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COLD WATER REFUGIA FEASIBILITY STUDY – OKANOGAN BASIN

Okanogan County, WA

Prepared for: Colville Confederated Tribes Fish and Wildlife

Project No. 090041-001-03 • May 11, 2010 Final

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Executive Summary

A limiting factor affecting recovery of Steelhead and other anadromous fish in the Okanogan Basin are mid- summer temperatures in the Okanogan and Similkameen Rivers. Summer-time temperatures typically exceed 23 degrees C, the temperature at which juvenile salmonids mortality occurs. Colville Confederated Tribes Fish and Wildlife (CCTFW) contracted with Aspect Consulting, LLC and Pacific Hydraulic Engineers and Scientists (PHES) to perform a Feasibility Study (Study) for development of areas of thermal refuge that would increase survival of steelhead and other anadromous fish in the Okanogan Basin. The purpose of this Study is to investigate possibilities for establishing refugia for salmonids, primarily the juvenile life stages, from the high water temperatures typical of the Okanogan and Similkameen Rivers during the summer season.

Project areas include the Similkameen River in the Oroville area and the Okanogan River in the Riverside area. Studies indicate anadromous fish use and several spawning areas along the Similkameen River in the Oroville area. In addition, CCTFW biologists identified the Pharr Road property on the west side of the mainstem Okanogan River as a potential project location. The Pharr Road property is located downstream of several well known and utilized spawning sites.

Surface and groundwater sources were identified and combined with discharge locations to create five principal alternatives for thermal refuge. Source water criteria included sufficient flow and temperature to achieve a maximum acceptable project temperature of 22 degrees C in the created habitat. Project flow objectives were nominally set at 1 cubic foot per second (cfs) for discharge to mainstem rivers with the recognition that much lower flows may be acceptable for discharge to constructed or natural side channels. Potential water sources include the Okanogan Tonasket Irrigation District (OTID) water, Similkameen River water, groundwater from the high yielding Shallow Alluvial Aquifer in the Oroville area, and groundwater from a low to moderate yielding deeper Glacial Aquifer on the west side of the Similkameen River. At the Pharr Road property, existing shallow irrigation wells completed in a shallow alluvial aquifer appear to meet project criteria.

Habitat and discharge areas included the mainstem Similkameen River, existing natural channels and constructed channels. Criteria for side channel selection/development included:

- located as close as practical to the main channel spawning areas;
- near deeper, slack water pools in the mainstem that provide refuge for juvenile fish;
- protection from floods and progressive erosion; and,
- close to source water.

Water delivery methods to habitat/discharge areas included infiltration ponds and direct discharge. Infiltration ponds were coupled with surface water sources, and would be

located such that cold water sources infiltrated from April through mid-June would discharge during July-August period when river temperatures exceeded 22 degrees C. Delivery of water by direct discharge to habitat areas would be limited to groundwater sources which remain cool during the period of elevated mid-summer river temperatures (temperature limited measurements indicate less than 16 degrees C year round).

Five principal alternatives were developed based on potential water sources and habitat/discharge locations. The alternatives in the Oroville area are shown on Figure 3.1.1 and the location of the Riverside alternative is shown on Figure 2.1.11. These alternatives include:

- Alternative 1 (A) – West Side Artificial Recharge: (OTID as source water; natural discharge to mainstem Similkameen).
- Alternative 1 (B) – West Side Artificial Recharge: (Similkameen source, discharge to constructed channel on west side of Similkameen).
- Alternative 1 (C) – West Side Artificial Recharge: (OTID Source, discharge to constructed channel on west side of Similkameen).
- Alternative 2 – West side Well Source, discharge to mainstem Similkameen.
- Alternative 3 (A) – East Side Artificial Recharge (OTID water source; natural discharge to mainstem Similkameen or east side back-channel).
- Alternative 3 (B) – East Side Artificial Recharge (Similkameen source, discharge to engineered channel on the east side of Similkameen).
- Alternative 3 (C) – East Side Artificial Recharge: (OTID Source, discharge to engineered channel on the east side of Similkameen).
- Alternative 4 – East Side Well Source, discharge to natural side channel on the east side of Similkameen.
- Alternative 5 – Pharr Road Well Discharge: One alternative was developed for the Pharr Road site that makes use of existing well(s) for a water source and enhancement of the natural channel on the property.

Alternatives were ranked based on:

- the ability to meet project objectives,
- water availability and engineering uncertainties,
- land ownership,
- permitting,
- water rights,
- readiness to proceed,
- capital and operational costs; and
- potential for negative public comment.

Scores are summarized in Table 5.1.1. Alternative 4 scored the highest and it is recommended that this alternative proceed to conceptual design. This alternative includes drilling a new well or purchasing an existing well on the east side of the Similkameen River, south of Oroville and conveying the water via a new pipeline to an existing natural side channel of the Similkameen River. The capital cost for this option was the lowest of the evaluated alternatives (estimated at about $480,000) and is considered to be relatively ready to implement.

The Pharr Road site (Alternative 5) scored just slightly lower than Alternative 4 (score of 107.5 for Alternative 5 versus 112 for Alternative 4), primarily as a result of greater engineering requirements for side channel enhancements and greater capital costs ($860,000). Both Alternatives 4 and 5 require purchase and/or easement through private property.

1 Introduction

The Colville Confederated Tribes (CCT) have taken a leading role in the recovery of the endangered Upper Columbia River Steelhead. Steelhead was listed as an endangered species in August 1997. A limiting factor affecting steelhead recovery and survival of other anadromous fish in the Okanogan Basin is mid-summer temperatures in the mainstem Okanogan and Similkameen Rivers, where summer-time water temperatures can exceed 23 degrees C, a temperature at which juvenile salmonid mortality occurs. Despite the high summer temperatures, extensive fish inventories conducted by the CCT Fish and Wildlife (CCTFW) program indicate small numbers of Okanogan Steelhead, salmon and resident fish can survive the mid-summer temperatures by taking refuge in isolated pockets of cooler water. The purpose of this Feasibility Study (Study) is to investigate possibilities for establishing refugia for salmonids, primarily the juvenile life stages, from the high water temperatures typical of the Okanogan and Similkameen Rivers during the summer season.

CCTFW contracted with Aspect Consulting, LLC and Pacific Hydraulic Engineers and Scientists (PHES) to perform a Feasibility Study for development of areas of thermal refuge that would increase survival of steelhead and other anadromous fish in the Okanogan and Similkameen mainstems. These areas would be created by introducing cool water to the stream either through artificial recharge or direct groundwater discharge during the summer months.

1.1 Purpose and Scope

This Study assembles project alternatives for cold water refuge, ranks these alternatives, and recommends a preferred alternative to move into a design phase. The project scope included the following work elements:

- compilation and review of existing hydrologic and hydrogeologic data, including elevation surveys to identify potential surface and groundwater coldwater sources and associated constraints;
- identification of critical habitat factors to identify areas where cold water refuge could provide the greatest potential benefit;
- development of thermal refugia alternatives, including evaluation of hydrogeologic conditions favorable to the project,
- development of alternatives using artificial recharge and direct discharge of pumped groundwater as potential sources; and,
- a ranking of the alternatives.

A conceptual design for the preferred alternative (Alternative 4 - direct discharge into an existing side channel from a well source) will be developed in a separate document. Potential sources of project funding will also be examined under the current work scope and presented in a separate document.

The remainder of this introduction describes the project locations. A surface and groundwater conceptual model is developed in Section 2 for the purposes of identifying project source water. Section 3 presents a description of biologic considerations for project success. Project alternatives are assembled in Section 4 and are ranked in Section 5.

1.2 Project Locations

The project is divided into two distinct geographic areas:

- the Similkameen River in the Oroville area; and,
- the Okanogan River in the Riverside area.

The project locations are shown on Figure 2.1.1.

1.2.1 Similkameen River/Oroville

The project area in the Oroville vicinity extends from the Similkameen-Okanogan River confluence upstream to Enloe Dam (Figure 2.1.1). Studies by CCTFW (2005 and unpublished surveys) and Entrix (2008) indicate anadromous fish use and several spawning areas along this reach. The highest population of mainstem Steelhead redds were identified in this reach in a survey of the Similkameen and Okanogan mainstems above the Wells pool influence.

1.2.2 Okanogan River/Riverside

A mainstem area of the Okanogan River near Riverside was identified by CCTFW biologists as a potential project area (Figure 2.1.1). The project site is located on the west river bank, 4 miles upstream from Riverside. Downcutting of the mainstem Okanogan at this site has left a natural channel remnant elevated a few feet above river level. Local residents indicate that the channel is dry except during the highest river flows.

2 Hydrologic Conditions

This section reviews surface and groundwater conditions in the project areas for the purposes of:

- developing a site conceptual model for surface and groundwater to evaluate project feasibility and potential impacts;
- evaluating surface and groundwater temperature and dissolved oxygen data to determine project operation periods; and
- identifying potential source water in the project areas, including water right strategies.

2.1 Surface Water

2.1.1 Oroville

Major surface water features in the Oroville study area include the Similkameen and Okanogan Rivers and Lake Osoyoos. The City of Oroville is located about 3 miles north of the natural Okanogan and Similkameen Rivers confluence and occupies the flood plain area between the two rivers.

The Similkameen River drains an area approximately 3,550 square miles lying mostly within British Columbia. The river runs approximately 21 miles between the Washington State-British Columbia border and its natural confluence with the Okanogan River. An excavated cross channel connects the Similkameen and Okanogan Rivers approximately 0.5 miles south of Oroville. Water generally flows through the cross channel from the Okanogan River toward the Similkameen River, but reverses when flows in the Similkameen River are exceptionally high. Enloe Dam is located at about RM 8.8. The dam was constructed in 1920 to support local mining operations and acquired by Okanogan PUD in 1945, operating as a run of the river power generation facility until 1959. Okanogan PUD is currently undertaking efforts to renew the Federal Energy Regulatory Commission (FERC) license to restore the Enloe Hydroelectric Project. In Washington State, Palmer Creek (tributaries include Sinlahekin Creek and Toats Coulee Creek) is the major tributary to the Similkameen River, joining about 20 miles upstream from the Okanogan River confluence. The Similkameen River is a snowmelt driven water shed.

The Okanogan River drains an area approximately 3,150 square miles lying mostly within British Columbia. The river enters Washington State as Osoyoos Lake that extends approximately 3 miles into Washington. Although Osoyoos Lake is a natural impoundment, lake level was raised by construction of the Zosel Dam. The dam maintains lake levels for the Okanogan-Tonasket Irrigation District (OTID) and for recreation. The dam was originally built in 1927 and was rebuilt in 1987. Zosel Dam is operated to maintain normal Osoyoos Lake levels at elevations between and 915.27 feet and 915.77 feet (NAVD 88 vertical datum) as dictated by international agreement. The dam flooded approximately 1 mile of the Okanogan River channel below the natural lake outlet forming a water body referred to as Zosel Mill Pond. The river is free-flowing below Zosel Dam, 3 miles upstream from its confluence with the Similkameen River. A portion of Okanogan River flow is diverted through the excavated cross channel connecting the two rivers above their confluence. The Similkameen River is the primary tributary to the Okanogan River in Washington State, contributing 70 percent of mean daily discharge to the Okanogan River below the confluence.

The region between the two rivers containing the City of Oroville is a relatively low-lying floodplain. Substantial migration of the river channels across the broad floodplain is evident in numerous geomorphological features including natural levees, oxbows and cut off meanders that primarily formed before development of Oroville. Anecdotal accounts from residents indicate the region between the two rivers has a history of flooding from high flows in the Similkameen and Okanogan Rivers. A levee has been constructed along the western and southern portions of Oroville and the region to the south to prevent flooding from the Similkameen River.

The OTID supplies water to agricultural lands in the Oroville vicinity. Water was formerly diverted from the Similkameen River near the USGS gauge near Nighthawk and conveyed to the Oroville area via gravity flume. Since the mid-1980s, all water has been supplied from the Okanogan River via a pump station that withdraws water from the impoundment behind Zosel Dam.

2.1.1.1 River Flow

Similkameen River streamflow data having various periods of record have been collected at several locations. Stream gaging stations in the project region are presented on Figure 2.1.1. Figure 2.1.2 presents temperature and gauging stations in the Oroville area. The most complete record of streamflow measurements is from the Similkameen River near Nighthawk USGS gauging station(Station ID 12442500, Figure 2.1.1) located at river mile 15.8 , approximately 3 miles downstream of Nighthawk, with nearly continuous data beginning in 1929 (USGS, 2010). The USGS also maintained stations below the Similkameen Falls near Enloe Dam and near the Highway 7 bridge in Oroville for varying periods between 1911 and 1928 (Figure 2.1.2, Stations 12443500 and 12443600). Since 1996, Washington State Department of Ecology (Ecology) has operated a stream gage at the Highway 7 bridge crossing at approximately river mile 5.0 (Figure 2.1.2, Ecology 49B070).

Streamflow statistics were analyzed for the Similkameen River at Nighthawk and the Similkameen River at Oroville (Figures 2.1.3 and 2.1.4, respectively). The hydrographs indicate a snowmelt dominated system with greatest flows occurring between April and mid-August with flows typically peaking from late May to early June. Peak mean monthly flow of 8,550 cubic feet per second (cfs) occurs in June. For the period of record at Nighthawk, the mean daily mean streamflow is 2,290 cfs.

Low flows typically occur from mid-August through March, with a slight increase in flows occurring in November and December, in response to fall rain events. Lowest mean monthly flows of 588 cfs occur during September. Mean monthly flows are 2,930 cfs and 903 cfs during July and August, respectively, when water temperatures are highest (see Section 2.1.1.2 for temperature discussion).

Okanogan River flows, gaged about 3.2 miles upstream from the confluence with the Similkameen River (Okanogan River at Oroville USGS gauging station, Station ID

12439500, located downstream of the Zosel Dam), average about one tenth those of the Similkameen River, with a mean daily streamflow of 684 cfs. Highest mean monthly flows occur during May and June with average flows of about 1,140 cfs (Figure 2.1.5). Lowest mean monthly flows of 453 cfs occur during September, and are about 75% of the Similkameen flow during this month. Thus, the relative contribution of Lake Osoyoos outflow to Okanogan River flows is significantly greater during low flow periods.

Lake Osoyoos regulates the flow of the Okanogan River resulting in peak monthly flows that are about 2.5 times greater than lowest monthly flow. Peak monthly flows in the Similkameen, by contrast, are nearly 15 times greater than the mean low flow month.

The Similkameen River between Nighthawk and the Highway 7 Bridge appears to lose to the groundwater system during low flow periods. There are no significant surface tributaries between the Nighthawk and Oroville gauging stations. Figure 2.1.6 presents the gain/loss in Similkameen River flow between these two stations. Losses from the river to the groundwater typically occur from July through October. A second period of shorter duration and of lesser groundwater loss occurs during February and March.

2.1.1.2 Temperature

A project temperature objective of 22 degrees has been set as the maximum acceptable temperature for salmonid survival. Lower temperatures are obviously desirable.

Similkameen River

Surface water temperatures in the Similkameen River have consistently exceeded the project objective temperature of 22 degrees C. Summer temperatures over 25 degrees C have been recorded during some years. The location of temperature monitoring stations in the Oroville area is shown on Figure 2.1.2. Long-term temperature data below Enloe Dam are available at Ecology Station at Oroville (49B070) from 2004 to present. In 2006, Entrix monitored temperature at several locations upstream and downstream (RM5.3 to 12.2) of Enloe Dam as part of the FERC license application (Entrix, 2008). During the summer of 2009, Aspect Consulting made temperature measurements at several locations in the Oroville area to investigate:

- Thermal stratification;
- Potential river cooling below the Oroville Sewage Treatment Plant outfall; and
- Better characterization of river temperature to support evaluation of alternatives.

Continuous Similkameen River water temperature measurements were recorded using Hobo Tidbit dataloggers placed on the riverbed in waters 3 to 4 feet deep (Figure 2.1.2):

- Near Well 28M01 located approximately ¼ mile upstream of the Highway 7 crossing; and,
- About 10 feet downstream of the City of Oroville sewer treatment plant (STP) outfall.

Additionally, spot measurements were collected using a YSI 95 temperature/dissolved oxygen meter at various locations. Areas targeted for spot temperature measurements included deeper, slower river reaches within ½ mile upstream and downstream of the STP outfall having the greatest potential for thermal stratification with depth.

Maximum daily temperature at the Ecology station at Highway 7 Bridge in Oroville is presented on Figure 2.1.7 and was evaluated to determine typical and worst case project operation periods. The project objective temperature of 22 degrees C is exceeded during each summer (Figure 2.1.7). Table 2.1.1 presents the first and last date the maximum daily temperature exceeded 22 degrees C for each year of measurement. The longest exceedance period extended from July 3 to September 8 in 2006. Temperatures exceeded 22 degrees C for 41 days of this 68-day period. The shortest period occurred in 2008 where the 22-degree project objective was first exceeded on August 5 and last exceeded on August 20. The average exceedance period is from July 18 through September 1. The project should be designed to deliver cold water for up to a 2-month period (allowing for an approximate 2-week safety factor), but during average years, the period of water delivery would be on the order of a 6-week period starting in mid-July and running through August.

As discussed above, the project objective of 22 degrees C has been set at the maximum acceptable temperature for salmonid survival. Ecology has promulgated a freshwater temperature criteria of 17.5 degrees for the 7-day average of the daily average maximum (7-DADMax) for salmonid spawning, rearing, and migration (Washington Administrative Code [WAC] 173-201A-200). Figure 2.1.8 presents the 7-DADMax for the Ecology station at Highway 7 Bridge. To meet this criterion would increase project operation periods by about 1 month.

Data collected by Aspect Consulting in summer 2009 is summarized in Table 2.1.2. The stream temperature profiles did not indicate any significant stratification within the river. Several measurements were targeted in deep, slow moving pools where stratification was most likely to occur. Little temperature variation was identified within the mainstem Similkameen River which is consistent with a losing stream where upwelling of cold groundwater is absent.

The effluent temperature discharging from the STP outfall was found to be about the same temperature as the river (20 degrees C). Specific conductance was elevated in effluent at the outfall compared to river measurements, consistent with discharge of treated effluent.

Dissolved oxygen (DO) measurements indicated supersaturated conditions at all measurement points. Saturated DO conditions would be about 9 milligrams per lit (mg/L) for the altitude and water temperature at the time of DO measurements. In general, the highest DO measurements were taken near the water surface and DO generally decreased with depth, although all depths were found to be supersaturated.

Temperature loggers were installed in the river near Well 28M01at a depth of 4 feet (Similkameen River at Teas, Figure 2.1.2) and 10 feet downstream of the STP at a depth of 3 feet (Similkameen River at STP, Figure 2.1.2). Temperature records are presented on Figure 2.1.9. Very little discernible difference in temperature occurs between these two locations. Flow from Ecology station at Highway 7 Bridge is shown on the bottom of Figure 2.1.9. The 5-degree decline in water temperature recorded by dataloggers during the monitoring period is accompanied by an increase in flows (Figure 2.1.9). Because water temperatures decrease appreciably with river flows, project operation may not be necessary during summer precipitation events.

Okanogan River

The Okanogan River presents a potential for project source water. Surface water temperatures were evaluated in the Okanogan River downstream of Zosel Dam to characterize river temperatures (Figure 2.1.10). The most complete daily temperature measurements are from the USGS Gauging Station at Oroville (Auxiliary Gauge) dating to 1986. Ecology collected daily temperature measurements during summer and fall months from 2001 to 2009 (Ecology Site 49A190).

Highest mean daily temperatures in the Okanogan River for the period of record at the USGS Gauging Station at Oroville (Auxiliary Gauge) occur in the months June through September when temperatures exceed 22 C project criteria for several weeks each year (Figure 2.1.10).

2.1.1.3 Potential Surface Water Sources

Both the Similkameen and Okanogan Rivers are potential water sources, if coupled with an infiltration project. An infiltration project could allow for cold water to be infiltrated during the spring and, if appropriately sited with favorable hydrogeologic conditions, would delay discharge of infiltrated water into the Similkameen such that it occurred during the July-August time window. Infiltrated water would also cool in the subsurface during the travel period from the infiltration basin to the discharge point.

The Okanogan and Similkameen Rivers were evaluated as potential sources based on the following criteria:

- Temperature less than 17.5 degrees C.
- Sufficient quantity.
- Available such that discharge occurs during the time of project need.
- Existing infrastructure.

Okanogan River water obtained from the OTID system shows the greatest potential for a surface water source meeting these criteria and supporting project objectives. Benefits of using OTID water sources from the Okanogan River/Osoyoos Lake include:

- Reliable water source.
- Existing infrastructure (pump station and conveyance).
- Existing Permit.
- Favorable water temperatures until mid-June, when surface water temperatures exceed peak groundwater temperatures of about 15 C.

The outtake for OTID, constructed in 1988, is located just downstream of Osoyoos Lake State Park, in the mill pond region above Zosel Dam and below the natural lake outlet. OTID indicates that turbidity is not problematic, but an occasional algae bloom occurs that causes slime within the piping. This source is discussed further in the Section 4.

The Similkameen River is considered less favorable than OTID water. The snow melt driven source area results in frequent episodes of high river turbidity during the April – June anticipated period of operation. There is currently no pump station or conveyance system known to be in place. Pump station design/operation would be impacted by river flows that vary widely and rapidly over a given season frequently with high turbidity. A rock-basket or shallow well in hydraulic connection with the river could be used to mitigate potential issue involving water level fluctuations and possibly turbidity.

Water from the 2-mile-long impoundment behind Enloe Dam was briefly evaluated as a surface water source. Temperature data obtained in 2006 indicates that lower and upper reservoirs exceed the project objective of 22 degrees C for several weeks (Entrix, 2008). Additionally, there is no existing conveyance infrastructure connecting the dam vicinity with potential artificial recharge areas downstream. A gravity flume that once conveyed OTID water diverted from the Similkameen River near Nighthawk has not been operational since the OTID pump station on Osoyoos Lake was built in the mid-1980s.

2.1.2 Riverside

The Pharr Road site location is shown on Figure 2.1.11.

2.1.3 River Flow

River flow in the Riverside area largely reflects the composite hydrographs of the Similkameen and Okanogan Rivers. Flow hydrograph for the Okanogan River at Tonasket (USGS Gage 12445000) is presented on Figure 2.1.12 and the gaging station location is shown on Figure 2.1.1. The Tonasket gauging station is the closest station to Riverside and the Pharr Road project area. The significantly larger contribution of flows to the Similkameen to a large degree control the flow characteristics at this gaging station. During summer low flows, the Okanogan River provides a more significant contribution to downstream flows. Tributaries that enter the Okanogan River downstream of Oroville include Antoine Creek, Siwash Creek, Bonaparte Creek and Tunk Creek which enters immediately across from the Pharr Road site. Mean annual flows in each of these tributaries are less than 5 cfs and peak flows occurring during snowmelt from April through July are typically less than 10 cfs (Entrix, 2006).

2.1.3.1 Temperature

Stream temperatures at the Okanogan River near Tonasket are warmer than measured in the Oroville area (Figure 2.1.13). The longest period of exceedance of the 22-degree C project criteria occurred in 1987 from June 26 to September 2 (Table 2.1.1). The shortest interval of project exceedance was from July 15 to August 20, 2008. The average dates exceeding project criteria span an approximate 2-month period extending from July 9 through August 24.The exceedance duration of the 7-DAD max state water quality standard is typically about a 3-month duration (Figure 2.1.14).

A temperature datalogger was installed by Aspect Consulting in a deep, slow-moving pool at the upstream portion of the Pharr Road site. The logger location is shown on Figure 2.1.11 and the recorded data is presented on Figure 2.1.15. The temperature trends are similar to those observed in the Similkameen, but temperatures are typically about 1 to 2 degrees warmer near the Pharr Road site than in the Oroville area.

2.1.3.2 Potential Surface Water Sources

The Okanogan River could be a potential water source for a project using artificial recharge. However, two high capacity production wells are present on the Pharr Road site that could meet project objectives using groundwater discharge. The Okanogan River was not considered further as a source due to the absence of existing infrastructure and the presence of a known and developed groundwater supply. If an artificial recharge project is considered for this site in the future, then the Okanogan River should be evaluated as a source.

2.2 Groundwater

2.2.1 Oroville

2.2.1.1 Hydrogeologic Framework

Geology

The geologic setting of the Oroville vicinity is characterized by bedrock uplands overlain by unconsolidated sediments in the Similkameen/Okanogan River valley. The principal geologic units from a 1:100,000 scale map compilation from Washington Department of Natural Resources are presented on Figure 2.2.1. The relatively flat valley bottom has an elevation of approximately 900 feet and is comprised primarily of alluvium. Glacial deposits form gently sloping terraces on the valley margins to elevations of approximately 1,200 feet. Bedrock outcrops in the upland areas extend from the glacial terraces to elevations up to 2,600 feet.

Alluvium consisting of layered silt, clay, and sand and gravel was deposited across the Similkameen and Okanogan River floodplains in the period following retreat of the glacial ice sheet. Geomorphologic features, including natural levees, oxbows and cut-off meanders, provide evidence of regular channel migration across the floodplain and form laterally-discontinuous zones of fine and coarse-grained deposits including buried channels. The unincorporated region to the south of Oroville is located on alluvium.

Glacial deposits consisting primarily of silt, clay, fine sand and thin layers of coarse sand and gravel were deposited by the Okanogan lobe of the Cordilleran continental glacial ice sheet, approximately 10,000 to 12,000 years ago. Following glacial ice retreat, the Similkameen and Okanogan Rivers incised glacial sediments occupying the entire valley leaving behind remnant glacial terraces along the valley margins. Glacial terraces are most prominent on the west side of the valley and upstream of Oroville on both sides of the Similkameen River. The majority of the City of Oroville is located or deposits mapped as glacial drifts (Figure 2.2.1). Glacial deposits in this area have likely been reworked by alluvial processes.

Bedrock forming the mountains surrounding the City of Oroville and the river valleys is primarily mapped as continental sedimentary and conglomerate and intrusive rocks. These rocks have little or no intrinsic permeability and yield limited water from secondary fractures.

Hydrostratigraphic Units and Aquifers

A summary of well data in the Oroville vicinity obtained from Ecology’s well database is presented in Table 2.2.1 and locations of these wells are shown on Figure 2.2.2. Wells presented on Figure 2.2.2 are located with varying accuracy as indicated by color. Well logs are typically located to the nearest 40-acre subsection on the well log, and are often mislocated. Erlandsen Surveying, under subcontract to Aspect Consulting, surveyed the locations and elevations of several wells in the Oroville area. In addition, locational accuracy of several wells was improved by resource grade GPS locations by Aspect

Consulting and by matching well log information with assessor's parcel information. The following levels of accuracy resulted from this process: surveyed, map-grade GPS, parcel, quarter-quarter section, quarter section and section. Well use is differentiated by symbol shape with water supply wells indicated by circles, resource protection wells indicated by squares, and decommissioned wells indicated by triangles. Well construction information is summarized in Table 2.2.1.

An aquifer is a water-bearing unit comprised of some combination or part of geologic formations that can yield significant quantities of water to wells and springs. An aquitard is some combination or part of a geologic unit that retards groundwater flow. The principal hydrostratigraphic units in the Oroville area identified are:

- Shallow Alluvial Aquifer
- Glacial Aquifer/Aquitard
- Bedrock Aquifer/Aquitard

Approximate limits of the aquifer extents based on well log information are shown by dashed lines on Figure 2.2.2. A cross section through the study area shows stratigraphic relationships between major hydrogeologic units (Figure 2.2.3). The distribution, hydraulic characteristics, and use of the aquifers are described below.

<u>Shallow Alluvial Aquifer</u> – this aquifer consists of shallow, coarse-grained alluvial, and glacial deposits in the valley bottoms. Several high production wells tap this unit in the Oroville area. The water bearing characteristics of this unit are uncertain on the west side of the river, where wells are completed in deeper glacial deposits.

The region lying east of the Similkameen River and west of the Okanogan River (the region occupied by the City of Oroville, Figure 2.2.2) is characterized by high-yield, shallow wells completed in the alluvial aquifer overlying an aquitard of unknown thickness. Most of this region is served by the City of Oroville municipal water system. Therefore, existing wells are either part of the City's water system, provide for irrigation, or are located outside of the water system service area. Several resource protection monitoring wells are also present in downtown Oroville.

Drilling logs indicate wells in the Shallow Alluvial Aquifer are completed at depths typically ranging from 10 to 80 feet. These data indicate coarse sediments (sand and gravel) comprise an aquifer overlying fine sediments (silt and clay). Driller's logs indicate water levels within the sand and gravel aquifer range from 10 to 47 feet. The thickness of the underlying silt and clay aquitard could not be identified based on available well log information. The potential for a deeper aquifer beneath the Shallow Alluvial Aquifer in the Oroville area, on the east side of the River is unknown.

Wells completed in the Shallow Alluvial Aquifer typically produce water from depths less than 40 feet. Open or screened intervals range from 10 to 80 feet with most wells screened at depths between approximately 20 to 40 feet. Well yields in 6-inch drilled wells range from 12 gallons per minute (gpm) to 60 gpm. Well yields in larger diameter wells range from 200 gpm to 1,700 gpm (Table 2.2.1). The high producing wells range from 20 to 48 inches in diameter and are open or screened at depths between 24 and 80 feet in sand or sand and gravel. Available data indicate specific capacities (a measure of well yield per foot of drawdown) for high producing wells are on high--the order of 4.4 gpm/ft to 10 gpm/ft—indicating high yields are likely from properly designed and constructed wells.

The presence of the Shallow Alluvial Aquifer on the west side of the Similkameen River is uncertain. Several shallow wells completed at depths less than 40 feet indicate shallow, fine grained material, and tap water-bearing zones present in interbedded mixtures of clay, silt, sand, gravel within the fine-grained unit. Other well logs indicate the presence of shallow, coarse-grained sand and gravel but the units are not noted as saturated on the well logs and the wells are completed beneath this unit suggesting that, if the unit were saturated, it was not sufficiently thick to provide for domestic use.

Glacial Aquitard/Aquifer – a clay aquitard of varying depth was identified through most of the study area. In the Oroville area, the aquitard underlies the shallow, unconsolidated alluvial aquifer and is inferred to be of glacial origin. On the west side of the River, a relatively finer-grained water-bearing zone appears to be present beneath or within the aquitard. This unit consists predominantly of fine sands and was identified on the west side of the River where it is utilized by domestic wells.

The Glacial Aquifer is characterized by low to moderate yielding wells located on the west side of the Similkameen River (Figure 2.2.2). Nearly all wells in this region are 6-inch-diameter and used for domestic purposes. Drilling logs indicate wells are completed at depths ranging from 25 to 297 feet. These data indicate unsaturated coarse sediments (sand and gravel) approximately 10 to 30 feet thick overlie silt and clay. The silt and clay comprise an aquitard underlain by bedrock at depths of at least 300 feet. Thin layers of interbedded fine sand are present at various depths within the aquitard, resulting in wide variation in depths of screened or open intervals that range from 20 to 297 feet. Well yields range from 6 to 30 gpm.

Bedrock Aquifer/Aquitard – Fractures within the bedrock provide low yields generally suitable for domestic purposes. Unfractured portions of the bedrock will act as an aquitard.

Three wells completed in low-yield bedrock were identified on both sides of the Similkameen River, upstream of the City of Oroville. The area east of the Similkameen River, northwest of Oroville lies within the City of Oroville municipal water system. Drilling logs indicate the few wells present in this area are completed in bedrock at depths ranging from 150 to 300 feet with well yields ranging from 1 to 6 gpm.

2.2.1.2 Groundwater Flow

Water levels in wells and surface waters were used to define groundwater flow and to assess losing/gaining characteristics of the Similkameen River. As discussed in more detail below, an infiltration projects efficiency (i.e., water infiltrated that returns to the river at the desired location) depends on the losing/gaining characteristics of the River. Water levels were measured by Aspect Consulting coincident with Erlandsen survey on October 26, 2009. Surface and groundwater elevations were contoured to map the groundwater elevations across the study area and evaluate groundwater flow directions. The resulting groundwater elevation or potentiometric surface map displays groundwater elevation contours in 2-foot intervals (Figure 2.2.4). Groundwater flow is perpendicular to the groundwater elevation contours and is indicated by arrows. The cross section through the study area shows water levels at various wells and surface water locations (Figure 2.2.3). The Similkameen River experiences large water level fluctuations resulting from wide variation in stream discharge and groundwater levels are expected to experience a dynamic response to surface water fluctuations. Therefore, surface and groundwater elevations displayed on Figure 2.2.4 and discussed below are a snapshot of conditions at the time of data collection and flow patterns as well as groundwater/surface water groundwater interactions are expected to change throughout the year.

Groundwater flow is generally to the southeast in the region between the two rivers characterized by the Shallow Alluvial Aquifer. Here, groundwater flows away from the Similkameen River and away from the Okanogan River above Zosel Dam, converging near the middle of this region and flowing southeast. Groundwater gradients are generally 5 to 7 feet per mile and increase upvalley. The presence of the shallow aquifer on the east side of the river below Copper Mountain is uncertain.

The convergence of groundwater flow in the Oroville area reflect the pumping influence of the City of Oroville wells. Well 28L01 had a static water elevation about 3 ft lower than the Similkameen River and about 4 ft lower than Lake Osoyoos above Zosel Dam. This well was not pumping at the time of water level measurements, but is located near several other City wells that may have been pumping at the time of the water level measurements.

Groundwater recharge occurs from direct precipitation, concentrated runoff that infiltrates the valley bottom (mountain front recharge), crop irrigation return flow, and from Similkameen River seepage and Okanogan River/Lake Osoyoos losses above Zosel Dam. Primary natural discharge from the Shallow Alluvial Aquifer is inferred to be into downstream reaches of the Similkameen River, into the Okanogan River downstream of Zosel Dam, and into the channel connecting the Similkameen and Okanogan Rivers.

In a gaining river reach, a stream receives groundwater input from surrounding aquifers. In a losing river reach, a stream loses water to surrounding aquifers. An understanding of gaining/losing characteristics of the Similkameen River is important to evaluate alternatives for providing thermal refugia. For example, the success of an artificial recharge project would be limited if it were sited on a losing stream reach. Recharge from uplands to the west apparently create a local gaining condition in the Similkameen River, while river losses in the Oroville area create a losing condition. On the west side of the Similkameen River, groundwater flow is inferred to be generally to the east, toward the Similkameen River (Figure 2.2.4). Water level measurements at the 28M01 and 29A01 wells both have higher heads than the Similkameen River and indicate an upward vertical gradient with discharge to the shallow alluvial unit and/or Similkameen River. The absence of measurably colder water upwelling into the River suggest groundwater discharge to the River is relatively small.

As discussed above, analysis of streamflow data from two locations on the Similkameen River shows a net loss of up to 100 cfs in the river between the USGS gaging station near Nighthawk and Ecology’s gaging station at the Highway 7 crossing during the summer and fall months (Figure 2.1.6). Figure 2.2.4 shows groundwater elevations east of the Similkameen River are lower than the river consistent with a losing condition. Therefore, Similkameen River is likely losing water to the shallow alluvial aquifer beneath the City of Oroville. Infiltration projects located in the area of stream losses in the Oroville area would be expected to lose a portion of the infiltrated groundwater to the aquifer with likely discharge to the Okanogan River.

2.2.1.3 Groundwater Quality

Groundwater quality parameters potentially affecting project success include:

- temperature;
- dissolved oxygen; and,
- metal concentrations.

Groundwater temperature data has been collected by Aspect Consulting and by the City of Oroville. Groundwater temperature measured in a domestic water well on the west side of the Similkameen River (28M01) was 12.5 degrees C on August 19, 2009 (Table 2.1.2). During their GUI study, the City of Oroville collected weekly groundwater temperatures in their well field (Sources 1 [Well 28L01], 2 and 3). During the 1 year of data collection, groundwater temperature varied from 13.8 C to 15 C with the longest stretch of 15-degree temperatures occurring during the months November to January (Figure 3.1.2).

The concentration of dissolved oxygen measured at Well 28M01 on August 19 was 0.2 mg/L. No other DO data were identified for groundwater in the Oroville vicinity.

Other contaminants of concern include copper and zinc metals. Groundwater samples from City of Oroville water system source wells are periodically collected and submitted for laboratory analysis of metals for Washington State Department of Health (WDOH). Groundwater quality data are discussed relative to salmonid growth and survival criteria in Section 3,

2.2.1.4 Potential Groundwater Sources

The Shallow Alluvial Aquifer east of Similkameen River shows the greatest potential as a groundwater source capable of meeting project objectives. Well yields in large diameter wells range from 200 to 1,700 gpm and average approximately 685 gpm. Data from the City of Oroville's GUI study indicate groundwater temperatures from shallow wells are sufficiently cool and experience little annual variation. DO data are not available, but DO is assumed to be low for the purposes of developing groundwater as a project source. WDOH records for the City of Oroville well field indicate copper and zinc metals do not occur in significant concentrations to impair fish (see Section 3).

The Glacial Deposit Aquifer on the west side of the Similkameen River is less productive, than the Shallow Alluvial Aquifer on the west side. The highest identified well yield is 30 gpm. An appropriately designed well may be expected to yield on the order of 50 to 100 gpm. Water occurs at various depths up to nearly 300 feet. Water temperature is sufficiently cool, but DO is low. Despite lower yields, the Glacial Deposit Aquifer could support a thermal refugia project requiring relatively moderate discharge.

Bedrock Aquifers are very low yield (highest yield is 6 gpm) and are not feasible as groundwater sources capable of supporting project objectives.

2.2.2 Riverside

Geology

The geologic setting of the Riverside vicinity is characterized by bedrock uplands and bedrock overlain by unconsolidated sediments in the Okanogan River valley. The principal geologic units from a 1:100,000 scale map compilation from Washington Department of Natural Resources are presented on Figure 2.2.5. The relatively flat valley bottom has an elevation of approximately 900 feet and ranges in width from ¾ mile to less than ½ mile near the Pharr Road site. The valley bottom is mapped primarily as glacial deposits overlain in places by recent alluvium from surrounding hillside drainages and the Okanogan River. Glacial deposits and alluvium form a flat, low-lying terrace on the valley bottom lying 10 to 20 feet above the current riverbed. Above the glacial deposits, bedrock outcrops in uplands extend to elevations of 2,300 feet.

Alluvium primarily consisting of sand and gravel was deposited across the Okanogan River floodplain in the period following retreat of the glacial ice sheet (see below). Well log data indicate a thin layer of alluvium/reworked glacial deposits up to 60 feet thick overlies glacial deposits across much of the valley floor near the Pharr Road site, some of which appears to be mapped as glacial deposits. Portions of the low-lying alluvial and glacial terrace are periodically flooded by the Okanogan River resulting in geomorphological features including remnant channels. At least three remnant channels were identified during the field reconnaissance of the Pharr Road site.

Glacial deposits consisting primarily of layered silt, clay, and fine sand were deposited by the Okanogan lobe of the Cordilleran continental glacial ice sheet, approximately 10,000 to 12,000 years ago. Following glacial ice retreat, the Okanogan River incised glacial sediments occupying the valley floor. Local well log data indicate glacial deposits extend to depths as deep as 440 feet.

Bedrock forming the mountains surrounding the Okanogan River valley is primarily mapped as metamorphic igneous and sedimentary rocks. These rocks have little or no intrinsic permeability and yield water from secondary fractures.

2.2.2.1 Hydrostratigraphic Units/Aquifers

Hydrostratigraphic Units and Aquifers

Erlandsen Surveying, under subcontract to Aspect Consulting, surveyed the locations and elevations of three wells at the Pharr Road site. The locations of these wells are presented on Figure 2.2.6 along with wells located to the nearest ¼, ¼ section obtained from Ecology well database. A well construction summary is presented in Table 2.2.1. No logs were available for the four surveyed wells on the Pharr Road property (07D01, 06N01, 06P01, 07D02). In the Pharr Road vicinity, three principal aquifers were identified:

- Shallow Alluvial Aquifer
- Glacial Aquifer/Aquitard
- Bedrock Aquifer

Approximate limits of the aquifer extents based on well log information are shown by dashed lines on Figure 2.2.6. The distribution, hydraulic characteristics and use of the aquifers are described below.

Shallow Alluvial Aquifer – this aquifer consists of shallow, coarse-grained alluvial, and glacial deposits in the valley bottom. Several high production wells tap this unit including three shallow wells on the Pharr Road site. Limited well log data indicate the thickness of unconsolidated sediments is approximately 60 feet over glacial sediments or bedrock.

The region lying in the valley bottom is characterized by high-yield, shallow wells completed in an alluvial aquifer overlying aquitards comprised of fine-grained glacial sediment or bedrock. The high production wells in the shallow alluvial aquifer are used primarily for irrigation. Drilling logs indicate wells are completed at depths ranging from 30 to 60 feet. Some wells may be shallower. The well log data indicate coarse sediments (sand and gravel) up to about 60 feet thick comprise an aquifer overlying silt and clay of variable thickness (glacial deposits) or bedrock. Water was identified during drilling within the sand and gravel aquifer at depths ranging from 14 to 34 feet. Well completion intervals (perforations, open casing, screens) are generally located at depths of 30 to 60 feet. Reported well yields range from 75 to 1,200 gpm.

Glacial Aquifer – this aquifer typically consists of layers of saturated fine sand within glacial silts and clays. Well log data indicate layered glacial deposits are locally over 440 feet thick.

More specifically, the Glacial Aquifer is characterized by thin, laterally discontinuous layers of water-bearing, fine sand interbedded within thick, fine-grained glacial deposits. Layers of fine -grained sediments form aquitards between water-bearing layers of fine sand having various yields. In most places, the Glacial Aquifer underlies the high yield, Shallow Alluvial Aquifer. However, glacial deposits are absent in places where alluvium overlies bedrock. Wells completed in the Glacial Aquifer have moderate yields, are 6- to 10-inch-diameter, and used for domestic purposes. Drilling logs indicate wells are completed at depths ranging from approximately 150 to 440 feet. Thin layers of interbedded fine sand are present at various depths within the aquitard, resulting in well completion intervals varying widely from 110 to 395 feet. Shallowest groundwater in the Glacial Aquifer was identified during drilling in lenses of fine sand, at depths ranging from 112 to 304 feet. Well yields are low in this predominantly fine grained unit, ranging from 12 to 50 gpm.

Bedrock Aquifer –Fractures within the bedrock provide low yields generally suitable for domestic purposes. Several wells completed in low to moderate yield bedrock were identified on both sides of the Okanogan River in the vicinity of the Pharr Road site. These wells lie along the margin of the valley floor, where alluvial and glacial deposits are thinner. Drilling logs indicate wells are completed in bedrock at depths ranging from 147 to 506 feet, with well yields ranging from less than 1 to 75 gpm.

2.2.3 Groundwater Flow

Existing groundwater elevation data are not sufficient to map groundwater flow in the Pharr Road area, but the geomorphic setting suggests the following:

- Mountain front recharge from bedrock uplands likely occurs through runoff concentrated into the mouths of tributary drainages.
- The major source of groundwater in the valley is likely associated with the Okanogan River and the resulting groundwater flow direction is likely oriented

down-valley. Limited elevation data collected at the Pharr Road site during this study from two wells and two surface water elevations are consistent with the assumption that general groundwater flow directions at the Pharr Road site are parallel to river flow.

Losing/gaining characteristics of the Okanogan River are unknown, but seasonal, focused mountain front recharge likely results in at least localized areas of groundwater gain.

2.2.4 Groundwater Quality

Groundwater temperature data from two wells are summarized in Table 2.1.2. Groundwater temperature measured in a domestic water well at the Pharr Road site (06N01) was 16.2 C on August 19, 2009. Groundwater temperatures measured in an irrigation well (07D01) at the Pharr Road site were 11.9 C on August 19 and September 29, 2009. The August temperature measurement in the irrigation well (07D01) was collected after the well had been pumping for several weeks with an owner reported discharge of at least 300 gpm. The well had not been used extensively in the days prior to the September measurement. The notable temperature difference between the domestic and irrigation well are likely due to these wells being completed in different aquifers. Although logs were not definitively matched to either well, the owner-reported well depth indicates the irrigation well is completed at about 30 feet in the shallow alluvial aquifer and the domestic well is completed in the underlying glacial deposit or bedrock aquifers. The notably higher temperature in the domestic well suggests minor geothermal influences in this deeper well.

The concentration of DO measured at the domestic well (06N01) was 1.2 mg/L in August. DO concentrations at the irrigation well were 3.2 mg/L and 2.4 mg/L in August and September, respectively (Table 2.1.2). No other dissolved oxygen data were identified for groundwater in the Pharr Road vicinity. Metals data for groundwater are very limited in the Pharr Road vicinity. The nearest sampling location for metals data is source wells the Town of Riverside water system, approximately 4 miles downstream. These results are discussed in Section 3.

2.2.4.1 Potential Groundwater Sources

The Shallow Alluvial Aquifer at the Pharr Road site shows the greatest potential as a groundwater source capable of meeting project objectives. Nearby well yields range from 75 to 1,200 gpm and on-site well yields reportedly exceed 300 gpm at Well 07D01. The yield and construction of the Pharr Road property wells should be confirmed before property acquisition. Groundwater temperature measurement data indicate temperatures at 07D01 did not exceed 12 degrees C during a period of extended pumping at rates exceeding 300 gpm taking place in mid-summer. Well 07D01 is completed in the high-yield Shallow Alluvial Aquifer. Although groundwater in this Aquifer is likely in hydraulic continuity with the Okanogan River, subsurface residence time is sufficient to maintain cool water temperatures. DO is low.

The deeper, low to moderate-yield Glacial Aquifer is likely not capable of providing water quantities required to meet project objectives and a single temperature from this unit (well 06N01) suggests deeper wells in the site vicinity may produce water temperatures that are somewhat warmer than the Shallow Alluvial Aquifer. Bedrock aquifers are generally low yielding and although two nearby wells showing yields of 60 and 75 gpm, the bedrock is considered a high-risk source.

2.3 Water Rights

Because the project lies off of Reservation and Trust Lands, we understand that a water right from the State will be required. Options for acquiring a water right include purchasing or leasing shares of an existing water right, purchasing an existing water right, or obtaining a new water right.

Accessing shares of OTID water has potential for high costs considering this option requires purchasing valuable agricultural land and taking it out of crop. Costs associated with the Hillis Rule alternative will generally be lower than purchasing and changing an existing water right. However, some level of hydrogeologic analysis would be required to support water right acquisition under Hillis Rule to demonstrate a proposed withdrawal meets Hillis Rule requirements. Any proposed use of an existing or new water right would be required to demonstrate non-impairment of adjacent senior water rights. An impairment analysis was not conducted as part of this study, but the potential for impairment is anticipated to be low at this point, considering the non-consumptive nature of the project.

2.3.1 Purchase or Lease of OTID Ditch Shares

Alternatives involving artificial recharge would infiltrate water from a surface water source. Shares of the existing OTID water right could be acquired through purchase or lease. This process would likely require purchasing land currently in agricultural use, converting land use to one not requiring irrigation water and conversion of the purpose of use for a portion of the OTID water right from irrigation to fisheries enhancement. The period of withdrawal would have to coincide with the OTID water right withdrawal period (typically from April 1 through October 15).

2.3.2 Transfer of Existing Water Right

Surface or groundwater rights may be obtained from either a new or existing surface water right. Existing water rights identified in the project areas are discussed in Sections 2.3.4 and 2.3.5, below. Purchase of an existing water right would require changes in place of use and purpose. A new surface water right for the project obtained through expedited processing might be possible provided certain conditions are met as described below.

2.3.3 New Water Right – Expedited Processing

Should a new permit be required, a preferred water right strategy for habitat/fisheries enhancement projects is to pursue priority processing for a new non-consumptive water right under WAC 173-152-050, commonly known as the Hillis Rule. This legislation allows Ecology to prioritize the processing of new water right applications that are water budget neutral (non-consumptive) and include qualifying measures that substantially enhance or protect environmental quality in a watershed. Guidance regarding classification of water uses as non-consumptive for surface water is given by Ecology's Water Resources Program Policy POL 1020 (Ecology, 1991). The policy defines water use as non-consumptive when "…there is no diversion from the water source or diminishment of the source". Furthermore, an exception is allowed for projects (such as fish hatcheries) when the "…water is returned to the same pool from which it is diverted and the pool's water elevation is not changed…". POL 1020 also specifies that water use to initial fill or charge the system is allowed, subject to instream flows and existing rights. Ecology recognizes that certain projects may have a small component of water consumption – such as, through an increase in bank storage or evaporation rate. However, as a matter of policy, Ecology classifies these types of projects as non-consumptive (Ecology, 1991). Source water withdrawal should not create a "bypass" reach where the discharge is located at the point downstream of the point of withdrawal. Flow mitigation may be required if a bypass reach is crated.

2.3.4 Oroville Area Water Rights

Ecology Water Right Tracking System (WRTS) records were accessed to create a summary of existing surface water and groundwater rights for the Oroville vicinity shown in Tables 2.3.1 and 2.3.2, respectively. The project objective for flow is 1 cfs, but as discussed in Section 3, lower flows may be acceptable for discharge to constructed or natural channels. For purposes of screening water rights, a minimum instantaneous flow quantity of 0.5 cfs (224 gpm; see Section 3) is considered necessary for a successful project. Therefore, a water right must have an instantaneous quantity (Qi) equal to or greater than this value. There are 9 certificated/permitted surface water rights in the Oroville vicinity and 14 in the Riverside vicinity meeting this criterion. There are 11 certificated/permitted groundwater rights in the Oroville vicinity and 5 in the Pharr Road vicinity meeting this criterion. With one exception (S4-28273), all of these water rights have annual quantities (Qa) that allow for use of the full Qi during the entire period when river temperatures exceed 22^{o} C, typically during the period late July and August (Table 2.1.1).

2.3.5 Riverside Area Water Rights

Groundwater and surface water rights identified from the WRTS records are summarized in Tables 2.3.3 and 2.3.4, respectively. Existing water rights in the vicinity of the Pharr Road site consist of one groundwater and two surface water rights. It is anticipated these water rights would be acquired by the CCT as part of a site purchase agreement. The groundwater right that appears to accompany the Voelckers property at the Pharr Road site (G4-23600CWRIS) has a Qi of 0.75 cfs (335 gpm) and annual quantity (Qa) of 131.5 acre-feet, which is adequate to support pumping at the permitted Qi for the duration of the period when Okanogan River temperatures exceed 22 degrees C (Table 2.3.3). Irrigation well 07D01 lies on the Voelckers property. Two surface water rights appear to accompany the Petersen property: S4-08332CWRIS and S4-08331CWRIS having Qi of 0.12 and 0.33 to irrigate 8 acres and 24.5 acres, respectively. Both certificates do not have a Qa assigned. No surface water diversion was identified at the Petersen property in summer 2009, but 2 shallow irrigation wells (06P01 and 07D02) were identified (Figure 2.2.6).

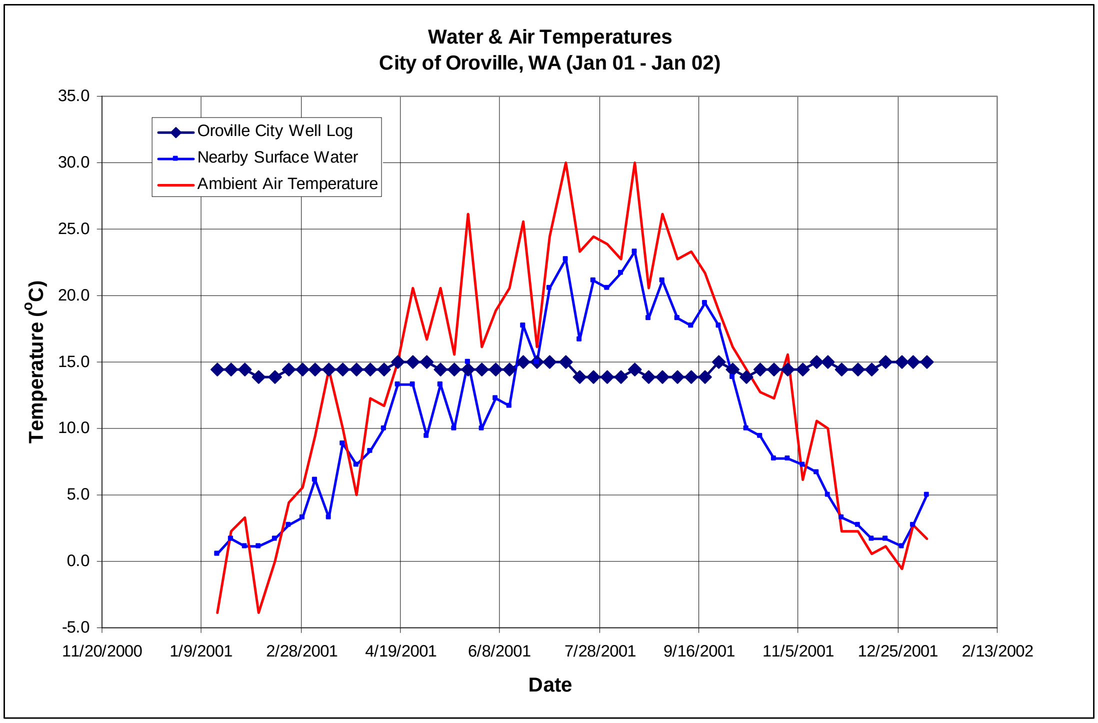
3 Biologic Considerations

Development of alternatives for salmonid refugia require that consideration be given to particular environmental parameters necessary for optimum, or even tolerable, survival and growth conditions. High water temperatures in the system currently limit available habitat to marginal zones of extremely limited spatial extent and the several small tributary streams fed largely by cool groundwater throughout the Okanogan River system. Production of salmonid species requiring over-summer rearing habitat is consequentially quite limited. Figure 3.1.1 presents identified habitat areas within the Oroville area. Assembled alternatives, discussed in Section 4 are also shown on Figure 3.1.1. This section discusses biologic affects of water temperature and other water quality parameters, considerations for fish passage engineered, and natural channels and summarizes other, current, similar projects occurring in the basin.

3.1 Water Temperature Considerations

Of the various water quality parameters that are critical to growth and survival of salmonids in the Okanogan/Similkameen River system, temperature is the most significant (Fisher, 2009). The optimum temperature range (for salmonid growth is greater than 7 degrees C and less than 17 degrees C (Bell, 1991, and Wydoski and Whitney, 2003), and the maximum tolerable temperature for survival is about 23 degrees C for juvenile Chinook. As discussed in Section 2, the optimum temperature range is exceeded each summer and many summers exceed the 23 degree lethal threshold.

As discussed in Section 2.2, groundwater temperatures in the project areas were also investigated as part of this study. For sites near the City of Oroville, well data show that available well sources within the City would provide water temperatures between 13 degrees C and 15 degrees C year-round, while surface water sources vary from as low as 0 degrees C and as high as 24 degrees C (Figure 3.1.2 below).



<u>Figure 3.1.2</u> Well Water, Surface Water, and Ambient Air Temperatures – Oroville, WA (City of Oroville, 2001).

Additional well data were collected as part of this study, and are reported in Section 2.2 of this document. All show that well water sources meet the temperature criteria established for salmonid juvenile rearing and adult holding and spawning life stages (i.e., less than 17 degrees C).

3.2 Other Water Quality Requirements

In general, it is apparent that the available groundwater well sources for all alternatives considered provide water of adequate temperature; however, other parameters of importance include dissolved oxygen content, metals concentrations, and pH. Some data are available for a few well sites and surface water sources pertaining to pH and DO levels, but less information is available regarding metals concentrations. Bell (1991) and others have stated that salmonids tend to be more sensitive to pH than other fish species, and are as a result more sensitive to heavy metals concentrations, which often are higher in acidic waters wherever free metals are available. In addition, salmonids' relatively primitive gill structure and oxygen intake efficiency is intolerant of low DO content, which is not unsurprisingly characteristic of cool-water species evolving in high quality, well aerated waters (Wydoski and Whitney, 2003). The table below list typical ranges of these critical water quality parameters for salmonid species.

Table 3.2.1 - Water Quality Sensitivity for Salmonid Species (Bell, 1991)

Parameter	Value	Units	Notes
pH $critical_{(max)}$	**8.3**	**ppm (mg/L)**	(i.e. preference for slightly alkaline)
pH $critical_{(min)}$	**6.7**	**ppm (mg/L)**	
$Copper_{(max)}$	**0.3**	**ppm (mg/L)**	(though acidic waters magnify Cu toxicity considerably)
$Zinc_{(max)}$	**0.3**	**ppm (mg/L)**	(slightly less toxic than Cu)
Dissolved $Oxygen_{(min)}$	**5**	**ppm (mg/L)**	
Dissolved $Oxygen_{(max)}$	**9 to 15**	**ppm (mg/L)**	(or saturation level, by temperature)
$Temperature_{(min)}$ Rearing	**7**	**^{o}C**	
$Temperature_{(max)}$ Rearing	**17**	**^{o}C**	(though fall Chinook can sometimes tolerate up to 20^{o}C)
Pesticides (chlorinated hydrocarbons)	(minute concentrations)		(biomagnifies up to 10,000 times)
Pesticides (organic phosphates)	(minute concentrations)		(less toxic than chlorinated hydrocarbons)

Well data collected from several sites within the City of Oroville, and from the Town of Riverside show that the critical dissolved metals concentration parameters for juvenile salmonid growth and survival can be met using wells within these areas. Table 3.2.2 below shows the recent sample data for the various wells tested as part of this study.

Table 3.2.2 - Concentrations of Selected Metals in Groundwater, Similkameen, Oroville, and Riverside Sites

Source	Date	Copper (mg/L)	Zinc (mg/L)
City of Oroville Water System			
Source #4	7/25/2004	0.002	0.02
Source #4	7/17/2001	0.2	0.2
Source #4	8/24/2001	0.002	0.02
Source #5	9/12/2007	0.002	0.02
Source #5	7/25/2004	0.002	0.02
Source #5	7/17/2001	0.2	0.2
Source #5	8/24/1998	0.008	0.02
Source #4	10/3/2007	0.0035	0.02
Source #4	8/24/1998	0.002	0.02
Source #4	8/23/1993	0.02	0.05
Source #1	8/24/1993	0.02	0.05
Town of Riverside Water System			
Source #1	11/30/1999	0.2	0.2
Source #1	9/4/1996	0.02	0.05
Source #2	11/24/2003	0.2	0.2
Source #2	11/30/1999	0.2	0.2
Source #2	9/4/1996	0.02	0.05
Source: Washington State Department of Health			

Groundwater pH data and DO levels were not available at the time of the preparation of this report. However, a more detailed data collection program will be implemented for any well sites selected to supply a preferred refugia alternative. It is generally known that most groundwater wells within the lower terraces of the Okanogan River are principally more alkaline than acidic (Entrix, 2006). Thus, it is likely that the pH criteria can be met using shallow aquifer wells along the river.

Limited DO measurements made in the this study show groundwater DO to be below the 5 mg/L salmonid criteria (Tables 2.1.2 and 3.2.1). Should a developed project groundwater source be depressed DO, the water can be effectively treated using a variety of means at the wellhead prior to delivery into any fish-bearing flow. Aeration towers, aeration baffling flow systems, and several other systems can all bring the oxygen content to saturation levels at ambient temperature and pressure equilibrium conditions. These systems can be readily designed for site-specific applications, once a preferred alternative is selected, and the source water is developed.

3.3 Engineered Channel Design Considerations

Of the locations under consideration for an artificial or natural refugia channel, most would consist of a constructed channel excavated into the floodplain or upper terrace of the Okanogan or Similkameen River channels. Depth of excavation would necessarily be near the existing mainstem river channel bed elevation at the downstream end and rising moderately to the upstream end of the constructed channel. In some locations under consideration, the depth of excavation might range from as little as 5 feet to as much as 15 to 20 feet. Materials are expected to be similar at all locations under consideration, with loosely to densely consolidated alluvial materials comprising a typically homogeneous terrace, but explorations would be necessary to confirm this. In some locations, especially those on the upper terrace above the west bank of the Similkameen River site, the soils may be comprised partially of glacial deposits of either till or terminal moraine. Where the engineered channel might be excavated into existing alluvial materials, we expect the natural angle of repose of bank materials will be between 1V:3H (Vertical:Horizontal) and 1V:5H, with some settling occurring over time once riparian processes and natural weathering modifies standing slopes. Pending site-specific geotechnical evaluation, we will assume a constructed bank slope of 1V:5H will be required for long-term stability of channel form. Given that available flow from well sites will likely be limited to less than about 1,000 gpm (2.23 cfs), the constructed channel bottom width need not be much larger than about 3 to 8 feet in width, depending on longitudinal slope, substrate gradation, and channel discharge. Larger and deeper pools may be constructed where appropriate as part of the engineered channel to increase channel habitat complexity.

It may be possible to add spawning-suitable reaches within the engineered channel, though channel discharge may be too limited to support successful spawning. In any case, suitable substrate would be available if adults wished to establish redds. Engineered channel longitudinal profile would vary, depending on the particular location of the engineered channel alternative under consideration.

Though design criteria for thermal refugia (for juvenile fish) rarely include such physical characteristics as depth, flow velocity, and flow width, these are important parameters in this evaluation. There are no requirements in these regards known to the authors, but deduction can be made from similar requirements for adult fish passage design criteria.

For example, adult passage criteria states that minimum flow depth be not less than 9 inches. This value is based on a flow depth at least equal to one (1) body depth (with dorsal fin fully submerged) of the largest fish that might be expected to utilize the channel. Similarly, maximum flow velocity is generally limited to about 4 feet per second (fps) for sustained swimming, or about 8 fps for energetic swimming for up to 15 seconds. Translated into terms of body dimensions, these values are generally equivalent to about 2 body lengths per second for sustained swimming, and 4 body lengths per second for energetic swimming of 15 second time limitation. Flow depth, though not generally required to meet some maximum limit, is more often limited by the available discharge passing through the channel, and the channel regime characteristics.

From this simplified approach, we can assume basic design criteria for an engineered channel suitable for juvenile salmonid thermal refugia might include the following criteria, based on the ‘body length’ relationship:

- Depth (min) = 0.2 ft (or about 1xbody depth of large juvenile salmonid)
- Depth (max) = 1.0 ft (, or about 5xbody depth of large juvenile salmonid)
- Flow Velocity (min) = 0 (for deep pools), or about 0.1 fps (for running flow)
- Flow Velocity (max. sustained swimming) = 0.66 fps (or about 2x100mm body length/second)
- Flow Velocity (max. energetic swimming) = 1.32 fps (or about 4x100mm body length/second)
- Unit Discharge (min. per foot of channel width) = 0.02 cfs (10 gpm)
- Unit Discharge (max. per foot of channel width) = 1.34 cfs (600 gpm)
- Thalweg slope (max) = 11ft/mile

These basic criteria yield very different engineered (and natural) channel dimensions, if one were to simply apply them directly. Preferred channel dimensions will be wholly dependent on the reasonable expected groundwater supply source discharge volumes and well capacity, combined with the application of these criteria to define channel depth, width, slope, and substrate composition.

Channel inflow area design considerations include protection of the bed and banks from erosion that might arise from discharge of inflow. This would be accomplished at least cost using erosion protection comprised of riprap, riprap with vegetation, artificial geotextile reinforcement or geogrid reinforcement, or a combination of a variety of structurally stable materials. Alternatively, if sufficient space is available, the inflow discharge could be passed into a preformed scour pool of sufficient size and depth to reduce the inflow energy and distribute it into the receiving refugia channel without excessive bed and bank shear stress.

Of primary importance in the design of an engineered channel, and possibly much easier to accommodate than a natural channel, is protection against flood damage in the event of a large runoff event on the adjacent mainstem channel. Large flows in the adjacent river channel may overtop the bank and pass into the engineered channel. If no levee protection is available to prevent this, it will be necessary to consider periodic and possibly major reconstruction and/or repair or maintenance to ensure effective function over the long term. If levee protection is a possibility, repairs and maintenance might be limited to only the periodic removal of accumulated fine sediments that would deposit during high flows sufficient to backwater the engineered channel from the main river. If the adjacent river channel has a relatively steep slope, a large flood event overtopping the floodplain or berm separating the engineered channel from the main channel may result in excessive erosion. Hence, in this situation the engineered channel would likely require erosion protection throughout its length, or at least in reaches where it is especially susceptible to such erosion damage.

3.4 Natural Channel Design Considerations

Similar to the engineered channel design considerations, natural channels or potential channels would be constrained by criteria as identified above. Groundwater well sources are finite in delivery volume, and by extension, create a finite constraint on effective channel size. Simply because a larger natural channel might be available does not mean that it has additional potential benefit over an engineered channel if water cannot be supplied to make the additional potential habitat available and of the same or higher overall quality. Accordingly, natural channels of about the same size, slope, and length as engineered channels are the most appropriate candidates for this project. In the Similkameen – Okanogan River system, the best candidates for natural channel refugia appear to be old abandoned oxbow channels or flood overflow channels that have largely become infilled with sediment and thus reduced in cross section. Though several of the natural channel candidates possess the approximate desired dimensions, none have coarse substrate, mainly because they were created as a result of infilling with fine flood-borne sediments. This limits their usefulness as spawning habitat.

Within the several general reaches of the Similkameen – Okanogan River mainstem, CCT has identified a few potential natural channel alternatives, generally concentrated around Oroville. All are either old remnant channel structures or flood overflow channels, which roughly parallel the existing channel. Therefore, available channel slope is small throughout most of the length of the channel, hence the flow velocity will necessarily be well below the maximum criteria provided above. Channel slope at the extreme downstream end of natural channels of this geomorphic origin may have oversteepened reaches at the exit end, resulting from fine sediment deposition occurring within the side channel typically at bankfull stage and above in the main channel, with commensurate high main channel stage. However, bank and riparian vegetation is generally well-developed, yielding stable (though usually oversteepened) banks and adequate shading/invertebrate production critical to full function of the refugia.

Criteria for natural channels, where different from, or in addition to those for engineered channels, are provided below:

- Bank side slope (max in fine silts) = 1V:3H
- Bank side slope (max in coarse gradation mat’ls) = 1V:2H
- Thalweg slope (min) = adjacent mainstem channel slope
- Thalweg slope (max) = 3ft/100ft (3%)

Design considerations for the inflow area of the natural channel must include the avoidance of excessive erosion of either channel bottom or side slopes resulting from the higher energy discharge of supply water. In addition, the natural channel would have to be protected from erosion damage resulting from high flow events in the main river channel adjacent to the refugia channel. Similar protection against excessive damage resulting from overtopping flows or backwatering flows as for the engineered channel (as discussed above) must be considered for any natural channel alternative. Alternately, the natural channel refugia may be designed as a transient feature in the floodplain, with the full expectation that major damage or main channel changes could obliterate or significantly adversely affect the refugia channel. In this case, the cost to relocate the source water discharge to another location might be considered economically viable and of sufficient permanence to achieve the biological goals of the project.

3.5 Preferred Refugia Channel Characteristics

The location of the preferred refugia channel is necessarily constrained by the proximity to salmonid inhabitants of the desired life stage at the critical season of the year. For example, the entrance (confluence with the main river channel) should be as near as practical to potential main channel spawning areas, such that juvenile fish could easily locate the mouth of the refugia channel and pass into it under their own locomotion. Given that the highest function of a thermal refugia channel is to provide cool water of sufficient productivity to support growth during the hottest seasons, it is very likely that these times will occur concurrently with lowest main channel flows. Hence, since the most vulnerable life stages of most salmonids would be of relatively small physical size, it would be desirable to locate the refugia confluence nearest deeper slackwater pools in the main channel rather than adjacent to rapids or riffles. The slackwater characteristics of the main channel receiving water body would enhance the thermal signature and enable smaller fish of lesser swimming capability to easily enter the refugia.

To avoid excessive losses of pumped groundwater to the hyporheic zone, the channel would be ideally excavated to the water table or river level. Under this configuration, cold groundwater pumped into the channel would move toward the mainstem as surface flow rather than seeping into the hyporheic zone.

In addition to the above considerations, it would be desirable to locate the refugia channel such that it is generally protected against rapid lateral migration of the main channel, either resulting from single flood events or due to progressive and continued bank erosion. Also, it is highly desirable to locate the refugia channel such that there could be a protective berm or higher ground separating the refugia channel from the main channel, to limit potential risk of major erosion damage should overtopping flows occupy the refugia channel. If a protective berm or high ground is not naturally available, it would be advantageous to construct such a berm.

In addition to the above-stated considerations, the location of a thermal refugia channel should also be near enough to the source water as to be economical to pipe the desired flow to the channel.

3.6 Constraints and Issues with other CCT and Basin-wide Concurrent Projects

The Colville Confederated Tribes (CCT) are in the process of designing and constructing a large salmon hatchery near Chief Joseph Dam, which is just upstream of the mouth of the Okanogan River on the mainstem Columbia River. Part of this hatchery program includes a broodstock collection and harvest collection weir on the lower Okanogan near Malott. Since the Malott collection weir site is several tens of miles below the furthest downstream refugia channel location (Pharr Road, near Riverside), it is highly unlikely that there would be adverse consequences arising with the refugia channel design, should the Pharr Road site be selected now or in the future. The upstream sites, located nearly 100 miles upstream of the proposed hatchery complex and at least 50 miles upstream from the proposed collection weir, would not be adversely impacted, nor would themselves adversely impact operations of the hatchery or collection weir facility.

At least some of the several potential refugia channel sites near Oroville have been evaluated in a cursory fashion by other sponsors recently. Namely, the Okanogan County PUD (OPUD) considered side channel enhancements at several sites near the Oroville area to serve as aquatic habitat mitigation for the proposed re-licensing of Enloe Dam. Two of these sites are located at the location of Alternative 4 (described in Section 4, below) and one of these sites is proposed for construction beginning in 2015 (Figure 3.1.3).

Figure 3.1.3 **Potential Channel Enhancement, Sites 1 and 2 developed by OPUD (2008) as part of the Enloe Dam Relicensing. Site 2 is the discharge point under Alternative 4 in this Study.**

4 Thermal Refugia Alternatives

Project alternatives were assembled based on potential water sources and discharge locations suitable for thermal refuge.

4.1 Source Water

In the Oroville area, the following alternatives for source water and discharge locations were identified:

4.1.1 Oroville Area

Source water alternatives in the Oroville area include OTID, Similkameen River, and groundwater. Each of these potential sources are discussed below.

OTID – Provides water from Osoyoos Lake typically from April 1 through October 15. Existing temperature data indicate this water is sufficiently cold to meet the 22-degree C project objectives during the period April through mid-June and would require purchase of existing water shares and corresponding retirement of irrigated orchard area., Use of OTID water beyond June would require subsurface cooling. To create a thermal refuge using OTID water will require an approximate 75-day delay between the period of recharge and the period of discharge to the Similkameen River. Ideally, cold water infiltrated from April through mid-June would discharge to the Similkameen River during late July and August, when river temperatures are warmest.

A simple analytical model was developed to estimate the travel time from an infiltration pond located on the lower terrace where the Teas well is located. Aquifer hydraulic parameters were estimated from well log data. In the model, water is first directed to storage to create a groundwater mound at the pond bottom. Water then moves away from the mound at a velocity computed using Darcy's Law. Results of the analysis indicate that a pond located about 300 feet from the river would delay discharge about 75 days. There is considerable uncertainty in the estimation of aquifer hydraulic parameters that could greatly affect results of this analysis. If infiltration is pursued as an option, hydraulic parameters would have to be better defined through infiltration and/or pump tests and more rigorous mounding analysis using a numerical model should be performed. Based on the limited existing data, an infiltration system appears feasible.

Similkameen River – Cold water is available in the Similkameen River until mid-June. As with OTID option, use of Similkameen River water would require infiltration to meet the project discharge timing requirements. A rock-basket or shallow alluvial well in hydraulic connection with the river could be used to help mitigate potential issue involving water level fluctuations and turbidity. This source option is generally viewed less favorably than OTID, because of the absence of existing infrastructure and the need for a new or transferred water right.

Well(s) completed in Shallow Alluvial Aquifer east of river – High yielding wells in the Oroville area indicate a prolific aquifer that could meet project needs by providing cold water that could be directly discharged during July and August. DO will likely be low and an aeration facility that minimizes heat gain would need to be developed.

Well(s) completed in deeper aquifer west of river – Moderate yielding wells could likely be developed in this area, but would likely require several wells to meet project flow objectives. DO constraints discussed above also apply to this alternative.

4.1.2 Discharge Locations

Identified spawning and habitat reaches extend for a several mile reach in the Oroville area (Figure 3.1.1). To meet project objectives, 1 cfs is considered the target minimum flow for juvenile salmon refuge. As discussed in Section 3.3, the target flow will vary considerably depending on discharge channel dimensions. Based on habitat and water source considerations, the following discharge locations were identified:

Direct discharge to mainstem Similkameen – Discharge could occur to the mainstem of the Similkameen River. The entire reach of the mainstem may be suitable for a project, providing cold water is available is sufficient quantity to overcome the effects of mixing; however, discharge areas in slow moving pools that limit mixing and are located in close proximity to spawning areas are preferred.

Natural side channel located downstream of STP – A side channel was previously identified approximately 1,600 feet downstream of the STP by CCTFW and Entrix (2008). Discharge to a side channel offers the advantage of having the cold discharge water being the sole or major proportion of water discharged, significantly reducing the warming effects of mixing with the main channel.

Natural side channel north of Oroville on east side of river -– This channel was identified during our field reconnaissance and appears to be a back channel that is filled during higher river stages.

Constructed side channel – A constructed side channel offers the same advantages as the natural channel. Constructed channels could be located at several areas in the project location. Identifying exact locations for constructed channels was deferred until after the alternative screening to focus effort on the leading alternative.

4.1.3 Assembled Alternatives

The following alternatives were assembled based on these potential water sources and discharge locations. Of these alternatives, specific locations were identified for Alternatives 4 (East Side Well Source, discharge to natural side channel) and Alternative 5 (Pharr Road Well Discharge). Locations of Alternatives 1 through 3 are more generalized at this feasibility stage pending resolution of engineering issues. Photographs of the alternative areas are presented on Figures 4.1.1 through 4.1.5.

Alternative 1A – West side Artificial Recharge (OTID source; natural discharge to mainstem).

Description: Develop artificial groundwater recharge on the west side of the Similkameen River to increase groundwater seepage into the mainstem river. Apply water obtained from OTID to an infiltration basin located on one of several terraces comprised of glacial sediments on the west side of the river. Water from OTID is sourced from the Okanogan River/Lake Osoyoos. OTID water would be infiltrated during the period April through mid-June, when source water temperatures are low. The infiltration basin would be located to time discharge to the river during the period July through September. Natural discharge to the river will be controlled by hydrogeologic conditions. Where seepage occurs above river level, seepage would be captured and gravity conveyed to point discharge locations, where feasible. Key engineering considerations include an infiltration basin and improvements to existing conveyance.

Alternative 1 (B) – West side Artificial Recharge: (Similkameen source, discharge to constructed channel).

Description: Develop artificial groundwater recharge on the west side of the Similkameen River to increase groundwater seepage into a constructed channel. Apply water pumped from the Similkameen River. Obtain water right under Hillis Rule, construct new pump station and conveyance to an infiltration basin located on one of several terraces comprised of glacial sediments on the west side of the river. Water would be pumped from the river during high water flows and infiltrated until mid-June, when source water temperatures increase. The infiltration basin would be located to target discharge to the river during the period July through September. Discharge to the river would be controlled by constructing an engineered channel meeting habitat objectives (e.g., back channel). Key engineering considerations include pump station, conveyance, infiltration basin and engineered channel.

Alternative 1 (C) – West side Artificial Recharge: (OTID Source, discharge to constructed channel).

Description: Develop artificial groundwater recharge on the west side of the Similkameen River to increase groundwater seepage into a constructed channel. Apply water obtained from OTID to an infiltration basin located on one of several terraces comprised of glacial sediments on the west side of the river. Discharge to the river will be controlled by constructing an engineered channel meeting habitat objectives (e.g., back channel), and setback of the infiltration pond from this channel. Water would be infiltrated from April through mid-June and targeted for discharge in July-September. Key engineering considerations include an infiltration basin, improvements to existing OTID conveyance, and an engineered channel.

Alternative 2 – West side Well Source, discharge to mainstem.

Description: Pump groundwater from a low to moderate-yield aquifer on the west side of the Similkameen River to existing habitat (river pool). Water would be made available for pumping during warm river temperature periods from July to September. Key engineering considerations consist of well design, aeration facility, conveyance, discharge location, and engineered channel.

Alternative 3 (A) – East Side Artificial Recharge (OTID water source; natural discharge to mainstem or east side backchannel).

Description: Develop artificial groundwater recharge on the east side of the Similkameen River, northwest of downtown Oroville to increase groundwater seepage into the mainstem river. Apply water obtained from OTID to an infiltration basin located on a narrow terrace comprised of glacial sediments on the east side of the river. Water from OTID is sourced from the Okanogan River/Lake Osoyoos. OTID water would be infiltrated during the period April through mid-June, when source water temperatures are low. The infiltration basin would be located to target discharge to the river during the period July through September. Natural discharge to the river will be controlled by hydrogeologic conditions. Where seepage occurs above river level, seepage would be captured and gravity conveyed to point discharge locations, where feasible. Key engineering considerations include an infiltration basin and moderate improvements to existing OTID conveyance.

Alternative 3 (B) – East Side Artificial Recharge (Similkameen source, discharge to engineered channel)

Description: Develop artificial groundwater recharge on the east side of the Similkameen River to increase groundwater seepage into an engineered channel. Obtain water right, construct new pump station and conveyance or rehabilitate gravity conveyance system delivering water to an infiltration basin located on a narrow terrace comprised of glacial sediments on the east side of the river. Water would be pumped from the river or diverted into rehabilitated gravity conveyance during high water flows and infiltrated until mid-June, when source water temperatures increase. The infiltration basin would be located to target discharge to the river during the period July through September. Discharge to the river will be controlled by constructing an engineered channel meeting habitat objectives (e.g., back channel). Key engineering considerations include pump station, conveyance, infiltration basin and engineered channel. Rehabilitation of the gravity system would require substantial engineering.

Alternative 3 (C) – East Side Artificial Recharge: (OTID Source, discharge to engineered channel).

Description: Develop artificial groundwater recharge on the east side of the Similkameen River to increase groundwater seepage into an engineered channel. Apply water obtained from OTID to an infiltration basin located on the narrow terrace comprised of glacial sediments on the east side of the river. Discharge to the river will be controlled by constructing an engineered channel meeting habitat objectives (e.g., back channel). Key engineering considerations include an infiltration basin, moderate improvements to existing OTID conveyance and an engineered channel.

Alternative 4 – East Side Well Source, discharge to natural side channel.

Description: Pump groundwater from a shallow, high-yield aquifer on the East side of the Similkameen River to existing side channel (Site 2, Figure 3.1.3). Water would be pumped during the period July through September. Key engineering considerations consist of well design, aeration facility, conveyance, discharge location, and potential channel enhancements. The water source pipe would necessarily have to penetrate an existing low flood damage protection levee along the southwest margin of the town of Oroville. Penetration of this levee carries with it other considerations, namely that the pipeline be protected against seepage along the pipe through the penetration location. Design alternatives may include seepage barrier rings installed at the time of pipe installation, or construction of proper filter blanket material on the landward side of the levee to minimize loss of fines from the levee structure as a result of high seepage along the pipe.

4.2 Riverside Alternative

Alternative 5 – Pharr Road Well Discharge **–** One alternative was developed for the Pharr Road site that makes use of existing well(s) for a water source and enhancement of the natural channel on the property.

Description: Pump groundwater from a shallow, high-yield aquifer on the Pharr Road properties to engineered side channel. Possibly draw additional water from Okanogan River via gravity culvert/gate or pump station, when temperature is suitable for mixing with well water. Water would be pumped during the period July through September. Key engineering considerations consist of well design, aeration facility, conveyance and discharge location or engineered channel. The Alternative 5 Pharr Road (Riverside) Site is adjacent to a reach of the Okanogan River that has an average slope of about 2.5 to 3 ft/mile as well.

Figure 4.1.1 - Alternative 1 Location Photo - Artificial recharge on the west side of the Similkameen River. Water from OTID or a new pump station would be applied to an infiltration basin located on the lower terrace (foreground) or upper terrace (background). Artificially-recharged water would discharge naturally into the riverbed or into a constructed channel.

Figure 4.1.2 - Alternative 2 Location Photo - Direct groundwater discharge from a well completed in the low to moderate-yield aquifer on the west side of the Similkameen River. Water would be discharged to a pool in the river or a small constructed channel.

Figure 4.1.3a - Alternative 3 Location Photo - Artificial recharge on the east side of the Similkameen River using water from OTID or a new pump station applied to an infiltration basin located on a terrace above the river. Photo showing infiltration area

Figure 4.1.3b - Alternative 3 Location Photo - An existing natural backchannel (across river) could be enhanced to intercept artificially-recharged groundwater.

Figure 4.1.4 - Alternative 4 Location Photo - Direct groundwater discharge from a well completed in the high-yield aquifer on the east side of the Similkameen River and discharge to nearby natural channel previously identified. The proposed side channel for discharge is shown entering the Similkameen River in the photo (see Channel 2 in Figure 3.1.3).

Figure 4.1.5a - Alternative 5 Location Photo Direct groundwater discharge from one or more existing wells at the Pharr Road site. Wells would discharge into a constructed side channel running the length of the site. Trees are located along west bank of Okanogan River. View is east looking east along survey transect G (see Appendix A).

Figure 4.1.5b - Alternative 5 Location Photo – View north showing former channel. Okanogan River located on right side of photo.

5 Evaluation of Alternatives

Five principal alternatives were developed and ranked using a variety of criteria to identify the most feasible projects. Ranking criteria are described below followed by a description of the alternatives and considerations used in ranking each alternative. Scores are presented Table 5.1.1.

5.1 Evaluation Criteria

5.1.1 Meet Project Objectives (20 points)

The overall project objective is to increase fish survival during warm water months by providing thermal refugia. The project flow objective for juvenile salmon refuge is 1 cfs flow at a maximum temperature of 22 degrees C. Under certain discharge conditions (e.g. constructed channels) lower flows will be acceptable (see Section 3.3). Channel specific conditions (wetted perimeter, depth, velocity, and shading characteristics) will need to be evaluated to determine lower flows that would meet project objectives. Alternatives with more certainty in meeting the project flow and temperature objectives score higher in this criterion. A successful project will:

- Deliver cool and oxygenated water of suitable water quality during periods of elevated river temperature (typically July through September).
- Deliver water in sufficient quantity to maintain localized river water temperatures below 22 degrees C in the main stem river and/or in an engineered channel during periods of elevated temperatures in the mainstem.
- Provide habitat that is favorable and accessible to fish.

5.1.2 Physical Availability of Water and Uncertainties (20 points)

A reliable source of water is essential to meet project objectives. Alternatives with little risk in developing the water source score higher in this criterion. Considerations include:

- Sufficient quantity of groundwater and/or surface water to meet target flows.
- Sufficiently cool and oxygenated water source of suitable water quality.
- Timing of water availability.
- Proximity to favorable habitat or location for engineered channel.

5.1.3 Engineering Feasibility and Uncertainties (10 points)

Alternatives with more complex engineering requirements and related uncertainties in success of design score lower in this criterion, while projects with fewer engineering requirements score higher. For artificial recharge, hydrogeologic conditions affecting infiltration, timing, losses, groundwater flow paths and discharge locations maybe uncertain. For groundwater sourced projects, potential for drilling a new well to meet project demands has some uncertainty. Projects with a greater degree of hydrogeologic uncertainty score lower. Criteria include:

- Complexity of water conveyance infrastructure.
- Special features: pump station, aeration facility, levee crossing.
- Discharge to mainstem river or engineered channel.
- Hydrogeologic uncertainty.

5.1.4 Land Ownership (10 points)

Alternatives involving fewer properties or where purchase has already been initiated score higher. Considerations in scoring this criteria are as follows:

- Real estate transactions (purchase, lease, easements), including numbers of affected properties.
- Access during predesign/design study phases.
- Existing land uses: orchard, residential, platted, open space.
- Existing land ownership: private, public.

5.1.5 Permitting (15 points)

Alternatives with more complex permitting requirements will score lower under this criterion. In scoring this criterion, the following permit elements and their related complexity are considered:

- Shoreline Development and Instream: JARPA, HPA, USACE.
- Ecology artificial recharge.
- Ecology well permits.
- Grading, construction, building.
- Other regulatory issues.

5.1.6 Water Rights (15 points)

Projects moving forward under the Hillis Rule or that use OTID water are expected to be the easiest to implement and are scored highest. Alternatives with more complex water right requirements such as purchasing or leasing a water right that could require more negotiation are ranked lower. The potential for impairment is considered based on proximity of nearby wells. Water right mechanisms and considerations used to score this category are as follows:

- Obtain new water right- Hillis Rule.
- Purchase or lease existing water right.
- Purchase shares of existing OTID water right.
- Level of effort required to obtain, transfer, change of use including additional technical analysis.
- Impairment potential.

5.1.7 Readiness to Proceed (10 points)

Project readiness scores the relative speed for project implementation. Projects that can be implemented more quickly due to simpler design or permitting score higher than complex projects. Project elements considered in scoring this criterion are as follows:

- Complete feasibility work and resolve engineering and hydrogeologic uncertainties.
- Complete design.
- Obtain water rights.
- Secure permits.
- Secure properties.
- Complete construction.

5.1.8 Capital Cost (15 points)

Alternatives with lower capital costs score higher in this criterion. Capital costs will be affected by:

- Engineering and hydrogeologic feasibility studies.
- Project design.
- Securing property.
- Securing water rights.
- Permitting.
- Construction.
- Proximity to and level of usable existing infrastructure.

Capital costs are summarized in Table 5.1.2.

5.1.9 Operations and Maintenance Costs (10 points)

Long-term operations and maintenance costs are considered in this criterion.

- Operator requirements.
- Power use/pumping lift.
- Conveyance system maintenance.
- Well maintenance.
- Administrative costs.
- Annual fees for leased water/land.

5.1.10 Potential for Negative Public Comment (5 points)

Although the project objective is not anticipated to generate negative public opinion, aspects of the project listed below may be generating negative public opinion among individuals:

- Water right impairment.
- Loss of orchard.

5.2 Alternatives Evaluations

5.2.1 Alternative 1 –West Side Artificial Recharge

5.2.1.1 Alternative 1 (A) – West Side Artificial Recharge (Use OTID water; natural discharge)

Summary: Develop artificial groundwater recharge on the west side of the Similkameen River to increase groundwater seepage into the mainstem river. Apply water obtained from OTID to an infiltration basin located on one of several terraces comprised of glacial sediments on the west side of the river.

Strengths: Maximizes existing infrastructure, relatively easy to implement.

Weaknesses: Uncertain effectiveness due to hydrogeologic uncertainties that will require additional hydrogeologic study, high capital cost.

Ranking Criteria

Meet Project Objectives

- A portion of the infiltrated water may be subject to losses.
- Discharge location of infiltrated water unknown; likely widely dispersed; difficult to predict/control.
- Discharge location may not coincide with preferred habitat enhancement areas.
- Subject to dilution by river water.

Physical Water Availability and Uncertainty

- ~ 3 acre-feet/3.8 gpm/0.008 cfs of water available per acre of orchard; quantity of water available for infiltration limited by capacity of OTID conveyance, water right instantaneous quantity (Qi) and water demands of other OTID water users.
- Known and reliable surface water source with existing capacity to deliver relatively large quantities of water.
- Source water temperatures favorable during period April through mid-June; likely high DO.
- Window to infiltrate water likely limited to months of April through mid-June; constrained by OTID system start up (approximately April 1) and increased source water temperatures, respectively. Peak water use for project not likely to overlap OTID peak irrigation water demand.

Engineering Feasibility and Uncertainties

- Discharge location (lateral and vertical) undefined (seepage observed above river level).
- Groundwater flow paths and timing undefined.
- Uses existing OTID and on-farm conveyance; few new infrastructure.

Land Ownership

- May require purchasing site to support taking large area out of orchard; or
- Lease infiltration site and obtain additional OTID shares.

Permitting

- Ecology artificial recharge.

Water Rights

- Purchase shares of existing OTID right; convert purpose of use to fisheries enhancement.

Readiness to Proceed

- Water source identified, low infrastructure requirements.
- Resolve uncertainties of effectiveness and hydrogeology.
- Permitting.

Capital Costs

- Purchase/lease water shares and/or site.
- Substantial hydrogeologic analysis.
- Moderate permitting.
- Relatively high capital costs due to land owner considerations (Table 5.1.2).

Operations and Maintenance Costs

- Relatively few requirements.

Potential for Negative Public Comment

- Water use competes with agricultural uses.

5.2.1.2 Alternative 1 (B) – West Side Artificial Recharge: (Similkameen source, discharge to engineered channel)

Summary: Develop artificial groundwater recharge on the west side of the Similkameen River to increase groundwater seepage into the engineered channel. Apply water pumped from the Similkameen River.

Strengths: Potential for large quantity of water, controlled discharge location.

Weaknesses: Readiness to proceed, capital and operations/maintenance costs.

Ranking Criteria

Meet Project Objectives

- Greatest potential for large quantities of water compared to OTID and groundwater sources.
- Discharge to engineered channel results in fewer losses; discharge to engineered habitat reducing importance of discharge to natural habitat.

Physical Water Availability and Uncertainties

- Water quantity limited only by conditions of water right and pump/conveyance system capacity.
- Source water temperatures favorable until mid-June; likely high DO .
- Window to infiltrate water may be longer than Alternative 1A. (i.e., water potentially available prior to April 1).
- Likely very high turbidity during spring freshet and beyond, requiring engineering of outtake structure (rock basket, shallow well, etc.) or more extensive infiltration basin and annual cleaning.

Engineering Feasibility and Uncertainties

- Substantial engineering complexity.
- Few opportunities to use existing infrastructure.
- Requires restrictive soil layer/gaining stream to ensure infiltrated water discharges to constructed channel.

Land Ownership

- Requires substantial real estate transactions supporting sites for pump station, conveyance, engineered channel.
- Does not require land use conversion from orchard.

Permitting

- Ecology artificial recharge.
- Instream (JARPA, HPA, USACE); shorelines?
- Grading, construction, building.

Water Rights

- Hillis Rule.

Readiness to Proceed

- Requires substantial engineering design and permitting.

Capital Costs

- Purchase/lease site; may require easements.
- Substantial permitting, design and construction.
- Low to moderate capital costs (Table 5.1.2).

Operations and Maintenance Costs

- Annual system start-up.
- Relatively complex system maintenance.
- Power use.

Potential for Negative Public Comment

- Does not compete with agricultural uses.

5.2.1.3 Alternative 1 (C) – West Side Artificial Recharge: (OTID Source, discharge to constructed channel)

Summary: Develop artificial groundwater recharge on the west side of the Similkameen River to increase groundwater seepage into a constructed channel. Apply water obtained from OTID to an infiltration basin located on one of several terraces comprised of glacial sediments on the west side of the river.

Strengths: Maximizes existing infrastructure, source water identified, controlled discharge location, lower capital and operations/maintenance costs.

Weaknesses: Requires improvements to existing OTID infrastructure, permitting.

Ranking Criteria

Meet Project Objectives

- Discharge to engineered channel results in fewer losses; discharge to engineered habitat reducing importance of discharge to natural habitat.

Physical Water Availability and Uncertainty

- ~ 3 acre-feet/3.8 gpm/0.008 cfs of water available per acre of orchard; quantity of water available for infiltration limited by capacity of OTID conveyance, water right instantaneous quantity (Qi) and water demands of other OTID water users.
- Known and reliable surface water source with existing capacity to deliver relatively large quantities of water.
- Source water temperatures favorable during period April through mid-June; likely high DO.
- Window to infiltrate water likely limited to months of April through mid-June; constrained by OTID system start up (approximately April 1) and increased source water temperatures, respectively. Peak water use for project not likely to overlap OTID peak irrigation water demand.

Engineering Feasibility and Uncertainties

- Uses existing OTID and on-farm conveyance (typical service to orchard tracts are 6-inch lines); few new infrastructure.
- Requires restrictive soil layer/gaining stream to ensure infiltrated water discharges to constructed channel.

Land Ownership

- May require purchasing site to support taking large area out of orchard; or
- Lease infiltration site and obtain additional OTID shares.
- Requires real estate transactions supporting sites for engineered channel; possible easements for conveyance.

Permitting

- Ecology artificial recharge.
- Instream (JARPA, HPA, USACE); shorelines?
- Grading, construction, building.

Water Rights

- Purchase shares of existing OTID right.

Readiness to Proceed

- Water source identified, moderate infrastructure requirements.
- Substantial engineering design and permitting.

Capital Costs

- Purchase/lease water shares and/or site; may require easements.
- Moderate engineering design, construction and permitting.
- Highest capital costs of all alternatives (Table 5.1.2).

Operations and Maintenance Costs

- Relatively few requirements

Potential for Negative Public Comment

- Water use competes with agricultural uses.

5.2.2 Alternative 2 – West Side Well Discharge

Summary: Pump groundwater from a low to moderate-yield aquifer on the west side of the Similkameen River to existing habitat (river pool). Water would be available for pumping during warm river temperature periods from July to September. Key engineering considerations consist of well design, aeration facility, conveyance and discharge location or engineered channel.

Strengths: Easy to implement, lower costs.

Weaknesses: Discharge limited by aquifer yield, existing wells suggest low to moderate yields.

Ranking Criteria

Meet Project Objectives

- Low to moderate quantity of water (15 to 30 gpm existing; 100 gpm potential).
- Precise discharge location.

Physical Availability of Water and Uncertainties

- Requires minimal additional hydrogeologic analysis (pump test; impairment).
- Low to moderate-yielding aquifer.
- Constant low temperature.
- Low DO.

Engineering Feasibility and Uncertainties

- Requires drilling new well(s); could be sited to minimize conveyance requirements.
- Low DO may require aeration facility.

Land Ownership

- Relatively few real estate actions.
- Lease or purchase well site near discharge location.

Permitting

- Well; possible instream (USACE, HPA).

Water Rights

- Hillis Rule.

Readiness to Proceed

- Requires less hydrogeologic analysis and engineering design than Alternatives 1 and 3.

Capital Costs

- Well and discharge location engineering design; permitting; construction.
- Property lease/purchase.
- Lowest capital costs of all Alternatives (Table 5.1.2)

Operations and Maintenance Costs

- Power use.

Potential for negative Public Comment

- Low impairment potential for properly sited well.

5.3 East Side Artificial Recharge Alternatives

5.3.1 Alternative 3 (A) – East Side Artificial Recharge (OTID water source; natural discharge)

Summary: Develop artificial groundwater recharge on the east side of the Similkameen River, northwest of downtown Oroville to increase groundwater seepage into the mainstem river. Apply water obtained from OTID to an infiltration basin located on a narrow terrace comprised of glacial sediments on the east side of the river.

Strengths: Maximizes existing infrastructure, easy to construct; potential for low cost.

Weaknesses: Unknown effectiveness, hydrogeologic uncertainties warrant additional hydrogeologic study.

Ranking Criteria

Same as for Alternative 1 (A) with the following exceptions:

Engineering Feasibility and Uncertainties

- Existing OTID conveyance may be limited due to less land remaining in orchard.
- Relatively narrow terrace could limit locations for infiltration basin.

Land Ownership

- Less land remaining in orchard than on west side.

5.3.2 Alternative 3 (B) – East Side Artificial Recharge (Similkameen source, discharge to engineered channel)

Summary: Develop artificial groundwater recharge on the east side of the Similkameen River to increase groundwater seepage into an engineered channel. Obtain water right, construct new pump station and conveyance or rehabilitate gravity conveyance system delivering water to an infiltration basin located on a narrow terrace comprised of glacial sediments on the east side of the river.

Strengths: Quantity of water, controlled discharge location.

Weaknesses: Readiness to proceed, capital and operations/maintenance cost.

Ranking Criteria

Same as for Alternative 1 (B) with the following exceptions/comments:

Meet Project Objectives

- Fewer opportunities to implement an engineered channel.

Physical Water Availability and Uncertainty

- Potential for gravity conveyance from Similkameen River.

Engineering Feasibility and Uncertainties

- Relatively narrow terrace could limit locations for infiltration basin.
- Rehabilitation of gravity conveyance requires engineering feasibility analysis.

Land Ownership

- Less land remaining in orchard than on west side.

Water Rights

- Gravity conveyance would require obtaining water right; may require mitigation for by-pass reach.

Capital Costs

- Rehabilitation of gravity conveyance.

Operations and Maintenance Costs

- Gravity conveyance operation and maintenance.

5.3.3 Alternative 3 (C) – East Side Artificial Recharge: (OTID Source, discharge to engineered channel)

Summary: Develop artificial groundwater recharge on the east side of the Similkameen River to increase groundwater seepage into an engineered channel. Apply water obtained from OTID to an infiltration basin located on the narrow terrace comprised of glacial sediments on the east side of the river.

Strengths: Maximizes existing infrastructure, source water identified, controlled discharge location, lower capital and operations/maintenance costs.

Weaknesses: Requires improvements to existing OTID infrastructure, permitting.

Ranking Criteria

Same as for Alternative 1 (C) with the following exceptions:

Engineering Feasibility and Uncertainties

- Relatively narrow terrace could limit locations for infiltration basin.

Land Ownership

- Less land remaining in orchard than on west side.

5.4 Alternative 4 – East Side Well Discharge

Summary: Pump groundwater from a shallow, high-yield aquifer on the East side of the Similkameen River to existing habitat (river pool). Water would be pumped during the period July through September. Key engineering considerations consist of well design, aeration facility, conveyance and discharge location or engineered channel.

Strengths: Easy to implement, higher discharge than west side alternative, proximity to habitat, lower costs.

Weaknesses: Might require conveyance through residential area and across levee.

Ranking Criteria

Same as for Alternative 2 with the following exceptions:

Meet Project Objectives

- Larger quantity of water available (>300 gpm) indicated by existing wells.
- Close to identified existing habitat sites and sites proposed for engineered habitat improvements.

Land Ownership

- Property access/acquisition; residential area within city limits; farm land south of city limits.

Engineering Feasibility and Uncertainties

- Potentially opportunities to use existing private wells.
- Likely have to penetrate levee with delivery pipeline.

Capital Cost

- Lowest of all Alternatives (Table 5.1.2).

5.5 Alternative 5 – Pharr Road Well Discharge

Summary: Pump groundwater from a shallow, high-yield aquifer on the Pharr Road properties to engineered side channel. Possibly draw additional water from Okanogan River via gravity culvert/gate or pump station, when temperature is suitable for mixing with well water. Water would be pumped during the period July through September. Key engineering considerations consist of well design, aeration facility, conveyance and discharge location or engineered channel.

Strengths: Reliable water source, property ownership, readiness to proceed.

Weaknesses: Permitting, design and construction of large engineered side channel.

Ranking Criteria

Meet Project Objectives

- Existing well has relatively high yield (300 gpm or higher).
- Water source close to natural side channel that will be enhanced.

Physical Availability of Water and Uncertainties

- Requires little additional hydrogeologic analysis (pump test)
- High-yield aquifer
- Constant low temperature
- Low dissolved oxygen

Engineering Feasibility and Uncertainties

- Requires improvements to existing wells; new well unlikely.
- Minor conveyance requirements.
- Low dissolved oxygen may require aeration facility.
- Proposed engineered side channel larger and longer than other alternatives.
- Proposed engineered side channel infrequently flooded and is considered relatively well protected from high river flood flows.

Land Ownership

- CCT considering purchase.

Permitting

- Instream (JARPA, USACE, HPA).

Water Rights

- Change of use for existing or Hillis Rule.

Readiness to Proceed

- Groundwater likely could be sourced from existing wells.
- Permitting, design and construction for engineered side channel.

Capital Costs

- Well improvements, minor conveyance, aeration facility.

- Permitting, design and construction for engineered side channel.

Operations and Maintenance Costs

- Power use.
- Maintenance of engineered side channel.

Potential for negative Public Comment

- Low potential.

5.6 Recommendations for Further Evaluation

Based on our findings and the evaluation of the available alternatives presented in this report, we recommend the CCT pursue final design for Alternative 4 East Side Well Discharge. Alternative 5 Pharr Road Well Discharge scored just slightly lower in our evaluation table (107.5 total score for Alternative 5 versus 112 for Alternative 4), as a result of greater engineering complexity and higher capital costs. The real estate upon which Alternative 5 refugia channel would be located remains at present within private ownership and is not yet available. The CCT is actively pursuing purchase of that parcel, but at this time has not yet reached closure, and thus Alternative 5 cannot be recommended for immediate implementation. The Alternative 4 site lies on private and public lands. Washington State Department of Natural Resources (WDNR) generally owns stream channels to the high water mark. The Okanogan County Assessor's map shows the existing channel proposed for enhancement lying along boundary between WDNR and adjacent private land owners with most of the channel lying on WDNR property. Except for city-owned property at the waste water treatment plant, property near the existing channel is privately owned. Siting the well source on City property could potentially reduce the cost and complexity of implementation; however, the conveyance line would have to pass through at least one private property for a well located on City property.

The Alternative 4 site is one of two adjacent natural side channels in the Oroville reach of the mainstem Similkameen River (Site 1 is just upstream of Site 2; both are on the east bank [Figure 3.1.3]). The confluence of the Alternative 4 channel is located within a moderately deep slack water pool of the Similkameen River, and is located just downstream of known spawning locations (Figure 4.1.4). Of the two east side sites (Site 1 and Site 2), the selected natural channel (Site 2) is of longer available length, and appears to be better protected from high Similkameen River discharge overflows. In addition, the Alternative 4 site is influenced to a greater degree by the confluence cross channel of the Okanogan River, where the mainstem Similkameen River slope declines significantly. This will aid in reducing the mainstem flow velocity, increase downstream stage, and reduce the potential for damaging high velocity overflows to which the upstream Alternative 1 and 2 reaches are subject.

Alternative 4 can be brought to completion at relatively low cost, since the natural side channel already exists, and the well water source is nearby and the consequent pipe installation would be economical. Nearby well data indicates the Shallow Alluvial Aquifer from which the channel flow would be drawn to be of high quality, with uniform ideal temperature characteristics, and there is considerable capacity available at low pumping cost due to the shallow setting of the aquifer.

We also recommend that the CCT continue to pursue Alternative 5 Pharr Road Well Discharge project, since it also scored very high in the evaluation. The Pharr Road site would be an engineered channel within an existing high floodplain terrace, and as such could be made to withstand high Okanogan River flood flow stages without damage to the refugia channel. The confluence of the refugia channel with the mainstem river channel would be located in a deeper reach of slower moving flow (especially at low summer flow), and though not a true slack water reach, would lend itself well to meeting the criteria established above regarding juvenile salmonid access. In addition, the entrance (confluence) of the proposed refugia channel would be located just downstream of several known and well-utilized spawning sites on the Okanogan River. These factors make the Pharr Road location attractive, though implementation cost is likely to be significantly higher than the preferred Alternative 4.

6 References Cited

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Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Colville Confederated Tribes Fish and Wildlife for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 2.1.1 - Maximum Temperature Exceedance Dates

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Station	First Date 22°C Exceedance	Last Date 22°C Exceedance	Total Days	Days > 22°C	Comments
Similkameen at Oroville (Ecology 49B070)	7/15/04	9/1/04	49	39	
	7/28/05	9/3/05	38	34	
	7/3/06	9/8/06	68	41	
	7/12/07	9/6/07	57	31	
	8/5/08	8/20/08	16	12	
	7/17/09	9/4/09	50	38	
Average date	7/18	9/1	46		
Okanogan near Tonasket (USGS 12445000)					
	7/21/86	9/4/86	46	38	
	6/26/87	9/2/87	69	39	
	7/13/05	after 8/5/05	> 24	> 22	8/05/05 exceeds 22°C. Missing data after this date.
	6/27/06	from 8/19/06 to 8/29/06	> 54	> 41	8/19/06 exceeds 22°C and 8/30/06 less than 22°C. Missing data between these dates.
	7/5/07	8/24/07	51	40	
	7/15/08	8/20/08	37	34	
	7/16/09	9/4/09	51	42	
Average date	7/9	8/24	47		

Table 2.1.2 - Summary of Field Water Quality Measurements

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Site		Date	Depth in River ft	Position from Left	Temperature °C	Specific Conductanc µS/cm	Dissolved Oxygen mg/l	Water Level ft
Teas domestic well		8/19/09			**12.5**	**527**	**0.02**	**12.15**
Similkameen River at Teas		8/19/09	0.5		20.6	142	12.8	
			4.0		20.6	131	11.7	
Similkameen River at STP	1/2 mile above outfall	8/25/09	4.0		19.2	175	-	
			7.0 to 9.0		19.4	175	-	
Similkameen River at STP	5' above outfall	8/25/09	0.5		20.0	175	-	
			1.5		19.8	175	-	
			2		19.8	175	-	
			2.5		19.8	175	-	
STP Effluent		*8/25/09*			*19.8*	*440*	-	
Similkameen River at STP	10' below outfall	8/25/09	0.5	0	21.0	175	-	
			2.0	10	20.0	175	-	
			2.5	20	19.9	182	-	
			3.0	25	19.9	192	-	
			3.0	30	19.8	176	-	
			3.5	40	19.7	175	-	
			2.0	50	19.7	175	-	
			2.0	80	19.7	175	-	
			2.5	100	19.7	175	-	
			3.0	120	19.7	175	-	
			3.0	140	19.7	175	-	
Similkameen River at STP	backchannel on left bank 100' below outfall	8/25/09	0.5		22.8	187	-	
			2.3		20.5	191	-	
Similkameen River at WDFW	riffle	8/19/09	1.0		20.7	143	13.5	
	pool		7.0		20.7	143	12.8	
Okanogan River above Riverside	pool on right bank at north end of Peterson property	8/19/09	0.5		22.0	179	13.9	
			8.0		21.9	179	11.59	
Well 06N01		8/19/09			**16.2**	**702**	**1.2**	**35.50**
Voelckers irrigation well 07D01		8/19/09			**11.9**	**492**	**3.2**	**21.52**
		9/29/09			**11.9**	**-**	**2.4**	**-**

Notes:

STP = sewage treatment plant.

Groundwater data is bold and left justified, river water data is centered, and effluent data is italic and right justified.

Table 2.2.1 - Well Summary

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Owner of Record (well log)	Project Well ID	Ecology Well ID	Well Use	T-R-S	Well Diameter (in)	Top Open/Screened Interval Depth (ft)	Bott Open/Screened Interval Depth (ft)	Total Depth (ft)	Completion Material	Static Water Level (ft)	Water Level Date	Well Head Elevation (ft)	Elevation Accuracy	Capacity (gpm)	Test Duration (hrs)	Drawdown (ft)	Specific Capacity (gpm/ft)	Installation Date
Oroville Vicinity																		
Moon	33H01		D	40-27-33	6	35	35	35	U	13.05	10/26/2009	922.77	S	50	1			10/15/1993
Teas	28M01		D	40-27-28	6	90	100	100	U	12.38	10/26/2009	931.45	S	15	2	0		2/8/1992
Alpine Bldg Dev LLC	29A01	BAB768	D	40-27-29	6	91	96	100	U	24.22	10/26/2009	943.61	S	30	2			5/21/2000
Long	33F01	APE455	D	40-27-33	8	26	26	34	U	19.71	10/26/2009	930.75	S	8				8/27/2008
Eisen Chevron	28G01		R	40-27-28	3					12	10/26/2009	924.26	S					
Eisen Chevron	28G02		R	40-27-28	2					10.65	10/26/2009	923.07	S					
Eisen Chevron	28G03		R	40-27-28	2					11.75	10/26/2009	924.26	S					
Eisen Chevron	28G04		R	40-27-28	2					12.73	10/26/2009	925.13	S					
Town of Oroville	28L01	AGJ207	M	40-27-28	24	32	37	32	U	21.14	10/26/2009	932.34	S	540	24	10	54.0	3/13/1981
Town of Oroville	28B01	AGJ209	M	40-27-28	20	53	73	85	U	24.52	10/26/2009	937.47	S	1700	9	4.4	386.4	8/12/1987
Jackson	34D01		O	40-27-34	36			20		8.89	10/26/2009	920.25	S	200				
Fat boys Diner Inc.	28G05		R	40-27-28	2					11.72	10/26/2009	924.20	S					
Fat boys Diner Inc.	28G06		R	40-27-28	2					11.76	10/26/2009	924.11	S					
Well log not identified	33G01		D	40-27-33	36					9.79	10/26/2009	919.97	S					
Thompson	28N01	ALE509	D	40-27-28	6	290	295	297	B	128	ATD			25	1			6/13/2006
Thompson	28N02	ALE508	D	40-27-28	6	158	163	163	B	132	ATD			20	1			6/8/2006
Thompson	28N03	ALE507	D	40-27-28	6	228	238	280	U	105	ATD			15	2	100	0.2	6/7/2006
Antrim	28M02	AKW803	D	40-27-28	6	128	138	138	U	25	ATD			15		20	0.8	6/4/2003
Scott	29L01	AKW843	D	40-27-29	6	168	178	178	U	30	ATD			15	1	20	0.8	10/14/2003
Rogers	28R01			40-27-28	48			24	U					300				4/6/1964
Demartino	33H02	BAR248	D	40-27-33	6	49	54	58	U	4	ATD			60	1			6/4/2009
Bergh	28Q01		D	40-27-28	6	30	30	30	U	20	ATD			50				6/1/1989
Finsen	33F02	AAK638	D	40-27-33	6	20	25	25	U	19	ATD			7	4	0.5	14.0	8/18/1994
Howerton	33L01	ALF318	D	40-27-33	6	37	42	42	U	20.6	ATD			20				6/8/2008
Riverside (Pharr Road Site) Vicinity																		
Well log not identified	07D01		I	35-27-7	36			~30*				868.12	>300*					
Well log not identified	06N01	ALF105	D	35-27-6	6							883.43	>300*					
Well log not identified	06P01		I	35-27-6	48							862.99	>300*					
Well log not identified	07D02		I	35-27-7	36								>300*					
Adams	06M01	APE491	D	35-27-6	4	466	506	506	B	28	ATD			0.7	2	504	0.001	7/28/2008
Arnold	01R01	ACF516	D	35-26-1	6	80	320	320	B	131	7/18/1996			6	0.5			7/16/1996
Cook	32R01		I	36-27-32	8	58	60	60	U	35	ATD			200				6/6/1979
Dent	08R01	ALC495	D	35-27-8	6	185	190	192	U	98	ATD			30	4			12/3/2007
Dent	09N01	AEM890	D	35-27-9	6	112	122	124	U	62	ATD			12	4.5			5/26/1999
Dixon	08M01		I	35-27-8	10	110	114	117	U	78	ATD							Aug-74

Table 2.2.1 - Well Summary

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Owner of Record (well log)	Project Well ID	Ecology Well ID	Well Use	T-R-S	Well Diameter (in)	Top Open/Screened Interval Depth (ft)	Bott Open/Screened Interval Depth (ft)	Total Depth (ft)	Completion Material	Static Water Level (ft)	Water Level Date	Well Head Elevation (ft)	Elevation Accuracy	Capacity (gpm)	Test Duration (hrs)	Drawdown (ft)	Specific Capacity (gpm/ft)	Installation Date
Braaten	08M02		D	35-27-8	6	142	142	142	U	86	ATD			15				8/28/1979
Ellis	08M03	AKO013	D	35-27-8	4	246	286	306	B	150	ATD			60	4			12/9/2005
Jacklin	09D01	AFQ794	D	35-27-9	8	51	53	53	B	27	ATD			75		4	18.75	3/20/2002
Keystone Ranch	33M01		I	36-27-33				147	B									
Longacre	06F01		I	35-27-6	72	30	30	30	U	14	ATD							3/21/1961
Metropolitan Mortgage	31C01		D	36-27-31				390	U					Dry Hole				7/21/1990
Metropolitan Mortgage	31C02		D	36-27-31	6	395	400	440	U	260	ATD			50	6			9/29/1990
Zaser-Longston	35G01		I	35-27-5	12	37	50	50	U	31				1200	3	6	200	

ATD At time of drilling
D Domestic
I Irrigation
M Municipal
R Resource Protection
O Other
B Bedrock
U Unconsolidated (Glacial and/or alluvial deposits)

*Owner reported information.

Table 2.3.1 - Summary of Existing Groundwater Rights - Oroville Area

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Certificates and Permits

File #	Cert #	Person	Doc	Priority Dt	Purpose	Qi	UOM	Qa	Ir Acres	TRS	QQ/Q	Src's	1stSrc
G4-*07846AKSCWRIS	05783A	RINGWOOD E J	Cert	11/1/1965	IR	250	GPM	465	155	39.0N 27.0E 03		1	WELL
G4-*03795CWRIS	2257	VAN POOL H L	Cert	10/29/1954	IR	200	GPM	80	20	39.0N 27.0E 04		1	WELL
G4-*09319CWRIS	6380	ALLEN M J	Cert	3/19/1968	IR	55	GPM	15	5	39.0N 27.0E 04	SW/SE	1	INFILTRATION TREN
G4-23023CWRIS		GREENE WILLIAM G	Cert	5/31/1974	DM	21	GPM	7		39.0N 27.0E 04	SW/SW	1	WELL
G4-28933GWRIS		LITTLEFIELD DOROTHY	Cert	5/14/1986	IR,DS	100	GPM	25.5	7	39.0N 27.0E 04	SE/SW	1	WELL
G4-*07672CWRIS	6112	THORNDIKE T A	Cert	7/1/1965	IR	175	GPM	96	24	39.0N 27.0E 05		1	WELL
G4-01201CWRIS		Oroville Cattle Co	Cert	9/11/1970	ST,IR	750	GPM	331	75	39.0N 27.0E 09		1	WELL
G3-+00829CWRIS		THORNDIKE R J & J P	Cert	3/29/1971	ST,IR	150	GPM	59.6	13	39.0N 27.0E 10	SE/SW	1	WELL
G4-*05865CWRIS	4678	THORNDIKE J J	Cert	3/9/1961	IR	200	GPM	80	20	39.0N 27.0E 10	SE/SW	1	WELL
G4-22828GWRIS		ALBRECHT WILLIAM B	Cert	4/2/1974	ST,IR	75	GPM	28.4	6	39.0N 27.0E 10		1	WELL
G4-27319GWRIS		GEMMELL FRANK N	Cert	11/6/1980	IR	30	GPM	30	10	40.0N 27.0E 20	SW/SE	1	WELL
G4-*00064BDSWRIS	32	Oroville City	Cert	11/1/1941	MU,CI	675	GPM	1095		40.0N 27.0E 21	SW/SE	1	well #4
G4-*04678CWRIS	2991	WILSON G H	Cert	9/10/1957	IR,DS	17	GPM	9.6	1	40.0N 27.0E 22		1	WELL
G4-28434CWRIS		Eastlake Water Association	Cert	4/18/1984	DM	12	GPM	11.5		40.0N 27.0E 22		1	Well 1
G3-+20596CWRIS		Oroville Association Growers	Cert	11/3/1972	DM,CI	140	GPM	17		40.0N 27.0E 27		1	WELL
G4-*09982CWRIS	6954	THORNDIKE D J	Cert	1/17/1969	IR	250	GPM	113	35	40.0N 27.0E 27		1	WELL
G4-23540CWRIS		HASKELL & BURNS	Cert	6/28/1974	HE	248	GPM	397		40.0N 27.0E 27	NW/SW	1	WELL
G4-26214CWRIS		GOLD DIGGER APPLES	Cert	4/18/1979	DM,CI	50	GPM	12.5		40.0N 27.0E 27	SW/SE	1	WELL
G4-28693CWRIS		PORTER STAN	Cert	5/17/1985	DM	30	GPM	4		40.0N 27.0E 27	NW/NW	1	WELL
G4-*03455CWRIS	1868	THORNDIKE D A & SONS	Cert	12/14/1953	HE	200	GPM	133		40.0N 27.0E 28		1	WELL
G4-23539CWRIS		HASKELL & BURNS	Cert	6/28/1974	HE	121	GPM	194		40.0N 27.0E 28	NE/SE	1	WELL
G4-27168ALCWRIS		Oroville City	Cert	11/14/1980	MU	1000	GPM	1095		40.0N 27.0E 28	NE/SW	2	WELL
G4-27169ALCWRIS		Oroville City	Cert	11/14/1980	MU,CI	600	GPM	968		40.0N 27.0E 28	NE/SW	2	well 1
G4-27211ALCWRIS		Oroville City	Cert	12/12/1980	MU,CI	500	GPM	807		40.0N 27.0E 28	NE/SW	2	WELL
G3-+00996CWRIS		REID JAMES B	Cert	8/6/1971	IR	106	GPM	61.9	13.5	40.0N 27.0E 33	SE/NE	1	WELL
G3-+00997CWRIS		REID JAMES B	Cert	8/6/1971	IR	40	GPM	18.5	4	40.0N 27.0E 33		1	WELL
G3-+20317CWRIS		MCDOUGALL ROY E	Cert	6/22/1972	IR	200	GPM	111	24	40.0N 27.0E 33		1	WELL
G4-*03949CWRIS	3015	CURTIS E H	Cert	3/31/1955	IR	350	GPM	240	60	40.0N 27.0E 33		1	2 wells
G4-23419CWRIS		NELSON TRUMAN	Cert	7/10/1974	DS	5	GPM	2		40.0N 27.0E 33		1	WELL
G4-26705GWRIS		HERNANDEZ ERNEST	Cert	4/23/1980	IR,DS	105	GPM	50	15	40.0N 27.0E 33	NW/SE	1	WELL
G3-+00827AACWRIS		PETRY MERWIN E	Cert	11/30/1971	ST,IR	51	GPM	17.3	3.7	40.0N 27.0E 34	NW/NW	1	WELL
G3-+00827BACWRIS		JACKSON ALFRED G	Cert	11/30/1971	ST,IR	158	GPM	61	13.8	40.0N 27.0E 34	NW/NW	1	WELL
G3-+00827CACWRIS		KEENY OLIVER A	Cert	11/30/1971	ST,IR	11	GPM	3.2	0.5	40.0N 27.0E 34	NW/NW	1	WELL
G4-*03491CWRIS	2263	MOONEY G	Cert	1/25/1954	IR	520	GPM	208	52	40.0N 27.0E 34	NW/SW	1	WELL
G4-*03572CWRIS	1895	ENOUF E	Cert	4/8/1954	IR	70	GPM	28	7	40.0N 27.0E 34		1	WELL
G4-*04016CWRIS	2465	HARDENBURGH J T	Cert	5/25/1955	IR,DS	250	GPM	105.6	25	40.0N 27.0E 34		1	WELL
G4-CV2P824		ROGERS GEORGE J.	CertChg	1/1/1930	IR	125	GPM	82	13	40.0N 27.0E 28		1	
G4-CV1-4P197		BEITZ VERNETTE	CertChg	2/10/1977	IR	100	GPM	75	15	40.0N 27.0E 34		1	
CG4-03015C	3015	Georgia Laine Developments LTD	Chng/ROE	10/24/2007	MU	100	GPM	80		40.0N 27.0E 28	NE/SW	6	well 1
G4-29679		Nelson Stanley	Pmt	3/15/1988	IR,FP	300	GPM	11	9	39.0N 27.0E 04		1	WELL
G4-28903		Hansen Scott	Pmt	4/2/1986	IR	750	GPM	350	100	39.0N 27.0E 09		1	WELL
G4-35014		Oroville School District	Short Term	4/29/2005	HE		GPM			40.0N 27.0E 28	SW/SE	1	

Table 2.3.1 - Summary of Existing Groundwater Rights - Oroville Area

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

New Applications and Change Applications

File #	Cert #	Person	Doc	Priority Dt	Purpose	Qi	UOM	Qa	Ir Acres	TRS	QQ/Q	Src's	1stSrc
CG4-28434C		Eastlake Water Association	ChgApp	7/17/1998	DM	12	GPM	11.5		40.0N 27.0E 22		2	Well 1
G4-28656		Oroville City	NewApp	4/1/1985	MU	300	GPM			40.0N 27.0E 21		1	WELL
G4-29150		Oroville City	NewApp	11/7/1986	SR,RW	1000	GPM			40.0N 27.0E 21		1	WELL
G4-32389		Chelan Cnty PUD 1	NewApp	12/13/1995	FS	250	GPM			40.0N 27.0E 33		1	WELL
G4-32390		Chelan Cnty PUD 1	NewApp	12/13/1995	FS	450	GPM			40.0N 27.0E 33		1	WELL

Notes:

Compiled by the Department of Ecology (12/14/09).

Qa in acre-feet.

Table 2.3.2 - Summary of Existing Surface Water Rights - Oroville Area

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Certificates and Permits

File #	Cert #	Person	Doc	Priority Dt	Purpose	Qi	UOM	Qa	Ir Acres	TRS	QQ/Q	Src's	1stSrc
S4-*13314CWRIS	6242	HOMAN R E	Cert	2/28/1955	IR,DS	0.05	CFS		3	39.0N 27.0E 04		1	SIMILKAMEEN RIVER
S4-*20858CWRIS	10654	IMHOFF A C	Cert	4/2/1968	IR	0.45	CFS	27	9	39.0N 27.0E 04		1	UNNAMED POND
S4-*06675CWRIS	8002	DOYLE A F	Cert	9/18/1945	IR	0.54	CFS	140	35	39.0N 27.0E 09	SE/NE	1	OKANOGAN RIVER
S3-+22053GWRIS		DEVON DALE LOUIS	Cert	11/9/1973	ST,IR	1.5	CFS	372	80	40.0N 26.0E 13		1	SIMILKAMEEN RIVER
S4-*19571CWRIS	9834	KERNAN FARMS	Cert	4/5/1966	IR	1.4	CFS	280	70	40.0N 27.0E 20		1	SIMILKAMEEN RIVER
S4-01154CWRIS		WA PARKS	Cert	10/5/1965	IR	0.36	CFS	33.24	8.31	40.0N 27.0E 21		1	OKANOGAN RIVER
S4-23420CWRIS		BALMES GLENEVA	Cert	7/8/1974	IR	0.25	CFS	69	15	40.0N 27.0E 21	NW/NW	1	OSOYOOS LAKE
S4-23447CWRIS		PRINCE JAMES H	Cert	8/20/1974	DS	0.016	CFS	1	0.67	40.0N 27.0E 21	NW/NE	1	OSOYOOS LAKE
S4-*03459CWRIS	1405	BARLAS N G	Cert	7/21/1931	IR	0.32	CFS		16	40.0N 27.0E 22		1	OSOYOOS LAKE
S4-*07375CWRIS	2659	IRWIN D T	Cert	8/9/1946	IR	0.08	CFS		4	40.0N 27.0E 22	SW/NE	1	UNNAMED POND
R4-*01931CWRIS	5566	ZOSEL W	Cert	11/18/1926	CI		CFS	126		40.0N 27.0E 27	SE/SW	1	OKANOGAN RIVER
R4-28809C(A)		WA ECY	Cert	10/7/1985	SR	0	CFS	22900	0	40.0N 27.0E 27	E2/SW	1	OKANOGAN RIVER
R4-28809C(B)		Oroville Tonasket Irrigation District*	Cert	10/7/1985	IR	0	CFS	5700	0	40.0N 27.0E 27	E2/SW	1	OKANOGAN RIVER
S4-*18856CWRIS	9452	WA DFW	Cert	1/27/1965	FS	24	CFS			40.0N 27.0E 27		1	OKANOGAN RIVER
S3-+22723CWRIS		WILDER DALHART D	Cert	3/5/1974	IR	0.03	CFS	5.3	1.35	40.0N 27.0E 28		1	OKANOGAN RIVER
S4-*08181CWRIS	3557	CHAMBERLIN H W	Cert	1/14/1948	IR	0.05	CFS		7.5	40.0N 27.0E 28		1	SIMILKAMEEN RIVER
S4-*02914CWRIS	723	BROWN M C	Cert	4/3/1930	IR	0.5	CFS		12	40.0N 27.0E 33	SE/NW	1	SIMILKAMEEN RIVER
S4-*14818CWRIS	7497	VANDIVER G L	Cert	5/21/1958	IR	0.06	CFS	12	3	40.0N 27.0E 34		1	OKANOGAN RIVER
S4-*15374CWRIS	7651	BARLAS E	Cert	4/3/1959	IR,DS	0.03	CFS	4	1	40.0N 27.0E 34		1	OKANOGAN RIVER
S4-CV1P243		Okanogan Cnty PUD 1*	CertChg	3/1/1912	PO	1000	CFS			40.0N 26.0E 13		1	SIMILKAMEEN RIVER
CS4-ADJ01P2		Oroville Tonasket Irrigation District	Chng/ROE	3/12/2001	IR	0.6	CFS	150	30	40.0N 26.0E 13	SW/NE	1	SIMILKAMEEN RIVER
CS4-SWC10694		Oroville Tonasket Irrigation District	Chng/ROE	3/19/1979	IR	30	CFS		1600	40.0N 27.0E 27		7	OKANOGAN RIVER
S4-27411		Stucker Elizabeth	Pmt	4/8/1981	DS	0.02	CFS	2		39.0N 27.0E 05		1	UNNAMED SPRING
S4-31519		DeVon Dale	Pmt	10/30/1992	ST	0.02	CFS	1.3		40.0N 27.0E 20		1	SIMILKAMEEN RIVER
S4-29889		Chelan Cnty PUD 1	Pmt	1/5/1989	FS	21.4	CFS	10250		40.0N 27.0E 33		1	SIMILKAMEEN RIVER

Notes:

Compiled by the Department of Ecology (12/14/09).

Table 2.3.3 - Summary of Existing Groundwater Rights - Riverside Area

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Certificates and Permits

File #	Cert #	Person	Doc	Priority Dt	Purpose	Qi	UOM	Qa	Ir Acres	TRS	QQ/Q	Src's	1stSrc
G4-24490CWRIS		Zaser & Longston Inc**	Cert	1/3/1977	IR	1000	GPM	638	125	35.0N 27.0E 05	SE/NE	1	WELL
G4-*01714CWRIS	961	SACKMAN R	Cert	10/26/1950	IR	360	GPM	148	37	35.0N 27.0E 07		1	WELL
G4-23600CWRIS		VOELCKERS CARL E	Cert	7/1/1974	IR	335	GPM	131.5	32.5	35.0N 27.0E 07		1	WELL
G4-22747CWRIS		DIXON EDWIN W	Cert	3/8/1974	IR	300	GPM	139.25	30	35.0N 27.0E 08		1	WELL
G4-24381GWRIS		Zaser & Longston Inc**	Cert	8/11/1976	IR,DM	300	GPM	216	20	36.0N 27.0E 32		1	orig well

New Applications and Change Applications

File #	Cert #	Person	Doc	Priority Dt	Purpose	Qi	UOM	Qa	Ir Acres	TRS	QQ/Q	Src's	1stSrc
CG4-24490C@1		Zaser & Longston Inc**	ChgApp	4/20/2006	IR	1000	GPM	638	125	35.0N 27.0E 05	SE/NE	2	WELL
CG4-24381C@1		Keystone Fruit Co LLC	ChgApp	5/20/2009	IFlow	0	GPM	127		36.0N 27.0E 32		1	orig well
G4-32445		Brauns-Wick Jan	NewApp	4/30/1996	ST,IR	220	GPM		20	36.0N 27.0E 33		2	WELL

Table 2.3.4 - Summary of Existing Surface Water Rights - Riverside Area

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Certificates and Permits

File #	Cert #	Person	Doc	Priority Dt	Purpose	Qi	UOM	Qa	Ir Acres	TRS	QQ/Q	Src's	1stSrc
S4-*08332CWRIS	4323	PETERSON C C / M E	Cert	3/27/1948	IR	0.12	CFS		8	35.0N 27.0E 06		1	OKANOGAN RIVER
S4-*14487ALCWRIS	07827A	SACKMAN R F	Cert	9/6/1957	IR	2	CFS	412	103	35.0N 27.0E 06		2	OKANOGAN RIVER
S4-*08331CWRIS	4324	PETERSON C C / M E	Cert	3/27/1948	IR	0.33	CFS		24.5	35.0N 27.0E 07		1	OKANOGAN RIVER
S4-*21133CWRIS	11749	CROFOOT K D	Cert	8/2/1968	IR	0.94	CFS	141	47	35.0N 27.0E 07		1	OKANOGAN RIVER
S4-10416(A)	10416(A)	Long Kenneth	Cert	1/22/1965	IR	0.98	CFS	196	49	35.0N 27.0E 07		1	OKANOGAN RIVER
S4-10416(B)	10416(B)	Long Kenneth R & Meredith K	Cert	1/22/1965	IR	0.68	CFS	136	34	35.0N 27.0E 07		2	OKANOGAN RIVER
S4-10416(C)	10416(C)	Blue James C & Marilyn K	Cert	1/22/1965	IR	0.64	CFS	128	32	35.0N 27.0E 07		2	OKANOGAN RIVER
S4-10416(D)	10416(D)	Jeffries Richard & Larraine	Cert	1/22/1965	IR	0.696	CFS	139.2	34.8	35.0N 27.0E 07		1	OKANOGAN RIVER
S4-*08218CWRIS	3492	BRAATEN I J	Cert	2/9/1948	IR	0.16	CFS		8	35.0N 27.0E 08		1	OKANOGAN RIVER
S4-*19166CWRIS	9580	PIERCE W S	Cert	7/29/1965	IR	0.56	CFS	112	28	35.0N 27.0E 08		1	OKANOGAN RIVER
S4-*01749CWRIS	380	WEIST H N	Cert	6/9/1926	IR	1.5	CFS		60	36.0N 27.0E 32		1	OKANOGAN RIVER
CS4-ADJ01VOL1P2		Oroville Tonasket Irrigation District*	Chng/ROE	3/19/1979	IR		CFS					6	OKANOGAN RIVER
CS4-SWC10379		Oroville Tonasket Irrigation District*	Chng/ROE	3/19/1979	IR	150	CFS		8000			6	OKANOGAN RIVER
S4-28272		Keystone Fruit Co LLC	Pmt	8/5/1983	IR,FP	2.33	CFS	138.56	30	35.0N 27.0E 05		1	OKANOGAN RIVER
S4-28273		Keystone Fruit Co LLC	Pmt	8/5/1983	FP	9.72	CFS	77.3		35.0N 27.0E 05	SW/NE	1	OKANOGAN RIVER
S4-26554		Keystone Fruit Co LLC	Pmt	2/14/1980	IR,FP	2.5	CFS	160	25	36.0N 27.0E 32		1	OKANOGAN RIVER
S4-26567		Keystone Fruit Co LLC	Pmt	2/26/1980	IR,FP	6	CFS	230	46	36.0N 27.0E 32		2	OKANOGAN RIVER

New Applications and Change Applications

File #	Cert #	Person	Doc	Priority Dt	Purpose	Qi	UOM	Qa	Ir Acres	TRS	QQ/Q	Src's	1stSrc
CS4-28272		Keystone Fruit Co LLC	ChgApp	3/18/1993	IR,FP	2.33	CFS	138.56		35.0N 27.0E 05	SW/NE	2	OKANOGAN RIVER
CS4-28273		Keystone Fruit Co LLC	ChgApp	2/8/2006	FP	9.72	CFS	77.3		35.0N 27.0E 05	SE/NE	2	
CS4-SWC11749	11749	Keystone Fruit Co LLC	ChgApp	7/22/1992	IR	0.94	CFS	141	47	35.0N 27.0E 05		3	OKANOGAN RIVER
CS4-26554@1		Keystone Fruit Co LLC	ChgApp	11/13/1995	IR,FP	2.5	CFS	160	35	35.0N 27.0E 07		2	OKANOGAN RIVER
CS4-SWC10416(A)	10416(A)	Long Kenneth	ChgApp	7/28/1994	IR	0.266	CFS	56.8	14.2	35.0N 27.0E 07		4	OKANOGAN RIVER
CS4-SWC10416(D)	10416(D)	Jeffries Richard & Larraine	ChgApp	7/28/1994	IR	0.696	CFS	139.2	34.8	35.0N 27.0E 07		4	OKANOGAN RIVER
CS4-SWC10416@3	10416	Long Kenneth	ChgApp	7/2/2001	IR	2.3	CFS	460	115	35.0N 27.0E 07		1	WELL
CS4-26567		Keystone Fruit Co LLC	ChgApp	5/18/1993	IR,FP	6	CFS	230		36.0N 27.0E 32		2	OKANOGAN RIVER
CS4-SWC380		Keystone Fruit Co LLC	ChgApp	4/27/1987	IR		CFS			36.0N 27.0E 32		2	OKANOGAN RIVER
S4-29310		Keystone Fruit Co LLC	NewApp	6/15/1987	IR	2.16	CFS	67.47	97	36.0N 27.0E 32		2	OKANOGAN RIVER
S4-32470		Keystone Fruit Co LLC	NewApp	8/26/1996	IR	0.45	CFS		21	36.0N 27.0E 32		1	OKANOGAN RIVER

Table 5.1.1 - Alternatives Ranking Matrix

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

	Meet Project Objectives	Physical Water Availability + Uncertainties	Engineering Feasibility + Uncertainties	Land Ownership	Permitting	Water Rights	Readiness to Proceed	Capital Cost	Operations and Maintenance Costs	Potential for Negative Public Comment	**Total Score**
Alternative 1 (A)	10	20	5	5	10	15	5	1	10	0	**81**
Alternative 1 (B)	7.5	10	5	5	5	10	5	11	0	5	**63.5**
Alternative 1 (C)	10	20	5	0	5	15	5	0	7.5	0	**67.5**
Alternative 2	15	15	5	5	15	10	10	12	5	5	**97**
Alternative 3 (A)	10	20	5	5	10	15	5	1	10	0	**81**
Alternative 3 (B)	10	10	5	5	5	10	0	11	0	5	**61**
Alternative 3 (C)	10	20	5	0	5	15	5	0	7.5	0	**67.5**
Alternative 4	20	20	10	5	15	10	10	12	5	5	**112**
Alternative 5	20	20	7.5	5	10	15	10	10	5	5	**107.5**
Maximum Score	***20***	***20***	***10***	***10***	***15***	***15***	***10***	***15***	***10***	***5***	***130***

Alternatives

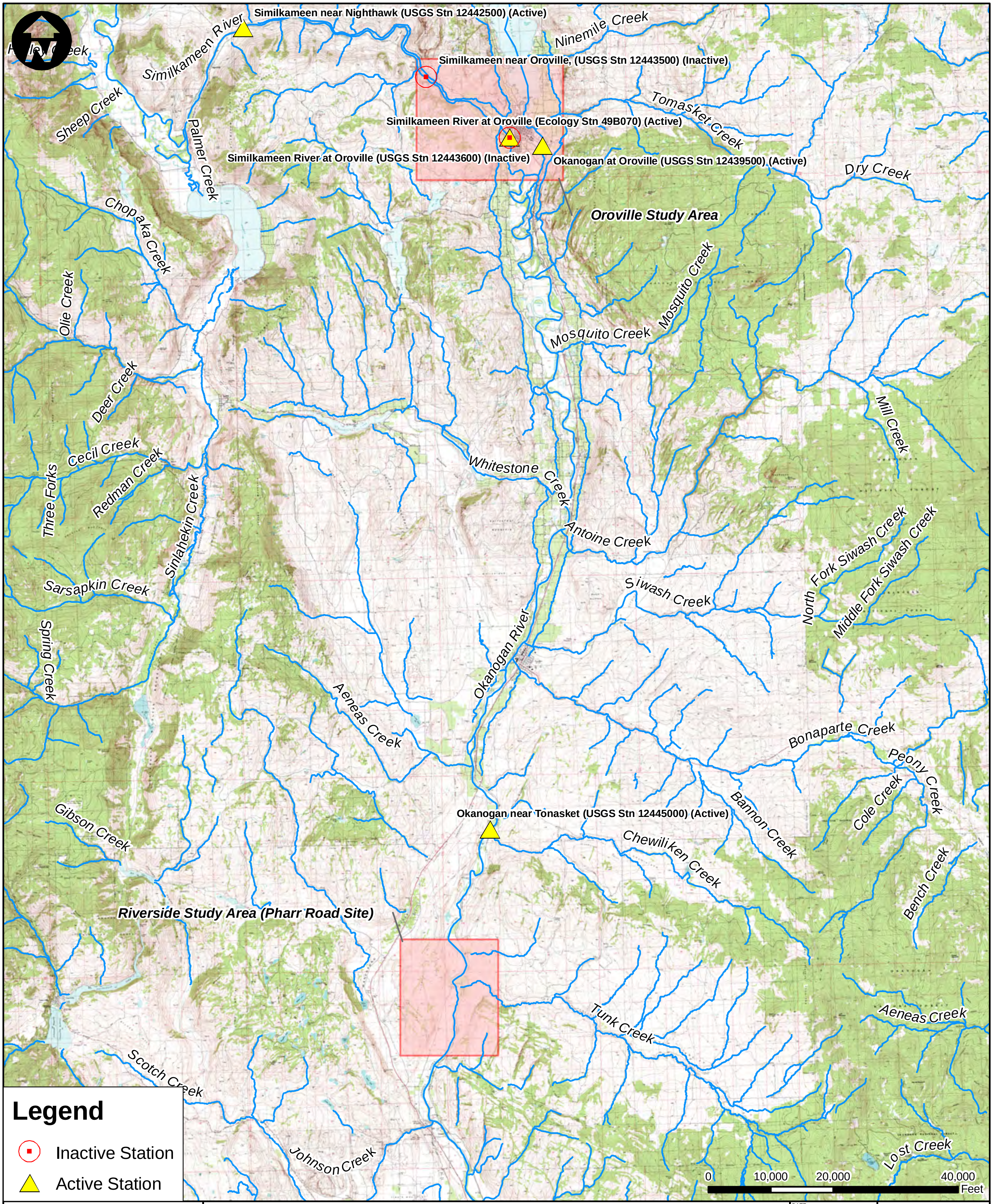
Alternative 1 (A)	Westside Artificial Recharge: Use OTID water; natural discharge; capture bank seepage and gravity convey to point discharge
Alternative 1 (B)	Westside Artificial Recharge: New water source; discharge to engineered channel
Alternative 1 (C)	Westside Artificial Recharge: Blended Alternatives 1(A) and 1(B)
Alternative 2	Westside Well Discharge
Alternative 3 (A)	Eastside Artificial Recharge: Use OTID water; natural discharge
Alternative 3 (B)	Eastside Artificial Recharge: New water source; discharge to engineered channel
Alternative 3 (C)	Eastside Artificial Recharge: Blended Alternatives 4(A) and 4(B)
Alternative 4	Eastside Well Discharge
Alternative 5	Pharr Road Well Discharge

Table 5.1.2 - Cost Estimates for Project Alternatives

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Project Alternative	Item	Cost	Comments
Alternatives 1A, 3A	Pre-Design and Feasibility	$ 130,500	Considerable hydrogeologic analysis
	Engineering Design	$ 40,000	Less infrastructure design required
	Permitting and Agency Coordination	$ 83,000	
	Real Estate (purchase site; obtain OTID shares)	$ 2,000,000	Assumes purchase orchard lands to acquire OTID shares
	Construction	$ 38,525	Assuming minor OTID conveyance improvements required
	Total	***$ 2,292,025***	
Alternatives 1B, 3B	Pre-Design and Feasibility	$ 130,500	Considerable engineering analysis; less hydrogeologic
	Engineering Design	$ 47,500	Assumes simple pump station/conveyance design
	Permitting and Agency Coordination	$ 83,000	
	Real Estate (purchase site and right-of-way)	$ 100,000	
	Construction	$ 337,775	Infiltration basin, engineered channel, pump station and conveyance
	Total	***$ 698,775***	
Alternatives 1C, 3C	Pre-Design and Feasibility	$ 130,500	Considerable engineering analysis; less hydrogeologic
	Engineering Design	$ 47,500	Less infrastructure design required
	Permitting and Agency Coordination	$ 83,000	
	Real Estate (purchase site and right-of-way)	$ 2,000,000	Assumes purchase orchard lands to acquire OTID shares
	Construction	$ 137,457	No pump station; most costs for engineered channel
	Total	***$ 2,398,457***	
Alternatives 2, 4	Pre-Design and Feasibility	$ 80,000	Includes well construction (use test well for production)
	Engineering Design	$ 51,500	
	Permitting and Agency Coordination	$ 38,000	
	Real Estate (purchase site and right-of-way)	$ 25,000	Assumes source well near discharge location
	Construction	$ 285,663	Engineered channel, well house and conveyance
	Total	***$ 480,163***	
Alternative 5	Pre-Design and Feasibility	$ 85,000	Includes well construction (if required)
	Engineering Design	$ 47,000	
	Permitting and Agency Coordination	$ 45,000	
	Real Estate (assume site owned by Colville Tribes)	-	Cost for property not factored
	Construction	$ 685,958	Large engineered channel, well improvements, conveyance
	Total	***$ 862,958***	

Construction costs are feasibility level developed for the purposes of screening alternatives.



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Project and Regional Stream Gage Locations

Coldwater Refugia Feasibility Study
Okanogan Basin, WA

DATE: May 2010	PROJECT NO. 090041
DESIGNED BY: WMS	
DRAWN BY: MS	FIGURE NO. 2.1.1
REVISED BY: -	

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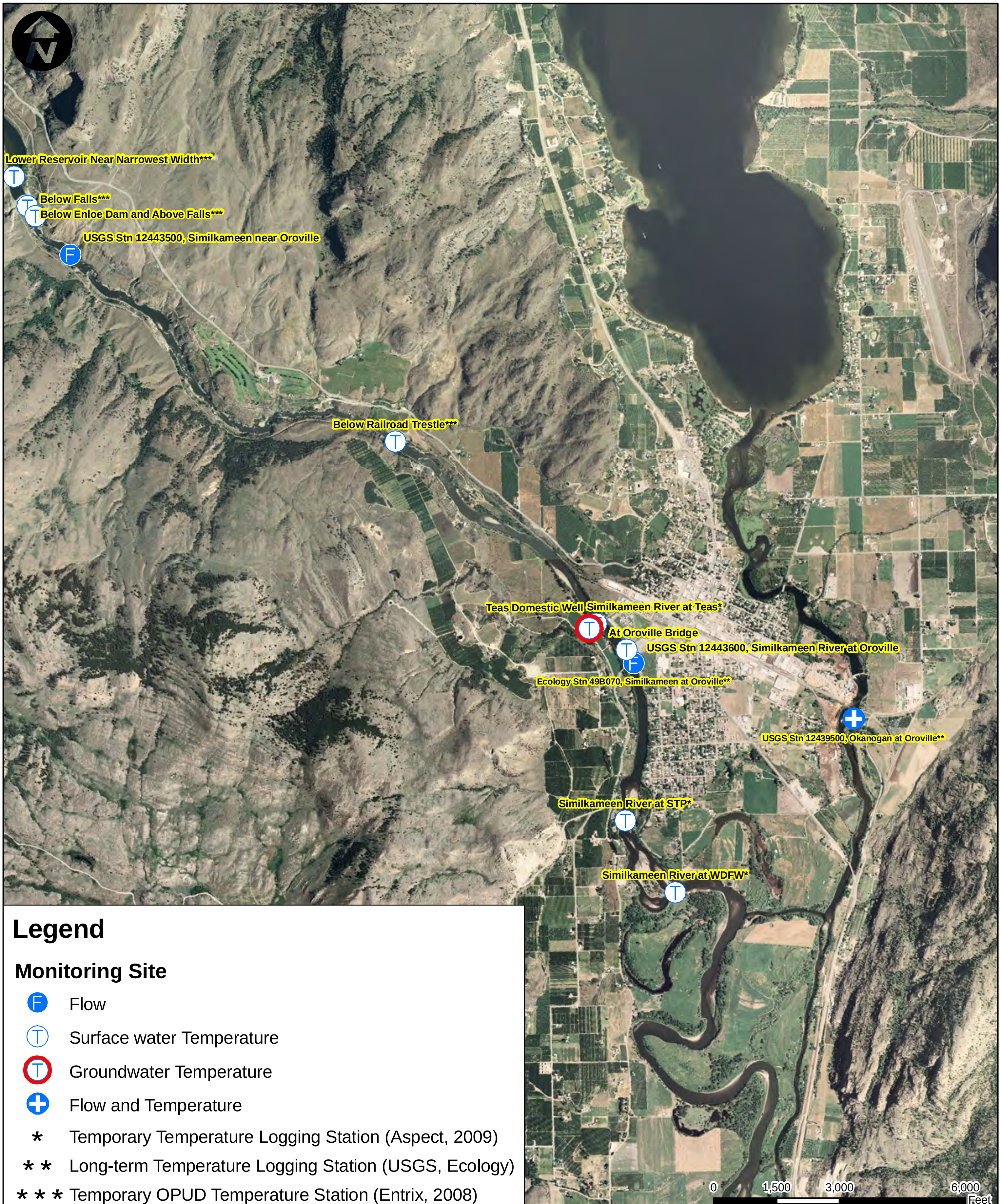

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Stream Gaging and Temperature Stations
Oroville Area

Coldwater Refugia Feasibility Study
Okanogan Basin, WA

DATE: May 2010	PROJECT NO. 090041
DESIGNED BY: WMS	
DRAWN BY: MS	FIGURE NO. 2.1.2
REVISED BY: -	

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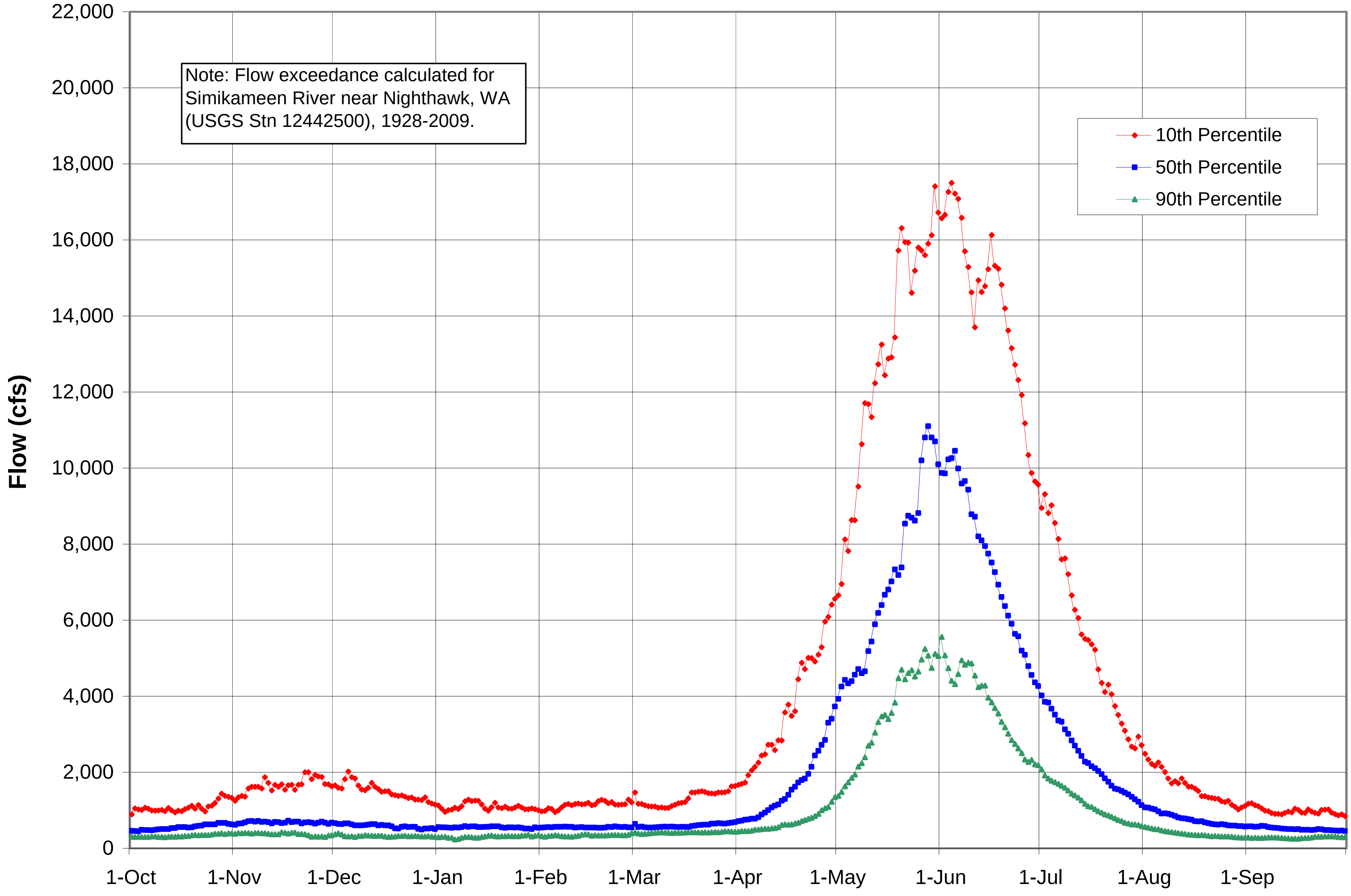

Figure 2.1.3

Flow Exceedance Graph,

Similkameen River near Nighthawk

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Aspect Consulting

5/11/2010

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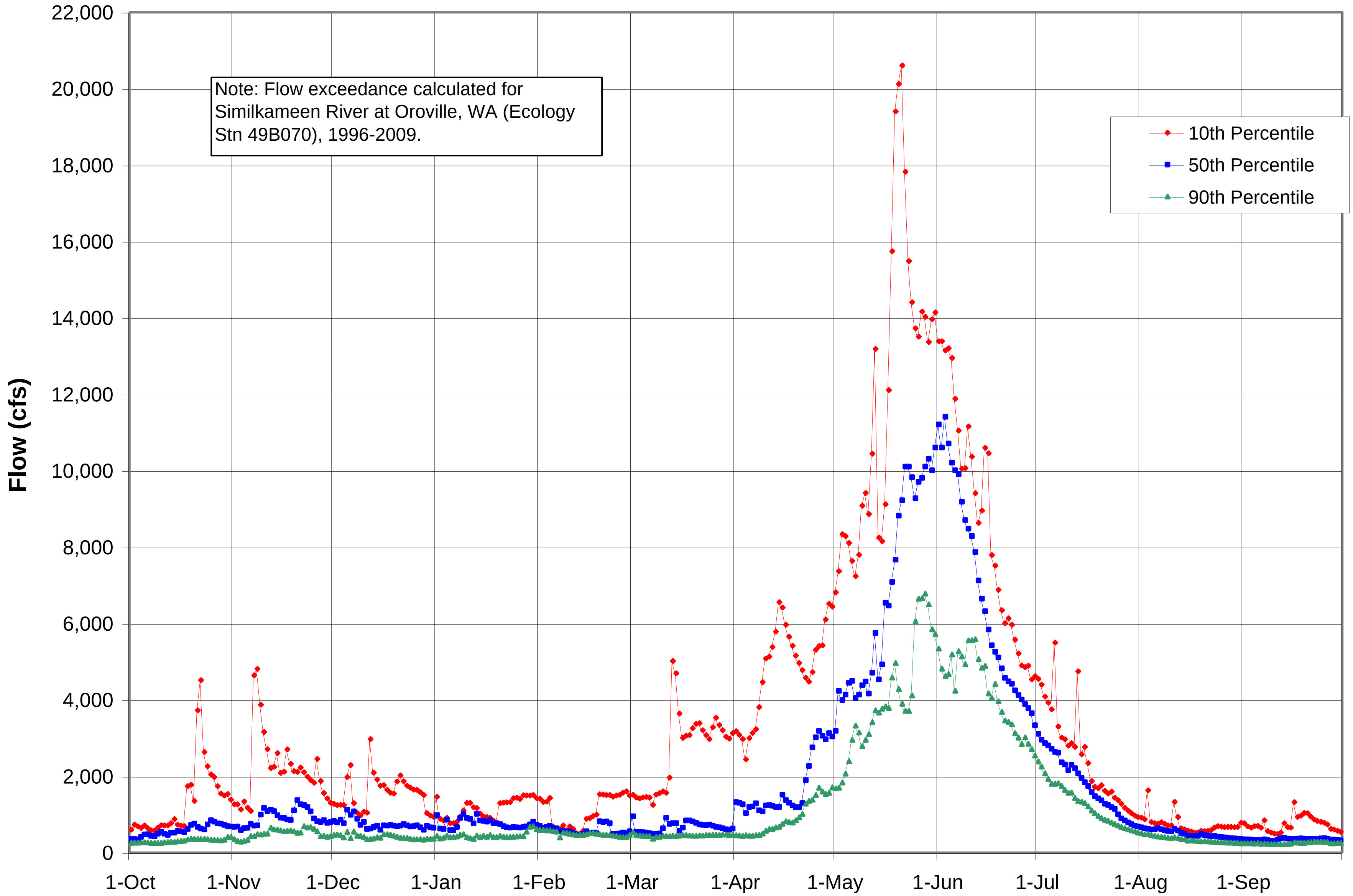

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W:\090041 CT Artificial Recharge Feasibility Study\Deliverables\Feasibility Report\Final\FlowData - Plot(SimOroEco)

Figure 2.1.4
Flow Exceedance Graph, Similkameen River at Oroville
Coldwater Refugia Feasibility Study, Okanogan Basin, WA

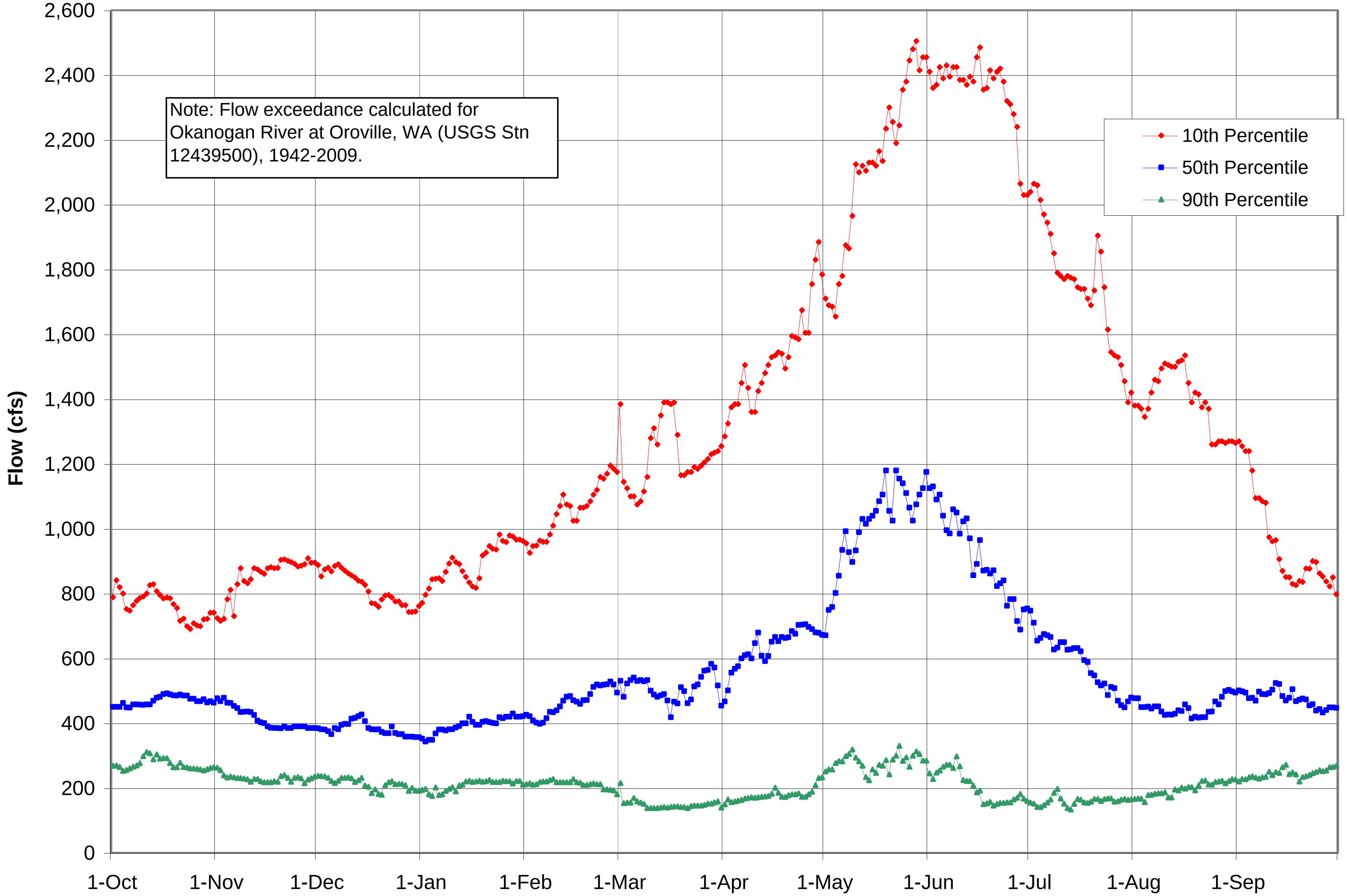

Figure 2.1.5
Flow Exceedance Graph, Okanogan River at Oroville
Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Aspect Consulting
5/11/2010
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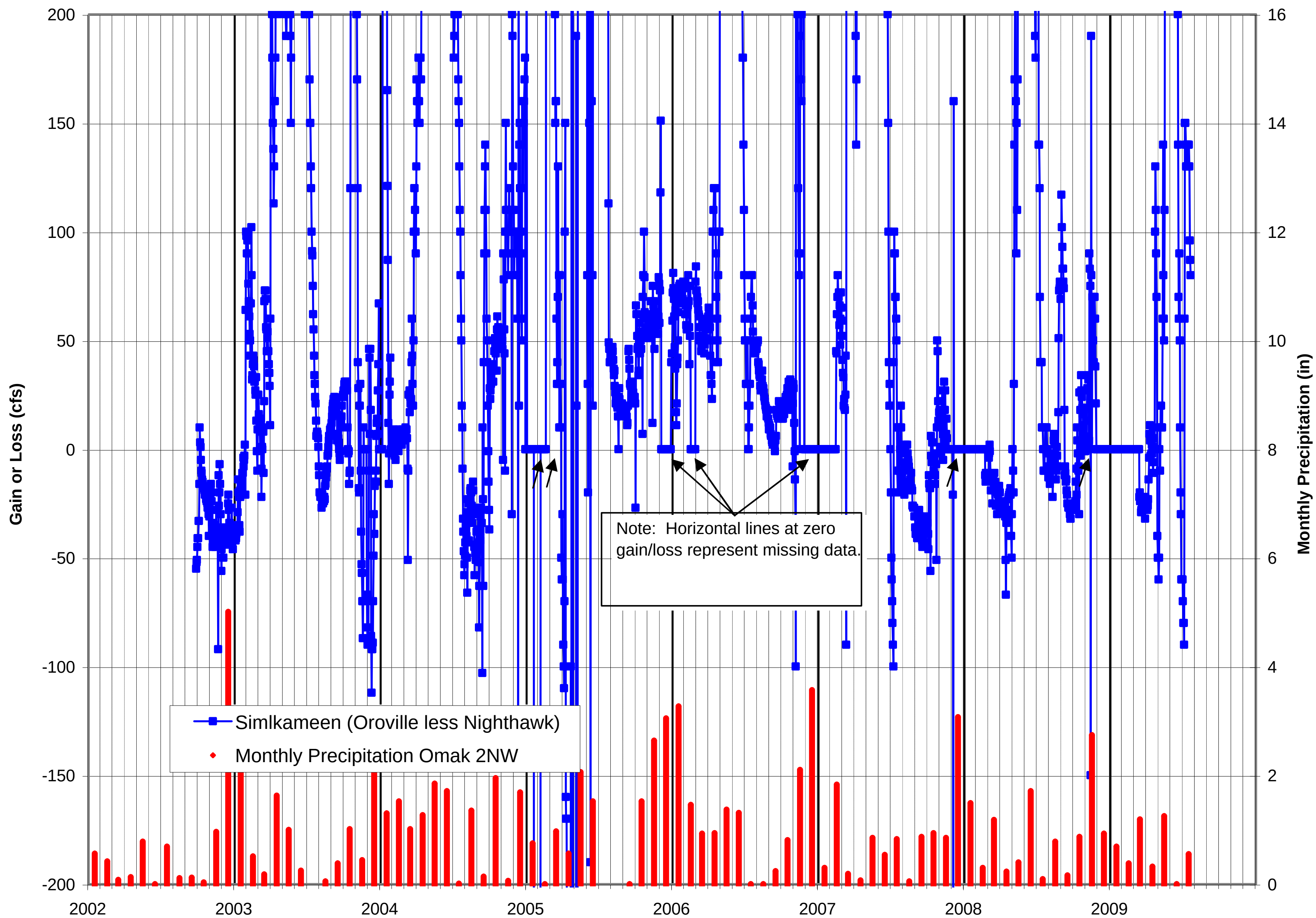

Figure 2.1.6
Similkameen River Gain or Loss from Nighthawk to Oroville
Coldwater Refugia Feasibility Study, Okanogan Basin, WA

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W:\090041 CT Artificial Recharge Feasibility Study\Deliverables\Feasibility Report\Final\FlowData - Fig 2.1.6 GainLossPlot2

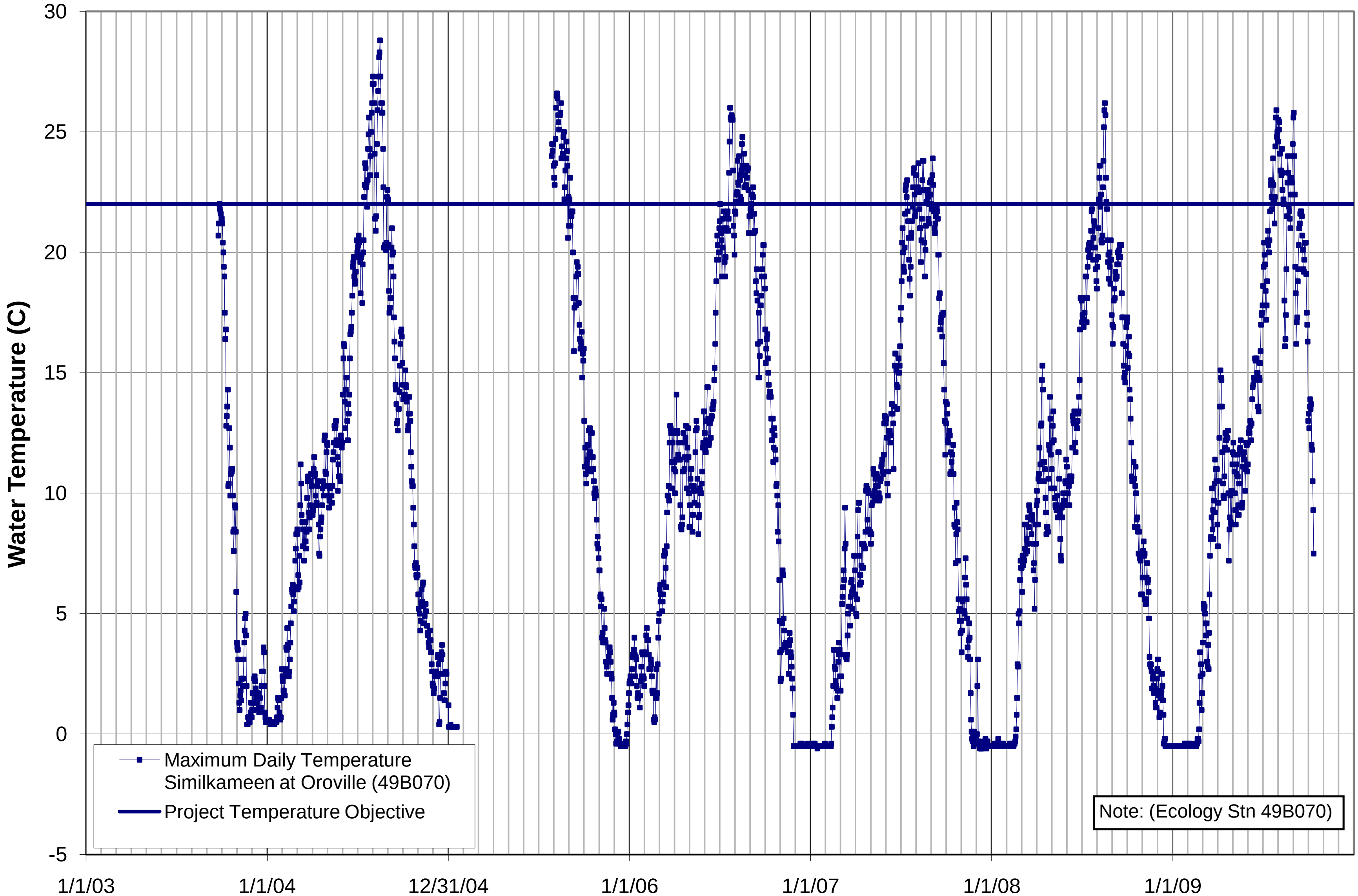

Figure 2.1.7
Maximum Daily Temperature for Similkameen River at Oroville
Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Aspect Consulting
5/11/2010
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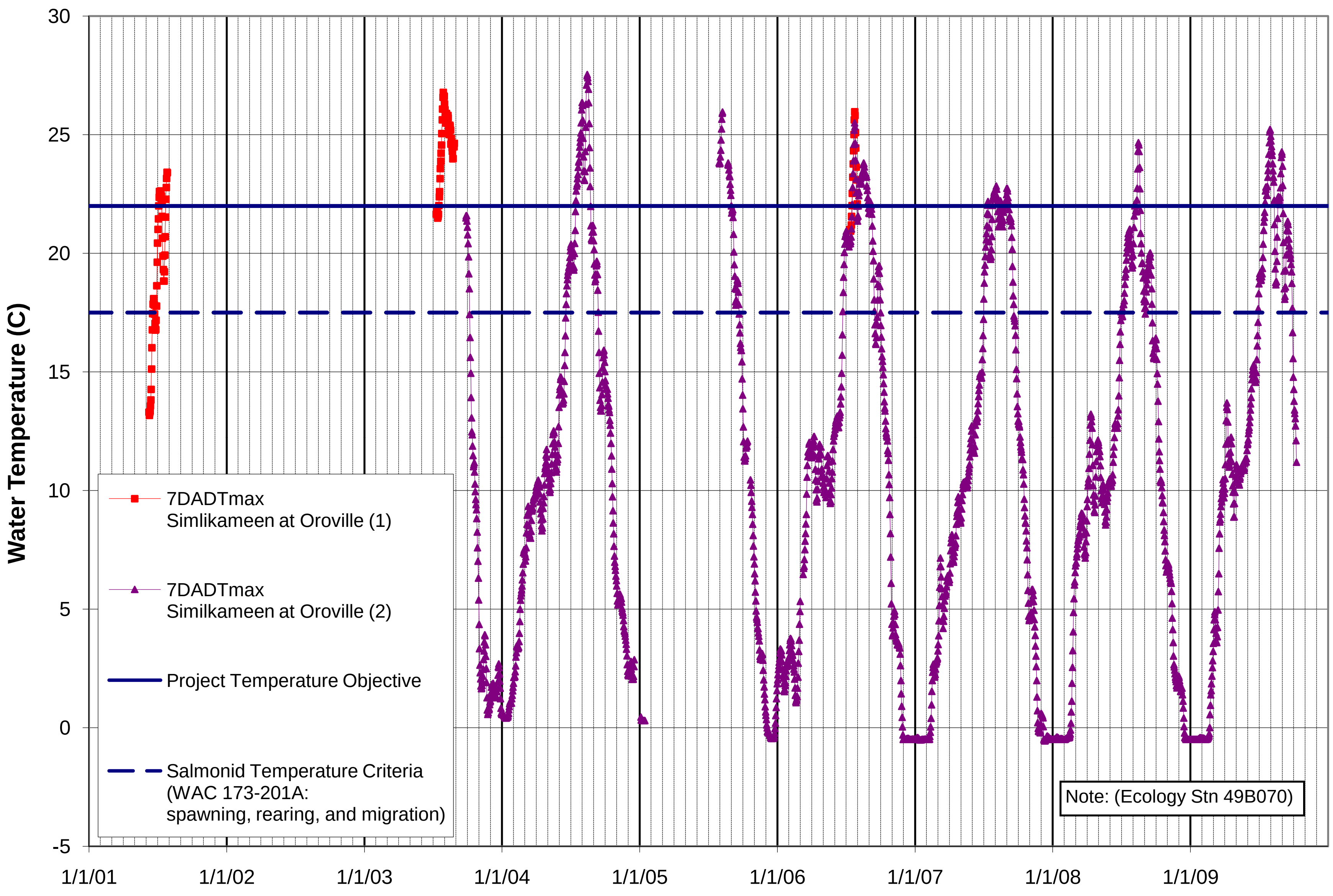

Figure 2.1.8
7DAD Maximum Temperature for
Similkameen River at Oroville
Coldwater Refugia Feasibility Study, Okanogan Basin, WA

Aspect Consulting
5/11/2010
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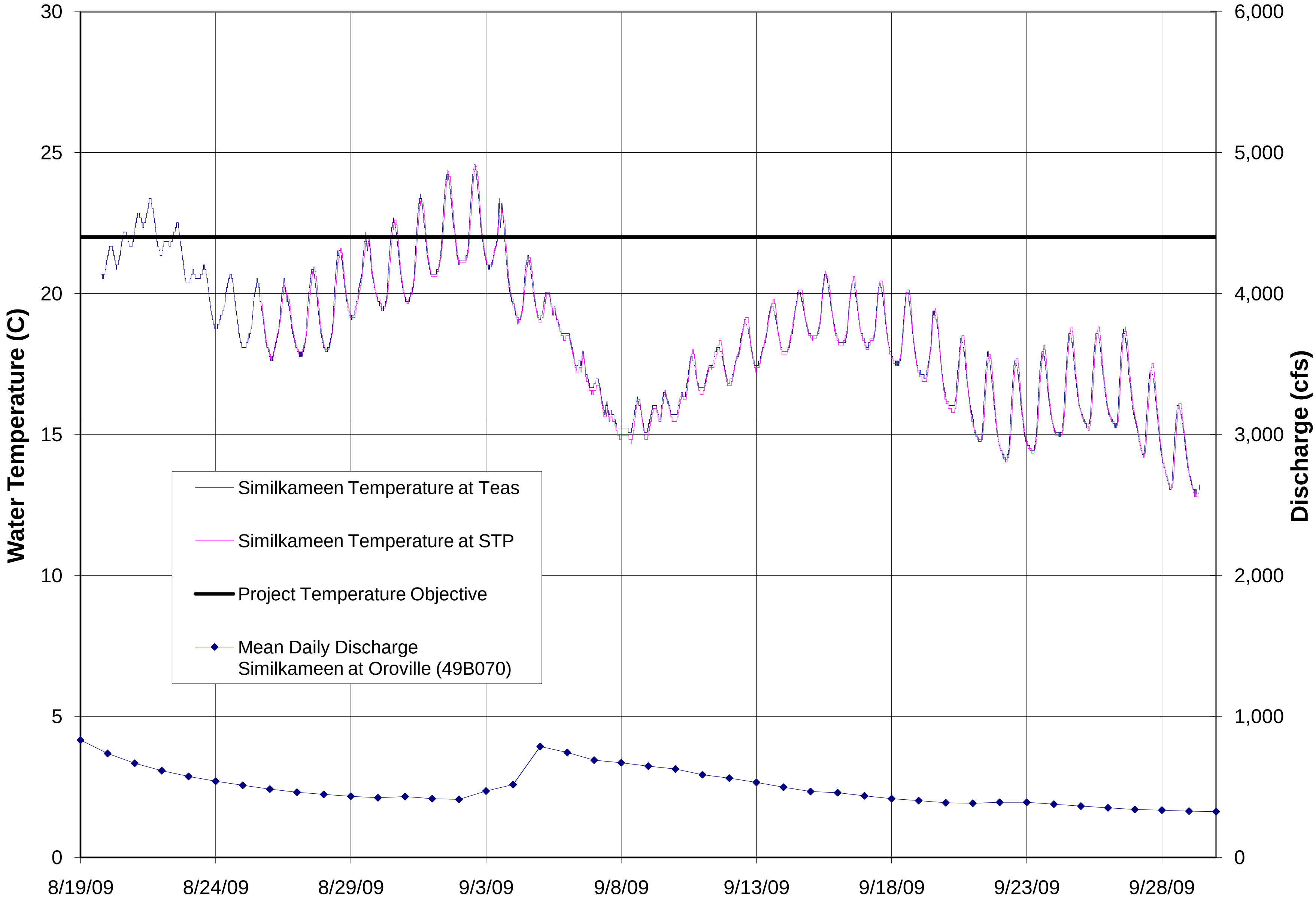

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W:\090041 CT Artificial Recharge Feasibility Study\Deliverables\Feasibility Report\Final\Tidbit Temp Plots.xls - TdbtTPlt1

Figure 2.1.9
Continuous Temperature for Similkameen River
Coldwater Refugia Feasibility Study, Okanogan Basin, WA

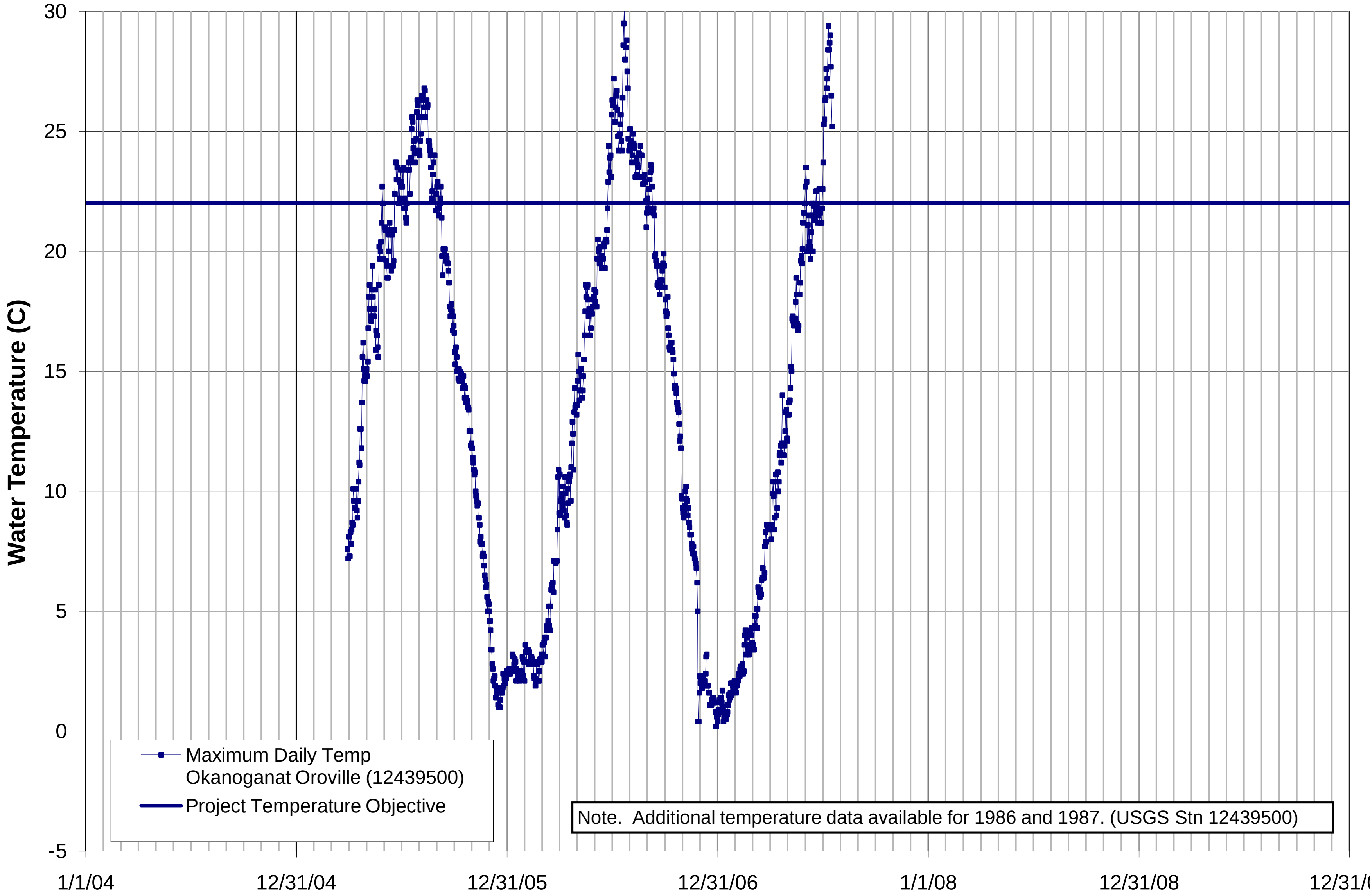

Figure 2.1.10

Maximum Daily Temperature for Okanogan River at Oroville

Coldwater Refugia Feasibility Study, Okanogan Basin, WA

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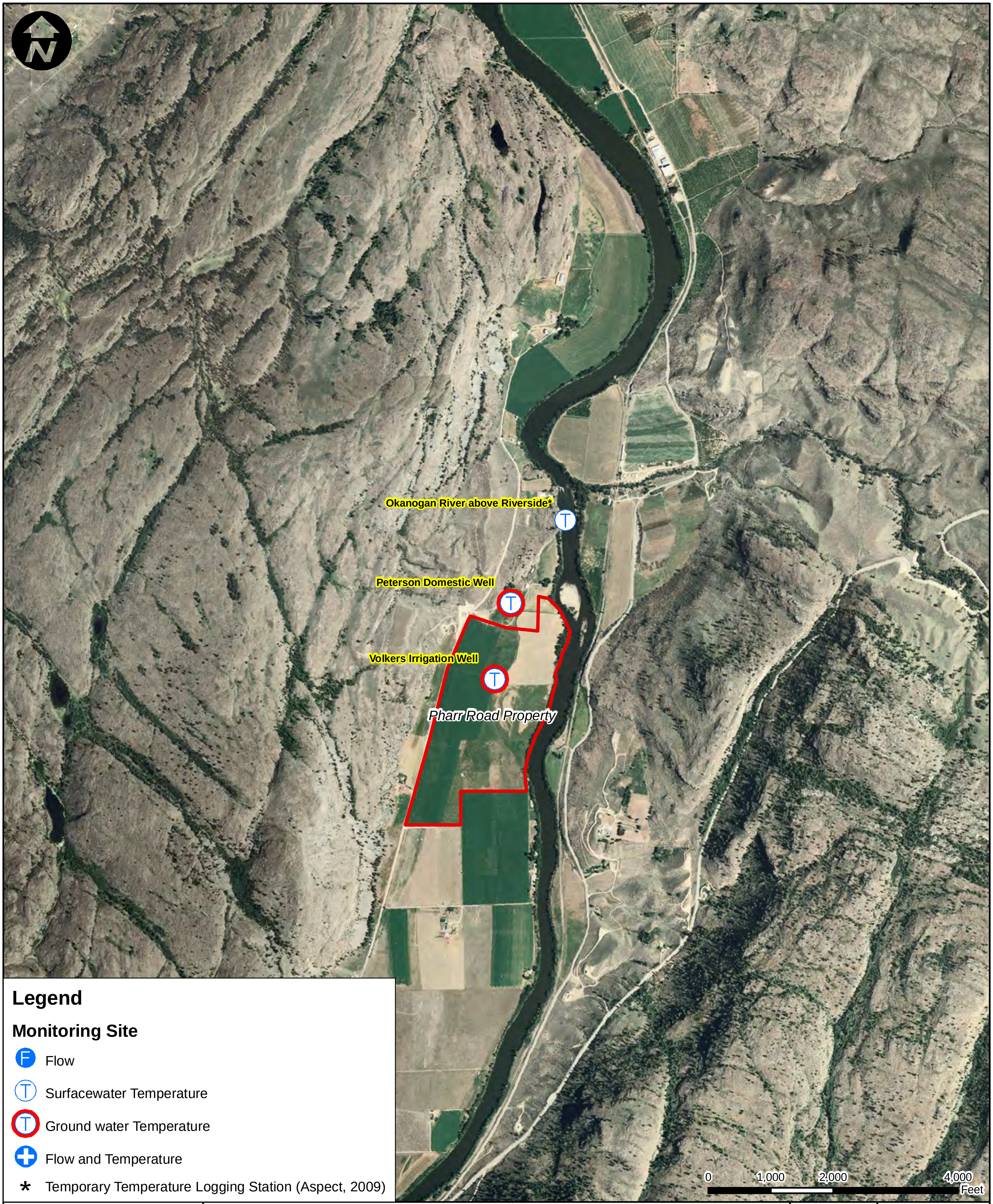

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Temperature Stations Riverside Area

Coldwater Refugia Feasibility Study
Okanogan Basin, WA

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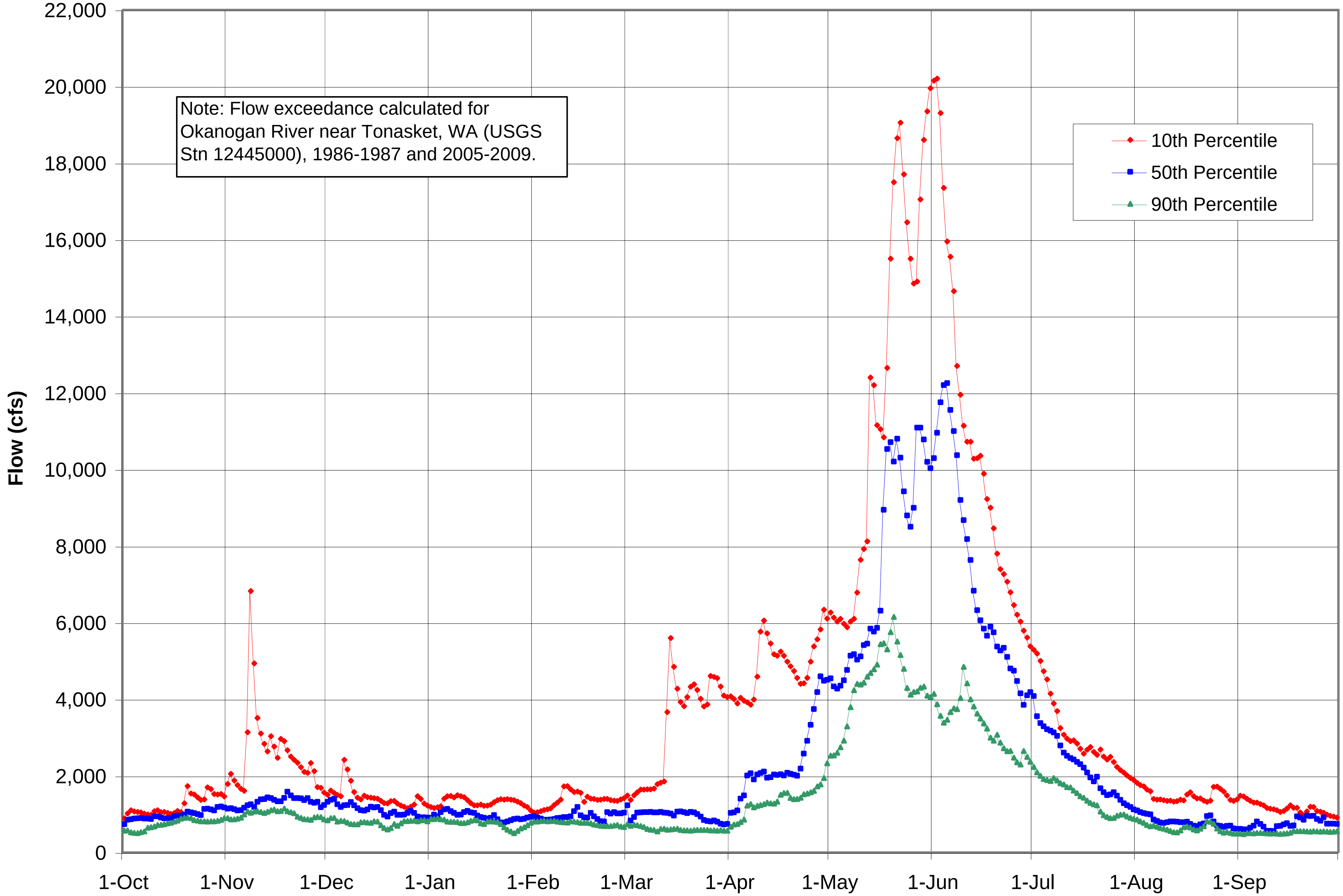
DRAWN BY: MS	FIGURE NO. 2.1.11
REVISED BY: -	

T:\Projects_8\Similkameen\Delivered\2010-05 Final\2010-05 Riverside Monitoring Stations.mxd



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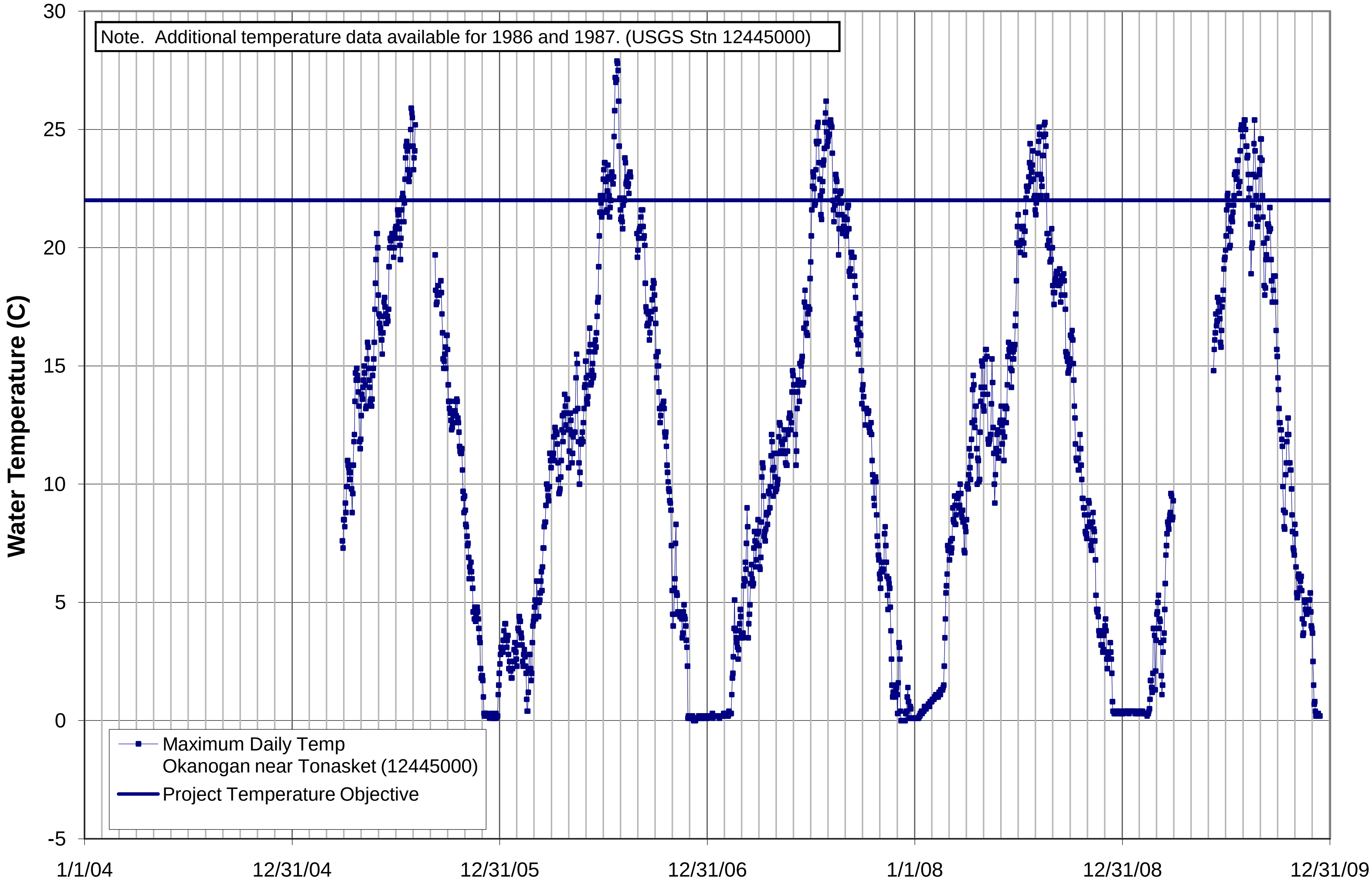
5/11/2010
W:\090041 CT Artificial Recharge Feasibility Study\Deliverables\Feasibility Report\Final\FlowData - Plot(OkanTon)

Figure 2.1.12
Flow Exceedance Graph,
Okanogan River near Tonasket
Coldwater Refugia Feasibility Study, Okanogan Basin, WA



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W:\090041 CT Artificial Recharge Feasibility Study\Deliverables\Feasibility Report\Final\TempData.xls - Tmax12445000Plt

Figure 2.1.13
Maximum Daily Temperature for Okanogan River near Tonasket
Coldwater Refugia Feasibility Study, Okanogan Basin, WA

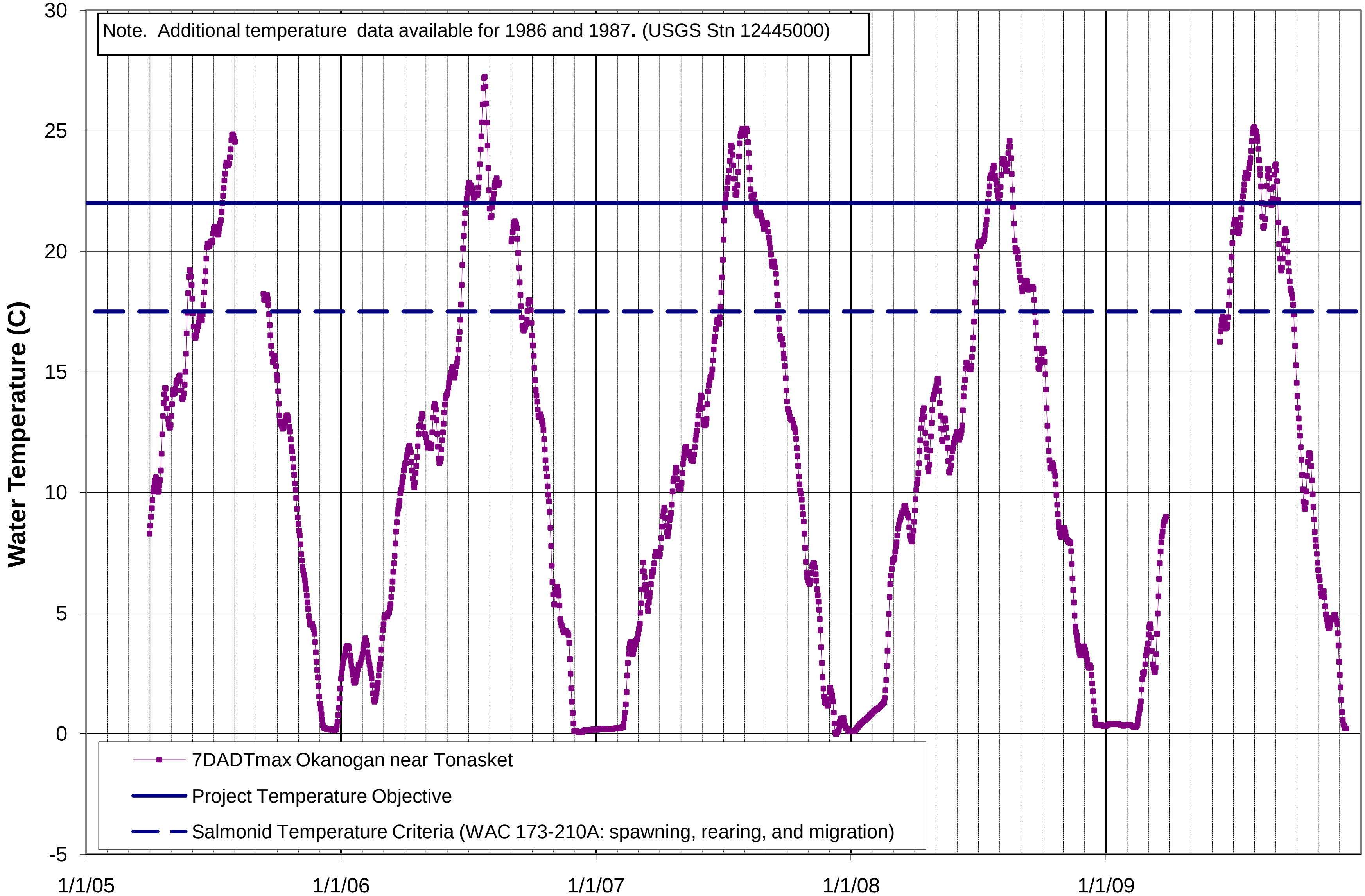

Figure 2.1.14
7DAD Maximum Temperature for Okanogan River near Tonasket
Coldwater Refugia Feasibility Study, Okanogan Basin, WA

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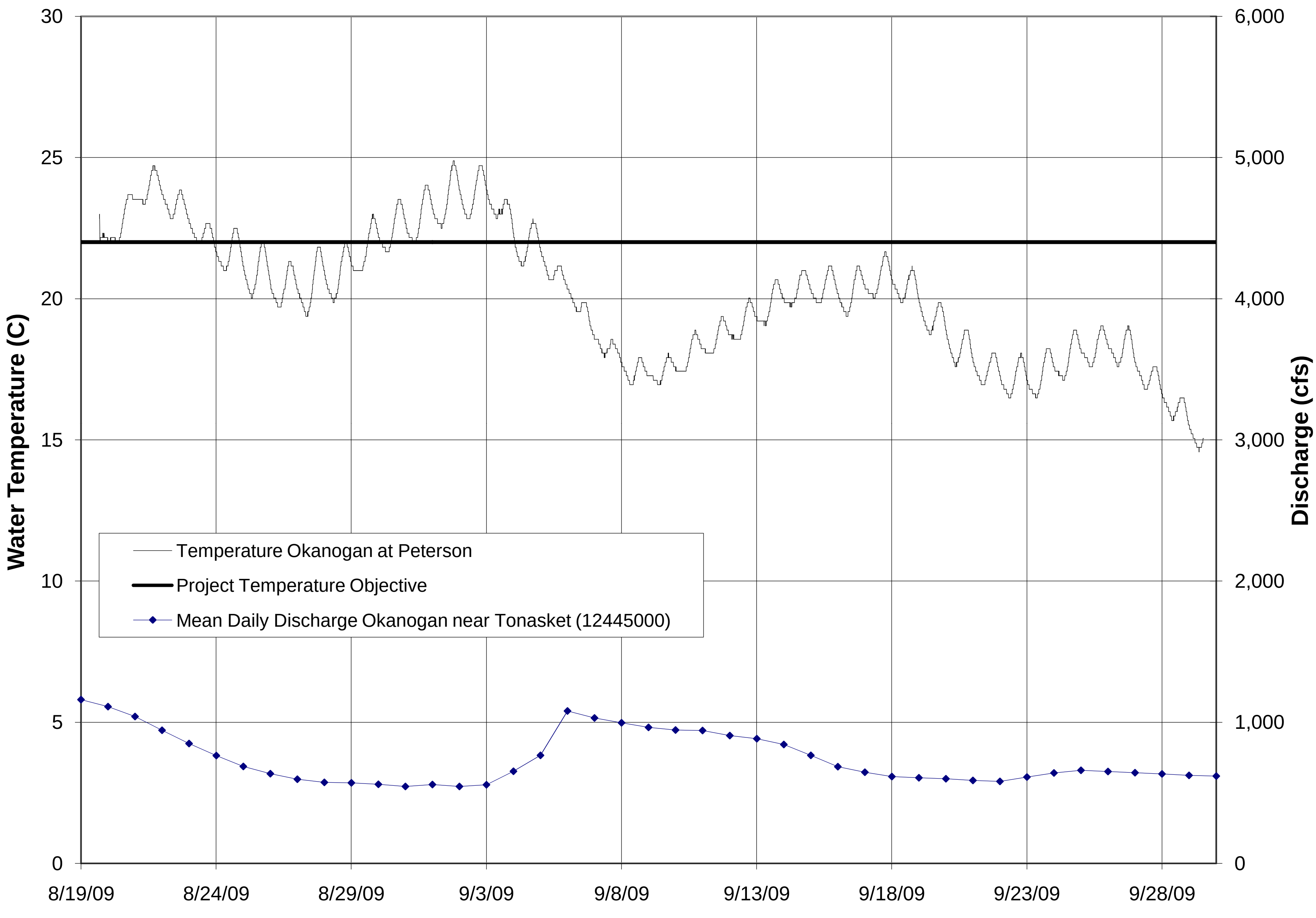

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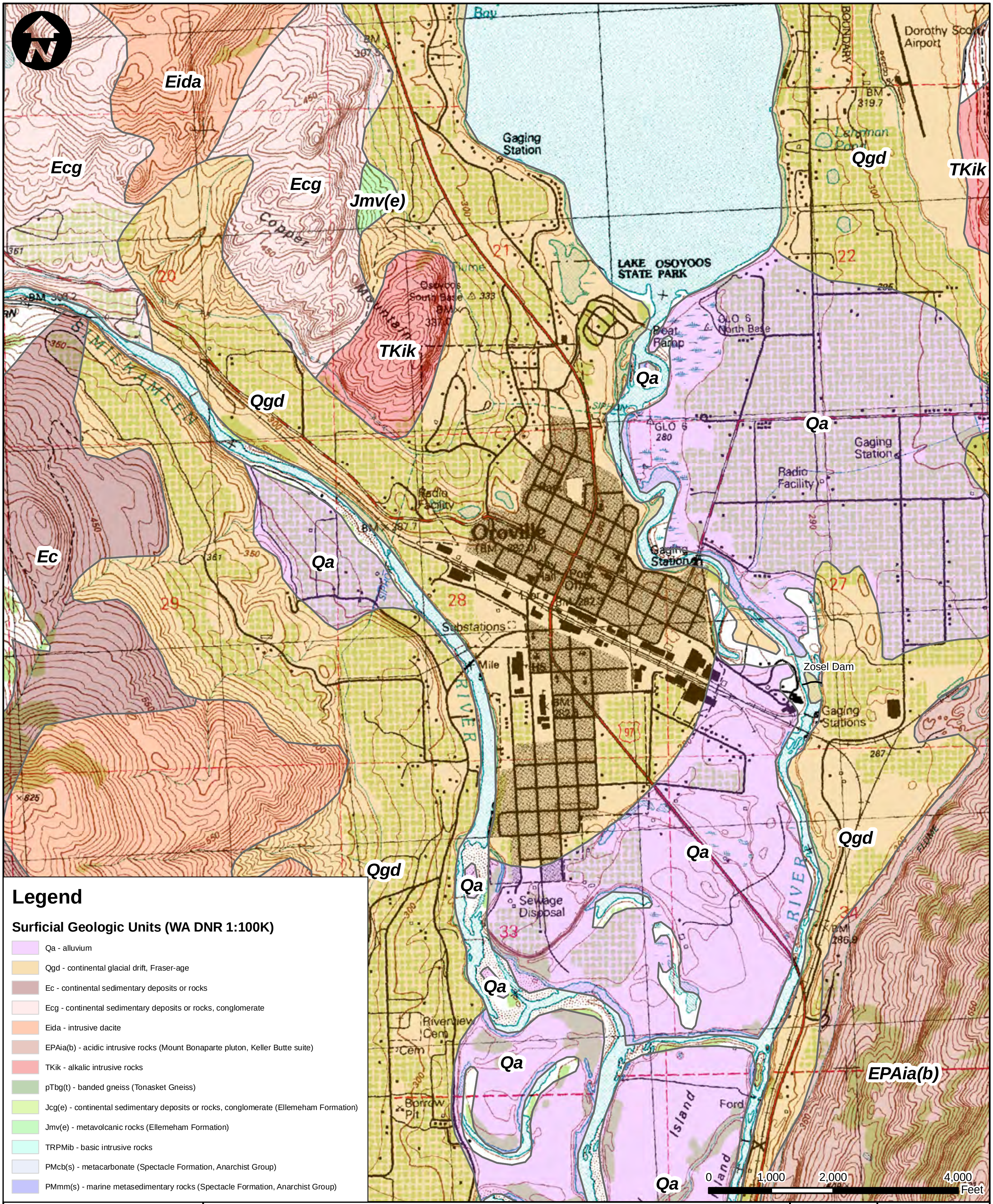
W:\090041 CT Artificial Recharge Feasibility Study\Deliverables\Feasibility Report\Final\Tidbit Temp Plots.xls - TdbtTPlt2

Figure 2.1.15
Okanogan River Temperature near Riverside
Coldwater Refugia Feasibility Study, Okanogan Basin, WA



Legend

Surficial Geologic Units (WA DNR 1:100K)

- Qa - alluvium
- Qgd - continental glacial drift, Fraser-age
- Ec - continental sedimentary deposits or rocks
- Ecg - continental sedimentary deposits or rocks, conglomerate
- Eida - intrusive dacite
- EPAia(b) - acidic intrusive rocks (Mount Bonaparte pluton, Keller Butte suite)
- TKik - alkalic intrusive rocks
- pTbg(t) - banded gneiss (Tonasket Gneiss)
- Jcg(e) - continental sedimentary deposits or rocks, conglomerate (Ellemeham Formation)
- Jmv(e) - metavolcanic rocks (Ellemeham Formation)
- TRPMib - basic intrusive rocks
- PMcb(s) - metacarbonate (Spectacle Formation, Anarchist Group)
- PMmm(s) - marine metasedimentary rocks (Spectacle Formation, Anarchist Group)

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Oroville Area Geology

Coldwater Refugia Feasibility Study
Okanogan Basin, WA

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DRAWN BY: MS	FIGURE NO. 2.2.1
REVISED BY: -	

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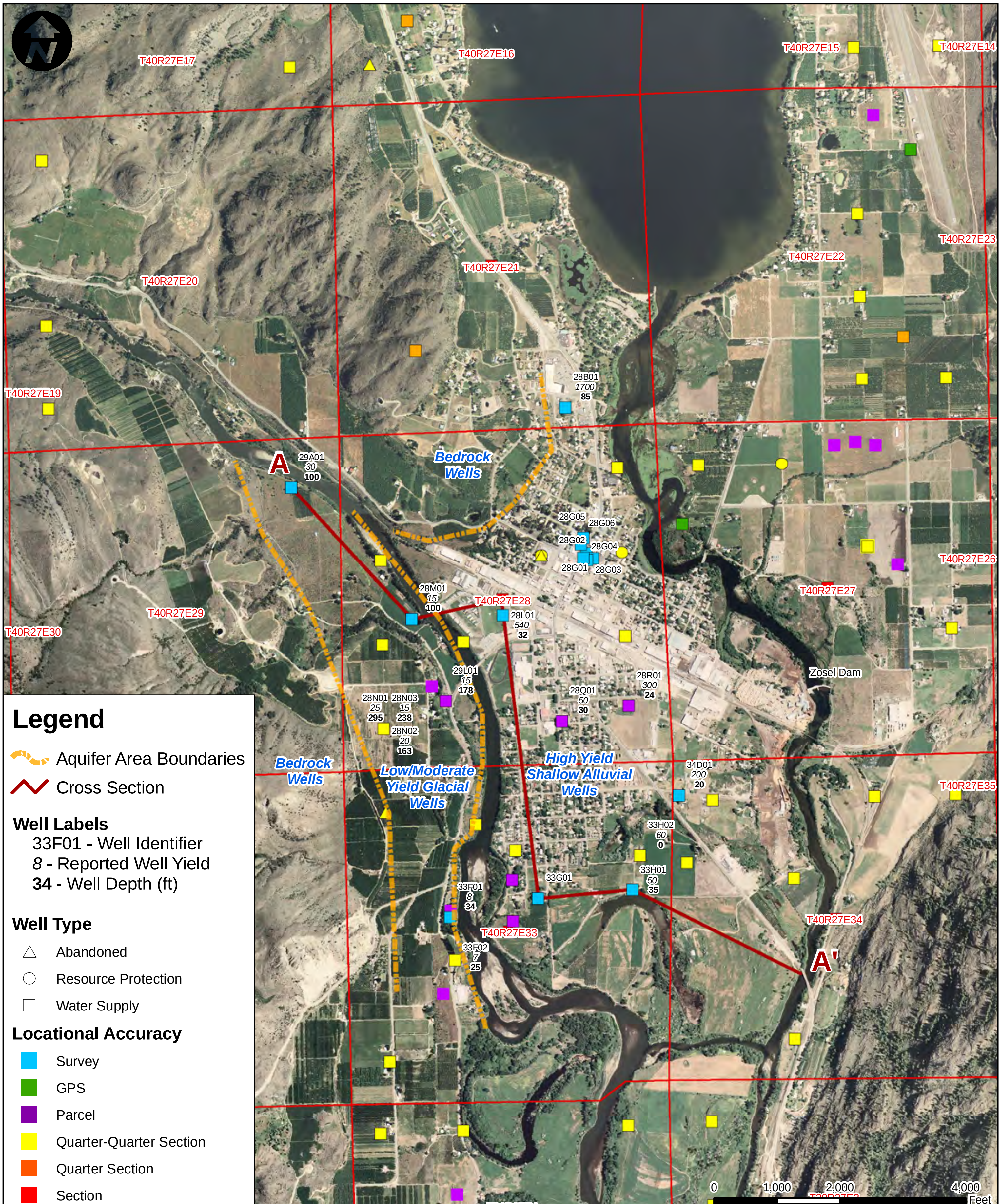

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Oroville Area Wells

Coldwater Refugia Feasibility Study
Okanogan Basin, WA

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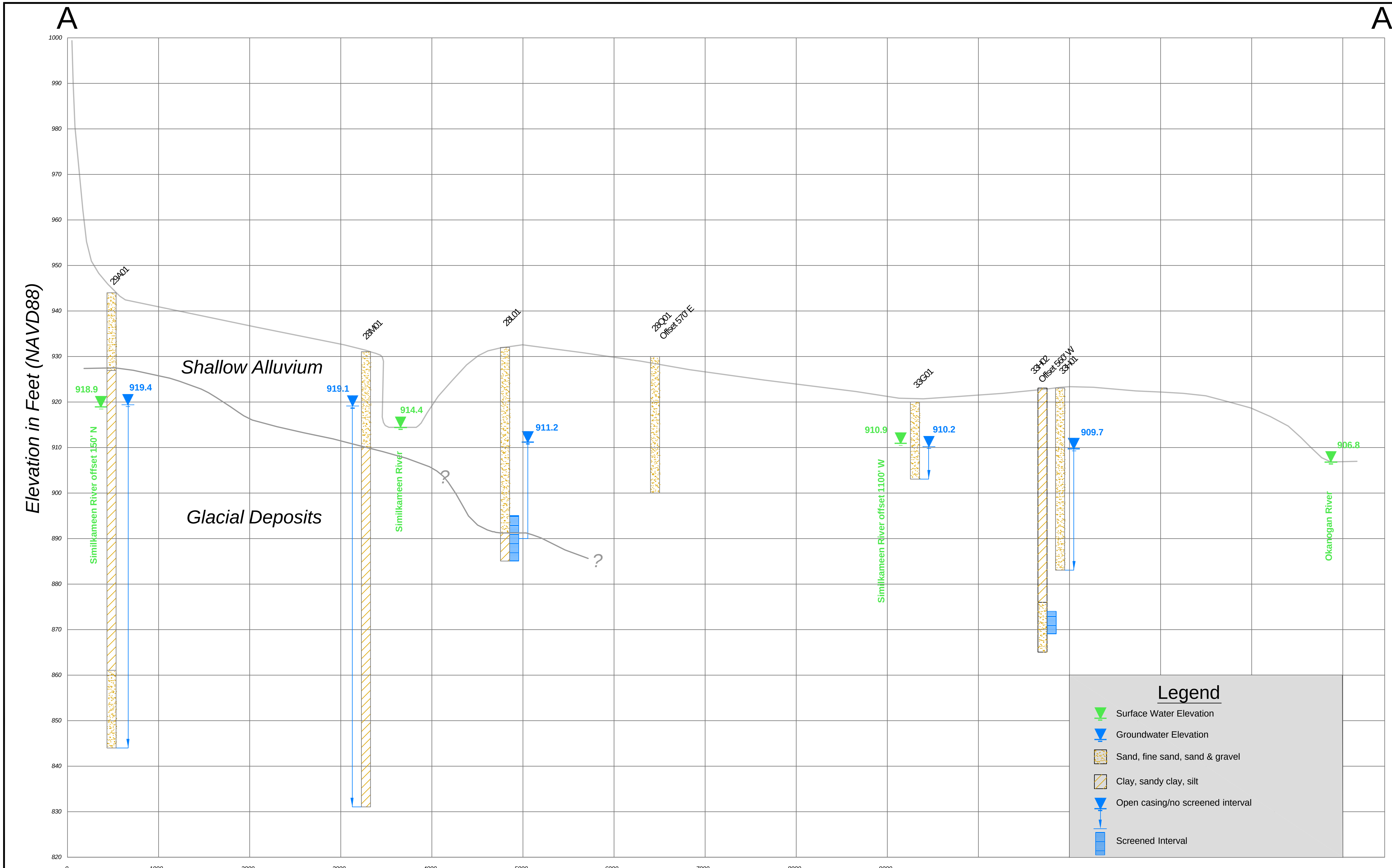
REVISED BY: -

PROJECT NO. 090041

FIGURE NO. 2.2.2

T:\Projects_8\Similkameen\Delivered\2010-05 Final\2010-05 Oroville Well Map.mxd



Scale: 1"=1000'

Vertical Exaggeration 5:1

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Cross Section A-A'

Coldwater Refugia Feasibility Study

Okanogan Basin, Washington

DATE: December 2009

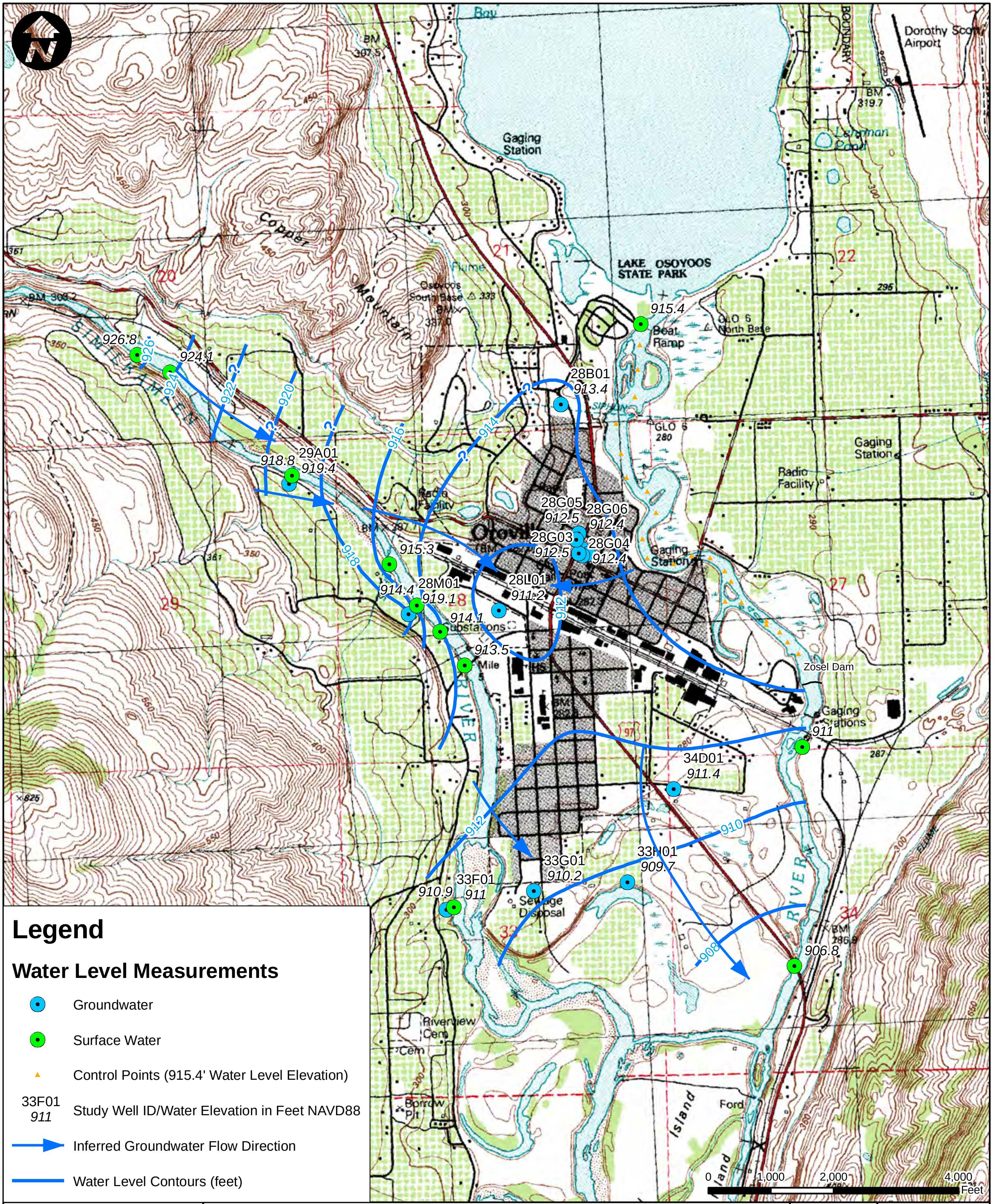
DESIGNED BY: WMS

DRAWN BY: MS

REVISED BY: -

PROJECT NO. 090041

FIGURE NO. **2.2.3**



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Water Level Contours

Coldwater Refugia Feasibility Study
Okanogan Basin, WA

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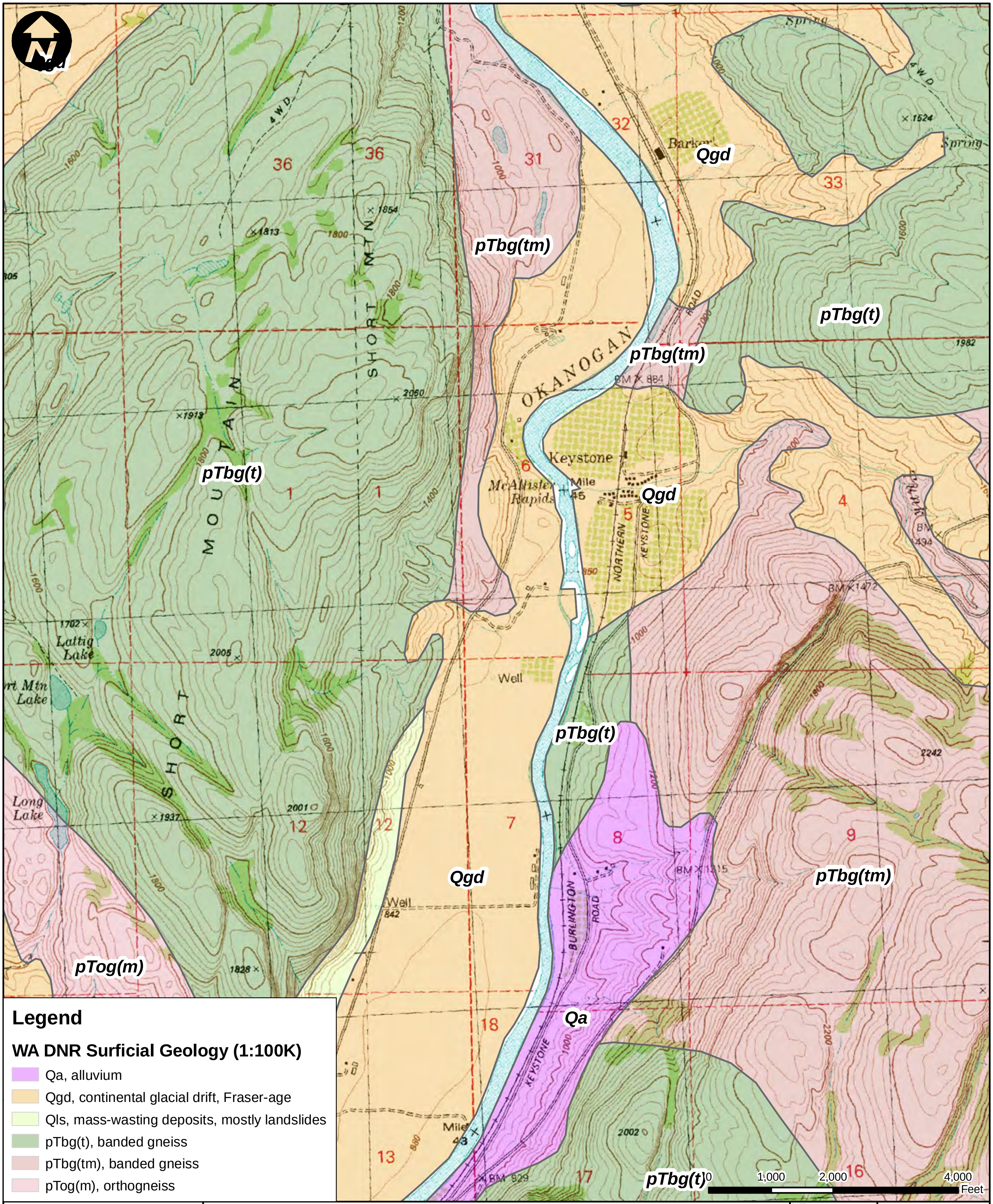

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Riverside Area Geology

Coldwater Refugia Feasibility Study
Okanogan Basin, WA

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DESIGNED BY: WMS	
DRAWN BY: MS	FIGURE NO. 2.2.5
REVISED BY: -	

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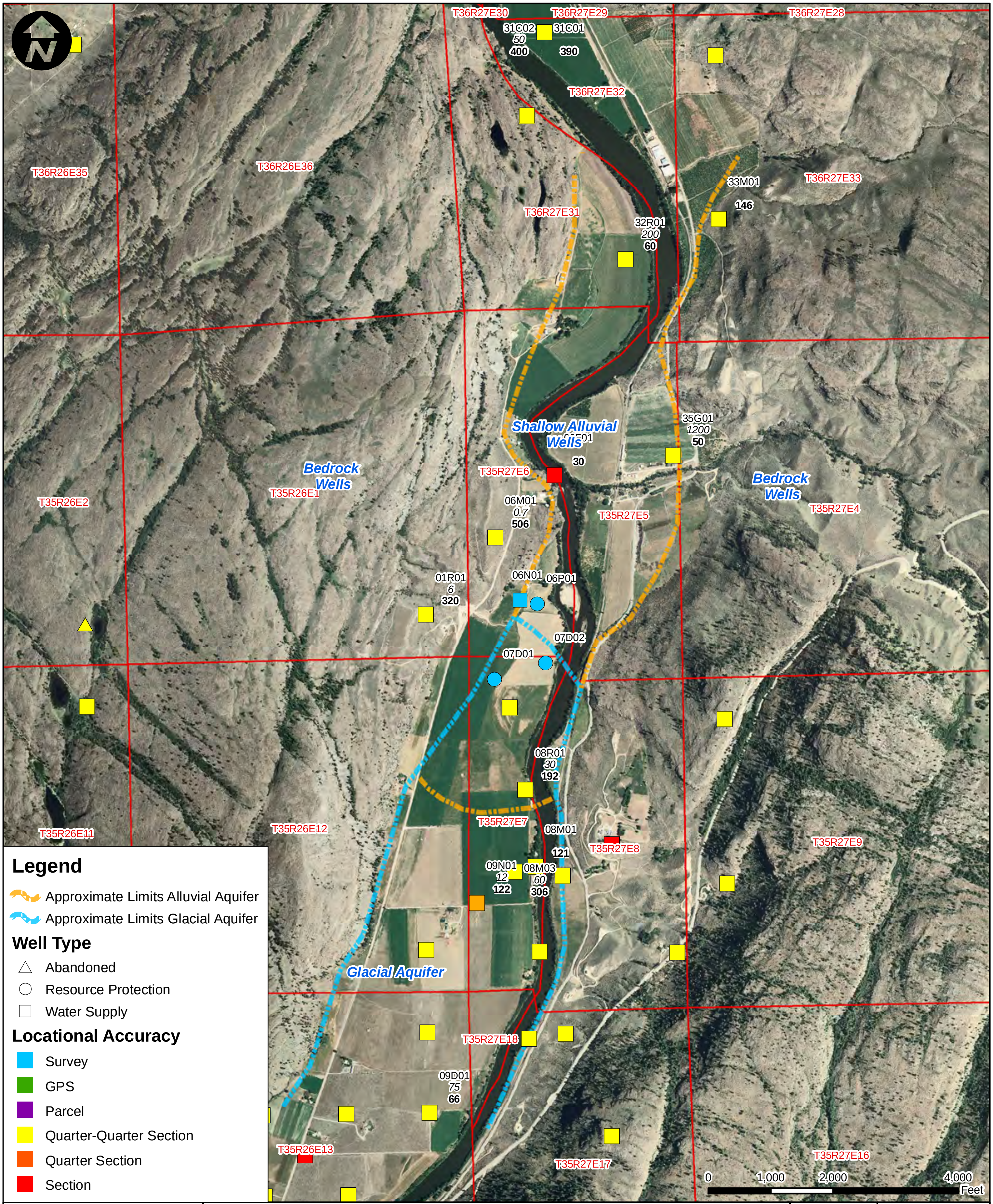

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Riverside Area Wells

Coldwater Refugia Feasibility Study

Okanogan Basin, WA

DATE: May 2010	PROJECT NO. 090041
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DRAWN BY: MS	FIGURE NO. 2.2.6
REVISED BY: -	

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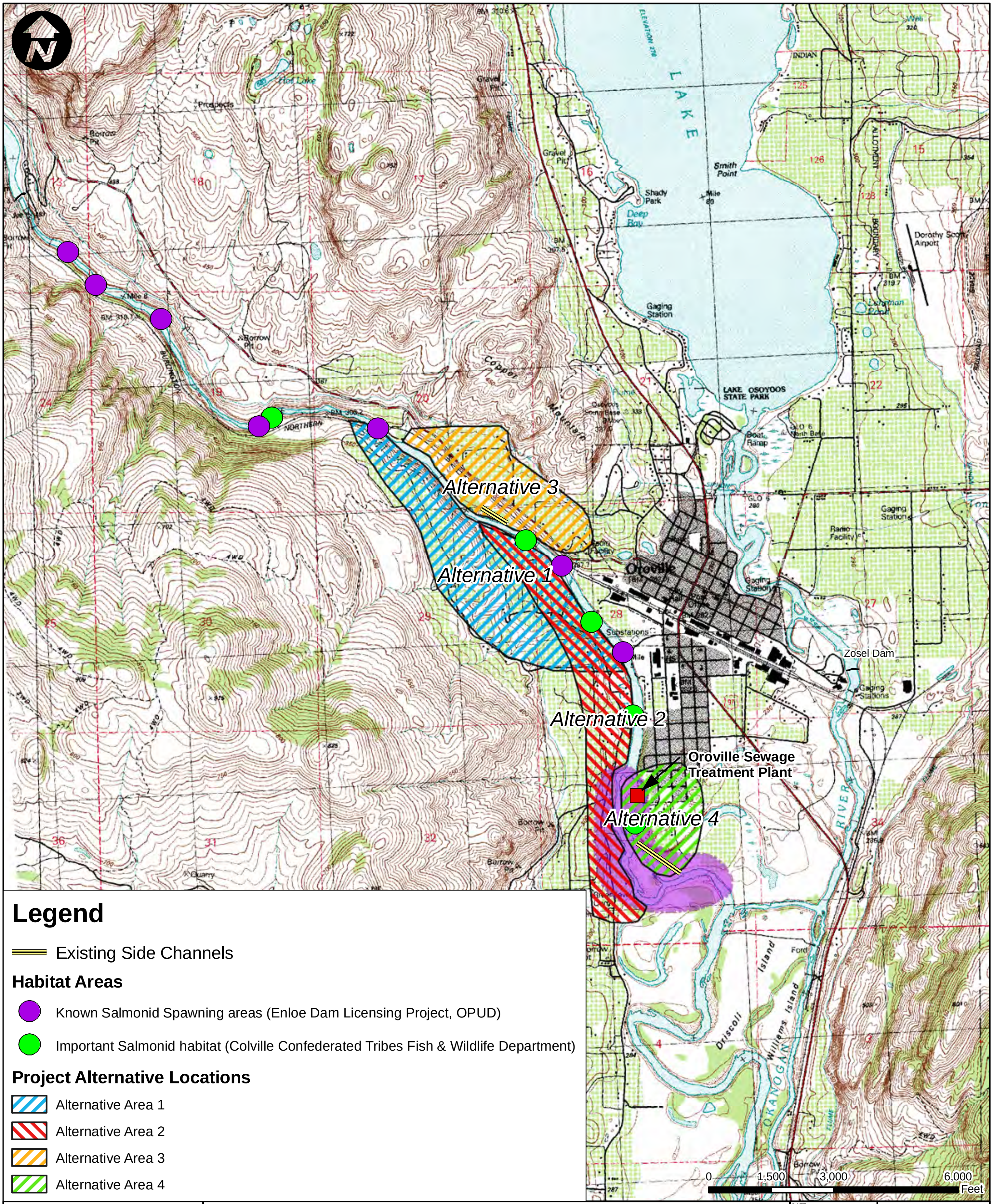

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Identified Habitat Areas and Project Alternative Locations

Coldwater Refugia Feasibility Study
Okanogan Basin, WA

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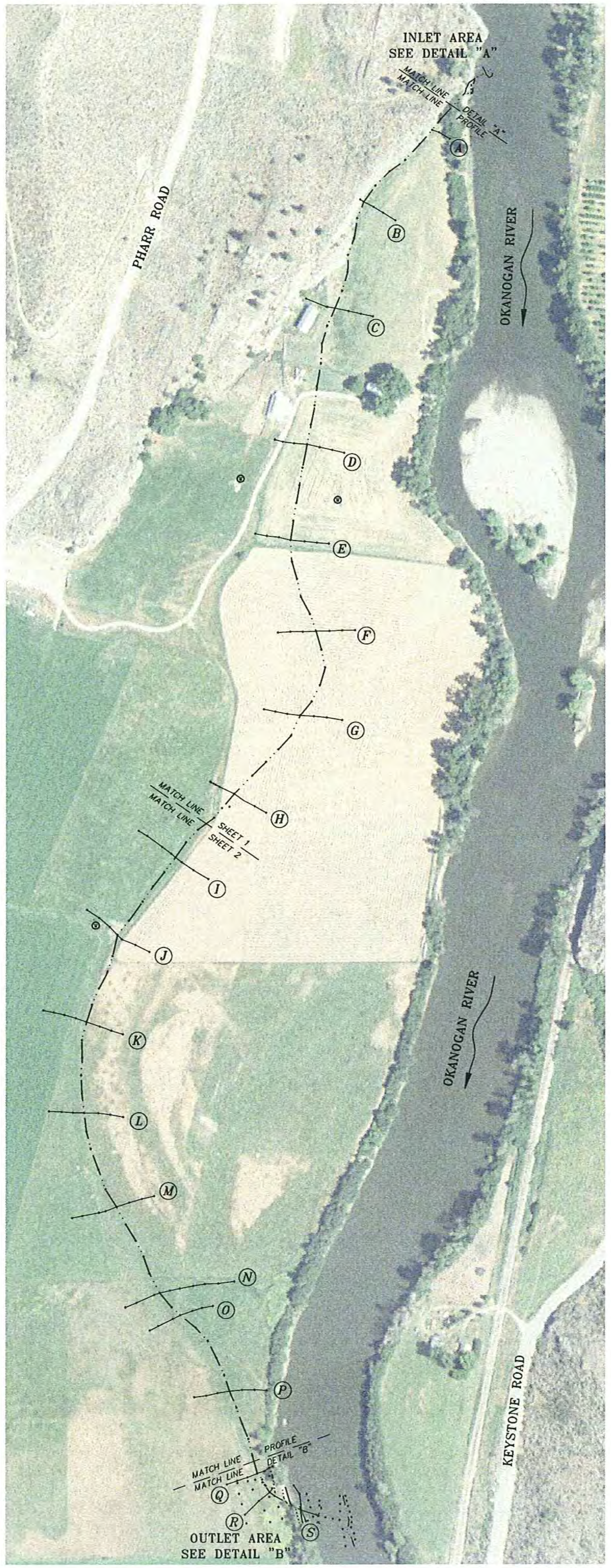
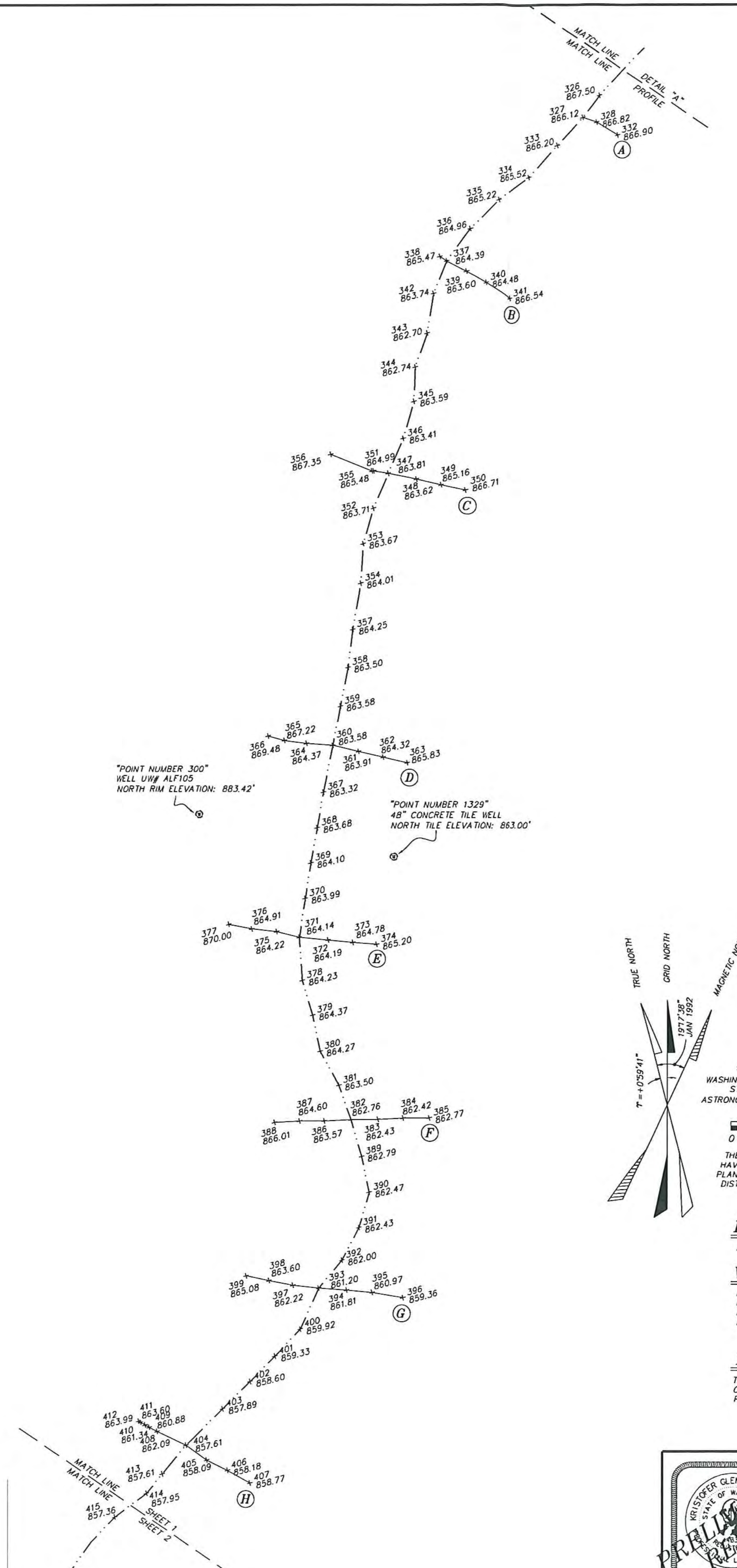
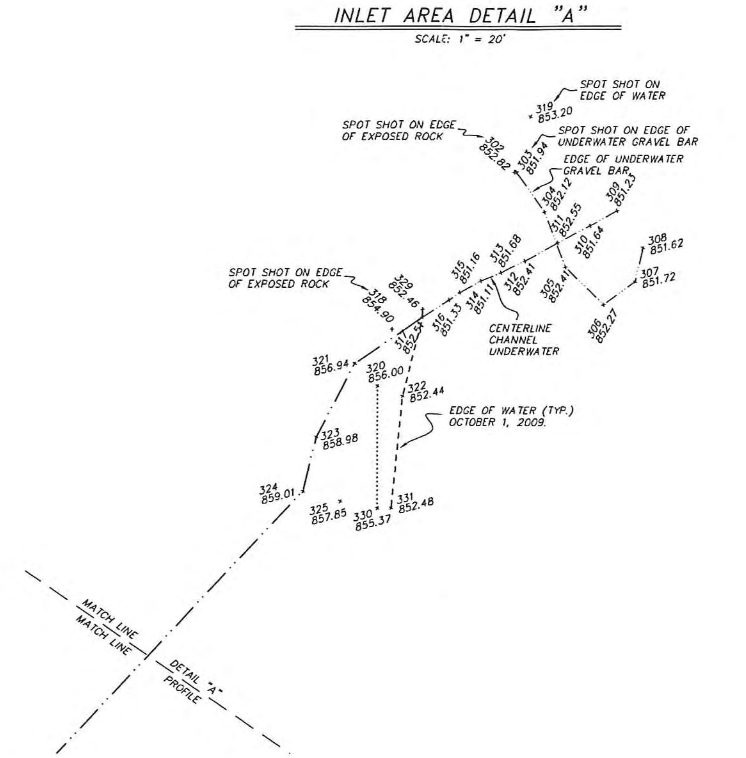
T:\Projects_8\Similkameen\Delivered\2010-05 Oroville Fish Habitat.mxd

APPENDIX A

Survey Data







BASIS OF BEARINGS:

WASHINGTON STATE PLANE GRID NORTH ZONE BASED ON STATIC OR RAPID STATIC GPS MEASUREMENTS. ASTRONOMIC NORTH BEARS APPROXIMATELY N 00°59'41" W

SCALE: 1" = 100'

0 50' 100' 200' 300'

THE MEASURED DISTANCES SHOWN ON THIS MAP HAVE BEEN ADJUSTED TO THE WASHINGTON STATE PLANE COORDINATE GRID. MULTIPLY THE MEASURED DISTANCES SHOWN BY A FACTOR OF 1.000077 TO OBTAIN THE ACTUAL GROUND DISTANCE.

HORIZONTAL DATUM

NAD 83/91

VERTICAL DATUM

NAVD 88
ELEVATIONS DERIVED FROM GPS OBSERVATIONS OF NGS DATA POINT "B-513" A STAINLESS STEEL ROD IN MONUMENT CASE STAMPED "B-513 1981"

NOTES

THIS TOPOGRAPHICAL SURVEY WAS DONE AT THE REQUEST OF ASPECT CONSULTING FOR SITE DESIGN AND PLANNING PURPOSES. THIS IS NOT A BOUNDARY SURVEY.

EQUIPMENT & PROCEDURES

EQUIPMENT: LEICA TCRP 1203 TOTAL STATION
LEICA GX 1230 GPS SYSTEM

PROCEDURES: INITIAL CONTROL ESTABLISHED BY RAPID-STATIC GPS OBSERVATIONS, WITH A PRECISION OF ±2CM. CONVENTIONAL TRAVERSES WERE PERFORMED BETWEEN THIS CONTROL TO OBTAIN ADDITIONAL SITE SPECIFIC DATA AND FOR CORNER MONUMENTATION. POSITIONAL ERROR ADJUSTMENTS WERE MADE USING LEAST SQUARES ANALYSIS. PROCEDURES MEET OR EXCEED W.A.C. 332-130-090.

DATES OF SURVEY: SURVEY PERFORMED: 09/29/2009 AND 10/01/2009

LEGEND

—··—	CENTERLINE FUTURE CHANNEL
—··—··—	CENTER LINE UNDERWATER CHANNEL
—···—	EDGE OF UNDERWATER GRAVEL BAR
- - - - -	EDGE OF WATER
....	TOP OF SLOPE/BANK
— — —	TOE OF SLOPE/BANK
———	CROSS SECTION
⊙	WELL
+1005	SPOT ELEVATION

KRISTOFER GLENN ERLANDSEN, STATE OF WASHINGTON, REGISTERED PROFESSIONAL LAND SURVEYOR
PRELIMINARY REVIEW

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PHARR ROAD PROPERTY
CHANNEL AND WELL LOCATION
SECTION 6 AND 7, T35N, R26E, W.M.

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DATE: 10-09-2009 FILE NO: 20090067-000EX
SCALE: 1"=100' JOB NO: 20090067-000

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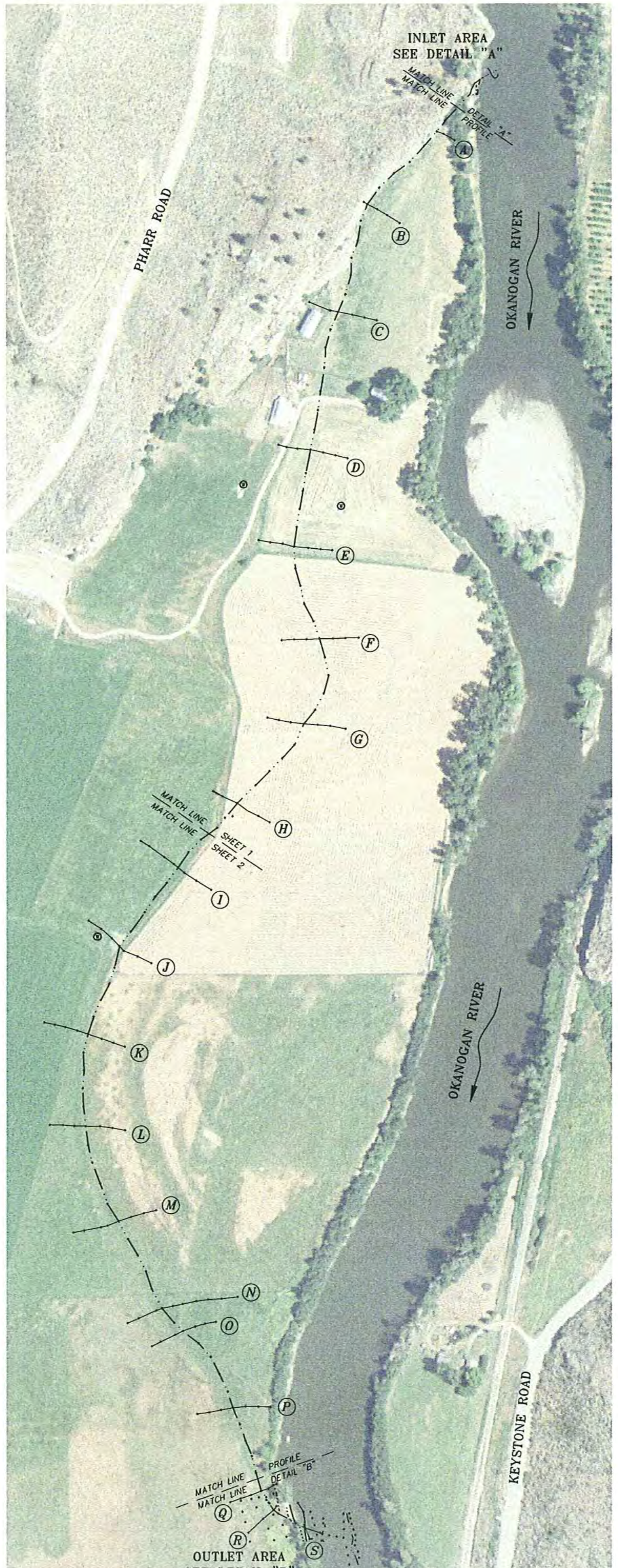

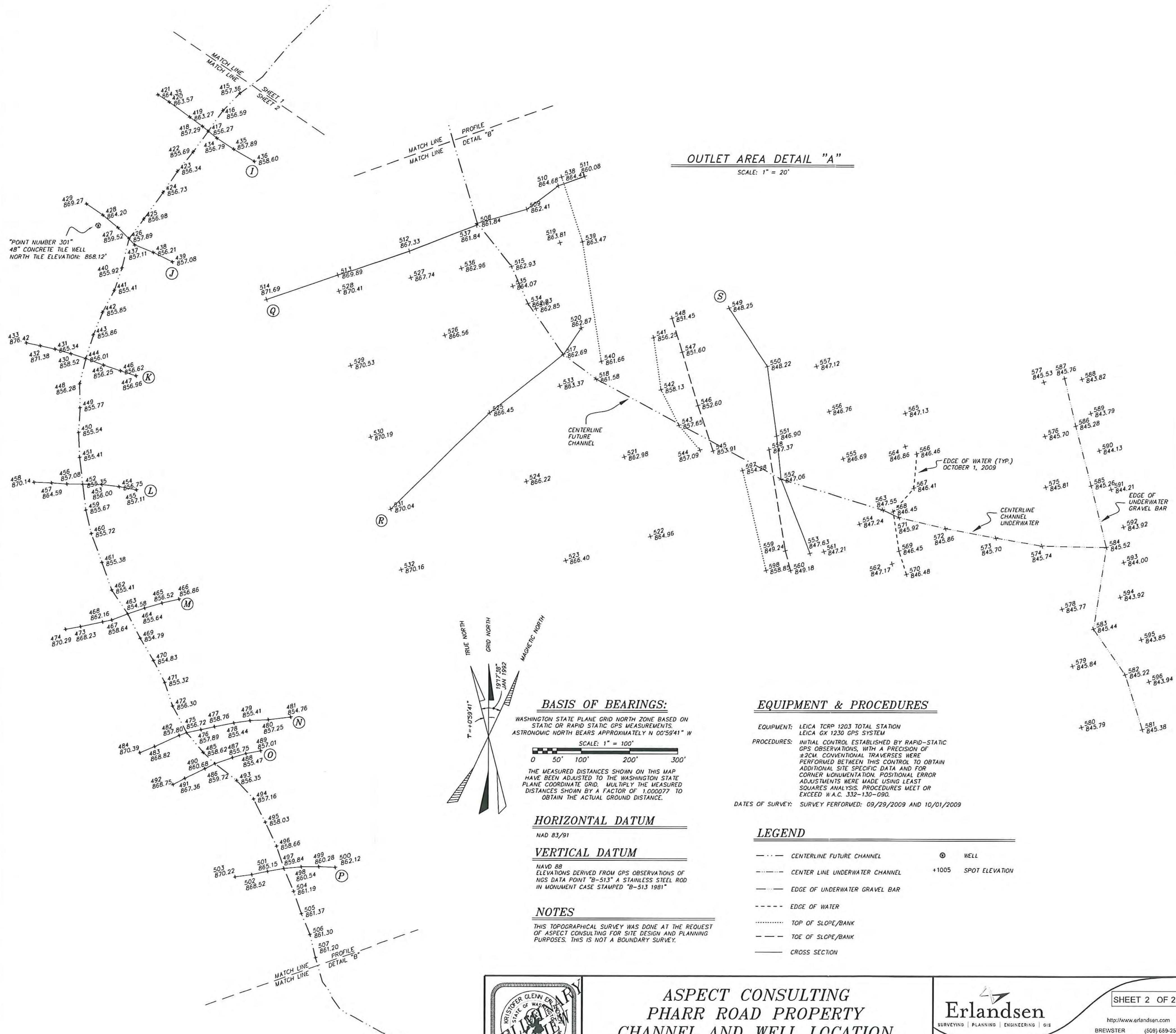

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WASHINGTON STATE PLANE GRID NORTH ZONE BASED ON STATIC OR RAPID STATIC GPS MEASUREMENTS. ASTRONOMIC NORTH BEARS APPROXIMATELY N 00°59'41" W

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0 50' 100' 200' 300'

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HORIZONTAL DATUM

NAD 83/91

VERTICAL DATUM

NAVD 88
ELEVATIONS DERIVED FROM GPS OBSERVATIONS OF NGS DATA POINT "B-513" A STAINLESS STEEL ROD IN MONUMENT CASE STAMPED "B-513 1981"

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EQUIPMENT: LEICA TCRP 1203 TOTAL STATION
LEICA GX 1230 GPS SYSTEM

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DATES OF SURVEY: SURVEY PERFORMED: 09/29/2009 AND 10/01/2009

LEGEND

— · · —	CENTERLINE FUTURE CHANNEL
— · · · —	CENTER LINE UNDERWATER CHANNEL
— —	EDGE OF UNDERWATER GRAVEL BAR
- - - -	EDGE OF WATER
········	TOP OF SLOPE/BANK
— —	TOE OF SLOPE/BANK
———	CROSS SECTION
⊙	WELL
+1005	SPOT ELEVATION

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JOB NO: 20090067-000

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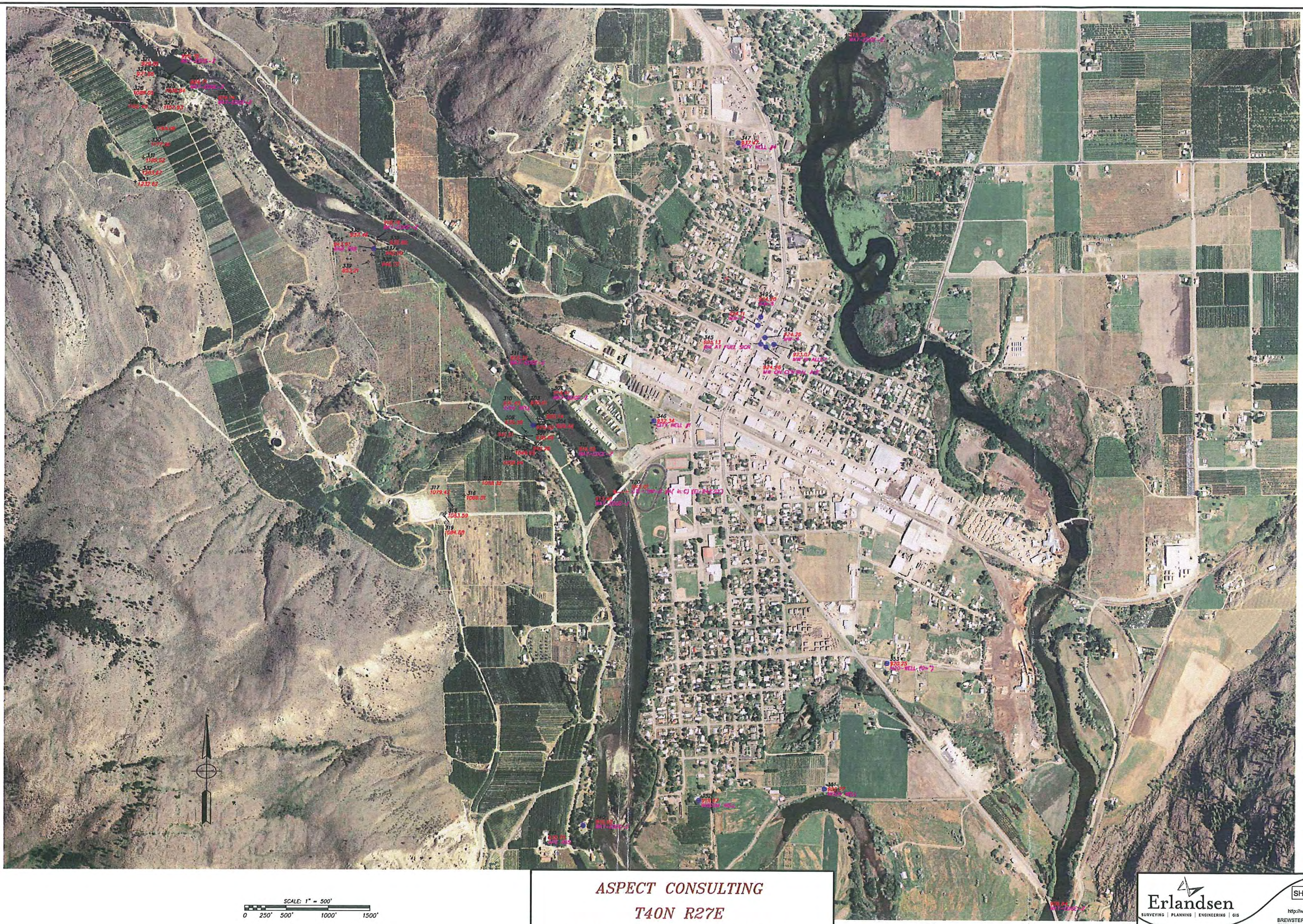

SCALE: 1" = 500'
0 250' 500' 1000' 1500'

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SCALE: 1" = 500'
LAYOUT: 36 X24 WS
FILE NO: 20090067-002 WK1
JOB NO: 20090067-002

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