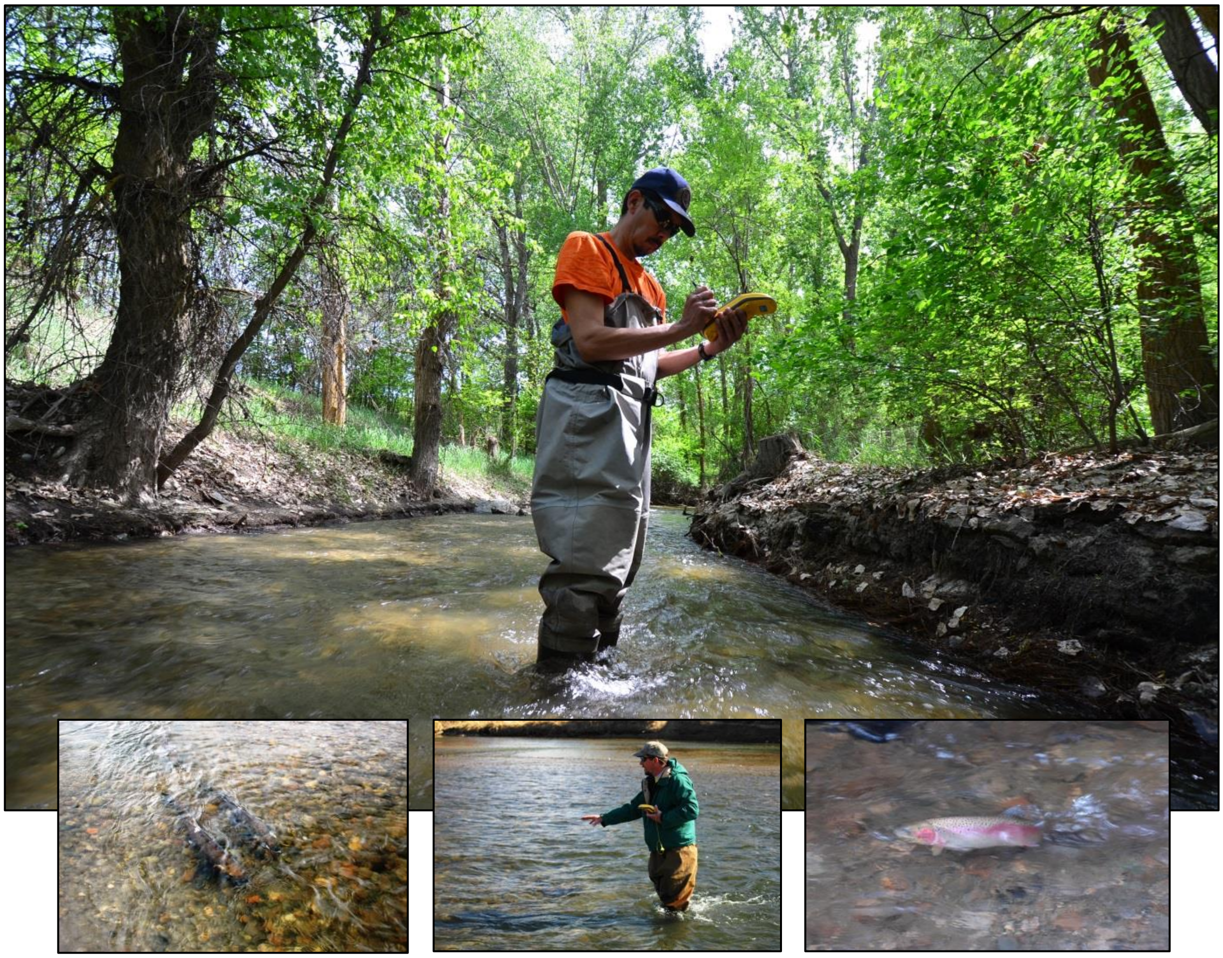
Colville Tribes, Fish & Wildlife Department

2015 Okanogan Subbasin Steelhead Spawning Abundance and Distribution



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2016

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Executive Summary

The Okanogan Basin Monitoring and Evaluation Program (OBMEP) monitored summer steelhead (*Oncorhynchus mykiss*) spawner abundance and distribution within the Okanogan River subbasin from 2005 through 2015. Monitoring was conducted through a combination of redd surveys, underwater video counts, and Passive Integrated Transponder (PIT) tag detections. Over the past 11 years of monitoring, the estimated average total number of steelhead spawners in the Okanogan subbasin was 1,785. The average natural origin spawner abundance (NOSA) was 322. Spawning estimates were also compared with recovery goals, as outlined by the Interior Columbia Basin Technical Recovery Team (ICBTRT). The Upper Columbia Spring Chinook and Steelhead Recovery Plan states that 500 naturally produced Steelhead adults would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin; if the Canadian portion of the subbasin was included, minimum abundance recovery criteria would be 1,000 naturally produced adults (UCSRB 2007).

Results from adult steelhead enumeration efforts in the Okanogan subbasin indicate that the number of spawning steelhead in the Okanogan River, both hatchery and naturally produced, has been increasing since data collection began in 2005. The slope of the trend line from 2005 to 2015 abundance estimates suggests that the number of natural origin spawners increased at an average rate of 33 fish per year. Much of these increases may have been due to a large spawning cohort in 2010. The proportion of hatchery origin spawners (pHOS) from 2005 through 2013 averaged 0.85, but the pHOS decreased to an average of 0.65 in 2014 and 2015. Spawning occurred throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable water velocities and spawning substrates. Steelhead spawning has been documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. It is likely that distribution of spawning may have been influenced by stocking location as juvenile hatchery steelhead have been released in Omak Creek, Salmon Creek, and the Similkameen River.

Steelhead redd surveys can provide a reasonable depiction of spawning distribution and an estimate of escapement on years when spring runoff occurs post-spawning. Defining the physical location of redds informs managers about which, and to what extent, habitats are being used for spawning and allow for tracking of spatial status and trends through time. However, conducting redd surveys on years with early runoff is not always effective due to poor water clarity. Since OBMEP began collecting steelhead spawning data in 2005, the importance of not relying solely on redd surveys for abundance estimates has become evident. Implementation of Upper Columbia Basin-wide PIT tag interrogation systems (Project # 2010-034-00), coupled with the representative marking of returning adults at Priest Rapids Dam, allowed managers an additional means to estimate abundance on years with poor water visibility, to validate redd survey efficiency, and describe spatial distribution and upstream extent of spawning, where previously unknown. The Fish and Wildlife Program should consider continuing these efforts to allow managers to more accurately describe the spatial extent of spawning in tributaries, to monitor effectiveness of barrier removal projects, and better define escapement estimates.

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1.0 Introduction

Within the Upper Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous habitat is found in the Okanogan River. Summer steelhead (*Oncorhynchus mykiss*) are listed as threatened in the Upper Columbia Evolutionarily Significant Unit (ESU) under the Endangered Species Act (ESA) (NMFS 2009). To recover this ESU requires that all four populations (Wenatchee, Entitat, Methow, and Okanogan) meet minimum adult abundance thresholds, have positive population growth rates, and each population must be widely distributed within respective basins (UCSRB 2007). Within the Okanogan River subbasin, the Okanogan Basin Monitoring and Evaluation Program (OBMEP) monitors adult abundance attributes. OBMEP developed protocols derived from the Upper Columbia Strategy (Hillman 2004) that called for a complete census of all spawning. Preliminary methodologies for implementing redd surveys were developed in 2005 and these methods were later revised in 2007 (Arterburn et al. 2007). In addition to redd surveys, adult weir traps, Passive Integrated Transponder (PIT) tag arrays, and underwater video counting were combined to improve escapement estimates and coordinate with other on-going data collection efforts. In cooperation with the Washington Department of Fish and Wildlife (WDFW), OBMEP expanded the use of PIT tag arrays to enhance monitoring adult summer steelhead use of small tributaries to the Okanogan River.

This document builds upon knowledge and information gained from preceding years' surveys. A literature review of historic spawning information related to the Okanogan River subbasin can be found in Arterburn et al. 2005. Previous years' data and reports can be accessed at: www.colvilletribes.com/obmep.php.

2.0 Methods

OBMEP - Adult Abundance - Redd Surveys (ID:192)
https://www.monitoringmethods.org/Protocol/Details/192
OBMEP - Adult Abundance - Adult Weir and Video Array (ID:6)
https://www.monitoringmethods.org/Protocol/Details/6
Estimate the abundance and origin of Upper Columbia steelhead (2010-034-00) v1.0 (ID:235)
https://www.monitoringmethods.org/Protocol/Details/235

The Okanogan River flows from the northern headwaters near Vernon, BC to the confluence with the Columbia River near Brewster, WA (Figure 1). Counts of summer steelhead spawning downstream of anadromous fish migration barriers in the mainstem and all accessible tributaries of the Okanogan and Similkameen River drainages were conducted within the United States (Arterburn et al. 2007, Walsh and Long 2006). Adult weir traps, PIT tag arrays, and underwater video counts were used at locations where habitat was extensive or difficult for surveys to be performed on foot.

Summer steelhead were enumerated in all remaining spawning habitats following the OBMEP redd survey protocol. The area of the Okanogan River downstream from Chiliwist Creek has very low gradient and is inundated by the Columbia River (Wells Pool/Lake Pateros). Consequently, this lower reach (~23 km) of the Okanogan River was excluded from surveys because it lacks appropriate velocity and substrate needed for summer steelhead to spawn. Mainstem and tributary redd survey reaches are listed in Table 1. The Okanogan River was divided into seven survey reaches and the Similkameen River was surveyed as two reaches. Survey reaches were determined by access points along the river and directly related to the EDT reach layer, used in habitat monitoring. Discharge data, air and water temperature, and local knowledge of fish movements collected from previous years were used to determine when to begin surveys on the mainstem. Mainstem surveys were conducted from rafts and on foot in a downstream progression. All island sections or other mainstem areas that could not be floated due to limited access and/or obstacles (e.g. wood debris, braided channels, and diversions) were surveyed on foot. Raft surveys were conducted by a minimum of two people using 10' catarafts. Small tributaries were surveyed on foot, walking in an upstream direction, once per week during the steelhead spawning period.

Geographic position of redds were collected with a Trimble GeoXT™ GPS unit and downloaded into GPS Pathfinder® after each survey. The GIS data were reviewed and differentially corrected. To avoid recounting, redds were marked by flagging tied to bushes or trees adjacent to the area where they were observed. Individual flags were marked with the survey date, direction and distance from the redd(s), consecutive flag number, total number of redds represented by the flag, and surveyor initials. Incomplete redds or test pits were not flagged or counted.

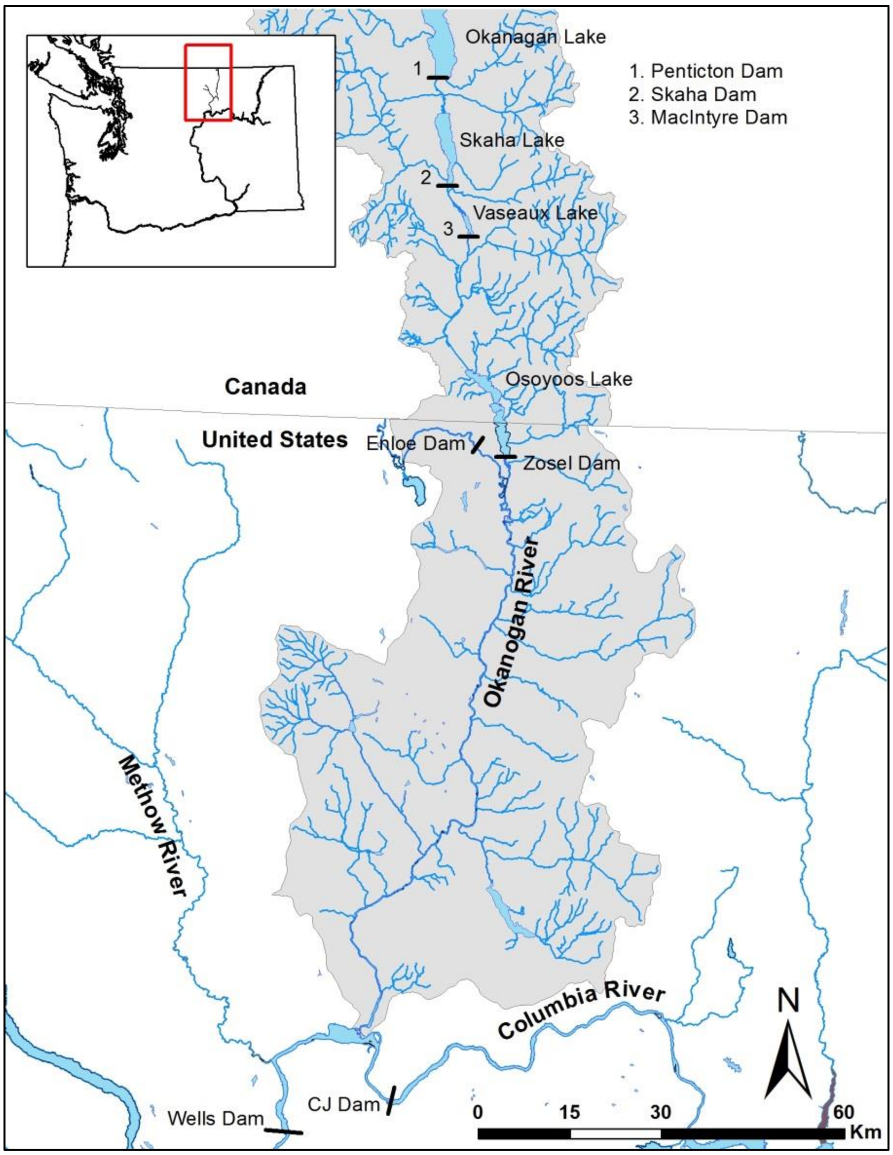

Figure 1. Study area, the Okanogan River subbasin in north-central Washington State and southern British Columbia.

Table 1. Okanogan subbasin steelhead redd survey reaches.

Redd Survey Reach	Location and Description	Reach Length (km)
Okanogan River 1	Okanogan River at Loup Loup Creek (26.7) to Salmon Creek (41.4)	14.7
Okanogan River 2	Okanogan River at Salmon Creek (41.4) to the office (52.3)	10.9
Okanogan River 3	Okanogan River at the office (52.3) to Riverside (66.1)	13.8
Okanogan River 4	Okanogan River at Riverside (66.1) to Janis Bridge (84.6)	18.5
Okanogan River 5	Okanogan River at Janis Bridge (84.6) to Tonasket Park (91.4)	6.8
Okanogan River 6	Ok. R. at Horseshoe Lake (112.4) to confluence with Similk. R. (119.5)	7.1
Okanogan River 7	Okanogan River at Similk. R. confluence (119.5) to Zosel Dam (127.0)	7.5
Similkameen River 1	Similkameen/Okanogan Confluence (0) to sewer plant (6.6)	6.6
Similkameen River 2	Similkameen from sewer plant (6.6) Enloe Dam (14.6)	8.0
Loup Loup Cr	Loup Loup Creek/Ok. R. confluence to Loup Loup Creek diversion (2.3)	2.3
Salmon Cr	Salmon Creek/Okanogan River confluence (0) to OID diversion (7.2)	7.2
Omak Cr	Omak Creek/Ok. R. Confluence (0) to Omak Creek trap site (1.5)	1.5
Wanacut Cr	Wanacut Creek/Okanogan River confluence (0) to the falls (2.5)	2.5
Johnson Cr	Johnson Cr./Ok. R. conf. (0) to PIT tag array above Hwy 97 (0.5)	0.5
Tunk Cr	Tunk Creek/Okanogan River confluence (0) to the falls (1)	1.0
Aeneas Cr	Aeneas Creek/Okanogan River confluence (0) to the barrier (0.4)	0.4
Bonaparte Cr	Bonaparte Creek/Ok. River confluence (0) to the falls (1.6)	1.6
Antoine Cr	Antoine Creek/Okanogan River confluence (0) to video weir (1.3)	1.3
Wildhorse Sp Cr	Wildhorse Spring Creek/Okanogan River confluence to barrier (1.1)	1.1
Tonasket Cr	Tonasket Creek/Okanogan River confluence (0) to the falls (3.5)	3.5
Ninemile Cr	Ninemile Creek from Lake Osoyoos (0) to PIT tag array (0.7)	0.7
Foster Cr	Foster Creek/Columbia River confluence (0) to barrier (1.7)	1.7

2.1 Sex Ratio and Number of Fish Per Redd

OBMEP employed the method currently used by Washington Department of Fish and Wildlife in the Upper Columbia Basin to extrapolate escapement estimates from redd counts using the sex ratio of fish collected randomly over the run at Wells Dam. A sample of 423 summer steelhead, including 131 males (101 hatchery and 30 natural origin) and 293 females (207 hatchery and 86 natural origin), were sexed at Wells Dam during the 2014 upstream migration by WDFW personnel (Charles Frady, WDFW, pers. comm.). Adjusted proportionally for the run, a sex ratio of 0.447 males per female or 1.447 fish per redd (FPR) was used to expand redd counts on the mainstem Okanogan River into steelhead spawning estimates. All calculations using sex ratio multipliers assume that each female will produce only one redd.

2.2 PIT Tag Expansion Estimates

Permanent and seasonally operated PIT tag arrays were operated near the mouth of all tributaries to the Okanogan River known to contain steelhead spawning, throughout the spring of 2015. The WDFW operates as the lead investigator on project number 2010-034-00 and the study is conducted in conjunction with the CCT. The CCT operates and maintains detection sites in the Okanogan subbasin, along with data collection and management of those datasets. Any expanded PIT tag estimates presented in this document should be considered preliminary estimates as data analyses are currently in progress for the entire Upper Columbia for multiple years of the project. Final analyses of these data will be reported under project number 2010-034-00.

Population estimates derived from PIT tag detections were calculated following Murdoch et al. 2011. In the 2014 up-river migration year, a random representative sample of steelhead were captured at Priest Rapids Dam, two to three days per week over the course of the run, from July through November. A proportion of fish, approximately 17.4%, were tagged and released above Priest Rapids Dam (Ben Truscott, WDFW, pers. comm.). The mark-rate was used to expand the number of detections into escapement estimates for tributaries with PIT tag arrays. For example, if three hatchery and two natural origin steelhead were detected at a given creek in the Okanogan subbasin, the escapement estimate would be 17 hatchery steelhead (17=3/0.174) and 12 natural origin steelhead (12=2/0.174), calculated from the mark-rate at Priest Rapids Dam. This method assumes that marked fish are representative of unmarked fish. Based on the relatively few numbers of detections at many locations, particularly at smaller tributaries, escapement estimate confidence bounds derived from PIT tag detections may be quite wide and the estimate should be considered general. In addition to fish tagged at Priest Rapids, steelhead may have also received PIT tags at other locations (such as out-migrating juveniles, adults returning to Bonneville Dam, Wells Dam, among others); however, it is unknown how representative of the run those fish were. Therefore, any extrapolations from PIT tag detections to an escapement estimate were derived only from the Priest Rapids release group. Detections of steelhead tagged at other locations may be mentioned anecdotally in this report.

2.3 Percent-Wild

Mainstem percent-wild.

A number of steelhead from the PRD mark-release group were detected only at OKL (lower Okanogan PIT array near Malott, WA). After factoring for OKL array efficiency, based on detections from upstream locations, it is likely that these fish may represent a mainstem-spawning component of the population. The percent-wild of these fish was approximately 20.1% (86 total tags: 68 hatchery, 18 wild). This percent-wild value was applied to all mainstem Okanogan River reaches to estimate the number of natural origin steelhead that spawned in mainstem.

Tributary percent-wild.

A unique value for each subwatershed was calculated for the percent of natural origin steelhead spawning in tributaries to the Okanogan River. The estimated number of wild steelhead spawning in each tributary, as determined by the PRD mark-release group, was divided by the total number of steelhead spawning in that system. Each unique percent-wild number was then applied to the number of steelhead calculated from redd surveys in individual tributaries.

3.0 Results

In 2015, it was estimated that a total of 1,461 summer steelhead (1,009 hatchery and 452 natural origin) spawned in the Okanogan subbasin. A summary of the estimated number of adult steelhead spawners, distributed by mainstem survey reach and individual tributaries, are presented in Table 2. Detailed results for unique spawning reaches and tributaries are further detailed in sections 3.1 to 3.3 of this document. Over the past 11 years (2005-2015), it was estimated that an average of 1,785 steelhead spawned in the Okanogan subbasin (Table 3). The 11 year average for natural origin steelhead was estimated to be 322.

Table 2. Estimated number of total and natural origin steelhead spawning for each sub-watershed or assessment unit in 2015.

Distribution of Steelhead Spawning in the Okanogan Subbasin, 2015

Category	Description/location	Estimated Total Spawner Abundance	Estimated Natural Origin Spawner Abundance
WA Mainstem	Okanogan River 1	7	1
WA Mainstem	Okanogan River 2	26	5
WA Mainstem	Okanogan River 3	6	1
WA Mainstem	Okanogan River 4	23	5
WA Mainstem	Okanogan River 5	36	7
WA Mainstem	Okanogan River 6	10	2
WA Mainstem	Okanogan River 7	233	47
WA Mainstem	Similkameen River 1	79	16
WA Mainstem	Similkameen River 2	59	12
WA Tributary	Loup Loup Creek	12	6
WA Tributary	Salmon Creek	98	29
WA Tributary	Omak Creek	551	172
WA Tributary	Wanacut Creek	0	0
WA Tributary	Johnson Creek	41	12
WA Tributary	Tunk Creek	41	8
WA Tributary	Aeneas Creek	0	0
WA Tributary	Bonaparte Creek	138	63
WA Tributary	Antoine Creek	8	0
WA Tributary	Wild Horse Spring Creek	0	0
WA Tributary	Tonasket Creek	0	0
WA Tributary	Ninemile Creek	2	1
Subtotal	**Washington State Mainstem**	**479**	**96**
Subtotal	**Washington State Tributaries**	**891**	**291**
Subtotal	**British Columbia**	**91**	**65**
Grand total		**1,461**	**452**

*Estimates based on a combination of expanded redd counts, PIT tag detections, and underwater video observations.

Table 3. Estimated summer steelhead spawner abundance in the Okanogan subbasin, 2005-2015.

Year	Hatchery Origin	Natural Origin	Total
2005	1,080	146	1,226
2006	702	197	899
2007	1,116	152	1,268
2008	1,161	225	1,386
2009	1,921	212	2,133
2010	2,768	728	3,496
2011	1,341	333	1,674
2012	2,475	327	2,802
2013	1,687	250	1,937
2014	838	518	1,356
2015	1,009	452	1,461
Average	1,463	322	1,785

3.1 Steelhead Spawning Estimates: Okanogan and Similkameen River Mainstem

Due to an early onset of runoff in the Similkameen River which began in early February (Figure 2), redd surveys were largely unsuccessful at documenting the spawning activity of steelhead in the Okanogan River mainstem reaches in the spring of 2015 due to high flows and turbid water conditions. Flows remained high through June, when spawning had long since concluded and steelhead redds were indistinguishable. However, three complete surveys were conducted in Okanogan River Reach 7 which is located above the Similkameen confluence. During previous years surveys, approximately 49% of the total mainstem spawning had been documented in in that section of river.

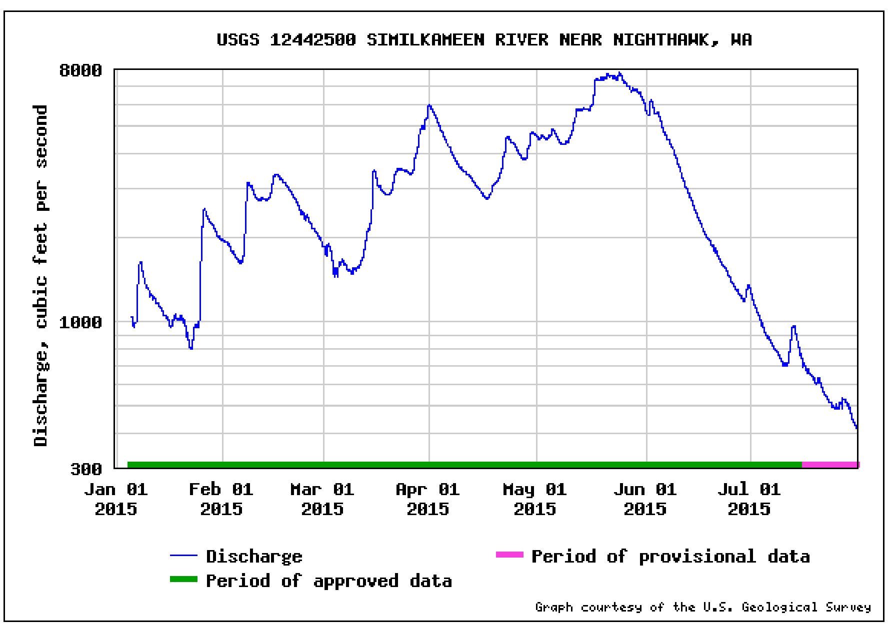

Figure 2. Similkameen River discharge from January through July, 2015 (USGS).

Although redd surveys were unable to capture the complete spawning activity of summer steelhead in all mainstem reaches of the Okanogan River, an estimate of mainstem spawning for 2015 was calculated as follows: assuming that the proportion of spawning mainstem reaches in 2015 remained similar to previous years' surveys, spawner estimates for 2015 were calculated by using previous years' redd distributions to proportion the complete redd counts documented in 2015 in Okanogan Reach 7 (Table 4 and 5). A total of 479 summer steelhead (383 hatchery and 96 natural origin) were estimated to have spawned in the mainstem Okanogan and Similkameen Rivers in 2015.

Table 4. Redd survey steelhead spawning estimates for mainstem reaches, 2015.

Redd Survey Reach	A. GPS'd Steelhead Redds	B. Total Steelhead Estimate [a] (B=A*1.447)	C. Wild Steelhead Estimate [b] (C=B*0.201)	D. Hatchery Steelhead Estimate (D=B-C)	Complete Redd Counts?
Okanogan River 1	n/a	n/a	n/a	n/a	No
Okanogan River 2	n/a	n/a	n/a	n/a	No
Okanogan River 3	n/a	n/a	n/a	n/a	No
Okanogan River 4	n/a	n/a	n/a	n/a	No
Okanogan River 5	n/a	n/a	n/a	n/a	No
Okanogan River 6	n/a	n/a	n/a	n/a	No
Okanogan River 7	161	233	47	186	Yes
Similkameen River 1	n/a	n/a	n/a	n/a	No
Similkameen River 2	n/a	n/a	n/a	n/a	No

[a] Observed redds were multiplied by the fish per redd value (1.447) for a total steelhead estimate.
[b] The total steelhead estimate was multiplied by the proportion of naturally produced steelhead from the PRD mark-release group detected only on site OKL (0.201) to calculate a mainstem natural origin steelhead estimate.

Table 5. Modeled estimate of mainstem steelhead spawning, 2015.

Mainstem Survey Reach	E. Avg. Proportion of Mainstem Spawning by Reach (2005-2011)	F. Total Estimate [a] (F=E*479)	G. Wild Steelhead [b] (G=F*0.201)	H. Hatchery Steelhead (H=F-G)
Okanogan River 1	0.015	7	1	6
Okanogan River 2	0.055	26	5	21
Okanogan River 3	0.012	6	1	5
Okanogan River 4	0.047	23	5	18
Okanogan River 5	0.076	36	7	29
Okanogan River 6	0.020	10	2	8
Okanogan River 7	0.486	233[c]	47	186
Similkameen River 1	0.165	79	16	63
Similkameen River 2	0.124	59	12	47
Mainstem Total	1.000	479[a]	96	383

[a] The Okanogan mainstem spawning estimate of 479 (479=233[b]/0.486) was multiplied by the average proportion from previous spawning years in each mainstem reach.
[b] The total estimate was multiplied by the proportion of naturally produced steelhead from the PRD mark-release group (0.201) to calculate a mainstem wild steelhead estimate.
[c] Number of steelhead documented in Okanogan Reach 7, from Table 4.

3.2 Steelhead Spawning Estimates: Tributaries to the Okanogan River

Redd surveys conducted on tributaries to the Okanogan River were more successful at documenting locations of spawning steelhead when compared to the mainstem. Redd surveys occurred weekly from March 18 through May 28, 2015. Redd survey efforts on tributaries to the Okanogan River were rarely limited by high or turbid water events from snow melt and precipitation and most tributaries were successfully surveyed weekly across the entire spawning period. The upstream extent of each survey was limited by either a natural fish passage barrier, access to private land, or extensive reach length that would preclude walking surveys. Redd surveys documented 247 summer steelhead redds in tributaries to the Okanogan River. These redds were expanded to an estimated number of steelhead spawners (Table 6). A number of additional steelhead were documented passing beyond areas surveyed for redds by weir traps and underwater video. Detailed results are presented in the following sections for individual subwatersheds, and outline spatial and temporal distribution of redds, video observations, and weir counts. The number of redds documented and PIT tag detections by survey week in tributaries to the Okanogan River are shown in Figure 3.

In-stream PIT tag interrogation sites were installed and successfully operated on 12 tributaries to the Okanogan River. The number of tags detected at discrete locations and the expanded summer steelhead spawning estimates are presented in Table 7. In the following sections, a summary of spawning estimates for steelhead in tributaries to the Okanogan River are presented, detailing both redd survey and PIT tag expansion methods.

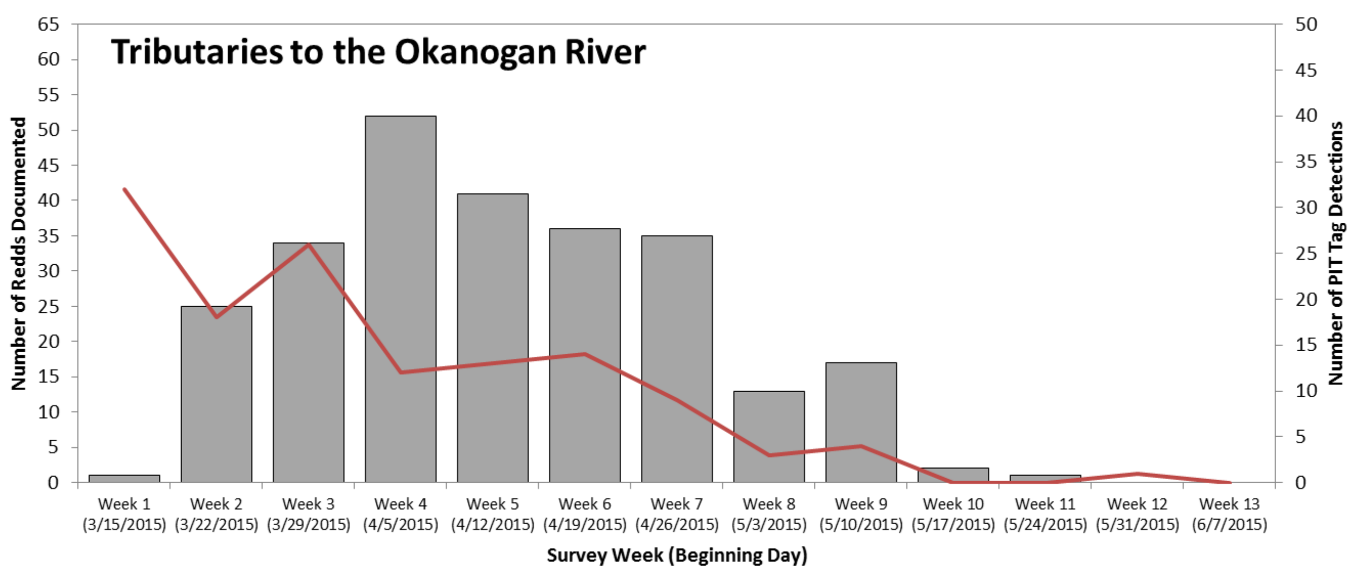

Figure 3. Number of steelhead redds (bar) documented by week in tributaries to the Okanogan River compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on interrogation sites and grouped by week.

Table 6. Redd survey and steelhead spawning estimates for tributary survey reaches, 2015.

Redd Survey Reach	I. GPS'd Steelhead Redds	J. Total Steelhead Estimate [a] (J=I*1.447)	K. Wild Steelhead Estimate [b] (K=J*%wild)	L. Hatchery Steelhead Estimate (L=J-K)	Complete Redd Counts?
Loup Loup Cr	3	4	2	2	Yes
Salmon Cr, below PIT tag array	0	0	0	0	Yes
Salmon Cr, above array/below diversion	38	55	16	39	Yes
Omak Cr, below weir trap	108	156	49	107	Yes
Wanacut Cr	0	0	0	0	Yes
Johnson Cr, below gabion weir	13	19	5	14	Yes
Tunk Cr	28	41	8	33	Yes
Aeneas Cr	0	0	0	0	Yes
Bonaparte Cr	55	80	37	43	Yes
Antoine Cr, below PIT tag array	1	2	0	2	Yes
Wildhorse Spring Cr	0	0	0	0	Yes
Tonasket Cr	0	0	0	0	Yes
Ninemile Cr, below PIT tag array	1	2	1	1	Yes
Tributary Total	247	359	118	241	

[a] Observed redds were multiplied by the WDFW fish per redd value (1.447) for a total steelhead estimate.
[b] The total estimate was multiplied by the proportion of naturally produced steelhead from the PRD mark-release group (Table 7) to calculate a tributary wild steelhead estimate.
* Totals do not include weir or underwater video counts.

Table 7. PIT tag expansion estimates at tributary detection sites in the Okanogan subbasin, 2015.

Creek (Interrogation Site)	M. PRD Wild PIT Tags	N. PRD Hatchery PIT Tags	O. Expanded Wild [a] (O=M/0.174)	P. Expanded Hatchery [a] (P=N/0.174)	Q. Expanded Total (Q=M+N)
Loup Loup Cr (LLC)	1	1	6	6	12
Salmon Cr (SA1)	5	12	29	69	98
Omak Cr (OMK)	30	66	172	379	551
Wanacut Cr (WAN)	0	0	0	0	0
Johnson Cr (JOH)	2	5	12	29	41
Tunk Cr (TNK)	1	4	6	23	29
Aeneas Cr (AEN)	0	0	0	0	0
Bonaparte Cr (BPC)	11	13	63	75	138
Antoine Cr (ANT)	0	1	0	6	6
Wildhorse Spring Cr (WHS)	0	0	0	0	0
Tonasket Cr (TON)	0	0	0	0	0
Ninemile Cr (NMC)	0	0	0	0	0
Total	50	102	288	587	875

[a] PIT tag detections in tributaries were divided by the proportion steelhead observed in the PRD mark group (0.174).

3.2.1 Loup Loup Creek

Conditions in Loup Loup Creek remained favorable to conduct weekly redd surveys throughout the spring of 2015. Walking surveys were conducted weekly from March 18 through May 28 and a total of 3 redds were documented (Figure 4 and 5). Two large sections of the creek were not surveyed due to lack of landowner permissions. An estimated spawner abundance from redd surveys was calculated by expanding the observed redds by the FPR value of 1.447, which rendered a total spawning estimate of 4 steelhead in Loup Loup Creek.

One natural origin and one hatchery PIT tagged steelhead from the PRD mark-release group were detected in Loup Loup Creek (site LLC) in the spring of 2015. These were expanded to 6 wild and 6 hatchery steelhead, for a total spawning estimate of 12 steelhead. The number of redds documented by survey week were compared to weekly unique PIT tag detections and are presented in Figure 4. The redd survey method derived a lower spawning estimate, likely due to redds being located in sections of the creek that were not surveyed (Figure 5).

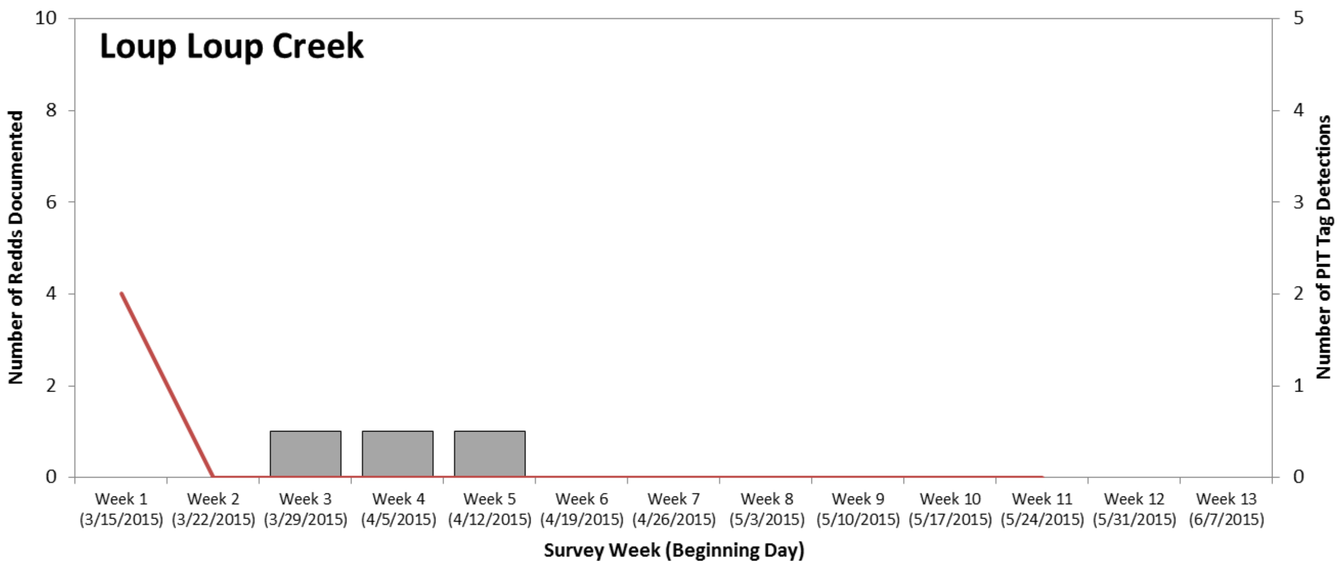

Figure 4. Number of steelhead redds documented by week in Loup Loup Creek (bar) compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on the interrogation site and grouped by week.

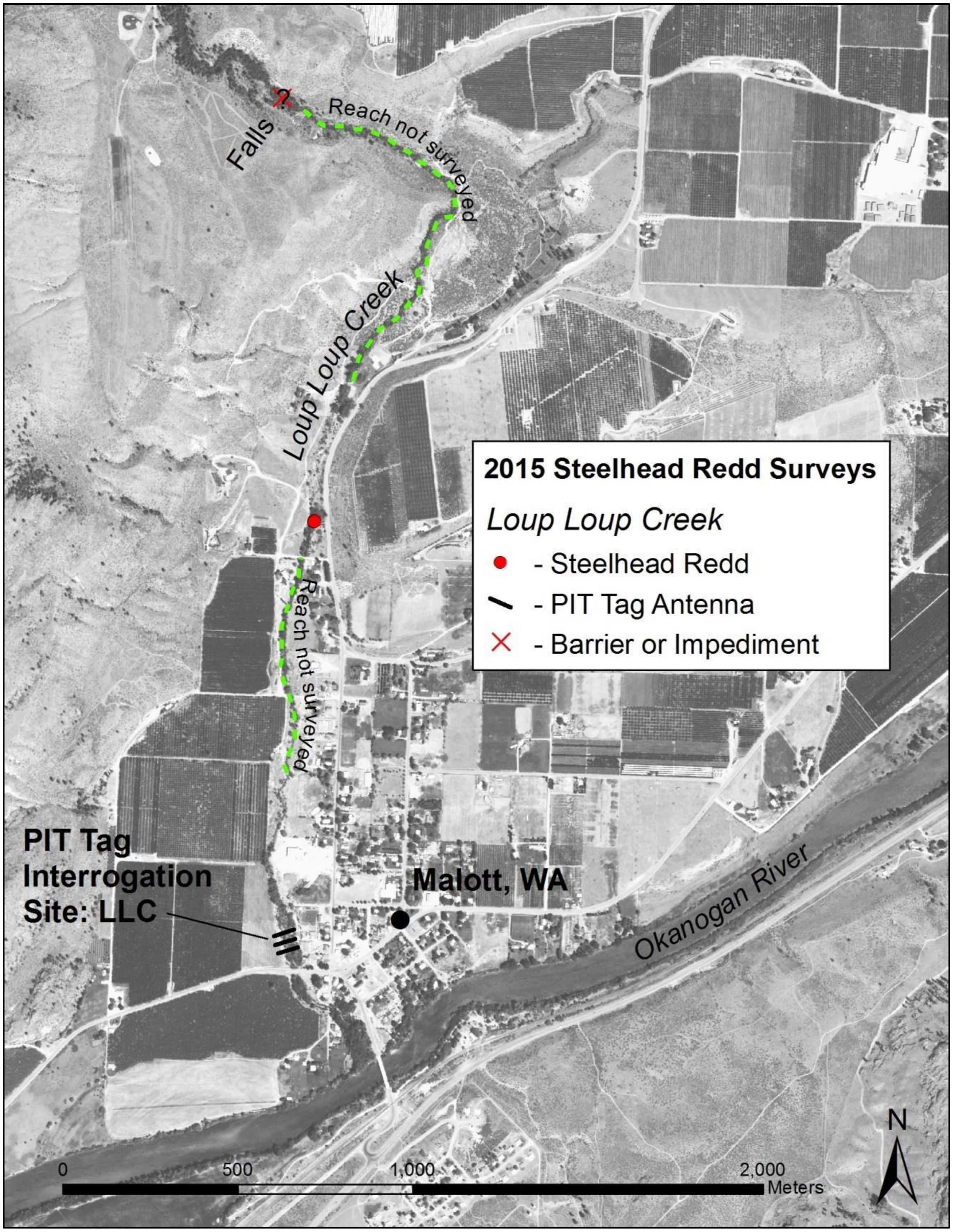

Figure 5. Spatial distribution of summer steelhead redds documented in Loup Loup Creek in 2015.

3.2.2 Salmon Creek

Salmon Creek was divided into three reaches, based on survey access points and an irrigation diversion site: (1) from the confluence with the Okanogan River to the PIT tag array located approximately 2.9 km upstream, (2) from the PIT tag array to the Okanogan Irrigation District (OID) diversion, and (3) from the OID diversion to Conconully dam. Redd surveys were conducted weekly from the confluence to the OID diversion and an underwater video system was operated at the OID diversion to monitor passage past that point.

Zero redds were found from the confluence to the PIT tag array and 38 redds were documented between the PIT tag array and the diversion (Figure 6 and 7). The redds were expanded to an estimated 55 steelhead spawning below the OID diversion. Additionally, 70 adult steelhead were counted passing the OID diversion (26 adipose present and 44 hatchery origin, or 37.1% wild). The combined redd survey and video count provided a total estimate of 124 steelhead (46 wild, 78 hatchery) spawning in Salmon Creek in 2015.

Five natural and 12 hatchery origin PIT tagged steelhead from the PRD mark-release group were detected at PIT tag site SA1 during the spring of 2015. This led to an estimated 29 natural and 69 hatchery origin steelhead passing that point, for a combined estimate of 98 steelhead. Due a number of potential complications viewing fish passage at the diversion (such as fish jumping over the spillways or double counting), the PRD expansion method was selected as the final estimate.

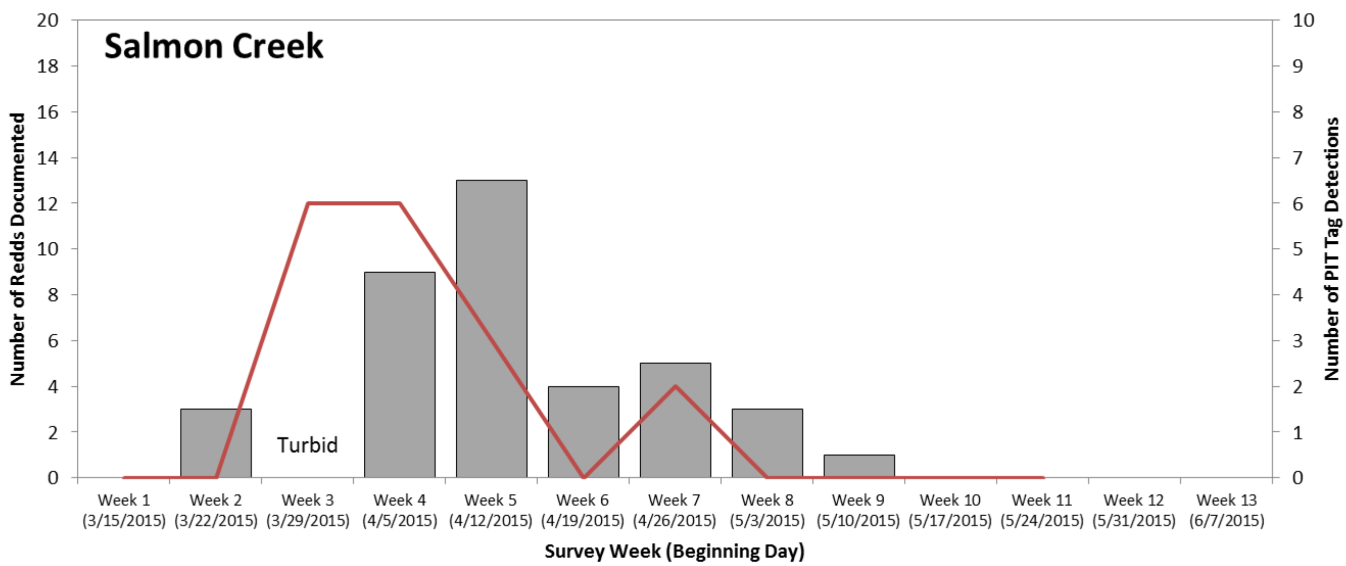

Figure 6. Number of steelhead redds documented by week in Salmon Creek (bar) compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on the interrogation site and grouped by week.

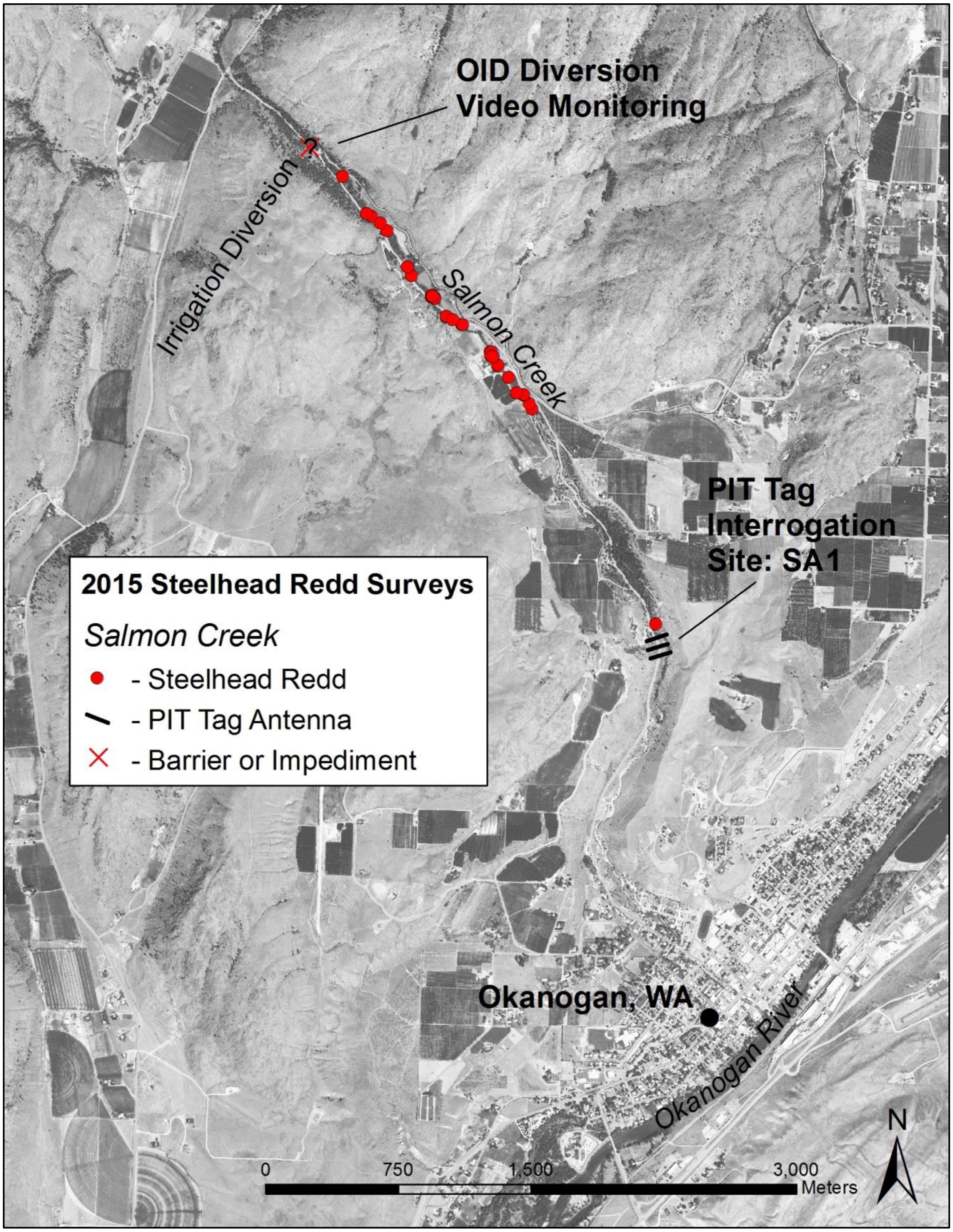

Figure 7. Spatial distribution of summer steelhead redds documented in Salmon Creek in 2015.

3.2.3 Omak Creek

Steelhead surveys on Omak Creek consisted of weekly redd surveys from the confluence of the Okanogan River up to an adult weir trap, located approximately 1.5 km upstream. A total of 108 redds were documented below the adult weir trap in 2015, and when expanded by 1.447 FPR, an estimated 156 steelhead spawned between the mouth and the weir. Additionally, a single peak spawning redd survey (4/21/2015) was conducted between the weir and Mission Falls to characterize spatial distribution of spawning in that reach. The positions of 92 redds were recorded during that survey (Figure 9).

A permanent PIT tag array, site OMK, was operational throughout the spring of 2015 near the mouth of Omak Creek. Thirty natural origin and 66 hatchery origin steelhead from the PRD mark-release group were detected at this location. The expanded Omak Creek estimate from PRD PIT tag detections rendered 172 natural origin and 379 hatchery origin steelhead, for a total of 551 steelhead.

Two additional temporary antennas were installed above and below Mission Falls in 2015 to examine potential passage after habitat modifications in previous years. All steelhead captured and placed upstream of the weir were implanted with a PIT tag, if not previously tagged. Fifty-nine adult steelhead (43 F and 16 M) were transported from the weir trap to locations above Mission Falls in 2015, primarily due to the low water year and potential passage issues at that site (Rhonda Dasher, pers. comm.). Due to an unknown number of steelhead passing the weir uncaptured, steelhead being transported above Mission Falls from the weir, and superimposition of redds downstream of the weir, it is likely that the PIT tag method better captured the total spawning estimate for Omak Creek in 2015.

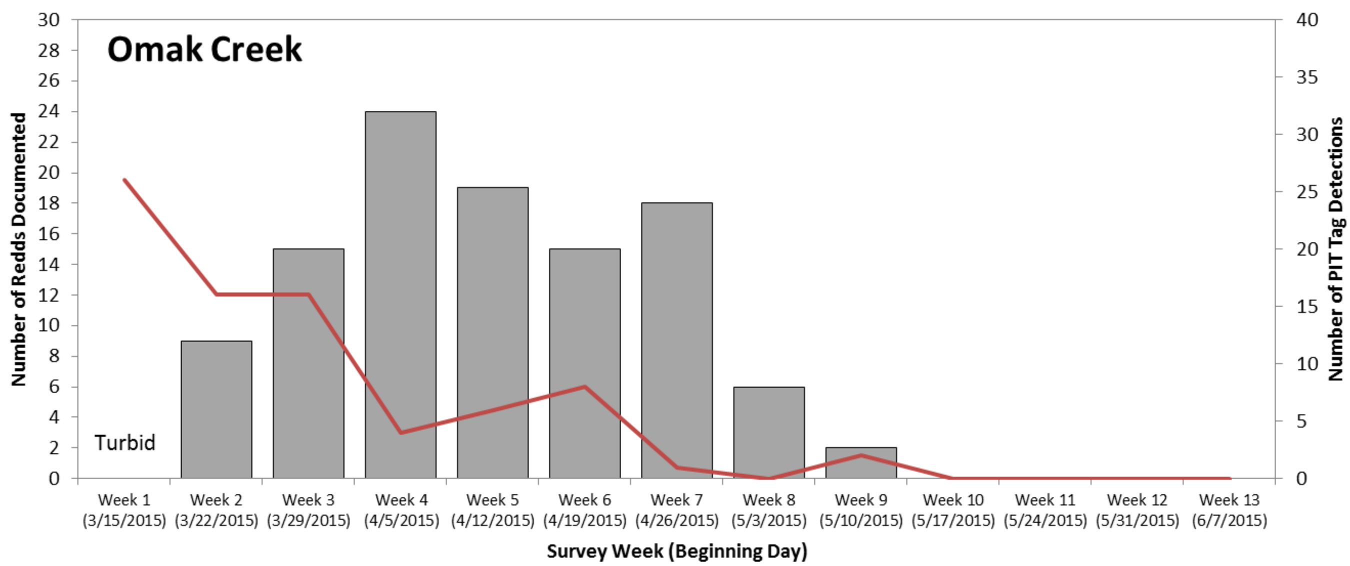

Figure 8. Number of steelhead redds documented by week in Omak Creek below the weir trap (bar) compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on the interrogation site and grouped by week.

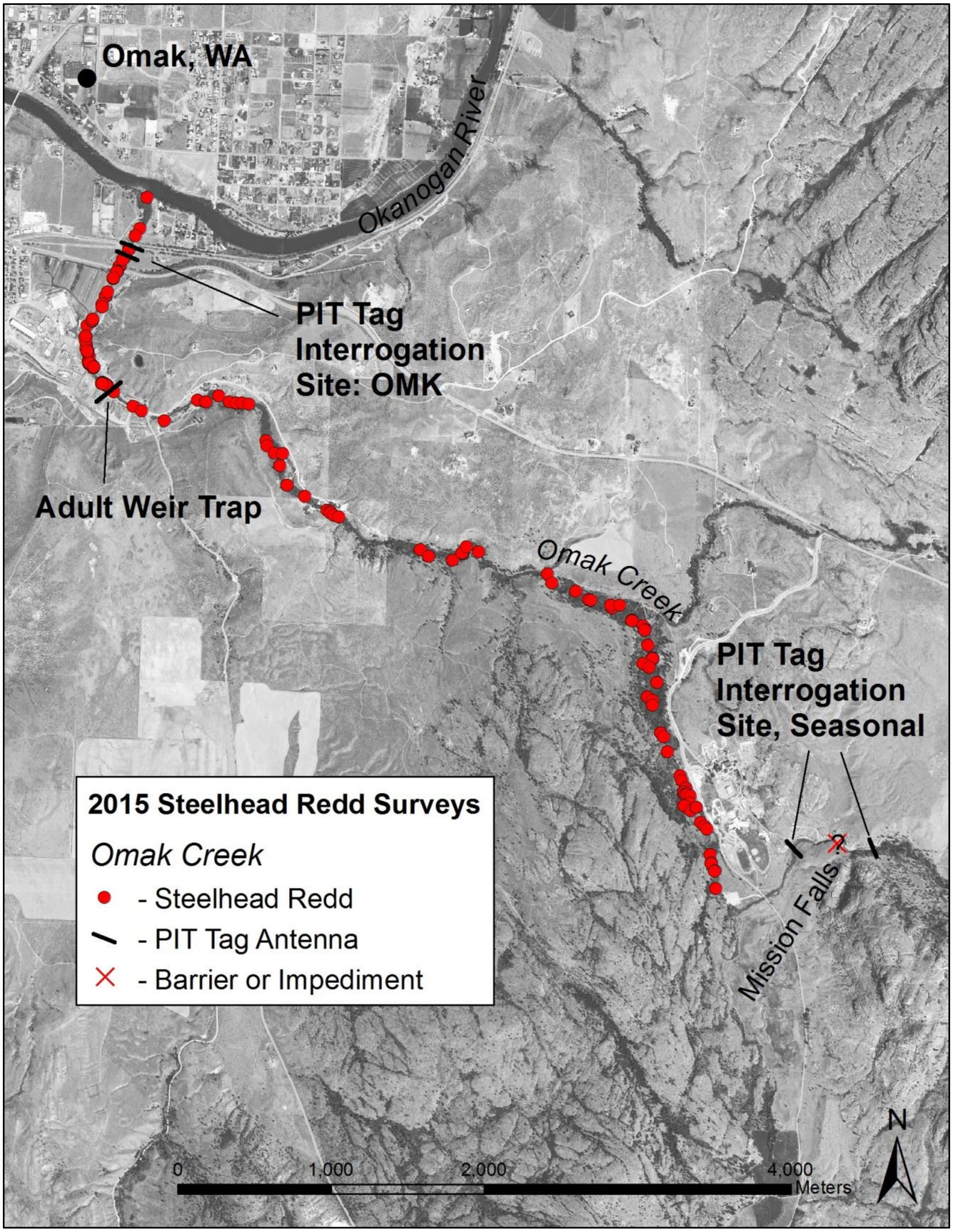

Figure 9. Spatial distribution of summer steelhead redds documented in Omak Creek in 2015.

3.2.4 Wanacut Creek

Due to the low snow pack in the lower elevations of the Okanogan subbasin, including Omak Mountain, Wanacut Creek only flowed intermittently during the spring of 2015. The creek was mostly dry by the end of April. No redds were documented when water was present in the creek and zero PIT tagged steelhead were detected at the interrogation site near the mouth of the creek. It is likely that no steelhead utilized Wanacut Creek for spawning in 2015 due to extremely low water levels.

3.2.5 Johnson Creek

Redd surveys occurred weekly in Johnson Creek throughout the spring of 2015 due to clear water conditions and stable water flows. A total of 13 redds were documented between the mouth and the highway culvert representing a spawner abundance estimate of 19 total steelhead (Figure 10 and 11).

Seven PIT tags from the PRD mark-release group near the mouth of Johnson Creek, 2 of natural origin and 5 of hatchery origin. These tags were expanded to 12 natural origin and 29 hatchery, for a total of 41 steelhead. In 2015, only one tag was detected above the gabion weir; the remainder likely spawned below the highway culvert in the town of Riverside, WA.

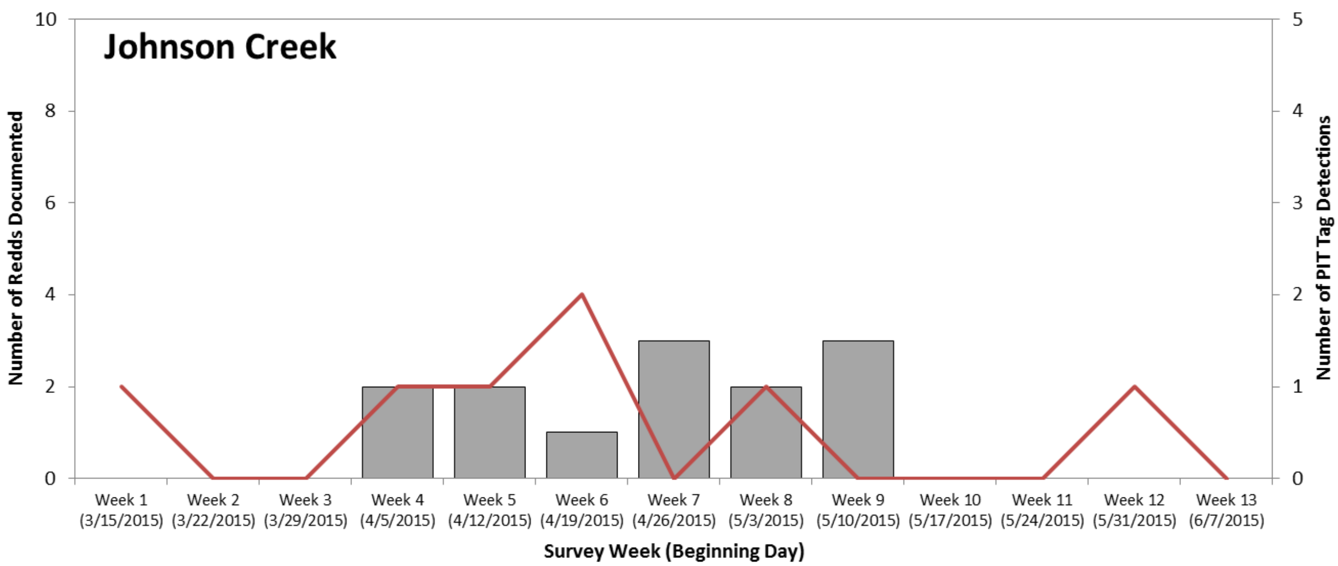

Figure 10. Number of steelhead redds documented by week in Johnson Creek (bar) compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on the interrogation site and grouped by week.

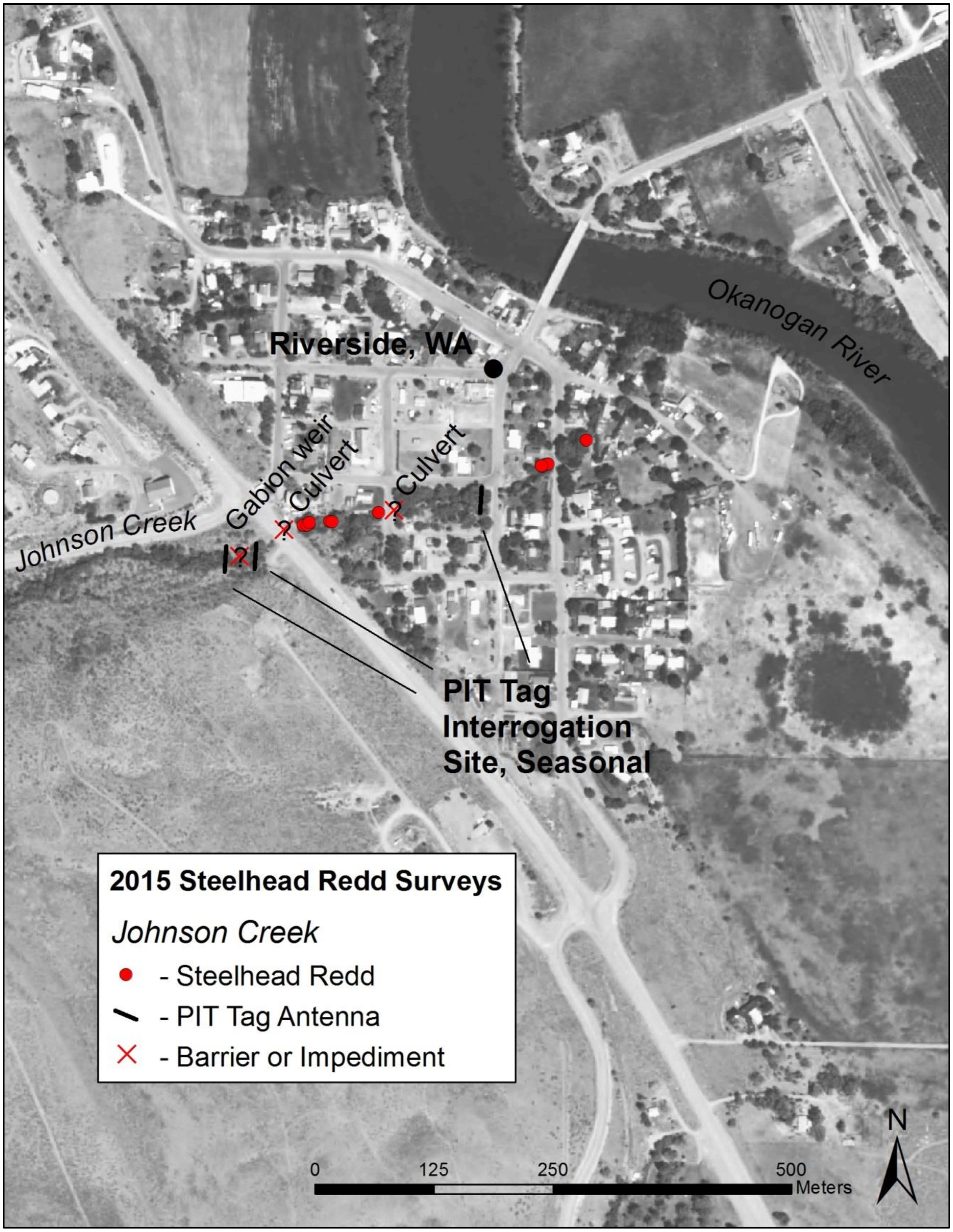

Figure 11. Spatial distribution of summer steelhead redds documented in Johnson Creek in 2015.

3.2.6 Tunk Creek

Redd surveys were successfully conducted weekly in Tunk Creek. A total of 28 redds were documented in 2015 (Figure 12 and 13), when expanded by 1.447 FPR, 41 steelhead were represented by redd surveys. The 41 total spawners were divided into 8 natural origin and 33 hatchery steelhead, determined by the percent-wild of PRD PIT tags.

One wild and 4 hatchery steelhead from the PRD PIT tag mark-release group were detected in Tunk Creek during the spring of 2015. These detections were expanded to 6 natural origin and 23 hatchery steelhead, for a total of 29. Due to successful redd surveys, the redd expansion method was selected as the final estimate.

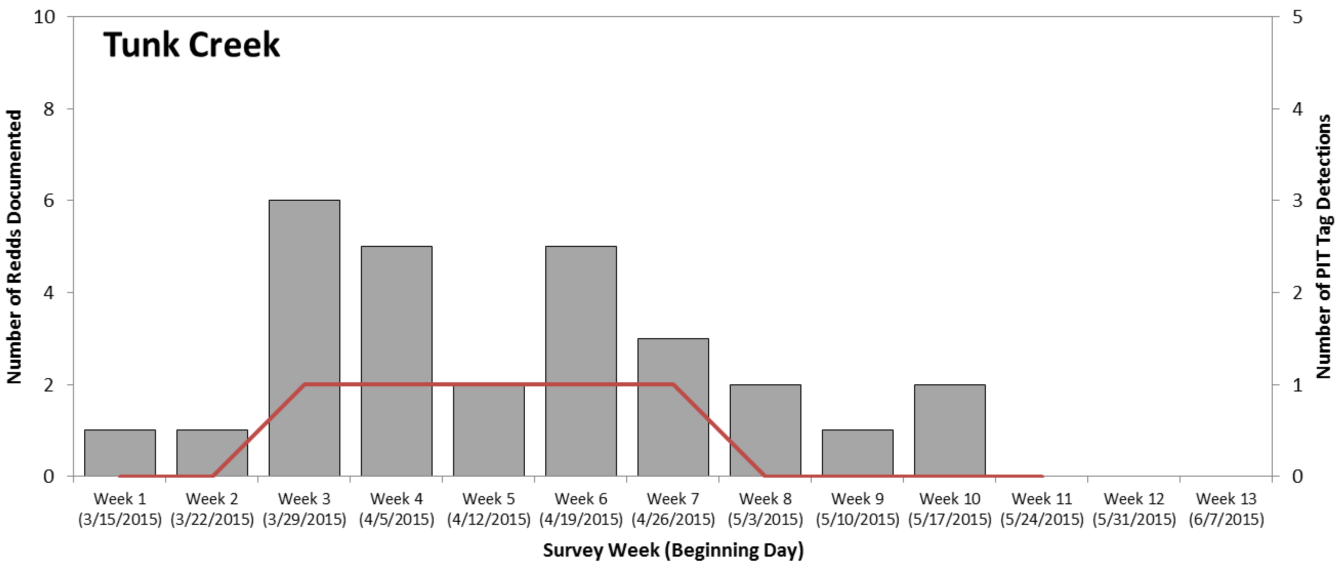

Figure 12. Number of steelhead redds documented by week in Tunk Creek (bar) compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on the interrogation site and grouped by week.

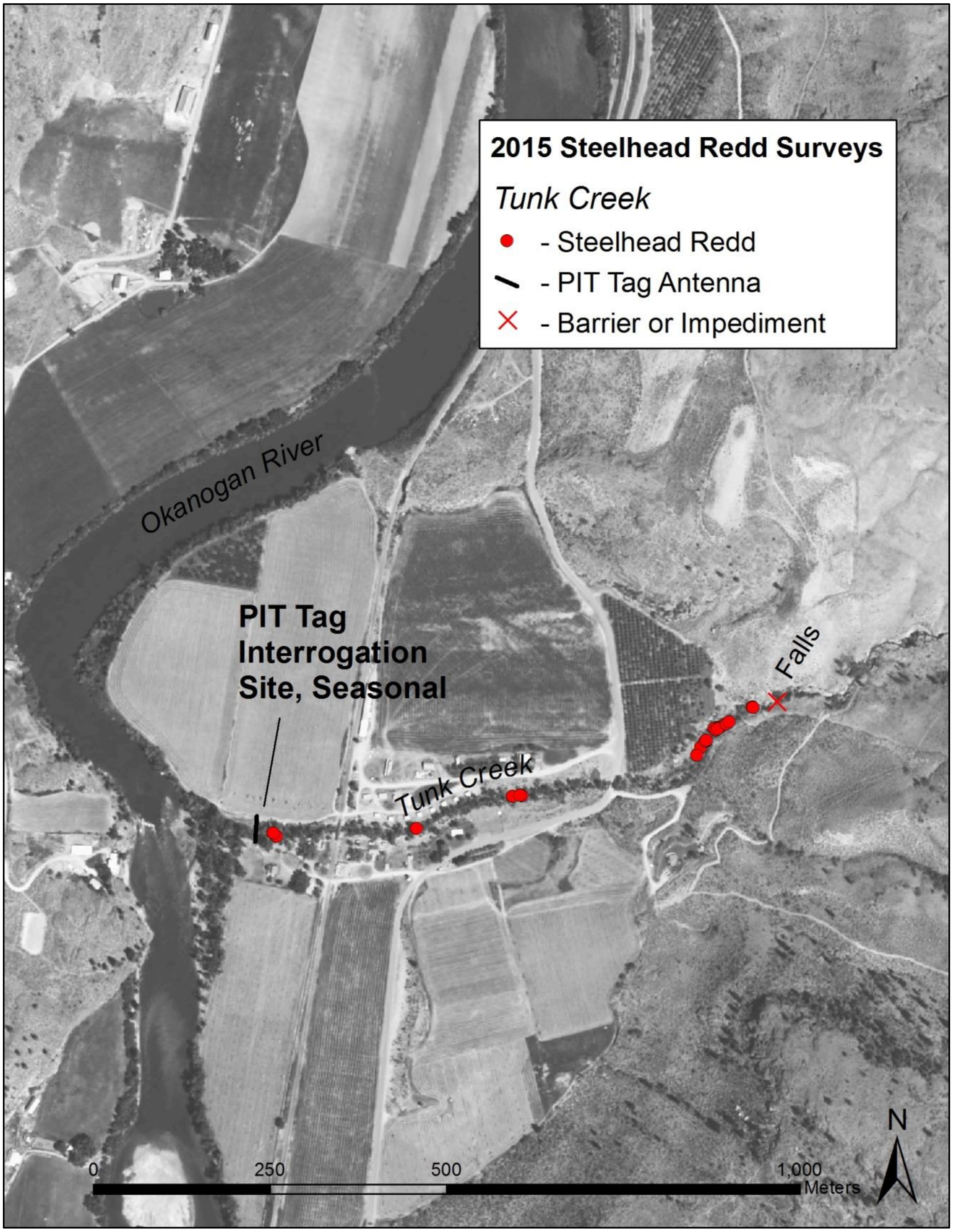

Figure 13. Spatial distribution of summer steelhead redds documented in Tunk Creek in 2015.

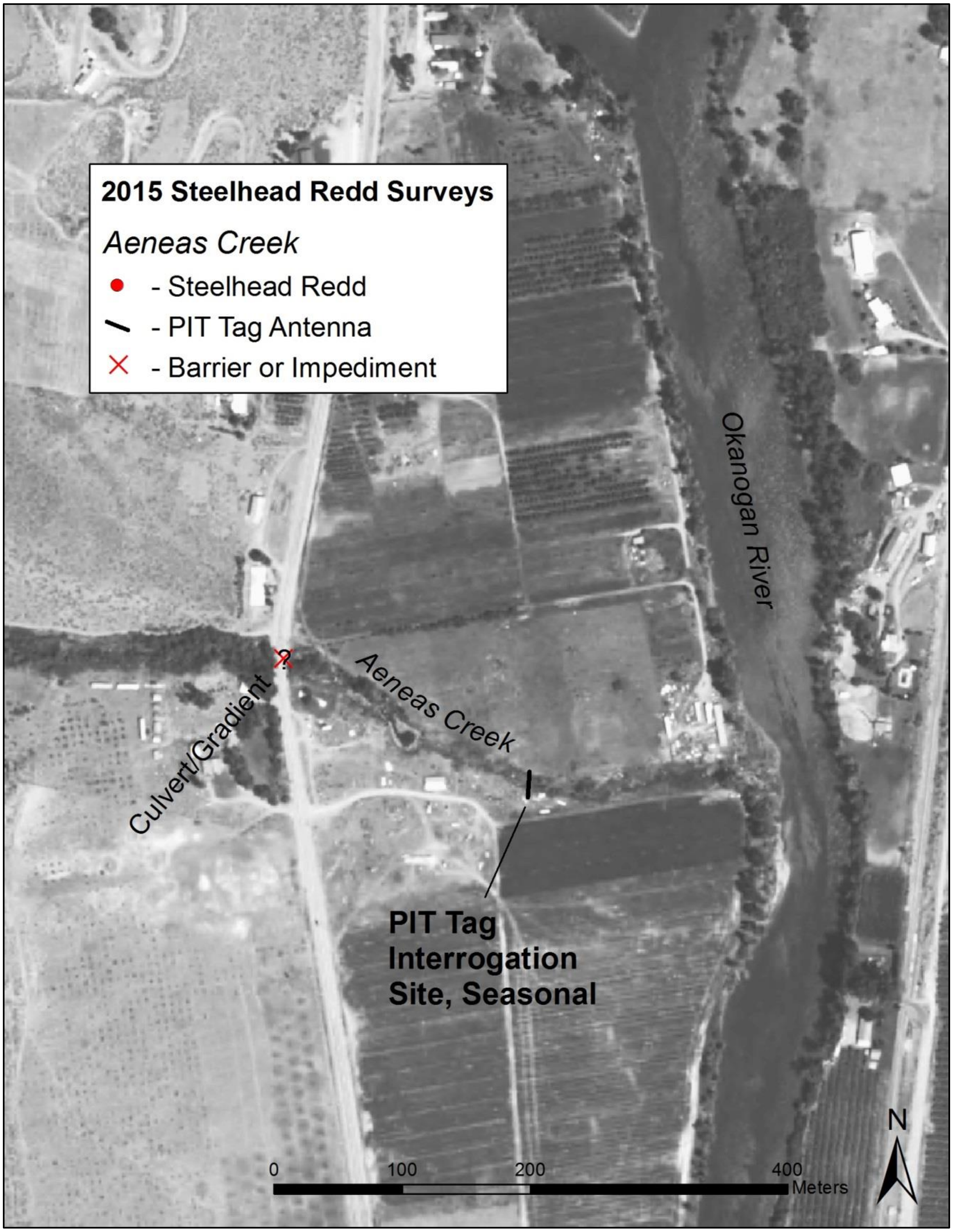

Figure 14. Spatial distribution of summer steelhead redds documented in Aeneas Creek in 2015.

3.2.7 Aeneas Creek

Adult steelhead were documented in Aeneas Creek for the first time in 2014 after a project removed a series of large beaver dams filled with sediment. Although adult passage at the highway culvert has not been examined, the combination of steep gradient and a culvert likely presents a significant passage impediment beyond that point. Water conditions again remained favorable to conduct spawning surveys in Aeneas Creek throughout the spring of 2015 and zero redds were located (Figure 14). Additionally, zero PIT tag detections were recorded in the Aeneas Creek in 2015.

3.2.8 Bonaparte Creek

Redd surveys were successfully completed on Bonaparte Creek throughout the spring of 2015, with the exception of the first survey on March 16, due to turbid water conditions. A total of 55 redds were documented (Figure 15 and 16), which were expanded by 1.447 FPR to 80 steelhead.

Eleven natural origin and 13 hatchery PRD PIT tagged steelhead were detected at interrogation site BPC, near the mouth of the creek. These detections rendered a spawning estimate of 63 natural origin and 75 hatchery steelhead, for a total of 138 steelhead. Due to a large number of steelhead spawning in a relatively short section of creek, most of which occurred near the base of the falls, a large amount of superimposition was noted. Therefore, redds may have been missed and the tag expansion method likely serves as the most reliable estimate.

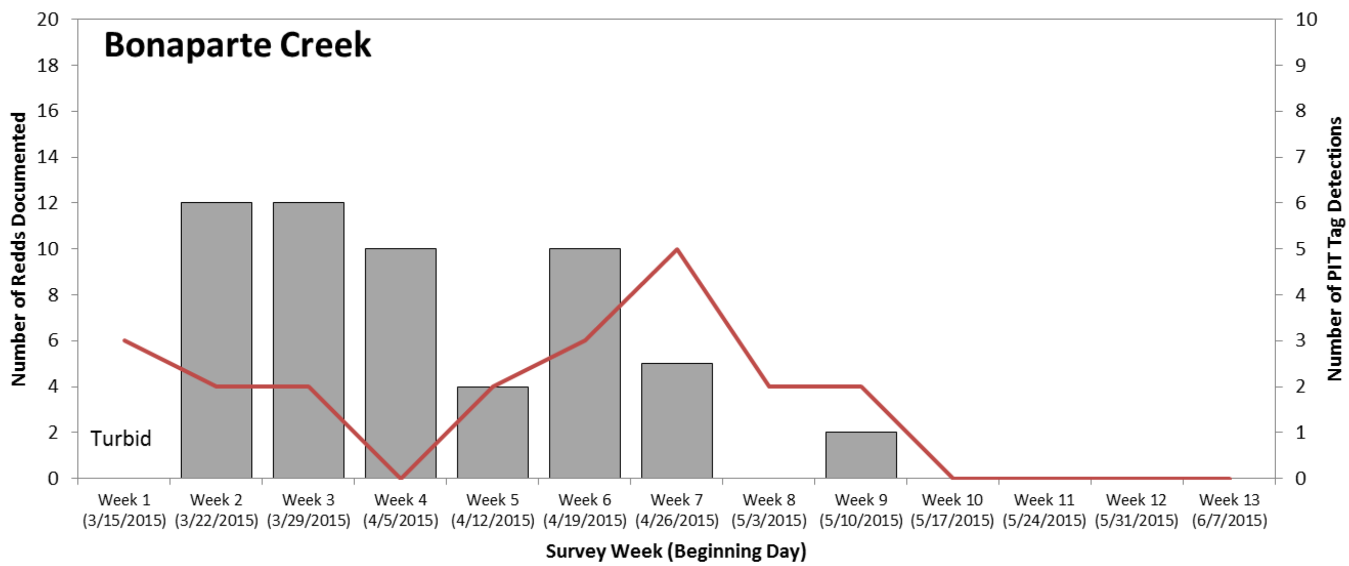

Figure 15. Number of steelhead redds documented by week in Bonaparte Creek (bar) compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on the interrogation site and grouped by week.

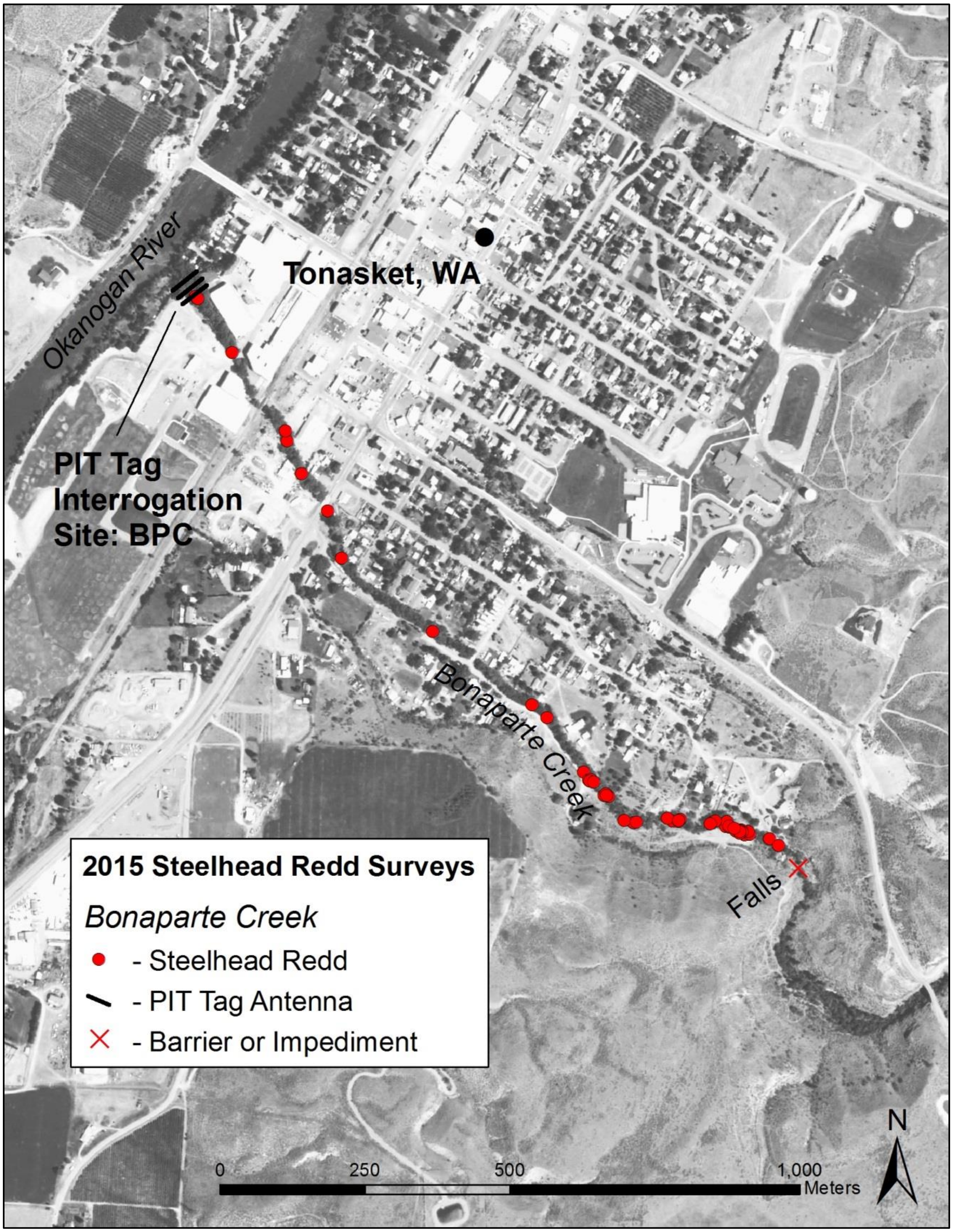

Figure 16. Spatial distribution of summer steelhead redds documented in Bonaparte Creek in 2015.

3.2.10 Antoine Creek

A small concrete dam was removed in the fall of 2013, which opened up an additional 11 km of habitat in upper Antoine Creek. A permanent PIT tag interrogation site was in operation near the mouth of Antoine Creek (site ANT) and a seasonally operated PIT tag antenna was installed above where the dam was removed to document potential passage above that point. One PRD hatchery steelhead was detected at the lower array only during the spring of 2015, which represented 6 hatchery steelhead. Additionally, two other PIT tagged steelhead, not part of the PRD study, were detected at the lower array; one of those was also detected passing the upper antenna. Redd surveys occurred from the mouth of the creek to PIT tag site ANT weekly. Only one redd was located in that reach (Figure 17 and 18). The combined redd survey and PIT tag estimate led to an estimated 8 hatchery steelhead spawning in Antoine Creek in 2015.

An underwater video array was operated in Antoine Creek below the PIT tag site, however accuracy of video counts may have been affected by turbid water and fish behavior. Steelhead used the gravels immediately upstream of the video array for spawning and were observed frequently passing back and forth and holding in the video box over multiple days. After reviewing all recorded passage events, an estimated three hatchery and three natural origin steelhead were counted at the video array.

While Antoine Creek appears to have sufficient habitat and juvenile *O. mykiss* are observed in the creek, utilization by adult steelhead has been minimal, as monitored by OBMEP from 2005-2015, potentially due to poor accessibility near the mouth of the creek. In previous years, and also in 2015, there was an approximately 6 foot high cut bank falls with a very shallow plunge pool near the confluence with the Okanogan River. Frequently, wood debris piled up in this slot and may have inhibited upstream passage. In late 2015, habitat modifications were completed near the mouth of Antoine Creek which should increase passage success for the 2016 spawning period (Keith Kistler, CCT, pers. comm.).

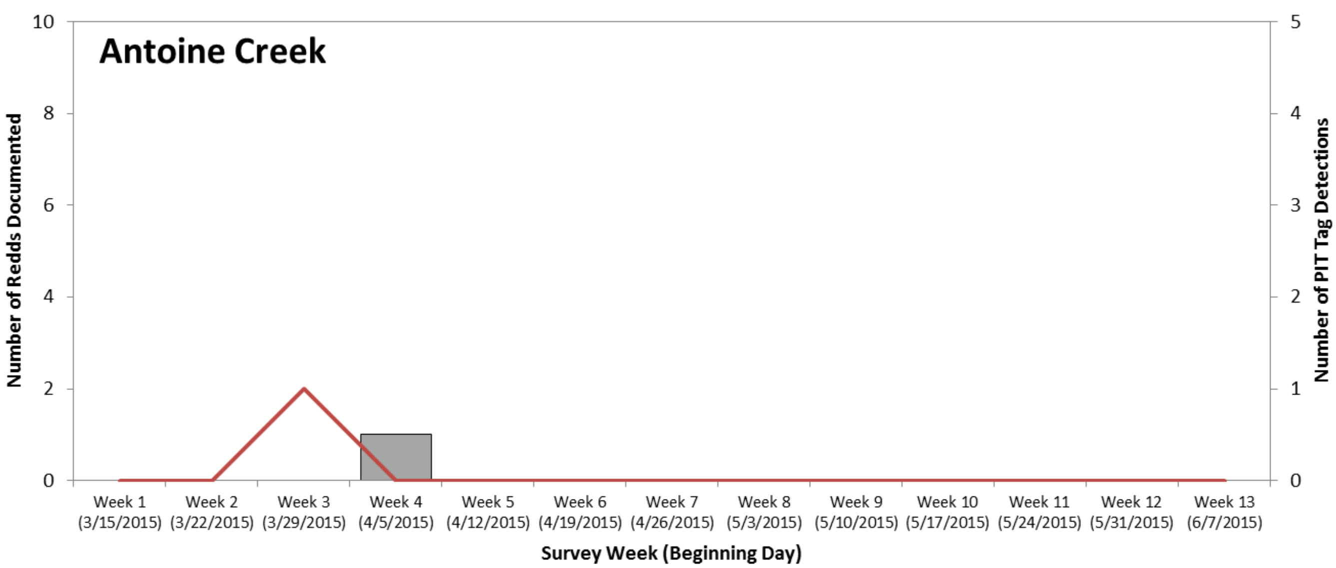

Figure 17. Number of steelhead redds documented by week in Antoine Creek (bar) compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on the interrogation site and grouped by week.

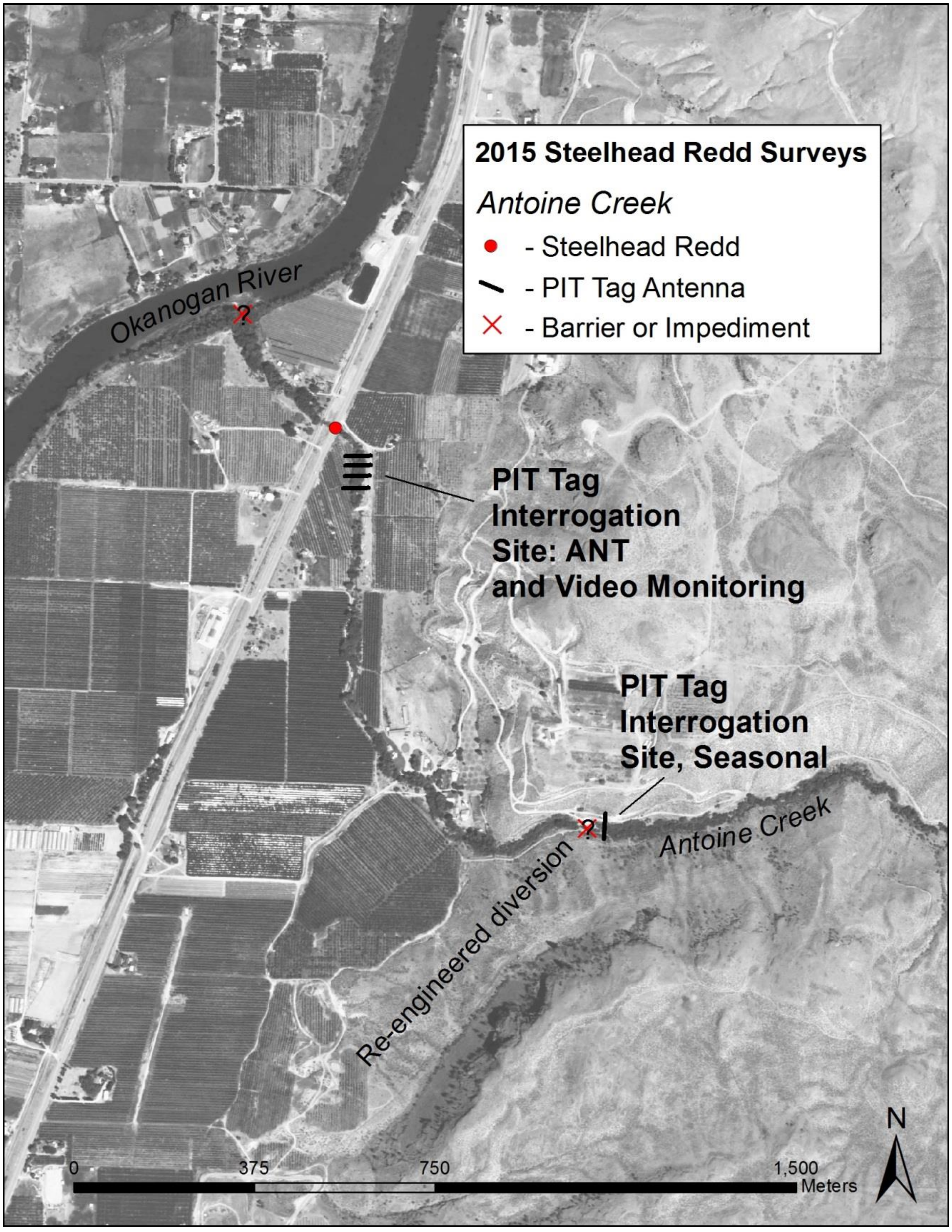

Figure 18. Spatial distribution of summer steelhead redds documented in Antoine Creek in 2015.

3.2.11 Wildhorse Spring Creek

In 2015, a very small amount of water flowed down Wildhorse Spring Creek, which appeared to be insufficient for adult steelhead passage. The lower portion of the creek remained dry after May due to low snowpack and water availability in the lower elevations. No redds were observed and no PIT tag detections were recorded throughout the spring of 2015 (Figure 19).

3.2.12 Tonasket Creek

A large flood occurred in Tonasket Creek in mid-February which caused the creek to leave the confined creek bed and flood through orchards, a softball field, and eventually enter the Okanogan River at a different location along a county road. Shortly after that event, the creek was re-routed back into the channel and the depth of water at the mouth of Tonasket Creek was likely too low for adult passage. Redd surveys occurred from March through April, but no redds were located (Figure 20). No PIT tag detections occurred at the detection site (site TON). The mouth of the creek was dry at the beginning of May.

3.2.13 Ninemile Creek

In Ninemile Creek, redd surveys were conducted from the mouth up to the PIT tag interrogation site (NMC), and tag detections were used to calculate escapement above that point. One redd was documented in the lower reaches in 2015 (Figure 21), for an estimated 2 steelhead spawning below the antenna, divided into one hatchery and one natural origin steelhead. Two PIT tag detection sites were operated on Ninemile Creek, one permanent site near the mouth (NMC) and additional temporary PIT tag antenna in the upstream reaches of Ninemile Creek, to examine upstream distribution of adult steelhead in the creek. During the spring of 2015, no PIT tagged steelhead were detected at either interrogation site. The one redd in the lower reaches of the creek provided a total estimate of two steelhead spawning below the PIT tag antenna.

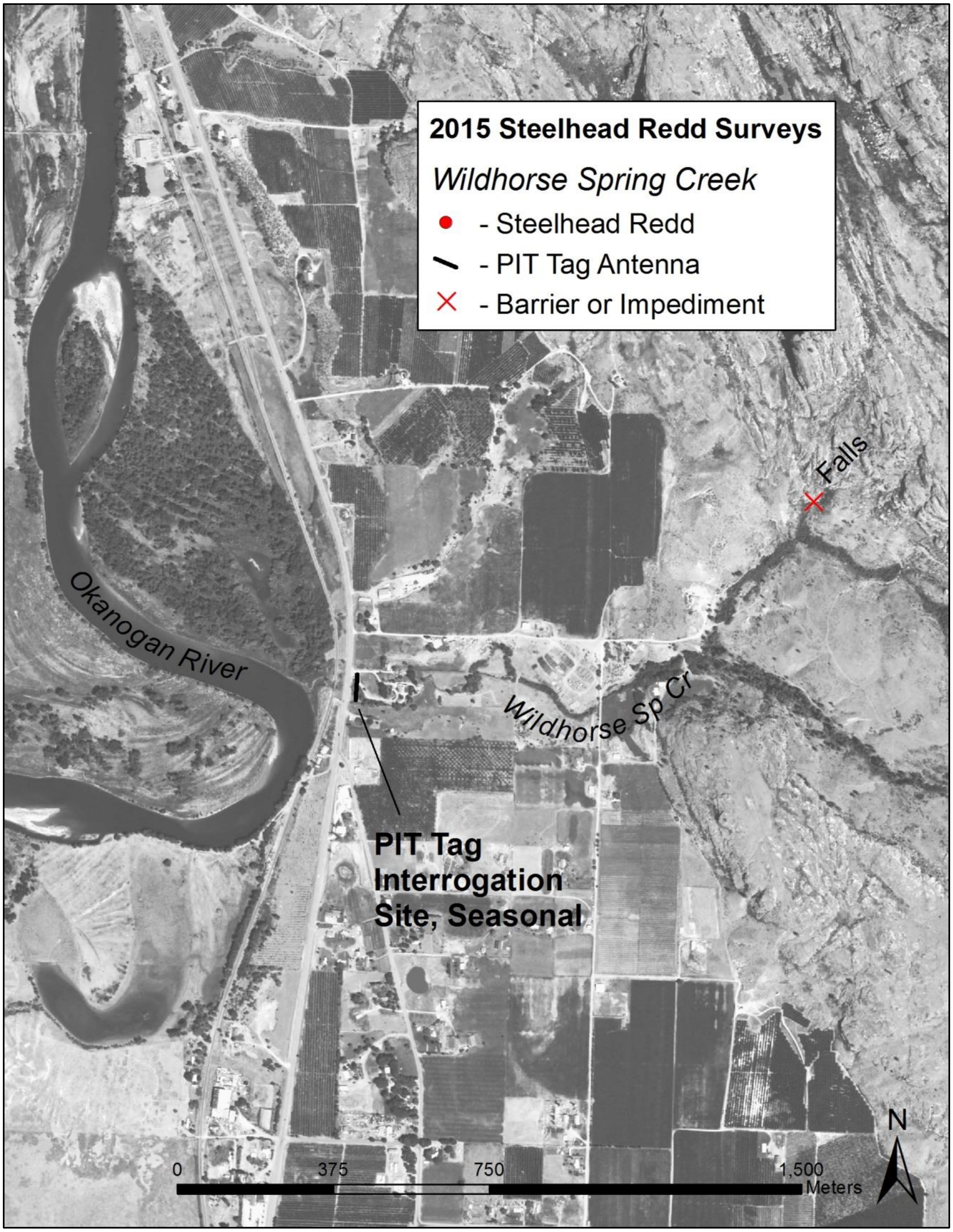

Figure 19. Spatial distribution of summer steelhead redds documented in Wildhorse Spring Creek in 2015.

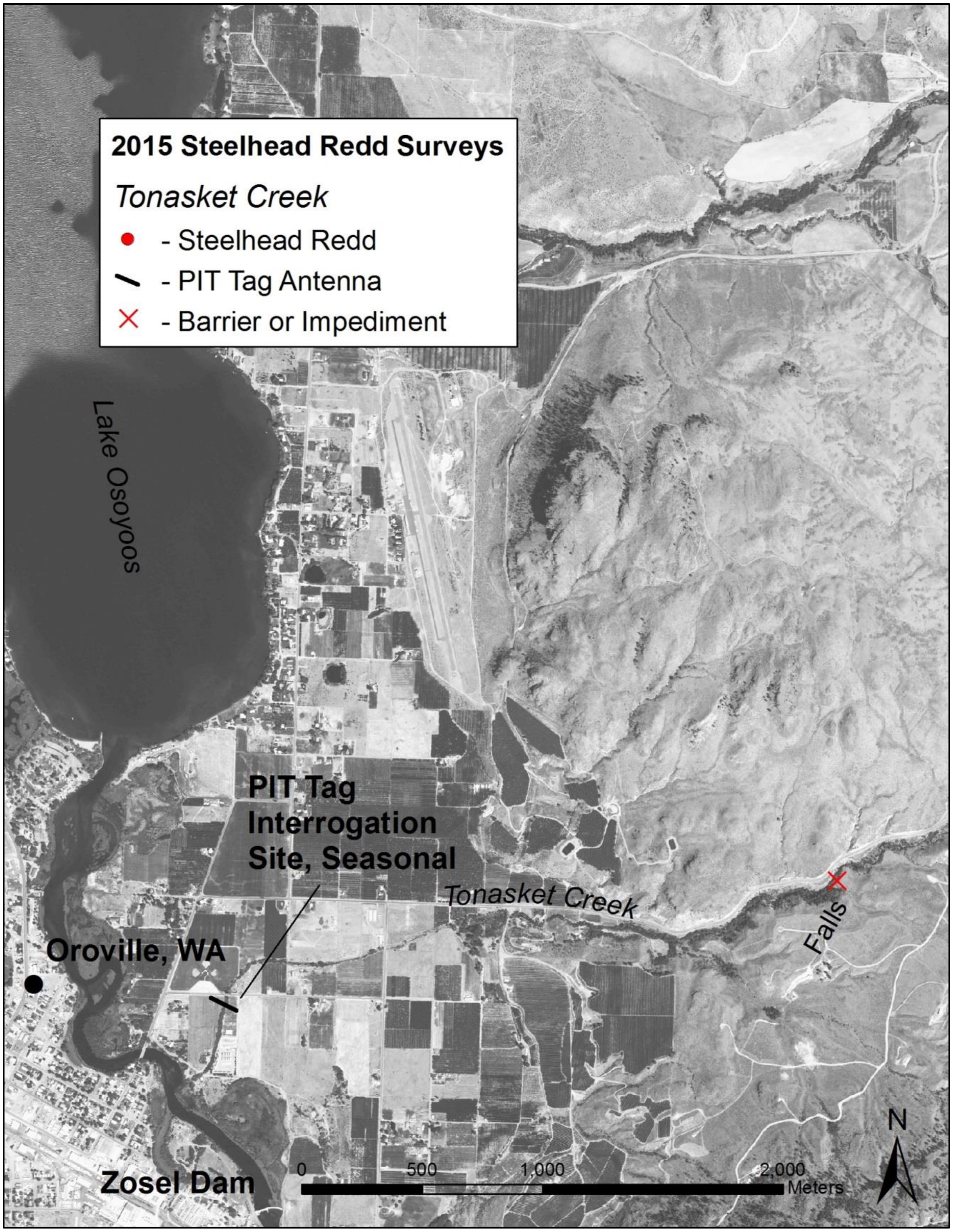

Figure 20. Spatial distribution of summer steelhead redds documented in Tonasket Creek in 2015.

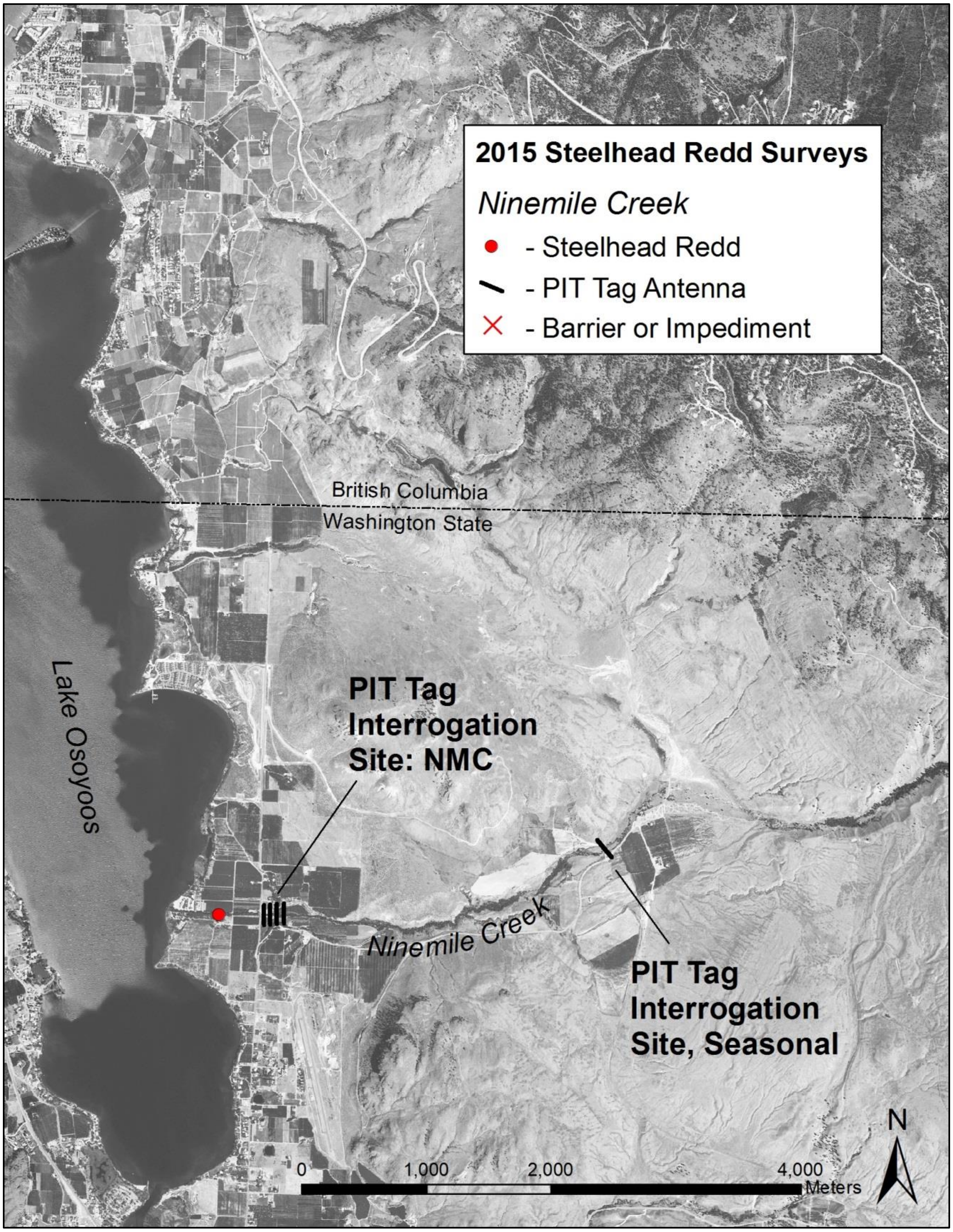

Figure 21. Spatial distribution of summer steelhead redds documented in Ninemile Creek in 2015.

3.3 Zosel Dam and Upstream Locations

Zosel Dam is located at the downstream end of Osoyoos Lake immediately above Okanogan River Reach 7, the largest steelhead spawning area in the Okanogan subbasin. The fall back rate at Zosel Dam is currently unknown, but may be relatively large due to the heavily utilized spawning habitat available in Okanogan Reach 7. Zosel Dam was constructed in its current state in 1987 with undershot spillways and when the spillway gates are raised to a height of more than 12 inches, fish may be able to ascend through the spillways and bypass the fishway monitoring systems. Underwater video monitoring was conducted at Zosel Dam between February 25, 2015 and June 15, 2015. The spillway gates were lowered on March 11, 2015 to a level at which fish began to utilize the fishway monitoring system. A total of 255 steelhead were counted passing upstream in the underwater video array, including 171 wild and 84 hatchery fish as observed by the presence or absence of the adipose fin (Figure 22). The number of steelhead that passed Zosel Dam through the open spillway gates when they were raised above 12 inches remained unknown. A total of 27 unique PIT tagged steelhead were detected in the fishways, including 5 wild and 14 hatchery PRD marked fish.

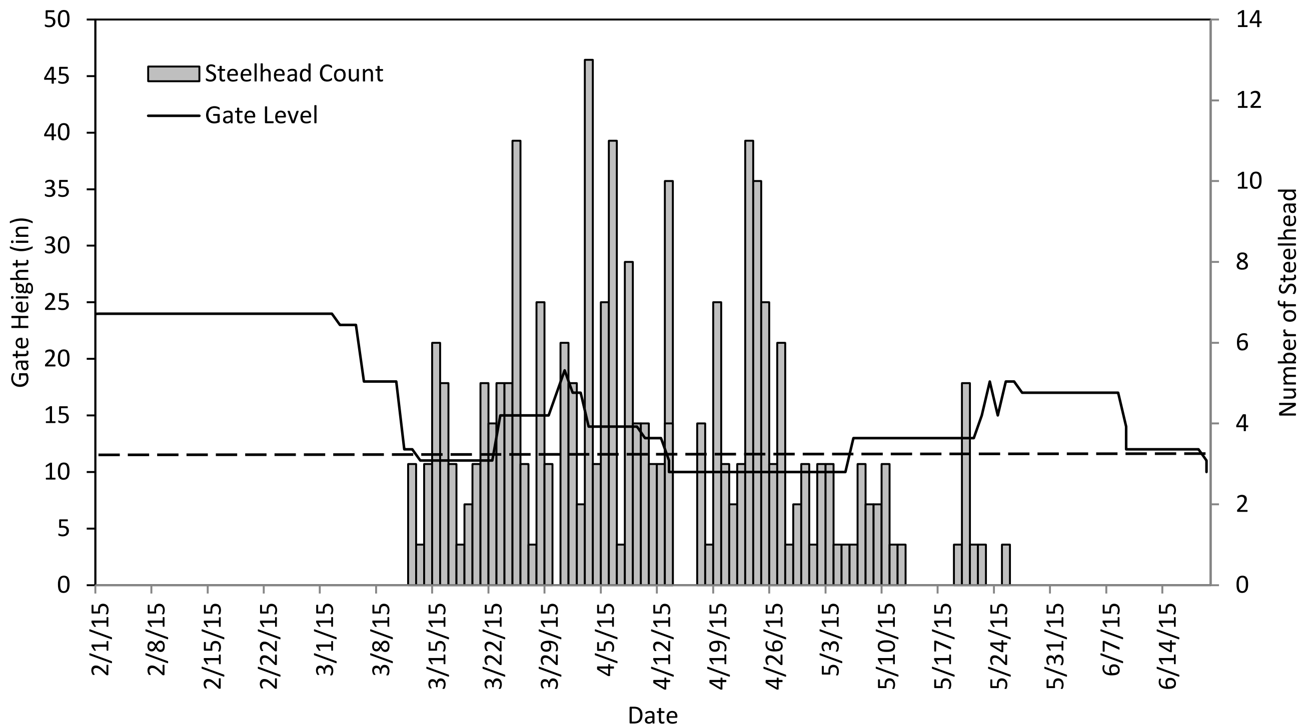

Figure 22. Zosel Dam undershot gate height (line) and underwater video passage counts of adult steelhead (bar).

Zosel Dam is the outlet of Lake Osoyoos, which extends into the Canadian portion of the subbasin. Besides the mainstem Okanagan River, three other major tributaries flow into Lake Osoyoos, two are located on the Washington State side of the border (Ninemile and Tonasket creeks) and one is located in British Columbia (Inkaneep Creek). Both Ninemile and Tonasket creeks have had PIT tag interrogation sites installed for a number of years; additionally, a permanent PIT array was installed in Inkaneep Creek on April 27, 2015. Although wild and hatchery origin steelhead were detected in Inkaneep Creek in 2015, the final installation date was too late in the spawning season to derive abundance estimates. PIT arrays were also installed on Shingle and Shuttleworth creeks, although no detections occurred at those locations in 2015.

Approximately 5 km upstream of Lake Osoyoos, on the Okanagan River mainstem, a permanent PIT array spans the entire channel (site OKC situated at Vertical Drop Structure 3) and has been in place since 2010. Since all salmon migrating upstream of Lake Osoyoos must cross over OKC, it has been a pivotal detection site for enumerating adult salmon abundance and observing migration timing. In 2015, ten natural and four hatchery origin steelhead were detected at OKC, which were also tagged as part of the PRD mark-release group. Using the PRD tag rate for 2015, these detections represent approximately 58 natural and 23 hatchery origin steelhead. While the detection rate for steelhead at OKC during spring flows has not yet been determined, previous studies of sockeye in the summer reported a detection rate at OKC of 89 percent (Fryer et al. 2014). Using this detection rate, the detections of steelhead could represent an estimate of 65 natural and 26 hatchery origin steelhead migrating upstream of OKC. Site OKC was upgraded on August 25, 2015 (installed IS1001 transceivers), which more than doubled the detection range on a number of the antennas (Joe Enns, ONA Fisheries Biologist pers. comm.). As more PIT detections are observed upstream of OKC in the future at different sites, more specific detection rates can be developed for steelhead at OKC.

Until 2009, the outlet dam of Vaseux Lake (McIntyre Dam) was the upstream migration barrier for anadromous salmonids. The dam was redesigned in 2009 and, currently, the outlet dam of Okanagan Lake at Penticton, BC is the upstream barrier. A dam also exists at the outlet of Skaha Lake (Okanagan Falls, BC), which had a fish ladder installed in 2014. As well, 17 Vertical Drop Structures (VDS) currently exist along the Okanagan mainstem, 13 between Oliver, BC and Lake Osoyoos, and four between Skaha Lake and Vaseux Lake. The majority of the Canadian portion of the mainstem Okanagan River is characterized as being straightened and channelized. The main tributaries to the mainstem Okanagan River include Shingle Creek, Ellis Creek, McLean Creek, Shuttleworth Creek, Vaseux Creek, and a number of small perennial streams.

3.4 Foster Creek (located outside the Okanogan subbasin)

Although Foster Creek is not located within the Okanogan subbasin, OBMEP installed a PIT tag antenna and conducted redd surveys every other week in 2015 (Figure 23) to further describe the spatial extent of Upper Columbia River steelhead above Wells Dam. Foster Creek was successfully surveyed across the entire 2015 spawning period, due to clear water and stable flows. A total of 10 steelhead redds were observed for an estimated total of 15 steelhead. All redds were located below the Chief Joseph Dam outflow pipe (Figure 24), where water is bypassed from the Chief Joseph Dam forebay into the lower reaches of Foster Creek. No redds were documented in the upper reaches of Foster Creek in 2015, likely due to low water levels in Foster Creek proper, above the outflow pipe.

The PIT tag interrogation site (FST) detected 1 wild and 2 hatchery PIT tagged steelhead from the PRD mark-release group, which led to an estimated 6 wild and 12 hatchery steelhead, for a total spawning estimate of 18. Both methods provided similar results.

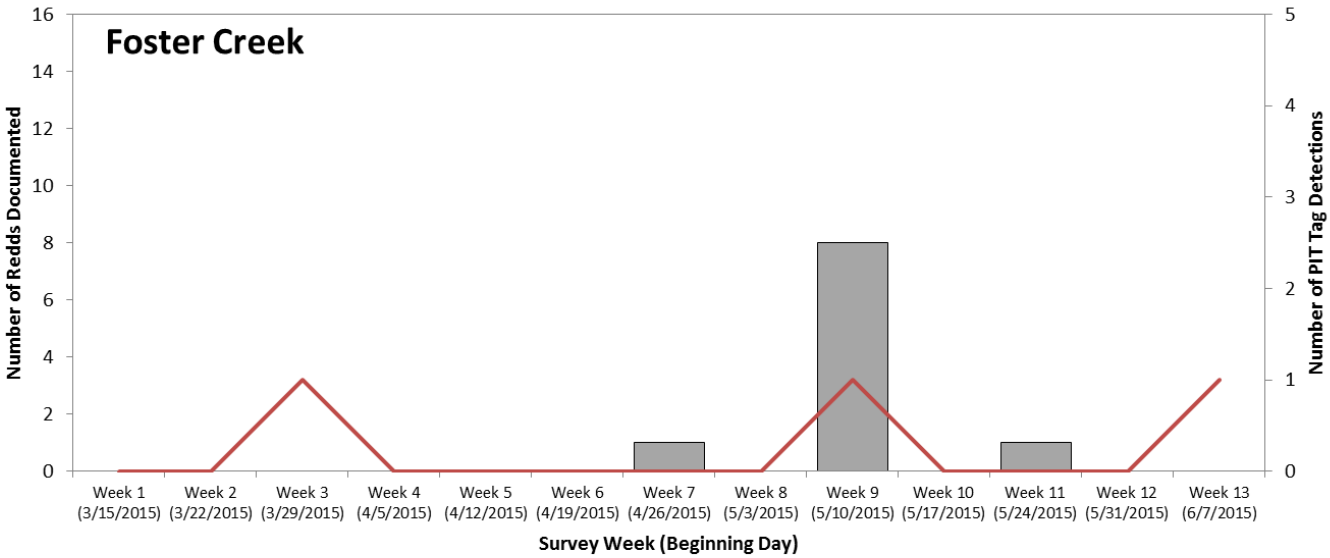

Figure 23. Number of steelhead redds documented in Foster Creek (bar) compared with PIT tag detections (line). PIT tag detections are presented by date of first detection of unique tag codes on the interrogation site and grouped by week.

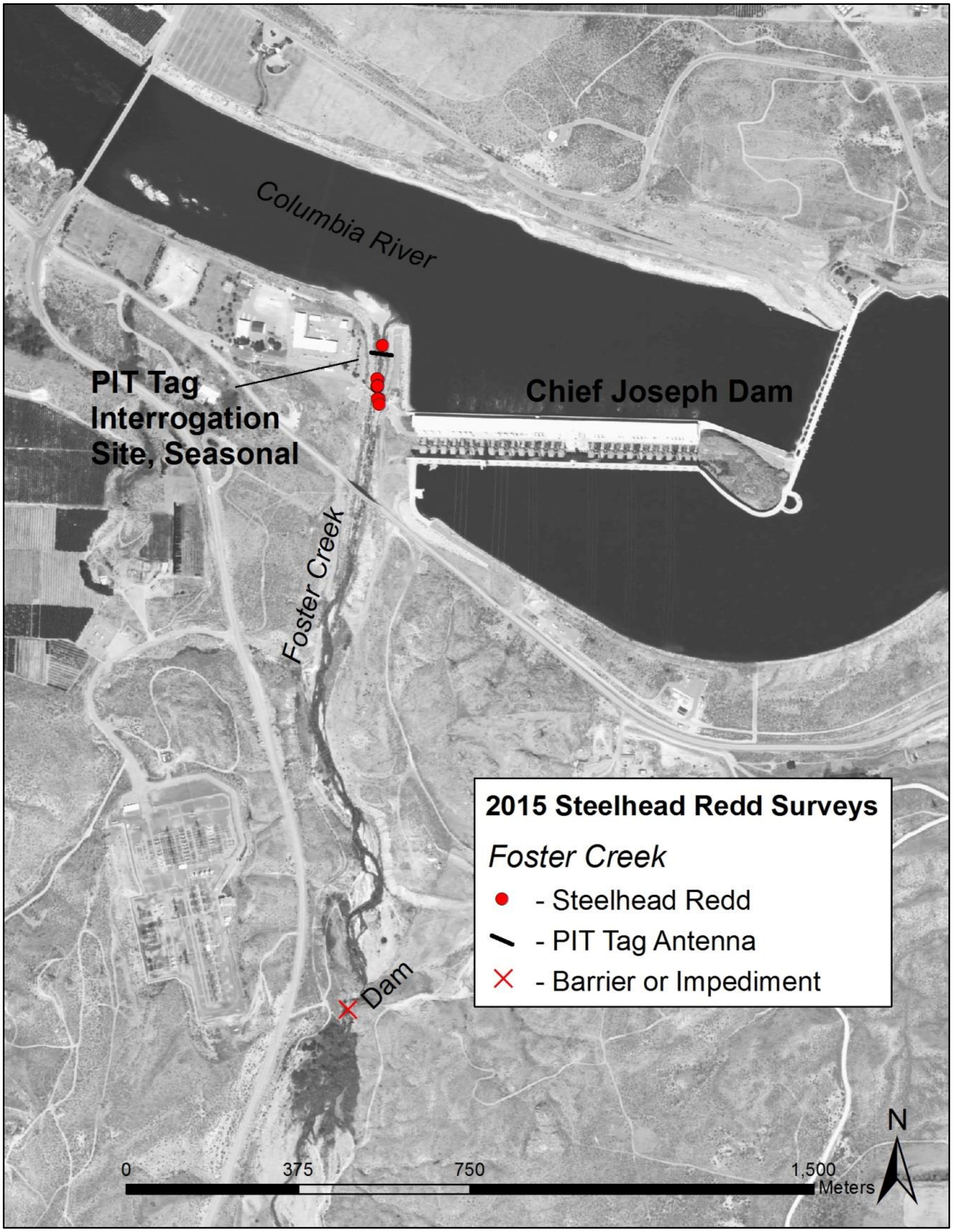

Figure 24. Spatial distribution of summer steelhead redds documented in Foster Creek in 2014.

4.0 Discussion

In the United States, summer steelhead are currently listed as "threatened" under the Endangered Species Act in the Upper Columbia River ESU (NMFS 2009). OBMEP monitored adult Viable Salmonid Population (VSP) abundance attributes (McElhany et al. 2000) within the subbasin for Okanogan River summer steelhead. Adult monitoring was conducted through redd surveys, underwater video counts, and PIT tag expansion estimates. A summary of spawning estimates in the Okanogan subbasin from 2005 through 2015, for both hatchery and naturally produced steelhead is presented in Figure 25. The average total number of steelhead spawners in the Okanogan subbasin was 1,785 and the average number of naturally produced spawning steelhead was 322. The proportion of hatchery origin spawners (pHOS) from 2005 through 2013 averaged 0.85, but the average pHOS decreased to 0.65 in 2014 and 2015.

Summer steelhead spawning estimates were compared with recovery goals outlined by the Upper Columbia Spring Chinook and Steelhead Recovery Plan (UCSRB 2007). The Upper Columbia Spring Chinook and Steelhead Recovery Plan states that 500 naturally produced adult steelhead would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin; if the Canadian portion of the subbasin was included, minimum abundance recovery criteria would be 1,000 naturally produced adults (UCSRB 2007).

Results from steelhead adult enumeration efforts indicate that the number of spawning steelhead in the Okanogan River subbasin, both hatchery and naturally produced, increased since data collection began in 2005. The slope of the 2005 through 2015 eleven year trend line suggests that the number of hatchery steelhead spawning in the Okanogan subbasin increased at an average rate of 78 fish per year and the number of naturally produced spawners increased at an average rate of 33 fish per year (Figure 25). Spawning occurred throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable spawning substrates and water velocities. Steelhead spawning has been documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. It is likely that distribution of spawning is influenced by stocking location because juvenile hatchery steelhead have been released in the Similkameen River, Omak Creek, and Salmon Creek where high volumes of spawners are estimated.

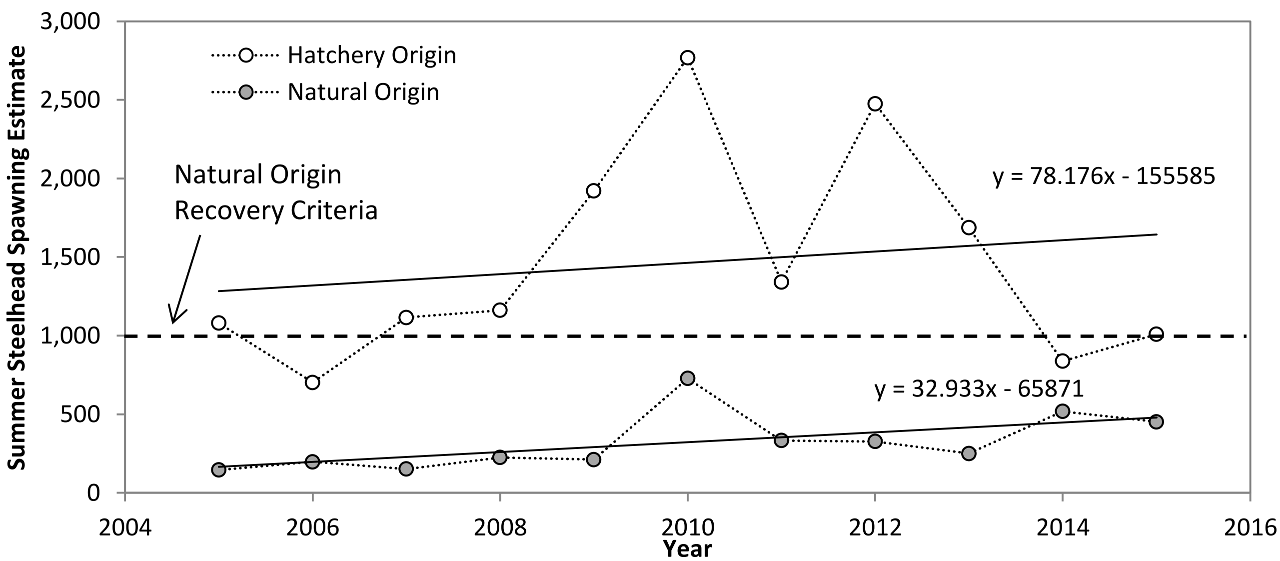

Figure 25. Trend in the estimated number of summer steelhead spawning in the Okanogan River subbasin, 2005 - 2015.

Detailed percent-wild information has been provided annually and every attempt has been made to ensure that these estimates are as accurate as stated methods currently allow. However, these data should be used with caution, as it is difficult to define natal origin through visual observation alone (i.e. intact adipose fin) on redd surveys and underwater video. Values presented in this document represent our best estimate from available information, but the variability surrounding point estimates are currently undefined.

Large variations in estimates exist in many reaches from year to year, but often, these accurately reflect real-world situations rather than survey bias or calculation error. Small creeks may have extremely low flows for two years, blocking access with no spawning occurring, and then experience a large run of fish the following year when sufficient flows exist (e.g. Loup Loup Creek escapement of 0, 0, and 125 for 2008, 2009, and 2010, respectively). This irregular nature of small scale population data frequently results in data being scattered loosely around a linear trend line. Numerous methods have been described in the literature for analyzing complex fisheries data. When more years of data become available, additional detailed data analysis methods may be employed. We have made every effort to ensure that the reported values are as accurate as possible, including using multiple data collection methods for validation, comprehensive on-the-ground surveys, and best scientific judgment based on extensive local experience with the subbasin.

Annual variations in physical habitat and environmental factors can profoundly impact redd distributions in small tributaries to the Okanogan River. Changes in summer steelhead spawning distribution within tributaries appear to be driven by the following four factors: 1) discharge and elevation of the Okanogan River, 2) discharge of the tributary streams, 3) timing of runoff in relation to run timing of steelhead, and 4) stocking location of hatchery fish. The first three factors are largely based upon natural environmental conditions, which can be altered dramatically by such things as water releases from dams, irrigation withdrawals, and climate change. Years such as 2006, 2008, and 2009 clearly show how low tributary discharge can dramatically alter spawning location and reduce the available tributary habitat for steelhead to utilize. Habitat alterations at the mouths of key spawning tributaries may improve access, provided that sufficient discharge is available.

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