BARRIERS TO ANADROMOUS FISH IN THE OKANOGAN RIVER BASIN

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ANADROMOUS FISH PASSAGE BARRIERS IN THE OKANOGAN BASIN

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Introduction:

The Okanogan River Basin is large, spanning over 8,000 square miles and is located within north central Washington State and south central British Columbia (Figure 1). Tributary habitat for anadromous salmonids was historically limited because of the geographic features of the Okanogan river valley. Anthropogenic changes such as irrigation diversion and road culverts have further reduced the amount of tributary habitats accessible to anadromous fish for both spawning and rearing. Basic information on both historic and current habitats accessible to anadromous salmonids can be determined relatively easily by experienced biologists. For most streams the terminus for anadromous fish is defined by a substantial geomorphic or man-made feature such as falls, dams, culverts, gradients, diversions, etc... Little information exists for several streams most importantly in reaches accessible by anadromous salmonids. In an effort to evaluate current habitat conditions of tributaries of the Okanogan River Basin as associated with the anadromous salmonids, primarily summer steelhead, surveys were conducted in Antoine Creek, Ninemile Creek, Loup Loup Creek, Tonasket Creek, Bonaparte Creek, Wanacut Creek, Whistler Canyon Creek and Wildhorse Spring Creek in the United States (Figure 2) and along major tributaries in Canada. These surveys provide important information that can be utilized by agencies, managers, planning group, tribes, and the public. Factors that are limiting summer steelhead production will help address recovery needs for the entire upper Columbia ESU that has been listed as endangered since 1997. This document is organized in an upstream direction with information from Chiliwist Creek first and streams in Canada last.

Methods:

Observational surveys for fish passage barriers were conducted during the months of May and June in 2004, 2005, and 2006 throughout the Okanogan Basin watershed. All parameters were evaluated subjectively, using the professional judgment of at least two independent biologists. Each tributary was surveyed in an upstream direction, beginning at the confluence with the Okanogan River, until a fish passage barrier was identified. Each potential impediment to fish passage was evaluated under the existing flow conditions. The evaluation of fish passage barriers included pool depth immediately downstream of the barrier, the height of the barrier and in the case of culvert, the length and gradient of the pipe.

Habitat and water condition information was collected from existing sources where-ever possible. Information was gathered through several documents including the Okanogan River limiting factors document (Entrix 2001), web-base data such as the Washington Department of Ecology (WDOE) gauging station and water quality data, and data collected as part of the Okanogan Basin Monitoring and Evaluation Program (OBMEP). OBMEP data was collected using the established protocols for this project (Arterburn et al. 2005a, Arterburn et al. 2006a, and Arterburn et al. 2005b). Flow was calculated from

habitat and velocity measurements on some streams in an attempt to determine water loss from diversions. Velocity was measured using a Scientific Instruments Inc., current meter digitizer, model 9000 digimeter at 0.4 of the depth. Velocities and depth were measured at three equidistant points along a transect perpendicular to the direction of the current. All measurements were recorded to the nearest 0.1 ft. A rough estimate of discharge was calculated by multiplying the wetted width, mean depth and velocity.

Redd information and spawning potential was taken from OBMEP redd surveys reports for 2005 and 2006 (Arterburn and Kistler 2006, and Arterburn et al. 2005c) or based upon other Colville Tribal reports prior to 2004. Estimates of redd potential was derived from existing discharge and channel morphology measurements to estimate total habitat area. This area was reduced assuming total habitat contained 25% gravel substrate and 30% of this habitat being the proper type gravel for the species (Burner 1951) and only 25% of these areas having the appropriate depth and velocity requirements (Bjornn and Reiser 1991). This reduced area was then divided by the average size of a steelhead redd as described in (Bjorn and Reiser 1991) and rounded down to the nearest whole number.

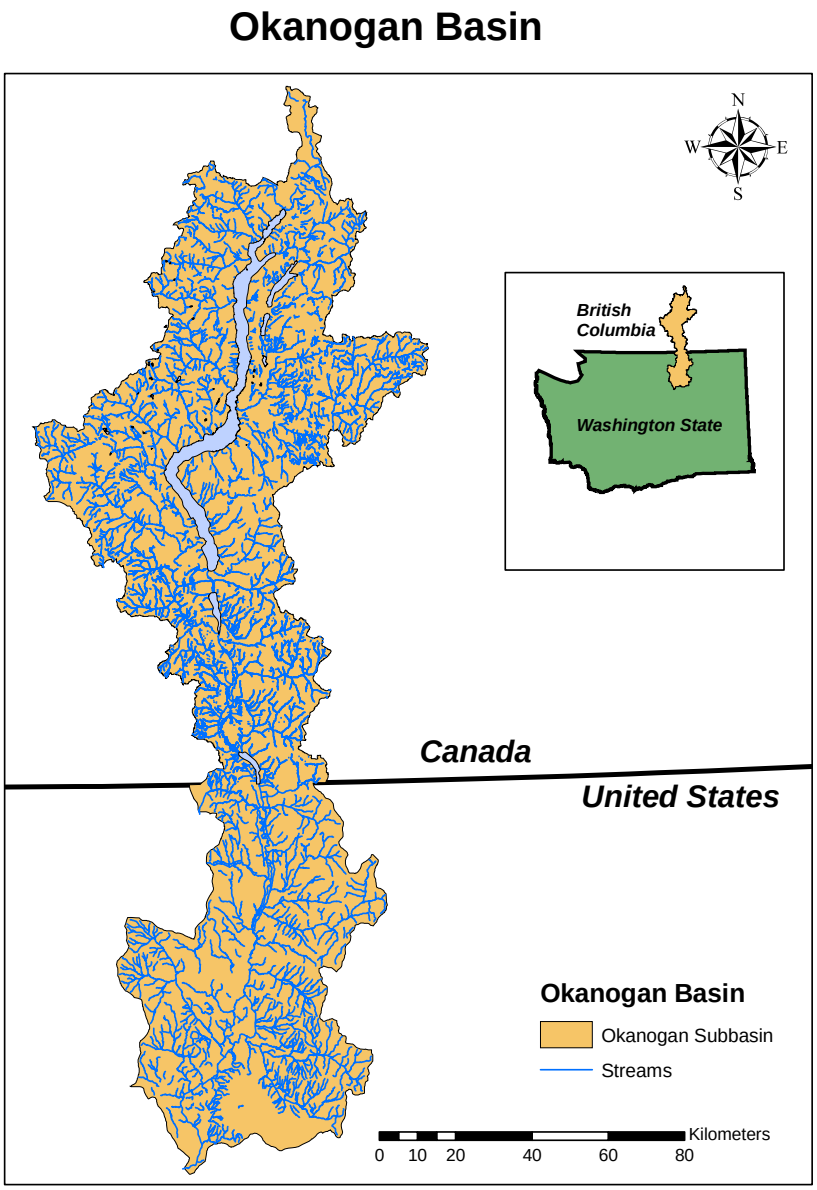

Figure 1. The Okanogan River enters the Columbia River just downstream of river mile 534 near the town of Brewster, WA. The majority of the watershed is located in Canada, however, this picture does not depict the Similkameen River which is the single largest tributary to the Okanogan River and is almost wholly contained within the province of British Columbia.

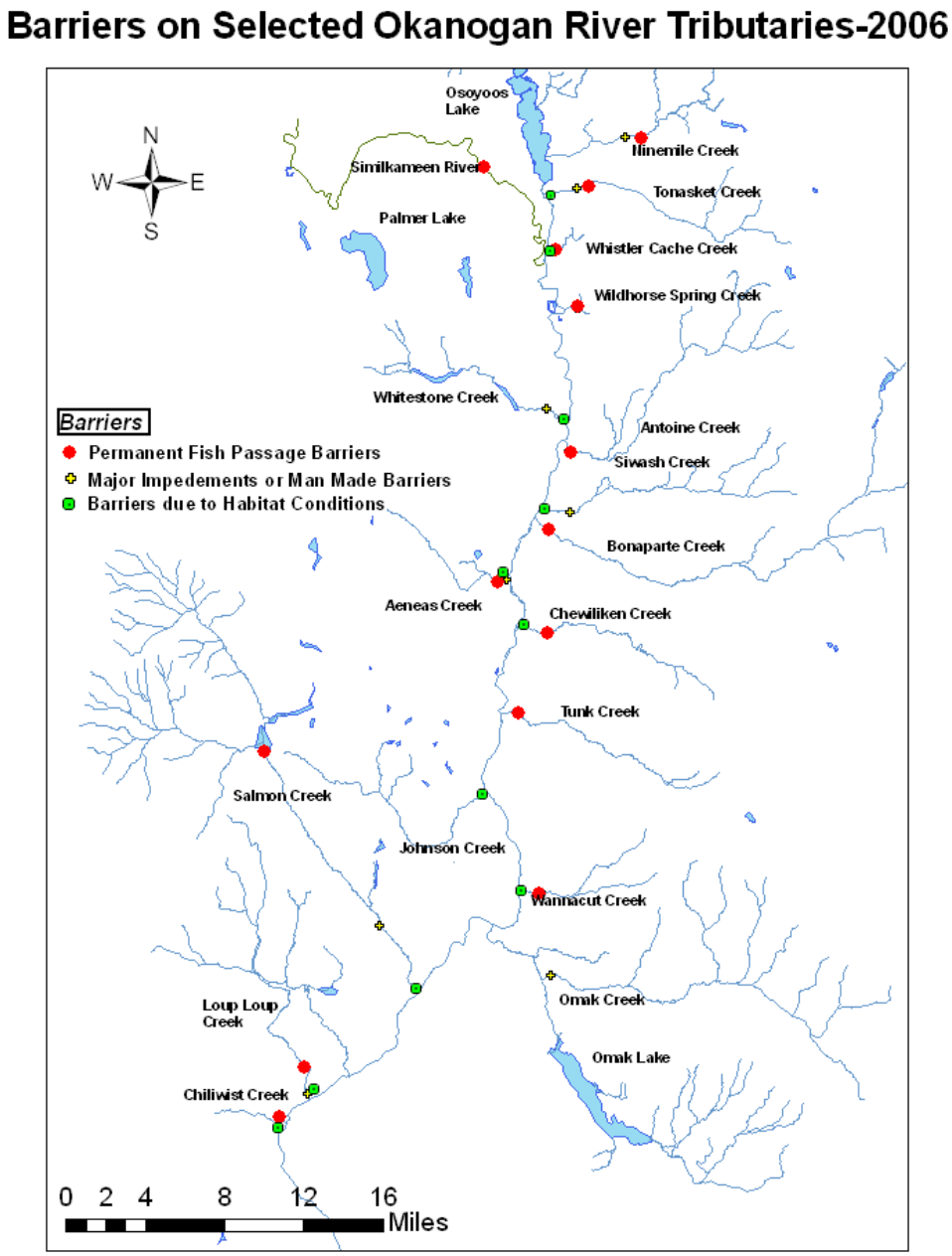

Figure 2. Location of anadromous fish barriers documented within the U.S. portion of the Okanogan River sub-basin.

Results and Discussion

Chiliwist Creek

The Colville Tribes did not conduct a thorough field investigation of Chiliwist Creek for the purposes of this document, knowledge of this watershed is sufficient to validate the findings of past documents. The Okanogan Conservation District (OCD) identified that only about the lower ½ mile of Chiliwist Creek is accessible to anadromous salmonids because a natural gradient barrier likely prevents further access upstream (OCD 2002). The area around the confluence with the Okanogan River provides a thermal refuge for adult salmon and steelhead migrating upstream during the summer months. If juvenile fish could navigate impediments within the first 100 yards of this stream, water quality would not preclude juvenile rearing by summer steelhead or spring Chinook but little or no spawning habitat or substrate is known to exist (Figure 3). In 1988, 41 summer steelhead smolts were counted in the Chiliwist subwatershed (WDFW 1988).

During much of the growing season all surface flows from lower Chiliwist Creek are diverted for irrigation (Walters 1974). Within and downstream of the Chiliwist Valley the flow in Chiliwist Creek becomes erratic and often subterranean. The OCD identified a natural barrier they named Chiliwist Falls at 0.56 miles upstream of the confluence with the Okanogan River, this was likely the historic limit of anadromous fish distributions (OCD 2002). However, insufficient stream discharge and lack of cover, constrain fish production in Chiliwist Creek (WDFW 1988).

Figure 3: Both panels above show views of the confluence of Chiliwist Creek to the Okanogan River (6/14/2001).

Loup Loup Creek

Historically, Loup Loup Creek provided access to 2.04 miles of potential summer steelhead and spring Chinook spawning and rearing habitat. Surveys verified the historic terminus for steelhead fish passage as Loup Loup Falls (Figure 4). In most years, the terminus for fish passage is a perched culvert at river mile 0.14 within the town of Malott, Washington (Figure 5). In 2006, steelhead redds were discovered above this culvert (Arterburn and Kistler 2006). Utilization of Loup Loup Creek by summer steelhead is limited by man-made barriers, and irrigation water withdrawals. Currently the creek goes dry during the summer due to an irrigation withdrawal at river mile 1.34 (Figure 6). Loup Loup Creek has good spawning substrate but has been artificially confined through the town of Malott, WA and lacks habitat diversity primarily due to a lack of pools and pool tailouts. This creek is currently being surveyed as part of OBMEP and more information on physical habitat, and water quality can be found in the OBMEP annual report in 2007. Currently, insufficient data exists to estimate production or habitat available and without consistent flows it is difficult to predict salmonid production. However, model predictions indicate that conservatively their is potential for up to 53 summer steelhead redds, assuming both flow and passage barrier issues are addressed making all 2 miles of habitat accessible.

Figure 3: Loup Loup Falls are located 2.04 miles upstream of the confluence with the Okanogan River (6/08/06).

Figure 5: Perched culvert located with in the town of Malott, WA is only 0.14 miles upstream of the confluence with the Okanogan River (6/08/06).

Figure 6: Loup Loup Creek diversion pictured in the open position at high flows (6/8/06) is located at river mile 1.34. When closed during the low discharge period the entire stream can be diverted.

Salmon Creek

Salmon Creek enters the Okanogan River at the town of Okanogan, WA. Mountains surround Salmon Creek forming its hydrologic divides. The basin is generally oriented on a northwest-southeast axis, with a broad upper watershed about 8 to 10 miles wide and 12 to 15 miles long. The North Fork, West Fork, and South Fork of Salmon Creek converge at Conconully, WA draining the 119 square-mile upper Salmon watershed. This area is inaccessible to anadromous fish because of Conconully Dam which forms Conconully Reservoir (Figure 7). Conconully Dam is approximately 15 miles upstream from the mouth of Salmon Creek. Although data or written references are unavailable to define historic use of the upper watershed by anadromous salmonids, professional opinion is that it was probably limited to less than three miles above the dam site (Entrix 2001.)

The Okanogan Irrigation District (OID) manages Conconully Reservoir to serve District lands east of the watershed. Controlled releases for irrigation deliveries are made from Conconully Reservoir (Figure 7) between April and October. These releases are conveyed through 11 miles of natural and modified stream channel (referred to as the middle reach of Salmon Creek) to the OID diversion dam (Figure 8), located 4.3 stream miles above the mouth of Salmon Creek. For more than eighty years, the 4.3 miles of Salmon Creek downstream of the OID diversion dam (referred to as lower Salmon Creek), have been dewatered, except during above average snow pack years resulting in uncontrolled spill at the Conconully Reservoir Dam and the OID diversion dam.

As of 2006, water is not available consistently in the lower 4.3 miles of Salmon Creek. The spring of 2006 did bring water down the creek due to an above average snow pack but these releases were too late for steelhead to ascend the creek. The CCT is currently trying to secure water to allow steelhead passage for spawning and rearing up to Conconully Dam (RM 15.) Habitat conditions are considered excellent for summer steelhead and spring Chinook with an abundance of good spawning and rearing areas. The highest abundance of resident *O. mykiss* observed in any Okanogan River tributary during snorkel surveys attests to the quality of this habitat (Kistler and Arterburn 2006). Salmon Creek is one of the colder tributaries to the Okanogan River thus providing unique habitat that is especially productive to summer steelhead and spring Chinook (Figure 9).

Figure 7: Aerial photo of Conconully Reservoir and Dam (lower left of picture) built by the Bureau of Reclamation in 1908 provides no fish passage to the headwaters of Salmon Creek.

Figure 8: Fish ladder constructed at OID diversion has the potential to provide passage around the diversion when sufficient discharge exists.

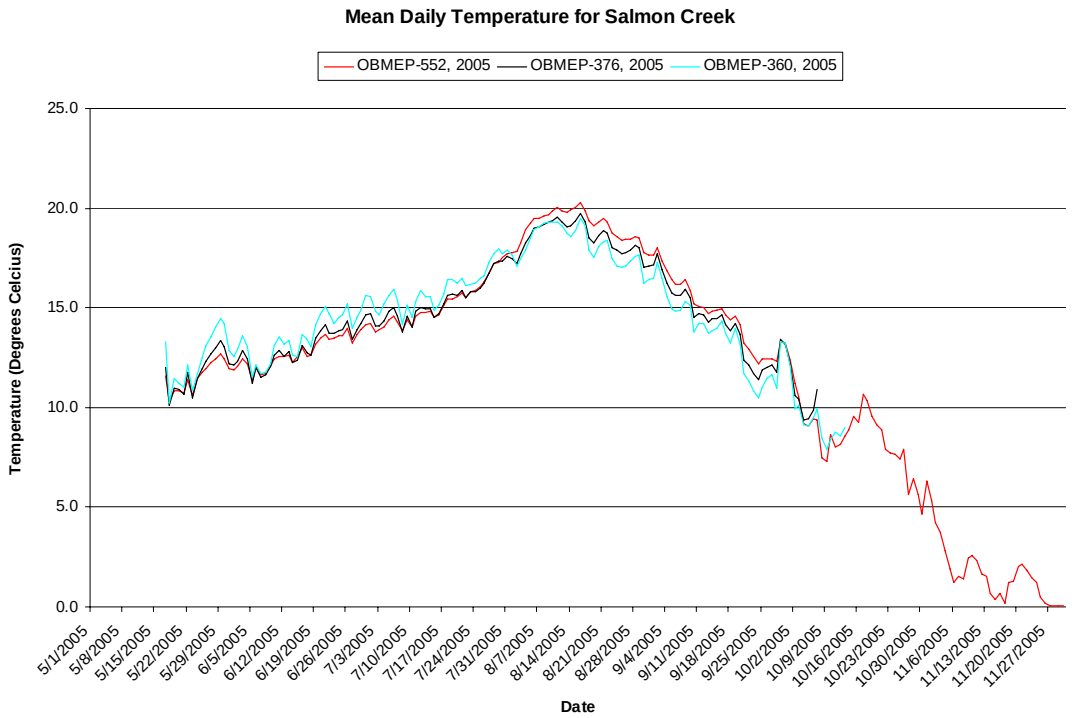

Figure 9: Mean daily temperature recorded from Salmon Creek from May to November of 2005 at multiple monitoring sites.

Omak Creek

The Omak Creek watershed has the potential to provide 27 miles of spawning and up to 40 miles of rearing habitat (USDA 1995). The watershed supports a variety of fish species, including resident rainbow and brook trout, and the federally threatened summer steelhead. It is presumed that historically steelhead utilized most of the perennial stream channels within the watershed. Major summer steelhead spawning events have not been documented above Mission Falls (Figure 10) despite efforts to improve fish passage that occurred in 1999 and 2005 (Figure 11). Mission Falls, located 5.4miles upstream of the confluence with the Okanogan River, remains an effective barrier to Chinook salmon and a major impediment to summer steelhead.

Physical habitat conditions below Mission Falls are in good condition for both spawning and rearing. Above the falls, an abundance of fine sediments resulting from high road densities and highly erosive soils threaten spawning habitats. Fine sediment issues get increasingly severe as you progress upstream. Headwater habitats are severely degraded and responses from restoration efforts will take years to result in measurable habitat improvements. Water temperatures are lowest in the headwaters and increase as you progress downstream, with stream temperatures becoming stressful to salmonids during summer months in the lowest reaches (Figure 12). It is estimated that habitat below Mission Falls could support 160 summer steelhead redds but production above Mission Falls is impossible to model because passage has never been quantified.

Figure 10: Mission Falls during high flows (April 18, 2006).

Figure 11: Steep pool structures installed at Mission Falls to aid in fish passage (September 28, 2005)

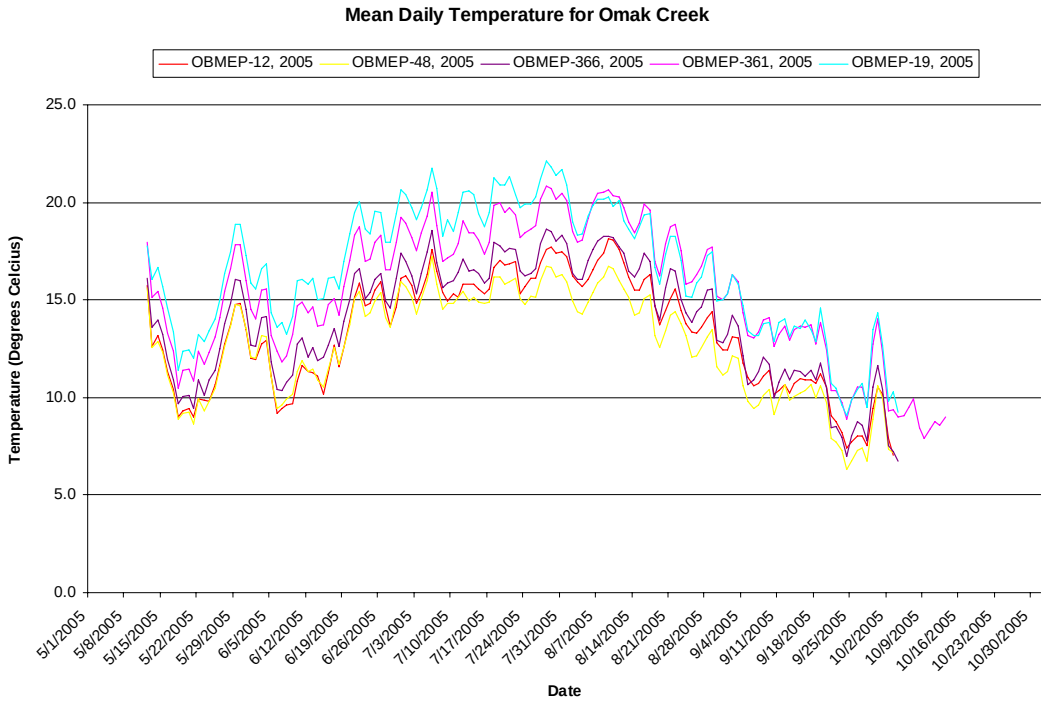

Figure 12: Mean daily temperature recorded from Omak Creek from May to November of 2005 at various monitoring sites.

Wanacut Creek

Wanacut Creek is a third order intermittent tributary to the Okanogan River located within the Colville Indian Reservation immediately north of the Omak Creek drainage. The Wanacut Creek main stem is approximately 7.6 miles long. However, anadromous fish have always been limited to the lower 1.2 miles due to the presence of a natural falls (Figure 13).

Steelhead habitat below the falls may exist intermittently when sufficient discharge provides adequate access to the creek from the Okanogan River. At the mouth of this creek no defined channel exists and a large delta has formed making it difficult for adult anadromous salmonids to gain access. Resident rainbow trout occupy habitats upstream of the falls. The creek is known to go dry in the summer months downstream of these falls. There was water in the creek all year round above the falls in 2006 (Kistler pers. com.) and water temperatures are conducive for salmonid production (Figure 14). Flow may be diverted between the falls and the confluence with the Okanogan River because data collection efforts have been limited this remains a data gap. Habitat rehabilitation efforts may be warranted if flow could be reestablished in the lower one mile section of the creek. Currently fish production estimates are impossible due to a lack of quantifiable data.

Figure 13: Wanacut Falls are located 1.2 miles upstream with the confluence of Wanacut Creek and the Okanogan River (September 2006).

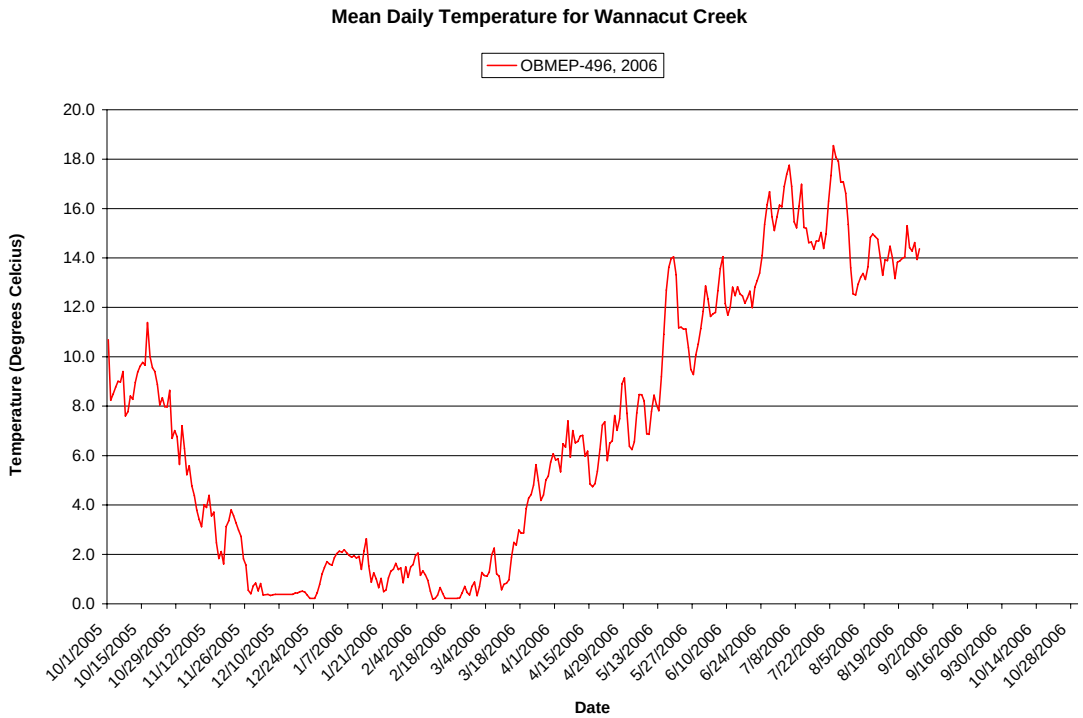

Figure 14: Mean daily temperature recorded from Wannacut Creek from October of 2005 to September of 2006 at the OBMEP monitoring site located above the falls.

Johnson Creek

Johnson Creek runs parallel to the Okanogan River for about 11 miles and joins the Okanogan River along its western shore at approximately RM 35, just south of town of Riverside, WA. Johnson Creek is approximately 7.9 miles long. Although the Washington Department of Ecology (WDOE) stream gauging data suggests that this stream is perennial, observations of this stream by Colville Tribal field staff indicate the reach of stream between Highway 97 and the confluence with the Okanogan River is intermittent and occasionally flows subsurface.

Physical habitat surveys conducted in 2004 as part of the OBMEP project identified that the substrate was composed of mostly clay and large cobble thus providing marginal spawning habitat for salmonids (Arterburn and Kistler 2004). Historically, WDFW stocked brown trout into the upper reaches of this stream and these fish survived for several years (Per Comm. Ken Williams: former WDFW regional biologist) but a lack of successful spawning did not allow these fish to persist. The Colville Tribes conducted snorkel surveys in Johnson Creek during 2004, but did not observe any fish. Based upon field observations (no fish observed) and marginal habitat (lack of appropriate spawning substrate and high stream gradient, 8-11%) we estimate potential for anadromous fish production to be low and unsustainable (Arterburn and Kistler 2004). Therefore, no barrier surveys were warranted upstream of Highway 97.

Tunk Creek

Little quantitative information exists for Tunk Creek especially below a natural falls, located approximately 1 mile upstream of the confluence with the Okanogan River (Figure 15). Summer steelhead spawning occurs in the lower portion of Tunk Creek that is contained within the high water mark of the Okanogan River (Arterburn et al. 2005, Arterburn and Kistler 2006). Steelhead access downstream of the falls is predicated upon perennial flows, thus, it is generally accessible to anadromous salmonids during the winter and spring months. Resident rainbow trout occupy habitats upstream of the falls and perennial flows have been documented since September of 2002. Water temperature data collected at the WDOE stream gauging station 49E080 which is located upstream of the falls at river mile 1.9 indicates that Tunk Creek is one of the colder water sources and is therefore important for anadromous fish in the Okanogan subbasin (Figure 16). Data collection efforts below the falls have been limited by lack of access due to private land ownership. Therefore, information is limited and until this information can be collected and analyzed for Tunk Creek, habitat rehabilitation efforts would be unwarranted.

Figure 15: Tunk Falls are located ¾ of a mile upstream with the confluence of Tunk Creek and the Okanogan River (Picture courtesy of the Okanogan Conservation District).

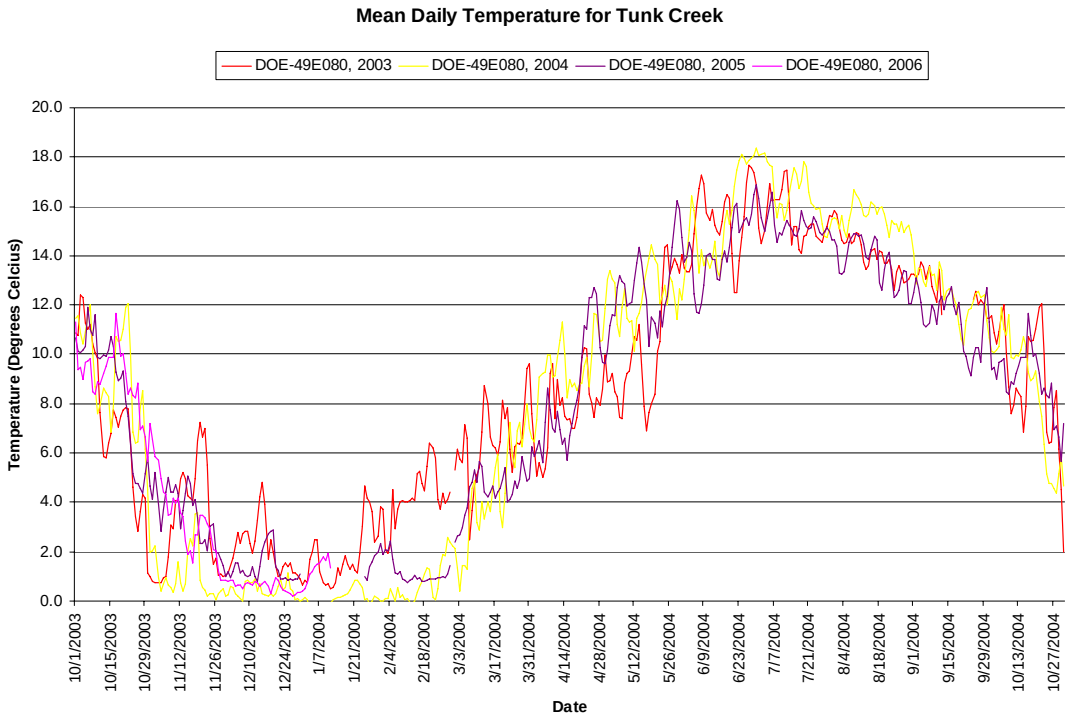

Figure 16: Mean daily average temperature data collected from October to October in 2003, 2004, 2005, and 2006 above the falls on Tunk Creek by WDOE.

Chewiliken Creek

Chewiliken Creek is a second order tributary to the Okanogan River. It flows to the west, and is located between the Tunk Creek watershed to the south, and the Bonaparte Creek watershed to the north. Chewiliken Creek likely has never had much potential for the production of anadromous fish due to its small drainage area, highly porous soils, and limited habitat. Today, discharge is intermittent which represents a significant passage barrier and spawning habitat is very limited because substrates are composed of mostly sand and large cobble. The lack of water probably was a historic condition in this watershed and likely prevented anadromous salmonid production. A natural falls exists at approximately RM 1.75 that would have further limited access to habitats in this Creek (OCD 2002).

Aeneas Creek

Aeneas Creek enters the Okanogan River at approximately river mile 50 and contains three distinct barriers within the first mile of its approximately 8.0 mile length. Two adult fish passage barriers were identified during joint surveys conducted by the Colville Confederated Tribes and Washington Department of Fish Wildlife during the summer of 1998. This survey indicated that the lowermost partial barrier is a concrete box culvert located approximately 0.25 miles upstream from the mouth where the stream passes beneath State Highway 7. Potential anadromous fish use is restricted to habitat up to the lowermost falls in the system at approximately RM 0.75 (Figure 17). During the spring of 2000 a picket-weir trap was installed by the Colville Tribes near the mouth of Aeneas Creek and monitored for approximately 8 weeks to address the potential use of this sub watershed by steelhead however, no adult steelhead were collected (Entrix 2001).

Additional field observations have indicated that a significant impediment exists at the mouth of this creek (Figure 17). The entrance into the creek is almost vertical and extends for about 5 to 6 feet unless the Okanogan River is at or near flood stage. Upstream of the confluence is a series of wetland pools would act as impediments to adult steelhead and offer mimnimal spawning habitat as this area is mostly comprised of fine sediments. These ponds could provide good rearing habitat but the lack of spawning habitat and the major obstruction to juvenile fish at the mouth make this habitat unlikely to be utilized.

During 1999, adult sockeye salmon were implanted with radio-tags to determine travel time through the Okanogan River. Adult sockeye were located for short periods of time at the confluence of Aeneas Creek during the migration from the mouth of the Okanogan River to Lake Osoyoos (pers. com. Shane Bickford Douglas PUD). It was presumed adult sockeye salmon were utilizing the confluence area of Aeneas Creek as a thermal refuge during their migration up the Okanogan River.

The lower portion of Aeneas Creek could be developed into a rearing or acclimation stream for hatchery produced summer steelhead. It would take considerable effort to alter the lower reaches enough to provide upstream juvenile passage for *O. mykiss.* However, if juvenile access was provided the rearing habitat in Aeneas Creek could be utilized by steelhead that spawn in the mainstem Okanogan River near the confluence of Aeneas Creek (Arterburn and Kistler 2005, Arterburn et al. 2005).

Figure 17: Top panels: Views of the waterfall in Aeneas Creek, approximately 0.75 miles upstream from the confluence. Bottom panel (c): A view of the confluence of Aeneas Creek to the Okanogan River (6/18/2001).

Bonaparte Creek

The confluence of the Okanogan River and Bonaparte Creek is located at the town of Tonasket, Washington. The lower reach of Bonaparte Creek flows through an urban setting resulting in artificial confinement of the stream channel. Artificial confinement results in less habitat diversity and reduced floodplain connectivity compared to historic conditions. Due to channel alterations within the watershed, more water is transported during spring runoff and storm events than historically (Entrix 2001). By increasing the force of the stream, changes in channel morphology, channel stability and water quality have resulted. Large amounts of sandy sediment are transported to the lower reaches of

Bonaparte Creek and into the Okanogan River from the channel erosion occurring between river miles 5.1 to river mile 10.8. Within these reaches agricultural and rangeland activities are common along most of this stream resulting in active erosion and head cutting. Past and current livestock operations adjacent to Bonaparte Creek have been the source of high levels of *E. coli*.

The lack of riparian area protection, the proximity of Highway 20 and poor land stewardship in the upper watershed have resulted in abundant fine sediments within the lower watershed that have reduced the quality of spawning habitats for anadromous salmonids. Water temperatures remain within acceptable limits for salmonids year round (Figure 18). Bonaparte Creek supports threatened summer steelhead and the lower 1.0 mile is considered highly utilized compared with other habitats in the Okanogan sub-basin. The use of this stream by summer steelhead for both spawning and rearing is well documented (Arterburn et al. 2005c, Arterburn and Kistler 2006, Kistler and Arterburn 2006). However, the extent of habitat accessible to anadromous fish is limited by Bonaparte Falls at river mile 1.0 (Figure 19).

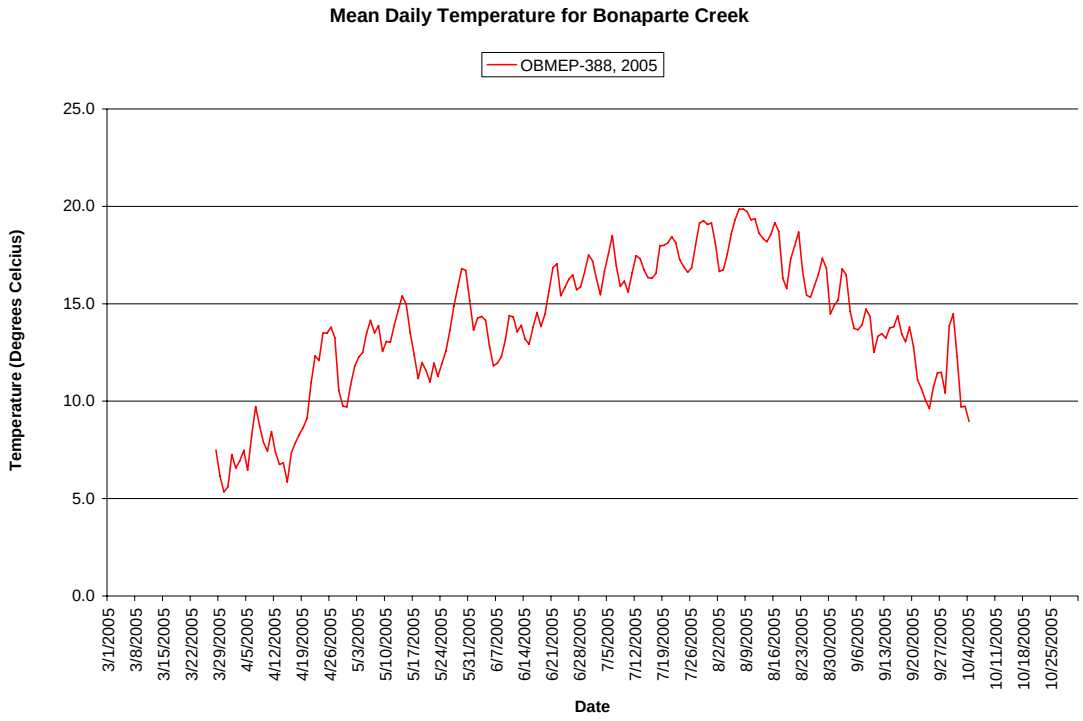

Figure 18: Mean daily temperature recorded for Bonaparte Creek from March to October of 2006 below the falls.

Figure 19: Bonaparte Falls at river mile 1.0 (9/16/04).

Siwash Creek

Siwash Creek is approximately 21 miles long but anadromous fisheries resources are restricted due to an impassible steep gradient reach located approximately 1.4 miles upstream of the confluence with the Okanogan River (OCD 2002). Siwash Creek has also been reported to have irrigation withdrawal structures on private lands. These structures can act as physical fish passage barriers, for up and/or downstream travel, in addition to exacerbating the existing low flow condition that occurs during the summer and fall (USDA 1999). The physical barriers mentioned above could not be verified as part of our effort due to lack of landowner permission. However, lack of water from mid-

summer to the spring of the following year is easily verified and occurs in most years on lower Siwash Creek.

The lack of late summer and fall flows is also thought to be an historic condition based upon hydrologic studies conducted in the mid-seventies by the United State Geological Survey and Washington State Department of Ecology (Walter 1974). The hydrology of Siwash Creek is characterized by high spring runoff from melting snow accumulated from late fall through the winter. Average annual surface flow is about 5 CFS for the Siwash watershed. Most tributaries to the main drainage go dry in most years during the fall and winter months. Peak stream flow averages about 40 CFS, but has been measured at 75 CFS. The Siwash watershed is relatively productive for ground water development. In the lower reaches of the basin, wells less than 50 feet deep have yields of 100 to 400 gallons per minute (Walters 1974). Summer and fall runoff is low, and fed through the release of stored water from riparian areas, flood plains, seeps and springs at the headwaters of tributary streams. Small tributaries to larger streams generally have surface flow only during peak snowmelt and are dry the remainder of the year (USDA 1999).

The mouth of Siwash Creek also represents a physical barrier due to a lack of sufficient discharge in most years (Figure 20). The extensive delta area does not confine flows making this area too shallow for adult fish to easily migrate through unless sufficient discharge in the Okanogan River exist to inundate the delta. High flows for the Okanogan River typically occur in June which is after most summer steelhead spawn. However, during the high flow period for the Okanogan River juvenile salmonids do invade the lower reaches of this stream. Suitable spawning habitat occurs in Siwash Creek when flows are sufficient to allow adult migration. The Colville Tribes conducted habitat and juvenile fish surveys on Siwash Creek in 2005 above the anadromous zone. This reach was located in an area that was spring fed and only eastern brook trout were observed (Arterburn Kistler 2005, Kistler and Arterburn 2006). Lack of overland flow along the lower reaches represents the most limiting factor for salmonid production in Siwash Creek. Groundwater resources are believed to be shared with the lower Antoine Creek watershed. Therefore, as ground water resources are developed in the form of wells or diversions in either watershed, surface flows are reduced in both frequency and duration within the Siwash watershed (Entrix 2001).

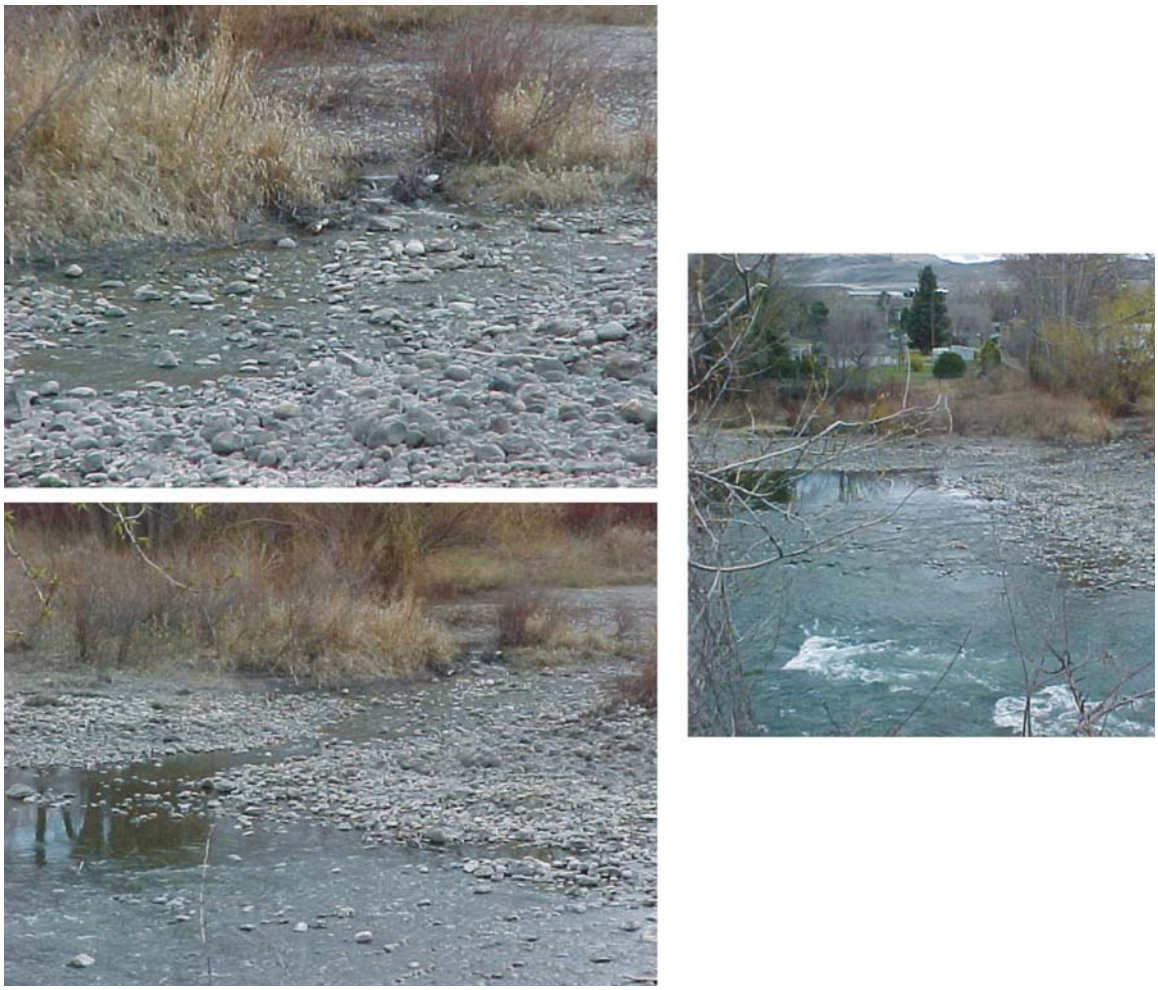

Figure 20: All panels are of the confluence of Siwash Creek to the Okanogan River (6/18/2001).

Antoine Creek

A review of the literature prior to undertaking this study uncovered documents that identified 11 miles of stream were accessible to anadromous salmonids within the Antoine Creek watershed although the barrier or barriers had not been documented (Entrix 2001). The lowest reach of Antoine Creek (approximately 0.5 miles) has been rerouted over the past century, to accommodate various human needs and ventures (USDA 1999). The original configuration of this lower reach and confluence with the Okanogan River (in its original setting) together or independently may have presented passage barriers to fish but no information has been located that confirms or denies this possibility (USDA 1999). The lower reaches of Antoine Creek are primarily bordered by fruit orchards. The Antoine Creek watershed has an annual surface flow of about 6 cubic feet per second (CFS) and ground water production has been reported at 100 to 400 gallons per minute for wells less than 50 feet deep (Walters, 1974). Surface stream flow in the lower reaches of Antoine Creek is occasionally reduced to no flow during the driest part of the year due to surface irrigation and ground water withdrawals (USDA 1999).

On April 7, 2004 and again on July 06, 2006, the Colville Tribes conducted stream surveys in an attempt to verify the information above and document the any fish passage barriers. We noticed that the stream banks appeared to be stable and vegetated but the presence of large wood within the riparian area was noticeably absent. Even so, canopy closure was sufficient in most areas to provide shade on the water surface. On April 7, 2004 at approximately RM 0.22 discharge was calculated to be 1.1 CFS, upstream of Highway 97 (RM 0.24) discharge was 1.2 CFS, and upstream of the first diversion dam (~ RM 1.0) discharge was 1.8 CFS. There was a difference in discharge calculations of 0.7CFS between the upstream diversion and the confluence with the Okanogan River indicating that this is a recharge reach for ground water or that other diversions are occurring that remained unidentified or are indirectly affecting surface water flows (i.e. wells withdrawing from the aquifer).

Three physical barriers were identified, the first was a bedrock chute that formed both a velocity and gradient barrier to fish migration at RM 0.98 (Figure 21). The second was located at the top of the bedrock shoot and consisted of a large pool with a small falls (Figure 22). Lastly, approximately 150' upstream of the small falls is an irrigation diversion that would represent a complete fish barrier when in operation (Figure 23). All three of these physical barriers represent significant impediments to fish passage but collectively they certainly represent a complete barrier to migrating fish. Preferred spawning substrate appeared isolated, scarce and what does exist is impacted by fine sediment throughout the surveyed reach (Figure 24). There is no indication that other environmental conditions might limit salmonid production, due to the presence of rainbow trout (*Oncorhynchus mykiss*) and Eastern brook trout (*Salvelinus fontinalis*) sampled during November 2001 (CCT unpublished data) and August 2005 (Kistler et al. 2006, Arterburn et al. 2006). Temperatures are favorable for coldwater salmonids throughout the year (Figure 25).

Preliminary modeling suggests that habitat for up to 26 redds is possible assuming; 3 times current discharge, improved substrate quality and quantity, and modified channel conditions occur. Options to increase flow may include but are not limited to: water right/land acquisition, improved irrigation delivery, or water lease. Based upon flow measurements and channel morphology (i.e. channel width) it is estimated a tripling of flow (~ 10 CFS) would provide sufficient discharge to allow adult steelhead to access into Antoine Creek during all years. This increase in flow would only be necessary during the expected steelhead spawning period (mid-March thru April) as long as a minimum flow of 0.8cfs was maintained throughout the remaining year. The lower reach of Antoine Creek is relatively accessible by motorized vehicle therefore opportunities do exist to easily augment spawning substrate by adding preferred gravel sized material near preferred spawning sites (i.e. downwelling, pool tailouts). Based upon our results sustainable steelhead populations in Antoine Creek are currently limited by low discharge plus marginal substrate and historically, were limited by access to the lower 0.98 river miles upstream of the confluence with the Okanogan River.

Figure 21: The lower reach (left) and upper reach (right) of the bedrock chute that is considered an impassable barrier for anadromous salmonids on Antoine Creek (4/7/04).

Figure 22: Bedrock falls above the bedrock chute on Antoine Creek (7/06).

Figure 23: Water diversion on Antoine Creek approximately 150 feet upstream of natural barrier (4/7/04).

Figure 24: Typical substrate at an anticipated spawning site in Antoine Creek (4/7/04).

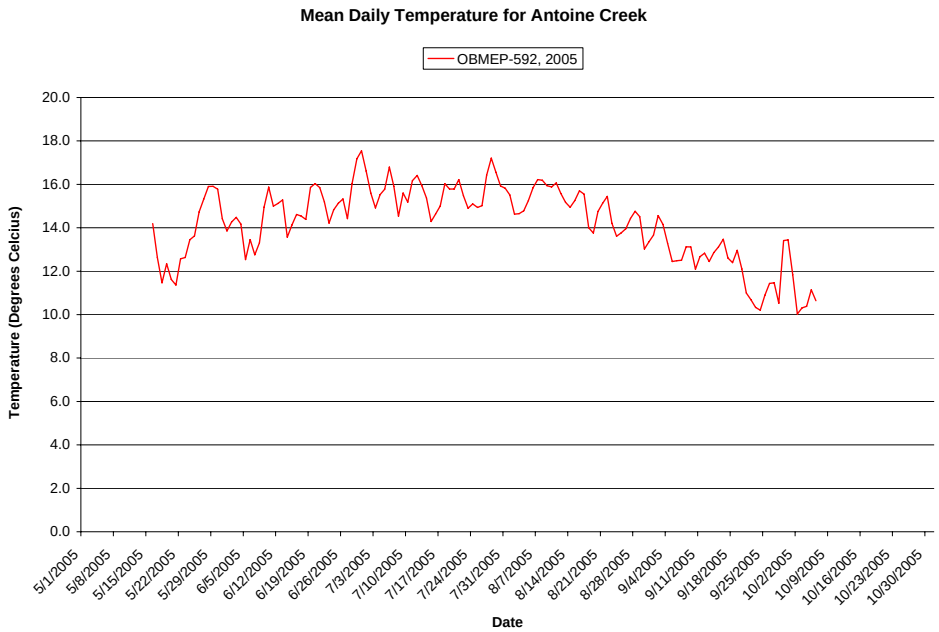

Figure 25: Mean daily temperature recorded from Antoine Creek from may to October of 2005.

Whitestone Creek

Whitestone Creek, through the development of Spectacle Lake and Whitestone Lake, provides considerable irrigation water over a large area. This water has been used for fruit production and other agricultural products throughout the watershed and surrounding area. Both of these lakes have been enlarged, increasing the amount of solar radiation absorbed by the water bodies. The increased exposure to thermal radiation along with the dam design that discharges the surface water from the lake as the water is passed downstream dramatically increases summer water temperatures. The Colville Tribes placed a temperature data logger into Whitestone Creek in April of 2005 and removed it in October of 2005. The mean daily average for this creek exceeded 22 °C for 9 days in both July and August (Figure 26). Modification made to the hydrology of this watershed have resulted in water temperatures that far exceed state water quality standards and exclude all coldwater fishes because instantaneous peak summer water temperatures exceeded 25 °Celsius.

Because water temperatures preclude salmonid production no formal fish habitat surveys have ever been conducted within the Whitestone Creek/Lake sub watershed. The Okanogan River Basin limiting factors analysis identified most possible limiting factors as data gaps (Entrix 2001). The Colville Tribes surveyed Whitestone Creek in April 22,

2005, from its confluence with the Okanogan River upstream to Hwy 7 (RM 0.55.) We were unable to verify the limiting factors reports assertion that summer steelhead could not migrate above River-Loop Road. During our surveys we saw no evidence of any barrier to passage through this culvert (Figure 27). Whitestone Creek also has a barrier designated by the OCD at RM 1.5 but this document did not elaborated on what type of barrier this was making it difficult to verify (OCD 2002).

Use of Whitestone Creek by anadromous fish, specifically Chinook and sockeye salmon has never been demonstrated and historical use has not been researched. No salmonid redds or juveniles have been observed or documented. In contrast, field observations by Colville Tribal biologists have documented common carp utilizing the lower reaches of this stream on multiple occasions. Summer steelhead historically could have utilized most of the 2.8 mile long main-stem because at present all barriers are known to be man-made (i.e. dams, culverts, irrigation diversions). A large irrigation diversion just east of highway 7 would represent an impediment but not a complete barrier to upstream migrating adult steelhead when in operation (Figure 27). The next potential barrier is located under Highway 7 but this culvert does not represent any sort of migration barrier. The entire Whitestone Creek watershed is located on private lands and we were unable to gain access to continue this stream survey above highway 7 (Figure 28).

Physical habitat along Whitestone Creek consists of substrates that are dominated by sand and gravel with substrates near the confluence with the Okanogan River comprised of mostly sand and coarse gravels in areas above the Okanogan River floodplain. Whitestone Creek has been channelized resulting in homogenous habitat throughout the reach below state Highway 7. The stream was highly turbid due to high flows in the Okanogan River that backed water up into Whitestone Creek for approximately 100 meters during (Figure 28). Rural development and lack of riparian vegetation were identified by the OWC (2000) as potentially resulting in channel erosion, sedimentation, and compromised water quality (Figure 28). Due to channelization throughout much of the sub watershed, it was ranked as poor for floodplain connectivity (Entrix 2001). However, thermal pollution would be the most important environmental factor to address on Whitestone Creek as it related to salmon and steelhead recovery efforts.

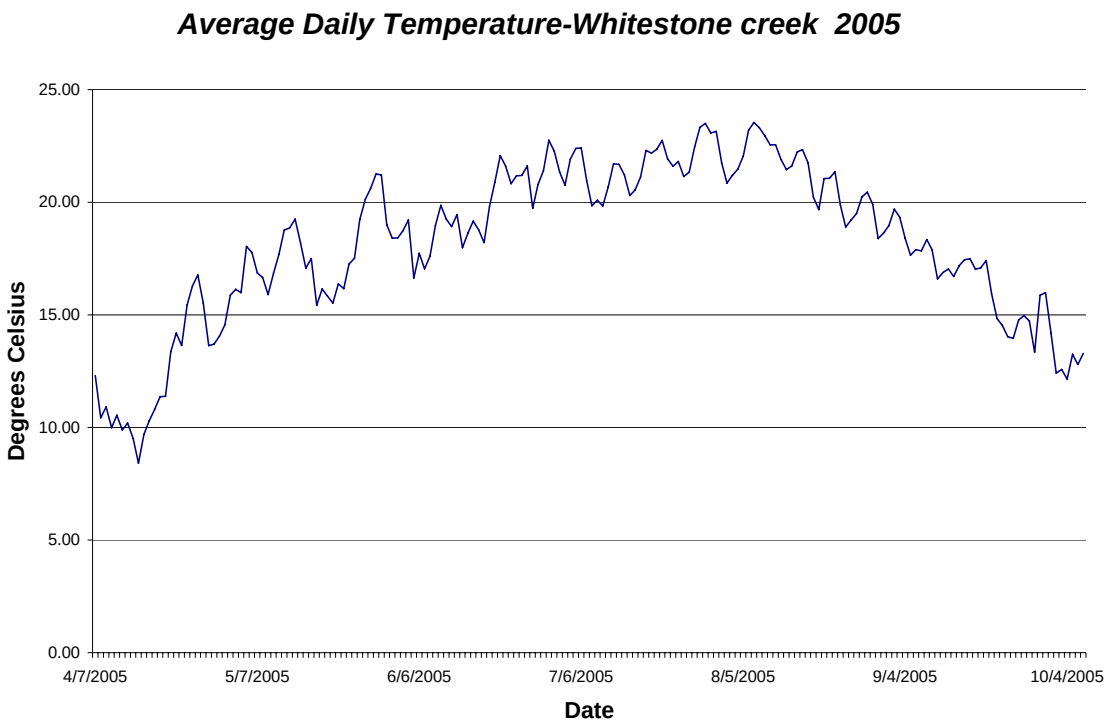

Figure 26: Mean daily temperature recorded from Whitestone Creek from April to October of 2005.

Figure 27: Top panels represent an irrigation withdrawl on Whitestone Creek just downstream of Highway 7. Bottom panels are pictures of culvert at Riverloop Road, approximately 0.25 miles upstream of the confluence (8/6/2001).

Figure 28: Left Panels show the confluence of Whitestone Creek with the Okanogan River (6/21/2001). Right panel shows the Whitestone Creek culvert (approximately 100 ft long) that runs under State Highway 7.

Wildhorse Spring Creek

Wildhorse Spring Creek crosses under State Highway 97 near the intersection with O'Neil Road between the towns of Ellisforde and Oroville, Washington. Summer steelhead were observed spawning by both Colville Tribal and Washington Department of Fish and Wildlife biologists on 4/24/06 (Arterburn and Kistler 2006). The lower quarter mile of the creek has good spawning substrate (Figure 29). Upstream of this reach the creek runs through a horse pasture were the stream banks have been destroyed causing the channel to become braided and filled with fine sediment (Figure 30). Upstream of the horse pasture, Wildhorse Spring Creek is well shaded by dense riparian shrubs. The stream contains multiple old box culverts (Figure 31). This stream eventually splits into two forks and the gradient increases dramatically. Both forks were considered impassable to steelhead beyond river mile 0.73 (Figure 32 & 33). Fish passage on the north fork terminates at an underground pipe while the south fork terminates at a high gradient bedrock slide.

During July and again in August 2006, snorkel surveys were conducted by the Colville Tribes Fish and Wildlife Department to determine the presence or absence of summer steelhead resulting from redds observed during the Spring. On both occasions, juvenile steelhead were observed both upstream and downstream of Highway 97. The water temperature of Wildhorse Spring Creek remained at 57°F throughout the summer compared to temperatures that commonly exceed 70°F in the Okanogan River. This small spring creek has considerable potential to produce summer steelhead during most years provided sufficient water remains. Although spawning area is very limited our model did estimate that current habitat would conservatively support 7 redds. The cold water and spring creek characteristics will likely result in excellent survival from egg-to-fry and from fry-to- smolt provided flows can be protected. The small size of the Wildhorse Spring Creek drainage allows for possible protection of the entire stream. The cost to enhance or rehabilitate this creek will be minimal and therefore makes it a good candidate to consider for protection, acquisition, and restoration activities in the near future.

Figure 29: Spawning gravels indicative of the lower 0.25 miles of Wildhorse Spring Creek (6/13/2006).

Figure 30: Horse pasture along Wildhorse Spring Creek (6/13/2006).

Figure 31: Old box culvert upstream of the horse pasture located along Wildhorse Spring Creek (6/13/2006).

Figure 32: Anadromous fish passage barrier located on North fork of Wildhorse Spring Creek (6/13/2006).

Figure 33: Anadromous fish passage barrier located on South fork of Wildhorse Spring Creek (6/13/2006).

Whistler Cache Creek

Whistler Cache Creek is located between Ellisforde and Oroville, Washington near the intersection of Gavin Road and State Highway 97. This stream has minimal potential for steelhead spawning and is intermittent so it provides no rearing habitat. From its confluence with the Okanogan River, Whistler Cache Creek first passes through a pasture that is fenced perpendicular to the flow and the channel contains considerable man-made refuse. Above the pasture is the lowest culvert located at Gavin Road. The Gavin Road culvert appears passable but less than 100 ft upstream is a railroad culvert that is a complete passage barrier with a gradient of 12 to 14%. The outlet discharges Whistler Cache Creek over broken concrete and rip-rap (Figure 34). After passing under State Highway 97 though an oddly configured concrete culvert this stream passes through a well manicured front yard (Figure 35). The landowner's family have lived adjacent to Whistler Cache Creek for several generations but had not observed steelhead, but had observed that the creek-bed, dry during most summers. At river mile 0.46 an unnamed falls is a complete barrier to anadromous fish passage (Figure 36). Whistler Cache Creek below the falls is limited by a lack of perennial flow and man-made passage impediments. The substrate consisted of 80% small and large cobble with the remainder consisting of fine sediment, gravel, and boulders. Even if passage barriers were removed, only select high water years would provide access to limited spawning habitats for summer steelhead.

Figure 34: Lower fish passage barrier culvert (RM 0.1) located at railroad tracks sandwiched between highway 97 and Gavin Road on Whistler Cache Creek (May, 2006).

Figure 35: Whistler Cache Creek as it flows through the manicured yard east of highway 97 (May, 2006).

Figure 36: Natural terminus to steelhead passage located at River mile 0.46 on Whistler Cache Creek (May, 2006).

Tonasket Creek

Tonasket Creek enters the Okanogan River east of the city of Oroville, WA (RM 77.8) and the main-stem channel of the creek is 14 miles long. The lower reaches of Tonasket Creek have been highly manipulated for a wide variety of land use activities and the relationship of current conditions to historic conditions is unknown. During July of 2001 the sub watershed experienced localized flash flooding that resulted in the loss of human life, and significant channel realignment. Flood plain connectivity is poor because Tonasket Creek has been channelized through orchards and along County Road 9480 for at least the lowest 1.0 mile. No flood plain was created when this channel was constructed (Entrix 2001). Shade has been greatly reduced in the lower portion of Tonasket Creek with most of the natural vegetation being replaced by orchards. Trees and other vegetation were also removed for the right of way of County Road 9480. Previous problems identified for the Tonasket Creek sub watershed by the OWC (2000) include: sediment from roads, irrigation de-watering, herbicide/fertilizer runoff, and noxious weeds.

Reports of summer steelhead using the habitats of Tonasket Creek have existed for almost 40 years. Steelhead fry were observed in the confluence area where Tonasket Creek joins the Okanogan River (Ken Williams, Area Fish Biologist Region 2 Washington Department Fish and Wildlife (retired)). He surmised that the fry were using the confluence area for rearing. Summer steelhead smolt counts conducted by WDFW totaled 148 from the mouth to the headwaters in 1988 (Entrix 2001). An adult steelhead was caught at approximately RM 1.8 in the late 1970s (D. Buckmiller, personal communication). An adult steelhead was observed constructing a redd during the spring of 2000(H. Bartlett WDFW and C. Fisher Colville Tribes, personal communication) Redd surveys conducted by the Colville Tribes in 2006 identified 5 redds and one steelhead carcass (Arterburn and Kistler 2006).

Tonasket Creek has potential for steelhead production but is limited by lack of consistent discharge and artificial confinement. Surveys conducted as part of this study identified the upstream limit for steelhead migration is below Tonasket Falls (RM 1.8) (Figure 37). The creek goes dry in the summer in most years (RM 1.0) and is confined by dykes as it goes through multiple orchards in the first mile (Figure 38). Water temperatures above the falls are consistently cold enough to support salmonids year round however; reaches below the falls dry up during the summer months of most years (Figure 39). Rehabilitation efforts should focus on increasing discharge during the summer months. Once perennial flow is established, efforts to increase habitat diversity and flood plain connectivity should be pursued. Tonasket Creek will continue to be surveyed for redds and habitat conditions through OBMEP.

Figure 37: The Falls at the Chesaw grade on Tonasket Creek is the terminus for summer steelhead passage and is located at river mile 1.8 (6/3/2006).

Figure 38: Tonasket Creek is artificially confined by earthen dykes along the lower 1.0 mile (6/3/2006).

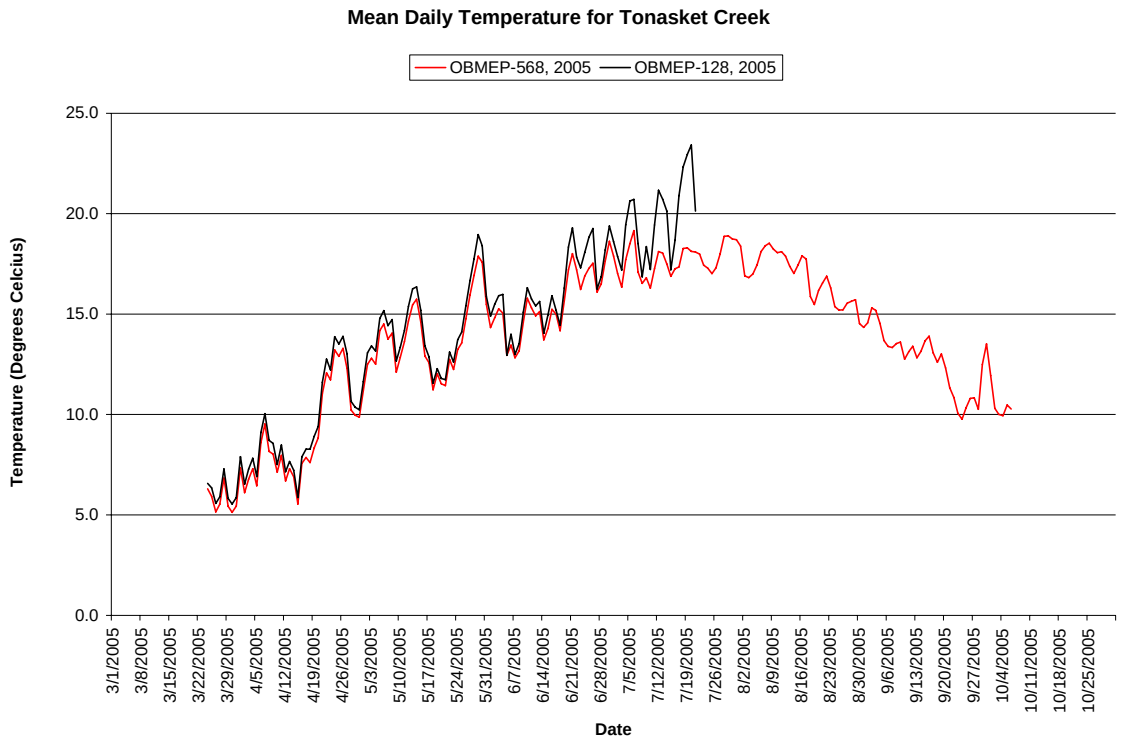

Figure 39: Water temperature for OBMEP site 128 located below the falls and OBMEP site 568 located above the falls on Tonasket Creek. Data not collected after July 21, 2005 from site 128 due to the stream going dry.

Ninemile Creek

Past documents that have attempted to characterize the fish habitats within the Okanogan Basin have clearly identified Ninemile Creek as a data gap (Entrix 2001). Ninemile Creek is a second order tributary with 6.8 miles of main-stem channel. The Creek flows directly into Lake Osoyoos along the eastern shore of the southern basin. Interviews with local landowners indicate that the lower reach of Ninemile Creek was channelized annually until approximately 20 years ago. On April 16, 2004, the Colville Tribes evaluated physical habitat conditions associated with supporting summer steelhead in the first mile of this Creek. On May 6, 2006, a survey was conducted on the upper portion of Ninemile Creek to determine the maximum habitat available to anadromous fish. Approximately 1.15 miles of the stream was surveyed in 2004 and 1.23 miles in 2006. The survey in 2004 originated at the mouth of the creek and concluded at the property line of Mr. Junior Eder. Access to private lands above this point could not be secured. The survey in 2006, originated on Ninemile ranch at Mallard Rd., approximately river mile 5.55 and ended above Mr. Eder's property at river mile 4.32.

During our survey we observed that spawning substrates were marginal and consist of mostly embedded gravel and cobble. Optimum spawning-size substrate was rarely observed and is therefore considered severely limiting. Vigorous riparian vegetation bordered the lower stream channel. However, in many areas the width of the riparian corridor was severely reduced by encroaching agricultural activity, typically orchards (Figure 40) and artificially confined by the presence of dikes. Upstream of the lower surveyed reach on private lands, the stream gradient lessens, the channel appeared more sinuous, and conditions appeared more favorable to spawning. However, impacts from livestock grazing were evident by reduced riparian vegetation and actively eroding stream banks. The reaches upstream of the private land is characterized by large and small boulders that create a series of rapids, cascades, plunge pools, and small falls (Figure 41). No fish would be able to ascend the 40 foot falls at river mile 5.16 (Figure 42). The habitat below the falls to approximately river mile 4 is very limited for steelhead spawning because of the lack of suitable substrate and steep gradient. However, these habitats could be utilized by juvenile salmonids for rearing.

Discharge was measured on April 16, 2004 at approximately RM 0.1 and RM 1.10 at a rate of 3.3 and 3.5 CFS, respectively and the stream averaged 6.3 feet wide. There is no indication that other environmental conditions might limit salmonid production, due to the presence of rainbow trout and Eastern brook trout sampled during August 2005 (Kistler et al. 2006, Arterburn et al. 2006). Temperatures are favorable for coldwater salmonids throughout the year (Figure 43).

During the 2004 survey, one adult steelhead was located approximately 600 yards upstream from the mouth. Additionally, in 2004, there was evidence of spawning activity (Figure 44) and this was reinforced by steelhead spawning surveys in 2005 and 2006 that identified up to nine redds each year in the lower surveyed reach (Arterburn et al. 2005c, Arterburn and Kistler 2006). Based upon this survey and additional observations there is ample evidence that Ninemile Creek has supported summer steelhead in the past, albeit in a limited basis due to the physical habitat conditions (channelized, limited pool habitat, limited preferred spawning substrate, etc.). Further evidence suggests that numbers of adult steelhead utilizing Ninemile Creek could be substantial as some migrant workers have fished for and harvested steelhead in the last 5 to 10 years. Preliminary modeling suggests that the lower 1.15 miles of this stream has a maximum production potential of 31 redds. Assuming that no barrier exist on the private lands this number would expand to 91 redds.

It appears Ninemile Creek has potential to produce substantial numbers of summer steelhead. However, information regarding the surface water diversions and information on private lands remains unknown and could limit production. The Colville Tribes through their OBMEP project has cooperated with the United States Geological Survey to establish a real-time stream gauging station on lower Ninemile Creek to improve knowledge related to discharge and temperature.

Figure 40: Riparian vegetation along lower Ninemile Creek (10/16/04).

Figure 41: Example of Ninemile Creek boulder/rapid habitat in the upper surveyed reach (05/06/06).

Figure 42: Ninemile Falls located on Ninemile Creek approximately 5.5 upstream of the confluence with Osyoos Lake (05/06/06).

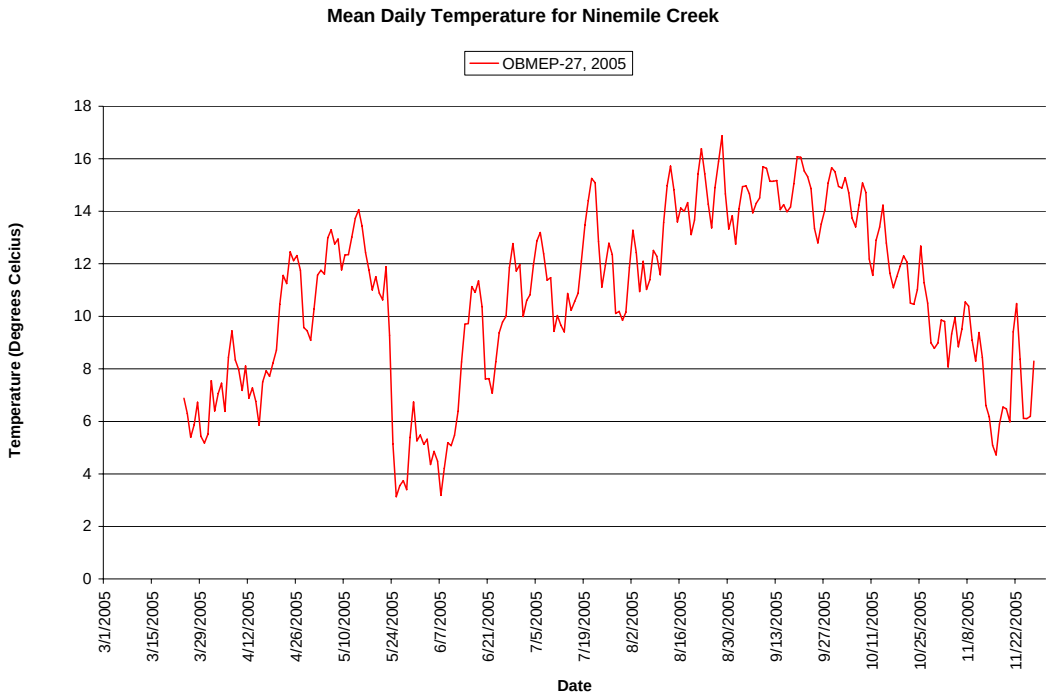

Figure 43. Mean daily temperature recorded from Ninemile Creek from March to November of 2005.

Figure 44: Redd identified in lower Ninemile Creek (4/16/04).

Over the last several years it has been established that summer steelhead are regularly utilizing Ninemile Creek for both spawning and rearing. Therefore, efforts should be directed towards improving habitat conditions in the lower 1.15 miles. Restoration actions involving in-stream structures can help to address low hydrological variability in the channelized reach by; expanding rearing habitat (low velocity pools for over-wintering), improving gravel deposition, and enhancing spawning habitat (pool tail-out areas). Gravel supplementation to restore gavel beds removed during channelization could easily occur. Where personal property improvements don't encroach on the creek, the stream channel should be reconnected to the natural floodplain or dykes set back to allow from channel migration. Based upon the stream gradient observed, it is assumed that the floodplain would not be extensive. However, by removing the dykes or setting them back, natural sinuosity can be restored thus improving habitat complexity. Channel restoration efforts would definitely increase summer steelhead production in Ninemile Creek and perhaps have tangible benefits at the Okanogan River population level. Improving relationships with local landowners will be critical to the success of these efforts.

Similkameen River

The Similkameen River is the largest tributary to the Okanogan River. It originates in the Canadian Coast range and also drains the northeastern Washington Cascades. Today, access for salmon in the Similkameen River is restricted to Enloe Dam, approximately 8.8 miles above the confluence with the Okanogan River (Figure 45). This 54 ft dam built between 1916 and 1923, was originally constructed for hydropower generation, but has not been in operation since 1959. However, the Okanogan County Public Utility District is currently pursuing to re-license this dam for power generation. Enloe Falls, prior to the construction of the dam, may have restricted anadromous access to the upper Similkameen watershed under nearly all flow conditions, although photographic interpretations of the falls suggest possible passage. The presence of redband trout upstream of Enloe Dam within several tributaries to the Similkameen River such as; Toats Coulee Creek, Pasayten River, and Asnola River drainages gives strong evidence that at certain times these falls were likely passable by Interior Columbia River Redband Steelhead. However, there is no historic record of anadromy upstream of the falls (OWC 2000) beyond the presence of this genetic material.

The Similkameen River below Enloe Dam is one of the most heavily utilized sections of the Okanogan watershed by summer/fall Chinook. Even though instream habitat has been impaired by sedimentation and increased water temperatures, summer Chinook salmon runs have increased slightly in the Similkameen River over the last 20 years (WDFW 2005). The use of the Similkameen by other anadromous salmonids is more limited. The Similkameen historically produced steelhead, and is still used by this species today (Arterburn and Kistler 2005 and 2006). A limited number of sockeye salmon use the Similkameen for spawning, although it is more commonly used as a staging area during migration to avoid high summer water temperatures in the Okanogan River.

Figure 45: Enloe dam 8.8 miles above the confluence with the Okanogan River (5/30/2006)

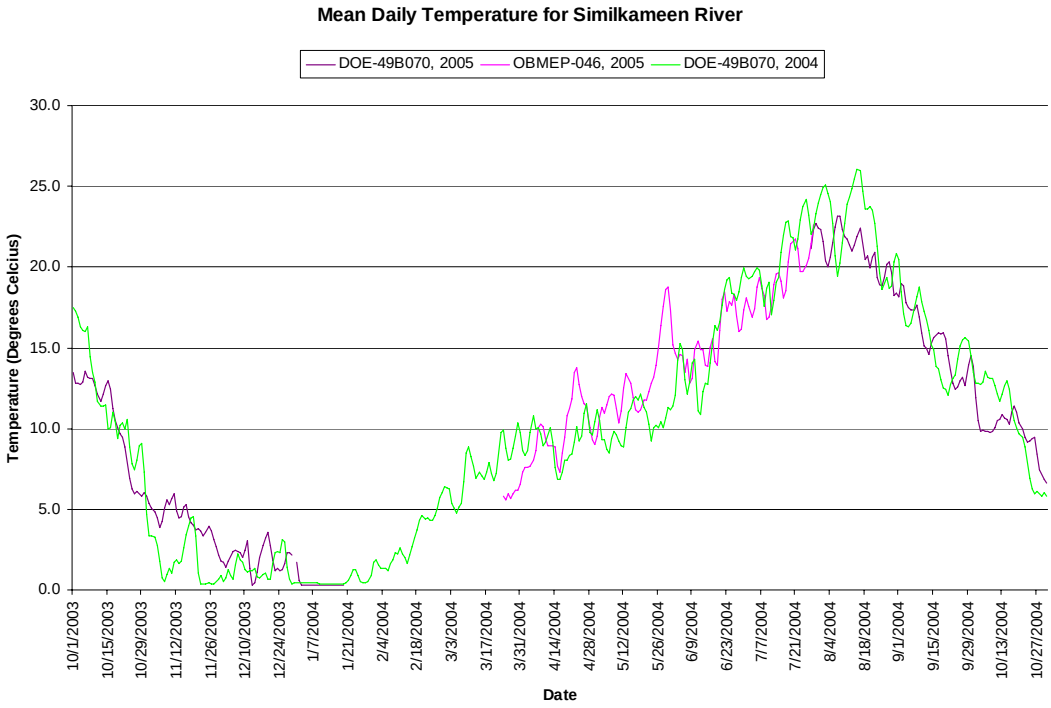

Figure 46. Mean daily temperature recorded from the Similkameen River for the 2004 and 2005 water year. The 2005 water year utilizes data from OBMEP site number 046 and Department of Ecology gauge DOE-49B070.

The use of the Similkameen River, as a cold water refuge for early returning salmon can result in considerable pre-spawn mortality such as occurred in 2004, if water temperatures peak in the later part of the summer (Figure 46).

The Similkameen River transects Canada and the United States and as a result habitat restoration activities within this basin may prompt international law. In addition, multiple State (Washington Dept. of Fish and Wildlife, Dept. of Ecology, etc.) and Federal (Bureau of Land Management, National Marine Fisheries Service, etc.) agencies would be involved if fish passage was proposed at Enloe Dam. Finally, Indian legend exists, with one interpretation suggesting that if anadromous fish could access the Similkameen River upstream of the falls, tragedy would be bestowed upon the aboriginal people of that region. Although Enloe Dam is an obvious barrier to anadromous fish and providing passage would likely result in substantial increases in salmon and steelhead productivity, transboundary issues, multiple jurisdictions and Tribal legend likely prevents passage from being pursued at this time.

Inkaneep Creek

Inkaneep Creek is a tributary to the Okanogan River and enters into the eastern shore of the northern basin of Lake Osoyoos. For year, members of the Inkaneep Indian Band have fished this creek to catch large *O. mykiss*. Based upon conversations with Tribal members it is estimated that as many as 50 fish may be harvested annually during the spring migration (R. Hall, Inkaneep Tribal member, personal communication).

On April 14, 2004, approximately 2.9 miles of the stream was surveyed. The survey originated at the mouth of the creek and concluded at the first physical fish passage barrier upstream. This barrier is a falls that drops 11 feet over a 12 foot horizontal distance. The pool depth created by this falls is 5.5 feet and doesn't provide ample depth for fish to navigate over this falls (Figure 47).

Flow was measured at 22.5 CFS at approximately RM 0.5, wetted stream width averaged 17 feet. Multiple unscreened irrigation diversions were observed. Due to high discharge and relatively turbid conditions, observations were not possible to assess spawning substrate. Approximately half of the 2.9 miles surveyed had steep gradient as depicted by white water and large substrate (cobble and larger), indicating that much of the substrate is likely too large to be utilized for spawning by steelhead except along the channel margins.

Streambanks along the lower reach, near the confluence with Lake Osoyoos, were unstable, vertical, and actively eroding. Streambank conditions result from concentrated livestock grazing. The lower floodplain area is heavily grazed by horses (R. Hall, Inkaneep Band-tribal member, personal communication). Two springs were identified within the surveyed reach. Water temperatures of these springs were, 1 to 3 degrees warmer than the water temperature in the main creek channel, suggesting connections to groundwater. Inkaneep Creek is a unique tributary capable of supporting harvest, albeit

minimal. Preliminary modeling efforts indicate a maximum potential of 206 redds is possible within the 2.9 miles of habitat available to anadromous salmonids.

Restoration efforts should be directed toward the lower reach. These efforts would primarily focus on improved range management practices. These practices would likely include off-site water troughs, exclusionary fences, and hardened rock crossings. Unscreened push-up dam style diversions should be converted to wells or properly screened to prevent juvenile salmonids from becoming entrained.

As efforts to establish a locally adapted summer steelhead program within the Okanogan River basin progress fish returning to Inkaneep Creek should be researched as a possible donor stock to expand these efforts. The OBMEP project has supported increasing the knowledge base related to the entire Okanogan River Watershed including Inkaneep Creek since 2004. However, additional research focused directly on steelhead entering Inkaneep Creek to determine abundance, run-timing, sex ratio, age structure, genetic integrity, etc would help to answer many ongoing questions related to the contribution of Inkaneep Creek to the Okanogan River summer steelhead population as a whole.

Figure 47: Inkaneep falls is the terminus for anadromous fish in Inkaneep Creek and is located 2.9 miles upstream of the mouth (August 2005).

Vaseux Creek

Vaseux Creek (which is sometimes referred to as McIntyre Creek), enters the Okanogan River approximately 0.10 miles downstream from McIntyre Dam (the current terminus for anadromous salmonids in the Okanogan River basin). On June 1, and July 9, 2004 we conducted a survey and found approximately 3.3 miles of Vaseux Creek is accessible by anadromous salmonids these findings were later reconfirmed by surveys conducted by

the Okanogan Nation Alliance (Walsh and Long 2006). However, the terminus at river mile 3.3 may not be complete and may be navigable by some salmonids, possibly steelhead, during certain flow conditions. Historic records indicate a small passable falls existed where people observed Chinook (possibly spring Chinook) entering the stream. This falls was removed when the irrigation diversion for the town of Oliver, BC was constructed across the width of the stream at this location (personal communication, Howie Wright-ONA). Scale samples of *O. mykiss* were collected at this site in the 1970's and a mixture of adfluvial rainbow trout and steelhead were recorded (personal communication, Howie Wright-ONA).

During spring run-off this creek carries large discharges and the broad wide braided channel provides abundant potential spawning areas under a variety of flow conditions. However, highly fluctuating flows have the potential to expose eggs and fry to desiccation and stranding. Due to high flow conditions, discharge was not measured during our surveys. However, it was sufficient to provide adequate depth and negotiable velocities to allow access and spawning for summer steelhead and spring Chinook salmon plus other native salmonids (i.e. whitefish, etc.).

The majority of substrate in the lower mile was gravel in the preferred sizes for summer steelhead and spring Chinook salmon. Upstream the channel enters a steep walled canyon, gradient increases and the substrate is primarily cobble, rubble, and boulder with some bedrock. Spawning habitat in the upper portion of the creek is discontinuous and limited in quantity. However, rearing habitat is more abundant in the step-pool habitats that dominate the canyon. The Okanogan River directly downstream of Vaseux Creek is a major sockeye spawning area due to gravel recruitment from the Vaseux Creek watershed.

In recent years, Vaseux Creek has flowed subsurface (Moore et al. 2004) in the lower reaches (approximately RM 1) during the summer low-flow period. It is hypothesized that the sub-surface condition has been exacerbated or entirely created by stream disturbance when the town of Oliver diversion was routed under the stream bed and alluvial deposits accumulated in place of the historic clay layer. Local residents have observed water flows downstream of the diversion crossing to the mouth, when no flow is present in the reach upstream indicating a shallow aquifer. In the 1990's, the historic streambed was relocated to allow the installation of a BC Hydro electrical substation. Dewatering has been observed in most years since the mid 1990's but overland flows persisted throughout the year in 2004 and 2005, but was dry in September and October of 2006.

Irrigation water withdrawal permits exist for more than 10 users. Two unscreened diversions were identified in the lowermost mile. The lowest diversion is an open ditch that on July 9, 2004 redirected a measured 11.5 cfs (Figure 48). However, it was estimated that two thirds of the diverted flow returned to the stream via overland or groundwater flow. The upper irrigation withdrawal, also unscreened, is located just downstream of a long shear-walled canyon and the flow diverted was estimated to be similar to the lower diversion (Figure 49). Water from the upper diversion is directed west. Irrigation demand is thought to be highest during the summer and fall. Both water

diversions divert water year-round but a head gate does exist on the upper diversion although a small amount of water continues down the irrigation canal even when this gate is closed. During the June 1, 2004 survey 1-*Oncorhynchus mykiss* redd was identified in a side channel just downstream of the upper irrigation diversion.

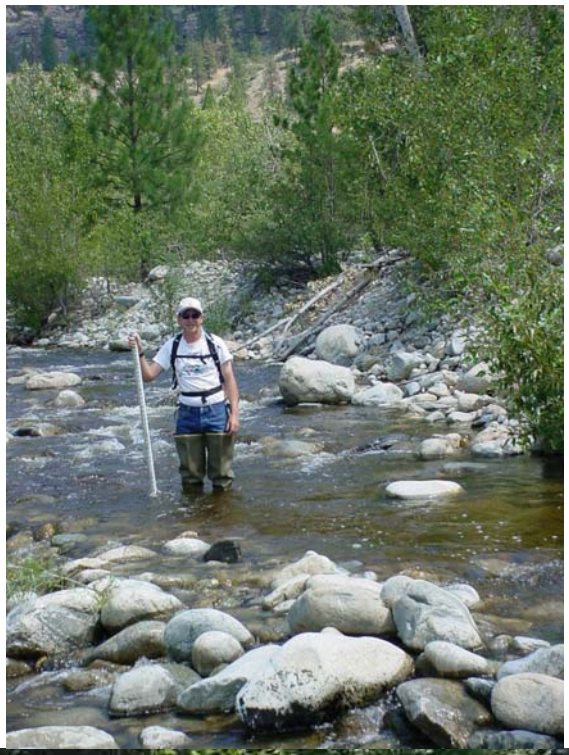

Figure 48: Measuring withdrawal at mouth of lowermost diversion on Vaseux Creek July 9, 2004. Diversion is an unscreened open ditch

Figure 49: Upper diversion on Vaseux Creek. Photo is taken facing down stream with diverted water exiting the stream to the right.

At approximately river mile 1.0, Vaseux Creek enters a canyon where minimal spawning habitat exists due to large substrate materials and high water velocities. However, deep pools, abundant pocket water, cold water temperatures, and perennial flows make this excellent salmonid rearing habitat. Access by anadromous fish was considered terminated at a series of small falls within a reach confined by bedrock cliffs (Figure 50). This constricted reach creates a venturi effect that generates a velocity barrier at high flows. Lack of pool depth creates an impediment at the lower falls and a possible barrier at the upper falls to migrating salmonids during lower flow periods. The height of the lower falls measured 6.9 feet and the upper falls was estimated at 8.0 feet high. The downstream pool at the lower falls was 5.0 feet deep (Figure 51&52) but the pool below the upper falls was not measured due to water velocities and pool depth that made direct measurement impossible (Figure 53).

Based upon information received and collected, flow in Vaseux Creek, particularly in the lower reach in certain years, may be discontinuous. An emphasis should be directed toward determining the lack of continuity in flow in Vaseux Creek. Furthermore, efforts should be made to prevent current salmonid production from being diverted into unscreened irrigation canal intakes. In addition, baseline fish population data should be collected including presence/absence, run timing, adult enumeration and juvenile (fry and smolt) production. The lack of baseline knowledge about this stream is a major limiting factor however, based on watershed size, stream flow, and streambed composition, Vaseux Creek appears to have substantial potential for salmonid production although insufficient data exists to quantify results or conduct modeling.

Figure 50: Confined section of Vaseux Creek, July 9th 2004. Falls begin in background.

Figure 51: Steep gradient approaching lower Falls on Vaseux Creek, July 9, 2004. This is considered a barrier for most anadromous fish due to vertical height and lack of pool depth during low discharge and due to velocities during higher flows.

Figure 52: Lower falls on McIntyre Creek, July 9, 2004. Note large substrate material and confinement indicating extremely high velocities at high discharge.

Figure 54: Upper falls is located in the right center of picture. Access to this location would require free climbing over very large boulders and through swift currents. The combination of vertical barriers, steep gradient, and high confinement lead us to believe that this reach would represent the terminus for anadromous fish migration on Vaseux Creek. Photo taken on July 9, 2004.

Park Rill Creek

Park Rill Creek enters into the Okanagan River North of the town of Oliver, British Columbia, Canada. Historically, the confluence between Park Rill Creek and the Okanagan River occurred in a side channel, however this fluvial connection was severed when the Okanagan River was channelized in the 1950's (Shulbert 1983). Currently, this reach of what was historically the Okanogan River, is now Park Rill Creek and contains a large area better described as a wetland or marsh than a stream (Figures 55). This lower reach contains several culverts that can be opened or closed to control water levels (Walsh and Long 2006).

The lower portion of Park Rill Creek is on private land and a group of landowners named, "Friends of Park Rill," are attempting to rehabilitate the creek by reestablishing flow, controlling purple loosestrife, limiting the amount of seasonal water withdrawal, and reducing sedimentation caused by agricultural practices. Interviews with local residents suggest that historically the stream supported healthy fish populations but they could not report any specific or recent observations of salmonids. Local residents

indicated that the stream currently flows subsurface in certain reaches and suffers from water withdrawal and agricultural impacts resulting in reduced flows and the high sedimentation loads.

A survey was conducted on August 5, 2004, starting at Highway 97 and Island Drive and terminating above Sportsman Bowl Road. Approximately 3 miles of stream were surveyed. Park Rill Creek averaged 2.5 m wide, with pools that were up to, 5 m wide. Currently, there is a large amount of fine sediment in the system punctuated by small areas of cobble and gravel substrates. Healthy riparian vegetation was limited in width by home sites and much of the stream was channelized with culverts under numerous roads including highway 97. An abundance of weed-choked wetland habitat exists due to culverts, beaver activity, and a lack of stream flow.

Discharge, temperature, and other basic environmental data have not been collected for Park Rill Creek. Based on observations, spawning substrate for salmonids is very minimal. The pool habitat would provide abundant rearing areas if fish had access and that water quality requirements for salmonids were met throughout the year. Information should be collected to better estimate the potential production of anadromous fish stocks. The following data should be collected: 1) A barrier inventory documenting every culvert and determining how each culvert would be operated modified or improved to provide fish passage, 2) Real-time discharge and temperature information collect for multiple years to establish the magnitude and duration of spring freshets and determine if water quality and water quantity are sufficient for salmonid production, 3) the quantity of spawning and rearing habitat available under different flow conditions, 4) the feasibility of reconnecting the Okanogan River side channel, 5) inventory the site, user, and amount of water withdrawn throughout this watershed.

Figure 55: Above Park Rill Creek at Island Drive and Highway 97, looking downstream and looking upstream (Below). Pictures were taken in August of 2004.
(August, 2004).

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Appendix A

GIS Locations of Permanent Anadromous Fish Barriers

Table 1: The decimal degree coordinates, description, and agency source of the information related to permanent physical barriers to anadromous fish passage located on tributaries to the Okanogan River within the United States.

Creek/River	Latitude	Longitude	Description	Source
Wannacut	**48.43019452**	**-119.4465967**	**Falls**	**CCT**
Tonasket	**48.94570016**	**-119.392249**	**Falls**	**CCT**
Ninemile	**48.9826501**	**-119.3203688**	**Falls**	**CCT**
Loup Loup	**48.3050518**	**-119.7090421**	**Falls**	**CCT**
Bonaparte	**48.69636469**	**-119.4310523**	**Falls**	**CCT**
Antoine	**48.75150601**	**-119.4040898**	**Rock shute**	**CCT**
Wild Horse Spring	**48.85753567**	**-119.3939255**	**Rock shute**	**CCT**
Wild Horse Spring	**48.85847686**	**-119.3954967**	**Gradient and Culvert**	**CCT**
Whiskey Cache	**48.90020939**	**-119.4219058**	**Falls**	**CCT**
Chewiliken	**48.620366**	**-119.433756**	**Natural Barrier**	**OCD**
Chilliwist	**48.267612**	**-119.7377**	**Falls**	**OCD**
Siwash	**48.708322**	**-119.407382**	**Falls**	**OCD**
Whitestone	**48.784547**	**-119.431969**	**Unknown**	**OCD**
Aeneas	**48.659203**	**-119.486195**	**Falls**	**OCD**
Tunk	**48.564463**	**-119.472803**	**Falls**	**OCD**
Salmon	**48.53**	**-119.75**	**Dam**	**GIS**
Johnson	**48.5**	**-119.51**	**Gradient Barrier**	**GIS**
Similkameen	**48.96**	**-119.5**	**Falls/Dam**	**GIS**