60146345 – YUKON ENERGY CORPORATION

Yukon River Instream Flow Chinook Salmon Passage and Spawning

Prepared for Yukon Energy Corporation.

Thomas R. Payne & Associates

February 2011

This report describes the Chinook Salmon PHABSIM study regarding the relationship of Yukon River discharge with upstream passage and spawning habitat in the vicinity of Whitehorse, Yukon.

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ACRONYMS AND ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
DFO	Department of Fisheries and Oceans Canada
HSC	Habitat Suitability Criteria
PHABSIM	Physical Habitat Simulation model developed by the U.S. Fish and Wildlife Service
RHABSIM	Riverine Habitat Simulation software conversion and enhancement of PHABSIM by TRPA
TRPA	Thomas R. Payne and Associates
WDGW	Washington Department of Game and Wildlife (Also WDF)
WSEL	Water Surface Elevation
WUA	Weighted Usable Area, a Habitat Index
YEC	Yukon Energy Corporation

1. INTRODUCTION

This report describes the adult Chinook salmon passage and spawning analysis of the instream flow data collected in 2009 for Yukon Energy Corporation (YEC) in the Yukon River near Whitehorse. YEC engaged AECOM to assist with implementation of key energy development and enhancement concepts as identified in YEC's 20-Year Resource Plan. One of the proposed enhancements identified in the plan, the Marsh Lake Fall-Winter Storage Concept, has the potential to increase winter energy generation at Whitehorse Rapids Generating Station by 7.7 GWh of increased long-term average energy and 1.6 MW of winter firm capacity.

Water potentially available for winter hydroelectric power generation at Whitehorse Rapids on the Yukon River could be augmented by modifying the operation of Lewes Dam at the exit of Marsh Lake and closing the flow regulation gates sooner than is currently permitted. Existing regulation stipulates that the flow regulation gates must remain open between May 15 and August 15 and when Marsh Lake is above the full supply level of 656.234 meters. This concept, anticipated to temporarily retain an additional 0.3 meter in lake storage elevation, would reduce Yukon River flows in the summer and fall and increase them in the winter, with volumes varying by water year type (i.e., the amount of precipitation available from October through September). In wet years, Marsh Lake would remain high through the summer and fall, and gates would not close until late summer or fall (e.g., October). In dry years, when the lake level is low, gates would close earlier than currently permitted and raise the lake elevation when releases are less than inflows.

Aquatic habitat downstream of Lewes Dam would likely be affected by the proposed changes to seasonal decreases and increases in flow. Adult Chinook salmon migrate up the Yukon River to tributaries above Lewes Dam in August and September. Chinook spawning is also reported to occur in portions of the river and tributary mouths below Whitehorse Rapids (Yukon Engineering Services et al. 1997). Chinook salmon require sufficient water depth to pass over shallow riffles without impeding their upstream migration. Additionally, a sufficient contiguous portion of the channel must be deep enough in order to present a clear passage route. For the passage analysis, the widely-used Thompson Method (Thompson 1972) was used in conjunction with the Physical Habitat Simulation Model (PHABSIM) instream flow data to determine whether passage would be impeded at flows down to 50 cubic meters per second (cms, the lowest mean monthly flow since 1944 ([http://www.r-arcticnet.sr.unh.edu/v3.0/Points/P5787.html]). For Chinook spawning, the PHABSIM Model generated an index of suitability (weighted usable area, or WUA) for flows ranging from 50 to 650 cms utilizing the measured cross-sections below the Whitehorse Rapids Generating Station as well as two cross-sections taken from the Robert Service Way Fish Habitat Compensation Plan (Yukon Engineering Services et al. 1997). The low frequency of Chinook spawning that currently occurs in the study reach prevented collection of adequate site-specific spawning habitat suitability criteria (HSC) and instead required utilizing non site-specific (HSC) selected after a thorough review of available Chinook spawning HSC.

2. STUDY AREA

The study area extended from Lewes Dam on the Upper Yukon River in Southern Yukon, Canada downstream to the Takhini River confluence. The river was split into two reaches, the 27.6 kilometre Lewes Reach (Upper Reach) and 18.1 kilometre Takhini Reach (Lower Reach). Lewes Reach is the section of the Yukon River between Lewes Dam and Schwatka Lake upstream of the Whitehorse Rapids Hydrogeneration Station. Takhini Reach is the section of the Yukon River between City of Whitehorse and the confluence of the Yukon River with the Takhini River. Figure 1 shows the map of the Marsh Lake Concept in the Yukon near the City of Whitehorse. The Upper Reach was separated from the Lower Reach at Schwatka Lake because the Whitehorse Rapids Hydrogeneration Station represents a project-influenced point of river flow control with a potentially different range of impacts. The Lower Reach ended at the Takhini River due to the significant volume of unregulated flow coming from that tributary and to the variable backwater effect of Lake Laberge on the Yukon River, approximately 14 kilometre downstream of the Takhini River confluence. The Chinook passage analysis was conducted for both reaches; however, the spawning analysis was limited to the Takhini Reach where spawning has been observed.

Map Sources/Notes:
Basedata (250,000 and 50,000 scales) from Natural Resources Canada, Province of British Columbia and Yukon Territorial Government, 2010. All Rights Reserved.

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1:250,000
UTM Zone 8N, NAD 83

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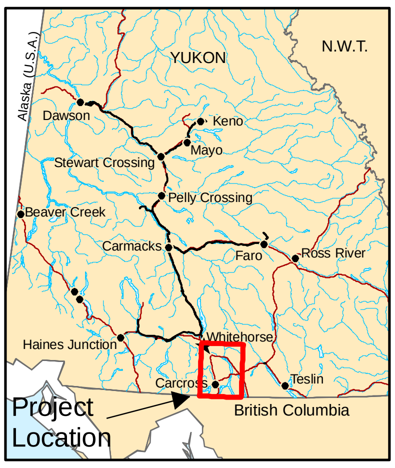
Legend

Transportation
- Highway
- Road
- Limited-used road
- Railway

Water Features
- Watercourse
- 🟦 Waterbody



YUKON ENERGY CORPORATION
MARSH LAKE FALL-WINTER STORAGE

Marsh Lake

Overview Map

February 2011
Project 60146345

AECOM

Figure 1

File Location: W:\GIS\Large Projects\YukonEnergy\Marsh Lake Fall-Winter Storage\MXD\MAP TEMPLATES\60146345_OVERVIEW_11x17_10Nov15.mxd
Date Revised: February 9, 2011
Prepared by: SM
Project: 60146345

3. METHODOLOGY

HABITAT MAPPING

The initial phase of assessing potential effects of flow alteration on a flowing river frequently consists of a physical description of the affected reaches using a quantitative approach that can also provide a data base for selecting sampling locations. One method which provides both a descriptive data base and the locations and characteristics of potential sample sites is mesohabitat mapping, or simply habitat mapping. Habitat mapping is implemented by identifying the principal mesohabitat types (e.g., pools, runs, and riffles) present and measuring the length of individual habitat units over the total distance of stream course within a project area (Morhardt et al. 1984). Habitat mapping allows for stratification and quantification of the mesohabitat types and subsequent proportional transect selection and weighting.

For the Yukon River study, habitat mapping was conducted with an Airmar digital 6 degree transducer beam echo sounder and a Trimble, satellite-corrected DGPS unit equipped boat. Each of the mesohabitat boundaries was determined by visual observation of surface conditions (e.g., changes in velocity or turbulence patterns) combined with use of the depth sounder, with the transition zones demarcated with a GPS waypoint. Within each mesohabitat unit, the maximum depth was recorded along with a width measured with an electronic range finder. Throughout the habitat mapping survey, depths and locations were electronically recorded at two second intervals. Digital photos were periodically taken and pertinent notes recorded. During the course of the survey, it was observed that only three principal types of habitat units exist in this study area: pools, low gradient riffles, and run/glides.

Pools are areas of substrate scour within the stream, which are typically deep and slow, and can have patches of very low or even negative velocities. Pools also generally lack surface agitation except at the head.

Low gradient riffles are sections of shallow stream channel having swiftly flowing and turbulent water. These riffles often contain some partially exposed substrates and or surface water affected by the current flowing over or through the substrate.

Runs/Glides have generally laminar flow with little surface agitation. The current transitions smoothly from bank to bank with little or no areas of very slow and reverse current.

In order to further stratify each reach by mesohabitat type, the pools and run/glides were divided into deep and shallow units. The depth division was determined by the median of the maximum depth frequency, with approximately one half of the number of units being classified as deep and the other half classified as shallow.

PHABSIM: TRANSECT SELECTION AND INSTALLATION

The second phase of the Yukon River aquatic habitat evaluation was implemented through the selection and placement of cross-sectional transects across which bottom profiles, water surface elevations (WSEL), water velocity patterns, and substrate descriptions were obtained. The transect data was used to assess potential limitations of flow conditions on upstream fish passage, on the general patterns of depths and velocities in relation to discharge, and calculate a habitat index describing the availability and suitability of the study area to provide Chinook spawning habitat at various flows.

A maximum of 30 transects were proposed for both study reaches between Lewes Dam and the confluence with the Takhini River, with transects distributed proportionally among identified mesohabitat types and a goal that no single transect would represent more than 10% of any sampled mesohabitat type. At least 15 transects in a large river has been shown to provide a sample size sufficient to produce a robust habitat index versus flow relationship (Payne et al. 2004). The total number of proposed transects was equally divided between the two reaches, with 15 transects installed in each reach.

Each transect was located in a randomly selected habitat unit with either rebar or nails marking the endpoints. The transects were positioned to be visually perpendicular to the surface flow at the time of placement. Also, temporary benchmarks were installed near each transect for an arbitrary elevation reference.

Additionally, two cross-section transects in the Takhini Reach were derived from the plans of the Robert Service Way Reconstruction Project Fish Compensation Area in the City of Whitehorse (Yukon Engineering Services and others 1997).

For passage assessment, the shallowest area of the shallow run/glide units were targeted for transect placement. These are the locations most likely to impede passage at lower river flows (Thompson 1972).

CALIBRATION FLOWS

Target calibration flows were established by scheduling the high flow field effort during the forecast peak flow period in August and the low flow field effort during the latest possible time prior to winter snow and ice precluding the work. The middle flow was chosen to be intermediate to the high and low flows. No flow control was possible for the high flow; however, YEC held the flow at Lewes Dam constant for the low and middle flows.

FIELD DATA COLLECTION

Depths and mean column water velocities were collected across each transect at the highest measured calibration flow. Water surface elevations were surveyed and discharge measured at the highest flow and at the middle and low flows. This combination of data allows development of stage-discharge rating curves and simulation of velocity patterns over a wide range of flows, provided that specific quality control standards are met (Payne 1987). Use of accurate rating curves and one set of measured velocities have shown to calculate habitat values very close to those obtained with three full sets of depth and velocity data (Payne 1988).

For this study, field data collection and the form of data recording followed the guidelines established in the IFIM field technique manuals with some modifications (Trihey and Wegner 1981; Milhous et al. 1984; Bovee 1997), along with supplemental quality control checks found valuable in previous studies.

VELOCITY MEASUREMENTS

The portions of the transects deeper than three meters were generally measured with an acoustic Doppler current profiler (ADCP), while the shallower bank portions were measured with handheld meters (Flowmate or Swoffer). The standard method for determining mean column velocity is a single measurement at 60% of the water depth in depths less than 0.75 meter, and the average of the velocities at 20% of the depth from the surface and 80% of the depth from the surface for depths between 0.75 meter and 1.25 meter. Velocities at all three points are measured where depths exceed 1.25 meter, or if the velocity distribution in the water column is abnormal and one or two points are not adequate to derive an accurate mean column water velocity. Mean column velocity for these circumstances is computed from the sum of the 20% measurement, the 80% measurement, and twice the 60% measurement, divided by four.

In the more prevalent deeper transects, an ADCP was employed to collect the depth and velocity measurements. The TRDI Rio Grande 1200kHz ADCP sends and receives acoustic pulses in order to measure the Doppler shift and phase change of the echoes to calculate depth and velocity patterns. For this project, the ADCP was mounted on an aluminum mount fastened to the bow of the survey vessel.

The digital 6 degree beam angle depth sounder was mounted adjacent to the ADCP and the satellite-corrected DGPS antenna was mounted directly above the ADCP. The DGPS enabled accurate tracking of the ADCP even when vegetation obscured the bottom or moving bed conditions existed. The depth sounder provided better depth measurements with a single vertical transducer than the average of the four ADCP transducers for deeper transects since the ADCP transducers are angled 20 degree off vertical. All electronic data was streamed to and recorded with a Panasonic Toughbook laptop running the WinRiver II software. Figure 2 shows the vessel set up used to conduct the instream flow field work.

Figure 2. The boat and equipment used to collect the depth and velocity data.

The use of an ADCP to collect instream flow field data required a few additional steps for data reduction and computer file building than standard velocity measurement collection methods. The ADCP data was distilled into the discrete stations at specified intervals and mean column velocities typical of instream flow studies. Depth and velocity ensemble data within each cell was averaged. The capability of the ADCP to define finer station intervals together with higher resolution of depths and velocities within each incremental station provided a much higher level of transect profile resolution than conventional methods.

Generally, several ADCP velocity/depth profiles were measured at each transect. The ADCP required configuration for each individual transect taking into account maximum depth and velocity, substrate complexity, and water surface dynamics. Often, several sets of measurements were completed before the optimum configuration was obtained. During the data analysis, the measured discharge, distance made good, and percent good ensemble count (all measures of quality control of the measured data) were considered in order to select the best data file for each transect.

SUBSTRATE

During the middle flow sampling trip, substrate characterization was classified along each transect using the Bovee code (1982). Table 1 shows the standard Bovee coding. Due to the turbid nature and the depth of the Yukon River, no Bovee code was assigned to deep sections, approximately 1.5 m to 2 m deep, of each transect,.

Table 1. Bovee code used for coding the Yukon River transects substrate.

Code	Description	Size (cm)
1	Organic/veg	
2	Mud/clay	
3	Silt	<0.005
4	Sand	0.005 – 0.25
5	Gravel	0.25 - 6
6	Cobble	6 - 25
7	Boulder	>25

The code is recorded as x.y, where x is the smaller of the dominant two adjacent substrate sizes and y is the percentage of the larger (Bovee 1982).

QUALITY ASSURANCE / QUALITY CONTROL

To assure quality control in the collection of field data, the following data collection procedures and protocols were utilized:

- Staff gauges were established and continually monitored throughout the course of collecting data on some transects. If significant changes occurred, water surface elevations were re-measured following collection of transect water velocity data.

- Independent benchmarks were established for each set of transects. The benchmark was an immovable tree, boulder, or other naturally occurring object not subject to tampering. Upon establishment of headpin and tailpin elevations, a level loop was shot to check the auto-level instrument for accuracy. Acceptable error tolerances on level loop measurements were set at 0.01 meter. This tolerance was also applicable to both headpin and tailpin measurements, unless extenuating circumstances (e.g., pins under sloped banks, shots through dense foliage) accounted for the discrepancies, and the accompanying headpin or tailpin met the tolerance criteria.

- Water surface elevations were measured on both banks on each transect. If possible, on more complex and uneven transects, such as riffles, water surface elevations were also measured at multiple locations across a transect. An attempt was made to measure water surface elevations at the same location (station or distance from pin) across each transect at each calibration flow. Water surface elevation measurements were obtained by placing the bottom of the stadia rod at the water surface until a meniscus formed at the base or selecting a stable area next to the water's edge.

- Pin and water surface elevations were calculated on-site during field measurement and compared to previous measurements. Changes in stage since the previous flow measurement were calculated. Patterns of stage change were compared between transects and determined if reasonable. If any discrepancies were discovered, potential sources of error were explored, corrected where possible, and noted.

- The ADCP was used to collect water velocity data from stations along each transect greater than one meter in depth. High-quality and well-maintained current velocity meters were used to collection velocities of shallower, edge cell velocity data.

- Prior to deployment, the ADCP system was checked and user configured for each individual transect with appropriate commands for the existing environmental conditions. Often several transect measurements were necessary to obtain the optimum configuration. Each transect measurement length and discharge calculation was compared to the actual values or to repetitive measurements in order to ensure accurate bottom tracking and velocity measurements. Real time graphic depictions of depth and velocity were examined during data collection for inconsistencies and obvious errors. As a precaution against data loss, all electronic data files were copied onto a separate USB drive at the end of each field day.

- All calculations were completed in the field, given adequate time and daylight. Pin elevations and changes in water surface elevations were compared between flows on the same transect. Discharges were calculated on-site and were compared between transects during the same flow (high, mid, and low). If an excessive amount of discharge (greater than 10% of the stream flow) was noted for an individual transect cell, additional adjacent stations were established to more precisely define the velocity distribution patterns at that portion of the transect.

Photographs were taken of all transects, downstream, across, and upstream at the three calibration flows. Photographs were taken from the same location at each of the flows, if possible. Photographs provided a valuable record of physical conditions and water surface levels that were utilized during hydraulic model calibration. Appendix C shows a photolog with some of photos taken during the calibration flows.

All data (stationing, depth profiles, velocities, substrate/cover codes) were entered into the riverine habitat simulation (RHABSIM) computer files. RHABSIM is software developed by Thomas R. Payne and Associates (TRPA) as a conversion and enhancement of the physical habitat model (PHABSIM) developed by the U.S. Fish and Wildlife Service (Bovee 1982). Internal data graphing routines were then used to review the bottom and velocity profiles for each transect separately and in context with others for quality control purposes. All data gaps (e.g., missing velocities) or discrepancies (e.g., conflicting records) were identified and corrected using available sources, such as field notes, photographs, or adjacent data points.

TRANSECT WEIGHTING

For the passage analysis, each transect was treated individually and weighted equally. For the spawning analysis, each transect was weighted proportionally to the amount of habitat that it represented.

HYDRAULIC SIMULATION

The purpose of hydraulic simulation under the PHABSIM framework is to simulate depths and velocities in streams under varying stream flow conditions. Simulated depth and velocity data are then used to calculate the physical habitat, either with or without substrate and/or cover information. Depths are not directly determined, but are calculated from water surface elevations and bottom contours. All depth, velocity, and substrate data was entered into the RHABSIM software used for this analysis.

WATER SURFACE ELEVATION PREDICTION

The water surface elevations, in conjunction with the transect profiles, are used to determine water depths at each flow. Water depth is an important parameter for determining the suitability of the habitat for both spawning and passage.

An empirical log/log regression formula of stage and flow based on measured data was used for this analysis. This method uses a stage-discharge relationship to determine water surface elevations. Each cross section is treated independently of all others in the data set. A minimum of three stage-discharge measurement pairs were used to calibrate the stage-discharge relationship. A theoretical stage zero flow was used due to the difficulty of measuring a physical stage zero flow in a large river.

4. HABITAT SUITABILITY CRITERIA

CHINOOK PASSAGE CRITERIA

The Thompson (1972) method was used for determining the extent to which low flow will limit the ability of Chinook salmon to migrate upstream. Thompson (1972) suggested that for adult Chinook salmon a suitable flow across each transect produces depths of at least 0.24 meters and mean column velocities less than 2.4 m/sec in at least 25% of the total width, with at least 10% of the suitable section contiguous. This criteria was used to determine if adult Chinook salmon passage impediments exist for the simulated flows at each transect.

CHINOOK SPAWNING CRITERIA

Chinook salmon build redds in and spawn over large gravels and cobles in riffles, runs, and pool tails with a great degree of variability between rivers (McPhail and Lindsey 1970, Geist and Dauble 1998). HSC curves best describe the habitat use when they are based on observations of actual habitat use at the study site (Beecher et.al. 2004). For our analysis, limited Chinook spawning within the study site makes it difficult to collect sufficient observations to create site specific HSC. No other site-specific Chinook spawning HSC have been developed for the Upper Yukon; however, there exists a myriad of curves, both general and site-specific for other rivers, which have been used for instream flow studies over the past 30 years (Table 2, Figure 3).

Table 2. Chinook Spawning HSC curves considered for use with the PHABSIM analysis.

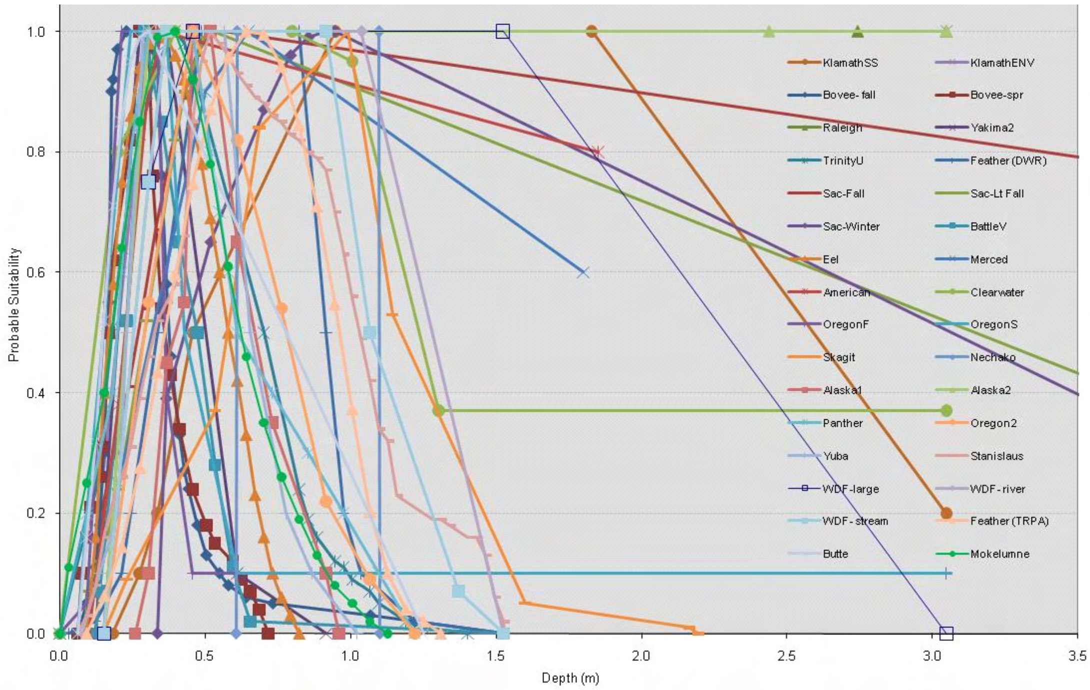
CHINOOK SALMON SPAWNING					
Curve ID		**Fish Characteristics**			
				Life-	
No.	**Name**	**Species**	**Race**	**stage**	**Reference**
1	BoveeF	Chinook	fall	spawning	Bovee, K.D. 1978. Probability-of-use criteria for the family Salmonidae. Instream Flow Information Paper No. 4. Cooperative Instream Flow Service Group, U.S. fish & Wildlife Service, Fort Collins, CO.
2	BoveeS	Chinook	spring	spawning	Bovee, K.D. 1978. Probability-of-use criteria for the family Salmonidae. Instream Flow Information Paper No. 4. Cooperative Instream Flow Service Group, U.S. fish & Wildlife Service, Fort Collins, CO.
3	Raleigh	Chinook	Fall + spring	spawning	Raleigh, R.F., W.J. Miller, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Chinook salmon. United States Fish and Wildlife Service, Biological Report 82(10.122). 64pp.
4	Yakima2	Chinook	spring	spawning	Stempel, J. M. 1984. Development of fish preference curves for spring Chinook and rainbow trout in the Yakima River Basin. U.S. fish & Wildlife Service, Moses Lake, WA.
5	TrinityU	Chinook	fall	spawning	Hampton, M. 1997. Microhabitat suitability criteria for anadromous salmonids of the Trinity River. U.S. Fish & Wildlife Service, Arcata, CA.
6	KlamathSS	Chinook	fall	spawning	Hardin-Davis Inc., RTG Fishery Research & Photography, Terraqua Inc., and CDFG. 2002 DRAFT. Habitat suitability criteria for anadromous salmonids in the Klamath River, Iron Gate Dam to Scott River, California. California Department of Fish & Game Stream Evaluation Report 01-1, 2001.
7	Feather (DWR)	Chinook	fall	spawning	Sommer, T., D. McEwan, and R. Brown. 2001. Factors affecting Chinook salmon spawning in the lower Feather River. Pages 269-297 in R.L. Brown, editor. Contributions to the biology of Central Valley salmonids. California Department of Fish and Game Fish Bulletin 179.
8	SacF	Chinook	fall	spawning	USFWS. 2002. Flow-habitat relationships for steelhead and fall, late-fall and winter-run Chinook salmon spawning in the Sacramento River between Keswick Dam and Battle Creek. Draft report 1/17/02. U.S. Fish & Wildlife Service, Sacramento Fish & Wildlife Office, Sacramento, CA.71 pp.
9	SacLF	Chinook	late-fall	spawning	USFWS. 2002. Flow-habitat relationships for steelhead and fall, late-fall and winter-run Chinook salmon spawning in the Sacramento River between Keswick Dam and Battle Creek. Draft report 1/17/02. U.S. Fish & Wildlife Service, Sacramento Fish & Wildlife Office, Sacramento, CA.71 pp.
10	SacW	Chinook	winter	spawning	USFWS. 2002. Flow-habitat relationships for steelhead and fall, late-fall and winter-run Chinook salmon spawning in the Sacramento River between Keswick Dam and Battle Creek. Draft report 1/17/02. U.S. Fish & Wildlife Service, Sacramento Fish & Wildlife Office, Sacramento, CA.71 pp.
11	BattleV	Chinook	fall	spawning	Vogel, D.A. 1982. Preferred spawning velocities, depths, and substrates for fall Chinook salmon in Battle Creek, California. U.S. Fish & Wildlife Service, Red bluff, California.
12	Eel	Chinook	fall	spawning	Steiner Environmental Consulting. 1990. Potter Valley Project monitoring program (FERC No. 77, Article 39). Effects of operations on upper Eel River anadromous salmonids. 1988-89 progress report. Report prepared for Pacific Gas and Electric Company, San Ramon, CA.

CHINOOK SALMON SPAWNING

Curve ID		**Fish Characteristics**			
No.	**Name**	**Species**	**Race**	**Life-stage**	**Reference**
13	Merced	Chinook	fall	spawning	Gard, M. 1997. Technique for adjusting spawning depth habitat utilization curves for availability. Rivers 6:94-102.
14	American	Chinook	fall	spawning	Gard, M. 1997. Technique for adjusting spawning depth habitat utilization curves for availability. Rivers 6:94-102.
15	Clearwater	Chinook		spawning	Arnsberg, B.D., W.P. Connor, and E. Connor. 1992. Mainstem Clearwater River study: assessment for salmonid spawning, incubation, and rearing. Final Report. United States Department of Energy, Bonneville Power Administration, DOE/BP- 37474-3. 201pp.
16	OregonF	Chinook	fall	spawning	Sams, R.E., and L.S. Pearson. 1963. Methods for determining spawning flows for anadromous salmonids. Oregon Fish Commission Draft Report.
17	OregonS	Chinook	spring	spawning	Sams, R.E., and L.S. Pearson. 1963. Methods for determining spawning flows for anadromous salmonids. Oregon Fish Commission Draft Report.
18	Oregon2	Chinook		spawning	Beak (possibly Sandy River data??)
19	Skagit	Chinook		spawning	Kurko, K.W. 1977. Investigations on the amount of potential spawning area available to Chinook, pink, and chum salmon in the upper Skagit River, Washington. M.S. Thesis, University of Washington, Seattle, WA.
20	Nechacko	Chinook		spawning	Shirvell, C.S. 1989. Ability of PHABSIM to predict Chinook salmon spawning habitat. Regulated Rivers: Research & Management 3:277-289.
21	Alaska1	Chinook		spawning	Estes
22	Alaska2	Chinook		spawning	Vincent-Lang, D., A. Hoffman, A. Bingham, and C. Estes. 1984. Habitat suitability criteria for Chinook, coho, and pink salmon spawning in tributaries of the Middle Susitna River. Chapter 9 In C.C. Estes and D.S. Vincent-Lang, editors. Aquatic habitat and instream flow investigations (May-October 1983). Alaska Department of Fish and Game, Susitna Hydro Aquatic Studies Report No. 3, Anchorage, AL.
23	SRBA	Chinook		spawning	
24	Panther	Chinook	spring	spawning	Reiser, D.W. 1985. Panther Creek, Idaho. Habitat rehabilitation - final report. Contract No. DE-AC79-84BP17449. Bonneville Power Administration, Portland, Oregon.
25	KlamathENV	Chinook	fall	spawning	Hardy, T.B. and R.C. Addley. 2001. Evaluation of interim instream flow needs in the Klamath River. Phase II Final Report. Prepared for U.S. Department of the Interior by Institute for Natural Systems Engineering, Utah Water Research Laboratory, Utah State University, Logan, UT.
26	Yuba	Chinook	fall	spawning	Beak Consultants, Inc. 1988. Yuba River fisheries investigations, 1986-88. Appendix D: Evaluation of microhabitat utilization for fall run Chinook salmon (Oncorhynchus tshawytscha) in the lower Yuba River California. Final report prepared for California Department of Fish & Game, Sacramento, California.
27	Stanislaus	Chinook	fall	spawning	Aceituno, M.E. 1990. Habitat preference criteria for fall-run Chinook salmon holding, spawning, and rearing in the Stanislaus River, California. U.S. Fish and Wildlife Service Report. Sacramento, CA.
28	WDF-large	Chinook	Fall + spring	spawning	Washington Department of Fisheries. 1987. Documentation and rationale for preference curves used 1983-1987 for IFIM studies, Washington Department of Fisheries, Habitat Management. Draft report by J. Caldwell and B. Caldwell.

CHINOOK SALMON SPAWNING					
Curve ID		**Fish Characteristics**			
				Life-	
No.	**Name**	**Species**	**Race**	**stage**	**Reference**
29	WDF-river	Chinook	Fall + spring	spawning	Washington Department of Fisheries. 1987. Documentation and rationale for preference curves used 1983-1987 for IFIM studies, Washington Department of Fisheries, Habitat Management. Draft report by J. Caldwell and B. Caldwell.
30	WDF-stream	Chinook	Fall + spring	spawning	Washington Department of Fisheries. 1987. Documentation and rationale for preference curves used 1983-1987 for IFIM studies, Washington Department of Fisheries, Habitat Management. Draft report by J. Caldwell and B. Caldwell.
31	Feather (TRPA)	Chinook	fall	spawning	DWR. 2004. Phase 2 Report: Evaluation of project effects on instream flow and fish habitat SP F-16. Oroville facilities relicensing, FERC Project No. 2100.
32	Butte	Chinook	spring	spawning	USFWS. 2003. Flow-habitat relationships for spring-run Chinook salmon spawning in Butte Creek. U.S. Fish & Wildlife Service, Sacramento Fish & Wildlife Office, Sacramento, CA.85 pp.
33	Mokelumne	Chinook	fall	spawning	curves redrawn from Beak 1988, referenced as preliminary data from Envirosphere 1988 (but no full citation given)

Figure 3. **Depth and velocity graphs for all HSC curves considered for the Takhini reach of the Upper Yukon Chinook physical habitat simulation model.**



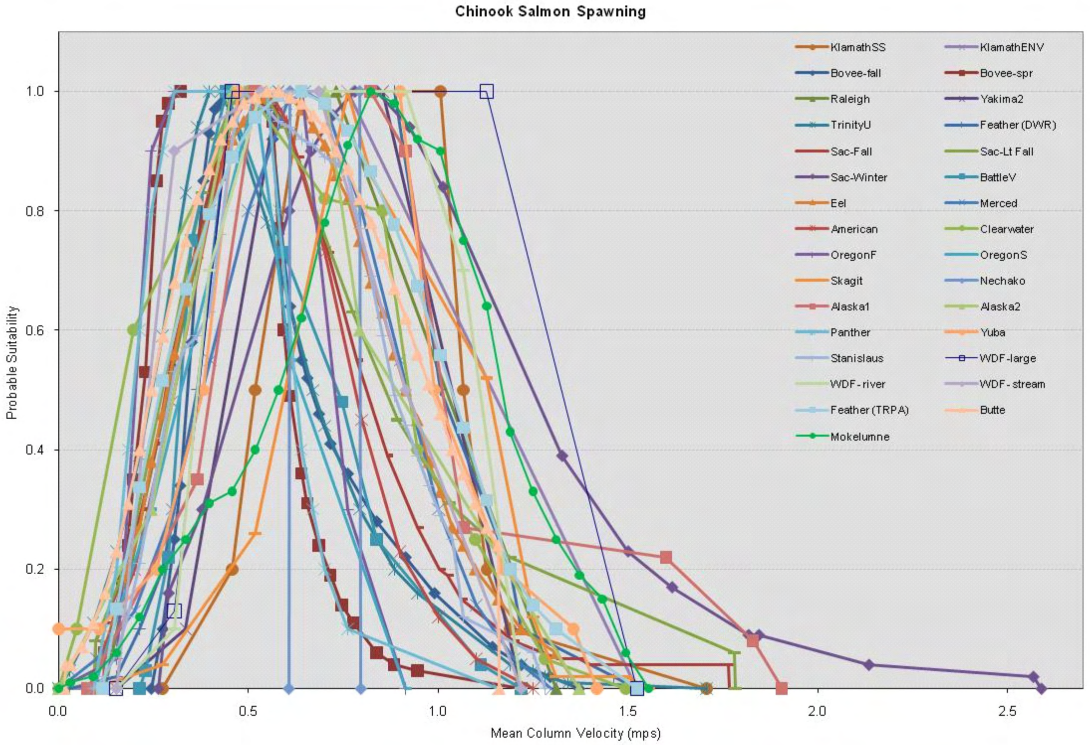
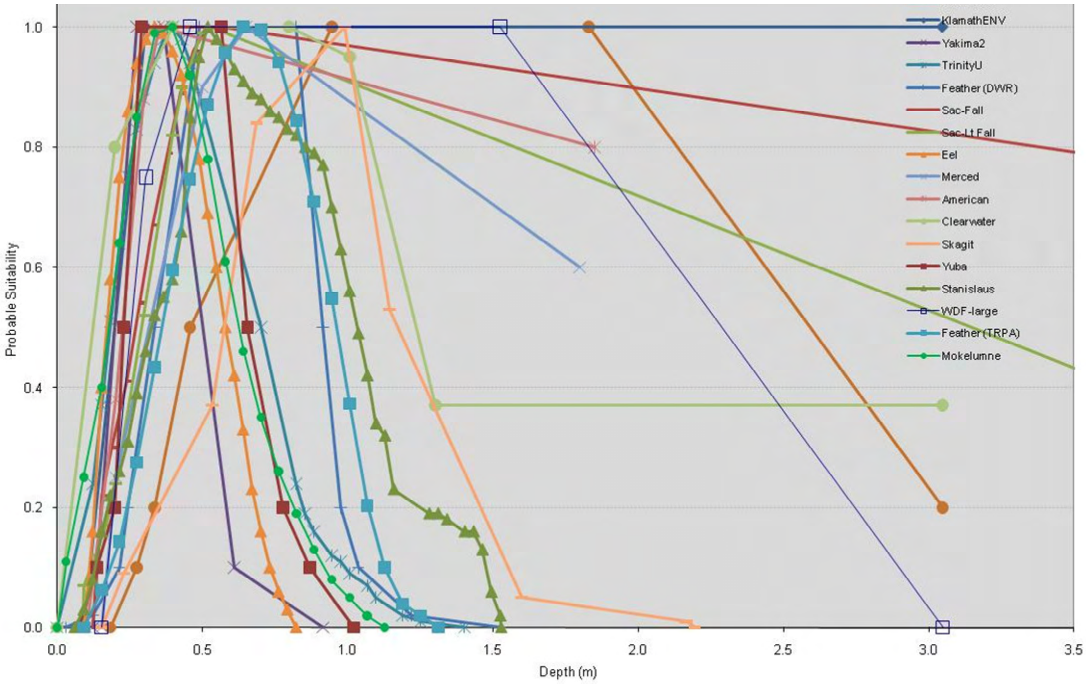
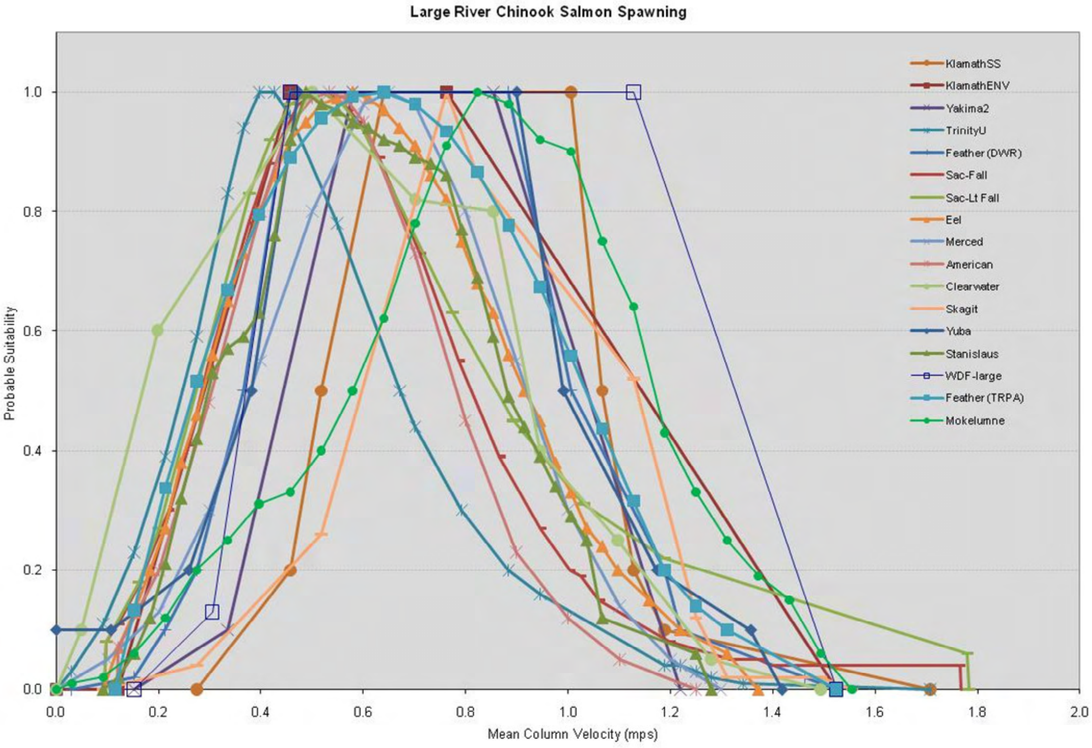


Figure 4. Depth and velocity graphs for large river, non-binary HSC curves considered for the Takhini reach of the Upper Yukon Chinook physical habitat simulation model.





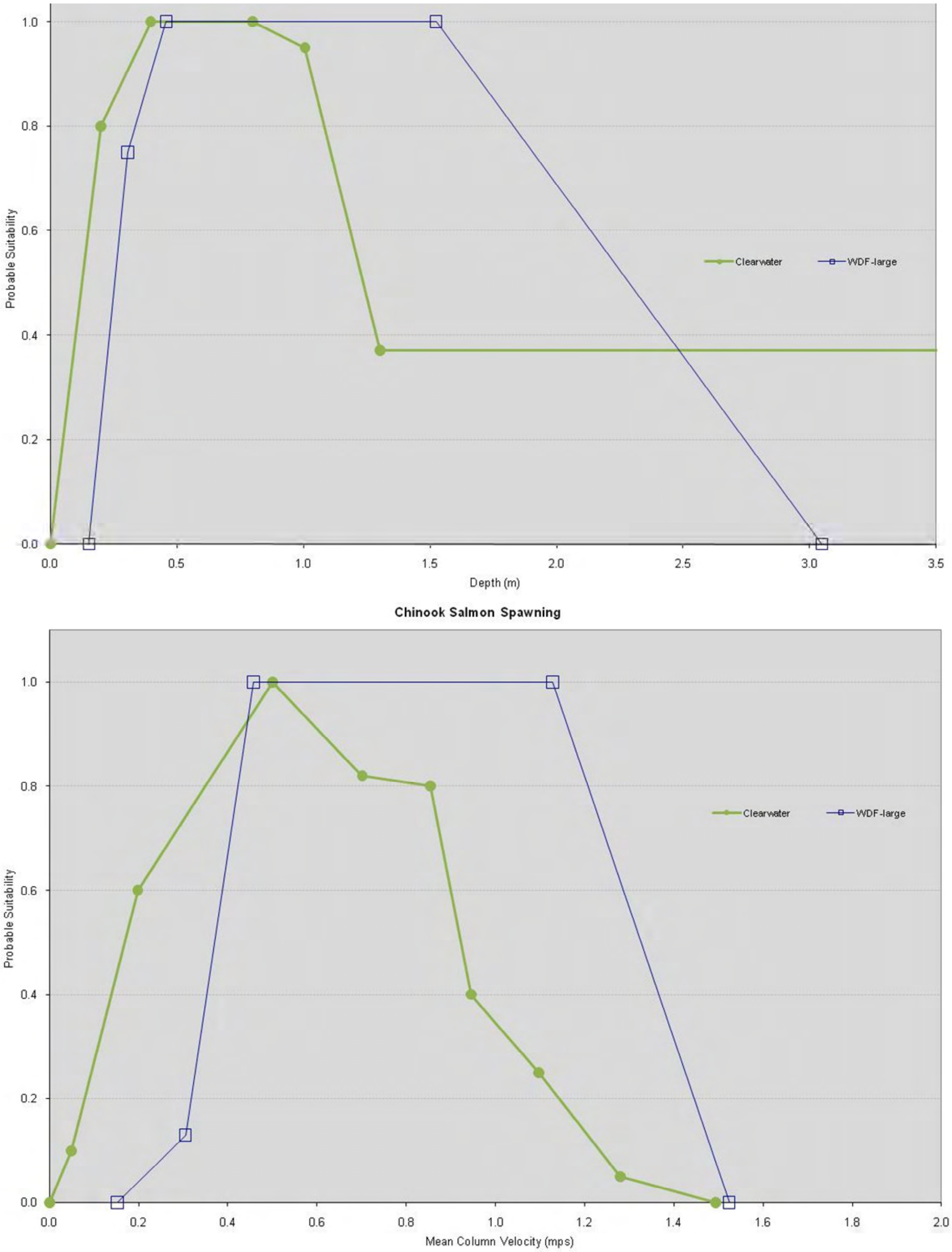
In order to determine which curve set was appropriate to model Chinook spawning habitat in the Upper Yukon, the HSC data sets were first filtered to exclude curves developed for small and mid-sized streams (mean annual discharge of less than about 30 cms) and curves which did not specify stream size (Figure 4). This eliminated curves developed for streams in which deeper depths either do not exist, or exist only in the deepest pools. The length of a river influences genetic separation of stocks, even along the length of a single river (Olsen et.al. 2010). Larger rivers also tend to have larger fish that use different velocities and substrate sizes (Washington Department of Fisheries 1987).

Second, the list was screened for binary curves, since given the diversity of spawning in nature; binary curves are considered a poor representation of actual use. Binary HSC rate habitat as either suitable or not suitable. For example, in binary HSC, a water velocity of 0.2 m/s could be 100% suitable and 0.19 m/s 100% unsuitable.

Third, curves were screened for the location and those curves developed for rivers in the southern end of the range were excluded. The Yukon River is in the extreme northern portion of the Chinook salmon range. Water temperature and hydrology (glacier melt verses rain driven) are markedly different between the northern and southern reaches of the range and the influence of these variables are not otherwise accounted for in the PHABSIM model. Finally, special consideration was given to Chinook salmon spawning HSC that have been used in British Columbia (R. Ptolemy personal communication), due to the close proximity of the Yukon study site.

The two HSC remaining after running these screens were from the Mainstem Clearwater River Study (Arnsberg et.al. 1992) and the Washington Department of Fish and Wildlife (WDFW) (Beecher et.al. 2004; Figure 5). Closer examination of the Clearwater HSC revealed that observations were not conducted on the Mainstem Clearwater, but rather on the smaller Wenatchee, South Fork Snake, and Trinity (California) rivers. The depth preference curve was then adjusted by assigning a suitability value of 0.37 to depths greater than 1.3 meters to account for deep water spawning observed in an impounded reach of the Columbia (Swan 1989). The WDFW curves were similarly compiled from multiple rivers, but the deep water spawning suitability was reserved for the Columbia and Snake Rivers where such behavior has been observed. For velocity, the Clearwater curve used nose velocity instead of mean column velocity. Nose velocity is the water speed near the river bottom. Although some studies utilize nose velocity, the majority use mean column velocity. Mean column velocity was collected for this study.

Figure 5. The Clearwater and WDFW HSC were the two hsc that were filtered out of the myrid of possible curves available for use in the Takhini reach of the Yukon River phabsim model.



The WDFW HSC was selected for comparison to the B.C. HSC. The reasons for selecting the WDFW HSC over the Clearwater HSC are summarized below:

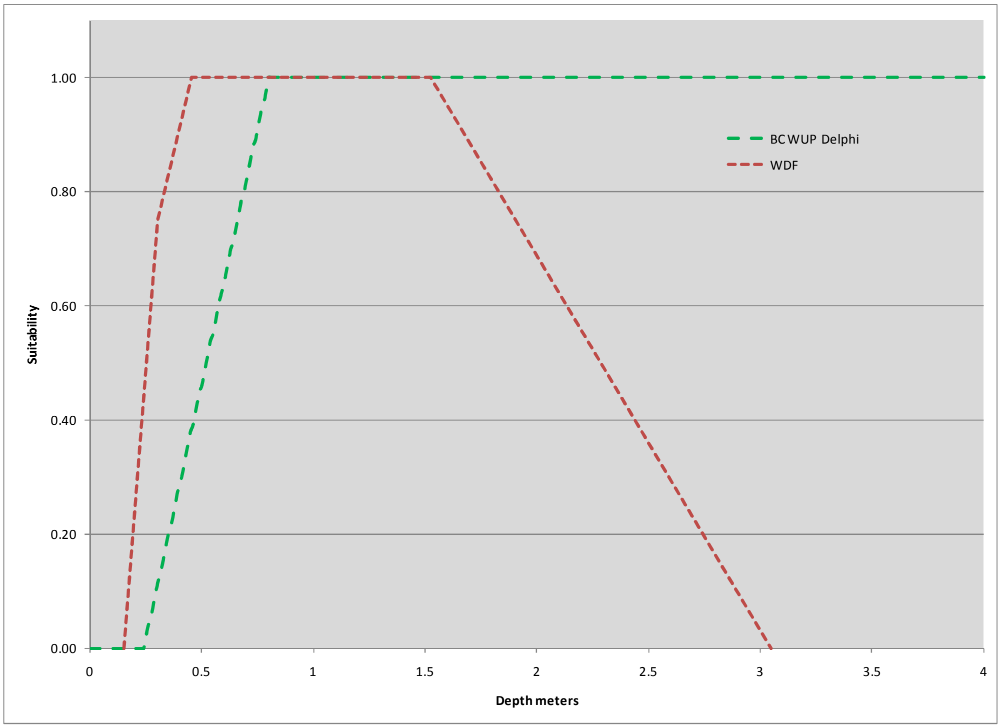
1. Part of the data was collected in the Trinity River, a river in the southern portion of the Chinook salmon range. We excluded those HSC developed for southern rivers because the Yukon is in the extreme northern end of the range.
2. All depths have some suitability in the Clearwater HSC . There is no evidence that Chinook spawn in deep water in the Upper Yukon.
3. The Clearwater velocity criteria used nose velocity and mean column velocity was collected on the Takhini Reach. An additional assumed relationship would have to be used to translate mean column to nose velocity.

Finally the British Columbia HSC was examined and compared to the WDFG curves selected from filtering the rest of the HSC. Figure 6 compares the B.C. curves to the WDFW curves previously selected. The B.C. curves were developed through a Delphi process; however, we have no information about the rivers from which or for which they were devised. The depth curve, with perfect suitability at all depths greater than 0.8 meters, indicates that the HSC curves were developed for a river in which deep water spawning is either known or suspected to occur. Deep water spawning requires specific hydraulic conditions to enable sufficient water infiltration through the gravel in deep water. Although this does occur in the Columbia River (Swan 1989), there is no evidence to suggest that it occurs in the Yukon River study area.

The B.C. Chinook spawning velocity curve indicates suitable velocity up to 2.15 m/sec whereas the WDFW large river curve indicates suitable velocity up to 1.52 m/sec. The B.C. velocity curve includes suitable velocities considerably higher than all other large river HSC curves considered for use in this analysis (Figure 4). Such exceptionally high velocities can only be used by large fish in very good condition. Data has shown a decline in the proportion of large Chinook in the Yukon River (Bales 2008). This is probably a result of nets targeting larger sized fish. Fisheries pressure can select for small fish by targeting the large fish causing a shift in length frequency to smaller sizes (Moyle 2002). Fish condition generally declines with the duration and length of upstream migration. The Yukon River study area Chinook have one of the longest migration routes in the world.

The B.C. HSC appear to have been derived for very large Chinook with a relatively short migration route to the spawning area where deep water spawning is either known or suspected to occur. Given these parameters, the curves are less appropriate for use in the Takhini Reach of the Yukon River than the WDFW curves selected from the other curves (Figures 7 and 8 and Tables 3 and 4).

Figure 6. **The B.C. Chinook spawning curves were given special consideration due to the proximity to the study site and compared to the WDFW HSC selected from the two HSC that remained in the filtered list of HSC.**



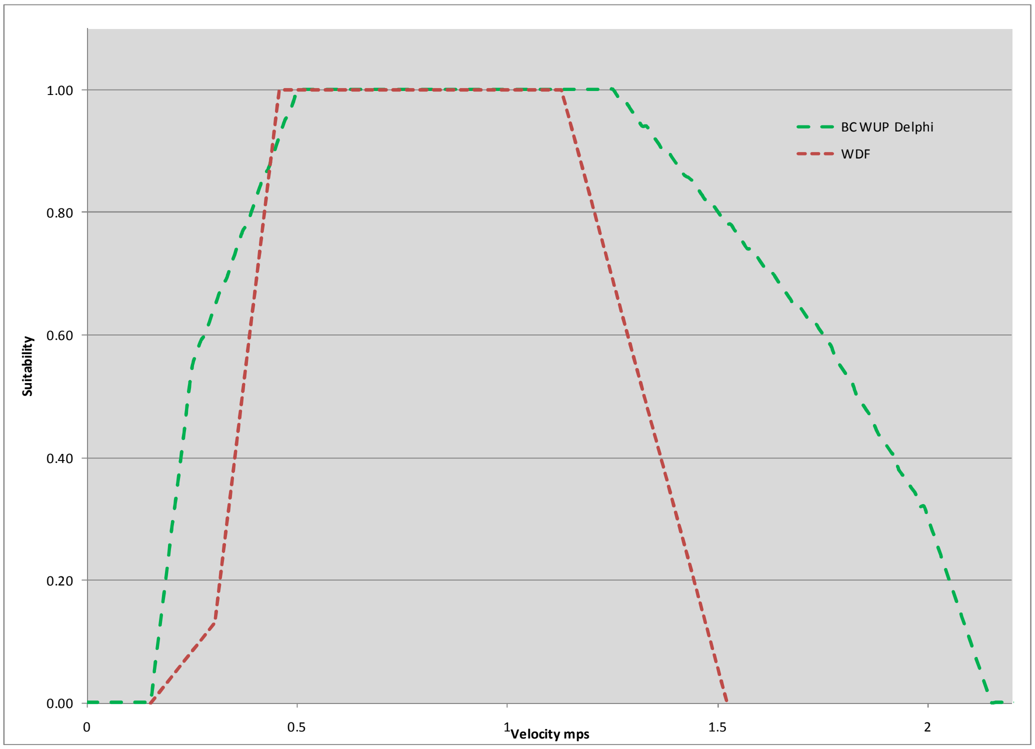
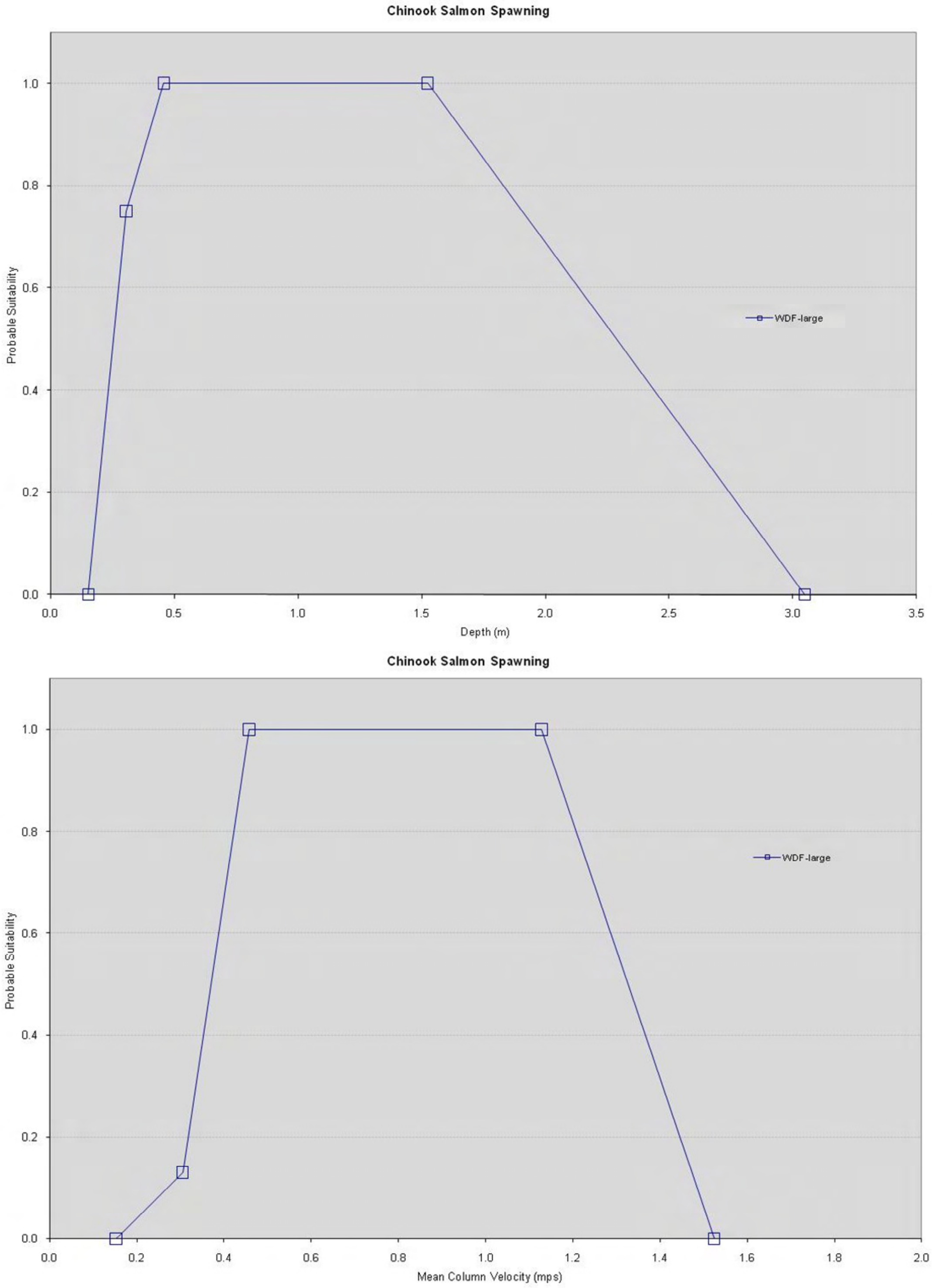


Figure 7. The WDFW Chinook Spawning HSC depth and velocity curves were chosen as the most appropriate for the takhini reach of the Upper Yukon Chinook physical habitat simulation model.



The WDFW substrate code differs slightly from the Bovee code used to code the substrate on the Takhini Reach of the Upper Yukon. This is often the case when the HSC are determined after the field data is collected. Table 9 translates the WDFG code to the Bovee code.

Figure 8. **WDFW CHINOOK spawning HSC substrate curve chosen for the Takhini reach of the Upper Yukon Chinook physical habitat simulation model.**

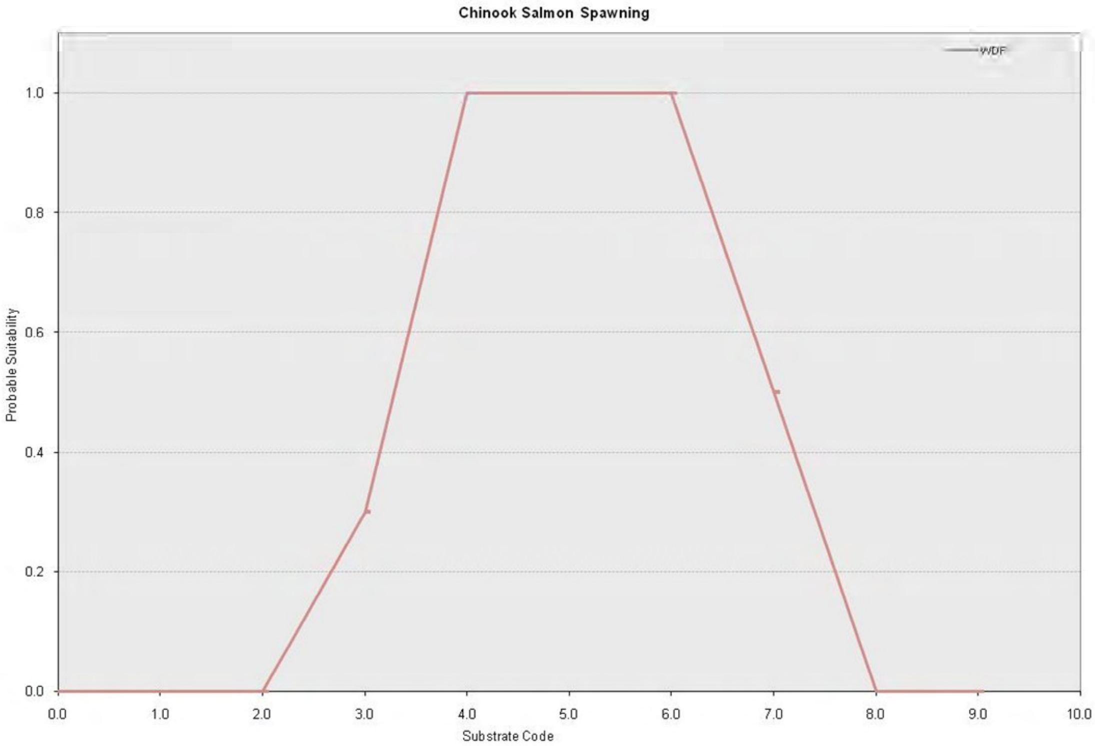


Table 3. **WDFW Chinook Salmon Spawning HSC to be used for the Takhini Reach of the Upper Yukon River Chinook Spawning physical habitat analysis.**

Velocity	WDF-large	Depth	WDF-large	Substrate	WDF-large
0.15	0.00	0.15	0.00	0	0.00
0.30	0.13	0.30	0.75	1	0.00
0.46	1.00	0.46	1.00	2	0.00
1.13	1.00	1.52	1.00	3	0.30
1.52	0.00	3.05	0.00	4	1.00
				5	1.00
				6	1.00
				7	0.50
				8	0.00
				9	0.00

Table 4. Substrate code definitions for both the WDFW and Bovee systems and the combined suitability.

WDFW			Bovee			Combined
Code	Substrate	Size mm	Code	Substrate	Size mm	Suitability
1	silt, clay, organic		1,2,3	silt, clay, organic		0
2	sand		4	sand	0.05-2.5	0
3	small gravel	2.5-12.7	5	gravel	2.5-60	1
4	medium gravel	12.7-38	5	gravel	2.5-60	1
5	large gravel	38-76	5	gravel	2.5-60	1
6	small cobble	76-152	6	cobble	60-250	0.5
7	large cobble	152-305	6	cobble	60-250	0.5
8	boulder	>305	7	boulder	>250	0
9	bedrock		8	bedrock		0

5. HABITAT SIMULATION

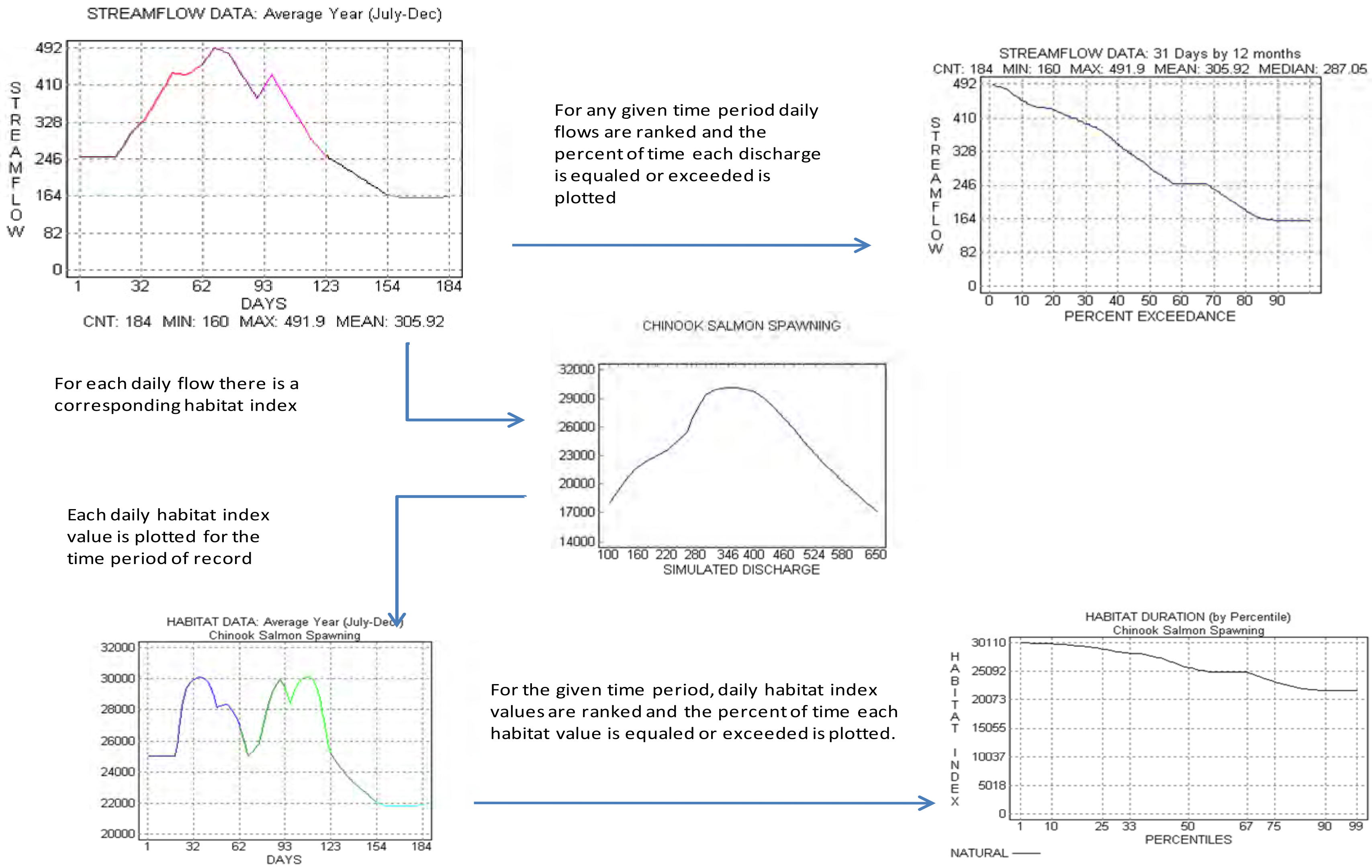
The hydraulic simulations of depth and velocity combined with the substrate data were run with the HSC in the RHABSIM software for flows from 50 to 650 cms. The resulting habitat model determined the relationship of the index of habitat suitability (WUA) and flow. For passage, the lowest flow simulated, 50 cms, was the primary interest. If the parameters of the Thompson Method (1972) are satisfied at the lowest flow, then all higher flows are also suitable.

For Chinook spawning, the relationship of WUA and flow was modeled throughout the range of simulated flows

6. TIME SERIES ANALYSIS

Time series analysis involves joining the hydrology with the WUA to determine the change in habitat over a period of time (Figure 9). For the Chinook spawning habitat analysis in the Takhini Reach of the Yukon River, the relevant time period is from July through December. Three typical water year types (wet, average, and dry) were used to compare the historical time series habitat to that which would have occurred with the modified Lewes Dam and operating parameters in place. The results are presented as habitat duration graphs and total usable area during each year.

Figure 9. Time series analysis flow chart.



For any given time period daily flows are ranked and the percent of time each discharge is equaled or exceeded is plotted

For each daily flow there is a corresponding habitat index

Each daily habitat index value is plotted for the time period of record

For the given time period, daily habitat index values are ranked and the percent of time each habitat value is equaled or exceeded is plotted.

7. RESULTS

HABITAT MAPPING

LEWES REACH

Habitat mapping was conducted in the Lewes Reach on August 15 and 16, 2009. This data was collected by boat, progressing downstream from Lewes Dam to Schwatka Lake at a flow of approximately 487 cms. The data is presented in Appendix A. Two habitat types were observed in the Lewes Reach: pools and run/glides. Maximum pool depths varied from 6.7 m to 18.7 m with a mode at 10 m as shown in Figure 10. The pools were further stratified using the median of the maximum depth frequency into deep pools (greater than 10 meters maximum depth) and shallow pools (less than or equal to 10 meters maximum depth). Maximum run/glide depth in the Lewes Reach varied between 5 m and 13.8 m with a mode at 7 meters and is shown in Figure 11. Run/glides in the Lewes Reach were stratified using the median of the maximum depth frequency into deep (maximum depth greater than 7 meters) and shallow (maximum depth less than or equal to 7 meters).

A summary of the Lewes Reach habitat mapping is presented in Table 5 and Figure 12 depicts the distribution of habitat types in the Lewes Reach on the Yukon River.

Figure 10. Maximum pool depth frequency in the Lewes Reach habitat mapping from August 2009.

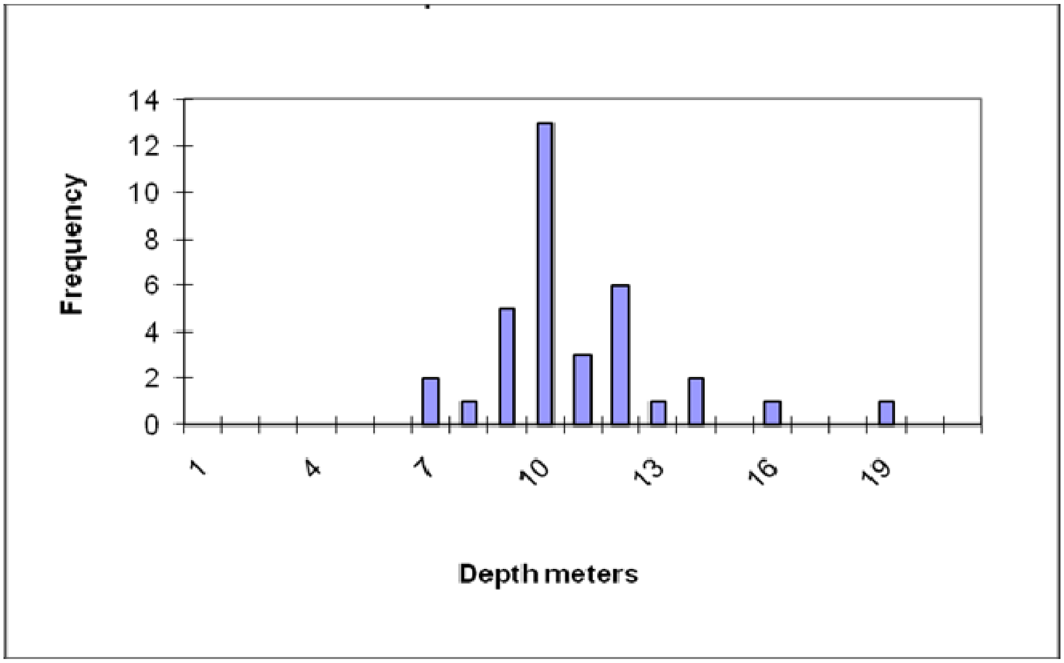


Figure 11. Maximum run/glide depth frequency in the LEWES reach habitat mapping from August 2009.

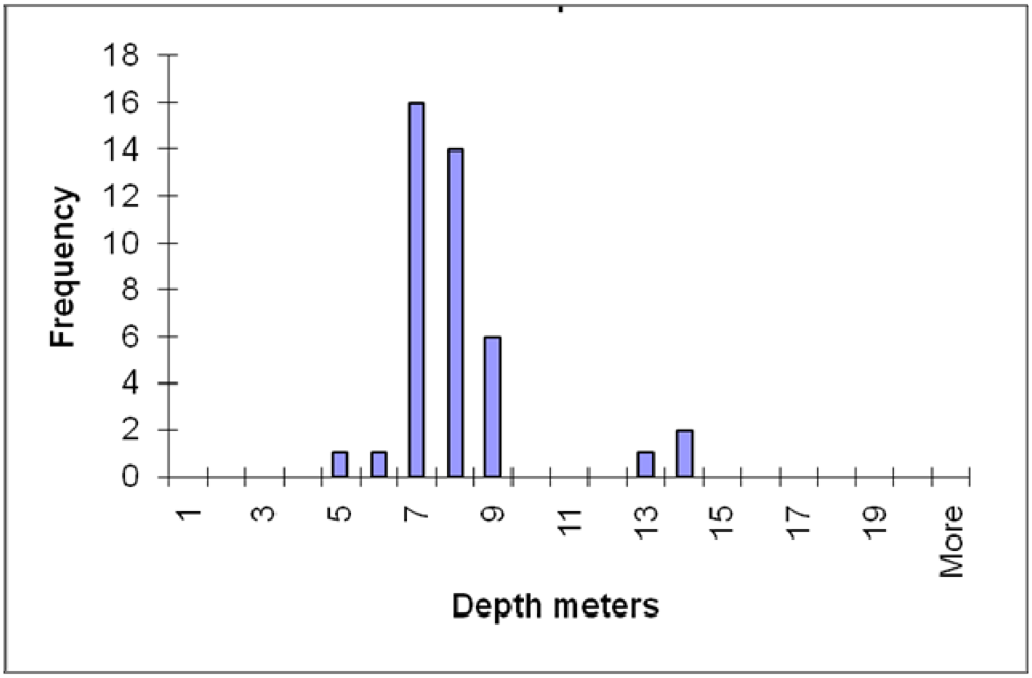
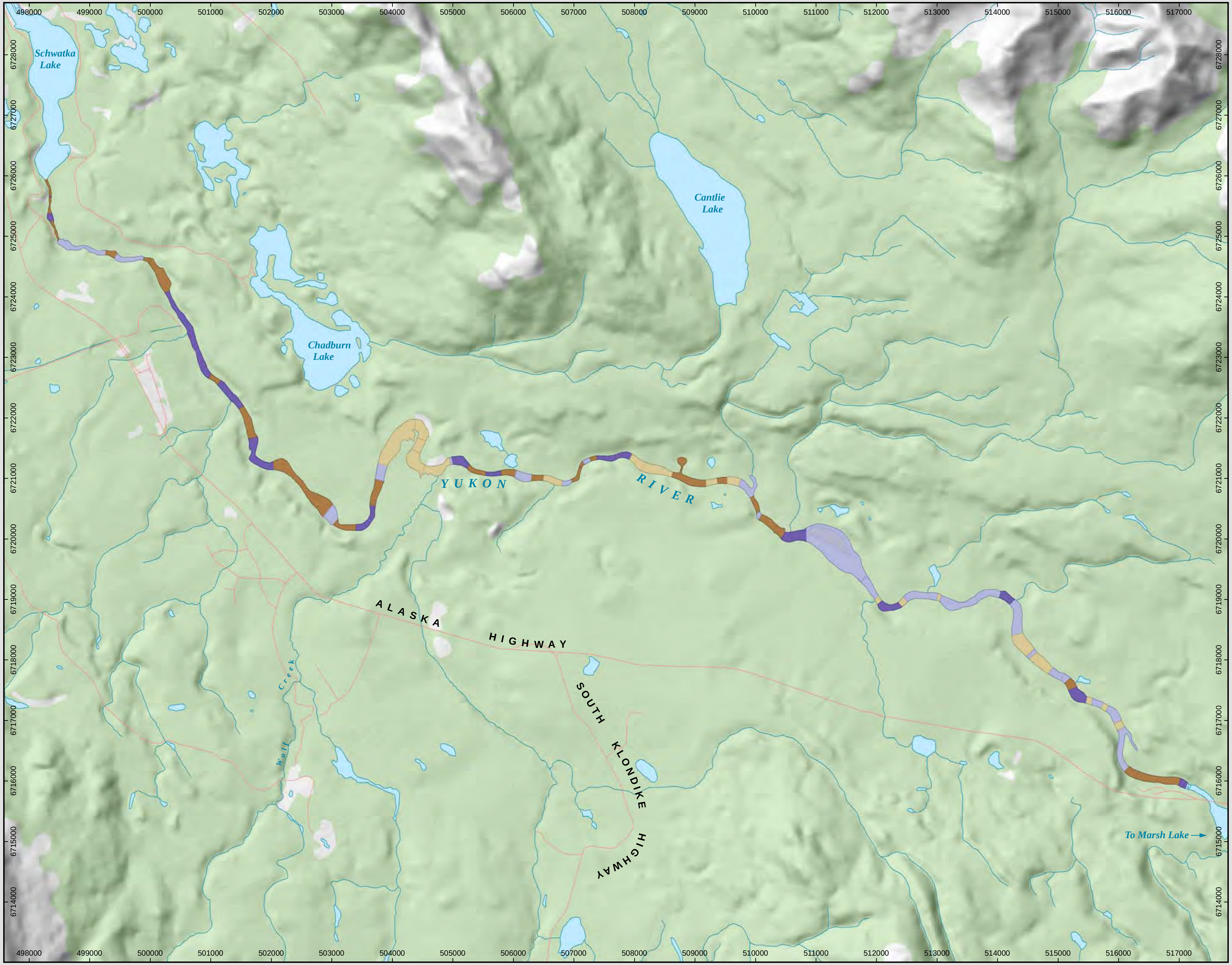


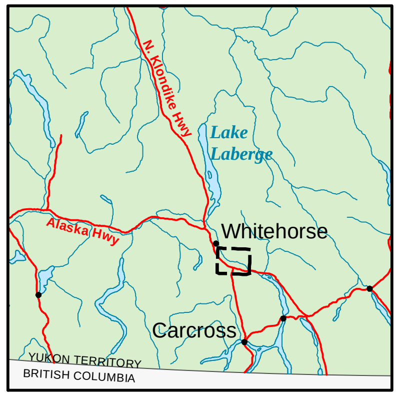
Table 5. Lewes Reach habitat mapping summary from August 15 and 16, 2009.

Habitat Type	Number of Units	Length (meters)	Length (%)	Normalized Length	Normalized Percent
Total Pool	35	14514	53	14514	53
Deep Pool (>10m)	14	6414	23	6414	23
Shallow Pool (<=10m)	21	8100	29	8100	29
Total Run/Glide	41	13090	47	13090	47
Deep Glide (>7m)	23	7991	29	7991	29
Shallow Glide (<=7m)	18	5099	18	5099	18
Low Gradient Riffle	0	0	0	0	0
Total	76	27604		27604	



Legend

🟨 Shallow Glide
🟫 Deep Glide
▨ Shallow Pool
🟪 Deep Pool
— Road Network
— Watercourse
🟦 Waterbody



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Upper Reach

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Figure 12

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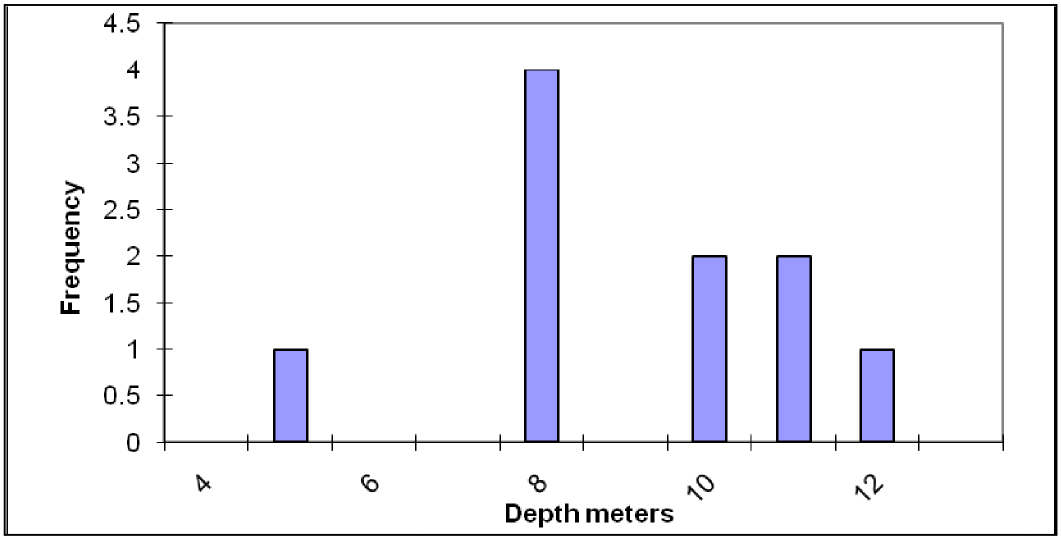
TAKHINI REACH

Habitat mapping on the Takhini Reach was conducted on August 17, 2009. This data was collected by boat, progressing downstream from approximately 1300 m downstream of Whitehorse Rapids Dam to the confluence with the Takhini River at a flow of approximately 487 cms. The data is presented in Appendix A. The starting point was chosen as the closest safe point to the Whitehorse Rapids Dam. Three habitat types were observed in the Takhini Reach: pools, run/glides, and low gradient riffles.

Maximum pool depths varied from 4.5 m to 11.2 m with a mode at 8 m as shown in Figure 13. The pools in the Takhini Reach were further stratified using the median of the maximum depth frequency into deep pools (maximum depth greater than 8 meters) and shallow pools with a maximum depth less than or equal to 8 meters.

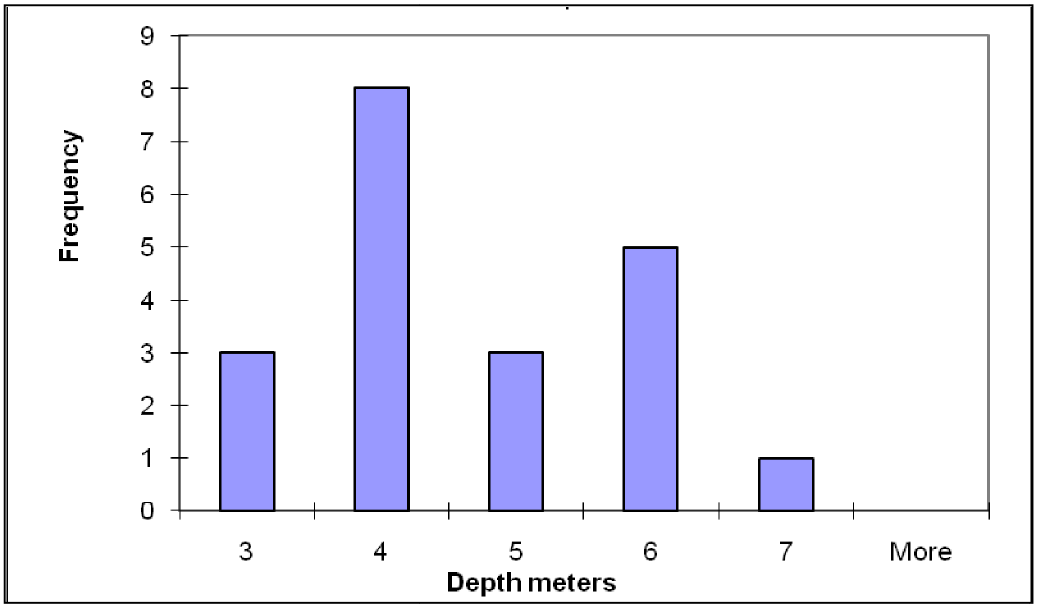
Figure 13. Maximum pool depth frequency in the Takhini reach habitat mapping from August 2009.



Maximum run/glide depth in the Takhini Reach varied between 3 m and 6.5 m with a mode at 4 m and is shown in Figure 14. Run/glides in the Takhini Reach were stratified using the median of the maximum depth frequency into deep (maximum depth greater than 4 m) and shallow (maximum depth less than or equal to 4 m).

Two low gradient riffles were identified in the Fish Habitat Compensation area at the upstream end of the reach.

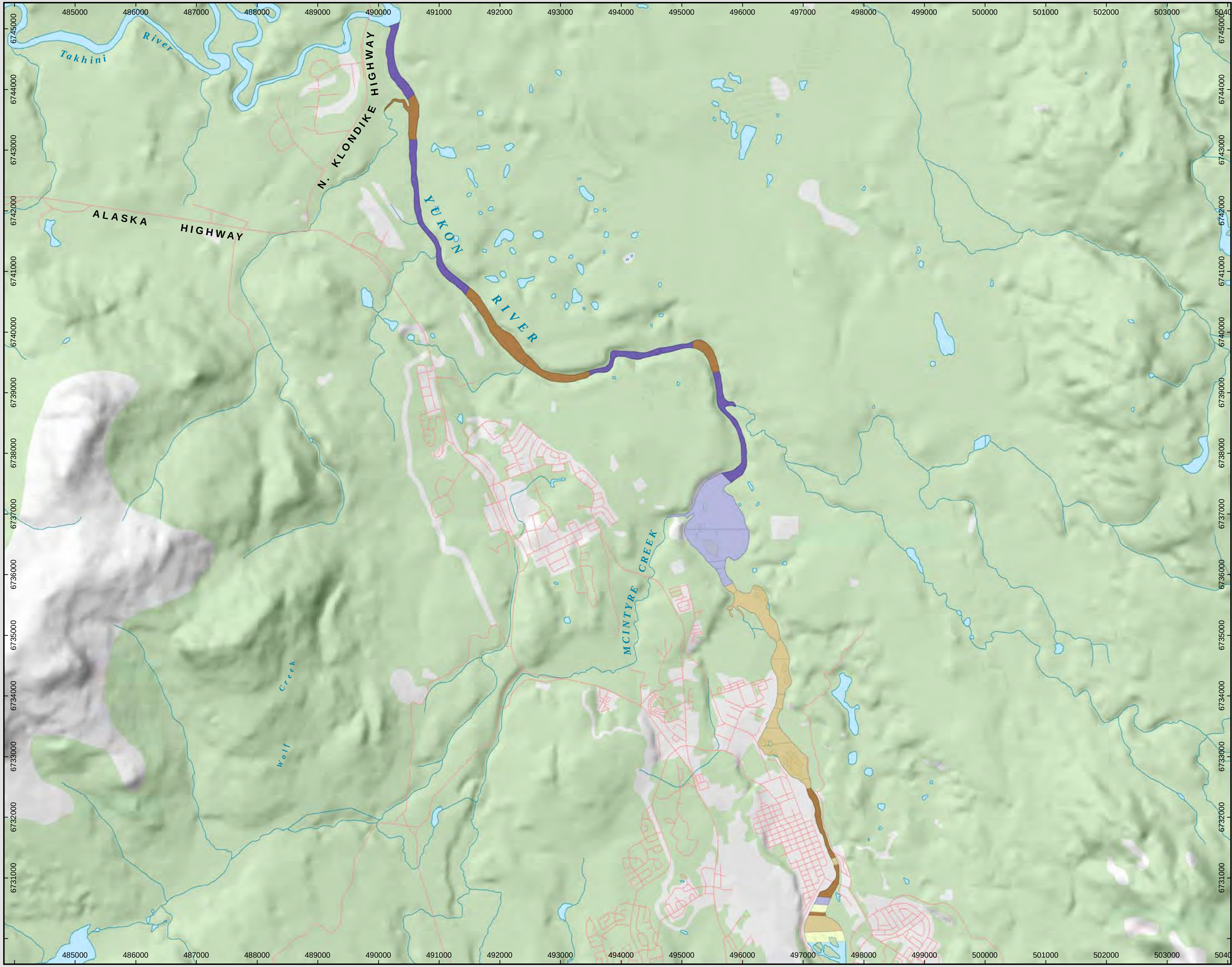
Figure 14. Run/glide maximum depth frequency in the Takhini reach habitat mapping from August 2009.



A summary of the Takhini Reach habitat mapping is presented in Table 6 and Figure 15 depicts the distribution of the habitat types in the Takhini Reach. The portion of the Takhini Reach from the starting point to the north end of the City of Whitehorse was not representative of the natural channel due to the extensive channel alterations and confinement and was not included in the normalized length summary.

Table 6. Takhini habitat mapping summary from August 17, 2009.

Habitat Type	Number of Units	Length (Meters)	Length (%)	Normalized Length	Normalized Percent
Total Pool	10	9992	48	9845	54
Deep Pool (>8m)	5	7951	38	7951	44
Shallow Pool (<=8m)	5	2041	10	1894	10
Total Glide/run	20	10311	50	8269	46
Deep Glide (>4m)	9	6043	29	4477	25
Shallow Glide (<=4m)	11	4268	21	3792	21
Low Gradient Riffle	2	374	2	0	0
Total	30	20677		18114	



Legend

- ▨ Low Gradient Riffle
- ▨ Shallow Glide
- ▨ Deep Glide
- ▨ Shallow Pool
- ▨ Deep Pool
- — Road Network
- — Watercourse
- ▨ Waterbody

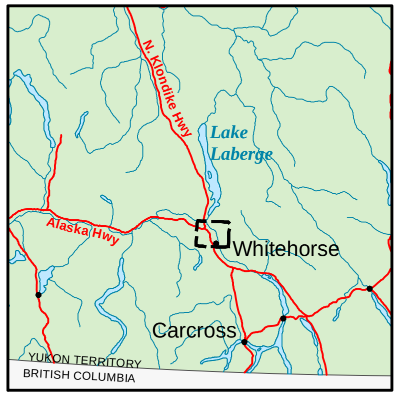


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Figure 15

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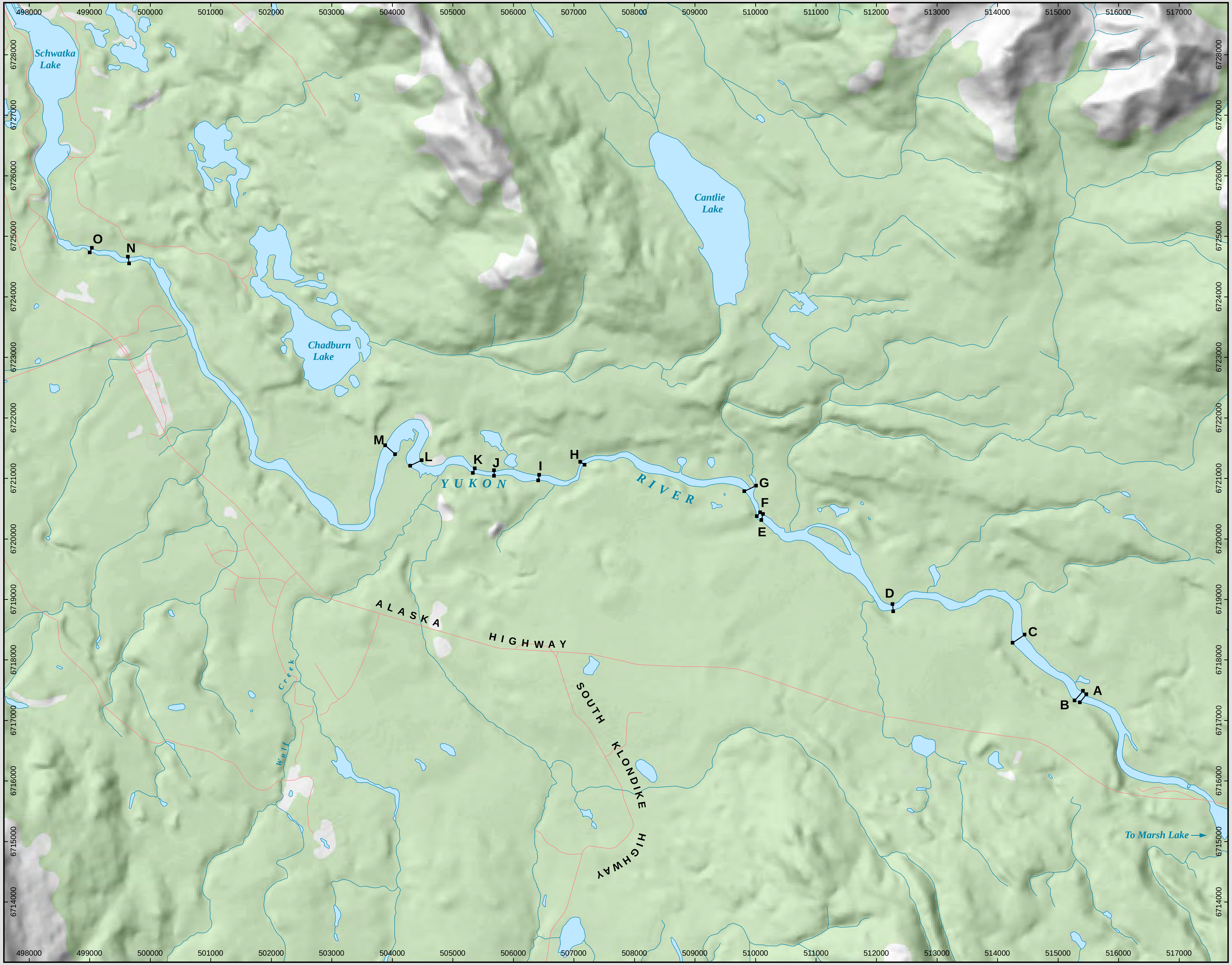
TRANSECT SELECTION

Fifteen transects were selected and installed in each of the two reaches; Lewes and Takhini. The number of transects selected for each habitat type was based on the normalized percent length composition of habitat types in each reach as shown in Table 7. Both low gradient riffles were in the highly-modified and engineered channel upstream of the City of Whitehorse and were not included for selection; however, for the Chinook spawning analysis two transects in this area were subsequently derived from the Fish Compensation Area Plan (Yukon Engineering Services and others, 1997). Each of the transects were installed in a habitat unit randomly selected from all of the units available in the reach. The shallowest areas were targeted in the shallow run units. The transect locations are depicted in Figure 16 and Figure 17.

Table 7. Numbers of transects selected for each habitat type based on the normalized percent length composition of each reach.

Habitat Type	Lewes Reach			Takhini Reach		
	Normalized Length	Normalized Percent	Number of Transects	Normalized Length	Normalized Percent	Number of Transects
Total Pool	14514	53		9845	54	
Deep Pool (>8m)	6414	23	4	7951	44	6
Shallow Pool (<=8m)	8100	29	4	1894	10	2
Total Glide/Run	13090	47		8269	46	
Deep Glide (>4m)	7991	29	4	4477	25	3
Shallow Glide (<=4m)	5099	18	3	3792	21	4
Low Gradient Riffle	0	0	0	0	0	0
Total	**27604**		**15**	**18114**		**15**



Legend

■	Yukon River Transects
—	Road Network
—	Watercourse
🟦	Waterbody

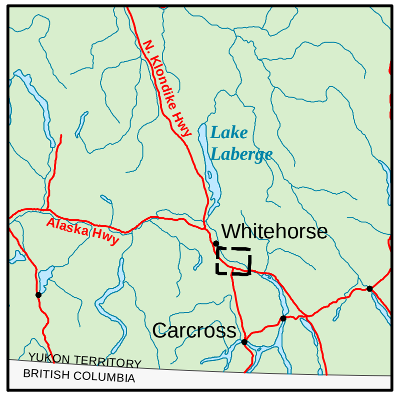


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Figure 16

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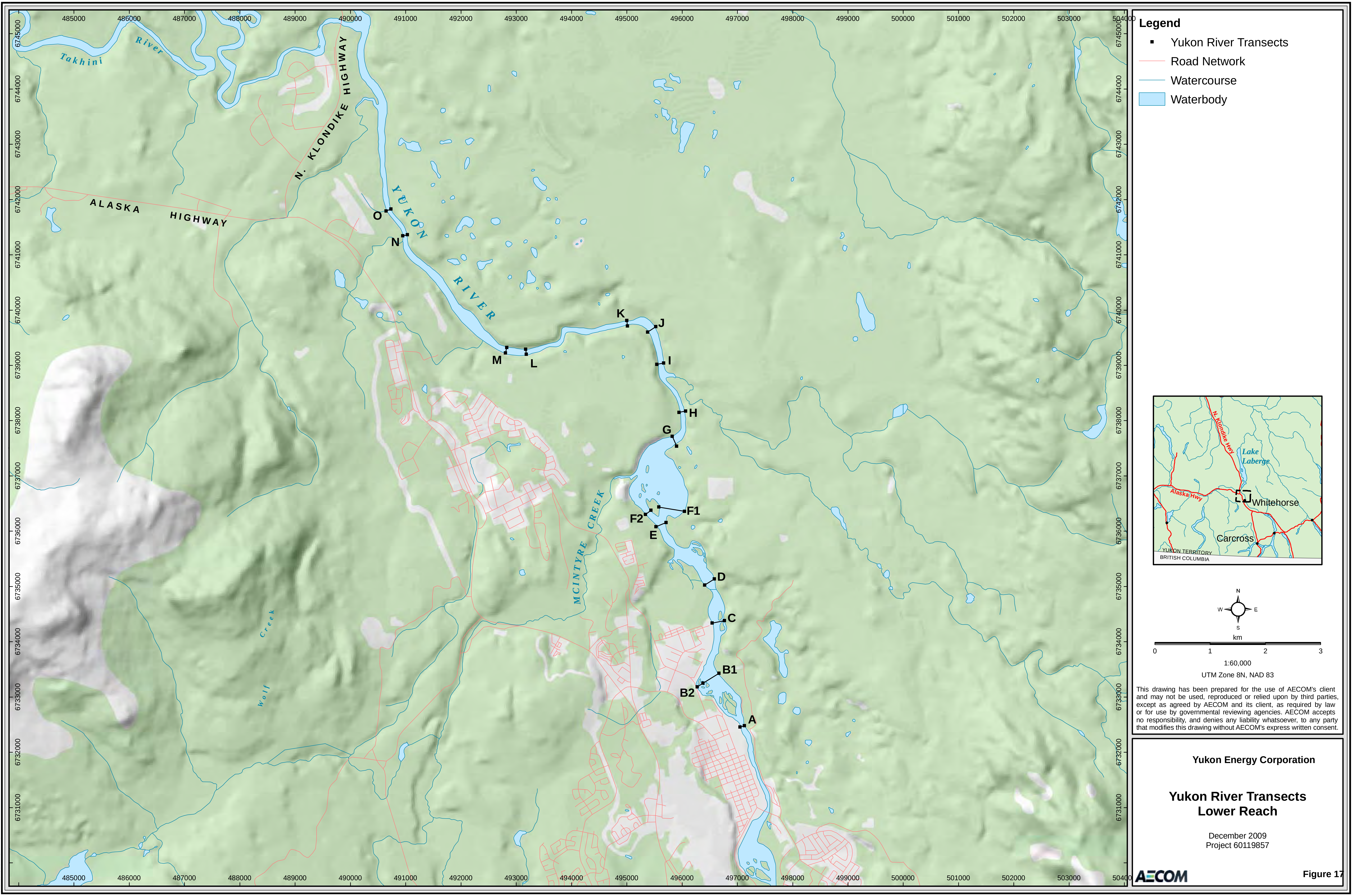

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Yukon River Transects
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Figure 17

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HYDRAULIC DATA

The bottom profiles, high flow velocity patterns, and water surface elevations at three calibration flows were surveyed for each of the Lewes and Takhini Reach transects are depicted in Appendix B.

The out-of-water profiles for all transects were surveyed in August 2009 during the high flow field trip. The substrate characterization occurred in October 2009 during the middle calibration flow field trip for both reaches.

LEWES REACH

Data was collected during the high flows at the 15 transects in the Lewes Reach on August 21 and 22, 2009 with average flows of 491 and 512 cms on the two consecutive days (Table 8). The middle flow data was collected at a flow of 337 cms on October 21, 2009. The low flow data was collected on November 8 and 9, 2009 with flows of 195 and 197 cms. For the high and middle flow, the discharge was measured with the ADCP; whereas, the corrected daily discharges at Whitehorse Rapids Dam provided by YEC were used for the low flow. The discharges provided by YEC were increased by 5% due to the consistent discrepancy between the ADCP measured discharge and the daily YEC discharge (The ADCP discharge values were 7 to 12 percent higher for the high flow and 5 to 8 percent higher for the middle flow).

Table 8. High flow discharges and widths in the Lewes Reach of the Yukon River.

Transect	Unit #	Habitat Type		Letter	Total Width	Discharge	Date	Time
1	71	Shallow	Pool	O	130.6	493	21-Aug	12:50
2	69	Shallow	Pool	N	112.2	489	21-Aug	11:40
3	56	Shallow	Glide	M	289	471	21-Aug	14:52
4	53	Shallow	Glide	L	231.3	475	21-Aug	15:06
5	49	Deep	Glide	K	89.35	497	21-Aug	16:30
6	48	Deep	Pool	J	99.3	484	21-Aug	17:19
7	45	Deep	Glide	I	103	469	21-Aug	17:53
8	41	Deep	Glide	H	82.6	494	22-Aug	10:18
9	31	Shallow	Pool	G	228.8	475	22-Aug	11:15
10	29	Shallow	Pool	F	170	511	22-Aug	12:39
11	28	Deep	Glide	E	113.1	524	22-Aug	13:00
12	23	Deep	Pool	D	130.95	497	22-Aug	14:40
13	16	Shallow	Glide	C	235.95	509	22-Aug	15:32
14	10	Deep	Pool	B	213	519	22-Aug	16:00
15	10	Deep	Pool	A	181.65	515	22-Aug	16:50

TAKHINI REACH

High calibration flow data was collected on the Takhini Reach of the Yukon River at the 15 transects on August 23, 25, and 26, 2009 with average flows of 509, 524, and 524 cms, respectively (Table 9). The middle flow data was collected on October 22, 2009 with a flow of 346 cms. The low flow data was collected on November 9 and 10, 2009 with flows of 197 and 195 cms.

Table 9. High flow discharges and widths in the Takhini Reach of the Yukon River.

Transect	Unit #	Habitat Type		Letter	Channel	Total Width	Discharge	Date	Time
1	30	Deep	Pool	O	MC	99.1	511	26-Aug	11:07
2	30	Deep	Pool	N	MC	92.7	521.7	26-Aug	10:46
3	28	Deep	Glide	M	MC	104.9	510.5	25-Aug	18:11
4	28	Deep	Glide	L	MC	102.5	522.5	25-Aug	17:45
5	26	Deep	Pool	K	MC	109.4	524.9	25-Aug	16:09
6	25	Shallow	Glide	J	MC	175	536.8	25-Aug	15:36
7	24	Deep	Pool	I	MC	115.81	508.7	25-Aug	14:52
8	24	Deep	Pool	H	MC	119.8	517.5	25-Aug	14:16
9	24	Deep	Pool	G	MC	182.1	502.4	25-Aug	13:52
10	22	Shallow	Pool	F	RC	479.61	387	23-Aug	16:12
10	22	Shallow	Pool	F	LC	125.98	135	23-Aug	15:30
11	21	Shallow	Pool	E	MC	204.7	524	23-Aug	14:16
12	18	Shallow	Glide	D	MC	204.6	528	23-Aug	15:01
13	16	Shallow	Glide	C	MC	243.55	487	23-Aug	13:27
14	13	Shallow	Glide	B	RC	334.7	507.5	23-Aug	11:36
14	13	Shallow	Glide	B	MC	35	1	23-Aug	11:52
14	13	Shallow	Glide	B	LC	81.2	11.3	23-Aug	12:06
15	10	Deep	Glide	A	MC	89	498	23-Aug	10:43

HYDRAULIC SIMULATION

RHABSIM software was used to simulate WSELs (from which the depths are derived) and velocities at each transect in both reaches for flows from 50 cms to 650 cms. These simulations, when combined with the HSC, were used for both the Chinook passage and spawning habitat analysis.

WATER SURFACE ELEVATION PREDICTION

WSELs were simulated for each flow at each transect. In conjunction with the bottom profile of a transect, the WSEL provides the depth of each cell. Depths are important for determining both the ability of fish to pass and for assessing spawning habitat. A summary of the water surface elevation predictions for the simulated flows is available in Appendix C and graphs are available in Appendix D.

VELOCITY CALIBRATIONS

For passage, a threshold mean column velocity of 2.4 m/sec is used with the Thompson method (1972). This velocity is rarely exceeded in a low gradient river at low flow where the use of this method is appropriate. For spawning, stream velocities play a critical role in determining the suitability of the habitat.

All velocity simulations utilized the measured high flow velocities and the single velocity method except for the spawning channel transects in the Fish Compensation area at the upstream end of the Takhini Reach. The depth calibration method was utilized for the spawning channel transects. Only minor calibrations to the roughness coefficients (e.g., changing the coefficient sign on near zero or bank cells) for more realistic simulations were made, except for Transect “F” in the Takhini Reach.

Transect F required a dual simulation of velocities at high and low calibration flows due to the low flow channel becoming a backwater at the high calibration flow. At high flows the water flowed over an area that was dry at low flows. The high flow velocities, when simulated to lower flows, allocated too little flow in the low flow channel, requiring calibration of the Manning’s N value for the low flows. Figure 18 depicts the simulation of velocities between 260 and 650 cms using the measured high flow velocities. Note that the island is truncated to a minimum channel separation in these graphs. At the high flow measurement, the velocities on the left side of the graph were all near zero, influenced by surge, wind, and limitations of the ADCP. These velocities were calibrated by eliminating the “spiky” positive/negative surge-influenced velocities. The high roughness required to maintain the low velocities in the deepest part of the channel at high flow, resulted in unreasonably high velocities in the right side of the main channel with decreasing discharge (and stage). In order to allow more flow in the left side at lower flows, a second calibration of roughness was required (Figure 19). This low flow calibration allows flow to distribute into the low flow channel as the right side of the main channel becomes dry.

CHINOOK UPSTREAM PASSAGE

Depths and velocities were simulated down to a low flow of 50 cms for each transect. The results of the Chinook salmon passage analysis found no passage impediments at any of the transects in either study reach for stream flows as low as 50 cms. Tables 10 and 11 give the wetted width, suitable width, percentage suitable (depth greater than 0.24 meter), contiguous suitable width, and percentage of the largest contiguous width that is suitable. Figures 20 and 21 depict the distribution of cells along each transect suitable for Chinook passage. Figures 22 and 23 graph the percentage of the total area suitable for Chinook passage for flows from 50 cms to 650 cms. Appendix E contains graphs of the cross-section profiles and suitability of each cell at 50 cms.

Figure 18. **Simulation of the transect f velocities from 260 cms to 650 cms using the measured high flow velocities. The WSELS and associated mean column water velocities are depicted in green.**

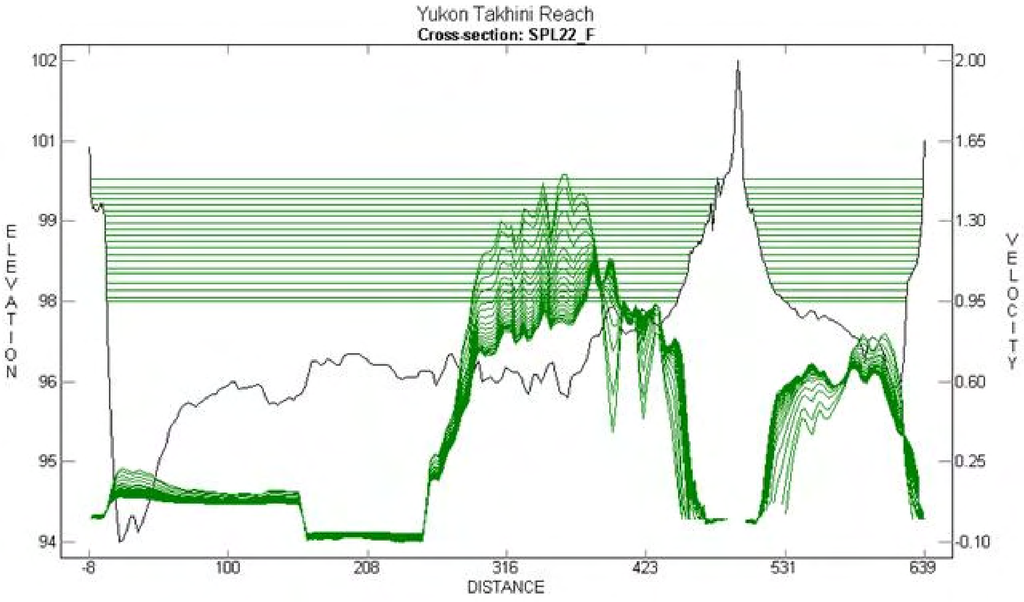


Figure 19. **Simulation of the transect f velocities from 50 cms to 260 cms using the calibrated roughness to allow flow in the left side of the channel. The WSELS and associated mean column water velocities are depicted in green.**

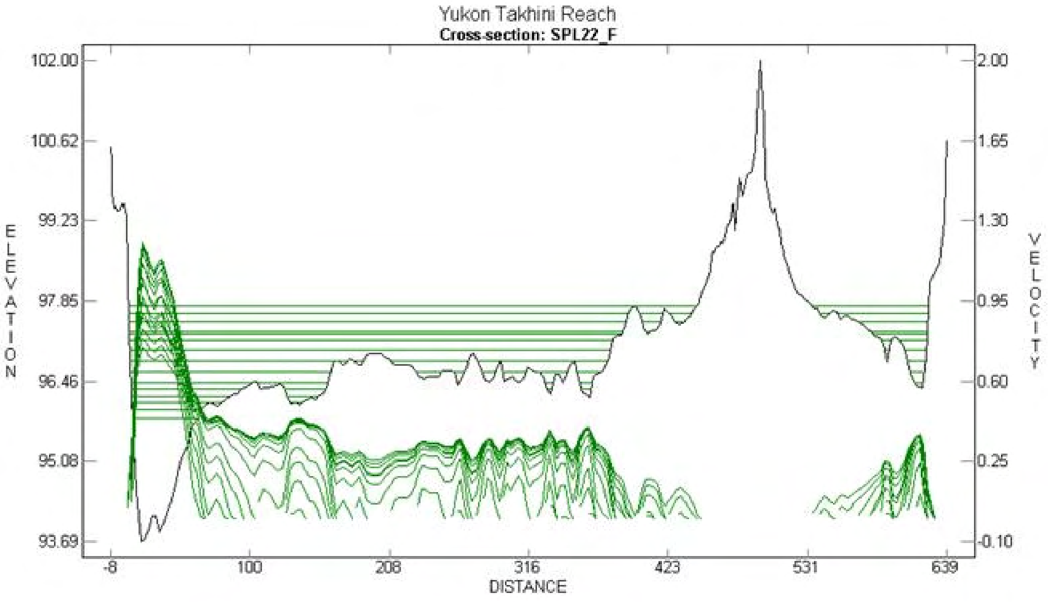


Table 10. The suitable width characteristics of each transect in the Lewes Reach for Chinook salmon passage.

Transect	Wetted Width	Suitable Width	% Suitable	Contiguous Width	% Contiguous
SPL71_O	123.15	114.15	93%	105.15	85%
SPL69_N	102.46	100.00	98%	100.00	98%
SGL56_M	212.88	169.00	79%	119.00	56%
SGL53_L	180.45	176.00	98%	176.00	98%
DGL49_K	76.21	75.00	98%	75.00	98%
DPL48_J	80.33	79.00	98%	79.00	98%
DGL45_I	82.27	77.00	94%	77.00	94%
DGL41_H	66.37	63.00	95%	63.00	95%
SPL31_G	103.66	95.00	92%	94.00	91%
SPL29_F	82.24	81.00	98%	81.00	98%
DGL28_E	93.27	92.00	99%	92.00	99%
DPL23_D	81.91	80.81	99%	80.81	99%
SGL16_C	204.44	202.00	99%	202.00	99%
DPL10_B	172.51	163.00	94%	143.00	83%
DPL10_A	148.44	147.00	99%	147.00	99%

Table 11. The suitable width characteristics of each transect in the Takhini Reach for Chinook salmon passage.

Transect	Wetted Width	Suitable Width	% Suitable	Contiguous Width	% Contiguous
DPL30_O	63.30	62.97	99%	62.97	99%
DPL30_N	56.30	54.00	96%	54.00	96%
DGL28_M	79.02	78.00	99%	78.00	99%
DGL28_L	73.70	72.68	99%	72.68	99%
DPL26_K	56.09	55.00	98%	55.00	98%
SGLD25_J	114.00	94.00	82%	52.00	46%
DPL24_I	80.39	78.99	98%	78.99	98%
DPL24_H	77.60	76.00	98%	76.00	98%
DPL24_G	110.00	103.00	94%	56.00	51%
SPL22_F	51.28	43.72	85%	43.72	85%
SPL21_E	62.83	33.31	53%	31.60	50%
SGL18_D	98.21	79.00	80%	70.00	71%
SGLD16_C	131.36	97.00	74%	52.00	40%
SGLD13_B	183.69	126.00	69%	68.00	37%
DGLD10_A	71.31	68.00	95%	68.00	95%

Figure 20. The distribution of cells suitable for Chinook passage at 50 cms along each transect in the Lewes reach.

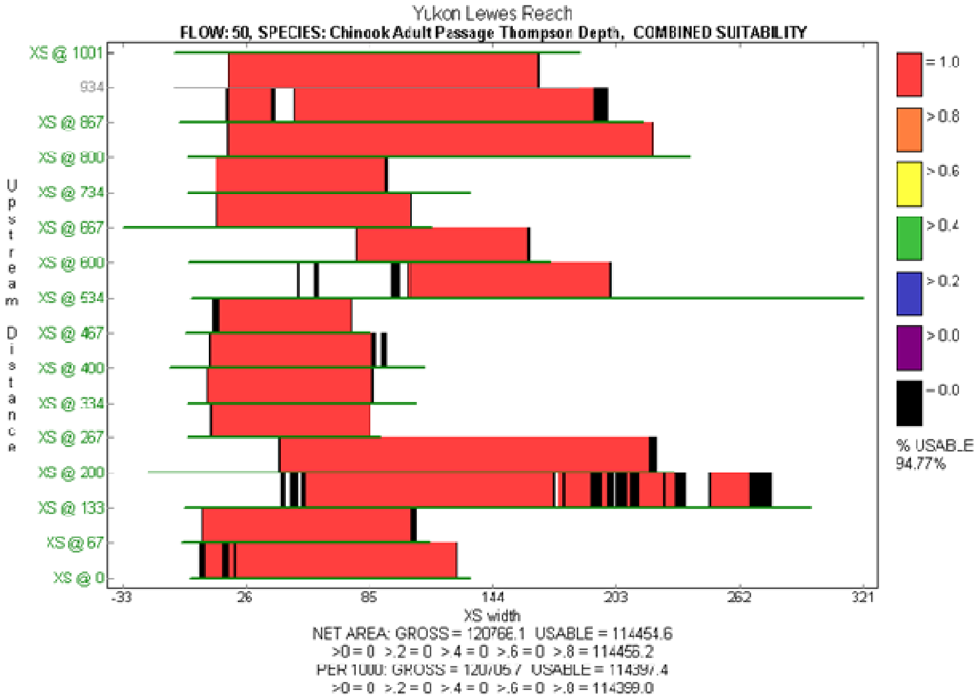


Figure 21. The distribution of cells suitable for Chinook passage at 50 cms along each transect in the Takhini Reach.

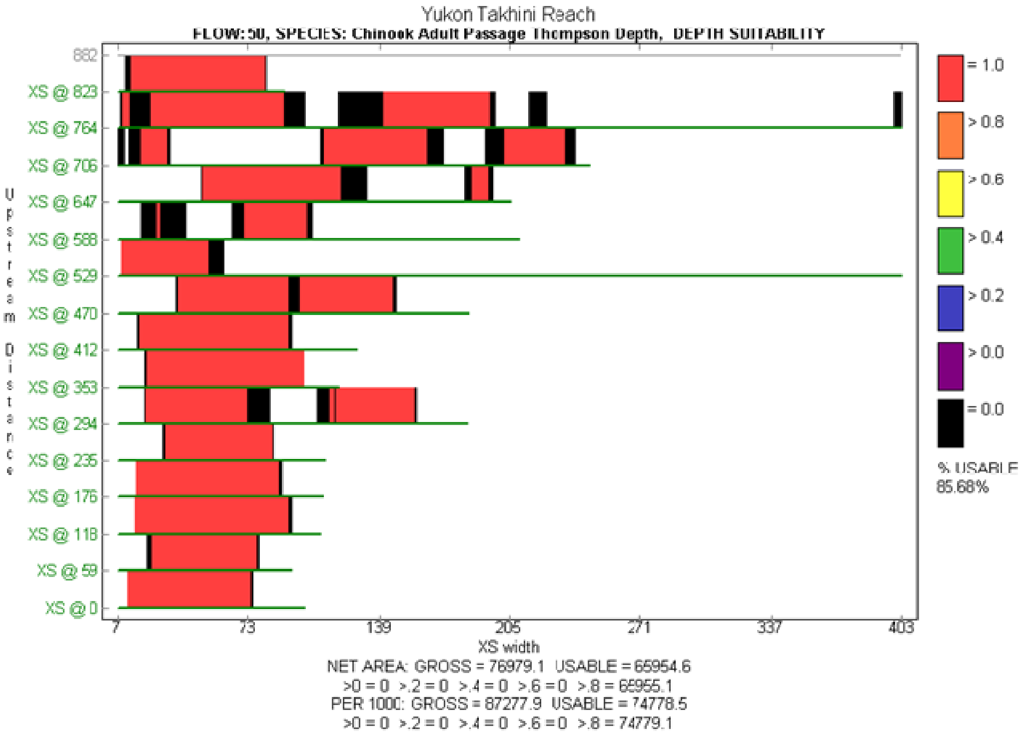


Figure 22. Percentage of the total area in the Lewes reach suitable for Chinook passage at flows from 50 cms to 700 cms.

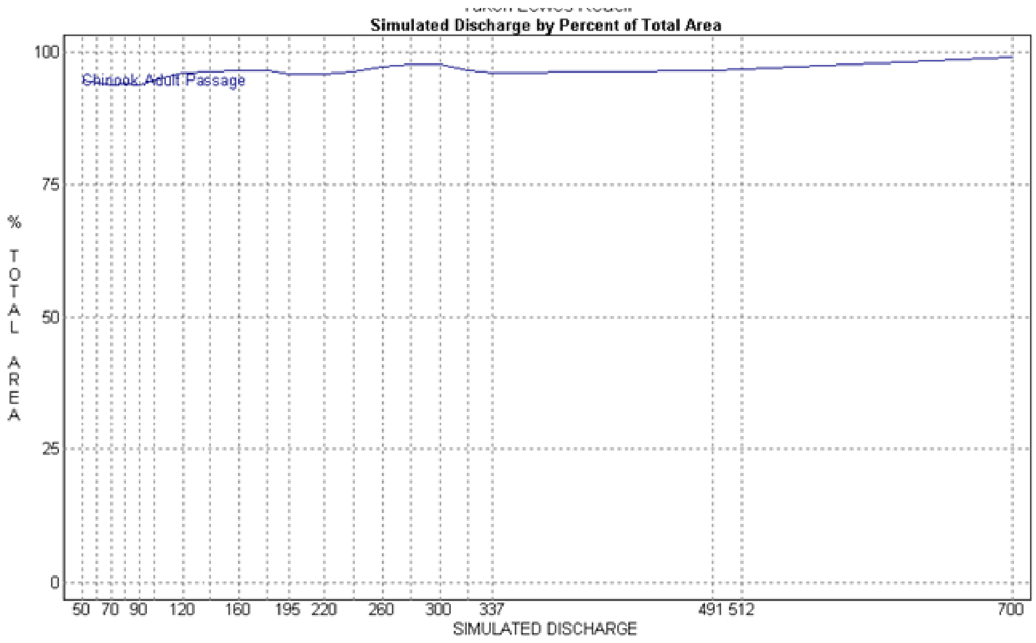
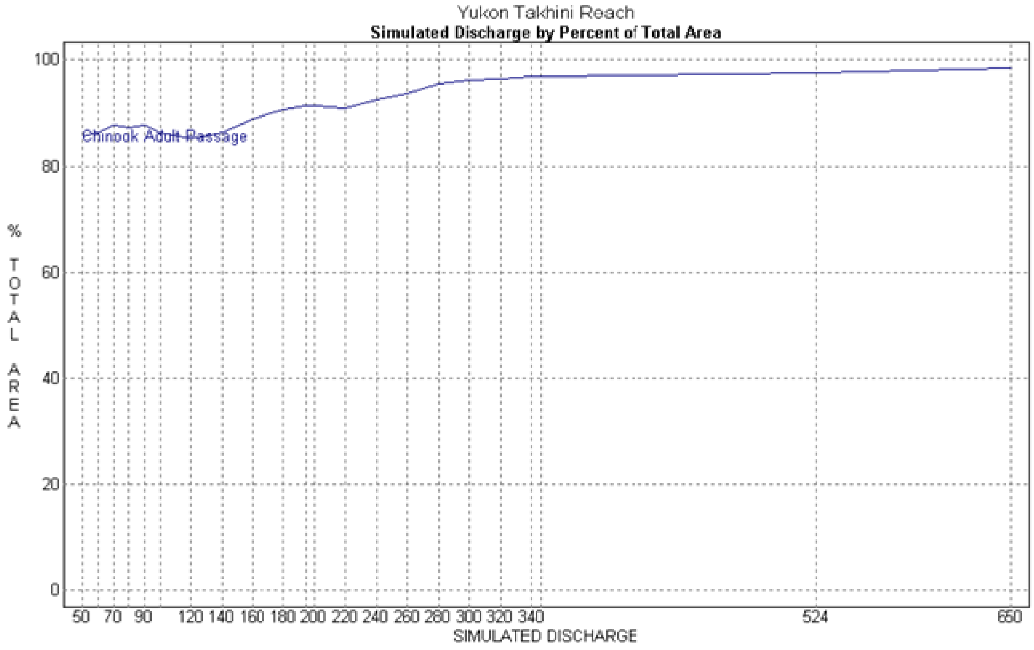


Figure 23. Percentage of the total area in the Takhini Reach suitable for Chinook passage at flows from 50 cms to 650 cms.



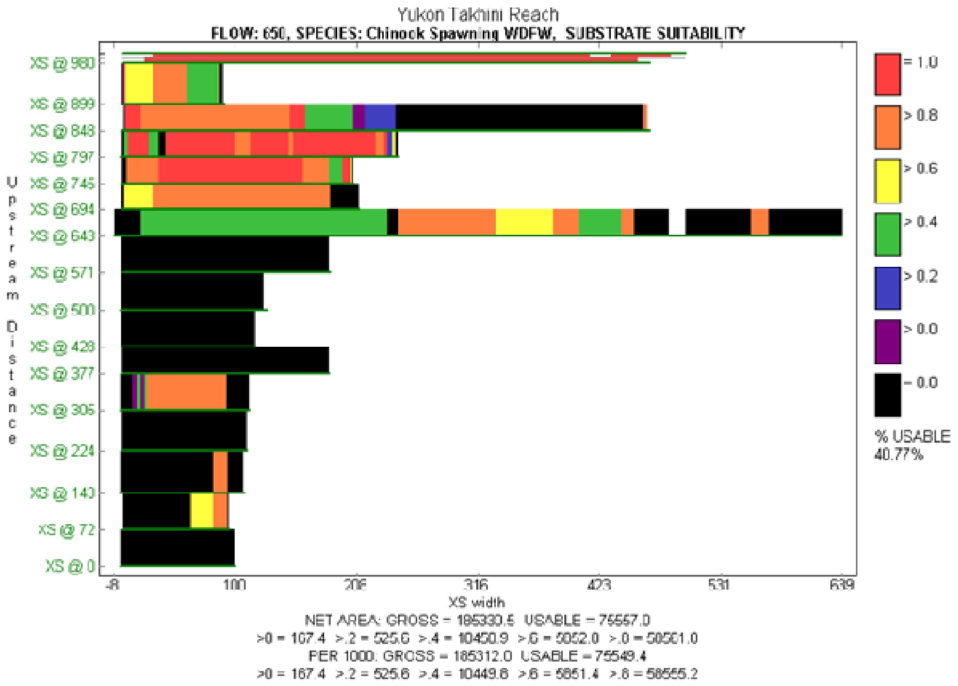
CHINOOK SPAWNING

The relationship of the index of Chinook spawning suitability (WUA) and flow is determined in our analysis by the three parameters: mean water column velocity, depth, and substrate. The depth and velocity vary with the flow, whereas the substrate is a constant that determines where spawning may occur when the velocity and depth variables are suitable. Spawning is known to occur in the Takhini Reach and one redd was observed by the field crew during the middle flow survey between Transects E and F. No spawning is known to occur in the Lewes Reach; however, DFO has stated that 50% of the Chinook spawning location upstream of the Whitehorse Rapids fish ladder is unknown. Further investigations into Chinook spawning locations are planned in 2011. For this report, the analysis was limited to spawning in the Takhini Reach where spawning is known to occur. If the further investigations determine that spawning occurs in the Lewes Reach, additional analysis would be required.

SUBSTRATE

Figure 24 depicts where suitable substrate exists within the Takhini Reach. Red depicts the most suitable substrate, whereas black depicts unsuitable substrate. The two Fish Compensation Area transects are at the top and Transect O at the bottom. Each transect is sized in proportion to the area it would represent in a 1000 meter reach. Most of the available spawning substrate is at or upstream of Transect F (the widest transect), upstream of the confluence with McIntyre Creek. Transect K (towards the bottom with the orange color), also has suitable substrate.

Figure 24. Chinook spawning substrate suitability in the Takini Reach of the Yukon River.



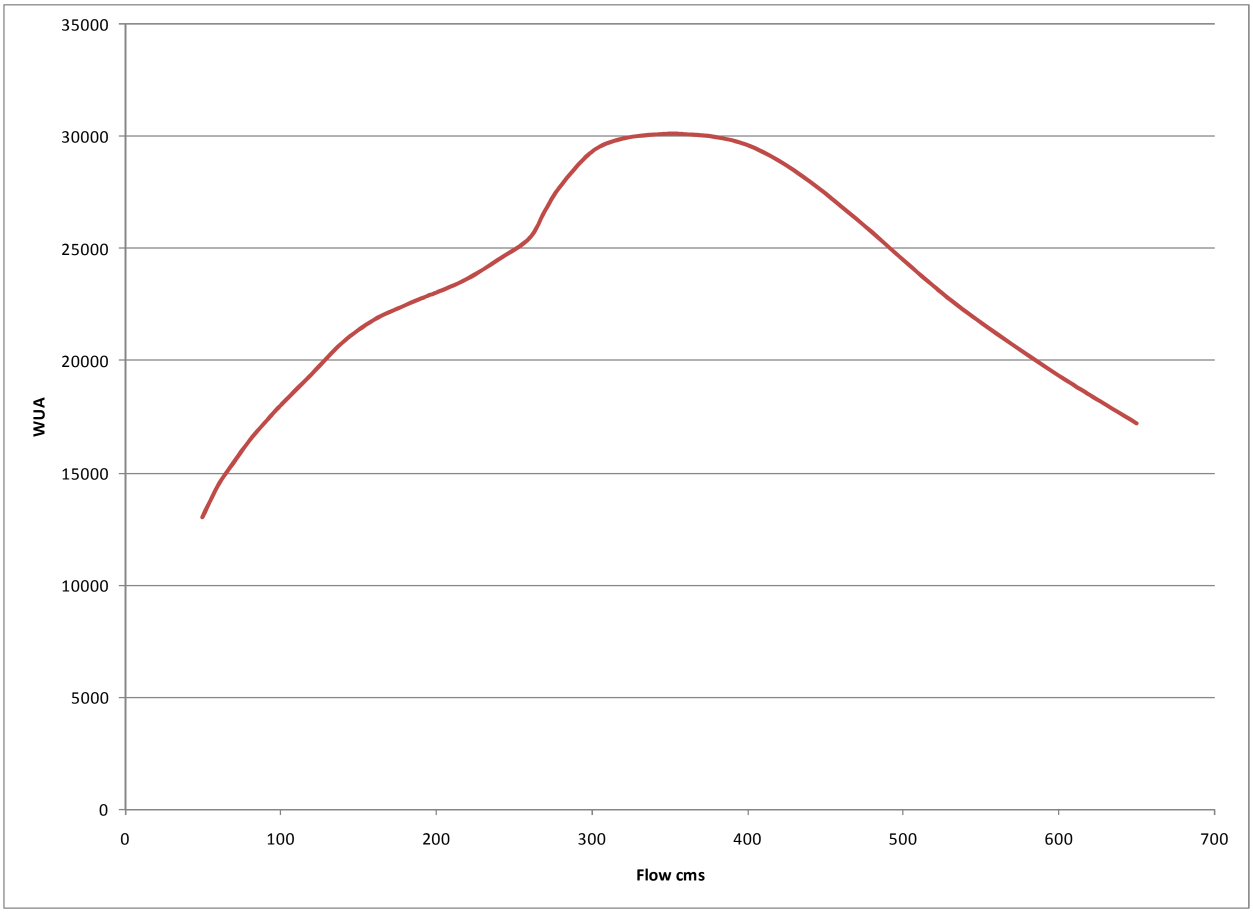
HABITAT INDEX

Due to the dual velocity calibrations at Transect F, the WUA had to be generated with two separate simulations and merged. The tabular values are presented in Table 12 and depicted in Figure 25. Based upon our PHABSIM analysis, the WUA for Chinook spawning in the Takhini Reach of the Yukon River increases with flow from 50 cms, peaks at flows ranging from 280 cms to 380 cms, and then declines with increasing flow.

Table 12. WUA for Chinook salmon spawning habitat in the Takhini Reach of the Yukon River.

Simulated Discharge	Total Surface Area	Weighted Usable Area	Percent of Total	Simulated Discharge	Total Surface Area	Weighted Usable Area	Percent of Total
50	85252.34	13001.12	15.25	320	159109.6	29907.74	18.8
60	89276.16	14407.21	16.14	346	161866.2	30114.44	18.6
70	92420.7	15437.8	16.7	360	163529.5	30103.61	18.41
80	95895.33	16400.34	17.1	380	165249.8	29974.44	18.14
90	99563.64	17214.57	17.29	400	166850.9	29621.71	17.75
100	104360.3	17977.51	17.23	420	168412.1	28928.78	17.18
120	113123	19376.35	17.13	440	171508.7	27994.38	16.32
140	121479.5	20799.15	17.12	460	173486.4	26895.33	15.5
160	127677.1	21807.72	17.08	480	175185.4	25731.57	14.69
180	133158.6	22455.94	16.86	500	176760.3	24492.06	13.86
195	137225	22897.24	16.69	524	178312.5	23063.84	12.93
200	138374.5	23027.28	16.64	540	179447.1	22199.15	12.37
220	142946.1	23639.23	16.54	560	181073	21202.34	11.71
240	148008	24504.96	16.56	580	182273.4	20243.03	11.11
260	152085.9	25456.25	16.74	600	183184.7	19321.71	10.55
270	153310.2	26679.33	17.4	620	184190.2	18452.54	10.02
280	154394.8	27784.52	18	650	185312	17190.79	9.28
300	156855.9	29314.34	18.69				

Figure 25. WUA for Chinook salmon spawning habitat in the Takhini Reach of the Yukon River.



TIME SERIES

The time series analysis combines the hydrology and WUA/flow relationship for Chinook spawning in the Takhini Reach. Two scenarios, historical and post-project, within the three water year types were modeled. The term “historical” in this context refers to the hydrology that actually happened in the years simulated with the Lewes Dam as it operated. The term “post-project” refers to the hydrology as it would have occurred if the proposed Marsh Lake Fall-Winter Storage Concept had been in place at that time. The flow time series graphs compares the Yukon River for the given years to the post-project flow for average, wet, and dry years with both scenarios in Figures 26, 27, and 28. In the average and dry water-year types, flows are reduced in the spring and early summer and decreased in the fall and winter (Figures 26 and 27). In the wet-year type the change is less evident (Figure 28).

The flow duration curves are depicted in Figures 29, 30, and 31. In average and dry water-year types, Figures 29 and 30, the moderately high flows are reduced and the moderately low flows are increased. For the wet water-year type, Figure 31, the difference between historical and post project flows is less evident.

The habitat duration curves are depicted in Figures 32, 33, and 34. The tabulated “area under the curve” values in the chart are the total habitat index values for the year. In an average water year, the area under the habitat duration curve is nearly identical for both the historical and post-project conditions (Figure 32). In a dry water year, there would be slightly less spawning habitat available post-project (Figure 33). In a wet water year there would be slightly more habitat available post-project (Figure 34).

Figure 26. **Historic flow and projected post-project flow for an average water year.**

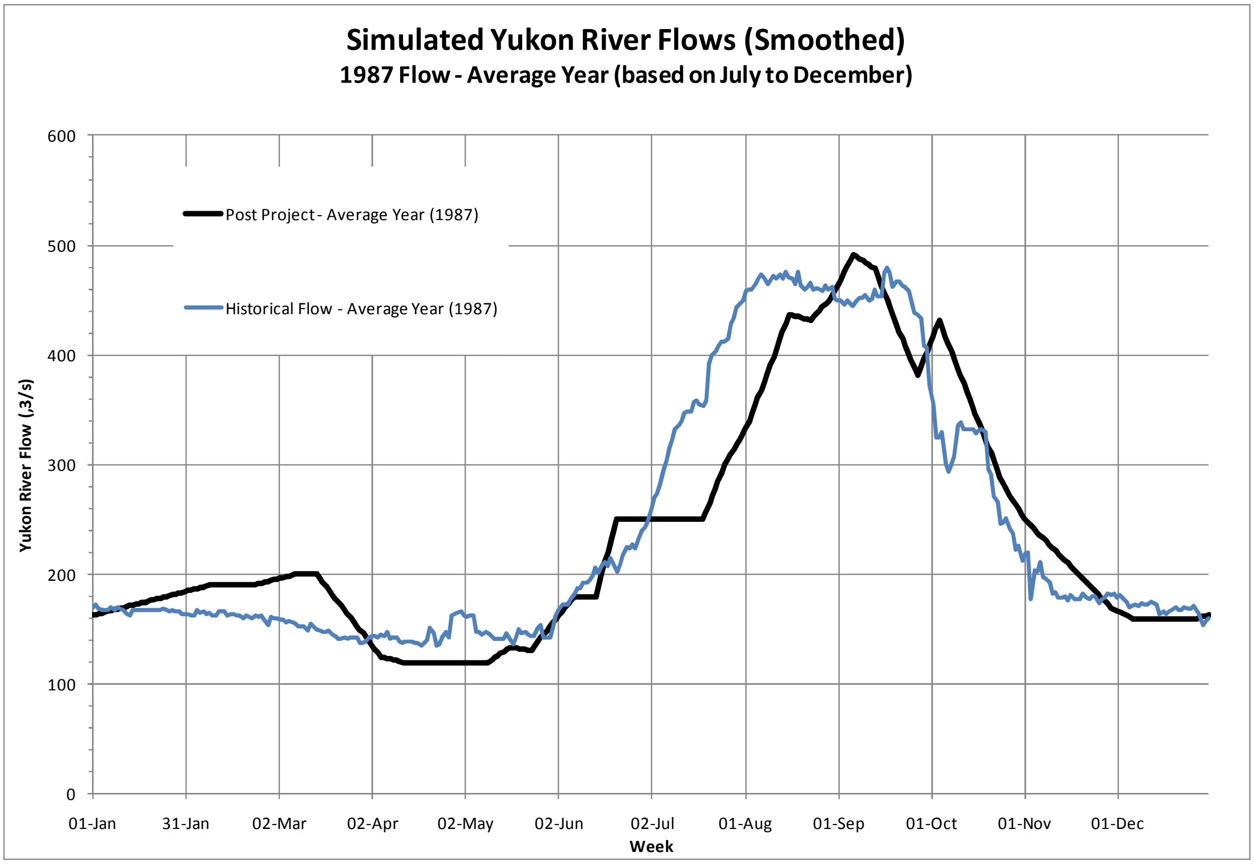


Figure 27. Historic flow and projected post-project flow for a wet water year.

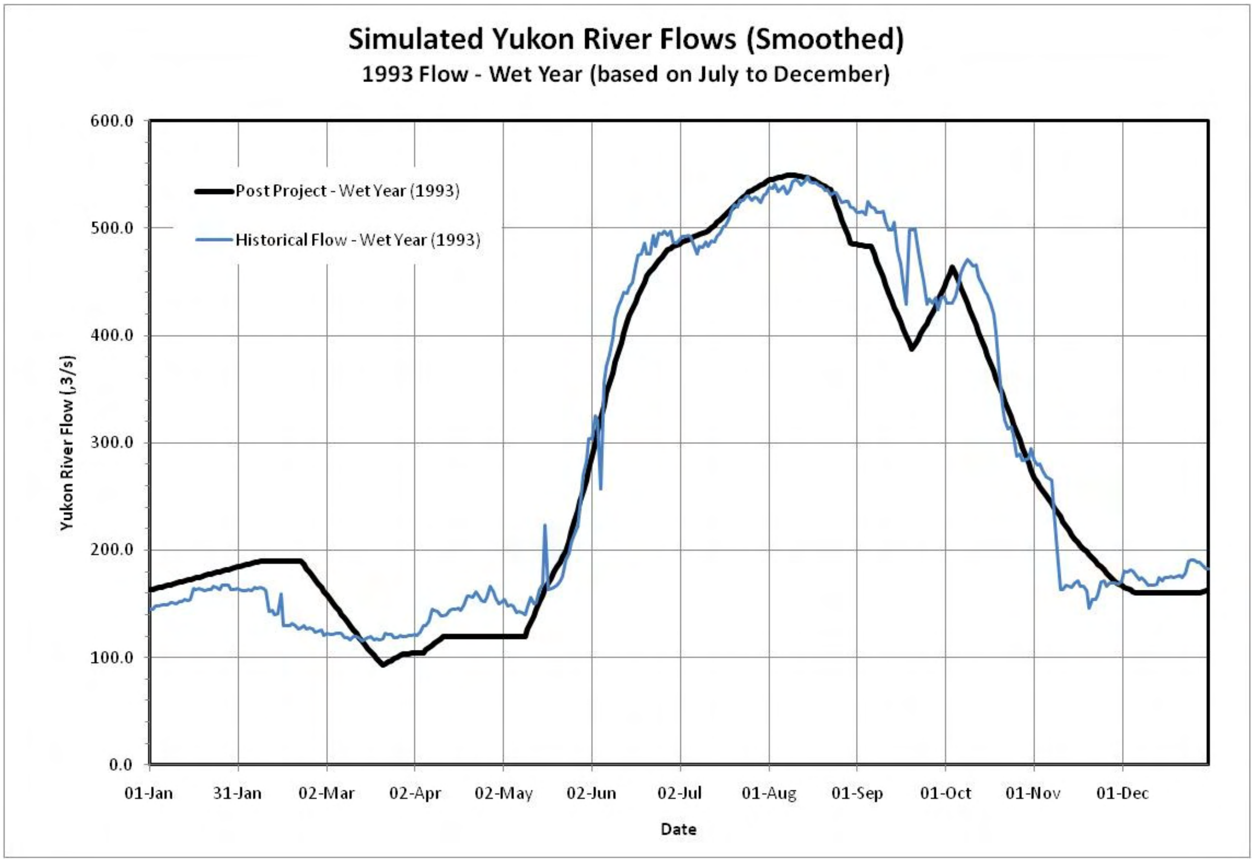


Figure 28. Historic flow and projected post-project flow for a dry water year.

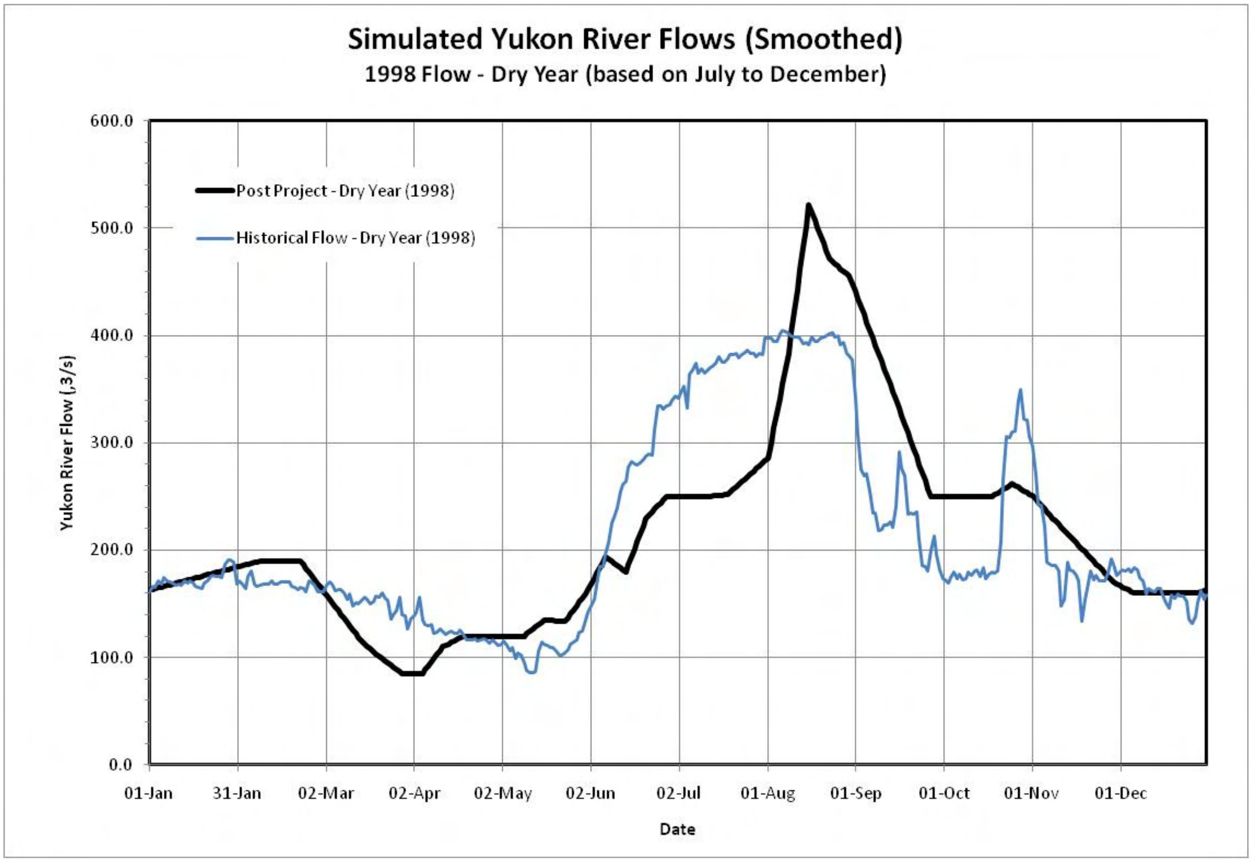


Figure 29. Historic and projected post-project daily average flow duration for an average water year.

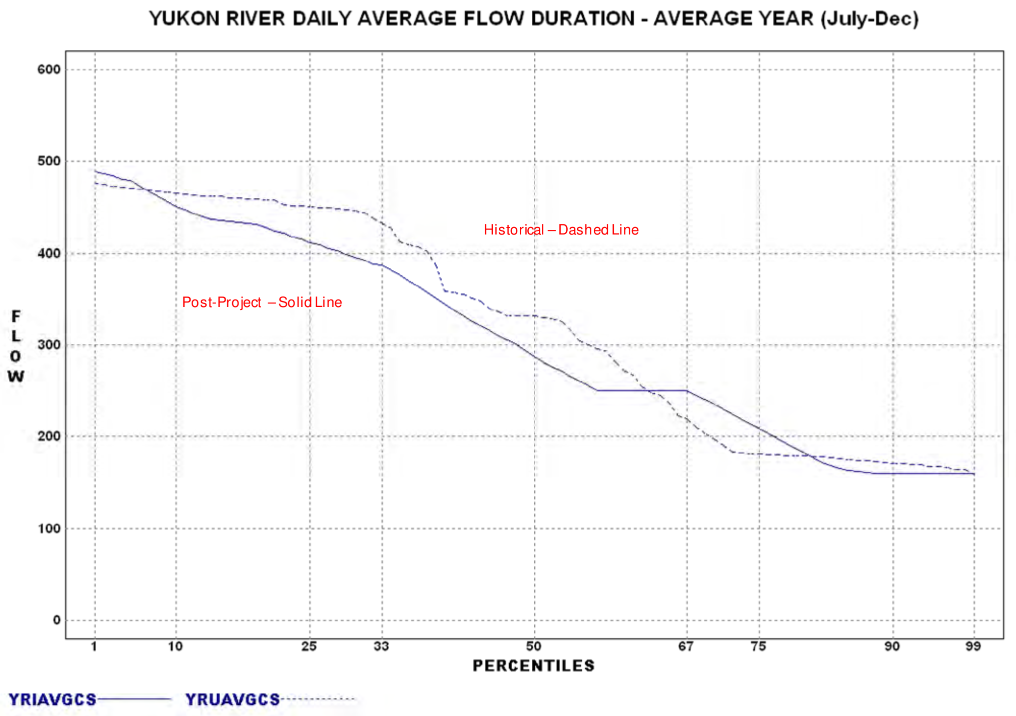


Figure 30. Historic and projected post-project daily average flow duration for a dry water year.

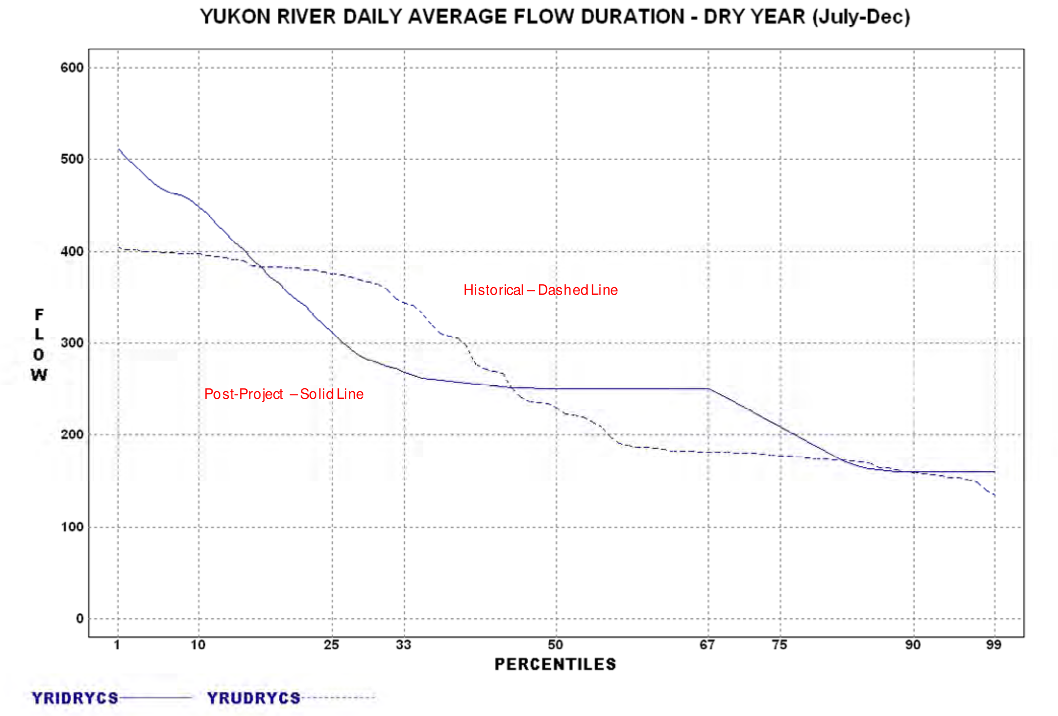


Figure 31. Historic and projected post-project daily average flow duration for a wet water year.

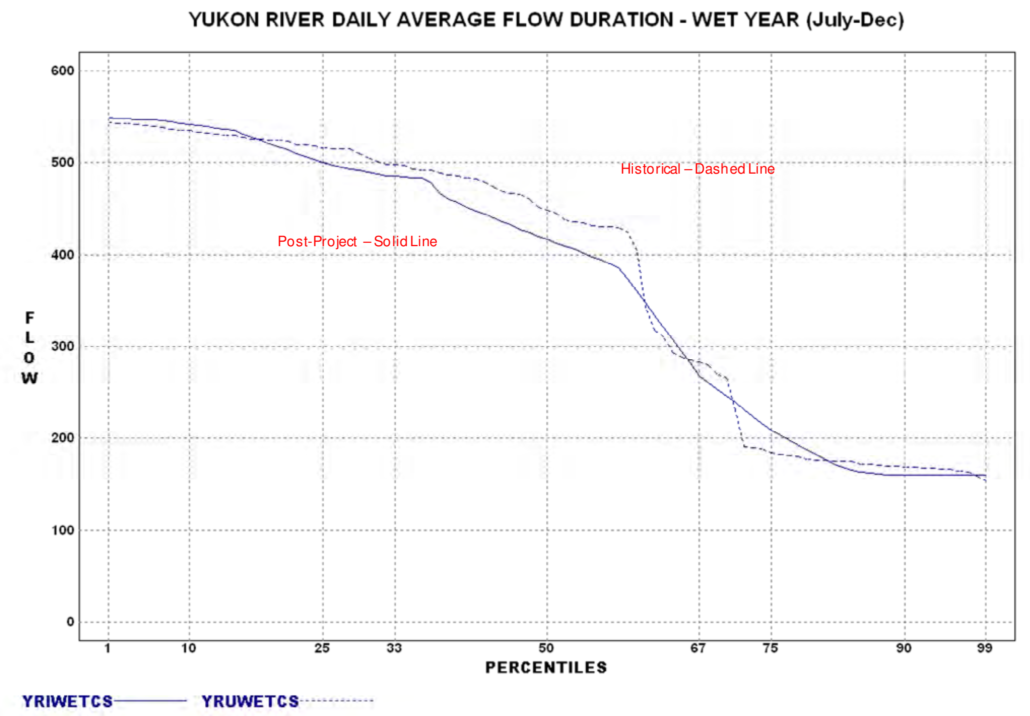
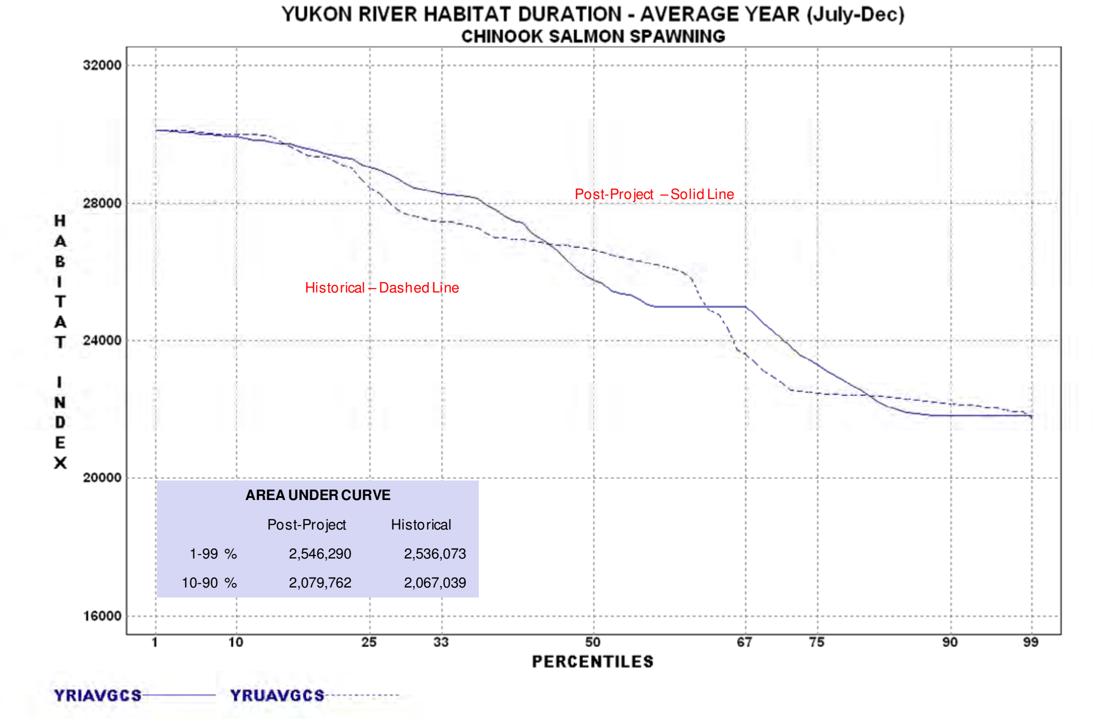


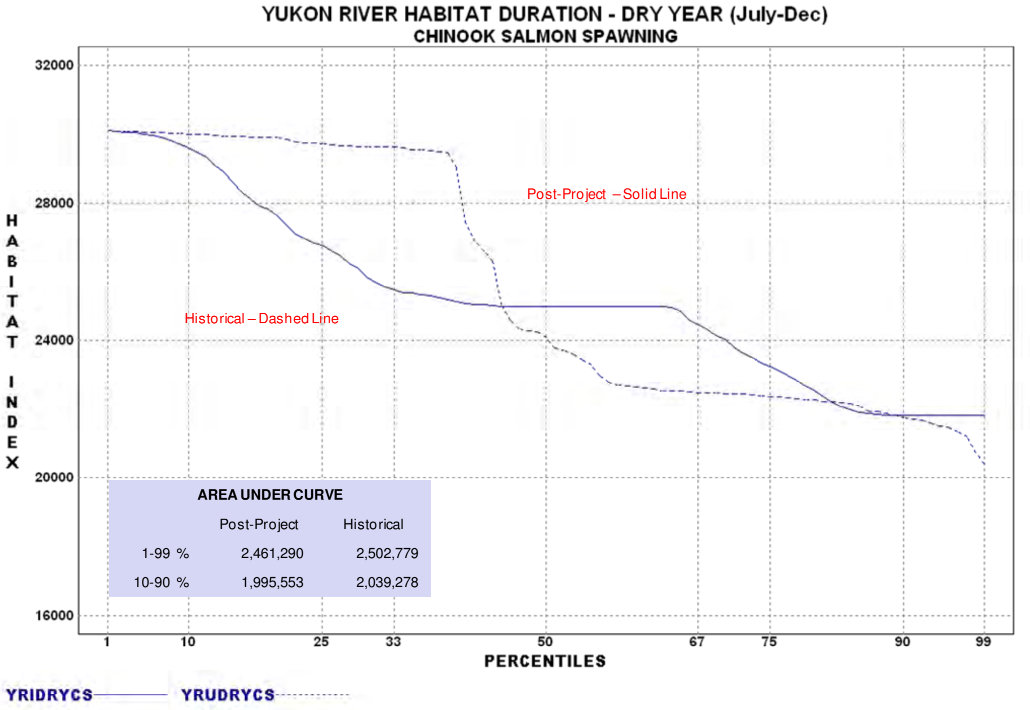
Figure 32. Historic and projected post-project habitat duration for an average water year.



AREA UNDER CURVE

	Post-Project	Historical
1-99 %	2,546,290	2,536,073
10-90 %	2,079,762	2,067,039

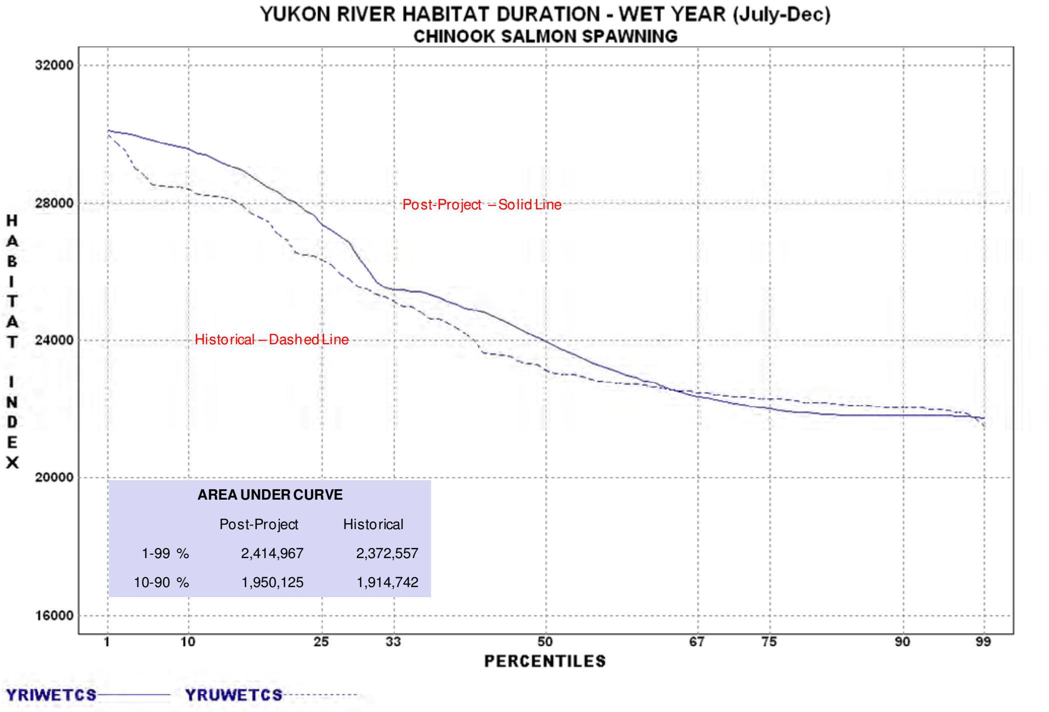
Figure 33. Historic and projected post-project habitat duration for a dry water year.



AREA UNDER CURVE

	Post-Project	Historical
1-99 %	2,461,290	2,502,779
10-90 %	1,995,553	2,039,278

Figure 34. **Historic and projected post-project habitat duration for a wet water year.**



AREA UNDER CURVE

	Post-Project	Historical
1-99 %	2,414,967	2,372,557
10-90 %	1,950,125	1,914,742

8. CONCLUSIONS

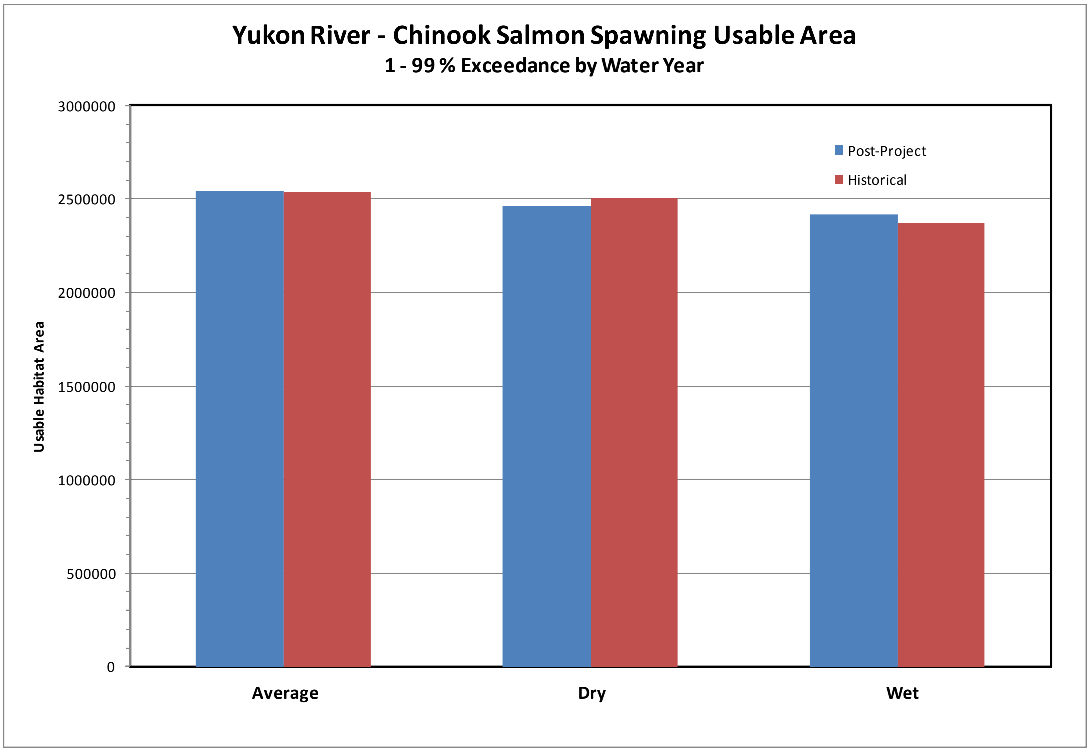
PASSAGE

No passage issues were detected by this analysis for flows as low as 50 cms in either the Lewes or Takhini reaches. The Marsh Lake Fall-Winter Storage Concept will not cause flows to drop lower than 50 cms and will not be a detriment to adult Chinook upstream passage.

SPAWNING

The time series analysis indicates that the Marsh Lake Fall-Winter Storage Concept flows would have very little impact on Chinook spawning habitat compared to the existing conditions in the Takhini Reach. Figure 35 compares the July through December historical and post –project habitat index values for the average, wet, and dry water-year types. The difference in habitat index values between that which occurs with the current operation of Lewes Dam and that which would occur if the Marsh Lake Fall-Winter Storage Concept were implemented is small.

Figure 35. **The time series Chinook salmon spawning habitat values for average, dry, and wet years under historical and post-project operation scenarios.**



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APPENDIX A

Habitat Mapping for the Marsh Lake PHABSIM Study

Appendix A - Habitat Mapping PHABSIM Study for Marsh Lake Fall-Winter Storage Concept
Reach 1 Lewes Dam to Schwatka Lake

Date: August 15-16, 2009
Weather: Partly Cloudy

Unit	Habitat	Length (m)	Max D (m)	Max D Sort	Width (m)	Photo	Wypt@bottom	Notes
1	PL	134	16	16	0	1335 d	8	Start at Lewes Dam (WYTPT 7) @ 1331 hrs (photo 1331)
2	RUN	716	9	9	0	1348 BW	11	
3	GLD	194	7.7	7.7	0	1356u	12	Glide/wide run
4	PL	692	9.1	9.1	0	2 u/d; 1404	13	with backwater; aquatic veg present
5	GLD	134	7	7	0		14	
6	PL	316	9.8	9.8	0		15	wide with shallow aq veg RB; bluffs LB
7	GLD	97	7	7	0		16	
8	PL	194	9	9	0		17	
9	GLD	94	7	7	0	1427d	18	
10	PL	264	18.7	18.7	0		19	
11	GLD	172	7.3	7.3	0	1433	20	LB cove
12	PL	115	8.2	8.2	0	1437 u/d	21	width taken at bottom
13	PL	214	10	10	0		22	narrows
14	GLD	382	7-May	7	0		23	
15	PL	79	7.8	7.8	0		24	short deeper area of similar habitat
16	GLD	348	6-Apr	6	0		25	shallower
17	PL	544	8.8	8.8	0		26	
18	PL	244	10.7	10.7	0	1503 u/d	27	deeper; LB bluff, tree RB, WD RB; transect profile
19	PL	1,053	10	10	0		28	
20	GLD	53	7	7	0		29	shallow short break (still PL)
21	PL	561	10-Aug	10	160		30	
22	GLD	124	7-Jun	7	0		31	
23	PL	347	11.4	11.4	0		32	
24	GLD	96	7-Apr	7	0		33	
25	PL	384	6.8	6.8	0	1548 u/d	34	bottom complexity; transect profile @ 1557
26	PL	1,174	6.7	6.7	0	06 u/d; 1607	37	wide with island (wypt 35-36); LB sand bluff; RB BOATS; LB shallow @ island; RB deep
27	PL	762	12.1	12.1	0		38	RB canoes
28	GLD	108	9-Jul	9	0		40	pump RB at bottom
29	PL	80	9.2	9.2	0		41	
30	RUN	281	8-Jul	8	0		42	faster control area
31	PL	339	9.5	9.5	0		44	Wypt 43=SC top island complex; inundated veg LB&RB; end island at Wypt 44
32	GLD	229	7-Jun	7	0		45	
33	GLD	181	8-Jul	8	0		46	same GLD
34	GLD	187	7-Jun	7	130		47	
35	GLD	585	8-Jul	8	0	1702 cove	49	LB cove; transect profile
36	GLD	493	7-Jun	7	0		50	
37	GLD	276	7-Jun	7	0	1722 u/d	51	
38	PL	597	12	12	0		53	end 8/15/09@1730hrs wyp 52; BW areas both banks; start 8/16/09 @113

Unit	Habitat	Length (m)	Max D (m)	Max D Sort	Width (m)	Photo	Wypt@bottom	Notes
39	GLD	117	8-Jul	8	0		54	
40	PL	125	9.6	9.6	0	1153 u/d	55	
41	GLD	102	8-Jul	8	0		56	
42	GLD	265	9-Aug	9	0		57	transect profile across control 6-7 meters max depth
43	PL	151	9.3	9.3	0	BW; 1204 isl	59	LB island complex submerged
44	GLD	348	7-Jun	7	0		60	LB island complex submerged (cont'd)
45	GLD	191	9-Aug	9	0		61	downstream of island complex
46	PL	274	9.1	9.1	0		62	transect profile 9.1 meters max depth
47	GLD	244	8-Jul	8	0	1217 u/d	63	beaver dam RB at bottom
48	PL	246	10.5	10.5	0		64	
49	GLD	293	9-Aug	9	0		65	
50	PL	415	11.6	11.6	0		67	submerged veg LB; aq veg in shallows; LB BW@ wypt 66; transect profile 9.1m max depth
51	PL	51	9.8	9.8	0	1236 u/d	68	narrow area of PL
52	GLD	469	7-Jun	7	0		69	wide GLD; several RB BW's; 7-8m deep at bottom
53	GLD	398	5-Apr	5	0	1255 u/d	70	deeper 5-6m at top, shallower 4-5 m depths at middle & bottom; just u/s "Big Bend"; RB beaver dam
54	GLD	274	7-Jun	7	0		71	deeper 6-7m at top
55	GLD	285	7-Jun	7	0		72	submerged MC island @ "Big Bend"; RB shallow
56	GLD	812	7-Jun	7	0	1308 u/d	73	downstream of MC island, RB shallow; PL-like surface vels
57	PL	258	9.5	9.5	0		74	
58	GLD	435	8-Jul	8	0		75	
59	PL	475	11.7	11.7	0		76	"Tarzan" PL
60	GLD	342	8-Jul	8	0	1356 u/d	78	
61	PL	245	9	9	0		79	
62	GLD	1,203	8-Jul	8	0		80	transect profile across top control 5.3m max depth
63	PL	689	11.3	11.3	0	1419 u/d	81	
64	GLD	552	8-Jul	8	0		82	2 boat docks at bottom RB
65	PL	554	10.9	10.9	0	1431 u/d	83	RB BW d/s house
66	GLD	190	9-Aug	9	0		84	short control
67	PL	1,540	11.7	11.7	0		85	RB dirt boat ramp road leading uphill
68	GLD	684	6-7.5	7.5	0	1452 u/d	86	transect profile 6.3m max depth
69	PL	447	9	9	0		87	LB most upstream occurrence of Miles Cyn basalt
70	GLD	188	8-Jul	8	0		88	
71	PL	804	9.6	9.6	0	; 1518 d @ c	90	LB aq veg at top; transect profile 9.5m max depth; faster vels at bottom as enter CYN
72	RUN	389	13.3	13.3	0	1528 u	92	Miles Canyon
73	PL	122	13.4	13.4	0		93	Miles Canyon (wide area in upper cyn); RB tribs at top & bottom (<<<1 cms)
75	RUN	263	13.8	13.8	0		94	Miles Canyon
76	PL	25	13.8	13.8	0		95	Miles Canyon (wide area in lower cyn)
77	RUN	296	12.9	12.9	0	1546 u/d	96	Miles Canyon; end survey at Schwatka Lake at 1550hrs

**PL - pool, GLD - glide*

**Dashes indicate no data*

Appendix A - Habitat Mapping PHABSIM Study for Marsh Lake Fall-Winter Storage Concept
Reach 2 Whitehorse Rapids Dam downstream to Takhini River confluence

Date: August 17, 2009
Weather: Cloudy with Showers

Unit	Habitat	Length (m)	Max D (m)	Max D Sort	Width (m)	Photo	Wypt@bottom	Notes
1	LGR	187	1.5	1.5	0	1108 u/d	101	Start at 1108hr at LB rip/rap/BO rapids across river from water intake(?) = waypt 100; in LC of **island complex**; widths for LC only; **engineered area**
2	GLD	335	3.2	3.2	0	1115 u LCH; 1118 u RCH	102	LC of **island complex**; widths for LC only; **engineered area**
3	GLD	194	4.1	4.1	0	-	103	below island complex; **engineered area**
4	LGR	187	3	3	0	-	106	riffle/cas along LB and middle; PL-like area along RB rip rap (4-6m); RB PL between Wypt 104 and 105; RCH 354 m wide; **engineered area;**
5	PL	147	7.2	7.2	---	1133 u/d	107	riffle-like on LB; **engineered area**
6	RUN	656	5-Apr	5.2	0	1138 u/d	109	wypt 108 = Riverdale Bridge; **engineered area**
7	RUN	141	4-Mar	4	0	-	111	narrow area in town,rip-rap LB; Whitehorse Visitor Center boat ramp RB=wypt 110; **engineered area**
8	RUN	133	6-May	6	0	-	112	deepest along LB rip-rap,only 1-2 m on RB; **engineered area**
9	RUN	583	5-Apr	5	0	1156 RB water discharge	114	shallow areas 2-3m; transect profile 4.6 m max depth; RB water discharge (sewage?) at bottom; **engineered area**
10	RUN	525	5-Apr	5	0	1202 u; 1204 RB discharge gate	116	begin natural channel; wpt 115= RB discharge gate
11	RUN	150	4-Mar	4	0	1210 d Rt SC	117	transect profile above Island 3.7 m max depth;
12	RUN	640	4-Mar	4	0	1212 u lft SC	118	**Island** (w/abandoned bridge); widths for LCH only
13	RUN	310	4-Mar	4	0	1217	119	d/s of big isl;and still in Island complex; transect profile at bottom of island complex 2.4 m max depth;
14	GLD	360	3-Feb	3	0	1231 u/d	120	shallowest area to date
15	GLD	250	4-Mar	4	0	-	122	-
16	GLD	582	3-Feb	3	0	1240 up	123	wypt 121 = top of **island complex;** wypt 123 bottom of island complex
17	GLD	299	4-Mar	4	0	1256 u LC of isl	124	transect profile at bottom of island complex MC grvl bar, 4.0 RCH max, 1.8 LCH max depth;
18	GLD	1,043	3-Feb	3	0	1345 u/d	125	short area of deep water at top (5m deep); submerged MC grvl bar; OVH powerlines nr bottom of gld
19	GLD	158	4-Mar	4	0	-	126	-
20	PL	303	4.5	4.5	0	-	127	narrow; cliff swallow dens LB
21	PL	123	7.9	7.9	0	-	128	wide; u/s MC Island
22	PL	539	7.9	7.9	0	1413 u/d	129	wide; island complex; width is LC only
23	PL	929	7.9	7.9	0	1423 up rt CH of lower island	130	wide; d/s MC Island; patch of thick aq veg nr RB ~100 m d/s lower island; Mtn View Golf Course overlook (and cars) RB at Bottom
24	PL	1,997	10.3	10.3	0	1431 u/d; 1449 u/d	133	narrow PL area; Croucher Crk LB at wypt 131; aq veg at mouth of crk; transect profile nr bottom 8.1 m max depth;
25	RUN	599	6-May	6	0	1504 u/d	134	-
26	PL	568	9.6	9.6	0	1515 u/d	135	short mid-PL control at wypt 135; transect profile at wypt 135 6.4 m max depth;
27	PL	1,338	11.2	11.2	0	1528 u/d	137	Porter Creek pipeline crossing at wypt 136; transect profile at bottom 6.4m max depth;
28	RUN	1,104	5-6.5	6.5	0	1537 u/d	140	small submerged MC bar nr bottom
29	GLD	1,523	4-5.5	5.5	0	1554 u/d	142	wide & PL-like little surface vels; transect profile 5.5m max depth
30	PL	2,790	10.5	10.5	0	1609 u/d	143	
31	GLD	726	6-May	6	0	1624 u/d	145	more shallow PL-like, little surface vel; unnamed RB trib at wypt 144; transect profile u/s RB trib 5.9m max depth
32	PL	1,258	9.4	9.4	0	1641 u/d; 1646 u Takhini	146	transect profile 9.1m max depth; end survey in mid-PL at confluence with Takhini River @1645hr

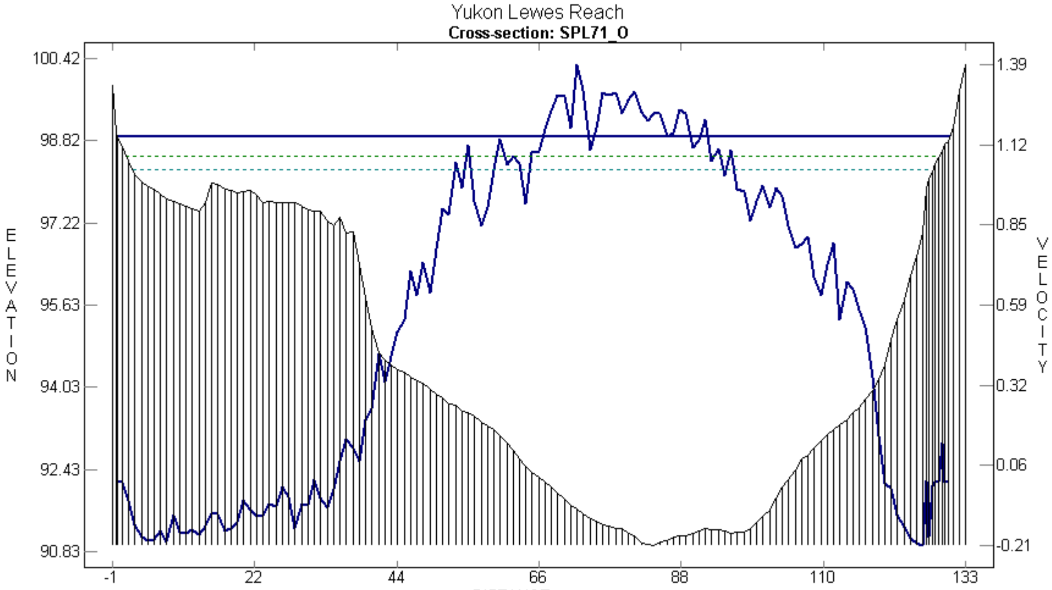
**LGR - low gradient riffle, PL - pool, GLD - glide*

**Dashes indicate no data*

APPENDIX B

Transect Profiles, and Calibration Flow Velocities and Water Surface Elevations

Lewes Reach



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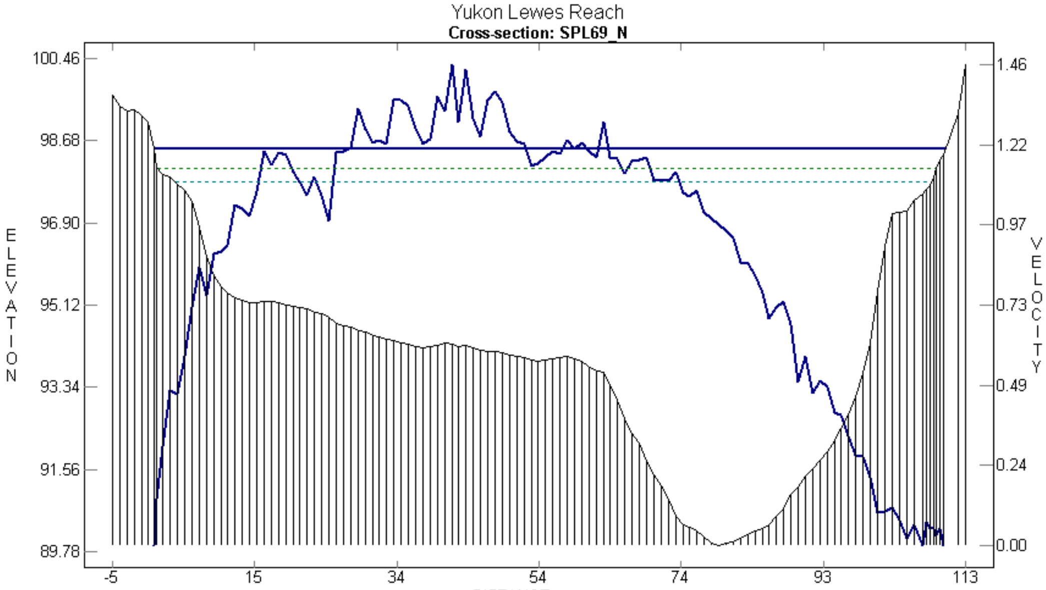

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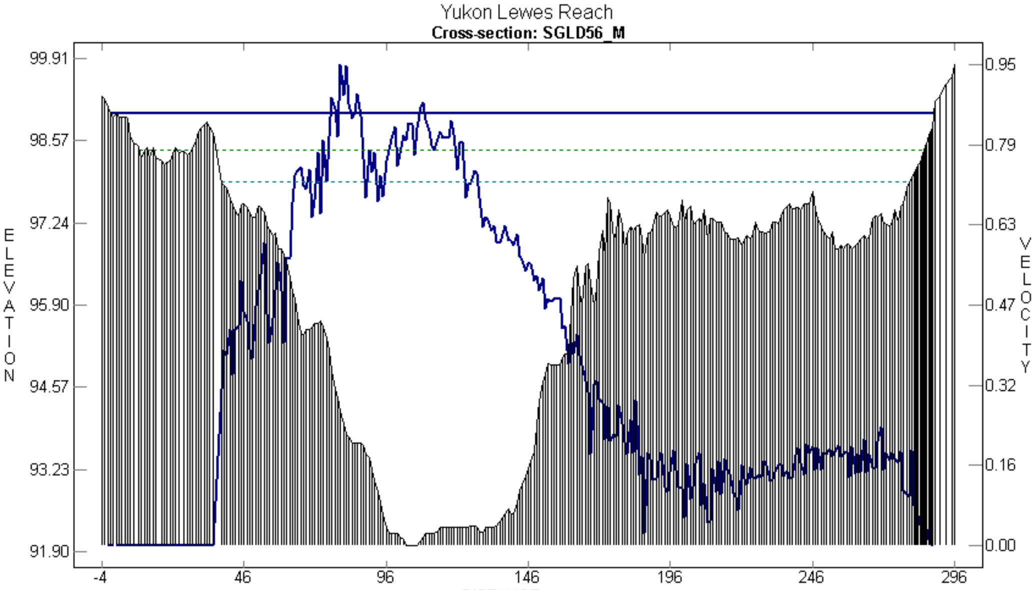

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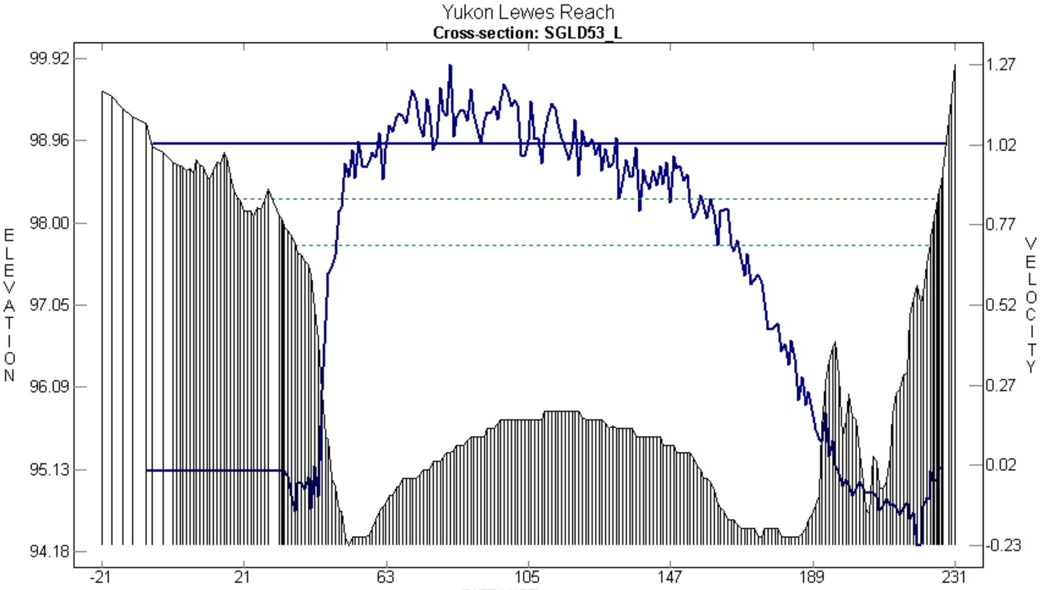

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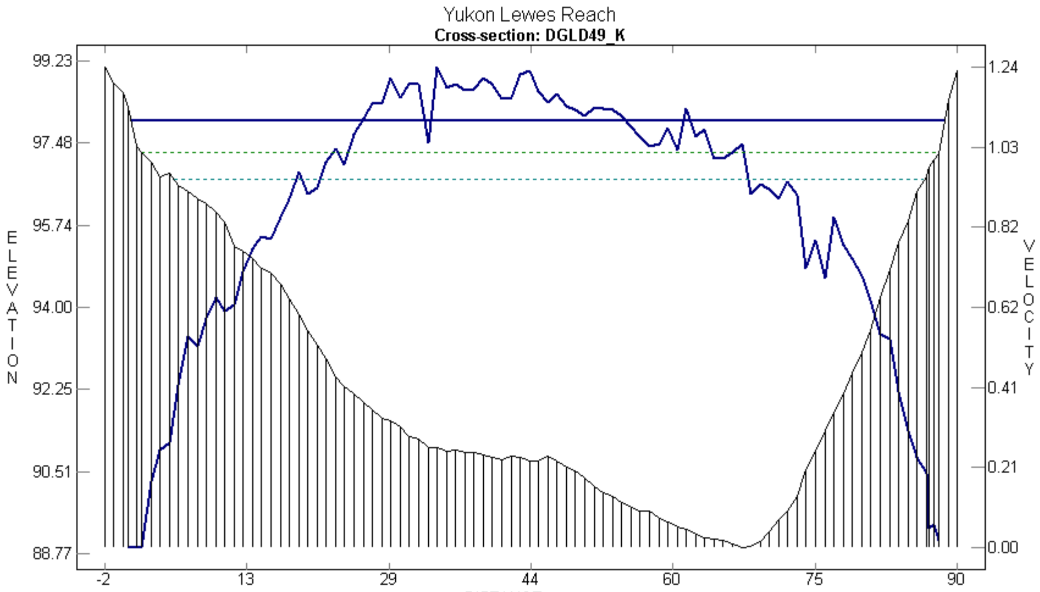

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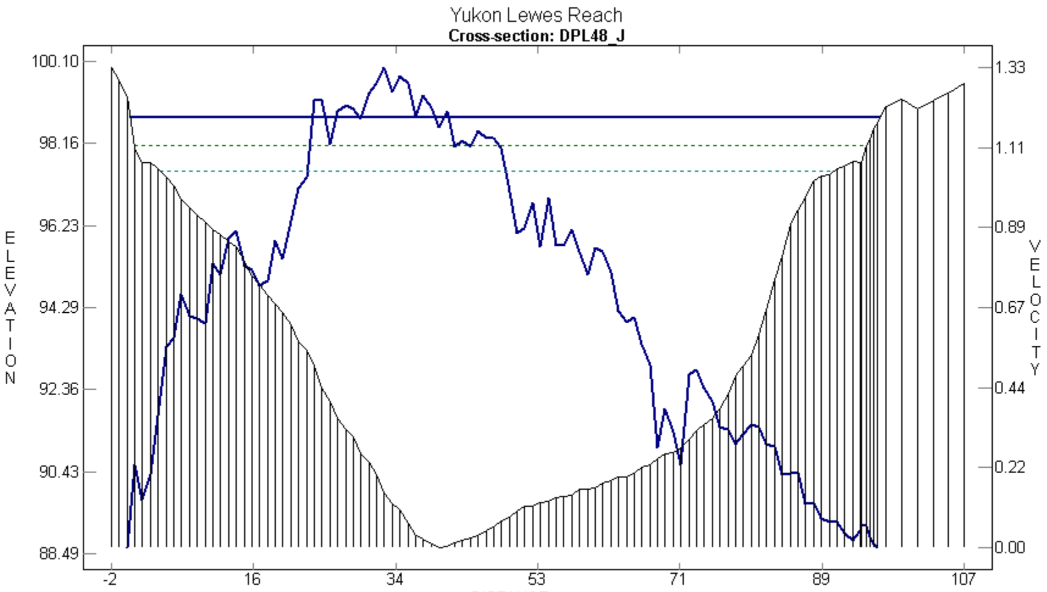

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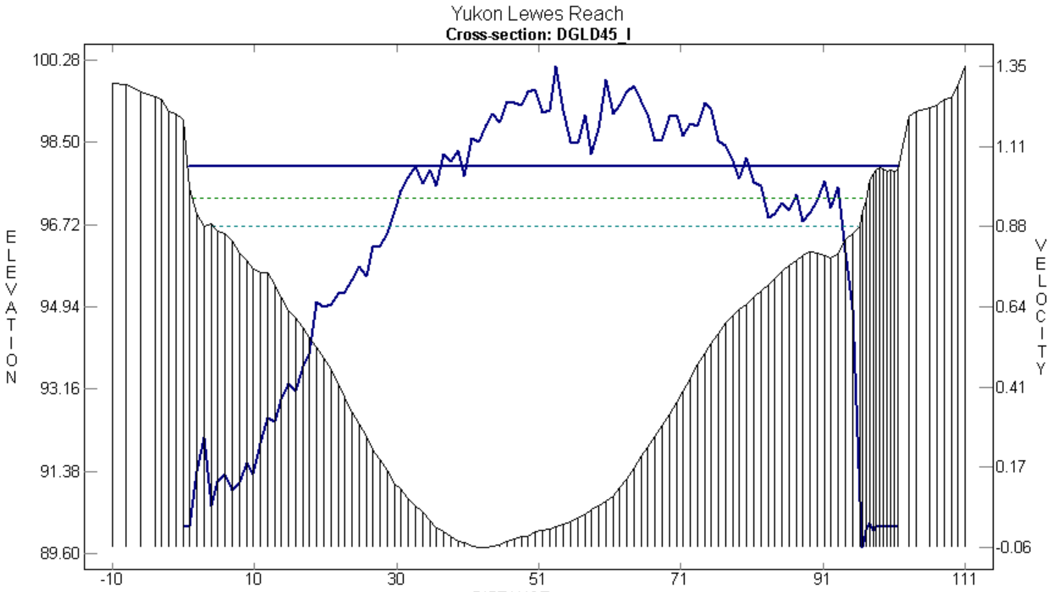

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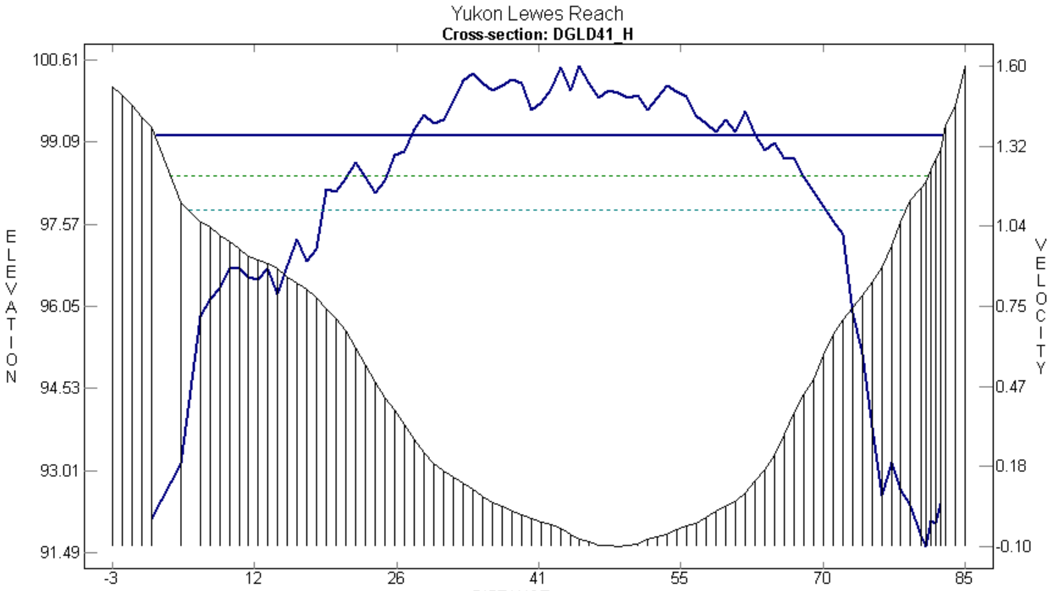

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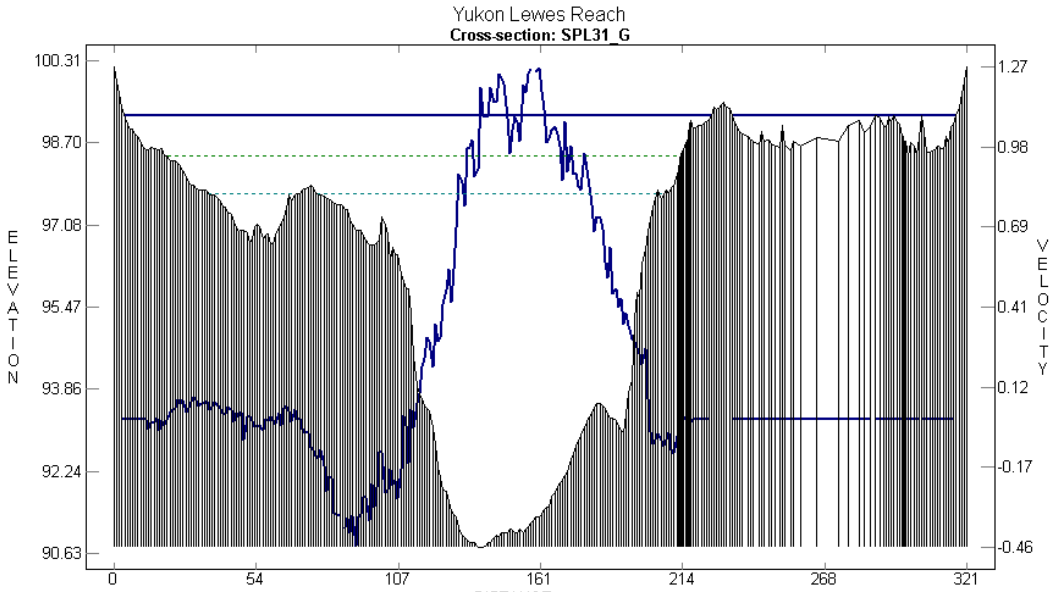

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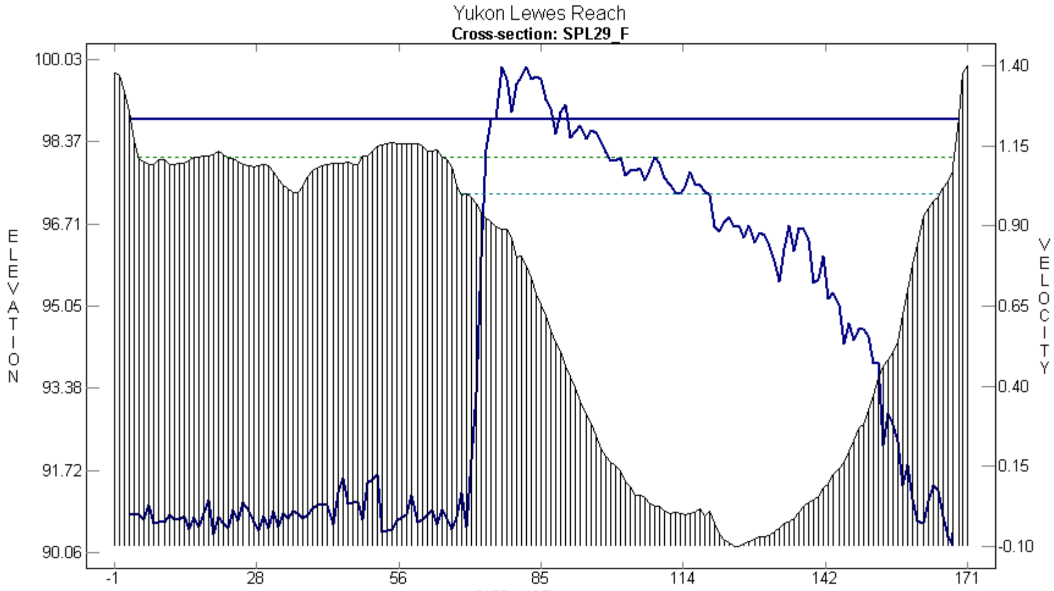

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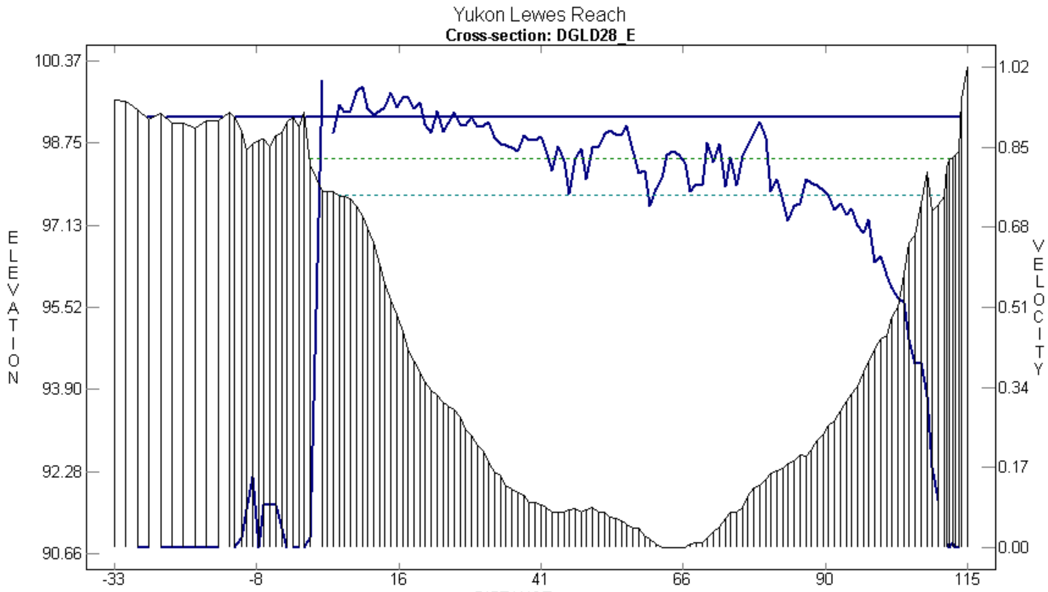

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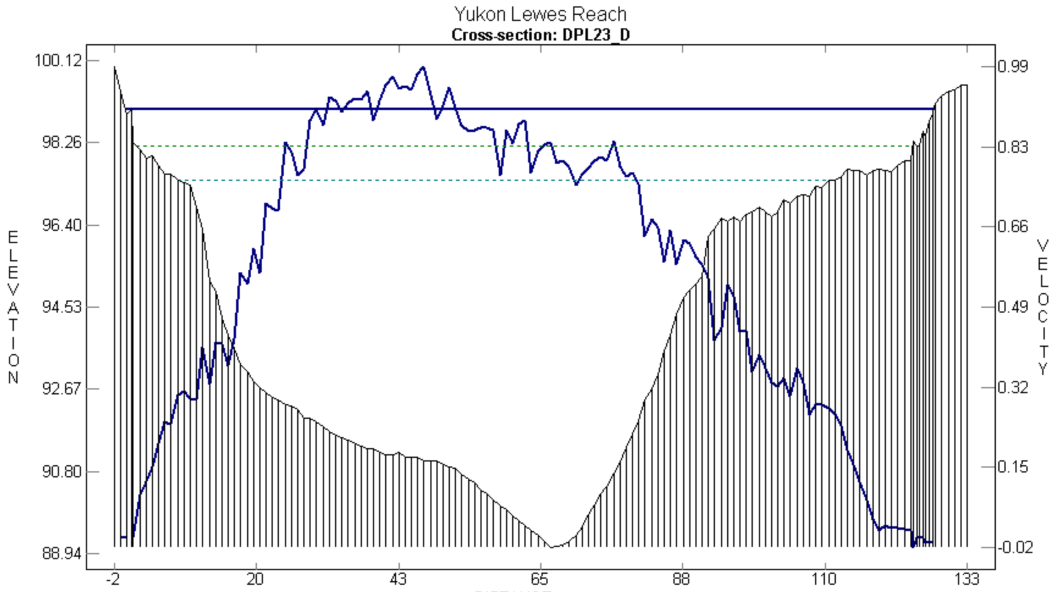

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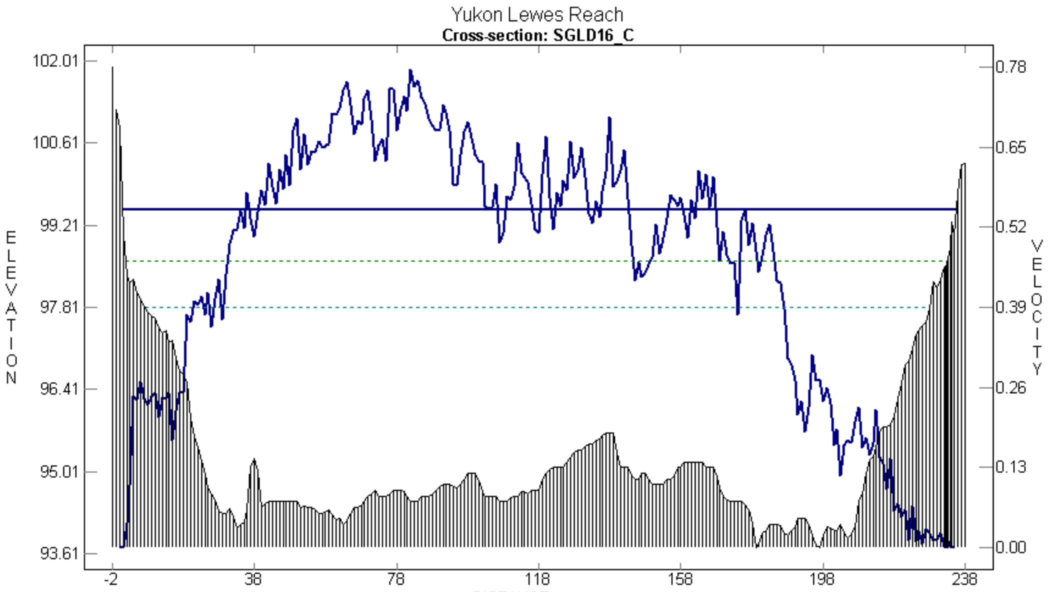

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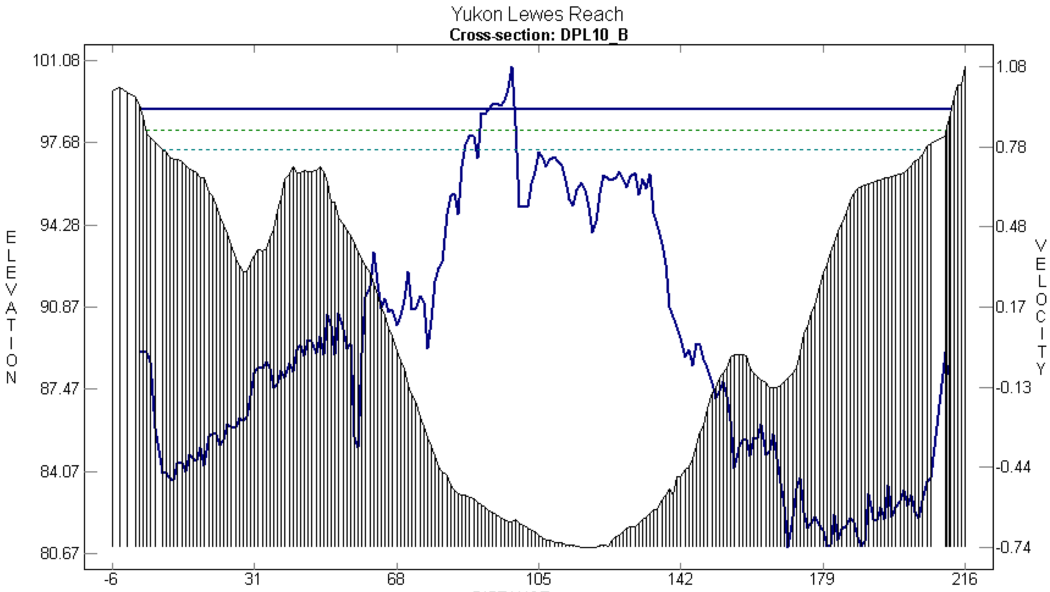

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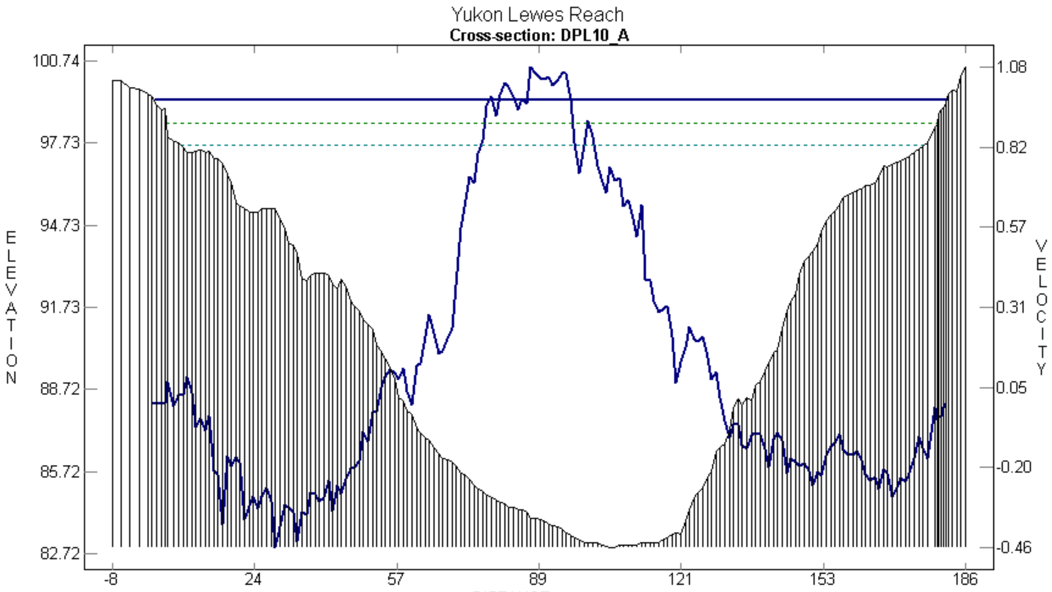

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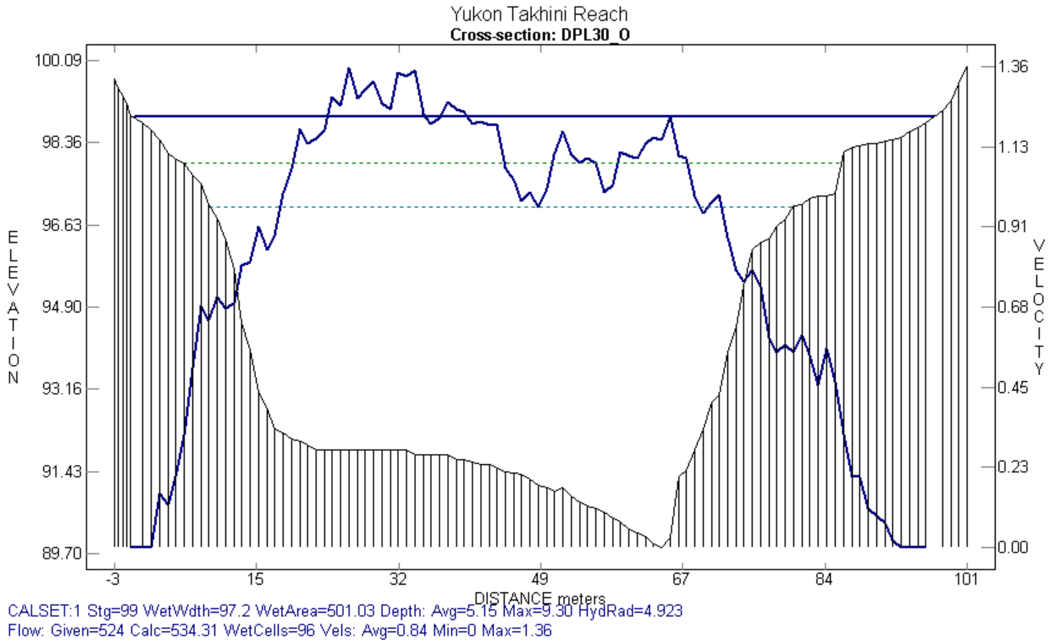
Takhini Reach



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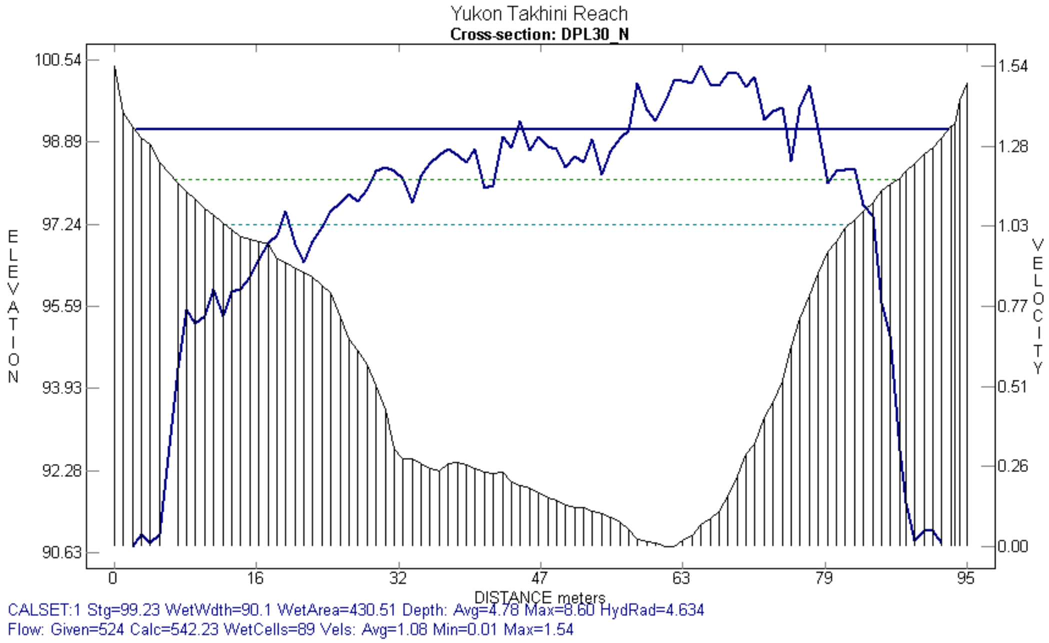

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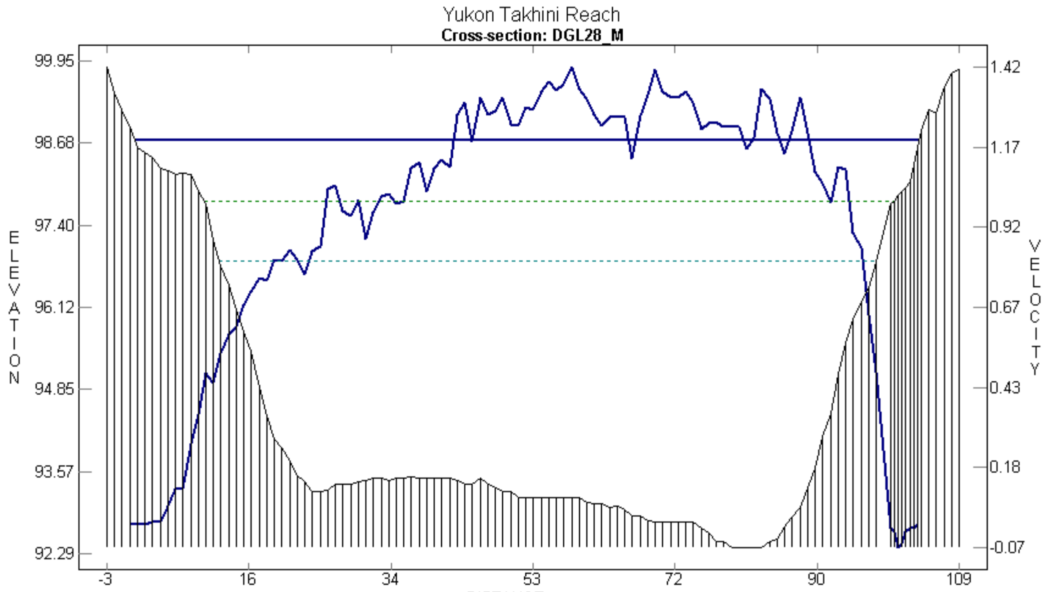

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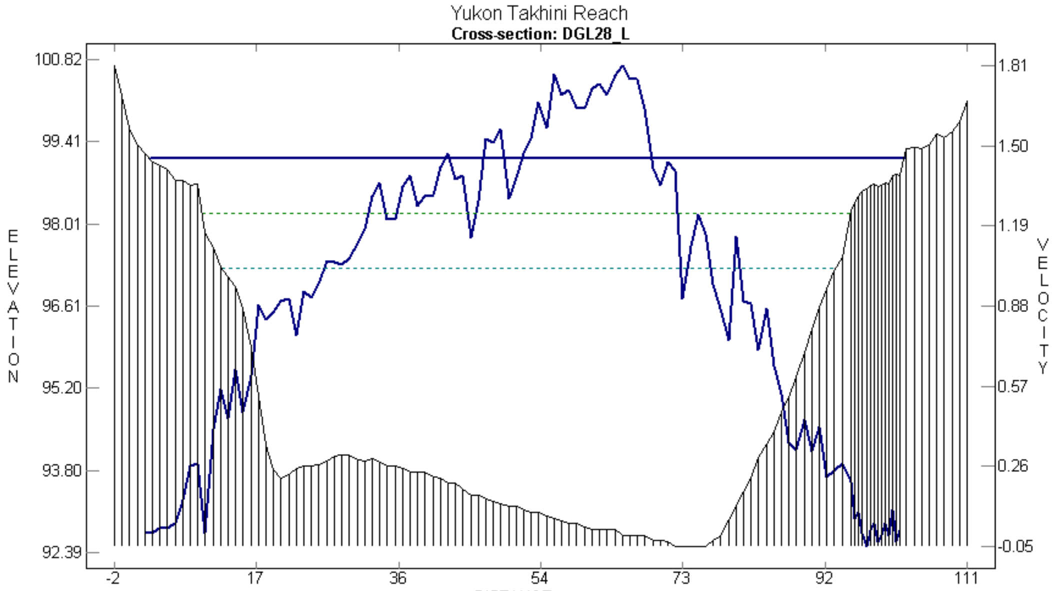

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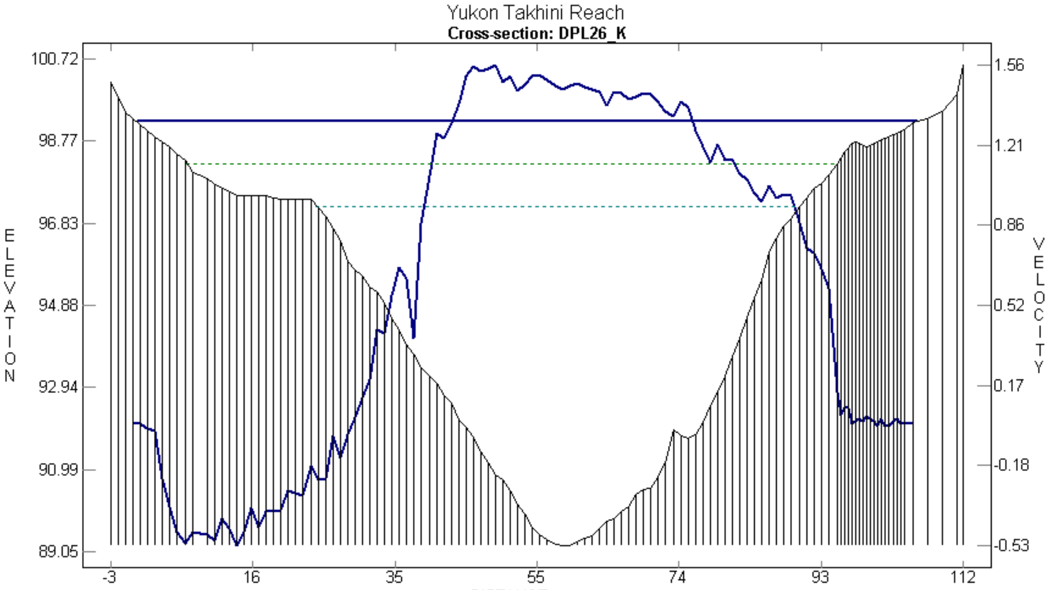

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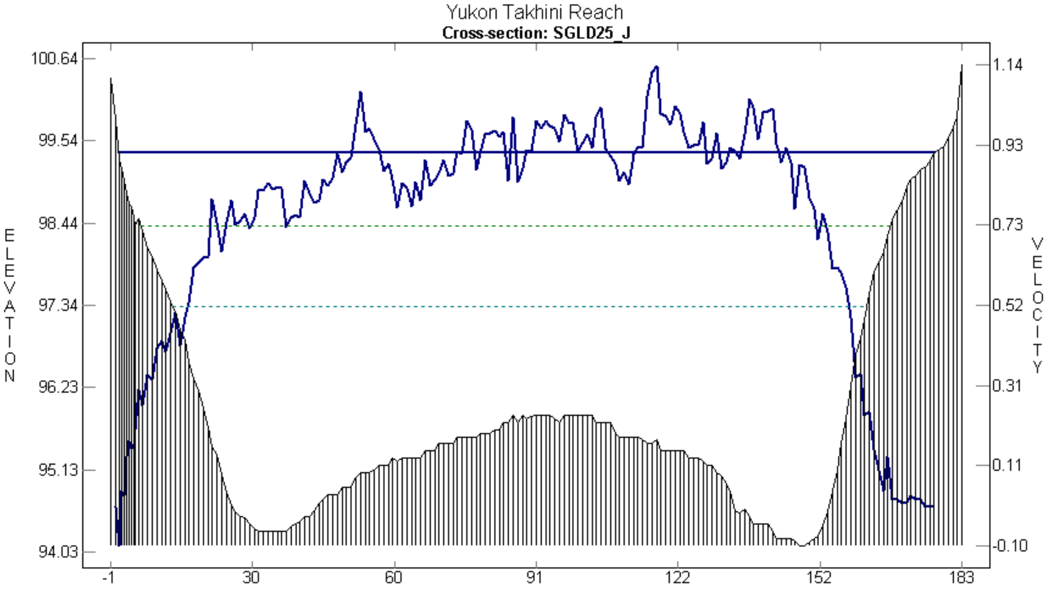

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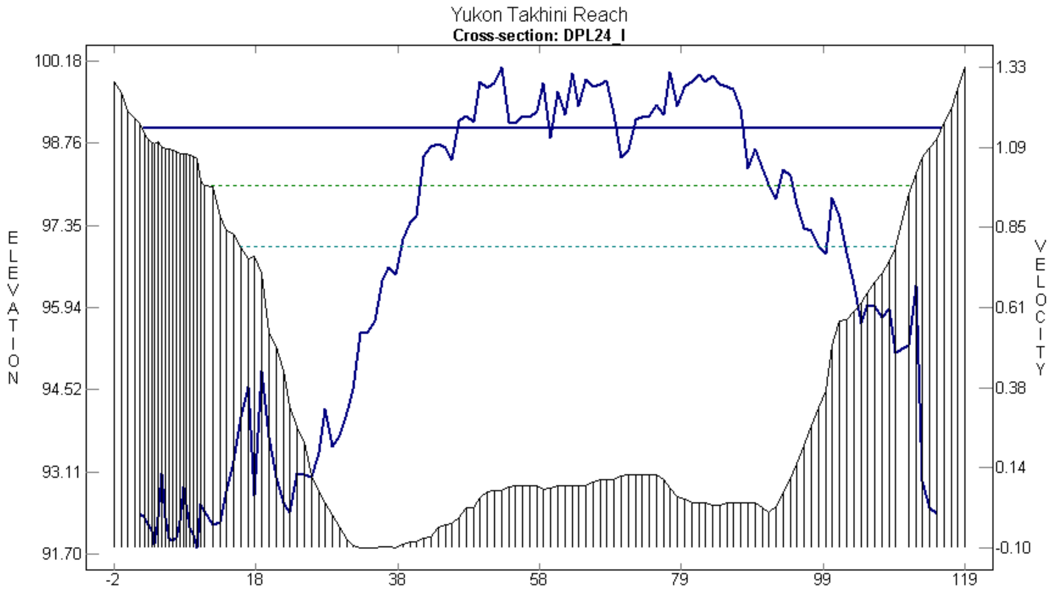

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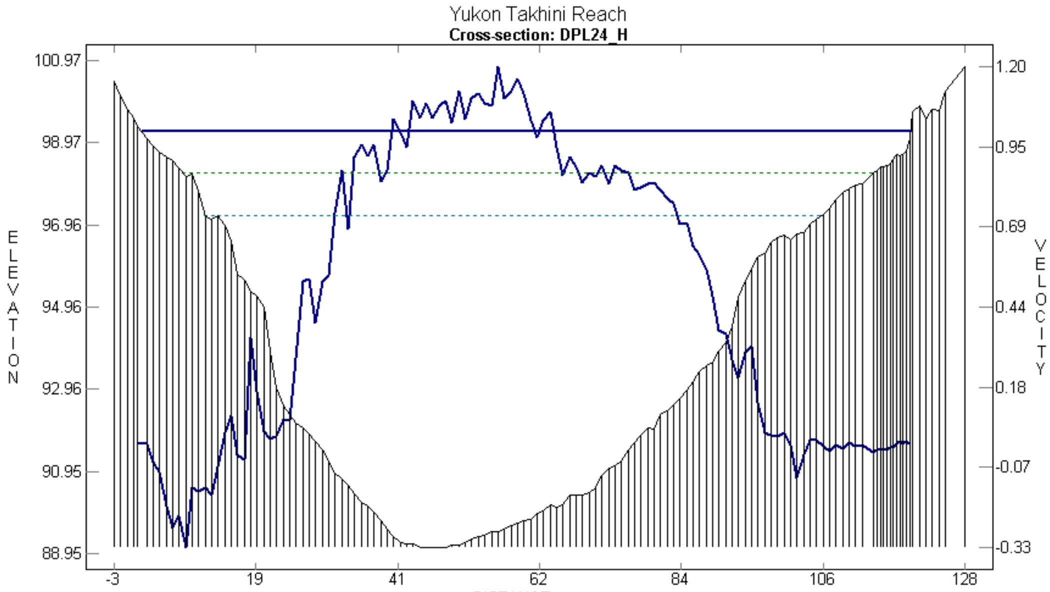

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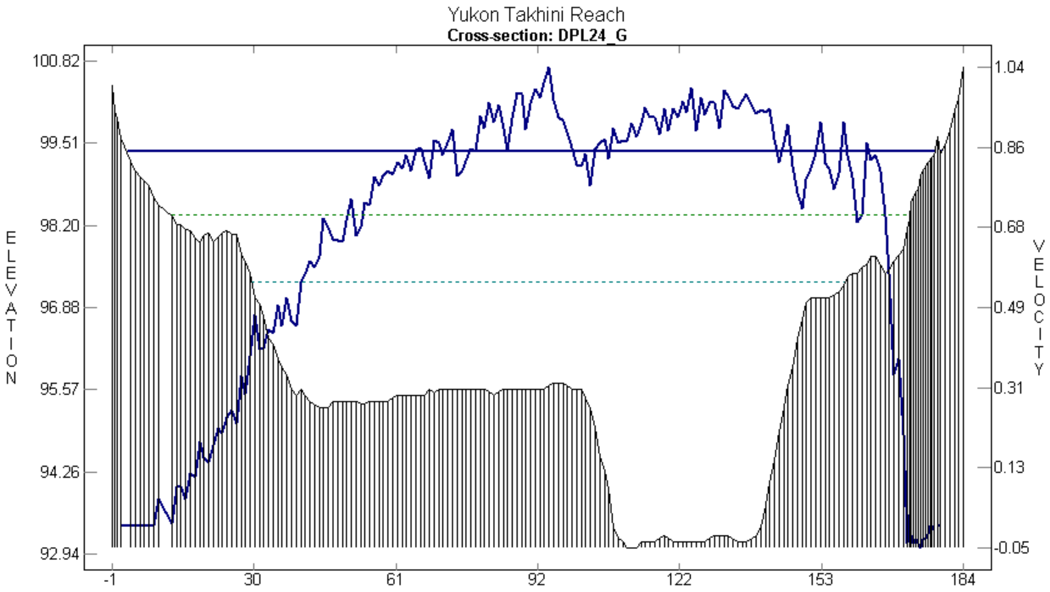
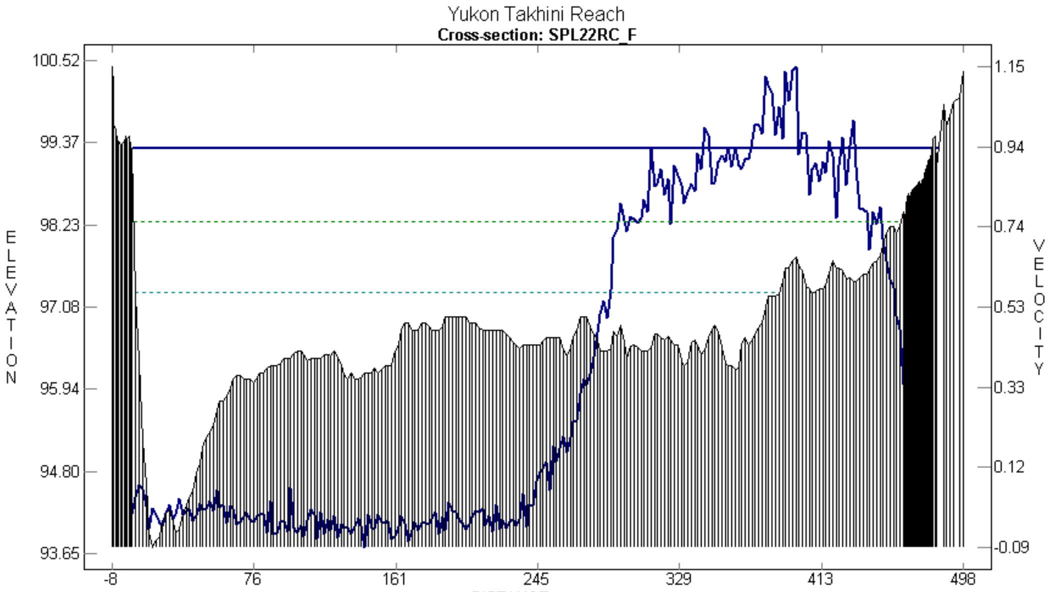
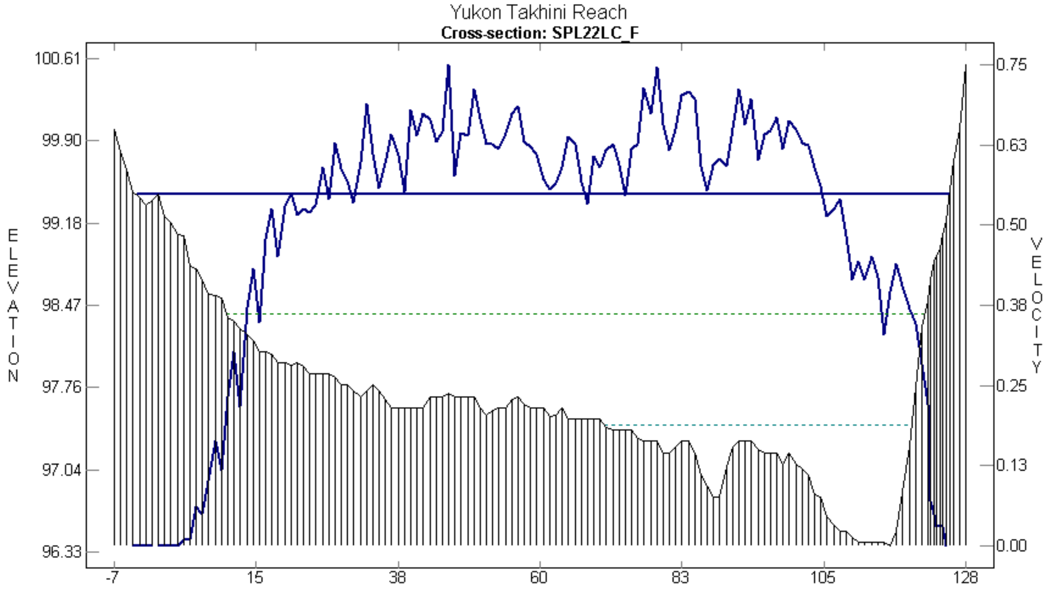
CALSET:1 Stg=99.35 WetWdth=118.3 WetArea=708.65 Depth: Avg=5.99 Max=10.4 HydRad=5.816
Flow: Given=524 Calc=528.81 WetCells=123 Vels: Avg=0.47 Min=-0.33 Max=1.20
```



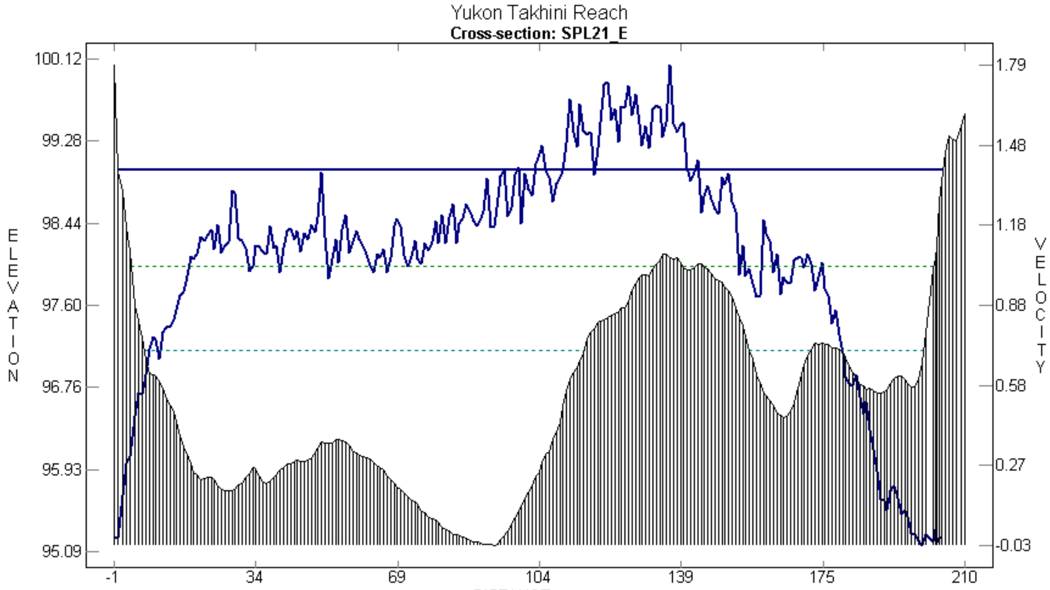
CALSET:1 Stg=99.44 WetWdth=176.1 WetArea=635.76 Depth: Avg=3.61 Max=6.5 HydRad=3.571
Flow: Given=524 Calc=508.44 WetCells=181 Vels: Avg=0.65 Min=-0.05 Max=1.04



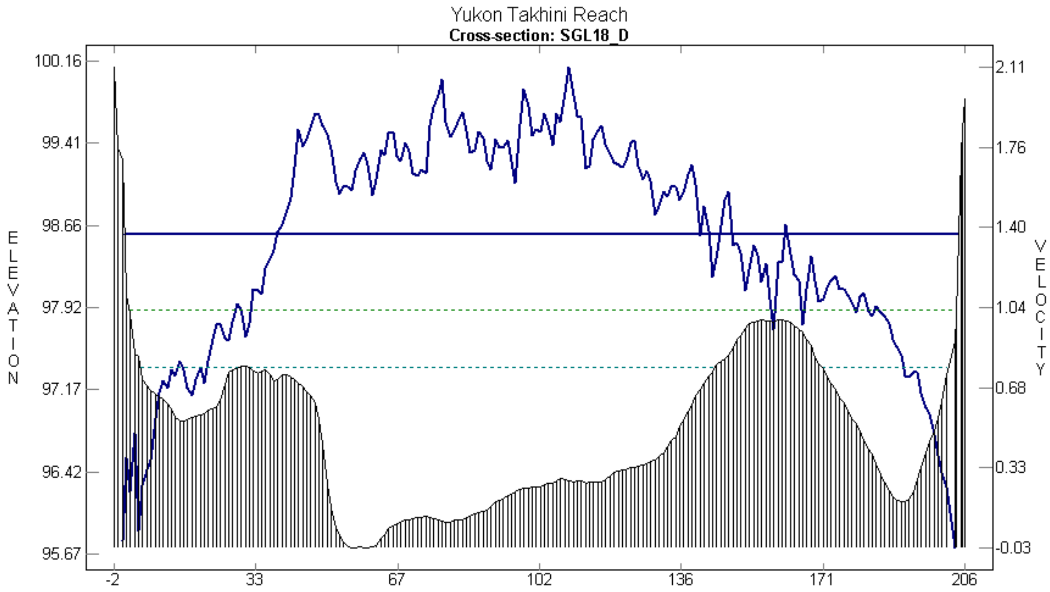
CALSET:1 Stg=99.35 WetWdth=476.8 WetArea=1309.86 Depth: Avg=2.75 Max=5.70 HydRad=2.734
Flow: Given=388.5 Calc=373.43 WetCells=263 Vels: Avg=0.32 Min=-0.09 Max=1.15



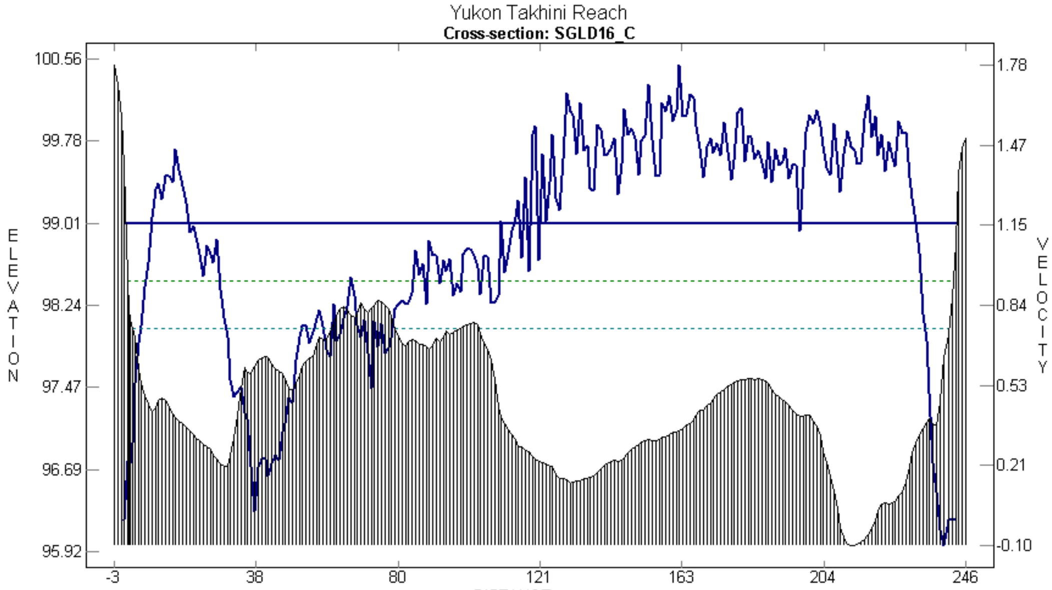
CALSET:1 Stg=99.46 WetWdth=128.9 WetArea=237.62 Depth: Avg=1.84 Max=3.13 HydRad=1.831
Flow: Given=135.7 Calc=132.10 WetCells=131 Vels: Avg=0.49 Min=0 Max=0.75



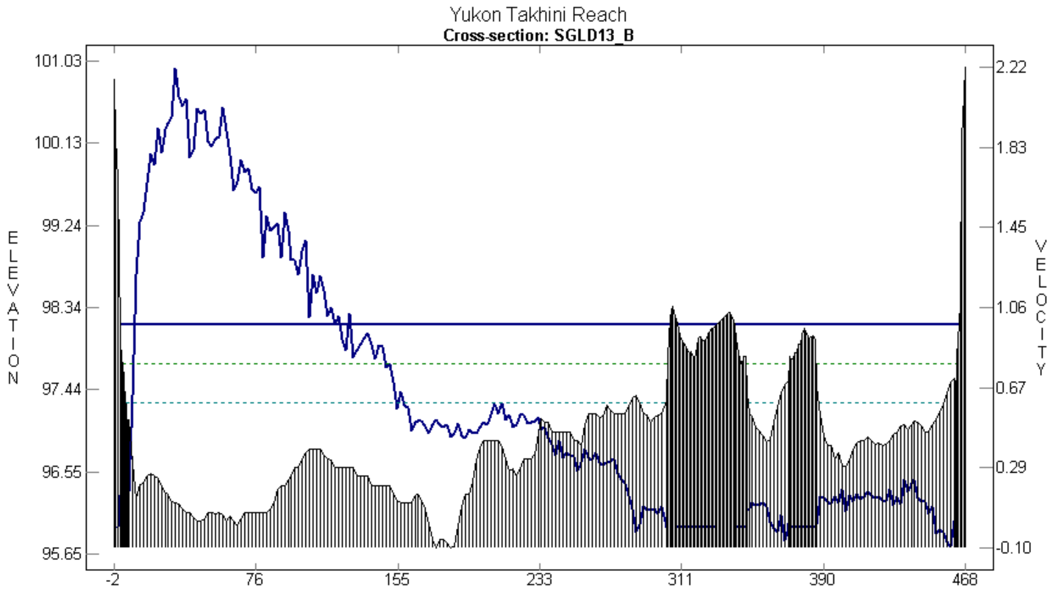
CALSET:1 Stg=99.02 WetWdth=204.2 WetArea=501.88 Depth: Avg=2.46 Max=3.94 HydRad=2.443
Flow: Given=524 Calc=538.02 WetCells=239 Vels: Avg=1.05 Min=-0.03 Max=1.79



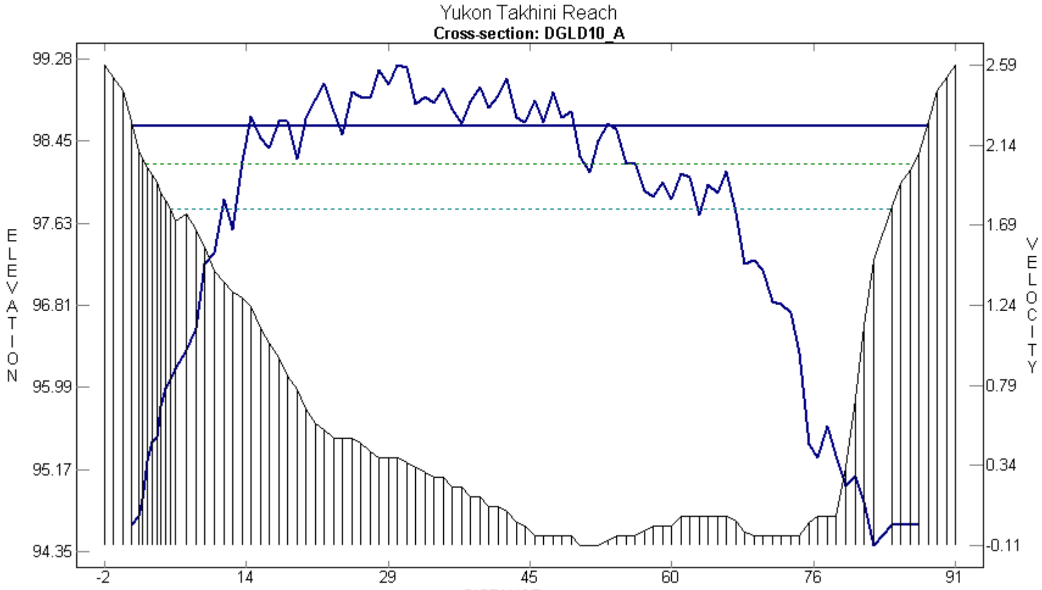
CALSET:1 Stg=98.6 WetWdth=203.6 WetArea=383.92 Depth: Avg=1.89 Max=2.93 HydRad=1.874
Flow: Given=509 Calc=548.11 WetCells=203 Vels: Avg=1.34 Min=-0.03 Max=2.11



CALSET:1 Stg=99.02 WetWdth=242.4 WetArea=428.79 Depth: Avg=1.77 Max=3.1 HydRad=1.760
Flow: Given=509 Calc=508.82 WetCells=244 Vels: Avg=1.09 Min=-0.10 Max=1.78



CALSET:1 Stg=98.15 WetWdth=448.8 WetArea=620.65 Depth: Avg=1.38 Max=2.5 HydRad=1.379
Flow: Given=509 Calc=504.23 WetCells=259 Vels: Avg=0.54 Min=-0.10 Max=2.22



CALSET:1 Stg=98.65 WetWdth=86.7 WetArea=268.57 Depth: Avg=3.10 Max=4.30 HydRad=3.049
Flow: Given=509 Calc=502.19 WetCells=89 Vels: Avg=1.65 Min=-0.11 Max=2.59

APPENDIX C

Calibration Summary for the Yukon River Marsh Lake PHABSIM Study

Lewes Reach

```
-----------------------------------------------------------------------------

Units: Metric


Number of Calibration Flows: 21

-----------------------------------------------------------------------------

CROSS-SECTION #   1  SPL71_O

Points = 140

 Slope = .0025

   SZF = 98.11


Weighting Factor = 1

Cross-section represents 7.34% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  6.867047E-05

Log/Log Regression B =  1.526829

WSL = 0 * Flow ^ 1.5268 + 98.11


   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1
```

```
--------------------------------------------------------------------------------
CROSS-SECTION #   2  SPL69_N
Points = 122
 Slope = .0025
   SZF = 97.63

Weighting Factor = 1
Cross-section represents 7.34% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  4.673616E-05
Log/Log Regression B =  1.600717
WSL = 0 * Flow ^ 1.6007 + 97.63

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

--------------------------------------------------------------------------------
CROSS-SECTION #   3  SGLD56_M
Points = 300
 Slope = .0025
   SZF = 97.36

Weighting Factor = 1
```

```
Cross-section represents 6.16% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  1.260113E-03

Log/Log Regression B =  1.166356

WSL = 0.0013 * Flow ^ 1.1664 + 97.36


   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


-------------------------------------------------------------------------------

CROSS-SECTION #   4  SGLD53_L

Points = 242

 Slope = .0025

   SZF = 97.12


Weighting Factor = 1

Cross-section represents 6.16% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  1.440387E-03

Log/Log Regression B =  1.155996

WSL = 0.0014 * Flow ^ 1.156 + 97.12
```

```
   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

-------------------------------------------------------------------------------
CROSS-SECTION #   5  DGLD49_K
Points = 96
 Slope = .0025
   SZF = 96.02

Weighting Factor = 1
Cross-section represents 7.24% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  2.75849E-03
Log/Log Regression B =  1.065667
WSL = 0.0028 * Flow ^ 1.0657 + 96.02

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1
```

```
------------------------------------------------------------------------------
CROSS-SECTION #   6  DPL48_J
Points = 108
 Slope = .0025
   SZF = 96.79

Weighting Factor = 1
Cross-section represents 5.81% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  3.442199E-03
Log/Log Regression B =  1.03476
WSL = 0.0034 * Flow ^ 1.0348 + 96.79

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

------------------------------------------------------------------------------
CROSS-SECTION #   7  DGLD45_I
Points = 123
 Slope = .0025
   SZF = 95.90

Weighting Factor = 1
```

```
Cross-section represents 7.24% of Total Reach.


   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  3.692506E-03
Log/Log Regression B =  1.027551
WSL = 0.0037 * Flow ^ 1.0276 + 95.90


   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1


------------------------------------------------------------------------------
CROSS-SECTION #   8  DGLD41_H
Points = 88
 Slope = .0025
   SZF = 96.72


Weighting Factor = 1
Cross-section represents 7.24% of Total Reach.


   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  1.437978E-02
Log/Log Regression B =  .83127
WSL = 0.0144 * Flow ^ 0.8313 + 96.72
```

```
   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

-----------------------------------------------------------------------------
CROSS-SECTION #   9  SPL31_G
Points = 300
 Slope = .0025
   SZF = 96.24

Weighting Factor = 1
Cross-section represents 7.34% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  3.238888E-02
Log/Log Regression B =  .7306076
WSL = 0.0324 * Flow ^ 0.7306 + 96.24

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1
```

```
-------------------------------------------------------------------------------
CROSS-SECTION #  10  SPL29_F
Points = 174
 Slope = .0025
   SZF = 95.93

Weighting Factor = 1
Cross-section represents 7.34% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  2.846891E-02
Log/Log Regression B =  .7467985
WSL = 0.0285 * Flow ^ 0.7468 + 95.93

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

-------------------------------------------------------------------------------
CROSS-SECTION #  11  DGLD28_E
Points = 141
 Slope = .0025
   SZF = 96.33

Weighting Factor = 1
```

```
Cross-section represents 7.24% of Total Reach.


   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  2.556994E-02
Log/Log Regression B =  .7653409
WSL = 0.0256 * Flow ^ 0.7653 + 96.33


   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1


------------------------------------------------------------------------------
CROSS-SECTION #  12  DPL23_D
Points = 141
 Slope = .0025
   SZF = 95.94


Weighting Factor = 1
Cross-section represents 5.81% of Total Reach.


   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  2.994298E-02
Log/Log Regression B =  .7487816
WSL = 0.03 * Flow ^ 0.7488 + 95.94
```

```
   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

-----------------------------------------------------------------------------
CROSS-SECTION #  13  SGLD16_C
Points = 244
 Slope = .0025
   SZF = 96.26

Weighting Factor = 1
Cross-section represents 6.16% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  2.655821E-02
Log/Log Regression B =  .7705483
WSL = 0.0266 * Flow ^ 0.7705 + 96.26

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1
```

```
----------------------------------------------------------------------------

CROSS-SECTION #  14  DPL10_B

Points = 218

 Slope = .0025

   SZF = 95.88


Weighting Factor = .4999998

Cross-section represents 5.81% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  3.349796E-02

Log/Log Regression B =  .7400622

WSL = 0.0335 * Flow ^ 0.74 + 95.88


   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


----------------------------------------------------------------------------

CROSS-SECTION #  15  DPL10_A

Points = 193

 Slope = .0025

   SZF = 96.18


Weighting Factor = 0
```

```
Cross-section represents 5.81% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  3.066352E-02

Log/Log Regression B =  .7517787

WSL = 0.0307 * Flow ^ 0.7518 + 96.18


   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


-----------------------------------------------------------------------------
```

Takhini Reach

```
----------------------------------------------------------------------------
Units: Metric


Number of Calibration Flows: 27
----------------------------------------------------------------------------
CROSS-SECTION #   1  DPL30_O
Points = 105
 Slope = .0025
   SZF = 95.46


Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.


   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  2.365966E-02
Log/Log Regression B =  .799733
WSL = 0.0237 * Flow ^ 0.7997 + 95.46


   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1


----------------------------------------------------------------------------
```

```
CROSS-SECTION #   2  DPL30_N
Points = 96
 Slope = .0025
   SZF = 95.72

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  2.026932E-02
Log/Log Regression B =  .8230764
WSL = 0.0203 * Flow ^ 0.823 + 95.72

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

---------------------------------------------------------------------------
CROSS-SECTION #   3  DGL28_M
Points = 116
 Slope = .0025
   SZF = 94.86

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.
```

```
   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  5.423819E-02

Log/Log Regression B =  .6840053

WSL = 0.0542 * Flow ^ 0.684 + 94.86


   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


----------------------------------------------------------------------------

CROSS-SECTION #   4  DGL28_L

Points = 120

 Slope = .0025

   SZF = 95.10


Weighting Factor = 1

Cross-section represents 5.88% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  7.224325E-02

Log/Log Regression B =  .6445933

WSL = 0.0722 * Flow ^ 0.6446 + 95.10
```

```
   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


-----------------------------------------------------------------------------

CROSS-SECTION #   5  DPL26_K

Points = 121

 Slope = .0025

   SZF = 94.72


Weighting Factor = 1

Cross-section represents 5.88% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  .1113075

Log/Log Regression B =  .595275

WSL = 0.1113 * Flow ^ 0.5953 + 94.72


   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


-----------------------------------------------------------------------------
```

```
CROSS-SECTION #   6  SGLD25_J
Points = 189
 Slope = .0025
   SZF = 94.03

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  .228886
Log/Log Regression B =  .504997
WSL = 0.2289 * Flow ^ 0.505 + 94.03

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

----------------------------------------------------------------------------
CROSS-SECTION #   7  DPL24_I
Points = 130
 Slope = .0025
   SZF = 94.03

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.
```

```
   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  .1809605

Log/Log Regression B =  .5322544

WSL = 0.181 * Flow ^ 0.5323 + 94.03


   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


-----------------------------------------------------------------------------

CROSS-SECTION #   8  DPL24_H

Points = 135

 Slope = .0025

   SZF = 94.31


Weighting Factor = 1

Cross-section represents 5.88% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  .1631362

Log/Log Regression B =  .5478462

WSL = 0.1631 * Flow ^ 0.5478 + 94.31
```

```
   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

-------------------------------------------------------------------------------
CROSS-SECTION #   9  DPL24_G
Points = 191
 Slope = .0025
   SZF = 94.57

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  .1268048
Log/Log Regression B =  .5826297
WSL = 0.1268 * Flow ^ 0.5826 + 94.57

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

-------------------------------------------------------------------------------
```

CROSS-SECTION # 10 SPL22_F FLOW HIGHER THAN 260 cms

Points = 274

Slope = .0025

SZF = 94.57

Weighting Factor = 1

Cross-section represents 5.88% of Total Reach.

>>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A = .1359866

Log/Log Regression B = .5677393

WSL = 0.136 * Flow ^ 0.5677 + 94.57

>>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet: 1

CROSS-SECTION # 10 SPL22_F FLOW LOWER THAN 260 cms

Points = 274

Slope = .0025

SZF = 94.57

Weighting Factor = 1

Cross-section represents 5.88% of Total Reach.

```
   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  .1359866
Log/Log Regression B =  .5677393
WSL = 0.136 * Flow ^ 0.5677 + 94.57

   >>> Velocity Calibrations <<<
Vel Calculation Method: Depth Calibration
Vel Algorithm: Manning's N
Use Given N's: Yes

-----------------------------------------------------------------------------
CROSS-SECTION #  11  SPL21_E
Points = 246
 Slope = .0025
   SZF = 95.09

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  6.105953E-02
Log/Log Regression B =  .6639603
WSL = 0.061 * Flow ^ 0.664 + 95.09

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
```

```
Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


----------------------------------------------------------------------------

CROSS-SECTION #  12  SGL18_D

Points = 209

 Slope = .0025

   SZF = 96.20


Weighting Factor = 1

Cross-section represents 5.88% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  2.098834E-02

Log/Log Regression B =  .757216

WSL = 0.021 * Flow ^ 0.7572 + 96.2


   >>> Velocity Calibrations <<<

Vel Calculation Method: 1-vel calibration

Vel Algorithm: Manning's N

Use Given N's: Yes

Vels calibrated to VelSet:  1


----------------------------------------------------------------------------

CROSS-SECTION #  13  SGLD16_C

Points = 251
```

```
 Slope = .0025
   SZF = 96.80

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  4.267329E-02
Log/Log Regression B =  .6314822
WSL = 0.0427 * Flow ^ 0.6315 + 96.8

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

----------------------------------------------------------------------------
CROSS-SECTION #  14  SGLD13_B
Points = 281
 Slope = .0025
   SZF = 96.00

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.

   >>> WSL Calibrations <<<
```

```
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  6.985125E-02
Log/Log Regression B =  .5487814
WSL = 0.0699 * Flow ^ 0.5488 + 96

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

-----------------------------------------------------------------------------
CROSS-SECTION #  15  DGLD10_A
Points = 97
 Slope = .0025
   SZF = 96.41

Weighting Factor = 1
Cross-section represents 5.88% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  .1002118
Log/Log Regression B =  .4987186
WSL = 0.1002 * Flow ^ 0.4987 + 96.41

   >>> Velocity Calibrations <<<
Vel Calculation Method: 1-vel calibration
```

```
Vel Algorithm: Manning's N
Use Given N's: Yes
Vels calibrated to VelSet:  1

---------------------------------------------------------------------------
CROSS-SECTION #  16  SPWN_2
Points = 193
 Slope = .0025
   SZF = 630.00

Weighting Factor = 1
Cross-section represents 11.8% of Total Reach.

   >>> WSL Calibrations <<<
WSL Calculation Method: Log/Log Regression
Log/Log Regression A =  3.310724E-02
Log/Log Regression B =  .6489665
WSL = 0.0331 * Flow ^ 0.649 + 630

   >>> Velocity Calibrations <<<
Vel Calculation Method: Depth Calibration
Vel Algorithm: Manning's N
Use Given N's: Yes

---------------------------------------------------------------------------
CROSS-SECTION #  17  SPWN_1
Points = 201
 Slope = .0025
```

```
   SZF = 630.00


Weighting Factor = 1

Cross-section represents 0% of Total Reach.


   >>> WSL Calibrations <<<

WSL Calculation Method: Log/Log Regression

Log/Log Regression A =  3.310724E-02

Log/Log Regression B =  .6489665

WSL = 0.0331 * Flow ^ 0.649 + 630


   >>> Velocity Calibrations <<<

Vel Calculation Method: Depth Calibration

Vel Algorithm: Manning's N

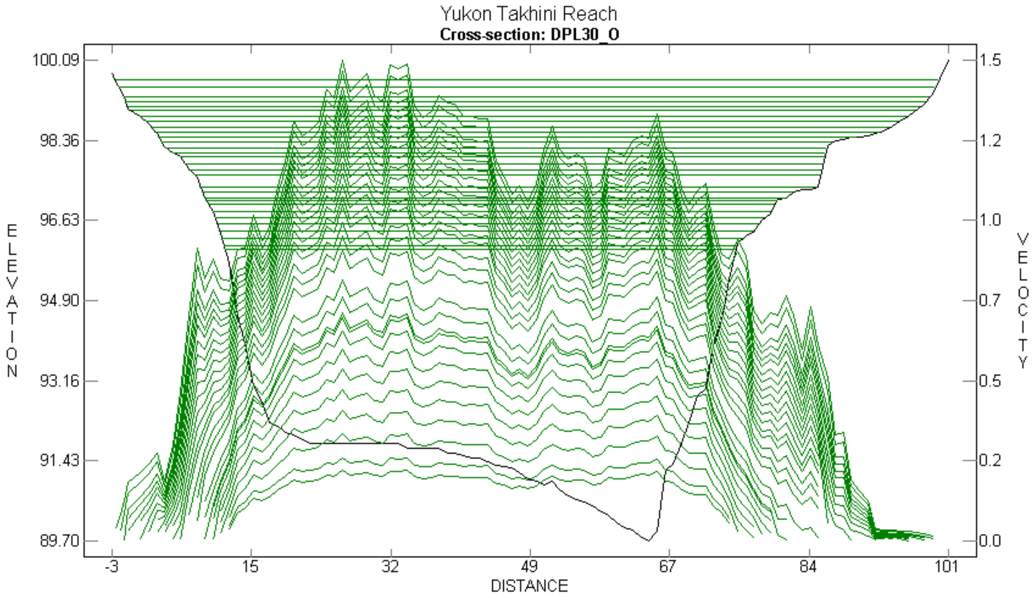
Use Given N's: Yes

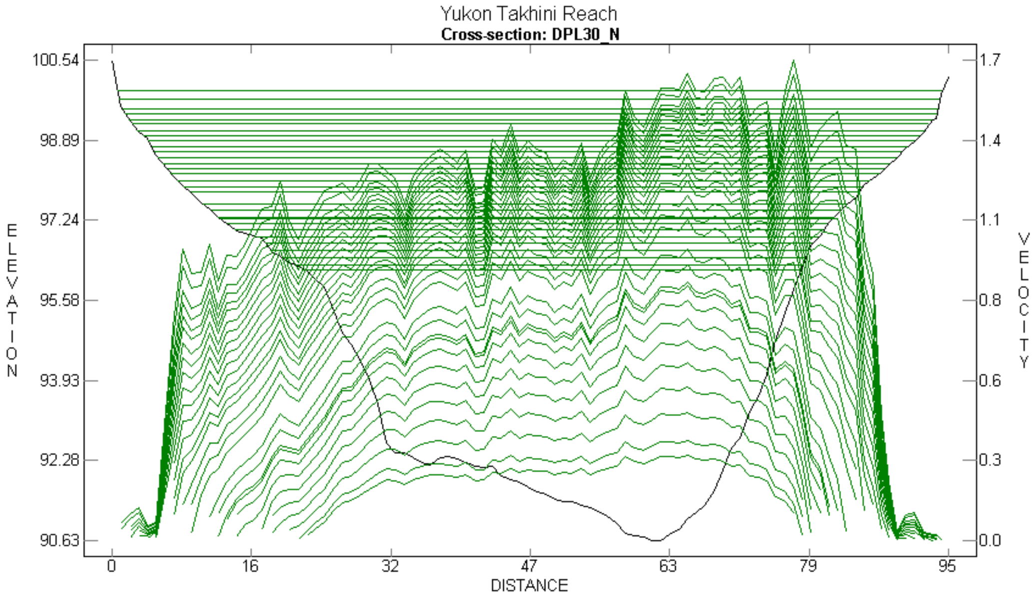

-----------------------------------------------------------------------------
```

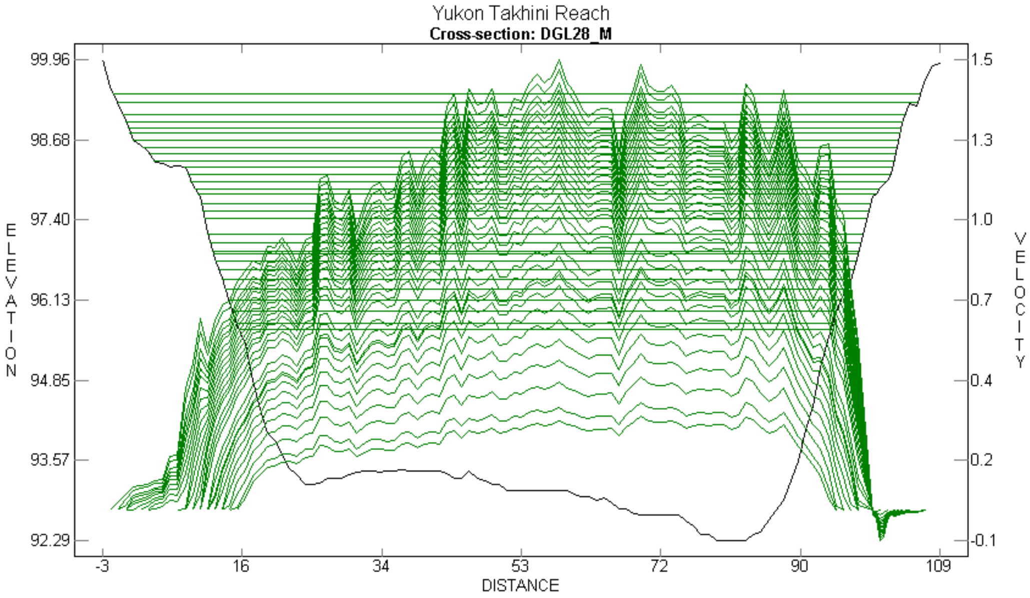
APPENDIX D

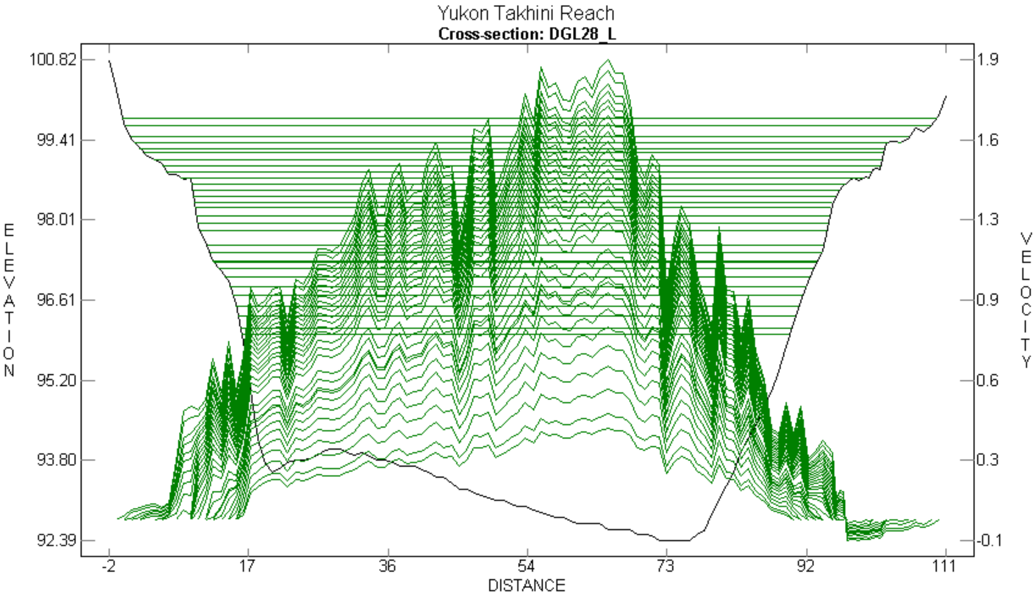
Simulated Water Surface Elevations and Velocities for the Takhini Reach

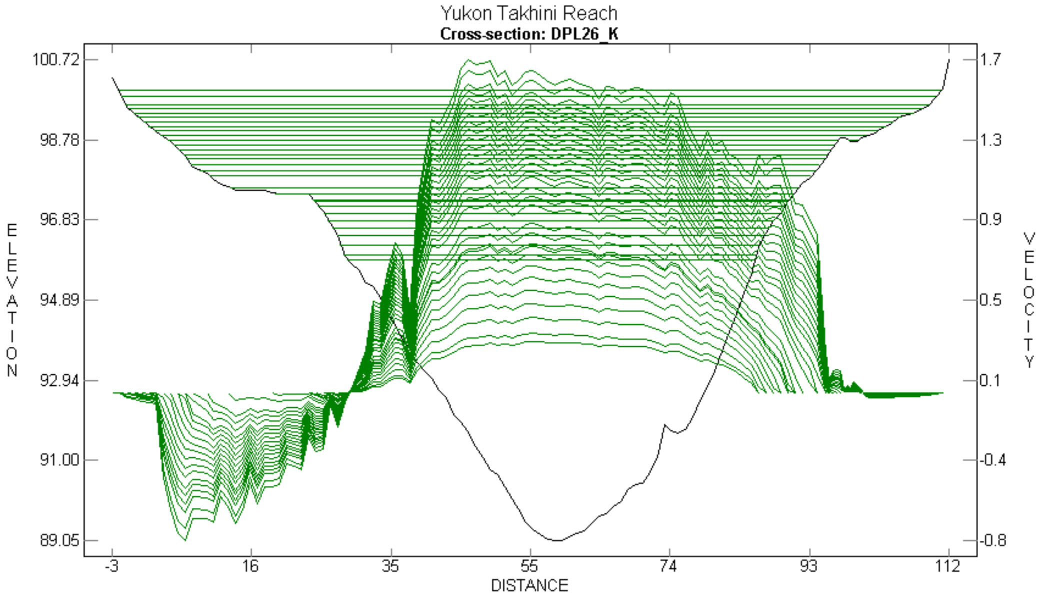
Takhini Reach

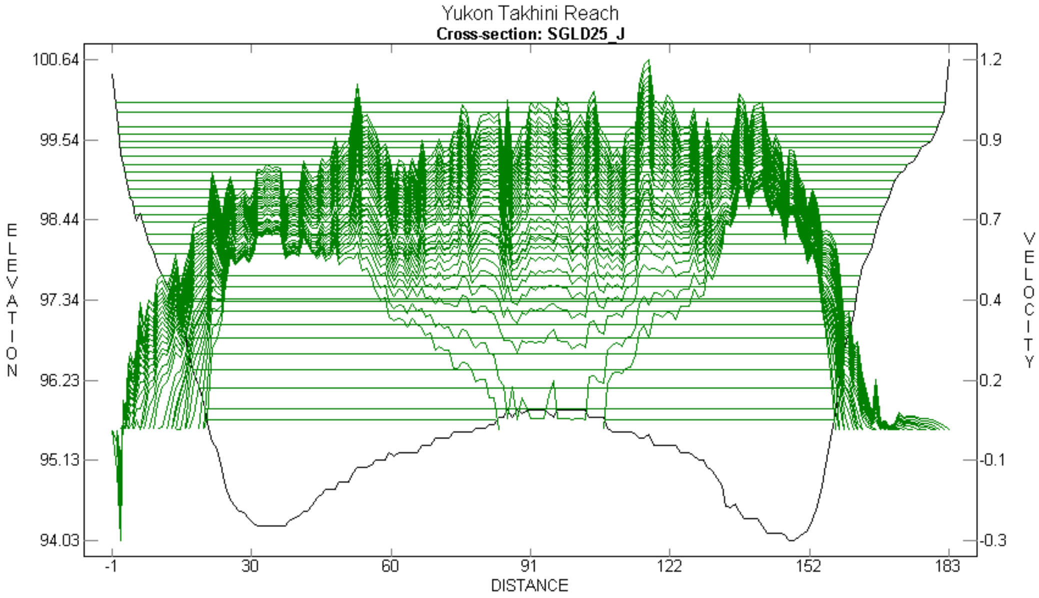


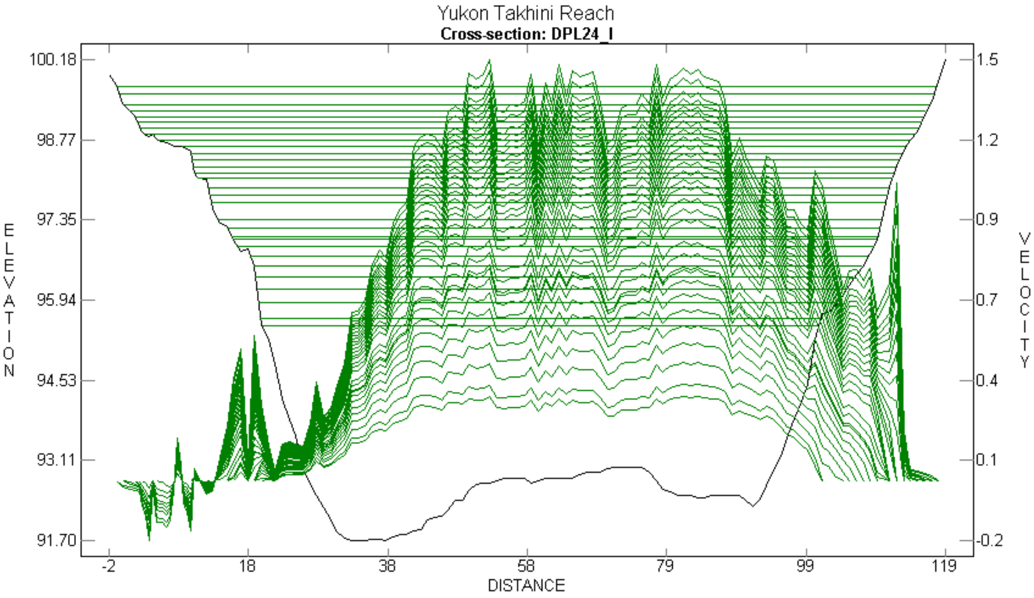


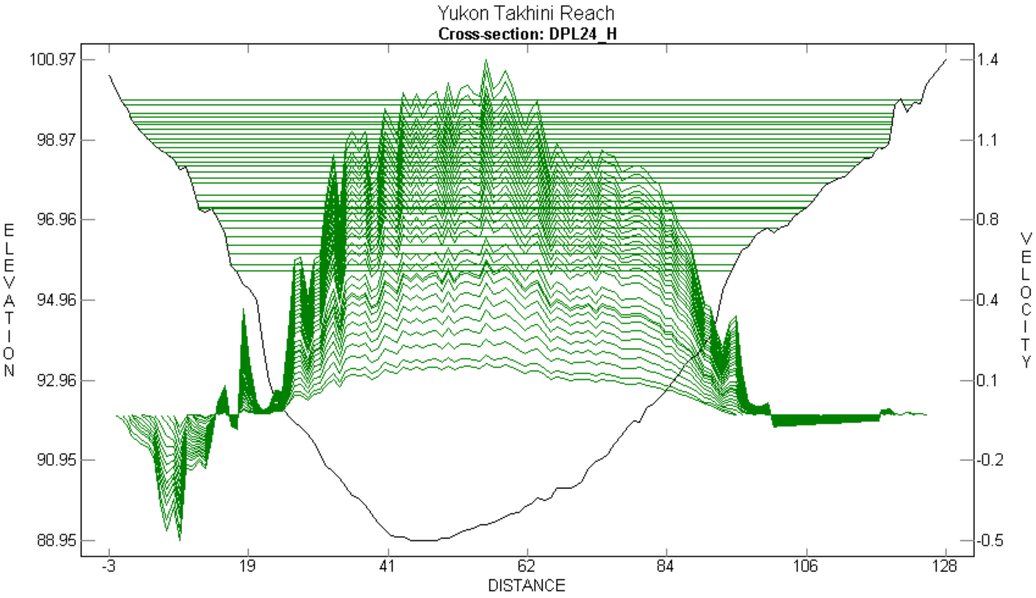

Yukon Takhini Reach
Cross-section: DGL28_M
ELEVATION
99.96
98.68
97.40
96.13
94.85
93.57
92.29
VELOCITY
1.5
1.3
1.0
0.7
0.4
0.2
-0.1
-3
16
34
53
72
90
109
DISTANCE

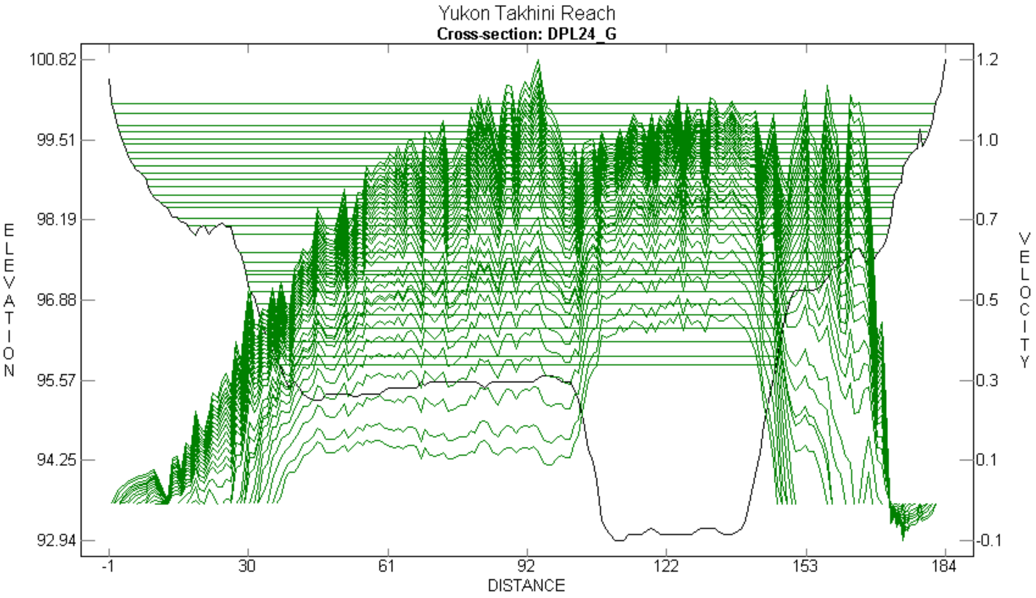

Yukon Takhini Reach
Cross-section: DGL28_L
ELEVATION
100.82
99.41
98.01
96.61
95.20
93.80
92.39
VELOCITY
1.9
1.6
1.3
0.9
0.6
0.3
-0.1
-2
17
36
54
73
92
111
DISTANCE

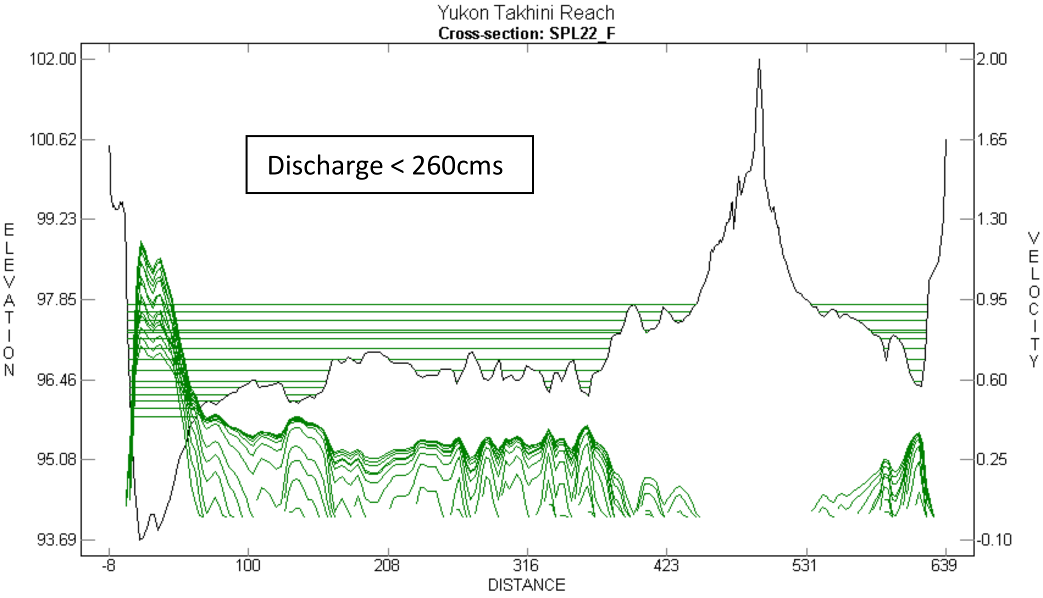

Yukon Takhini Reach
Cross-section: DPL26_K
ELEVATION
100.72
98.78
96.83
94.89
92.94
91.00
89.05
VELOCITY
1.7
1.3
0.9
0.5
0.1
-0.4
-0.8
-3
16
35
55
74
93
112
DISTANCE

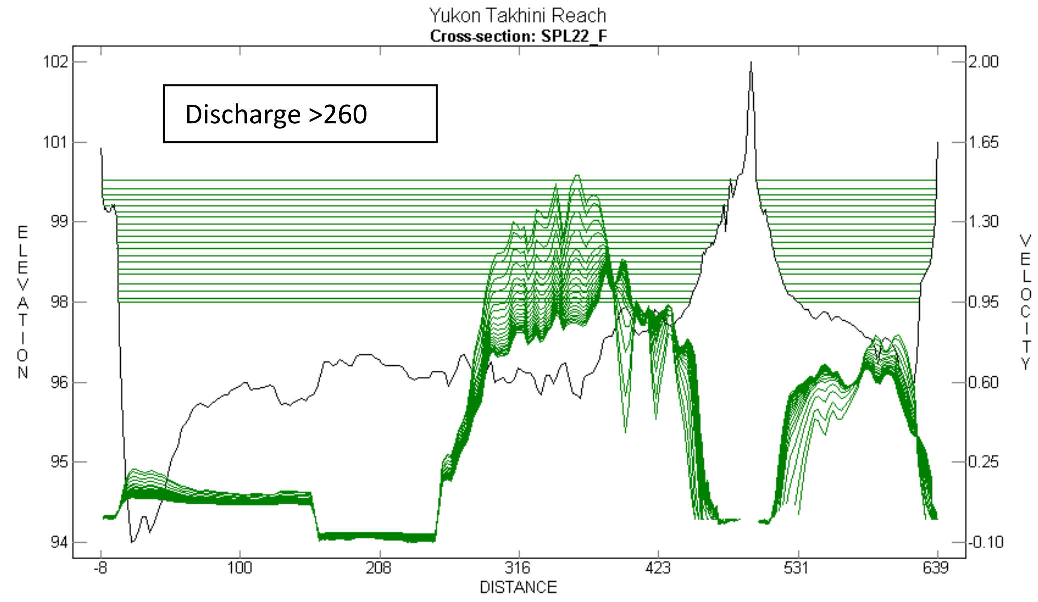

Yukon Takhini Reach
Cross-section: SGLD25_J
ELEVATION
100.64
99.54
98.44
97.34
96.23
95.13
94.03
VELOCITY
1.2
0.9
0.7
0.4
0.2
-0.1
-0.3
-1
30
60
91
122
152
183
DISTANCE

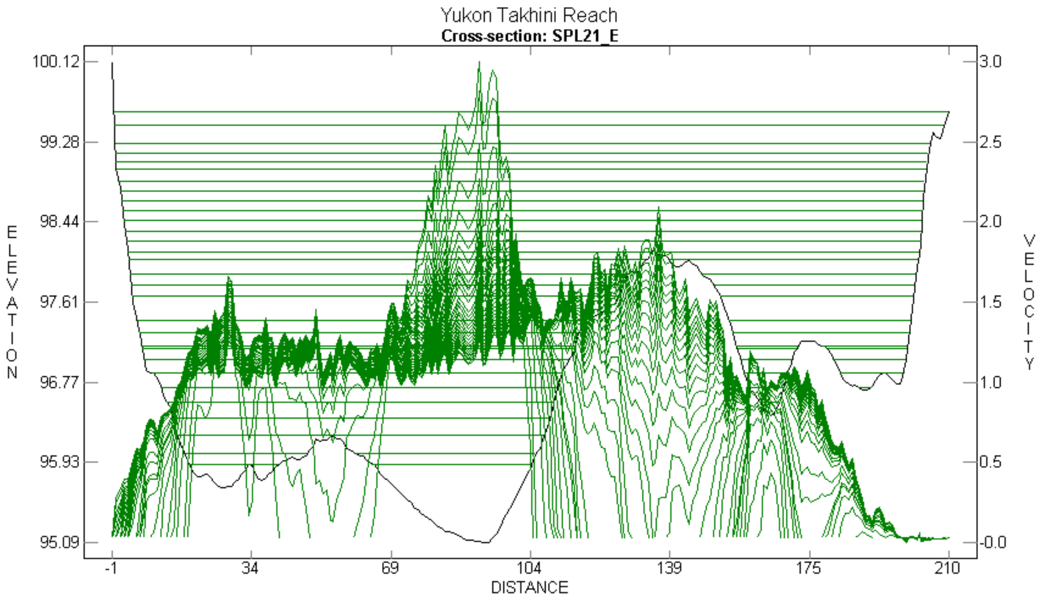

Yukon Takhini Reach
Cross-section: DPL24_I
ELEVATION
100.18
98.77
97.35
95.94
94.53
93.11
91.70
VELOCITY
1.5
1.2
0.9
0.7
0.4
0.1
-0.2
DISTANCE
-2
18
38
58
79
99
119

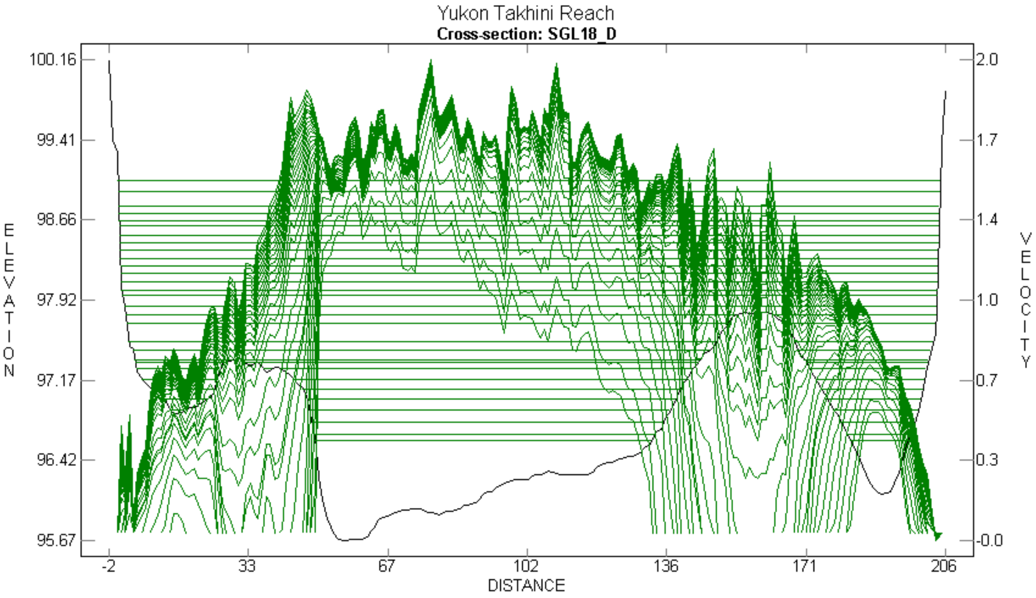

Yukon Takhini Reach
Cross-section: DPL24_H
ELEVATION
100.97
98.97
96.96
94.96
92.96
90.95
88.95
VELOCITY
1.4
1.1
0.8
0.4
0.1
-0.2
-0.5
DISTANCE
-3
19
41
62
84
106
128

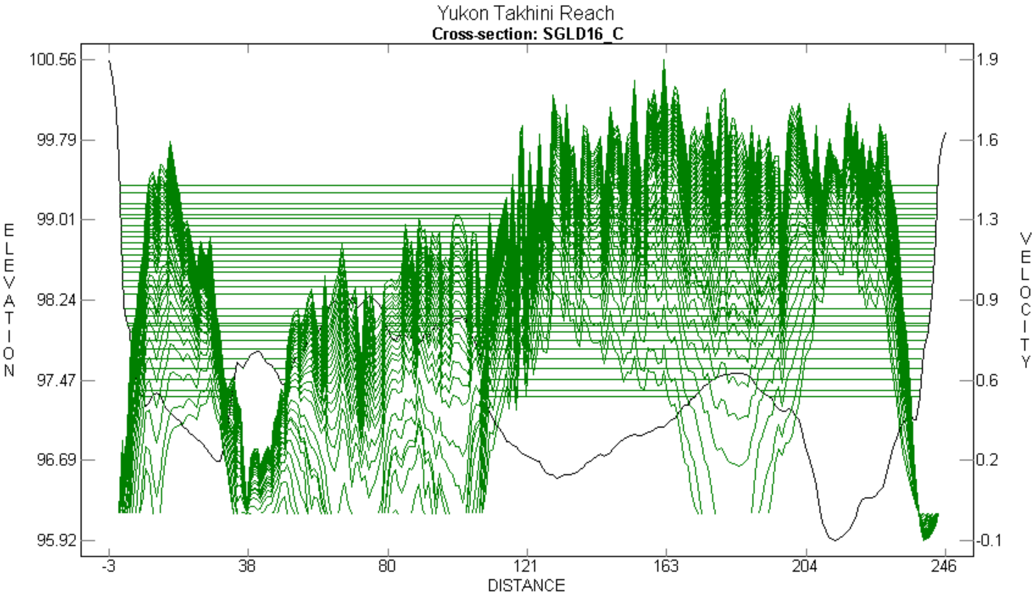

Yukon Takhini Reach
Cross-section: DPL24_G
ELEVATION
100.82
99.51
98.19
96.88
95.57
94.25
92.94
VELOCITY
1.2
1.0
0.7
0.5
0.3
0.1
-0.1
DISTANCE
-1
30
61
92
122
153
184

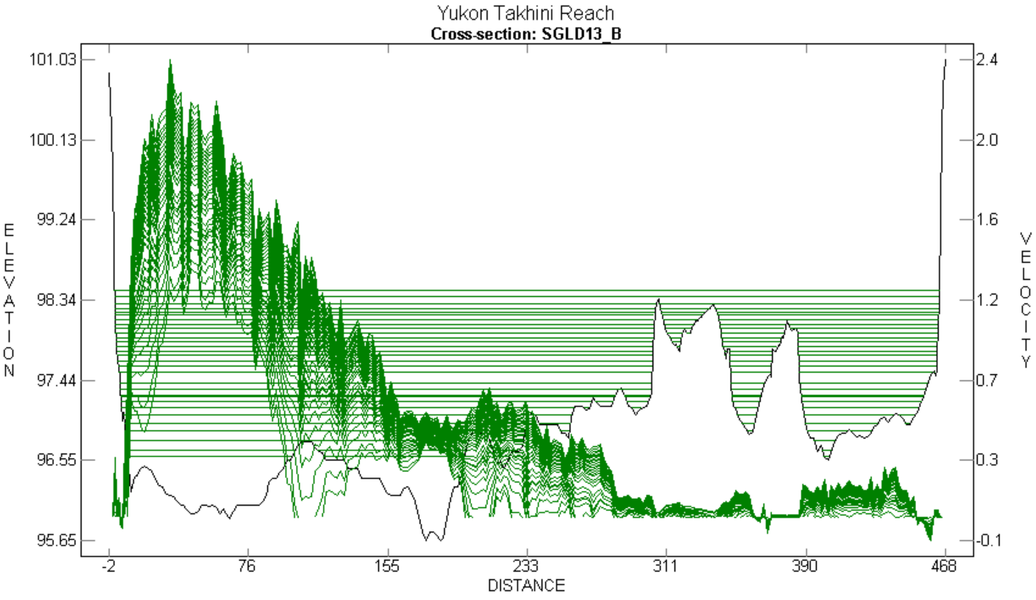

Yukon Takhini Reach
Cross-section: SPL22_F
Discharge < 260cms
ELEVATION
102.00
100.62
99.23
97.85
96.46
95.08
93.69
VELOCITY
2.00
1.65
1.30
0.95
0.60
0.25
-0.10
DISTANCE
-8
100
208
316
423
531
639

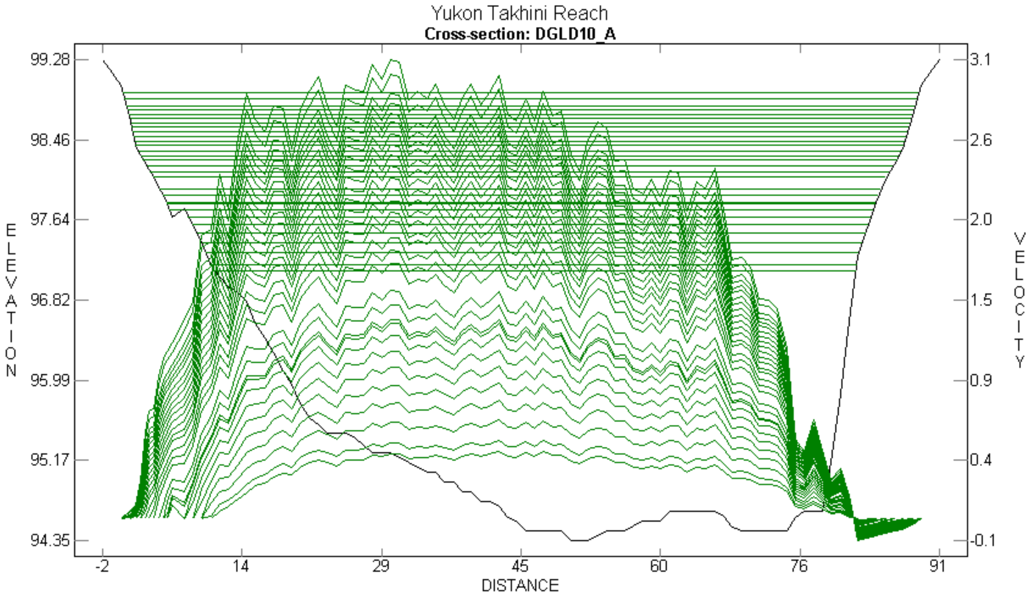

Yukon Takhini Reach
Cross-section: SPL22_F
Discharge >260
ELEVATION
102
101
99
98
96
95
94
VELOCITY
2.00
1.65
1.30
0.95
0.60
0.25
-0.10
DISTANCE
-8
100
208
316
423
531
639

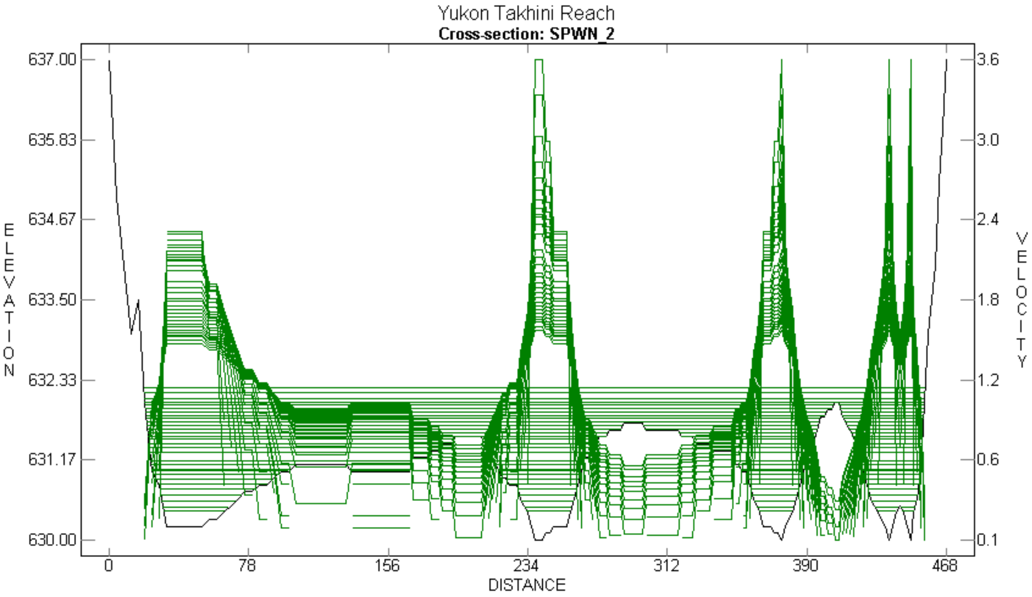

Yukon Takhini Reach
Cross-section: SPL21_E
ELEVATION
100.12
99.28
98.44
97.61
96.77
95.93
95.09
VELOCITY
3.0
2.5
2.0
1.5
1.0
0.5
-0.0
DISTANCE
-1
34
69
104
139
175
210

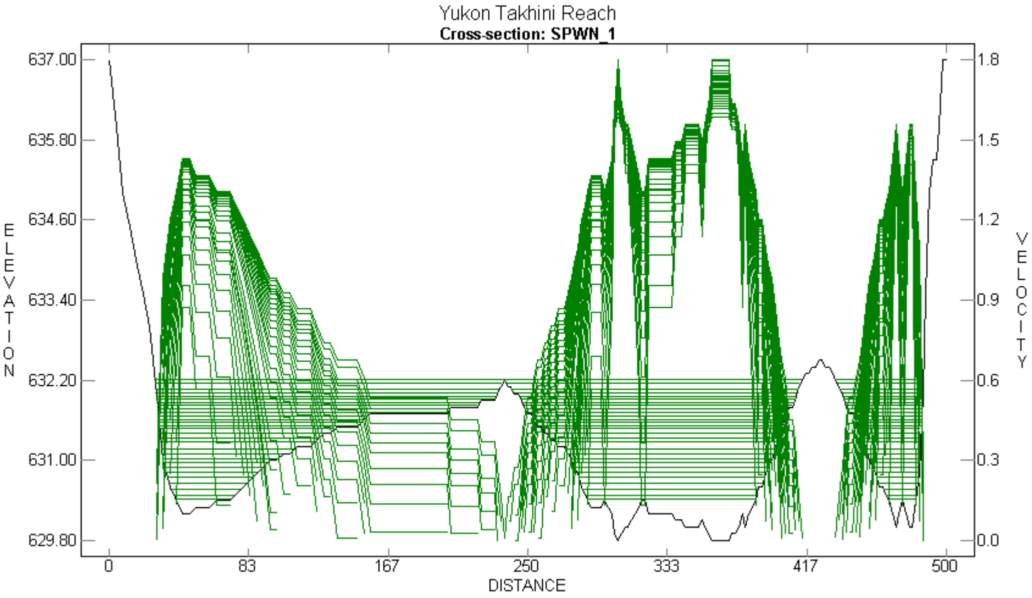

Yukon Takhini Reach
Cross-section: SGL18_D
100.16
99.41
98.66
97.92
97.17
96.42
95.67
ELEVATION
2.0
1.7
1.4
1.0
0.7
0.3
-0.0
VELOCITY
-2
33
67
102
136
171
206
DISTANCE


Yukon Takhini Reach
Cross-section: SGLD16_C
100.56
99.79
99.01
98.24
97.47
96.69
95.92
ELEVATION
1.9
1.6
1.3
0.9
0.6
0.2
-0.1
VELOCITY
-3
38
80
121
163
204
246
DISTANCE


Yukon Takhini Reach
Cross-section: SGLD13_B
ELEVATION
101.03
100.13
99.24
98.34
97.44
96.55
95.65
VELOCITY
2.4
2.0
1.6
1.2
0.7
0.3
-0.1
-2
76
155
233
311
390
468
DISTANCE


Yukon Takhini Reach
Cross-section: DGLD10_A
ELEVATION
99.28
98.46
97.64
96.82
95.99
95.17
94.35
VELOCITY
3.1
2.6
2.0
1.5
0.9
0.4
-0.1
-2
14
29
45
60
76
91
DISTANCE

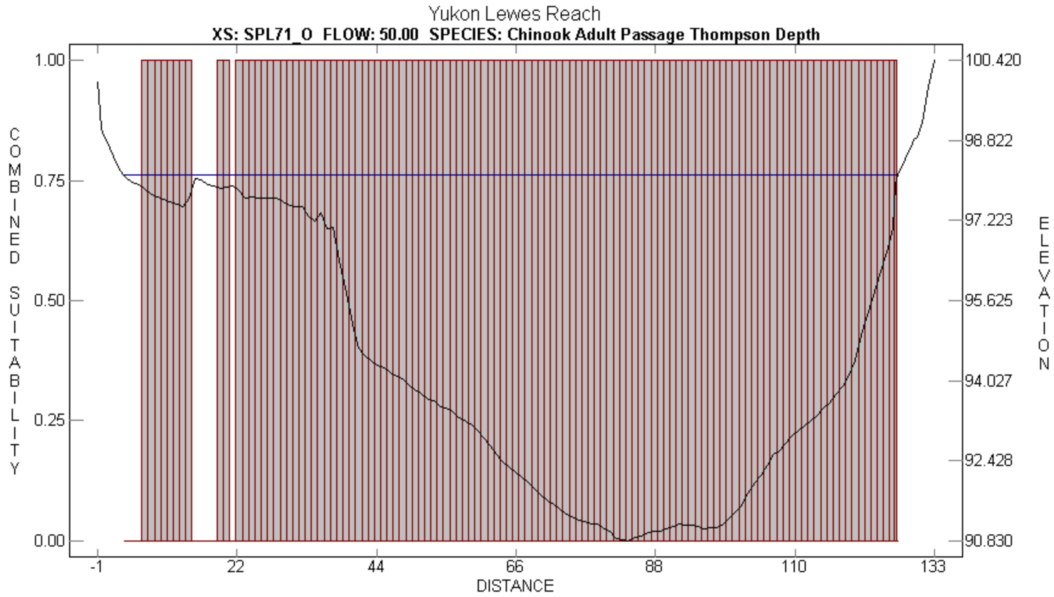

Yukon Takhini Reach
Cross-section: SPWN_2
ELEVATION
637.00
635.83
634.67
633.50
632.33
631.17
630.00
VELOCITY
3.6
3.0
2.4
1.8
1.2
0.6
0.1
0
78
156
234
312
390
468
DISTANCE


Yukon Takhini Reach
Cross-section: SPWN_1
ELEVATION
637.00
635.80
634.60
633.40
632.20
631.00
629.80
VELOCITY
1.8
1.5
1.2
0.9
0.6
0.3
0.0
0
83
167
250
333
417
500
DISTANCE

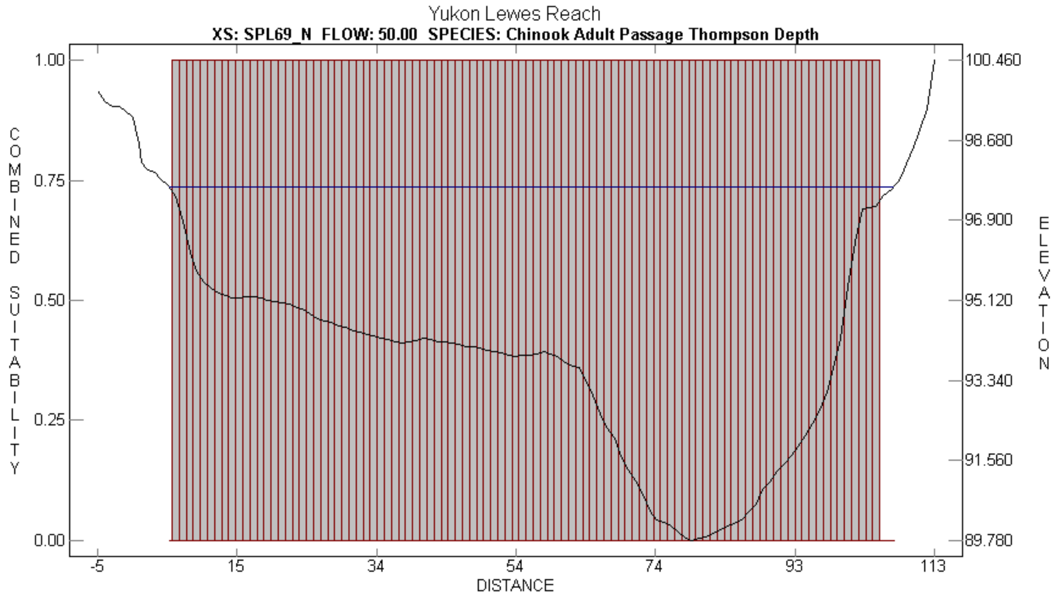
APPENDIX E

Profile, Water Surface Elevation, and Suitability for Adult Chinook Passage at 50 cms at the Lewes and Takhini Reach Transects.

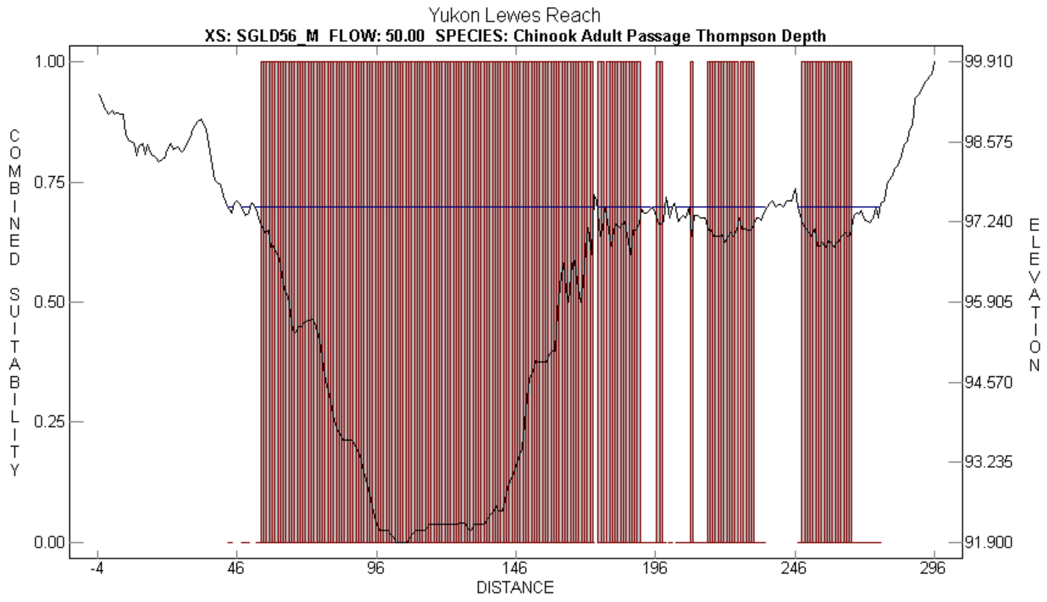
Lewes Reach

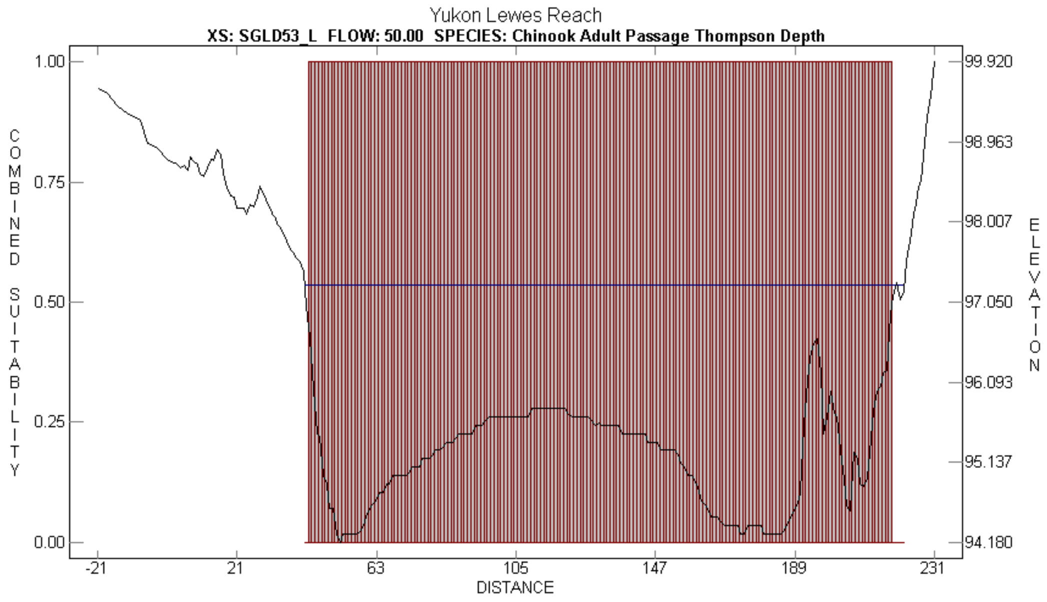


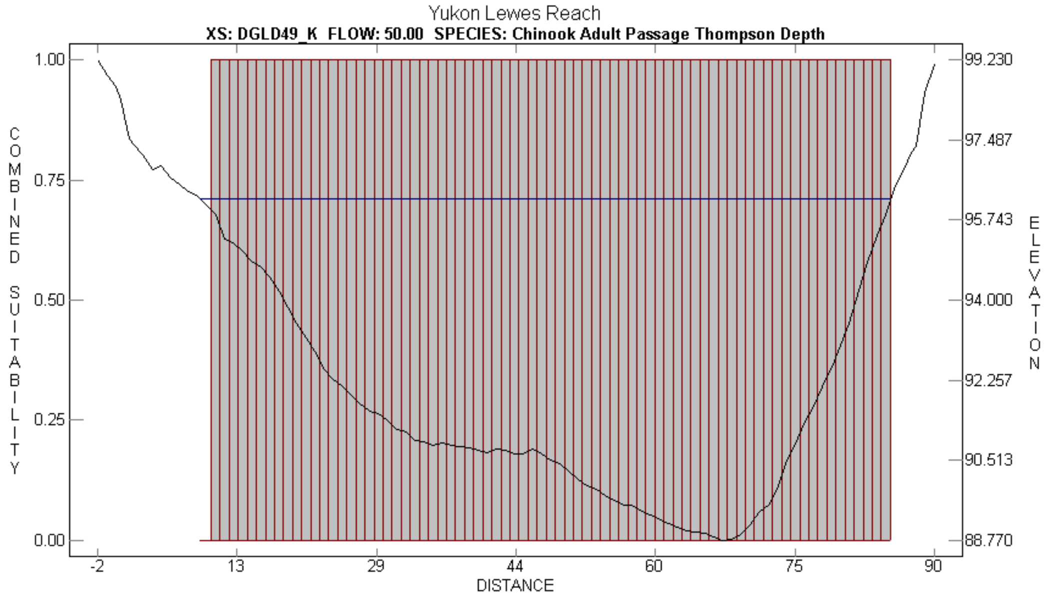
Yukon Lewes Reach
XS: SPL71_O FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.420
98.822
97.223
95.625
94.027
92.428
90.830
-1
22
44
66
88
110
133
DISTANCE

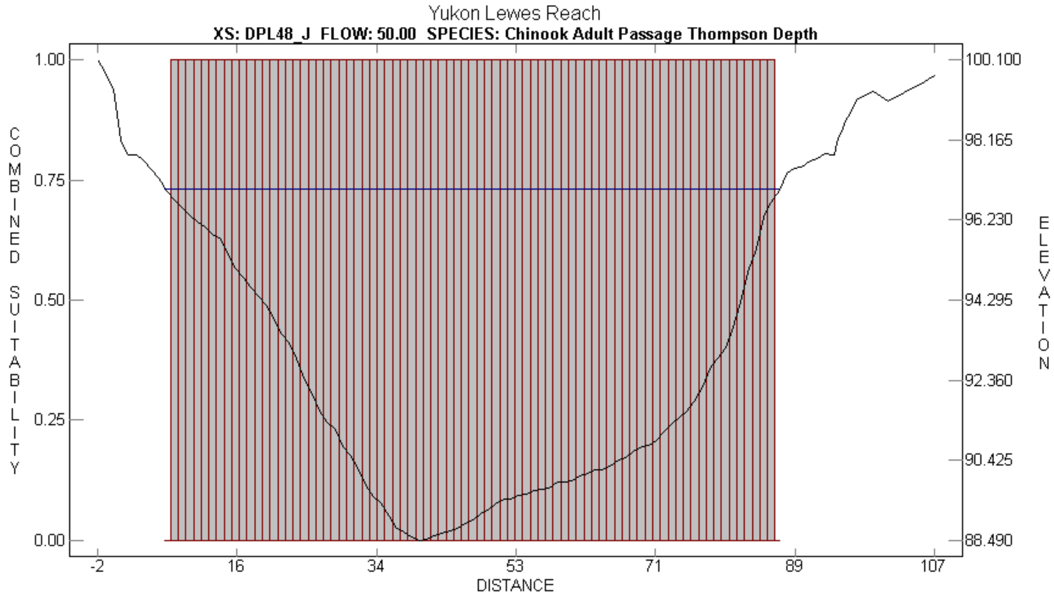


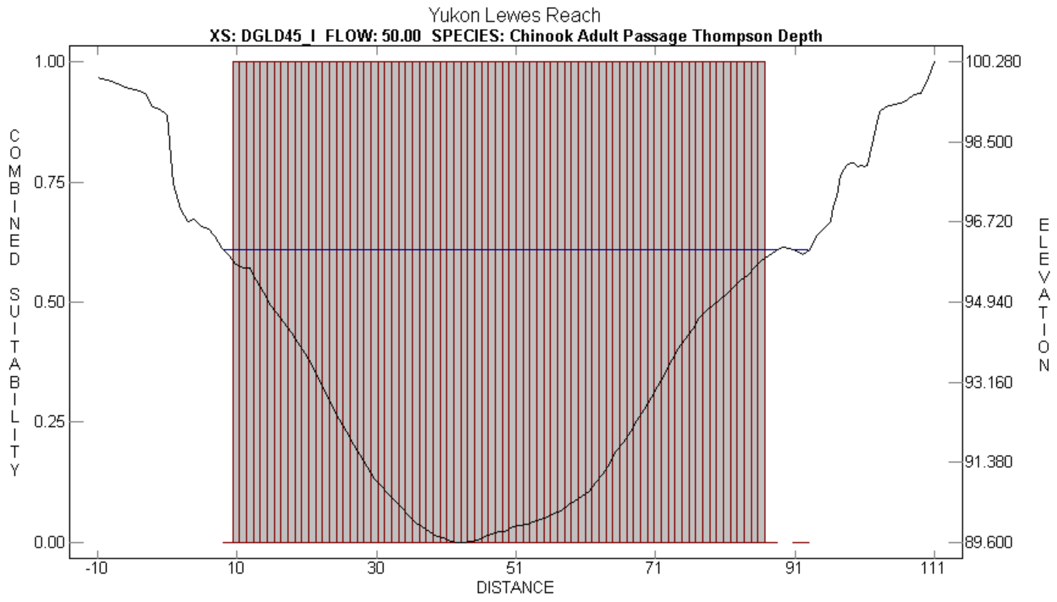
Yukon Lewes Reach
XS: SPL69_N FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.460
98.680
96.900
95.120
93.340
91.560
89.780
-5
15
34
54
74
93
113
DISTANCE

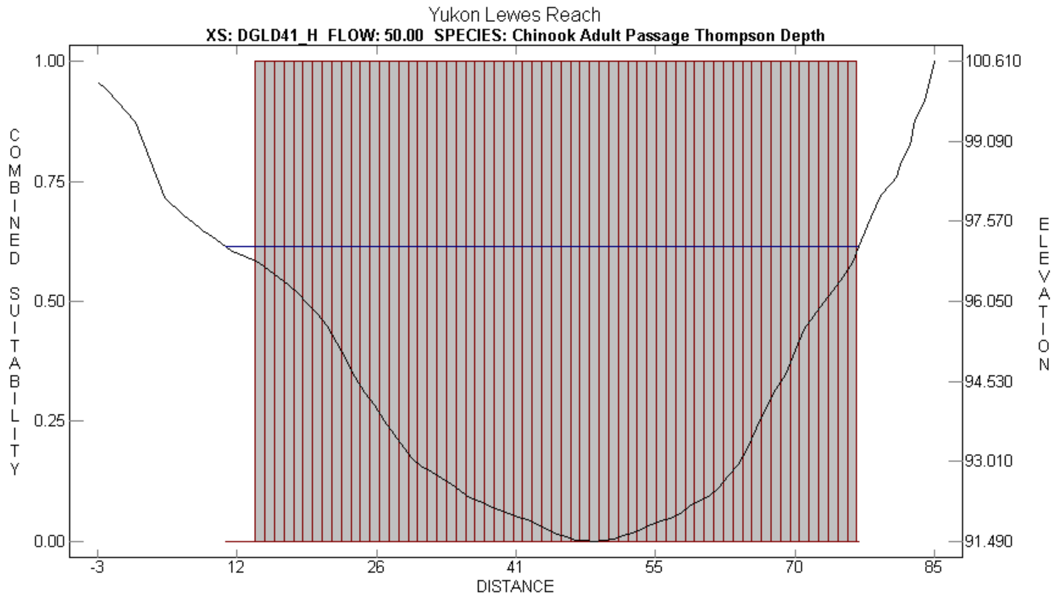

Yukon Lewes Reach
XS: SGLD56_M FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
99.910
98.575
97.240
95.905
94.570
93.235
91.900
-4
46
96
146
196
246
296
DISTANCE

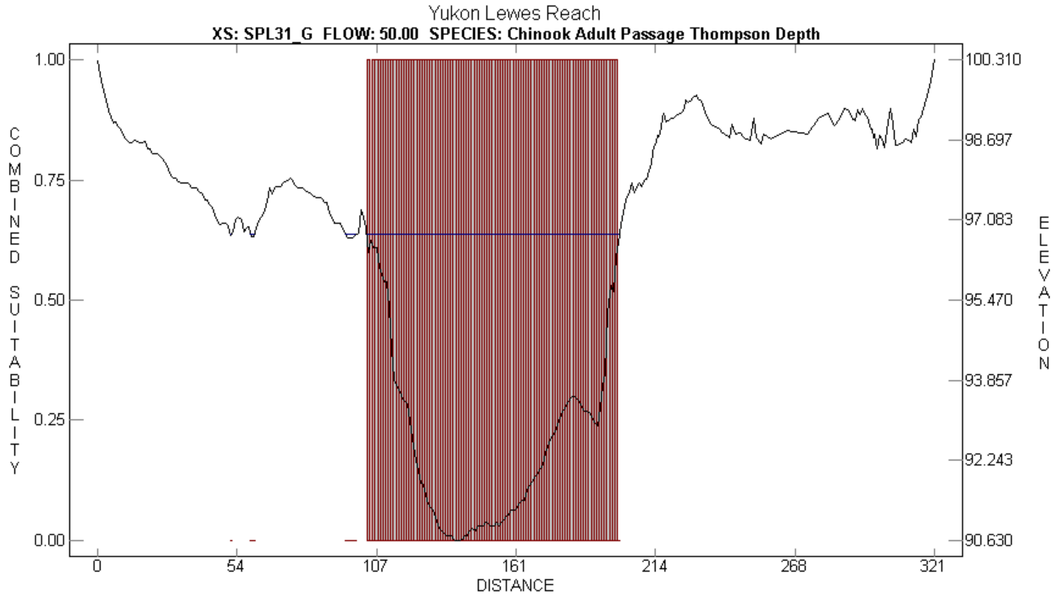

Yukon Lewes Reach
XS: SGLD53_L FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
99.920
98.963
98.007
97.050
96.093
95.137
94.180
-21
21
63
105
147
189
231
DISTANCE

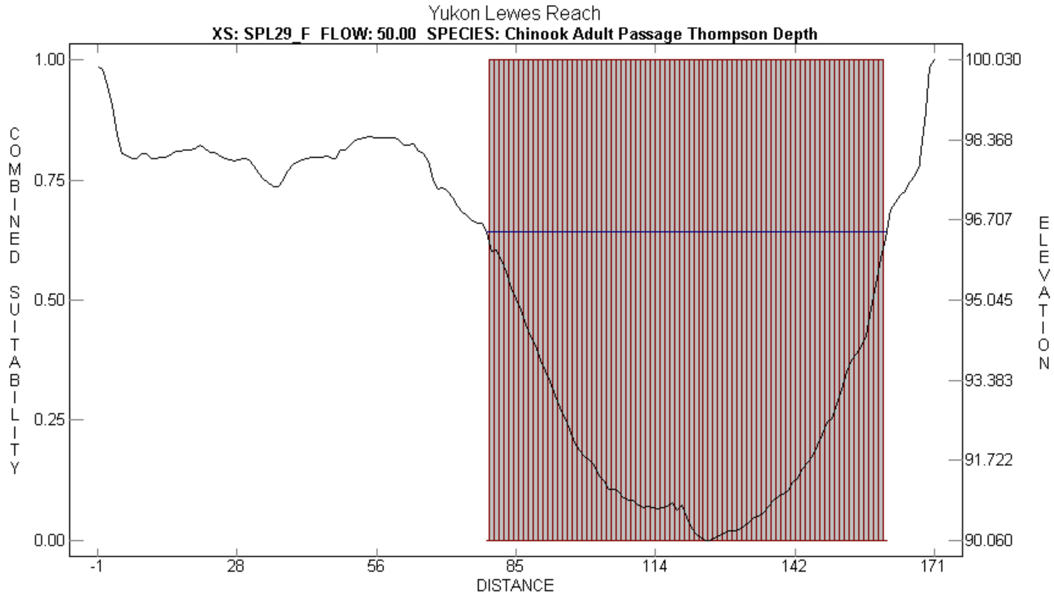

Yukon Lewes Reach
XS: DGLD49_K FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
99.230
97.487
95.743
94.000
92.257
90.513
88.770
-2
13
29
44
60
75
90
DISTANCE

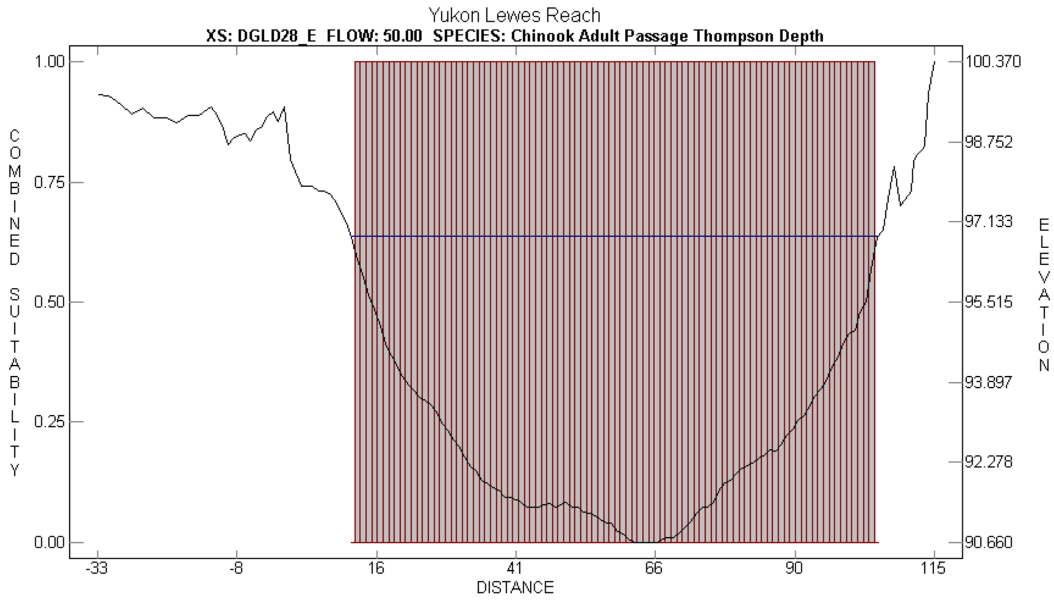

Yukon Lewes Reach
XS: DPL48_J FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.100
98.165
96.230
94.295
92.360
90.425
88.490
-2
16
34
53
71
89
107
DISTANCE

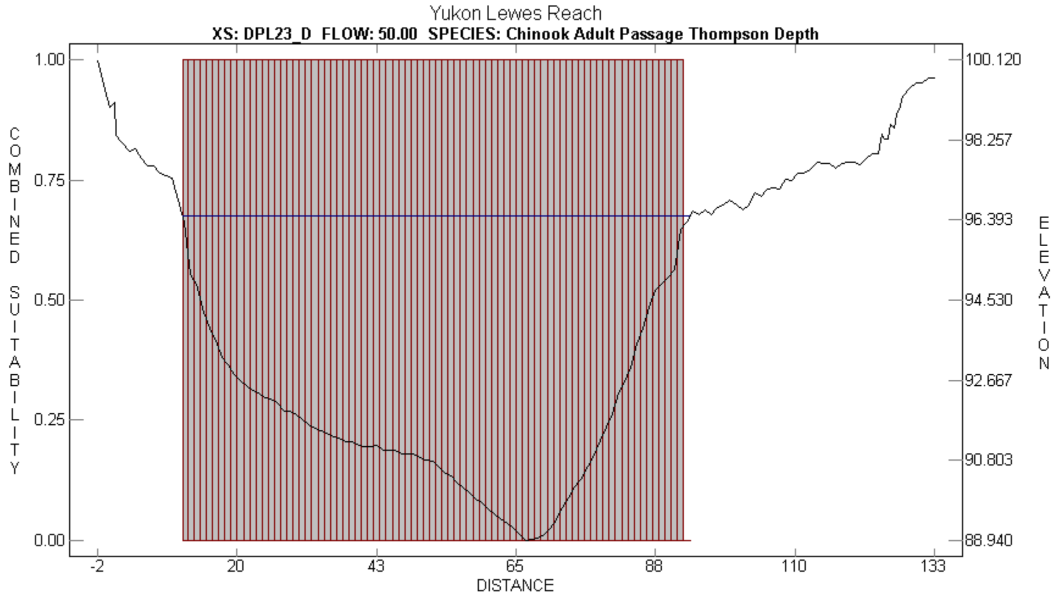

Yukon Lewes Reach
XS: DGLD45_I FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.280
98.500
96.720
94.940
93.160
91.380
89.600
-10
10
30
51
71
91
111
DISTANCE

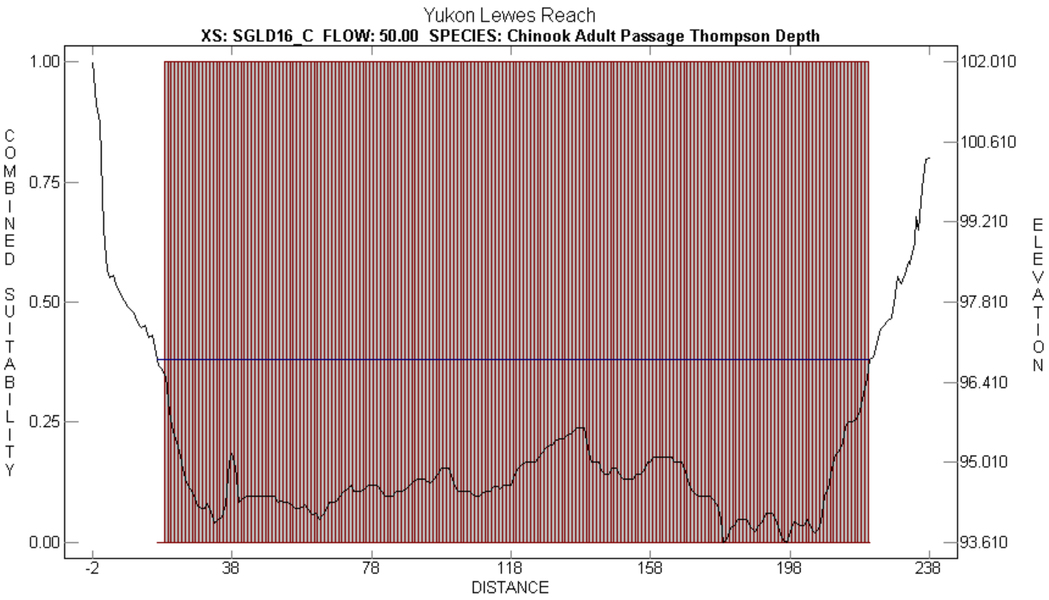

Yukon Lewes Reach
XS: DGLD41_H FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.610
99.090
97.570
96.050
94.530
93.010
91.490
-3
12
26
41
55
70
85
DISTANCE


Yukon Lewes Reach
XS: SPL31_G FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.310
98.697
97.083
95.470
93.857
92.243
90.630
DISTANCE
0
54
107
161
214
268
321

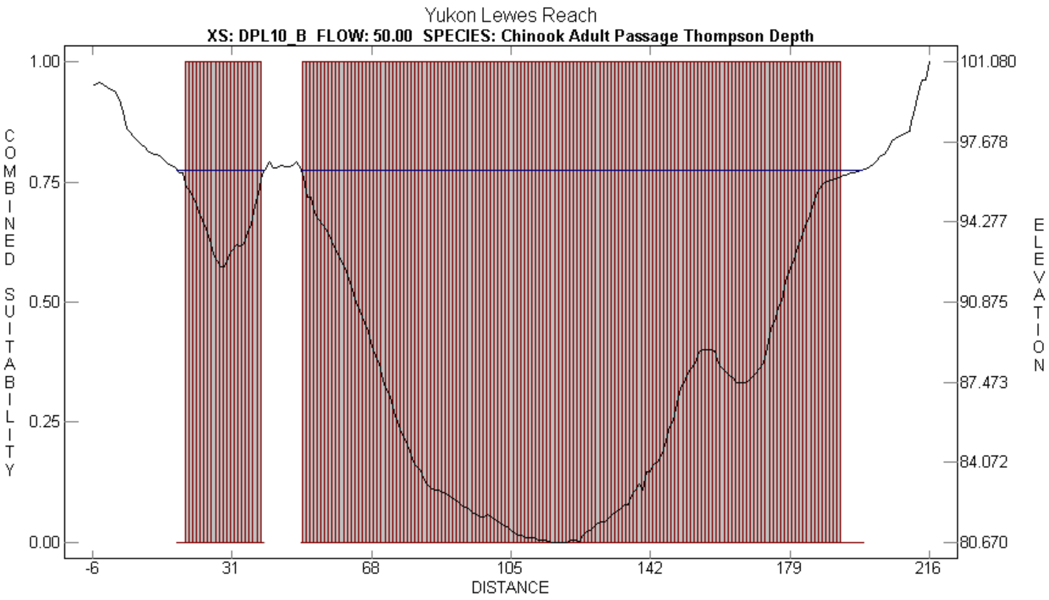

Yukon Lewes Reach
XS: SPL29_F FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.030
98.368
96.707
95.045
93.383
91.722
90.060
DISTANCE
-1
28
56
85
114
142
171


Yukon Lewes Reach
XS: DGLD28_E FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.370
98.752
97.133
95.515
93.897
92.278
90.660
-33
-8
16
41
66
90
115
DISTANCE

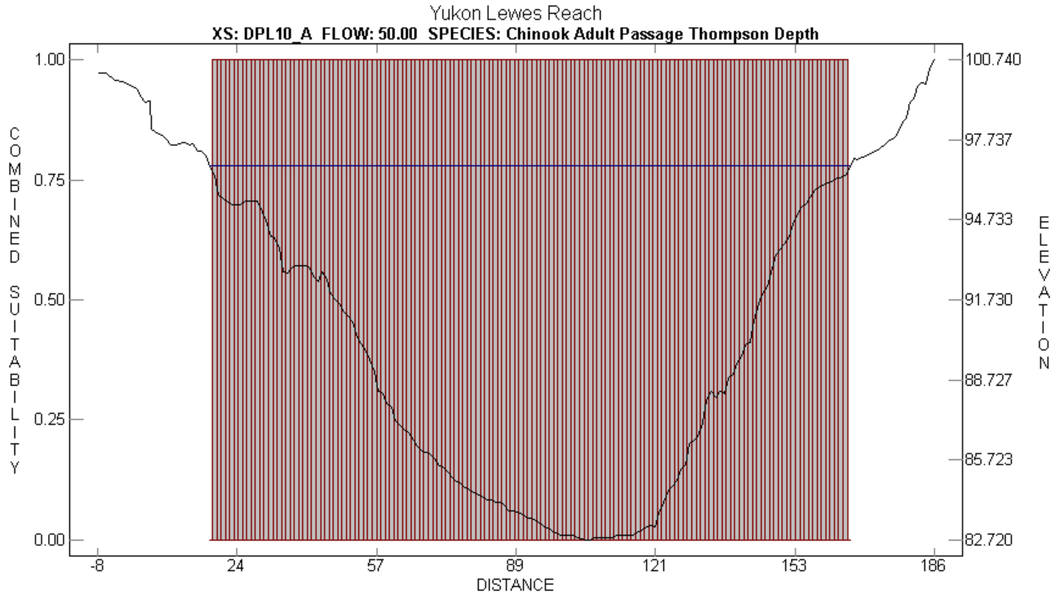

Yukon Lewes Reach
XS: DPL23_D FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.120
98.257
96.393
94.530
92.667
90.803
88.940
-2
20
43
65
88
110
133
DISTANCE


Yukon Lewes Reach

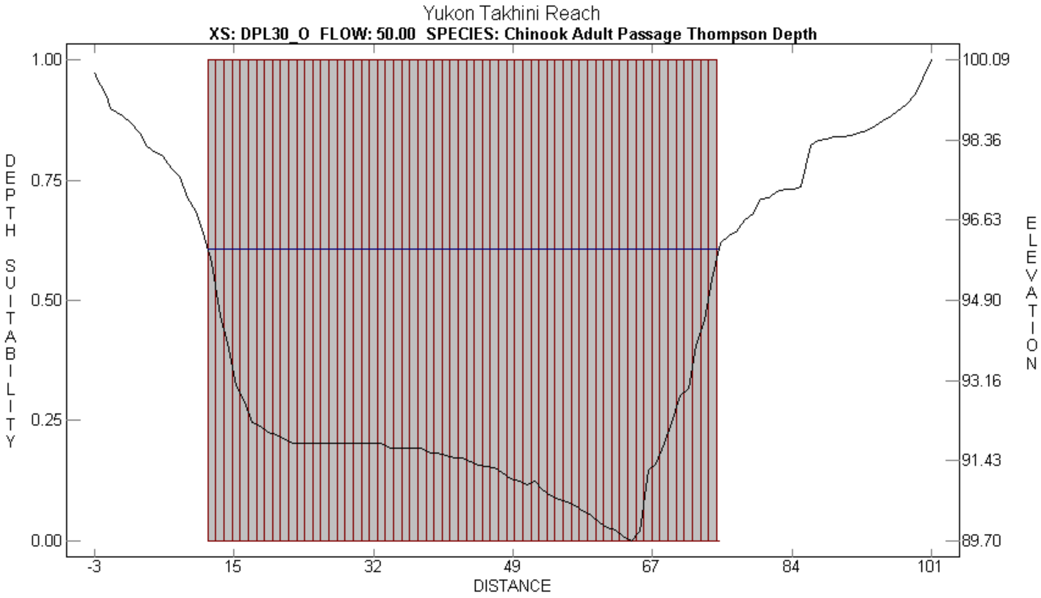
XS: SGLD16_C FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth

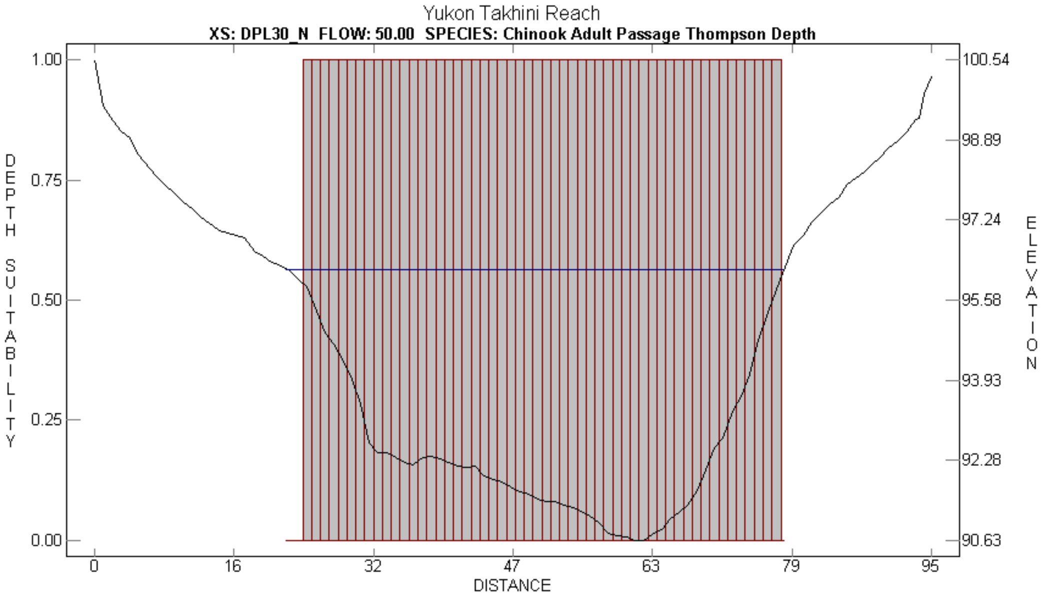

Yukon Lewes Reach

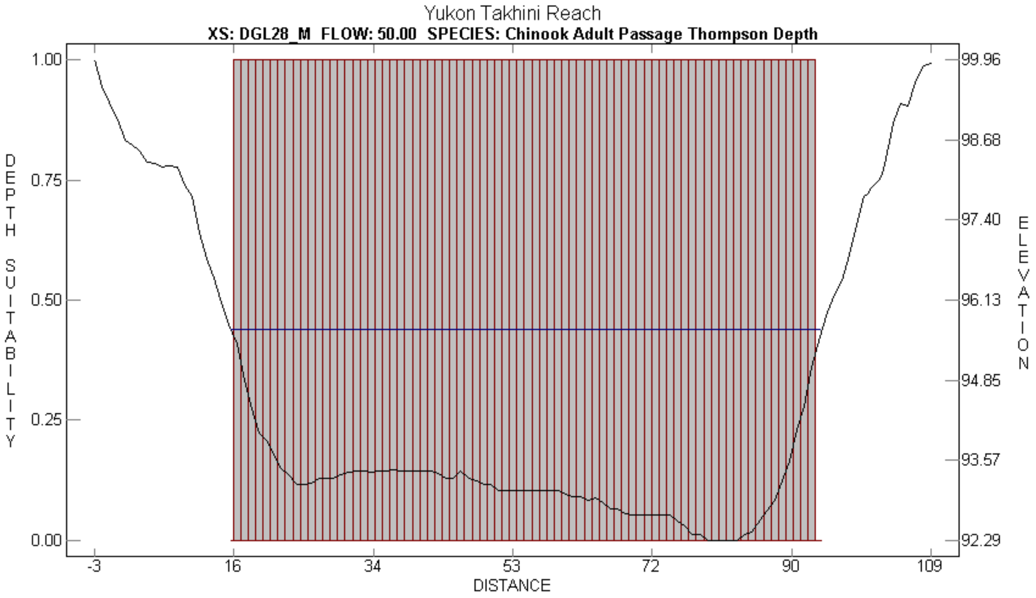
XS: DPL10_B FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth


Yukon Lewes Reach
XS: DPL10_A FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
COMBINED SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.740
97.737
94.733
91.730
88.727
85.723
82.720
-8
24
57
89
121
153
186
DISTANCE

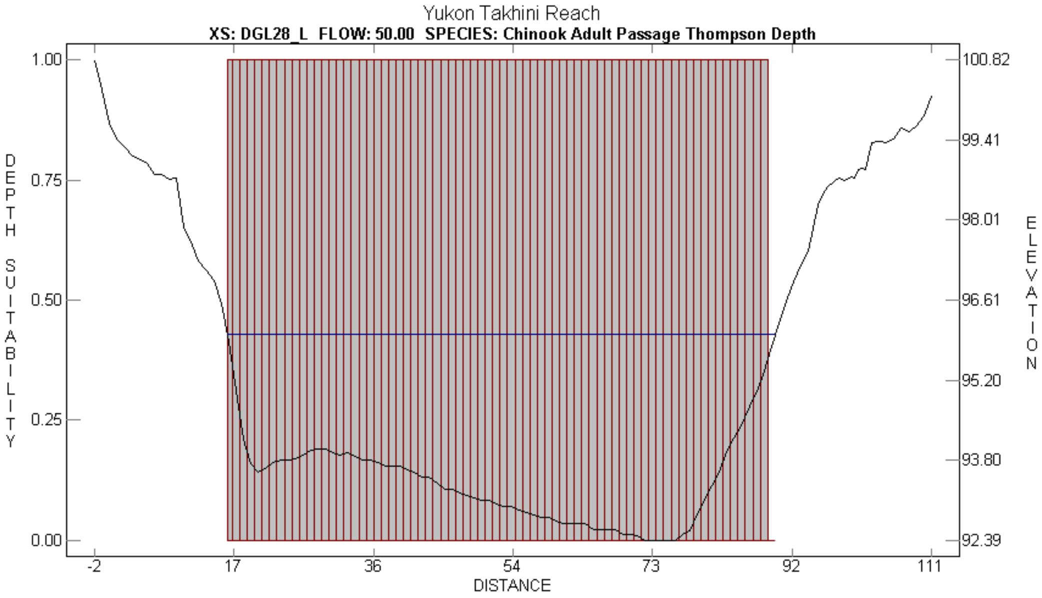
Takhini Reach



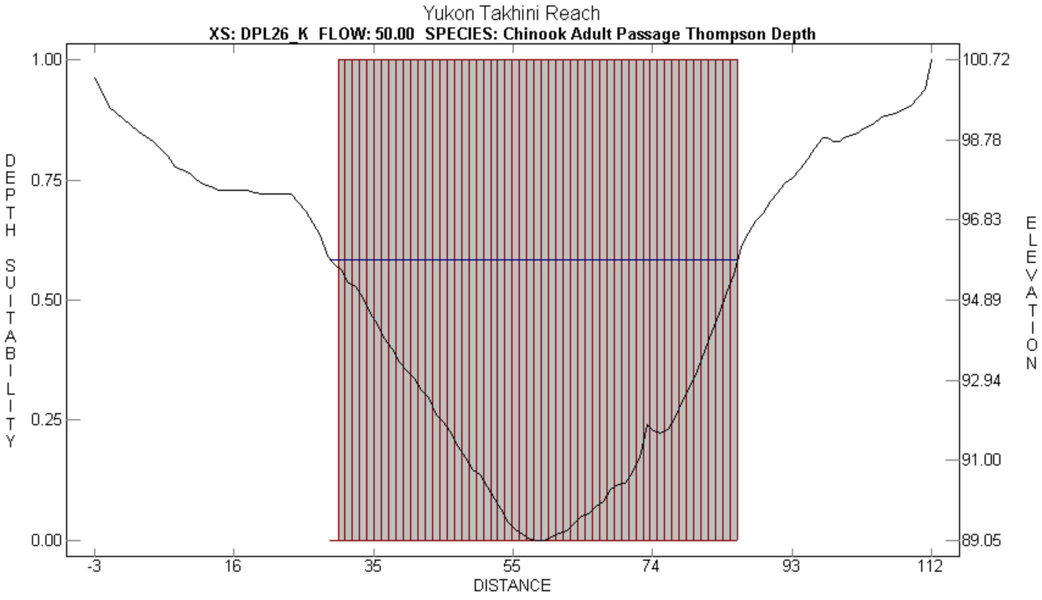


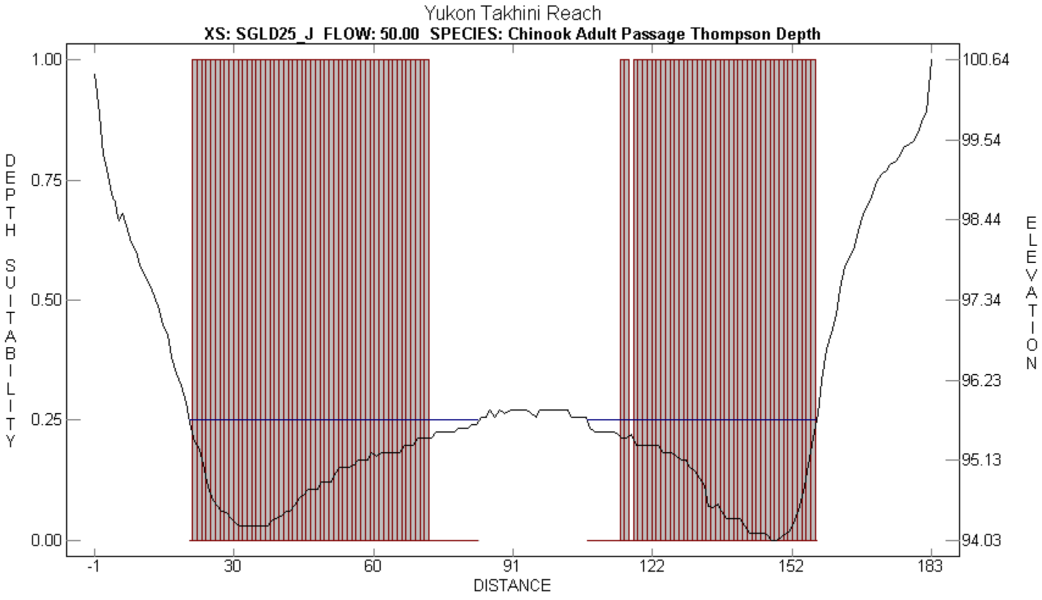


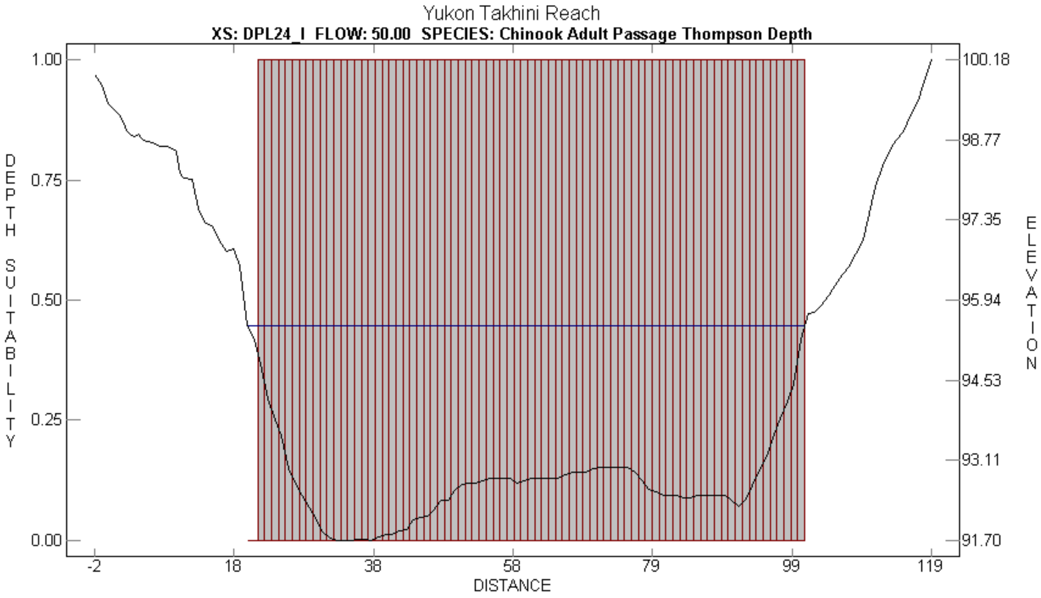
Yukon Takhini Reach
XS: DGL28_M FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
99.96
98.68
97.40
96.13
94.85
93.57
92.29
-3
16
34
53
72
90
109
DISTANCE

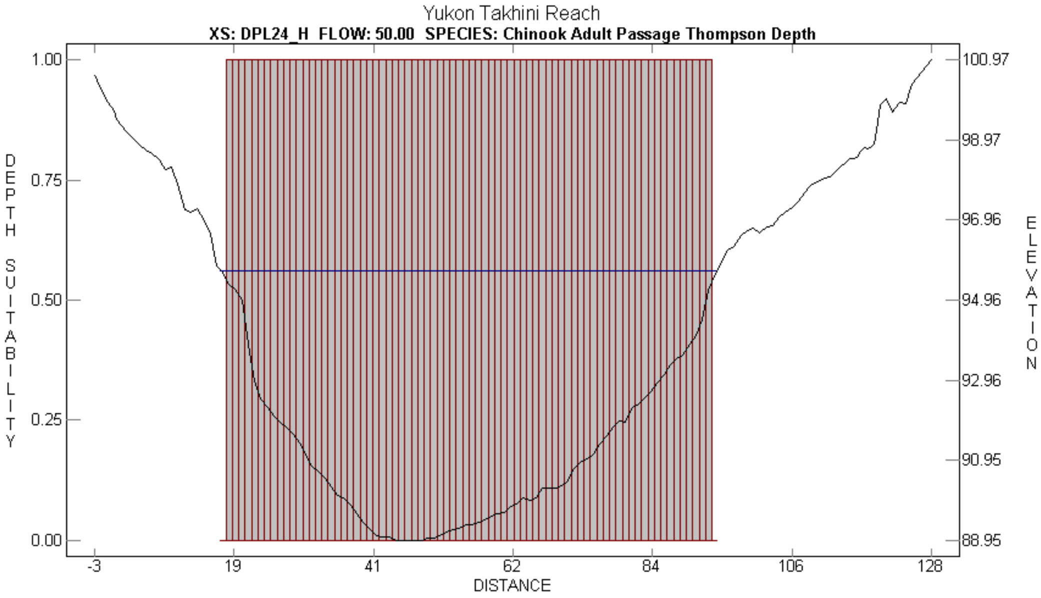


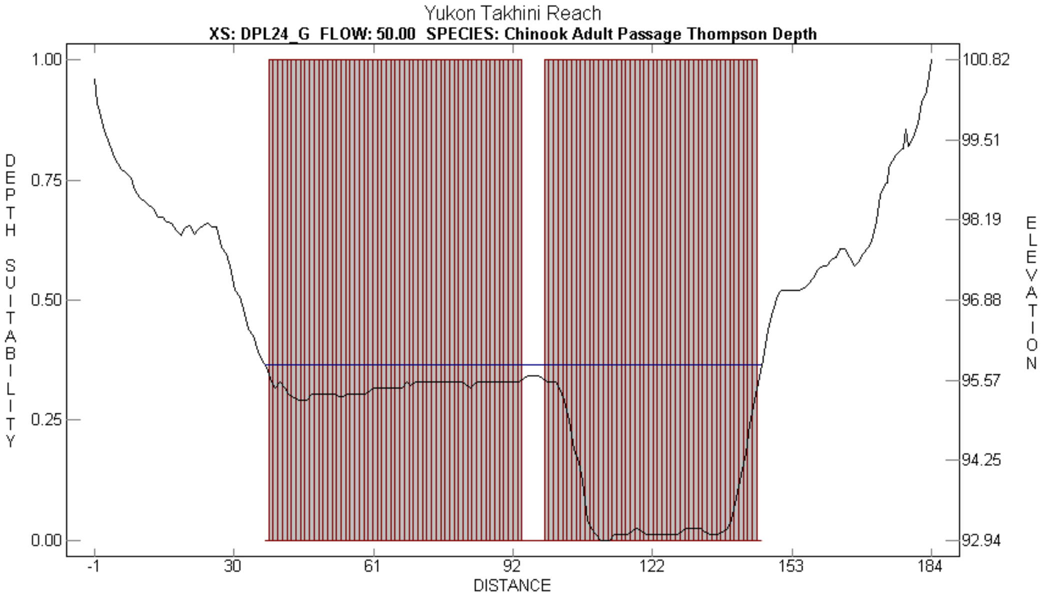
Yukon Takhini Reach
XS: DGL28_L FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.82
99.41
98.01
96.61
95.20
93.80
92.39
-2
17
36
54
73
92
111
DISTANCE

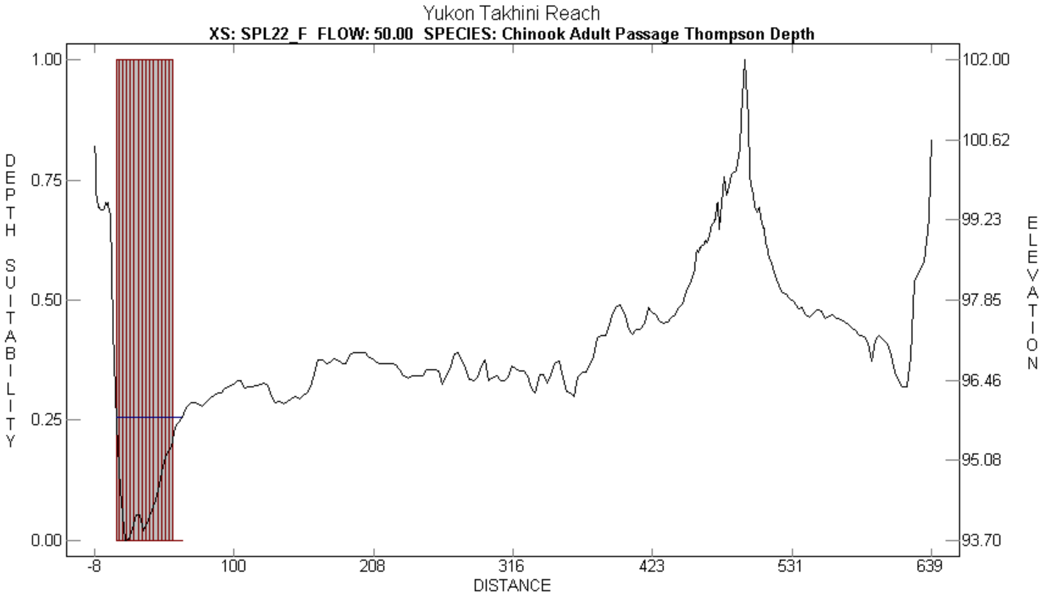

Yukon Takhini Reach
XS: DPL26_K FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.72
98.78
96.83
94.89
92.94
91.00
89.05
-3
16
35
55
74
93
112
DISTANCE

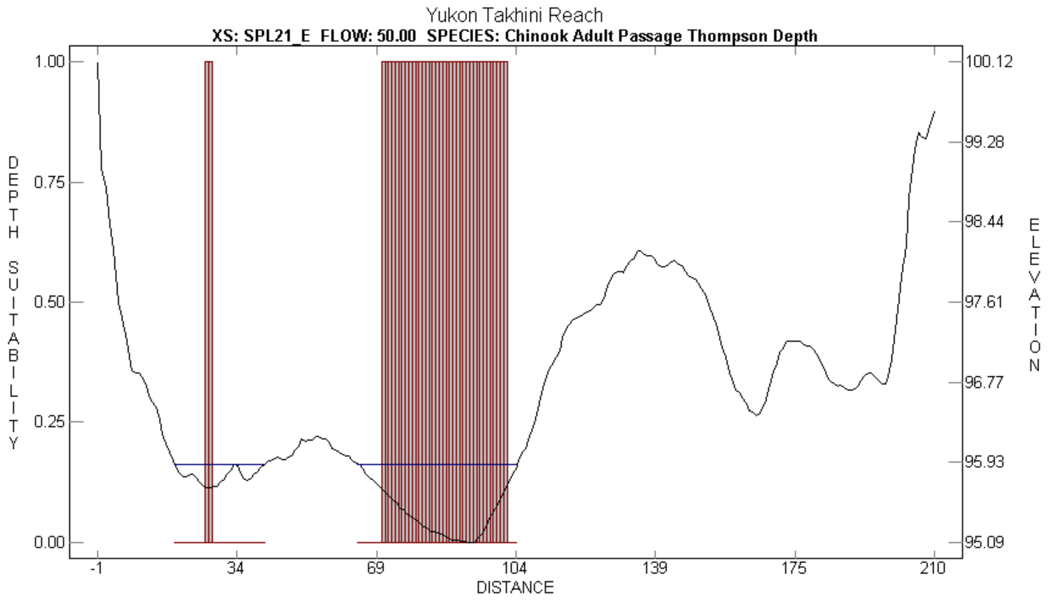

Yukon Takhini Reach
XS: SGLD25_J FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.64
99.54
98.44
97.34
96.23
95.13
94.03
-1
30
60
91
122
152
183
DISTANCE

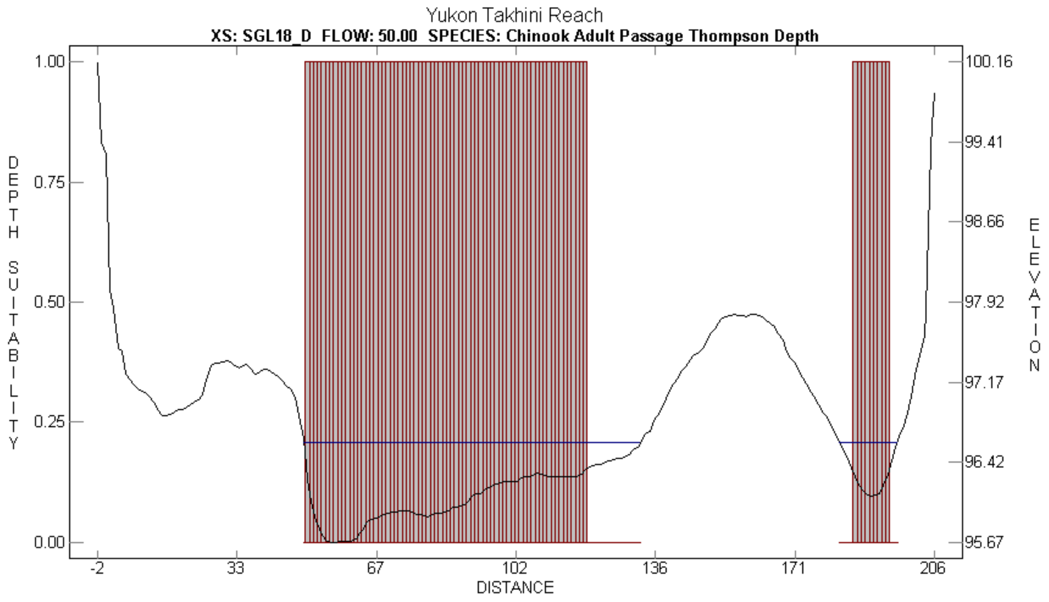

Yukon Takhini Reach
XS: DPL24_I FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.18
98.77
97.35
95.94
94.53
93.11
91.70
-2
18
38
58
79
99
119
DISTANCE

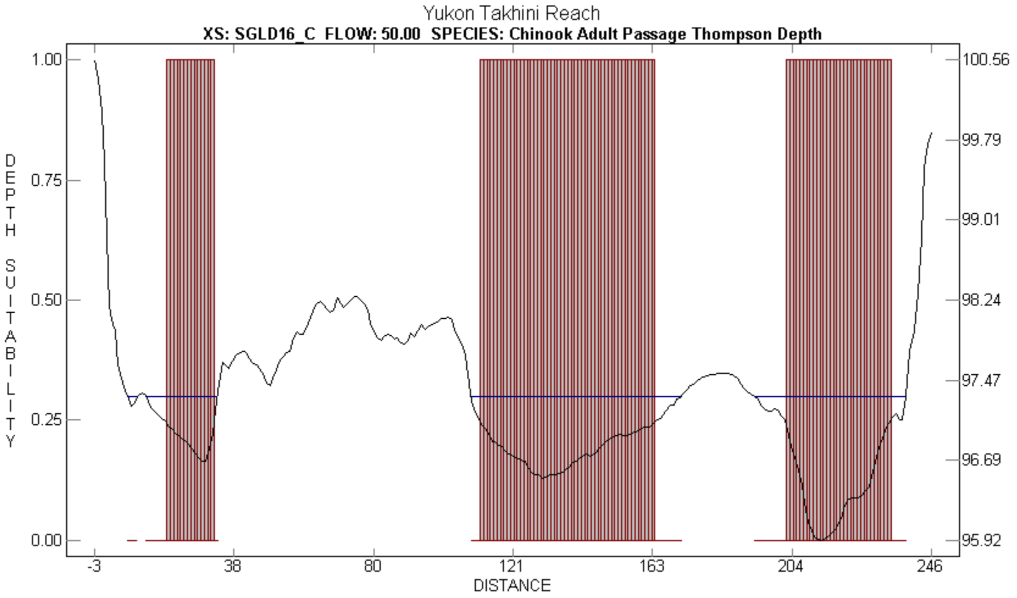

Yukon Takhini Reach
XS: DPL24_H FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.97
98.97
96.96
94.96
92.96
90.95
88.95
-3
19
41
62
84
106
128
DISTANCE

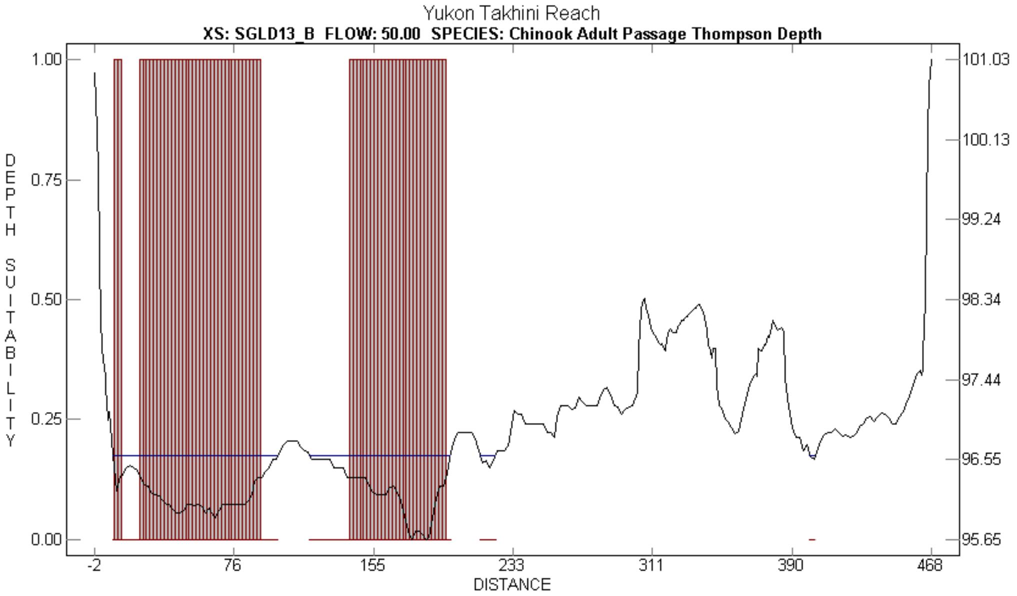

Yukon Takhini Reach
XS: DPL24_G FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.82
99.51
98.19
96.88
95.57
94.25
92.94
-1
30
61
92
122
153
184
DISTANCE

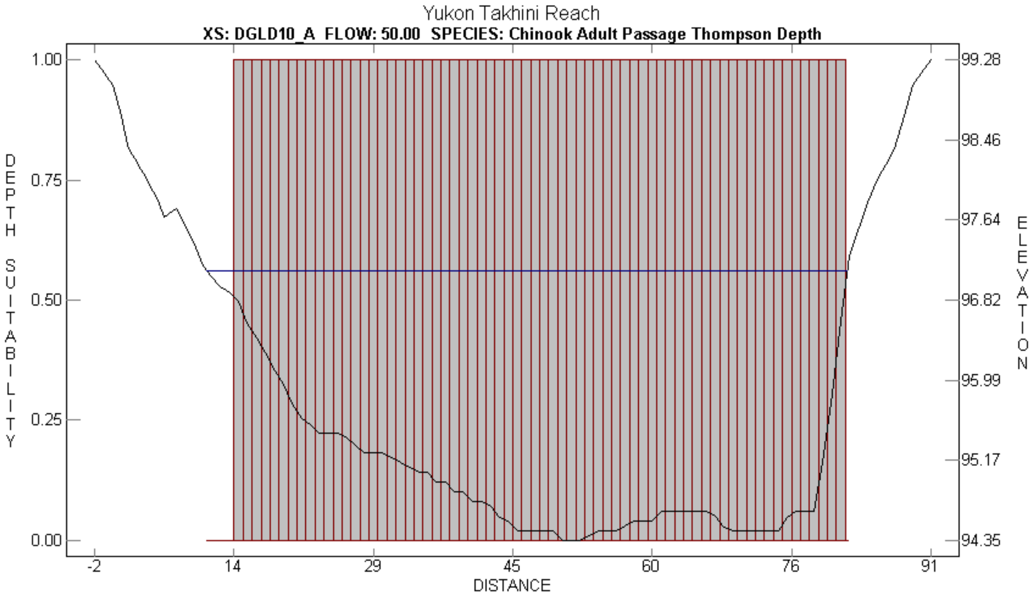

Yukon Takhini Reach
XS: SPL22_F FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
102.00
100.62
99.23
97.85
96.46
95.08
93.70
-8
100
208
316
423
531
639
DISTANCE


Yukon Takhini Reach
XS: SPL21_E FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.12
99.28
98.44
97.61
96.77
95.93
95.09
-1
34
69
104
139
175
210
DISTANCE


Yukon Takhini Reach
XS: SGL18_D FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.16
99.41
98.66
97.92
97.17
96.42
95.67
-2
33
67
102
136
171
206
DISTANCE


Yukon Takhini Reach
XS: SGLD16_C FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
100.56
99.79
99.01
98.24
97.47
96.69
95.92
-3
38
80
121
163
204
246
DISTANCE


Yukon Takhini Reach
XS: SGLD13_B FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
101.03
100.13
99.24
98.34
97.44
96.55
95.65
-2
76
155
233
311
390
468
DISTANCE


Yukon Takhini Reach
XS: DGLD10_A FLOW: 50.00 SPECIES: Chinook Adult Passage Thompson Depth
DEPTH SUITABILITY
1.00
0.75
0.50
0.25
0.00
ELEVATION
99.28
98.46
97.64
96.82
95.99
95.17
94.35
-2
14
29
45
60
76
91
DISTANCE