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Habitat Characteristics and Fish Use of Cold-water Refuges in the Upper Grande Ronde River

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April 2017

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Abstract

Cold-water refuges in streams can provide critical rearing and holding habitat for fishes and other aquatic taxa, particularly in streams with stressful summer water temperatures. We used forward looking infrared (FLIR) imagery combined with field surveys to describe the distribution, physical habitat characteristics, and fish use of cold-water refuges in the Upper Grande Ronde River basin in Northeast Oregon. Cold-water refuges were widespread throughout the Chinook-bearing portions of the Upper Grande Ronde basin, with refuge surface area totaling 17,945 m^2. Refuges were 5.8 °C cooler on average than the ambient water temperature, with temperature differences between ambient and refuges reaching as high as 12.7 °C. Despite having significantly cooler water temperatures, habitat conditions in cold-water refuges were generally poor, with the majority of refuges having shallow depths, very low water velocity, relatively little shade and cover for fish, and moderate to high levels of fine sediment. We predicted that cold-water refuges could support a maximum of 14,891 Chinook Salmon summer parr, and 1,980 juvenile steelhead. This represents approximately 10 % of the total estimated Chinook Salmon parr capacity for the Upper Grande Ronde Spring Chinook population. If we consider only refuges that were connected to the main channel (i.e., had refuge crest depths > 0.05 m) and contained salmonids, the predicted refuge capacity for Chinook parr and juvenile steelhead was 8,431 and 1,628, respectively. This equates to 5.6 % of the total Chinook Salmon parr capacity. These results provide managers with a baseline understanding of the distribution, habitat characteristics, and fish production potential of cold-water refuges in the Upper Grande Ronde Basin which can be used to aid in fish management decisions and direct future restoration actions including the preservation, enhancement, and creation of new cold-water refuges.

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Acknowledgements

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Introduction

High water temperature is an important habitat factor limiting abundance, productivity and spatial distribution of cold-water fish species in many streams across the Pacific Northwest (Beechie et al. 2013). In the Upper Grande Ronde River basin in Northeast Oregon, approximately 86 % of the stream network currently exceeds the 18 °C temperature standard designated for protection of salmon and trout migration and rearing (Justice et al. 2017). Cold-water refuges can help mediate the effects of warm water temperatures on fish by providing discrete zones of cool water rearing or holding habitat during periods of thermal stress (Torgersen et al. 1999, Ebersole et al. 2003, Sutton et al. 2007, Tate et al. 2007).

We used a combination of remotely-sensed forward looking infrared (FLIR) imagery and field surveys to evaluate the spatial distribution, physical characteristics, and fish use of cold-water refuges in the Upper Grande Ronde River basin. In addition, we used habitat suitability criteria to predict the carrying capacity of juvenile Chinook Salmon and steelhead in refuges to evaluate the potential contribution of refuge habitats to the overall population. This baseline understanding of cold-water refuge habitats could serve as a planning tool for restoration practitioners seeking to enhance or protect currently existing cold-water refuges and could be used in combination with ongoing fish and habitat monitoring and population modeling activities to address how refuge size, connectivity, or frequency influence salmon populations.

Methods

Remote Sensing Data Processing

We used FLIR data collected in 2010 (Watershed Sciences 2010) to delineate potential cold-water refuges within the current and historic Chinook Salmon distribution area in the Upper Grande Ronde River (upstream of the Catherine Creek confluence; Figure 1). We defined cold-water refuges as spatially-continuous patches of water with temperatures at least 2 °C less than the ambient water temperature (Kurylyk et al. 2014), less than 25 °C, and a surface area of at least 1 m^2. Refuge boundaries were delineated manually using ArcGIS for all stream reaches where ambient water temperatures exceeded a maximum weekly maximum temperature (MWMT) of 18 °C as determined from Heat Source temperature simulations calibrated to 2010 climate and hydrologic conditions (Watershed Sciences 2012). MWMT was defined as the maximum seven day running average of the daily maximum temperature. Cold-water refuges in portions of the stream network where ambient temperatures were below 18 °C were not delineated because they were assumed to provide minimal thermal benefits to Chinook Salmon and steelhead.

Refuges were classified into two size categories including channel unit-scale and segment-scale following the guidelines outlined in Torgersen et al. (2012). Channel unit-scale refuges are at the scale of geomorphic channel units such as pools and riffles and are generally less than 0.5 km in length and include features such as small tributary confluence plumes, lateral seeps, and cold alcoves. Segment-scale refuges typically have lengths in the order of 0.5–1 km in small streams and 5-10 km in large rivers often occur at large tributary confluences and where bounded alluvial valleys force cooler subsurface water upward into the surface water.

Qualifying refuges were classified by refuge type using the classification system described in Dugdale et al. (2013) and references cited therein. Refuge type was based on refuge geomorphology, refuge forming processes, and source of cold water (Table 1). Refuge types included: tributary confluence plume, lateral seep, springbrook, cold side channel, cold alcove, hyporheic upwelling, and wall-base channel. Refuge locations and descriptive information delineated from the FLIR data were then loaded to a GPS-enabled electronic data logger (iPad) along with aerial imagery to aid in navigation to refuge sites for field validation.

Field Data Collection

During summer of 2015, we conducted field surveys at a subset of the refuges that were delineated from the FLIR data to characterize physical habitat conditions, obtain more detailed water temperature measurements, and evaluate fish use using the protocol described in Appendix B of McCullough et al. (2016). These surveys were conducted during the period of summer base flow and maximum annual stream temperature (July 1 – August 31), when cold-water refuges are most important to fish and when contrast between refuge and ambient temperatures was maximized. In addition, surveys were conducted during the warmest time of day (1100 – 1800) to maximize the probability of detecting thermal refuges and to minimize the effect of temporal variation on refuge measurements.

No attempt was made to randomize the selection of refuges for inclusion in the field validation survey because many of the refuges were located on private land with limited access. Instead, we surveyed as many refuges as possible with priority given to refuges located in the mainstem Grande Ronde River and the lower ends of tributaries within the current Chinook use area. In addition, field surveys were focused on channel unit-scale refuges rather than segment-scale refuges because channel unit-scale refuges represented the majority of the cold-water refuge habitat present in the Upper Grande Ronde River.

After navigating to a potential refuge, we cautiously approached the refuge site and visually scanned the water using polarized glasses for fish prior to conducting any habitat measurements. If fish were observed using the refuge, we recorded the species present prior to making any other measurements at the site. When necessary, we used an underwater view scope to distinguish salmonids from other fish species. Next, we used a digital temperature probe (Atkins 35200-K, accuracy 0.1 °C) mounted to a telescoping pole to determine if the water temperature in the refuge met the criteria of being at least 2 °C lower than the ambient temperature and ≤ 25 °C. Refuge boundaries were assessed by sweeping the probe from side to side within five centimeters from the stream bottom. Ambient water temperature was measured in the mainstem channel just upstream of the refuge mixing zone. After delineating the refuge boundaries, we visually estimated the surface area of the refuge to determine if it met the minimum size criteria of ≥ 1 m^2. Additionally, we used the temperature probe to investigate other areas in the near vicinity of the original refuge (< 200 m) that had similar geomorphic characteristics to other cold-water refuges (e.g., alcoves, small side channels, downstream edges of large gravel bars, and deep pools), but that were not detected in the FLIR data.

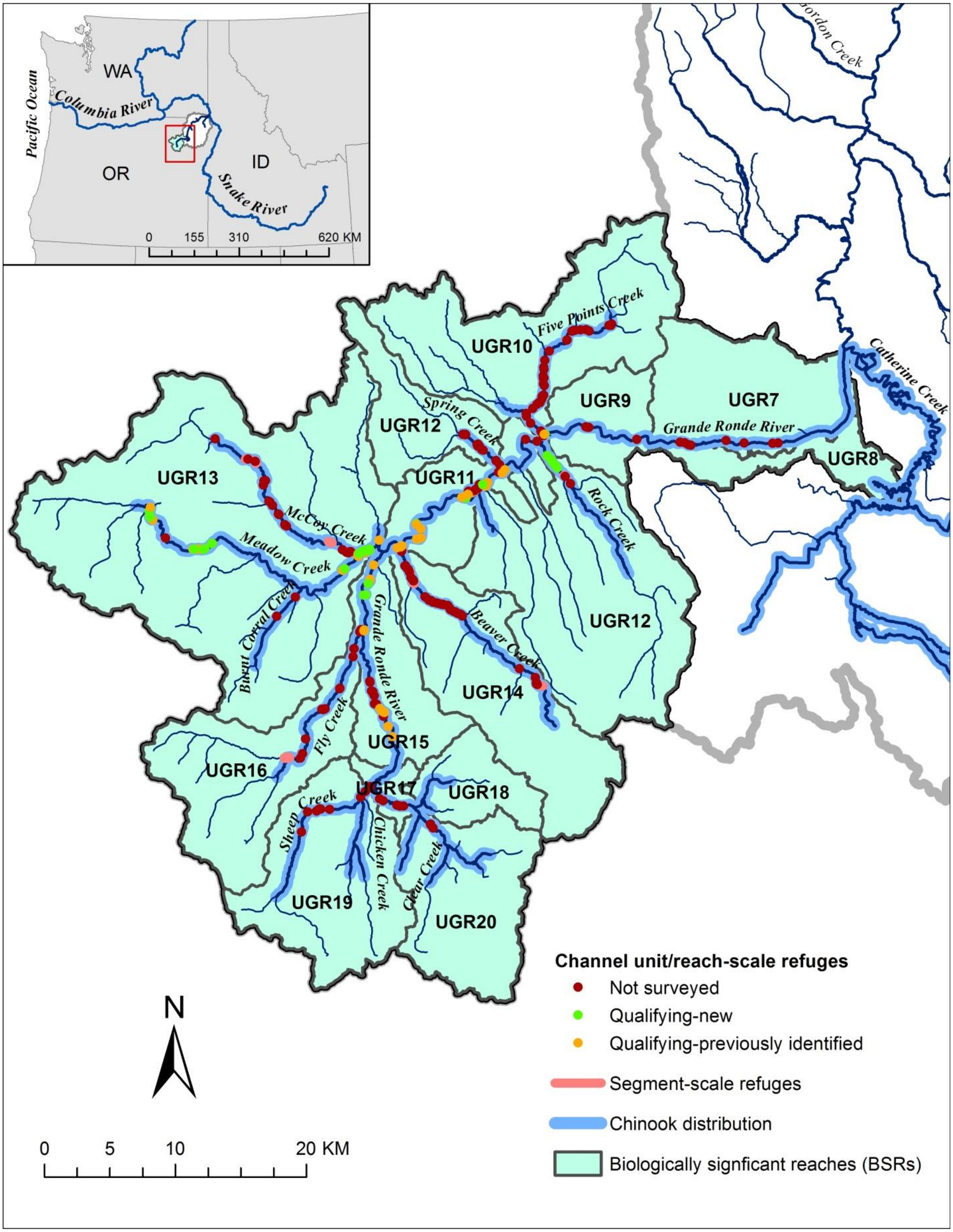
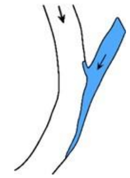
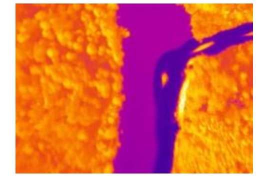
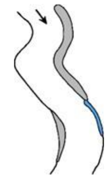
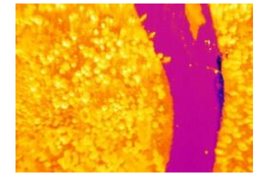
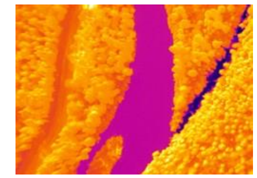
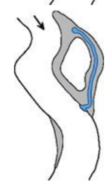
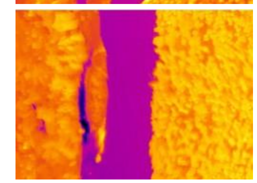
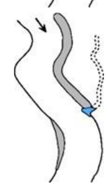
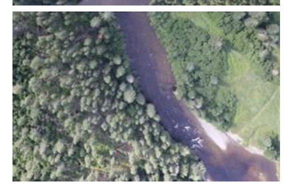
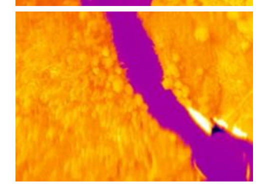
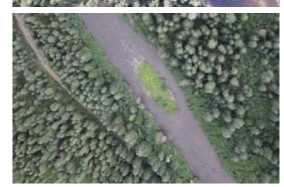
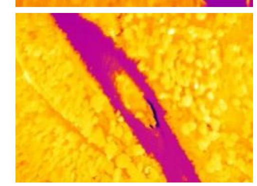
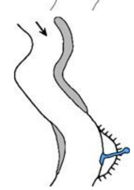
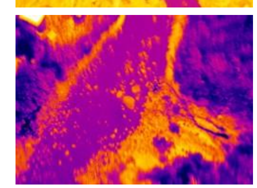


Figure 1. Study area in the Upper Grande Ronde River basin in northeast Oregon showing the location of cold-water refuges identified from Forward Looking Infrared (FLIR) in 2010 and subsequent field surveys in 2015.

Table 1. Descriptions and examples of cold-water refuge types (Dugdale *et al*. 2013).

Thermal refuge	Description	Schematic	Optical image example	TIR image example
Tributary confluence plume	Thermal plumes created prior to mixing where a cold tributary discharges into the main (warmer) river channel.			
Lateral seep	Elongated bank side filaments of cold water inflow observed when the active river channel intersects zones of groundwater flow (often in steep terraces or valleys).			
Springbrook	Cold-water channels flowing from springs, marshland or depressions adjacent to the channel; often associated with abandoned channels. Also includes springs within the main channel.			
Cold side channel	Cold secondary channels flowing in ephemeral flood pathways and normally completely wetted only during periods of high flow.			
Cold alcove	Zones of cold water found at the downstream edge of a bar and often associated with emergence of an abandoned channel or formed when groundwater pathways converge and accumulate in a backwater.			
Hyporheic upwelling	Resurgence of hyporheic flow from the streambed found at the downstream ends of gravel bars, mid-channel islands or in sequence with pool-riffle bedforms.			
Wall-base channel	Runoff-fed channels emerging from terraces or steep valley walls and then flowing over the immediate floodplain into the river channel.			

Potential refuges were assigned a refuge status based on whether or not they met the specified temperature and size criteria, and whether they were previously identified from FLIR data or newly observed in 2015. Refuge status designations included: (1) Qualifying-previously identified – Cold-water refuges that were previously identified from the FLIR data and met the temperature and size criteria; (2) Qualifying-new – Cold-water refuges that were newly identified in the field (i.e., were not present in FLIR data) and met the temperature and size criteria; (3) Non-qualifying – Potential refuges that were delineated from the FLIR data but did not meet the temperature and size criteria when surveyed in the field. These "false positives" may have resulted from thermal anomalies in the FLIR data resulting from shadows or moist vegetation, or from changes in channel morphology, discharge, or groundwater inputs that occurred after the FLIR data was collected; and (4) Not Surveyed – Potential cold-water refuges that were previously identified from the FLIR data but were not surveyed in the field because access was denied by landowners or because there was insufficient time to complete the surveys.

We measured a suite of physical habitat characteristics at each refuge included surface area, mean and max water depth, water velocity (not moving, slow (> 0 – 0.1 m/s), moderate to fast (> 0.1 – 1.1 m/s), or very fast (> 1.1 m/s)), mean bottom and surface water temperature, min water temperature, refuge crest depth, distance to the main channel, substrate composition, solar access percentage (i.e., percentage of solar radiation reaching the water surface), and fish cover (i.e., percentage by area containing boulders, aquatic vegetation, overhanging vegetation, woody debris, artificial structures, and undercut banks). The refuge crest was defined as the shallowest lateral cross section of the streambed within the wetted flow path connecting the refuge to the main channel. The refuge crest depth was measured at the deepest point along the refuge crest cross section. If the flow path was not continuously wetted, the refuge crest depth was recorded as zero. Further details on survey methods are provided in Appendix B of McCullough et al. (2016).

In addition to instantaneous temperature measurements taken at each refuge, we also deployed water temperature loggers (Onset Hobo Tidbit loggers) in 15 randomly selected refuges and in paired ambient mainstem locations to measure hourly water temperatures throughout the summer sampling period. Loggers within each refuge were placed at the stream bottom in a location representing the approximate mean temperature. Loggers in the main channel were placed upstream of the refuge mixing zone in a well-mixed location.

Data Analysis

We computed basic summary statistics of habitat conditions and fish use within the 99 qualifying cold-water refuges that were surveyed in 2015. In addition, we calculated a suite of temperature metrics for the 15 paired refuge and ambient sites where continuous temperature loggers were deployed including *AvgDailyMax* (average of the daily maximum temperatures), *AvgDailyMin* (average of the daily minimum temperatures), *AvgDailyAvg* (average of the daily average temperatures), *AvgDailyRange* (average of the daily range), *MWMT* (maximum weekly maximum temperature), *PctDaysOver18* (percentage of days when the daily maximum exceeded 18 °C), *PctDaysOver20* (percentage of days when the daily maximum exceeded 20 °C), and *PctDaysOver25* (percentage of days when the daily maximum exceeded 25 °C). The hourly temperature data was limited to a common time frame (July 23 – August 30) prior to calculating temperature metrics to ensure valid comparability across all sites. We

then used a paired t-test to evaluate whether temperature metrics in refuges were statistically different from ambient locations.

We calculated weighted usable area (WUA) for both Chinook Salmon and steelhead in refuges using methods similar to those used in the Physical Habitat Simulation System (PHABSIM) as described in Milhous et al. (1989) and later updated in USGS (2001). Briefly, this method utilizes habitat suitability index (HSI) curves for each fish species, life stage, and habitat variable of interest to quantify the amount of stream habitat that falls within a suitable range for each fish species. HSI curves are simple rating curves that range from zero to one, with one representing habitat conditions that are 100 % suitable and zero representing unsuitable conditions. Ideally, these suitability curves are developed using detailed field observations of micro-habitat fish use across a range of habitat conditions within the study stream of interest. However, in the absence of such data, literature-based curves from similar streams are commonly used (Bovee et al. 1998, Maret et al. 2006). Suitability index values for each habitat variable of interest are then combined into a single composite suitability index (CSI) by computing the geometric mean of the individual suitability index values ($CSI = (SI_{depth} \times SI_{velocity} \times SI_{n})^{1/n}$). Finally, WUA is computed by multiplying the CSI by the total stream surface area.

Predictions of WUA in each cold-water refuge were based on suitability curves for water depth, velocity, and water temperature. We used water depth and velocity HSI curves for juvenile Chinook Salmon and steelhead developed from field studies conducted in the Pacific Northwest and Idaho as reported in Maret et al. (2006) (Figures 2 and 3). We developed a water temperature HSI curve for juvenile Chinook salmon using empirical fish abundance estimates and water temperature data collected in the Upper Grande Ronde basin as described in Justice et al. (2017). Similarly, we used the water temperature/survival relationship for rainbow trout described in Bear et al. (2007) to develop a temperature HSI curve for juvenile steelhead (Figure 4). Although dissolved oxygen (DO) was not measured during our field surveys, we attempted to account for the effect of DO on suitability of refuge habitat for salmonids by applying a DO scalar based on data from Ebersole et al. (2003). Ebsersole et al. (2003) found that 91 % of cold-water refuges surveyed in the Upper Grande Ronde Basin had suitable DO levels (i.e., DO > 3 ppm). Thus, we multiplied all WUA estimates by 0.91 to account for potential negative effect of low DO on habitat suitability.

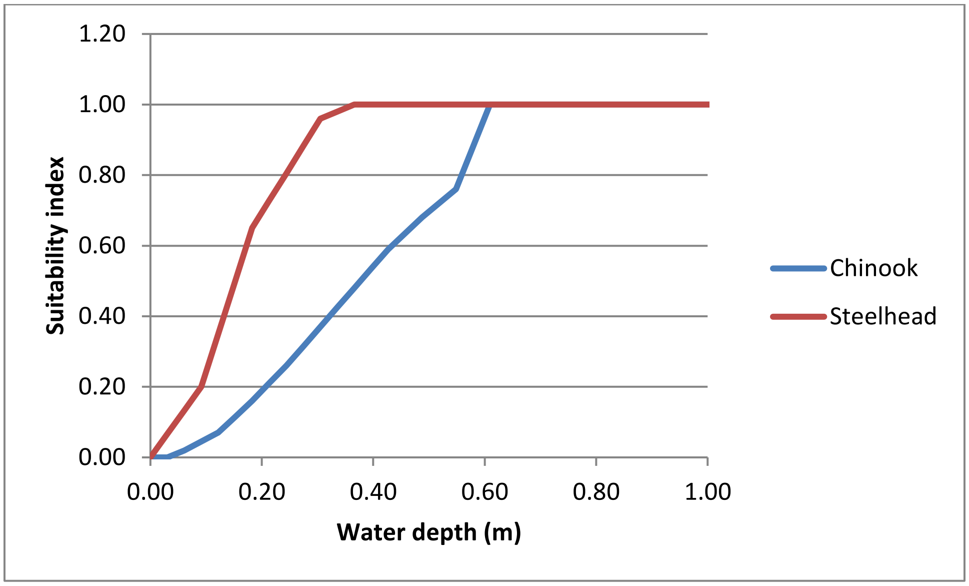


Figure 2. Water depth suitability index curves for juvenile Chinook Salmon and steelhead from Maret at al. (2006).

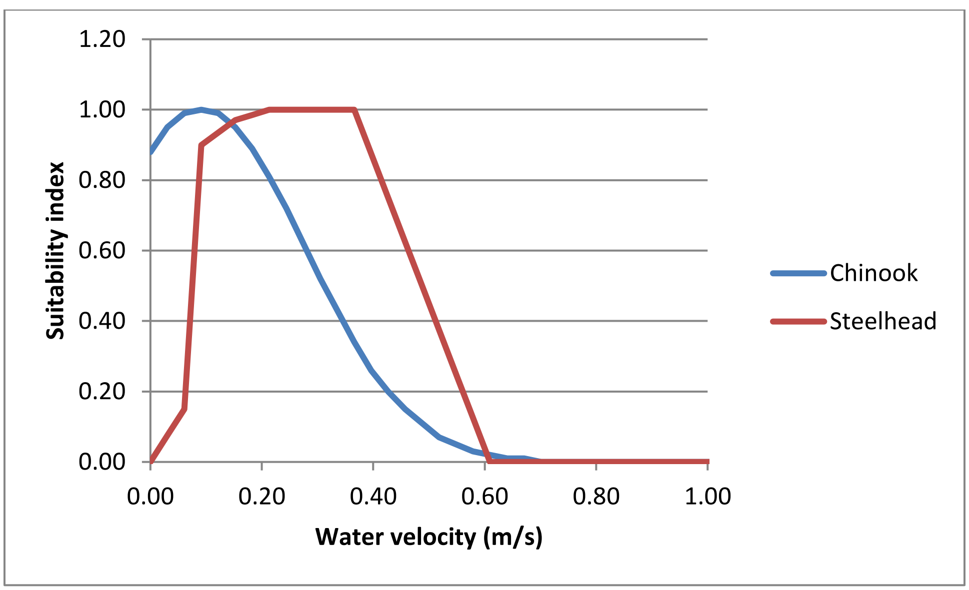


Figure 3. Water velocity suitability index curves for juvenile Chinook Salmon and steelhead from Maret at al. (2006).

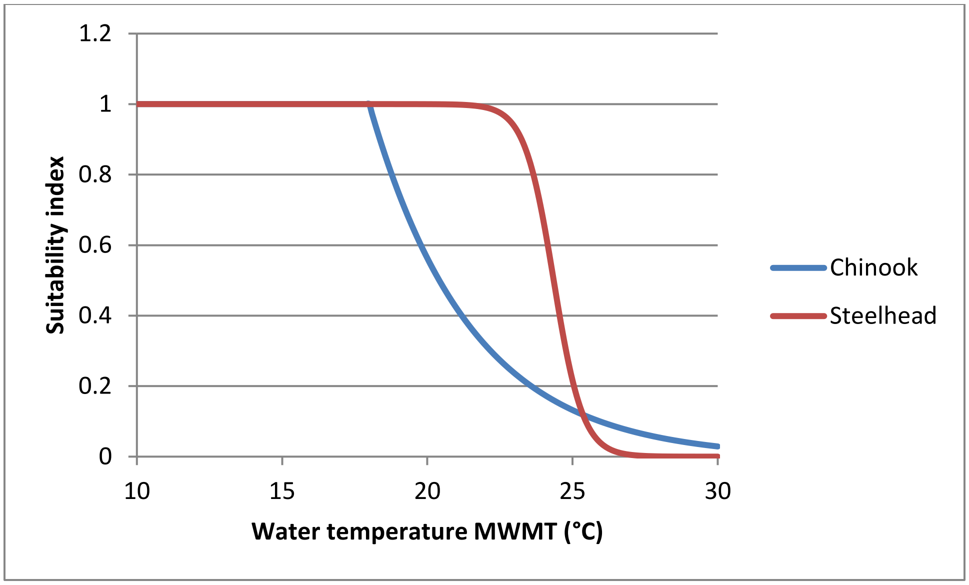


Figure 4. Water temperature suitability index curves for juvenile Chinook Salmon and steelhead from Justice et al. (2017) (Chinook) and Bear et al. (2007) (steelhead).

Field surveys were conducted for a relatively small subsample of the total number of cold-water refuges identified from the FLIR data. To estimate the total amount of refuge habitat present within the entire Upper Grande Ronde Chinook population area, we needed to account for potential refuge habitat that was not surveyed in the field. Specifically, we needed to estimate two things: 1) the area of unsurveyed refuge habitat identified from FLIR that was qualifying (i.e., met the minimum size and temperature criteria described above; termed "unsurveyed qualifying-previously identified"); and 2) the area of qualifying unsurveyed refuge habitat that was new (i.e., unsurveyed refuges that were newly created since 2010 or were not measurable in the 2010 FLIR data; termed "unsurveyed qualifying-new"). To calculate the first, we multiplied the total area of unsurveyed refuges identified from FLIR by the fraction of surveyed refuges identified from FLIR that were qualifying (0.59). To calculate the second, we multiplied the total area of unsurveyed refuges identified from FLIR by the ratio of new to previously-identified refuges (0.37). Finally, total qualifying refuge area was calculated by summing the surface area of surveyed qualifying refuges, unsurveyed qualifying-previously identified refuges, and unsurveyed qualifying-new refuges.

We used a similar method to estimate WUA for Chinook and steelhead in unsurveyed refuges. Specifically, WUA in unsurveyed refuges was calculated by multiplying the fraction of WUA in surveyed qualifying refuges out of the total surveyed qualifying refuge area by the estimated total unsurveyed qualifying refuge area. Thus, we assumed that the proportion of qualifying refuge habitat that was usable for fish would remain constant for the refuge habitat that was not surveyed in the field. Finally, we calculated total WUA by summing the WUA in surveyed and unsurveyed refuges.

We predicted rearing capacity of juvenile Chinook Salmon and steelhead within cold-water refuges by multiplying WUA in each refuge by the 95th percentile of the fish density values computed from channel

unit-scale snorkel survey data collected in the Upper Grande Ronde River between 2011 and 2015 (data downloaded from the ODFW/CRITFC snorkel database on March 10, 2016; data distributed by Chris Horn, ODFW, La Grande Fish Research). Fish density values for Chinook Salmon and steelhead used to estimate capacity were 1.6 and 1.1 fish/m^2 respectively.

To understand the potential contribution of cold-water refuges to the overall Chinook Salmon population in terms of fish capacity, we calculated the percentage of the total fish capacity for the population that came from refuges. To do this, we first estimated total population-level Chinook Salmon summer parr capacity using a Beverton-Holt stock recruitment function fit to the spawner and summer parr data estimated by ODFW (Brian Jonasson, La Grande Fish Research, distributed on Feb 2, 2016; Figure 5). These data included brood years 1992-1993, 2006, 2008-2013. Missing brood years were due to insufficient sample size required to estimate summer parr abundance. A detailed description of sampling and estimation methods for spawner abundance is provided in Feldhaus et al. (2017), while summer parr abundance estimation methods are described in Jonasson et al. (2015). To estimate the percentage of Chinook Salmon parr capacity from refuges, we simply divided the estimated parr capacity in refuges by the total population capacity and multiplied by 100. No attempt was made to estimate the percentage of juvenile steelhead capacity from refuges because data on total steelhead spawner and summer juvenile abundance were not available.

Despite meeting the temperature and size criteria to qualify as a cold-water refuge, many of the refuges we observed in the field were completely isolated from the main channel (i.e., refuges were not connected by flowing water to the main channel) and did not contain salmonids. It’s likely that these isolated refuges would provide a less meaningful contribution to the overall population because fish residing in isolated refuges may have a reduced ability to avoid predators and access food resources in the main channel (Brewitt et al. 2017), and because dissolved oxygen concentrations in isolated refuges may be lower due to the lack of surface flow inputs. To account for this, and to provide a more conservative and probably more accurate assessment of the overall contribution of refuge habitat to the salmonid populations, we also calculated total refuge area, WUA, and parr capacity for only those refuges that contained salmonids and that had a refuge crest depth greater than 0.05 m, a depth we assumed represented a significant barrier to movement of juvenile and adult salmonids. Owing to their much larger size and apparent accessibility to salmonids as determined from evaluation of the FLIR data, we assumed that all segment-scale refuges met these criteria of having salmonids present and crest depths > 0.05 m.

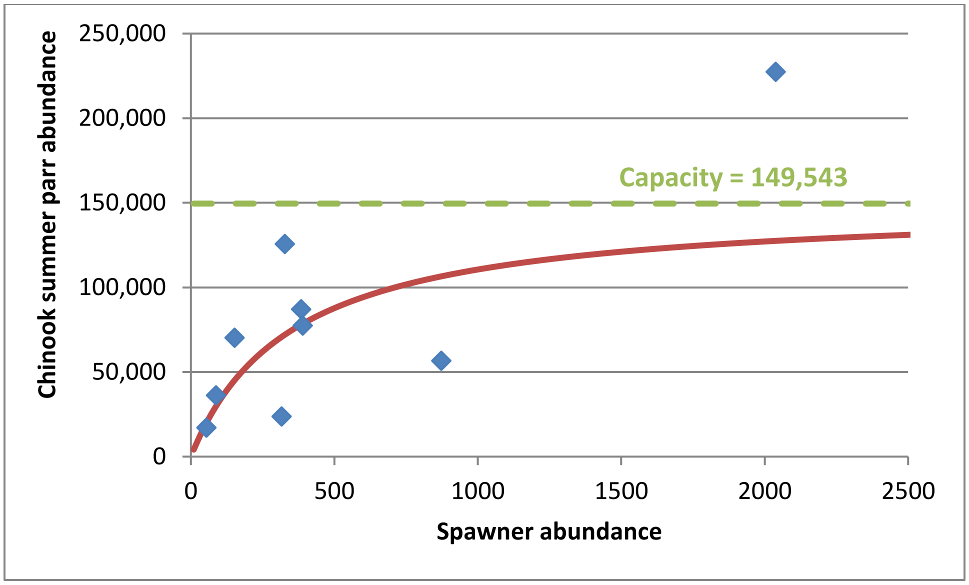


Figure 5. Relationship between spawner abundance and Chinook Salmon summer parr abundance in the Upper Grande Ronde River, brood years 1992-2013. The red line represents a Beverton-Holt curve fit to the data, and the green dashed line represents the estimated parr capacity as determined from the Beverton-Holt function.

Results and Discussion

A total of 322 channel unit-scale and 10 segment-scale cold-water refuges were identified in the Upper Grande Ronde basin using the 2010 FLIR data, totaling 18,357 m^2 of potential refuge habitat (Table 2). Of these, 97 refuges were surveyed in the field during the summer of 2015, with 48 determined to be non-qualifying and 49 qualifying. An additional 50 new refuges were surveyed in 2015 that were not present in the 2010 FLIR data.

Of the 99 qualifying cold-water refuges that were surveyed in the field, the majority (56.5 % by area) were classified as cold side channels (Table 3). Springbrooks were the second most common refuge type in terms of refuge area (12.3 %), followed closely by tributary confluence plumes (11.8 %). Lateral seeps represented the smallest percentage of total surveyed refuge area (3.8 %). The percentage of WUA for juvenile Chinook Salmon by refuge type closely followed the percentages by surface area (Table 3). However, the WUA results for juvenile steelhead showed a significant divergence from the aerial percentage of available refuge habitat (Table 3). For example, tributary confluence plumes represented the highest WUA for steelhead (55.8 %), but this refuge type represented only 11.8 % of the available refuge habitat. The disproportionately high WUA for steelhead in tributary confluence plumes is likely the result of higher water velocities in these refuge types (Table 4), and steelhead's corresponding preference for higher velocity habitats (Figure 3). Examples of the different refuge types surveyed in the field including photographs and descriptive information are provided in Appendix 1.

Salmonids were present in approximately 61.6 % (by area) of the cold-water refuges that were surveyed (Table 5). Approximately 24.9 % of the refuges did not have salmonids present, and salmonid presence could not be determined in the remaining 13.5 % due to poor visibility. As expected, weighted usable area for Chinook Salmon and steelhead was highest in cold-water refuges with salmonids present. For

example, refuges with salmonids present accounted for approximately 60 % of the Chinook WUA and 89.4 % of the steelhead WUA (Table 5). Similarly, refuges that contained Chinook Salmon only accounted for the largest percentage of WUA for Chinook (34.1 % of the total WUA), while refuges that contained steelhead accounted for the largest percentage of WUA for steelhead (63.1 %). These intuitive results lend some credibility to the habitat suitability index curves that were used to predict WUA.

Table 2. Number and surface area (m²) of cold-water refuges identified from Forward Looking Infrared (FLIR) and field surveys in the Upper Grande Ronde River basin by refuge scale (channel unit or segment)

			Percentage	
Refuge status	Count	Area (m²)	By count	By area
Channel unit-scale refuges				
Non-qualifying	48	2132	12.9	17.4
Not surveyed	225	5038	60.5	41.2
Qualifying-new	50	1922	13.4	15.7
Qualifying-previously identified	49	3132	13.2	25.6
Subtotal	372	12224	100.0	100.0
Segment-scale refuges				
Not surveyed	10	8055		
Total	382	20279		

Table 3. Surface area and weighted usable area (WUA) of channel unit-scale cold-water refuges surveyed in the field in 2015 by refuge type.

			Percentage		Chinook		Steelhead	
Refuge type	Count	Area (m²)	By count	By area	WUA	%	WUA	%
Cold alcove	11	338	11.1	6.7	174	6.6	52	10.4
Cold side channel	41	2858	41.4	56.5	1427	54.0	32	6.3
Hyporheic upwelling	17	445	17.2	8.8	289	10.9	65	13.0
Lateral seep	14	191	14.1	3.8	44	1.7	29	5.8
Springbrook	3	624	3.0	12.3	456	17.2	44	8.7
Tributary confluence plume	13	598	13.1	11.8	253	9.6	281	55.8
Total	99	5054	100.0	100.0	2643	100.0	503	100.0

Table 4. Mean depth, velocity, and temperature in channel unit-scale cold-water refuges by refuge type.

Refuge Type	Count	Mean refuge depth (m)	Mean refuge velocity (m/s)	Mean refuge bottom temperature (°C)
Cold alcove	11	0.30	0.014	19.2
Cold side channel	41	0.27	0.002	17.4
Hyporheic upwelling	17	0.35	0.012	17.0
Lateral seep	14	0.12	0.018	16.9
Springbrook	3	0.31	0.033	12.8
Tributary confluence plume	13	0.20	0.108	17.5
Total	99	0.26	0.022	17.4

Table 5. Salmonid presence/absence in channel unit-scale cold-water refuges.

			Percentage		Chinook		Steelhead	
Salmonids present	Count	Area (m²)	By count	By area	WUA	%	WUA	%
No	42	1258	42.4	24.9	638	24.1	26	5.2
Unknown	17	681	17.2	13.5	421	15.9	27	5.5
Yes	40	3115	40.4	61.6	1584	60.0	449	89.4
Chinook only	13	1489	13.1	29.5	900	34.1	119	23.7
Steelhead only	21	974	21.2	19.3	468	17.7	317	63.1
Chinook & Steelhead	4	581	4.0	11.5	187	7.1	13	2.5
Unknown	2	71	2.0	1.4	29	1.1	0	0.0
Total	99	5054	100.0	100.0	2643	100.0	503	100.0

Mean refuge bottom temperatures ranged from 9.7 to 23.3 °C (mean = 17.4 °C), while adjacent ambient temperatures ranged from 16.2 to 29.1 °C (mean = 23.2 °C) (Table 6). On average, refuges were 5.8 °C cooler than the ambient water temperature, with temperature differences between ambient and refuges reaching as high as 12.7 °C. This is a significant difference in terms of salmonid temperature tolerance limits. For example, in portions of the Grande Ronde River where temperatures reach 25 °C, the approximate upper incipient lethal limit for Chinook Salmon, cold-water refuges may have temperatures in the 19-20 °C range, and in some cases much cooler. While temperatures in this range are not optimal for salmonid rearing, they could potentially allow fish to survive through the warmest periods of the summer.

Vertical stratification of water temperatures within refuges (i.e., the difference between the surface and bottom water temperature) was generally low, but was quite high in some rare instances. The mean vertical temperature difference (surface – bottom) ranged from 0 to 10.7 °C (mean = 1.4 °C; Table 6) and tended to be highest in cold alcoves and lowest in springbrooks. The majority of refuges (75 %) had vertical temperature differences less than 1.9 °C.

A comparison of hourly water temperatures from July 23 to August 30 measured in 15 cold-water refuges and adjacent ambient mainstem sites showed consistently lower water temperatures in refuges compared with ambient locations (Figures 6 and 7). With the exception of the average daily minimum, all temperature metrics computed from the hourly temperature measurements were significantly lower in refuges compared with ambient mainstem locations ($p < 0.001$; Table 7). In addition, the daily temperature range in refuges varied considerably across sites. For example, water temperatures in some refuges were almost constant throughout the measurement period, with daily ranges as low as 0.1 °C (Figure 7, 119), while daily ranges were considerably higher (up to 7 °C) at other refuges. The magnitude of variation in hourly refuge temperatures at refuges did not appear to be consistently related to refuge type (i.e., cold alcove, cold side channel, tributary confluence plume).

With the exception of having cooler water temperatures than the ambient mainstem channel, physical habitat conditions for salmonids were generally poor among the 99 cold-water refuges surveyed in 2015. The majority of refuges (75 %) had water depths less than 0.3 meters (Table 6). According to the depth suitability curve from Maret et al. (2006) (Figure 2), a depth of 0.3 m is suboptimal for rearing juvenile Chinook Salmon, while depths above 0.6 meters are preferred. Similarly, water velocities in refuges were very low, averaging 0 m/s, with the majority of refuges (75 %) having velocities below 0.1 m/s. Slow flowing water is most problematic for juvenile steelhead according to the velocity suitability index curves from Maret et al. (2006) (Figure 3), although flowing water is critically important for most riverine fish species and stream ecosystems in general because it delivers food resources and nutrients from upstream, increases dissolved oxygen levels, and controls the distribution of substrate particles on the stream bottom, among other things.

Refuge crest depth, which indicates the minimum depth that fish would encounter along the flow path between the refuge and the main channel, ranged from 0 to 0.5 m (mean = 0.1 m). Approximately 68 % of the surveyed refuges had refuge crest depths < 0.05 m, and 31 % of refuges had a crest depth of 0, meaning they were completely isolated from the main channel. While some fish may be able to survive for limited periods of time in isolated refuge habitats, the lack of connectivity to the main channel presents a host of challenges for salmonids including limited ability to access food resources in the main channel (Brewitt et al. 2017), reduced dissolved oxygen concentration, and reduced ability to avoid predators.

Fine sediment (< 2 mm) concentrations on the stream bottom was moderate to high in cold-water refuges, with fine sediment levels averaging 37 % and ranging as high as 100 % (Table 6). In a study of fine sediment impacts on rearing juvenile salmonids in a northern California river, Suttle et al. (2004) found that increasing concentrations of fine sediment impaired growth and survival of juvenile steelhead trout and reduced macroinvertebrate prey availability. In addition, they found no threshold level of fine sediment below which fine-sediment had no effect on salmonid growth and survival. Fine sediment concentrations tended to be highest in isolated refuges with little or no streamflow and lowest in refuges that were in or directly adjacent to the main channel, such as tributary confluence plumes.

Table 6. Physical habitat characteristics measured at 99 channel unit-scale cold-water refuges in the Upper Grande Ronde River basin during the summer of 2015.

				Percentile		
Habitat metric	min	max	mean	25th	50th	75th
Refuge surface area (m²)	1.9	502.0	51.0	9.2	23.8	49.9
Mean refuge depth (m)	0.0	0.9	0.3	0.1	0.2	0.3
Max refuge depth (m)	0.1	1.1	0.4	0.3	0.4	0.5
Mean water velocity (m/s)	0.0	0.3	0.0	0.0	0.0	0.1
Mean refuge bottom temperature (°C)	9.7	23.3	17.4	15.6	17.1	19.3
Mean refuge surface temperature (°C)	9.8	25.3	18.7	16.3	18.8	21.5
Mean refuge vertical temp. diff. (°C) (surface - bottom)	0.0	10.7	1.4	0.2	0.9	1.9
Min refuge temperature (°C)	10.0	22.3	15.5	13.4	15.5	17.4
Ambient temperature (°C)	16.2	29.1	23.2	21.2	23.4	25.3
Mean temp. diff. (ambient - mean refuge bottom)	0.8	12.7	5.8	3.8	5.5	7.3
Max temp. diff. (ambient - min refuge)	2.1	15.4	7.7	5.2	7.1	9.8
Refuge crest depth (m)	0.0	0.5	0.1	0.0	0.1	0.1
Distance to main channel (m)	0.0	100.0	11.9	0.0	1.0	9.5
Sand and fines < 2 mm (%)	0.0	100.0	37.3	15.0	30.0	60.0
Solar access (%)	12.0	100.0	66.5	45.5	72.0	91.0
Total fish cover (%)	0.0	125.0	53.8	20.8	50.2	85.0
Boulders (%)	0.0	30.0	3.0	0.0	0.0	5.0
Aquatic vegetation (%)	0.0	100.0	34.7	0.0	15.0	72.5
Overhanging vegetation (%)	0.0	75.0	7.4	0.0	5.0	10.0
Woody debris (%)	0.0	65.0	6.7	0.0	0.0	5.0
Artificial structures (%)	0.0	5.0	0.1	0.0	0.0	0.0
Undercut banks (%)	0.0	43.7	1.8	0.0	0.0	0.5

Table 7. Summary statistics of hourly temperature data collected between July 23 and August 30, 2015 at 15 paired refuge and ambient river locations.

	Ambient			Refuge			Difference (Ambient - Refuge)		
Metric	Min	Max	Avg.	Min	Max	Avg.	Avg.	t Stat	p-value
AvgDailyMax	21.4	25.5	24.0	11.5	21.1	16.9	7.1	13.0	1.6E-09
AvgDailyMin	12.4	15.5	13.8	9.3	15.7	13.2	0.7	1.8	0.09*
AvgDailyAvg	16.9	20.2	18.7	11.4	17.4	14.9	3.7	9.0	1.6E-07
AvgDailyRange	8.5	11.6	10.2	0.1	7.0	3.7	6.5	14.3	4.7E-10
MWMT	23.5	28.4	26.5	11.8	22.3	18.0	8.5	13.4	1.1E-09
PctDaysOver18	94.9	100.0	97.3	0.0	97.4	44.8	52.5	4.9	1.1E-04
PctDaysOver20	79.5	97.4	92.5	0.0	84.6	16.8	75.7	12.2	3.8E-09
PctDaysOver25	2.6	64.1	39.5	0.0	0.0	0.0	39.5	7.1	2.6E-06

* Based on two-tailed critical t value; all other tests based on one-tailed critical t value.

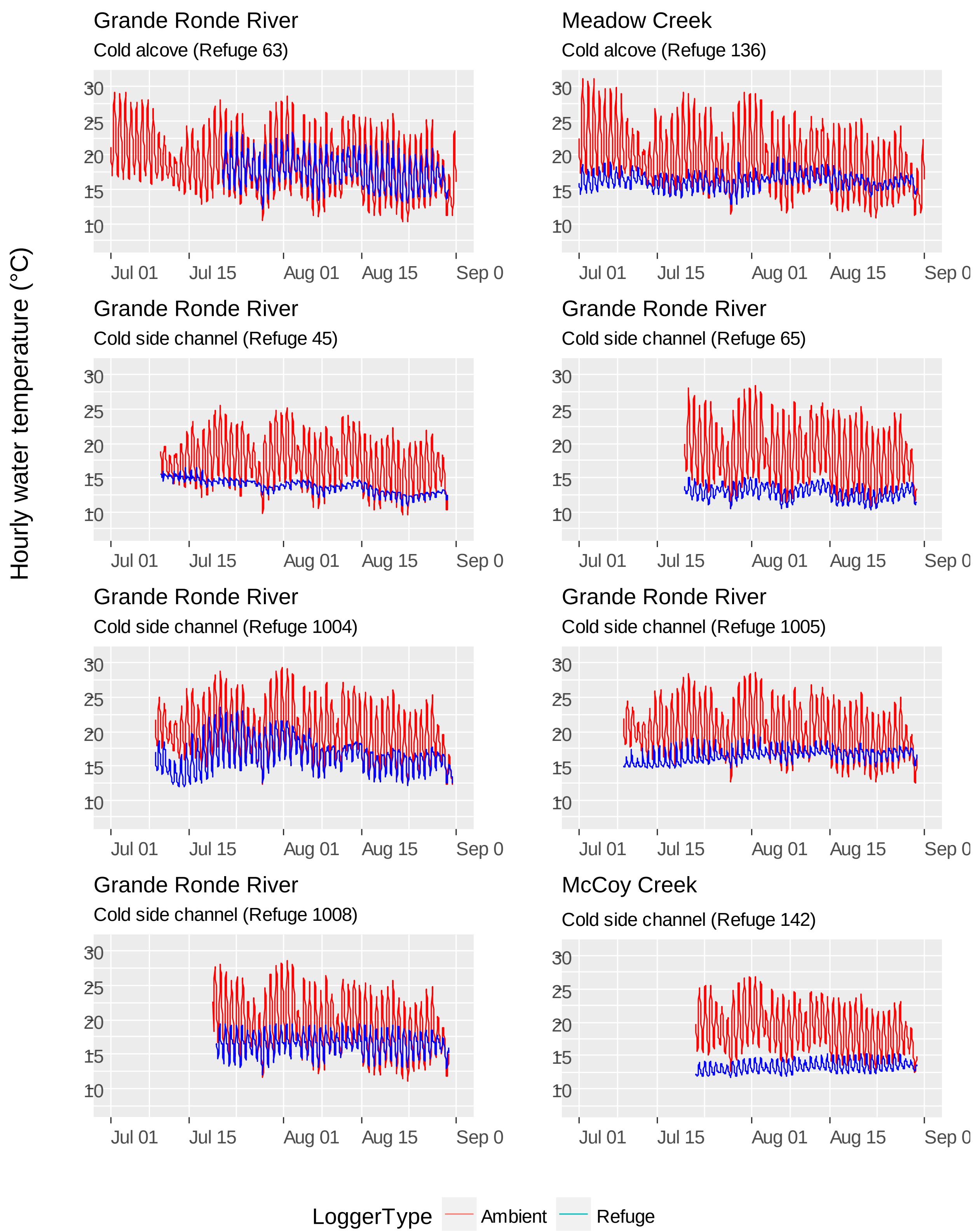


Figure 6. Hourly water temperature in 15 cold-water refuges and adjacent ambient mainstem sites in the Upper Grande Ronde River basin.

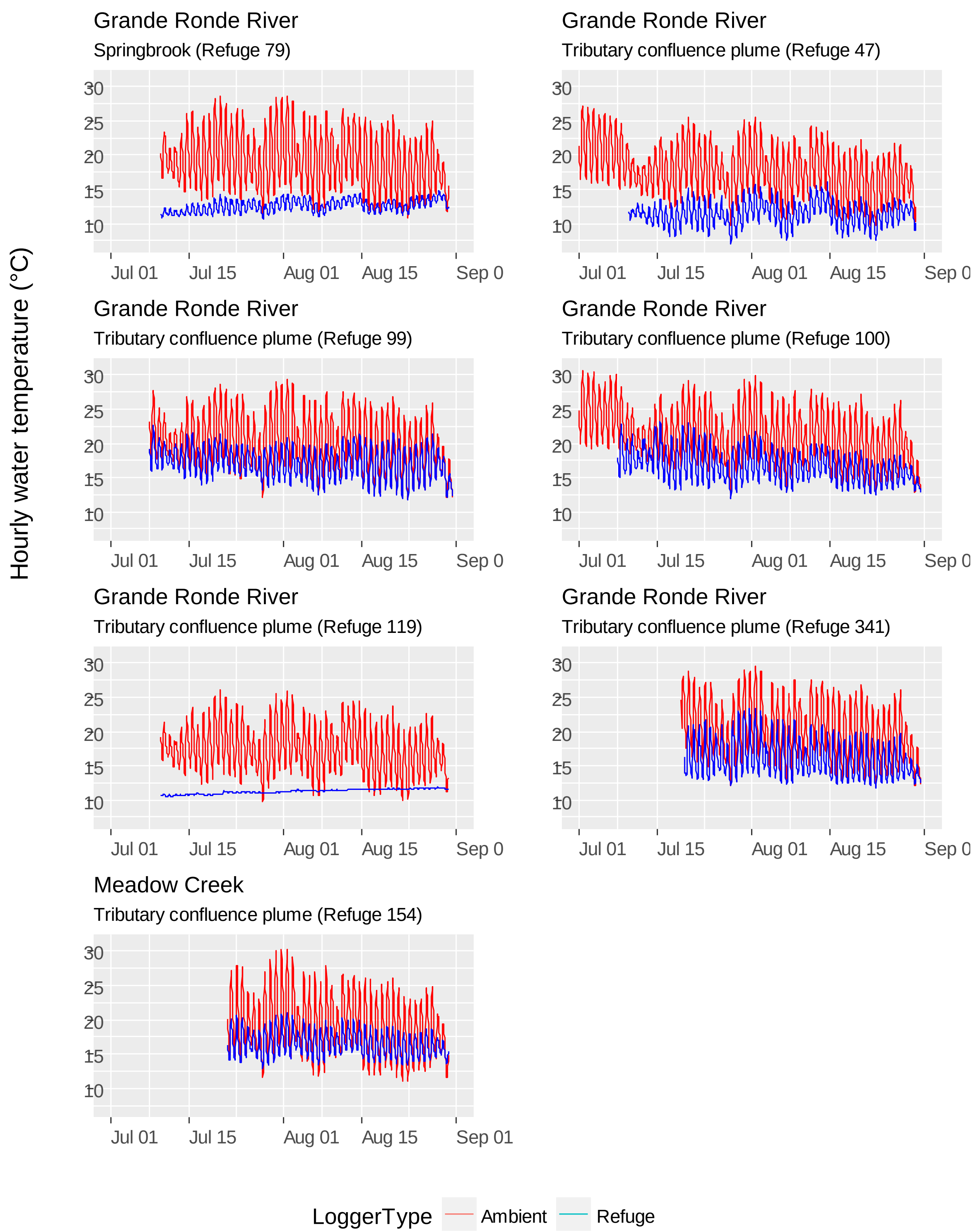


Figure 7. Hourly water temperature in 15 cold-water refuges and adjacent ambient mainstem sites in the Upper Grande Ronde River basin.

Solar access, or the percentage of solar radiation that reached the stream surface, ranged from 12 to 100 % (mean = 66.5 %) (Table 6). The complement of solar access is effective shade (i.e., effective shade = 100 – solar access). Thus, cold-water refuges averaged only 33.5 % shade, which is low compared with the more densely forested upper portions of the Grande Ronde River basin where effective shade typically ranged from 50-75 % (Watershed Sciences 2012). Higher levels of shade at refuge locations would be desirable to improve and maintain thermal benefits to fish, provide cover from avian predators, and provide a source of terrestrial invertebrate prey to fish.

Total fish cover in cold-water refuges ranged from 0 to 125 % (mean = 53.8 %) (Table 6). Values exceeding 100 % were due to overlapping cover elements (e.g., woody debris overlapped by overhanging vegetation. While an average cover value of 53.8 % sounds pretty good from a fish's perspective, the vast majority of this cover was attributed to aquatic vegetation (i.e., 34.7 % of the total cover). In some cases, aquatic vegetation provides useful cover to fish. However, in many cases, aquatic vegetation in largely composed of filamentous algae and other types of blue-green algae, which are often an indicator of impaired river conditions including low stream flow, high amounts of solar radiation, and in some cases, high nutrient inputs. If we consider only those cover elements that are most beneficial to juvenile salmonids (i.e., boulders, overhanging vegetation, woody debris, and undercut banks), then fish cover in refuges would average approximately 18.9 %. While not insignificant, this level of cover could be improved at refuges in order to provide additional shade and cover from predators.

Cold-water refuge area across the entire Upper Grande Ronde Chinook distribution area totaled 17,945 m², of which 9,890 (55 %) came from channel unit-scale refuges and 8,055 m² (45 %) came from segment-scale refuges (Table 8). Weighted usable area (WUA) for juvenile Chinook Salmon in refuges was estimated at 9,384 m², with the majority (55 %) coming from channel unit-scale refuges. Steelhead WUA totaled 1,785 m², with 55 % coming from channel unit-scale refuges. We estimated that channel unit- and segment-scale refuges combined could support a maximum capacity of 14,891 Chinook Salmon parr and 1,980 juvenile steelhead. The considerably higher predicted capacity for Chinook Salmon compared with steelhead in refuges was due primarily to very slow water velocities in most refuges and steelhead's comparatively lower preference for low-velocity habitat (Figure 3). Chinook Salmon capacity in refuges represented approximately 10 % of the total estimated Chinook Salmon parr capacity for the Upper Grande Ronde population, with 5.5 % coming from channel unit-scale refuges, and 4.5 % coming from segment-scale refuges.

Total area of cold-water refuges with salmonids present and having refuge crest depths > 0.05 m was estimated at 10,552 m² (Table 8). Chinook Salmon and steelhead WUA in these refuges totaled 5,313 and 1,468 m², respectively. Predicted Chinook parr capacity in these refuges was 8,431, while juvenile steelhead capacity totaled 1,628. Overall, these non-isolated refuge habitats accounted for approximately 5.6 % of the total Chinook Salmon parr capacity in the Upper Grande Ronde basin.

Cold-water refuge habitat was most abundant in biologically significant reach (BSR) UGR13 (Meadow Creek; Table 9), which contained approximately 4,747 m² of total refuge habitat, 2,675 m² of WUA for Chinook, and 480 m² of WUA for steelhead. Reaches UGR11 (mainstem Grande Ronde River between

Meadow Creek and Five Points Creek), and UGR16 (Fly Creek) contained the second and third most refuge habitat, with refuge area totaling 3,916 and 3,023 m², respectively. Reaches UGR14 (Beaver Creek) and UGR12 (Rock Creek and Spring Creek) also contained a substantial amount of cold-water refuge habitat (total refuge area = 2,932 and 1,507 m², respectively). These top five BSRs were predicted to contribute approximately 9 % of the total Chinook Salmon parr capacity for the Upper Grande Ronde basin. Detailed maps showing the locations of cold-water refuges within each of the Upper Grande Ronde BSRs is provided in Appendix 2.

After filtering out refuges that didn't contain salmonids and had refuge crest depths < 0.05 m, UGR16 was estimated to contain the largest amount of cold-water refuge habitat among all of the Upper Grande Ronde BSRs (total refuge area = 2,751 m²; Table 8). Reaches UGR13 and UGR14 (Beaver Creek) contained the next highest refuge area (total refuge area = 2,384 and 2271 m², respectively), followed by UGR11 (refuge area = 1,656 m²) and UGR12 (refuge area = 924 m²). These five BSRs contributed to approximately 5.4 % of the total Chinook Salmon parr capacity.

All supporting data referenced in this report is available upon request from CRITFC including FLIR data, ArcGIS files showing delineated cold-water refuge boundaries and midpoint locations, field survey data, and analysis files. In addition, we've provided basic information for all qualifying refuges such as refuge ID, type, status, and location in Appendix 3.

Table 8. Total refuge area, weighted usable area (WUA) and capacity for Chinook Salmon parr and juvenile steelhead in refuges, and percentage of total Chinook parr capacity from refuges for channel unit-scale refuges, segment-scale refuges, and all refuges combined. Results are shown for all qualifying refuges and for refuges limited to those with salmonids present and having refuge crest depth > 0.05m.

Refuge area and fish capacity estimates	Channel unit-scale refuges	Segment-scale refuges	All Refuges
All qualifying refuges			
Total refuge area (m²)	9890	8055	17945
WUA Chinook (m²)	5172	4212	9384
WUA steelhead (m²)	984	801	1785
Chinook parr capacity	8207	6684	14891
Steelhead juvenile capacity	1091	889	1980
Percentage of total population Chinook parr capacity	5.5	4.5	10.0
Refuges with salmonids present and refuge crest depth > 0.05 m			
Total refuge area (m²)	2497	8055	10552
WUA Chinook (m²)	1101	4212	5313
WUA steelhead (m²)	667	801	1468
Chinook parr capacity	1747	6684	8431
Steelhead juvenile capacity	739	889	1628
Percentage of total population Chinook parr capacity	1.2	4.5	5.6

Note: All segment-scale refuges were assumed to have salmonids present and refuge crest depths > 0.05 m.

Table 9. Total refuge area, weighted usable area (WUA) and capacity for Chinook Salmon parr and juvenile steelhead in refuges, and percentage of total Chinook parr capacity from refuges grouped by biologically significant reach (BSR). Results are shown for all qualifying refuges and for refuges limited to those with salmonids present and having refuge crest depth > 0.05m.

BSR	Refuge area (m²)	WUA Chinook (m²)	WUA Steelhead (m²)	Chinook parr capacity	Steelhead parr capacity	% of total Chinook capacity
All qualifying refuges						
UGR13	4747	2675	480	4244	532	2.8
UGR11	3916	1919	367	3046	408	2.0
UGR16	3023	1574	307	2497	340	1.7
UGR14	2932	1533	288	2433	320	1.6
UGR12	1507	810	121	1285	134	0.9
UGR10	716	374	71	594	79	0.4
UGR15	467	182	85	288	95	0.2
UGR9	285	134	31	213	34	0.1
UGR7	151	79	15	126	17	0.1
UGR19	121	64	12	101	13	0.1
UGR17	66	34	7	55	7	0.0
UGR20	12	6	1	10	1	0.0
Total	17945	9384	1785	14891	1980	10.0
Refuges with salmonids present and refuge crest depth > 0.05 m						
UGR16	2751	1432	287	2273	318	1.5
UGR13	2384	1205	338	1912	375	1.3
UGR14	2271	1170	261	1857	290	1.2
UGR11	1656	793	316	1258	351	0.8
UGR12	924	480	105	762	117	0.5
UGR15	203	86	66	137	73	0.1
UGR10	181	80	48	126	54	0.1
UGR9	94	29	23	45	25	0.0
UGR7	38	17	10	27	11	0.0
UGR19	31	14	8	21	9	0.0
UGR17	17	7	4	12	5	0.0
UGR20	3	1	1	2	1	0.0
Total	10552	5313	1468	8431	1628	5.6

Note: Data were sorted in descending order by Chinook parr capacity to aid in interpretation of the results.

Summary

This study provides a baseline summary of the quantity, spatial distribution, physical habitat conditions, and fish use of cold-water refuges in the Upper Grande Ronde River basin. Overall, we found that cold-water refuges were widespread throughout the Upper Grande Ronde River Chinook Salmon distribution area, with BSRs UGR13 (Meadow Creek), UGR11 (mainstem Grande Ronde River between Meadow Creek and Five Points Creek), and UGR16 (Fly Creek) containing the largest surface area of refuge

habitat. Of the various refuge types, cold side channels were by far the most abundant. Despite having significantly cooler water temperatures than the ambient mainstem river, habitat conditions in cold-water refuges were generally poor, with the majority of refuges having shallow depths, very low water velocity, relatively little shade and cover for fish, and moderate to high levels of fine sediment. In addition, only 41 % of the total predicted cold-water refuge area contained salmonids and had refuge crest depths > 0.05 m, indicating that a large proportion of the refuges were isolated from the main channel during base flow conditions when water temperatures were at their peak. These isolated refuges could prevent fish from accessing much needed food resources in the main channel (Brewitt et al. 2017), and could exacerbate problems with predation and low dissolved oxygen. However, this study was conducted in 2015, when streamflow was at historically low levels throughout the Pacific Northwest region. It's likely that the quantity and connectivity of refuge habitats would change substantially under different baseflow conditions (Dugdale et al. 2013) and in response to restoration actions and natural channel change. As such, additional FLIR and field validation surveys in different flow years could be informative for improving our understanding of the distribution and frequency of cold-water refuge habitats in the Grande Ronde basin.

We predicted that cold-water refuges could support a maximum of 14,891 Chinook Salmon summer parr, and 1,980 juvenile steelhead. This represents approximately 10 % of the total estimated Chinook Salmon parr capacity for the Upper Grande Ronde Spring Chinook population. If we consider only refuges that were connected to the main channel (i.e., had refuge crest depths > 0.05 m) and contained salmonids, the predicted refuge capacity for Chinook parr and juvenile steelhead was 8,431 and 1,628, respectively. This equates to 5.6 % of the total Chinook Salmon parr capacity. These capacity estimates represent a model-based prediction of potential fish abundance in refuges based largely on literature-derived habitat suitability curves. These estimates could be improved in the future by obtaining empirical estimates of fish abundance in cold-water refuges, and/or by developing habitat suitability curves using in-basin empirical data. That said, these results represent a reasonable estimate of fish capacity in refuges using the best available data, and highlight the important contribution of cold-water refuges to the overall salmon and steelhead populations in the Upper Grande Ronde basin.

The relatively poor habitat conditions in cold-water refuges as well as their limited connectivity to the main channel indicate the need and opportunity for land owners and natural resource managers to improve these vital refuge habitats. Increasing riparian vegetation cover at refuge sites would be a cost-effective way to enhance the thermal benefits of cold-water refuges for fish, increase cover from avian predators, and possibly improve food resources for fish by increasing inputs of allochthonous organic matter and terrestrial invertebrates. Vegetation enhancement could also stabilize streambanks at refuge sites and potentially reduce fine sediment inputs to the stream channel. Many refuge habitats could also benefit from addition of large woody debris (LWD) and other instream cover elements for fish. While the connectivity or size of refuges could be directly improved by restoration practitioners using heavy machinery or other means (Kurylyk et al. 2014), such actions have the potential to disrupt hyporheic flow paths and other geomorphic process that created the refuges in the first place. As such, direct manipulation of cold-water refuge connectivity should be implemented with careful consideration of the geomorphic context and hyporheic/groundwater dynamics at the refuge. Alternatively, a more broad-

scale holistic approach to stream restoration which focusses on improving floodplain and hyporheic connectivity and fostering healthy riparian ecosystems throughout the stream network, should provide more abundant and more flow-connected refugia over the long term.

Given the threat that climate change and associated warming of rivers poses to fish populations in the Pacific Northwest (Beechie et al. 2013) and across North America (Lynch et al. 2016), cold-water refugia will play an increasingly important role in preserving the viability of threatened fish populations. These results provide managers with a baseline understanding of the spatial distribution, physical habitat characteristics, and potential fish use of cold-water refuges in the Upper Grande Ronde Basin than can be used to help direct future restoration priorities and other research questions.

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Appendix 1 – Examples of Refuge Types

Cold Alcoves

Grande Ronde River (refuge 65):

Refuge temp = 18.6 °C, ambient temp = 26.5 °C, significant Chinook use, slow flowing water, dense aquatic vegetation, good connection to main channel.

Grande Ronde River (refuge 1039):

Refuge temp = 20.8 °C, ambient temp = 25.1 °C, salmonid use unknown, slow flowing water, very low fish cover, good connection to main channel.

Meadow Creek (refuge 1015):

Refuge temp = 14.6 °C, ambient temp = 26.2 °C, few non-salmonids present, non-flowing water, dense aquatic vegetation, good connection to main channel.

Meadow Creek (refuge 130):

Refuge temp = 20.2 °C, ambient temp = 26 °C, several steelhead present, non-flowing water, low fish cover, good connection to main channel.

Figure A1 - 1. Examples of cold alcove refuges in the Upper Grande Ronde River basin, 2015.

Cold Side Channels

Grande Ronde River (refuge 1008):

Refuge temp = 18.7 °C, ambient temp = 21 °C, abundant Chinook, descent woody debris cover, flowing water, good gravel/cobble substrate, shallow connection to main channel.

Grande Ronde River (refuge 86):

Refuge temp = 22.9 °C, ambient temp = 27.8 °C, a few non-salmonids present, non-flowing water, dense algae cover, poor connection to main channel.

Meadow Creek (refuge 1013):

Refuge temp = 20.6 °C, ambient temp = 26.7 °C, few steelhead present, shallow depth, poor cover, non-flowing water, good connection to main channel.

McCoy Creek (refuge 1027):

Refuge temp = 17.6 °C, ambient temp = 24.4 °C, salmonid presence unknown, mostly pikeminnow, non-flowing water, dense algae cover, descent connection main channel.

Figure A1 - 2. Examples of cold side channel refuges in the Upper Grande Ronde River basin, 2015.

Hyporheic Upwellings

Fly Creek (refuge 123):

Refuge temp = 16.3 °C, ambient temp = 24.5 °C, few unknown salmonids present, non-flowing water, good fish cover, poor connection to main channel.

McCoy Creek (refuge 1030):

Refuge temp = 21.3 °C, ambient temp = 23.7 °C, salmonid presence unknown, dominated by pikeminnow, slow-flowing water, low fish cover, in main channel.

Meadow Creek (refuge 1034):

Refuge temp = 17.3 °C, ambient temp = 22.5 °C, steelhead present, low fish cover, slow-flowing water, in main channel.

Rock Creek (refuge 1040):

Refuge temp = 15.9 °C, ambient temp = 20.2 °C, steelhead present, non-flowing water, minimal cover, in main channel.

Figure A1 - 3. Examples of hyporheic upwelling refuges in the Upper Grande Ronde River basin, 2015.

Lateral Seeps

Grande Ronde River (refuge 39):

Refuge temp = 15.4 °C, ambient temp = 21.7 °C, one Chinook present, non-flowing water, low/moderate fish cover, poor connection to main channel.

Grande Ronde River (refuge 46):

Refuge temp = 16.4 °C, ambient temp = 21.3 °C, no fish present, very shallow, non-flowing water, low fish cover, descent connection to main channel.

Grande Ronde River (refuge 75):

Refuge temp = 21.7 °C, ambient temp = 26 °C, abundant Chinook, slow-moving water, moderate cover from grasses and aquatic veg, narrow patch along main channel margin.

Grande Ronde River (refuge 96):

Refuge temp = 23.3 °C, ambient temp = 28.9 °C, school of 30-40 steelhead present, slow-flowing water, dense algae cover, narrow patch along main channel margin.

Figure A1 - 4. Examples of lateral seep refuges in the Upper Grande Ronde River basin, 2015.

Springbrooks

Grande Ronde River (refuge 79):

Refuge temp = 14.3 °C, ambient temp = 18.8 °C, Chinook present but mostly pikeminnow, non-flowing water, muddy substrate, dense algae cover, poor connection to main channel.

Meadow Creek (refuge 126):

Refuge temp = 9.7 °C, ambient temp = 20.4 °C, steelhead present, very shallow, slow-flowing water, good overhanging veg cover, good connection to main channel.

Meadow Creek (refuge 149):

Refuge temp = 14.3 °C, ambient temp = 23.3 °C, Chinook present in low numbers, slow-moving water, dense algae cover, good connection to main channel at lower end.

Figure A1 - 5. Examples of springbrook refuges in the Upper Grande Ronde River basin, 2015.

Tributary Confluence Plumes

Unnamed tributary confluence with Grande Ronde River (refuge 47):
Refuge temp = 11.7 °C, ambient temp = 21.0 °C, abundant Chinook, slow-moving water, good fish cover, good connection to main channel, great example of ideal refuge habitat

Beaver Creek confluence with Grande Ronde River (refuge 73):
Refuge temp = 23.1 °C, ambient temp = 25.4 °C, no fish present, moderate velocity water, low fish cover, minimal thermal refuge.

Spring Creek confluence with Grande Ronde River (refuge 99):
Refuge temp = 21.8 °C, ambient temp = 27.9 °C, steelhead present, slow-flowing water, minimal fish cover.

Dark Canyon Creek confluence with Meadow Creek (refuge 154):
Refuge temp = 19.6 °C, ambient temp = 25.4 °C, abundant Chinook and steelhead, some cover from boulders.

Figure A1 - 6. Examples of tributary confluence plume refuges in the Upper Grande Ronde River basin, 2015.

Appendix 2 – Maps of Refuges by Biologically Significant Reach (BSR)

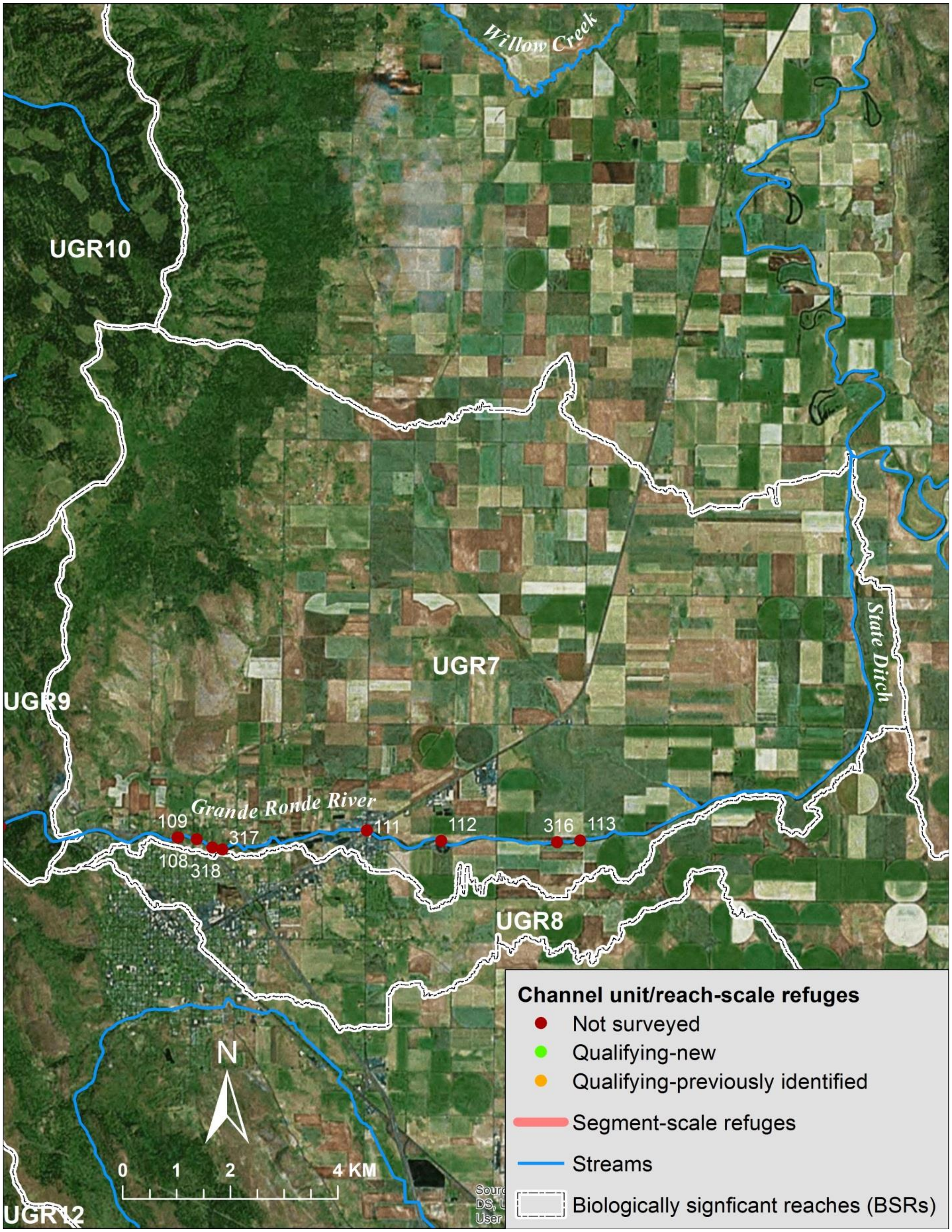

Figure A2 - 1. Map of cold-water refuges identified in biologically significant reach (BSR) UGR7.

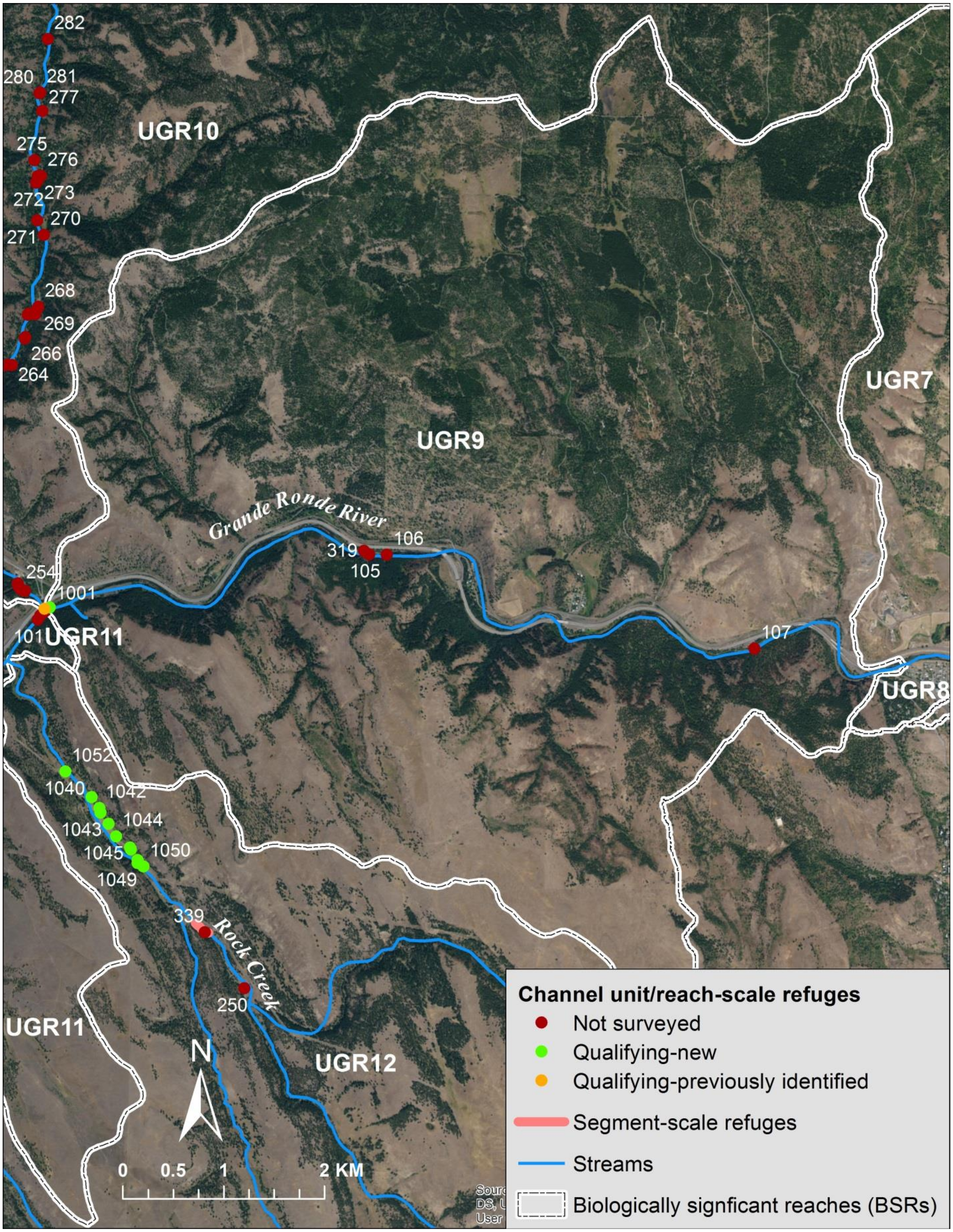

Figure A2 - 2. Map of cold-water refuges identified in biologically significant reach (BSR) UGR9.

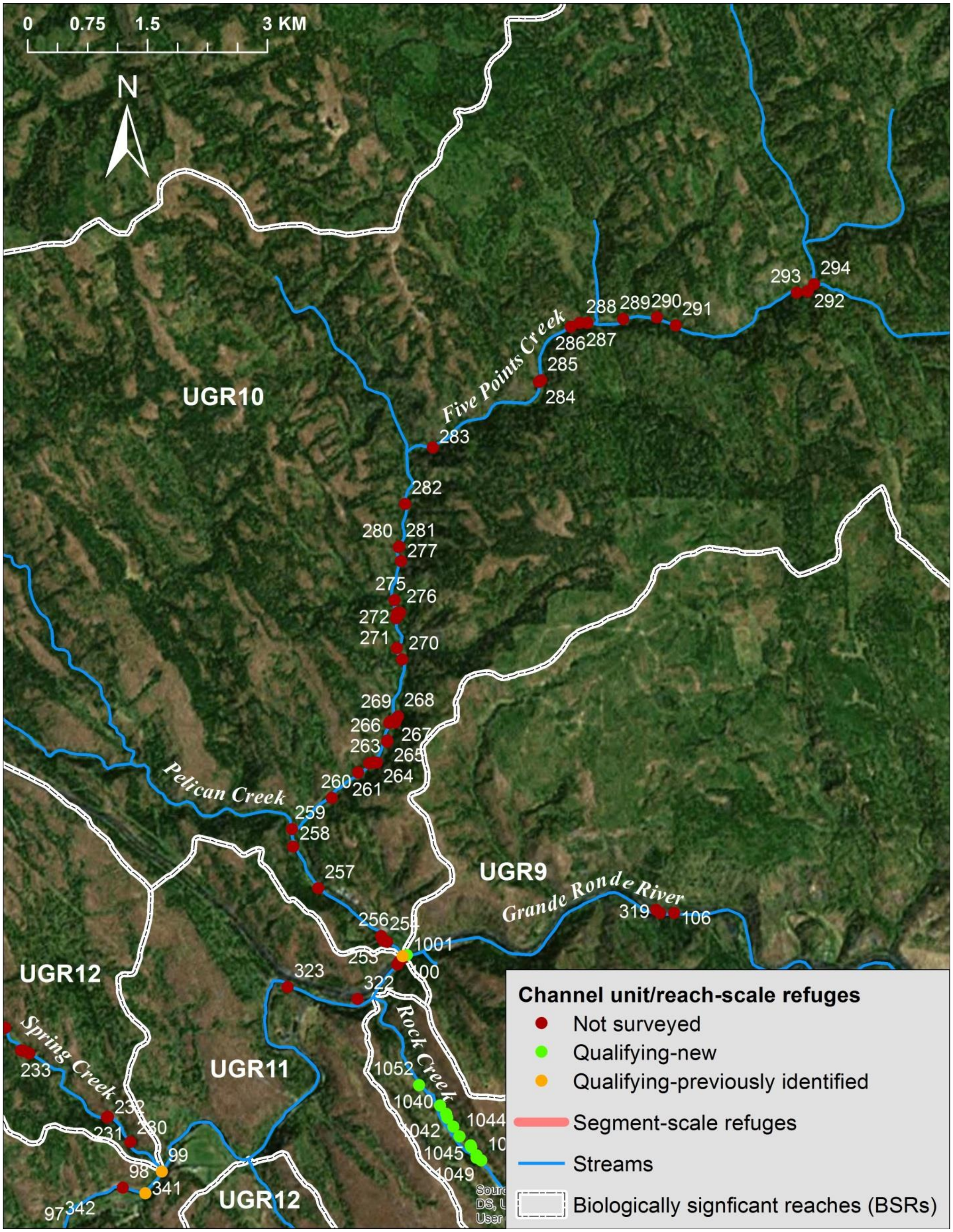

Figure A2 - 3. Map of cold-water refuges identified in biologically significant reach (BSR) UGR10.

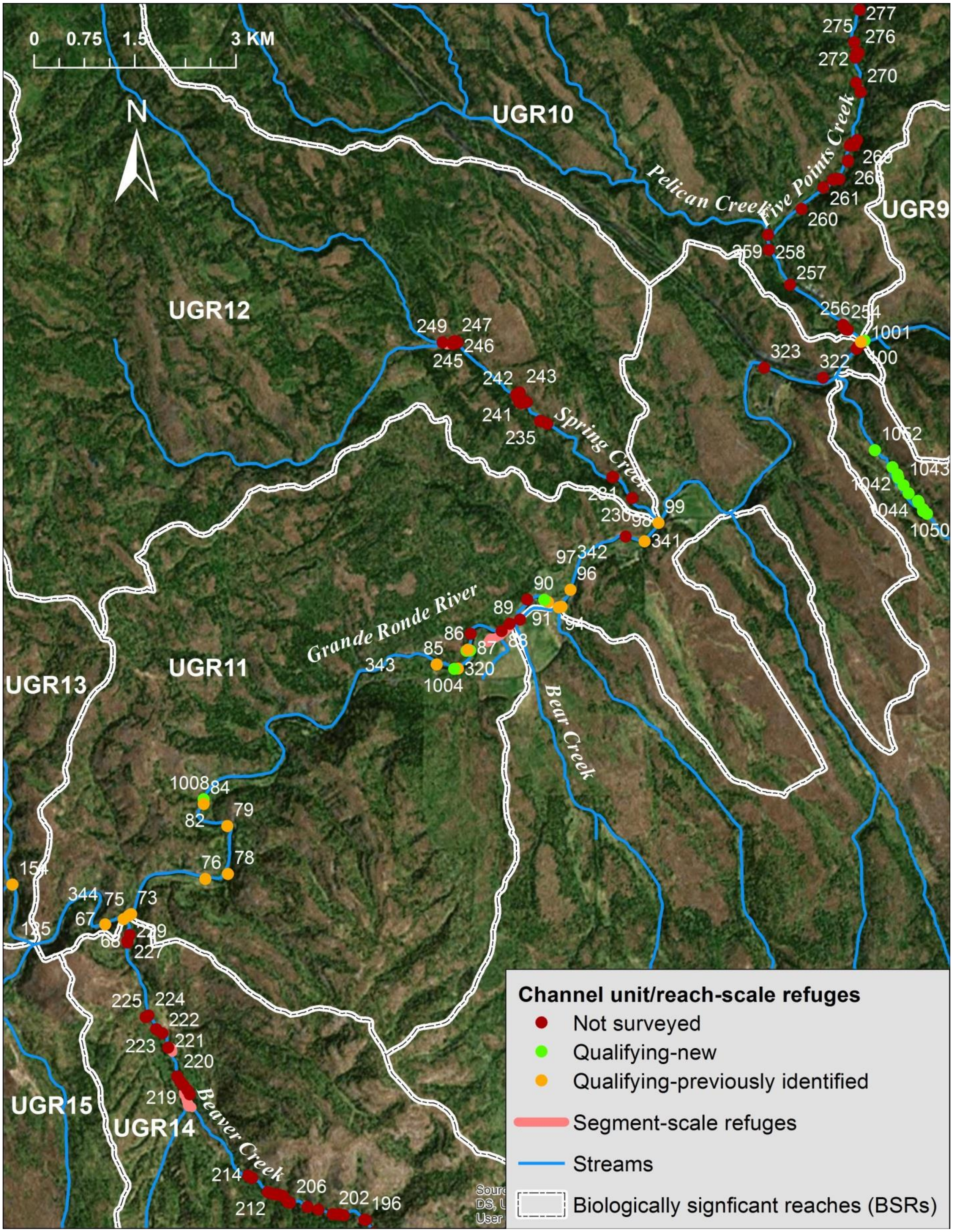

Figure A2 - 4. Map of cold-water refuges identified in biologically significant reach (BSR) UGR11.

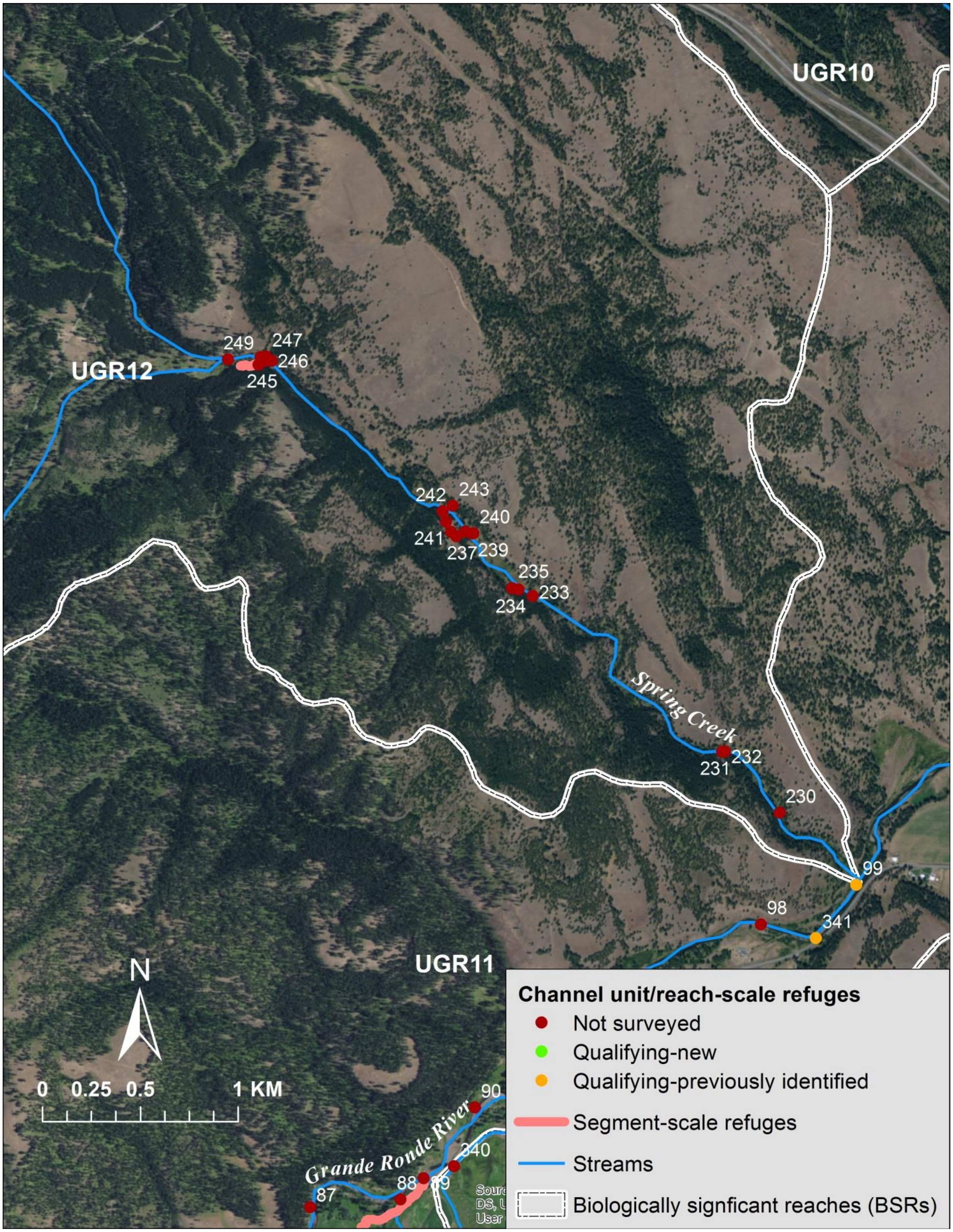

Figure A2 - 5. Map of cold-water refuges identified in biologically significant reach (BSR) UGR12 (Spring Creek).

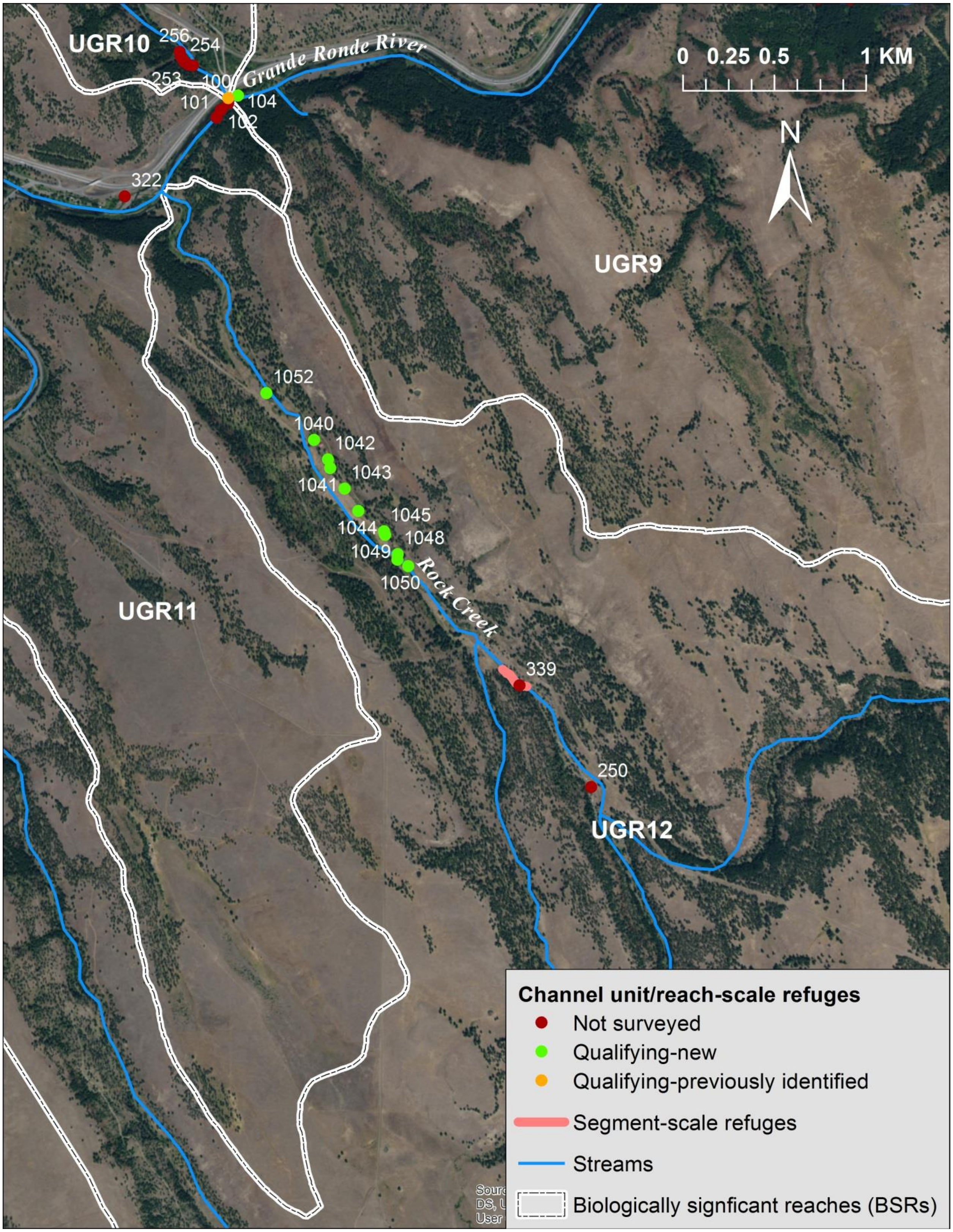

Figure A2 - 6. Map of cold-water refuges identified in biologically significant reach (BSR) UGR12 (Rock Creek).

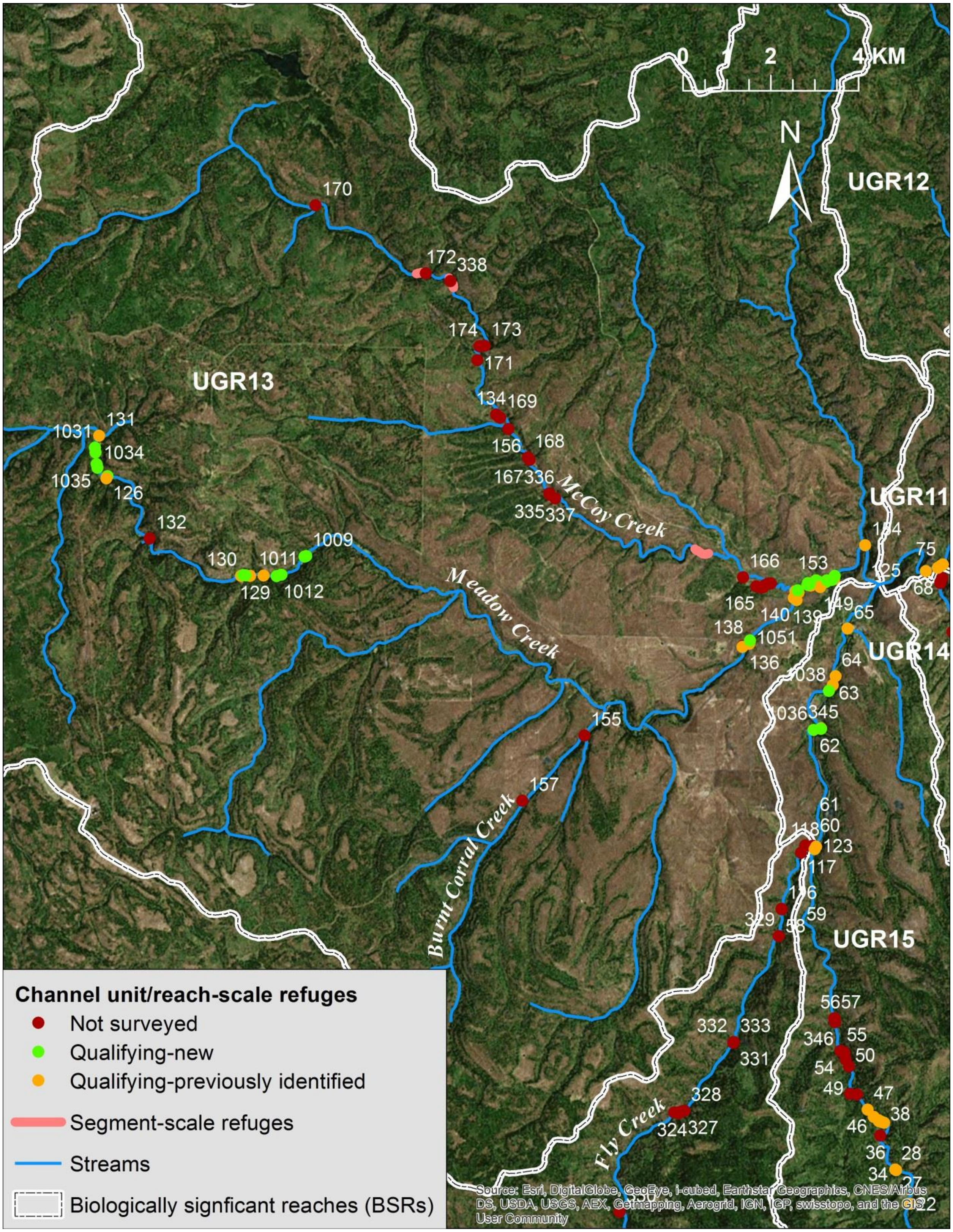

Figure A2 - 7. Map of cold-water refuges identified in biologically significant reach (BSR) UGR13.

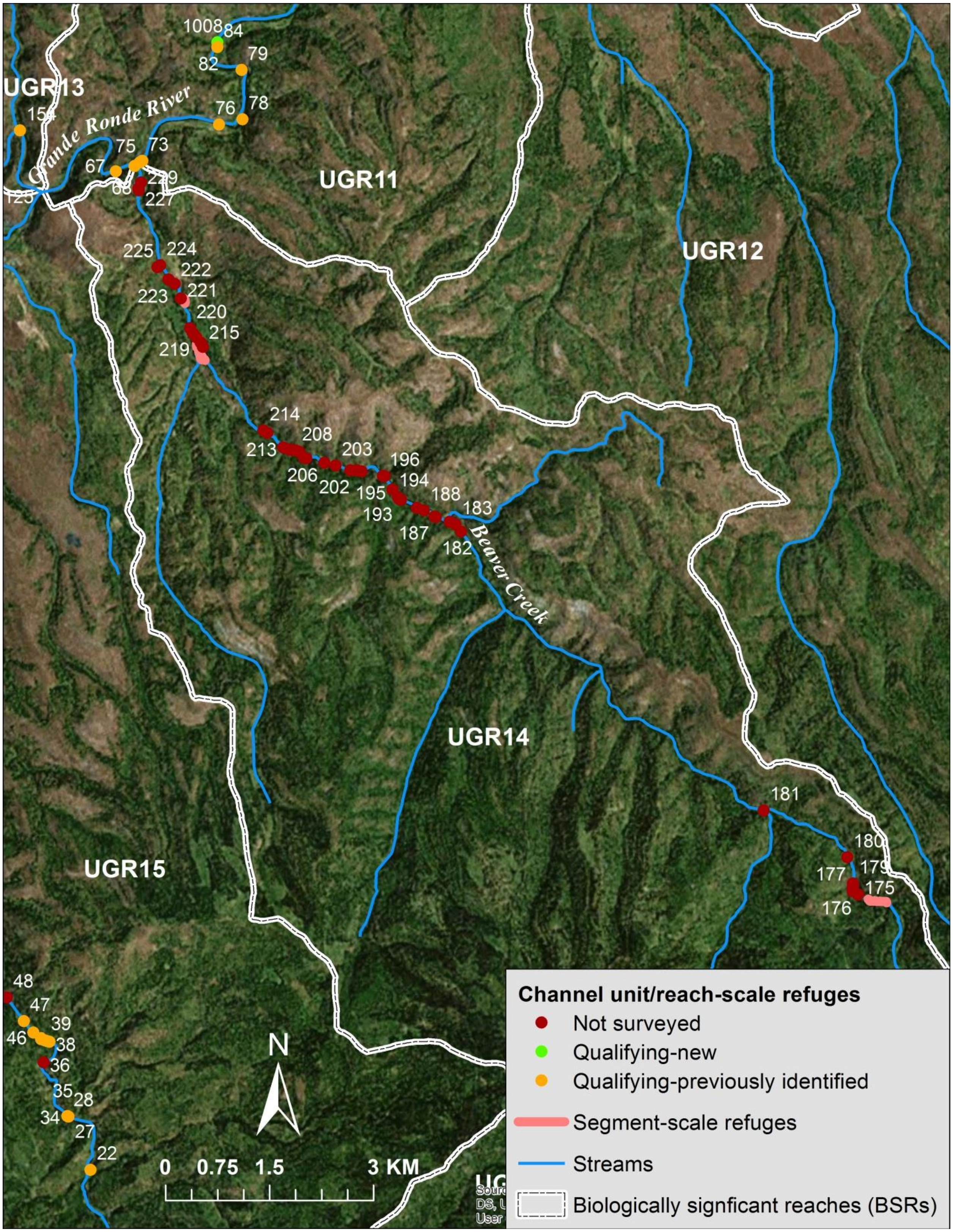

Figure A2 - 8. Map of cold-water refuges identified in biologically significant reach (BSR) UGR14.

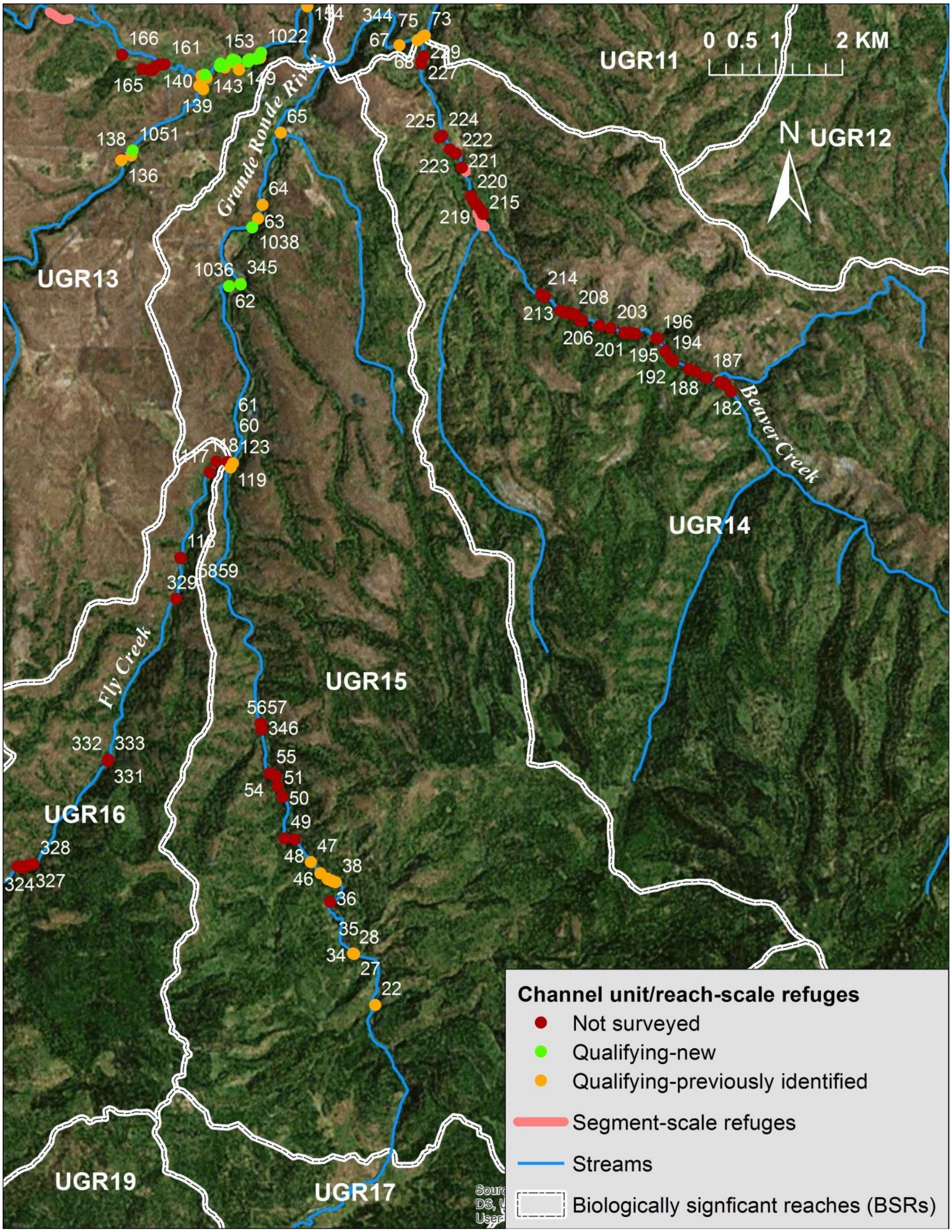

Figure A2 - 9. Map of cold-water refuges identified in biologically significant reach (BSR) UGR15.

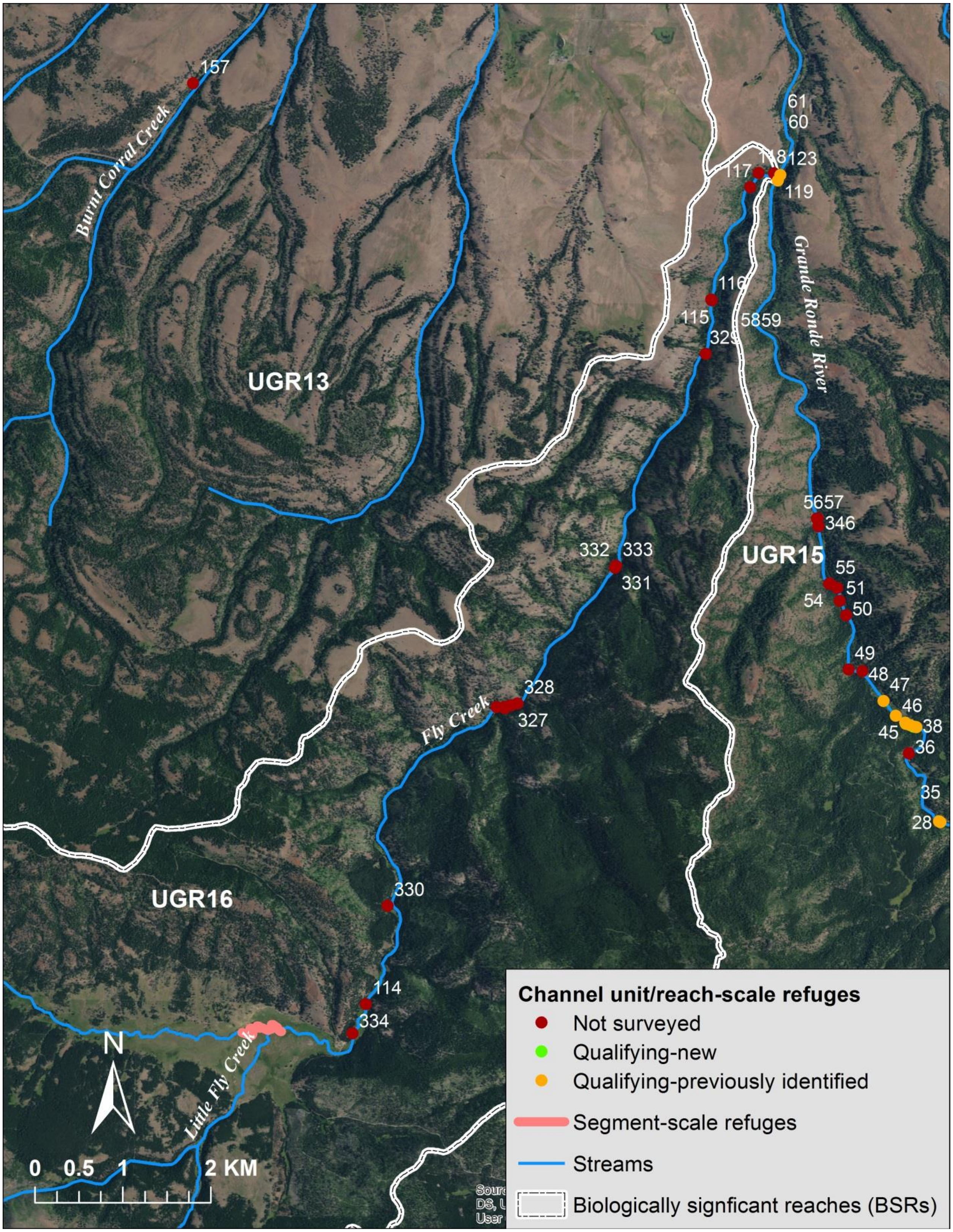

Figure A2 - 10. Map of cold-water refuges identified in biologically significant reach (BSR) UGR16.

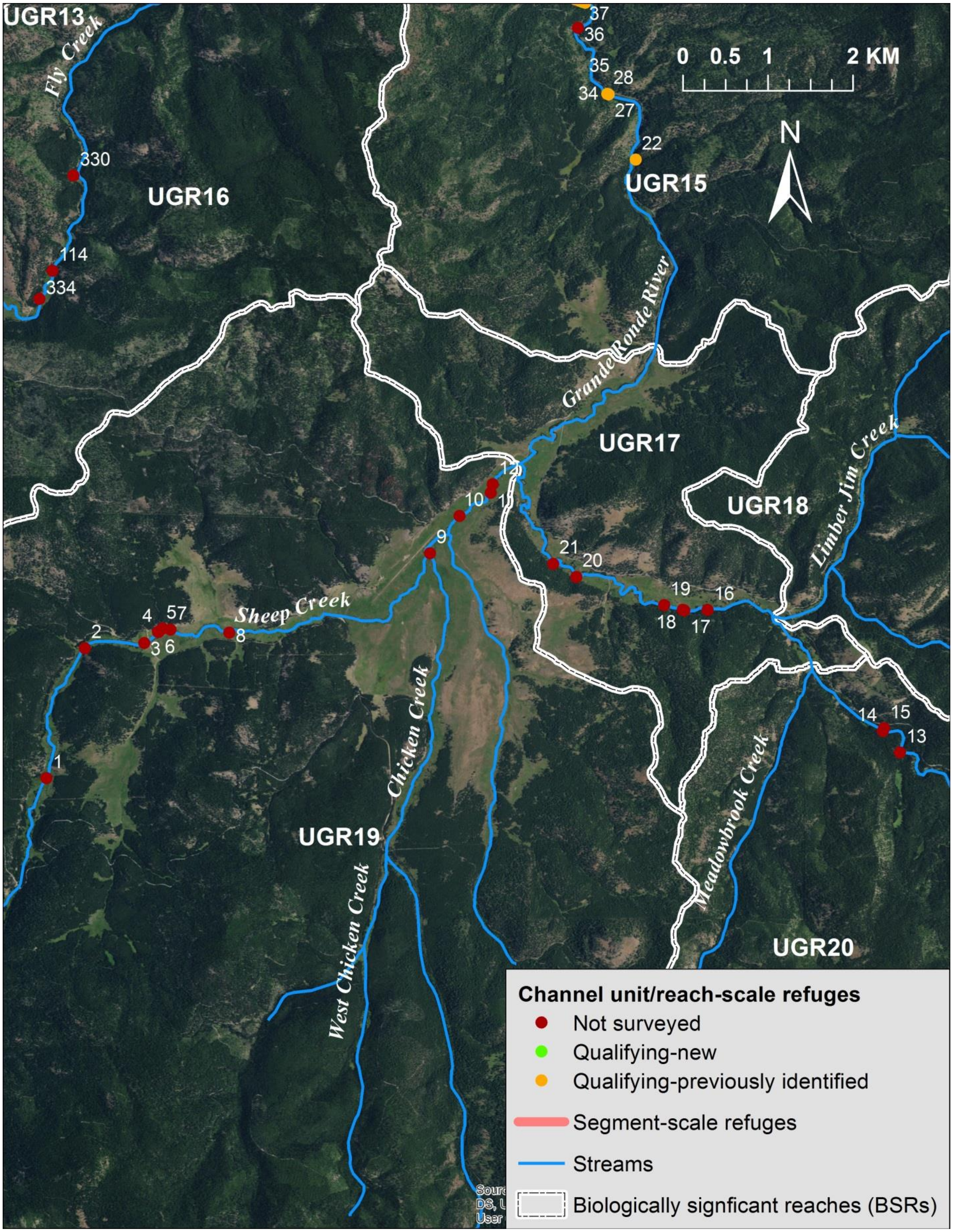

Figure A2 - 11. Map of cold-water refuges identified in biologically significant reaches (BSRs) UGR17-UGR20.

Appendix 3 – Table of Refuge Locations

Table A3 - 1. Type, status, and location of cold-water refuges identified from forward looking infrared (FLIR) and field surveys in the Upper Grande Ronde River basin, 2015.

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
1	Cold alcove	Not surveyed	Sheep Creek	UGR19	385712.5411	4991801.58
2	Tributary confluence plume	Not surveyed	Sheep Creek	UGR19	386166.0867	4993332.121
3	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	386861.6562	4993393.918
4	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	387022.8683	4993523.602
5	Lateral seep	Not surveyed	Sheep Creek	UGR19	387080.9262	4993564.162
6	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	387032.7277	4993525.374
7	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	387170.8769	4993550.709
8	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	387863.0604	4993515.607
9	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	390226.3395	4994450.812
10	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	390571.5628	4994889.124
11	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	390939.3155	4995160.399
12	Hyporheic upwelling	Not surveyed	Sheep Creek	UGR19	390963.8844	4995261.351
13	Cold alcove	Not surveyed	Grande Ronde River	UGR20	395756.8896	4992103.565
14	Cold side channel	Not surveyed	Grande Ronde River	UGR20	395555.7905	4992357.387
15	Cold side channel	Not surveyed	Grande Ronde River	UGR20	395567.8642	4992389.458
16	Cold side channel	Not surveyed	Grande Ronde River	UGR17	393493.4416	4993782.666
17	Cold side channel	Not surveyed	Grande Ronde River	UGR17	393215.9666	4993776.391
18	Hyporheic upwelling	Not surveyed	Grande Ronde River	UGR17	393199.8058	4993781.901
19	Cold side channel	Not surveyed	Grande Ronde River	UGR17	392978.9544	4993839.522
20	Lateral seep	Not	Grande Ronde	UGR17	391947.2416	4994171.749

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
		surveyed	River			
21	Hyporheic upwelling	Not surveyed	Grande Ronde River	UGR17	391674.0547	4994325.994
22	Tributary confluence plume	Qualifying-previously identified	Unnamed	UGR15	392644.5554	4999083.514
27	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR15	392327.2271	4999850.623
28	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR15	392309.831	4999858.919
36	Unknown	Not surveyed	Grande Ronde River	UGR15	391967.6506	5000634.232
38	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR15	392052.574	5000930.947
39	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR15	391982.2079	5000954.368
42	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR15	391932.9331	5000969.652
45	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR15	391926.1661	5000983.213
46	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR15	391819.7421	5001063.811
47	Tributary confluence plume	Qualifying-previously identified	Grande Ronde River	UGR15	391680.2528	5001229.316
48	Cold side channel	Not surveyed	Grande Ronde River	UGR15	391437.4875	5001571.534
49	Cold side channel	Not surveyed	Grande Ronde River	UGR15	391282.2781	5001588.416
50	Lateral seep	Not surveyed	Grande Ronde River	UGR15	391253.5382	5002208.865
51	Unknown	Not surveyed	Grande Ronde River	UGR15	391179.347	5002369.704
52	Lateral seep	Not surveyed	Grande Ronde River	UGR15	391152.1362	5002519.885
53	Lateral seep	Not	Grande Ronde	UGR15	391072.9667	5002564.7

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
		surveyed	River			
54	Lateral seep	Not surveyed	Grande Ronde River	UGR15	391068.287	5002566.828
55	Lateral seep	Not surveyed	Grande Ronde River	UGR15	391059.9955	5002567.593
56	Unknown	Not surveyed	Grande Ronde River	UGR15	390919.0182	5003309.774
57	Lateral seep	Not surveyed	Grande Ronde River	UGR15	390928.1607	5003309.341
62	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR15	390447.0852	5009883.036
63	Cold alcove	Qualifying-previously identified	Grande Ronde River	UGR15	390885.2815	5010903.153
64	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR15	390948.4481	5011106.534
65	Cold alcove	Qualifying-previously identified	Grande Ronde River	UGR15	391224.5877	5012191.918
68	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR11	393008.0188	5013502.781
73	Tributary confluence plume	Qualifying-previously identified	Beaver Creek	UGR11	393391.9178	5013652.985
74	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR14	393280.0338	5013579.307
75	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR11	393353.8889	5013631.401
76	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR11	394496.8947	5014178.963
78	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR11	394834.7125	5014252.234
79	Springbrook	Qualifying-previously identified	Grande Ronde River	UGR11	394824.6124	5014965.813

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
84	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR11	394473.9365	5015295.025
85	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR11	397942.9022	5017372.504
86	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR11	398404.9692	5017593.079
87	Lateral seep	Not surveyed	Grande Ronde River	UGR11	398447.3894	5017828.985
88	Lateral seep	Not surveyed	Grande Ronde River	UGR11	398909.8387	5017868.872
89	Tributary confluence plume	Not surveyed	Grande Ronde River	UGR11	399028.6438	5017978.451
90	Lateral seep	Not surveyed	Grande Ronde River	UGR11	399290.5694	5018339.659
91	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR11	399595.3578	5018300.226
93	Tributary confluence plume	Qualifying-previously identified	Grande Ronde River	UGR11	399801.0031	5018229.954
94	isolated pool	Qualifying-previously identified	Jordan Creek	UGR12	399757.5573	5018224.532
96	Lateral seep	Qualifying-previously identified	Grande Ronde River	UGR11	399931.7234	5018483.238
98	Cold alcove	Not surveyed	Grande Ronde River	UGR11	400753.5747	5019277.834
99	Tributary confluence plume	Qualifying-previously identified	Grande Ronde River	UGR11	401242.5622	5019480.469
100	Tributary confluence plume	Qualifying-previously identified	Grande Ronde River	UGR11	404256.0864	5022178.697
101	Cold side channel	Not surveyed	Grande Ronde River	UGR11	404191.3977	5022071.681
102	Cold side channel	Not surveyed	Grande Ronde River	UGR11	404216.3111	5022111.925
103	Cold side channel	Not	Grande Ronde	UGR11	404256.1224	5022149.53

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
		surveyed	River			
105	Cold side channel	Not surveyed	Grande Ronde River	UGR9	407481.1048	5022720.176
106	Cold side channel	Not surveyed	Grande Ronde River	UGR9	407656.2117	5022716.874
107	Cold side channel	Not surveyed	Grande Ronde River	UGR9	411306.1711	5021783.865
108	Cold side channel	Not surveyed	Grande Ronde River	UGR7	414606.9868	5021572.475
109	Cold side channel	Not surveyed	Grande Ronde River	UGR7	414621.4382	5021573.597
110	Cold alcove	Not surveyed	Grande Ronde River	UGR7	414966.9678	5021544.109
111	Cold side channel	Not surveyed	Grande Ronde River	UGR7	418132.919	5021705.266
112	Cold side channel	Not surveyed	Grande Ronde River	UGR7	419516.259	5021510.786
113	Lateral seep	Not surveyed	Grande Ronde River	UGR7	422107.6225	5021519.322
114	Cold alcove	Not surveyed	Fly Creek	UGR16	385783.6143	4997774.963
115	Lateral seep	Not surveyed	Fly Creek	UGR16	389723.0499	5005795.067
116	Lateral seep	Not surveyed	Fly Creek	UGR16	389716.2281	5005806.439
117	Lateral seep	Not surveyed	Fly Creek	UGR16	390161.2607	5007084.992
118	Lateral seep	Not surveyed	Fly Creek	UGR16	390255.2723	5007247.824
119	Tributary confluence plume	Qualifying-previously identified	Grande Ronde River	UGR16	390474.4139	5007162.01
120	Hyporheic upwelling	Not surveyed	Fly Creek	UGR16	390430.9321	5007243.153
121	Hyporheic upwelling	Not surveyed	Fly Creek	UGR16	390449.0202	5007225.441
122	Hyporheic upwelling	Not surveyed	Fly Creek	UGR16	390473.1465	5007202.55
123	Hyporheic upwelling	Qualifying-previously identified	Fly Creek	UGR15	390505.3291	5007223.705
126	Springbrook	Qualifying-previously identified	Meadow Creek	UGR13	374338.4943	5015619.393

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
128	Cold side channel	Qualifying-previously identified	Meadow Creek	UGR13	377918.2706	5013399.259
129	Cold side channel	Qualifying-previously identified	Meadow Creek	UGR13	377612.089	5013394.062
130	Cold alcove	Qualifying-previously identified	Meadow Creek	UGR13	377406.5203	5013396.931
131	Tributary confluence plume	Qualifying-previously identified	Smith Creek	UGR13	374175.5891	5016587.521
132	Tributary confluence plume	Not surveyed	Meadow Creek	UGR13	375321.9873	5014244.854
134	Springbrook	Not surveyed	McCoy Creek	UGR13	383215.4459	5017068.892
135	Cold side channel	Not surveyed	McCoy Creek	UGR13	383281.624	5017014.368
136	Cold alcove	Qualifying-previously identified	Meadow Creek	UGR13	388827.9323	5011776.614
137	Cold alcove	Not surveyed	Meadow Creek	UGR13	388833.1363	5011795.559
138	Cold side channel	Qualifying-previously identified	Meadow Creek	UGR13	388979.3172	5011846.411
139	Cold alcove	Qualifying-previously identified	Meadow Creek	UGR13	390059.4946	5012841.911
140	Cold alcove	Qualifying-previously identified	Meadow Creek	UGR13	389998.7555	5012891.862
142	Cold side channel	Qualifying-previously identified	McCoy Creek	UGR13	390033.8914	5013044.049
143	Cold side channel	Qualifying-previously identified	Meadow Creek	UGR13	390107.1352	5013013.772
145	Cold side channel	Qualifying-previously identified	Meadow Creek	UGR13	390386.9605	5013170.606

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
149	Springbrook	Qualifying-previously identified	Meadow Creek	UGR13	390598.4392	5013137.942
153	Cold side channel	Qualifying-previously identified	Meadow Creek	UGR13	390916.6266	5013317.916
154	Tributary confluence plume	Qualifying-previously identified	Meadow Creek	UGR13	391624.0032	5014092.523
155	Tributary confluence plume	Not surveyed	Burnt Corral Creek	UGR13	385227.9724	5009752.172
156	Cold side channel	Not surveyed	McCoy Creek	UGR13	383496.9074	5016740.194
157	Unknown	Not surveyed	Burnt Corral Creek	UGR13	383814.1905	5008270.013
158	Lateral seep	Not surveyed	McCoy Creek	UGR13	389341.7715	5013183.462
159	Hyporheic upwelling	Not surveyed	McCoy Creek	UGR13	389405.4081	5013216.322
160	Hyporheic upwelling	Not surveyed	McCoy Creek	UGR13	389451.3106	5013215.562
161	Hyporheic upwelling	Not surveyed	McCoy Creek	UGR13	389478.7198	5013221.487
162	Hyporheic upwelling	Not surveyed	McCoy Creek	UGR13	389298.8751	5013131.697
163	Hyporheic upwelling	Not surveyed	McCoy Creek	UGR13	389277.6717	5013127.998
164	Hyporheic upwelling	Not surveyed	McCoy Creek	UGR13	389255.9003	5013130.282
165	Hyporheic upwelling	Not surveyed	McCoy Creek	UGR13	389144.3344	5013150.489
166	Hyporheic upwelling	Not surveyed	McCoy Creek	UGR13	388839.4874	5013362.887
167	Springbrook	Not surveyed	McCoy Creek	UGR13	383979.558	5016033.37
168	Springbrook	Not surveyed	McCoy Creek	UGR13	383938.9588	5016091.843
169	Cold side channel	Not surveyed	McCoy Creek	UGR13	383311.3715	5016997.809
170	Tributary confluence plume	Not surveyed	McCoy Creek	UGR13	379103.7577	5021839.113
171	Cold side channel	Not	McCoy Creek	UGR13	382788.3882	5018307.74

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
		surveyed				
172	Springbrook	Not surveyed	McCoy Creek	UGR13	381617.4744	5020290.244
173	Tributary confluence plume	Not surveyed	McCoy Creek	UGR13	382956.8288	5018636.301
174	Cold side channel	Not surveyed	McCoy Creek	UGR13	382831.7681	5018623.232
175	Cold alcove	Not surveyed	Beaver Creek	UGR14	403721.6044	5003055.333
176	Cold side channel	Not surveyed	Beaver Creek	UGR14	403643.4902	5003103.847
177	Cold side channel	Not surveyed	Beaver Creek	UGR14	403642.5925	5003145.877
178	Cold side channel	Not surveyed	Beaver Creek	UGR14	403648.6662	5003167.853
179	Cold alcove	Not surveyed	Beaver Creek	UGR14	403647.3223	5003217.404
180	Lateral seep	Not surveyed	Beaver Creek	UGR14	403565.0557	5003594.495
181	Tributary confluence plume	Not surveyed	Beaver Creek	UGR14	402358.648	5004273.31
182	Cold alcove	Not surveyed	Beaver Creek	UGR14	397992.0684	5008301.355
183	Cold alcove	Not surveyed	Beaver Creek	UGR14	397909.4167	5008403.779
184	Cold side channel	Not surveyed	Beaver Creek	UGR14	397826.9374	5008441.545
185	Cold side channel	Not surveyed	Beaver Creek	UGR14	397629.089	5008510.601
186	Cold side channel	Not surveyed	Beaver Creek	UGR14	397622.5485	5008512.477
187	Cold side channel	Not surveyed	Beaver Creek	UGR14	397606.8851	5008518.234
188	Cold side channel	Not surveyed	Beaver Creek	UGR14	397456.4871	5008603.848
189	Cold alcove	Not surveyed	Beaver Creek	UGR14	397356.369	5008639.738
190	Cold side channel	Not surveyed	Beaver Creek	UGR14	397126.298	5008757.626
191	Cold side channel	Not surveyed	Beaver Creek	UGR14	397112.4443	5008763.72
192	Cold side channel	Not surveyed	Beaver Creek	UGR14	397097.304	5008772.282

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
193	Cold side channel	Not surveyed	Beaver Creek	UGR14	397084.4616	5008788.438
194	Cold side channel	Not surveyed	Beaver Creek	UGR14	397000.7029	5008905.612
195	Cold side channel	Not surveyed	Beaver Creek	UGR14	396886.3737	5009098.322
196	Cold side channel	Not surveyed	Beaver Creek	UGR14	396865.6023	5009103.447
197	Cold alcove	Not surveyed	Beaver Creek	UGR14	396557.9119	5009169.982
198	Cold alcove	Not surveyed	Beaver Creek	UGR14	396494.7025	5009181.082
199	Lateral seep	Not surveyed	Beaver Creek	UGR14	396487.1624	5009183.214
200	Lateral seep	Not surveyed	Beaver Creek	UGR14	396475.7978	5009182.679
201	Lateral seep	Not surveyed	Beaver Creek	UGR14	396481.5345	5009182.654
202	Lateral seep	Not surveyed	Beaver Creek	UGR14	396391.6825	5009184.6
203	Hyporheic upwelling	Not surveyed	Beaver Creek	UGR14	396180.8743	5009252.067
204	Cold side channel	Not surveyed	Beaver Creek	UGR14	396019.9701	5009291.372
205	Cold side channel	Not surveyed	Beaver Creek	UGR14	395724.5375	5009366.51
206	Cold side channel	Not surveyed	Beaver Creek	UGR14	395756.9296	5009356.39
207	Cold side channel	Not surveyed	Beaver Creek	UGR14	395654.4624	5009454.388
208	Cold alcove	Not surveyed	Beaver Creek	UGR14	395605.7894	5009468.886
209	Cold alcove	Not surveyed	Beaver Creek	UGR14	395574.1251	5009474.668
210	Cold side channel	Not surveyed	Beaver Creek	UGR14	395538.7021	5009480.41
211	Cold side channel	Not surveyed	Beaver Creek	UGR14	395494.0227	5009488
212	Cold side channel	Not surveyed	Beaver Creek	UGR14	395424.8617	5009515.2
213	Cold side channel	Not surveyed	Beaver Creek	UGR14	395193.5471	5009724.528
214	Cold alcove	Not surveyed	Beaver Creek	UGR14	395137.8551	5009759.445
215	Cold side channel	Not	Beaver Creek	UGR14	394262.9782	5010968.462

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
		surveyed				
216	Cold side channel	Not surveyed	Beaver Creek	UGR14	394232.9606	5011031.087
217	Hyporheic upwelling	Not surveyed	Beaver Creek	UGR14	394174.1222	5011102.762
218	Cold alcove	Not surveyed	Beaver Creek	UGR14	394165.9544	5011110.699
219	Cold side channel	Not surveyed	Beaver Creek	UGR14	394114.9239	5011171.36
220	Cold side channel	Not surveyed	Beaver Creek	UGR14	394079.2709	5011235.738
221	Cold side channel	Not surveyed	Beaver Creek	UGR14	393945.4824	5011666.83
222	Cold alcove	Not surveyed	Beaver Creek	UGR14	393856.8527	5011876.899
223	Lateral seep	Not surveyed	Beaver Creek	UGR14	393768.5365	5011938.882
224	Cold alcove	Not surveyed	Beaver Creek	UGR14	393650.1083	5012144.868
225	Springbrook	Not surveyed	Beaver Creek	UGR14	393610.3179	5012118.277
226	Cold side channel	Not surveyed	Beaver Creek	UGR14	393337.3749	5013243.231
227	Cold side channel	Not surveyed	Beaver Creek	UGR14	393340.6177	5013229.277
228	Cold side channel	Not surveyed	Beaver Creek	UGR14	393334.6134	5013252.128
229	Cold side channel	Not surveyed	Beaver Creek	UGR14	393372.493	5013341.432
230	Cold alcove	Not surveyed	Spring Creek	UGR12	400849.0265	5019848.646
231	Cold side channel	Not surveyed	Spring Creek	UGR12	400556.1377	5020161.691
232	Cold side channel	Not surveyed	Spring Creek	UGR12	400569.609	5020163.274
233	Lateral seep	Not surveyed	Spring Creek	UGR12	399586.2576	5020958.24
234	Lateral seep	Not surveyed	Spring Creek	UGR12	399513.882	5020991.939
235	Cold alcove	Not surveyed	Spring Creek	UGR12	399480.3117	5020999.391
236	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	399168.5067	5021286.3
237	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	399194.6961	5021263.663

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
238	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	399240.7803	5021288.166
239	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	399273.8597	5021278.289
240	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	399282.374	5021279.921
241	Springbrook	Not surveyed	Spring Creek	UGR12	399142.7456	5021339.08
242	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	399125.0879	5021392.475
243	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	399176.1207	5021420.822
244	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	398228.084	5022163.659
245	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	398183.1207	5022143.162
246	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	398250.1193	5022163.518
247	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	398220.7246	5022183.658
248	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	398193.1177	5022182.048
249	Hyporheic upwelling	Not surveyed	Spring Creek	UGR12	398026.8453	5022169.678
250	Hyporheic upwelling	Not surveyed	Rock Creek	UGR12	406240.1106	5018409.706
251	Lateral seep	Not surveyed	Five Points Creek	UGR10	404061.9798	5022356.52
252	Cold side channel	Not surveyed	Five Points Creek	UGR10	404037.8612	5022361.265
253	Cold side channel	Not surveyed	Five Points Creek	UGR10	404018.739	5022374.703
254	Cold side channel	Not surveyed	Five Points Creek	UGR10	404011.9237	5022380.475
255	Cold side channel	Not surveyed	Five Points Creek	UGR10	403998.2828	5022404.298
256	Lateral seep	Not surveyed	Five Points Creek	UGR10	403989.5453	5022430.634
257	Springbrook	Not surveyed	Five Points Creek	UGR10	403200.8975	5023030.013
258	Cold side channel	Not surveyed	Five Points Creek	UGR10	402885.0389	5023547.958
259	Tributary confluence	Not surveyed	Pelican Creek	UGR10	402872.9506	5023769.862

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
	plume					
260	Lateral seep	Not surveyed	Five Points Creek	UGR10	403370.5991	5024158.478
261	Hyporheic upwelling	Not surveyed	Five Points Creek	UGR10	403697.0918	5024476.866
262	Hyporheic upwelling	Not surveyed	Five Points Creek	UGR10	403839.022	5024593.857
263	Cold alcove	Not surveyed	Five Points Creek	UGR10	403890.9403	5024604.286
264	Springbrook	Not surveyed	Five Points Creek	UGR10	403933.3984	5024602.055
265	Lateral seep	Not surveyed	Five Points Creek	UGR10	404065.3556	5024879.248
266	Lateral seep	Not surveyed	Five Points Creek	UGR10	404060.9778	5024864.301
267	Springbrook	Not surveyed	Five Points Creek	UGR10	404161.6185	5025105.395
268	Lateral seep	Not surveyed	Five Points Creek	UGR10	404196.3355	5025179.81
269	Lateral seep	Not surveyed	Five Points Creek	UGR10	404186.7884	5025164.04
270	Lateral seep	Not surveyed	Five Points Creek	UGR10	404251.4479	5025893.558
271	Hyporheic upwelling	Not surveyed	Five Points Creek	UGR10	404184.2417	5026037.629
272	Cold side channel	Not surveyed	Five Points Creek	UGR10	404174.1101	5026410.917
273	Cold side channel	Not surveyed	Five Points Creek	UGR10	404190.6862	5026430.329
274	Cold side channel	Not surveyed	Five Points Creek	UGR10	404189.7338	5026476.779
275	Cold alcove	Not surveyed	Five Points Creek	UGR10	404156.9006	5026635.939
276	Cold alcove	Not surveyed	Five Points Creek	UGR10	404223.8869	5026480.138
277	Cold alcove	Not surveyed	Five Points Creek	UGR10	404234.5506	5027125.024
278	Cold side channel	Not surveyed	Five Points Creek	UGR10	404098.1415	5025111.083
279	Cold side channel	Not surveyed	Five Points Creek	UGR10	404089.1816	5025099.478
280	Cold alcove	Not surveyed	Five Points Creek	UGR10	404206.906	5027299.782
281	Cold alcove	Not	Five Points Creek	UGR10	404214.1257	5027307.383

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
		surveyed				
282	Cold alcove	Not surveyed	Five Points Creek	UGR10	404289.0732	5027839.411
283	Cold alcove	Not surveyed	Five Points Creek	UGR10	404635.1915	5028548.151
284	Cold side channel	Not surveyed	Five Points Creek	UGR10	405963.2456	5029368.049
285	Cold side channel	Not surveyed	Five Points Creek	UGR10	405989.6462	5029390.825
286	Cold side channel	Not surveyed	Five Points Creek	UGR10	406362.5974	5030061.217
287	Cold side channel	Not surveyed	Five Points Creek	UGR10	406473.114	5030107.845
288	Cold side channel	Not surveyed	Five Points Creek	UGR10	406571.2677	5030109.191
289	Cold alcove	Not surveyed	Five Points Creek	UGR10	407016.5148	5030156.131
290	Cold side channel	Not surveyed	Five Points Creek	UGR10	407438.9402	5030178.856
291	Cold side channel	Not surveyed	Five Points Creek	UGR10	407677.1978	5030079.106
292	Springbrook	Not surveyed	Five Points Creek	UGR10	409328.0088	5030502.103
293	Cold side channel	Not surveyed	Five Points Creek	UGR10	409192.3225	5030488.349
294	Tributary confluence plume	Not surveyed	Grande Ronde River	UGR10	409406.8499	5030594.035
316	Cold alcove	Not surveyed	Grande Ronde River	UGR7	421675.2506	5021488.921
317	Lateral seep	Not surveyed	Grande Ronde River	UGR7	415443.3682	5021349.436
318	Lateral seep	Not surveyed	Grande Ronde River	UGR7	415257.6429	5021387.161
319	Cold alcove	Not surveyed	Grande Ronde River	UGR9	407428.6935	5022755.221
320	Cold side channel	Qualifying-previously identified	Grande Ronde River	UGR11	398256.9238	5017310.99
322	Cold side channel	Not surveyed	Grande Ronde River	UGR11	403690.0532	5021640.098
323	Cold side channel	Not surveyed	Grande Ronde River	UGR11	402815.1056	5021790.602
324	Cold side channel	Not surveyed	Fly Creek	UGR16	387368.4895	5001146.454

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
325	Hyporheic upwelling	Not surveyed	Fly Creek	UGR16	387364.9245	5001162.642
326	Tributary confluence plume	Not surveyed	Fly Creek	UGR16	387270.4623	5001162.24
327	Cold side channel	Not surveyed	Fly Creek	UGR16	387441.3665	5001183.711
328	Lateral seep	Not surveyed	Fly Creek	UGR16	387509.6778	5001202.486
329	Lateral seep	Not surveyed	Fly Creek	UGR16	389653.253	5005186.42
330	Springbrook	Not surveyed	Fly Creek	UGR16	386031.2352	4998897.064
331	Lateral seep	Not surveyed	Fly Creek	UGR16	388622.1335	5002748.396
332	Lateral seep	Not surveyed	Fly Creek	UGR16	388626.3553	5002767.761
333	Lateral seep	Not surveyed	Fly Creek	UGR16	388633.7435	5002770.626
334	Lateral seep	Not surveyed	Fly Creek	UGR16	385630.2979	4997442.415
335	Cold side channel	Not surveyed	McCoy Creek	UGR13	384443.5102	5015242.745
336	Cold side channel	Not surveyed	McCoy Creek	UGR13	384428.3938	5015271.587
337	Cold side channel	Not surveyed	McCoy Creek	UGR13	384561.5688	5015161.981
338	Springbrook	Not surveyed	McCoy Creek	UGR13	382176.596	5020110.825
339	Springbrook	Not surveyed	Rock Creek	UGR12	405848.2547	5018965.683
340	Tributary confluence plume	Not surveyed	Grande Ronde River	UGR12	399182.9926	5018038.701
341	Tributary confluence plume	Qualifying-previously identified	Grande Ronde River	UGR11	401035.2418	5019207.024
345	Tributary confluence plume	Qualifying-previously identified	Warm Springs Creek	UGR15	390619.4438	5009920.173
346	Tributary confluence plume	Not surveyed	Grande Ronde River	UGR15	390938.2566	5003222.661
1001	Lateral seep	Qualifying-new	Grande Ronde River	UGR9	404308.7923	5022192.343

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
1004	Cold side channel	Qualifying-new	Grande Ronde River	UGR11	398202.7561	5017307.417
1005	Cold side channel	Qualifying-new	Grande Ronde River	UGR11	398385.8502	5017574.496
1006	Cold side channel	Qualifying-new	Grande Ronde River	UGR11	398437.6814	5017579.219
1007	Cold side channel	Qualifying-new	Grande Ronde River	UGR15	392018.9063	5000939.298
1008	Cold side channel	Qualifying-new	Grande Ronde River	UGR11	394471.9677	5015365.066
1009	Cold side channel	Qualifying-new	Meadow Creek	UGR13	378888.1469	5013841.819
1010	Cold side channel	Qualifying-new	Meadow Creek	UGR13	378851.0426	5013830.305
1011	Cold side channel	Qualifying-new	Meadow Creek	UGR13	378327.5022	5013416.936
1012	Cold side channel	Qualifying-new	Meadow Creek	UGR13	378220.2505	5013390.105
1013	Cold side channel	Qualifying-new	Meadow Creek	UGR13	377458.6006	5013411.48
1014	Cold alcove	Qualifying-new	Meadow Creek	UGR13	377507.1984	5013408.317
1015	Cold alcove	Qualifying-new	Meadow Creek	UGR13	390083.9502	5013061.515
1016	Cold side channel	Qualifying-new	Meadow Creek	UGR13	390307.9199	5013187.867
1017	Cold alcove	Qualifying-new	Meadow Creek	UGR13	390319.8243	5013227.221
1018	Cold alcove	Qualifying-new	Meadow Creek	UGR13	390361.084	5013203.503
1019	Cold side channel	Qualifying-new	Meadow Creek	UGR13	390852.9008	5013299.457
1020	Cold side channel	Qualifying-new	Meadow Creek	UGR13	390860.7251	5013307.212
1021	Cold side channel	Qualifying-new	Meadow Creek	UGR13	390876.3005	5013304.832
1022	Cold side channel	Qualifying-new	Meadow Creek	UGR13	390927.7336	5013393.178
1023	Cold side channel	Qualifying-new	Meadow Creek	UGR13	390752.9191	5013294.626
1024	Cold side channel	Qualifying-new	Meadow Creek	UGR13	390734.0039	5013280.84

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
1025	Cold side channel	Qualifying-new	Meadow Creek	UGR13	390733.1934	5013256.628
1026	Hyporheic upwelling	Qualifying-new	McCoy Creek	UGR13	390549.0713	5013269.146
1027	Cold side channel	Qualifying-new	McCoy Creek	UGR13	390530.9282	5013272.793
1028	Cold side channel	Qualifying-new	McCoy Creek	UGR13	390505.5513	5013289.235
1029	Cold side channel	Qualifying-new	McCoy Creek	UGR13	390497.3577	5013287.376
1030	Hyporheic upwelling	Qualifying-new	McCoy Creek	UGR13	390515.9451	5013241.382
1031	Lateral seep	Qualifying-new	Meadow Creek	UGR13	374077.3967	5016312.969
1032	Cold side channel	Qualifying-new	Meadow Creek	UGR13	374087.7384	5016205.96
1033	Tributary confluence plume	Qualifying-new	Meadow Creek	UGR13	374362.2934	5015664.153
1034	Hyporheic upwelling	Qualifying-new	Meadow Creek	UGR13	374135.7636	5015859.925
1035	Hyporheic upwelling	Qualifying-new	Meadow Creek	UGR13	374117.1375	5015937.091
1036	Lateral seep	Qualifying-new	Grande Ronde River	UGR15	390446.4172	5009885.27
1037	Tributary confluence plume	Qualifying-new	Warm Springs Creek	UGR15	390621.8345	5009908.575
1038	Cold side channel	Qualifying-new	Grande Ronde River	UGR15	390796.0576	5010768.674
1039	Cold alcove	Qualifying-new	Grande Ronde River	UGR11	399540.614	5018333.766
1040	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	404725.2556	5020308.128
1041	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	404813.69	5020153.673
1042	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	404801.7872	5020201.189
1043	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	404892.0255	5020041.373
1044	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	404967.9357	5019918.777

Refuge ID	Refuge type	Refuge status	Stream name	BSR	UTM Easting	UTM Northing
1045	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	405107.3705	5019808.562
1046	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	405114.1298	5019788.903
1047	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	405110.6351	5019796.29
1048	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	405181.602	5019683.327
1049	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	405180.8347	5019653.114
1050	Hyporheic upwelling	Qualifying-new	Rock Creek	UGR12	405239.652	5019618.34
1051	Cold side channel	Qualifying-new	Meadow Creek	UGR13	388999.8062	5011922.618
1052	Cold side channel	Qualifying-new	Rock Creek	UGR12	404464.5102	5020563.421