Enhancement of Rearing Habitat for Natal and Non-Natal Salmonids in McGarvey Creek - Lower Klamath River

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Introduction

The Yurok People have relied upon the Klamath River and coastal resources for their subsistence, cultural, and economic livelihood since time immemorial. Central to Yurok culture is harvest of anadromous fish. Runs of anadromous fish currently returning to spawn in Lower Klamath tributaries are depressed when compared with historical numbers. Extensive timber removal and road building activities have resulted in chronic sedimentation of streams and floodplains; a significant loss of channel-stored wood and riparian conifers; and a concomitant loss of habitat diversity and production potential in the sub-basin (Payne & Associates 1989; Gale and Randolph 2000; Beesley and Fiori 2007 & 2008; Voight and Gale 1998).

In the Klamath River, all runs of chinook salmon (*Oncorhynchus tshawytscha*), green sturgeon (*Acipenser medirostris*), and Pacific lamprey (*Lampetra tridentata*) are on the decline and coho salmon (*O. kisutch*) are listed as "threatened" under the Endangered Species Act. The Yurok Tribe is dedicated to rehabilitating degraded instream and riparian habitats to levels that support robust, self-sustaining populations of native anadromous fish. To help address this need, the Yurok Tribe's Fisheries (YTFP) and Watershed (YTWRD) programs have been conducting fisheries and watershed assessments, and implementing instream and upslope restoration activities in the Lower Klamath River Sub-basin since the late 1990s.

Initial restoration planning efforts included developing the Lower Klamath Sub-Basin Watershed Restoration Plan that prioritized upslope restoration and identified tributary specific restoration objectives for each Lower Klamath tributary (Gale and Randolph 2000). Sub-basin restoration objectives included: 1) reducing sediment inputs from upslope sources by treating high priority watershed road segments and stream crossings; 2) restoring native, conifer-dominated riparian forests; and 3) enhancing freshwater aquatic habitats. Since 2007, YTFP has been working with Rocco Fiori of Fiori GeoSciences (FGS) to design and implement innovative stream and floodplain enhancement projects in priority Lower Klamath tributaries. Treatments have included installation of constructed wood and engineered log jams (CWJs & ELJs) to facilitate formation and maintenance of productive fish habitats (e.g. spawning beds, deep pools with cover, slow velocity habitats), and enhancing off-channel habitats to increase salmonid rearing capacity (YTFP 2010; Hiner et al. 2011; Beesley and Fiori 2012a, 2012b, 2013a, 2013b, 2013c).

Project Area

McGarvey Creek is a third order watershed draining approximately 8.9 square miles (Figure 1). McGarvey Creek flows into the south side of the Lower Klamath River ~6.4 river miles upstream of the Pacific Ocean (Figure 1). The watershed supports anadromous populations of chinook and coho salmon, steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarkii clarkii*), and multiple species of lamprey. The watershed also provides critically valuable rearing habitat for non-natal juvenile coho salmon and thermal refuge to fish migrating through the river during the low flow period (YTFP 2009; Antonetti et al. 2012; Beesley and Fiori 2007). McGarvey Creek is located in the Klamath Glen Hydrologically Significant Area, which was given the highest priority rating in the Recovery Strategy for California Coho Salmon (CDFG 2004).

The McGarvey Creek watershed has been subjected to intense timber harvest and road building activities, including construction of the U.S. Highway 101 bypass through the headwaters in the mid-1980's (Gale and Randolph 2000). Historic and ongoing land management activities have resulted in removal of old growth conifers from riparian habitats, substantial simplification of stream and riparian habitats, increased rates of channel sedimentation, and loss of large wood and naturally formed jams in fluvial habitats (Figures 2-4) (Gale and Randolph 2000; Beesley and Fiori 2007).

YTFP has been conducting physical and biological monitoring and implementing enhancement activities in McGarvey Creek since the late 1990s (Gale and Randolph 2000; Beesley and Fiori 2007; YTFP 2009 & 2013; Fiori et al. 2009 & 2010; Antonetti et al. 2012). Initial activities included assessments of historic land-use activities to further characterize changes in fish habitats through time, identifying factors that limit native salmonid populations, and prioritizing restoration. To address upslope sediment sources in McGarvey Creek, YTWRD completed a prioritized road assessment in the late 1990s. Since this time, they have decommissioned a majority of the high and medium priority road segments and stream crossings in the watershed. To improve forest conditions in the watershed, YTFP has been planting native conifers in riparian habitats and along decommissioned roads and stream crossings since the late 1990s.

Following treatment of a majority of the potential road related sediment sources in McGarvey Creek; YTFP began working closely with our technical restoration lead Rocco Fiori (California Licensed Geologist, Fiori GeoSciences - FGS) to plan, design, and implement comprehensive wood loading and floodplain enhancement efforts in the watershed. The first instream projects conducted with FGS included installing constructed wood jams (CWJs) in lower West Fork McGarvey Creek in 2007 and in mainstem McGarvey Creek upstream of West Fork in 2008 (Figure 5) (Gale 2008 & 2009; Fiori et al. 2009 & 2010). Given the need and scope of the opportunities available to restore critical low gradient and off-channel habitats in lower McGarvey Creek, YTFP and FGS coordinated with YTWRD and Green Diamond Resource Company (GDRC – landowner) to develop a comprehensive stream and floodplain enhancement plan for the lower reaches of McGarvey Creek in 2009 (Figure 6).

Restoration priorities identified for lower McGarvey Creek were based on real time monitoring of fish use patterns in the watershed, assessment of geomorphic and hydrologic conditions, peer-reviewed research, previous experience, and landowner objectives. Specific objectives included: 1) increasing the amount of fluvial deposited wood and complex wood jams in stream and floodplain habitats; 2) increasing the quantity and quality of overwinter rearing habitat available to juvenile salmonids; and 3) removing riparian and floodplain roads that impair or threaten stream and floodplain function. These priorities were determined to be the most appropriate next step towards native salmon and trout recovery in McGarvey Creek.

YTFP and FGS began implementing the Lower McGarvey Restoration Plan in summer 2009 with funding from the U.S. Fish and Wildlife Service (USFWS – Partners for Fish and Wildlife) and the U.S. Bureau of Reclamation (BOR - Native American Affairs Program). In 2009, YTFP and FGS installed 10 CWJs in the upper portion of the Lower McGarvey Restoration Reach (Figures 7-8). In 2010, YTFP and FGS constructed the first off-channel habitat feature (McGarvey Alcove I) and installed three CWJs in Lower McGarvey (Figures 9-10).

Project Overview

In fall 2010, YTFP received funding from the U.S. Bureau of Reclamation (BOR) (Klamath Basin Restoration & Native American Affairs Programs) and additional funding from USFWS (Partners for Fish and Wildlife) to continue implementing the Lower McGarvey Restoration Plan (Figures 5-6). This report covers habitat restoration activities implemented in the Lower McGarvey Creek Reach from summer 2011 – summer 2013; as well as physical and biological monitoring conducted within the project reach from fall 2010 – fall 2013. Funding from the National Fish and Wildlife Foundation (NFWF – PacifiCorp's Klamath River Coho Enhancement Fund) was obtained in 2012 to help supplement restoration and monitoring efforts.

Lower McGarvey Creek Project objectives included:

- Increasing salmonid spawning and rearing habitat complexity in McGarvey Creek and reducing water quality impacts in the watershed by installing numerous constructed wood jams, creating off-channel habitat features, and planting native trees in riparian habitats;
- Evaluating project effectiveness to facilitate adaptive management of the project area; and
- Creating high quality, resource-based employment opportunities for Yurok tribal members.

Driving Directions & Project Location

The project site is located on property owned by Green Diamond Resource Company (GDRC - Contact: Ryan Bourque - Aquatic Monitoring Supervisor - PO Box 68; Korbel CA, 95550). Heading south from the town of Klamath on U.S. Highway 101, travel across the Klamath River. Take the first exit immediately after crossing the river (Klamath Beach Road - Exit 768). Turn right at the stop sign. Proceed under the highway and upriver ~one mile. Turn right onto the # M10 road. A GDRC key is required to pass through the gate located at the road turnoff. Follow the # M10 for ~ 1.5 miles to the bridge crossing McGarvey Creek. The proposed project reach can be accessed by hiking downstream for ~ 1,800 feet on the # M600 (Figures 5-6). The project coordinates are as follows: Downstream BND: Lat. 41.500; Long. -123.997; Upstream BND: Lat. 41.492; Long. -124.006 (Figures 5-6).

Riparian Tree Planting

Trees planted for this project were obtained from the Yurok Tribal Native Plant Nursery located in Klamath, California. All trees were planted using hoedads and/or tree planting spades according to methods outlined in Flosi and others (1998). Crews took precaution to properly stabilize the trees when burying root systems to prevent "J-rooting". Trees were planted at a spacing of ~ 8 - 10 feet, with crewmembers selecting the most favorable microsites for planting. YTFP crew leaders recorded daily tree planting information on datasheets and field maps. This information was also electronically entered into YTFP databases and GIS.

Crews first began planting native trees in riparian habitats of the Lower McGarvey Project Reach in early spring 2012. During this period, crews planted 398 coastal redwoods (*Sequoia sempervirens*) and 158 western red cedar (*Thuja plicata*) (Table 1; Figure 11). These trees were potted saplings that were a few years old and ranged from 4 - 6 feet in height. Planting efforts in spring 2012 were focused on riparian flats located on the western side of the valley and in habitats located downstream of the proposed instream and off-channel restoration sites (Figure

Table 1. Summary of trees planted in riparian habitats of McGarvey Creek during 2012.

Tree Species	**Tree Size (ft)**	**Spring 2012 Trees Planted**	**Winter 2012 Trees Planted**	**Total # Planted**
Coastal Redwood	4 - 6	398	203	601
Port Orford Cedar	4 - 6	0	31	31
Western Red Cedar	4 - 6	158	131	289
Totals		**556**	**365**	**921**

11). In winter 2012, crews planted 203 398 coastal redwoods, 131 western red cedar, and 31 Port-Orford cedar (*Chamaecyparis lawsoniana*) in areas treated during summer 2012 (Table 1; Figure 11). Crews have been tracking survival and thus far it appears the trees are doing well.

<u>Constructed Wood Jams and Off-Channel Habitat</u>

Installation of constructed wood jams (CWJs) was conducted within the lower portion of the project reach during the 2012 restoration season; while the upper portion of the reach was treated during the 2013 restoration season. CWJs installed for this project were a variation of Engineered Log Jams (ELJs) described by Abbe et al. (2003a, 2003b, 2005). CWJs were constructed using the same geomorphic and engineering principles as ELJs; where mechanically driven logs, riparian trees, and old growth stumps were used to create the resisting elements necessary for maintaining CWJ stability and function under a variety of flows. None of the CWJs relied on cable or rebar anchoring systems and no imported quarry rock was used.

The CWJs installed in McGarvey Creek were designed to facilitate formation and maintenance of productive fish habitats (e.g. spawning beds, deep pools with cover, slow velocity habitats), help meter channel stored sediment, and slow the delivery of sediment to downstream habitats (e.g. Klamath River), and to promote increased floodplain connectivity and fish passage into and out of constructed off-channel habitats. One of the key tools necessary for rebuilding complex, self-maintaining fish habitats in Lower Klamath tributaries is the use of whole tree materials (i.e. long stems with rootwads attached, long stems, medium and small pieces). CWJs installed for this project were constructed using whole Douglas fir trees purchased from GDRC and whole red alder trees that had to be taken down within the project area to facilitate restoration activities.

In summer 2012, YTFP and FGS installed eight CWJs and constructed the second off-channel habitat feature (McGarvey Alcove II) in the Lower McGarvey Creek Project Reach (Figures 12-18; Appendix A). McGarvey Alcove II is a fairly small off-channel habitat feature that was constructed on the eastern side of the valley just down valley from a small tributary (Figures 13-18). Alcove II and the outlet channel have fairly steep banks because the available footprint for the feature was relatively small. Large and small wood was placed within the main body of the alcove to increase rearing habitat complexity and a CWJ was installed at the outlet to promote long-term connectivity (i.e. fish passage) with the alcove (Figure 15).

FGS designed and constructed a rock sill and infiltration galley to promote increased surface and ground water inflow to the alcove from the tributary (Figures 15-17). The sill and infiltration gallery were constructed using clean, river run rock obtained from an unrelated restoration project in Terwer Creek. The purpose of the sill was to allow surface waters to flow from the tributary to the infiltration galley while discouraging sediment delivery to the constructed alcove. To create the infiltration gallery, a shallow channel was excavated from the tributary into Alcove II to transport surface and ground water flows. The channel was backfilled with river run rock to prohibit bank erosion during higher tributary flows and help promote improved water quality.

In summer 2013, YTFP and FGS installed 12 CWJs and constructed the third off-channel habitat feature (McGarvey Alcove III) in the Lower McGarvey Creek Project Reach (Figures 19-23; Appendix A). McGarvey Alcove III was constructed along the eastern valley side-wall just down valley from a small tributary. McGarvey Alcove III is a fairly large off-channel habitat feature relative to Alcove II and the form is more analogous to an abandoned channel segment. Alcove III is fairly deep throughout its footprint with intermediate to steep sides. The feature was receiving a significant amount of ground water inflow during construction, theoretically emanating from the tributary watershed. Therefore, FGS did not implement any additional measures to promote increased connectivity with the tributary as was done for Alcove II. We are currently monitoring water quality in this feature to help us assess habitat performance and determine if additional actions should be taken to increase surface and ground water inputs. As was done in Alcove II, large and small wood was placed in the alcove to increase salmonid rearing habitat complexity and provide sites for native amphibians to lay eggs, and CWJs were installed in the mainstem to facilitate long-term connectivity with Alcove III (Figures 21-22).

Topographic and Wood Surveys

YTFP conducted baseline 3-D topographic surveys of the channel and established multiple, permanent cross sections within the Lower McGarvey Creek Project Reach during summer 2011. All surveys were conducted using an optical total station and a hand-held data collector. Data was collected in meters using the following coordinate systems: projected coordinate system NAD_1983_UTM Zone_10N; geographic coordinate system GCS North American 1983. End points for the longitudinal profile survey and cross sections were marked using rebar with end caps and georeferenced using the optical total station. YTFP tied all project surveys to YTFP's long-term channel monitoring survey located within the watershed to expand and enhance physical monitoring activities in this priority Lower Klamath tributary. Following CWJ installation in 2012 and 2013, YTFP marked all the key logs with individual identification tags and surveyed their positions using the total station and data collector (Figure 24).

Photo-Monitoring

YTFP established a network of photographic monitoring sites within the project reach to help characterize habitat conditions and document changes over time (Table 2). Photo-monitoring location information was collected using a hand-held Garmin GPS Map 78s unit (Latitude, Longitude -decimal degrees, geographic coordinate system, WGS 84). Photographs were obtained throughout the project's duration in an effort to document pre-project and post-project conditions including CWJ site conditions and the alcoves under various flows (Appendix A).

Table 2. Photographic monitoring site information for the project: “Enhancement of Rearing Habitat for Natal and Non-Natal Salmonids in McGarvey Creek, Lower Klamath River.

Reach	Project_ID	Site_Name	Latitude	Longitude	Orientation
Lower McGarvey	McG_2012	McG2012_A-1	-123.9979	41.5003	270 W looking upstream
Lower McGarvey	McG_2012	McG2012_B-1	-123.9980	41.5000	0 N looking towards McGarvey (close-up)
Lower McGarvey	McG_2012	McG2012_B-2	-123.9980	41.5000	0 N looking towards McGarvey
Lower McGarvey	McG_2012	McG2012_B-3	-123.9980	41.5000	320 NW looking towards McGarvey
Lower McGarvey	McG_2012	McG2012_C-1	-123.9981	41.5003	180 S looking towards Alcove II
Lower McGarvey	McG_2012	McG2012_D-1	-123.9986	41.5005	100 SE looking downstream
Lower McGarvey	McG_2013	McG2013_A-1	-124.0060	41.4933	175 S looking upstream
Lower McGarvey	McG_2013	McG2013_B-1	-124.0060	41.4935	10 N looking downstream
Lower McGarvey	McG_2013	McG2013_B-2	-124.0056	41.4936	180 S looking upstream
Lower McGarvey	McG_2013	McG2013_C-1	-124.0062	41.4936	30 NE looking toward right bank
Lower McGarvey	McG_2013	McG2013_C-2	-124.00516	41.4938	220 SW looking upstream
Lower McGarvey	McG_2013	McG2013_D-1	-124.0052	41.4939	40 NE looking toward left bank
Lower McGarvey	McG_2013	McG2013_D-2	-124.0052	41.4939	75 NE looking downstream
Lower McGarvey	McG_2013	McG2013_E-1	-124.0051	41.4940	130 SE looking toward right bank
Lower McGarvey	McG_2013	McG2013_F-1	-124.0050	41.4940	15 NE looking downstream
Lower McGarvey	McG_2013	McG2013_G-1	-124.0043	41.4944	200 SW looking upstream

Water Quality Monitoring & Fish Use of Constructed Off-Channel Habitats

Since 2010-2011, YTFP has been assessing fish use and water quality conditions within the constructed alcoves of McGarvey Creek to improve our understanding of restoration performance and effectiveness, and use the information gained to inform and improve future designs and fish recovery actions. YTFP has been working with the Yurok Tribe Environmental Program (YTEP) to collect water quality data in the McGarvey alcoves since October 2010. We have been deploying a combination of YSI and Hydrolab datasondes in the alcoves at various times of the year to document diurnal and seasonal water quality conditions in these features.

We began assessing water quality in McGarvey Alcove I in October 2010 soon after it was constructed (Figure 24). During the period 10/15/10 – 10/18/10, water quality was monitored at three sites in Alcove I: Alcove I-Rear (most upstream portion of the habitat, Alcove I-Mid (Mid-point of the habitat), and Alcove I-Outlet (closest to confluence with mainstem McGarvey Creek). Water temperatures measured in McGarvey Alcove I during this period were similar among the three sites and ranged from 10.49 to 11.26 °C (Figure 24). Water temperatures measured in Alcove I were fairly typical of coastal habitats of the Lower Klamath; however, dissolved oxygen (DO) levels in this feature were quite low. DO values were the most variable and the highest at Alcove I-Outlet (Figure 24). DO values measured at this site ranged from 0.05 mg/L on 10/17/10 to 7.43 mg/L on 10/15/10 (Figure 24). DO values measured at the other two sites extremely low over the study period with values ranging from 0 to 0.42 mg/L (Figure 24).

Water quality was monitored fairly continuously from mid-January to mid-March 2011 at the middle and rear sites (Figure 25). DO measured from mid-January through mid-February was very low with values ranging from below zero to just above 4.0 mg/L. A storm event in mid-February appeared to result in fairly substantial increases in DO concentrations at the two sites. Storm events occurring in late February-early March also appeared to facilitate increased DO levels. DO values measured at the two sites from mid-February through mid-March were from 2.39 to 11.27 mg/L (Figure 25). YTFP first began assessing fish use in Alcove I during January 2011 with trapping efforts resulting in the capture of 54 age 1+ coho and a few older age cutthroat trout (Figure 25). As mentioned, DO concentrations were very low during this first fish trapping period and thus we proceeded with extra caution. YTFP crews conducted a trapping event in early March 2011 that resulted in the capture of one age 0+ coho and 20 age 1+ coho of which, five were fish that we had captured during the January sampling event (Figures 25-26).

The data collected in this first winter post-construction of Alcove I was very critical to improving our understanding of the hydro-geomorphic conditions in lower McGarvey and fish use of off-channel features that experience low DO. Water quality information collected in Alcove I also influenced how FGS designed Alcoves II and III. Both of these features were sited just down valley from a tributary and were constructed in a manner to avoid or minimize sediment delivery into the features while receiving increased surface and ground water inputs relative to Alcove I. The goal was to promote increased DO concentrations within these constructed features to improve their function as juvenile salmonid rearing habitats.

Additional fish sampling conducted in Alcove I during June 2011 resulted in the capture of 51 age 0+ coho salmon, one age 0+ chinook salmon, cutthroat trout, and multiple native fish and amphibian species. We did not have the sondes operating during this time so crews used a hand-held YSI water quality meter to document site conditions at the time of fish sampling. DO measured in McGarvey Alcove I during this sampling event was 3.44 mg/L (Water Temperature 15.6 °C). Water quality was next monitored at Alcove I-Rear and Alcove I-Mid during the period: 12/19/11 – 12/23/11 (Figure 27). DO concentrations remained extremely low at both sites during the entire study period. Water temperatures measured in Alcove I were relatively steady during this study period and ranged from 4.16 to 5.16 °C (Figure 27).

Prior to conducting an overwinter fish abundance survey, we monitored water quality at Alcove I-Mid during the period: 02/21/12 – 02/27/12. DO concentrations at this site were relatively high during this period with measured values ranging from 6.22 to 9.18 mg/L (Figure 28). Water temperatures were relatively stable during this period and were from 6.81 to 8.91 °C (Figure 28). In March 2012, YTFP conducted a mark-recapture population estimate in McGarvey Creek Alcove I using the Chapman modification of the Petersen estimator (Ricker 1975). These efforts resulted in an estimate of 213 juvenile coho residing in this feature (Figure 29). YTFP also conducted a summer fish abundance survey in McGarvey Alcove I during August 2012. These efforts resulted in an estimate of 58 age 0+ coho residing in this feature (Figure 29).

McGarvey Alcove II was constructed in summer 2012 and YTFP began monitoring water quality in this feature and Alcove I during November 2012. Sondes were placed at Alcove I-Mid and at a site located within the middle of Alcove II (Alcove II-Mid) for the period: 11/21/12 – 11/28/12 (Figure 30). DO values measured in Alcove I during this study period were low relative to those measured in Alcove II. There was an odd spike in DO concentrations on 11/22/12 and a smaller peak towards the end of the study period; however, DO values were never greater than 3.54 mg/L. DO concentrations measured in Alcove II were higher with values ranging from 5.99 to 8.28 mg/L. DO measures in Alcove II also were more variable on diurnal time scales (Figure

30). Water temperatures measured during this study period were from 9.27 to 10.78 °C in McGarvey Alcove I and from 10.6 to 11.3 °C in McGarvey Alcove II (Figure 30).

Prior to conducting an winter fish abundance surveys in Alcoves I-II, we monitored water quality at Alcove I-Rear, Alcove I-Mid, and Alcove II-Mid during the period: 01/14/13 – 01/28/13 (Figure 31). A sonde was also placed in mainstem McGarvey Creek upstream of Alcove I to allow a comparison of conditions within the constructed features to those in the creek (Figure 31). DO values measured during this study period were lowest in McGarvey Alcove I, intermediate in Alcove II, and highest at the McGarvey Creek site. DO values measured in Alcove I were from 1.10 to 5.98 mg/L; while values measured in Alcove II were from 7.33 to 9.43 mg/L. DO values measured in the creek ranged from 11.84 to 10.84 mg/L over the study period. Precipitation events beginning on 01/23/13 appeared to result in slight increases in DO in Alcove II over the remainder of the study period. The opposite seemed to have occurred in Alcove I where DO concentrations declined slightly following the accumulation of precipitation (Figure 31). During this same time period, water temperatures measured in Alcove I increased from ~4.5-4.9 °C to ~7.5-7.8 °C. Prior to this increase, water temperatures were relatively stable and low in Alcove I. Water temperatures measured in Alcove II during this study period fluctuated on a fairly consistent diurnal time scale until precipitation began accumulating on 01/23/13 (Figure 31). As was the case in Alcove I, water temperatures increased in Alcove II as precipitation accumulated; although, diurnal fluctuations were still apparent.

Prior to conducting summer fish abundance surveys in Alcoves I-II, we monitored water quality at Alcove I-Mid and Alcove II-Mid during the period: 07/22/13 – 07/29/13 (Figure 32). DO values measured in Alcove I during this study period displayed very strong diurnal patterns with dramatic spikes (e.g. from 0.15 to 6.29 mg/L) occurring in the early morning hours followed by more gradual drops back to ~zero (Figure 32). DO values measured in Alcove II were less variable relative to Alcove I; however, diurnal patterns were evident in the latter part of the study period. DO values measured in Alcove II were very and ranged from 0.01 to 1.95 mg/L. Water temperatures measured in Alcove I ranged from 14.71 to 15.58 °C; while water temperatures measured in Alcove II were much lower with values ranging from 11.05 to 11.77 °C (Figure 32). In late July-early August 2013, YTFP conducted mark-recapture population estimates in both McGarvey Creek Alcoves I and II. These efforts resulted in an estimated 38 age 0+ coho residing in Alcove I and an estimated 12 0+ coho residing in Alcove II (Figure 29).

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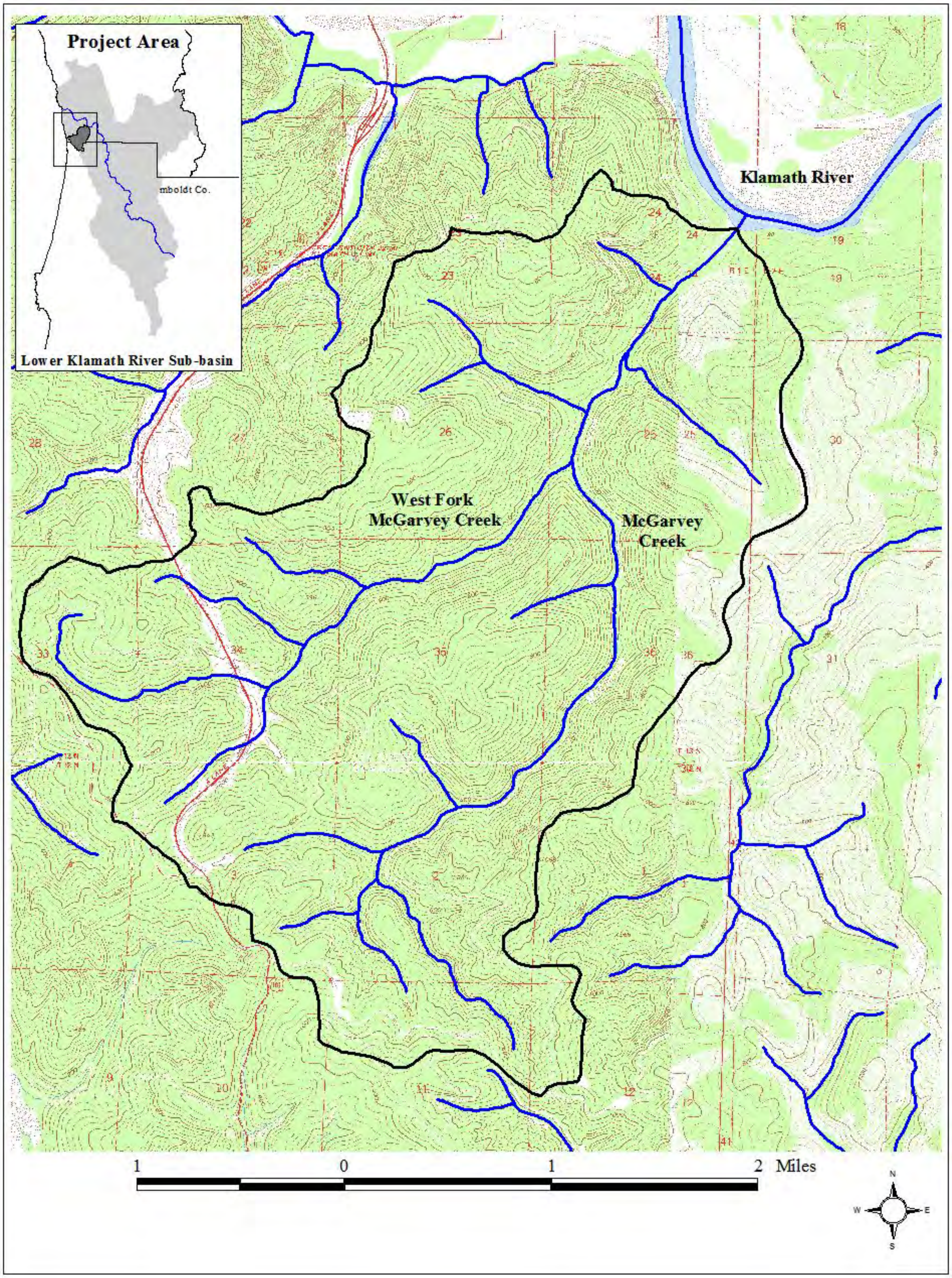


Figure 1. Map depicting the project location in lower McGarvey Creek, Lower Klamath River.

Figure 2. Photographs of a reach in upper McGarvey Creek prior to wood loading activities (Note: wood jams are lacking in the channel and mature alders dominate riparian habitats).

Figure 3. Photographs of a typical reach in lower McGarvey Creek where complex wood jams are lacking and mature conifers have been virtually eliminated from riparian recruitment zones.

Figure 4. Photograph of a typical floodplain in lower McGarvey Creek (Note: mature conifers have been eliminated from riparian recruitment zones and mature alders dominate the forests).

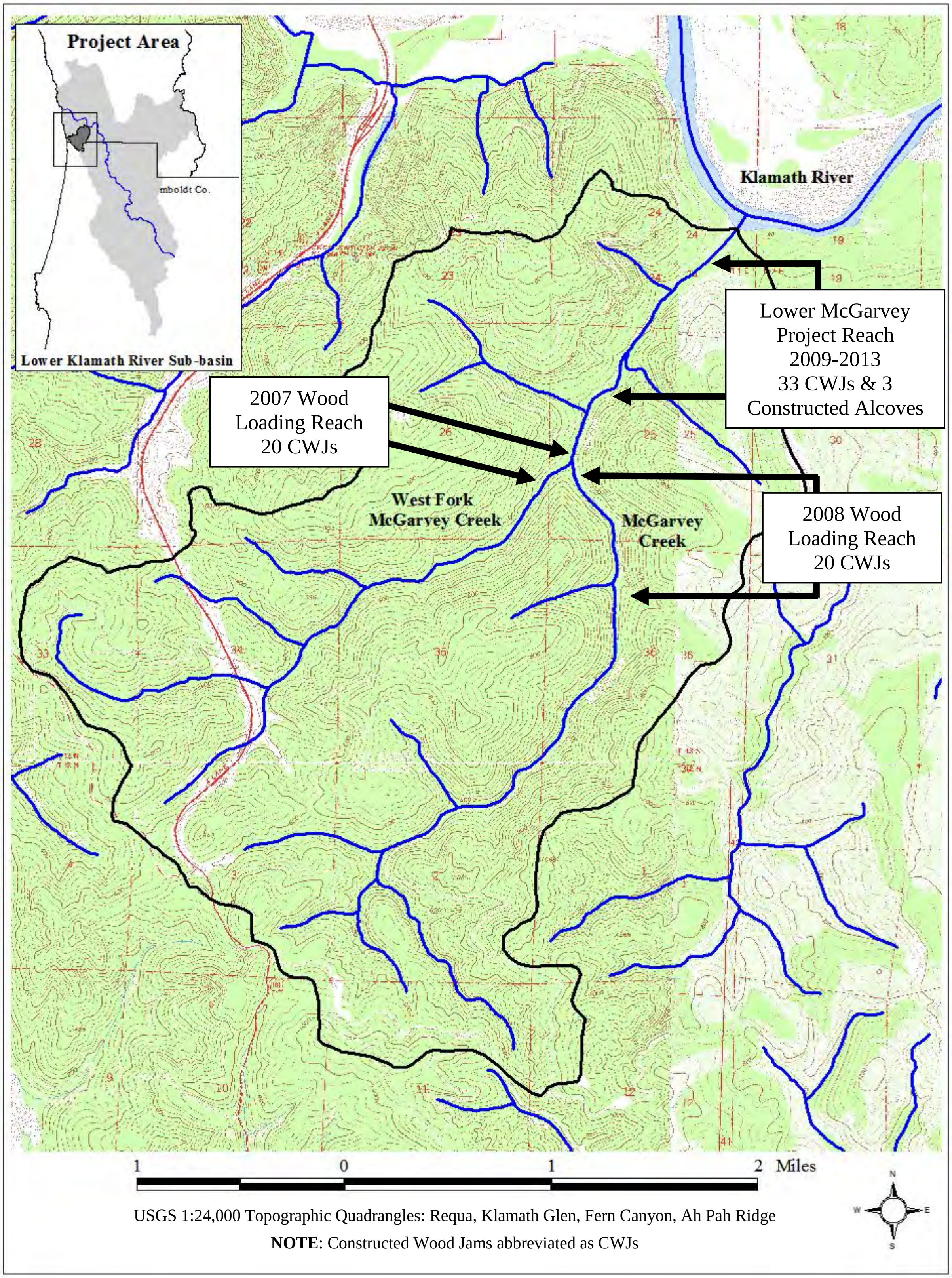


Figure 5. Map depicting restoration project locations in McGarvey Creek, Lower Klamath River.

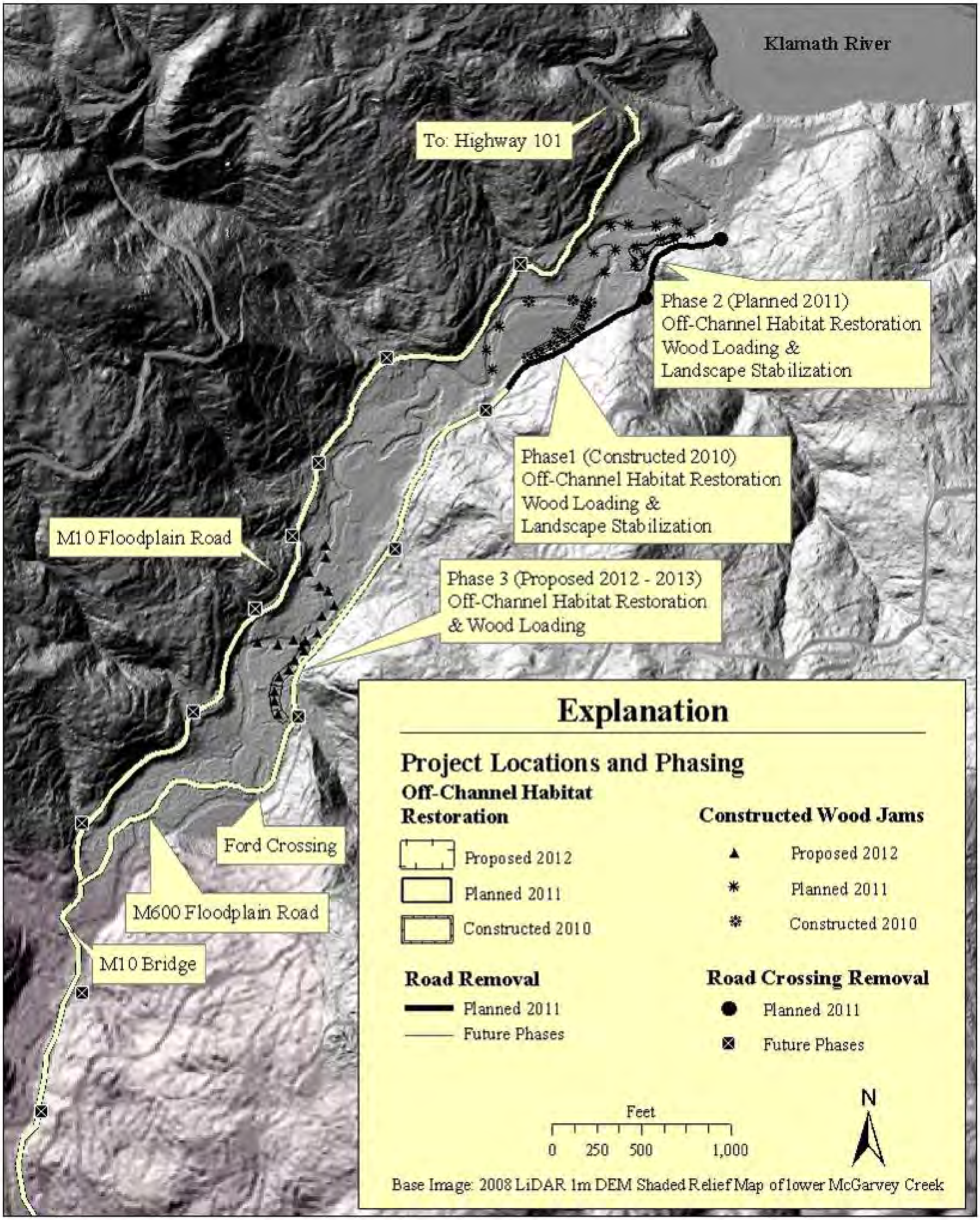


Figure 6. Map depicting a multi-phased approach to rehabilitating stream and floodplain habitats in lower McGarvey Creek, Lower Klamath River Sub-basin, California.

Figure 7. Photographs of McGarvey Creek 2009 wood loading Site #5 prior to construction (Top) and two years post-construction (Bottom).

Figure 8. Photographs of McGarvey Creek 2009 wood loading Site #8 during winter (2010).

Figure 9. Photographs looking downstream at McGarvey Creek Alcove I prior to construction (Top-2010), post-construction (Middle-2010), and 2.5 years post-construction (Bottom-2013).

Figure 10. Photographs looking at the confluence of McGarvey Creek and Alcove I prior to construction (Top-2010) and during winter flows post-construction (Bottom-Winter 2011).

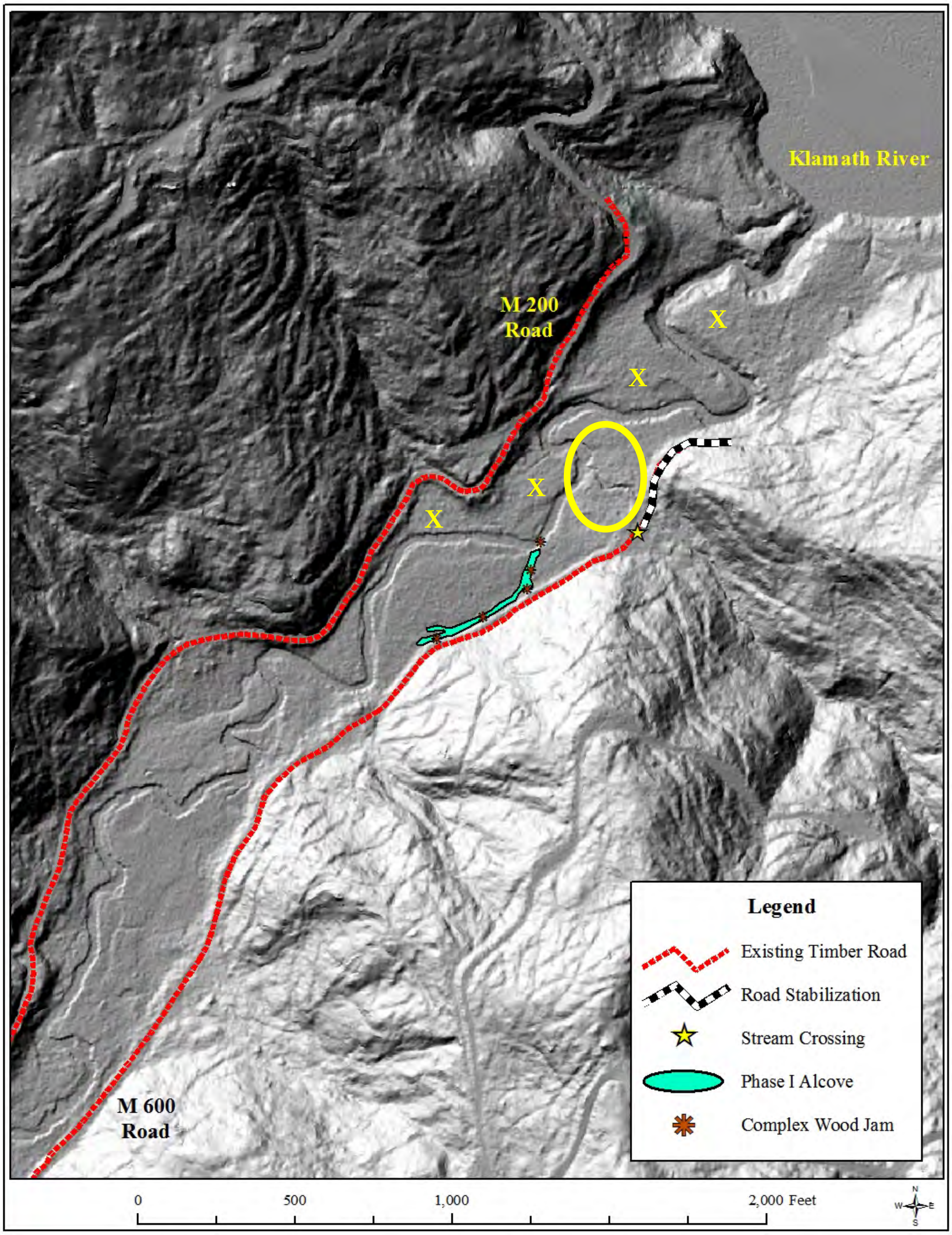


Figure 11. Map depicting riparian areas planted with native conifers in lower McGarvey Creek in spring 2012 (Marked with Xs) and in November-December 2012 (area within yellow oval).

Figures 12. Photographs looking downstream at constructed wood jams installed in lower McGarvey Creek in summer 2012 (Photo Date: 11/13/12).

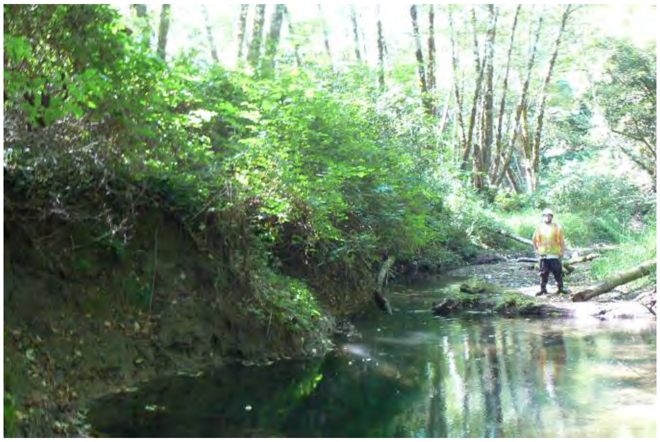


Figure 13. Photographs looking upstream at the confluence of McGarvey Creek and Alcove II prior to construction (Left-09/10/12) and during winter flows post-construction (Right-11/13/12).

Figure 14. Photographs looking downstream at McGarvey Creek Alcove II prior to construction (Top-09/10/12) and during winter flows post-construction (Right-01/03/13).

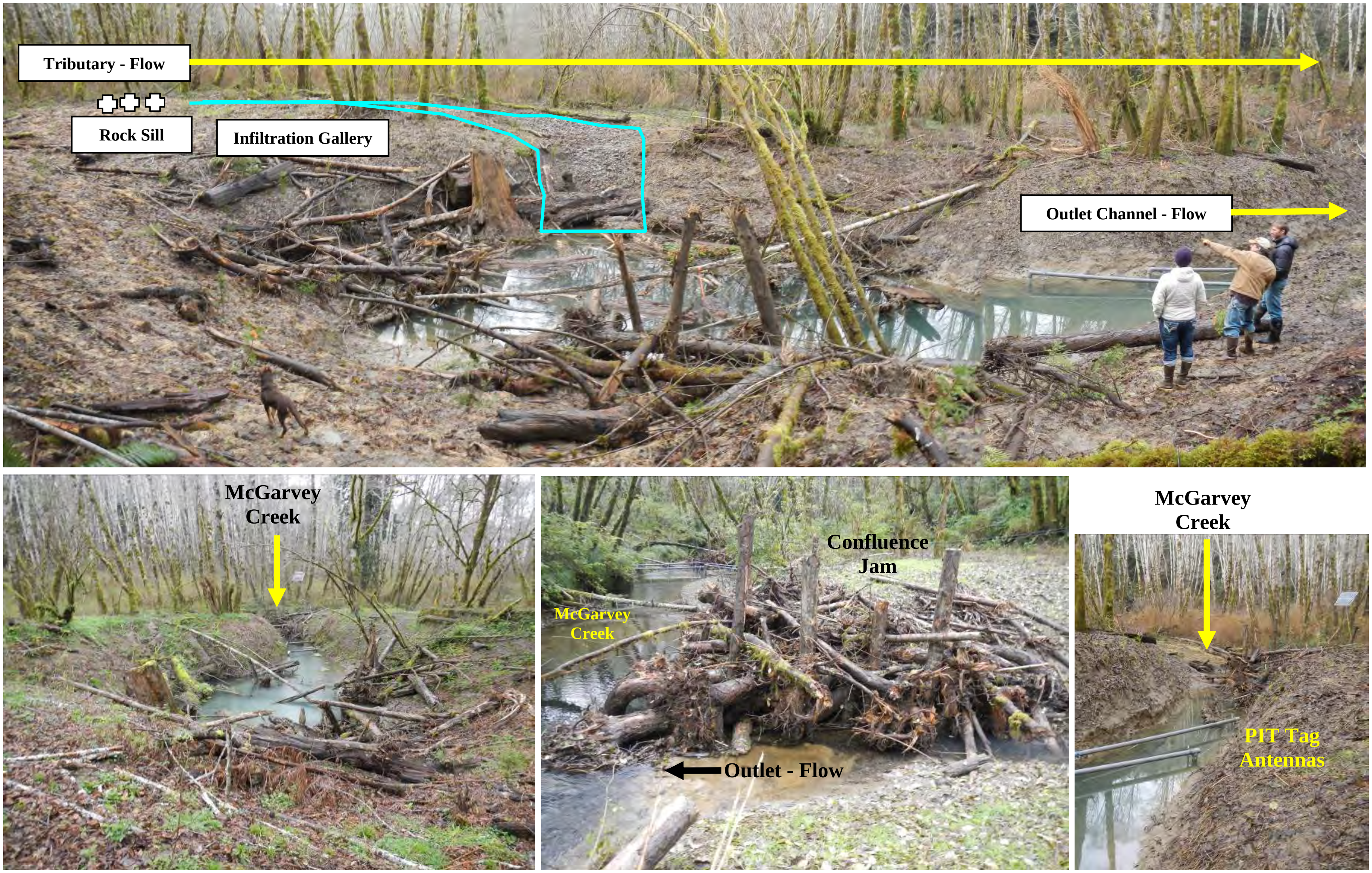


Figure 15. Photographs of McGarvey Creek Alcove II and the various design and habitat features constructed in summer 2012.

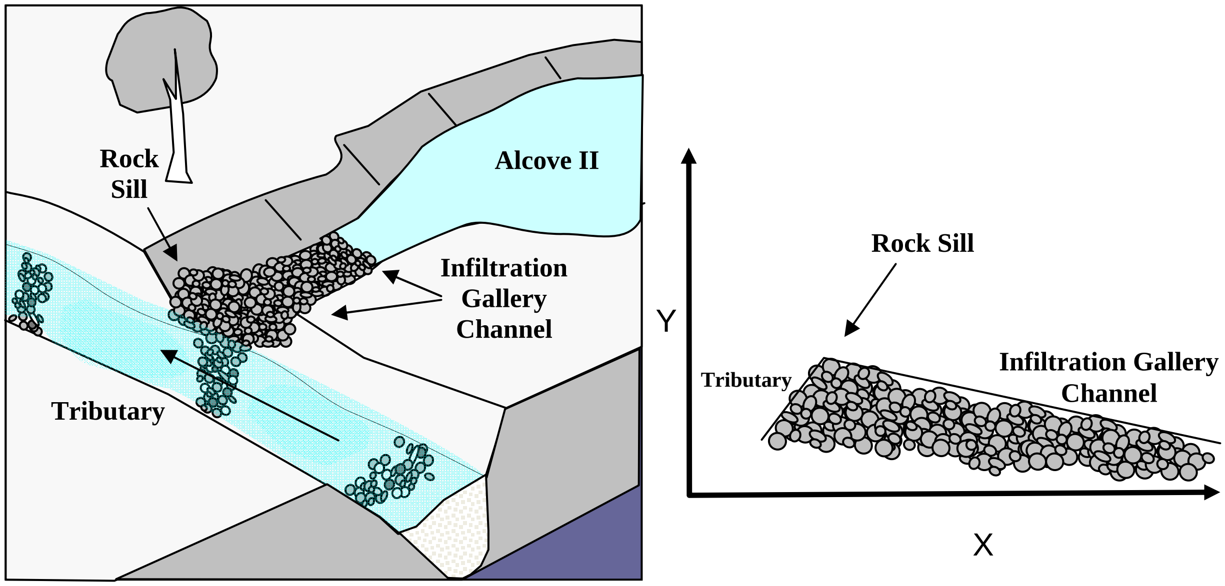


Figure 16. Diagrams depicting the infiltration gallery and rock sill constructed to promote increased delivery of tributary derived water (i.e. surface and ground water) into McGarvey Alcove II; while prohibiting delivery of tributary derived sediment into the constructed alcove.

Figure 17. Photographs looking upstream at the rock sill during winter 2013 (Left) and the McGarvey Alcove II infiltration gallery channel post-construction in summer 2012 (Right).

Figure 18. Photographs of McGarvey Creek Alcove II during low winter flows (Top-01/03/13) and during a Klamath River backwater flood event (Bottom-11/29/12).

Figure 19. Rocco Fiori (Fiori GeoSciences) building constructed wood jams in McGarvey Creek, 2013 (Upper Left – Weaving a log with rootwad attached into riparian trees; Upper Right – setting a vertical pile for jam stability; Bottom – placing log with rootwad attached).

Figure 20. Looking upstream at constructed wood jams installed in McGarvey Creek, 2013.

Figure 21. Looking upstream at McGarvey Alcove III during construction, 2013 (Top – alcove outlet prior to connecting the feature to McGarvey Creek; Bottom – alcove during excavation).

Figure 22. Looking downstream at McGarvey Alcove III post-construction (02/26/14).


Figure 23. Looking downstream at constructed wood jams (McG_2013 Sites 4-5) installed in lower McGarvey Creek (02/26/14).

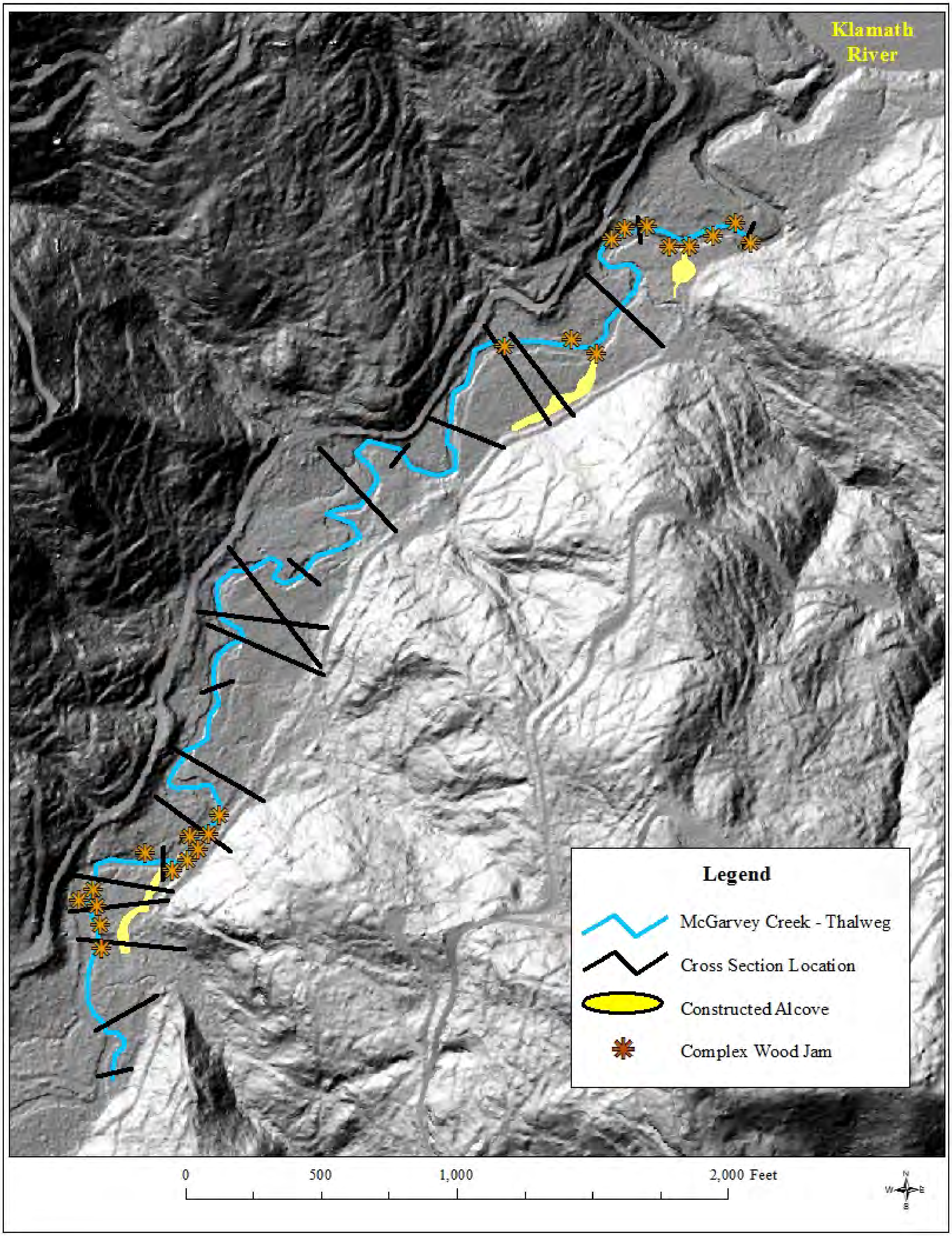
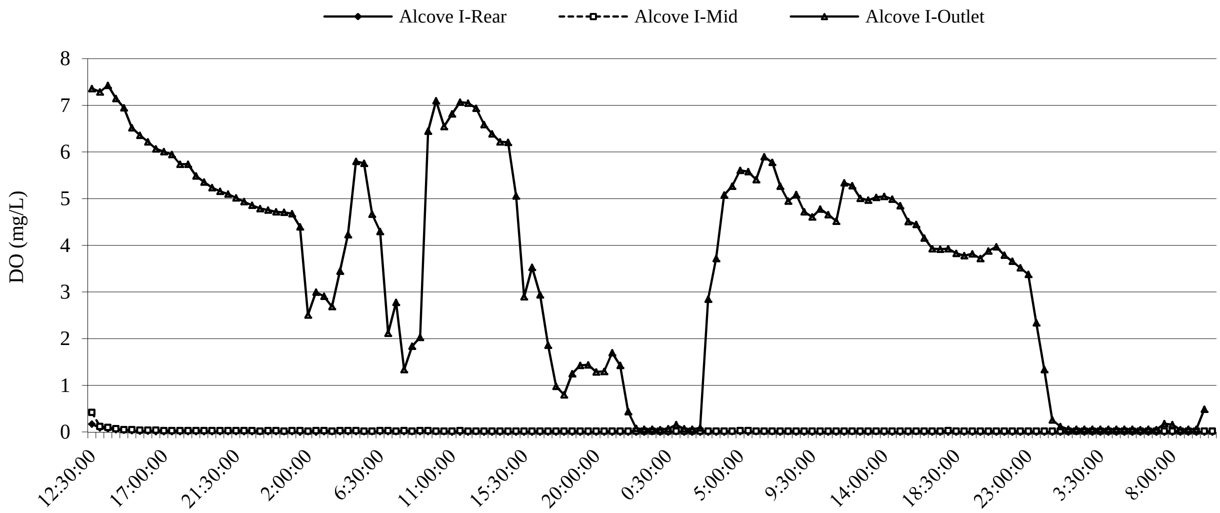


Figure 24. Map depicting locations of the channel survey, cross sections, constructed wood jams (CWJs), and the constructed off-channel habitats (Alcoves I-III) in McGarvey Creek.



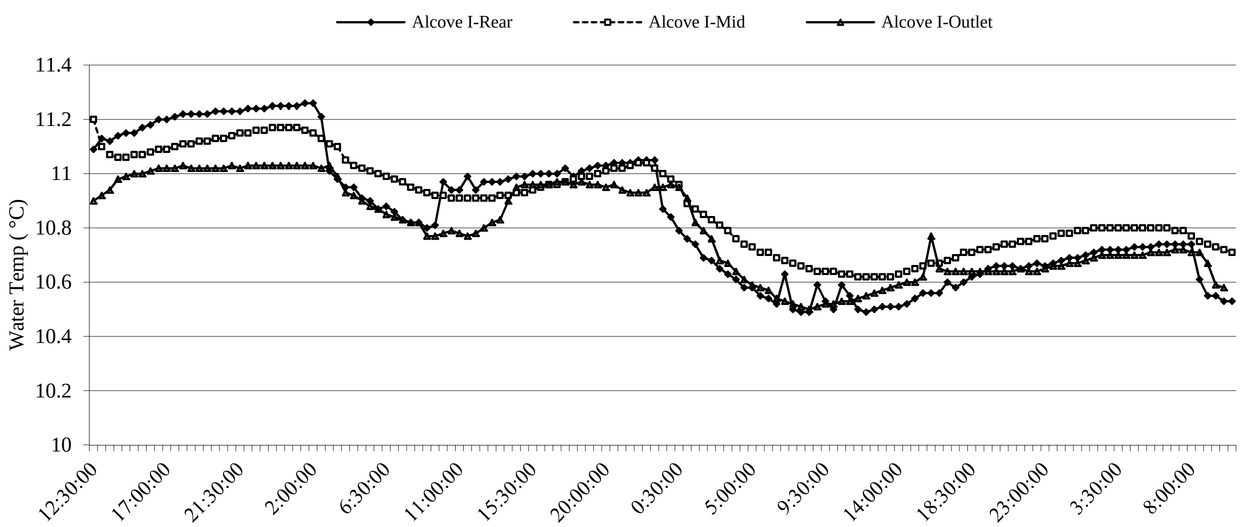


Figure 24. Water quality data collected in McGarvey Creek Alcove I – October 15 – 18, 2010.

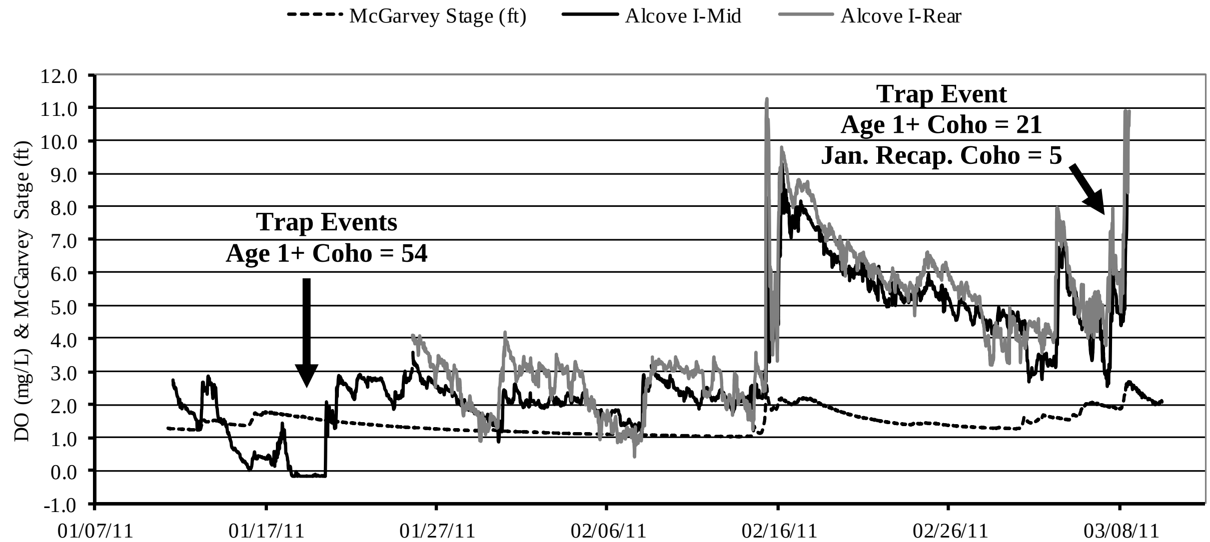


Figure 25. Dissolved oxygen data collected in McGarvey Creek Alcove I and McGarvey Creek stage data – January – March 2011.

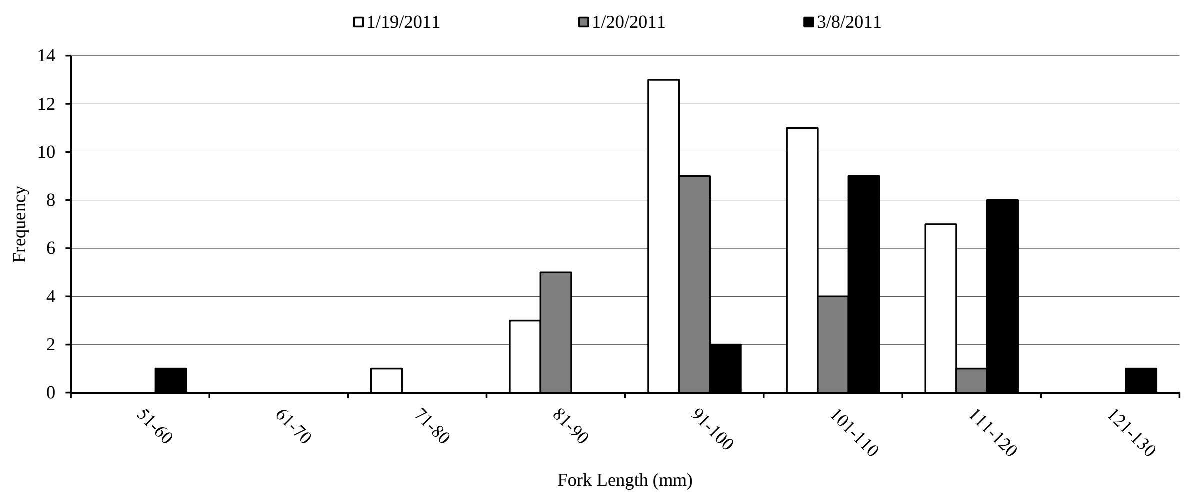
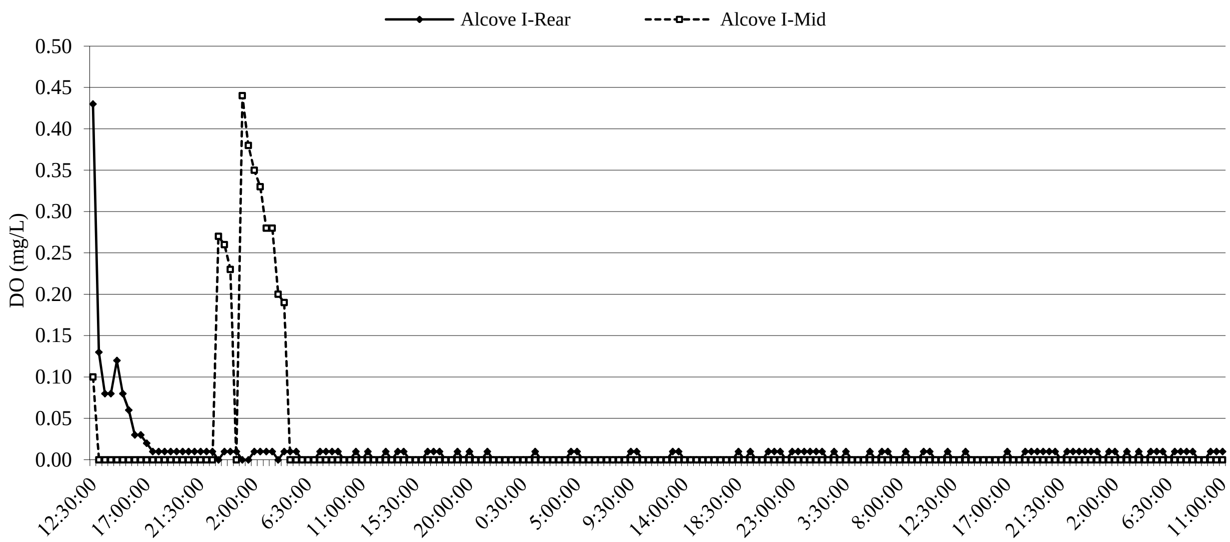


Figure 26. Fork length data for juvenile coho salmon captured in McGarvey Creek Alcove I during winter-spring 2011.



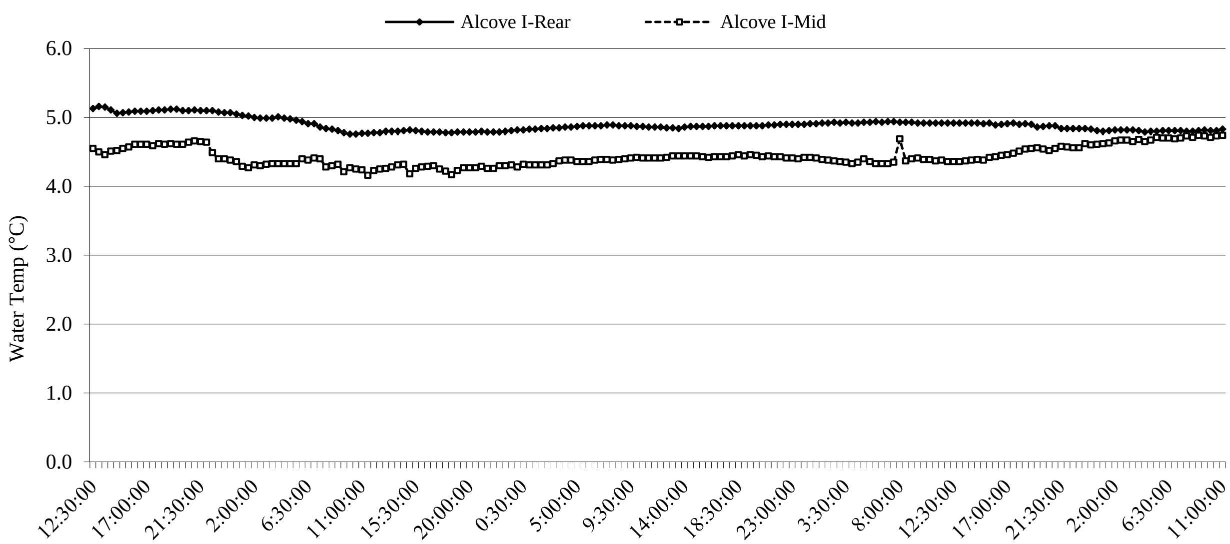


Figure 27. Water quality data collected in McGarvey Creek Alcove I – December 19 – 23, 2011.

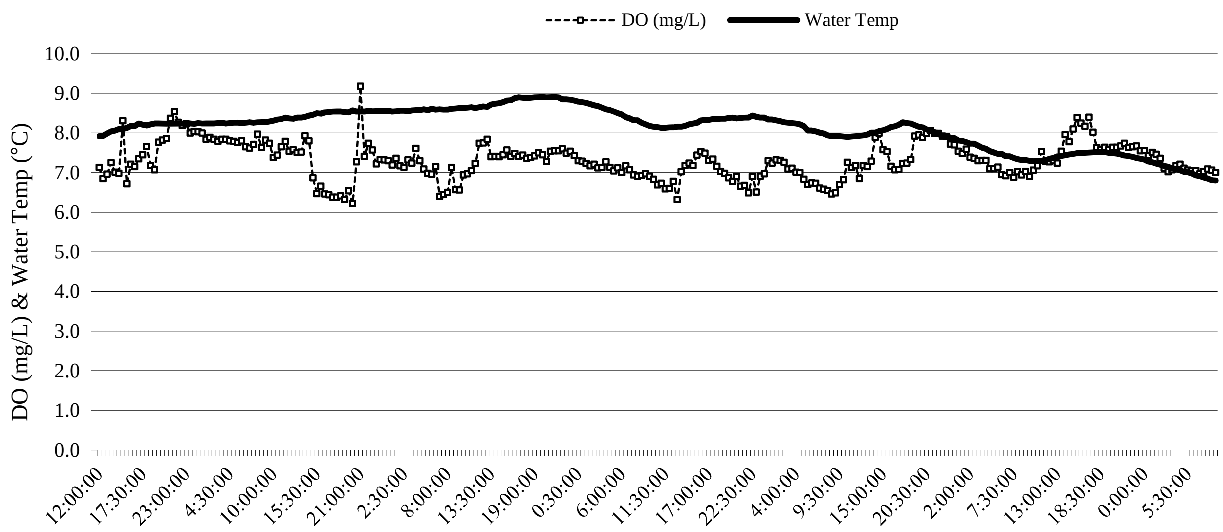


Figure 28. Water quality data collected in McGarvey Creek Alcove I – February 21 – 27, 2012.

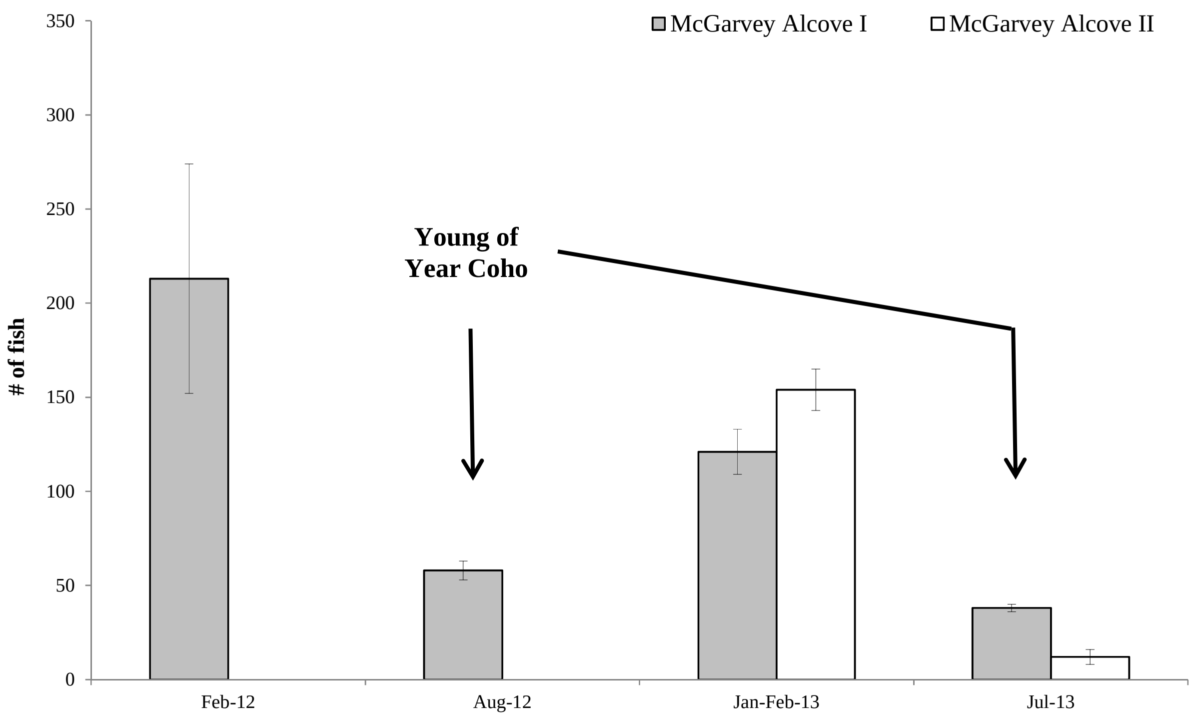


Figure 29. Mark-recapture population estimates for juvenile coho (Age 1+ coho except where otherwise indicated as young of the year) in constructed alcoves located in McGarvey Creek.

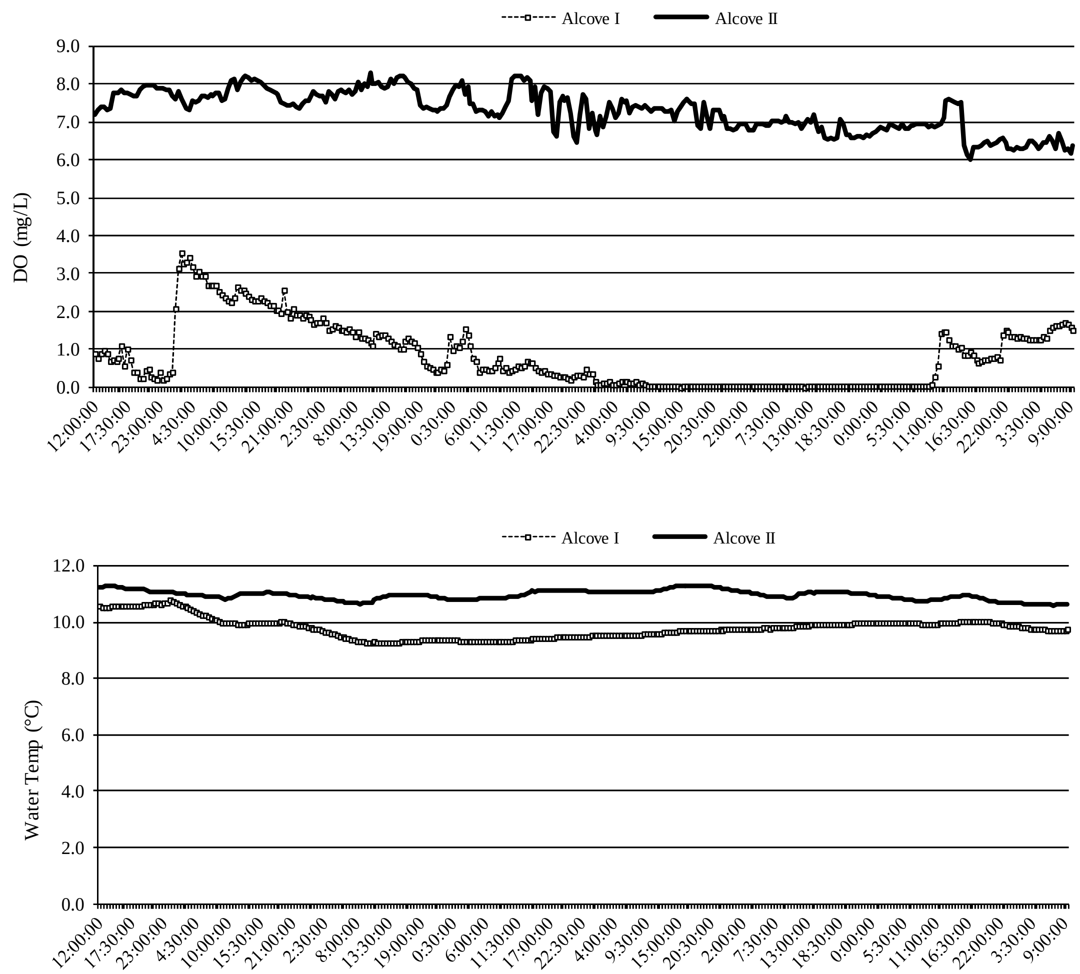
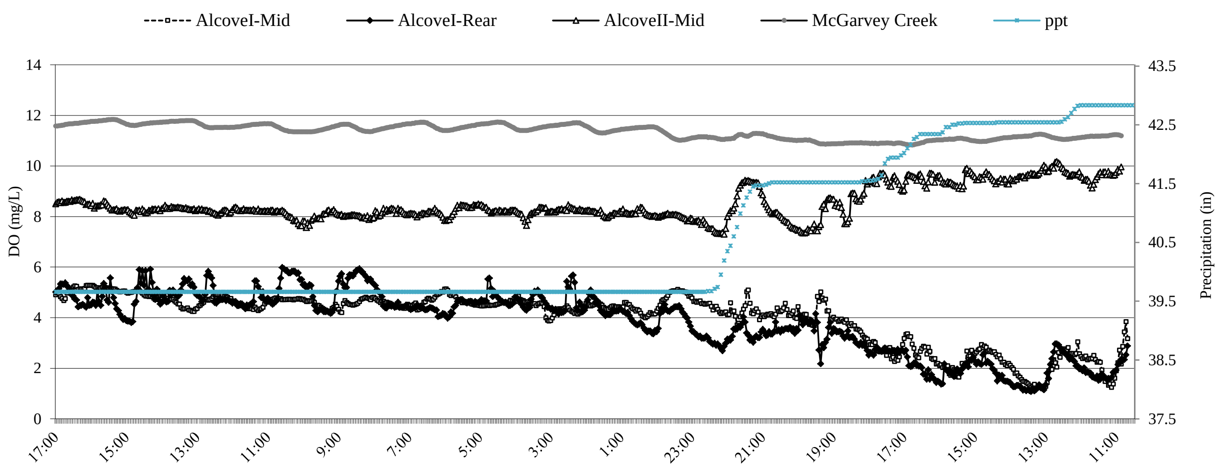


Figure 30. Water quality data collected in McGarvey Creek Alcove I – November 21 – 28, 2012.



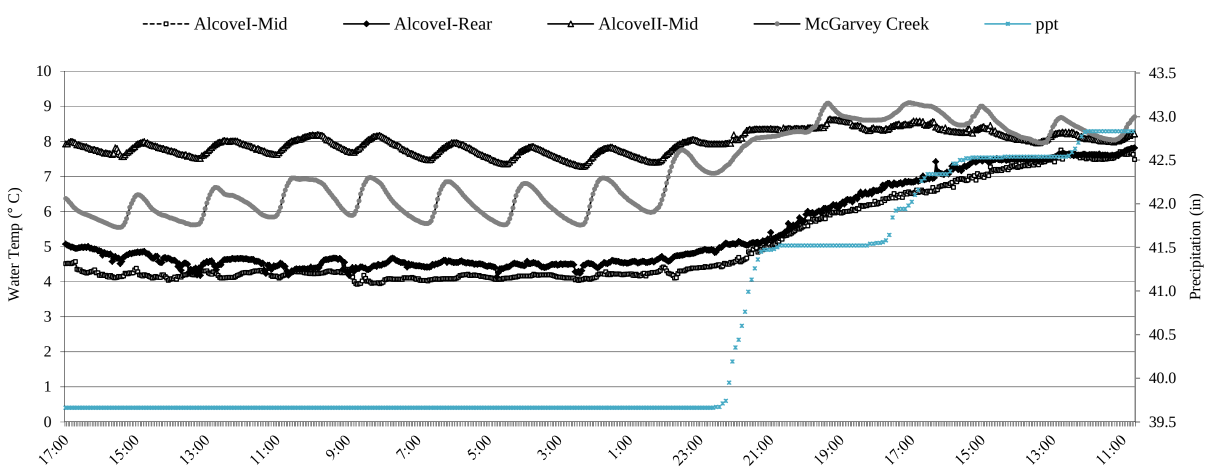
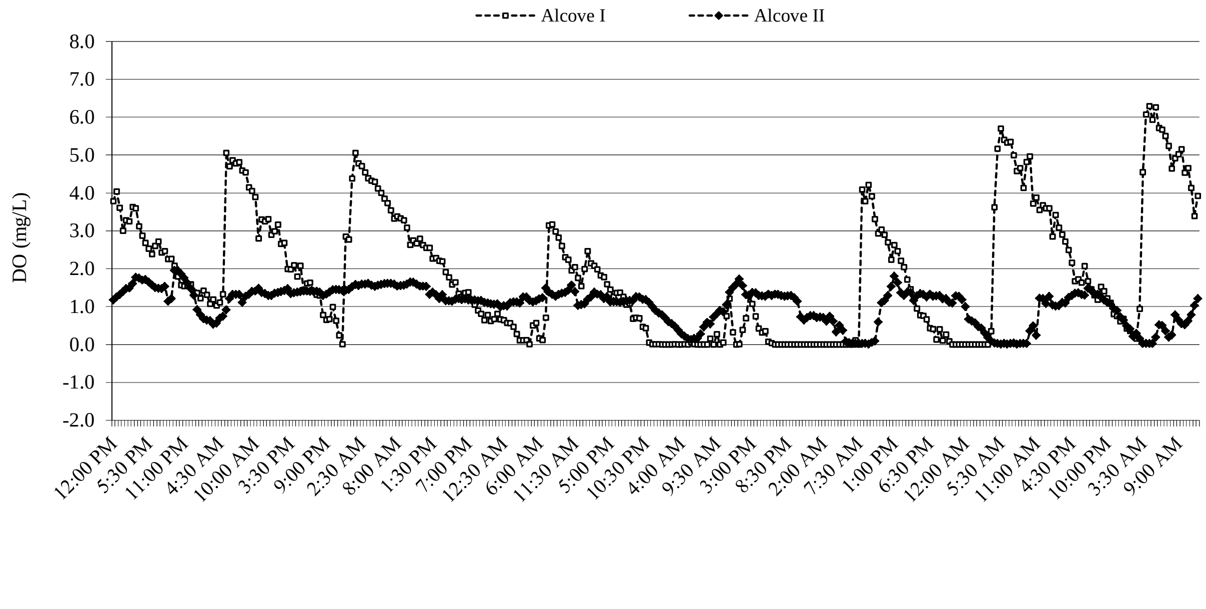


Figure 31. Water quality data collected in McGarvey Creek Alcoves I-II - January 14-28, 2013.



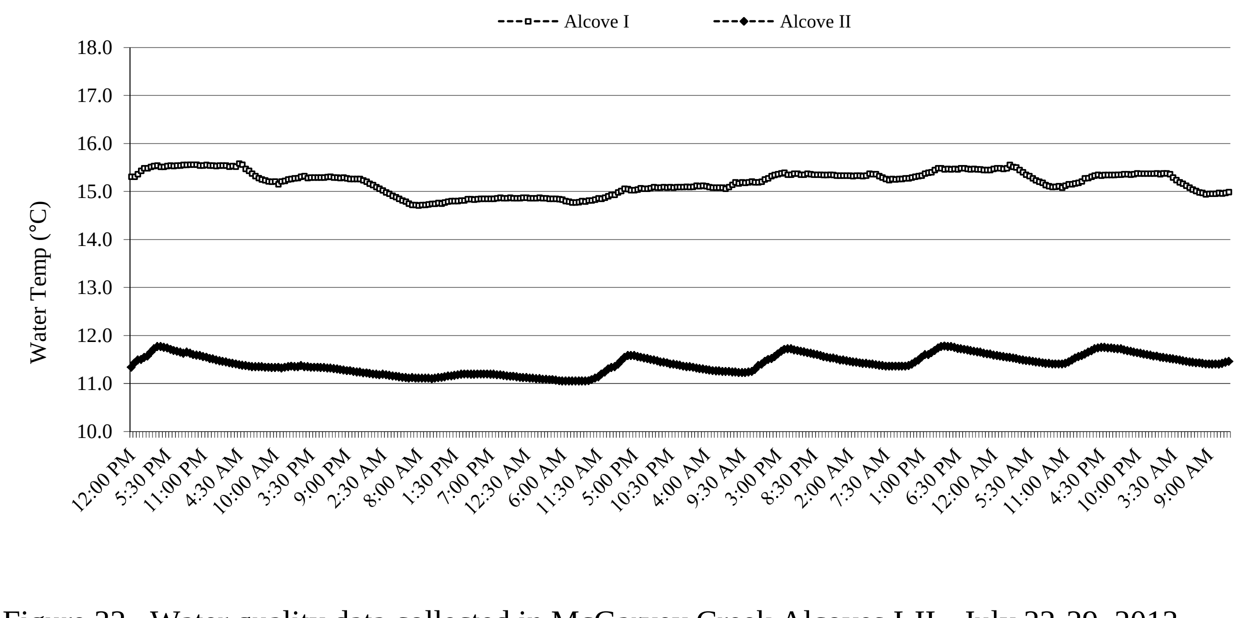


Figure 32. Water quality data collected in McGarvey Creek Alcoves I-II - July 22-29, 2013.

Appendix A. Photo-Monitoring of Habitat Enhancement (Constructed Wood Jams – CWJs and Alcoves II-III), Lower McGarvey Creek: 2012-2013

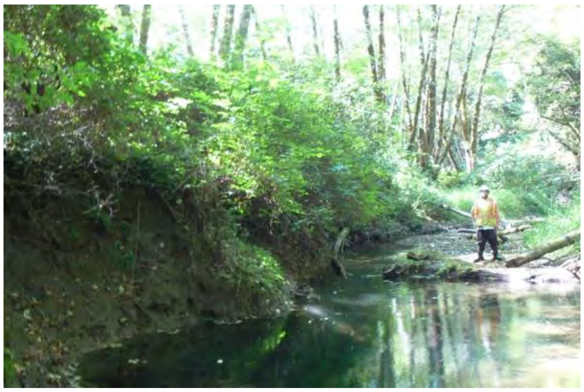
A  B 

Photo-Site McG2012_A-1: Looking upstream at McGarvey Alcove II confluence prior to construction (A. Right - 09/10/12) and following construction (B. Left - 02/19/14).

A  B 

Photo-Site McG2012_B-1: McGarvey Alcove II prior to construction (A. Right - 09/10/12) and following construction (B. Left - 02/19/14).

A  B 

Photo-Site McG2012_B-2: McGarvey Alcove II prior to construction (A. Right - 09/10/12) and following construction (B. Left - 02/19/14).

A  B 

Photo-Site McG2012_B-3: McGarvey Alcove II prior to construction (A. Right - 09/10/12) and following construction (B. Left - 02/19/14).

A  B 

Photo-Site McG2012_C-1: Looking towards McGarvey Alcove II confluence prior to construction (A. Right - 09/10/12) and following construction (B. Left - 02/19/14).

A. B.

C. D.

Photo-Site McG2012_D-1: Looking towards 2012 constructed wood jams following construction (A: 11/13/12; B: 03/13/13; C – 02/19/14; D – 02/26/14).

Photo-Site McG2013_A-1: Looking upstream at 2013 CWJ Site 1 pre-construction (10/09/13).

Photo-Site McG2013_A-1: Looking upstream at 2013 CWJ Site 1 post-construction (11/20/13).

Photo-Site McG2013_A-1: Looking upstream at 2013 CWJ Site 1 post-construction (02/10/14).

Photo-Site McG2013_A-1: Looking upstream at 2013 CWJ Site 1 post-construction (02/19/14).

Photo-Site McG2013_B-1: Looking downstream at 2013 CWJ Sites 3-5 pre-project (10/06/13).

Photo-Site McG2013_B-1: 2013 CWJ Sites 3-5 post-construction (10/06/13).

Photo-Site McG2013_B-1: 2013 CWJ Sites 3-5 post-construction (11/20/13).

Photo-Site McG2013_B-1: 2013 CWJ Sites 3-5 post-construction (02/10/14).

Photo-Site McG2013_B-1: 2013 CWJ Sites 3-5 post-construction (02/19/14).

Photo-Site McG2013_B-1: 2013 CWJ Sites 3-5 post-construction (02/26/14).

Photo-Site McG2013_C-1: Facing right bank towards 2013 CWJ Site 5 pre-project (10/06/13).

Photo-Site McG2013_C-1: 2013 CWJ Site 5 post-construction (10/06/13).

Photo-Site McG2013_C-1: 2013 CWJ Site 5 post-construction (11/20/13).

Photo-Site McG2013_C-1: 2013 CWJ Site 5 post-construction (02/10/14).

Photo-Site McG2013_C-1: 2013 CWJ Site 5 post-construction (02/19/14).

Photo-Site McG2013_D-1: Facing left bank towards 2013 CWJ Site 6 post-construction (11/20/13).

Photo-Site McG2013_D-1: 2013 CWJ Site 6 post-construction (02/10/14).

Photo-Site McG2013_D-1: 2013 CWJ Site 6 post-construction (02/19/14).

Photo-Site McG2013_D-2: Looking downstream at 2013 CWJ Site 7 post-construction (11/20/13).

Photo-Site McG2013_D-2: 2013 CWJ Site 7 post-construction (02/10/14).

Photo-Site McG2013_D-2: 2013 CWJ Site 7 post-construction (02/19/14).

Photo-Site McG2013_E-1: Facing right bank towards 2013 CWJ Site 8 post-construction (11/20/13).

Photo-Site McG2013_E-1: 2013 CWJ Site 8 post-construction (02/10/14).

Photo-Site McG2013_E-1: 2013 CWJ Site 8 post-construction (02/19/14).

Photo-Site McG2013_F-1: Looking downstream at 2013 CWJ Sites 10-12 pre-project (10/05/13).

Photo-Site McG2013_F-1: 2013 CWJ Sites 10-12 post-construction (10/05/13).


Photo-Site McG2013_F-1: 2013 CWJ Sites 10-12 post-construction (11/20/13).


Photo-Site McG2013_F-1: 2013 CWJ Sites 10-12 post-construction (02/10/14).

Photo-Site McG2013_F-1: 2013 CWJ Sites 10-12 post-construction (02/19/14).

Photo-Site McG2013_G-1: Looking upstream at 2013 CWJ Sites 9-10 during construction (10/05/13).

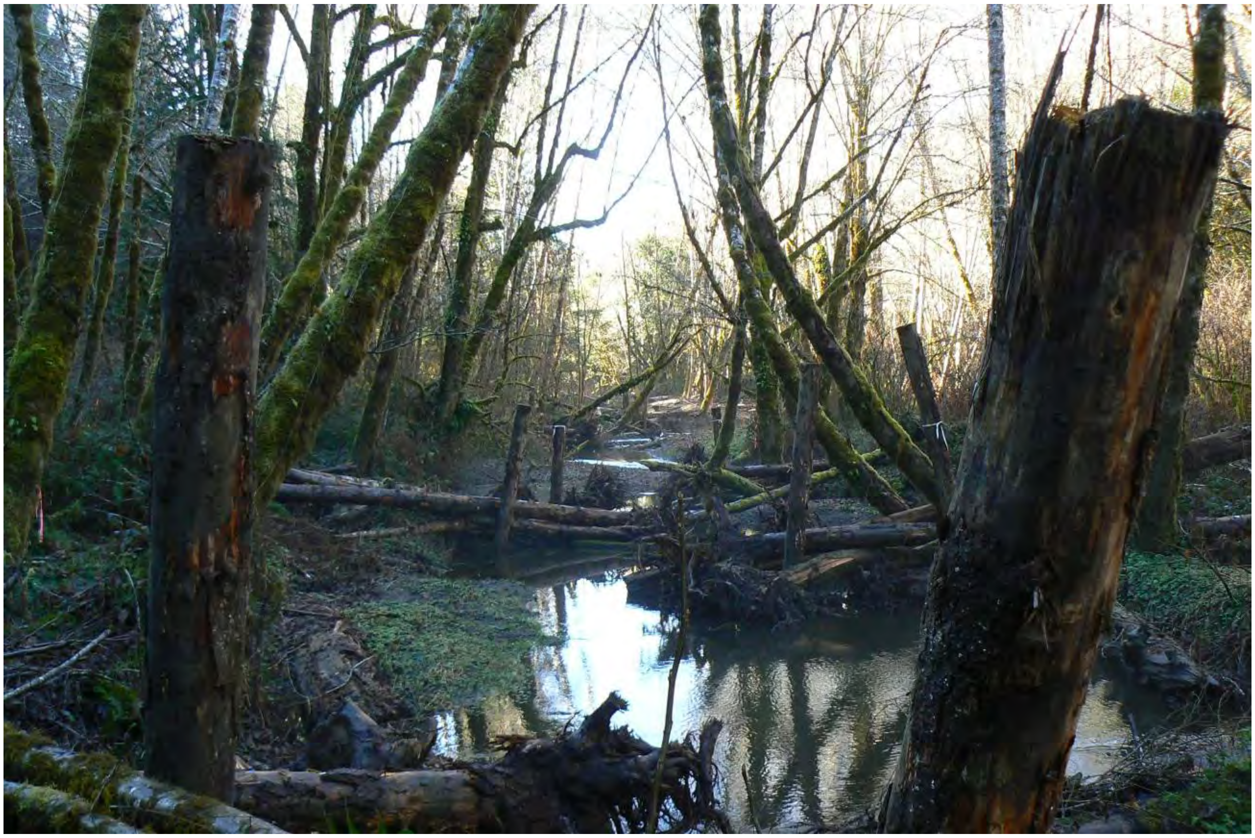


Photo-Site McG2013_G-1: 2013 CWJ Sites 9-10 post-construction (01/16/14).

Photo-Site McG2013_G-1: 2013 CWJ Sites 9-10 post-construction (02/10/14).

Photo-Site McG2013_G-1: 2013 CWJ Sites 9-10 post-construction (02/10/14).

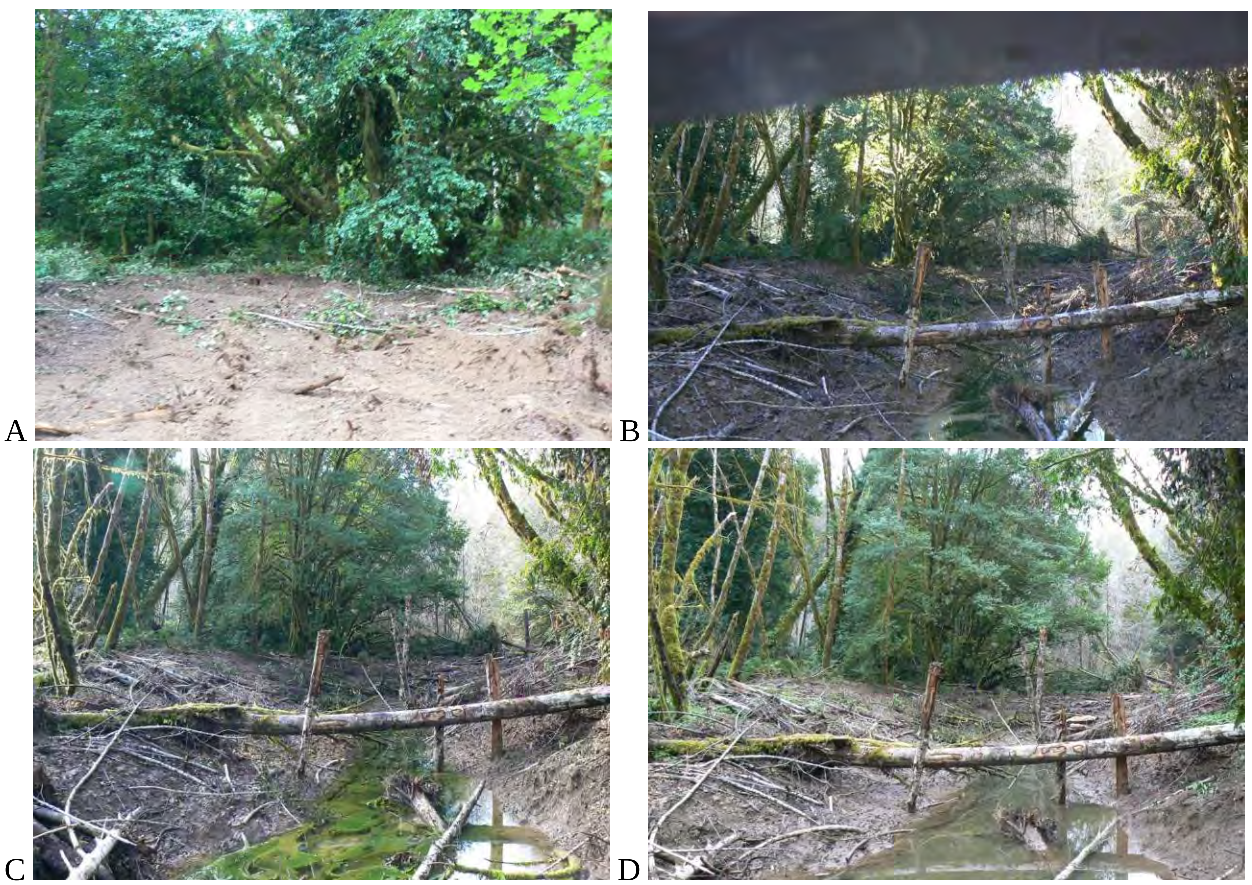


Photo site McG2013_B-2 of Alcove III (A - 09/17/13, B - 01/16/14, C - 02/10/14, D - 02/19/14).

A  B 

C  D 

Photo site McG_C-2 of Alcove III (A - 09/17/13, B - 01/16/14, C - 2/10/2014, D - 02/19/14).