Life History and Monitoring of Upper Klamath-Agency Lakes Adfluvial Redband Trout

William R. Tinniswood (Author)
Michael Harrington (Editor)
Klamath Watershed District
Oregon Department of Fish and Wildlife

2015

Introduction

Spawning surveys are the primary monitoring tool for monitoring bull trout and anadromous fish species in Oregon (Jacobs et al. 2009, Gallagher et al. 2007, Jacobsen et al. 2014,). Randomized redd counts are utilized to monitor steelhead escapement on coastal Oregon tributaries (Jacobsen et al. 2014).

Numerous studies of disparate salmonid species have shown positive significant relationships between redd counts and estimates of escapement (Gallagher et al. 2007), redd counts are strongly correlated with adult escapements (Dunham et al. 2001) and bull trout redd counts can detect a 50% decline in the population over 10 years (Howell and Sankovich 2012). However, redd counts can have significant sources of bias and error (Dunham et al. 2001), 5 year trends in redd counts can be misleading (Howell and Sankovich 2012) and redd counts should be conducted by experienced surveyors (Howell and Sankovich 2012, Muhlfield et al. 2006). The primary sources of spawning survey error include (Dunham et al. 2001, Holocek and Walters 2007).

1) Inexperienced and/or surveyor variability
2) Index surveys
3) Species overlap (ie. brown trout, brook trout, and hatchery rainbow trout)
4) Redd identification a. Test redds, b. Double counting , c. Omitting redds, d. Counting redds caused by hydraulic scour e. sample size otherwise known as number of spawning surveys conducted or redd age f. Superimposition g, substrate type, coloration, and productivity h. flow i. visibility j. habitat complexity k. mental and physical state of observer
5) Number of fish per redd

Inexperienced Surveyors

Redd counts for bull trout showed a wide variation but was not based on past experience with conducting bull trout spawning surveys (Dunham et al. 2001). Dunham found that experienced surveyors did not necessarily have reduced redd enumerating errors. Conversely, Hemmingsen et al. (2001) and Howell and Sankovich (2012) showed experienced redd surveyors had lower redd measurement error than inexperienced redd surveyors. Further, Muhlfield et al. (2006) found bias can be reduced with bull trout redd counts with experienced surveyors. Dunham et al. (2001) suggests ensuring that highly experienced surveyors or one individual count redds for a significant temporal frame similar to Montana redd counts where individuals have completed redd surveys on the same streams for 15 years. Dunham et al. (2001) also suggested tracking individual redds throughout the surveys and surveying the stream throughout the spawning season.

Redd identification

Bull trout redd identification error by omitting and false identifying redds was common (Dunham et al. 2001 and Muhlfield et al. 2006). Omissions of redds were more common in areas

of higher redd density and omissions were more common than false identification leading to underestimation (Dunham et al. 2001). Error in redd counts might be attributable to redd superimposition (Dunham et al. 2001). Numerous salmonids exhibit superimposition. Taniguchi et al. *(*2000) showed significant superimposition on introduced rainbow trout on native char. Hayes et al. (1987) showed significant superimposition between brown trout and rainbow trout. Weeber et al. (2010) showed superimposition of kokanee on bull trout. Gorta'zar et al. (2012) further corroborated findings by Essington et al. (1998) that brown trout select redd sites based on previous spawning at those sites which is not related to availability of spawning habitat and density of spawners

Index Surveys

Salmonid field protocol handbook describes the weaknesses of index surveys (Stevens et al. 2007 and Gallagher et al. 2007). Maxell (1999) Dunham et al. (2001), Issac and Thurow (2006) and Rieman and McIntyre (1996) all describe potential bias with index surveys. Index surveys are problematic as these surveys are assumed to be representative of the entire population. Due to the life history, genetic differences, fishery harvest differences and habitat diversity in the Klamath Basin certain populations might exhibit differing rates of mortality and exploitation. For example, the addition of spawning gravel in Spring Creek have increased the number of redds potentially by tenfold. Spawning surveys in the Klamath Basin need to consider habitat restoration projects especially gravel augmentation that might attract redband trout to the better habitat. Gravel augmentation in the Williamson River below Spring Creek might attract redband trout that were originally destined to spawn in Spring Creek. Census surveys have the ability to track population trends in both areas. Jacobs et al. (2009) suggested utilizing census spawning surveys for core bull trout areas in comparison to the generalized random tessellation stratified sampling design.

Test redds

Identification of redds can be significantly overestimated when test redds are counted. Holecek and Walters (2007) found that 33% of the suspected adfluvial redband trout redds were test redds. Holecek and Walters (2007) found a significant difference in size of redds versus test redds. However, an overlap occurred in the size of true redds and test redds.

Species Overlap

Gallagher and Gallagher (2005) has successfully used logistic regression to assign redds to species when overlap of spawning occurs from steelhead, coho salmon and Chinook salmon. Gough (2012) also used logistic regression for coho and Chinook salmon redds. Gough found redds could be differentiated 98.7% to 99.4% using date of redd observation and redd measurements.

Area Under the Curve (AUC)

Irvine et al. (1993) developed calculation methods for estimating escapement of salmon using Area Under the Curve (AUC) counts of live fish divided by the length of time fish spend on the

spawning ground otherwise known as residence time. Irvine et al. (1993) also recommended calculating observer efficiency to expand the AUC estimates since not all fish in a survey section are counted as some fish are not observed for various reasons. AUC estimates are the preferred method for estimating spawning escapement of coho and Chinook salmon with the exception of fish ladder counts, weirs or live fish tagging. AUC is the most cost effective of these methods. AUC escapement estimates using GRRTS protocol are the primary monitoring tool for chinook salmon and coho salmon on the coast of Oregon and California (Jacobsen et al. 2014, Lewis et al. 2014, Gough 2012, Gallagher et al 2010) and have been shown to be accurate when compared to other sampling methodologies (mark-recapture, redd surveys, carcass mark-recapture, peak counts, weir counts (Parken et al. 2003, Gough 2012, Gallagher et al. 2007). AUC methodology requires that salmonids are easily enumerated and the average time spent on spawning grounds is known. Parken et al. (2003) developed uncertainty methods for AUC counts. Uncertainty occurs in the fish counts, observer efficiency, residence time and the shape of the spawner curve. The two methods used to account for uncertainty was replicate fish counts and developing independent escapement estimates over many years.

Primary Objectives:

1) Develop a census spawning survey protocol in the Wood River, Williamson River and Crystal Creek watersheds that accounts for the primary sampling errors in redd surveys.

2) Determine population escapement trends using AUC and/or redd counts of adfluvial redband trout in most spawning areas of the Wood, Williamson, and Crystal Creek drainages.

3) Develop a protocol for monitoring spawning escapement of adfluvial redband trout on Kamkaun Springs (Sprague River) for comparison, control and index.

Management Implications:

Spawning surveys will assist ODFW fish managers and project partners (KBRT, KLLT, KWP, USFWS, BLM, Klamath Tribes, NRCS, USFS and SWCD) in the following ways

1) Provides the ability to effectively address angling regulation proposals and their potential for positive and negative impacts to the trophy trout fishery in Upper Klamath/Agency Lakes, Williamson and Wood Rivers.
2) Spawning surveys are utilized as the primary data source for stock status review and updating the range wide redband trout status report.
3) Spawning surveys monitor effectiveness of spawning habitat restoration projects and has/will result in the development of priority areas for restoration.
4) Spawning surveys identify the primary spawning habitat, thermal characteristics and life history of redband, brook and brown trout of which the data can be used for identifying and prioritizing Chinook salmon spawning habitat and reintroduction areas.
5) Spawning surveys also monitor habitat changes and potential illegal activities that might harm fish species and their habitat during the spawning period outside the inwater work period.

Life History of Klamath Basin Adfluvial Redband Trout

Much of the life history information of redband trout is discussed by water body in the following document but information on Upper Klamath and Agency Lakes is discussed below.

Historically the oldest adfluvial redband trout documented in Upper Klamath Lake was nine years old as determined by scale analysis and was 33 inches (ODFW unpublished data 1966). In 1991 a 31 inch female redband trout spawner was 8 years old and likely spawned six times in Spring Creek as determined by scale analysis (Buchanan et al. 1991).

Redband trout from Upper Klamath Lake typically reach 18 inches (450) mm by age 3 (Borgerson 1991). If the average size of redband trout entering the lake at age one is 4 inches (100 mm) then an average growth rate of 14 inches (350 mm) would occur in two years. Williamson River (Kirk Springs) redband trout with adipose clip were released in Spring Creek from Klamath Hatchery as yearlings in summer of 1990 and 1991. Average growth rate of redband trout recaptured in Spring Creek in 1992-93 spawn year from the release in 1990 was 15 inches in 2.5 years assuming that all the redband trout returning were from the 1990 release not the 1991 release. This is unlikely as some redband trout were likely from the summer release of 1991. Using Borgerson's (1991) data of length at age most redband trout retuning to spawn from the 1990 release would have been four years old. The average growth rate only increases to 16 inches in 2.5 years if only using redband trout that fall within the range of length at age 4. Maximum growth rate would have been 19 inches in 2.5 years from age 1 to age 3.5. Adipose clipped redband trout captured in Spring Creek in the 1992-1993 spawning season ranged from 15-24 inches and averaged 20 inches (Hemmingsen and Buchanan 1993). These redband trout were released as yearlings in the summer of 1990 and 1991 as 4-8 inch fish and averaging 5 inches.

One redband trout captured in the Link River at 9 inches (229 mm) and recaptured in Upper Klamath Lake at 23 (584 mm) showed a growth rate of 14 inches (355mm) in 14 months. Growth after spawning is very slow and typically only 25-50 mm per year (Hemmingsen and Buchanan 1993). Some redband trout only grew 25 mm in two years post spawn.

The maximum size of redband trout documented captured in the sport fishery in Upper Klamath/Agency Lakes was a 24 pound and 37 inch redband captured on a spoon on August 1956 in Pelican Bay (Oregon State Game Commission Annual Report 1956). This redband trout is mounted at Rocky Point Resort. The largest redband trout observed was 40 inches and approximately 30 pound mortality on Wood River spawning grounds. The date of this observation is unknown (Messmer and Smith 2007).

Adult adfluvial redband trout from Upper Klamath and Agency Lakes have been found to feed on tui chub, blue chub, sculpin species, midge larvae (particularly red chironomid larvae), leeches, scuds (gamphipods) water boatmen (Corixidae), fat head minnow and dyticidae beetle larvae. Fat head minnow, midges and leeches are the most common prey item (ODFW 2009-2010 Statistical Creel).

Adfluvial redband trout peak spawning occurs in December or January for most populations in the Wood River, Williamson and Crystal Creek watersheds. The Sprague River and tributaries Spring Creek and Sycan River also seem to follow this peak as well, but have not been studied as extensively. All known spawning occurs in reaches dominated by groundwater springs. In general most spawning occurs very near the source of springs. Peak spawning by redband trout likely occur during winter because emergence of fry occurs during peak productivity and food supply in the spring. Further, redband trout spawners can return to the lake and recover condition before the onset of poor water quality in early July.

Redband trout are unusually dark (almost black) during spawning. Typically redband trout do not develop distinctive red stripes but will show a reddish-purple wash. Fish in the Williamson River and Crystal Creek appear very dark (black) possibly due to the dark tannin colored water for a large part of the year.

Adfluvial redband trout are resistant to *Ceratomyxa shasta*. Redband trout are commonly parasitized by *Lernea* (external parasitic copepod) in Upper Klamath Lake. Black spot disease (*Neascus*) is also common in Upper Klamath and Agency Lakes and tributaries. Most redband trout captured show lamprey scars. Redband trout in Deming Creek and Spring Creek were tested for resistance to the parasite *C. shasta*. Spring Creek redband trout showed complete resistance to *C. shasta* where the Deming Creek population showed no resistance (Hemmingsen et al. 1988 and Buchanan *et al.* 1989). Due to *C. shasta* and water quality issues in Upper Klamath Lake redband trout have experienced little introgression with stocked hatchery rainbow trout. All hatchery rainbow trout utilized were of coastal origin with no resistance to *C. shasta*. Significant numbers of native trout have been sent to the ODFW Fish Pathology Lab in Corvallis for examination for disease and parasites. Results are published in the ODFW 2012 Stock Status Review.

Genetic analyses have been conducted by Buchanan et al. (1994), Currens (1997, 2009) and most recently Pearse et al. (2011). Three major populations appear to occur in the Klamath Basin. The upper headwater populations, populations associated with the adfluvial life history of Upper Klamath Lake and population related to Klamath River and steelhead. The redband trout of Spring Creek appear to be a distinct population that has evolved with rearing in Upper Klamath Lake and distinct from steelhead.

ODFW believes that redband trout primarily out-migrate to the lakes at age 1. ODFW captured juvenile redband trout from March-May in Agency Lake Delta in 2011 that ranged in size from 80-120 mm (ODFW 2012). Rotary screw traps have been operated on several sections of the Sprague, Wood and Williamson Rivers.

Study Area

The study area is the major spawning tributaries of Williamson River, Wood River, Sprague River, Crystal Creek and their tributaries for redband trout that rear in Upper Klamath/ Agency Lakes, Link River, Lake Ewauna, and Keno Reservoir in Klamath County, Oregon. A description of the areas utilized by adfluvial redband trout and all the past spawning surveys conducted are listed below.

Crystal Creek (Upper Klamath Lake)

Crystal Creek begins at Crystal Springs with 35-40 cfs (Geiger et al. 2000) of groundwater at 8°C (Table 3). Crystal Creek flows for 11.75 miles before entering Upper Klamath Lake in Pelican Bay. Crystal Creek increases in flow with the addition of numerous unnamed springs and Malone Springs (12.25 cfs, Geiger et al. 2000). Crystal Creek has only one tributary at Rock Creek which enters 1.5 miles downstream of Crystal Springs. Rock Creek increases flow in Crystal Creek during spring runoff that typically occurs from March-July. Crystal Creek splits and also forms Recreation Creek which is fed by numerous unnamed springs and flows 2.5 miles before entering Pelican Bay at Rocky Point Resort. Recreation Creek flows at 22 cfs and takes a significant amount of water from Crystal Creek as Crystal Creek measures 8 cfs downstream of the bifurcation. At the mouth of Crystal Creek water temperatures have warmed significantly but this area is one of the more popular angling sites in the summer. Historically Crystal Creek likely received flow from Fourmile and Sevenmile via the Fourmile slough. This channel still exists today and likely conveys some flow from Fourmile Canal. During higher lake levels in the spring Crystal Creek is entirely impounded by Upper Klamath Lake. By July Crystal Creek has a defined channel with flow.

Water temperatures remain cool in most of Crystal and Recreation Creeks and provide thermal refuge for thousands of redband trout in the summer. In addition to trout, yellow perch also congregate in Crystal and Recreation Creeks in the summer. In some years chub species can be observed in large numbers in Recreation Creek.

Nitrogen and nitrate-nitrogen levels are similar in Crystal, Malone and Fourmile Springs which all have redband trout spawning (Geiger et al. 2000). Harriman Springs which has two to three times the nitrate-nitrogen levels and the highest measured nitrogen level at 0.120 mg/l might explain the lack of spawning at the site.

Past Survey Data and Protocol

Landowner Dr. Carl Wenner discovered the new spawning population of redband trout in Crystal Creek in October of 2011. District staff first performed surveys in late December 2011 to confirm Dr. Wenner's observations. After the discovery of redband trout spawning in Crystal Creek a reconnaissance survey by boat was conducted of all springs in Crystal, Harriman, Recreation, Odessa and Short Creeks in December 2011. Spawning density was highest at Crystal Springs (Figure 1 and 9). Spawning by adfluvial redband trout was documented at

Malone Springs and a few unnamed springs on Crystal Creek (Figure 2). Some digging also occurred in Recreation Creek, Harriman Springs and mouth of Harriman Creek but this was likely test excavations or maybe kokanee spawning. Reconnaissance surveys at Crystal Springs from 2011-2012 showed that enumerating redband trout from drift boat was feasible and likely a reliable monitoring tool to reflect escapement. However, counts of redband trout should only be conducted along the spawning habitat on the western shoreline as this area is a rearing area for many redband trout that are not spawning. Four surveys were conducted from 2011 to 2012 to estimate variation and possible error of surveyors. These surveys included a rower and observer. The observer would count redband trout but not divulge the number of fish counted to the rower. The rower would then switch places with the observer and count fish. Variation of counts on these four surveys ranged from 6-24%. Average variation was 16%.

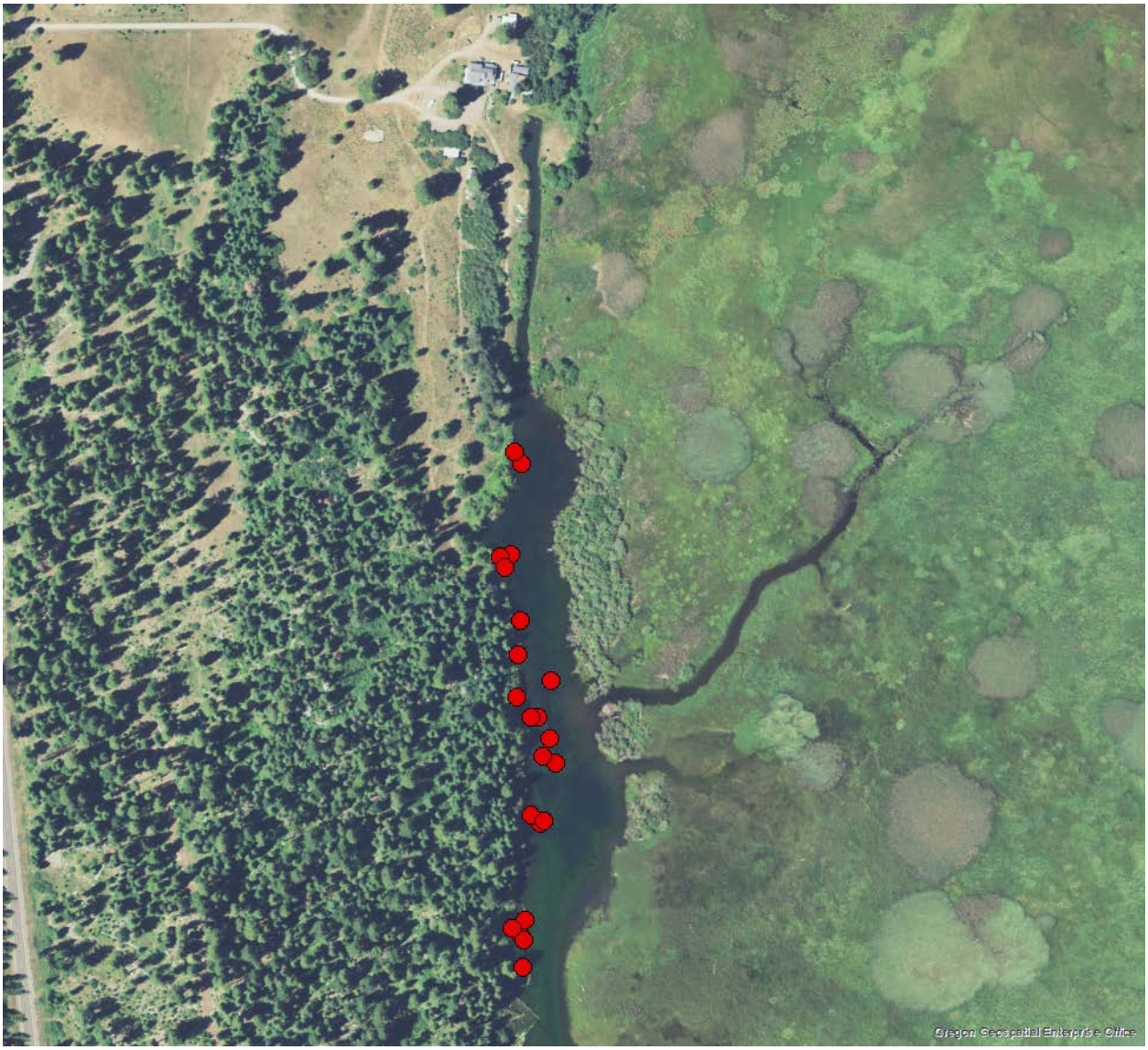

Figure 1. Spawning areas for redband trout at Crystal Springs at Crystal Creek headwaters (Upper Klamath Lake) in December 2011, Klamath County, Oregon.

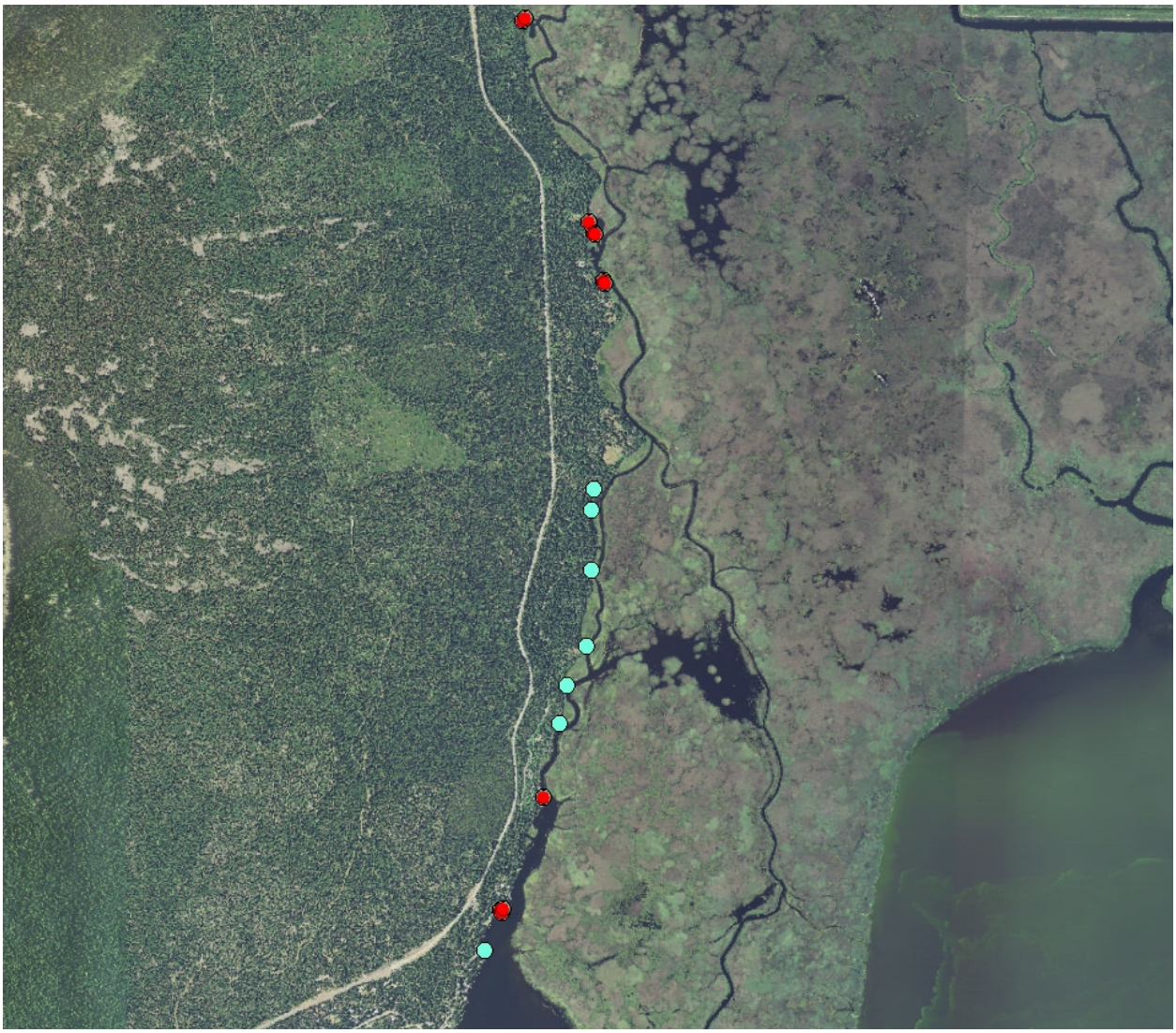

Figure 2. Spawning locations of redband trout (red dots) compared to observed springs (blue dots) in Crystal and Recreation Creeks from Malone Spring downstream to Rocky Point Resort in December 2011 Klamath County, OR (note: All Crystal Creek spring sites have observed spawning while Recreation Creek is likely test digs).

Wood River (Agency Lake)

The Wood River is a spring fed dominated system that begins with a series of springs that fluctuate annually from 160 to 250 cfs (Gannett et al. 2007 and OWRD Gage below Dixon Road) at Kimball State Park. The river flows for 20.18 miles to Agency Lake. Inputs of Annie Creek, Fort Creek and Crooked Creek typically increase flow to greater than 400 cfs during non-irrigation season. Gannet et al. (2007) calculated the Wood River valley had 490 cfs of groundwater from spring discharge. Flow can also increase at the Dixon Road Gage dramatically in excess of 100 cfs from run off from the cattle pasture above Dixon Road. Water temperatures typically average 5.8° C at the gauging station below Dixon road during peak spawning of redband trout (Table 3). Water temperatures differ at the various springs at Kimball State Park suggesting different sources of groundwater. Potential fish habitat availability for steelhead has been calculated by Huntington and Dunsmoor (2006). Over 1 $.07e^{7}$ ft ^{2} of low flow rearing habitat over 60 miles is available

Adfluvial redband trout are currently known to spawn in the Wood River from October into June from the Annie Creek confluence upstream to near the headwater springs at Kimball State Park (Figure 3). A total of 2.89 miles is currently known to be utilized for spawning by redband trout. Most spawning occurs from above Sun Pass Bridge to 930 meters above Dixon Road (Figure 3). Highest density of spawning occurs just above and below Dixon Road. Spawning substrate is composed of pumice rock, small gravels and introduced gravels ranging from 3/8 to 2 inches in diameter. Spawning gravel was first added sometime in the unknown past. Two hundred cubic yards of spawning gravel composed of round river rock ranging in size from 3/8 to 2" was added in 2009 from Dixon Road to just above Sun Pass Bridge. Woody material was also added in 2009 to the Wood River from Dixon Road to just upstream of the Melhase Canal. Most wood added to the river was keyed into the bank. Spawning likely does not occur below Annie Creek as tons of pumice moves out of Annie Creek annually (Figure 3). However, young of year redband trout have been captured in Annie Creek above the Sun Creek confluence.

Brown trout and brook trout also spawn above Melhase Canal on the Wood River. All brook trout observed spawning in this reach were less than 12 inches and have all been observed spawning near the headwaters. Brown trout have been observed spawning from October through December but have been observed on the spawning grounds year round. Observations of brown trout have increased significantly over the past five years compared to surveys conducted in the 1990's. Evidence from pit tagged brown trout that were recorded at Horseshoe Ranch but not at the Wood River weir at the Sun Pass weir suggests brown trout are also spawning elsewhere in the system.

An unknown density of spawning occurs in Melhase Canal (Figure 3). Spawning has been observed both above and below the crossing on Annie Creek. Year round, stable flow in Melhase Canal and the fact the fish screen has never operated efficiently results in spawning in Melhase Canal. Melhase canal also has adequate amount of spawning substrate. Redband trout are also falsely attracted to the canal as it enters Sevenmile Creek at Mcquiston Road.

ODFW believes that redband trout primarily out-migrate to the lakes at age 1. Rotary screw traps were operated by BLM on the Wood River just above the Wood River wetland Bridge from

1999-2001. Juvenile outmigration appeared to peak in late March-April and again in late August. The largest catch occurred on 4-14-2001. Most redband trout captured in August and September ranged in size from 2-5 inches (60-120 mm). The median length in February, March, April, September and October was 4 inches (100 mm). The median length for July and August was 3 ¾ (90) and 3 inches (80 mm), respectively. However, no sampling occurred from May-June. Rotary screw trap are also biased towards weaker swimming fish thus fish larger than eight inches (200 mm) can evade capture unless stream velocities and rotation time of the screw trap are high.

USFWS operated rotary screw traps from 2005-2008 at two locations on the Wood River. Young of the year redband trout dominated catch on the Wood River in 2006 with peak catch in March of redband averaging 40 mm. Juvenile redband trout peaked on the Wood River in March-May with a secondary peak in July of 2006 (Buettner et al. 2009)

Past Survey Data and Protocol

Enumeration of redband trout spawners began on the Wood River in Jan-April 1995 from Kimball State Park to Annie Creek. In 1996 and 1997 counts of adfluvial redband trout were almost conducted twice a month. In 1996 the count was separated into two reaches (Kimball to Dixon Road and Dixon Road to Melhase Canal. In 1997 three reaches 1) Kimball Park to Dixon Road Bridge 2) Dixon Road Bridge to Sun Pass Bridge 3) Sun Pass bridge to Melhase Canal were developed and the survey continued to follow this protocol until present (Figure 10-12). After 1998 fewer surveys were conducted and ODFW staff attempted to conduct one or two surveys during the observed peak in December or January.

More intensive spawning surveys began in 2010 when Native Fish Investigations conducted redd surveys and fish counts from Kimball State Park to Melhase Canal. In 2011-2012 NFI operated a video camera and pit tag array weir just below Sun Pass Bridge. In 2011 Native Fish Investigation only conducted surveys to the video camera weir at Sun Pass Bridge. Redd counts ranged from 485 in 2010-2011 from Kimball Park to Melhase Canal and 379 redds in 2011-2012 from Kimball State Park to Sun Pass Bridge. Another pit tag array was operated on the Wood River on Horseshoe Ranch (RM 13.4).

In 2011-2012 ODFW District Staff conducted Area Under the Curve reconnaissance surveys to evaluate the effectiveness of this protocol. This protocol was continued through 2014.

All counts conducted from 1994-2014 include counts in the caddis hole which is a staging area for redband trout (Figure 12). Schools of redband trout can be observed at the Caddis Hole as early as July. Since survey estimates include the caddis hole the AUC estimates are likely high as residence time can be significantly longer than 14 days. The AUC counts should also calculate how many fish were in the area above Sun Pass Bridge as it is unlikely redband trout stage above the Sun Pass Bridge and the 14 day residence time is more accurate.

District staff snorkeled the Wood River on 24 December 2009 from Dixon road to Sun Pass Bridge above the Caddis hole. A total of 21 redband trout ranging from 18-24” while 3 brown

trout (16-28”) and 1 unknown fish were observed. District staff took pictures underwater. No juvenile trout were observed.

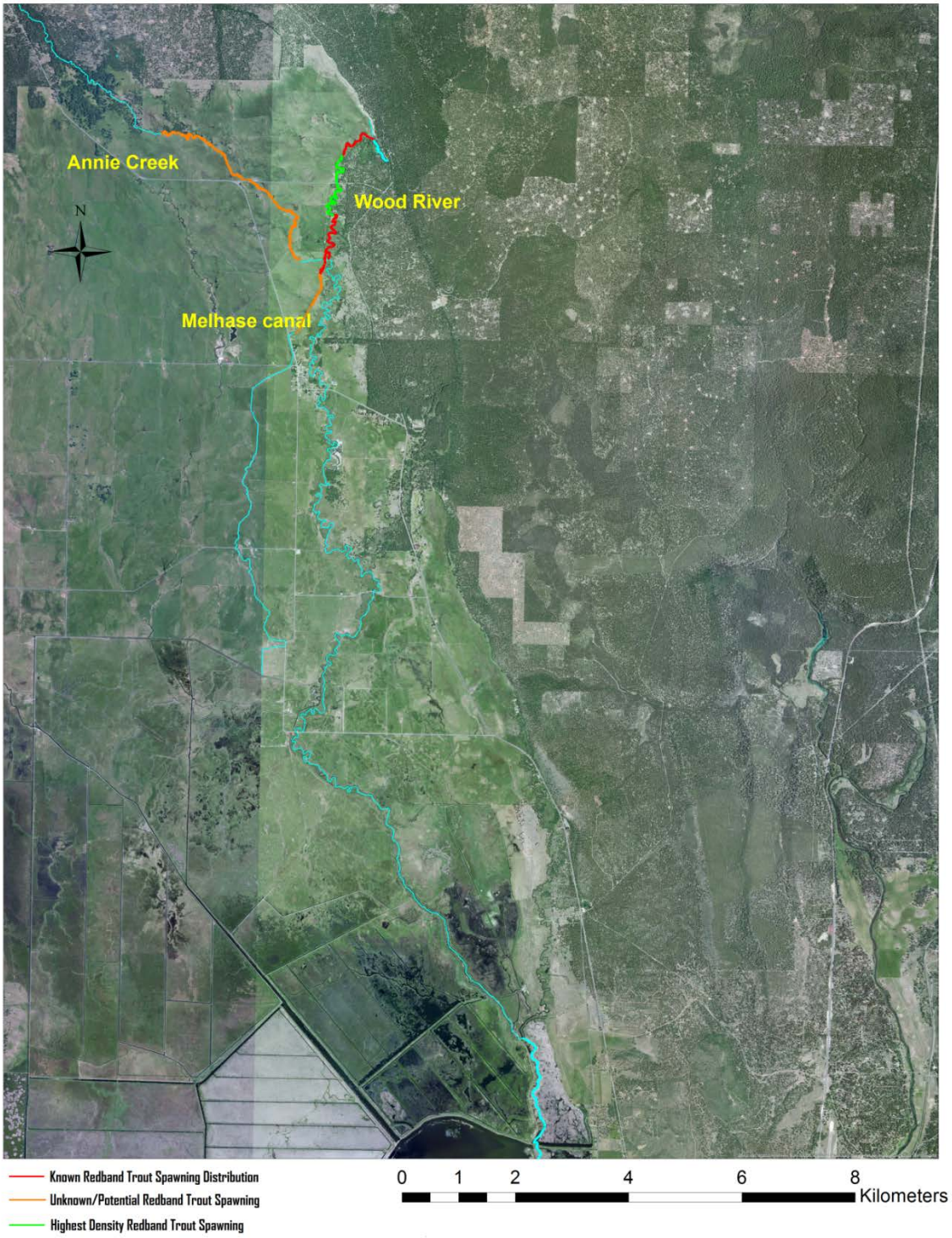

Figure 3. Known, potential and highest density spawning habitat (red, green, or orange lines) for redband trout and brown trout in the Wood River, Annie Creek and Melhase Canal Klamath County, OR.

Crooked Creek (Wood River)

Crooked Creek is a low gradient, sinuous, spring fed dominated system with an estimate of 43 cfs of groundwater input above Tecumseh Springs (Gannett et al. 2007). Agency Creek and Tecumseh Springs are the two primary tributaries. Water temperature at the springs vary but the springs at the Klamath Hatchery are 7°C and 9.4°C with water temperature averaging 8.9°C degrees at the outlet of Klamath Hatchery at the primary spawning grounds for adfluvial redband trout. Crooked Creek flows 12.26 miles from the small headwater springs located on Fremont-Winema National Forest. Immediately below the springs on the USFS Crooked Creek has been channelized until reaching Klamath Hatchery where a significant amount of flow enters the Crooked Creek from numerous springs.

Spawning habitat is extremely limited in Crooked Creek (Figure 4). Past surveys of all Crooked Creek below Klamath Hatchery have shown limited spawning or spawning habitat. A few areas where the stream channel is narrow and adequate pumice substrate is present you will find some spawning. Nearly all spawning occurs in areas where spawning gravel has been added. Spawning gravel made up of round river rock from Threemile Gravel Pit ranging in size from 3/8 to 1 1/2 inch diameter was placed in Crooked Creek in three locations in 2005 (Sites 1-3, Figure 13). One hundred cubic yards of spawning gravel was added to site 1, one hundred cubic yards was added to site 2 and fifty cubic yards were added to site 3 (Figure 4 and 13). In 2012 fifteen cubic yards of spawning gravel was added to site 3. Forty cubic yards of spawning gravel was added to Crooked Creek below highway 62 (Site 4) in 2013 (Figure 14).

Redband trout have been observed to spawn in Crooked Creek from October into April. Peak spawning typically occurs in early December. Hatchery rainbow trout have been observed spawning in early September and have been observed on the spawning grounds from September through April. Gravid hatchery rainbow trout have also been captured by net during spawning season. Hatchery rainbow trout can be easily distinguished from redband trout by coloration, spotting pattern, robustness, and behavior. Hatchery rainbow trout are much brighter and have a much more pronounced red stripe than redband trout spawners while native redband trout are very dark, almost black, with little coloration. Hatchery rainbow trout are heavily spotted all over the body whereas native redband do not have spotting below the lateral line. Hatchery rainbow trout have typically been fed all winter at the viewing deck on Crooked Creek therefore they are in excellent condition whereas redband trout are streamlined. Hatchery rainbow trout tend to have reduced flee response from disturbance and are easily observed. Hybridization likely occurs between the two subspecies as they have been observed spawning together. Survival of their offspring is likely lower due to intermediate resistance to *Ceratomyxa shasta* in Upper Klamath and Agency Lakes (Hemmingsen et al. 1988 and Buchanan *et al.* 1989). Hybrids would be difficult to identify.

Brook trout, brown trout and lamprey have been observed to spawn at Crooked Creek. In some years large numbers of brown trout have been observed spawning at site 3 (Klamath Hatchery).

Past Survey Data and Protocol

Spawning surveys utilizing hatchery staff were conducted in the only known spawning area in the mainstem Crooked Creek during the years 2003-2005 at site 3 (Klamath Hatchery). After the addition of spawning gravel at site 1 and site 2 volunteers with assistance from ODFW district staff were utilized for spawning surveys in 2005.

Beginning in 2006 through 2014 the ODFW assistant district fish biologist completed all redd counts on Crooked Creek at site 1-3 using the same protocol. Spawning surveys were conducted bimonthly from November-April with redds marked with colored rocks. Fish observed were enumerated and identified if possible with length estimated. From 2010-2012 spawning surveys were completed in October for an escapement estimate for redband trout in the Wood River Valley utilizing pit tags and video cameras. All redds were enumerated and treated equally until 2011 when redds were classified by size, whether the redd was superimposed, and potential secondary redd. Typically very small or test redds were not enumerated in any of the surveys.

Tecumseh Springs (Crooked Creek)

Tecumseh Springs is fed by 27 cfs of groundwater (Gannet et al. 2007) from two springs that are 8°C and 10°C and combine to average 8.3° C below highway 62 (Table 3). Historically most flow originating at Tecumseh Springs flowed down a ditch paralleling highway 62 and some flow also exited under highway 62 through a small culvert. Spawning by redband trout occurred in the ditch and at the springs. In 2003 all the flow was directed through one round, passable concrete culvert under highway 62 and subsequently the ditch was filled. In 2006 a 380 foot spawning channel was constructed by USFWS below highway 62 to the mouth with Crooked Creek (Figure 4). Total habitat length of Tecumseh Spring is 0.19 miles. Spawning gravel was added to the riffles and tailouts of the new channel. Gravel additions also occurred in 2008, 2011 (31 cubic yards) and 2014 (30 cubic yards) due to fish pushing the gavel into the pools. In 2008 a small amount of spawning gravel was added upstream of highway 62.

Tecumseh Springs is primarily utilized by redband trout from late October into April for spawning but brook trout, brown trout and hatchery rainbow trout have also been documented to spawn at the springs. All brook trout observed spawning in Tecumseh Springs have been less than 300 mm. A female brook trout was observed spawning with a male redband trout in 2011. In 2003 a fish salvage was conducted in the ditch parallel to highway 62 that was scheduled for fill. Dominant fish species in the ditch were lamprey ammocetes, sculpins species (marbled and slender) and redband trout juveniles (age 0-2). Brook and brown trout were also captured in lower numbers.

Past Survey Data and Protocol

Periodic counts of redband trout at the headwater springs at Tecumseh Spring was conducted from 1997-2003. Redds and fish were enumerated at Tecumseh Springs above highway 62 beginning in the winter of 2003 and continued through the year 2006. In 2006 a spawning channel was constructed downstream of the Highway 62 culvert. Redd and fish counts have been conducted from November through April in two sections (above the culvert and below the culvert) by ODFW assistant District fish Biologist from 2006-2014. During the NFI

investigations redd surveys were also conducted during the month of October in 2010-2011 and 2011-2012 spawning season. Snorkel surveys by ODFW and USFWS have been conducted at Tecumseh Springs in the winter of 2006 and 2007. Snorkel surveys observed more fish than were observed from surveying the stream from the bank. Beginnings in 2008 surveys were also conducted at the one site of spawning gravel that was placed on the Napier property. This area is also a staging area for redband trout that might be spawning in Tecumseh Springs or upstream.

Ranch Creek (Crooked Creek)

Ranch Creek spawning channel and pond was constructed in 1997 with a water right specifically for fish. Spawning gravel was added to all the tailouts of pools in the channel. All water from Ranch Creek is diverted from Agency Creek just above highway 62 (Figure 5). The Ranch Creek spawning channel is 0.38 miles in length and ends at the Forest Service boundary (Figure 5). At the USFS boundary the channelized channel travels 140 m to a standpipe. Fish passage is blocked at a standpipe that diverts water to the east. However, juvenile redband trout are found in the ditch above the standpipe suggesting there is a self-sufficient resident redband trout population above this barrier or redband trout are somehow able to migrate through the standpipe. Water temperature has been recorded in 1999-2000 by Klamath Tribes and 2011-2013 by ODFW (Table 3). Since water is diverted from Agency Creek water temperatures cool slightly but still remain warm compared to other tributaries and average 7.41°C during the peak of spawning in December (Table 1).

Ranch Creek is utilized by redband trout from late October into April for spawning. Large numbers of juvenile redband trout are observed using Ranch Creek. Currently no brown trout or brook trout have been documented using Ranch Creek for spawning. The Klamath Tribes sampled Ranch Creek in 1999 and only found age 0-2 redband trout and slender sculpins.

Past Survey Data and Protocol
The ODFW Assistant Fish Biologist completed a spawning survey in 2003-2004 spawning season. Spawning surveys were also completed by Native Fish Investigation staff for two spawning seasons from 2010-2012. A video camera and pit tag array was operated by NFI in Ranch Creek in the 2011-2012 spawning season. District staff began surveys again in 2012-2014 spawning season. Redd counts, size of redds, number of fish, size of fish observed have declined dramatically since surveys in 2003.

Agency Creek (Crooked Creek)

Agency Creek is an entirely spring fed system with a groundwater spring flow approximately 21 cfs (Gannet et al. 2007). Eight cfs is diverted to Ranch Creek during non-irrigation season. Matthews (2006) measured flows that ranged from 8.61 to 10.7 cfs from November 2005-June 2006. Instantaneous flows were calculated as 5.51 to 20.2 cfs (Matthews 2006). Agency Creek has one of the warmest thermal regimes during spawning of redband trout that averaged 9.6°C during peak of spawning in December (Table 3). An impassable concrete dam occurs immediately above highway 62. Crater Lake Spring Water obtains water from these springs. Agency Creek is 0.8 miles in length to highway 62 and one mile in total. Historically Agency Creek was also impounded 0.3 miles from the mouth by a small earthen dam. Spawning habitat

was minimal. Agency Creek was restored by USFWS in 2003 to a sinuous channel with spawning gravel placement within a 1600 foot section of the stream on Jim Root's property. Beaver activity is extensive in this area.

Agency Creek is utilized by redband trout from late October into April for spawning. Large numbers of juvenile redband trout are observed using Agency Creek. ODFW electrofished Agency Creek in 2002 before the implementation of the stream channel restoration project. Redband trout age 0 -2, sculpin species and lamprey were captured.

Past Survey Data and Protocol

District staff completed spawning survey in 2003 after completion of a new channel, the removal of an impassable dam and the placement of spawning gravel. Spawning surveys were also completed by Native Fish Investigation staff for two spawning seasons from 2010-2012 and again by district staff in 2012-2014. A video camera and pit tag array was operated for two spawning seasons on Agency Creek from 2010-2011 and 2011-2012. The video camera was moved downstream during the 2011-2012 spawning season due to the large number of redband trout moving back and forth past the video camera. The total count of upstream passage events past recorded on video of adult redband trout greater than 14 inches was 632 in Agency Creek (ODFW 2012). In Agency Creek peak observations of redband trout greater than 14 inches occurred during November in 2010-2011 with a trimodal distribution of spawning with additional peaks in January and late March (ODFW 2012). Adult redband trout spawners observed by video camera in Agency Creek were smaller than Fort Creek redband trout (ODFW 2012). Agency Creek has been the most productive of all the spawning surveys in the Crooked Creek system.

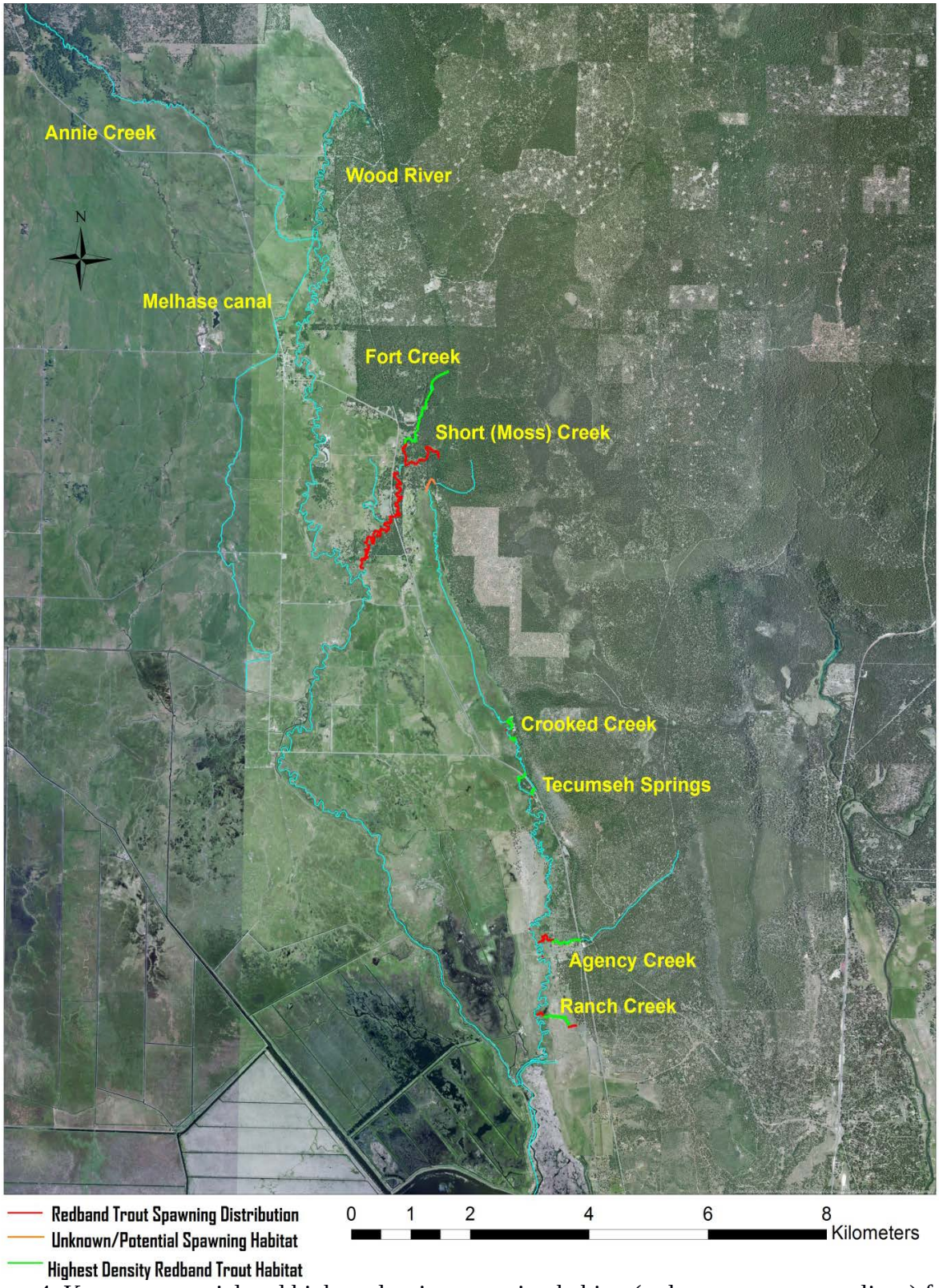

Figure 4. Known, potential and highest density spawning habitat (red, green, or orange lines) for redband trout and brown trout in Fort Creek, Short Creek, Crooked Creek, Agency Creek, Ranch Creek, and Tecumseh Springs, Klamath County, OR.

Fort Creek (Wood River)

Fort Creek is a spring fed dominated system beginning at Reservation Springs and flowing 3.82 miles into the Wood River. Fort Creek flows average 84 cfs from groundwater springs (Gannet et al. 2007). The primary tributary, Short (Moss) Creek is a spring fed tributary where flows were measured as 24 cfs in 2013 by Oregon Department of Forestry. Fort Creek flow was measured as 59 cfs above the confluence of Short Creek. Water temperature just downstream from Reservation Springs averages 7.8°C during the peak spawning season of redband trout (Table 3). Fort Creek above the dam contains only natural pumice substrate with smaller gravel less than pea size. Fort Creek on USFS property has a large amount of instream wood and is the best reference reach for habitat and water quality of all the streams utilized by adfluvial redband trout. This reach is dominated by old growth trees including white fir, ponderosa pine and western hemlock.

Prior to 1992 the area above the dam was impounded for gravity fed irrigation. Due to the failure of the dam on Fort Creek in 1992 spawning gravel and habitat structures were added to Fort Creek below the dam. Spawning gravel was added just above the tandem culvert crossing and adjacent to the cedar house below an upstream V log structure. In 2008 the culvert under highway 62 was replaced with a bridge and spawning gravel was placed under the bridge.

Only brook trout were found above the dam prior to dam failure (ODFW 1988 Monthly Report). In 1992 the dam failed and redband trout and brown trout were able to recolonize above the dam. The Klamath Tribes observed immediate recolonization of redband trout spawners above the dam**.** Spawning by brown trout or redband trout has been documented to occur from near the confluence with the Wood River to the headwaters at Reservation Springs. The highest density of redband trout spawning occurs above the dam and pump irrigation diversion. Introduced spawning gravel is heavily utilized by brown trout and redband trout in the areas added above Rivers of Light Bridge and under the highway 62 Bridge.

Past Survey Data and Protocol

Fort Creek surveys have been conducted from 1995 to 2014. In most years spawning surveys were conducted twice a month from November through April but some year surveys started in December. Surveys were conducted in October during the 2010-2011 spawning season. The survey was separated into two sections. One survey was completed from Rivers of Light Bridge to Dam (private property) and the other survey was completed from the dam to headwaters at Reservation Springs (USFS). Fort Creek redd data provides an excellent control as little habitat manipulation has occurred on the stream. The ease of identification of redds and reduced superimposition makes redd data on Fort Creek the most reliable of all the redd surveys in the Klamath Basin. Observations of spawning fish are reduced due to excellent habitat complexity due to abundance of large instream wood.

Brown trout have been observed spawning from October through December and likely dominate the spawning assemblage of the creek. Distribution of brown trout spawning appears to be larger than redband trout. Redband trout spawn from October through April with a majority of

spawning occurring near the headwaters (Figure 3). Native Fish Investigations operated a video camera on Fort Creek from 2010 to 2011 at the Rivers of Light Bridge and at Crater Lake Resort from 2011-2012. Peak observations of upstream passage by redband trout greater than 14 inches by video in 2010-2011 was in late January while brown trout observations peaked in November (ODFW 2012). Temporal distribution of spawning redband trout has a trimodal distribution of spawning with additional peaks in February and late March (ODFW 2012). Brown trout greater than 14 inches dominated the video recording in Fort Creek with 697 upstream passage recordings (ODFW 2012). Redband trout were significantly larger than brown trout in Fort Creek (ODFW 2012). The total count of upstream passage events past recorded on video of adult redband trout greater than 14 inches was 559 in Fort Creek (ODFW 2012). Brook trout occur in Fort Creek but appear to be primarily resident fish. Electrofish surveys above the dam have found brook trout to be the dominant salmonids with redband trout and brown trout. Few brook trout were recorded on video. A tiger trout was documented on video.

Short-Moss Creek (Fort Creek)

Short Creek is a spring fed stream with 24 cfs of groundwater flow. Water temperatures are cooler than Fort Creek and average 7°C during peak of redband trout spawning(Table 3). The stream flows mostly on private land for 0.85 miles into Fort Creek above highway 62. Spawning habitat has been significantly altered due to dam construction near the headwaters and resulting failure. A large amount of sediment has been added to Short Creek due to hill slope failure. This sediment has covered most of the spawning substrate. Due to these impacts very little spawning occurs in Short Creek (Figure 3).

Past Survey Data and Protocol

Spawning surveys were first conducted by NFI in 2010-2012. Redds were observed from October through April suggesting spawning by redband trout and brown trout. A small, precocial, male redband trout mortality was observed in 2013. Electrofishing data shows brook trout dominate followed by redband trout and brown trout. Sculpin species were also found but surprisingly no lamprey were found. Numerous adult brook trout up to 10 inches were captured and some males were gravid.

Williamson River

The Williamson River can be described as four different river systems (Below the confluence of the Sprague River, the spring fed dominated section from Sprague River confluence upstream to Spring Creek, Spring Creek to Kirk Springs and the Upper Williamson from headwater springs to Klamath Marsh). Redband trout spawn in the spring fed dominated section of the Williamson River. Williamson River flows 25 miles from the barrier waterfalls to the mouth. The river desiccates in the summer above these waterfalls. In total the Williamson River flows 86 miles to the headwater springs. The Williamson River is dominated by Spring Creek flows in the summer. Numerous other springs and spring fed tributaries Larkin and Sunnybrook Creeks provide the only flow below the waterfalls during the summer.

Documented spawning by redband trout and brown trout occur from just downstream of Pine

Cone Bridge to Kirk Springs (Figure 6). Upstream of Kirk Springs are impassable waterfalls and the river is dry at the Kirk Road gage during the summer into the late winter. No spawning occurs from Spring Creek upstream to just below Larkin Creek. The reach from Spring Creek to Larkin Creek is very important staging area in September and October as redband trout prepare to spawn. The highest density of spawning redband trout occurs at Kirk Springs (Figure 6 and 14). Of secondary importance for spawning of redband trout is the reach near the USFS campground (Figure 6 and 15). Only once have redband trout been observed spawning in Larkin Creek on USFS property. One hypothesis is that water temperatures are too cold in the winter (Table 4). It is unknown if large numbers of redband trout spawn in Upper Larkin Creek. However, ODFW sampling at the mouth of Larkin Creek has shown that brown trout dominate. Klamath Tribes monitoring in the late 1990's and early 2000 found only brown trout in Upper Larkin Creek.

In the 1989 spawning gravel was added to Kirk Springs (35 cubic yards) and at the USFS campground (40 cubic yards) (Figure 14 and 15). Spawning gravel was added to several areas above Knapp's dam in 2011(65 cubic yards) and 2012 (100 cubic yards) below Kirk Springs by barge with dump truck bed attached. Spawning gravel was added in 2012 (45 cubic yards), 2013 (225 cubic yards) and 2014 (15 cubic yards) to the Williamson River below Collier State Park on the Tuttle Ranch and on Jon Knapp's property (15 cubic yards) (Figure 13, 16-17).

Kirk Springs redband trout have been studied extensively by ODFW. Spawning occurs from November through March with peak typically in late December but has been observed in early December and January. The Kirk Springs stock of redband trout were collected for brood stock and the 28 Williamson River stock was developed. Buchanan *et al*. (1989-1991), Hemmingsen et al. (1992) and Borgerson (1991) made comparisons of the scale analysis and length frequency of Spring Creek redband trout spawners to the Kirk Springs spawning population on the Williamson River. Redband trout from Spring Creek had less scale resorption than the Kirk Springs redband trout. Redband trout were found to have a unique life history in Spring Creek. Marked redband trout from both Kirk Springs and Spring Creek returned to their respective spawning grounds. Hemmingsen suggested that the Kirk Springs (Williamson River) and Spring Creek redband trout populations were reproductively isolated. Williamson River redband trout spawning at Kirk Springs occurred from Age 2-6 (Buchanan et al. 1991). Redband trout in Spring Creek showed higher iteroparity rates than the Kirk Springs population. Repeat spawning occurs and has been documented up to four times but is less common than Spring Creek. Females have a higher level of repeat spawning than males in Spring Creek and Williamson River (Borgerson 1991. Williamson River at Kirk Springs average spawner was 500 mm with 2100 eggs per female (ODFW December 1989 Monthly Report). Once a broodstock was developed at Klamath Hatchery in 1993 these fish averaged 1431-2779 eggs per female from 1993-1998.

Temperature units (TU) to hatching at Klamath Hatchery of the Williamson River (Kirk Springs Broodstock ranged from 609-689. Fish spawned earlier had a longer hatching time. For example in the fish spawned on 12/16/92 there temperature unit to spawning was 689 while the fish spawned on 1-28-93 had temperature units of 653. (ODFW Klamath Hatchery Records)

Adfluvial redband trout spawners in Spring Creek were significantly larger than redband trout from Kirk Springs (22" compared to 20" Buchanan et al. 1991). Average size of females 20" (502 mm) is larger than males 19" (485 mm) for Kirk Springs. Spawners in Kirk Springs (Williamson River) ranged in size from 15" (388 mm) to 25" (630 mm) in 1990-1991 and 13" (323mm) to 26" (665mm) in 1991-1992 (Hemmingsen et al 1992). Size range in 1992-1993 ranged from 16-27" (403-670mm)(Hemmingsen and Buchanan 1993). The largest redband trout captured at Kirk Springs as part of the broodstock collection and life history studies was 27" (670 mm). Average size of spawning redband trout were determined during egg take at Kirk Springs (Williamson River) was 20" (506 mm) from 1986-1990 (ODFW Fort Klamath Hatchery Records) Adfluvial redband trout at Kirk Springs averaged in 1990-1991 was 20" (502 and 507 mm) in 1991-1992 (Hemmingsen et al 1992). Adfluvial redband trout were larger in Kirk Springs in 1992-1993 and average was 22" (544 mm) (Hemmingsen and Buchanan 1993)

Redband trout spawning in the Williamson River below Spring Creek follow the same timing as Spring Creek but also have a strong late run of fish well into June.

USFWS operated rotary screw traps from 2005-2008 at two locations (one just above Sprague River confluence and one near Modoc Point Diversion immediately above highway 97) crossing on the Williamson River. Peak numbers of juvenile redband trout occurred in May 2006 at mean size of 58 mm in the Williamson River above the Sprague River confluence. Redband trout ranged in size from 80-150 mm during outmigration in September and October (Buettner et al. 2009). Catch was low on the Williamson River in 2008 below the Sprague River confluence. Peak catch occurred in October of redband trout averaging 98 mm. (Buettner et al. 2009). Juvenile redband trout in the Williamson and Sprague River are very dark. The dark coloration allows them to be camouflaged during tannin colored flow and also blend in with the coloration of the substrate.

Past survey data and protocol

Historically, one redd survey in September was conducted on the Williamson River from Spring Creek to Pine Cone Mill (Table 1). The precision and accuracy of the redd counts is questionable as redds can be created as early as October the following year and superimposition is likely in this area. In most surveys redband trout were also enumerated. This survey was discontinued due to lack of statistical robustness and the survey takes significant time to complete. This survey could provide value if redband trout are enumerated on a more frequent basis during times of good water clarity which is usually occurs from September through March.

Table 1. Williamson River spawning surveys conducted from boat from Spring Creek to Pine Ridge Mill from 1974 to 2009.

Date	Year	Number of redds	Number redband
29-Aug	1974	43	250
10-Sep	1975	99	392
10-Aug	1976	117	158
4-Aug	1977	170	352
9-Aug	1978	125	182
1-Jan	1979	61	
5-Sep	1980	112	
1-Sep	1981	105	
23-May	1991	83	
3-Sep	1992	161	
10-Sep	1993	113	
13-Sep	1994	146	
11-Sep	1995	113	
4-Sep	1996	171	200
5-Sep	1997	96	250
	1998	No survey	
	1999	No Survey	
13-Sep	2000	153	700
21-Sep	2001	173	700
	2002	No Survey	
11-Sep	2003	116	537
14-Sep	2004	224	360
21-Sep	2006	140	809
17-Aug	2007	No Survey	300
	2008	No Survey	
25-Oct	2009	No Survey	388

Surveys began in 2003 at Kirk Springs (RM 22) to enumerate redband trout spawners (Figure 14). A survey was conducted during peak spawning in late December of every year to ensure adequate escapement. Mortalities of redband trout were also enumerated. Some surveys encountered high flows or high winds which resulted in poor survey conditions. In 2010 Native fish investigations completed redd and fish counts at Kirk Springs and USFS campground but surveys experienced high flows in early February thus surveys did not cover the entire timing of redband trout spawning.

Reconnaissance area under the curve surveys were conducted for two years from 2011-2013. This data showed a good peak count with depletion and appears more valuable than conducting one survey a year.

Spring Creek

Spring Creek is a large tributary to the Williamson River and the largest single source of groundwater in the Klamath Basin (Figure 6). Spring Creek enters the Williamson River at Rivermile 16.5. Spring Creek is 2.12 miles long and is fed by a series of springs. The majority of Spring Creek is located on public land with the first 0.8 miles being on State Park property the next 0.75 miles on private property and the last 0.5 miles on the USFS property. Discharge of Spring Creek is near 300 cfs (USGS 2007). Gannet et al. (2007) reported the measured instream flow in Spring Creek from 1914-2003. Flow peaked at 350 cfs in 1914 and a downward trend occurred in the mid 1930's. Flows nearly reached 350 cfs in the mid 1950's then remained fairly stable with highs in 1972 and 1973 and again reached a high of near 350 cfs in the mid 1980's then began a downward trend and was last measured in 2003 at nearly 300 cfs.

A thermograph was installed at the mouth of Spring Creek from November to May in 1976 by ODFW. Water temperature ranged from 39-49°C. ODFW operated two thermographs from 2010 to 2014 at the flow gauge near the mouth and at the picnic area (Table 5).

Spring Creek has the unusual colony of very large Mares Eggs or *Nostoc pruniforme* which is a cyanobacteria. *Nostoc* is common in most water ways but the size and density of the colony of Mares Eggs at the headwaters of Spring Creek is truly unique. Some individual Mares Eggs can be near the size of a large grapefruit. The Mares eggs are nitrogen fixers. Water samples collected at the headwaters indicate that the water is saturated with nitrogen. Despite the presence of spawning substrate and spring flows redband trout have not been observed spawning at the springs. The concentration of nitrogen is most likely the reason for the lack of spawning. Brook trout have been observed spawning at the springs located directly downstream of the headwater springs. The headwaters of Spring Creek have been found to be supersaturated with nitrogen which could gas bubble disease in fish. Trout fry are observed at the headwaters.

Fortune (1966) estimated Spring Creek contained no spawning habitat for steelhead or chinook salmon. His analysis was most likely based on the blocky native substrate and lack of gravel.
Redd counts began in Spring Creek in 1972 above highway 97 before the addition of spawning gravel. From 1972-1975 ODFW conducted one spawning survey above highway 97 in February or March. Total redds enumerated ranged from 77 to 88. Number of adult redband trout observed above highway 97 was 42 to 94. In 1975 a downstream U shaped gabion was constructed at the mouth of Spring Creek by ODFW and the Klamath Country Flycasters to retain the introduced gravel. A total of 300 cubic yards of spawning gravel ranging in size from 3/8 inch to 1 ½ inches were placed above the gabion. Beginning in 1975 a more intensive spawning survey was conducted at the gabion. An additional 200 cubic yards of spawning gravel was added in 1976. The spawning area above the gabion was estimated at 906 square yards (8156 sq ft). A total of 1430 cubic yards of spawning gravel has been added from 1975-2012 (Table 2).

Table 2. Cubic yards of spawning gravel (round river rock) ranging in size from 3/8 to 4" was added to three areas on Spring Creek (Williamson River) from 1975-2012 Klamath County, Oregon.

Year	*Gabion (RM 0-0.1)*	*Picnic Area (RM 0.4-0.7)*	*Lassett (RM 1.4)*
1975	300	10	
1978	200	50	
1979		40	
1980		50	
1985		100	
1987		70	
1989		80	
1993	40		
2010		140	
2011		100	100
2012		165	
2014		75	

In 1976, 25 redds were measured for depth and velocity at the gabion spawning area. Average velocity was 1.35 ft/sec and average depth of redds was 2.05 feet. In the 1976 ODFW monthly reports they report two interesting results that do not occur currently. ODFW reported spawning ended in March. This is the reason spawning surveys were only conducted until the end of March. Secondly, they report many small redband trout and brook trout spawning that are under 14". These two runs of fish are not observed today. Brook trout are known from Spring Creek but are seldom observed. Further, brown trout were not mentioned in surveys conducted in the 1970's. Today brown trout are easily observed spawning at the gabion. Currently, brown trout are observed spawning in October and November and into December.

Past Survey Data and Protocol

The populations of redband trout in Spring Creek has been monitored since 1972 using fish counts and redd surveys. The redd survey data is difficult to compare due to the different effort completed each year. In the years 1972-1975 only one redd count per spawning season was conducted in February or early March. After construction of the gabion in the fall of 1975 more effort was afforded with monitoring (Figure 6). ODFW Fish District staff began counting redds at the gabion and above highway 97 in a more consistent basis. Although a more concerted effort was afforded to the redd counts, changes in the introduced spawning gravel happened during these survey periods. The redd counts documented increased spawning activity due to additional gravel placement which may tend to mask environmental and fish management changes happening during the same period. Redd counts were conducted from November through March at the gabion and above highway 97. Biologists in the 1970's and early 80's believed that spawning ended in March. Beginning in 1980-1981 only two counts were conducted above highway 97 from a boat survey. From 1975-1989 and 2003-2010 adult redband trout were counted in the area upstream of highway 97 and at the gabion. AUC counts began in 2010-2011 spawning season

In the 1970s a portion of the redd counts were believed to be from brook trout. At the end of the 1975-1976 season at the gabion ODFW estimated that 65 spawning pair of redband trout used the gabion producing 90,000-130,000 eggs while brook trout production at the gabion was 15-20,000 eggs. Observations were made in 1976 that many of the redband trout on the spawning grounds were less than 14".

After 1980-1981 redd counts were extended into late April. This extension in redd counts were due to the new observation of redband trout spawning and fresh redds observed on 25 April 1980 (ODFW Monthly Report). Fortune (1980 ODFW Monthly Report) states that in the past few years no spawning of redband trout was observed after March.

In 1985 redds were observed below the gabion for the first time due to gravel spilling over the gabion and depositing just downstream. Redd counts have not normally been conducted below the gabion. After intensive spawning use by trout and the deterioration of the gabion in 1985 the first observation redds were observed. The gabion was constructed in an unusual downstream U formation.

Redband trout were observed spawning on the introduced gravel in 1985. The significant increase in redd counts in the year 1985-1986 was attributed to the gravel placed last fall in 1985. An increase in 200 redds were observed. Angling regulations at that time allowed for two fish per day harvest in the lake. Redband trout were observed spawning for the first time in October on the 15th in 1987.

In the years 1988-1990 the ODFW Native Trout Research performed extensive redd surveys at the gabion and above highway 97. The spawning surveys were conducted all year long on a bi monthly basis which accounts for the higher and more accurate redd counts during those years. In 1989 snorkel surveys were conducted to determine how much of the spawning observed occurred by brown trout. Snorkel surveys were conducted on 6 and 28 November and 18 December at the gabion area. Brown trout dominated the first count in November where 50 brown trout were observed whereas 8 redband trout. Redband trout dominated the observations after that with 41 and 61 observed respectively with 20 and 3 brown trout. Redd counts in November and December will need to be adjusted for brown trout spawning.

After 1990 spawning surveys were conducted from November-May due to the large number of spawners observed during the month of May. Adding spawning gravel to Spring Creek potentially increased the duration of spawning. The other possibility is that the spawning timing has not changed but the increase in spawners in Spring Creek has allowed for the observation of redds from April-August.

In 1992 ODFW organized a volunteer group from the Klamath Flycasters to try and re-wire the baskets on the gabion to keep them from falling apart further. The baskets have lost rocks as the wire broke. The reduction in height and configuration has help transport some gravel downstream. Trout have been a major factor on moving the gravel downstream.

Recent surveys have observed approximately 100 redband trout spawning in late May 2006. Snorkel surveys on 21 May 2010 observed 91 redband trout in the 0.8 miles from the private

property boundary to the confluence with the Williamson River. In 2010 redband trout spawning was observed into July. Buchanan et al. observed spawning 11 months out of the year with the exception of the month of September.

The redd counts at the gabion have a good data set as redd surveys were conducted at a fairly even effort when comparing the months November- March from 1975 through 2013. Redd counts above the gabion have went from zero prior 1975 to a high count of 366 redds in 1998-1999. Redd counts have increased from 62 redds counted in 1975-1976 immediately after the gabion was constructed to 366 redds a 590% increase.

Overall redd counts have increased at least by 210% in Spring Creek but there is confusion on the total number of redds observed above highway 97 from the years 1975-1977. The total number reported from these redd counts is much lower than the totals enumerated after summarizing the monthly counts. If you compare to the lowest year in 1981-1982 then total redd counts have increased by 520%. In general most redd counts did not show a significant increase the year after adding gravel with the exception of redd counts in 1986. This makes sense as the fish had to be attracted from somewhere else. The fish need to be at least 3 ½ years old and more likely 4 ½ years old to spawn. The increase in redd counts makes less sense under that scenario as you have decreased redds in another unknown area. It would take time to fill in the vacant habitat. This would suggest that the addition of spawning habitat is actually producing more fish instead of attracting more fish to better spawning habitat. For example, counts at the gabion slowly increased after significant amount of gravel was placed. When three hundred cubic yards of gravel was placed only 62 redds were observed. Redd counts doubled in 1983-1984 when 8 years had passed or nearly the maximum age of redband trout or near two generations of redband trout. However, the addition of spawning gravel in 2010 resulted in the immediate construction of over 100 redds in this area where only a few occurred historically.

Total redd counts have been as high as over 1000 redds in a season. Redd numbers are likely slightly higher due to the fact redds are not counted in July-August. Most redd counts above highway 97 have only been completed twice a year; once in February and once in May. A sample size of two redd surveys above highway 97 will result in lower counts of redds due to superimposition and redds losing their brightness after a month or so.

Life history of redband trout has been studied extensively in the late 1980's through early 1990s by NFI. Most of the studied revolved around the collection and development of the Williamson River broodstock to utilize for stocking in Spring Creek and other Klamath Basin waters. Spring Creek is the major spawning tributary for adfluvial redband trout and likely provides the largest escapement of redband trout in the Klamath Basin. Currently, peak spawning occurs during December thru January and is known to occur 11 months out of the year. This life history appears to still be functioning in 2010 as a pair redband trout were observed spawning in July in Spring Creek. Scale analysis for Spring Creek redband trout was conducted in 1990 and 1991. Redband trout were found to spawn up to six times from age 2 to age 8 in Spring Creek. (Borgerson 1991). A majority of the spawners were age 4-6 (Borgerson 1991). Redband trout were found to spawn 11 months out of the year with exception of September in Spring Creek (Buchanan et al 1991). Once a redband initiates spawning activity it will continue every year thereafter. Females have a higher level of repeat spawning than males in Spring Creek and

Williamson River (Borgerson 1991). Estimates in 1975 of eggs per female for Spring Creek redband trout ranged from 1300-2000 eggs per female. This is likely an underestimation (ODFW Annual Report 1975).

Average length of redband trout spawners on Spring Creek in 1990-1991 was 550 mm (Borgerson 1991). Average length of spawners in Spring Creek was 555 mm in 1991-1992 (Hemmingsen et al 1992) Average size of redband trout spawners in Spring Creek 1992-1993 was 569 mm (Hemmingsen and Buchanan 1993). In Spring Creek the largest redband trout enter in March and average 594 mm in length. Average length of redband trout is 540 mm for the entire spawning distribution. Spawners in Spring Creek ranged in size from 373 to 725 mm in 1990-1991 during this study (Borgerson 1991) and 339-705 in 1991-1992 (Hemmingsen et al 1992). Size range was 387-780 mm in 1992-1993 (Hemmingsen and Buchanan 1993). Maximum size of redband trout captured in Spring Creek was 780 mm in 1993. Female redband trout are slightly smaller (543 mm) than males (554mm) in Spring Creek (Buchanan et al 1991). In 1991 a 31 inch female redband trout was 8 years old and spawned six times in Spring Creek (Buchanan et al. 1991).

Sunnybrook Creek

Sunnybrook Creek is a 10 cfs spring fed tributary to the Williamson River with 0.7 miles of habitat and 0.5 miles of adfluvial redband trout spawning habitat to the waterfalls (Gannet et al. 2007) Water temperatures in Sunnybrook are warmer than most other spawning tributaries and average 10° C (Table 3). Forty-five cubic yards of spawning gravel has been added in 2011 and 2013 from just above the waterfalls to immediately downstream of the lowermost bridge crossing. A small amount of gravel was added above the falls but below the bridge crossing in 2013. Spawning gravel has also been added sometime in the past within the vicinity of the home and above the waterfalls. Adfluvial redband trout spawning occurs from the mouth to the waterfalls (Figure 6). Adfluvial redband trout or large redds have not been observed above the waterfalls. Small adult redband trout (10 in) have been documented above the falls suggesting that at some level redband trout are able to pass the water falls. Redband trout utilize the native substrate composed of blocky, yellow clay substrate. The highest density of spawners occurs at the introduced gravel near the landowner's house. All of Sunnybrook Creek is on private property.

Adfluvial redband trout utilize Sunnybrook Creek for spawning from November through March with peak spawning in late December and early January. Brook trout and brown trout have been found electrofishing the stream. Only brown trout have been observed on the spawning ground. Pit-Klamath brook lamprey have been observed spawning in February. Hatchery rainbow trout from Spring Creek have also been documented in Sunnybrook Creek.

Past Survey Data and protocol

Sunnybrook Creek was surveyed in 2010-2011. Redd counts were conducted twice a month from November- April. The landowner's house overlooks Sunnybrook and the landowner communicated that the 2012-2013 spawning season was the best he ever observed.

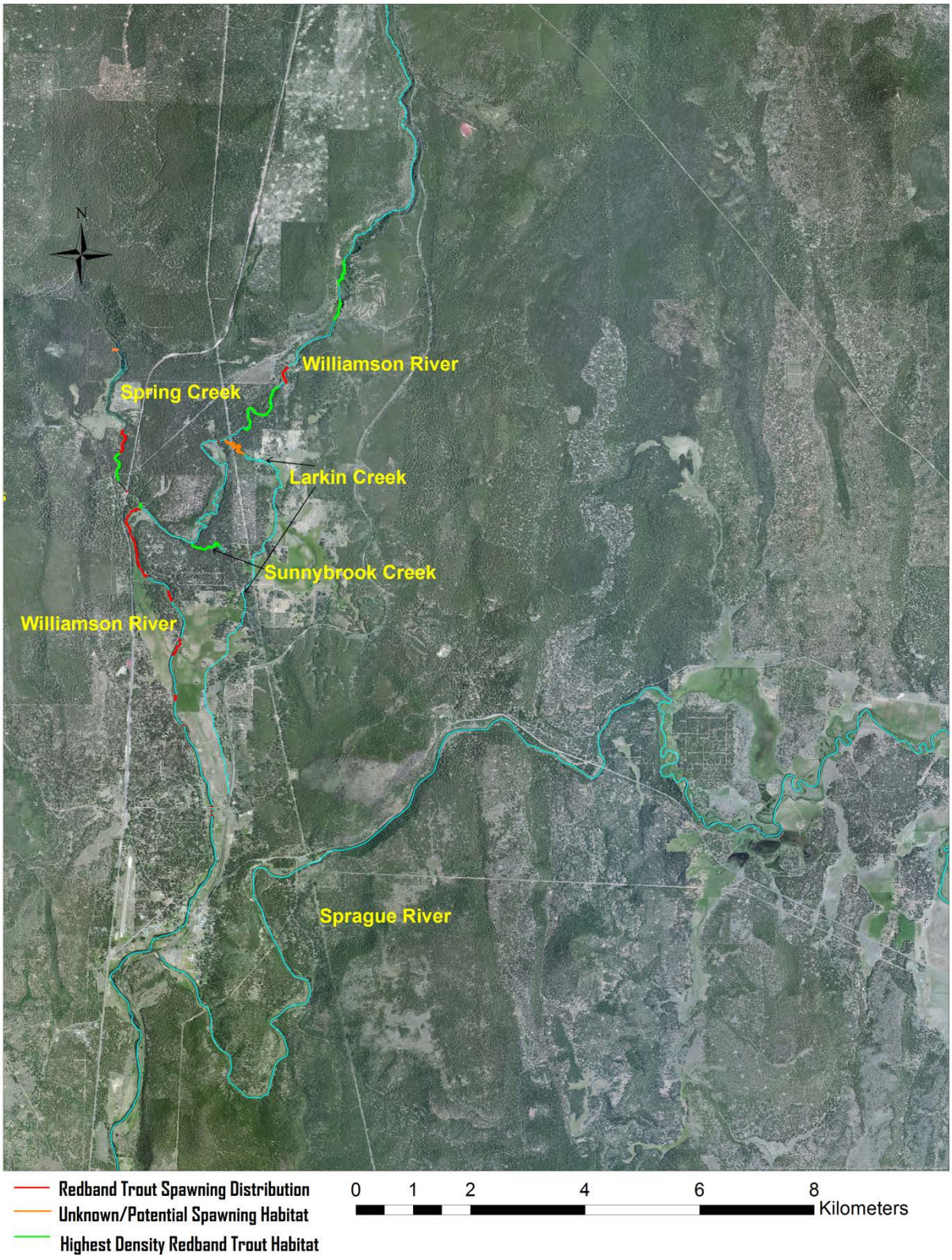

Figure 6. Known and potential spawning habitat (red, green, or orange lines) for redband trout and brown trout in Williamson River, Spring Creek, Sunnybrook Creek, and Larkin Creek Klamath County, OR.(Note: small red dots are small spawning areas)

Sprague and Sycan River

Study Area

The Sprague (85 miles), Sycan Rivers (40 miles) and a portion of their tributaries (Spring, Trout, Whiskey, SF Sprague, Fishhole, Brownsworth, Whitworth, NF Sprague, Fivemile, Meryl, Long Creek (Sycan), Brown Spring Creek (116 miles) have a large amount of potential adfluvial redband trout habitat but a paucity of spawning habitat for adfluvial redband trout (Figure 7 and 8). NF Sprague River currently has the most amount of spawning substrate available and is one of the only gravel rich streams in the area (Fortune 1966, Huntington and Dunsmoor 2006). Adfluvial redband trout do not likely pass the Sycan Marsh as redband trout in Paradise Creek are different genetically and have no resistance to *C. shasta*. The same pattern is observed in Deming Creek and likely occurs in other tributaries in the NF and SF Sprague Rivers. Genetically, redband trout from Paradise (Sycan), Long Creek (Sycan), Deming Creek, Brownsworth, Whitworth, Fishhole, Robinson Spring Creek, Upper NF Sprague, and Upper Williamson cluster together suggesting lack of connection with adfluvial redband trout populations (Pearse et al. 2011). Fivemile Creek appears to cluster between the headwater group and adfluvial group (Pearse et al. 2011). Trout and Rock Creek (Sprague) show similarities to Klamath River, OR groups (Pearse et al. 2011). However, two radio tagged Long Creek redband trout were found in Agency Lake (personal comm. Craig Bienz Nature Conservancy).

Adfluvial redband trout spawning habitat is not well known especially in the North Fork Sprague and tributaries and needs significant further study. All known spawning by adfluvial redband trout in the Sprague River occurs in or near groundwater sources such as Kamkaun Springs and the large spring fed complex near and in Spring Creek above the town of Beatty and downstream of River Springs in the Beatty Gap area (Figure 7). Most of the known spawning areas on the Sprague River are known by radio and acoustically tagging adfluvial redband trout at Chiloquin Dam fish ladder in December of 2005. Most radio tagged redband trout (6 of 12) traveled to Kamkaun Springs. One radio tagged redband trout was documented near Lalo Springs, two were documented near Medicine Springs (RM 74.2) on redds in that area and another was documented near River Springs (RM 80). Other source of information on redband trout spawning comes from reconnaissance spawning surveys. Trout Creek and Whiskey Creek likely have some level of spawning by adfluvial redband trout. Trout Creek redband trout have an intermediate resistance to C. shasta suggesting some level of interaction with redband trout from the Williamson River or Upper Klamath Lake.

Only one of the 12 redband trout were located on fixed acoustic equipment. The one acoustic tag was picked up at Ivory Pine Road on the NF Sprague in late January and returning in late March suggesting spawning somewhere in the NF Sprague River above Ivory Pine Road.

Spawning by adfluvial redband trout in the SF Sprague River is completely unknown as most streams and habitat of lower gradient where redband trout would spawn is poor spawning habitat (i.e. Lower SF Sprague, Lower Fishhole Creek, and lower Deming).

Known spawning also occurs just below springs on the Sycan River immediately below and above the Drews road crossing on Sycan River and downstream of the Snake Creek culvert. This

area is one of the only locations where the channel is narrow enough to create adequate site conditions suitable for clean, gravel substrate. Spawning has also been documented in Brown Springs Creek but is likely significantly reduced due to lack of substrate and habitat conditions due to four impoundments. In 2006 fish passage was provided to access the springs and a channel was created around the impoundments that marginally improved habitat for adfluvial redband trout. The spring fed Snake Creek would likely have spawning if fish passage was available. Fish passage has been in the works since 2008.

USFWS operated rotary screw traps from 2005-2008 at three locale on the Sprague River. Peak catch on the Sprague River of juvenile redband trout occurred in April at Beatty (RM 75) and May at Sprague River (RM 50) with no other peaks in 2007. Redband trout averaged 50 mm in May at Sprague River with average size of less than 40 mm at Beatty (Buettner et al 2009).Peak migration from 2006-2008 at Braymill (RM 8) occurred in June. Average length in June at Braymill in all three years was 80 mm. This emigration might be related to water temperature increases not necessarily migrating to Upper Klamath Lake (Buettner et al. 2009).

Past data and protocol

District staff snorkeled Kamkaun Spring on the Sprague River (RM 24) on the 11 December 2009. There were approximately 50 redband trout in the springs ranging from 14-30 inches. No small fish were observed. Air temperature was 37 while the spring's water temperature was 50. One hundred redband trout were observed in outlet channel to the Sprague River.

Reconnaissance spawning surveys have been conducted on the Sprague River from the confluence of Spring Creek to the easternmost old OC&E railroad crossing on Jan 20, 2009. Significant spawning activity occurs from the uppermost railroad crossing to just below the large bend in the river just below the second OC&E railroad crossing (Figure 8).A total of 46 redds and nine spawning redband trout were observed in this area. Three redds were also observed in Medicine Springs channel in between the two OC&E bridge crossing. Redds have also been observed here in 2004-2006.

Spawning surveys on Spring Creek (RM 73.2 Sprague River) from OC&E bridge downstream to confluence were conducted from November through March 2003-2006. Most spawning occurs just downstream of beaver dam very near the bridge crossing. Spawning substrate is rare. Water temperature was 10°- 11 °C. Total number of redds observed were 37 with seven redband trout in 2004-2005. Peak redd numbers occurred in January and February. Due to high flows on the Sprague River that occur annually that inundate Spring Creek these redd surveys were discontinued.

Spawning surveys were conducted at Drews Road from the first tailout below the bridge to the first tailout above the bridge on the Sycan River from 2003-2006 and 2009. Information of redds were obtained at this site location (GPS decimal degrees) redd size, velocities, depth, substrate type, habitat type were obtained on February 11, 2004. Peak redd counts occurred in 2004 when 20 were enumerated. The only year where redds counts could be conducted for a significant time without high flow event occurred from November 2, 2004 to February 9, 2005. Water temperature at the site varied from 3 to 6°C at this site in February 2004.

A spawning survey was conducted at Brown Springs on the Sprague River on February 2004 and January 2006. No redds or fish were observed. Water temperatures varied from 5 to 8°C during these two surveys. An 18" redband trout mortality was observed on March 28, 2006 suggesting some spawning occurs at the site despite marginal spawning habitat. A redband trout greater than 20" was observed on May 19, 2006.

Adfluvial redband trout were observed below Torrent Springs on District staff surveyed Torrent springs, Sycan River on 23 October 2006. Approximately 20 adult redband between 3 and 6 pounds were observed. Redband trout looked bright and in good condition. District staff does not know if these redband trout are spawners from this spring or just beginning a spawning migration. Additionally, eight suckers, assumed to be Klamath largescale, were observed. Water temperatures at the largest springs were measured at 9°C.

Sycan River was surveyed from the first major springs upstream of Torrent Springs at 42.69469 latitude 121.26611 longitude to just downstream of spring seven at coordinates 42.68752 latitude 121.27859 longitude on 28 July 2004. GPS locations were taken at all seven springs. Torrent springs is located at 42.68771 latitude and 121.27658 longitude. Five large redband trout ranging from 18 to 22 inches and several smaller redband trout were observed. Spawning substrate was good and several old redds were observed. From the size of redband trout observed it is theorized they came from Upper Klamath Lake and were unable to return after spawning. Redband trout were observed in areas of large boulders, deep pools, and spring input. This stretch lacked sufficient deep water pool habitat with maximum depth of approximately four feet. Water temperature was 8°C at most springs and 22°C on the Sycan River. River flow was approximately 5-10 cfs.

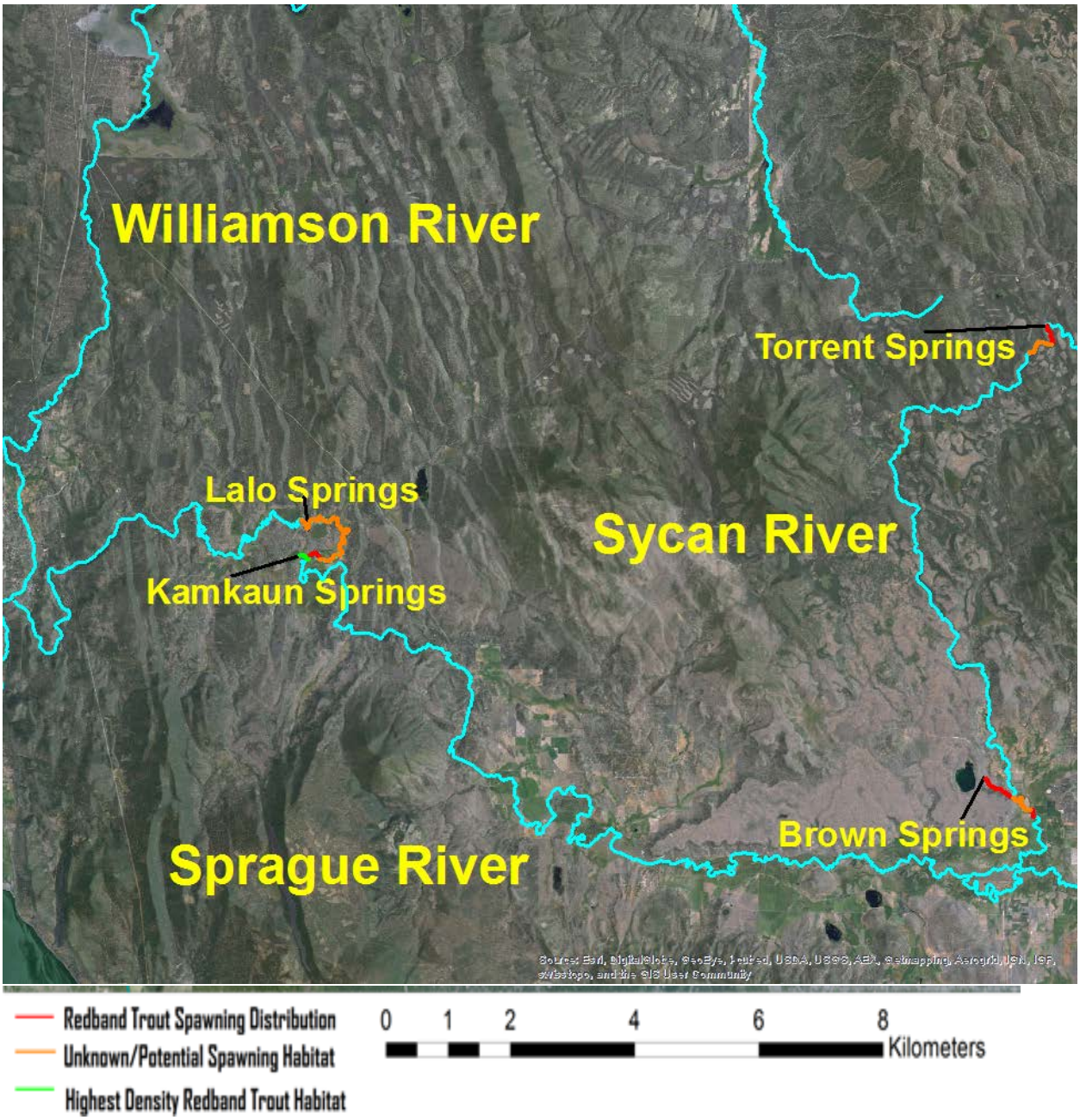

Figure 7. Known and potential spawning habitat (red, green, or orange lines) for adfluvial redband trout in Sprague River at Kamkaun and Lalo Springs and Sycan River near Brown Springs and Torrent Springs Klamath County, OR.

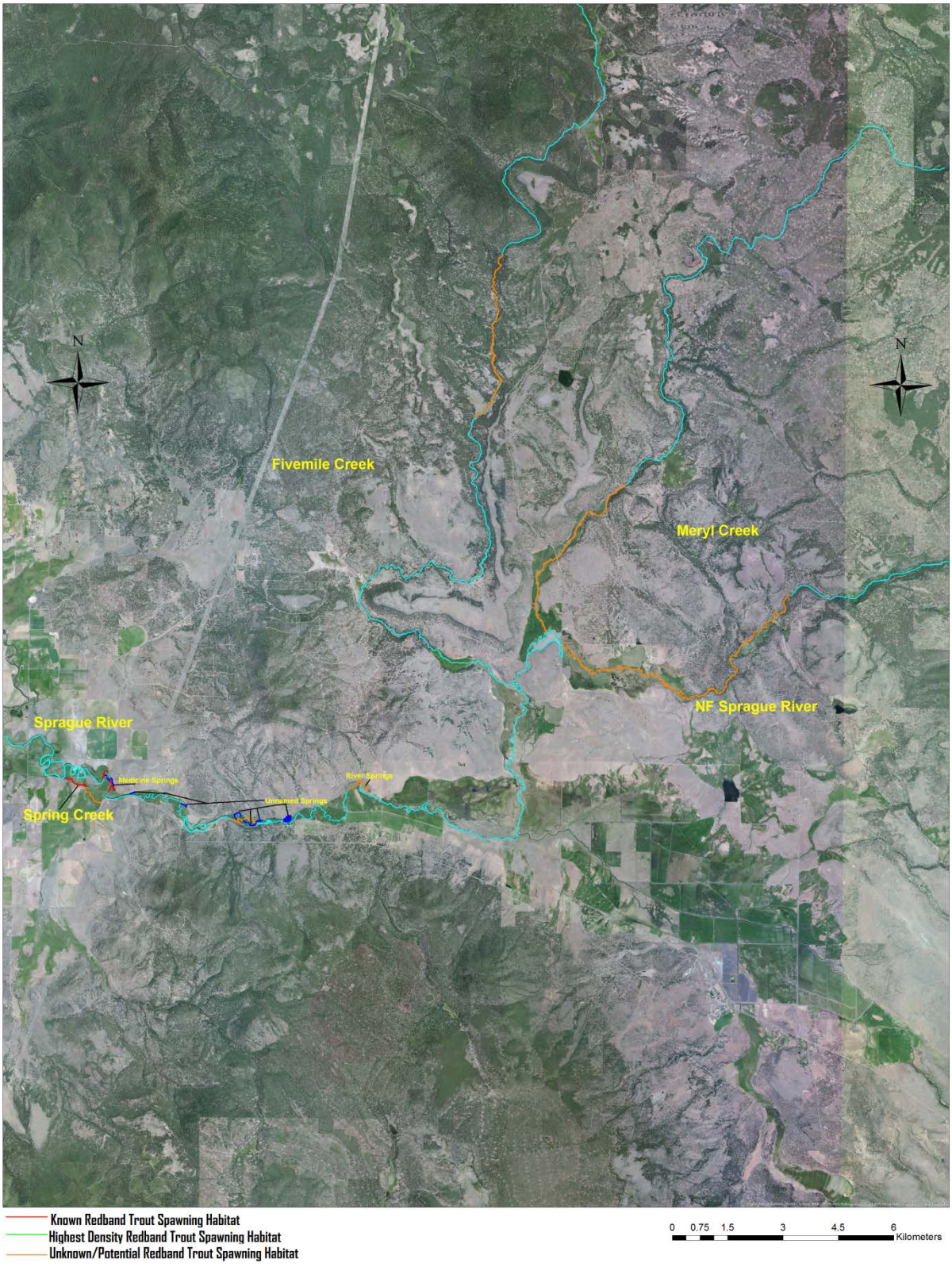

Figure 8. Known and potential spawning habitat (red, green, or orange lines) for adfluvial redband trout in Sprague River, Spring Creek, NF Sprague River, Fivemile and Meryl Creek (Klamath County, Oregon (Note: Zoom to see detail).

Table 3. Water temperature summary of primary adfluvial redband trout spawning streams in the Wood River, Williamson River, Crystal Creek watersheds and Kamkaun Springs (Sprague River) from 2011-2014.

Site	Average Temp °C	Temperature Range °C	Average Temperature at Peak spawning °C	Dates
Agency Creek	9.64	8.57-10.94	9.43	10/7/2012-4/14/2013
Crooked Creek Hatchery (Site 3)	8.85	8.37-9.66	8.78	10/7/2011-4/14/2012
Crooked Creek hwy 62 (Site 1)	6.93	3.1-10.39	6.2	10/7/2011-4/14/2012
Crystal Creek Crystal Springs #2*	8.15	6.81-8.7	8.15	12/21-4/15-2012 and 10/7/2012-11/23/2012
Fort Creek near Headwaters	7.82	7.47-8.23	7.79	10/7/2011-4/14/2012
Ranch Creek	8.29	4.5-12-89	7.79	12/9/2011-4/14/2012
Ranch Creek	8.45	2.1-14.12	7.41	10/7/2012-4/14/2013
Sprague River (Kamkaun Springs)	10.1	5-10.5	10.1	5/6/2013-11/1/2014
Spring Creek Gabion	5.73	4.25-7.97	5.44	10/7/2011-4/14/2012
Spring Creek Gabion (Spring Spawner)	6.95	5.1-9.83	7	4/15/2012-6/6/2012
Spring Creek Picnic	5.64	4.01-7.89	5.23	10/7/2011-4/14/2012
Spring Creek Picnic (Spring Spawner)	6.96	4.9-9.8	7	4/15/2012-6/6/2012
Sunnybrook Creek	10.63	9.9-11.6	10.5	12/2/2013-4/14/2014
Tecumseh Springs	8.31	7.89-9.01	8.28	10/7/2011-4/15/2012
Williamson River (Below Kirk Springs)	7.14	1.4-10.81	8	10/7/2011-4-14-2012

Williamson River (Tuttle)*	5.41	2.39-9.386	4.6	10/7/2011-4/15/2012
Williamson River (USFS Campground)	5.92	.989-11.71	5.1	10/7/2011-4/15/2012
Williamson River Canyon Springs	7.51	2.15-12.5	7.35	11/20/2012-4/15/2013
Williamson River at Kirk Springs	9.89	9.78-10.02	9.86	10/7/2011-4/15/2012
Wood River (Gauging Station)	6.05	4.61-8.69	5.83	10/7/2011-4/15/2012
Wood River (Gauging Station)	6.11	4.27-9.01	5.74	10/7/2012-4/15/2013

(note: Average temperature at peak spawning is during the month of December for Crooked Creek and Tributaries, Crystal Creek, Short Creek and January for Wood River, Fort Creek, Spring Creek, and Williamson River. * Peak spawning is unknown for these areas but peak spawning on the Williamson River on Tuttle's appears to occur in the late spring May-June).

Table 4. Thermal regime of secondary spawning areas of adfluvial redband trout in the Wood River, Williamson River and Crystal Creek watersheds from 2011-2014 Klamath County, OR.

Site	Average Temp C	Temperature Range C	Average Temperature at Peak spawning C	Dates
Crystal Creek Malone Springs	6.71	3.27-10.32	6.89	12/21/2011-4/14/2012
Fort Creek Crater Lake Resort (Above Hwy 62)	6.98	5.26-10.4	6.7	10/7/2011-4/14/2012
Fort Creek Hwy 62	7.1	5.21-10.64	6.8	10/7/2011-4/14/2012
Larkin Creek (Mouth)*	3.95	.024-11.17	0.86	10/7/2011-4/14/2012
Short (Moss Creek)	6.68	5.67-8.29	6.68	10/7/2012-4/14/2013
Williamson River Knapp (RM 13)*	5.41	2.53-9.46	4.54	10/7/2011-4/15/2012

*Peak spawning is unknown for these areas but peak spawning on the Williamson River on Knapp's appears to occur in the late spring May-June.

Methods

Data Entry and data forms

For the 2013-2014 spawning season six Pendragon forms were created to be utilized with a Nomad handheld computer. Pendragon forms were developed to begin developing a standard protocol and database for spawning surveys. The three forms are: 1) a header form for each survey, 2) a form for redd information and 3) a form for fish observations and Area Under the Curve counts. An additional three forms were developed to monitor the utilization of spawning gravel in Spring Creek. As part of this protocol each survey will have information regarding surveyor, time of survey, weather, visibility, gps location of survey, gps redd location on a subset of redds, number and species of fish observed and gps location of fish, approximate and measured redd size, whether redd is superimposed, substrate type (introduced or native gravel), whether fish is observed on redd, whether the redd is a secondary redd or test redd.

All information is transferred from the Nomad Handheld Computer to a the Pendragon Forms 3.2 Microsoft Access Database on a personal office computer to six separate datasheets. Forms for these spawning surveys were first created in 2011 and improvements were made thereafter.

Header Form

Surveyor: The surveyor will typically be the ODFW Assistant Fish Biologist. Occasionally the District Fish Biologist or volunteer Chris Engle or other volunteers will assist.

Time of Survey: The start and end times are recorded in the header from of each survey.

Weather:
A popup list will show a list to choose from.
Weather affects visibility of fish and potentially redds if raining or snowing. Categories for weather are:

Partly cloudy
Mostly cloudy
Overcast
Sunny
Rain
Snow

Visibility definitions:

Poor- very little visibility into water due to wind, rain, snow, darkness, turbidity, fog or combination thereof. Typically surveys not conducted during such times. Most surveys are completed in groundwater dominated systems therefore poor visibility is rare.

Fair- some visibility but wind, shadows, darkness, cloudiness, fog reduce distance of visibility.

Good- Usually sunny day with little wind or dark day but very calm with little glare. Clouds, glare and/or light wind could reduce visibility at times

Excellent- calm, sunny day with survey completed when sun is near peak. Two surveyors. One rower and one observer. Little to no glare. Can easily distinguish between species of fish.

GPS start and end of survey:

GPS coordinates will be recorded in UTM for the start and end of the survey in WGS 84 datum. Due to the time needed to acquire accurate locations gps positions will only be acquired on new or different surveys. The Nomad PDA has a built in Trimble GPS.

Redd Data Form

Redd size

Redd size will be estimated using the five categories from very small to very large (Table 5). Redd sizes were categorized by 813 measured redds in the Williamson and Wood River watersheds in 2010-2012 and plotting the frequency of redds.

Table 5. Categories for redd size in the Williamson and Wood River watersheds from 2011-2014 in Klamath County, OR.

0.01-0.5 m^2	very small
0.51-1.0 m^2	small
1.1-2.5 m^2	medium
2.5-6 m^2	large
>6 m^2	very large

Substrate Type

Redds will be classified as created on introduced or native substrate. Introduced gravel is 3/8 to 4 inch round river rock that was placed by gravel slinger or backhoe. Native substrate is defined as the material that was native to the area. In some cases the substrate is unknown. For example at the Klamath Hatchery there is significant amount of road cinder gravel that has been washed into Crooked Creek. This gravel will be classified as native since the gravel was not deliberately added to the stream. Introduced spawning gravel has been added to all survey sections except Fort Creek above the dam, Moss (Short Creek), Crystal Creek, and Kamkaun Springs.

Native gravel in Fort Creek is composed primary of pumice with small pea gravel. The Wood River primary gravel is small gravels with pumice. Native substrate in Spring Creek and Sunnybrook Creek are primarily yellow clays with pumice. The Williamson River above Spring Creek has natural round river rock spawning gravel. The Williamson River below Spring Creek is a mix of yellow clay, some round river rock with small pea gravels. Agency Creek native substrate is composed very small pea gravel and potentially road cinder gravels.

Secondary Redd:

The form will ask yes or no whether the classified redd is potentially a secondary redd. Secondary redds are defined as redds that are very near a larger redd and appear to be the same age and potentially created by the same female fish.

Test Redd:

The form will ask yes or no whether the classified redd is potentially a test redd. Test redds are typically so small and occasionally abundant in certain staging areas such as the Caddis Hole on the Wood River and the Picnic Table Hole on the Williamson River that they are ignored.

Superimposition:

The form will ask if the redd is created on top of another redd. This is a judgment call on recollection of whether a redd occurred here before if the colored rock has been covered with substrate.

Fish on redd*:*

The form will ask if fish is observed on redd. Most of time fish are spooked off redds as survey begins.

Rivermile:

Rivermiles listed on spawning surveys is from the Oregon Water Resources Board (1971) map 14.6 of the Klamath Drainage Area.

Fortnightly Redd survey sites

Wood River Watershed

Crooked Creek

Spawning Survey	*Starting Easting*	*Starting Northing*	*Ending Easting*	*Ending Northing*
Agency Creek (Fence to 62)				
Crooked Creek below 62	586391.59	4.7217272e06	586443.59	4721765.4
Crooked Creek Site 1	586477.6	4.7217930e06	586486.33	4721816.4
Crooked Creek Site 2	586311.17	4.7223848e06	586206.5	4722402.6
Crooked Creek Site 3	586215.04	4.7225861e06	586247.72	4722693.3
Ranch Creek				
Tecumseh Springs above culvert	586638.28	4.7215978e06	586650.84	4721662.2
Tecumseh Springs below culvert	586606.45	4.7214875e06	586638.28	4721597.8

Fort Creek

Spawning Survey	*Starting Easting*	*Starting Northing*	*Ending Easting*	*Ending Northing*
Fort Creek (Dam to headwaters)	584520.95	4.7275498e06	584987.19	4728308.9
Fort Creek (Rivers of Light bridge to Dam (Weir)	584315.54	4.7271823e06	584553.14	4727516.6

Williamson River watershed

Williamson River

Spawning Survey	*Starting Easting*	*Starting Northing*	*Ending Easting*	*Ending Northing*
Williamson River (Tuttle 2013 spawning gravel RM 16)	592207.09	4720332.60	592005.56	4720588.3
Williamson River (Larkin Creek to Private Property)	593786.67	4723027.60	594354.85	4723728.4

Spring Creek (same as AUC surveys)
Spring Creek (Below Gabion)
Spring Creek (Above Gabion)
Spring Creek (Picnic Area)
Spring Creek (2010 spawning gravel)

Sunnybrook Creek

Spawning Survey	*Starting Easting*	*Starting Northing*	*Ending Easting*	*Ending Northing*
Sunnybrook Creek	592955.62	4720974.84	593450.02	4720941.51

Area Under the Curve Surveys (Fish count)

Wood River

Spawning Survey	*Starting Easting*	*Starting Northing*	*Ending Easting*	*Ending Northing*
Wood River (Kimball State Park to Dixon Rd)	583585.51	4732289.44	582820.40	4731739.84
Wood River (Dixon Road to Sun Pass Bridge)	582820.40	4731739.84	582749.47	4731204.14
Wood River (Sun Pass Bridge to Melhase Canal)	582749.47	4731204.14	582658.63	4730519.90

Crystal Creek (Crystal Springs)

Spawning Survey	*Starting Easting*	*Starting Northing*	*Ending Easting*	*Ending Northing*
Crystal Creek (Crystal Springs	575389.33	4713565.40	575339.94	4713964.2

Spring Creek

Spawning Survey	*Starting Easting*	*Starting Northing*	*Ending Easting*	*Ending Northing*
Spring Creek (Below Gabion)	591991.89	4721587.70	592036.42	4721601.42
Spring Creek (Above Gabion)	592036.42	4721601.42	592008.62	4721684.76
Spring Creek (Picnic Area)	591612.74	4722077.30	591576.05	4722440.7
Spring Creek (2010 Spawning gravel)	591540.11	4722430.60	591624.25	4722497.2

Spawning Survey	*Starting Easting*	*Starting Northing*	*Ending Easting*	*Ending Northing*

Williamson River (Kirk Springs Area)	595345.58	4725597.30	595483.41	4725930.7

Sprague River

Spawning Survey	***Starting Easting***	***Starting Northing***	***Ending Easting***	***Ending Northing***
Kamkaun Springs	606333.57	4716431.24	606433.91	4716261.98
Kamkaun Springs outlet	606433.91	4716261.98	606525.67	4716275.14

Monthly to Annual Redd Survey Sites

Spawning Survey Section	*StartingEasting*	*StartingNorthing*	*EndingEasting*	*EndingNorthing*
Crane Creek below Mares Egg Spring	576327.56	4.7228363e06	576315.63	4722899.2
Crystal Creek (Downstream from Malone Springs)	575628.71	4.7076858e06		
Crystal Creek (Malone Springs)	575140.82	4.7090624e06		
Fort Creek (Moss Creek to Rivers of Light Bridge	584327.45	4.7271735e06		
Fort Creek Weir to Falls	584230.3	4.7262424e06	584191.37	4726627.9
Fort Creek Weir to mouth	584206.42	4.7261781e06	583587.37	4724957.1
Fourmile Creek (Fourmile Springs)	575654.8	4.7205065e06		
Harriman Creek	574771.23	4.7024202e06		
Moss Creek	584777.91	4.7271040e06		
Odessa Creek	577270.49	4.6980313e06	577173.17	4698015.9
Pelican Bay	575063.67	4.7032074e06		
Recreation Creek	575368.11	4.7040182e06		
Sevenmile Creek	576348.39	4.7259508e06	576354.78	4725980.3
Short Creek (Sevenmile)	575736.64	4.7250596e06	575424.14	4725513.8
Spring Creek 2011 Lassett	591439.63	4.7233596e06		
Williamson River	594375.18	4.7237400e06	594566.01	4724142.4
Williamson River Knapps 2012 gravel	592895.42	4.7178018e06		
Williamson River Tuttle 2012 and 2013 spawning gravel RM 15	592727.92	4719126.00	592776.72	4719249

Redd Survey and AUC Methods

Spawning surveys will be conducted fortnightly to reduce the error associated with missing redds due to aging to the point of the redd being unrecognizable (Gallagher et al. 2007). Redd counts will be conducted before the initiation of spawning to the end of spawning as recommended by Dunham et al. (2001). Colored rocks will be placed adjacent to the redd

Area under the curve (AUC) methodology will be utilized as described by Irvine et al. (1993) and recently examined by Gough (2010) and used by ODFW for Oregon Coastal Salmonid Inventory (2012). Area under the curve surveys will be conducted to as near to 14 days as possible.

Area under the population curve estimates were calculated by stream or river reach as described in Irvine et al (1993). Three calcualtions are made 1) Survey estimate 2) Area under the population curve estimate 3) Overall AUC escapement estimate.

Survey estimate is calculated as the mean density (y) of fish for each survey period (i)

survey period (*i*) to be estimated by

$$yi=\frac{fo_i}{oe}$$

where *fo* = number of redband trout observed and
oe = observation efficiency.

Observation efficiency is the percentage of redband trout observed compared to the true value. Since observation efficiency has not been validated for Klamath Basin redband trout escapement observation efficiency has not been determined. For coho salmon and chinook salmon observation efficiency has averaged from 69 to 75% (Gough 2010). Observation efficiency of 69% will be utilized to estimate overall escapement since Klamath redband trout are of similar size to spawning coho salmon.

The daily population estimates for redband trout are plotted against the time redband trout spend on the spawning grounds, and the *auc* is estimated by the sum of the rectangular areas that approximate the area under the escapement curve. This is expressed mathematically as

$$AUC = 0.5 \bullet \sum (t_1 - t_{i-1}) \bullet (p_1 + p_{i-l})$$

where t_1 is the number of days from the first survey day to the ith survey day inclusive. The

surveys range from the first survey day to the last (nth) survey day when P_1 and P_n should be equal to zero.

The AUC redband trout escapement estimate is calculated by,

$$Escapement = auc * rt^{-1}$$

Where rt=residence time

Residence time is defined as the time redband trout spend on the spawning grounds or more specifically in the survey area. Residence time has only been determined on a few redband trout in the Klamath Basin (In Press ODFW 2014). Residence time of 14 days was used based on time spent on spawning grounds of Wood River, Chewaucan and Goose Lake adfluvial redband trout (Tinniswood 2007).

Statistical Analyses

Redd surveys were analyzed using TRENDS software (Gerrodette 1993) similarly to Maxell (1999) and (Howell and Sankovich 2012) Redds were plotted as linear and polynomial regression of Log_e of redds versus year. Observer efficiency was assumed constant since 2003 due to the same experienced surveyor conducted surveys through that time frame.

Correlation of redds and fish counts was calculated for each stream compared to the water year Oct-Sept of Williamson River average flow below Sprague, Upper Klamath Lake mean lake levels, Pacific Decadal Oscillation (PDO), Link River average flows, Upper Klamath Lake mean levels 3-6 years prior, PDO 4-5 years prior and PDO October-Mar same year and 3-5 years prior. Further, correlation of redd counts and AUC surveys will be compared to each other to determine if trends are similar, potential for error or accuracy of survey, potential differing limiting factors to the populations.

Crystal Creek (AUC survey)

The survey will be conducted from the USFS boundary upstream to Crystalwood Lodge (Figure 9). This survey encompasses the entire spawning habitat near Crystal Springs and where 99% of redband trout spawning in the spring fed areas of the northern section of Upper Klamath Lake occurs (This includes Crystal, Recreation, Pelican Bay, Harriman, Odessa and Short Creeks). Surveyors will wear hats and polarized glasses with a preference of gray lenses for sunny days and amber lenses for cloudy days. Surveys will be conducted during times when the sun is highest in the sky and not shaded by the Cascade Mountains.

Preferably observers will stand on bow of drift boat and kayak to get maximum elevation to maximize visibility. Surveys will be completed spatially and temporally with best visibility. Two counts will be conducted in an upstream and then downstream direction switching observers when two observers are available. Surveys will begin in mid-October and proceed through March or when counts decline to zero. If snow precludes launching drift boat then the survey will be completed by one surveyor standing in a one man inflatable kayak. At least one observer will remain the same throughout the surveys to reduce error.

Residence time of redband trout spawners in Crystal Creek is unknown. Redband trout are the only known salmonid spawning in Crystal Springs reducing error associated with identification of fish species. The residence time in Crystal Creek at the spawning grounds might be longer as this area is likely used as a staging area and thermal refuge.

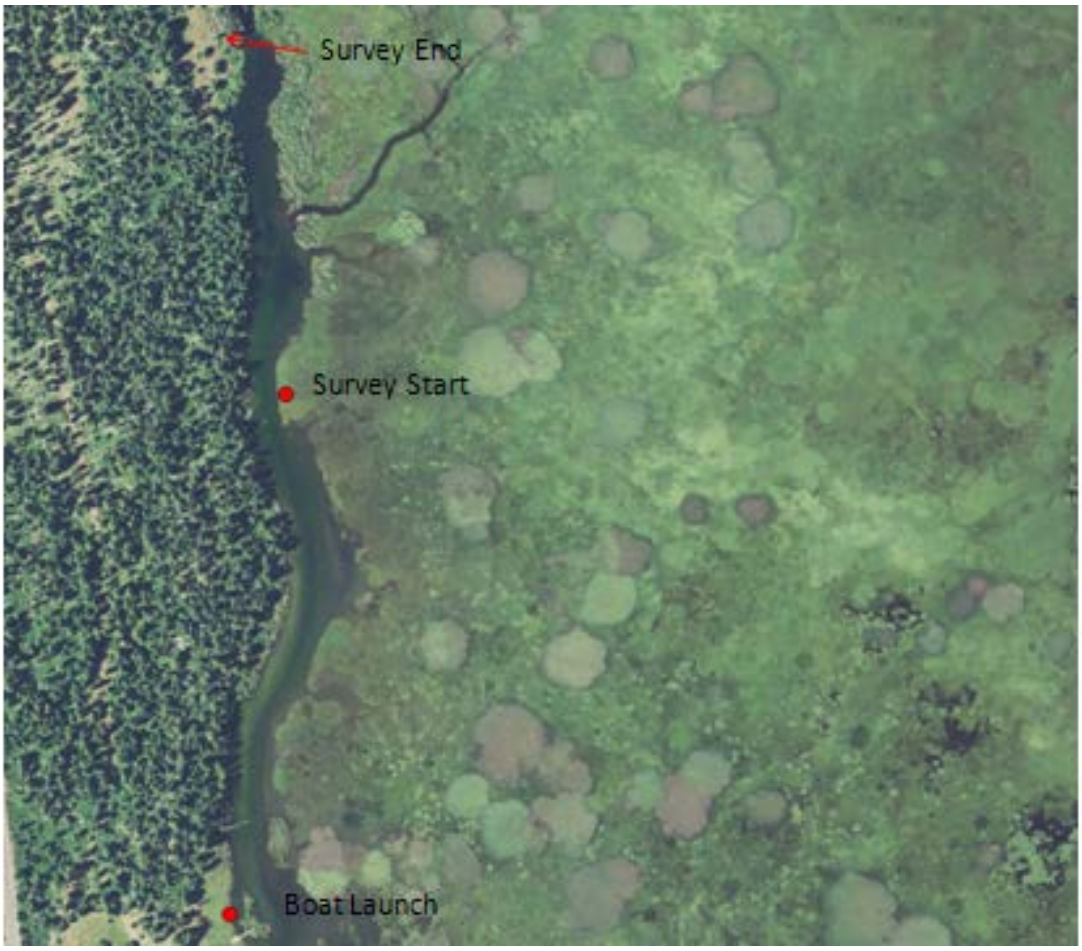

Figure 9. Redband trout AUC boat survey location from 2011-2014 on Crystal Creek (Upper Klamath Lake) Klamath County, OR.

Wood River (AUC Survey)

Surveys will generally be conducted by one surveyor fortnightly from an inflatable kayak using Area under the curve (AUC) methodology from Kimball State Park to Melhase canal. Surveys will begin by ODFW staff in October and proceed through end of spawning in May or June. Chris Engle will perform surveys from July-September with two surveyors from a flat bottom boat with one rower and one observer standing and enumerating fish. Most surveys conducted by Chris Engle will occur in the caddis hole (Staging area Figure 12) on the Wood River. The Wood River survey will take place from Kimball State Park to Melhase Canal. The survey will enumerate all salmonids observed and identify to species. The survey will be divided into three sections (Kimball to Dixon Road, Dixon Road to Sun Pass Bridge and Sun Pass Bridge to Melhase Canal (Figure 10-12). Surveys will generally begin at 10 am and conclude at 1230 and conducted during days of best visibility.

Figure 10. Area under the curve boat survey on the Wood River (Agency Lake) from Kimball State Park to Dixon Road Bridge from 1997-2013, Klamath County, OR.

Figure 11. Area Under the Curve boat survey on the Wood River (Agency Lake) from Dixon Road Bridge to Sun Pass Bridge from 1997-2014 Klamath County, OR.

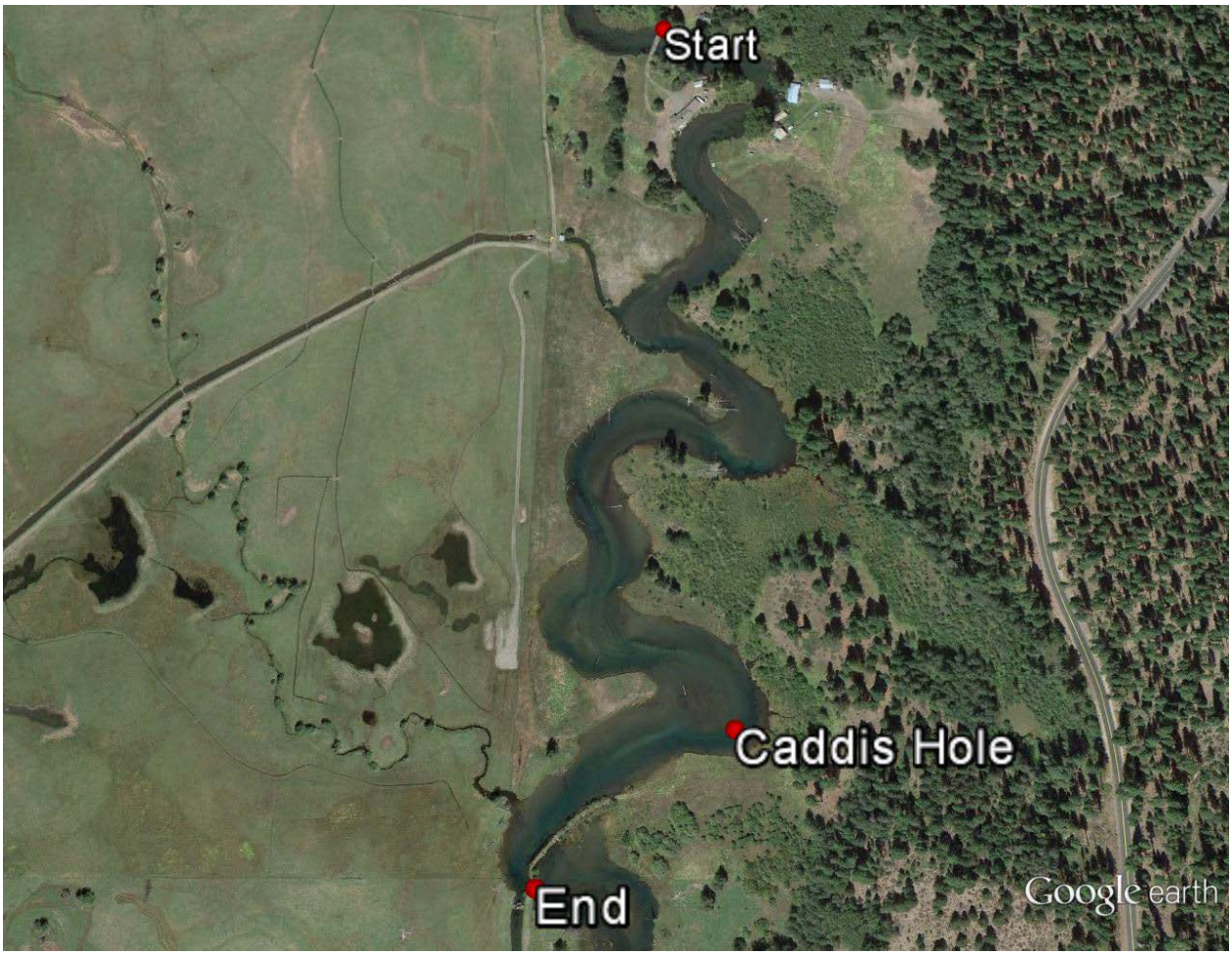

Figure 12. Area Under the Curve boat survey on the Wood River (Agency Lake) from Sun Pass bridge to Melhase canal from 1997-2014 Klamath County, OR.

Crooked Creek (redd and AUC surveys)

Redd surveys will follow the same protocol as developed in 2006 and improved in 2010. Redd counts will be conducted fortnightly from November through April on Crooked Creek at site 1-4 (Figure 13-14). Redds will be marked with colored rocks. All fish will be identified to species with length estimated. Fish and redds will be enumerated at the gravel augmentation at Napier site just around the bend downstream from Tecumseh Springs. The pool in this area is likely a staging area for spawning in Tecumseh Springs.

Tecumseh Springs (redd and AUC surveys)

Redd surveys will follow the same protocol as developed in 2006. Redd and fish counts will be conducted fortnightly from November-April on Tecumseh Springs (Figure 13). This survey is split into two surveys. One survey is conducted below the highway 62 culvert and one survey is conducted above the highway 62 culvert. This survey is divided into two surveys due to the fact that spawning only occurred above the culvert for several years after the new culvert was replaced.

Figure 13. Spawning Survey sites on Crooked Creek (Wood River) from 2005-2014 and Tecumseh Springs from 2006-2014 Klamath County, OR (Spawning gravel added at Crooked Creek sites in 2005 and Tecumseh Springs in 2006, 2008, 2012).

Figure 14. Spawning survey site on Crooked Creek site 4 (Wood River) below highway 62 from 2013-2014 (Spawning gravel added here in 2013).

Ranch Creek (Redd survey)

Redd counts will be conducted fortnightly from November through April on Ranch Creek (Figure 15). Redds will be marked with colored rocks. All fish will be identified to species with length estimated. As time allows a survey (Ranch Ditch) will also be conducted in the channelized reach to the vertical head gate on USFS property.

Agency Creek (Redd survey)

Redd counts will be conducted fortnightly from November through April on Agency Creek from the fence line to highway 62 (Figure 15). Redds will be marked with colored rocks. All fish will be identified to species with length estimated. The survey will be divided into two surveys. The survey from the mouth to the fence line on Kurt Thomas's property will not be completed as little to no spawning gravel exists due to extensive beaver activity in the area (Figure 15). Little spawning habitat occurs on this survey but beaver dams could hinder fish passage causing fish to spawn or hold in less than optimum habitat.

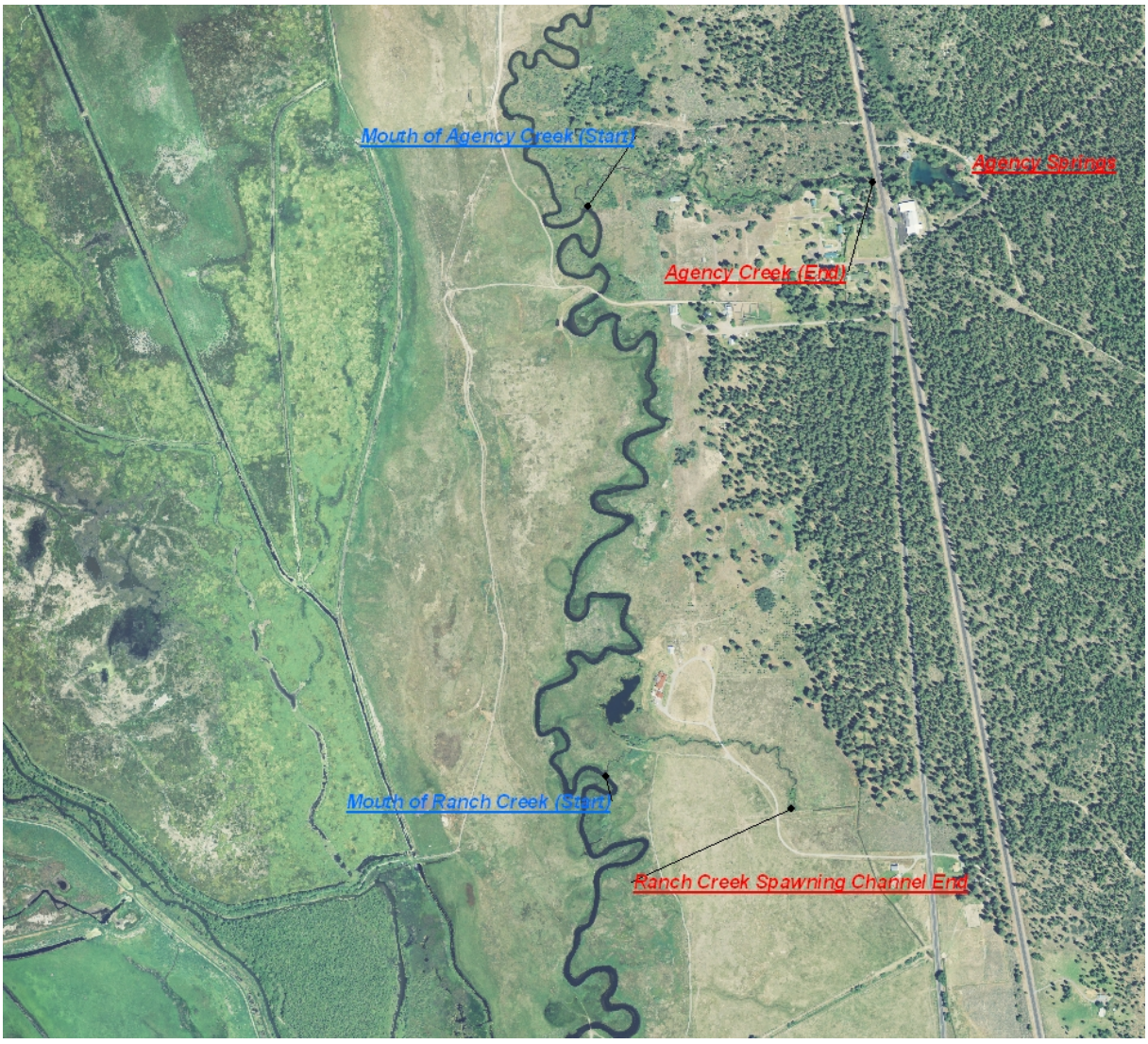

Figure 15. Agency Creek and Ranch Creek (Crooked Creek) spawning survey locations in 2003-2004 and 2010-2014 Klamath County, OR (Ranch Creek spawning channel created 1997).

Figure 16. Redband trout spawning survey locations on Agency Creek (Crooked Creek) in 2003-2004 and 2010-2014 Klamath County, OR (dam removed 2003 and spawning gravel added).

Fort Creek (Redd Survey)

Fort Creek will be surveyed bimonthly from November till the end of April from Rivers of Light Bridge to the headwaters at Reservation Springs (Figure 16-17). Redd surveys will be conducted exactly like all past surveys but with significantly more data collection as described in general methods. All redds will be marked with colored rocks. All fish observed will be identified, enumerated, and length estimated. All fish mortalities will be noted. The survey is divided into two survey segment. One survey is conducted from Rivers of Light Bridge to the old dam site (Figure 16). The other survey occurs from the old dam site to headwaters at Reservation Springs (Figure 17).

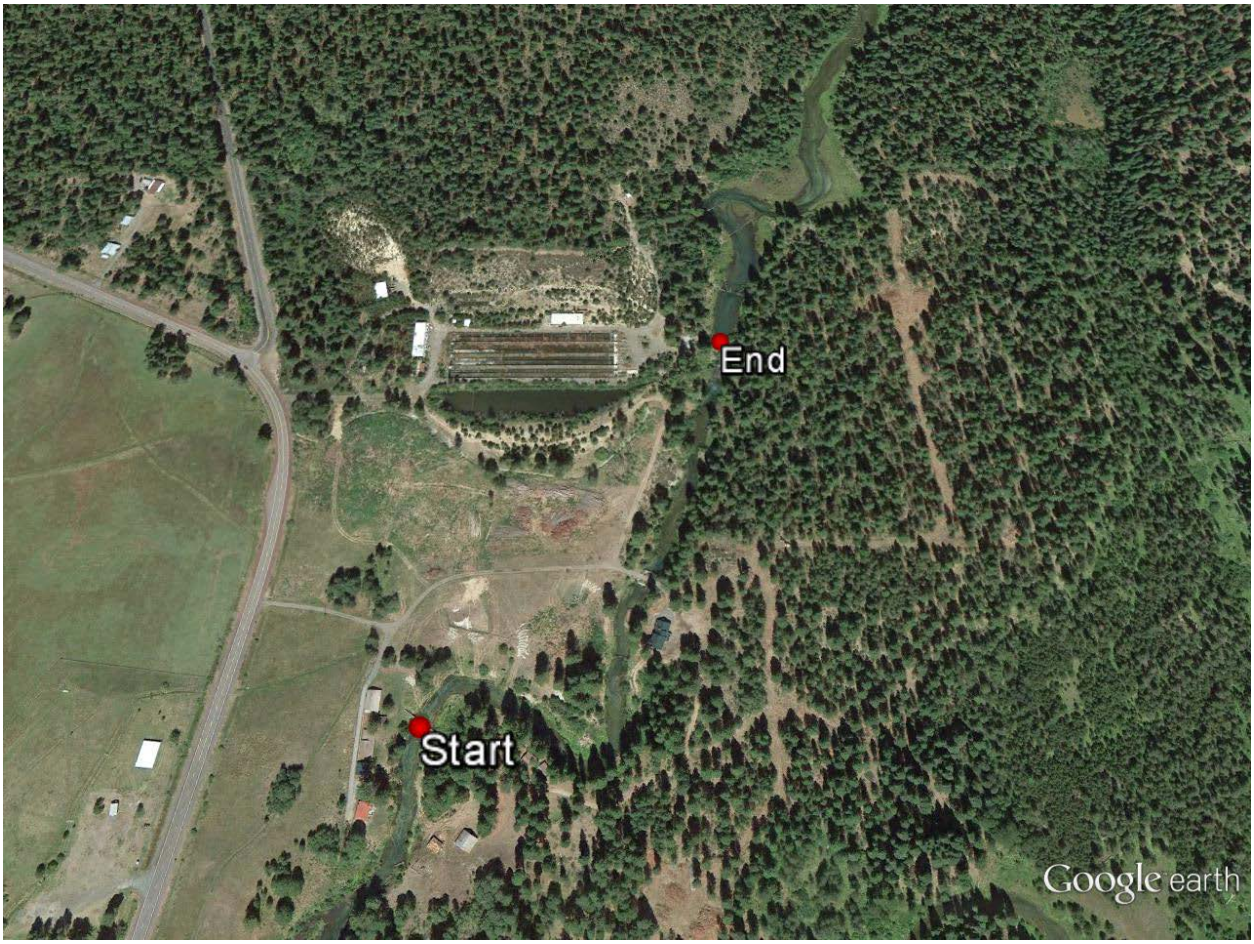

Figure 17. Redband trout spawning survey site on Fort Creek from Rivers of Light Bridge to Dam from 1995-2014 (Fish screen) Klamath County, OR.

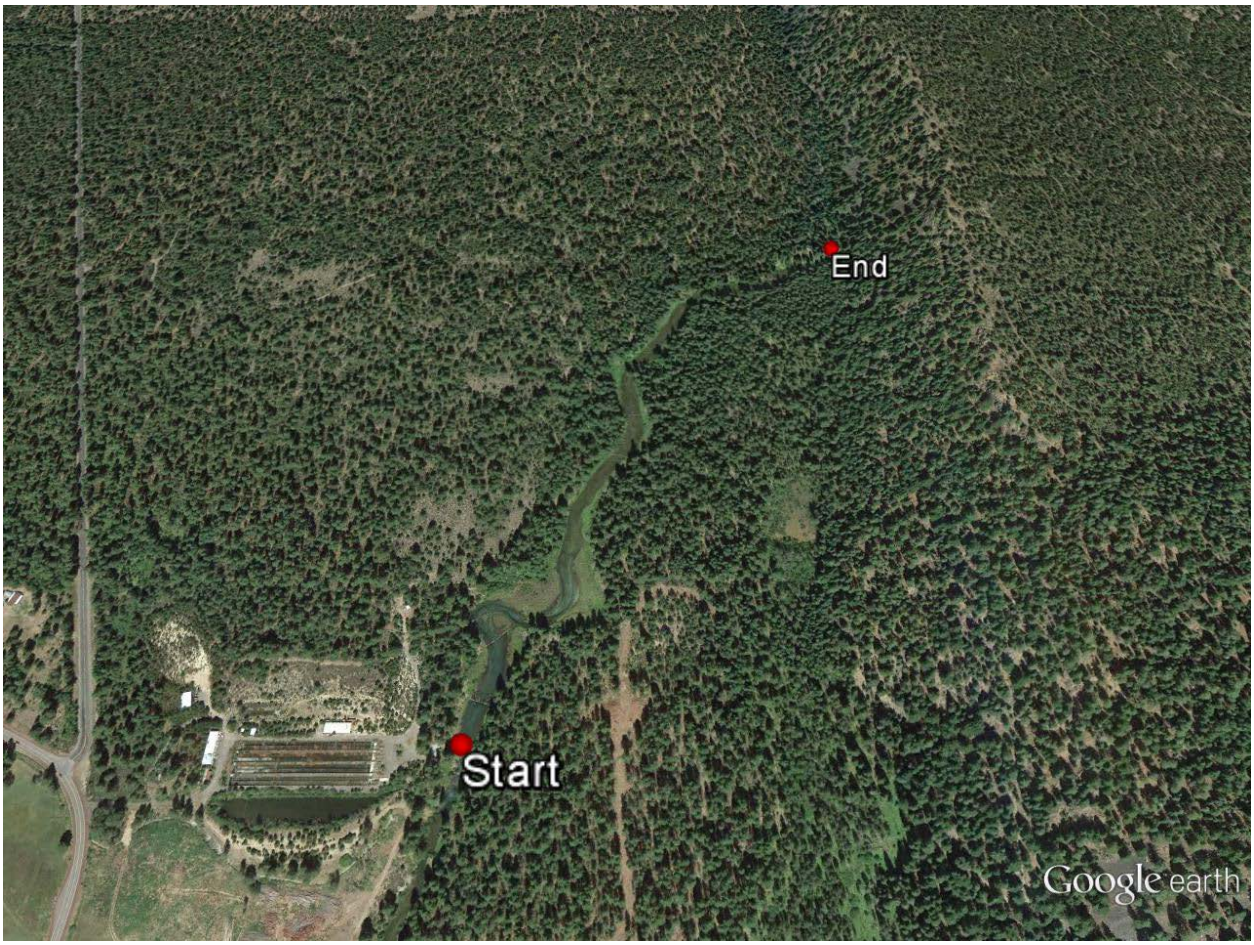

Figure 18. Fort Creek (Wood River) spawning survey from dam (fish screen) to headwaters from 1995-2014 Klamath County, OR.

Short-Moss Creek (Redd Survey)

Short Creek will be surveyed as time allows from the mouth to the headwater springs (Figure 11). All redds will be marked with colored rocks. All fish observed will be noted with number, length, and species recorded. While conducting this survey the area from Rivers of Light bridge downstream to the mouth will be surveyed (Figure 19.)

Figure 19. Redband trout spawning survey location on Short Creek aka Moss Creek (mouth to headwaters) a tributary to Fort Creek from 2010-2014, Klamath County, OR.

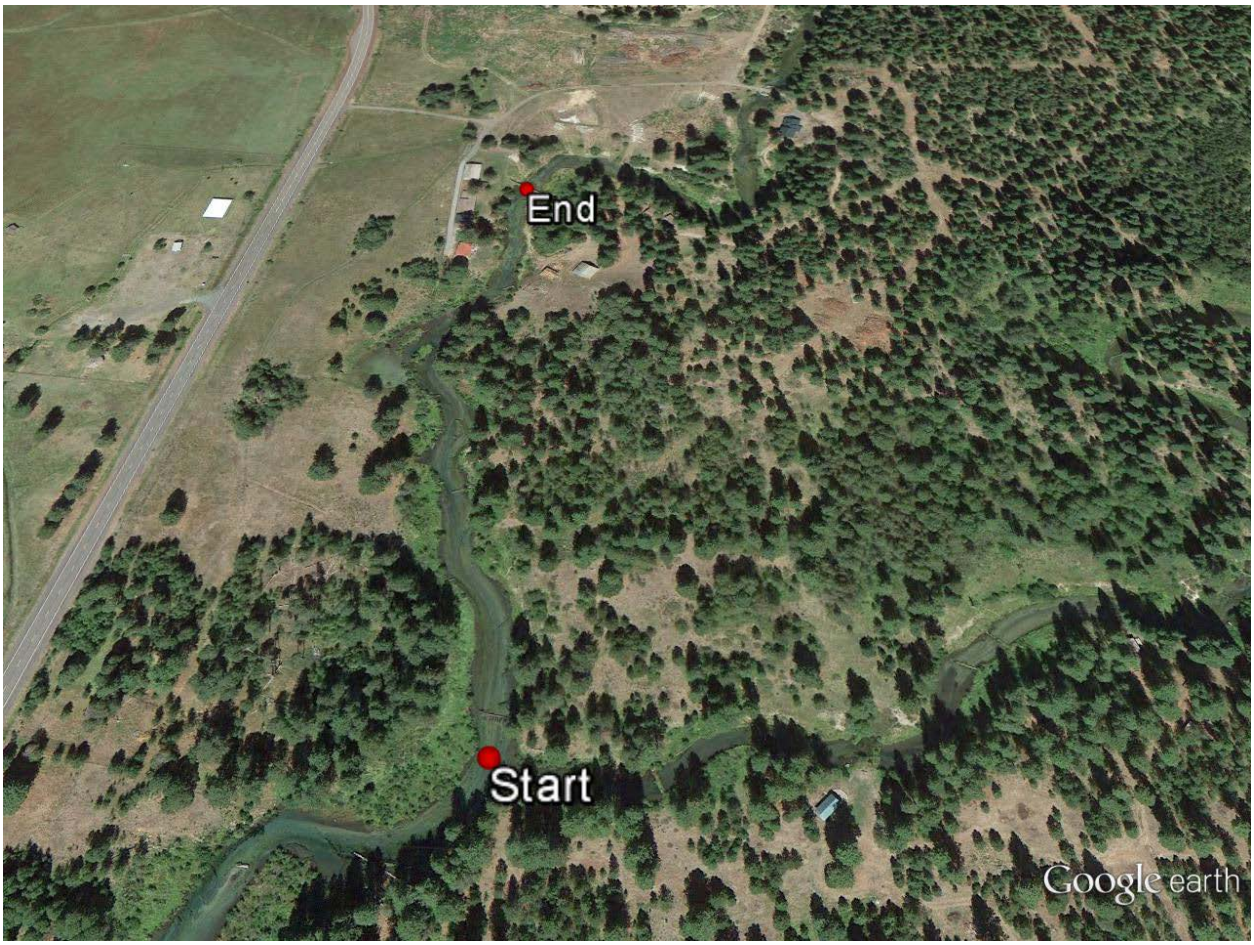

Figure 20. Redband trout spawning survey on Fort Creek from confluence of Moss Creek to Rivers of Light Bridge from 2010-2014 Klamath County, OR.

Williamson River (Redd and AUC surveys)

Williamson River (RM 16) Tuttle Spawning Gravel 2013 (Redd survey)

Redds will be enumerated monthly from November-July from the shore on the Williamson River from the pump station to the Collier State Park boundary where spawning gravel was added in 2013 (Figure 21) All fish observed will be enumerated, identified, and length estimated.

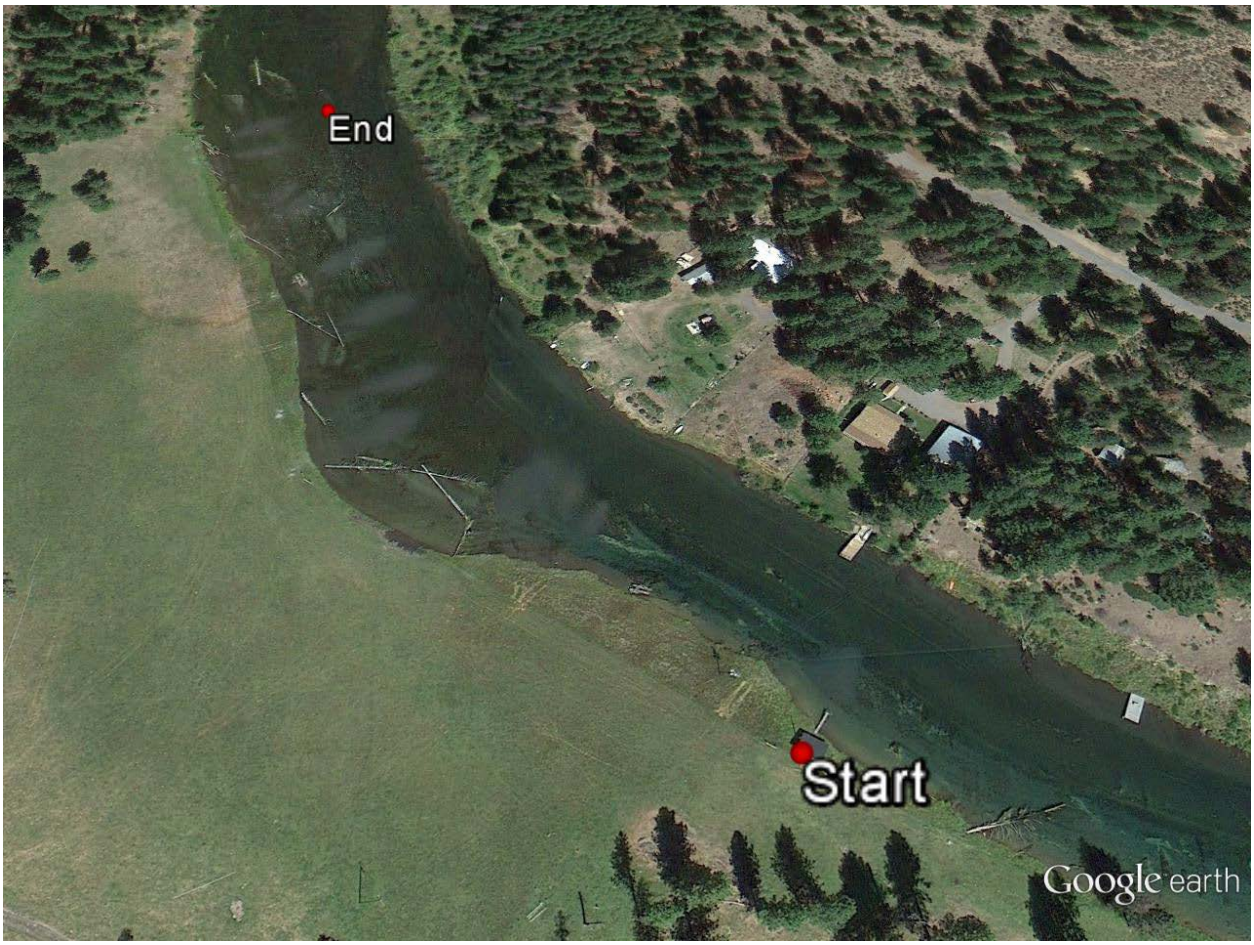

Figure 21. Williamson River spawning survey from pump station to Collier State Park boundary at Tuttle (RM 16) property from 2013-2014 (2013 spawning gravel addition grey splotches). Klamath County, OR.

Williamson River at Kirk Springs (AUC Survey)

AUC surveys will be conducted from shore fortnightly from November through March at the Kirk Springs area (Figure 22). All fish will be identified, enumerated and a range of length estimated. All spring channels will be surveyed. Notes will be taken on the amount of redds in the area. All fish mortalities will be identified and enumerated.

Figure 22. Redband trout spawning survey location on the Williamson River at the Kirk Springs site 2003-2014 Klamath County, OR (spawning gravel added 1989, 2011 and 2012).

Williamson River Larkin to Private Property-USFS Campground (Redd survey)

Spawning surveys will be conducted bimonthly from November to March (Figure 23). All new redds will be marked with a colored rock following protocol for redd counts. All fish will be identified, enumerated and a range of length estimated.

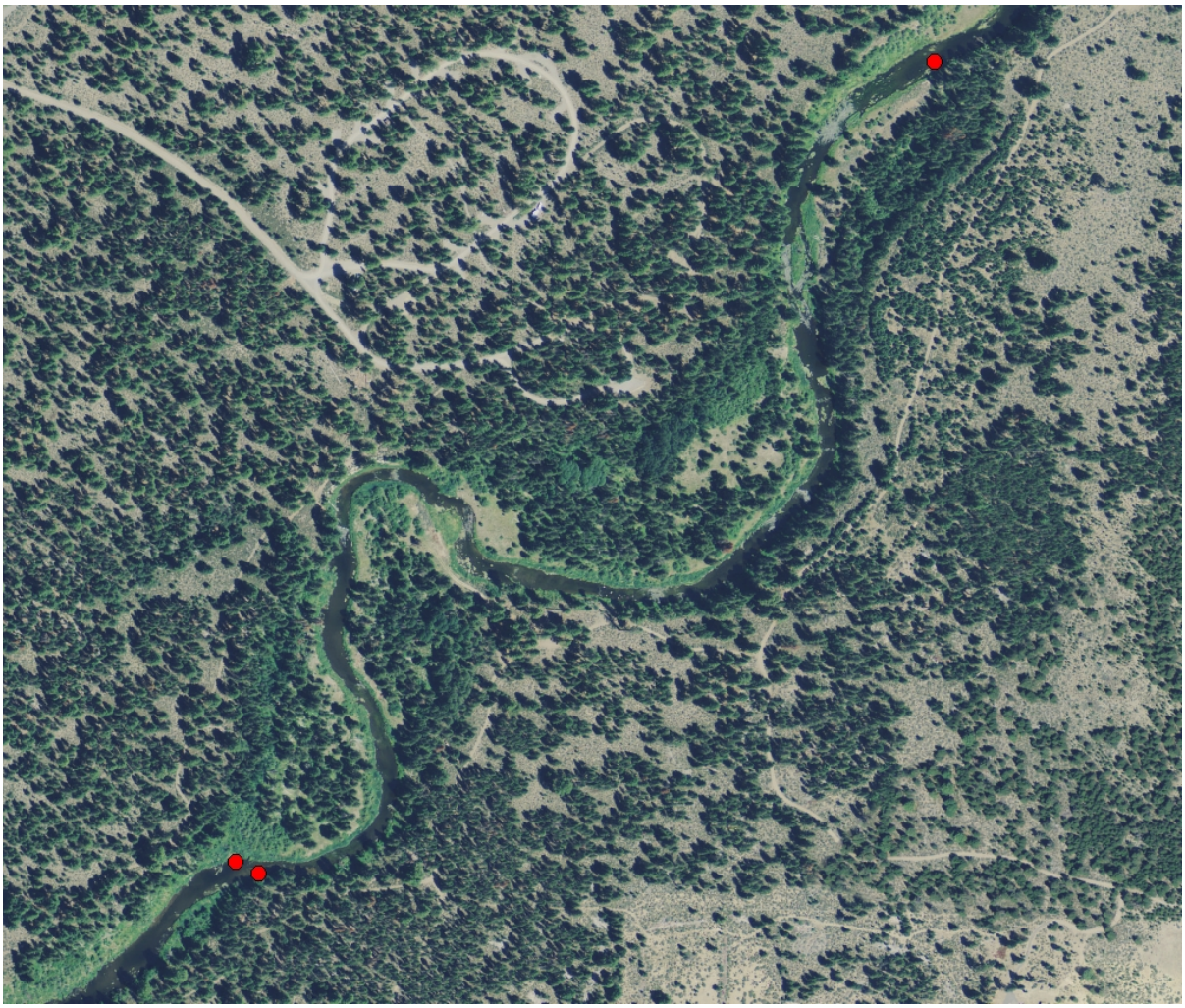

Figure 23. Redband trout spawning survey location on the Williamson River near the USFS campground site from just upstream of Larkin Creek to Private Property boundary from 2010-2014, Klamath County, OR (Spawning gravel added 1989) .

Williamson River Spawning gravel Sites at Tuttle RM 15-15.5 and Knapp's RM 14 (Redd Survey)

One redd survey will be conducted annually in early June (Figure 23-25). All redds will be enumerated that are still distinguishable. All fish will be identified, enumerated and a range of length estimated.

Figure 24. Williamson River (RM 15.5) spawing gravel augmentation sites on Tuttle property in 2013 Klamath County, OR.

Figure 25. Williamson River (RM 15) spawing gravel augmentation (2012-2013) spawning survey sites on Tuttle property in 2012-2014 Klamath County, OR.

Figure 26. Redband trout spawning gravel augmentation (2012) spawning survey site at Knapp's on the Williamson River from 2012-2014 (RM 13).

Spring Creek Picnic Area (AUC survey)

AUC surveys will be conducted fortnightly from standing in a flat bottom boat during October-July on Spring Creek at the Picnic Table Area (Figure 26). No redd count will occur in this area. All fish will be identified, enumerated and a range of length estimated. Typically one surveyor will stand and row in a boat in a downstream direction counting fish until reaching the cascade. The surveyor will then row upstream while sitting down and count fish in an upstream direction.

Figure 27. Redband trout AUC survey on Spring Creek (Williamson River) at the Picnic Area site from 2010-2014 (note: Redd counts have been conducted here sporadically since 1972).

Spring Creek 2010 Spawning Gravel (AUC and Redd Survey)

AUC and redd surveys will follow the protocol in the aforementioned methods section. Specific methods include the following. AUC surveys will be conducted fortnightly from standing in a flat bottom boat during October-July on Spring Creek at the Picnic Table Area (Figure 27). Typically one surveyor will stand and row in a boat in a downstream direction counting fish. All new redds will be marked with a colored rock. All fish will be identified, enumerated and a range of length estimated.

Figure 28. Redband trout spawning survey location on Spring Creek (Williamson River) at 2010 spawning gravel site from 2010-2014.

Spring Creek Above Gabion (AUC and Redd Survey)

AUC and redd surveys will follow the protocol in the aforementioned methods section. Specific methods include the following .AUC surveys will be conducted fortnightly from wading Spring Creek during October-July (Figure 29). All new redds will be marked with a colored rock.

Spring Creek Below Gabion (AUC and Redd Survey)

AUC and redd surveys will follow the protocol in the aforementioned methods section. Specific methods include the following. AUC surveys will be conducted fortnightly from wading Spring Creek during October-July (Figure 29). All new redds will be marked with a colored rock.

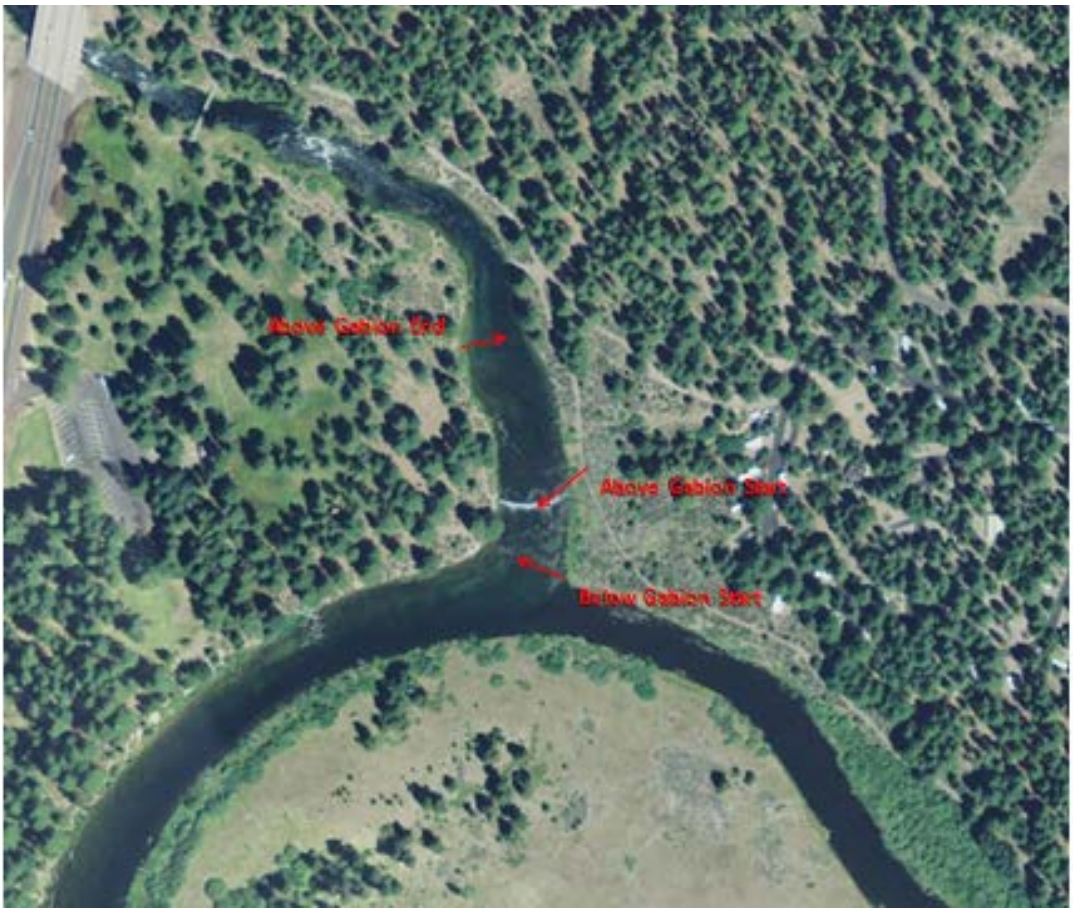

Figure 29. Redband trout spawning survey at Spring Creek (Williamson River) Below Gabion (2010-2014) and Above Gabion (1972-2014) Klamath County, OR.

Spring Creek Lassett Spawning Gravel 2011 (Redd survey)

One redd survey will be conducted annually in early June (Figure 30). All redds will be enumerated that are still distinguishable. All fish will be identified, enumerated and a range of length estimated.

Figure 30. Spawning gravel augmentation site at Lassett in 2011 on Spring Creek (Williamson River) (2011-2014) Klamath County, OR.

Sunnybrook Creek (Redd survey)

After contacting the landowner redd counts will conducted from November through March starting at the confluence to the waterfalls (Figure 31). Survey will be conducted by wading the stream. All new redds will be marked with a colored rock. All fish will be identified, enumerated and a range of length estimated.

Figure 31. Spawning survey area on Sunnybrook Creek (Williamson River RM 17.3) from mouth to water falls during 2010-2011 and 2013-2014.

Results

Agency Creek

Redd and redband trout counts were conducted bimonthly from November through April in 2012-2013 (Table 6). Peak counts were observed in late November. The 2012-2013 redband trout redd count was 144% of average (Table 6). However, redd counts in 2012-2013 were conducted by district staff instead of Native Fish Investigations. Agency Creek had the most amount of spawning activity of any site in the Crooked Creek system.

Nine spawning surveys were conducted in 2013-2014. Redd and redband trout counts declined sharply in 2013-2014 (Table 6). Redd counts were 85% of the five survey average with redband trout observations 36% of the five survey average. Redd and redband counts peaked in early December (Table 10).

Most redds in Agency Creek ranged in size from 1.1 to 2.5 m^2 suggesting smaller sized adult redband trout compared to Spring and Fort Creeks (Table 7). Most redds occurred in areas of introduced spawning gravel (71%) but this is the lowest of any Crooked Creek site (Table 8). Few redds were identified as having the potential of a secondary redd (Table 9). A more accurate estimate of adfluvial redband trout spawning is the sum of medium and large redds. Small redds are likely secondary redds or redds created by smaller resident redband trout. Brook or brown trout have not been documented to spawn in Agency Creek.

Table 6. A comparison of redband trout redd surveys completed in Agency Creek in 2003-2004 and 2010-2014 (note: 2010 and 2011 surveys completed by NFI).

Survey Dates	Year	Number Surveys	Total Redds	Total Redband trout
11/7 to 3/25	2003-2004	8	186	158
10/5 to 4/4	2010-2011	10	70	15
10/11 to 4/2	2011-2012	10	83	27
11/1 to 3/21	2012-2013	10	192	149
10/31 to 3/27	2013-2014	9	109	32

Table 7. Estimated size of redband trout redds in Agency Creek (Crooked Creek) during the 2013-2014 season Klamath County, Oregon

Estimated Redd Size	Number Redds
Large (2.5-6m^2)	17
Medium (1.1-2.5 m^2)	78
Small (.51-1.0 m^2)	14
Total	109

Table 8. Type of substrate utilized for spawning by redband trout in Agency Creek (Crooked Creek) during the 2013-2014 spawning season Klamath County, OR

Type of Substrate	*Number of redds*
Combination (native and introd.)	24
Introduced	54
Native	31
Total	109

Table 9. Number of secondary redds on Agency Creek (Crooked Creek) during the 2013-2014 spawning season Klamath County, OR

Secondary Redd Y/N	Number of Redds
N	106
Y	3
Total	109

Table 10. Number of redds and adult redband trout observed on Agency Creek (Crooked Creek) during the 2013-2014 spawning surveys Klamath County, OR.

Date	Number Redds	Number Adult Redband Trout > 300 mm
10/31	0	0
11/14	19	8
12/2	37	16
12/20	12	6
1/6	15	1
1/22	10	0
2/13	9	0
3/3	5	1
3/27	2	0

Ranch Creek

Nine redd and redband trout counts were conducted bimonthly from November through April. The 2012-2013 redband trout redd count was 86% of average (Table 11). Most redds in Ranch Creek were small and few large adult redband trout greater than 500 mm were observed. Nine spawning surveys were conducted from 10-31-2013 to 3-27-2014. Redd counts in Ranch Creek were at an all-time low in 2013-2014 with a near complete failure of escapement (Table 11). Only three redds were documented that were likely created by large redband trout. Most redds and observed fish were small (Table 12). All 23 redds were observed in introduced spawning gravel. Flows were low and during one survey flows were going subsurface and a 17" redband trout mortality was observed at the location of desiccation. Redd counts were 34% of the five survey average.

Table 11. A comparison of redband trout redd surveys completed in Ranch Creek (Crooked Creek) Klamath County, OR in 2003-2004 and 2010-2014 (note: 2010 and 2011 surveys completed by NFI).

Year	Total # Redds	Total # redband trout
2003-2004	187	68
2010-2011	76	No count
2011-2012	110	No Count
2012-2013	103	8
2013-2014	23	4

Table 12. Estimated size and number of redds on Ranch Creek (Crooked Creek) Klamath County, OR during the 2013-2014 spawning surveys.

Estimated Redd Size	*Number Redds*
Medium (1.1-2.5 ^{m2})	3
Small (.51-1.0 ^{m2})	18
Very small (.01-.5 ^{m2})	2
Total	23

Crooked Creek

Ten redd and redband trout counts were conducted bimonthly from 11-1-2012 to 4-4-2013 at the three spawning areas above highway 62. High flows in late November 2012 caused limited to no visibility for the first time while completing these surveys. The 2012-2013 redband trout redd count was 133% of average and counts of redband trout spawners was 186% of average. The large difference between counts of spawners and redd counts might be attributed to the fact that redband trout were observed during the surveys during high flows where redds could not be distinguished in certain areas. Observations of redband trout in Crooked Creek were the highest on record since surveys began in the 2005-2006 spawning season (Figure 4).

Ten spawning surveys were conducted on Crooked Creek at all three sites from 10/31/2013 to 4-7-2014. Redd observations peaked in early December while adult counts peaked in late January and an additional peak of adults observed in March (Table 14). After three years of high redd and redband trout numbers the counts declined substantially in 2013-2014. The 2013-2014 redd count was 76% of the five year average and redband trout count was 87% of the five year average. All surveys average over nine years of data was 89% for redds and 108% for redband trout observations.

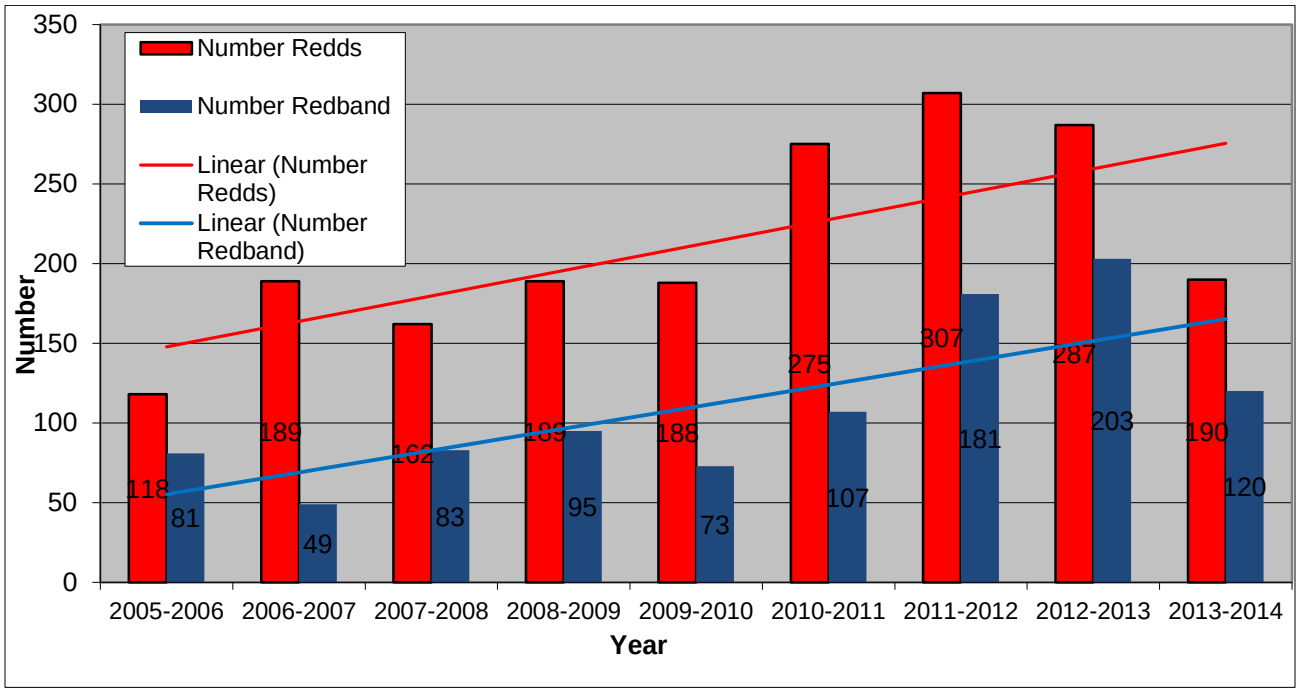

Figure 32. Redd and redband trout observations by spawning year in all the main stem redd survey areas above highway 62 sites 1 -3 Crooked Creek (Wood River) from 2006-2014.

Observations of other trout species at site 3 on Crooked Creek at the hatchery has declined substantially since 2009-2012 (Table 13).

Table 13. Other fish species observed greater than 6" on Crooked Creek (Wood River) at Site 3 (Klamath Hatchery) from November-April during the 2006-2014 spawning seasons. (note: October-April counts in parenthesis for 2010-2012).

Species	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014
Brook Trout	0	0	1	5	1 (9)	20 (33)	8	29
Brown Trout	1	1	0	60	65 (144)	13 (16)	9	4
Hatchery rainbow trout	5	12	28	77	20 (34)	17 (24)	30	38
Unknown	3	8	74	149	104 (139)	154 (216)	82	46

Table 14. Number of redds and adult redband trout observed on all Crooked Creek (Wood River) surveys 1-4 during the 2013-2014 season.

Date	Number Redds	Number Adult Redband Trout > 300 mm
10/31	28	18
11/14	22	7
12/4	39	15
12/20	20	9
1/6	24	28
1/22	28	10
2/11	7	5
2/13	11	5
3/5	16	16
3/20	15	8
4/7	0	3

Correlation to most environmental factors tested were weak but a few were strongly negative. Comparing redd count by year from 2006-2013 to mean Upper Klamath Lake levels was strongly negative correlation of -0.86. The strongest positive correlation was comparing redd counts to PDO five years prior which was 0.55 and Upper Klamath Lake mean levels five year prior was 0.22.

A strong positive correlation exists between other spawning surveys versus total redd counts in Crooked Creek comparing the years 2006-2014. Fort Creek redd counts (0.89) and Wood River AUC estimates showed the strongest correlation (0.75), Williamson River Kirk Springs Peak

(0.59). Redd counts in Tecumseh Springs 0.45 and Spring Creek 0.28 showed weaker correlations from 2006-2013.

Crooked Creek redd counts were also compared to all other surveys from 2010-2014 due to the increased effort, sample size and accuracy of the data. Crooked Creek had a very high correlation with Ranch Creek (0.98) Spring Creek redds counts (0.98), Williamson River Peak (0.91), Tecumseh (0.84) Wood River AUC (0.68) while much lower positive correlation with Spring Creek AUC (0.38) and Agency Creek redd count(0.04).

Crooked Creek Site 4 (Downstream Highway 62 crossing)

Eight spawning surveys were conducted below highway 62 from November-April 2014 on the spawning gravel placed in the summer of 2013. A total of 20 redds and 9 adfluvial redband trout were observed. Redband trout were observed spawning on the new gravel.

Crooked Creek (Napier)

A new survey was developed in 2013 when large numbers of redband trout were observed just above the gravel bar addition just downstream of the Napier's cabin (Table. The 2012-2013 missed a survey during peak migration. Ten surveys were conducted in 2013-2014 while only eight were conducted in 2012-2013.

Table 15. Number of redband trout and other species observed in the pool at the Napier's cabin from 2012-2014.

Species	2012-2013	2013- 2014
Redband Trout	42	46
Brown Trout	0	1
Hatchery rainbow trout	0	1
Unknown	0	0

Table 16. Estimated size of all redds observed at the four sites on Crooked Creek during the 2013-2014 spawning surveys

Site	Estimated Size of Redd	Number of redds
Crooked Creek below Highway 62	Large (2.5-6 ^{m2})	10
	Medium (1.1-2.5 ^{m2})	7
	Small (.51-1.0 ^{m2})	3
	Total	20
Crooked Creek Site 1	Large (2.5-6 ^{m2})	8
	Medium (1.1-2.5 ^{m2})	22
	Total	30

Crooked Creek Site 2	Large (2.5-6 ^{m2})	17
	Medium (1.1-2.5 ^{m2})	21
	Small (.51-1.0 ^{m2})	2
	Total	40
Crooked Creek Site 3	Large (2.5-6 ^{m2})	27
	Medium (1.1-2.5 ^{m2})	69
	Small (.51-1.0 ^{m2})	21
	Very large (>6 ^{m2})	3
	Total	120

Table 17. Type of substrate where redds were observed at all four sites on Crooked Creek during the 2013-2014 spawning season.

Site	Type of Substrate	Number of redds
Crooked Creek below Highway 62	Combination (native and introdu	12
	Introduced	8
	Total	20
Crooked Creek Site 1	Combination (native and introdu	17
	Introduced	12
	Native	1
	Total	30
Crooked Creek Site 2	Combination (native and introdu	16
	Introduced	18
	Native	6
	Total	40
Crooked Creek Site 3	Combination (native and introdu	72
	Introduced	14
	Native	34
	Total	120

Table 18. Number of redds adjacent to a larger, primary redd at sites 1-4 in Crooked Creek during 2013-2014 spawning surveys.

Site	Secondary Redd Y/N	Number redds
Crooked Creek below Highway 62	N	20
	Total	20
Crooked Creek Site 1	N	30
	Total	30
Crooked Creek Site 2	N	40
	Total	40
Crooked Creek Site 3	N	118
	Y	2
	Total	120

Tecumseh Springs (Crooked Creek)

Redd and redband trout counts were conducted bimonthly from November through April. The 2012-2013 redband trout redd count was 101% of average and observations of redband trout spawners which was 177% of average (Figure 5). Beavers had plugged the culvert at highway 62 which reduced the number of redds and spawners in this area.

Ten spawning surveys were conducted from 10-31-2013 to 4-7-2014. Redd counts peaked in December. The 2013-2014 redd and redband trout count has decreased significantly (Figure 5). Redd counts were 84% of the 8 year average whereas redband trout observations were 66% of the 8 year average. Five year averages were also low with 56% of average for redband trout observation and 85% of average for redd count. All redds occurred in areas of introduced spawning gravel or a combination of the introduced spawning gravel with native substrate. Only two redds were identified as having potential for a secondary redd however, all the small redds identified could be secondary redds. Most redds were medium but the rate of large redds was the highest in Crooked Creek (Table). Only one redd was observed above the highway 62 culvert due to blockage of the culvert by beavers. Brown trout, brook trout and hatchery rainbow trout were observed spawning at Tecumseh Springs during 2013-2014.

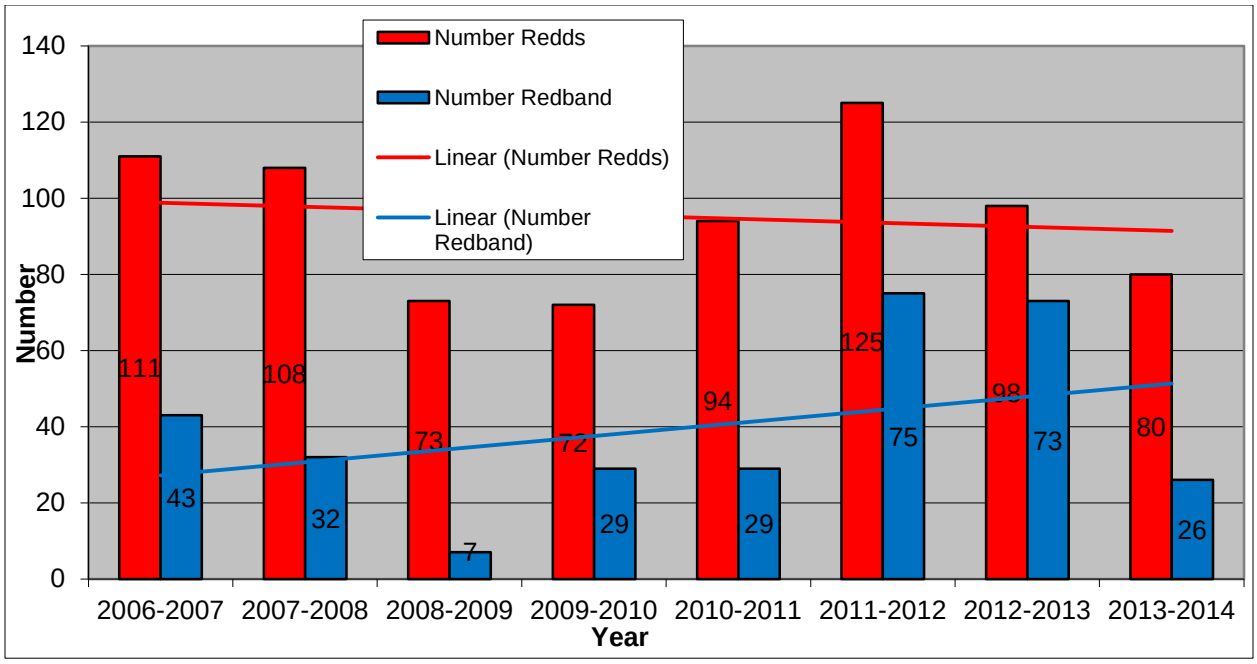

Figure 33. Redd and redband trout observations in Tecumseh Springs by spawning year (Crooked Creek) from 2006-2014.

Table 19. Estimated size of all redds observed at Tecumseh Springs (Crooked Creek) during the 2013-2014 spawning surveys.

Estimated Redd Size	*Number Redds*
Large (2.5-6 ^{m2})	18
Medium (1.1-2.5 ^{m2})	48
Small (.51-1.0 ^{m2})	13
Very large (>6 ^{m2})	1
Total	80

Crooked Creek Redband Trout Population Summary

A summary of all redds and redband trout observed on all spawning surveys conducted from 2003-2014 (Table 15). The increase in redds in 2006 compared to 2004 and 2005 is likely due to the construction of the Tecumseh Springs spawning channel. The increase in redds in 2005 might be due to the gravel added at two new sites on Crooked Creek that had no prior spawning. The most comparable data set occurs from the years 2010-2014 when all spawning habitat was surveyed (Table 16) with the exception of habitat above the Klamath Hatchery which is likely very limiting at this time. The redband population appears to be performing very well with an exceptional spawning season in 2012-2013.

Table 20. Summary of all spawning surveys conducted in Crooked Creek, Tecumseh Springs, Agency Creek and Ranch Creek from the years 2003-2014. (note: In 2012 redds and fish were counted at Napier's gravel and in 2013 redd and fish counts were conducted at the new gravel added in September of 2013).

Year	Total redband	Total redds	Surveys completed
2003-2004	252	384	Agency, Ranch, Tecumseh
2004-2005	86	94	Crooked and Tecumseh
2005-2006	101	142	Crooked and Tecumseh
2006-2007	92	300	Crooked and Tecumseh
2007-2008	115	270	Crooked and Tecumseh
2008-2009	102	262	Crooked and Tecumseh
2009-2010	102	260	Crooked and Tecumseh
2010-2011	151	515	All except Napier
2011-2012	283	625	All except Napier
2012-2013	475	687	All
2013-2014	237	430	All includes new gravel site
2014-2015	500	624	All

Table 21. Summary of all spawning surveys conducted in Crooked Creek site 1-3, Tecumseh Springs, Ranch Creek and Agency Creek from 2010-2014.(Note: all the same surveys compared)

Year	Total redband	Total redds	Surveys summarized
2010-2011	151	515	All except Napier
2011-2012	283	625	All except Napier
2012-2013	433	680	All except Napier
2013-2014	182	402	All except Napier and 2013 gravel
2014-2015	384	584	All except Napier and 2013 gravel

Fort Creek

The 2012-2013 redband trout redd count from middle December was 175% of the 17 year average which was the highest on record. The overall redd count was also the highest observed since surveys began in the 1995-1996 spawning season and was 200% of the 17 year average (Figure 34).

A total of 229 redds were observed from Rivers of Light bridge to the headwaters from October 31, 2013 to April 26, 2014. Redd counts in 2013-2014 declined significantly but remain 132% above the 19 year average. Redd counts from mid-December to end of April which correlate primarily with redband trout spawning were 88% of the five year average. Peak redd counts occurred in early February. Most redds created in Fort Creek were classified as large. All redds above the dam were created in native substrate. A total of 66% of the redds below the dam were created in native substrate.

Table 20. Estimated size of redds in Fort Creek (Wood River) at two sites in 2013-2014

Site	Type of Substrate	Number of redds
Fort Creek (Dam to headwaters)	Large (2.5-6 ^{m2})	61
	Medium (1.1-2.5 ^{m2})	37
	Small (.51-1.0 ^{m2})	27
	Very large (>6 ^{m2})	13
	Total	138
Fort Creek Rivers of Light Bridge to Dam	Large (2.5-6 ^{m2})	41
	Medium (1.1-2.5 ^{m2})	32
	Small (.51-1.0 ^{m2})	9
	Very large (>6 ^{m2})	9
	Total	91

Table 21. Type of substrate where redds were observed at Fort Creek (Wood River) during the 2013-2014 spawning season.

Site	Type of Substrate	Number of redds
Fort Creek (Dam to headwaters)	Native	138
	Total	138
Fort Creek Rivers of Light Bridge to Dam	Combination (native and introduced)	30
	Introduced	1
	Native	60
	Total	91

Table 22. Number of redds adjacent to a larger, primary redd in Fort Creek during 2013-2014 spawning surveys.

Spawning Survey Site	*Secondary Redd Y/N*	*Number of redd*
Fort Creek (Dam to headwaters)	N	120
	Y	18
	Total	138
Fort Creek Rivers of Light Bridge to Dam	N	82
	Y	9
	Total	91

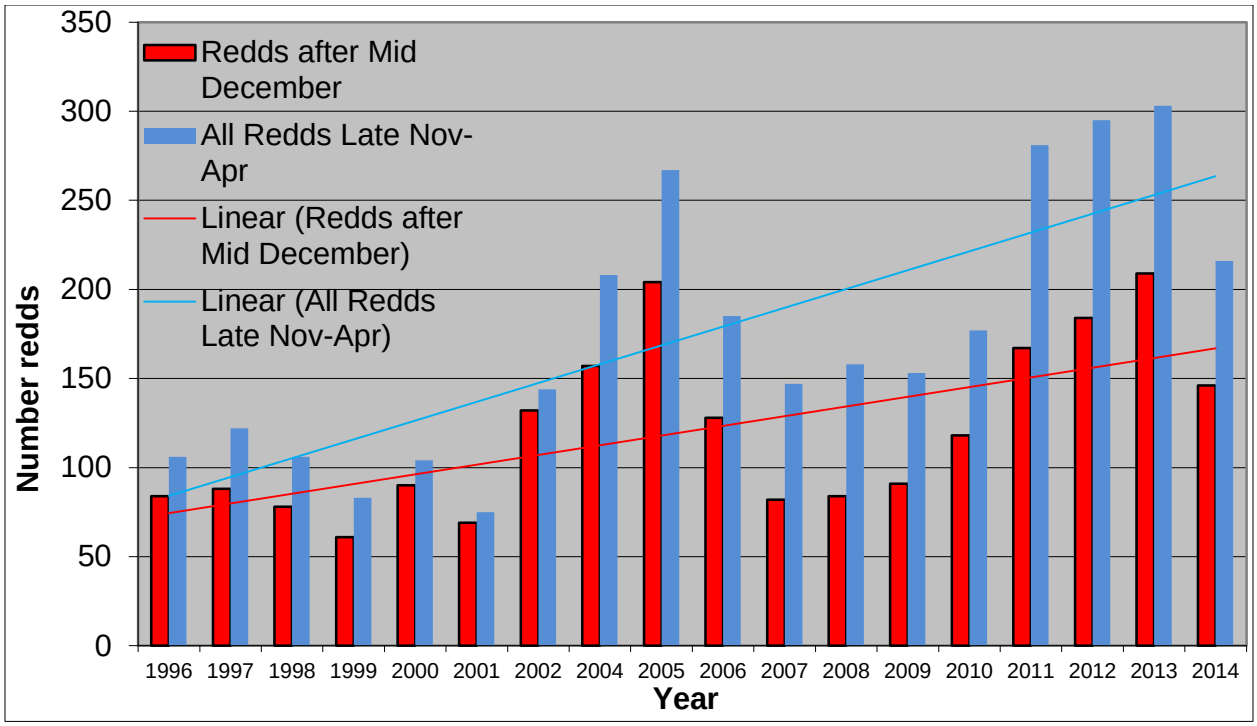

Figure 34. Redd counts in Fort Creek (Rivers of Light bridge to headwaters) from 1995-2014 from mid-December thru April (red bars) and all redds from November-April (blue bars). (Note: the red bars represent mostly redband trout after mid-December and prior to mid-December is primarily brown trout spawning).

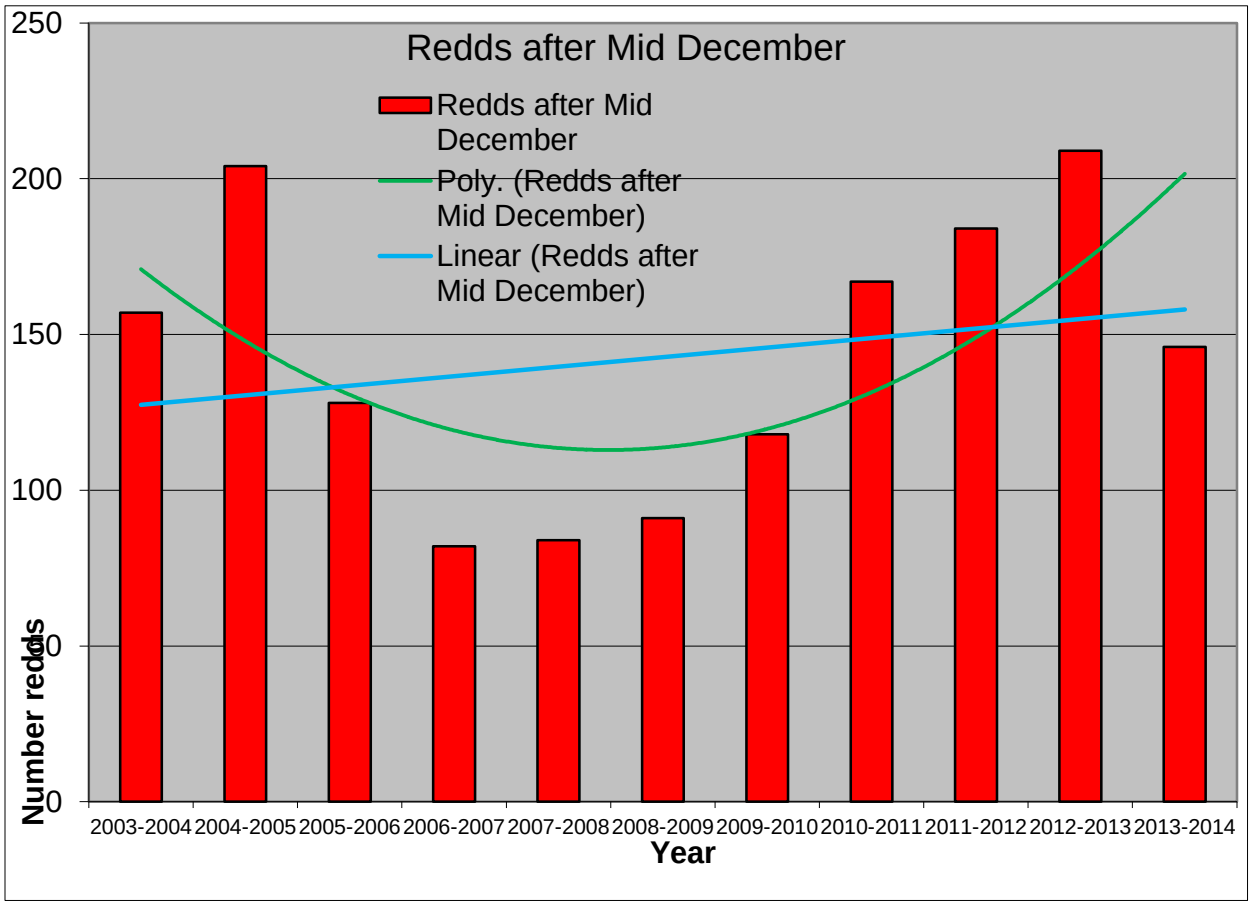

Figure 35. Redd counts from 2003-2014 in Fort Creek with Polynomial and linear regression line (Wood River)

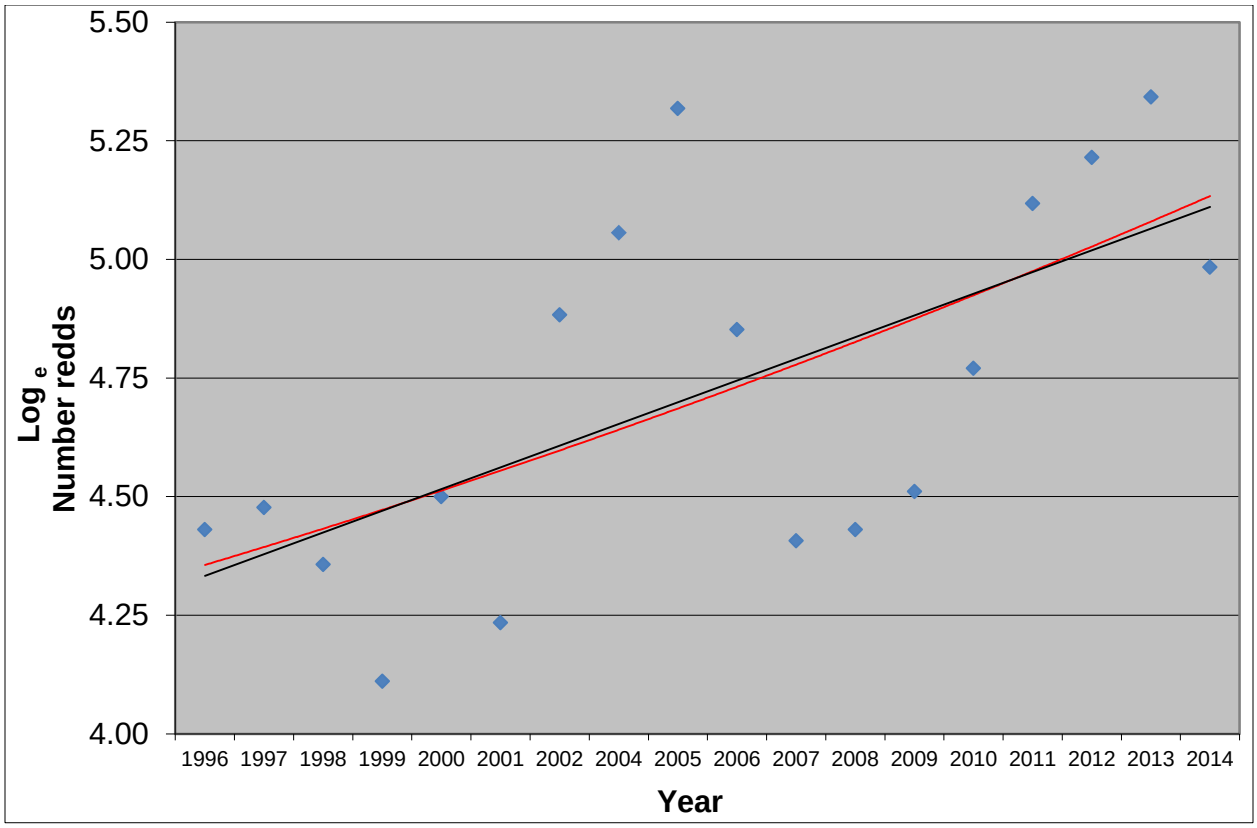

Figure 36. Fort Creek log e redds from mid-December through April 2013-2014 versus year with polynomial and linear regression lines.

Correlation to most environmental factors tested were weak but a few were strongly negative. Comparing redd counts from mid-December to April by year from 1995-2013 to mean Upper Klamath Lake levels was negative correlation of -0.58. The strongest positive correlation was comparing redd counts to Upper Klamath Lake mean levels four, five and six years prior was 0.39, 0.50 and 0.47.

Fort Creek redd counts from 1995-2014 have a weak correlation with Wood River Peak Counts (0.26) and a negative correlation with Spring Creek redd counts -0.64.
Fort Creek redd counts compared from 2003-2014 to Williamson River Peak counts was 0.43.

Fort Creek redd counts 2006-2014 versus Crooked Creek 0.89 and Tecumseh Springs 0.21.

Fort Creek redd counts from mid-December-April from 2010-2014 compared to AUC estimates on Spring Creek has a strong positive correlation of 0.81, Spring Creek Redds 0.89, Williamson River Peak 0.96, Ranch 0.87, Agency 0.66 Wood River AUC 0.98.

Short-Moss Creek (Fort Creek)

Only four surveys were conducted on Short Creek in the 2012-2013 and 2013-2014 season. Spawning is limited but redds were observed on each survey

Wood River

Observations of redband trout spawners in the Wood River was near the highest on record in 2012-2013 but declined dramatically in the 2013-2014 (Table 23-24). Only counts of adult redband trout were conducted from October-May. The highest fish count on record occurred on November 6, 2012 when 264 redband trout, 159 brown trout and 8 brook trout were enumerated (Figure 37).

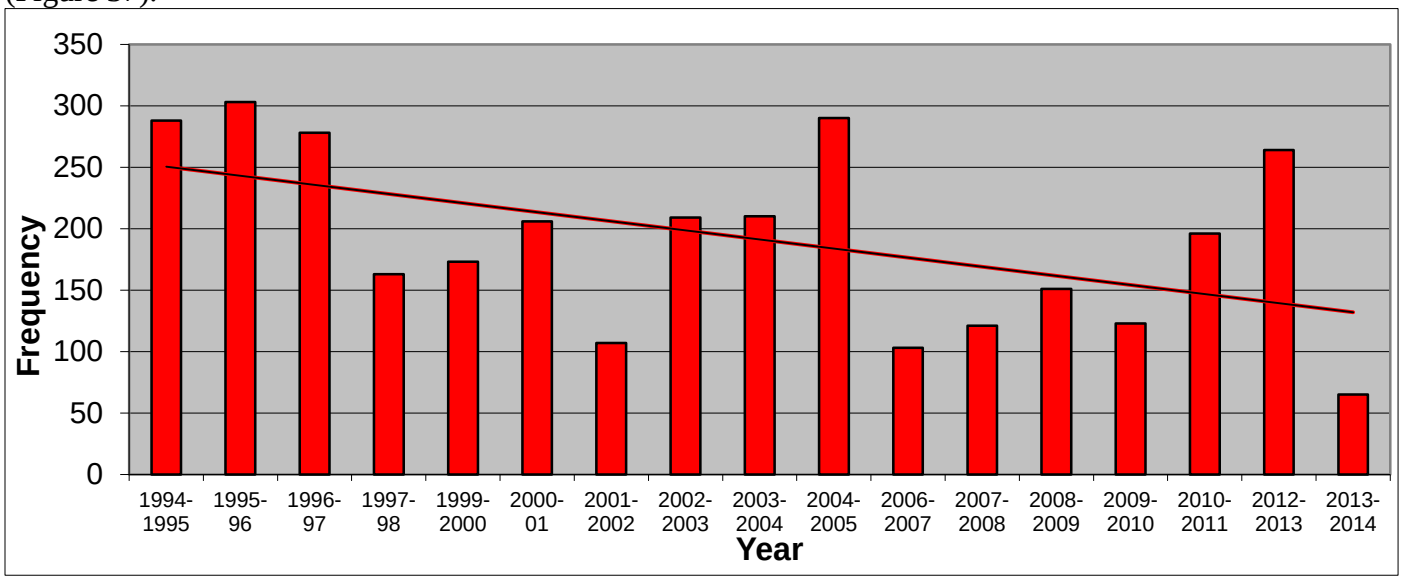

Figure 37. Annual peak redband trout enumeration from boat beginning at Kimball State Park to Melhase Canal from 1994-2014.

Table 23. Raw AUC redband trout counts on the Wood River from Kimball State Park to Melhase Canal in the 2012-2013 and 2013-2014 spawning season.(* only includes counts in Caddis Hole)

Date	# Redband observed	Date	# Redband observed
7/14/2012*	2	6/28/2013*	12
7/22/2012*	20	7/10/2013*	25
8/5/2012*	36	8/15/2013*	51
8/19/2012*	50	8/26/2013*	59
8/27/2012*	0 (5 otters)	9/27/2013*	50
9/12/2012*	116	10/2/2013*	12
10/4/2012	135	10/21/2013	83
11/6/2012	262	11/27/2013	65
11/26/2012	175	12/10/2013	19
12/21/2012	49	12/31/2013	30
1/16/2013	120	1/21/2014	46
2/1/2013	35	2/11/2014	31
2/11/2013	147	3/14/2014	61
2/26/2013	64	4/7/2014	8
3/18/2013	52		
4/10/2013	18		
5/6/2013	1		

Table 24. Summary statistics for AUC adfluvial redband trout surveys on the Wood River from Kimball State Park to Melhase Canal (Note: AUC likely overestimated as redband trout residence time is likely extended in caddis hole).

Year	Sample size	Mean count	Peak count	Date of Peak
94-95	5	125	288	2/16
95-96	14	94	303	1/5
96-97	11	98	278	12/18
97-98	9	82	163	11/3
98-99	1		98	12/18
99-2000	2	136	173	12/29
2000-2001	8	88	206	12/29
2001-2002	7	54	107	1/15
2002-2003	6	123	209	1/7
2003-2004	6	106	210	12/19
2004-2005	4	225	290	12/21
2006-2007	4	58	103	12/20
2007-2008	7	72	121	12/11
2008-2009	6	89	151	11/21
2009-2010	4	95	123	3/1
2010-2011	13	57	147	10/14
2012-2013	11	96	262	11/6
2013-2014	9	39	83	10/21

Correlation for Wood River peak counts was compared to all other spawning surveys.
Wood River Peak counts from 1994-2014 vs Spring Creek redd counts correlate weakly (0.32).

Wood River peak counts from 1994-2014 vs Fort Creek redd counts correlate weakly (0.43)

Wood River peak counts from 2006-2014 correlate strongly with Crooked Creek redds (0.73) but weakly with Tecumseh Springs (0.13).

Correlation of Wood River AUC counts from 2010-2014 correlates strongly to Spring Creek AUC counts (0.98), Williamson River Kirk Springs Peak Counts (0.88), Fort Creek redd counts (0.98), Ranch Creek redd counts (0.83), Agency Creek redd counts (0.91)

Wood River peak counts from 2003-2014 correlate extremely well vs Williamson River peak counts at 0.98.

Spring Creek

Index spawning surveys have been conducted on Spring Creek since 1972. Beginning in 2010 nearly all the spawning habitat was surveyed from the mouth to Collier State Park Boundary (RM 0.8) at the four primary spawning areas divided into four surveys (2010 Gravel augmentation site, Picnic Area, Above Gabion, Below Gabion). Negligible spawning occurs above Collier State Park and in between spawning survey sections.

Redband trout were observed spawning from October through July 2012-2013. One survey was completed on September 11, 2012. No fish or redds were observed. In the 2012-2013 spawning season a total of 925 redds were enumerated in Spring Creek in the exact locations surveyed the prior year from October-June. A total of 1068 redband trout were observed during these surveys. In comparison to the spawning season 2010-2011 this is nearly a threefold increase of spawning redband trout. Survey conditions were similar and the comparison of fish observations between the two years is valid. An Area Under the Curve Estimate using a spawning period of 14 days and fish observation efficiency of 69% calculated the number of redband trout in Spring Creek as 686 in 2010-2011, 1506 in 2011-2012, and 2031 in 2012-2013 (Table 25).

Eighteen Area Under the Curve surveys were conducted from October-July 2013-2014 at the four primary spawning areas on Spring Creek. Redband trout were observed on the spawning grounds from October 31, 2013 until July 7, 2014. Number of adult redband trout declined compared to the past two spawning seasons but was better than the 2010-2011 estimate (Table 25).

Table 25. Summary statistics for AUC adfluvial redband trout surveys on the Spring Creek at the four spawning survey sites of below gabion, above gabion, Picnic area and 2010 gravel site at Collier State Park from 2010-2014 Klamath County, OR (note: AUC estimate not multiplied by observer efficiency).

Year	AUC Estimate	Sample size	Mean count	Peak count	Date of Peak
2010-2011	473	19	24	82	12/23
2011-2012	1039	16	59	130	1/11
2012-2013	1402	15	76	185	1/9
2013-2014	785	18	51	108	1/6

Gabion

A total of 231 redds were observed above the gabion from October through June 2012-2013. (Table 26). Redd numbers at the gabion were similar from 2010-2013 but declined in 2013-2014. The gabion continues to fail and gravel is transported below the gabion. Spawning area above the gabion has been reduced compared to historical conditions. Redband trout are utilizing the spawning substrate below the gabion (Table 27).

Redd surveys were conducted at the gabion from October 31, 2013 to July 7, 2014. Redd numbers have declined at these sites (Table 26 and 27).

Table 26. Redd counts above the gabion on Spring Creek (Williamson River) from 2010-2014

Year	Total Redds
2010-2011	233
2011-2012	234
2012-2013	231
2013-2014	138

Table 27. Redd counts below the gabion on Spring Creek (Williamson River) from 2010-2014

Year	Total Redds
2010-2011	117
2011-2012	169
2012-2013	106
2013-2014	31

More observations of brown trout spawning occurred at the gabion than at the Picnic Area. Brown trout observations increased significantly at the gabion in the 2011-2012 spawning season where 30 brown trout were observed in November and December and 30 unknown fish that were most likely a majority brown trout. Twenty six brown trout and 21 unknown fish that were likely primarily brown trout were observed above and below the gabion in October-December of 2013.

The AUC redband trout counts appear to more accurately reflect abundance on Spring Creek than redd counts (Table 28). Redds in Spring Creek are easy to discern. However, the problem with redd counts in Spring Creek is the lack of optimal spawning habitat which causes most spawning to occur on the introduced gravel resulting in a large number of redds being superimposed. Distinguishing an old redd from a new redd can be challenging when redband trout and brown trout spawn in the same areas for 11 months.

Table 28. Number of redband trout and redds observed at the four spawning survey sites on Spring Creek from 2010-2014.

Year	Total Redds	Total Redband trout
2010-2011	891	377
2011-2012	1021	889
2012-2013	914	1068
2013-2014	No complete survey	656

2010 Gravel Augmentation Site

Spawning surveys were conducted from October 31, 2013 to July, 7, 2014 at the 2010 gravel augmentation site. Redd numbers had declined compared to the previous two spawning seasons (Table 29).

Table 29. Number of redds observed at 2010 Gravel Augmentation Site on Spring Creek from 2010-2014.

Year	Total Redds
2010-2011	106
2011-2012	169
2012-2013	160
2013-2014	112

Picnic Area

Redd counts were conducted at the Picnic area on Spring Creek from October through June 2010-2013. No counts were conducted in 2013-2014 spawning season.

The spawning gravel placed in 2011 and 2012 was monitored at the picnic area during the spawning years of 2011-2012 and 2012-2013. A total of 78 out of 449 redds enumerated at the Picnic Area in the 2011-2012 season were constructed on spawning gravel placed in 2011.

In the 2012-2013 season a total of 69 redds were enumerated on the gravel placed in 2011 and 142 redds were enumerated on the gravel placed in 2012.

Table 30. Number of redds observed at Picnic Area Site on Spring Creek from 2010-2014.

Year	Total Redds
2010-2011	435
2011-2012	449
2012-2013	417
2013-2014	No survey

Redd counts at the gabion from 1997-2011 were strongly correlated positively to Williamson River flow at Kirk 0.94, Link River flows 1.00, and UKL mean lake elevation 0.98. Redd counts were strongly negatively correlated with mean Upper Klamath Lake level at four (-0.33) and (-0.71) five years prior.

Crystal Creek

Area under the Curve survey were completed from 2011-2014 at the spawning area at Crystal Springs (Table 31). Surveys were conducted by drift boat with one observer and one rower in November and by kayak with one observer once snow or ice prohibited launching boats. Two counts are conducted by drift boat with the rower and observer changing duties.

Table 31. Number of redband trout observed at the spawning area on Crystal Creek at Crystal Springs from 2011-2014.

Date	# Redband observed
12-17-2011 Upstream	105
12-21-2011 Upstream	128
12-21-2011 Downstream	168
2-15-2012	106
11-9-2012 Upstream	167
11-9-2012 Downstream	177
11-26-2012 Upstream	196
11-26-2012 Downstream	217
1-16-2013	1
4-24-2013	0
10/30/2013	245
11/21/2013 Upstream	289
11/21/2013 Downstream	332
12/10/2013	51
1/3/2014	0
1/21/2014	0

Williamson River

Kirk Springs

Five Area Under the Curve (AUC) surveys were conducted at Kirk Springs beginning on November 20, 2012 and ending February 14, 2013 (Table 32). Peak spawning was a month prior than 2011-2012 and occurred in early December. Heavy rains in November 2012 might have initiated early spawning timing. On December 20, 2012 GPS coordinates were taken of a subsample of redds at the Kirk Springs area and downstream for a database of all spawning areas for redband trout in the basin.

Table 32. AUC surveys conducted on the Williamson River of adfluvial redband trout spawners observed at Kirk Spring in 2012-2013.

Date	Total Live Redband trout
11-20-2012	0
12-6-2012	274
12-20-2012	56
1-15-2013	6
2-14-2013	0

Seven Area Under the Curve surveys were conducted on the Williamson River at Kirk Spring November through March. All surveys showed extremely low counts with the lowest peak count ever recorded (Table 33 and 34). Observations of redds at Kirk Springs was very low.

Table 33. AUC adfluvial redband trout spawning surveys conducted on the Williamson River at Kirk Springs during the 2013-2014 spawning season.

Date	Total Live Redband trout
11-18-2013	0
12-12-2013	1
12-29-2013	0
1-6-2014	6
1-20-2014	1
1-31-2014	4
3-3-2014	1

Table 34. Summary of peak adfluvial redband trout counts at Kirk Springs on the Williamson River in the years 1980, 2003-2014.

Year	Number Redband	Total Number Mortalities	Sample Size	Date of Peak
1980-1981	300	0	2	12/10
2003-2004	500	15	1	12/18
2004-2005	400	8	1	12/22
2005-2006	50	1	1	12/16
2006-2007	41	1	1	12/14
2007-2008	>100	3	1	1/3
2008-2009	280	0	5	1/9
2009-2010	300	0	1	12/26
2010-2011	157	0	4	12/21
2011-2012	209	1	6	1/8
2012-2013	272	5	5	12/6
2013-2014	6	1	7	1/6

USFS Campground Area (Larkin Creek to Private Property)

Redd surveys were conducted from October 30, 2012 to February 14, 2013. A total of 143 redds were observed with the peak count on December 6. Brown trout contribute to redds in this area. This is the third year of completing spawning surveys in this area. Redd counts are incomparable due to different effort due to high flows during the winter of 2012 (Table 35). Surveys from 2010-2012 were completed by NFI.

Table 35. Redd survey results on the Williamson River from Larkin Creek to private property from 2010-2014.

Dates	Spawning Year	Number Surveys	Total Redds
11/15 to 1/7	2010-2011	3	192
11/7 to 12/14	2011-2012	3	99
10/30 to 2/14	2012-2013	7	143
11/18 to 3/13	2013-2014	6	113

Six spawning surveys were conducted from upstream of Larkin Creek to private property on the Williamson River from November 18, 2013 to March 13, 2014. No survey was conducted on March 13 as the river was black from water coming from the marsh. Most redds in this area were medium in size and created in native substrate (Table 36). Spawning gravel was added to this reach in the past but can't be differentiated from the native substrate. A total of 15 secondary redds were enumerated out of the 113 total redds (Table 37).

Table 36. Estimated size of redds in the Williamson River (Larkin Creek to Private Property) in the 2013-2014 spawning season Klamath County, OR.

Size of redd	Number of Redds
Large (2.5-6 m^2)	22
Medium (1.1-2.5 m^2)	68
Small (.51-1.0 m^2)	23
Total	113

Table 37. Number of redds that were adjacent to a primary redd that have potential of a secondary redd of the same female.

Adjacent to Primary redd Yes (Y) or No (N)	Number Redds
N	98
Y	15
Total	113

2012 Spawning gravel at Knapp's (RM 13)

A survey was conducted June 11, 2013 on the spawning gravel added to John Knapp' property in 2012. Eight redband trout were actively spawning on June 11 and six new redds were observed at the site. A survey on 11-20-2012 observed no fish or redds.

Two spawning surveys were conducted on June 9 and July 7, 2014. Seven new redds were observed on June 9 and six adult redband trout spawners were observed on those redds. One female redband trout was observed actively excavating the redd. On July 7, no new redds were observed but four redband trout spawners were observed upstream of the spawning gravel site as well as two redds in the native substrate.

2012 and 2013 Spawning Gravel Site at Tuttle (RM 15, 15.5, 15.6)

Two surveys were conducted on Tuttle's property (RM 15) where spawning gravel was placed in 2012. A total of six new redds were observed April 30, 2013 and three new redds on July 8, 2013.

One redd survey was conducted on June 9, 2014 at Tuttle's property (RM 15) where spawning gravel was placed in 2012 and 2013. A total of 44 redds of differing age were observed. Two of the 44 redds were likely secondary redds. Twelve of the 44 were created in native substrate while 32 were created in introduced or a combination of introduced with native substrate. Most redds were large (18), followed by medium (17), small (8), and very large (1). Fifteen adult redband trout spawners were observed on redds on June 9, 2014.

One redd survey was conducted on June 9, 2014 at the spawning gravel sites added in 2013 at rivermile 15.5 to 15.6. Two redds were observed below the tailout and below the A-Frame cabin. UTM coordinates were recorded for both redds observed. Both redds were located in introduced gravel.

2013 Spawning Gravel Site at Tuttle (RM 16)

Eight spawning surveys were conducted from December 12, 2013 to July 7, 2014 at the location of spawning gravel addition in 2013. A total of 46 redds were enumerated. Peak redd counts occurred on June 9, 2014. Most redds enumerated were small (19). Nine redds were large and 18 medium. Thirteen of the redds were on native substrate in this area. Twenty three redds were located on introduced gravel or a combination of native and introduced gravels. No superimposition was observed at this site. Seventeen of the forty six redds were likely secondary redds.

2011 and 2012 Spawning gravel below Kirk Springs (RM 21.3 to 21.6)

The spawning gravel placed below Kirk Springs on the Williamson River was monitored for utilization on November 20, 2012 and February 1, 2013. Redband trout were utilizing all the areas where spawning gravel was placed. Pictures were taken of redband trout using new large wood and spawning gravel on February 1, 2013.

Sunnybrook Creek

Redd surveys and fish counts were conducted from November 14 through March 20, 2014. Surveys were completed for the duration of spawning for the second time. A total of 399 redds were observed. In the 2010-2011 spawning survey year 440 total redds were observed but 46 of these redds were determined to be very small and early in the season (Table 38). Redds early in the season were likely from brook or brown trout. Most redds were medium in size (Table 39). The majority of spawning occurs in introduced gravel from the falls downstream to the second bridge crossing. A total of 73 redds occurred in 2013-2014 on spawning gravel added to the stream in September 2013. Most spawning occurs in introduced gravel (Table 40). No introduced gravel occurs below this bridge. A significant amount of spawning occurs all the way to the mouth on fragmented yellow clay substrate and pumice. Superimposition occurs at an approximate rate of 19% (Table 46). Most superimposition occurs near the introduced spawning gravel near the house. Twenty six redds were identified as secondary redds due to their proximity and size compared to the primary adjacent redds (Table 41).

Peak numbers of redband trout were observed on December 2, 2013 when 40 adult redband trout were observed. Spawning redband trout were observed on every survey except March 20, 2014 (Table 38). Four unknown fish were observed and one brown trout during the 2013-2014 survey.

Table 38. Redd survey results on Sunnybrook Creek in 2010-2011 and 2013-2014.

Dates	Year	Number Surveys	Total # Redds	Total # redband trout
11/3 to 4/25	2010-2011	10	394	43
11/14 to 3/20	2013-2014	8	399	111

Table 39. Estimated size of redds in Sunnybrook Creek (Williamson River) in the 2013-2014 spawning season Klamath County, OR.

Redd Size	Total Number of redds
Large (2.5-6 m^2)	71
Medium (1.1-2.5 m^2)	228
Small (.51-1.0 m^2)	99
Very large (>6 m^2)	1

Table 40. Type of substrate utilized for spawning by redband trout in Sunnybrook Creek during the 2013-2014 spawning season Klamath County, OR.

Substrate Type	Number Redds
Combination (native and intro)	191
Introduced	72
Native	136
Total	399

Table 41. Number of redds in Sunnybrook Creek (Williamson River) that were adjacent to a primary redd that have potential of a secondary redd of the same female.

Adjacent to Primary redd Yes (Y) or No (N)	Number Redds
N	373
Y	26
Total	399

Other surveys

Six adfluvial redband trout were observed from drift boat above Knapps dam near rivermile 21 on the Williamson River on August 2, 2012. This is the earliest adfluvial redband trout have been observed in this area.

Spawning Survey Summary

Spawning escapement of redband trout in the Williamson River and Wood River watersheds was very good in the 2012-2013 and exceeded average in all locations where a long term data set exists (Table 42). In many areas such as Fort Creek redd counts, Spring Creek AUC surveys and parts of Crooked Creek the 2012-2013 season was record breaking. Contrastingly, the 2013-2014 spawning numbers declined sharply at all surveys (Table 43). Estimates of redband trout and observations of redds in Kirk Springs, Wood River and Ranch Creek were at all-time lows in the 2013-2014 surveys. Most data sets show a recent increasing trend for the past five years but for the longer term data set of over 10 years show a declining trend such as Kirk Springs, Spring Creek at the gabion, Agency Creek, Ranch Creek, and Wood River. Only Fort Creek shows an upward trend in redd counts since 2003.

Table 42. Five year average of redd counts and redband trout counts in the Williamson River, Wood River, Crooked Creek and Fort Creek during the 2012-2013 spawning season Klamath County, OR. (* Only four years of AUC data).

Stream	Percent of 5 year average redd count	Percent of 5 Year average redband count
Crooked Creek	115	154
Fort Creek	135	Low sample size
Spring Creek AUC	n/a	136*
Spring Creek (Redd count (gabion)	103	See AUC survey
Tecumseh Springs	106	171
Williamson River Peak Count (Kirk Springs)	n/a	118
Wood River (Peak Count)	n/a	163

Table 43. Five and Ten Year Averages of redd counts and counts of redband in the Williamson and Wood River watersheds during the 2013-2014 spawning season Klamath County, OR. (* 4 years of data, Crooked Creek 9 years, Tecumseh 8 years).

Stream	% 5 year average redd count	% 10 year average redd count	% of 5 Year average redband count	% 10 year average Redband count
Crooked Creek	76	89	87	108
Ranch Creek	34	n/a	n/a	n/a
Agency Creek	85	n/a	36	n/a
Tecumseh Springs	85	84	56	66
Fort Creek	88	103	n/a	n/a
Wood River (Peak Count)	n/a	n/a	43	38
Spring Creek (Gabion)	66	58	n/a	n/a
Spring Creek (AUC)	n/a	n/a	100*	n/a
Williamson River (Peak Count)Kirk Springs	n/a	n/a	3	3

Per American Fisheries Society protocol redds per 100 m^2 of the stream survey section was calculated (Table 44 and 45) (Dunham et al. 2009).In most survey sections redd density is very high per survey reach. Redd density is very high in sections of Crooked Creek, Tecumseh Springs and Spring Creek. Superimposition is also very high in most surveys (Table 46).

Table 44. Summary statistics and number of redds observed per 100 m^2 of habitat in all redd surveys completed in 2012-2013 spawning season in the Williamson and Wood River watersheds, Klamath County OR.

Stream Section	Redds/ 100 m^2	Survey Length (m)	Average Width (m)
Williamson River USFS	0.7	1347	15
Spring Creek Below Gabion	11.2	27	35
Spring Creek Above Gabion	6.6	99	35
Spring Creek Picnic Area	2.0	415	50
Spring Creek 2010 Gravel	5.7	59	47
Ranch Creek	6.0	684	2.5
Agency Creek	6.4	750	4
Tecumseh Springs	14.1	126	5.5
Crooked Creek #1	11.9	39	10.5
Crooked Creek #2	2.6	179	9.3
Crooked Creek #3	9.3	300	7
Fort Creek	1.3	1629	15.5

Table 45. Summary statistics and number of redds observed per 100 m^2 of habitat in all redd surveys completed in 2013-2014 spawning season in the Williamson and Wood River watersheds, Klamath County OR.

Stream Section	Redds/ 100 m^2	Survey Length (m)	Average Width (m)
Williamson River USFS	0.56	1347	15
Sunnybrook Creek	11.3	704	5
Williamson River Tuttle RM 16	0.25	295	61
Spring Creek Below Gabion	3.2	27	35
Spring Creek Above Gabion	3.9	99	35
Spring Creek 2010 Gravel	4	59	47
Ranch Creek	1.35	684	2.5
Agency Creek	3.6	750	4
Tecumseh Springs	11.5	126	5.5
Crooked Creek #1	7.5	39	10.5
Crooked Creek #2	2.5	179	9.3
Crooked Creek #3	5.7	300	7
Crooked Creek Site #4	1.6	156	8
Fort Creek	0.91	1629	15.5

Table 46. Percent of redds that were superimposed in all survey sites from 2011-2014 in the Williamson and Wood River watersheds Klamath County, OR.

Site	*2011-2012*	*2012-2013*	*2013-2014*
Agency Creek	No data	0.18	0.22
Crooked Creek Below Hwy 62	No survey	No Survey	0.10
Crooked Creek Site 1	0.68	0.73	0.47
Crooked Creek Site 2	0.55	0.41	0.58
Crooked Creek Site 3	0.70	0.46	0.40
Fort Creek (Dam to headwaters)	0.03	0	0.01
Fort Creek (Rivers of Light bridge to Dam)	0.25	0.14	0.13
Ranch Creek	No data	0.13	0.04
Spring Creek 2010 gravel	0.46	0.47	0.58
Spring Creek above gabion	0.68	0.56	0.57
Spring Creek below gabion	0.51	0.59	0.29
Spring Creek Picnic Area	0.54	0.41	No survey
Sunnybrook	No survey	No Survey	0.19
Tecumseh Springs below Culvert	0.68	0.5	0.43
Williamson River (Larkin to Private property)	0.01	0.04	0.03

Discussion

All surveys showed a decline compared to the last two years. Of utmost concern are the Wood River and Williamson River Kirk Springs surveys which showed the lowest peak count on record despite the intensive sampling conducted. The Wood River and Kirk Springs populations likely have some different limiting factors than Sunnybrook, Spring, and Crooked Creeks. Some hypotheses are instream flow and the correlation with habitat availability for juveniles. Flows in the Williamson River at the Kirk Gauge have been on a significant downward trend. The unusually cold with limited precipitation in December might have reduced the movement of redband trout in the Williamson River to Kirk Springs. The Kirk Springs fish might have spawned elsewhere. However, a heavy rain occurred in early December and redd counts on the Williamson River below Knapps Dam along the USFS reach were not high.

Redd Identification

The Klamath basin has unique attributes of the spawning population of redband trout. Spawning in the Wood River and Williamson River typically occurs in spring fed dominated streams or areas with stable hydrology. The excavation of redds usually lasts indefinitely in these systems as the only bedload movement occurs annually during the spawning season when fish move the substrate. Redds are easily visible in this environment as periphyton, snails and dark coloration on substrate is easily removed and redds can be extremely bright especially in pumice dominated systems where redds are bright white. The size of redband trout coming from Upper Klamath and Agency Lakes also make redds easily visible. However, due to the paucity of spawning habitat in the Wood and Williamson Rivers spawning can be extremely concentrated at most spawning survey sites. Due to this concentration redband trout might have developed a more protracted spawning duration in some areas. This concentration makes new redd identification arduous. Significant superimposition occurs which might result in missing redds that are new to the system. The opposite affect can also occur as the same redd can be counted twice as the marker (colored rock) could disappear by extensive spawning activity. Flags can be used in certain areas but often many redds occur in a typical cross section making flagging impossible.

Holecek and Walters (2007) published findings of adfluvial redband trout in the Kootenai Basin. Significant differences occur in the life history of Klamath redband trout and this study. Maximum size of redband trout in this study was 450 mm. Average sizes of redband trout in the Klamath Basin spawners ranges from 500 mm (Kirk Springs) and 540 mm (Spring Creek). Further, most of the spawning occurs in the groundwater dominated systems peaking in December or January whereas the redband trout in Trail Creek were spawning in the spring at the tail end of the peak of the hydrograph of a snow melt dominated stream. Larger bull trout from 400-700 mm were found to disturb a large area of substrate (Rieman and Mcintyre 1993). Therefore, the error associated with counting test redds as true redds is likely not problematic in the area of adfluvial redband trout spawning.

Crystal Creek

Redband trout spawning timing has yet to be determined at Crystal Creek but appears to be earlier than other sites. For example, 245 redband trout were observed on the spawning grounds on October 30, 2013. However, when other areas were peaking in early January of 2014 the Crystal Creek count was zero. Further information should be collected to determine the spawning timing of redband trout in Crystal Creek. The Crystal Creek spawning population is significant with a high count of 332 redband trout observed on November 21, 2013. A larger sample size will provide more significance to these surveys. Since these surveys tend to reflect abundance and there is little variation between surveyors more surveys will be conducted in this area in the future.

Ranch Creek

Redd and redband trout numbers in Ranch Creek declined from a high of 180 in 2003-2004 to only 27 in 2013-2014. The Ranch Creek redband trout spawners might have converted to a smaller fluvial redband trout form due to the increase in productivity of Crooked Creek. Lower flows might have reduced spawning in Ranch Creek and also lessened the likelihood of larger sized redband trout. In 2003-2004 large numbers of redd and adult redband trout were observed spawning in Ranch Creek. One reason for this large number might have been the lack of spawning habitat. For example the Tecumseh Springs channel that paralleled highway 62 was filled the spawning channel was not constructed until 2006. Other spawning habitats at Napier and above highway 62 on Crooked Creek were not developed until 2005 and 2006. The only other significant spawning habitat in Crooked Creek was at the Klamath hatchery and Agency Creek. Agency Creek also showed large numbers of redds and redband in 2003-2004.

Management Implications

Minimum adfluvial redband trout escapement levels

Using existing data minimum escapement levels should be developed for Spring Creek, Wood River, and Kirk Springs on the Williamson River.

Trophy Trout management

Regulation changes should consider increasing size, age and catch rate of adfluvial redband trout in the fisheries. Statistical creel surveys in 2009-20010 showed a dismal catch rate in Upper Klamath and Agency Lakes through most of the fishery. Catch and release mortality in the summer refuge areas (Pelican Bay and Agency Lake) using bait and spoons with treble hooks is likely very high.

Habitat Restoration Projects

Habitat restoration projects should focus on increasing spawning habitat in groundwater dominated streams or sections of rivers. Areas with high superimposition rates such as Crooked

Creek, Spring Creek and Sunnybrook Creek should consider additional spawning gravel augmentation to reduce superimposition. Adding gravel to Spring Creek at Collier State Park or immediately upstream on private land should be implemented. The addition of spawning gravel on Agency and Crooked Creeks at the hatchery should be completed. The addition of spawning gravel at Tuttle's at RM 15 is receiving lots of use and more gravel should be prioritized here. Conversely, spawning gravel added at RM 16 is receiving little use.

Despite measuring redd characteristics such as size, depth and velocity more effort should be completed to understand the preferences for spawning to increase spawning distribution. All spawning gravel augmentation sites should be at least monitored annually to determine utilization as some sites will surprising get little to no use. For example, the Lassett 2011 gravel augmentation site on Spring Creek received no use.

Reintroduction of anadromous fish

The spawning areas identified for adfluvial redband trout are likely the primary spawning locations for Chinook salmon especially the fall Chinook salmon life history or the ocean type life history that spawns in the fall and outmigrates in the late spring. This life history type needs to get thermal units to emerge from the gravel in time to reach the Pacific Ocean the following summer. The current known distribution of adfluvial redband trout is the best spawning habitat in upper Klamath Basin and will be a good place to start reintroduction efforts for various Chinook salmon life history types.

Correlation

Most spawning surveys in the Wood River watershed correlated more positively with positive environmental condition four and five years prior. This correlation suggests that fry and juvenile survival is the limiting factor for these populations. Conversely, recent Spring Creek redd counts at the gabion correlate extremely well with flows in the Williamson River the same year suggesting adult survival might be most limiting in the Williamson River populations. However, the spawning habitat area above gabion has decreased which could result in lower redd numbers. With the exception of Tecumseh Springs, Ranch and Agency Creeks, all the redds surveys are strongly positively correlated since 2010. The increase in sampling effort, improved protocol, and same experienced surveyor for all surveys appear to have improved precision of redd and AUC counts. Agency and Ranch Creek correlation likely differ due to different surveyors in 2010-2012 and differing amount of spawning habitat available in the Crooked Creek system. Difference in Tecumseh Spring is likely due to reduced spawning habitat in the stream as explained below. Further, the beaver dams in Agency Creek and the lower flows in Ranch Creek might redistribute the spawners to other areas.

Trends

The slight downward trend in redd counts on Tecumseh Springs could be more related to loss of habitat than an actual trend. Much of the spawning gravel is annually pushed out of the tailout which reduced spawning habitat. Further, spawning habitat above the highway 62 culvert was inaccessible for trout due to beavers clogging the culvert from fall 2012 through 2014.

Additional gravel has been added to Tecumseh Springs due to the aforementioned issues. Due to the low cost of adding spawning gravel more spawning gravel should be added when spawning habitat is reduced.

Spawning surveys show that the redband trout abundance is cyclic. The importance of using ten year averages as suggested by Howell and Sankovich (2012) is important since all five year averages show an upward trend in abundance while data going back to 2003 all show a downward trend in abundance with the exception of Fort Creek redd counts. District staff did not begin to perform redd counts in the Crooked Creek system until 2006, except Ranch and Agency Creeks, therefore counts were started when the population was low and has increased significantly. All other surveys began in 2003 when numbers of redband trout were peaking such as Wood River, Williamson River, Spring Creek, Agency Creek and Ranch Creek. A decline in numbers occurred after 2003 but then an increase occurred from 2011-2013. The increase in escapement does not seem to reach the high numbers observed from 2003-2005 in most surveys except Fort Creek. Most surveys from 2003 to 2014 were conducted by the same surveyor except Ranch and Agency Creeks (2010-2012). Surveys prior to 2003 were conducted by other surveyors therefore error could be significant when comparing across temporal frame.

Future Recommendations for Spawning Survey Monitoring

Recently, all surveys have a strong correlation with either increasing or decreasing trends. This suggests that one factor, likely climate, is driving adfluvial redband trout spawner escapement. Some of the sites appear to have more variation than others with a disturbing decline in recent surveys. These sites include AUC surveys on Kirk Springs on the Williamson River and Wood River from Kimball State Park to Melhase Canal and redd survey on Ranch Creek. These three surveys should be continued. Further, Spring Creek AUC count at all sites (Picnic Area, Below Gabion, Above Gabion, and 2010 gravel) should be continued since the survey is quick, easily accessible and there is a long term data set. Redd counts should be discontinued on Spring Creek unless specifically monitoring gravel augmentation at a new site. Fort Creek redd counts should continue from Rivers of Light Bridge to headwaters at Reservation Springs. This survey has the best, long term data set as observer efficiency is likely highest due to the high visibility of redds, size of redds, and reduced superimposition on Fort Creek. These surveys could be accomplished in one 10 hour survey day if snow did not significantly increase survey length time.

Future Studies

Observer efficiency should be estimated for redd counts as described by Gallagher et al. (2007). Two methods should be utilized. One method requires counting and categorizing all redds observed on all surveys and observed efficiency is calculated on the percentage of known flagged redds observed. Observer efficiency can also be calculated by surveying the same reach multiple times on the same day by different surveyors. The high count or the count by the experienced survey is the known number of redds. Observer efficiency is also described in Gallagher and Gallagher (2005). Observer efficiency should also be calculated for AUC surveys as described by Parken et al. (2003).

Future studies should focus on determining redd life. Determining redd life can assist with determining observer efficiency and calculating effort required for redd surveys to ensure all redds are counted. Also, attempts should be made to distinguish between brown trout and redband trout redds on Spring and Fort Creeks. A good data set exists on measured and estimated size of redds. This data can be used with logistic regression (Gallagher and Gallagher 2005) to accurately identify which redd belong to which species. In Spring Creek brown trout also appear to spawn in the higher velocity areas and closer to the mouth. In Fort Creek brown trout spawning appears to be less concentrated and fewer brown trout redds occur above the dam.

Residence time as used in AUC survey calculations should be more accurately calculated. Current video camera data in the Wood River watershed can be potentially utilized to calculate residence time in Ranch, Agency, Wood River and Fort Creek. A small sample size currently exists in the Wood River watershed from pit tagged individual redband trout and brown trout.

Eventually redd data should be validated with fish counts using estimates using video, weirs or traps. This will allow for correction of redd counts and the ability to calculate number of redds per female and number of fish per redd.

AUC redd counts should also be conducted in areas where AUC redband counts are enumerated. Protocol should follow Gallagher et al 2007. For example AUC redd counts can be conducted on Crystal Creek, Wood River, Spring Creek and Kamkaun Springs and Kirk Springs on the Williamson River.

Another method that is worth exploring is measuring redd area as described in Gallagher and Gallagher (2005). Spawning in February-June is 100% redband trout therefore redd area along with observer efficiency could be utilized to calculate number of female spawner.

Future studies should focus on the distribution of adfluvial redband trout by performing reconnaissance spawning surveys on NF Sprague and tributaries Fivemile and Meryl Creek, SF Sprague and tributaries Brownsworth, Whitworth and Fishhole Creek, Sycan River and tributary Long Creek, Cherry Creek and Rock Creek. Another method to determine whether redband trout from the Williamson River or Upper Klamath Lake are spawning in aforementioned tributaries would be to collect juvenile redband trout from tributaries and expose to *C. shasta* in the lower Williamson River. For example, Trout Creek redband trout showed intermediate resistance to C. shasta suggesting some redband trout from the Upper Klamath Lake or Williamson River enter Trout Creek to spawn. Conversely, Paradise Creek (Sycan) and Deming Creek showed no resistance suggesting isolation from redband trout from the Williamson River or Upper Klamath Lake.

Table 47. Results of redband trout spawning habitat restoration funded by National Fish and Wildlife Foundation or USFWS during the year 2006-2014 (only Tecumseh Springs has had complete redd monitoring since beginning of project).

Stream	*Spawning Gravel added Cu yds*	*Spawning Habitat Created m^2* *Rough estimate*	*Number redds observed on gravel*	*Redband Trout Utilizing Gravel*
Spring Creek	465	2679	836	Yes
Williamson River	440	3077	78	Yes
Wood River	200	410	No redd count	Yes
Crooked Creek	55	64	20	Yes
Tecumseh Springs	120	117	761	Yes
Sevenmile Creek 2014	15	9		Placed this Year

Table 48. Summary of all gravel augmentation projects in the Williamson, Wood and Sevenmile watersheds Klamath County from years 1975-2014.

Stream Site	Year Placed	Years Monitored	Spawning Gravel added Cu yds	Number redds on gravel	Redband Trout Utilizing Gravel
Spring Creek above highway 97 1975-1989	1975, 1978,1979 1980,1985 1987, 1989	1972-2000, 2003, 2010-2013	400	7256	Y
Spring Creek 2010 Gravel	2010	2010-2013	140	547	Y
Spring Creek Gabion	1975,1978, 1993	1975-2000, 2003,2005, 2007-2013	540	7612	Y
Spring Creek 2011 Gravel	2011	2011-2012	100	147	Y
Spring Creek 2012 Gravel	2012	2012	150	142	Y
Spring Creek Lassett	2011	2011-2013	100	0	N
Spring Creek 2014	2014	2014	75		Y
Williamson River Tuttle (RM 16)	2013-2014	2013	195	46	Y
Williamson River Tuttle (RM 15)	2012-2013	2012-2013*	75	41	Y
Williamson River (Tuttle Cabin RM	2013	2013	15	2	Y

15.6)					
Williamson River Knapps	2012	2012-2013*	15	15	Y
Sunnybrook Creek	2010 and 2013	2010 and 2013	75	475	Y
Williamson River (Kirk Springs area)	1989 and 2011 and 2012	2010-2011	200	No separation of redd counts	Y
Williamson River (USFS Campground)	1989	2010-2013	40	No separation of redds	Y
Fort Creek (Hwy 62)	2006	2011 and 2012 and 2015 spot survey	Ca. 30	14	Y
Fort Creek (Rivers of Light Ranch)	1992	2011-2013 (1995-2013)	Ca. 30	124	Y
Wood River (Below Dixon Road)	2009	2010-2012	200	No Separation of redd count	Y
Wood River (Above Dixon Road)	?	2010-2012	?	No Separation of redd count	Y
Crooked Creek (above Highway 62)	2005	2005-2013	115	338	Y
Crooked Creek (below Highway 62)	2013	2013	40	20	Y
Crooked Creek (site 2)	2005	2005-2013	100	432	Y
Crooked Creek Site 3 Klamath Hatchery	2005 and 2012	2011-2013	75	448	Y
Tecumseh Springs	2006, 2008, 2011, 2014	2006-2013	120	761	Y
Crooked Creek Napier	2006	2013	15	16	Y
Agency Creek	2003	2012-2013	600	245	Y
Ranch Creek	1997 and	2012-2013		141	Y
Sevenmile Creek (Sevenmile Road)	2014		15		N
Crane Creek	2008		100?		Y?
Short Creek (7-mile)	2008		50?		N
Sevenmile Creek (Fish Screen)	2012		15		N
Totals			**3600**	**18822**	

Literature Cited

Al-Chokhachy, R., P. Budy, and H. Schaller. 2005. Understanding the significance of redd counts: a comparison between two methods for estimating the abundance of and monitoring bull trout populations. North American Journal of Fisheries Management 25:1505–1512.

Borgerson, L.A. 1991. Scale Analysis. Oregon Department of Fish and Wildlife. Fish Research Project F-144-R-4, Annual Progress Report, Portland.

Buettner, M., J.Hodge, J.Murphy and R. Parrish. 2009. Juvenile Fish Emigration in the Sprague, Williamson and Wood Rivers, Klamath County, Oregon 2005-2008. USFWS ERO Office, Klamath Falls, OR.

Buchanan, D.V., A.R. Hemmingsen, D.L. Bottom, R.A. French and K.P. Currens.1989. Native Trout Project. Oregon Department of Fish and Wildlife. Fish Research Project F-136-R, Annual Progress Report, Portland.

Buchanan, D.V., A.R. Hemmingsen, D.L. Bottom, P.J. Howell, R.A. French and K.P. Currens.1990. Native Trout Project. Oregon Department of Fish and Wildlife. Fish Research Project F-136-R, Annual Progress Report, Portland.

Buchanan, D.V., A.R. Hemmingsen, D.L. Bottom, P.J. Howell, R.A. French and K.P. Currens.1991. Native Trout Project. Oregon Department of Fish and Wildlife. Fish Research Project F-136-R, Annual Progress Report, Portland.

Buchanan, D.V., A.R. Hemmingsen, and K.P. Currens.1994. Native Trout Project. Oregon Department of Fish and Wildlife. Fish Research Project F-136-R, Annual Progress Report, Portland

Currens, K.P. 1997. Evolution and risk in conservation of Pacific salmon. PHD Thesis, Oregon State University, Corvallis, Oregon.

Currens, K.P., Carl B. Schreck, and Hiram W. Li. 2009.Evolutionary Ecology of Redband Trout. Transactions of the American Fisheries Society 138:797–817.

Dunham, J., B. Rieman, and K. Davis. 2001. Sources and magnitude of sampling error in redd counts for bull trout. North American Journal of Fisheries Management 21:343–352.

Essington, T.E., Sorensen, P.W. & Paron, D.G. 1998. High rate of redd superimposition by brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta) in a Minnesota stream cannot be explained by habitat availability alone. Canadian Journal of Fisheries and Aquatic Sciences 55: 2310–2316.

Fortune, J. D., A. R. Gerlach, and C. J. Hanel. 1966. A study to determine the feasibility of establishing salmon and steelhead in the Upper Klamath Basin, Oregon State Game Commission and Pacific Power and Light Company, Portland, OR.

Gallagher, S. P., and C. M. Gallagher. 2005. Discrimination of Chinook and coho salmon and

steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in northern California. North American Journal of Fisheries Management 25:284–300.

Gallagher, S., P. K. Hahn, and D.H. Johnson. 2007. Redd counts. Pages 197–234 *in* D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Gallagher,S.P., D. W. Wright, B. W. Collins & P.B. Adams. 2010 A Regional Approach for Monitoring Salmonid Status and Trends: Results from a Pilot Study in Coastal Mendocino County, California, North American Journal of Fisheries Management, 30:5, 1075-1085

Gamperl, A. K., and coauthors. 2002. Metabolism, Swimming Performance, and Tissue Biochemistry of High Desert Redband Trout (*Oncorhynchus mykiss* ssp.): Evidence for Phenotypic Differences in Physiological Function. Physiology, Morphology, and Genetics of Redband Trout. Physiological & Biochemical Zoology. Dept. of Ecology & Evolutionary Biology. University of California, Irvine, CA.

Gamperl, A. K., and coauthors. 2002. Metabolism, swimming performance, and tissue biochemistry of high desert redband trout (*Oncorhynchus mykiss* ssp.): evidence for phenotypic differences in physiological function. Physiol Biochem Zool 75(5):413-31.

Gamperl, K. 2003. Metabolic and thermal physiology of Eastern Oregon Redband Trout: Recommendations for Appropriate Numeric Temperature Criteria. Final Report.

Gerrodette, T. 1993. Program TRENDS: user's guide. Southwest Fisheries Science Center, La Jolla, California.

Gorta´zar, J., C. Alonso, D. Garcı´a de Jalo´. 2012. Brown trout redd superimposition in relation to spawning habitat availability. Ecology of Freshwater Fish

Hayes, J.W. 1987. Competition for spawning space between brown (Salmo trutta) and rainbow trout (S. gairdneri) in a lake inlet tributary, New Zealand. Canadian Journal of Fisheries and Aquatic Sciences 44: 40–47.

Holecek, D.E. and Jody P. Walters. 2007. Spawning Characteristics of Adfluvial Rainbow Trout in a North Idaho Stream: Implications for Error in Redd Counts, North American Journal of Fisheries Management, 27:3.

Howell P.J. and Paul M. Sankovich.2012. An Evaluation of Redd Counts as a Measure of Bull Trout Population Size and Trend. North American Journal of Fisheries Management, 32:1, 1-13.

Hemmingsen, A.R., R.A. French, D.V. Buchanan, D.L. Bottom, and K.Currens. 1992. Native Trout Project. Oregon Department of Fish and Wildlife. Fish Research Project F-136-R, Annual Progress Report, Portland, Oregon.

Hemmingsen, A.R., and D.V. Buchanan. 1993. Native Trout Project. Oregon Department of Fish and Wildlife. Fish Research Project F-136-R-6, Annual Progress Report, Portland, Oregon.

Isaak, D. J., and R. F. Thurow. 2006. Network-scale patterns of spatial and temporal variation in Chinook salmon redd distributions: patterns inferred from spatially continuous replicate surveys. Canadian Journal of Fisheries and Aquatic Sciences 63:285–296

Jacobs, S. E., S. J. Starcevich, and W. Tinniswood. 2007. Effects of Impoundments and Hydroelectric Facilities on the Movement and Life History of Redband Trout in the Upper Klamath River: A Summary and Synthesis of Past and Recent Studies. Pages 67-75 in R. F. Carline and C. LoSapio, editors. Sustaining wild trout in a changing world. Proceedings of the Wild Trout IX Symposium, Joseph Urbani & Associates, Bozeman, Montana Klamath River Basin. Journal of Aquatic Animal Health 18:194-202.

Jacobs, S. E., W. Gaeuman, M. A. Weeber, S. L. Gunckel, and S. J. Starcevich. 2009. Utility of a probabilistic sampling design to determine bull trout population status using redd counts in basins of the Columbia River plateau. North American Journal of Fisheries Management 29:1590–1604.

Jacobsen R., J. Nott, E. Brown, M. Weeber, M. Lewis, and E. Hughes. 2013. Assessment of Western Oregon Adult Winter Steelhead – Redd Surveys 2013. Monitoring Program Report Number OPSW-ODFW-2013-09. Oregon Department of Fish and Wildlife, Salem, Oregon.

Lewis, M., B. Sounhein, M. Weeber and E. Brown. 2014. Status of Oregon stocks of coho salmon, 2012. Monitoring Program Report Number OPSW-ODFW-2013-3, Oregon Department of Fish and Wildlife, Salem, Oregon.

Li, H. W., J. Dambacher, and D. V. Buchanan. 2007. Phenotypic Variation in Redband Trout. Pages 14-18 in R. K. Schroeder, and J. D. Hall, editors. Redband trout: resilience and challenge in a changing landscape. Oregon Chapter, American Fisheries Society, Corvallis

Messmer, R. T., and R. C. Smith. 2007. Adaptive Management for Klamath Lake Redband Trout. Pages 92-98 in R. K. Schroeder, and J. D. Hall, editors. Redband trout: resilience and challenge in a changing landscape. Oregon Chapter, American Fisheries Society, Corvallis.

Muhlfeld, C. C., M. L. Taper, D. F. Staples, and B. B. Shepard. 2006. Observer error structure in bull trout redd counts in Montana streams: implications for inference on true redd numbers. Transactions of the American Fisheries Society 135:643–654.

Murphy, J., and R. Parrish. 2008. Juvenile Fish Emigration in the Wood, Williamson, and Sprague Rivers. DRAFT. U. S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon.

Parken, C.K., R.E. Bailey, and J.R. Irvine. 2003. Incorporating uncertainty into area under the curve and peak count salmon escapement estimation. North American Journal of Fisheries Management 23: 78–90.

Pearse, D., S. Gunckel, and S. Jacobs. 2011. Population structure and genetic divergence of coastal rainbow trout and redband trout (*Oncorhynchus mykiss*) in the upper Klamath Basin. Trans. Am. Fish. Soc. 140:587-597.

Rieman, B. E.. and J. D. Mclntyre. 1996. Spatial and temporal variability in bull trout redd counts. North American Journal of Fisheries Management 16:132-141.

Rieman, B. E., and D. L. Myers. 1997. Use of redd counts to detect trends in bull trout (*Salvelinus confluentus*) populations. Conservation Biology 11:1015–1018.

Stevens, D.L.,D.P Larsen and A.R.Olsen. 2007. The Role of Sample Surveys: Why Should Practioners Consider Using Statistical Sampling Design? Pages 11-23. *in* D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Stocking, R. W., R. A. Holt, J. S. Foot, and J. L. Bartholomew. 2006. Spatial and Temporal Occurrence of the Salmonid Parasite *Ceratomyxa shasta* in the Oregon–California.

Taniguchi, Y., Miyake, Y., Saito, T., Urabe, H. & Nakano, S. 2000. Redd superimposition by introduced rainbow trout, Oncorhynchus mykiss, on native charrs in a Japanese stream. Ichthyological Research 47: 149–156.

Weeber, M.A., Giannico, G.R. & Jacobs, S.E. 2010. Effects of redd superimposition by introduced kokanee on the spawning success of native bull trout. North American Journal of Fisheries Management 30: 47–54.