Minimum Instream Flow Study of Tucannon River at Marengo

Submitted to

WRIA 35 Planning Unit

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Executive Summary

Field measurements of depths and velocities were made during the April-July 2003 time period at eight representative stations along the river just downstream of the Marengo bridge crossing. Flows ranged from a high of 181 cfs in April to a low of approximately 59 cfs in July. Based on this information, Weighted Usable Area (WUA) values were developed for the Tucannon River using the PHABSIM model for steelhead, chinook and bull trout. These results are summarized in the following figures and table.

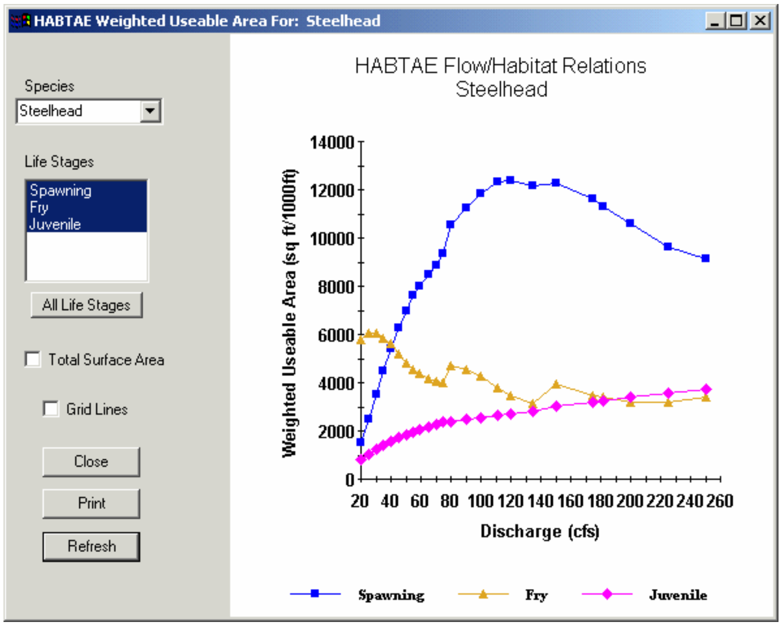

Figure. WUA for Steelhead Life Stages

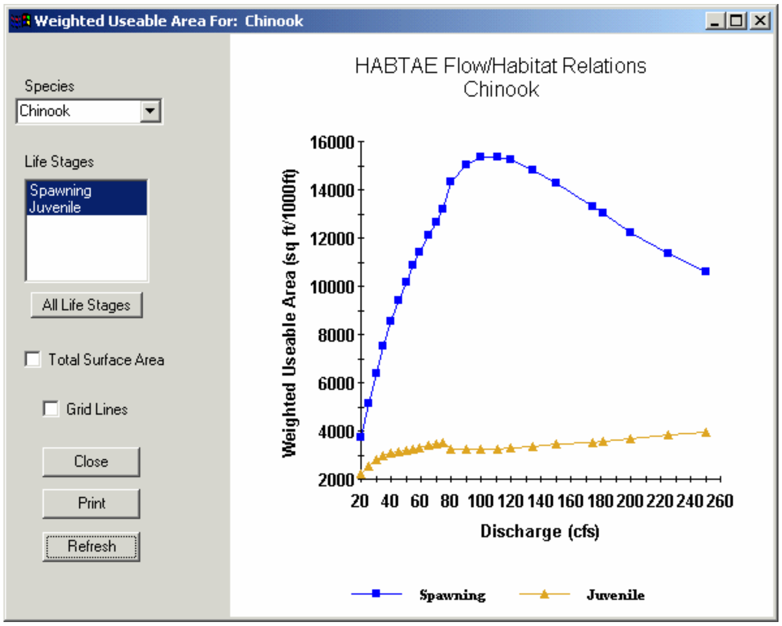

Figure. WUA for Chinook Life Stages

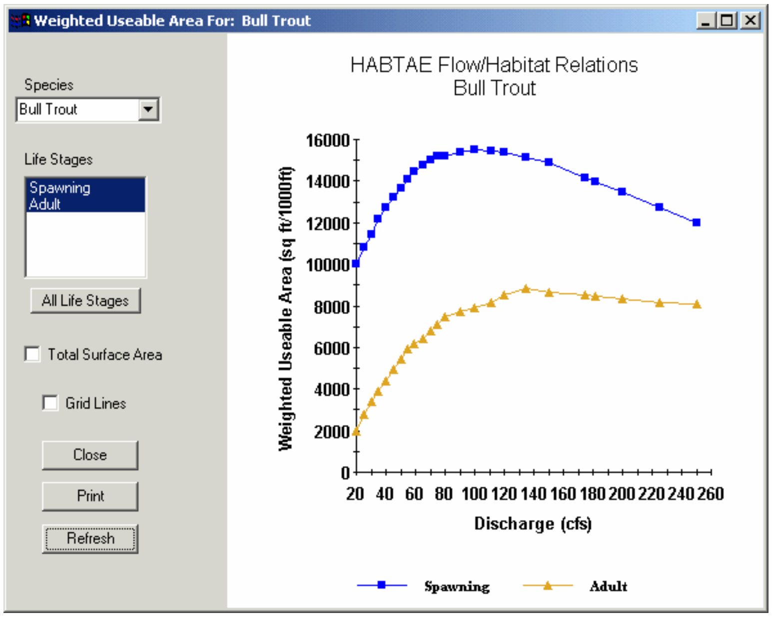

Figure. WUA for Bull Trout Life Stages

Table. Summary of WUA Results

	Steelhead			Chinook		Bull Trout	
Flow	Spawn	Fry	Juvenile	Spawn	Juvenile	Spawn	Adult
20.0	1,503	5,759	831	3,754	2,239	10,016	1,972
25.0	2,482	6,054	1,044	5,146	2,546	10,825	2,785
30.0	3,492	**6,064**	1,248	6,389	2,794	11,454	3,425
35.0	4,470	5,851	1,427	7,518	2,980	12,139	3,916
40.0	5,411	5,637	1,588	8,526	3,089	12,733	4,379
45.0	6,255	5,210	1,720	9,384	3,141	13,194	4,912
50.0	6,985	4,823	1,847	10,163	3,201	13,670	5,458
55.0	7,613	4,533	1,971	10,859	3,247	14,096	5,912
59.2	8,027	4,365	2,064	11,410	3,305	14,432	6,156
65.0	8,468	4,166	2,173	12,129	3,383	14,793	6,430
70.0	8,872	4,078	2,268	12,661	3,444	15,036	6,784
75.0	9,333	3,999	2,360	13,170	3,504	15,223	7,097
80.0	10,533	4,715	2,392	14,299	3,236	15,207	7,503
90.0	11,251	4,553	2,473	15,010	3,231	15,402	7,749
100.0	11,859	4,248	2,539	**15,339**	3,232	**15,487**	7,907
111.1	12,305	3,773	2,633	15,328	3,267	15,435	8,172
120.0	**12,362**	3,472	2,700	15,226	3,285	15,368	8,525
135.0	12,175	3,152	2,819	14,805	3,330	15,115	**8,816**
150.0	12,254	3,963	3,009	14,271	3,439	14,896	8,669
175.0	11,613	3,463	3,191	13,307	3,533	14,160	8,528
181.6	11,313	3,381	3,241	13,032	3,573	13,976	8,448
200.0	10,591	3,178	3,381	12,227	3,689	13,454	8,338
225.0	9,636	3,216	3,564	11,332	3,846	12,712	8,182
250.0	9,109	3,384	**3,722**	10,591	**3,946**	11,980	8,080

The results of the PHABSIM investigation were relatively consistent with the results found by Caldwell (1995) at the mouth of the Tucannon. Caldwell found that steelhead spawning potential was highest at 105 cfs versus the 120 cfs found in this study. Similarly, Caldwell found that 85 cfs was needed to maximize Chinook spawning versus 100 cfs in this study. Given the change in channel characteristics between the mouth and the reach at Marengo, this small variation appears to be a reasonable expectation.

Based on this information as well as on the timing of fish utilization, temperatures, and historic gage flows at Starbuck, the following preliminary discussion flow recommendations were made. It is important to note that these flows are intended to be initial starting points for setting minimum instream flow recommendations. Actual setting of such flows requires complex negotiation among stakeholders and State regulatory and resource agencies and may consequently be quite different than those shown here.

Table. Preliminary discussion flow recommendations.

Month	Discussion Flow (cfs)
October	90
November	100
December	110
January	110
February	120
March	120
April	120
May	120
June	100
July	70
August	60
September	65

Minimum Instream Flow Study of Tucannon River at Marengo

1.0 Introduction

The Tucannon River is an important aquatic resource in that empties into the Snake River at River Mile 62.2 between Little Goose and Lower Monumental dams approximately 386 miles from the mouth of the Columbia River. Because of increasing concerns for resident bull trout and anadromous salmonid species in WRIA 35, minimum instream flows are needed to protect several important rearing and spawning reaches in the river system. Additional data are also needed to help make management decisions regarding the implementation and prioritization of watershed restoration activities. In 1972, the Washington Department of Fisheries recommended a minimum instream flow of 50 cfs at the mouth of the Tucannon River. A subsequent study in 1993 by the Washington Department of Ecology used the USGS gaging data at Starbuck (River Mile 7.9) as the basis for a recommended 65 cfs minimum instream flow requirement during the summer irrigation season (Covert *et al.* 1995). Consequently, surface water rights issued between 1972 and 1993 are subject to the 50 cfs low flow recommendation while rights after 1993 must abide by the higher flow requirement. Caldwell (1995) performed an Instream Flow Incremental Methodology (IFIM) study at River Mile 5.8 of the Tucannon approximately 500 feet upstream of the Starbuck dam. The study found flow requirements of 40 to 160 cfs to maximize weighted usable area (WUA) estimates depending of fish species and life stage.

While flow requirements at the mouth of the watershed may protect threatened and endangered fish species, except for Fall Chinook, most of the actual usable spawning habitat on the Tucannon is considerably upstream of the Starbuck location. A newly installed gage on the Tucannon River at River Mile 24 immediately downstream of the Turner Road Bridge near Marengo, Washington may permit better management of the watershed as the Starbuck gage includes potentially significant inflows from the Pataha Creek basin. As a result, an assessment of flow requirements was conducted near this new gage location. The approximate study site location is shown in Figure 1. This report documents the results of the PHABSIM analysis performed on data collected during three field trips in water year 2003.

Eight representative cross-sections were selected at each of the seven stream segments based on this initial field reconnaissance survey. Care was taken to include pool, spawning, riffle and other unique stream characteristics. Depth and velocity profiles were measured at each of the cross-sections. Data collection involved measuring these parameters at three different water stages: high, medium, and low. Substrate grab samples were taken along each of the eight reaches for subsequent analysis. Temperature data were also recorded during sampling. An assessment of vegetative cover was also performed. Photographs of each site were taken in order to help document items such as cover, stream conditions, and site characteristics. Minimum instream flow modeling and analysis were conducted using the PHABSIM/IFIM technique for the Tucannon River at Marengo site. Habitat suitability indices were assigned to each stream cell. This report documents the assumptions, procedures, and results of this investigation.

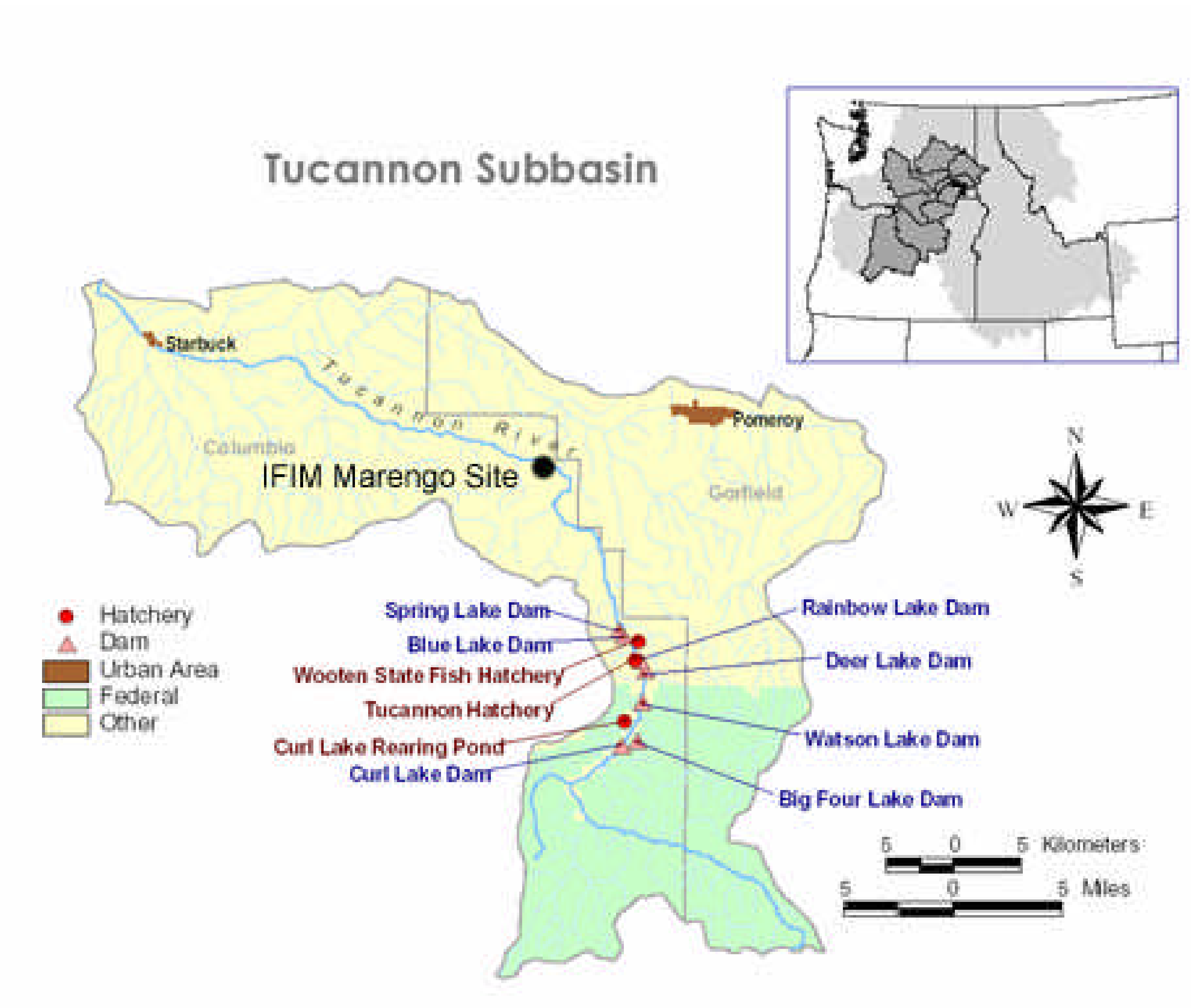

Figure 1. Map of Study Area (After CBFWA, 2001)

2.0 Background

2.1 PHABSIM Approach

The quantity of water needed for minimum instream flow is determined by considering existing data, the hydrology of a stream and its natural variations in flow over the year, fish requirements and other related factors. A wide range of procedures are available for determining minimum flow requirements, ranging from standard-setting techniques to incremental techniques. The three most commonly used methods are the: (1) IFIM, (2) toe-width, and (3) Tennant (aka “Montana”) method (Rushton 2000). In keeping with the format adopted by the WDOE, the IFIM technique was adopted for each of the three river segments listed above. IFIM was originally developed by the U.S. Fish and Wildlife Service (Trihey and Stalnaker 1985) primarily as a means of determining flow requirements downstream of hydropower relicensing efforts. The methodology integrated water supply requirements with analytical models from hydraulic and water quality engineering and empirically derived habitat versus flow functions. Over a period of 15 years, IFIM has developed into a river network analysis that incorporates fish habitat, recreational opportunity, and woody vegetation response to alternative water management schemes (Stalnaker *et al*. 1995).

There are *five critical steps* to conducting an IFIM analysis:

1) Problem Identification,
2) Study Planning,
3) Study Implementation,
4) Alternative Analysis, and
5) Problem Resolution.

These steps interact to form the basis for the watershed plan. For example, under “Problem Identification” it was assumed that minimum instream flows are necessary to protect and restore anadromous fish runs and bull trout in the Tucannon River system. There may be additional reasons or other species needing protection, but those would not necessarily be accounted for in the current investigation. Similarly, segments of the river other than those identified in the study planning meeting may prove to be more important.

The Physical HABitat Simulation (PHABSIM) computer model was used in this investigation. PHABSIM is commonly used to calculate the “weighted usable area” (WUA) for each cross-section over a range of flows. The WUA can essentially be computed using an equation in the form of:

$$WUA = \sum_{\mathrm{i=1}}^{\mathrm{N}} A_i \ * \left(\mathrm{PF_d} * \mathrm{PF_v} * \mathrm{PF_s} * \mathrm{PF_c}\right) \tag{1}$$

where A is the cell area, PF_d is a depth preference or weighting factor, PF_v is a velocity preference factor, PF_s is a substrate preference factor, PF_c is a cover preference factor, and N is the number of cells in the cross-section.

The components of a river system that determine fisheries productivity can be summarized into four major categories. These are:

1) flow regime,
2) physical habitat structure-channel form, substrate distribution, and riparian vegetation,
3) water quality, and
4) watershed energy inputs (sediments, nutrients and organic matter).

Often, IFIM is equated only to the PHABSIM model. The intended purpose of PHABSIM is to simulate streamflow and physical habitat relationships for various life stages or recreational activities. Consequently, many of the other factors are routinely overlooked. The cost of obtaining meaningful data for each of the categories listed as Items 3 and 4 (quality and energy) can be enormous for complex or large watersheds. To the maximum extent possible, these factors are included in the analysis. However, except for some additional flow and temperature data, new information was not collected as part of this study. Decisions were drawn from existing studies and local experience.

Although IFIM is the most widely used approach for setting instream flow requirements, there are several underlying assumptions that must be considered to fully understand the recommendations and values proposed in this report. Stein (1997) examined the implications of these assumptions for a particular watershed and concluded that they were valid under many circumstances. Nevertheless, readers should be aware of the three most significant assumptions when interpreting IFIM results. First, IFIM is governed by scientific evidence demonstrating that fish prefer water with a certain depth and velocity. Second, it also assumes a direct positive correlation between the WUA and fish abundance. Third, it is also posits that the preference curves are more accurate predictors of fish distribution than utilization curves.

While each of these suppositions appears valid for the Tucannon River system, the body of evidence supporting these assumptions is far from complete. For example, preference curves have generally been determined by snorkeling or observing the location of fish during daylight hours and usually for a narrow range of flow rates. Behavior under nighttime conditions or extrapolating to different water levels may introduce uncertainty into the analysis. Moreover, the entire premise of the second assumptions is that fish populations are limited primarily by habitat availability. The consequences of downstream impacts are not considered. Consequently, factors such as the operation of Columbia River dams are not seen as impacting fish populations.

In spite of these issues, the IFIM procedure appears to represent the best tool currently available for predicting flow requirements. The remainder of this report describes the historic information, data collection, and analytical techniques used to implement the study.

2.2 Fisheries Concerns

While there are a number of important species potentially present in the Tucannon watershed, this study focuses on spawning and rearing requirements for steelhead, chinook, and bull trout. Understanding the interpretation and limitations of the WUA modeling requires a brief overview of the life history patterns of these species. For example, it is critical to realize that flow without proper water temperatures will not achieve the desired results. It is also important to realize that when looking at WUA flows for spawning that spawning may take place only for a relatively short period of time. A complete review of fisheries is beyond the scope of this project. For readers wanting more information concerning Tucannon fish populations, a thorough description of salmonid and bull trout utilization can be found in the Ecosystem Analysis conducted by the US Forest Service (Bassett et al. 2002).

Steelhead

Although severely depressed from historic levels, steelhead continue to be an important anadromous fish species in the Tucannon. Steelhead begin entering the stream in September once temperatures begin to fall. However, exceeding cold water temperatures in December and January often significantly reduce upstream adult migration. As illustrated in Table 1, spawning begins in February and typically runs through May. In some years spawning has continued into early June, but peak spawning occurs in March, April and May. Fry generally emerge April through early June. Juvenile steelhead rear in the watershed for up to two years before migrating out to the ocean (WDF, 1990).

Table 1. Freshwater life history patterns (LHP) of steelhead.

LHP	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adult upstream migration	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes			Yes
Spawning					Yes	Yes	Yes	Yes	Yes			
Incubation/ emergence					Yes	Yes	Yes	Yes	Yes			
Juvenile rearing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adult/Juvenile out migration				Yes	Yes	Yes	Yes	Yes	Yes			

Chinook

The spawning window for Spring Chinook in the Tucannon is limited to late August through mid-September, a period when flows and temperature may limit movement of adult fish into spawning beds. Insufficient flows during the onset of incubation may severely limit survival since redds require adequate flushing and oxygenation. Table 2 indicates that the lower reaches of the Tucannon are temperature limited and therefore provide little to no viable habitat. Reports also indicate the sedimentation and lack of deep pools may also limit the usability of lower stream segments.

Table 2. Description of Five Spring Chinook Strata in Tucannon River
(after Gillinat *et al*. 2001)

Strata	Land Ownership/Usage	Spring Chinook Habitat	River Mile
Lower	Private/ Agriculture & Ranching	Not Usable (temperature)	0.0 – 12.5
Marengo	Private/ Agriculture & Ranching	Marginal (temperature)	12.5 – 25.0
Hartsock	Private/Agriculture & Ranching	Fair to Good	25.0 – 35.5
HMA	State and Forest Service/ Recreation	Good to Excellent	35.5 – 46.3
Wilderness	Forest Service/Recreation	Excellent	46.3 – 53.6

The life history pattern of Spring Chinook is quite different than steelhead. Table 3 summarizes the LHP of Spring Chinook in the Tucannon. As indicated, Chinook arrive later April through mid-June and spawning begins in late August. Emergence occurs in the following spring. Reports indicate that smolt out migration may occur as early as November although April and May are still regarded as the peak months.

Table 3. Freshwater life history patterns (LHP) of Spring Chinook

LHP	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adult upstream migration							Yes	Yes	Yes			
Spawning											Yes	Yes
Incubation/ emergence					Yes	Yes						
Juvenile rearing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Juvenile/Smolt out migration		Yes	Yes	Yes	Yes	Yes	Yes	Yes				

Bull Trout

According to the US Fish and Wildlife Service, the Critical Habitat Subunits include the Tucannon River, Little Tucannon River, and Pataha Creek watersheds and their upstream tributaries. Bull trout have been observed using the entire length of the Tucannon River as rearing habitat. Cummings Creek is the most downstream of the upper Tucannon tributaries containing bull trout (WDFW, 1998). As summarized in Table 4, spawning starts in September and continues through October and sometimes into early November. Bull trout are susceptible to mortality during unstable channel and flow conditions as a result of their extended residence in the substrate. Successful reproduction requires channel and substrate stability and adequate winter water flow to prevent the substrate from freezing. A considerable amount of work remains to be done to firm up our understanding of Bull Trout LHP in the Tucannon River.

Table 4. Freshwater life history patterns (LHP) of bull trout.

LHP	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adult upstream migration									■	■	■	■
Spawning	■											■
Incubation/ emergence	■	■	■	■	■	■	■	■	■	■	■	■
Juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
Adult/sub-adult migration and overwintering	■	■	■	■	■							

2.3 Existing Stream Flow and Water Temperature Data

The elevation of the Tucannon rises from 500 ft at the mouth to nearly 6,840 ft at the headwaters. The total watershed area is approximately 502 mi^2 and generates a mean annual flow of 166 cfs at the Starbuck gage. Because of the elevation differences, much of the runoff is generated at higher levels in the basin. This is indicated by the high flows generated by snowmelt in May and June. Average daily flow data for the USGS Tucannon River gage at Starbuck is available. Figure 2 illustrates the temporal change in discharge for the most recent period. Intermittent records have been kept on the stream since 1914 but to sparsely to add to the figure.

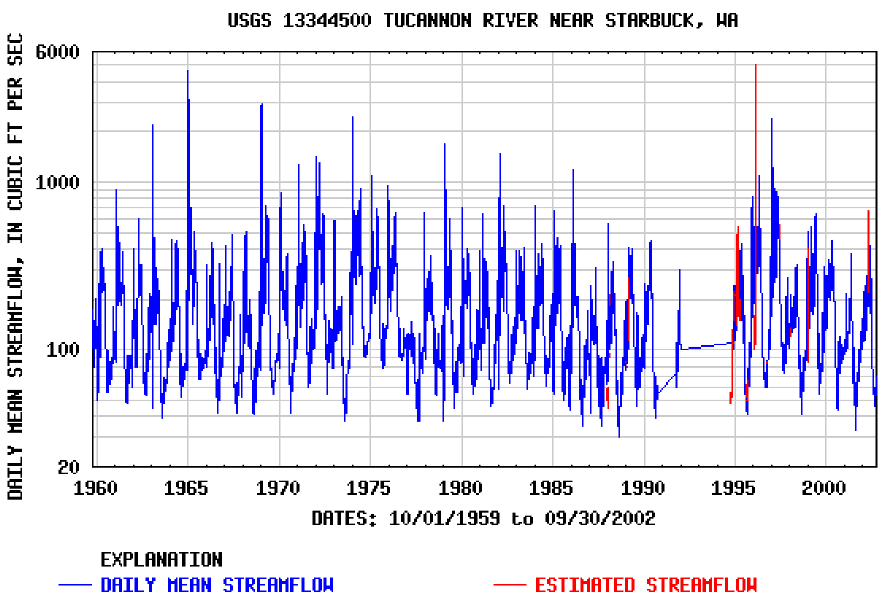

Figure 2. Average daily flow at Tucannon River gage at Starbuck.

In order to provide readers with more useful information on the annual fluctuations, a subset of the data record is provided in Figure 3. As illustrated, the flows vary considerably over the course of a water year (Oct – Sep).

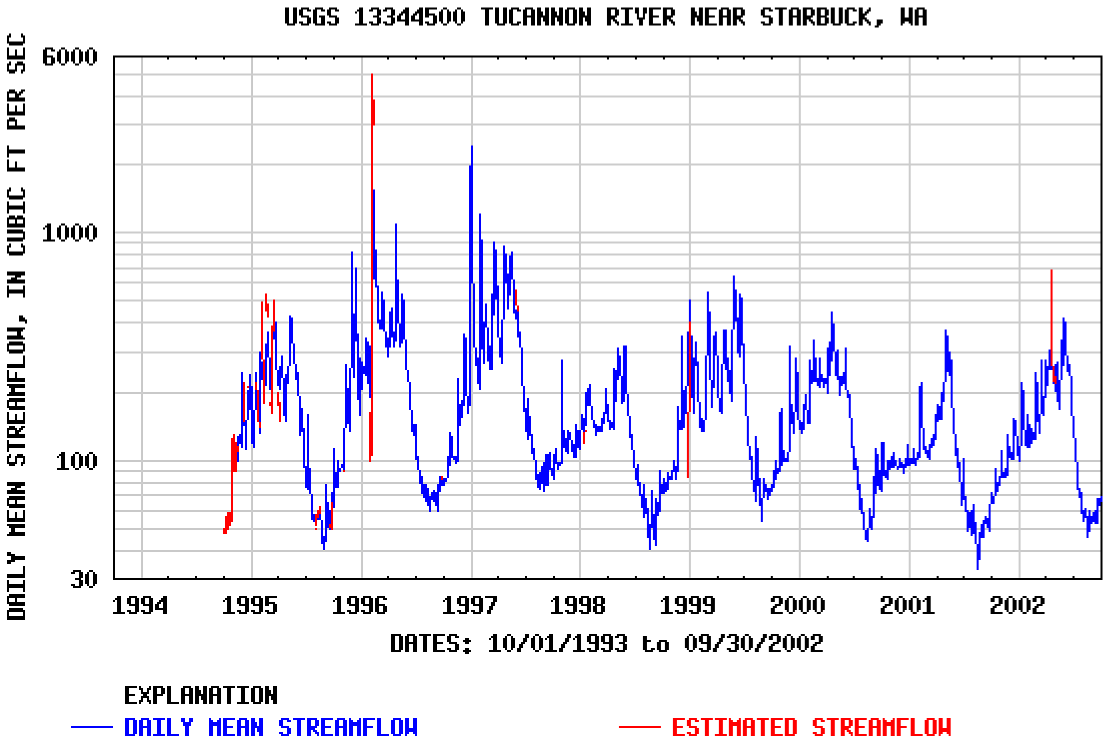

Figure 3. Average daily flow at Starbuck gage since 1995

It is evident from Figure 3 that average daily streamflows in four of the past five years have fallen below 50 and 65 cfs values recommended by Ecology at least briefly during the summer months. Figure 4 provides a look at summertime averages (July 1 through October 31) for all 47 years of record at the gage. While the average minimum daily flow hovers just below 60 cfs during mid-August (low of 57.3 cfs on August 11), there are numerous years when the flow is considerably lower than the average. For example, also shown in the Figure, are the 90 % exceedance flows as computed by the USGS. These are statistically generated values that would theoretically be exceeded in nine out of ten years based on the historic record. The corresponding 90% exceedance flow on August 11 is 37.2 cfs and the worst case is 34.7 cfs several days later.

The average monthly flows are shown in Figure 5. This figure illustrates the rapid decline in streamflows as soon as the snowmelt ends. Given the scarcity of summer precipitation, this is typical of all streams in the area. It also demonstrates the need for temporary off-stream storage as winter and spring flows are more than sufficient to meet Ecology flow requirements.

One pattern not available from the USGS data is the daily fluctuations. There are currently 67 state-issued surface water rights and 54 state-issued ground water rights on file with Ecology for the Tucannon Watershed. Surface water rights amount to a cumulative instantaneous diversion of 60 cfs (Covert *et al.* 1995). Because many diversions occur only during daylight hours, there is often a diurnal fluctuation in streamflows that could exacerbate low flows.

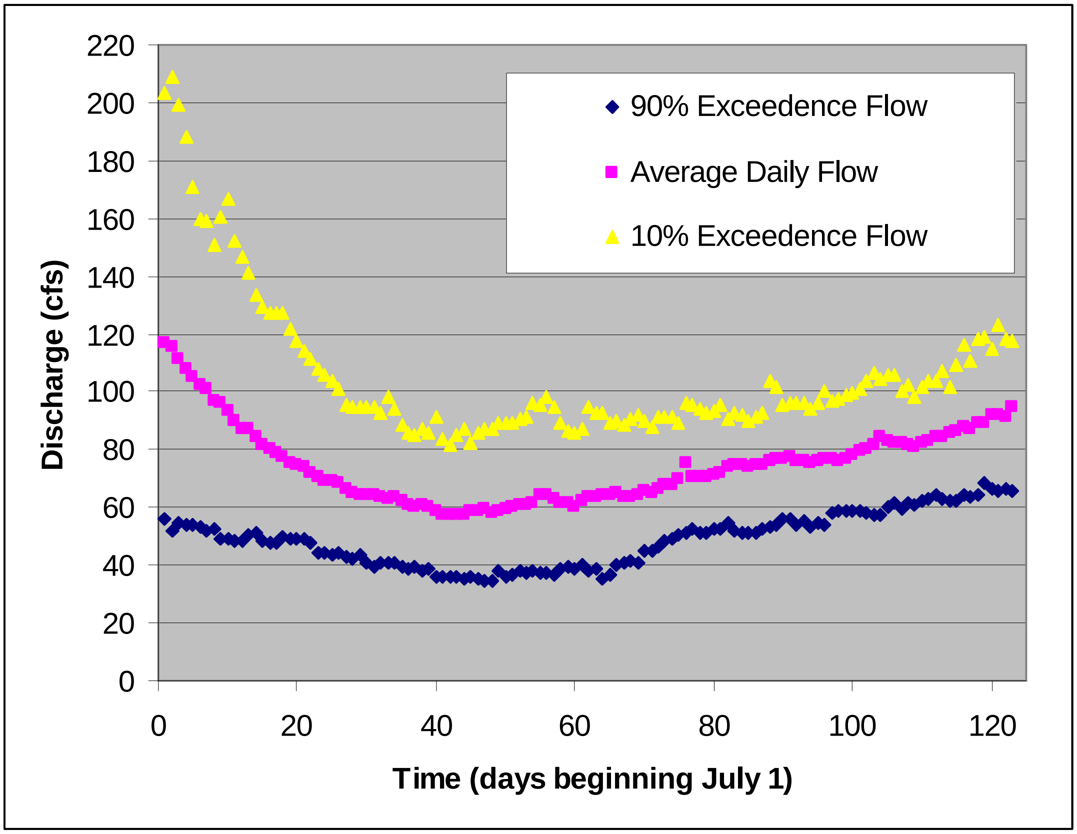

Figure 4. July through October average daily flow values

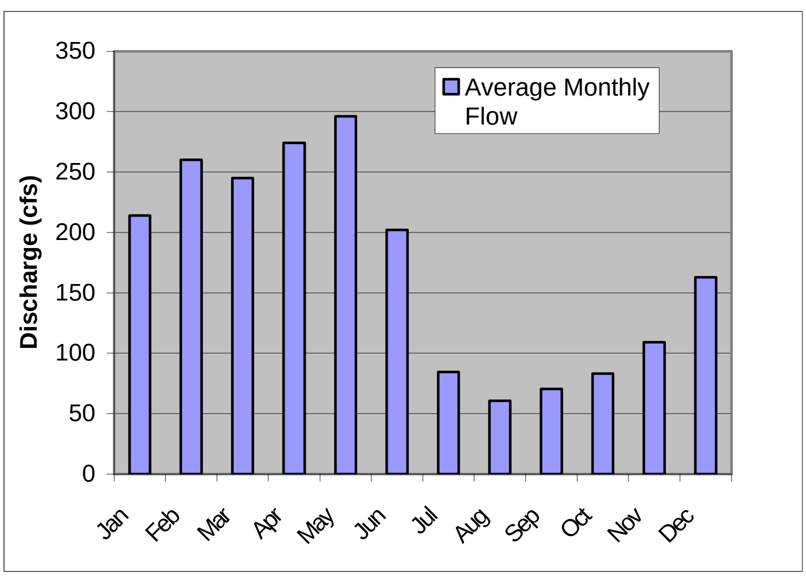

Figure 5. Average Monthly Flows at Starbuck Gage

Temperature is a critical water quality parameter affecting the suitability of river segments for spawning and rearing purposes. Table 5 summarizes typical water temperature requirements for various life history patterns of species of interest in the basin. These values should not be taken as absolutes. Fisheries experts are continuing to study refugia issues and thresholds that are unique to local species, however the temperatures are indicative of acceptable norms.

Table 5. Temperature (^{o}F) requirements of key fish species in the Tucannon watershed.

Life History Pattern	Steelhead	Bull Trout[d]	Spring Chinook	Lamprey[e]
Spawning migration	< 63.5[a]	50.0 - 54.0	38.0 – 56.0[b]	< 68.0
Spawning	39.0 – 49.0[b]	39.0 - 50.0	42.0 – 57.0[b]	< 68.0
Embryonic development & emergence	47.3 – 57.2[a]	34.0 - 43.0	41.0 – 58.0[b]	N/A
Juvenile rearing	45.1 – 58.3[c]	39.0 - 50.0	< 62.6[a]	< 68.0
Juvenile migration	< 58.0[a]	N/A	< 62.6[a]	N/A

[a] Hicks, 1999
[b] Bell, 1986
[c] Beschta *et al*., 1987
[d] Buchanan and Gregory, 1997
[e] Mallatt, 1983

Based on a single season of water temperature data, temperature is a problem on the lower reaches of the Tucannon. Figure 6 represents the average maximum temperature as well as the maximum temperature and the average minimum temperature from May through October, 2001. Average maximum temperatures near the mouth of the river exceed 67^{o}F (19^{o}C). Maximum temperatures are even higher; approaching 80^{o}F (27^{o}C). These temperatures are too warm for most of the LHP of salmonids. Additional flows, from aquifer storage and recovery projects or any other remediation/mitigation measure, may help address this problem. It is clear, however, that solutions to increasing flow for enhancing fish habitat should also include temperature considerations.

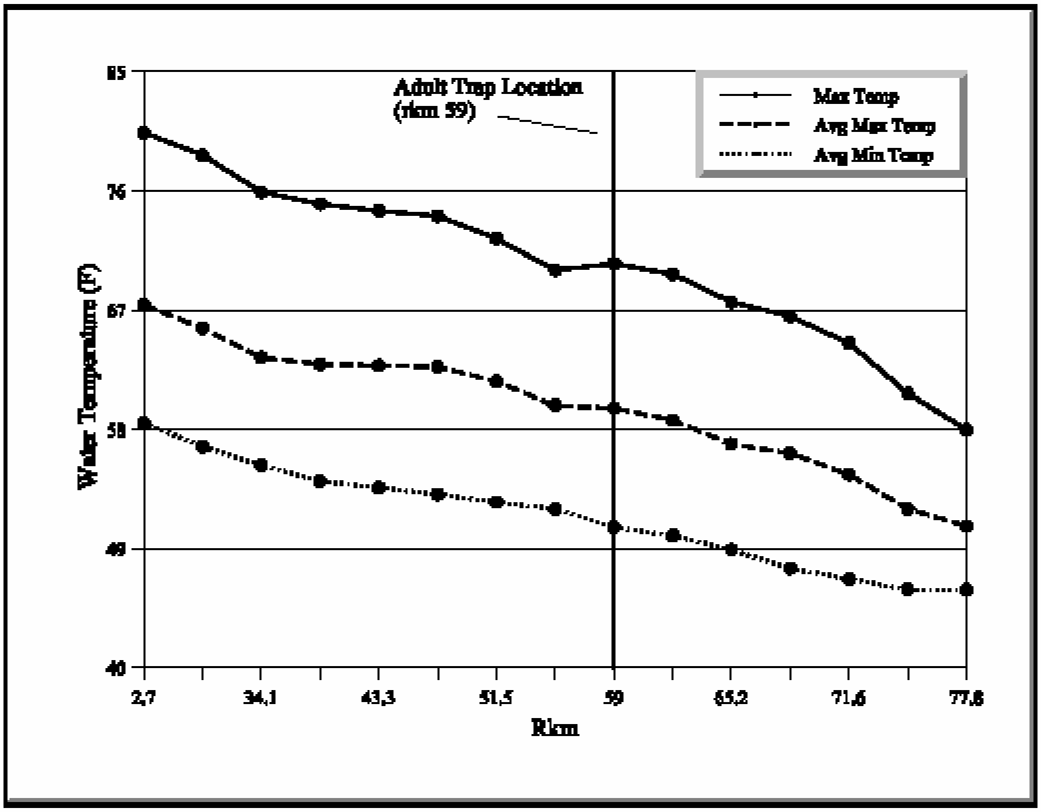

Figure 6. Temperature profile on Tucannon River.
(after Gallinat *et al.* 2002)

2.4 Preference Factors

As indicated in Equation 1, depth, velocity, substrate and cover preference factors are needed for the three species being considered in the IFIM analysis: steelhead, chinook, and bull trout. Ideally, localized factors could be developed by performing snorkeling surveys of the streams during various life phases. However, this is a costly and time consuming process that was outside the scope of the current project. Instead, default values in line with those developed by Hal Beecher (WDFW) and Brad Caldwell (WDOE) were used. Appendix A1 contains the tables for these curves. Table A1-1 contains the depth and velocity preference factors for steelhead during spawning. The depth and velocity preference factors for steelhead fry are given in Table A1-2. Similar values for juvenile steelhead are shown in Table A1-3. Chinook depth and velocity preference factors are presented in Table A1-4. Similar curves for juvenile chinook rearing are presented in Table A1-5. Depth and velocity preference factors for spawning and juvenile/adult bull trout are in Appendix A1 Tables A1-6 and A1-7, respectively. Substrate preference codes are given in Table A1-8. Cover codes are presented in Table A1-9.

3.0 Data Collection

On three separate occasions (April, June, and July), depth and velocity data were collected at eight representative sites at River Mile 24 immediately downstream of the Turner Road Bridge near Marengo, Washington. The eight cross-sections were selected to represent pools, riffles, and glide areas deemed typical of the river reach. The transect weighting (i.e., what % of the reach each cross-section represents) was based on the midpoint distance to the upstream and downstream cross-sections. The locations of the cross-sections were selected to insure that this assumption was reasonable. Steel pins were driven into each stream bank so consistent measurement points could be established for the three sampling events. The GPS coordinates of the sections are shown in Table 6. Velocity measurements were taken using standard procedures for use with Price and Pygmy current meters. Appendix B contains the raw data from the stream surveys. Table 7 contains a summary of the velocity data converted into discharge data for each cross-section. As can be seen, there is very good agreement between each of the measurements with deviations from the mean flow value within 10-15 percent.

Table 6. GPS coordinates of cross-sections on Tucannon River

Cross-Section	GPS Coordinates
1	N 46^o 26.464’ – W 117^o 45.186’
2	N 46^o 26.433’ – W 117^o 45.185’
3	N 46^o 26.430’ – W 117^o 45.139’
4	N 46^o 26.433’ – W 117^o 45.136’
5	N 46^o 26.423’ – W 117^o 45.139’
6	N 46^o 26.411’ – W 117^o 45.109’
7	N 46^o 26.414’ – W 117^o 45.083’
8	N 46^o 25.830’ – W 117^o 45.063’

Table 7. Summary of stream discharge measurements (in cfs)

Cross-Section	Field Trip No. 1 April 29, 2003	Field Trip No. 2 June 15, 2003	Field Trip No. 3 July 29, 2003
1	189.5	105.0	57.3
2	197.3	116.3	54.4
3	177.1	104.1	60.0
4	180.0	111.0	61.6
5	174.4	126.3	60.2
6	167.4	113.7	60.0
7	179.7	111.2	58.6
8	187.6	101.5	61.5
Average	181.6 cfs	111.1 cfs	59.2 cfs

During the collection of depth and velocity data, water temperatures were also measured at the upstream cross-section just downstream of the bridge. Table 8 indicates temperature and time. Time is significant because the stream became noticeably warmer in the afternoon. A measurement made during the July trip before and after the cross-sections data were collected indicated that the water temperature increased by nearly 11 ^{o}F.

Table 8. Summary of stream temperature at Cross-Section 8 (in ^{o}F)

Field Trip No. 1 April 29, 2003	Field Trip No. 2 June 15, 2003	Field Trip No. 3 July 29, 2003
49.1 @ 11:30 am	56.5 @ 9:30 am	64.0 @ 10:00 am
		74.8 @ 4:00 pm

Substrate data were also examined at each station on all eight cross-sections during a period of low flow when observations could be readily made. The typical procedure is shown in Figure 7. These values are presented in Appendix B3 Table B3-1. Using the weighing factors in Appendix A1 Table A1-8, these values were converted into numeric preference factors and input into the PHABSIM model.

Figure 7. Examining substrate data at cross-section No. 8 on Tucannon

4.0 Analysis and Results

The PHABSIM model requires detailed velocity and discharge measurements as well as various preference factors that were collected and reported previously in this study. Three main PHABSIM Version 1.2 modules used to determine the recommended instream flow requirements: (1) WSL (water surface level), (2) Velocity, and (3) Habtae. Results from each of the component are presented below.

4.1 Water Surface Level (WSL)

The WSL module was run using the average discharges shown in Table 7 from all eight cross-sections for the three field events. The observed versus simulated results for the reach are shown in Tables 9, 10, and 11. The stage-discharge (STGQ) option was used to calculate the water surface levels along with the “Best Estimated Discharge” (average of flow measurements at all eight cross-sections). The simulated depths corresponded closely to the measured results at all three calibration flows. Since the model is adjusting velocity to fit the measured water surface elevation the fact that the surface elevations agree to within a small tolerance was expected. It should be explicitly stated that the elevations shown this report are in reference to an arbitrary elevation established during the original cross-section survey. No attempt was ever made to link these values to actual Mean Sea Level measurements.

Table 9. Observed versus simulated WSL on the Tucannon at low flow.

Station	Observed Water Surface Level (feet)	Flow = 59.2 cfs	
		Simulated Water Surface Level (feet)	Difference (feet)
0.00	90.03	90.009	-0.021
181.88	92.32	92.328	-0.002
289.88	92.90	92.884	-0.016
310.81	93.35	93.321	-0.029
332.06	93.38	93.332	-0.048
453.19	95.92	95.917	-0.003
596.31	98.00	97.991	-0.009
707.94	99.33	99.315	-0.015

Table 10. Observed versus simulated WSL on the Tucannon at intermediate flow.

Station	Observed Water Surface Level (feet)	Flow = 111.1 cfs	
		Simulated Water Surface Level (feet)	Difference (feet)
0.00	90.31	90.357	0.047
181.88	92.70	92.705	0.005
289.88	93.22	93.258	0.038
310.81	93.69	93.751	0.061
332.06	93.69	93.785	0.095
453.19	96.20	96.209	0.009
596.31	98.29	98.313	0.023
707.94	99.60	99.634	0.034

Table 11. Observed versus simulated WSL on the Tucannon at high flow

Station	Observed Water Surface Level (feet)	Flow = 181.6 cfs	
		Simulated Water Surface Level (feet)	Difference (feet)
0.00	90.71	90.684	-0.026
181.88	93.07	93.006	-0.004
289.88	93.63	93.608	-0.022
310.81	94.18	94.147	-0.033
332.06	94.25	94.205	-0.045
453.19	96.49	96.484	-0.006
596.31	98.63	98.616	-0.014
707.94	99.94	99.921	-0.019

The plotting option in PHABSIM was used to graphically illustrate the longitudinal profile throughout the study reach. Figure 8 illustrates what is essentially shown in Table 11. An inspection of the simulated water surface levels at all discharges was performed to verify that the results were valid for the entire flow range. Although somewhat compressed in Figure 9, the simulated results all follow a similar pattern indicating that no modeling anomalies (such as water flowing uphill) were present.

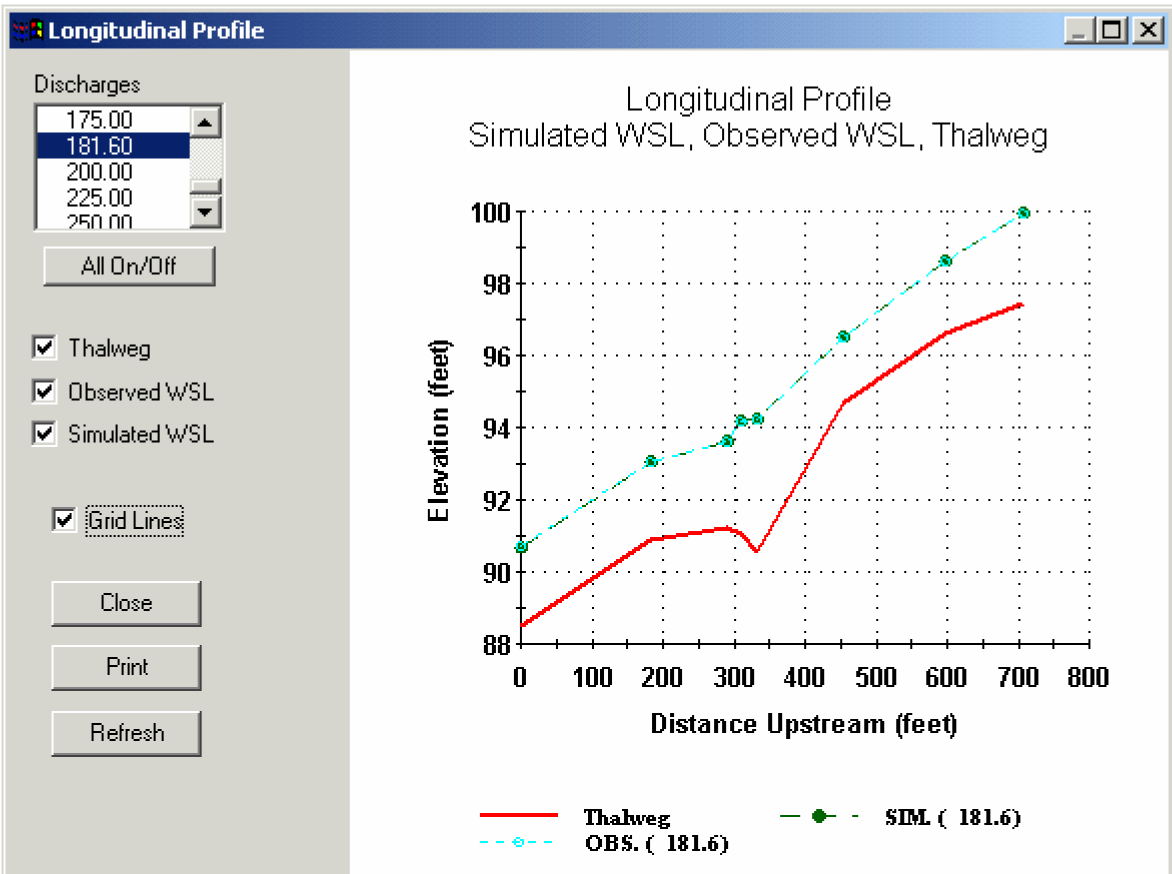

Figure 8. Observed versus simulated flow depths at high flow

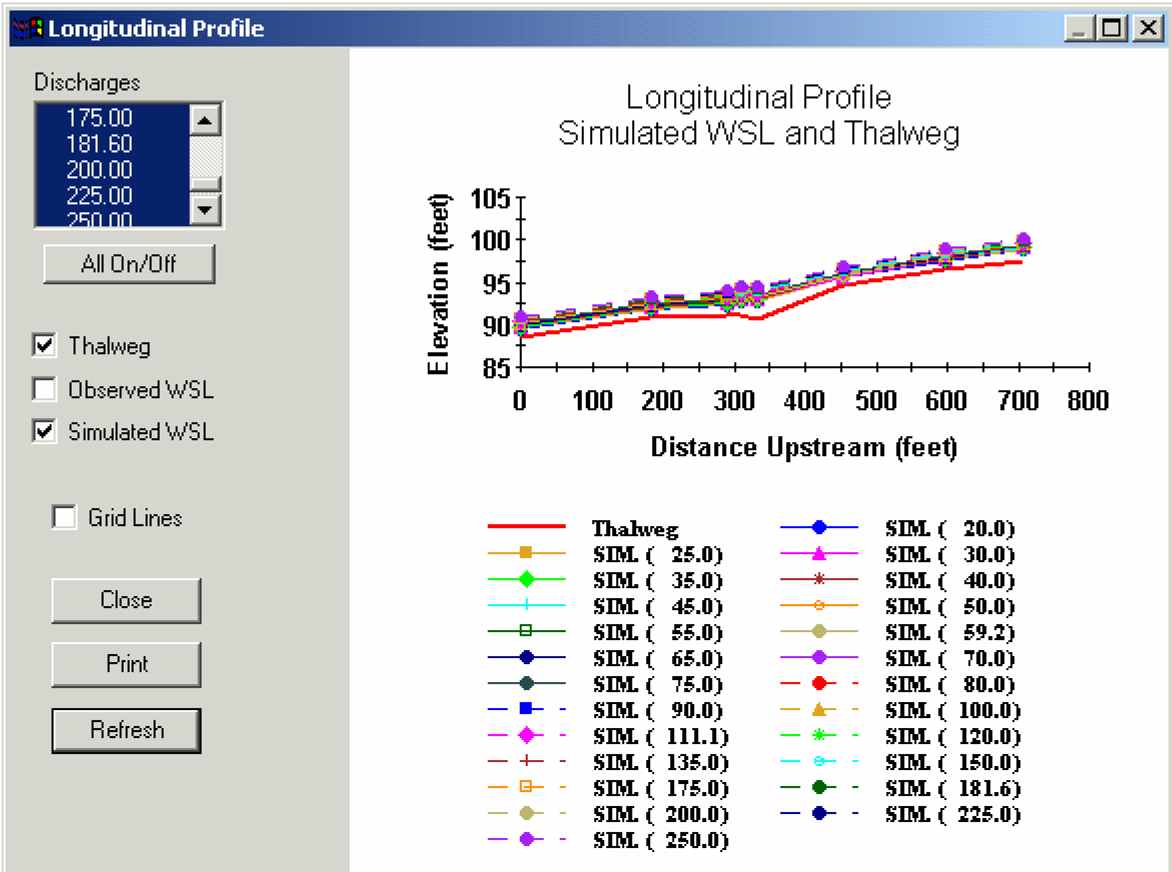

Figure 9. Summary of all simulated water surface elevations

4.2 Velocity Calibration

Once the water surface elevations are established, the process of matching simulated to measured velocities begins through the "Velocity" model of PHABSIM. The objective of this phase is to select the best combination of calibration velocity(s) and simulation options to represent the velocity profiles at each cross section over the range of simulated flows. The degree to which the Velocity Adjustment Factor (VAF) departs from 1.0 at a particular calibration flow is a function of the difference between the calculated discharge and the "best estimate of discharge", as well as the difference between predicted and observed WSLs. However, developing velocity profiles that reasonably approach the measured values is the most important component of the model. The program predicts VAFs at flows other than those that were measured but these are only trends as there is no data to support the actual value. Since the effect of bottom roughness decreases with increasing discharge, VAFs should be less than 1.0 for flows below the calibration flow and greater than 1.0 for flows above the calibration flow.

Figure 10 illustrates the Velocity Simulation module contained in PHABSIM. The user selects computational options and velocity calibration set assignments and examines the trends in the VAF values generated. Before discussing the effects of varying the computational options, a brief description of the implications is in order. As illustrated in Figure 10, the user can check four "option" boxes. Checking the first option box, "Use Velocity Adjustment Factor (IOC 11)", simply allows the simulated velocities to be adjusted so that the resulting discharge is equal to the specified discharge. Turning this option OFF is sometimes referred to as "turning off mass balancing" and is therefore not recommended. Consequently, all simulations used at least this option. The second option, "Limit Manning's N", allows the user to limit the range of Manning's roughness coefficient (n) to the region shown in the two boxes. Several combinations of this option were investigated. The third box, "Use Variable Roughness Coefficient (IOC 16)", makes it possible to adjust the roughness in each cell as a function of the water depth in that cell. While this option helps alleviate the problem of overly high roughness coefficients along the shallow bank regions of the cross-section, little guidance is available for selection of the appropriate beta coefficient. The beta coefficient is generally between 0.0 and -2.04, with typical values in the -0.3 to -0.8 range. Three runs were made with this option (-0.3, -0.5 and -0.8) to determine the sensitivity. The fourth option, "Calculate N for Wet Cells (IOC 12)" allows the program to use calculated Manning's roughness coefficients if the user did not supply the values. The default is OFF. If ON, the model uses calculated roughness values for cells with water and specified roughness values provided on the Edit/Cross-section data set for dry cells (those below the WSL for which no observed velocity was measured). When checked OFF, the program uses the supplied roughness values or calculates a roughness if the supplied value is zero.

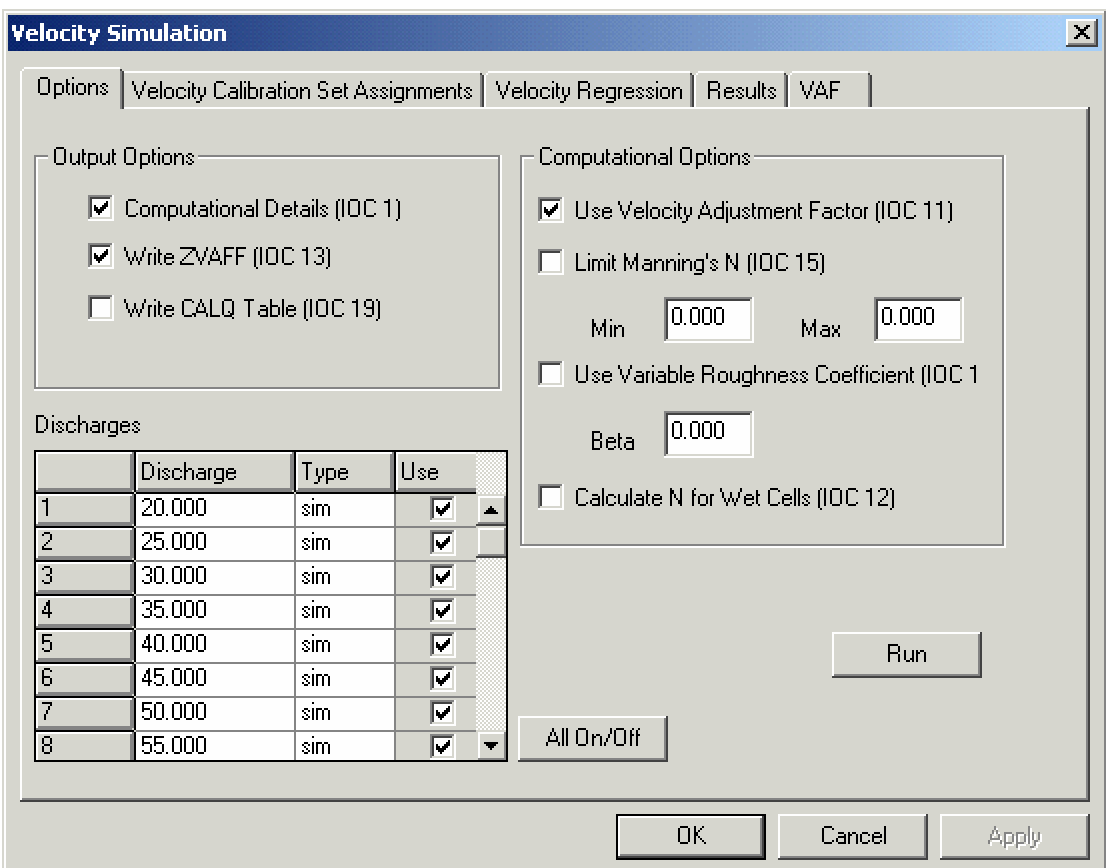

Figure 10. PHABSIM screen capture of Velocity Calibration Options

The “best” combination of options can only be determined by examining model performance and the objectives of the particular study. Consequently, numerous possible combinations of the calibration velocity sets and computational limits were explored during the calibration phase.

One final comment must be made concerning the interpretation of VAFs for shallow mountain streams such as those in the Tucannon watershed. Unlike deeper rivers or streams with nearly uniform bottom sediments, the stream examined in this study was shallow (seldom greater than 2.0 feet deep) and contained many upstream and downstream anomalies such as large submerged rocks, submerged logs, vegetation and gravelbars. As such, the measured velocity profiles were quite variable from cell to cell. The PHABSIM model does not specifically account for any of these factors. As a result, it is to be expected that the VAFs are somewhat larger than those generated for deeper streams where the velocity profiles are more logarithmic. The potential negative impact of channel geometry heterogeneity was specifically pointed out in the sample problem provided with the model. So, while it is desirable to have the VAFs for the three calibration flows between 0.8 and 1.2 for all of the cross-sections, it may not always be possible.

After completing and examining numerous options, a final calibrated velocity model was created. Table 12 presents the final velocity calibration assignments for the range of discharge values used in the model. As illustrated, all three flow events were used in the final analysis of WUA. Flows bracketing changes in the assignment sets (e.g., the transitions occurs between 75 and 80 and between 135 and 150 cfs) are shown. All flows between the values shown have the same combination as those presented on either side. For example, the set associated with 30 cfs uses the same values as those shown in Table 12 for 20 and 59.2 cfs. Table 13 summarizes the VAFs for this model. As illustrated in the table, all but one of the values falls within the desired range. Figures 11, 12, 13 and 14 illustrate typical examples of the excellent agreement between simulated and observed velocities generally observed at high, intermediate and low discharges.

Table 12. Velocity calibration set assignments

Station (ft)	Velocity Assignment Set								
	Discharges (cfs)								
	20	**59.2**	75	80	**111.1**	135	150	**181.6**	250
0.00	1	1	1	2	2	2	3	3	3
181.88	1	1	1	2	2	2	3	3	3
289.88	1	1	1	2	2	2	3	3	3
310.81	1	1	1	2	2	2	3	3	3
332.06	3	3	3	3	3	3	3	3	3
453.19	1	1	1	2	2	2	3	3	3
596.31	1	1	1	2	2	2	3	3	3
707.94	3	3	3	2	2	2	3	3	3

Notes: BOLD values represent measured flow velocities and discharges
1 represents the low flow, 2 the medium flow, and 3 is the high flow calibration set

Table 13. Final VAF values from velocity calibration

Station (ft)	VAF		
	Q = 59.2 cfs	Q = 111.1 cfs	Q = 181.6 cfs
0.00	1.0279	1.0173	0.9856
181.88	1.0149	0.9227	0.9212
289.88	1.0768	1.0291	1.0493
310.81	0.9628	0.9359	1.1077
332.06	0.6927	0.8810	1.0559
453.19	1.0018	0.9650	1.1274
596.31	1.0155	0.9965	1.0541
707.94	0.8065	0.9903	0.8721

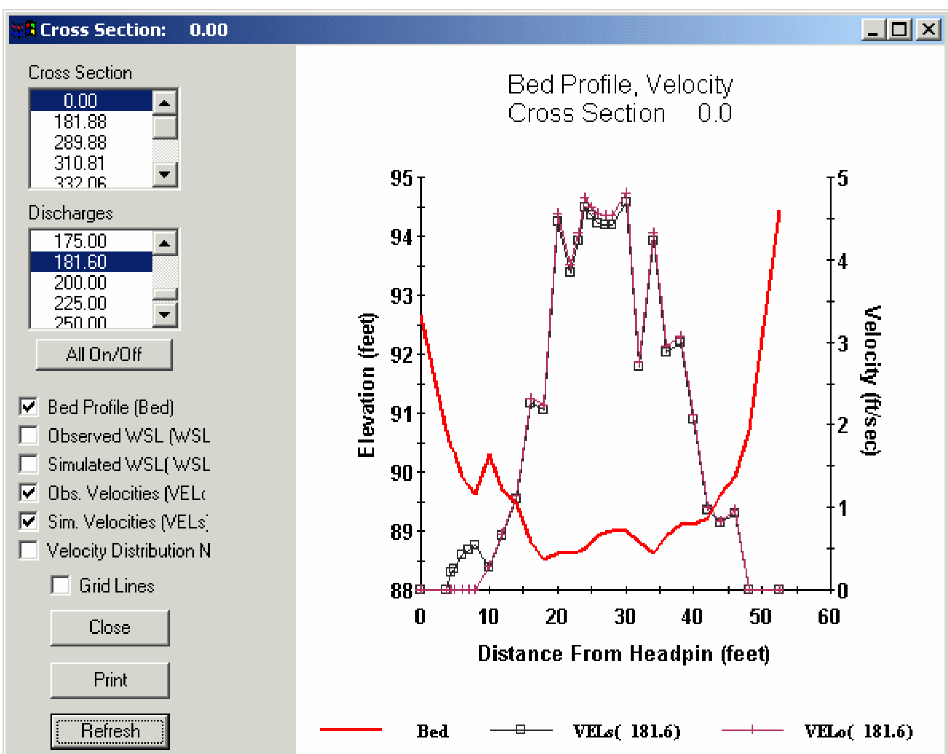

Figure 11. Example of measured versus predicted high flow velocities at Station 0

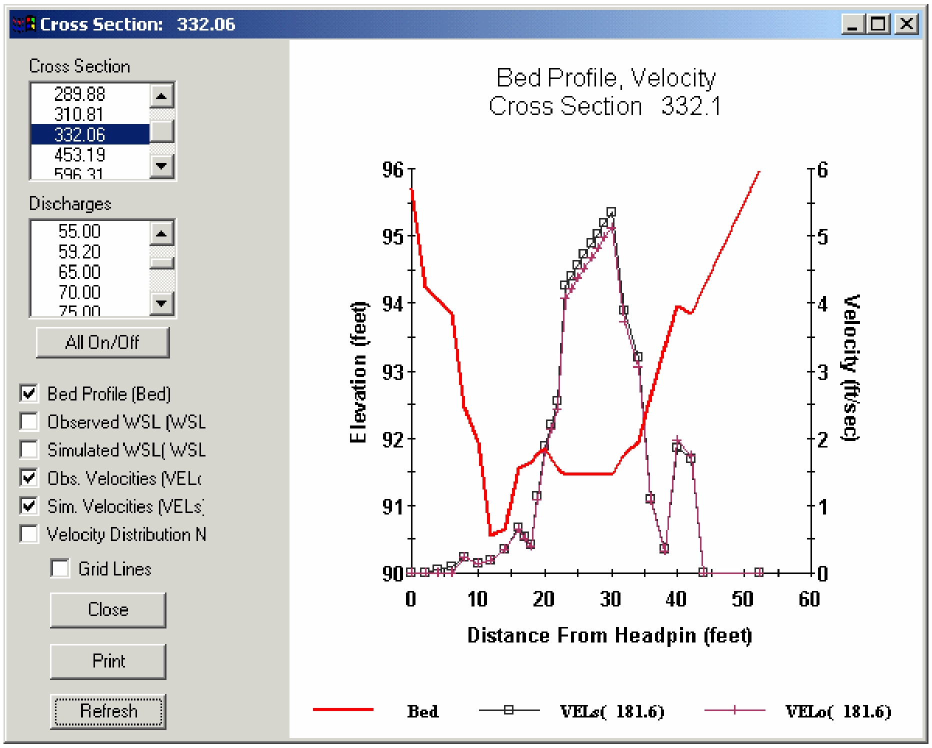

Figure 12. Example of measured versus predicted high flow velocities at Station 332.1

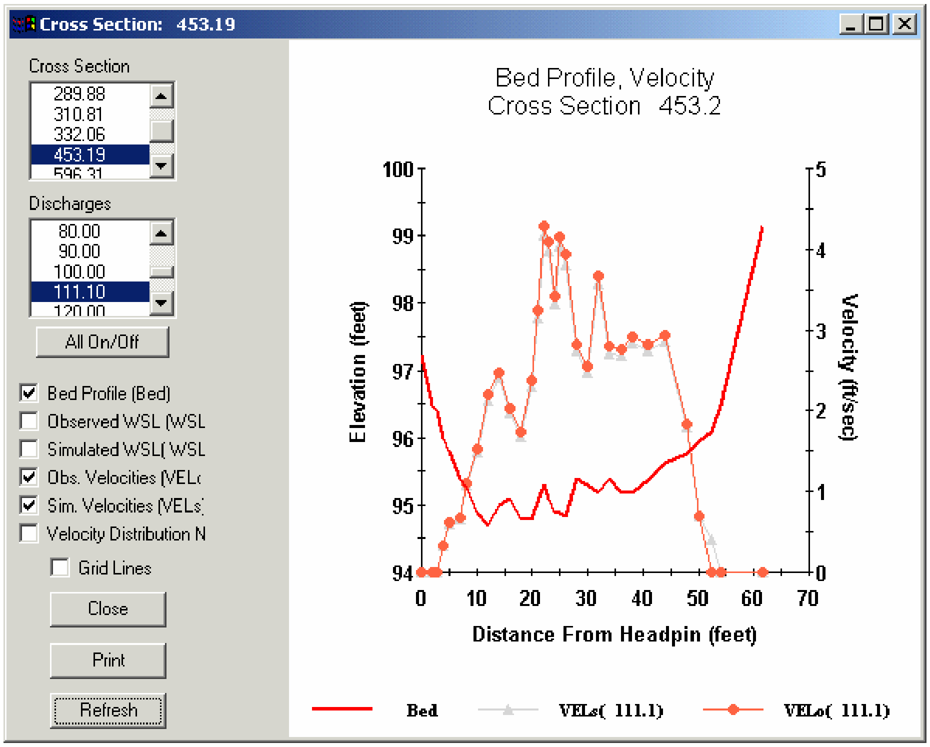

Figure 13. Example of measured versus predicted intermediate flow velocities at Station 453.2

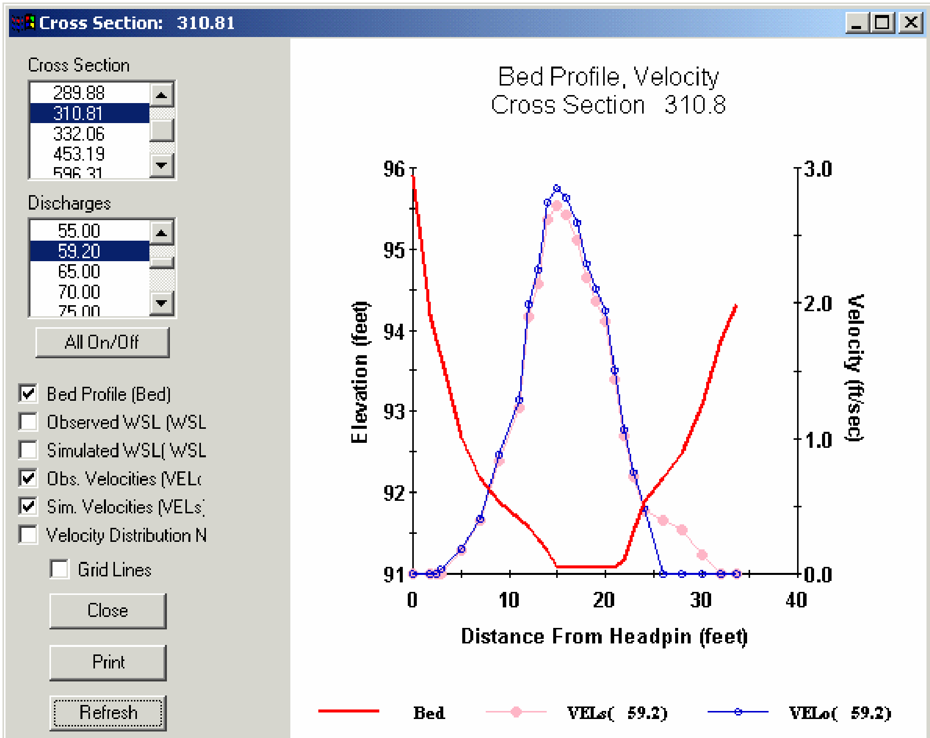

Figure 14. Example of measured versus predicted low flow velocities at Station 310.8

At low flow, the VAF for Station 332.06 is below the minimum target value. Several attempts to find calibration parameters that would alleviate this problem were evaluated without success. Examination of the input data provided a plausible explanation of the deviation. The cross-section at this location (Station 332.06) is at the top of a relatively large pool. The upstream rock configuration channels a great deal of water towards an opening at the head of the pool. There are large stagnant zones on either side of the opening. Over the measurement period of April through July, rock movements varied the location of peak flow from upstream. This phenomenon is illustrated in Figure 15. Notice that during high flow conditions the measured peak velocity occurs 30 ft from the headpin, while at low flow the peak has shifted to 21 ft. As a result, the observed velocities were in a different location than the simulated results. Furthermore, the velocities were higher and more narrowly confined than predicted. Figure 16 illustrates the difference between observed and simulated velocities. It is believed that this change caused the calibration difficulties at this cross-section during low flow. Because the head of the pool and the underlying substrate of rock does not make for good spawning habitat and the high velocities do not encourage juvenile rearing, this calibration discrepancy was not believed to materially affect the modeling results.

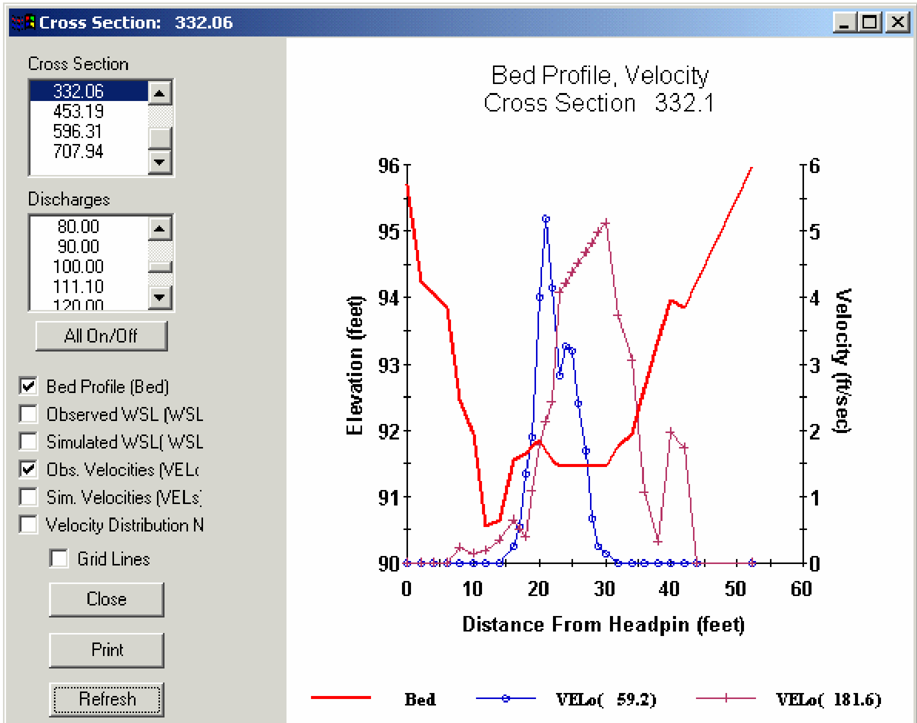

Figure 15. Shift in velocity profiles between high and low sampling periods

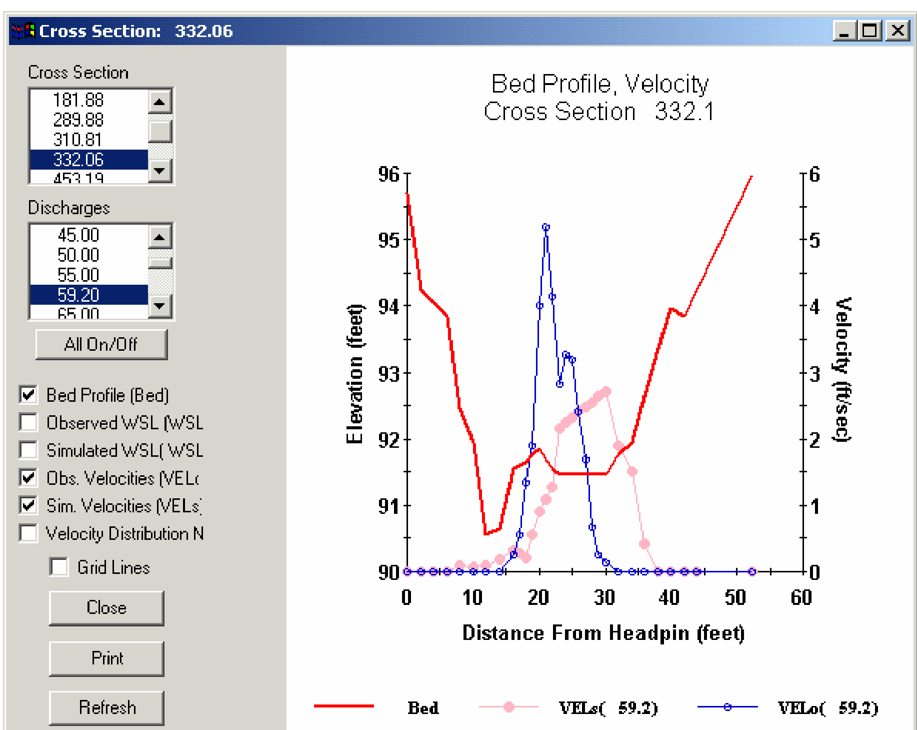

Figure 16. Measured versus observed velocities at low flow for Station 332.06

The simulated velocity results in this study were obtained without modifying the measured data. It is generally considered acceptable to slightly adjust the measured velocities within the accuracy of field measurements if necessary to eliminate anomalies that may occur. This is particularly true for measurements taken in shallow areas where backwater eddies, vegetation, and small shifts in channel geometry over time can lead to erroneous velocity measurements. As was reported in a memorandum to EES by Kaje (2004), the adjustments should be no more than 20% or 0.2 ft/sec. However, the philosophy employed in this study was to use the data as recorded rather than attempt to justify changes for the sake of better model performance. The potential downside to this approach is that in some instances the regressions could produce inconsistent velocity predictions at interpolated flow values. Examination of modeling results did not reveal such as situation. As illustrated in Figure 17, the entire range of discharges simulated produced a well-behaved family of velocity curves. Although not included in this report, inspection other predicted velocities at all other discharges revealed similar patterns of behavior.

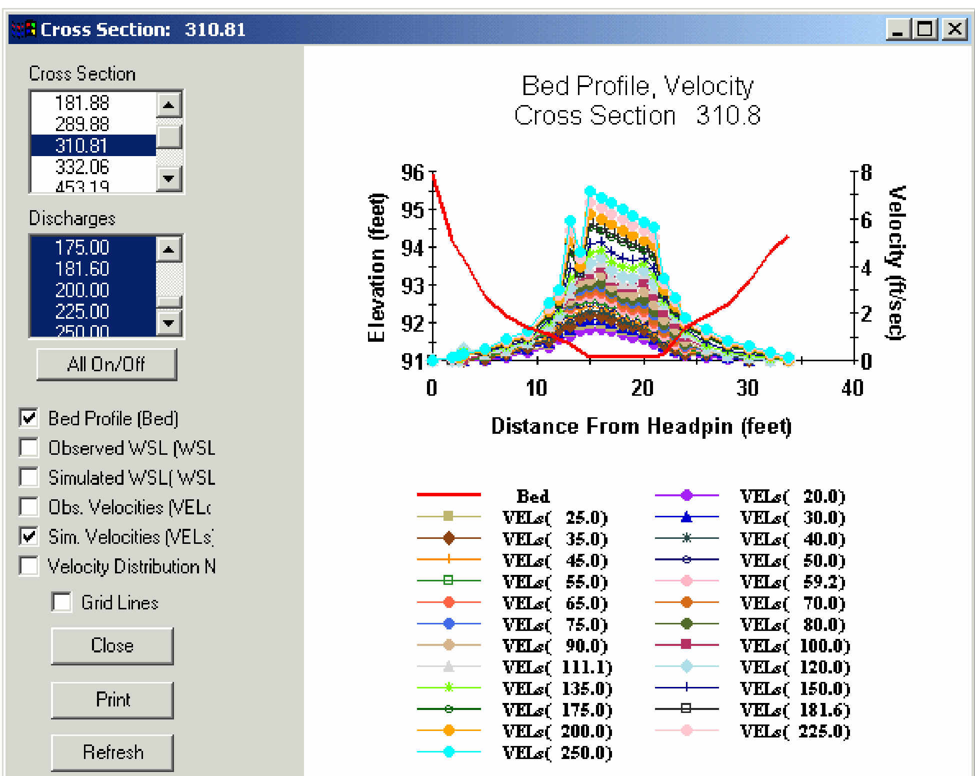

Figure 17. Predicted velocities for entire flow range at Station 310.81

4.3 Habtae

The PHABSIM Habtae module was run using the calibrated velocity model described previously in this report. Block-centered preference factor curves were utilized in the study for all three species: steelhead, chinook, and bull trout. These curves were developed by the Washington State Department of Ecology and the Washington Department of Fish and Game. The model produced the following Weighted Usable Area (WUA) curves. Graphically WUA results for the three species are presented in Figures 18, 19, and 20. A numerical summary is presented in Table 14. As typical in such simulations, there are significant differences in optimum flows depending on species and life stage.

The results of the PHABSIM investigation were relatively consistent with the results found by Caldwell (1995) at the mouth of the Tucannon. Caldwell found that steelhead spawning potential was highest at 105 cfs versus the 120 cfs found in this study. Similarly, Caldwell found that 85 cfs was needed to maximize Chinook spawning versus 100 cfs in this study. Given the change in channel characteristics between the mouth and the reach at Marengo, this small variation appears to be a reasonable expectation.

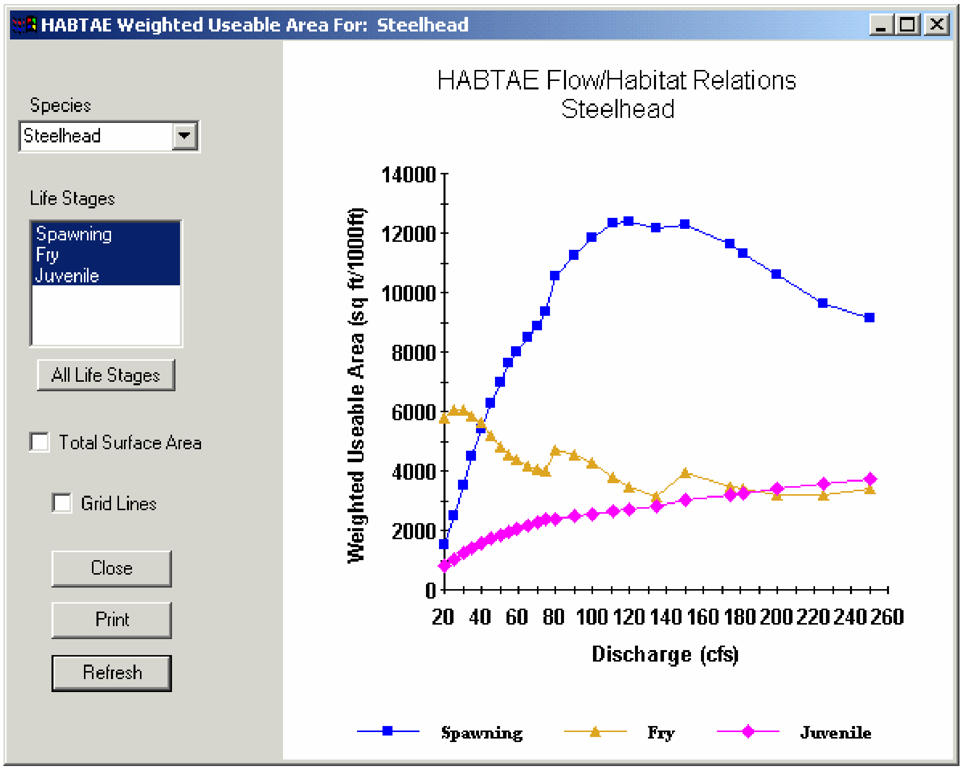

Figure 18. WUA for Steelhead Life Stages

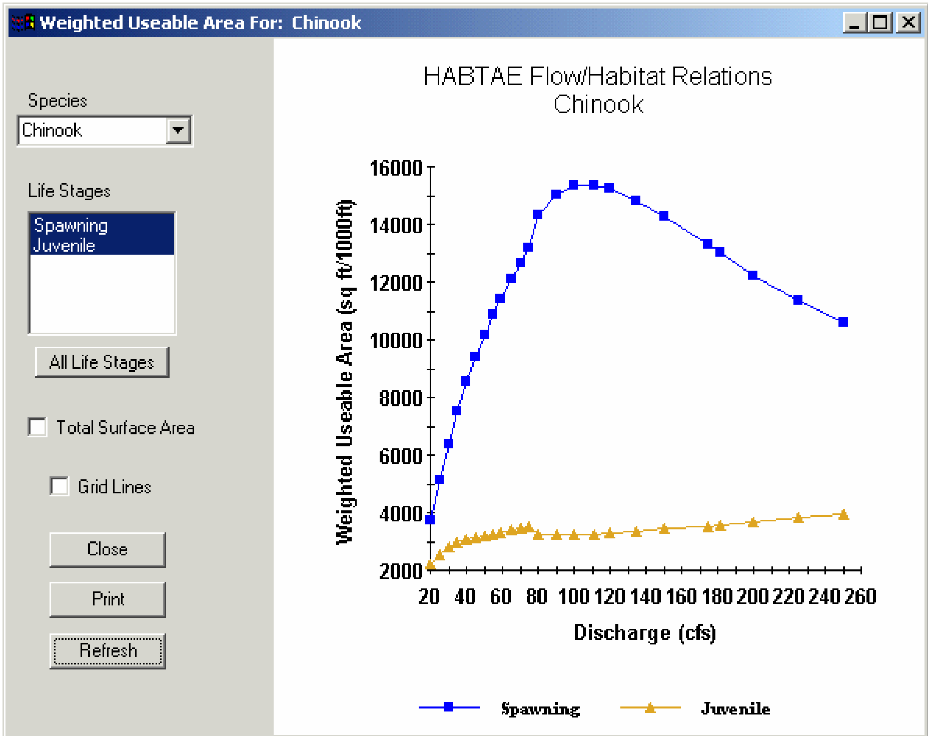

Figure 19. WUA for Chinook Life Stages

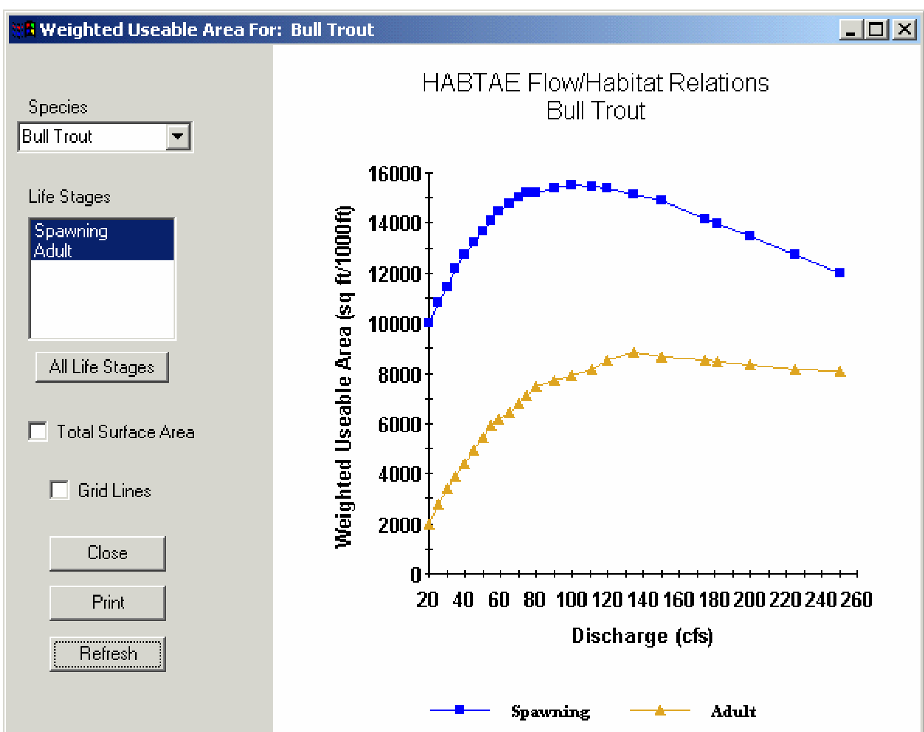

Figure 20. WUA for Bull Trout Life Stages

Table 14. Summary of WUA Results

Flow	Steelhead Spawn	Steelhead Fry	Steelhead Juvenile	Chinook Spawn	Chinook Juvenile	Bull Trout Spawn	Bull Trout Adult
20.0	1,503	5,759	831	3,754	2,239	10,016	1,972
25.0	2,482	6,054	1,044	5,146	2,546	10,825	2,785
30.0	3,492	**6,064**	1,248	6,389	2,794	11,454	3,425
35.0	4,470	5,851	1,427	7,518	2,980	12,139	3,916
40.0	5,411	5,637	1,588	8,526	3,089	12,733	4,379
45.0	6,255	5,210	1,720	9,384	3,141	13,194	4,912
50.0	6,985	4,823	1,847	10,163	3,201	13,670	5,458
55.0	7,613	4,533	1,971	10,859	3,247	14,096	5,912
59.2	8,027	4,365	2,064	11,410	3,305	14,432	6,156
65.0	8,468	4,166	2,173	12,129	3,383	14,793	6,430
70.0	8,872	4,078	2,268	12,661	3,444	15,036	6,784
75.0	9,333	3,999	2,360	13,170	3,504	15,223	7,097
80.0	10,533	4,715	2,392	14,299	3,236	15,207	7,503
90.0	11,251	4,553	2,473	15,010	3,231	15,402	7,749
100.0	11,859	4,248	2,539	**15,339**	3,232	**15,487**	7,907
111.1	12,305	3,773	2,633	15,328	3,267	15,435	8,172
120.0	**12,362**	3,472	2,700	15,226	3,285	15,368	8,525
135.0	12,175	3,152	2,819	14,805	3,330	15,115	**8,816**
150.0	12,254	3,963	3,009	14,271	3,439	14,896	8,669
175.0	11,613	3,463	3,191	13,307	3,533	14,160	8,528
181.6	11,313	3,381	3,241	13,032	3,573	13,976	8,448
200.0	10,591	3,178	3,381	12,227	3,689	13,454	8,338
225.0	9,636	3,216	3,564	11,332	3,846	12,712	8,182
250.0	9,109	3,384	**3,722**	10,591	**3,946**	11,980	8,080

Figures 21 and 22 demonstrate the spatial variability in usable habitat. At low flows, there is very little high quality habitat (as indicated by the red color) whereas at high flows, not only is there more WUA but it is better connected. Also, as discussed in the velocity calibration section, the pool head reach centered around Station 322.06 does not contribute significantly to the WUA results at either flow thereby substantiating the hypothesis that the relatively poor VAF at the low discharge point does not materially impact the results.

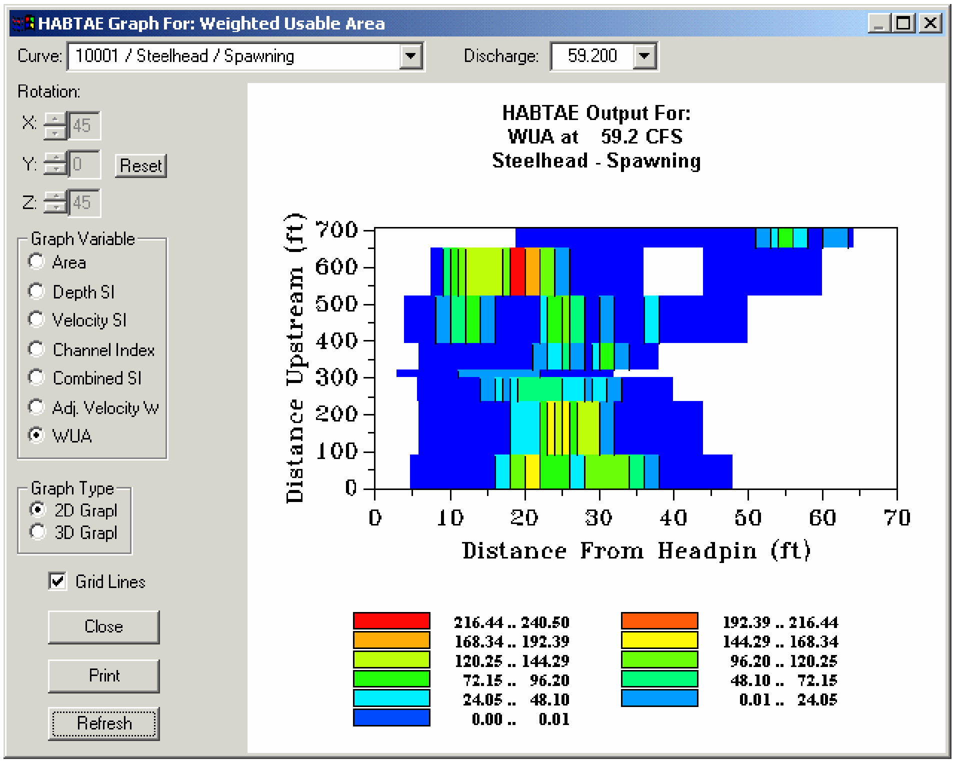

Figure 21. Spatial distribution of WUA for Steelhead Spawning at low flow measurement

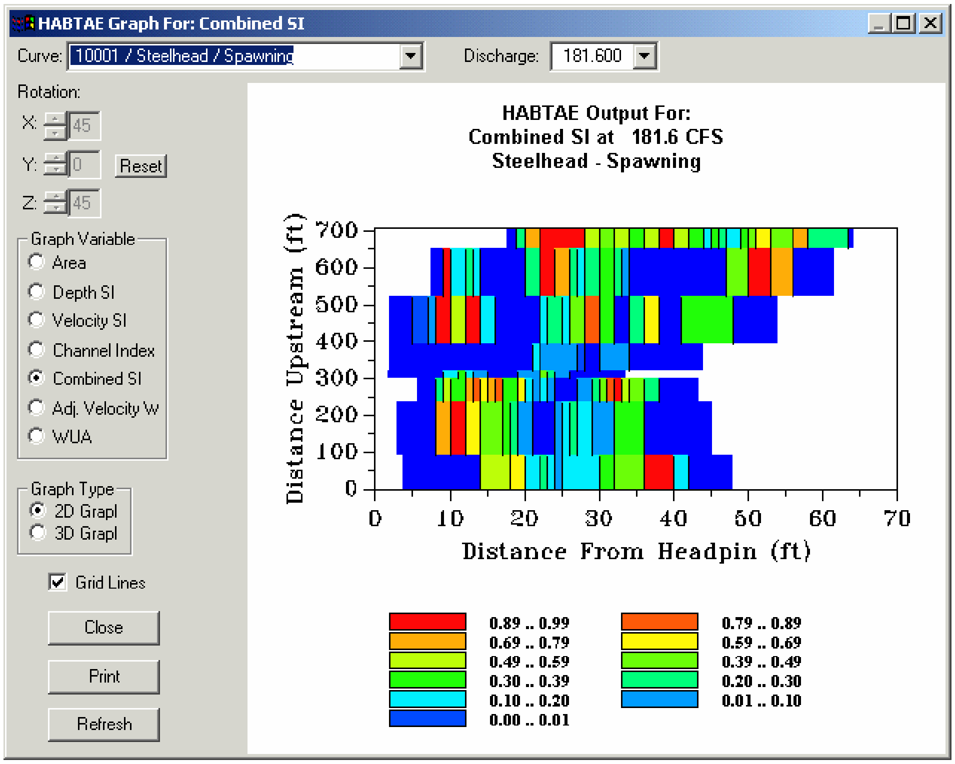

Figure 22. Spatial distribution of WUA for Steelhead Spawning at high flow measurement

5.0 Recommendations

Converting the WUA values in Figures 18 through 20 into recommendations for minimum instream flow values involves negotiations and consideration of other factors that the stakeholders of the watershed deem important. It should not be perceived as simply picking the flows corresponding to the maximum WUA values. To the maximum extent possible, all of the major stakeholders in the basin need to be involved in the decision making process as well as the implementation phase if this exercise is to succeed. Nevertheless, a starting point for discussing is needed. Table 15 suggests twelve seasonally varying "discussion" flows based on the life cycles of salmonids (steelhead, Chinook and bull trout), water temperature, and flow.

Table 15. Preliminary discussion flow recommendations.

Month	Discussion Flow (cfs)
October	90
November	100
December	110
January	110
February	120
March	120
April	120
May	120
June	100
July	70
August	60
September	65

It seems important to talk about limiting factors influencing fish populations in the Tucannon River. Much of the literature points to the excessive stream temperature and sediment deposition as constraints to downstream channel use. There is a direct link between flow and temperature so improving flow may facilitate the lowering of temperature. Studies should be conducted to quantify this relationship so that the impacts of future water right purchases or conservation practices can be determined. Riparian vegetation may help temperature and reduce sediment. Riparian vegetation also leads to large woody debris and subsequent pools. However, intermediate steps may be necessary to help preserve the fish populations. A study of sediment yield may also be warranted. This could help identify areas that need sediment traps or riparian areas. The flows at the new gage should be used to help quantify all of these efforts. It seems that opportunities for off-channel storage or other conservation practices should be examined.

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Appendix A1 – Preference Factors

Table A1-1. Depth and velocity preference factors for spawning steelhead.

Depth Interval (ft)	Depth Composite Preference	Recommended Depth Preference	Velocity Interval (ft/sec)	Velocity Composite Preference	Recommended Velocity Preference
0.00 - 0.59	0.00	0.00	0.00 - 1.09	0.00	0.00
0.60 - 0.69	0.00	0.00	1.10 - 2.09	0.44	0.45
0.70 - 0.99	0.48	0.50	2.10 - 2.89	0.97	0.97
1.00 - 1.49	1.00	1.00	2.90 - 3.19	1.00	1.00
1.50 - 1.59	1.00	1.00	3.20 - 3.29	1.00	1.00
1.60 - 2.19	0.73	0.75	3.30 - 3.59	0.62	0.62
2.20 - 2.39	0.58	0.60	3.60 - 3.99	0.62	0.40
2.40^{+}	0.06	0.50	4.00 - 4.49	0.62	0.20
			4.50 - 4.99	0.62	0.10
			5.00^{+}	0.62	0.00

Table A1-2. Depth and velocity preference factors for steelhead fry.

Depth Interval (ft)	Depth Composite Preference	Recommended Depth Preference	Velocity Interval (ft/sec)	Velocity Composite Preference	Recommended Velocity Preference
0.00 - 0.09	0.00	0.00	0.00 - 0.09	0.55	0.55
0.10 - 0.19	0.90	0.90	0.10 - 0.19	1.00	1.00
0.20 - 0.69	1.00	1.00	0.20 - 0.29	0.60	0.87
0.70 - 1.09	0.12	0.30	0.30 - 0.39	0.47	0.73
1.10 - 1.39	0.03	0.30	0.40 - 0.59	0.60	0.60
1.40 - 1.99	0.27	0.30	0.60 - 0.69	0.64	0.50
2.00 - 2.69	0.41	0.30	0.70 - 0.79	0.40	0.40
2.70 - 4.99	0.29	0.30	0.80 - 0.89	0.17	0.30
5.00+	0.01	0.01	0.90 - 0.99	0.21	0.20
			1.00 - 1.09	0.39	0.18
			1.10 - 1.19	0.71	0.16
			1.20 - 1.29	0.54	0.14
			1.30 - 1.39	0.55	0.12
			1.40 - 1.49	0.43	0.10
			1.50 - 1.69	0.42	0.08
			1.70 - 1.79	0.41	0.05
			1.80 -3.29	0.51	0.02
			3.30+	0.51	0.00

Table A1-3. Depth and velocity preference factors for juvenile steelhead.

Depth Interval (ft)	Depth Composite Preference	Recommended Depth Preference	Velocity Interval (ft/sec)	Velocity Composite Preference	Recommended Velocity Preference
0.00 - 0.49	0.00	0.00	0.00 - 0.09	0.23	0.23
0.50 - 0.59	0.03	0.03	0.10 - 0.19	0.26	0.26
0.60 - 0.69	0.04	0.05	0.20 - 0.29	0.32	0.30
0.70 - 0.79	0.07	0.07	0.30 - 0.39	0.29	0.37
0.80 - 0.89	0.11	0.09	0.40 - 0.49	0.43	0.43
0.90 - 0.99	0.10	0.11	0.50 - 0.59	0.50	0.50
1.00 - 1.09	0.24	0.18	0.60 - 0.69	0.60	0.58
1.10 - 1.29	0.26	0.25	0.70 - 0.79	0.65	0.65
1.30 - 1.49	0.30	0.28	0.80 - 0.89	0.81	0.72
1.50 - 1.59	0.32	0.31	0.90 - 0.99	0.78	0.80
1.60 - 1.69	0.37	0.35	1.00 - 1.09	0.85	0.85
1.70 - 1.89	0.39	0.37	1.10 - 1.19	0.72	0.90
1.90 - 1.99	0.41	0.40	1.20 - 1.29	0.74	0.95
2.00 - 2.09	0.69	0.52	1.30 - 1.39	1.00	1.00
2.10 - 2.19	0.65	0.65	1.40 - 1.49	0.99	0.98
2.20 - 2.49	0.84	0.85	1.50 - 1.59	0.97	0.97
2.50 - 2.59	0.89	0.90	1.60 - 1.69	0.81	0.94
2.60 - 2.99	1.00	1.00	1.70 - 1.89	0.77	0.92
3.00 - 3.19	0.80	0.95	1.90 - 1.99	0.75	0.90
3.20 - 3.39	0.79	0.90	2.00 - 2.09	0.66	0.88
3.40 - 3.99	0.86	0.86	2.10 - 2.19	0.71	0.86
4.00 - 4.49	0.69	0.75	2.20 - 2.29	0.93	0.84
4.50^{+}	0.64	0.64	2.30 - 2.39	0.92	0.82
			2.40 _ 2.59	0.23	0.80
			2.60 _ 2.69	0.26	0.73
			2.70 _ 2.79	0.32	0.67
			2.80 _ 2.89	0.29	0.60

Table A1-3. Depth and velocity preference factors for juvenile steelhead (continued).

Depth Interval (ft)	Depth Composite Preference	Recommended Depth Preference	Velocity Interval (ft/sec)	Velocity Composite Preference	Recommended Velocity Preference
			2.90 - 2.99	0.39	0.48
			3.00 - 3.19	0.38	0.35
			3.20 - 3.49	0.34	0.31
			3.50 - 3.59	0.28	0.26
			3.60 - 3.69	0.22	0.22
			3.70 - 4.99	0.19	0.19
			5.00 - 5.99	0.16	0.16
			6.00^+	0.00	0.00

Table A1-4. Depth and velocity preference factors for spawning chinook

Depth (ft)	Recommended Depth Preference		Velocity (ft/sec)	Recommended Velocity Preference
0.00	0.00		0.00	0.00
0.50	0.00		0.50	0.00
1.00	0.75		1.00	0.10
1.20	1.00		1.30	0.70
3.40	1.00		1.75	1.00
5.00	0.00		3.00	1.00
100.00	0.00		3.50	0.70
			4.00	0.00
			100.00	0.00

Table A1-5. Depth and velocity preference factors for juvenile chinook

Depth (ft)	Recommended Depth Preference		Velocity (ft/sec)	Recommended Velocity Preference
0.00	0.00		0.00	0.30
0.49	0.00		0.50	1.00
0.80	0.28		0.90	1.00
1.20	0.75		1.80	0.60
1.60	1.00		2.20	0.15
5.00	1.00		3.60	0.00
100.00	1.00		5.00	0.00
			6.00	0.00
			100.00	0.00

Table A1-6. Depth and velocity preference factors for spawning bull trout.

Depth Interval (ft)	Depth Composite Preference	Recommended Depth Preference	Velocity Interval (ft/sec)	Velocity Composite Preference	Recommended Velocity Preference
0.00 - 0.39	0.00	0.00	0.00 - 0.59	1.00	1.00
0.40 - 0.89	1.00	1.00	0.60 - 0.99	0.89	0.91
0.90^+	0.93	0.93	1.00 - 1.09	0.78	0.83
			1.10 - 1.39	0.75	0.75
			1.40 - 2.49	0.59	0.62
			2.50 - 3.49	0.59	0.50
			3.50 - 4.49	0.59	0.25
			4.50^+		0.00

Table A1-7. Depth and velocity preference factors for juvenile and adult bull trout.

Depth Interval (ft)	Depth Composite Preference	Recommended Depth Preference	Velocity Interval (ft/sec)	Velocity Composite Preference	Recommended Velocity Preference
0.00 - 0.49	0.00	0.00	0.00 - 0.29	0.22	0.22
0.50 - 0.69	0.01	0.02	0.30 - 0.39	0.26	0.26
0.70 - 0.79	0.17	0.17	0.40 - 0.59	0.74	0.74
0.80 - 0.99	0.27	0.27	0.60 - 0.89	0.83	0.83
1.00^{+}	1.00	1.00	0.90 - 1.29	0.48	0.92
			1.30 - 3.29	1.00	1.00
			3.30 - 3.49	0.76	0.76
			3.50 - 4.99	0.46	0.46
			4.50^{+}	0.46	0.00

Table A1-8. Substrate preference factors for the State of Washington
(after WDFW/DOE, 1996)

Substrate Code	Description	Spawning					Rearing/Holding			
		steelhead	bull trout	trout	Chinook & other salmon	Steelhead fry	juvenile salmon	adult bull trout & brook trout	adult steelhead	adult salmon
0	organic detritus fine organic	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10
1	silt, clay	0.00	0.00	0.00	0.00	0.10	0.40	0.10	0.10	0.10
2	sand	0.00	0.00	0.00	0.00	0.10	0.40	0.10	0.10	0.10
3	small gravel (0.1-0.5 in)	0.50	1.00	0.80	0.30	1.00	0.40	0.10	0.10	0.10
4	medium gravel (0.5-1.5 in)	1.00	1.00	1.00	1.00	1.00	0.50	0.20	0.20	0.30
5	large gravel (1.5-3.0 in)	1.00	1.00	0.80	1.00	1.00	0.50	0.30	0.30	0.30
6	small cobble (3.0-6.0 in)	1.00	0.70	0.50	1.00	1.00	0.70	0.50	0.30	0.30
7	large cobble (6-12 in)	0.30	0.70	0.00	0.50	1.00	0.80	0.70	0.30	0.30
8	boulder (> 12 in)	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
9	bedrock	0.00	0.00	0.00	0.00	0.10	0.30	0.30	0.30	0.30

Table A1-9. Cover preference factors for rearing and holding

Cover Code	Description	Rearing/Holding				
		fry	juvenile salmon	adult trout	adult steelhead	salmon
0.0	organic detritus/fine organic	0.10	0.10	0.10	0.10	0.10
0.1	undercut bank	1.00	1.00	1.00	1.00	1.00
0.2	overhanging vegetation touching water	1.00	1.00	1.00	1.00	1.00
0.3	rootwad (including partly undercut)	1.00	1.00	1.00	1.00	1.00
0.4	log jam or submerged brush pile	1.00	1.00	1.00	1.00	1.00
0.5	log(s) parallel to bank	0.30	0.80	0.80	0.80	0.80
0.6	submerged aquatic vegetation	1.00	1.00	0.80	0.60	0.80
0.7	submerged terrestrial grass	0.40	0.10	0.20	0.10	0.10
0.8	overhead cover not touching water		0.20		0.20	0.20
0.9	fine organic substrate	0.10	0.10	0.10	0.10	0.10

Appendix B1 – Tucannon Streamflow Data

Table B1-1. Tucannon Streamflow Gaging Data from Field Trip No 1 (page 1 of 8).

Stream Segment: Tucannon River at Marengo — **Date:** 4/29/2003

Cross-Section & Description: # 1 - Riffle (Downstream end) — **Time:** 5:25 PM

Sampling Crew: T. Hauser and M. Barber

Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)
L. Bank	3.7	0				
1	6.0	0.80	0.32	0	0	0.00
2	8.0	1.10	0.44	0	0	0.00
3	10.0	0.40	0.16	10	83.00	0.28
4	12.0	1.00	0.40	20	67.56	0.67
5	14.0	1.25	0.50	20	38.93	1.14
6	16.0	1.90	0.76	40	37.90	2.32
7	18.0	2.20	0.88	40	39.50	2.23
8	20.0	2.10	0.84	40	19.18	4.56
9	22.0	2.10	0.84	40	22.28	3.93
10	24.0	2.00	0.80	40	18.45	4.74
11	26.0	1.80	0.72	40	19.21	4.55
12	28.0	1.70	0.68	40	19.30	4.53
13	30.0	1.70	0.68	40	18.20	4.81
14	32.0	1.90	0.76	40	31.64	2.77
15	34.0	2.10	0.84	40	20.25	4.32
16	36.0	1.80	0.72	40	29.78	2.95
17	38.0	1.60	0.64	40	28.53	3.07
18	40.0	1.60	0.64	40	41.53	2.12
19	42.0	1.50	0.60	20	44.71	1.00
20	44.0	1.10	0.44	20	53.52	0.83
21	46.0	0.80	0.32	20	46.42	0.96
R. Bank	48.0	0	0	0		0.00
Pin	52.5					

Table B1-1. Tucannon Streamflow Gaging Data from Field Trip No 1 (continued page 2 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 4/29/2003

Cross-Section & Description: # 2 – Riffle and side pool **Time:** 4:40 PM

Sampling Crew: T. Hauser and M. Barber

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	3	0					
	1	4	0.35	0.14	20	34.21	0.00	
	2	6	0.40	0.16	40	41.21	0.00	
	3	8	0.90	0.36	40	38.61	2.28	
	4	10	1.20	0.48	40	27.43	3.20	
	5	12	1.20	0.48	40	26.06	3.36	
	6	14	1.30	0.52	40	21.77	4.02	
	7	16	1.20	0.48	40	22.05	3.97	
	8	18	1.40	0.56	40	19.58	4.47	
	9	20	1.70	0.68	40	17.37	5.03	
	10	22	2.00	0.80	40	15.53	5.63	
	11	24	2.10	0.84	40	15.64	5.59	
	12	26	2.20	0.88	40	21.43	4.08	
	13	28	2.00	0.80	40	17.77	4.92	
	14	30	2.00	0.80	40	17.52	4.99	
	15	32	1.70	0.68	40	29.45	2.98	
	16	34	1.90	0.76	40	33.30	2.64	
	17	36	1.70	0.68	30	76.78	0.87	
	18	38	1.20	0.48	10	89.08	0.26	
	19	40	0.70	0.28	10	69.16	0.34	
	20	42	0.90	0.00	0	0	0.00	
	21	44	0.30	0.12	0	0	0.00	
	R. Bank	45.3	0					
	Pin	52.5						

Table B1-1. Tucannon Streamflow Gaging Data from Field Trip No 1 (continued page 3 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 4/29/2003

Cross-Section & Description: # 3 – Pool Tail **Time:** 3:20 PM

Sampling Crew: T. Hauser and M. Barber

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	LB Pin	3						
	L. Bank	5.7	0					
	1	7	1.0	0.40	0	0	0.00	
	2	8	0.9	0.36	10	42.25	0.54	
	3	10	1.1	0.44	40	41.34	2.13	
	4	12	1.1	0.44	40	33.33	2.64	
	5	14	1.5	0.60	40	31.95	2.75	
	6	15	1.5	0.60	40	37.28	2.36	
	7	16	1.6	0.64	40	41.23	2.14	
	8	18	1.8	0.72	40	34.00	2.58	
	9	20	2.3	0.92	40	34.61	2.54	
	10	22	2.1	0.84	40	18.84	4.64	
	11	24	2.2	0.88	40	22.36	3.92	
	12	26	2.4	0.96	40	14.86	5.88	
	13	28	2.3	0.92	40	18.27	4.79	
	14	30	2.0	0.8	40	21.84	4.01	
	15	31	1.8	0.72	40	25.31	3.46	
	16	32	1.8	0.72	40	28.30	3.10	
	17	34	1.3	0.52	40	36.98	2.38	
	18	36	1.2	0.48	40	42.46	2.07	
	19	38	1.0	0.40	40	43.34	2.03	
	20	40	0.5	0	40	71.37	1.24	
	21	42	0.1	0.04	0	0	0.00	
	R. Bank	43.4	0					
	Pin	47.7						

Table B1-1. Tucannon Streamflow Gaging Data from Field Trip No 1 (continued page 4 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 4/29/2003

Cross-Section & Description: # 4 – Middle of pool **Time:** 2:40 PM

Sampling Crew: T. Hauser and M. Barber

Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)
L. Bank	1.8	0				
1	3.0	0.5	0.20	0		0.00
2	5.0	1.5	0.60	20	60.30	0.35
3	7.0	2.0	0.80	40	62.43	0.65
4	9.0	2.3	0.92	40	45.77	0.88
5	12.0	2.6	1.04	40	18.03	2.20
6	14.0	2.9	1.16	40	25.98	3.37
7	15.0	3.1	1.24	40	16.55	5.28
8	16.0	3.1 e				5.09
9	17.0	3.1 e				4.90
10	18.0	3.1 e				4.71
11	19.0	3.1 e				4.52
12	20.0	3.1 e				4.33
13	21.0	3.1	1.24	40	21.17	4.13
14	22.0	3.0	1.20	40	21.21	4.13
15	24.0	2.3	0.92	45	38.59	2.56
16	26.0	2.0	0.80	40	30.33	1.32
17	28.0	1.7	0.68	40	42.81	0.94
18	30.0	1.1	0.44	20	35.42	0.58
19	32.0	0.3	0.12	0		0.00
R. Bank	33.7	0	0			0.00
Pin	37.4					

Note: e – estimated: depth/velocity too large to safely gage: averaged between Sta 7 & 13

Table B1-1. Tucannon Streamflow Gaging Data from Field Trip No 1 (continued page 5 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 4/29/2003

Cross-Section & Description: # 5 – Top of Pool **Time:** 1:50 PM

Sampling Crew: T. Hauser and M. Barber

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	2.0	0					
	1	6.0	0.4	0.16			0.00	
	2	8.0	0.8	0.32	20	98.23	0.23	
	3	10.0	2.3	0.92	20	185.46	0.13	
	4	12.0	3.7	1.48	20	126.92	0.18	
	5	14.0	3.6	1.44	20	61.93	0.34	
	6	16.0	2.7	1.08	40	64.27	0.64	
	7	18.0	2.6	1.04	10	59.15	0.39	
	8	20.0	1.4	0.56	40	49.31	1.79	
	9	22.0	2.7	1.08	40	36.00	2.44	
	10	23.0	2.8	1.12	40	21.53	4.07	
	11	30.0	2.8	1.12	40	17.08	5.12	
	12	32.0	2.5	1.00	40	23.55	3.72	
	13	34.0	2.3	0.92	40	28.70	3.06	
	14	36.0	1.6	0.64	40	84.40	1.06	
	15	38.0	0.9	0.36	10	69.28	0.33	
	16	40.0	0.3	0.12	40	20.27	1.96	
	17	42.0	0.4	0.16	40	22.90	1.73	
	R. Bank	44.0	0				0.00	
	Pin	52.3						

Note: Flow depth/velocity between Sta 10 and 11 unsafe to gage.

Table B1-1. Tucannon Streamflow Gaging Data from Field Trip No 1 (continued page 6 of 8).

Stream Segment:	Tucannon River at Marengo						**Date:**	4/29/2003
Cross-Section & Description:		# 6 – Riffle					**Time:**	1:00 PM
Sampling Crew:	T. Hauser and M. Barber							
	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	1.9	0.00					
	1	4	0.50	0.20	0	0	0.00	
	2	7	1.10	0.44	40	54.96	1.61	
	3	10	1.60	0.64	40	33.58	2.62	
	4	12	1.80	0.72	40	28.09	3.12	
	5	14	1.50	0.60	40	32.12	2.73	
	6	16	1.40	0.56	40	39.81	2.21	
	7	18	1.70	0.68	40	50.56	1.75	
	8	20	1.70	0.68	40	60.83	1.46	
	9	22	1.20	0.48	40	21.67	4.04	
	10	24	1.60	0.64	40	25.39	3.45	
	11	26	1.65	0.66	40	22.30	3.93	
	12	28	1.10	0.44	40	30.68	2.86	
	13	30	1.20	0.48	40	40.13	2.19	
	14	32	1.30	0.52	40	18.98	4.61	
	15	34	1.10	0.44	40	19.48	4.49	
	16	36	1.30	0.52	40	31.02	2.83	
	17	38	1.30	0.52	40	27.21	3.22	
	18	40	1.30	0.52	40	23.17	3.78	
	19	43	0.80	0.32	40	28.05	3.13	
	20	46	1.00	0.00	40	33.98	2.59	
	21	49	0.60	0.24	10	21.90	1.02	
	22	52	0.40	0.16	10	49.33	0.46	
	R. Bank	54	0				0.00	
	Pin	61.6						

Table B1-1. Tucannon Streamflow Gaging Data from Field Trip No 1 (continued page 7 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 4/29/2003

Cross-Section & Description: # 7 – Bank Cut and Shelf **Time:** 12:10 PM

Sampling Crew: T. Hauser and M. Barber

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	7.5	0.00					
	1	8.5	1.30	0.52	40	57.39	1.54	
	2	10	1.70	0.68	40	23.30	3.76	
	3	11	1.70	0.68	40	20.15	4.34	
	4	12	1.90	0.76	40	21.21	4.13	
	5	13	2.00	0.80	40	26.18	3.35	
	6	14	1.85	0.74	40	16.70	5.23	
	7	15	2.00	0.80	40	15.02	5.82	
	8	16	1.90	0.76	40	18.45	4.74	
	9	18	2.00	0.80	40	16.50	5.30	
	10	20	1.70	0.68	40	19.71	4.44	
	11	22	1.60	0.64	40	25.34	3.46	
	12	24	1.60	0.64	40	36.43	2.41	
	13	27	1.00	0.40	40	73.98	1.20	
	14	30	1.05	0.42	40	53.83	1.64	
	15	33	0.75	0.30	40	44.42	1.98	
	16	36	0.60	0.24	40	129.83	0.70	
	17	44	0.50	0.20	40	47.64	1.85	
	18	47	0.80	0.32	40	29.71	2.95	
	19	50	0.90	0.36	40	29.33	2.99	
	20	53	1.60	0	40	27.53	3.19	
	21	56	1.40	0.56	40	121.20	0.74	
	R. Bank	61.5	0			0	0.00	
	Pin	66.6						

Table B1-1. Tucannon Streamflow Gaging Data from Field Trip No 1 (continued page 8 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 4/29/2003

Cross-Section & Description: # 8 – Upstream Log and Riffle **Time:** 11:30 AM

Sampling Crew: T. Hauser and M. Barber

Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)
L. Bank	17.6	0				
1	20	1.10	0.44	40	33.78	2.60
2	22	1.20	0.48	40	28.93	3.03
3	24	1.20	0.48	40	25.45	3.44
4	26	1.20	0.48	40	24.43	3.59
5	28	1.25	0.50	40	22.86	3.83
6	30	1.10	0.44	40	20.68	4.23
7	32	1.10	0.44	40	23.9	3.67
8	34	1.00	0.40	40	20.93	4.18
9	36	1.10	0.44	40	19.64	4.45
10	38	1.30	0.52	40	25.55	3.43
11	40	1.20	0.48	40	21.36	4.10
12	42	1.30	0.52	40	21.36	4.10
13	44	1.25	0.50	40	16.81	5.20
14	46	1.20	0.48	40	20.25	4.32
15	48	1.10	0.44	40	17.28	5.06
16	50	1.20	0.48	40	20.96	4.18
17	52	1.45	0.58	40	22.89	3.83
18	54	1.60	0.64	40	19.46	4.50
19	56	1.80	0.72	40	23.68	3.70
20	58	1.80	0.72	40	56.52	1.56
21	60	2.20	0.88			0.00
22	61.5	2.55	1.02			0.00
23	63.3	2.35	0.94			0.00
R. Bank	64.2	0	0			0.00
Pin	68					

Note: Sta 21, 22, and 23 behind large boulder, deep but little/no velocity

Table B1-2. Tucannon Streamflow Gaging Data from Field Trip No. 2

Stream Segment: Tucannon River at Marengo **Date:** 6/15/2003

Cross-Section & Description: # 1 - Riffle (Downstream end) **Time:** 2:45 PM

Sampling Crew: T. Hauser and P. Flanagan

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	4.5						
	1	7.0	0.85	0.34	0	0	0.00	
	2	13.0	0.70	0.28	10	25.3	0.88	
	3	16.0	1.60	0.64	30	36.8	1.80	
	4	18.0	1.80	0.72	40	33.8	2.60	
	5	20.0	1.70	0.68	40	30.9	2.84	
	6	21.0	1.60	0.64	40	29.8	2.94	
	7	22.0	1.50	0.60	40	28.8	3.05	
	8	23.0	1.40	0.56	40	26.8	3.27	
	9	24.0	1.50	0.60	40	23.6	3.71	
	10	25.0	1.40	0.56	40	24.6	3.56	
	11	26.0	1.40	0.56	40	27.4	3.20	
	12	27.0	1.50	0.60	40	26.9	3.26	
	13	29.0	1.40	0.56	40	29.1	3.01	
	14	31.0	1.50	0.60	40	30.1	2.92	
	15	33.0	1.50	0.60	40	44.6	1.98	
	16	35.0	1.60	0.64	40	37.8	2.33	
	17	37.0	1.40	0.56	30	40.1	1.65	
	18	39.0	1.20	0.48	30	46	1.44	
	19	41.0	1.20	0.48	20	45.1	0.99	
	20	43.0	0.95	0.38	10	40.5	0.56	
	21	45.5	0.60	0.24	5	24.4	0.47	
	R. Bank	46.8	0.00	0.00			0.00	
	Pin	52.4						

Table B1-2. Tucannon Streamflow Gaging Data from Field Trip No 2 (continued page 2 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 6/15/2003

Cross-Section & Description: # 2 – Riffle and side pool **Time:** 2:00 PM

Sampling Crew: T. Hauser and P. Flanagan

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	4.3						
	1	6.0	0.10	0.04	20	62.8	0.71	
	2	8.5	0.60	0.24	0	0	0.00	
	3	10.0	0.80	0.32	40	45.7	1.93	
	4	12.0	0.75	0.30	40	39.9	2.21	
	5	14.0	0.75	0.30	40	38.5	2.28	
	6	16.0	0.65	0.26	40	34.2	2.57	
	7	17.0	0.90	0.36	40	31.1	2.82	
	8	18.0	1.10	0.44	40	23.4	3.74	
	9	19.0	1.00	0.40	40	38.2	2.30	
	10	20.0	1.40	0.56	40	19.5	4.49	
	11	21.0	1.40	0.56	40	28.1	3.12	
	12	22.0	1.50	0.60	40	21.4	4.09	
	13	23.0	1.60	0.64	40	15.9	5.50	
	14	23.5	1.70	0.68	40	18.4	4.75	
	15	24.0	1.80	0.72	40	18.9	4.63	
	16	25.0	1.90	0.76	40	22.2	3.94	
	17	26.0	1.90	0.76	40	24.9	3.52	
	18	27.0	1.80	0.72	40	17.9	4.89	
	19	28.0	1.80	0.72	40	21.6	4.05	
	20	29.0	1.60	0.00	40	19.5	4.49	
	21	30.0	1.65	0.66	40	26.8	3.27	
	22	32.0	1.30	0.52	40	27.6	3.18	
	23	34.0	1.50	0.60	30	35.6	1.86	
	24	37.0	1.2	0.48	5	47.8	0.25	
	25	39.0	0.9	0.36	0	0	0.00	
	R. Bank	44.1						
	Pin	52.4						

Table B1-2. Tucannon Streamflow Gaging Data from Field Trip No 2 (continued page 3 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 6/15/2003

Cross-Section & Description: # 3 – Pool Tail **Time:** 1:20 PM

Sampling Crew: T. Hauser and P. Flanagan

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	LB Pin	3.0						
	L. Bank	6.4						
	1	7.0	0.55	0.22	0	0.0	0.00	
	2	9.0	0.30	0.12	20	32.6	1.36	
	3	11.0	0.80	0.32	20	26.6	1.66	
	4	13.0	1.00	0.40	30	33.7	1.96	
	5	15.0	1.10	0.44	40	48.2	1.83	
	6	17.0	1.30	0.52	40	41.8	2.11	
	7	18.5	1.70	0.68	40	29.0	3.03	
	8	20.0	1.85	0.74	40	23.5	3.73	
	9	21.5	1.75	0.70	40	26.7	3.28	
	10	23.0	1.80	0.72	40	23.9	3.67	
	11	24.5	1.75	0.70	40	26.2	3.35	
	12	26.0	1.85	0.74	40	29.7	2.95	
	13	27.5	1.75	0.70	40	27.2	3.22	
	14	29.0	1.70	0.68	40	32.3	2.72	
	15	30.5	1.45	0.58	40	32.2	2.73	
	16	32.0	1.20	0.48	40	36.0	2.44	
	17	34.0	1.15	0.46	30	40.6	1.63	
	18	36.0	0.85	0.34	20	31.4	1.41	
	19	38.0	0.60	0.24	20	48.2	0.92	
	R. Bank	40.8						
	Pin	47.9						

Table B1-2. Tucannon Streamflow Gaging Data from Field Trip No 2 (continued page 4 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 6/15/2003

Cross-Section & Description: # 4 – Middle of pool **Time:** 12:50 PM

Sampling Crew: T. Hauser and P. Flanagan

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	2.5						
	1	4.0	0.75	0.30	5	47.7	0.25	
	2	6.0	1.50	0.60	10	58.4	0.39	
	3	8.0	1.80	0.72	10	41.3	0.55	
	4	10.0	1.75	0.70	20	45	0.99	
	5	12.0	1.95	0.78	40	44	2.00	
	6	14.0	2.30	0.92	40	22.3	3.93	
	7	15.0	2.50	1.00	40	21.5	4.07	
	8	16.0	2.60	1.04	40	19.9	4.40	
	9	17.0	2.50	1.00	40	23.4	3.74	
	10	18.0	2.40	0.96	40	25.3	3.46	
	11	19.0	2.50	1.00	40	25.3	3.46	
	12	20.0	2.45	0.98	45	25.3	3.89	
	13	21.0	2.60	1.04	40	27	3.25	
	14	22.0	2.50	1.00	40	35.7	2.46	
	15	23.0	2.40	0.96	30	34.6	1.91	
	16	24.0	2.10	0.84	20	36	1.23	
	17	26.0	1.60	0.64	10	45.4	0.50	
	18	28.0	1.30	0.52	5	58.1	0.21	
	19	30.0	0.65	0.26	0	0	0.00	
	R. Bank	32.1						
	Pin	37.7						

Table B1-2. Tucannon Streamflow Gaging Data from Field Trip No 2 (continued page 5 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 6/15/2003

Cross-Section & Description: # 5 – Top of Pool **Time:** 11:45 AM

Sampling Crew: T. Hauser and P. Flanagan

Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)
L. Bank	1.5					
1	3.0	0.30	0.12	0	0	0.00
2	4.0	0.00	0.00	0	0	0.00
3	8.0	1.90	0.76	5	60.0	0.20
4	12.0	3.60	1.44	5	35.6	0.33
5	15.0	4.50	1.80	10	80.0	0.29
6	17.0	2.00	0.80	30	61.2	1.09
7	19.0	1.90	0.76	30	50.0	1.33
8	20.0	1.90	0.76	40	24.8	3.53
9	21.0	2.40	0.96	40	15.6	5.60
10	22.0	2.40	0.96	40	16.4	5.33
11	23.0	2.10	0.84	40	15.0	5.83
12	24.0	2.00	0.80	40	14.2	6.15
13	25.0	1.90	0.76	40	19.8	4.42
14	26.0	1.95	0.78	40	17.8	4.91
15	27.0	2.00	0.80	40	16.6	5.27
16	28.0	2.00	0.80	40	19.1	4.58
17	29.0	2.10	0.84	40	28.3	3.10
18	30.0	1.90	0.76	30	35.4	1.87
19	31.0	1.80	0.72	30	35.8	1.85
20	32.0	1.40	0.56	10	45.1	0.50
21	33.0	1.20	0.48	0	0.0	0.00
22	34.0	1.10	0.44	0	0.0	0.00
23	35.0	0.50	0.20	0	0.0	0.00
R. Bank	36.6					
Pin	50.3					

Table B1-2. Tucannon Streamflow Gaging Data from Field Trip No 2 (continued page 6 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 6/15/2003

Cross-Section & Description: # 6 – Riffle **Time:** 10:49 AM

Sampling Crew: T. Hauser and P. Flanagan

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	2.8						
	1	5.0	0.35	0.14	10	37.0	0.61	
	2	7.0	1.00	0.40	20	65.9	0.68	
	3	9.0	1.20	0.48	30	43.1	1.54	
	4	11.0	1.35	0.54	30	43.5	1.52	
	5	13.0	1.20	0.48	40	30.6	2.87	
	6	15.0	1.10	0.44	40	42.4	2.08	
	7	17.0	1.10	0.44	40	45.0	1.96	
	8	19.0	1.55	0.62	20	29.2	1.51	
	9	21.0	1.25	0.50	40	27.0	3.25	
	10	22.0	0.90	0.36	40	20.4	4.29	
	11	23.0	1.10	0.44	40	21.4	4.09	
	12	24.0	1.20	0.48	40	25.6	3.42	
	13	25.0	1.25	0.50	50	26.3	4.16	
	14	26.0	1.40	0.56	40	22.3	3.93	
	15	27.0	1.25	0.50	40	34.0	2.58	
	16	28.0	1.10	0.44	40	31.1	2.82	
	17	29.0	0.85	0.34	40	31.0	2.83	
	18	30.0	0.80	0.32	40	34.4	2.55	
	19	32.0	0.85	0.34	40	23.9	3.67	
	20	34.0	0.75	0.00	40	31.5	2.79	
	21	36.0	0.85	0.34	40	31.8	2.76	
	22	38.0	1.00	0.40	40	30.1	2.92	
	23	41.0	0.90	0.36	40	31.1	2.82	
	24	44.0	0.70	0.28	40	30.0	2.93	
	25	48.0	0.55	0.22	40	48.3	1.83	
	R. Bank	53.2					0.00	
	Pin	61.7						

Table B1-2. Tucannon Streamflow Gaging Data from Field Trip No 2 (continued page 7 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 6/15/2003

Cross-Section & Description: # 7 – Bank Cut and Shelf **Time:** 10:05 AM

Sampling Crew: T. Hauser and P. Flanagan

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	7.5						
	1	9.0	1.20	0.48	40	46.4	1.90	
	2	10.0	1.40	0.56	40	29.5	2.97	
	3	11.0	1.40	0.56	40	26.8	3.27	
	4	12.0	1.60	0.64	40	25.0	3.51	
	5	13.0	1.50	0.60	40	29.2	3.00	
	6	14.0	1.50	0.60	40	19.9	4.40	
	7	15.0	1.50	0.60	40	24.1	3.63	
	8	16.0	1.40	0.56	40	24.6	3.56	
	9	17.0	1.35	0.54	40	23.9	3.67	
	10	18.0	1.50	0.60	45	25.3	3.89	
	11	19.0	1.50	0.60	40	25.5	3.44	
	12	20.0	1.30	0.52	40	25.4	3.45	
	13	21.0	1.35	0.54	40	27.8	3.15	
	14	22.0	1.25	0.50	40	29.8	2.94	
	15	24.0	1.30	0.52	40	35.9	2.45	
	16	26.0	0.90	0.36	30	31.1	2.12	
	17	28.0	0.70	0.28	30	35.7	1.85	
	18	30.0	0.60	0.24	20	32.1	1.38	
	19	32.0	0.30	0.12	20	40.9	1.09	
	20	34.0	0.55	0.00	20	32.7	1.35	
	21	36.0	0.25	0.10	20	57.7	0.78	
	22	38.0	0.25	0.10	0	0.0	0.00	
	23	40.0	0.10	0.04	0	0.0	0.00	
	24	42.0	0.20	0.08	0	0.0	0.00	
	25	43.0	0.40	0.16	20	32.5	1.36	
	26	45.0	0.45	0.18	40	36.4	2.42	
	27	49.0	0.80	0.32	40	39.1	2.25	
	28	52.0	0.90	0.36	40	31.6	2.78	
	29	54.0	1.45	0.58	40	43.3	2.03	
	30	56.0	1.15	0.46	20	54.3	0.82	
	R. Bank	59.9	0					

Table B1-2. Tucannon Streamflow Gaging Data from Field Trip No 2 (continued page 8 of 8).

Stream Segment: Tucannon River at Marengo **Date:** 6/15/2003

Cross-Section & Description: # 8 – Upstream Log and Riffle **Time:** 9:30 AM

Sampling Crew: T. Hauser and P. Flanagan

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	18.0						
	1	20.0	0.50	0.20	40	52.1	1.69	
	2	22.0	0.80	0.32	40	32.0	2.74	
	3	24.0	0.90	0.36	40	39.5	2.23	
	4	26.0	0.70	0.28	40	33.9	2.59	
	5	28.0	0.80	0.32	40	38.8	2.27	
	6	30.0	1.00	0.40	40	30.0	2.93	
	7	32.0	0.90	0.36	40	36.0	2.44	
	8	34.0	0.80	0.32	40	31.3	2.80	
	9	36.0	0.70	0.28	40	28.4	3.09	
	10	38.0	0.90	0.36	40	27.7	3.17	
	11	40.0	0.75	0.30	40	28.6	3.07	
	12	42.0	0.90	0.36	40	28.6	3.07	
	13	44.0	1.10	0.44	40	30.3	2.90	
	14	45.0	1.00	0.40	40	27.1	3.24	
	15	46.0	1.00	0.40	40	29.7	2.95	
	16	47.0	1.10	0.44	40	25.6	3.42	
	17	48.0	0.90	0.36	40	27.3	3.21	
	18	49.0	0.70	0.28	40	26.5	3.31	
	19	50.0	0.70	0.28	40	22.8	3.84	
	20	51.0	0.90	0.36	40	32.2	2.73	
	21	52.0	0.90	0.36	40	27.8	3.15	
	22	53.0	1.10	0.44	40	26.5	3.31	
	23	54.0	1.40	0.56	40	24.6	3.56	
	24	55.0	1.40	0.56	40	34.8	2.53	
	25	57.0	1.65	0.66	40	49.8	1.77	
	26	59.0	1.80	0.72	30	35.1	1.88	
	27	61.0	1.95	0.78	5	81.0	0.15	
	R. Bank	63.4						
	Pin	68.2						

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No. 3

Stream Segment: Tucannon River at Marengo | **Date:** 7/29/2003

Cross-Section & Description: # 1 - Riffle (Downstream end) | **Time:** 3:37 PM

Sampling Crew: T. Hauser and L. Olinde

Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)
L. Bank	4.8					
1	7.0	0.60	0.24	0	0	0.00
2	10.0	0.00	0.00	0	0	0.00
3	12.0	0.50	0.20	10	57.6	0.40
4	14.0	0.60	0.24	10	42.3	0.54
5	16.0	1.30	0.52	30	59.4	1.12
6	18.0	1.50	0.60	40	54.7	1.62
7	20.0	1.40	0.56	45	47.7	2.08
8	22.0	1.20	0.48	40	36.4	2.42
9	23.0	1.10	0.44	40	39.3	2.24
10	24.0	1.10	0.44	40	33.5	2.62
11	25.0	1.10	0.44	40	25.5	3.44
12	26.0	1.10	0.44	40	42.4	2.08
13	27.0	1.10	0.44	40	43.9	2.01
14	28.0	1.10	0.44	40	45.1	1.95
15	30.0	1.10	0.44	40	36.2	2.43
16	32.0	1.10	0.44	40	46.3	1.90
17	34.0	1.30	0.52	40	52.7	1.68
18	36.0	1.20	0.48	30	51	1.30
19	39.0	0.80	0.32	30	58.5	1.14
20	42.0	0.80	0.32	10	68.5	0.34
R. Bank	46.4	0.00	0.00			0.00
Pin	52.5					

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No 3 (continued page 2 of 9).

Stream Segment: Tucannon River at Marengo **Date:** 7/29/2003

Cross-Section & Description: # 2 – Riffle and side pool **Time:** 2:47 PM

Sampling Crew: T. Hauser and L. Olinde

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	5.1						
	1	7.0	0.30	0.12	15	33.1	1.01	
	2	9.0	0.40	0.16	10	36.8	0.61	
	3	11.0	0.50	0.20	30	53.2	1.25	
	4	14.0	0.40	0.16	20	43.9	1.01	
	5	17.0	0.50	0.20	40	43.5	2.03	
	6	18.0	0.70	0.28	20	49.7	0.90	
	7	18.5	0.30	0.12	40	55.9	1.58	
	8	19.0	1.00	0.40	40	22.7	3.86	
	9	19.5	0.90	0.36	45	30.6	3.22	
	10	20.0	1.00	0.40	40	42	2.10	
	11	21.0	1.20	0.48	40	24.4	3.59	
	12	22.0	1.15	0.46	40	24.4	3.59	
	13	23.0	1.10	0.44	40	27.7	3.17	
	14	24.0	1.30	0.52	40	26.6	3.30	
	15	25.0	1.20	0.48	40	30.6	2.87	
	16	26.0	1.30	0.52	40	25.9	3.38	
	17	27.0	0.80	0.32	40	24.5	3.58	
	18	28.0	1.30	0.52	40	29.4	2.98	
	19	29.0	1.10	0.44	40	31.2	2.81	
	20	30.0	1.20	0.00	40	37.3	2.36	
	21	33.0	1.00	0.40	10	38.4	0.59	
	22	35.0	1.00	0.40	0	0	0.00	
	23	37.0	0.75	0.30	5	65.9	0.19	
	24	40.0	0.25	0.10	0	0	0.00	
	25	43.0	0.15	0.06	0	0	0.00	
	R. Bank	44.0						
	Pin	52.4						

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No 3 (continued page 3 of 9).

Stream Segment: Tucannon River at Marengo **Date:** 7/29/2003

Cross-Section & Description: # 3 – Pool Tail **Time:** 2:07 PM

Sampling Crew: T. Hauser and L. Olinde

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	3.7						
	1	5.0	0.20	0.08	0	0.0	0.00	
	2	7.0	0.30	0.12	20	39.0	1.14	
	3	9.0	0.60	0.24	20	36.2	1.22	
	4	11.0	0.80	0.32	40	49.4	1.79	
	5	13.0	0.80	0.32	30	60.4	1.10	
	6	15.0	1.00	0.40	20	46.4	0.96	
	7	16.0	1.50	0.60	40	43.2	2.04	
	8	17.0	1.40	0.56	40	37.6	2.34	
	9	18.0	1.30	0.52	40	36.0	2.44	
	10	19.0	1.30	0.52	40	33.9	2.59	
					40			
	11	20.0	1.40	0.56	40	31.8	2.76	
	12	21.0	1.50	0.60	40	33.2	2.65	
	13	22.0	1.60	0.64	40	35.7	2.46	
	14	23.0	1.60	0.64	40	35.6	2.47	
	15	24.0	1.40	0.56	40	35.7	2.46	
	16	25.0	1.40	0.56	40	38.8	2.27	
	17	26.0	1.40	0.56	40	42.9	2.05	
	18	27.0	1.10	0.44	40	48.7	1.81	
	19	28.0	1.05	0.42	40	42.2	2.09	
	20	29.0	0.90	0.36	40	47.1	1.87	
	21	31.0	0.90	0.36	40	55.2	1.60	
	22	33.0	0.50	0.20	40	67.0	1.32	
	23	35.0	0.20	0.08	15	43.2	0.78	
	R. Bank	36.5						
	Pin	45.0						

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No 3 (continued page 4 of 9).

Stream Segment: Tucannon River at Marengo **Date:** 7/29/2003

Cross-Section & Description: # 4 – Middle of pool **Time:** 1:35 PM

Sampling Crew: T. Hauser and L. Olinde

Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)
L. Bank	2.8					
1	5.0	0.65	0.26	5	63.9	0.19
2	7.0	1.30	0.52	10	56.3	0.41
3	9.0	1.50	0.60	10	25.4	0.88
4	11.0	1.55	0.62	20	34.2	1.29
5	12.0	1.60	0.64	40	44.2	1.99
6	13.0	1.70	0.68	40	39.1	2.25
7	13.5	1.90	0.76	40	32.9	2.67
8	14.0	2.10	0.84	40	32.0	2.74
9	14.5	2.10	0.84	40	32.1	2.74
10	15.0	2.30	0.92	40	30.8	2.85
11	15.5	2.10	0.84	40	30.9	2.84
12	16.0	2.40	0.96	40	31.6	2.78
13	16.5	2.10	0.84	40	34.7	2.53
14	17.0	2.20	0.88	40	33.9	2.59
15	18.0	2.10	0.84	40	38.4	2.29
16	19.0	2.00	0.80	40	41.7	2.11
17	20.0	2.10	0.84	40	45.1	1.95
18	21.0	2.20	0.88	40	58.7	1.51
19	22.0	2.20	0.88	20	41.7	1.07
20	23.0	1.90	0.76	15	44.8	0.75
21	24	1.70	0.68	10	46.2	0.49
22	26	1.25	0.50	0	0	0.00
23	28	0.90	0.36	0	0	0.00
R. Bank	30.9					
Pin	37.7					

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No 3 (continued page 5 of 9).

Stream Segment: Tucannon River at Marengo **Date:** 7/29/2003

Cross-Section & Description: # 5 – Top of Pool **Time:** 12:25 PM

Sampling Crew: T. Hauser and L. Olinde

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	2.5						
	1	4.0	0.00					
	2	5.0	0.00					
	3	6.0	0.10	0.04	0	0	0.00	
	4	7.0	1.50	0.60	0	0	0.00	
	5	8.0	1.70	0.68	0	0	0.00	
	6	9.0	1.90	0.76	0	0	0.00	
	7	10.0	3.00	1.20	0	0	0.00	
	8	11.0	3.10	1.24	0	0	0.00	
	9	12.0	3.30	1.32	0	0	0.00	
	10	13.0	3.90	1.56	0	0	0.00	
							0.00	
	11	14.0	1.90	0.76	0	0	0.00	
	12	15.0	4.00	1.60	0	0	0.00	
	13	16.0	1.90	0.76	5	47.4	0.25	
	14	17.0	1.80	0.72	10	40.5	0.56	
	15	18.0	1.60	0.64	20	33.1	1.34	
	16	19.0	1.65	0.66	40	46.5	1.90	
	17	19.5	1.80	0.72	40	25.1	3.49	
	18	20.0	1.90	0.76	40	21.9	4.00	
	19	20.5	2.10	0.84	40	16.8	5.20	
	20	21.0	2.10	0.84	40	16.8	5.20	
	21	21.5	2.20	0.88	40	17.5	5.00	
	22	22.0	2.10	0.84	40	21.1	4.15	
	23	22.5	1.60	0.64	40	27.8	3.15	
	24	23.0	1.90	0.76	40	31.1	2.82	
	25	24.0	1.90	0.76	50	33.5	3.27	
	26	25.0	1.60	0.64	40	27.5	3.19	
	27	26.0	1.65	0.66	40	36.7	2.40	
	28	27.0	1.80	0.72	40	52.2	1.69	
	29	28.0	1.50	0.60	10	33.6	0.67	
	30	29.0	1.70	0.68	10	90.9	0.26	

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No 3 (continued page 6 of 9).

Stream Segment: Tucannon River at Marengo **Date:** 7/29/2003

Cross-Section & Description: # 5 – Top of Pool (CONTINUED) **Time:** 12:25 PM

Sampling Crew: T. Hauser and L. Olinde

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	Cont.							
	31	31.0	1.40	0.56	0	0.0	0.00	
	32	33.0	1.00	0.40	0	0.0	0.00	
	R. Bank	35.8						
	Pin	50.3						

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No 3 (continued page 7 of 9).

Stream Segment: Tucannon River at Marengo **Date:** 7/29/2003

Cross-Section & Description: # 6 – Riffle **Time:** 10:49 AM

Sampling Crew: T. Hauser and L. Olinde

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	3.7						
	1	5.2	0.15	0.06	20	75.1	0.60	
	2	8.0	0.85	0.34	20	56.2	0.80	
	3	10.0	1.00	0.40	40	55.9	1.58	
	4	12.0	1.00	0.40	40	53.2	1.66	
	5	14.0	0.70	0.28	40	56.4	1.57	
	6	16.0	0.80	0.32	40	53.7	1.65	
	7	18.0	1.00	0.40	40	56.7	1.56	
	8	20.0	1.15	0.46	40	34.1	2.58	
	9	21.0	1.20	0.48	40	25.6	3.42	
	10	22.0	1.00	0.40	40	26.9	3.26	
	11	23.0	1.00	0.40	40	33.7	2.61	
	12	24.0	1.00	0.40	40	30.1	2.92	
	13	25.0	0.90	0.36	50	30.1	3.63	
	14	26.0	0.90	0.36	40	57.0	1.55	
	15	28.0	0.60	0.24	40	43.5	2.03	
	16	30.0	0.50	0.20	10	48.0	0.47	
	17	33.0	0.50	0.20	40	34.9	2.52	
	18	35.0	0.60	0.24	40	38.8	2.27	
	19	38.0	0.70	0.28	40	34.7	2.53	
	20	41.0	0.60	0.00	40	44.0	2.00	
	21	44.0	0.30	0.12	15	50.0	0.67	
	22	48.0	0.30	0.12	40	54.0	1.64	
	23	50.0	0.00	0.00	0	0.0	0.00	
	R. Bank	52.4						
	Pin	61.6						

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No 3 (continued page 8 of 9).

Stream Segment: Tucannon River at Marengo **Date:** 7/29/2003

Cross-Section & Description: # 7 – Bank Cut and Shelf **Time:** 10:45 AM

Sampling Crew: T. Hauser and L. Olinde

Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)
L. Bank	7.6					
1	9.0	0.90	0.36	40	40.2	2.19
2	10.0	0.90	0.36	40	38.8	2.27
3	11.0	1.10	0.44	40	40.0	2.20
4	12.0	1.20	0.48	40	37.4	2.35
5	13.0	1.20	0.48	40	32.7	2.69
6	14.0	1.20	0.48	40	27.3	3.21
7	15.0	1.20	0.48	40	34.2	2.57
8	16.0	1.10	0.44	40	29.7	2.95
9	17.0	1.00	0.40	40	25.9	3.38
10	18.0	1.20	0.48	40	27.6	3.18
11	20.0	1.00	0.40	40	33.9	2.59
12	22.0	0.90	0.36	50	46.7	2.35
13	24.0	0.90	0.36	40	48.6	1.82
14	26.0	0.55	0.22	15	35.3	0.95
15	29.0	0.20	0.08	20	30.6	1.44
16	30.0	0.20	0.08	20	31.8	1.39
17	32.0	0.20	0.08	20	29.4	1.50
18	34.0	0.30	0.12	20	51.2	0.87
19	36.0	0.20	0.08	10	41.3	0.55
20	38.0	0.20	0.00	10	31.1	0.72
21	40.0	0.00	0.00	0	0.0	0.00
22	43.0	0.20	0.08	10	32.4	0.00
23	45.0	0.2	0.08	10	26.6	0.00
24	47.0	0.5	0.20	40	63.9	0.00
25	49.0	0.6	0.24	40	55.2	1.60
26	51.0	0.5	0.20	40	45.4	1.94
27	53.2	1.1	0.44	40	54.3	1.63
28	55.0	1.3	0.52	10	24.3	0.92
29	57.0	0.6	0.24	0	0.0	0.00
R. Bank	59.1	0				

Table B1-3. Tucannon Streamflow Gaging Data from Field Trip No 3 (continued page 9 of 9).

Stream Segment: Tucannon River at Marengo **Date:** 7/29/2003

Cross-Section & Description: # 8 – Upstream Log and Riffle **Time:** 10:00 AM

Sampling Crew: T. Hauser and L. Olinde

	Station No.	Station Position (ft)	Total Depth (ft)	Depth	Rev	Time (s)	Velocity (ft/s)	
	L. Bank	18.9						
	1	21.0	0.50	0.20	40	42.5	2.07	
	2	23.0	0.60	0.24	40	40.8	2.16	
	3	25.0	0.30	0.12	40	42.9	2.05	
	4	27.0	0.60	0.24	40	35.9	2.45	
	5	29.0	0.60	0.24	40	56.1	1.58	
	6	31.0	0.65	0.26	40	50.8	1.74	
	7	33.0	0.70	0.28	40	43.3	2.03	
	8	35.0	0.55	0.22	40	39.7	2.22	
	9	37.0	0.55	0.22	40	42.5	2.07	
	10	39.0	0.70	0.28	40	36.5	2.41	
	11	41.0	0.60	0.24	40	50.3	1.75	
	12	43.0	0.65	0.26	40	34.8	2.53	
	13	45.0	0.80	0.32	40	46.1	1.91	
	14	47.0	0.70	0.28	40	51.7	1.71	
	15	49.0	0.50	0.20	40	48.6	1.82	
	16	51.0	0.70	0.28	40	35.3	2.49	
	17	52.0	0.70	0.28	40	36.9	2.38	
	18	53.0	1.00	0.40	40	36.4	2.42	
	19	54.0	1.10	0.44	40	34.6	2.54	
	20	56.0	1.30	0.52	50	39.8	2.76	
	21	58.0	1.40	0.56	40	54.3	1.63	
	22	60.5	1.90	0.76	15	78.2	0.44	
	23	62.0	0.00	0.00	0	0.0	0.00	
	R. Bank	62.9						
	Pin	68.0						

Appendix B2 – Tucannon Survey Data

TABLE B-1. SURVEY DATA FOR THE TUCANNON RIVER (PG 1 OF 2).

Field Personnel: P. Flanagan, T. Hauser, and L. Olinde Date: June 2003

Location	Horizontal Angle	Vertical Angle	Distance (ft)	Height (ft)		X (ft)	Y (ft)
				Instrument	Rod		
TP No. 1				5.35			100.00
Cross section 8 - RB pin	0.000	88.423	116.695		8.00	116.65	100.56
Cross section 8 - LB pin	28.099	89.891	142.925		5.00	142.92	100.62
Cross section 7 - LB pin	78.588	90.510	74.495		5.60	74.49	99.09
Cross section 7 - RB pin	57.070	90.726	8.695		5.60	8.69	99.64
Cross section 6 - LB pin	172.962	91.205	158.955		4.80	158.92	97.21
TP No. 2	221.387	90.332	156.020		4.80	156.02	99.65
Backsite to TP No. 1	0.000	89.825	155.970	5.28	5.30	155.97	100.10
Cross section 6 - RB pin	43.553	90.658	84.875		4.80	84.87	99.15
Cross section 5 - RB pin	138.909	98.544	27.920	5.28	4.80	27.61	95.98
Cross section 5 - LB pin	135.048	90.899	77.455		8.00	77.45	95.71

Notes:

TABLE B-1. SURVEY DATA FOR THE TUCANNON RIVER (CONTINUED PG 2 OF 2).

Field Personnel: P. Flanagan, T. Hauser, and L. Olinde Date: June 2003

Location	Horizontal Angle	Vertical Angle	Distance (ft)	Height (ft)		X (ft)	Y (ft)
				Instrument	Rod		
Cross section 4 - RB pin	169.965	98.205	40.700		4.80	40.28	94.32
Cross section 4 - LB pin	151.514	90.793	73.545		8.00	73.54	95.91
Cross section 3 - RB pin	192.519	95.899	53.935		4.80	53.65	94.59
Cross section 3 - LB pin	164.768	93.113	84.770		4.80	84.64	95.52
Cross section 2 - RB pin	207.824	90.095	163.305		8.50	163.30	96.16
Cross section 2 - LB pin	190.106	91.841	172.455		5.30	172.37	94.09
TP No. 3	221.105	92.022	136.545	5.28	5.00	136.46	95.11
Backsite to TP No. 2	0.000	88.350	136.520	5.53	4.77	136.46	99.80
TP No. 4	163.889	89.884	162.390	5.53	5.00	162.39	95.97
Backsite to TP No. 3	0.000	90.535	162.495	5.55	4.77	162.49	95.23
Cross section 1 - RB pin	168.513	88.959	50.130	5.55	8.00	50.12	94.43
Cross section 1 - LB pin	133.705	92.606	85.005	5.55	5.00	84.92	92.66

Notes:

Appendix B3 – Substrate Data

Table B3-1. Substrate Codes for Tucannon River at Marengo

Cell No.	Cross-Section Downstream							Upstream
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
LB	01.9	73.8	80.8	84.8	25.8	75.8	45.8	45.9
1	01.9	73.8	80.8	84.8	25.8	75.8	56.8	45.9
2	01.9	64.8	83.8	56.8	98.9	75.8	56.8	54.8
3	01.9	64.8	83.8	36.8	21.9	87.9	56.8	54.8
4	45.8	64.8	53.8	34.5	21.9	86.9	64.9	45.9
5	45.8	54.8	53.8	34.5	98.9	86.9	64.8	45.9
6	85.7	54.8	37.8	53.8	98.9	45.8	65.8	56.8
7	56.8	54.8	37.8	53.8	98.9	35.8	65.8	56.8
8	56.8	45.8	57.8	56.8	48.8	46.8	65.8	56.8
9	45.8	45.8	57.8	56.8	48.8	86.8	64.6	56.6
10	45.8	64.8	34.6	75.8	98.9	98.9	64.6	56.8
11	45.7	64.8	63.8	75.8	98.9	98.9	46.8	56.8
12	45.7	64.8	63.8	65.8	98.9	98.9	45.8	56.8
13	45.7	76.8	75.8	65.8	78.8	98.9	45.8	56.6
14	45.8	76.8	75.8	65.8	78.8	46.8	45.8	56.5
15	45.8	76.8	56.5	75.8	65.9	46.8	45.8	56.5
16	45.8	65.8	56.5	75.6	65.9	46.8	45.8	65.8
17	53.8	65.8	64.8	85.9	65.8	56.8	65.8	65.8
18	53.8	57.8	64.8	56.8	76.8	56.8	65.8	57.8
19	45.6	56.8	64.8	56.8	85.8	45.8	65.8	57.8
20	45.8	56.8	64.8	73.8	89.9	46.6	65.8	65.8
21	45.8	56.8	65.8	71.5	57.8	46.7	65.8	65.8
22	54.8	56.8	65.8	01.9	57.8	45.8	65.8	57.8
23	54.8	57.8	75.6	46.8	24.8	45.8	65.8	56.8
24	54.8	85.9	75.6	35.8	89.9	98.9	65.8	56.8
25	75.8	75.8	63.8		03.8	56.8	65.8	56.8
26	65.8	56.8	46.8		03.8	45.8	56.7	56.8
27	60.9	64.8	46.8		45.8	45.8	46.8	56.8
28	60.9	45.7	46.8		45.8	43.8	65.9	65.8
29		72.8	36.8			54.8	76.8	65.8
30		95.8	36.8				65.8	65.8
31		09.8	35.8				65.8	65.8

32			35.8					21.9
33			35.8					
34			35.8					
35			35.8					