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Big Meadows Restoration and Post-Implementation Monitoring Report

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Cover photo: Big Meadows during spring 2008 by Wayne Luallen.

Table of Contents

EXECUTIVE SUMMARY ES-1

1 BACKGROUND AND PURPOSE 1

1.1 Big Meadows Location and History 1
1.2 Restoration Goals and Implementation 3
1.3 Implementation of Big Meadows Restoration 3
1.4 Restoration Monitoring and Purpose of this Report 4

2 MONITORING METHODS AND RESULTS 6

2.1 Surface Water Hydrology and Temperature 6
2.2 Groundwater 13
2.3 Channel Cross-sections 17
2.4 Sediment Character 18
2.5 Benthic Macroinvertebrates 19
2.6 Vegetation 20
2.6.1 Range condition transects 20
2.6.2 Percent length of channel lined with willows 25
2.7 Wildlife and Bird Habitat 26

3 SUMMARY OF FINDINGS AND RECOMMENDATIONS 28

3.1 Summary of Findings 28
3.2 Overview of Monitoring and Adaptive Management 29
3.3 Monitoring Recommendations for Big Meadows 30
3.3.1 Field data collection 31
3.3.2 Cross-sections and change in channel form and condition 31
3.3.3 Groundwater monitoring 31
3.3.4 Benthic invertebrate monitoring 31
3.3.5 Vegetation monitoring 31
3.3.6 Data management 32

4 LITERATURE CITED 33

Tables

Table 2-1. Monitoring data collected at the Big Meadows Restoration Project site. 6
Table 2-2. Atmospheric data available from CDWR measurement stations in the BMRP vicinity. 7
Table 2-3. Surface-water data available from USGS measurement stations in the BMRP vicinity. 8
Table 2-4. Piezometers and other feaures in the BMRP vicinity. 14
Table 2-5. Particle sizes from Big Meadows Creek, collected by the USDA Forest Service in 2008. 18
Table 2-6. Species lists from three vegetation transects in Big Meadows. 23
Table 2-7. Percent shade along pre-project reaches, recorded using a Solar Pathfinder by Olin in summer 2004. 26
Table 3-1. Summary of pre- and post-project implementation findings in relation to stated project goals. 28

Figures

Figure 1-1. Location of Big Meadows in the south-central Sierra Nevada, within the Sequoia National Forest. 2
Figure 1-2. Big Meadows restoration design. From Wilcox 2010. 4
Figure 2-1. Aerial image of Big Meadows showing location of CDWR atmospheric stations, and the local stream gauge and piezometers used to measure surface and groundwater levels in the BMRP area (imagery source: Google Earth 2012). 7
Figure 2-2. Incremental precipitation computed at the CDWR BIM gauge (Sensor 45) in the BMRP area. 10
Figure 2-3. Daily discharge computed at the USGS 11218800 gauge on the North Fork Kings River near the confluence with the mainstem Kings River and upstream of Pine Flat Reservoir. 11
Figure 2-4. Stream stage computed at the datalogger station on Big Meadows Creek at the downstream end of the BMRP area. 11
Figure 2-5. Daily average air temperature computed at the CDWR BIM gauge (Sensor 30) in the BMRP area. 12
Figure 2-6. Water temperature computed at the stream gauge (datalogger) on Big Meadows Creek at the downstream end of the BMRP area. Data gaps indicate no data were collected. 12
Figure 2-7. Water temperature computed at four ponds and the stream gauge (dataloggers) on Big Meadows Creek for September 2010–June 2011. 13
Figure 2-8. Groundwater levels observed by Olin in 2004 and Lee in 2007–2008, as originally reported by Lee (2009, figures 5, 6, and 7). 15
Figure 2-11. Relative abundance of macroinvertebrate functional feeder groups in pre-project implementation riffles (n=5) and post-project implementation ponds (n=4); means with standard deviations. 20
Figure 2-12. Relative abundance of macroinvertebrate genera groups in pre-project implementation riffles (n=5) and post-project implementation ponds (n=4); means with standard deviations. 20
Figure 2-13. Approximate locations of Transects 1(1969), Transect 2 (1960 and 1965), and Transect 3 (2008); closer Google Earth image of vegetation types sampled for Transects 1 and 3, illustrating similarity in color and texture as possible indication of similar plant communities at both locations. 22
Figure 2-14. Relative frequencies of early, mid and late successional species along transects in a tributary meadow (Transect 1) and in the main meadow (Transects 1 and 3) before and after project implementation in 2006. 24
Figure 2-15. Relative frequencies of plant species by wetland indicator group along vegetation transects sampled in Big Meadows over time. 24
Figure 2-16. Bird count locations in Big Meadows. 27
Figure 3-1. Process-directed monitoring goals and metrics are used to monitor restoration or enhancement effects. Iterative loops of continued monitoring occur when indicators reflect desired responses; whereas adaptive management is performed when indicators reflect undesired process responses. ... 30

Appendices

Appendix A. Project Timeline
Appendix B. Channel Cross-Sections
Appendix C. Sediment Characteristics
Appendix D. Aquatic Invertebrate Data Reports
Appendix E. Photopoint Monitoring
Appendix F. Hydrology Report, Lee 2009
Appendix G. Range Condition Report, Weixelman 2009
Appendix H. List of Data Files and Other Documents Used for this Monitoring Summary Report

EXECUTIVE SUMMARY

This report summarizes pre- and post-restoration monitoring at Big Meadows, located in Sequoia National Forest, Giant Sequoia National Monument. Several reaches of incised stream channels are found in Big Meadows that drained the adjacent meadow areas and allowed drier site plant species, including lodgepole pine, to establish in what is thought to have previously been a moist to wet sedge-dominated meadow. After many decades of incremental check-dam installations intended to raise the stream channel bed and therefore groundwater levels, the Big Meadows team decided to apply a relatively new technique, commonly referred to as “pond and plug”, to improve meadow condition and functionality. This restoration project was implemented in September and October 2007, and involved creation of 14 borrow pits (ponds) to build 19 plugs in the gullied channel. This forced meadow surface flow to reconnect with nearly 7,000 feet of sinuous remnant channels and enabled annual flooding of 79 acres of meadow. The project was implemented with the following goals: (1) establish a primary-thread low flow channel with multiple ancillary channels, (2) reduce flow peaks and increase/extend summer base flows, (3) increase instream cover and shading, (4) enhance aquatic and terrestrial habitat, (5) improve water quality, and (6) raise local groundwater level within the meadow (USDA Forest Service 2007).

Pre-project monitoring for many aspects of Big Meadows was completed by Jason Olin for his master’s thesis in 2004 and 2005. Subsequent pre- and post-implementation monitoring was performed by multiple parties, including the Forest Service, Fresno Fly Fishers for Conservation, and the Feather River Coordinated Resource Management Group (CRM_ (Jim Wilcox), as well as California State University at Fresno. Monitoring data were collected on the following meadow attributes: (1) meadow channel cross-sections, (2) channel surface water flow, (3) groundwater levels, (4) meadow channel bed material, (5) meadow vegetation, (6) aquatic macroinvertebrates, (7) stream and pond temperature, (8) and bird diversity and abundance. Of these eight attributes, seven were measured in some form both pre- and post-restoration; only bird diversity and abundance were not measured pre-project. In this report, we summarize the findings from these monitoring efforts. We apply this information to attempt to address whether progress towards the six project goals enumerated above was made during the study period (2005– 2011). We also provide recommendations for on-going monitoring of the Big Meadows area.

1 BACKGROUND AND PURPOSE

1.1 Big Meadows Location and History

Big Meadows is a high-elevation (2,317 m, approximately 7,600 ft above MSL) meadow in Sequoia National Forest, roughly 55 miles east of Fresno, California (Figure 1-1). Big Meadows Creek drains a 28-km^2 granitic-floored watershed and flows in a northwesterly direction across the meadow towards its confluence with the Kings River in Kings Canyon National Park. Since the late 1800s, the Big Meadows area was used for seasonal sheep and cattle grazing under private ownership; grazing continued when Big Meadow shifted to public ownership with the US Forest Service in the early 1900's. The meadow became incised during the early part of the 20th century, and multiple efforts to restore a higher groundwater table that would support a moister and more productive plant community occurred through the years, including placement of various types of check dams. As was intended during their installation, these check dams effectively retained sediment behind them (upstream) and raised the stream grade, but the stream channel between the check dams remained down-cut. This condition concentrates flood flow, resulting in accelerated erosion that impacts aquatic habitat. With the meadow streambed and water table elevation approximately 1 m (roughly 2.5–4.0 feet) lower than the historical floodplain, more of the meadow groundwater drained out; as a result the plant community on the meadow's upper terraces favored drier upland plants than the plant communities on the lower surfaces closer to the water table. It is believed that the lowered water table led to lodgepole pine encroachment in the meadow. In addition, nearly the entire channel through the check dam treatment area had a flat bottom and sandy substrate vegetated with aquatic grasses. These conditions provided poor habitat for fish and other aquatic species due to the mobile substrate and lack of instream cover and shading. These on-going relatively degraded conditions led to efforts to restore functionality to Big Meadows, as described in this document.

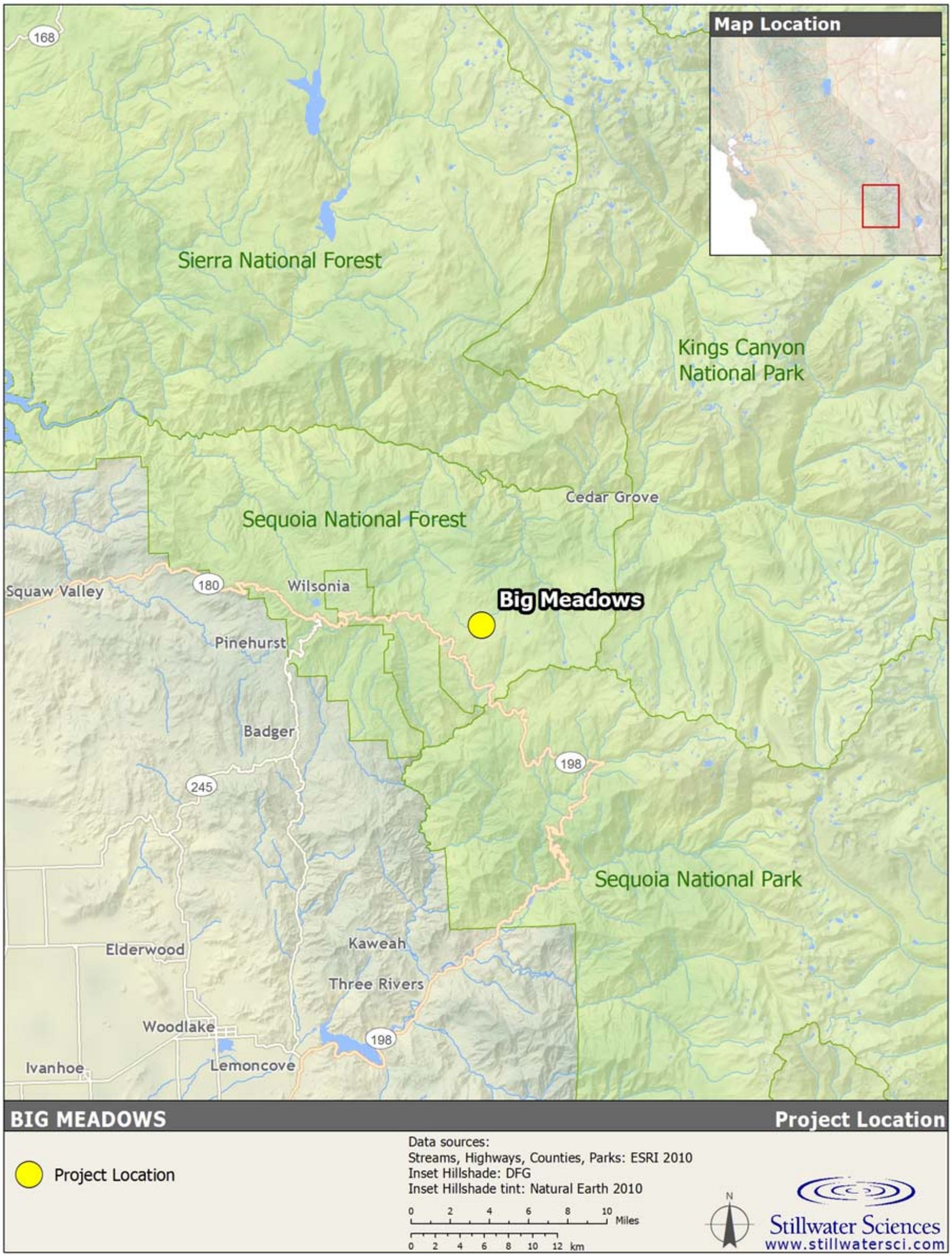


Figure 1-1. Location of Big Meadows in the south-central Sierra Nevada, within the Sequoia National Forest.

1.2 Restoration Goals and Implementation

In 2003 Fly Fishers for Conservation (Fresno, California) received funds from member Ted Martin to accomplish a conservation project. Local members suggested accomplishing this conservation project at a Sierra meadow they had fished since the early 1970s. The members had watched this beautiful meadow and its fish populations degrade during the 30 years they had fished there. Thus, the Ted Martin funds provided "seed" money to develop the Big Meadows restoration project. Jayne Ferrante, First Vice President of FFC, contacted CSU Fresno and initiated a collaborative effort which ultimately provided funds for student Jason Olin to focus his Master's thesis on Big Meadows. This thesis created much of the scientific groundwork needed to design and implement a project to restore functionality to the Big Meadows area.

Dr. Roland Brady, engineering geologist and professor at California State University (CSU) Fresno suggested collaborating with Jim Wilcox, an innovative practitioner from Plumas County who had developed a holistic meadow rewatering technique based on Rosgen theory, and then, over the past fourteen years, had pioneered and refined its use for restoring meadows in the upper Feather River Basin. This meadow rewatering technique is referred to as "pond and plug" and has been implemented in numerous meadows in northern California but prior to this project, had not been applied in the Southern Sierra. Mr. Wilcox became an integral member of the Big Meadows restoration team, supervising, teaching, and guiding efforts to increase technical and institutional capacity in the Southern Sierra.

The general goal of the restoration project is to restore Big Meadows ecosystem functions and associated riparian and aquatic habitat while maintaining existing land uses such as recreation and grazing. The specific project goals are to:

1. Establish a primary single-thread low flow channel with multiple ancillary channels,
2. Reduce flow peaks and increase/extend summer base flows,
3. Increase instream cover and shading,
4. Enhance aquatic and terrestrial habitat,
5. Improve water quality, and
6. Raise local groundwater level within the meadow (USDA Forest Service 2007).

1.3 Implementation of Big Meadows Restoration

Since Big Meadows is located on federally managed Forest Service lands, NEPA review was required prior to any on-the-ground actions. Following NEPA documentation, review, and public comment and response, the USDA Forest Service decided to apply the "pond and plug" technique to improve meadow condition and functionality at Big Meadows (USDA Forest Service 2007). This restoration project was implemented in September and October 2007. The restoration filled incised (down-cut) stream channel segments with soil (plugs) from alluvium excavated within the floodplain of the meadow. The excavated areas form ponds on the floodplain which are filled via the restored groundwater table. The surface flow naturally reconnects to existing low gradient, remnant stream channels. Open soils on the plugs were replanted using sections of native vegetation set aside from the areas designated for excavation. Immediate replanting with local rhizomatous species as well as local willow twigs helps to increase bank resistance to scour and reduce incidents of plug failure. This restoration project involved creation of 14 borrow pits (ponds) to build 19 plugs in the gullied channel. This forced meadow surface flow to reconnect with nearly 7,000 feet of sinuous remnant channels, which overlap with many of the ponds, and enabled annual flooding of 79 acres of meadow. The conceptual design for this project is illustrated in Figure 1-2 below.

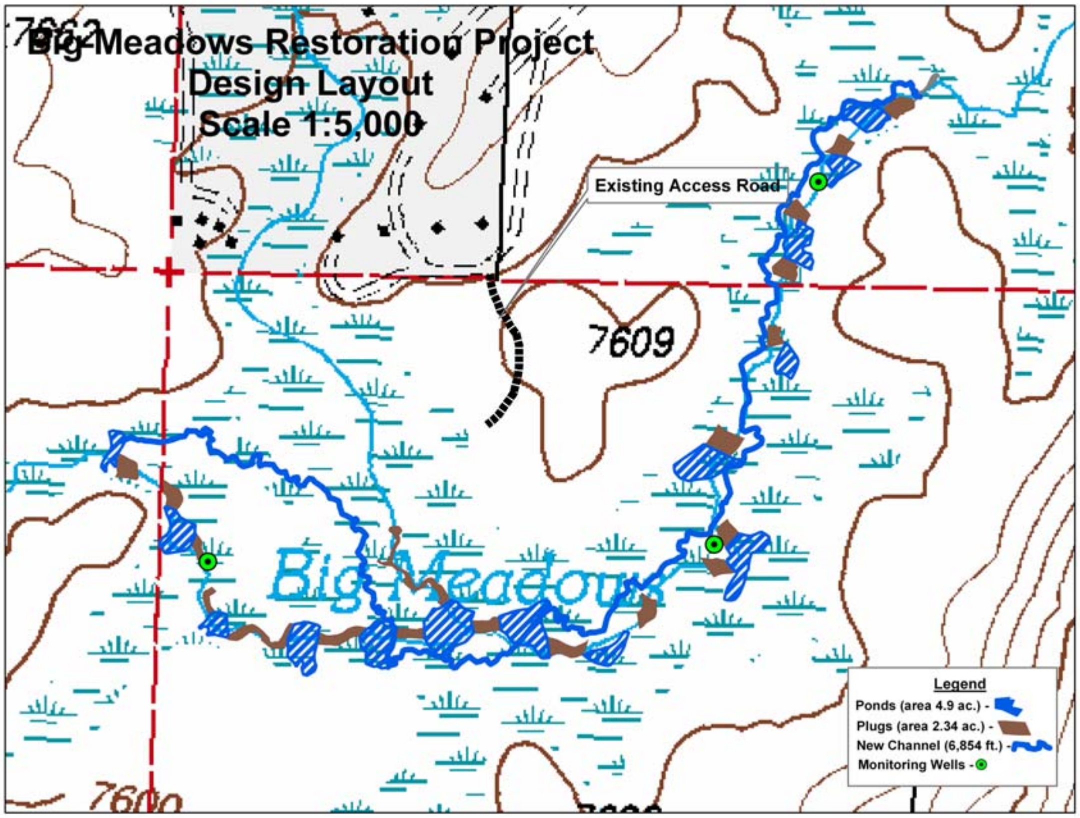


Figure 2-2. Big Meadows restoration design. From Wilcox 2010.

1.4 Restoration Monitoring and Purpose of this Report

Fly Fishers for Conservation, in cooperation with the USDA Forest Service and funded in part by the Sierra Nevada Conservancy, conducted post-project monitoring in Big Meadows from 2008 through 2011. Specifically, Fly Fishers for Conservation performed the following tasks under the Sierra Nevada Conservancy contract, the findings from which are reported in this document:

- Conduct photo-monitoring from established photo points
- Monitor surface water flows and groundwater levels
- Visually inspect channel and improvement areas
- Study wildlife habitat and recovery for project site in partnership with Fresno State University
- Recommend future monitoring and adaptive management

Post-project monitoring was performed in order to document changes in Big Meadows that indicate progress towards the restoration project goals and to inform adaptive management. In this report, we apply information gathered through these monitoring tasks in order to attempt to address whether progress towards the project goals was made during the study period (2005–2011). We also provide recommendations for on-going monitoring of the Big Meadows area.

2 MONITORING METHODS AND RESULTS

In this chapter, we summarize field observations collected before and following implementation of the Big Meadows Restoration Project (BMRP) in 2007 (Table 2-1). These observations include those made by Olin (2005) as part of his graduate studies, and Lee (2009), Fly Fishers for Conservation (2009), and Wilcox (2010) as part of post-restoration monitoring and reporting. Post-restoration data from the USDA Forest Service are also incorporated into the summaries presented below. To the extent the data allow, we have interpreted and summarized the restoration-induced trends detectable in the observed features.

Table 2-1. Monitoring data collected at the Big Meadows Restoration Project site.

Data type	Year						
	1960s	2004–2006	2007	2008	2009	2010	2011
Stream water flow			X	X	X	X	X
Water temperature in stream			X	X	X	X	X
Water temperature in ponds						X	X
Groundwater depth		X	X	X	X	X	
Cross-sections		X		X		X	
Sediment character							
Aquatic macroinvertebrates		X		X		X	
Vegetation transects	X			X			
Bird species presence and abundance					X		X

2.1 Surface Water Hydrology and Temperature

Several long-term atmospheric and river discharge stations operated by the California Department of Water Resources (CDWR) and U.S. Geological Survey (USGS) are present in the vicinity of Big Meadows, including an atmospheric station operated in the northern portion of Big Meadows since 1980 (Figure 2-1). Together, these facilities provide a reliable dataset on precipitation (rainfall and snow pack), air temperature, and runoff. Tables 2-2 and 2-3 list the CDWR atmospheric and USGS river gauging stations, respectively, in the project vicinity.

In addition to the permanent monitoring facilities, local field measurements of stream discharge, water surface stage, and water temperature have been recently collected in Big Meadows to monitor pre- and post-restoration conditions. These efforts include:

- instantaneous flow measurements taken at several locations along Big Meadows Creek in the project area by Olin (2005) in the summers of 2004–2005;
- staff gauge readings made at the downstream gauging station by Lee (2009) in spring–summer of 2008;
- continuous recording of water-surface stage and water temperature at the downstream gauging station by USDA Forest Service personnel since late 2006; and
- continuous recording of water temperature in four of the created ponds by USDA Forest Service personnel during September 2010–June 2011.

Figure 2-1. Aerial image of Big Meadows showing location of CDWR atmospheric stations, and the local stream gauge and piezometers used to measure surface and groundwater levels in the BMRP area (imagery source: Google Earth 2012).

Table 2-2. Atmospheric data available from CDWR measurement stations in the BMRP vicinity.

Station Name (ID)	Total period of record (water years) [A]	Drainage basin	Measurement parameters	Distance from BMRP (linear miles) [B]	Source [C]
BIG MEADOWS–DWR (BIM)	1980–present	Kings River	Precip. (rain and snow) and temp.	<1	CDWR CDEC [1]
BIG MEADOWS (BMS)	1930–present	Kings River	Precip. (snow)	<1	CDWR CDEC [2]
BEAR TRAP MEADOW (BRM)	1935–present	Kaweah River	Precip. (rain)	3	CDWR CDEC [3]
KENNEDY MEADOWS (KNM)	1930–1942	Kings River	Precip. (snow)	4	CDWR CDEC [4]
HORSE CORRAL MEADOW (HCM)	1930–present	Kings River	Precip. (snow)	6	CDWR CDEC [5]
ROWELL MEADOW (RWM)	1931–present	Kings River	Precip. (snow)	6	CDWR CDEC [6]

Station Name (ID)	Total period of record (water years) [A]	Drainage basin	Measurement parameters	Distance from BMRP (linear miles) [B]	Source [C]
MITCHELL MEADOW (MTM)	1970–present	Kings River	Precip. (snow) and temp.	7	CDWR CDEC [7]
RIDGE TRAIL (RGT)	2007–present	Kings River	Precip. (snow)	7	CDWR CDEC [8]
GRANT GROVE (GNG)	1930–present	Kings River	Precip. (snow)	7	CDWR CDEC [9]
GRANT GROVE (GRO)	1924–present	Kings River	Precip. (rain)	7	CDWR CDEC [10]
LODGEPOLE (LDG)	1950–present	Kaweah River	Precip. (rain)	10	CDWR CDEC [11]
SUGARLOAF (SGL)	1993–present	Kings River	Precip. (rain), temp., and wind	10	CDWR CDEC [12]

[A] A water year spans October 1st–September 30th (e.g., October 1, 2000–September 30, 2001 is in water year 2001).
[B] Distance between BMRP and the atmospheric measurement station as measured in a straight line.
[C] Hyperlinks to online data posted on the California Department of Water Resources' California Data Exchange Center (CDWR CDEC) website (accessed March 8, 2012):
[1] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=BIM
[2] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=BMS
[3] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=BRM
[4] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=KNM
[5] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=HCM
[6] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=RWM
[7] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=MTM
[8] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=RGT
[9] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=GNG
[10] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=GRO
[11] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=LDG
[12] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=SGL

Table 2-3. Surface-water data available from USGS measurement stations in the BMRP vicinity.

Station Name	Period of record (water years) [A]	Waterbody	Drainage area (sq. mi.)	Distance from BMRP (river miles) [B]	Source [C]
11212500 [SF KINGS R NR CEDAR GROVE CA]	1951–1967	South Fork Kings River	408	14 mi. [u/s of river confluence]	USGS NWIS [1]
11212450 [GRIZZLY C NR CEDAR GROVE CA]	1960–1973	Grizzly Creek [tributary to South Fork Kings River]	10	14.5 mi. [u/s of river confluence]	USGS NWIS [2]
11213000 [KINGS R NR HUME CA]	1922–1958	Kings River	835	17 mi. [d/s of river confluence]	USGS NWIS [3]

Station Name	Period of record (water years) [A]	Waterbody	Drainage area (sq. mi.)	Distance from BMRP (river miles) [B]	Source [C]
11213500 [KINGS R AB NF NR TRIMMER CA]	1927–1982	Kings River	952	31 mi. [d/s of river confluence]	USGS NWIS [4]
11218400 [NF KINGS R BL DINKEY C NR BALCH CAMP CA]	1960–present	North Fork Kings River	387	32 mi. [d/s of river confluence]	USGS NWIS [5]
11218499 [COMBINED FLOW KINGS R AB NF & NF KINGS R CA]	1976–1978	Kings River (just above Pine Flat Lake reservoir)	1,342	33 mi. [d/s of river confluence]	USGS NWIS [6]
11218500 [KINGS R BL NF NR TRIMMER CA]	1956–1993				USGS NWIS [7]
11218501 [COMBINED FLOW KINGS R BL N F & KINGS R PP CA]	1952–1993				USGS NWIS [8]
11218700 [KINGS R PH NR BALCH CAMP CA]	1970–present	Kings River (just above Pine Flat Lake Reservoir)		34 mi. [d/s of river confluence]	USGS NWIS [9]

[A] A water year spans October 1st-September 30th (e.g., October 1, 2000-September 30, 2001 is in water year 2001).
[B] Distance between BMRP to the stream gauge station as measured along the stream network; "River confluence" refers to the confluence of Boulder Creek and the South Fork Kings River, and "u/s" or "d/s" indicate that the gauge station is along the Kings River either upstream or downstream of this confluence, respectively.
[C] Hyperlinks to online data posted by the U.S. Geological Survey's National Water Information System (accessed March 8, 2012):
[1] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11212500&target=_
[2] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11212450&target=_
[3] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11213000&target=_
[4] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11213500&target=_
[5] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11218400&target=_
[6] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11218499&target=_
[7] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11218500&target=_
[8] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11218501&target=_
[9] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11218700&target=_

Methods and results of field data collected by Olin (2005) and Lee (2009) are documented in their respective publications. The active stream gauge station that continues to record stage and temperature consists of a readable staff plate and an electronic datalogger. The water surface stage is measured by a pressure transducer (Campbell Scientific CS420/CS425) and the water temperature is measured with a temperature probe (Campbell Scientific 107), both of which are wired directly to the datalogger (Rickly Hydrological Company CR510 Basic Datalogger). Water temperature was also measured in ponds 1, 2, and 4 from September 2010 through the end of June 2011. Pond 4 is located at the upper-most end of the restoration project area and ponds 2 and 1 are connected to the main channel. Pond 1 is the downstream-most pond in the project area.

Temperatures were not collected in the ponds during July and August, the warmest part of the year.

We compiled and reviewed the available data from October 1, 2006 to September 30, 2011, which spans restoration implementation in September 2007 (Figures 2-2 through 2-7). Data interpretation is presented below.

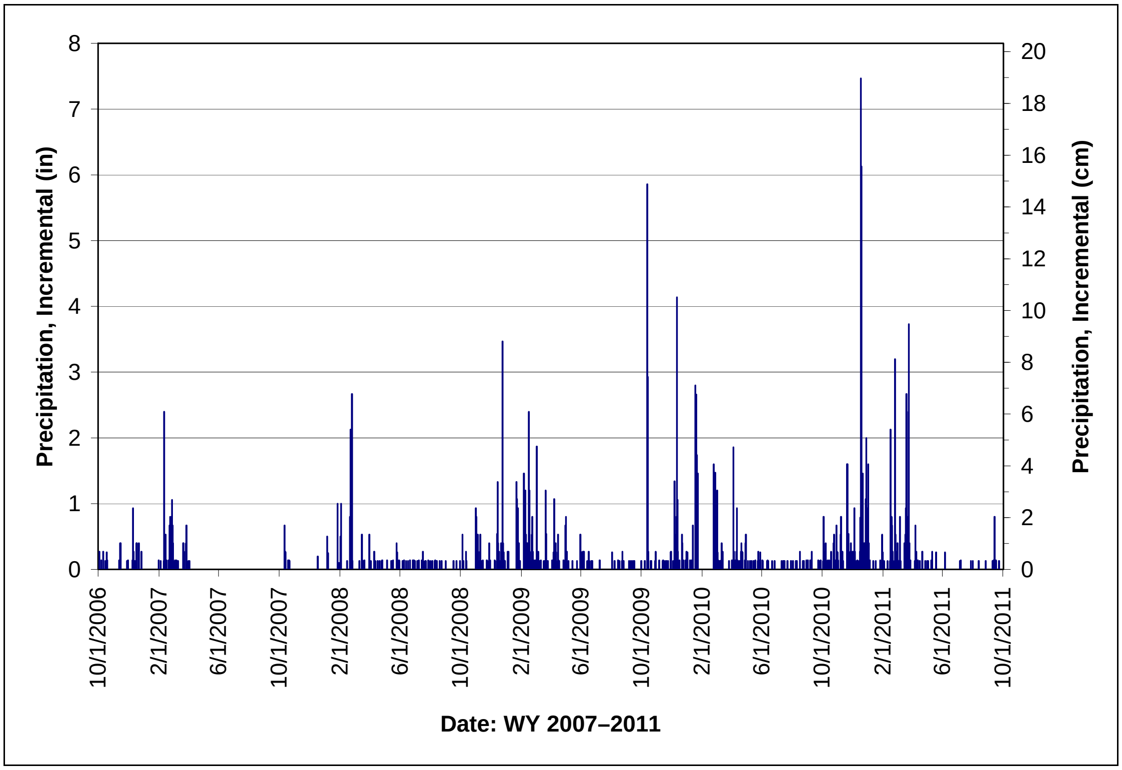


Figure 2-2. Incremental precipitation computed at the CDWR BIM gauge (Sensor 45) in the BMRP area.

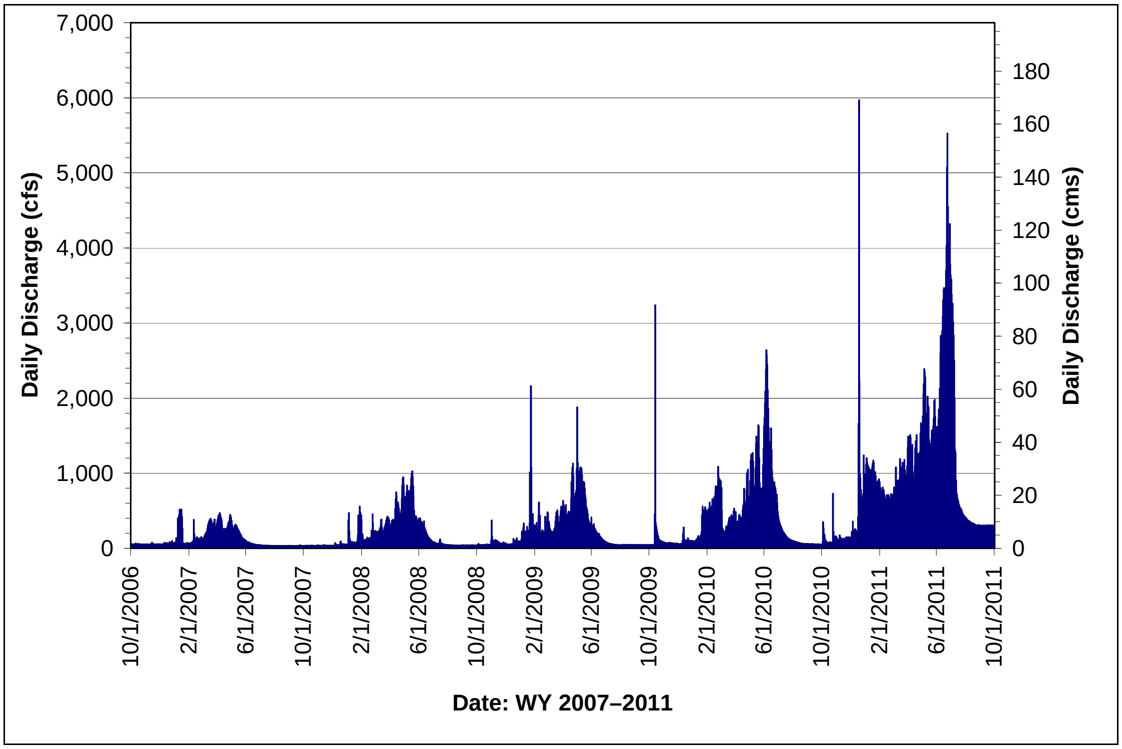


Figure 2-3. Daily discharge computed at the USGS 11218800 gauge on the North Fork Kings River near the confluence with the mainstem Kings River and upstream of Pine Flat Reservoir.

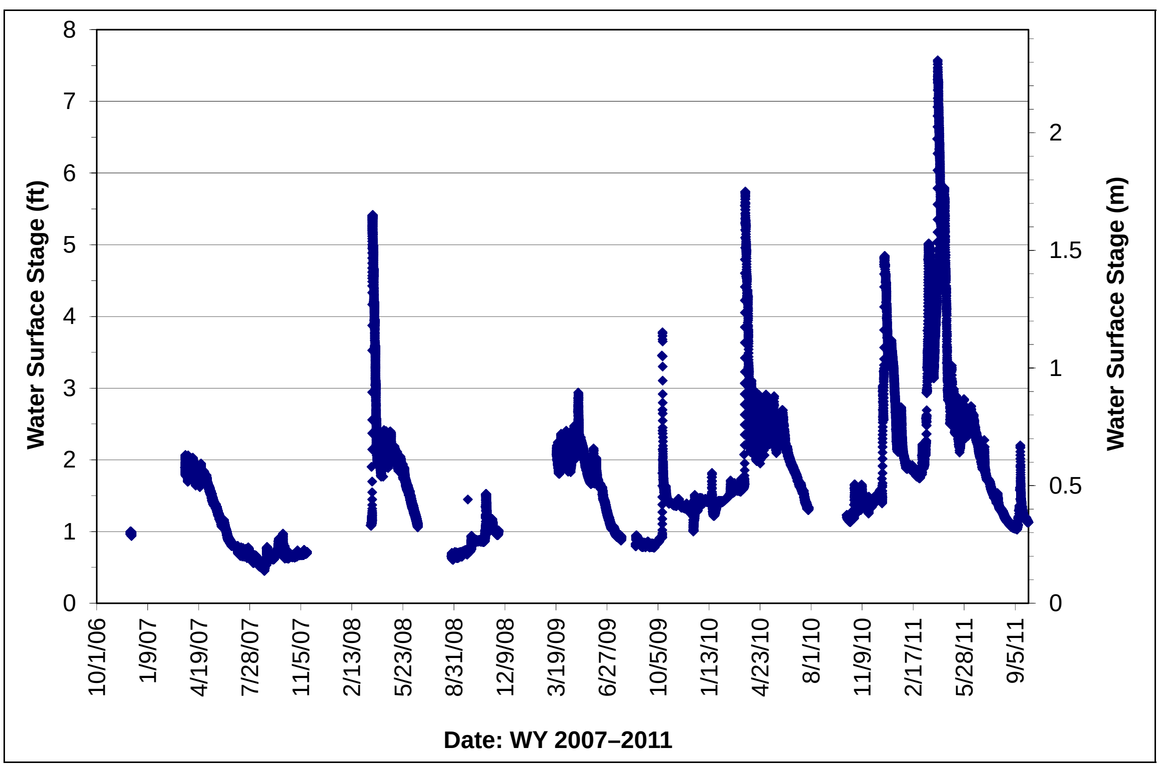


Figure 2-4. Stream stage computed at the datalogger station on Big Meadows Creek at the downstream end of the BMRP area.

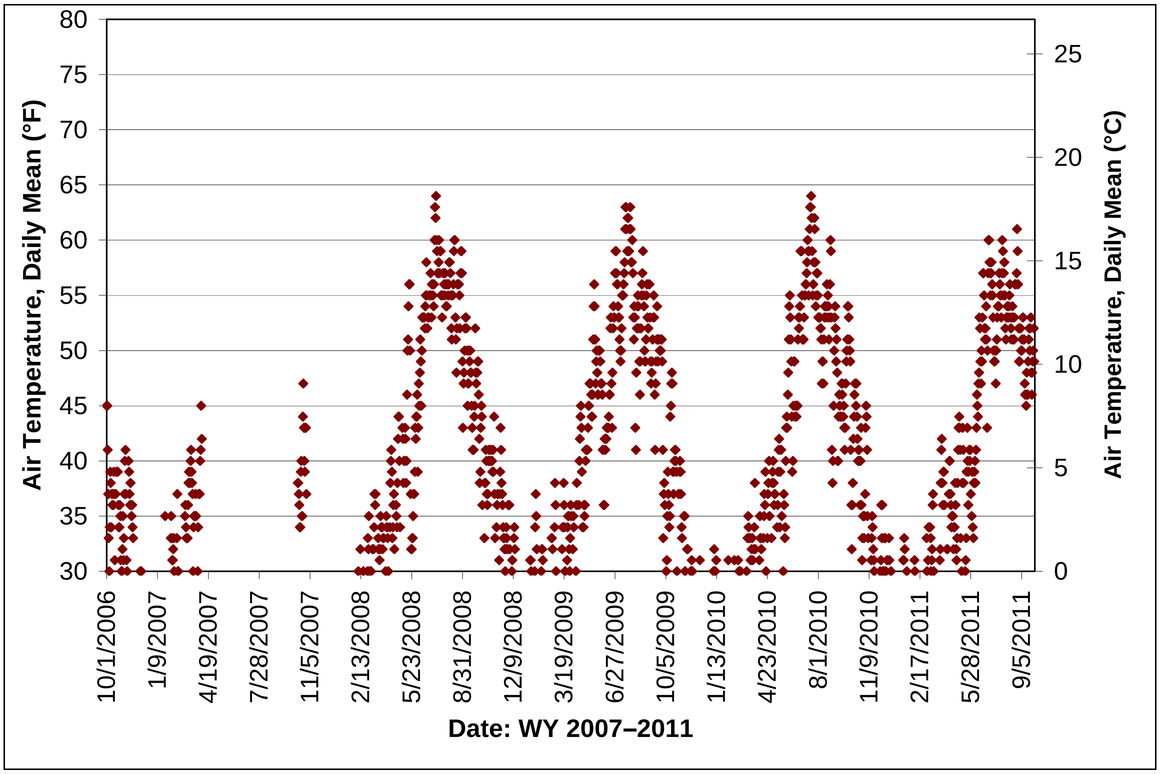


Figure 2-5. Daily average air temperature computed at the CDWR BIM gauge (Sensor 30) in the BMRP area.

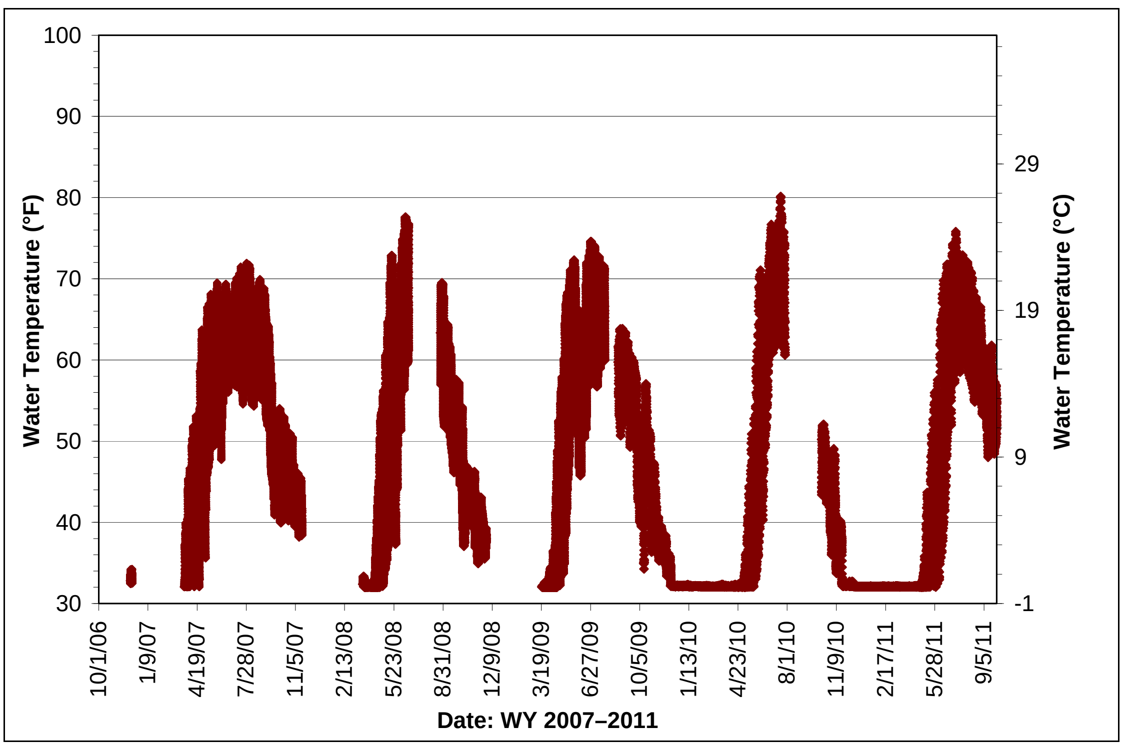


Figure 2-6. Water temperature computed at the stream gauge (datalogger) on Big Meadows Creek at the downstream end of the BMRP area. Data gaps indicate no data were collected.

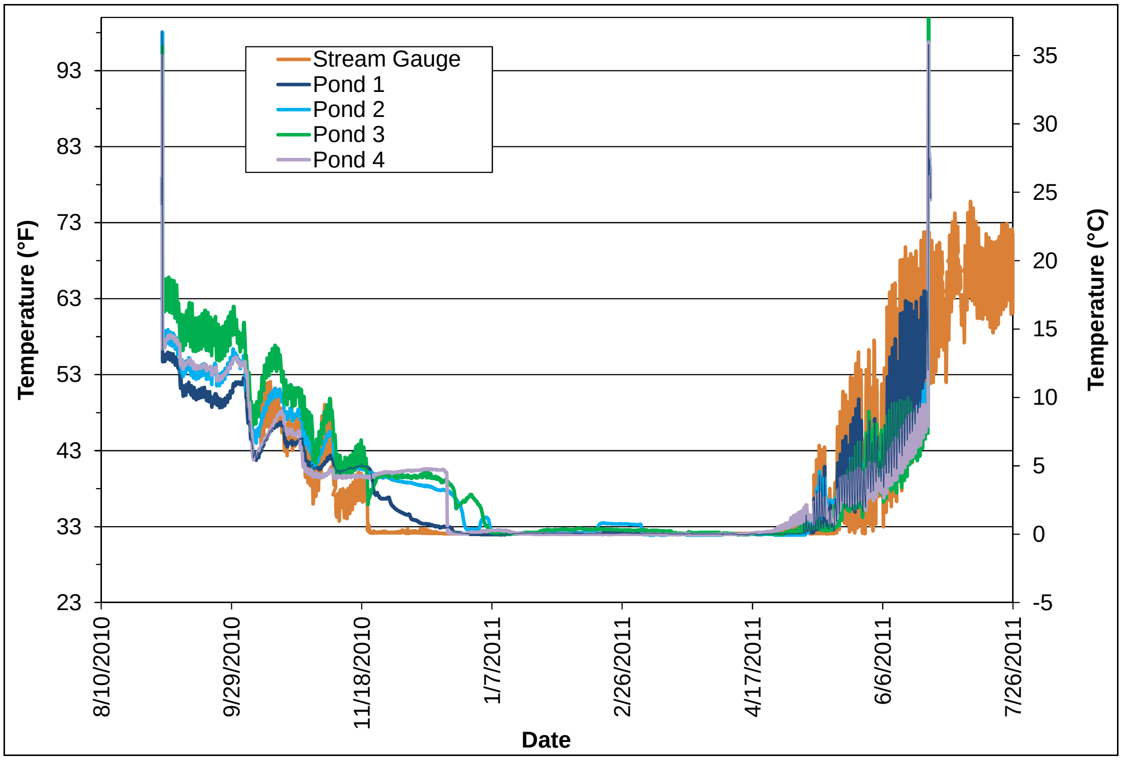


Figure 2-7. Water temperature computed at four ponds and the stream gauge (dataloggers) on Big Meadows Creek for September 2010-June 2011.

Hydrologic conditions in Big Meadows are characterized by winter snow and rain events with associated spring snow-melt typical of high Sierra landscapes. As expected, runoff in the project reach of Big Meadows Creek, as represented by water surface stage (Figure 2-4), responds quickly to local rainfall and snow-melt timing as represented by warming air and water temperatures (Figures 2-2, 2-5, and 2-6). Overall, the air, stream and pond water temperatures, as well as the stream flow and stage datasets exhibit similar timing patterns, as depicted in the above figures. However, a much longer pre-project data set would be needed to understand and statistically compare the variability in response to rainfall and/or snow melt events under pre- and post-project conditions.

2.2 Groundwater

Groundwater levels have been monitored periodically throughout the BMRP area, beginning with Olin's 2004 measurements to establish baseline conditions, Lee's 2006–2008 measurements to further establish the pre-restoration baseline and to capture initial conditions following restoration, and Ferrante's 2009–2010 measurements to continue the evaluation of post-restoration conditions. Olin (2005) established a network of 13 shallow piezometers, 3 of which have continued to be used to present day: Upper Piezometer, Middle Piezometer, and Lower Piezometer. General attributes of the piezometers and other related features are summarized in Table 2-4, and their locations are shown in Figure 2-1.

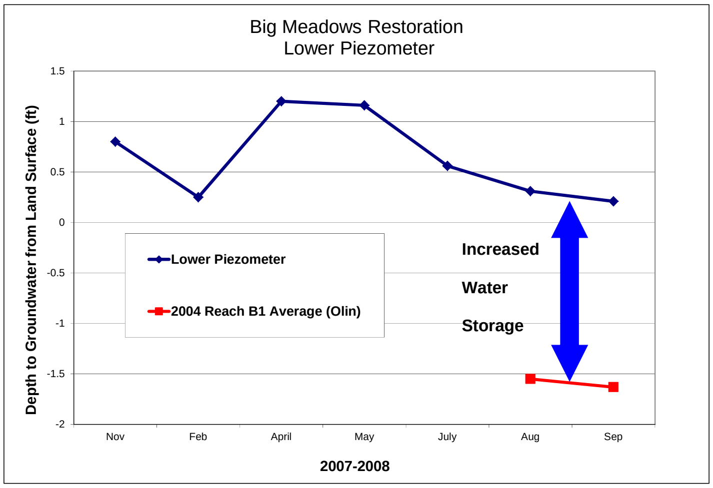
Table 2-4. Piezometers and other feaures in the BMRP vicinity.

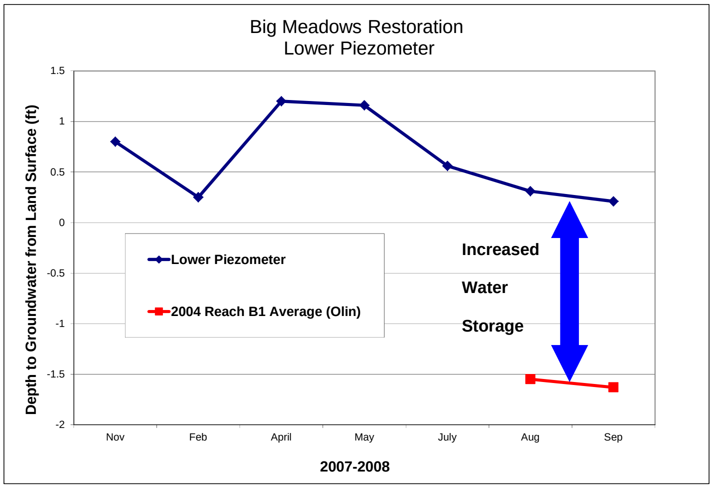
Measurement equipment	Latitude	Longitude	Attributes
Upper Piezometer [Olin's #PD]	36.710433°	-118.843700°	¾-inch galvanized riser with drive point screen
Middle Piezometer [Olin's #PB2]	36.710767°	-118.836977°	
Lower Piezometer [Olin's #PB1]	36.714467°	-118.835533°	
Stream gauge (datalogger)	36.715529°	-118.833171°	Pressure transducer, temperature probe, and staff plate
Grade control structure	36.715611°	-118.834270°	Compacted rock fill

Source: Lee (2009)

Lee (2009) compiled Olin's water table measurements with those taken during 2007–2008 at the three piezometers, and deduced a marked increase in water table elevation and, accordingly, an increase in subsurface water storage throughout the meadow. Lee attributed this response directly to the pond and plug restoration that maintained a much higher degree of meadow inundation. We have re-presented Lee's data plots here in Figure 2-8.

Data collected by J. Ferrante of Fly Fishers for Conservation at all three piezometers in 2009–2011 have been added to the overall groundwater dataset. These measurements show continued increase in elevation of groundwater levels through the 2009 and 2010 years. The compiled groundwater level data for 2004 through 2010 are presented in Figure 2-9.





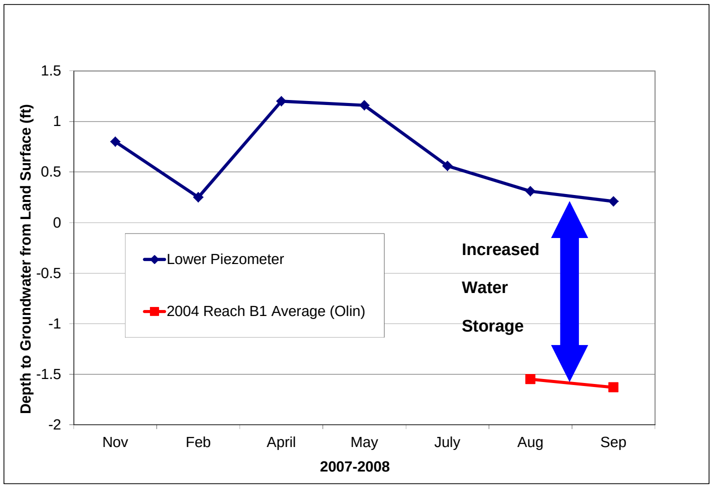


Figure 2-8. Groundwater levels observed by Olin in 2004 and Lee in 2007–2008, as originally reported by Lee (2009, figures 5, 6, and 7).

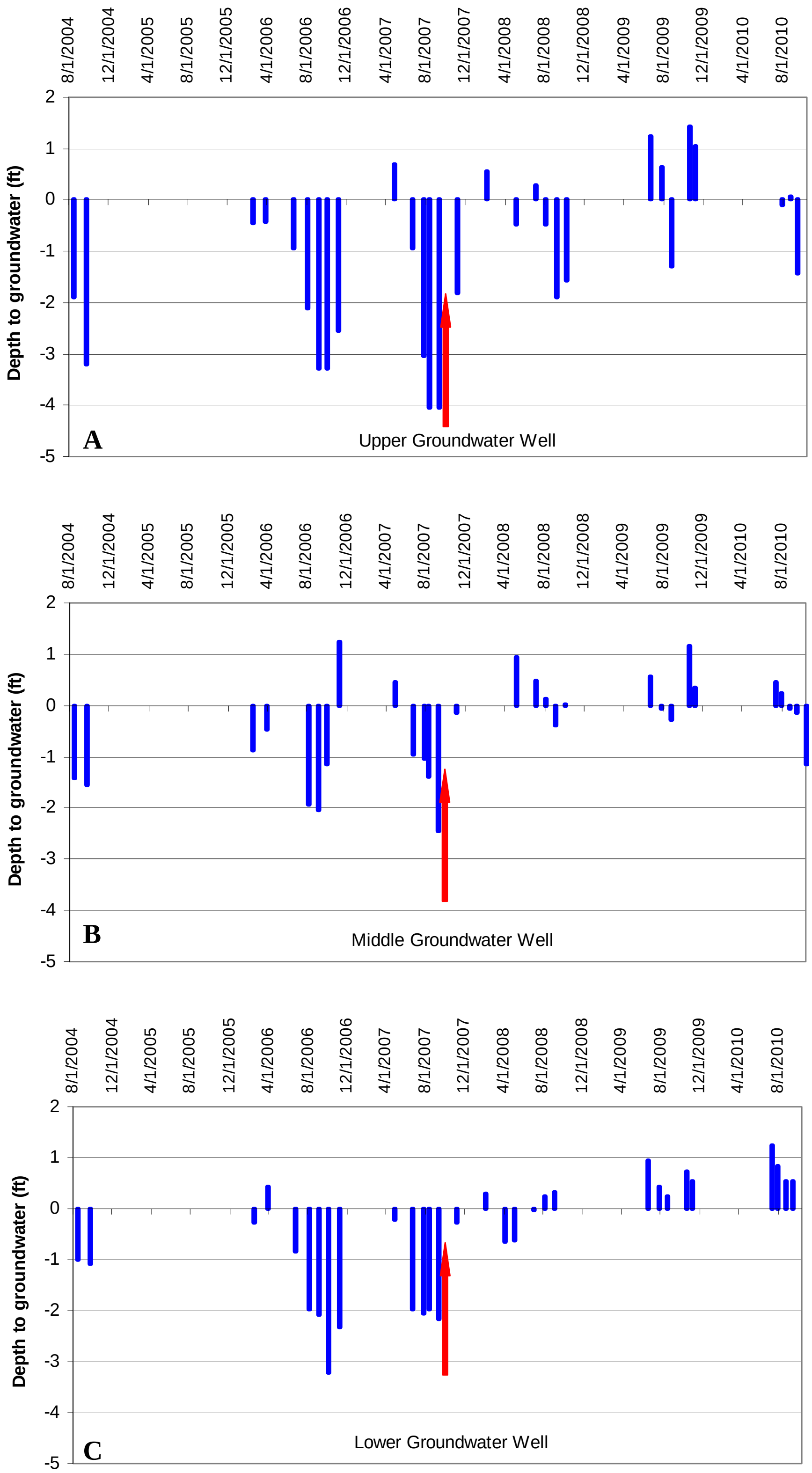


Figure 2-9. Groundwater levels at upper (a), middle (b) and lower (c) piezometers 2004-2010. Red arrow indicates time of project implementation (Fall 2007).

2.3 Channel Cross-sections

Topographic data of Big Meadows Creek within the BMRP area have been collected in the form of cross-sections and longitudinal profiles. Olin (2005) surveyed a total of 43 cross-sections in 2004, which are presented in his master's thesis. In 2006, the USDA Forest Service established a new array of cross-sections throughout the area totaling 14, with two of these having two distinct portions: cross sections 3 and 13 (see Figure 2-10). All surveys were conducted using traditional field equipment, including a total station, stadia rod with prism, and measurement tape. These pre-restoration surveys were conducted to ascertain the degree of stream channel down-cutting in the meadow.

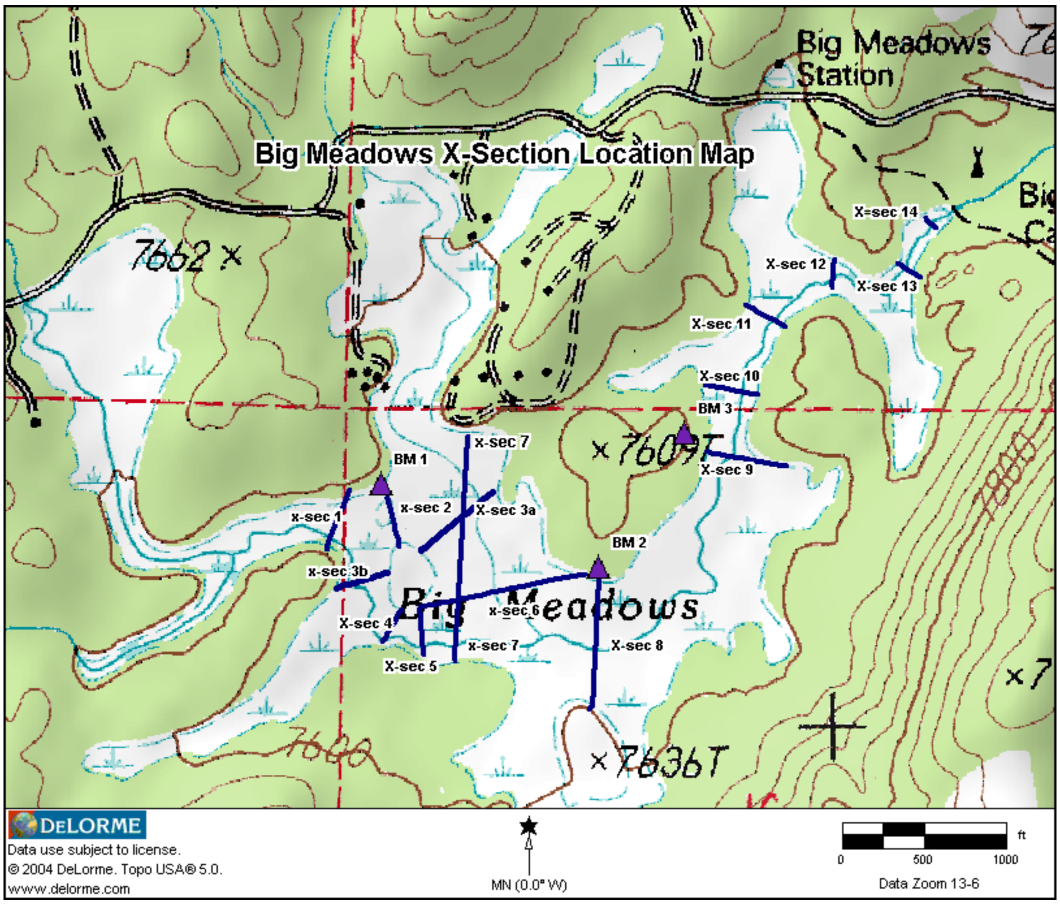


Figure 2-10. Map of the 14 cross-sections established in the BMRP area by USDA Forest Service personnel and surveyed in 2006 prior to restoration. These cross-section locations have been moved slightly for the post-restoration surveys.

In 2008 and 2010, the USDA Forest Service attempted to reoccupy these cross-sections; however since many of the survey end-pins were removed during 2007 project implementation, some of the cross-sections do not exactly overlap with the pre-implementation locations. Additionally, a longitudinal profile of the stream channel was surveyed in 2008. The purpose of these recent survey efforts is to monitor the physical evolution of the stream channel and the pond and plug features.

We have compiled and overlain the 2006, 2008, and 2010 cross-section data to qualitatively evaluate post-restoration changes, to the extent possible. Plots of these data are presented in Appendix B; we point out that large questions remain in the alignment of the cross-sections because of the recognized station shifts before and after restoration. Therefore, we have not drawn any inferences here about the natural meadow and channel changes occurring since before restoration.

The post-restoration data from 2008 to 2010 thus far reveal minimal to no change in channel profile, which is not wholly unexpected given that no substantial channel-altering flood events have occurred over this short time period. Several cross-section comparisons do exhibit subtle (~1-ft change in the vertical) variations from 2008 to 2010; however, these variations cannot be reasonably interpreted as real change in profile because they are likely within the range of normal survey error. Within those areas where the pond and plug features were implemented, there are a few notable and mostly unexplained changes in cross-section profile from 2008 to 2010, where elevation changes exceed 1–2 feet (cross-sections 3b, 4, 6, and 7). The cause of these larger variations is not readily apparent and would require additional years of surveying to better understand. Additionally, there is little substantial evidence of continued channel down-cutting below the downstream-most pond and plug unit, as represented at cross-sections 12, 13a, 13b, and 14. Without knowing the rate of down-cutting pre-dating project implementation, we cannot assert that this lack of substantial post-implementation down-cutting is a result of the project; but it does indicate that channel form has been relatively stable since project implementation.

2.4 Sediment Character

Olin (2005) characterized the channel bed substrate present along Big Meadows Creek through the collection and analysis of bulk samples and field-based pebble counts. Olin found most reaches to consist of very fine to fine gravel (2–8 mm), without notable differences between sediment stored in riffles or pools. Olin deduced through simple hydraulic estimates that the dominant particle sizes were slightly larger than the channel's capacity to transport during bankfull flow events, thereby providing for a mostly stable channel.

Sediment samples were collected via pebble-count method at each cross-section by USDA Forest Service personnel during the 2008 field surveys to establish a new, post-restoration baseline of channel bed substrate. We have compiled and reviewed these data (Table 2-5 and Appendix C). These data generally agree with Olin's characterization, but there are now more fine reaches present that are directly attributed to the large-scale channel reconfiguration associated with implementation of the pond and plug features.

Table 2-5. Particle sizes from Big Meadows Creek, collected by the USDA Forest Service in 2008.

Cross-section	D_{16}	D_{50}	D_{84}	Facies [A]
1	NA	NA	NA	silt/clay
2	NA	NA	NA	silt/clay
3	NA	NA	NA	silt/clay
4	NA	NA	2	sandy silt/clay
5	1	22	58	silty scG
6	NA	1	6	silty gS
7	NA	1	26	silty gS
8	NA	NA	NA	silt/clay

Cross-section	D_{16}	D_{50}	D_{84}	Facies [A]
9	NA	2	17	silty bgS
10	1	3	5	silty sG
11	10	60	245	bcG
12	1	3	5	silty sG
13	NA	NA	NA	silt/clay
14	1	3	8	silty sG

NA = not applicable because no valid reading can be made of the sediment size distribution due to a lack of values below this size class.
[A] S = sand (0.0625–2 mm), G= gravel (2–64 mm), C= cobble (64–256 mm), B = boulder (>256 mm); Upper case indicates dominant substrate; lower case indicates subdominant types.

2.5 Benthic Macroinvertebrates

A benthic macroinvertebrate study was performed to record macroinvertebrate populations at Big Meadows in the years following restoration. Lee hypothesized that by redirecting water from the incised channel to the remnant channel; more suitable habitat would be created for benthic macroinvertebrates (Lee 2008). Baseline samples were collected from four reaches in the stream channel by Olin in 2004. Following project implementation, samples were collected from four ponds and no stream channels by Lee in October 2008 and by Ferrante in 2010. Macroinvertebrate samples collected during July 2004 and September 2008 were sent for taxonomic identification to the BLM/USU National Aquatic Monitoring Center (aka, The Bug Lab) in the Department of Watershed Sciences at Utah State University in Logan, Utah. The 2010 samples were sent to the Bug Lab for identification in January 2012; results will be available later in the spring of 2012. Findings from the Bug Lab will be sent to the Sierra Nevada Conservancy as an addendum to this report.

Overall, differences were found in the relative abundance of five feeder groups between the before and after project implementation samples collected (Figure 2-11). Similarly, differences in relative abundance of genera are also apparent among sample dates (Figure 2-12). However, none of these differences can be attributed to the project itself other than the obvious creation of pond habitat. Ponds were the only habitat type sampled post-implementation and, as expected, were found to have a different macroinvertebrate composition than riffle habitats. Riffle habitat was the only habitat type sampled before project implementation. Post-project sampling of riffle habitats would offer a comparable data set for pre- and post-project macroinvertebrate community composition.

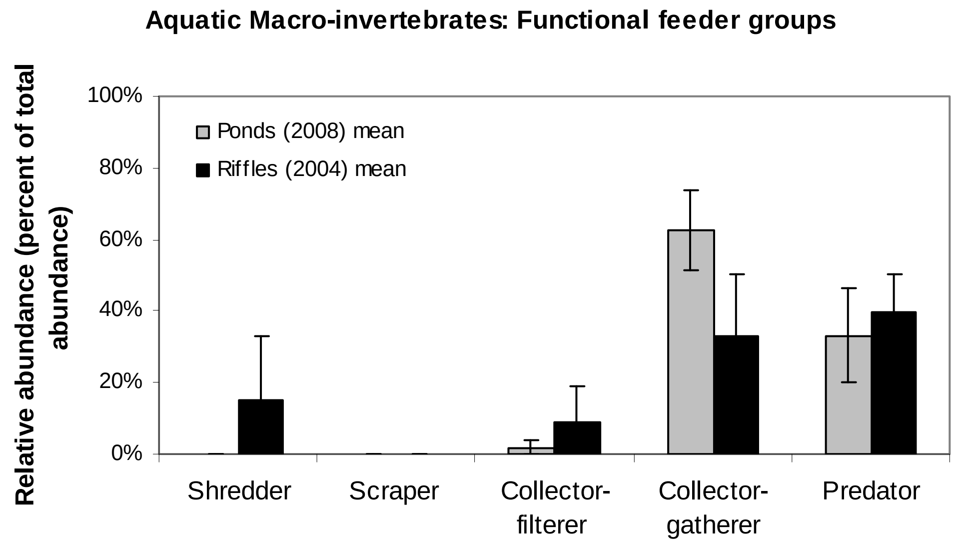


Figure 2-91. Relative abundance of macroinvertebrate functional feeder groups in pre-project implementation riffles (n=5) and post-project implementation ponds (n=4); means with standard deviations.

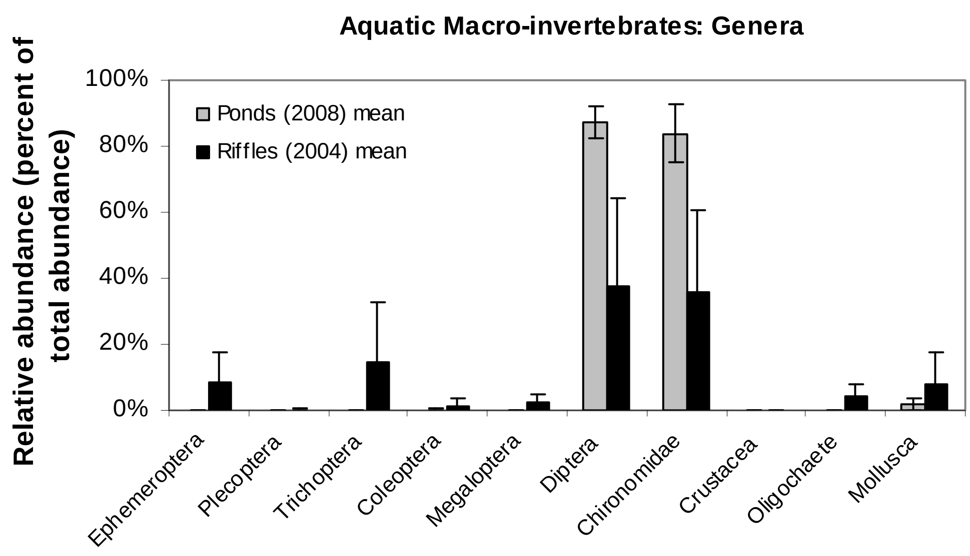


Figure 2-102. Relative abundance of macroinvertebrate genera groups in pre-project implementation riffles (n=5) and post-project implementation ponds (n=4); means with standard deviations.

2.6 Vegetation

2.6.1 Range condition transects

Range condition transects and condition assessments were performed by the USDA Forest Service Range Program in the 1960s prior to the pond and plug project and in 2008 following implementation. Transects within several hundred feet of the restored channel were collected both pre- and post-project (1969 and 2008), and although not co-located, can provide some general idea of whether or not large changes in vegetation in the "main meadow" occurred between sample dates. Information sources include Olin (2005), Weixelman (2009), and D. Weixelman, Tahoe National Forest, pers. comm., 28 February 2012. As illustrated in Figure 2-13 showing the approximate transect locations, Transects 2 and 3 are both located in the "main section" of Big Meadows and appear to be on similar vegetation types (based on color and texture of the Google Earth September 7, 2010 imagery).

We assume the vegetation sampling methods applied for transects 1 and 2 during the 1960s was the "Parker 3-Step" method in which a 100-ft transect is placed within an area of consistent vegetation and a 0.75-in diameter loop is placed on the ground every foot along that transect. Species composition, and litter and soil cover are recorded for every "loop"; final values are reported as percent cover (Parker 1954). Problems in the Parker 3-Step method, due primarily to the small sampling unit size (0.75-in diameter loop) led to cessation of its use in the 1980s. In the 1990s the Region 5 Range program developed a new methodology for tracking range condition and have been applying this in California since the late 1990s (Weixelman et al. 2003). Methods in the current program include establishing six 10-m transects and collecting rooted frequency data on species composition, litter and bare soil, as well as several other soil attributes, in a total of 60–100-cm^2 quadrats (Tahoe National Forest 2004).

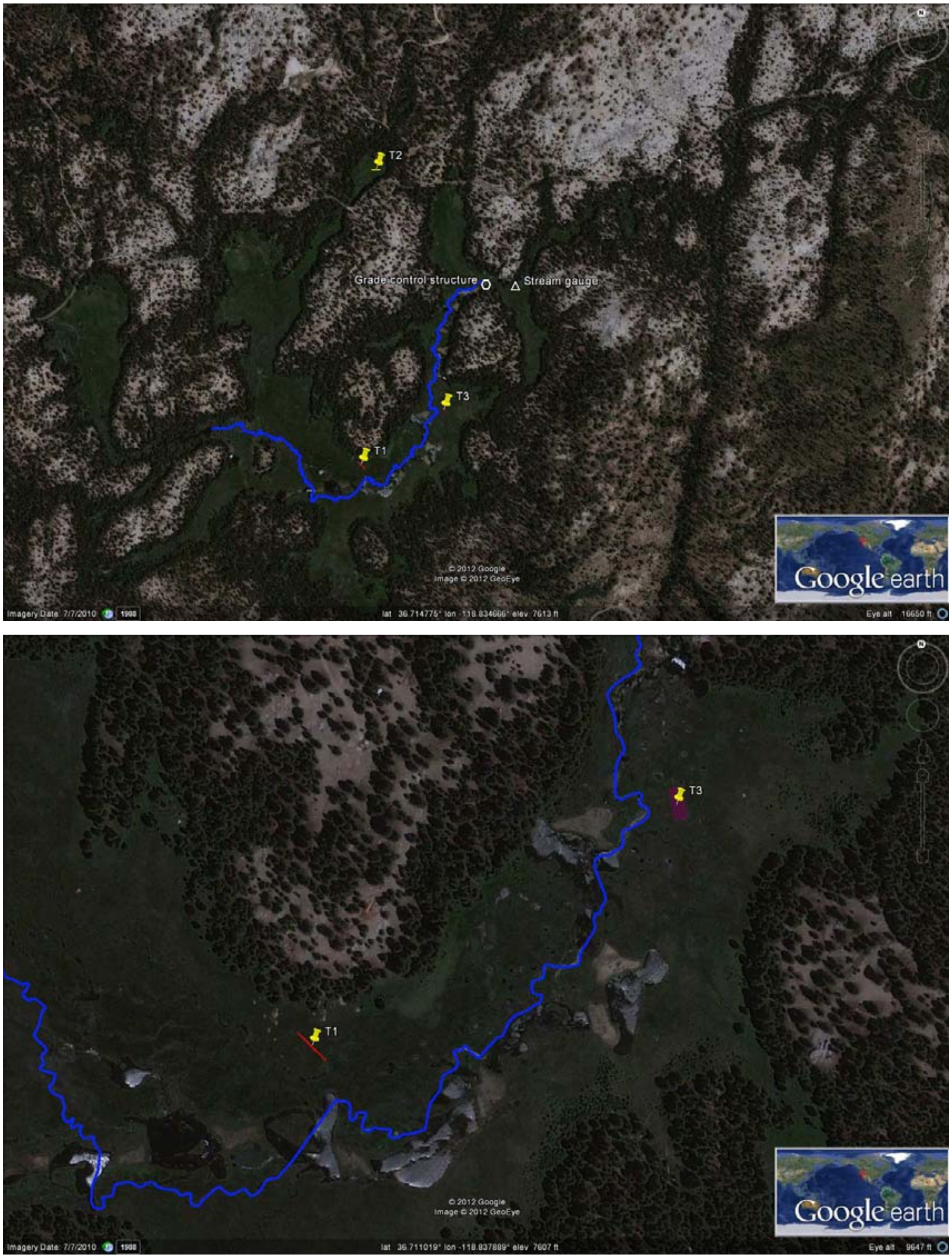


Figure 2-113. Approximate locations of Transects 1(1969), Transect 2 (1960 and 1965), and Transect 3 (2008); closer Google Earth image of vegetation types sampled for Transects 1 and 3, illustrating similarity in color and texture as possible indication of similar plant communities at both locations.

Findings reported on relative percent frequency (percent of sub-plots in which x species occurred over the total number of species occurrences in all sub-plots together; does not include bare soil or litter) for the three transects, including two time-periods for Transect 1 (1960 and 1965), are presented in Table 2-6 and Figures 2-14 and 2-15. Plant species are classified as early, mid and late seral indicators (Figure 2-14) and classified by plant type (Figure 2-15). The early, mid and late seral, or successional species classes were assigned according to the Region 5 list for functional groups and seral ratings for plant species found in meadows and fens, provided to A. G. Merrill of Stillwater Sciences by D. Weixelman, Tahoe National Forest, October 27, 2010. The Wetland indicator status classifications are assigned according to the Army Corps of Engineers approved list for wetland delineation in California (Reed 1988).

Table 2-6. Species lists from three vegetation transects (Transect 2 sampled on two dates) in Big Meadows.

Scientific name (Jepson 2012)	Common name	T2 1960	T2 1965	T1 1969	T3 2008
Achillea millefolium	common yarrow				x
Aster spp.	aster species	x	x		
Carex aquatilis	water sedge		x		
Carex feta	Greensheath sedge	x			
Carex filifolia	threadleaf sedge	x	x		
Carex nebrascensis	Nebraska sedge	x		x	x
Carex spp.	sedge species			x	
Carex vesicaria	blister sedge				x
Comastoma tenellum	Dane's dwarf gentian				x
Danthonia californica	California oatgrass				x
Deschampsia cespitosa	tufted hairgrass				x
Drymocallis glandulosa	sticky cinquefoil				x
Eleocharis quinqueflora	few-flowered spikerush				x
Galium trifidum	threepetal bedstraw				x
Hypericum anagalloides	tinker's penny				x
Juncus balticus	Baltic rush	x			
Juncus drummondii	Drummond's rush		x		
Juncus orthophyllus	straightleaf rush				x
Juncus spp.	rush species	x	x		
Muhlenbergia filiformis	pullup muhly	x	x	x	x
Oreostemma alpigenum	tundra aster				x
Perideridia parishii	Parish's yampah				x
Pinus contorta	lodgepole pine				x
Potentilla spp.	cinquefoil species	x			
Symphyotrichum spathulatum	western mountain aster				x
Trifolium spp.	clover species		x		
Viola MaCloskeyi	MaCloskey's violet				x
Achillea millefolium	common yarrow				x

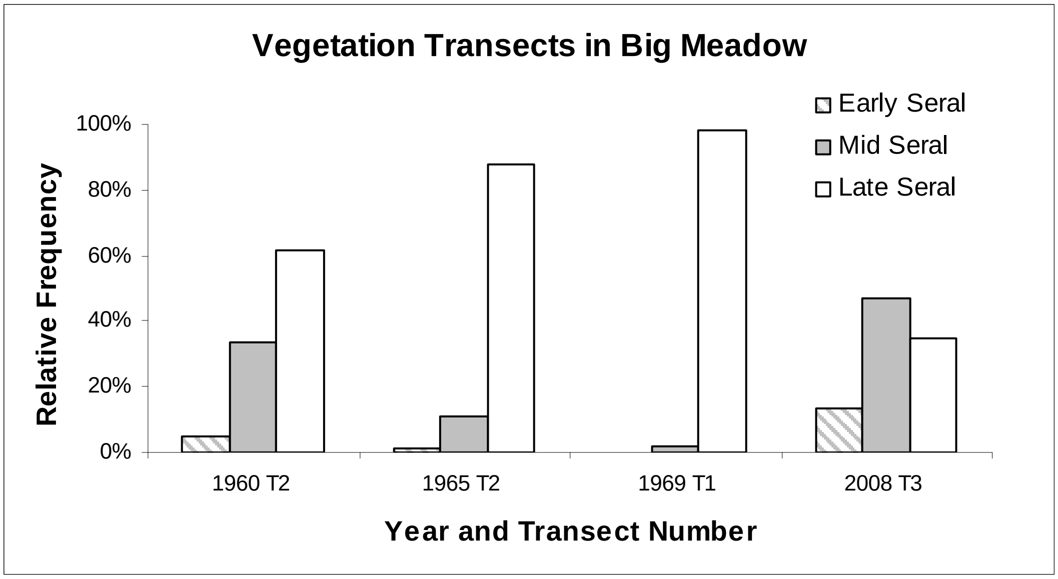


Figure 2-124. Relative frequencies of early, mid and late successional species along transects in a tributary meadow (Transect 1) and in the main meadow (Transects 1 and 3) before and after project implementation in 2006.

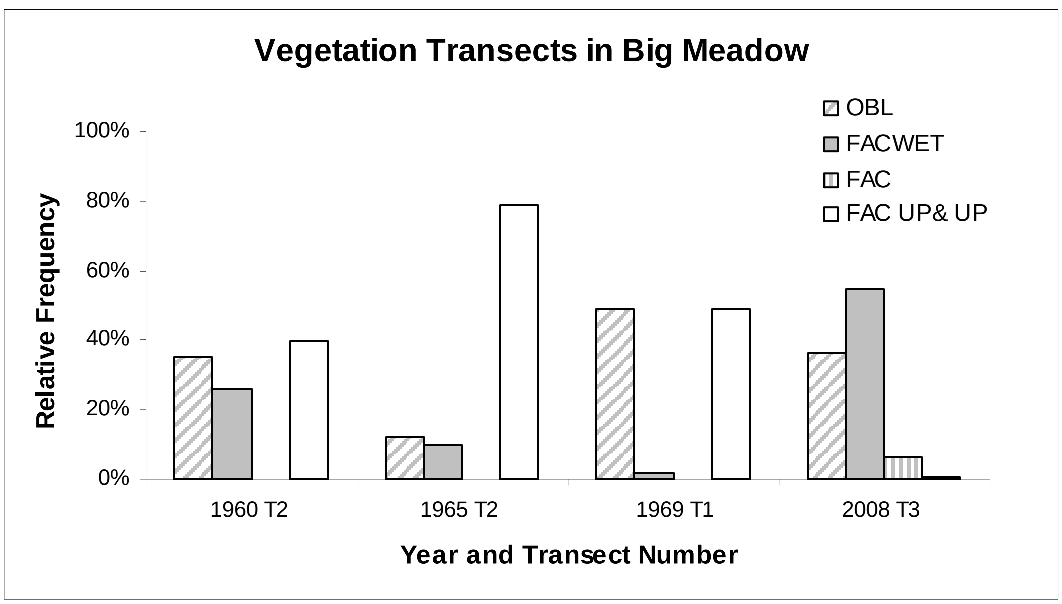


Figure 2-135. Relative frequencies of plant species by wetland indicator group along vegetation transects sampled in Big Meadows over time.

According to Olin (2005), Big Meadows pre-restoration could be classified a “moist meadow” because it did not dry out until the end of summer (Olin 2005). During Olin’s field surveys, he noted scattered willows along the upper channels of the meadow and ground cover was dominated by sedge and rush species. Olin also observed that lodgepole pine growing adjacent to the meadow was encroaching into the meadow itself.

Vegetation measured along Transect 2 in 1960, was classified as being in “fair condition”, while the soils were classified as in good condition and stable (Olin 2005). In 1965, the vegetation along Transect 2 was upgraded to “good condition and improving,” while the soil was downgraded to “fair condition and declining” (Olin 2005). However, since Transect 2 is located in a tributary meadow over 3,000 ft (900 m) from the restoration project, it is difficult to infer trends or vegetation responses to project-related condition changes in the meadow.

Olin reports that the Transect 1 (1965) vegetation survey showed no bare soil, high litter cover (46%) and relatively low overall vegetation cover (54%) (Olin 2005). Oddly, the vegetation survey for Transect 1 (1969) includes only three species (*Carex nebrascensis, Muhlenbergia filiformis,* and an unknown *Carex* species); this seems unlikely for 100 points in this ecosystem type and suggests that the transect was unfortunately located in an atypical area, that there was some data loss, or there was incomplete reporting. However, the preponderance of sedge species, including Nebraska sedge which is a late-seral and obligate wetland species, suggests that the site was in at least “good” condition, despite the relatively low total vegetation cover and reported low species diversity.

Downstream of Transect 1 and following restoration, Transect 3 was established in an area of the main meadow that appears to have similar color and texture to Transect 1 on the Google Earth imagery (Figure 2-14) and could therefore, support a similar vegetation type. Many more species were reported in the 2008 survey (16, excluding lodgepole pine), again with high frequency of Nebraska sedge (present in 58 out of 60 100 cm2 quadrats). The Region 5 Range Program rated this site “high ecological status” or in “excellent condition” with excellent plant vigor and soil stability. Depth to saturation on the sample date, 9 October 2008, was 30 inches (75 cm) (Weixelman 2009).

Transects 1 (1965) and 3 (2008) appear to have been located within the main meadow and within 150 ft (45 m) of the restored channel. Therefore information from these transects could provide a reasonable source of information on whether or not very coarse changes in vegetation community type occurred within the main meadow between 1965 and 2008. Because reports from these two surveys both indicate relatively high cover of Nebraska sedge and other sedge species, and the synthesized range assessments both indicate good to excellent conditions, we can infer that the meadow vegetation has not changed drastically between these measurement dates. More specific inferences on changes in meadow vegetation in response to project implementation are not possible due to the coarseness and age (22-year pre-project) of the pre-project data and lack of spatial overlap in sampling areas.

2.6.2 Percent length of channel lined with willows

No measurements of the extent of willows along the channel were available at the time of writing this report. However, Olin (2005) used a solar pathfinder to measure shade at 30 points along the pre-restoration channel and found that shade ranged from 0.5 to 92% (see Table 2-7).

Table 2-7. Percent shade along pre-project reaches, recorded using a Solar Pathfinder by Olin in summer 2004 (Olin 2005).

Olin Reach	Corollary USDA Forest Service Transect(s)	% Shade (via Pathfinder
A	12, 13, 14	29
B1	9, 10	13
B2	na	2.2
B3	4,5,6,7	37
D	3b	0.5
ESF	na	49

These data provide a baseline from which future shade measurements could be made, using the same techniques and reach areas to allow for better pre- and post-project comparison. Percent shade overhanging the pond edges was also recorded at the time that aquatic macro-invertebrates were sampled in 2008. For ponds 1, 2, 3, and 4, over-bank shade covered 0 to 80, 0 to 15, 0, and 0 to 50% of the pond edge (see Appendix D).

2.7 Wildlife and Bird Habitat

Olin (2005) summarized wildlife habitat suitability for several listed wildlife species including great gray owls, willow fly catcher, and the mountain yellow-legged frog. Big Meadows is within the geographic range of the great gray owl and offers high quality potential habitat for this species, such as the large (>24 inch dbh) trees surrounding the large moist meadow. The sparse cover of willows and other deciduous shrub and small tree species in Big Meadows does not offer ideal willow fly catcher habitat and, although Big Meadows could provide the kinds of conditions preferred by Mountain yellow-legged frogs, Olin (2005) reports no recent sightings of the species along Big Meadows Creek under pre-project conditions.

Pre-project USDA Forest Service surveys for NEPA documentation of the Big Meadows restoration area found no Great Gray Owls were occupying the site vicinity in 2002 (Emmendorfer et al. 2007). Through the short-form Biological Evaluation, the USDA Forest Service also found that there was, prior to restoration, no potentially suitable willow flycatcher habitat within a 0.5-mile radius of the project area (Emmendorfer et al. 2007). The USDA Forest Service also surveyed Big Meadows for amphibians in 2001 and found no mountain yellow-legged frogs, relictual salamanders or other sensitive species in the area. Moreover, theUSDA Forest Service wildlife biologist indicated that the restoration project would improve habitat conditions for the Mountain yellow-legged frog, which prior to restoration, was limited due to the degraded channel and presence of predatory non-native brook trout. The Bald Eagle and California Condor are both federally listed endangered species that occur within the Sequoia National Forest. However, the USDA Forest Service wildlife biologist determined that the Big Meadows project is outside the occupied range of both of these species.

The USDA Forest Service wildlife biology team also developed and performed bird surveys at Big Meadows following project implementation. The Big Meadows post-project bird monitoring, was performed using 5-minute, variable circular plot (VCP) point counts one time a month during June, July, August, and September of 2008 and 2011. The survey protocol was based on meadow survey methods developed by Siegel and Wilkerson (2005). Nine permanent point count locations were designated in Big Meadows (Figure 2-16). The points were spaced about 200 m apart, and at least 20 m from the meadow edge by the Jeff Cordes, the Hume Lakes District Wildlife Biologist. More details on the method used are provided in Cordes (2008, 2011).

Overall, Cordes reports detecting an average of 18 and 12 bird species during the 2008 and 2011 visits. The most abundant species included mallards, Brewer's blackbirds, mountain chickadees, violet-green swallows, yellow-rumped warblers, chipping sparrows, pine siskins, and red-breasted nuthatches. A summary of the bird findings in the 2011report states:

> *Although we have no bird counts prior to the restoration for comparison, it is clear that the bird community at Big Meadows is now what would be expected in a healthy southern Sierra meadow. Successful nesting by species like mallards and spotted sandpipers is likely a direct result of the restoration.*

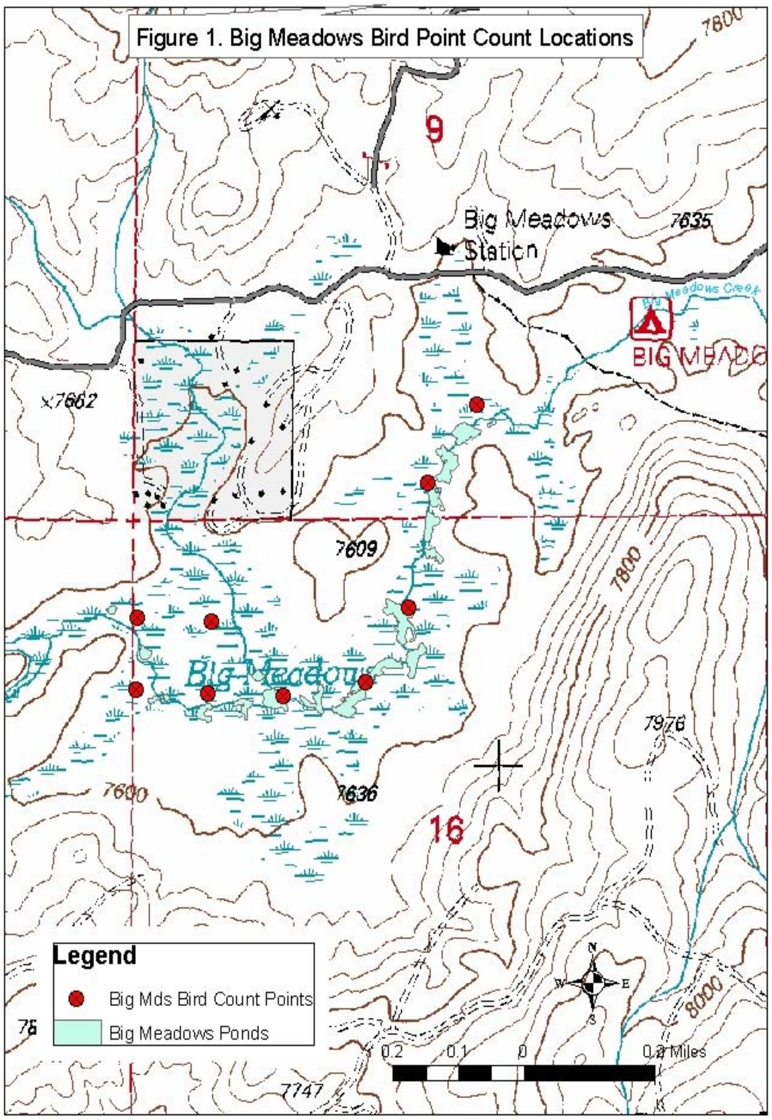


Figure 2-146. Bird count locations in Big Meadows.

3 SUMMARY OF FINDINGS AND RECOMMENDATIONS

3.1 Summary of Findings

Findings from pre- and post-project implementation surveys are presented in Table 3-1 below. At a coarse level, there are no indications of gross changes in the channel form other than those created during project implementation. Similarly, no very large changes in vegetation appeared to occur in the central portion of the meadow. Detection of any less coarse (e.g., from moist to wet meadow vegetation type) changes from pre to post implementation or during the post-implementation period is not possible given the current data available.

Table 3-1. Summary of pre- and post-project implementation findings in relation to stated project goals.

Project goals	Field metrics applied	Location of measurement	Period of measurement	Indications from current findings
Establish primary single thread low flow channel	Cross-sections	Similar but not exact locations pre- and post-implementation	2006, 2008, 2010	No coarse changes in channel structure detected other than created ponds and plugs.
Establish primary single thread low flow channel	Google earth images	Entire meadow	1988, 1993, 1998, 2002, 2004, 2005, 2009, 2010	Single thread channel visible on Google earth images, pre- and post-implementation
Reduce peak flows	Continuous stream gage	Downstream end of project	Late 2006 through 2011	Insufficient pre-project data to detect change
Extend summer base flows	Continuous stream gage at downstream end	Downstream end of project	Late 2006 through 2011	Insufficient pre-project data to detect change
Raise local groundwater level	Piezometers: 13 measured 2004; 3 measured post project implementation	3 consistently located piezometers pre- and post-project	2004, 2006-2010	Increase in groundwater elevation post-project per Lee (2009); and Ferrante (2009-2010)
Enhance water quality	Stream water temperature	Downstream end of project	Late 2006 through 2011	Insufficient pre-project data to detect change
Enhance water quality	Pond water temperature	Ponds 1, 2, and 4 located at the lower, mid, and upper portions of the project area, respectively	Sept. 2010 through June 2011	Insufficient pre-project data to detect change
Enhance aquatic habitat	Benthic macroinvertebrate sampling	Stream measurements pre project; pond measurements post project	2004, 2008, 2010	Lack of continuity between pre- and post-project data to quantify change within habitat types; increase in slow-moving water habitat and species typical of those habitats with restoration and creation of ponds.

Project goals	Field metrics applied	Location of measurement	Period of measurement	Indications from current findings
Increase in-stream cover and shading	Solar pathfinder measurements along xy stream reaches	30 locations along incised channel under pre-project conditions	2004	Pre-project and Post-project data were collected using different techniques and in different areas. Both observation sets cover very broad ranges of shade.
Enhance terrestrial habitat	Vegetation transects	Both 1969 and 2008 transects in different locations within the main meadow; Other surveys in tributary meadow	1960, 1965, 1969, 2008	At a very coarse level, no change apparent; insufficient pre-project data for more specific change detection
Enhance terrestrial habitat	Bird Surveys	Big Meadows area	2008 and 2011	No pre-project data available. Bird diversity and composition were indicative of a healthy meadow.

3.2 Overview of Monitoring and Adaptive Management

Ongoing monitoring and adaptive management is an important part of any restoration plan since few if any restoration or enhancement projects require no management adjustments once the initial actions are complete. Monitoring provides the critical information on which adaptive management decisions can be made. One of the main purposes of monitoring is to provide an early warning for negative or unexpected changes in the meadow and to help identify when ecological thresholds are going to be crossed, sending the meadow into an alternative state. Identifying and incorporating these thresholds in a monitoring program makes it possible for the manager to track when such thresholds are being approached, and thus to take early, preventative actions.

Meadow restoration goals, defined early in the project planning process, should be the starting point for development of any monitoring and adaptive management plan. Project goals for increased or decreased process rates or structural characteristics need to be translated into metrics with specific thresholds for action. If monitoring results indicate that meadow processes are not changing in the targeted direction, then alternative management strategies can be applied. If monitoring indicates that meadow processes are moving in the target direction, then there is no change in management, but continued monitoring and assessment. The overall process of developing project goals, selecting appropriate management/restoration or enhancement methods, and tailoring the pre- and post-implementation monitoring plan to those goals and methods with “iteration loops” for on-going monitoring and adaptive response, is depicted in Figure 3-1 below.

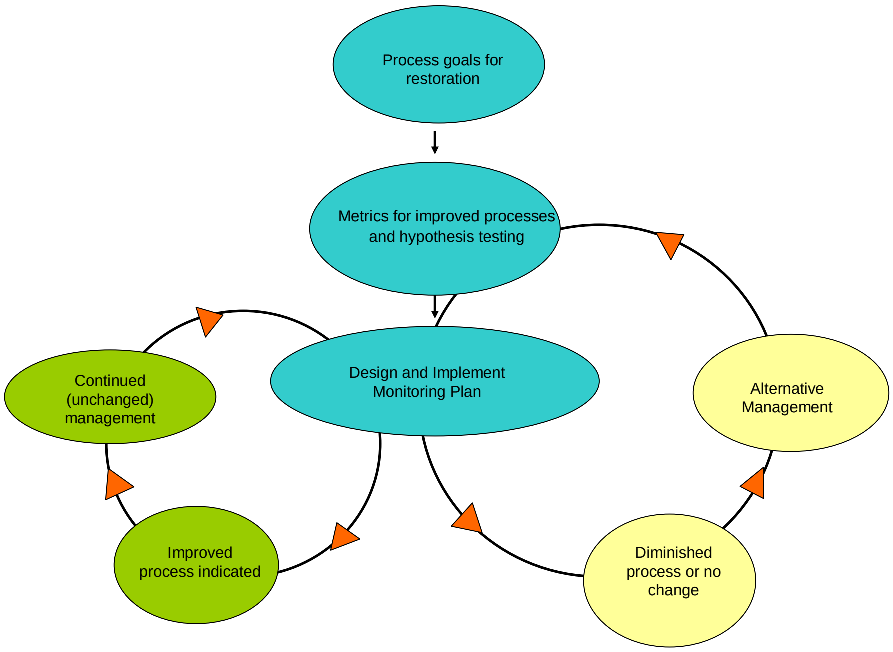


Figure 3-1. Process-directed monitoring goals and metrics are used to monitor restoration or enhancement effects. Iterative loops of continued monitoring occur when indicators reflect desired responses; whereas adaptive management is performed when indicators reflect undesired process responses.

3.3 Monitoring Recommendations for Big Meadows

For Big Meadows, the project goals were clearly articulated early on in the project development. The goals themselves are a mix of physical conditions (e.g., raise ground water levels, increase stream cover and shade) and processes (e.g., reduce peak flows and extend summer flows). Processes that create and maintain the physical template of the meadow, particularly the transport and overbank distribution of sediment and water as it flows through the meadow, are critical for maintaining meadow aquatic and terrestrial functions. Measurements of changes in channel form through repeated cross-section surveys, of stream flow using continuous gage recorders, and of groundwater level in multiple piezometer arrays, are all excellent ways of tracking meadow processes and response to changes in management. All of these metrics have been collected at Big Meadows both before and for two to three years following project implementation. The excellent work and analysis performed by Olin (2005) also sets a baseline of understanding and information on the meadow under pre-project conditions. In this way, Big Meadows is an example of a restoration project in which a large body of data—and conceptual understanding of the system—was developed before project implementation. A broad array of data was also collected post-restoration, covering information on geomorphology, hydrology, water quality and aquatic foodwebs, vegetation, and bird habitat. This diversity of data can support an integrated understanding and corresponding management of the meadow and its surrounding lands.

However, the brevity of some pre-project measurements, inconsistencies in what specific field methods were selected and how they were applied, and in challenges in data management have detracted from the value of the monitoring data collected. Overall, the most important data gaps are due to (1) paucity of pre-project data, since several years' worth of ground and surface water data are needed to understand the natural range of variability; and (2) imprecise, or non-existent, spatial overlap between pre- and post-project monitoring locations, precluding the possibility of making quantitative before and after comparisons. In the following section, we offer recommendations for future monitoring at Big Meadows and other similar project sites.

3.3.1 Field data collection

- Collect several years of pre-project data, particularly for stream water flow, stream water temperature, and groundwater levels.
- Ensure that the methodology, distribution, and intensity of field measurements are sufficient for detecting change and targeted for the relevant process/characteristic.
- Apply the same methodology throughout the pre- and post project implementation periods.
- Develop very specific field methodology instructions to support consistency over time and personnel turn-over.
- Locate all measurements in the exact same locations over time using GPS points for all data collections on every date.
- Co-locate sets of measurements, such as groundwater level and stream flow, to demonstrate linkage between these characteristics.
- Record any irregularities in equipment or field methods that occur.

3.3.2 Cross-sections and change in channel form and condition

- Locate cross-sections strategically in order to test hypotheses about process: e.g., place them above and below the ponds to check for scour and head cutting.
- Tie elevations to permanent elevation markers.
- Record exact location of transect endpoints; units, specific dates, names of field personnel.

3.3.3 Groundwater monitoring

- Re-locate at least NINE more groundwater well locations used by Olin so that groundwater level transects can be monitored at the upper, mid and lower portions of the meadow.
- Record elevation and extent of screening in piezometers.

3.3.4 Benthic invertebrate monitoring

- Include at least 3 sampling sites from riffles in current channel as well as ponds so that comparisons across similar habitat types under pre- and post-project conditions can be made.

3.3.5 Vegetation monitoring

- See Stillwater Sciences 2011 for vegetation monitoring protocol that will cover changes in entire meadow rather than in very finite locations.
- Apply Weixelman et al. 2011 meadow hydrogeomorphic meadow classification to place Big Meadows into the broader range of meadow types that occur in the Sierra Nevada.
- Locate vegetation transects in exact same positions (or at least community patches) over time.

3.3.6 Data management

- Develop appropriate field data collection sheets with clearly marked units for every measurement during pre-project monitoring and use throughout pre- and post-project period.
- Scan field data sheets and archive; if corrections are made to field data sheets in office, rescan and archive corrected versions separately.
- Document any corrections made to field data in the office so that a reader understands exactly what was done to correct the data and what information sources were used to make the correction.

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Appendices

Appendix A

Project Timeline

Spring / Summer 2004

- Data collection
- Comprehensive field study

Spring 2005

- Data analysis & interpretation
- Program development, grant proposals, partial funding

Fall/ Winter2005

- Jason Olin Thesis published, SERCAL presentation
- October Stakeholder walk
- Stakeholder meetings and resolution: October 2005
- Complete ground review with Jim Wilcox
- Jayne Ferrante receives training on grant proposal writing and grant management from Plumas Corporation staff.
- Fund raiser for Big Meadows (Fly Fishing Team USA)
- Coordinated with Sequoia National Forest NEPA process
- Nordic Ski club and Fly Fishing Club members help collect data all winter in the Meadow
- Grant writing efforts to fund the project.

Spring 2006

- June: Stakeholders conducted cross section surveys in the meadow, expanding our data. Terry Henry, Sequoia National Forest Hydrologist and Jim Wilcox, Plumas Corp supervised.
- Completed restoration design and budget projections, Jim
- Wilcox.
- Held a Stream Restoration Class for the general public taught by
- Jim Wilcox of Plumas Corporation with a focus on basic elements of geomorphic restoration techniques. A variety of stakeholders attended, including various agencies, the Sierra Club as well as members of two local Fly Fishing clubs.

Fall/Winter 2006

- Installed Datalogger & Pressure Transducer to monitor stream temperature and flow
- Further collection of baseline piezometer data.

Winter/Spring 2007

- Collaborate with Sequoia National Forest as they completed the final tasks of Environmental Assessment (EA) which is the current choice of documenting the NEPA process.
- Installed signs for the public describing the problems and
- restoration process
- Further developed relationship with the grazer/permittee

Fall 2007

- Further developed our relationship with Sequoia ForestKeeper, a local stakeholder against the project. Negotiated and educated about this work as we accomplished an agreement with them to pull their formal Appeal that was blocking the project.
- PROJECT INSTALLATION. This project accomplished three activities: gully elimination using the pond and plug technique, incorporating whole trees into the meadow channel and ponds, and the staging and installation of a rock/vegetation valley grade feature at the lower end of the meadow to address the need to restore the natural meadow and stream water table, stream channel characteristics, and vegetation components.
- Three volunteer days of vegetation work, one volunteer day of Electro-shocking fish and moving them before the work on the project.
- Monitoring of restoration areas weekly for two months, then monthly.

2008

- Monitoring of restoration areas monthly
- Shay Overton MA, Geological Engineer, 1 month training with
- Jim Wilcox onsite
- Meadow Restoration Class 2008
- Presented by Fly Fishers for Conservation and the
- Sierra Nevada Conservancy
- June 9th–13th, 2008, Hume Lake Camp & Big Meadows in Sequoia National Forest
- Class description: This is intended to be an intensive course requiring significant preexisting knowledge in applied geomorphology, hydrology, and engineering. The subject matter will be geared for individuals who will actually be developing and implementing meadow re-watering projects. We intend to spread the attendees between participating agencies, including USDA Forest Service, CDFG, NPS and private/watershed entities. Expect coursework to take 10–12 hours per day.
- Macroinvertebrate collection from ponds, Hobo water temps installed.

2009

- Ground water monitoring
- Surface water monitoring
- Cross-section surveys

2010

- Ground water monitoring
- Surface water monitoring
- Cross-section surveys
- Bird surveys
- Macroinvertebrate collection from ponds

2011

- Surface water monitoring

Appendix B

Channel Cross-sections

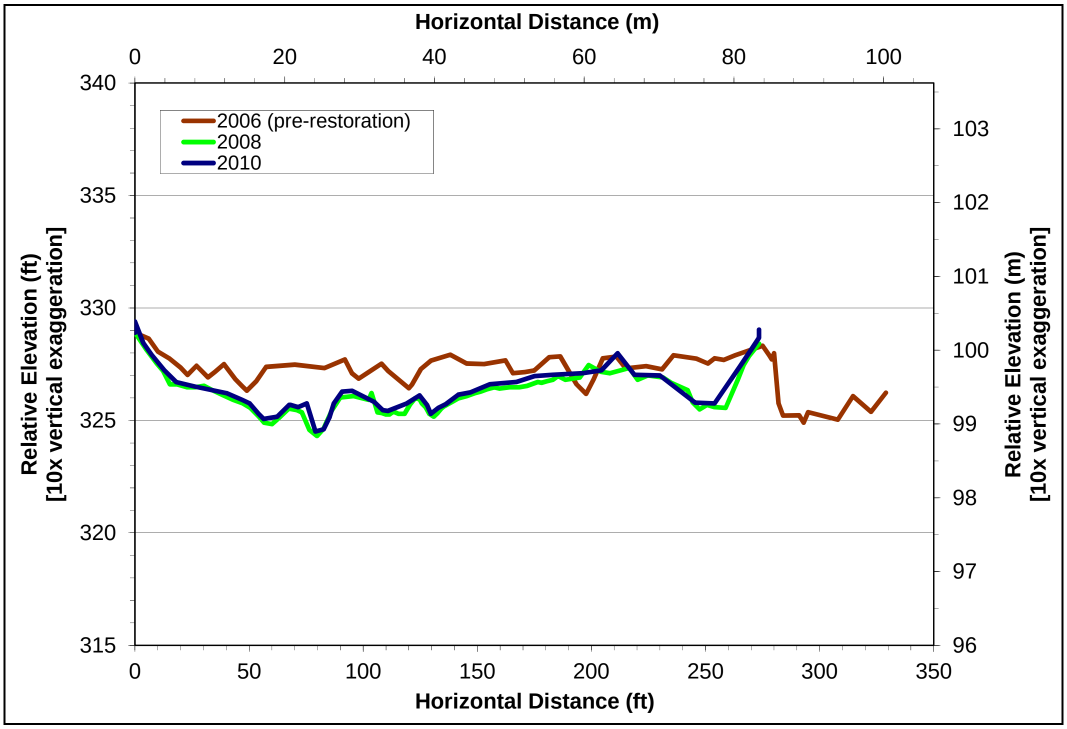


Figure B-1. Comparison of repeat surveys at Cross-section 1 (X-Sec 1). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

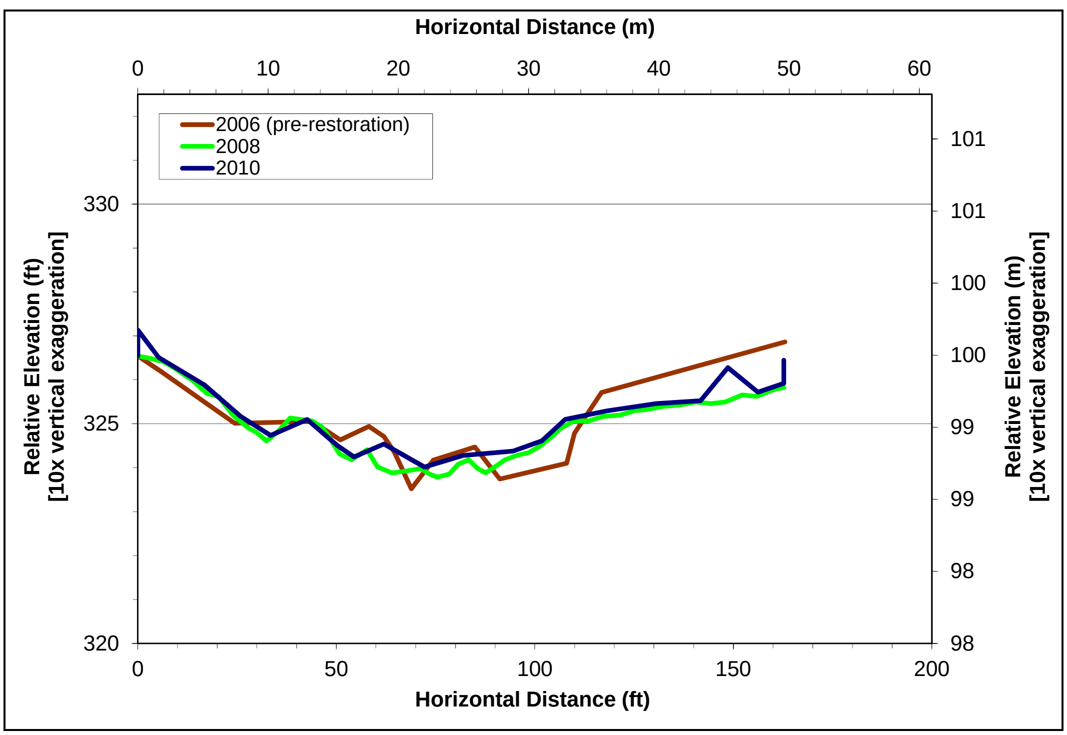


Figure B-2. Comparison of repeat surveys at Cross-section 2 (X-Sec 2). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

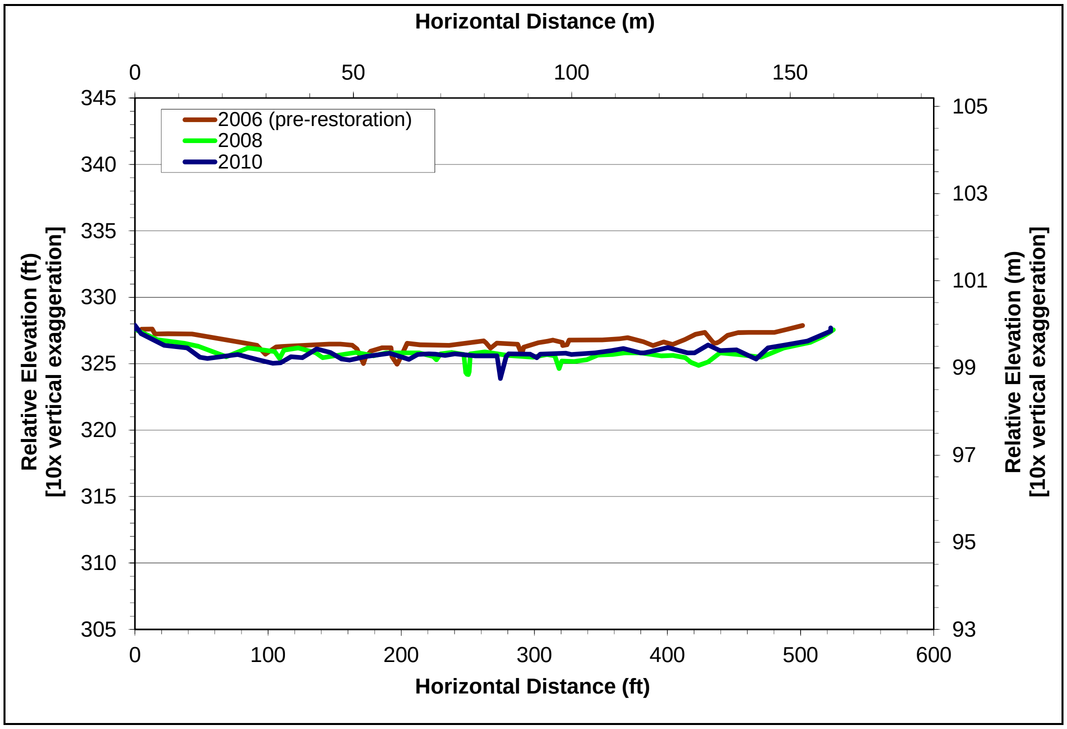


Figure B-3a. Comparison of repeat surveys at Cross-section 3a (X-Sec 3a). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

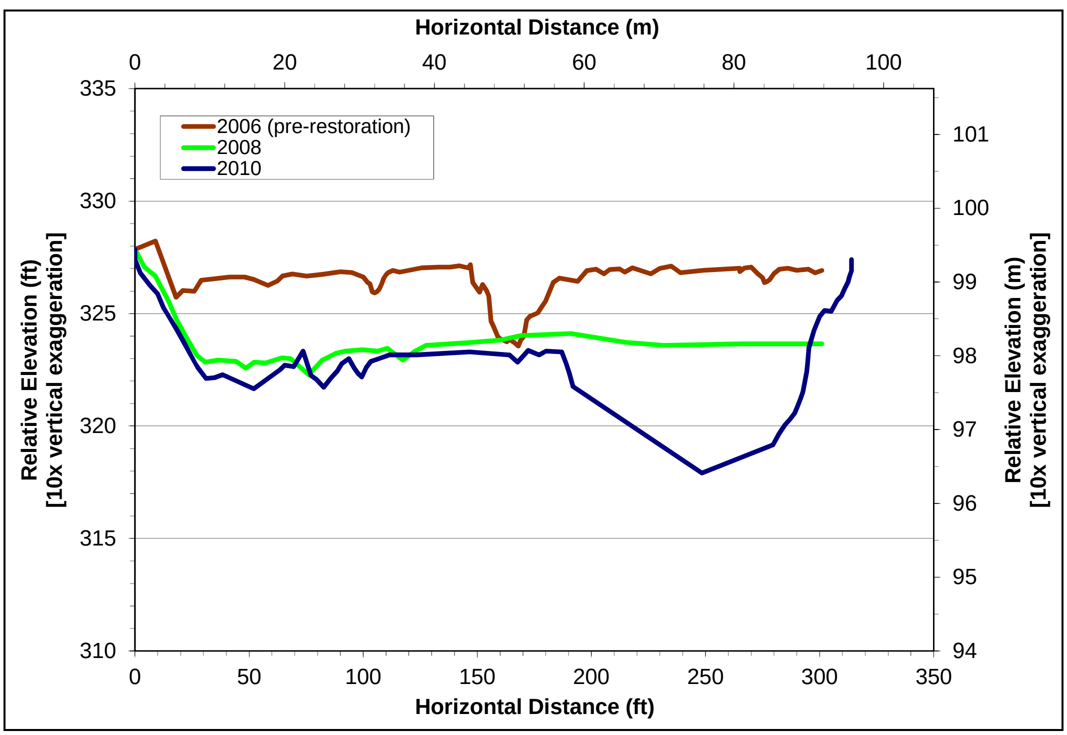


Figure B-3b. Comparison of repeat surveys at Cross-section 3b (X-Sec 3b). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

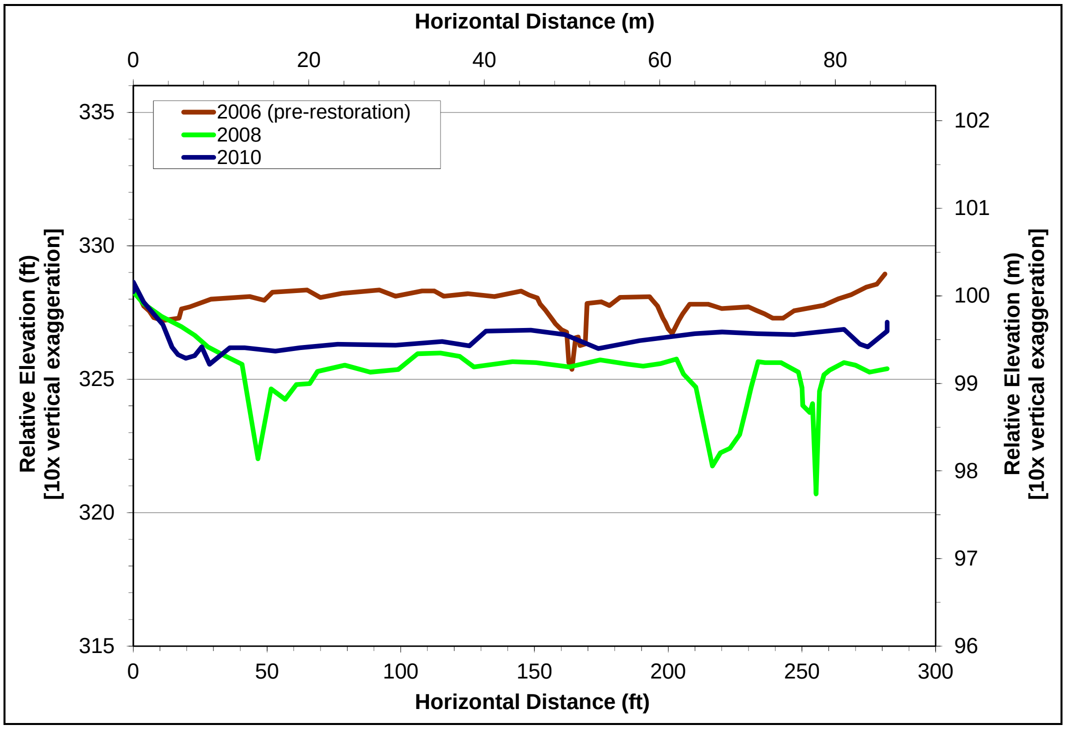


Figure B-4. Comparison of repeat surveys at Cross-section 4 (X-Sec 4). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

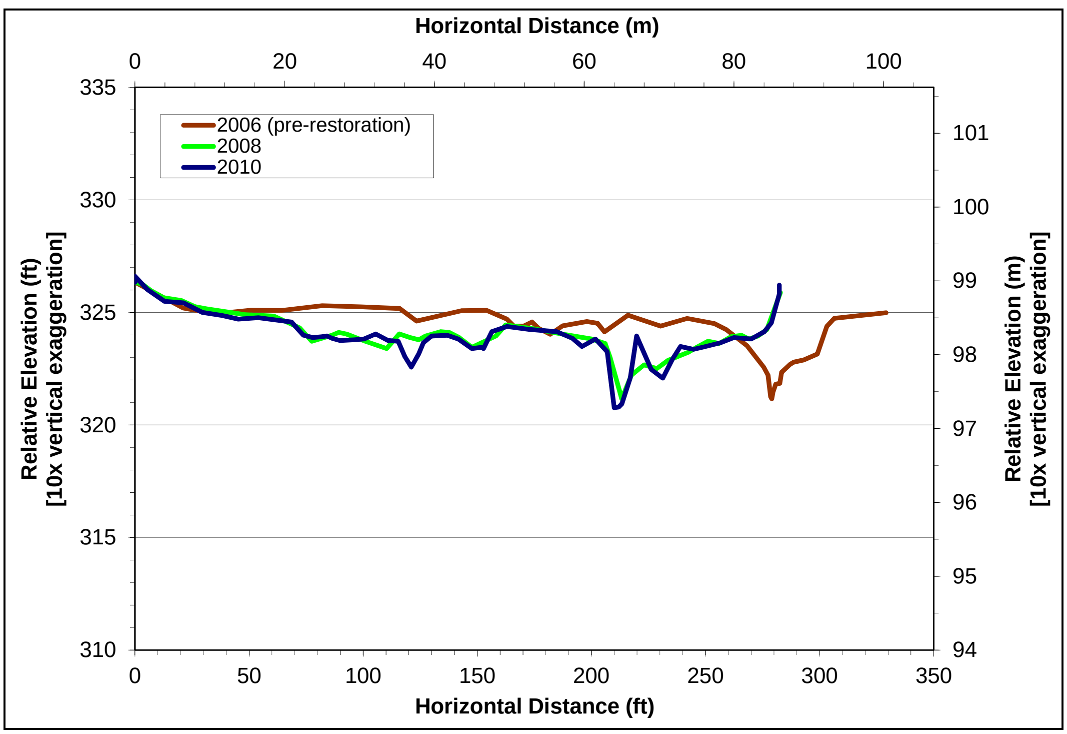


Figure B-5. Comparison of repeat surveys at Cross-section 5 (X-Sec 5). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

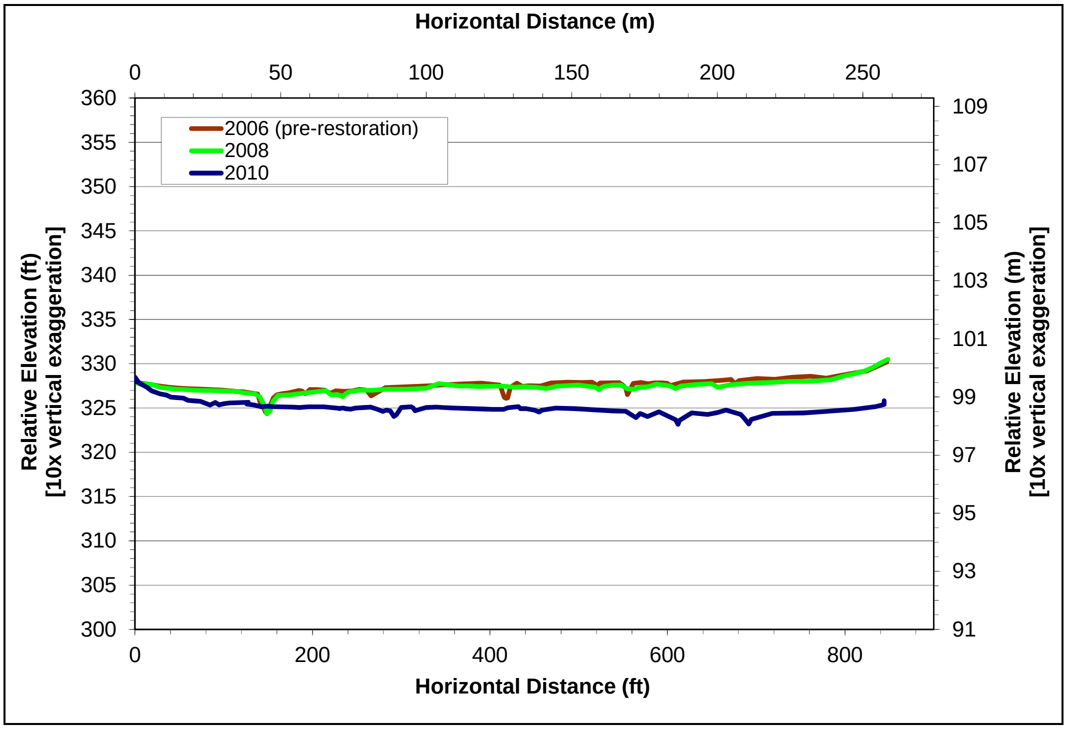


Figure B-6. Comparison of repeat surveys at Cross-section 6 (X-Sec 6). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

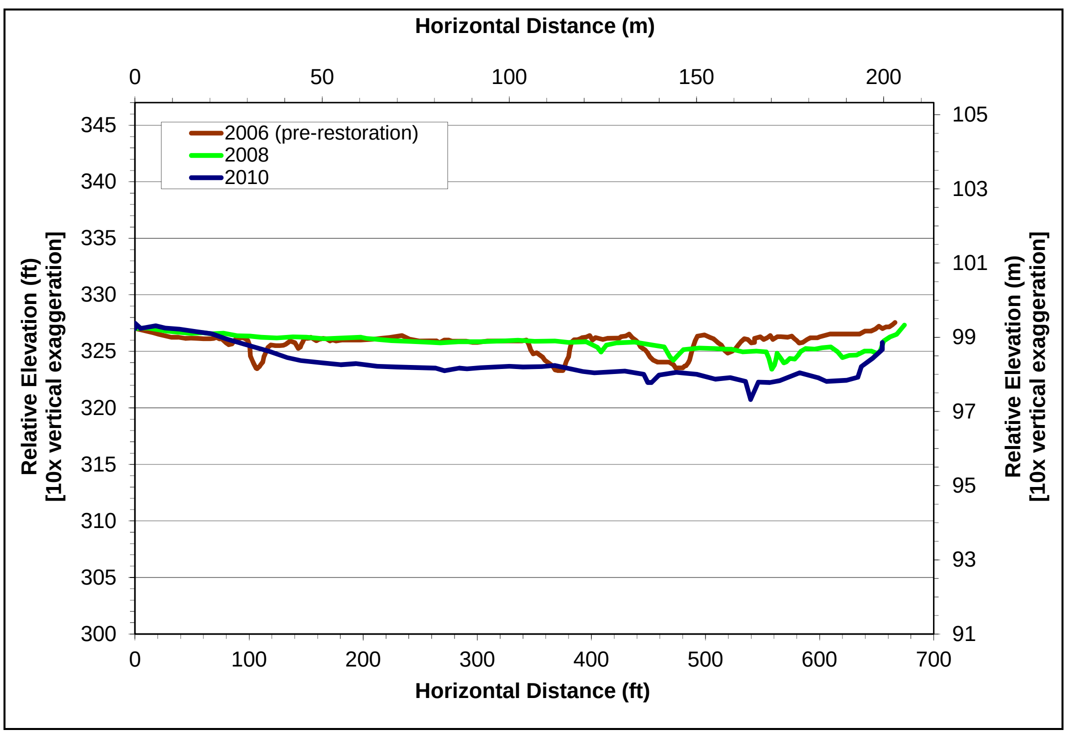


Figure B-7. Comparison of repeat surveys at Cross-section 7 (X-Sec 7). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

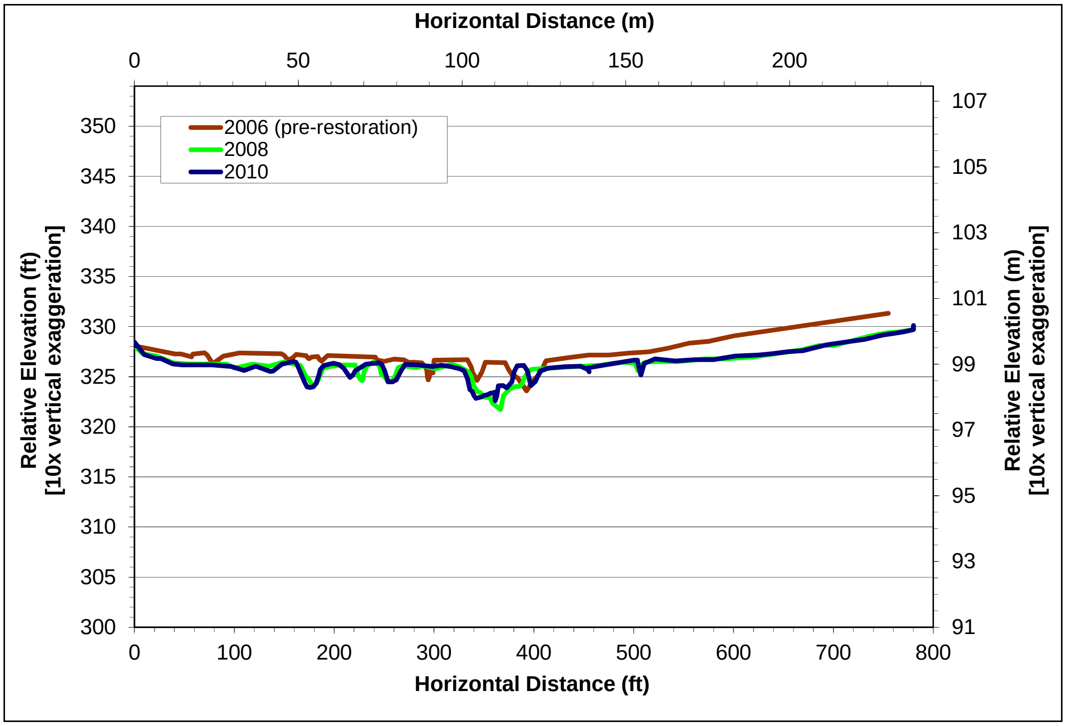


Figure B-8. Comparison of repeat surveys at Cross-section 8 (X-Sec 8). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

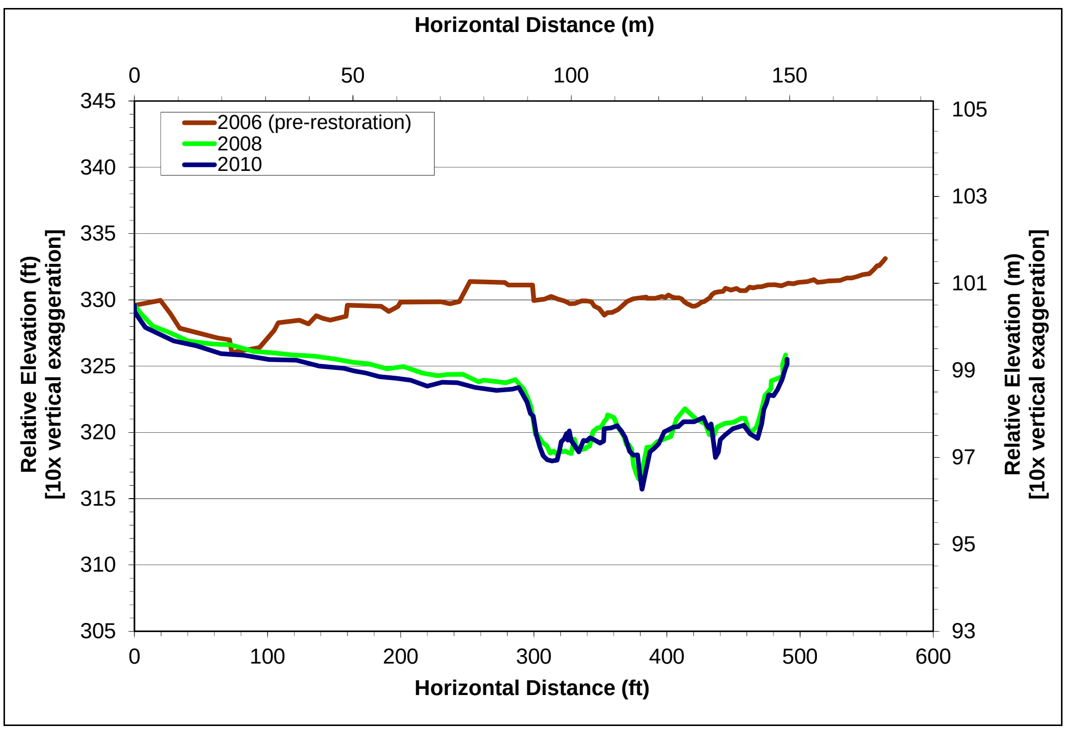


Figure B-9. Comparison of repeat surveys at Cross-section 9 (X-Sec 9). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

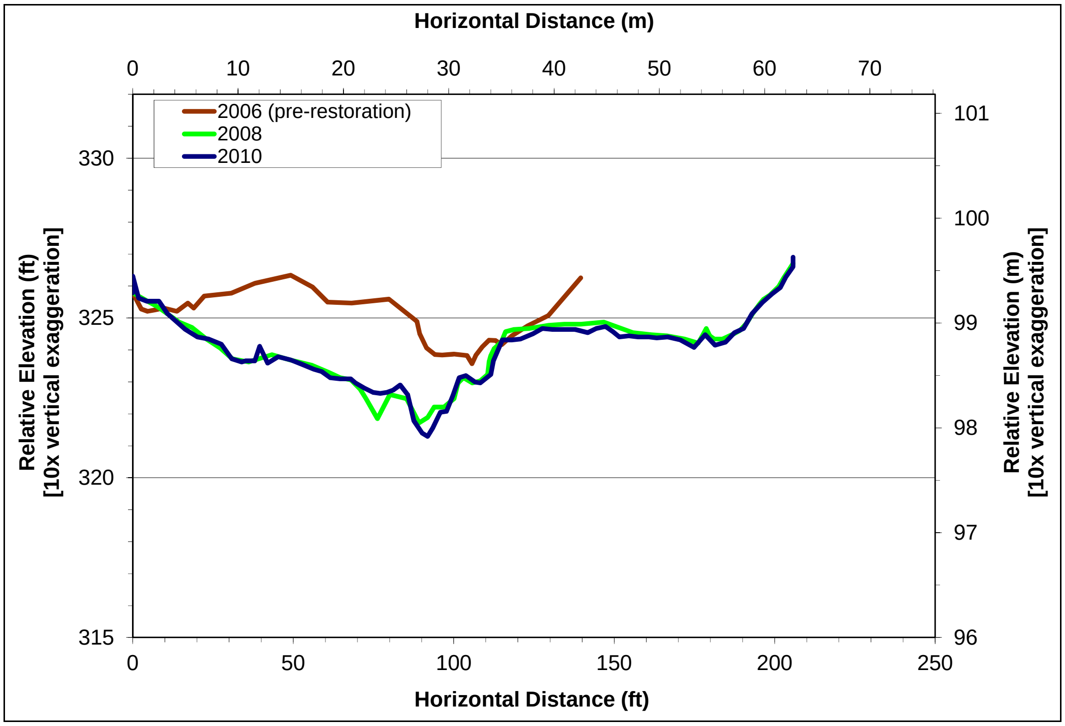


Figure B-10. Comparison of repeat surveys at Cross-section 10 (X-Sec 10). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

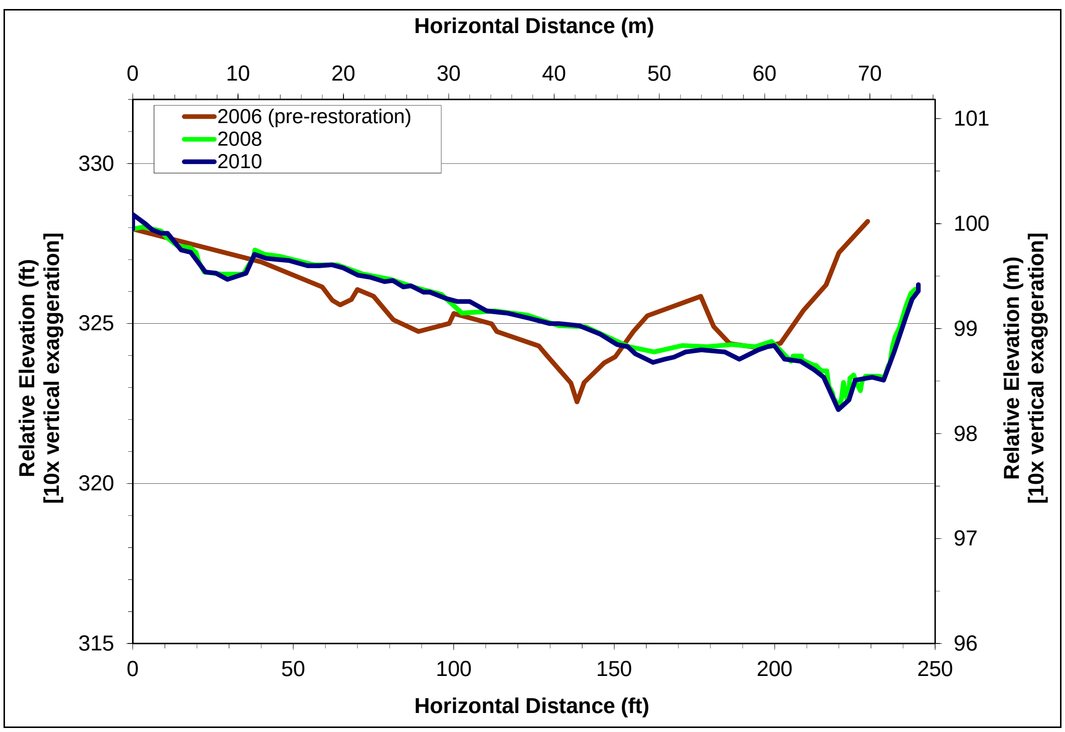


Figure B-11. Comparison of repeat surveys at Cross-section 11 (X-Sec 11). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

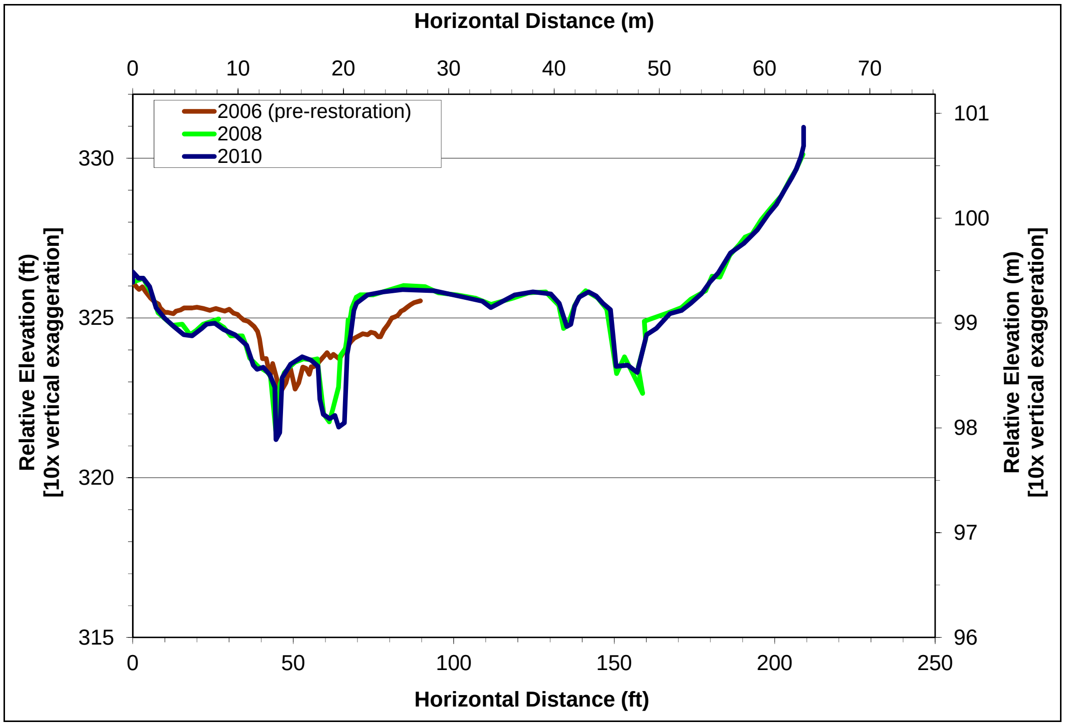


Figure B-12. Comparison of repeat surveys at Cross-section 12 (X-Sec 12). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

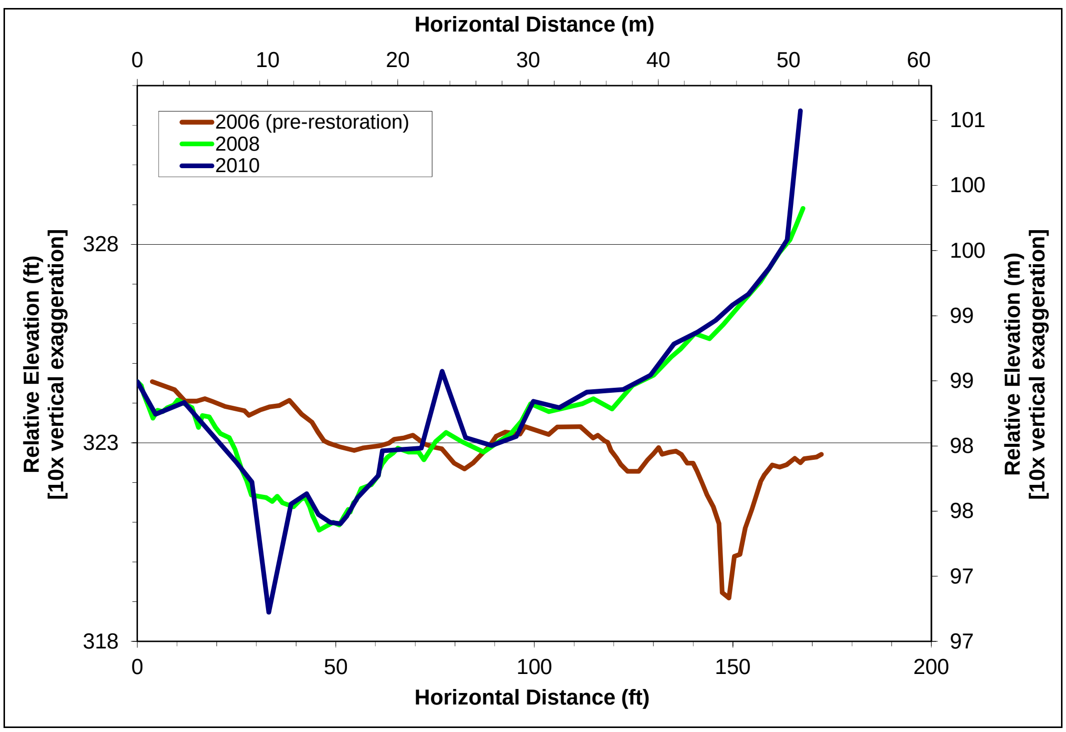


Figure B-13a. Comparison of repeat surveys at Cross-section 13a (X-Sec 13a). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

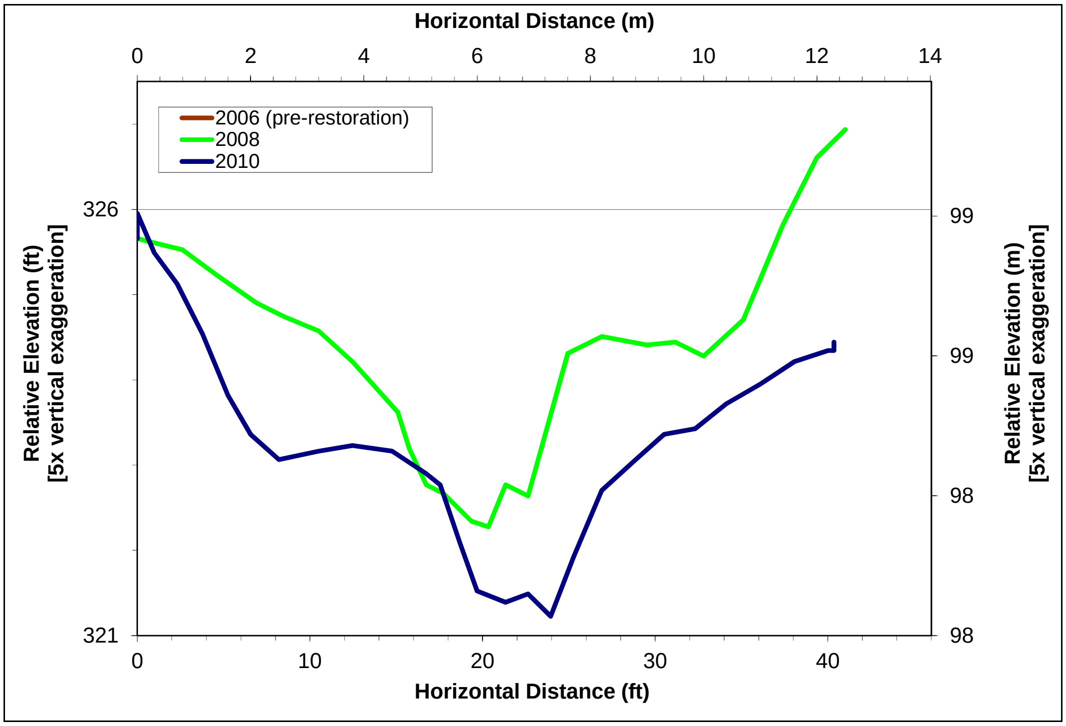


Figure B-13b. Comparison of repeat surveys at Cross-section 13b (X-Sec 13b). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

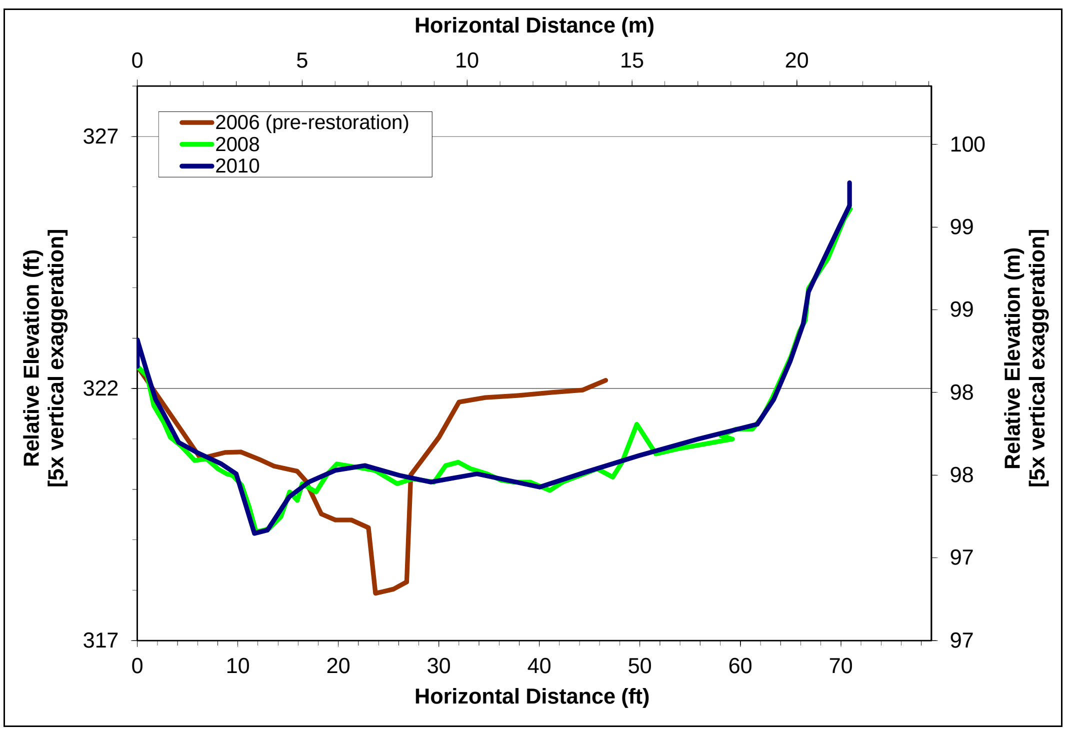


Figure B-14. Comparison of repeat surveys at Cross-section 14 (X-Sec 14). Note that the pre- and post-restoration surveys may not share a common alignment and/or starting and ending positions. (Source: USDA Forest Service.)

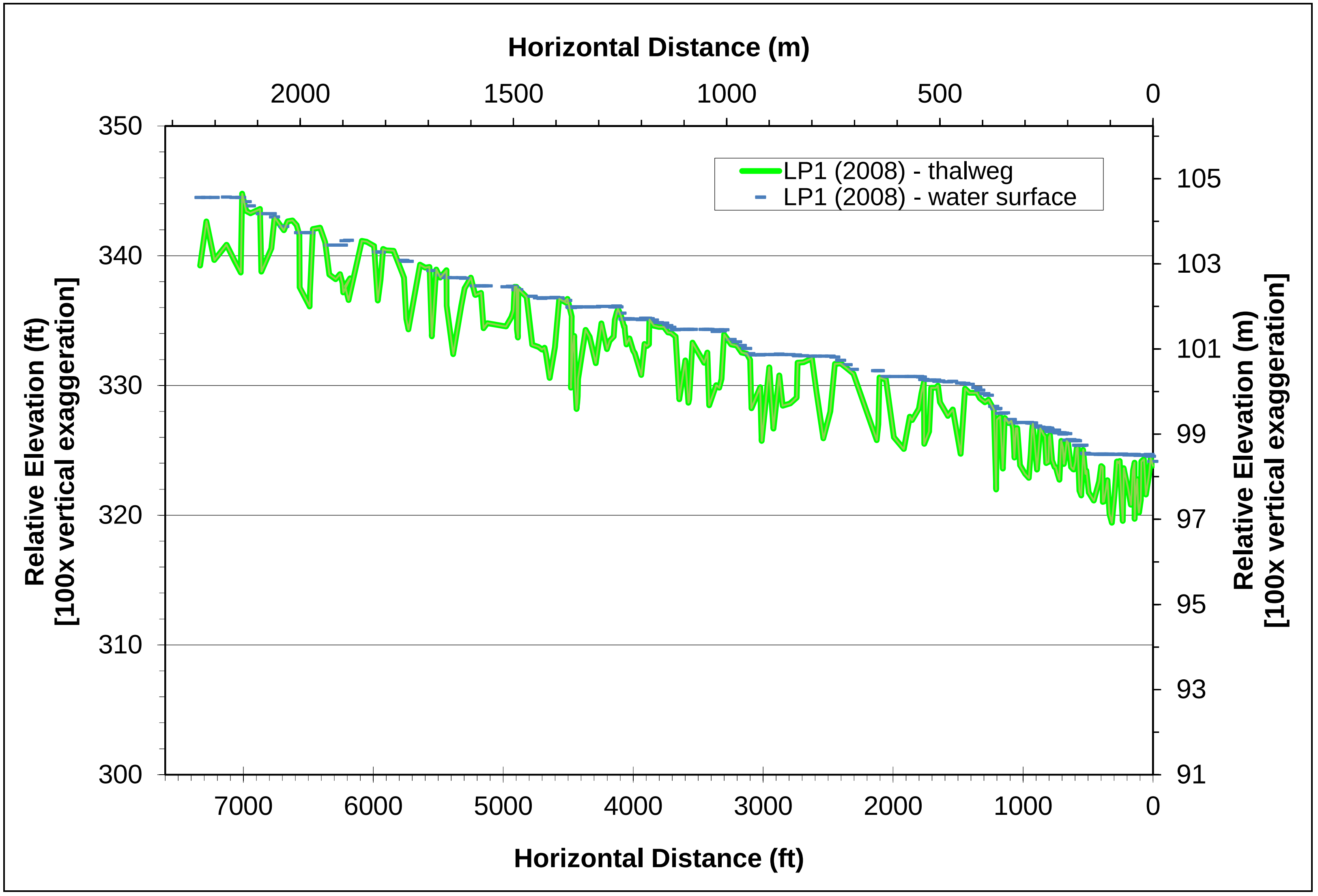


Figure B-15. Longitudinal profile of the entire length of Big Meadows Creek within the BMRP area. (Source: USDA Forest Service.)

Appendix C

Sediment Character at Cross-sections

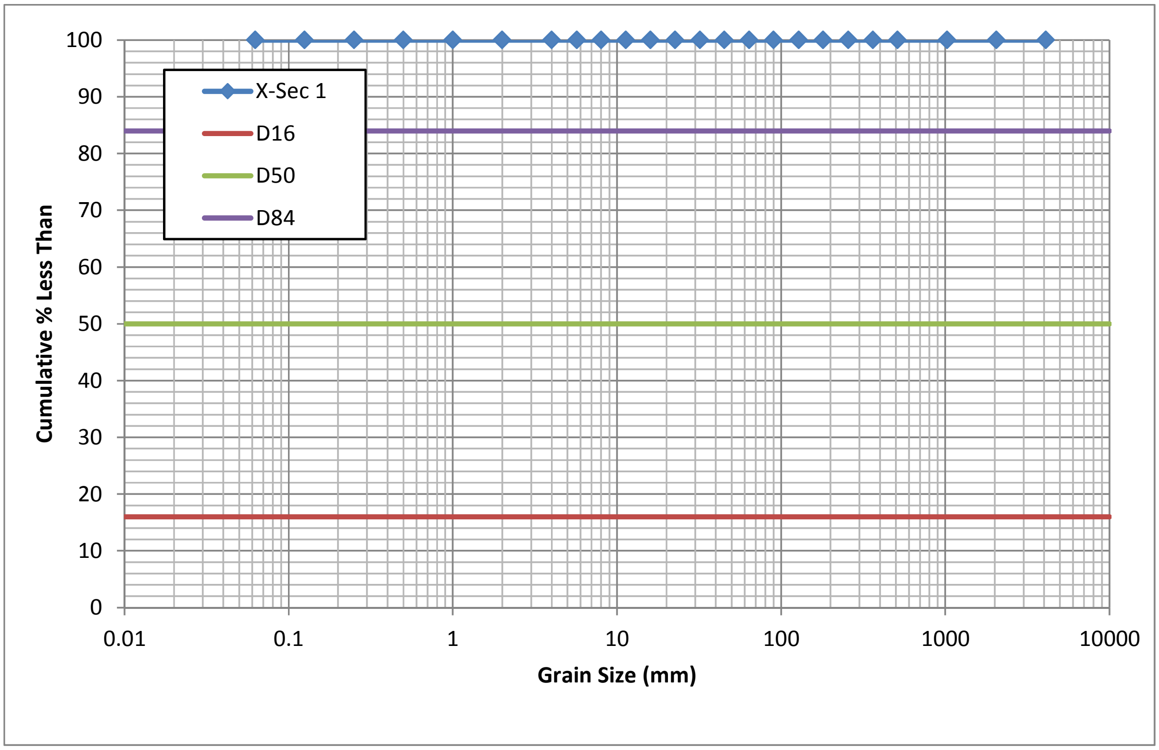


Figure C-1. Sediment size distribution at Cross-section 1 (X-Sec 1). Dominant sediment is silt/clay. (Source: USDA Forest Service.)

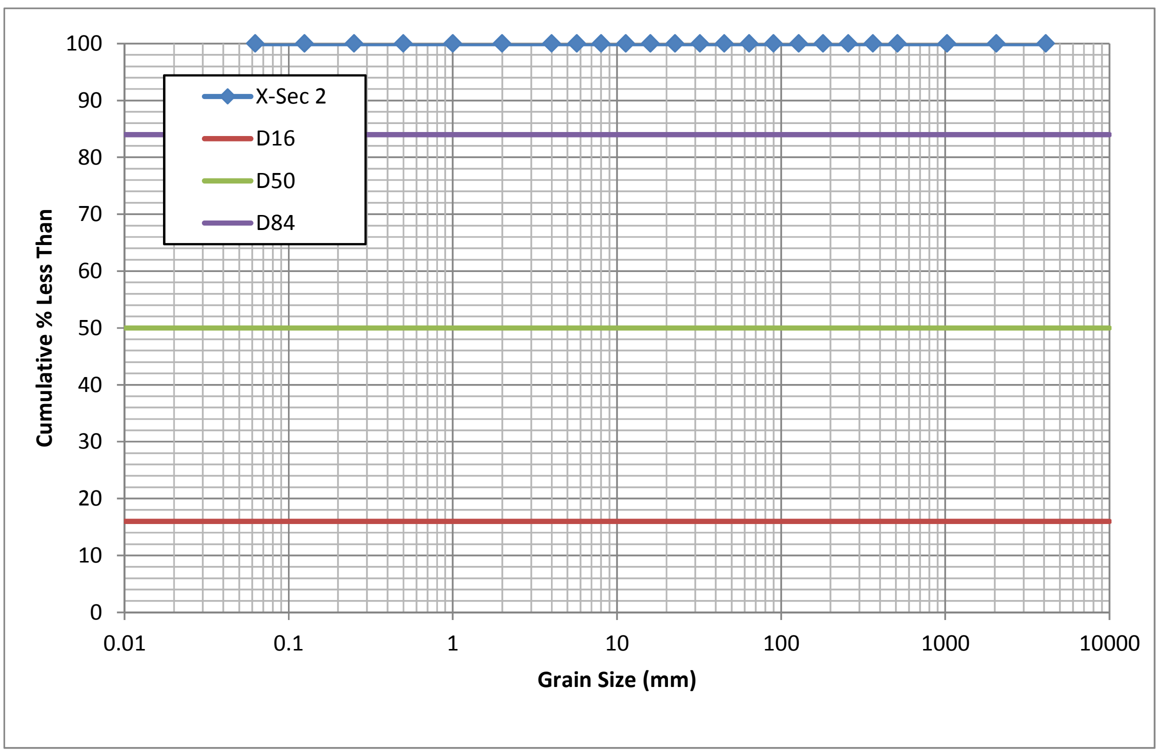


Figure C-2. Sediment size distribution at Cross-section 2 (X-Sec 2). Dominant sediment is silt/clay. (Source: USDA Forest Service.)

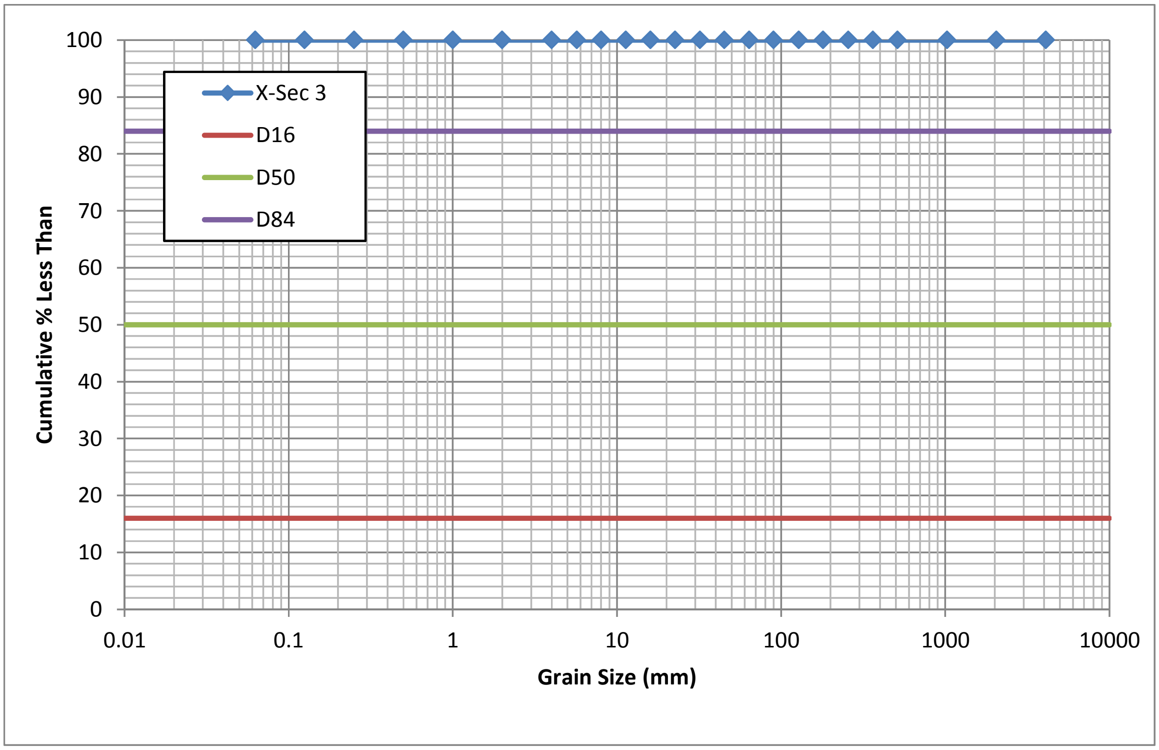


Figure C-3. Sediment size distribution at Cross-section 3 (X-Sec 3). Dominant sediment is silt/clay. (Source: USDA Forest Service.)

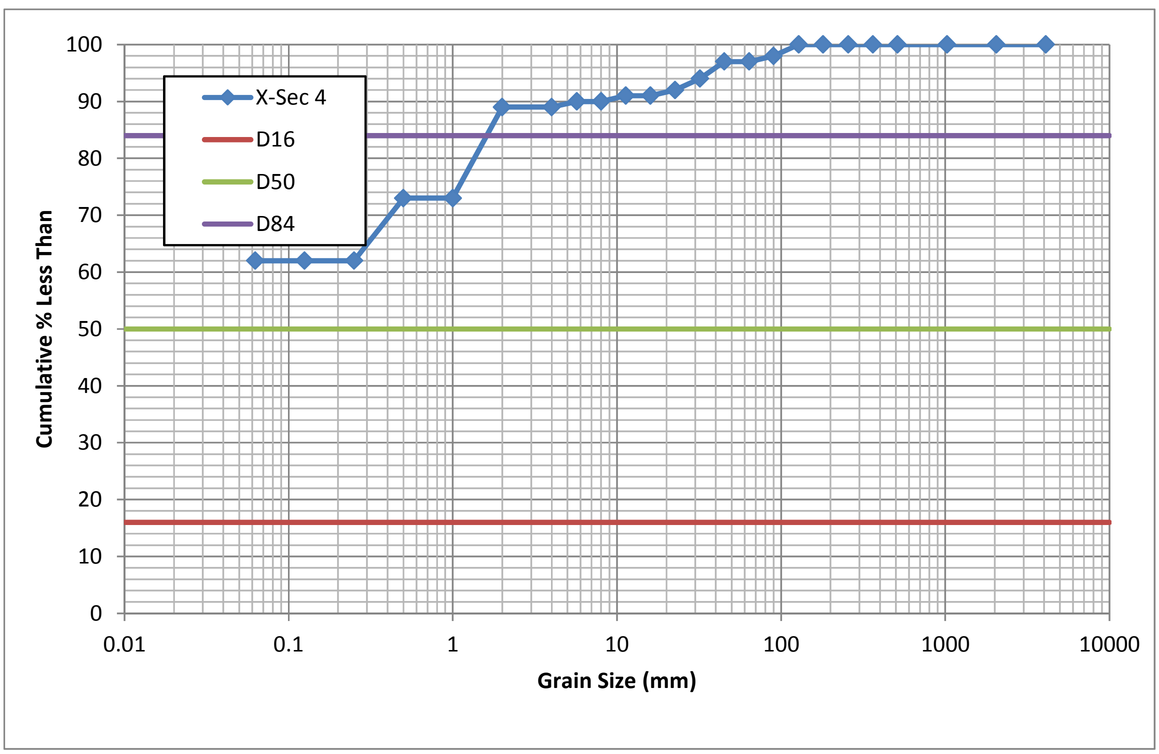


Figure C-4. Sediment size distribution at Cross-section 4 (X-Sec 4). Dominant sediment is sandy silt/clay. (Source: USDA Forest Service.)

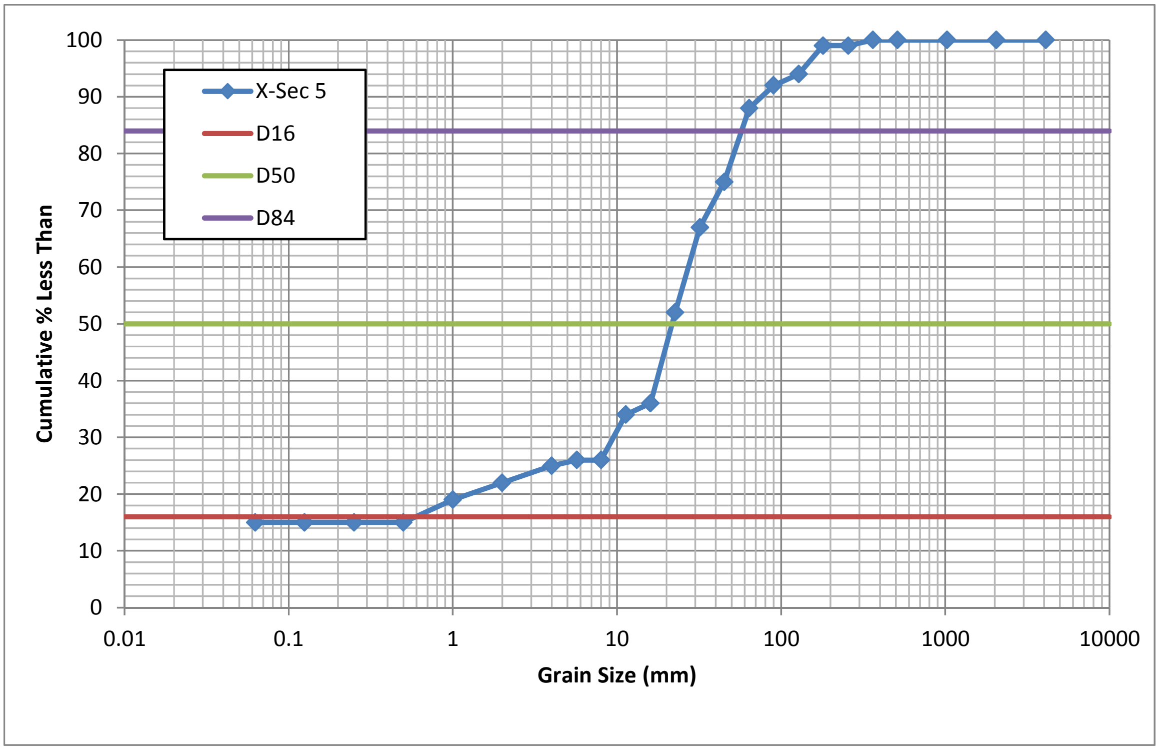


Figure C-5. Sediment size distribution at Cross-section 5 (X-Sec 5). Dominant sediment is silty sand-cobble-Gravel. (Source: USDA Forest Service.)

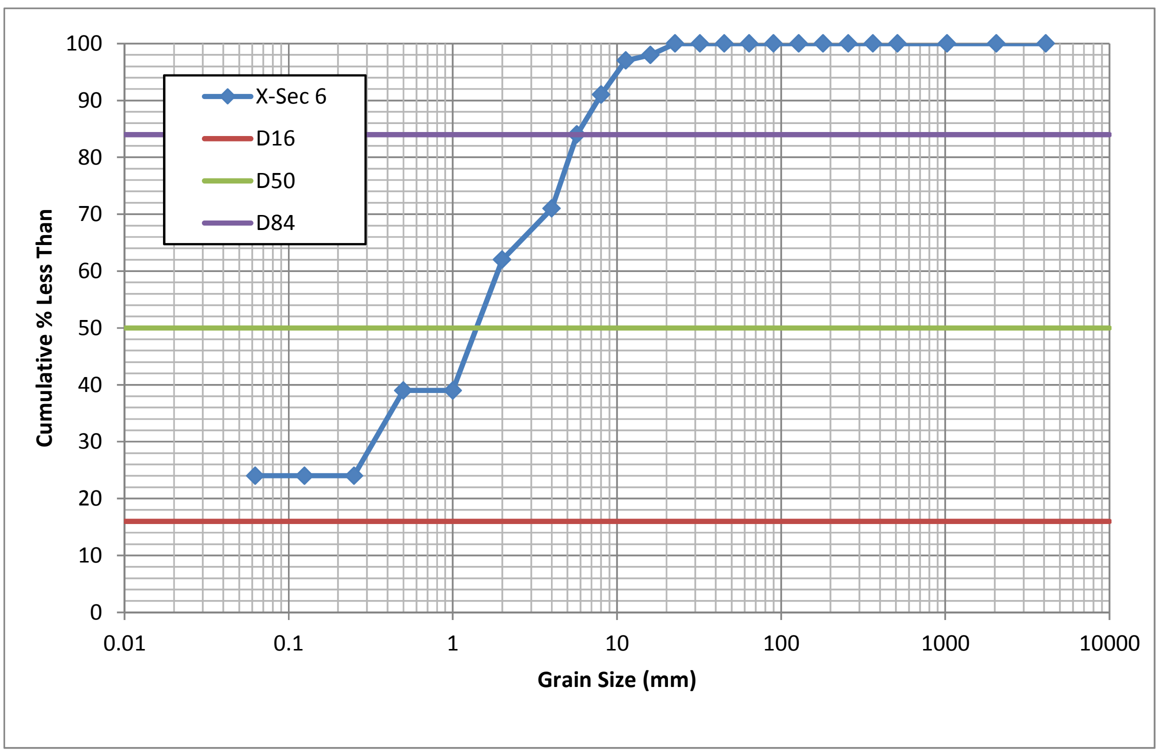


Figure C-6. Sediment size distribution at Cross-section 6 (X-Sec 6). Dominant sediment is silty gravel-Sand. (Source: USDA Forest Service.)

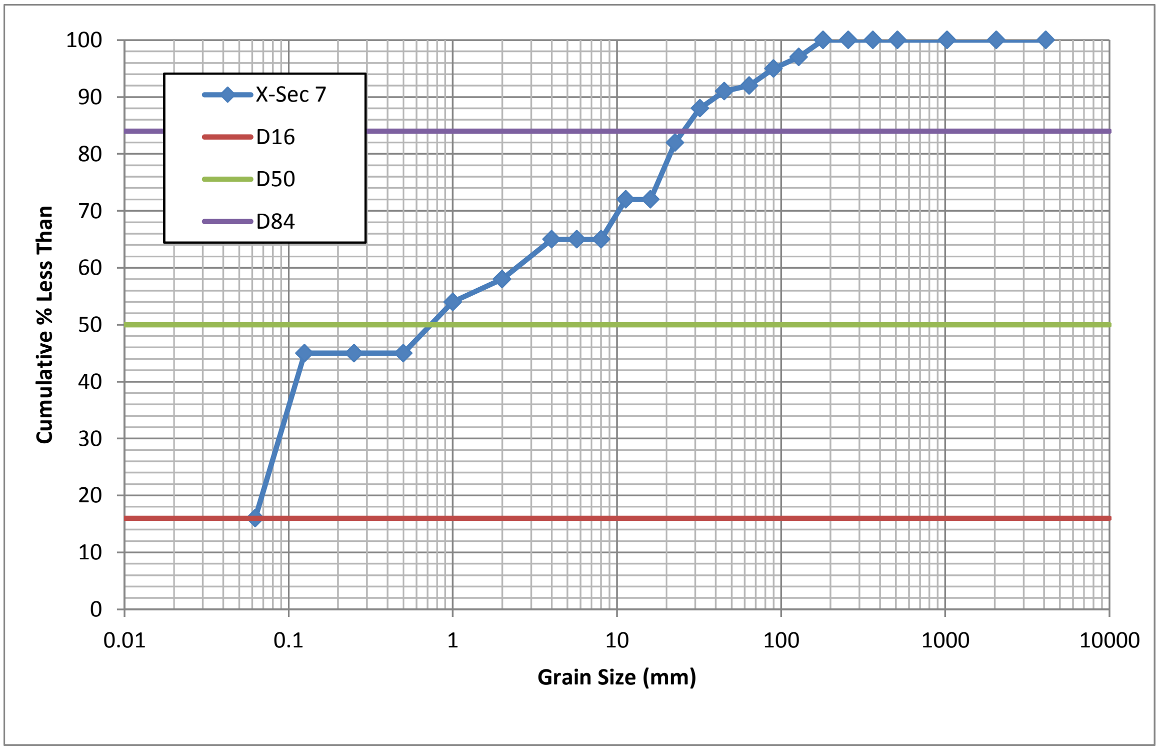


Figure C-7. Sediment size distribution at Cross-section 7 (X-Sec 7). Dominant sediment is silty gravel-Sand. (Source: USDA Forest Service.)

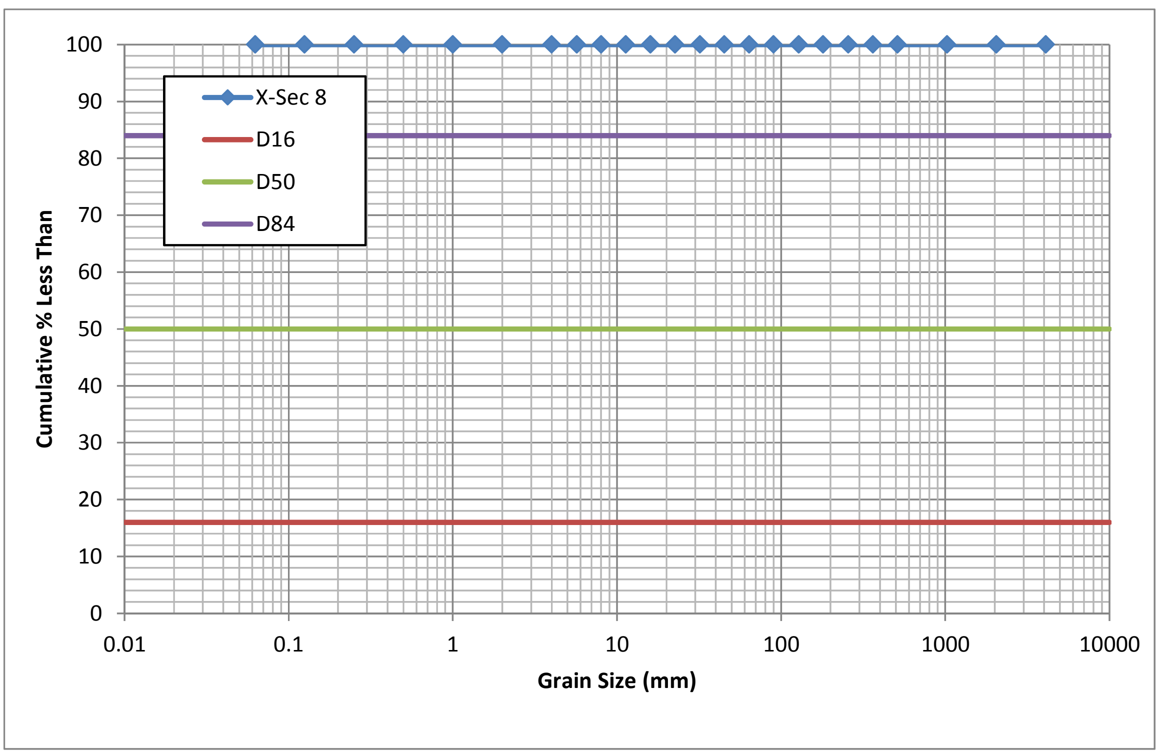


Figure C-8. Sediment size distribution at Cross-section 8 (X-Sec 8). Dominant sediment is silt/clay. (Source: USDA Forest Service.)

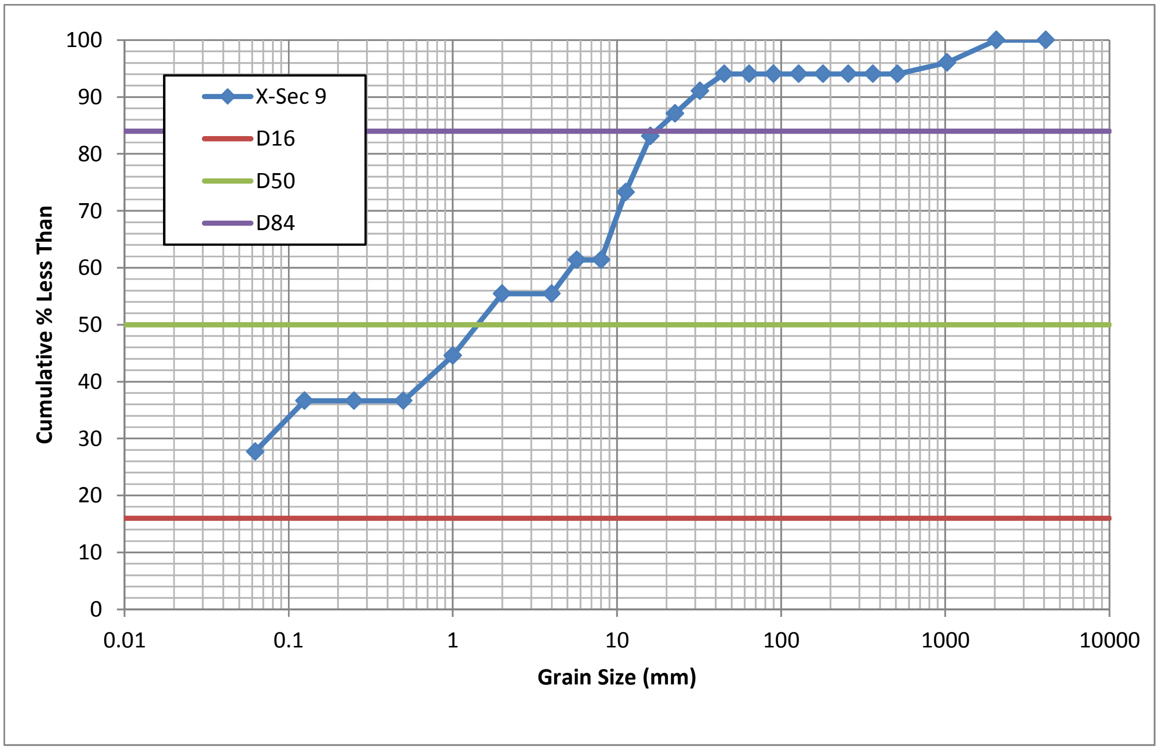


Figure C-9. Sediment size distribution at Cross-section 9 (X-Sec 9). Dominant sediment is silty gravel-Sand with boulder. (Source: USDA Forest Service.)

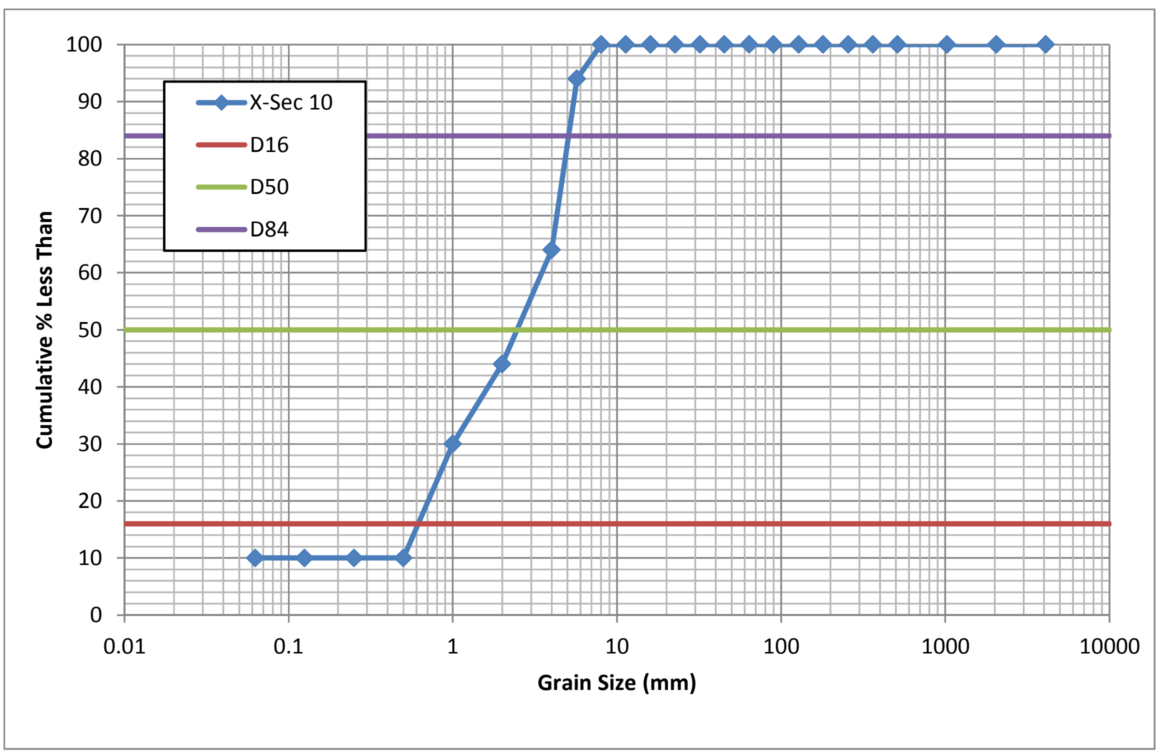


Figure C-10. Sediment size distribution at Cross-section 10 (X-Sec 10). Dominant sediment is silty sand-Gravel. (Source: USDA Forest Service.)

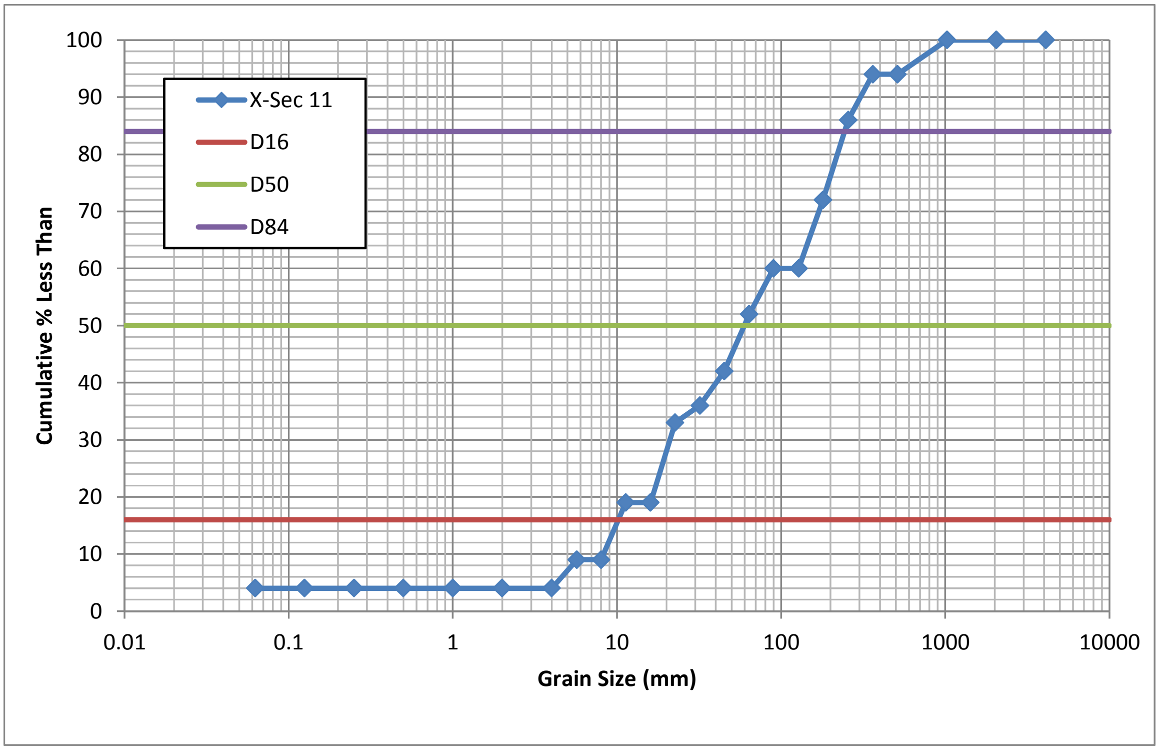


Figure C-11. Sediment size distribution at Cross-section 11 (X-Sec 11). Dominant sediment is boulder-cobble-Gravel. (Source: USDA Forest Service.)

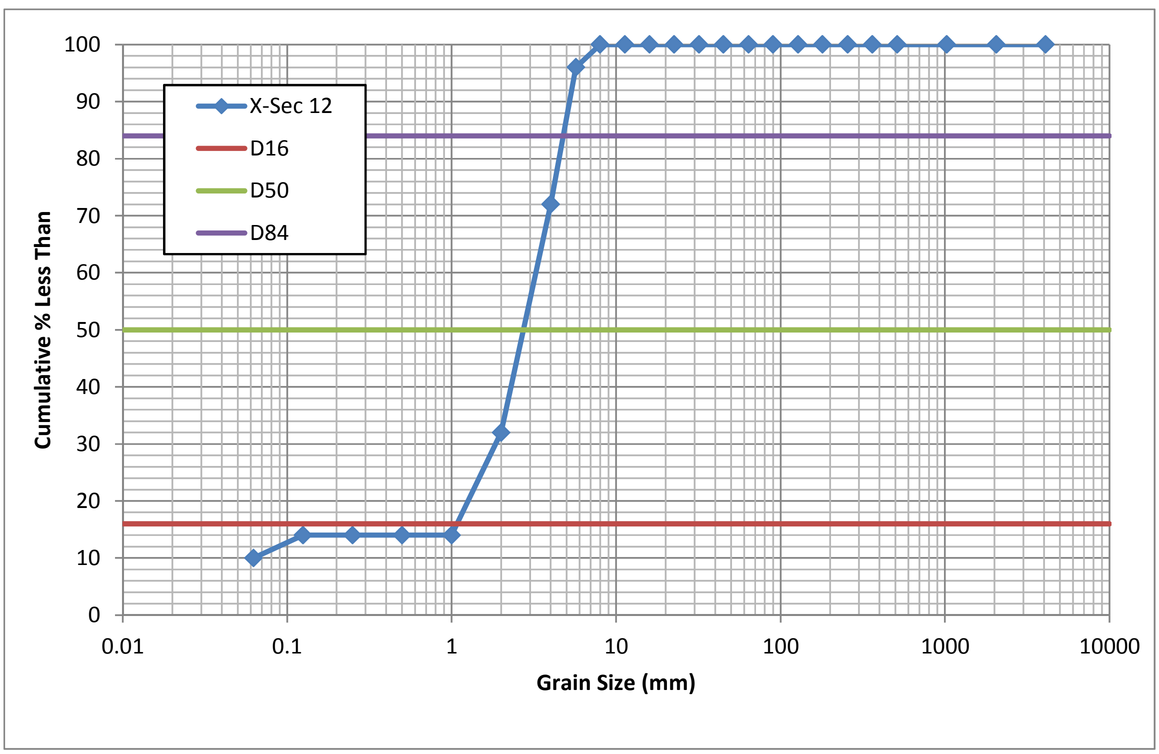


Figure C-12. Sediment size distribution at Cross-section 12 (X-Sec 12). Dominant sediment is silty sand-Gravel. (Source: USDA Forest Service.)

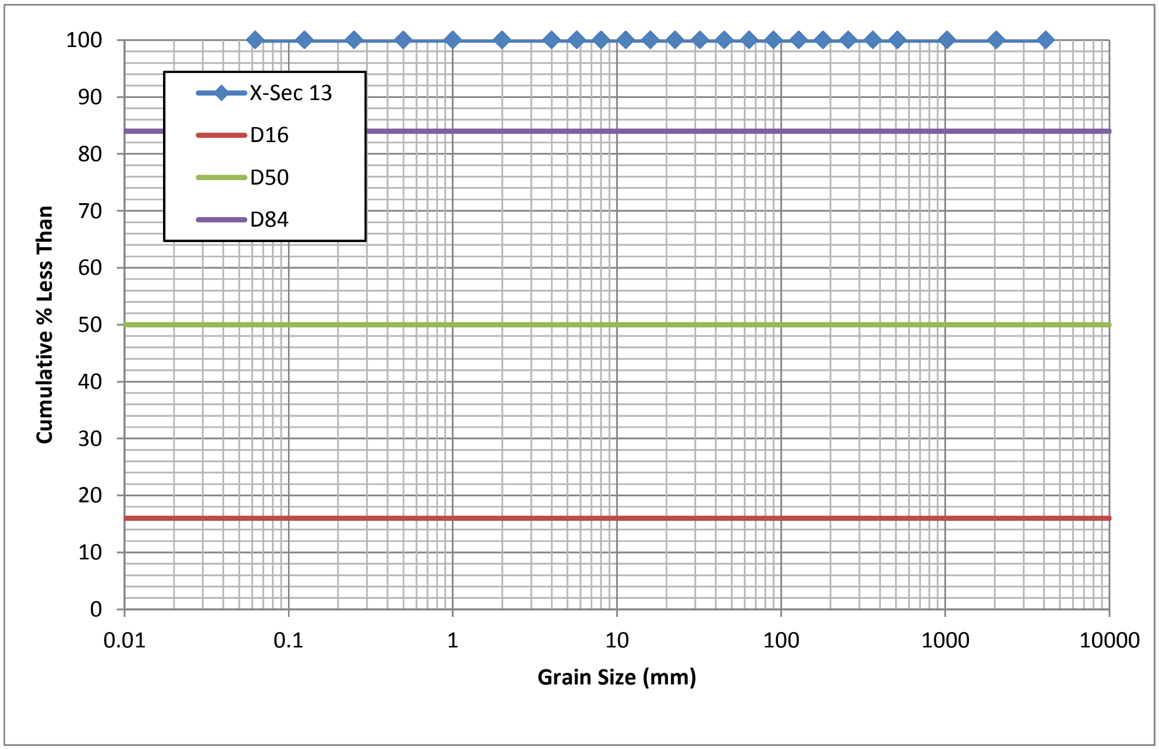


Figure C-13. Sediment size distribution at Cross-section 13 (X-Sec 13). Dominant sediment is silt/clay. (Source: USDA Forest Service.)

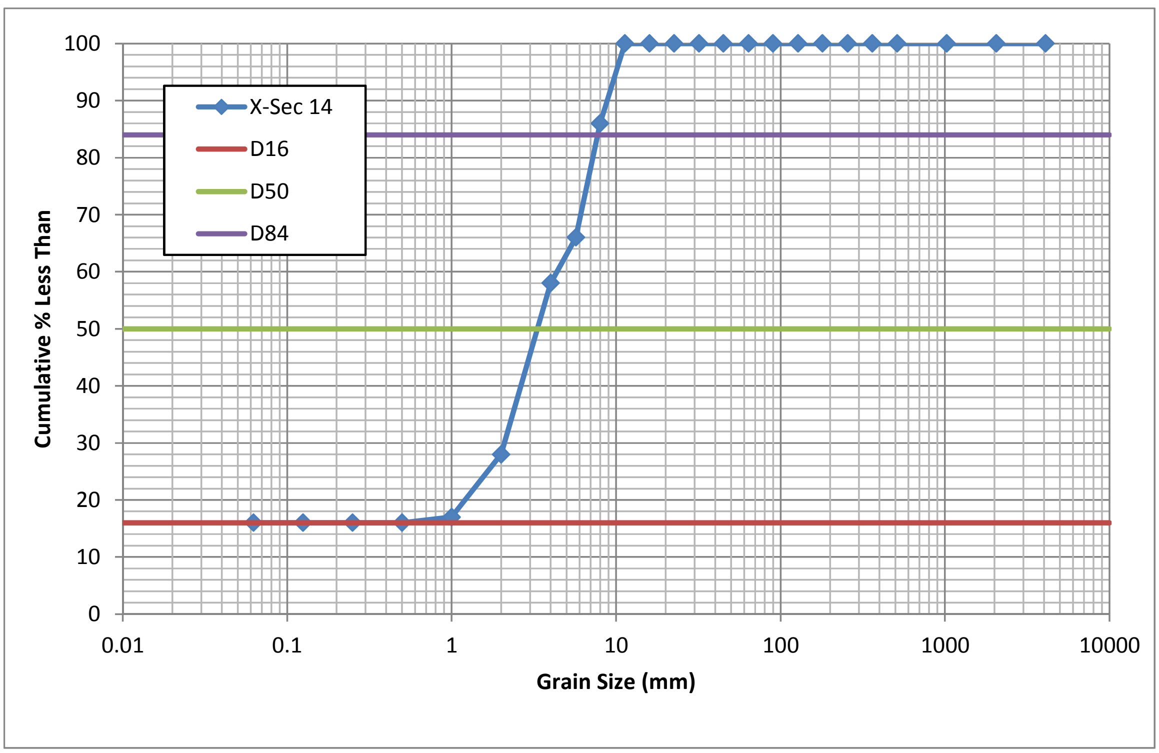


Figure C-14. Sediment size distribution at Cross-section 14 (X-Sec 14). Dominant sediment is silty sand-Gravel. (Source: USDA Forest Service.)

Appendix D

Aquatic Macroinvertebrate Data Reports

Table D-1. Location, richness and abundance data for aquatic macro-invertebrates samples in Big Meadows restoration area. (Source: Fresno Fly Fishers for Conservation).

SampleID	Station	Stream	Latitude	Longitude	Elevation	Watershed size above collection point Mi2	Collection Date	Habitat	Collection Method	Field Split	Lab Split	# of Subsampled Organisms	Richness	Abundance
146723	BGMDW-02	Big Meadow Creek - Pond 2	36.71168	-118.8372	2316	4.1	9/19/2008	Multiple	Sampler: Wildco Bottom Sled with Net	100	25	606	9	613
146722	BGMDW-01	Big Meadow Creek Ponds (1)	36.71541	-118.8351	2316	4.1	9/19/2008	Multiple	Sampler: Wildco Bottom Sled with Net	100	31.25	611	11	643
146724	BGMDW-03	Big Meadow Creek, Pond 3	36.71079	-118.8364	2316	4.1	9/19/2008	Multiple	Sampler: Wildco Bottom Sled with Net	100	75	621	16	624
146725	BGMDW-04	Big Meadow Creek, Pond 4	36.71174	-118.8449	2316	4.1	9/19/2008	Multiple	Sampler: Wildco Bottom Sled with Net	100	100	364	9	364
122473	BMEAD-01	Big Meadows Creek, Reach B1	36.7155	-118.8345	2316	4.1	7/15/2004	Targeted Riffle	Surber net	100	100	157	12	157
122474	BMEAD-02	Big Meadows Creek, Reach B2A	36.7118	-118.837	2316	4.1	7/18/2004	Targeted Riffle	Surber net	100	100	31	9	31
122475	BMEAD-03	Big Meadows Creek, Reach B2B	36.7153	-118.8353	2316	4.1	7/18/2004	Targeted Riffle	Surber net	100	100	129	19	129
122476	BMEAD-04	Big Meadows Creek, Reach D	36.7099	-118.8436	2316	4.1	7/11/2004	Targeted Riffle	Surber net	100	100	100	20	100
	BMEAD-05	Big Meadows Creek, Reach ESF	36.7109	-118.8466	2304	4.1	7/13/2004	Targeted Riffle	Surber net	100	100	182	17	182

Table D-2. Diversity indices for aquatic macro-invertebrates samples in Big Meadows restoration area. (Source: Fresno Fly Fishers for Conservation).

SampleID	Stream	Collection Date	Shannons Diversity	Simpsons Diversity	Evenness	# of Families	Abundance of Dominant Families	Abundance of Dominant Taxa	# of Genera	# of EPT taxa	EPT taxa abundance	# of Intolerant Taxa (HBI = 0, 1, or 2)	# of Tolerant Taxa (HBI = 8, 9, or 10)	Intolerant Taxa abundance (HBI = 0, 1, or 2)	Tolerant Taxa abundance (HBI = 8, 9, or 10)	Hilsenhoff Biotic Index
146723	Big Meadow Creek - Pond 2	9/19/2008	1.41	0.68	0.64	6	553	290	1	0	0	0	1	0	24	5.86
146722	Big Meadow Creek Ponds (1)	9/19/2008	1.35	0.67	0.56	8	572	296	2	0	0	0	1	0	27	5.94
146724	Big Meadow Creek, Pond 3	9/19/2008	1.34	0.55	0.48	9	442	407	7	0	0	0	2	0	67	5.84
146725	Big Meadow Creek, Pond 4	9/19/2008	1.36	0.7	0.62	7	312	144	3	0	0	0	1	0	43	6.24
122473	Big Meadows Creek, Reach B1	7/15/2004	2.09	0.85	0.84	9	38	38	6	3	48	2	2	10	27	3.45
122474	Big Meadows Creek, Reach B2A	7/18/2004	1.69	0.77	0.77	8	13	13	4	1	13	0	1	0	8	4.42
122475	Big Meadows Creek, Reach B2B	7/18/2004	2.57	0.91	0.87	14	46	18	8	2	21	1	4	18	28	4.82
122476	Big Meadows Creek, Reach D	7/11/2004	2.33	0.86	0.78	15	63	26	4	2	2	1	2	1	6	4.74
	Big Meadows Creek, Reach ESF	7/13/2004	2.07	0.82	0.73	13	104	55	5	4	46	3	1	45	3	4.35

Table D-3. Functional feeding groups for aquatic macro-invertebrates samples in Big Meadows restoration area. (Source: Fresno Fly Fishers for Conservation).

SampleID	Stream	Collection Date	# of clingers	Long-lived Taxa	Elmidae abundance	USFS Community Tolerance Quotient (d)	# of shredder taxa	Shredder Abundance	# of scraper taxa	Scraper abundance	# of collector-filterer taxa	Collector-filterer abundance	# of collector-gatherer taxa	Collector-gatherer abundance	# of predator taxa	Predator abundance	# of Ephemeroptera taxa	Ephemeroptera abundance	# of Plecoptera taxa	Plecoptera abundance	# of Trichoptera taxa	Trichoptera abundance
146723	Big Meadow Creek - Pond 2	9/19/2008	0	1	0	107	0	0	0	0	1	17	3	434	4	152	0	0	0	0	0	0
146722	Big Meadow Creek Ponds (1)	9/19/2008	0	2	0	107	0	0	0	0	1	2	2	436	7	182	0	0	0	0	0	0
146724	Big Meadow Creek, Pond 3	9/19/2008	0	2	0	104	0	0	0	0	2	25	2	411	9	167	0	0	0	0	0	0
146725	Big Meadow Creek, Pond 4	9/19/2008	1	2	0	108	0	0	0	0	1	1	2	168	5	193	0	0	0	0	0	0
122473	Big Meadows Creek, Reach B1	7/15/2004	1	2	0	92	2	39	0	0	1	36	4	44	4	37	1	9	0	0	2	39
122474	Big Meadows Creek, Reach B2A	7/18/2004	0	2	0	76	1	13	0	0	0	0	2	2	6	16	0	0	0	0	1	13
122475	Big Meadows Creek, Reach B2B	7/18/2004	2	6	0	87	2	4	0	0	2	21	5	47	9	56	1	18	0	0	1	3
122476	Big Meadows Creek, Reach D	7/11/2004	1	5	0	99	2	3	0	0	1	2	6	40	9	44	2	2	0	0	0	0
	Big Meadows Creek, Reach ESF	7/13/2004	1	3	0	89	3	7	0	0	2	8	5	98	6	65	1	39	1	1	2	6

Table D-4. Genera data for aquatic macro-invertebrates samples in Big Meadows restoration area. (Source: Fresno Fly Fishers for Conservation).

SampleID	Stream	Collection Date	# of Coleoptera taxa	Coleoptera abundance	# of Megaloptera taxa	Megaloptera abundance	# of Diptera taxa	Diptera abundance	# of Chironomidae taxa	Chironomidae abundance	# of Crustacea taxa	Crustacea abundance	# of Oligochaete taxa	Oligochaete abundance	# of Mollusca taxa	Mollusca abundance	# of other taxa	Other abundance	# of Insect taxa	Insect abundance	# of non-insect taxa	Non-insect abundance
146723	Big Meadow Creek - Pond 2	9/19/2008	0	0	0	0	5	561	4	553	0	0	0	0	1	17	2	11	7	595	2	18
146722	Big Meadow Creek Ponds (1)	9/19/2008	0	0	0	0	5	582	3	572	0	0	0	0	1	2	3	31	9	634	2	9
146724	Big Meadow Creek, Pond 3	9/19/2008	0	0	1	2	6	503	3	442	0	0	0	0	2	25	5	27	13	596	3	28
146725	Big Meadow Creek, Pond 4	9/19/2008	1	2	0	0	4	314	3	312	0	0	0	0	1	1	2	4	8	363	1	1
122473	Big Meadows Creek, Reach B1	7/15/2004	0	0	1	4	3	25	3	25	0	0	1	16	1	36	1	1	10	105	2	52
122474	Big Meadows Creek, Reach B2A	7/18/2004	0	0	1	2	2	2	2	2	0	0	1	1	0	0	1	2	7	29	2	2
122475	Big Meadows Creek, Reach B2B	7/18/2004	2	2	1	4	5	50	4	46	0	0	1	1	1	17	1	1	16	109	3	20
122476	Big Meadows Creek, Reach D	7/11/2004	4	5	0	0	7	67	4	63	0	0	1	1	1	2	2	11	17	96	3	4
	Big Meadows Creek, Reach ESF	7/13/2004	1	1	0	0	5	111	4	104	0	0	1	10	1	1	3	7	14	169	3	13

Table D-5. Physical site conditions and water quality data for 2008 aquatic macro-invertebrates sampling locations in Big Meadows restoration area. (Source: Fresno Fly Fishers for Conservation).

SampleID	Stream	Collection Date	Sanlinity (ppt)	pH	Conductivity (micro Siemens)	Water Temp in °C	Stream Gradient	Dominant Substrate	Over- stream Shade (%)	Dissolved Oxygen (mg/L)
146723	Big Meadow Creek - Pond 2	9/19/2008	0.03	7.03/6.82	79.1/78.6	14.2/14.0	N/A	Sand	0 to 15	7.72/7.38
146722	Big Meadow Creek Ponds (1)	9/19/2008	0.02	6.84/6.81	57.5/57.9	11.0	N/A	Sand	0 to 80	6.35/6.33
146724	Big Meadow Creek, Pond 3	9/19/2008	0	7.42/7.65	27/26.9	15.6/15.1	N/A	Sand	0.0	8.13/8.22
146725	Big Meadow Creek, Pond 4	9/19/2008	0	6.68/6.72	23/22.8	18.85/17.7	N/A	Sand	0 to 50	7.45/7.46
122473	Big Meadows Creek, Reach B1	7/15/2004								
122474	Big Meadows Creek, Reach B2A	7/18/2004								
122475	Big Meadows Creek, Reach B2B	7/18/2004								
122476	Big Meadows Creek, Reach D	7/11/2004								
	Big Meadows Creek, Reach ESF	7/13/2004								

Appendix E

Photopoint Monitoring

Locations of upper, mid and lower photopoints for time-series of photographs displayed in the following pages.

November 17 2007
One month post project

Upper Meadow

Mid Meadow

Lower Meadow

July 6, 2008
One year post project

Lower photopoint

Middle photopoint

Upper photopoint

July 25, 2009
Second season post project

Lower photopoint

Middle photopoint
Notice the stream channel beginning to establish in comparison to the year before.

Upper photopoint

June 23, 2011
Fourth growing season post project

Willows growing along lower pond, June 23, 2011

Upstream of middle piezometer on June 23, 2011

Upstream of middle piezometer on June 23, 2011

Solar panel attached to thermo-temp datalogger deployed in one of the created ponds at Big Meadows (July 2010; photograph by J. Ferrante).

Lilies growing in one of the created ponds at Big Meadows (July 2010; photograph by J. Ferrante).

Appendix F

Hydrology Report

DRAFT Hydrologic Monitoring Report – Water Year 2008

Big Meadows Creek Restoration Project

Sequoia National Forest, Tulare County, California

Prepared For:

Fly Fishers for Conservation

With Support from:

National Fish & Wildlife Foundation

Sierra Nevada Conservancy

Prepared By:

Stephen Lee, Hydrogeologist

March, 2009

DRAFT

1. Introduction

Big Meadows is a high elevation (2317 m, approximately 7600 ft. MSL) meadow in the Sequoia National Forest located in Tulare County, CA. Big Meadows Creek flows in a northwesterly direction across the meadow towards its confluence with the Kings River in Kings Canyon National Park. The stream drains a 28 km^2 granitic floored watershed in the southern Sierra Nevada Mountain Range. The Meadow has been restored utilizing the "plug and pond" method whereby highly incised (down cutting) stream channel segments were filled with soil and rock (plugs) from alluvium excavated within the floodplain of the meadow. The excavated areas form ponds on the floodplain which are connected by a low gradient, remnant stream channel on the meadow surface. The general objective of the restoration project is to restore Big Meadows ecosystem functions and associated riparian and aquatic habitat while maintaining existing land uses such as recreation and grazing.

2. Background

Olin (2005) designed a plan to restore Big Meadows Creek to include the aquatic/terrestrial habitat and fishery while maintaining existing land uses such as grazing and recreation. He concluded that Big Meadows Creek was incising (down cutting) in the study area before 1940 due to natural influences and land use practices (Olin, 2005). The USDA Forest Service (USDA Forest Service) installed check dams in the 1980s which arrested incision, but 40% of the stream remained degraded (Olin, 2005). The Big Meadows Creek improvement project was implemented in the summer of 2007 by the USDA Forest Service (USDA Forest Service) in partnership with the Fly Fishers for Conservation, and the Plumas Corporation, Feather River Coordinated Resource Management (FR-CRM). Grant funding obtained from the National Fish & Wildlife Foundation (NFWF), and the Sierra Nevada Conservancy was used to implement the project. The goal of the project is to restore 6100 feet of degraded stream channel within the meadow to enhance aquatic species habitat while maintaining existing land uses including recreation and grazing (USDA Forest Service, 2006). The project utilized the "plug and pond" method of restoration which eliminates the existing down cut channel and redirects stream flow back into stable, historical remnant channels on the meadow surface (Figures 1 and 2). The project is expected to provide the following ecosystem benefits: 1) establish a single-thread, low flow channel, 2) reduce flow peaks and increase/extend summer base flows, 3) increase in-stream cover and shading, 4) enhance aquatic and terrestrial habitat, 5) improve water quality, and 6) raise local groundwater level within the meadow (USDA Forest Service, 2006).

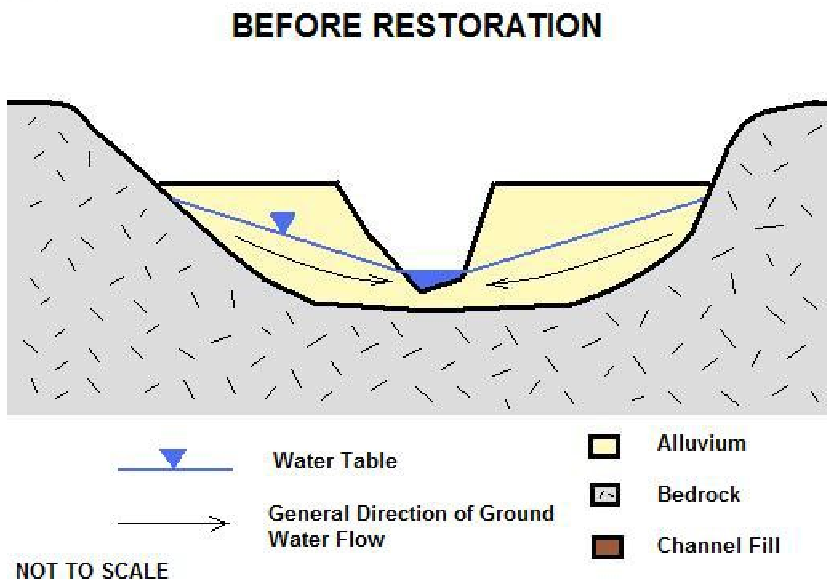


Figure 1. Conceptual Model of groundwater conditions in Big Meadows before restoration. The deeply incised stream channel acts as a drain for groundwater lowering the water-table surface in the meadow creating dry conditions.

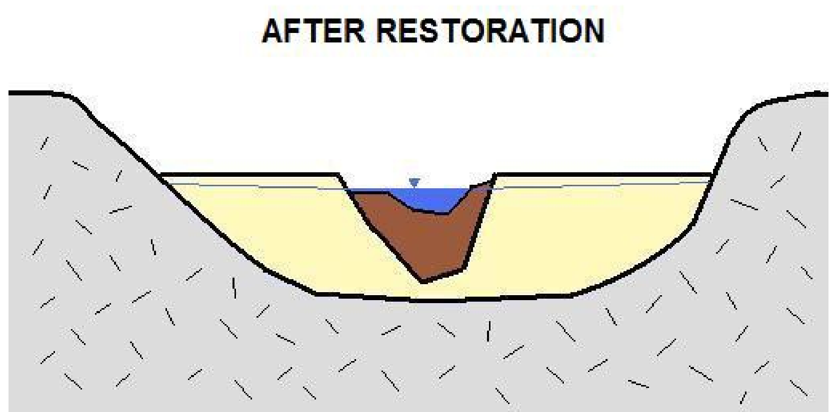


Figure 2. Conceptual Model of groundwater conditions in Big Meadows after restoration. The incised channel segments are filled with alluvium excavated from a series of ponds in the meadow. The elevation of the streambed and the groundwater table are raised creating wet conditions in the meadow over longer time periods throughout the water year.

3. Purpose

Monitoring is an important aspect of any restoration project. Comparison of pre- and post-project monitoring data can provide valuable indications of whether restoration goals have been achieved or not. The purpose of this report is to document the hydrologic monitoring that has been implemented during Water Year 2008 (October 1, 2007 – September 30, 2008), which is the first year following the completion of the restoration
project in the fall of 2007. Post-project groundwater levels are compared with pre-project groundwater levels to estimate the effect of the restoration project on groundwater levels at the Big Meadows Restoration Project.

4. Methods

The monitoring system to measure the hydrologic conditions in the meadow consists of a stream gage at the downstream end of the project, and three piezometers designed to measure the shallow groundwater table response. A snow sensor that is part of the CA Cooperative Snow Survey is located at the upper end of the meadow. The monitoring system features are summarized in Table 1 and shown on a Google Earth image of the project area in Figure 3.

Table 1. Big Meadows Project Features.

Feature	Lat (deg N)	Long (deg W)	Comments
Stream Gage	36 42.932	118 49.990	Pressure Transducer, Campbell Scientific CR 510 Data logger, and staff gage
Grade Control Structure	36 42.937	118 50.056	Compacted Rock Fill
“Lower” Piezometer	36 42.868	118 50.132	¾ inch galvanized riser with drive point screen
“Middle” Piezometer	36 42.646	118 50.219	Same as “Lower”
“Upper” Piezometer	36 42.626	118 50.622	Same as “Lower”
Big Meadows Snow Sensor	36 42.923	118 50.629	CA Cooperative Snow Survey Site

Groundwater levels in three piezometers installed by Olin were measured once during November, 2007 and in February, May, July, August, and September, 2008 in each piezometer. The “lower” piezometer was also measured once in April, 2008. Access to the site is limited during the winter and spring months and is gained by cross
county skiing. Piezometer readings were used to assess groundwater conditions in the meadow over the course of the 2008 water year (October, 2007-September, 2008). Piezometers were read using an electric sounding device as established in

the monitoring protocol for the project. Groundwater data were recorded in a field notebook and entered into an EXCEL spreadsheet for analysis. Groundwater data and meta-data for the piezometers are summarized in Appendix A. Groundwater data from the 2008 water year are compared to pre-project data collected by Olin (2005) to assess the impact of the project on groundwater levels in the meadow (Appendix A). An estimate of change in groundwater storage due to the restoration project was made using the fall piezometer data and by projecting the areal extent of groundwater rise over the meadow surface using the image in shown in Figure 3 and the overlay shown in Appendix B.

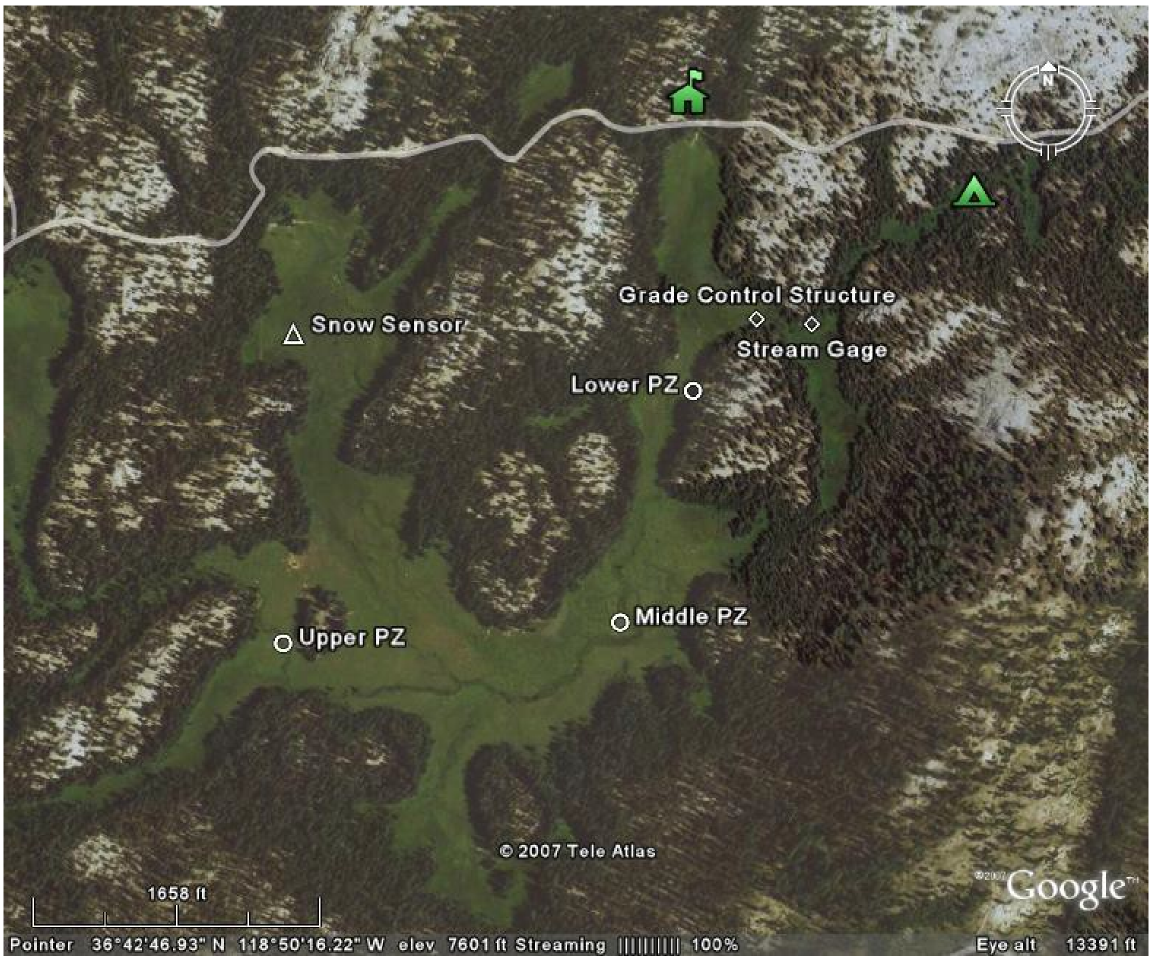


Figure 3. Google Earth image of Big Meadows showing project monitoring features. Note: PZ= Piezometer.

The stage of Big Meadows Creek was recorded by observing the outside staff gage reading during the field trips and a qualitative estimate of stream flow was made. No discharge measurements were made during the 2008 field work. Photos of the stream channel and ponds were taken during each field trip and general observations were recorded in the field notebook.

5.0 Results.

5.1 Snowmelt. The average annual precipitation in Big Meadows is approximately 32.3 inches; which comes primarily in the form of snow with infrequent spring and summer rain (Olin, 2005). The Snow water content recorded at the Big Meadows weather station operated by the California Department of Water Resources (DWR) for the 2008 water year peaked near the end of February at 37.3 inches and the snow was completely melted by the first week of May as shown in Figure 4.

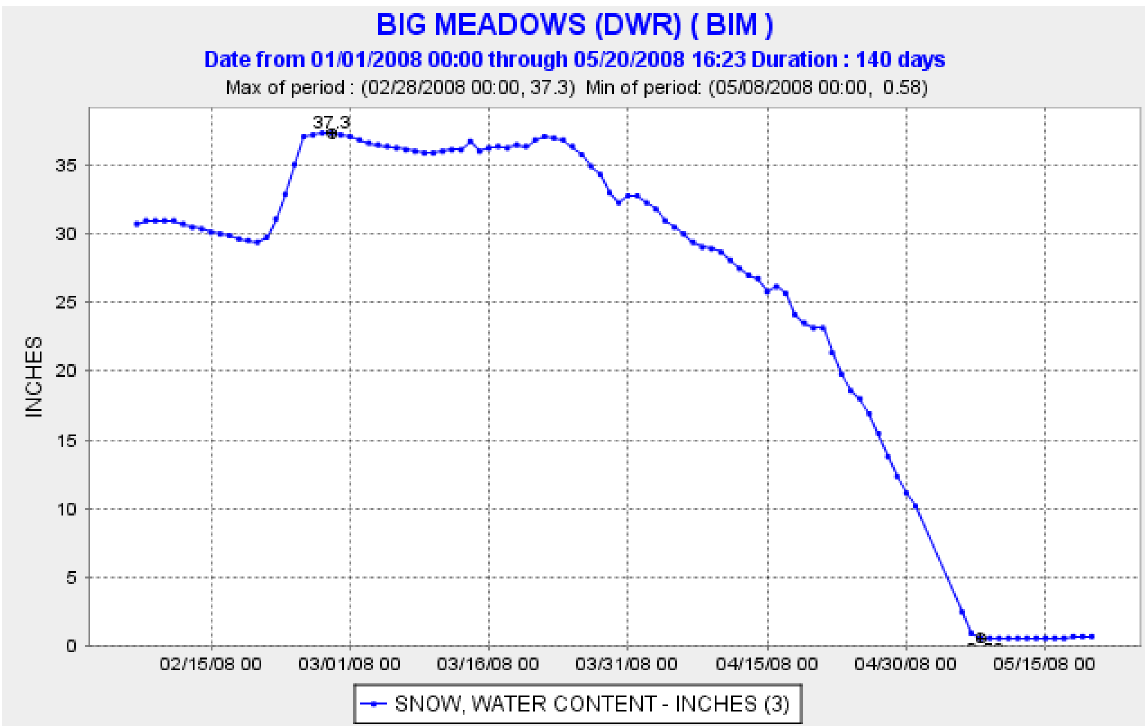


Figure 4. Snow Water Content observed at the Big Meadows Snow Survey Station during 2008 (California Department of Water Resources, 2008).

5.2 Groundwater.

Groundwater levels peaked in the upper meadow in May, 2008 at approximately 1.2 feet above ground surface and declined to a level approximately 2.6 feet below ground surface by September as shown in Figure 5. Groundwater levels peaked in the middle meadow at approximately 0.3 feet below ground surface in May, 2008 and declined to approximately 1.6 feet below ground surface by September (Figure 6). Groundwater levels peaked in the lower meadow at approximately 1.2 feet above ground surface in May, 2008 and declined to approximately 0.2 feet above ground surface by September (Figure 7).

The upper and lower piezometers are located in close proximity to ponds that were constructed as part of the restoration project and therefore reflect the effect of the ponded surface water available to recharge shallow groundwater in the meadow and sustain groundwater levels in the meadow over a longer portion of the water year.

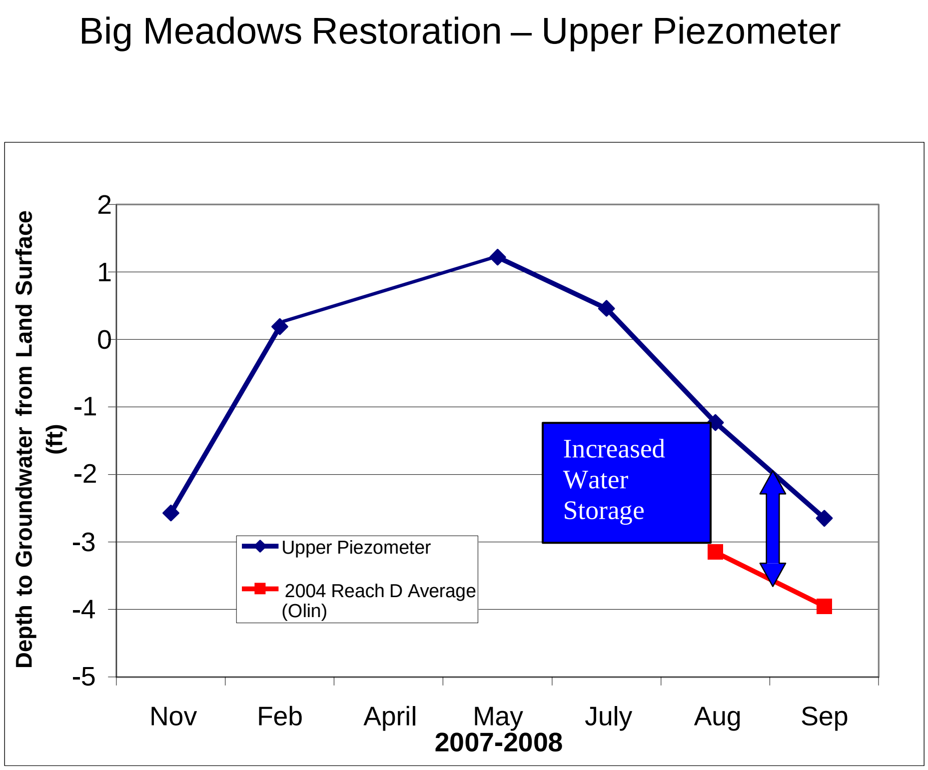


Figure 5. Groundwater levels observed at the Upper Piezometer (Reach D) during 2007-2008 compared with observations made by Olin in 2004. Note the increase in water storage in the Reach during the late summer due to the restoration project.

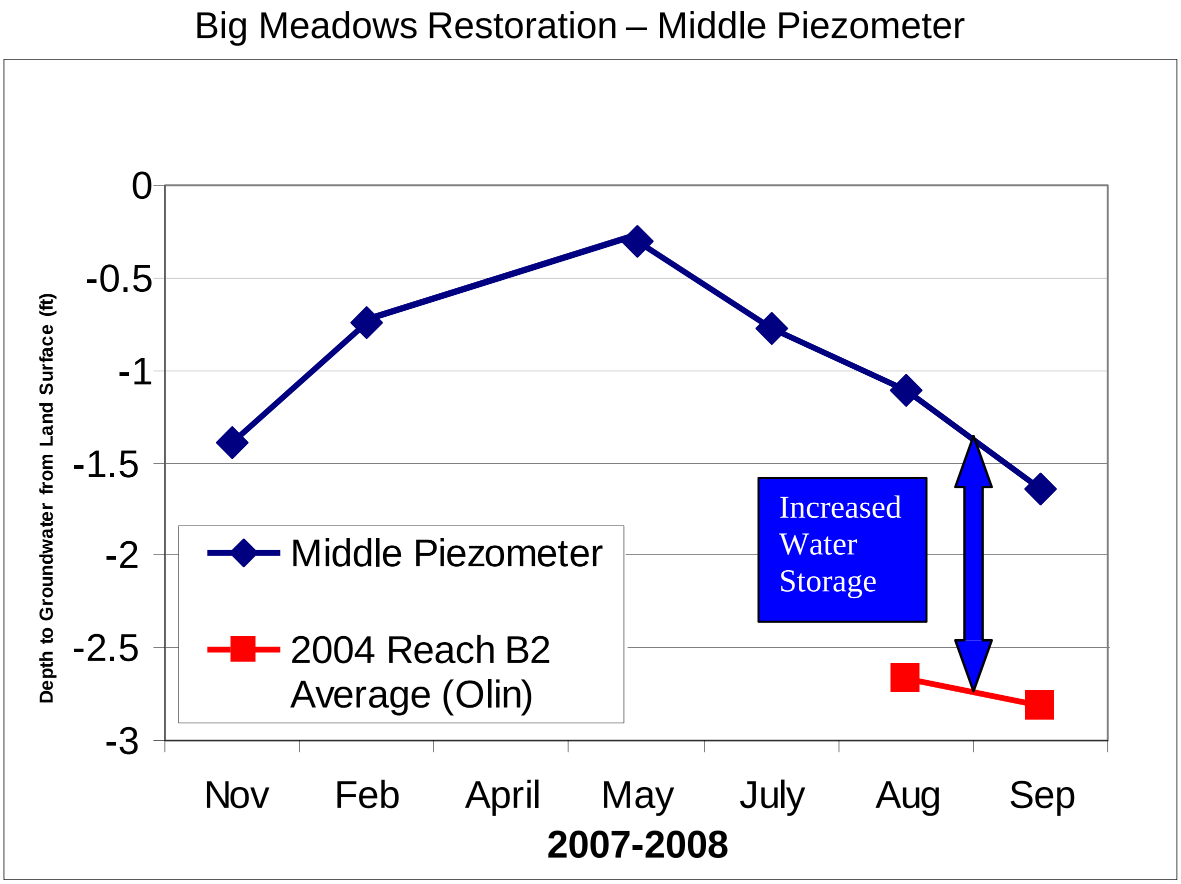
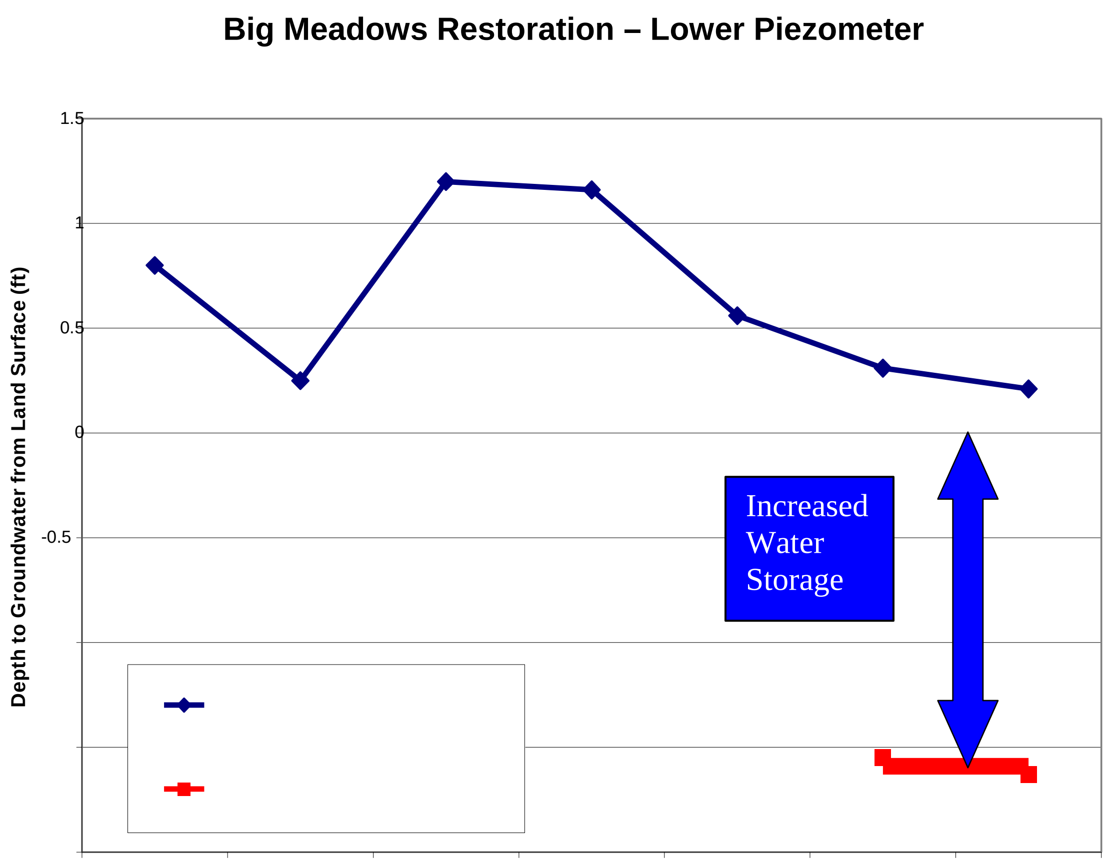


Figure 6. Groundwater levels observed at the Middle Piezometer (Reach B2) during 2007-2008 compared with observations made by Olin in 2004. Note the increase in water storage in the Reach during the late summer due to the restoration project.


Big Meadows Restoration – Lower Piezometer
1.5
1
0.5
0
-0.5
Depth to Groundwater from Land Surface (ft)
Increased
Water
Storage

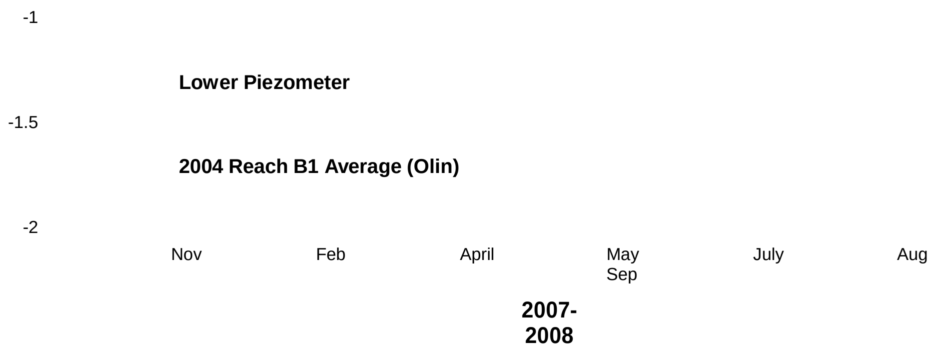


Figure 7. Groundwater levels observed at the Lower Piezometer (Reach B1) during 2007-2008 compared with observations made by Olin in 2004. Note the increase in water storage in the Reach during the late summer due to the restoration project.

5.3 Increased Groundwater Storage.

Higher late summer and fall groundwater levels in Big Meadows are an indicator of success of the restoration effort. The higher water-table in the meadow should reverse the conversion of the vegetative community from wet meadow perennial grasses to dry meadow annual grasses and forbs. The higher water-table and the ponds constructed for the project should store water in the meadow for longer periods of time over the water year and help attenuate peak flows and extend summer base flows in Big Meadows Creek. As shown in figures 5-7 the August-September water- table measured at the three piezometers were approximately 1.5 to 1.7 feet higher than pre-project levels observed by Olin in 2004. The higher water-table observed at the piezometers were projected over the entire meadow surface in order to estimate the increase in late summer-early fall groundwater storage resulting from the restoration project. As shown in Table 2 the increase in groundwater storage for the entire meadow was approximately 220 acre-feet. (An acre-foot is the volume of water 1 foot deep covering an area the size of an acre or; approximately 325,000 gallons of water). Estimated increases in groundwater storage for the upper, middle and lower sub areas of the Big Meadows are 103, 77 and 38 acre-feet, respectively (Table 2). The estimates in table 2 assume a porosity of 40% for the near surface soils in the meadow.

Table 2. Estimated increase in late summer – fall groundwater storage resulting from the restoration of Big Meadows.

Meadow Sub area	Acres	Increase in Aug-Sep Water-table (ft)	Assumed Porosity (%)	Increase in Groundwater Storage (Acre-ft)
Upper	172	1.5	0.40	103
Middle	129	1.5	0.40	77
Lower	56	1.7	0.40	38
TOTAL	357			218

5.4 Surface Water Observations.

The stage of Big Meadows Creek was observed at the outside staff gage located at the stream gage at the lower end of the meadow (Figure1). Staff gage readings and visual estimates of stream flow during 2008 are summarized in Table 3. No discharge measurements were made, but the maximum estimated discharge observed was approximately 5-10 cfs in May, 2008. Olin (2005) estimated that the bankfull discharge for Big Meadows Creek ranged from 7.7 to 18.3 cfs. Bankfull discharge is defined as the flow that creates and maintains channel morphology, and over time, transports more sediment than any other single flow event due to its high frequency (Rosgen,1996). Summer base flow during 2008 was estimated at less than 0.1 cfs

Table 3. Surface Water Observations on Big Meadows Creek at Big Meadows.

Date	Time	Outside Staff Gage Reading	Estimated Flow (cfs)
5/23/08	1306	4.95	5-10 cfs
7/5/08	1054	4.06	< 1cfs
8/16/08	1043	3.83	< 0.1 cfs
9/29/08	1303	3.83	<0.1 cfs

The ponds constructed as part of the restoration project held water throughout the summer with water depths ranging from approximately 1-3 feet. The low gradient remnant stream channel connecting the ponds was flowing at near capacity in May (Photo 5). There was no evidence of excessive erosion or degradation of the channel connecting the ponds. The Meadow was saturated to very wet as to be expected during the spring runoff as evidenced by high water-table observations surface and flow conditions observed (Photos 1, 4 and 5, Appendix C).

6.0 Conclusions

Hydrologic Monitoring conducted during Water Year 2008 at the Big Meadows Creek Restoration Project supports the following conclusions.

- Restoration of Big Meadows Creek in the project area by the “plug and pond” method have resulted in late summer/fall groundwater levels that are 1.5 – 1.7 feet higher than pre-project groundwater levels observed by Olin in 2004.

- Estimates of late summer/fall groundwater storage at the Big Meadows Creek Restoration Project site indicate that post-project groundwater storage in the meadow has increased by over 200 acre-feet.

- Increased groundwater storage and the higher post-project water-table in the meadow resulting from the restoration project should provide conditions that are favorable for the reestablishment of native wet meadow perennial grasses in the meadow.

- The restoration project has successfully reestablished a single thread low gradient stream channel on the meadow surface. No evidence of excessive erosion or degradation of the stream channel was observed during 2008.

7.0 References

California Department of Water Resources, 2008. Data obtained from the California Department of Water Resources website. (Sep, 2008). http://cdec.water.ca.gov/cgiprogs/staMeta?station_id=BIM

Olin, J.T., 2005. Stream Character, Aquatic Habitat and Restoration Plan for Big Meadows Creek. MS thesis, California State University Fresno, Fresno, CA. 178 p.

U.S. Department of Agriculture, Forest Service, 2006. Scoping Letter, Big Meadows Creek Improvement Project, Hume Lake Ranger District, Sequoia National Forest. 5p.

Rosgen, D.L., 1996. Applied River Morphology: Minneapolis, MN, Printed Media Companies, 343 p.

Appendix A – Piezometer Data

Piezometer	Nov	Feb	April	May	July	Aug	Sep	Oct
Upper Piezometer	-2.57	0.19	NR	1.22	0.46	-1.23	-2.65	-2.33
Middle Piezometer	-1.39	-0.74	NR	-0.3	-0.77	-1.11	-1.64	-1.23
Lower Piezometer	0.8	0.25	1.2	1.16	0.56	0.31	0.21	0.54
2004 Reach D Average (Olin)						-3.15	-3.95	
2004 Reach B2 Average (Olin)						-2.67	-2.81	
2004 Reach B1 Average (Olin)						-1.55	-1.63	

Piezometer readings from Big Meadows Restoration Project - Sequoia Nat. Forest, 2007-08
Piezometer readings are in feet of water from ground surface i.e. (+) above ground surface (-) below ground surface
Upper Piezometer Located in Reach D
Middle Piezometer Located in Reach B2
Lower Piezometer Located in Reach B1

Piezometer	Reach	Riser Stickup (ft)	Depth T.O.R.(ft)	Depth G.S.(ft)	Latitude (deg N)	Longitude (deg W)
Upper Piezometer	D	6.2	11.7	5.5	36 42.626	118 50.622
Middle Piezometer	B2	6.2	11	4.8	36 42.646	118 50.219
Lower Piezometer	B1	6.5	9	2.5	36 42.868	118 50.132

T.O.R.=Top of Riser G.S. = Ground Surface NR=not read (no access)

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56 acre × 1.7 ft = 95.2 acre-ft

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Estimated Acreage = 129 acres

Increase Aug-Sep PZ reading = + 1.5 ft

Increase late summer water storage

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APPENDIX C – PHOTOS

Photo 1. Lower Piezometer (Reach B1) looking toward the right bank with surface water flowing at a depth of approximately 1 foot at the base of the riser pipe (Date: May 23,
2008).

Photo 2. Middle Piezometer (Reach B2) looking upstream (Date: July 5, 2008)

Photo 3. Upper Piezometer (Reach D) looking upstream (Date: July 5, 2008)

Photo 4. Upper Meadow (Reach B3) looking upstream showing saturated conditions during the spring runoff (Date: May 23, 2008).

Photo 5. Middle Meadow (Reach B2) looking upstream at meandering stream channel and pond in background (Date: May 23, 2008).

Photo 6. Edge of Pond in mid-meadow (Reach B2) showing growth of willow poles planted on the "plug" constructed downstream of the pond. Date of Photo- July 5, 2008.

Photo 7. Staff gage used to measure stage of Big Meadows Creek (Date: Nov 7, 2007).

Photo 8. Middle piezometer (Reach B2) showing electric sounding device used to measure groundwater levels. Photo looking toward right bank with pond in background (Date: July 5, 2008).

Appendix G

Range Condition Report

Dave A Weixelman/R5/USDAFS
07/07/2009 08:37 AM

To Paul Roche/R5/USDAFS@FSNOTES
cc John Exline/R5/USDAFS@FSNOTES, Mark Stieler/R5/USDAFS@FSNOTES, Dave A Weixelman/R5/USDAFS@FSNOTES
bee
Subject Re: Big Meadows plot on Hume Lake R.D.

History: **This message has been forwarded.**

Paul - here is the data summary for this plot. The condition ratings are excellent from a range condition standpoint.

Big Meadow, Hume Lake District

Established: Oct. 9, 2008
Elevation: 7571 ft.
Slope: 1%
Aspect: 40 degrees
Depth to soil saturation: 75 em Soil
texture: sandy clay loam Meadow
classification: wet meadow
Root depth: 29 em, represents excellent plant vigor and soil stability
Bare soil: 1%, represents excellent ground cover
Veg high: 76%, represents high proportion of desirable plant species for meadow function
Veg mod: 16%,
Veg low: 8%
Vegetative condition: high ecological status, i.e. excellent condition
Vegetative and soil condition: high ecological status, i.e. excellent condition

Dave Weixelman, Range Ecology
U.S. Forest Service
631 Coyote Street
Nevada City, CA 95959
(530)478-6843
e-mail: dweixelman@fs.fed.us
FAX (530)- 478-6844
Paul Roche/R5/USDAFS

Paul Roche/R5/USDAFS
07/06/2009 03:21 PM

To Dave A Weixelman/R5/USDAFS@FSNOTES
cc John Exline/R5/USDAFS@FSNOTES
Subject

Dave,

Would you please send us all the available information that you have on the permanent plot I helped you establish at Big Meadows on the Hume Lake Ranger District last summer.