TECHNICAL REPORT #1 January, 22, 2010

Big Meadows Restoration Project, October 14, 2009 Flood Event

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Introduction:

The purpose of this report is to document the performance of a meadow restoration project to a major flood event. This has relevance in that the Big Meadows Restoration Project utilized a relatively new technology, called pond and plug, to re-connect the channel to its naturally evolved floodplain. The technology has had very few major flood "tests". This report documents project performance in this test.

Background:

The Big Meadows Restoration Project is located in the Sequoia National Forest, Giant Sequoia National Monument, Hume Lake Ranger District approximately 56 miles east of Fresno, Ca. at an elevation of 7,600'. Big Meadows Creek was incised in Big Meadows for many years, likely a result from a combination of drainage manipulation and historic livestock use prior to national forest management. The incision gradually dried the wet meadow system converting the vegetation to a more xeric community. Efforts to stabilize the incised channel have been ongoing since the 1930's (Photo #1), utilizing a variety of techniques ranging from brush dams/revetments to a suite of checkdam methods such as gabions, loose rock and rock/mortar (Photo #2). Big Meadows again became the focus of a restoration effort in 2004-05 with the development of a restoration plan by Jason Olin (Olin, 2005). The purpose of the project was to restore full channel/floodplain connectivity to the meadow and any attendant ecosystem benefits resulting from this condition.

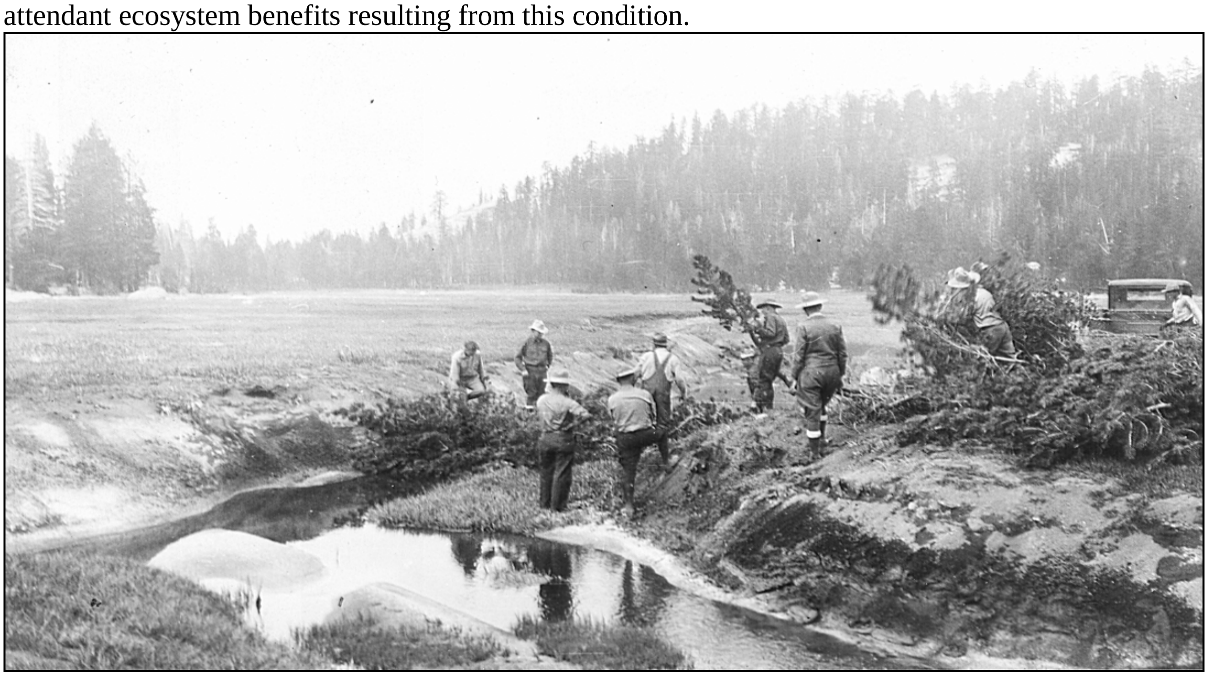


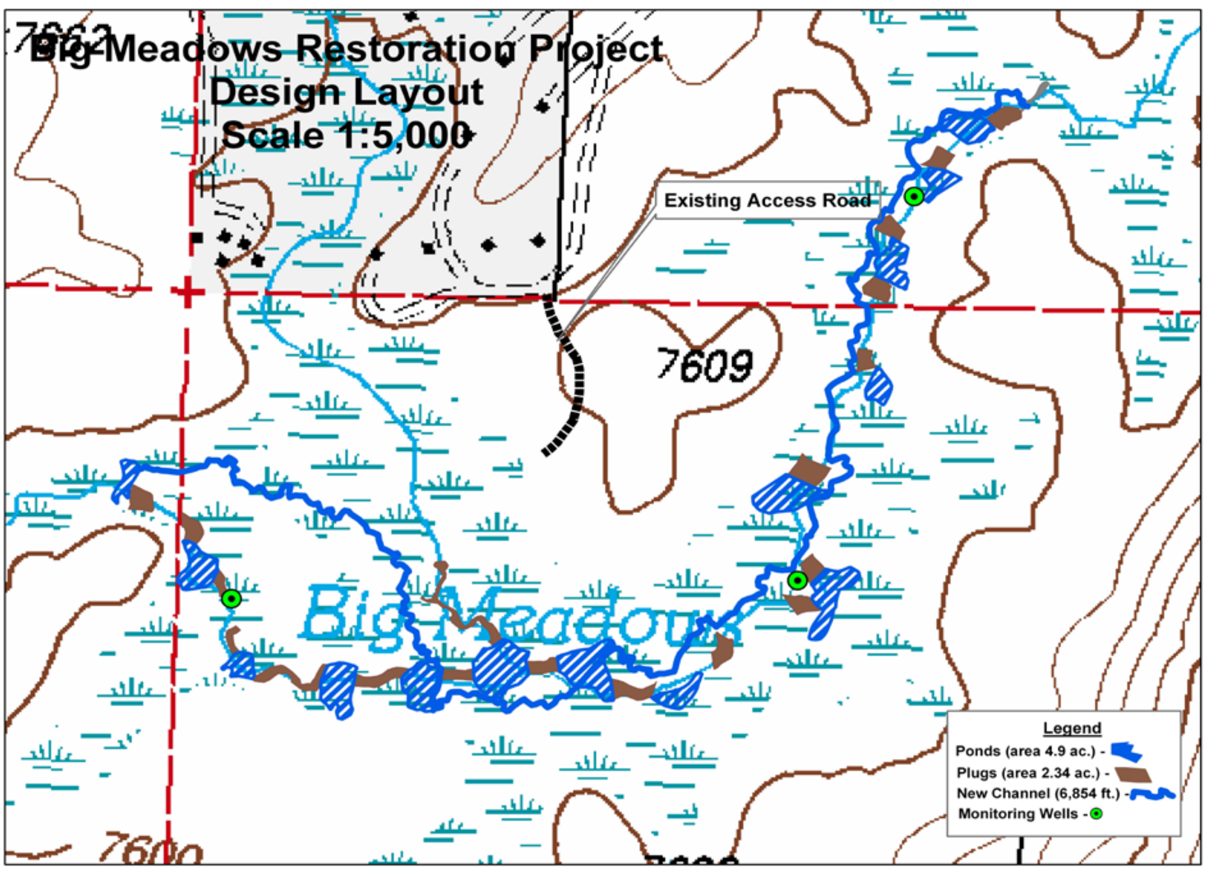
Photo #1. brushdams, circa. 1934 (Note: similar meadow location as photo series 7b & 7e) USFS Archives

The Olin restoration plan had several proposed phases, one of which entailed eliminating a portion of the incised channel (gully) using an innovative technique called pond and plug (Lindquist et.al., 2000). This research and planning effort was sponsored in part by the Fresno Chapter of Flyfishers for Conservation (FFC), and in cooperation with the Hume Lake Ranger District, Sequoia National Forest (SQF). Project sponsors and SQF chose to implement a modified version of the restoration plan which entailed treating the entire meadow to eliminate the gully altogether and return streamflows to the surface of the meadow.

The project would use the pond and plug technology. FFC and SQF combined efforts to secure funding from multiple sources to construct the project in the fall, 2007. These funding sources included the National Fish and Wildlife Foundation and Sequoia NF as well as local and regional fishing organizations, and individuals.

Photo #2. Gabion checkdams Photo by: unknown

Project construction began September 16, 2007 and required three weeks to complete. The project consisted of the excavating 13,150 yds^3 of material from 14 borrow areas (ponds) to construct 19 plugs (Map #1). The elimination of the existing gully returned channel flows to 6,854' of existing remnant channel system and re-connected all flows to 79 acres of meadow floodplain (photo #s 7a, 7b, 7c). Valley slope varied from .2% -1.5% with an average of .7%. Grazing returned in 2009, after one year of rest (new fence shown in photo 7f). The project final design and construction supervision was overseen by the author. Author has made several monitoring trips post-project and monitors conditions on the ground and with existing publicly-accessible remote weather, snow course and stream gage stations. SQF continues annual pre- and post project monitoring initiated in 2006, along with avian surveys.



Map #1. Big Meadows Project as-built restoration design.

Hydrologic Setting:

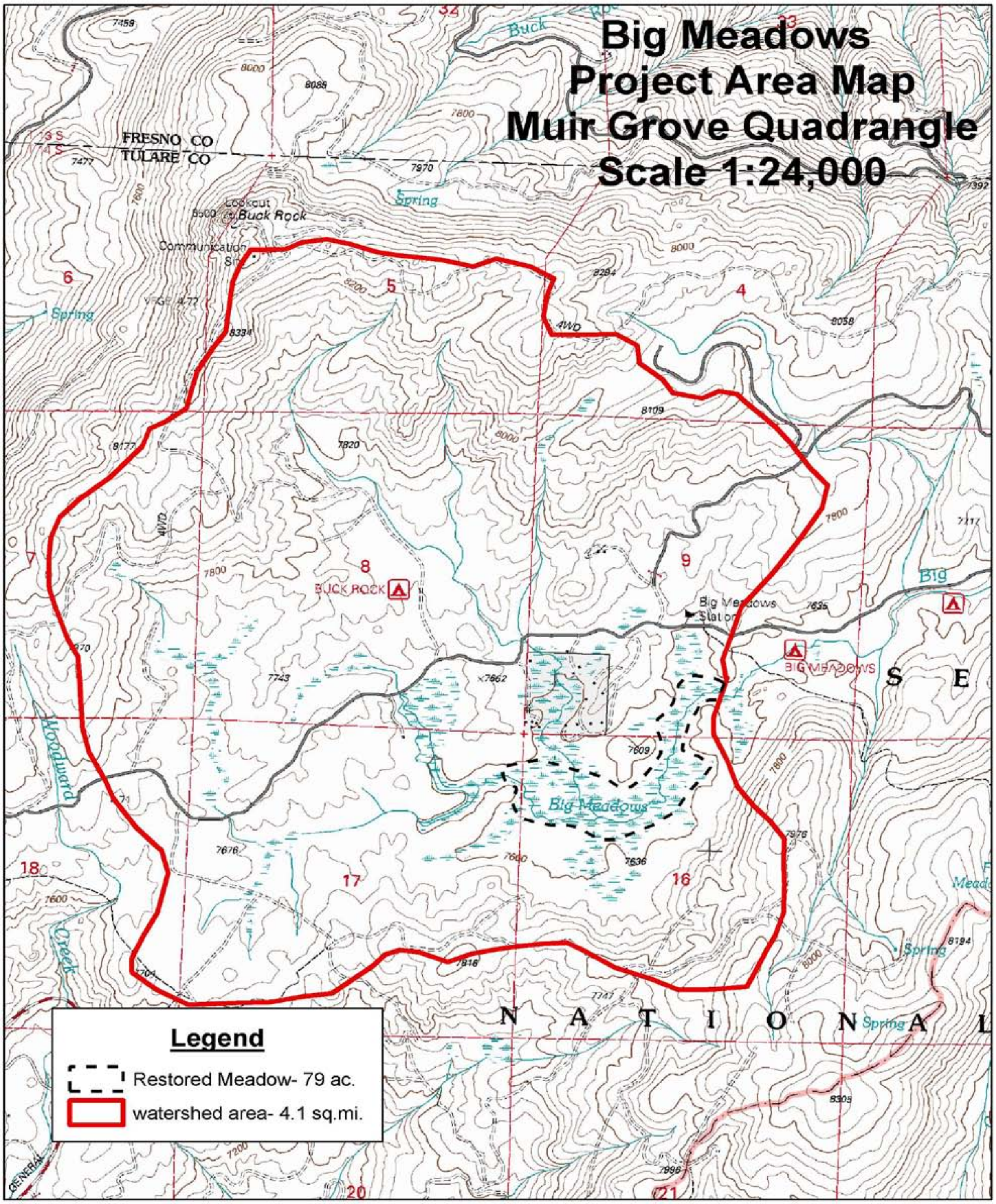
The Big Meadows Restoration Project drains a 4.1 mi^2 watershed (Map #2) perched on the main ridge separating the Kings River basin and the Kaweah River basin. The watershed has moderate to low relief ranging from 8500 ft. at Buck Rock to 7600 ft. at the meadow. The geology is glaciated Cretaceous granite with significant areas of exposed bedrock (Photo #3). Declivities and drainages have shallow to moderately deep sandy to loamy sand soils with moderately high to rapid infiltration and groundwater transmissivity. Big Meadows is composed of Quaternary alluvium (Sisson and Moore, 1984) with bedrock regularly encountered at approximately 6 feet of depth during excavation of the soil borrow areas (ponds). Upland vegetation is predominately lodgepole pine with sparse understory. Annual precipitation averages 35 inches commonly falling between October and April, predominately in the form of snow. Rain-on-snow events occur infrequently. The primary flow regime is spring snow melt.

Photo #3. Big Meadows post project- spring, 2008 (streamflow is left to right). Photo by: Wayne Luallen

Event Hydrology:

The Big Meadows Restoration Project was subjected to a high volume, high intensity rainfall event on October 13-14, 2009. Between 1200 hours, Oct. 13 and 0700 hours, Oct. 14, 8.27" of rain fell in the Big Meadows area. This measurement was recorded by the Big Meadows RAWS (Remote Automated Weather Station, Figure #1), located in the meadow. Between 1800 hours/Oct. 13 and 0300 hours/Oct. 14, rainfall rates averaged 0.62 inches/hr. with a sustained two-hour rate of 0.8 inches/hr. There was no snow in the basin and there was no antecedent moisture. This was a meso-scale rainfall event extending over much of the Kings River watershed and portions of the Kaweah basin. Post-event field observations and stream gage records from the Kings River watershed indicate that a high discharge, flash flood-type event occurred in the project and surrounding area. Figure #2 shows that plotted rainfall in the North

Fork Kings River watershed was very similar to what occurred in the project watershed. Figures #3 & 4 are stream gage records from the mainstem Kings River and North Fork Kings River, respectively, showing high peak flows from this storm.



Map #2. Watershed area and project area map.

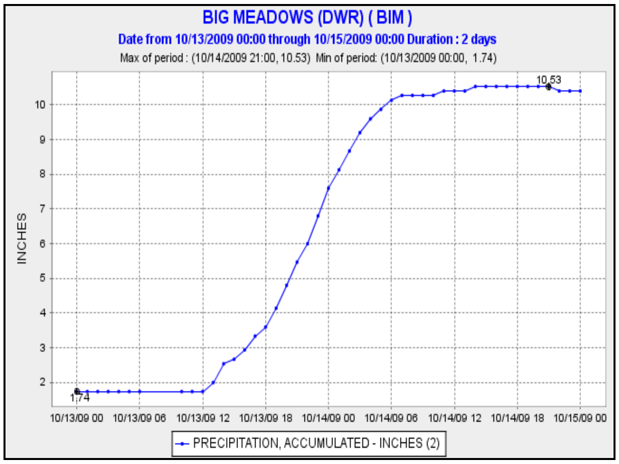


Fig. 1

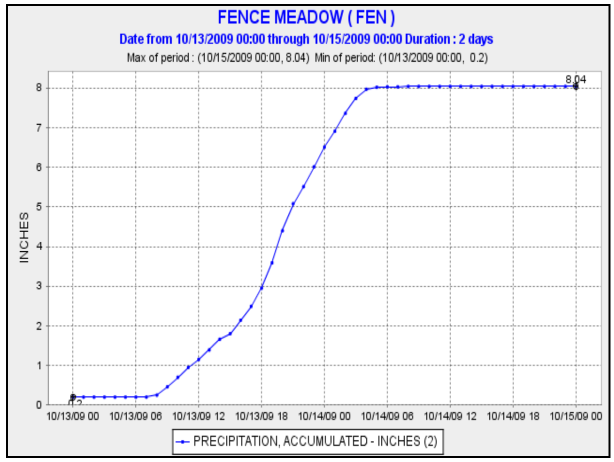


Fig. 2

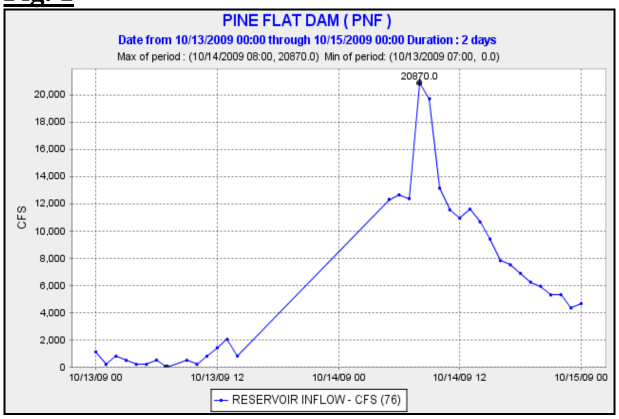


Fig. 3

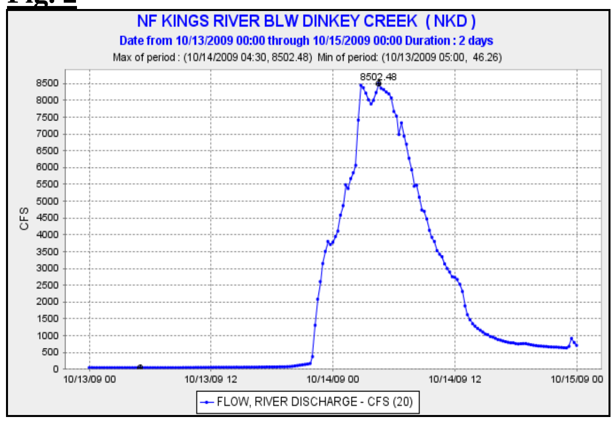


Fig. 4

Remote monitoring indicated a significant hydrologic event might be underway at the project area. Phone calls to the local project participants were too late to generate real-time observations/measurements. The first known observations were from John Exline, Hume Lake District Ranger on Thursday, Oct. 15, he stated "the meadow looked like a lake" (Exline, 2009). Several days later, the project was visited by Jayne Ferrante, Fresno Flyfishers, who staked high water marks and took numerous photos of the project area. The author made a monitoring trip on Nov. 5 to survey slope-area cross-sections and profiles in order to calculate the peak flow discharge amount and to qualitatively evaluate project performance/response to the event. Photos 7a-f , are from established permanent photo points of the remnant channel system and illustrate strong channel and floodplain stability.

Photo #4. Meadow extent at S/A X-section #1 (11/5/09).

Two cross-sections were surveyed for a slope-area calculation of the peak discharge. The first cross-section was surveyed where the wide meadow narrows near the downstream end of the project (Photos #4 & 5). The second was taken immediately downstream of the end of the project in a natural constriction (photo #6). Water surface widths were 162 ft. and 95 ft., respectively. Average depths were 1.6 ft. and 3.23 ft., respectively.

Photo #5. Slope area X-section #1 looking from right to left. Plug in foreground (11/5/09).

Water surface slope measured as the slope of the peak flow indicators, was 1% at both cross-section locations. Discharges were calculated for individual cells with like roughness values. Three (3) cells were identified across the relatively uniform cross-section #1 (Fig. 5). Cross-section #2 was divided into five (5) cells (Fig.6). Total discharge calculated at cross-section #1 was 1242 cubic feet per second (cfs), and cross-section #2 was 1282 cfs.

Cross-section #1 contained debris deposited at the left high water level and duff scour for the right. Cross-section #2 exhibited duff/soil scour down to conifer roots for the left high water level and debris deposition on the right.

Photo #6. Slope area X-section #2 below project looking from left to right (11/5/09).

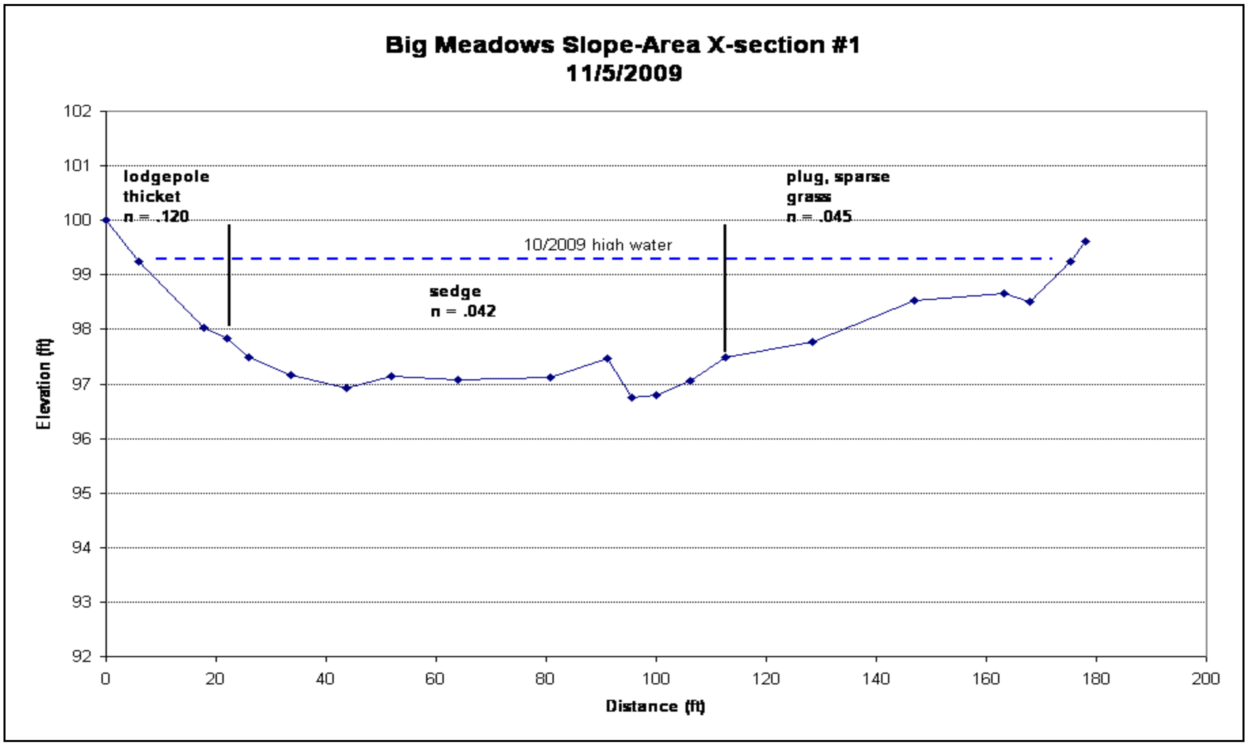


Figure 5.

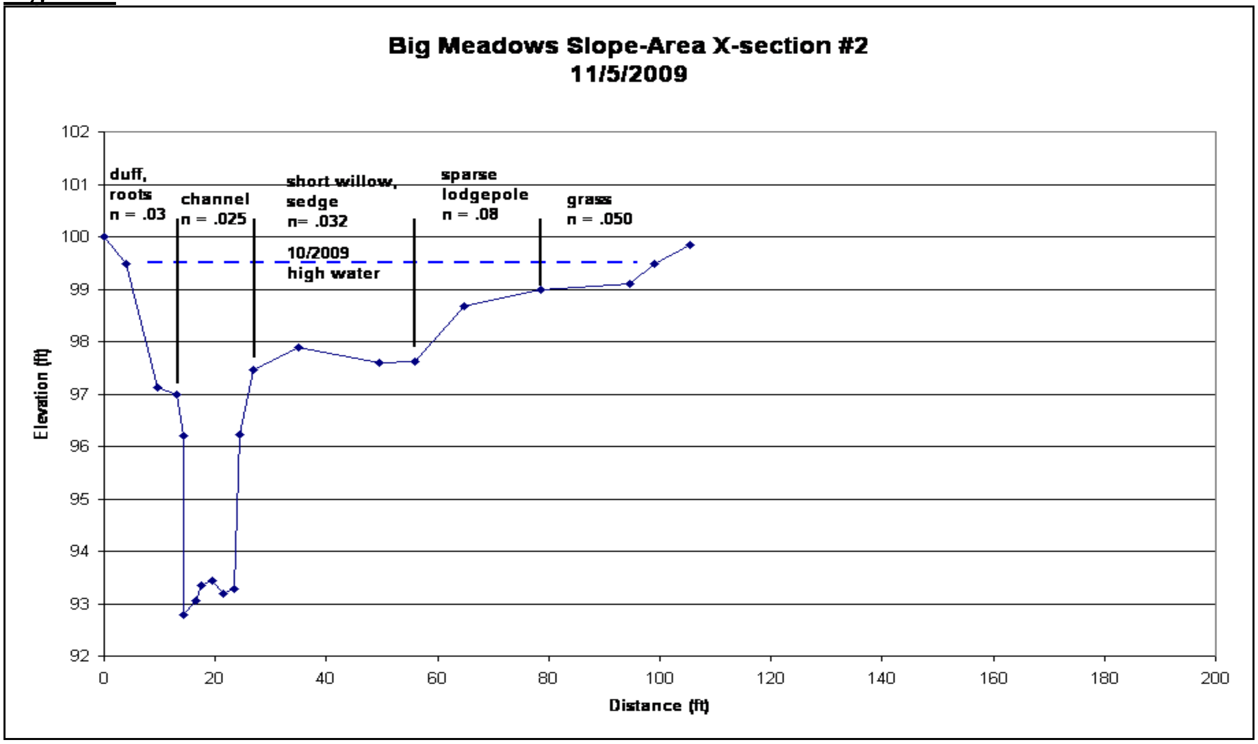
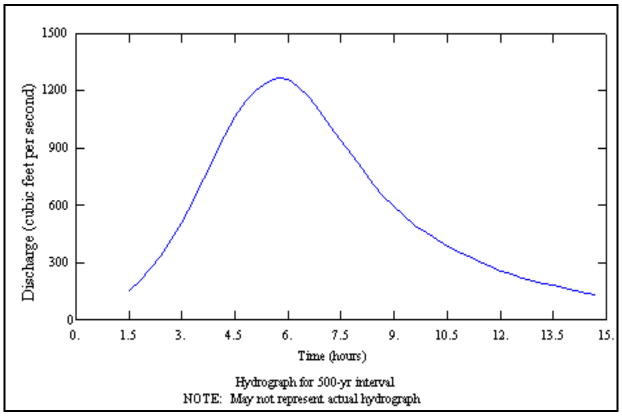


Figure 6.

A flood frequency determination (Fig. 7a & 7b) was developed using the National Stream Statistics program (2009) available from United States Geological Survey (USGS). These data placed the October 13-14, 2009 flood event in the 500-year return interval category, with a 0.2% chance occurrence (Table #1). However, it is the author's professional judgment that, given the dry moisture condition and lack of a snowpack, this event is more likely between a 100 to 50 year event (1%- 2% chance of occurrence).



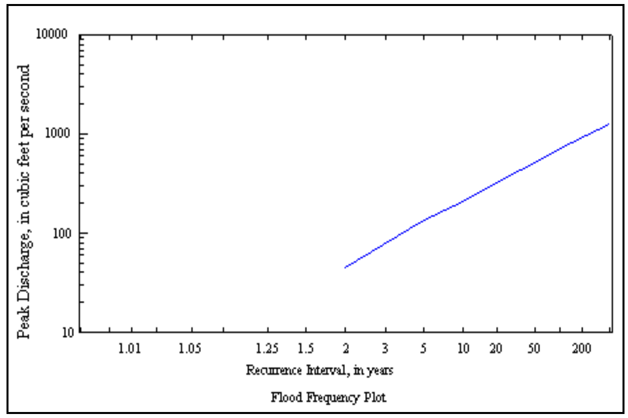


Figure 7a & b. Flood Frequency Analysis and Hydrograph (USGS, National Streamflow Statistics, 2009). NSS data from USGS- Water Supply Paper 1887, p. 52 (Crippen and Bue, 1977).

Table 1.

Recurrence Interval	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	500 yr*
Discharge (in cfs)	44.2	134	210	368	505	723	1270

***Extrapolated value maximum: 19800 (for C&B region 17)**

Technical Performance:

Because the pond and plug technology is relatively new (about 15 years), reservations have been expressed in numerous venues about the resilience of the technology over time and under large flood events. Obviously, local conditions (slope, depths, frequency, vegetative conditions) will dictate the degree of resilience associated with any given project. The Big Meadows Restoration Project was considered by the author as a high resilience, low risk project due to expansive floodplain, existing/expected vegetative response and low valley slope. The primary concern in most instances is erosion/loss of the gully plugs during high flow events. There are two mechanisms by which plugs could be compromised or lost: 1.) initiation of headcutting from the down-valley face due to the head differential between plug surface and downstream pond water surface elevation; 2.) general mobilization of plug material as flows inundate a plug and shear stresses rise.

To ameliorate the first mechanism, the Big Meadows design maintained a 0.5’ or less head differential at all plug/pond interface zones expected to experience overland flow. Additionally, abundant meadow sedge mats were recovered from the gully bottom prior to excavation and then tightly replanted along the down-valley lip of the plugs, extending from the plug surface down to pond water elevation. The second mechanism is generally addressed by one or a combination of the following: 1.) fostering a rapid vegetative cover on the plugs through mature vegetation transplants, top dressing with salvaged topsoil and supplemental seeding; 2.) scattering wood debris on the plugs to assist in keeping flow velocities below the soil entrainment threshold; and, 3.) incorporating subtle topographic attributes such as a lateral slope to lengthen down-valley flows. The plugs at Big Meadows were constructed from sand to sandy loam material with limited cohesion. Supplemental seeding was not performed, relying instead on the native seed bank of the topsoil that was initially saved and then replaced on the plugs. Consequently, most plugs have only scattered mature vegetation transplants and sparse grasses after two growing seasons, 2008 & 2009. Plugs expected to sustain relatively deep, or frequent, overland flow such as those in the narrow, lower third of the project were sloped slightly from hillslope to native floodplain or slightly crowned to lengthen flow paths. Big Meadows exhibited no adverse responses to this event. A series of permanent channel photo points (Photos 7a- 7f) illustrate virtually no change in remnant channel condition. It was expected as a design consideration that channel morphometry would be refined and maintained via elevated flows under a snowpack confinement regime. There was no snowpack during this event. Expected long-term changes include a more vigorous vegetation community and a narrowing and deepening of the channel system

7a. Big Meadows upper meadow remnant- June, 2008

7d. Big Meadows upper meadow remnant- Nov., 2009

7b. Big Meadows mid-meadow remnant- June, 2008

7e. Big Meadows mid-meadow remnant- Nov., 2009

7c. Big Meadows lower meadow remnant- June, 2008

7f. Big Meadows lower meadow remnant- Nov., 2009

This late dry-season, flash flood-type event occurred when the meadow structures (plugs) were at their most vulnerable. Most ponds in the project area had drained to well below meadow elevation as is normal for early fall. This resulted in a short period of much greater than design elevation differential between plug surfaces and pond water surfaces with an attendant headcut risk. Every plug was examined with no headcuts being located. Additionally, as illustrated in photo series #8a-f below, virtually all plugs sustained some overland flow during this event. Despite depths of up to 2 ft. and velocities up to 3.5 feet per second (fps), there was very little particle mobilization on any of the plugs. As illustrated in photos 8d and 8f, those particles that were mobilized quickly re-deposited. Even more illustrative is that the tooth drag marks on plugs 8d, e & f were not eroded. This lack of mobility is directly attributable to the properties of dispersed, or sheet, overland flow which minimizes the convergence mechanisms necessary to translate mobilizing velocities to the soil/water boundary.

Photos # 8a & b. Upper meadow plug/pond set. Note plug slope and plug/pond vegetation.

Photos by Jayne Ferrante

Photos # 8c & d. Central meadow plugs; left well vegetated, right sparsely vegetated

Photos #8e & f. Lower meadow plugs sparsely vegetated; +1' of flow depths.

Many pond and plug projects require some variant of a valley grade structure. This is generally a relatively low gradient (3%- 5%) soil, rock and vegetation structure to transition the restored hydraulic elevations/gradients down to existing channel and gully elevations/gradients. Typically, these structures are located at natural landscape constrictions that provide lateral control and restrict all flows to the armored/vegetated structure. The Big Meadow valley grade structure was a relatively simple variant in that the gradient differential was only 2 ft. The floodplain was well vegetated so rock was only needed to raise downstream incised riffle elevations to match the remnant channel grade. Photo #9 shows the lowest plug, post event, left background, with scattered existing large wood and vegetated face. Photo #10 illustrates the valley grade structure, post event, existing channel/floodplain interface.

Photo # 9. Lowest valley plug and remnant channel.

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Summary:

The Big Meadows restoration Project was subjected to a major rain storm on Oct. 14, 2009 which generated a large, flashy flood through the project. Peak flood flows reached between 1200 and 1300 cfs from the 4.1 mi^2 basin. Intensive field investigation of flood effects on the project components (ponds, plugs and channel) showed no damage or un-expected responses.

Photo #10. Existing channel/floodplain interface. Photo by Jayne Ferrante

REFERENCES

California Data Exchange Center, 2009, Precipitation and stream flow data. **http://cdec.water.ca.gov/**

Exline, J, 2009, personal communication.

Lindquist, D.S., and Wilcox, J., 2000, New concepts for meadow restoration in the Northern Sierra Nevada, in Proceedings of the International Erosion Control Association, Conference 31, Palm Springs, CA, p. 145-152.

Olin, J.T., 2005, Stream Character, Aquatic Habitat, and Restoration Plan for Big Meadows Creek, Sequoia National Forest, Tulare County, California: Masters Thesis, California State University, Fresno

Sisson, T.W., and Moore, J.G., 1984, Geology of the Giant Forest – Lodgepole area, Sequoia National Park, California: U.S. Geological Survey Open File Report OF84-254, 13 p.

United States Department of Agriculture, Sequoia National Forest, Photo Archives

United States Geological Survey, 1991, Muir Grove, California 7.5' quadrangle, United States Geological Survey, scale 1:24000.

United States Geological Survey, 1993, Data obtained from the US Geological Survey website from Water-Resources Investigation Report 94-2002. (April 2005). http://water.usgs.gov/software/nff_manual/ca/index.html.