PROJECT REPORT 2000-7

sustainable forest management network

réseau sur la gestion durable des forêts

Two-dimensional modelling of effluent mixing in the Athabasca River downstream of Weldwood of Canada Ltd., Hinton, Alberta

Gordon Putz and Daniel W. Smith

A Network of Centres of Excellence
Un réseau de centres d'excellence

For copies of this or other SFM publications contact:

Sustainable Forest Management Network
G208 Biological Sciences Building
University of Alberta
Edmonton, Alberta, T6G 2E9
Ph: (780) 492 6659
Fax: (780) 492 8160
http://www.ualberta.ca/sfm/

ISBN 1-55261-065-9

Two-dimensional modelling of effluent mixing in the Athabasca River downstream of Weldwood of Canada Ltd., Hinton, Alberta

Development and Verification of a Two-Dimensional Hydraulic and Kinetic Model for the Prediction of Effluent Transport in Rivers

by

Gordon Putz
Department of Civil Engineering
University of Saskatchewan, Saskatoon, Saskatchewan

and

Daniel W. Smith
Department of Civil and Environmental Engineering
University of Alberta, Edmonton, Alberta

May 2000

ABSTRACT

Field studies to determine the river mixing and potential attenuation in concentration of selected water quality parameters downstream of a pulp mill effluent diffuser are described. The field studies were conducted on the Athabasca River downstream of the Weldwood of Canada Ltd. pulp mill at Hinton, Alberta. The river mixing in the study reach was determined based upon analysis of two tracer tests. A continuous input steady-state fluorescent tracer test and a slug input fluorescent tracer test conducted at the site. Tracer samples collected from the river were used to delineate the pulp mill effluent plume, and to quantify the transverse and longitudinal mixing occurring in the river.

The effluent mixing within the river was successfully simulated utilizing a computer model based upon the Advection Optimized Grid method. Data required to run the model included input concentration conditions, and the hydrometric characteristics of the study reach. Extensive hydrometric surveys were conducted during the field study to provide the required data for the computer model.

Colour and adsorbable organic halide (AOX) samples were collected from the river on the same day as the continuous input tracer test. In this manner, the dilution effects of the river mixing are defined by the tracer test allowing an assessment of any other attenuation of these parameters within the receiving stream. Colour concentrations were at or below detection limits immediately downstream of the mill effluent diffuser. AOX concentrations were close to detection limits. Consequently, the measured river concentrations of both water quality parameters were quite variable.

Despite problems with variability of the AOX concentration measurements in the river the samples indicate AOX persists in the water column in the river for at least 11 km downstream of the diffuser site. Measured AOX levels in the river were much higher than predicted based upon calculations utilizing mass inflow data based upon average daily effluent flow.

ACKNOWLEDGEMENTS

The authors thank Weldwood of Canada Ltd. (JoAnne Volk) for providing access to mill locations, engineering drawings of the diffuser structure, and copies of previous water quality studies. We also thank the graduate students and staff of the Environmental Engineering Group, University of Alberta, and Ifeanyi Odigboh, Division of Environmental Engineering, University of Saskatchewan, for their participation in the 1998 field and laboratory studies. Their assistance and hard work was invaluable. Christine Brodie of the Sustainable Forest Management Network of Centres of Excellence also participated in the fieldwork. Special thanks to Kevin McCullum for organizing the field equipment and compiling much of the raw data. The study was financially supported by the Sustainable Forest Management Network of Centres of Excellence, Minimum Impact Technologies Theme.

INTRODUCTION

The overall purpose of this SFMNCE (Sustainable Forest Management Network of Centres of Excellence) research project is to further verify and develop a two-dimensional, unsteady effluent input, river mixing and transport model. Adaptations to this mixing model can provide the capability to simulate environmental reaction of water quality parameters, within a river, in combination with the river mixing and transport. Therefore, the model can be used to study the transport, mixing and fate of forest industry effluent substances discharged to river systems.

A unique feature of the model is that unsteady effluent input conditions can be accounted for, and that the resulting time-varying, effluent substance concentrations across a stream and in the downstream direction can be predicted. More popular and widely applied water quality models do not have this time-dependent, two-dimensional capability. The need for this type of model and details regarding the numerical method used by the model are described by Putz and Smith (1996), Putz (1996) and Putz et al. (2000).

The first objective of the overall project involved the verification of the river mixing and transport portion of the model using tracer tests conducted at several mill discharge locations. Previous verifications studies of the numerical method used in the model to simulate river mixing were described by Putz and Smith (1998). These studies were based upon tracer tests conducted on several major western Canadian rivers. However, the data available from these tracer tests was limited, as they had not been conducted with the express purpose of model verification. Additional more comprehensive field studies were conducted in August 1997 with support from the SFMNCE. Results of these studies are reported by Putz et al. (2000).

The second objective of the overall project is to adapt the model to predict the fate of selected mill effluent substances within the river environment. Effluent parameters such as colour, COD, AOX and toxic compounds are possible candidates for incorporation into the model. The model can be adapted by incorporating kinetic expressions for environmental reaction of these non-conservative substances into the computer code. Substance concentrations predicted by the model can be compared to measurements taken in the river and adjustments made to the mixing and kinetic coefficients as necessary in order to calibrate the model. Further SFMNCE field studies were conducted in August 1998 on the Wapiti and Athabasca Rivers in order to collect data to address the second objective.

The work conducted on the Athabasca River near Hinton, Alberta downstream of the Weldwood of Canada Ltd. mill site is described in this report. The work conducted on the Wapiti River near Grande Prairie downstream of the Weyerhaeuser Canada Ltd. mill site is described in a companion report (Putz and Smith, 2000).

Athabasca River near Hinton 1998 Field Studies

Background

On August 17 to 21, 1998 field studies were conducted on the Athabasca River near Hinton, Alberta. The field studies consisted of hydrometric surveys, two tracer tests, and water quality sampling conducted on a reach of the Athabasca River downstream of the Weldwood of Canada Ltd. pulp mill site. The primary intent of the field studies was to conduct a steady state tracer test and simultaneously sample for selected water quality parameters downstream of a pulp mill effluent discharge. In this manner, the attenuation of effluent parameters can be assessed against a well-defined mixing regime. The second intent of the work was to conduct a slug tracer test to further assess the capability of the mixing model to simulate transient input conditions.

Planning for the Athabasca River field tests progressed through the spring and early summer of 1998. Air photos, maps, historical discharge data and past cross section surveys for the river reach were obtained from Alberta Environmental Protection and Water Survey of Canada. In addition, engineering drawings of the effluent pipeline and diffuser structure and previous mixing studies on the river were obtained from Weldwood of Canada Ltd. All this information was required to plan the details of the tracer tests such as the location of the tracer injection point, quantities of tracer required, tracer flow rates, location of sampling sections, sampling schedules, numbers of boats and sampling crews, etc. The background information was also required for a preliminary assessment of the length of the two-dimensional mixing zone and to prepare an application to Alberta Environmental Protection for permission to conduct the tracer tests.

As part of the planning process, water quality data on the mill effluent was also obtained from Weldwood of Canada Ltd. The effluent data was reviewed to select water quality parameters for sampling in the river. The intention was to pick water quality parameters that would remain above detection limits for some distance downstream of the discharge point. In addition, parameters were chosen which would potentially react within the river system and decrease in concentration in comparison to the mass conservative tracer. After reviewing the effluent data, and estimating the immediate dilution at the diffuser with the anticipated river flow for late August (approx. 354 m^3/s), colour and AOX (adsorbable organic halide) were selected for sampling and analysis. The colour levels in the effluent plume were however expected to be very close to the limits of detection.

Objectives of the 1998 Wapiti River field studies

The initial objectives of the 1998 field studies on the Athabasca River downstream of the Weldwood of Canada Ltd. mill site were:

- Conduct a continuous input fluorescent tracer test to document the steady-state transverse mixing occurring in approximately a 20 km reach downstream of the diffuser structure.
- Conduct a slug input fluorescent tracer test to characterize the time dependent transverse mixing and transport occurring in a 30 km reach downstream of the diffuser structure.
- Conduct hydrometric surveys to obtain sufficient data to construct a mixing model of the river reach.
- Model the river mixing of the tracer input for the continuous input and slug input conditions.
- Sample the river reach for colour and AOX in conjunction with the continuous input tracer test.
- Assess the river concentrations of the water quality parameters in comparison to the tracer concentrations in order to identify any attenuation other than the mixing process.
- Attempt to model the water quality parameters in the reach accounting for river mixing and attenuation mechanisms.

The anticipated flow for early August, based upon analysis of Water Survey of Canada records, was approximately 354 m^3/s. Actual flow during the fieldwork was in the range of 334 to 365 m^3/s. Travel on the river during the fieldwork utilizing the prop survey boats available was generally possible. However, caution had to be exercised in the shallower sections of the river. The water level dropped as the work progressed causing travel downstream of 20.6 km to become quite difficult due to a significant rapids section. Consequently, the length of the study reach for the slug test was restricted to approximately 20.6 km downstream of the Weldwood of Canada Ltd. diffuser structure. This distance avoided the more challenging and potentially dangerous rapids sections located further downstream.

RIVER MIXING AND MASS BALANCE

Most rivers have a large width to depth ratio. Therefore, dissolved substances will rapidly become uniformly mixed in the vertical direction (over depth) in comparison to the transverse (across stream) and longitudinal (downstream) directions (see Putz et al., 2000 for a overview description of the mixing processes). Hence, for most situations a two-dimensional, depth-averaged description of the mixing and transport in a river is appropriate.

The mixing, transport and in-stream reaction of a neutrally buoyant, non-conservative substance in the transverse mixing zone can be described by the following mass balance equation (see Putz, 1996 for derivation of this equation, see Figure 1 for the coordinate system definition):

$$\frac{\partial}{\partial t}(hc) + \frac{\partial}{\partial x}(huc) = \frac{\partial}{\partial z}\left(hE_z \frac{\partial c}{\partial z}\right) + hR \qquad [1]$$

in which x is the longitudinal direction, z is the transverse direction, c is depth-averaged concentration, u is local depth-averaged velocity in the longitudinal direction, h is the local depth and E_z is the transverse mixing coefficient. The second term on the left of [1] represents advective mass transport in the longitudinal direction. The first term on the right represents diffusive transport across the stream. The general term R represents an in-stream reaction rate expression. For example, if the reaction rate was first order R could be replaced by Kc where K would be a first order rate constant.

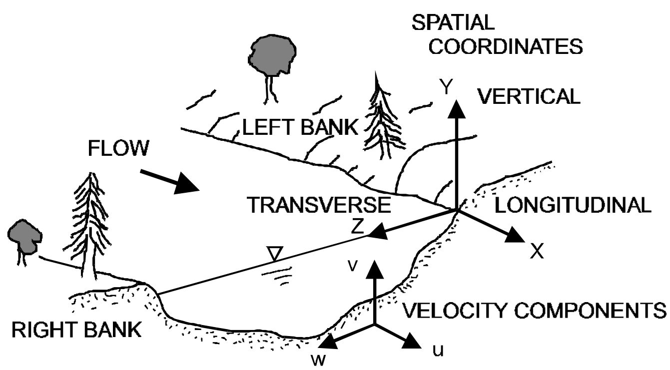


Figure 1 Coordinate system for mixing analysis.

The magnitude of the transverse mixing coefficient E_z represents the amount of mixing which occurs or how quickly an effluent plume will spread across a channel. It is generally given by an expression in the form[1]:

$$E_z = \beta L \Omega \qquad [2]$$

where L is a length scale representative of the mixing length or eddy size, Ω is a velocity scale representative of the level of turbulence, and β is the dimensionless transverse mixing coefficient. The length scale is generally taken to be the local depth h, or the channel average

[1] See Putz (1996) for a review of the development of this expression and methods for estimating E_z.

stream depth H. The velocity scale is generally taken to be the local shear velocity u* or the channel average U* given by the expression:

$$u^* = \sqrt{g\,r\,S} \quad \text{or} \quad U^* = \sqrt{g\,R\,S} \qquad [3]$$

where g is the gravitational constant, r is the local hydraulic radius, R is the channel average hydraulic radius, and S is the slope of the energy grade line (slope of the water surface for uniform flow). The dimensionless transverse mixing coefficient β is used to characterize the mixing in a river reach. If β is known, or can be estimated, then E_z can be determined with [2] using the appropriate value of the length and velocity scale for a particular location on the river.

Frequently a streamtube approach employing a transformation of the transverse coordinate z, to cumulative flow q is utilized in mixing analysis and modelling (see Yotsukura and Cobb, 1972). Cumulative flow is determined as follows:

$$q_{(z)} = \int_0^z uh\,dz \qquad [4]$$

where z = 0 represents the left bank (looking downstream) as shown in Figure 2; and u is the depth averaged velocity in the direction of flow. At the right bank z = W, the total stream width, and q = Q, the total stream discharge. Transverse coordinates are then expressed as a dimensionless q/Q ratio, where q/Q=0 is the left bank and q/Q=1 is the right bank.

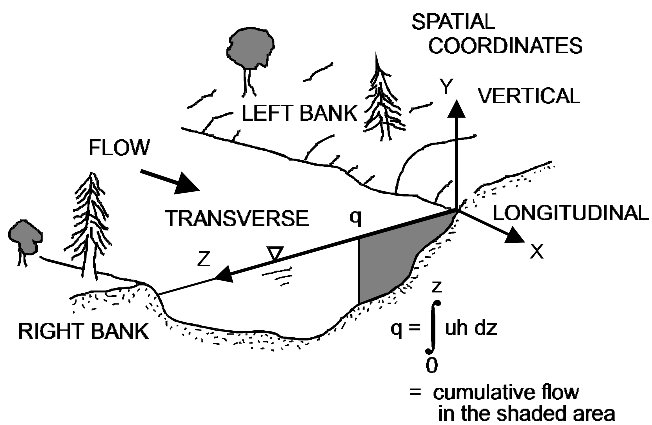


Figure 2 Transverse coordinate transformation.

The q transformation converts the plan view of a natural stream of variable width to a simple rectilinear form of constant width Q. A line of constant q along the stream represents a streamline and adjacent lines of constant q define a streamtube. There is no average flow across a streamline and therefore there is no depth-averaged transverse advection across streamlines. In the derivation of [1] the term representing transverse advective transport is omitted based upon an order of magnitude argument (see derivation in Putz, 1996). The adaptation of a streamtube approach for representation of the river flow and the use of this concept in the numerical solution further justifies not including a transverse advective term in [1].

A tracer test allows accurate definition of the river mixing (i.e. dilution effects) described by the advection and diffusion terms of [1]. Analysis of tracer test results will define the transverse mixing coefficient along a river study reach. The transverse mixing coefficient, combined with hydrometric survey data, allows a mathematical model of the river mixing to be constructed. The model can then be utilized for mixing simulations in the reach (see Odigboh, 1999 for a description of this process for the SFMNCE tracer tests conducted in 1997).

Water quality samples collected during a tracer test can be assessed relative to the tracer concentrations to determine if specific parameters are non-conservative. The mass recovery of a non-conservative parameter as a function of distance or travel time downstream of a discharge point can then be used as an aid to ascertain the form of the reaction equation. Mass balance analysis for several water quality parameters in the Athabasca River is described in this report.

SITE CHARACTERIZATION

Introduction

The study reach is located downstream of the Weldwood of Canada Ltd. effluent diffuser structure on the Athabasca River near Hinton, Alberta. A plan view of the study reach is shown in Figure 3.

The river discharge encountered during the field survey and tracer tests was very close to seasonal norms. The average flow at Hinton during August based upon Water Survey of Canada records (1961-1995) is 354 m^3/s. The estimated 30Q10 flow under ice-covered conditions is 22 m^3/s based upon Water Survey of Canada records.

Hydrometric Data

Cross-section Surveys

Extensive hydrometric surveys of the study reach were conducted on August 18 to 19, 1998. Twenty six cross sections were established and surveyed. The cross section locations in relation to the Weldwood diffuser structure were measured using Global Positioning System (GPS) equipment. Once the position of each section was located on a map the distance downstream of the diffuser was determined by scaling the distance along the river channel. The location of each section and its distance downstream of the diffuser is shown in Figure 3. Depths across each cross section were measured using echo sounding equipment. The positions of the depth measurements were determined by simultaneous GPS measurement of the sounding boat location. A summary of the section characteristics measured on August 18, 1998 is given in Table 1.

Detailed cross section tabulations and plots were prepared for each section for the date on which each tracer tests was conducted (August 19 and 20, 1998). This required minor adjustments of the survey measurements to account for the change in river flow between the survey date and the test date. These tabulations were then used to prepare data files for the mixing simulations. An example of a detailed tabulation and plot is shown in Table 2 and Figure 4. A complete set of cross section tabulations and plots for the study reach for August 19, 1998 is presented in Appendix A.

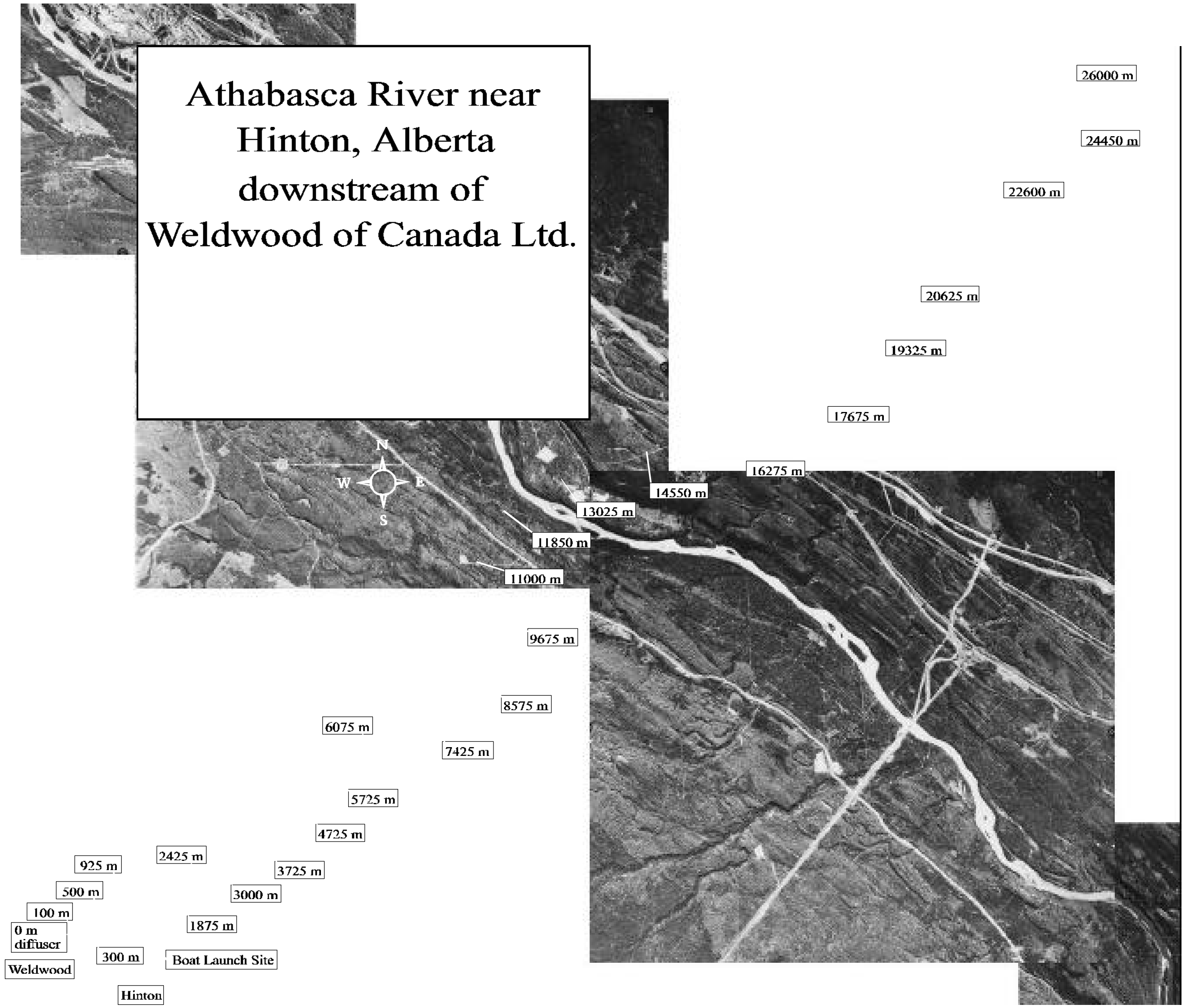


Figure 3 Athabasca River study reach downstream of the Weldwood of Canada diffuser.

Table 1 Summary of cross section characteristics and flow.

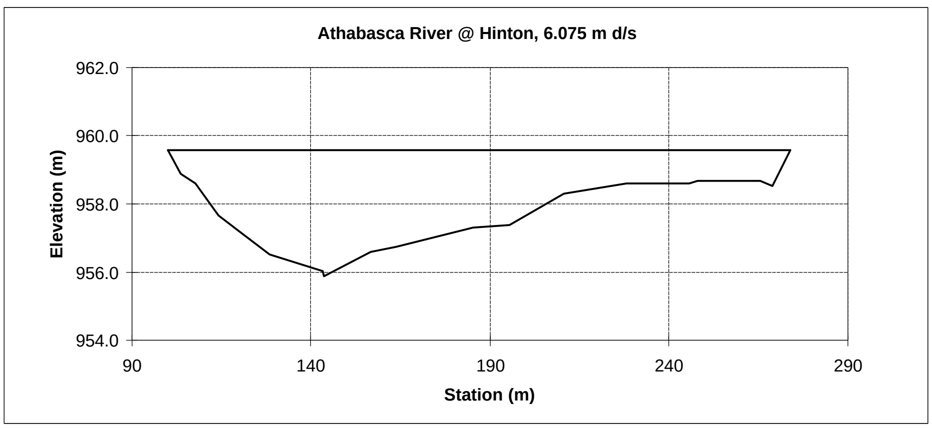
Cross Section (distance d/s) (m)	River Width (m)	Avg. Depth (m)	Avg. Velocity (m/s)
0	106	2.26	1.51
100	102	2.88	1.23
300	100	2.60	1.40
500	162	1.58	1.42
925	202	1.13	1.61
1875	147	2.33	1.06
2425	137	2.58	1.03
3000	185	1.06	1.85
3725	192	1.61	1.18
4725	158	1.68	1.38
5725	170	1.83	1.18
6075	174	1.90	1.10
7425	225	1.40	1.16
8575	75	3.43	1.42
9675	120	2.06	1.47
11000	136	1.92	1.39
11850	134	2.21	1.23
13025	232	1.37	1.15
14550	157	1.72	1.34
16275	151	1.88	1.28
17675	152	2.71	0.88
19325	177	1.62	1.17
20625	195	1.87	1.00
22600	122	1.54	1.95
24450	139	2.04	1.29
26000	114	1.68	1.90
Average	147	1.88	1.28

Note: The section characteristics shown are for August 18 (Q = 365 m^3/s). All characteristics were adjusted to the estimated flow of 363.6 m^3/s during the continuous tracer test and water quality sampling, and to 334 m^3/s the flow during the slug test.

Table 2 Example cross section tabulation.

X-SECTION	Athabasca River @ Hinton, 6.075 m d/s		
DATE	August 19, 1998		
DISCHARGE m3/s	363.60		
WIDTH m	173.96	Est. Water Surface Elev.	959.58
MEAN DEPTH m	1.90	LB 100.02	959.58
AREA m^2	330.27	RB 273.97	959.58
MEAN VELOCITY m/s	1.101		

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.02	959.58	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
103.70	958.89	0.70	0.021	0.565	0.36	0.00088	1.3	0.498
107.74	958.60	0.99	0.044	0.711	2.17	0.00615	4.7	0.627
114.14	957.67	1.92	0.081	1.108	8.44	0.02663	14.0	0.977
119.60	957.24	2.35	0.113	1.268	13.84	0.06019	25.6	1.118
128.43	956.52	3.06	0.163	1.52	33.26	0.14084	49.5	1.34
143.32	956.02	3.57	0.249	1.68	78.76	0.33183	98.9	1.48
143.63	955.88	3.71	0.251	1.72	1.92	0.33649	100.0	1.52
156.67	956.59	2.99	0.326	1.49	70.16	0.50663	143.7	1.31
163.88	956.74	2.85	0.367	1.44	30.93	0.58163	164.8	1.27
185.32	957.31	2.28	0.490	1.24	73.79	0.76055	219.7	1.10
195.63	957.38	2.20	0.550	1.22	28.38	0.82937	242.8	1.07
210.76	958.31	1.27	0.637	0.84	27.08	0.89505	269.1	0.74
228.21	958.60	0.99	0.737	0.71	15.30	0.93215	288.8	0.63
245.68	958.60	0.99	0.837	0.71	12.24	0.96182	306.0	0.63
248.00	958.67	0.91	0.851	0.68	1.53	0.96554	308.2	0.60
265.61	958.67	0.91	0.952	0.68	10.88	0.99191	324.3	0.60
268.96	958.53	1.06	0.971	0.75	2.35	0.99761	327.6	0.66
273.97	959.58	0.00	1.000	0.00	0.99	1.00000	330.3	0.00
				Est. Total	412.38			



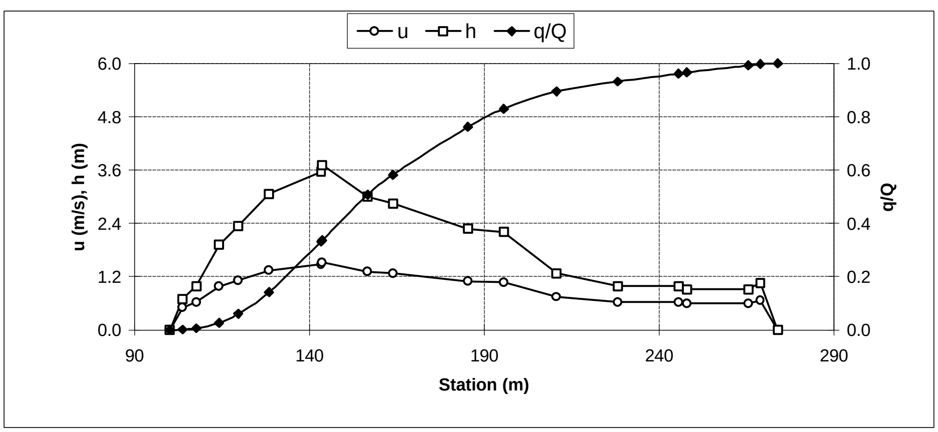


Figure 4 Example cross section plot.

Channel Slope

The slope of the water surface through the study reach was determined using elevation measurements taken using GPS equipment. Approximately 12 to 15 individual measurements of the water surface were recorded at each section as the depth soundings were conducted. The average of these measurements at each section versus distance is plotted in Figure 5. The slope upstream of 20.6 km is approximately 0.0008 m/m as indicated by the regression line shown in Figure 5. The figure also clearly indicates a significant increase in river slope downstream of 20.6 km in the region of the river that became dangerous for boat travel as the water level dropped.

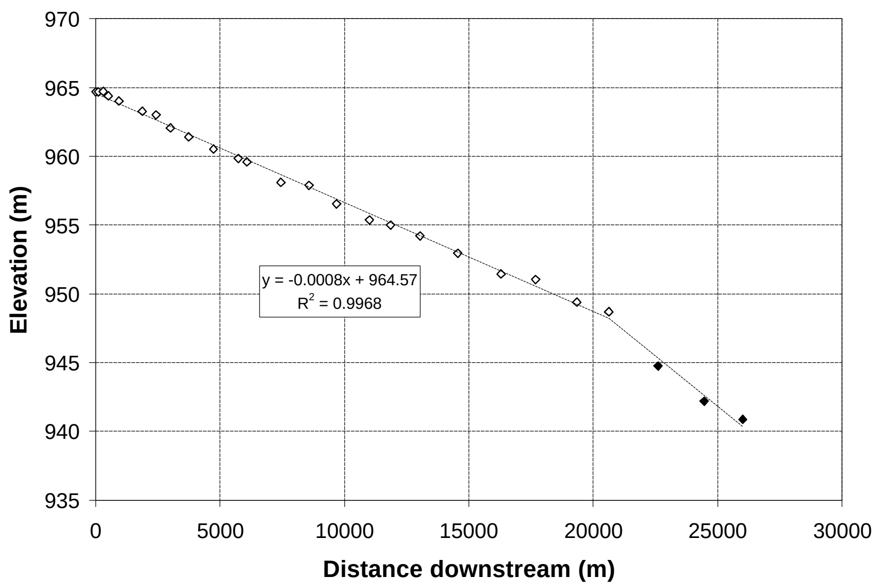


Figure 5 Water surface elevation versus distance.

Velocity and Discharge

Environment Canada monitors flow and water level in the Athabasca River at a gauging station located approximately 500 m downstream of the Weldwood diffuser structure. As part of the hydrometric surveys river discharge was measured at four cross sections. Velocity measurements were taken across each of the sections using a standard Price current meter suspended with a cable and weight from the survey boat. Whenever possible the survey boat was anchored during these measurements. However, in some instances the boat had to be held against the current using the motor. A sufficient number of measurements were taken across each section to allow a reasonably accurate estimate of the discharge (10 locations in most cases). The position of the boat was determined by GPS measurement. The results of these discharge measurements are shown in Table 3. The average daily gauge reading reported during each the flow measurement is also shown in Table 3. The discrepancy between the gauge reading and the field measurements is less than 10%. These results indicate the gauge readings are representative of the entire study reach.

Table 3 Discharge measurements compared to gauge readings

Cross Section	Date Measured	Q m^3/s measured	Q m^3/s gauge*	% difference
1875	Aug 20	331	334	-0.9
2425	Aug 21	317	320	-0.9
6075	Aug 19	332	364	-8.8
17675	Aug 18	330	365	-9.6

* average daily discharge indicated by the Water Survey of Canada gauge at Hinton

A velocity distribution was synthesized across each cross section using Manning's equation, average depth H, local depth h, and average velocity U.

$$u = \frac{1}{n} r^{2/3} S^{1/2} \quad \text{and} \quad U = \frac{1}{n} R^{2/3} S^{1/2} \quad \therefore \quad u = U\left(\frac{h}{H}\right)^{2/3} \qquad [5]$$

H and U are determined utilizing the cross section area A and width W from hydrometric surveys and the total river flow Q. An example plot comparing measured and synthesized velocities across a section is shown in Figure 6. For most of the sections the measured and synthesized velocities are in reasonable agreement.

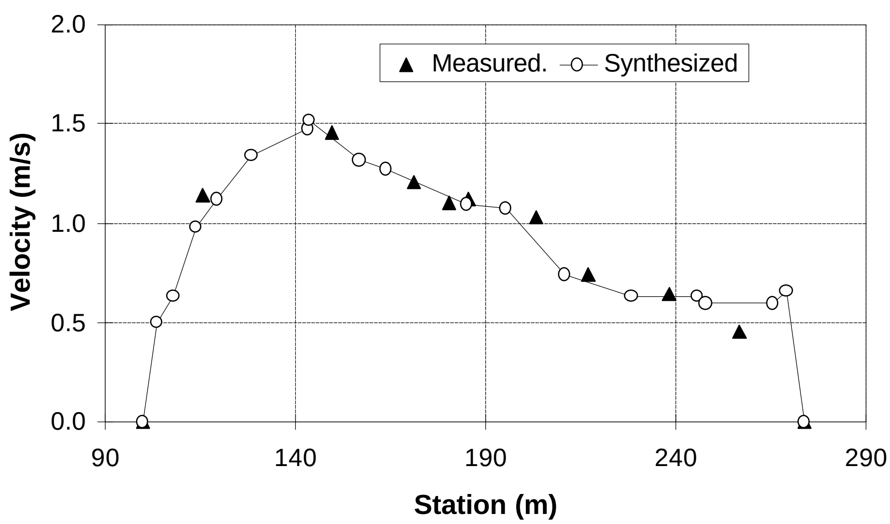


Figure 6 Measured and synthesized velocity distribution at 6075 m downstream.

Synthesized velocities and local depths were used to estimate the q distribution at each section according to [4] (see Putz, 1983 or Odigboh, 1999 for details of this procedure). A tabulation and plot of local velocity u, and dimensionless cumulative flow q/Q was prepared for each cross section for the day of the tracer test (see Table 2 and Figure 4, and Appendix A).

TRACER TESTS

Introduction

A continuous input, fluorescent tracer test was conducted on August 19, 1998 downstream of the Weldwood of Canada Ltd. effluent diffuser structure. The tracer was injected into the mill effluent stream in order to delineate the effluent plume in the river. Samples were collected at established cross sections up to a distance of 17.7 km downstream of the diffuser. Beyond this distance, the tracer was expected to be fully mixed with the river flow.

In addition a slug input, fluorescent tracer test was conducted on August 20, 1998. For this test the tracer was injected directly into the river near the diffuser. Samples were collected at four cross sections downstream of the diffuser (4.7 km, 11.9 km, 16.3 km, 20.6 km).

A summary of the tracer input conditions for each test, sampling procedures and analysis results is presented in this section of the report.

Input Conditions

The continuous input of tracer consisted of injection of 20% Rhodamine WT fluorescent dye into the mill effluent stream at a volumetric flow rate of 78 mL/minute. The tracer was pumped into at a head tank located at the entrance to the diffuser structure. The tracer then entered the river with the mill effluent through the submerged diffuser. The diffuser is about 15 m long, oriented approximately perpendicular to the river flow, and extends into the flow from the south bank of the river. The effluent is discharged through six nozzles at the riverbed spaced at approximately 3 m intervals. The effluent initially mixed with approximately 37% of the river flow over 14% of the channel width for the prevailing flow conditions.

A sufficiently long period of continuous injection was maintained in order to establish a ‘window’ of steady-state concentration conditions at each cross section during sampling. A summary of the input conditions for the continuous input tracer test is presented in Table 4.

Table 4 Summary of input conditions for continuous input tracer test.

q_{in} (m^3/s)	C_o ($\mu g/L$)	Duration (hours)	Q (m^3/s)	$C_{background}$ ($\mu g/L$)	C_∞ ($\mu g/L$)
1.3×10^{-6}	2.3×10^{8}	5.25	363.6	0.05	0.82*

* In excess of the background concentration

In Table 4 C_∞ represents the fully mixed tracer concentration in the river flow (in excess of background levels). C_∞ is given by the expression:

$$C_\infty = q_{in} C_o / (Q + q_{in}) \approx q_{in} C_o / Q \quad \text{for } q_{in} << Q \qquad [6]$$

where q_{in} is the tracer input flow, C_o is the tracer input concentration and Q is the total river flow. The background concentration in the river was determined based upon samples taken from upstream of the diffuser structure.

The slug input test consisted of a rapid direct injection of 10 litres of 20% Rhodamine WT fluorescent dye (2.30 Kg. of fluorescent component). The dye was dumped at the diffuser location near the first nozzle outlet closest to the right bank. The injection position was recorded using GPS equipment. The injection time was 9:24 a.m. on August 20, 1998.

Sampling Procedure and Analysis

During the continuous input tracer test, samples were taken at each cross section within the steady-state concentration 'window'. The position of each sample was recorded using GPS equipment as the survey boat traversed across a section. Samples were taken approximately 0.3 metres below the water surface and collected in 150 mL plastic bottles. The sample bottles were immediately placed in a cooler container to isolate them from sunlight. The samples were stored in the coolers until they were transported to Edmonton on August 21 for analysis using a Turner Designs fluorometer.

During the slug test, the passage of the dye cloud was sampled at four cross sections downstream of the diffuser. At 11.9 km and 20.6 km the sections were traversed and sampled approximately twelve times during the expected passage of the dye cloud. At 4.7 km and 16.3 km a survey boat without GPS equipment was anchored at one position within the stream, and samples taken at equal time intervals during the expected passage of the dye. The sampling period at each section was scheduled to begin before the dye cloud arrived and was to continue until the extent of the cloud had passed. As for the continuous test, samples were taken approximately 0.3 metres below the water surface and collected in 150 mL plastic bottles. The sample bottles were immediately placed in a cooler container to isolate them from sunlight. The samples were stored in the coolers until they were transported to Edmonton on August 21 for analysis using a Turner Designs fluorometer.

Tracer Measurement Results

Continuous Input Tests

The results of the tracer measurements are shown in Figure 7. The horizontal axis of each plot represents dimensionless cumulative flow, q/Q, where q is the flow accumulated from the left bank (looking downstream) and Q is the total stream flow. The vertical axis represents non-dimensional concentration C' given by:

$$C' = c/C_{\infty} \qquad [7]$$

where, c is a normalized measured concentration and C_{∞} is the fully mixed concentration of the tracer mass within the river flow. Note that the fully mixed condition expressed in terms of dimensionless concentration is C' = 1. Both c and C_{∞} represent concentrations in excess of background readings. The background and fully mixed tracer concentration are given in Table 4.

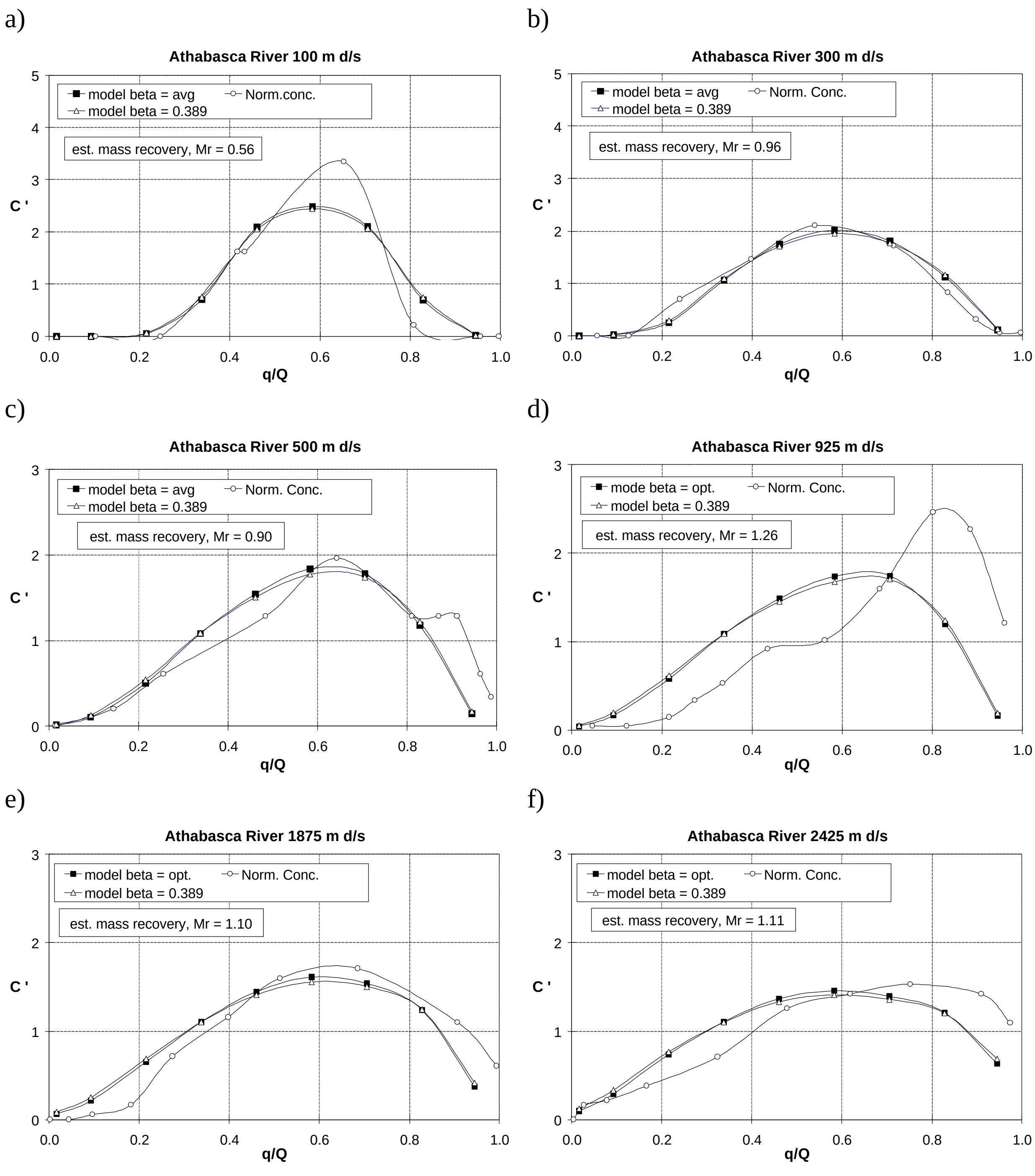
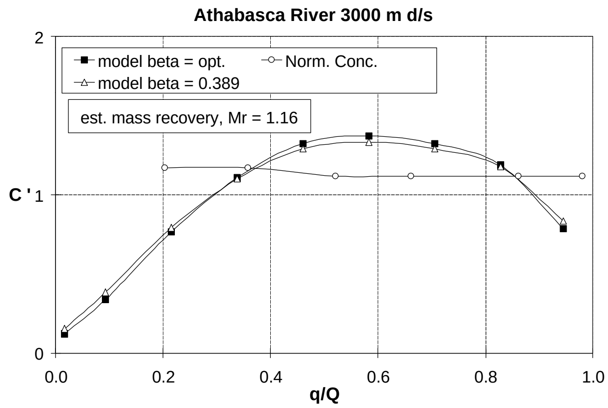
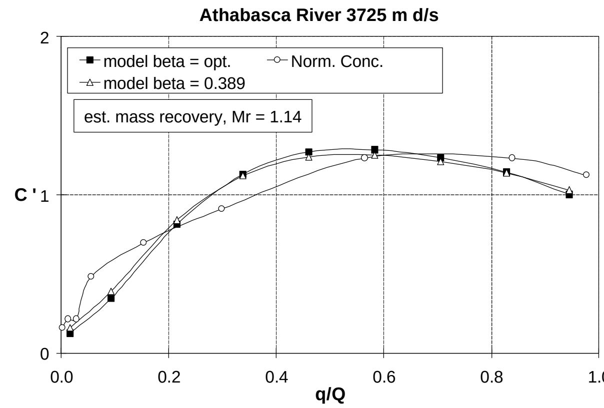


Figure 7 Normalized dimensionless tracer concentration versus q/Q.

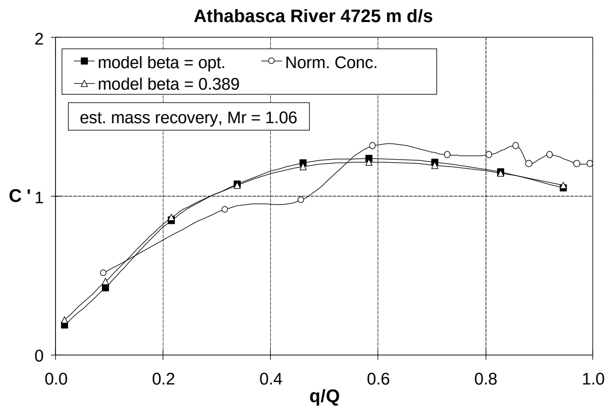
g)



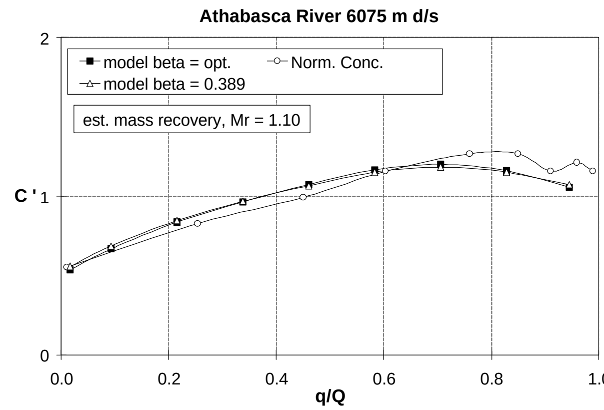
h)



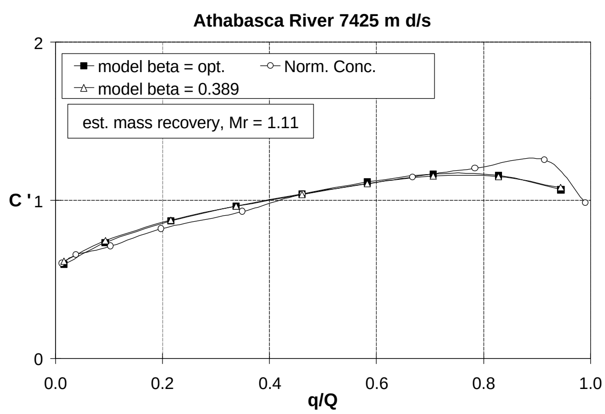
i)



j)



k)



l)

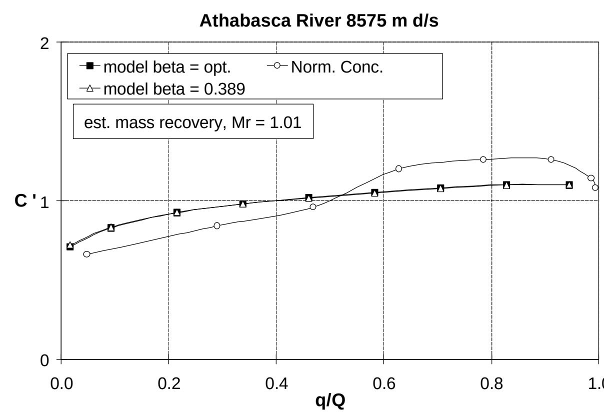
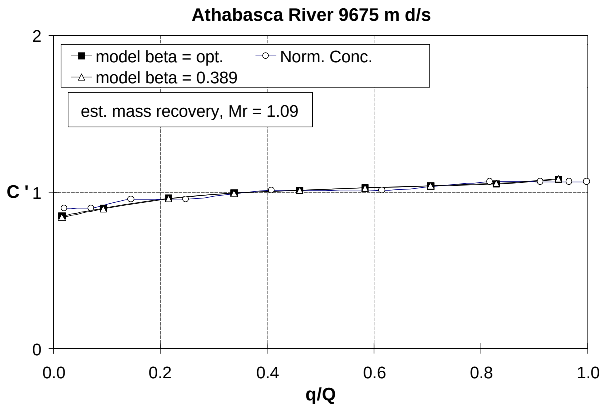
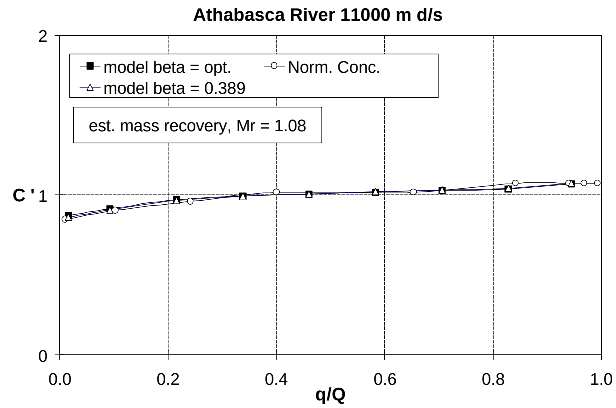


Figure 7 cont. Normalized dimensionless tracer concentration versus q/Q.

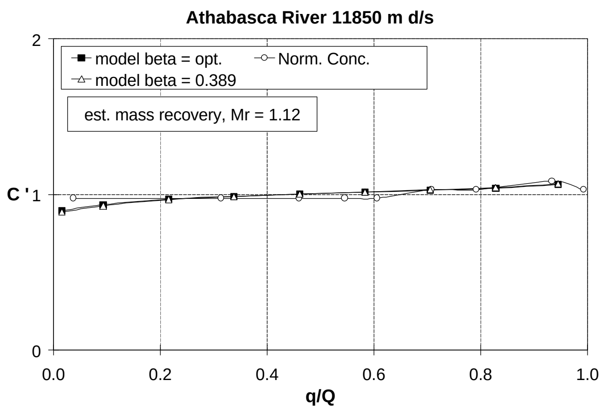
m)



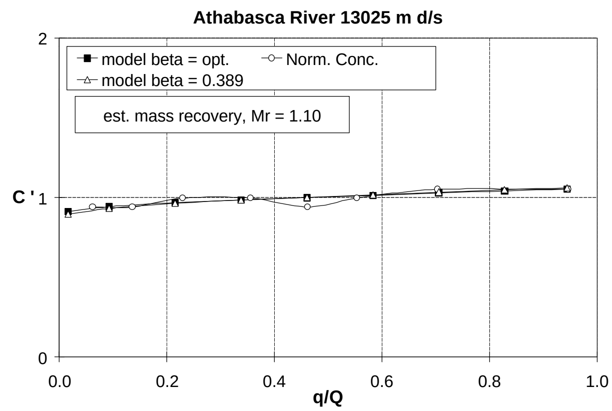
n)



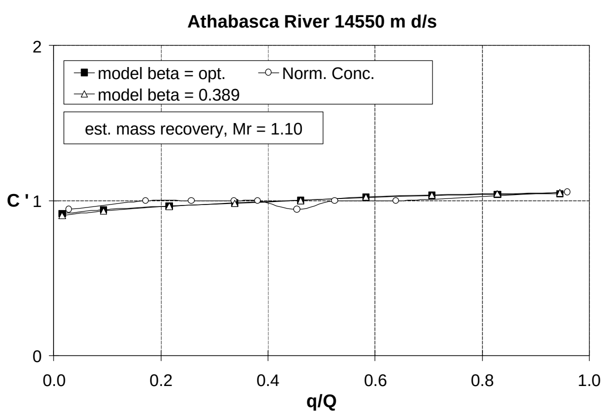
o)



p)



q)



r)

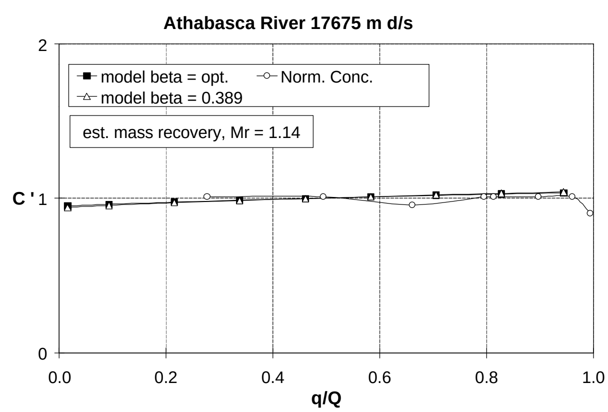


Figure 7 cont. Normalized dimensionless tracer concentration versus q/Q.

The tracer concentrations are normalized to adjust for small inaccuracies in tracer mass recovery at individual sections. The normalized curves act as a benchmark indicating the concentration distribution of a completely mass conservative substance at each section. Individual tracer measurements are normalized by dividing them by the mass recovery ratio at an individual section. The mass recovery ratio (Mr) at each section was determined by integrating the measured dimensionless tracer concentration versus cumulative flow curve. The tracer mass recovery ratio at each section is given in **Error! Not a valid bookmark self-reference.** and also in the upper left corner of each plot in Figure 7. Note a value of 1.0 for Mr represents 100% mass recovery.

Complete vertical mixing of effluent is generally assumed to occur within a short distance (approximately 100 river depths) downstream of a discharge point. The river depth in the vicinity of the diffuser is approximately 4 to 4.5 m. Since the tracer samples were collected approximately 0.3 m below the water surface the tracer recovery of only 56% at the 100 m downstream is an indication of incomplete vertical mixing. The tracer recovery at 300 m and 500 m is 96% and 90% respectively. Therefore, it appears a distance of approximately 100 depths is sufficient for complete vertical mixing at this site.

Excluding the first section, the tracer recoveries range from 90 to 126% along the rest of the study reach (see **Error! Not a valid bookmark self-reference.**). The majority of the tracer mass recoveries are about 10% more than the injected mass flow (the average tracer recovery excluding the first section is 109%). This percentage error is somewhat higher than experienced in similar tracer tests (see Putz et al., 2000; Putz and Smith, 2000). The high recoveries possibly indicate over estimation of the total river flow based upon the stage discharge relationship at the gauging station. Another possibility is that the tracer solution as supplied by the manufacturer may have been slightly greater than the specified 20% fluorescent content. Unfortunately, the supplied concentration was not verified.

An anomalous result for the tracer measurements occurs at 925 m downstream. This section is located immediately downstream of a logging road bridge, in a wide, shallow, swiftly flowing stretch of the river. The tracer recovery at this section is 126%. This magnitude of error cannot be explained by minor inaccuracies in the river discharge estimation or the strength of the tracer feed solution. Error in estimation of the flow distribution synthesis at this difficult section may contribute to the recovery error. However, this potential source of error and those mentioned above cannot explain how the peak concentration at 925 m downstream can exceed that at 300 m and 500 m downstream. The increase in peak concentration is even more pronounced than shown in Figure 7(b) (c) and (d) since these plots utilize normalized concentrations. Two possible explanations are: 1) the samples near the right bank at 925 m were contaminated during handling, or 2) there is an additional source of fluorescence entering the river independent of the tracer input.

The tracer measurements indicate the transverse mixing downstream of the effluent diffuser progresses relatively rapidly. At cross section 11.0 km (see Figure 7(n)) the tracer is almost completely mixed with the river flow. Beyond this distance, one-dimensional mixing conditions are applicable.

Table 5 Tracer mass recovery ratios for continuous input tracer test.

Cross Section (m)	Ratio
100	0.56
300	0.96
500	0.90
925	1.26
1875	1.10
2425	1.11
3000	1.16
3725	1.14
4725	1.06
6075	1.10
7425	1.11
8575	1.01
9675	1.09
11000	1.08
11850	1.12
13025	1.10
14550	1.10
17675	1.14
Average[a]	1.09

[a] average excludes recovery at section 100 m

Slug Input Test

The results of the tracer measurements for the slug test are plotted using two different approaches. The first approach is shown in Figure 8 for the cross sections that were repeatedly traversed during the passage of the tracer cloud (i.e. 11.6 and 20.9 km). The vertical axis in these plots represents normalized dimensionless dosage. Analysis of slug input tests using the dosage concept was developed by Beltaos (1975). Plots of normalized dimensionless dosage versus cumulative flow are analogous to plots of normalized C' versus q/Q for the continuous input tests.

The mass recovery ratio for each section that was repeatedly traversed during the slug test is given in the upper left corner of the individual plots shown in Figure 8. The average mass recovery for the two sections is 0.94. Note the average mass recovery is lower that for the continuous input tests. In the continuous input tests the steady-state conditions likely allow saturation of tracer adsorption sites on the bottom sediments of the river. Hence, when the samples are taken from the water column there is near complete mass recovery. In the slug test the exposure of the tracer to the bottom sediments is transient and it is likely some tracer is lost to bottom sediments.

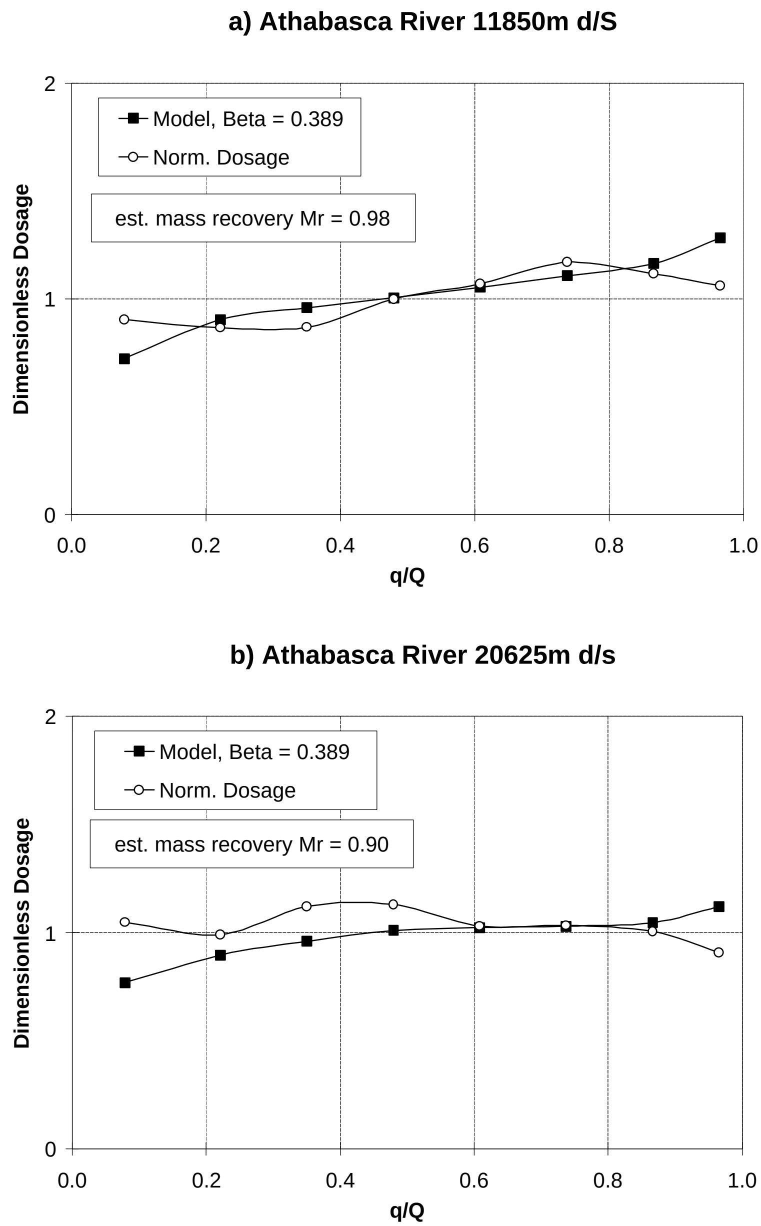


Figure 8 Normalized dosage versus q/Q.

The second approach for showing the results of the slug test is to plot the tracer measurements as a concentration versus time series (c-t curves) for selected q/Q locations across each section. The concentration time series at a particular q/Q location is interpolated from the aggregate sample measurements using the GPS position and time stamp information. The q/Q locations selected for interpolation were chosen to correspond with the output locations of the modelling procedure (see the next section). This selection of interpolation locations facilitates comparison of the measurements and the model results. The concentration versus time plots for measurements at each section sampled during the slug test are presented in Figure 9 to Figure 12.

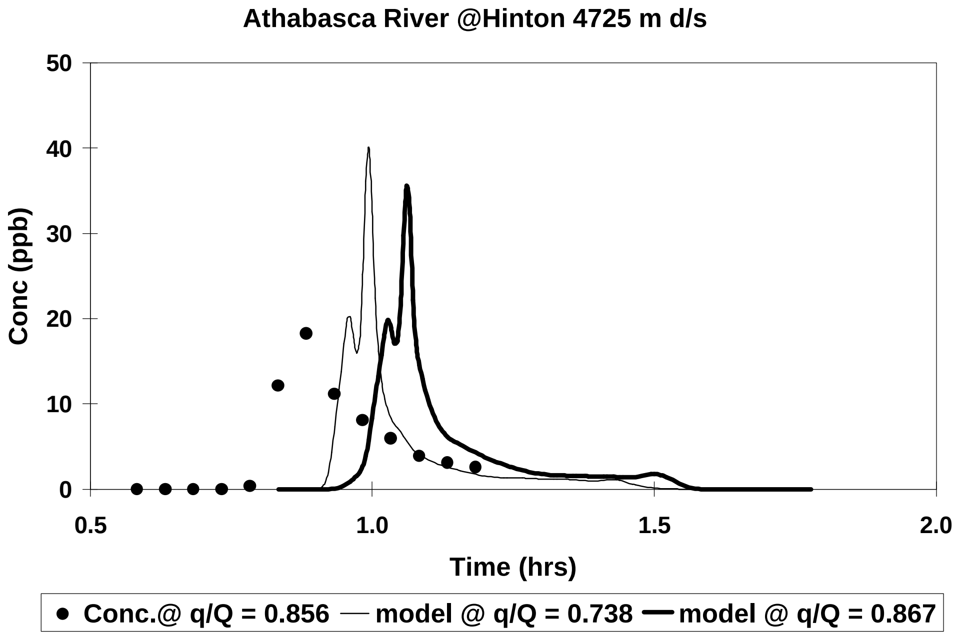


Figure 9 Athabasca River, c-t curve at 4725 m, 334 m^3/s, slug input.

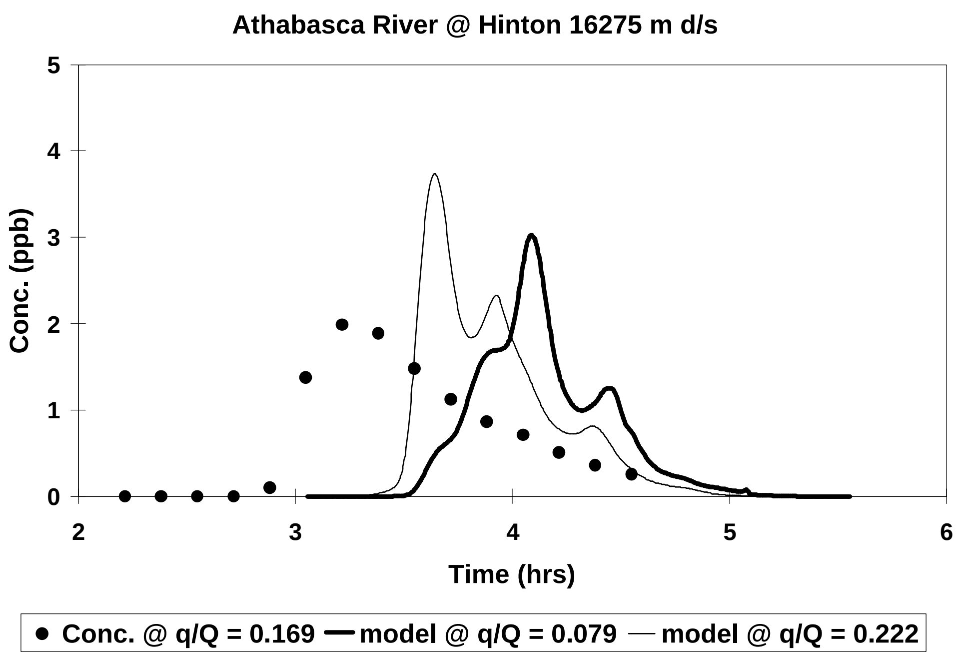


Figure 10 Athabasca River, c-t curve at 16275 m, 334 m^3/s, slug input.

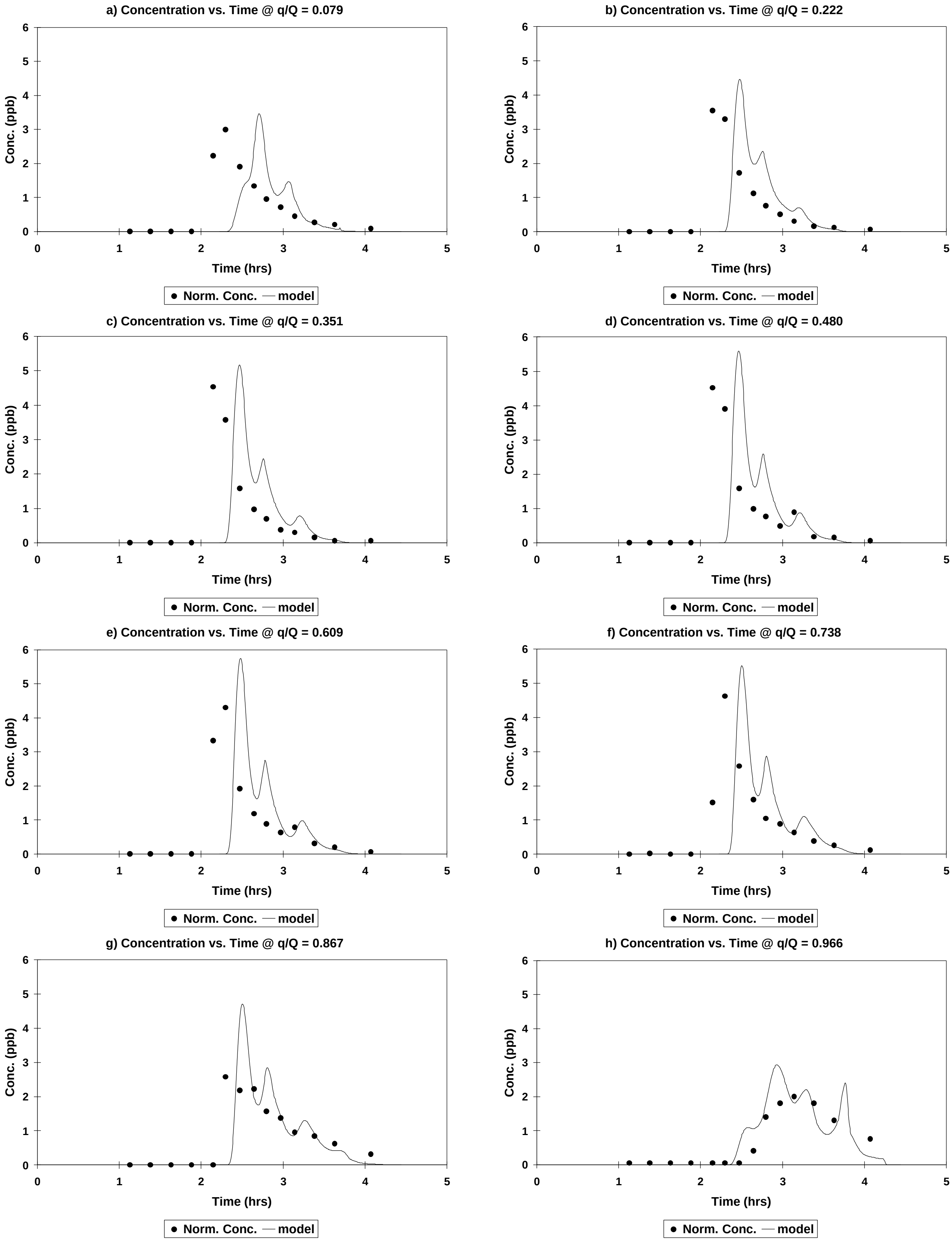


Figure 11 Athabasca River, c-t curves at 11850 m, 334 m^3/s, slug input.

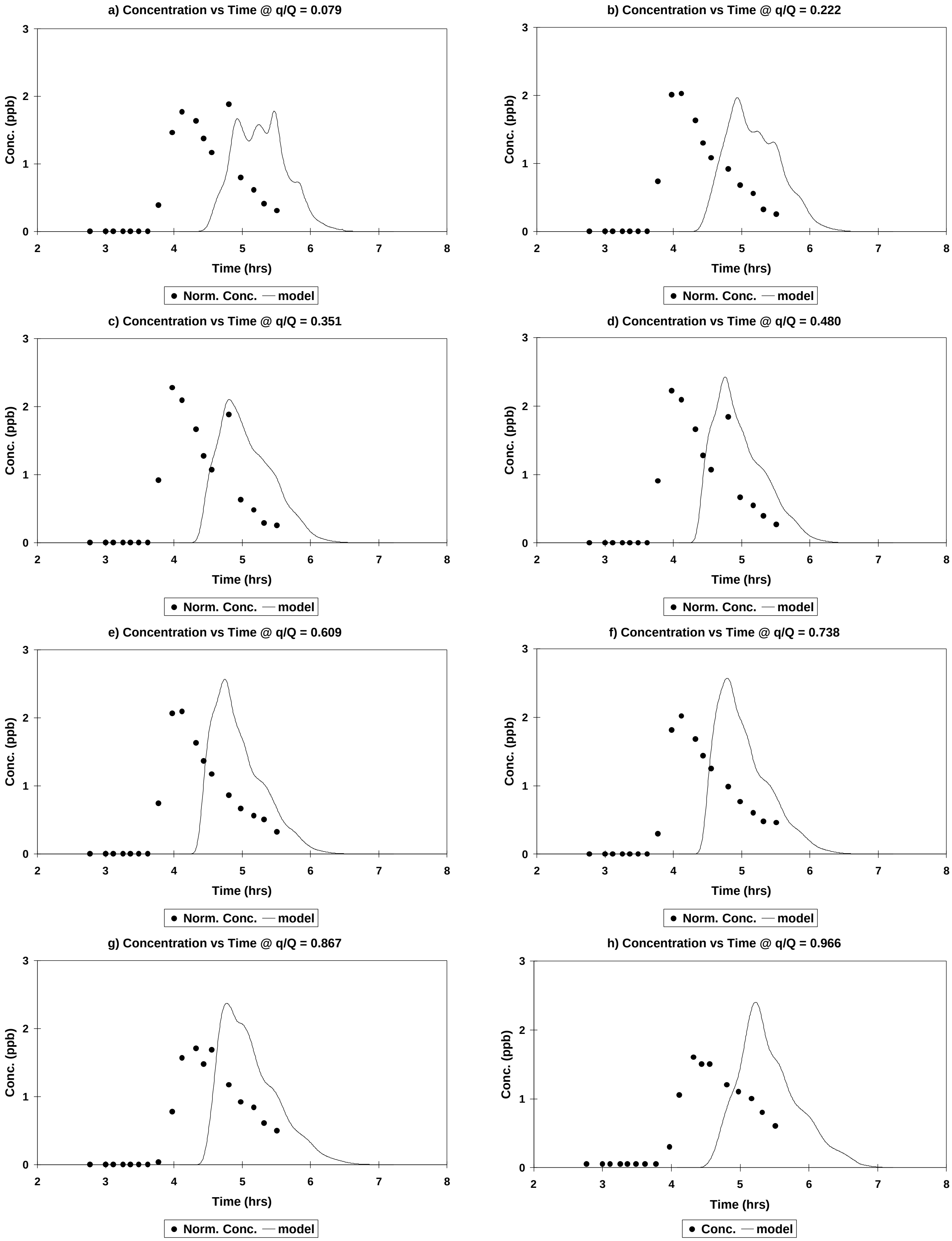


Figure 12 Athabasca River, c-t curves at 20625 m, 334 m^3/s, slug input.

MODELLING RESULTS

Details regarding the Advection Optimized Grid (AOG) model (the modeling procedure utilized in this study) are described by Putz (1996), Odigboh (1999) and Putz et al. (2000). The study reach was divided into streamtubes and sub-reaches in order to utilize the model. Streamtube boundaries were located at q/Q = 0.0, 0.031, 0.154, 0.277, 0.399, 0.522, 0.644, 0.767, 0.890, and 1.00. Generally, the surveyed cross sections were taken to be the sub-reach boundaries.

A numerical grid file and an input concentration file were constructed using the procedures described by Odigboh (1999). The data contained within the grid file is required to conduct the numerical calculations of the mixing simulation. This data is derived from the hydrometric surveys conducted on the river by incorporating water level and flow adjustments between the survey date and the date of the tracer test. Sufficient hydrometric data must be available for accurate representation of the reach characteristics.

Once the concentration input and grid file are constructed (for a particular flow and input condition), then successive runs of the model are executed. β is varied (see [1] and [2]) for each sub-reach, until an optimum[2] match is obtained compared to the measured tracer data. In this manner, the model is calibrated for a particular flow condition. The slug test simulation was run using a average value of β obtained from the continuous input test.

Continuous Input Tests

Modelling results compared to normalized tracer measurements for the continuous input test are shown in Figure 7. Two sets of modelling results are presented. The curves labeled optimum β (indicated with solid squares) represent the best fit to the normalized measured concentrations utilizing variable β along the reach (i.e. the optimum value of β is used in each sub-reach). A plot of β utilized versus distance is shown in Figure 13.

Overall, the AOG model utilizing optimum β values provides a very good representation of the transverse mixing in the reach. The only significant discrepancies between the model and tracer results are evident at 925m and 3000 m downstream. It is unclear what the problem may be a 925 m other than poor characterization of the channel near the bridge crossing the channel. Recall this is also the section with the anomalous peak concentration of tracer described earlier. At 3000 m the discrepancy is undoubtedly due to poor channel characterization. At this location it was only possible to survey the right side of the channel passing an island (see Figure 3). The left side of the channel was too shallow and swiftly flowing to conduct surveys. As result, estimates of the channel characteristics on the left had to be incorporated into the simulation.

The second set of model results utilized a constant average β of 0.389. These results are shown with open triangles in Figure 7. The simulation utilizing the average β also provides a very reliable representation of the transverse mixing in the reach.

---

[2] In all cases the optimum fit was judged by visually comparing the model results to normalized measurements

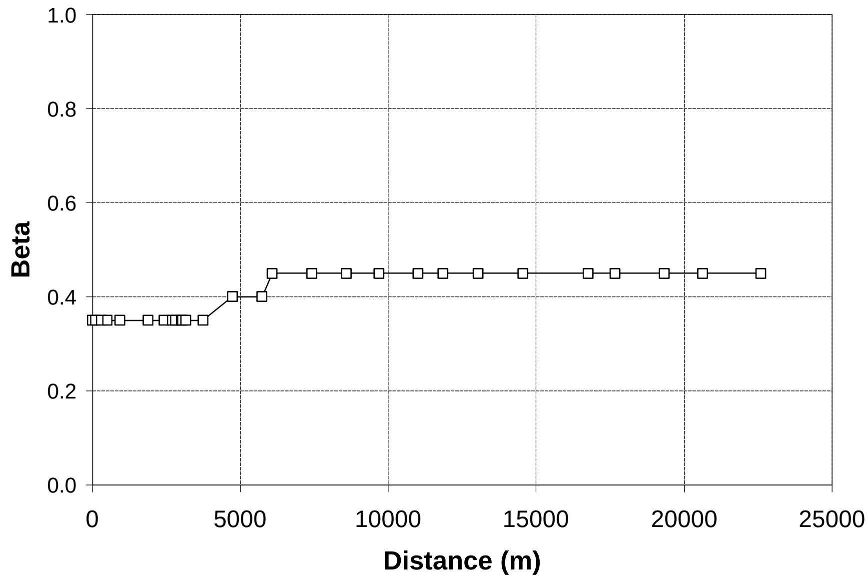


Figure 13 Optimum β versus distance downstream.

Slug Input Test

Modelling results for the slug test using the dosage approach are presented in Figure 8. The model simulations for the slug test were run using a constant average $\beta = 0.389$. As for the continuous tests, the AOG model provides a reliable representation of the transverse distribution of tracer mass resulting from the slug input.

The c-t curves generated by the model for constant average β are shown in Figure 9 through Figure 12 with the normalized c-t distributions measured at each sampling location. In general, there is a good agreement between the time base of the modelled and measured waveforms (i.e. the time between tracer arrival and departure at a section). However, there are discrepancies between the measured and simulated elapsed time to peak concentration. These discrepancies are not large compared to the elapsed time to peak (in the range of 9 to 17%). However, they are somewhat larger than what would be expected to occur as a result of accuracy limitations in stream flow measurements, and the subsequent generation of the velocity and flow distribution at each cross section based upon these measurements. Poor channel definition in portions of the reach where islands and gravel bars create shallow water with high velocity has likely contributed to this error[3].

At some locations, the model also appears to over estimate the peak tracer concentration. However, this may simply be because the actual peak concentration has not been captured in the sampling. Note for example at 4.7 km, $q/Q = 0.867$ the passage of the major portion of the tracer cloud occurs in approximately 10 minutes. Only two or three samples were collected during this period hence the peak concentration could easily have been missed.

---

[3] Most cross sections were located at sections with sufficient water depth to allow operation of the survey boat across the entire width of the section.

WATER QUALITY PARAMETERS

Introduction

Water quality samples were collected during the continuous tracer test. The position of each sample was recorded using GPS equipment. Samples were taken approximately 0.3 metres below the water surface and collected in glass bottles or vials (which ever was appropriate for the analysis to be conducted). The sample bottles were immediately placed in a cooler container to isolate them from sunlight. The samples were transported to Edmonton the same day for analysis using standard laboratory procedures.

Water samples were also taken from the head tank at the entrance to the effluent diffuser immediately before and after the tracer injection test. These undiluted effluent samples and the flow reported by the mill were used to estimate the mass flow rate of colour and AOX into the river. The background, effluent and fully mixed concentrations for each water quality parameter are given in Table 6. Composite sample results reported by the mill on August 16 for colour and on August 17 for AOX were respectively 300 CU[4] and 1300 μg/L.

Table 6 Input and fully mixed conditions for water quality parameters.

Parameter	Background Conc.[a]	Input Conc.[b]	Volumetric Flow [c]	Fully Mixed Conc.[d]
Tracer	0.05 μg/L	0.23×10^{9} μg/L	1.3×10^{-6} m^3/s	0.82 μg/L
Colour	6.3 CU	368 CU	1.52 m^3/s	1.5 CU
AOX	3.2 μg/L	2445 μg/L	1.52 m^3/s	10.2 μg/L

[a] based upon samples taken outside the plume region
[b] tracer feed 20% by weight, S.G. 1.15; average concentration of four colour and AOX measurements of the effluent flow, colour measurements ranged from 360 to 375 CU, AOX from 2280 to 2576 μg/L.
[c] tracer feed rate 78 mL/minute; average effluent flow reported by the mill for August 18th and 19th was used for water quality parameters because the river samples were taken the morning of August 19th.
[d] fully mixed river concentration in excess of background (combined river and effluent flow of 364 m^3/s)

Water Quality Sample Results

The results of the water quality measurements in the river are shown in Figure 14. In Figure 14 the primary and secondary vertical axes represent dimensional concentrations in excess of background levels (Colour in CU[4] and AOX in μg/L). The results of the water quality measurements are also shown in Figure 15 plotted on the same axis as the tracer concentrations. The vertical axis on these plots represents non-dimensional concentration C' in excess of background. The tracer concentrations in these plots have not been normalized. Therefore, the figure illustrates the recovery of each water quality parameter compared to tracer results.

[4] True colour unit, one true colour unit equals one mg/L platinum-cobalt colour standard

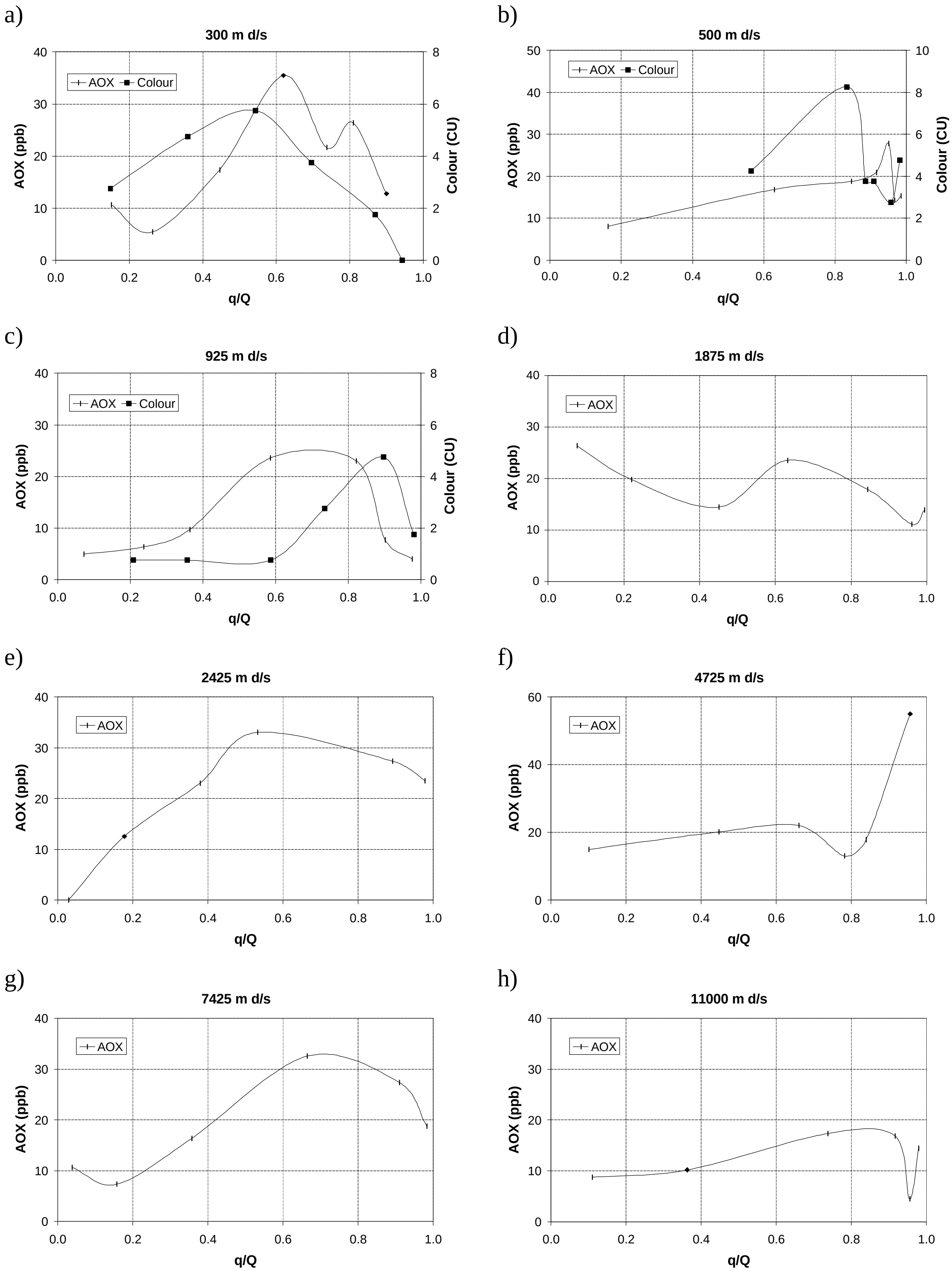


Figure 14 Water quality parameter concentrations.

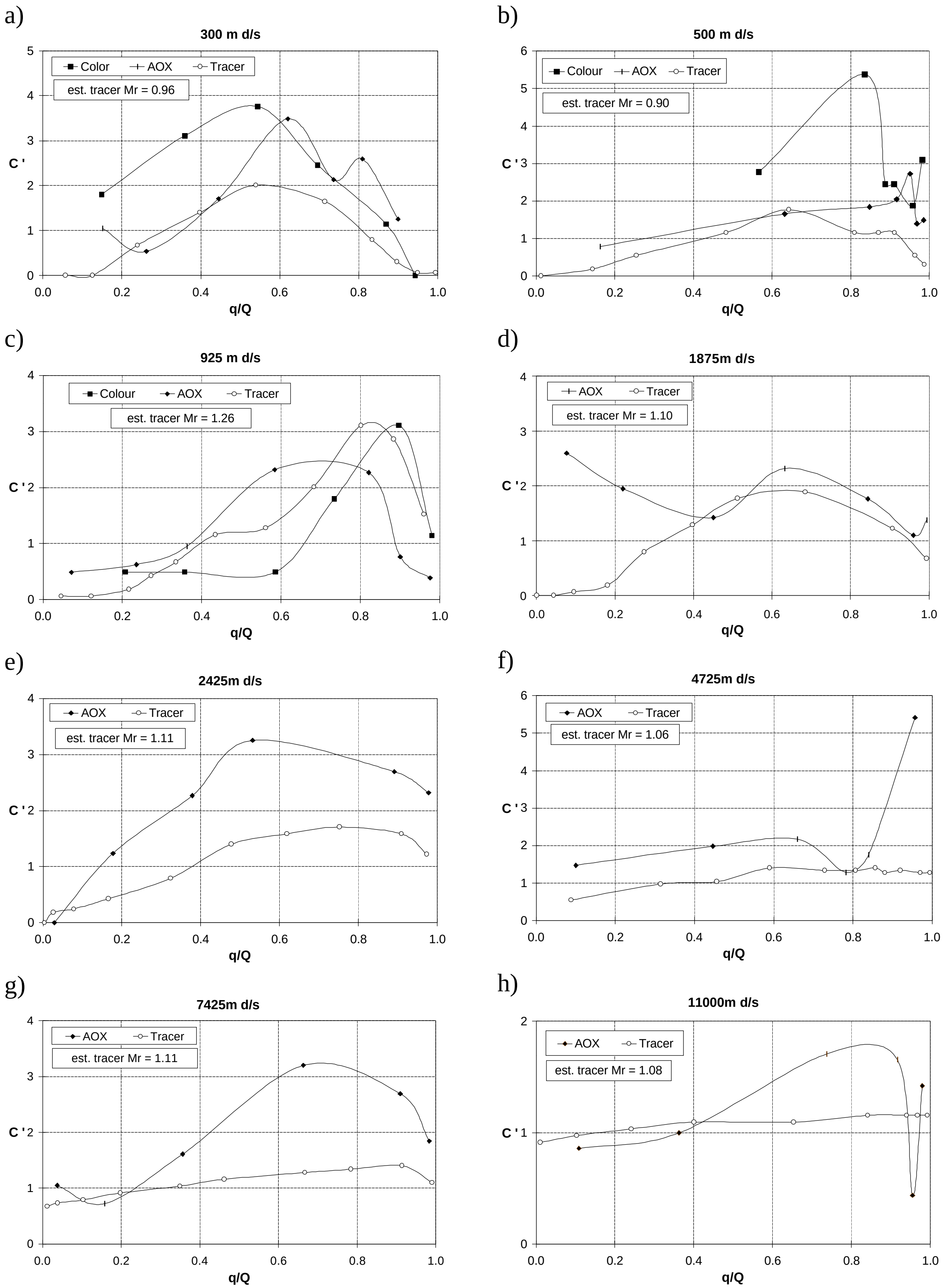


Figure 15 Tracer and water quality parameter dimensionless concentrations.

The results for both water quality parameters are quite variable. This is most likely the result of attempting to measure concentrations close to the limits of detection of the analytical methods. For example, the peak colour levels measured in the river in excess of background were in the range of 6 to 8 CU (see Figure 14 9a) and 9b)). Whereas, the detection limit for analysis of colour is in the order of 10 CU. The detection limit for AOX is in the order of 5 to 10 μg/L.

Duplicate water quality samples were collected 500 m downstream. The results of the analysis on these samples are shown in Table 7. Significant variability in the analysis results is evident. Such variability in results was not evident in a similar sampling program conducted on the Wapiti River (see Putz and Smith, 2000). The averages of the duplicate samples were plotted in Figure 14 and Figure 15.

Table 7 Results of duplicate sample analysis.

Sample Location	Colour Sample 1	Colour Sample 2	AOX Sample 1	AOX Sample 2
1	5	4	10	6
2	11	6	11	23
3	4	4	24	13
4	3	5	16	26
5	0	6	16	40
6	5	5	6	22
7	-	-	11	20

Note: all concentrations are in excess of background levels

Despite this variability in analysis results, the mass recovery of the water quality parameters was determined using the same procedure as outlined for the tracer. The mass recovery at each section is presented in Table 8. The recoveries given in Table 8 and the dimensionless plots presented in Figure 15 indicate that more colour and AOX was detected in the river than can be accounted for using the calculated input mass flow. Curiously, the colour measurements at 925 m downstream closely parallel the inexplicably high peak concentrations of tracer measured at this section. In general, the AOX recovery is in the order of twice the tracer recover at most sections. However, because of the controlled injection it is known that the error in tracer mass recovery is at most in the order of 10%. Therefore, any AOX recovery greater than 110% must be the result of analysis error, or error in quantifying the mass inflow in the effluent.

Incomplete adsorption of halide to granular activated carbon in the micro-columns used in AOX analysis would generally result in less AOX being recovered from the samples. Yet, the AOX recoveries were much higher than expected based upon mass balance calculations. Perhaps inorganic halides present in the river were not completed removed before analysis proceeded. Another plausible explanation may be a much higher effluent flow than the daily average reported by the mill. Perhaps a spike in effluent flow occurred during the water quality sampling period. Of course, these explanations are highly speculative. Further sampling of the effluent stream and the river are required to definitively resolve the issue.

Table 8 Mass recovery ratios for tracer and effluent parameters.

Cross Section Downstream (m)	Tracer	Colour	AOX
300	0.96	2.25	1.70
500	0.90	3.15	1.37
925	1.26	1.06	1.30
1875	1.10	-	1.90
2425	1.11	-	2.28
4725	1.06	-	2.14
7425	1.11	-	2.04
11000	1.08	-	1.23
Average	1.07	2.15	1.75

Although the AOX results are quite variable and the recoveries are greater than expected it evident that AOX persists in the river for significant distances downstream of the effluent diffuser. It is impossible to make any statement about colour since all samples taken from the river were below limits of sensitivity and hence the results were very erratic. Because of the variable nature of the water quality sample results no attempt was made to model the colour and AOX using the AOG model.

MANAGEMENT APPLICATIONS

The results of the fluorescent tracer test described in this report can be used to delineate the two-dimensional effluent plume in the Athabasca River downstream of Weldwood of Canada Ltd. (for flow conditions of 364 m^3/s). The two-dimensional mixing zone extended approximately 11.0 kilometers downstream of the diffuser structure during the tracer test. Beyond this distance, the mill effluent is virtually fully mixed with the river flow.

The distance required for establishment of a fully mixed condition has implications for receiving water quality monitoring programs conducted at this site. For flow conditions of approximately 364 m^3/s, consideration of transverse variations in concentration is not required beyond approximately 11 km. Beyond this distance samples taken from any mid channel location should be representative of the channel mean. For distances less than 11 km several samples must be taken across each section to document the two-dimensional nature of the effluent plume.

The calibrated river mixing model prepared as part of the project can serve as a valuable management tool for efficient planning of receiving stream water quality monitoring programs. The mixing model can also be used to assess the environmental impact of abnormal conditions such as spills and/or low river flow conditions on receiving stream water quality. These applications are in reference to the existing diffuser structure. An additional application of the model is to predict the effect upon mixing of the location and configuration of a new diffuser or of altering the existing structure. Once the receiving stream characteristics are defined within the model the effects of input location and configuration are simply handled by altering the input files.

The results of the water quality sampling program described in this report indicated the following within the 17 km river reach sampled:

- Colour levels are at or near detection limits immediately downstream of the diffuser. As a result it was impossible to determine if colour was attenuating in the river by any mechanism other than dilution.
- AOX levels in the river were also close to detection limits. Duplicate samples indicated very erratic analysis results.
- More AOX was recovered from the river than mass balance analysis indicated was being input to the river in the effluent stream. The amount of additional mass recovered in the river was in the order of 2 times the expected mass and thus far in excess of what could be accounted for by analysis error alone.

These results imply that AOX is persisting in the water column in the river for a significant distance downstream. They also imply more AOX is present in the river than can be accounted for by mass balance calculations based upon daily average effluent flow, and composite sample concentrations. Further water quality sampling should be conducted in conjunction with tracer tests to double check upon the river AOX levels, and to definitively measure and document the input mass flow of AOX.

CONCLUSIONS AND RECOMMENDATIONS

The following may be concluded from the Athabasca River field study:

1. Vertical mixing of the effluent is complete between 0.3 and 0.5 km downstream of the diffuser for the prevailing flow conditions.
2. Transverse mixing of the effluent occurs relatively quickly for the prevailing flow conditions. The transverse mixing is virtually complete 11 km downstream of the diffuser.
3. The steady-state tracer test combined with hydrometric surveys provides an accurate definition of the river mixing and dilution. Water quality sampling in conjunction with the tracer test provides a means of assessing attenuation of parameters by mechanisms other than dilution effects.
4. The Advection Optimized Grid (AOG) mixing model utilized in the study can accurately simulate the transverse mixing of neutrally buoyant mass conservative parameters input to the river via a continuous or slug injection.
5. The AOG mixing model can also simulate with reasonable accuracy the longitudinal dispersion of neutrally buoyant, mass conservative parameters instantaneously discharged to the river. Minor discrepancies in the time to peak concentration are evident between the model and samples. However these discrepancies are relatively small (< 17%) and are likely the result of inaccuracies in measurements of channel and flow parameters.
6. The dimensionless mixing coefficient for this reach of the Athabasca River ranges from 0.35 to 0.45 for the prevailing flow conditions. A constant average value of 0.389 gave satisfactory results in the mixing simulations.
7. Assessment of the attenuation of colour and AOX was confounded due to the erratic nature of the analysis results. Colour was at or near detection limits immediately downstream of the diffuser. AOX samples remained slightly above detection limits for the 11 km reach sampled. The proximity of the sample concentrations to detection limits most likely contributed to the erratic nature of the results.
8. A greater mass of AOX was detected in the river than could be predicted by mass balance calculations utilizing the mass flow of AOX into the river with the mill effluent. No specific cause for this result could be identified with the data available

The following actions are recommended as follow up to the field study:

1. An additional tracer study should be conducted to delineate the extent of the two-dimensional mixing zone at lower river flow. Water quality sampling for AOX and colour should also be conducted at the lower flow to assess their attenuation in the river by mechanisms other than dilution.
2. Time series sampling of the effluent flow and concentration should be conducted to determine if diurnal fluctuations could be responsible for the increased recovery of AOX in the river compared to mass balance calculations based upon average flow and concentration.

REFERENCES

Beltaos, S. 1975. Evaluation of transverse mixing coefficients from slug tests. Journal of Hydraulic Research, 13(4):351-360.

Odigboh, I. 1999. Characterization and modelling of the mixing in the Athabasca River downstream of a pulp mill. M.Sc. thesis, Division of Environmental Engineering, University of Saskatchewan, Saskatoon, Saskatchewan.

Putz, G. 1996. Dynamic two-dimensional river quality modeling, Ph.D. thesis, Department of Civil Engineering, University of Alberta, Edmonton, Alberta.

Putz, G., and Smith, D.W. 2000. River mixing and mass balance of several water quality parameters in the Wapiti River downstream of Weyerhaeuser Canada Ltd. SFMNCE Research Project Report, Edmonton, Alberta, 28p.

Putz, G., and Smith, D.W. 1998. Verification of a transient input, two-dimensional, river mixing model. Canadian journal of Civil Engineering, 25(1):51-66.

Putz, G. and Smith, D.W. 1996. Two-dimensional modelling of unsteady effluent discharges to rivers. Proceedings, Conference on Sustainable Forestry Partnerships: Forging a Network of Excellence, Sustainable Forest Management Network of Centres of Excellence, March 8-10, 1996, Edmonton, pp. 46-53.

Putz, G., Odigboh, I. and Smith, D.W. 2000. Two-dimensional modelling of effluent mixing in the Athabasca River downstream of Alberta Pacific Forest Industries, Inc. SFMNCE Research Project Report, Edmonton, Alberta, 37p.

Yotsukura, N., and Cobb, E.D. 1972. Transverse diffusion of solutes in natural streams. United States Geological Survey, Professional Paper, 582-C, pp. c1-c19.

APPENDIX A

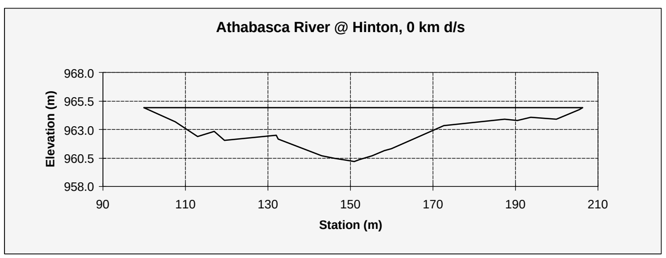
CROSS SECTION TABLES AND PLOTS

ATHABASCA RIVER @ HINTON, 364 M3/S

Table A1 Cross Section – 0.000 km d/s

X-SECTION	Athabasca River @ Hinton, 0 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	364.00			
WIDTH m	106.30	Est. Water Surface Elev.		964.92
MEAN DEPTH m	2.26	LB	100.00	964.92
AREA m^2	240.07	RB	206.30	964.92
MEAN VELOCITY m/s	1.516			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.00	964.92	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
100.00	964.92	0.00	0.000	0.009	0.00	0.00000	0.0	0.008
107.59	963.72	1.20	0.071	0.997	2.30	0.00541	4.6	0.853
112.99	962.43	2.50	0.122	1.621	13.06	0.03610	14.6	1.386
117.04	962.86	2.07	0.160	1.428	14.11	0.06925	23.8	1.222
119.51	962.07	2.85	0.184	1.772	9.72	0.09209	29.9	1.516
132.07	962.50	2.42	0.302	1.589	55.68	0.22290	63.0	1.359
132.52	962.21	2.71	0.306	1.712	1.93	0.22744	64.2	1.464
143.07	960.71	4.21	0.405	2.297	73.10	0.39919	100.7	1.964
143.12	960.71	4.22	0.406	2.299	0.50	0.40036	100.9	1.966
146.11	960.52	4.41	0.434	2.368	30.14	0.47117	113.8	2.025
149.16	960.32	4.60	0.462	2.437	32.98	0.54866	127.5	2.084
150.99	960.20	4.72	0.480	2.478	20.91	0.59780	136.0	2.119
152.21	960.36	4.56	0.491	2.423	13.90	0.63045	141.7	2.072
155.25	960.75	4.17	0.520	2.284	31.28	0.70394	155.0	1.953
158.31	961.14	3.78	0.548	2.139	26.85	0.76701	167.1	1.829
159.97	961.35	3.57	0.564	2.058	12.83	0.79715	173.2	1.760
164.90	962.14	2.78	0.611	1.743	29.77	0.86709	188.9	1.490
172.74	963.36	1.56	0.684	1.186	24.94	0.92568	205.9	1.015
187.39	963.93	0.99	0.822	0.875	19.28	0.97097	224.6	0.748
190.51	963.79	1.13	0.851	0.957	3.03	0.97810	227.9	0.819
193.81	964.08	0.85	0.882	0.788	2.84	0.98478	231.2	0.674
200.02	963.93	0.99	0.941	0.875	4.74	0.99592	236.9	0.748
205.47	964.78	0.14	0.992	0.243	1.73	0.99998	240.0	0.208
206.30	964.92	0.00	1.000	0.000	0.01	1.00000	240.1	0.000
				Est. Total	425.64			



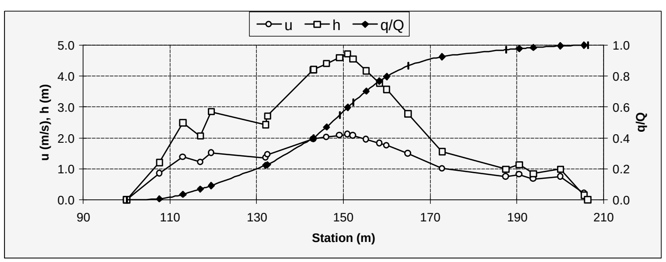
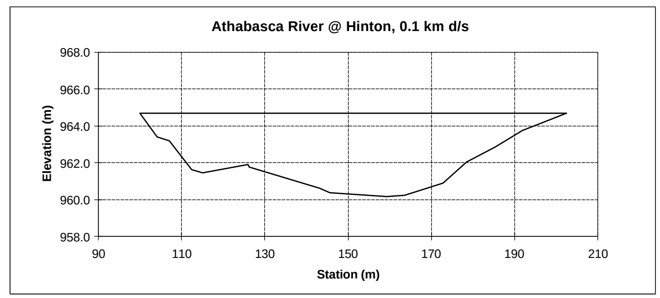


Figure A1 Cross Section - 0.000 km d/s

Table A2 Cross Secttion – 0.100 km d/s

X-SECTION	Athabasca River @ Hinton, 0.1 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	102.47	Est. Water Surface Elev.		964.68
MEAN DEPTH m	2.88	LB	100.00	964.68
AREA m^2	294.73	RB	202.47	964.68
MEAN VELOCITY m/s	1.234			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.00	964.68	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
104.15	963.41	1.28	0.041	0.717	0.95	0.00233	2.6	0.641
107.06	963.19	1.49	0.069	0.796	3.04	0.00981	6.7	0.711
112.37	961.62	3.07	0.121	1.288	12.59	0.04077	18.8	1.151
115.02	961.47	3.21	0.147	1.328	10.91	0.06758	27.1	1.187
125.85	961.90	2.78	0.252	1.21	41.08	0.16856	59.5	1.08
126.16	961.76	2.92	0.255	1.25	1.11	0.17127	60.4	1.11
143.17	960.61	4.07	0.421	1.56	83.32	0.37609	119.9	1.39
145.54	960.40	4.29	0.444	1.61	15.67	0.41460	129.8	1.44
159.29	960.18	4.50	0.579	1.66	98.88	0.65766	190.2	1.49
163.55	960.26	4.43	0.620	1.65	31.50	0.73510	209.3	1.47
172.88	960.90	3.78	0.711	1.48	59.86	0.88226	247.6	1.32
178.54	962.05	2.64	0.767	1.16	24.06	0.94140	265.7	1.04
185.25	962.84	1.85	0.832	0.92	15.67	0.97992	280.8	0.82
191.80	963.77	0.92	0.896	0.58	6.76	0.99654	289.8	0.51
202.47	964.68	0.00	1.000	0.00	1.41	1.00000	294.7	0.00
				Est. Total	406.81			



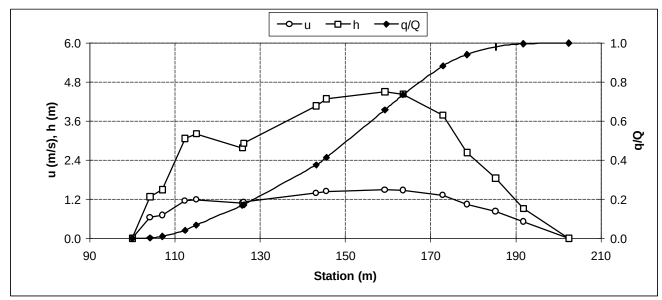
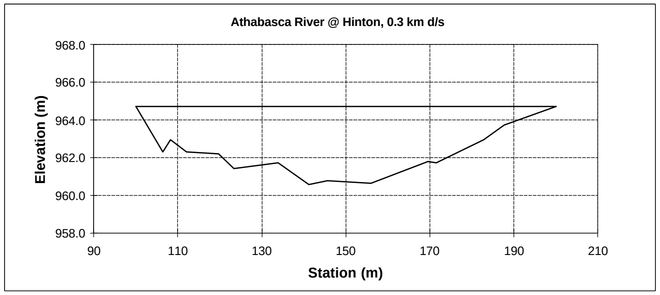


Figure A.2 Cross Section - 0.100 km d/s

Table A.3 Cross Section - 0.300 km d/s

X-SECTION	Athabasca River @ Hinton, 0.3 km d/s		
DATE	August 19, 1998		
DISCHARGE m3/s	363.60		
WIDTH m	100.07	Est. Water Surface Elev.	964.72
MEAN DEPTH m	2.60	LB 100.01	964.72
AREA m^2	260.36	RB 200.08	964.72
MEAN VELOCITY m/s	1.397		

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	964.72	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
106.37	962.30	2.42	0.064	1.330	5.12	0.01278	7.7	1.207
108.21	962.94	1.77	0.082	1.082	4.63	0.02433	11.5	0.981
112.10	962.30	2.42	0.121	1.330	9.84	0.04888	19.7	1.207
119.70	962.23	2.49	0.197	1.357	25.09	0.11148	38.4	1.231
123.38	961.44	3.28	0.234	1.63	15.86	0.15106	49.0	1.48
133.80	961.72	2.99	0.338	1.53	51.65	0.27993	81.7	1.39
141.18	960.58	4.14	0.411	1.90	45.24	0.39280	108.0	1.73
145.63	960.79	3.92	0.456	1.84	33.53	0.47646	125.9	1.67
156.03	960.65	4.07	0.560	1.88	77.26	0.66922	167.5	1.71
169.50	961.80	2.92	0.694	1.51	79.83	0.86840	214.6	1.37
171.58	961.72	2.99	0.715	1.53	9.33	0.89167	220.7	1.39
182.83	962.94	1.77	0.828	1.08	35.07	0.97917	247.5	0.98
187.73	963.73	0.99	0.877	0.73	6.13	0.99445	254.3	0.66
200.08	964.72	0.00	1.000	0.00	2.22	1.00000	260.4	0.00
				Est. Total	400.80			



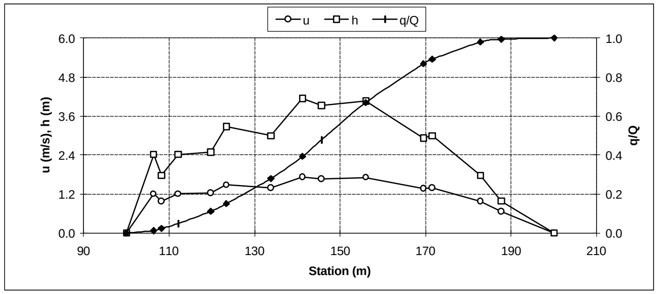
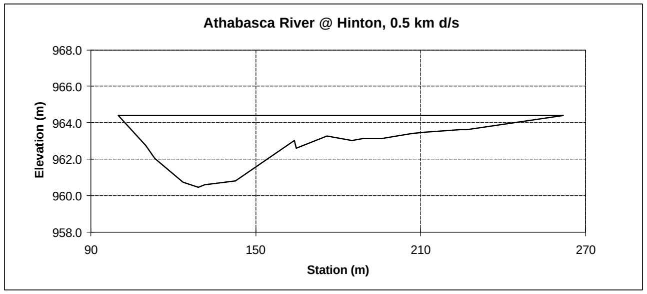


Figure A3 Cross Section - 0.300 km d/s

Table A.4 Cross Section - 0.500 km d/s

X-SECTION	Athabasca River @ Hinton, 0.5 km d/s		
DATE	August19, 1998		
DISCHARGE m3/s	363.60		
WIDTH m	161.77	Est. Water Surface Elev.	964.39
MEAN DEPTH m	1.58	LB 100.00	964.39
AREA m^2	255.02	RB 261.77	964.39
MEAN VELOCITY m/s	1.426		

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.00	964.39	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
110.08	962.76	1.63	0.062	1.460	6.01	0.01326	8.2	1.170
113.30	962.04	2.35	0.082	1.861	10.63	0.03669	14.6	1.492
123.47	960.75	3.64	0.145	2.492	66.35	0.18297	45.1	1.997
129.09	960.46	3.93	0.180	2.621	54.36	0.30280	66.4	2.101
131.42	960.61	3.78	0.194	2.56	23.18	0.35389	75.3	2.05
142.63	960.82	3.57	0.264	2.46	103.43	0.58191	116.6	1.97
164.04	963.04	1.35	0.396	1.28	98.47	0.79899	169.2	1.03
164.78	962.61	1.78	0.400	1.54	1.64	0.80261	170.4	1.24
175.81	963.26	1.13	0.469	1.14	21.55	0.85012	186.4	0.92
184.98	963.04	1.35	0.525	1.28	13.79	0.88052	197.8	1.03
189.04	963.11	1.28	0.550	1.24	6.71	0.89530	203.1	0.99
195.80	963.11	1.28	0.592	1.24	10.68	0.91884	211.7	0.99
206.93	963.40	0.99	0.661	1.04	14.37	0.95052	224.3	0.84
211.63	963.47	0.92	0.690	0.99	4.57	0.96059	228.8	0.80
218.16	963.54	0.85	0.730	0.94	5.56	0.97285	234.5	0.75
224.26	963.62	0.77	0.768	0.89	4.51	0.98279	239.5	0.71
226.93	963.62	0.77	0.785	0.89	1.83	0.98683	241.5	0.71
261.77	964.39	0.00	1.000	0.00	5.97	1.00000	255.0	0.00
				Est. Total	453.63			



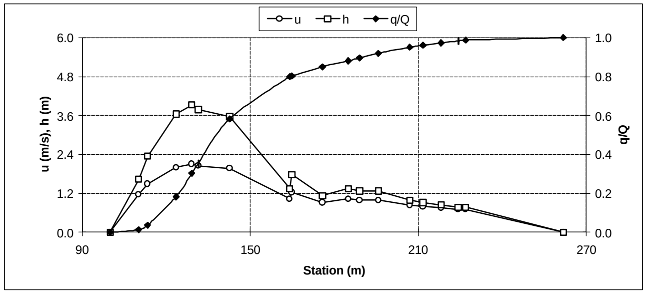
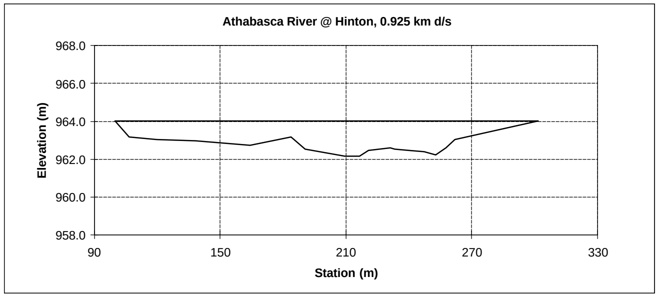


Figure A4 Cross Section - 0.500 km d/s

Table A5 Cross Section – 0.925 km d/s

X-SECTION	Athabasca River @ Hinton, 0.925 km d/s							
DATE	August 19, 1998							
DISCHARGE m3/s	363.60							
WIDTH m	201.50			Est. Water Surface Elev.			964.02	
MEAN DEPTH m	1.12			LB		100.02	964.02	
AREA m^2	226.50			RB		301.52	964.02	
MEAN VELOCITY m/s	1.605							

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.02	964.02	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
106.66	963.18	0.84	0.033	1.324	1.85	0.00475	2.8	1.236
119.81	963.03	0.99	0.098	1.470	16.79	0.04785	14.8	1.372
138.47	962.96	1.06	0.191	1.541	28.70	0.12152	33.9	1.438
164.24	962.74	1.27	0.319	1.744	49.28	0.24803	63.9	1.627
183.67	963.18	0.84	0.415	1.32	31.51	0.32893	84.4	1.24
190.41	962.53	1.49	0.449	1.93	12.78	0.36174	92.3	1.81
209.47	962.17	1.85	0.543	2.23	66.23	0.53174	124.0	2.09
216.49	962.17	1.85	0.578	2.23	28.96	0.60608	137.0	2.09
220.68	962.46	1.56	0.599	2.00	15.12	0.64489	144.1	1.86
231.15	962.60	1.42	0.651	1.87	30.12	0.72220	159.7	1.75
233.10	962.53	1.49	0.660	1.93	5.39	0.73604	162.5	1.81
239.89	962.46	1.56	0.694	2.00	20.33	0.78823	172.9	1.86
247.18	962.39	1.63	0.730	2.06	23.54	0.84866	184.5	1.92
252.61	962.24	1.77	0.757	2.18	19.58	0.89892	193.8	2.03
257.74	962.60	1.42	0.783	1.87	16.55	0.94141	201.9	1.75
261.97	963.03	0.99	0.804	1.47	8.50	0.96322	207.0	1.37
301.52	964.02	0.00	1.000	0.00	14.33	1.00000	226.5	0.00
				Est. Total	389.56			



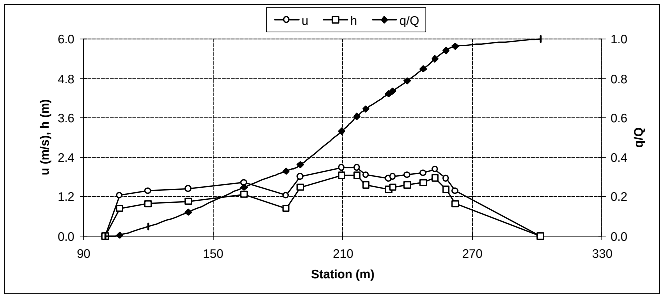
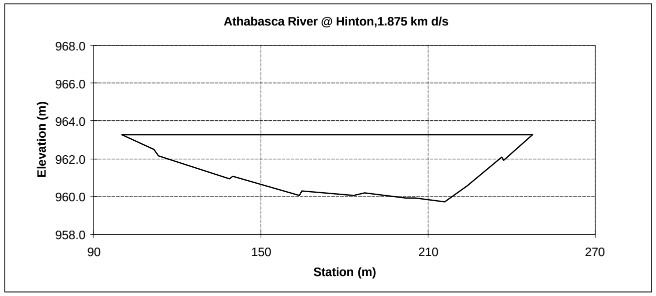


Figure A5 Cross Section – 0.925 km d/s

Table A.6 Cross Section – 1.875 km d/s

X-SECTION	Athabasca River @ Hinton,1.875 km d/s							
DATE	August 19, 1998							
DISCHARGE m3/s	363.60							
WIDTH m	147.36			Est. Water Surface Elev.			963.27	
MEAN DEPTH m	2.33			LB		100.04	963.27	
AREA m^2	343.11			RB		247.41	963.27	
MEAN VELOCITY m/s	1.060							

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.04	963.27	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
111.55	962.50	0.77	0.078	0.507	1.12	0.00282	4.4	0.463
113.06	962.14	1.13	0.088	0.654	0.83	0.00491	5.9	0.597
138.74	960.93	2.35	0.263	1.066	38.37	0.10131	50.5	0.973
139.81	961.07	2.20	0.270	1.022	2.56	0.10774	52.9	0.933
163.64	960.06	3.21	0.432	1.31	75.24	0.29677	117.4	1.20
164.76	960.28	2.99	0.439	1.25	4.44	0.30792	120.9	1.14
183.30	960.06	3.21	0.565	1.31	73.73	0.49316	178.4	1.20
187.21	960.21	3.06	0.592	1.27	15.86	0.53300	190.6	1.16
202.00	959.92	3.35	0.692	1.35	62.23	0.68934	238.1	1.23
205.43	959.92	3.35	0.715	1.35	15.52	0.72833	249.6	1.23
215.82	959.71	3.57	0.786	1.41	49.60	0.85295	285.5	1.29
223.95	960.57	2.71	0.841	1.17	32.86	0.93550	311.0	1.07
236.32	962.07	1.20	0.925	0.68	22.39	0.99176	335.2	0.62
237.15	961.93	1.34	0.930	0.73	0.75	0.99364	336.2	0.67
247.41	963.27	0.00	1.000	0.00	2.53	1.00000	343.1	0.00
				Est. Total	398.03			



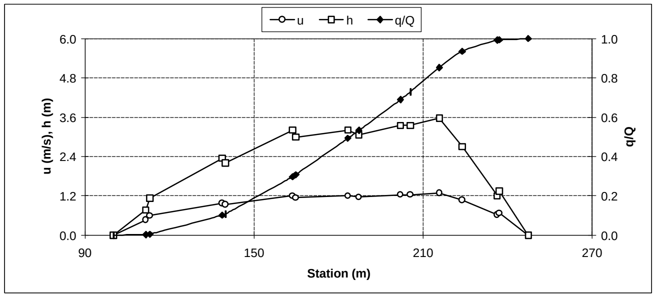
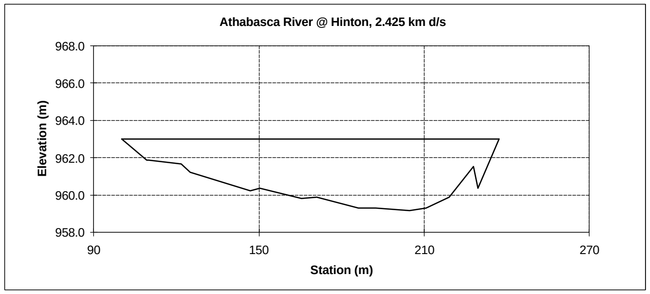


Figure A.6 Cross Section – 1.875 km d/s

Table A7 Cross Section - 2.425 km d/s

X-SECTION	Athabasca River @ Hinton, 2.425 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	137.09	Est. Water Surface Elev.		963.01
MEAN DEPTH m	2.58	LB	100.02	963.01
AREA m^2	353.24	RB	237.12	963.01
MEAN VELOCITY m/s	1.029			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.02	963.01	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
109.32	961.89	1.13	0.068	0.594	1.56	0.00397	5.2	0.551
109.96	961.89	1.13	0.072	0.594	0.43	0.00506	6.0	0.551
121.82	961.67	1.34	0.159	0.667	9.25	0.02865	20.6	0.618
124.95	961.24	1.77	0.182	0.803	3.58	0.03780	25.5	0.744
146.95	960.24	2.78	0.342	1.08	47.18	0.15814	75.6	1.00
150.35	960.38	2.63	0.367	1.04	9.77	0.18306	84.8	0.97
165.34	959.81	3.21	0.476	1.19	48.96	0.30794	128.6	1.10
171.06	959.88	3.14	0.518	1.17	21.47	0.36270	146.7	1.09
186.12	959.31	3.71	0.628	1.31	64.07	0.52614	198.3	1.22
192.38	959.31	3.71	0.674	1.31	30.48	0.60387	221.5	1.22
204.72	959.16	3.85	0.764	1.35	62.03	0.76211	268.1	1.25
210.79	959.31	3.71	0.808	1.31	30.52	0.83996	291.1	1.22
219.16	959.88	3.14	0.869	1.17	35.59	0.93074	319.7	1.09
227.92	961.53	1.49	0.933	0.71	19.12	0.97950	340.0	0.66
229.45	960.38	2.63	0.944	1.04	2.76	0.98653	343.1	0.97
237.12	963.01	0.00	1.000	0.00	5.28	1.00000	353.2	0.00
				Est. Total	392.03			



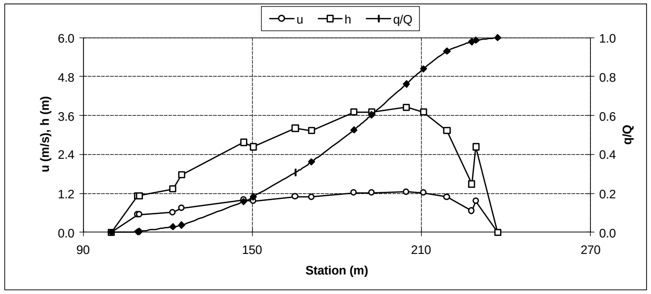
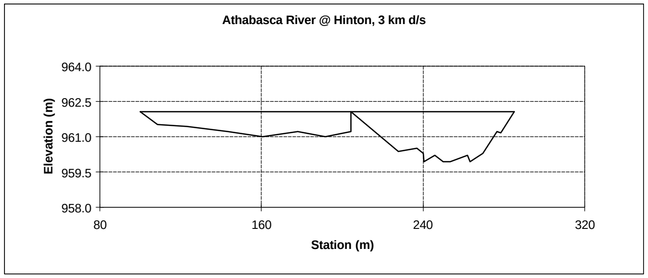


Figure A7 Cross Section - 2.425 km d/s

Table A8 Cross Section - 3.000 km d/s

X-SECTION	Athabasca River @ Hinton, 3 km d/s			
DATE	August 18, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	185.13	Est. Water Surface Elev.		962.07
MEAN DEPTH m	1.06	LB	100.05	962.07
AREA m^2	196.63	RB	285.18	962.07
MEAN VELOCITY m/s	1.849			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.05	962.07	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
108.43	961.52	0.56	0.045	1.200	1.40	0.00351	2.3	1.096
123.14	961.45	0.63	0.125	1.301	10.88	0.03083	11.0	1.188
143.35	961.23	0.84	0.234	1.584	21.42	0.08462	25.9	1.447
160.51	961.02	1.06	0.327	1.844	27.93	0.15476	42.2	1.683
178.03	961.23	0.84	0.421	1.584	28.51	0.22638	58.8	1.447
191.64	961.02	1.06	0.495	1.844	22.14	0.28199	71.7	1.683
204.30	961.23	0.84	0.563	1.584	20.60	0.33374	83.8	1.447
204.30	962.07	0.00	0.563	0.000	0.00	0.33374	83.8	0.000
227.72	960.37	1.70	0.690	2.533	25.24	0.39714	103.7	2.313
237.01	960.52	1.56	0.740	2.389	37.29	0.49080	118.8	2.181
240.11	960.30	1.77	0.757	2.604	12.90	0.52321	124.0	2.378
240.25	959.94	2.13	0.757	2.944	0.74	0.52507	124.3	2.688
245.65	960.23	1.85	0.786	2.673	30.20	0.60091	135.0	2.441
250.06	959.94	2.13	0.810	2.944	24.60	0.66270	143.8	2.688
253.55	959.94	2.13	0.829	2.944	21.91	0.71772	151.2	2.688
261.91	960.23	1.85	0.874	2.673	46.70	0.83500	167.9	2.441
263.20	959.94	2.13	0.881	2.944	7.25	0.85321	170.4	2.688
269.41	960.30	1.77	0.915	2.604	33.63	0.93766	182.6	2.378
276.62	961.23	0.84	0.954	1.584	19.75	0.98726	192.0	1.447
278.34	961.16	0.91	0.963	1.673	2.46	0.99343	193.5	1.528
285.18	962.07	0.00	1.000	0.000	2.61	1.00000	196.6	0.000
				Est. Total	398.17			



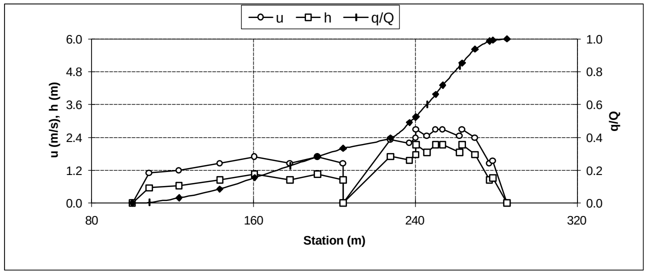
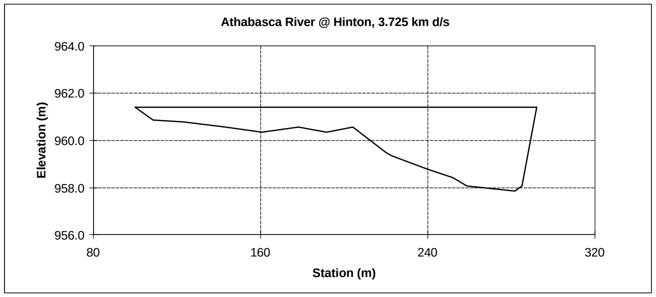


Figure A8 Cross Section - 3.000 km d/s

Table A9 Cross Section - 3.725 km d/s

X-SECTION	Athabasca River @ Hinton, 3.725 km d/s		
DATE	August 19, 1998		
DISCHARGE m3/s	363.60		
WIDTH m	192.13	Est. Water Surface Elev.	961.41
MEAN DEPTH m	1.61	LB 100.05	961.41
AREA m^2	309.25	RB 292.17	961.41
MEAN VELOCITY m/s	1.176		

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.05	961.41	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
108.43	960.85	0.56	0.044	0.578	0.67	0.00153	2.3	0.476
123.14	960.78	0.63	0.120	0.627	5.24	0.01340	11.0	0.517
143.35	960.57	0.84	0.225	0.763	10.32	0.03678	25.9	0.629
160.51	960.35	1.06	0.315	0.888	13.46	0.06727	42.2	0.732
178.03	960.57	0.84	0.406	0.76	13.74	0.09840	58.8	0.63
191.64	960.35	1.06	0.477	0.89	10.67	0.12258	71.7	0.73
204.30	960.57	0.84	0.543	0.76	9.93	0.14507	83.8	0.63
220.13	959.49	1.92	0.625	1.32	22.77	0.19667	105.6	1.09
222.81	959.35	2.06	0.639	1.39	7.21	0.21300	110.9	1.14
240.14	958.77	2.63	0.729	1.63	61.43	0.35219	151.6	1.35
252.15	958.42	2.99	0.792	1.78	57.63	0.48276	185.4	1.46
258.80	958.06	3.35	0.826	1.92	38.95	0.57102	206.5	1.58
281.80	957.84	3.57	0.946	2.00	155.80	0.92401	286.1	1.65
285.07	958.06	3.35	0.963	1.92	22.13	0.97416	297.4	1.58
292.17	961.41	0.00	1.000	0.00	11.41	1.00000	309.3	0.00
				Est. Total	441.36			



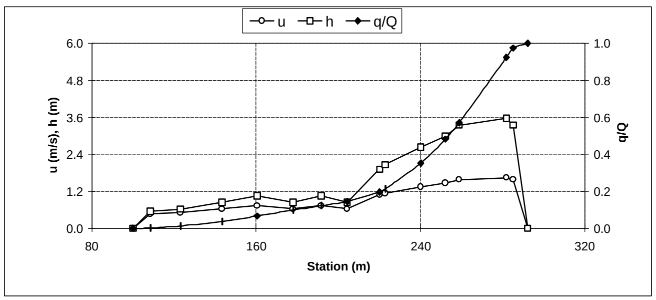
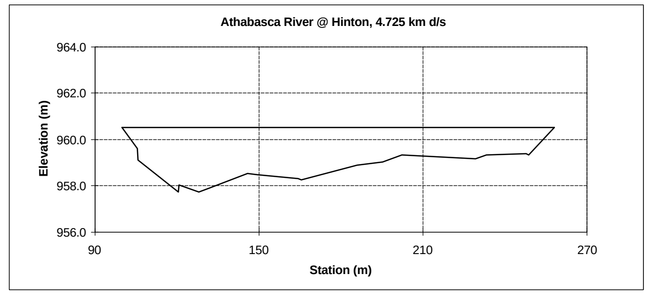


Figure A9 Cross Section - 3.725 km d/s

Table A10 Cross Section - 4.725 km d/s

X-SECTION	Athabasca River @ Hinton, 4.725 km d/s		
DATE	August 19, 1998		
DISCHARGE m3/s	363.60		
WIDTH m	158.00	Est. Water Surface Elev.	960.52
MEAN DEPTH m	1.67	LB 100.02	960.52
AREA m^2	264.60	RB 258.01	960.52
MEAN VELOCITY m/s	1.374		

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.02	960.52	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
105.68	959.61	0.91	0.036	0.917	1.19	0.00307	2.6	0.863
105.72	959.10	1.42	0.036	1.228	0.05	0.00320	2.6	1.155
120.59	957.74	2.78	0.130	1.926	49.16	0.13032	33.8	1.811
120.74	958.03	2.49	0.131	1.791	0.75	0.13225	34.2	1.684
128.14	957.74	2.78	0.178	1.93	36.21	0.22589	53.7	1.81
131.90	957.89	2.63	0.202	1.86	19.27	0.27572	63.9	1.75
145.93	958.53	1.99	0.291	1.54	55.12	0.41827	96.3	1.45
149.70	958.46	2.06	0.314	1.58	11.92	0.44910	103.9	1.48
164.42	958.32	2.20	0.408	1.65	50.67	0.58014	135.3	1.55
165.59	958.24	2.28	0.415	1.69	4.36	0.59140	138.0	1.59
185.93	958.89	1.63	0.544	1.35	60.33	0.74740	177.7	1.27
195.31	959.03	1.49	0.603	1.27	19.14	0.79690	192.3	1.19
202.24	959.32	1.20	0.647	1.10	11.04	0.82545	201.6	1.03
229.13	959.18	1.34	0.817	1.19	39.12	0.92662	235.8	1.12
233.24	959.32	1.20	0.843	1.10	5.97	0.94206	241.1	1.03
247.80	959.39	1.13	0.935	1.06	18.29	0.98936	258.0	0.99
248.60	959.32	1.20	0.940	1.10	1.00	0.99196	259.0	1.03
258.01	960.52	0.00	1.000	0.00	3.11	1.00000	264.6	0.00
				Est. Total	386.71			



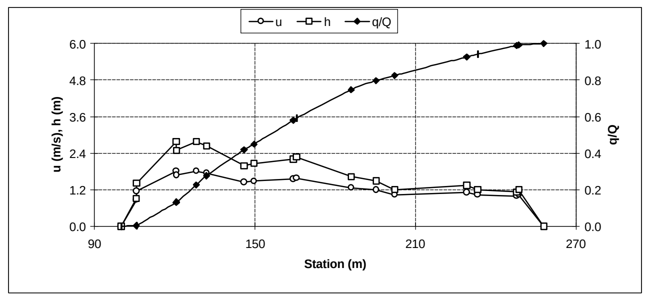
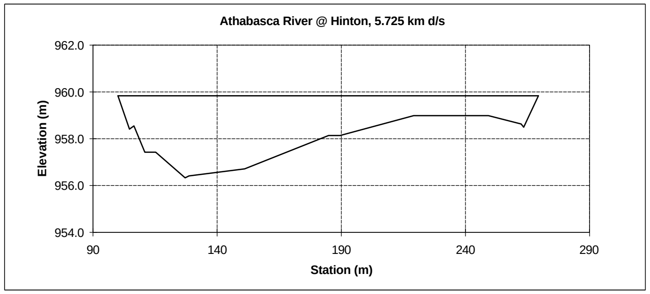


Figure A10 Cross Section - 4.725 km d/s

Table A11 Cross Section - 5.725 km d/s

X-SECTION	Athabasca River @ Hinton, 5.725 km d/s		
DATE	August 19, 1998		
DISCHARGE m3/s	363.60		
WIDTH m	169.50	Est. Water Surface Elev.	959.84
MEAN DEPTH m	1.83	LB 100.01	959.84
AREA m^2	309.77	RB 269.51	959.84
MEAN VELOCITY m/s	1.174		

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	959.84	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
104.68	958.42	1.42	0.028	0.990	1.64	0.00398	3.3	0.876
106.32	958.56	1.27	0.037	0.922	2.10	0.00910	5.5	0.815
110.84	957.42	2.42	0.064	1.415	9.74	0.03281	13.8	1.252
115.27	957.42	2.42	0.090	1.415	15.19	0.06975	24.6	1.252
126.91	956.34	3.49	0.159	1.81	55.47	0.20471	59.0	1.60
128.67	956.41	3.42	0.169	1.78	10.93	0.23129	65.1	1.58
150.95	956.70	3.14	0.301	1.68	126.62	0.53933	138.1	1.49
150.99	956.70	3.14	0.301	1.68	0.23	0.53990	138.3	1.49
184.66	958.13	1.70	0.499	1.12	114.14	0.81758	219.7	0.99
189.56	958.13	1.70	0.528	1.12	9.33	0.84029	228.1	0.99
219.05	958.99	0.84	0.702	0.70	34.13	0.92332	265.6	0.62
219.86	958.99	0.84	0.707	0.70	0.48	0.92449	266.3	0.62
243.48	958.99	0.84	0.846	0.70	13.93	0.95837	286.2	0.62
249.32	958.99	0.84	0.881	0.70	3.44	0.96674	291.1	0.62
262.52	958.64	1.20	0.959	0.89	10.70	0.99276	304.6	0.78
263.37	958.49	1.34	0.964	0.96	1.00	0.99520	305.6	0.85
269.51	959.84	0.00	1.000	0.00	1.97	1.00000	309.8	0.00
			Est. Total		411.06			



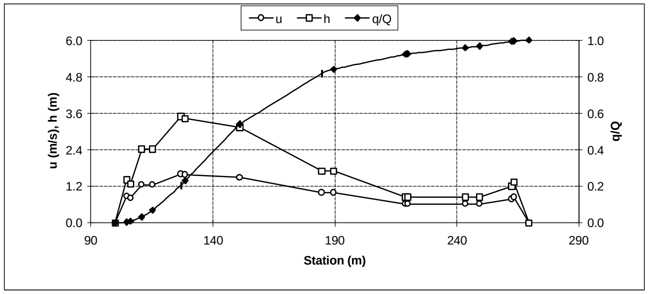
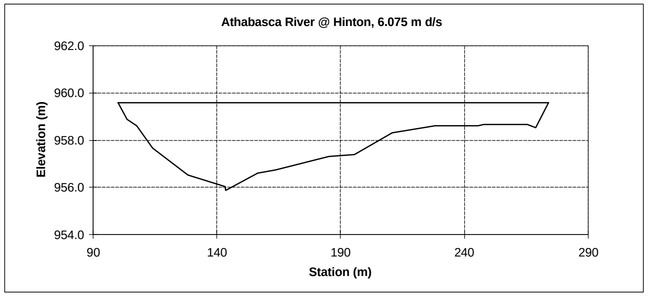


Figure A11 Cross Section - 5.725 km d/s

Table A12 Cross Section - 6.075 km d/s

X-SECTION	Athabasca River @ Hinton, 6.075 m d/s		
DATE	August 19, 1998		
DISCHARGE m3/s	363.60		
WIDTH m	173.96	Est. Water Surface Elev.	959.58
MEAN DEPTH m	1.90	LB 100.02	959.58
AREA m^2	330.27	RB 273.97	959.58
MEAN VELOCITY m/s	1.101		

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.02	959.58	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
103.70	958.89	0.70	0.021	0.565	0.36	0.00088	1.3	0.498
107.74	958.60	0.99	0.044	0.711	2.17	0.00615	4.7	0.627
114.14	957.67	1.92	0.081	1.108	8.44	0.02663	14.0	0.977
119.60	957.24	2.35	0.113	1.268	13.84	0.06019	25.6	1.118
128.43	956.52	3.06	0.163	1.52	33.26	0.14084	49.5	1.34
143.32	956.02	3.57	0.249	1.68	78.76	0.33183	98.9	1.48
143.63	955.88	3.71	0.251	1.72	1.92	0.33649	100.0	1.52
156.67	956.59	2.99	0.326	1.49	70.16	0.50663	143.7	1.31
163.88	956.74	2.85	0.367	1.44	30.93	0.58163	164.8	1.27
185.32	957.31	2.28	0.490	1.24	73.79	0.76055	219.7	1.10
195.63	957.38	2.20	0.550	1.22	28.38	0.82937	242.8	1.07
210.76	958.31	1.27	0.637	0.84	27.08	0.89505	269.1	0.74
228.21	958.60	0.99	0.737	0.71	15.30	0.93215	288.8	0.63
245.68	958.60	0.99	0.837	0.71	12.24	0.96182	306.0	0.63
248.00	958.67	0.91	0.851	0.68	1.53	0.96554	308.2	0.60
265.61	958.67	0.91	0.952	0.68	10.88	0.99191	324.3	0.60
268.96	958.53	1.06	0.971	0.75	2.35	0.99761	327.6	0.66
273.97	959.58	0.00	1.000	0.00	0.99	1.00000	330.3	0.00
			Est. Total		412.38			



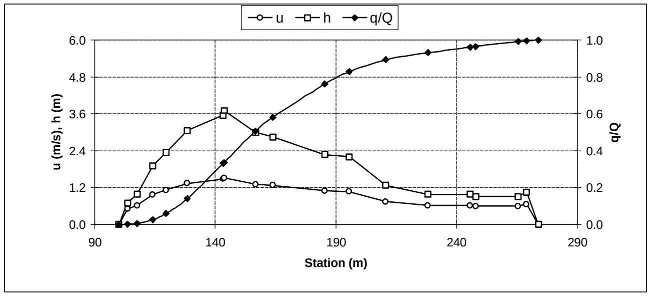
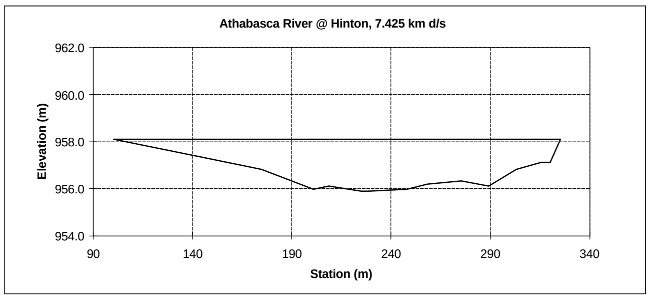


Figure A12 Cross Section - 6.075 km d/s

Table A13 Cross Section - 7.425 km d/s

X-SECTION	Athabasca River @ Hinton, 7.425 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	225.05	Est. Water Surface Elev.		958.10
MEAN DEPTH m	1.40	LB	100.17	958.10
AREA m^2	314.43	RB	325.23	958.10
MEAN VELOCITY m/s	1.156			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.17	958.10	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
144.67	957.33	0.77	0.198	0.777	6.66	0.01641	17.1	0.696
174.77	956.83	1.27	0.331	1.086	28.65	0.08694	47.9	0.973
201.01	955.97	2.13	0.448	1.533	58.51	0.23100	92.6	1.372
208.47	956.12	1.99	0.481	1.464	23.03	0.28771	107.9	1.310
225.05	955.90	2.20	0.555	1.57	52.68	0.41742	142.7	1.40
228.33	955.90	2.20	0.569	1.57	11.34	0.44534	149.9	1.40
247.79	955.97	2.13	0.656	1.53	65.41	0.60637	192.1	1.37
258.09	956.19	1.92	0.702	1.43	30.88	0.68239	213.0	1.28
275.15	956.33	1.77	0.777	1.36	43.84	0.79034	244.5	1.21
289.12	956.12	1.99	0.840	1.46	37.05	0.88154	270.7	1.31
302.88	956.83	1.27	0.901	1.09	28.62	0.95201	293.2	0.97
315.53	957.12	0.99	0.957	0.92	14.30	0.98721	307.5	0.82
319.97	957.12	0.99	0.977	0.92	4.01	0.99708	311.8	0.82
325.23	958.10	0.00	1.000	0.00	1.19	1.00000	314.4	0.00
				Est. Total	406.16			



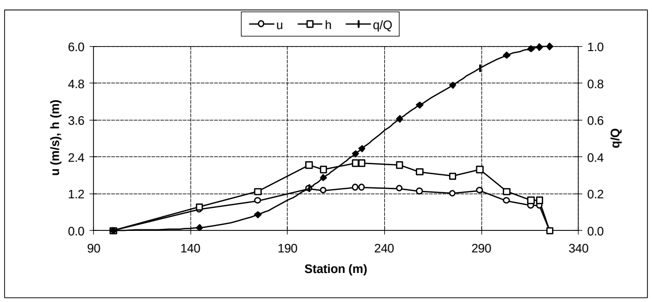
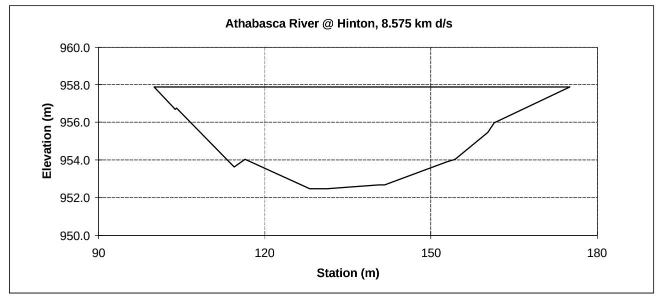


Figure A13 Cross Section - 7.425 km d/s

Table A14 Cross Section - 8.575 km d/s

X-SECTION	Athabasca River @ Hinton, 8.575 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	74.99	Est. Water Surface Elev.		957.89
MEAN DEPTH m	3.42	LB	100.01	957.89
AREA m^2	256.81	RB	175.00	957.89
MEAN VELOCITY m/s	1.416			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	957.89	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
103.88	956.69	1.20	0.052	0.704	0.82	0.00200	2.3	0.625
104.05	956.77	1.13	0.054	0.675	0.14	0.00233	2.5	0.600
114.52	953.61	4.28	0.193	1.644	32.86	0.08260	30.9	1.460
116.42	954.04	3.85	0.219	1.532	12.24	0.11250	38.6	1.361
128.06	952.46	5.43	0.374	1.93	93.42	0.34073	92.6	1.71
131.23	952.46	5.43	0.416	1.93	33.11	0.42163	109.8	1.71
140.59	952.68	5.21	0.541	1.87	94.72	0.65303	159.7	1.66
141.71	952.68	5.21	0.556	1.87	10.90	0.67966	165.5	1.66
152.90	953.90	4.00	0.705	1.57	88.75	0.89649	217.0	1.39
154.41	954.04	3.85	0.725	1.53	9.17	0.91890	222.9	1.36
160.24	955.48	2.42	0.803	1.12	24.28	0.97820	241.2	1.00
161.42	955.98	1.92	0.819	0.96	2.66	0.98471	243.8	0.85
175.00	957.89	0.00	1.000	0.00	6.26	1.00000	256.8	0.00
				Est. Total	409.33			



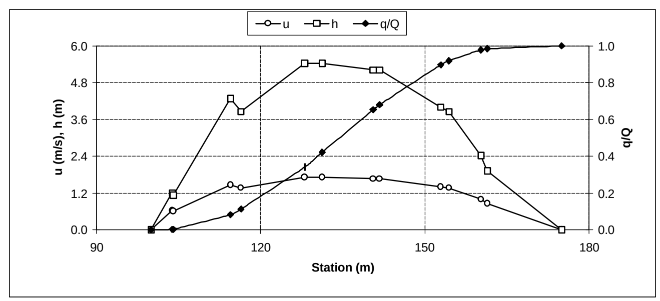
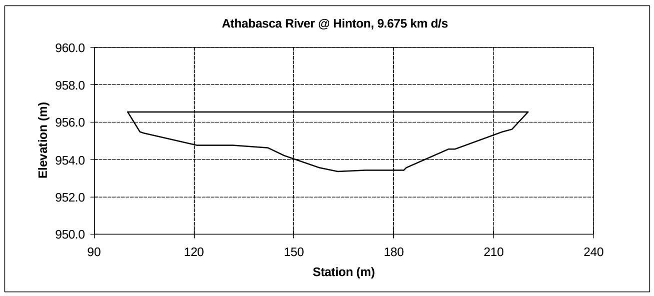


Figure A14 Cross Section - 8.575 km d/s

Table A15 Cross Section - 9.675 km d/s

X-SECTION	Athabasca River @ Hinton, 9.675 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	120.36	Est. Water Surface Elev.		956.55
MEAN DEPTH m	2.06	LB	100.01	956.55
AREA m^2	247.87	RB	220.37	956.55
MEAN VELOCITY m/s	1.467			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	956.55	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
103.82	955.49	1.06	0.032	0.940	0.95	0.00242	2.0	0.872
104.96	955.42	1.13	0.041	0.982	1.20	0.00548	3.3	0.911
120.89	954.78	1.77	0.173	1.328	26.70	0.07355	26.4	1.231
131.58	954.78	1.77	0.262	1.328	25.18	0.13775	45.3	1.231
142.16	954.63	1.92	0.350	1.40	26.63	0.20566	64.9	1.30
147.01	954.20	2.35	0.390	1.60	15.50	0.24518	75.2	1.48
157.61	953.56	2.99	0.479	1.88	49.30	0.37087	103.5	1.74
163.14	953.34	3.21	0.525	1.97	33.06	0.45516	120.7	1.83
171.43	953.42	3.14	0.593	1.94	51.44	0.58632	147.0	1.80
183.10	953.42	3.14	0.690	1.94	71.10	0.76761	183.6	1.80
183.83	953.56	2.99	0.696	1.88	4.27	0.77850	185.8	1.74
196.42	954.56	1.99	0.801	1.43	51.97	0.91101	217.2	1.33
198.36	954.56	1.99	0.817	1.43	5.53	0.92512	221.0	1.33
212.66	955.49	1.06	0.936	0.94	25.86	0.99104	242.8	0.87
215.58	955.64	0.91	0.960	0.85	2.58	0.99762	245.7	0.79
220.37	956.55	0.00	1.000	0.00	0.93	1.00000	247.9	0.00
				Est. Total	392.19			



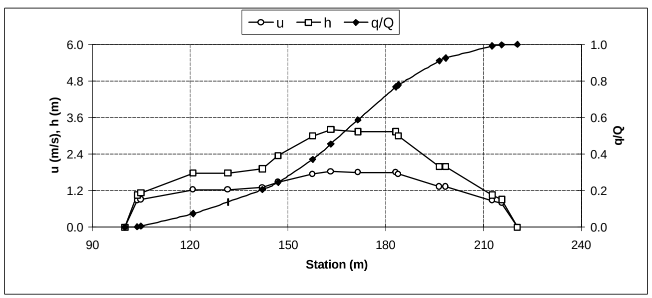
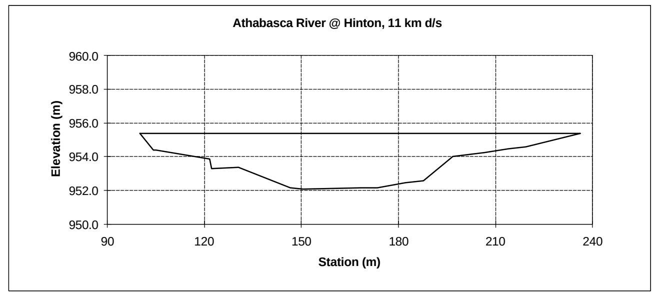


Figure A15 Cross Section - 9.675 km d/s

Table A16 Cross Section – 11.000 km d/s

X-SECTION	Athabasca River @ Hinton, 11 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	136.34	Est. Water Surface Elev.		955.36
MEAN DEPTH m	1.92	LB	100.01	955.36
AREA m^2	262.00	RB	236.35	955.36
MEAN VELOCITY m/s	1.388			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	955.36	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
104.25	954.38	0.99	0.031	0.889	0.93	0.00220	2.1	0.767
105.05	954.38	0.99	0.037	0.889	0.70	0.00386	2.9	0.767
121.68	953.88	1.49	0.159	1.170	21.17	0.05412	23.4	1.010
122.15	953.30	2.06	0.162	1.454	1.09	0.05672	24.3	1.255
130.56	953.37	1.99	0.224	1.42	24.46	0.11479	41.3	1.23
146.57	952.15	3.21	0.342	1.95	70.19	0.28142	82.9	1.69
150.60	952.08	3.28	0.371	1.98	25.69	0.34242	96.0	1.71
168.62	952.15	3.21	0.503	1.95	115.03	0.61550	154.4	1.69
173.50	952.15	3.21	0.539	1.95	30.55	0.68802	170.1	1.69
182.27	952.44	2.92	0.603	1.83	50.90	0.80886	196.9	1.58
187.79	952.58	2.78	0.644	1.77	28.36	0.87620	212.7	1.53
196.81	954.02	1.34	0.710	1.09	26.67	0.93951	231.3	0.94
206.55	954.23	1.13	0.781	0.97	12.45	0.96905	243.3	0.84
214.14	954.45	0.91	0.837	0.85	7.05	0.98579	251.1	0.73
219.37	954.59	0.77	0.875	0.75	3.52	0.99414	255.5	0.65
236.35	955.36	0.00	1.000	0.00	2.47	1.00000	262.0	0.00
				Est. Total	421.22			



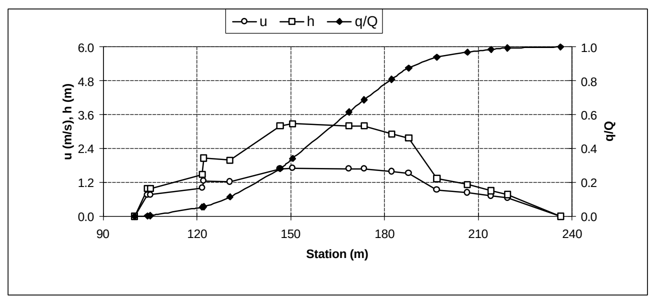
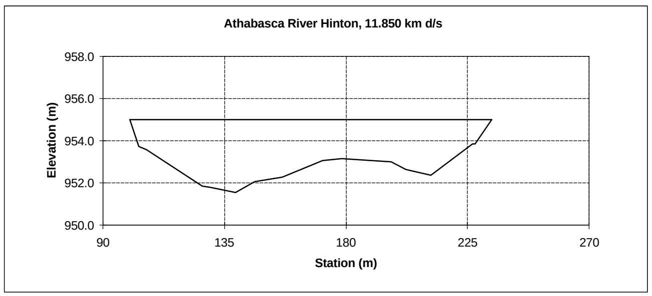


Figure A16 Cross Section – 11.000 km d/s

Table A17 Cross Section - 11.850 km d/s

X-SECTION	Athabasca River Hinton, 11.850 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	133.87	Est. Water Surface Elev.		954.99
MEAN DEPTH m	2.21	LB	100.01	954.99
AREA m^2	295.81	RB	233.88	954.99
MEAN VELOCITY m/s	1.229			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	954.99	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
103.19	953.72	1.27	0.024	0.851	0.86	0.00227	2.0	0.815
106.09	953.57	1.42	0.045	0.913	3.44	0.01133	5.9	0.875
126.78	951.85	3.14	0.200	1.552	58.06	0.16433	53.0	1.488
129.85	951.78	3.21	0.223	1.576	15.20	0.20439	62.7	1.510
138.97	951.57	3.42	0.291	1.65	48.70	0.33273	93.0	1.58
146.18	952.07	2.92	0.345	1.48	35.76	0.42695	115.8	1.42
156.22	952.28	2.71	0.420	1.41	40.81	0.53450	144.1	1.35
171.35	953.07	1.92	0.533	1.12	44.14	0.65081	179.1	1.07
178.50	953.14	1.85	0.586	1.09	14.86	0.68997	192.5	1.04
196.73	953.00	1.99	0.723	1.15	39.09	0.79297	227.5	1.10
202.12	952.64	2.35	0.763	1.28	14.17	0.83032	239.2	1.23
211.41	952.36	2.63	0.832	1.38	30.80	0.91149	262.3	1.32
226.77	953.86	1.13	0.947	0.79	31.32	0.99403	291.2	0.75
227.81	953.86	1.13	0.955	0.79	0.92	0.99646	292.4	0.75
233.88	954.99	0.00	1.000	0.00	1.34	1.00000	295.8	0.00
				Est. Total	379.48			



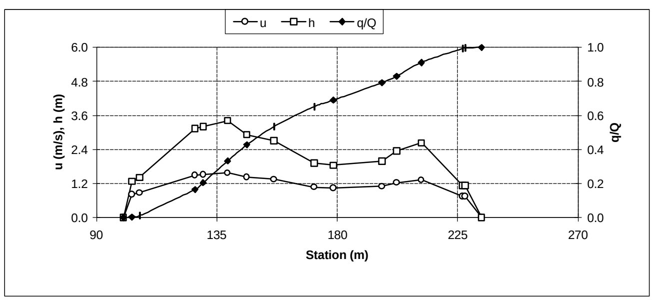
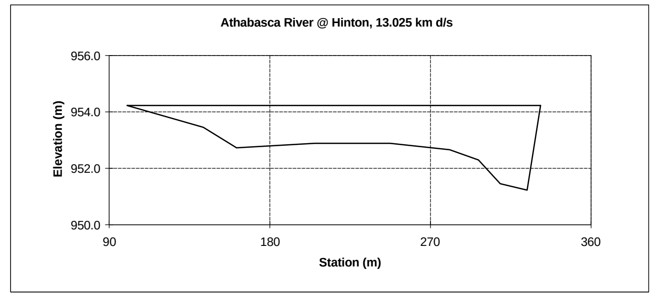


Figure A17 Cross Section - 11.850 km d/s

Table A18 Cross Section - 13.025 km d/s

X-SECTION	Athabasca River @ Hinton, 13.025 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	231.43	Est. Water Surface Elev.		954.21
MEAN DEPTH m	1.36	LB	100.17	954.21
AREA m^2	315.63	RB	331.60	954.21
MEAN VELOCITY m/s	1.152			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.17	954.21	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
142.67	953.44	0.77	0.184	0.787	6.44	0.01605	16.4	0.713
161.49	952.73	1.49	0.265	1.221	21.33	0.06919	37.6	1.106
205.19	952.87	1.34	0.454	1.141	73.04	0.25116	99.5	1.033
247.50	952.87	1.34	0.637	1.141	64.87	0.41276	156.3	1.033
280.88	952.65	1.56	0.781	1.26	58.14	0.55761	204.8	1.14
297.10	952.30	1.92	0.851	1.45	38.14	0.65262	233.0	1.31
309.18	951.44	2.78	0.903	1.85	46.76	0.76913	261.4	1.68
324.11	951.22	2.99	0.968	1.95	81.77	0.97283	304.4	1.76
331.60	954.21	0.00	1.000	0.00	10.91	1.00000	315.6	0.00
				Est. Total	401.40			



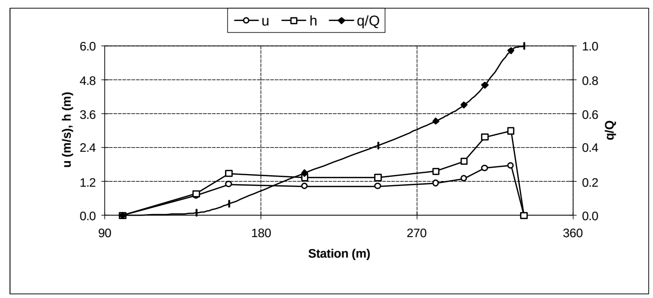
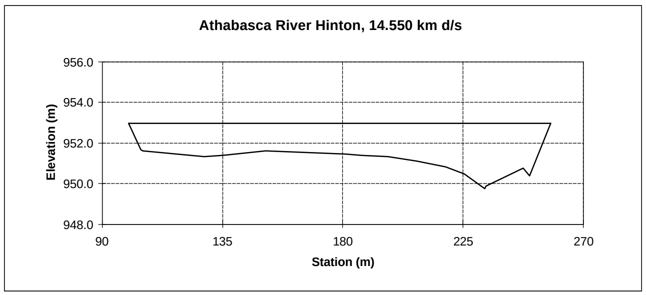


Figure A18 Cross Section - 13.025 km d/s

Table A19 Cross Section - 14.550 km d/s

X-SECTION	Athabasca River Hinton, 14.550 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	157.58	Est. Water Surface Elev.		952.95
MEAN DEPTH m	1.72	LB	100.01	952.95
AREA m^2	271.18	RB	257.59	952.95
MEAN VELOCITY m/s	1.341			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	952.95	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
104.42	951.68	1.27	0.028	1.096	1.54	0.00408	2.8	1.057
105.25	951.61	1.34	0.033	1.137	1.21	0.00729	3.9	1.096
128.13	951.32	1.63	0.178	1.294	41.35	0.11696	37.9	1.247
135.09	951.39	1.56	0.223	1.255	14.16	0.15450	49.0	1.210
151.07	951.61	1.34	0.324	1.14	27.74	0.22808	72.2	1.10
181.11	951.47	1.49	0.515	1.22	50.04	0.36079	114.7	1.17
186.81	951.39	1.56	0.551	1.26	10.74	0.38926	123.4	1.21
196.98	951.32	1.63	0.615	1.29	20.65	0.44403	139.6	1.25
207.55	951.11	1.85	0.682	1.40	24.80	0.50979	158.0	1.35
218.29	950.82	2.13	0.751	1.55	31.53	0.59341	179.4	1.49
225.39	950.46	2.49	0.796	1.72	26.78	0.66443	195.8	1.65
233.13	949.75	3.21	0.845	2.03	41.31	0.77398	217.8	1.96
233.48	949.89	3.06	0.847	1.97	2.21	0.77985	218.9	1.90
247.39	950.75	2.20	0.935	1.58	65.09	0.95245	255.6	1.53
249.67	950.39	2.56	0.950	1.75	9.06	0.97647	261.0	1.69
257.59	952.95	0.00	1.000	0.00	8.87	1.00000	271.2	0.00
				Est. Total	377.07			



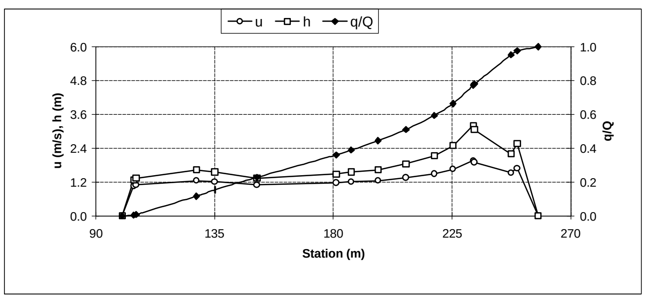
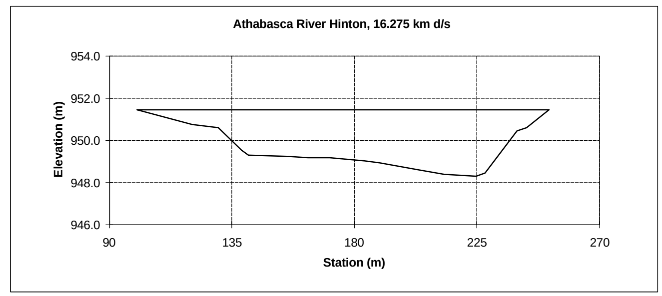


Figure A19 Cross Section - 14.550 km d/s

Table A20 Cross Section - 16.275 km d/s

X-SECTION	Athabasca River Hinton, 16.275 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	151.37	Est. Water Surface Elev.		951.44
MEAN DEPTH m	1.87	LB	100.09	951.44
AREA m^2	283.68	RB	251.46	951.44
MEAN VELOCITY m/s	1.282			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.09	951.44	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
120.43	950.75	0.70	0.134	0.664	2.36	0.00569	7.1	0.582
130.00	950.60	0.84	0.198	0.752	5.22	0.01828	14.5	0.659
138.36	949.53	1.92	0.253	1.301	11.84	0.04684	26.0	1.141
141.11	949.31	2.13	0.271	1.397	7.51	0.06496	31.6	1.225
155.95	949.24	2.20	0.369	1.43	45.46	0.17461	63.8	1.25
162.97	949.17	2.28	0.415	1.46	22.71	0.22939	79.5	1.28
170.79	949.17	2.28	0.467	1.46	25.96	0.29201	97.3	1.28
183.86	949.02	2.42	0.553	1.52	45.72	0.40229	128.0	1.33
189.25	948.95	2.49	0.589	1.55	20.29	0.45123	141.2	1.36
203.43	948.59	2.85	0.683	1.70	61.42	0.59939	179.1	1.49
213.01	948.38	3.06	0.746	1.78	49.22	0.71811	207.4	1.56
224.66	948.31	3.14	0.823	1.81	64.78	0.87437	243.5	1.58
227.97	948.45	2.99	0.845	1.75	18.03	0.91786	253.6	1.54
239.72	950.46	0.99	0.922	0.83	30.24	0.99079	277.0	0.73
243.18	950.60	0.84	0.945	0.75	2.51	0.99684	280.2	0.66
251.46	951.44	0.00	1.000	0.00	1.31	1.00000	283.7	0.00
				Est. Total	414.56			



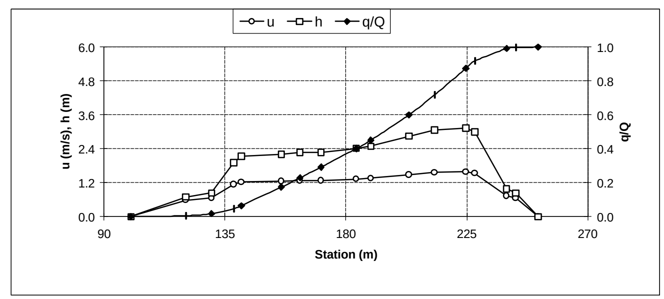
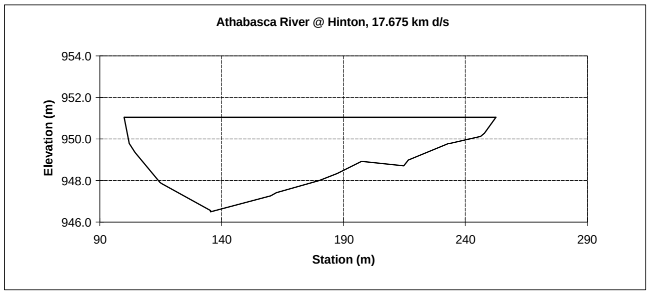


Figure A20 Cross Section - 16.275 km d/s

Table A21 Cross Section - 17.675 km d/s

X-SECTION	Athabasca River @ Hinton, 17.675 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	152.41	Est. Water Surface Elev.		951.05
MEAN DEPTH m	2.71	LB	100.01	951.05
AREA m^2	412.85	RB	252.41	951.05
MEAN VELOCITY m/s	0.881			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	951.05	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
102.21	949.78	1.27	0.014	0.532	0.37	0.00094	1.4	0.486
104.38	949.35	1.70	0.029	0.646	1.91	0.00573	4.6	0.590
114.77	947.91	3.14	0.097	0.971	20.31	0.05676	29.8	0.887
115.52	947.84	3.21	0.102	0.986	2.34	0.06263	32.1	0.901
135.41	946.55	4.50	0.232	1.24	85.10	0.27650	108.8	1.13
135.48	946.48	4.57	0.233	1.25	0.39	0.27749	109.1	1.14
160.02	947.27	3.78	0.394	1.10	120.35	0.57991	211.6	1.01
162.36	947.41	3.64	0.409	1.07	9.42	0.60359	220.3	0.98
180.01	947.98	3.06	0.525	0.96	59.99	0.75434	279.4	0.87
187.45	948.34	2.71	0.574	0.88	19.69	0.80383	300.9	0.80
197.51	948.92	2.13	0.640	0.75	19.86	0.85372	325.2	0.69
214.72	948.70	2.35	0.753	0.80	29.89	0.92885	363.7	0.73
216.47	948.99	2.06	0.764	0.73	2.96	0.93628	367.6	0.67
233.02	949.78	1.27	0.873	0.53	17.45	0.98015	395.2	0.49
233.62	949.78	1.27	0.877	0.53	0.41	0.98118	396.0	0.49
246.29	950.14	0.91	0.960	0.43	6.64	0.99785	409.8	0.39
247.81	950.28	0.77	0.970	0.38	0.52	0.99915	411.1	0.35
252.41	951.05	0.00	1.000	0.00	0.34	1.00000	412.9	0.00
			Est. Total		397.93			



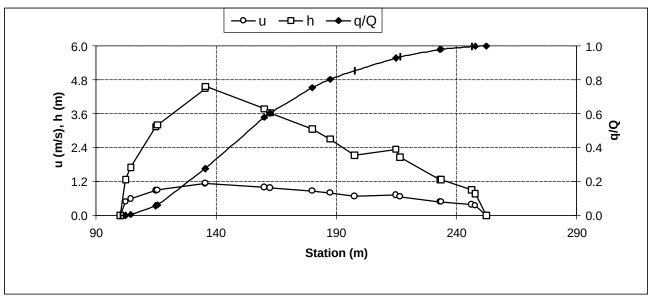
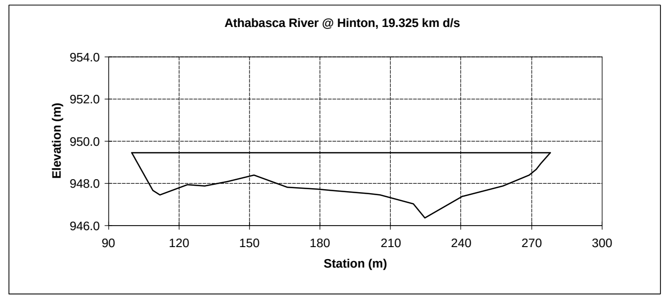


Figure A21 Cross Section - 17.675 km d/s

Table A22 Cross Section - 19.325 km d/s

X-SECTION	Athabasca River @ Hinton, 19.325 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	178.11	Est. Water Surface Elev.		949.44
MEAN DEPTH m	1.68	LB	100.01	949.44
AREA m^2	298.79	RB	278.13	949.44
MEAN VELOCITY m/s	1.217			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	949.44	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
108.78	947.66	1.77	0.049	1.263	4.91	0.01289	7.8	1.205
111.69	947.45	1.99	0.066	1.363	7.19	0.03175	13.3	1.301
123.54	947.95	1.49	0.132	1.123	25.60	0.09892	33.8	1.071
131.00	947.88	1.56	0.174	1.159	12.97	0.13295	45.2	1.106
140.66	948.09	1.34	0.228	1.05	15.48	0.17356	59.2	1.00
151.93	948.38	1.06	0.291	0.89	13.15	0.20807	72.8	0.85
165.95	947.81	1.63	0.370	1.19	19.67	0.25969	91.6	1.14
179.09	947.74	1.70	0.444	1.23	26.55	0.32934	113.5	1.17
184.97	947.66	1.77	0.477	1.26	12.73	0.36274	123.7	1.21
201.03	947.52	1.92	0.567	1.33	38.43	0.46356	153.4	1.27
205.73	947.45	1.99	0.594	1.36	12.38	0.49606	162.6	1.30
219.63	947.02	2.42	0.672	1.55	44.67	0.61326	193.2	1.48
224.66	946.37	3.06	0.700	1.82	23.26	0.67428	207.0	1.74
240.61	947.38	2.06	0.789	1.40	65.72	0.84672	247.9	1.33
240.88	947.38	2.06	0.791	1.40	0.78	0.84876	248.4	1.33
257.99	947.88	1.56	0.887	1.16	39.56	0.95254	279.4	1.11
269.11	948.38	1.06	0.949	0.89	14.93	0.99172	293.9	0.85
271.94	948.67	0.77	0.965	0.72	2.09	0.99721	296.5	0.69
273.96	948.95	0.48	0.977	0.53	0.79	0.99930	297.8	0.51
278.13	949.44	0.00	1.000	0.000	0.27	1.00000	298.8	0.000
			Est. Total		381.13			



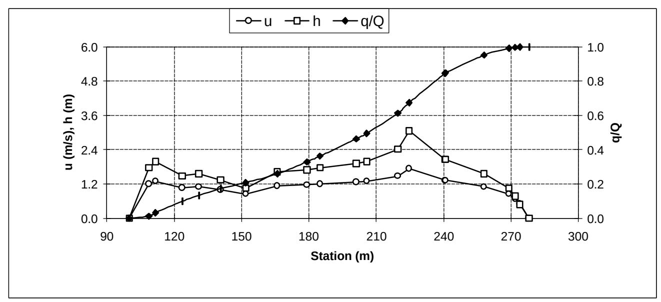
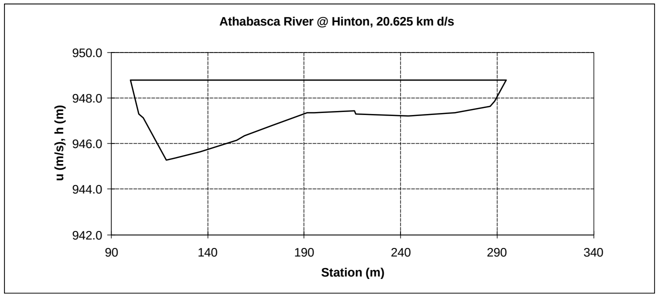


Figure A22 Cross Section - 19.325 km d/s

Table A23 Cross Section - 20.625 km d/s

X-SECTION	Athabasca River @ Hinton, 20.625 km d/s			
DATE	August 18, 1998			
DISCHARGE m3/s	364.00			
WIDTH m	194.68	Est. Water Surface Elev.		948.76
MEAN DEPTH m	1.87	LB	100.01	948.76
AREA m^2	363.70	RB	294.68	948.76
MEAN VELOCITY m/s	1.001			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	948.76	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
104.37	947.28	1.49	0.022	0.860	1.39	0.00354	3.2	0.795
106.49	947.13	1.63	0.033	0.914	2.93	0.01099	6.5	0.846
118.44	945.27	3.49	0.095	1.520	37.28	0.10574	37.2	1.406
122.91	945.34	3.42	0.118	1.499	23.34	0.16506	52.6	1.387
132.17	945.56	3.21	0.165	1.44	45.04	0.27953	83.3	1.33
136.09	945.63	3.14	0.185	1.41	17.71	0.32454	95.8	1.31
154.91	946.13	2.63	0.282	1.26	72.56	0.50897	150.1	1.16
159.12	946.35	2.42	0.304	1.19	13.00	0.54202	160.7	1.10
173.22	946.78	1.99	0.376	1.04	34.69	0.63020	191.8	0.97
191.68	947.35	1.42	0.471	0.83	29.48	0.70512	223.2	0.77
195.22	947.35	1.42	0.489	0.83	4.16	0.71570	228.2	0.77
216.18	947.42	1.34	0.597	0.80	23.64	0.77580	257.1	0.74
216.69	947.28	1.49	0.599	0.86	0.60	0.77733	257.9	0.80
243.72	947.21	1.56	0.738	0.89	35.96	0.86873	299.0	0.82
244.28	947.21	1.56	0.741	0.89	0.77	0.87069	299.9	0.82
268.05	947.35	1.42	0.863	0.83	30.39	0.94792	335.3	0.77
286.50	947.64	1.13	0.958	0.72	18.15	0.99407	358.7	0.66
288.67	947.85	0.91	0.969	0.62	1.48	0.99783	360.9	0.57
294.68	948.76	0.00	1.000	0.00	0.85	1.00000	363.7	0.00
				Est. Total	393.44			



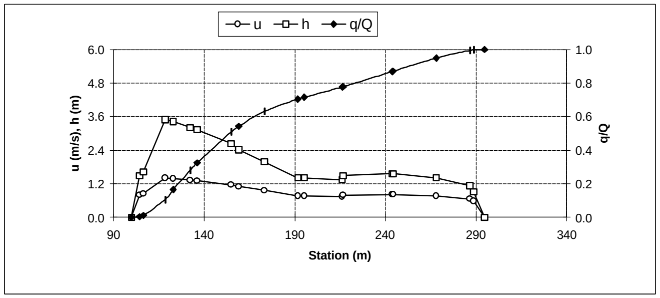
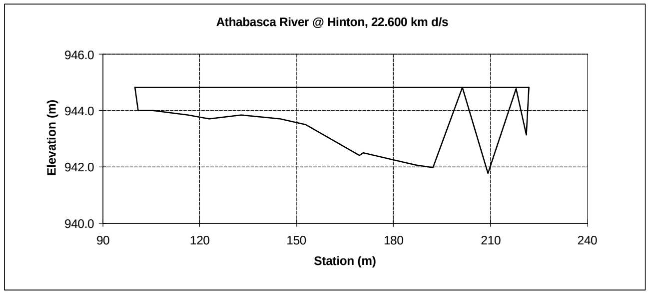


Figure A23 Cross Section - 20.625 km d/s

Table A24 Cross Section - 22.600 km d/s

X-SECTION	Athabasca River @ Hinton, 22.600 km d/s			
DATE	August 19, 1998			
DISCHARGE m3/s	363.60			
WIDTH m	121.84	Est. Water Surface Elev.		944.83
MEAN DEPTH m	1.53	LB	100.00	944.83
AREA m^2	186.97	RB	221.84	944.83
MEAN VELOCITY m/s	1.945			

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.00	944.83	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
101.04	943.99	0.84	0.008	1.303	0.28	0.00075	0.4	1.249
105.53	943.99	0.84	0.045	1.303	4.93	0.01374	4.2	1.249
116.32	943.85	0.99	0.134	1.447	13.56	0.04948	14.1	1.387
122.96	943.71	1.13	0.188	1.585	10.65	0.07756	21.1	1.519
132.84	943.85	0.99	0.269	1.45	15.82	0.11928	31.5	1.39
144.83	943.71	1.13	0.368	1.58	19.21	0.16992	44.2	1.52
152.73	943.49	1.34	0.433	1.78	16.44	0.21327	54.0	1.71
169.43	942.41	2.42	0.570	2.63	69.37	0.39614	85.4	2.53
170.64	942.49	2.35	0.580	2.58	7.48	0.41586	88.3	2.47
186.78	942.06	2.78	0.712	2.89	113.13	0.71408	129.6	2.77
192.25	941.98	2.85	0.757	2.94	44.88	0.83239	145.0	2.82
201.39	944.83	0.00	0.832	0.00	19.13	0.88282	158.1	0.00
209.23	941.77	3.06	0.897	3.08	18.53	0.93168	170.1	2.96
217.83	944.78	0.05	0.967	0.20	21.99	0.98964	183.5	0.19
221.09	943.13	1.70	0.994	2.08	3.27	0.99825	186.3	2.00
221.84	944.83	0.00	1.000	0.00	0.66	1.00000	187.0	0.00
				Est. Total	379.35			



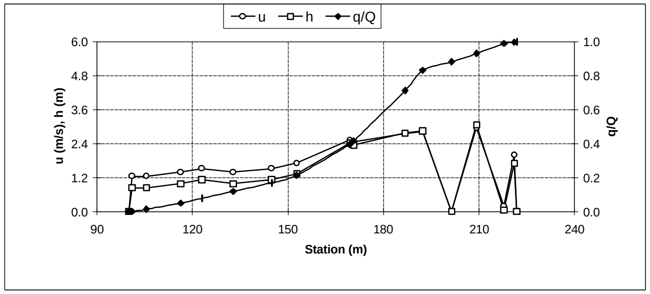
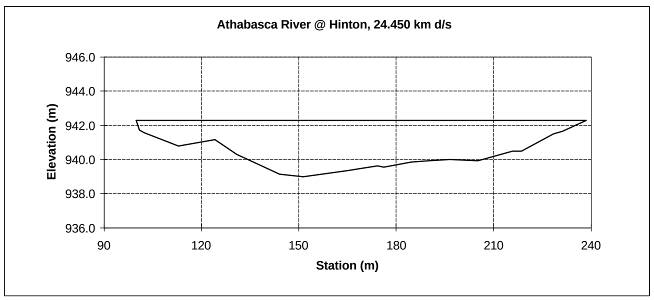


Figure A24 Cross Section - 22.600 km d/s

Table A25 Cross Section - 24.450 km d/s

X-SECTION	Athabasca River @ Hinton, 24.450 km d/s	
DATE	August 19, 1998	
DISCHARGE m3/s	363.60	
WIDTH m	138.46	Est. Water Surface Elev. 942.27
MEAN DEPTH m	2.03	LB 100.01 942.27
AREA m^2	281.66	RB 238.46 942.27
MEAN VELOCITY m/s	1.291	

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.01	942.27	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
101.02	941.71	0.56	0.007	0.543	0.08	0.00019	0.3	0.497
102.23	941.57	0.70	0.016	0.633	0.44	0.00131	1.0	0.579
112.89	940.78	1.49	0.093	1.048	9.79	0.02596	12.7	0.959
124.18	941.14	1.13	0.175	0.872	14.18	0.06165	27.5	0.798
130.85	940.28	1.99	0.223	1.27	11.14	0.08971	37.9	1.16
144.01	939.13	3.14	0.318	1.72	50.51	0.21688	71.6	1.58
151.39	938.99	3.28	0.371	1.78	41.39	0.32109	95.3	1.63
165.65	939.35	2.92	0.474	1.64	75.54	0.51128	139.5	1.50
167.87	939.42	2.85	0.490	1.62	10.45	0.53760	145.9	1.48
174.23	939.63	2.63	0.536	1.53	27.47	0.60677	163.3	1.40
176.15	939.56	2.71	0.550	1.56	7.93	0.62674	168.4	1.43
184.74	939.85	2.42	0.612	1.45	33.14	0.71018	190.5	1.33
190.11	939.92	2.35	0.651	1.42	18.34	0.75637	203.2	1.30
196.45	939.99	2.28	0.697	1.39	20.62	0.80829	217.9	1.27
205.26	939.92	2.35	0.760	1.42	28.62	0.88034	238.3	1.30
215.79	940.49	1.77	0.836	1.18	28.20	0.95133	260.0	1.08
218.54	940.49	1.77	0.856	1.18	5.74	0.96579	264.8	1.08
228.45	941.50	0.77	0.928	0.68	11.69	0.99522	277.5	0.62
231.23	941.64	0.63	0.948	0.59	1.23	0.99832	279.4	0.54
238.46	942.27	0.00	1.000	0.000	0.67	1.00000	281.7	0.000
				Est. Total	397.17			



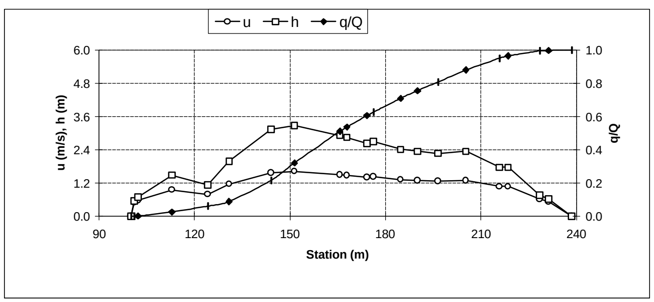
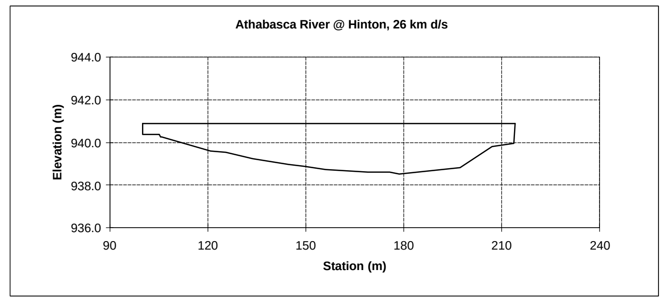


Figure A25 Cross Section - 24.450 km d/s

Table A26 Cross Section – 26.000 km d/s

X-SECTION	Athabasca River @ Hinton, 26 km d/s	
DATE	August 19, 1998	
DISCHARGE m3/s	363.60	
WIDTH m	114.04	Est. Water Surface Elev. 940.87
MEAN DEPTH m	1.68	LB 100.00 940.87
AREA m^2	191.26	RB 214.04 940.87
MEAN VELOCITY m/s	1.901	

Sta. (m)	Elev. (m)	h (m)	w/W	u (m/s)	DQ	q/Q	Area m^2	adj. U (m/s)
100.00	940.87	0.00	0.000	0.000	0.00	0.00000	0.0	0.000
100.10	940.39	0.48	0.001	0.830	0.01	0.00003	0.0	0.782
105.26	940.39	0.48	0.046	0.830	2.07	0.00540	2.5	0.782
105.63	940.25	0.63	0.049	0.986	0.19	0.00588	2.7	0.930
105.96	940.25	0.63	0.052	0.986	0.20	0.00641	2.9	0.930
120.88	939.60	1.27	0.183	1.58	18.18	0.05357	17.1	1.49
125.63	939.53	1.34	0.225	1.64	10.01	0.07952	23.3	1.55
133.71	939.24	1.63	0.296	1.87	21.07	0.13416	35.3	1.76
144.80	938.96	1.92	0.393	2.08	38.81	0.23481	55.0	1.96
149.68	938.89	1.99	0.436	2.13	20.05	0.28680	64.5	2.01
156.06	938.74	2.13	0.492	2.23	28.70	0.36123	77.7	2.10
169.05	938.60	2.28	0.605	2.33	65.26	0.53048	106.3	2.20
175.62	938.60	2.28	0.663	2.33	34.88	0.62093	121.3	2.20
178.63	938.53	2.35	0.690	2.38	16.37	0.66340	128.2	2.24
197.30	938.81	2.06	0.853	2.18	93.80	0.90664	169.4	2.06
207.07	939.82	1.06	0.939	1.40	27.27	0.97736	184.6	1.32
213.63	939.96	0.91	0.996	1.27	8.61	0.99969	191.1	1.20
214.04	940.87	0.00	1.000	0.00	0.12	1.00000	191.3	0.00
				Est. Total	385.60			



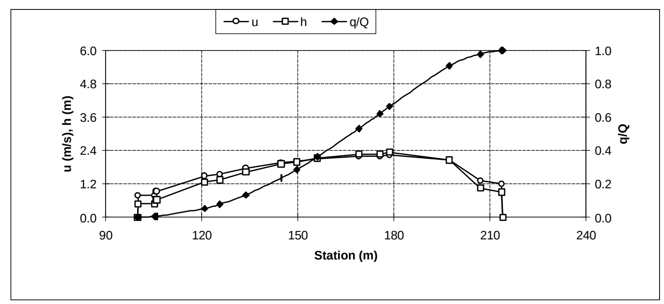


Figure A26 Cross Section – 26.000 km d/s