Mountain Meadows Creek Restoration Project
90% Design Report

April 5, 2023

Jeanie Hinds & Jim Wilcox, Plumas Corporation

Background

The Mountain Meadows Creek Restoration Project encompasses 441 acres of meadow, 139 acres of montane riparian corridor and 252 acres of fuel reduction work in adjacent timberland. These lands are owned by RRF Westwood LLC. Active land management of the project areas is conducted by W.M. Beaty & Associates. The project area is located approximately six miles southeast of Westwood, CA, in Lassen County (Figure 1). In 2010, Beaty & Associates contacted Plumas Corporation, a meadow restoration group in Plumas County, to conduct data collection and design services for a suite of meadow restoration projects in the Mountain Meadows area, of which Mountain Meadows Creek is a part. The nearby Greenville Creek and East Creek projects were constructed in 2016 and 2019, respectively.

Design Approach

The design approach utilized for Mountain Meadows Creek applies the principles of fluvial geomorphology, the science of landscapes formed by flowing water, to understand the processes that have governed the development of the meadow through the Holocene period (last 10,000 years). This approach also helps identify possible mechanisms that have led to channel degradation and loss of floodplain connection/ecosystem function. The approach combines significant quantitative data with qualitative observation and historical overview of land uses, both onsite and watershed-wide. Further, this approach helps distinguish alternatives to restore lost connections/functions consistent with landowner and funder goals and objectives. As with most Sierran meadows, Mountain Meadows Creek has aggraded steadily through extreme multi-year droughts and floods in the above temporal period, based on observable features.

Geomorphic Setting and Qualitative Analysis

Mountain Meadows Creek occupies a complex alluvial fan in the southeast corner of the larger 7,000+ acres Mountain Meadows complex. Mountain Meadows, similar to numerous other valleys in the upper Feather River is the result of fault block processes of the Basin and Range geologic province to the east (Durell, 1987). These fault block valleys were Pleistocene lakes that have infilled/drained, then overlaid by alluvial sediments. These processes result in wide floodplain, low-gradient channel/meadow systems. The low energy environments of these valleys resulted in vegetated, resilient meadows, often with multiple channels. Railroad and road building, along with channel modification for drainage and/or irrigation, have been the primary underlying causes for channel degradation.

The Mountain Meadows Creek alluvial fan historically functioned to meter basin-derived sediments through a series of “segments or steps” (illustrated in Figure 2) from two contributing basins, a small northern basin and the larger eastern basin (see Appendix A, Watershed Area Map). The larger basin is the source of episodic debris torrents from landslides, particularly off of Cairn Butte, the steep peak to the east. The smaller basin converges in the upper fan, generally following the fan/hillslope interface to the north. The upper fan segment consists of a mix of fine to coarse alluvium with pockets of well sorted cobbles (the cobbles were extracted for historic use, described in greater detail in the section that follows) . This segment has been mapped as the

Inville soil series, very gravelly sandy loam in alluvial fan settings. Historically, a network of distributary channels diverged in the upper fan, with periodic realignment from large wood and debris torrent processes. The distinct metering from medium to large cobble (4"- 8") at the upstream end to medium gravel/small cobble at the downstream margins, illustrates that this upper fan segment historically removed substantial material and energy from the system. In the early 1900s, a complex of historic railroad grades intercepted, combined, and re-aligned these channels into a "main" channel in the northeast corner. Subsequent modifications for irrigation purposes have resulted in further degradation and concentration of flow in this flowpath. Once incision began to change the hydrology, the vigor and resilience of the vegetative community to hydraulic stresses, livestock use, and other manipulations diminished significantly (Photo 1).

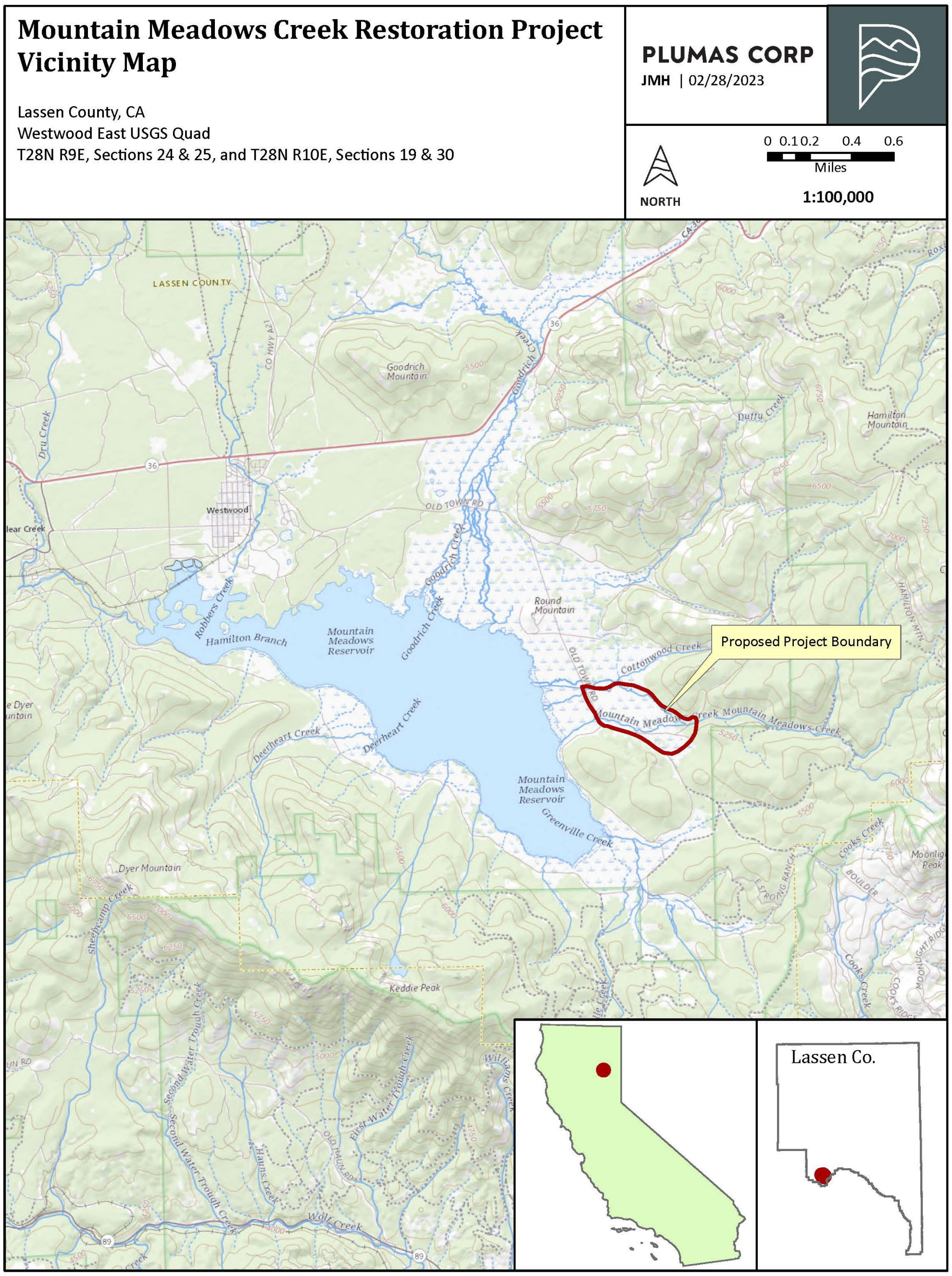


Figure 1: Project Location Map

The middle fan step is comprised of a mix of smaller gravels, sands and loam. Through this step, soils are mapped as Dotta gravelly loam soils. The middle fan segment has been subjected to channel manipulation for irrigation and to avoid erosion sites. The lower fan step continues transitioning to Dotta gravelly loam, high water table soils. The western (downstream) third of the project is a much lower gradient, fine grained alluvium over lacustrine deposits, typified by the hydric, Mountmed loam soils present.

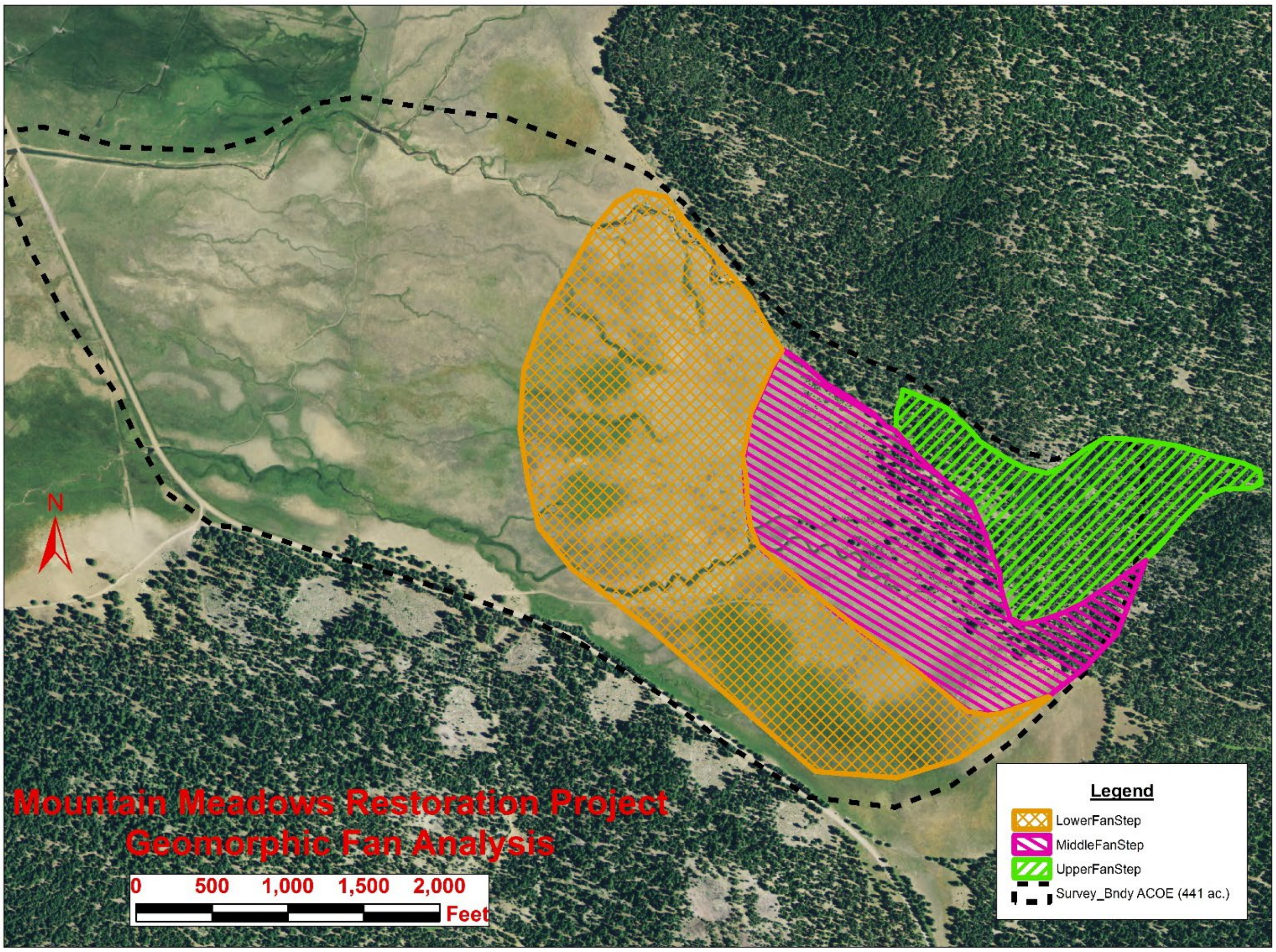


***Figure 2**: Geomorphic Fan Map*

Photo 1: *Foreground shows former wet meadow area that has become dominated by xeric species.*

Quantitative Analysis

The 441-acre meadow area and 139-acre montane riparian area were, historically, a multiple channel system. Legacy land use impacts have resulted in an active, deeply incised channel that follows the north edge of the alluvial fan/boundary of the meadow (see Photos 2 and 3). The downstream portion of this channel has been historically dredged and re-purposed to carry irrigation return flows and groundwater discharge to a bridge on Moonlight Road, which serves as draft point for water trucks working at dust abatement (Photo 4). Two deeply incised channels in the center of the fan are disconnected from the current active flow (Photo 5). These features all show signs of direct human alteration (e.g., levees and culverts), likely to facilitate drainage of the meadow for early season use, then later to convey irrigation water to extend seasonal productivity. Concurrently, the construction and maintenance of a network of railroad logging grades across the fan also disrupted channel processes. Additionally, the pockets of concentrated 3”- 6” cobbles described in the Geomorphic Setting section above were excavated (mined) for ballast rock for the railroad tracks. These excavated pits provided material far in excess of the immediate local need. These pits were concentrated in the northwest portion of the upper fan step. One of the larger depressions has created scrub-shrub riparian habitat that seasonally contains ponded surface water.

Fifteen valley-wide cross-sections were surveyed perpendicular to the axis of the alluvial fan/meadow. These cross-sections have been plotted and appended to this report (see Appendix A for maps; Appendix B for paired existing and proposed). **All cross-sections are viewed with left and right looking downstream.** A longitudinal profile was developed using data from the valley-wide cross-sections. These cross-sections guided practitioners to the conceptual design level. LiDAR data, acquired and funded through a grant from the California Wildlife Conservation Board’s Forest Conservation Program, was synthesized into a Digital Elevation Model (DEM), which was used for final design development, flow line analysis, and development of a HEC-RAS model of 10- and 100-year flows under existing and project conditions.

All cross-sections were analyzed for the morphological attributes of the principal features in the project area: width, depth and cross-sectional area of the incised channel(s), road(s) and the remnant channel(s), as well as the effective floodplain width. This data is summarized in Table 1. Erosion of the active gully channel, the two abandoned gully features and inset roads has removed approximately 428,000 yds^3 of meadow soils. It will require excavation and placement of approximately 214,000 yds^3 to partially fill (plug) the gully and road features using material borrowed from onsite borrow areas. The main incised channel/floodplain has an average width of 150 ft. with an average max depth of 7.0 ft. The average width of the historic floodplain is 1,368 feet.

Table 1. *Data Summary Values*

MOUNTAIN MEADOWS CREEK CROSS-SECTION DATA SUMMARY - 2021								
X-section #	Gully A (sqft)	Gully W (ft)	Gully D (ft)	ReCh A (sqft)	ReCh W (ft)	ReCh D (ft)	Flpln W (ft)	
1							400	
2				5	10	0.75	400	
3	85							
4	185	50	4.75				300	
5	1510	189	9	37	52	2	1000	3 gully/3 remn
6	1800	335	13.25	25	27	1.25	2200	3 gully/2 remn
7	1020	170	12.5	20	30	1.5	1700	2 gully/2 remn
8	605	111	8.5	32.5	83	1	1100	2 gully/2 remn
9	493	165	8.5	75	120	2.25	1089	2 gully/3 remn
10	485	255	7	65	89	0.75	1200	2 gully/2 remn
11	210	100	4.5	40	24	2	2400	1 gully/2 remn
12	115	110	2.5	10	15	0.75	1600	2 gully/1 remn
13	135	132	2.5	15	20	1.25	2200	2 gully/1 remn
14	80	42	4	20	32	2.5	2200	1 gully/1 remn
Average:	**560.3**	**150.8**	**7.0**	**31.32**	**45.64**	**1.45**	**1368.38**	
Reach	Length (ft)	Volume (sqft)	Void (cu. yds)	Fill (cu. yds)				
Mtn Meadows	20,662	560.30	428,775	214,387				

Photo 2: *Active gully in the vicinity of X-section #6*

Photo 3: *Main gully near cross-section #7*

Photo 4: *Active gully at Moonlight Road bridge, looking upstream. Note dredge spoil 'levees' to either side*

Photo 5: *Typical abandoned gully in the middle fan step. Bottom vegetation is supported by seasonal groundwater discharge.*

Design Narrative

The project area landowner, RRF Westwood LLC, through its land management agency, WM Beaty & Associates, requested assistance from Plumas Corporation to implement restoration of the Mountain Meadows Creek Project area. The purpose of the restoration is to improve the ecological function and productivity of the meadow by restoring the channel-floodplain connection. Plumas Corporation staff began surveying design-level cross-sections in collaboration with the landowners and other local stakeholders in 2018.

Through discussions and site visits with WM Beaty & Associates and Plumas County Fire Safe Council Staff, Plumas Corporation expanded the scope of the meadow restoration to include forest health and hazardous fuel reduction treatments in the forest adjoining the meadow and in the upstream riparian corridor. The adjacent forest was characterized by an unhealthy forest structure with an accumulation of ladder vegetation and ground fuels, which increases the risk of catastrophic fire, forest mortality, and fire-related water quality impacts. Along the remnant channel and forested floodplain, relict patches of gallery riparian forest are present, including decadent black cottonwood, alder, and willow. Regeneration had been limited by substantial conifer encroachment across the floodplain. WM Beaty & Associates developed timber harvest prescriptions to improve forest health and provide strategic fuelbreaks for the surrounding forest and riparian corridor. For the smaller trees encroaching the meadow, Plumas Corporation proposed conifer removal via mastication on the upper and middle fan steps as part of the overall meadow restoration design. After these features were proposed and incorporated into the design, the 2021 Dixie Fire burned through the upper portions of the project with varying intensities (Photo 6). As a result, forestry treatments have shifted to a salvage and reforestation focus.

Photo 6: *Looking south at forest conditions in the watershed upstream of Mountain Meadows Creek, post-Dixie Fire. Merchantable fire-killed trees will be salvaged, with the remainder being removed and chipped for cogeneration. Seedlings will be planted thereafter.*

The Mountain Meadows Creek Restoration Project design proposes to restore the hydrologic function of the channel/floodplain system and its attendant ecosystem benefits through partial fill of the active incised channel, the two abandoned incised channels, and inset road segments. In addition, portions of the active incised channels that will continue to function as channel will have riffle augmentation treatment (both rock and sod riffles) to achieve restored base level goals. Fill material would be excavated from approximately 37 borrow ponds and an area of terrace cut. Riffle material will be comprised of a locally-sourced rock/soil mix and on-site meadow sod, depending on location. Mountain Meadows Creek is a low gradient channel with a slope of 0.5%, representing low risk of potential re-incision. All features of the meadow design are presented in a plan view Design Map series (see Figure 3 and Appendix A).

The principal function of the borrow ponds is to provide native fill material for plug construction (gully fill). Additionally, ponds will serve the function of dispersing flows from the main incised channel into a remnant channel network at two key locations. The borrow areas will fill with groundwater and maintain some ponded water year-round; accordingly, habitat features and diversity are incorporated into their construction. These features include varying water depths, islands, peninsulas, basking logs, etc., which are developed as fill needs are met. During excavation, topsoil is removed and stockpiled adjacent to the fill zone to top dress the completed fill. When available, native sedges and grasses from the impacted channel are saved and re-planted on the surface of the newly-constructed fill areas.

The fill areas and borrow ponds are sited and configured to accommodate surface and subsurface throughflow as well as adjacent hillslope-generated surface and groundwater inflows. This reduces the risk of re-incision through either fill or native soil during infrequent, short duration flood events. The downstream edges of the fill are also heavily planted with sedge mats recovered from the gully bottom prior to filling.

The fills are constructed with wheel loader(s) to provide wheel compaction of the fill material. The compaction levels are intended to match the porosity/transmissivity of the native meadow. This allows moisture to move freely within the fill soil profile and support erosion resistant meadow vegetation for long term durability as well as preventing preferential pathways for subsurface flows either in the fill or the native material.

Riffle augmentation will be used in both the main channel at the bottom (northwest) end of the project area and in a swale along the southern edge of the meadow. Riffles will be used to raise the base level of the channels in their existing alignment. In the main channel, riffles will be comprised of a rock/soil mix at frequent intervals (~50 ft.) to maintain 0.20- 0.30 ft. of head differential per riffle. Use of riffles in this location allows for a transition of the new meadow gradient to the existing grade at the downstream end of the project, while maintaining existing anthropogenic uses of the channel at the downstream end of the project. In the swale, stockpiled meadow sod from borrow areas will be placed within the channel to maintain the same degree of drop (0.2-0.3 ft) per riffle.

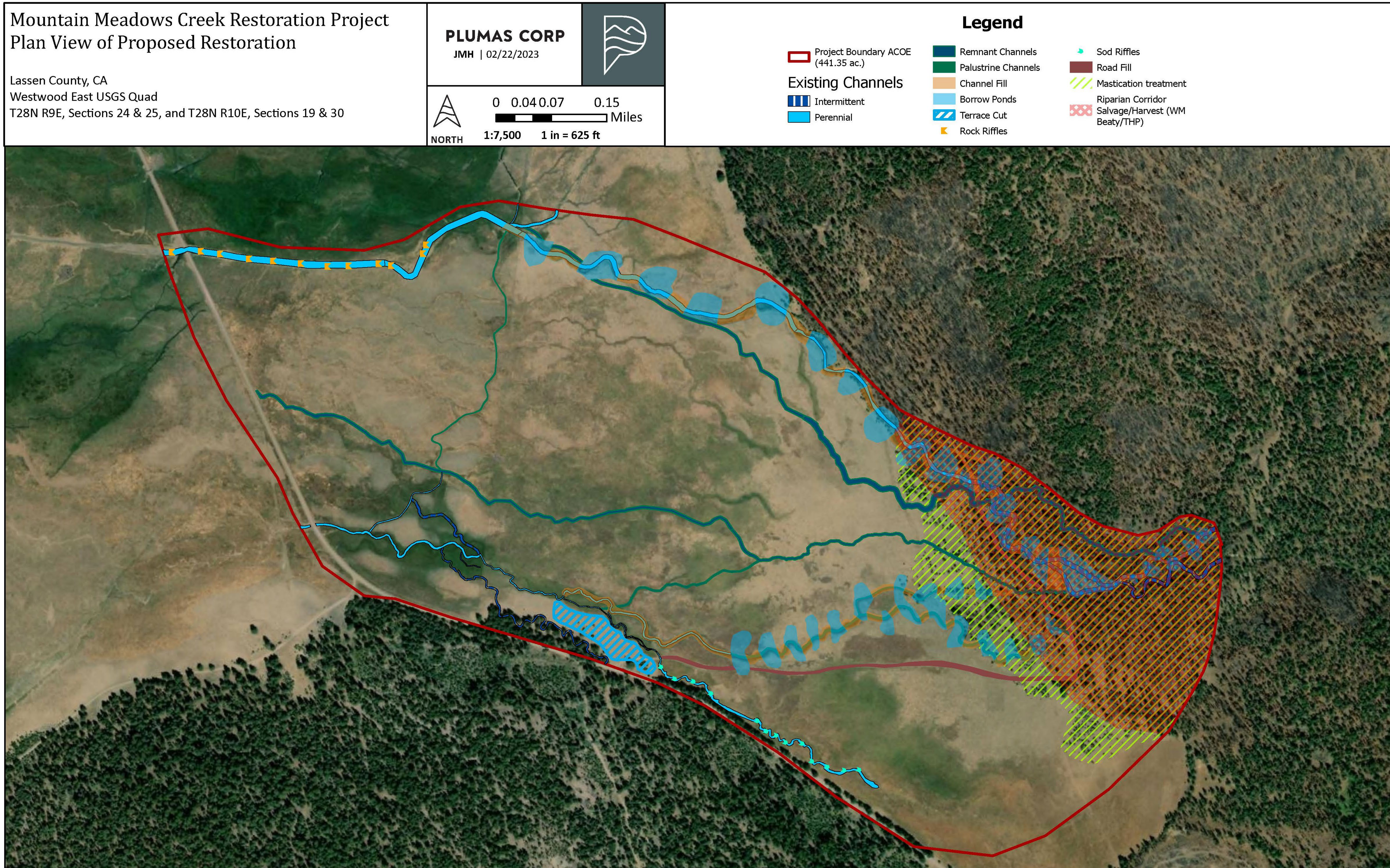


Figure 3: *Plan view map of proposed restoration design within the meadow project area boundary.*

Construction

Construction would require approximately 11 weeks during the low flow period (typically between August 1 and October 30, currently proposed for August 1 through October 13, 2023). Only incidental diversion of water will be required during Project construction (stream segments will be temporarily dewatered, with flows re-routed around the work zone or pumped into remnant channels), in the lower reach of stream channel during riffle construction or placement of lower fills.

The Project will require one full suite of equipment throughout the duration of construction and an additional suite of equipment for half the construction period. This equates to 2.5 excavators (one 36"-bucket and one 48"-bucket full-time and one with 48"-bucket for half the duration); 1.5 wheel loaders with 4+ yard buckets (one loader full-time, the other loader for half the duration); 1 track loader with 4-in-1 bucket full-time; and 1.5 water trucks (one water truck full-time, the other for half the duration).

Best Management Practices

The project includes the following procedures for the protection of the environment. These design criteria were incorporated into the project based on recommendations from resource surveys and reports conducted in 2021:

(1) Project implementation will be conducted during the dry season when flows are minimal or absent (typically August 1 through October 30).

(2) Work areas will be isolated from flowing waters through use of pumps to route flows around active earth-moving activities. Any trout found in work areas would be relocated to suitable locations in the watershed. Plumas Corp staff member Leslie Mink, who has a valid Scientific Collecting Permit for Inland Fisheries, will supervise any fish relocation activities.

(3) Existing vegetation (meadow sod and riparian shrubs) in disturbance areas will be salvaged and replanted in appropriate locations throughout the Project area.

(4) All work will be conducted in accordance with the Construction General Permit and a site-specific Stormwater Pollution Prevention Plan (SWPPP). Fugitive dust will be controlled with the continuous operation of water trucks throughout the work area.

(5) A spill kit will be kept in proximity to active work areas.

(6) Surveys for greater sandhill crane and northern goshawk will be conducted if work is planned to begin prior to the limited operating periods (LOPs) of August 1 and August 15, respectively.

(7) A third-party biologist will be retained to conduct protocol surveys for Sierra Nevada yellow-legged frog (SNYLF) in spring 2023. If any SNYLF are detected, the Lead Agency and Project proponent will ensure the permitting agencies are notified so that State and Federal consultation can proceed prior to Project implementation.

(8) The Project proponent will coordinate with the California Department of Fish and Wildlife on gray wolf activity in the Project vicinity. A site-specific LOP may be required if wolf activity is detected within 2 miles of the Project; specific LOP requirements will be dependent on the nature of wolf activities in the project vicinity (e.g., rendezvous site vs. den), presence of mitigating natural geographic barriers, and habitat conditions during time of construction.

(9) Pre-construction surveys for the sensitive plant species *Penstemon sudans* (California Rare Plant Rank 4.3) will be conducted and any occurrences will be flagged for avoidance.

(10) All staging areas shall be surveyed for noxious weeds and treated prior to work. Infestations will be flagged for avoidance and vegetation will be removed (hand pulled or dug with heavy equipment) and buried deep in the channel fill.

(11) Vehicles and other equipment operating in the project area shall be cleaned before entering the project according to standard vehicle washing guidelines.

(12) Known invasive plant infestations of ventenata grass (*Ventenata dubia*) and Canada thistle (*Cirsium arvense*) or newly identified infestations would be located, flagged where possible, and mapped for this project. Locations will be displayed on contract maps. Canada thistle sites within or adjacent to the project area containing isolated patches with small plant numbers would be treated (hand pulled or dug and buried deep under channel fill) prior to Project implementation. Canada thistle sites outside of the zone of equipment travel will also be treated with a black plastic overlayment, which reduces resprouting from rhizomes.

Revegetation

All disturbed areas will be seeded with a blend of native graminoids and forbs. Additionally, the project includes planting and fencing of up to 300 native shrubs in the riparian corridor, willow staking, and construction of cross-pasture fencing to implement grazing management changes that promote habitat quality in the meadow.

Other Alternatives Considered

Other alternatives considered include: 1) Organic structural components to raise base level via aggradation: Inflow to the top of the meadow is seasonal with a limited annual sediment supply from the upper basin. Beaver dam analogues (BDAs) or woody structures would be likely to deteriorate before being effective. Further, there are no beavers are in the area that could disperse to the project to colonize and maintain the structures, making this an unlikely strategy for achieving project objectives in either the short- or long-term; 2) Biomass incorporation into fill material: Trees removed from the surrounding forest could be chipped and incorporated into fill, reducing the volume and extent of borrow sites. This technique has been experimented with in the Sequoia National Park (Wolf et al., 2019), and has the potential to increase plant vigor where mineral soils are used for channel fill. This alternative was eliminated from further consideration because of the size of the gully void—the technique is not yet scalable to gullies as large Mountain Meadows Creek. Further, the small area of conifer removal/mastication proposed for the project will be provide woody material to spread on the soil surface, helping replenish soil carbon over a larger area relative to that achieved by incorporating chips into the gully fill.

Hydrology

Design Hydrology

The hydrology analysis entails a full regression analysis, basin area regressions and direct measurements of the identified historic channel. Regression analyses were calculated for three nearby gages to provide comparison and to “bracket’ the variability inherent in regression analyses. These values were used to develop a hydrologic risk analysis, presented in the following section (HEC-RAS analysis). The full computations of the comparative analyses are included in Appendix C. Regression analyses only project discharges. An equal, contributing input for channel dimension(s) is the character and volume of the annual sediment supply from the upper basin. Using flow regression analysis alone can often lead to incorrect channel design. As the sediment metering processes mentioned above reduce the weight and volume of sediments through the project area, channel dimensions would be expected to change. Usually quantitative data on sediment supply is non-existent. In lieu of reliable data, best professional judgement based on qualitative observation of numerous metrics is incorporated into the design process. Mountain Meadows is a seasonal stream, with inflow cessation between early- and late June depending on water year. Irrigation return flows from the main

Goodrich Creek ditch maintain some flow in the downstream 25% of channel, which is often drafted by water trucks for dust abatement. The project is not expected to result in perennial flow.

Table 2a. *Summary of Regression Analyses- Mountain Meadows Creek Project*

Reach Name	Q2	Q5	Q10	Q25	Q50	Q100	Method
Mountain Meadows Cr.	101	280	425	724	975	1368	Multiple Regression*****
	27.5	53	75	107	136	170	Area Reg.- Pine Cr.*****
	109	242	373	598	810	1067	Area Reg.- Hough Cr.*****
	126	272	412	655	884	1155	Area Reg.- Almanor.*****
StreamStats	97	244	399	654	909	1210	
Bankfull	167**						Cross-section

*Derived from Waananen & Crippen "Magnitude and Frequency of Floods in California", 1977
**Cumulative calculated capacity of all connected remnants.

HEC-RAS Analysis

The HEC-RAS analysis was performed by Pacific Hydrologic Incorporated (PHI) by Norman Braithwaite, P.E. The analysis utilized peak flows for the most probable 10- and 100-year storm events of 399- and 1210-cfs respectively identified using the USGS Streamstats noted above in Table 2a.

A two-dimensional (2D) backwater model representing existing conditions was prepared to provide a basis of comparison for evaluation of the project. The US Army Corps of Engineers' HEC-RAS v6.3.1 backwater program has been selected for the 2D backwater model. The model relied on 1-meter terrain data provided by LiDAR flown over the site in summer 2021. Terrain data representing channels was checked against surveyed cross-section data described herein. A single adjustment was made to terrain data in order to better represent the channel at the box culvert downstream of the project area. Overland flow roughness coefficients were derived from 2016 land cover from the National Land Cover Database (NLCD 2016) using values recommended in the HEC-RAS user's manual. The model was run in a quasi-steady state mode where flow was ramped up to the 100-year flood peak flow over a period of several hours then held steady at the design event peak flow.

The restoration project backwater model was prepared by replacing terrain data within the project area with a terrain data patch representing the project and re-running the model. The patch consisted of editing the LiDAR contours to eliminate the scoured channels and connect the floodplain on each side of the channels. Ponds and plugs were shown as flat grade across the channels to be removed. Detailed contours for the ponds were not included as the ponds will be full during the flood flows and operate as flat topography.

Conclusions

Review of the HEC-RAS analysis results was completed by VESTRA Resources, Inc., Susan Goodwin, P.E. An Engineering Review of the proposed project is provided in Appendix D. Based on the analysis, overall post restoration project reflects the reactivation of the floodplain with the spreading of the flows across the meadow and travelling at lower velocities. Figures representing the maximum depths and velocities for the 10- and 100-year storm events for pre and post project are included on Figures D1 to D8 in Appendix D.

The 10-year event existing condition shows that the water flowing through the area is contained within the scoured channels, mainly the northerly channel. The depths within the existing scoured channels are greater than 2 feet in depth. Only where Mountain Meadows main scour channel joins a northerly tributary do the 10-year flows access the floodplain. Within the project tributary area the floodplain is accessed within 1,000 feet of the roadway. Along the southerly portion of the project area there is almost no utilization of the floodplain. During the existing 100-year condition there is some additional spreading of flood flows along the remnant tributaries within the southerly portion of the project area. Also, the southerly scoured channel carries additional water at depths above 2 feet, which allows those flows to spread across the floodplain immediately above and below the roadway. The majority of the floodplain within the middle of the project area does not carry flow during either of the existing 10-year or 100-year events. The depths on the floodplain during the existing events generally range from less than 0.5 foot to approximately one foot.

Post project with the filling of the main scour channels on the north and south allows for the spreading of water across the entire floodplain at the base of the meadow which then sends the majority of the water across the middle and south portions of Mountain Meadows floodplain area with both the 10- and 100-year events. The depth of the 10-year event water across the floodplain is mostly less than one foot with some areas within the remnant channels approaching two feet. During the 100-year event, the flow spreads out even further across the floodplain. The remnant channels along the middle and south portion of the meadow direct a greater amount of flow to the southerly remnant channel where the depths reach two feet. The spreading of water across the floodplain also allows more water to access the culverts south of the bridge, thereby increasing the watered area downstream of the roadway. During the 100-year event, the entire area downstream of the roadway is covered with water at depths ranging from less than 0.5 foot to 1.5 feet.

Velocities for the 10-year existing conditions within the scoured channels reach 3.5 feet per second (fps) and average around 1-1.5 fps throughout the remainder of the area. The restored project within the remnant channels shows the velocities up to 2 fps with the increased flow in those areas but remain less than 1fps across the floodplain.

For the 100-year event, the existing condition scoured channels reflect velocities above 3 fps with the minimal floodplain flows of 1 fps or less. Post project with more flows accessing the floodplain, the velocities increase slightly along the remnant channels to 1.5-2 fps, but the floodplain remain around 1 fps. The southerly remnant channel sees the largest increase in flows and velocities. The model shows some localized areas 2.5 to 3 fps.

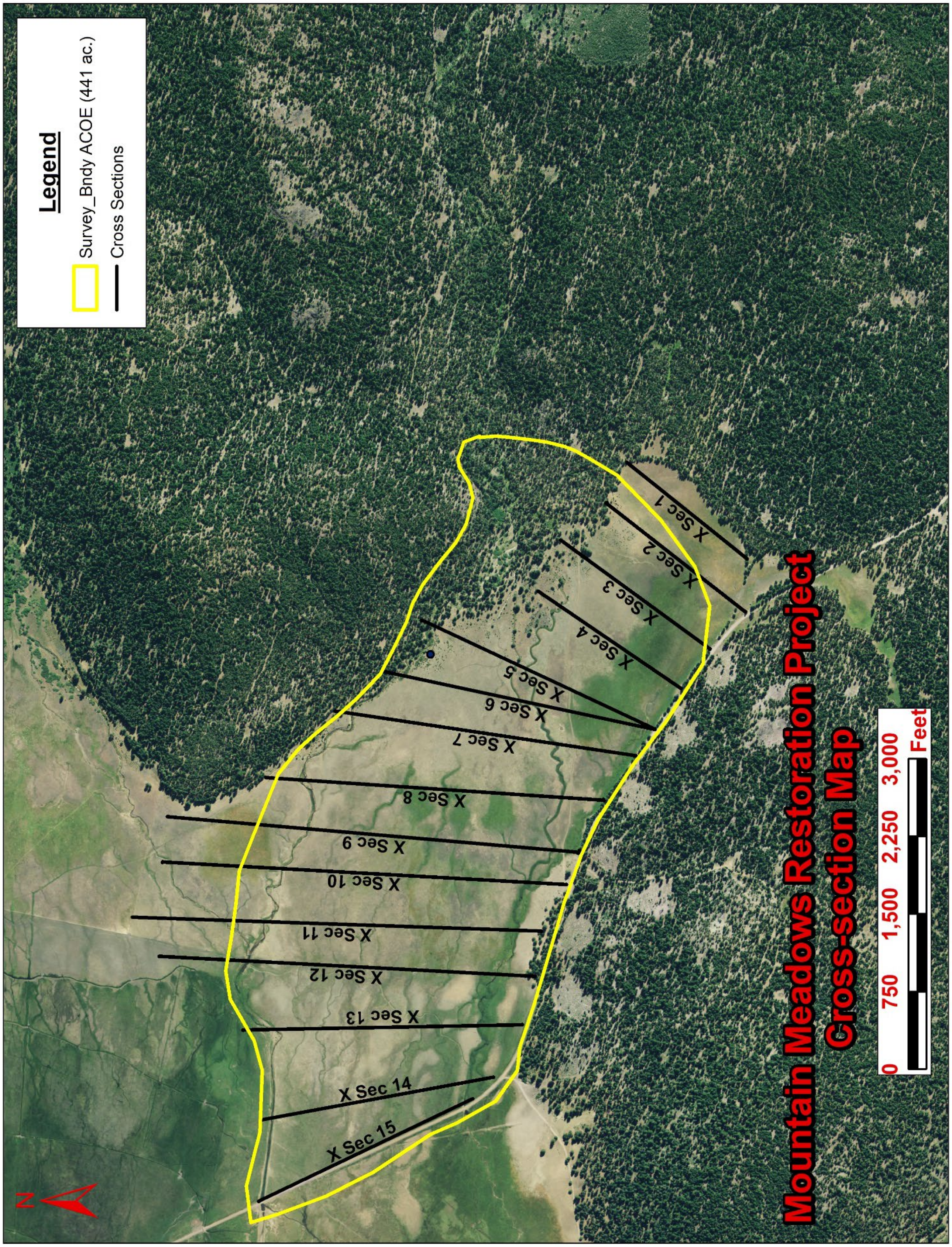
The potential for scour is based on the type of soils and cover of the area. The Caltrans Highway Design Manual lists Permissible Shear and Velocity for Selected Lining Materials. For exposed soils of loam and fine gravels the permissible velocities are 1.5 to 2.5 fps. Alluvial silt and graded loam/silt to cobbles are 3.75 to 4 fps. For vegetated channels of long and short native grasses the permissible velocities are 4-6 fps.

The southerly remnant channel that will see the highest velocities of 2-3 fps is fairly well vegetated with thick meadow vegetation. Based on the referenced permissible velocities of 4-6 fps, the chance of erosion of the remnant channel during the 100-year event is minimal. There is one area where the modeled velocity approaches 3.9 fps. The project can add additional erosion BMPs (e.g., using fully intact sedge mats salvaged from the gully bottoms) on the proposed sod riffles at this location to slow the water down in this area.

At the roadway and culverts both the 10-year and 100-year the capacity is exceeded for most of the culverts allowing the water to pond along the roadway and flow over the roadway in one location nearest the bridge at the 10-year and at additional locations working to the south during the 100-year event. Post project shifts the ponding and overflow locations to the middle of the meadow road crossing. With the spreading of the flow, the depth of flow across the roadway is reduced at the culvert immediately south of the bridge. The depth of flow across the roadway is less than 0.5 feet. The number of overflow areas does not increase with the project; the project just shifts the location away from the bridge and to the south. The velocities across the roadway for the 10-year event pre and post project are 1-2 fps, which is lower than the typical scour velocity of 2.5 to 2.8 fps. For the 100-year event, there is an area just south of the bridge where the velocities are at 3 fps. Post project shows the velocities of the flows crossing the roadway at 2 fps or less. Therefore, the project is not anticipated to have an adverse impact on the roadway. Based on the model and observations of the roadway culverts during site visits, no changes to the culverts or bridge are recommended at this time. The existing access running east/west through the meadow will be decommissioned as part of the restoration project using native materials, thereby eliminating the chance of the roadway becoming a conduit for flows during flood events.

The results of the analysis shown on the attached figures clearly show the benefits the restoration project will have on flood flows accessing the meadow. It also shows that the velocities of the water across the meadow will be low and not have an eroding impact on the meadow. The goal of the restoration project is to reactivate the floodplain in the meadow and the HEC-RAS analysis has demonstrated that this will occur.

APPENDIX A


Mountain Meadows Restoration Project
Cross-section Map
Legend
Survey_Bndy ACOE (441 ac.)
Cross Sections
X Sec 1
X Sec 2
X Sec 3
X Sec 4
X Sec 5
X Sec 6
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X Sec 8
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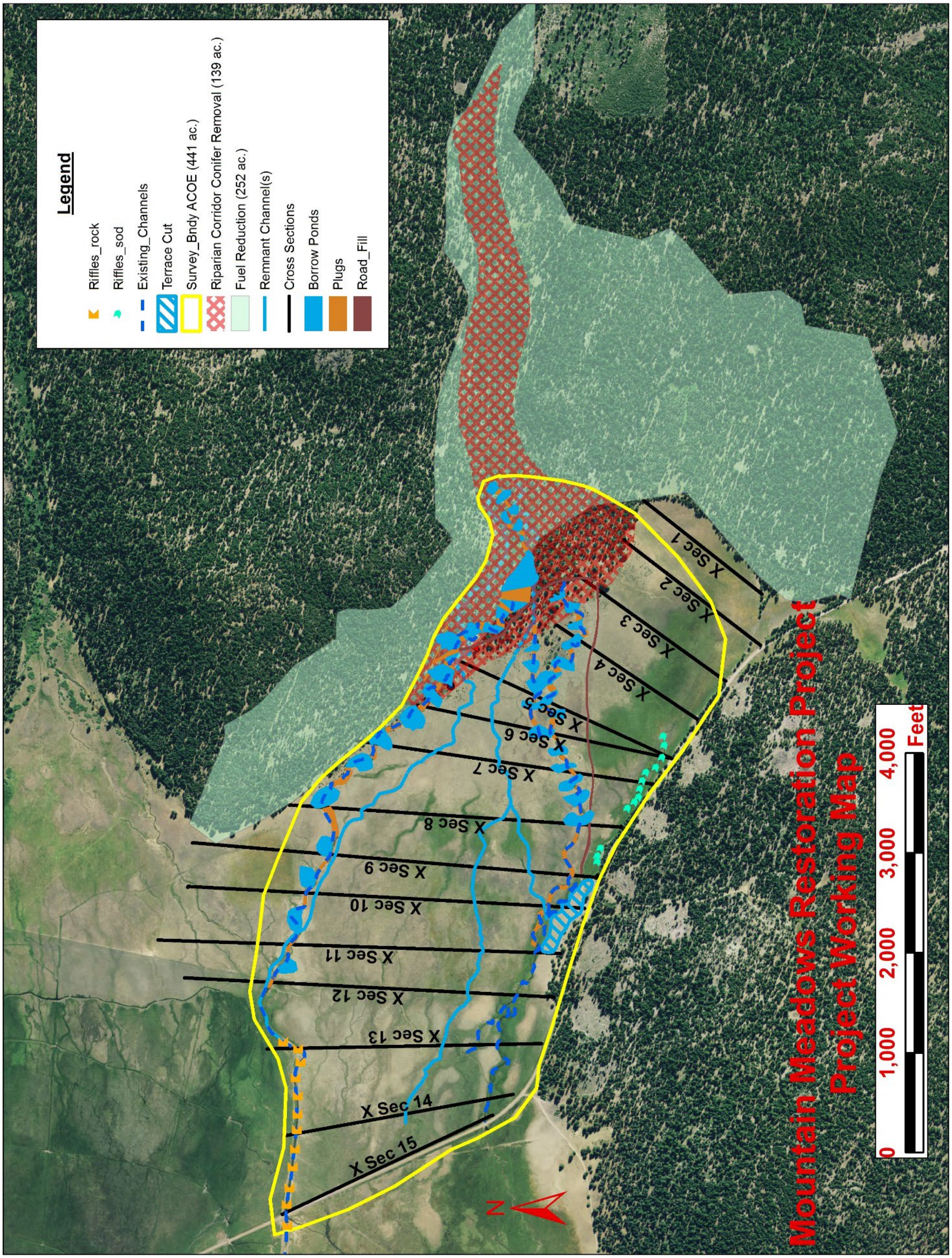
Legend
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Riffles_sod
Existing_Channels
Terrace Cut
Survey_Bndy ACOE (441 ac.)
Riparian Corridor Conifer Removal (139 ac.)
Fuel Reduction (252 ac.)
Remnant Channel(s)
Cross Sections
Borrow Ponds
Plugs
Road_Fill
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X Sec 3
X Sec 4
X Sec 5
X Sec 6
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Mountain Meadows Restoration Project
Project Working Map
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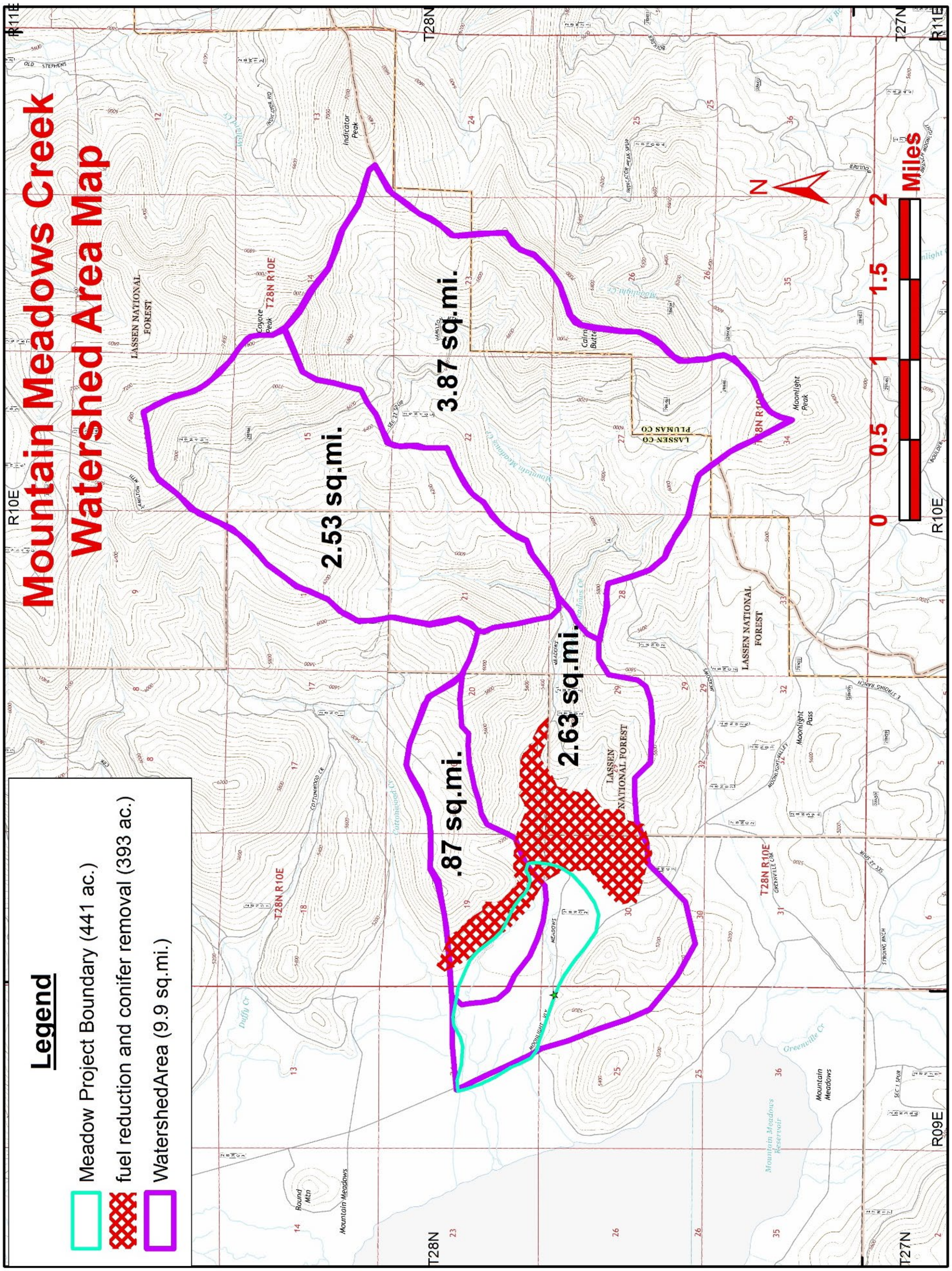
Feet


Mountain Meadows Creek
Watershed Area Map
Legend
Meadow Project Boundary (441 ac.)
fuel reduction and conifer removal (393 ac.)
WatershedArea (9.9 sq.mi.)
2.53 sq.mi.
3.87 sq.mi.
2.63 sq.mi.
.87 sq.mi.
N
0
0.5
1
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2
Miles
LASSEN NATIONAL FOREST
LASSEN CO
PLUMAS CO
Coyote Peak
Indicator Peak
Moonlight Peak
Moonlight Pass
Mountain Meadows Reservoir
T28N R10E
T28N
T27N
R10E
R11E
R09E

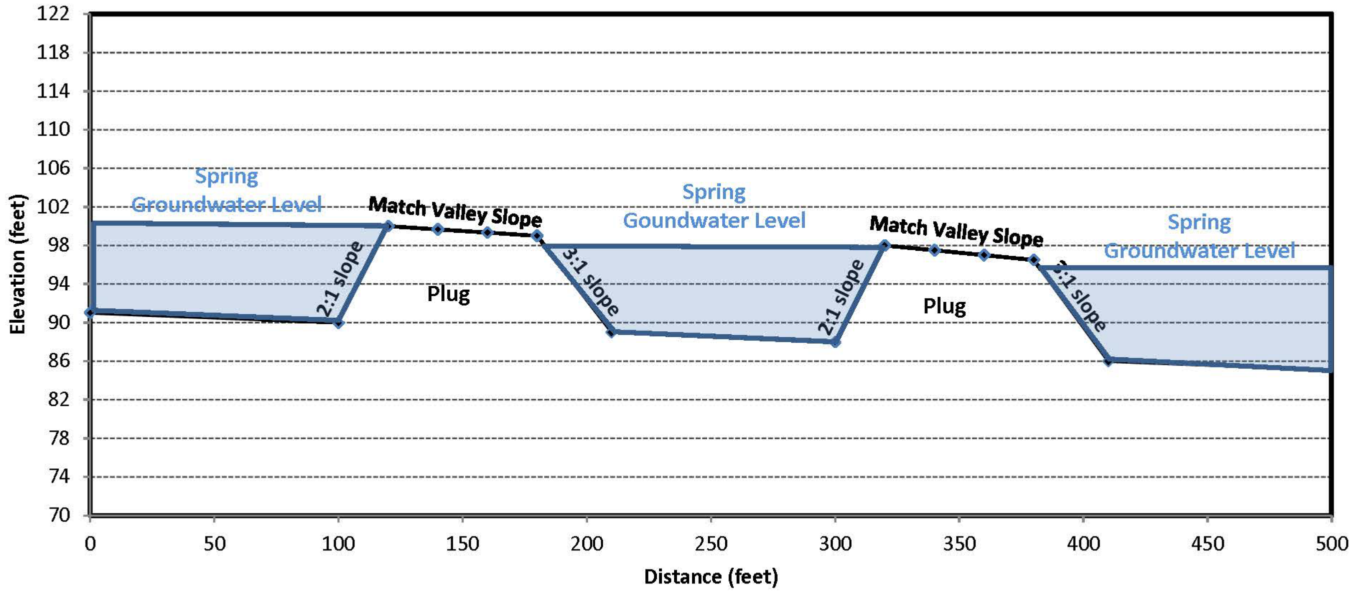


Figure A1. *Sample longitudinal profile of stream channel showing partial channel fill and seasonally (springtime) inundated unfilled sections of channel.*

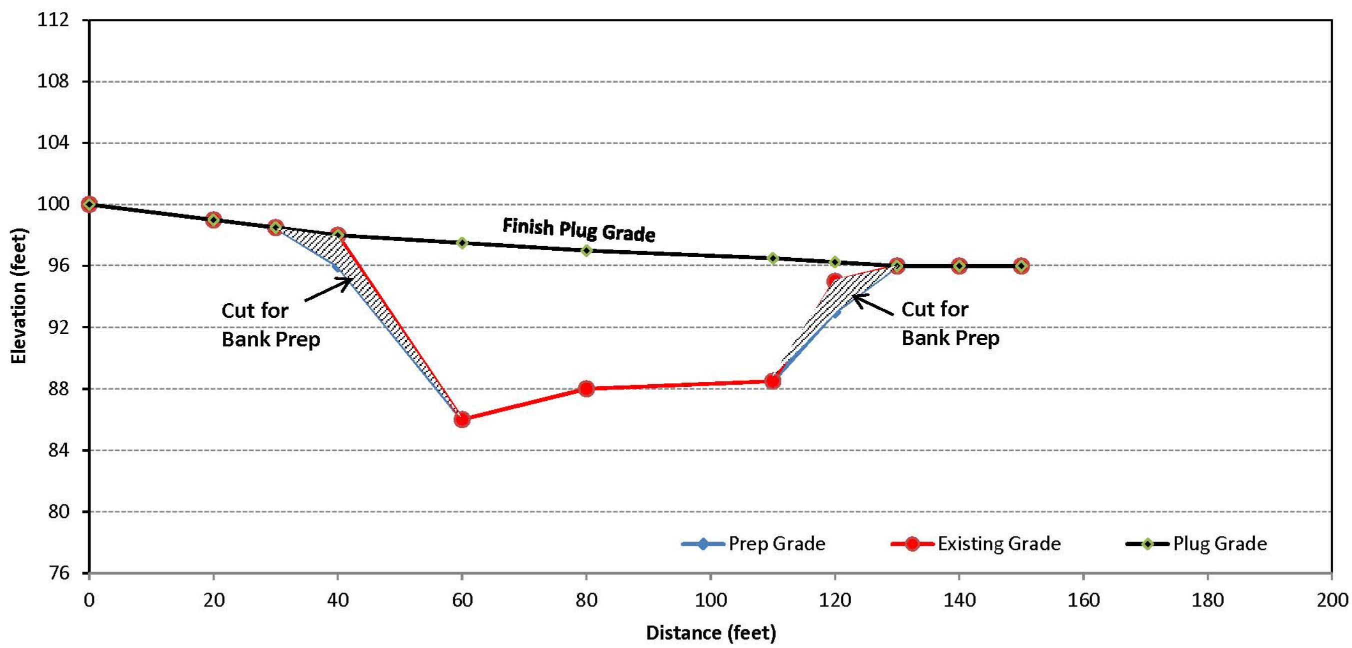


Figure A2. *Sample cross-sectional profile of stream channel showing channel fill detail*

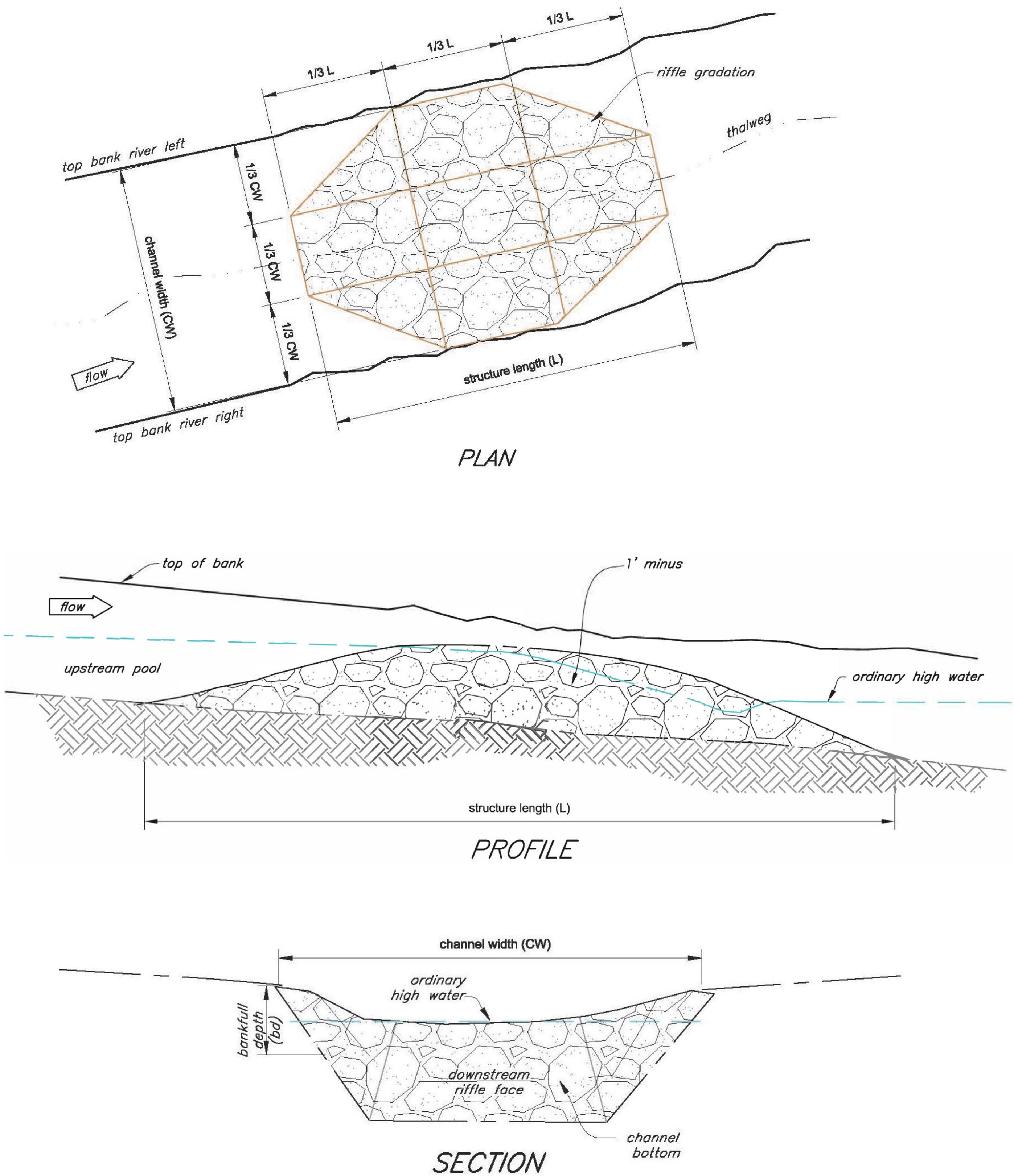


Figure A3. *Plan, profile, and cross-section views of representative riffle construction details. Drawings not to scale*. Credit: Vestra Resources, Inc.

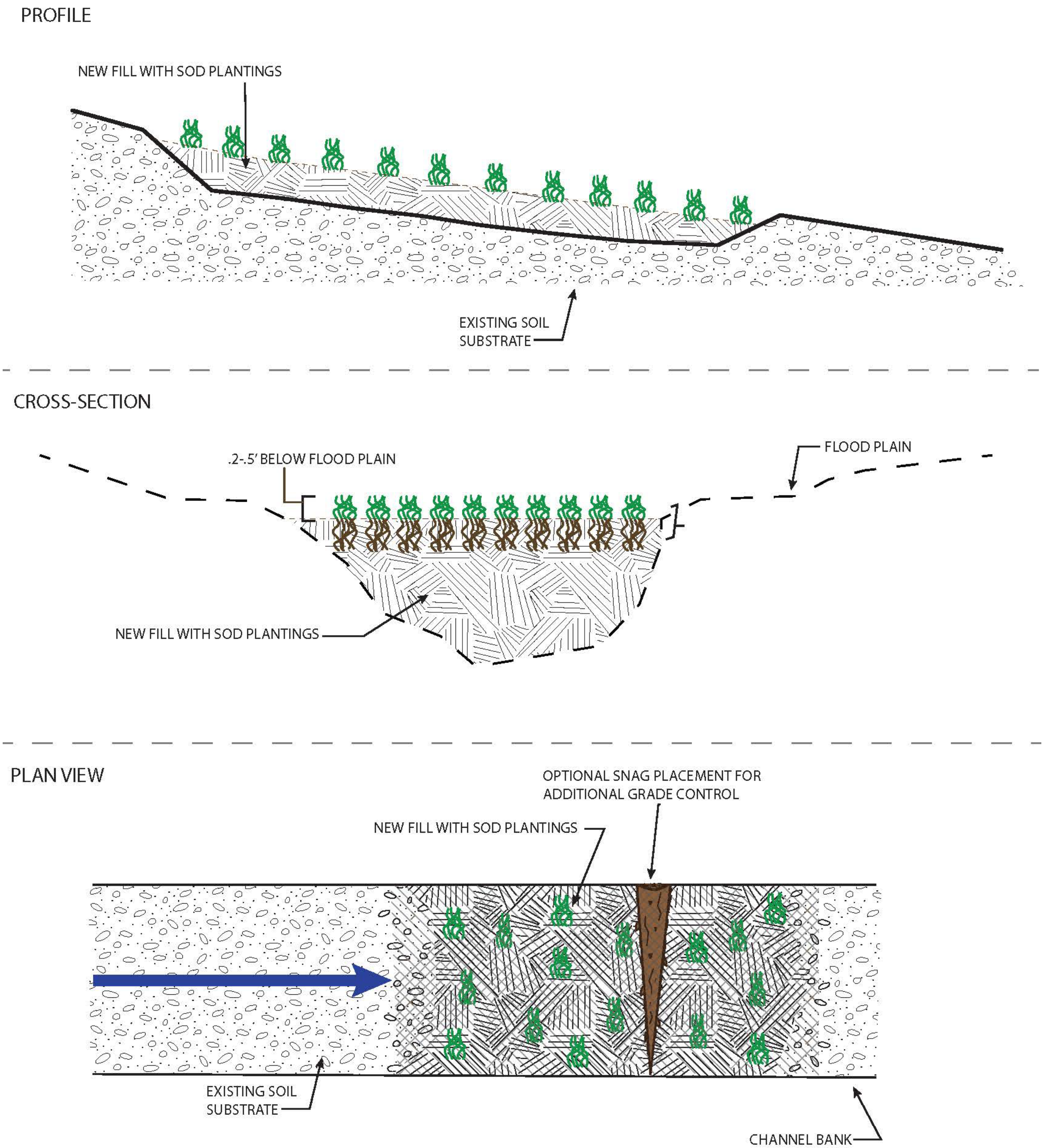
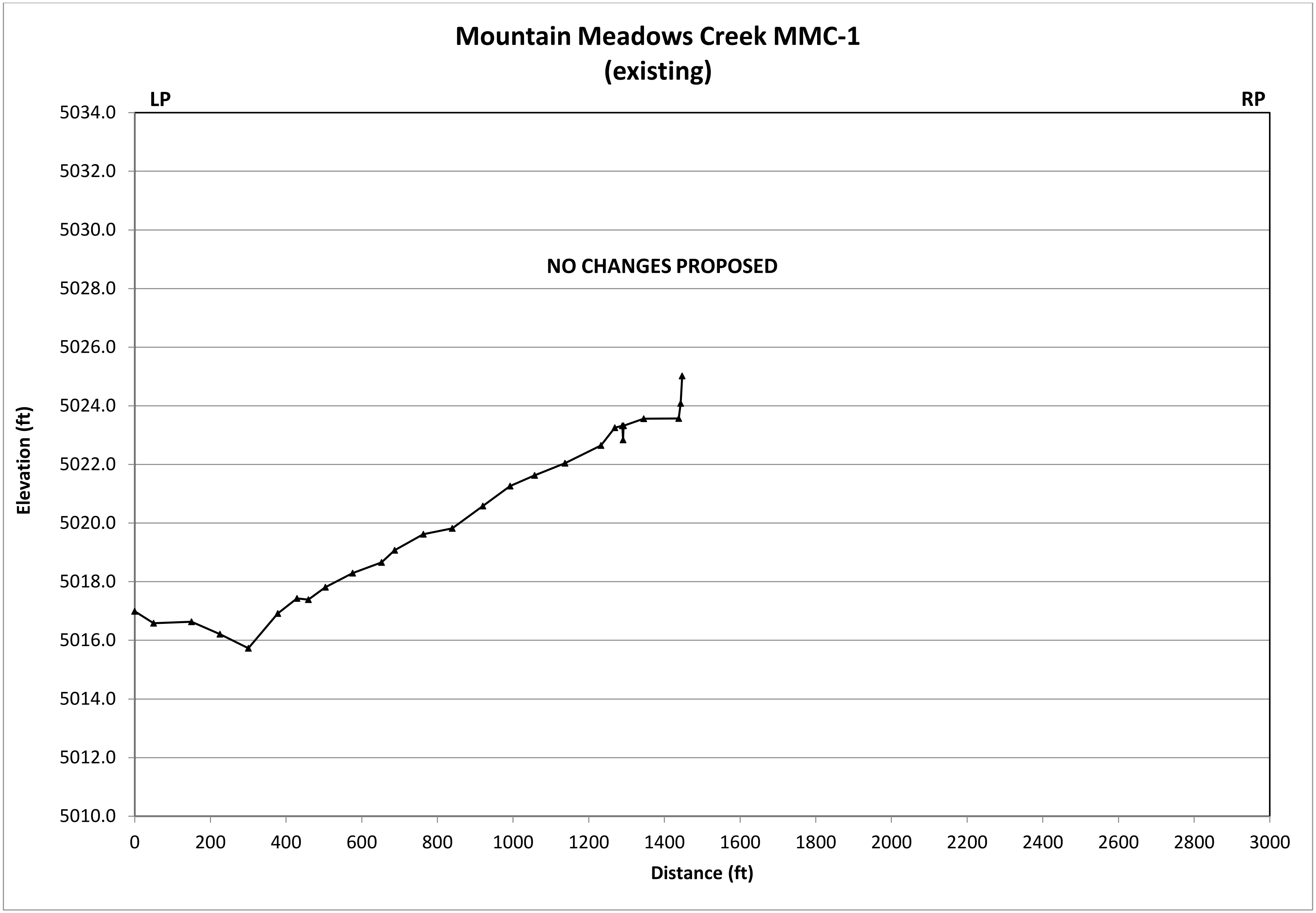


Figure A4. *Profile, cross-section, and plan views of representative sod riffle construction details. Drawings not to scale.* Credit: Modified from drawings prepared by Symbiotic Restoration.

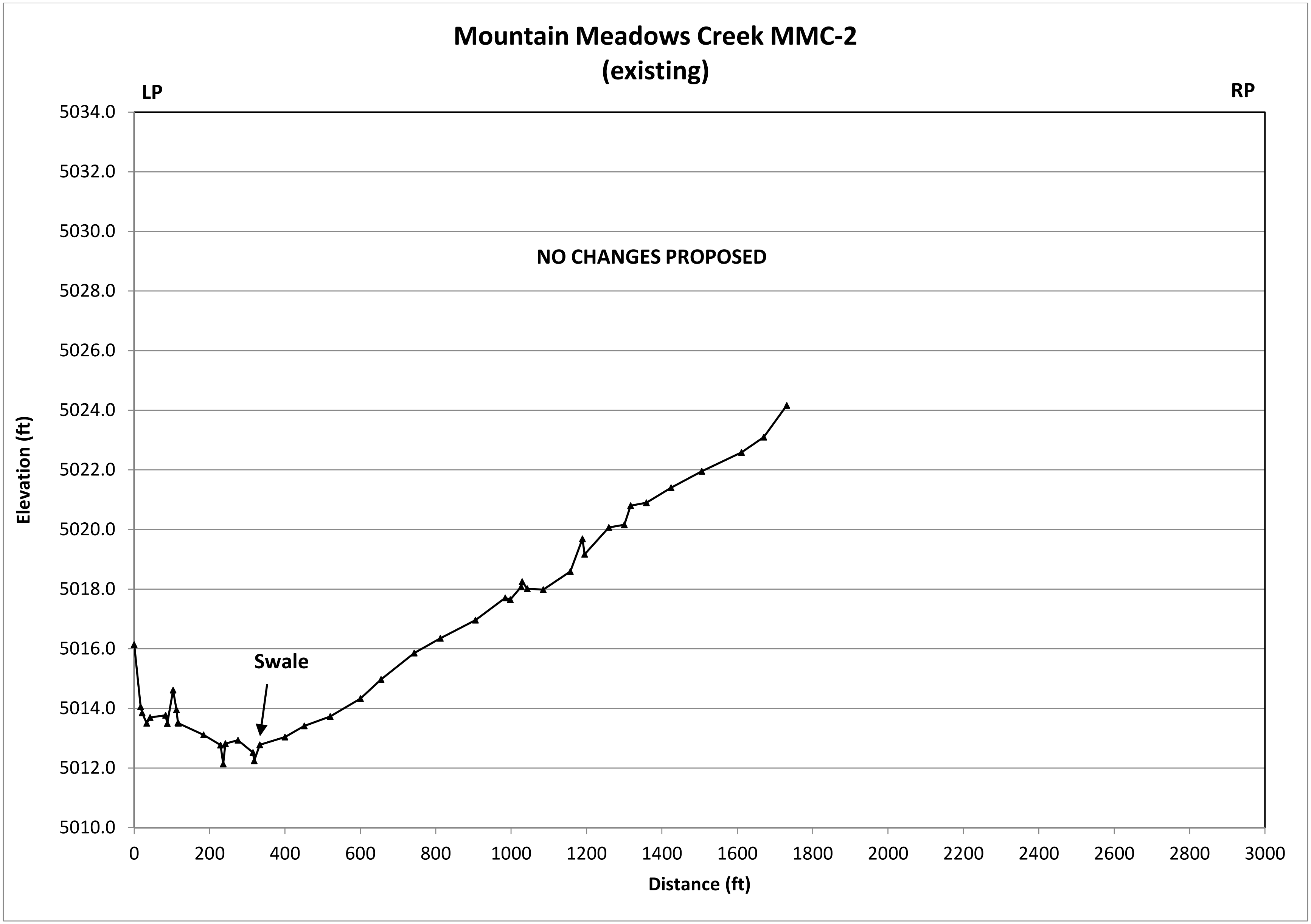
APPENDIX B

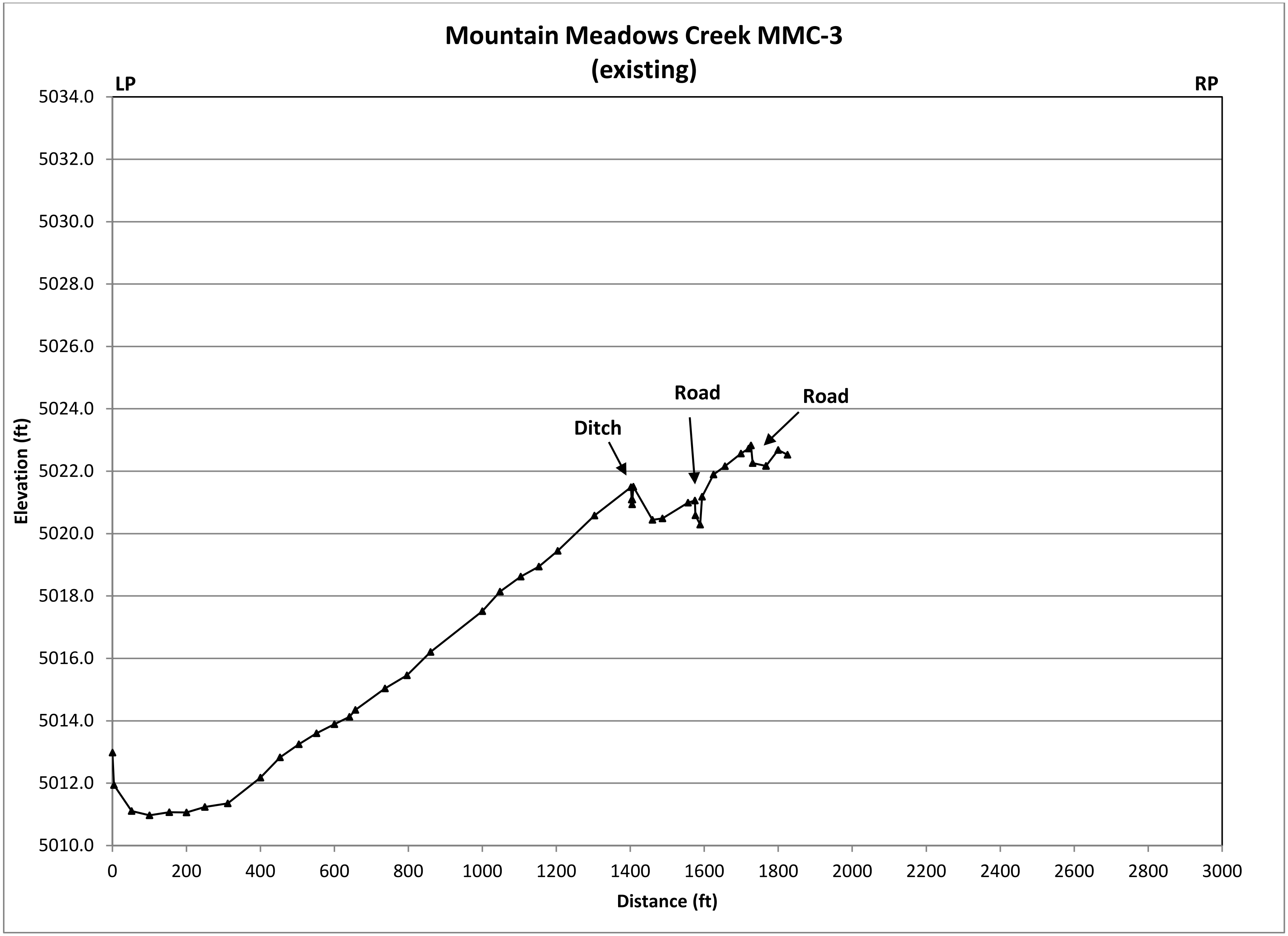
Pages 24-50: Mountain Meadows Creek Project Cross-sections: Paired existing and proposed

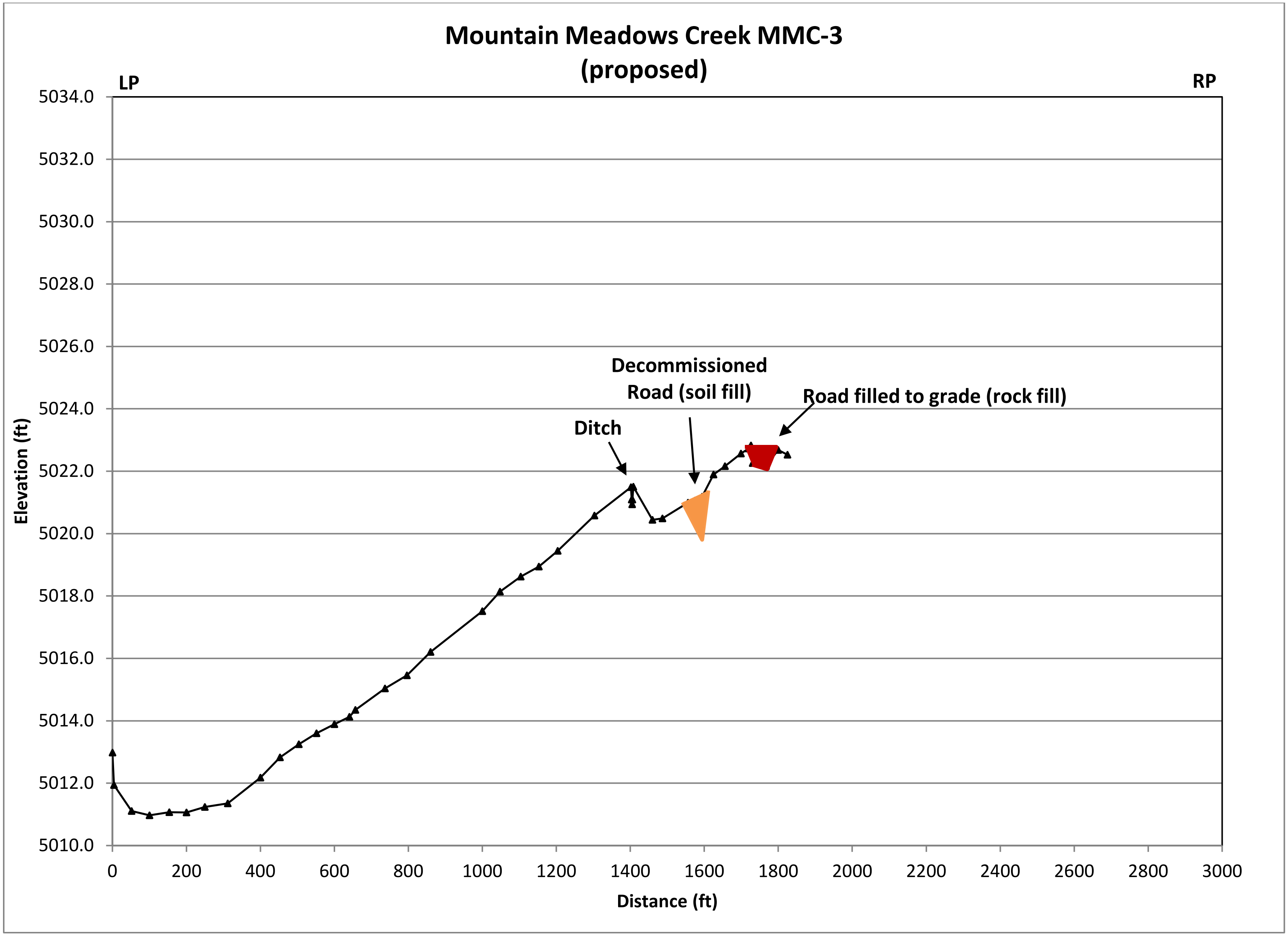
Page 51: Longitudinal Profile: Mountain Meadows Creek Meadow

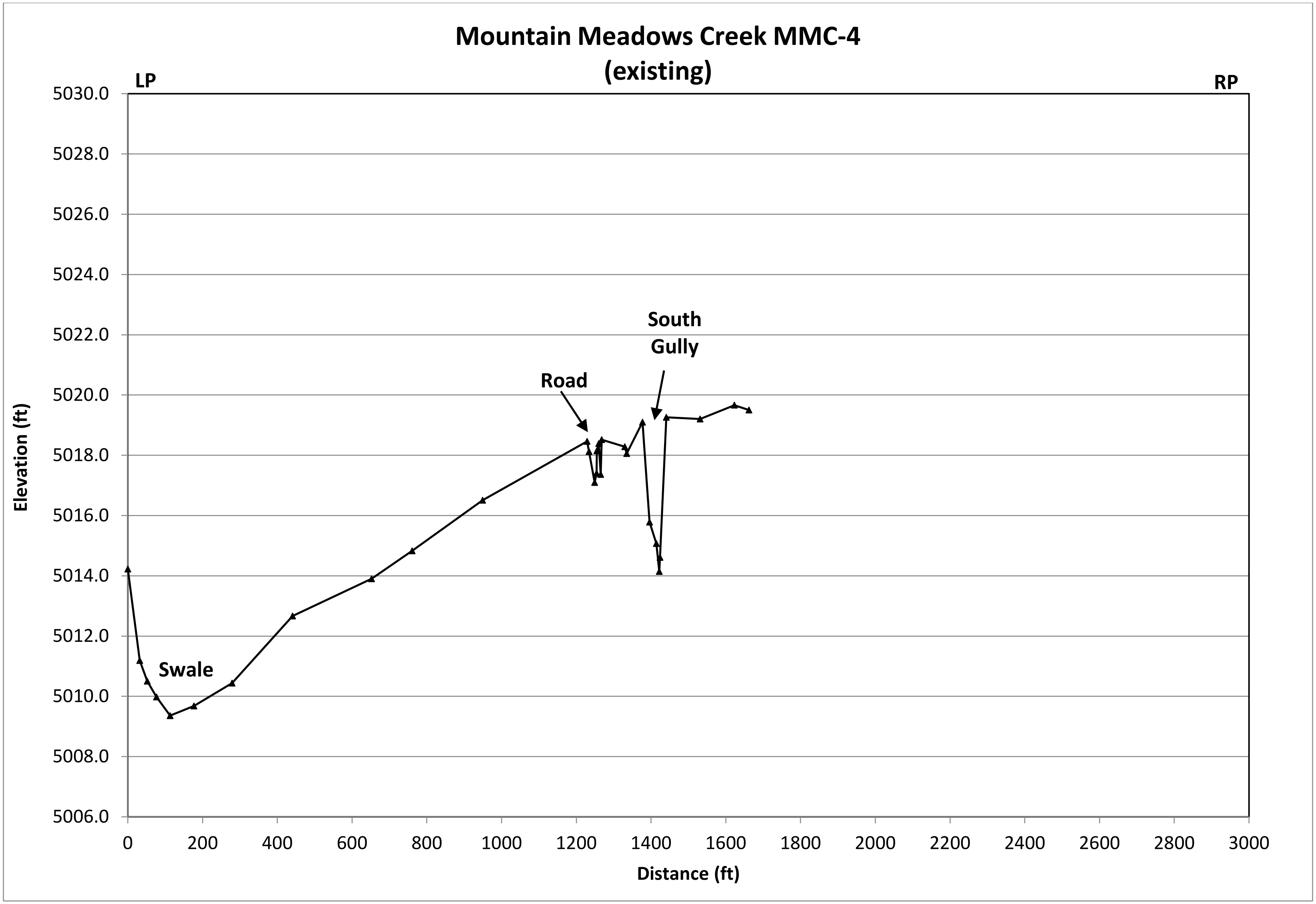


Mountain Meadows Creek MMC-1
(existing)
LP
RP
NO CHANGES PROPOSED
Elevation (ft)
Distance (ft)
5034.0
5032.0
5030.0
5028.0
5026.0
5024.0
5022.0
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000

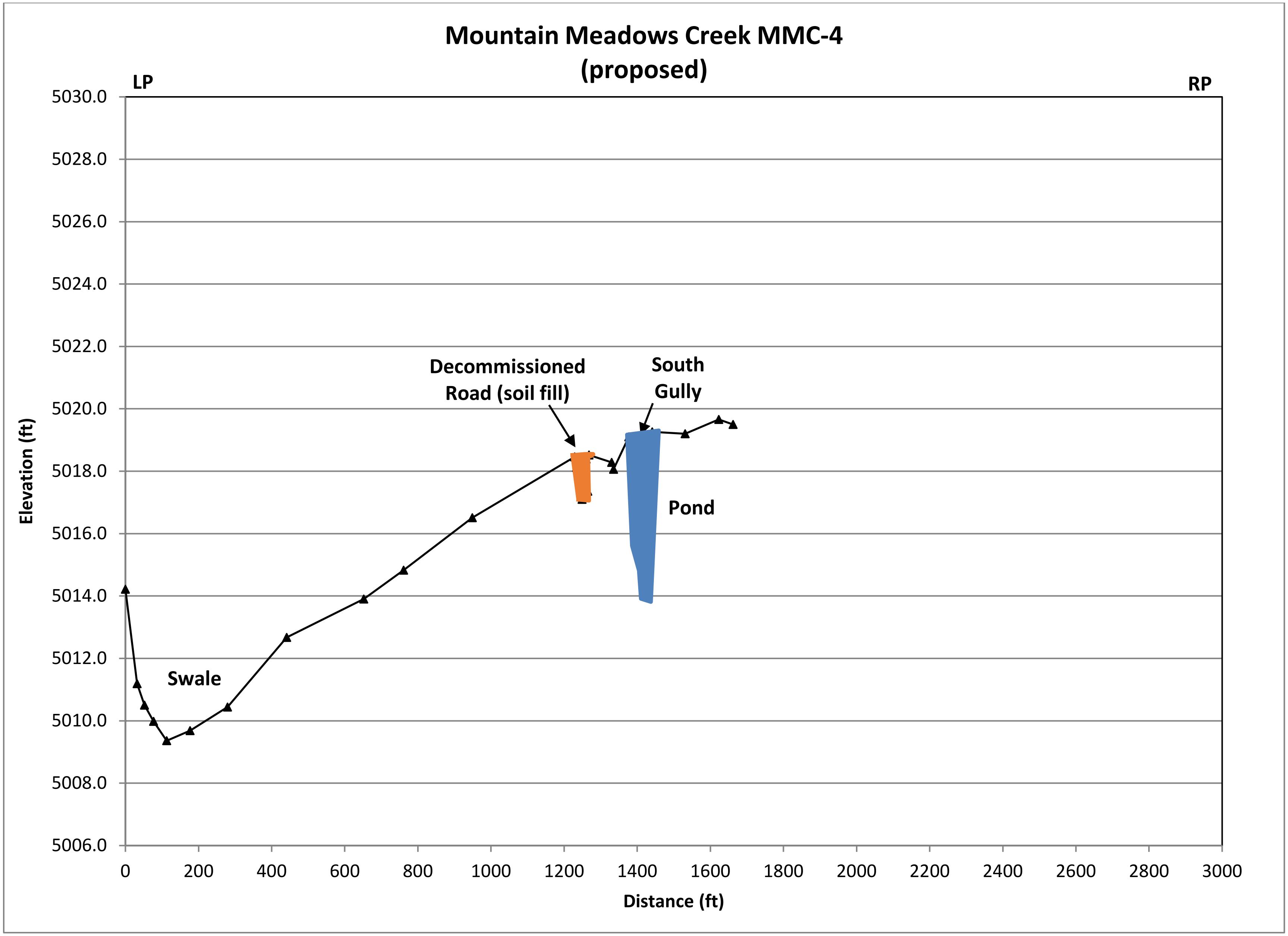

Mountain Meadows Creek MMC-2
(existing)
LP
RP
NO CHANGES PROPOSED
Swale
Elevation (ft)
Distance (ft)
5034.0
5032.0
5030.0
5028.0
5026.0
5024.0
5022.0
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000


Mountain Meadows Creek MMC-3
(existing)
LP
RP
Ditch
Road
Road
Elevation (ft)
Distance (ft)
5034.0
5032.0
5030.0
5028.0
5026.0
5024.0
5022.0
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000

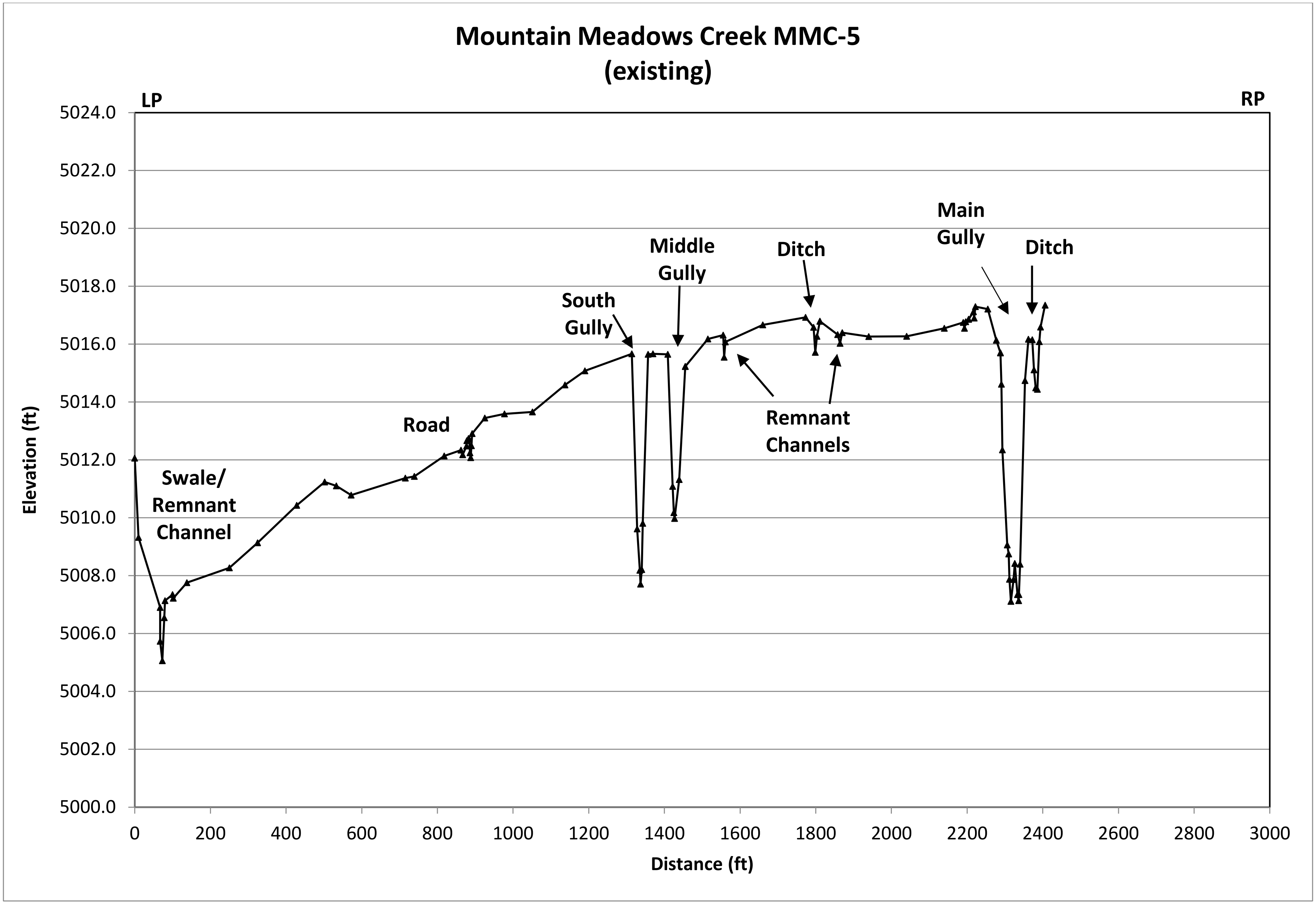

Mountain Meadows Creek MMC-3
(proposed)
LP
RP
Elevation (ft)
Distance (ft)
Ditch
Decommissioned
Road (soil fill)
Road filled to grade (rock fill)
5034.0
5032.0
5030.0
5028.0
5026.0
5024.0
5022.0
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000

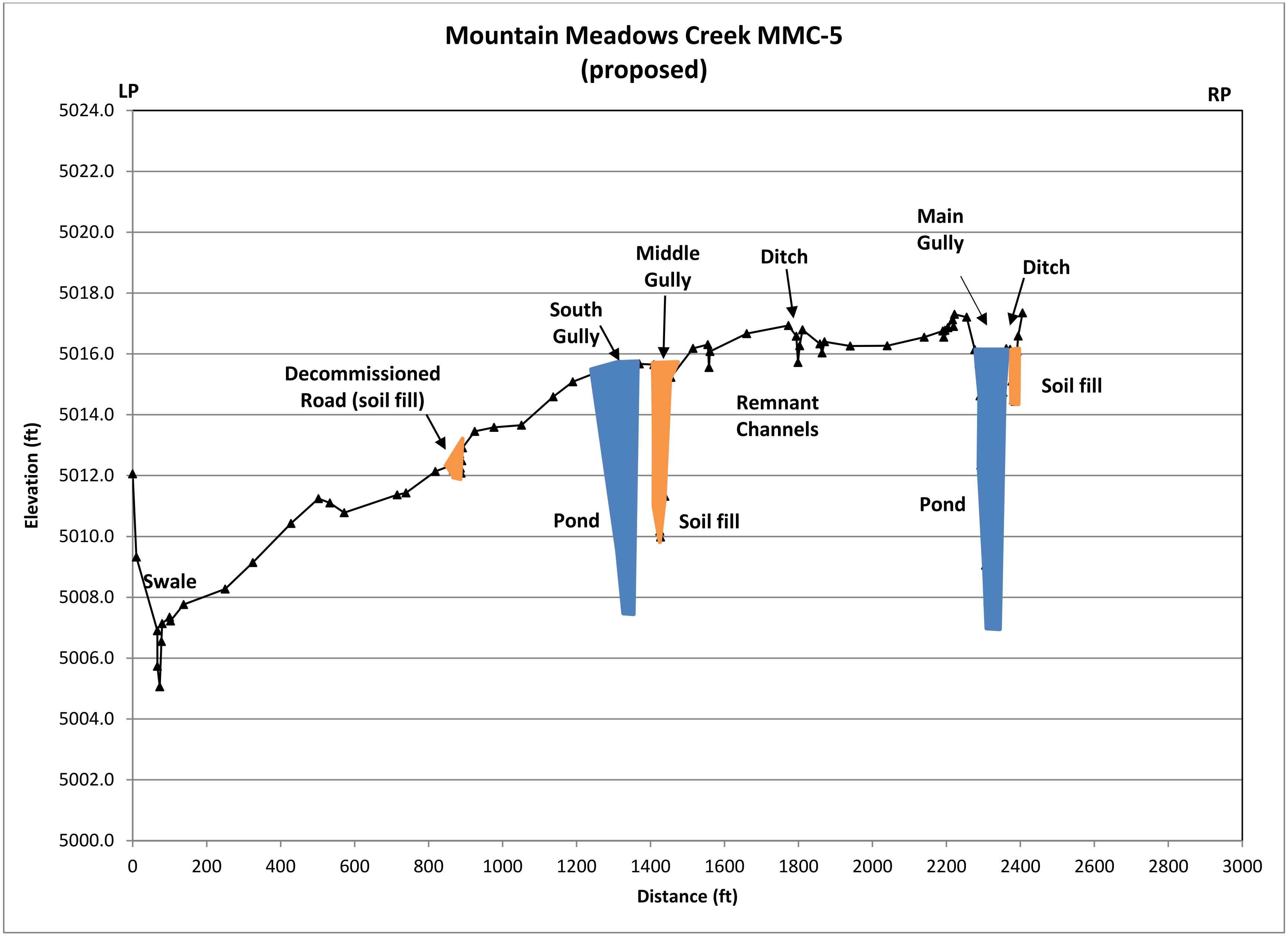


Mountain Meadows Creek MMC-4
(existing)
LP
RP
5030.0
5028.0
5026.0
5024.0
5022.0
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
5008.0
5006.0
Elevation (ft)
South
Gully
Road
Swale
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Distance (ft)

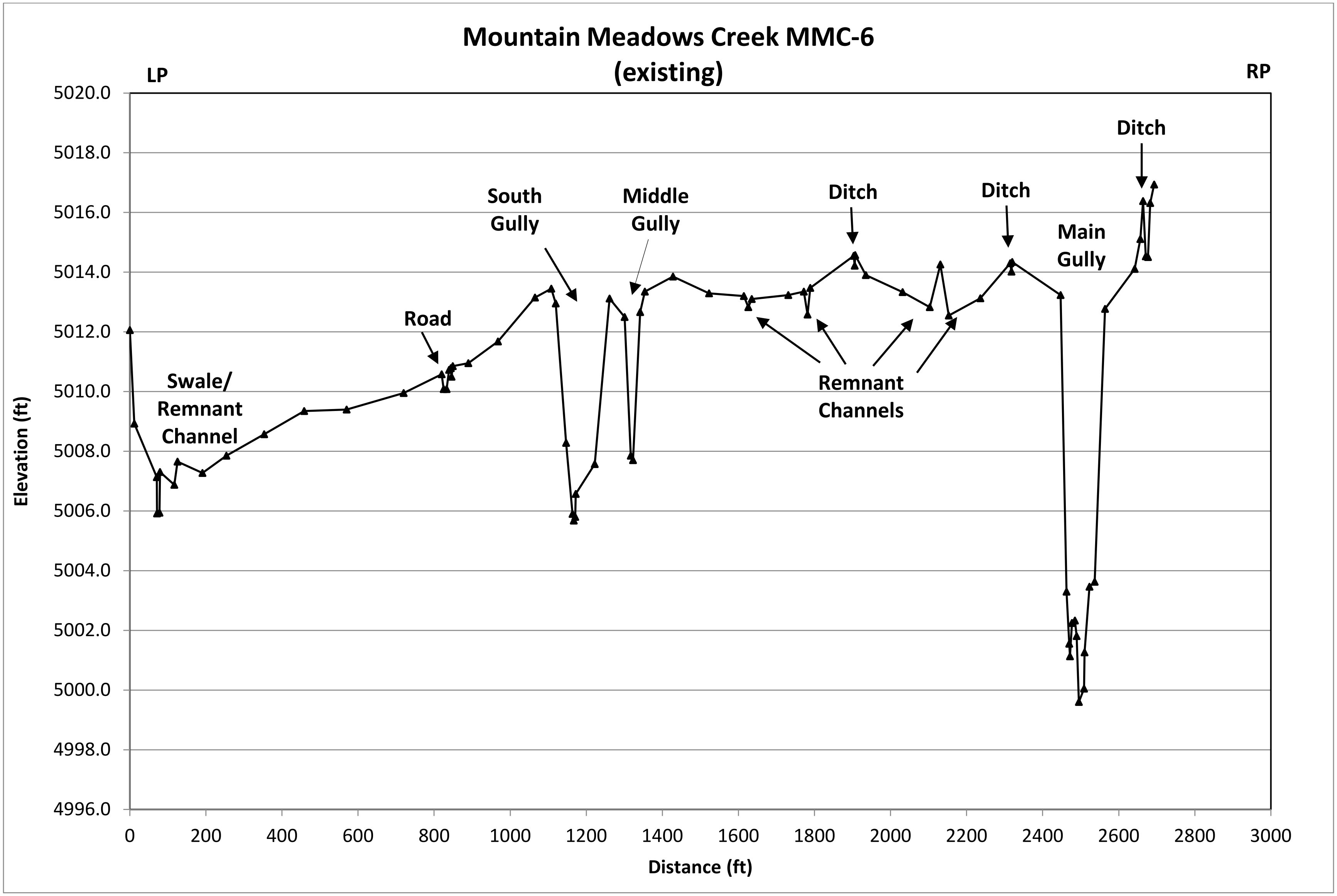


Mountain Meadows Creek MMC-4
(proposed)
LP
RP
5030.0
5028.0
5026.0
5024.0
5022.0
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
5008.0
5006.0
Elevation (ft)
Decommissioned
Road (soil fill)
South
Gully
Pond
Swale
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Distance (ft)

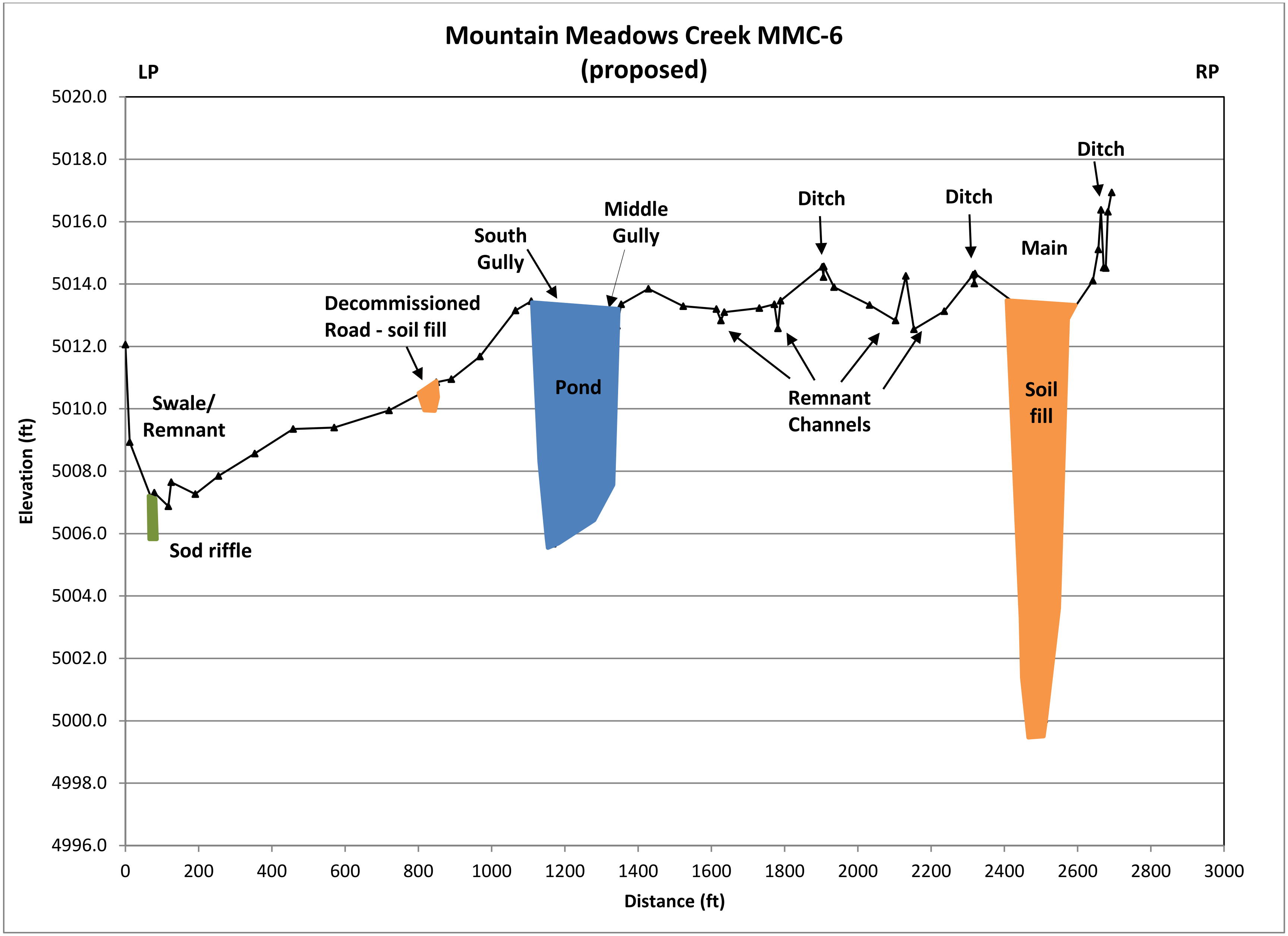

Mountain Meadows Creek MMC-5
(existing)
LP
RP
Elevation (ft)
Distance (ft)
5024.0
5022.0
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Swale/
Remnant
Channel
Road
South
Gully
Middle
Gully
Ditch
Remnant
Channels
Main
Gully
Ditch



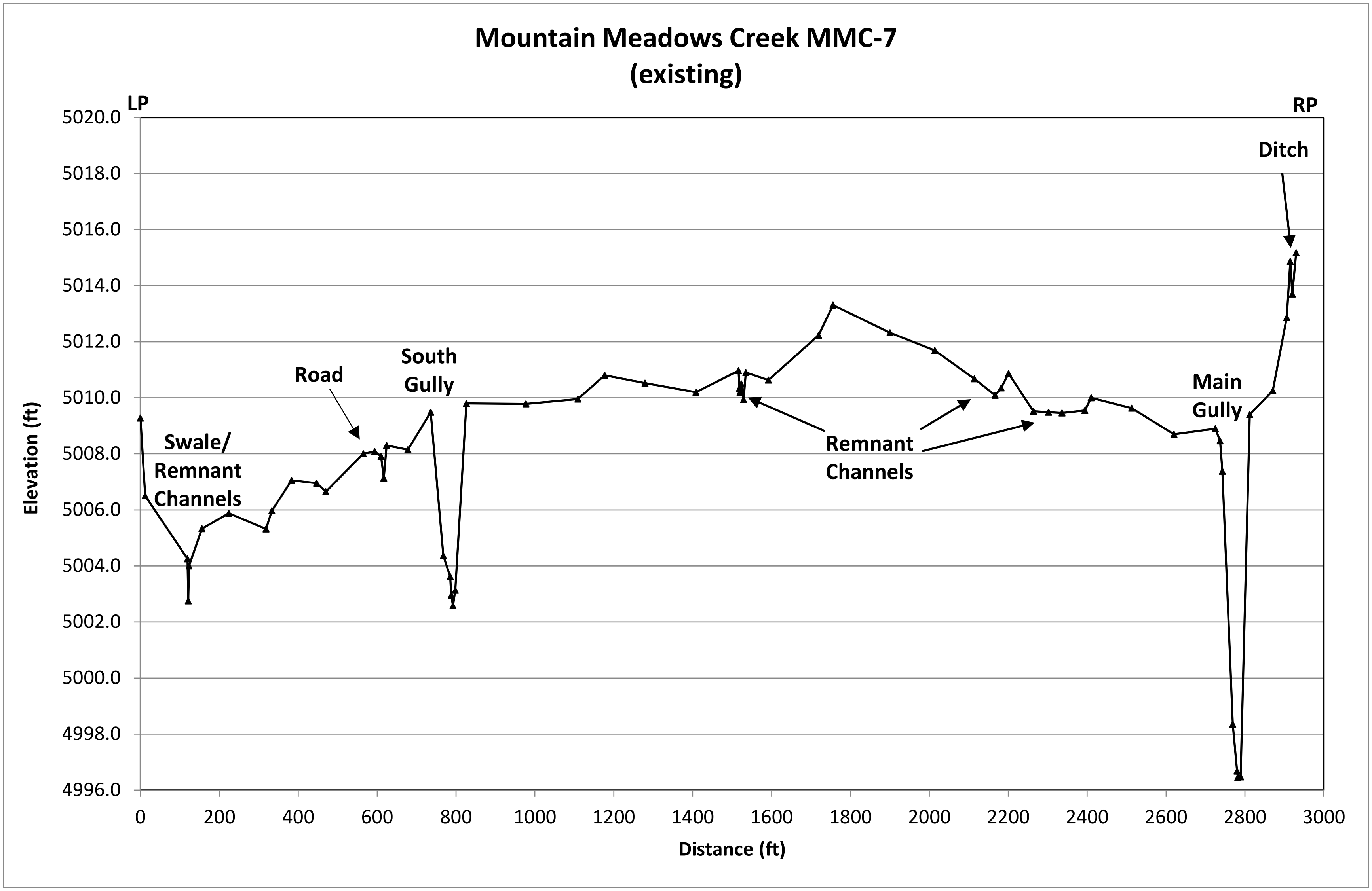
Mountain Meadows Creek MMC-5
(proposed)
LP
RP
Elevation (ft)
5024.0
5022.0
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Distance (ft)
Swale
Decommissioned Road (soil fill)
South Gully
Middle Gully
Ditch
Main Gully
Ditch
Pond
Soil fill
Remnant Channels
Pond
Soil fill

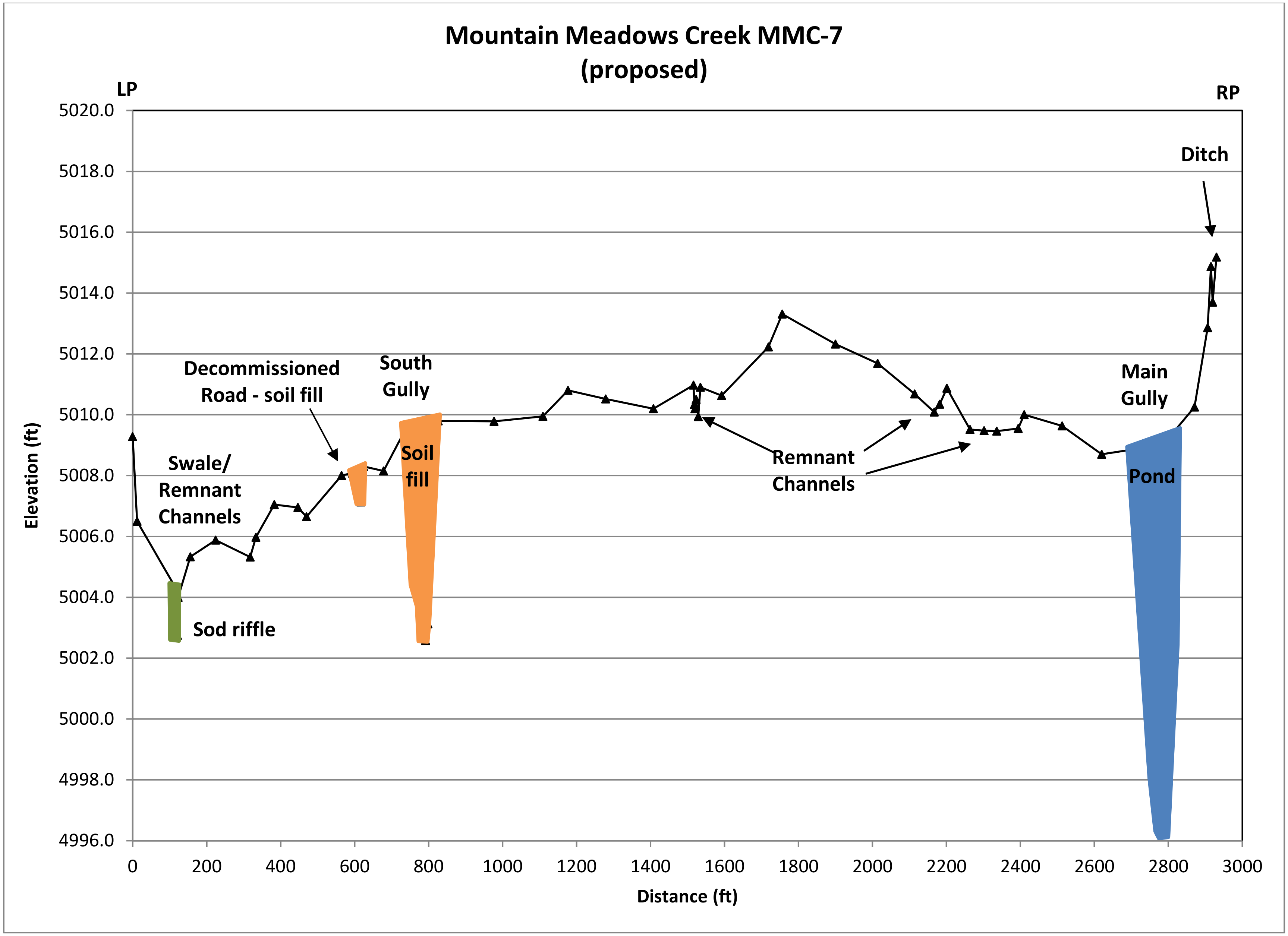


Mountain Meadows Creek MMC-6
(existing)
LP
RP
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
4998.0
4996.0
Elevation (ft)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Distance (ft)
Swale/
Remnant
Channel
Road
South
Gully
Middle
Gully
Ditch
Ditch
Main
Gully
Ditch
Remnant
Channels

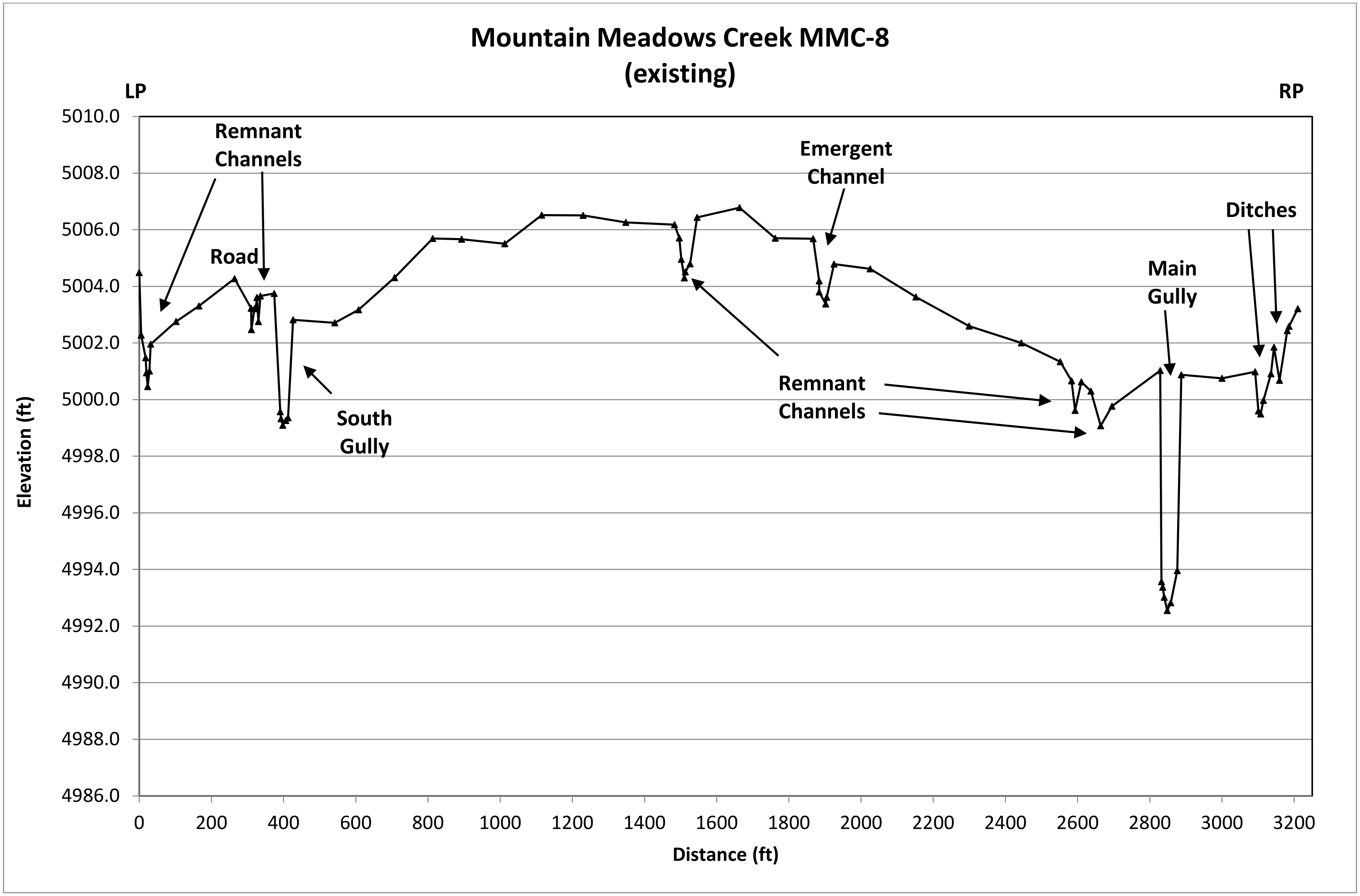


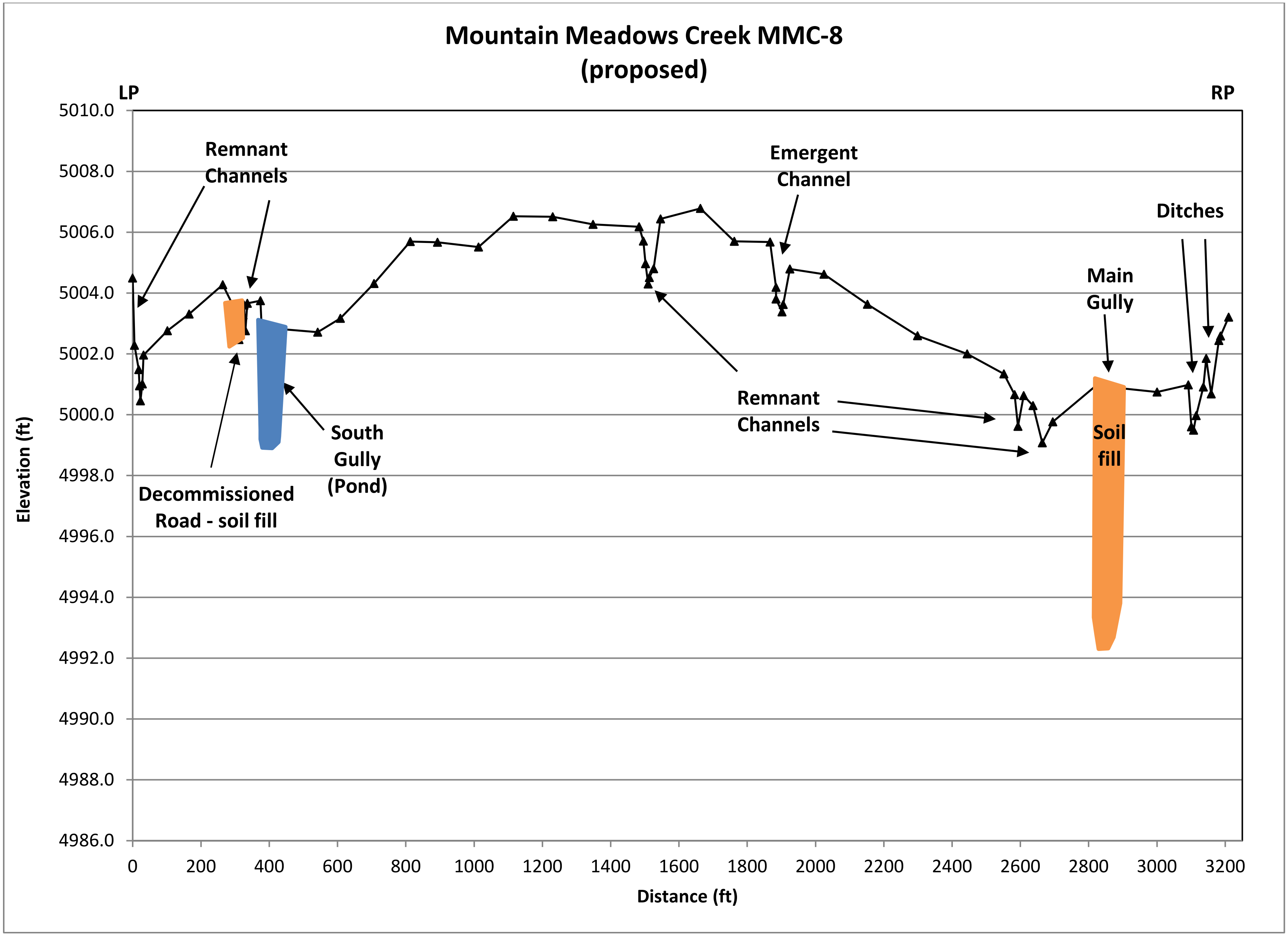
Mountain Meadows Creek MMC-6
(proposed)
LP
RP
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
4998.0
4996.0
Elevation (ft)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Distance (ft)
Swale/
Remnant
Sod riffle
Decommissioned
Road - soil fill
South
Gully
Middle
Gully
Pond
Ditch
Ditch
Ditch
Main
Remnant
Channels
Soil
fill


Mountain Meadows Creek MMC-7
(existing)
LP
RP
Ditch
Road
South Gully
Swale/ Remnant Channels
Remnant Channels
Main Gully
Elevation (ft)
Distance (ft)
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
4998.0
4996.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000

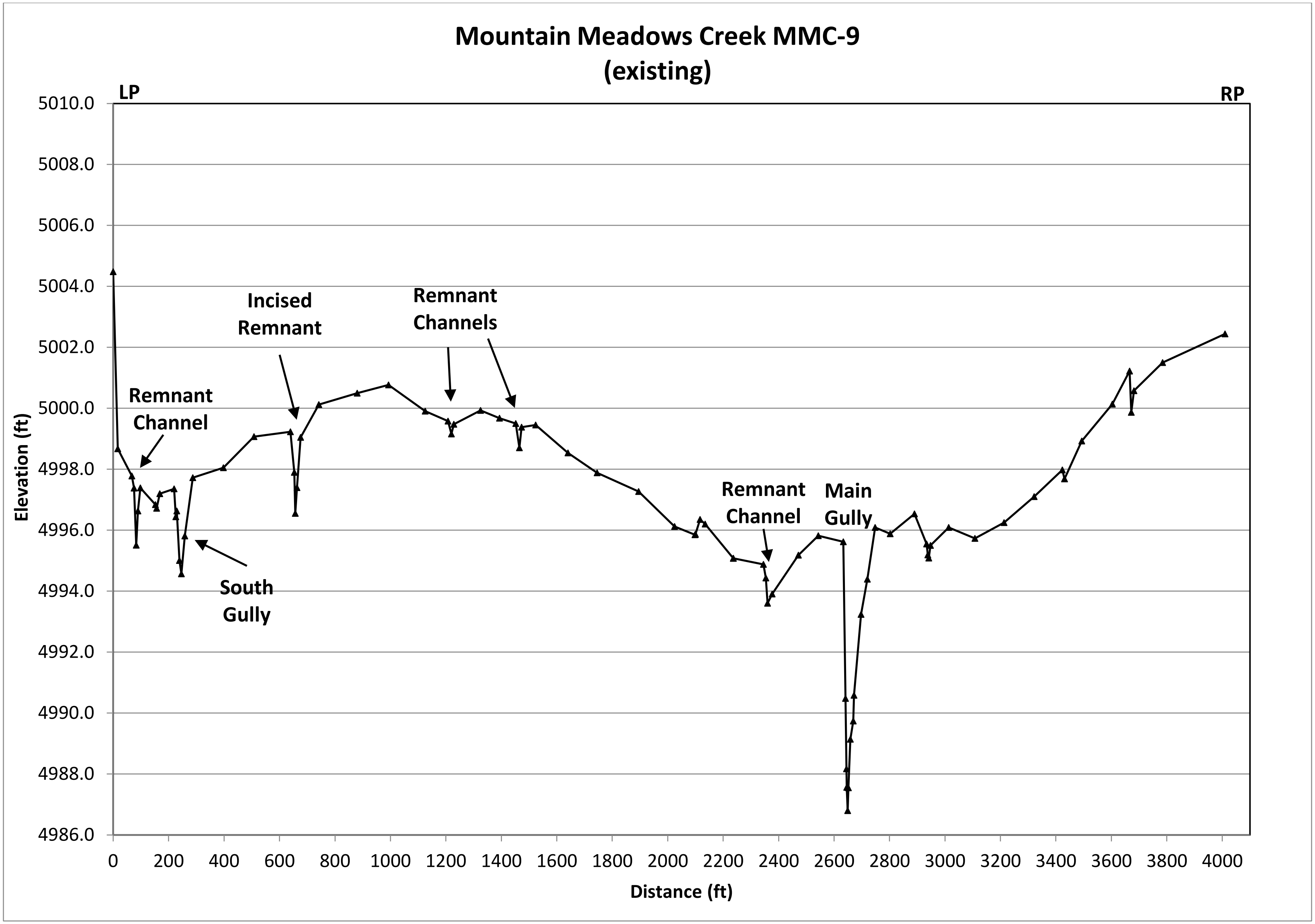


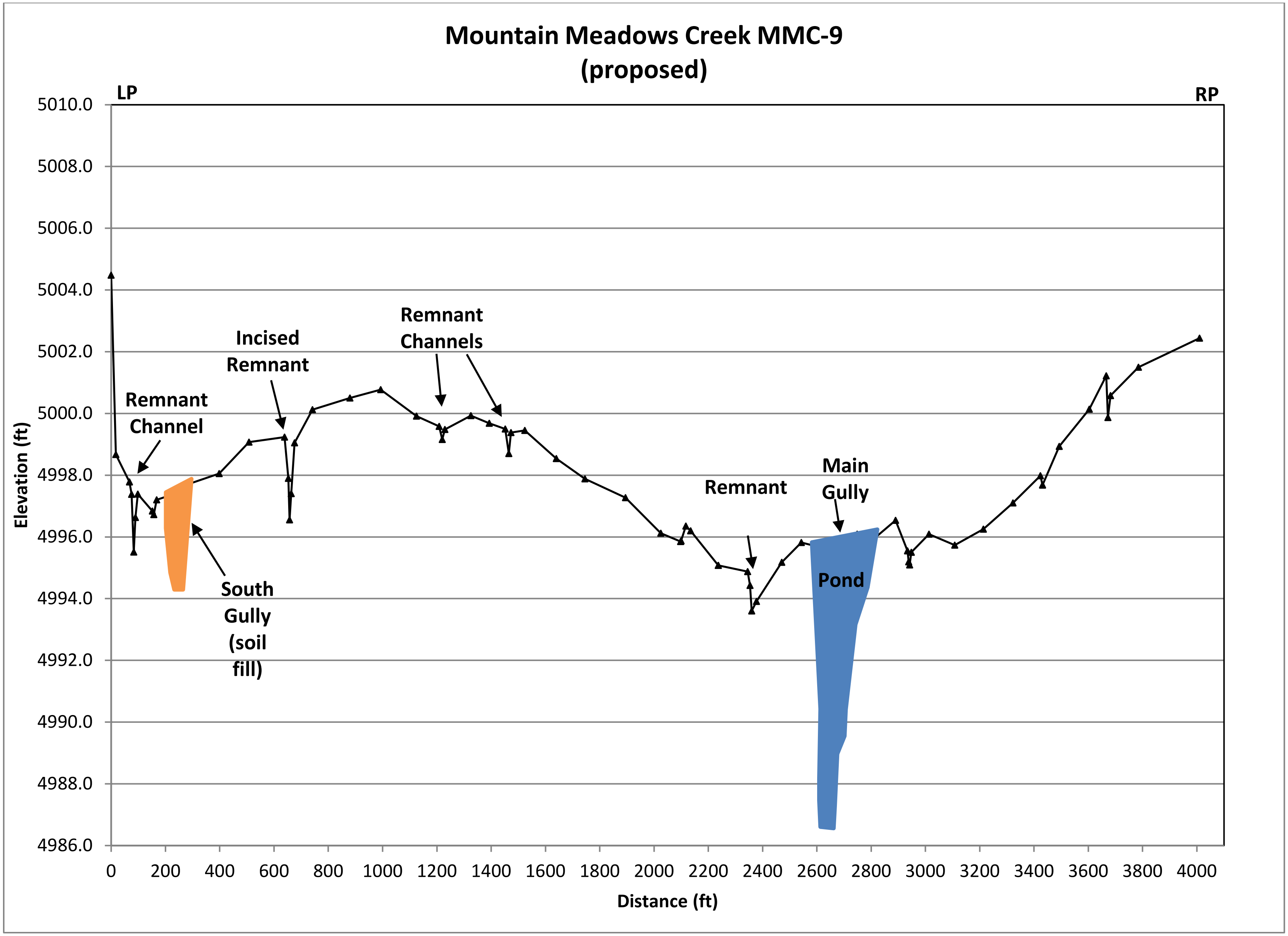
Mountain Meadows Creek MMC-7
(proposed)
LP
RP
Ditch
Main Gully
Pond
Remnant Channels
South Gully
Soil fill
Decommissioned Road - soil fill
Swale/ Remnant Channels
Sod riffle
Elevation (ft)
Distance (ft)
5020.0
5018.0
5016.0
5014.0
5012.0
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
4998.0
4996.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000


Mountain Meadows Creek MMC-8
(existing)
LP
RP
Remnant Channels
Road
South Gully
Emergent Channel
Remnant Channels
Main Gully
Ditches
Elevation (ft)
Distance (ft)
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200

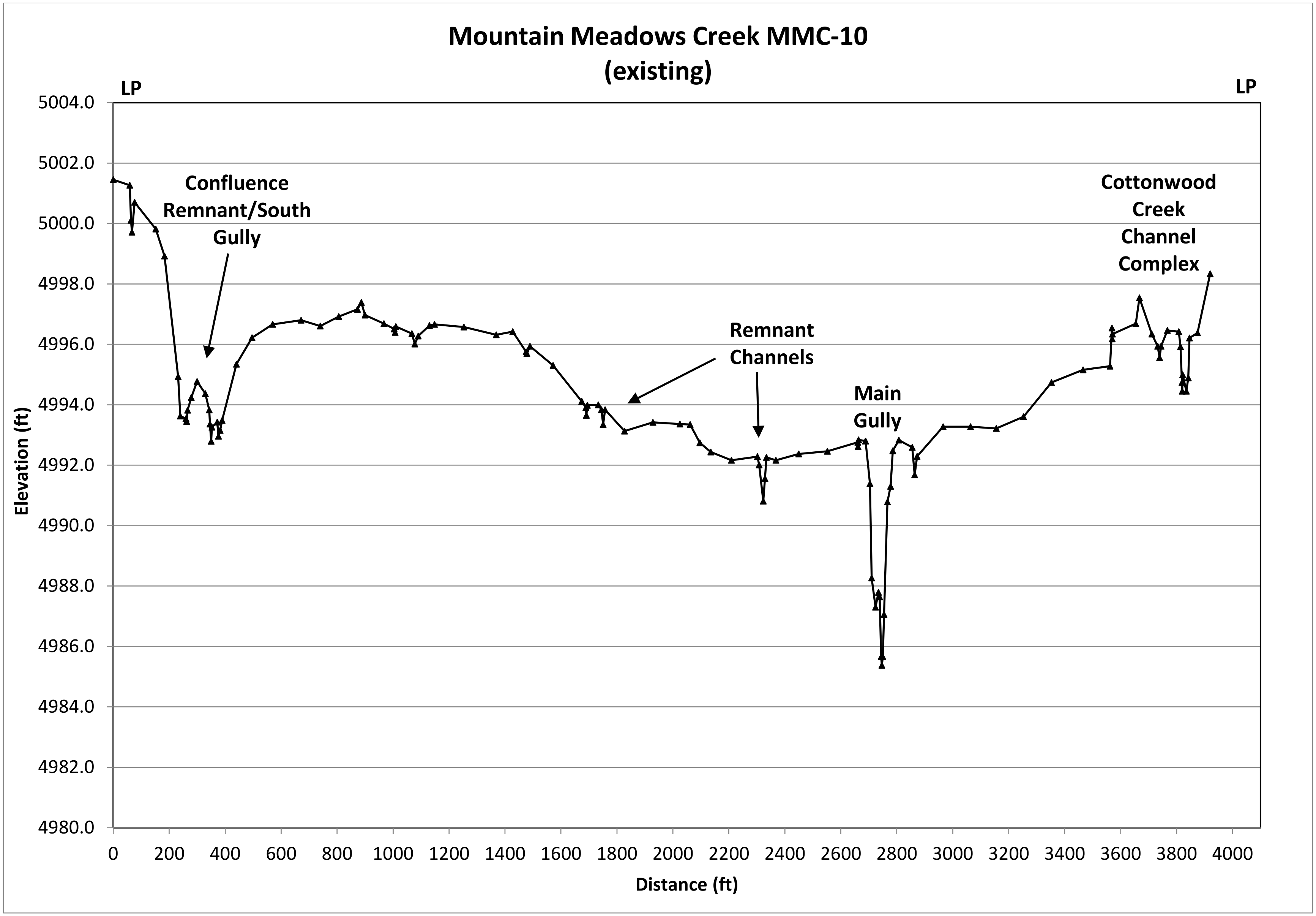


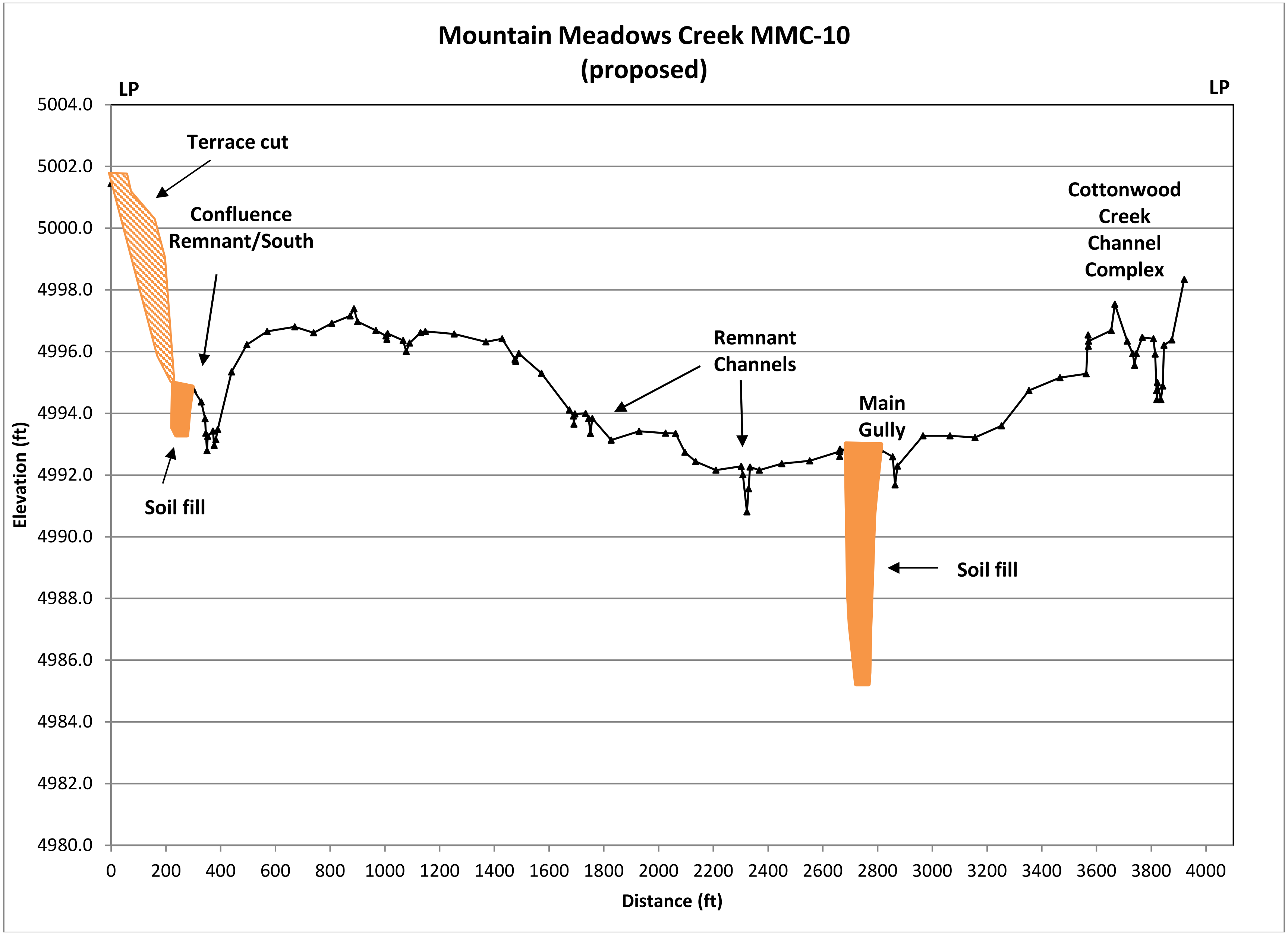
Mountain Meadows Creek MMC-8
(proposed)
LP
RP
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
Elevation (ft)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
Distance (ft)
Remnant Channels
Decommissioned Road - soil fill
South Gully (Pond)
Emergent Channel
Remnant Channels
Ditches
Main Gully
Soil fill

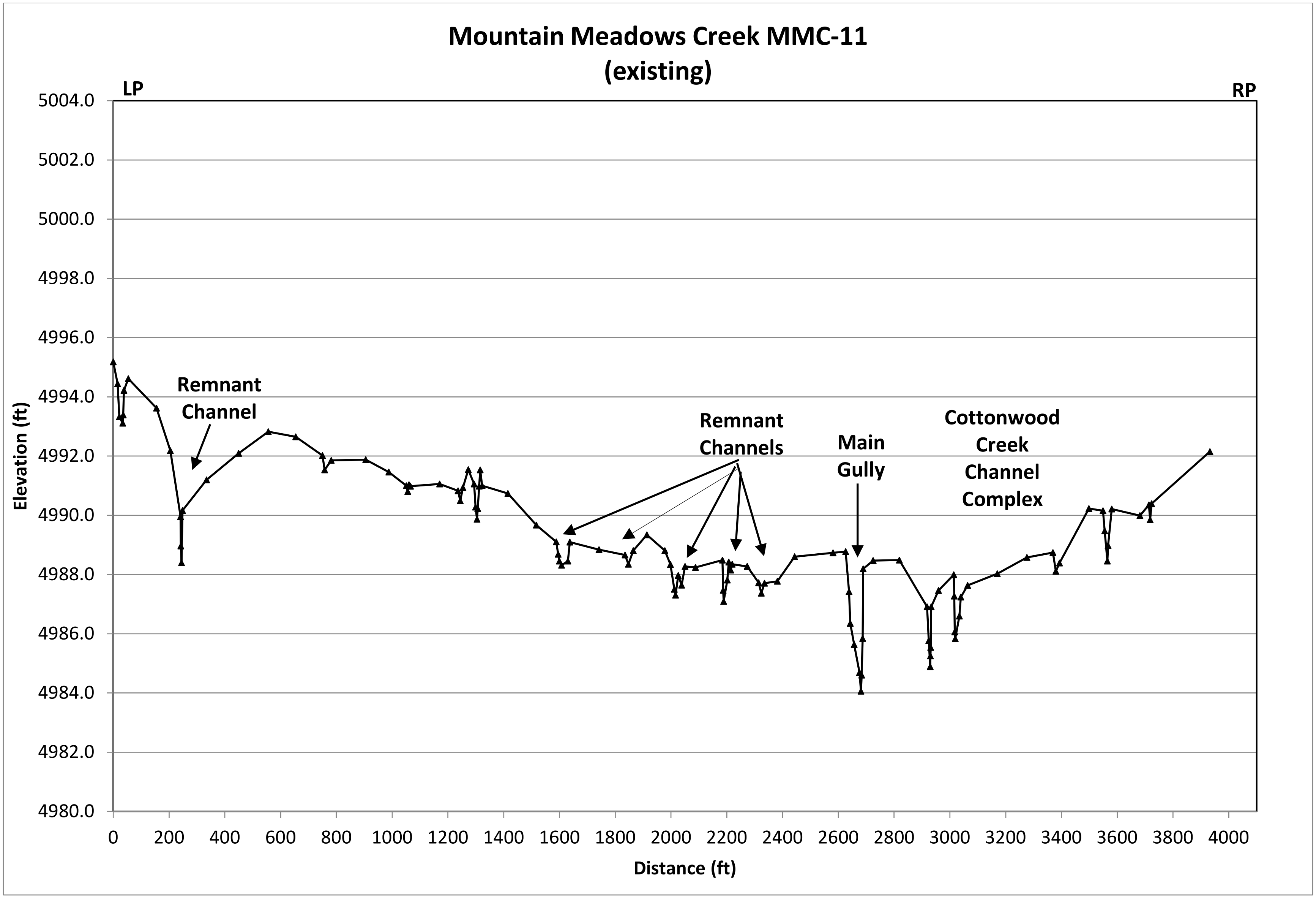

Mountain Meadows Creek MMC-9
(existing)
LP
RP
Elevation (ft)
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
Distance (ft)
Remnant Channel
South Gully
Incised Remnant
Remnant Channels
Remnant Channel
Main Gully

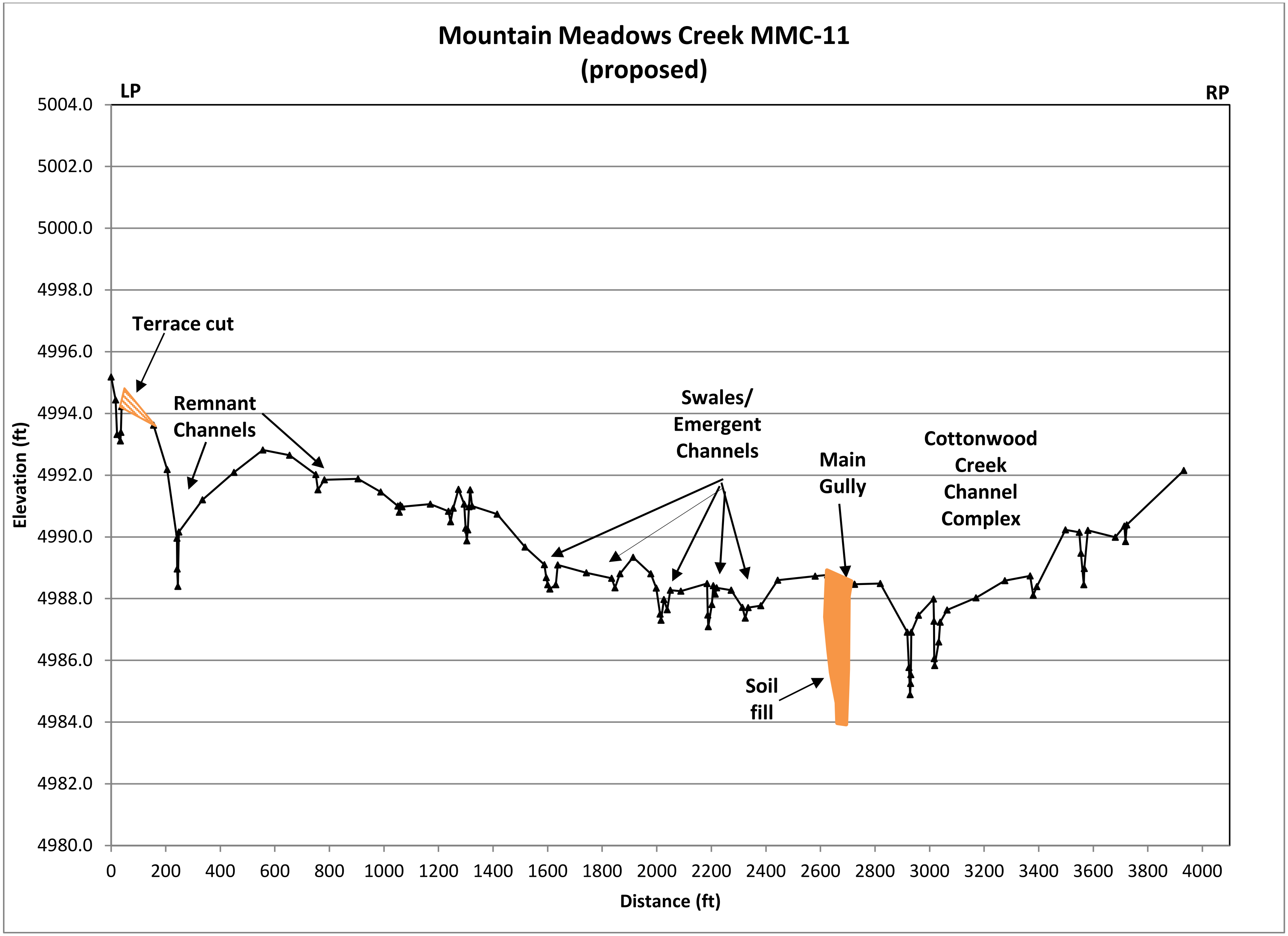


Mountain Meadows Creek MMC-9
(proposed)
LP
RP
5010.0
5008.0
5006.0
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
Elevation (ft)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
Distance (ft)
Remnant Channel
Incised Remnant
Remnant Channels
South Gully (soil fill)
Remnant
Main Gully
Pond

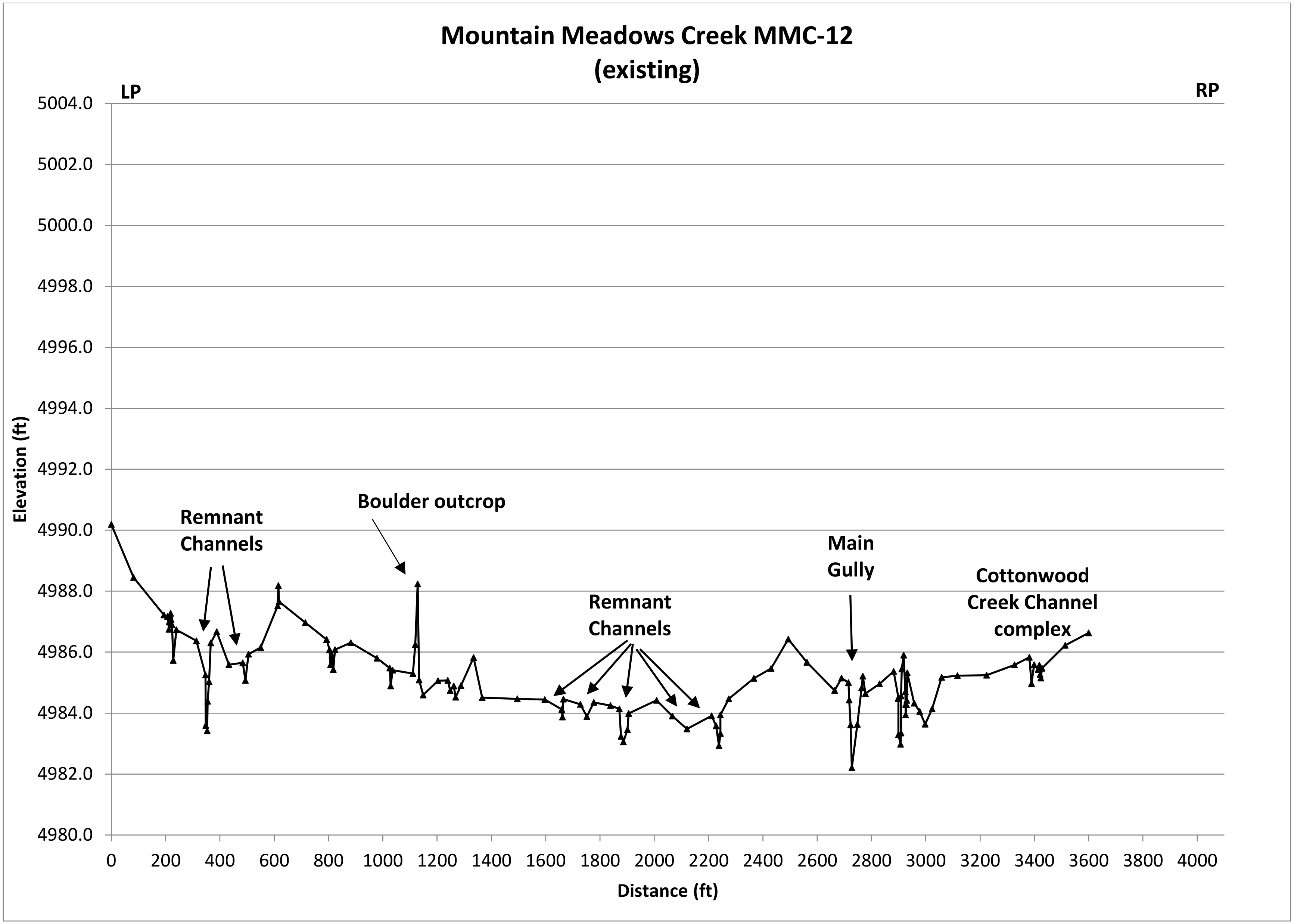

Mountain Meadows Creek MMC-10
(existing)
LP
LP
Confluence Remnant/South Gully
Remnant Channels
Main Gully
Cottonwood Creek Channel Complex
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
Elevation (ft)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
Distance (ft)


Mountain Meadows Creek MMC-10
(proposed)
LP
LP
Terrace cut
Confluence
Remnant/South
Soil fill
Remnant
Channels
Main
Gully
Soil fill
Cottonwood
Creek
Channel
Complex
Elevation (ft)
Distance (ft)
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000

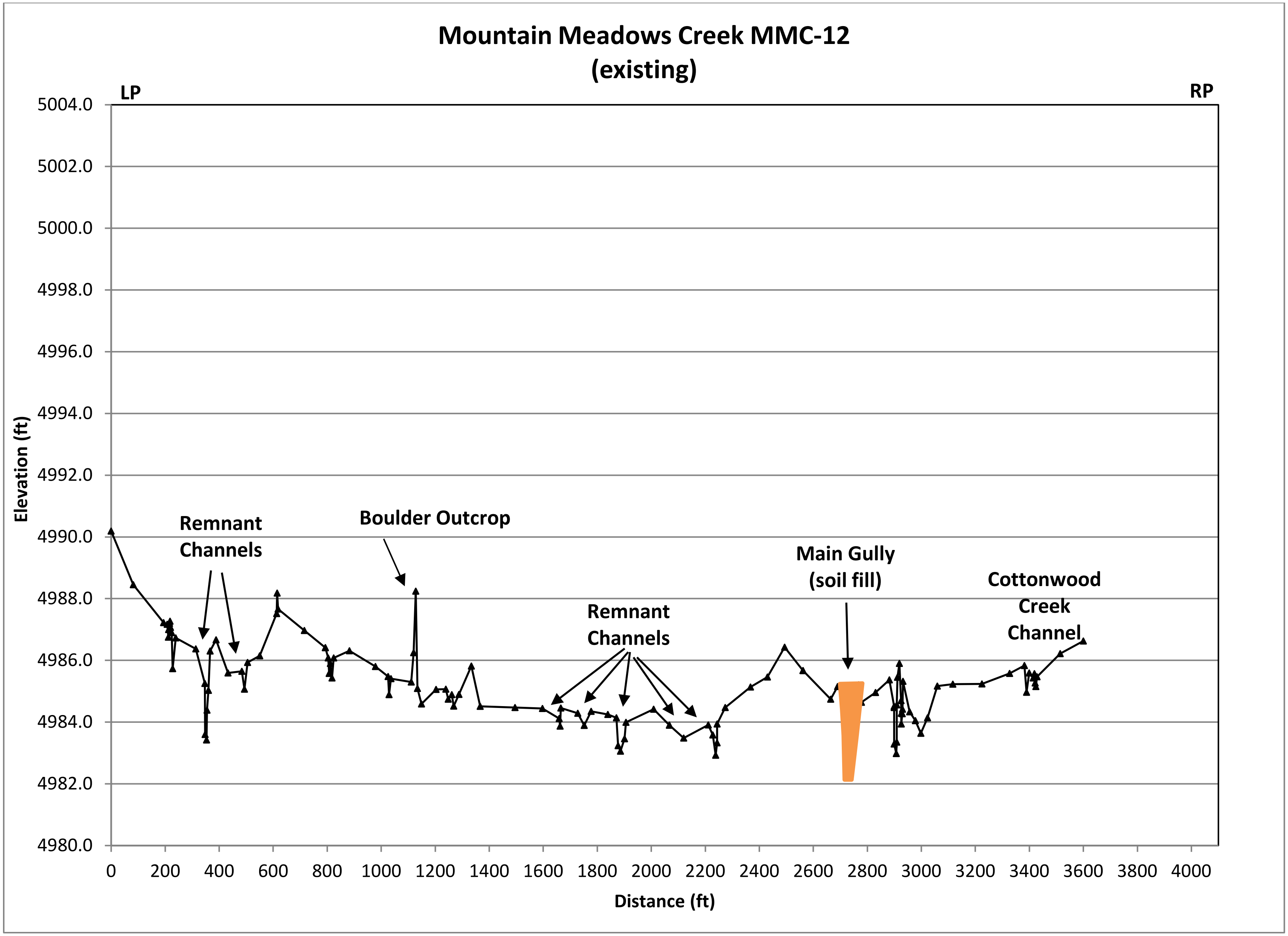

Mountain Meadows Creek MMC-11
(existing)
LP
RP
Elevation (ft)
Distance (ft)
Remnant Channel
Remnant Channels
Main Gully
Cottonwood Creek Channel Complex
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000

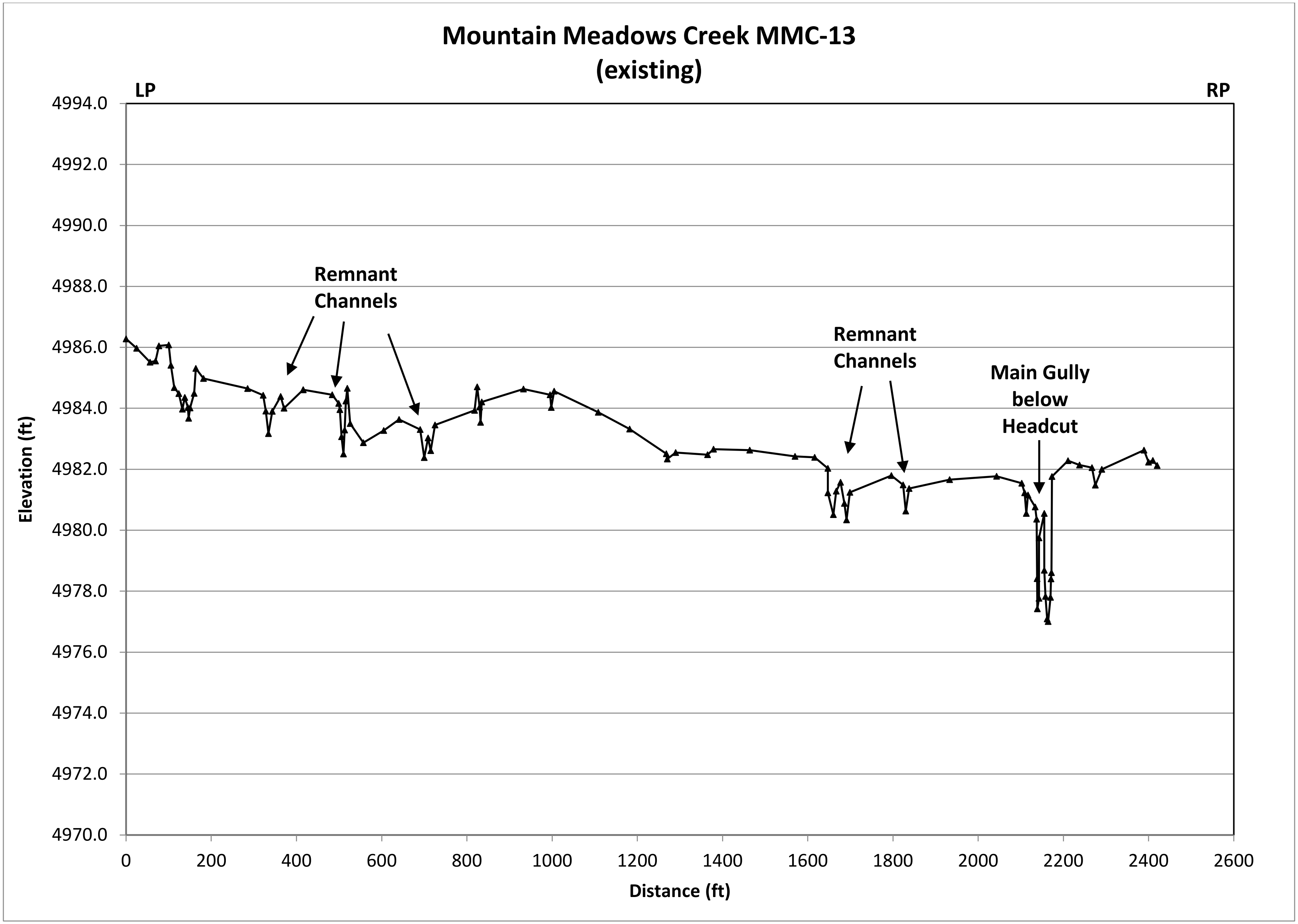


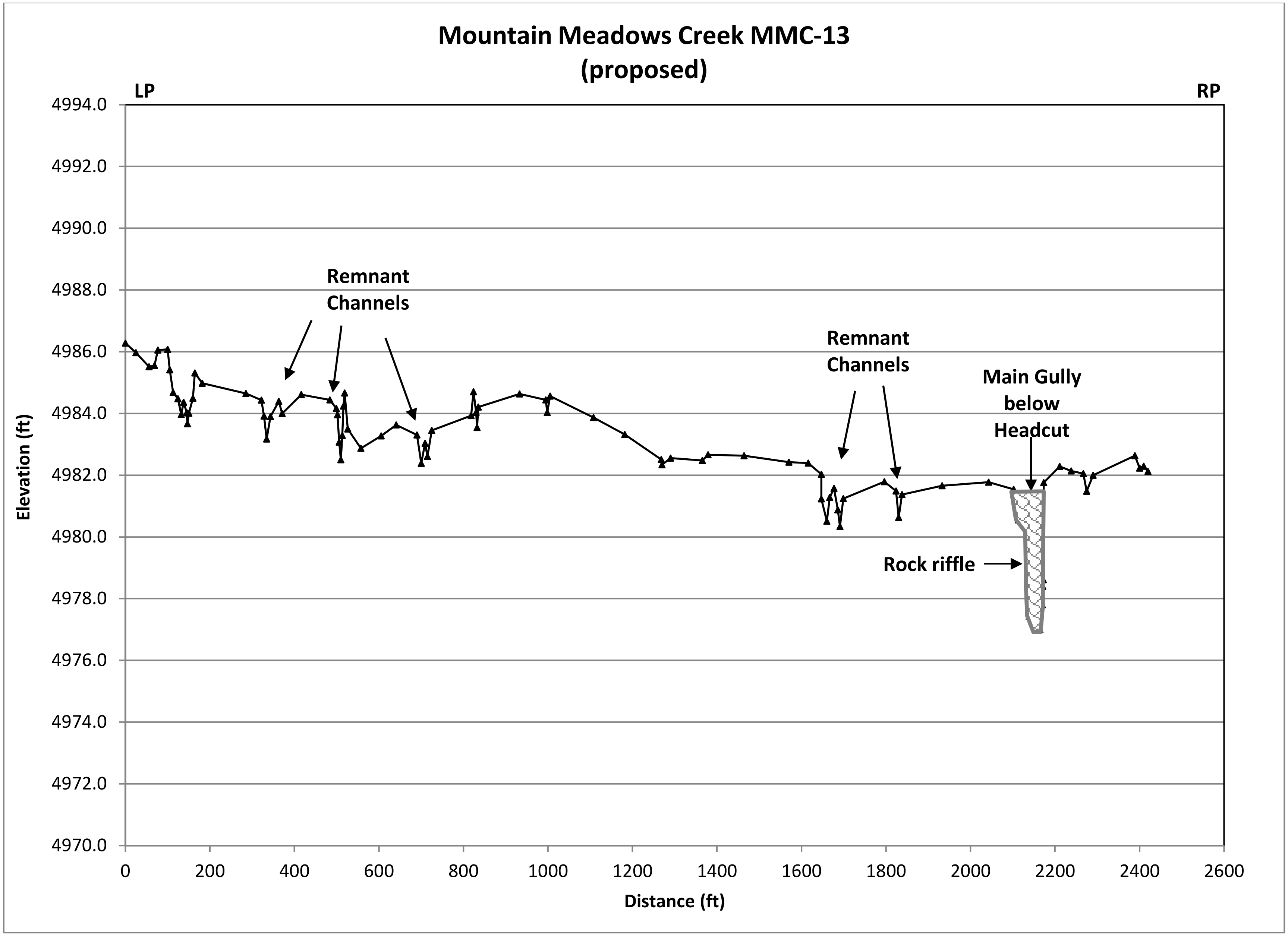
Mountain Meadows Creek MMC-11
(proposed)
LP
RP
Terrace cut
Remnant
Channels
Swales/
Emergent
Channels
Main
Gully
Cottonwood
Creek
Channel
Complex
Soil
fill
Elevation (ft)
Distance (ft)
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000

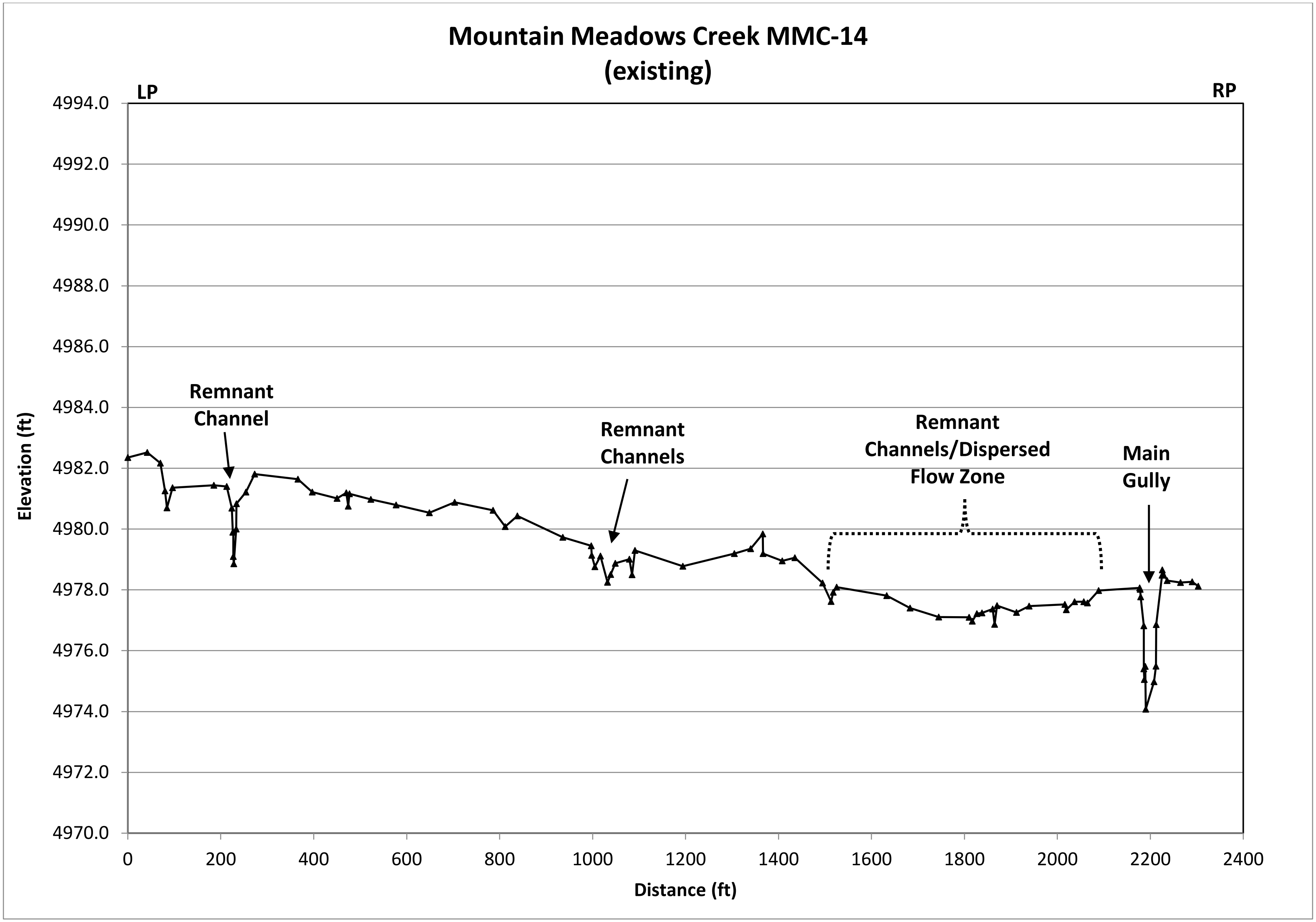


Mountain Meadows Creek MMC-12
(existing)
LP
RP
Elevation (ft)
Distance (ft)
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
Remnant Channels
Boulder outcrop
Remnant Channels
Main Gully
Cottonwood Creek Channel complex

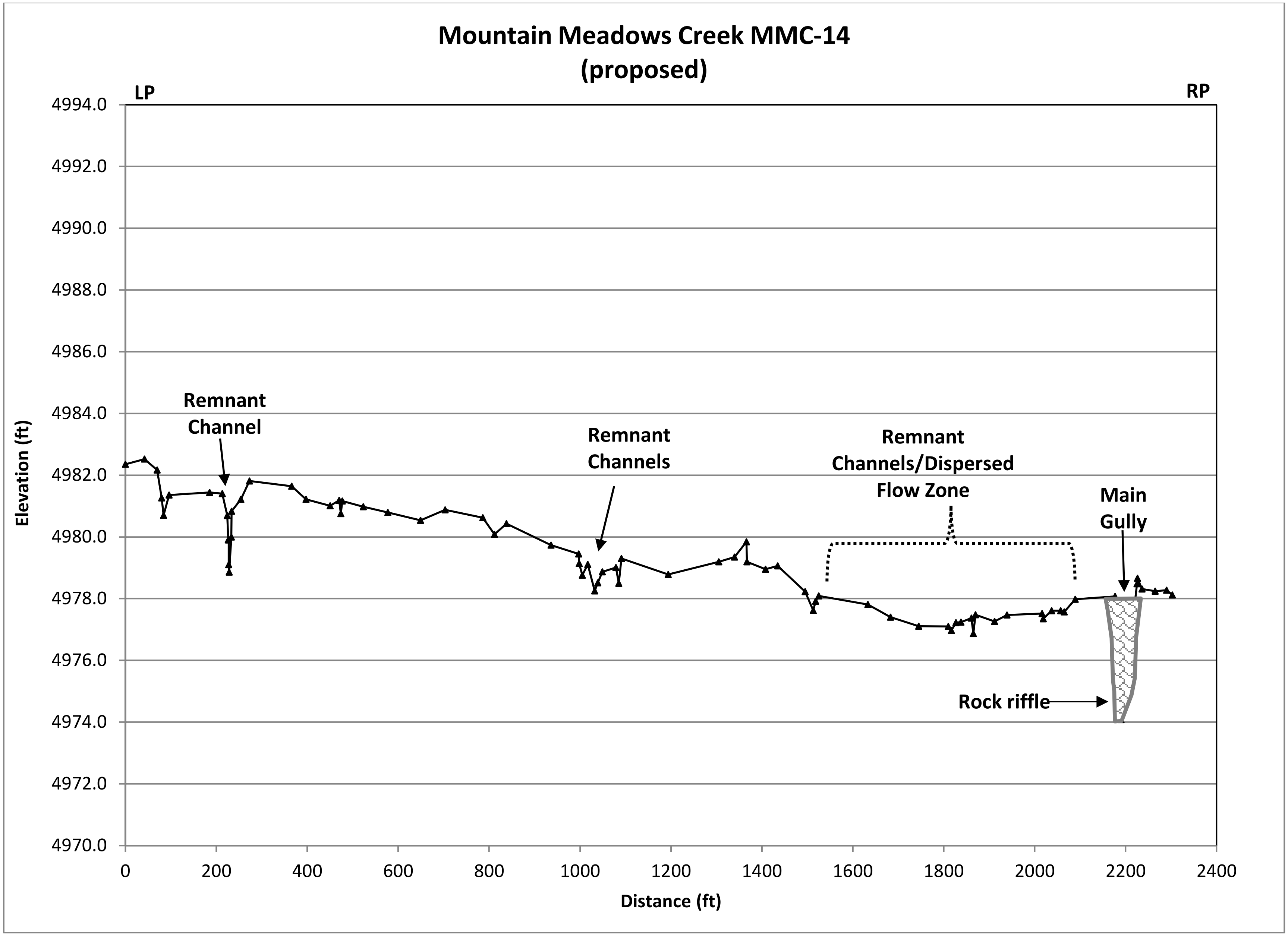

Mountain Meadows Creek MMC-12
(existing)
LP
RP
Elevation (ft)
5004.0
5002.0
5000.0
4998.0
4996.0
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
Remnant
Channels
Boulder Outcrop
Remnant
Channels
Main Gully
(soil fill)
Cottonwood
Creek
Channel
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
Distance (ft)

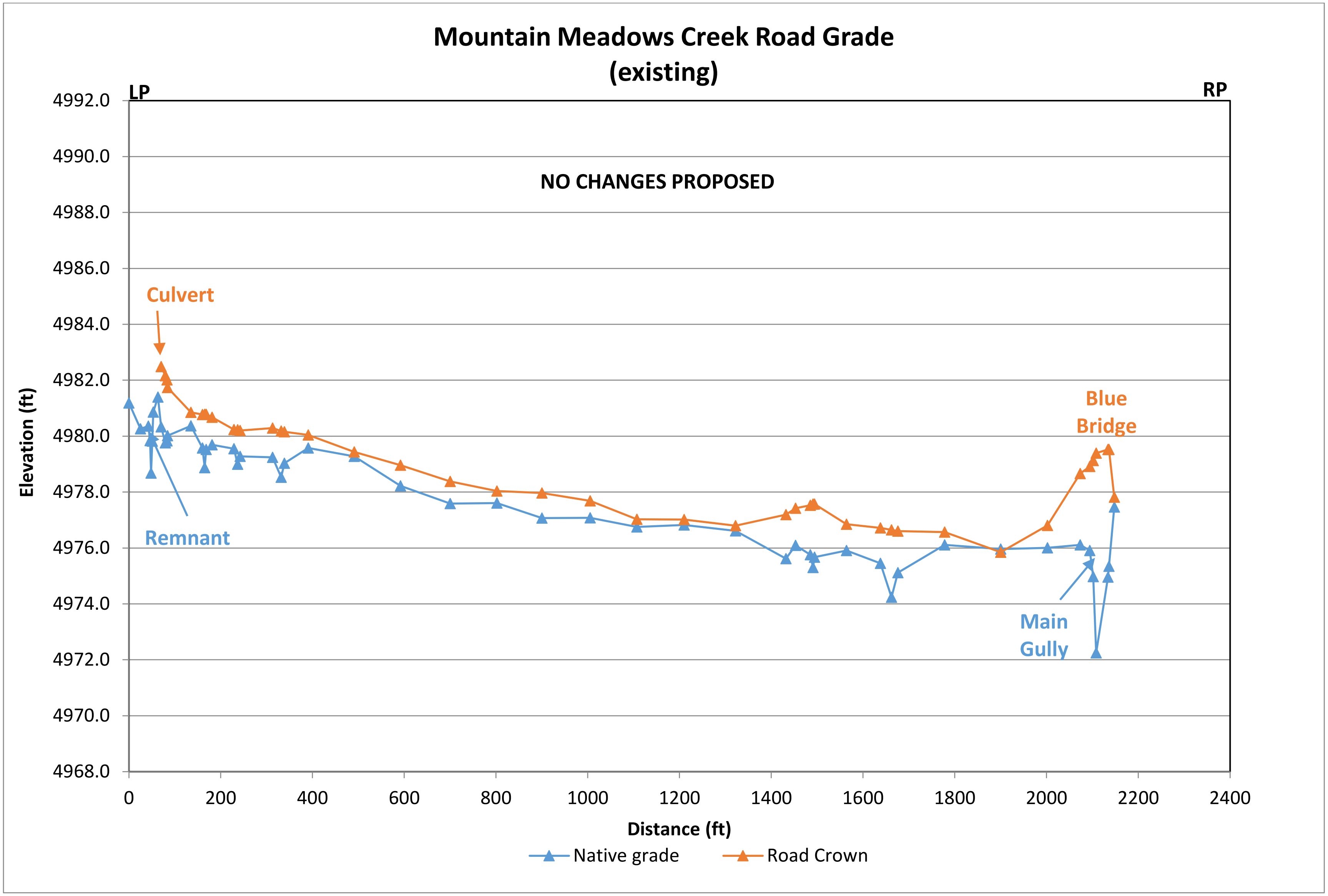

Mountain Meadows Creek MMC-13
(existing)
LP
RP
Remnant Channels
Remnant Channels
Main Gully below Headcut
Elevation (ft)
Distance (ft)
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
4978.0
4976.0
4974.0
4972.0
4970.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600

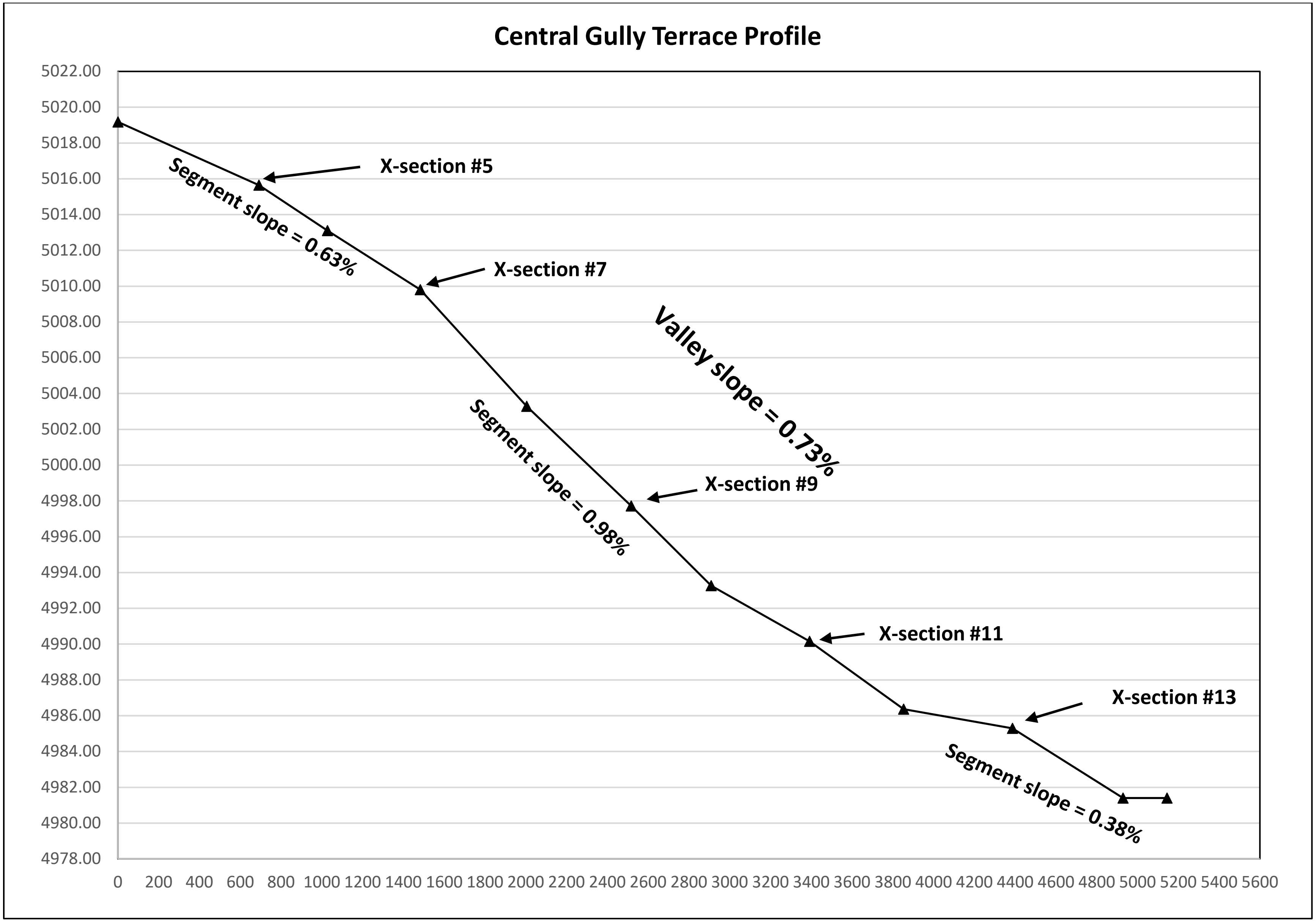

Mountain Meadows Creek MMC-13
(proposed)
LP
RP
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
4978.0
4976.0
4974.0
4972.0
4970.0
Elevation (ft)
Remnant Channels
Remnant Channels
Main Gully below Headcut
Rock riffle
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
Distance (ft)



Mountain Meadows Creek MMC-14
(existing)
LP
RP
Remnant
Channel
Remnant
Channels
Remnant
Channels/Dispersed
Flow Zone
Main
Gully
Elevation (ft)
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
4978.0
4976.0
4974.0
4972.0
4970.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Distance (ft)


Mountain Meadows Creek MMC-14
(proposed)
LP
RP
Elevation (ft)
Distance (ft)
4994.0
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
4978.0
4976.0
4974.0
4972.0
4970.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Remnant Channel
Remnant Channels
Remnant Channels/Dispersed Flow Zone
Main Gully
Rock riffle


Mountain Meadows Creek Road Grade
(existing)
LP
RP
NO CHANGES PROPOSED
Culvert
Remnant
Blue
Bridge
Main
Gully
Elevation (ft)
4992.0
4990.0
4988.0
4986.0
4984.0
4982.0
4980.0
4978.0
4976.0
4974.0
4972.0
4970.0
4968.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Distance (ft)
Native grade
Road Crown


Central Gully Terrace Profile
5022.00
5020.00
5018.00
5016.00
5014.00
5012.00
5010.00
5008.00
5006.00
5004.00
5002.00
5000.00
4998.00
4996.00
4994.00
4992.00
4990.00
4988.00
4986.00
4984.00
4982.00
4980.00
4978.00
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000 4200 4400 4600 4800 5000 5200 5400 5600
X-section #5
Segment slope = 0.63%
X-section #7
Valley slope = 0.73%
Segment slope = 0.98%
X-section #9
X-section #11
X-section #13
Segment slope = 0.38%

APPENDIX C

Mountain Meadows Creek

Comparative Watershed Method

Standard Formula: Qu = Qg(Au/Ag)^b

Qu = discharge of ungaged stream

Qg = discharge of gaged stream

b = regional coefficient (Sierra)

Au = watershed area of ungaged stream

Ag = watershed area of gaged stream

Mountain Meadows		-	**Hough CReek**	
Q2	=		108.8	cfs
Q5	=		242.4	cfs
Q10	=		373.4	cfs
Q25	=		597.8	cfs
Q50	=		810.4	cfs
Q100	=		1066.2	cfs
Mountain Meadows		-	**Pine Creek (Westwood)**	
Q2	=		27.5	cfs
Q5	=		52.7	cfs
Q10	=		74.5	cfs
Q25	=		106.9	cfs
Q50	=		136.0	cfs
Q100	=		170.2	cfs
Mountain Meadows		-	**Almanor trib**	
Q2	=		125.9	cfs
Q5	=		271.6	cfs
Q10	=		412.0	cfs
Q25	=		655.3	cfs
Q50	=		884.5	cfs
Q100	=		1155.1	cfs

Mountain Meadows Creek

Channel Characteristics

Bkf Width	31 ft	**Bkf Wetted Perimete**	34	ft
Bkf Depth:	1.45 ft	**Hydraulic Radius:**	1.32	
Bkf Area	45 sqft	**Slope:**	0.007	ft/ft
		Roughness:	0.038	

Mannings Formula: V = 1.4/n(r)^2/3(s)^1/2

V=	**3.72**	**fps**	
Q=	**AV**		
Q=	**45.00**	**X**	**3.72**
Q=	**167.21**	**cfs**	

Multiple Regresion Analysis

Watershed Area (A):	7.6	
Mean Precip (P):	37.3	
Mean Elevation (H):	6.218	
Q2=	**100.9**	**cfs**
Q5=	**279.7**	**cfs**
Q10=	**425.5**	**cfs**
Q25=	**723.9**	**cfs**
Q50=	**975.3**	**cfs**
Q100=	**1367.7**	**cfs**

Equation:

Q2=	.24(A^.88)(P^1.58)(H^-.80)
Q5=	1.2(A^.82)(P^1.37)(H^-.64)
Q10=	2.63(A^.80)(P^1.25)(H^-.58)
Q25=	6.55(A^.79)(P^1.12)(H^-.52)
Q50=	10.40(A^.78)(P^1.06)(H^-.48)
Q100=	15.70(A^.77)(P^1.02)(H^-.43)

Summary Table of Discharge Values

Reach Name	Q2	Q5	Q10	Q25	Q50	Q100	Method
Mountain Meadows Cr.	101	280	425	724	975	1368	Multiple Regression
	27.5	53	75	107	136	170	Area Reg.- Pine Cr.
	109	242	373	598	810	1067	Area Reg.- Hough Cr.
	126	272	412	655	884	1155	Area Reg.- Almanor.
StreamStats	97	244	399	654	909	1210	
Bankfull	167**						Cross-section

****Cumulative calculated capacity of all connected remnants.**

Mountain Meadows Creek StreamStats Report

Region ID: CA
Workspace ID: CA20210504210554283000
Clicked Point (Latitude, Longitude): 40.26495, -120.89145
Time: 2021-05-04 14:06:15 -0700

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	7.6	square miles
ELEV	Mean Basin Elevation	6218	feet
PRECIP	Mean Annual Precipitation	37.3	inches

Peak-Flow Statistics Parameters [100.0 Percent (7.59 square miles) 2012 5113 Region 3 Sierra Nevada]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	7.6	square miles	0.07	2000
ELEV	Mean Basin Elevation	6218	feet	90	11000
PRECIP	Mean Annual Precipitation	37.3	inches	15	100

Peak-Flow Statistics Flow Report [100.0 Percent (7.59 square miles) 2012 5113 Region 3 Sierra Nevada]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	SEp
50-percent AEP flood	96.9	ft^3/s	32.4	289	74.4
20-percent AEP flood	244	ft^3/s	104	571	54.4
10-percent AEP flood	399	ft^3/s	177	897	51.5
4-percent AEP flood	654	ft^3/s	290	1480	52.3
2-percent AEP flood	909	ft^3/s	388	2130	54.6
1-percent AEP flood	1210	ft^3/s	495	2960	58
0.5-percent AEP flood	1570	ft^3/s	611	4040	61.5
0.2-percent AEP flood	2140	ft^3/s	770	5950	67.3

Peak-Flow Statistics Citations

Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, Charles,2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2012–5113, 38 p., 1 pl. (http://pubs.usgs.gov/sir/2012/5113/)

APPENDIX D