OWEB Grant # 211-2046-8951:

Wolf Creek In-stream EM, Final Project Completion Report

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March 29, 2013

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Introduction

The Oregon Department of Fish and Wildlife (ODFW) Umpqua Watershed District joined with the Partnership for the Umpqua Rivers (PUR) and Roseburg Bureau of Land Management (BLM) in an effort to continue ongoing fish population monitoring within the Umpqua Basin. Since little is empirically known about stream specific limiting factors and fish production response to various habitat restoration treatments such as log or boulder placement, these long term data sets will help to understand fish response related to or resulting from habitat restoration projects. The goals of this partnership are to: 1) gather additional information regarding the anadromous salmonid response to various land management practices; 2) monitor coho salmon trends in response to habitat enhancement work. To accomplish this, ODFW, BLM, PUR and Oregon State University (OSU) have been conducting surveys that observe life history traits which include: summer parr densities, habitat surveys, and adult spawning salmonid surveys in various Umpqua River tributaries.

Monitoring work was conducted throughout the Wolf Creek basin to gather biological data. The installation of in-stream structures is made with the assumption that if physical habitat is improved, the result will be increased salmonid densities as long as enough of the correct type of habitat is modified. Wolf Creek basin was targeted for habitat enhancement projects, habitat surveys, summer seeding surveys, stream temperature data logging at log structures and adult spawning salmon surveys. An additional graduate student study by Rosalinda Gonzales and Steven Clark at Oregon State University (OSU) is being conducted to quantify post restoration attributes. Their work is designed to describe the link between coho redd locations and substrate changes within reaches of Little Wolf Creek and also look at larval lamprey and juvenile coho rearing. Results from Steve Clark's graduate research project are expected to be available in April

2013 and results from Rosalinda Gonzales' work are expected in December 2013 and will be available at http://osulibrary.oregonstate.edu.

In-stream habitat restoration projects in the Little Wolf Creek and Wolf Creek Basins have been taking place off and on since 1992, with a recent surge of projects from 2008 to 2012 (Figure 1). Both log and boulder structures have been placed by ODFW, PUR and BLM in the mainstem and tributaries of Little Wolf and Wolf Creek. Habitat enhancement projects (boulder and log structures) have been implemented within the Little Wolf Creek and Wolf Creek basins in 2008 and 2009 (Figure 2). Helicopter log placement in upper Wolf Creek basin took place in 2011. In 2012, partners went in and finished restoring a few additional Wolf Creek reaches. In total, partners on this project have restored 13.0 miles of stream habitat which includes 185 in-stream restoration sites, 1450 logs, 6500 boulders, and three culvert replacements.

In order to gain more insight as to whether or not restoration efforts improve fish populations and address limiting factors in this basin, baseline and post treatment surveys are needed. These recent restoration projects provided a unique opportunity to examine stream and fish responses to log-only and boulder-only in-stream placements. However, limited pre-treatment data exists on these streams for smolt outmigration, summer habitat, spawning adults, summer seeding, channel cross-sections and temperature.

The Oregon Coastal Coho Salmon population of coho salmon are federally listed as threatened, designated a single Evolutionarily Significant Unit (ESU), and have received a great deal of attention by the State of Oregon, federal agencies, and local and private organizations. The formation of the Oregon Plan for Salmon and Watersheds in 1997 prompted extensive conservation efforts by government agencies and nongovernmental entities to restore fish populations throughout Oregon, including those coho salmon populations which constitute the Oregon Coastal Coho ESU. Coho salmon in Wolf Creek basin are considered part of the Middle Umpqua population unit, a smaller monitoring area within the Oregon Coastal Coho ESU, and have been the focus of significant restoration efforts in recent years.

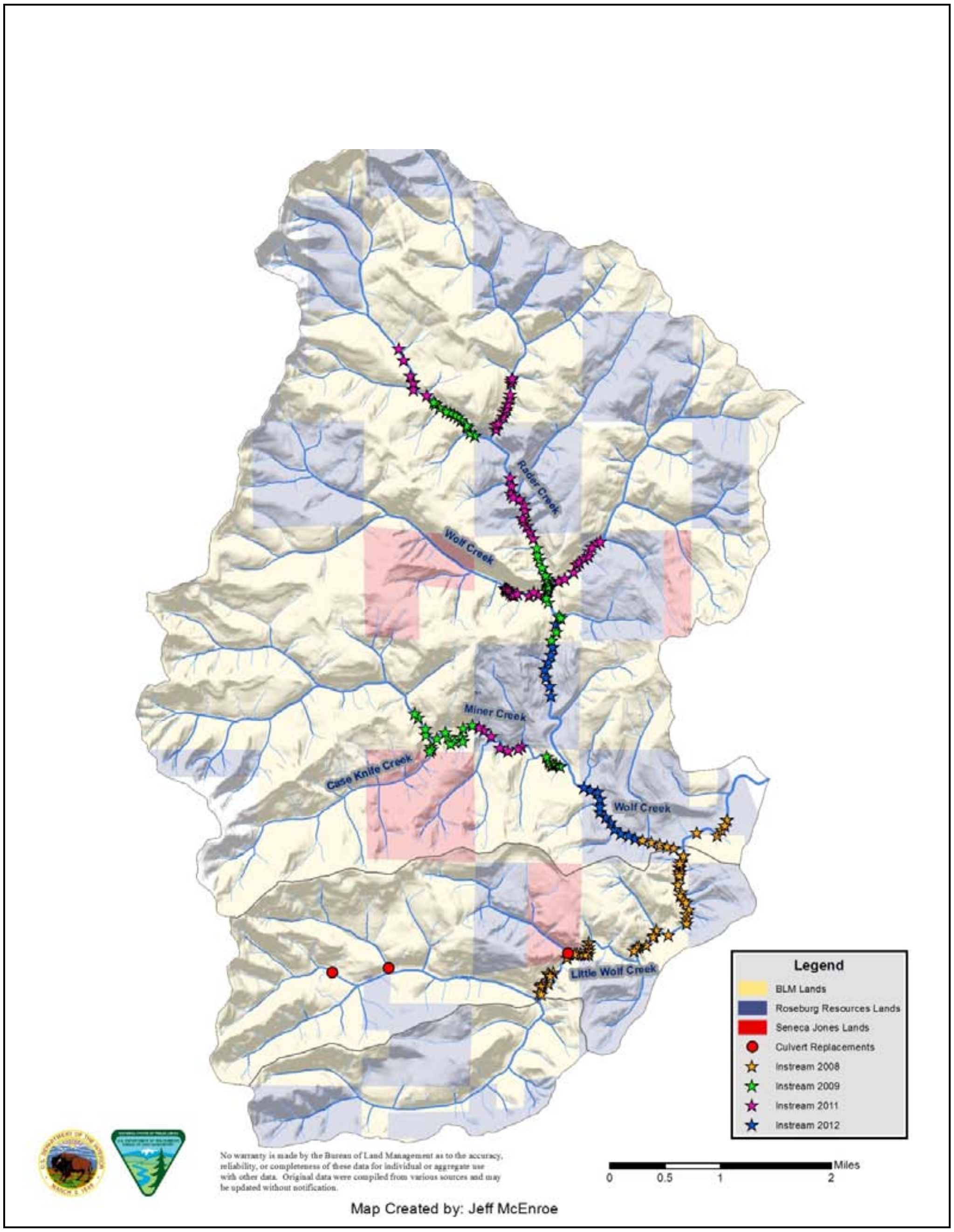

Figure 1. Locations of in-stream habitat restoration projects in Wolf Creek basin from 2008-2012.

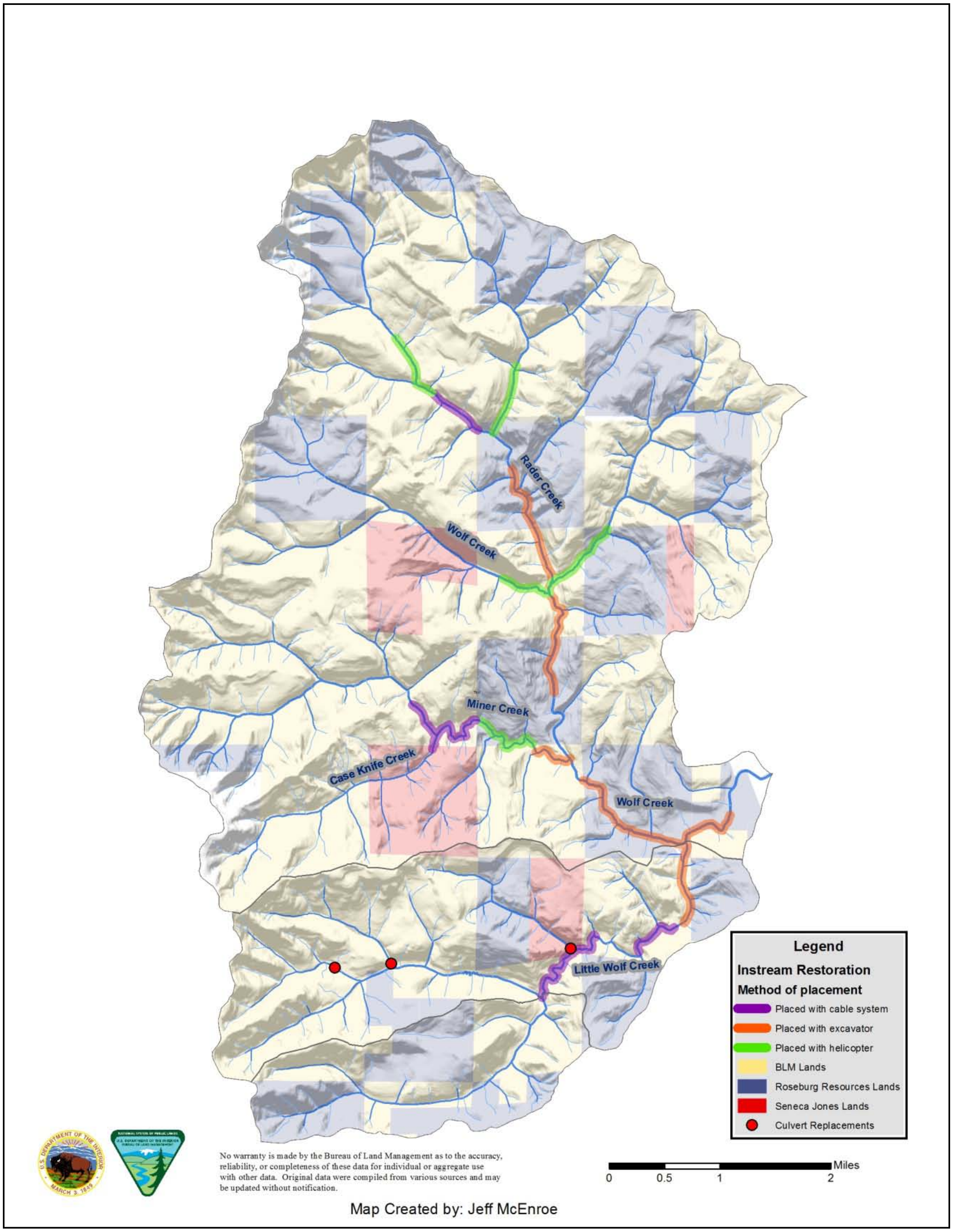

Figure 2. In-stream restoration in Wolf Basin by method of placement, 2008-2012.

Study Area

Wolf Creek Watershed

Wolf Creek is a direct tributary to the mainstem Umpqua River, located approximately 14 miles south of the town of Elkton. This 6th field watershed has a total drainage area of approximately 23,500 acres. Salmonid fish species that inhabit Wolf Creek watershed include fall chinook salmon, coho salmon, winter steelhead trout, and cutthroat trout. Coho salmon and winter steelhead spawn in many of the watershed's major tributaries.

Methods

Seeding Surveys

From 2008-2012, surveyors snorkeled both control and treatment seeding sites on mainstem and tributary reaches in Wolf Creek and Little Wolf Creek. Most standard sites were initially set up as 1000 meter reaches. Only pools that were greater than six square meters in surface area and at least 0.40 meters deep were surveyed. For each pool surveyed, pool length in meters from tail out to pool head, mean width in meters, max depth in meters, and water temperature were recorded. Each reach was sampled by the same surveyor to reduce between observer biases. Surveyors snorkeled each pool from the tail out up to the head, targeting counts of coho salmon but also recorded other species when reasonable.

Summer pool coho seeding density is calculated based on number of fish per square meter per pool, then averaged for all pools per reach. Snorkel data is reported here as raw, unexpanded number of fish observed.

Spawning Surveys

In the summer of 2007, PUR staff conducted habitat surveys through the entire Wolf Creek Basin following ODFW habitat typing protocols (Aquatic Inventories Project 2007). During these field operations, Wolf Creek Basin was broken into twenty seven individual stream reaches (approximately 18.1 mi) to conduct spawning surveys on based on channel morphology and other guidelines described in the ODFW habitat typing protocol.

The intent of these initial set up surveys was to ensure that all coho salmon spawning habitat in the Wolf Creek basin was surveyed. The twenty seven stream reaches delineated in 2007 were deemed to be suitable coho salmon habitat and were surveyed for spawning fish once every ten days throughout the entire coho salmon spawning seasons from 2007 thru January 2013. Meanwhile, Little Wolf Creek basin was divided into seven standard reaches and surveyed by BLM staff.

Corvallis ODFW's Oregon Adult Salmonid Inventory & Sampling (OASIS) project was consulted annually to make sure that no survey was duplicated since they also conduct random coho spawning ground surveys in Wolf Creek basin. If one of the surveys from this project was being sampled by the OASIS staff, we would not survey that year and simply acquired the data from OASIS for AUC (area under the curve) calculations. Surveys were conducted following the ODFW OASIS protocol (OASIS 2007), except for: no lengths or fish activity were recorded and no biological samples were taken. While the presence of chinook salmon and steelhead were recorded, primary data was only collected on coho salmon. To determine the end of the coho salmon spawning season and ensure a representative sample throughout the duration of the run, surveys were conducted until two weeks after the last live fish was observed in each stream reach. To reduce individual surveyor bias, the two person team alternated surveying the reaches each week throughout the spawning season. Prior to field investigations, landowners were contacted to gain permission to walk the streams that ran through their property.

All live coho salmon were tallied per reach each survey day. Coho salmon were visually observed to either have an adipose fin or not and were recorded as unmarked (UnMA) or marked (MkA) respectively. Fish that were observed and identified but the presence of an adipose fin was undetermined, were recorded as an unknown (UnKA). Live jack coho salmon were also recorded. All coho salmon carcasses encountered were sexed as either male or female and if this could not be determined, they were recorded as an unknown (UnK). The caudal fins of all handled carcasses were completely removed to identify the fish as being previously counted. Subsequent surveys identified carcasses as either a new fish or a previously handled adult or jack (PHA or PHJ).

Stream surveys were broken down into three separate categories with regards to water clarity. The classification of a "one" indicated that the entire water column was visible. The classification of a "two" indicated that some or all of the pools were clouded to an extent beyond clear visual inspection but riffles and pool crest were clear. The classification of a "three" meant that water quality prevented any visual inspection of the survey reaches. The weather was also recorded for each reach, being labeled as either clear (C), overcast (O), foggy (F), rain (R), snow (S) or partly cloudy (P). For each reach during every survey, the streams flow was described as either low, moderate, high or flooding. Only surveys that had a visibility ranking of a "one" or "two" were included in AUC estimates.

The goal for frequency of sampling each reach is to keep every survey within a ten day rotation. By surveying every ten days, staff count fish throughout the season to ensure a peak count is recorded for each survey (barring any floods or visibility "three" surveys). Since 11.3 days represents the average spawning life for coho salmon in survey streams (Willis 1954, Beidler and Nickelson 1980, and Perrin and Irvine 1990), surveying within a ten day rotation [in theory] avoids missing any fish in each reach as long as the surveyor had ideal viewing conditions.

For every survey in each reach, all redds were recorded. Redds were recounted throughout the survey season as long as they were still completely discernible. Beginning in 2010, redds in Wolf Creek and tributaries were marked with flags that contained the date in which the redd was first observed. After the survey season was over, the location of each redd was recorded using GPS (NAD 83, accuracy <15 ft) by standing as close as possible to each actual redd location without damaging the redd. The survey mileage for each reach was then calculated by selecting the survey reach on the stream layer and summing the shape length in meters, then converting to miles.

To estimate coho abundance, an AUC was calculated each year for every survey reach. First, the estimated number of coho within each survey between survey dates was calculated by averaging the total number of coho observed (adults and jacks) in two successive surveys multiplied by the number of days between the surveys.

The following equation represents the calculation for the estimated number of coho present during a time period:

$$F = ((C1 + C2)/2)(D)$$

where

F = estimated number of coho salmon present in a survey reach during a time period,

C1 = total number of coho salmon (adults and jacks) observed in one survey,

C2 = total number of coho salmon (adults and jacks) observed in following survey,

D = number of days between the two surveys.

The AUC was then calculated for each survey reach by dividing the season total estimated number of coho salmon present in each reach by 11.3 days and then dividing that total by the visibility factor of 0.75. The 11.3 days represents the average spawning life for coho salmon spawning in survey streams (Willis 1954, Beidler and Nickelson 1980, and Perrin and Irvine 1990). The visibility factor 0.75 is explained by the Mario factor (Solazzi 1984). This was a study that showed surveyors only see 75% of the coho actually present. The estimated spawning density (total coho salmon per mile) was then calculated for each stream reach by dividing the AUC by the stream mileage for each survey reach. The following equation represents the AUC calculation:

$$AUC = (F/L)/V$$

where

F = season total estimated number of coho salmon present within each survey reach,

L = 11.3 = average spawning life in days for coho salmon spawning in survey streams,

V = 0.75 = visibility factor.

Basin AUC was calculated by summing AUC estimates for each reach. Basin estimated spawning density (total coho salmon per mile) was also calculated by dividing the basin AUC by the total stream mileage of all the survey reaches. The AUC calculations used in this project were similar to Corvallis OASIS protocol except that we included all surveys in the estimate where Corvallis discards surveys that have more than one gap of 12-15 days between surveys or have any gaps over 16 days.

Habitat Mapping

Aquatic Riparian Effectiveness Monitoring crews (AREMP) used total station survey equipment to map habitat changes in Little Wolf Creek as a result of in-stream restoration. Four study reaches were identified. 1.) A **reference** reach (i.e. Control – High Quality) where existing habitat quality is in very good condition. 2.) A **control** reach (i.e. Control – Low Quality) where the channel is dominated by bedrock and the existing aquatic habitat is in poor condition. Both these reaches were left as control reaches with no in-stream restoration work. 3.) **Treatment Reach 1** (Upper treatment reach) contains a channel which was dominated by bedrock but did have some gravel and cobble substrate and was considered in moderately poor condition. In-stream restoration was implemented in this reach in 2008. 4.) **Treatment Reach 2** (Lower treatment reach) contains a channel which was dominated by bedrock with very little to no gravel or cobble substrate. This reach was considered in very poor condition. In-stream restoration was also implanted in this reach in 2008. Both treatment reaches are downstream of the control reaches (Figure 3). Each study reach was approximately 300 meters (1000 feet) in length. Survey crews mapped natural and placed large wood, debris jams, thalwag, wetted width, pools, and substrate type (bedrock, gravel, sand, and mixed bed load) in each reach.

The reaches were surveyed in 2008 right after the initial in-stream restoration took place to map pre-restoration conditions and placed log locations. Post restoration surveys were conducted in 2009 and 2012. Future surveys are planned every 3-5 years depending on funding.

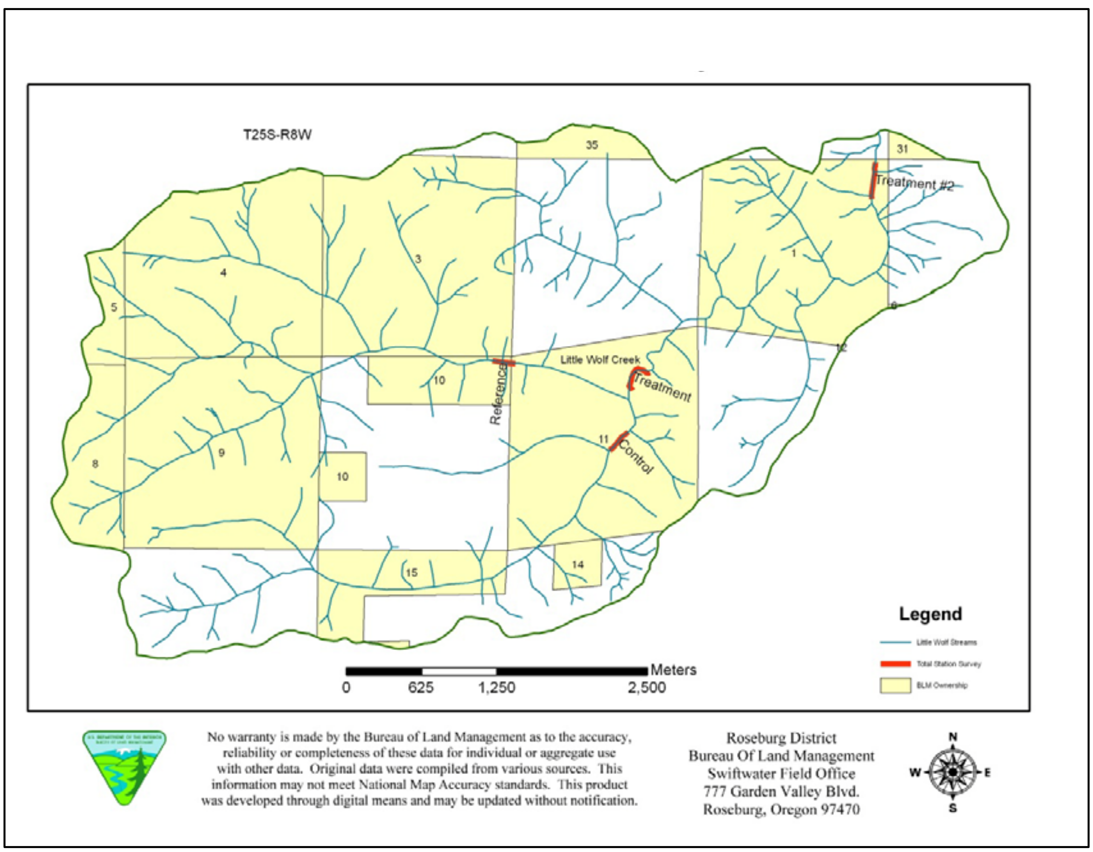

Figure 3: Map of total station survey reaches in Little Wolf Creek.

Results

Seeding Surveys

Pools were surveyed in late summer from 2007-2012 by field staff that were experienced and trained in conducting snorkel surveys and identification of juvenile salmonids. Seven standard reaches in Wolf Creek basin (Figure 4) were surveyed by ODFW, while BLM partners surveyed four standard reaches on Little Wolf Creek annually.

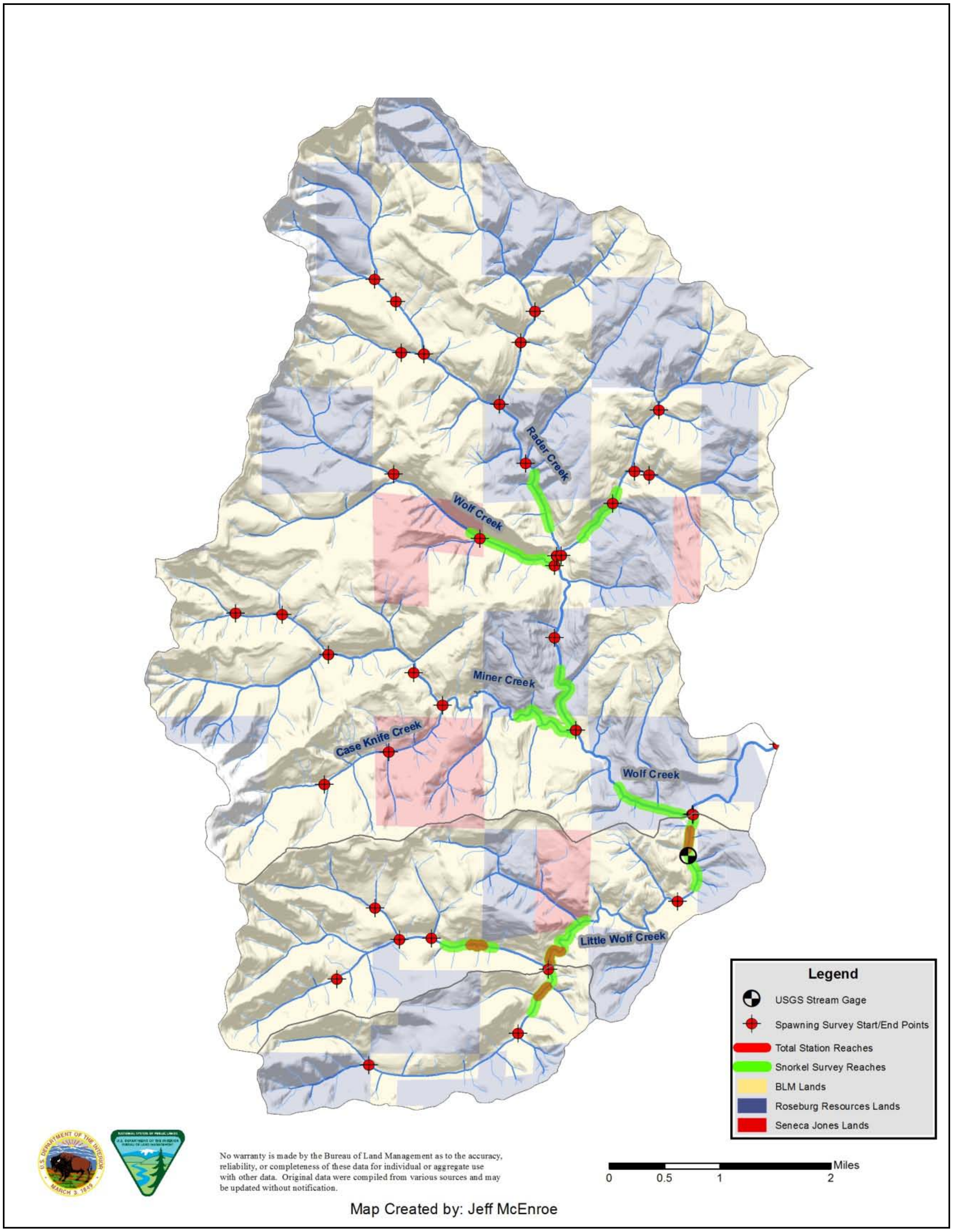

Figure 4. Summer pool snorkel standard reaches and spawning ground survey standard reaches in Wolf Creek basin.

Wolf Creek snorkel surveys have been completed during 2007-2012 on seven standard reaches (Figure 4). Surveys in 2008 were conducted in late September on a total of 142 pools. 2009 surveys were conducted in early September on a total of 142 pools. In 2010, surveys were conducted in early September on a total of 127 pools. Surveys in 2011 were conducted in August on a total of 134 pools. Surveys in 2012 were conducted in mid August on 144 pools. Differences in number of pools surveyed each year are due to how many pools meet the minimum survey criteria in each reach from year to year which can depend on summer flows and changes in-stream form.

During 2007-12, treatment reaches in Wolf Creek basin (Figure 5) did not show significant differences in pre and post treatment coho abundance based on paired t-test results. The only reach that was close to having a significant difference was Miner reach 1 which showed an almost significant (p=0.0744) decrease in abundance from pre to post treatment coho densities. Overall coho densities (Table 1) in all reaches except for Wolf Creek Reach 1 decreased in summer 2010. Wolf Creek Reach 4 has consistently been the highest seeded reach of those surveyed except in 2012 when the restored Wolf Creek reach 3 surpassed it by 0.2 coho/ m^2. Four of the seven reaches have reached fully seeded levels (>0.7 coho/m^2) based on Rodgers et al. (1992) in two or more years during the project. However, all of these reaches were already fully seeded prior to restoration.

Figure 6 shows seeding densities for coho in four standard Little Wolf Creek basin reaches from surveys conducted by BLM. Seeding levels increased significantly in Treatments #1 and moderately in Treatment #2 after restoration was completed in 2009. Prior to 2012, three of the reaches were fully seeded every summer since 2009 and as of 2012 all reaches are fully seeded for the first time.

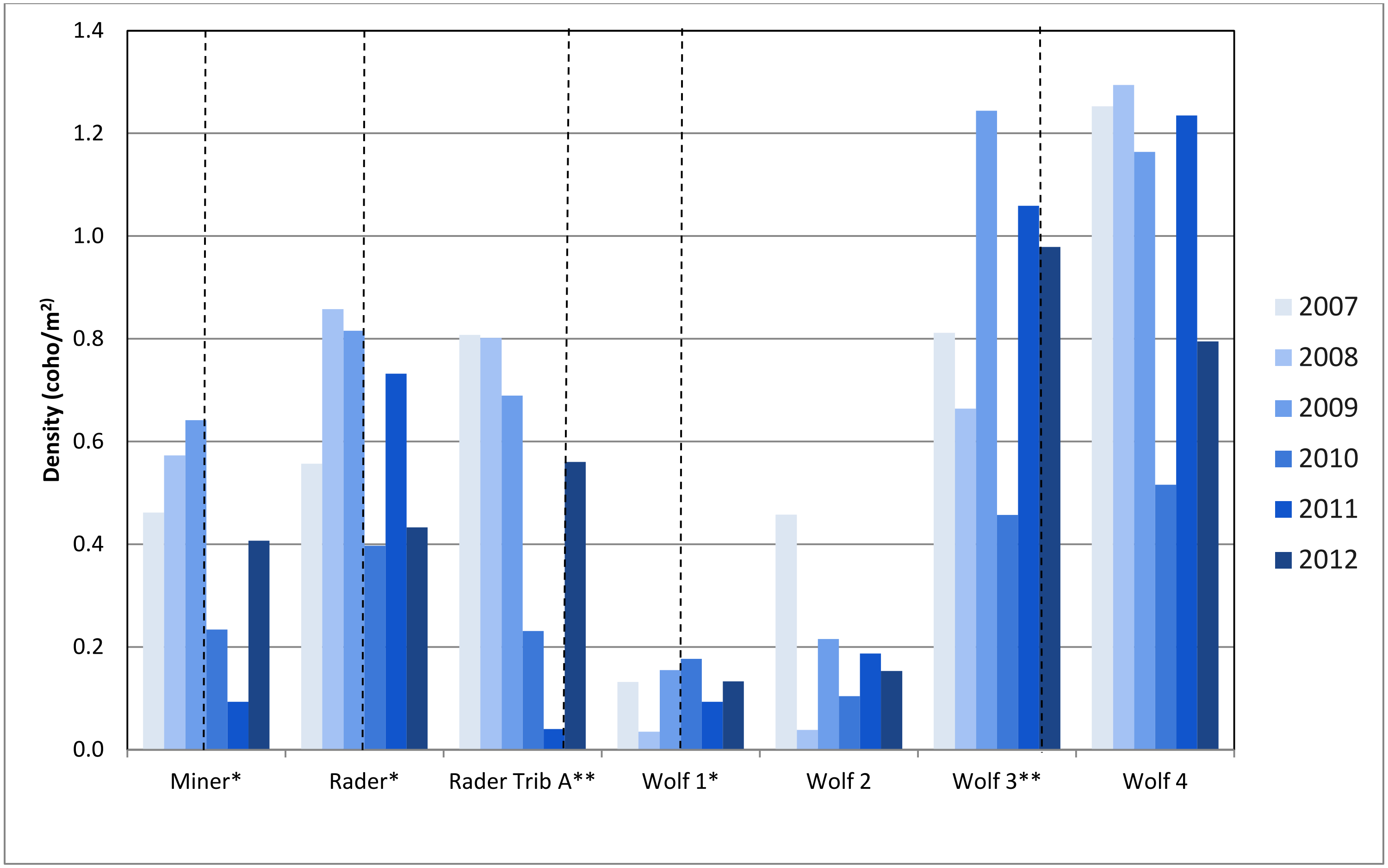

Figure 5. Wolf Creek seeding data from 2007-2012 by reach. Reaches labeled with an asterisk indicate restoration reaches with year of restoration marked with a vertical dashed line.

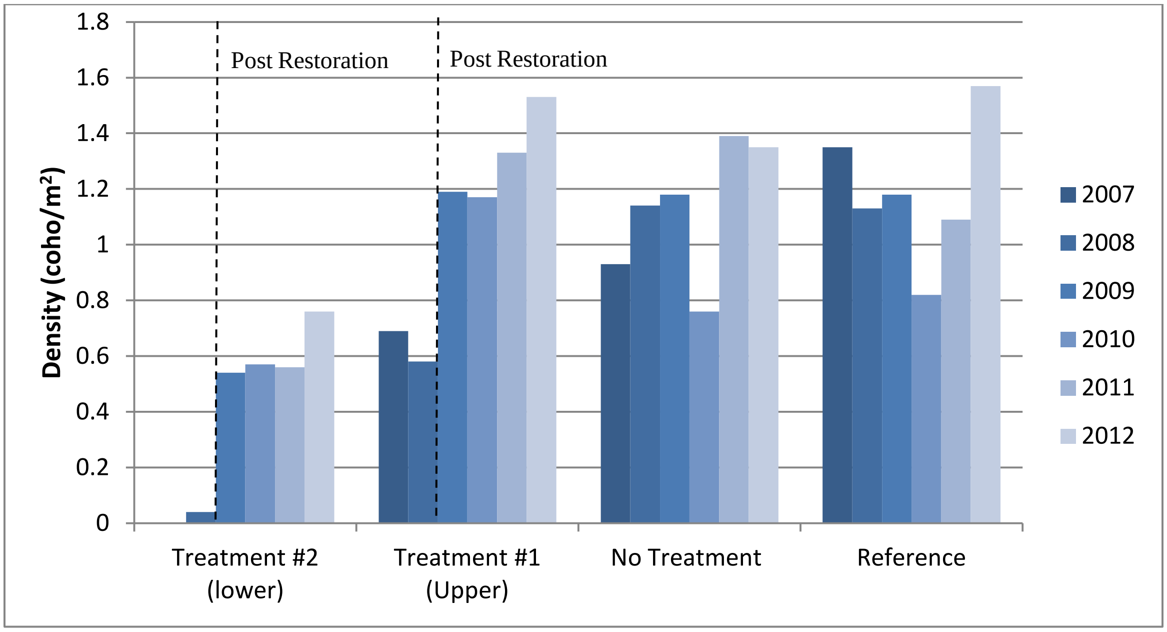

Figure 6. Little Wolf Creek Seeding data, 2007-2012. Restoration was done in 2008-9 on reaches Treatment #1 and Treatment #2. Surveys were not conducted in 2007 on Treatment #2.

Table 1. Coho seeding densities (coho/m^2) observed in Wolf and Little Wolf Creek basin juvenile snorkel surveys from 2007-2012. Reaches with in-stream restoration are highlighted by year of restoration.

	2007	2008	2009	2010	2011	2012
Miner	0.462	0.573	0.642	0.234	0.093	0.407
Rader	0.557	0.858	0.816	0.397	0.732	0.433
Rader Trib A	0.807	0.802	0.69	0.231	0.040	0.56
Wolf 1	0.132	0.035	0.155	0.177	0.093	0.133
Wolf 2	0.458	0.038	0.215	0.104	0.187	0.153
Wolf 3	0.812	0.664	1.244	0.457	1.059	0.979
Wolf 4	1.253	1.294	1.164	0.516	1.235	0.795
Little Wolf Treatment 1		0.040	0.540	0.570	0.560	0.760
Little Wolf Treatment 2	0.690	0.580	1.190	1.170	1.330	1.530
Little Wolf- No Treatment	0.930	1.140	1.180	0.760	1.390	1.350
Little Wolf- Reference	1.350	1.130	1.180	0.820	1.090	1.570

Spawning Surveys

Spawning surveys were conducted on this project annually from fall 2007 through January 2013. Wolf Creek reach locations and acronyms (Table 2) are visible in Figure 7, and varied year to year depending on what surveys Corvallis ODFW OASIS was sampling for each year. PUR staff conducted the majority of the surveys in Wolf Creek basin while ODFW OASIS staff surveyed Wolf Creek Reach 3 in 2011-12, and Wolf Creek Reaches 3 & 5 in 2012-13. BLM staff annually surveys six reaches in Little Wolf Creek basin (Figure 8), along with a newly established survey in a tributary to reach 4. Results are presented by year for both Wolf Creek and Little Wolf Creek AUC estimates (Table 3 & 4) and a Wolf Creek peak redd table is available in Appendix 1.

2012 was expected to be an exciting year for the project as spawners that used new habitat in Little Wolf Creek and Wolf Creek during 2009 would have their first generation of offspring returning during this year. However, due to a low water and low run year, we did not see the high numbers of fish we hoped to see using reaches with in-stream restoration to spawn. The total escapement estimate for Wolf Creek basin was 2,698 coho in 2011-12 and 196 in 2012-13. Corvallis OASIS project estimated the Middle Umpqua population at 19,962 coho in 2011-12 and a preliminary estimate of 2,352 for 2012-13. In 2012, overall escapement was 7% of 2011-12 returns in Wolf Creek and 11% of 2011-12 returns in Middle Umpqua population, so we did not see Wolf Creek basin improve on percent of returns to the basin in a low abundance year. Little Wolf basin contributed 25% of the total basin estimated spawners in 2011 and 38% of the spawners in 2012.

Throughout the years of this study, big mainstem habitat (reaches W1, W2, W3, W4, LW1) spawning has accounted for an average of 9.3% (range: 2-26%) of total spawners while tributary spawning accounted for an average of 90.7% (range: 73.6-98%) of spawners. Flows were recorded at Little Wolf USGS gauging station and are reported in Figure 9.

Table 2. Acronyms from Figure 6 associated with spawning ground survey reach names.

Start/End	Survey name
W1	Wolf Creek Reach 1
W2	Wolf Creek Reach 2
W3	Wolf Creek Reach 3
W4	Wolf Creek Reach 4
W5	Wolf Creek Reach 5
W6	Wolf Creek Reach 6
M1	Miner Creek Reach 1
M2	Miner Creek Reach 2
M3	Miner Creek Reach 3
WC1	Whiskey Camp Creek Reach 1
WC2	Whiskey Camp Creek Reach 2
CK1	Case Knife Creek Reach 1
CK2	Case Knife Creek Reach 2
R1	Rader Creek Reach 1
R2	Rader Creek Reach 2
R3	Rader Creek Reach 3
R4	Rader Creek Reach 4
R5	Rader Creek Reach 5
R6	Rader Creek Reach 6
WF1	West Fork Rader Creek Reach 1
TA1	Rader Creek Tributary A Reach 1
TA2	Rader Creek Tributary A Reach 2
TA3	Rader Creek Tributary A Reach 3
TA4	Rader Creek Tributary A Reach 4
TA5	Rader Creek Tributary A Reach 5
EF1	East Fork Rader Creek Reach 1
EF2	East Fork Rader Creek Reach 2

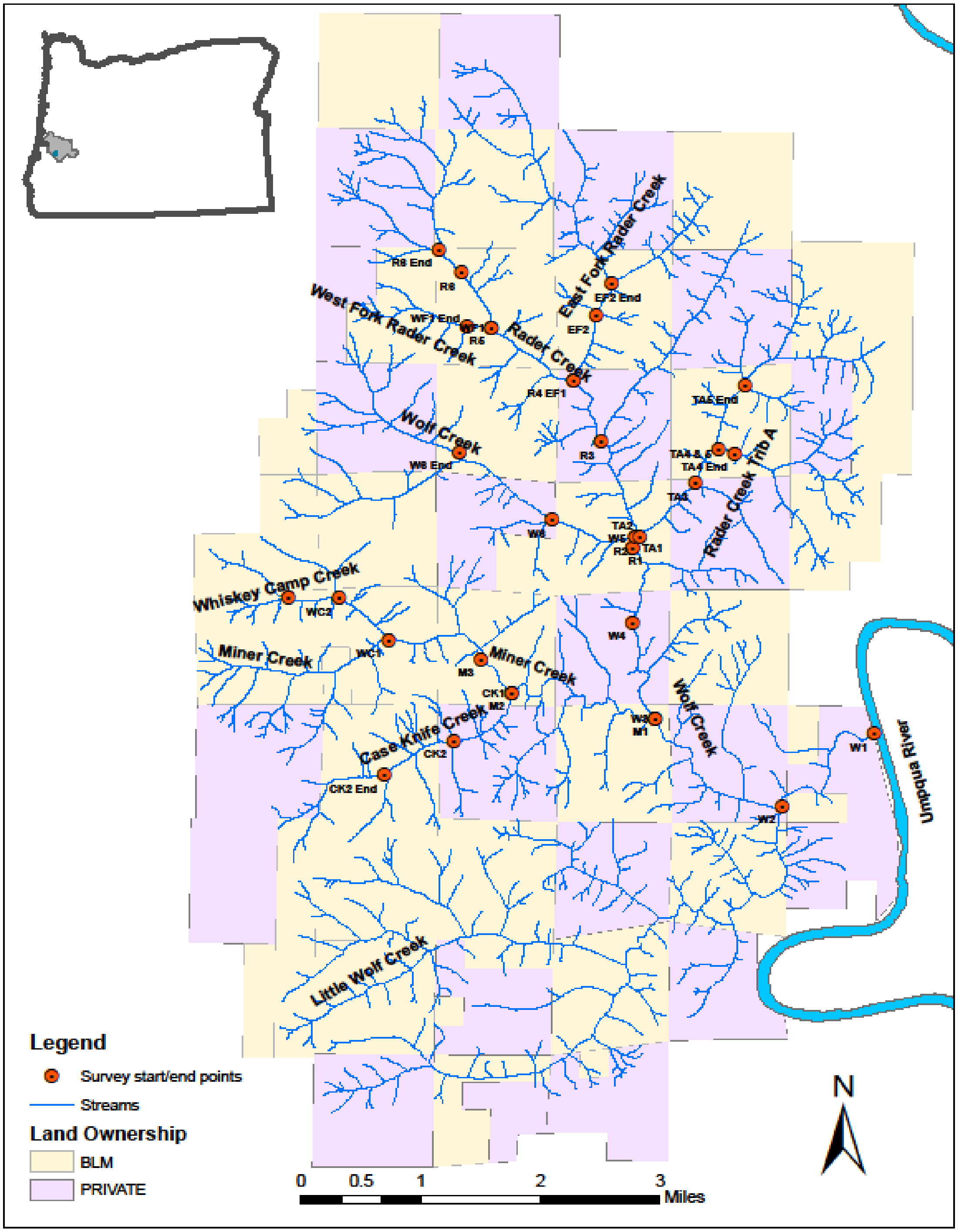

Figure 7. Location of spawning ground surveys in Wolf Creek basin. See Table 2 for description of acronyms.

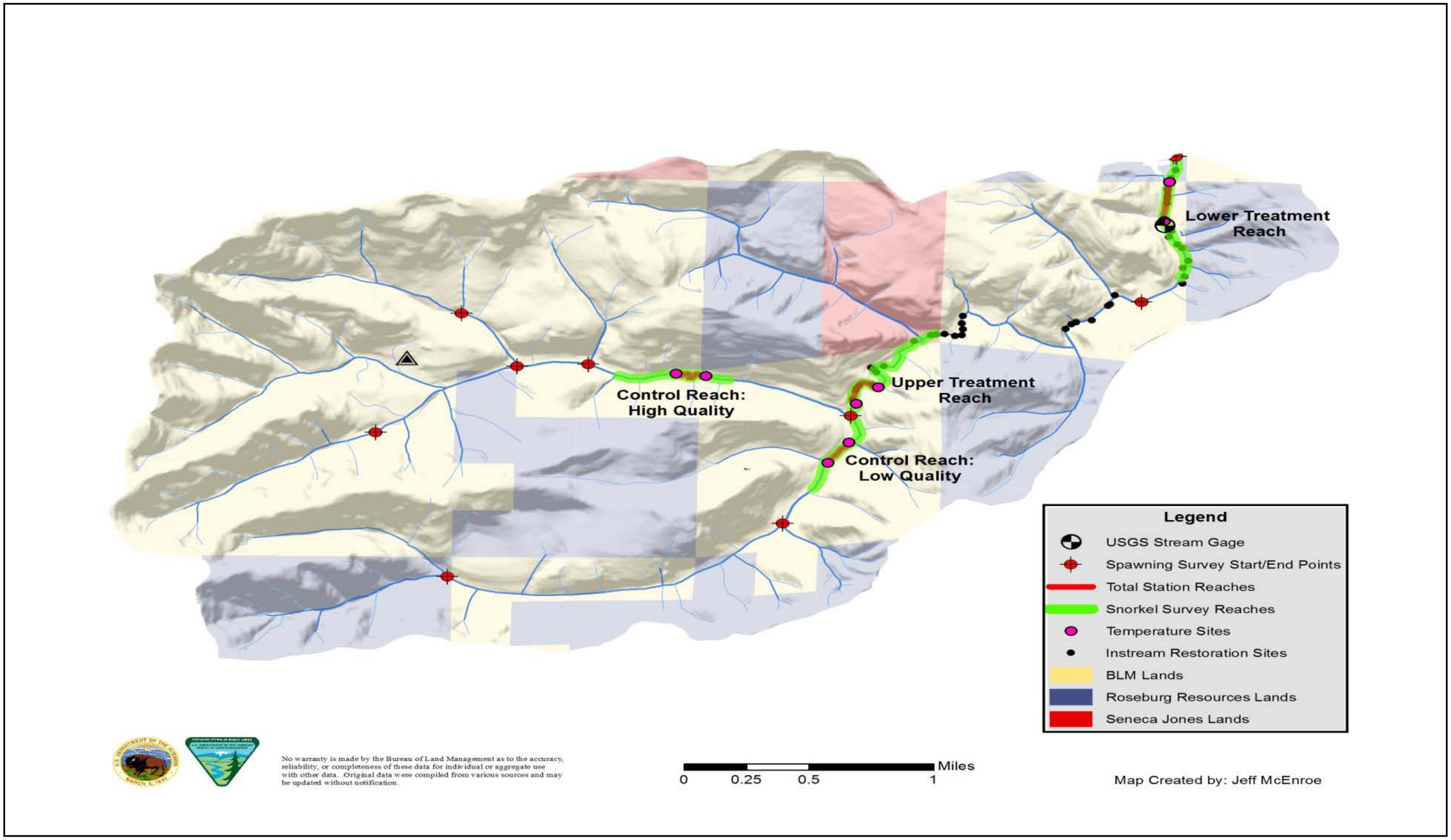

Figure 8. Location of spawning ground surveys in Little Wolf Creek basin.

Table 3. Total Coho Observed, Area Under the Curve (AUC) Escapement Estimate, and estimated coho per mile for Wolf Creek Basin from 2007-2013. Reaches with restoration are highlighted based on when restoration occurred.

	2007-08			2008-09			2009-10			2010-11			2011-12			2012-13			
Survey Reach	Number of Coho Observed	AUC	AUC Coho/Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Reach Mileage
Wolf Creek 1	2	2	1.49	79	74	55.2	10	9	6.7	20	19	14.2	196	202	150.8	1	2	1.5	1.34
Wolf Creek 2	0	0	0.00	6	6	4.0	27	28	18.8	12	35	23.5	187	163	109.4	1	1	0.7	1.49
Wolf Creek 3	0	0	0.00	3	5	5.1	13	15	15.2	6	6	6.1	0	0	0.0	0	0	0.0	0.99
Wolf Creek 4	0	0	0.00	42	39	47.0	24	22	26.5	7	7	8.4	102	88	106.0	1	1	1.2	0.83
Wolf Creek 5	0	0	0.00	1	2	2.7	63	63	86.3	42	41	56.2	122	132	180.8	0	0	0.0	0.73
Wolf Creek 6	0	0	0.00	2	2	2.0	81	83	83.8	63	66	66.7	72	75	75.8	4	4	4.0	0.99
Miner Creek 1	0	0	0.00	3	4	2.2	57	61	34.3	60	74	41.6	159	134	75.3	2	2	1.1	1.78
Miner Creek 2	5	7	16.28	1	2	4.7	41	46	107.0	48	46	107.0	88	121	281.4	4	3	7.0	0.43
Miner Creek 3	0	0	0.00	0	0	0.0	56	63	67.7	34	34	36.6	18	21	22.6	3	3	3.2	0.93
Case Knife Creek 1	7	11	15.94	14	22	31.9	155	121	175.4	150	127	184.1	190	222	321.7	37	33	47.8	0.69
Case Knife Creek 2	2	2	3.03	2	3	4.5	29	22	33.3	34	26	39.4	32	38	57.6	8	8	12.1	0.66
Whiskey Camp Creek 1	NS	NS	NS	0	0	0.0	0	0	0.0	3	3	5.5	5	5	9.1	11	6	10.9	0.55
Whiskey Camp Creek 2	NS	NS	NS	0	0	0.0	0	0	0.0	4	4	9.3	0	0	0.0	2	2	4.7	0.43
Rader Creek 1	1	3	50.00	3	2	33.3	8	7	116.7	1	1	16.7	6	5	83.3	0	0	0.0	0.06
Rader Creek 2	3	9	10.23	10	12	13.6	83	75	85.2	35	42	47.7	132	109	123.9	3	3	3.4	0.88
Rader Creek 3	0	0	0.00	5	8	12.3	119	106	163.1	38	40	61.5	122	130	200.0	2	3	4.6	0.65
Rader Creek 4	1	2	2.33	27	38	44.2	154	133	154.7	148	139	161.6	167	175	203.5	21	15	17.4	0.86
Rader Creek 5	8	8	13.79	5	8	13.8	50	44	75.9	19	18	31.0	73	79	136.2	10	8	13.8	0.58
Rader Creek 6	0	0	0.00	0	0	0.0	5	4	14.3	12	13	46.4	10	9	32.1	2	3	10.7	0.28
West Fork Rader Creek	0	0	0.00	7	12	54.5	9	8	36.4	4	4	18.2	22	21	95.5	10	10	45.5	0.22
Rader Creek Trib A 1	0	0	0.00	0*	0*	0.0	**	**	**	2	2	66.7	6	4	133.3	0	0	0.0	0.03
Rader Creek Trib A 2	0	0	0.00	3	6	9.1	14	17	25.8	45	42	63.6	83	91	137.9	4	5	7.6	0.66
Rader Creek Trib A 3	0	0	0.00	1	2	5.3	23	29	76.3	35	32	84.2	54	55	144.7	0	0	0.0	0.38
Rader Creek Trib A 4	0	0	0.00	0	0	0.0	1	1	6.3	0	0	0.0	17	17	106.3	1	1	6.3	0.16
Rader Creek Trib A 5	9	11	18.64	7	11	18.6	0	0	0.0	68	68	115.3	17	18	30.5	2	2	3.4	0.59
East Fork Rader Creek 1	5	11	18.03	6	5	8.2	44	40	65.6	36	38	62.3	96	78	127.9	3	3	4.9	0.61
East Fork Rader Creek 2	1	3	9.38	5	5	15.6	43	38	118.8	22	24	75.0	28	22	68.8	3	4	12.5	0.32
Totals	44	69	6.37	232	268	14.4	1109	1035	61.3	948	951	53.7	2004	2014	111.1	135	122	8.3	18.12

NS = Not surveyed
*** Incomplete data set**
**** Rader Trib A1 data combined with Rader Trib A2**

Table 4. Total Coho Observed, Area Under the Curve (AUC) Escapement Estimate, and estimated coho per mile for Little Wolf Creek Basin from 2007-2013. Reaches with restoration are highlighted based on when restoration occurred.

Survey Reach	2007-08			2008-09			2009-10			2010-11			2011-12			2012-13			Reach Mileage
	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	Number of Coho Observed	AUC	AUC Coho/ Mile	
Little Wolf Cr 1	0	0	0.0	8	7	7.8	16	18	20.0	2	2	2.2	76	52	57.8	2	2	2.2	0.9
Little Wolf Cr 2	8	6	2.7	86	77	35.0	258	230	104.5	159	113	51.4	344	256	116.4	18	17	7.7	2.2
Little Wolf Cr 3	12	8	5.0	60	58	36.3	206	137	85.6	263	168	105.0	270	134	83.8	30	30	18.8	1.6
Little Wolf Cr 4	0	0	0.0	24	30	30.0	139	126	126.0	171	112	112.0	155	123	123.0	3	4	4.0	1
Little Wolf Cr 5	5	3	3.3	12	13	14.4	79	79	87.8	112	59	65.6	113	41	45.6	6	6	6.7	0.9
Little Wolf Cr 6	0	0	0.0	20	23	15.3	63	65	43.3	92	101	67.3	105	78	52.0	13	15	10.0	1.5
Totals	25	17	1.8	210	208	23.1	761	655	77.9	799	555	67.2	1063	684	79.7	72	74	8.2	8.1

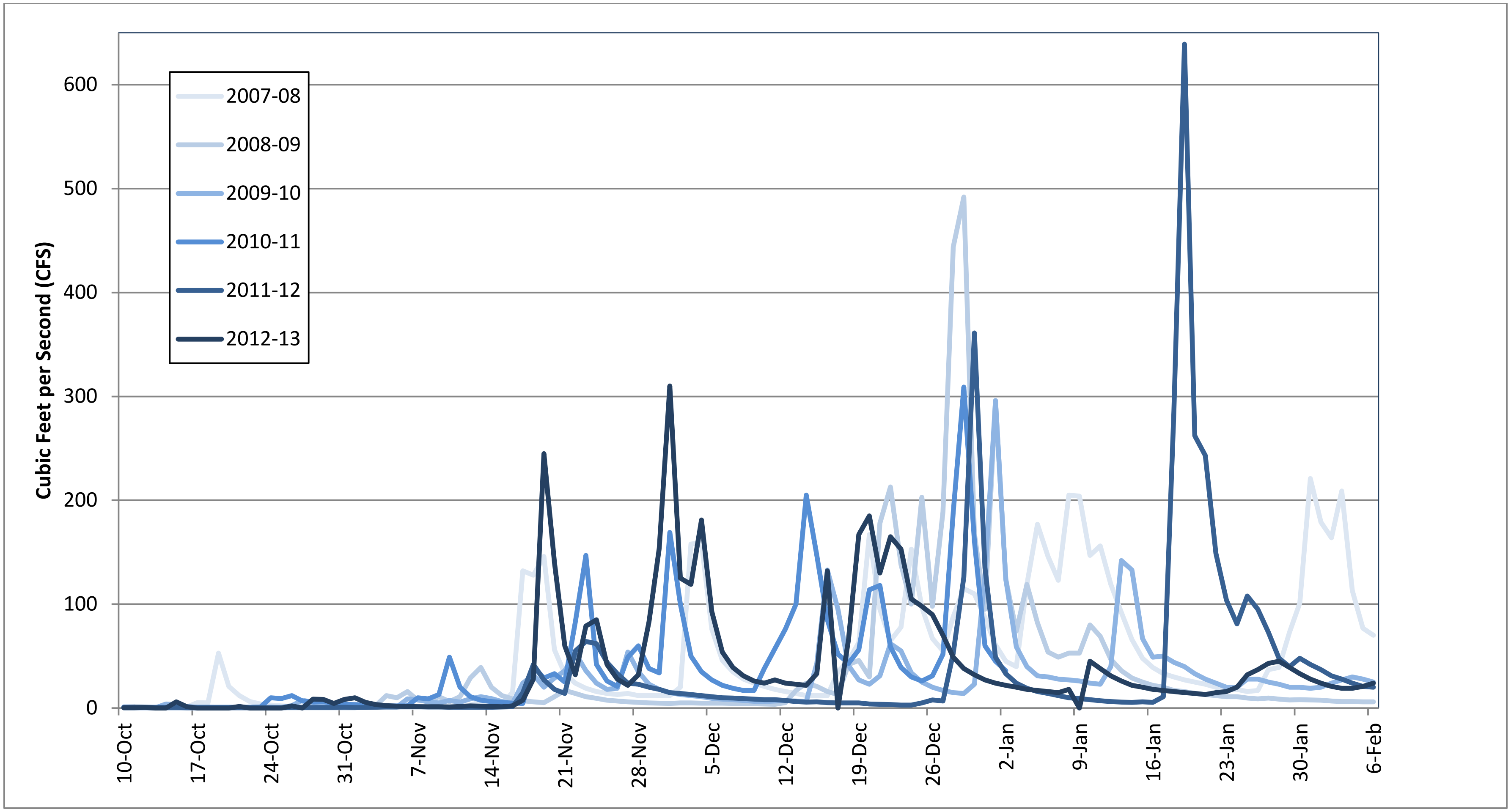

Figure 9. Little Wolf Creek Discharge (Survey Seasons 2007-08, 2008-09, 2009-10, 2010-11, 2011-12, 2012-13). Data collected by USGS.

Restoration work completed by ODFW, BLM, and PUR in Wolf Creek basin was mapped in ArcMap to show distribution of restoration projects within spawning ground survey reaches (Figure 1 & 2). Redds that were flagged from 2010-2013 were mapped in ArcMap to show distribution and densities of redds in various spawning ground reaches (Figures 9, 10, 11).

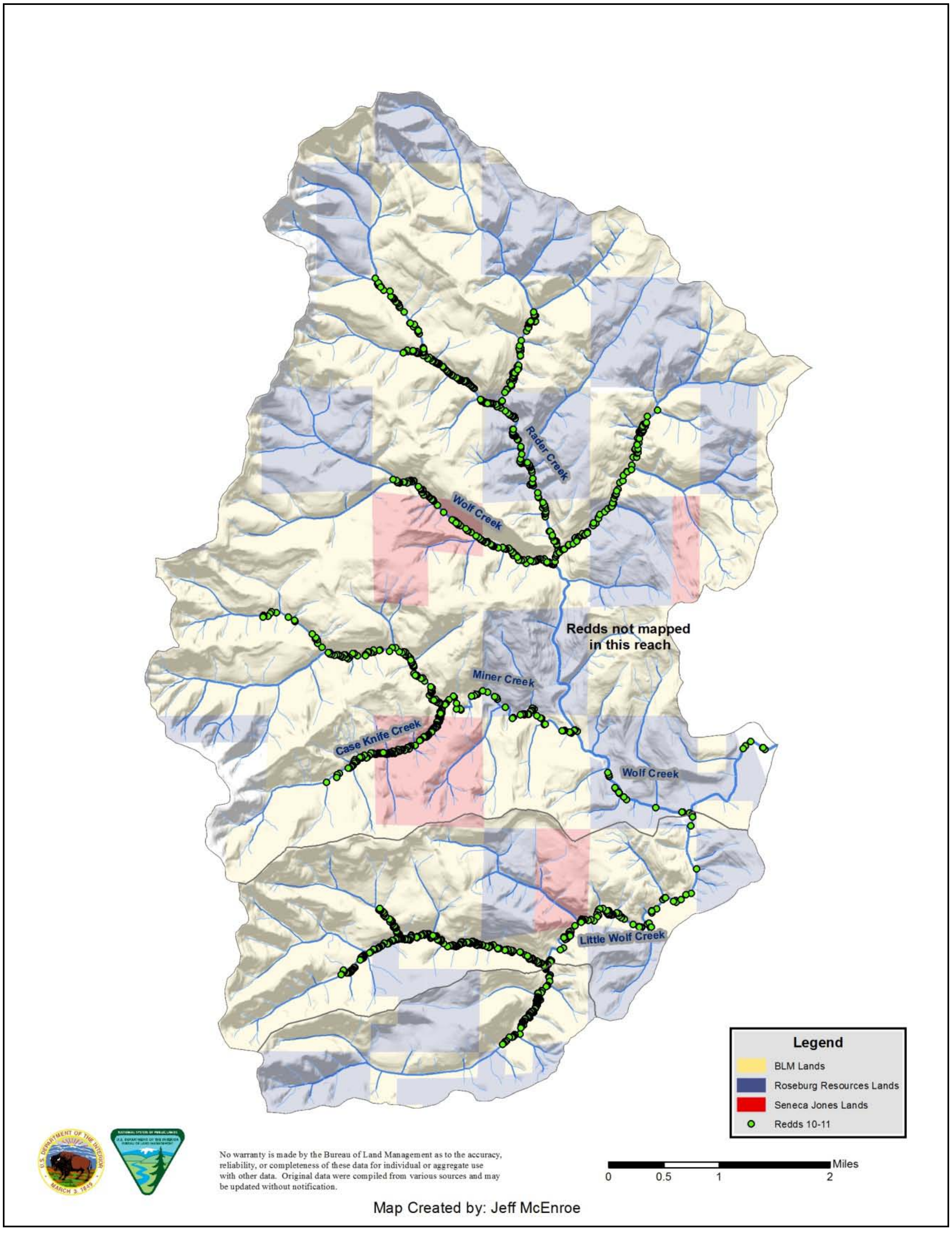

Figure 10. 2010-11 coho salmon redd distribution. Redd locations were not recorded for surveys done by ODFW (half of Wolf Creek 1; Wolf Creek 3; Wolf Creek 4).

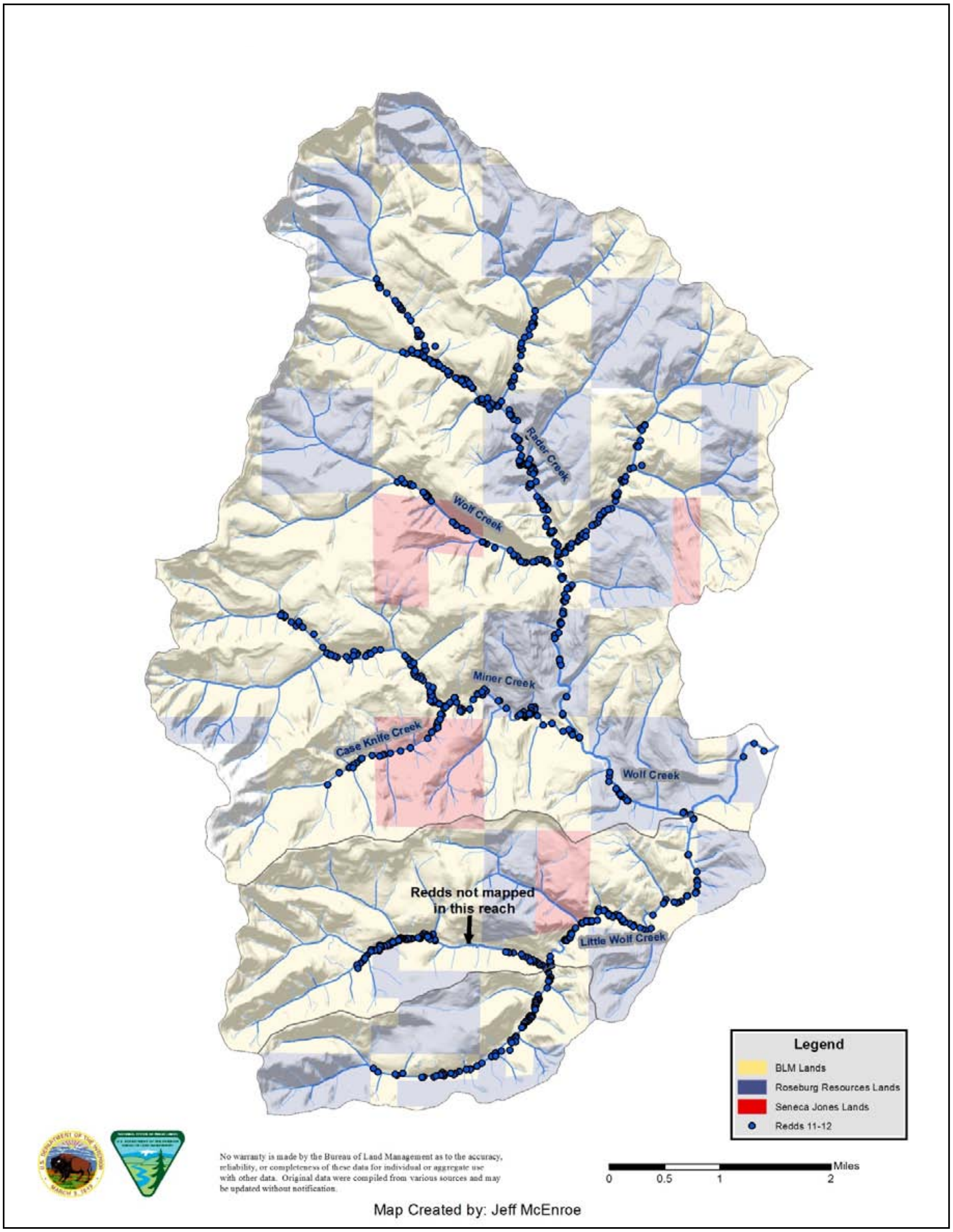

Figure 11. 2011-12 coho salmon redd distribution in Wolf Creek Basin.

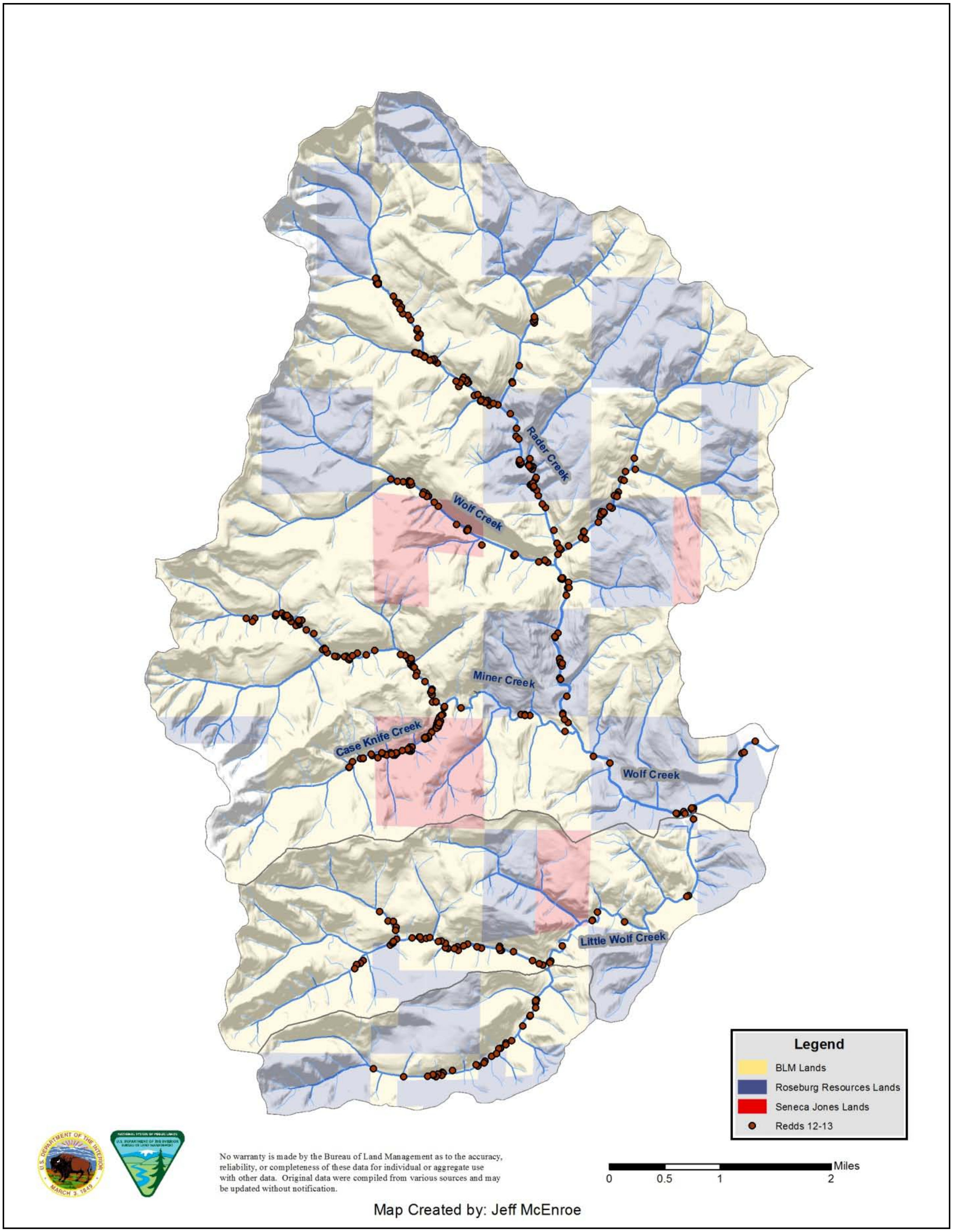

Figure 12. 2012-13 coho salmon redd distribution in Wolf Creek Basin.

Habitat Mapping

Using the total station survey maps, we were able to calculate the area of each type of substrate within the control and treatment reaches both pre and post in-stream restoration. The percent change in substrate type is then calculated for each reach. The pre-treatment conditions of each reach are represented in Figure 13 and show the percent composition of each substrate type.

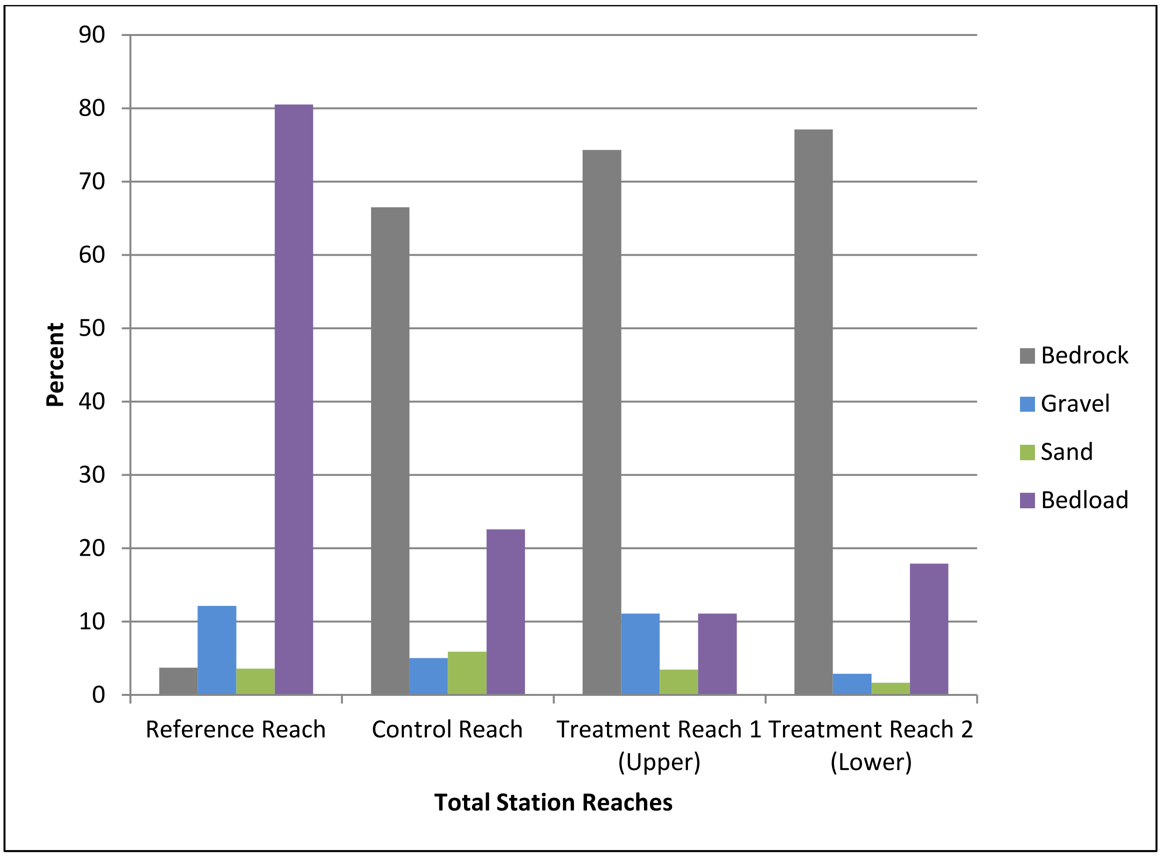

Figure 13: Percent composition of channel substrate prior to in-stream restoration in Little Wolf Creek.

The bedrock component of the stream substrate decreased by an average of 55% in both treatment reaches, while remaining relatively stable in the control reaches (Figure 14). This is a strong indication that the in-stream structures are doing what they were designed to do and allowing bed load to aggrade in the channel rather than being flushed out during winter flows.

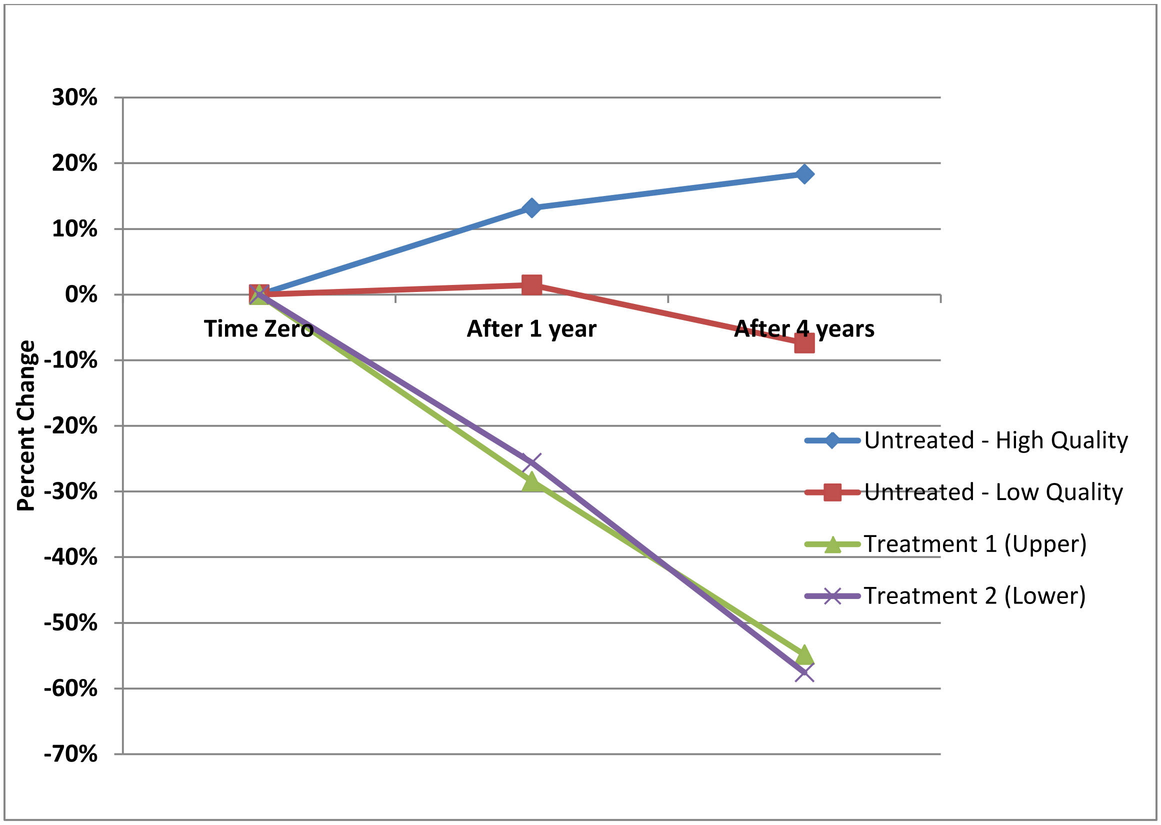

Figure 14: Percent composition of bedrock in Little Wolf Creek.

All reaches showed increases in the sand component of stream substrate, while the treatment reach increases in the sand component were an order of magnitude higher than in the control reaches (Figure 15). While lamprey were not surveyed during this project, they are present in the Little Wolf Creek basin. These results show an average increase of 1600% in available lamprey habitat in both treatment reaches.

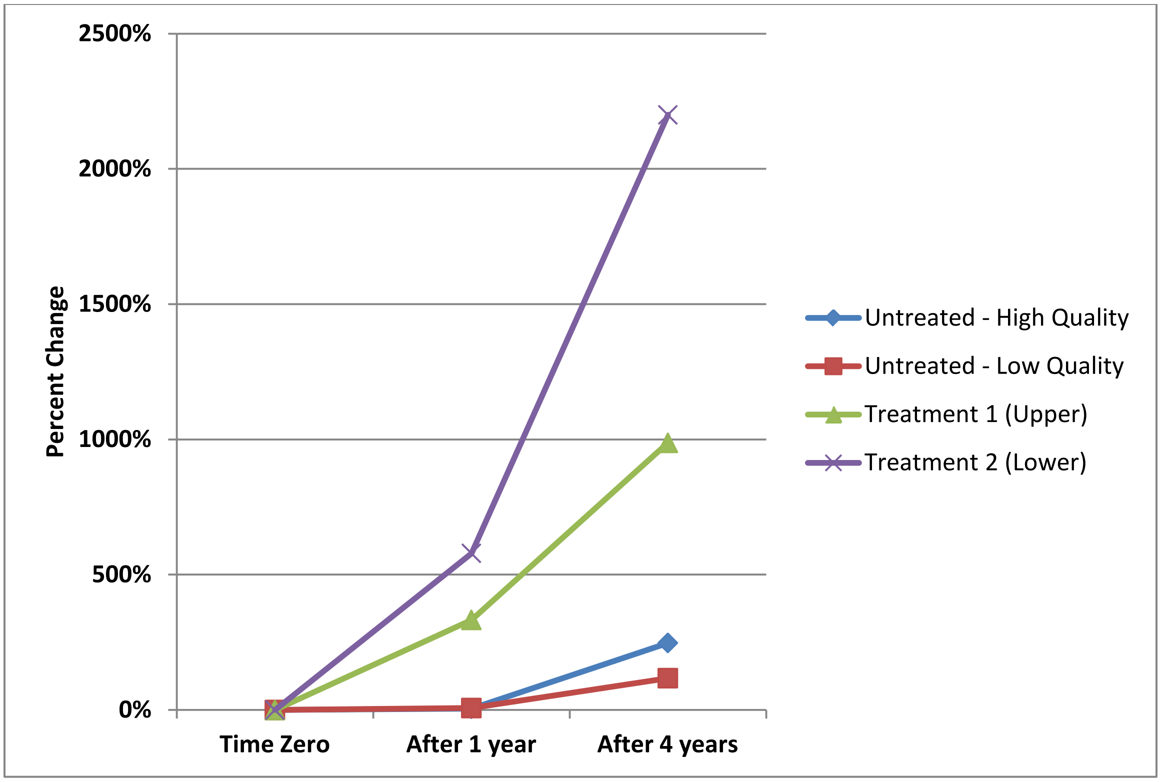

Figure 15: Percent composition of sand substrate in Little Wolf Creek.

In order to be classified as gravel, the substrate had to be well sorted. The gravel component of each reach was highly variable and actually decreased in the Reference, Control, and Treatment 2 reaches, but increased in the Treatment 1 reach (Figure 16). This may be misleading in that only the surface substrate was mapped in each reach, so the reaches may not have lost gravel, but it could have been covered in sand. Sand would be the substrate component that would drop out last as winter high flows recede.

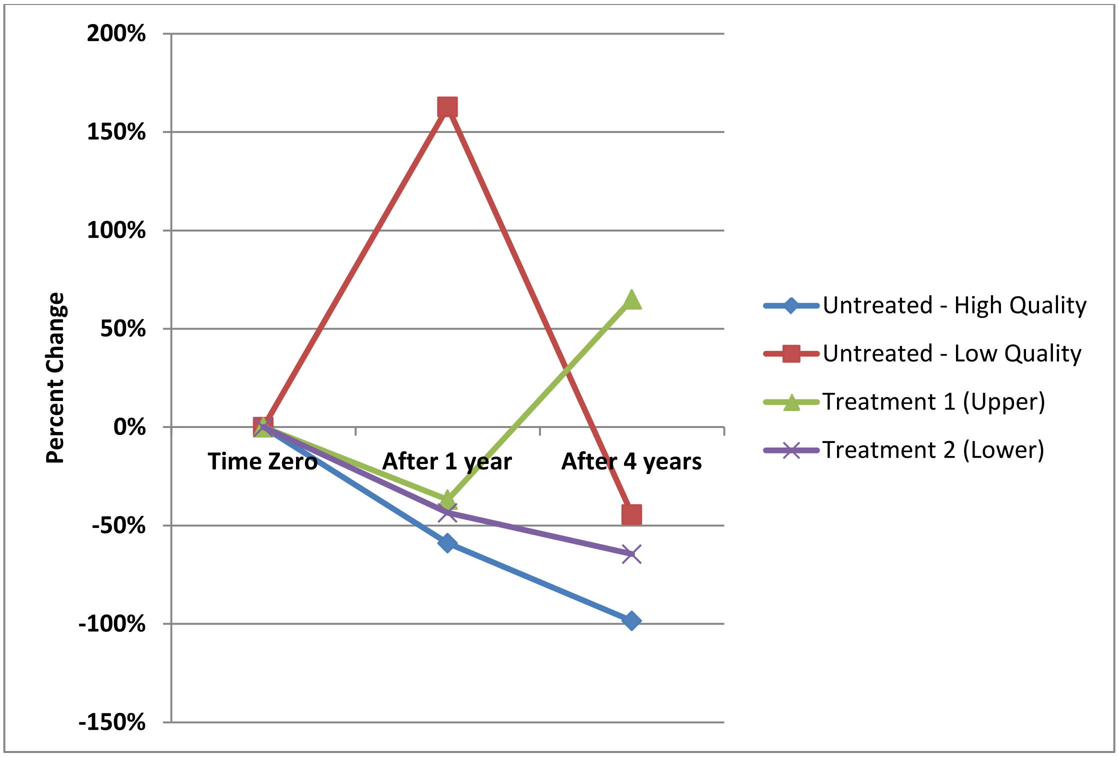

Figure 16: Percent composition of gravel substrate in Little Wolf Creek.

The bed load substrate classification is what all unsorted bed load was grouped into and included a mix of cobble, gravel, and sand substrates. Bed load increased significantly in all reaches, except for the Reference Reach (Figure 17). Bed load accumulation is important because this is channel aggradation that is available to become sorted substrate as hydraulic changes occur in the stream reach. Note that the Reference Reach is dominated by unsorted bed load (Figure 17.) When we look at the percent increase in sorted bed load (combining sand and gravel sorted substrates), we see an increase in both Treatment reaches over the Control Reaches (Figure 18.)

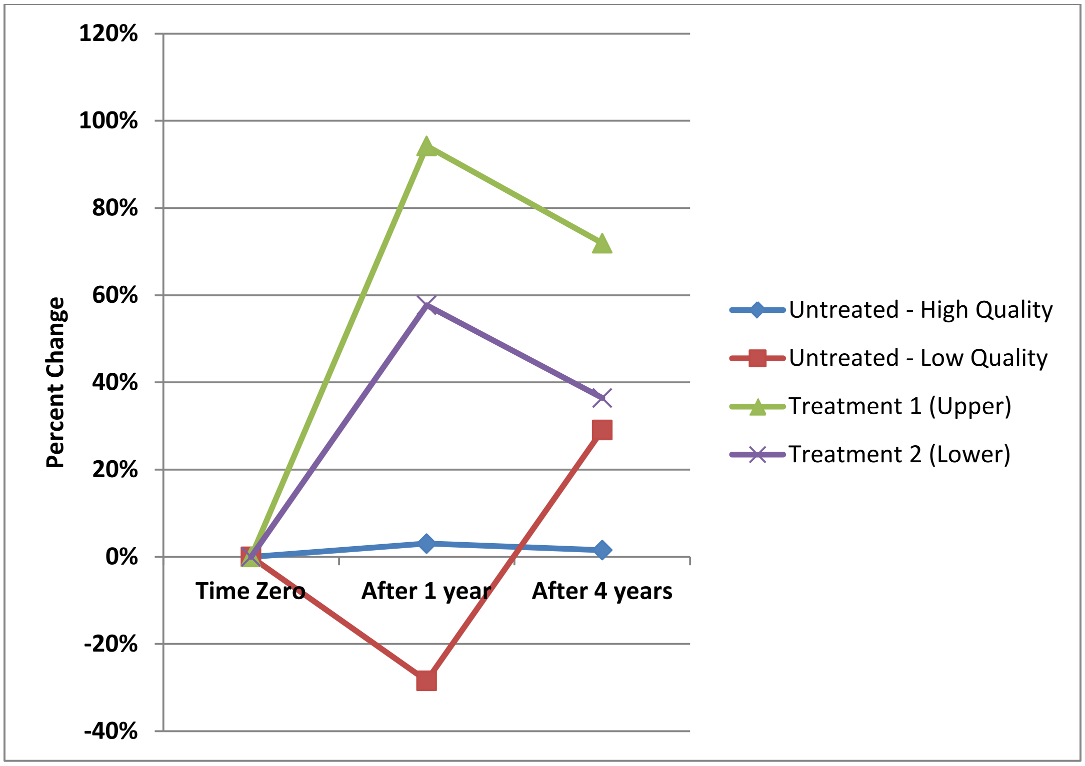

Figure 17: Percent composition of unsorted bed load substrate in Little Wolf Creek.

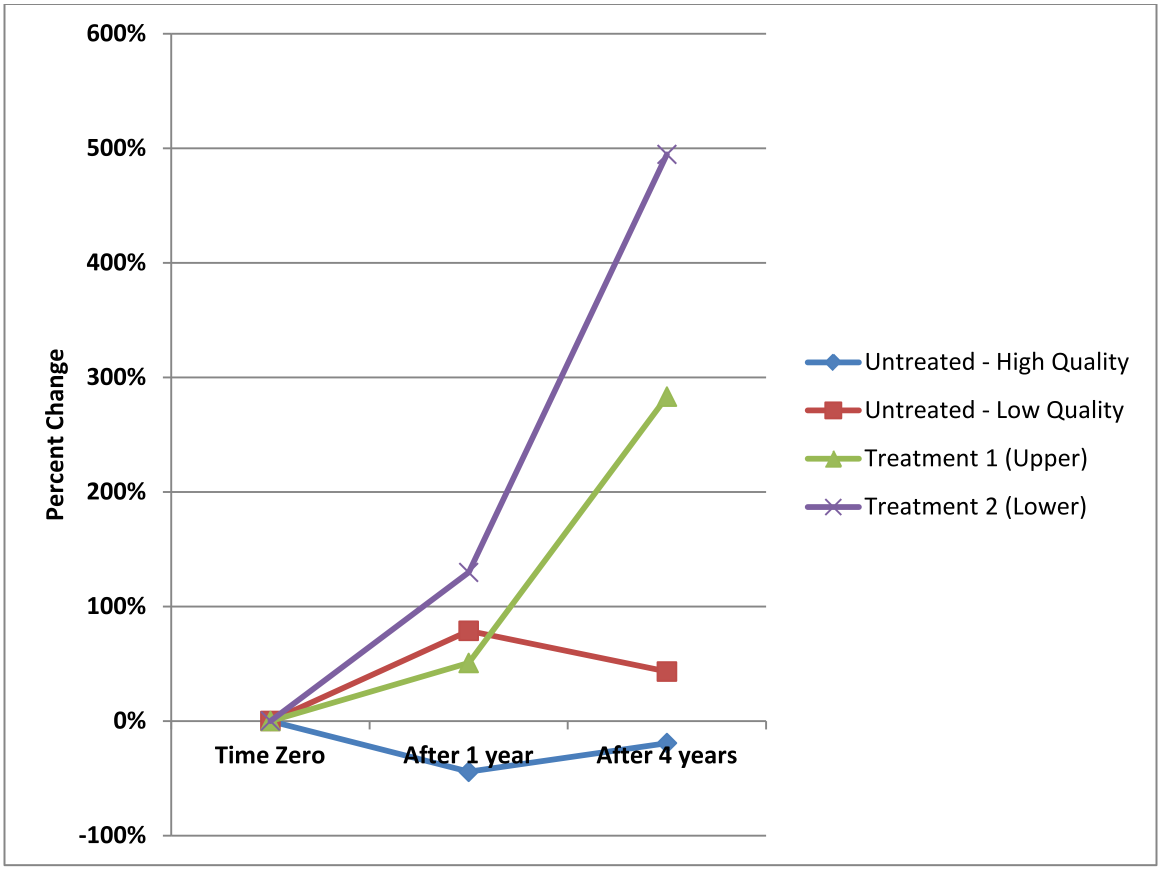

Figure 18: Percent composition of sorted bed load substrate in Little Wolf Creek. This is combined sand and gravel substrate.

When we put all this information together in the maps of each reach, we can see significant changes in the treatment reaches. Only Treatment Reach 1, the upper treatment reach map, was included in this report in order to save space. These maps showed the most significant changes post restoration. The other maps are available by request from Roseburg BLM. Figures 19-21 show the total station maps for Treatment Reach 1 in 2008 (pre-restoration), 2009 (1 year post restoration), and 2012 (4 years post restoration).

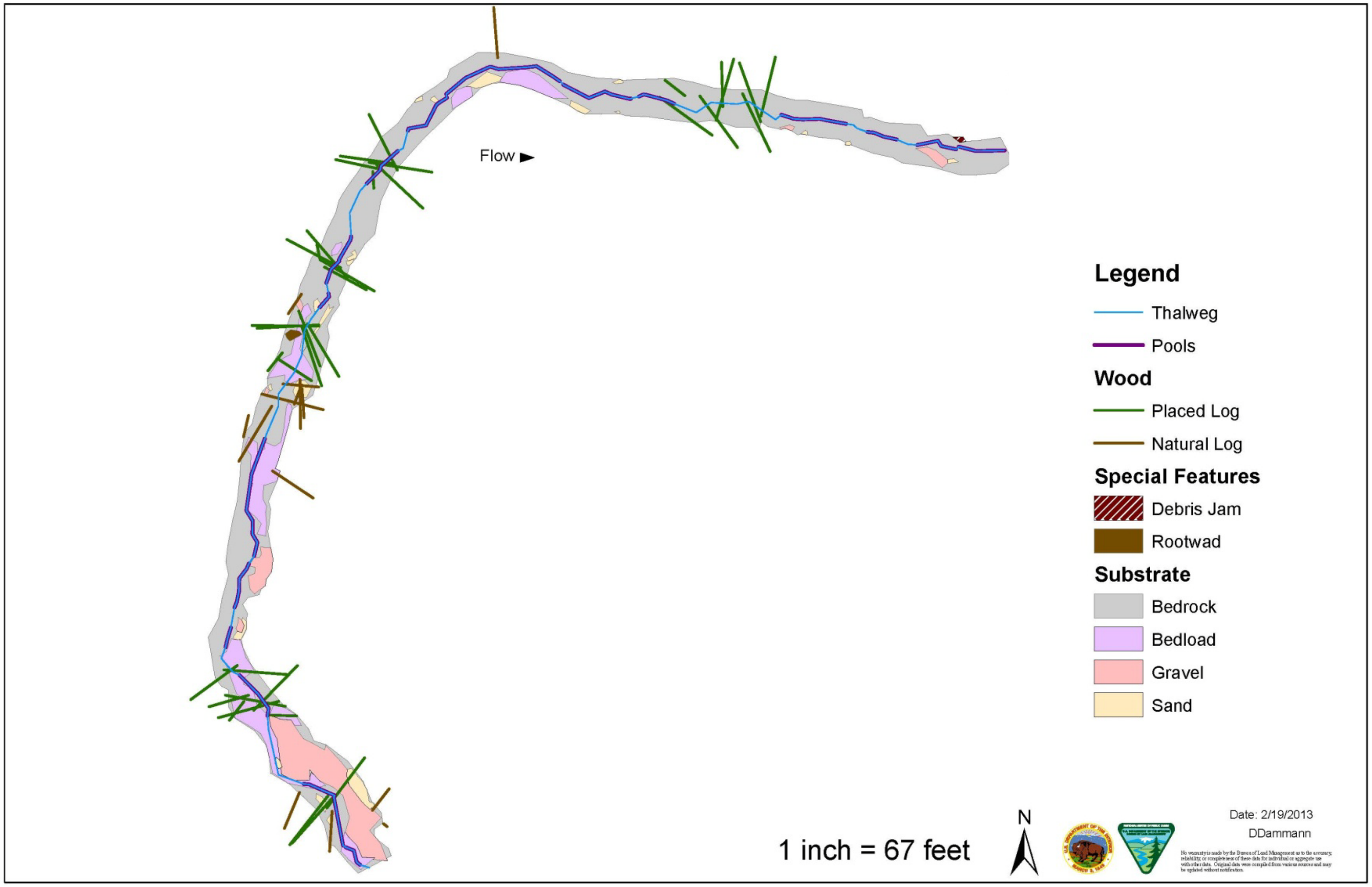

Figure 19: Total Station Map of Treatment Reach #1 in Little Wolf Creek. This map represents the stream conditions just after initial log placement in 2008 (green lines).

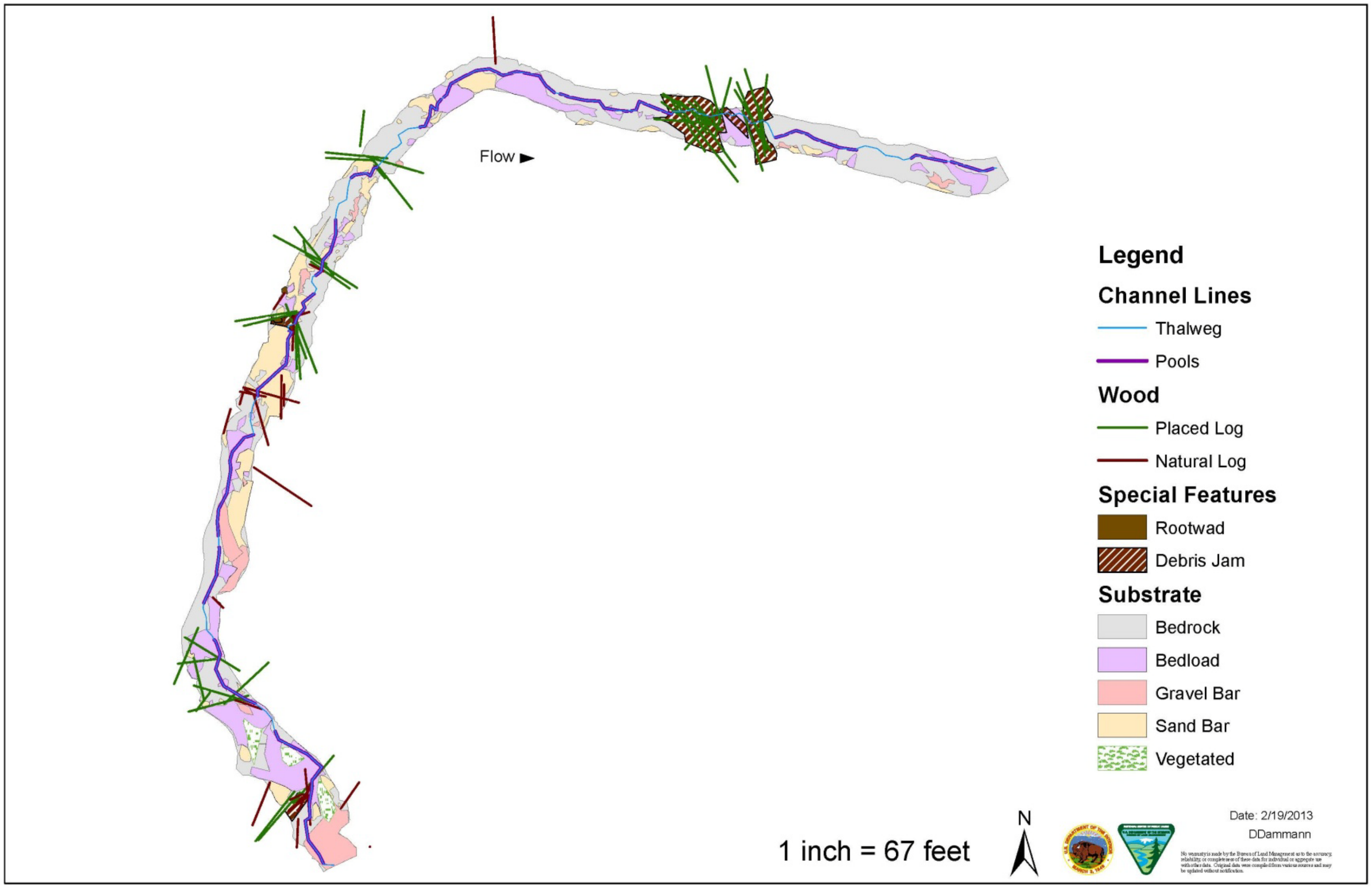

Figure 20: Total Station Map of Treatment Reach #1 in Little Wolf Creek. This map represents the stream conditions 1 year post restoration.

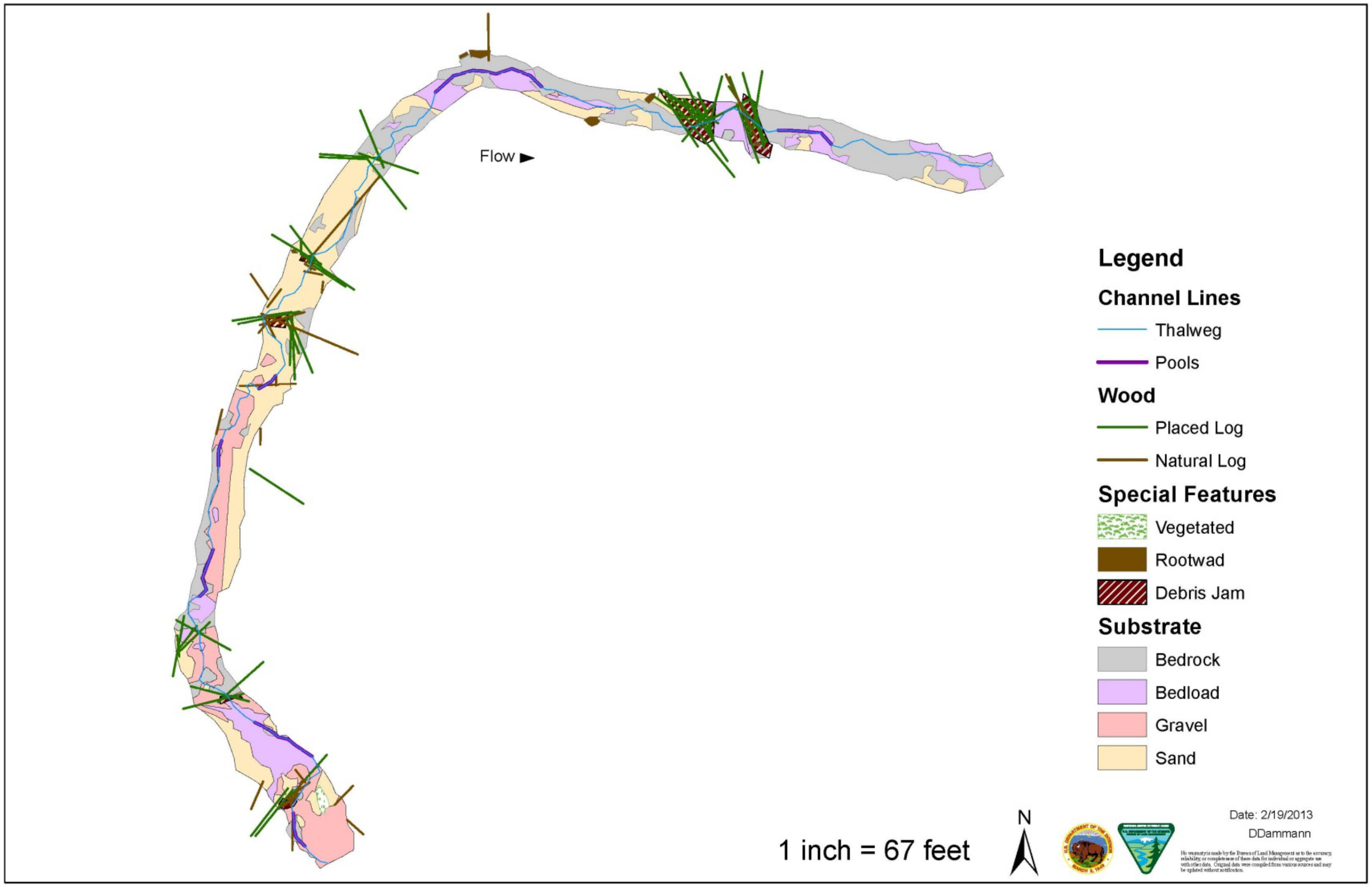

Figure 21: Total Station Map of Treatment Reach #1 in Little Wolf Creek. This map represents the stream conditions 4 years post restoration.

Discussion

Seeding Surveys

In general for seeding surveys, a value of 0.7 coho/m^2 is used for fully seeded in pool only snorkeling projects based off observed coho salmon. This number was based on work completed by ODFW (Nickelson et al. 1992) where a value of 1.0 coho/m^2 was determined as fully seeded for Oregon coastal coho salmon streams. Then the 0.7 coho/m^2 value for fully seeded was derived from pool snorkeling by Rodgers et al. (1992) based on the number of fish visually seen by surveyors versus total fish present (Erik Suring, ODFW Corvallis-personal communication). The variety of characteristics in morphology and location within the basin make different subsections of the basin more appropriate for comparison. Dividing the basin into three parts: mainstem Wolf Creek (Wolf Reach 1, Wolf Reach 2, Wolf Reach 3 and Wolf Reach 4) , Little Wolf Creek (Treatment 1, Treatment 2, No Treatment and Reference) and Upper Wolf Creek Tributaries (Miner, Rader and Rader Tributary A) allows trends to be more evident. The trend that reaches across the entire basin is the decreased parr density in 2010 (Figures 5 and 6).

Little Wolf Creek surveys indicate restoration done on Treatment 1 and Treatment 2 in 2009 has had a positive effect on increasing parr density. We saw increased rearing capacity in both treated reaches to exceed the fully seeded level of 0.7 coho per square meter in 2012. The upper treatment reach contained better habitat to begin with and seeding levels doubled after restoration. The seeding levels in all reaches of Little Wolf creek improved in 2012. The overall fish densities dropped in these reaches however the percent decline was not as significant as in untreated reaches (Figure 22). The seeding levels of Little Wolf Creek are higher and still increasing which indicates they have not reached their full capacity even though they are considered fully seeded. Adults that returned last year (2011-12) were the first generation from fish that spawned after initial 2008 restoration (one reach treated with boulders in Wolf Creek, and log placement in Treatment 1 and 2 reaches in Little Wolf Creek). Adults returning this year (2012-13) were the first generation from fish that spawned in the first 2009 Wolf Creek log structure restoration reaches.

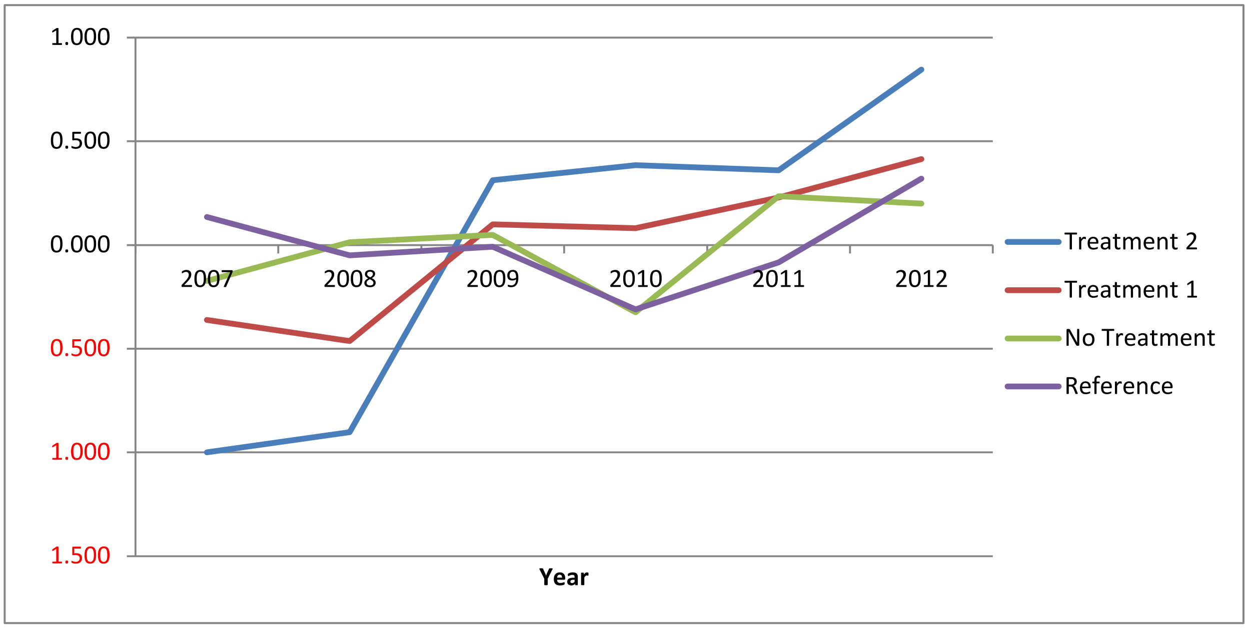

Figure 22. Percent variation in Little Wolf Creek reaches from the average densities from 2007 to 2012.

Wolf Creek seeding surveys have shown low coho salmon densities in the lower two mainstem sites (Wolf Reach 1 & 2) presumably because of low quality (large, straight, simple pools, and small pockets of gravel and bedrock) habitat for summer rearing and spawning. Whiteway et al. (2010) showed that boulder structures had a larger effect on salmonid densities than did LWD structures, so we expect to see changes in density in this reach as the boulder structures mature. In addition, Roni et al. (2006) showed that boulder weir restored reaches had 1.4 times higher abundance of coho and trout than in control reaches. In Roni's study, high coho abundance was positively correlated with difference in pool area. In our Wolf Creek study, we did not show a significant increase in abundance of coho post treatment, but total pool area in Wolf 1 increased from 4,619 m^2 in 2007 to 11,534 m^2 in 2012 which was a goal of the boulder placement project.

Wolf Creek reaches 3 & 4 and Rader Trib A underwent helicopter log placements in 2011 after snorkel surveys were completed. Wolf Reach 4 has an average seeding level of 1.06 coho salmon per square meter which is above fully seeded levels of 0.7. Rader Trib A was averaging 0.66 coho salmon per square meter and was almost fully seeded prior restoration. In the first season after logs were placed, the seeding level increased from the prior year but was still below average. A meta-analysis of relationships between fish density monitoring as affected by in-stream habitat restoration projects notes it may take up to five years post installation to see the full effect on (Whiteway et al. 2010). There were not any significant changes in juvenile densities from in-stream restoration placed in Wolf Creek seeding reaches (Wolf 1, Miner 1, Rader 1), but continued monitoring of these reaches may show changes in juvenile densities related to certain reaches or overall in the basin. We will be evaluating overall fish densities in coming years to monitor the juvenile coho populations. Adult coho are using these areas with structures for spawning (Figures 10, 11, 12), and as time progresses we expect these structures to raise the water level and provide some winter refuge for juvenile fish.

Spawning Surveys

Weather and water conditions play a big role in the success of gathering spawning survey data. The greatest movement of fish into their spawning grounds occurs during the raising of water levels and it is common for these events to render survey reaches unsurveyable due to poor visibility and dangerous wading conditions. The optimal time to observe live fish is after a high water event when the stream is receding and clearing. Some seasons have better surveying conditions than others and this is something to be taken into consideration when comparing data between reaches and seasons. The Little Wolf Creek discharge data collected by the USGS (Figure 9) will be referred to when discussing water conditions.

During all spawning seasons surveyed in Wolf Creek basin, most of the peak live fish counts occurred from December 20th through January 14th following high water events. In 2012-13, the biggest rain events and flow peaks occurred prior to December with only one smaller freshet in late December.

In-stream structures were designed to function differently depending on what reach they were placed in. Overall, boulder structures in Wolf Reaches 1 & 2 were designed for winter refuge, flood plain interaction, and holding water for adult fish. Most other restoration reaches were designed to slow water flow and drop out sediment to increase spawn habitat which was believed to be a limiting factor in the basin.

Throughout the project, the highest densities of both live fish and redds were observed most consistently in Case Knife Creek Reach 1, Rader Creek Reach 4, along with Little Wolf Reach 2 and 3. These reaches were observed to have the most abundant and best spawning habitat of all the reaches surveyed and Little Wolf Reach 3 is the only one that has not had in-stream restoration work. These reaches are all unconstrained valley bottoms with relatively quick response times to restoration projects. All of these reaches maintain ample stream flow for fish passage throughout the duration of the spawning season. The large woody debris that is dispersed throughout these reaches, much of which was placed during restoration projects, provides cover for fish and slows down the transport of substrate downstream creating ideal spawning habitat. The lower portion of Case Knife Reach 1, in particular, exhibits several positive changes in response to log structures, including a meandering stream with split channels with an abundance of spawning gravel. Due to its close proximity to the road and its general lack of habitat diversity, Rader Creek has been the focus of numerous habitat enhancement projects including log weirs and structures. Rader Creek Reach 4, being the highest up of the reaches on Rader Creek that have had restoration done, is holding back gravel and cobble that fish are utilizing for spawning. Although there are still large stretches of [primarily] bedrock on Rader Creek Reaches 1, 2 and 3, the areas that have good spawning habitat are well utilized.

Miner Creek Reaches 1 and 2 have also been the focus of restoration projects including rock weirs and log structures. The streambed in the proximity of the habitat structures on the lower portion of Miner Creek Reach 1, consists of mainly bedrock and loose fine particulates. The habitat in this section is comprised largely of several long pools where few fish are spawning, and hopefully will accumulate spawning gravel in future years to attract more spawners. The middle and upper portions of Miner Creek

Reach 1, however, exhibit more diverse habitat and the fish and redd densities reflect this. There are numerous log jams in this section several of which are placed, that are building up material at every high water event.

Wolf Creek Reaches 1-4, which are below the confluence of Rader Creek, consist primarily of bedrock and fine substrate with very little large woody debris or spawning gravel present. The habitat modifications on these reaches consist mostly of boulder structures and weirs, with a few log placements in Wolf Creek Reach 4, and recent log placement work during 2012 in reaches 2, 3, and 4. To date, the long slow pools upstream of the boulder weir placements in Wolf Reach 1 & 2 have not accumulated much gravel but are instead accumulating mostly fine substrate and organic material. Gravel deposition behind the boulder weirs on the lower Wolf Creek reaches is expected to be slow since there is more gravel recruitment higher in the watershed and there are numerous log structures in both of the major tributaries to Wolf Creek (Miner Creek and Rader Creek). The purpose of these structures in Wolf Reach 1 & 2 was to offer overwinter habitat refuge and adult fish holding water. Structures did not get sealed with gravel or small fines after their installation in 2008 (Dan Jenkins-ODFW, personal communication), so likely did not offer benefit until sometime after 2009. However, areas that have accumulated suitable gravel are attracting spawning fish such as Miner Creek Reaches 1 & 2 along with Rader Creek Reaches 1, 2, and 4 (Figures 10, 11, and 12).

During the course of the 2008-09 and 2010-11 survey seasons, redd superimposition was quite common, particularly in lower reaches in the system. This is often caused by high densities of spawners or low habitat quantity, quality, or both. Redd superimposition can cause partial to full mortality to previously fertile eggs (Groot and Margolis 1991). In-stream restoration projects are attempting to solve these issues; however it may be several years before the habitat quantity and quality improve enough to lower the occurrence of redd superimposition.

The Umpqua ESU is separated into four monitoring areas within the Umpqua River basin. Wolf Creek is included in the Middle Umpqua monitoring area. This area includes the mainstem Umpqua and all of the tributaries from just above Elk Creek to the confluence of the North and South Forks of the

Umpqua River. The AUC estimate for coho salmon abundance is calculated by OASIS (Figure 23) for the Middle Umpqua and Umpqua populations, so we can use these estimates to compare with Wolf Creek basin estimates.

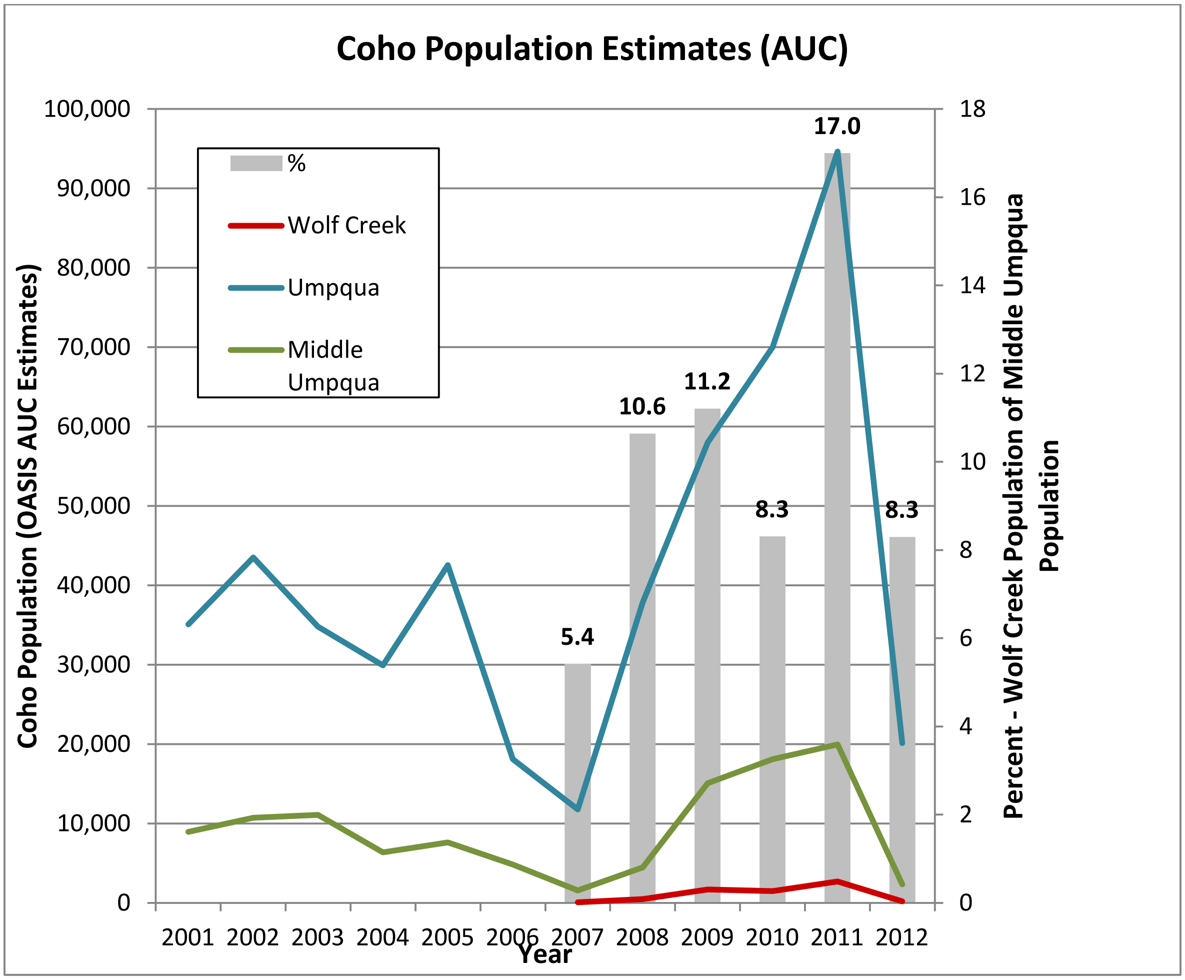

Figure 23. Umpqua, Middle Umpqua, and Wolf Creek AUC escapement estimates, 2001-2012.

This data concludes that between 5.4% and 17% of the spawning coho salmon in the Middle Umpqua monitoring area were estimated to be present in Wolf Creek basin between 2007 and 2012. The estimated percentages of Wolf Creek basin coho abundance starting in 2009 were higher (11.2% in 2009, 8.3% in 2010, 17% in 2011, and 8.3% in 2012) and more accurate than the previous two seasons (5.4% in 2007 and 10.6% in 2008) possibly due to the stream flows for those years. It is possible that the AUC estimates for the 2007-08 and 2008-09 seasons were underestimated because the surveyors missed surveys during the peak spawning periods (the last 2-3 weeks of December) due to poor survey conditions.

The Wolf Creek and Middle Umpqua AUC estimate trends matches that of the other Oregon Coast monitoring areas during the same time period. In the last decade there have been two peaks of coho salmon spawner abundance. From the previous decade, coho salmon abundance increased dramatically from 2001 through 2004, following favorable ocean conditions. Coho salmon abundance then declined in 2004- 2007, during a period of reduced ocean survival. The spawner abundance has rebounded in recent years as ocean conditions have once again become favorable. The AUC estimates for coho salmon abundance in the Middle Umpqua monitoring area for the 2009-11 seasons, are the highest on record since 1990 (http://oregonstate.edu/dept/ODFW/spawn/pdf%20files/coho/AnnualEstESU1995- 2011.pdf). The other streams that comprise the Middle Umpqua monitoring area are influenced by similar water conditions to that of Wolf Creek, therefore they exhibit similar trends in surveying conditions.

The AUC estimates calculated for Wolf Creek and Little Wolf Creek basins correspond with the Middle Umpqua estimates in terms of general abundance. The goal is to survey all possible coho habitat and estimate total escapement. However, in 2010 field season it was discovered that approximately 0.6 miles of coho habitat in Little Wolf (Jeff McEnroe, BLM- personal communication 4/13/11), and approximately 1 mile in Wolf Creek is not currently included in surveys. This means, total basin AUC is slightly underestimated in 2007- 2010. Figure 23 shows that on average, Wolf Creek basin produces 10% of the estimated number of Middle Umpqua coho salmon. As the 13 miles of in-stream restoration work mature and high water events move gravel, we hope that these structures can recruit gravel, create pools and spawning habitat and increase the overall survival, condition, and densities of both juvenile and adult coho in Wolf Creek basin.

Habitat Mapping

Total station mapping surveys on control and treatment reaches show that large wood structures are allowing low quality treatment reaches to start channel aggradation. This aggradation on the surface has comprised mostly of sand and unsorted bed load. It is important to keep in mind that these calculations are made with just the surface substrate and are area, not volume calculations. Since sand is the smallest component, it is likely to drop out last as winter high flows recede possibly covering up gravel, cobble, or unsorted bed load in the stream channel. What is important to note is the 55% reduction in bedrock in the treatment reaches. Bedrock has little ecological value, so covering it up with any substrate and allowing the channel to aggrade will result in higher ecological function. Future total station surveys will allow us to track channel evolution in response to large wood restoration over time.

Overall Summary

The effectiveness of habitat restoration projects for salmonids can be shown by increases in fish production or increases in fish fitness. Also, once the habitat reaches its carrying capacity there will be a limitation of “x” number of adults can only produce “x” number of juvenile fish at which increased adult fish abundance may not mean increased juvenile fish since it could be limited by rearing or spawning habitat. Many peer reviewed articles and studies conclude that salmonid abundance typically increases post restoration projects in both boulder weir and log structure applications, even if some case studies are not successful due to other environmental variables (Roni et al. 2006; Stewart et al. 2009; Whiteway et al. 2010). In addition, it is difficult to distinguish between changes in fish densities resulting from other variables such as ocean survival, recruitment, and redistribution within a basin. Our results show inconclusive answers to the question many effectiveness monitoring projects are trying to answer: do log and boulder structures increase fish abundance? However, our results have shown improvements in fish abundance that we believe are direct results of in-stream work in Wolf Creek Basin.

Out of the eleven juvenile coho snorkel sites throughout the project area, five were fully seeded pre-treatment. Post treatment monitoring has shown that the two reaches that were treated in Little Wolf

Creek are now also fully seeded. In Wolf Creek, two of the reaches (Rader and Rader Trib A) that were fully seeded prior to restoration are no longer fully seeded, and no treated reaches have become seeded yet. A longer time period may be needed to detect change in Wolf Creek juvenile coho densities and this seeding survey data provides index data at standard sites that hopefully in future years can be an effective way to compare trends in the basin. Seeding surveys are an effective survey technique to cover a lot of ground in different stretches of creek and habitats. However, as we have shown here, the seeding surveys may not detect changes expected during short periods of time.

Basin escapement estimates from adult coho spawning surveys show that throughout 2007-2012, Wolf Creek basin total estimated coho comprised from 5.4% to 17.0% of the Middle Umpqua coho population. Since most of the restoration on this project was done in 2009, the project is in the early phases of detecting increases in adult spawners back to Wolf Creek basin as gravel is just beginning to accumulate at structures to create new spawning areas and F1 generations of fish are starting to return from fish spawned post restoration in 2009.

Habitat monitoring results have shown increases in pool area in Wolf Creek snorkel reach one which was designed to increase winter refuge, flood plain interaction, and adult fish holding water. While we did not monitor winter refuge or flood plain interaction, more pool area should mean a benefit to fish. Little Wolf Creek treatment reaches showed a 55% reduction in bedrock and 1000-2000% increase in sand substrate. Future habitat monitoring as these structures mature should document additional spawning gravel available for spawners. While no habitat total station mapping was conducted in Wolf Creek, many of the reaches are similar in Wolf Creek tributaries as compared in Little Wolf Creek Treatment Reaches 1 & 2.

Selecting good pre and post monitoring sites that are not subsequently influenced by new habitat projects during the post project monitoring phase is also important in detecting trends. The Wolf Creek effectiveness monitoring project was designed to be a long-term project. So far, the project has spanned six years, but due to limited recent funding for monitoring will likely conclude or be limited to summer pool seeding counts in the future. Additional monitoring that was not conducted as part of this study could include assessing adult fish fitness as affected by large slow holding pools in Wolf Reach 1 & 2 and winter snorkel surveys to assess winter refuge provided by structures.

Additional Data

As part of the OWEB grant agreement, information from this project is posted to the NRIMP Data Clearinghouse. Raw data is housed at the ODFW Southwest Regional and Roseburg BLM offices.

Acknowledgements

Funding for this reporting phase of the project was provided by OWEB and US-BLM Challenge Cost Share. In-kind staff time, training, data analysis and management, report writing, and supervision of field staff were provided by ODFW Umpqua Watershed and Roseburg BLM. Thank you to the private landowners Roseburg Resources and Seneca Jones Timber who continually allow permission to conduct this ongoing study. Partners on this project include Roseburg BLM, Partnership for the Umpqua Rivers, OWEB, Corvallis ODFW OASIS project, Roseburg Resources, and Seneca Jones Timber.

A note of appreciation to all the ODFW, BLM, and PUR field staff throughout the years that have braved all sorts of weather and conditions to make this long term dataset continue with high quality data. A special thanks to Greg Huchko who was the field crew supervisor for 2012-13, and Thomas Kaufman, Chris Sheely, and Summer Cross who conducted 2011-2013 field work. Thank you to Dan Dammann (BLM) for synthesis of AREMP habitat mapping data and Corvallis ODFW OASIS project for data sharing. Thank you to Laura Jackson for comments and review of the final draft of this report.

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Appendix

Appendix 1. Peak redds observed and number of times surveyed by reach and year in Wolf Creek basin. Reaches with restoration are highlighted.

Survey Name	2007-08			2008-09			2009-10			2010-11			2011-12			2012-13		
	Number of Times Surveyed	Peak Redds	Date	Number of Times Surveyed	Peak Redds	Date	Number of Times Surveyed	Peak Redds	Date	Number of Times Surveyed	Peak Redds	Date	Number of Times Surveyed	Peak Redds	Date	Number of Times Surveyed	Peak Redds	Date
Wolf Creek 1	6	1	11/25/2007	12	10	12/15/2008	15	13	12/14/2009	11	12	11/9/2010	16	6	11/21/2011	9	2	1/3/2013
Wolf Creek 2	4	4	11/29/2007	12	11	1/14/2009	15	31	12/7/2009	11	25	1/5/2011	17	14	1/9/2012	9	3	12/11/2012
Wolf Creek 3	4	0		11	6	1/27/2009	10	16	12/6/2009	11	16	1/26/2011	19	12	1/11/2012	14	2	12/10/2012
Wolf Creek 4	4	3	12/12/2007	12	8	12/15/2008	16	35	12/14/2009	10	23	12/23/2010	18	18	1/9/2012	11	3	11/28/2012
Wolf Creek 5	4	0		12	8	1/12/2009	16	34	12/27/2009	15	77	12/24/2010	18	61	1/5/2012	14	2	12/10/2012
Wolf Creek 6	4	1	11/24/2007	12	13	1/20/2009	17	47	12/20/2009	15	70	12/27/2010	18	33	1/5/2012	12	3	11/28/2012
Miner Creek 1	5	3	11/28/2007	11	13	1/22/2009	15	40	12/28/2009	14	60	12/18/2010	18	37	1/4/2012	12	4	11/27/2012
Miner Creek 2	6	4	12/10/2007	11	5	12/3/2008	15	26	12/28/2009	15	31	12/23/2010	16	24	1/4/2012	13	2	12/13/2012
Miner Creek 3	6	4	12/10/2007	11	1	1/14/2009	15	33	12/28/2009	15	36	1/24/2011	16	11	2/7/2012	13	3	1/16/2012
Case Knife 1	6	3	12/10/2007	11	11	1/22/2009	17	87	12/28/2009	16	127	12/27/2010	17	74	1/4/2012	13	17	12/13/2012
Case Knife 2	7	3	11/28/2007	11	4	1/14/2009	18	32	12/28/2009	16	46	1/10/2011	16	13	1/3/2012	13	5	12/6/2012
Whiskey Camp 1	NS	NS	NS	11	0		15	0		15	8	1/24/2011	16	5	2/7/2012	13	4	12/19/2012
Whiskey Camp 2	NS	NS	NS	11	0		15	0		15	6	1/3/2011	16	1	2/1/2012	13	2	12/29/2012
Rader Creek 1	4	0		12	5	1/20/2009	17	7	12/8/2009	13	6	12/6/2010	17	4	1/3/2012	12	0	
Rader Creek 2	4	0		12	5	12/8/2008	16	49	12/14/2009	13	52	12/18/2010	18	22	1/3/2012	12	8	12/12/2012
Rader Creek 3	4	1	12/11/2007	12	7	12/8/2008	17	34	12/20/2009	14	43	12/18/2010	17	25	1/10/2012	12	3	12/30/2012
Rader Creek 4	7	2	1/2/2008	12	26	1/13/2009	17	53	12/20/2009	15	125	12/27/2010	17	55	1/3/2012	13	12	12/11/2012
Rader Creek 5	6	0		11	8	1/27/2009	17	18	1/4/2010	15	29	1/11/2011	17	21	1/3/2012	13	5	12/6/2012
Rader Creek 6	4	0		11	1	1/21/2009	16	4	1/12/2010	15	18	12/18/2010	17	5	1/2/2012	13	3	12/6/2012
West Fork Rader Creek	7	6	12/7/2007	11	4	1/13/2009	16	10	12/29/2009	15	19	12/18/2010	17	8	1/3/2012	12	5	12/11/2012
Rader Trib A 1	6	5	12/9/2007	4*	0*	*	**	**	**	15	2	12/17/2010	17	3	1/5/2012	12	1	12/8/2012
Rader Trib A 2	7	8	12/9/2007	10	5	1/21/2009	14	20	12/27/2009	15	29	12/24/2010	16	25	1/5/2012	12	4	12/30/2012
Rader Trib A 3	7	5	1/2/2008	10	3	1/21/2009	14	14	12/27/2009	15	20	12/24/2010	17	13	1/5/2012	12	2	12/12/2012
Rader Trib A 4	6	3	1/2/2008	10	0		14	0		15	0		17	3	1/30/2012	12	1	12/8/2012
Rader Trib A 5	6	2	11/24/2007	11	6	1/14/2009	14	8	1/20/2010	15	39	12/24/2010	17	10	1/5/2012	12	1	12/8/2012
East Fork Rader Creek 1	5	2	11/27/2007	12	4	1/5/2009	16	23	12/29/2009	15	37	1/4/2011	18	16	1/2/2012	12	2	12/12/2012
East Fork Rader Creek 2	4	0		12	5	1/26/2009	17	24	12/29/2009	15	25	12/27/2010	18	6	1/2/2012	12	1	12/7/2012

NS = Not surveyed
*** Incomplete data set**
**** Rader Trib A1 data combined with Rader Trib A2**

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