A Conceptual Proposal for a Salmon Enumeration Facility on the Okanogan River

Prepared for:

Confederated Tribes of the Colville Reservation
Fish and Wildlife Department
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INTRODUCTION

As part of the Okanogan Basin Monitoring and Evaluation Program (OBMEP) to promote the recovery of Pacific salmon and steelhead populations, the Confederated Tribes of the Colville Reservation (CCT) initiated in 2005 a project titled the "*Design and construction of video detection systems in the Okanogan River Basin to enumerate adult salmon and steelhead*" to provide census counts at strategic locations in the basin. The ultimate goal of the census program was to enumerate adult salmonids at several locations in the basin to determine basin and tributary specific spawner distribution, and evaluate the status and trends of natural production in the basin. The target species include anadromous forms of Oncorhynchus that have known production in the basin including sockeye, steelhead, and Chinook. This project was the result of an initial feasibility assessment of potential sites in the Okanogan Basin to use video detection systems (VDS) for enumerating fish passage (Nass and Bocking, 2005).

The primary objectives of the over-riding project were to:

1. Design, install, operate, monitor and evaluate a VDS at Zosel Dam to enumerate steelhead, sockeye, and Chinook;
2. Design, install, operate, monitor and evaluate three portable VDS to be pilot tested at selected tributaries to enumerate steelhead and Chinook; and
3. Conduct a feasibility assessment for remote counting of anadromous salmon and steelhead migrating upstream of the lower Okanogan River, and develop a conceptual design.

This report documents the results of activities associated with conducting Objective 3, and more specifically, to evaluate potential sites for the successful operation of a fish enumeration facility that would achieve a species-specific, system-wide census count of anadromous fish using a "hands off" and automated method.

To achieve the goal of enumerating adult salmon in the Okanogan River requires careful consideration of site characteristics, the logistics of implementation activities, labor and capital costs, and the potential performance of an enumeration facility. There are numerous different methods of enumeration that could be considered for collecting population abundance information including mark-recapture, hydroacoustics, DIDSON, resistivity, and underwater video. Based on the potential for achieving the stated goal of the program and the inherent characteristics of each method, the CCT initiated this pilot study to investigate the potential for using underwater video in combination with fish guidance structures (FGS) as it had the highest likelihood for success. When installed with fish migration guidance structures such as a weir, and the presence of relatively clear water transparency, video detection systems can provide the ability to efficiently monitor fish passage and allow species-specific enumeration without handling the fish. A secondary goal of the CCT was to investigate the feasibility of using the enumeration facility for the collection of broodstock, particularly steelhead, and was also addressed as part of this work.

STUDY AREA

The study area for this assessment included a reach in the lower Okanogan River in the vicinity of Malott, WA (Figure 1). Previous investigations by Nass and Bocking (2005) identified this section of the river as having the best potential for operating a fish counting facility by virtue of its location below the spawning grounds of anadromous fish, and its physical channel characteristics.

METHODS

The primary activities carried out for this project included:

(1) Identify potential sites for which to design an enumeration facility;

(2) Conduct an assessment of physical site characteristics including channel profile and flows;

(3) Develop a conceptual design for an enumeration facility;

(4) Evaluate the feasibility of a picket weir video system as a suitable method to meet the species-specific, system wide census count objective.

The feasibility assessment began with an on-the-ground inventory survey of the Okanogan River between Malott, WA and Chilliwist Creek on September 17 – 19, 2006 by representatives of LGL and nhc. Two preferred locations on the Okanogan River identified in prior reconnaissance surveys were selected for a detailed survey. The purpose of this survey was to conduct a topographic/bathymetric inventory of each site to construct a rudimentary numerical computer hydraulic model to evaluate the water surface profile conditions and velocities. The hydraulic analyses are supported by the development of a coarse topographic map of each site and from which horizontal and vertical profiles are derived. Additional information collected included photo documentation, bank height, sediment gradation, sediment stability and transport, site accessibility, and adjacent land ownership.

The first site investigated was located just upstream of Okanogan River's confluence with Chilliwist Creek (hereafter *Chilliwist*). The second site was located about one-half mile upstream, adjacent to Raymar's Orchard (hereafter *Raymar*). At each location, over 200 elevation points were collected using a Total Station electronic laser survey instrument.

Hydrologic Modeling

Real-time and historical flow records for the USGS stream gauge at Malott were used to determine the discharge at the time of survey, as well as for calculating estimated flood frequency quantiles for each site. Using the HEC-FFA, a statistical analysis program developed by the U.S. Army Corps of Engineers, forty-six years (1958 – 2004) of instantaneous annual peak flows were analyzed to determine the 2-, 5-, 10-, 50-, and 100-year flood frequency events.

Hydraulic Modeling

To evaluate the hydraulic performance of existing and estimated conditions at each site, a simple hydraulic model was created for the active stream channel, using HECRAS, a one-dimensional steady state computer water surface profile model. The extents of each HEC-RAS model encompassed approximately 800-ft to 900-ft of linear channel, placing the proposed location of the enumeration site within the middle third of each modeled reach. The models were initially calibrated for low flows using the water surface elevations determined at the time of the topographic mapping (during a flow of approximately 750 cfs). Using bench elevations and vegetation lines documented during the survey, the models were further refined to match flows at or near the typical annual flood flow, or roughly equivalent to the 1- to 2-yr flood event. The models were then used to estimate stage-discharge relationships, velocities, and wetted channel width for a range of flows.

Site survey data and modeled water flow characteristics were then evaluated with respect to the optimal characteristics of a site that would support an enumeration facility. Preferred characteristics of a site include:

- ✓ Relatively straight, wide, and low slope channel to distribute flow and minimize water depth and velocity;
- ✓ The presence of a riffle below the site to promote active fish migration, and a pool or run above the site to provide a low energy environment for fish after passing the site;
- ✓ Peak discharge that is within the target operational design specification;
- ✓ Suitable site access and the availability of power.

In addition, a conceptual facility was designed to assess the potential success of operations with respect to normal flow conditions.

RESULTS AND DISCUSSION

Site Descriptions

The Chilliwist and Raymar sites are located approximately 17 river miles upstream of the confluence with the Columbia River (Figure 2). Chilliwist is located between to major bends in the river channel, and Raymar is located at the end of a long, straight section of the river (Photo 1). Bathymetric profiles for Raymar and Chilliwist are presented in Figure 3 and Figure 4, respectively, and illustrate that Raymar has a flatter cross-sectional profile compared to Chilliwist. Similarly, horizontal profiles are presented in Figure 5 and illustrate that Raymar has a flatter linear profile compared to Chilliwist. The Chilliwist site is hydraulically more complex because of its location between two major bends in the river, and its proximity to a cross-channel bar.

Raymar

Raymar is characterized as a run type habitat with laminar flows and relatively low slope (Photo 2 and Photo 3). Channel width is approximately 350 ft and lies within land owned by the Colville

Tribes on the left bank, and Raymar Orchards and Douglas County PUD on the right bank. This site has a predominantly cobble-boulder substrate, although there are areas of accumulated sand (Photo 4). Field tests indicate that the substrate armor layer was approximately 1 to 2 ft thick. The most attractive location for an enumeration facility at this site is at the upstream end of a riffle section, adjacent to an existing power pole and irrigation pump diversion. Bank slopes above the active channel are typically in the range of 2 horizontal to 1 vertical.

Chilliwist

Chilliwist is characterized as a run and riffle type of habitat with moderate slope (Photo 5). Channel width is 260 ft and lies within land owned by Douglas County PUD on both banks. This site has a predominantly cobble-boulder substrate with aquatic vegetation and freshwater mussels (Photo 6). Field tests show that the upper one to two feet of the bed is armored, with a finer gradation of sediment present beneath this. The most attractive location for an enumeration facility at Chilliwist is just upstream from a large, mid-stream sediment bar that appeared to be a created by a significant past flood event. Immediately downstream of the bar crest, a fast moving riffle section extends downstream several hundred yards to a deep pool at the mouth of Chilliwist Creek. Immediately upstream from the proposed site near the bar crest was another deep pool along the outside of a broad bend in the river. The channel banks slope at approximately 2 horizontal to 1 vertical.

Hydraulic Analyses

Based on the USGS stage-discharge relationship (Figure 6), Table 1 summarizes calculated flood frequency quantiles, along with the flow estimated for the date of the survey.

The above data was then used to calculate a stage-discharge rating curve for the Raymar and Chilliwist sites, respectively (Figure 7 and Figure 8). Comparison of these figures illustrate the stage-discharge relationship is very similar between the two sites for a given increase in discharge, and results in approximately the same increase in water depth for both sites. However, the difference in the average bed elevation and depth of the thalwag is less at Raymar (0.4 ft at Raymar versus 2.1 ft at Chilliwist). Therefore, the average water height over the cross-channel at Raymar is always shallower compared to Chilliwist at a given discharge. The implications of this characteristic is clearly illustrated in Figure 9 that shows a person would be better able to wade at Raymar compared to Chilliwist, and that an enumeration facility will operate longer at a given design specification.

The stage-discharge relationship and bathymetry data were then used to model water velocity at each site (Table 2). Raymar could expect to see an average depth of 4.4-ft and velocity of 4.8 ft/sec at a 1-yr recurrence interval flood event. During a 10-yr flood event, an average depth of 9.9-ft and a velocity of 7.4 ft/sec and are possible. Because of a uniform channel shape, the maximum depths at the Raymar Creek site are only about 0.4-ft higher than the average depths listed above. Chilliwist could expect to see an average depth of 4.5-ft and velocity of 6.8 ft/sec at a 1-yr recurrence interval flow event. During a 10-yr flood, an average depth of 9.5-ft and a velocity of 11.1 ft/sec are possible. Maximum depths at the Chilliwist Creek site are approximately 2.1-ft higher than the average depths listed above. These data indicate that water velocity is always lower at Raymar, and that the difference increases with increasing discharge.

Site Evaluation

The Raymar site is the most suitable for constructing and maintaining a salmon enumeration facility on the lower Okanogan River. The Raymar site provides a cross-section that is wider, straighter, and more uniform compared to the Chilliwist Creek site. Since this site has a much wider channel section than at the Chilliwist Creek site (350-ft versus 260-ft), the channel velocities and depths are more accommodating to an in-stream structure. The expected shallow depth and higher velocities within the riffle section at the Chilliwist Creek site would make construction and operation of an in-stream station potentially difficult. Placement of an in-stream structure upstream from this riffle may be more feasible due to the lower velocities, but still could present challenges due the irregular channel shape and deep water. These physical characteristics contribute to more desirable hydraulic conditions at Raymar such as lower velocities, shallower depths, and in turn, a less armored bed with smaller bed material (making construction easier). In addition, Raymar has excellent access and the availability of power.

Conceptual Design

We believe the method with the highest likelihood for successfully achieving the objective of a species-specific, system-wide census count of anadromous fish using a "hands off" and automated method is an enumeration facility design that includes a semi-permanent, floating picket weir in conjunction with a series of underwater video camera arrays at the Raymar site (Photo 7 and Photo 8). This method of counting upstream migrating fish has been accomplished with relatively good success in several other locations (Demarchi and Miller 2002; Baxter et al. 2004; Miller et al. 2004). A simplified layout of this type of facility is presented in Figure 10 and illustrates the preferred location of a structure at the Raymar site.

The weir option for the lower Okanogan River has several operational and logistical constraints, and a variety of other potential issues that may make it an unattractive venture. First, it is likely that a structure with an appropriate design flow specification to meet the census objective would be very expensive. To meet the species-specific, census objective for peak flows of 20 kcfs would require a facility more resembling a dam and fishway, rather than a typical picket weir. In addition, at flows over 5 kcfs, it is likely that turbidity would be high enough to prohibit the collection of suitable video imagery.

However, if the objective is relaxed to maximize the opportunity to count fish at flows up to 5 kcfs, the weir and video option has the potential to be successful. At this design flow, the scale of the structure is small enough to have a reasonable cost, and produce useful monitoring information. At 5 kcfs, water depth and velocity at the site would be approximately 3.4 ft and 4.2 ft/sec, respectively. One of the greatest challenges to operating such a facility would be the installation of the structure on the descending limb of the spring freshet, and minimizing the number of missed fish migrating prior to this time. Installation could likely be achieved at flows less than 1 kcfs, but these are not typically observed until at least mid-July (Figure 11). Based on run timing data from radio-telemetry studies, Chinook have been observed to enter the Okanogan on 15 June, sockeye on 6 July, and steelhead on 20 September, and yearly timing is highly temperature dependent (Alexander et al. 1998; English et al. 2003). Therefore, some portion of the earliest migrants would be missed. The most likely time period for operation would then be mid-July through November, with the potential for a non-operational period due to a fall freshet.

The weir could likely be run longer into the winter until ice-up requires termination. The weir could also be operated after ice-out for the period February through April to target potential movements of steelhead. We believe it would be prudent to not have the structure in place during the spring freshet period (May-June) to avoid severe damage to the components.

The estimated cost for constructing of a 5 kcfs enumeration facility would range from approximately $600,000 to $1,000,000 depending on the specific design options. A table of considerations when designing a weir is provided in Appendix A, and a projected time table for activities are provided in Appendix B. Also note that the weir option provides a strong potential for accomplishing the CCT's secondary goal of collecting broodstock for Okanogan River stocks.

RECOMMENDATIONS

In the event that the CCT is interested in pursuing the weir and video option, the following advanced design activities should be considered:

- ✓ Investigate permitting requirements and agency/public support for the conceptual facility;
- ✓ Develop land and power access agreements;
- ✓ Conduct in-river tests of video data collection at a variety of river stages to assess image quality;
- ✓ Develop a detailed design and construction budget.
- ✓ Consider relaxing the data requirement of census counts to that of rigorous population estimates. For example, a mark-recapture program could potentially be conducted for substantially lower cost, and provide credible data.

TABLES

Table 1. Calculated flow quantiles for the Okanogan River.

Observed (cfs)	Flood Frequency Quantiles (cfs)				
Sept. 18, 2005	1-yr	2-yr	10-yr	50-yr	100-yr
750	7200	15700	25500	34840	39040

Table 2. Estimated water discharge, stage, and velocity at the Raymar and Chilliwist sites.

Raymar			**Chilliwist**		
Discharge (cfs)	WSEL (ft)	Velocity (ft/sec)	Discharge (cfs)	WSEL (ft)	Velocity (ft/sec)
750	100.3	2.3	750	95.6	2.4
1000	100.5	2.5	1000	95.9	2.8
2000	101.2	3.2	2000	96.6	3.8
3000	101.8	3.6	3000	97.1	4.6
4000	102.3	3.9	4000	97.6	5.3
5000	102.8	4.2	5000	98.0	5.8
6000	103.3	4.5	6000	98.4	6.3
7000	103.7	4.7	7000	98.8	6.7
7201	103.8	4.8	7201	98.9	6.8
8000	104.1	4.9	8000	99.1	7.1
9000	104.5	5.1	9000	99.5	7.4
10000	104.8	5.3	10000	99.8	7.7
15700	106.7	6.2	15700	101.5	9.2
21490	108.3	6.9	21490	102.9	10.4
25500	109.3	7.4	25500	103.9	11.1

FIGURES

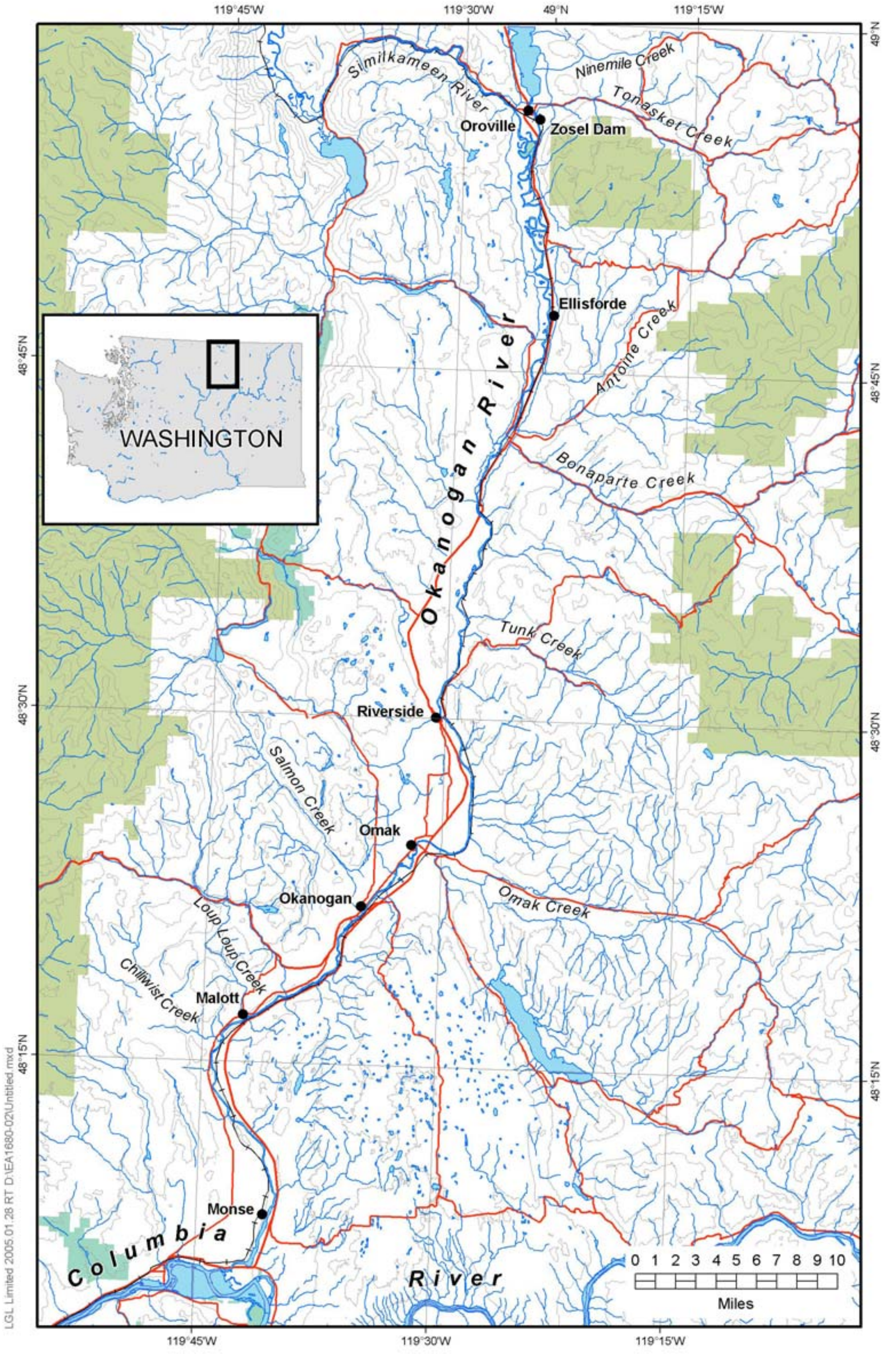


Figure 1. Map of the US portion of the Okanogan River, WA.

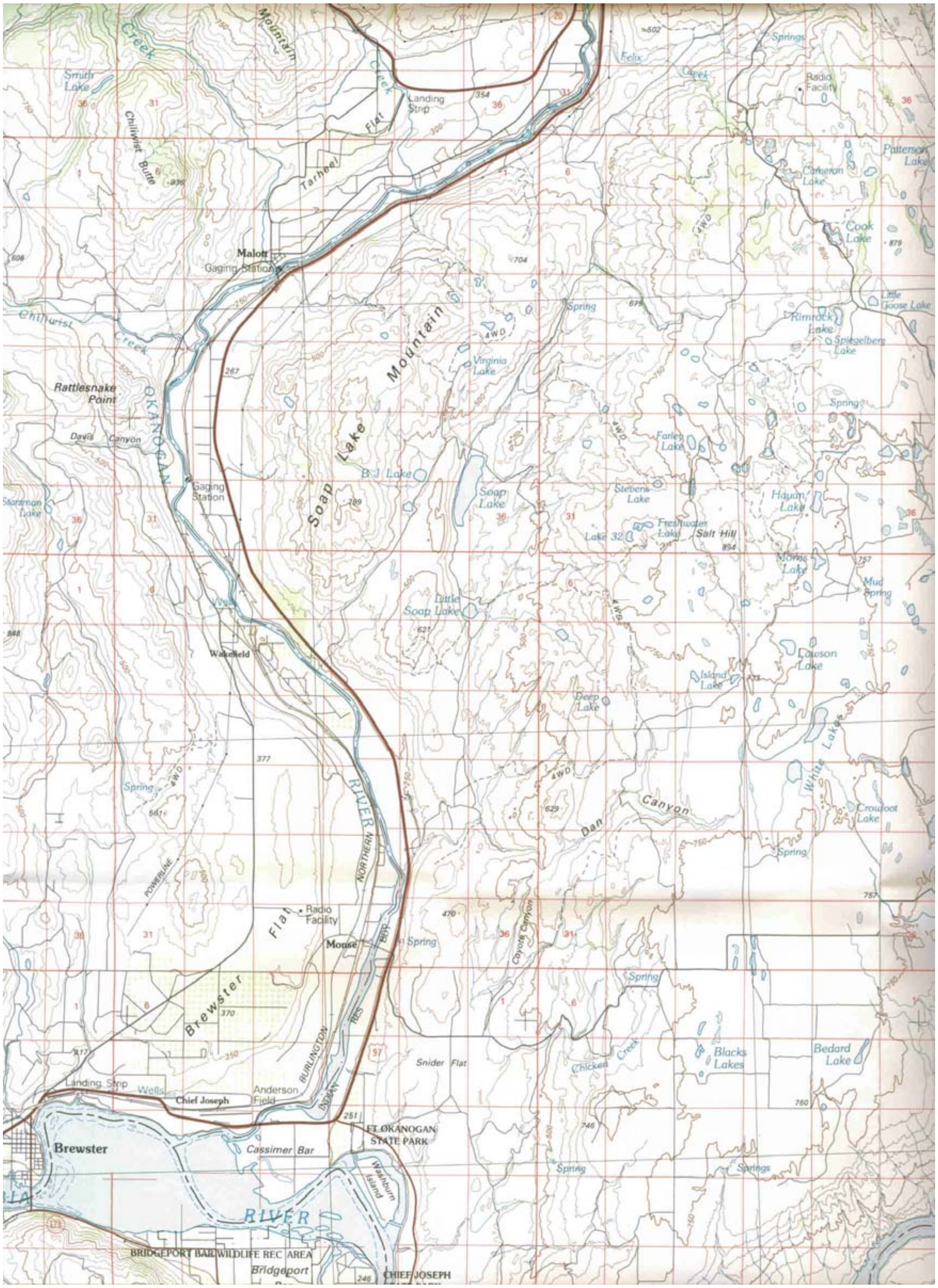


Figure 2. Map of the lower Okanogan River, WA.

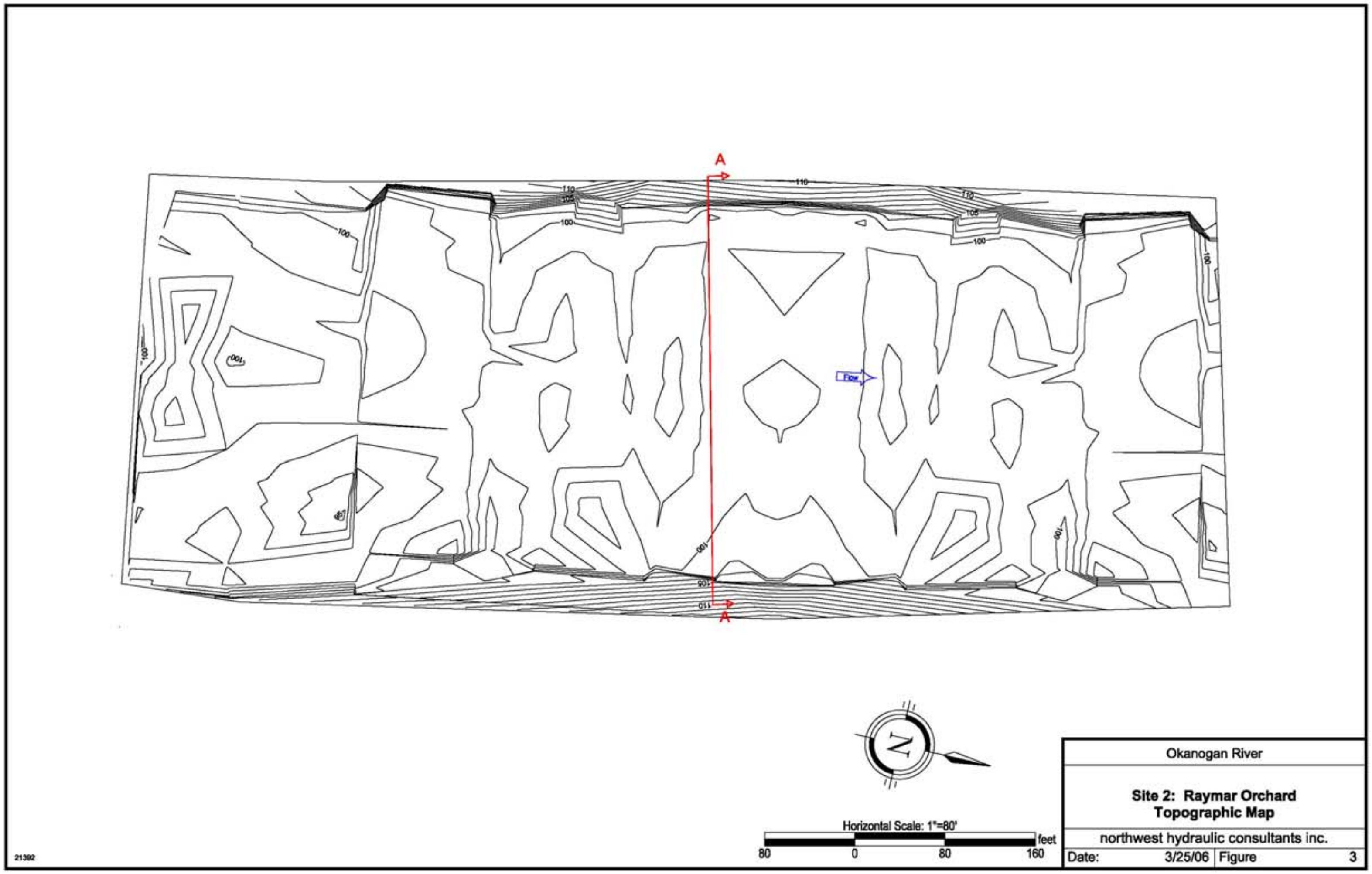


Figure 3. Bathymetric profile for the Raymar site. Cross-section A is 350 ft.

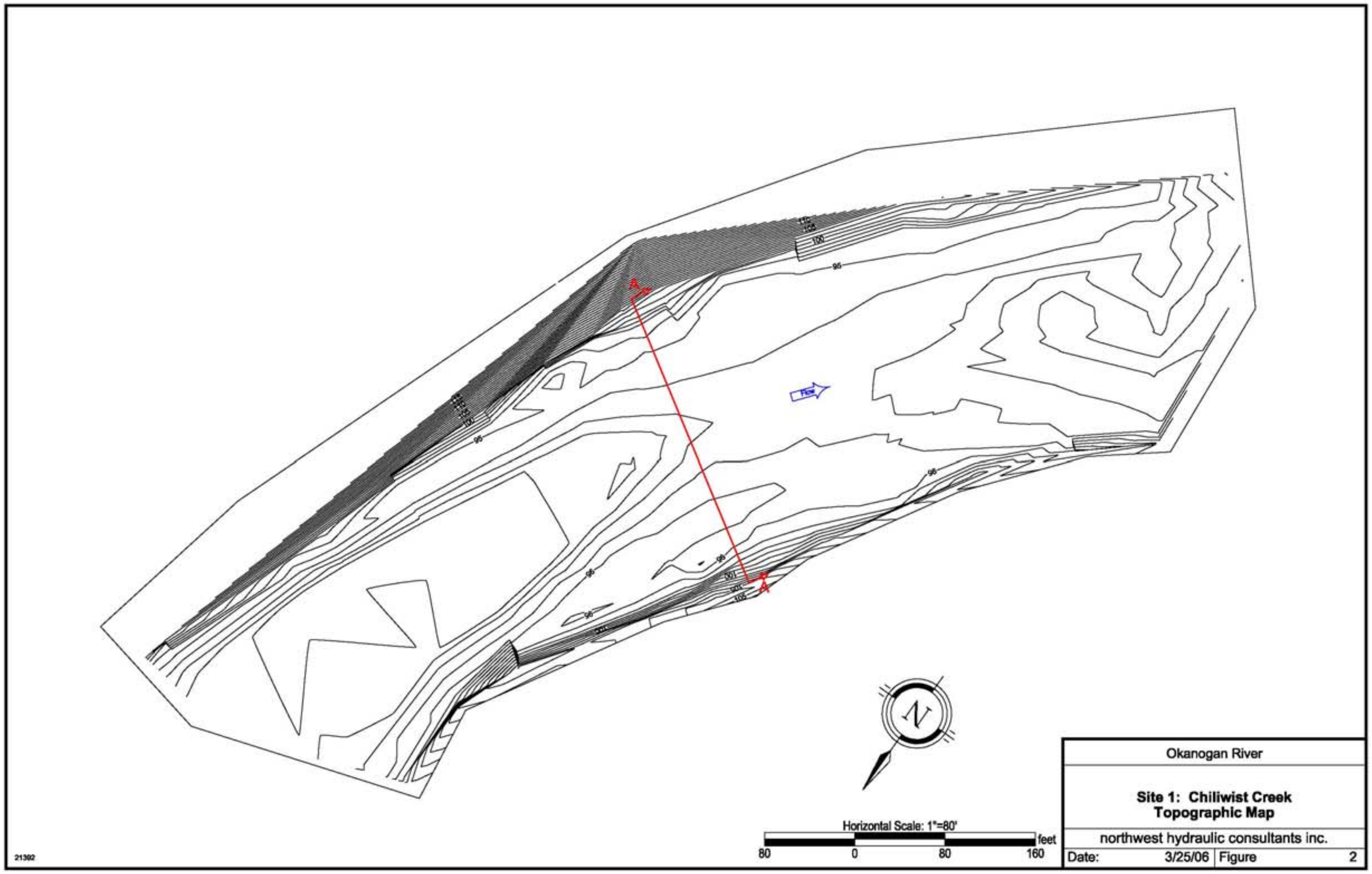
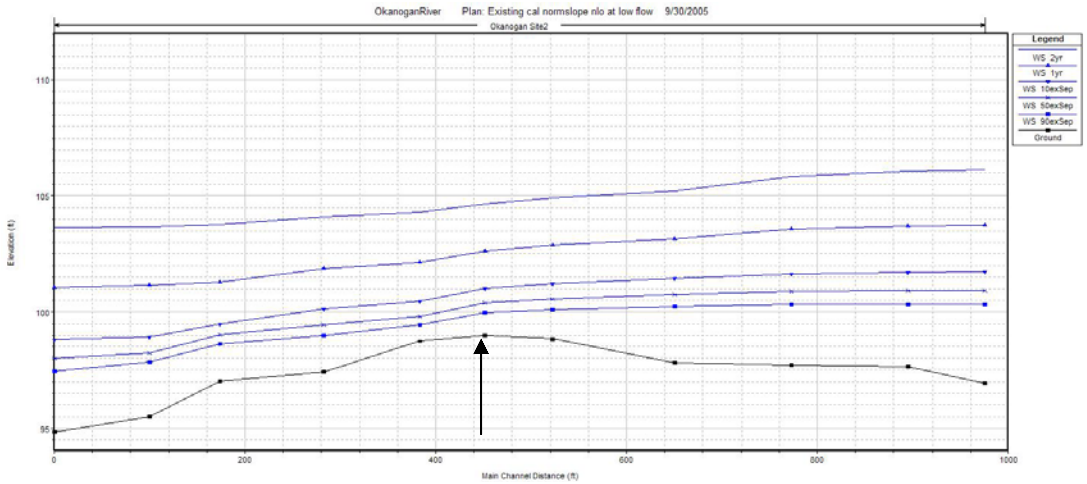
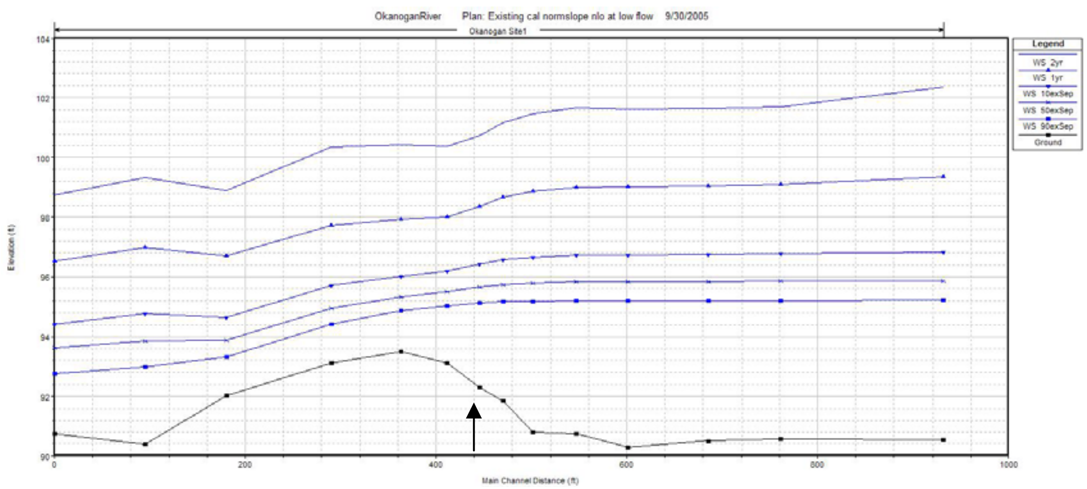


Figure 4. Bathymetric profile for the Chilliwist site. Cross-section A is 260 ft.



Raymar



Chilliwist

Figure 5. Horizontal channel profiles for Raymar and Chilliwist sites. Preferred cross-section is marked.

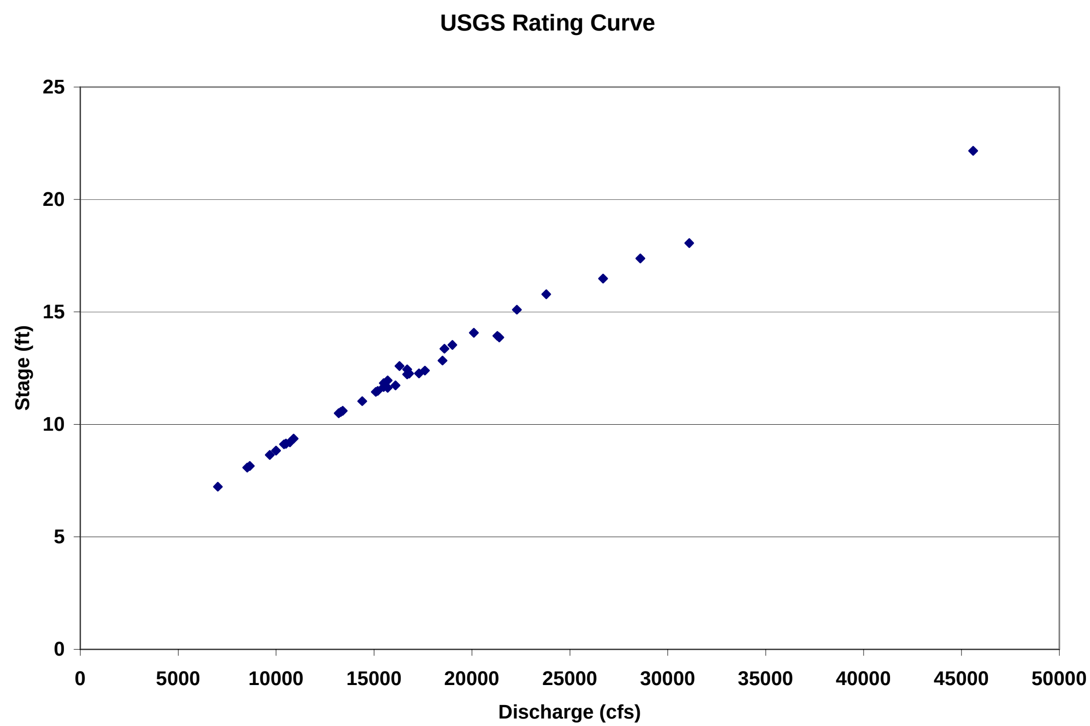
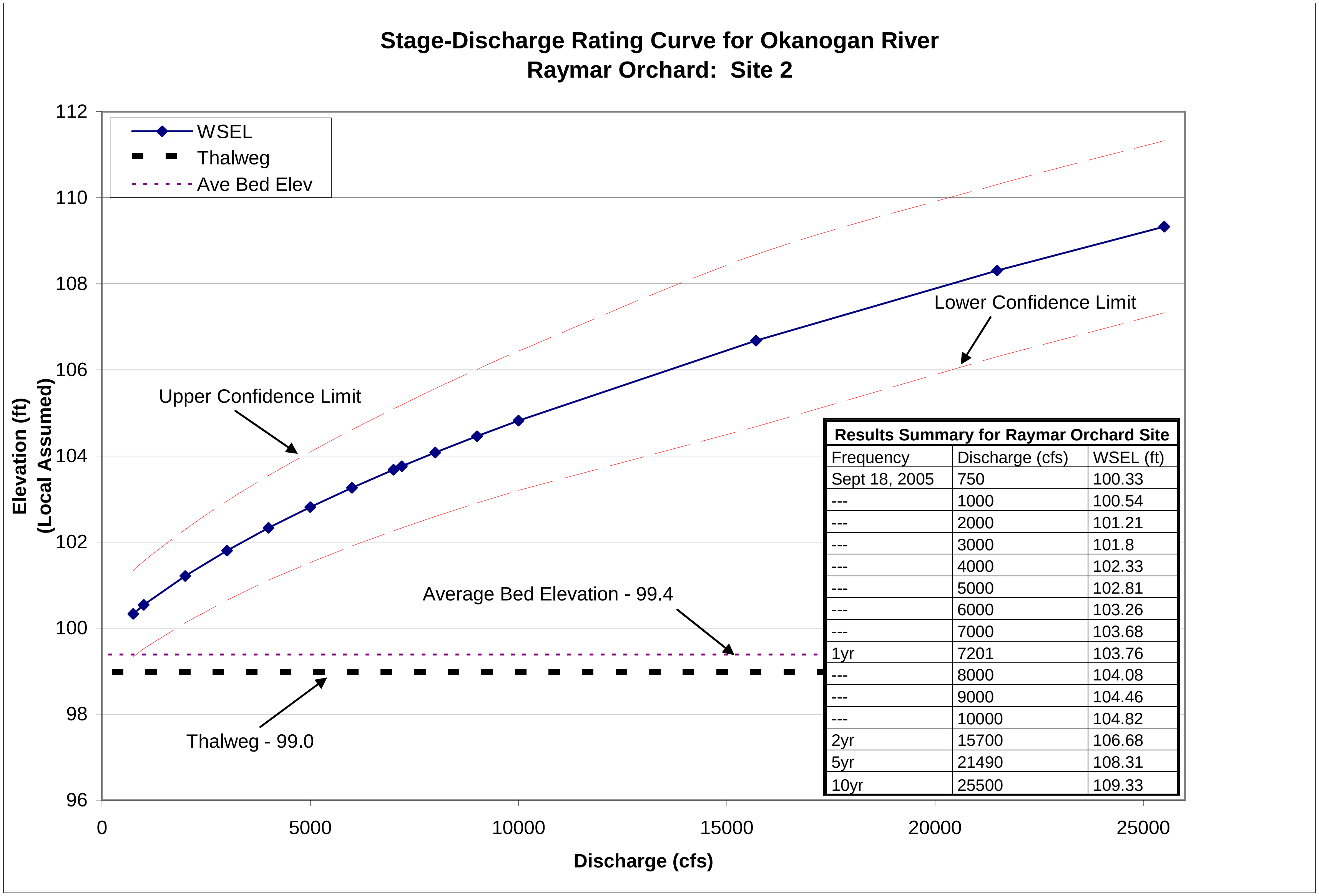


Figure 6. Stage-discharge rating curve data points for Okanogan River.



Results Summary for Raymar Orchard Site		
Frequency	Discharge (cfs)	WSEL (ft)
Sept 18, 2005	750	100.33
---	1000	100.54
---	2000	101.21
---	3000	101.8
---	4000	102.33
---	5000	102.81
---	6000	103.26
---	7000	103.68
1yr	7201	103.76
---	8000	104.08
---	9000	104.46
---	10000	104.82
2yr	15700	106.68
5yr	21490	108.31
10yr	25500	109.33

Figure 7. Stage-discharge curve for Raymar site.

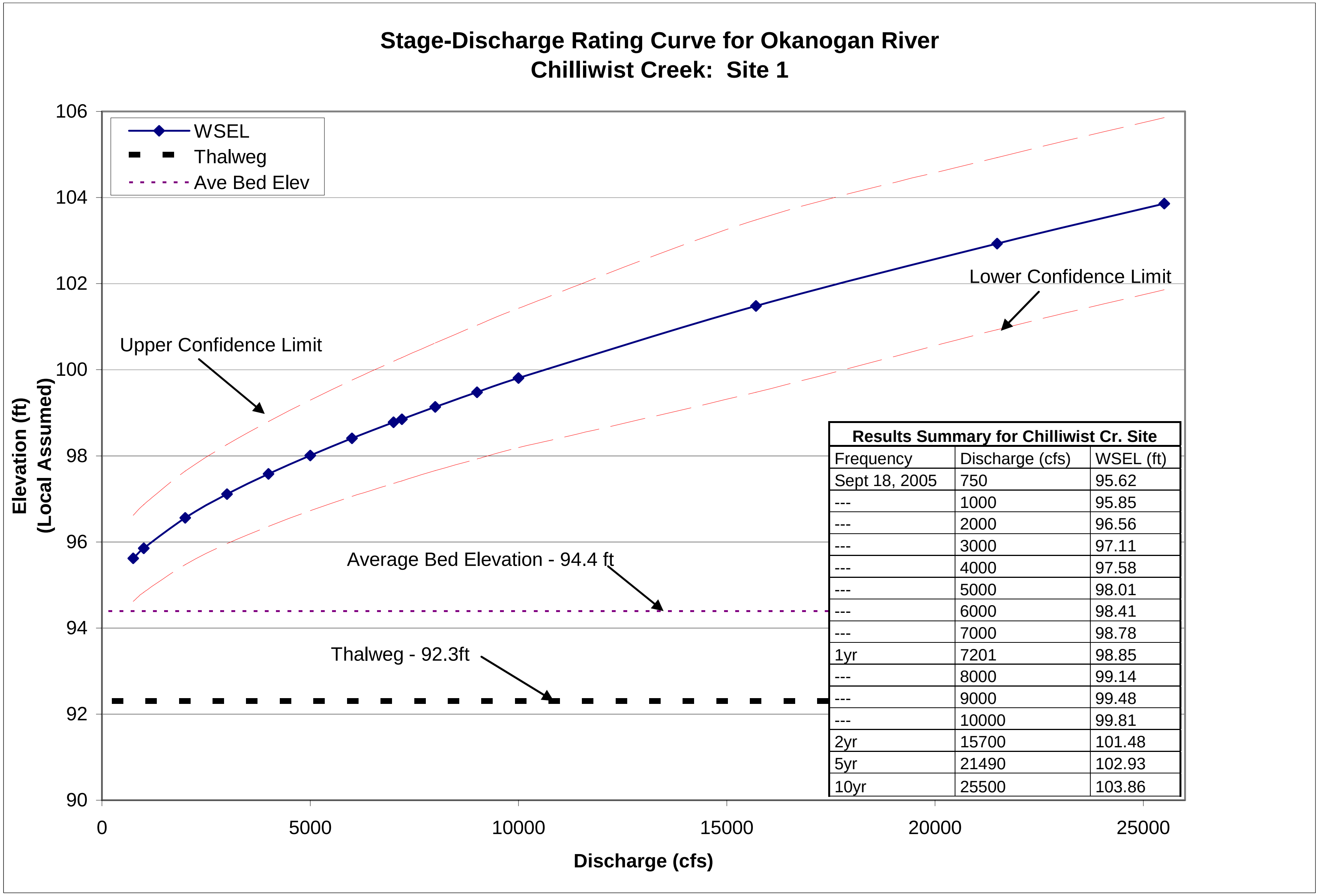


Figure 8. Stage-discharge curve for Chilliwist site.

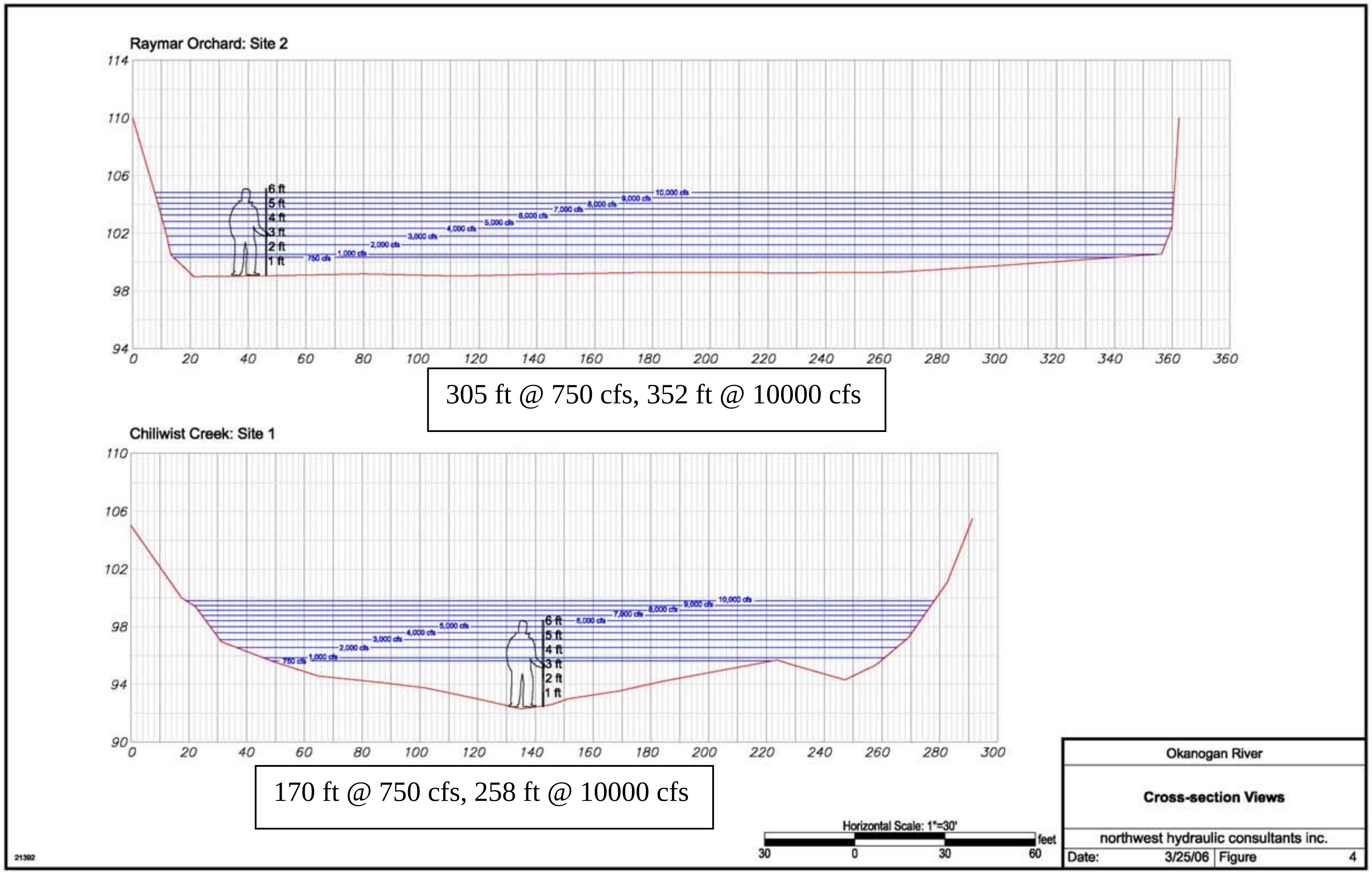


Figure 9. Cross-sectional profiles for Raymar and Chilliwist sites.

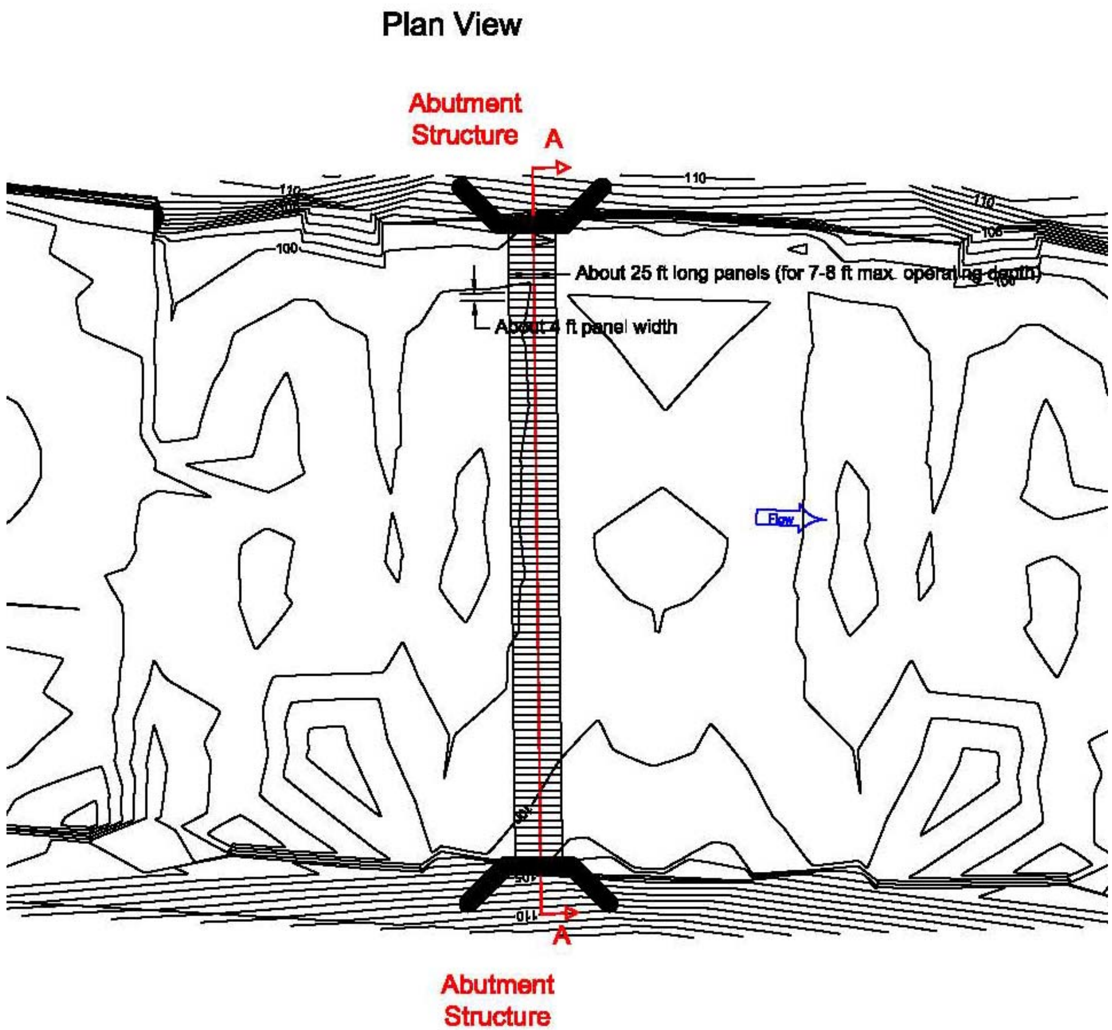


Figure 10. Conceptual design of a picket weir at the Raymar site.

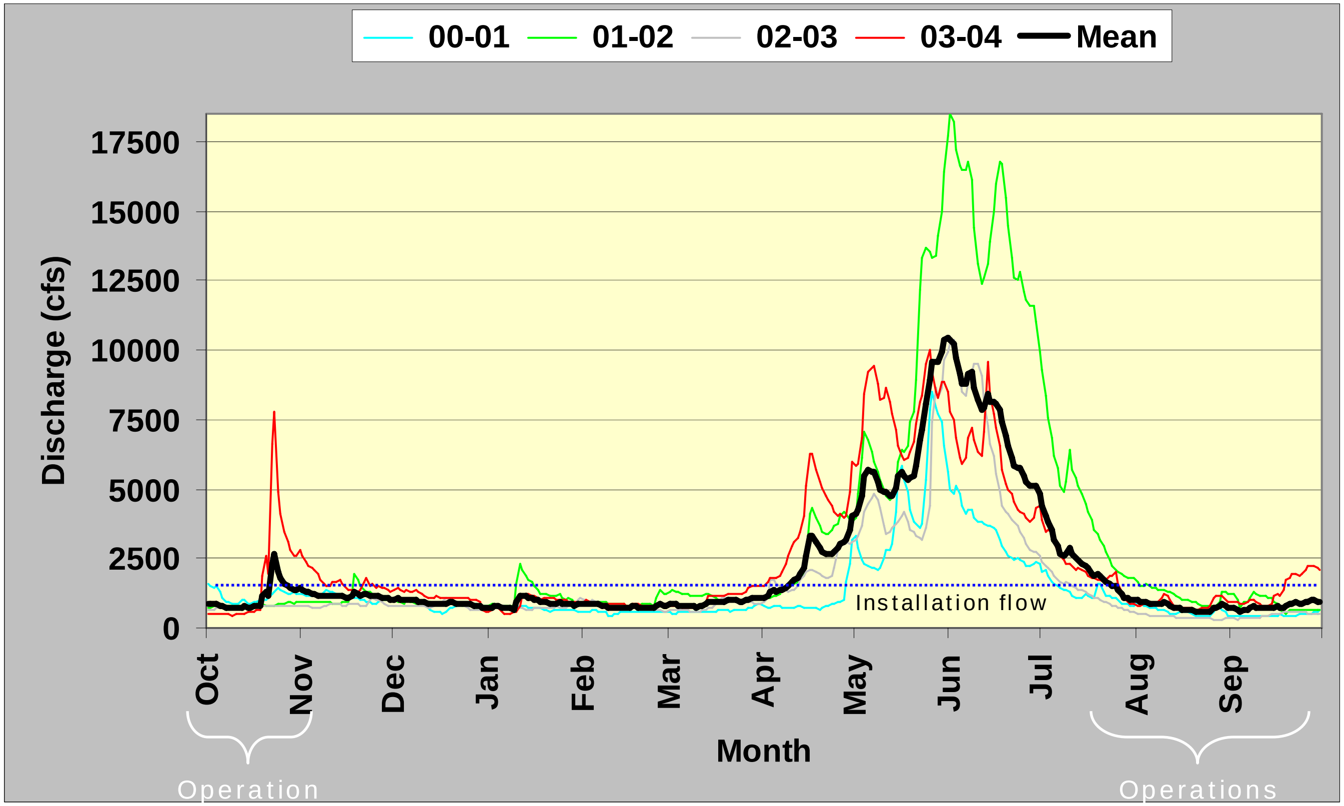


Figure 11. Discharge of the Okanogan River, 2000-2004.

PHOTOS

Photo 1. Aerial overview of the Raymar and Chilliwist sites. White lines indicate preferred cross-section.

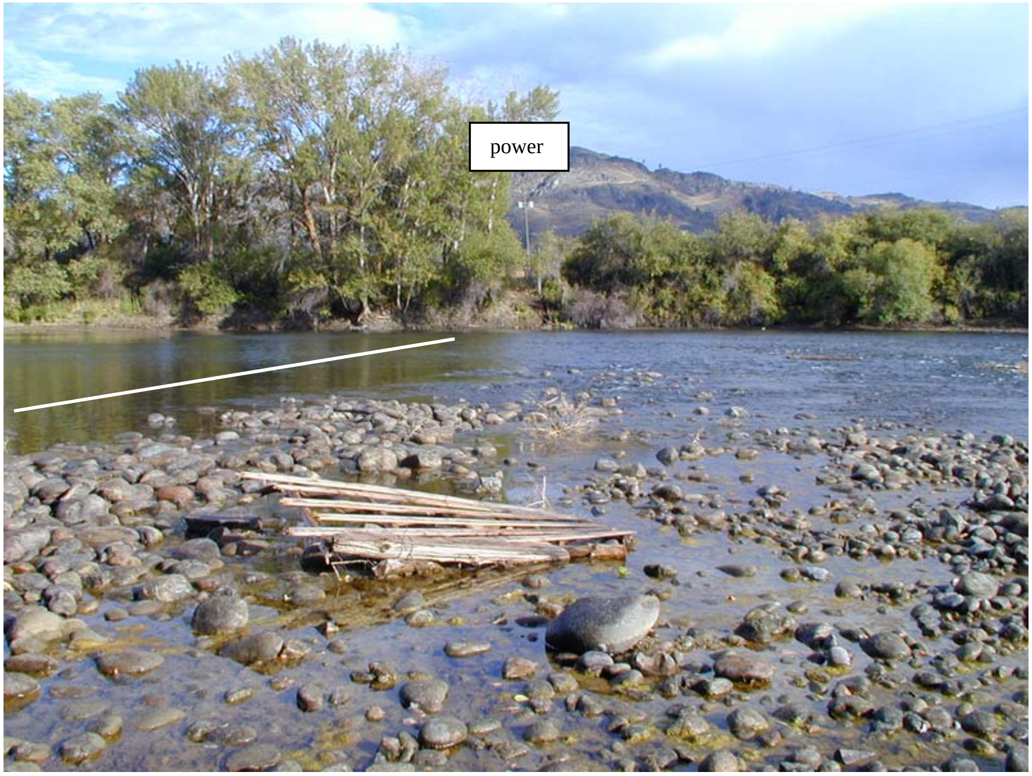


Photo 2. Raymar site looking cross-channel. White line is preferred cross-section.

Photo 3. Raymar site looking upstream. White line is preferred cross-section.

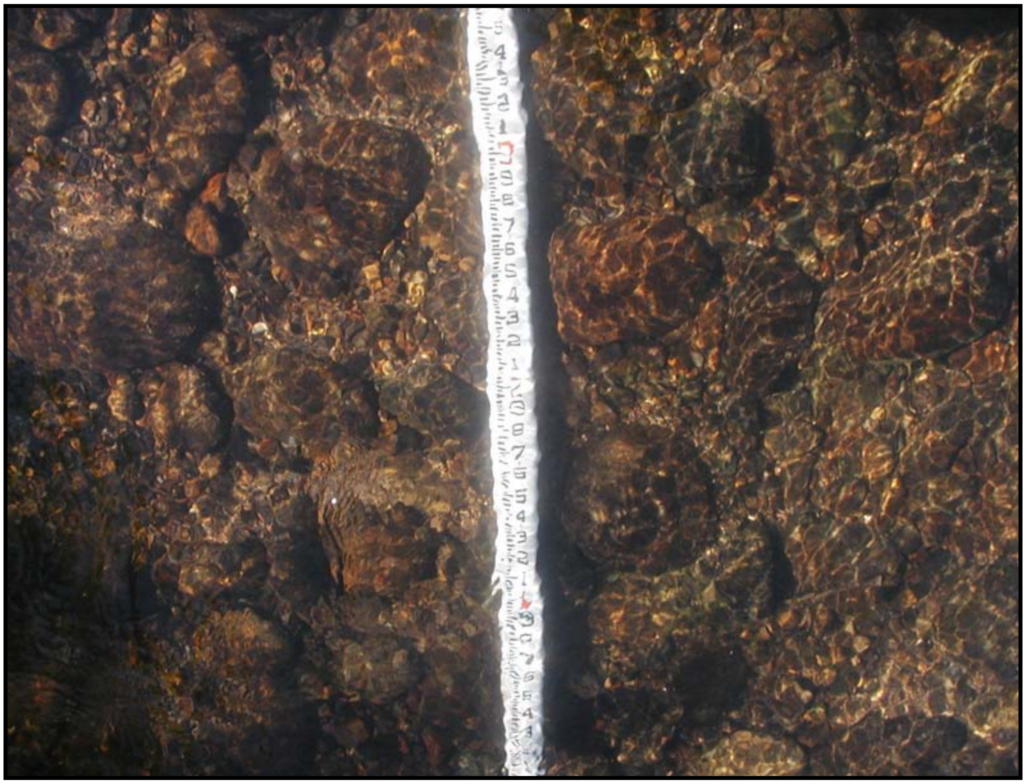


Photo 4. Typical sediment gradation at Raymar site.

Photo 5. Chilliwist site looking cross-channel. White line is preferred cross-section.

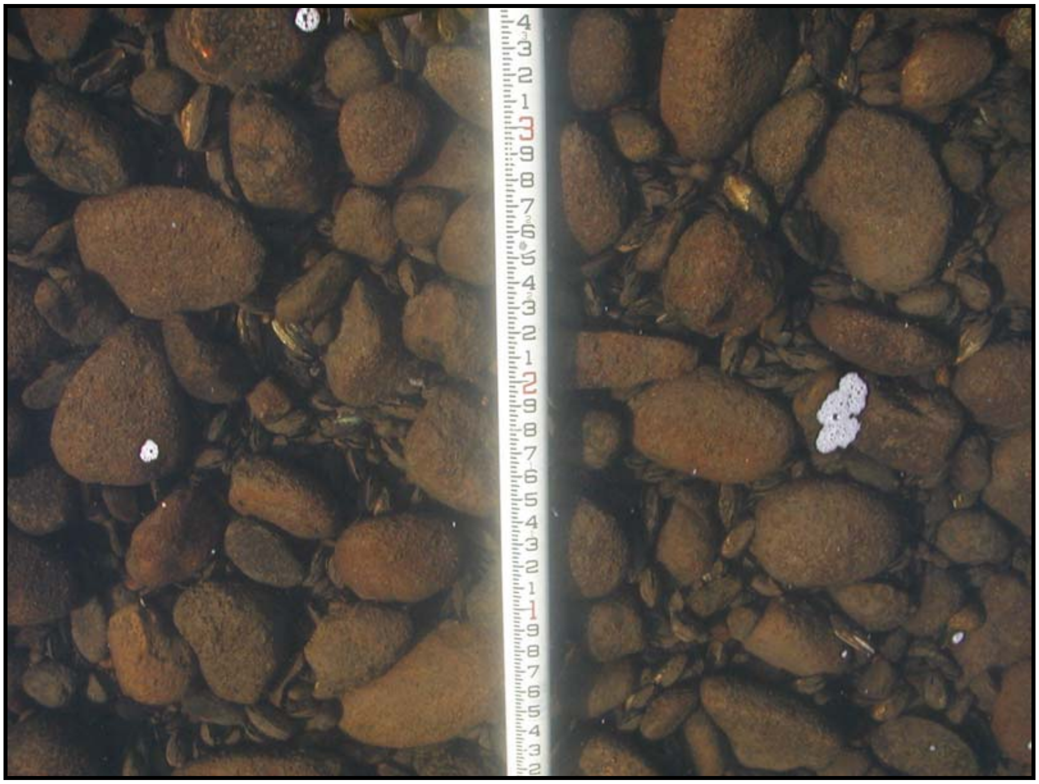


Photo 6. Typical sediment gradation at Chilliwist site.

Photo 7. Conceptual illustration of a picket weir and video array, looking across.

Photo 8. Conceptual illustration of a picket weir and video array, looking downstream.

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APPENDICES

Appendix A. Table of considerations for designing a picket weir.

Aspect	Consideration	Permanent	Semi-Permanent
Structure Complexity	Complex or Simple	Complex	Simple
Implementation Time Line	Level of complexity will determine how long it will take to design and permit.	Six months to a year	Two to four months
Installation Time Line	Level of complexity will determine how long it will take to install.	Two to four weeks initially, one week in subsequent seasons	One to Two weeks, every season
Site Impact	What is the environmental impact of the structure footprint?	Substantial bank and channel disturbance	Minimal bank and channel disturbance
Permitting Complexity	Degree of Site Impact will determine the extent of effort required to determine project effects and needs for mitigation.	Substantial number of issues to address and likelihood for mitigation measures	Typically straight-forward issues
Project Life	How long can the structure reasonably last for future use?	10-20 years	3-5 years
Transferability of Infrastructure	Can the components of the structure be used at other sites?	Removable components can be used at other sites	Very mobile, but prone to damage during setup, take-down and transport
Adaptability of Infrastructure	Can the structure serve other purposes or be readily modified to serve other purposes?	Rigid structure typically allows for modification to serve other purposes. Very adaptable	Semi-rigid structure needs to be substantially jerry-rigged to make it work for other purposes
Operational Period	What is the likelihood of fishing for the entire migration period?	high likelihood to fish all season	low likelihood to fish all season
Operational Complexity	Does the structure make operations and fish processing easy or difficult?	Well thought out structures are a pleasure to work at	Usually under some degree of repair all season long making for potentially frustrating work days
Operational Safety	Does the structure make operations and fish processing safe or potentially unsafe?	Typically very safe	Typically more hazardous to personnel
Capital / Infrastructure Costs	What is the relative scale of the structure?	Mostly one-time costs, but are 3 to 5 times higher than semi-permanent	Many components require replacement or repair each season. Plan on 30% recurring costs, annually
Technical Support Costs	How much technical support time will be required to design, permit, install and operate the structure?	Relatively high up-front costs, but diminishing over time	Recurring costs on an annual basis

Permanent: a structure designed and built to last 10-20 years, or withstand extreme hydraulic conditions for an extended period of time. Typically, permanent weirs have abutments embedded into the channel banks, a concrete or steel sill crossing the channel, and panels made of aluminum. Traps are custom designed to accommodate a variety of needs. Depending on the size of the system, it may include a cat-walk over the channel. Some components of the structure remain in place during non-operational periods.

Semi-Permanent: a structure designed and built to last 3-5 years, and usually is not operational at high system flows. Typically, semi permanent weirs have temporary abutments, a single steel rail for a sill, and panels made of PVC pipe. Traps are simple PVC and need to be monitored constantly or shut down. Can become unsafe at high water levels. Few to any of the components remain in place during off-season periods.

Appendix B. Time table for designing, permitting, and constructing a picket weir.

Task		2006												2007												2008									
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Okanogan Conceptual Design	■																																		
CT endorsement of concept		■																																	
Investigate permitting requirements					■	■																													
Conduct in-river tests							■	■	■	■																									
Detailed Facility Design											■	■	■																						
JARPA / County Permitting Process														■	■	■	■	■	■																
EIS / NEPA Permitting Process														■	■	■	■	■	■																
Final Operations and Weir Design																				■	■														
Access and Site Construction																						■	■	■											
Weir Fabrication																						■	■	■											
Operational Components Procurement																								■	■	■	■								
Sill Installation																												■							
Weir Operation																															■	■	■	■	■