Restoration Plan for Upper Halstead Meadow, Sequoia National Park, California

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Introduction and Problem Statement

Wet meadows and fens are critical and relatively rare ecosystems in the Sierra Nevada. A recent survey of meadows in Sequoia National Forest found that approximately 0.1 to 0.5 % of the land area is occupied by wet meadows and fens (Linton personal communication). The strongly seasonal precipitation pattern of heavy winter snow and rain with predominantly dry and hot summers indicates that only areas with perennial groundwater discharge have saturated soils during the majority of the growing season and can support wet meadows and fens. These wetland ecosystems provide important habitat for a wide range of animals, ecosystem services such as water quality improvement, and aesthetic value for human visitors.

Halstead Meadow is the largest meadow crossed by the Generals Highway in Sequoia and Kings Canyon National Parks. It is a wet meadow and fen complex with a deeply incised stream channel both upstream and downstream from the highway. The cause of gullying is likely several factors, starting with heavy livestock grazing in the Caucasian settlement period of the late 1800s and early 1900s, which impacted meadow vegetation and initiated channelization processes. In addition, where the highway crosses the meadow all water has been channelized into a culvert, and very dramatic erosion has occurred both downstream of the culverts, as well as upstream, via head-cutting.

The eroded channel section above the highway is approximately 1500 feet long, has incised to more than 15 feet deep in places (cover photo), and ~8000 cubic yards of sediment has been eroded from the meadow. The channelized flow path quickly transports water away from the meadow and the deep gully has lowered the local water table, causing water to drain into the creek from the vertical meadow banks. In addition, the steep banks are eroding laterally causing the gully to widen and in some areas the gully is more than 40 feet wide, and piping of water is occurring where the meadow sediments have settled, been undercut, or where water is running through pocket gopher tunnels.

Sierra Nevada meadows were formed from mineral sediment and peat accumulating in layers over the past 10,000 years (Wood 1975). These layers are apparent when viewing the meadow soil stratigraphy from inside the incised channel. Our topographic, hydrologic and ecological analysis of intact meadows in the Halstead Meadow vicinity within Sequoia National

Park during 2005 illustrates that all meadows have nearly level cross sectional surfaces perpendicular to the flow of water (see Photo 1 in Appendix 1), allowing the development and maintenance of sheet flow across their surfaces (Cooper and Wolf 2006). Most meadows studied do not have stream channels, although a few small channels may occur, and incision was seen only where human impacts had occurred. All meadows supported dense herbaceous vegetation of sedges, bulrush, grasses and herbaceous dicots, and lacked pocket gopher activity. The location of Halstead Meadow and the reference meadows are shown in Figure 1.

The plan detailed in this document describes the approach that will be used to restore Halstead Meadow. It will use the same fundamental processe that created Halstead Meadow, which was the accretion of layer upon layer of sediment, to create a meadow system that is level perpendicular to the flow of water, and supports a sheet flow system with dense herbaceous vegetation across the entire meadow width. These concepts will be used to rebuild the eroded gully to the level of the intact meadow as viewed in profile. This report is part of the second phase in a three phase restoration plan for Halstead Meadow. The first phase was to collect hydrologic and vegetation data in Halstead and reference meadows to compare Halstead Meadow to intact reference sites (Cooper and Wolf 2006). Five reference meadows in the area were studied to determine the topography, hydrology and vegetation of naturally functioning meadows that lacked deep gullies. The second phase of the restoration is the pilot project upstream of the Generals Highway to demonstrate the approach for meadow restoration techniques, and is outlined in this document. All methods and calculations presented here apply to the Halstead Meadow pilot restoration project for the area above the highway. Restoration of the meadow down gradient from the highway, including construction of a new highway potentially with a bridge, will be phase three of the project, and will be addressed in a future document.

Project Goals

The project goal is to restore the landforms, hydrologic regime, vegetation and wetland functions in the portion of Halstead Meadow upgradient from the Generals Highway to what existed prior to meadow damage. The reference condition time frame for this meadow restoration is the middle to late 1800’s. Due to the cumulative effects of livestock grazing, road construction, channel development, channel head cutting, water table decline, upland plant invasion, and pocket gopher invasion of the once wet meadow the meadow has been severely impacted (Photo 2, Appendix 1). The most northern portion of Halstead Meadow, and the western portion of the lower portion of Halstead Meadow are both unimpacted by gully development, and several other reference meadows in the vicinity provide excellent reference conditions upon which to set project goals. The project goals fall into four categories, (1) topography and landform, (2) hydrologic regime, (3) vegetation composition and coverage, (4) wetland functioning.

1. **Topography and landform**. A key element of this design is the creation of a meadow surface that is nearly level in cross section. The topography of Halstead Meadow should be level for the entire meadow width, perpendicular to the direction of water flow. There should be no hummocks, channels, or other landforms including pocket gopher mounds or tunnels. Logs should be placed perpendicular to the flow direction to disperse water flow and maintain the level topography of the meadow.
2. **Hydrologic processes**. The primary hydrologic goals are to reestablish a saturated sheet flow system across the entire upper meadow (see Photo 3, Appendix 1), and the creation and maintenance of a water table near the soil surface for most or all of the summer throughout the meadow. These goals were developed by analysis of reference meadows, including intact portions of Halstead Meadow as well as the five intact meadows discussed earlier. These areas had water tables that remained within 6 to 12 inches of the ground surface throughout the growing season of 2005. By contrast, the water table in the impacted portions of upper Halstead Meadow dropped to as much as 6 feet below the ground surface during the growing season. The reestablishment of a perennially shallow water table throughout Halstead Meadow, similar to the reference sites, would be accomplished by filling the eroded channel, other channels and areas of piping and other erosion, so that water would be naturally dispersed across a wide area, moving through plants with low velocity and with low erosive potential. A specific hydrologic goal would be that the water table at monitoring wells within the restoration area must be within ±1 standard deviation of the mean water table of a suite of wells in the reference meadows

for every day that water levels are measured during 2007 to 2011. In addition, no channelization of flow or erosion should occur.

3. **Vegetation restoration**. The vegetation goal is to reestablish self perpetuating and rapidly spreading populations of *Scirpus microcarpus*, *Oxypolis occidentalis* and *Glyceria elata* in the restoration area (Photo 4, Appendix 1). The restoration would be accomplished by propagating seedlings of these three species from seed collected in Halstead Meadow during the summer of 2006. Seed would be germinated in the spring of 2007, grown into seedlings at a commercial nursery, and planted during the early summer of 2007. Through time other native wetland plants will become established in the restored communities by clonal spread from the wetland margins, or seed dispersal into the wetland, and species diversity will become similar to that found in the reference meadows. Specific goals for the plantings are:
    a. a minimum mean of 75% seedling survival after three years, and
    b. the density of shoots of species planted in monitoring plots should have a steady increase over time.
4. **Restoration of wetland functions**. The hydrologic and vegetation goals for Halstead Meadow will create conditions that will allow organic matter accumulation in soils. Layers of organic soils can be seen in the meadow stratigraphic section, and occur at the surface in portions of Halstead Meadow today. Most of the meadow will likely not develop organic or peat soils, however where perennially saturated conditions occur the rate of organic matter accumulation will exceed the rate of organic matter decomposition due to water-logging and organic matter will accumulate in the soil. Soil organic matter is critical to the functioning of wetlands by increasing water storage, providing an adequate seed bed for native plants, nutrient sequestration, improved plant production and thus the development of dense vegetation which will disperse and slow the flow of water. The current hydrologic regime does not maintain saturated conditions throughout the meadow, and organic matter cannot accumulate. However, a trend of increasing soil organic matter is an important goal for this project and a positive indication that wetland soil processes have been restored. This wetland function will be analyzed annually by collecting three replicate soil samples from the vicinity of each monitoring well to be installed with the monitoring program, and analyzing the pooled sample for % organic

matter using loss on ignition. There should be a long-term trend of increasing organic matter in these soils that would over time match that found in reference meadows.

Restoration Approaches

Topography and Hydrology

To restore the sheet-flowing hydrologic regime across Upper Halstead meadow, the existing topography (Figures 2 and 3) must be altered to eliminate major and minor channels, underground piping of water, and pocket gopher works that rapidly conduct surface water out of the meadow, and create surface instability. The ground surface must be evenly sloping with contours crossing the meadow perpendicular to the direction of flow to prevent future rill or gully formation. The major gully on the east side of the meadow is the primary channel draining the meadow.

The gully will be completely filled from 50 ft above the highway to the uppermost point on the headcut. The gully will be filled to a level that in cross section matches the ground surface of the adjacent meadow area to the west (Figure 4). Approximately 8000 to 8500 yd^3 of sediment will be required to fill the gully. Fill material is available in a stockpile at the end of Wolverton Road, ~2.0 miles southeast of Halstead Meadow (Figure 9). The ~20,000 cubic yards of fill material stored at this site is mixed sand and gravel. An additional 1000 to 2000 cubic yards of fill material is available at the Dorst Wood Yard, approximately 4 miles northwest of Halstead Meadow. The Dorst material is mixed sand, gravel, and asphalt screened to ¾ inch. The asphalt content of the fill is less than 10%, acceptably low for placement in the meadow, so additional sieving or separation will not be necessary.

We envision seven steps in the site construction process, each of which is discussed below: (1) stream diversion, (2) construction of access road into meadow and filling the gully, (3) stabilization of the fill area and slope near the highway, (4) placement of trees across the meadow, (5) minor grading in meadow to remove small channels, piping, and gopher tunnels, (6) removal of all vehicle impacts to the meadow including access road, (7) removal of stream diversion pipes and rerouting the stream into the meadow.

(1) Stream diversion.

Halstead Creek should be completely blocked at the very upper project edge, north of the area where fill will be placed, and a water diversion pipe system installed to move the entire surface flow to the lower portion of the project area. The goal of this activity is to completely dry out the gully to facilitate its filling. All surface flow should be moved in a pipeline along the western meadow edge where it would then be discharged in the 50 foot highway buffer area, and directed to flow through the existing culverts under the highway. The pipeline should be sized to handle the entire flow of Halstead Creek for the construction period. The 50 foot buffer zone above the highway that is to be used as the reservoir to receive the diverted water may need to be excavated or otherwise altered. The buffer zone reservoir must achieve three primary functions: 1) accommodate all diverted water such that the project work area remains dry, 2) deliver the diverted water through any or all of the four existing culverts under the Generals Highway, and 3) pose no threat of flooding or other damage to the road. When the construction is completed in the fall of 2006, the pipe and dam structures will be removed. There may be ground water entering the gully in several areas, and the contractor should be prepared to use small pumps to dewater the channel, if necessary.

(2) Construction of an access road into the meadow and filling the gully.

A temporary road must be built to allow dump trucks and other heavy equipment to move from the highway onto the meadow surface (Photo 5, Appendix 1). Major surface irregularities in the gully, such as shrubs, logs, and other debris should be removed prior to the initiation of filling operations. Trucks will arrive at the meadow filled with dirt. Filling of the gully could occur in at least two ways: (i) trucks could drive into the gully back up to the point where they dump their loads and drive out of the gully, or (ii) a number of dumping points could be created on the gully edge. These dumping points will be identified and graded to have a gentler bank slope to eliminate the risk of bank failure. Once material is placed into the gully it should be spread into thin layers with a bulldozer, and compacted by the weight of the bulldozer. Periodically watering the placed fill may help to increase compaction as well. Rocks, boulders and other large material could be placed in the gully and mixed in with the sand sized material. It is desirable to have finer than sand sized sediment mixed into the fill. Park staff, Dr.

Cooper, or a similar skilled professional will assist in quality control during the fill procedure, including determining whether proper final topography has been achieved.

Because ground water will enter the channel from adjacent hillslopes some water management, such as using a small pump with hosing to remove water, may be necessary to maintain a dry gully.

Vehicles may be parked along the access road or in the gully overnight. If vehicles are left parked within the project area, precautions must be taken to prevent oil, or other fluid leaked from a vehicle, from contaminating soil. In addition, a large pullout at a picnic area near the site will be available for some staging activities (Figure 9). At no time during the construction process are vehicles or other equipment to be off-road outside of the work area, shown as a yellow dotted line in Figure 10. During nighttime, weekends, or any other time that the project site is unattended, a fence and warning sign must be erected on the north side of the road to keep visitors out of the project area (Figure 10).

(3) Stabilization of the fill area and slope near the highway.

The gully will be filled to within 50 feet of the Generals Highway (Figures 5, 6, and 7). The gully fill will gradually slope down at a moderate slope to create a buffer area 50 feet wide. The primary gully area to be filled is 1.351 acres, and is indicated by the red outline in Figures 3 and 5, and by the width measurements with bars in the cross-sectional profiles (Figure 4). The entire area of bare ground that results from filling operations must be stabilized with layers of Curlex excelsior mats or other similar material to prevent erosion and head cutting into the fill material (Figure 8). These mats must be anchored with a wood, natural fiber, or other biodegradable staple or stake. Filled areas where intact vegetation has been set aside and replaced on top of fill should not be covered with excelsior matting. This fill retainer may be constructed in a number of ways including the use of netting, rebar to secure logs or a combination of treatments.

(4) Placement of trees across the meadow.

Filling the gully will allow the restoration of ground surface contours that match those of reference meadows, which are nearly level in cross section. This level ground surface will create a sheet flow system during the early to middle summer. Fallen trees can be seen protruding into the gully from the valley alluvium indicating that the input of large wood is an important component of the formation of meadows. Trees that lie across the slope can help to maintain the dispersion of water (Photo 6, Appendix 1). To dissipate flow energy and reduce the chance of erosion or rilling of the fill material, logs will be laid on the contour across the gully fill and valley width at breaks in slope (Figure 8). Logs will be acquired from either the gully debris removed prior to filling, or from trees felled from the surrounding hillslopes. Selection of the specific trees to be felled will be made with consideration of impact to the visual appearance and local ecology. If live trees are felled, the branches do not need to be removed prior to placing the tree in the desired location. The logs do not need to be anchored to the surface, and there is little likelihood of them moving. Approximately 10 to 15 logs will be placed in the meadow. Their exact location will be determined by the location of large dead trees on the meadow slopes that can be felled into Halstead Meadow, and critical locations that appear to need a stabilizing effect. If enough large trees cannot be cut, then several small one, laid end to end could be used in places. In addition, Park staff have access to a stockpile of used excelsior Curlex sediment logs. The excelsior logs can be used fill gaps both to the side of and underneath natural logs. The excelsior logs must be anchored in place with wooden, natural fiber, or other biodegradable stakes.

(5) Minor grading in meadow to remove small channels, piping, gopher tunnels.

Prior to the placement of any fill in Halstead Meadow, the existing meadow surface west of the channel must be leveled to remove existing channels, areas of piping, gopher works and eroded or mounded areas. The final grade would not be developed at this point, but features that need attention are best addressed before heavy equipment begins to move in the meadow. This work would ideally be accomplished by hand, using shovels, wheelbarrows, and other hand tools. If a small rubber-tired front end loader or other equipment is needed, precautions must be taken to prevent compaction and tracking in the ungraded meadow. Mats, boards, or metal sheeting may be used to spread out the weight of any equipment that may need to drive across intact meadow. If filling outside of the main gully is needed in areas with intact and desirable wetland vegetation, this vegetation is not to be buried. It should be removed in sods no smaller than 2 ft by 2ft, by 1 ft deep, set aside upright, and replaced on top of the fill material to produce the final grade. Areas outside of the main gully that will likely need to be filled are identified in the cross-sectional profiles as shaded regions without width measurements, west of the main gully (Figure 4). In addition, some sloping areas of the western gully bank may be vegetated with natural and desirable plant species. These areas should be treated as above and may account for as much as 0.3 acres of the 1.351 acres of gully area to be filled.

(6) Removal of all vehicle impacts to the meadow including access road.

Once the gully is filled and logs placed, minor earthwork may be necessary to remove tire tracks, gouges from felled trees, and other artifacts of the construction process. This work can likely be done by one small rubber-tired loader.

(7) Removal of stream diversion pipes and rerouting stream into meadow.

The last step is to remove the diversion pipes, all dam material, and restore the flow of the stream across the meadow. At this time a small crew may be necessary to evaluate the sheet flow and place small logs and other debris on the meadow surface to disperse water where it is forming rills.

Vegetation

Plants will be grown in a commercial greenhouse and brought to the Halstead area in early summer of 2007. Planting will be initiated on June 4, 2007 and shall be fully completed by June 15, 2007. At this time water levels will allow access to the meadow by the planting crew. Plants will be installed at a density of 4 plants per square yard in an area of ~2.5 acres in the area outlined in red and green on Figure 3. Plants will be planted at a density of 1:3:1, for *Glyceria elata*, *Scirpus microcarpus* and *Oxypolis occidentalis*. Plants will be planted in rows with individuals planted in the following order *Scirpus, Scirpus, Glyceria*, *Scirpus, Oxypolis, Scirpus, Scirpus, Glyceria*, *Scirpus, Oxypolis,* etc. It is also possible that rows of one species should be installed across the meadow, with the rows following the order outlined above. Complete specifications for plantings are in the following document: “Sequoia and Kings Canyon National Parks, Upper Halstead Meadow Pilot Restoration Project, Wetland Plant Materials and Installation Scope of Work.”

Post construction monitoring

Post construction monitoring must include four components: (1) hydrologic analysis, (2) vegetation analysis, (3) soil analysis, and (4) a jurisdictional wetland delineation. Each component is described below. Monitoring should occur for at least three consecutive years, stating in 2007, and ideally continue for a longer time period.

(1) Hydrologic analysis.

Transects of monitoring wells are necessary to measure water table depth throughout the meadow and determine whether the water table depths meet the stated goal of being within ±1 standard deviation of the mean for any date during the summer for the suite of reference sites. Reference site wells must also be measured during the monitoring period. For upper Halstead Meadow five transects of five wells each, for a total of 25 to 30 fully slotted ground water monitoring wells should be installed. A large number of wells already exist from our 2005 study, and should be either protected during the construction period, or removed and reinstalled in exactly the same location in the fall of 2006. Wells should be constructed from 1.5 inch inside diameter Schedule 40 PVC pipe, which are installed into hand augered holes approximately 3 feet deep. Wells should be measured weekly or biweekly during the growing season from June through early September. Wells should be topographically surveyed so that the elevation of the water table and the ground can be used to make water table depth maps. Water table depth data for each well should be compared with the reference suite of wells each year.

(2) Vegetation analysis.

Around each monitoring well, three herbaceous vegetation plots should be established in the summer of 2007 just after seedlings are planted. Each plot consists of three rebar stakes, two of which are spaced 30 cm apart in an area where no seedlings were planted, and the third stake 70 cm away from one of the other rebar, and in a straight line. A circular metal hoop with a diameter of 1 m should be made that fits over the two rebar that are farthest apart. All seedlings within the plot should be counted by species in the late summer of each year to determine % survival. A smaller metal hoop with a diameter of 30 cm should be placed over the two closer rebar and the number of shoots present should be counted by species. These data will be used to show trends in shoot density by species over time.

(3) Soil analysis.

Three soil samples, each approximately 5 x 5 x 5 cm in size should be collected from randomly selected sites on the ground surface around each well. The samples should be pooled, and analyzed for % organic matter, by loss on ignition. Samples should be collected in late summer of each year. In addition, hydrologic data for each well should be used to determine which sites have saturated soils of sufficient duration to be considered hydric according to the 1987 US Army Corps of Engineers Wetland Delineation Manual.

(4) Wetland delineation.

All data on water table depth, vegetation composition and soils should be used to do a formal jurisdictional wetland delineation to determine the area of jurisdictional wetland that has been restored.

A report will be submitted to Sequoia National Park each year including all monitoring data, and the jurisdictional delineation will be performed at the end of year 3, in the late summer of 2009.

Literature Cited

Cooper, D.J. and Wolf, E.C. 2006. Analysis of Meadow Hydrology, Vegetation, and Soils and Suggestions for Restoration of upper Halstead Meadow, Sequoia National Park, California. Report to Sequoia National Park.

Linton, F. Personal communication. Botanist, Sequoia National Forest. 1 March 2006.

Wood, S.H. 1975. Holocene stratigraphy and chronology of mountain meadows, Sierra Nevada, California. California Institute of Technology, Pasadena, CA.

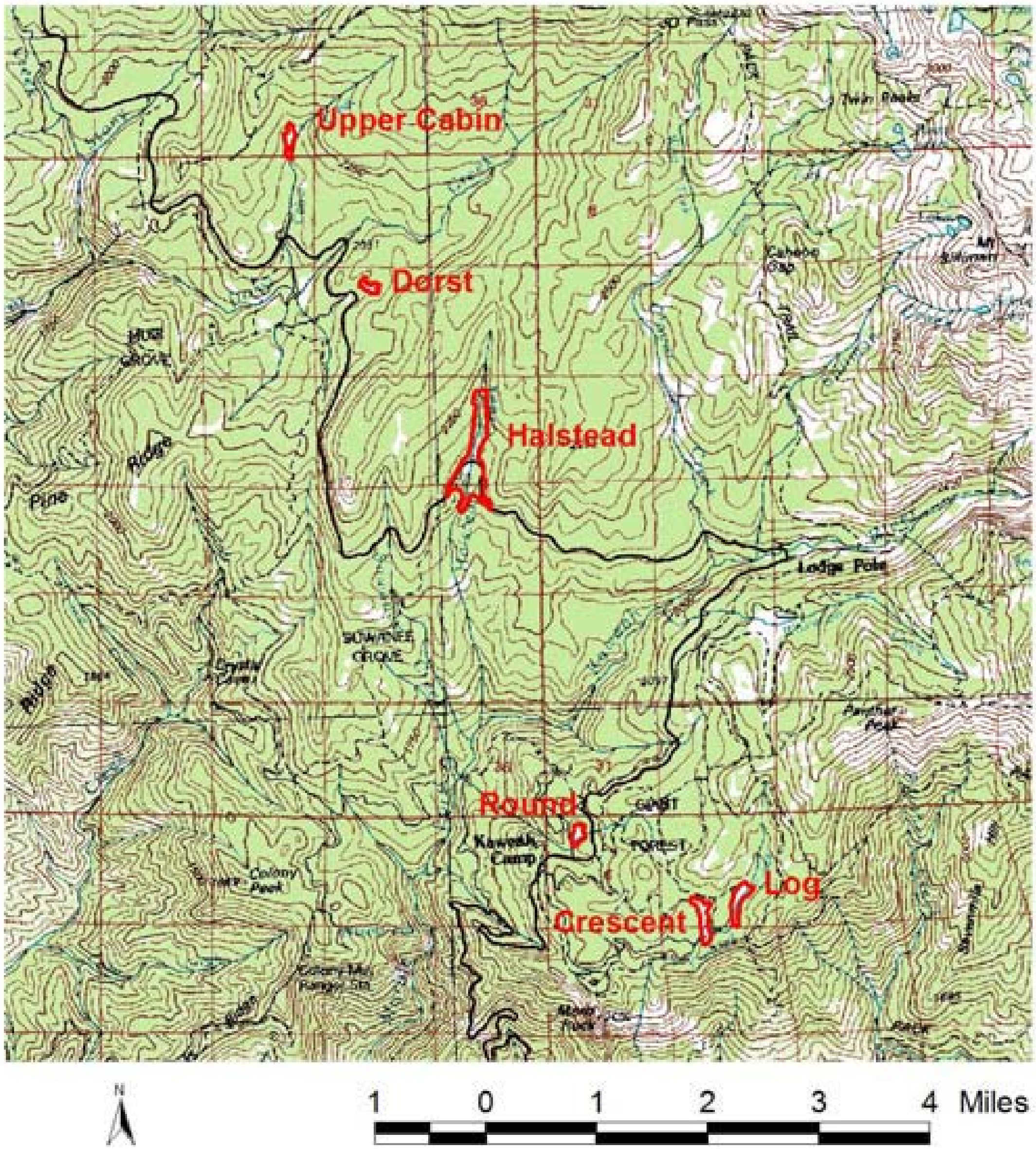


Figure 1. Map showing location of Halstead meadow and reference meadows, Upper Cabin, Dorst, Round, Crescent, and Log.

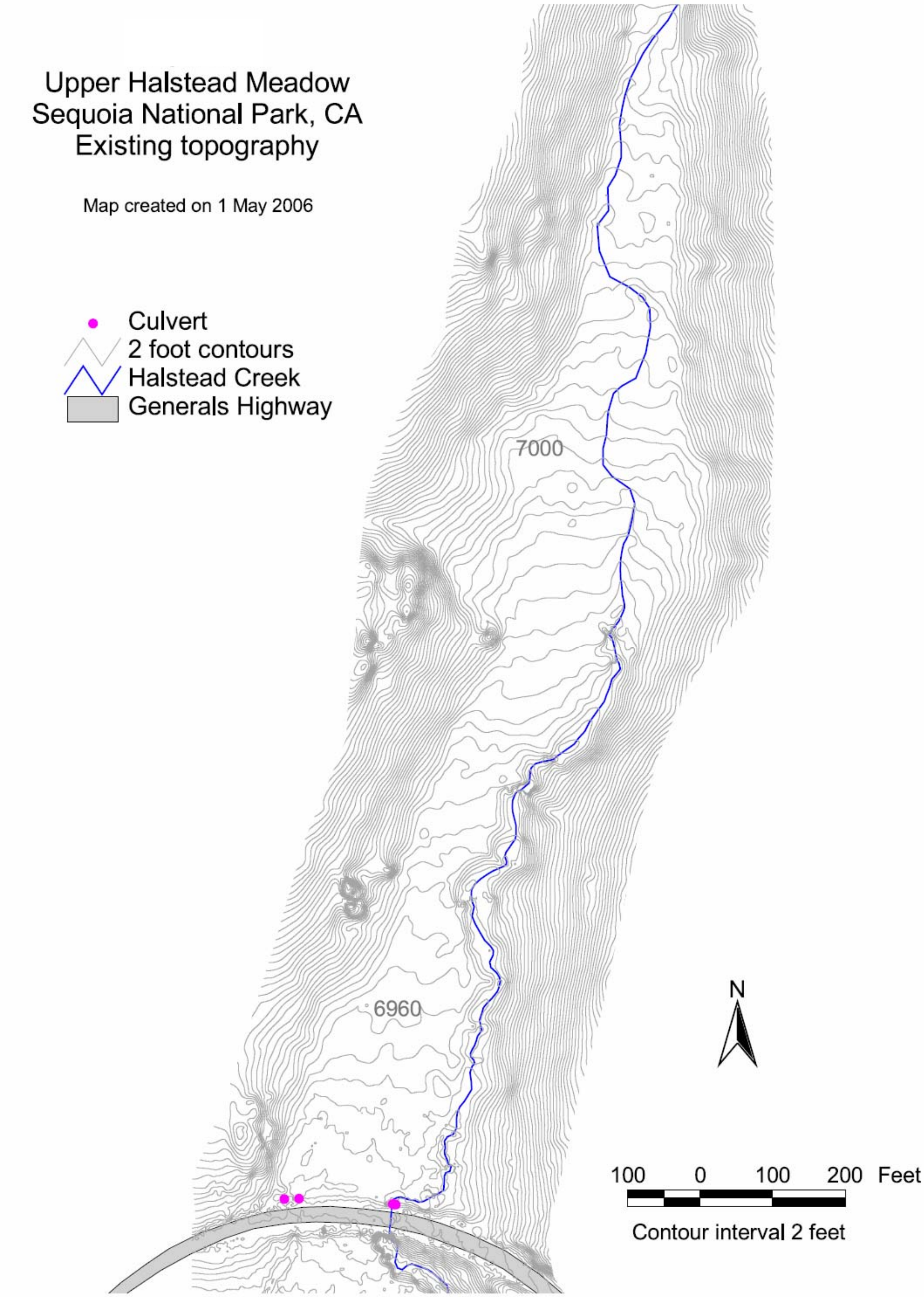


Figure 2. Existing Topography.

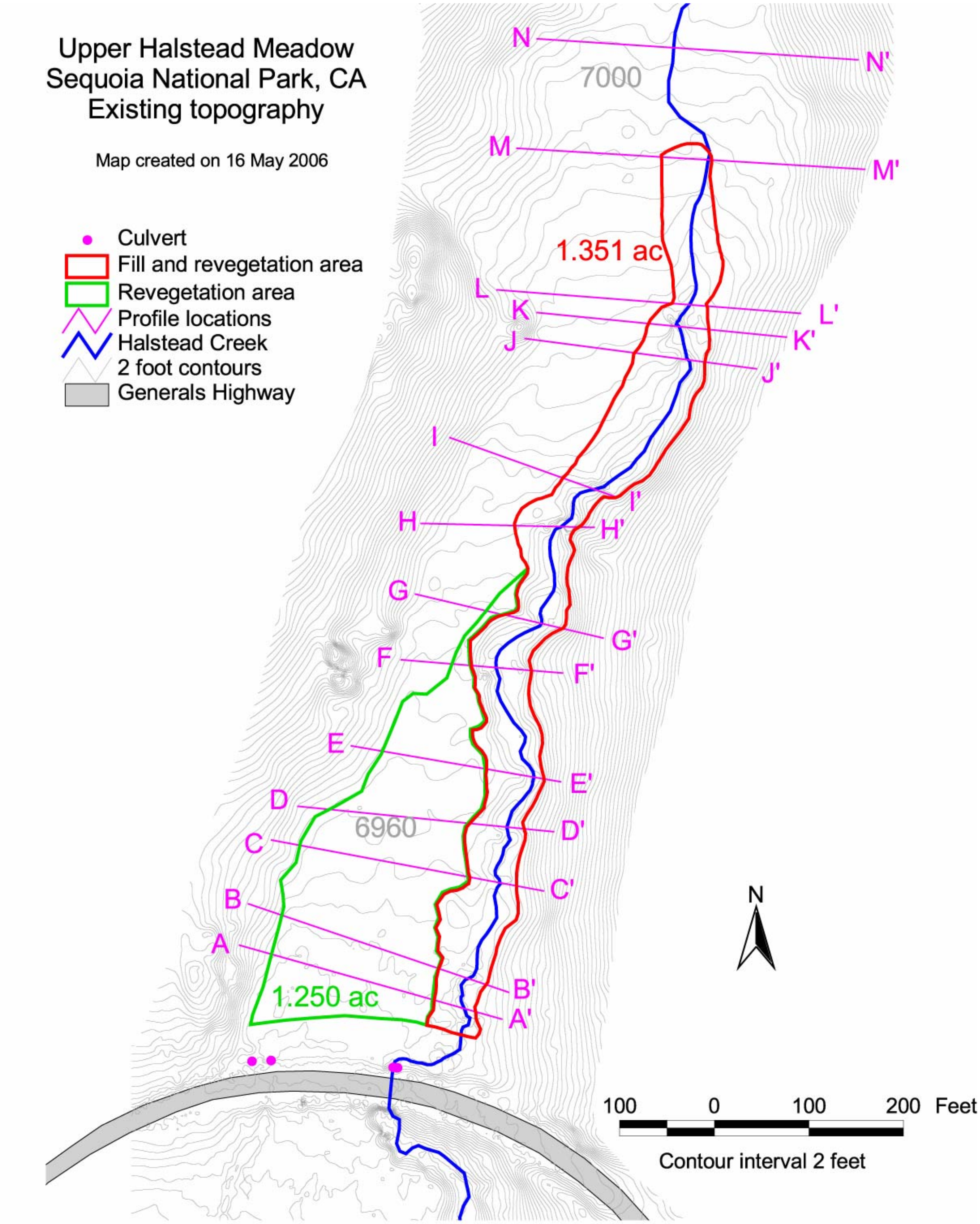
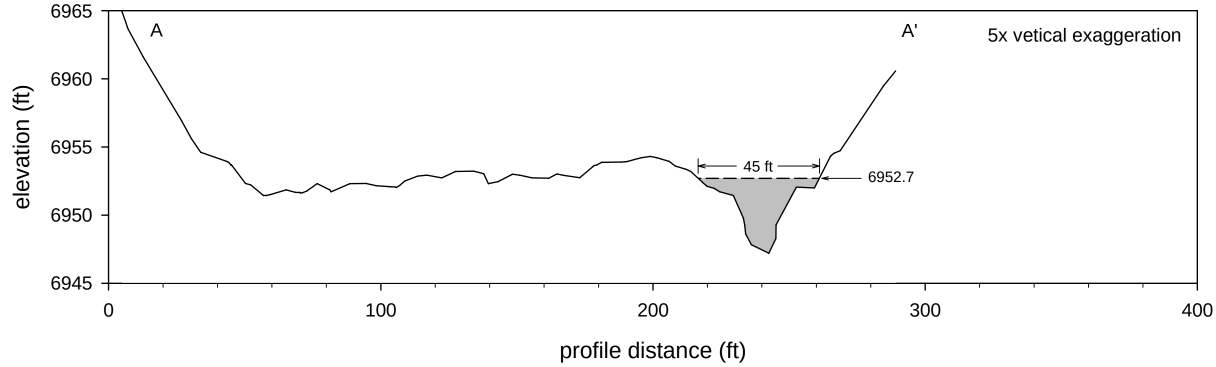


Figure 3. Existing topography showing location of cross sections.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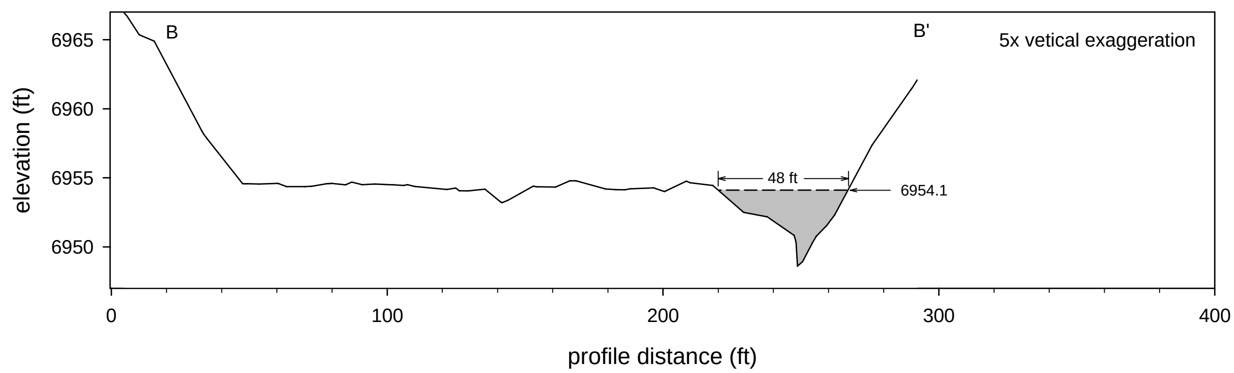
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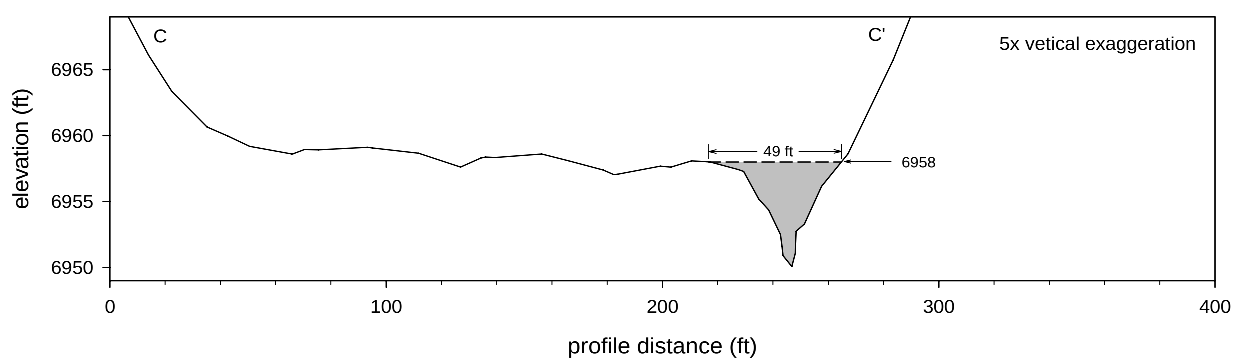
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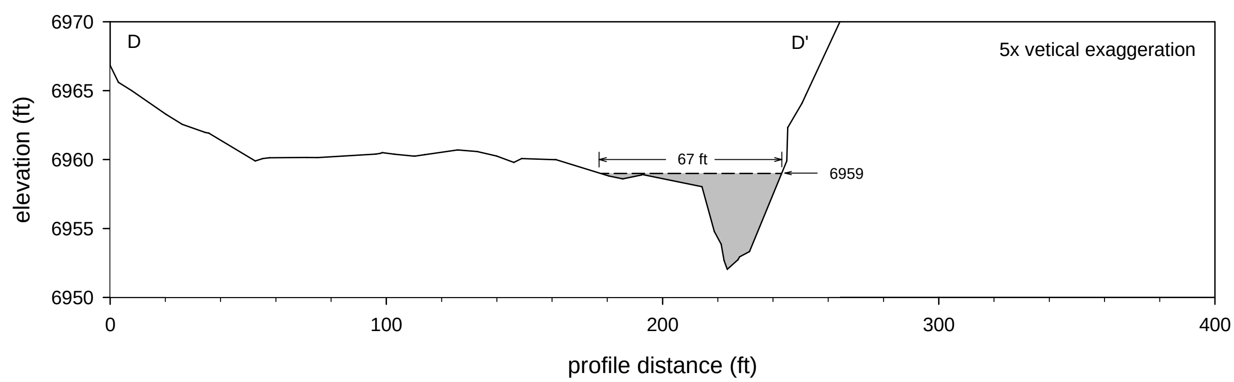
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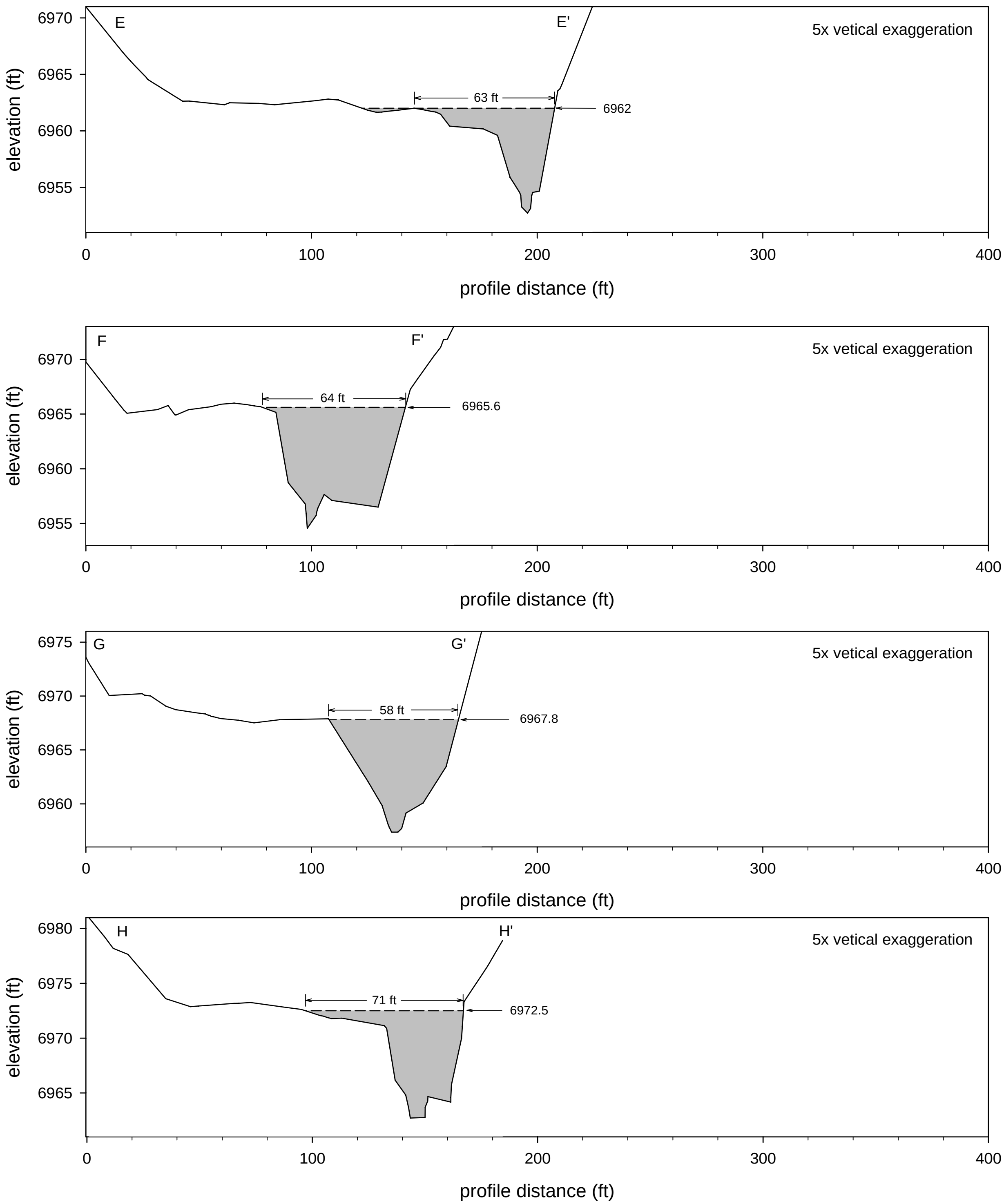
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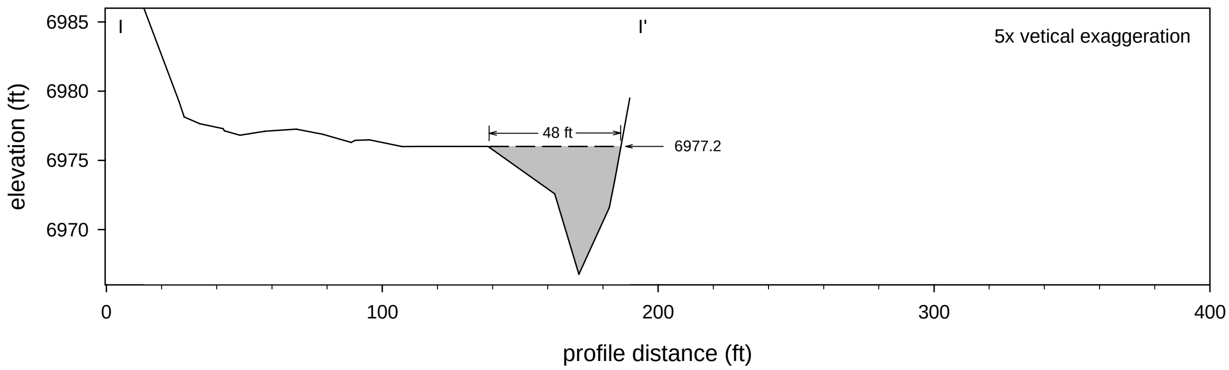
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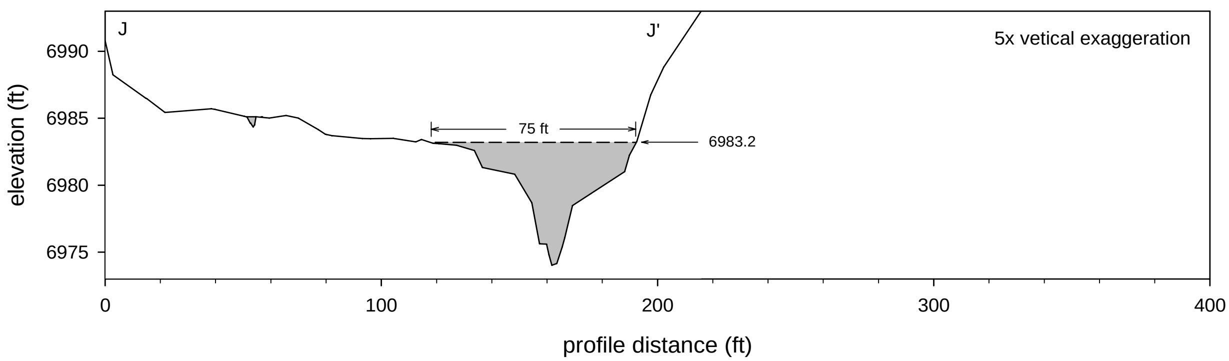
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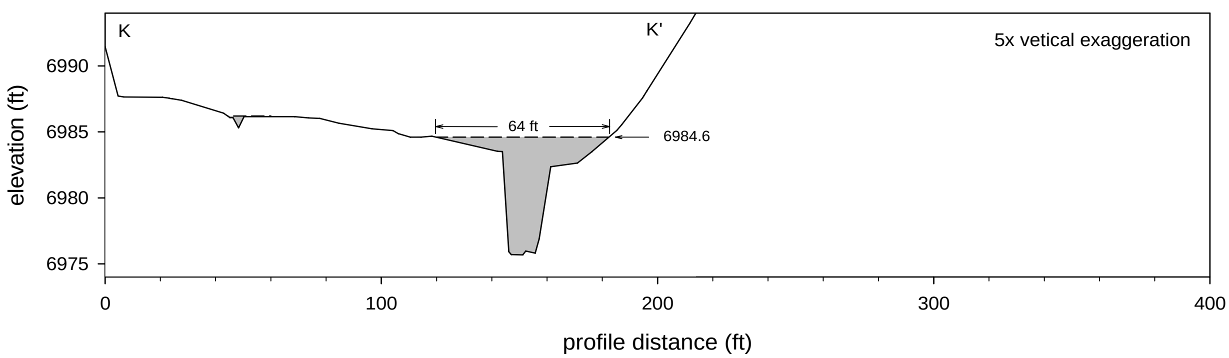
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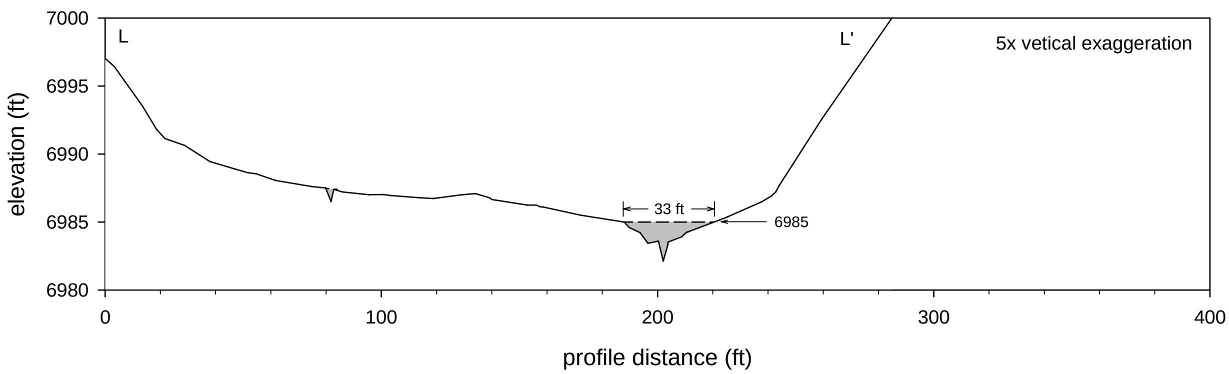
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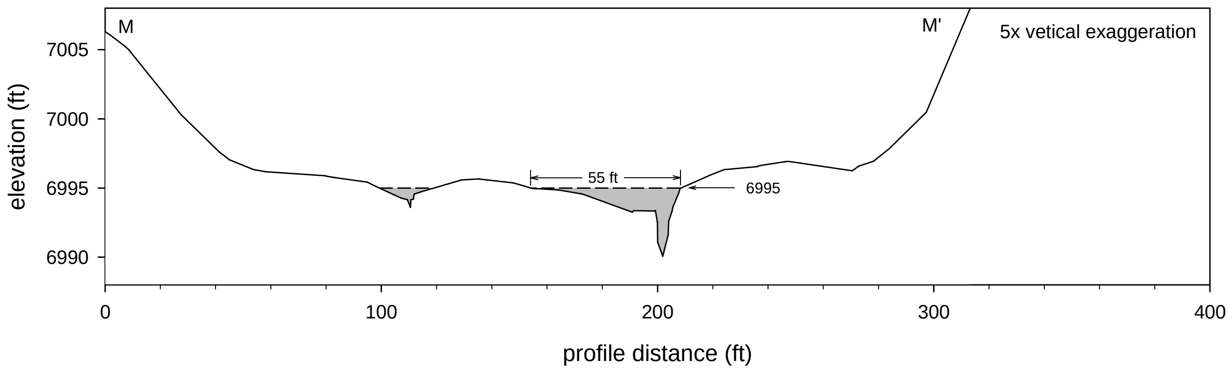

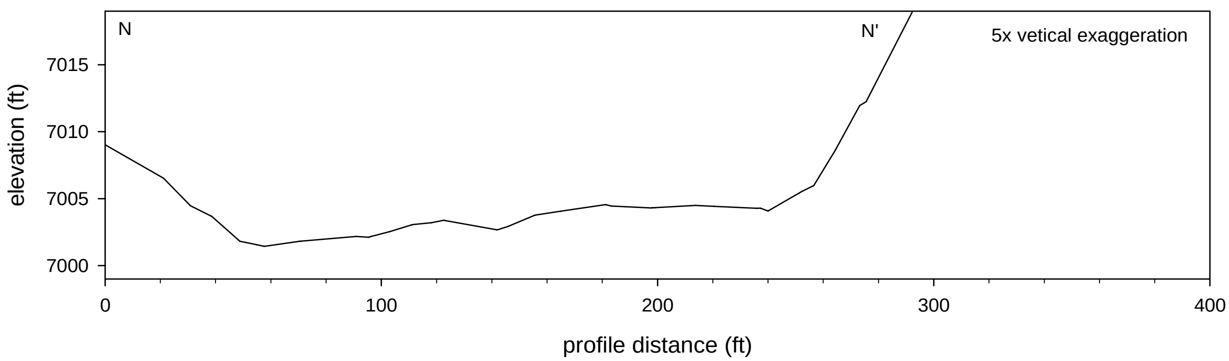

Figure 4. Cross sectional profiles. Area to be filled is shown in grey with the top of the fill indicated by a dashed line. Width of the fill at the main gully is indicated by value between the capped arrows, elevation of the fill level is shown with a regular arrow. Additional areas that may need to be filled are shaded grey outside the main gully.

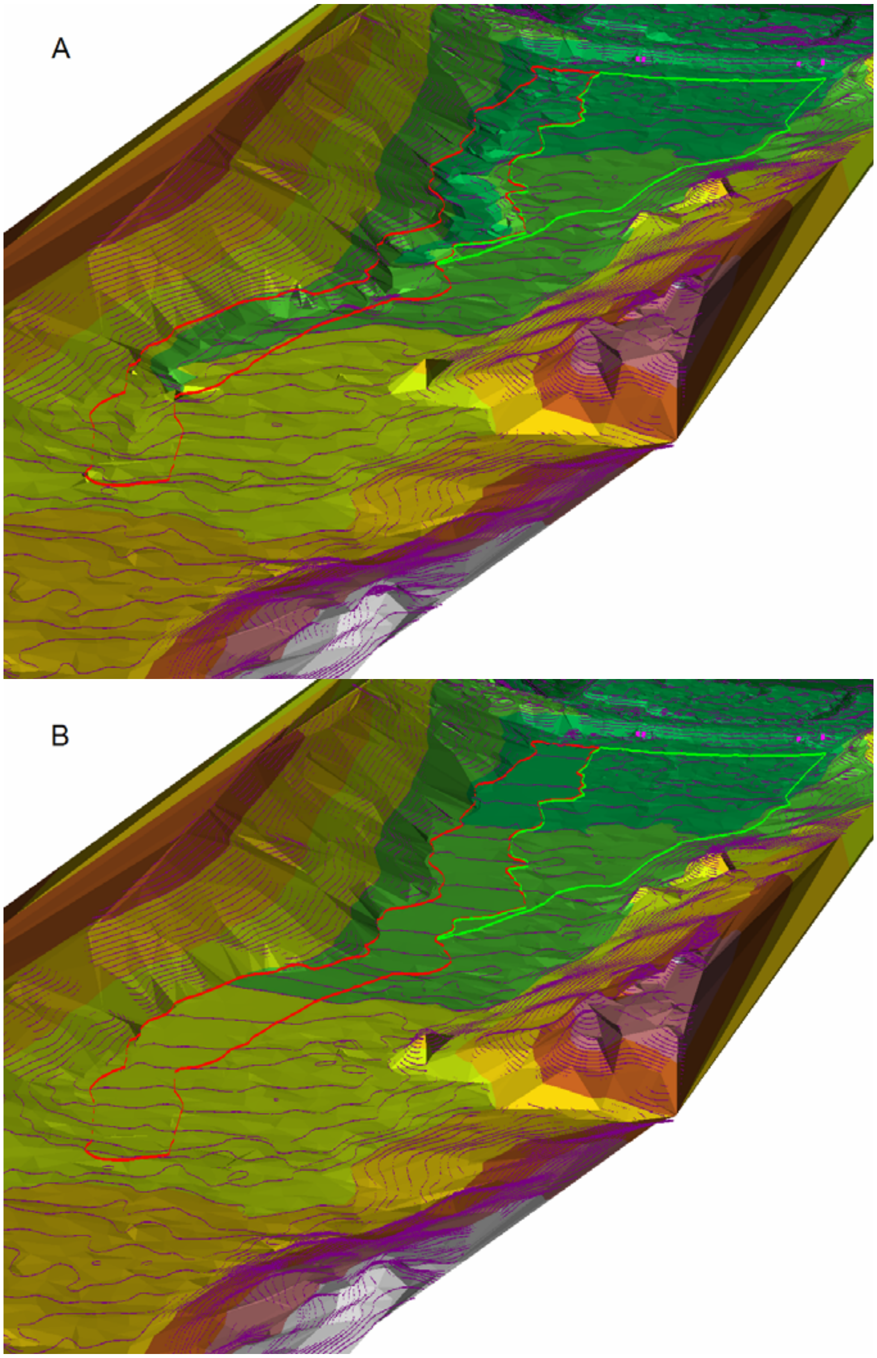

Figure 5. Schematic of the existing (A) and post-fill (B) topography. Point of view is from above and north of Halstead Meadow, looking south. Color bands are 20 foot elevation zones, the orange-yellow boundary is 7000 feet, purple lines are 2 foot contours. The valley slopes down to the upper right of the image where it is crossed by the Generals Highway, with 4 culverts underneath (pink dots).

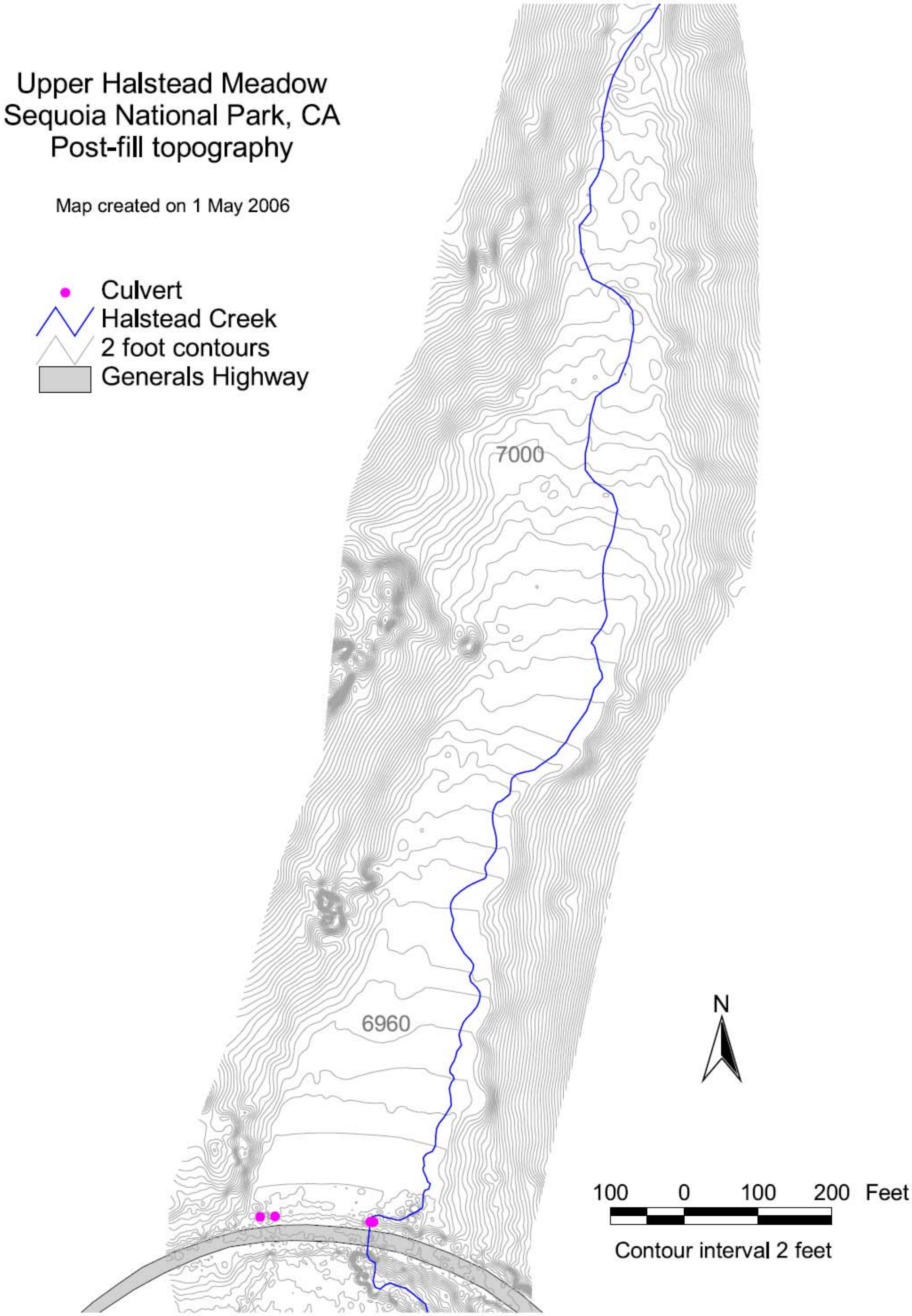

Figure 6. Post fill topography.

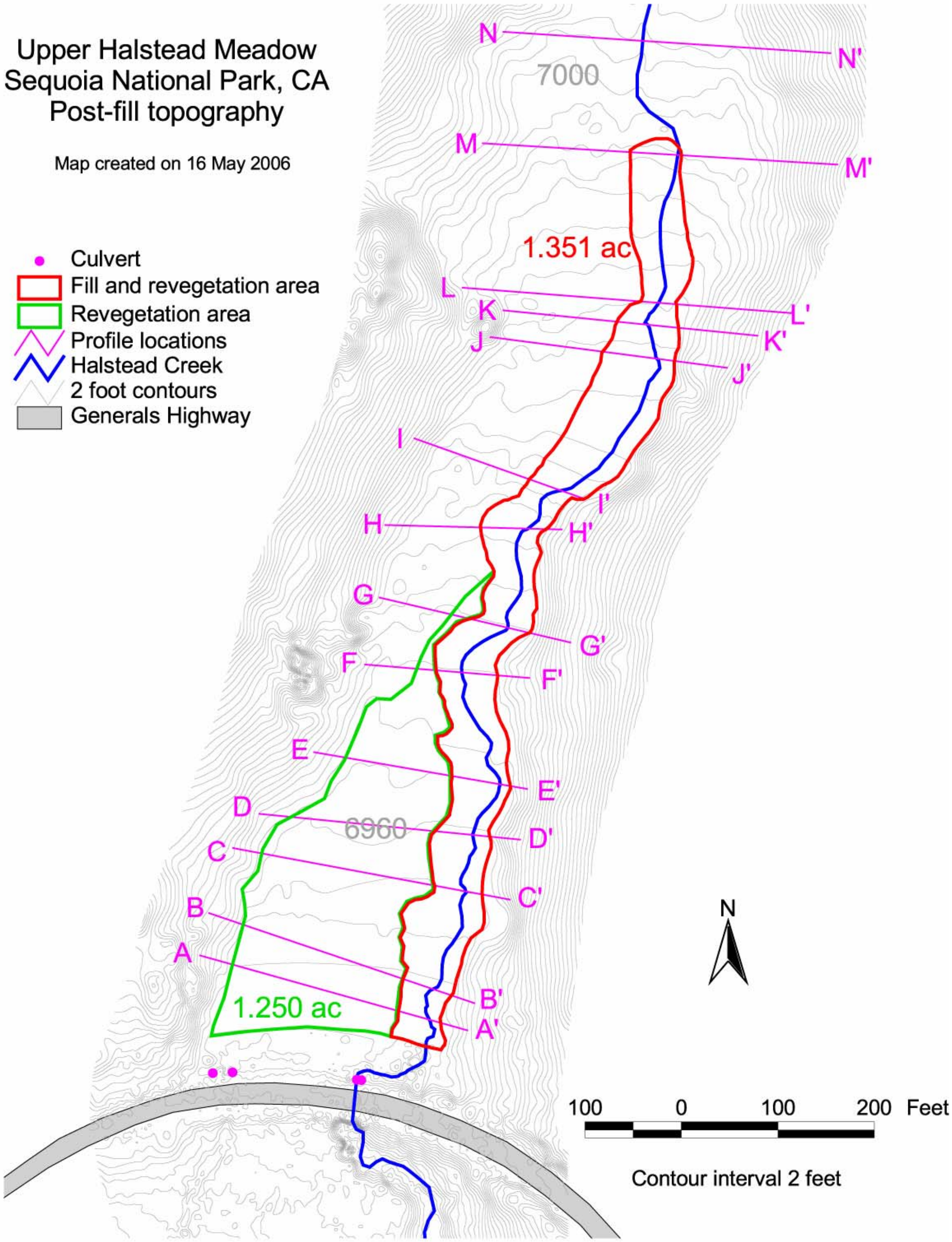

Figure 7. Post fill topography showing locations of cross sections.

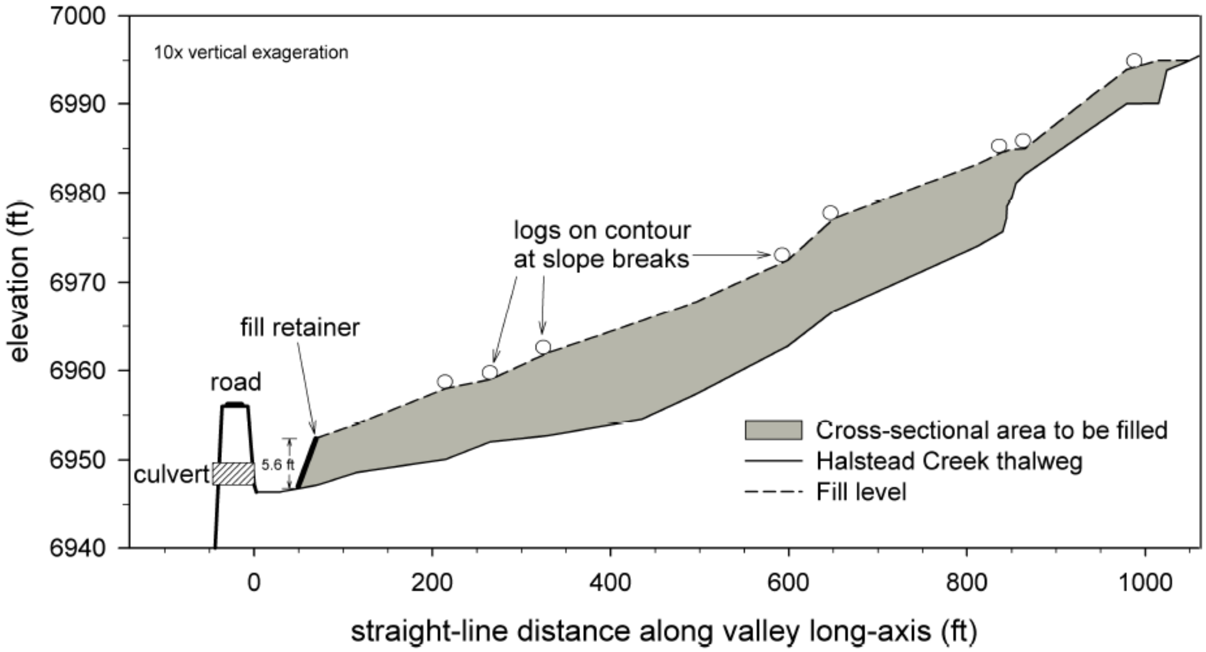

Figure 8. Post fill longitudinal meadow profile.

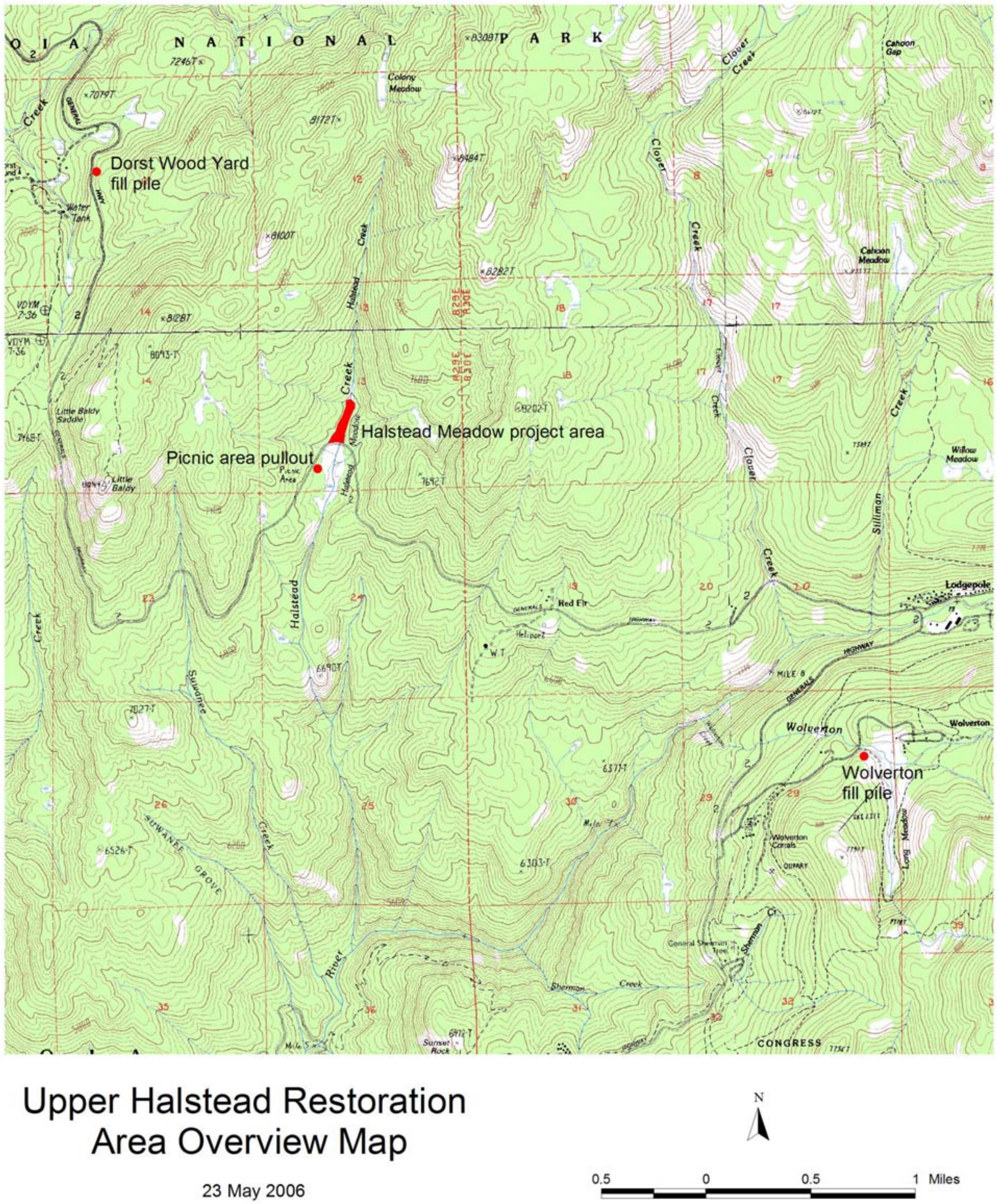

Figure 9. Map showing the location of the two fill piles and the picnic area pullout in relation to the project area.

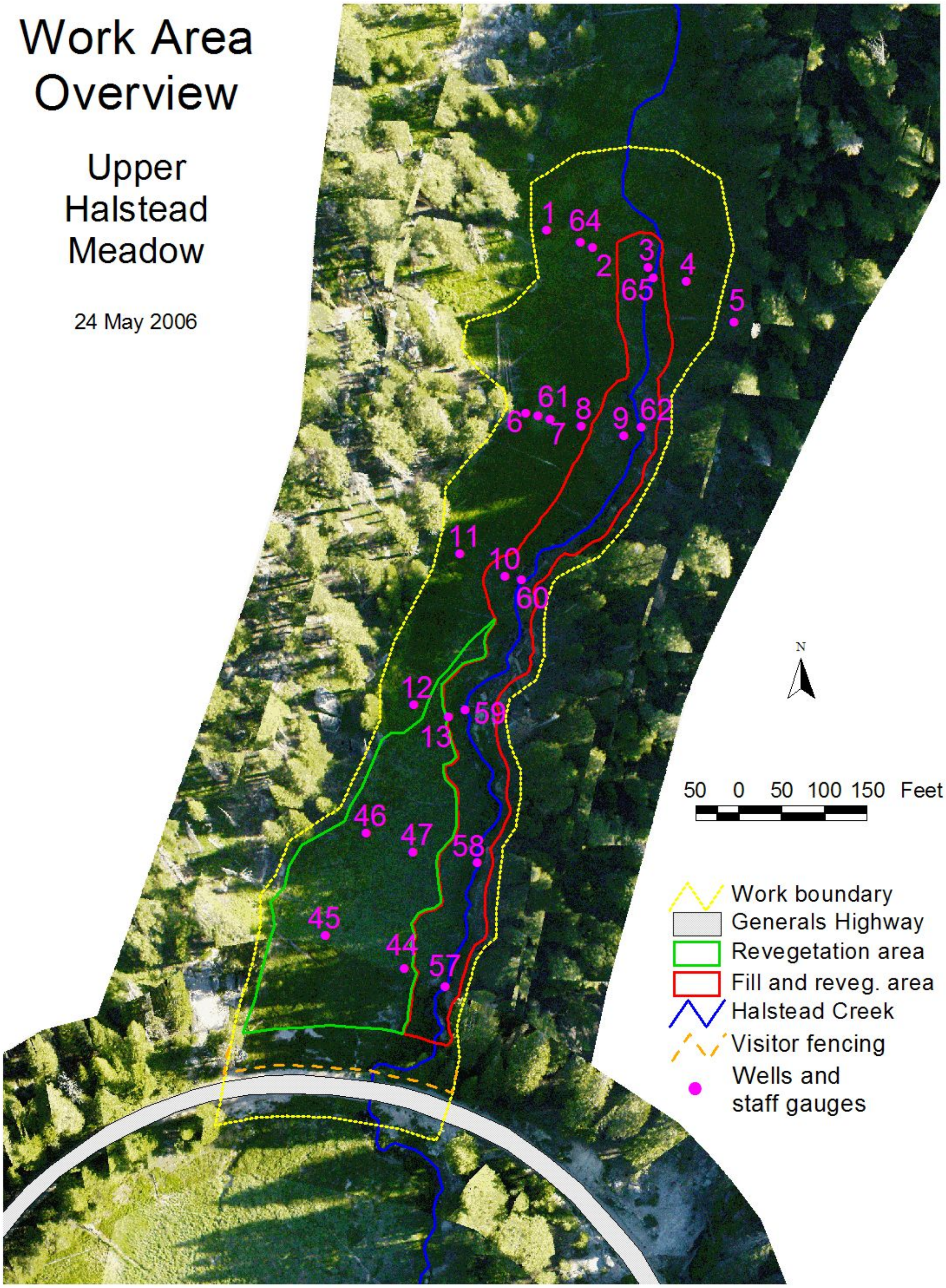

Figure 10. Aerial photo showing the location of wells and staff gauges, work areas, and fence line to keep visitors off-site.

Appendix 1

Photo 1. Crescent meadow, illustrating the level cross sectional profile. Water flow is toward the viewer.

Photo 2. Looking north up Halstead Meadow, the foreground vegetation is dominated by herbaceous dicots which do not occur in areas that have not been hydrologically impacted by gully development. The northern portion of the meadow, beyond the dashed black line, is intact and dominated by *Scirpus microcarpus.*

Photo 3. Sheet flow system in early summer in Round Meadow. Unchannelized water flows across the entire meadow, throughout the early to middle summer.

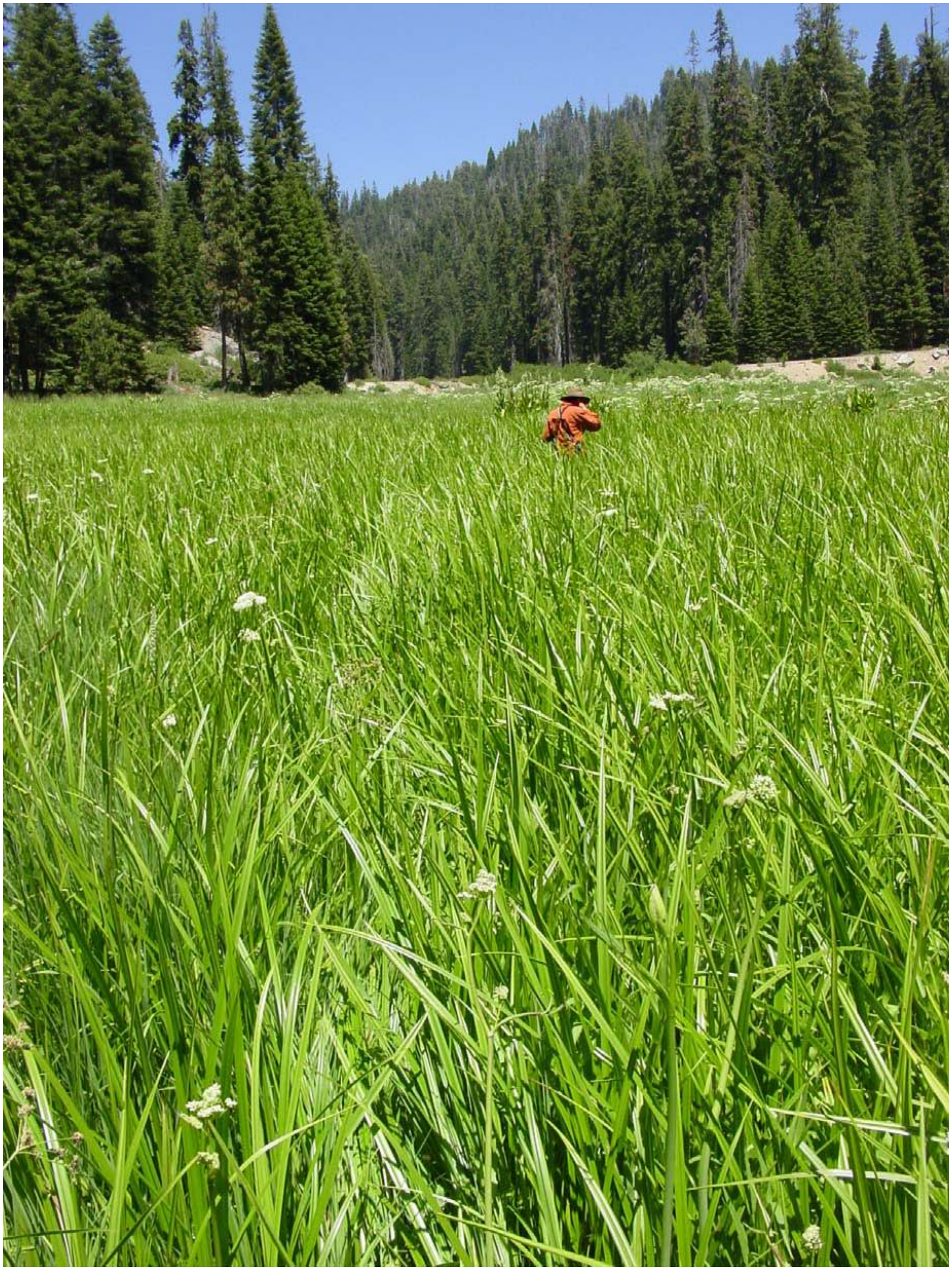

Photo 4. Dense vegetation of *Scirpus microcarpus* the narrow leaf plant, and *Oxypolis occidentalis* the white flowered plant.

Photo 5. Looking south from upper Halstead Meadow to the Generals Highway. An access road would have to be constructed to allow vehicle access from the highway to the meadow. The gully cannot be seen, but is to the left.

Photo 6. Fallen logs in Crescent Meadow help disperse the flow of water and maintain sheet flow.