Determination of Optimal Flows to Support Chum Salmon Spawning in the Lower Theodosia River

Prepared by:

J.D.C. Craig, AScT
BC Conservation Foundation
Nanaimo, BC

Living rivers
GEORGIA BASIN
VANCOUVER ISLAND

February 2011

Determination of Optimal Flows to Support Chum Salmon Spawning in the Lower Theodosia River

Introduction

In spring 2010, Fisheries and Oceans Canada (DFO) organized an assessment of salmon spawning habitat in the lower Theodosia River, 25 km north of the City of Powell River, BC. Study participants included fisheries staff from Sliammon First Nation (SFN), BC Conservation Foundation (BCCF) and DFO. The study's goal was to determine optimal flows required to support chum salmon spawning in historical areas of the lower river. This document should be paired with results of a flow assessment completed in 2011 by KWL Associates, Victoria, BC (*Tech Memo – Summer Flow Distribution Assessment, December 13, 2011, file 0673-020*).

Methods

In consultation with SFN, topographic maps of the study area were examined in advance of field work to determine appropriate access and potential sites. In April 2010, the primary and one secondary stream channel in the lower flood plain were inspected and, based on current field conditions and SFN historical observations, representative chum spawning sites were selected for study. Sites were accessed by an old logging spur crossing the floodplain.

Data loggers (water level, barometric pressure, temperature; Solinst, model 3001) were installed and bench-marked in each channel to record water levels every hour over the spring, summer and fall. Level loggers were installed in existing (abandoned) housings at bridge crossings or in vented steel pipes pounded into stream substrates. The barologger was left in a SFN staff pick-up parked at the estuary over the study period.

Individual transects perpendicular to the stream flow were selected primarily on the basis of having appropriate characteristics for chum spawners: pool or run tailouts with clean gravel/cobble substrate and shallow depths less of than 1.0 m. Crews set rebar and flagging on each bank and GPS located each site.

A primary consideration for this study was how appropriate sites examined for chum spawning suitability as described above would be for measuring discharge. Following site selection and discharge measurement procedures as described in the Manual for British Columbia Hydrometric Standards (Province of BC 2009), the study team chose the transects to accomplish both tasks – the analysis of chum spawning habitat suitability, and the measurement of stream discharge. Fortunately, chum spawners tend to utilize sites that are quite suited to discharge measurements.

Beneath a 50-m tape suspended between rebar anchors, crews recorded depths and employed a recently calibrated velocity meter (Swoffer, model 3000 or 2100) to measure water velocities. A minimum of 20 stations (RIC standards) were measured across each transect, and photographs were taken looking downstream and upstream at each site.

Transect measurements and photographs were repeated periodically between April and November 2010 under as wide a range of flow conditions as possible.

Transect and downloaded logger data were entered into Excel spreadsheets to generate habitat suitability results and seasonal hydrographs. Developed by BC Hydro for water use planning and regularly used by provincial and federal fisheries staff, habitat suitability index (HSI) curves for spawning chum were used to determine how flow-related changes in depth and velocity at transect sites affected usability. For example, in the case of chum salmon spawners, habitat is generally considered 100% suitable with water depths of 0.27 – 0.40 m and water velocities of 0.55 – 0.75 m. As values diverge away from these ranges, suitability for spawning chum eventually drops to zero.

Results

On April 21, 2010, crews established two transects in each of two stream channels: the primary channel (T3) on the south side of the valley floor, and a secondary channel (T1) running along the north side of the floodplain (Figure 1; Table 1). A third channel (T2) in the middle of the floodplain was completely dry, appeared to flow only during floods, and was dropped from the study. Data loggers were installed in T1 and T3 in protected locations at elevations expected to stay wet through the summer.

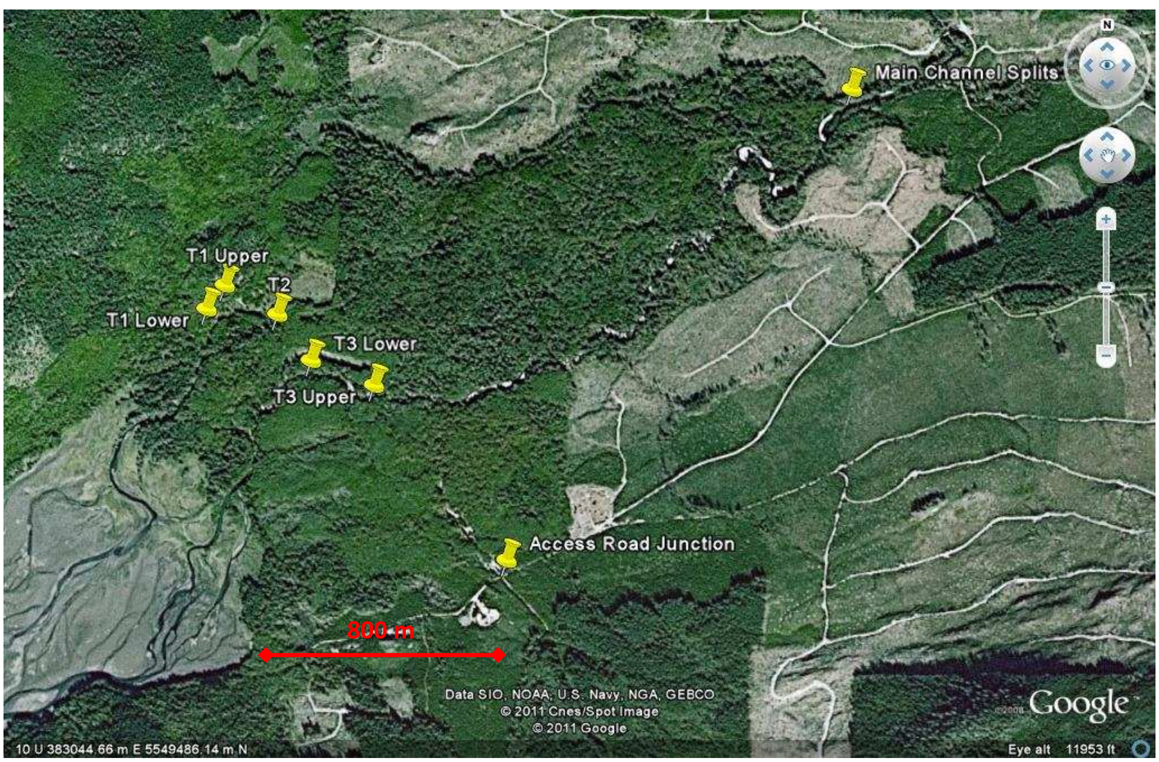


Figure 1. Satellite view of the lower Theodosia River flowing from top right to lower left. Also shown are the estuary at left, various access roads, the study sites, and the approximate location of where main channel splits on the lower floodplain.

Table 1. Study sites and locations.

Channel	Transect	Location	GPS
Primary	T3 Upper	~10 m d/s of bridge crossing	382270, 5549436
	T3 Lower	~230 m d/s of logging bridge	382041, 5549532
Secondary	*T2*	*(dry channel – dropped from study)*	*381921, 5549703*
Secondary	T1 Upper	~20 m d/s of the end of the access road ~10 m d/s of level logger	381731, 5549813
	T1 Lower	~60 m d/s of the end of the access road ~50 m d/s of level logger	381663, 5549728

Over the summer, crews returned to the sites on five occasions, acquiring a total of six sets of flow transect data (Table 2). Relatively high flows in the primary channel during Trips 2 and 6 prevented crews from safely collecting data at that location.

Table 2. Summary of discharge (Q) and habitat suitability index (HSI) data over the duration of the study.

Trip#	Date		T1 Upper	T1 Lower	T3 Upper	T3 Lower
1	**21-Apr**	**Q (m^3/s)**	1.82	1.78	8.18	8.36
		HSI (%)	58.7	74.2	30.5	57.8
2	**2-Jun**	**Q (m^3/s)**	2.89	2.70		
		HSI (%)	39.4	74.3		
3	**20-Jul**	**Q (m^3/s)**	0.78	0.74	1.83	1.63
		HSI (%)	18.0	13.0	25.0	5.0
4	**24-Aug**	**Q (m^3/s)**	0.34	0.33	0.40	0.36
		HSI (%)	8.0	0.0	0.0	0.0
5	**30-Sep**	**Q (m^3/s)**	0.81	0.75	4.15	4.36
		HSI (%)	28.0	15.0	34.0	45.0
6	**16-Nov**	**Q (m^3/s)**	1.49	1.60		
		HSI (%)	51.0	62.0		

Hydrology

Data loggers were removed on November 16, 2010 and subsequently downloaded. During removal, the elevation of the T3 logger in the old culvert housing appeared not to have changed but was not verified relative to the benchmark established in April. At T1, the cable suspending the data logger beneath the tube cap was found to have broken, and the logger was retrieved from the bottom of the tube. The “drop” of the data logger was obvious in the data record and was later corrected for. The elevation of the steel tube was not verified relative to April benchmarks.

Hourly level logger data were examined for irregularities and found to have unexplainable "jumps" at certain times of the study that could not have been natural events. Differing in magnitude but averaging 20 cm, these 2-4 hour duration "jumps" in water height were spaced at approximately 24-hour intervals. They would repeat daily for a week to 10 days, then be absent for one or two weeks, then return. They were easily identified and subsequently replaced by interpolated values. Hourly barologger data showed a handful of irregularities, but these were singular events separated by a month or more, and were easily identified and adjusted.

The cleaned data sets were used to finalize stream stage values and, in conjunction with the discharge measurements collected over the study period, used to create stage-discharge curves and ultimately discharge records for the T1 and T3 channels (Figures 2 and 3).

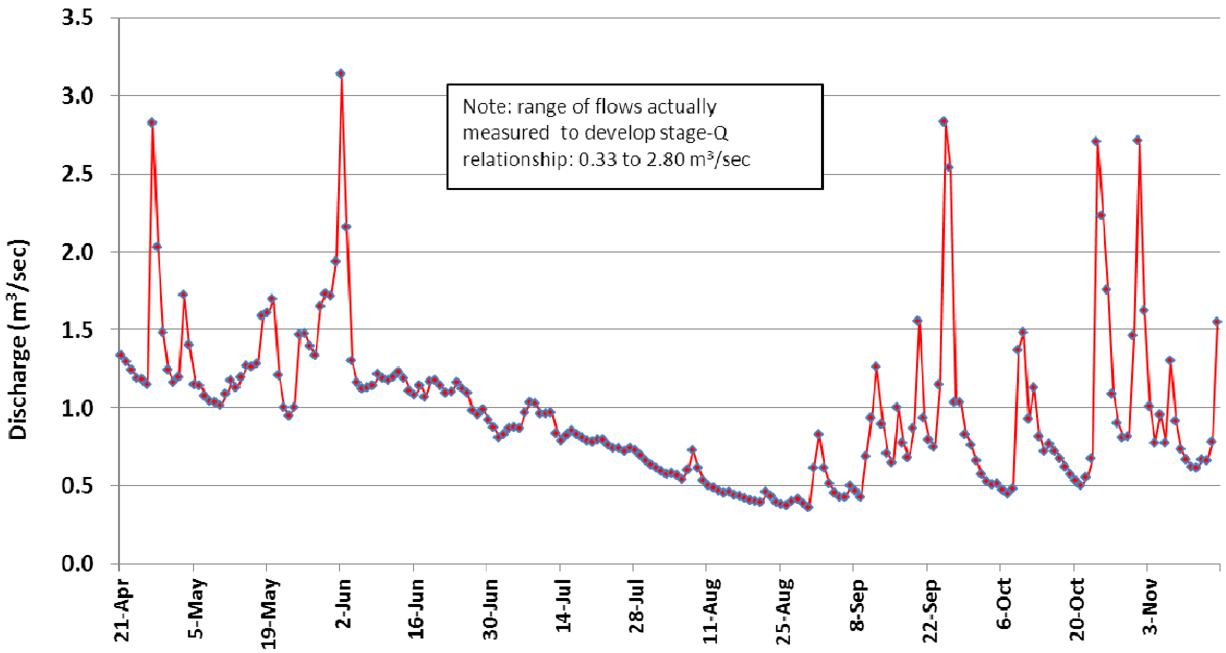


Figure 2. Mean daily discharge in Theodosia T1 Channel, Apr 21 - Nov 16, 2010.

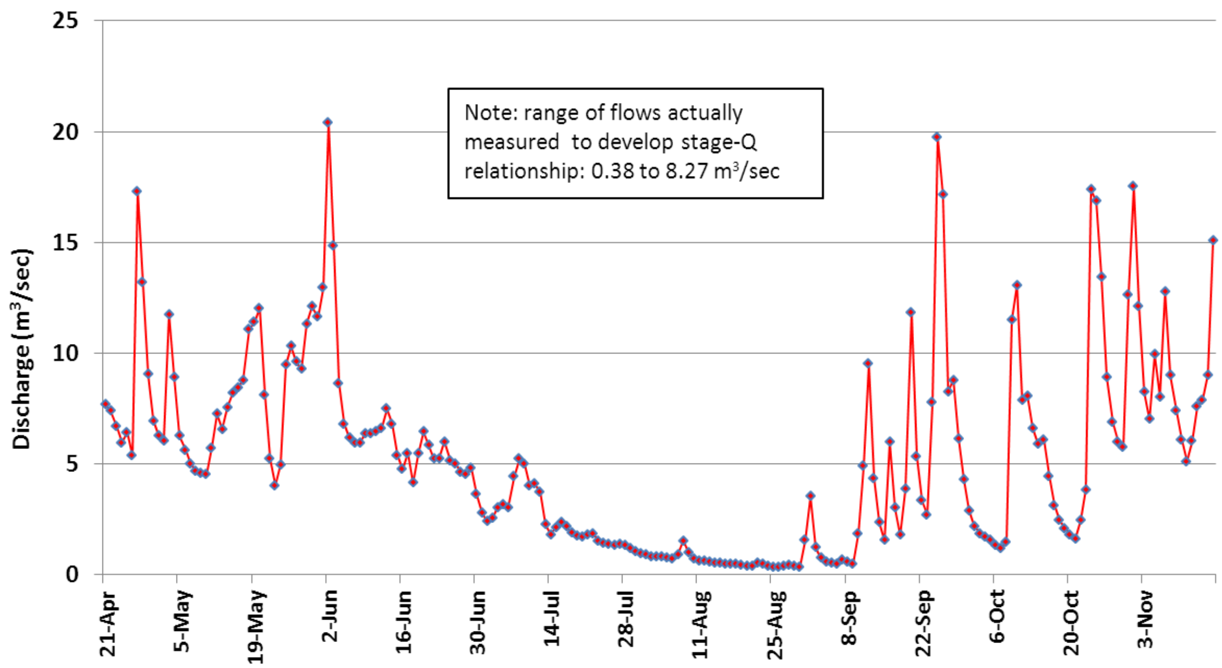


Figure 3. Mean daily discharge in Theodosia T3 Channel, Apr 21 – Nov 16, 2010.

Habitat Suitability

Scatter plots of discharge versus HSI values were generated for each of the two transects in each of the two channels. Best fit polynomial trend lines were applied in each case to describe the relationship, and the discharge corresponding to maximum habitat suitability for chum spawners was identified.

At the two T1 sites, optimal suitability likely occurred at a discharge of 2.0 m^3/s. According to the data, peak suitability actually occurred at 2.29 m^3/s, but peaks were skewed high due to insufficient high flow measurements. With additional high flow values, maximum suitability would likely shift to approximately 2.0 m^3/s.

At the two T3 sites, optimal suitability likely occurred at a discharge of 6.0 m^3/s. According to the data, peak suitability actually occurred at 6.94 m^3/s, but once again peaks were skewed high because only one high flow measurement was available. With additional high flow values, maximum suitability would likely shift to approximately 6.0 m^3/s in Channel T3.

To ascertain a total river discharge that maximizes habitat suitability for spawning chum, flows in T1 and T3 were considered in aggregate. The proportion of total discharge that each channel receives is likely controlled in part by an historic log jam ~2 km upstream that divides the single thread channel into the two that were studied. A comparison of the two hydrographs shows that T1 conveys an average of 14% of the aggregate lower river flow. As a result, the chances of having optimal flows occur in both channels at once (6.0 m^3/s in T3; 2.0 m^3/s or 25% in T1) are low.

Accordingly, an aggregate flow that supports the highest chum spawning suitability overall was determined. Using the flow data sets, the relationship between same-day discharges in each channel was derived and used to predict flows in one channel given *optimal flows in the other*. With 2.0 m^3/s in T1 (optimal for that channel), T3 would be conveying ~13.6 m^3/s, a discharge that significantly drops suitability in that channel from an average of 46% (40% and 52%) to less than 20% (0 and 39%). In contrast, with 6.0 m^3/s in T3 (optimal for that channel), T1 would be conveying ~1.0 m^3/s, reducing suitability in that channel from an average of 63% (55% and 71%) to 39% (39% and 39%). Therefore, an aggregate flow of ~7 m^3/s would generate maximum suitability in the T3 primary channel, while still affording reasonable spawning conditions in the T1 secondary channel.

Summary

Discharge and spawning habitat conditions in the two channels of the lower Theodosia River were measured over a range of river stage conditions. Data loggers installed in the channels during the study produced hourly stage data that were combined with field discharge measurements to produce stage-discharge relationships and seasonal hydrographs for each channel for the period April 21 to November 16, 2010.

Habitat suitability index curves describing chum spawner depth and velocity preferences were used to determine how site usability varied with discharge. Through analysis of the six sets of field data collected spring through fall, habitat suitability for chum spawners appeared to reach optimal conditions with flows of 6 m^3/s in the T3 primary channel and 2 m^3/s in the T1 secondary channel. However, T1 typically receives ~14% of the aggregate lower river discharge during the spawning periods, meaning that optimal conditions in both channels does not occur simultaneously.

An analysis of conditions in one channel when conditions in the other are optimal showed that supplying T3's optimal 6 m^3/s discharge and ~1.0 m^3/s to the T1 secondary channel (i.e., aggregate ~7 m^3/s to lower river) generates the best conditions overall.

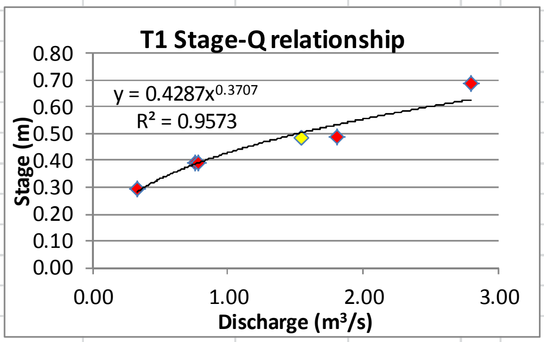
Appendices

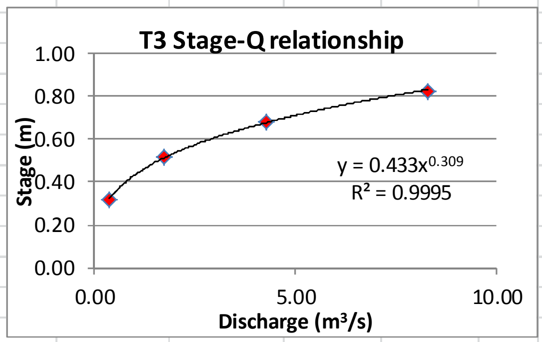
Theodosia River CM Flow Study

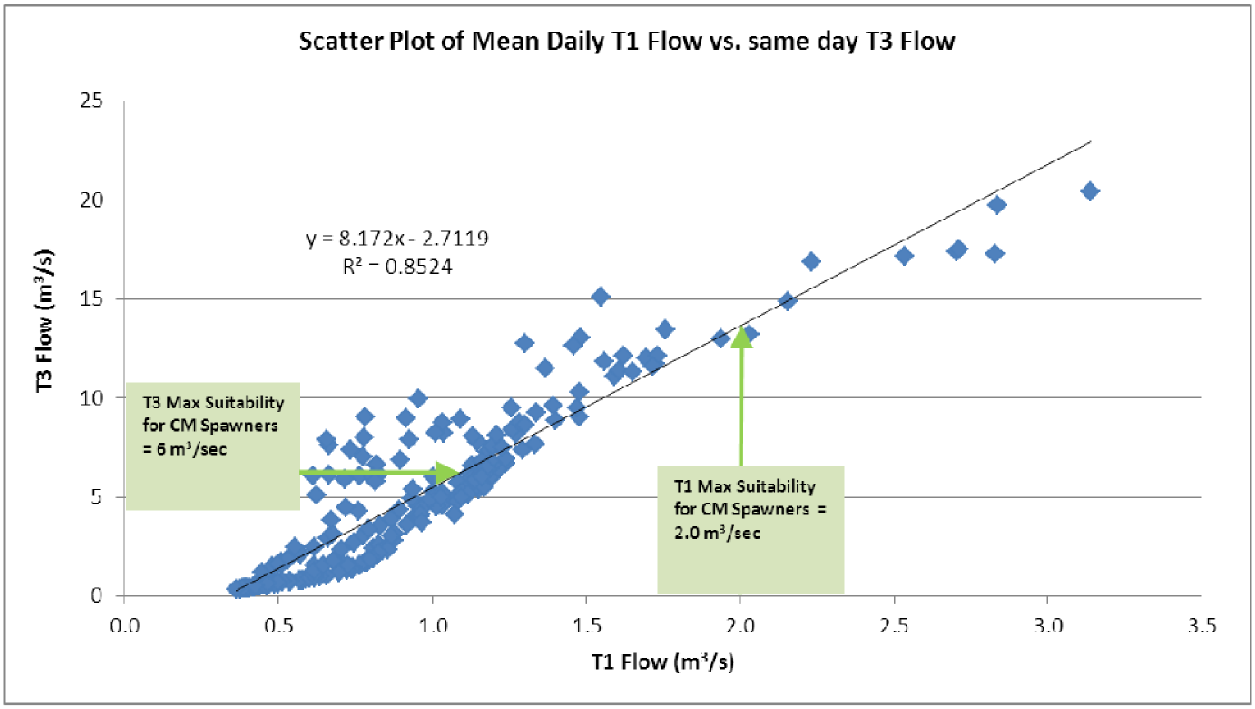
		T1			T3	
		Q	STAGE *		Q	STAGE *
TRIP 1	21-Apr-10	1.80	0.4900		8.27	0.8258
TRIP 2	2-Jun-10	2.80	0.6886			
TRIP 3	20-Jul-10	0.76	0.3894		1.73	0.5191
TRIP 4	24-Aug-10	0.33	0.2920		0.38	0.3197
TRIP 5	30-Sep-10	0.78	0.3914		4.26	0.6785
TRIP 6	16-Nov-10	1.54	0.4844	**		

* STAGE value used was the first reading after noon on the day the Q was measured.

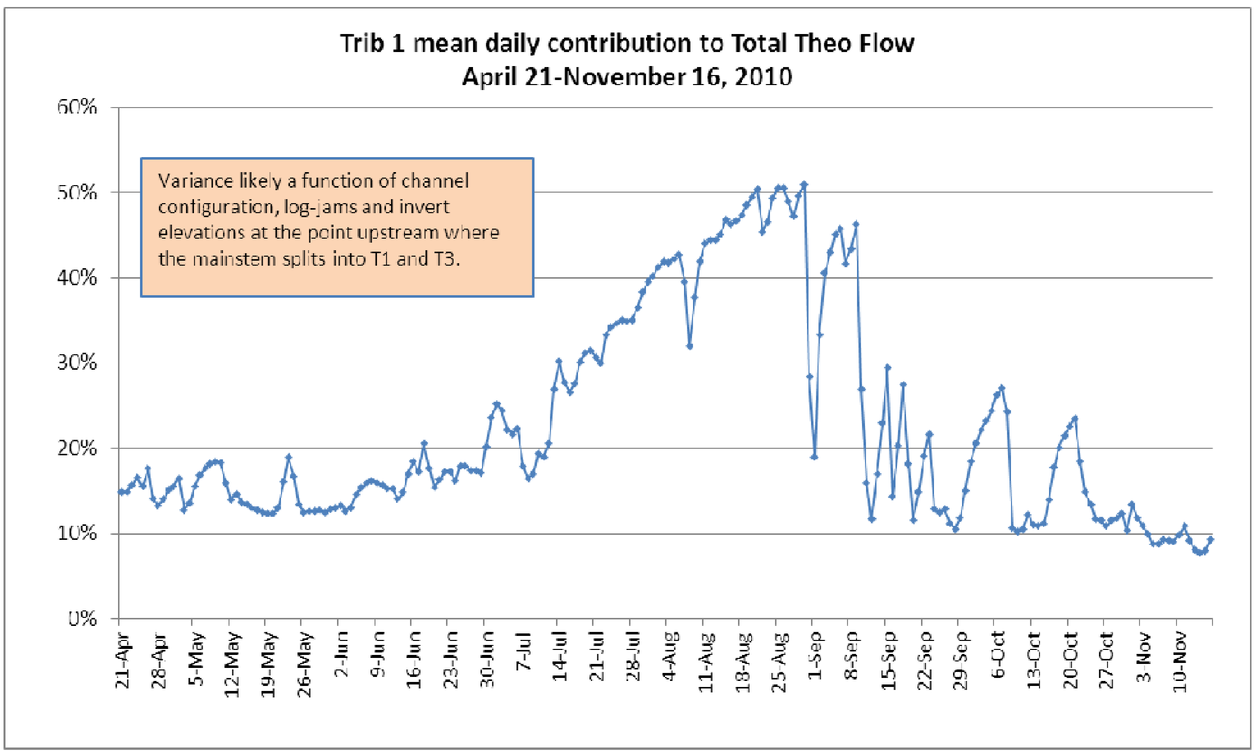
** STAGE value for this date/time has been reduced by 0.40 m to adjust for levellogger cable breaking (and the unit falling) in steel housing tube on Nov 4, 2010 at about 1300 hrs. Value of 0.40 m is approximate mean of the difference evident in the two levellogger data sets prior to the cable breaking in the October/November period.



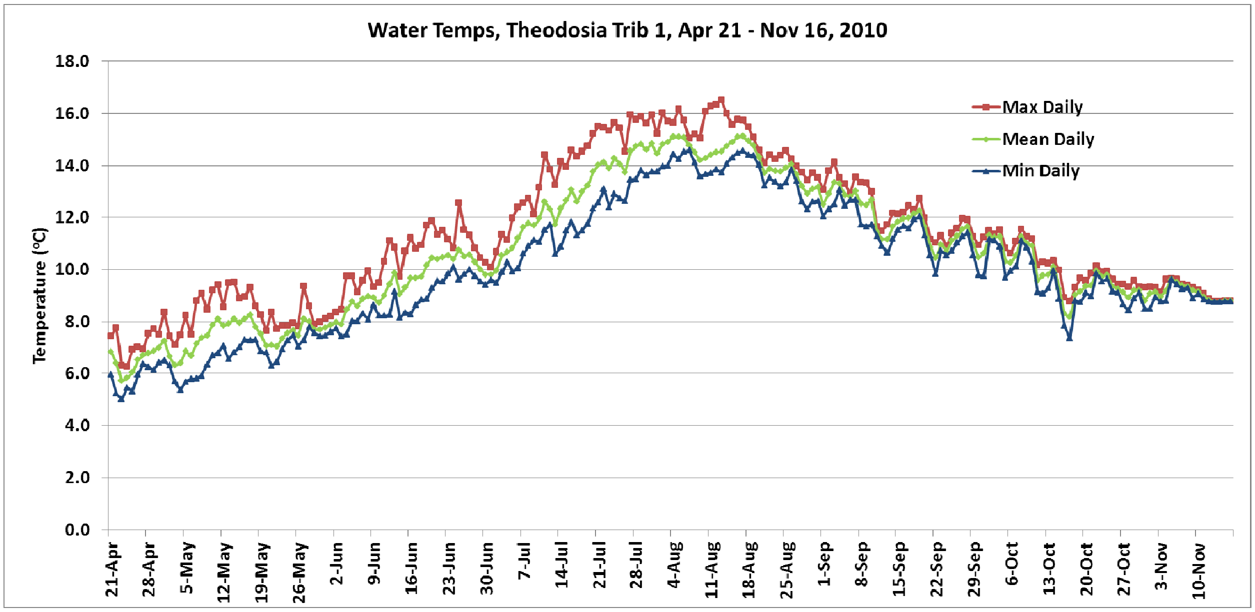


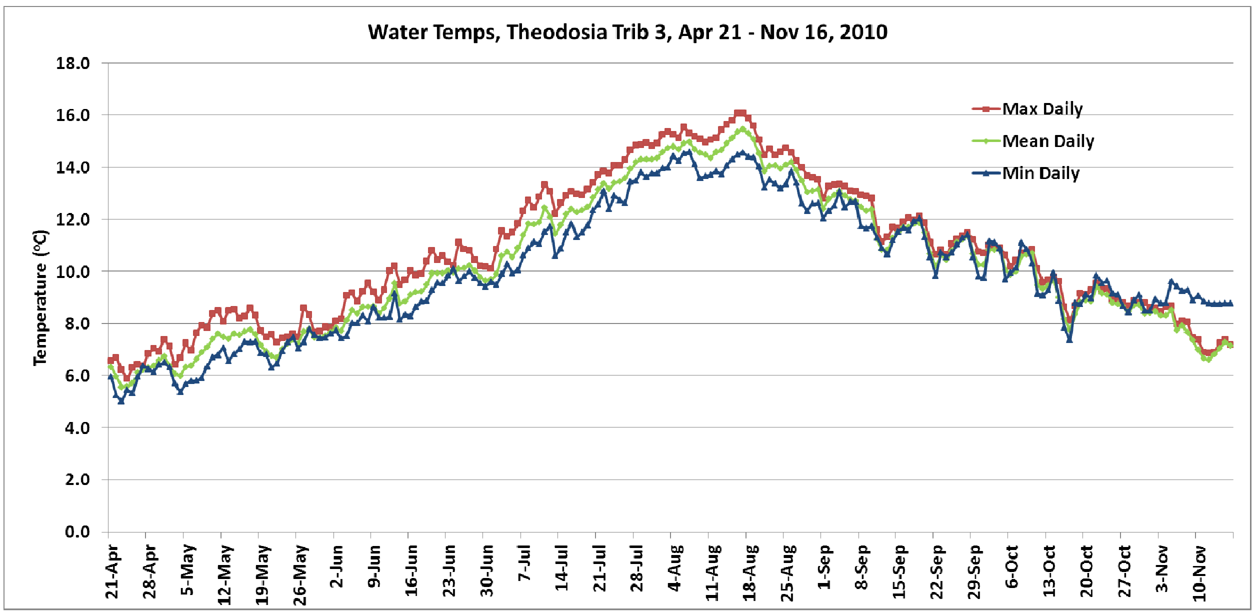


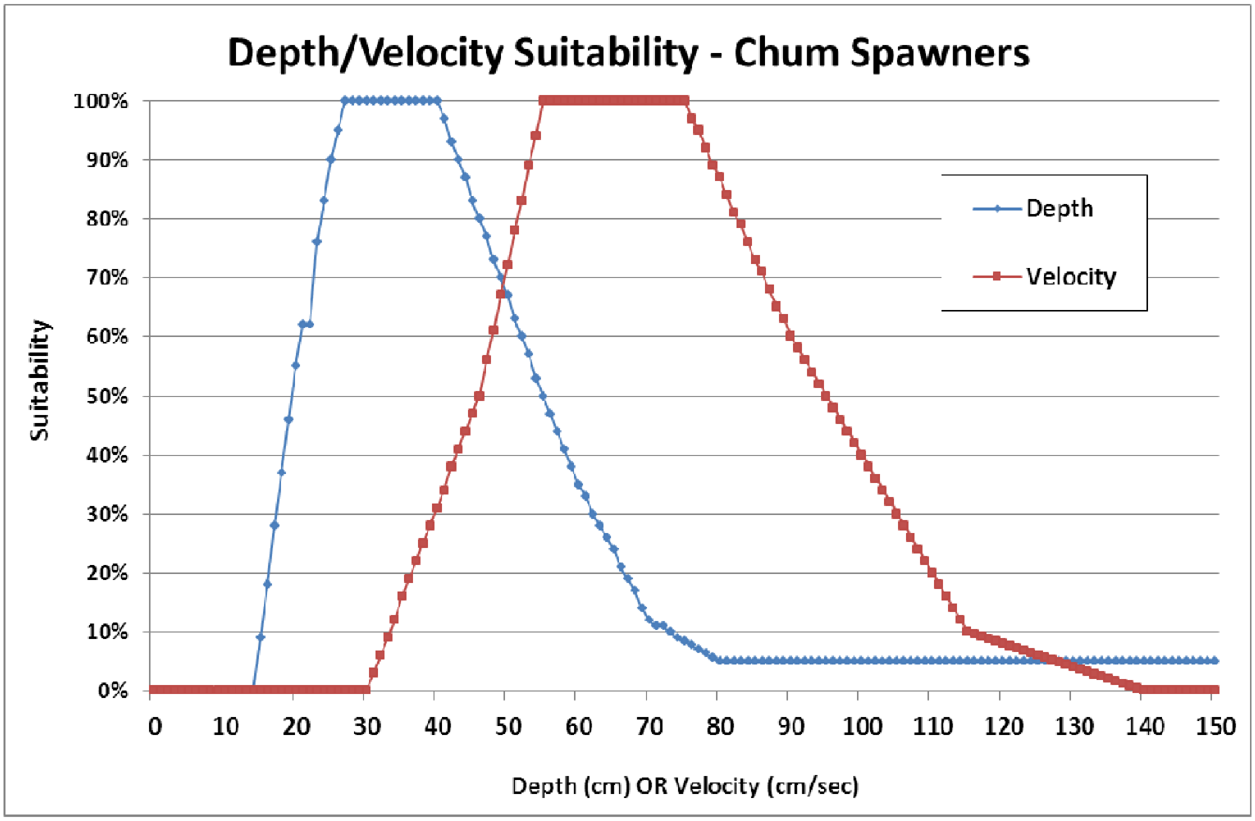
Scatter Plot of Mean Daily T1 Flow vs. same day T3 Flow
y = 8.172x - 2.7119
R² = 0.8524
T3 Max Suitability for CM Spawners = 6 m³/sec
T1 Max Suitability for CM Spawners = 2.0 m³/sec
T3 Flow (m³/s)
T1 Flow (m³/s)
0
5
10
15
20
25
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

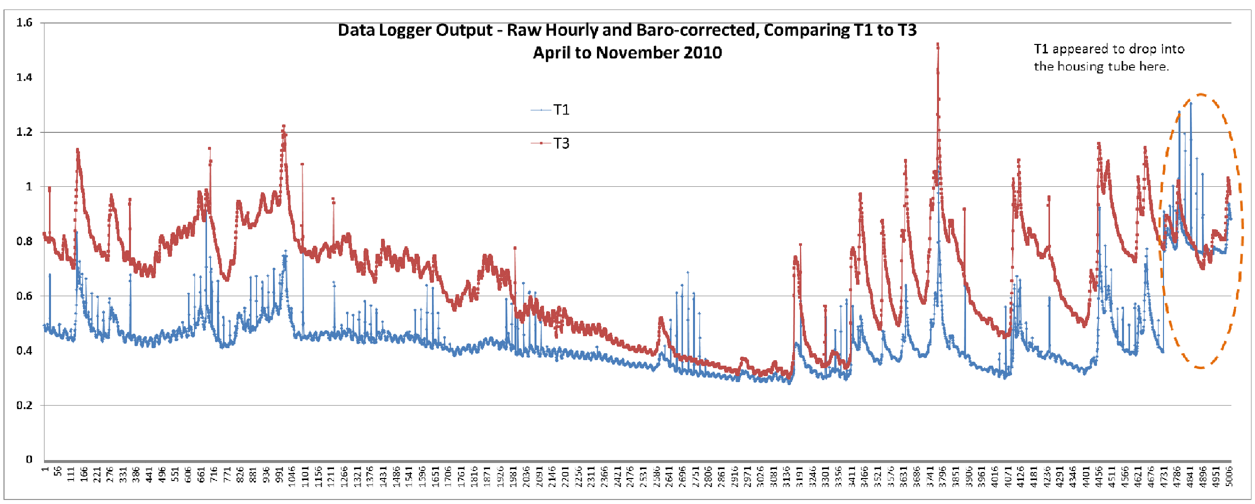


Trib 1 mean daily contribution to Total Theo Flow
April 21-November 16, 2010
Variance likely a function of channel configuration, log-jams and invert elevations at the point upstream where the mainstem splits into T1 and T3.
0%
10%
20%
30%
40%
50%
60%
21-Apr
28-Apr
5-May
12-May
19-May
26-May
2-Jun
9-Jun
16-Jun
23-Jun
30-Jun
7-Jul
14-Jul
21-Jul
28-Jul
4-Aug
11-Aug
18-Aug
25-Aug
1-Sep
8-Sep
15-Sep
22-Sep
29-Sep
6-Oct
13-Oct
20-Oct
27-Oct
3-Nov
10-Nov


Water Temps, Theodosia Trib 1, Apr 21 - Nov 16, 2010
Temperature (ºC)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Max Daily
Mean Daily
Min Daily
21-Apr
28-Apr
5-May
12-May
19-May
26-May
2-Jun
9-Jun
16-Jun
23-Jun
30-Jun
7-Jul
14-Jul
21-Jul
28-Jul
4-Aug
11-Aug
18-Aug
25-Aug
1-Sep
8-Sep
15-Sep
22-Sep
29-Sep
6-Oct
13-Oct
20-Oct
27-Oct
3-Nov
10-Nov


Water Temps, Theodosia Trib 3, Apr 21 - Nov 16, 2010
Temperature (ºC)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Max Daily
Mean Daily
Min Daily
21-Apr
28-Apr
5-May
12-May
19-May
26-May
2-Jun
9-Jun
16-Jun
23-Jun
30-Jun
7-Jul
14-Jul
21-Jul
28-Jul
4-Aug
11-Aug
18-Aug
25-Aug
1-Sep
8-Sep
15-Sep
22-Sep
29-Sep
6-Oct
13-Oct
20-Oct
27-Oct
3-Nov
10-Nov


Depth/Velocity Suitability - Chum Spawners
Suitability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Depth (cm) OR Velocity (cm/sec)
Depth
Velocity


Data Logger Output - Raw Hourly and Baro-corrected, Comparing T1 to T3
April to November 2010
T1 appeared to drop into
the housing tube here.
T1
T3
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0