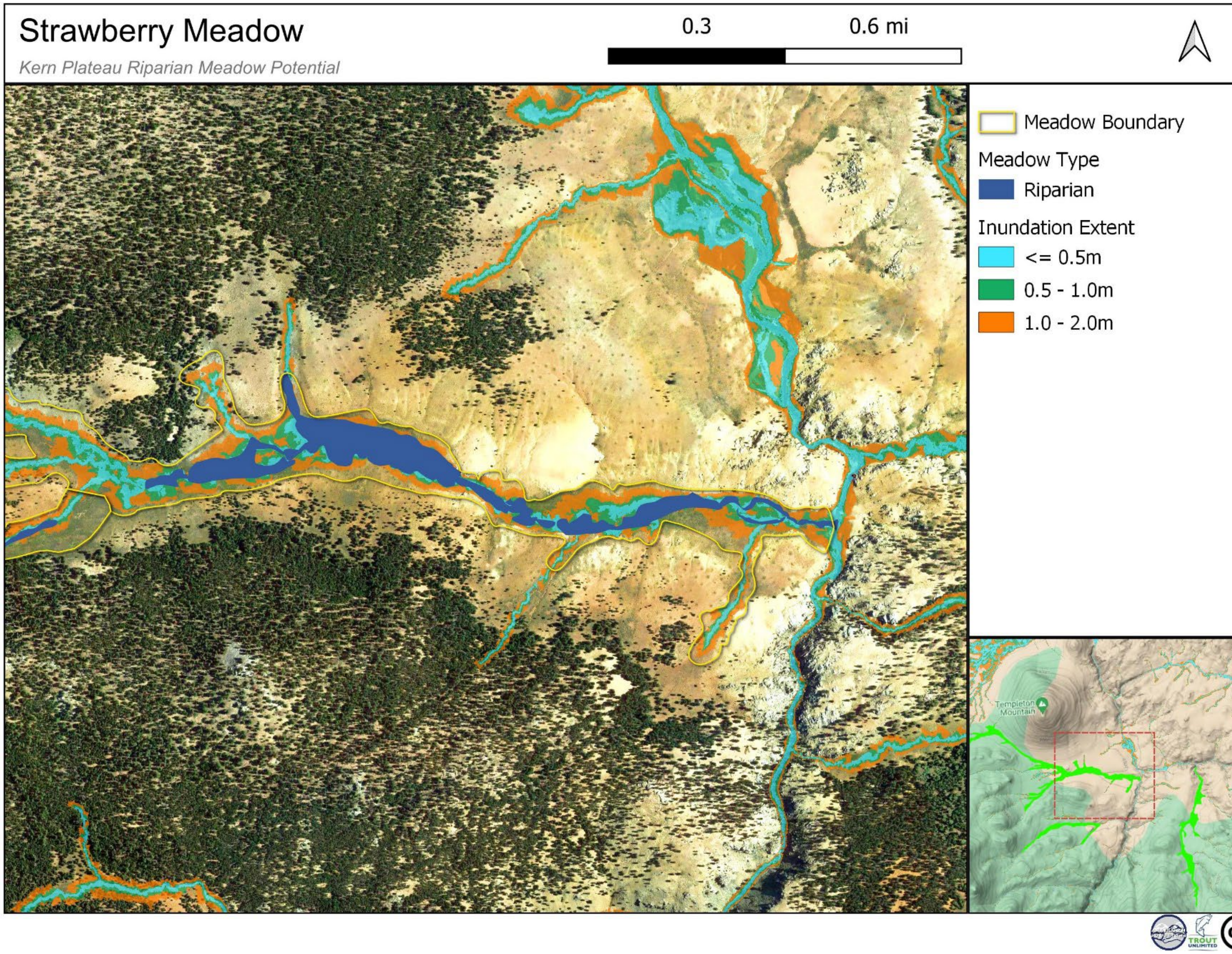

Figure 33. Dark blue represents the current riparian meadow in lower Strawberry Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

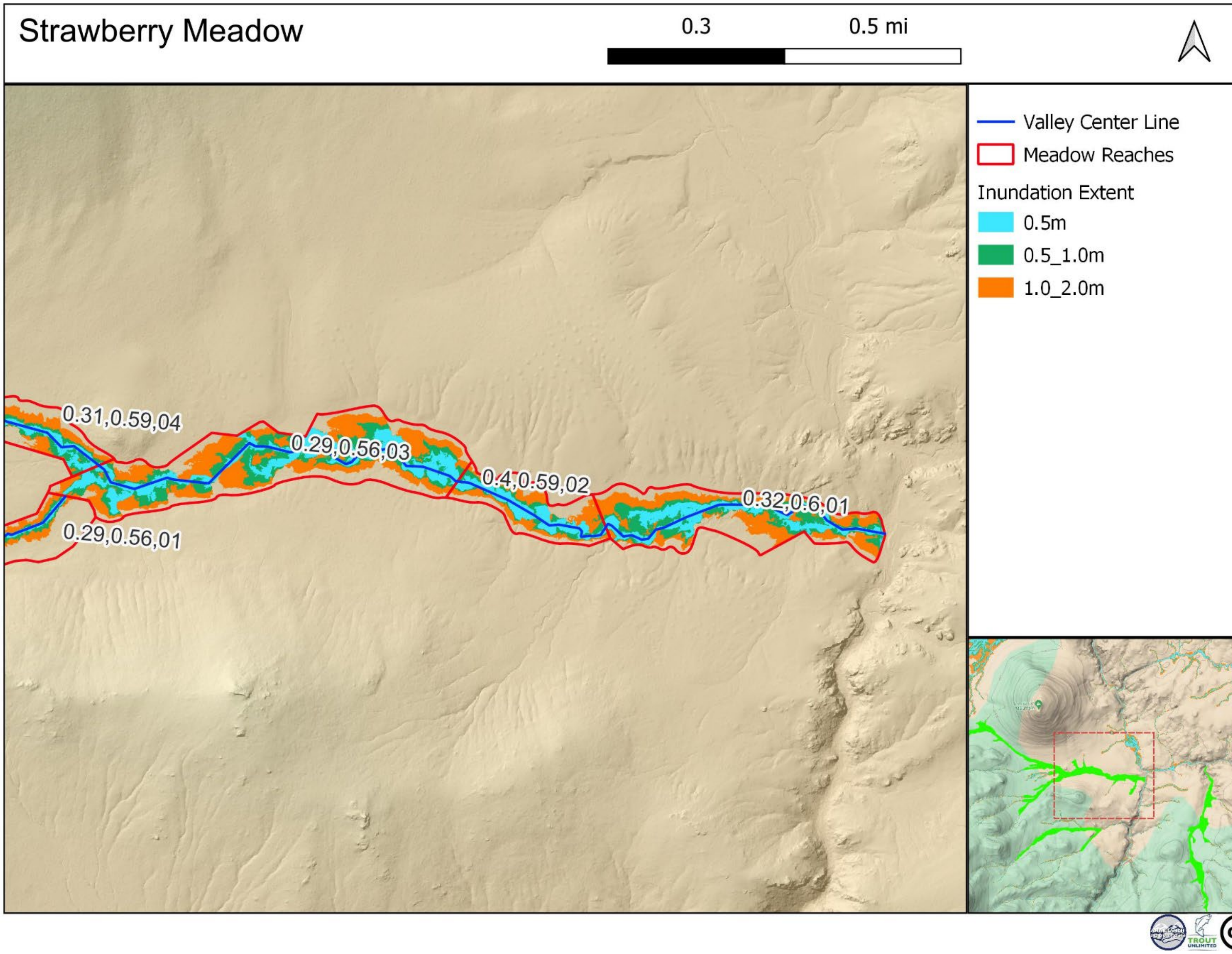

Figure 34. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 1-3 of Strawberry Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

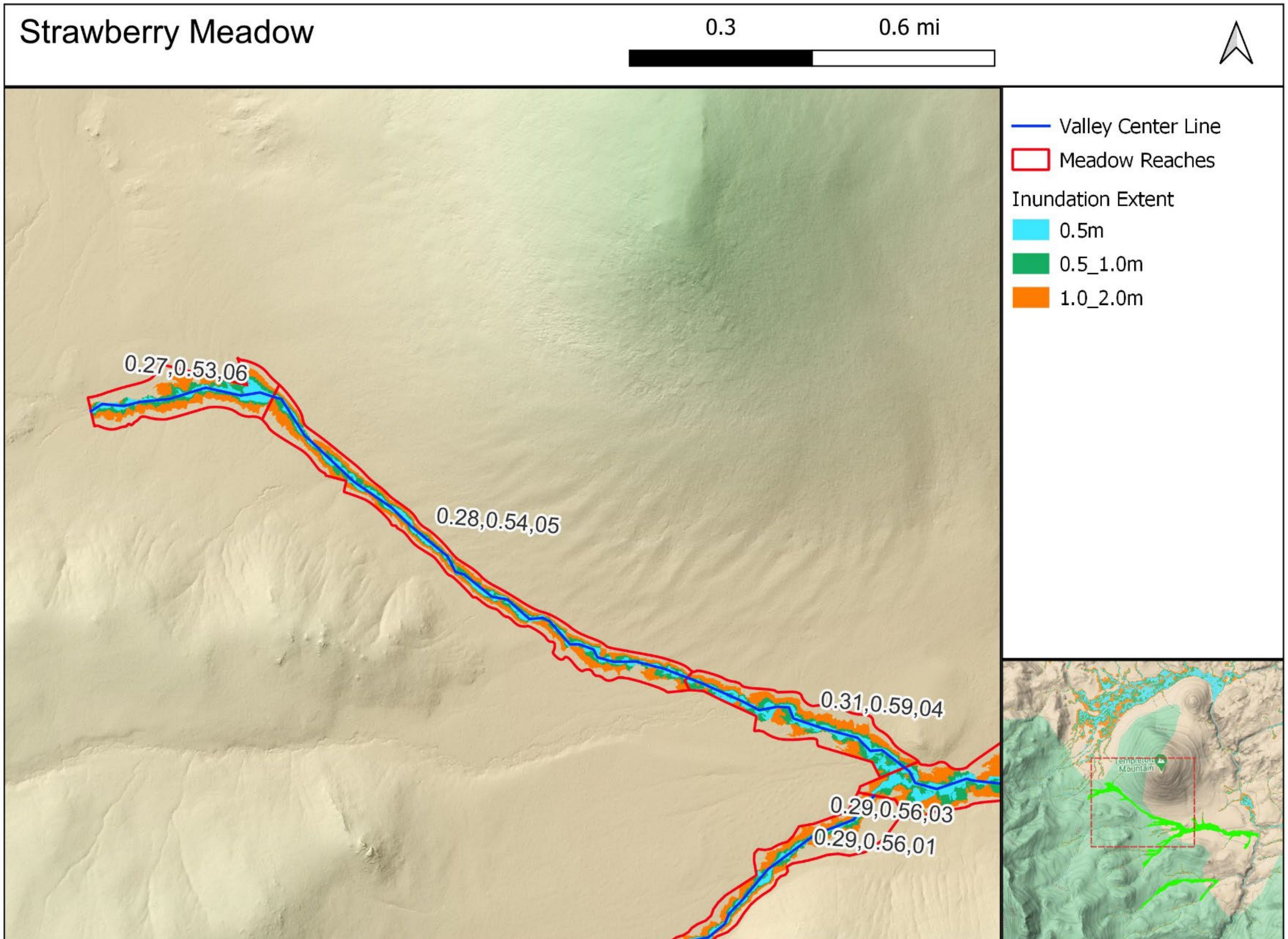

Figure 35. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 4-6 of Strawberry Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

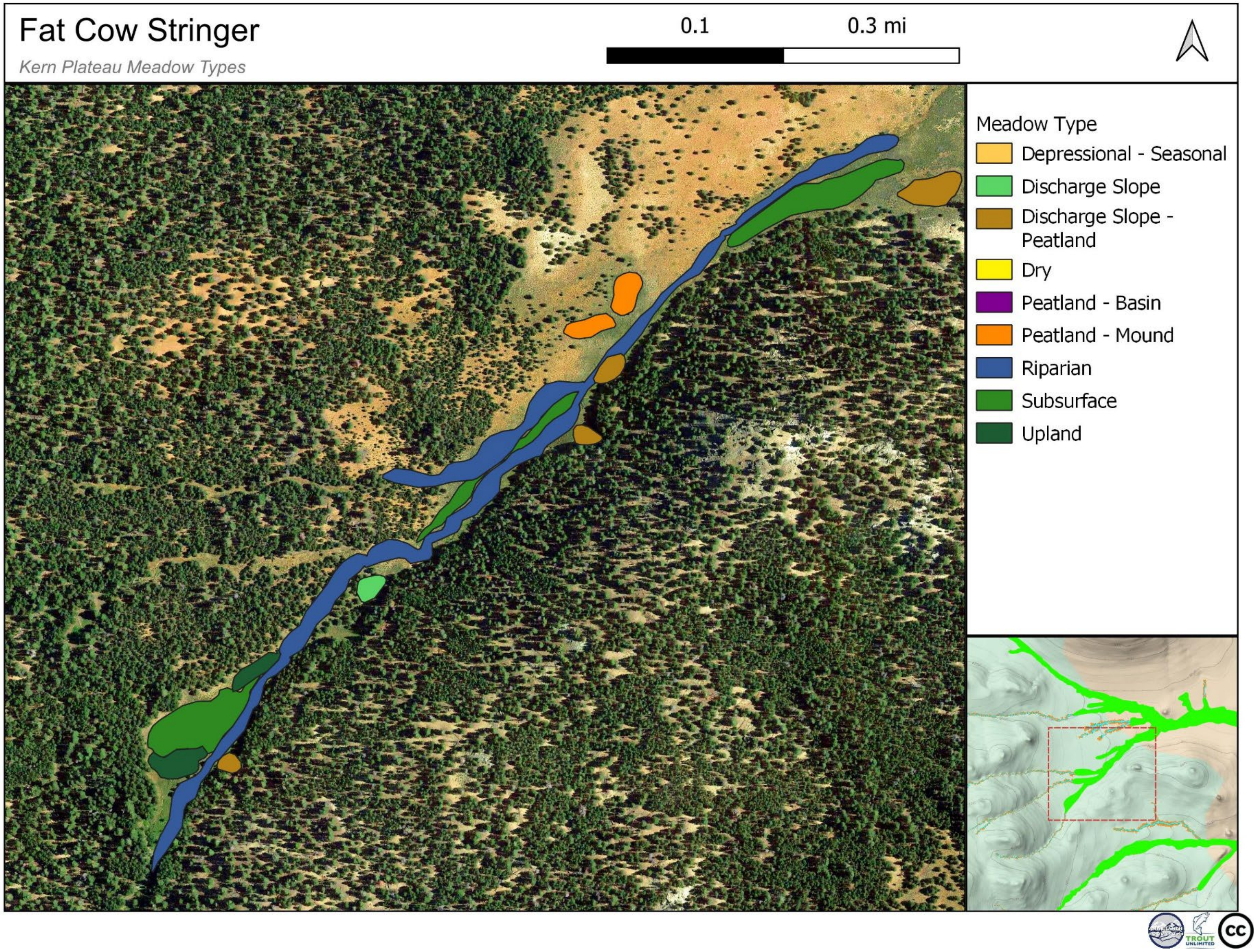

Figure 36. Distribution of meadow types in Fat Cow Stringer.

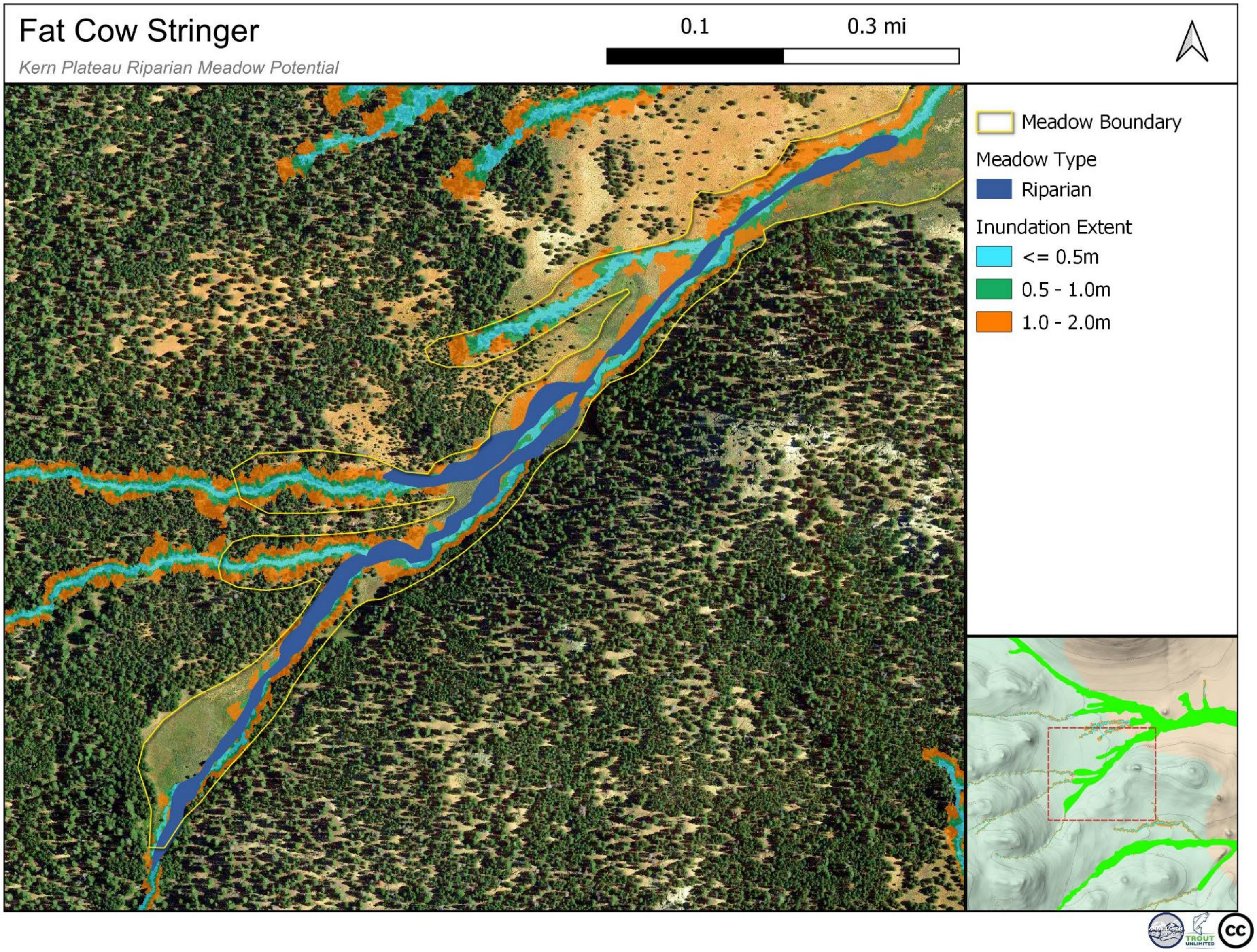

Figure 37. Dark blue represents the current riparian meadow in Fat Cow Stringer. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

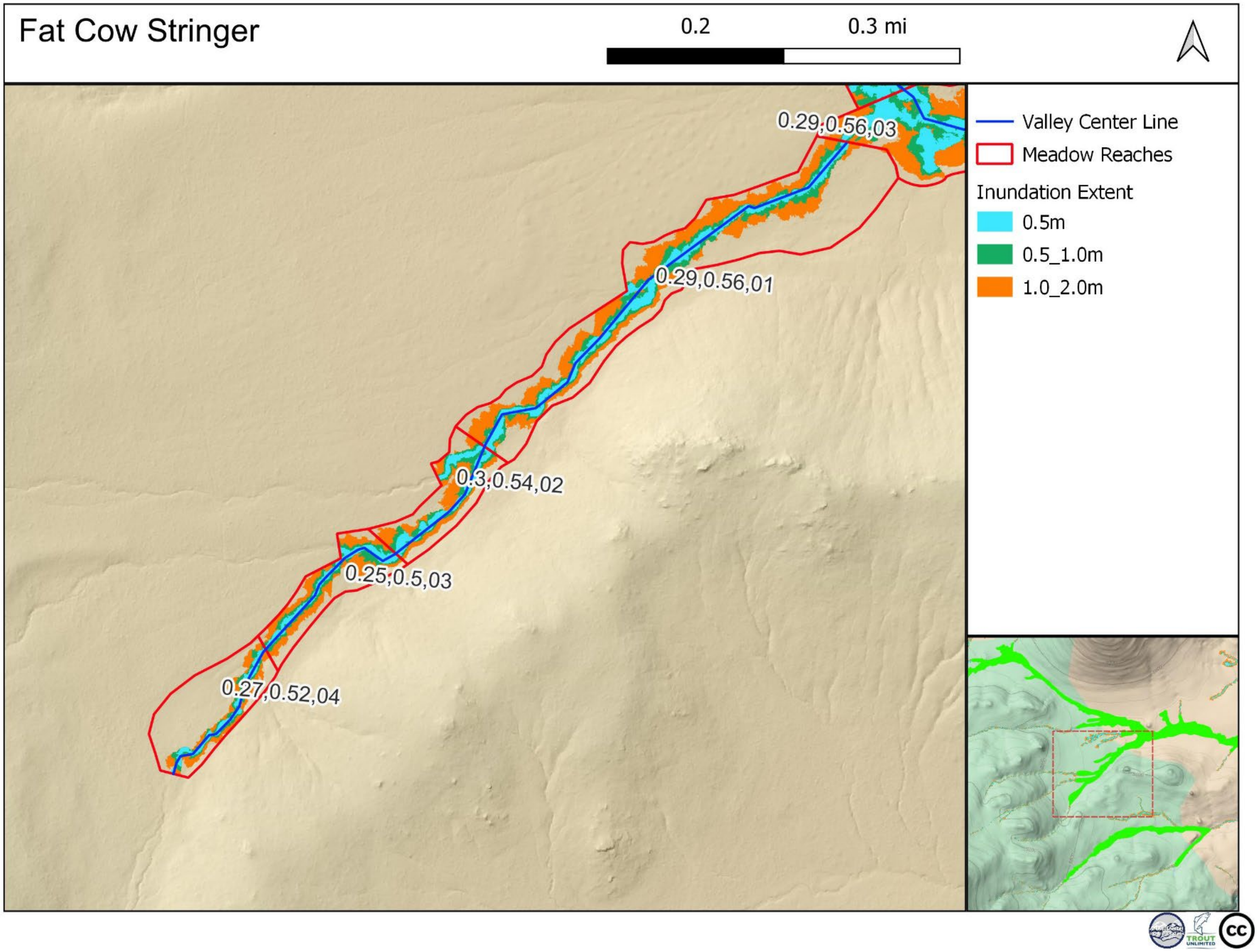

Figure 38. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Fat Cow Stringer. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

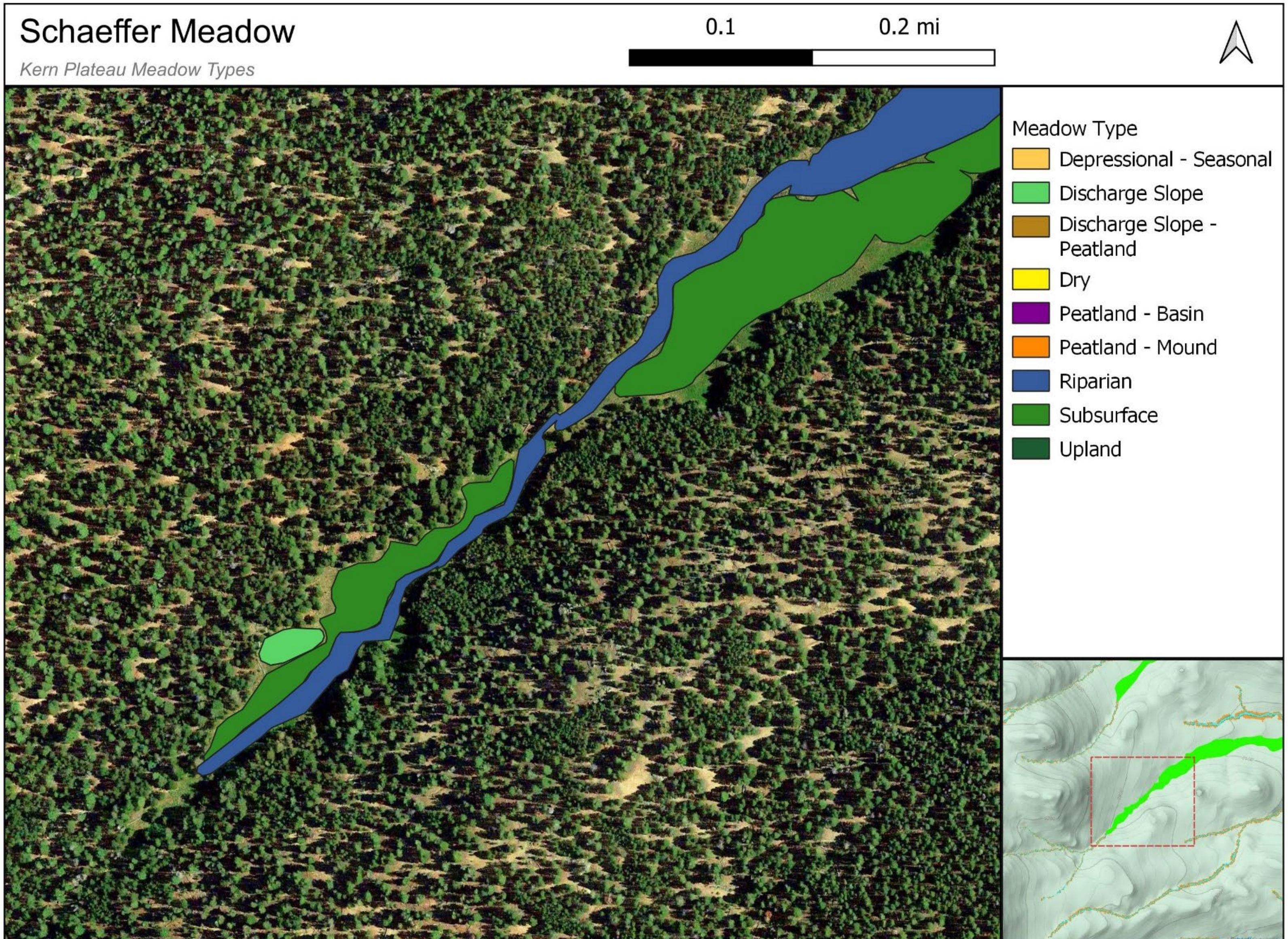

Figure 39. Distribution of meadow types in Schaeffer Meadow.

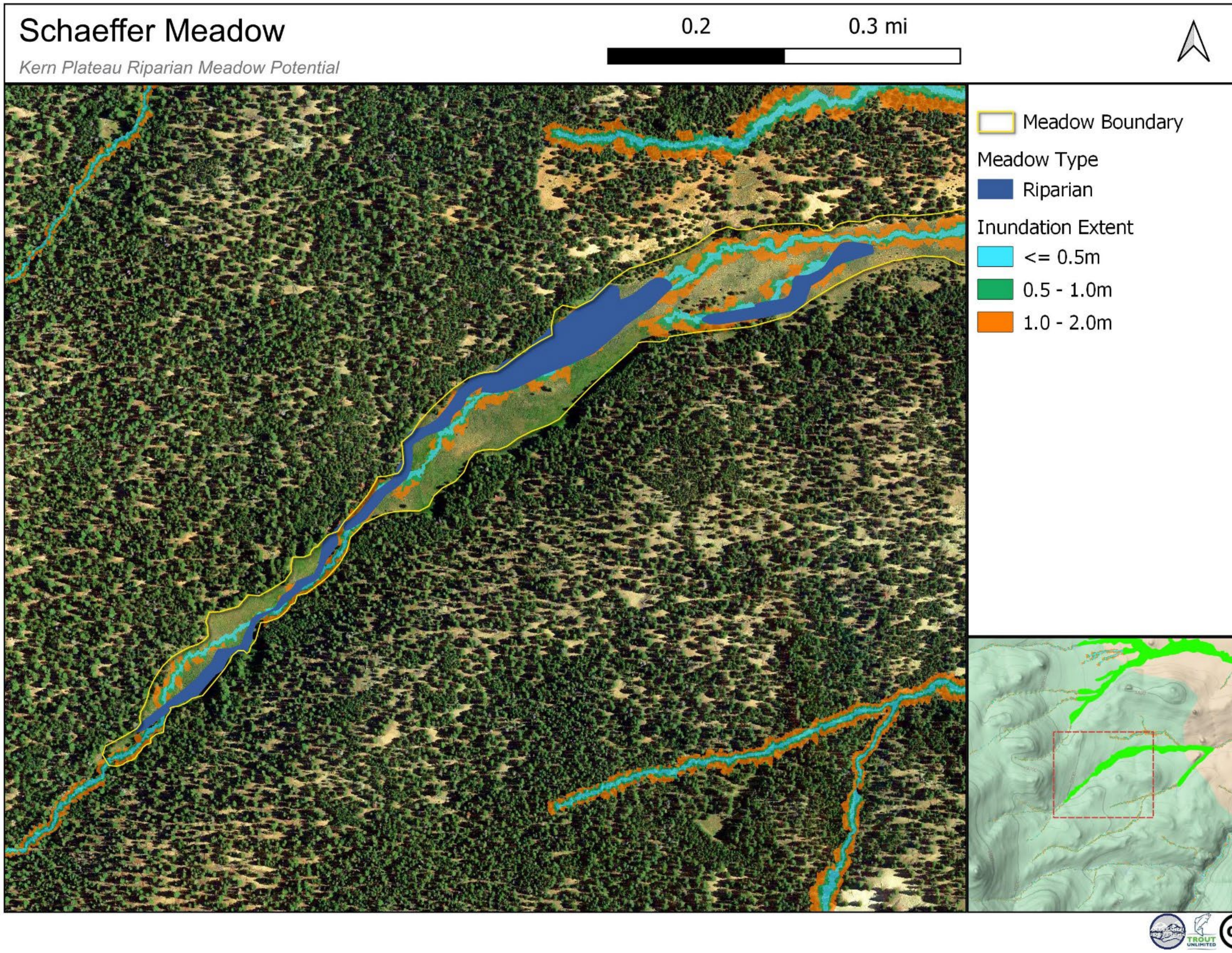

Figure 40. Dark blue represents the current riparian meadow in Schaeffer Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

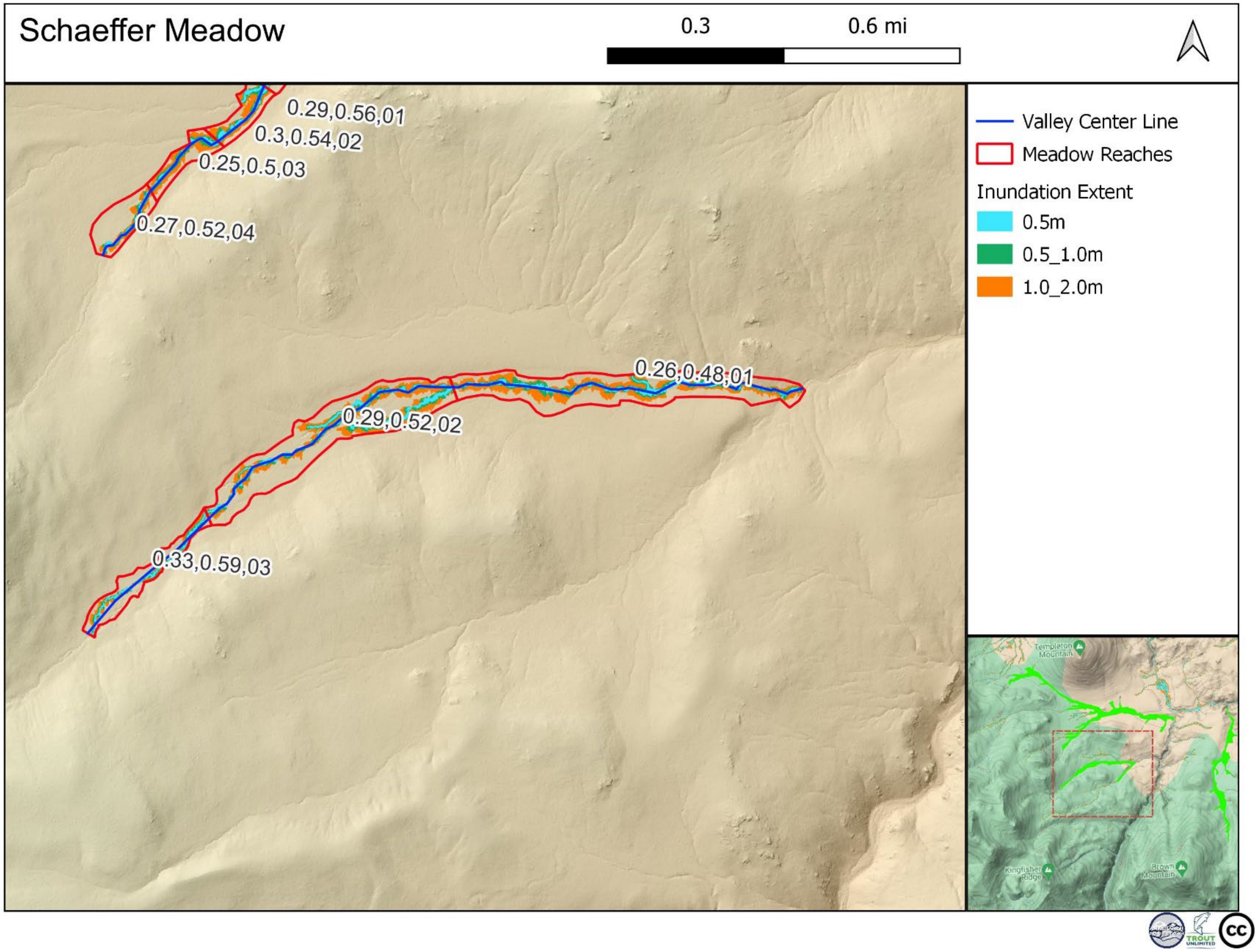

Figure 41. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Schaeffer Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

BROWN MEADOW

Brown Meadow is a very long, narrow moderate to high gradient meadow that is located east of the South Fork Kern canyon. Riparian and subsurface meadows are abundant although several areas have suffered from deep incision resulting in encroachment of upland vegetation (Table 9 & Figure 43 & Figure 44). The lower reaches are in a less confined valley setting but incision in several place can be over 1 m and sometimes >2m (Figure 47). Dense stands of willow and hydric meadow vegetation throughout the active floodplain zone. The hillslopes confining the meadow to the west are relatively barren with only sparse conifers and tiny annual forbs holding the unconsolidated decomposing granite material.

The middle of Brown Meadow enters the broader, lower gradient valley at the Brown Cow Camp. Throughout this zone the channel is incised ~2.5-3 meters below the historic floodplain surface leaving a narrow inset floodplain channel that supports hydric meadow species but has no connectivity to its historic floodplain. Several significant tributaries enter this section of the meadow from the east forming a sloping alluvial fan perpendicular to the valley gradient that is also contains a significantly incised channel. A second tributary just south of this fan has a very large, active headcut that threatens high quality habitat above. There are several log check dam installations in this section of meadow that have all filled with sediment suggesting structures promote aggradation and that, despite the typical low flows on Brown Creek. Numerous springs and discharge slopes provide additional surface and subsurface flows and support a variety of meadow hydrogeomorphic types including subsurface, discharge slope peatlands, and riparian meadow types. The groundwater flowing through from the alluvial fan as well as springs helps to maintain areas of intact meadow on the historic surface, but the deep channel incision creates a drain on groundwater leaving the margins of the channel dry and covered in encroaching sagebrush.

Brown's headwater zone is typical of the higher gradient upper reaches of many of the meadows in this area with an indistinct channel through a subsurface high gradient meadow type supporting mesic and hydric meadow vegetation. This section likely has sheet flow during periods of high runoff but soon concentrates into a distinct channel that has had numerous headcuts. As the stream descends, the channel becomes increasingly incised and becomes a narrow inset floodplain with sagebrush and upland species encroachment on the adjacent terrace (former meadow surface).

Table 9. Acres and percentage of total for each meadow type found in Brown Meadow.

Meadow	Acres	% Total
Brown	**75.9**	**100%**
Discharge Slope	5.0	7%
Discharge Slope - Peatland	3.6	5%
Riparian	28.0	37%
Subsurface	16.8	22%
Upland	22.5	30%

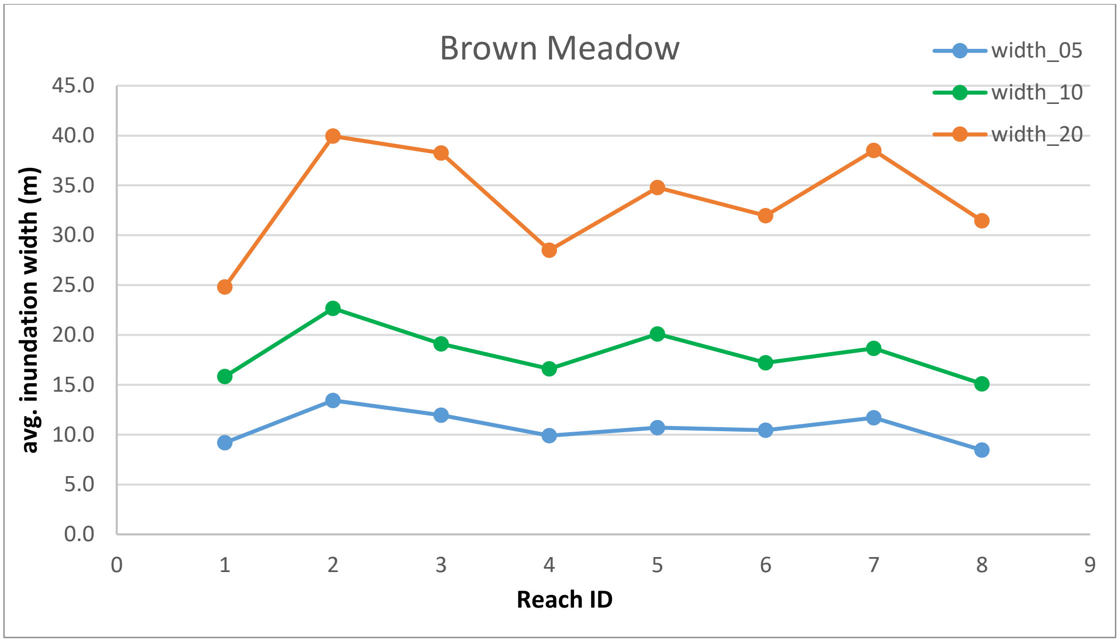

Figure 42. Brown Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

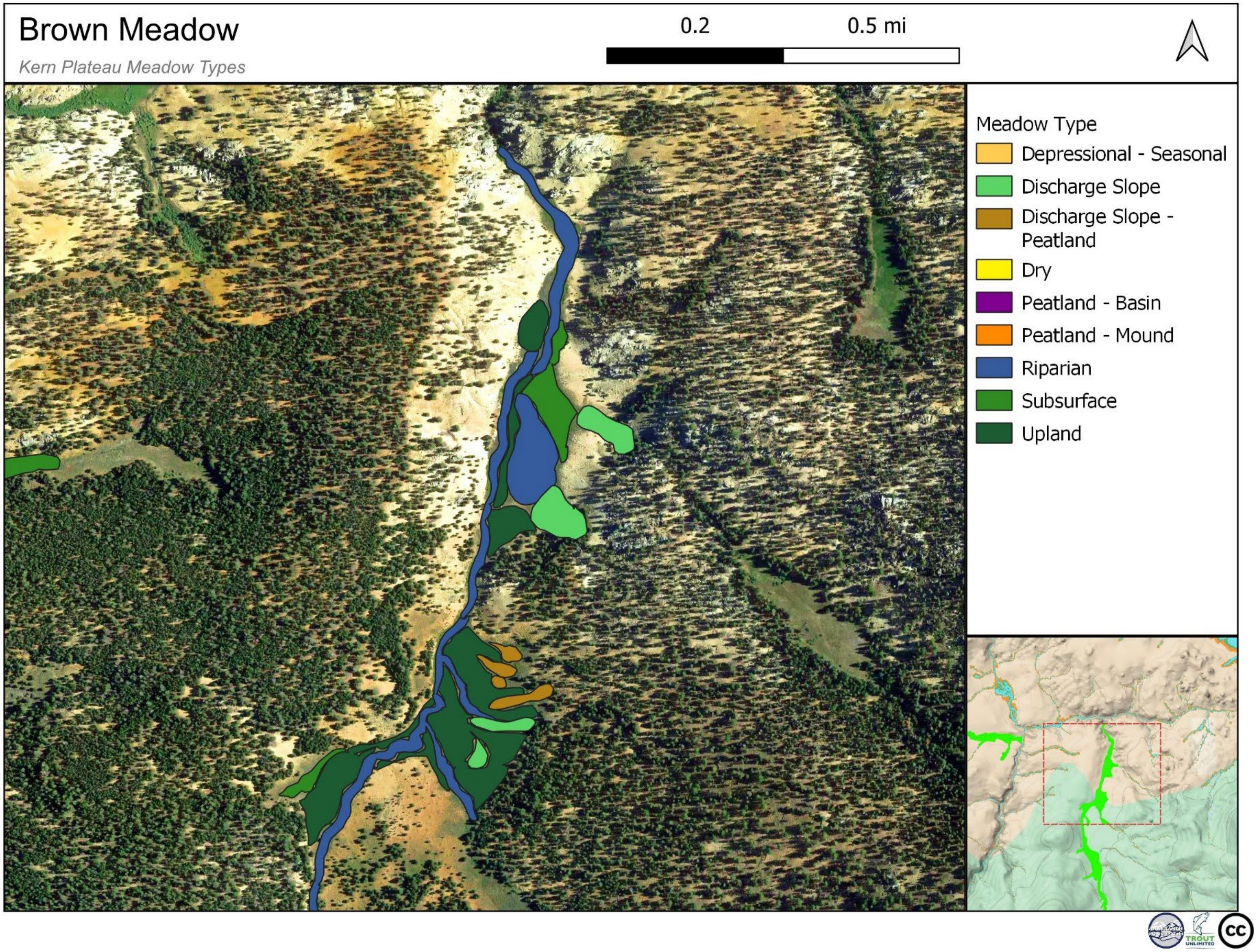

Figure 43. Distribution of meadow types in lower Brown.

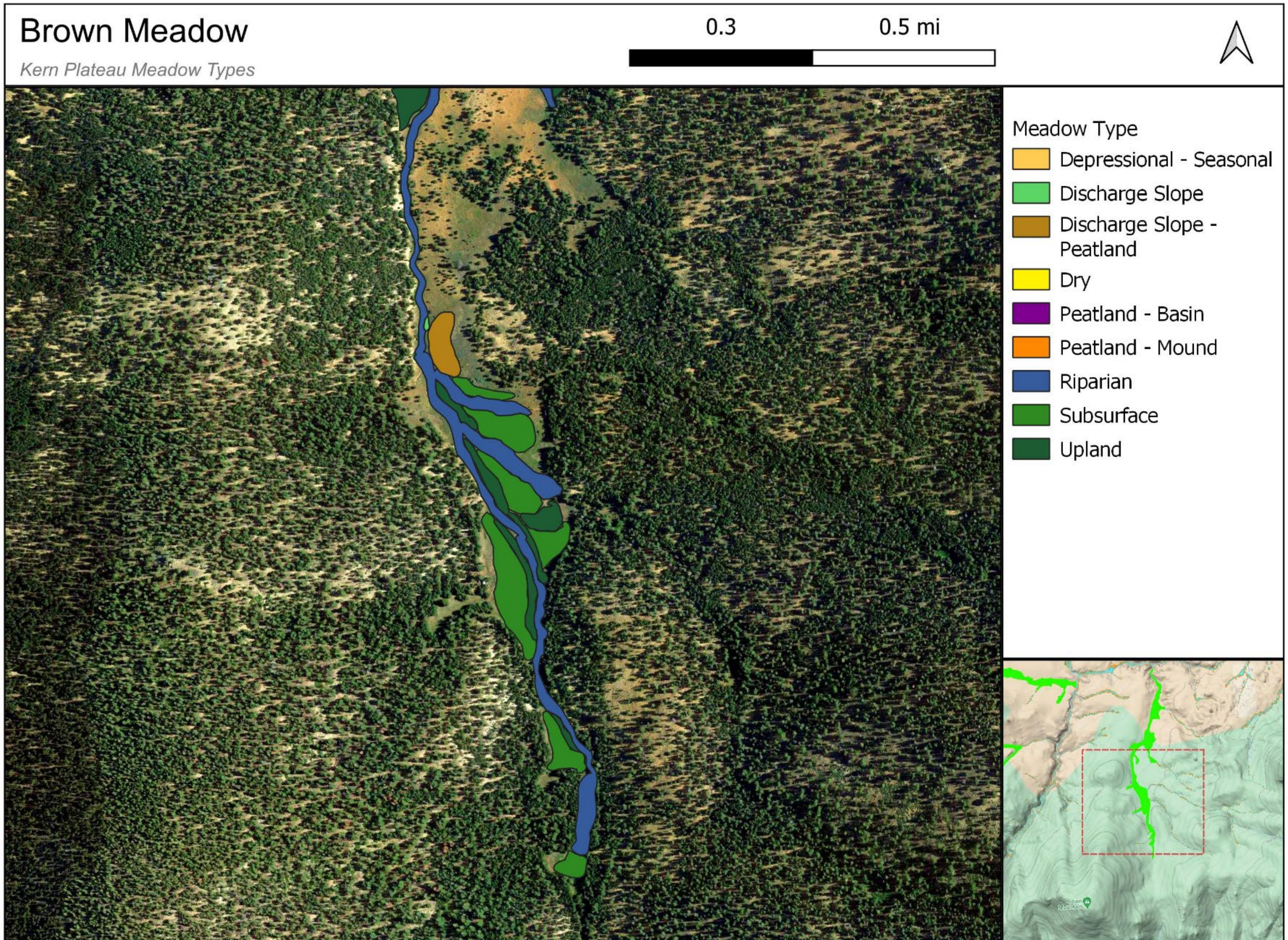

Figure 44. Distribution of meadow types in upper Brown.

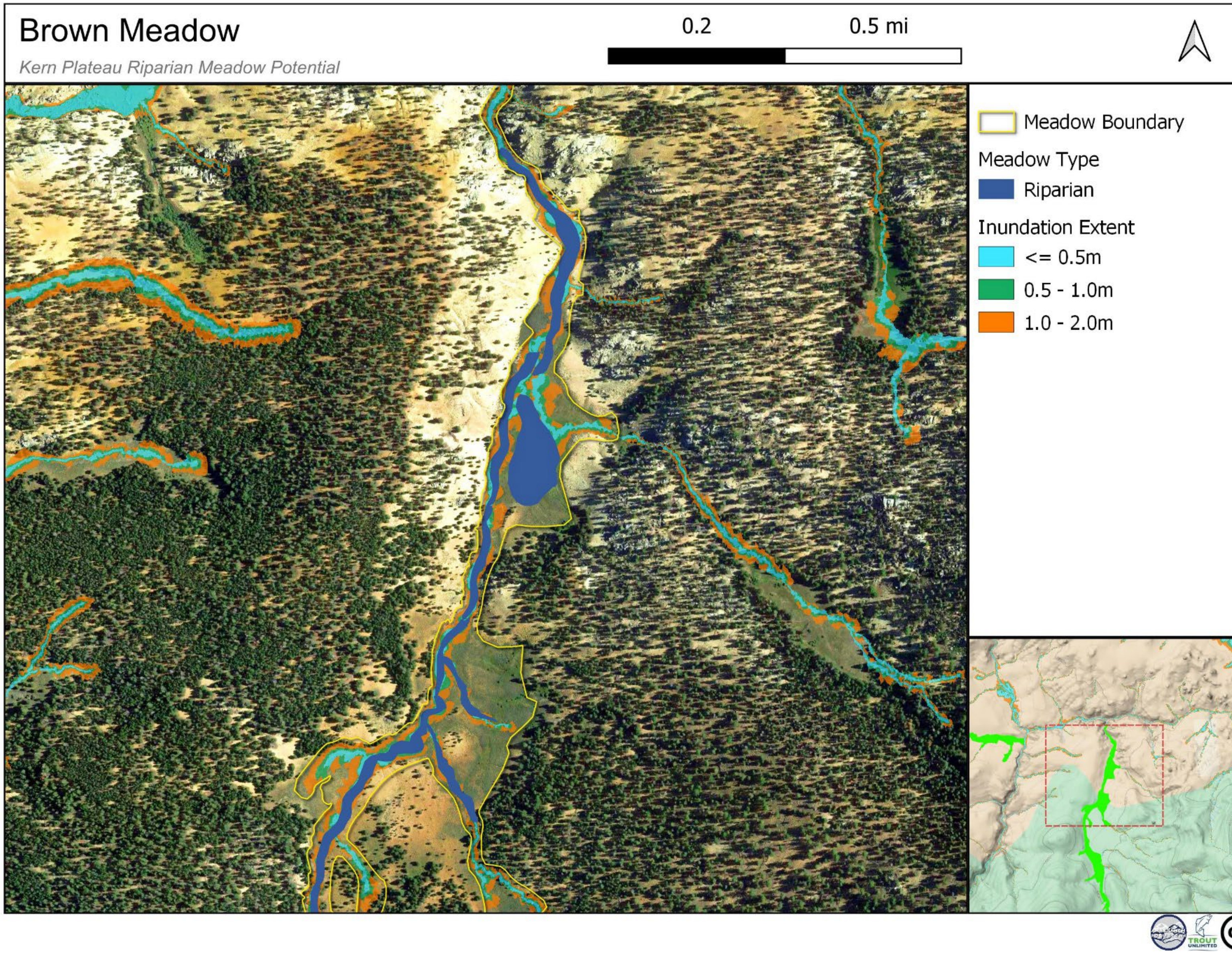

Figure 45. Dark blue represents the current riparian meadow in lower Brown Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

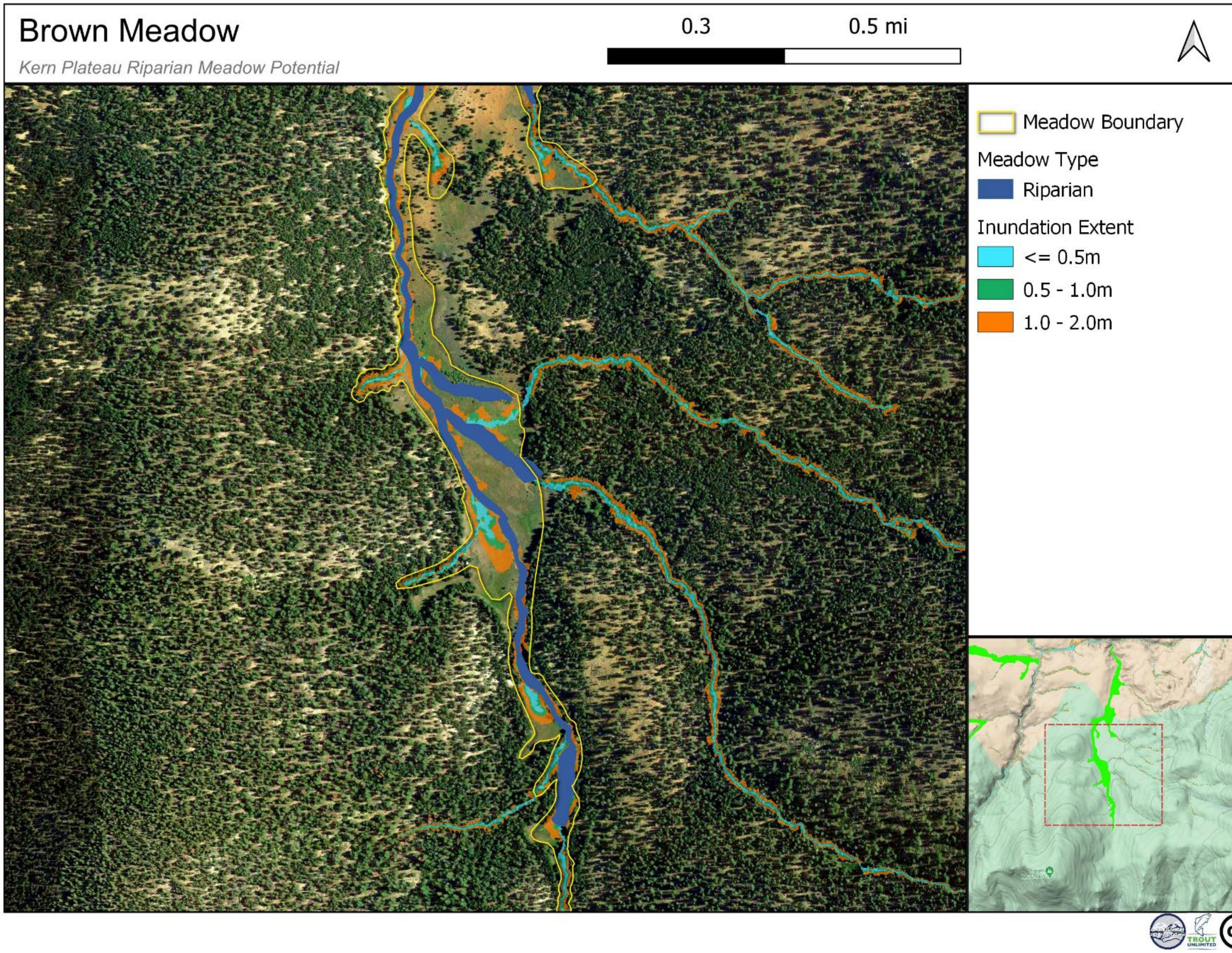

Figure 46. Dark blue represents the current riparian meadow in upper Brown Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

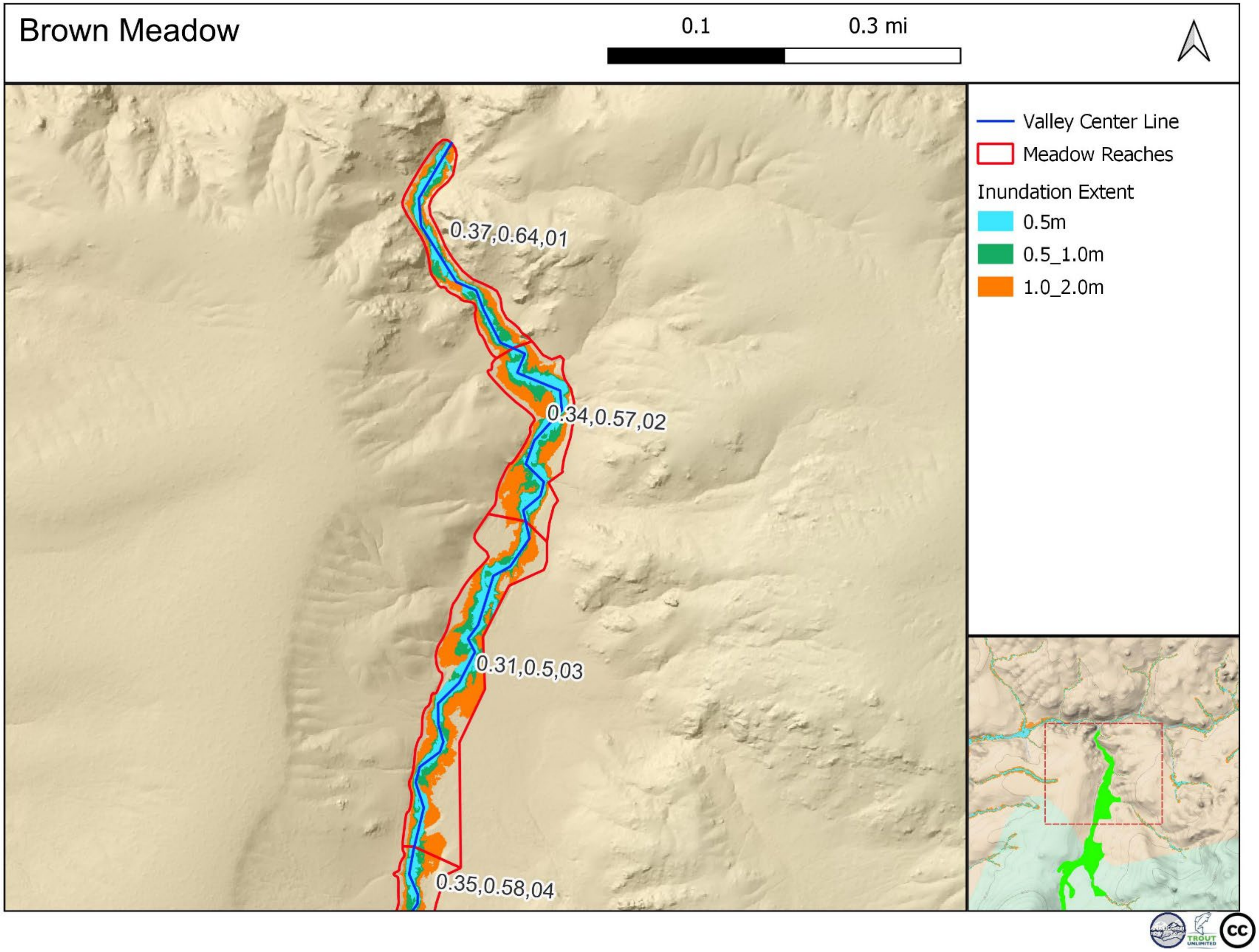

Figure 47. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 1-3 of Brown Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

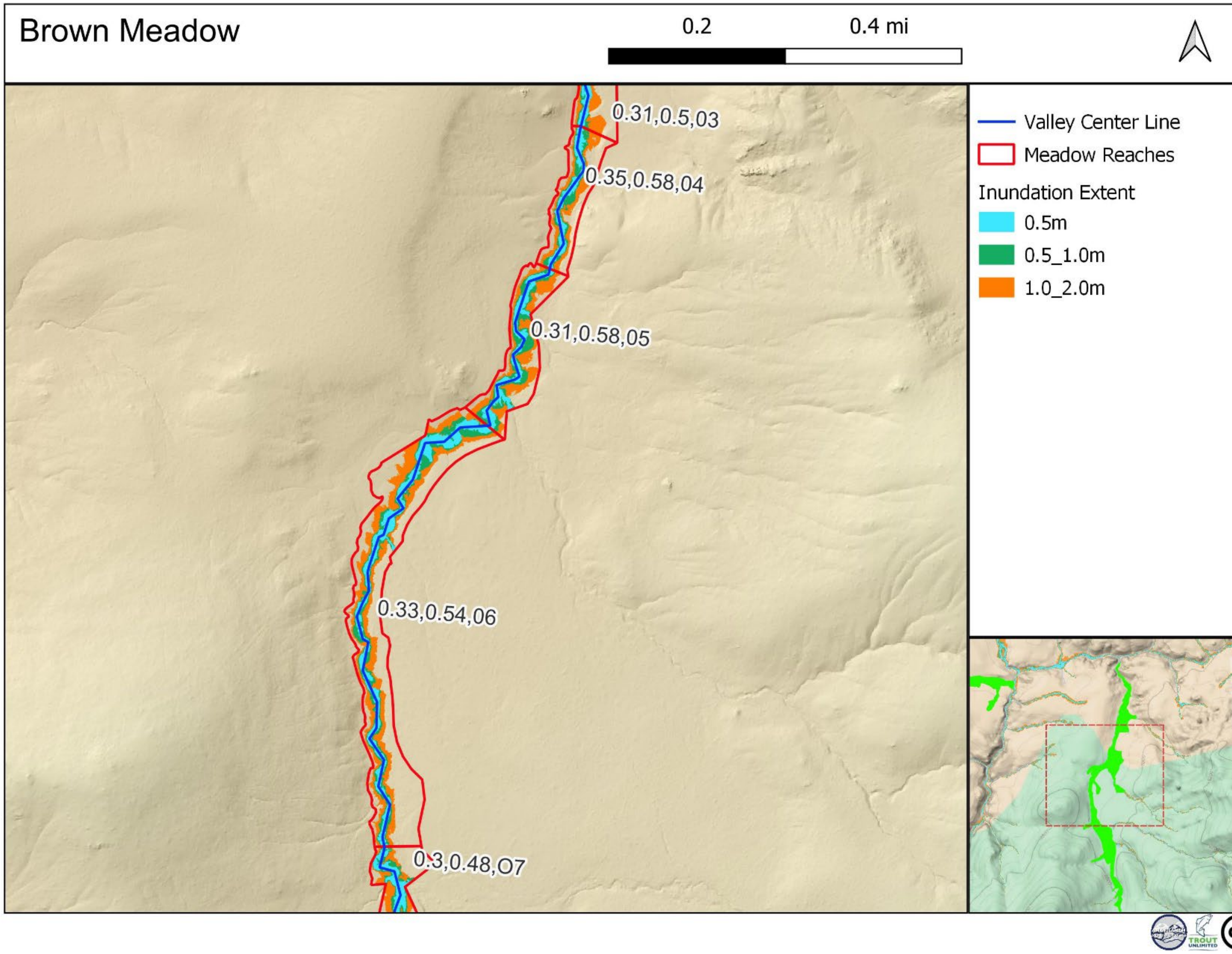

Figure 48. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 4-6 of Brown Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

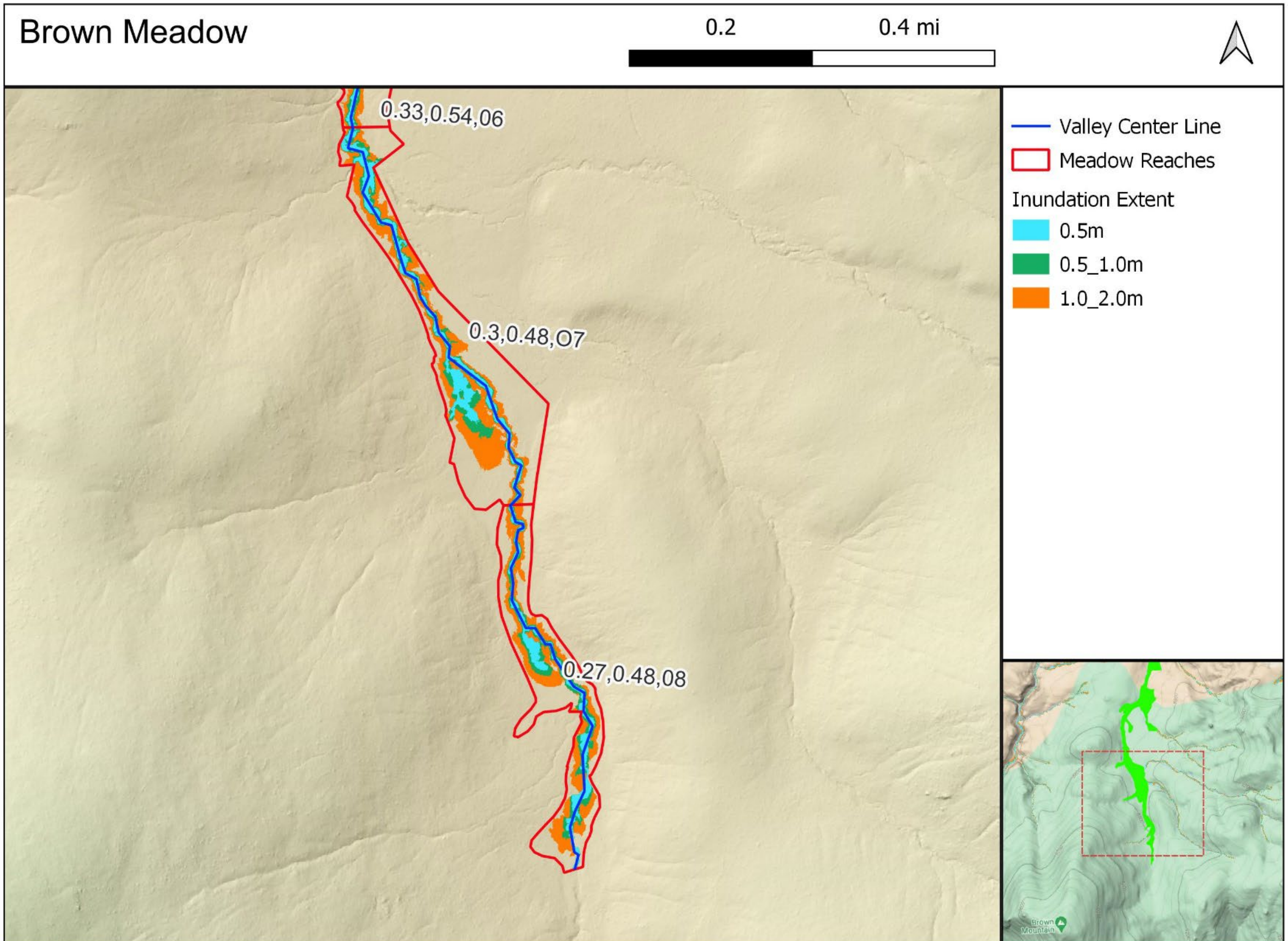

Figure 49. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for geomorphic reaches 7 & 8 of Brown Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

KINGFISHER STRINGER MEADOW

Kingfisher Stringer is located to the northwest of Monache Mountain and is a tributary of Soda Creek. The small meadow has two main tributaries flowing in. Meadow typing was not completed for this meadow. The two channels come together and become more deeply entrenched downstream of the confluence. In the lower reach, the eastern flank of the channel is a sagebrush terrace ~1.5 m above the inset channel. Although the proportion of the 2 m inundation filled by 0.5 m and 1 m appears high, this is driven by an ephemeral channel to the east that rarely ever flow but was delineated by HAND based on topograph and erroneously added to the inundation extent layers (Figure 54). The western tributary enters the meadow midway down its western flank and has flow paths which are essentially intact with full floodplain access. The eastern tributary is the dominant flow path and is therefore significantly more impacted. The eastern tributary has incised 0.5 to 1m below the historic floodplain surface and has formed the typical inset floodplain channel with encroaching sagebrush along the terrace margins where groundwater dives well below the surface to drain into the incised channel forcing a conversion to upland vegetation. At the upstream end of the meadow, the channel is very shallow and fully vegetated and becomes progressively deeper and more eroded as it proceeds downstream.

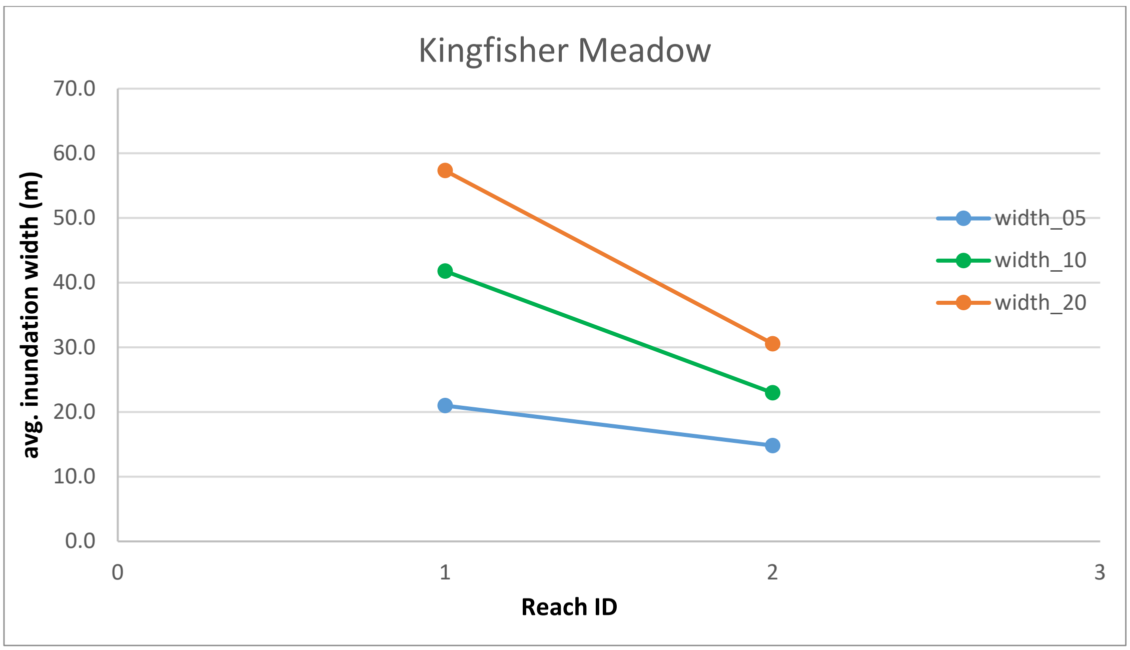

Figure 50. Kingfisher Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

SODA CREEK MEADOW

Soda Creek Meadow is part of the immense Monache Meadow Complex centered on Monache Mountain located on the north side of Monache Mountain just south of Bake Oven Dune. A high percentage of the meadow has been converted to upland (Table 10). The channel is low-gradient but is significantly (~2m) incised in the lowest reach (Figure 54 & Figure 57). The next reaches have the ability to inundate large areas with increases in water surface elevation of 0.5 & 1 m (Figure 54). There are several discharge slope springs coming from the margin of the meadow on the toe slope of Monache Mountain that provide surface and groundwater throughput into the riparian channel (Figure 55) having high potential to convert upland vegetation to riparian meadow type (Figure

56). The historic floodplain surface north of the channel has a lot of sagebrush encroachment due to the channel incision draining groundwater and then gradually returns to subsurface meadow type supported by a small tributary (usually dry) entering from the northern edge of the meadow. The inset floodplain and channel support hydric meadow vegetation, but in most areas, the channel is too deeply incised to activate the floodplain in most high flow events.

Table 10. Acres and percentage of total for each meadow type found in Soda Creek Meadow.

Meadow	Acres	% Total
Soda	**66.5**	**100%**
Discharge Slope	0.3	0%
Discharge Slope - Peatland	3.2	5%
Riparian	12.7	19%
Subsurface	25.6	39%
Upland	24.6	37%

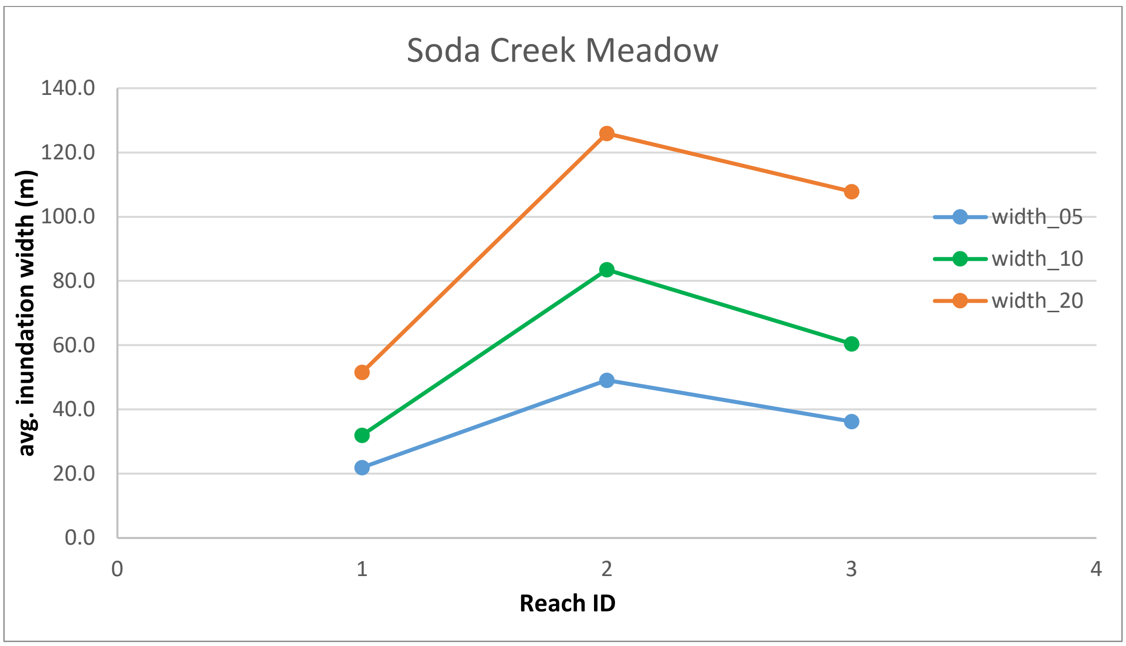

Figure 51. Soda Creek Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

ROUND MOUNTAIN MEADOW

Round Mountain Meadow is a relatively small meadow that is mostly unproductive riparian meadow type with some subsurface meadow with sheetflow (Table 11 & Figure 55). The flow is ephemeral and the channel and meadow are dry throughout most of the year. Channel incision has occurred and appears to be maintained by cattle using the channels as trails. Although the inundation extents are wide and there appears to be some riparian meadow potential (Figure 52 & Figure 59 & Figure 60), the ephemeral nature of the flows make increase expansion and production of riparian meadows unlikely.

Table 11. Acres and percent of total for each meadow type found in Round Mountain Meadow.

Meadow	Acres	% Total
Round_Mtn	**68.4**	**100%**
Discharge Slope	7.3	11%
Riparian	47.7	70%
Subsurface	13.4	20%

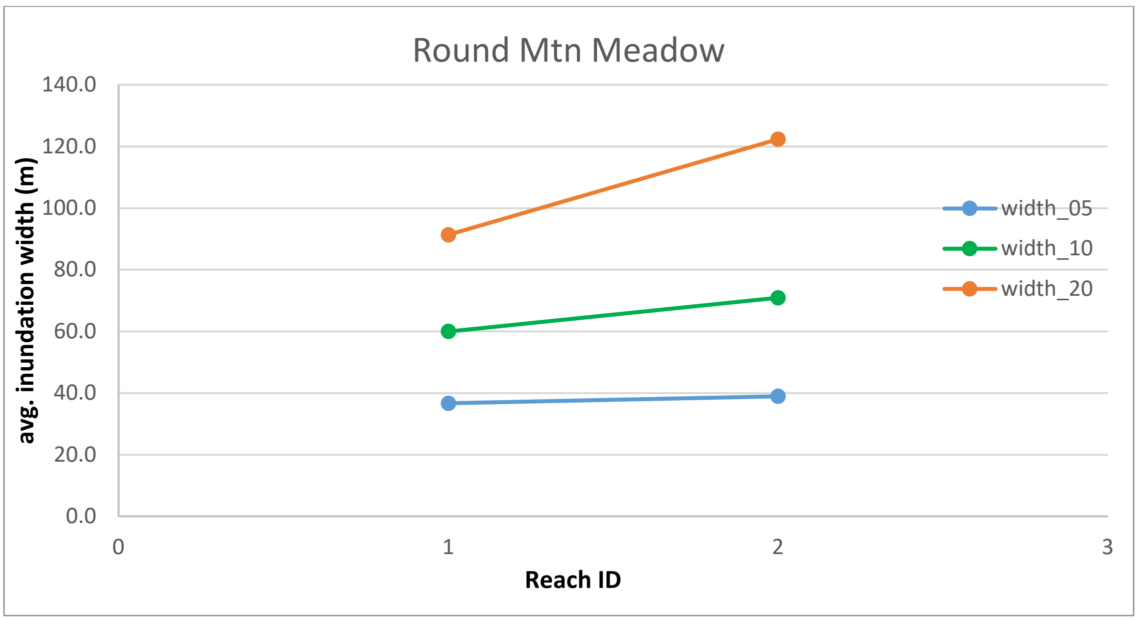

Figure 52.Round Mountain Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

SNAKE CREEK MEADOW

Snake Creek is located south of Monache Mountain and is one of the last significant tributaries to flow into the South Fork Kern River in the Monache Meadow Complex. Much of the meadow is of dry meadow type and upland (Table 1 & Figure 61). The lower reaches are not very incised with 0.5 m to 1 m filling a large proportion of the 2 m inundation (Figure 63) and has a very wide historical floodplain surface (Figure 60). The valley gradient is very low and historically this channel would likely have been indistinct in many areas with sheetflow and swale-type channel during times of runoff. It is currently ephemeral though it likely flowed more perennially in previous centuries (a combination of better meadow conditions and wetter climatic conditions). The channel may actually be a captured livestock trail that continues to become wider and deeper as livestock walk through and across it).

There is large potential for riparian expansion if the incised channel aggraded and flows were more frequent (Figure 62). Upstream of Snake Creek bridge and the channel is incised 1.5 – 2.5 m below the historical meadow surface with the attendant sagebrush encroachment at the terrace margins and a confined narrow inset channel and floodplain that has become an alternative stable state disconnected from the full valley bottom.

Table 12. Acres and percent of total for each meadow type found in Snake Creek Meadow.

Meadow	Acres	% Total
Snake	**228.9**	**100%**
Discharge Slope - Peatland	0.9	0%
Dry	107.8	47%
Riparian	29.6	13%
Subsurface	32.3	14%
Upland	58.3	25%

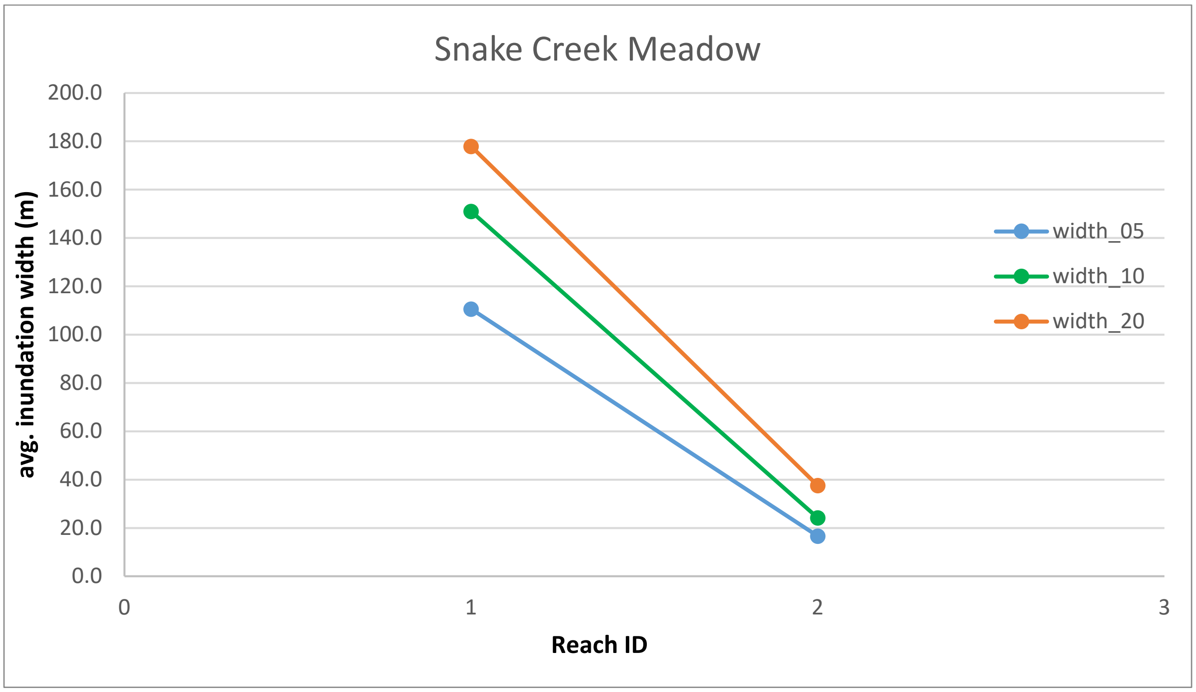

Figure 53. Snake Creek Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

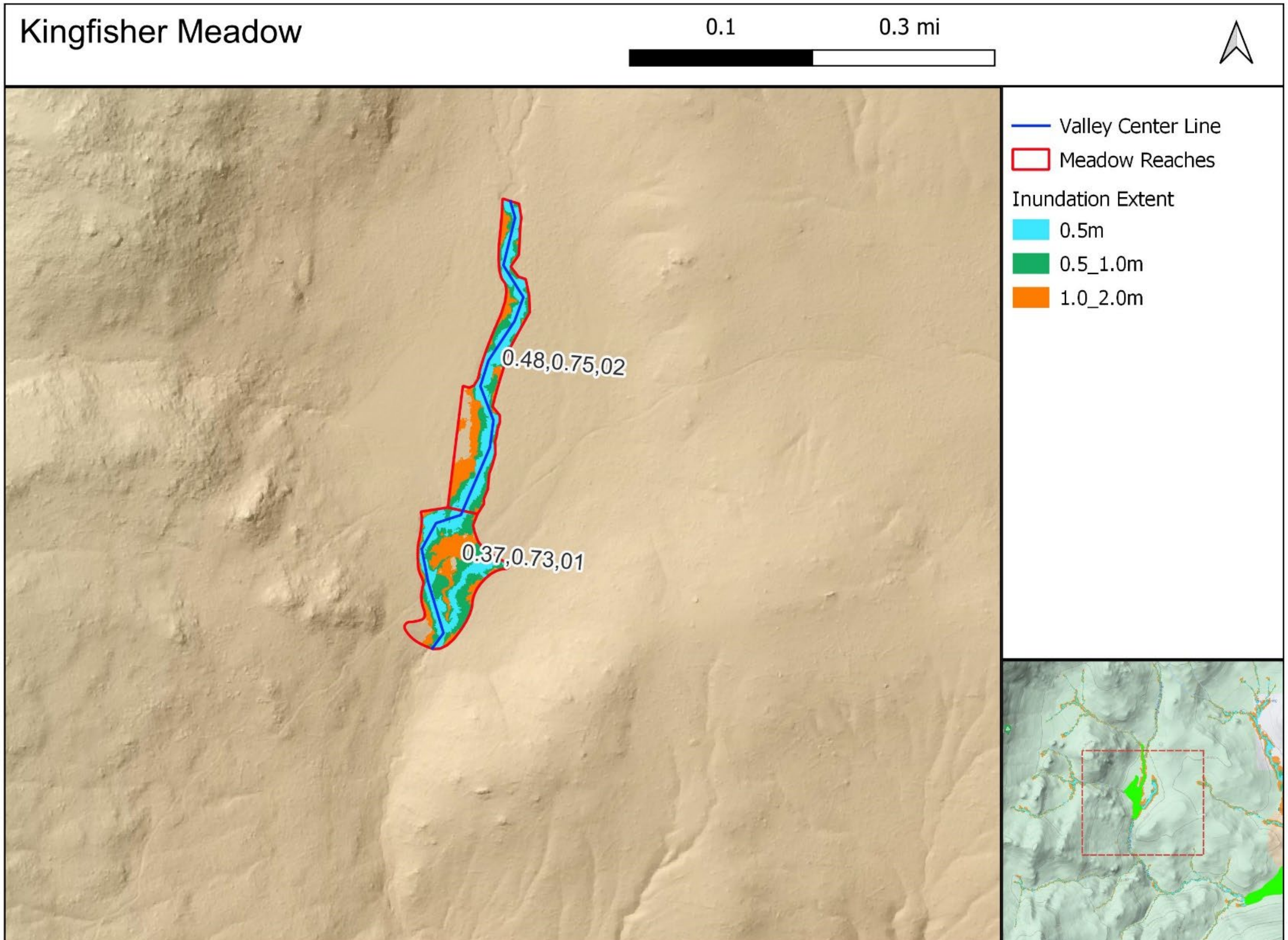

Figure 54. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Kingfisher Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

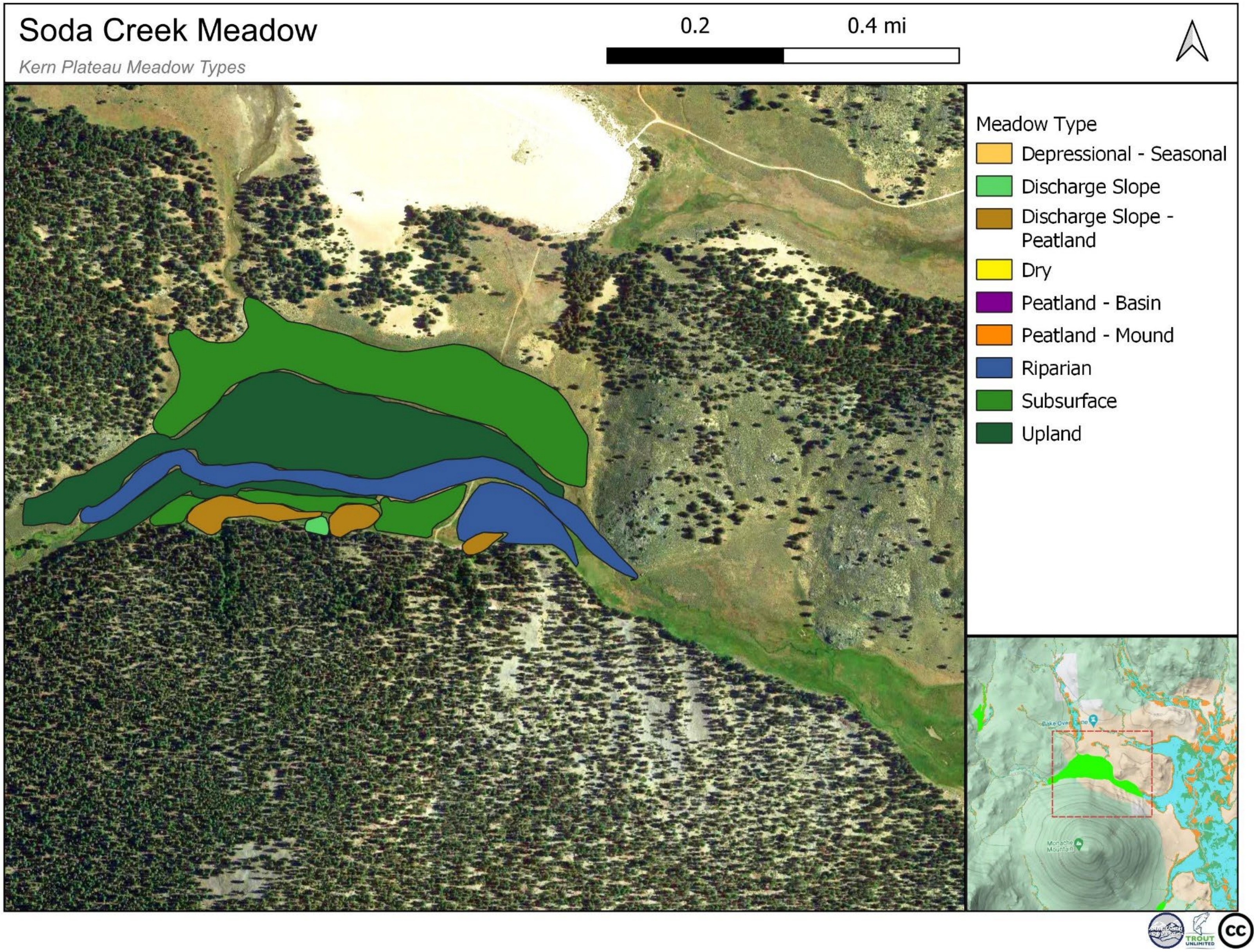

Figure 55. Distribution of meadow types in Soda Creek Meadow.

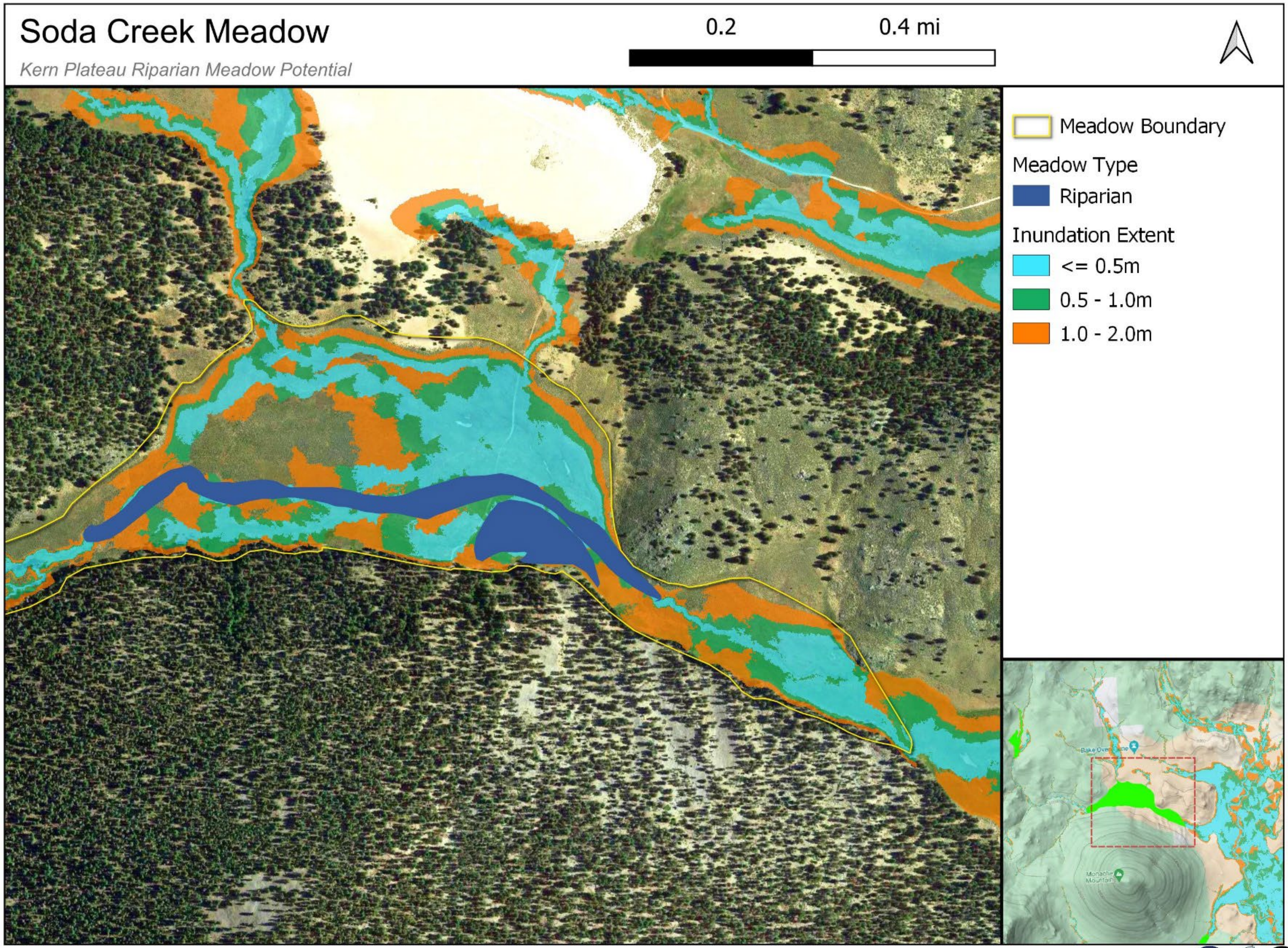

Figure 56. Dark blue represents the current riparian meadow in Soda Creek Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

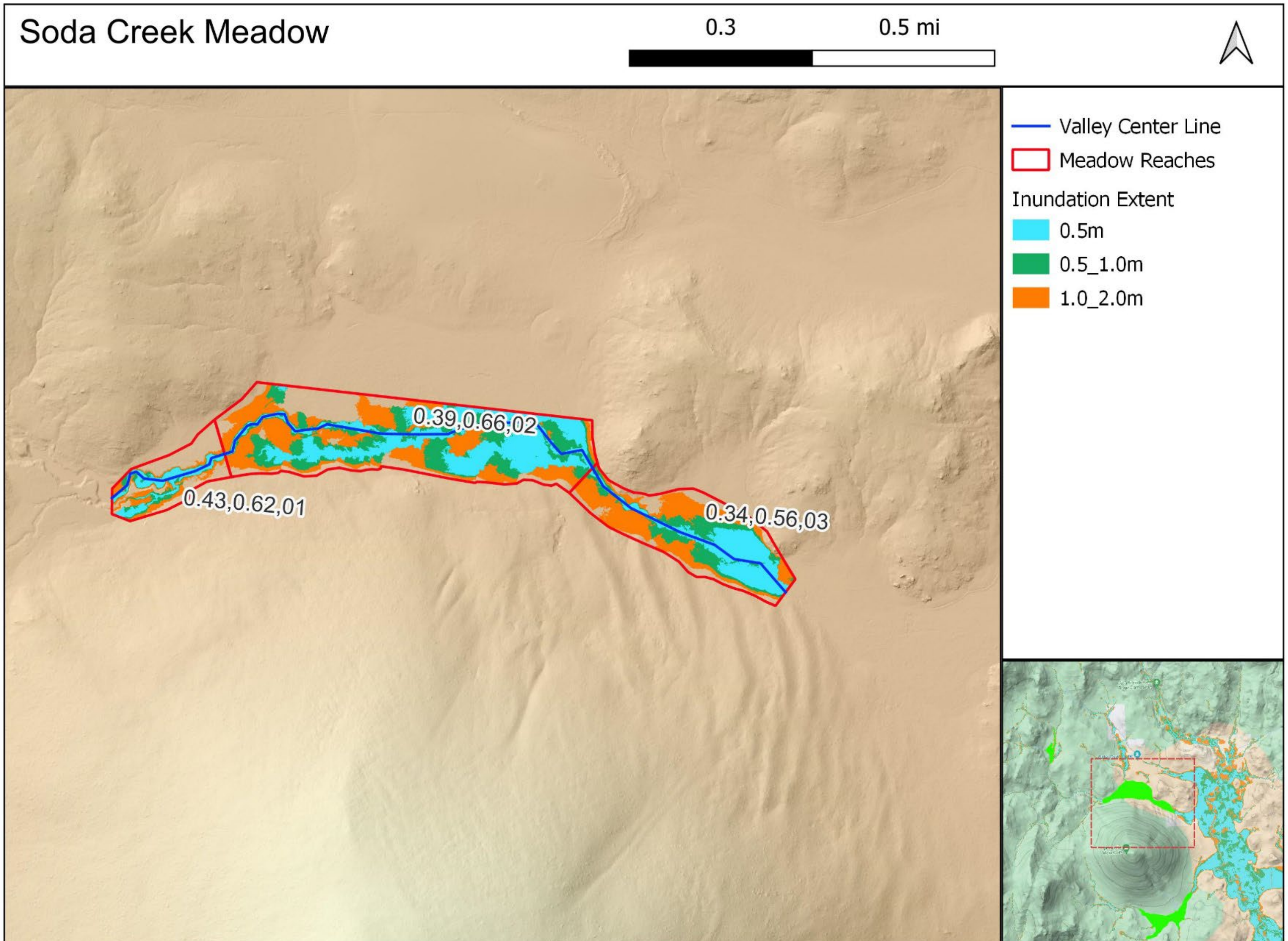

Figure 57. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Soda Creek Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

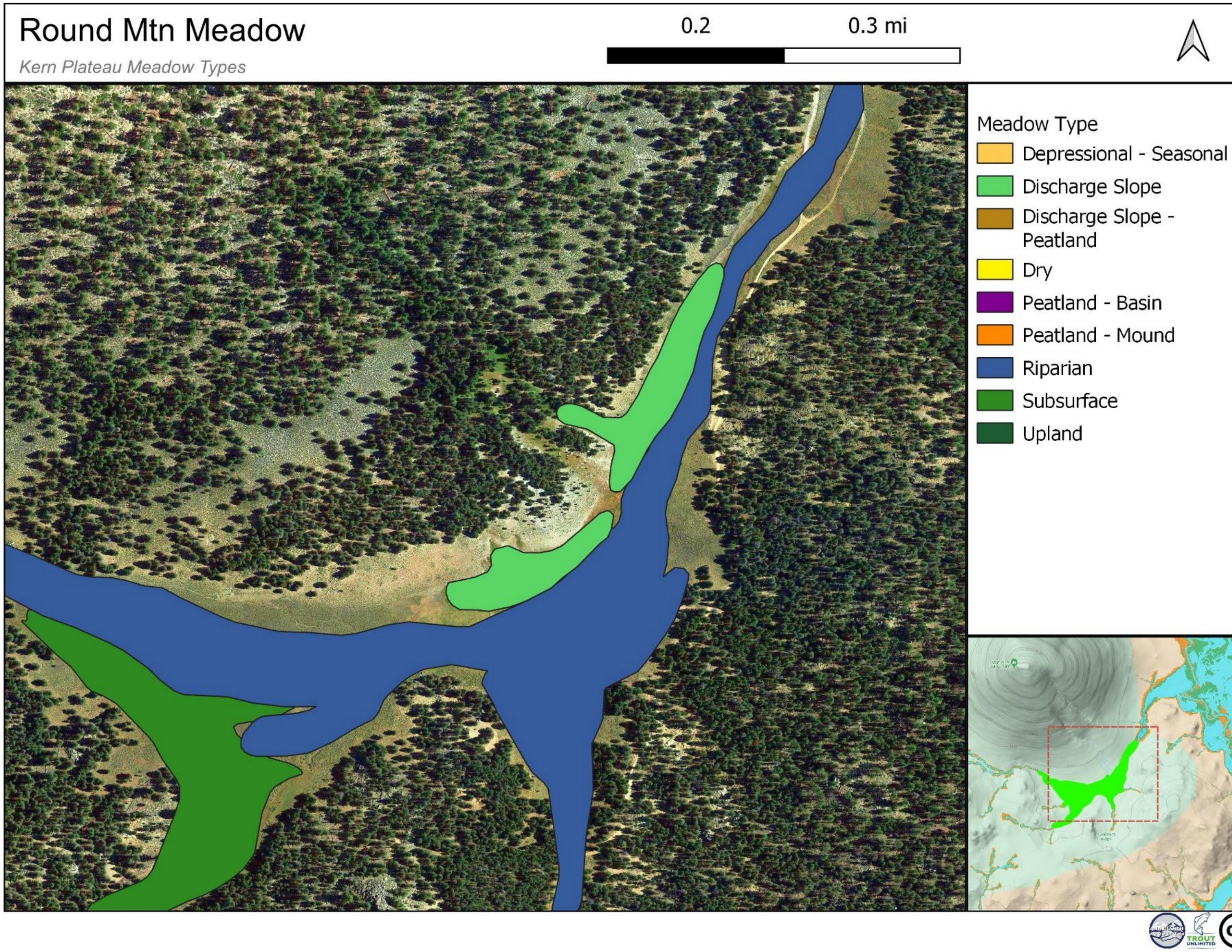

Figure 58. Distribution of meadow types in Round Mountain Meadow.

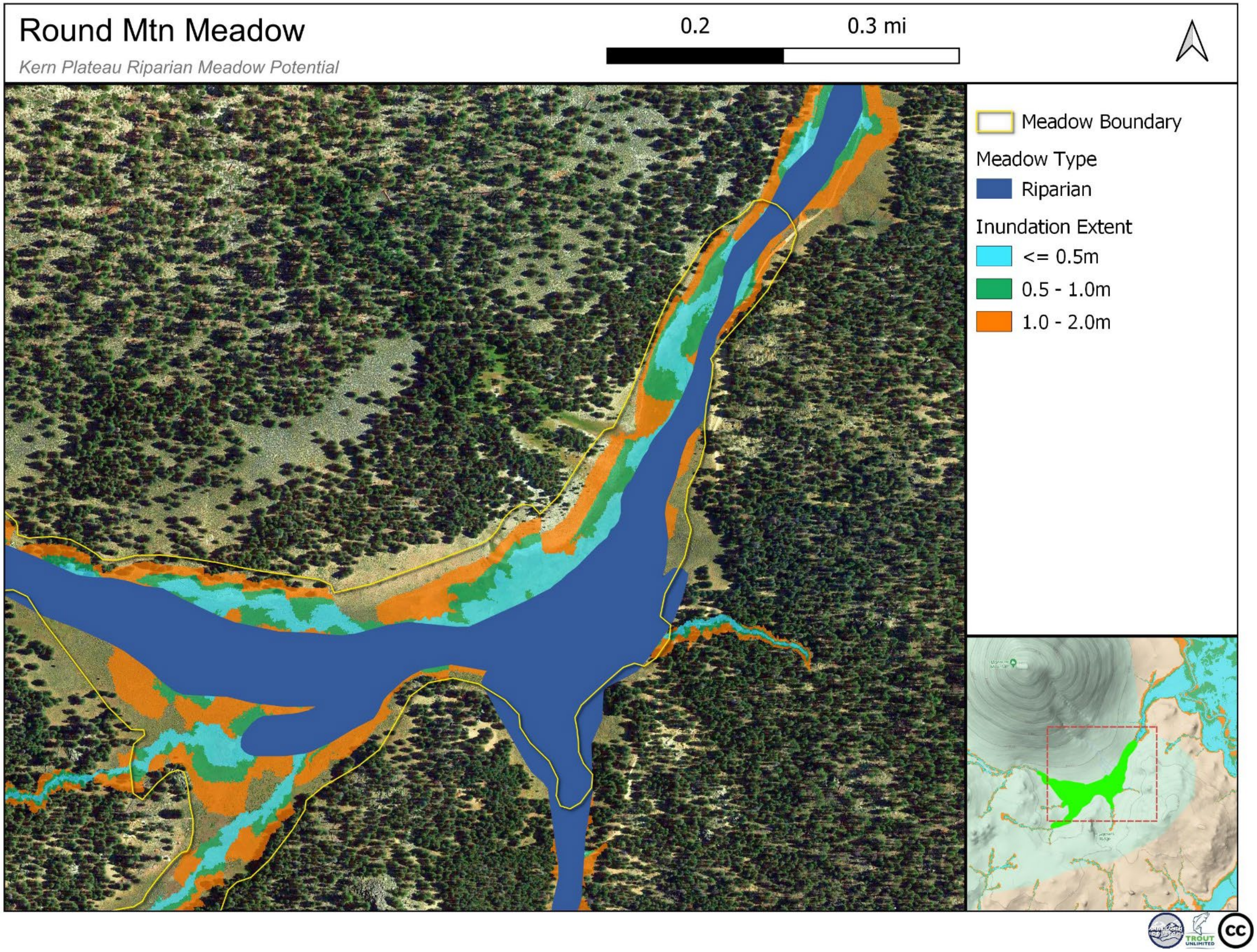

Figure 59. Dark blue represents the current riparian meadow in Round Mountain Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

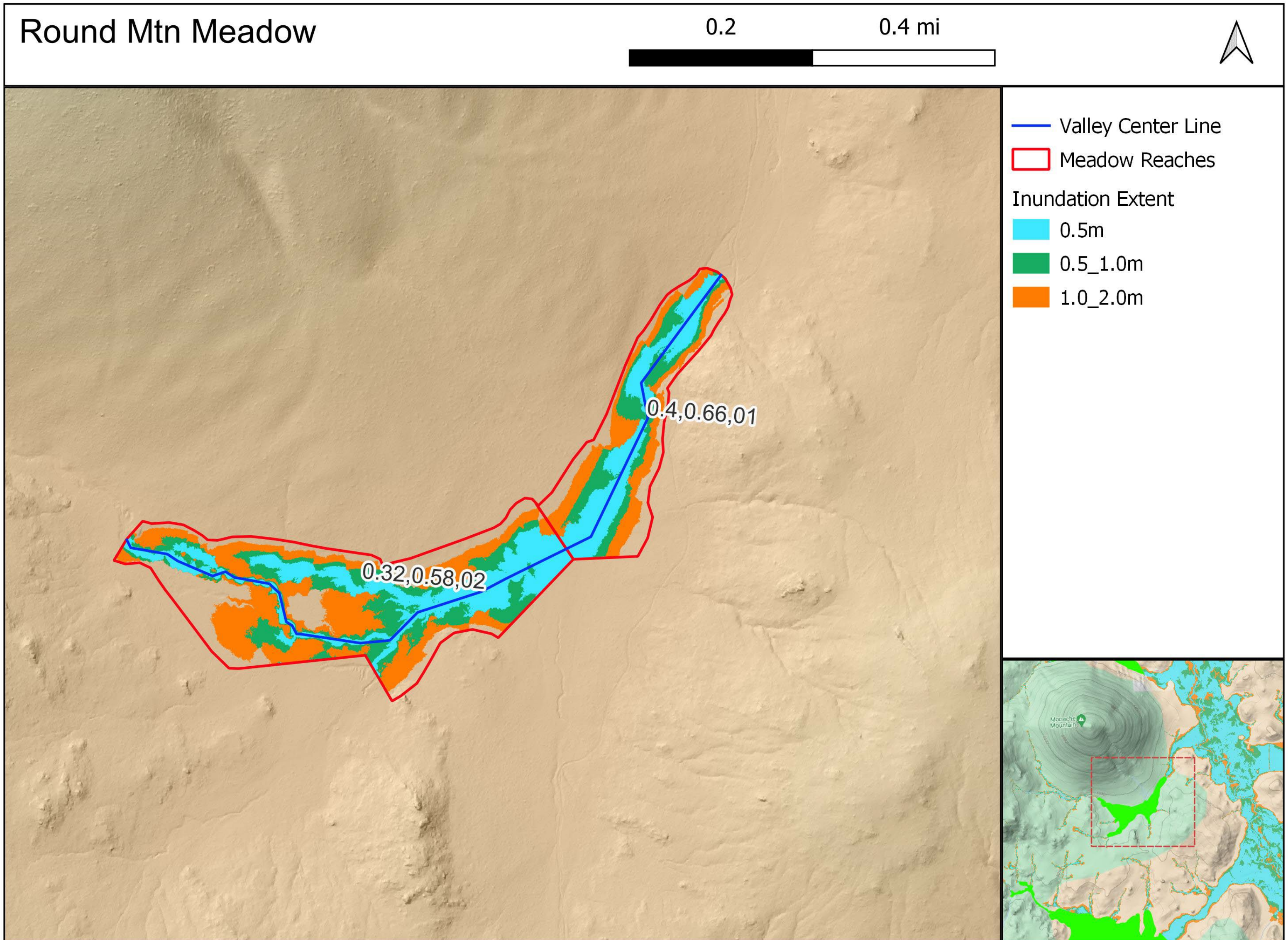

Figure 60. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Round Mountain Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

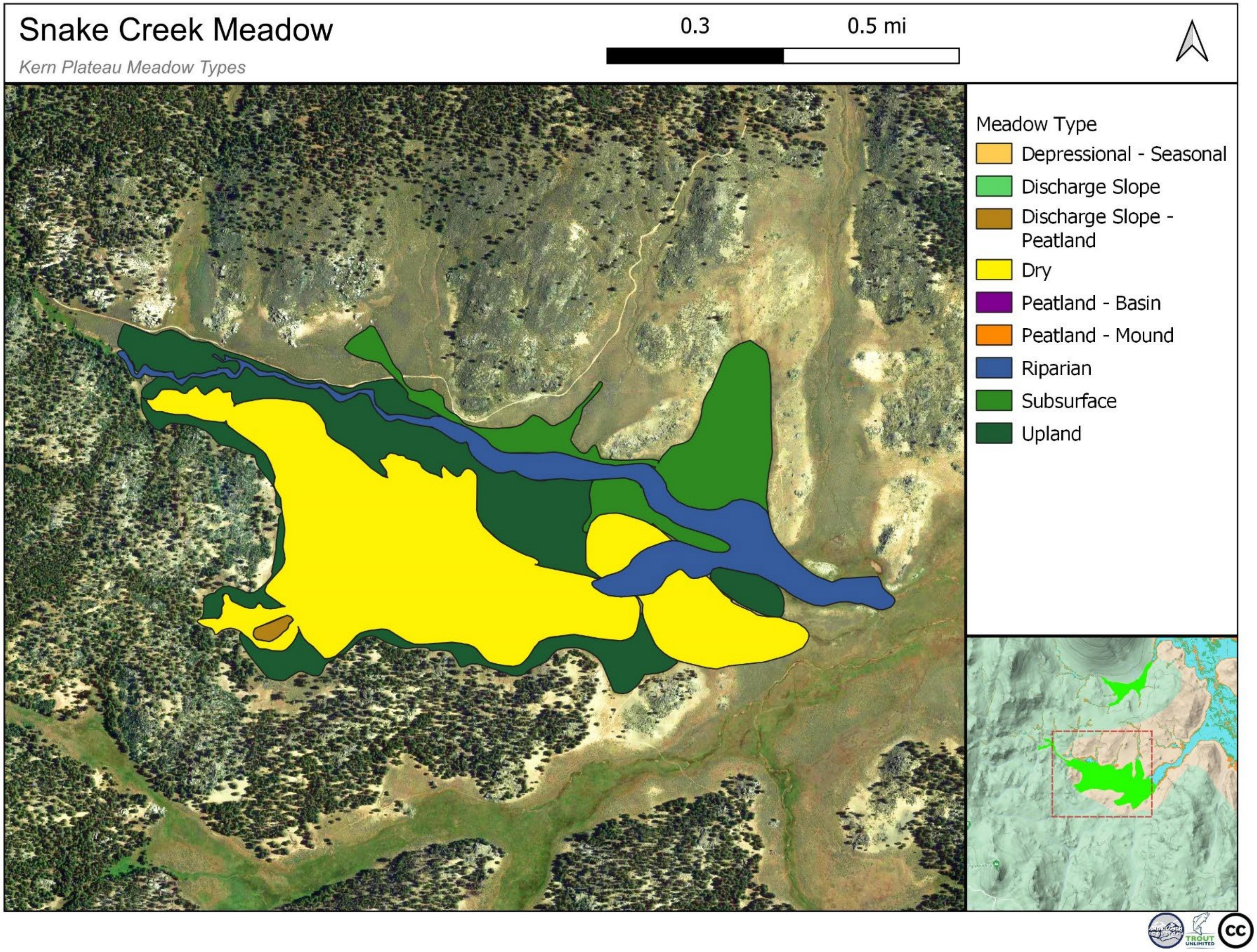

Figure 61. Distribution of meadow types in Snake Creek Meadow.

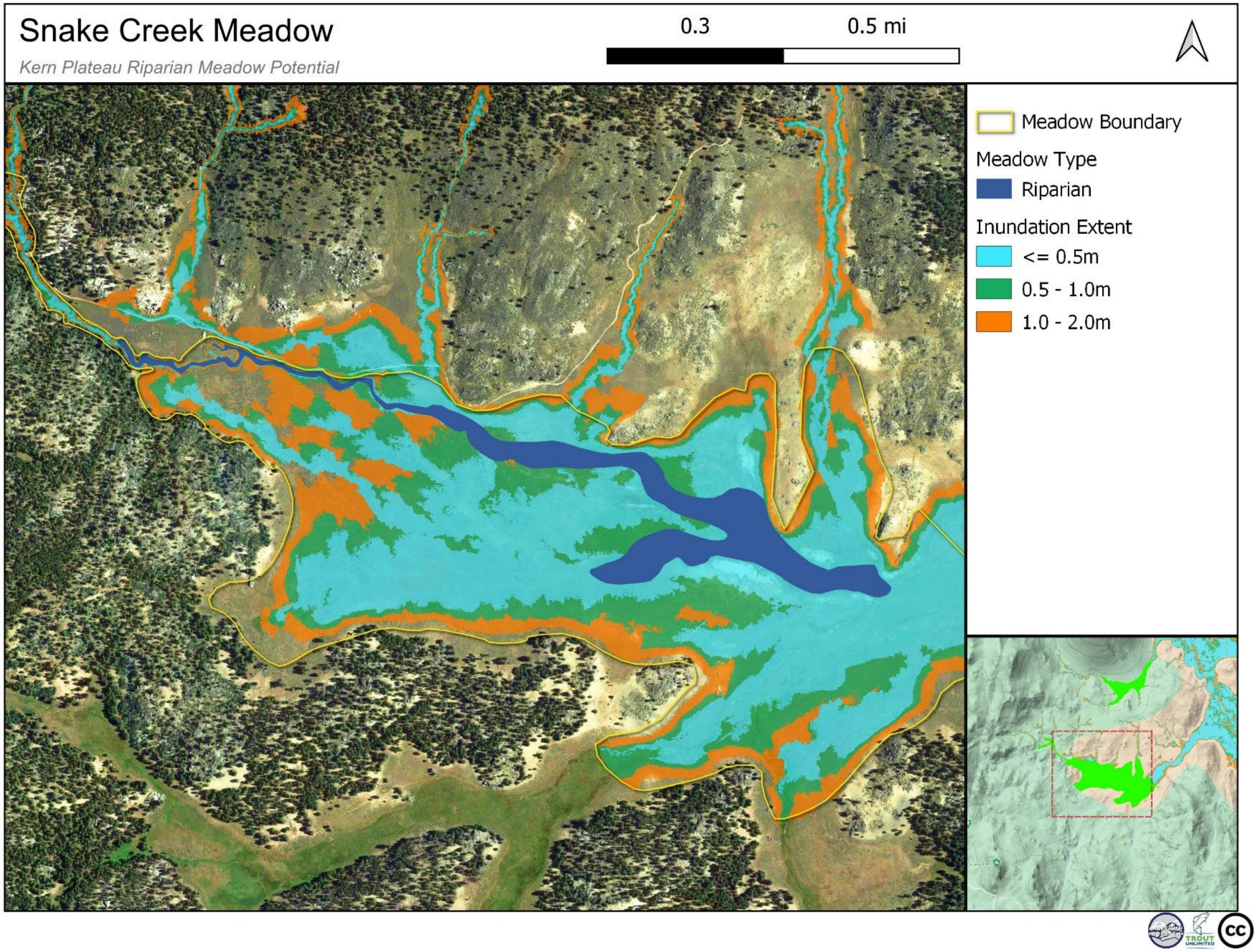

Figure 62. Dark blue represents the current riparian meadow in Snake Creek Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

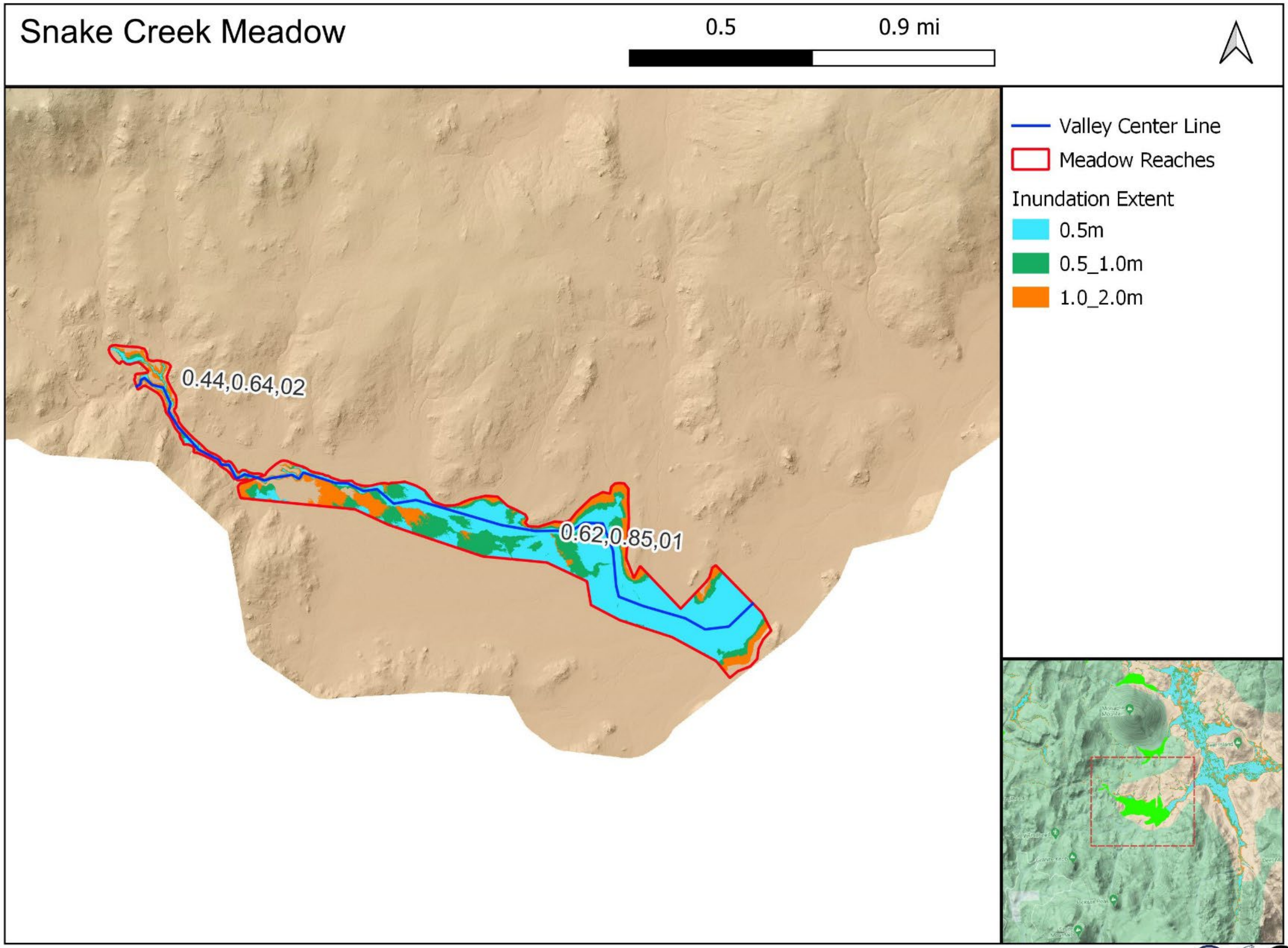

Figure 63. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Snake Creek Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.

CASA VIEJA MEADOW

Casa Vieja Meadow is the southwestern limit of the project and is the headwaters of Ninemile Creek which flows into the mainstem Kern River. A large portion of the meadow is subsurface meadow type with the majority of the remaining being riparian meadow type (Table 13 & Figure 65). The lower portion of reach 1 has high potential to convert to riparian if modest channel incision is mitigated (Figure 66 & Figure 67). Much of the remaining reach is currently riparian with large areas that can be inundated (Figure 64). Because incision is low and several discontinuous channels are found in this wet meadow, TauDEM was unable to correctly identify the main channel from 2 m resolution LiDAR data. In this area there are also numerous discharge slope springs and large areas of groundwater-mediated subsurface meadows feeding the main channel. A significant tributary enters from the northern edge of the meadow and joins the mainstem just before it goes into the steep canyon west of the meadow. The numerous tributary channels on all sides of the meadow have hydric sedges and bryophytes.

The headwaters of the meadow start in two wings at the eastern end of the meadow with a northerly (the larger) and southerly wing that have many discharge slope springs and seeps. Each wing has a small, moderate to high gradient channel which come together then turn west down a confined pinch point that then opens up into the larger main meadow at Casa Vieja. The north lobe has significant riparian potential if the incised channel were to aggrade (Figure 66).

Table 13. Acres and percent of total for each meadow type found in Casa Vieja Meadow.

Meadow	Acres	% Total
Casa_Vieja	**145.1**	**100%**
Discharge Slope	0.1	0%
Discharge Slope - Peatland	10.5	7%
Peatland - Mound	0.3	0%
Riparian	47.5	33%
Subsurface	86.1	59%
Upland	0.5	0%

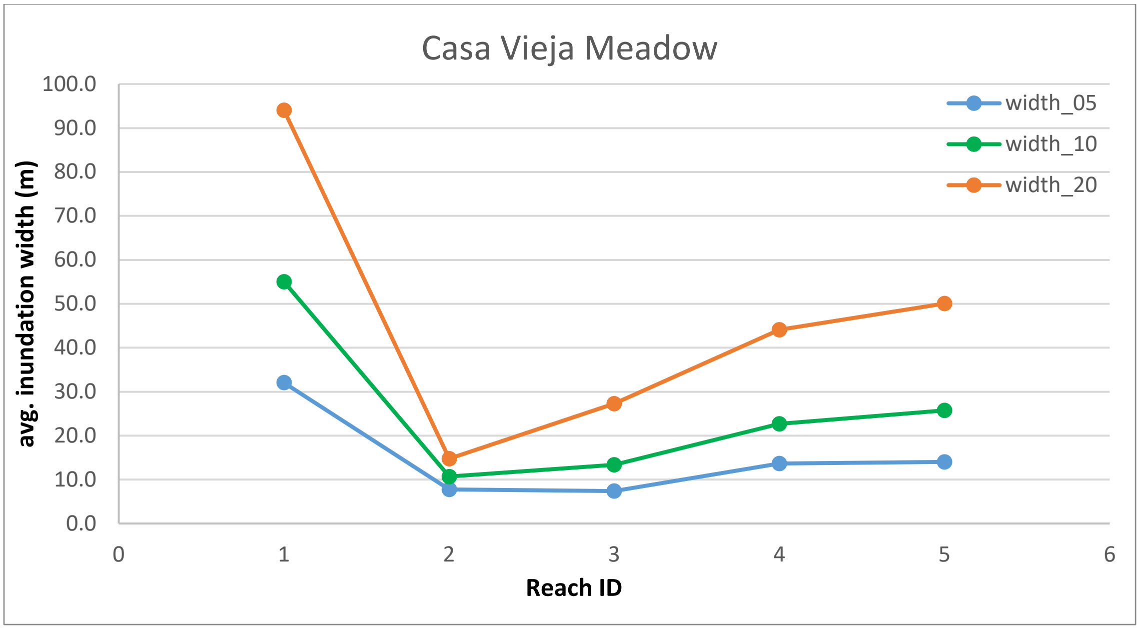

Figure 64. Casa Vieja Meadow integrated width (inundation area/length) of each geomorphic reach for 0.5 m (blue), 1.0 m (green), 2.0 m (orange) inundation extents.

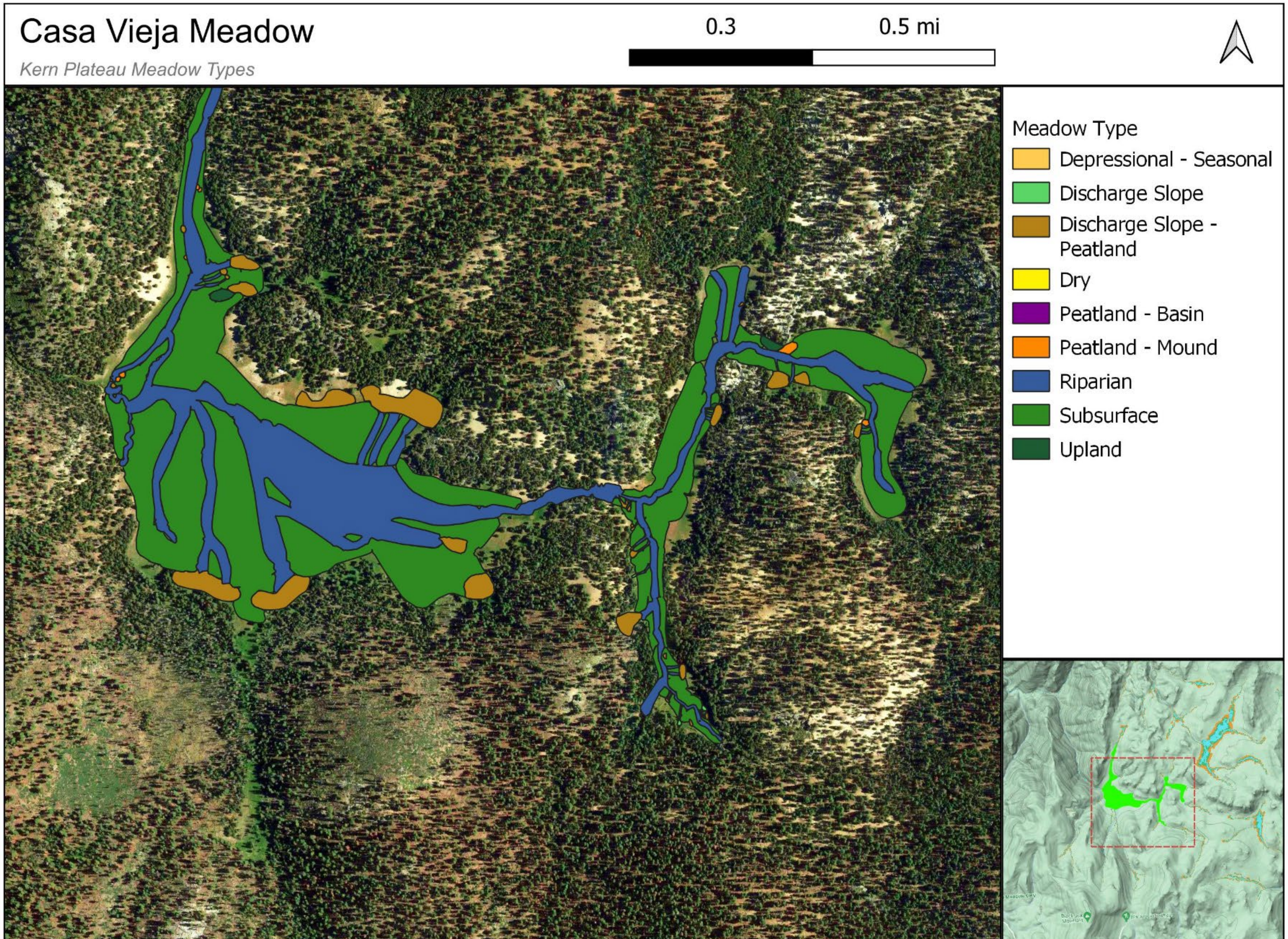

Figure 65. Distribution of meadow types in Casa Vieja Meadow.

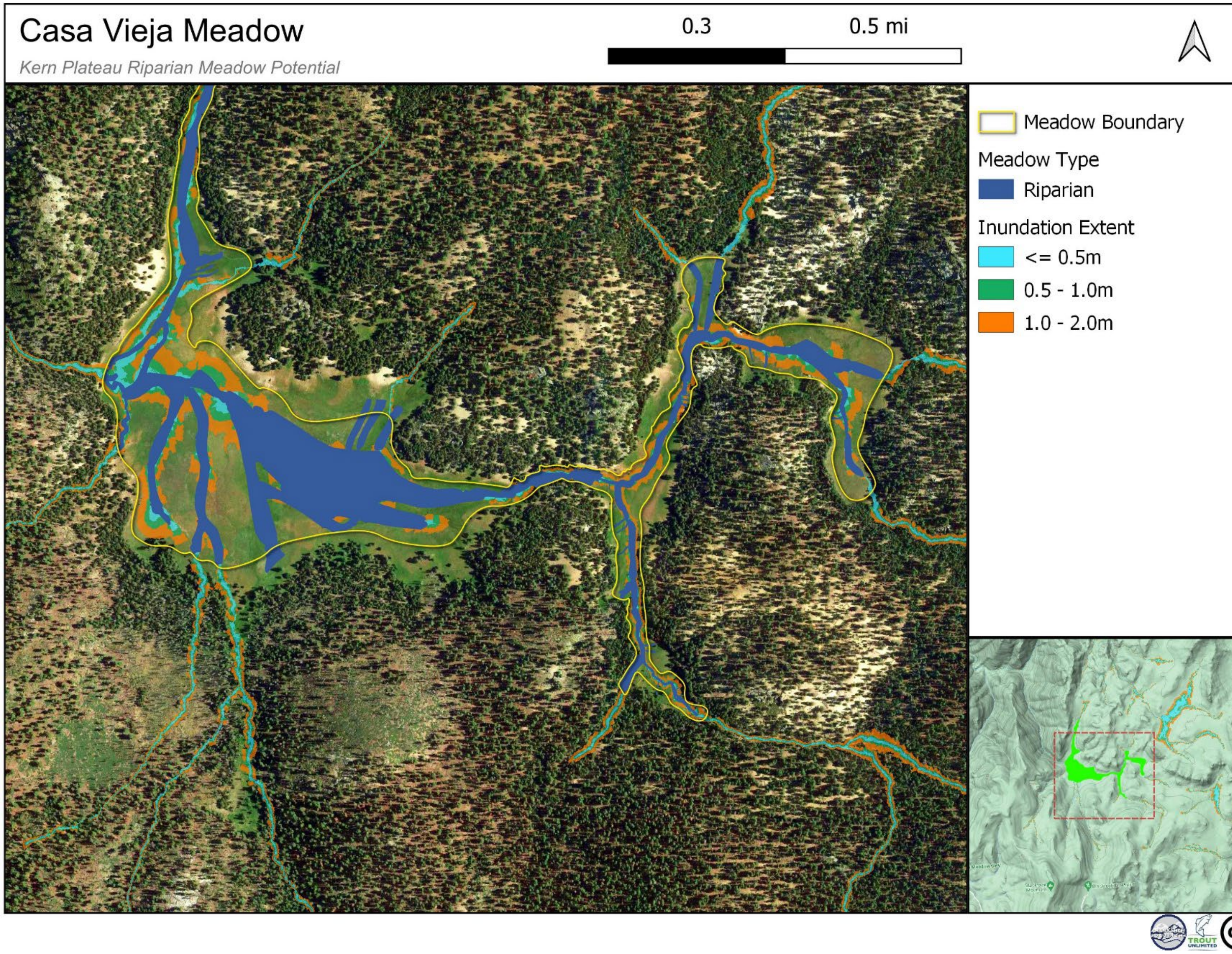

Figure 66. Dark blue represents the current riparian meadow in Casa Vieja Meadow. Riparian meadow potential, assuming a restored channel raises water surface elevations above the current incised channel, is the inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange).

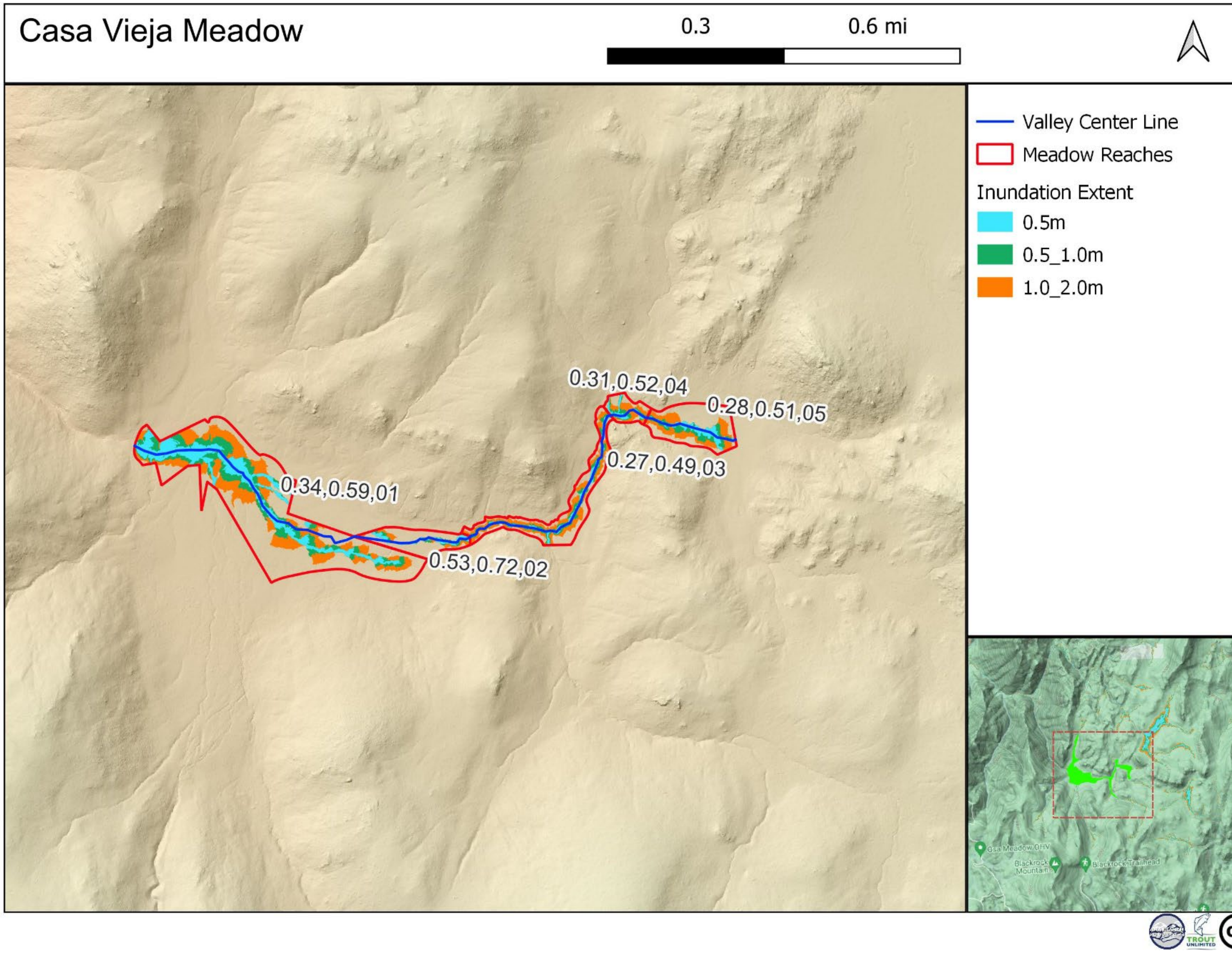

Figure 67. The inundation extent of the 0.5 m (light blue), 1.0 m (green), and 2.0 m (orange) for each geomorphic reach in Casa Vieja Meadow. The proportion of the 2 m extent filled by the 0.5 m, and 1 m extents, and geomorphic reach number are represented by the numbers in each reach, respectively.