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Physical mixing patterns of water and contaminants in the North Saskatchewan River

Prepared for:

Alberta Environment

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EXECUTIVE SUMMARY

A ten day field campaign was carried out on North Saskatchewan River to study the physical mixing with the ambient river water of effluent from the Goldbar Wastewater Treatment Plant (WWTP), Capital Region WWTP and Agrium Redwater operations. In this report we present rhodamine concentrations, depth averaged water velocities, and flow depths across surveyed sections in reaches downstream of each plant.

The objectives of the study were twofold. The primary objective was to determine the downstream distance required to achieve full mixing of the effluent. Full mixing was defined as the location where tracer concentration was uniform across the section. The second objective was to measure spatially distributed tracer concentration and water velocity in the mixing zone, such that dispersion patterns could be determined.

Rhodamine WT was used a tracer of plant effluent. The Rhodamine WT was injected in the Agrium effluent for 6 hours on October 25, 2011 and was traced on the same day over a 12 km reach downstream of the plant. The Capital Region WWTP injection occurred for 13 hours on October 26, 2011, and the rhodamine plume was traced for a period of three days (October 26-28, 2011) over a total distance of 83km along the river path. Lastly, Rhodamine WT injection into final plant effluent occurred for 13 hours on October 29, 2011 at the Goldbar WWTP, and the plume was traced for three days (October 29-31, 2011) over a 93km reach.

The tracer concentration was tracked from a boat moving both across and along the river using an *in situ* fluorometer integrated into a Seabird Conductivity-Temperature-Depth (CTD) instrument. Physical water samples were also collected at various locations in the river for subsequent laboratory analysis of rhodamine concentration. The measured physical sample rhodamine concentrations suitably verified the *in situ* fluorometer results.

The river hydrodynamics were also measured using a Sontek M9 Riversurveyor Acoustic Doppler Current Profiler (ADCP). The ADCP was mounted to the survey vessel, and was specifically selected for surveying the relatively shallow depths of the North Saskatchewan River in October. An anemometer was also set-up near the outfall to monitor wind speed and direction.

The CTD and ADCP data were collected simultaneously and synchronized by means of Global Positioning System (GPS) position and time-stamp data that were integrated into the data streams collected by both the CTD and ADCP. The survey was conducted by collecting data along multiple transects in each reach. In this report we present rhodamine concentrations, depth averaged water velocities, and flow depths across these sections. The measured reach-average depth and depth-averaged velocity were 1.42m and 0.52m/s, respectively.

For each plant, the maximum measured Rhodamine WT concentrations were found at the location of discharge to the river. These locations were at the right river bank for the two WWTPs and near the left river bank at Agrium, thus the plume began near a river bank in each case. The plume was observed to disperse to the opposite bank by 6.3 km (Capital Region WWTP), 11.6 km (Goldbar WWTP), and 12 km (Agrium) downstream from the outfall. The rhodamine concentration reduced gradually along the river path as the tracer mixed with ambient water. Despite the massive survey effort over many river km, full mixing to the point of uniform concentration across the section was not observed. For the Goldbar survey, the rhodamine concentration reduced to 0.26 ppb on the right bank at 92km from the outfall, where the average measured tracer concentration across the section was 0.23 ppb. While the 95% confidence intervals for rhodamine concentration across the 92 km section suggest that full mixing had not yet been achieved, the difference in concentration between the right and left banks (0.05 ppb) was only 20% of the mean concentration at the section. A dispersion model based on these results suggests that the distance required for full mixing of the Goldbar WWTP effluent was approximately 123 km, wherein full mixing is defined as no greater than a 5% difference in concentration across the section.

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1- Introduction

This report is prepared as a part of "Physical mixing patterns of water and contaminants in the North Saskatchewan River" project which was carried out by the research team from the Civil Engineering departments of the University of Ottawa and the University of Alberta, between 23rd to 31st of October 2011. The outfall mixing pattern has been studied for three plants proposed by Alberta Environment; Goldbar Wastewater Treatment Plant (WWTP), Capital Region Waste Water Treatment Plant and Agrium Redwater plant (Fig. 1-1).

For each plant Rhodamine WT was injected as tracer at the outfall location and the mixing pattern was tracked using an *in situ* flourometer. In addition to *in situ* concentration measurement, water samples were collected at several sections along the measurement path to allow for verification of the *in situ* flourometer results based on subsequent laboratory analysis of Rhodamine WT concentration in the water samples. The hydraulic characteristics of flow in the river were also investigated simultaneously by measuring depth averaged velocity and water depth in the river using an Acoustic Doppler Current Profiler (ADCP). Wind speed and direction can be important for physical mixing in surface water, and thus wind was also measured at the outfall of each plant using an anemometer.

The objectives of the study were twofold. The primary objective was to determine the downstream distance required to achieve full mixing of the effluent. Full mixing was defined as the location where tracer concentration was uniform across the section. The second objective was to measure spatially distributed tracer concentration and water velocity in the mixing zone, such that dispersion patterns could be determined.

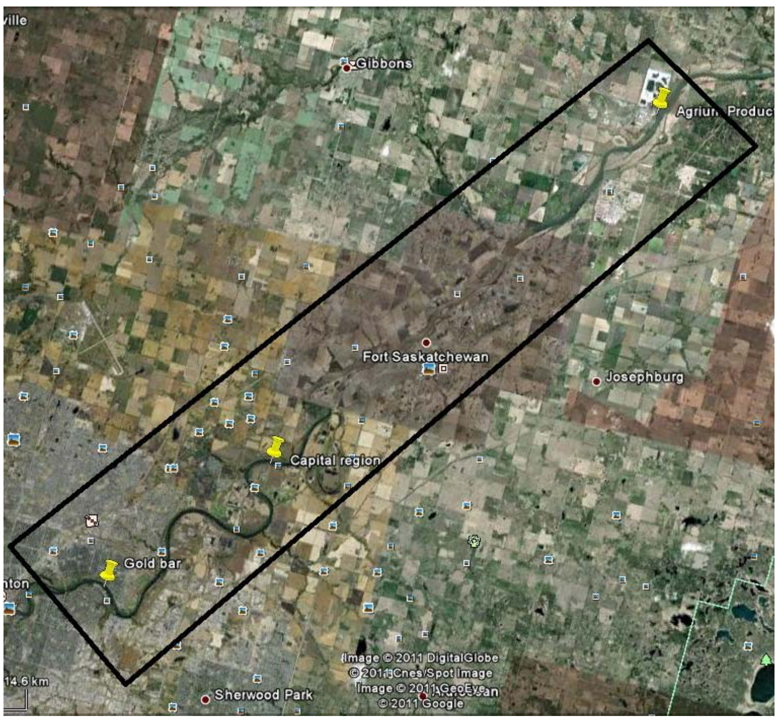


Figure 1-1: Investigated site locations (adopted form Google Earth). Flow is from left to right.

Agrium Redwater is a fertilizer producing plant, with approximate outfall discharge of 4600m^3/day to North Saskatchewan river (Figure 1-2).

Figure 1-2: Agrium Redwater outfall (Left) and site location (right) (right picture adopted from Google Earth)

Capital region Waste Water Treatment plant (WWTP) is the fourth-largest treatment facility in Alberta. It treats the wastewater and sewage needs of more than 200,000 people each day and the current capacity of this plant is 140 ML/d (Figure 1-3).

Figure 1-3:Capital Region WWTP outfal (Left) and site location (right) (right picture adopted from Google Earth)

Goldbar WWTP is located in the North Saskatchewan River Valley. It treats waste water for 700000 people. The current capacity of this plant is 82MGD (310 ML/d). (Figure 1-4)

Figure 1-4:Goldbar WWTP site location, left picture from Drainage Information Systems Drainage Services

The field campaign was started on October 25 at Agrium Redwater which was the most downstream plant effluent surveyed during the field campaign and proceeded upstream to Capital Region WWTP on October 26-28 and then Goldbar WWTP on October 29-31, 2011. The Rhodamine WT injection date, tracing duration and tracing distance along river path are presented in Table 1-1.

Table 1-1: Surveying date and traced distance

Plant	Surveying date	Traced distance
Agrium Redwater	October 25	12km
Capital Region (WWTP)	October 26-28	83km
Goldbar (WWTP)	October 29-31	93km

This report is prepared in five sections. In section 1, the project is introduced and the main procedure and goals of the study are described. Section 2 explains the study procedure and equipment used for tracer injection and field measurement activities on the river, as well as software and analytical methods used for data post processing. The results of the study including tracer concentration, sample concentration, depth averaged velocity, water depth, and wind speed and direction at some sections are presented in Section 3, and the results for all sections are presented in the appendices. Section 4 provides discussion of the presented data. The primary results, discussion, and conclusions are summarized in Section 5.

2- Method

The survey study procedure consisted of three main components; 1) set up and tracer injection at outfall location 2)field activity on the river including *in situ* concentration measurements by fluorometer, depth averaged velocity and bed elevation by ADCP and water sampling 3) post processing .

The main equipment used in the field study was as follows:

- Seabird Conductivity, temperature, and pressure (CTD) SBE19plusV2 equipped with *in situ* fluorometer and turbidity sensor
- Acoustic Doppler Current Profiler (ADCP)
- Windsonic anemometer
- Peristaltic pump
- Global Positioning System (GPS)

2-1- CTD

A CTD is primarily designed to measure salinity, temperature and depth using conductivity, temperature and pressure sensors respectively (Fig. 2-1). Due to availability of recent technology developments and invention of new *in situ* sensors, the CTD utilized in the present study integrated an additional fluorometer and a turbidity sensor. A CTD is lowered down into the water and continuously records data from each of its sensors. The fluorometer used in the present study is suitable for detection of Rhodamine WT concentrations ranging from 0.01 ppb to 230 ppb with 0.01 ppb sensitivity (i.e., resolution). Rhodamine WT concentrations were recorded with a sampling frequency of 4Hz.

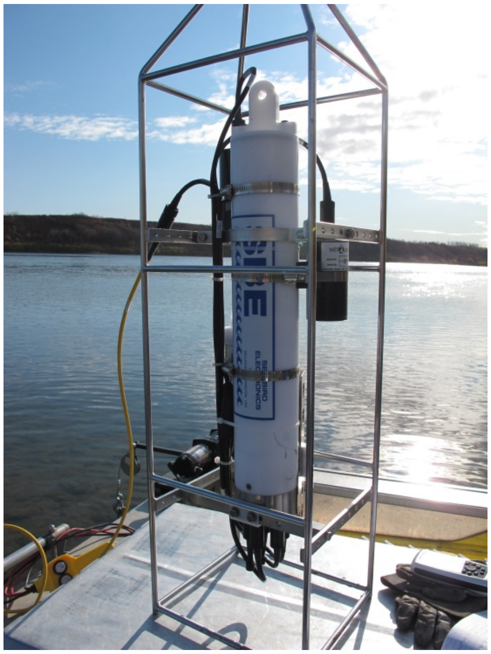


Figure 2-1: Seabird CTD SBE19plusV2

2-2- ADCP

Depth averaged velocity and bed elevation was measured using a SonTek M9 Riversurveyor ADCP. An ADCP measures spatial averages of the three principal water velocity components in individual “bins” throughout a vertical column of water, and can be operated from a moving vessel. ADCPs use the Doppler principle to measure water velocities, utilizing four acoustic transducers. Each transducer is orthogonal to the others (spaced at 90º around the circle), and angled from the vertical (at 25º for the present instrument). From each of the four transducers, an acoustic pulse (“ping”) is transmitted. The acoustic pulse scatters off particles in the fluid, which are assumed to be traveling at the velocity of the fluid. The frequency of the scattered sound is changed due to the Doppler shift related to the velocity of the particles. The backscattered sound is received by the transducer, and the along-beam component of particle (fluid) velocity is estimated based on the observed Doppler shift. Furthermore, the backscattered sound is “range-gated”, meaning it is processed in sequences, which allows for determination of velocity at sequential depths (“bins”) below the instrument. A coordinate transform allows for estimation of the three Cartesian velocity components at all depths below the instrument. A separate “bottom track” (Doppler sonar) pulse is used to measure the local water depth and the speed of the vessel. Lastly, an on-board compass allows for rotation of the measured velocities into Earth coordinates (East, North, Up).

The ADCP was mounted at the side of the boat (Fig. 2-2). This M9 ADCP was selected for this research because it can utilize either 3 MHz or 1 MHz transducers. The 3 MHz transducers are utilized in shallow water to obtain data with better vertical resolution. Most importantly, this ADCP has a small “blanking distance” of 20 cm, i.e., it obtains its first measurement bin only 20 cm from the transducers, which was essential for this project because the river was shallow with depths of only O(1 m) during the survey. The ADCP measured water velocities and depths at 1 Hz sampling frequency.

The collected ADCP data were post-processed in Matlab using scripts developed by Rennie. The Matlab scripts included routines to calculate depth averaged velocity from the individual profile data. Unfortunately, *in situ* calibration of the compass proved to be difficult in the field conditions encountered during the study, thus transformation to Earth coordinates has some degree of uncertainty. In this report we present depth-averaged velocity magnitudes.

Figure 2-2: ADCP, mounted on the boat side

2-3- Anemometer

Wind speed and direction were measured using a WindSonic anemometer. This instrument include the anemometer sensor, a data logger, and a solar battery. The data were collected with 4Hz frequency with 0.01m/s and 1º resolution for velocity and direction, respectively.

Figure 2-3: Anemometer set (Anemometer sensor, Data logger and Solar battery)

2-4- GPS

A survey grade dual frequency real-time kinematic (RTK) Global Differential Positioning System was employed on the boat to locate the measurements. The GPS was manufactured by Novatel, and included a Novatel DL-V3-L1L2 base receiver and a Novatel Propak LB+ rover receiver with reported relative horizontal position accuracy of ±2 cm CEP (i.e. 50% of position estimates have error < 2 cm). The precision of the RTK-DGPS system was previously evaluated by Rennie and Rainville (2006), wherein average error of measured RTK-DGPS velocity equalled 2.6 cm/s. The radio communication between base and receiver had a range of about 10 km, which limited RTK accuracy to this range. For sampling at larger distances from the outlet, differential correction was obtained conventionally using the Wide Area Augmentation Strategy (WAAS), which has position accuracy of O(1 m) and average velocity error of about 10 cm/s. Position data were collected at 10 Hz, and were integrated into the CTD and ADCP data sets for correct positioning and synchronization of the CTD and ADCP data.

2-5- Peristaltic pump

A peristaltic pump (Fig. 2-4 left) was used for injecting Rhodamine WT with a specific flow rate into the WWTP effluent at the plant outfall before entering the river. In order to determine the flow rate corresponding to the specific speed of the pump, a calibration curve of the pump was prepared (Fig. 2-4 right).

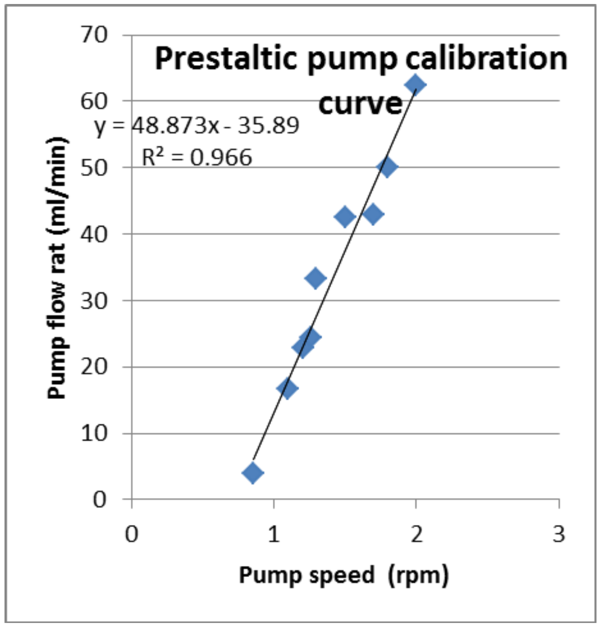


Figure 2-4: Prestaltic pump (left), Calibration curve for peristaltic pump

According to environmental code of practice for Hydrologic Tracing Analysis Studies by government of Alberta, Rhodamine WT dye should be used as the tracer-dye, unless an alternate tracer-dye is authorized. Following government of Alberta environmental code, in this study Rhodamine WT was used as tracer.

Rhodamine WT is a highly fluorescent material with the unique ability to absorb green light and emit red light. Very few compounds have this property, so interferences from other substances are very rare. This makes Rhodamine WT a highly specific tracer. This property is used in the design of the fluorometer.

Rhodamine WT density is 1.26g/cm^3, thus it was diluted with an equal volume of methanol with 0.7918 g/cm^3 density in order to produce a neutrally buoyant mixture with lower viscosity and surface tension characteristics

The major advantages of rhodamine are as follows:
- Continuous onboard measurement using electronic sensors is possible for this tracer
- It is nontoxic, thus not harmful to the environment
- It is relatively inexpensive, which makes continuous injection possible for several hours
- It is conservative, with no reaction and negligible deposition
- It is easy to measure at very low concentrations,
- It is stable during the course of the study

2-6- Setting up instruments and tracer injection at outfall location

At each surveyed plant, tracer injection was started at the final effluent outfall location inside the plant, followed by setting-up the anemometer and GPS base station (2-5), and then the survey boat was deployed.

Figure 2-5: Setting up annemomeer (left), injecting rhodamine at Goldbar WWTP (right)

The rhodamine injection date, starting time and duration, as well as peristaltic pump rpm and consequently injection flow rate are presented in table 2-1. Using the peristaltic pump calibration curve (Fig. 2-4 right) the flow rate for the recorded pump speed was found in ml/min.

Table 2-1: Tracer injection information for studied plants

Plant	Injection starting time	Injection duration (hour)	Peristaltic pump rpm	Injection flow rate (ml/min)	Average outfall flow rate (m^3/s)	Expected concentration at outfall (ppb)
Agrium	10AM	6	1.15	20.31	0.07	483.66
Capital region WWTP	11AM	13	1.8	52.08	0.64	135.62
Goldbar WWTP	6AM	13	1.26	25.7	3.21	13.34

Rhodamine WT comes as a 20% solution. As it has been diluted with equal volume of methanol the injected tracer was 10% solution.

Assuming constant rhodamine mass flux in the system and using the average outfall flow rate during the injection date provided by the surveyed plant technical office, the expected concentration at outfall location was estimated using the following relationship:

Injection concentration × injection flow rate =concentration at outfall × outfall flow rate

Using the above relationship the expected concentration at the outfall was calculated for each plant (Table 2-1).

Furthermore, river discharge during the field campaign was approximately 120m^3/s (Figure 2-6). From Hydat (Water Survey Canada) data source, the average October North Saskatchewan River flow rate from 2000 to 2009 was calculated equal to 163m^3/s and the average flow rate for 29th of October was also obtained 135.12m^3/s. Thus, river discharge during the survey was slightly below the long term average for the period of the survey. Using the outfall concentration and flow rate (Table 2-1), and the river discharge of 120 m^3/s, the Rhodamine WT concentration when fully mixed with the river flow was estimated to be 0.28 ppb (Agrium), 0.72 ppb (Capital Region WWTP), and 0.35 ppb (Goldbar WWTP).

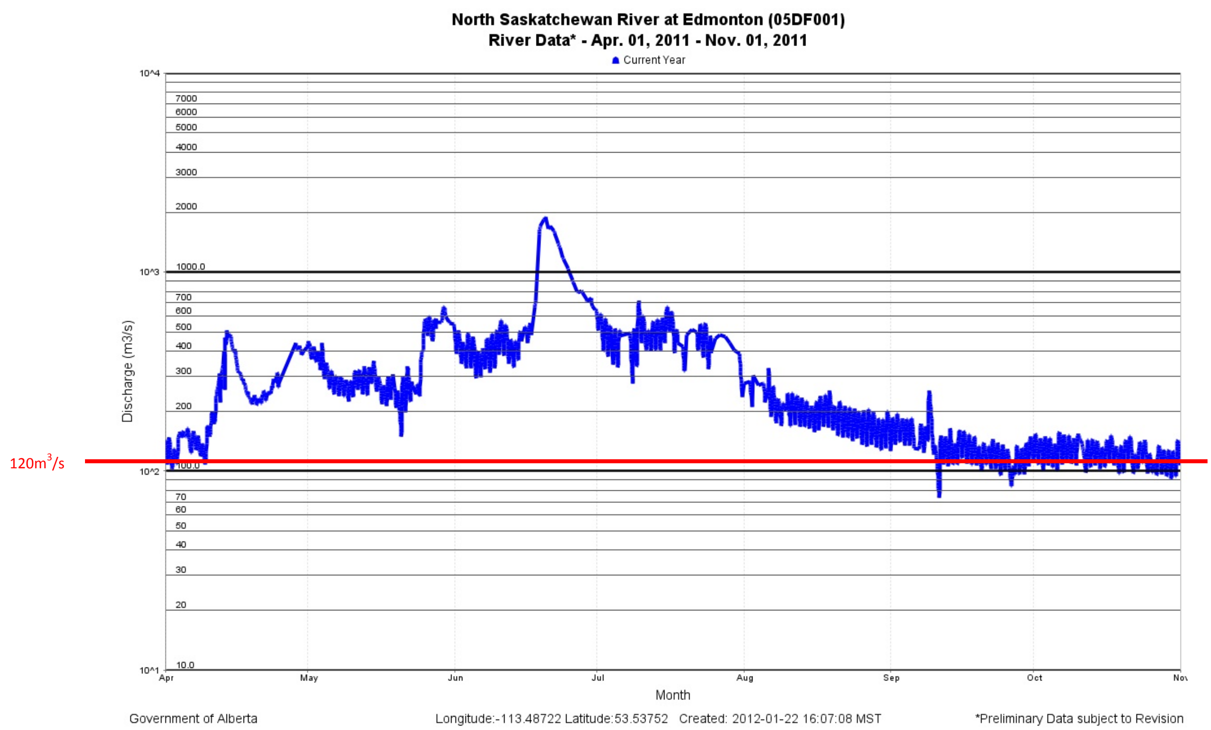


Figure 2-6: North Saskatchewan River flow rate, downloaded from http://www.environment.alberta.ca

2-7- Field activity in the river

The ADCP was mounted at the side of the boat (Fig. 2-7 left) and surveying started 2-3 hours after tracer injection. At the beginning, the survey was carried out in several sections upstream of the outfall location to measure the background value of the fluorescence concentration in the river before injecting the tracer. The surveyed sections of and their approximated distance to outfall location are summarised in Table 2-2. The spatial location of surveyed sections is also presented in figure 2-8 to 2-10.

Table 2-2: Summary of surveyed section date and range for investigated plant

Date	Plant	Surveyed sections range	Spatial location figure
October 25	Agrium	Outfall-12km	Figure 2-7
October 26	Capital Region WWTP	Outfall-12km	Figure 2-8a
October 27	Capital Region WWTP	39km-62km	Figure 2-8b
October 28	Capital Region WWTP	39km-83km	Figure 2-8c
October 29	Goldbar WWTP	Outfall- 16.2km	Figure 2-9a
October 30	Goldbar WWTP	37.5km-51.3km	Figure 2-9b
October 31	Goldbar WWTP	56.5km-93km	Figure 2-9c

Field activity on the river included measuring rhodamine concentration (CTD), velocity and bed elevation (ADCP), and water sampling. During the survey the CTD was lowered down into the water (Fig. 2-7 right) and concentration data was collected continuously in real time. The innovative aspect of this study was real-time data collecting and graphing with the fluorometer. This capability greatly helped for verifying the tracking path and reliability of collected data. The authors are unaware of a previous similar study in Canada using an *in situ* fluorometer. CTD data were collected at one elevation in the flow, assuming zero vertical concentration gradient. This was a reasonable assumption because the river was very shallow at the outfall (less than 1m), thus full vertical mixing occurred very close to the outfall. Furthermore, the shallow water depth and the relatively large size of the CTD made it impossible to the move the CTD up and down in the flow, thus it was not possible to collect 3D concentration data.

Figure 2-7: Measuring flow velocity by ADCP, left picture; and concentration by CTD, right picture

Figure 2-8: Some of the sections surveyed on October 25, 2011 downstream of Agrium. Base image from Google Earth.

Figure 2-9a: Some of the sections surveyed on October 26, 2011 downstream of Capital Region WWTP. Base image from Google Earth.

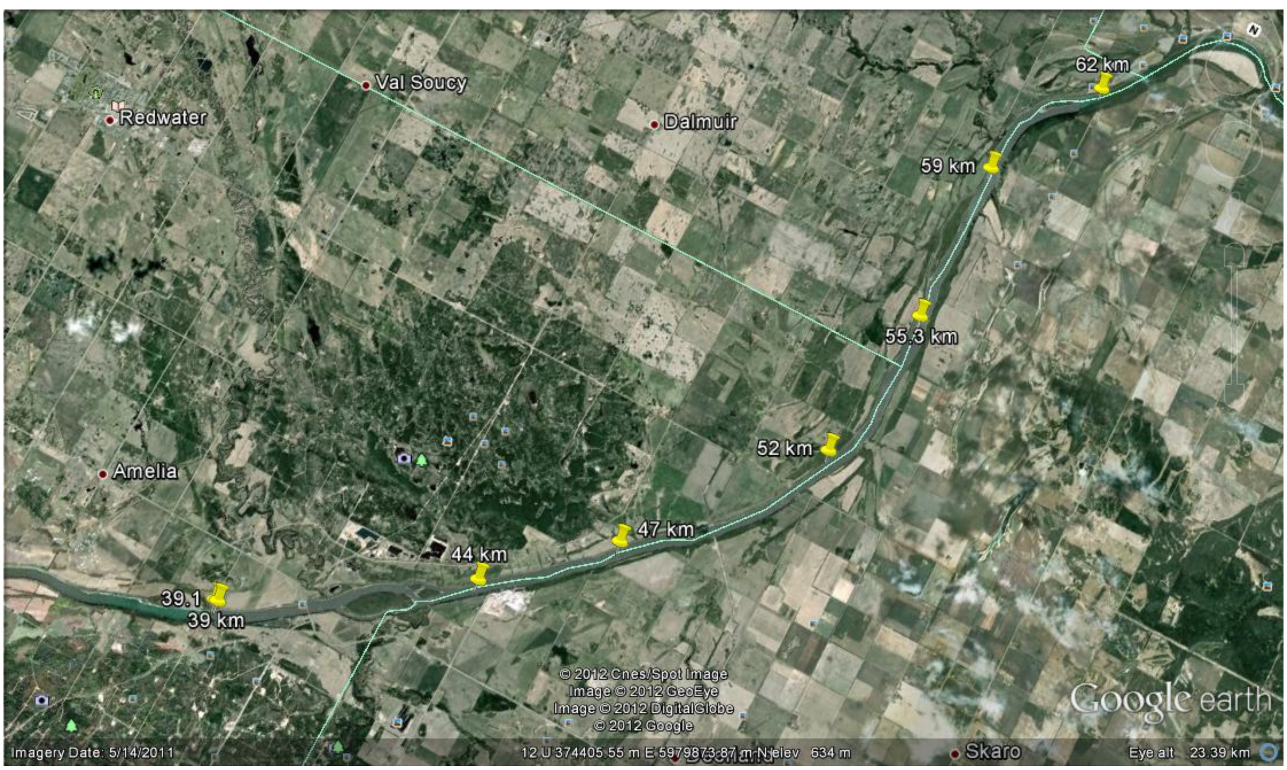


Figure 2-9b: Some of the sections surveyed on October 27, 2011 downstream of Capital Region WWTP. Base image from Google Earth.

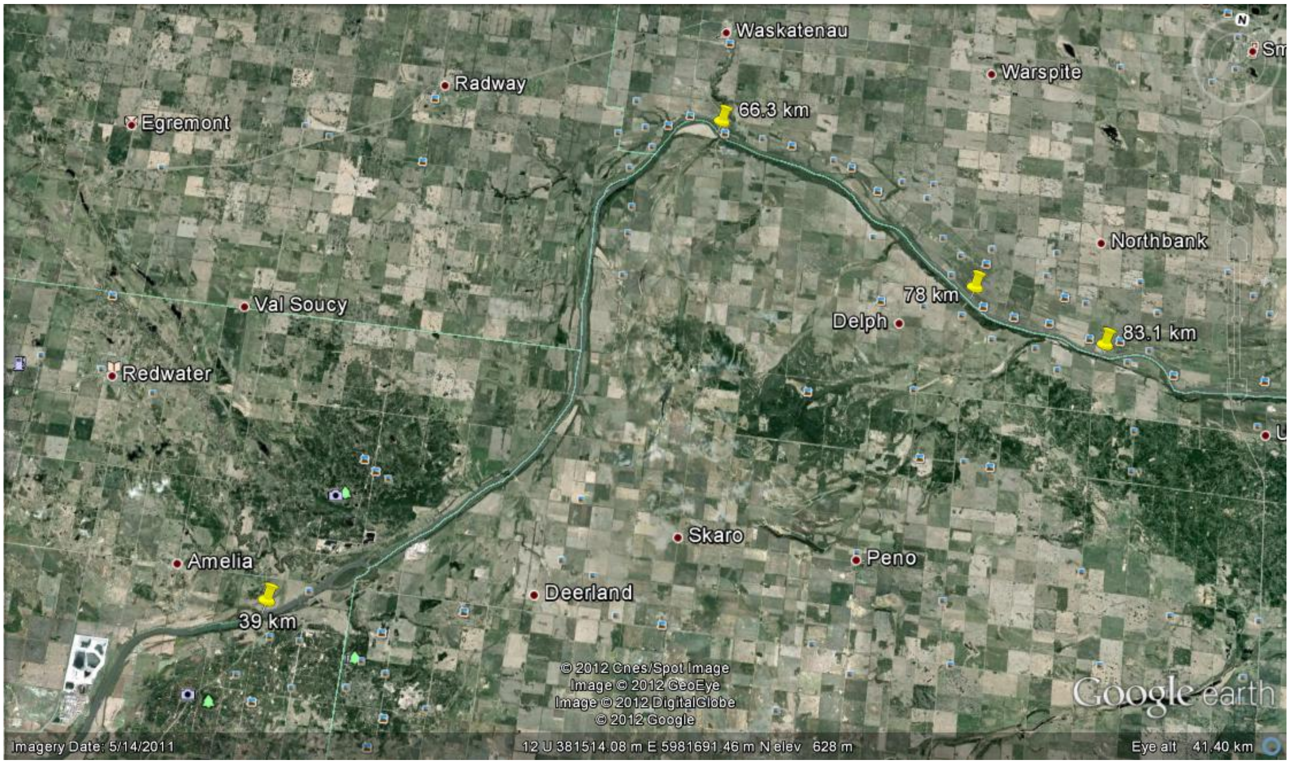


Figure 2-9c: Some of the sections surveyed on October 28, 2011 downstream of Capital Region WWTP. Base image from Google Earth.

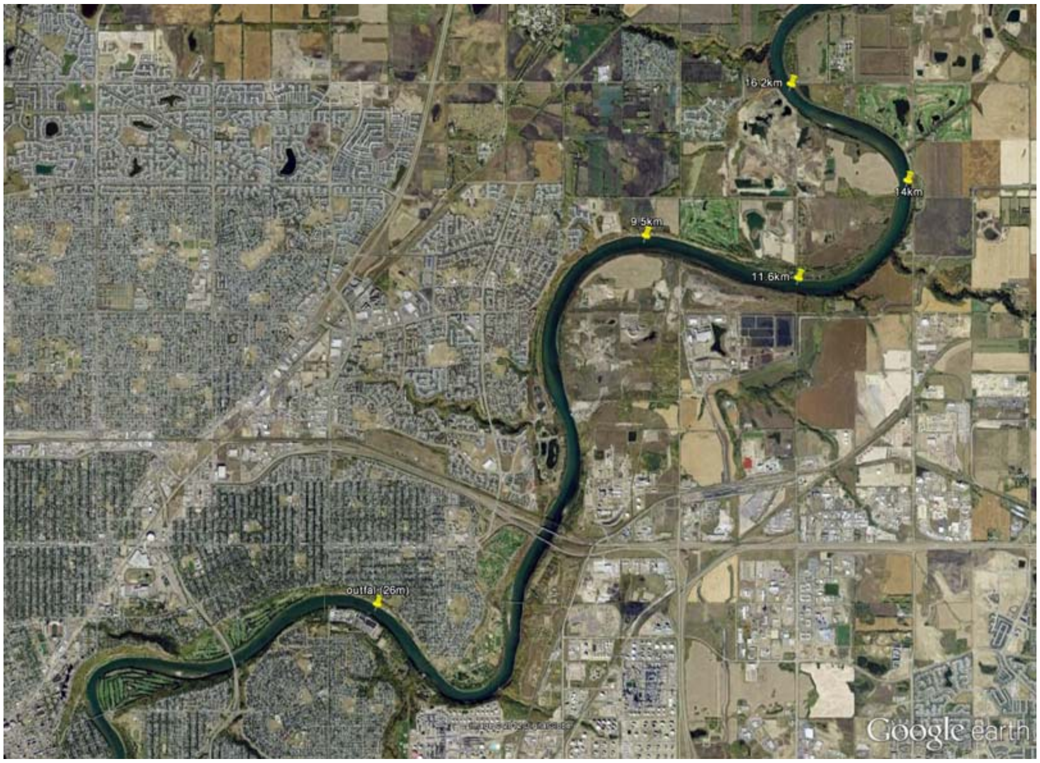


Figure 2-10a: Some of the sections surveyed on October 29, 2011 downstream of Goldbar WWTP. Base image from Google Earth.

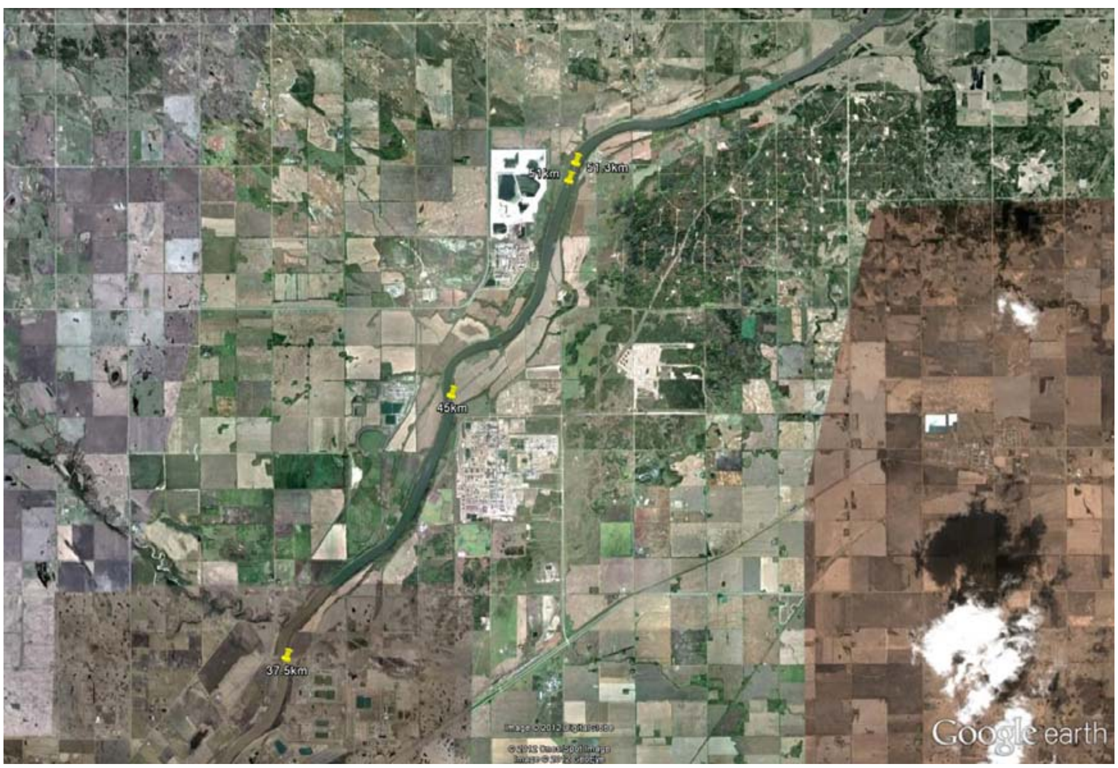


Figure 2-10b: Some of the sections surveyed on October 30, 2011 downstream of Goldbar WWTP. Base image from Google Earth.

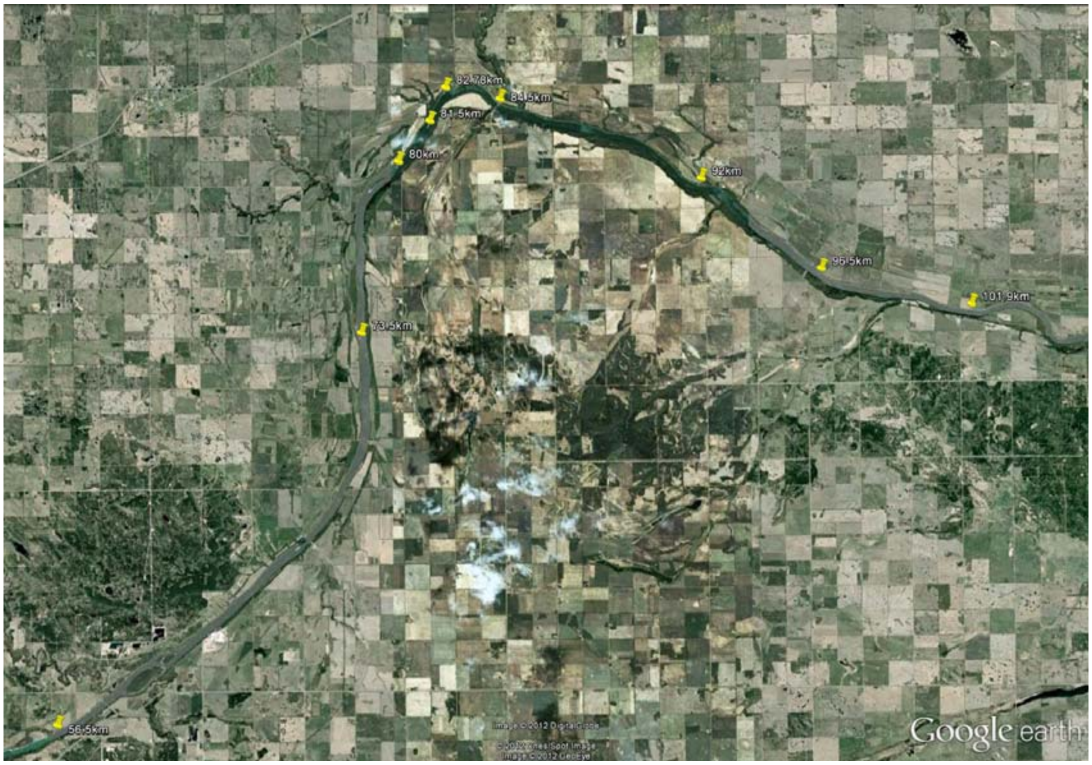


Figure 2-10c: Some of the sections surveyed on October 31, 2011 downstream of Goldbar WWTP. Base image from Google Earth.

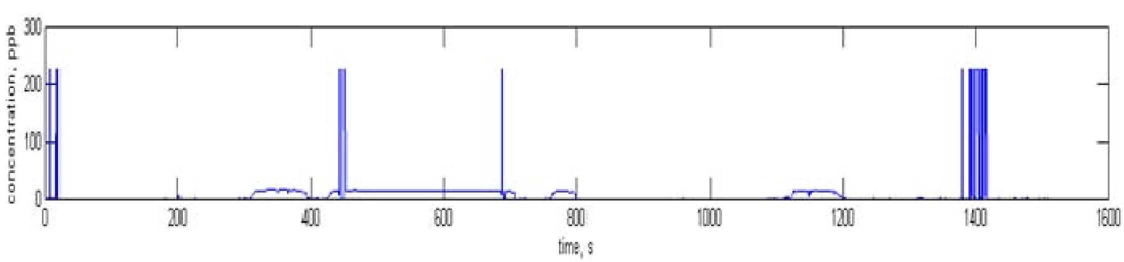
Rhodamine concentration was also measured by taking water samples at several sections along the river in addition to CTD measurements. The water sampling was helpful especially where shallow water depth prevented lowering of the CTD into the water. This generally occurred close to the river bank and at some locations in middle of the river. As mentioned previously, full vertical mixing happened very close to the outfall. There was thus no concern about sampling depth and the samples were taken from one depth near the water surface. According to the Rhodamine WT Material Safety Datasheet, Rhodamine WT should be kept in cool, dry area and away from excessive heat and direct sunlight. It also sticks to plastic. Accordingly, the samples were kept in brown glass bottle samples and stored in a cooler after sampling during transportation to the lab (Fig. 2-11). They were also kept in a refrigerator in the lab.

Figure 2-11: Keeping sample in the cooler to prevent degradation

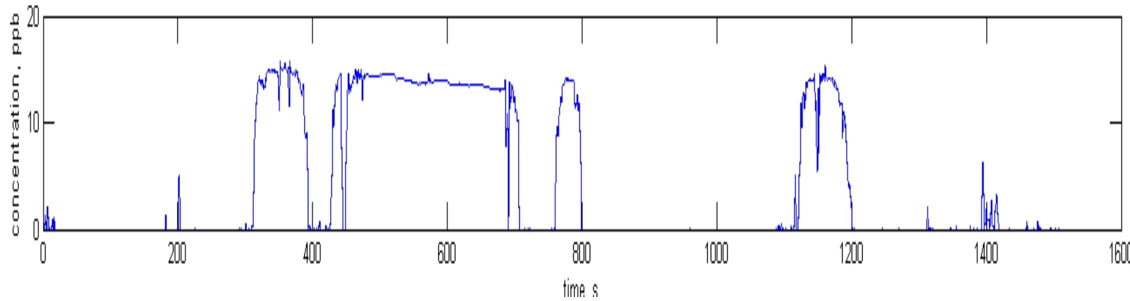
2-8- Post processing

The recorded data were processed and graphed in three steps. In the first step the raw data were imported into MATLAB code. As previously mentioned one of the main difficulties in surveying was shallow water depth. This fact prevented us from having CTD in the water for the whole cross section. In the first step, the negative values given for clear water by the fluorometer were replaced by a 0 value (Fig 2-12a). The Fluorometer also showed very high values (around 200 ppb) when out of the water. These values were much larger than maximum expected concentration based on the rhodamine concentration calculated to be in the effluent (Table 2-1). These very high values were removed in the MATLAB code (Fig. 2-12b). Then a despiking procedure was employed, in which the highest 5% of data were removed from moving blocks of 50 data points, which was equivalent to a 12.5s time series data block (Fig. 2-12c). In the last step a low pass filter was implemented (2-12d).

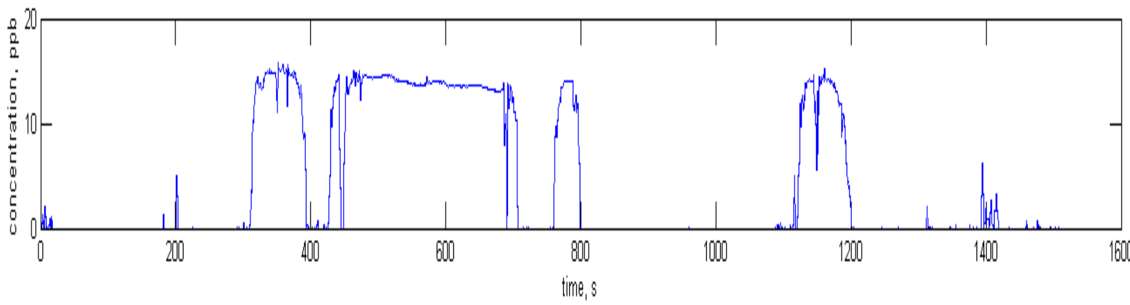
a)



b)



c)



d)

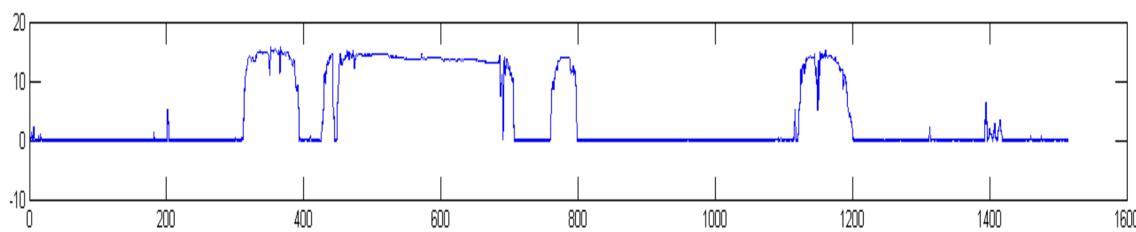


Figure 2-12: Processing raw data using MATLAB code, a) removing negative data, b) removing high values c)removing upper 5 percent d) lowpas filtering. These data were collected at the outfall location, with the boat moving in and out of the effluent plume.

The processed data from MATALAB code containing relevant parameters (concentration, velocity, depth, bed elevation and longitude and latitude) were imported into ARCGIS(9.3) and superimposed on a North Saskatchewan river boundary shape file, downloaded from http://www.geobase.ca/geobase/en/index.html (Fig. 2-13).

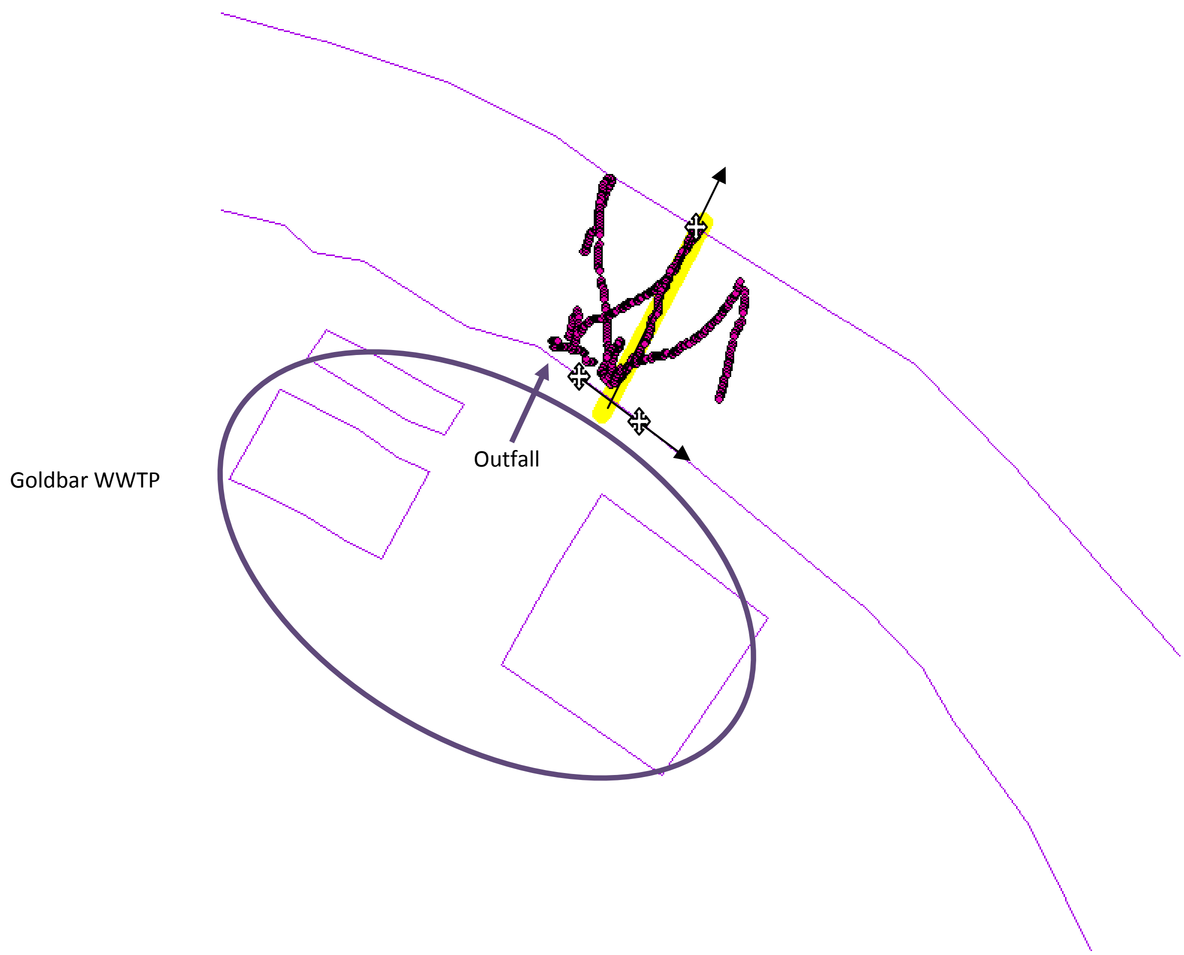


Figure 2-13: Boat moving path plugged into ARCGIS and superimposed on river boundary

Due to river flow, the boat moving across the river was not on a straight line (Fig 2-13). A straight line perpendicular to the river banks was drawn near the most parallel boat transect. Adjacent upstream and downstream data points were snapped perpendicularly to this drawn line. The snapped data were then used to represent the concentration and/or velocity at this transect.

Up to this step we could obtain point values along a straight line across the river section with their GPS location in UTM coordinates. Graphs showing the distribution of velocity, concentration and depth across the river section were obtained from ARCGIS using a VBA code developed at the University of Ottawa. The code uses coordinates of three points (Fig. 2-13) from the river boundary shape file. It transforms and rotates the current coordinate system (UTM) to a coordinate system in which the vertical axis is the data extracting line.

2-9- Laboratory Analysis

A total of 390 physical water samples were collected and stored during the entire 10 day field survey of the three effluent plumes. Rhodamine WT concentration in the physical water samples was measured in the University of Ottawa Environmental Engineering Laboratory using a Turner Model 450 fluorometer. The method was calibrated using a series of standard concentration solutions. The whole set of standard concentration solutions were prepared with distilled water (DW) as following: 0.01ppb, 0.05ppb, 0.1ppb, 1ppb, 2ppb, 4ppb, 5ppb, 10ppb. A linear calibration curve for rhodamine concentration as a function of measured fluorescence was established using these standard samples, as follows. Standard solutions were prepared freshly before testing each day. The amplifying factor for the instrument was initially set to be 2000. The fluorescence meter was first zeroed with DW. The fluorescence readings for the 1ppb and 5ppb standard solutions were then recorded. If results from these two standard solutions plus the zero point did not show a linear trend, all materials related to the procedure were cleaned and new standard solutions were mixed. If, on the other hand, a linear trend was apparent, the remaining standard solutions were tested. If a linear calibration curve with r^2>0.98 was not obtained using data from all the standard solutions, then the calibration procedure was repeated with a new zero reading and new standard solutions.

A set of 80 test tubes was used for the analyses. Prior to testing each day, all materials were washed by rinsing with DW ten times each and residual water was removed. Samples were tested in groups of < 65 to ensure no change in temperature during the procedure. Test tubes were rinsed three times with the physical water sample before filling in the last time for the test. Prior to inserting the sample vial into the fluorescence meter, the vial was cleaned with kimwipes to remove water drops and fingerprints from the external surface. Readings were observed 15 s after insertion in the fluorescence meter, and values were recorded after the reading was stable for 5 s. If the reading did not stabilize, then a new sample was tested and the value of the new sample was recorded. If the new sample did not stabilize, an average value was recorded. To ensure maintenance of the calibration, two standard solution samples were read every ten measurements. If the standard solutions reading changed during testing of a group of samples, the standard solution was re-evaluated using a new test tube. If the reading still did not match the calibration curve, the calibration procedure was repeated.

3- Results

In this section the study results for each investigated plant are presented separately in its corresponding subsection. In each subsection, the study results are presented for concentration (CTD and sample), water velocity, bed elevation and wind (speed and direction). The data presented herein are for rivers sections corresponding to the outfall location, the location where the effluent was observed to have mixed to the opposite bank, and the most downstream section of the survey. Data for all sections are presented in the appendices.

CTD concentration results are presented as a band of discrete points across the section. Due to shallow water depth, there were some sections in which the CTD could not be kept in the water for the whole section, thus no *in situ* rhodamine concentration data are presented for those parts of the sections. The concentration data are presented both with respect to the measured location across the section (i.e., width from the left bank), and with respect to the accumulated specific discharge at the measurement point. The specific discharge is the local depth-velocity product, and this is accumulated while traversing the section from the left bank.

The physical sampling results are also shown as discrete points with different colour on the graphs for Capital Region WWTP and Goldbar WWTP. In general, the physical samples confirm the results from the *in situ* fluorometer. The physical sample results are in good agreement with CTD results, particularly for the higher measured concentrations. At lower concentrations the estimated concentrations for physical samples were somewhat greater than the *in situ* fluorometer concentrations, as the physical samples did not show values less than 0.4 ppb. Furthermore, for 12 triplicate samples collected in the field, the average standard deviation was 0.7 ppb, and the average coefficient of variation was 0.07. This suggests the quantification limit of laboratory samples was on the order of 1 ppb. Thus, differences between the CTD results and laboratory samples at low concentrations are attributed to lower reliability of the physical samples due to physical field sampling, sample transport, and laboratory procedures. It appears the *in situ* fluorometer provided more reliable results than physical samples.

Depth averaged velocity is shown by discrete data points on the graphs across the sections with different distance from the outfall location. Similar to the concentration graphs, data are not provided across the entire cross-section if the section was too shallow to survey. In general, the expected distribution of increased depth-averaged velocities in the centre of each section was observed.

Water depth was simultaneously measured with velocity by the ADCP for the surveyed cross sections. For water depth data, a continuous bathymetry line across the measured section is useful. Therefore, discrete point-wise data were first interpolated using the kriging interpolation method and continuous water depth was generated. Then depth data were extracted along the line which had been used for extracting velocity data. This has caused some errors in water depth data in the regions where there is no real measured data available, particularly at channel edges. In order to mitigate this deficiency and show the regions in which the depth data may be erroneous and not reliable, depth and velocity data are presented on the same graph. It should be mentioned that for the regions of a section in which there are no velocity data, the presented depth data are likely erroneous and generated by interpolation of an area with no measured depth data.

Wind is an important parameter which affects the mixing procedure. The summary of anemometer results are presented in a corresponding table for each plant.

In order to be able to infer mixing pattern and characteristics from collected sample data, each cross section was split into 10 equal intervals. The average, upper and lower limits of values within which the concentration is expected to lie with 95% confidence, was calculated for each interval of the surveyed sections using the “t distribution” (Figure 3-1).

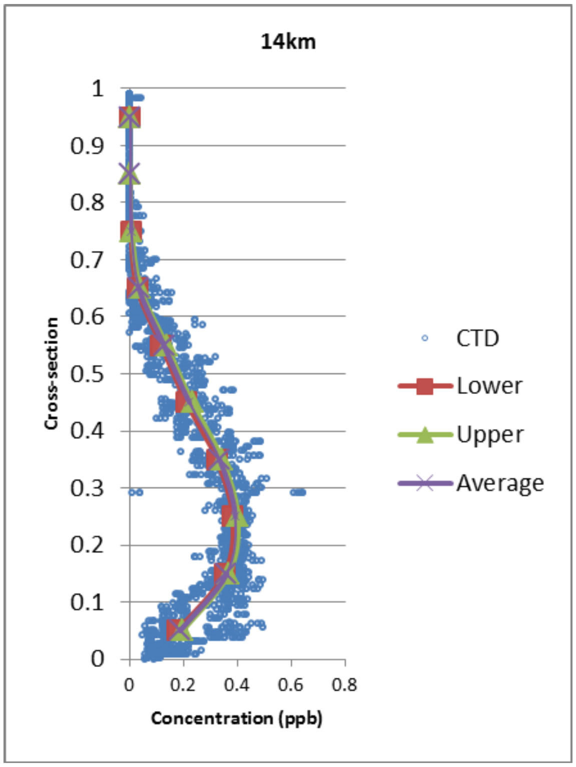


Figure 3-1:Average, upper and lower limit range of concentration with 95% confidential probability across the river section

Upper and lower limit values are calculated using (3-1) and (3-2) for data within each interval.

$$L = \bar{y} - \frac{s_y}{\sqrt{n}} t_{\alpha/2,n-1} \qquad \textbf{(3-1)}$$

$$U = \bar{y} + \frac{s_y}{\sqrt{n}} t_{\alpha/2,n-1} \qquad \textbf{(3-2)}$$

L : Lower limit of the range
U : Upper limit of the range
$\bar{y}$: Average of data samples
s_y : Standard deviation
n : Number of data samples
$t_{\alpha/2,n-1}$: The standard random variable for t distribution for a probability of $\alpha/2$

A summary table showing rhodamine distribution across the section with 95% confidence is also provided in for each surveyed section (Tables 3-1, 3-3, and 3-5).

3-1- Agrium Redwater

The maximum measured concentration at Agrium outfall location was 279ppb. This value was obtained from physical sampling. Due to shallow water depth, we could not use CTD for measuring rhodamine concentration at the outfall. The nearest to the outfall and whole width surveyed section with CTD was 200m from the outfall (Figure3-2 to 3-4, Table 3-1).

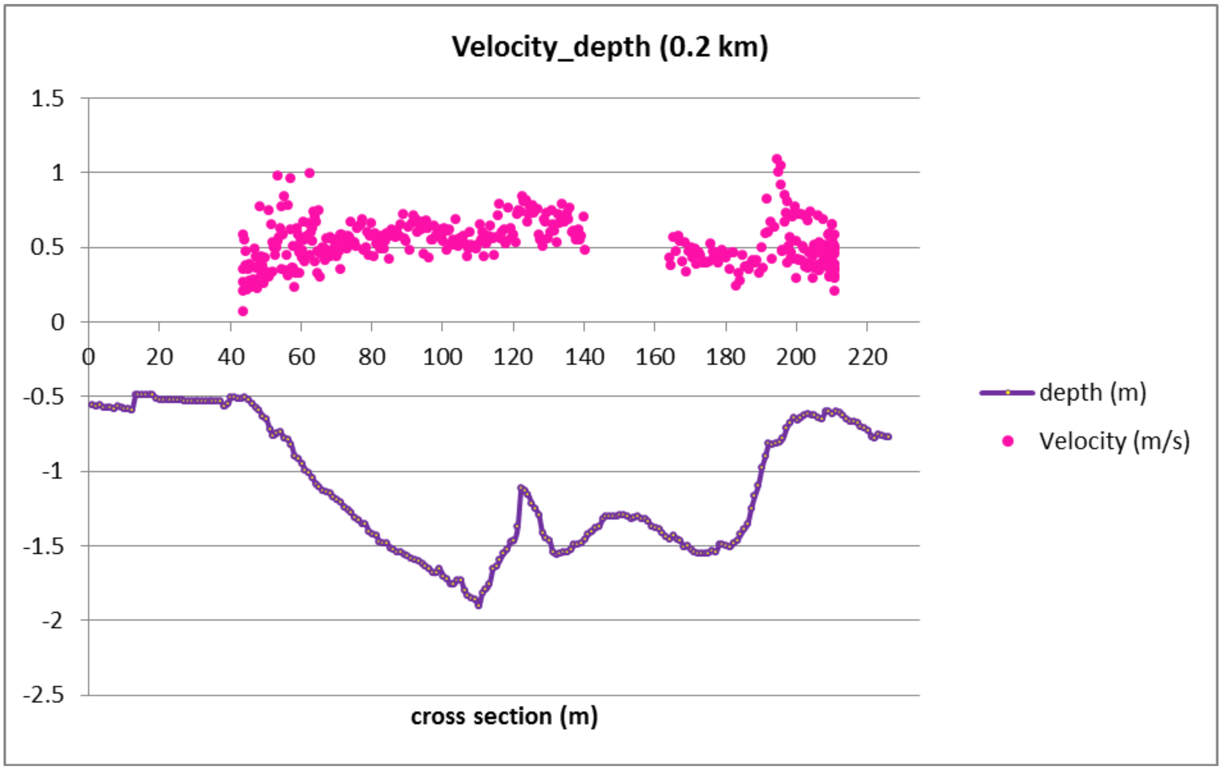


Figure 3-2: Depth averaged velocity across the nearest surveyed section to the Agrium outfall

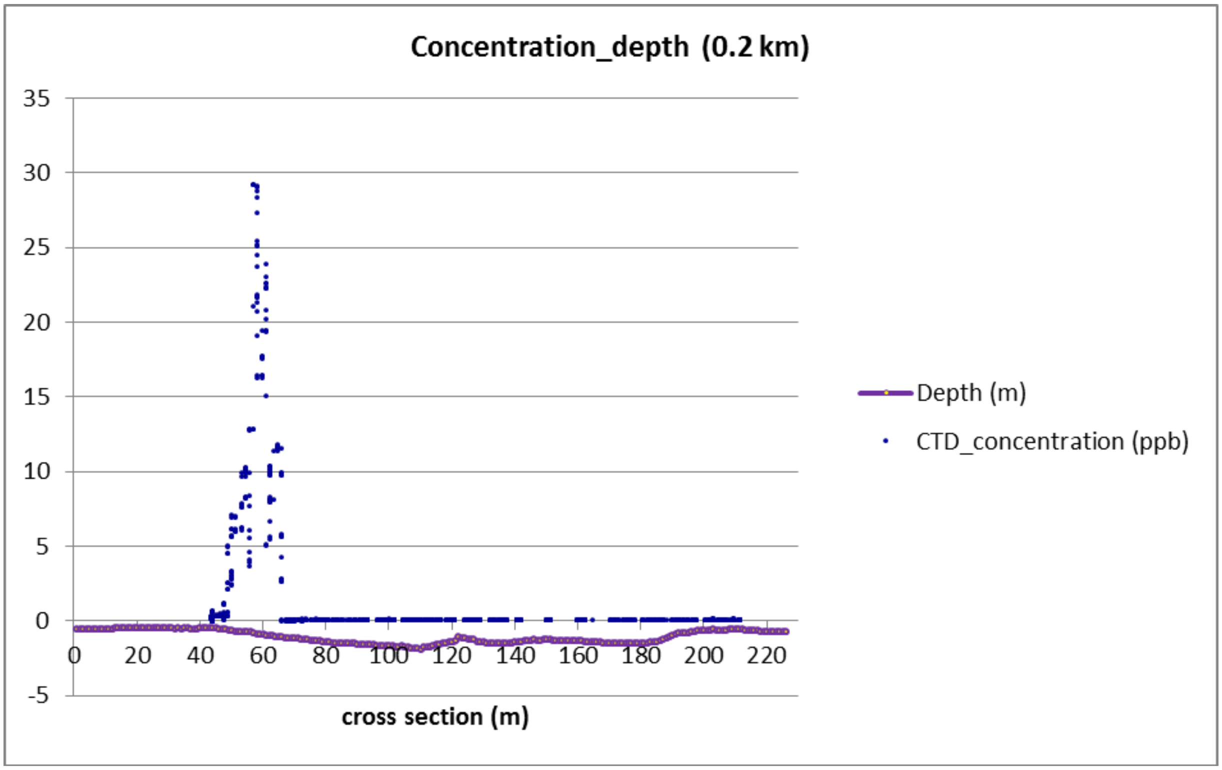


Figure 3-3: Rhodamine concentration across the nearest surveyed section to the Agrium outfall

Table 3-1: **95% confidence intervals for mean rhodamine concentration across the nearest surveyed section to the Agrium outfall**

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.025			
0.025-0.05			
0.05-0.075			
0.075-0.1			
0.1-0.125			
0.125-0.15			
0.15-0.175			
0.175-0.2	0.18	0.32	0.25
0.2-0.225	4.11	5.56	4.84
0.225-0.25	13.36	17.99	15.68
0.25-0.275	11.95	15.19	13.57
0.275-0.3	0.56	1.90	1.23
0.3-0.325	0.01	0.02	0.01
0.325-0.35	0.00	0.00	0.00

0.35-0.375	0.00	0.01	0.00
0.375-0.4	0.00	0.00	0.00
0.4-0.425	0.01	0.02	0.01
0.425-0.45	0.01	0.02	0.01
0.45-0.475	0.00	0.01	0.01
0.475-0.5	0.01	0.02	0.01
0.5-0.525	0.00	0.00	0.00
0.525-0.55	0.00	0.01	0.01
0.55-0.575	0.01	0.01	0.01
0.575-0.6	0.00	0.01	0.01
0.6-0.625	0.01	0.03	0.02
0.625-0.65	0.01	0.03	0.02
0.65-0.675	0.00	0.02	0.01
0.675-0.7	0.01	0.02	0.01
0.7-0.725	0.02	0.03	0.02
0.725-0.75	0.02	0.03	0.03
0.75-0.775	0.01	0.02	0.02
0.775-0.8	0.01	0.02	0.02
0.8-0.825	0.00	0.01	0.00
0.825-0.85	0.01	0.03	0.02
0.85-0.875	0.02	0.03	0.02
0.875-0.9			
0.9-0.925			
0.925-0.95			
0.95-0.975			
0.975-1			
Approximate width(m)	238.90		
Approximate distance from outfall(km)	31.3		
Time and date	13:14:32	Oct 25 2011	

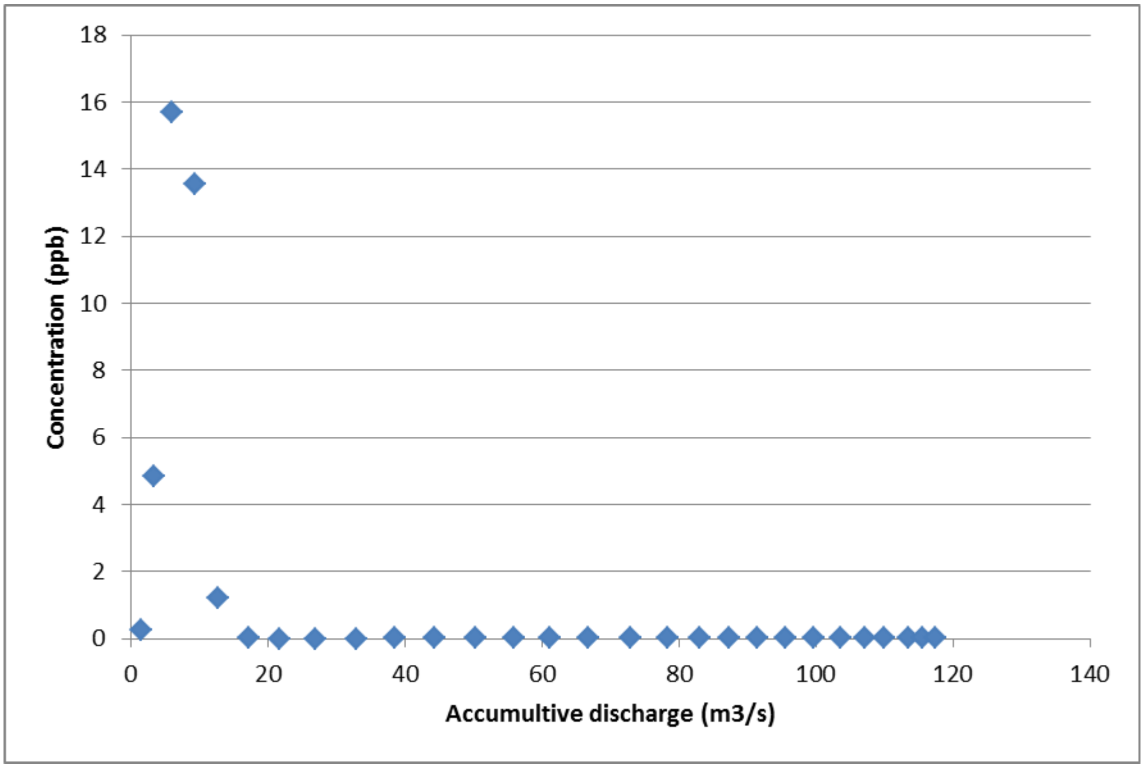


Figure 3-4: Rhodamine WT concentration as a function of accumulative discharge across the nearest surveyed section to the Agrium outfall

The outfall is located closer to left bank of the river in Agrium. So in the initial sections, the rhodamine concentration was higher in the left bank side and 0 in the right bank side. Following the field work plan for Agrium plant, surveying was carried out for one day at Agrium plant. The maximum surveyed section for this plant was 12 km from the outfall location. The survey vessel was unable to traverse a shallow riffle downstream of this location. At the 11.5km section, which was the left channel amongst an series of islands, rhodamine was still more concentrated in the left side of the river (Figure 3-5).

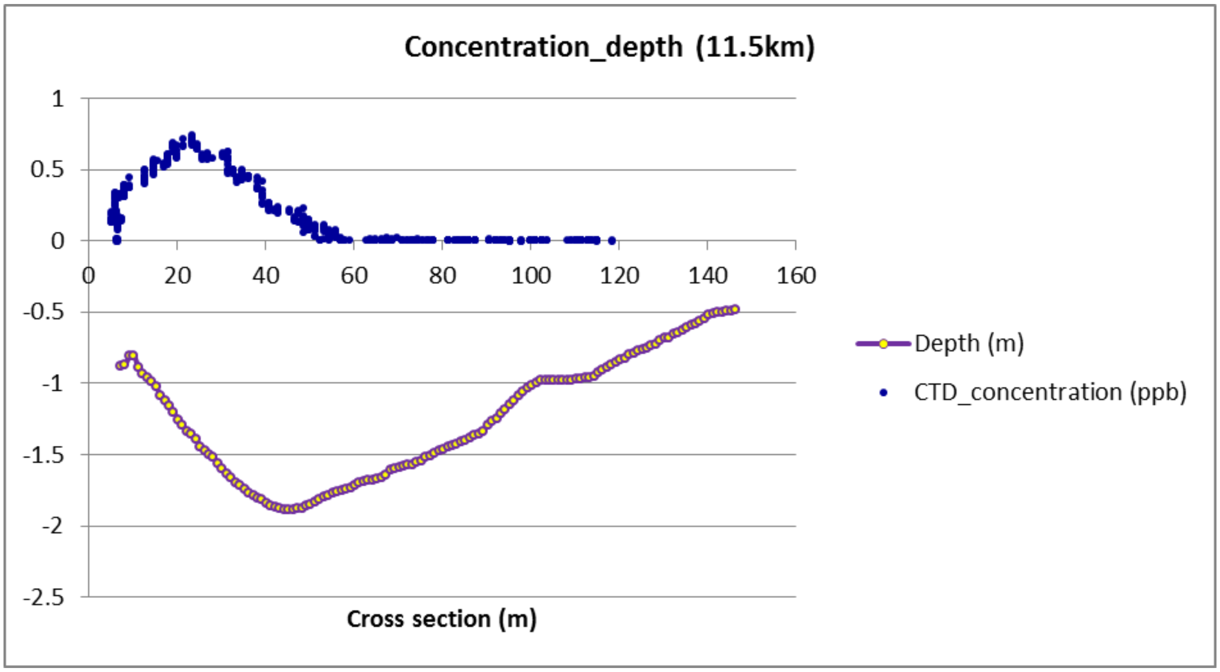


Figure 3-5: Rhodamine concentration across the 11.5km section from the Agrium outfall

Past the 11.5km section, flow is split by a second island located in the middle of the river section (Figure 2-8). The diffluence produces a complex flow pattern which leads to a uniform rhodamine concentration distribution across the right-hand channel (Figure 3-6). Total collected data from the Agrium plant field survey are presented in appendix A. The excel source file name is also provided below each graph.

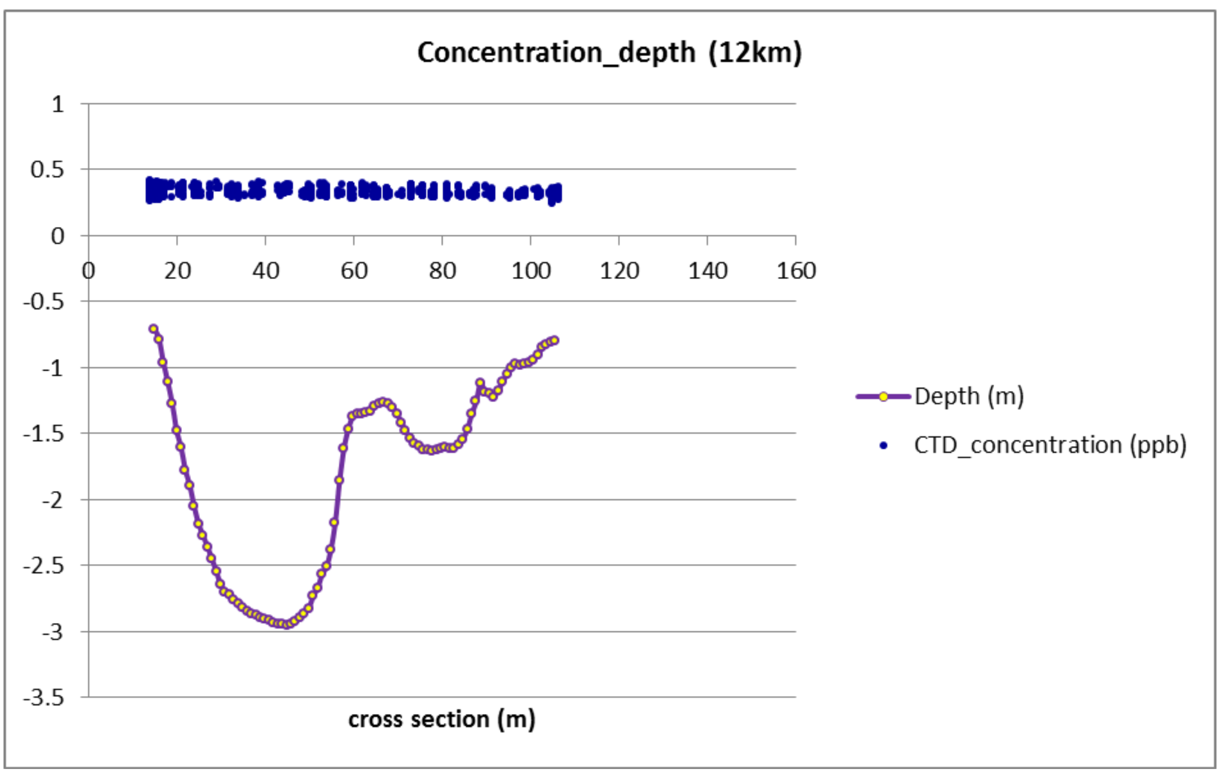


Figure 3-6: Rhodamine concentration across the 12km section from the Agrium outfall

3-1-2- Wind

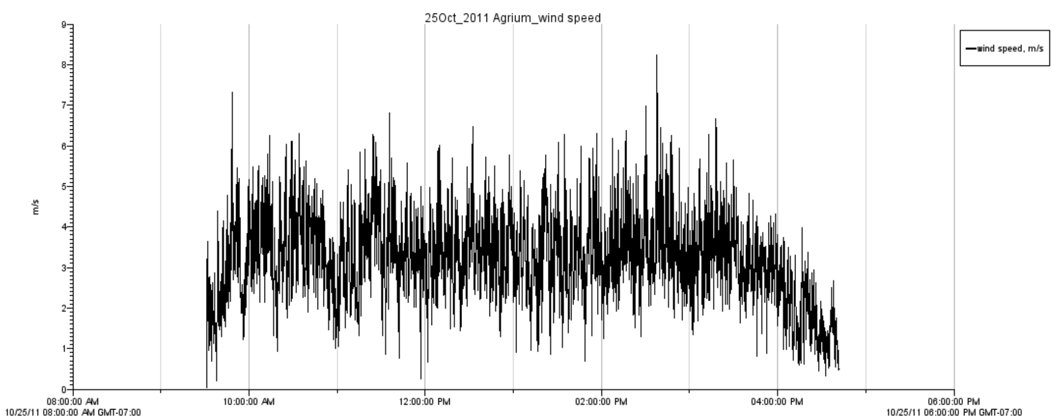
For Agrium plant the wind direction and speed was measured on Oct 25 at outfall location for 7 hours (Figure 3-7 and 3-8), and the summary of measured data is presented in Table 3-2.

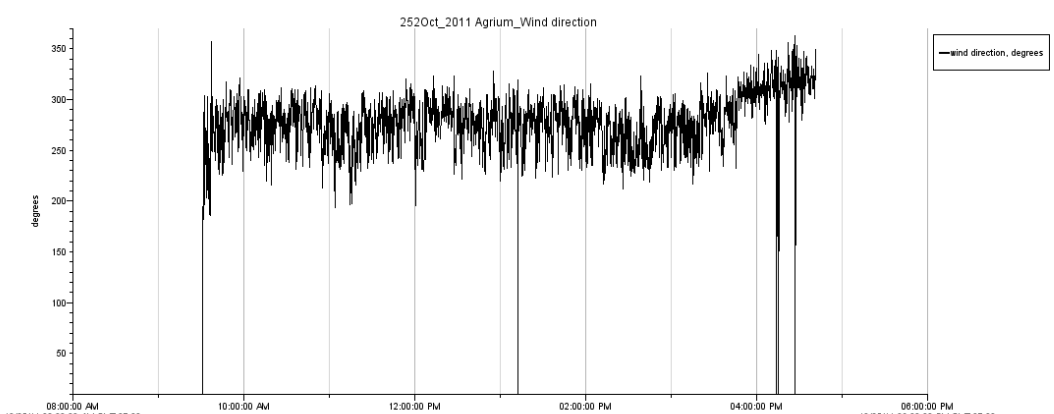
Table 3-2: Summery of anemometer results at Agrium

Date	25 Oct
Number of samples	2585
Parameter	Wind direction
Average(degree)	277.42
Standard deviation(degree)	28.76

Date	25 Oct
Number of samples	2585
Parameter	Wind speed
Max(m/s)	8.23
Min(m/s)	0.03
Average(m/s)	3.22
Standard deviation(m/s)	1.13

Figure 3-7:Annemometer results, wind speed and wind direction at Capital Region WWTP for Oct 25, 2011





3-2- Capital Region

At Capital Region outfall location, due to the shallow water depth, we could not measure the rhodamine concentration across the entire cross-section 720m downstream of the outfall. We measured the average rhodamine concentration at the closest possible location to the outfall with the CTD. The average of measured value was 100ppb which is in good agreement with expected value from table 2-1(130ppb). The nearest whole surveyed section was 720m from the outfall (Figure3-8 to 3-10, Table 3-3).

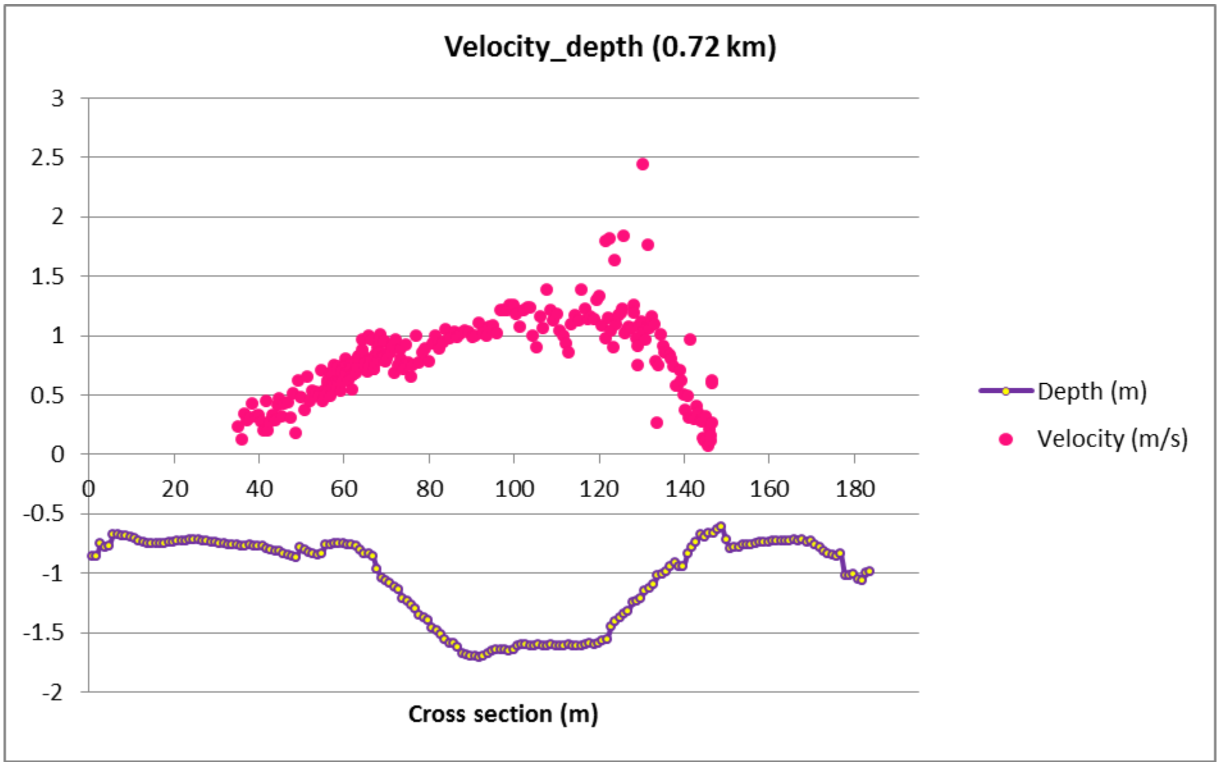


Figure 3-8: Depth averaged velocity across the nearest surveyed section

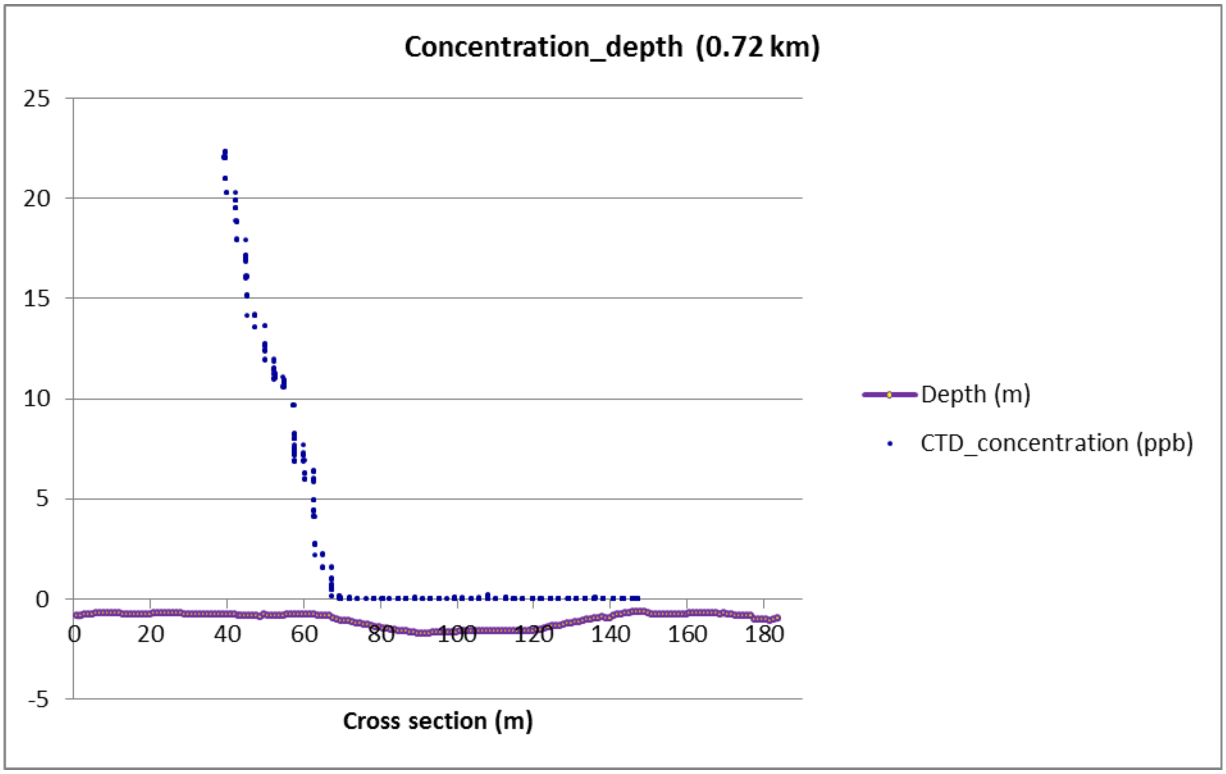


Figure 3-9: Rhodamine concentration across the nearest surveyed section

Table 3-3: **95% confidence intervals for mean rhodamine concentration across the nearest surveyed section to the Capital Region outfall**

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	14.68	16.13	15.40
0.3-0.4	3.10	4.16	3.63
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.01	0.02	0.02
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9			
0.9-1			
Approximate width(m)	185.28		
Approximate distance from outfall(km)	0.72		
Time and date	13:45:57	Oct 26th, 2011	

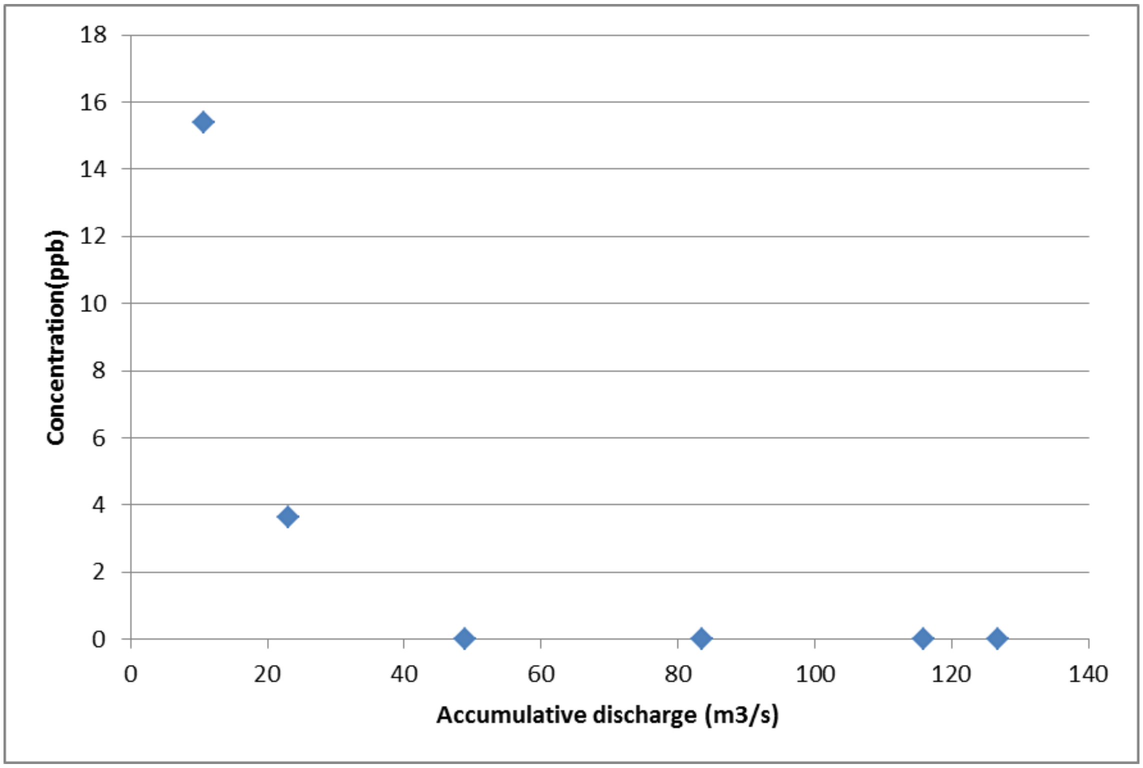


Figure 3-10: Rhodamine WT concentration as a function of accumulative discharge across the nearest surveyed section to the Capital Region WWTP outfall

The outfall is located in the right bank side of the river. So the rhodamine concentration was higher in the left bank side in sections closer to the outfall. The rhodamine concentration was 0 in the left bank side in initial sections. It required about 6 km for rhodamine to first reach the left bank (Figure 3-11).

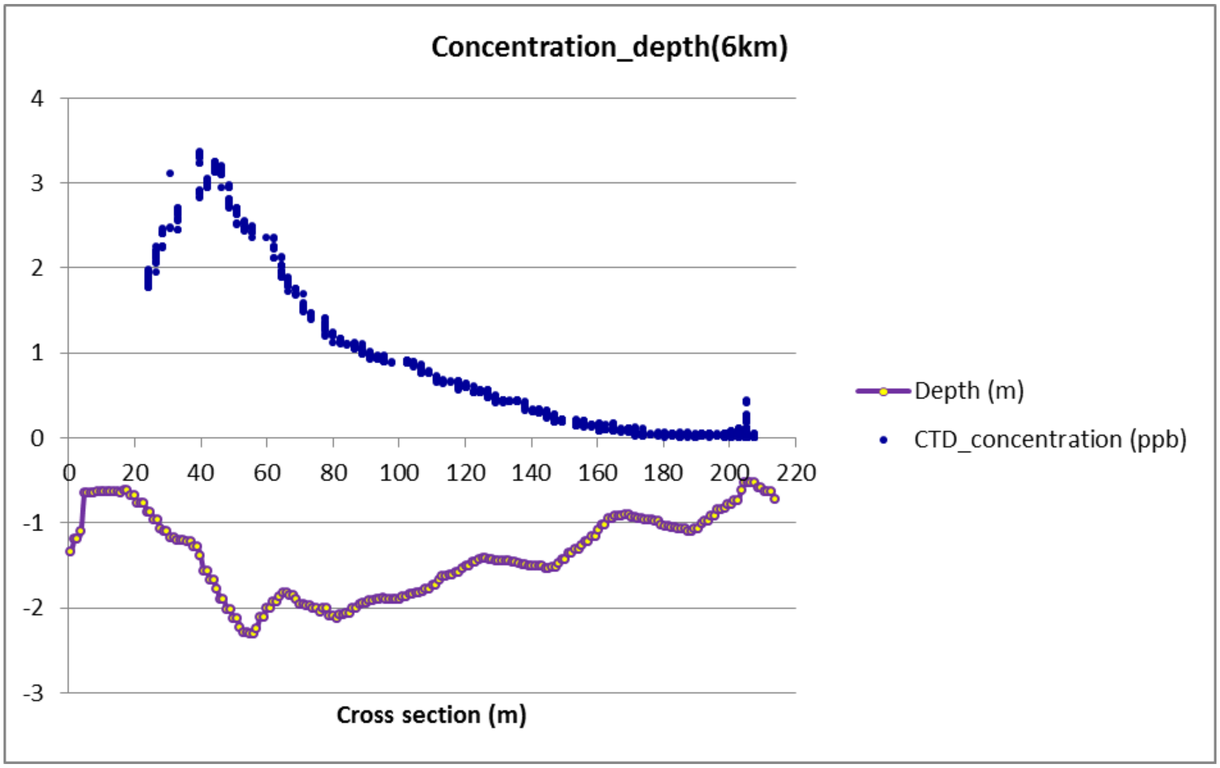


Figure 3-11: Rhodamine concentration across the 6km section

Following the river path, rhodamine gradually mixed and the difference between rhodamine concentration in left and right bank sides reduced. In the last surveyed section at about 83km from the outfall (Figure 3-12), the average rhodamine concentration in the left bank was 0.83ppb against 0.56ppb in the right bank side. The entire collected data for Capital Region WWTP including depth averaged velocity, concentration and depth is provided in appendix B. The excel source file name is also provided below each graph.

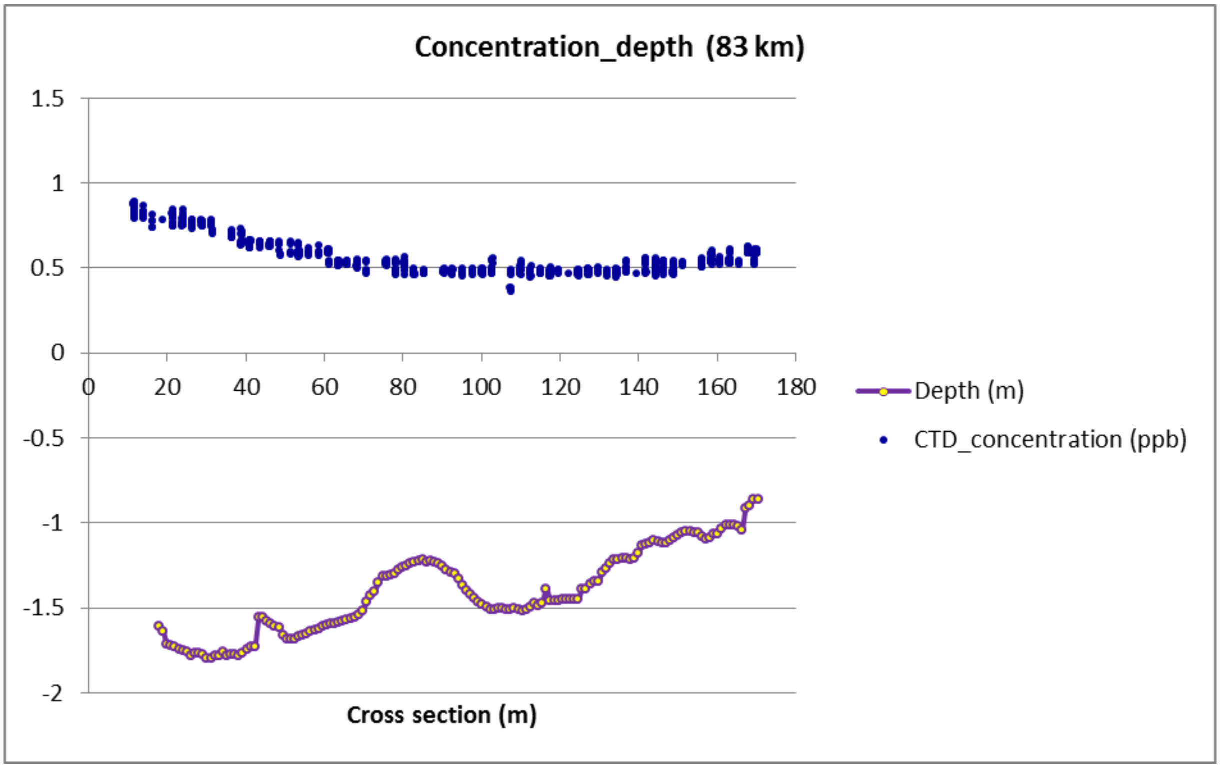


Figure 3-12: Rhodamine concentration across the 83km section

3-2-2- Wind

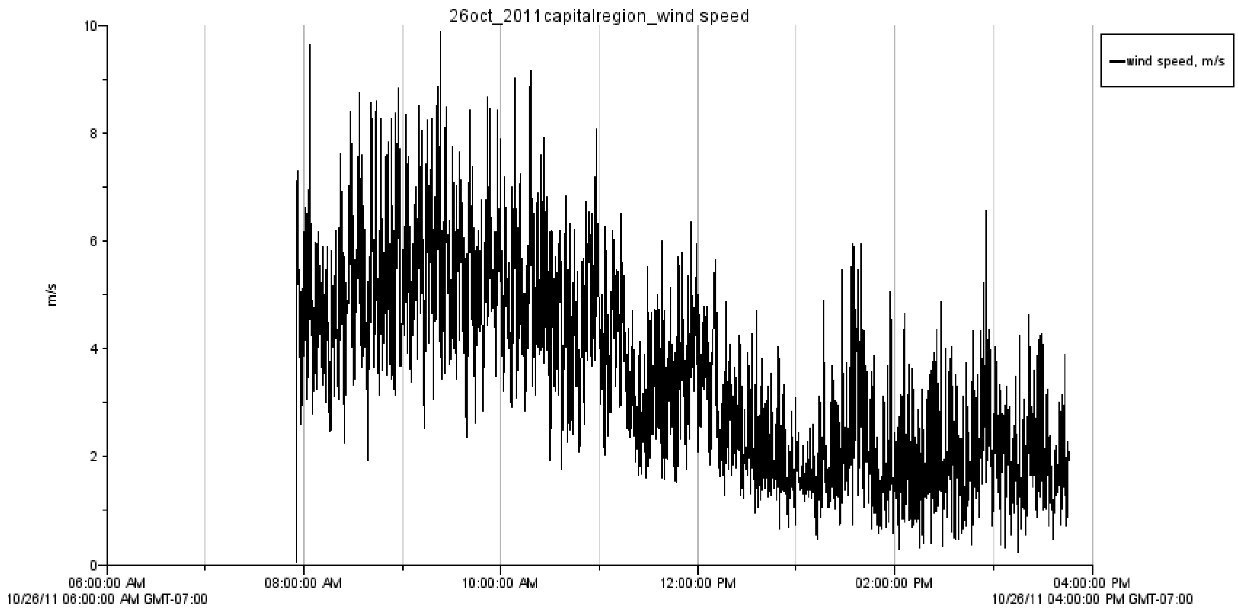
Capital Region WWTP wind data were collected for October 26 and 27 (Figure 3-13). The summary of collected data is presented in table 3-4 individually for each day.

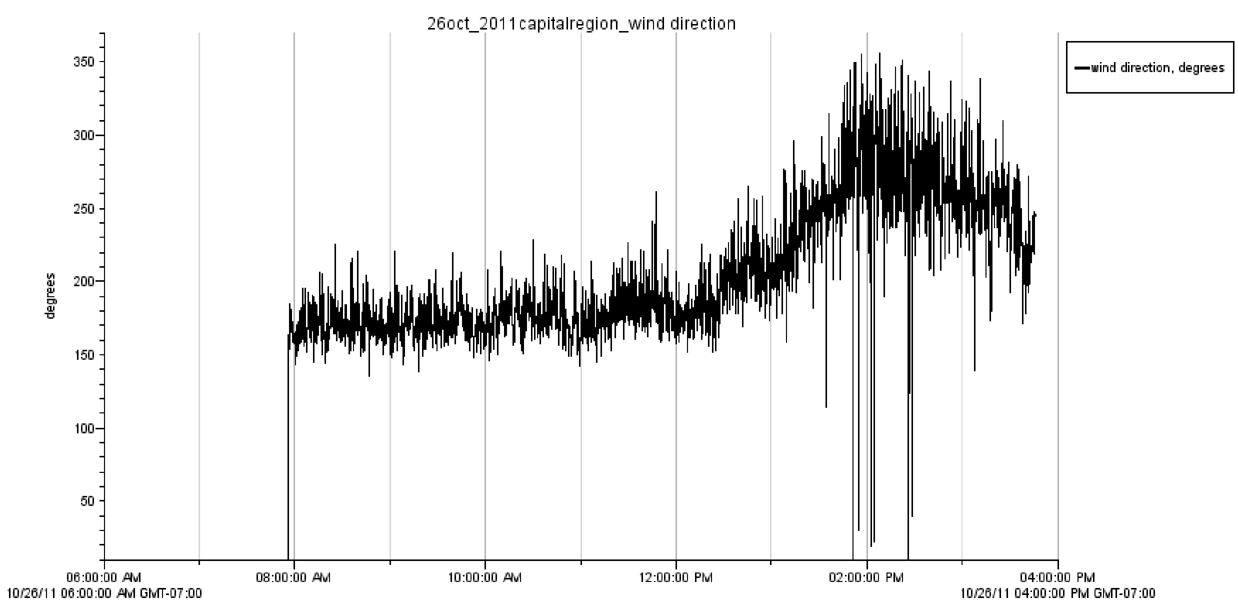
Table 3-4: Summery of anemometer results at Capital Region WWTP

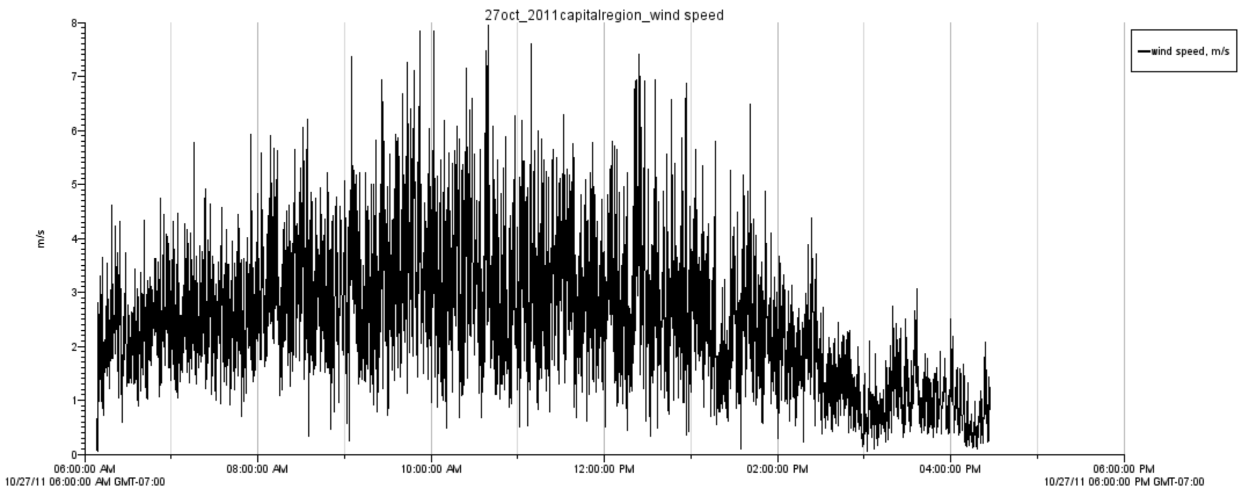
Date	26 Oct
Number of samples	2821
Parameter	Wind direction
Average(degree)	205.464
Standard deviation(degree)	45.629

Date	27 Oct
Number of samples	3713
Parameter	Wind direction
Average(degree)	257.92
Standard deviation(degree)	37.04

Date	26 Oct
Number of samples	2821
Parameter	Wind speed
Max(m/s)	9.89
Min(m/s)	0.05
Average(m/s)	3.52
Standard deviation(m/s)	1.78
Date	27 Oct
Number of samples	3713
Parameter	Wind speed
Max(m/s)	7.95
Min(m/s)	0.05
Average(m/s)	2.48
Standard deviation(m/s)	1.33


26oct_2011capitalregion_wind speed
wind speed, m/s
m/s
0
2
4
6
8
10
06:00:00 AM
10/26/11 06:00:00 AM GMT-07:00
08:00:00 AM
10:00:00 AM
12:00:00 PM
02:00:00 PM
04:00:00 PM
10/26/11 04:00:00 PM GMT-07:00


26oct_2011capitalregion_wind direction
wind direction, degrees
degrees
50
100
150
200
250
300
350
06:00:00 AM
10/26/11 06:00:00 AM GMT-07:00
08:00:00 AM
10:00:00 AM
12:00:00 PM
02:00:00 PM
04:00:00 PM
10/26/11 04:00:00 PM GMT-07:00



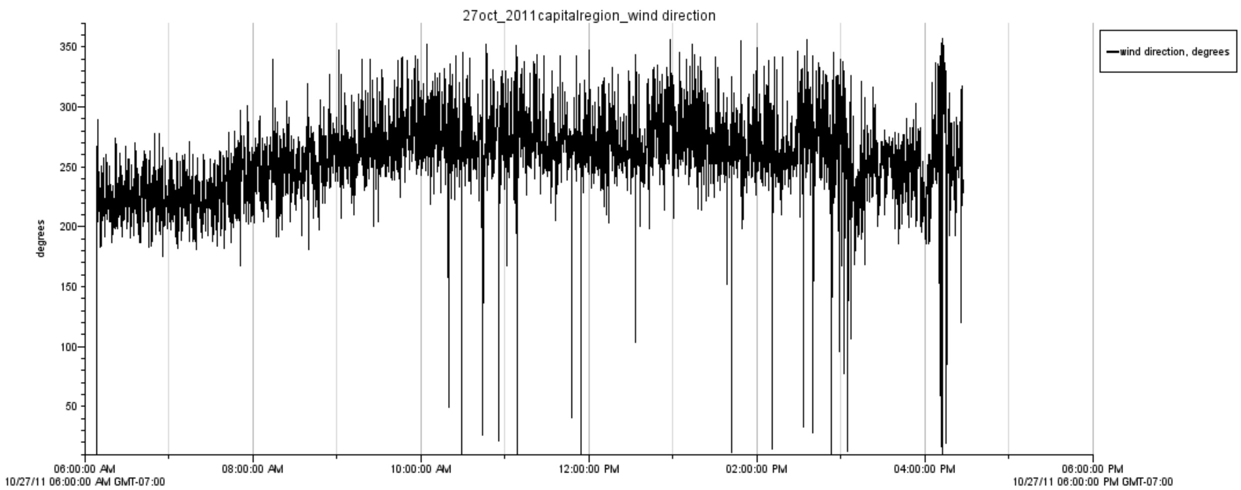


Figure 3-13: Annemometer results, wind speed and wind direction at Capital Region WWTP for Oct 26 and 27, 2011

3-3-Goldbar

The maximum concentration, measured with CTD, at the outfall was 13.75 ppb which was measured in a section at about 26m from the outfall (Figure 3-14, 3-15 and table 3-5). The section is normalized by approximate width of the river on surveyed sections from river boundary shape file. The maximum measured concentration at outfall is in good agreement with the expected concentration of 13.2ppb (Table 2-1), despite the fact that the expected concentration at the outfall was calculated using the average outfall flow rate.

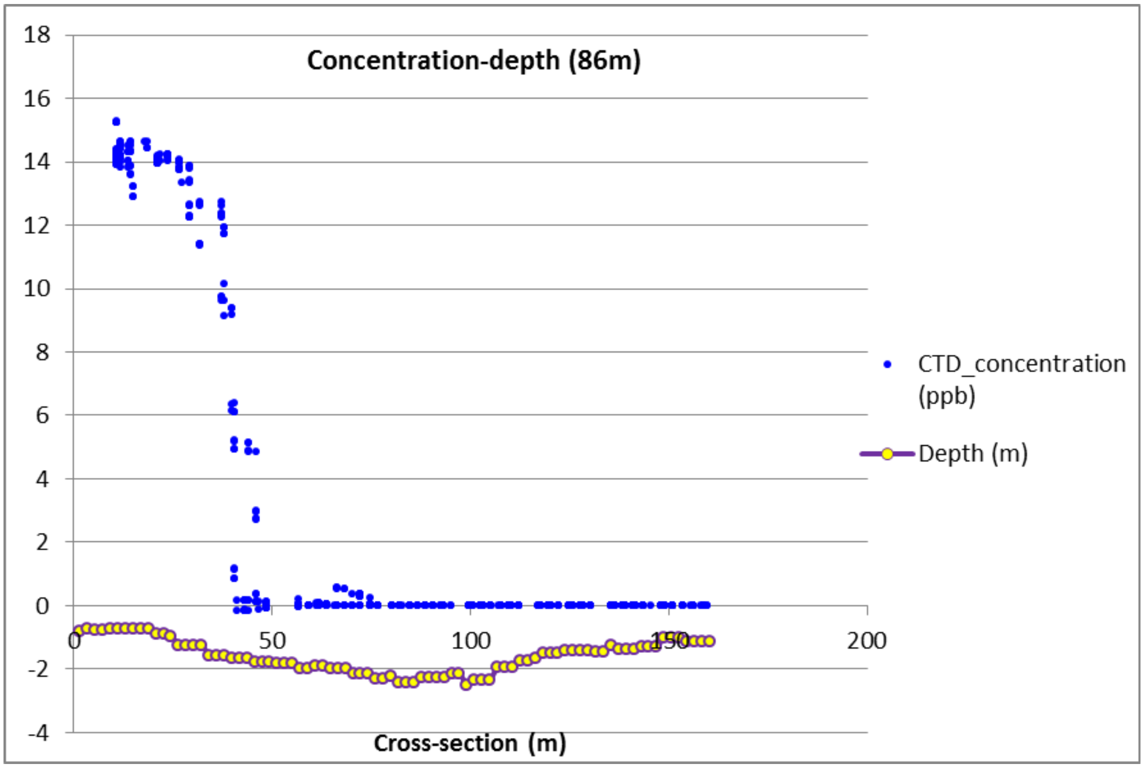


Figure 3-14: CTD and Sample concentration result across the river section at outfall

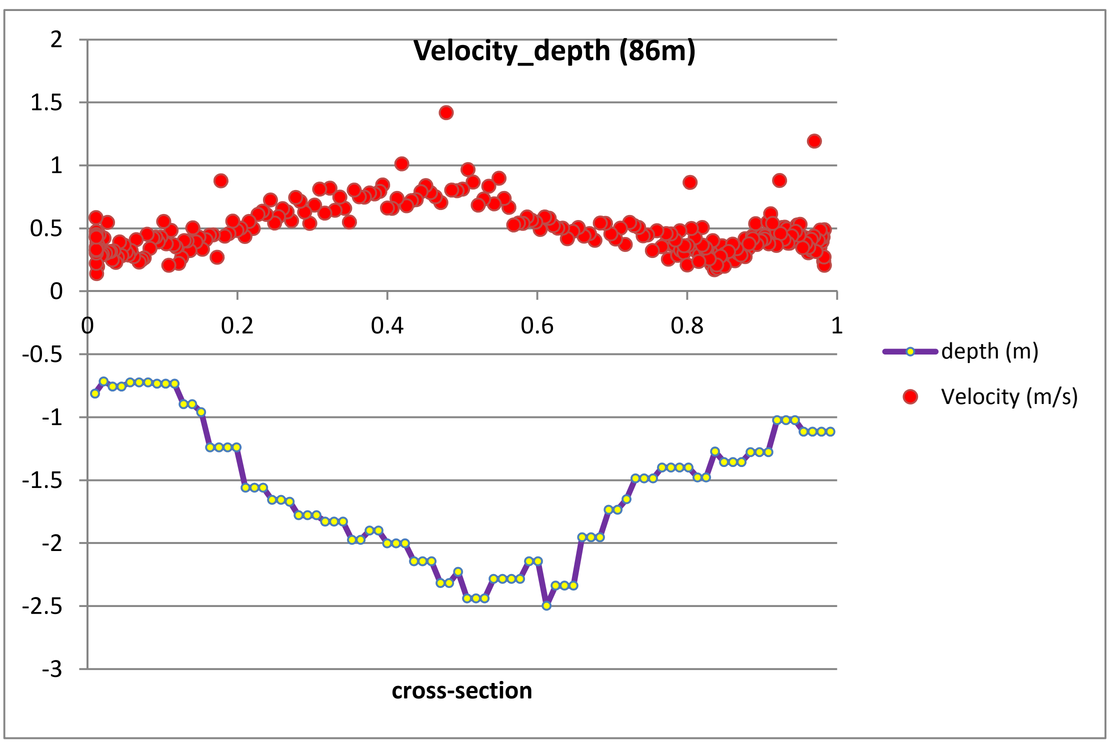


Figure 3-15: Depth average velocity and interpolated depth across the river sections

Table 3-5: 95% confidence intervals for mean rhodamine concentration at outfall

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	12.81	13.27	13.72
0.1-0.2	9.75	10.37	10.99
0.2-0.3	2.64	3.62	4.61
0.3-0.4	0.00	0.02	0.03
0.4-0.5	0.05	0.10	0.15
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Aproximate width(m)	161.80		
Approximate distance from outfall(km)	0.026		
Time and date	11:41:36 Oct 29 2011		

The outfall is located in the right bank side of the river in Goldbar WWTP. In the initial sections rhodamine was concentrated on the right half of the river and the concentration was 0 on the left bank side. The first section in which rhodamine concentration was observed on the left bank side of the river was located at approximately 11.6km (Figure 3-15) from the outfall location. As the river follows its path, effluent gradually mixes with ambient water due to turbulent dispersion. In addition, passing through river bends will also accelerate the mixing procedure. For this study, especially in the sections closer to the outfall with concentrated rhodamine on one side of the river, the rhodamine mass center moved to left when passing a right turn bend and moved to right as flow passed a left turn bend.

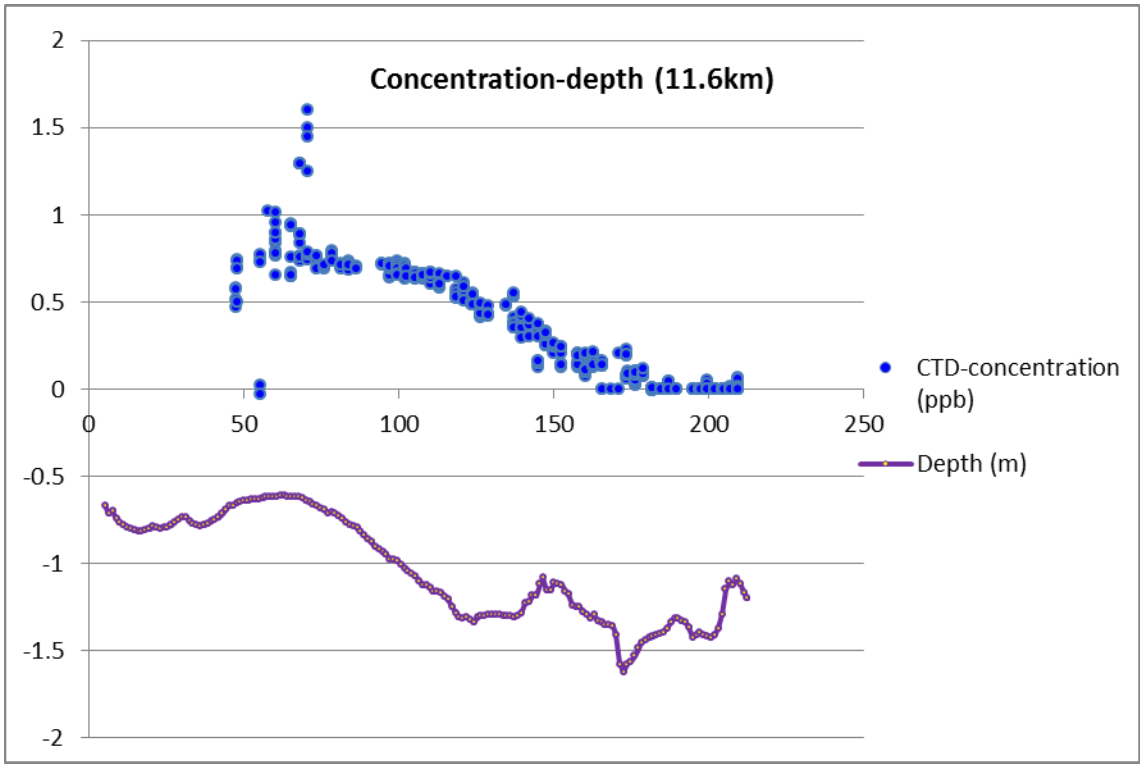


Figure 3-16: CTD and Sample concentration result across the river section at 11.6km section

The last surveyed section for Goldbar WWTP effluent study was located at about 92km from the outfall location (Figure 3-17). The average rhodamine concentration in right and left bank of this section were 0.23ppb and 0.18 ppb respectively.

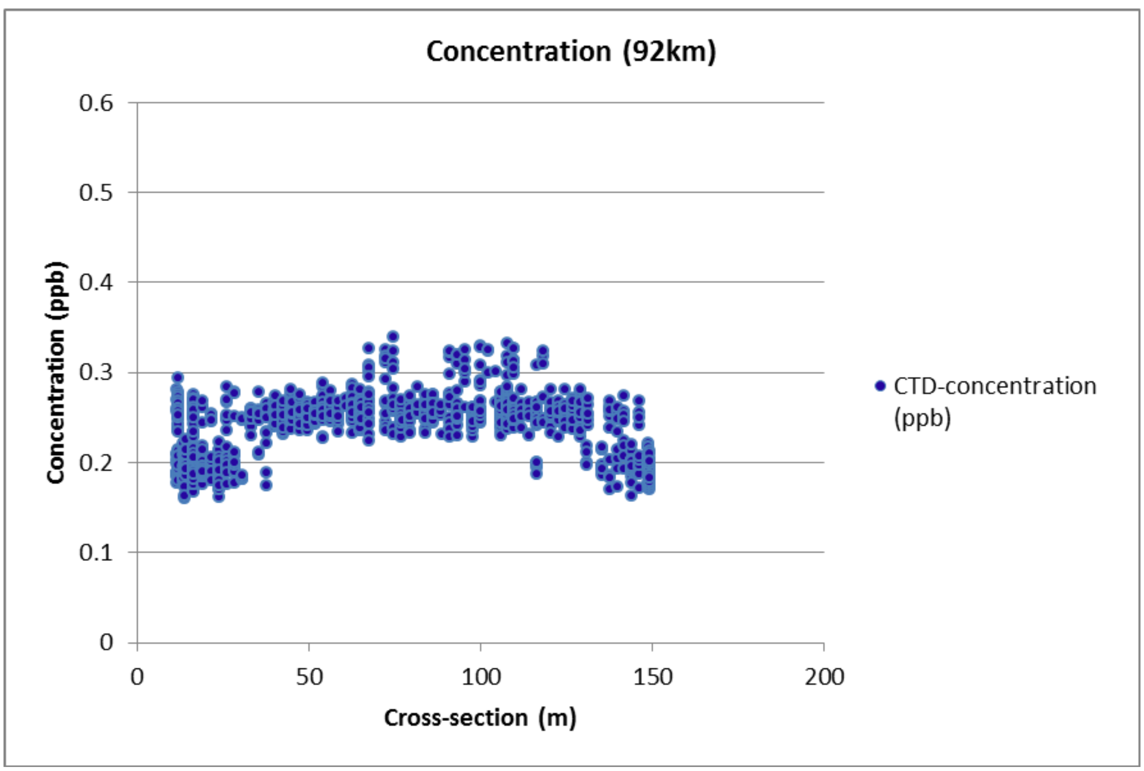


Figure 3-17: CTD concentration result across the river at the last surveyed section

3-3-2- Wind

Goldbar WWTP wind data were collected over three days from October 29 to October 31 (Figure 3-18). The summary of collected data is presented in Table 3-6 individually for each day.

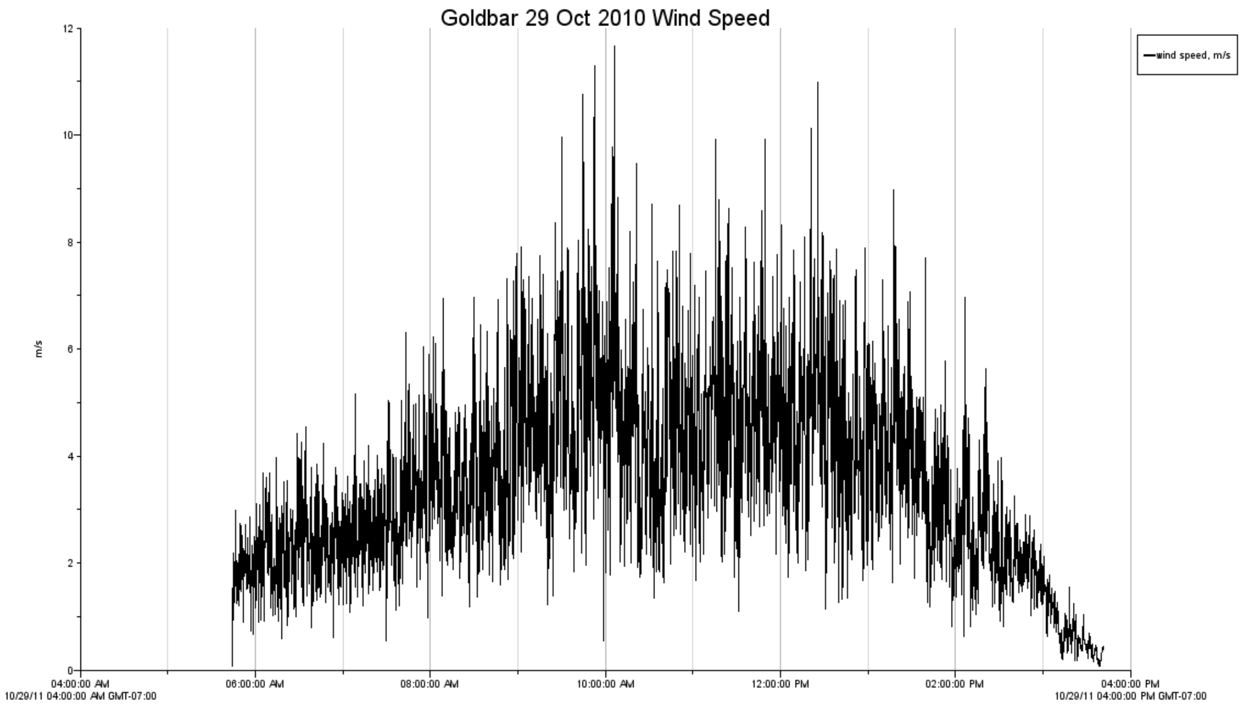
Table 3-6: Summary of anemometer results at Goldbar WWTP

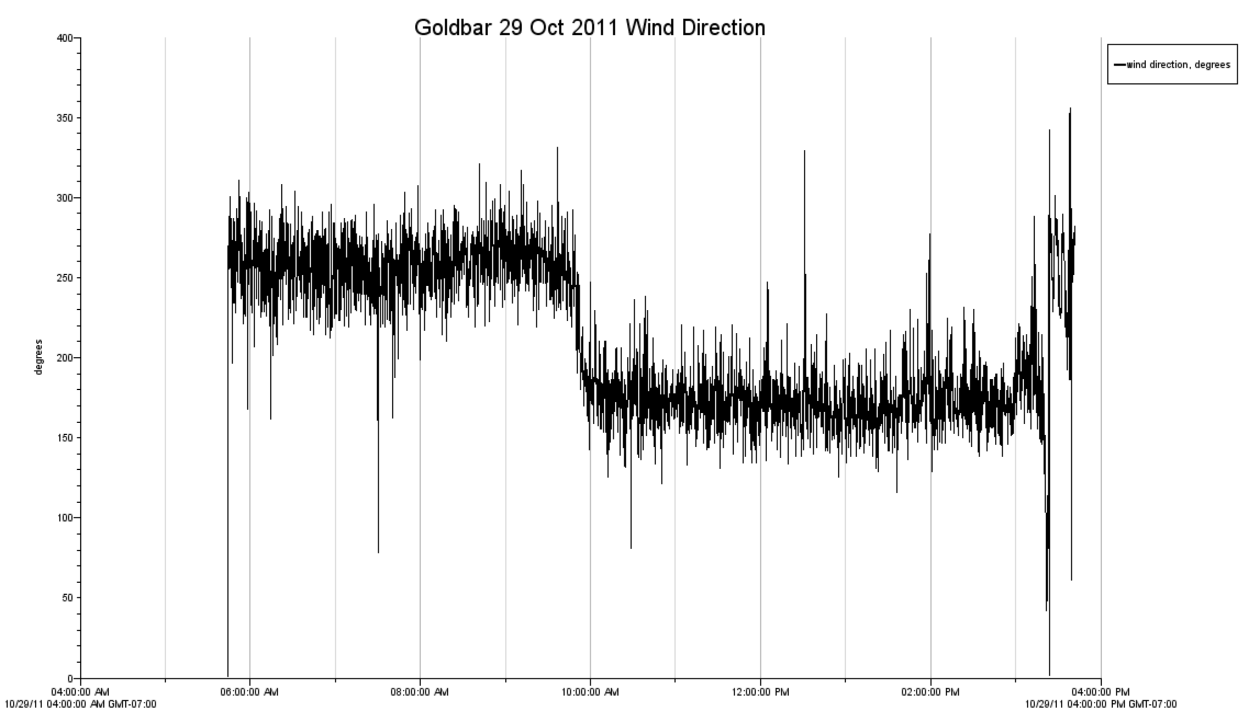
Date	29 Oct
Number of samples	3586
Parameter	Wind direction
Average	211.049
Standard deviation	47.295

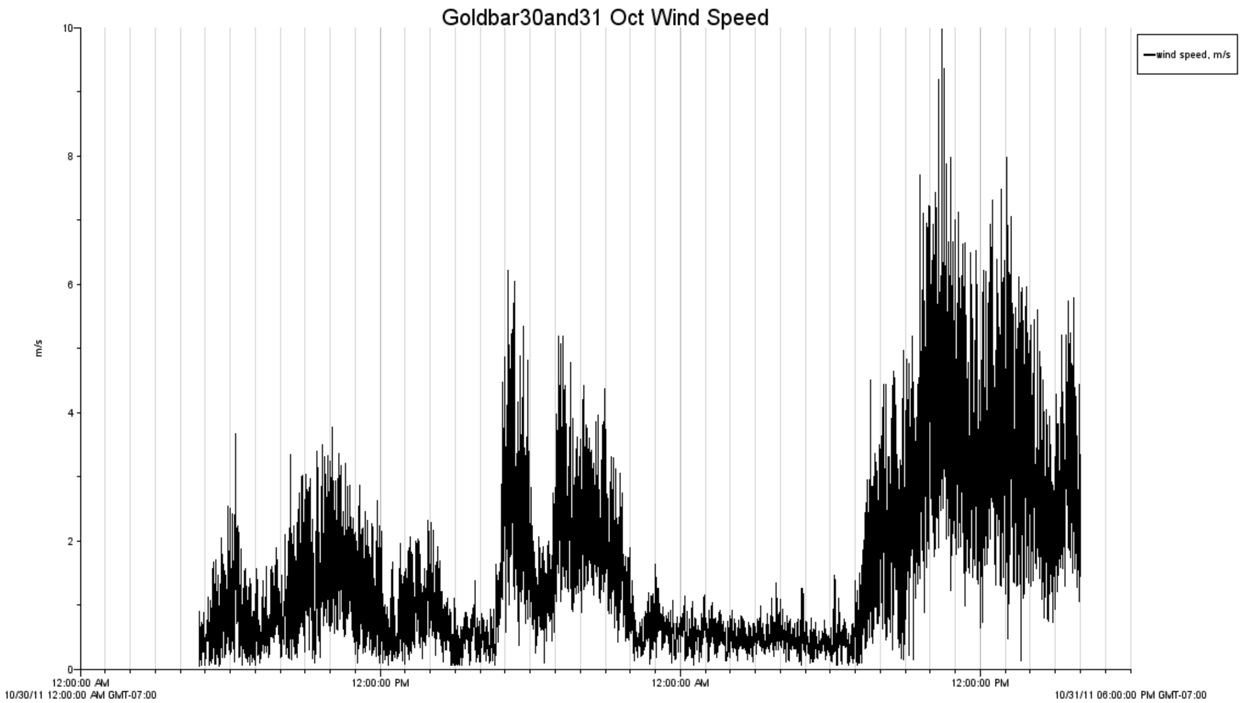
Date	30 Oct
Number of samples	6930
Parameter	Wind direction
Average	213.03
Standard deviation	87.36

Date	31 Oct
Number of samples	5759
Parameter	Wind direction
Average	242.81
Standard deviation	87.87

Date	29 Oct
Number of samples	3586
Parameter	Wind speed
Max	11.66
Min	0.0654
Average	3.51
Standard deviation	1.7797
Date	30 Oct
Number of samples	6930
Parameter	Wind speed
Max	6.21
Min	0.04
Average	1.20
Standard deviation	0.85
Date	31 Oct
Number of samples	5759
Parameter	Wind speed
Max	9.97
Min	0.06
Average	1.91
Standard deviation	1.64


Goldbar 29 Oct 2010 Wind Speed
wind speed, m/s
m/s
12
10
8
6
4
2
0
04:00:00 AM
10/29/11 04:00:00 AM GMT-07:00
06:00:00 AM
08:00:00 AM
10:00:00 AM
12:00:00 PM
02:00:00 PM
04:00:00 PM
10/29/11 04:00:00 PM GMT-07:00


Goldbar 29 Oct 2011 Wind Direction
wind direction, degrees
degrees
400
350
300
250
200
150
100
50
0
04:00:00 AM
10/29/11 04:00:00 AM GMT-07:00
06:00:00 AM
08:00:00 AM
10:00:00 AM
12:00:00 PM
02:00:00 PM
04:00:00 PM
10/29/11 04:00:00 PM GMT-07:00



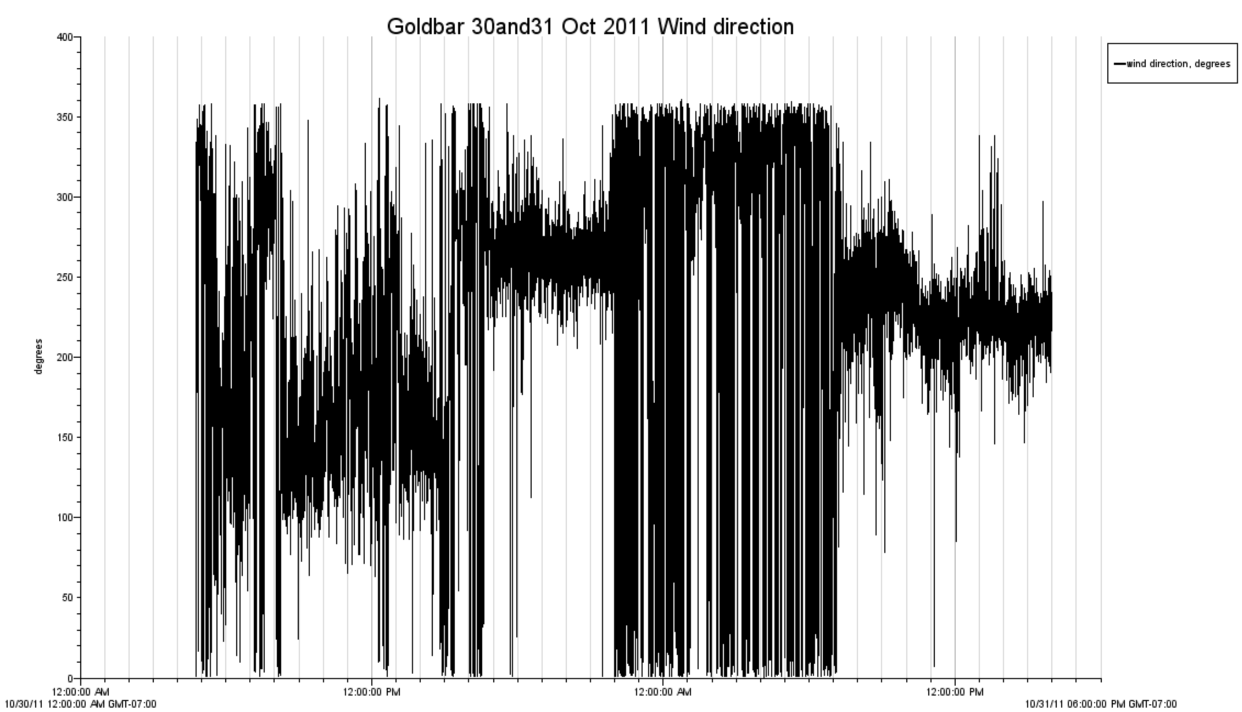


Figure 3-18: Annemometer results, wind speed and wind direction at Goldbar WWTP for Oct 29-31 2011

4- Discussion

The main concern of this study is the mixing pattern of effluent discharged to the North Saskatchewan River. Thus, rhodamine concentration was measured and graphed at several sections with different distance from outfall locations along the river. In the previous section, discrete data points were presented for concentration in several sections along the river path. These data are now used to estimate the distance required to achieve full mixing. The average values across various sections are plotted in Figure 4-1 to 4-4.

The gradual mixing of effluent with ambient water is observed in the Agrium results within the surveyed distance (Fig. 4-1). At 12km from the outfall location, river flow is separated due to the presence of an island in the middle of the river section. The consequent complex flow pattern leads to a uniform rhodamine concentration distribution across the last surveyed section in the right-hand channel. However, the left-hand channel at 11.5 km did not display a uniform concentration distribution, thus, full mixing was not observed.

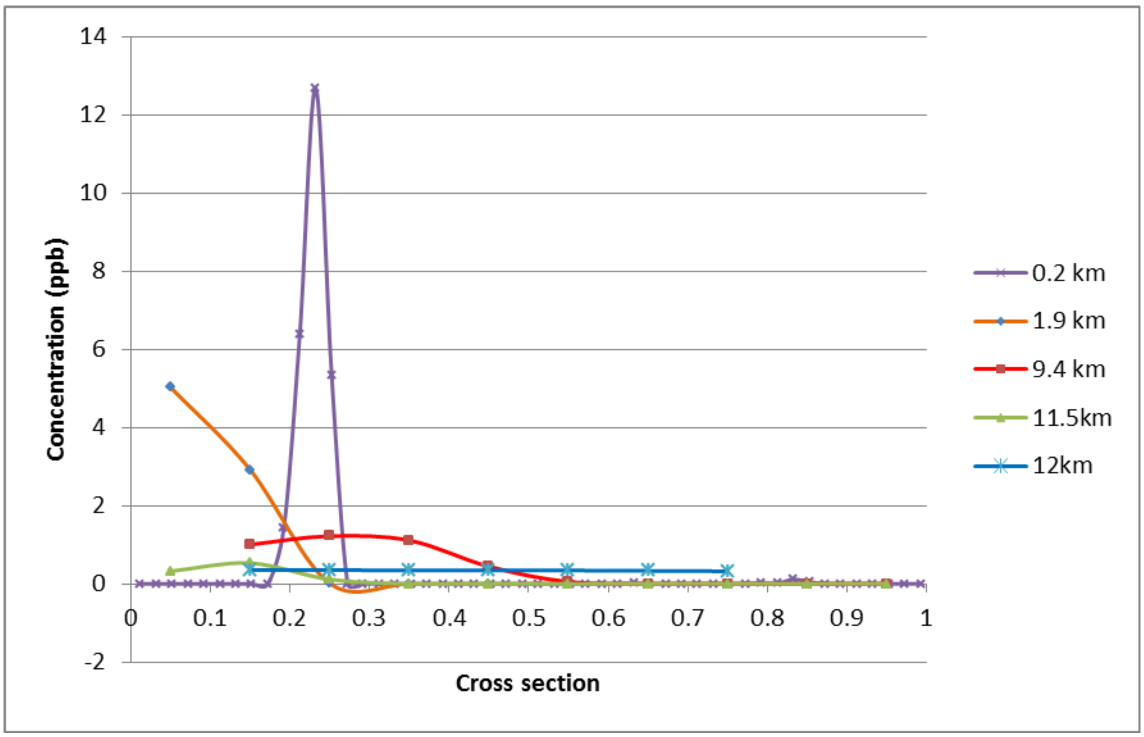


Figure 4-1: Mixing trend along river path from Agrium surveying results, based on mean rhodamine concentrations at each section. Location across the section is non-dimensionalized such that the left bank is at 0 and the left bank is at 1

In Capital Region WWTP the 100ppb difference between rhodamine concentration in right and left bank side of the river decreased continuously along the river (Fig 4-2 and 4-3). As previously mentioned, because rhodamine was injected from the right bank into the river, it was highly concentrated in the right bank side of the river and measured concentration on the left bank side was 0 for initial sections. The rhodamine reached the left bank at the 6km section from the outfall. The high rhodamine concentration difference between left bank side and right bank side reduced from 100 ppb at the outfall to 0.27 ppb at the 83km section. However, this value is still 46% of the average rhodamine concentration at the 83km section, which means that the full mixing condition was not achieved.

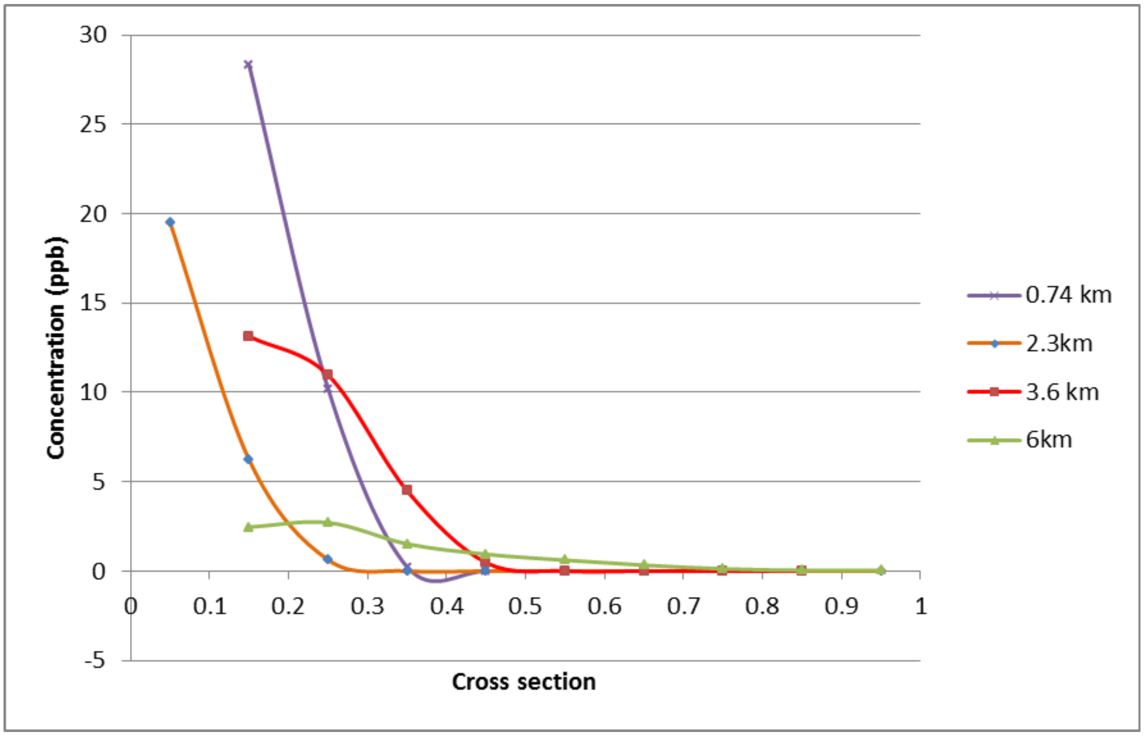


Figure 4-2: Mixing trend along river path (outfall to 6km section) from Capital Region WWTP surveying results, based on mean rhodamine concentrations at each section. Location across the section is non-dimensionalized such that the right bank is at 0 and the left bank is at 1

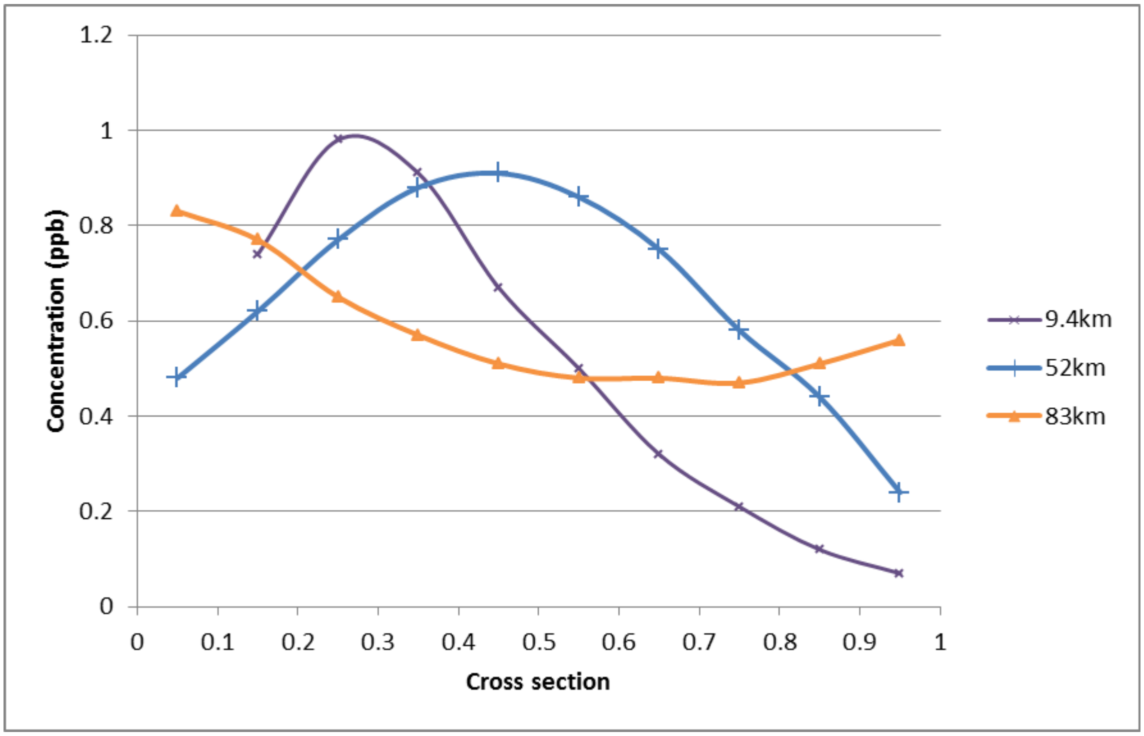


Figure 4-3: Mixing trend along river path (9.4km to 83km section) from Capital Region WWTP surveying results, based on mean rhodamine concentrations at each section. Location across the section is non-dimensionalized such that the right bank is at 0 and the left bank is at 1

For Goldbar WWTP the outfall location is also located on the right bank, thus in the initial sections rhodamine was concentrated on the right half of the river and the concentration was 0 on the left bank side (Fig. 4-4). The first section in which rhodamine concentration was observed on the left bank side of the river was located at approximately 11.6km (Figure 3-16) from the outfall location.

Downstream of where the effluent reaches the left side of the river, measured concentration continues to be higher on the right bank side compared to left bank side. The high concentration difference between right bank and left bank at the outfall (about 13 ppb) reduced to 0.11 ppb at the 80 km section. For the 92 km section this difference reduced to 0.05 ppb. However, the 95% confidence intervals for concentration at the right bank and left bank at the 92 km section do not overlap, so it appears that full mixing still has not been achieved. Still, the difference across the section of 0.05 ppb is only 20% of the average sectional concentration of 0.23 ppb. Fischer et al. (1979, Eq5.9 and Fig. 5.5 therein) provided an analytical approach to estimate the distance required to achieve full mixing given measurements of the transverse distribution of concentration within the plume. Based on this analytical approach, the 20% concentration difference across the 92 km section should occur at approximately 75% of the distance required to achieve a 5% concentration difference across the section. Thus, the 95% confidence level fully mixed condition should have occurred at approximately 92km/0.75 = 123 km downstream of the Goldbar plant.

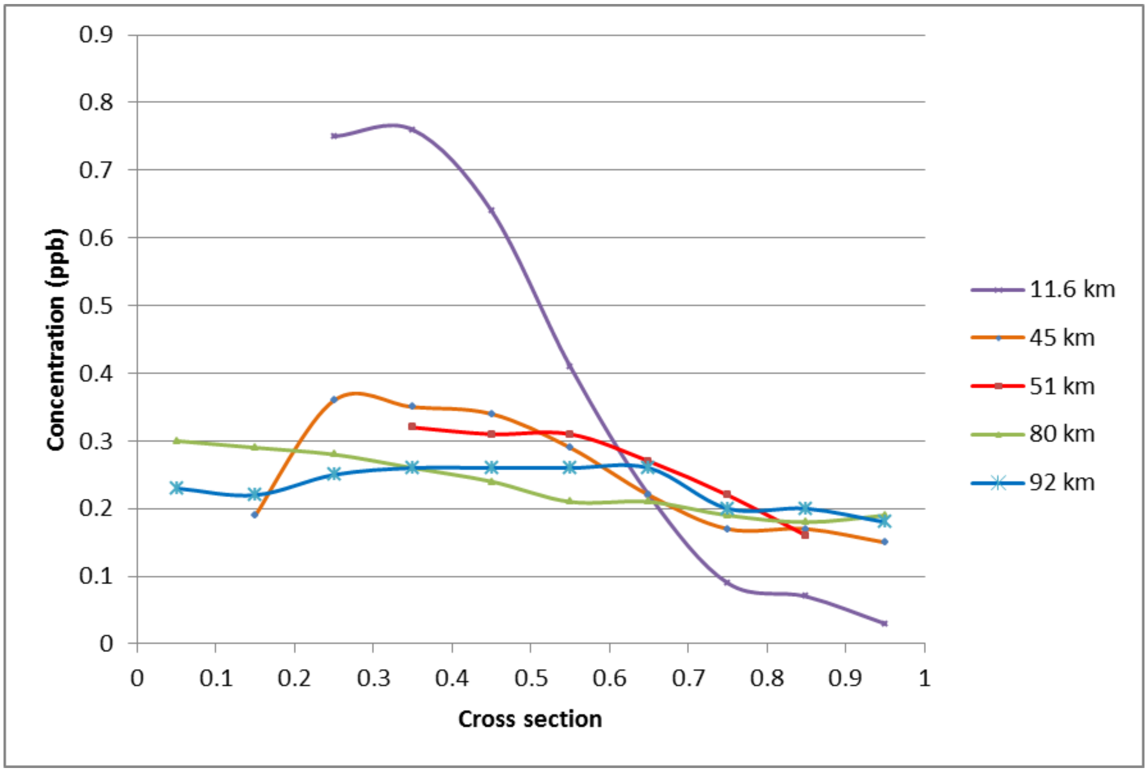


Figure 4-4: Mixing trend along river path (11.6km to 92km section) from Goldbar WWTP surveying results, based on mean rhodamine concentrations at each section. Location across the section is non-dimensionalized such that the right bank is at 0 and the left bank is at 1

For each investigated plant, the average depth and depth averaged velocity were calculated for the surveyed sections and presented in Tables 4-1 to 4-3 . The average of depth-averaged velocity, river depth and width were calculated for the river along the surveyed path by calculating the reach means of width and sectional-averaged depth-averaged velocity and depth. It should be stated that the width of each section was measured using the downloaded shape file of North Saskatchewan river boundary and no specific measurement was carried out for width while in the field. This fact in addition to the change in the river boundary in different seasons due to the change in water level means that the presented values for river width are not as accurate as the measured values for depth and depth-averaged velocity.

Table 4-1: Flow hydraulic characteristics in the surveyed sections for Agrium

Distance(km)	Average depth (m)	Average depth averaged velocity (m/s)	Width(m)
0.2	1.12	0.46	242.17
1.9	1.28	0.40	255.36
4.2	1.29	0.49	212.9
9.4	1.78	0.35	225.32
11.5	1.25	0.53	199.32
12	1.8	0.3	135.46
Average	1.42	0.42	211.75

Table 4-2: Flow hydraulic characteristics in the surveyed sections for Capital Region WWTP

Distance(km)	Average depth (m)	Average depth averaged velocity (m/s)	Width(m)
0.74	1.04	0.74	185.15
2.3	1.35	0.60	181.49
3.6	1.33	0.54	193.38
6	1.37	0.44	218.18
9.4	1.34	0.55	189.67
10.7	1.77	0.62	186.69
12.3	1	0.61	219.17
39	1.83	0.39	172.89
44	2.21	0.41	193.23
47	1.19	0.55	251.95
52	1.57	0.33	226.78
55	0.89	0.61	249.61
59	1.57	0.6	227
66	1.37	0.62	204.18
78	0.87	0.76	248.7
83	1.41	0.57	170.82
Average	1.38	0.56	207.4

Table 4-3: Flow hydraulic characteristics in the surveyed sections for Goldbar WWTP

Distance	Average depth (m)	Average depth averaged velocity (m/s)	Width(m)
26m	1.77	0.43	154.38
86m	1.59	0.45	169.67
126m	1.65	0.45	183.63
176m	1.36	0.49	185.26
226m	1.59	0.46	199.61
276m	1.63	0.42	199.14
326m	1.40	0.53	226.13
376m	1.38	0.54	219.97
5.2km	1.30	0.52	231.35
5.5km	1.43	0.46	212.26
6.3km	1.13	0.62	250.87
7.2km	1.23	0.83	215.15
9.5km	1.18	0.80	212.00
11.6km	1.06	0.79	191.70
11.6km	1.03	0.78	193.32
14km	2.10	0.39	166.26
16.2km	2.10	0.35	201.51
74km	1.86	0.46	192.83

80km	1.01	0.80	209.28
84.4km	1.07	0.89	202.14
93.4km	1.62	0.43	229.22
Average	1.47	0.57	202.17

Regarding wind data, the average wind direction between October 23 to 31 ranged between 211 degrees (with respect to north direction) on October 29th to 277 degrees on October 25 . Within the survey days, October 26 had the maximum average wind speed of 3.5 m/s. In all survey days, higher wind speed was observed during the day time especially around noon. The average wind speed between 23th and 31st of October was 2.64m/s.

5- Conclusions

In order to study the physical mixing patterns of water and contaminants in the North Saskatchewan River, a ten day field campaign was carried out on North Saskatchewan River for Goldbar WWTP, Capital Region WTP and Agrium Redwater plant. Rhodamine WT was used as a tracer of the effluent, and was tracked with a moving boat across the river and along the river using an *in situ* fluorometer integrated into a CTD instrument. For the first surveyed plant (Agrium), the tracer concentration was tracked for 12km along the river path. As the full mixing condition could not be achieved in 12km, the tracing distance was increased to 83km for Capital Region WWTP. The difference of 46% between rhodamine concentration in bank sides and average concentration across the river showed that the full mixing condition has not been achieved in 83km section. So the tracing distance was increased for Golbar WWTP to 92km. The maximum measured concentration was found to be 13.72 ppb at the right bank side in the outfall location and was reduced gradually along the river path as tracer mixing with ambient water progressed and finally reduced to 0.26 ppb on the right bank at 92km from the outfall. The average measured tracer concentration at this section was 0.23 ppb.

According to relatively small difference between rhodamine concentration in left and right bank side, it can be stated that full mixing has almost been achieved at this section, and the full mixing length in the river is of O(100 km) from the outfall.. An analytical extrapolation of the data suggests the fully mixed condition would have occurred at 123 km from the outfall.

During the survey, the depth-averaged velocity and water depth were also measured with an ADCP. The average depth and depth-averaged velocity along river were 1.42m and 0.52m/s respectively.

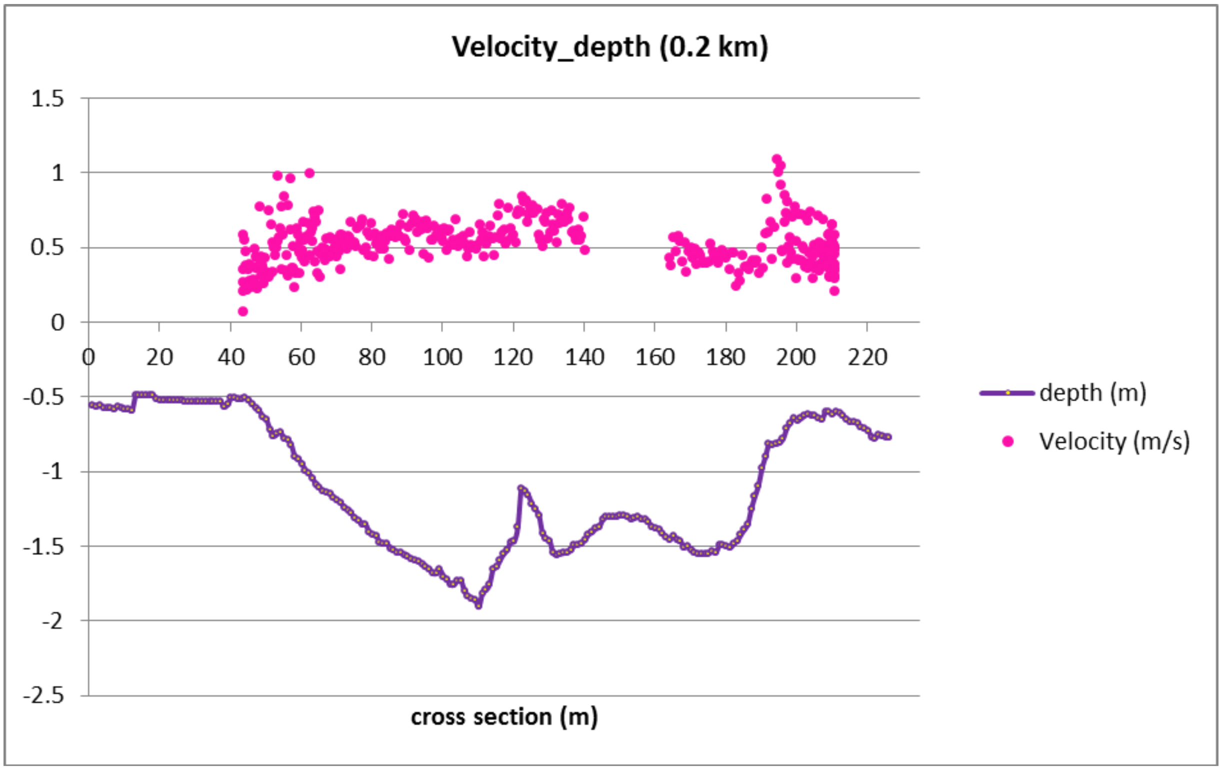
In addition, wind speed and direction were also measured simultaneously using an anemometer at the outfall location. The average wind direction between October 25-31, 2011 was 211° and the average wind speed was 2.64 m/s.

6- References

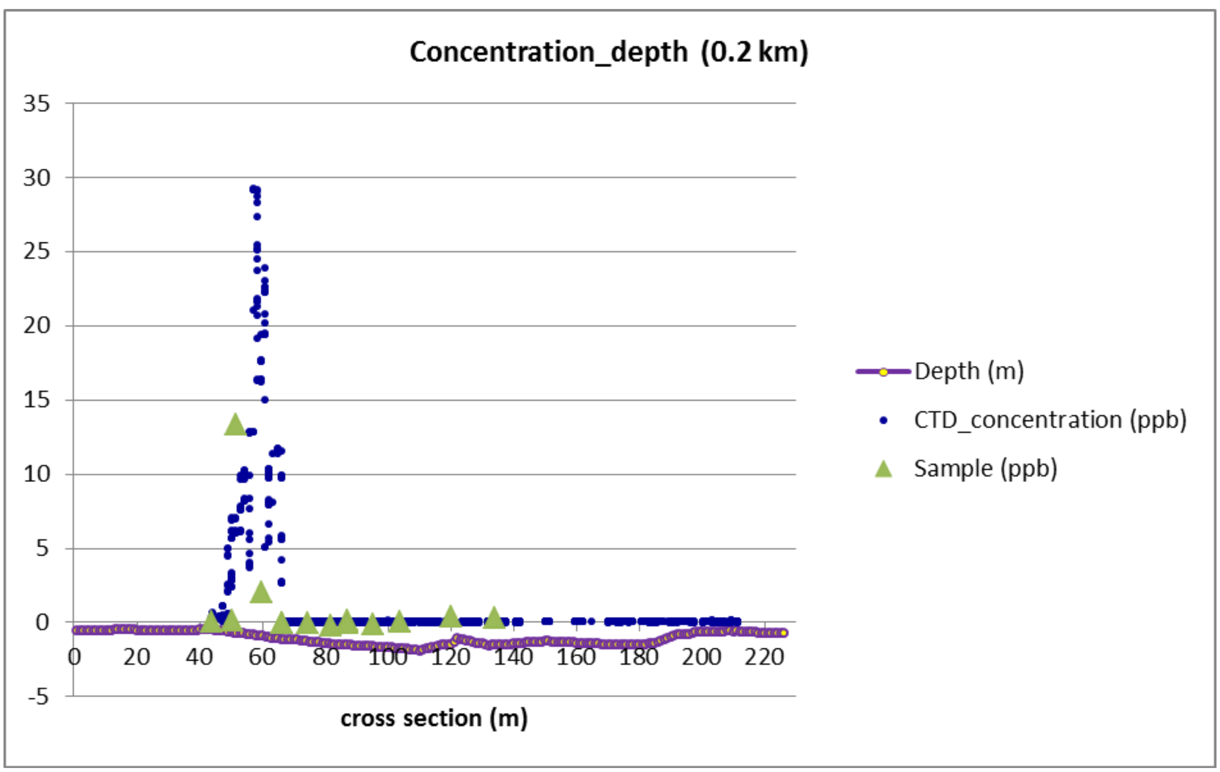
Fischer, H.B., List, E.J., Koh, R.C.Y., Imberger, J., Brooks, N.H. (1979). *Mixing in Inland and Coastal Waters*, Academic Press, London.

Rennie, C.D., Rainville, F. “Case study of precision of GPS differential correction strategies: Influence on aDcp velocity and discharge estimates”, *J. Hydraulic Eng. (ASCE),* 132(3):225-234, 2006.

Appendix A: Agrium Results



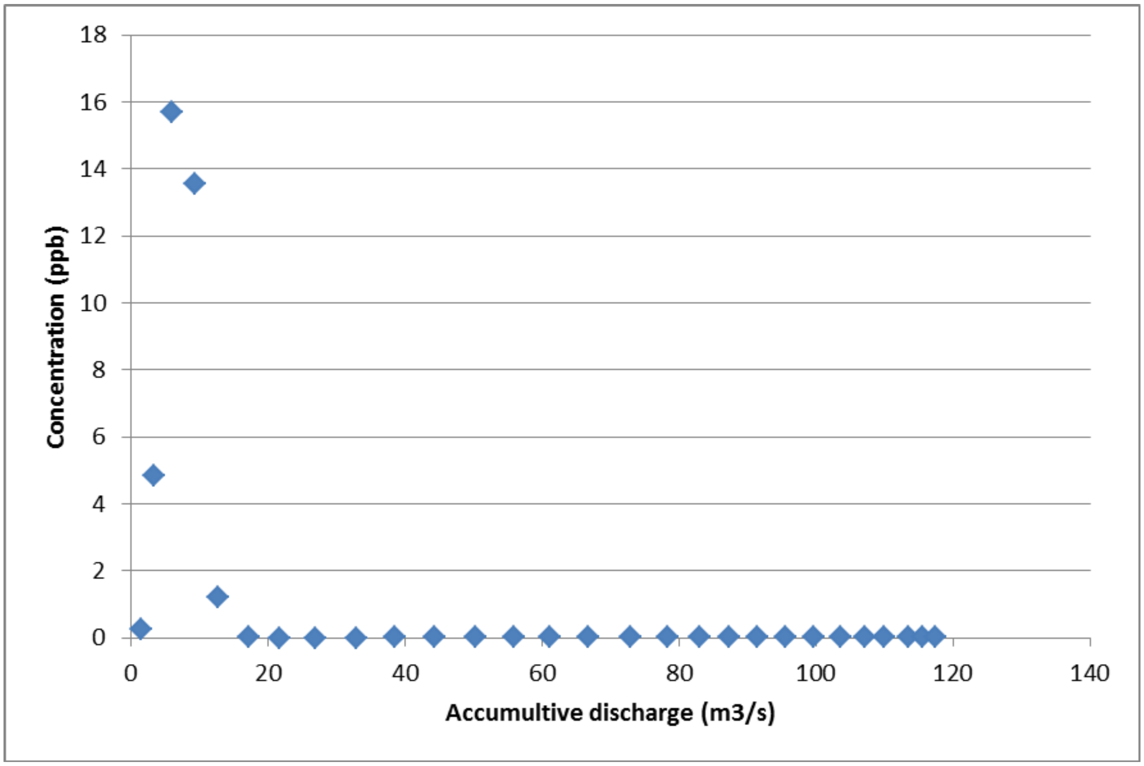
Velocity 0.2km_1

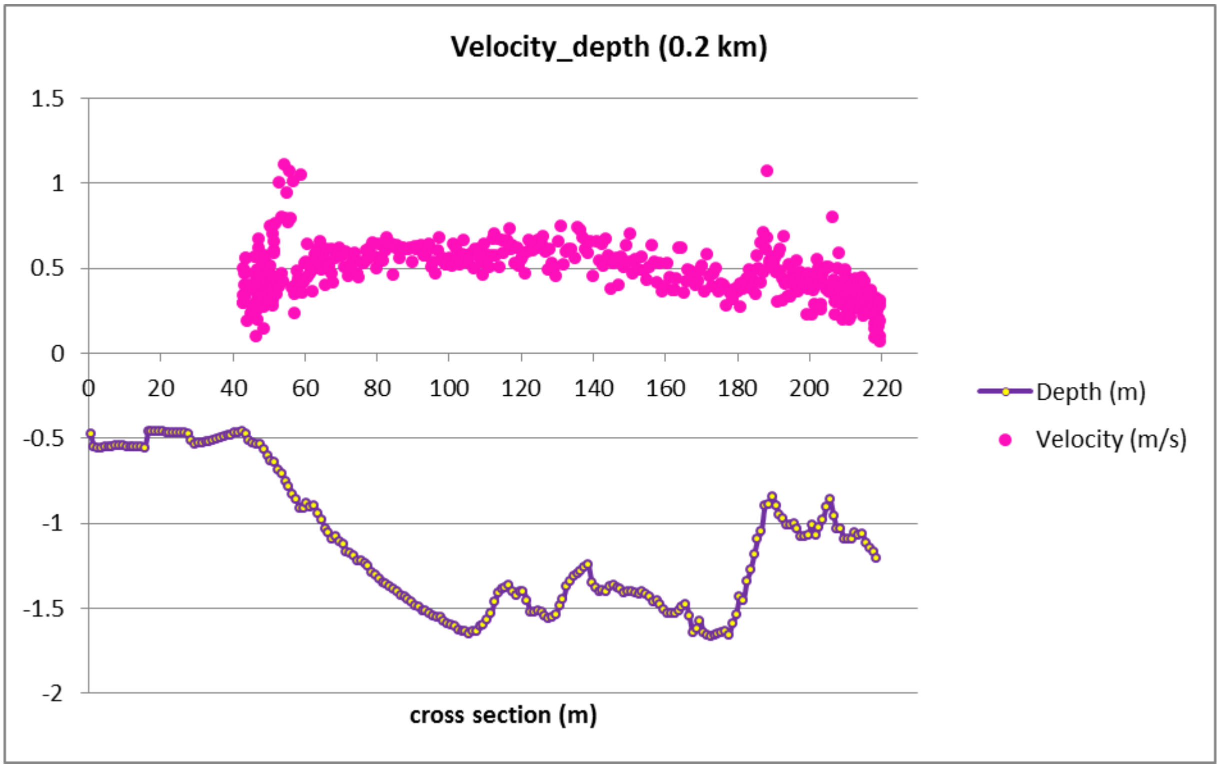


Concentration 0.2km_1

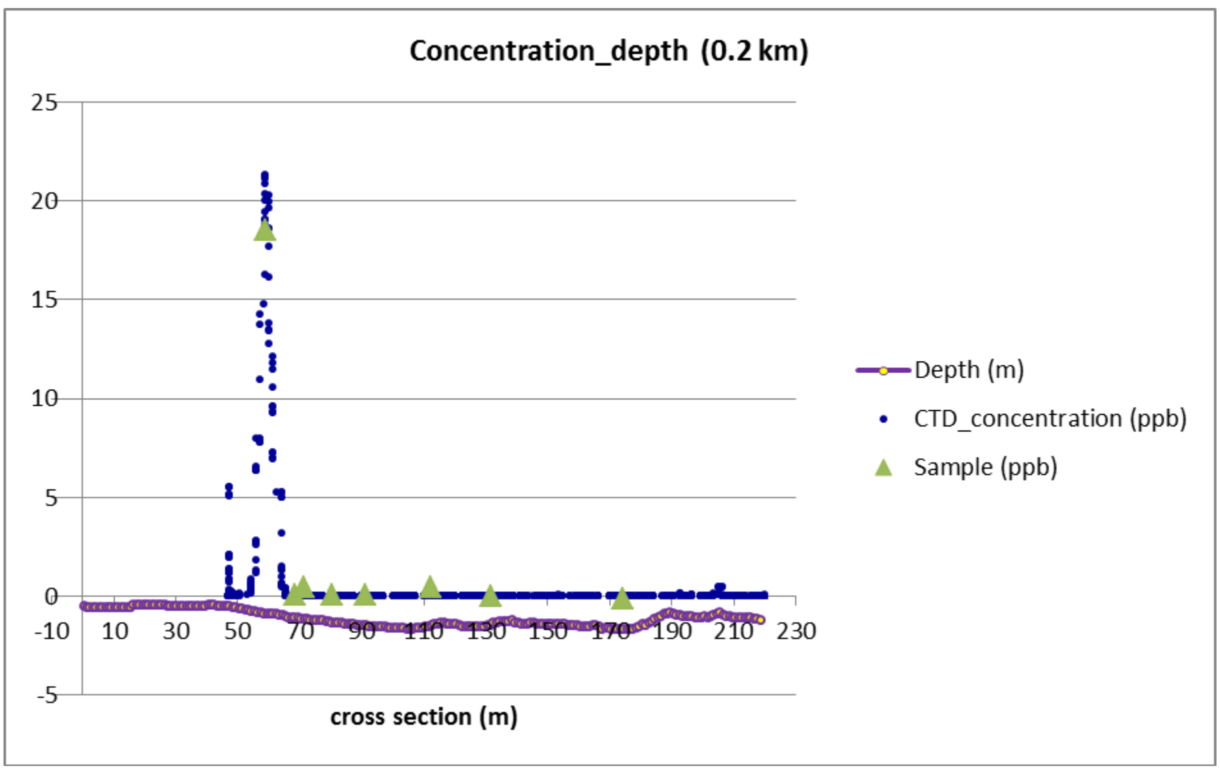
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.025			
0.025-0.05			
0.05-0.075			
0.075-0.1			
0.1-0.125			
0.125-0.15			
0.15-0.175			
0.175-0.2	0.18	0.32	0.25
0.2-0.225	4.11	5.56	4.84
0.225-0.25	13.36	17.99	15.68
0.25-0.275	11.95	15.19	13.57
0.275-0.3	0.56	1.90	1.23
0.3-0.325	0.01	0.02	0.01
0.325-0.35	0.00	0.00	0.00
0.35-0.375	0.00	0.01	0.00
0.375-0.4	0.00	0.00	0.00
0.4-0.425	0.01	0.02	0.01
0.425-0.45	0.01	0.02	0.01
0.45-0.475	0.00	0.01	0.01
0.475-0.5	0.01	0.02	0.01
0.5-0.525	0.00	0.00	0.00
0.525-0.55	0.00	0.01	0.01
0.55-0.575	0.01	0.01	0.01
0.575-0.6	0.00	0.01	0.01
0.6-0.625	0.01	0.03	0.02
0.625-0.65	0.01	0.03	0.02
0.65-0.675	0.00	0.02	0.01
0.675-0.7	0.01	0.02	0.01
0.7-0.725	0.02	0.03	0.02
0.725-0.75	0.02	0.03	0.03
0.75-0.775	0.01	0.02	0.02
0.775-0.8	0.01	0.02	0.02
0.8-0.825	0.00	0.01	0.00
0.825-0.85	0.01	0.03	0.02
0.85-0.875	0.02	0.03	0.02
0.875-0.9			
0.9-0.925			
0.925-0.95			
0.95-0.975			
0.975-1			
Approximate width(m)	238.90		

Approximate distance from outfall(km)	31.3		
Time and date	13:14:32	Oct 25 2011	





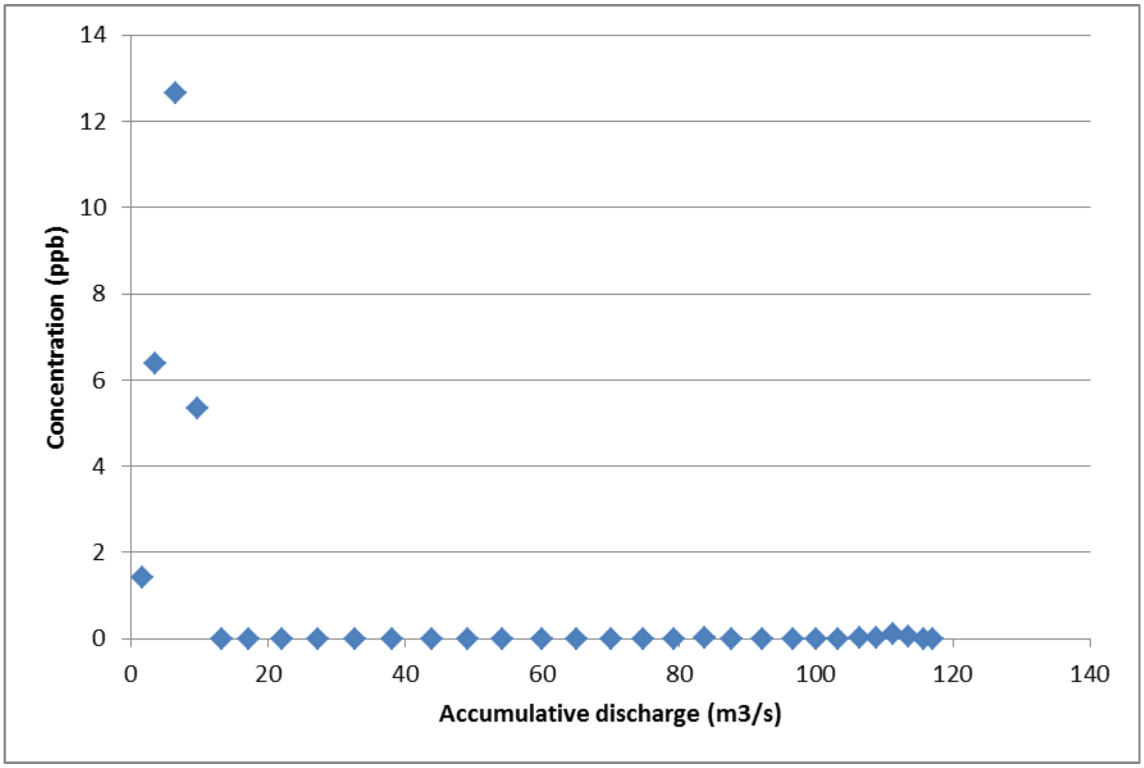
Velocity 0.2km_1

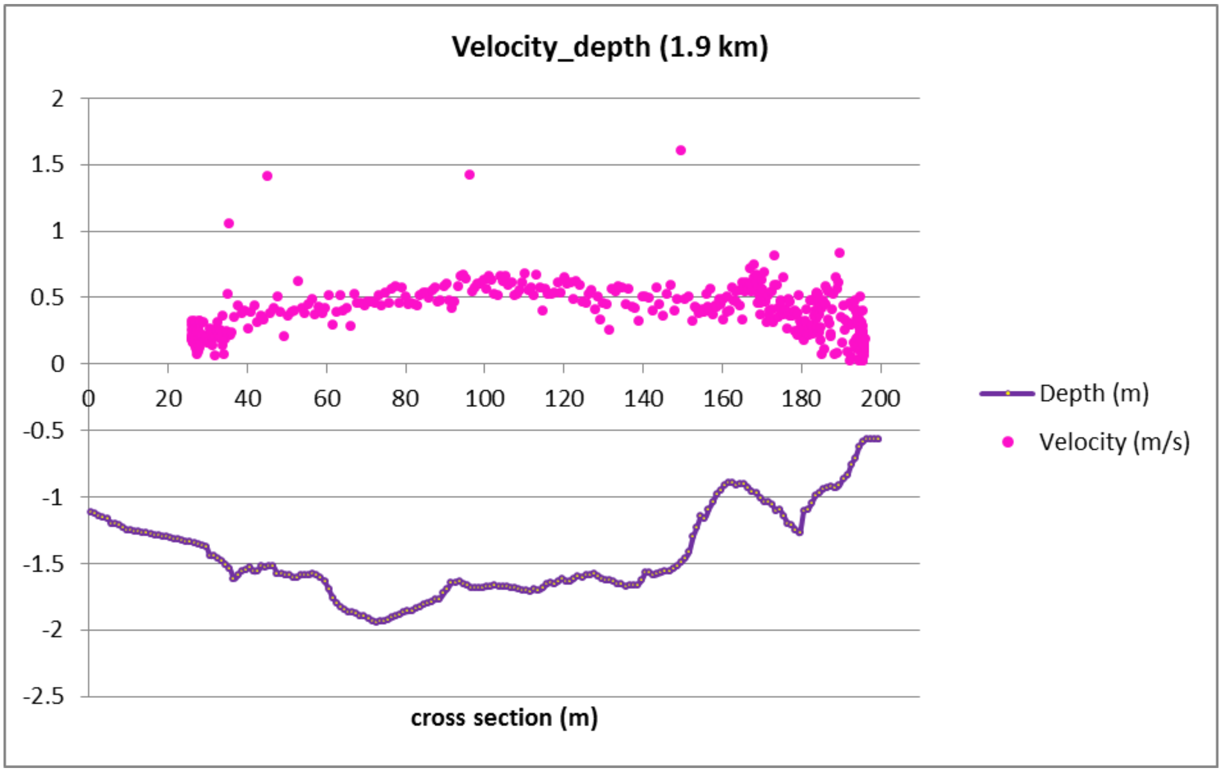


Concentration 0.2km_1

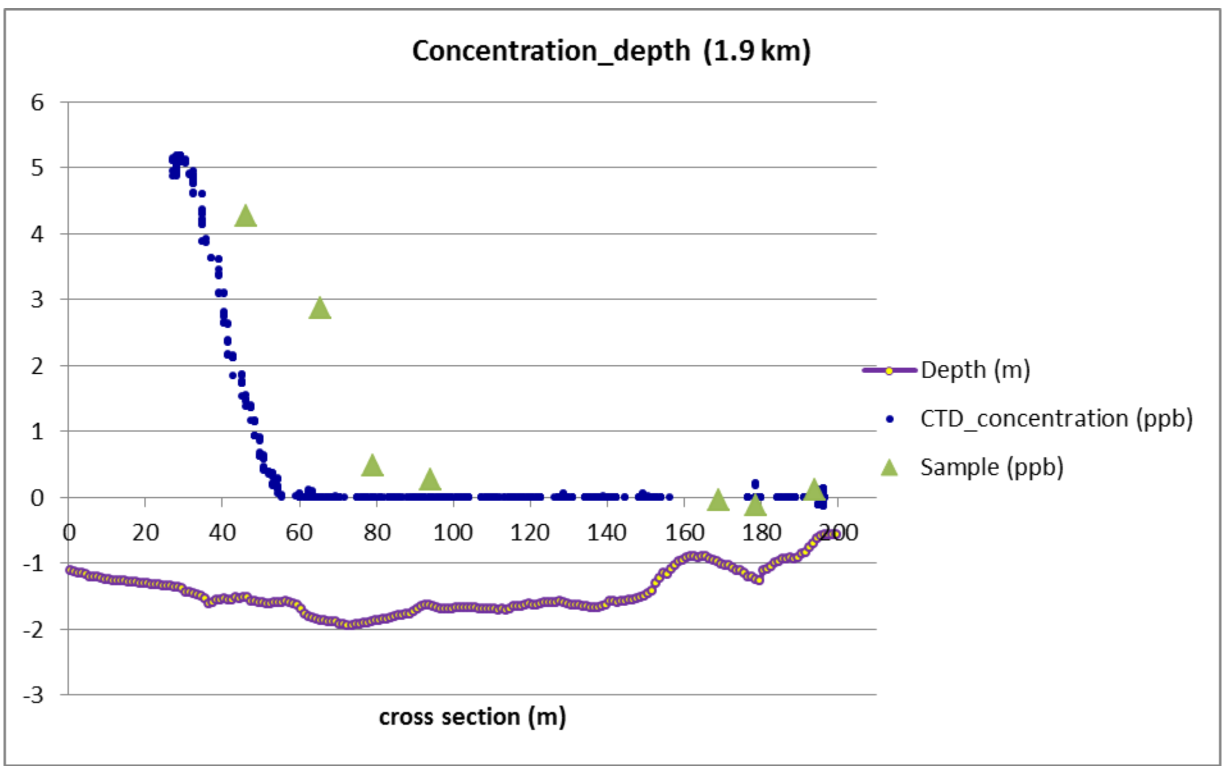
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.025			
0.025-0.05			
0.05-0.075			
0.075-0.1			
0.1-0.125			
0.125-0.15			
0.15-0.175			
0.175-0.2	1.03	0.63	1.43
0.2-0.225	5.45	4.52	6.39
0.225-0.25	10.51	8.35	12.67
0.25-0.275	3.96	2.59	5.33
0.275-0.3	0.00	0.00	0.00
0.3-0.325	0.00	0.00	0.00
0.325-0.35	0.00	0.00	0.00
0.35-0.375	0.00	0.00	0.00
0.375-0.4	0.00	0.00	0.00
0.4-0.425	0.00	0.00	0.00
0.425-0.45	0.00	0.00	0.00
0.45-0.475	0.00	0.00	0.00
0.475-0.5	0.00	0.00	0.00
0.5-0.525	0.00	0.00	0.00
0.525-0.55	0.00	0.00	0.00
0.55-0.575	0.00	0.00	0.00
0.575-0.6	0.00	0.00	0.00
0.6-0.625	0.00	0.00	0.00
0.625-0.65	0.00	0.00	0.01
0.65-0.675	0.00	0.00	0.00
0.675-0.7	0.00	0.00	0.00
0.7-0.725	0.00	0.00	0.00
0.725-0.75	0.00	0.00	0.00
0.75-0.775	0.00	0.00	0.00
0.775-0.8	0.01	0.00	0.02
0.8-0.825	0.01	0.00	0.01
0.825-0.85	0.06	0.01	0.11
0.85-0.875	0.02	0.00	0.05
0.875-0.9	0.00	0.00	0.00
0.9-0.925	0.00	0.00	0.00
0.925-0.95			
0.95-0.975			
0.975-1			
Approximate width(m)	242.17		
Approximate distance from outfall(km)	31.3		

Time and date	13:14:32	Oct 25 2011	



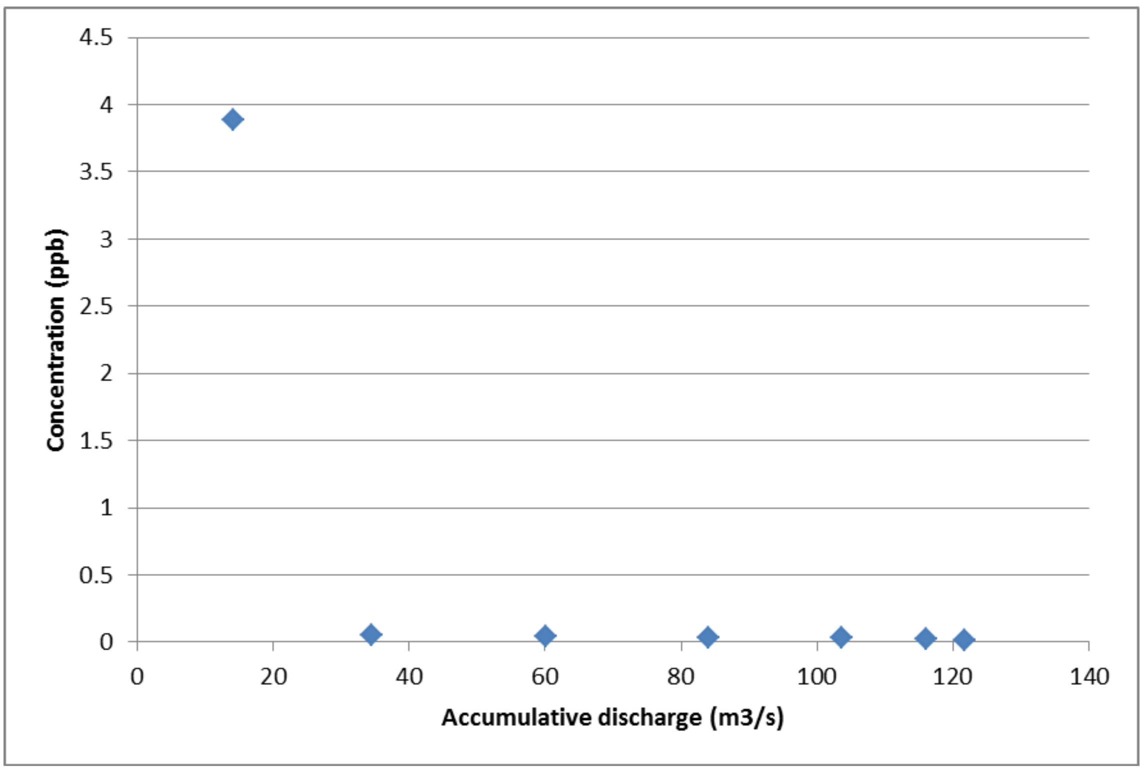


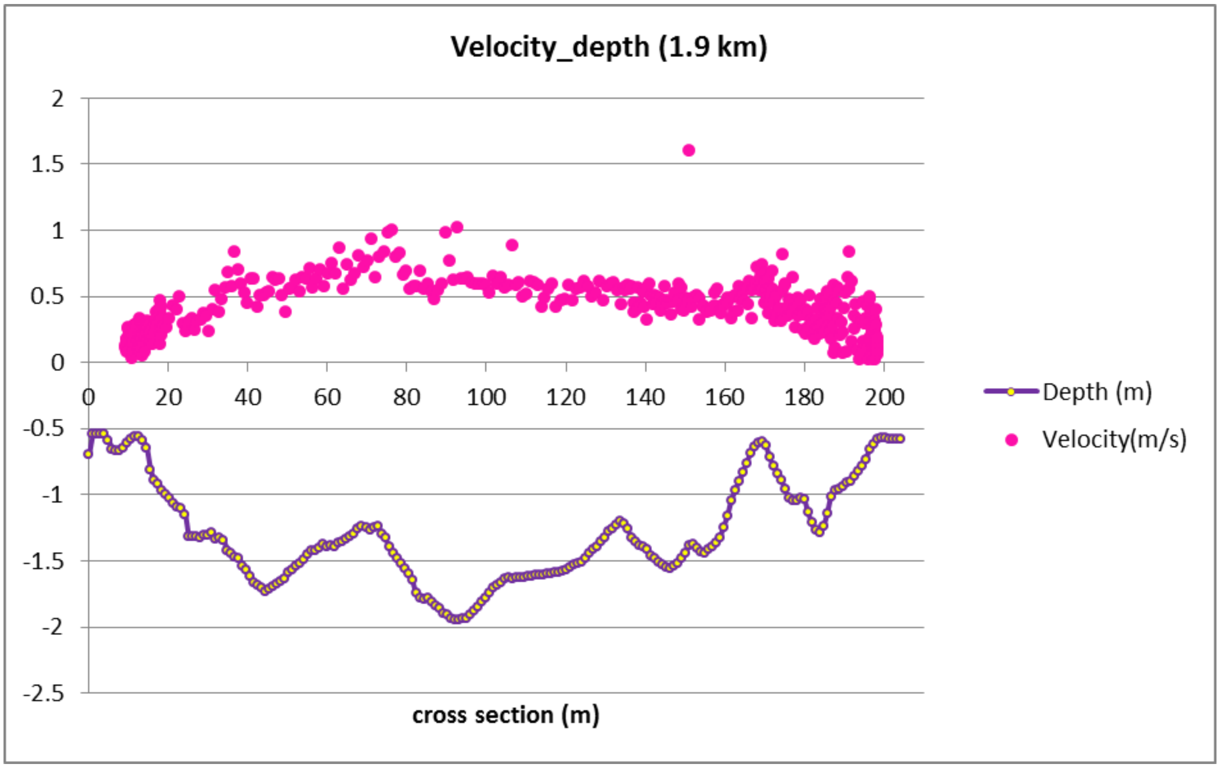
Velocity 1.9km_1



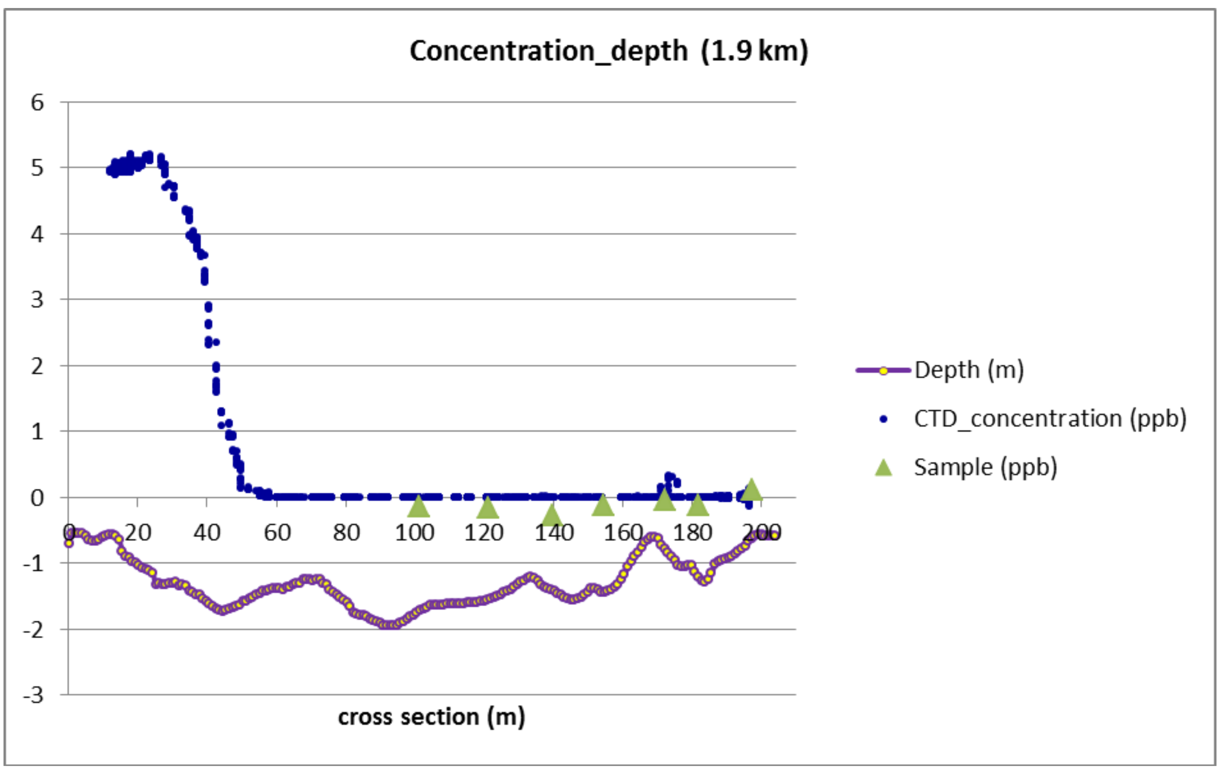
Concentration 1.9km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	3.68	4.10	3.89
0.2-0.3	0.03	0.07	0.05
0.3-0.4	0.00	0.00	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.04	0.02
0.7-0.8	0.00	0.00	0.00
0.8-0.9			
0.9-1			
Approximate width(m)	258.23		
Approximate distance from outfall(km)	1.9		
Time and date	14:34:35	Oct 25 2011	



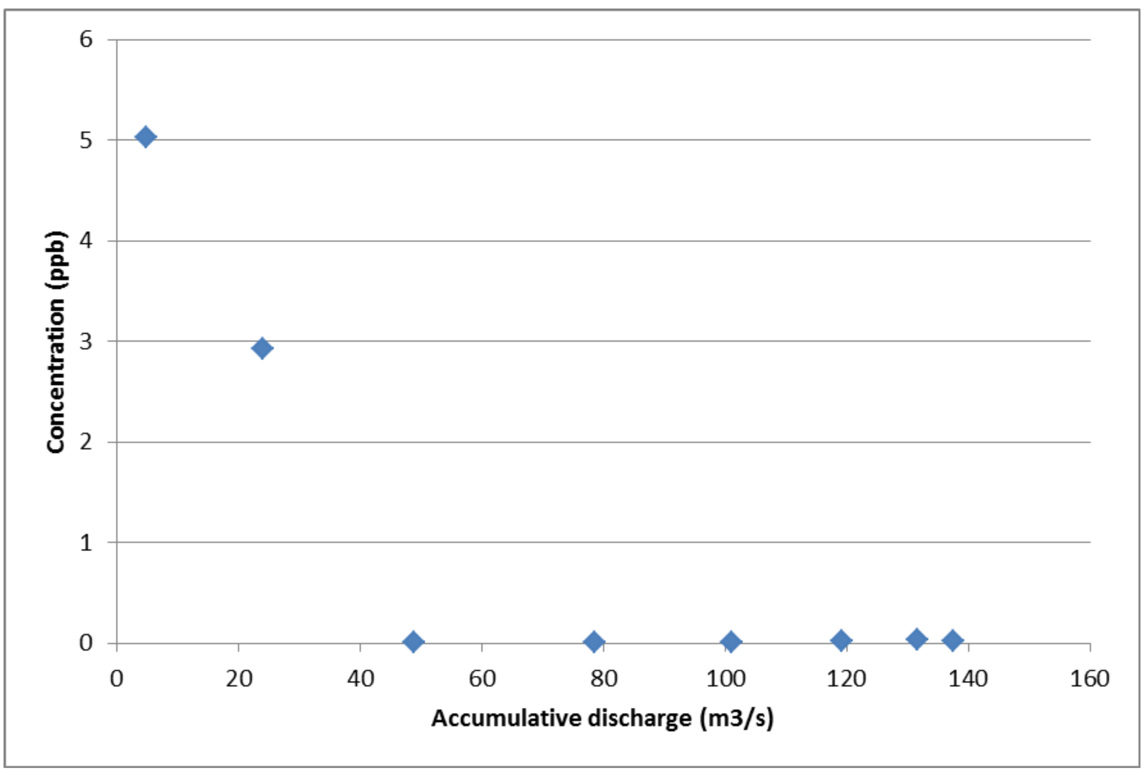


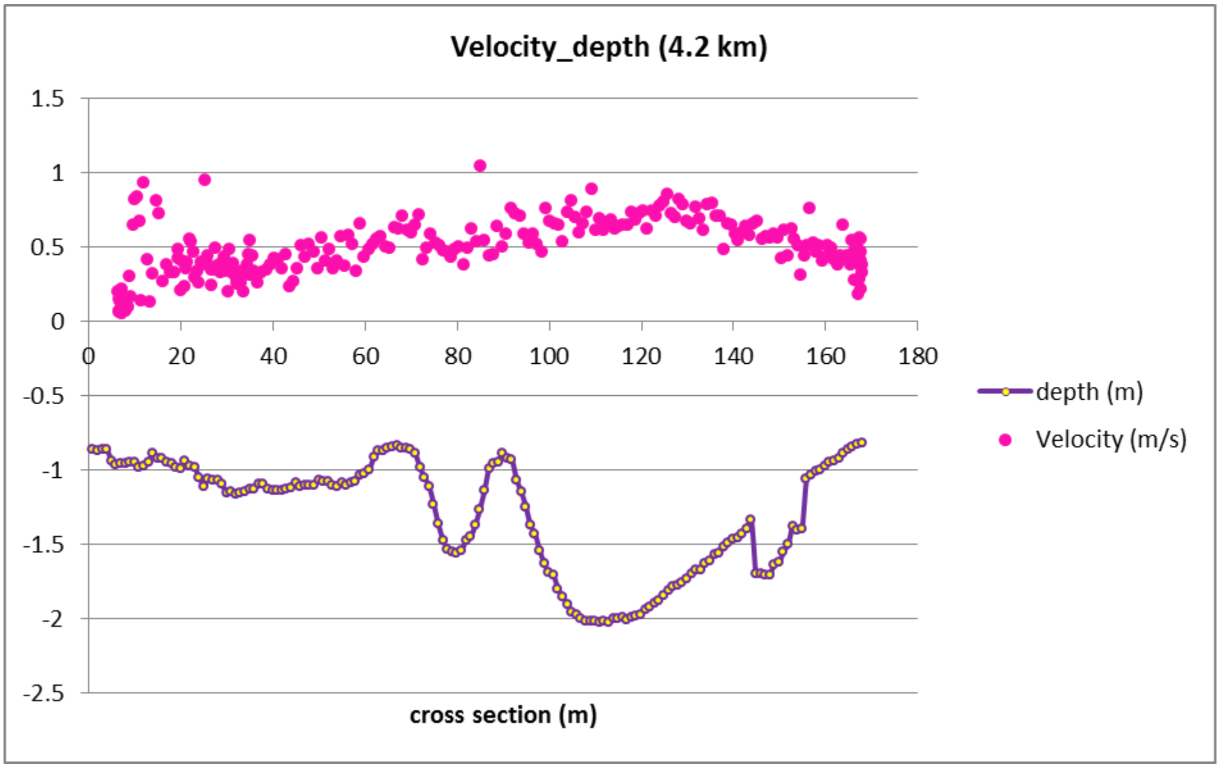
Velocity 1pt9km_2



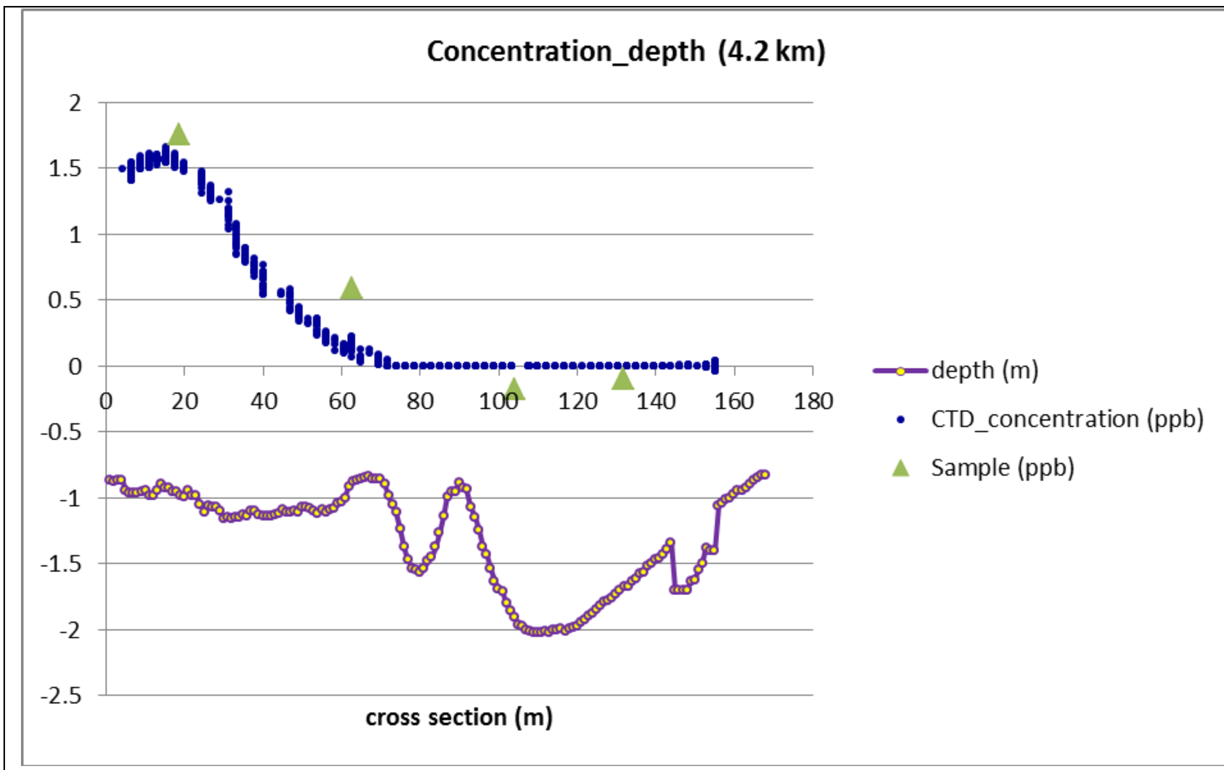
Concentration 1.9km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	5.02	5.04	5.03
0.1-0.2	2.64	3.21	2.92
0.2-0.3	0.01	0.02	0.01
0.3-0.4	0.00	0.00	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.01	0.04	0.03
0.7-0.8	0.00	0.00	0.00
0.8-0.9			
0.9-1			
Approximate width(m)	255.36		
Approximate distance from outfall(km)	1.9		
Time and date	14:40:18	Oct 25 2011	



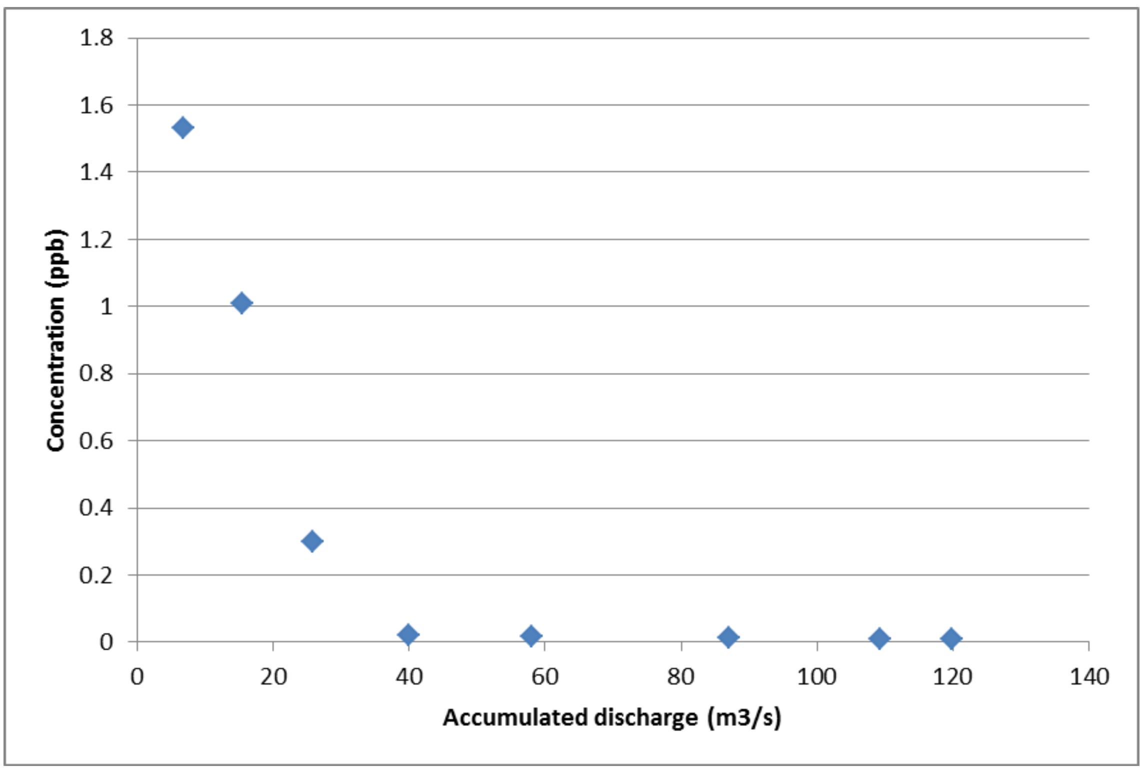


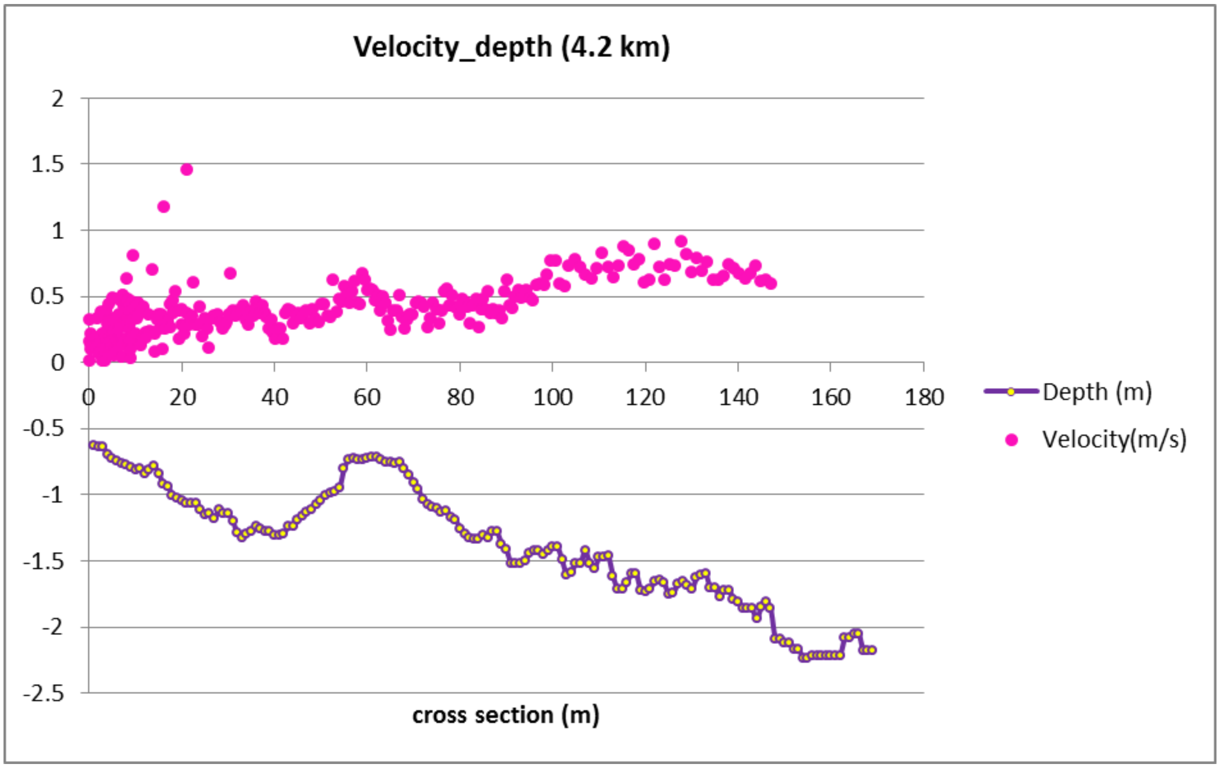
Velocity 4pt2km_1



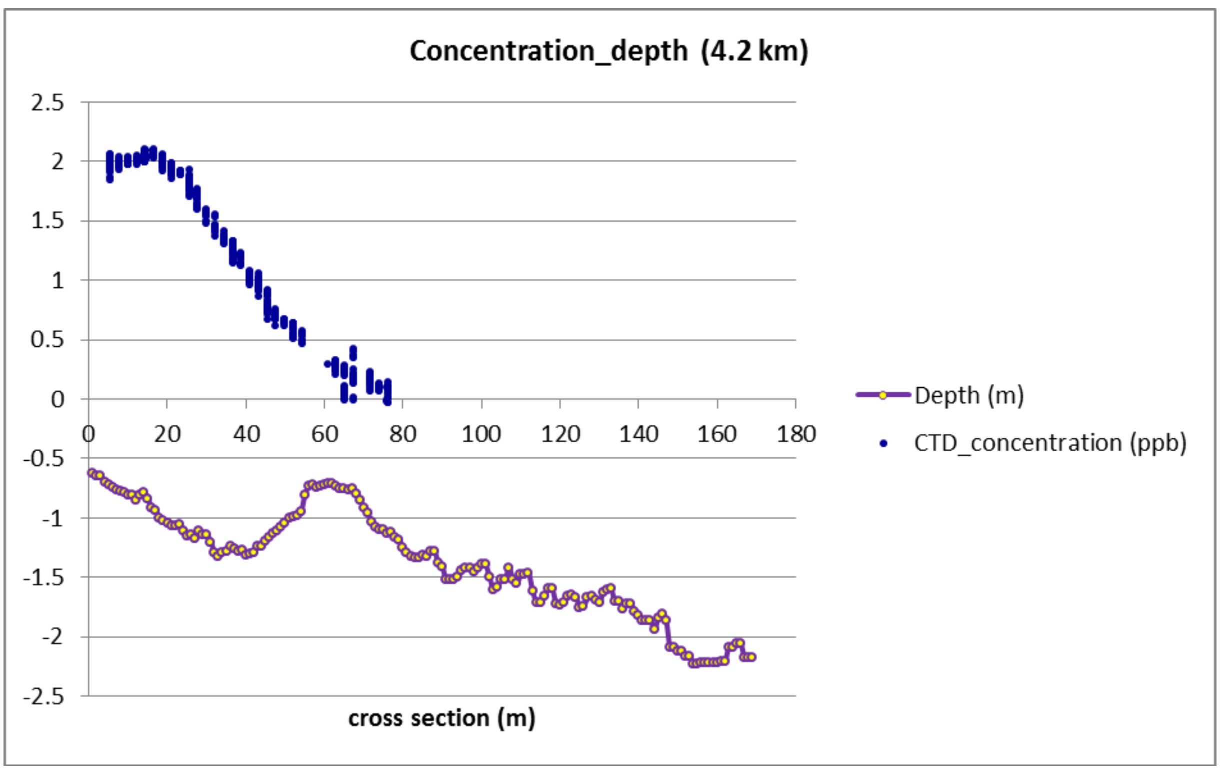
Concentration 4.2km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.52	1.53	1.53
0.1-0.2	0.96	1.07	1.01
0.2-0.3	0.27	0.33	0.30
0.3-0.4	0.01	0.02	0.02
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	-0.01	0.01	0.00
0.8-0.9			
0.9-1			
Approximate width(m)	212.90		
Approximate distance from outfall(km)	4.2		
Time and date	15:26:57	Oct 25 2011	



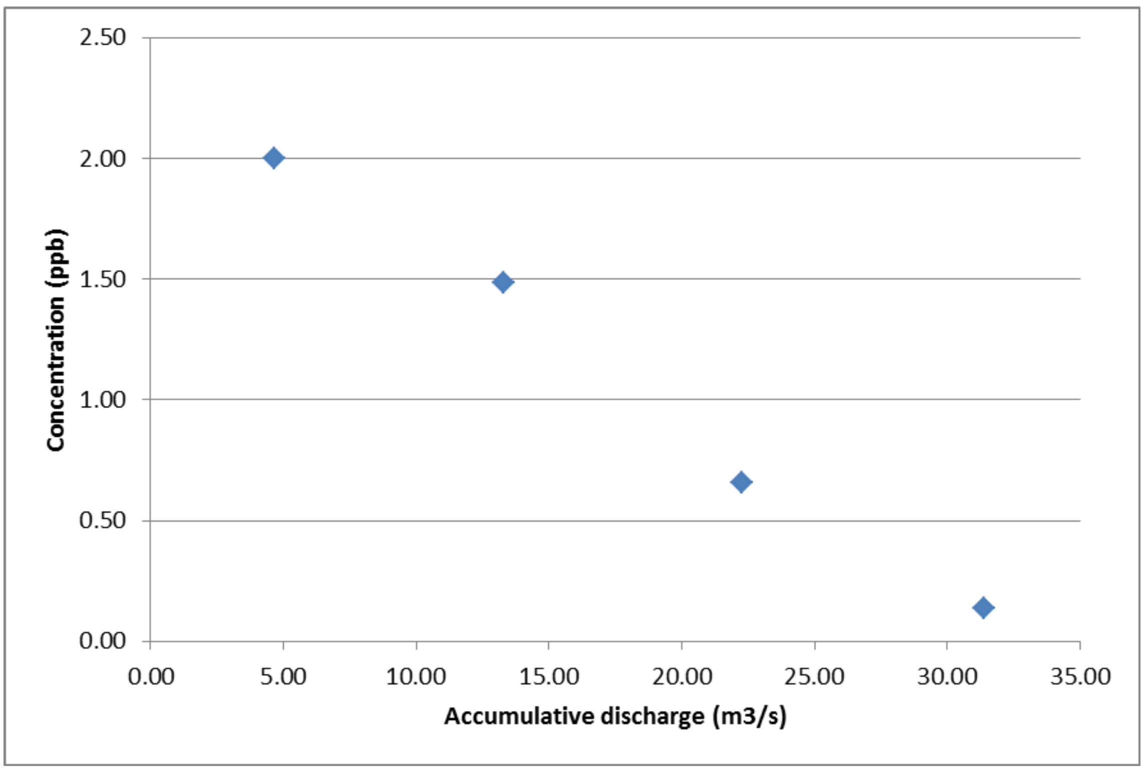


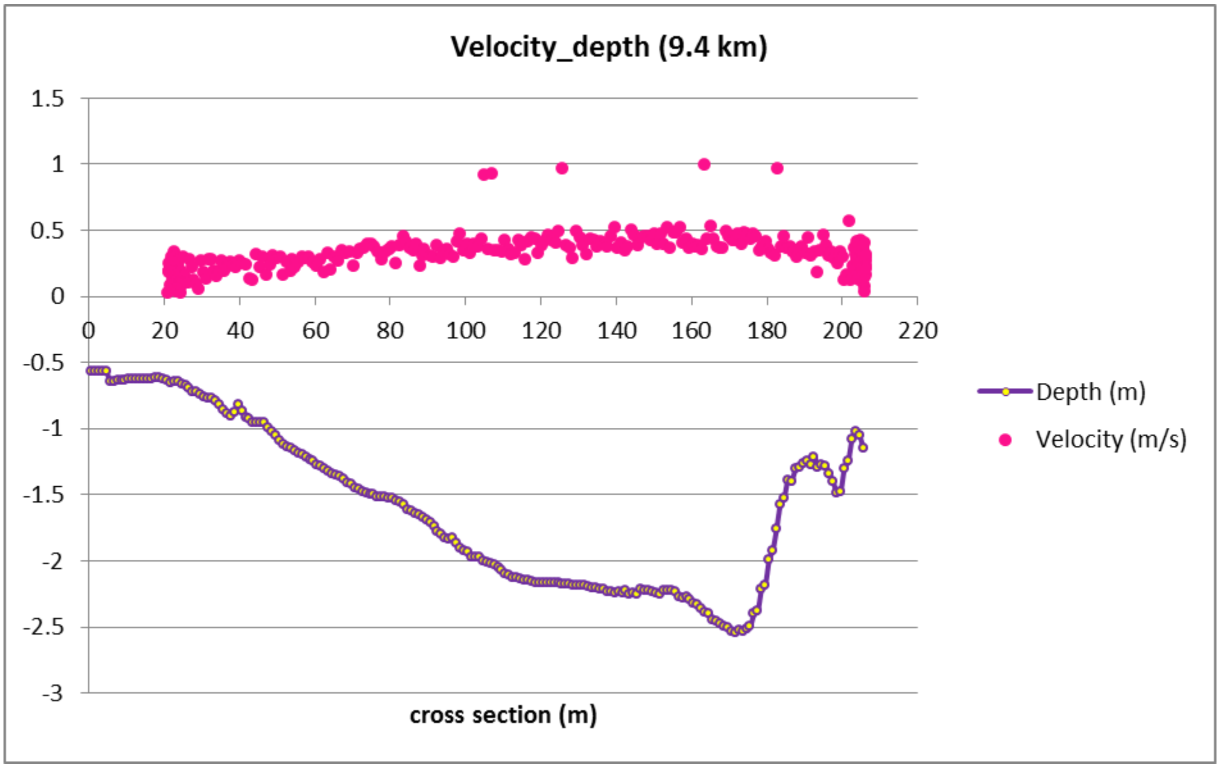
Velocity 4.2km_2



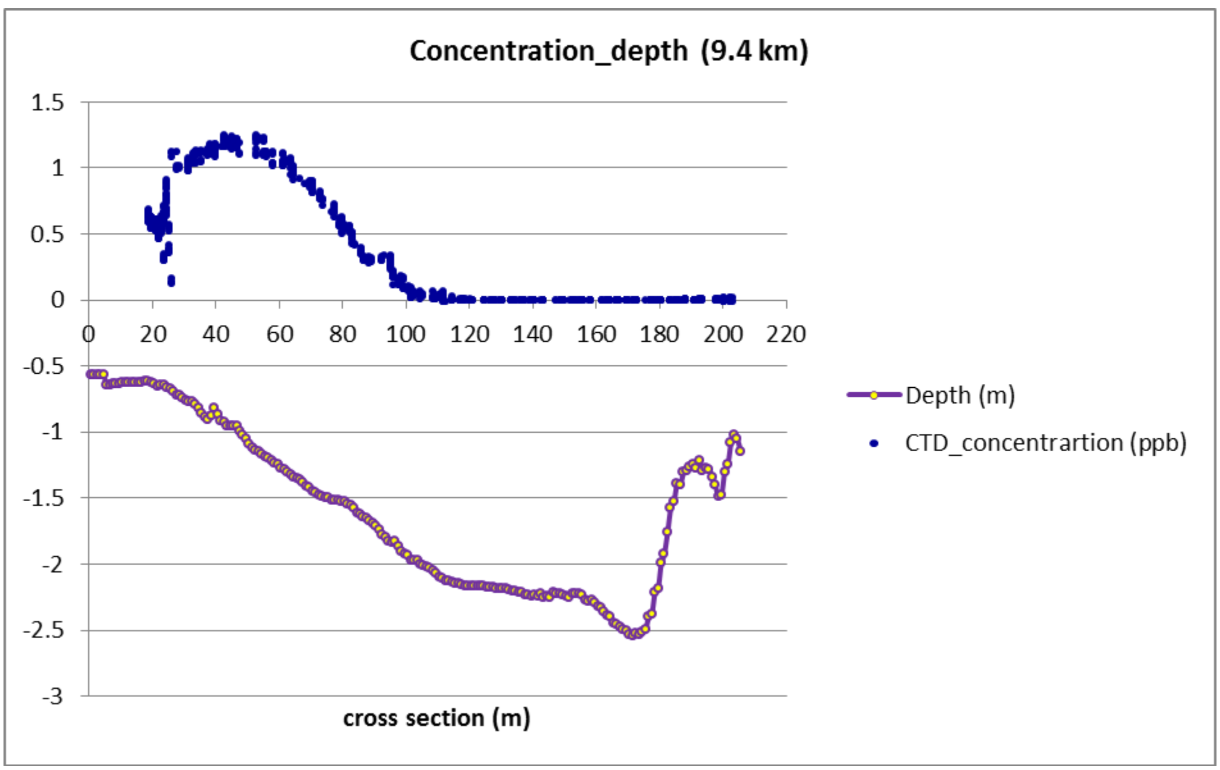
Concentration 4.2km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.99	2.01	2.00
0.1-0.2	1.44	1.53	1.48
0.2-0.3	0.61	0.70	0.65
0.3-0.4	0.12	0.16	0.14
0.4-0.5			
0.5-0.6			
0.6-0.7			
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	214.50		
Approximate distance from outfall(km)	4.2		
Time and date	15:32:28	Oct 25 2011	



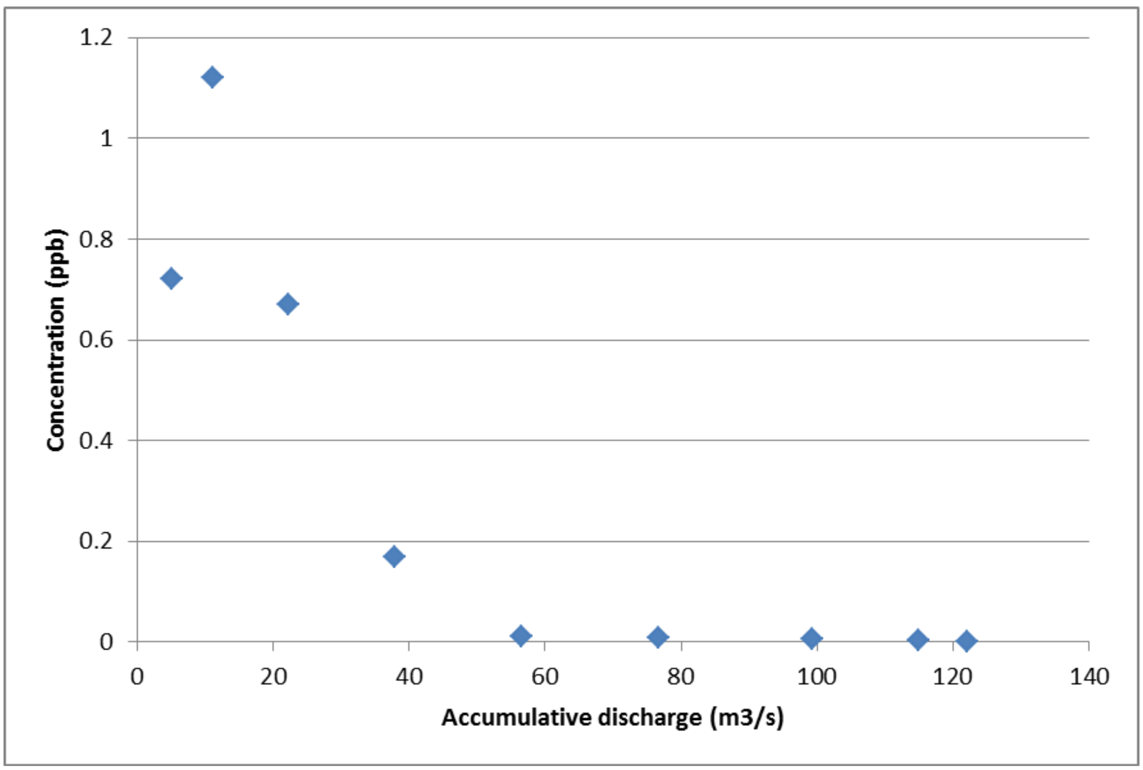


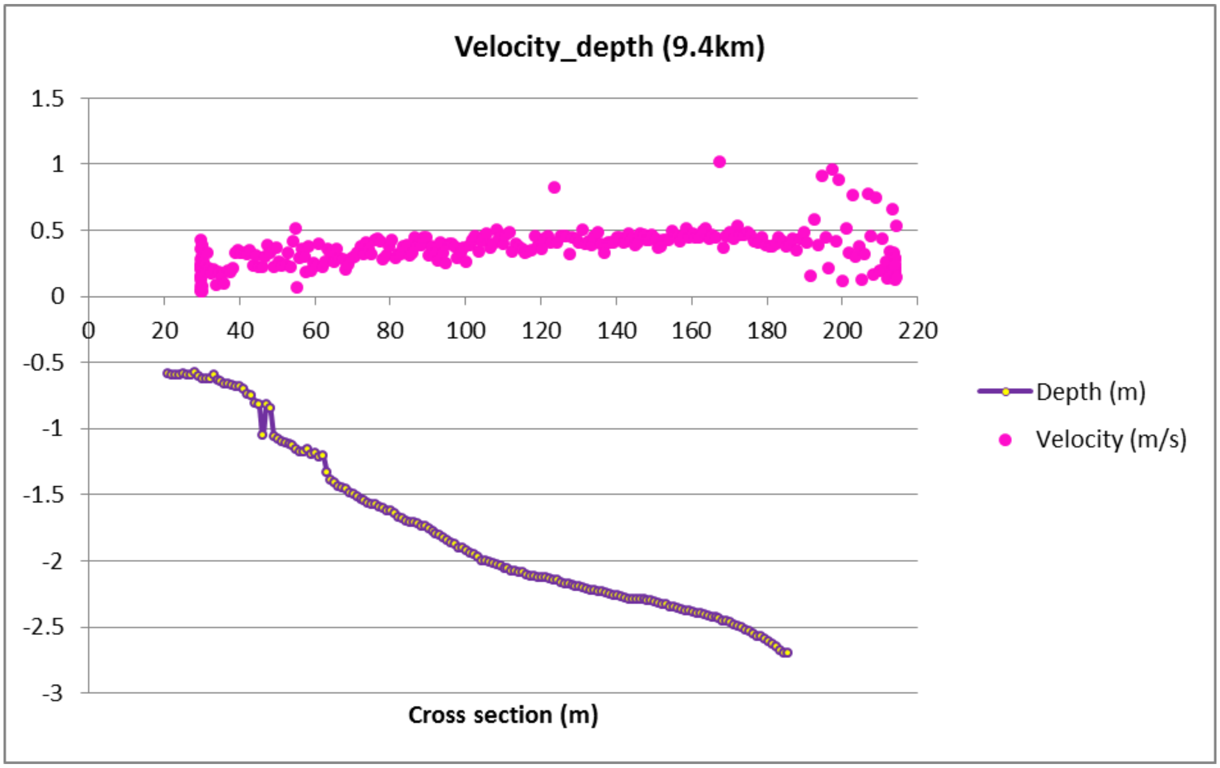
Velocity 9.4km_1



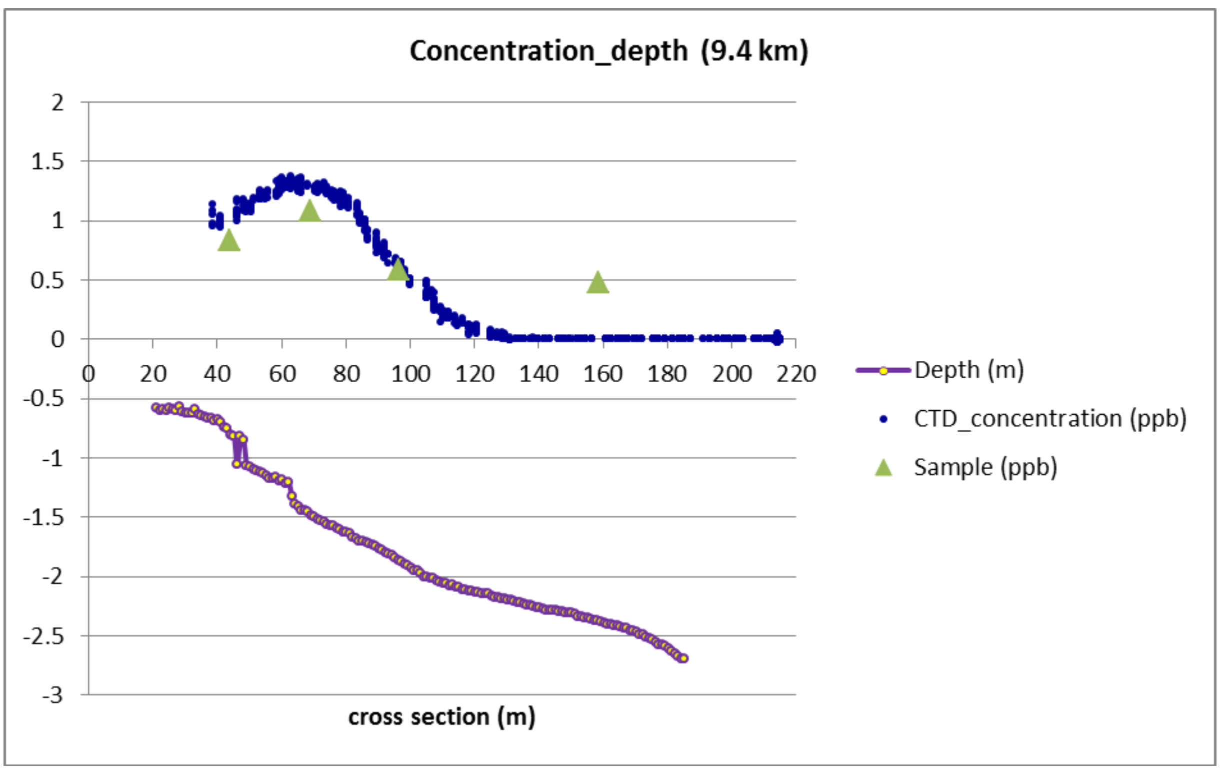
Concentration 9.4km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.69	0.75	0.72
0.2-0.3	1.11	1.14	1.12
0.3-0.4	0.63	0.71	0.67
0.4-0.5	0.15	0.20	0.17
0.5-0.6	0.00	0.01	0.01
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	214.93		
Approximate distance from outfall(km)	9.4		
Time and date	15:50:39	Oct 25 2011	



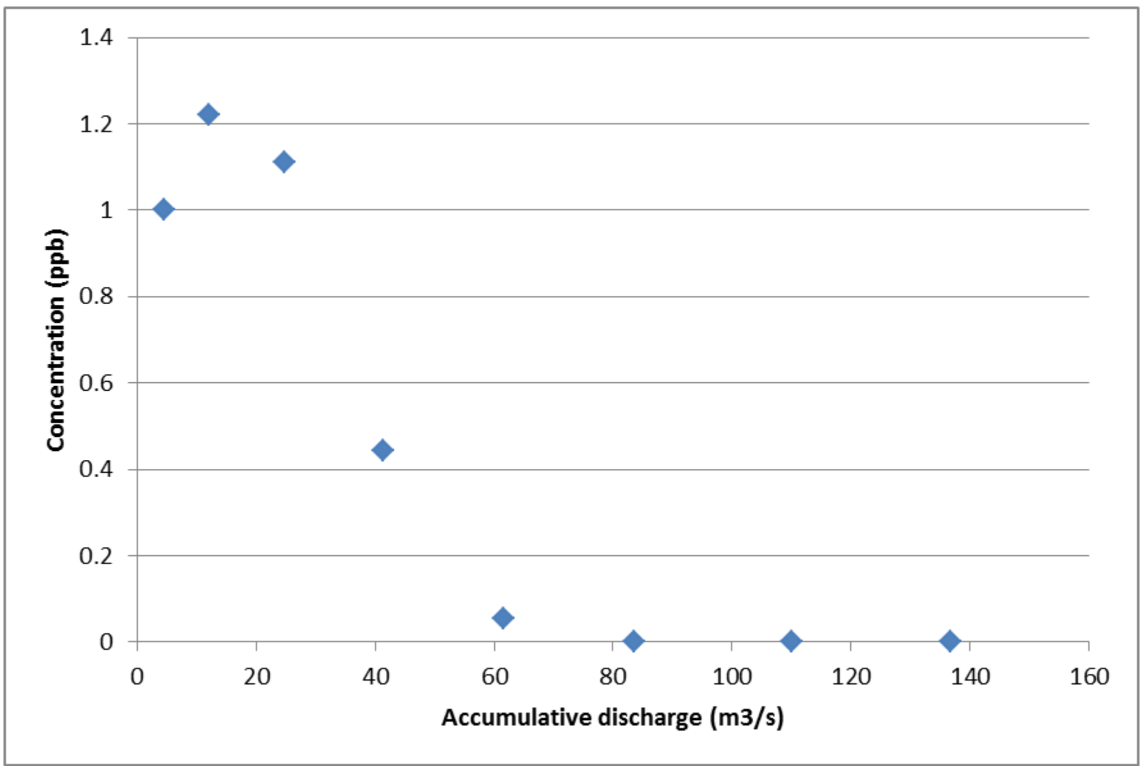


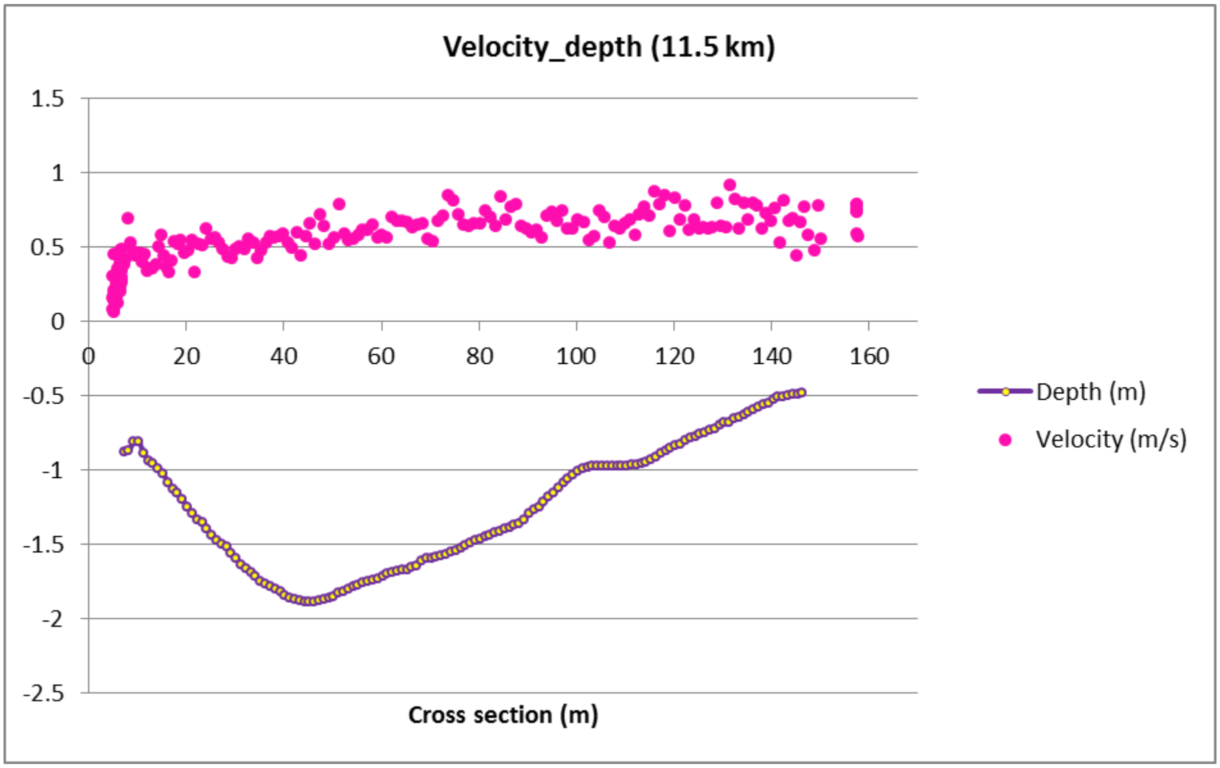
Velocity 9pt4km_2



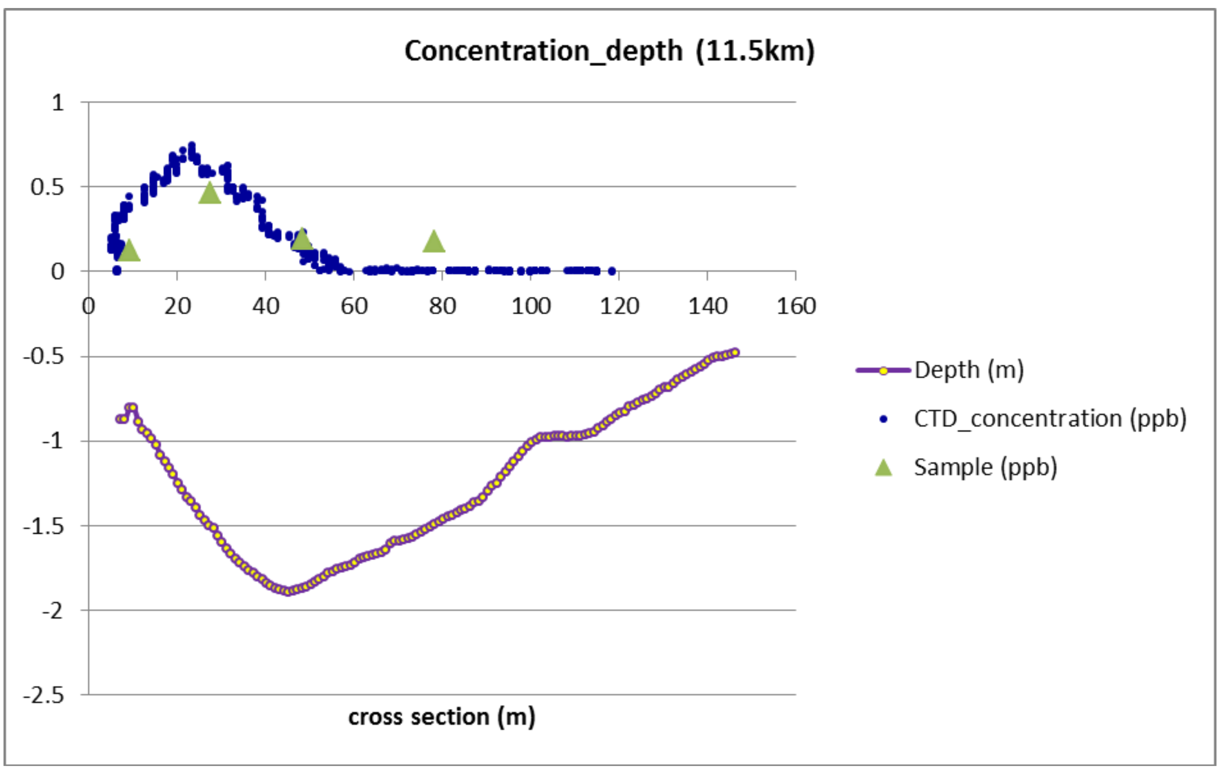
Concentration 9pt4km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.98	1.02	1.00
0.2-0.3	1.20	1.24	1.22
0.3-0.4	1.08	1.14	1.11
0.4-0.5	0.41	0.48	0.44
0.5-0.6	0.04	0.06	0.05
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	225.32		
Approximate distance from outfall(km)	9.4		
Time and date	15:56:43	Oct 25 2011	



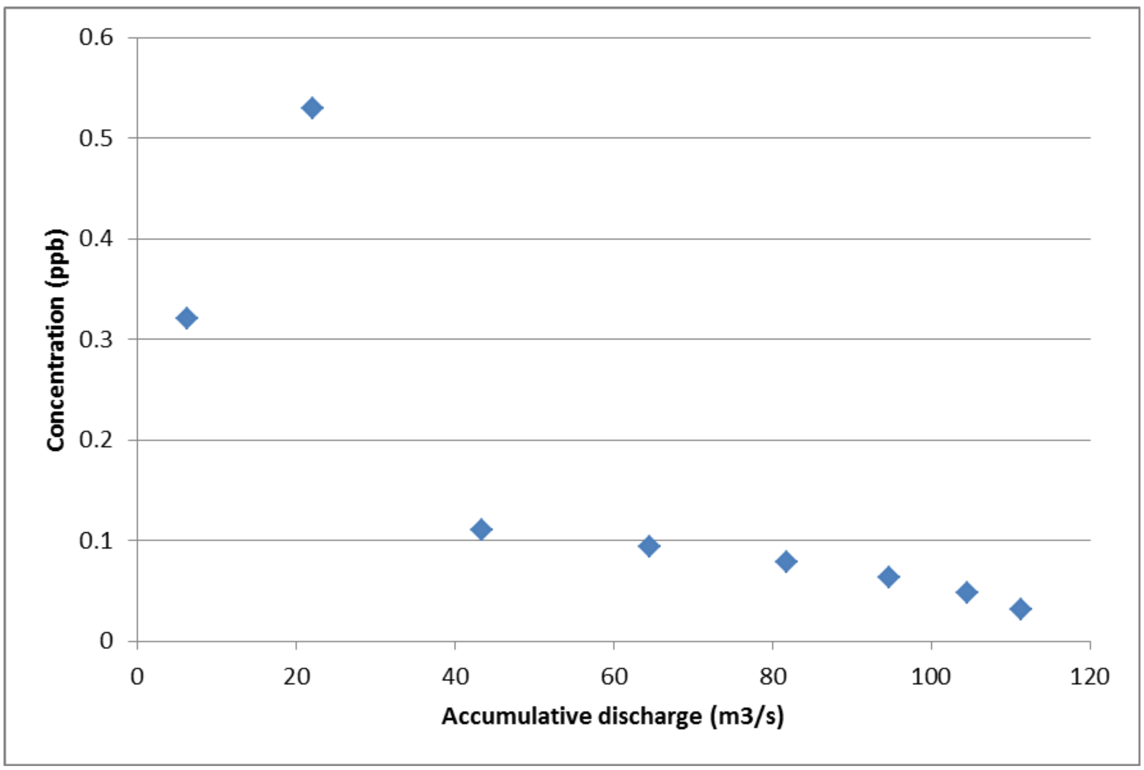


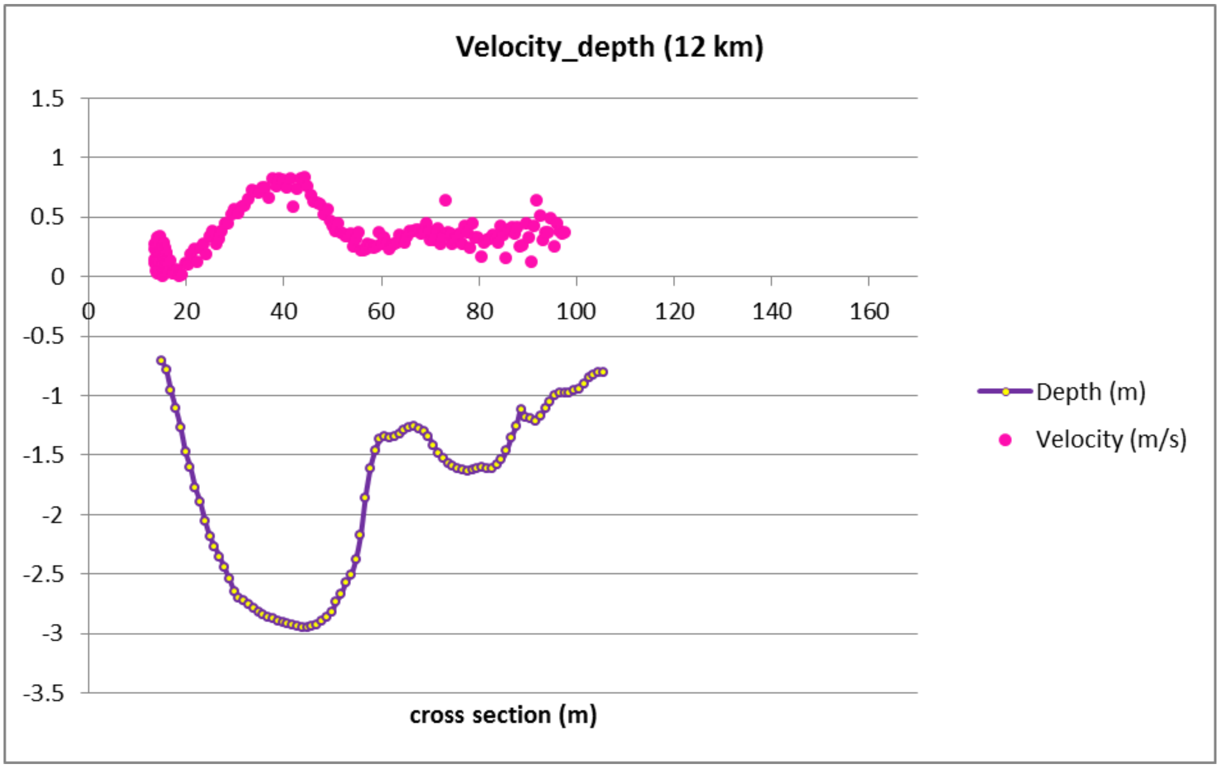
Velocity 11.5km



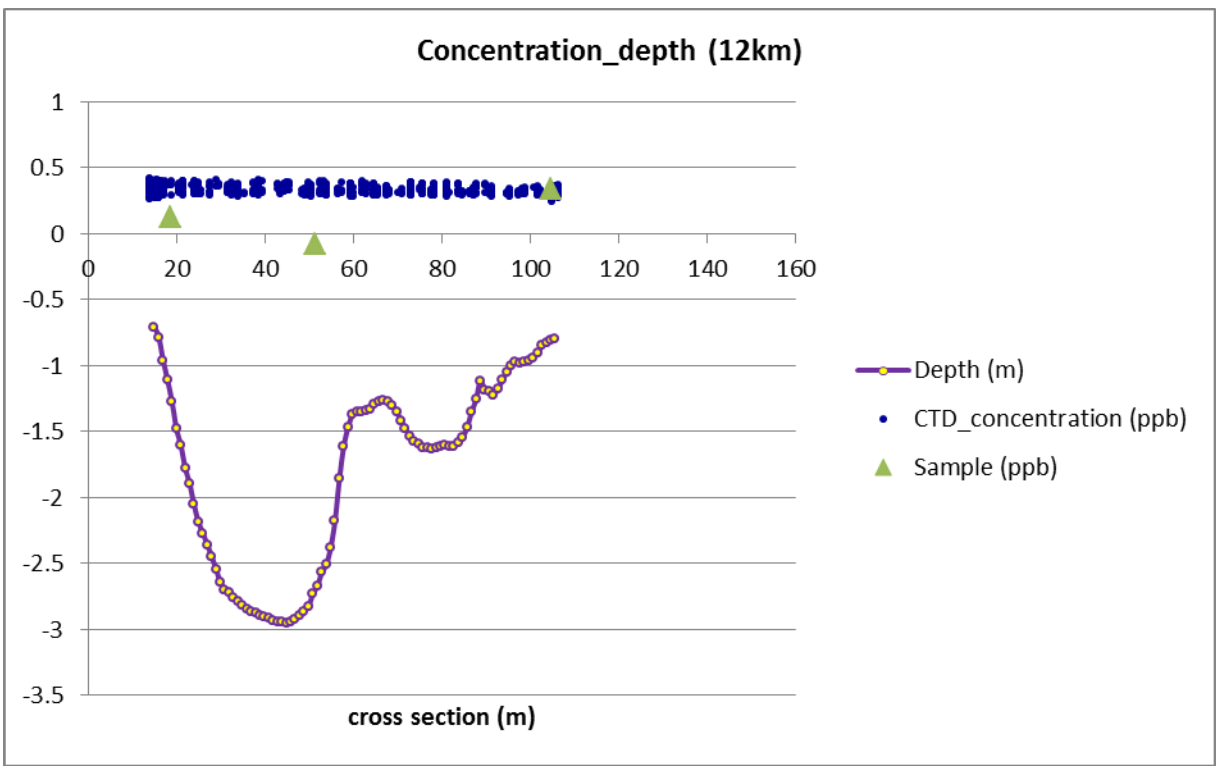
Concentration 11.5km

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.30	0.35	0.32
0.1-0.2	0.51	0.56	0.53
0.2-0.3	0.09	0.12	0.11
0.3-0.4	0.00	0.00	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7			
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	199.32		
Approximate distance from outfall(km)	11.5		
Time and date	16:09:53	Oct 25 2011	



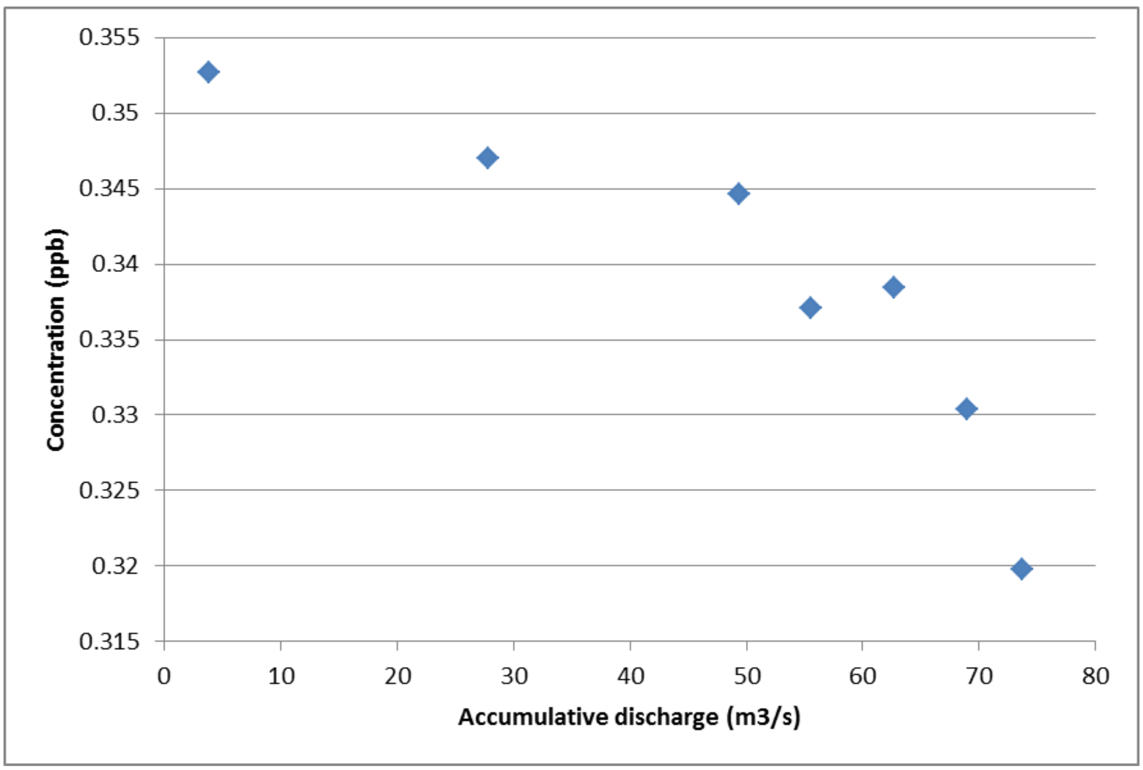


Velocity 12km

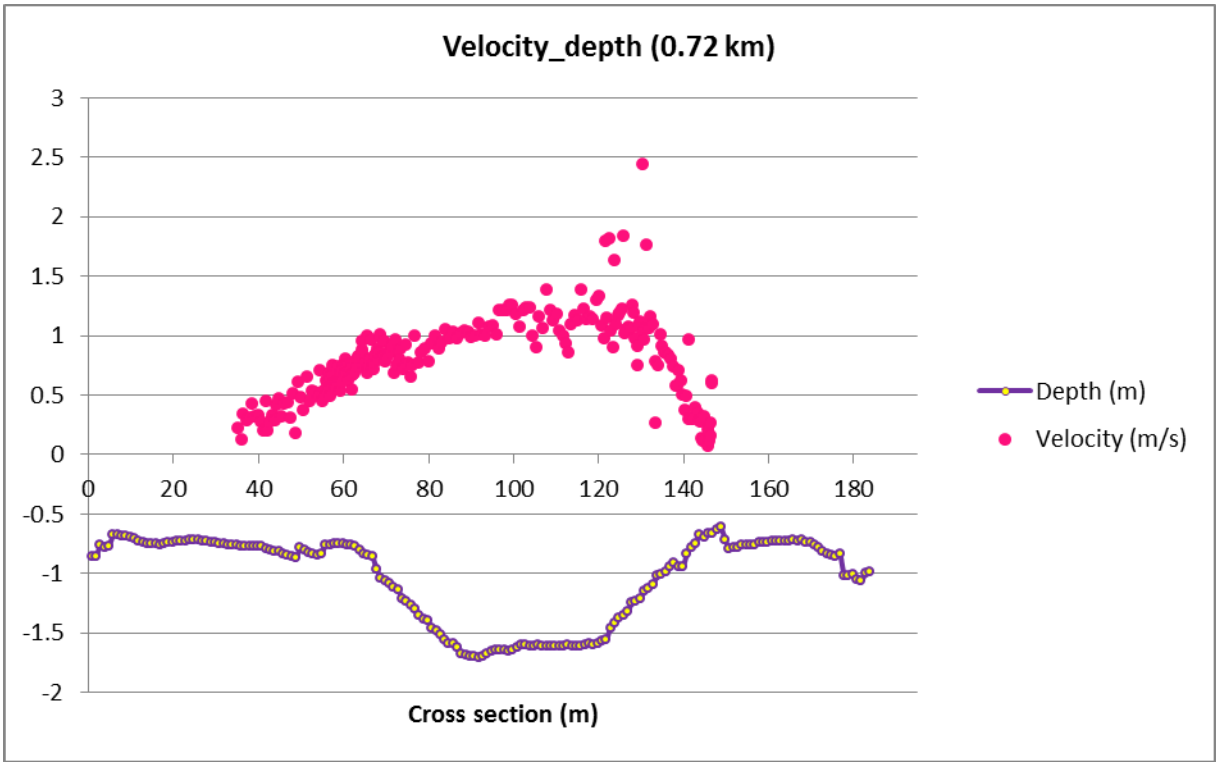


Concentration 12km

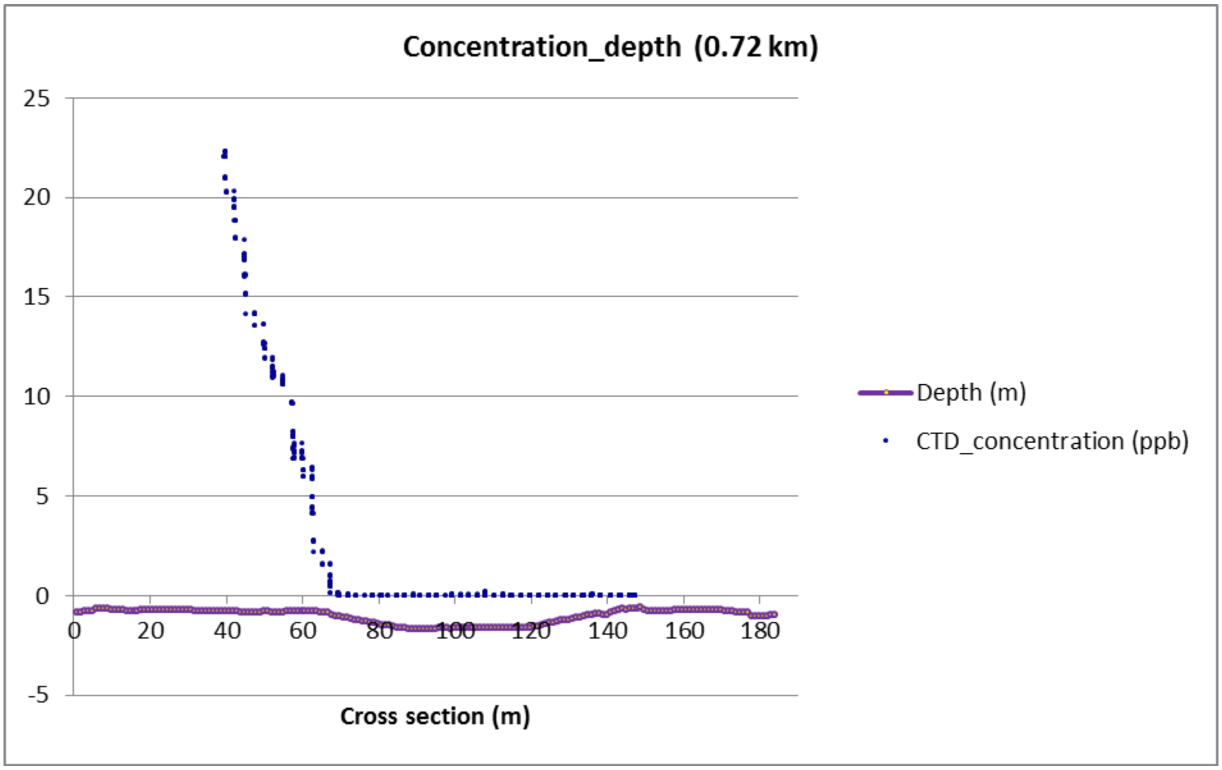
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.35	0.35	0.35
0.2-0.3	0.34	0.33	0.35
0.3-0.4	0.34	0.33	0.34
0.4-0.5	0.33	0.33	0.34
0.5-0.6	0.33	0.33	0.34
0.6-0.7	0.33	0.32	0.33
0.7-0.8	0.32	0.31	0.32
0.8-0.9			
0.9-1			
Approximate width(m)	135.46		
Approximate distance from outfall(km)	12		
Time and date	16:09:53	Oct 25 2011	



Appendix : Capital Region

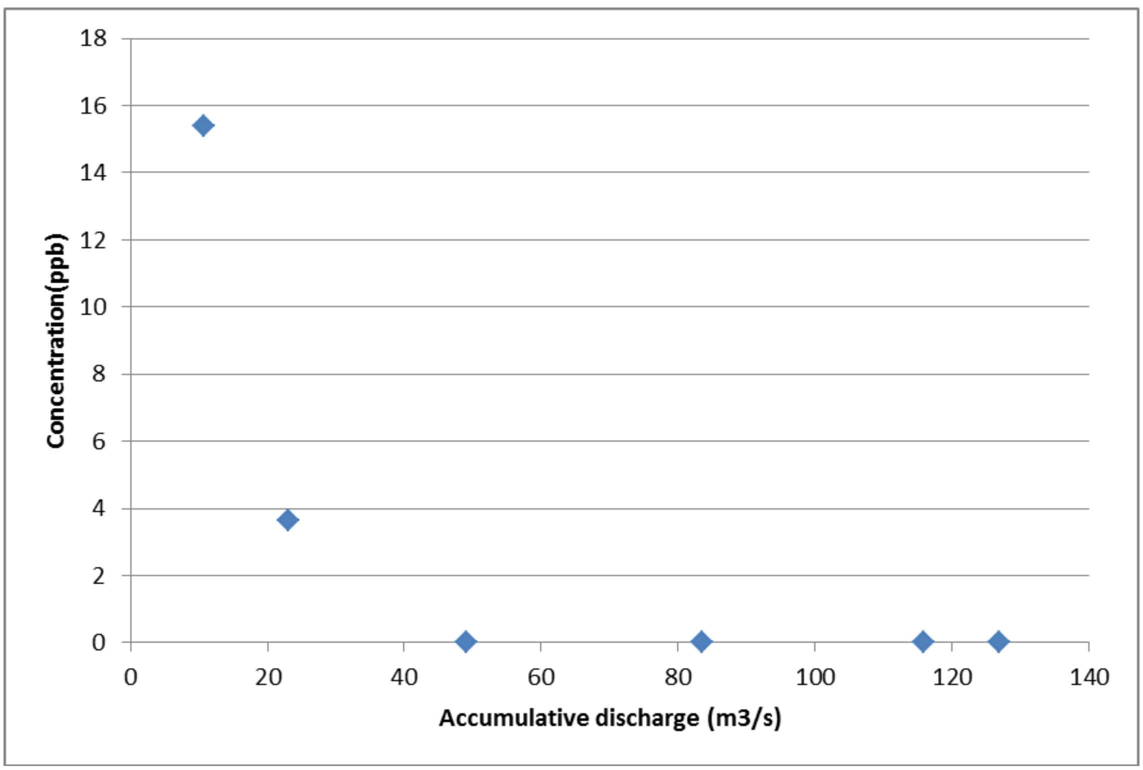


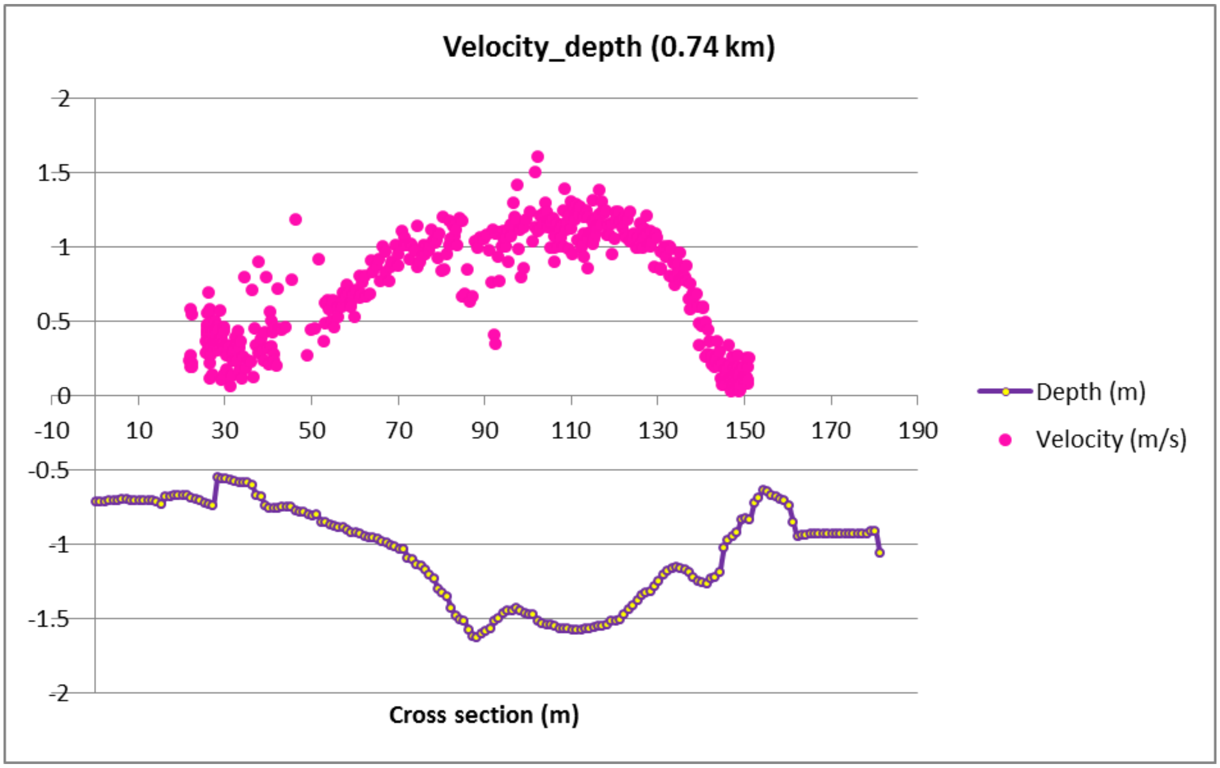
Velocity 0.72km_1



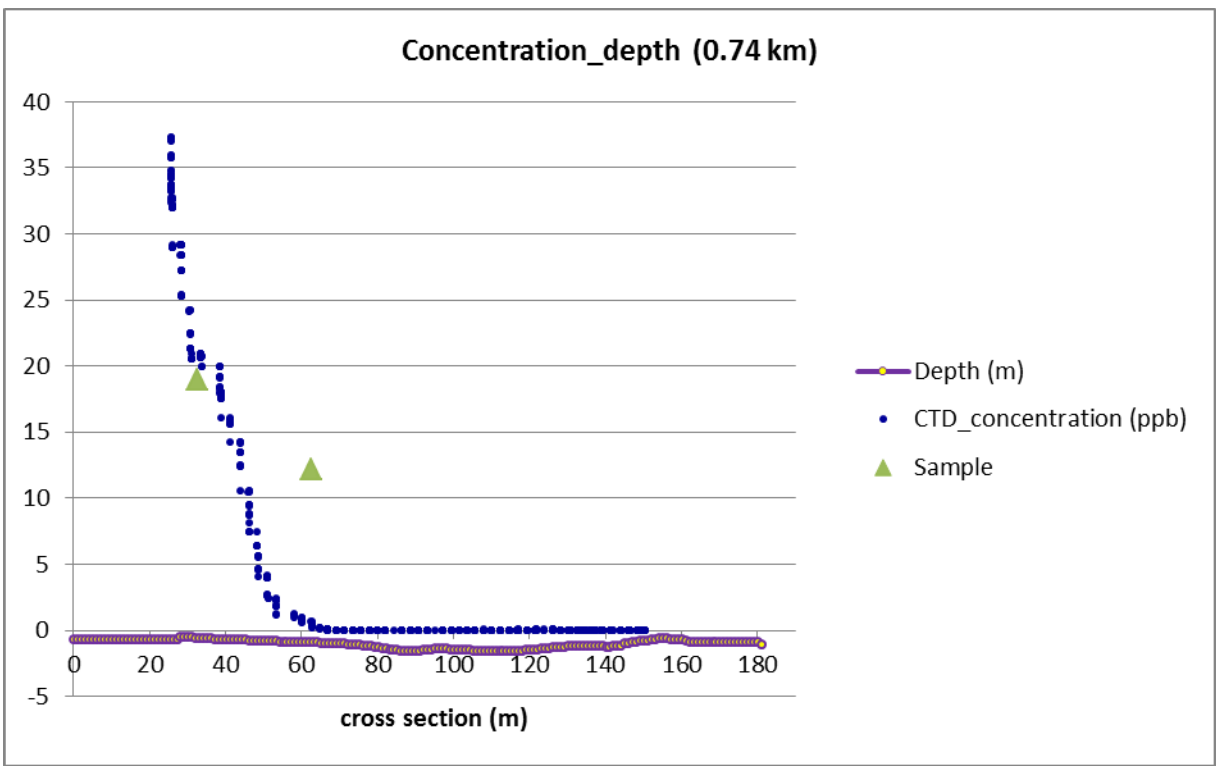
Concentration 0.72km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	14.68	16.13	15.40
0.3-0.4	3.10	4.16	3.63
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.01	0.02	0.02
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9			
0.9-1			
Approximate width(m)	185.28		
Approximate distance from outfall(km)	0.72		
Time and date	13:45:57	Oct 26th, 2011	



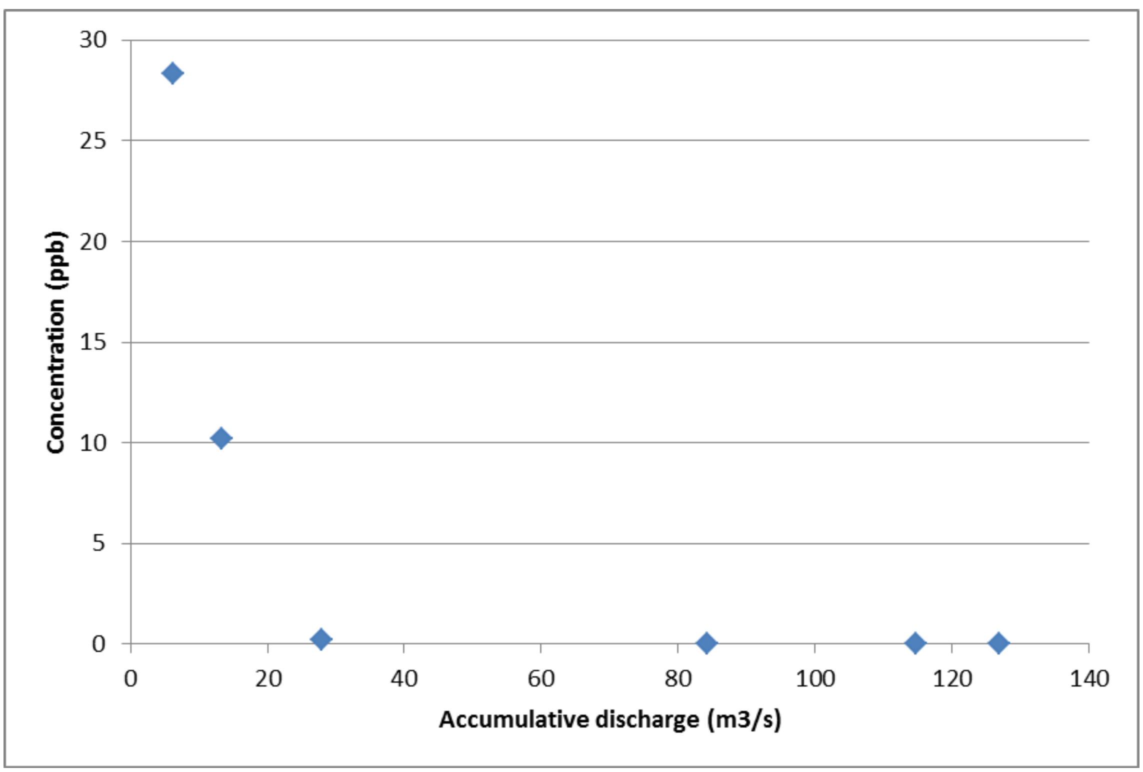


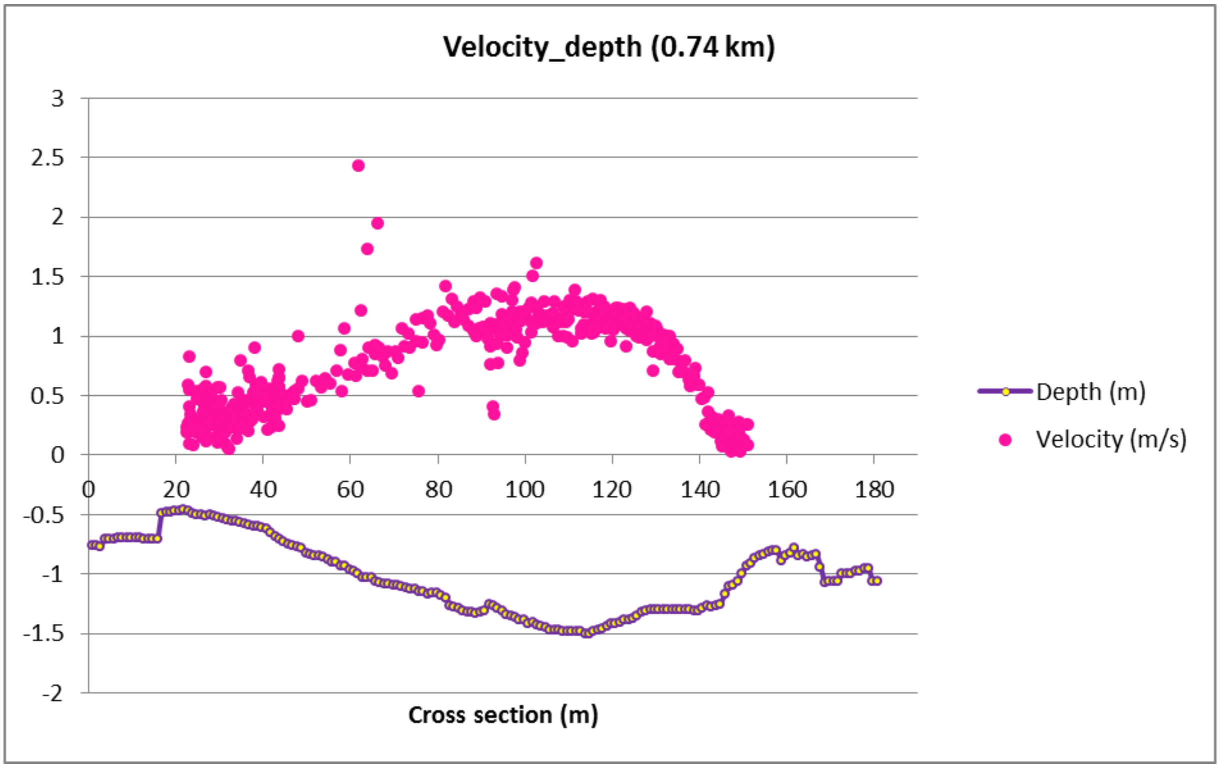
Velocity 0.74km_2



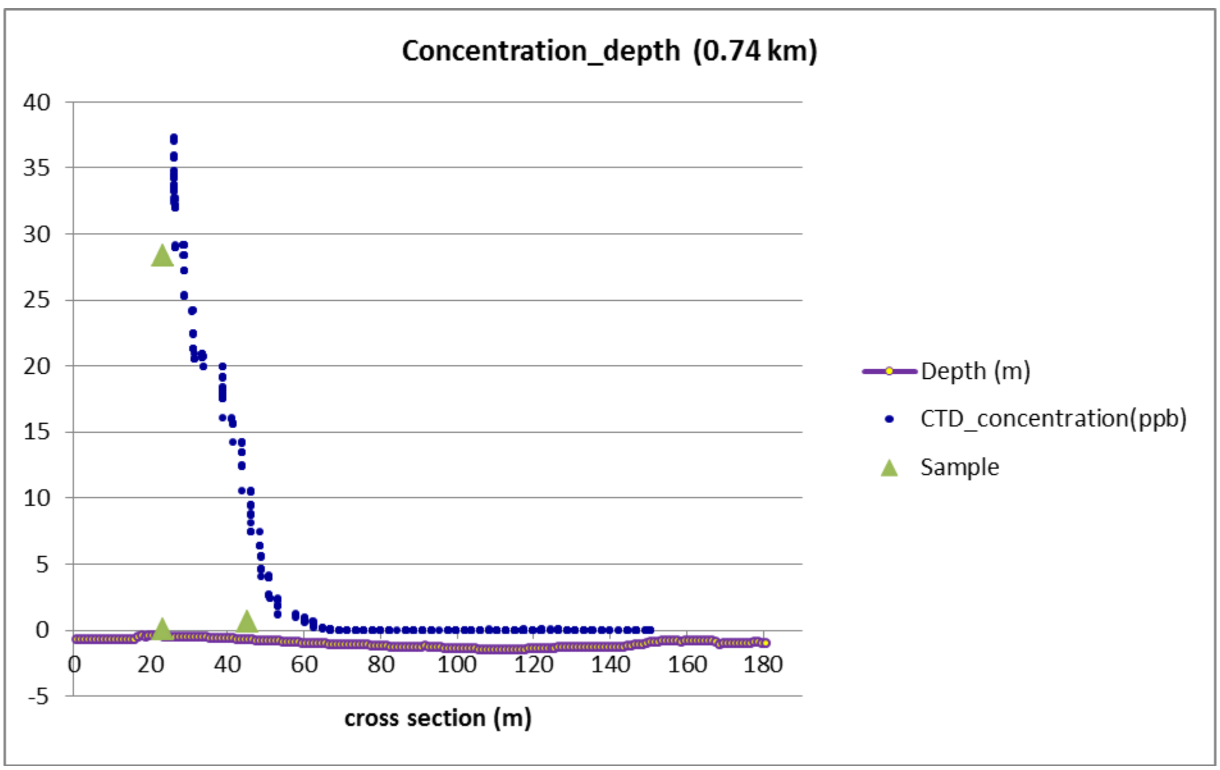
Concentration 0.74km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	27.20	29.42	28.31
0.2-0.3	9.00	11.39	10.20
0.3-0.4	0.16	0.29	0.23
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	185.15		
Approximate distance from outfall(km)	0.74		
Time and date	13:45:57	Oct 26th, 2011	



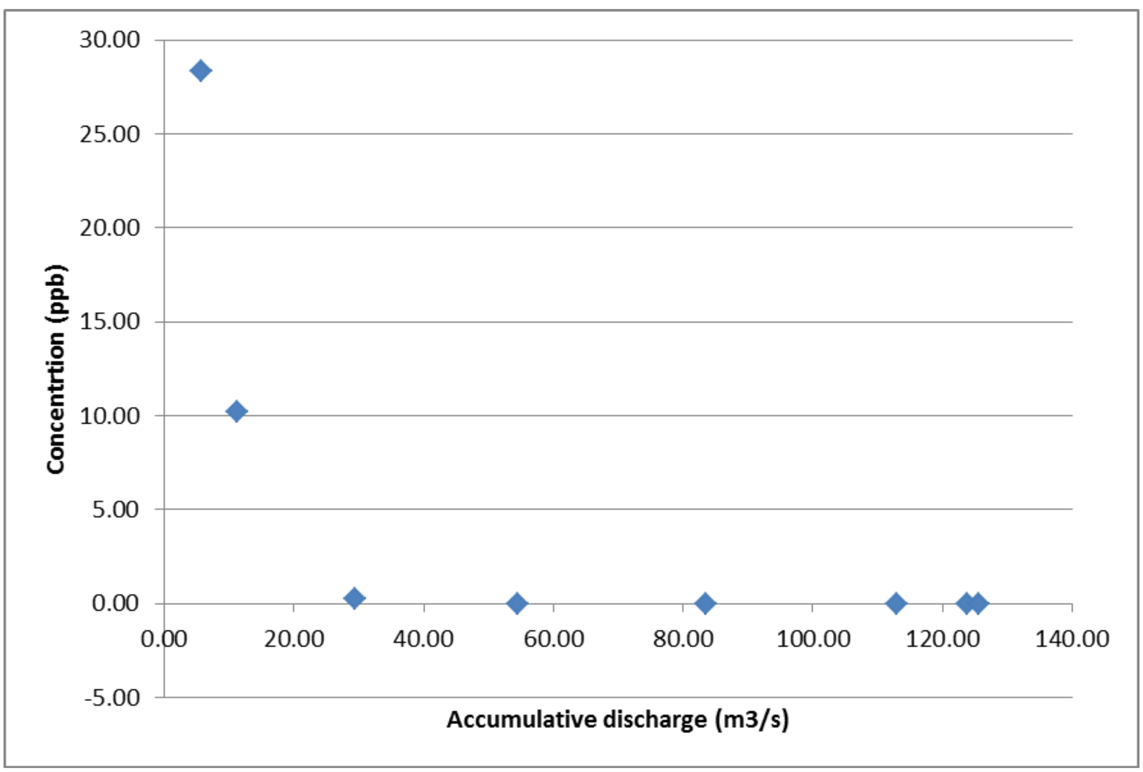


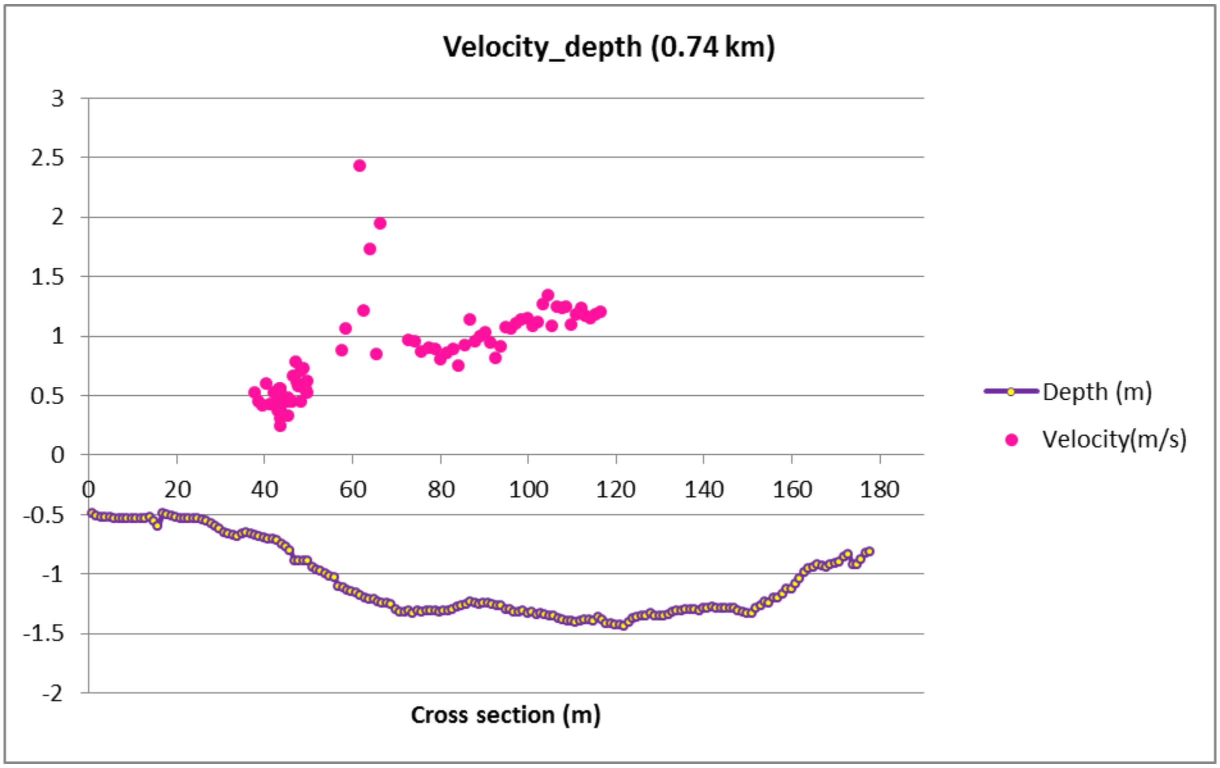
Velocity 0.74km_3



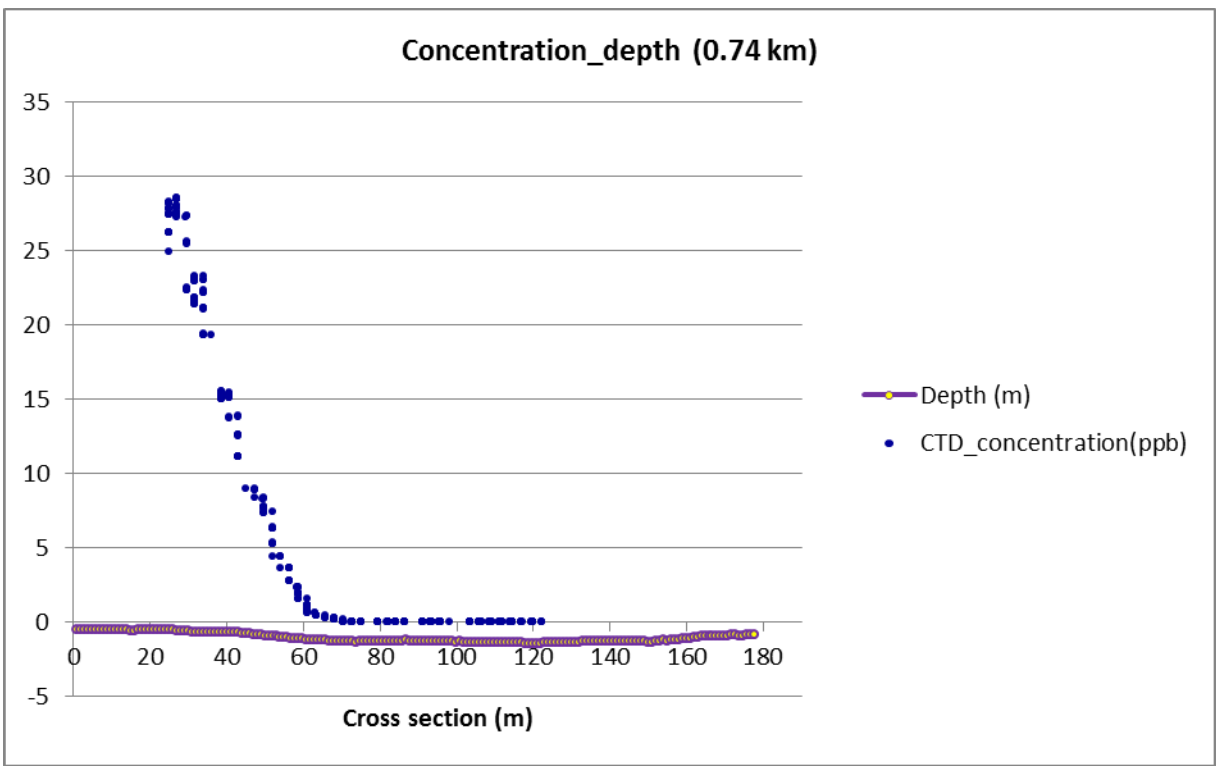
Concentration 0.74km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	27.20	29.42	28.31
0.2-0.3	9.00	11.39	10.20
0.3-0.4	0.16	0.29	0.23
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	185.57		
Approximate distance from outfall(km)	0.74		
Time and date	13:45:57	Oct 26th, 2011	



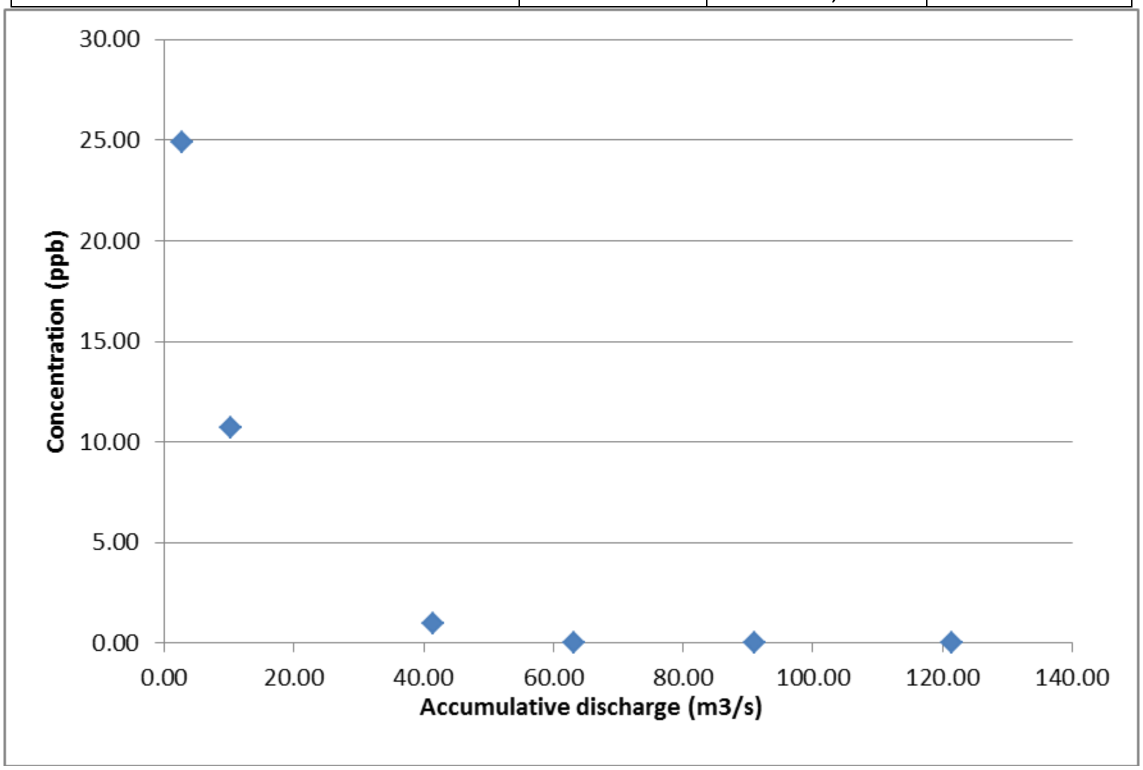


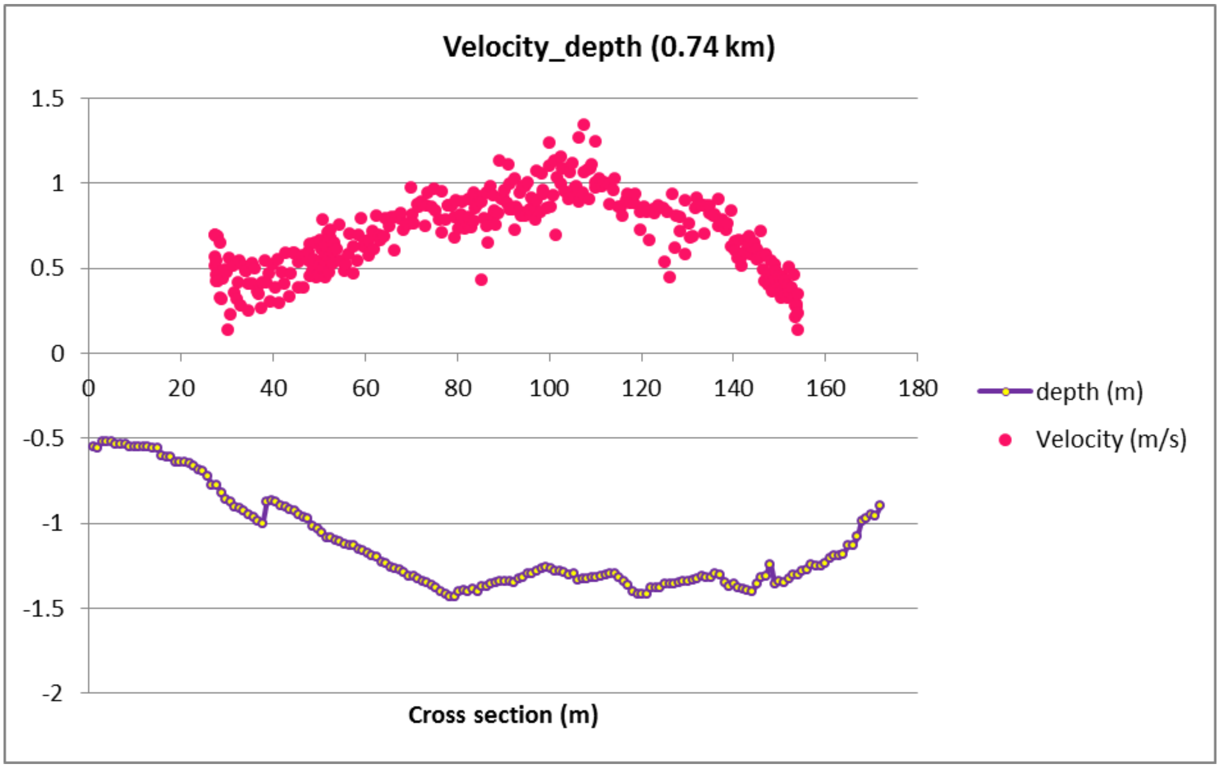
Velocity 0.74_4



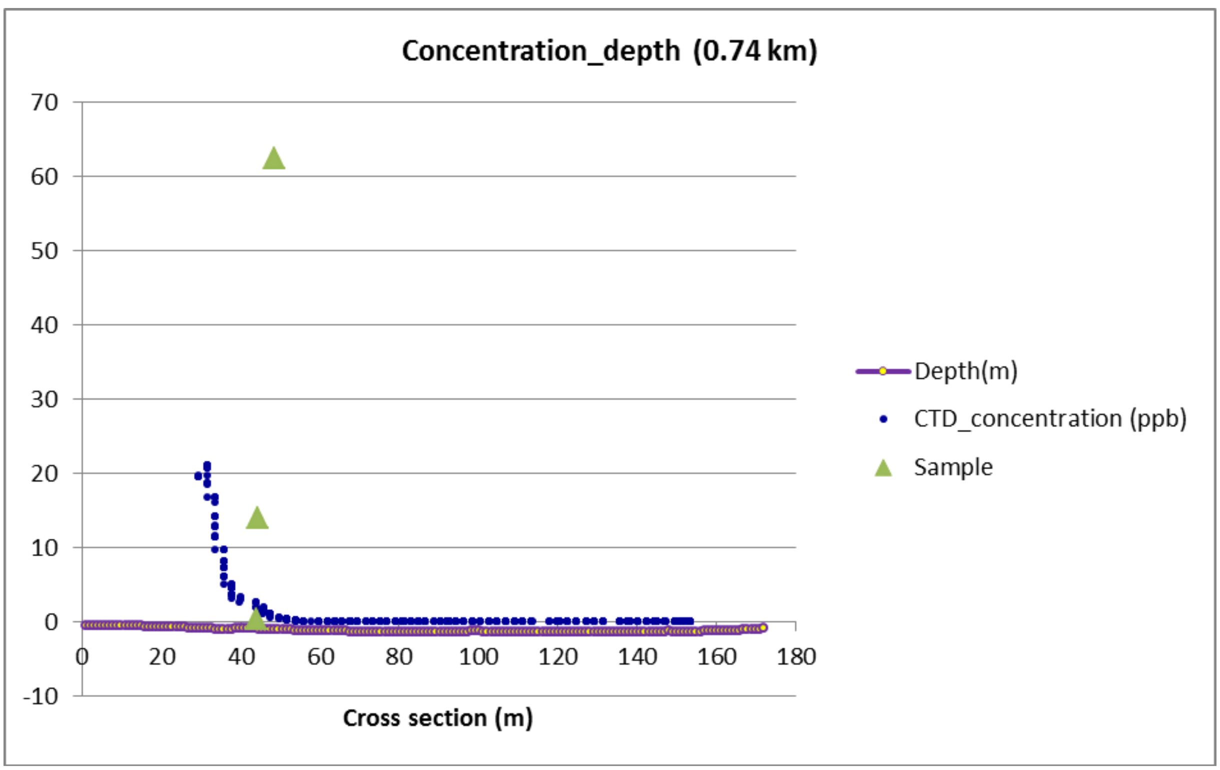
Concentration 0.74_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	24.21	25.53	24.87
0.2-0.3	9.73	11.71	10.72
0.3-0.4	0.73	1.25	0.99
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	185.14		
Approximate distance from outfall(km)	0.74		
Time and date	0.57	Oct 26th, 2011	



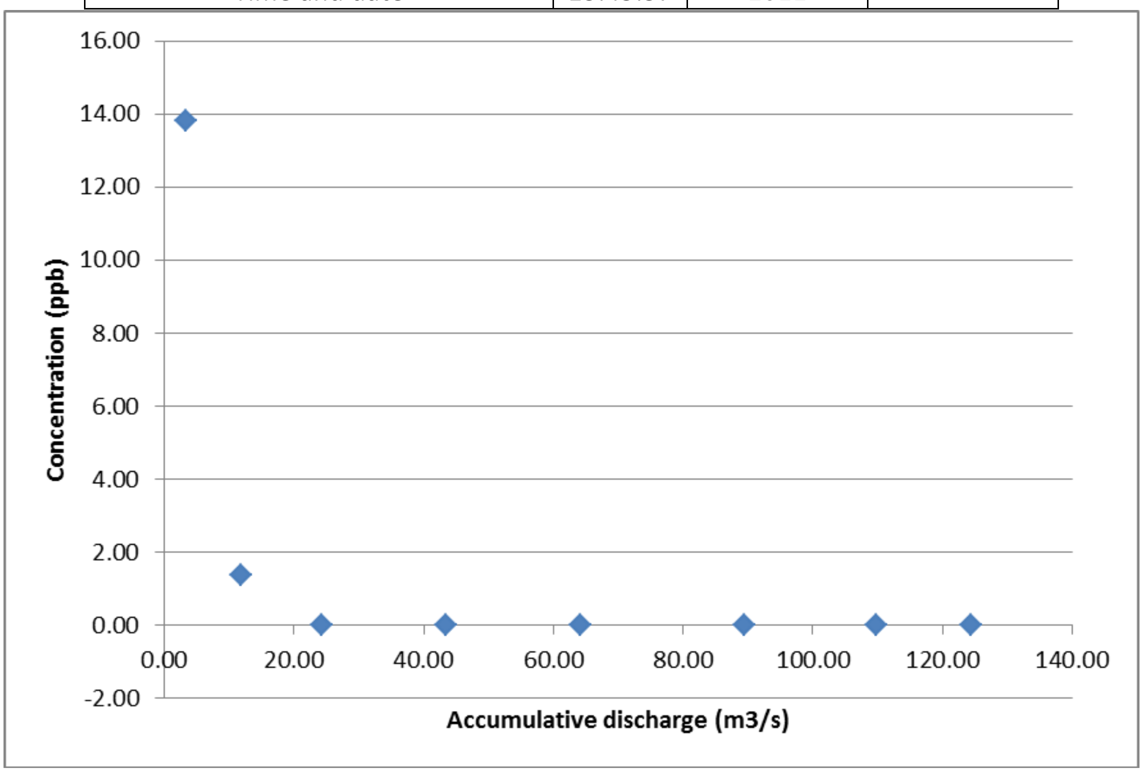


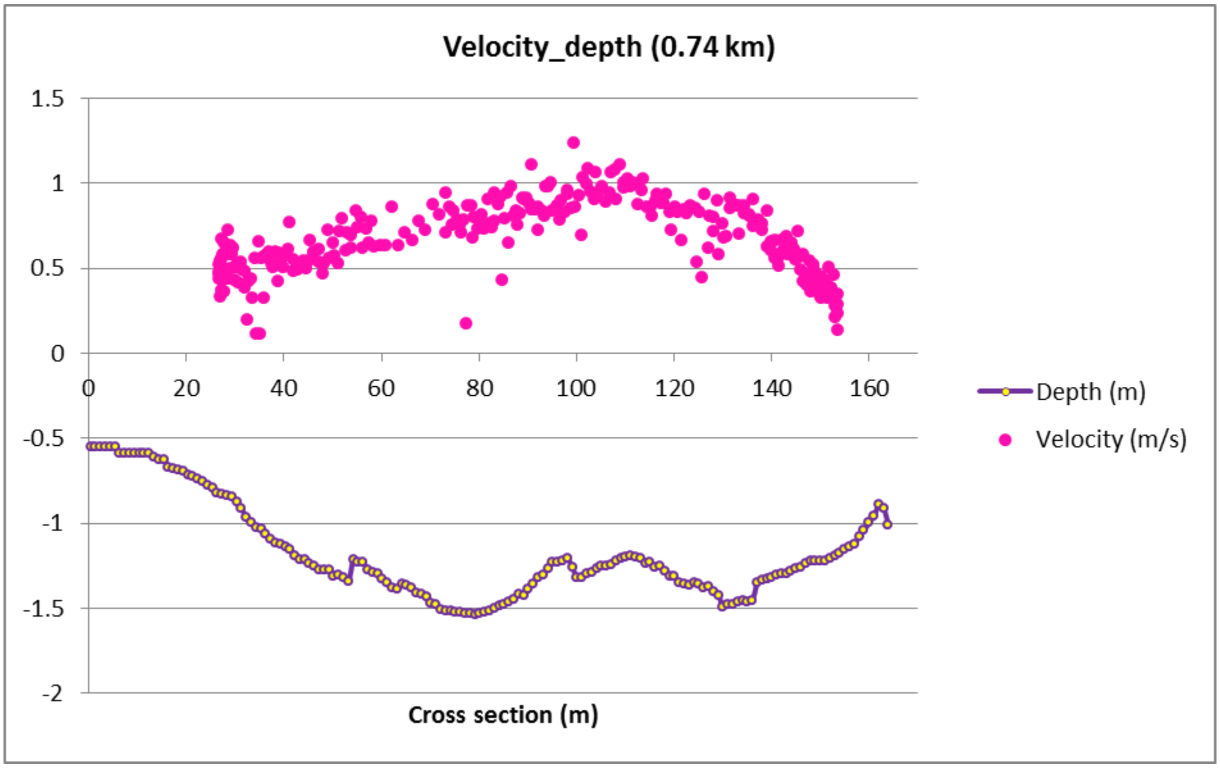
Velocity 0.74_5



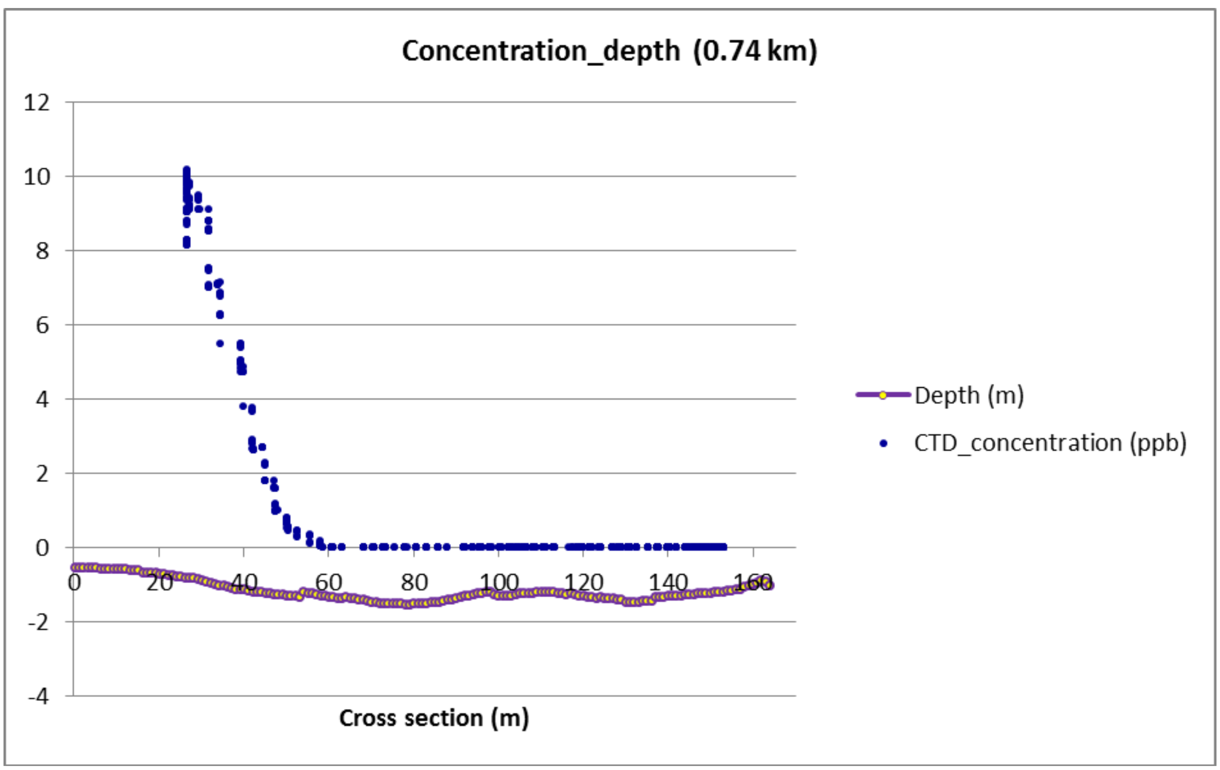
Concentration 0.74_5

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	12.35	15.27	13.81
0.2-0.3	1.06	1.71	1.39
0.3-0.4	0.00	0.00	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	187.97		
Approximate distance from outfall(km)	0.74		
Time and date	13:45:57	Oct 26th, 2011	



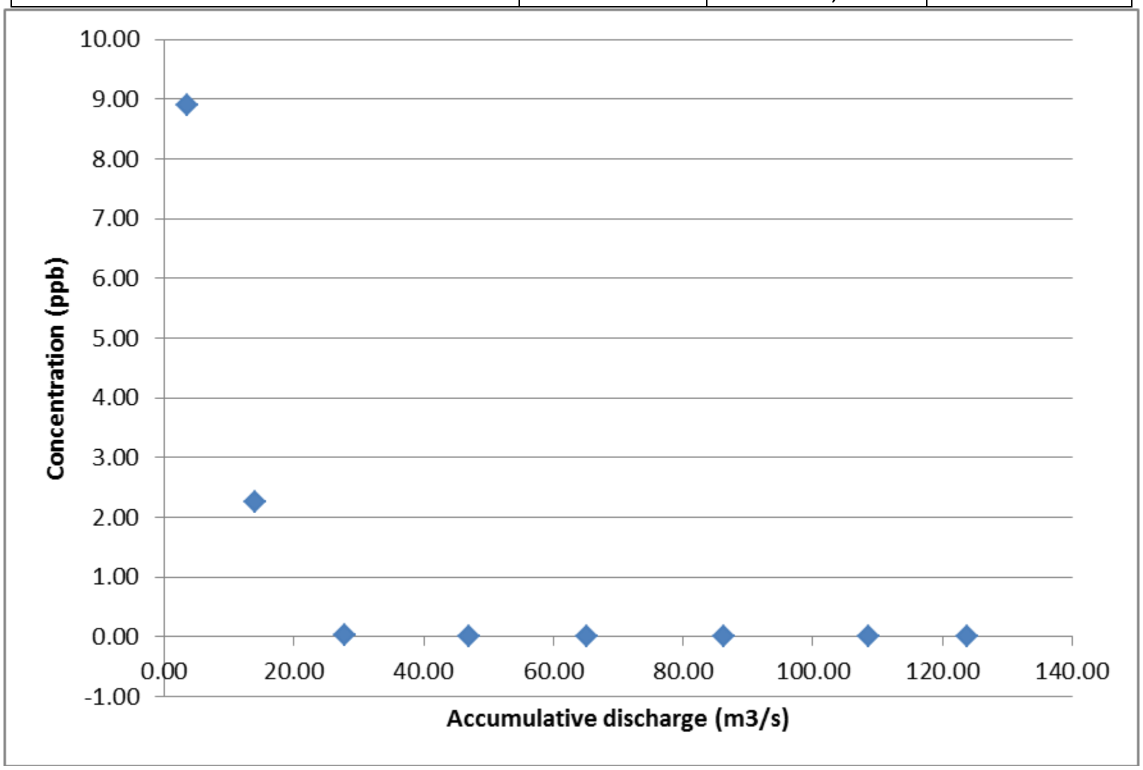


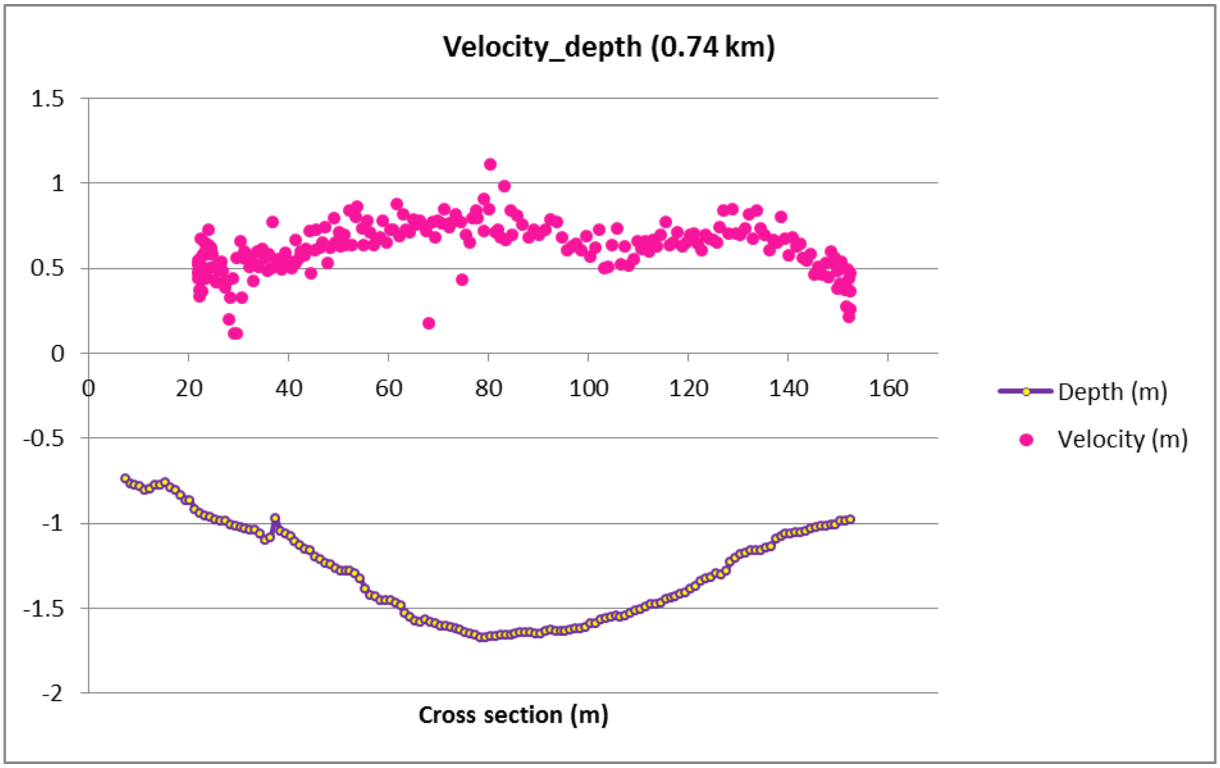
Velocity 0.74_6



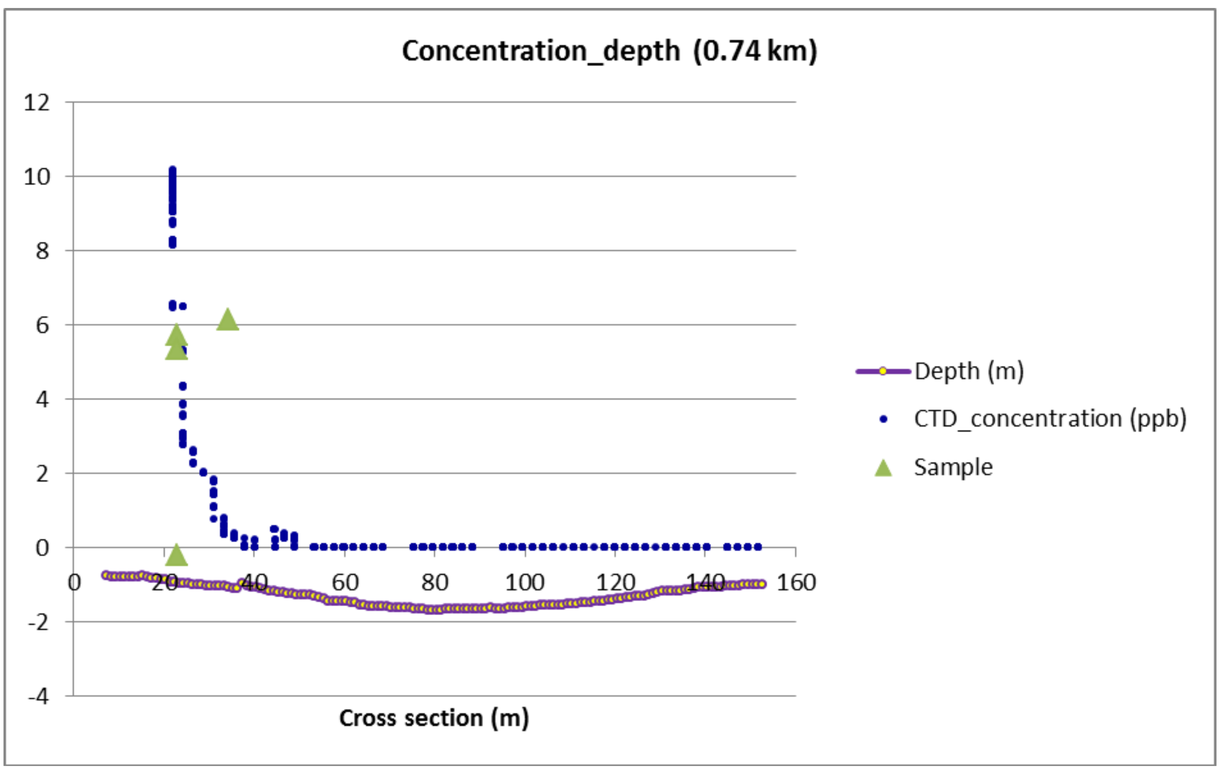
Concentration 0.74_6

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	8.71	9.09	8.90
0.2-0.3	1.88	2.65	2.26
0.3-0.4	0.01	0.06	0.04
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	179.54		
Approximate distance from outfall(km)	0.74		
Time and date	13:45:57	Oct 26th, 2011	



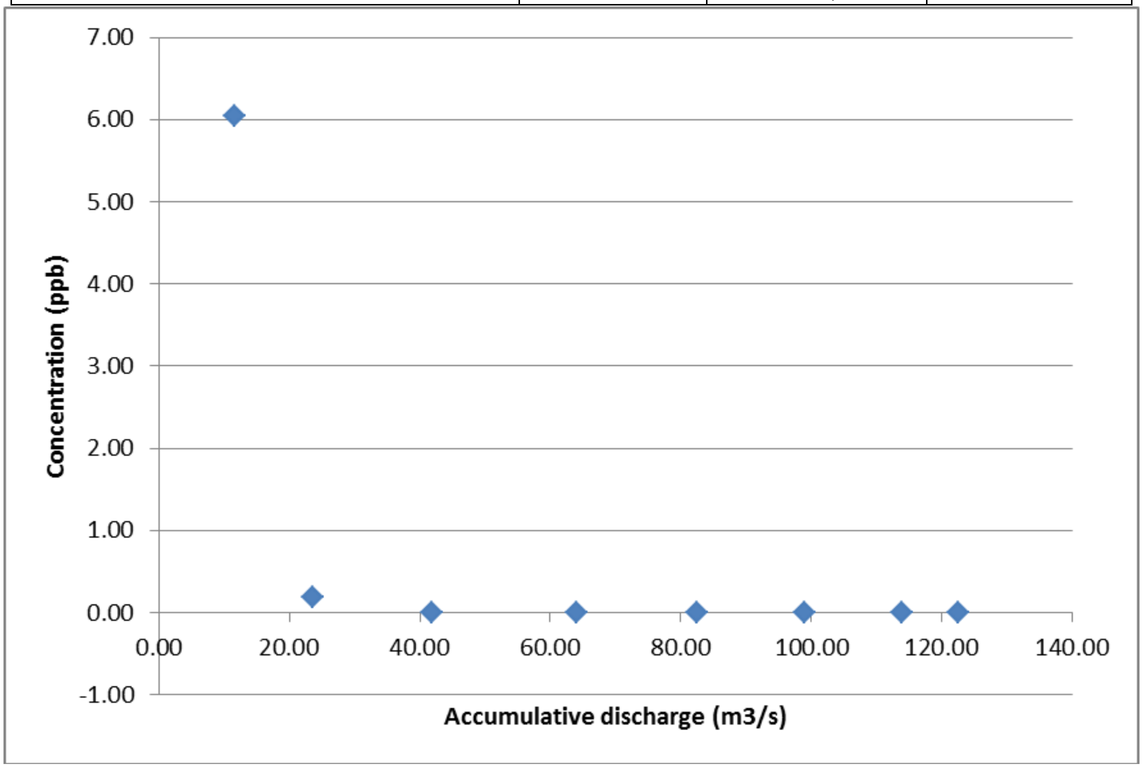


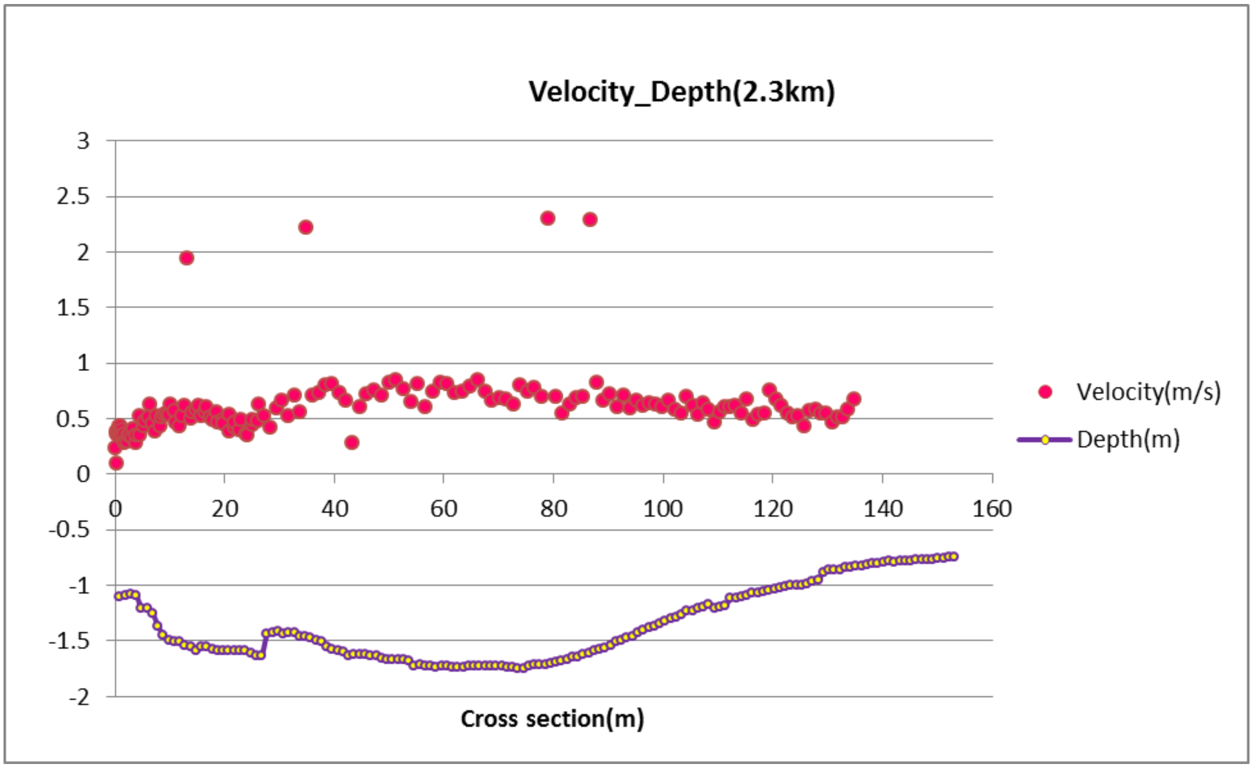
Velocity 0.74_7



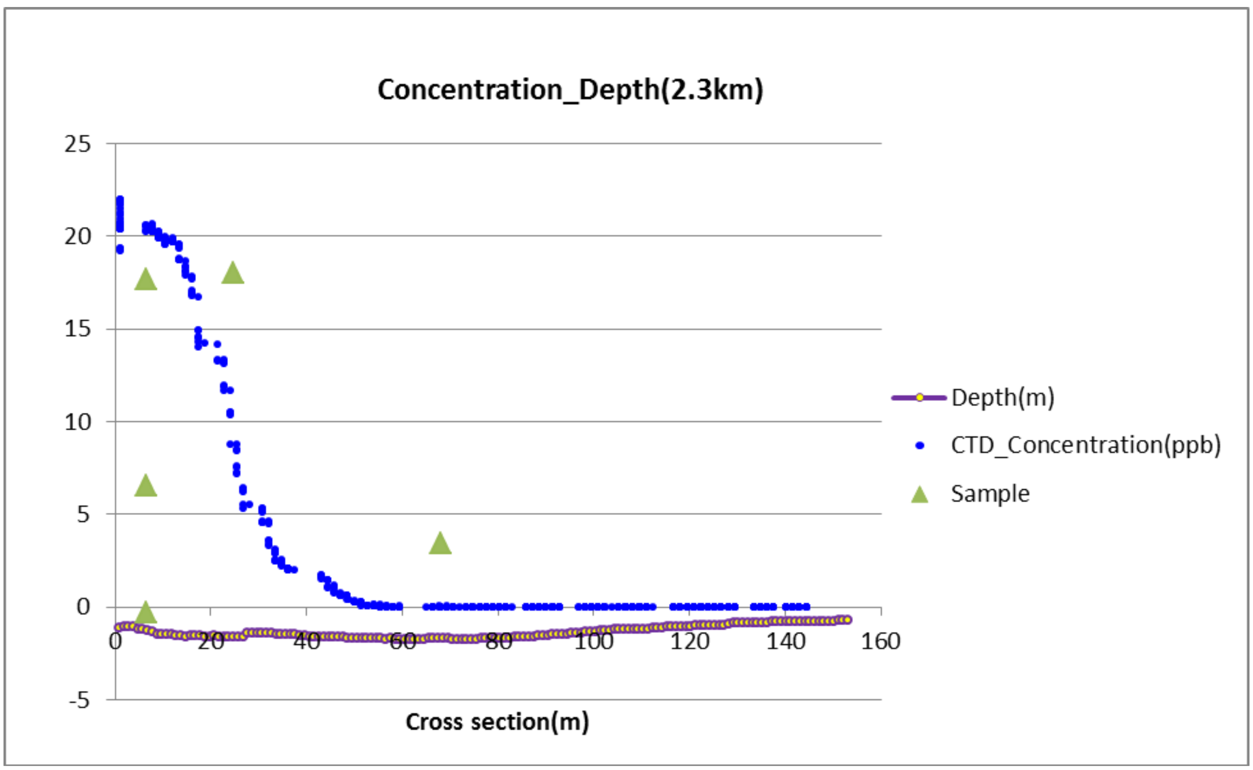
Concentration 0.74_7

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	5.50	6.59	6.04
0.2-0.3	0.14	0.23	0.19
0.3-0.4	0.00	0.00	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	174.04		
Approximate distance from outfall(km)	0.74		
Time and date	13:45:57	Oct 26th, 2011	



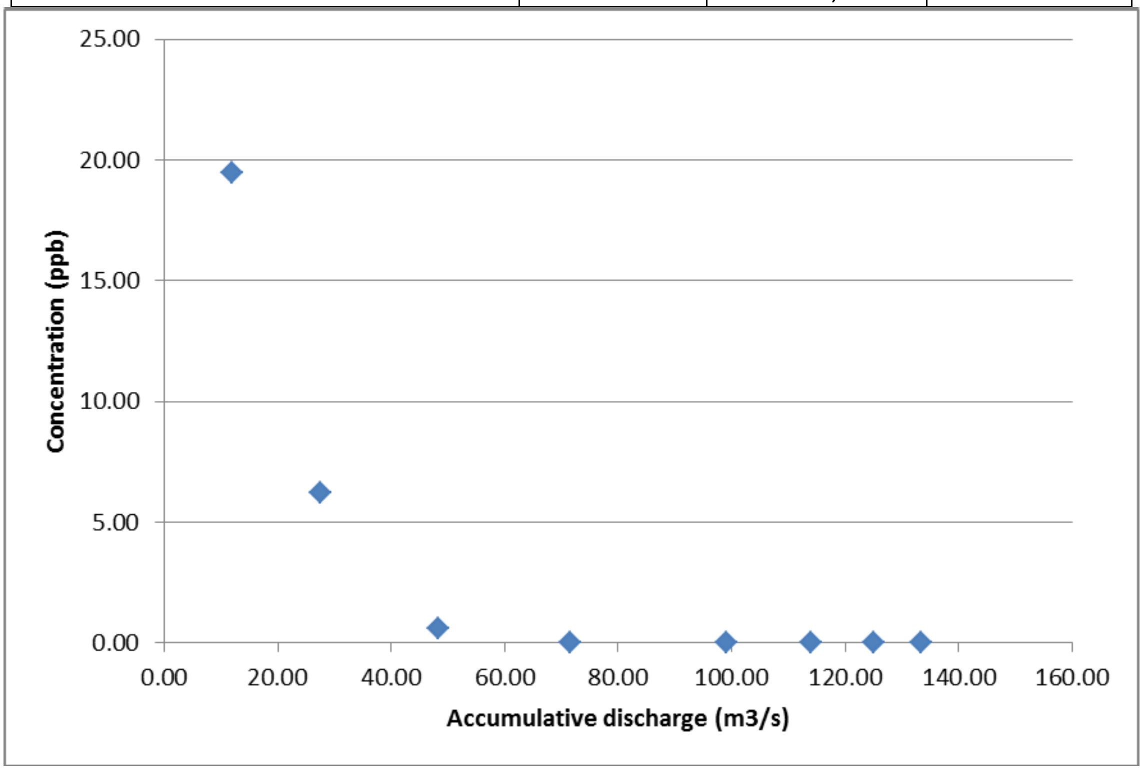


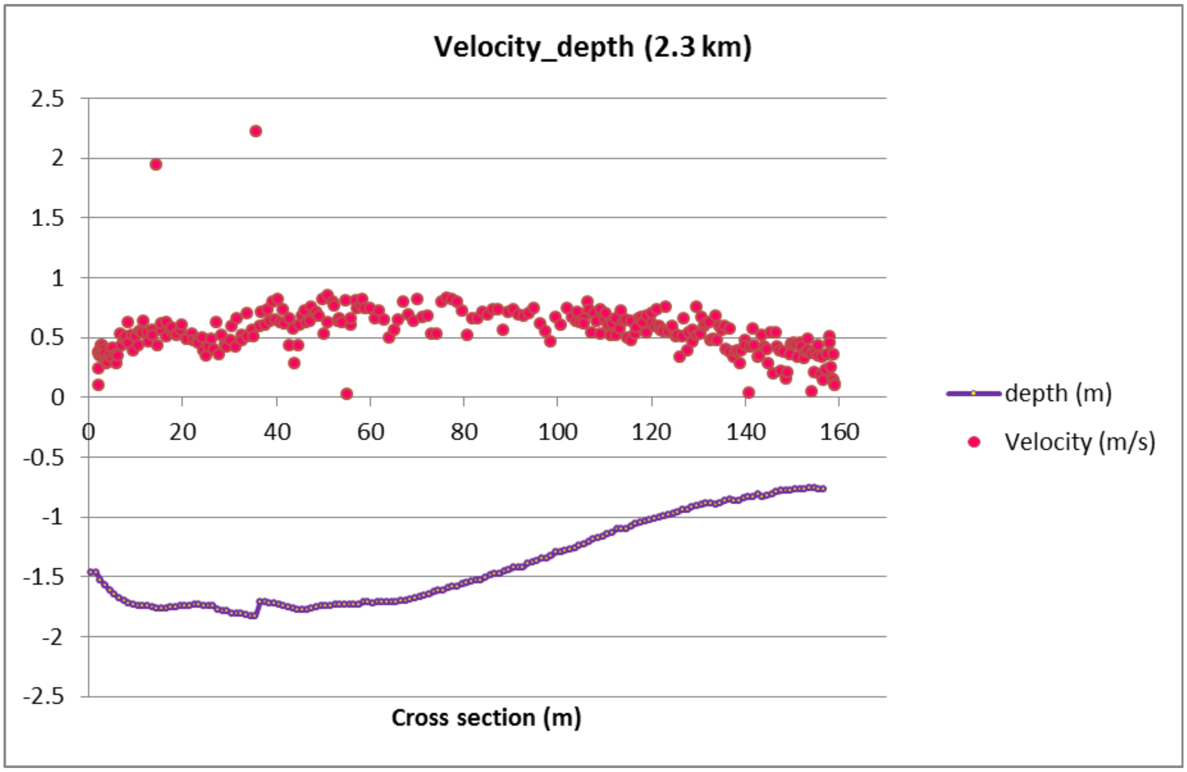
Velocity 2.3km_1



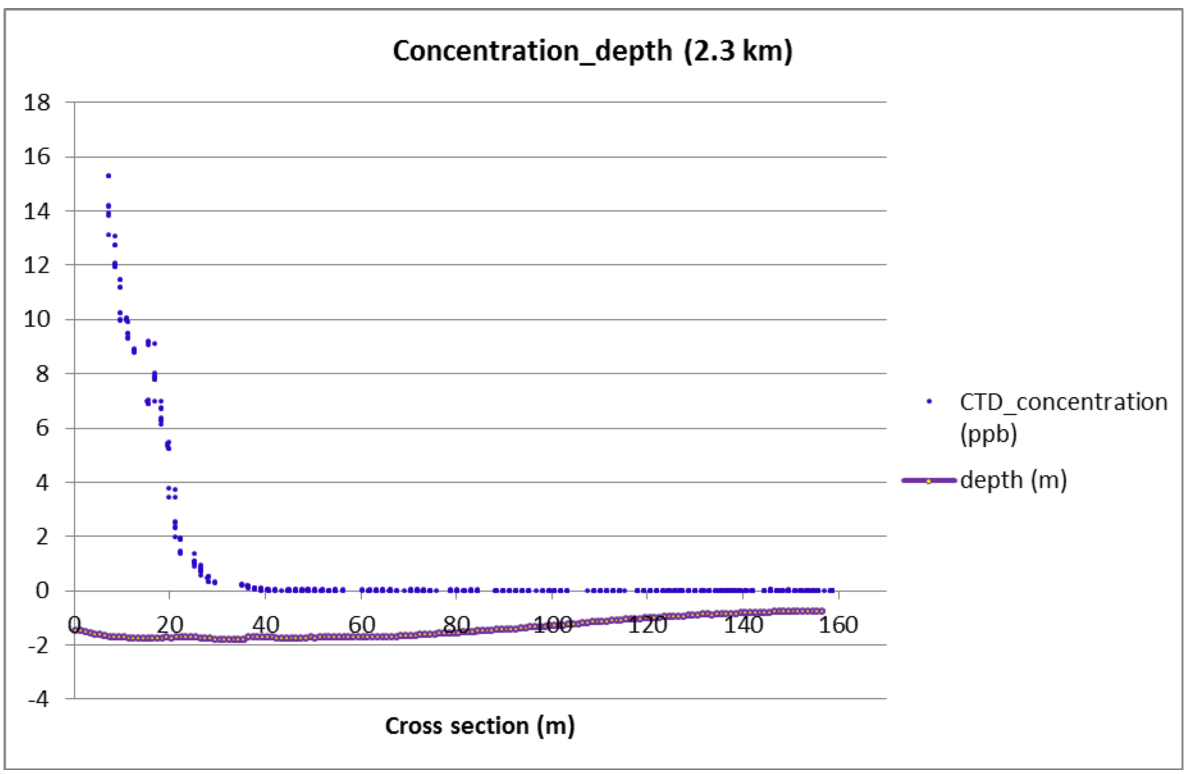
Concentration 2.3km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	19.14	19.84	19.49
0.1-0.2	5.29	7.17	6.23
0.2-0.3	0.47	0.78	0.63
0.3-0.4	0.00	0.01	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9			
0.9-1			
Approximate width(m)	181.49		
Approximate distance from outfall(km)	2.3		
Time and date	14:12:57	Oct 26th, 2011	



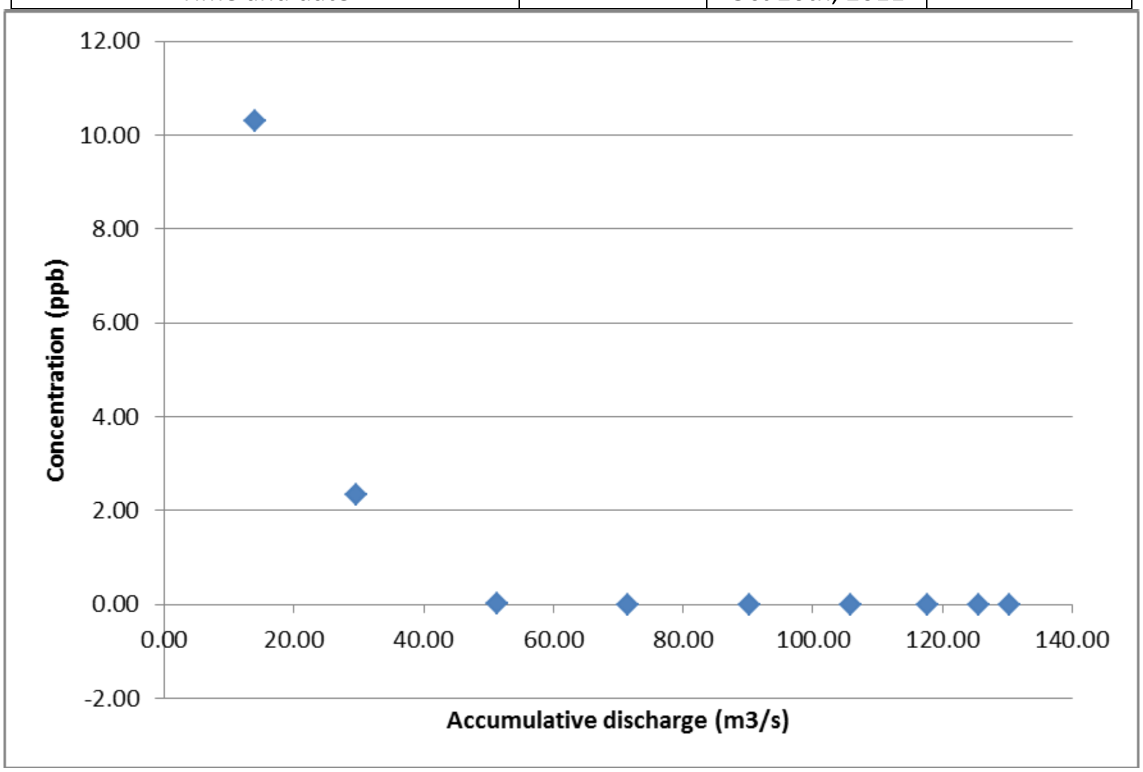


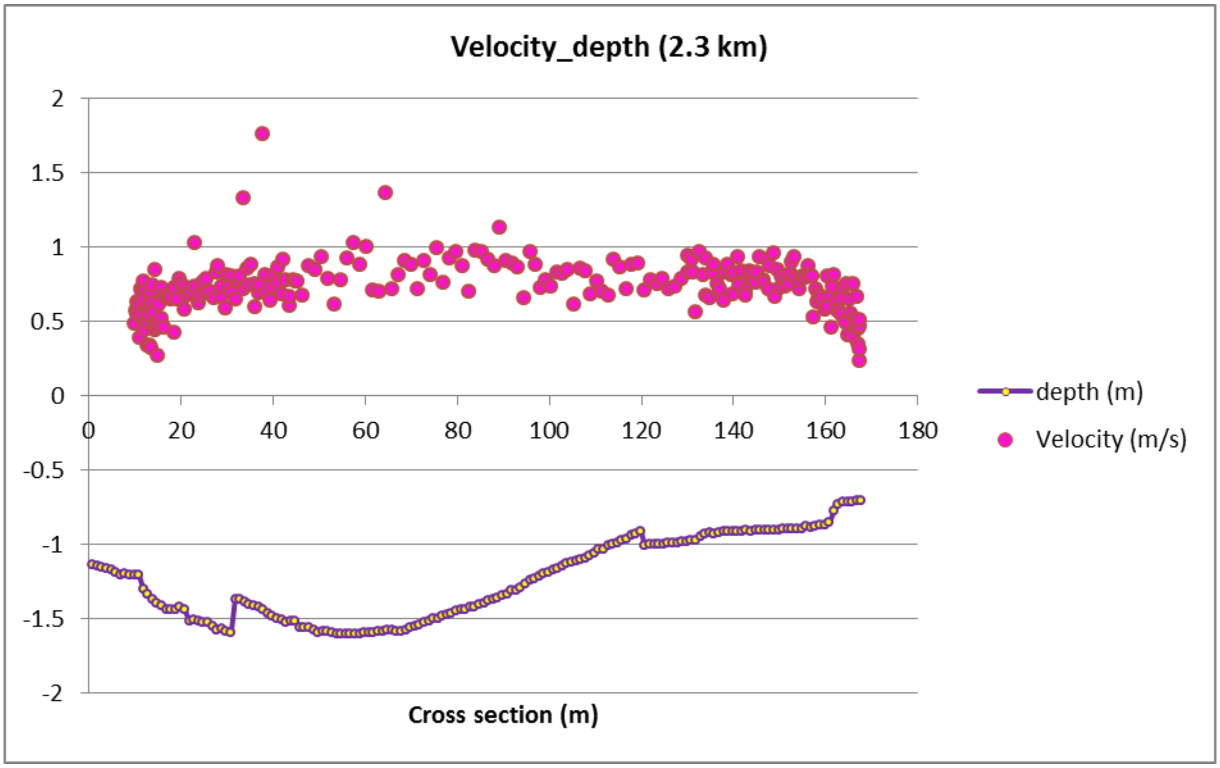
Velocity 2.3km_2



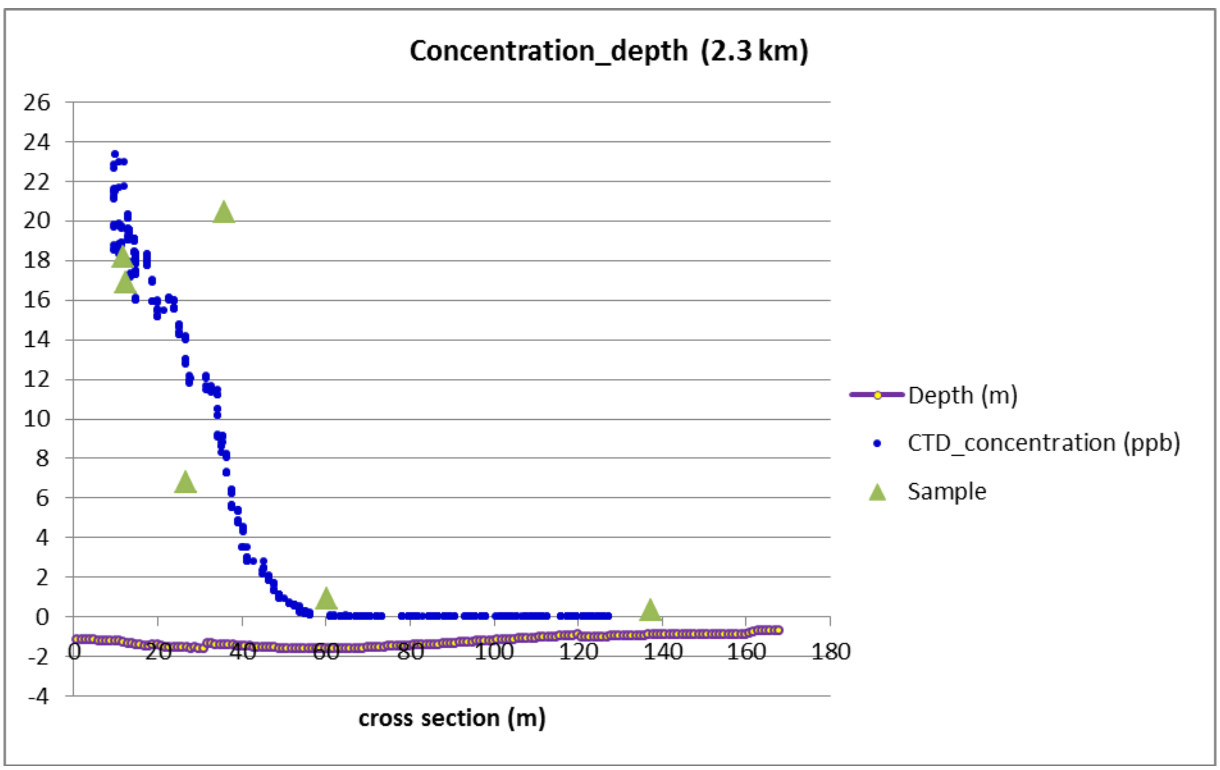
Concentration 2.3km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	9.67	10.95	10.31
0.1-0.2	1.76	2.94	2.35
0.2-0.3	0.01	0.03	0.02
0.3-0.4	0.00	0.00	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	177.16		
Approximate distance from outfall(km)	2.3		
Time and date	14:12:57	Oct 26th, 2011	



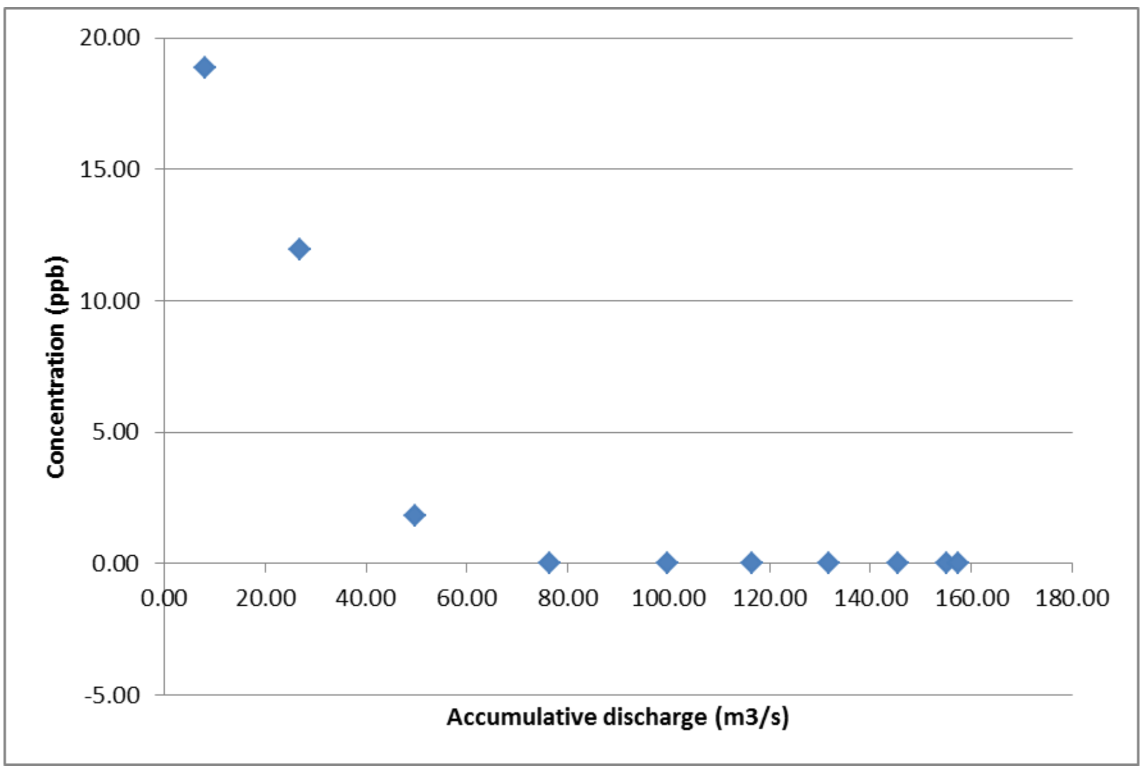


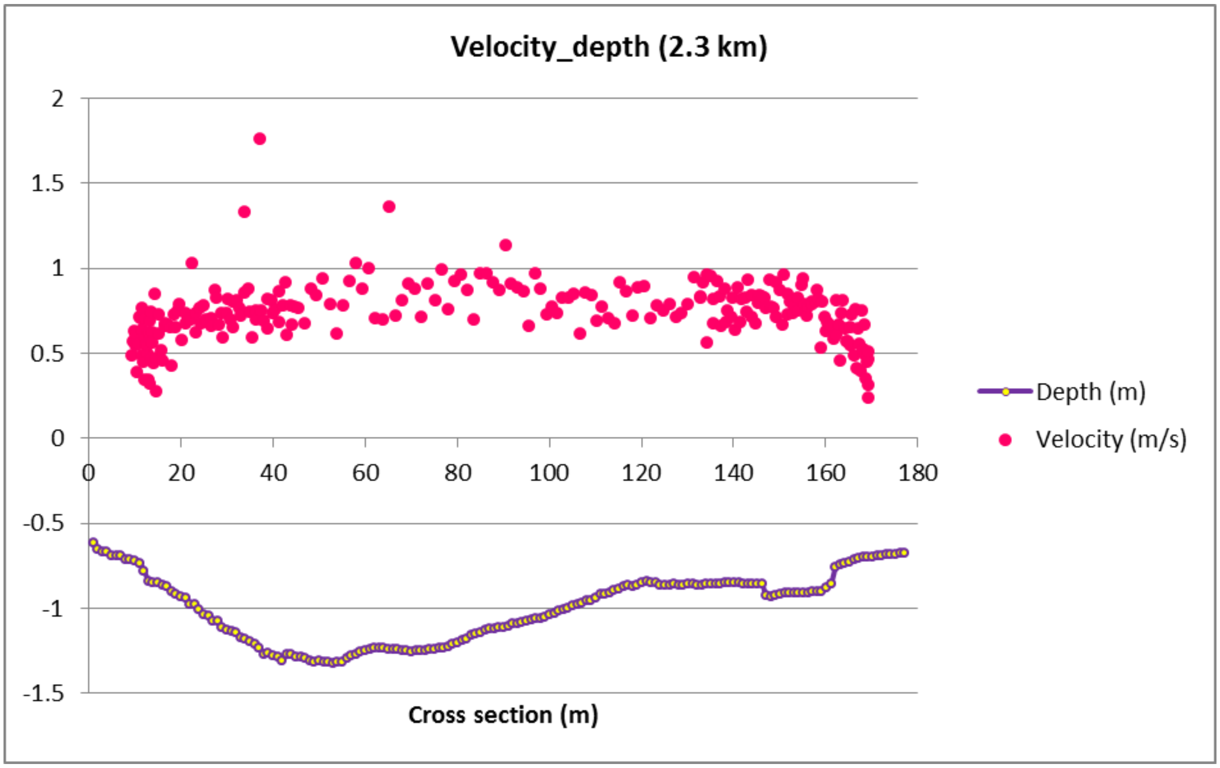
Velocity 2.3km_3



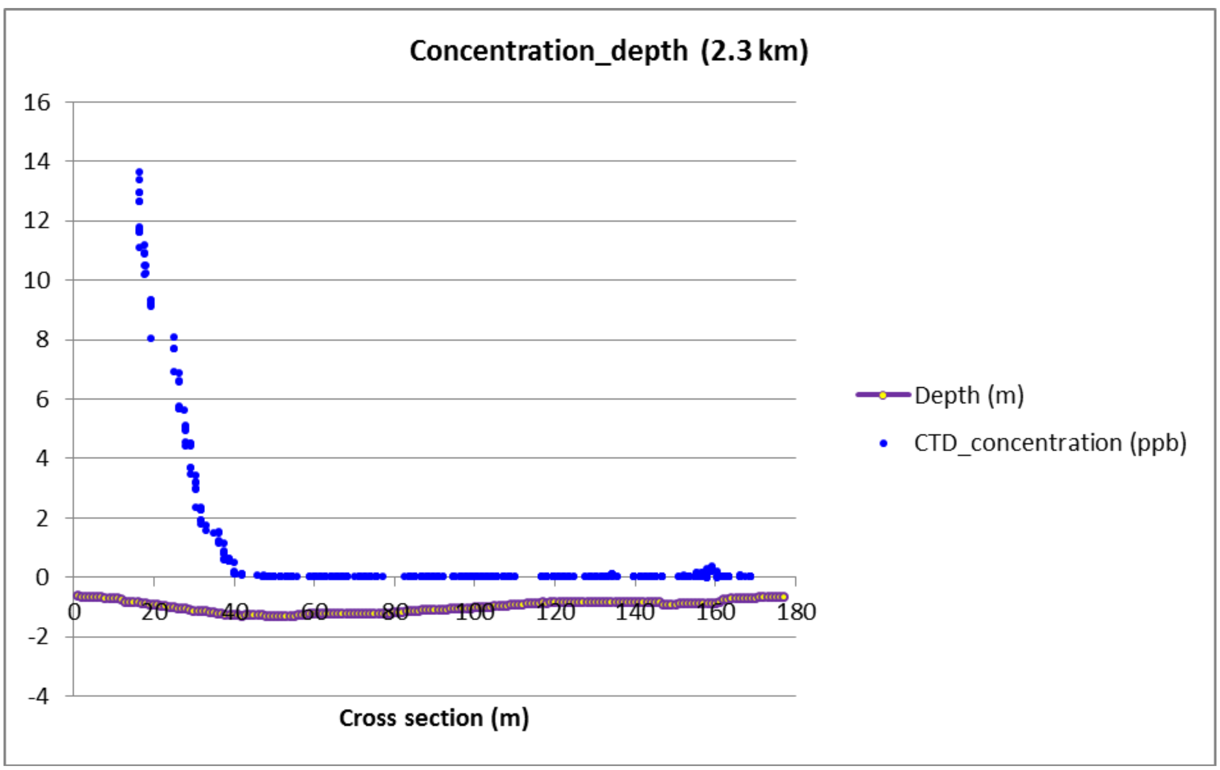
Concentration 2.3km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	18.58	19.14	18.86
0.1-0.2	11.27	12.60	11.93
0.2-0.3	1.48	2.14	1.81
0.3-0.4	0.00	0.01	0.01
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0	0	0
0.8-0.9	0	0	0
0.9-1			
Approximate width(m)	191.42		
Approximate distance from outfall(km)	2.3		
Time and date	14:12:57	Oct 26th, 2011	





Velocity 2.3km_4



Concentration 2.3km_4

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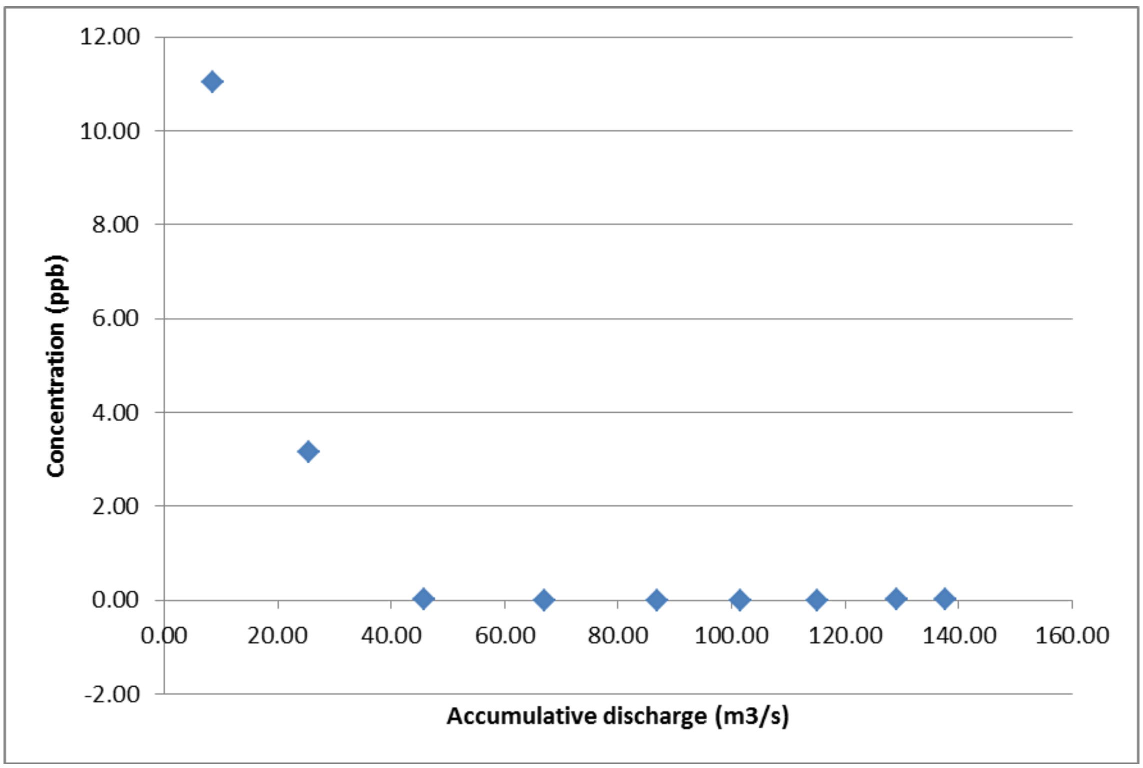
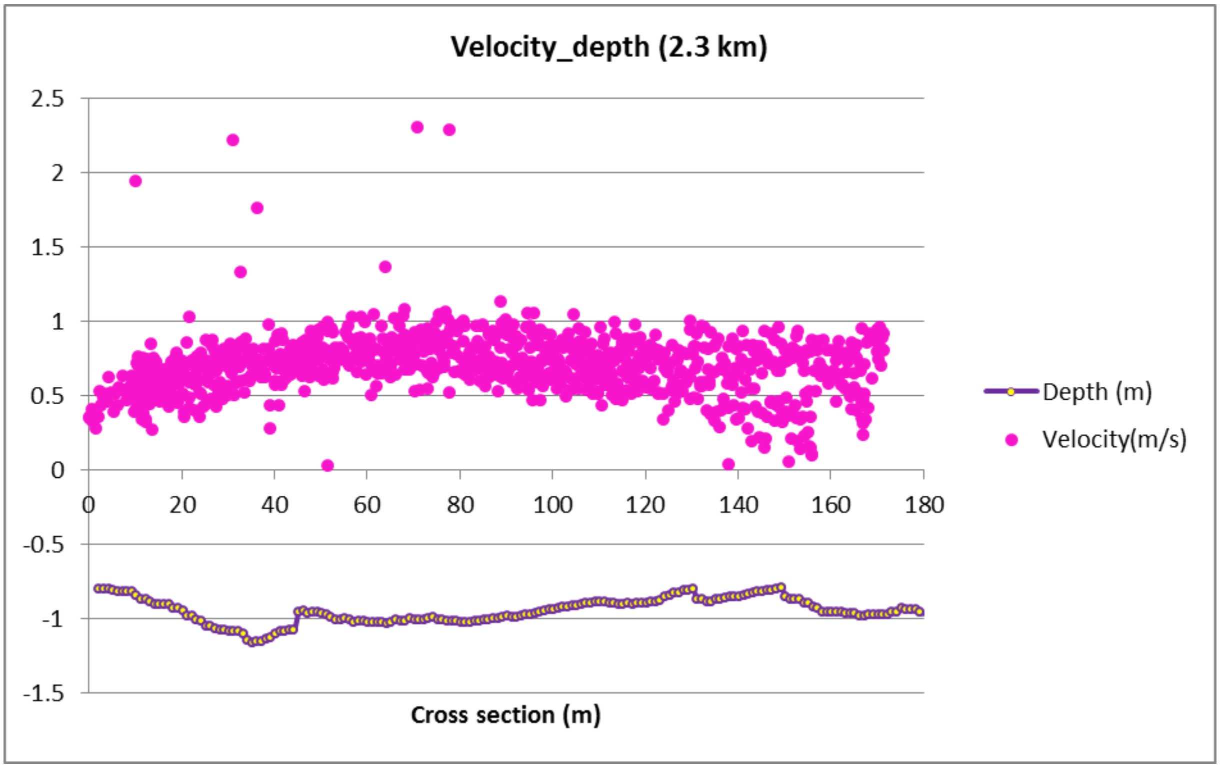
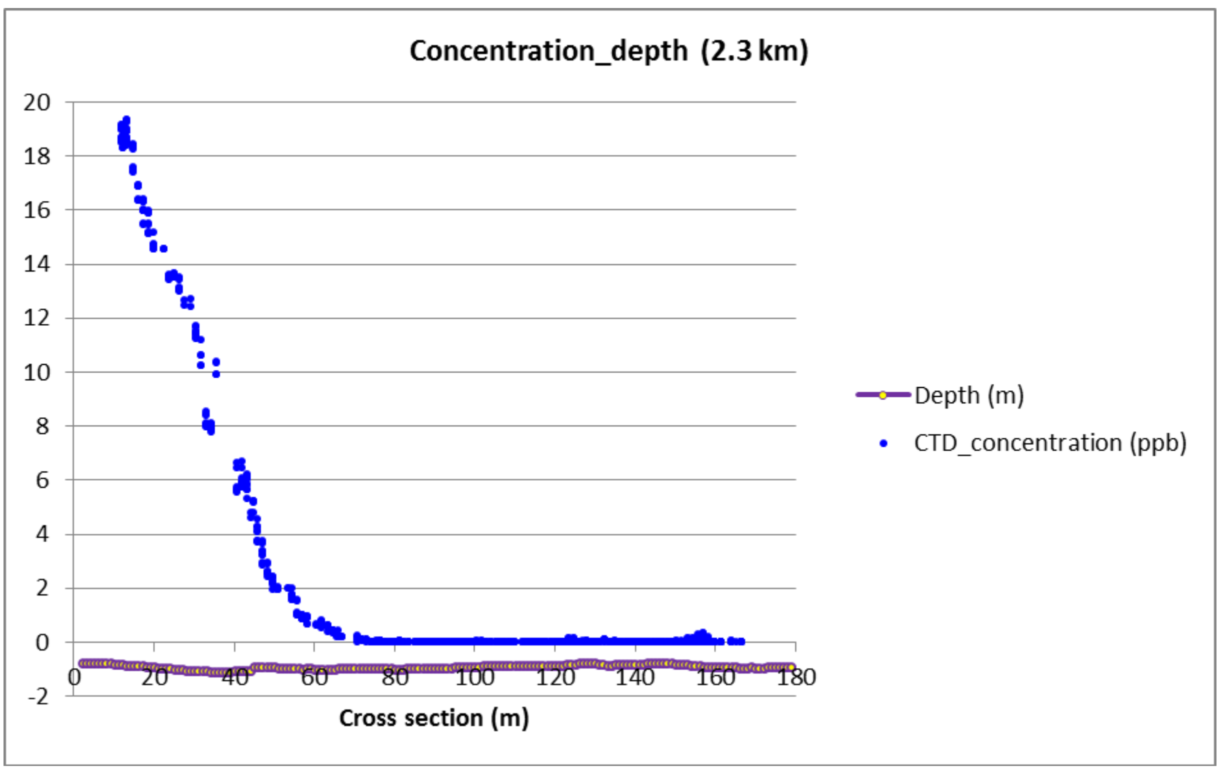
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	10.42	11.65	11.04
0.1-0.2	2.57	3.74	3.16
0.2-0.3	0.01	0.06	0.03
0.3-0.4	0.00	0.00	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.01	0.01
0.7-0.8	0.00	0.03	0.01
0.8-0.9	0.01	0.05	0.03
0.9-1			
Approximate width(m)	198.08		
Approximate distance from outfall(km)	2.3		
Time and date	14:12:57	Oct 26th, 2011	



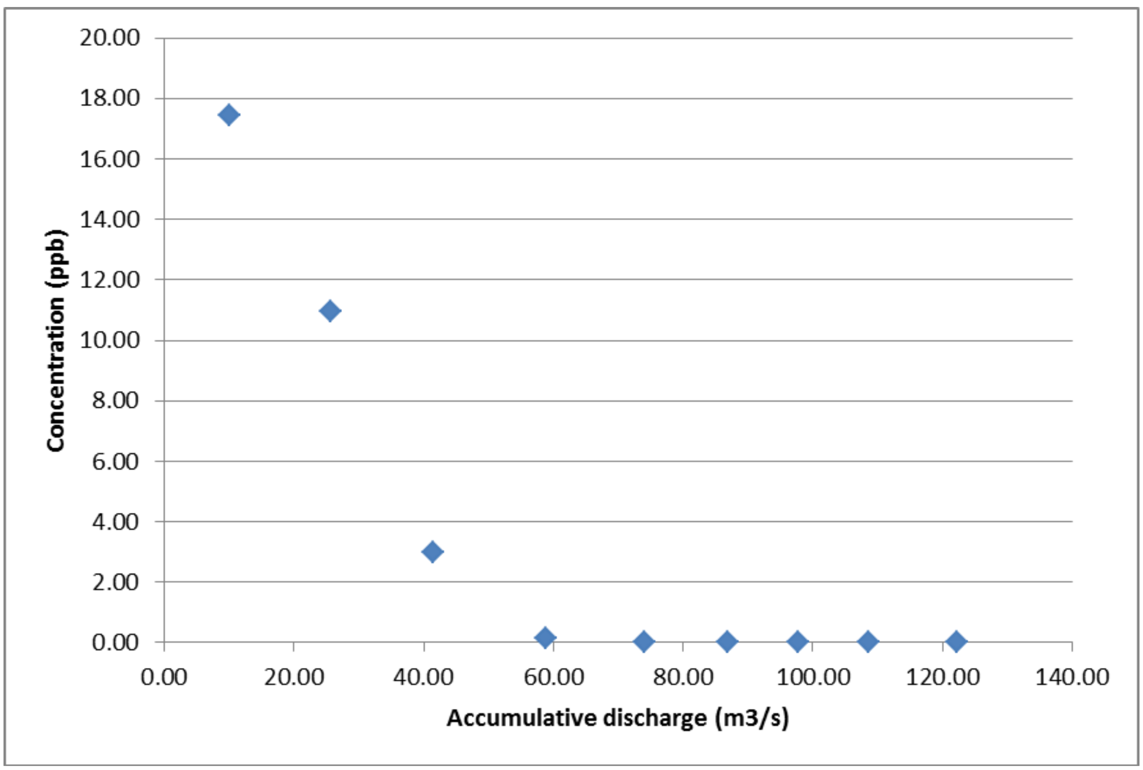


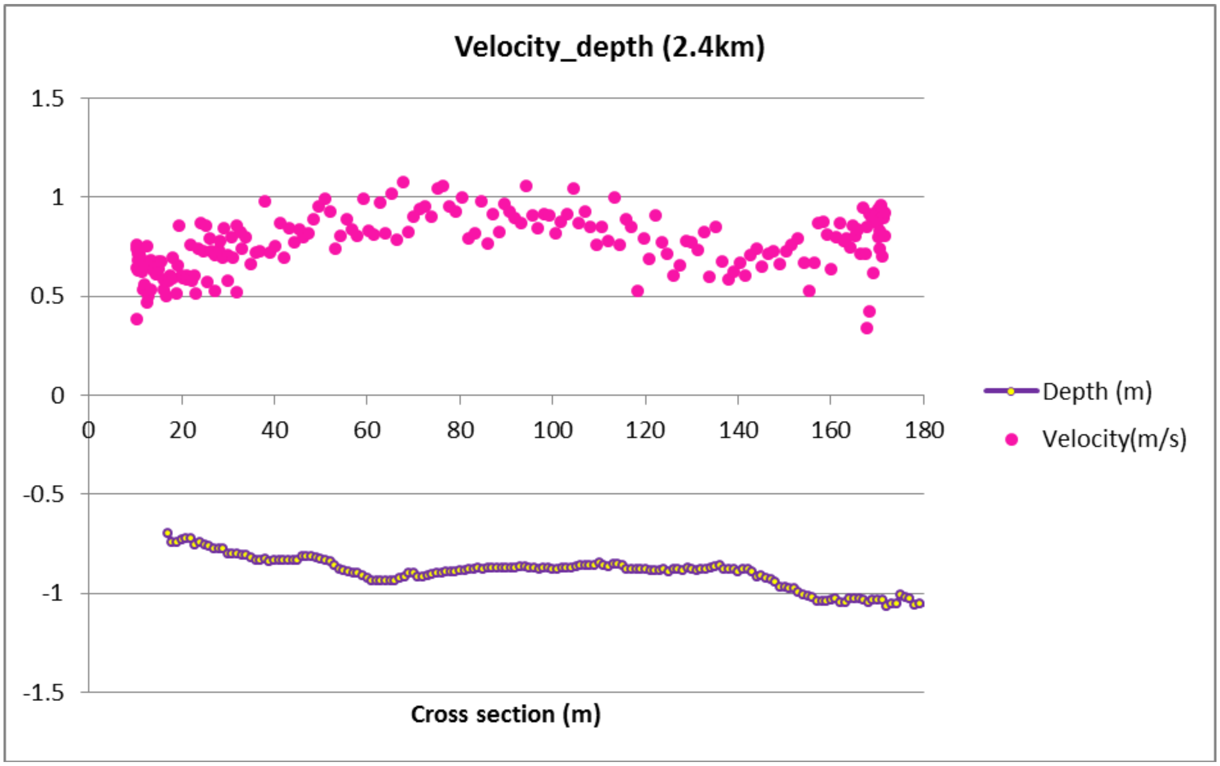
Velocity 2.3km_5



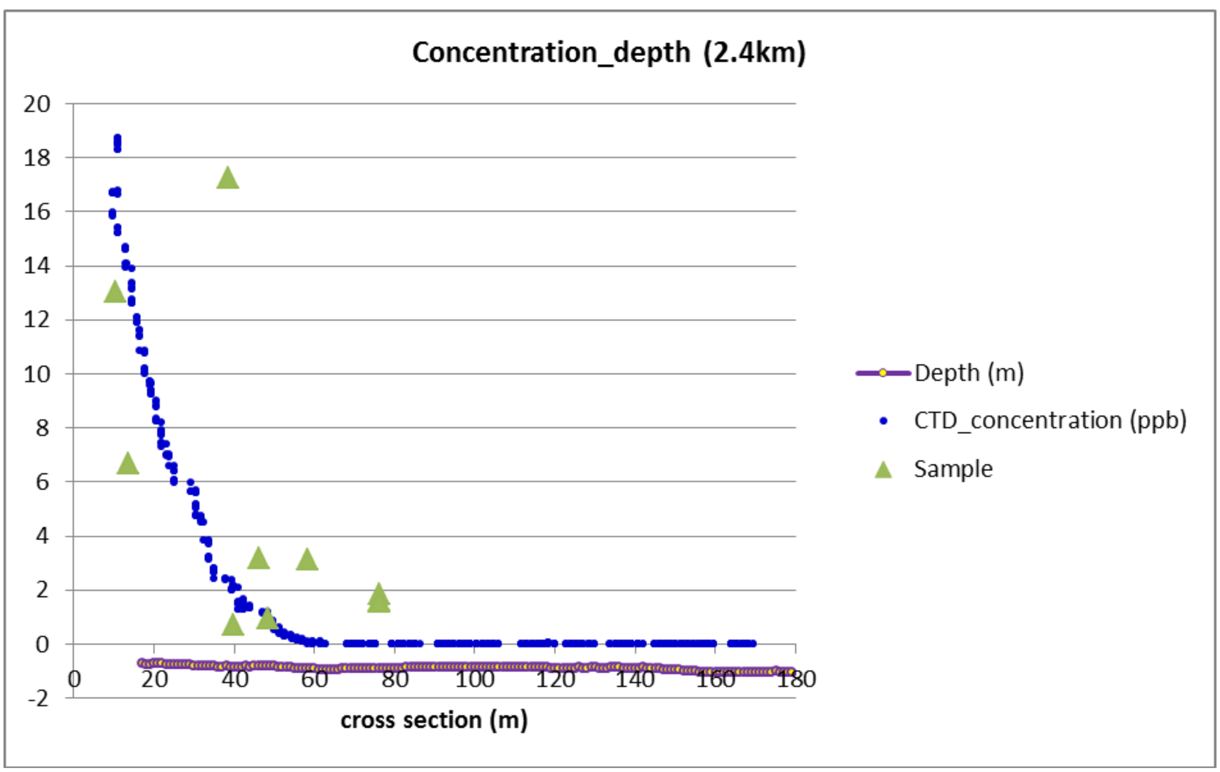
Concentration 2.3km_5

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	17.12	17.76	17.44
0.1-0.2	10.31	11.57	10.94
0.2-0.3	2.61	3.36	2.98
0.3-0.4	0.11	0.19	0.15
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.01	0.01
0.7-0.8	0.01	0.03	0.02
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	205.26		
Approximate distance from outfall(km)	2.3		
Time and date	14:12:57	Oct 26th, 2011	



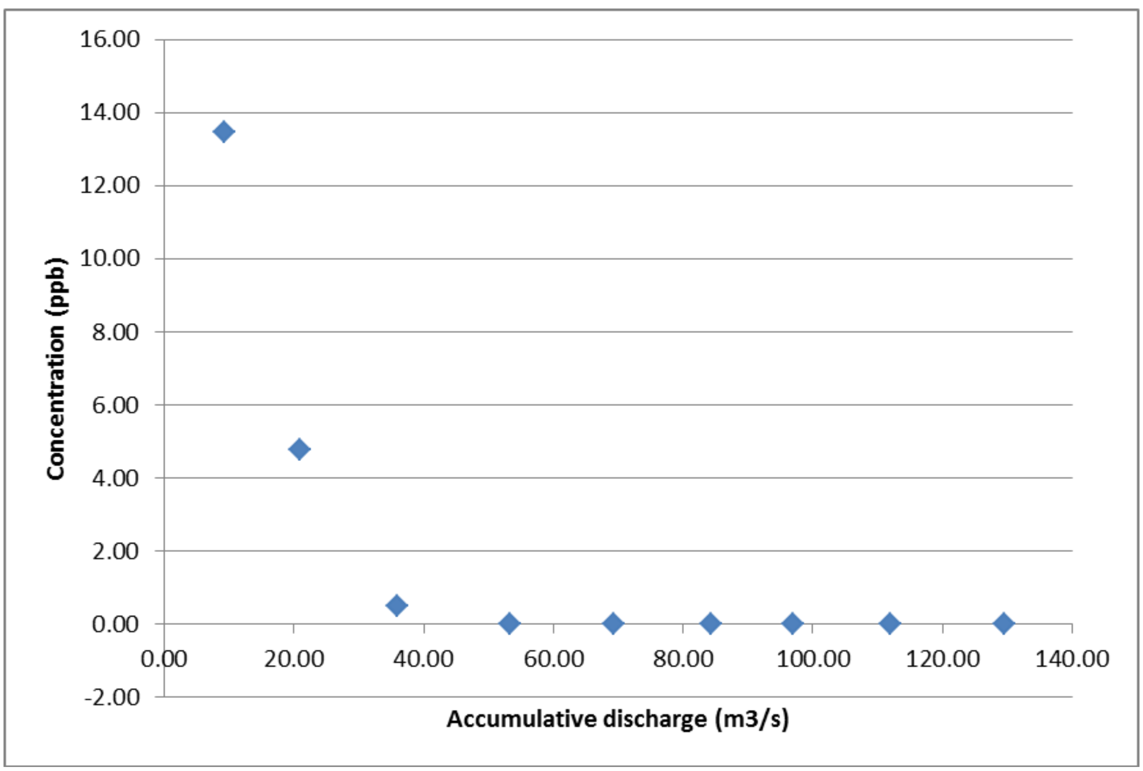


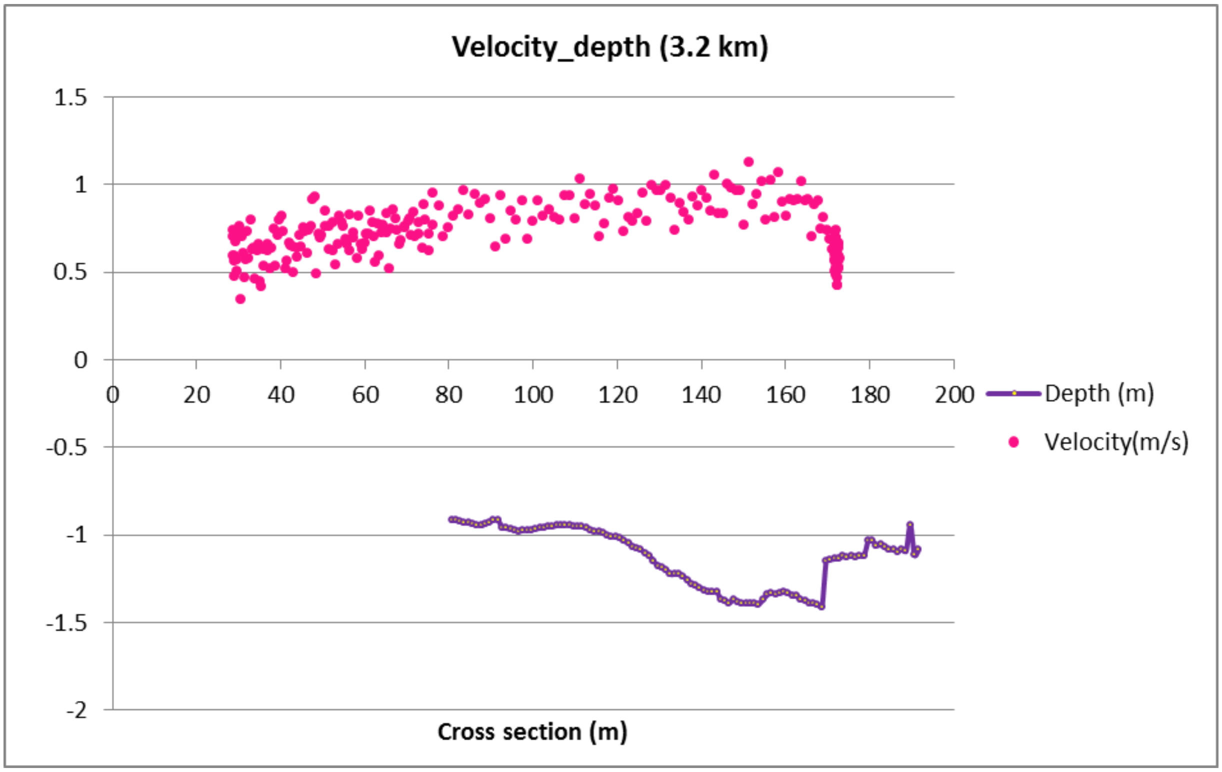
Velocity 2.4km_6



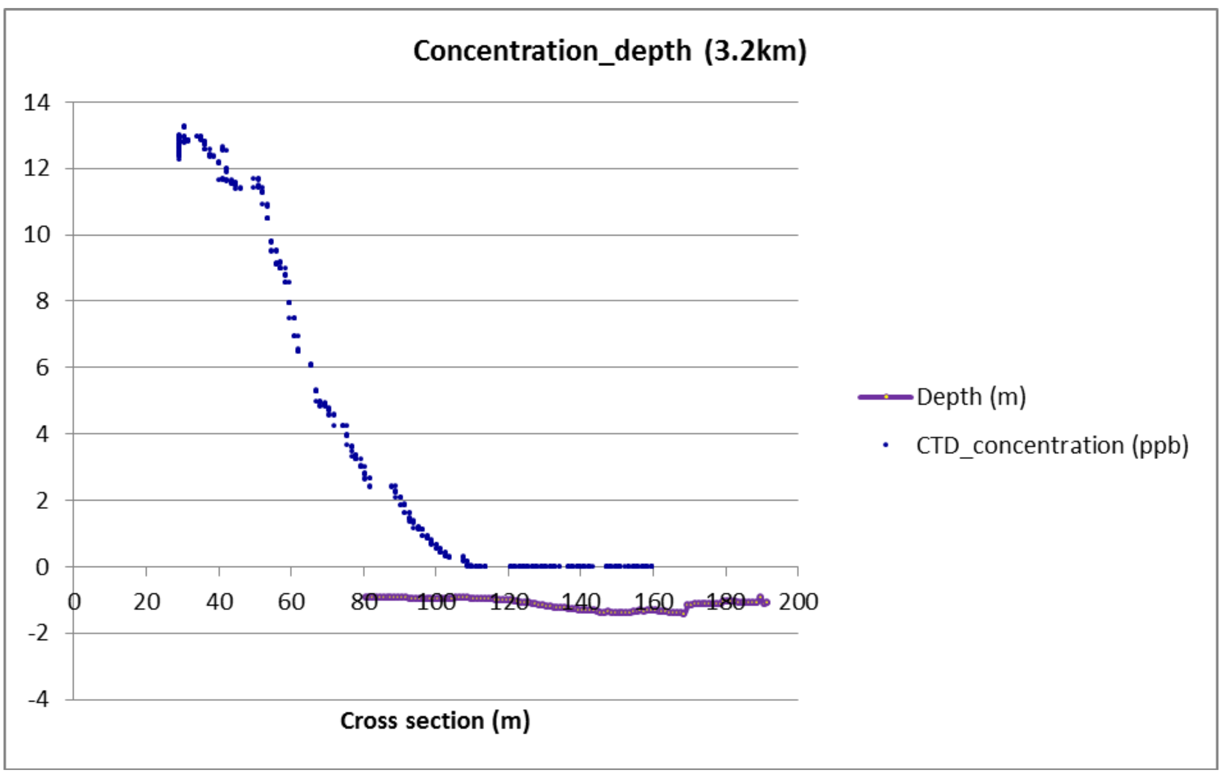
Concentration 2.4km_6

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	12.75	14.20	13.47
0.1-0.2	4.26	5.26	4.76
0.2-0.3	0.40	0.62	0.51
0.3-0.4	0.00	0.00	0.00
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	205.93		
Approximate distance from outfall(km)	2.4		
Time and date	14:12:57	Oct 26th, 2011	



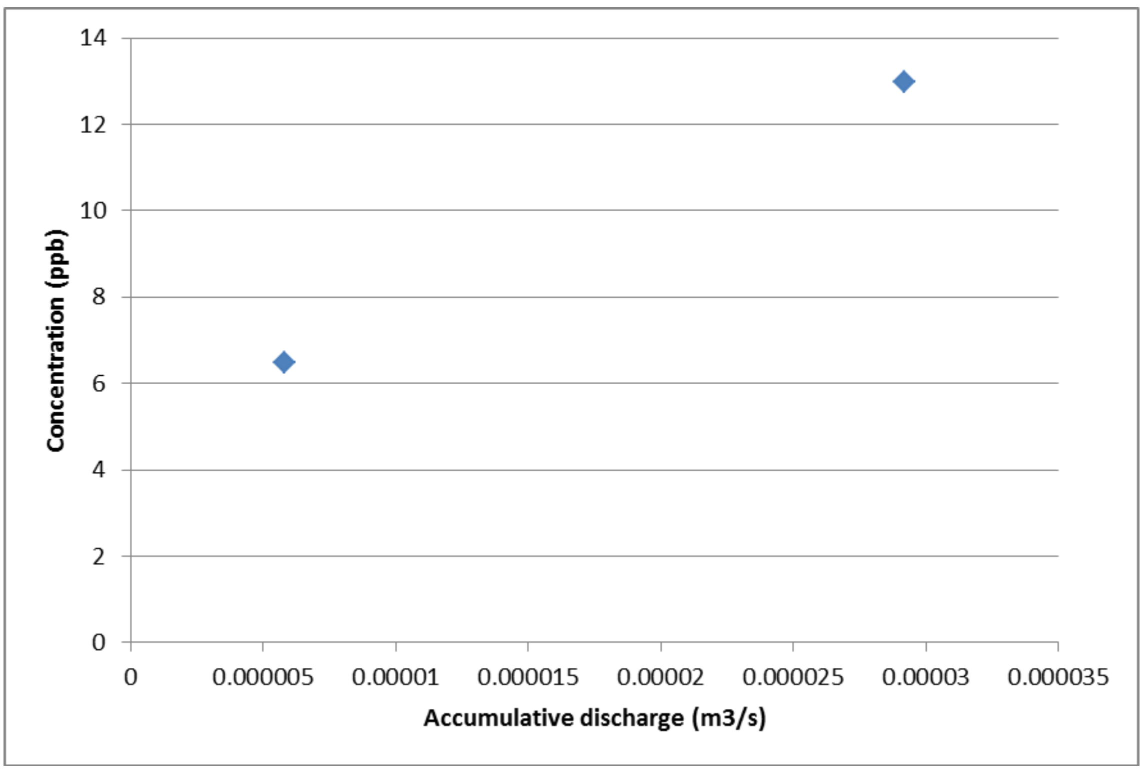


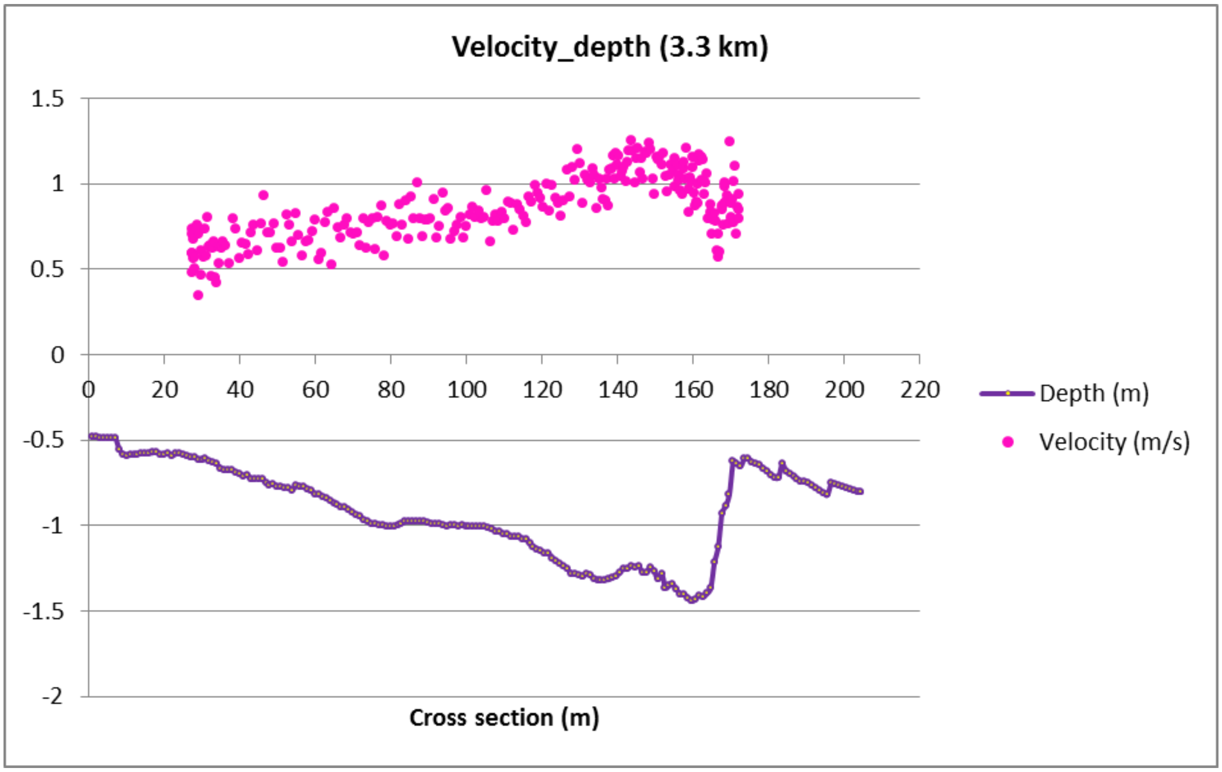
Velocity 3.2km_1



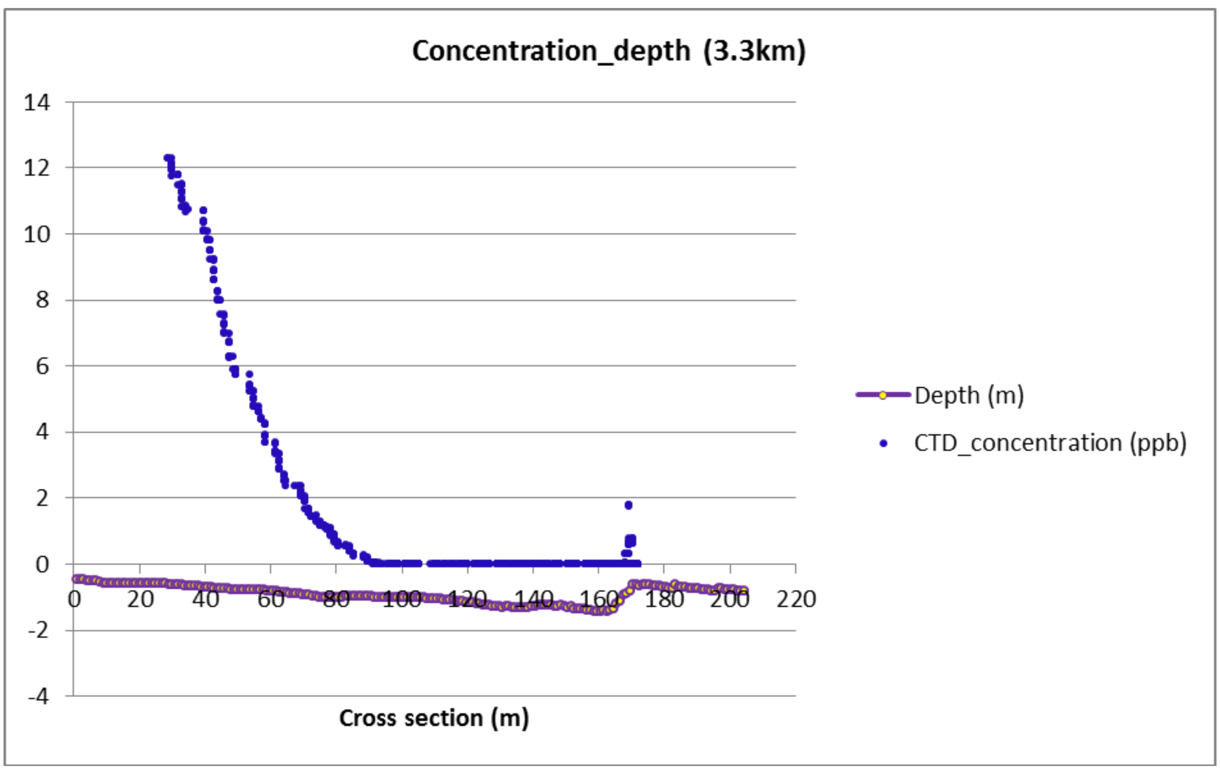
Concentration 3.2km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	12.37	12.37	12.97
0.2-0.3	10.18	10.18	10.18
0.3-0.4	5.8	5.8	5.8
0.4-0.5	2.08	2.08	2.08
0.5-0.6	0.29	0.29	0.29
0.6-0.7	0	0	0
0.7-0.8	0	0	0
0.8-0.9	0	0	0
0.9-1			
Approximate width(m)	193.23		
Approximate distance from outfall(km)	3.2		
Time and date	15:10:20	Oct 26th, 2011	



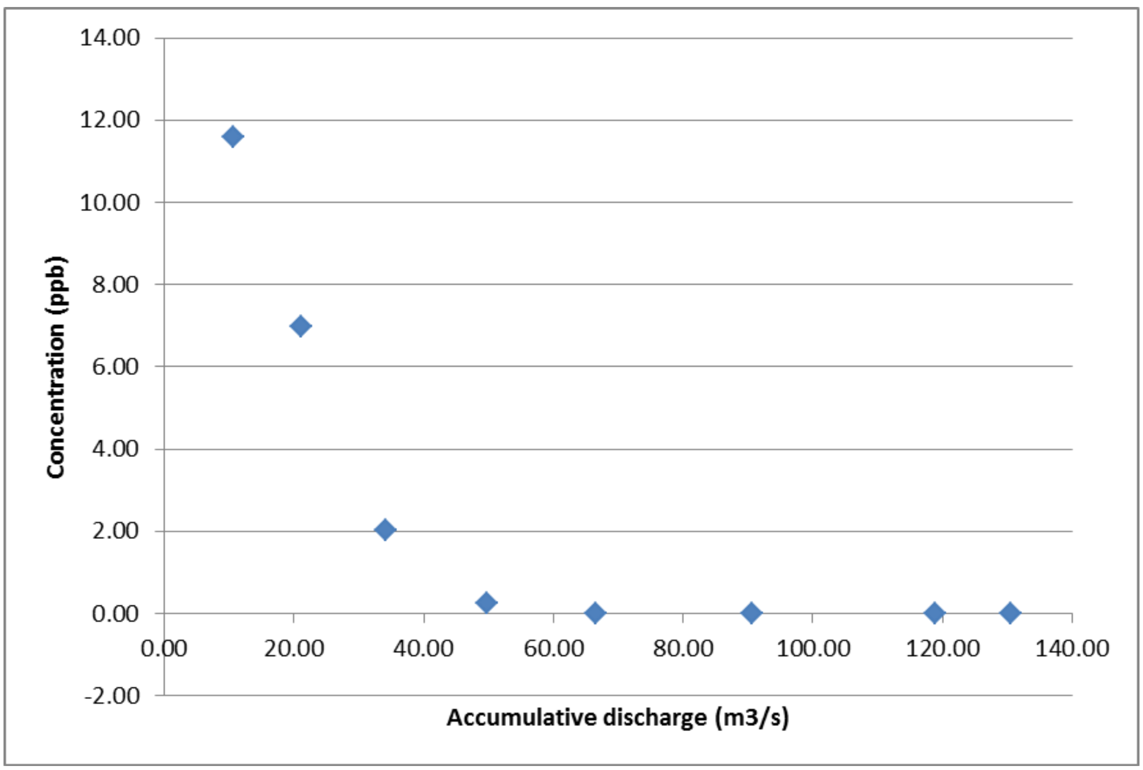


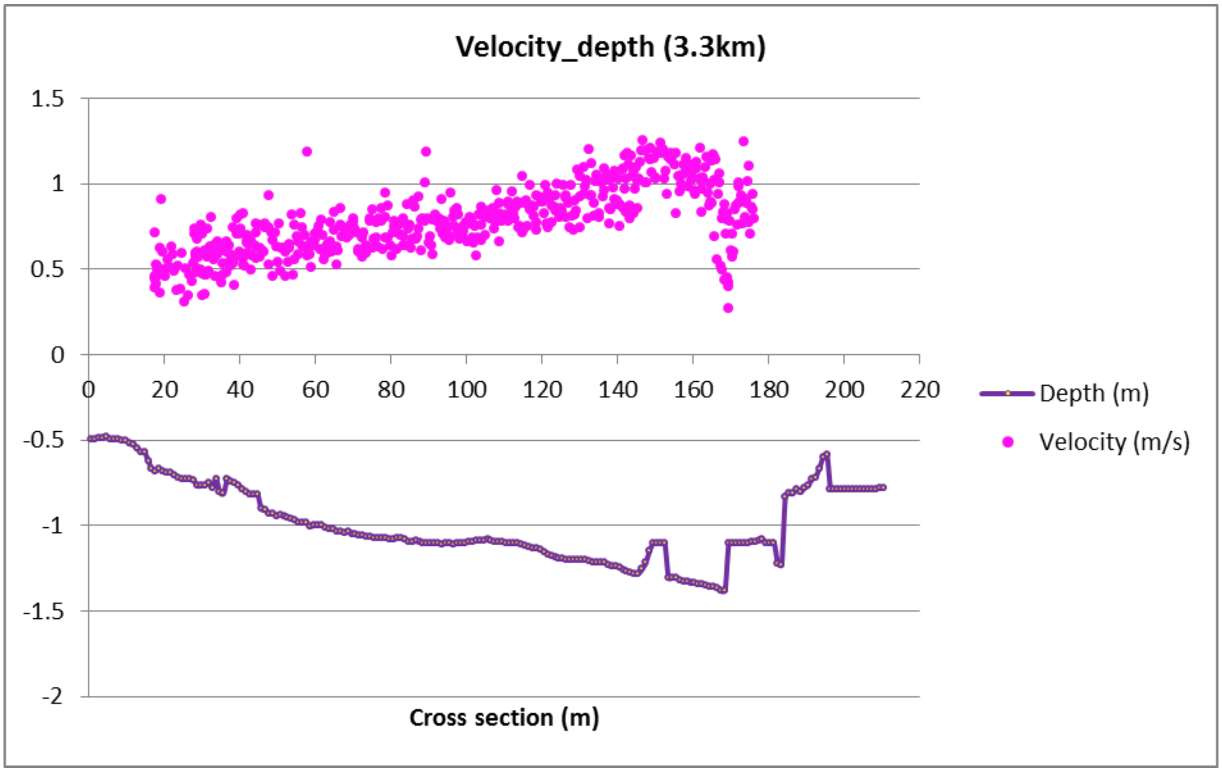
Velocity 3.3km_2



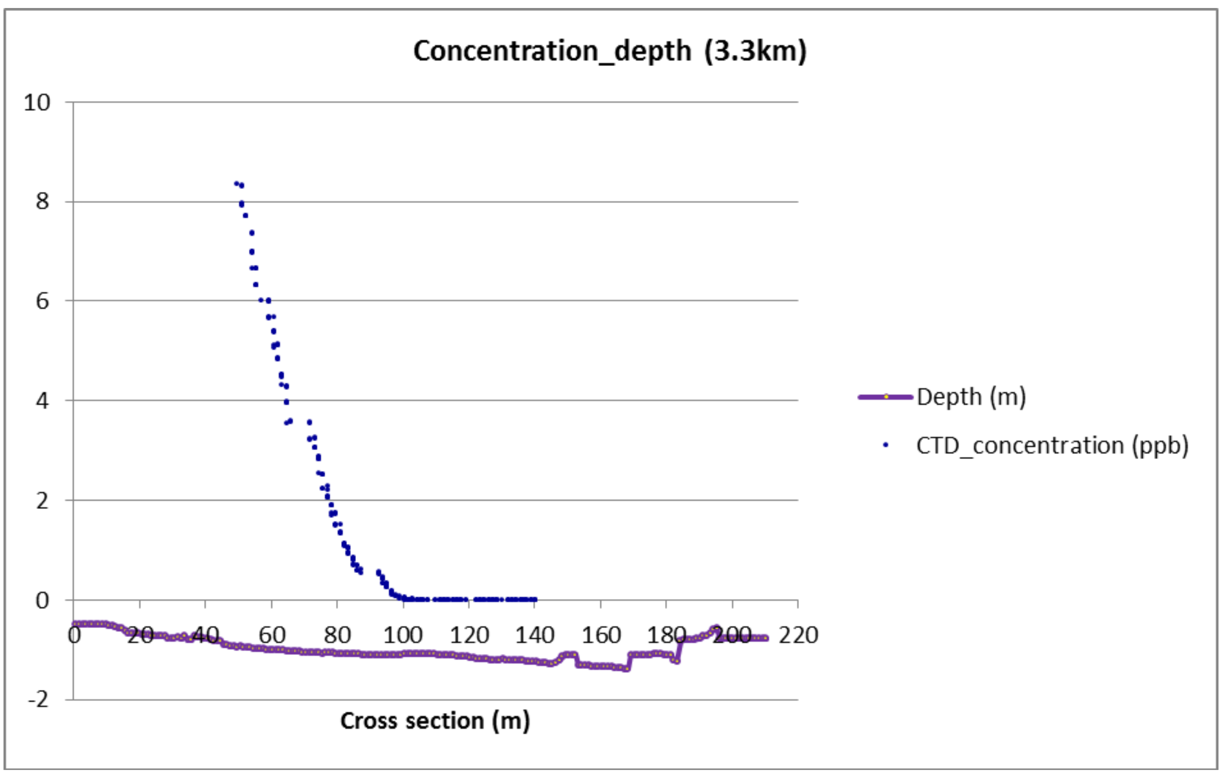
Concentration 3.3km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	11.42	11.74	11.58
0.2-0.3	6.59	7.38	6.99
0.3-0.4	1.84	2.19	2.01
0.4-0.5	0.19	0.30	0.25
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.06	0.16	0.11
0.9-1			
Approximate width(m)	197.66		
Approximate distance from outfall(km)	3.3		
Time and date	15:10:20	Oct 26th, 2011	



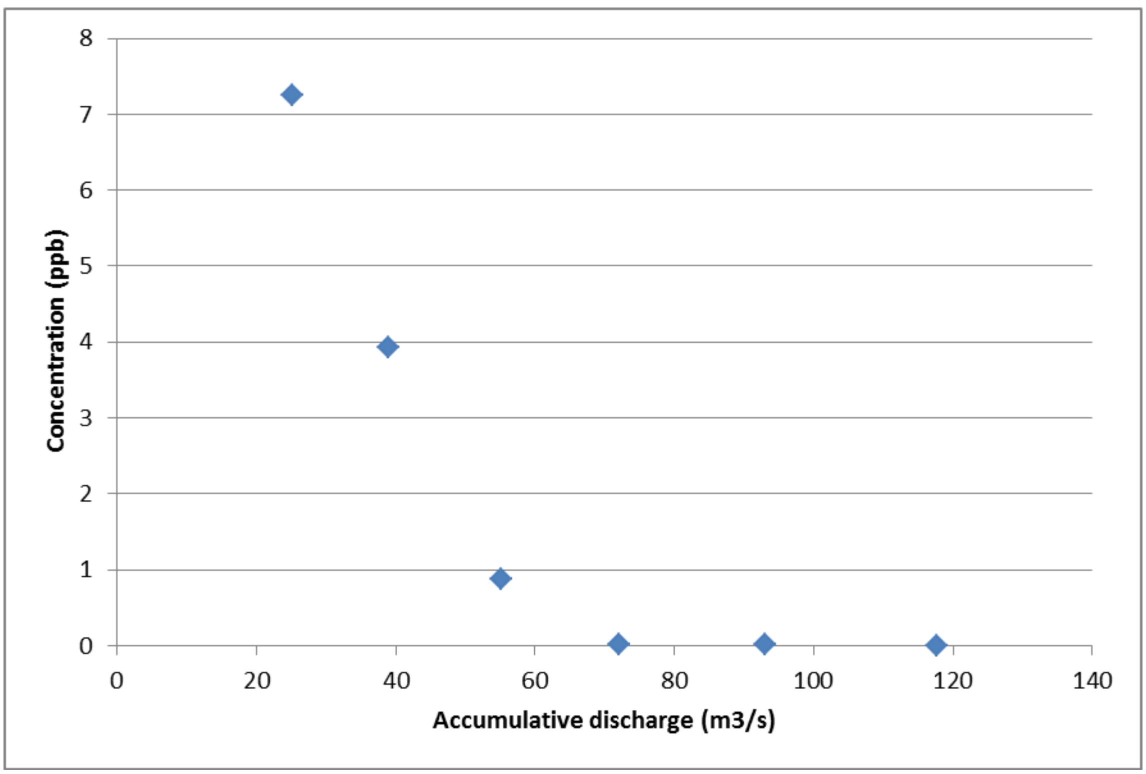


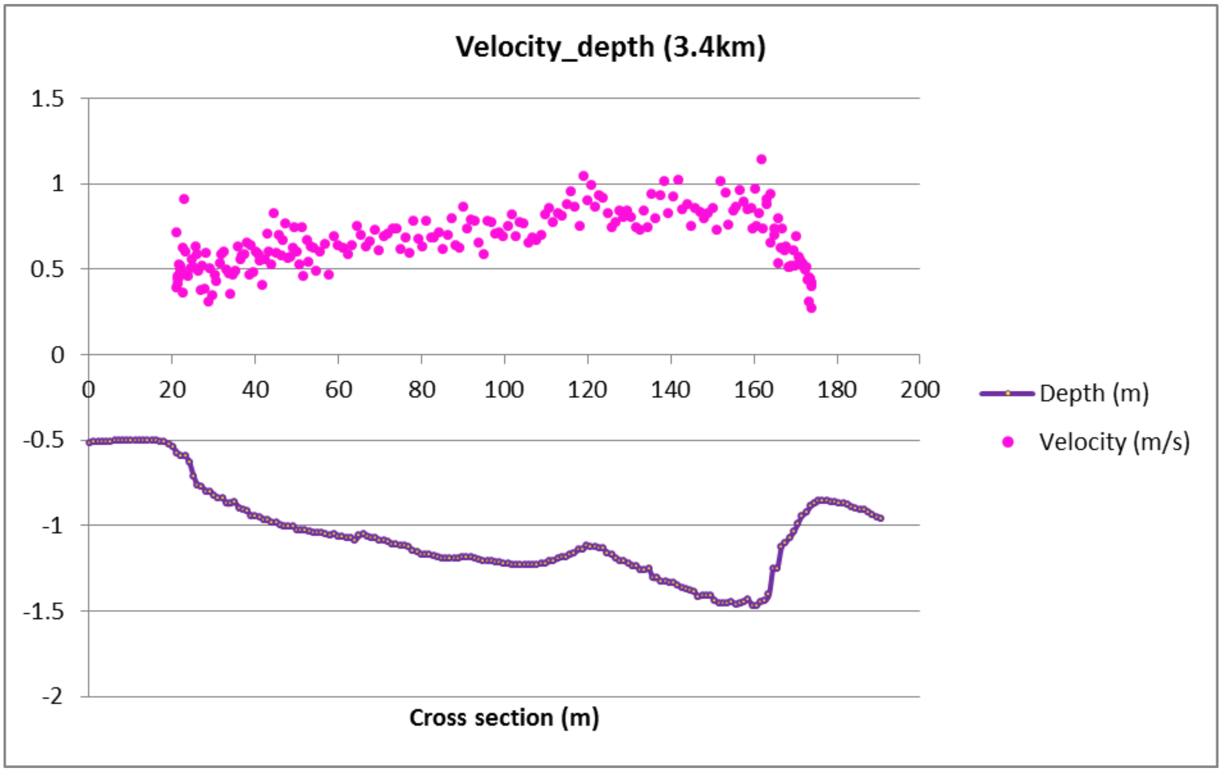
Velocity 3.3km_3



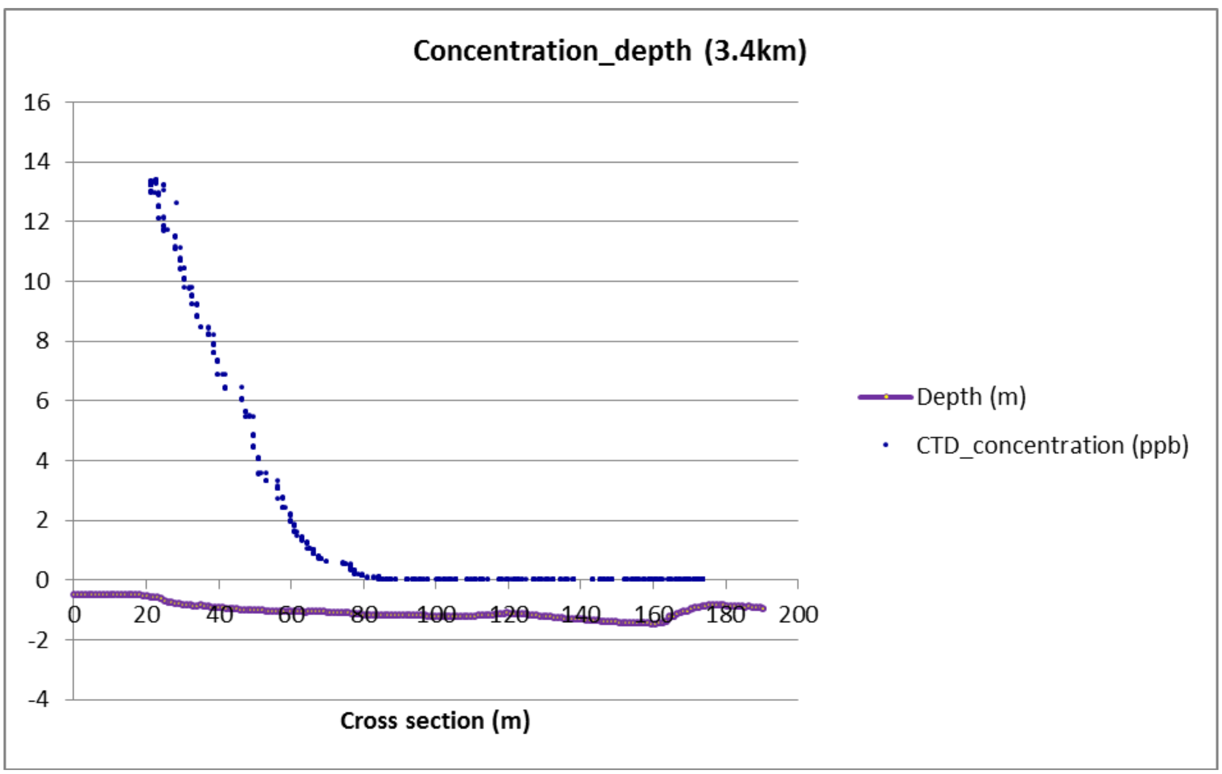
Concentration 3.3km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	6.98	7.53	7.26
0.3-0.4	3.62	4.23	3.93
0.4-0.5	0.75	1.01	0.88
0.5-0.6	0.00	0.01	0.01
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9			
0.9-1			
Approximate width(m)	195.05		
Approximate distance from outfall(km)	3.3		
Time and date	0.63	Oct 26th, 2011	



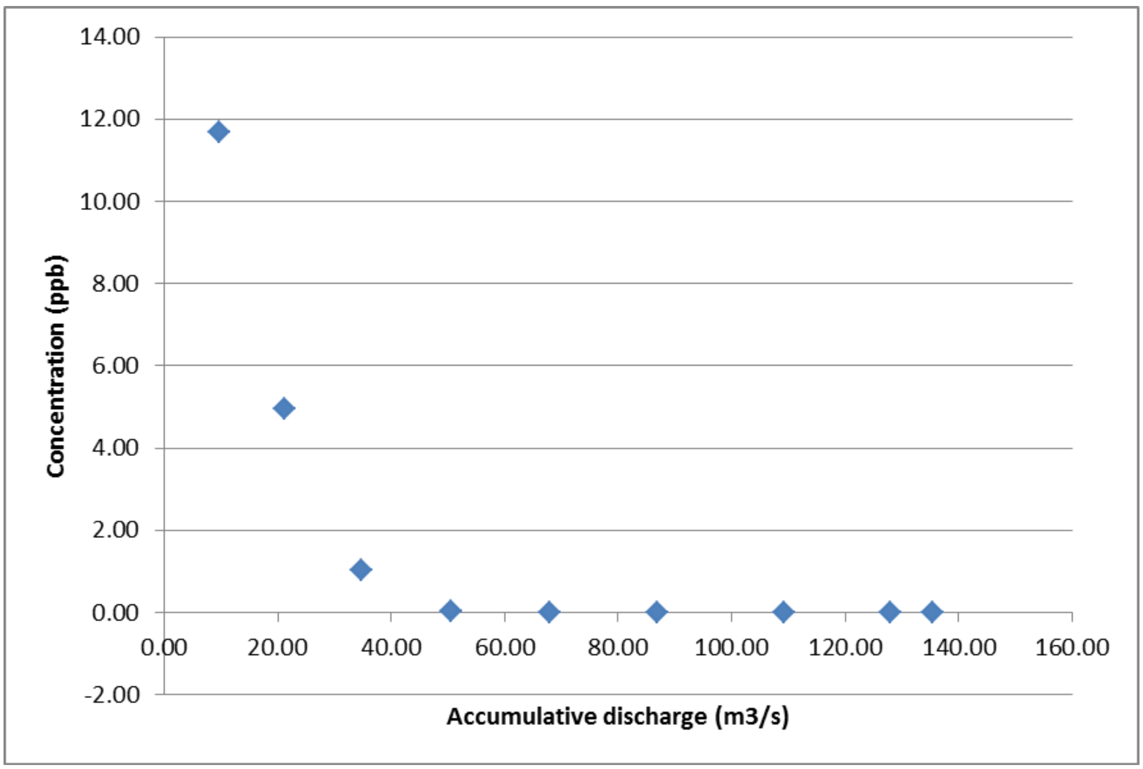


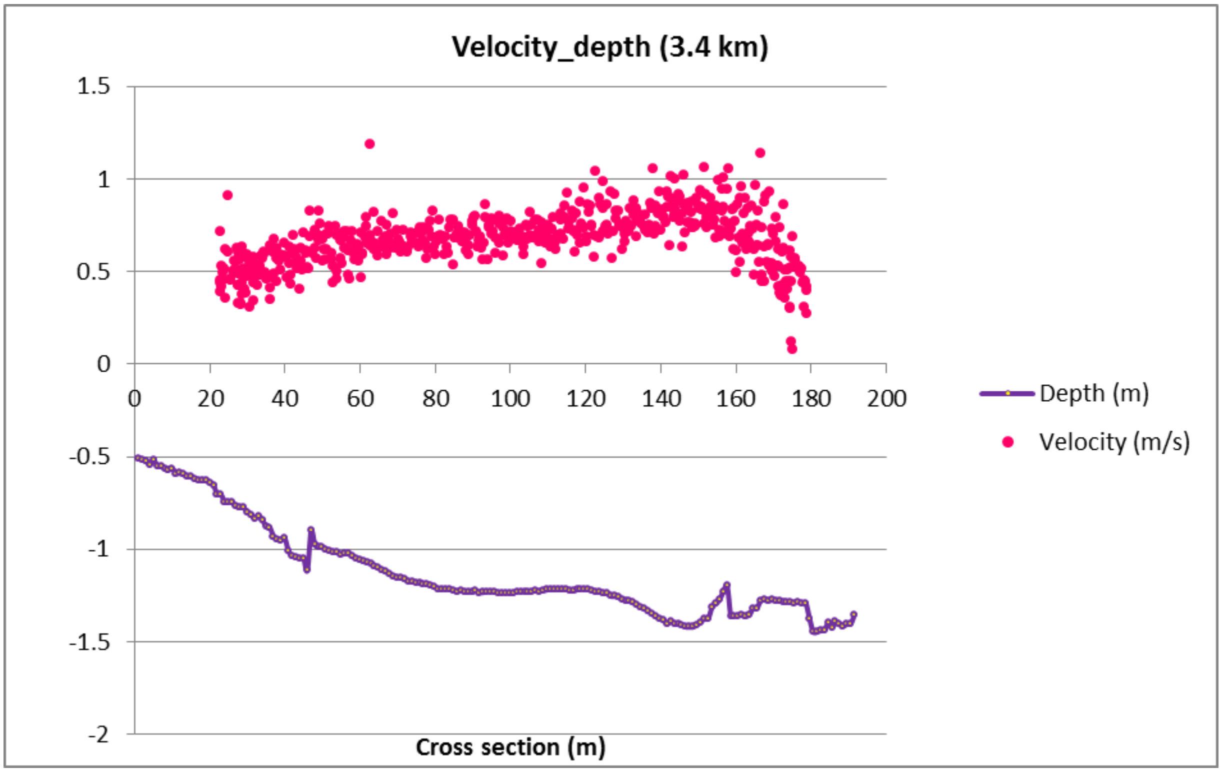
Velocity 3.4km_4



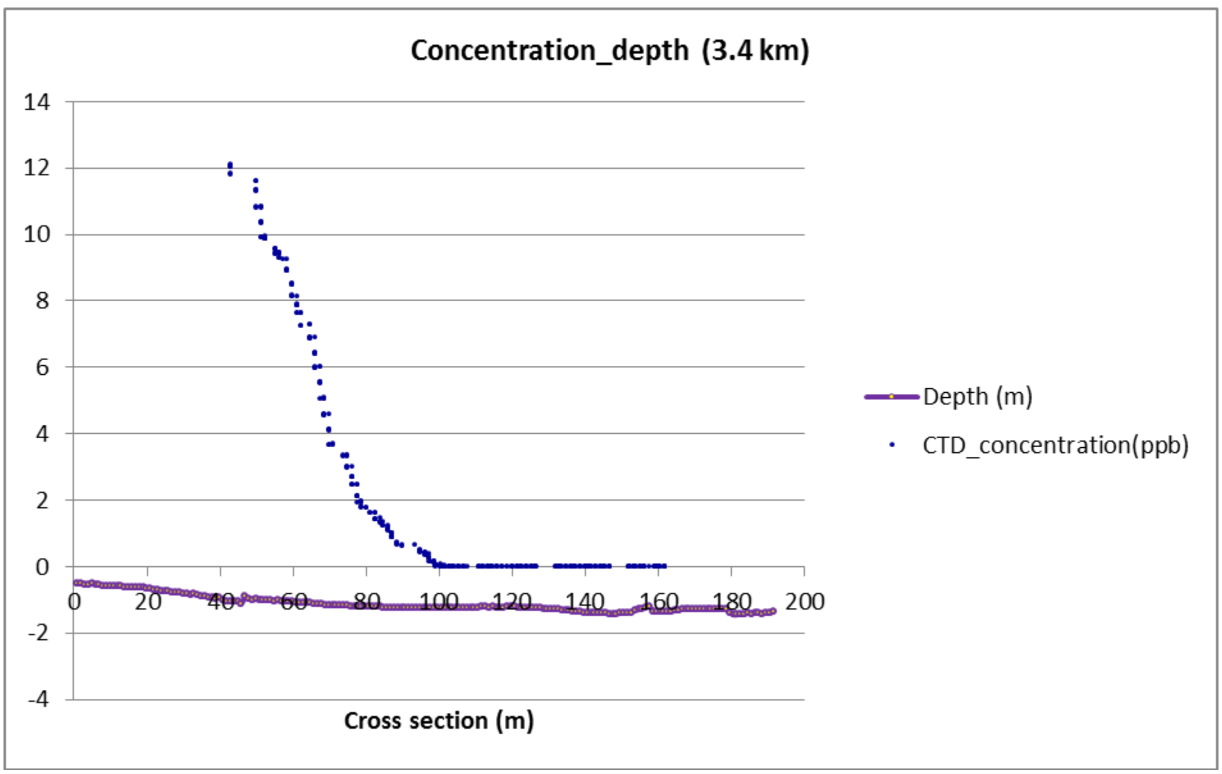
Concentration 3.4km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	11.37	11.99	11.68
0.2-0.3	4.53	5.39	4.96
0.3-0.4	0.90	1.14	1.02
0.4-0.5	0.03	0.06	0.04
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	190.63		
Approximate distance from outfall(km)	3.4		
Time and date	15:10:20	Oct 26th, 2011	



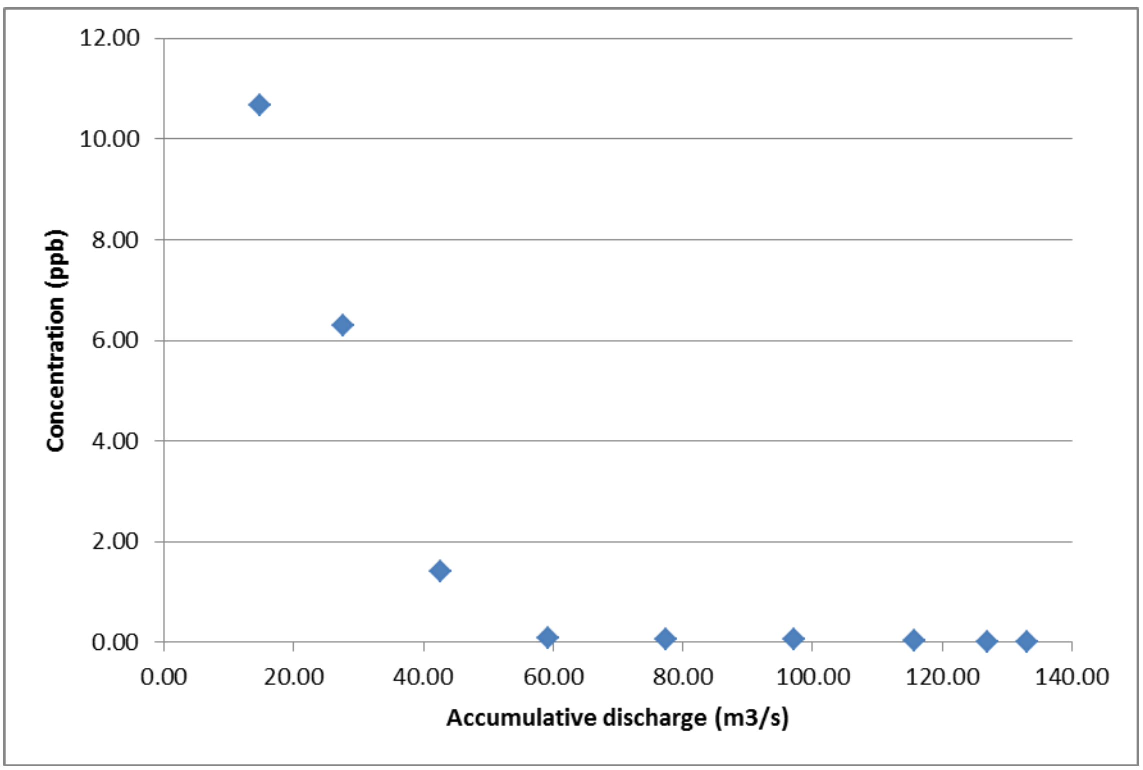


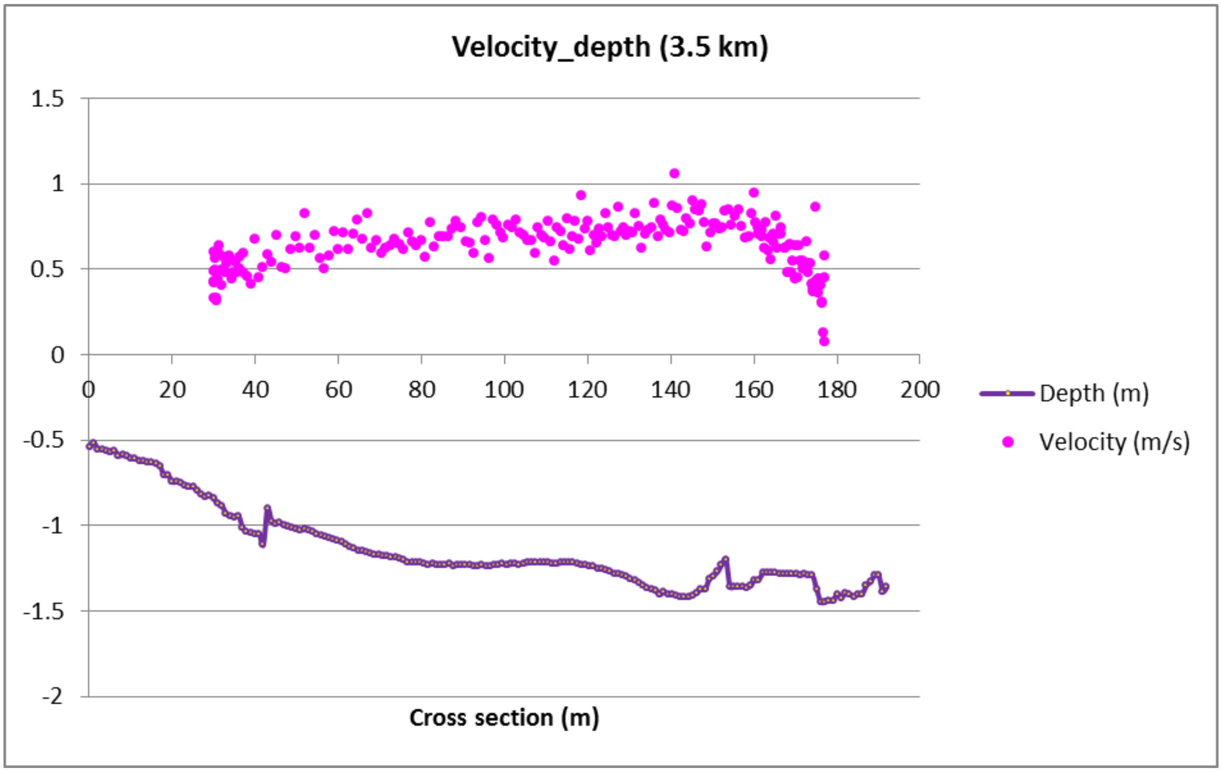
Velocity 3.4km_5



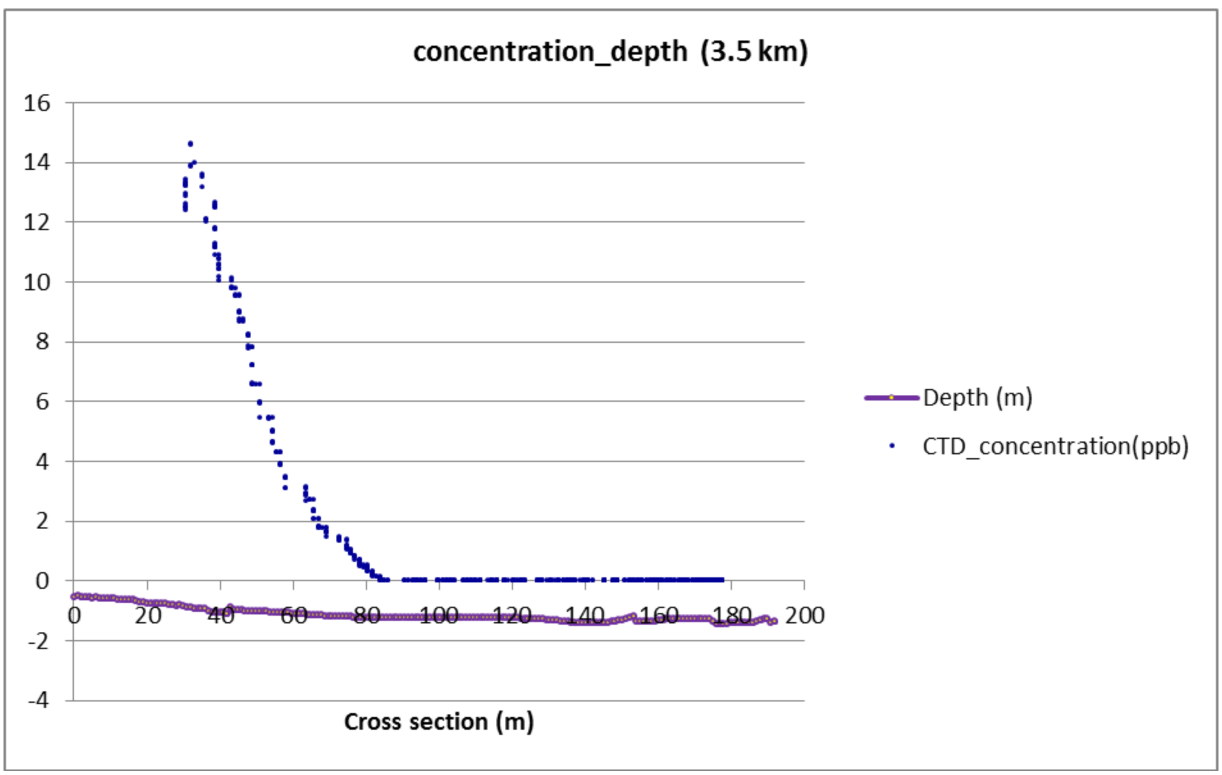
Concentration 3.4km_5

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	10.38	10.10	10.66
0.2-0.3	5.80	5.33	6.28
0.3-0.4	1.27	1.13	1.41
0.4-0.5	0.06	0.04	0.09
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0	0	0
0.9-1	0	0	0
Approximate width(m)	192.1		
Approximate distance from outfall(km)	3.4		
Time and date	15:10:20	Oct 26th, 2011	



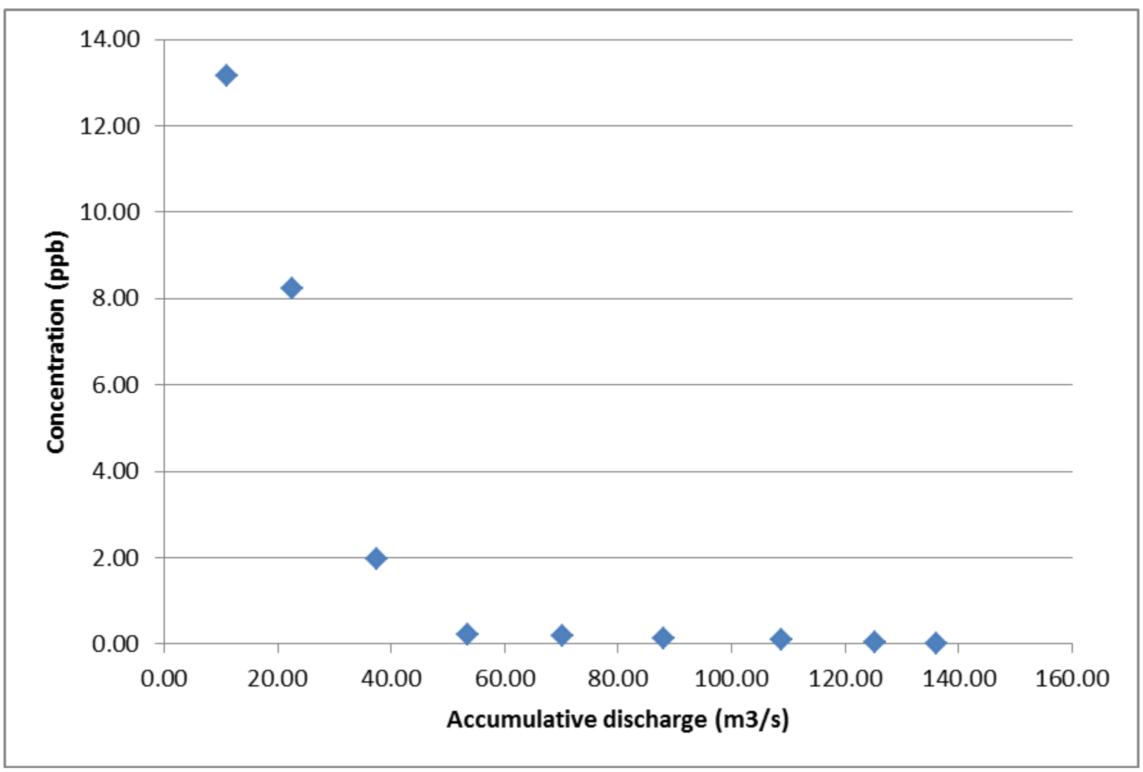


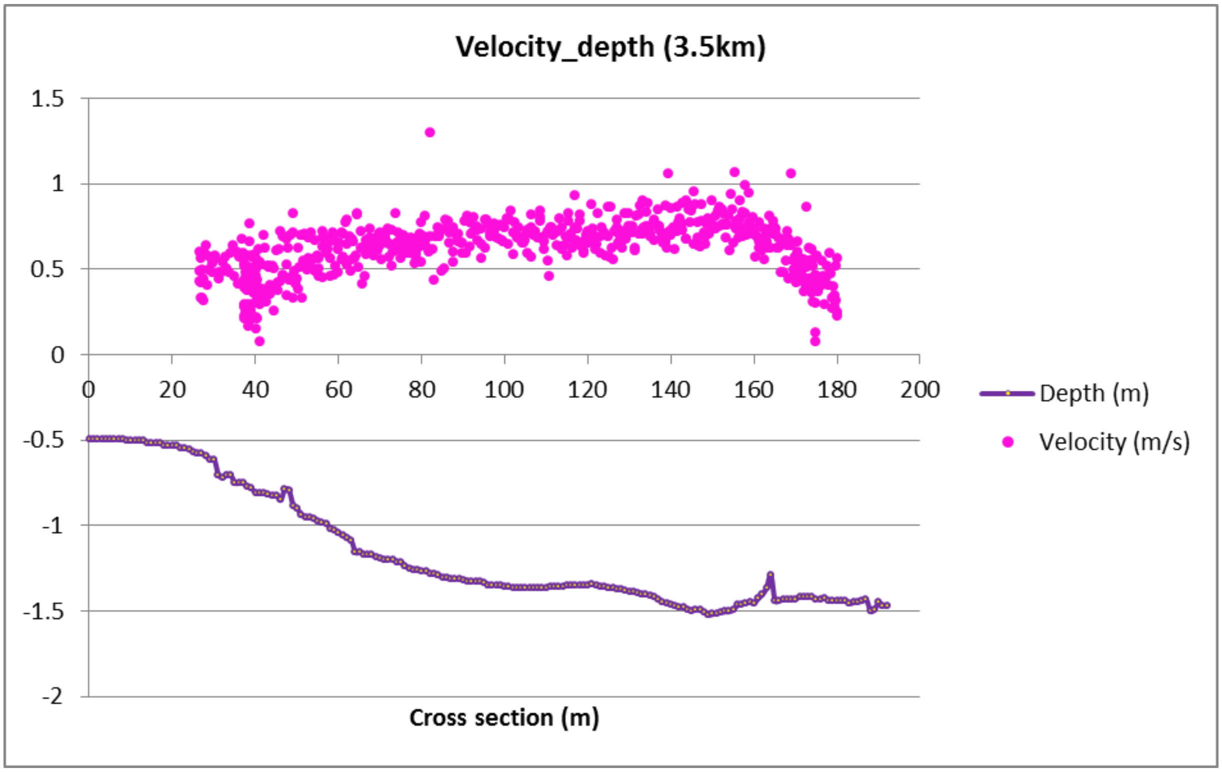
Velocity 3.5km_6



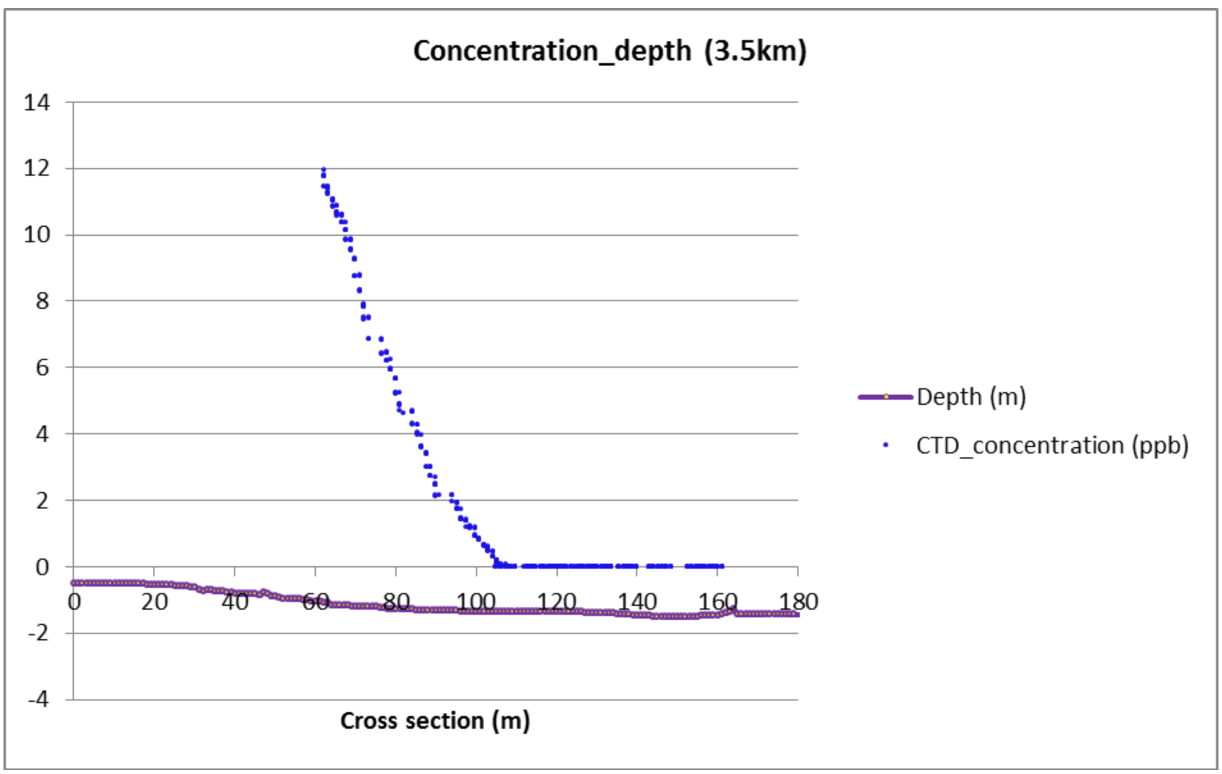
Concentration 3.5km_6

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	12.84	13.46	13.15
0.2-0.3	7.68	8.79	8.24
0.3-0.4	1.78	2.18	1.98
0.4-0.5	0.15	0.28	0.22
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	192.65		
Approximate distance from outfall(km)	3.5		
Time and date	15:10:20	Oct 26th, 2011	



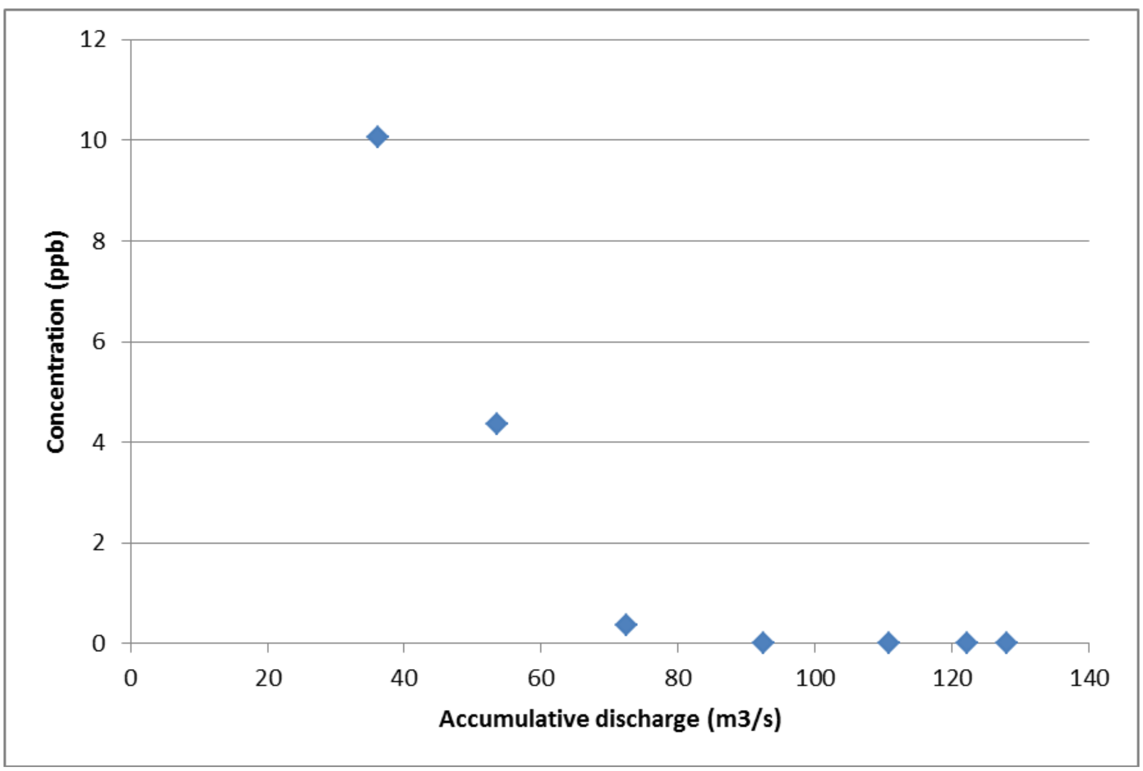


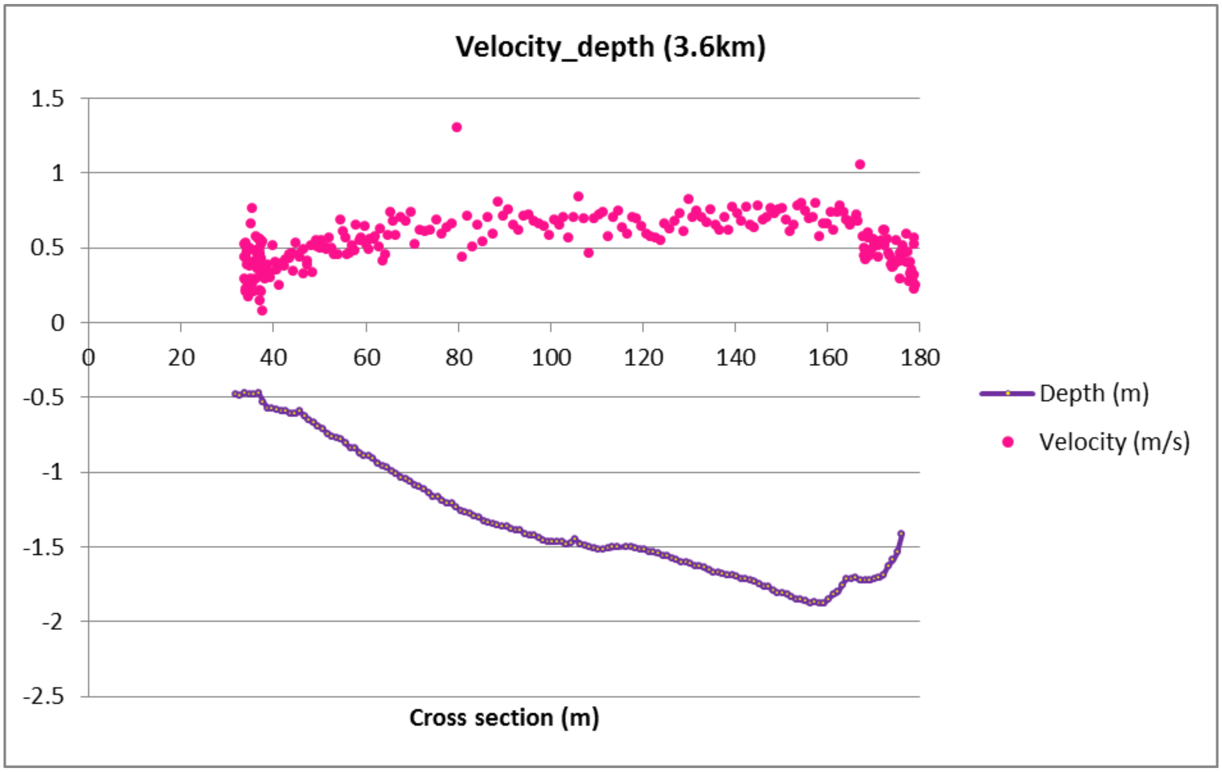
Velocity 3.5km_7



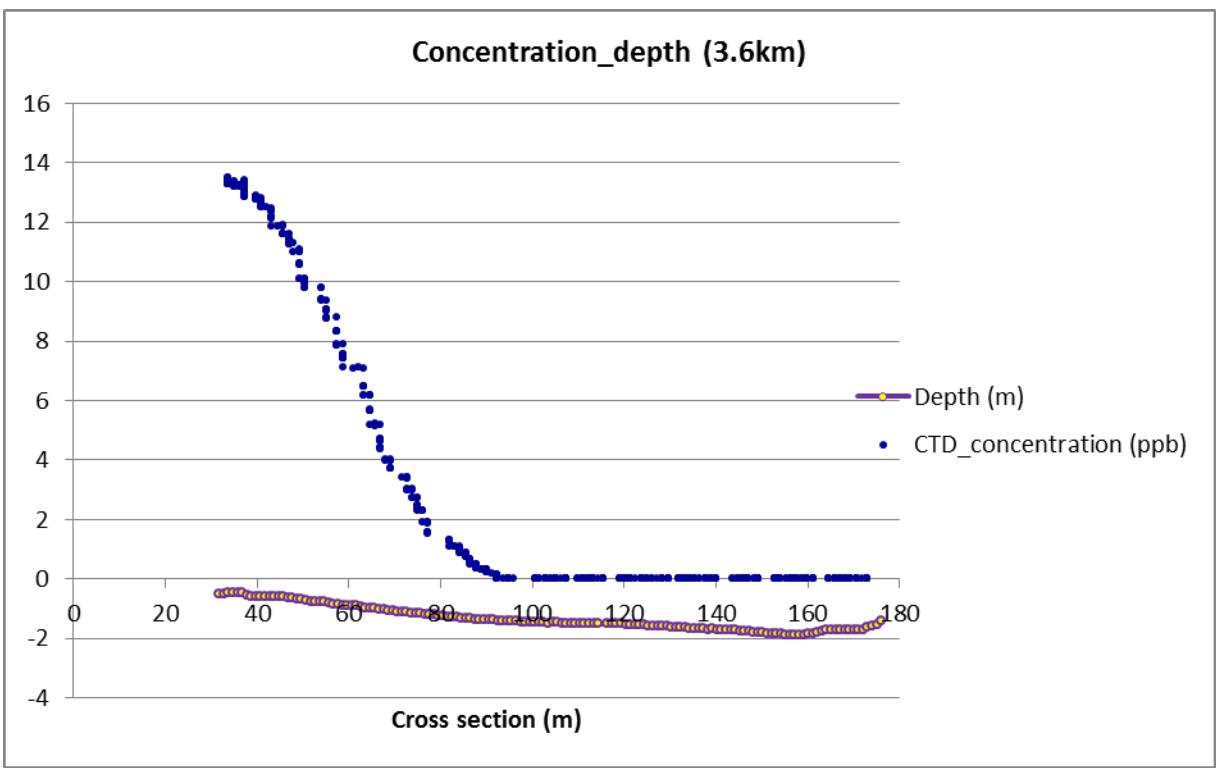
Concentration 3.5km_7

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3			
0.3-0.4	9.72	9.38	10.07
0.4-0.5	4.01	3.66	4.36
0.5-0.6	0.30	0.22	0.38
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	192.26		
Approximate distance from outfall(km)	3.5		
Time and date	15:10:20	Oct 26th, 2011	



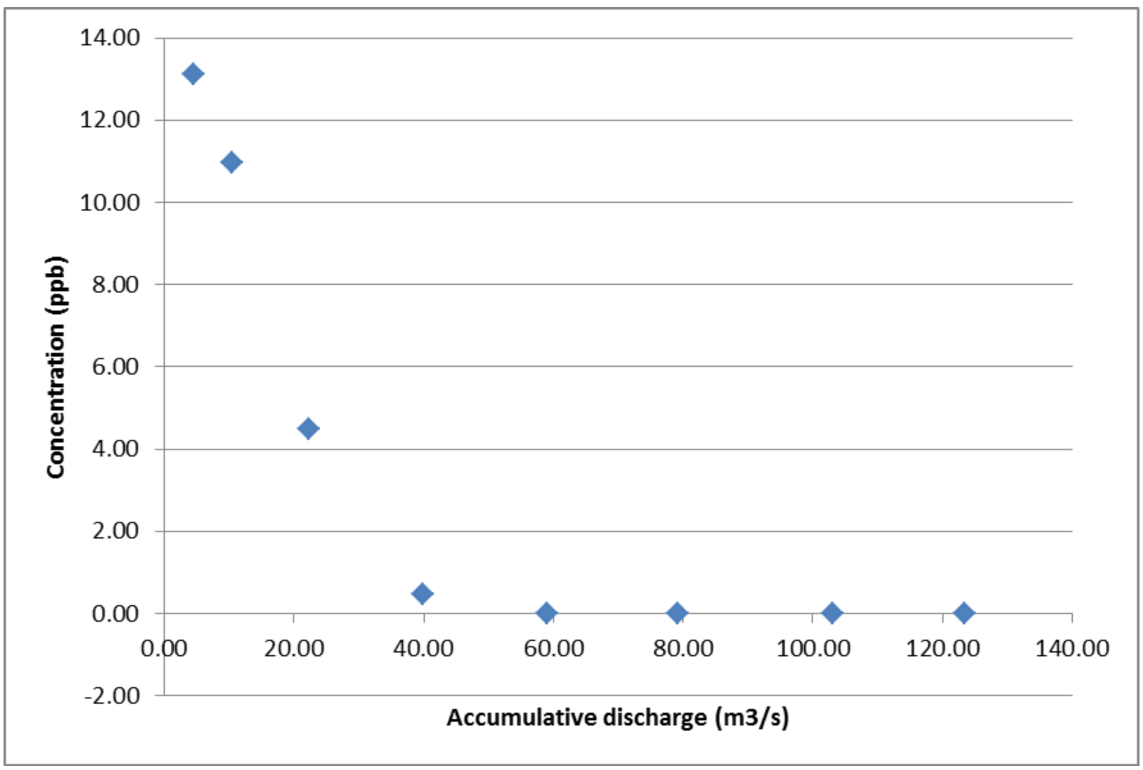


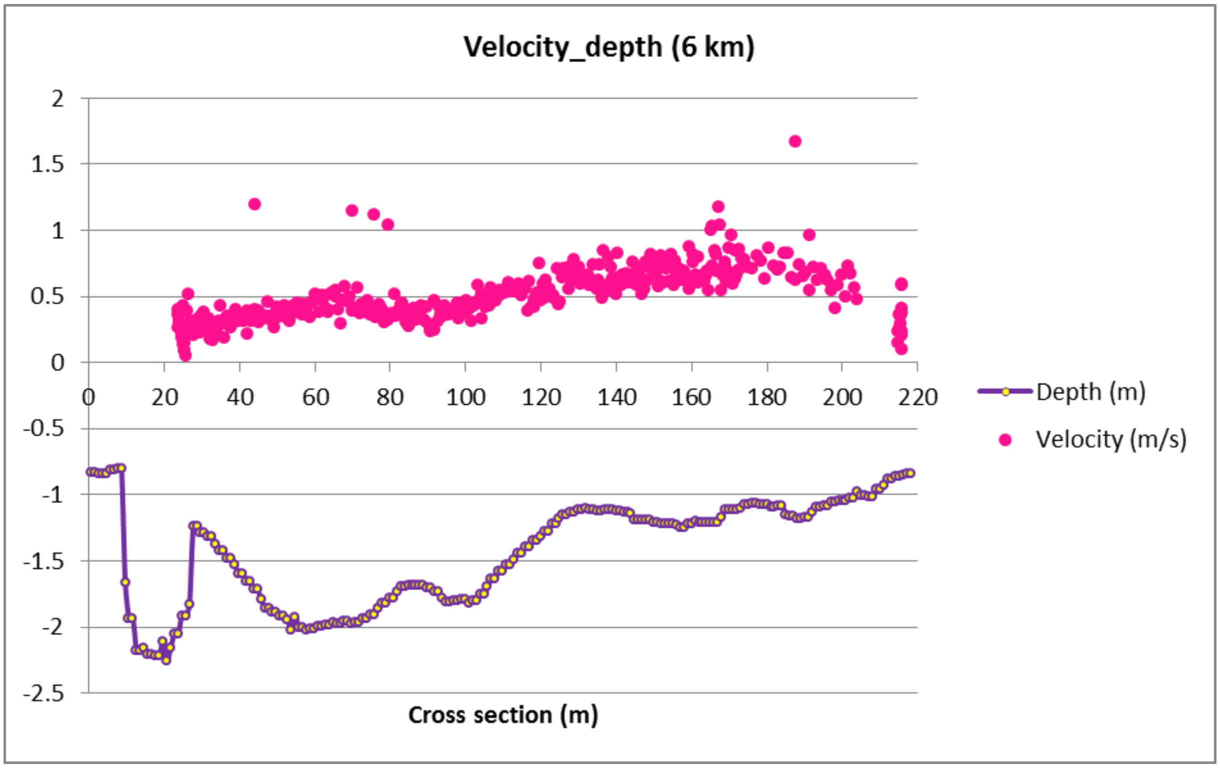
Velocity 3.6km_8



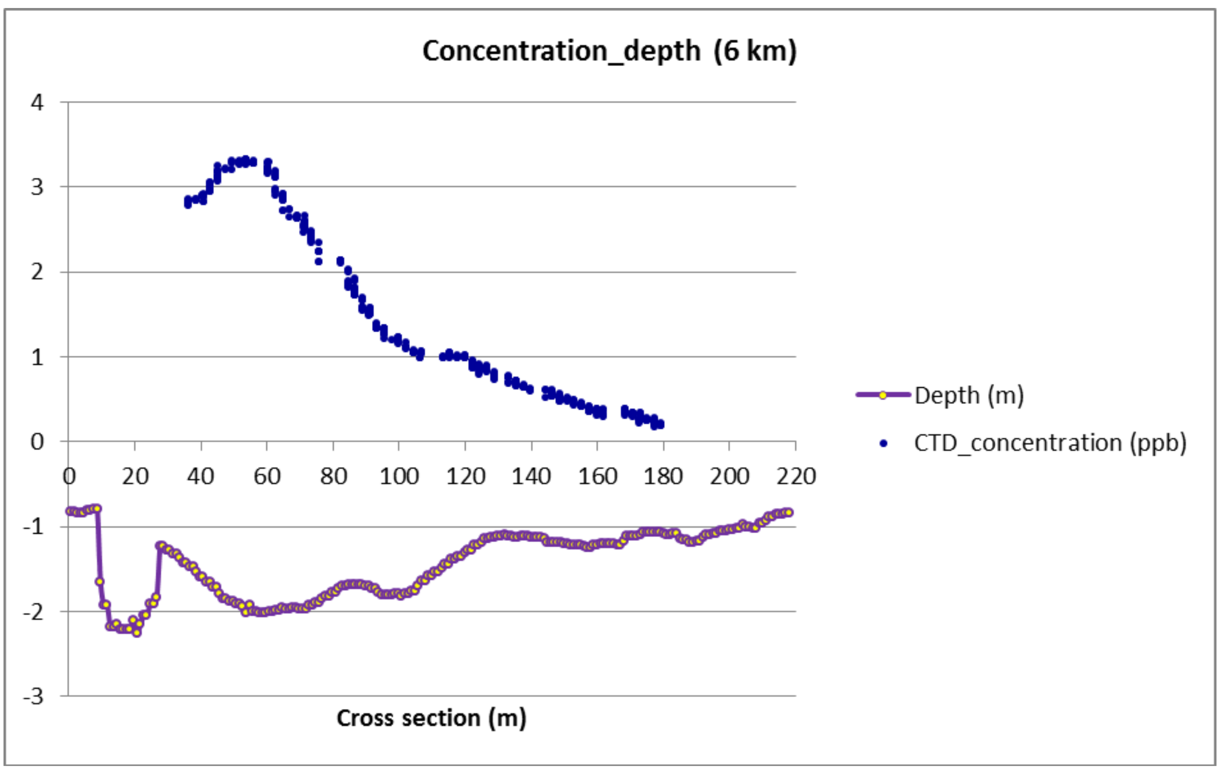
Concentration 3.6km_8

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	13.10	13.15	13.13
0.2-0.3	10.65	11.29	10.97
0.3-0.4	4.05	4.92	4.49
0.4-0.5	0.37	0.57	0.47
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	193.38		
Approximate distance from outfall(km)	3.6		
Time and date	15:10:20	Oct 26th, 2011	



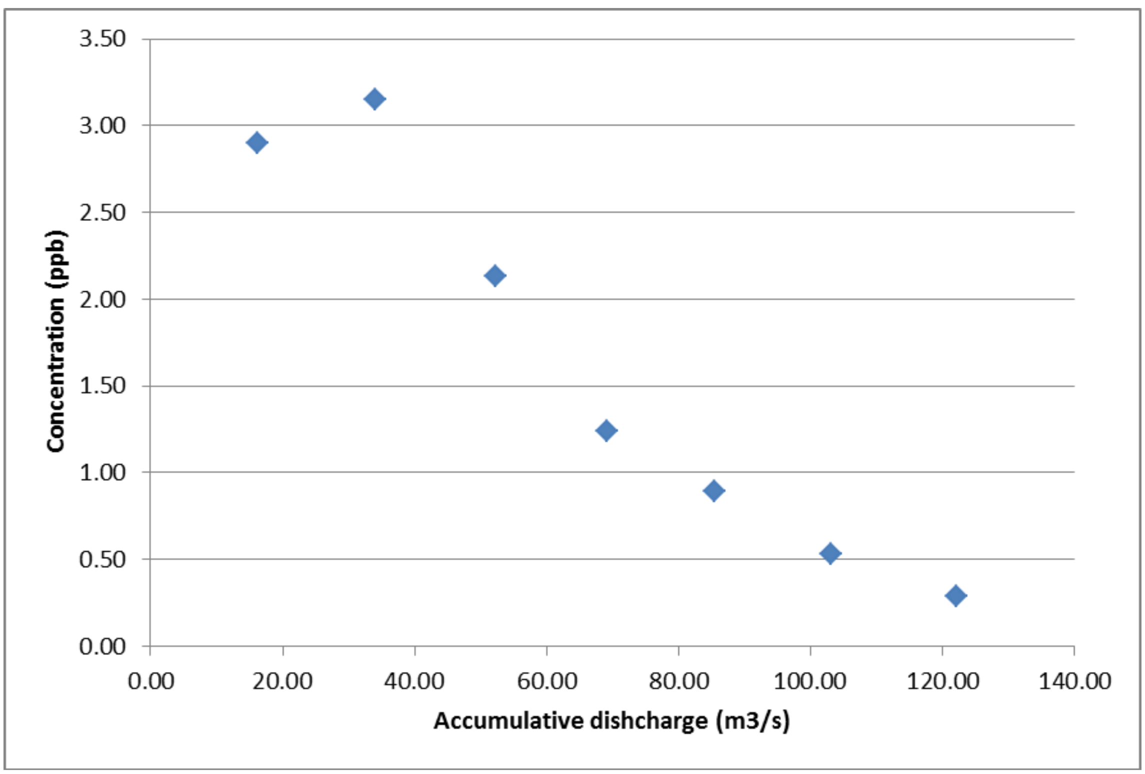


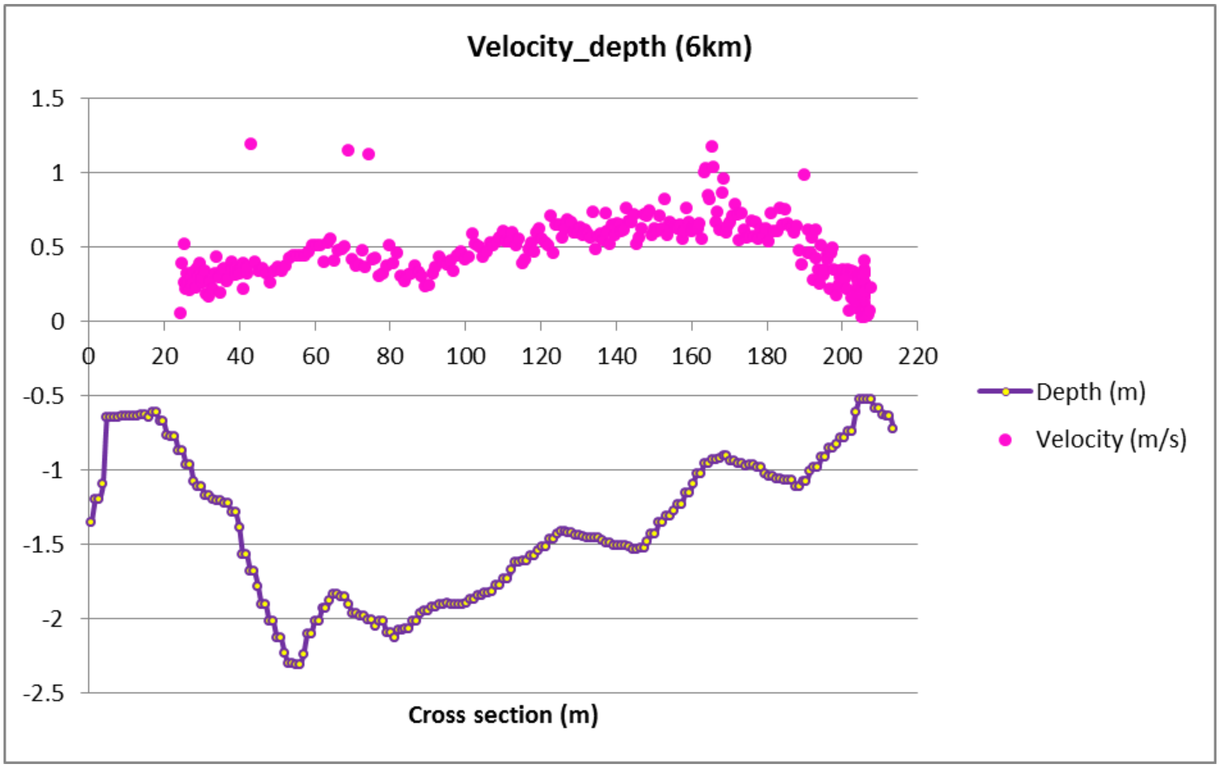
Velocity 6km_1



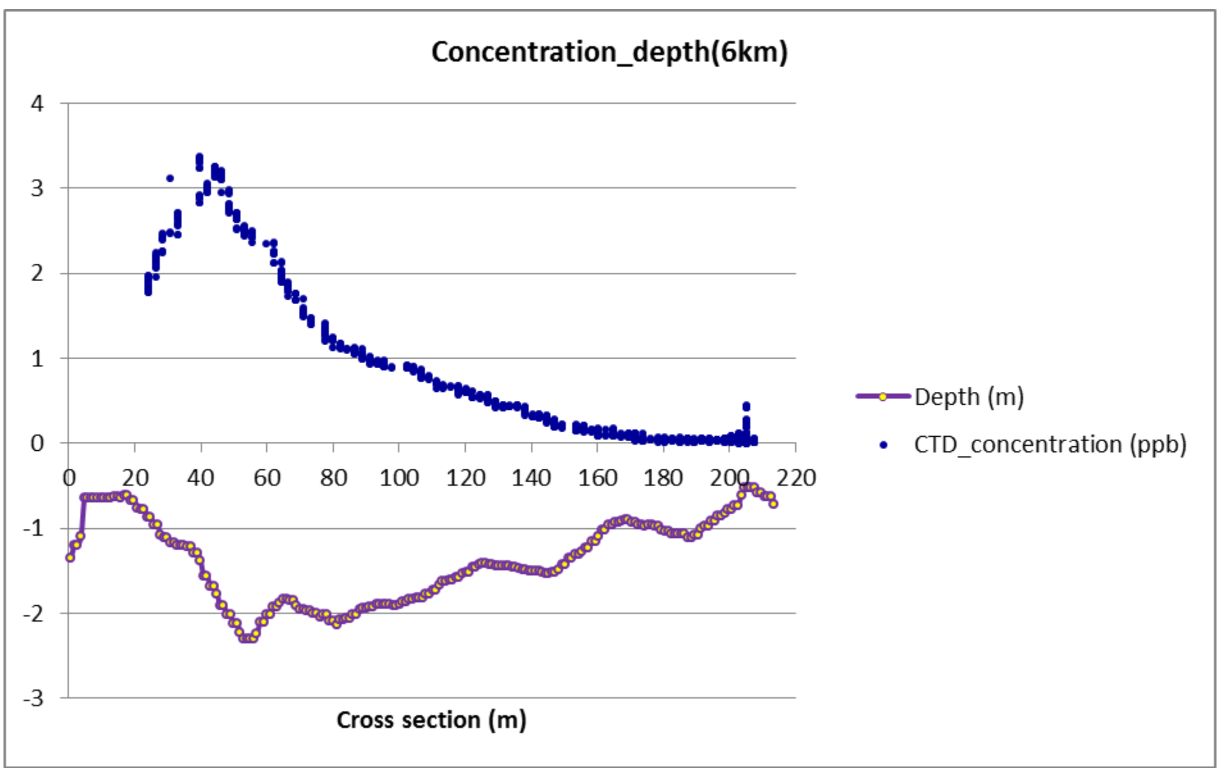
Concentration 6km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	2.87	2.93	2.90
0.2-0.3	3.11	3.19	3.15
0.3-0.4	2.05	2.22	2.13
0.4-0.5	1.20	1.28	1.24
0.5-0.6	0.87	0.92	0.90
0.6-0.7	0.51	0.56	0.53
0.7-0.8	0.27	0.30	0.29
0.8-0.9			
0.9-1			
Approximate width(m)	225.31		
Approximate distance from outfall(km)	6		
Time and date	15:39:14	Oct 26th, 2011	



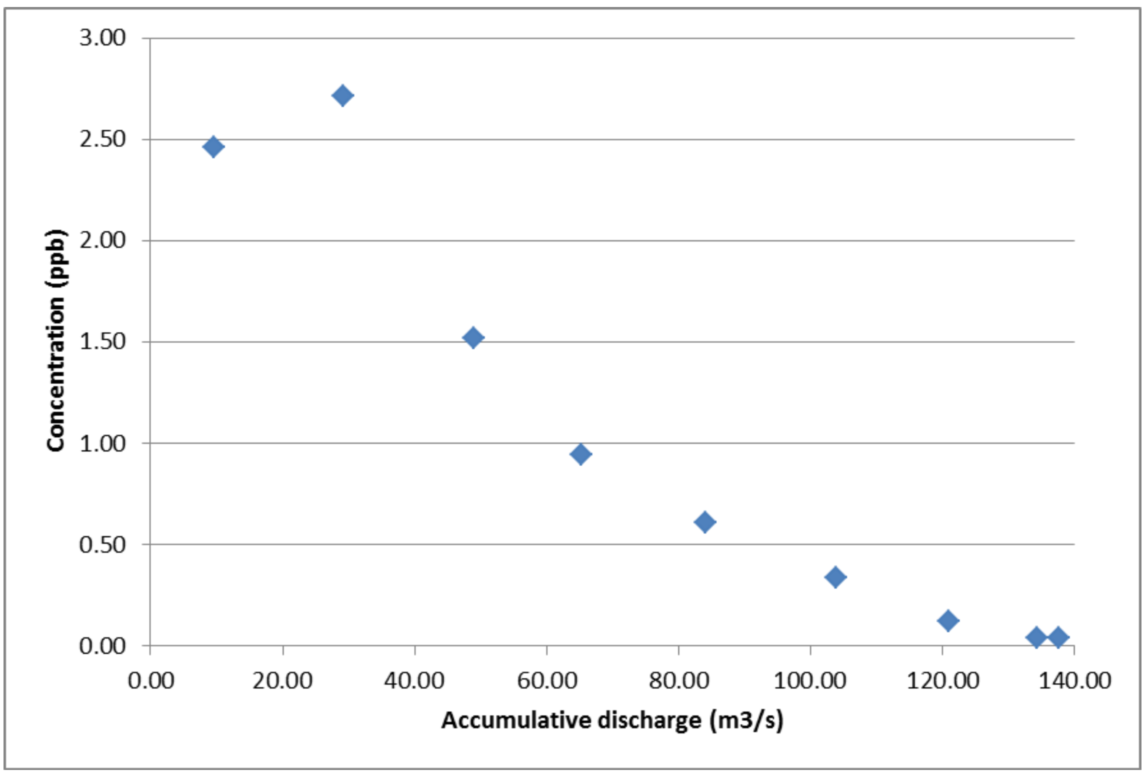


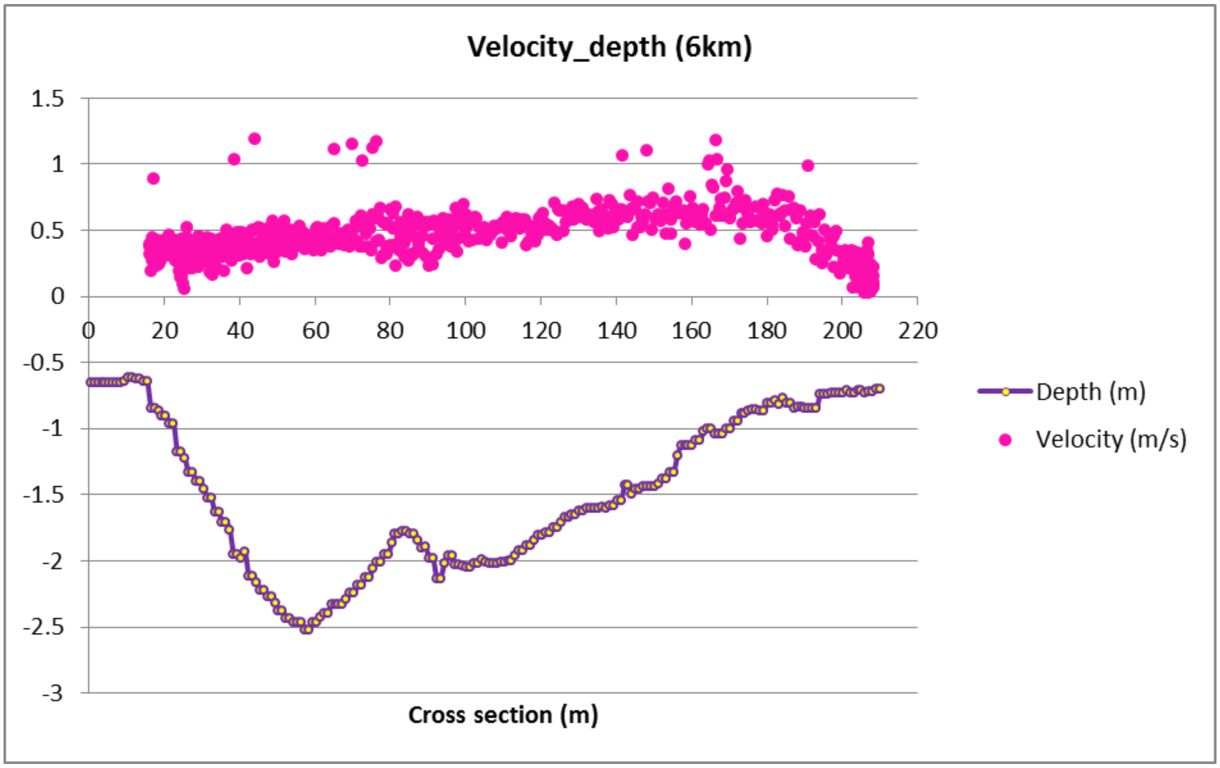
Velocity 6km_2



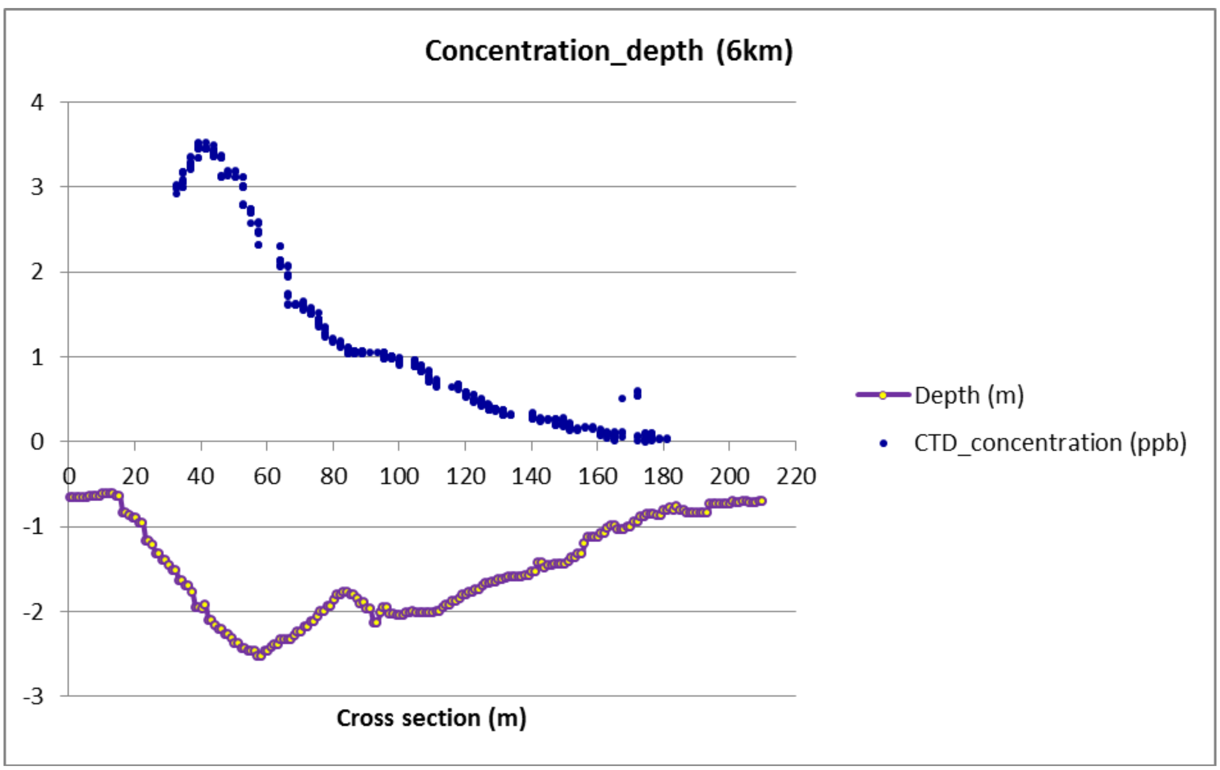
Concentration 6km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	2.36	2.56	2.46
0.2-0.3	2.64	2.79	2.71
0.3-0.4	1.45	1.58	1.52
0.4-0.5	0.92	0.96	0.94
0.5-0.6	0.59	0.62	0.61
0.6-0.7	0.32	0.35	0.33
0.7-0.8	0.12	0.13	0.12
0.8-0.9	0.03	0.04	0.04
0.9-1	0.03	0.04	0.04
Approximate width(m)	214.18		
Approximate distance from outfall(km)	6		
Time and date	15:39:14	Oct 26th, 2011	



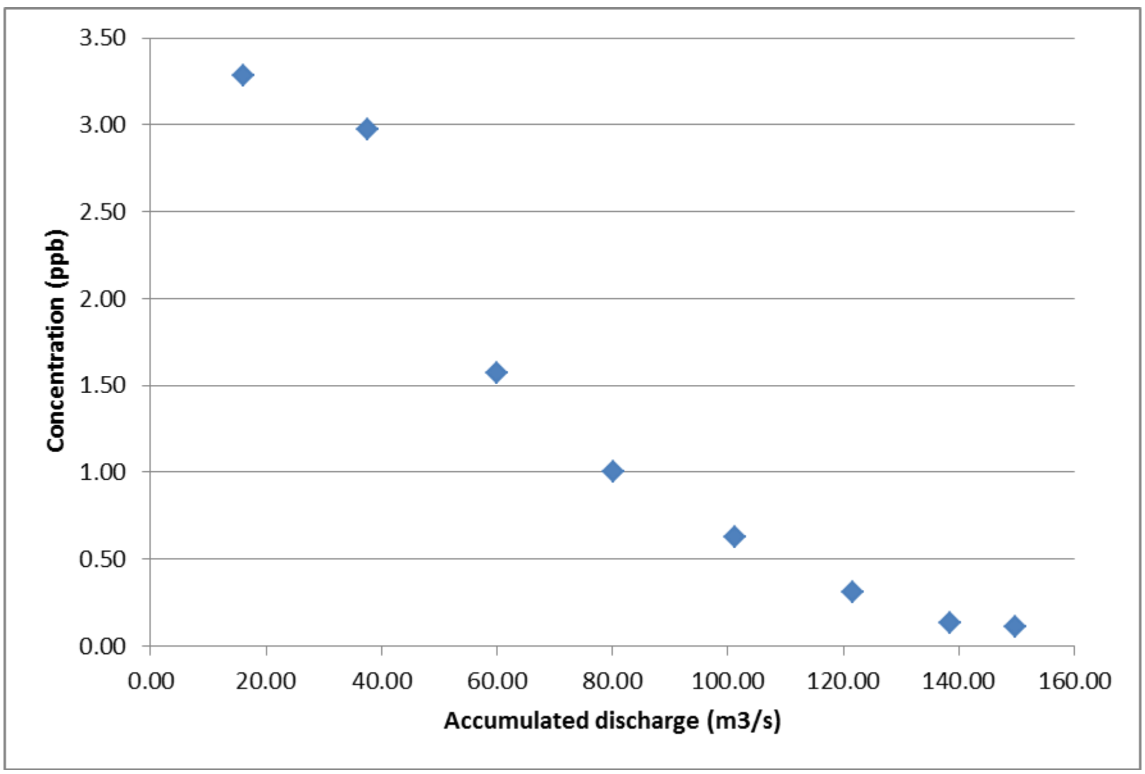


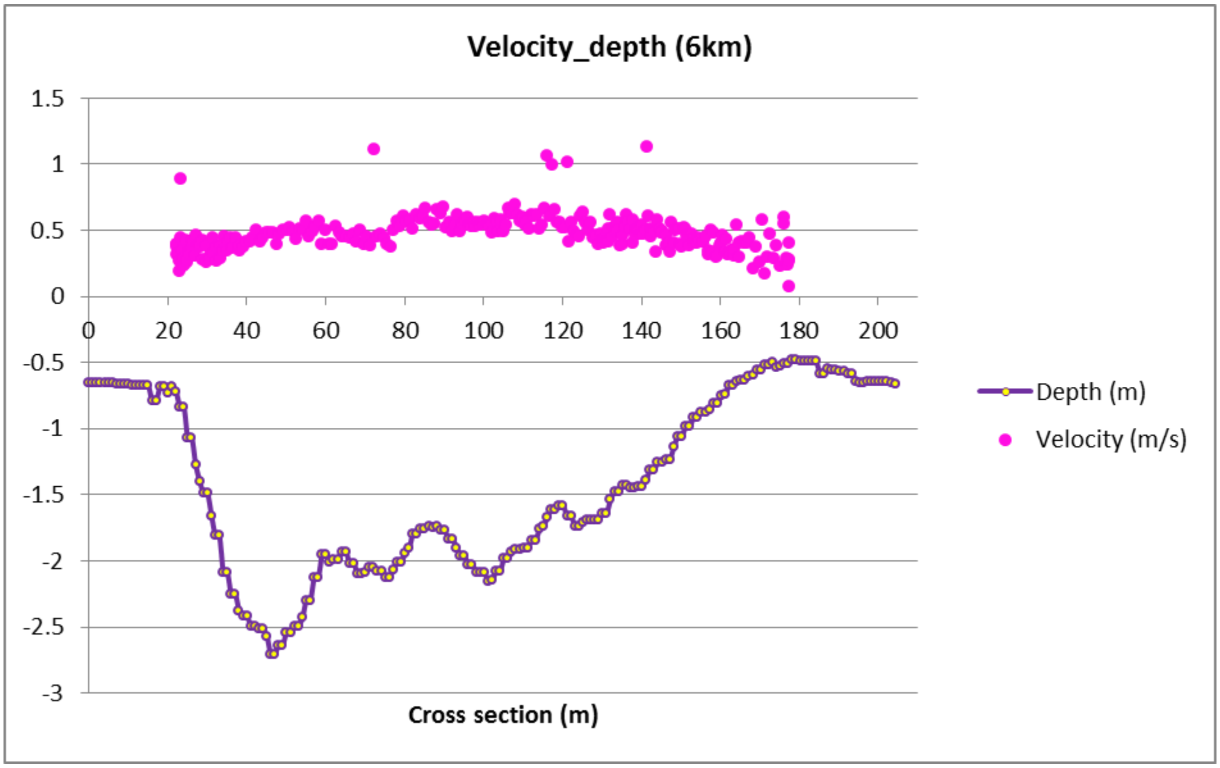
Velocity 6km_3



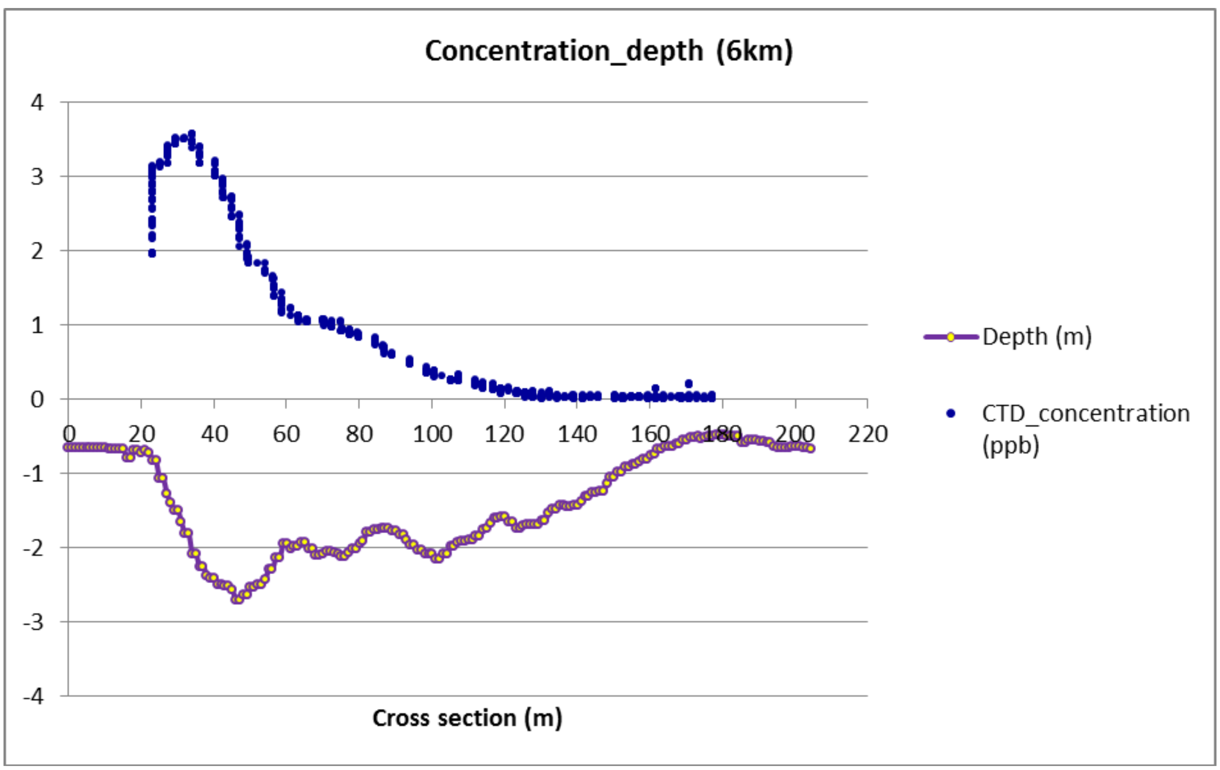
Concentration 6km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	3.23	3.34	3.28
0.2-0.3	2.88	3.06	2.97
0.3-0.4	1.50	1.64	1.57
0.4-0.5	0.99	1.02	1.00
0.5-0.6	0.59	0.66	0.63
0.6-0.7	0.29	0.33	0.31
0.7-0.8	0.12	0.15	0.13
0.8-0.9	0.04	0.17	0.11
0.9-1			
Approximate width(m)	210.95		
Approximate distance from outfall(km)	6		
Time and date	15:39:14	Oct 26th, 2011	



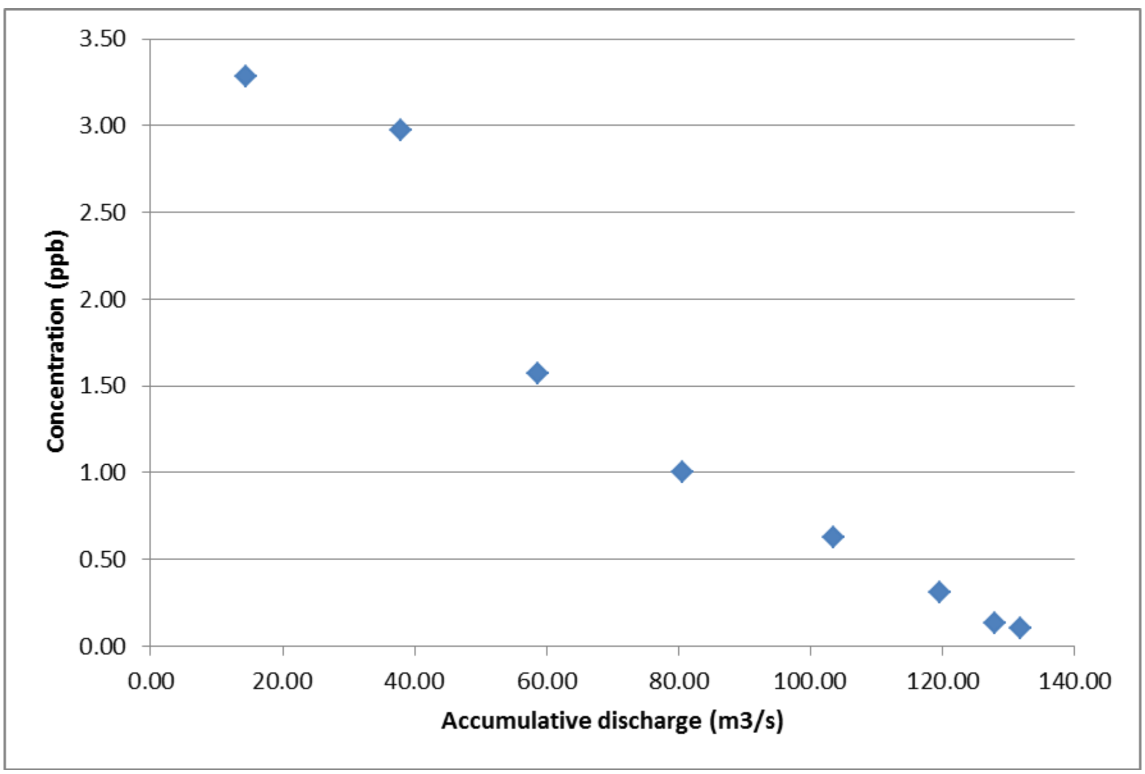


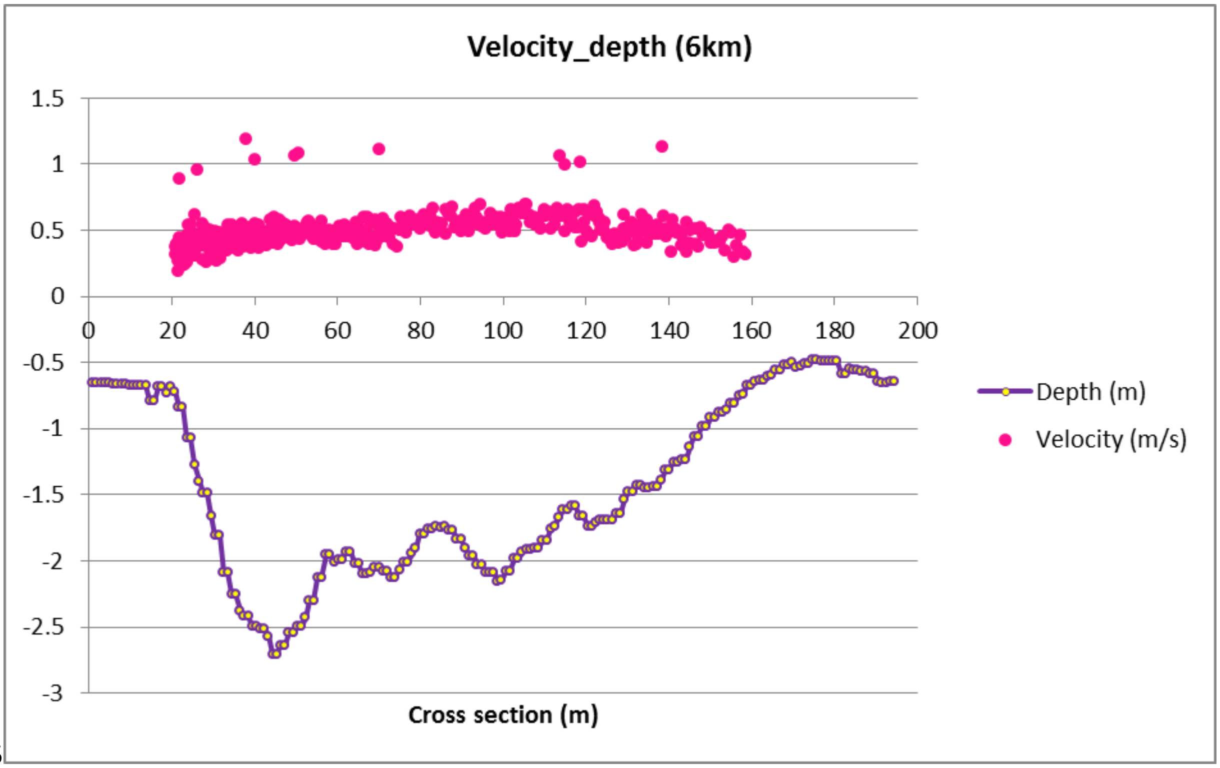
Velocity 6km_4



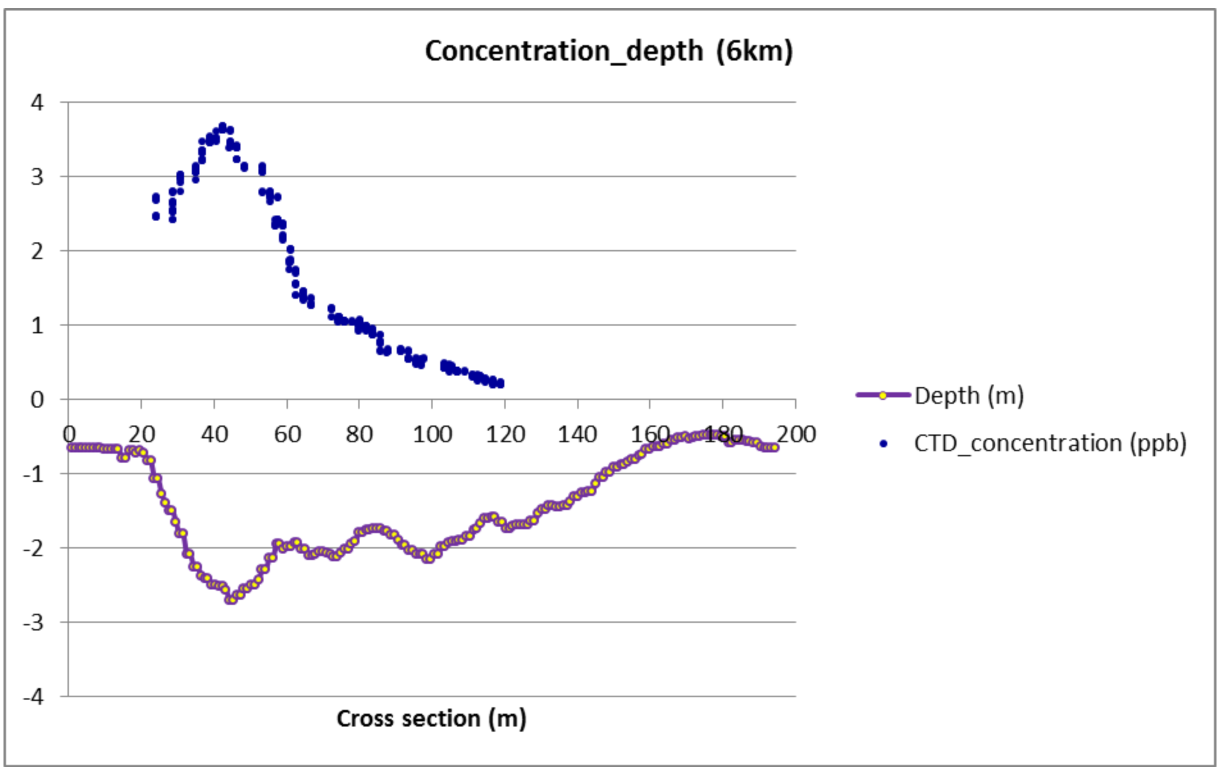
Concentration 6km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	2.96	3.12	3.04
0.2-0.3	1.90	2.13	2.01
0.3-0.4	0.97	1.00	0.99
0.4-0.5	0.50	0.57	0.54
0.5-0.6	0.19	0.21	0.20
0.6-0.7	0.04	0.05	0.04
0.7-0.8	0.02	0.03	0.03
0.8-0.9	0.02	0.04	0.03
0.9-1			
Approximate width(m)	204.56		
Approximate distance from outfall(km)	6		
Time and date	15:39:14	Oct 26th, 2011	



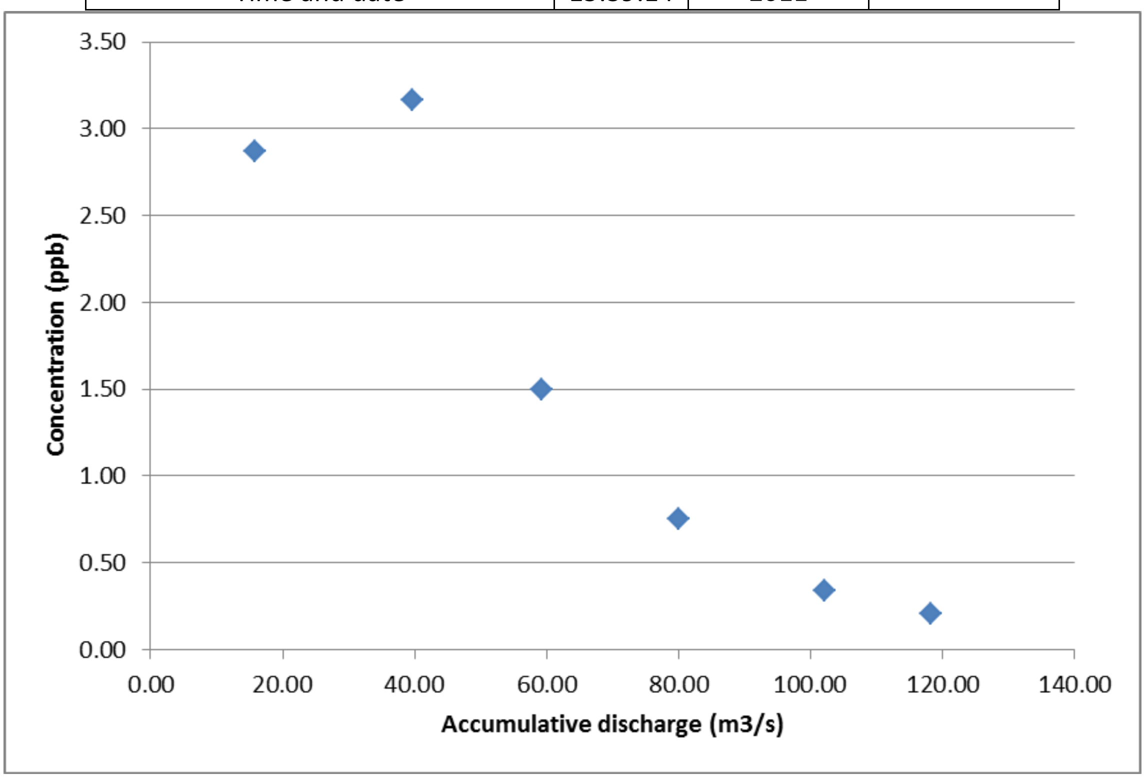
5 

Velocity 6km_5

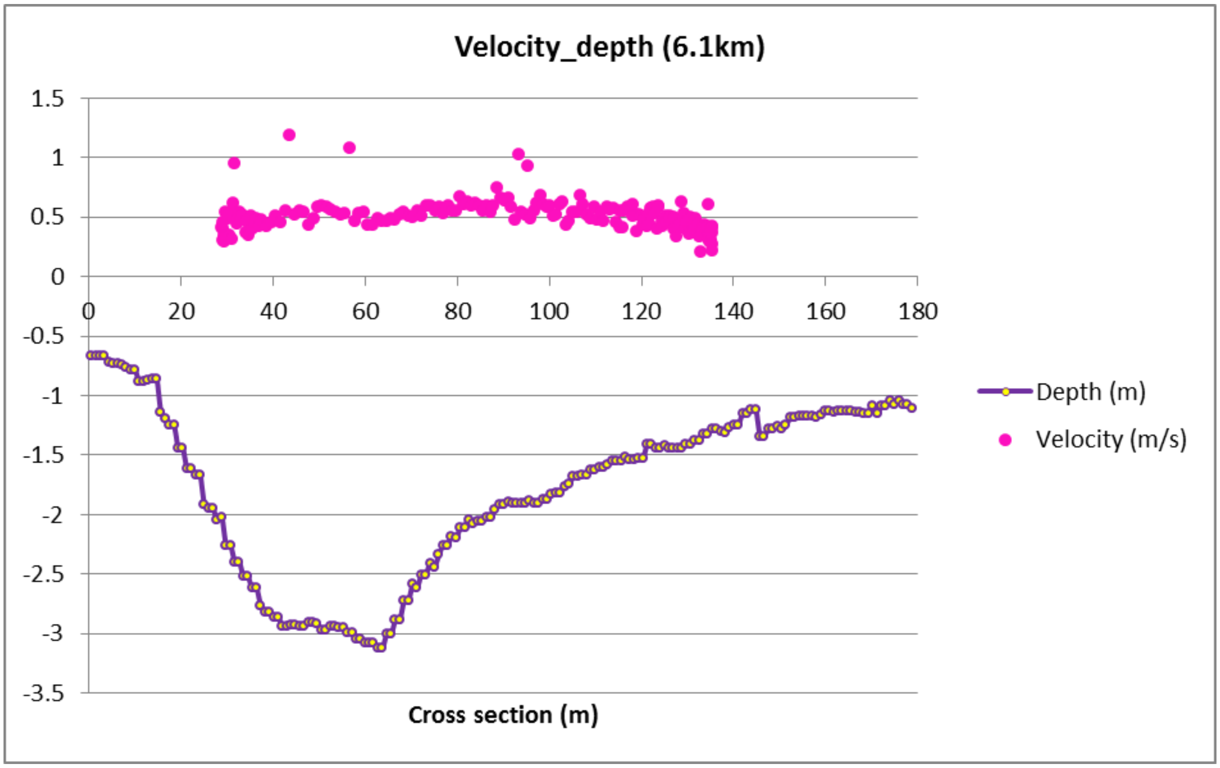


Concentration 6km_5

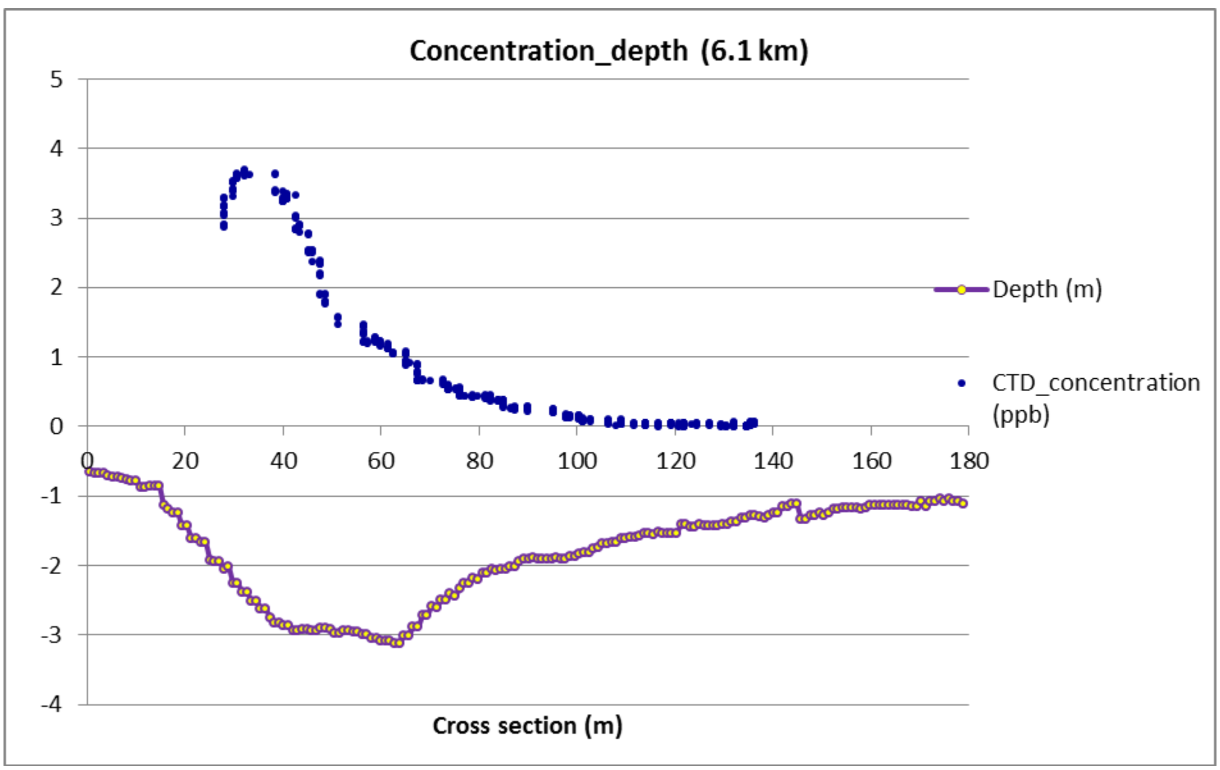
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	2.79	2.95	2.87
0.2-0.3	3.07	3.26	3.16
0.3-0.4	1.40	1.60	1.50
0.4-0.5	0.71	0.80	0.75
0.5-0.6	0.32	0.36	0.34
0.6-0.7	0.19	0.22	0.20
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	194.87		
Approximate distance from outfall(km)	6		
Time and date	15:39:14	Oct 26th, 2011	



6

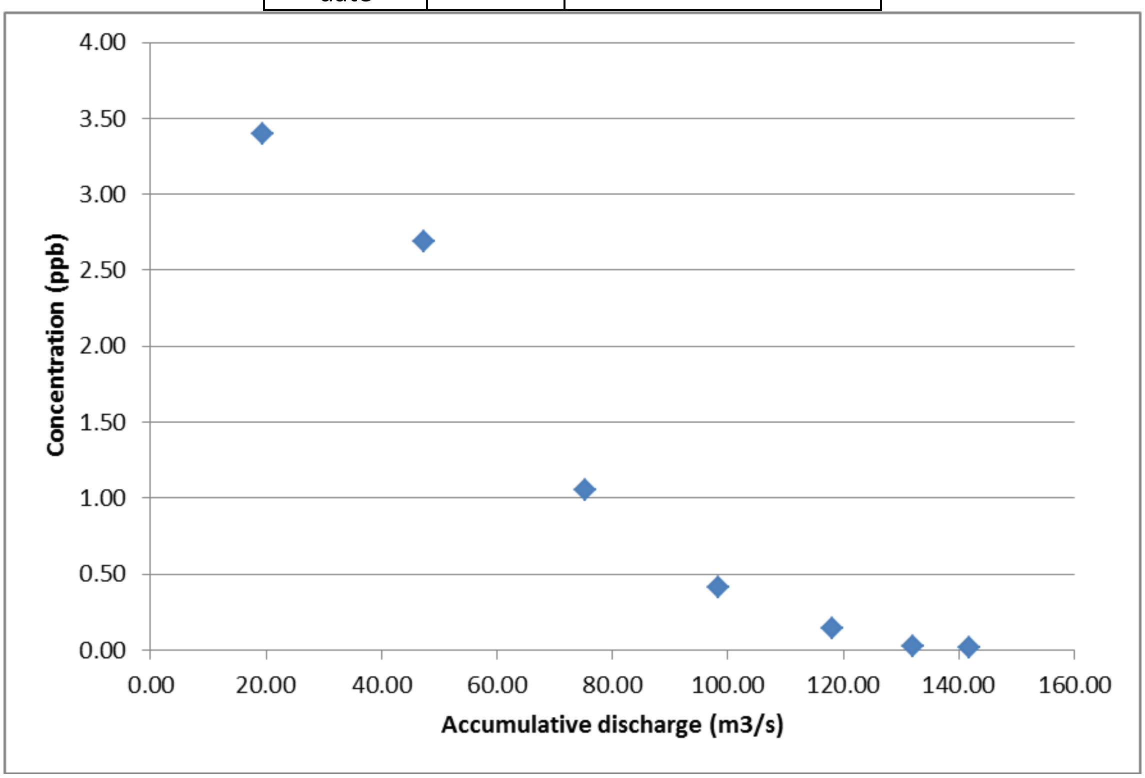


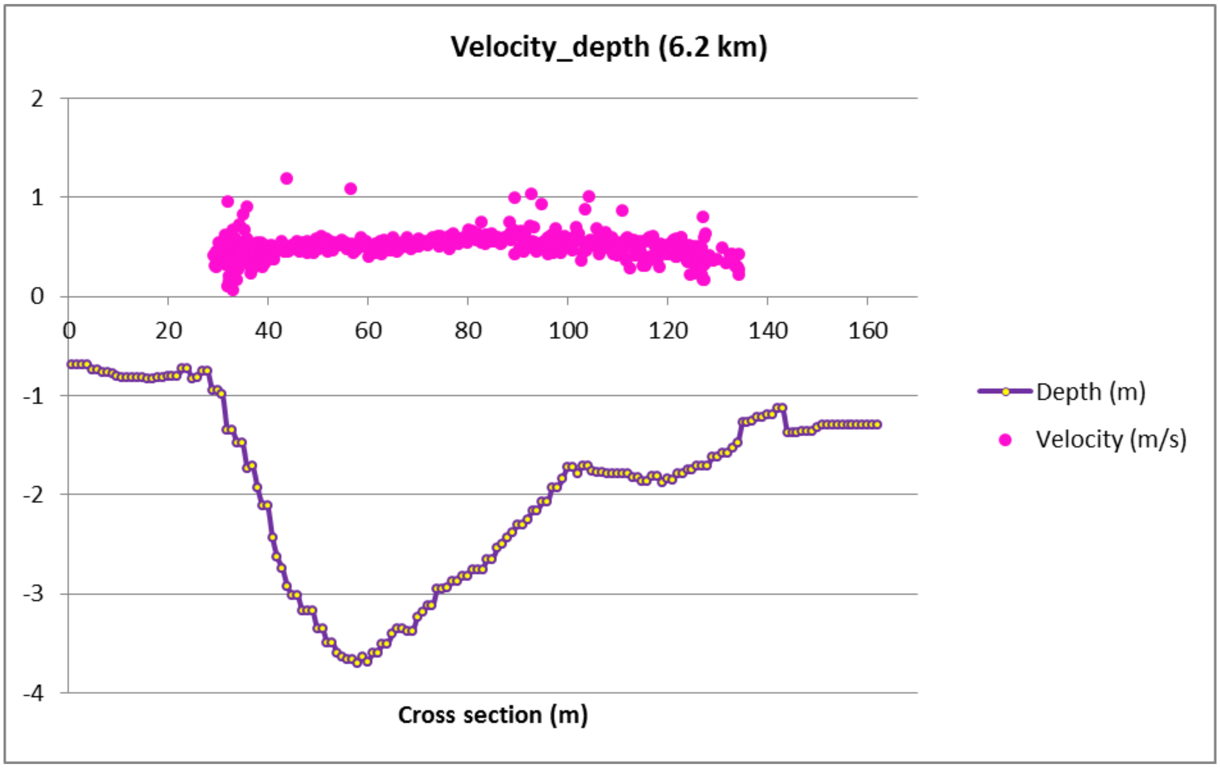
Velocity 6.1km_6



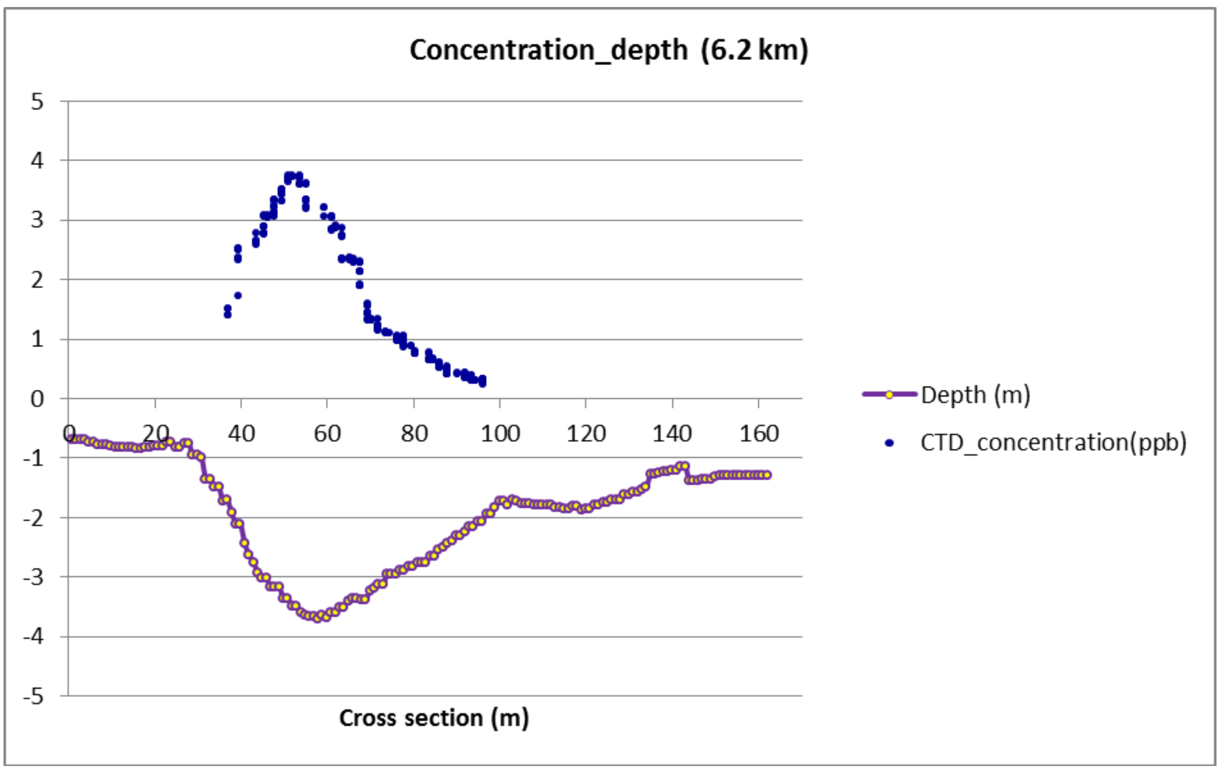
Concentration 6.1km_6

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	3.32	3.47	3.39
0.2-0.3	2.55	2.83	2.69
0.3-0.4	1.00	1.11	1.06
0.4-0.5	0.39	0.43	0.41
0.5-0.6	0.13	0.16	0.15
0.6-0.7	0.02	0.03	0.03
0.7-0.8	0.02	0.02	0.02
0.8-0.9			
0.9-1			
Approximate width(m)	178.78		
Approximate distance from outfall(km)	6.1		
Time and date	15:39:14	Oct 26th, 2011	



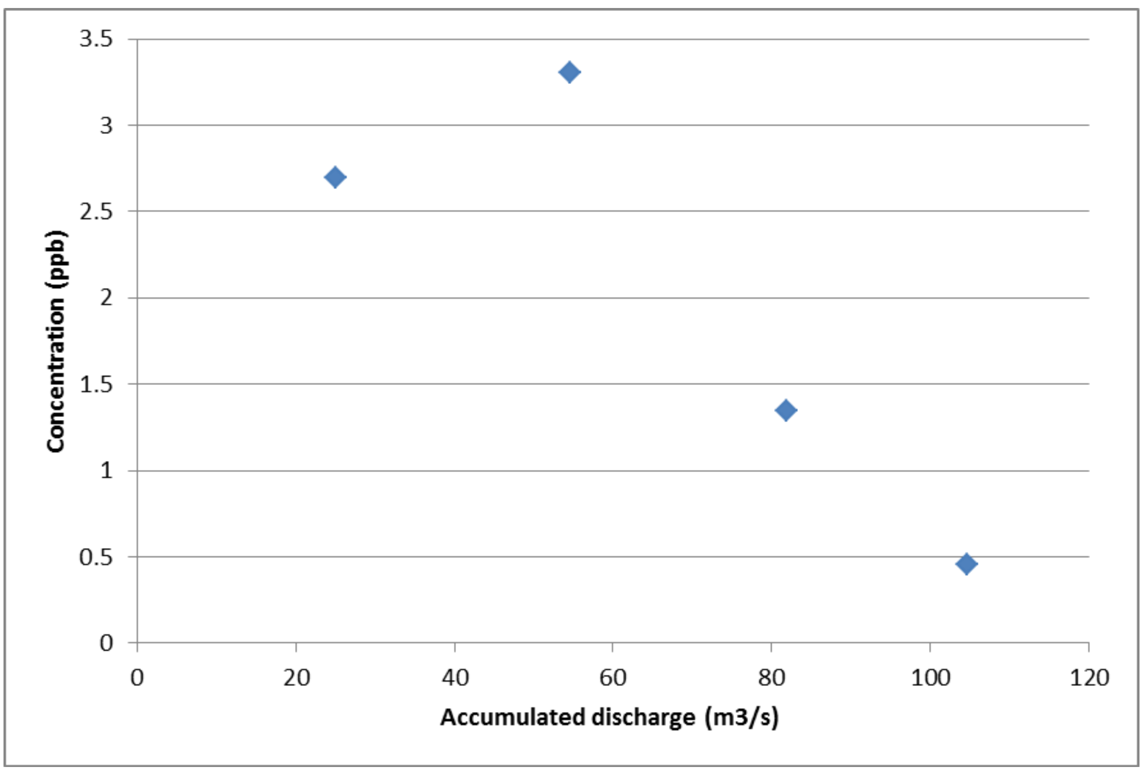


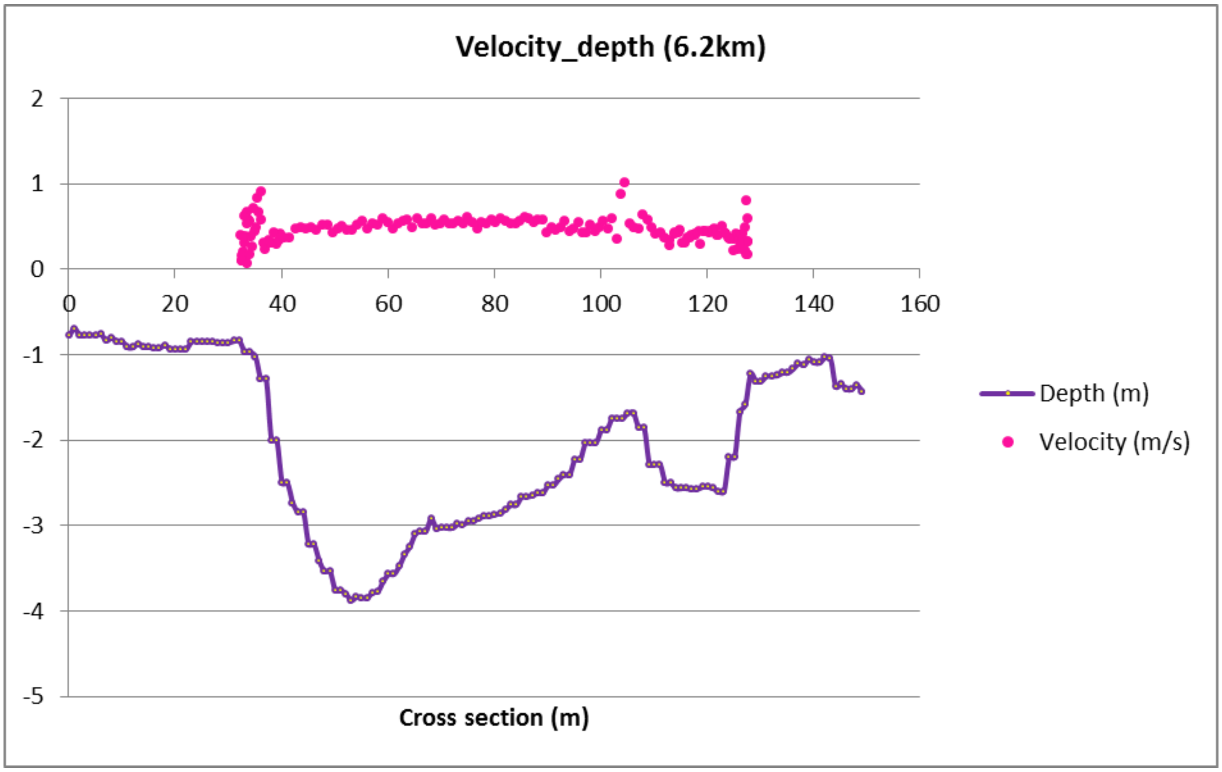
Velocity 6.2km_7



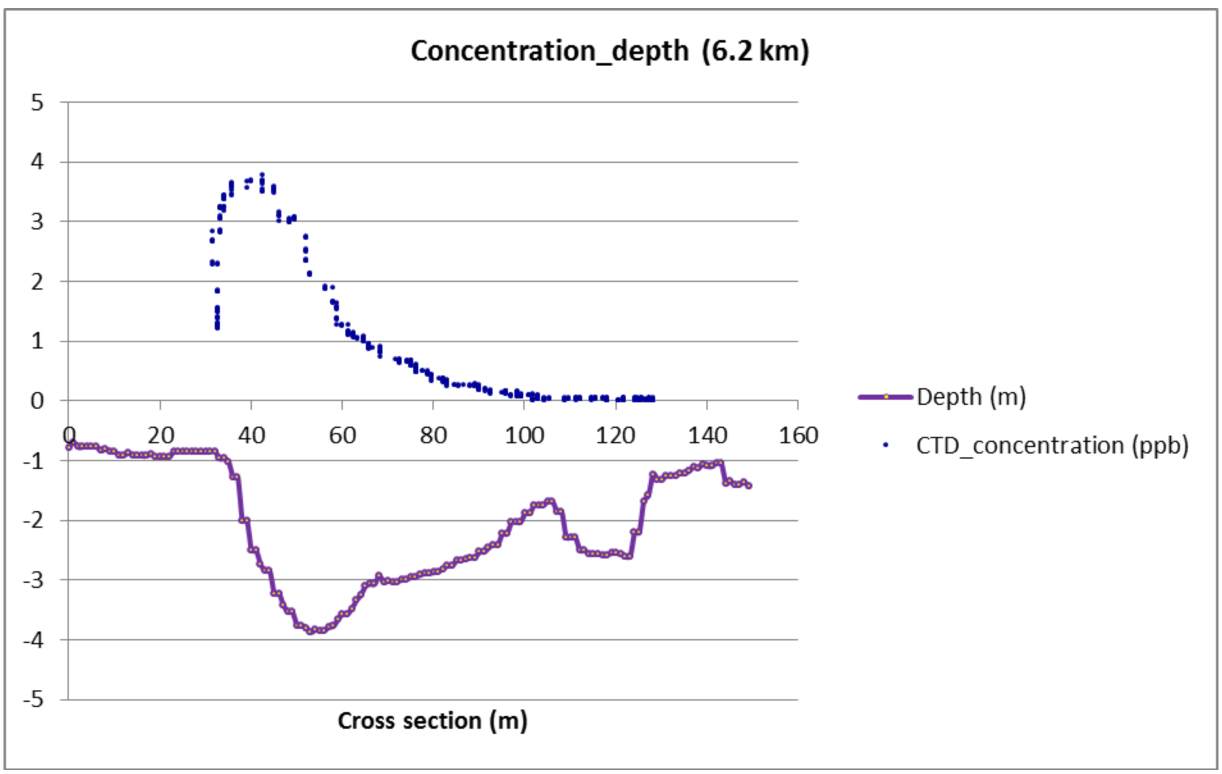
Concentration 6.2km_7

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	2.53	2.87	2.70
0.3-0.4	3.20	3.41	3.30
0.4-0.5	1.23	1.46	1.34
0.5-0.6	0.42	0.48	0.45
0.6-0.7			
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	162.01		
Approximate distance from outfall(km)	6.2		
Time and date	15:39:14	Oct 26th, 2011	



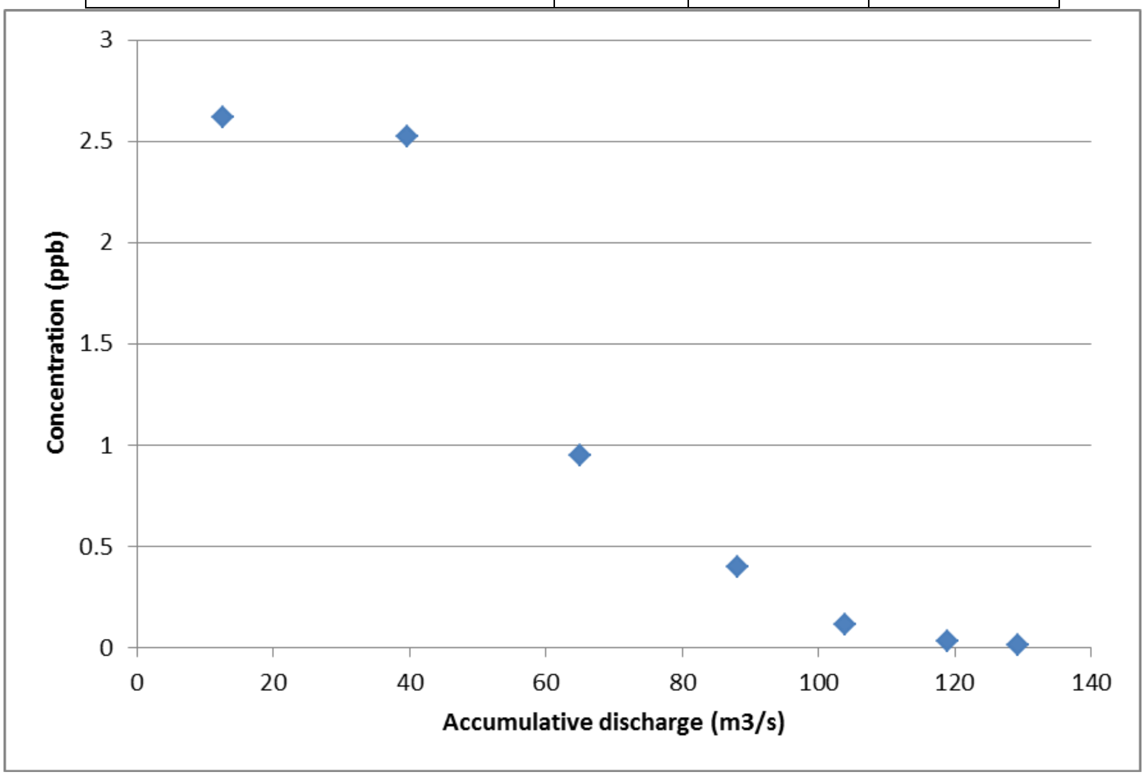


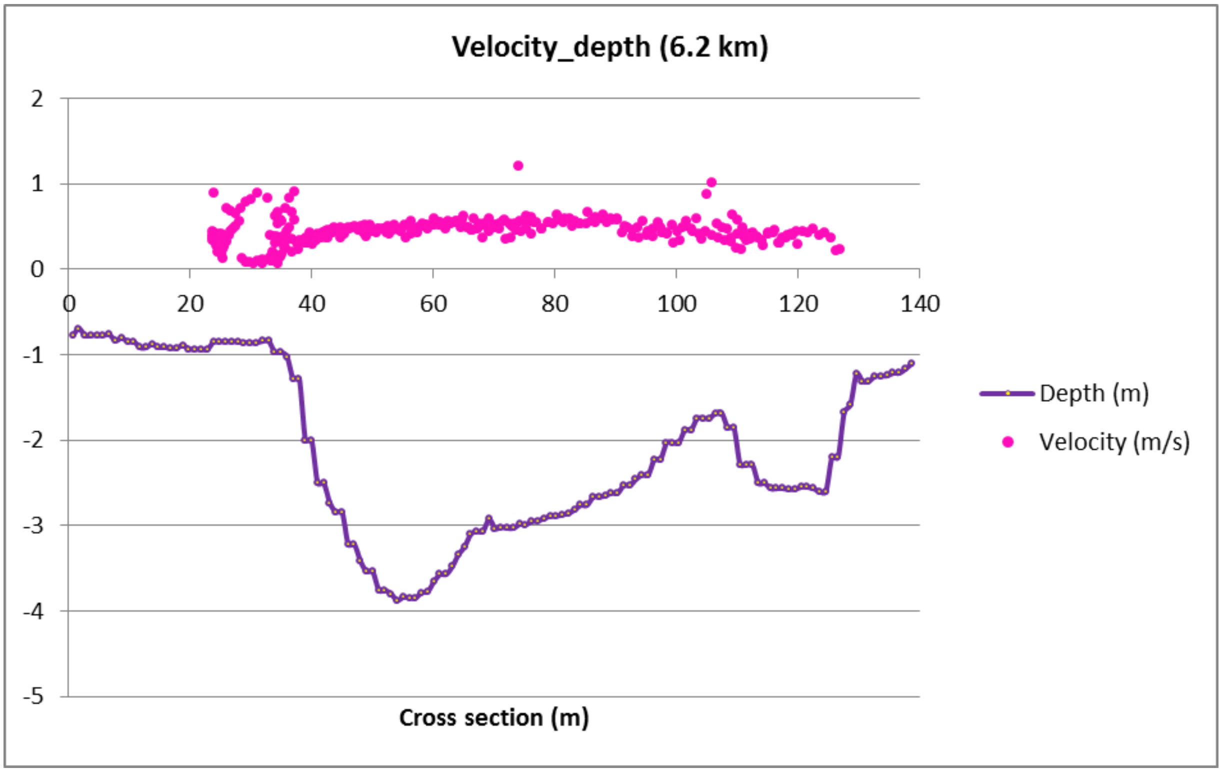
Velocity 6.2km_8



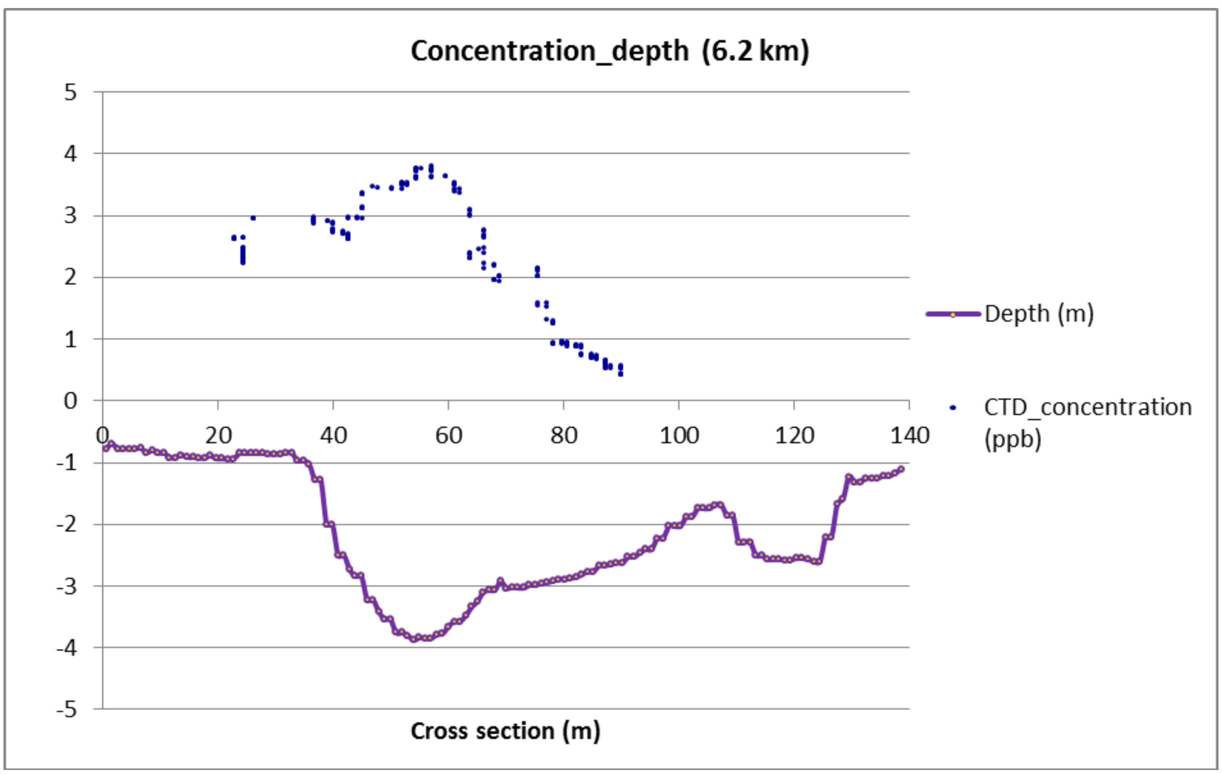
Concentration 6.2km_8

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	2.62	2.62	2.62
0.3-0.4	2.52	2.52	2.52
0.4-0.5	0.95	0.95	0.95
0.5-0.6	0.40	0.40	0.40
0.6-0.7	0.11	0.11	0.11
0.7-0.8	0.03	0.03	0.03
0.8-0.9	0.01	0.01	0.01
0.9-1			
Approximate width(m)	149.24		
Approximate distance from outfall(km)	6.2		
Time and date	15:39:14	Oct 26th, 2011	



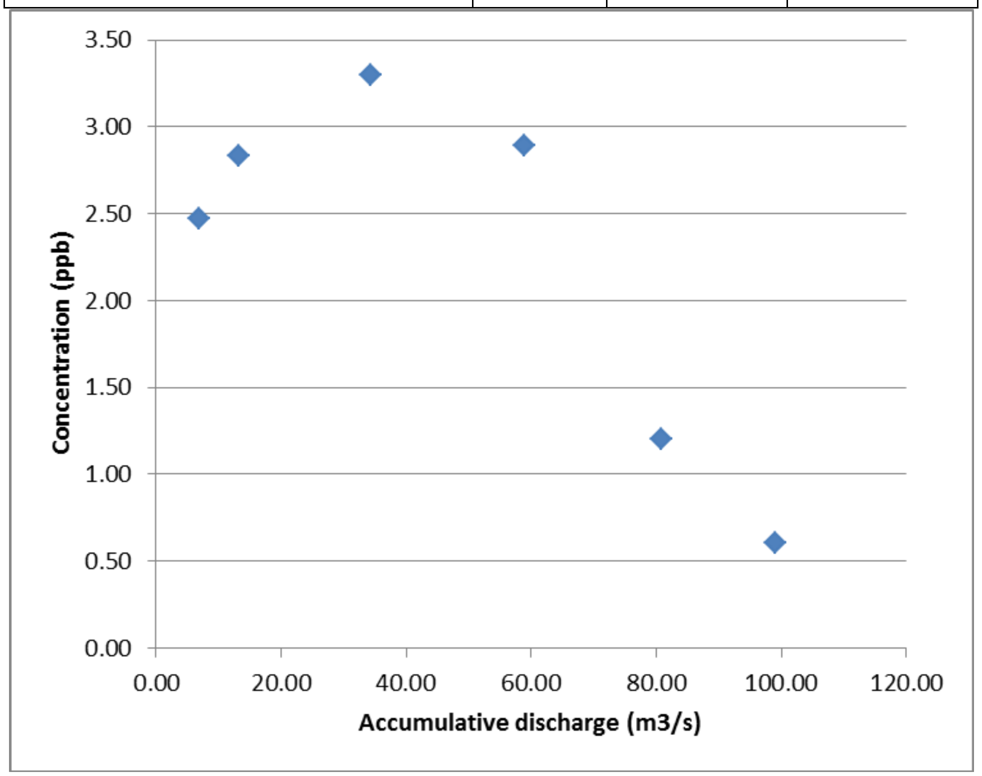


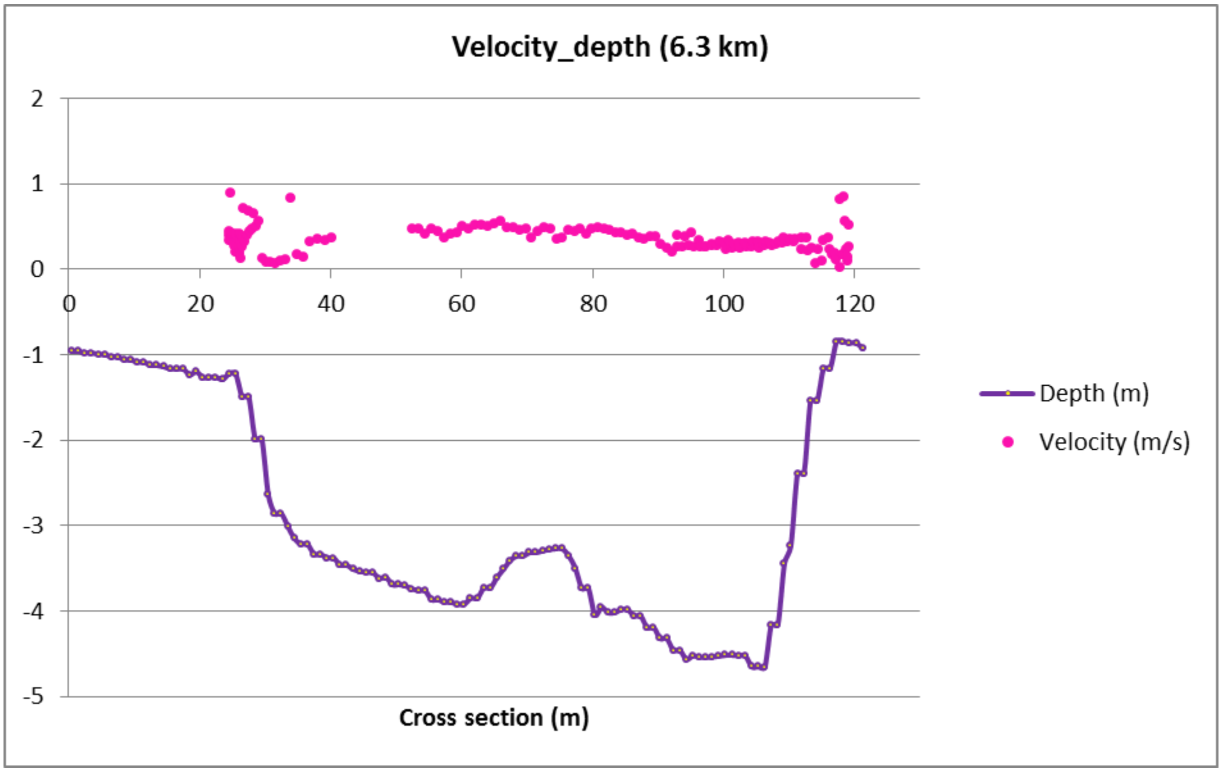
Velocity 6.2km_9



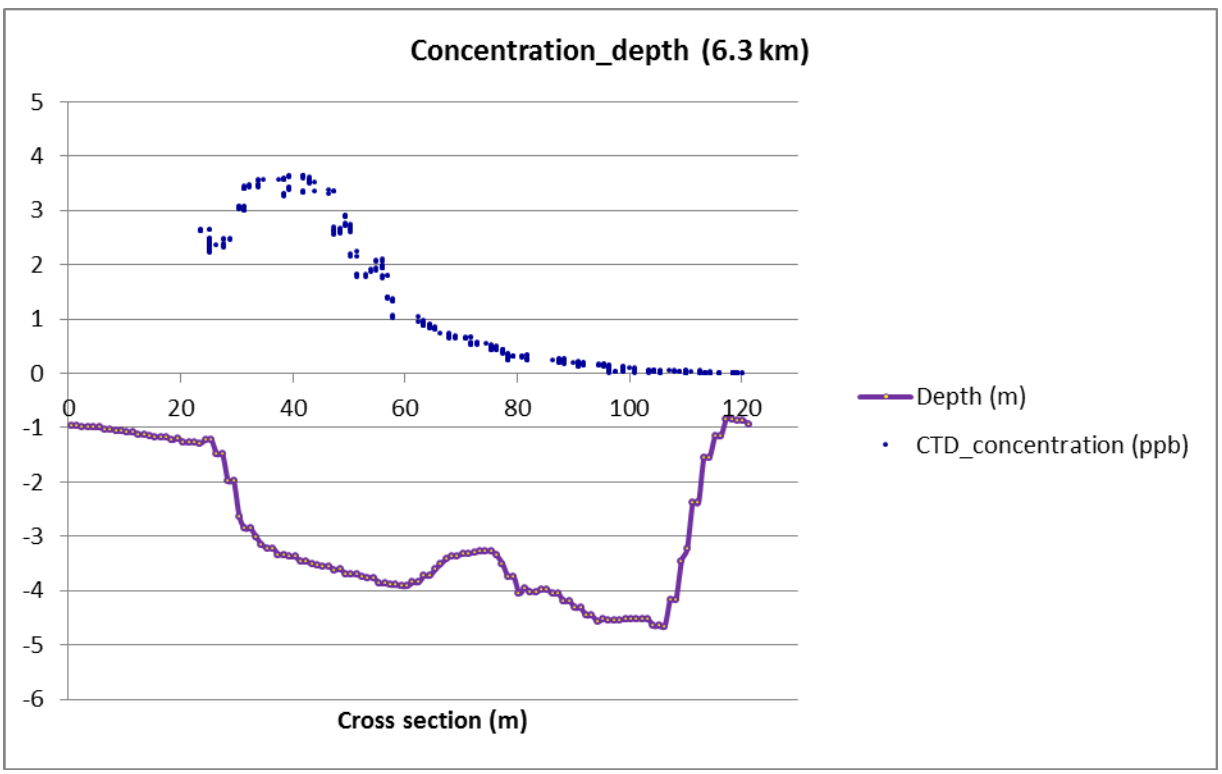
Concentration 6.2km_9

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	2.39	2.54	2.47
0.2-0.3	2.79	2.87	2.83
0.3-0.4	3.19	3.41	3.30
0.4-0.5	2.70	3.08	2.89
0.5-0.6	1.06	1.35	1.21
0.6-0.7	0.57	0.64	0.60
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	139.45		
Approximate distance from outfall(km)	6.2		
Time and date	15:39:14	Oct 26th, 2011	



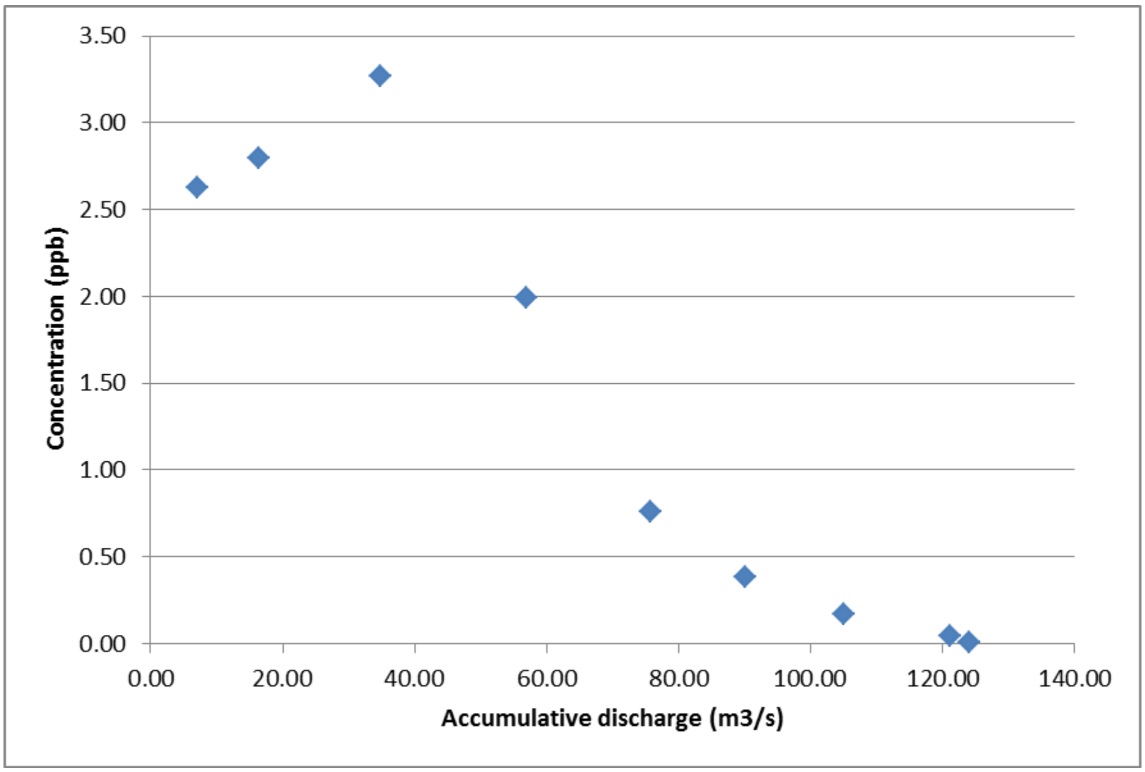


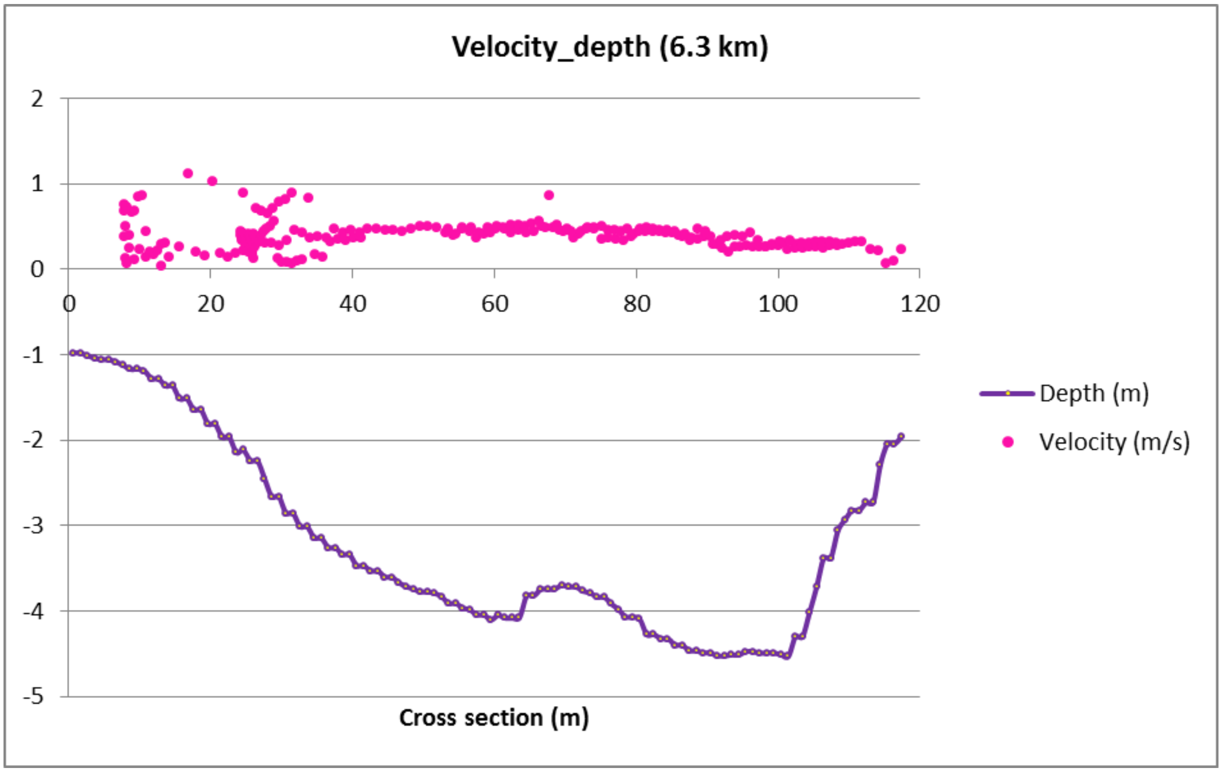
Velocity 6.3km_10



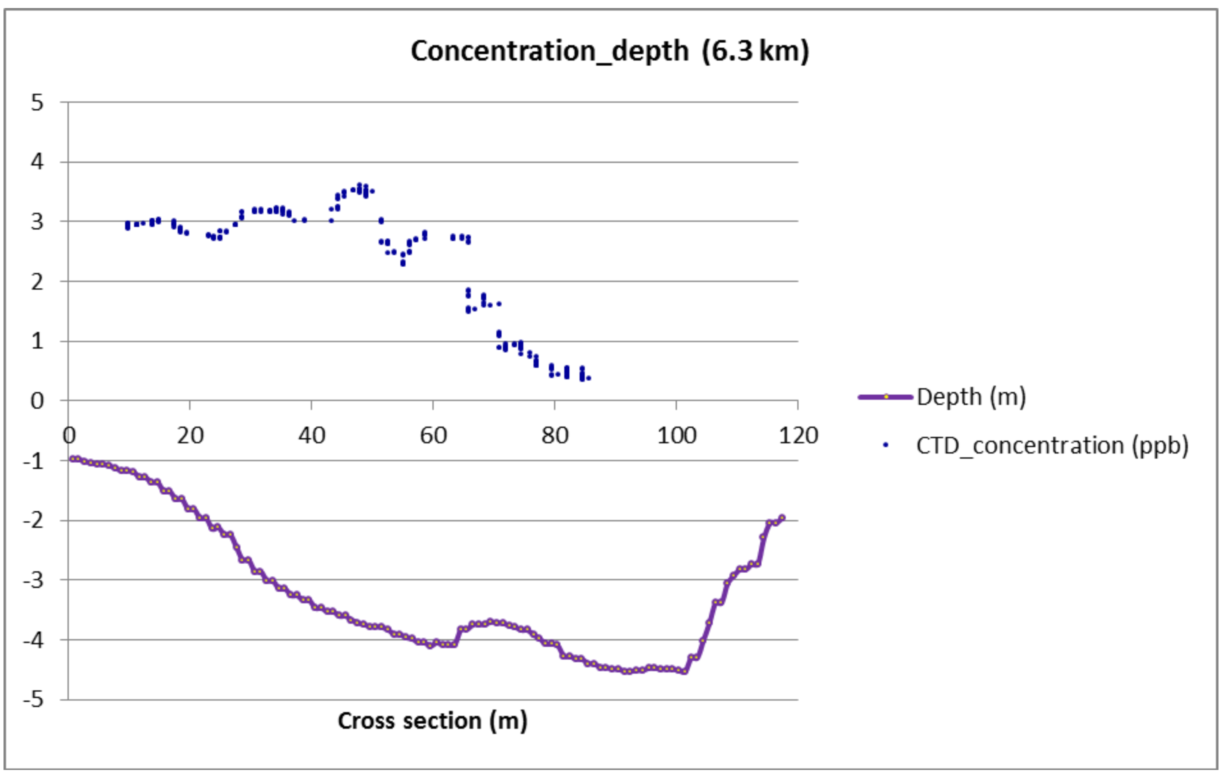
Concentration 6.3km_10

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	2.61	2.64	2.63
0.2-0.3	2.68	2.92	2.80
0.3-0.4	3.16	3.37	3.27
0.4-0.5	1.84	2.14	1.99
0.5-0.6	0.72	0.80	0.76
0.6-0.7	0.36	0.41	0.39
0.7-0.8	0.15	0.18	0.17
0.8-0.9	0.03	0.05	0.04
0.9-1	0.00	0.01	0.00
Approximate width(m)	121.29		
Approximate distance from outfall(km)	6.3		
Time and date	15:39:14	Oct 26th, 2011	



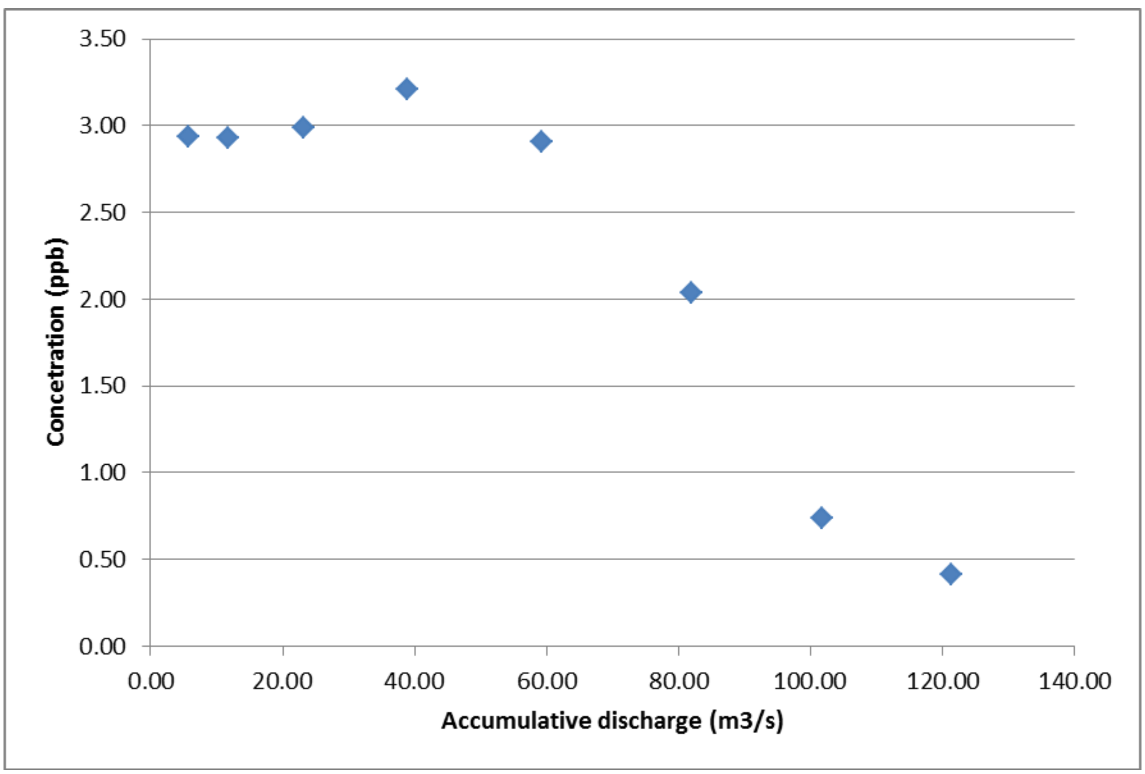


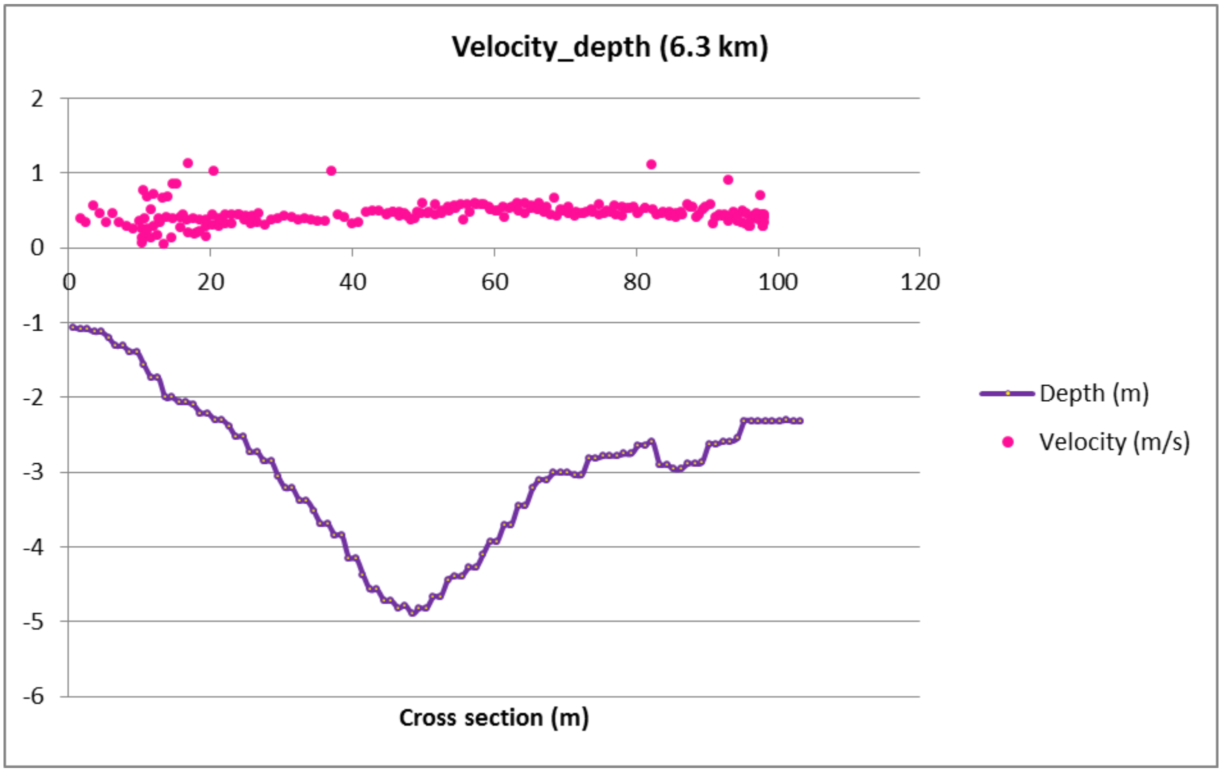
Velocity 6.3km_11



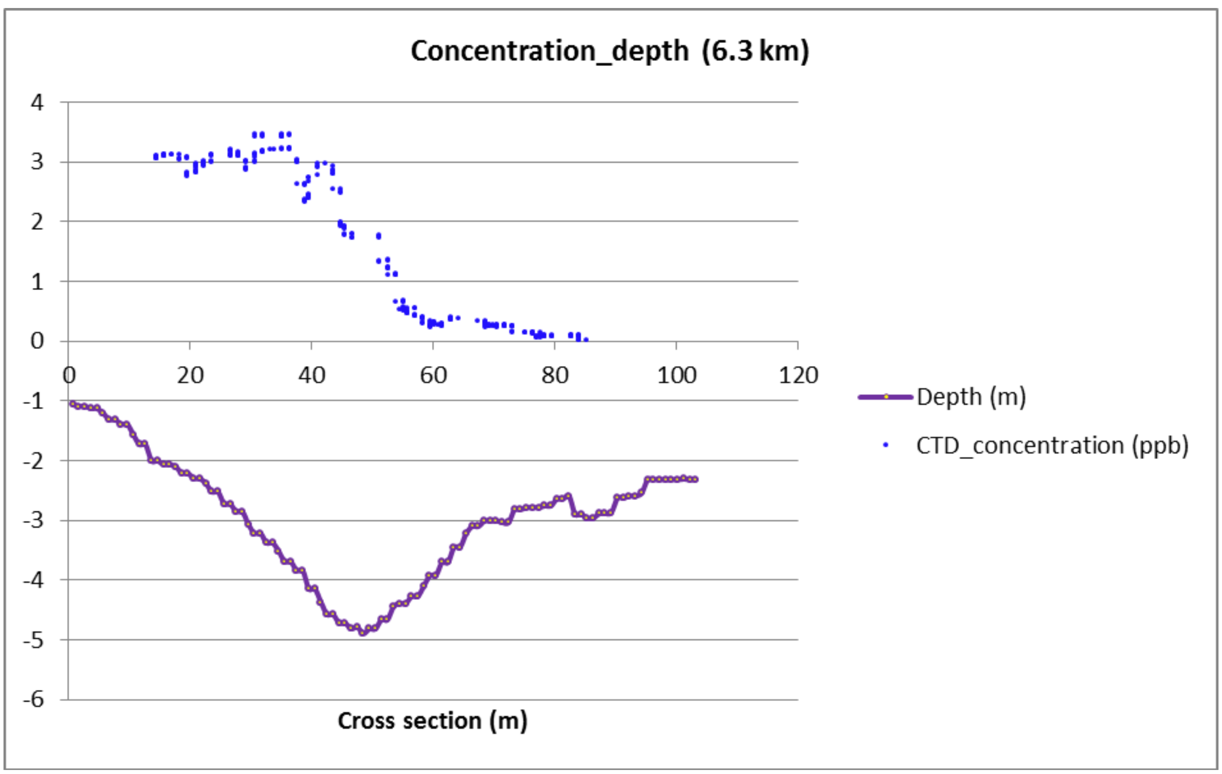
Concentration 6.3km_11

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	2.93	2.93	2.93
0.1-0.2	2.93	2.93	2.93
0.2-0.3	2.99	2.99	2.99
0.3-0.4	3.21	3.21	3.21
0.4-0.5	2.91	2.91	2.91
0.5-0.6	2.04	2.04	2.04
0.6-0.7	0.74	0.74	0.74
0.7-0.8	0.41	0.41	0.41
0.8-0.9			
0.9-1			
Approximate width(m)	117.39		
Approximate distance from outfall(km)	6.3		
Time and date	15:39:14	Oct 26th, 2011	



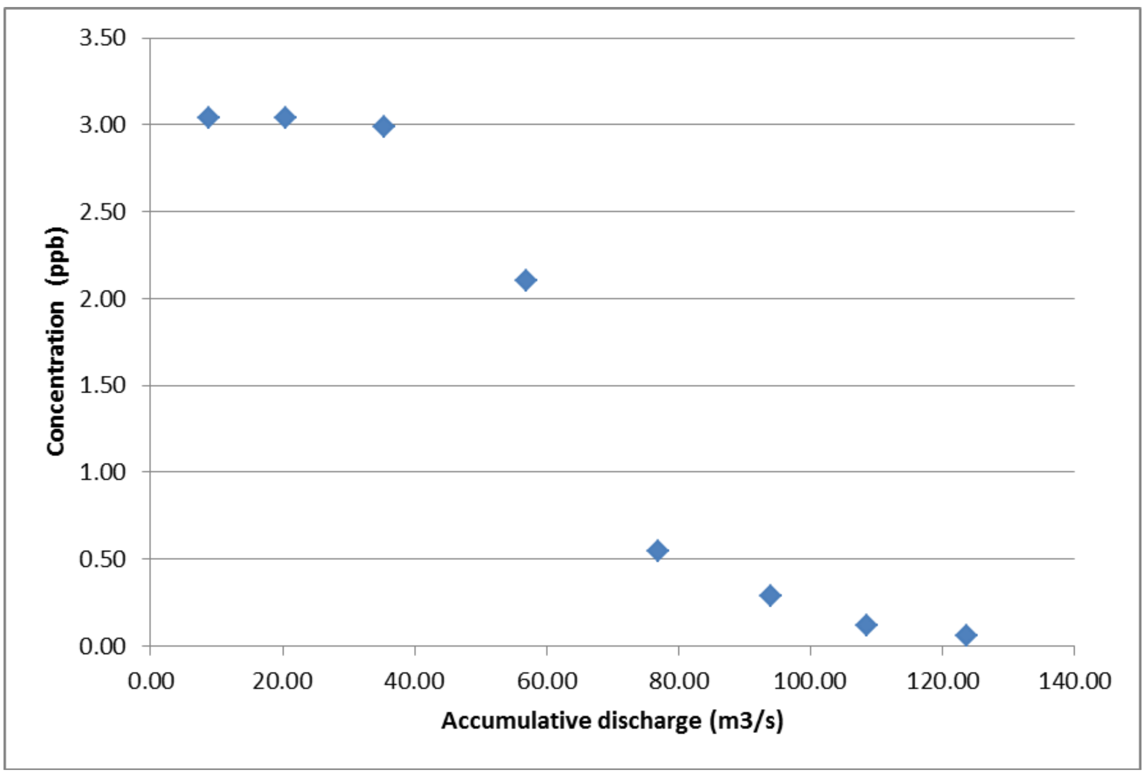


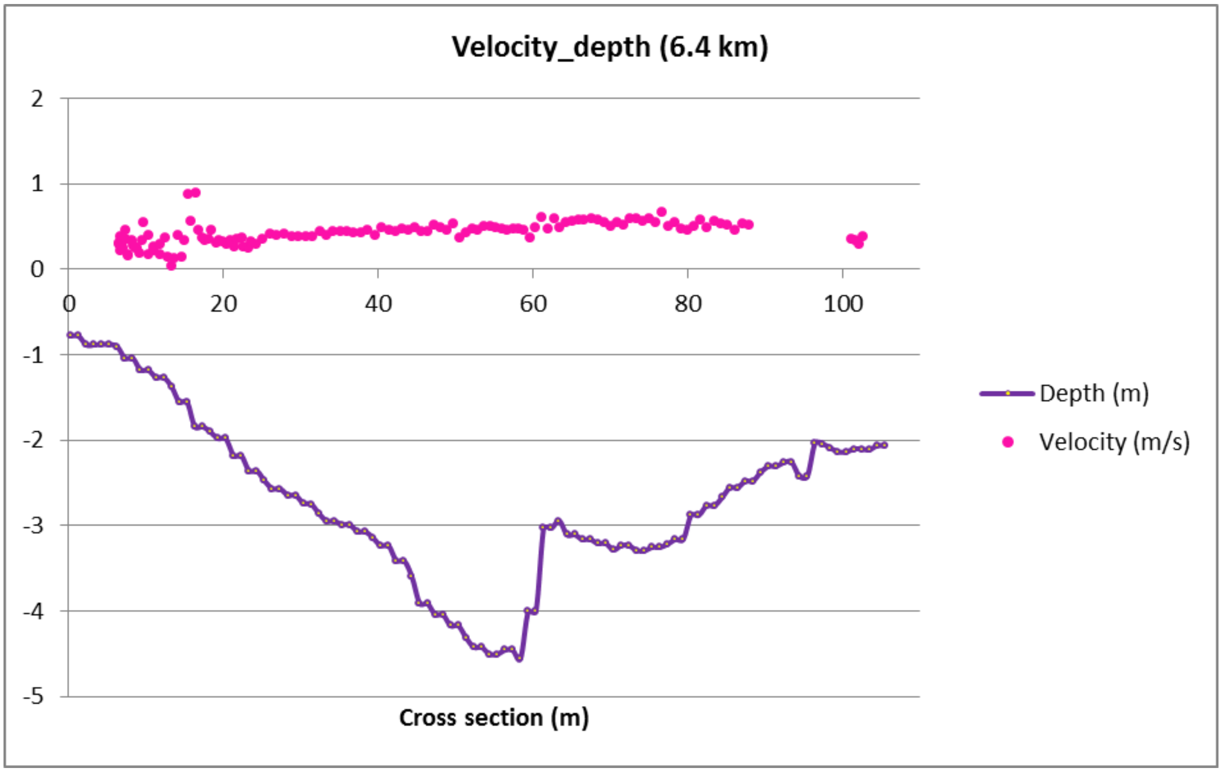
Velocity 6.3km_12



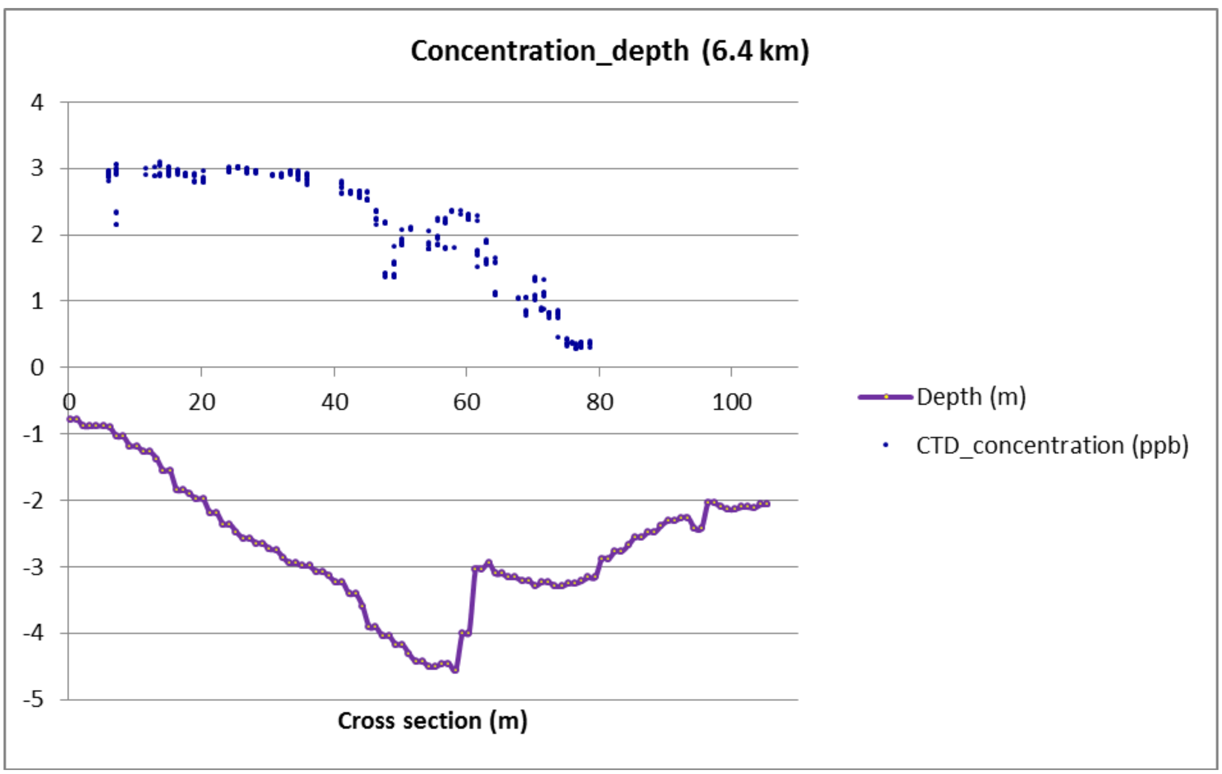
Concentration 6.3_12

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	2.99	3.08	3.04
0.2-0.3	3.00	3.08	3.04
0.3-0.4	2.88	3.10	2.99
0.4-0.5	1.93	2.29	2.11
0.5-0.6	0.46	0.63	0.55
0.6-0.7	0.27	0.30	0.29
0.7-0.8	0.10	0.14	0.12
0.8-0.9	0.03	0.09	0.06
0.9-1			
Approximate width(m)	104.25		
Approximate distance from outfall(km)	6.3		
Time and date	15:39:14	Oct 26th, 2011	



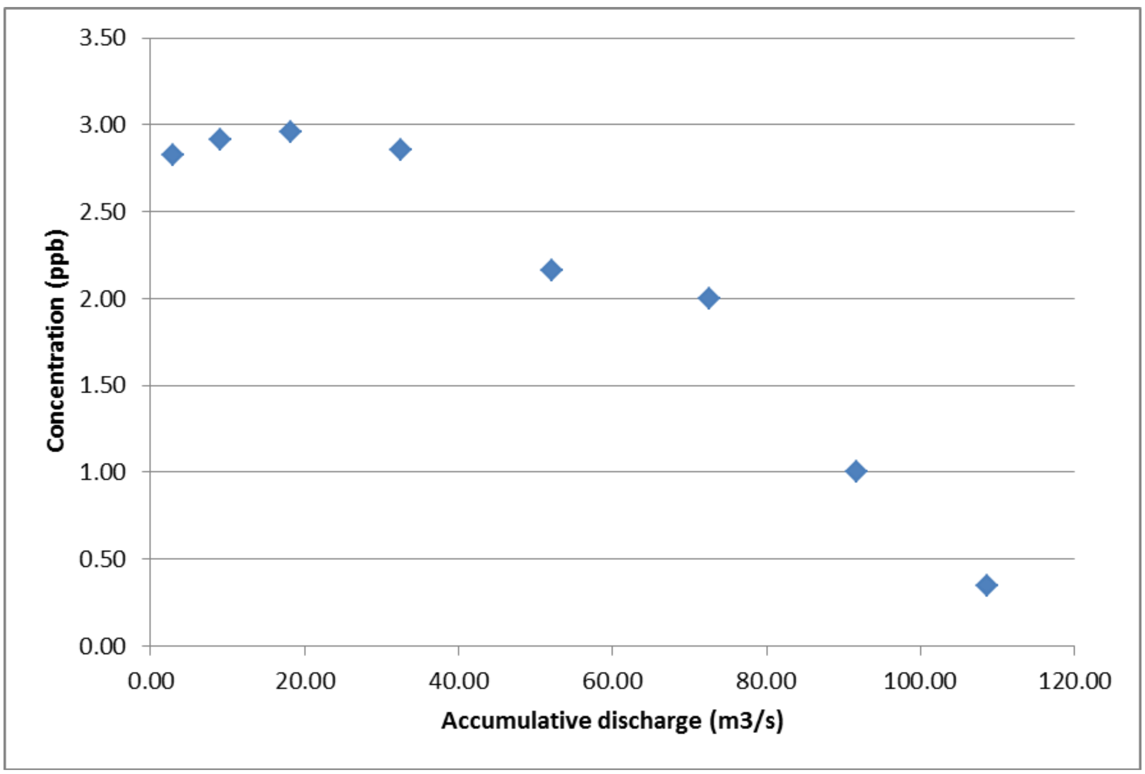


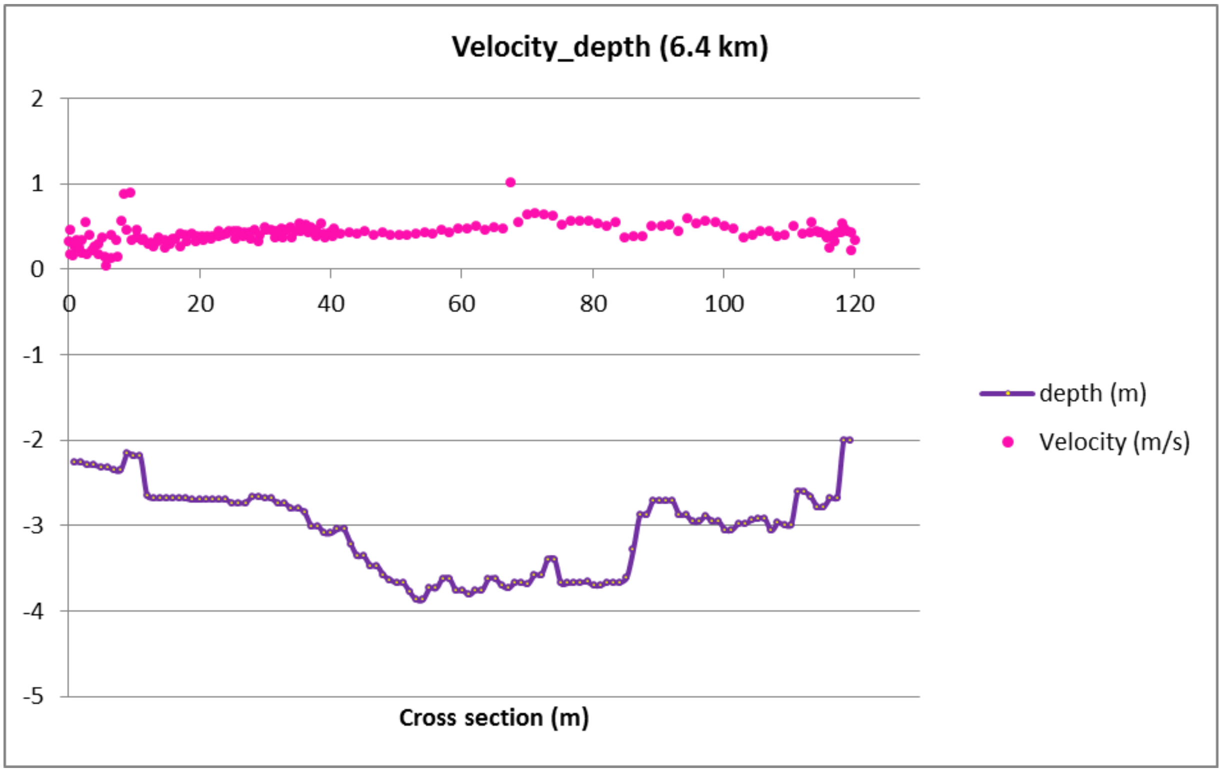
Velocity 6.4km_13



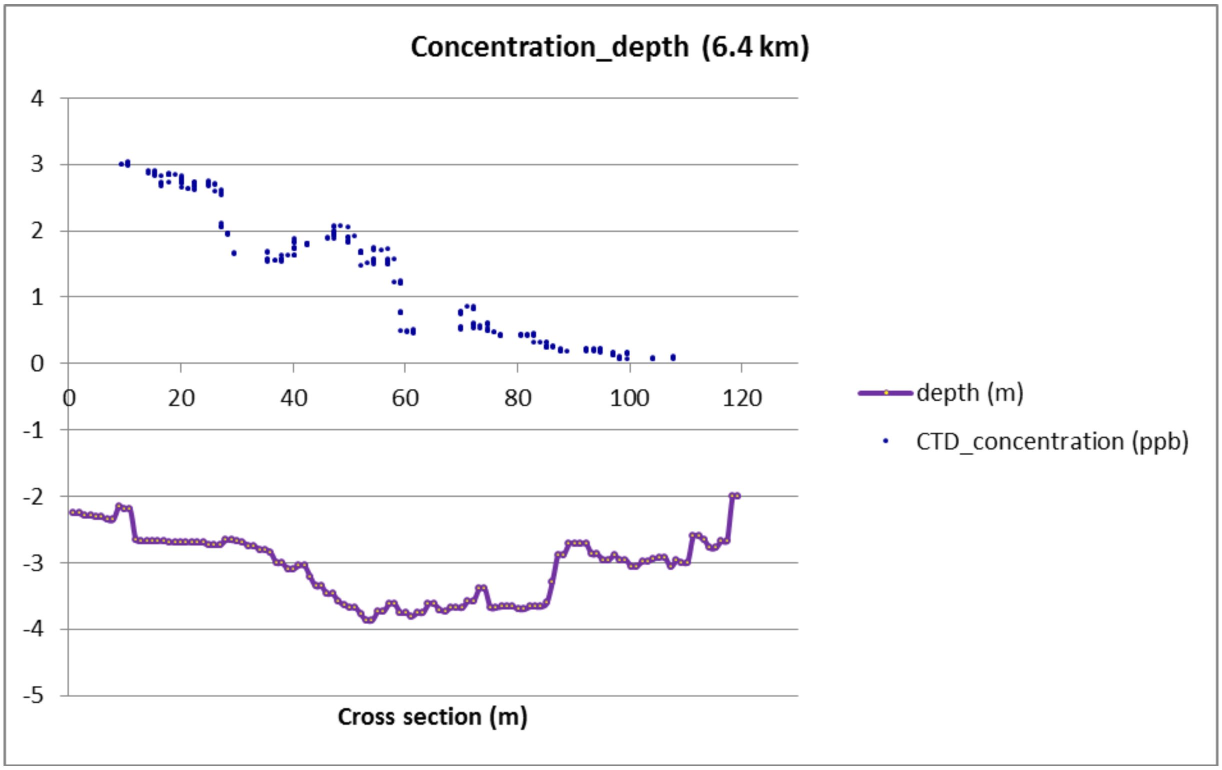
Concentration 6.4km_13

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	2.73	2.93	2.83
0.1-0.2	2.89	2.93	2.91
0.2-0.3	2.95	2.97	2.96
0.3-0.4	2.83	2.89	2.86
0.4-0.5	2.05	2.28	2.16
0.5-0.6	1.93	2.06	2.00
0.6-0.7	0.93	1.07	1.00
0.7-0.8	0.33	0.36	0.35
0.8-0.9			
0.9-1			
Approximate width(m)	106.30		
Approximate distance from outfall(km)	6.4		
Time and date	15:39:14	Oct 26th, 2011	



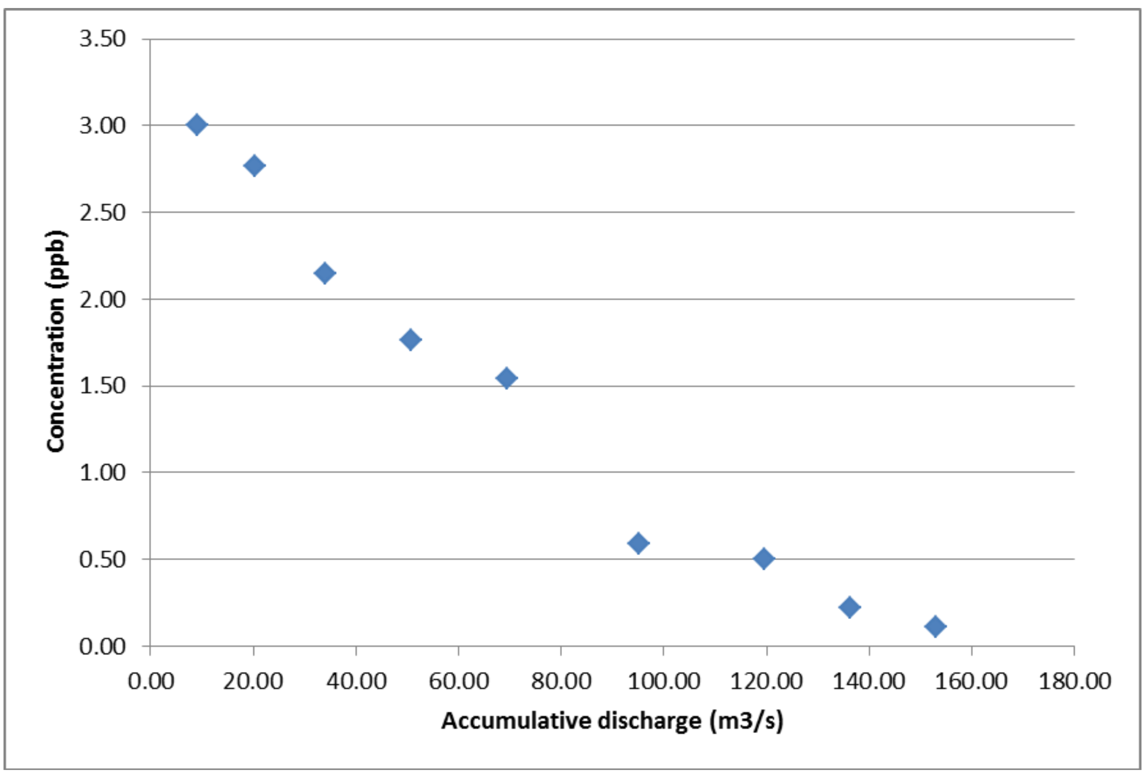


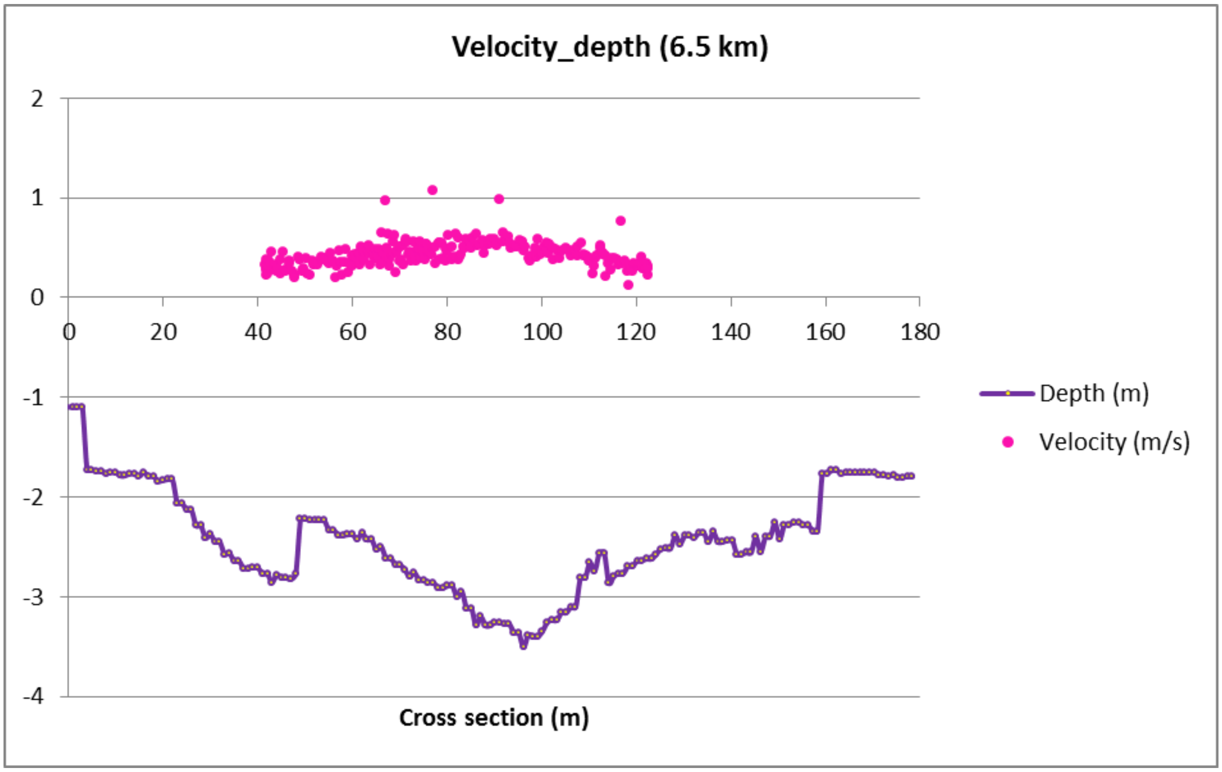
Velocity 6.4km_15



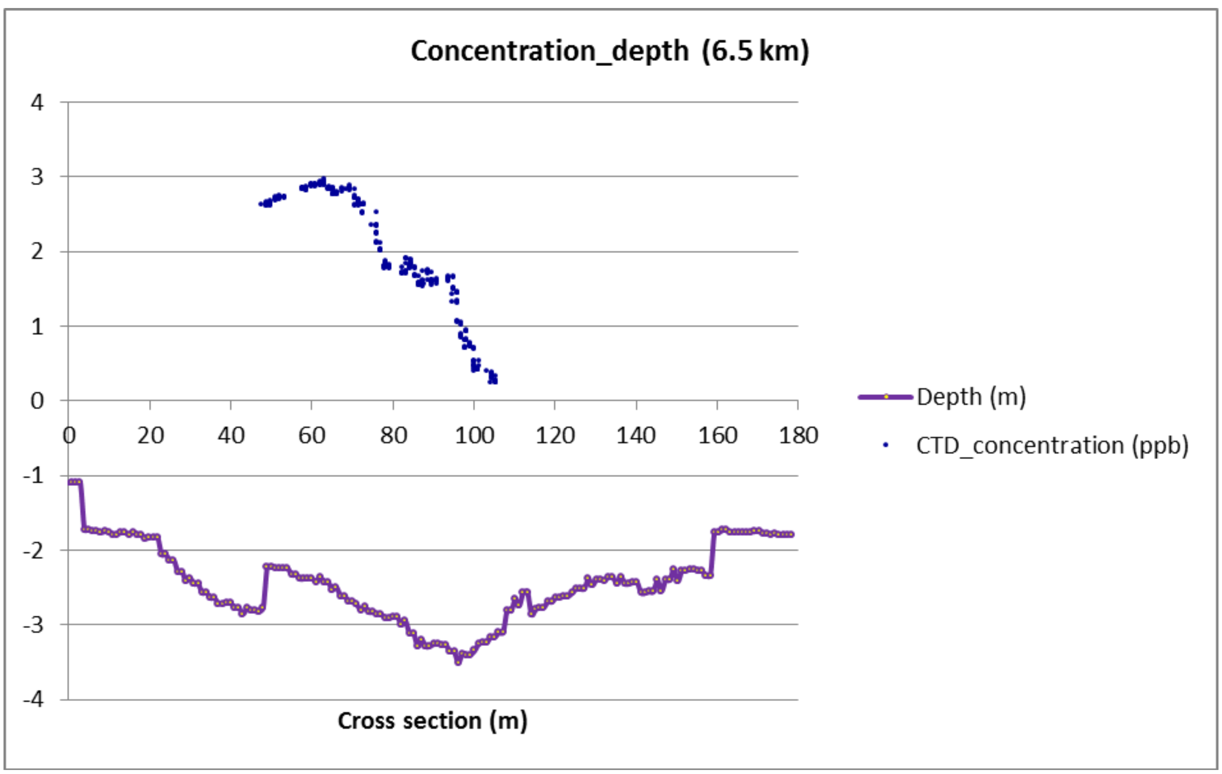
Concentration 6.4km_15

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	3.00	3.01	3.00
0.1-0.2	2.74	2.79	2.77
0.2-0.3	1.97	2.32	2.15
0.3-0.4	1.72	1.81	1.76
0.4-0.5	1.45	1.64	1.54
0.5-0.6	0.52	0.66	0.59
0.6-0.7	0.46	0.54	0.50
0.7-0.8	0.20	0.23	0.22
0.8-0.9	0.09	0.12	0.11
0.9-1			
Approximate width(m)	120.23		
Approximate distance from outfall(km)	6.4		
Time and date	15:39:14	Oct 26th, 2011	



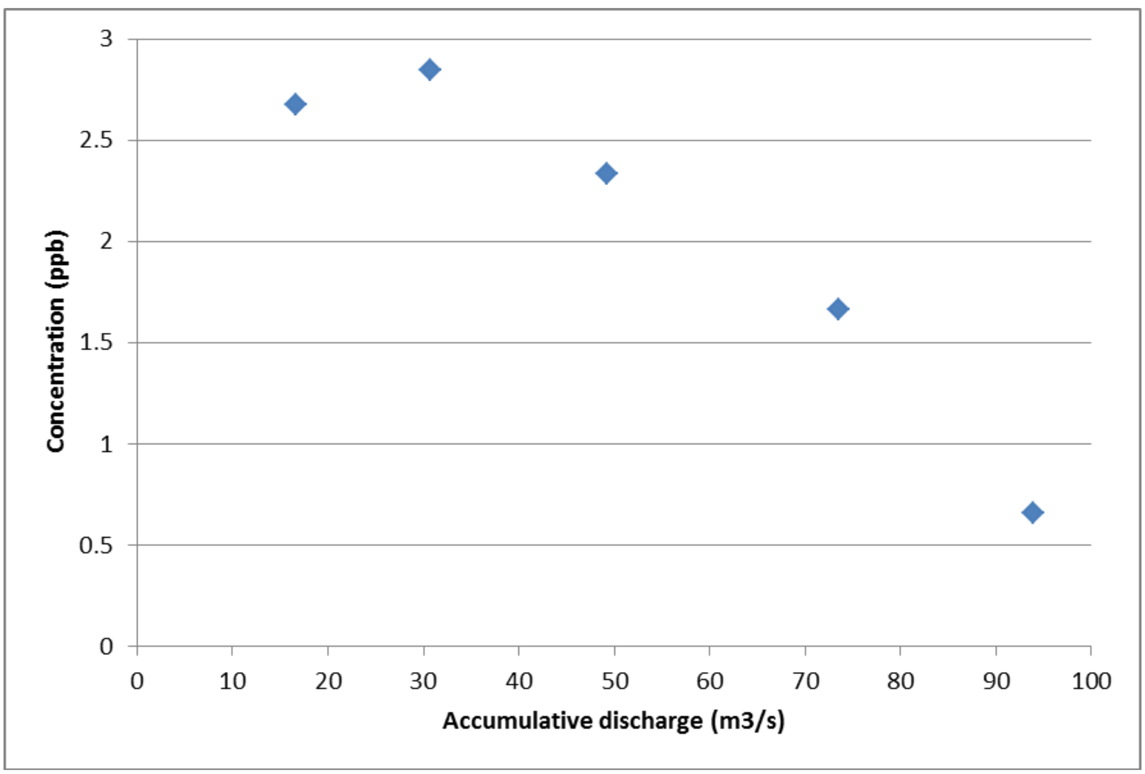


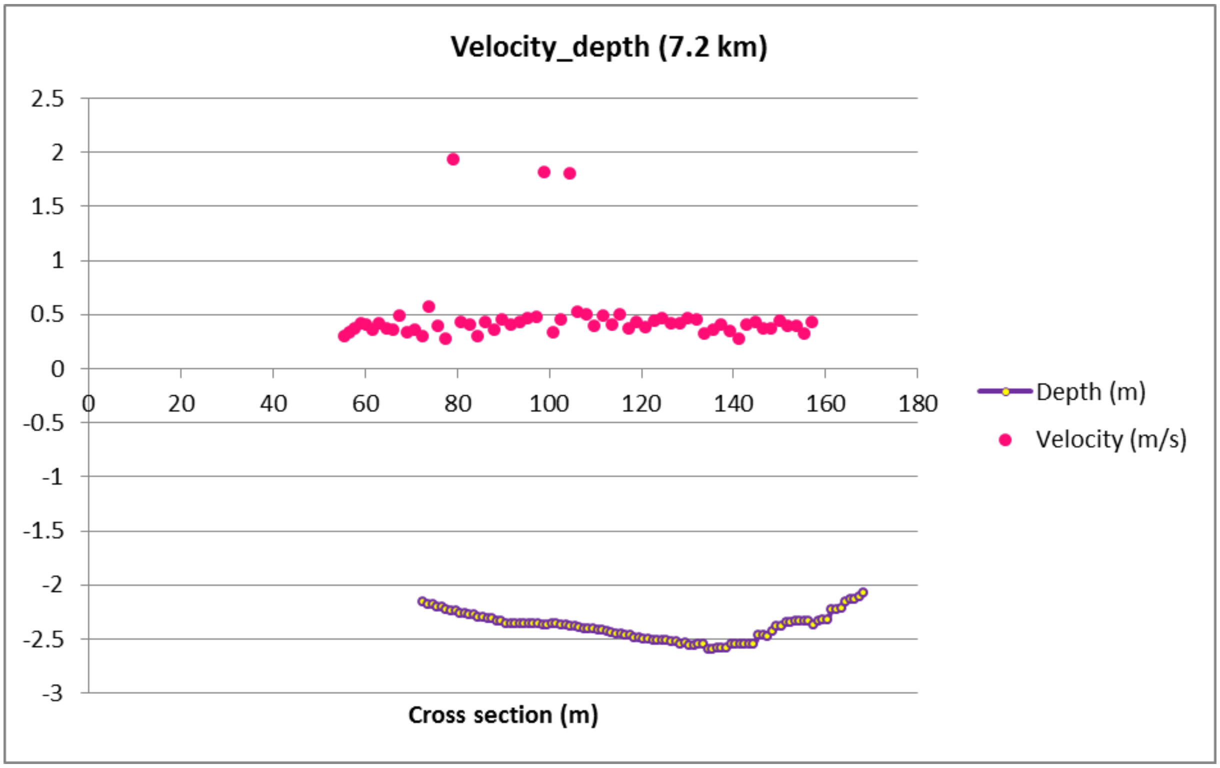
Velocity 6.5km_16



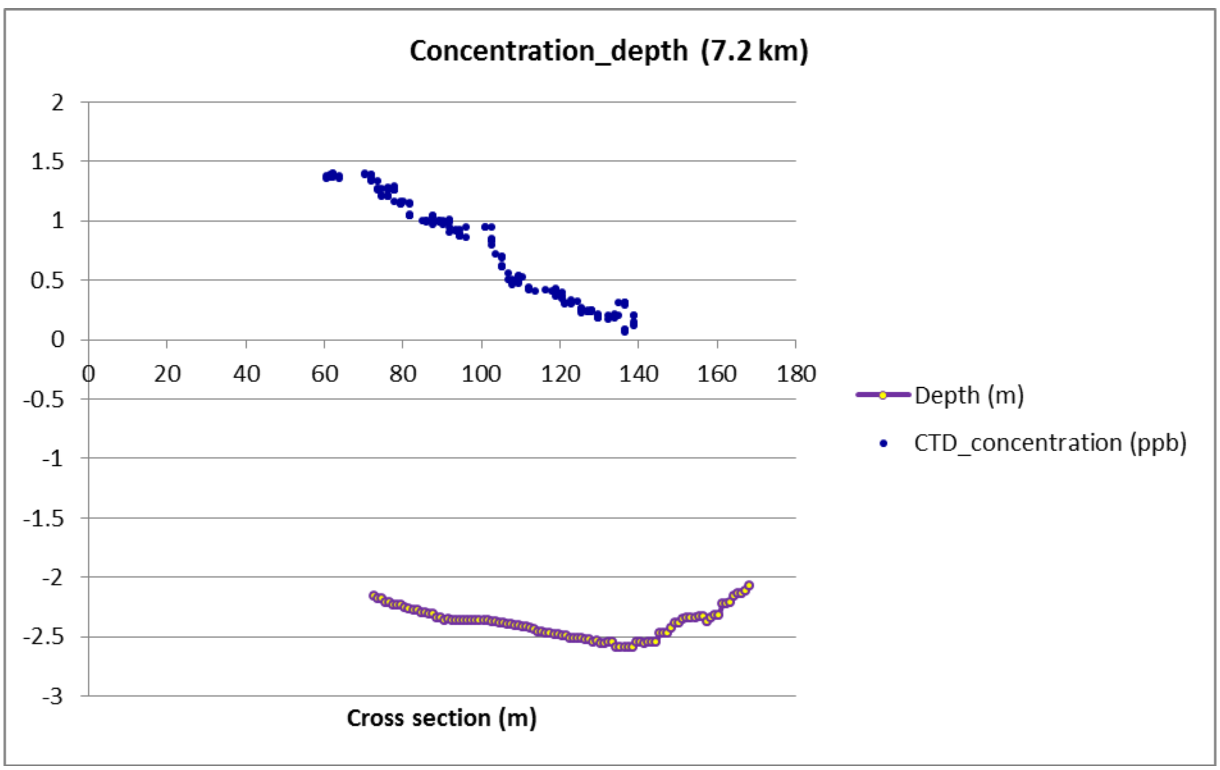
Concentration 6.5km_16

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3			
0.3-0.4	2.66	2.69	2.67
0.4-0.5	2.84	2.86	2.85
0.5-0.6	2.24	2.42	2.33
0.6-0.7	1.64	1.69	1.66
0.7-0.8	0.58	0.74	0.66
0.8-0.9			
0.9-1			
Approximate width(m)	136.91		
Approximate distance from outfall(km)	6.5		
Time and date	15:39:14	Oct 26th, 2011	



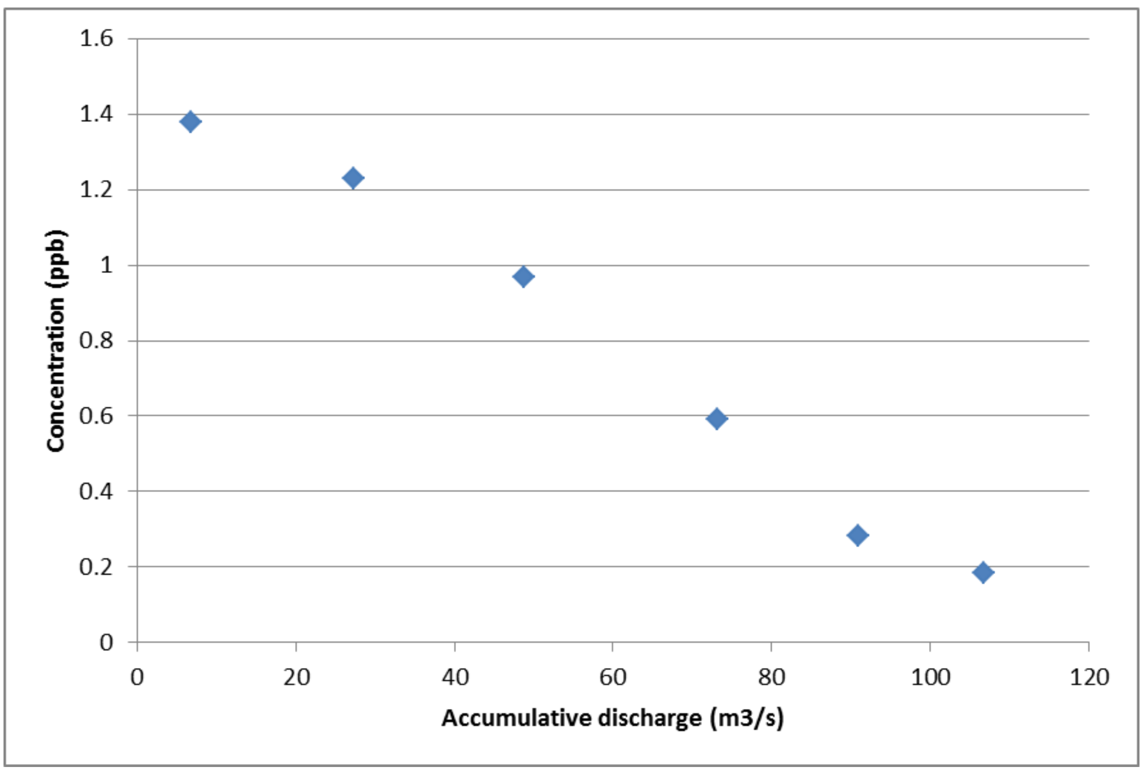


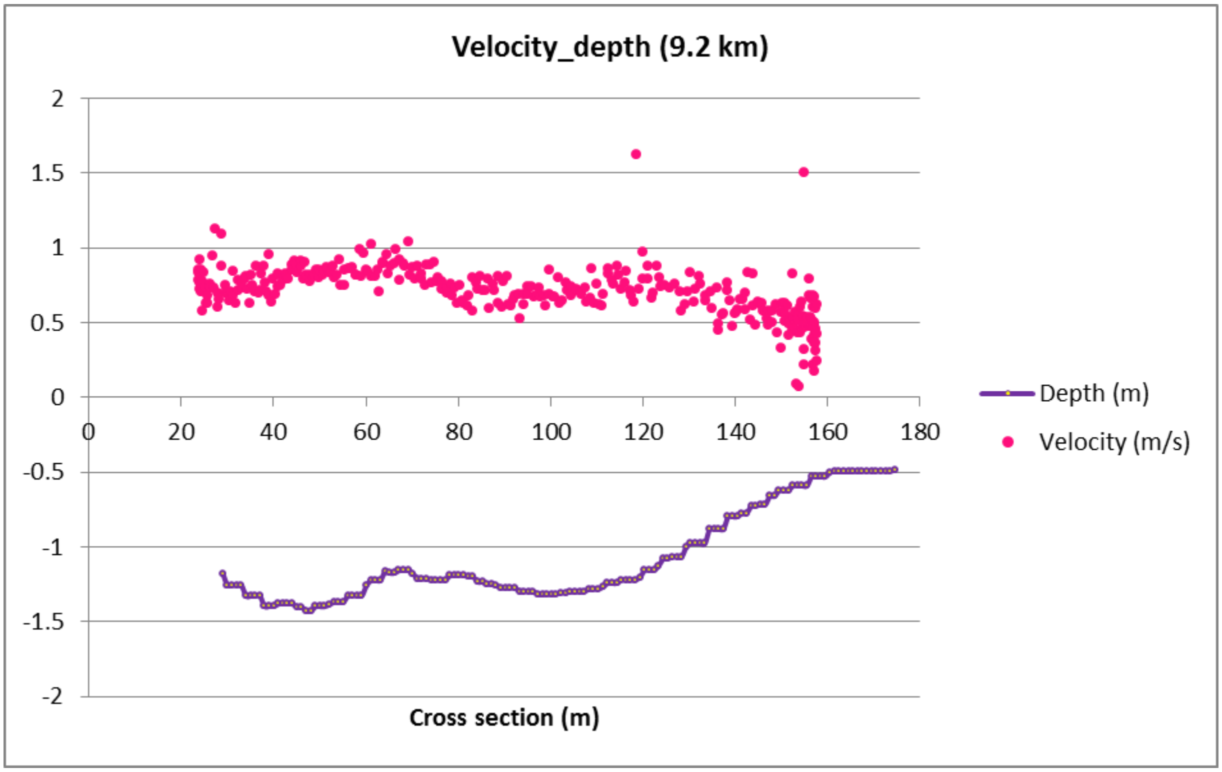
Velocity 7.2km_17



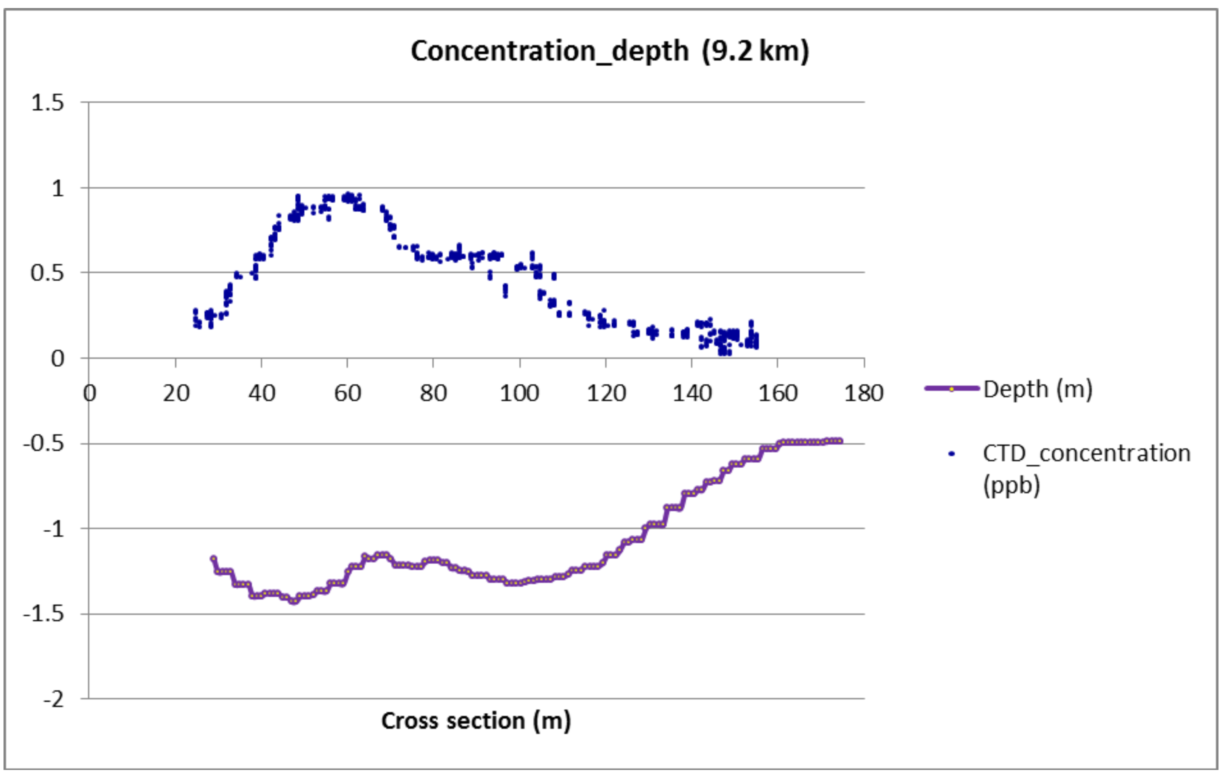
Concentration 7.2km_17

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3			
0.3-0.4	1.37	1.39	1.38
0.4-0.5	1.20	1.26	1.23
0.5-0.6	0.95	0.99	0.97
0.6-0.7	0.54	0.65	0.59
0.7-0.8	0.26	0.30	0.28
0.8-0.9	0.13	0.24	0.19
0.9-1			
Approximate width(m)	168.46		
Approximate distance from outfall(km)	7.2		
Time and date	15:39:14	Oct 26th, 2011	



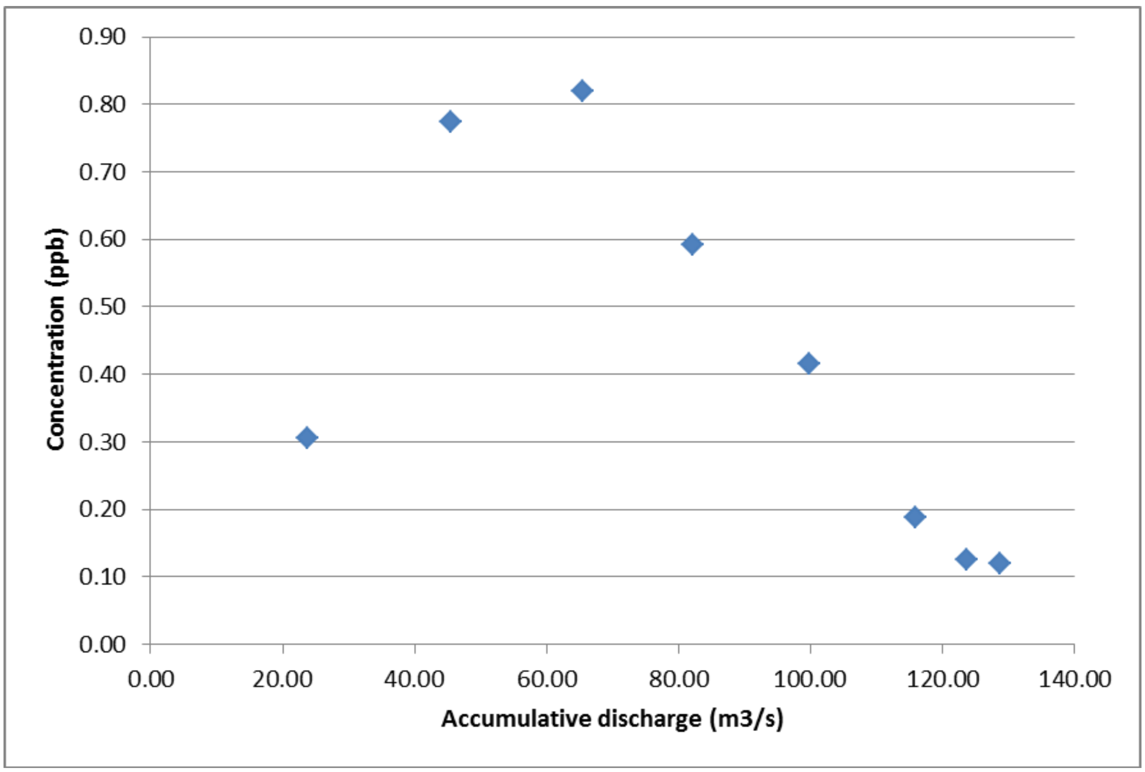


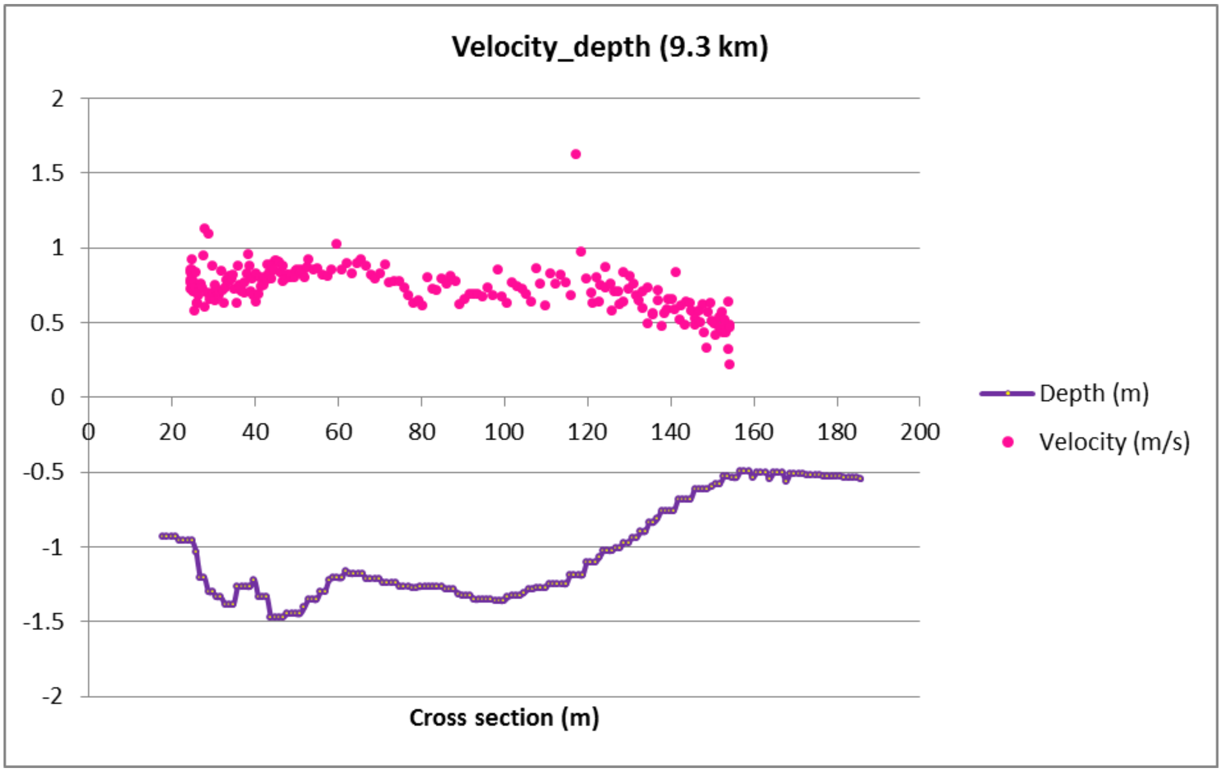
Velocity 9.2km_1



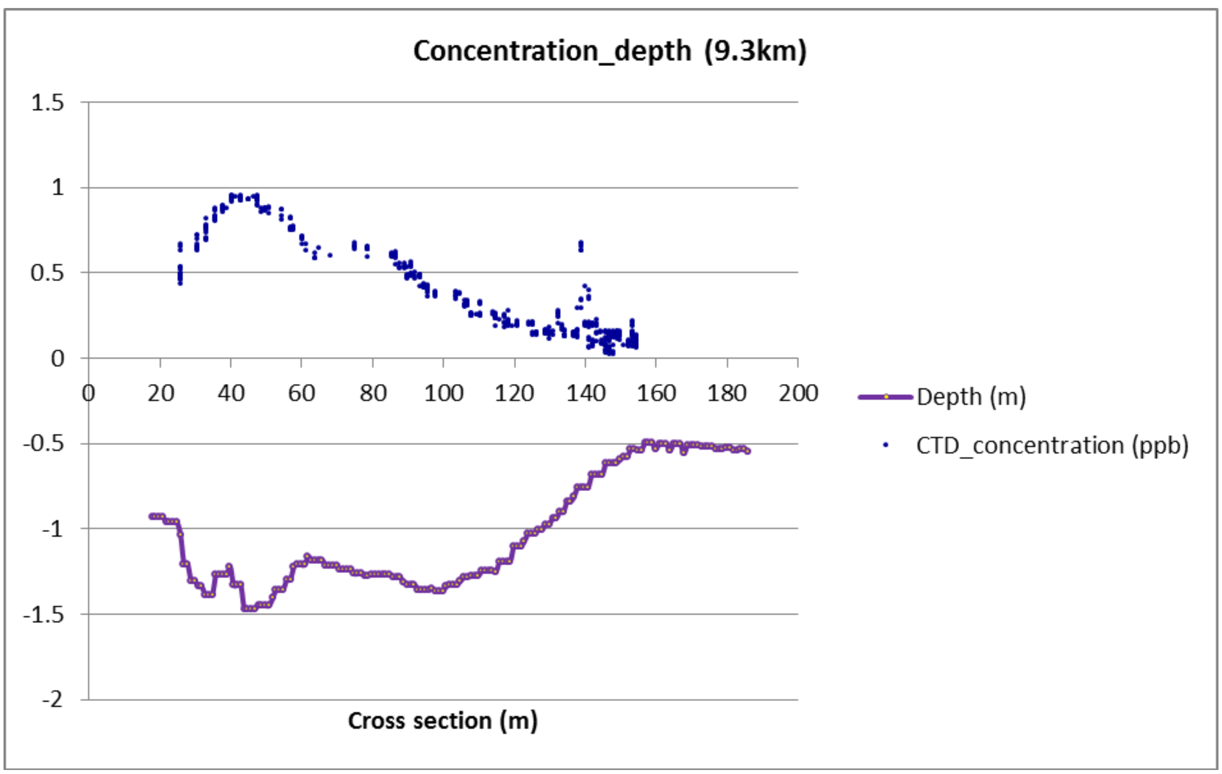
Concentration 9.2km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.29	0.32	0.30
0.2-0.3	0.75	0.80	0.77
0.3-0.4	0.80	0.84	0.82
0.4-0.5	0.59	0.60	0.59
0.5-0.6	0.39	0.44	0.41
0.6-0.7	0.18	0.20	0.19
0.7-0.8	0.12	0.13	0.12
0.8-0.9	0.10	0.14	0.12
0.9-1			
Approximate width(m)	192.55		
Approximate distance from outfall(km)	9.2		
Time and date	16:30:01	Oct 26th, 2011	



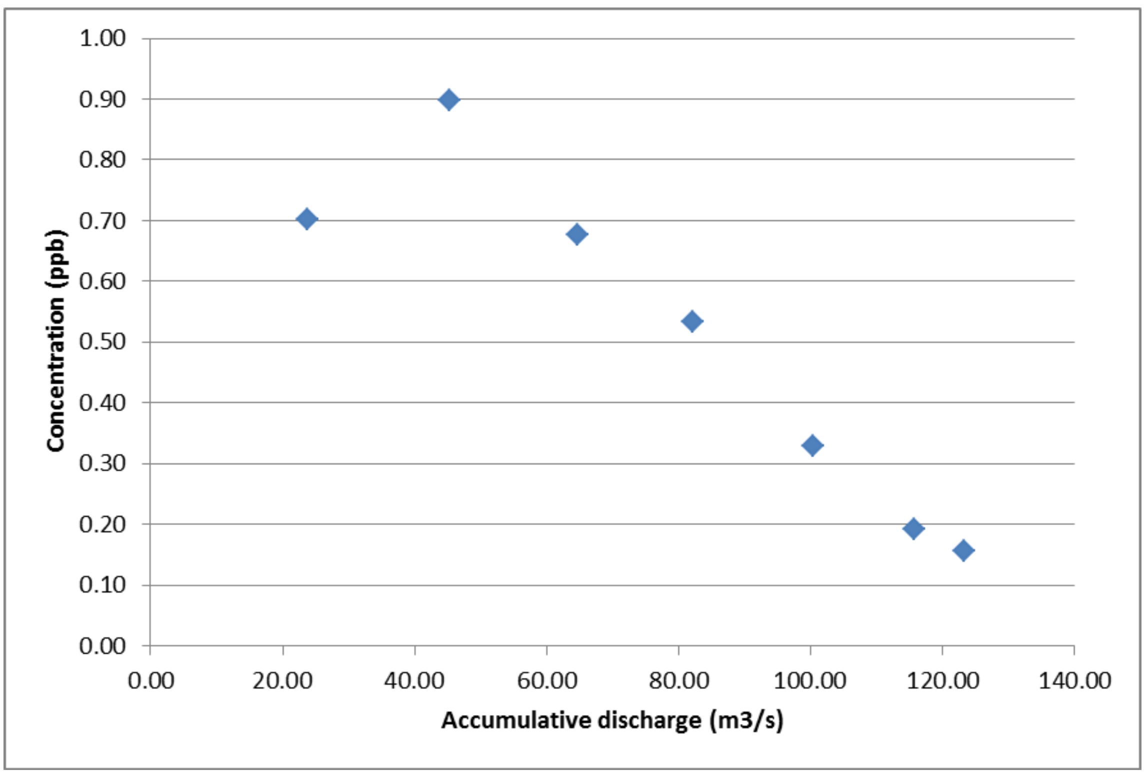


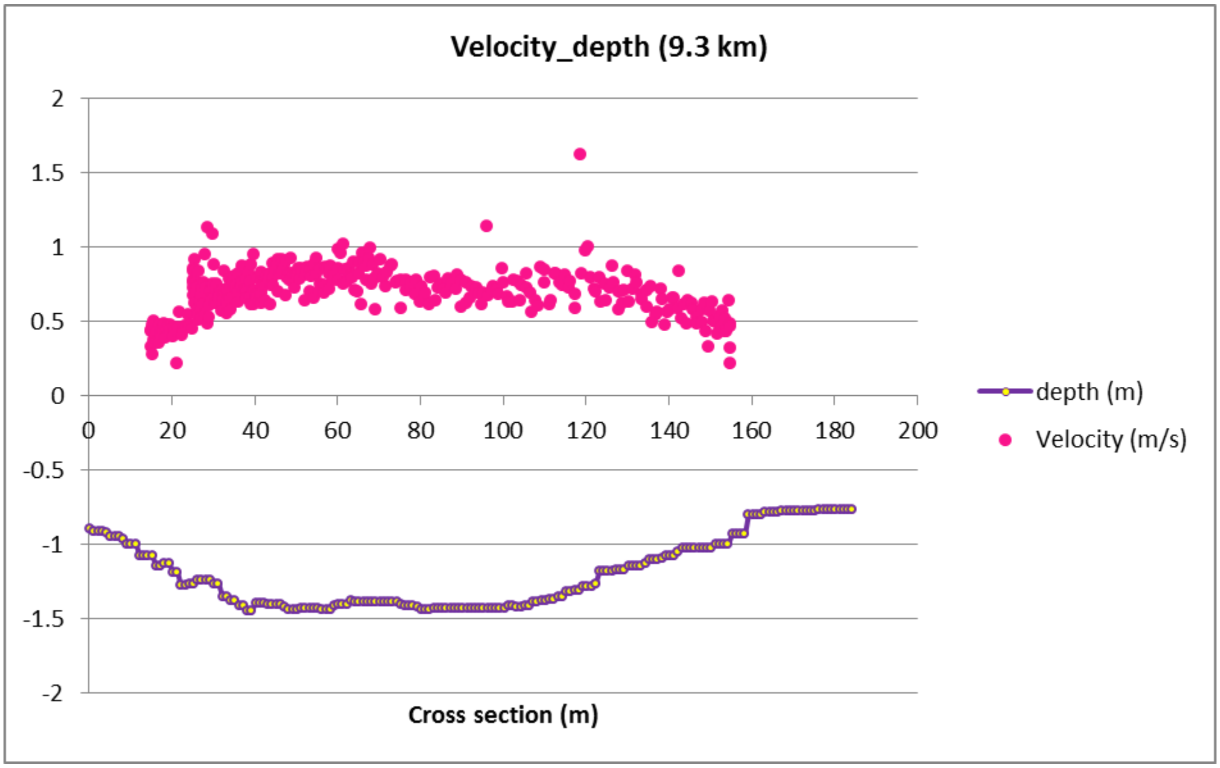
Velocity 9.3km_2



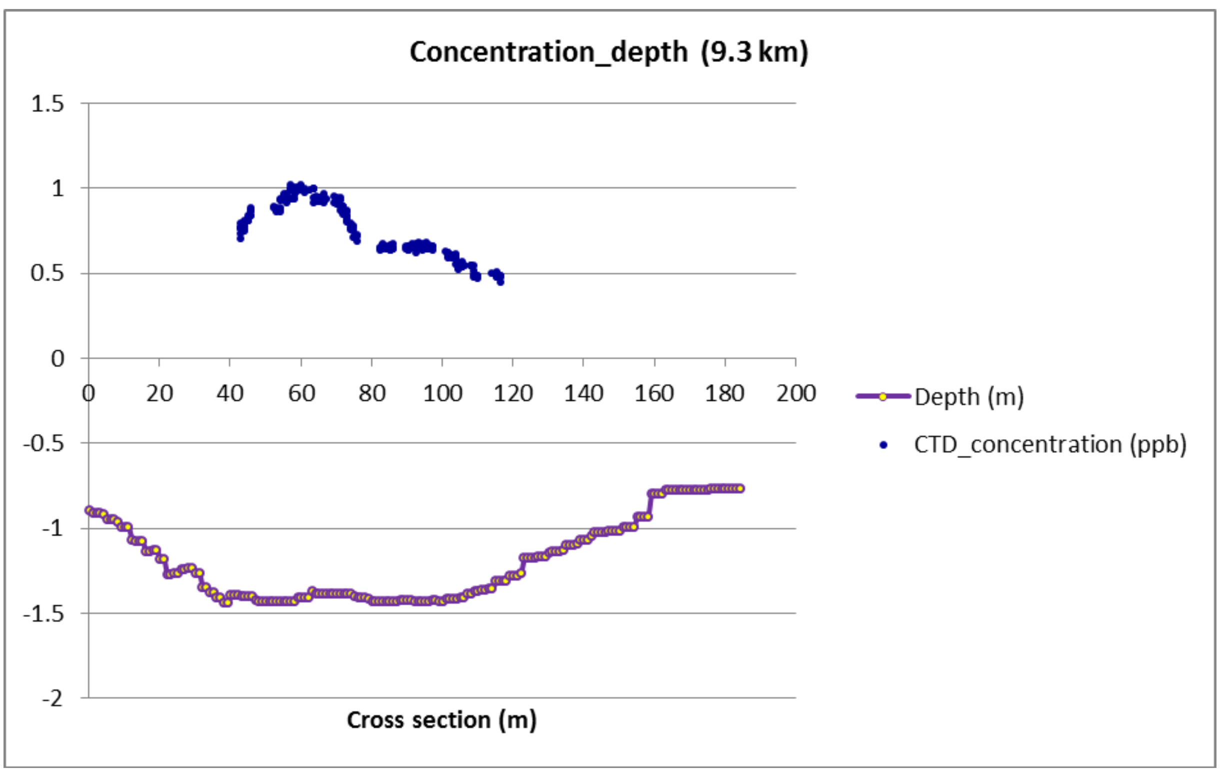
Concentration 9.3km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.67	0.74	0.70
0.2-0.3	0.88	0.91	0.90
0.3-0.4	0.65	0.70	0.68
0.4-0.5	0.51	0.55	0.53
0.5-0.6	0.31	0.34	0.33
0.6-0.7	0.18	0.20	0.19
0.7-0.8	0.14	0.18	0.16
0.8-0.9			
0.9-1			
Approximate width(m)	190.44		
Approximate distance from outfall(km)	9.3		
Time and date	16:30:01	Oct 26th, 2011	



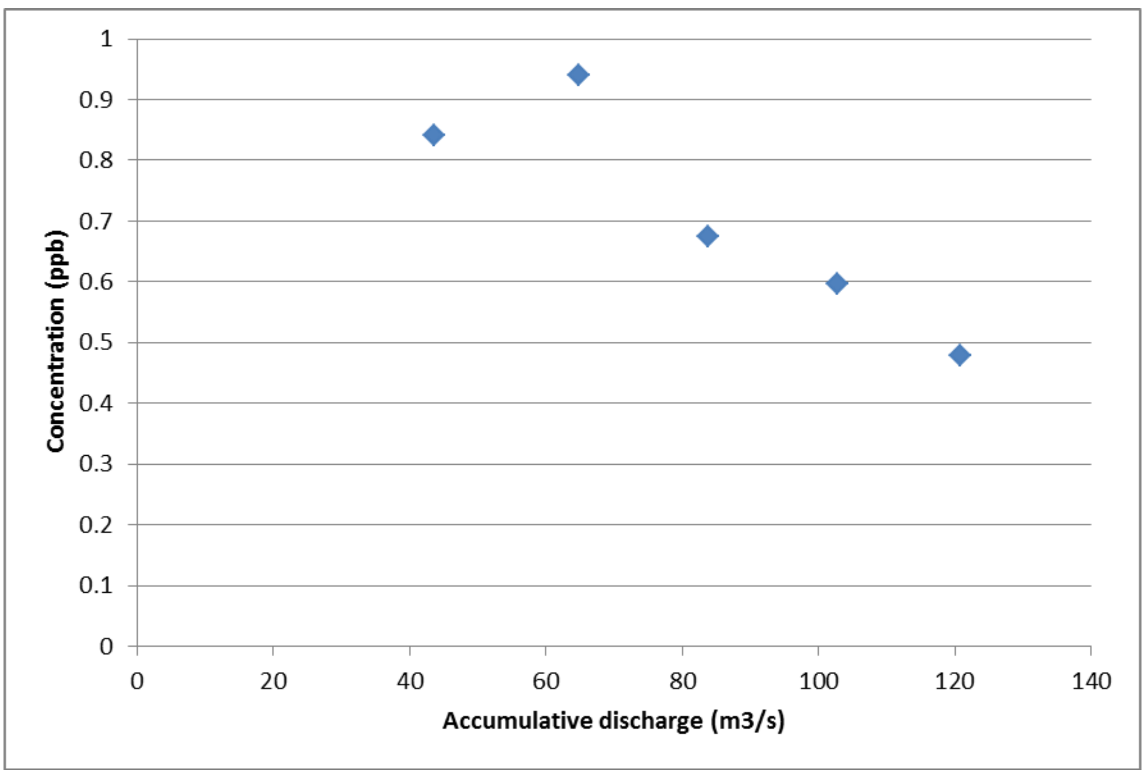


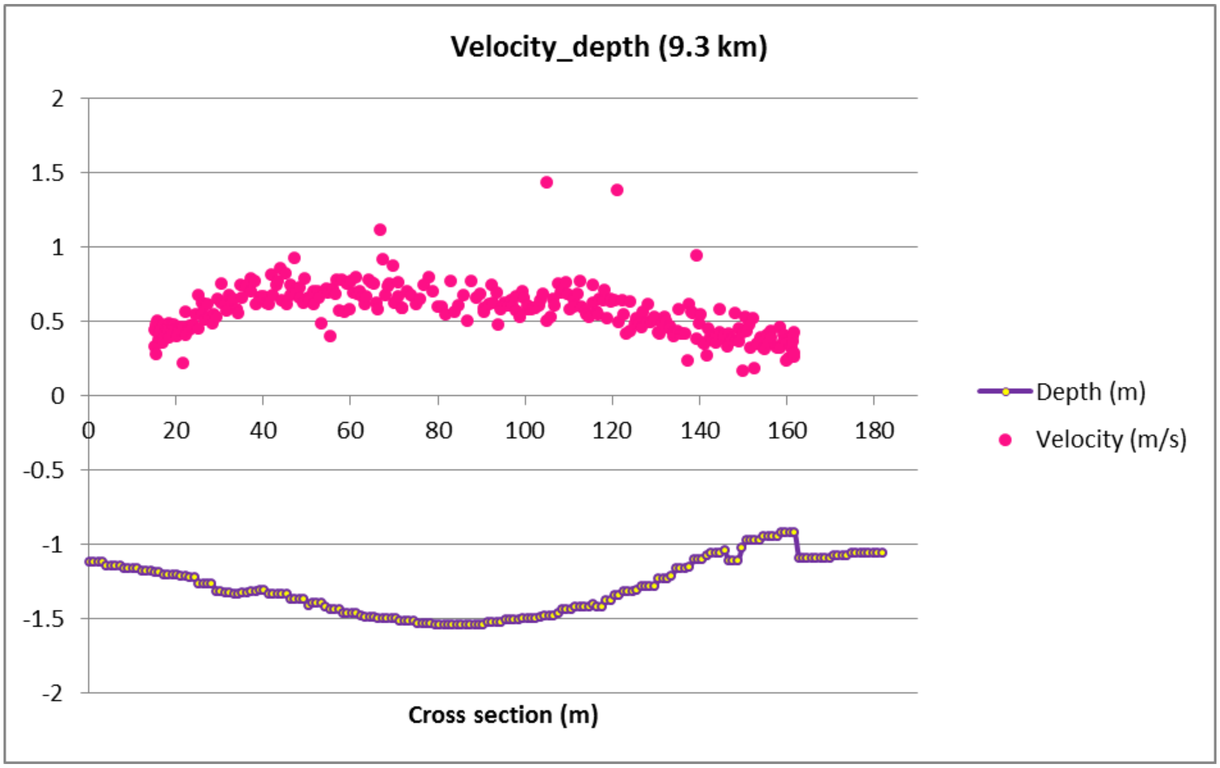
Velocity 9.3km_3



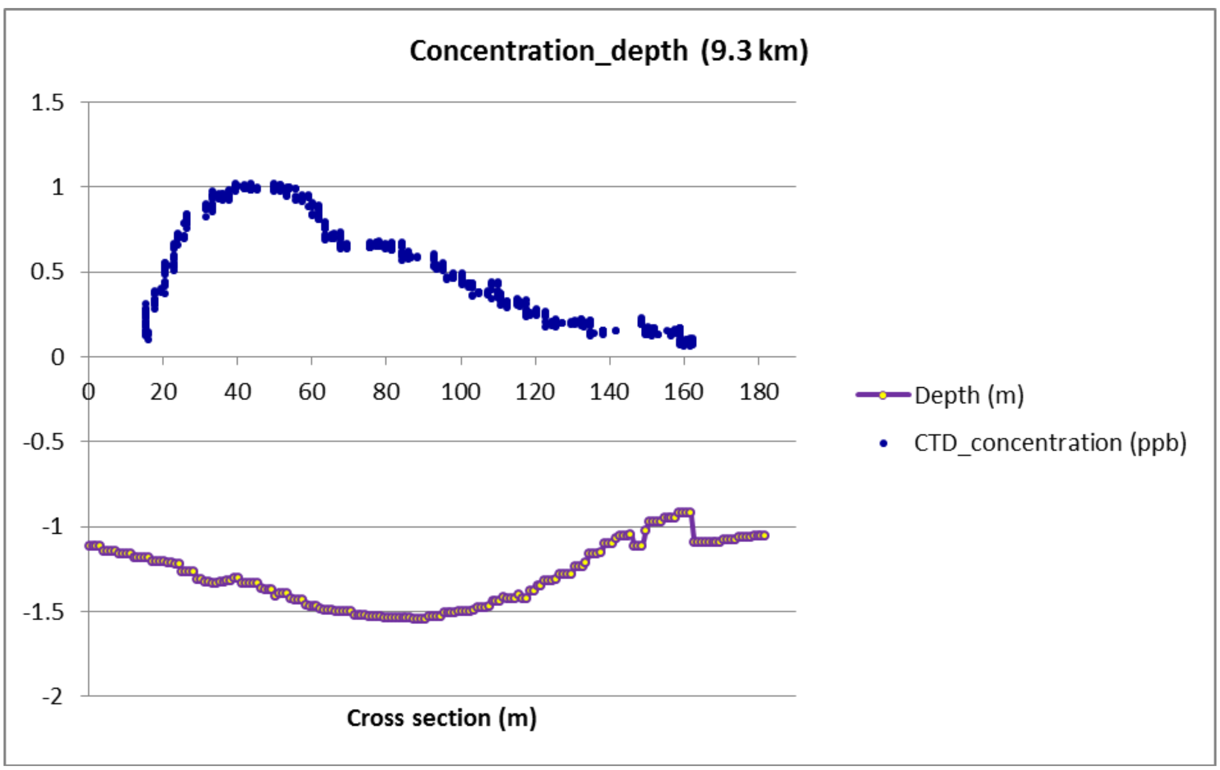
Concentration 9.3km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	0.82	0.86	0.84
0.3-0.4	0.93	0.95	0.94
0.4-0.5	0.66	0.69	0.67
0.5-0.6	0.58	0.61	0.60
0.6-0.7	0.47	0.49	0.48
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	185.03		
Approximate distance from outfall(km)	9.3		
Time and date	16:30:01	Oct 26th, 2011	



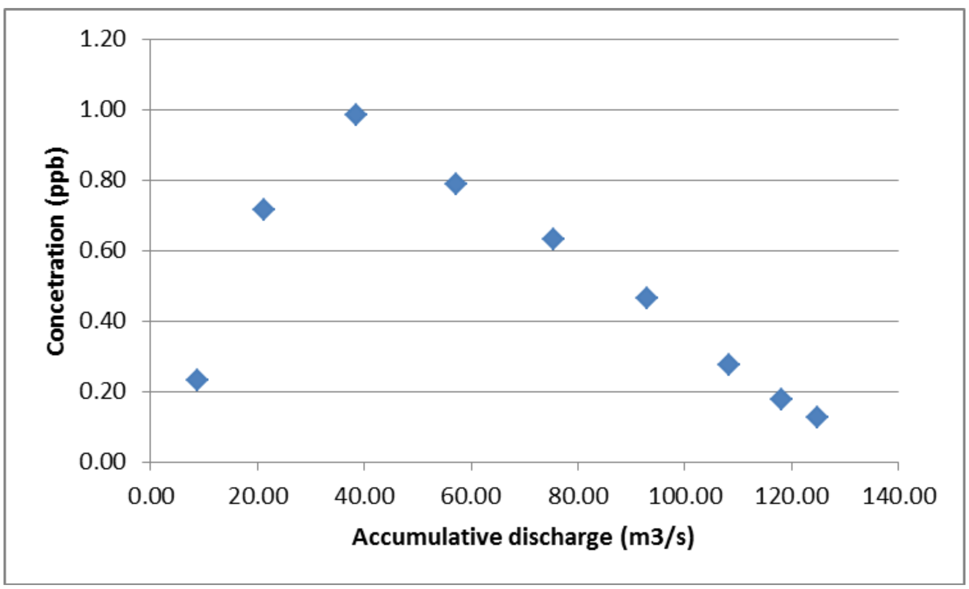


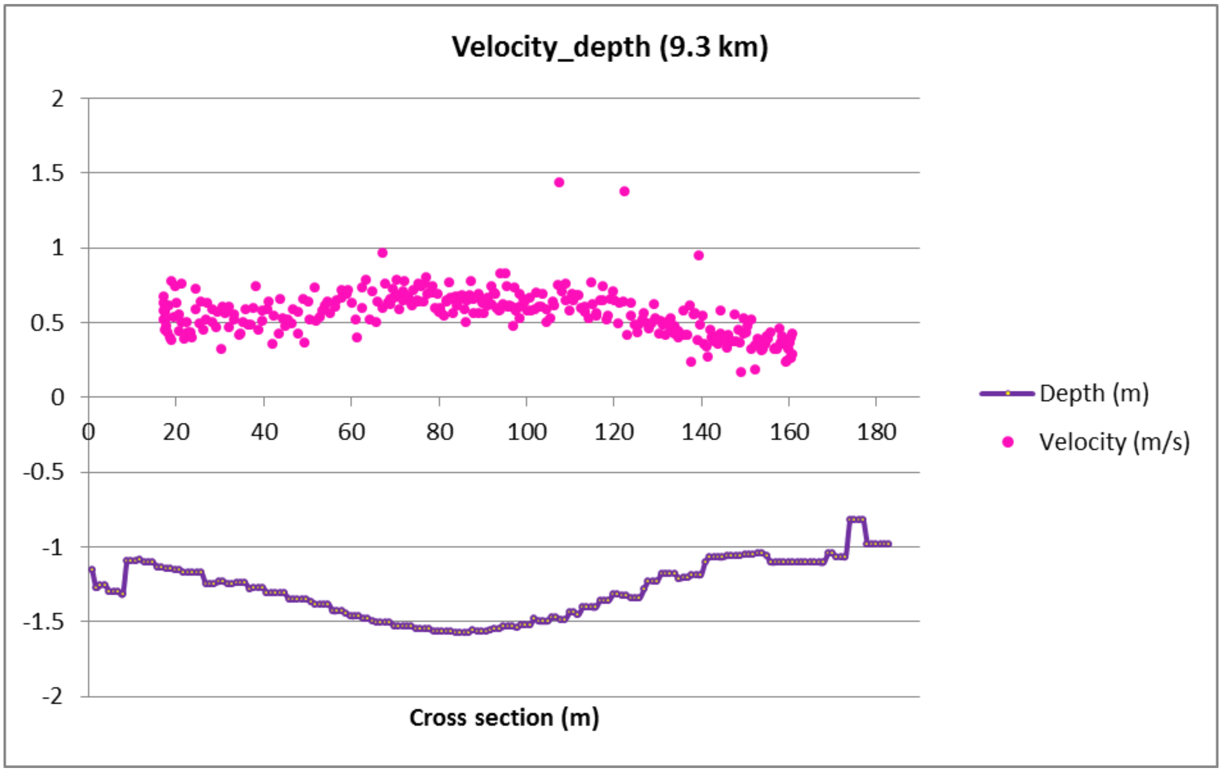
Velocity 9.3km_4



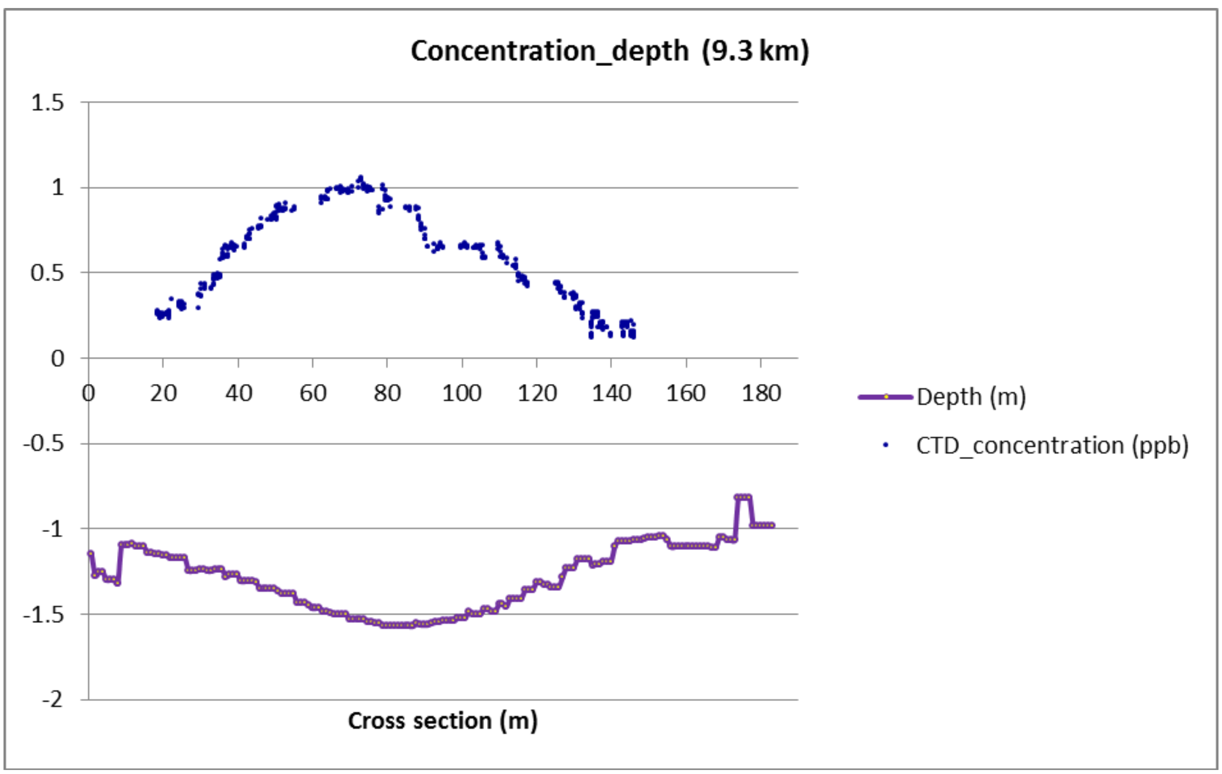
Concentration 9.3km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.21	0.25	0.23
0.1-0.2	0.68	0.75	0.71
0.2-0.3	0.98	0.99	0.99
0.3-0.4	0.76	0.81	0.79
0.4-0.5	0.63	0.64	0.63
0.5-0.6	0.45	0.48	0.47
0.6-0.7	0.26	0.29	0.27
0.7-0.8	0.17	0.18	0.18
0.8-0.9	0.12	0.13	0.12
0.9-1			
Approximate width(m)	182.03		
Approximate distance from outfall(km)	9.3		
Time and date	16:30:01	Oct 26th, 2011	



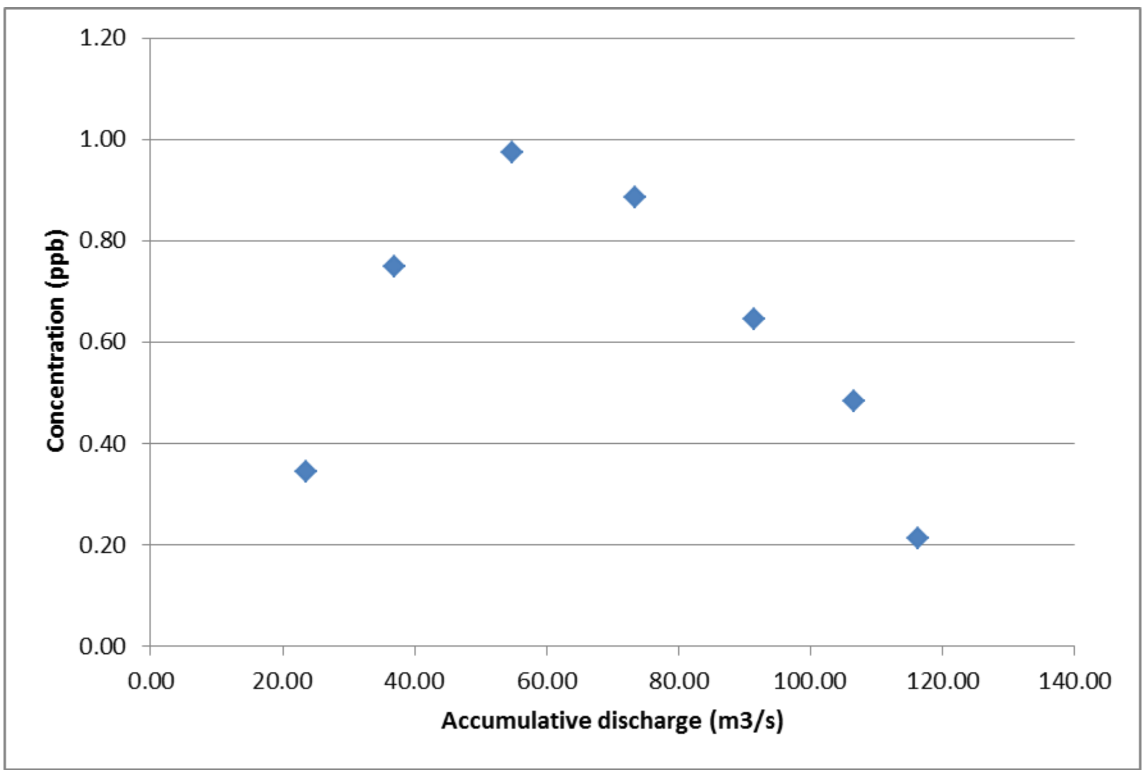


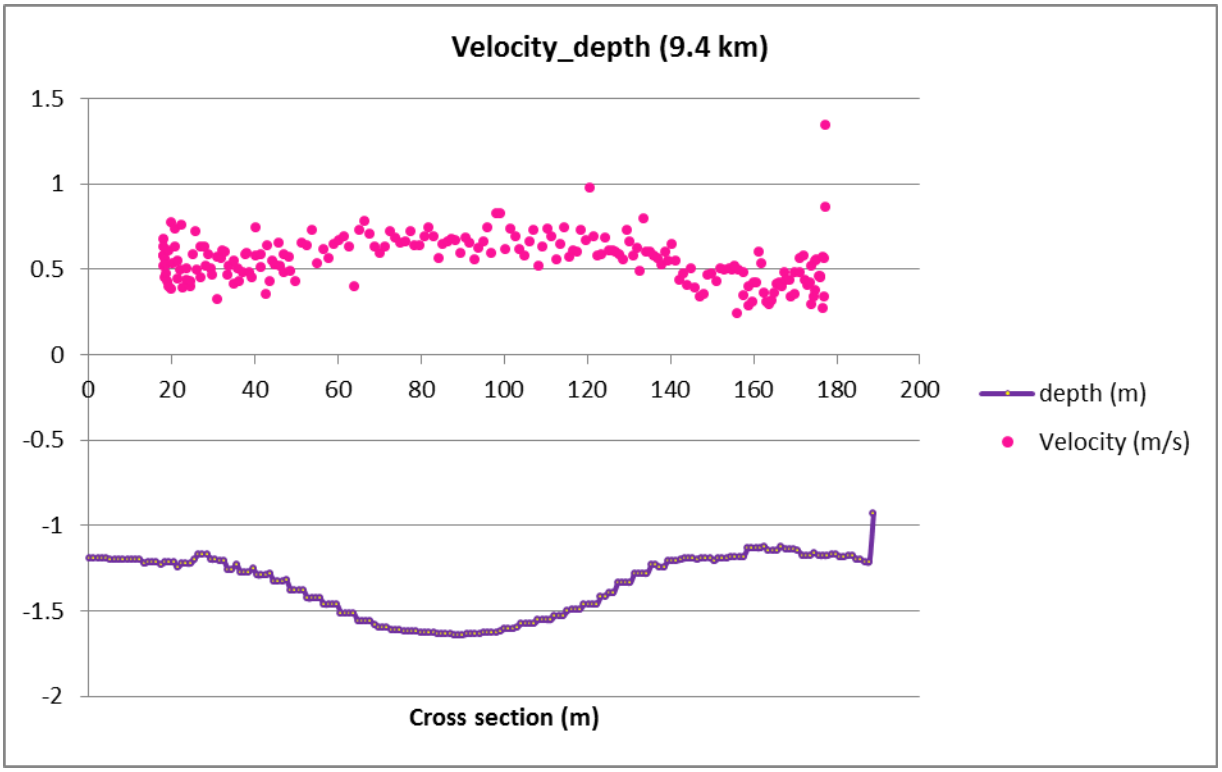
Velocity 9.3_5



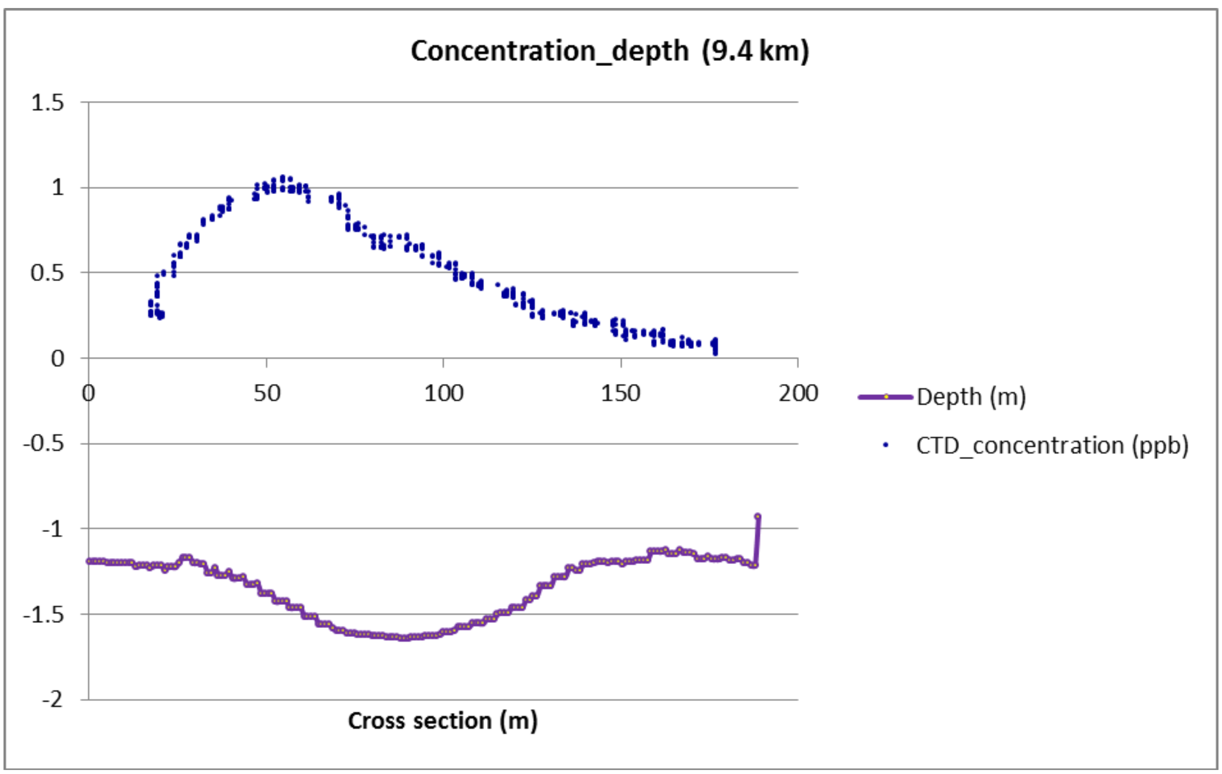
Concentration 9.3km_5

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.32	0.37	0.34
0.2-0.3	0.73	0.77	0.75
0.3-0.4	0.96	0.99	0.97
0.4-0.5	0.86	0.91	0.89
0.5-0.6	0.64	0.65	0.65
0.6-0.7	0.46	0.50	0.48
0.7-0.8	0.20	0.22	0.21
0.8-0.9			
0.9-1			
Approximate width(m)	183.37		
Approximate distance from outfall(km)	9.3		
Time and date	16:30:01	Oct 26th, 2011	



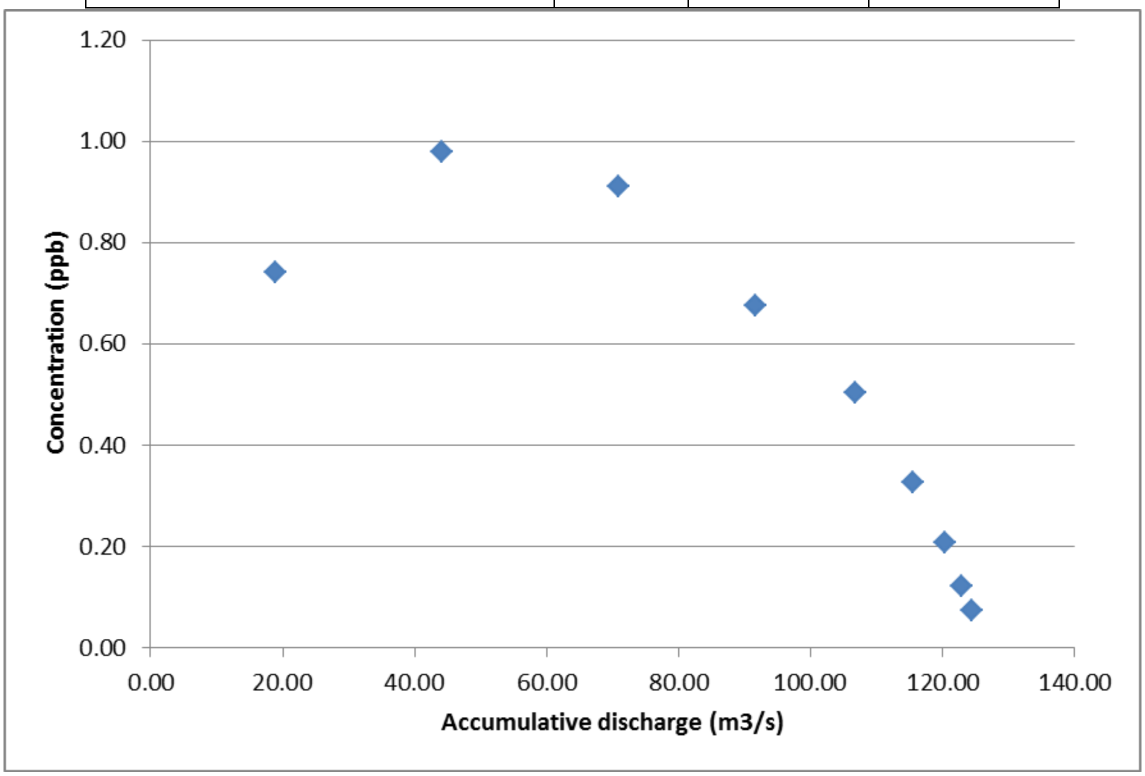


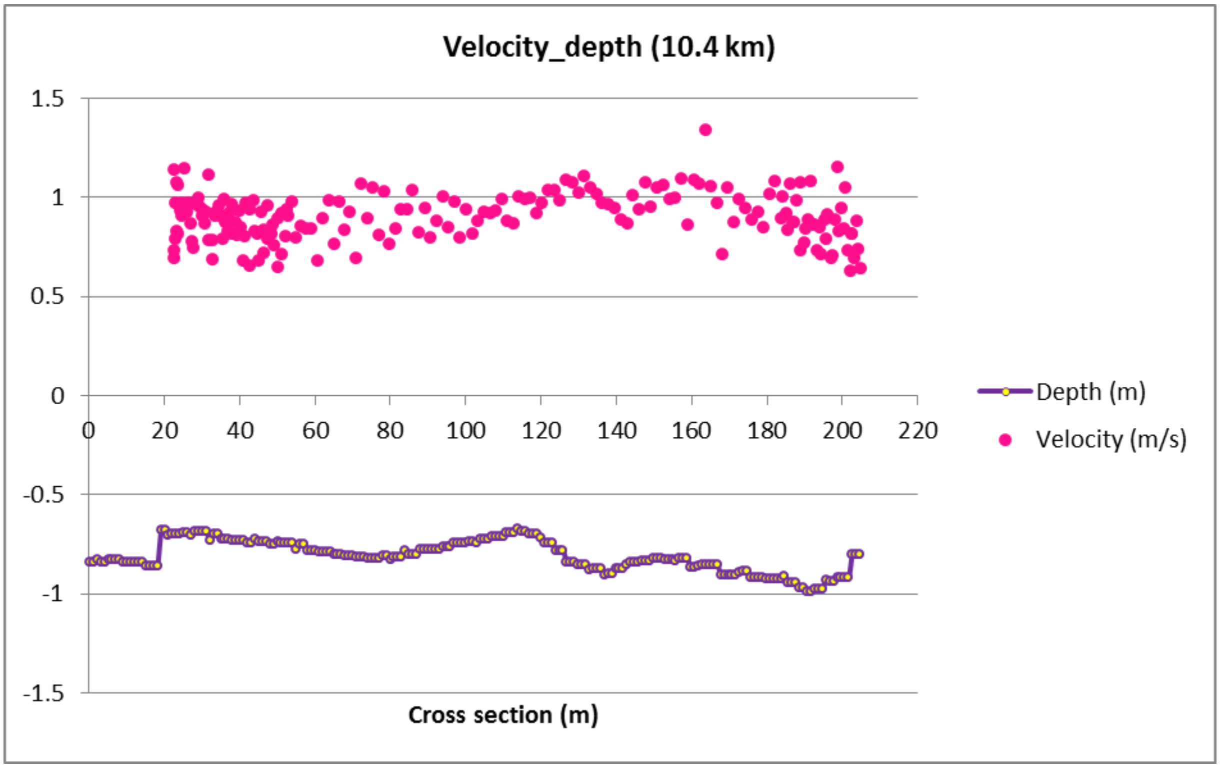
Velocity 9.4km_6



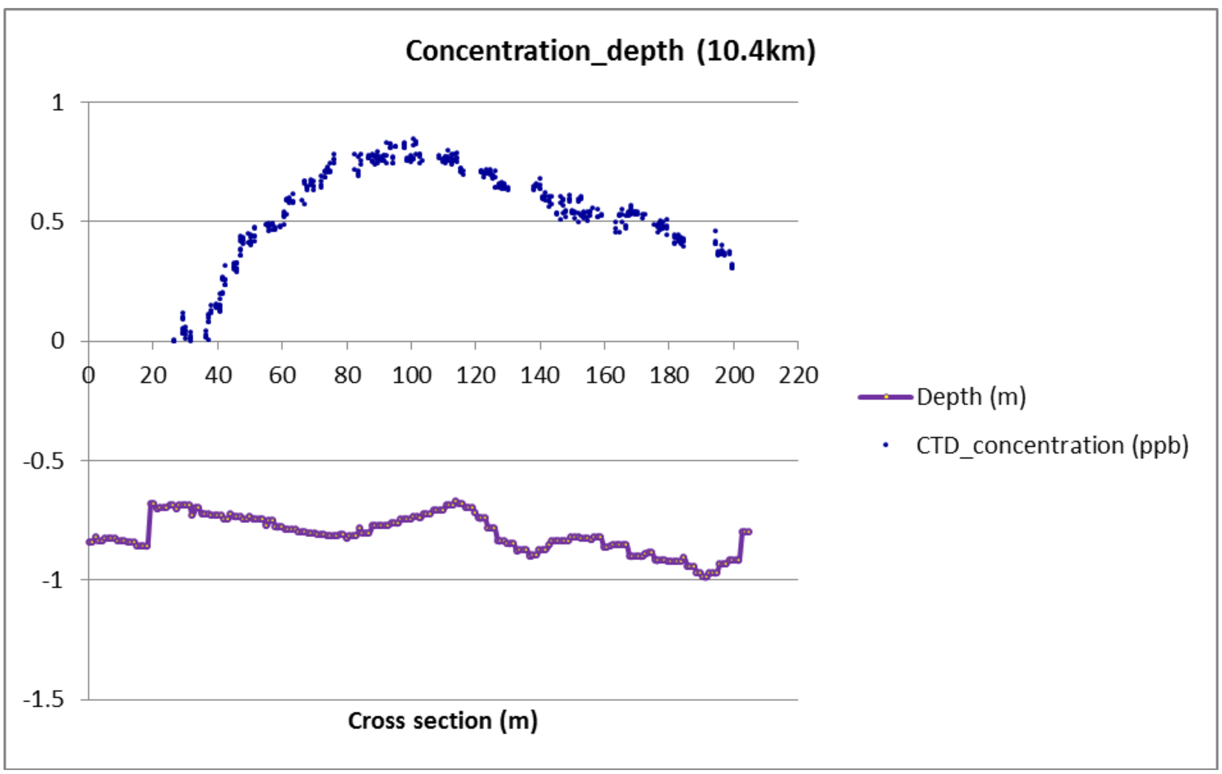
Concentration 9.4km_6

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.71	0.77	0.74
0.2-0.3	0.97	0.99	0.98
0.3-0.4	0.89	0.93	0.91
0.4-0.5	0.66	0.68	0.67
0.5-0.6	0.49	0.52	0.50
0.6-0.7	0.31	0.34	0.32
0.7-0.8	0.20	0.22	0.21
0.8-0.9	0.11	0.13	0.12
0.9-1	0.06	0.08	0.07
Approximate width(m)	189.67		
Approximate distance from outfall(km)	9.4		
Time and date	16:30:01	Oct 26th, 2011	



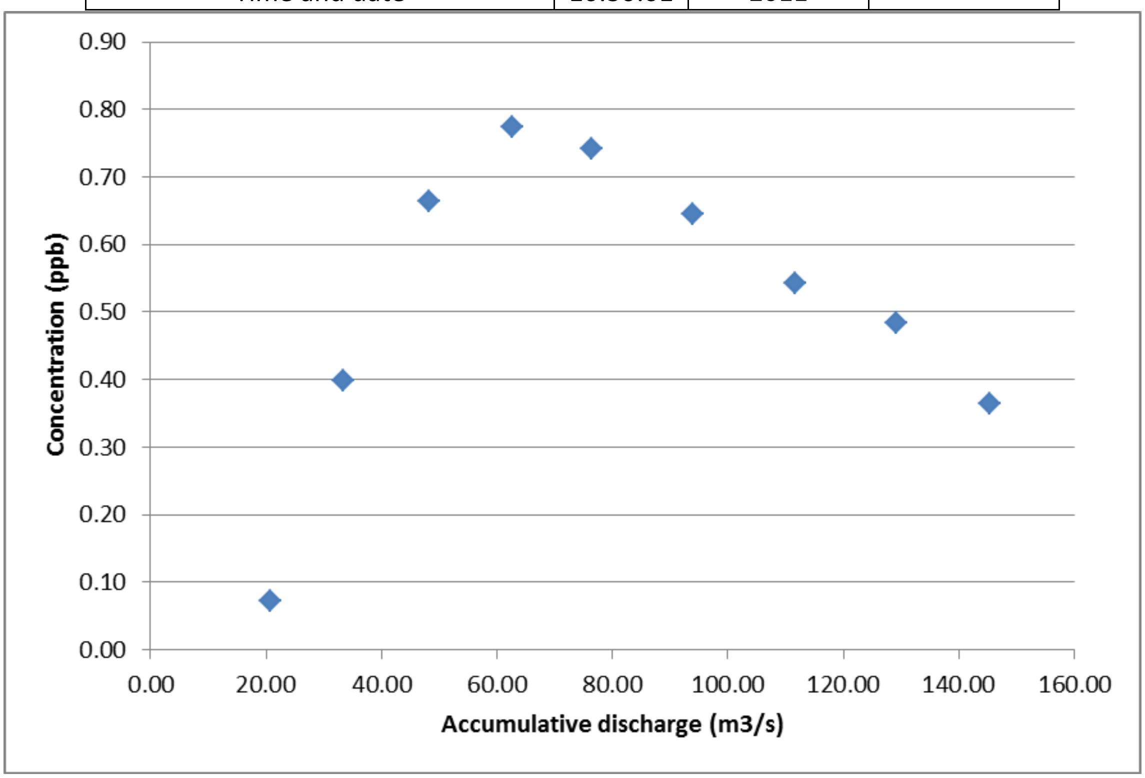


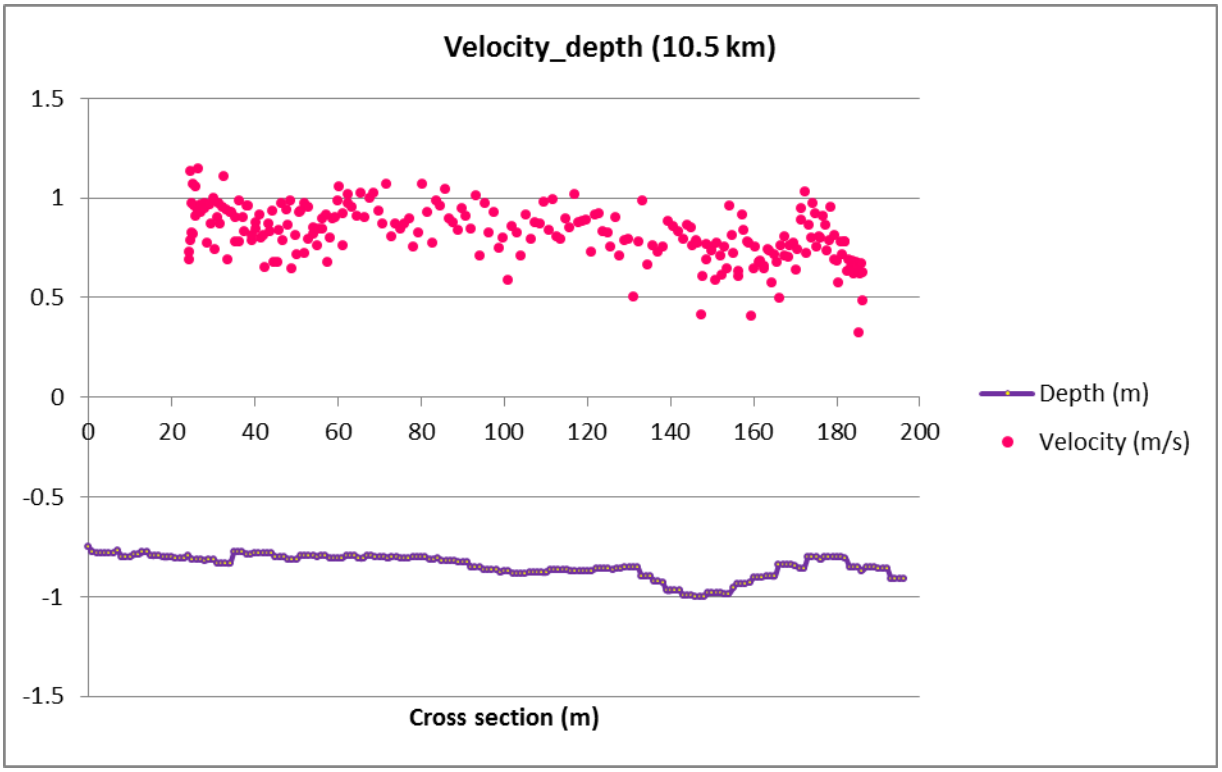
Velocity 10.4km_7



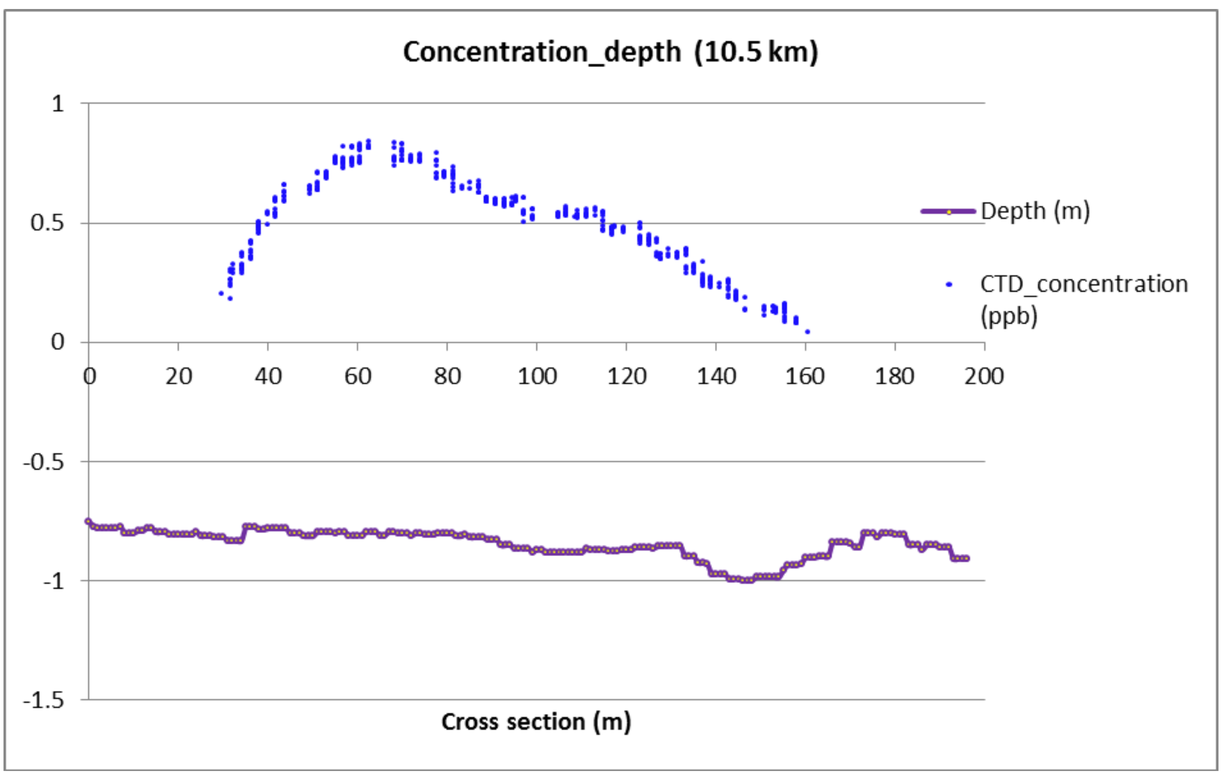
Concentration 10.4km_7

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.06	0.09	0.07
0.2-0.3	0.37	0.42	0.40
0.3-0.4	0.65	0.68	0.66
0.4-0.5	0.77	0.78	0.77
0.5-0.6	0.73	0.75	0.74
0.6-0.7	0.63	0.66	0.64
0.7-0.8	0.53	0.55	0.54
0.8-0.9	0.47	0.49	0.48
0.9-1	0.35	0.38	0.36
Approximate width(m)	205.35		
Approximate distance from outfall(km)	10.4		
Time and date	16:30:01	Oct 26th, 2011	



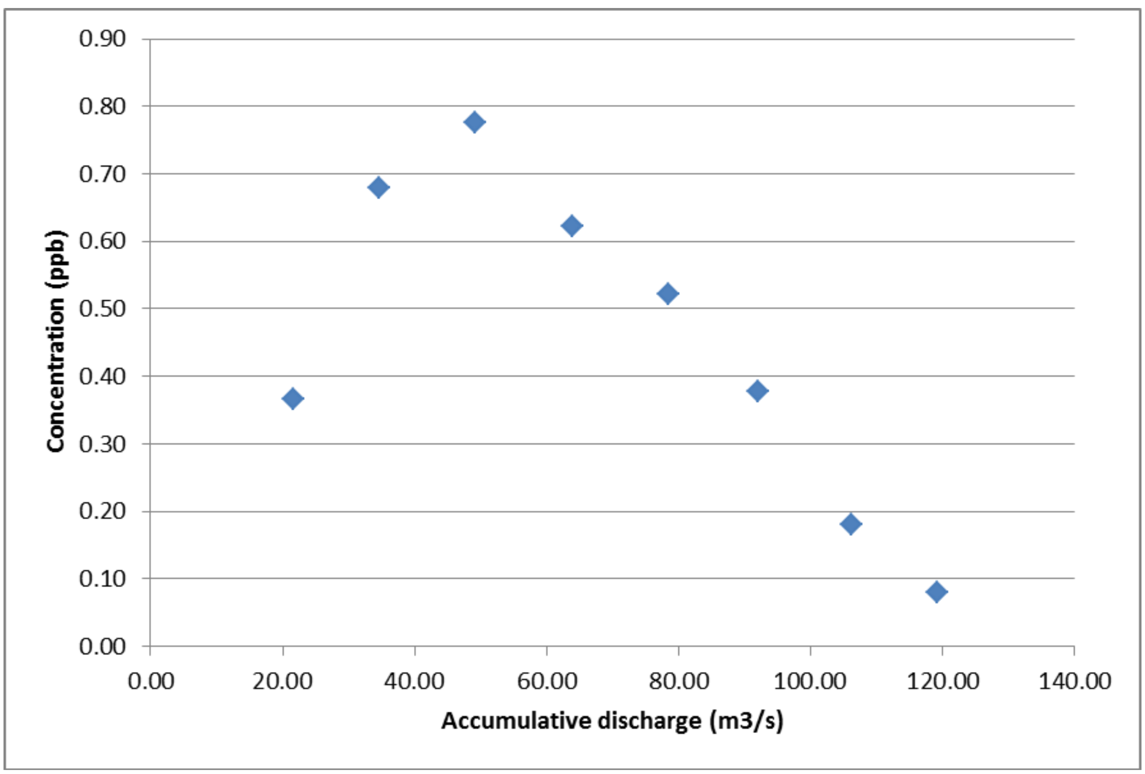


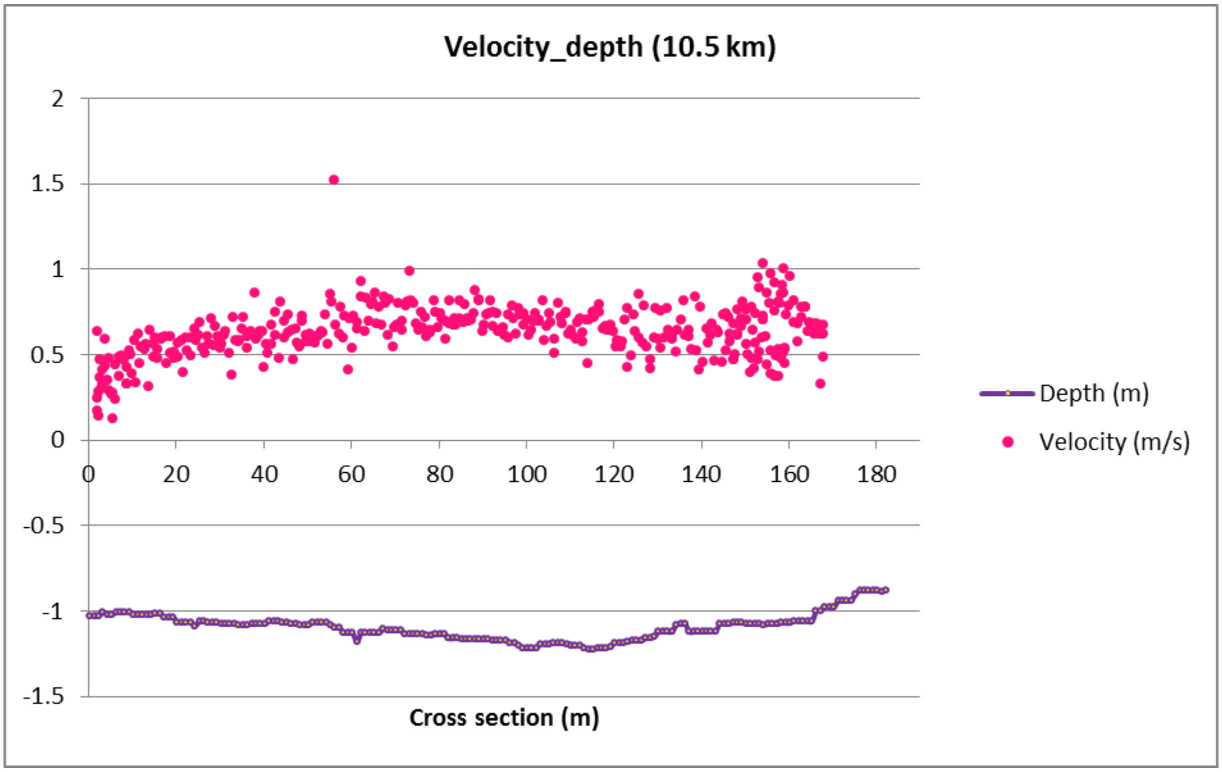
Velocity 10.5km_8



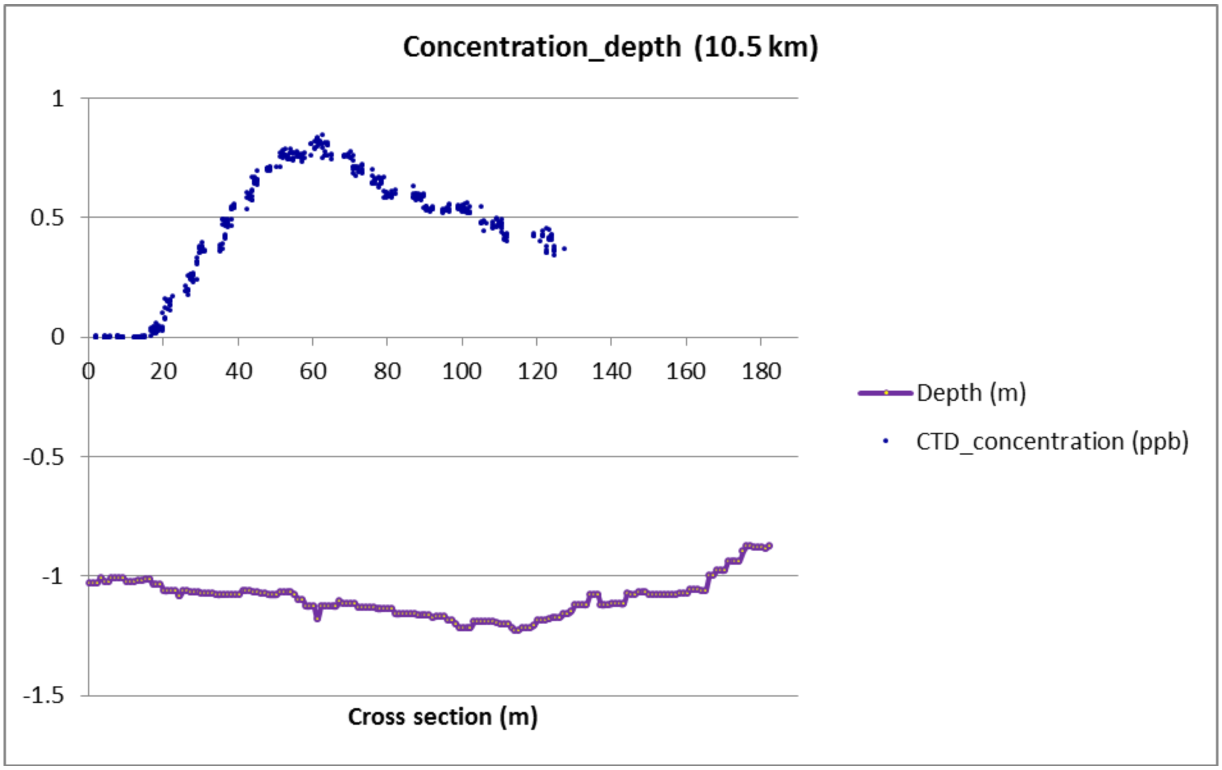
Concentration 10.5km_8

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.37	0.37	0.37
0.2-0.3	0.68	0.68	0.68
0.3-0.4	0.78	0.78	0.78
0.4-0.5	0.62	0.62	0.62
0.5-0.6	0.52	0.52	0.52
0.6-0.7	0.38	0.38	0.38
0.7-0.8	0.18	0.18	0.18
0.8-0.9	0.08	0.08	0.08
0.9-1			
Approximate width(m)	196.47		
Approximate distance from outfall(km)	10.5		
Time and date	16:30:01	Oct 26th, 2011	



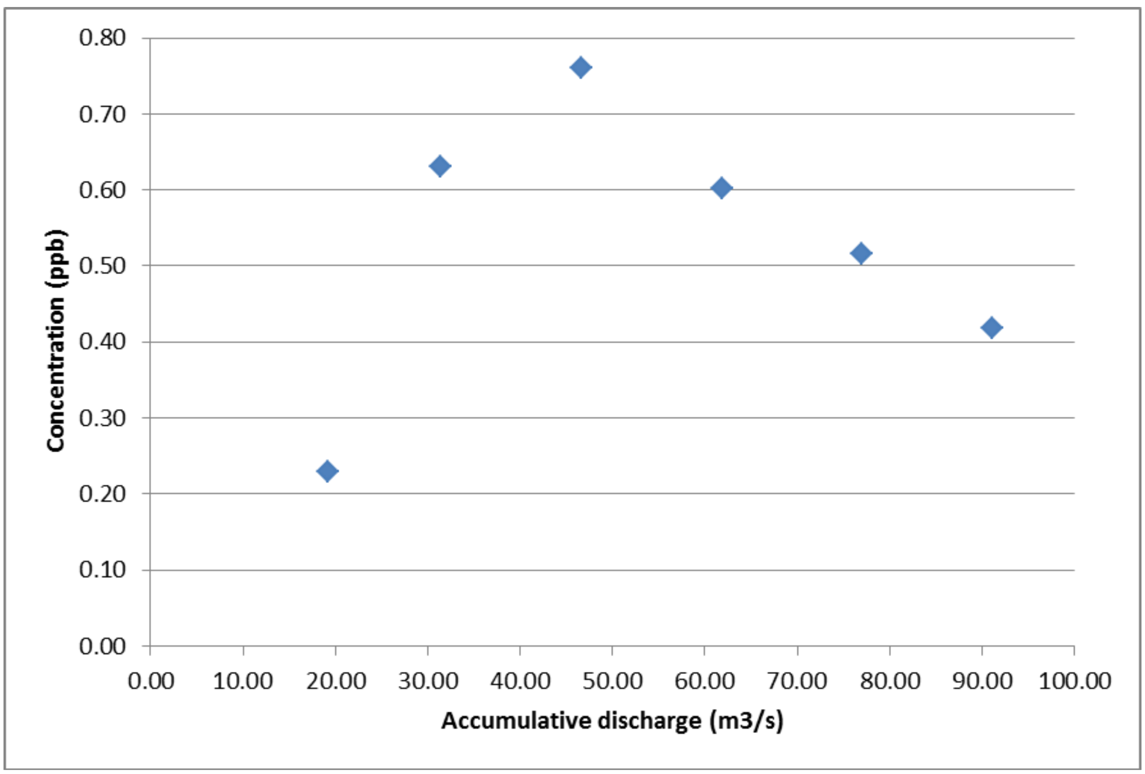


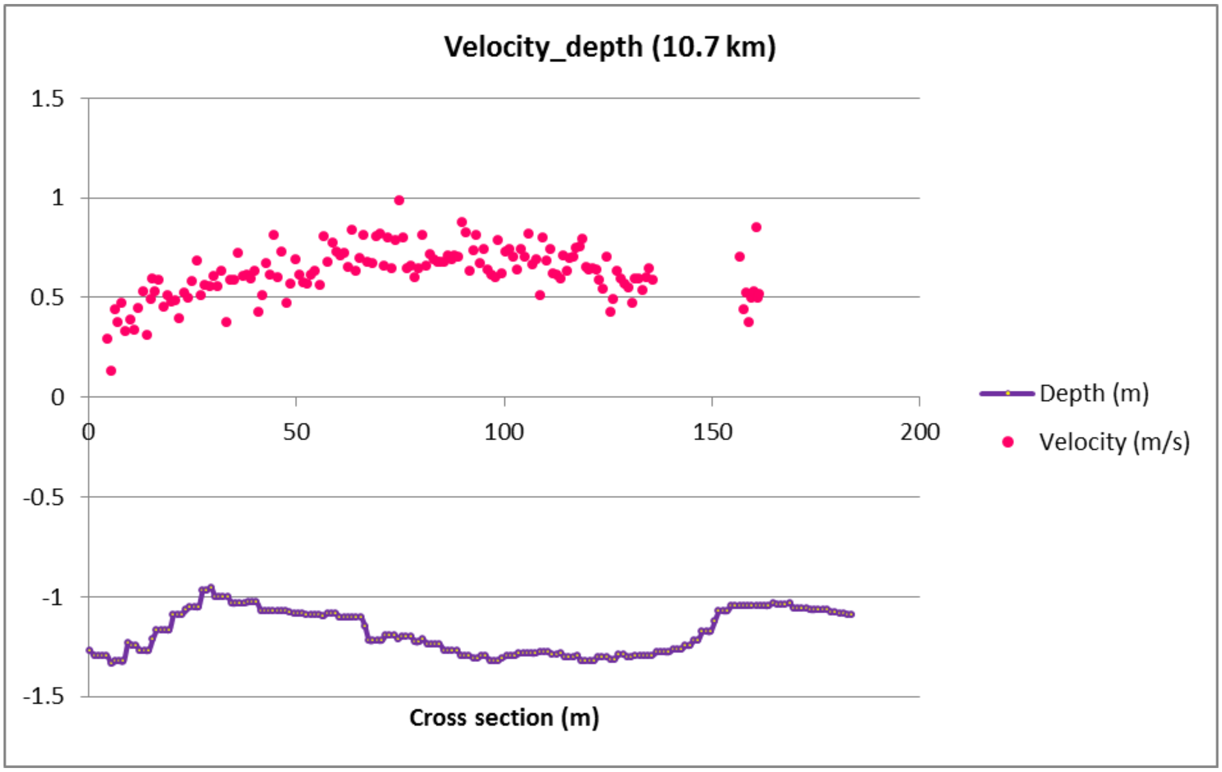
Velocity 10.5km_9



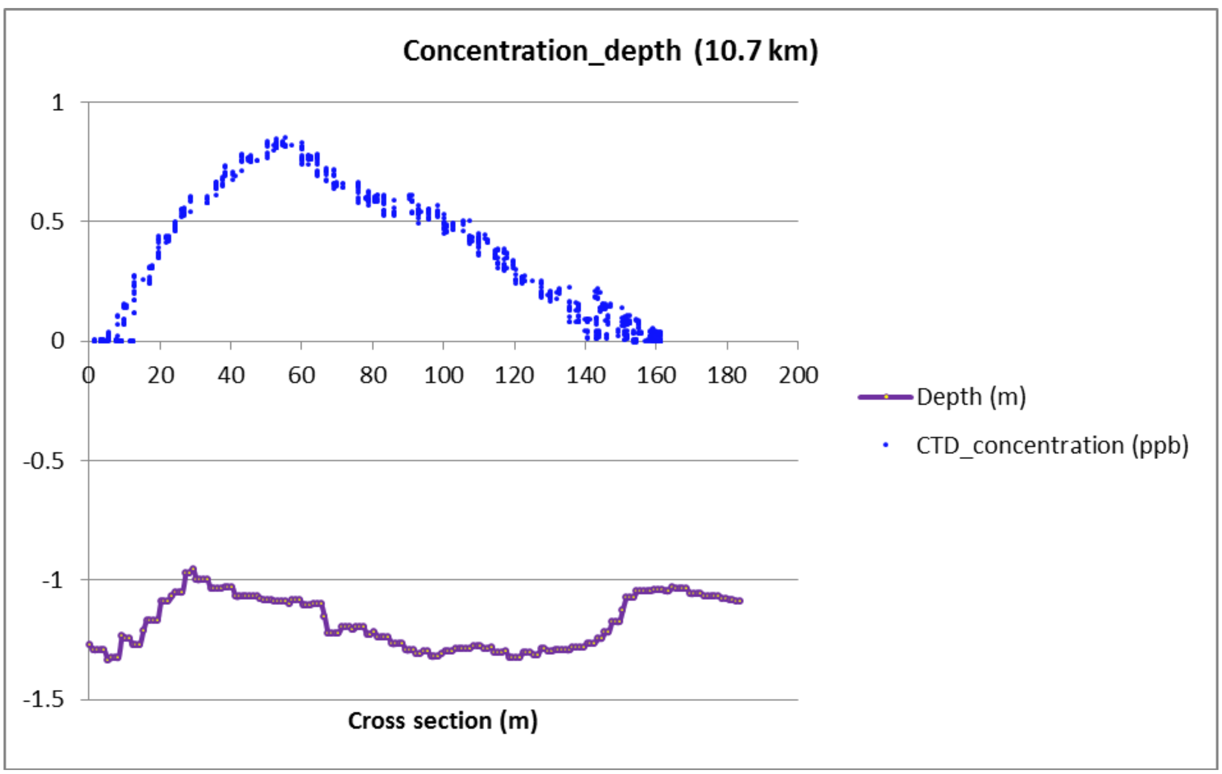
Concentration 10.5km_9

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.00	0.01	0.00
0.1-0.2	0.20	0.26	0.23
0.2-0.3	0.61	0.65	0.63
0.3-0.4	0.75	0.77	0.76
0.4-0.5	0.59	0.61	0.60
0.5-0.6	0.51	0.52	0.52
0.6-0.7	0.41	0.43	0.42
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	182.97		
Approximate distance from outfall(km)	10.5		
Time and date	16:30:01	Oct 26th, 2011	



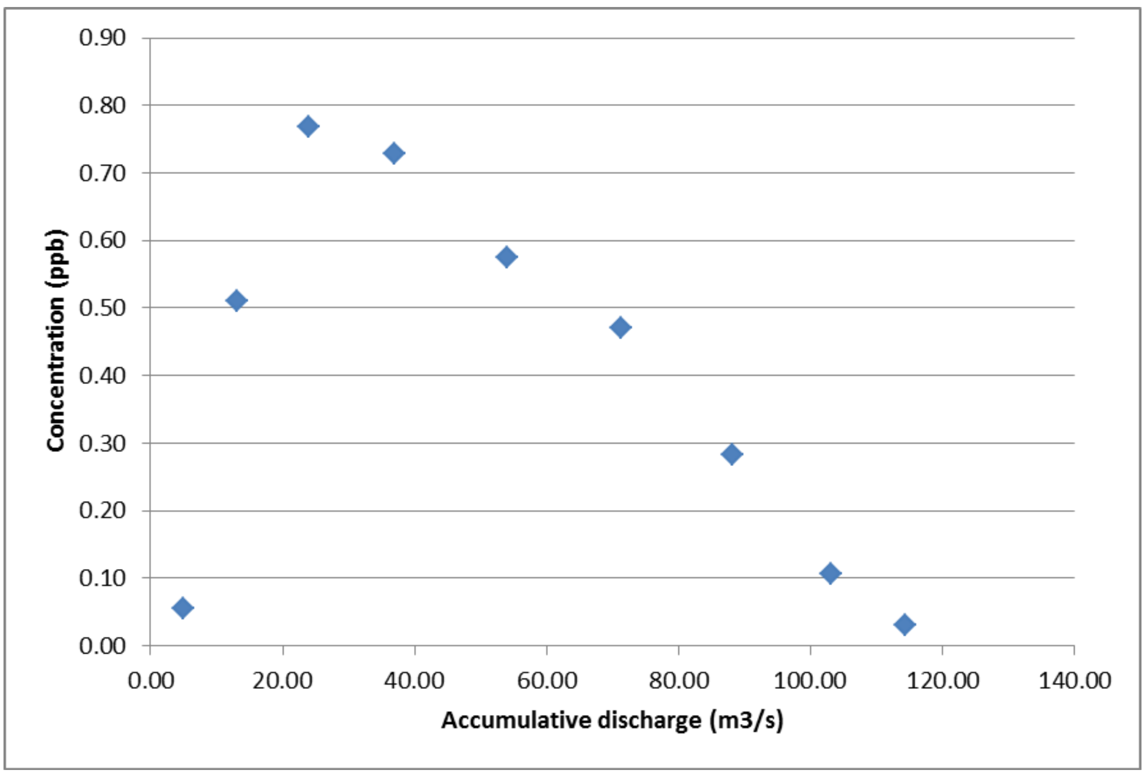


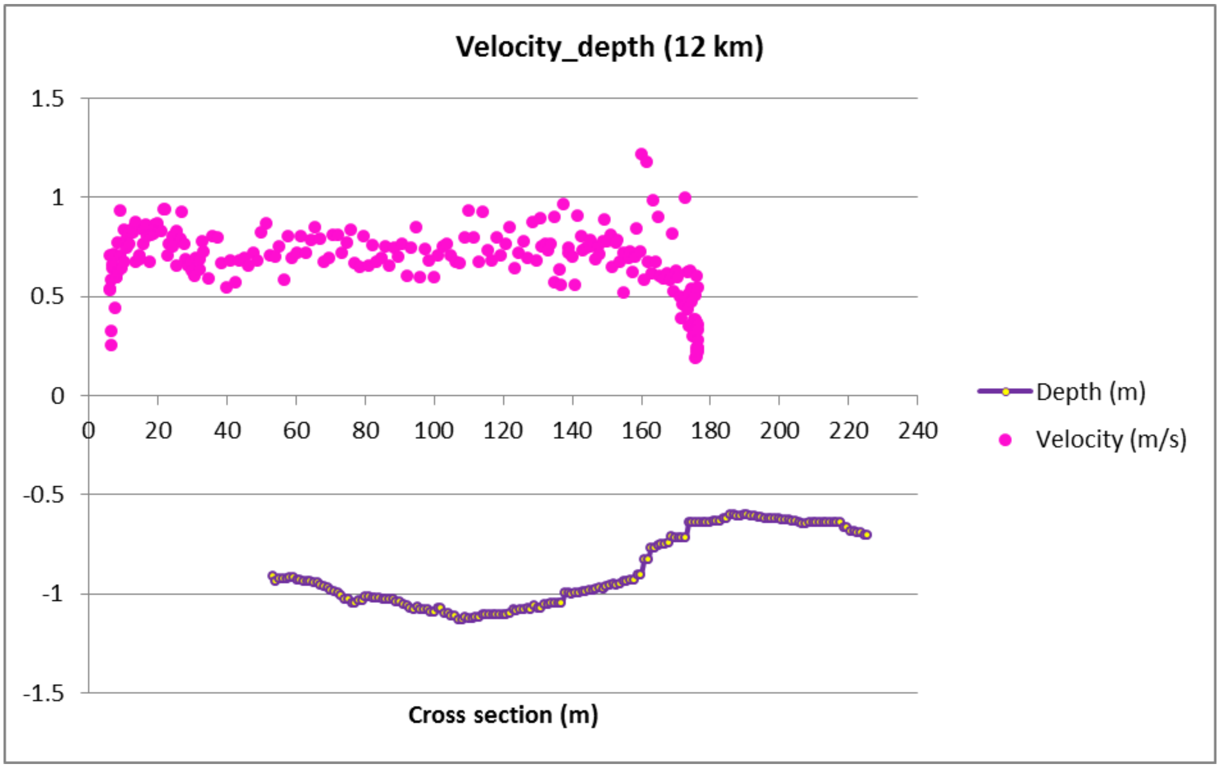
Velocity 10.7km_10



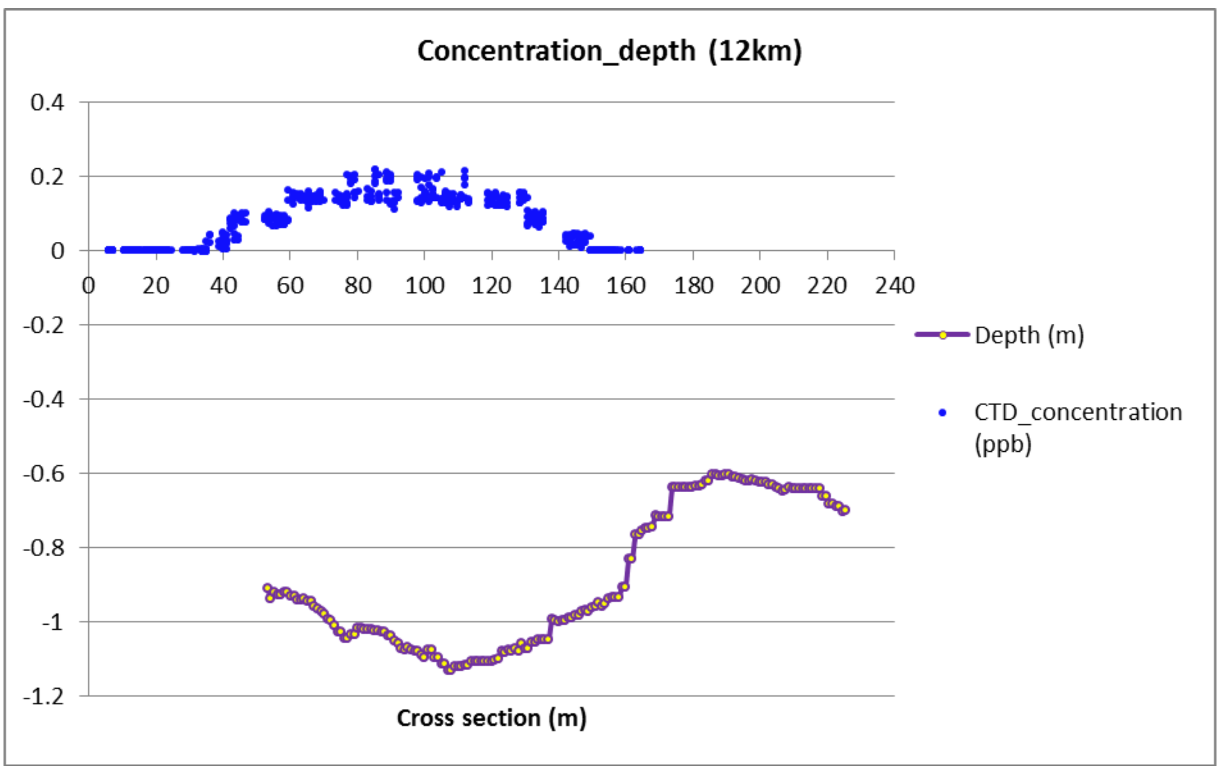
Concentration 10.7km_10

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.04	0.07	0.05
0.1-0.2	0.49	0.53	0.51
0.2-0.3	0.76	0.78	0.77
0.3-0.4	0.72	0.74	0.73
0.4-0.5	0.57	0.58	0.58
0.5-0.6	0.46	0.48	0.47
0.6-0.7	0.27	0.30	0.28
0.7-0.8	0.09	0.12	0.11
0.8-0.9	0.02	0.03	0.03
0.9-1			
Approximate width(m)	186.69		
Approximate distance from outfall(km)	10.7		
Time and date	16:30:01	Oct 26th, 2011	



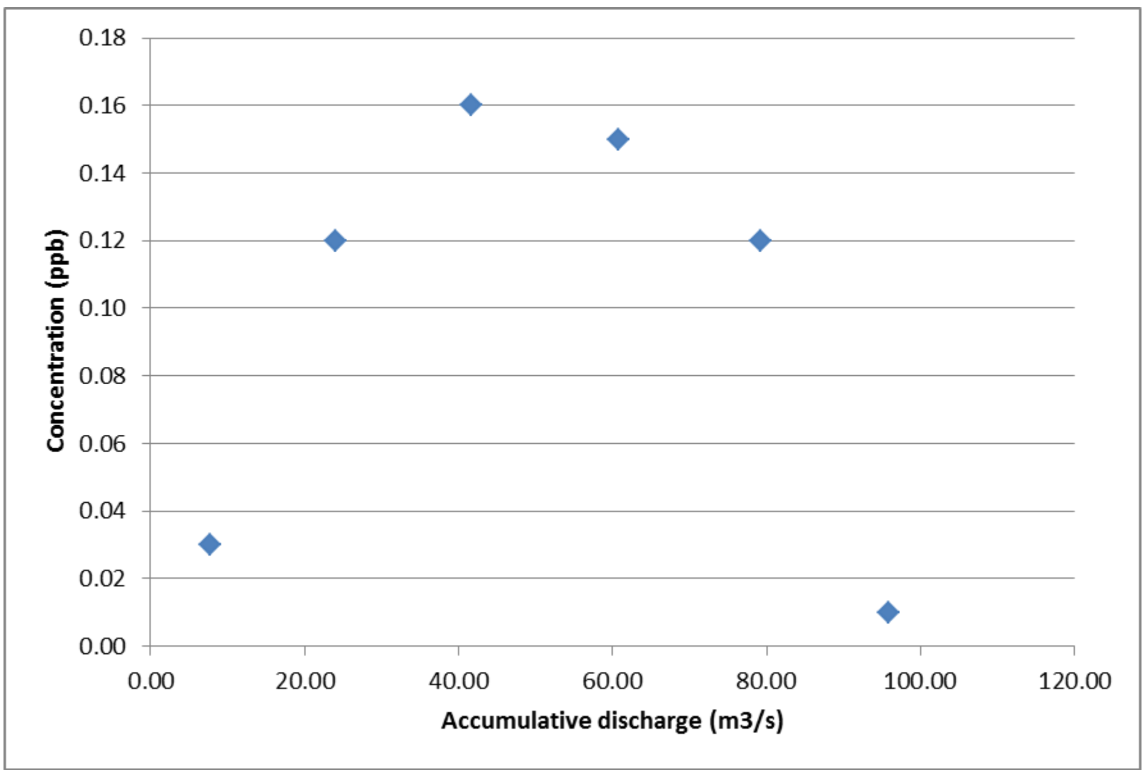


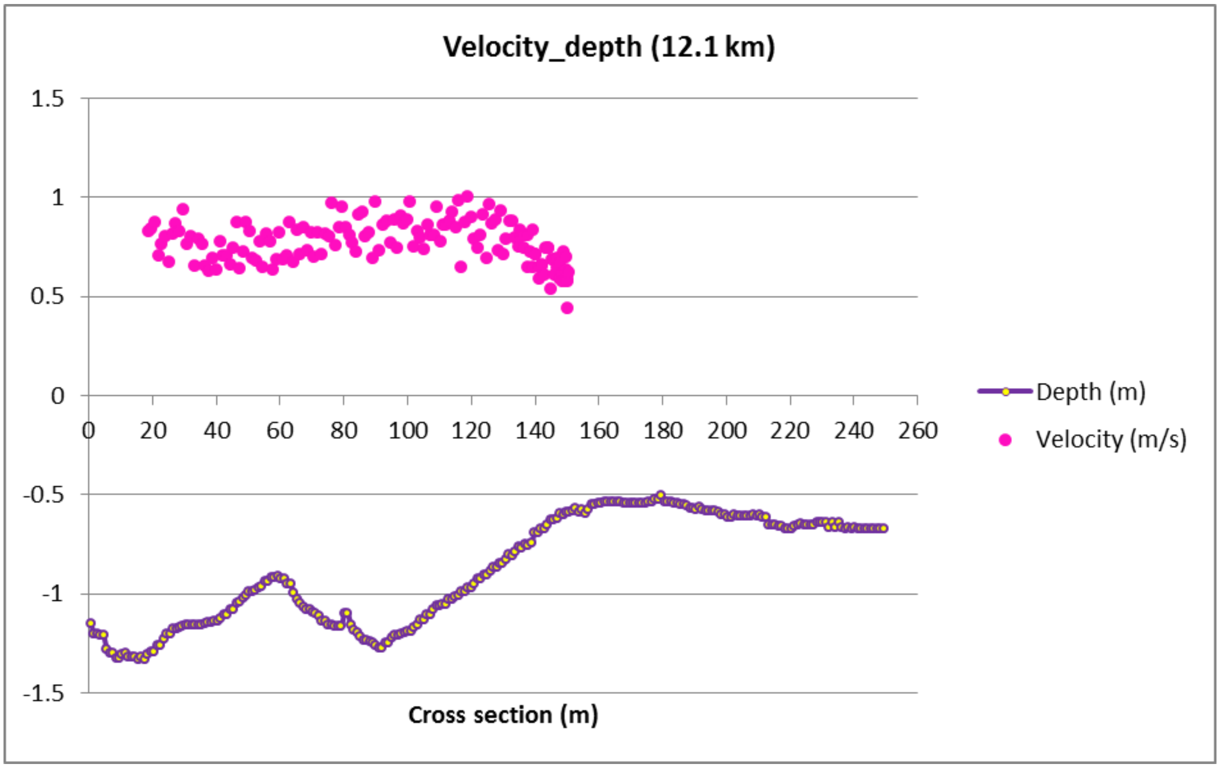
Velocity 12km_1



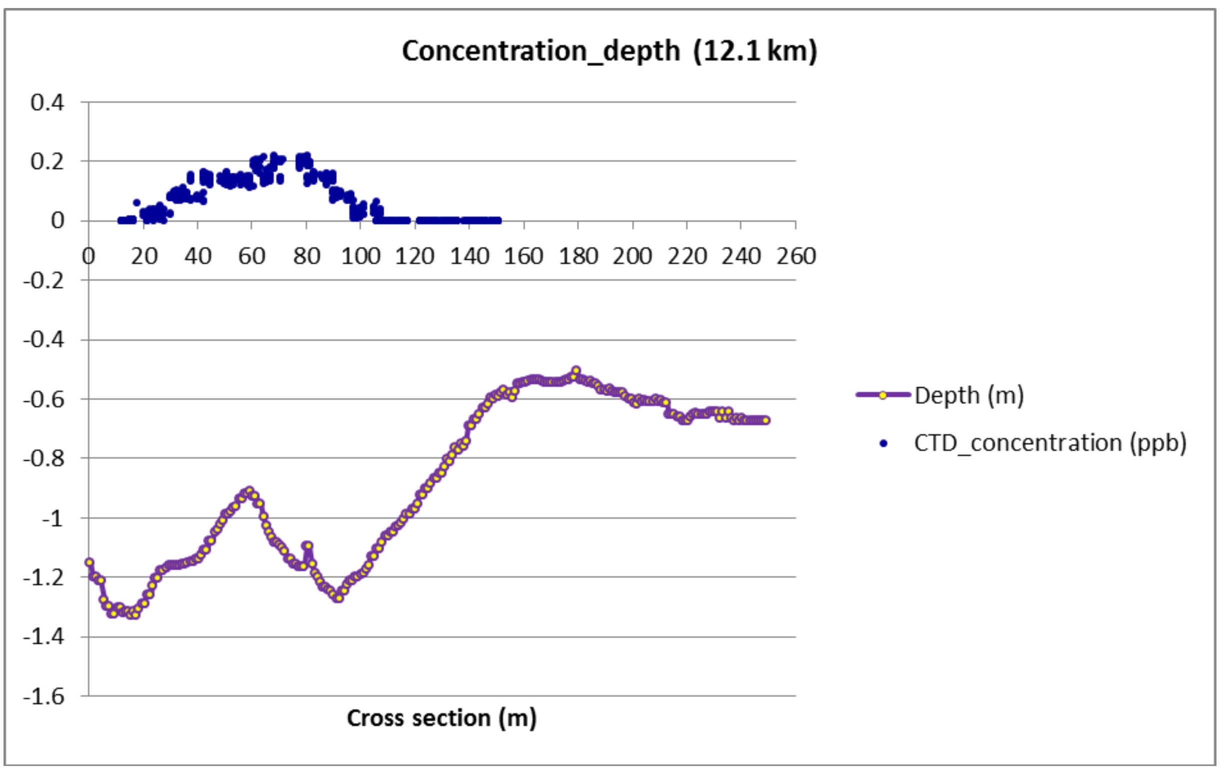
Concentration 12km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.00	0.00	0.00
0.1-0.2	0.02	0.04	0.03
0.2-0.3	0.11	0.13	0.12
0.3-0.4	0.15	0.17	0.16
0.4-0.5	0.15	0.16	0.15
0.5-0.6	0.11	0.12	0.12
0.6-0.7	0.01	0.01	0.01
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	235.41		
Approximate distance from outfall(km)	12		
Time and date	17:07:33	Oct 26th, 2011	



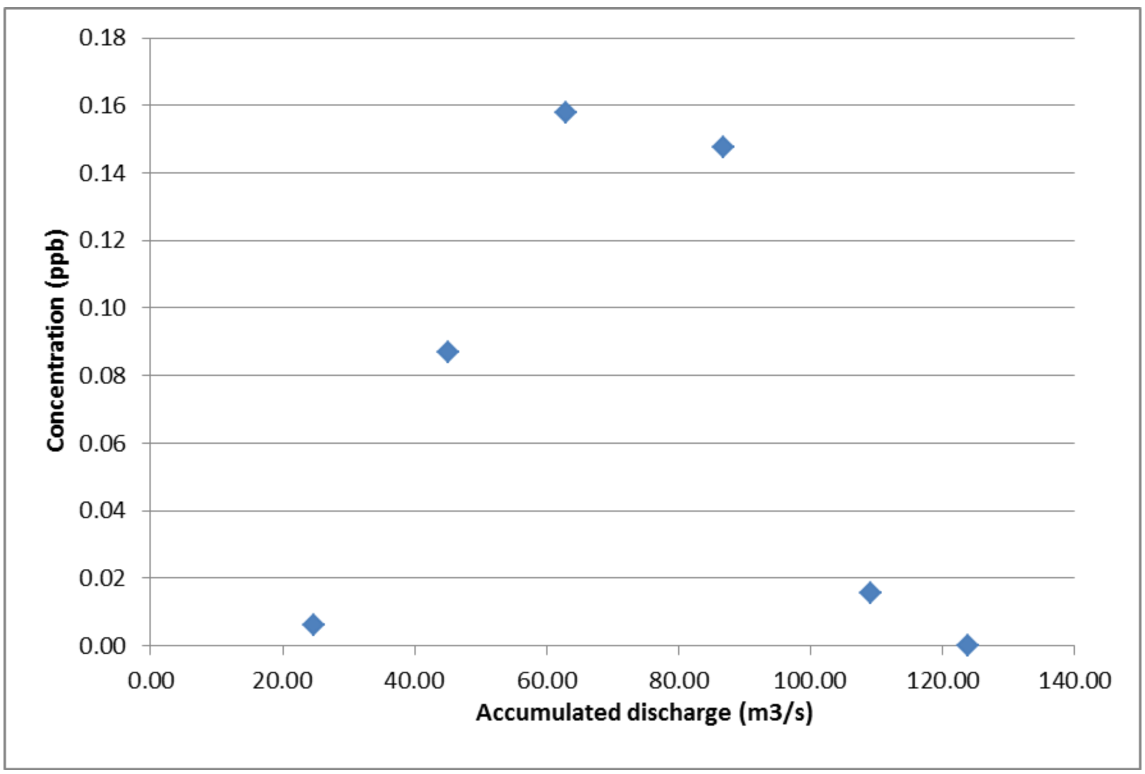


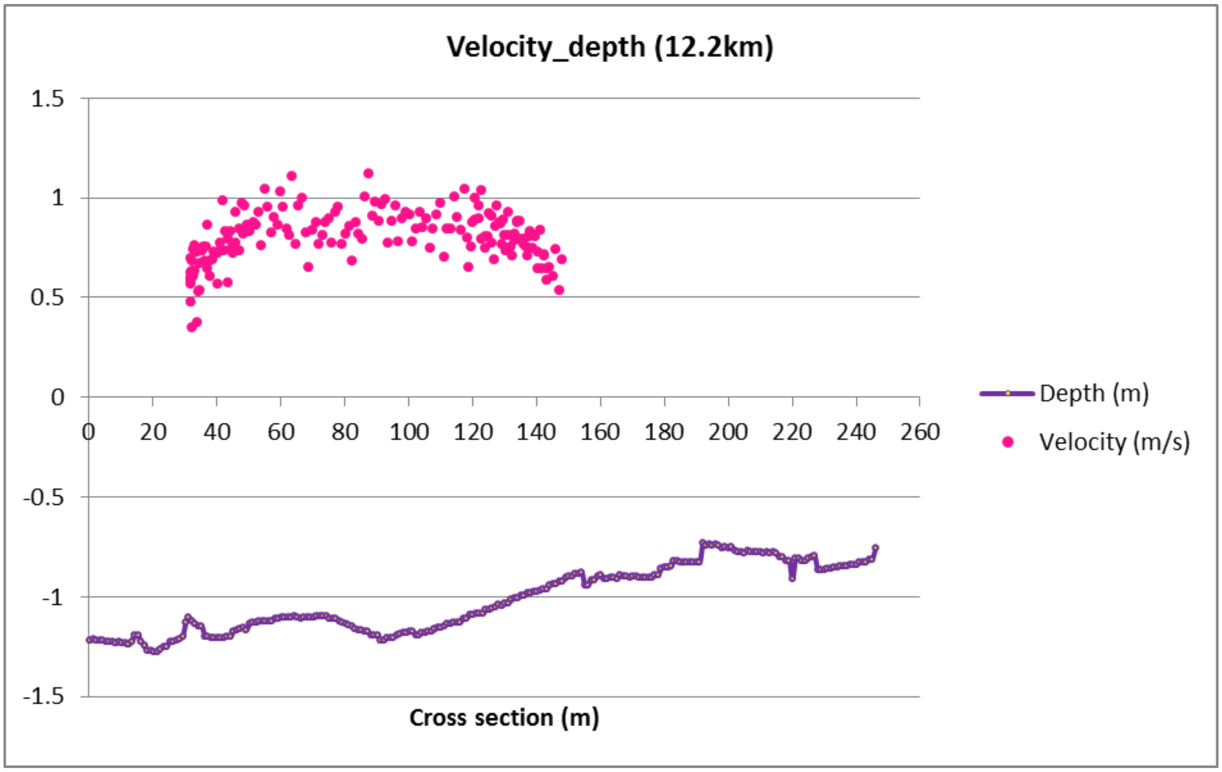
Velocity 12.1km_2



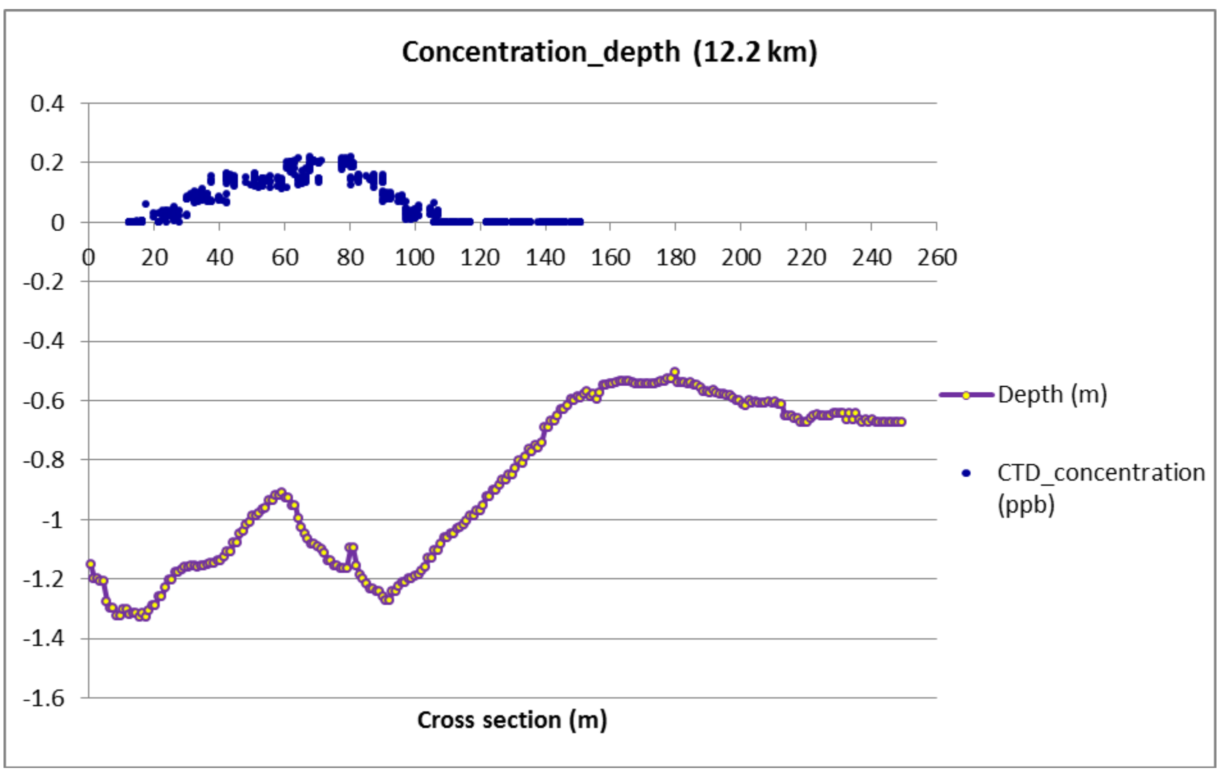
Concentration 12.1km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.00	0.01	0.01
0.1-0.2	0.08	0.10	0.09
0.2-0.3	0.15	0.16	0.16
0.3-0.4	0.14	0.16	0.15
0.4-0.5	0.01	0.02	0.02
0.5-0.6	0.00	0.00	0.00
0.6-0.7			
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	240.67		
Approximate distance from outfall(km)	12.1		
Time and date	17:07:33	Oct 26th, 2011	



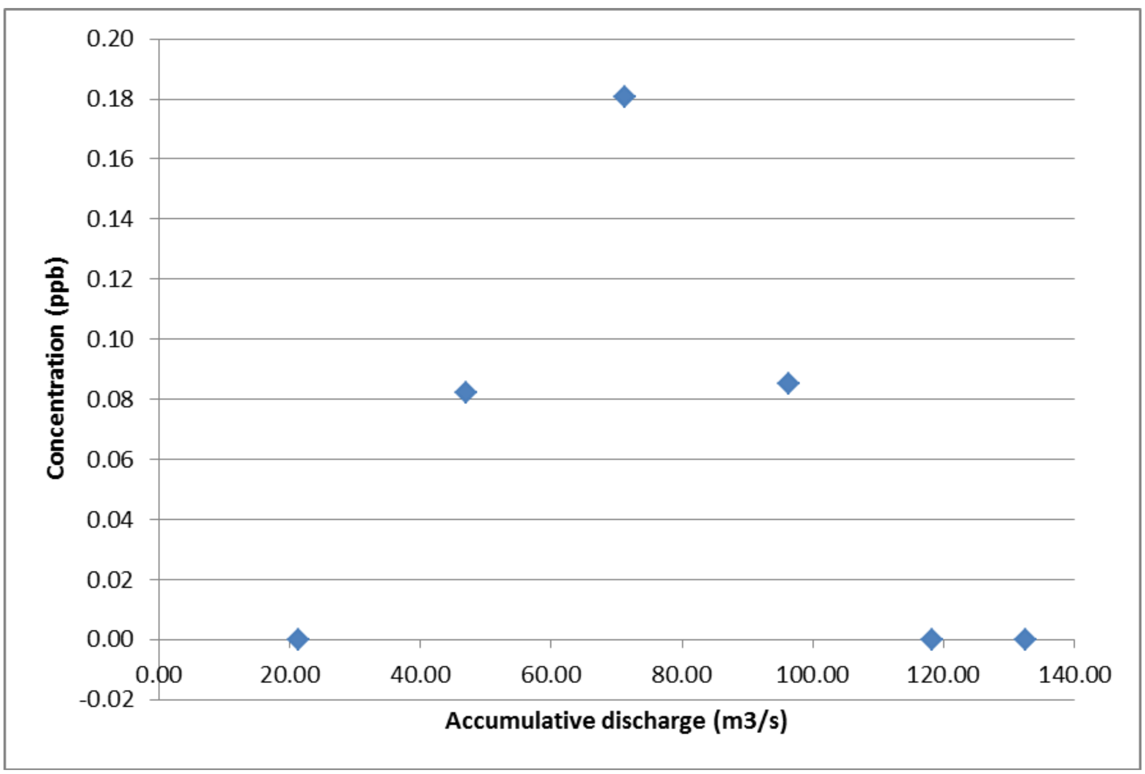


Velocity 12.2km_3

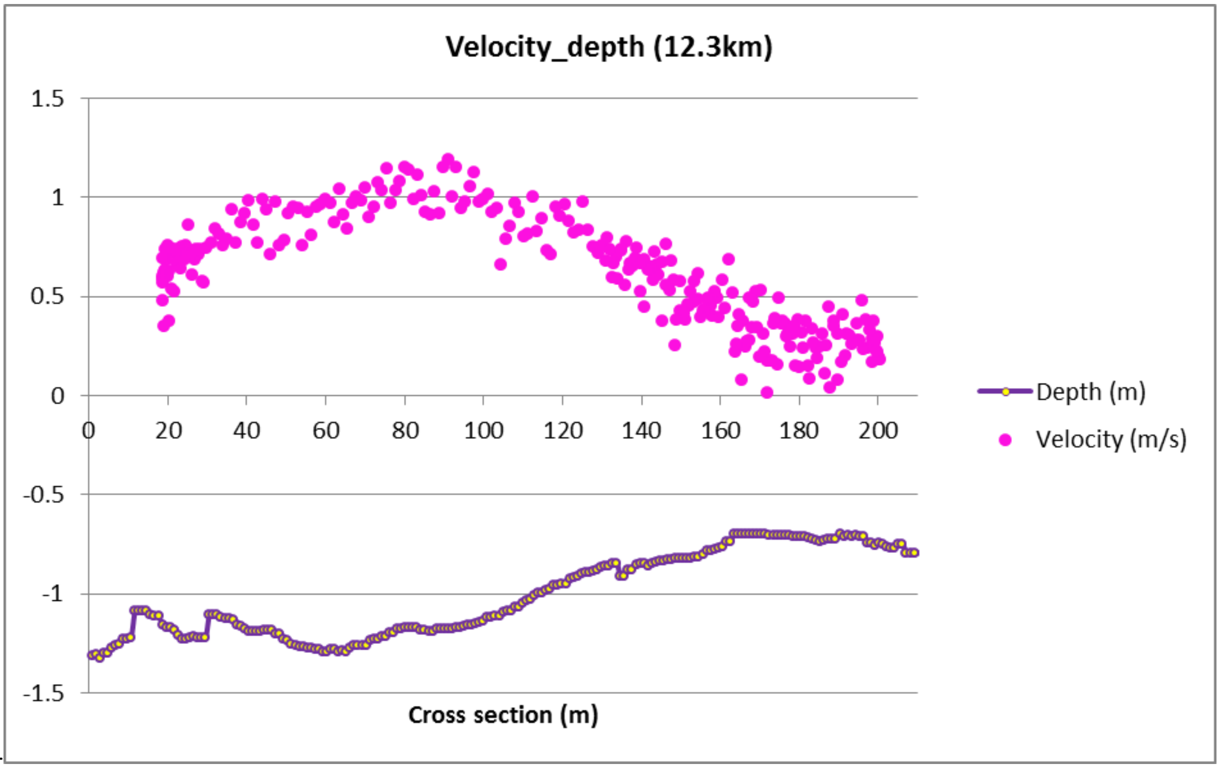


Concentration 12.2km_3

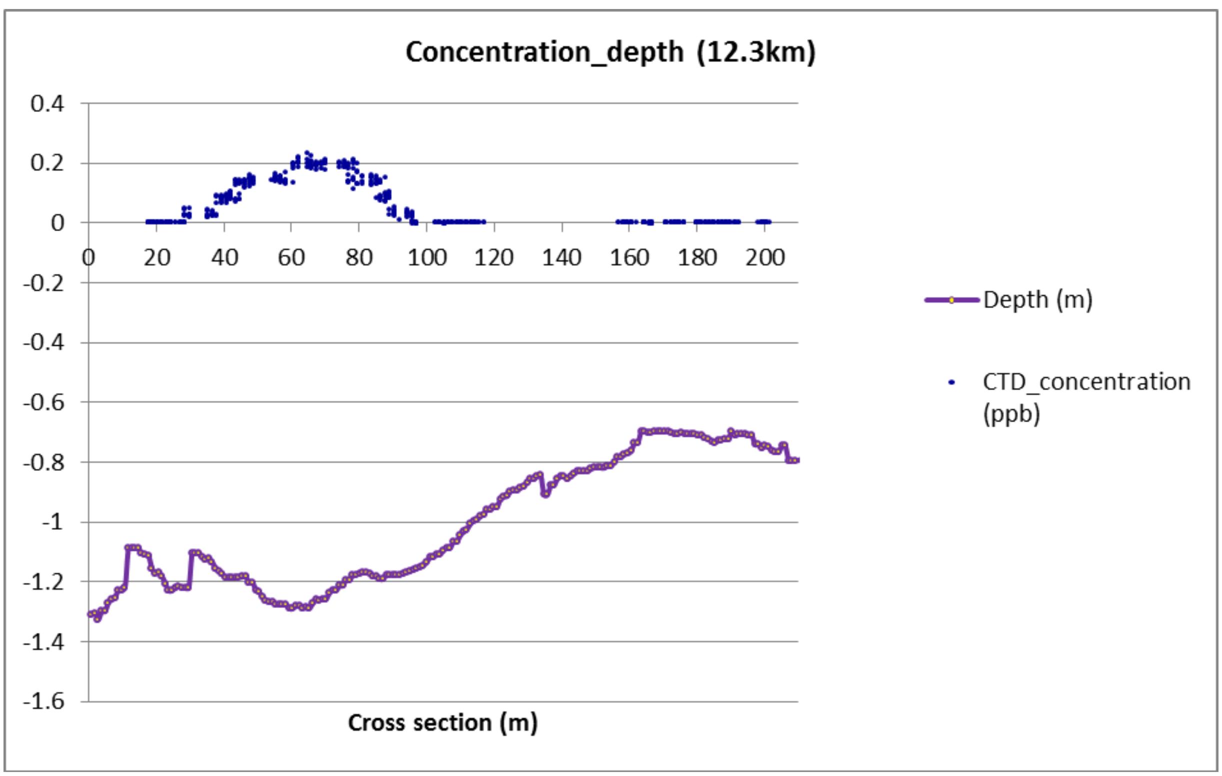
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.00	0.00	0.00
0.1-0.2	0.07	0.09	0.08
0.2-0.3	0.17	0.19	0.18
0.3-0.4	0.07	0.10	0.08
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7			
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	246.71		
Approximate distance from outfall(km)	12.2		
Time and date	17:07:33	Oct 26th, 2011	



4

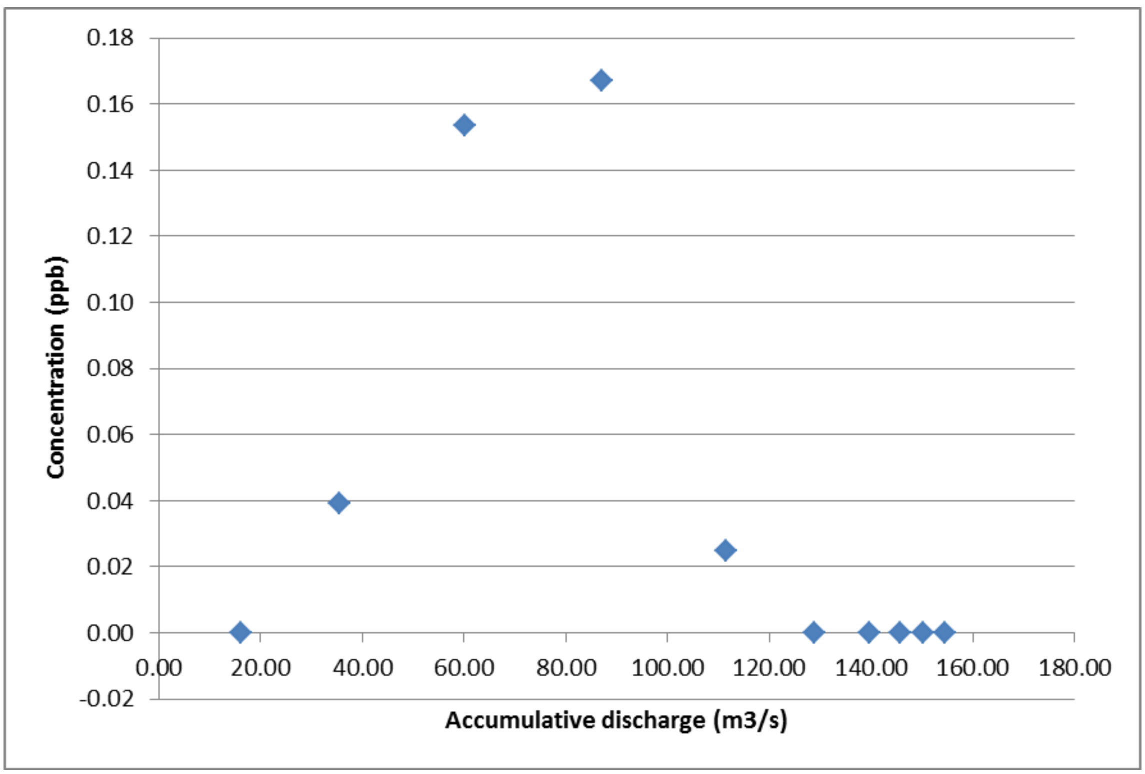


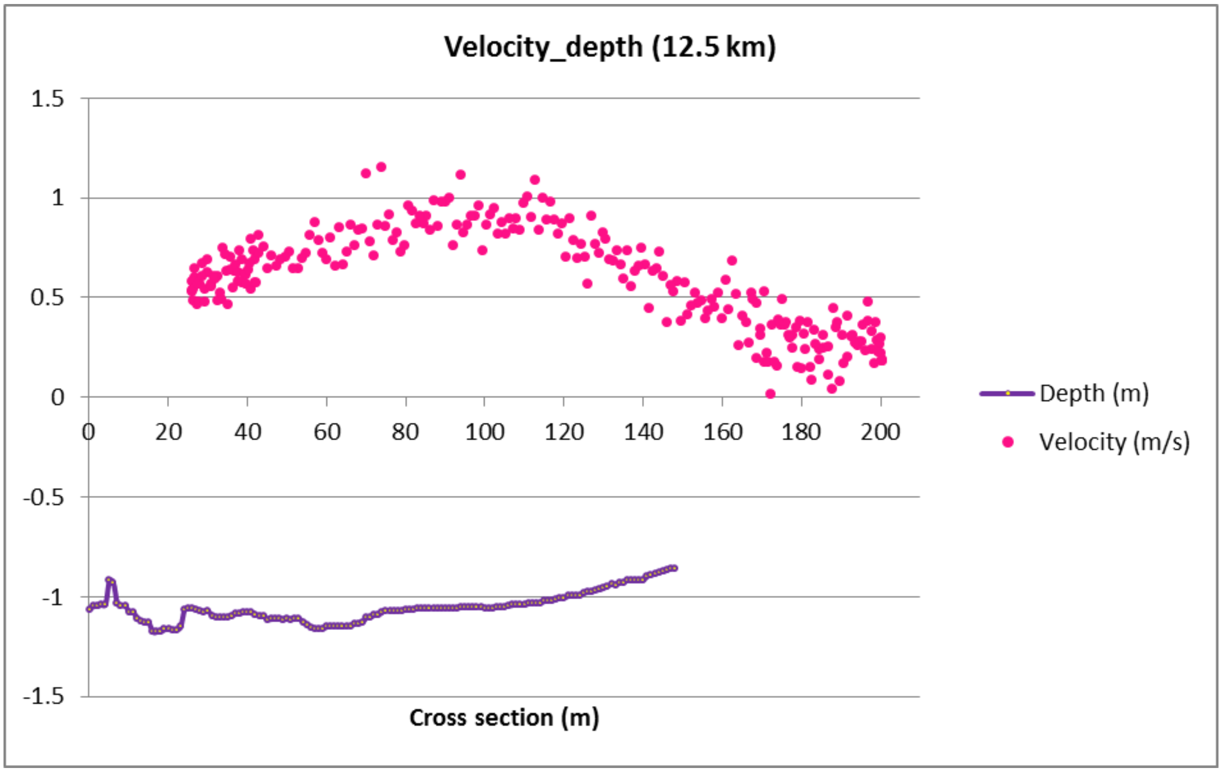
Velocity 12.3km_4



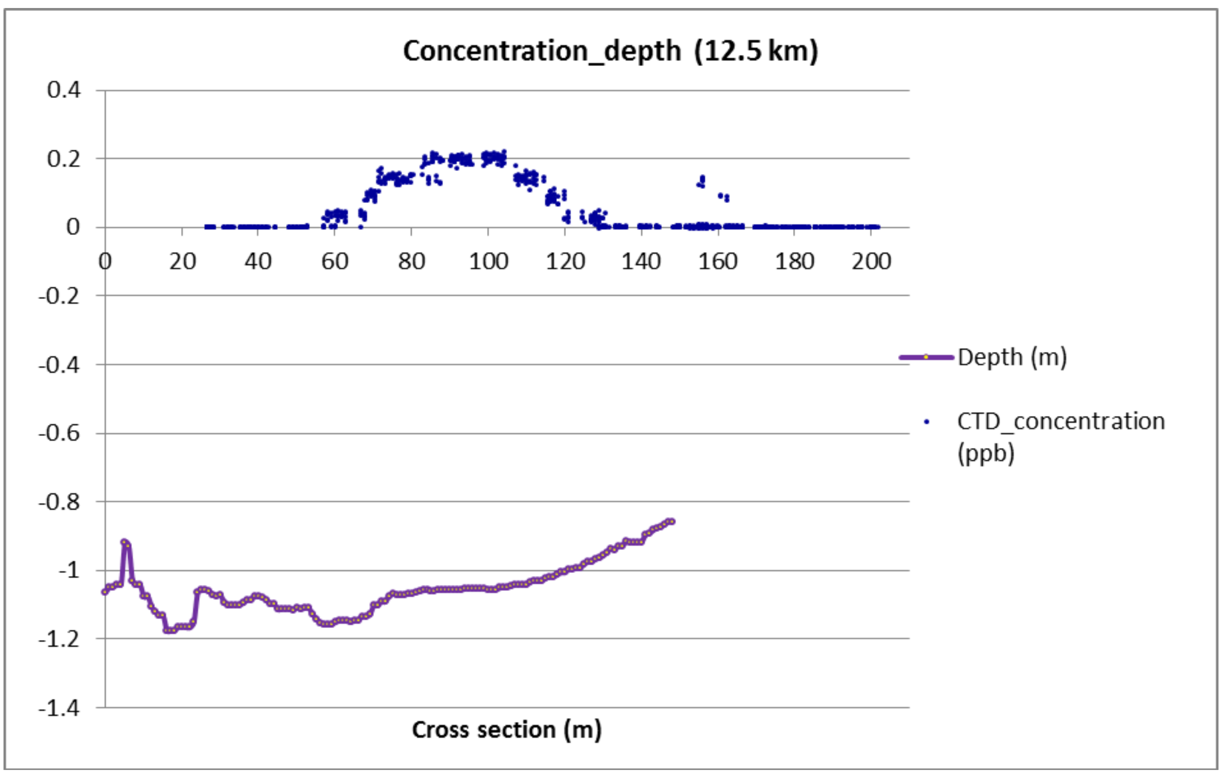
Concentration 12.3km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.00	0.00	0.00
0.1-0.2	0.03	0.05	0.04
0.2-0.3	0.15	0.16	0.15
0.3-0.4	0.16	0.18	0.17
0.4-0.5	0.02	0.03	0.02
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	219.17		
Approximate distance from outfall(km)	12.3		
Time and date	17:07:33	Oct 26th, 2011	



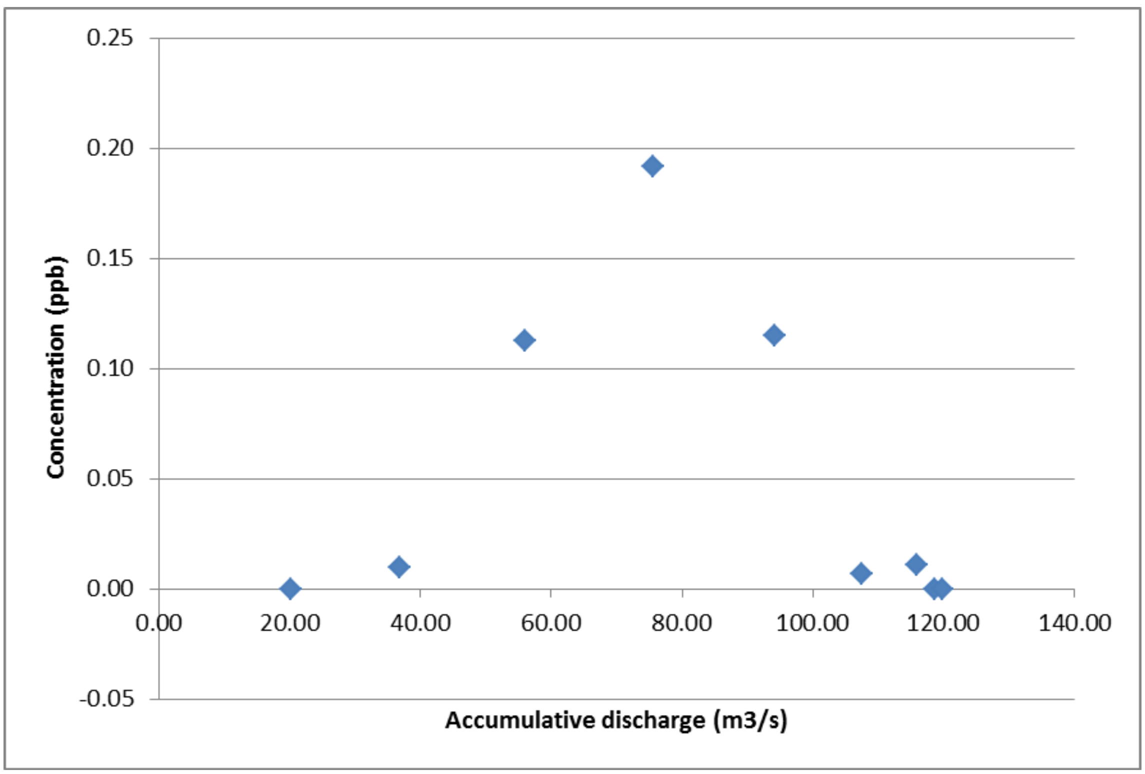


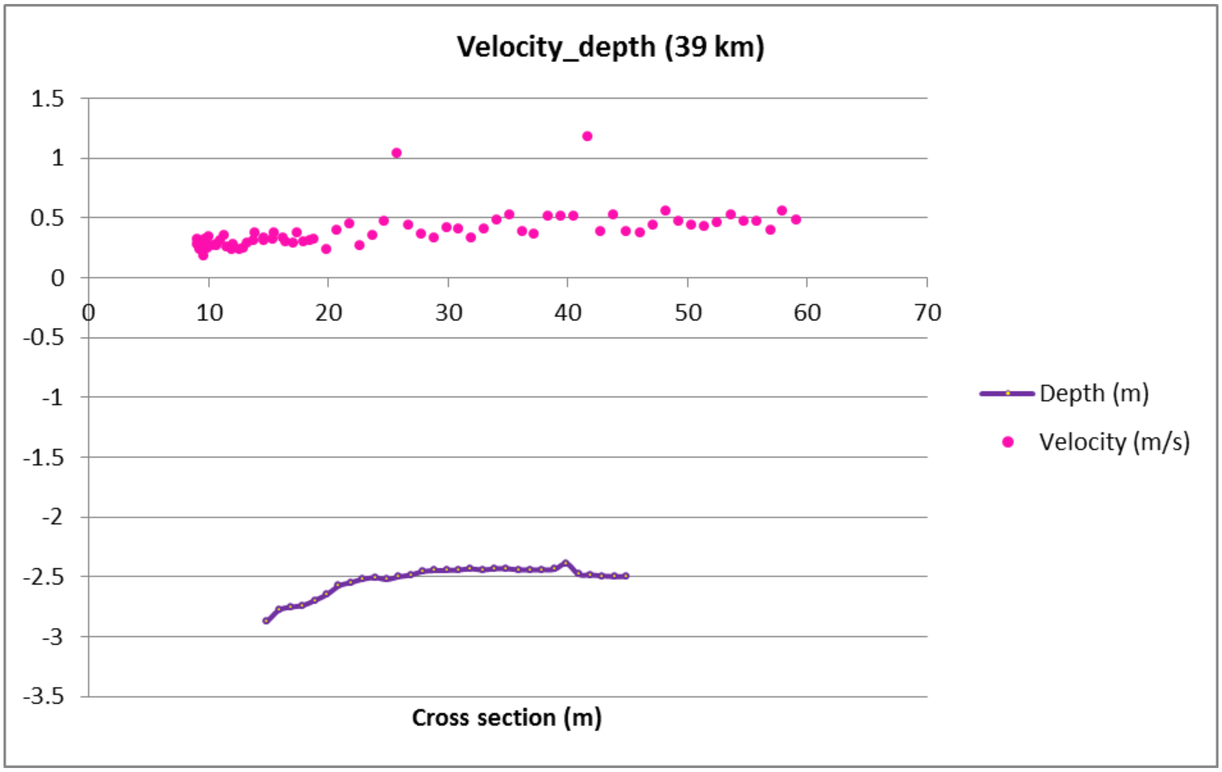
Velocity 12.5km_5



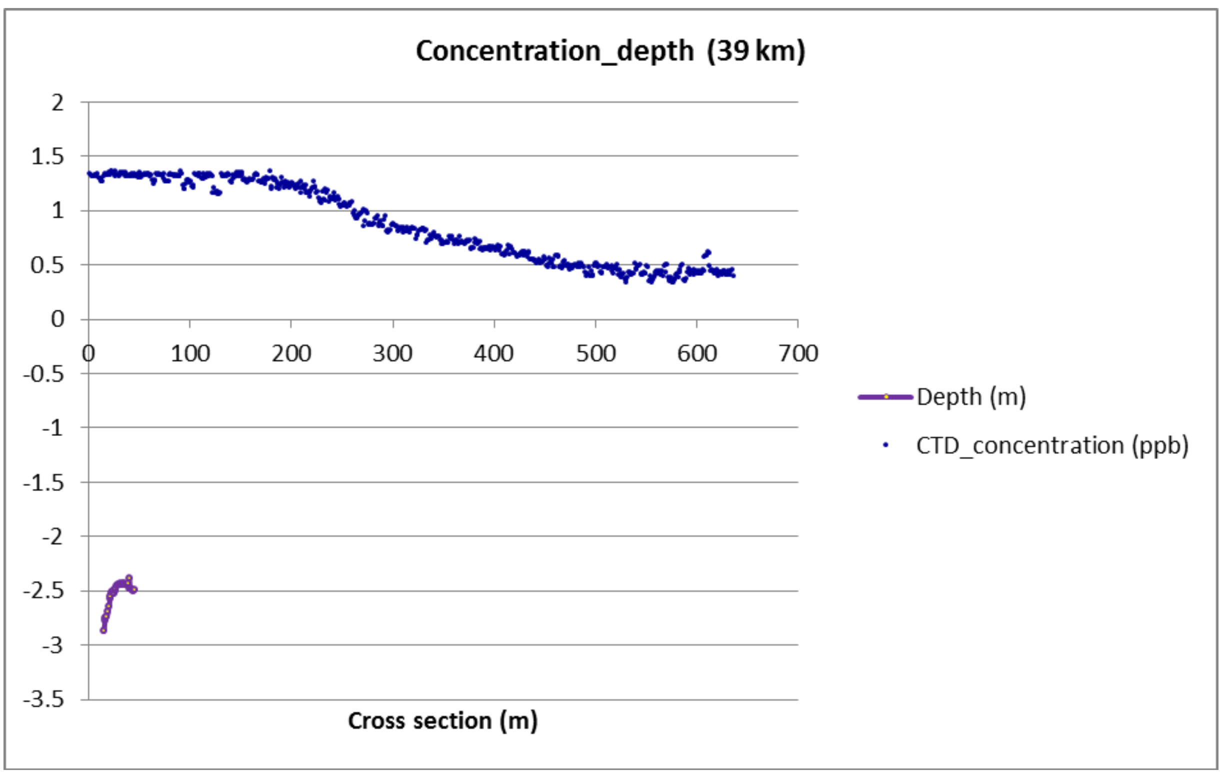
Concentration 12.5km_5

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.00	0.00	0.00
0.2-0.3	0.01	0.01	0.01
0.3-0.4	0.10	0.12	0.11
0.4-0.5	0.19	0.20	0.19
0.5-0.6	0.10	0.13	0.11
0.6-0.7	0.00	0.01	0.01
0.7-0.8	0.00	0.02	0.01
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	207.25		
Approximate distance from outfall(km)	12.5		
Time and date	17:07:33	Oct 26th, 2011	



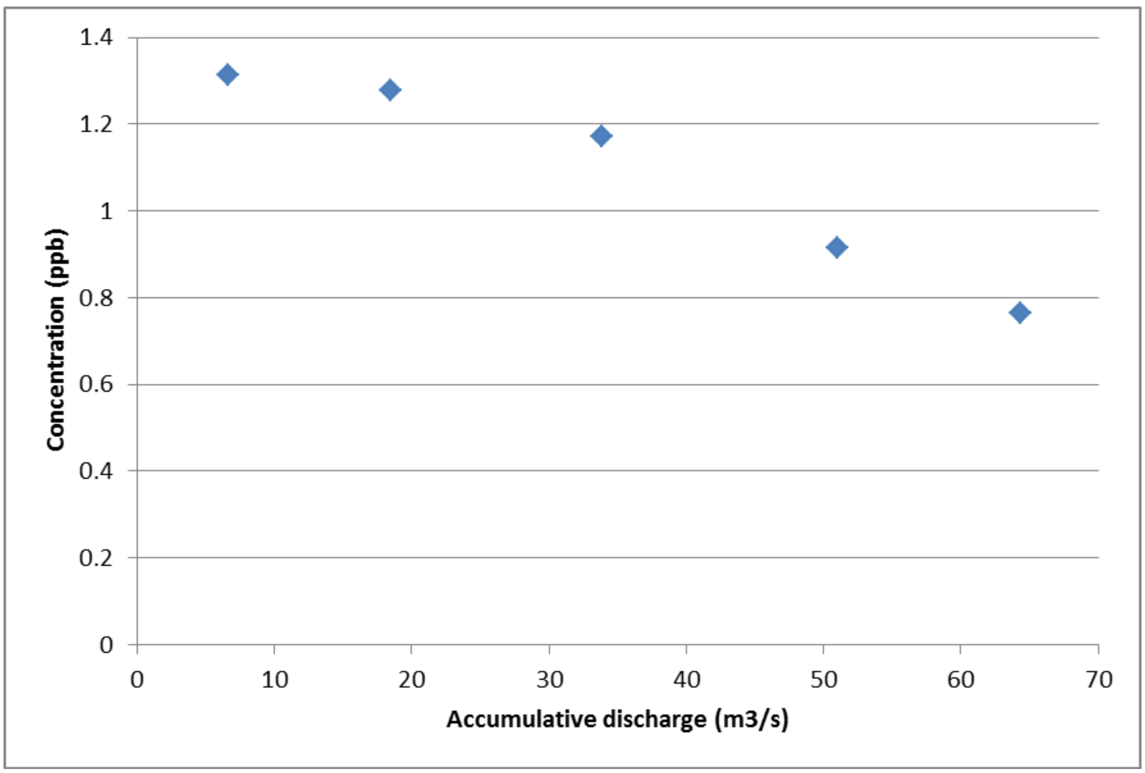


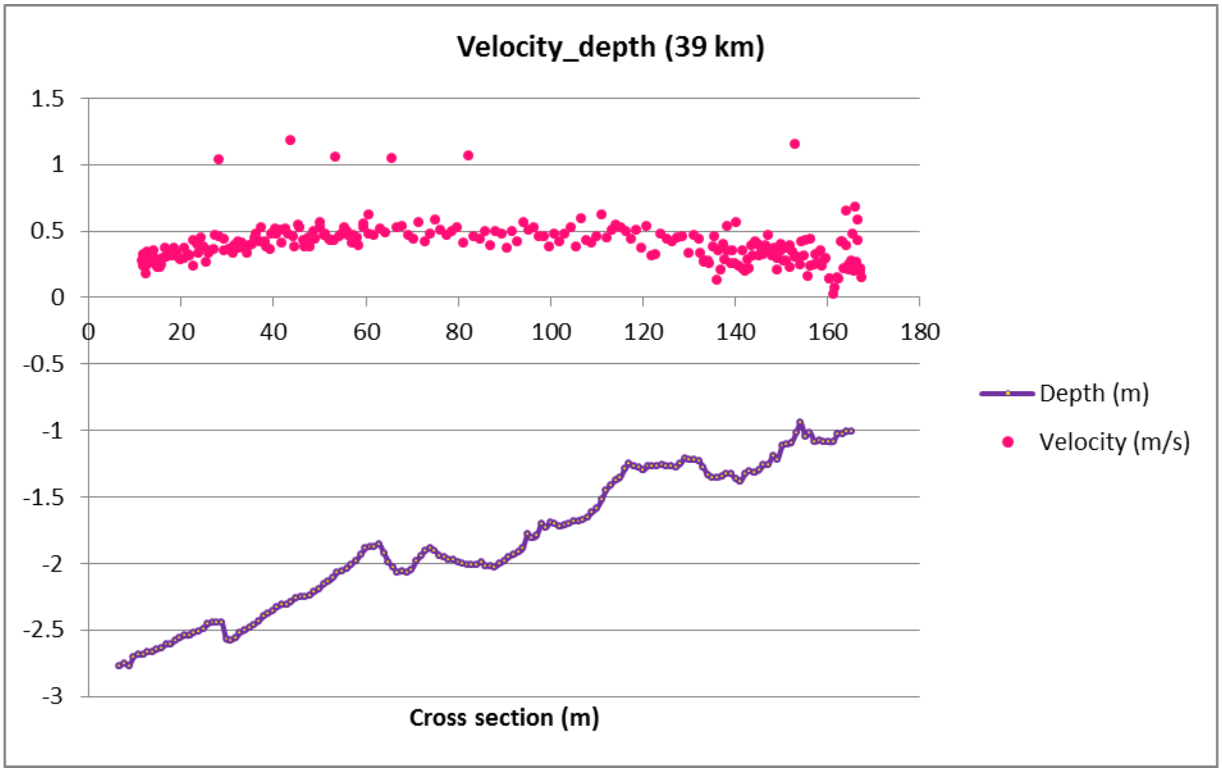
Velocity 39km_1



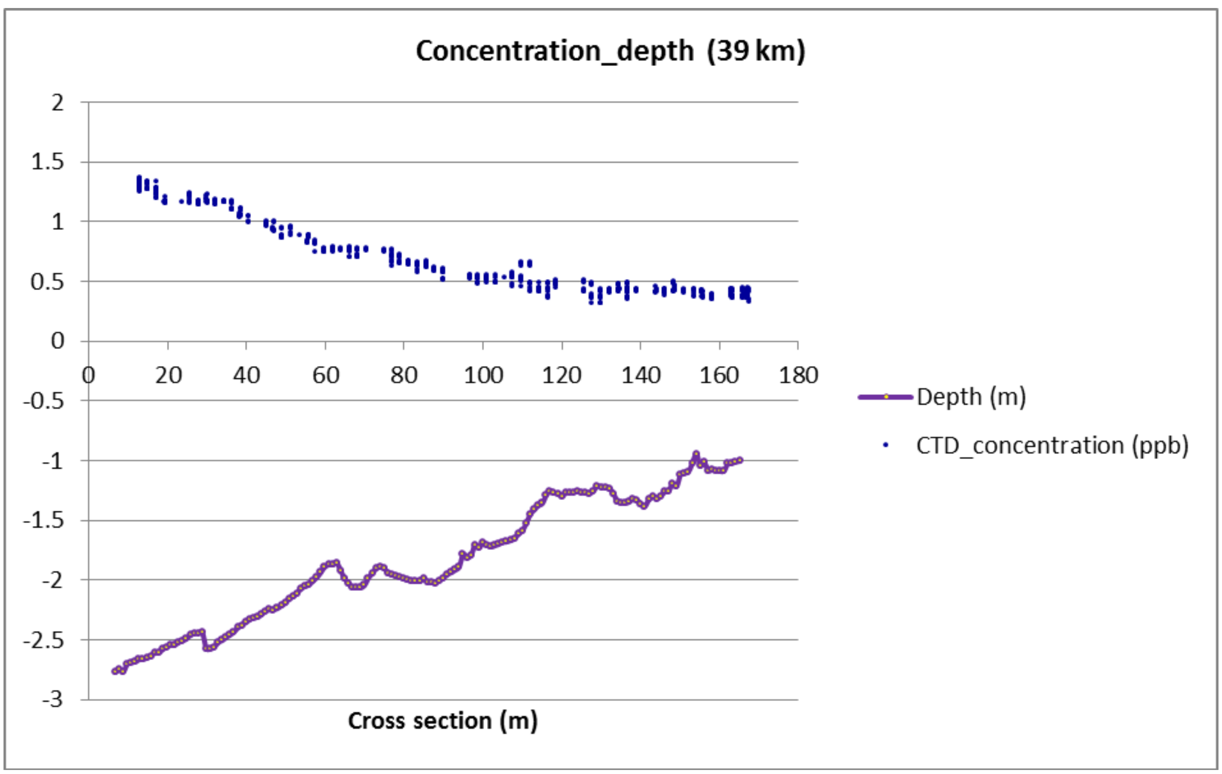
Concentration 39km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.31	1.32	1.31
0.1-0.2	1.26	1.29	1.28
0.2-0.3	1.15	1.19	1.17
0.3-0.4	0.90	0.94	0.92
0.4-0.5	0.75	0.78	0.76
0.5-0.6	0.64	0.66	0.65
0.6-0.7	0.51	0.53	0.52
0.7-0.8	0.44	0.46	0.45
0.8-0.9	0.42	0.44	0.43
0.9-1			
Approximate width(m)	162.56		
Approximate distance from outfall(km)	39		
Time and date	17:29:38	Oct 27 2011	



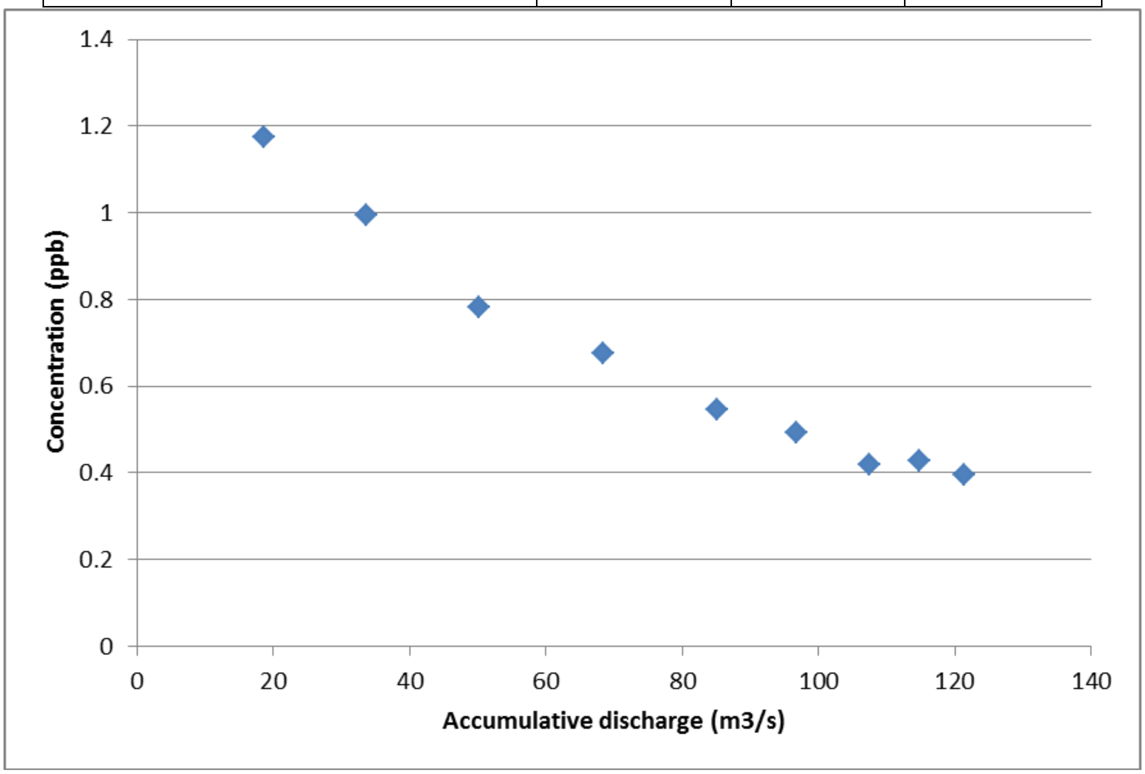


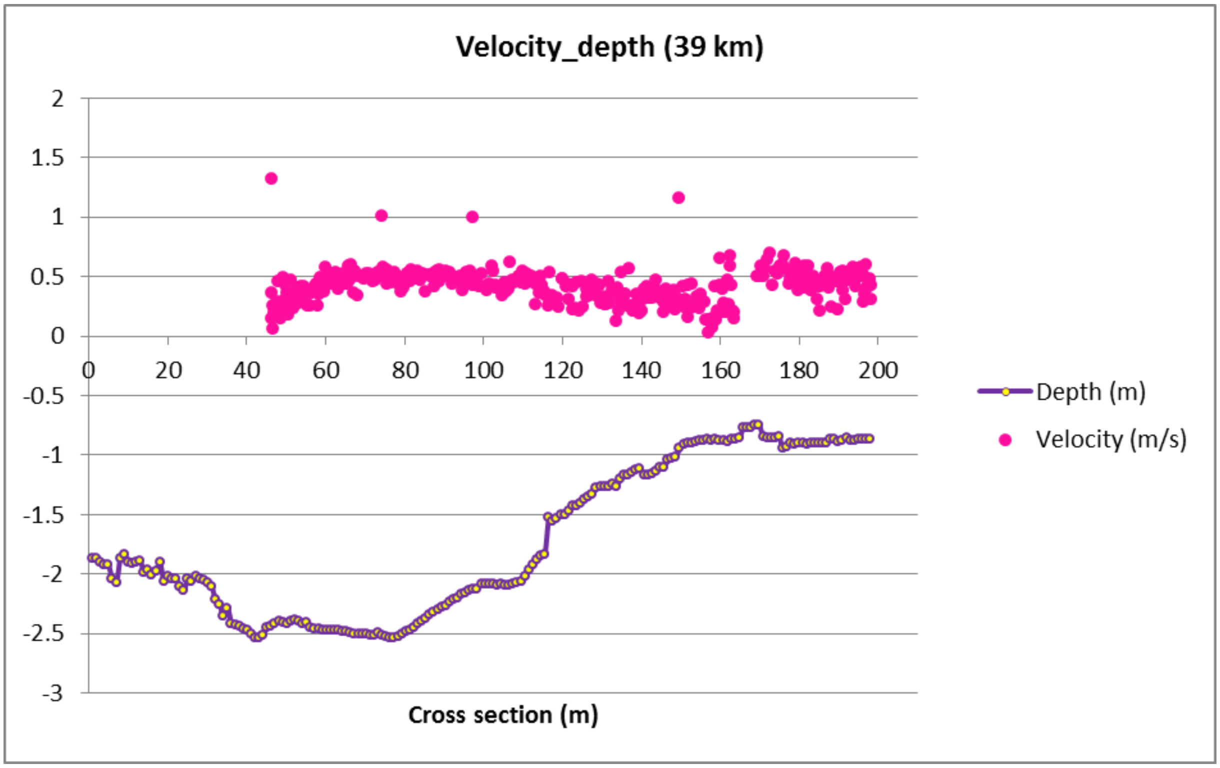
Velocity 39km_2



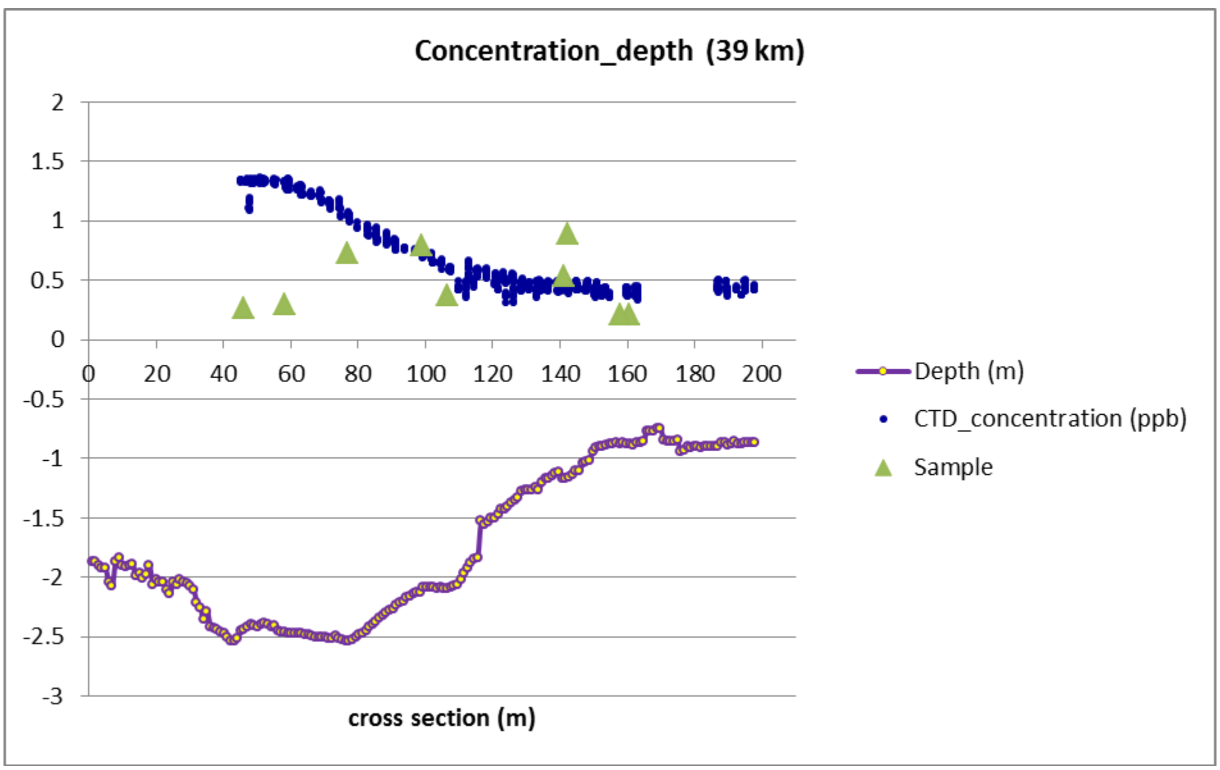
Concentration 39km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.30	1.32	1.31
0.1-0.2	1.17	1.18	1.18
0.2-0.3	0.97	1.02	1.00
0.3-0.4	0.77	0.79	0.78
0.4-0.5	0.66	0.69	0.68
0.5-0.6	0.54	0.56	0.55
0.6-0.7	0.48	0.51	0.49
0.7-0.8	0.41	0.43	0.42
0.8-0.9	0.42	0.43	0.43
0.9-1	0.39	0.40	0.40
Approximate width(m)	172.89		
Approximate distance from outfall(km)	39		
Time and date	17:29:38	Oct 27 2011	



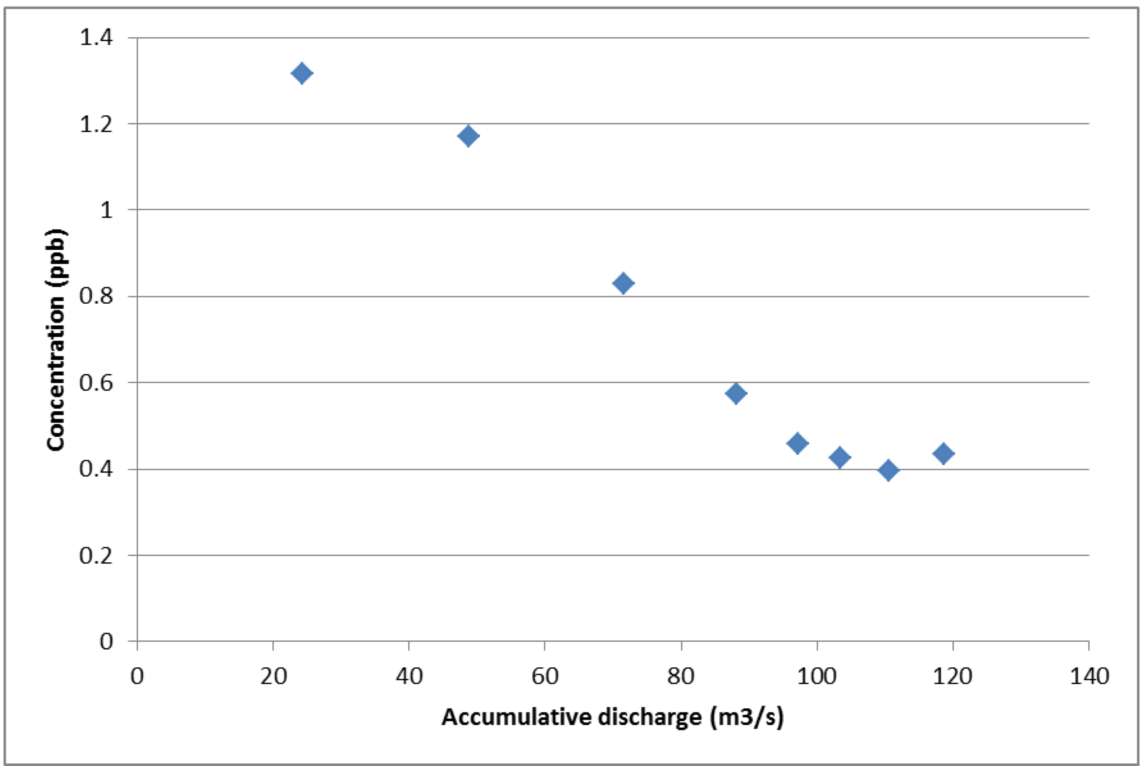


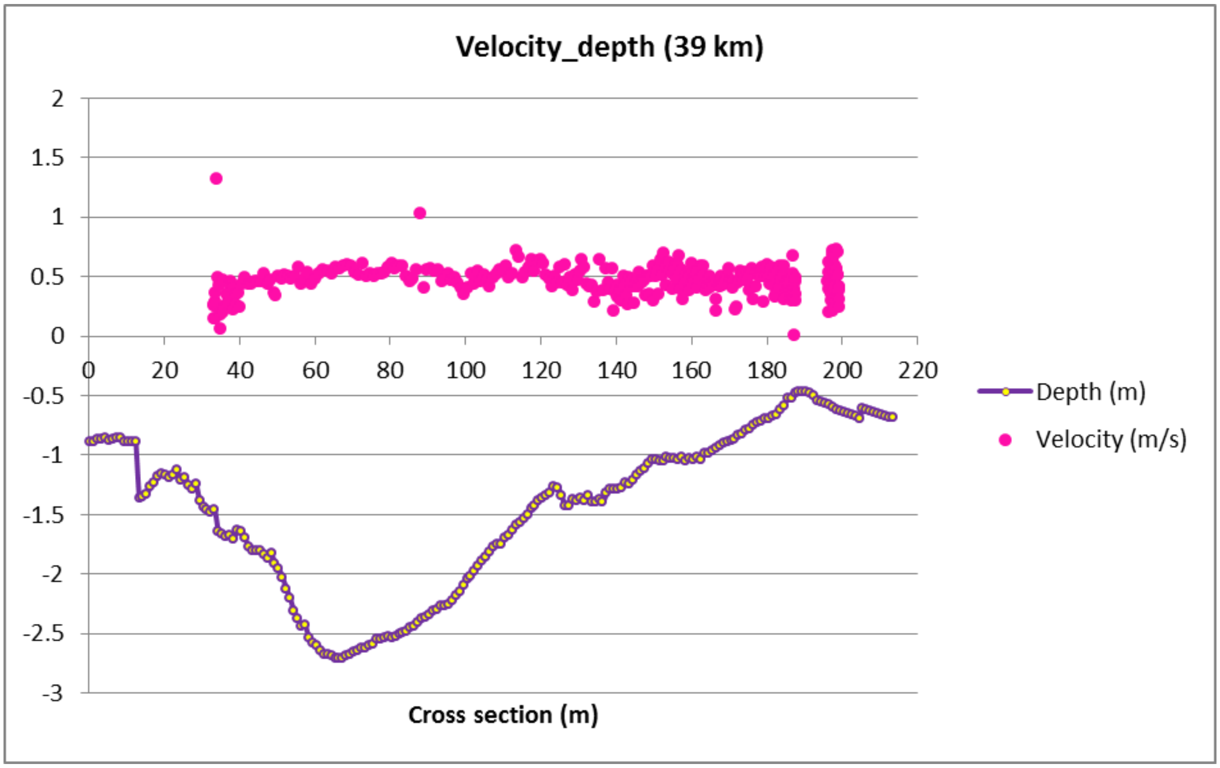
Velocity 39km_3



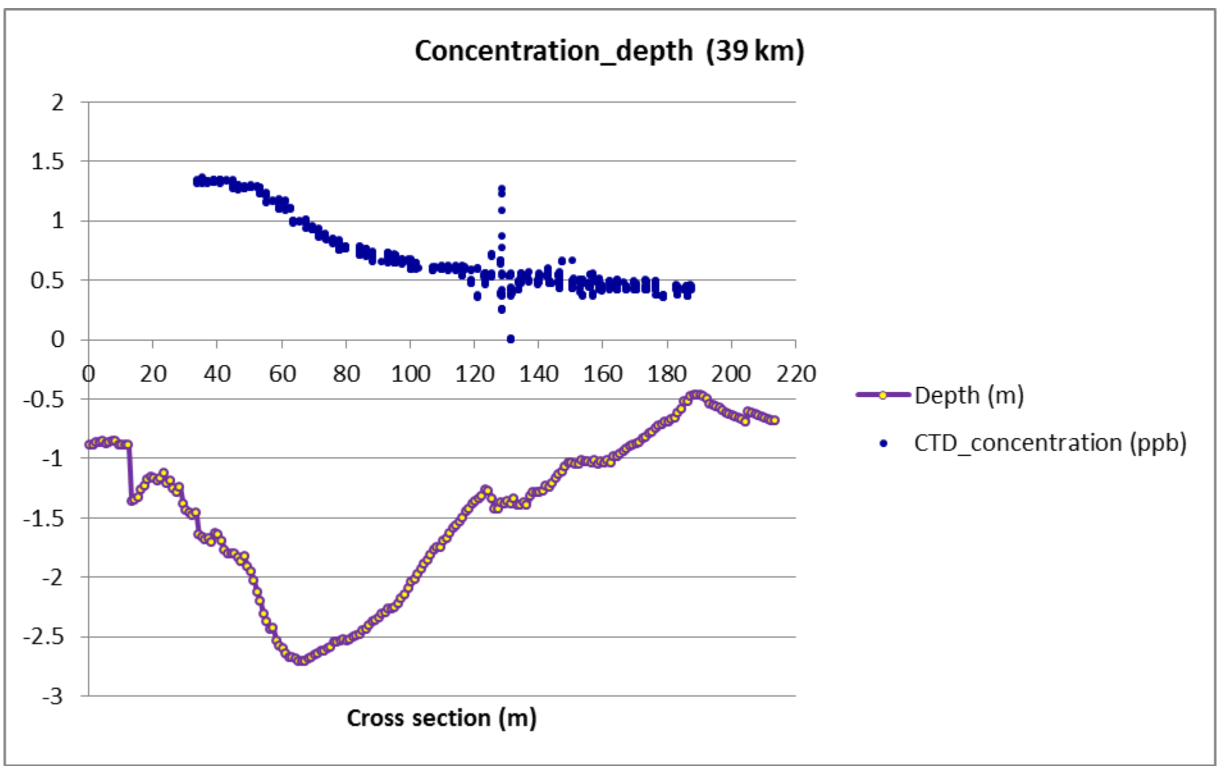
Concentration 39km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	1.31	1.32	1.32
0.3-0.4	1.16	1.19	1.17
0.4-0.5	0.81	0.85	0.83
0.5-0.6	0.56	0.59	0.57
0.6-0.7	0.45	0.47	0.46
0.7-0.8	0.42	0.43	0.43
0.8-0.9	0.39	0.40	0.40
0.9-1	0.43	0.44	0.43
Approximate width(m)	198.78		
Approximate distance from outfall(km)	39		
Time and date	17:29:38	Oct 27 2011	



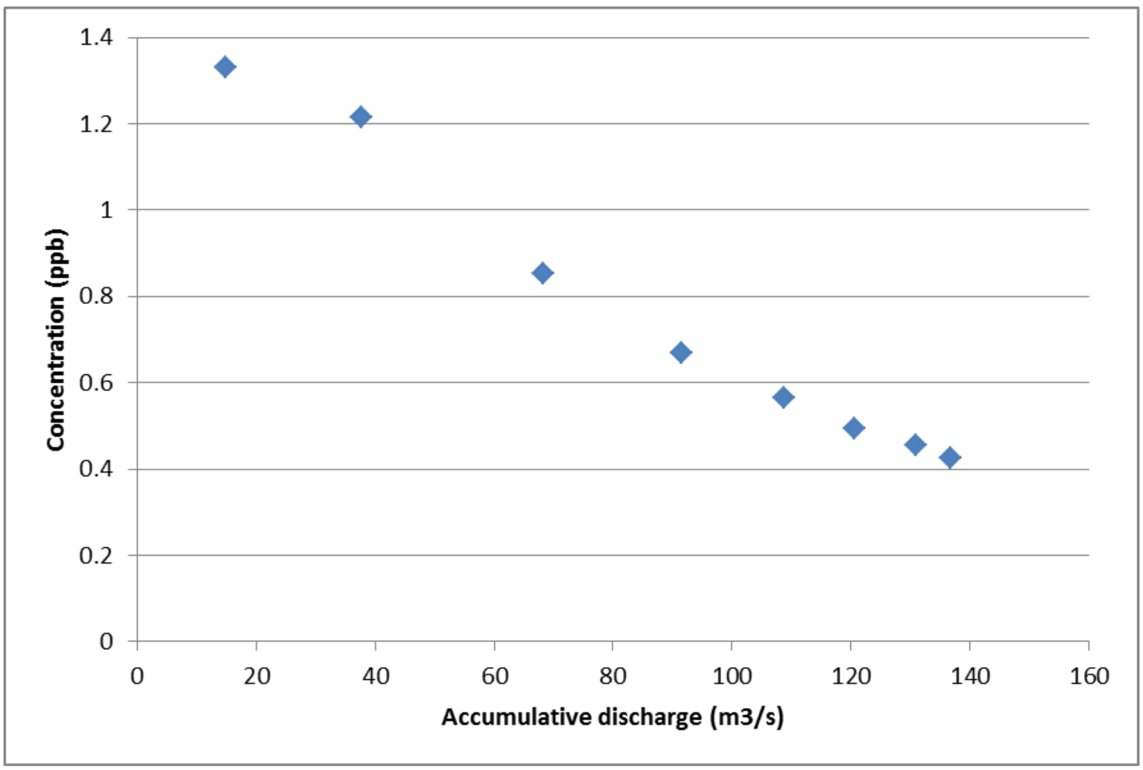


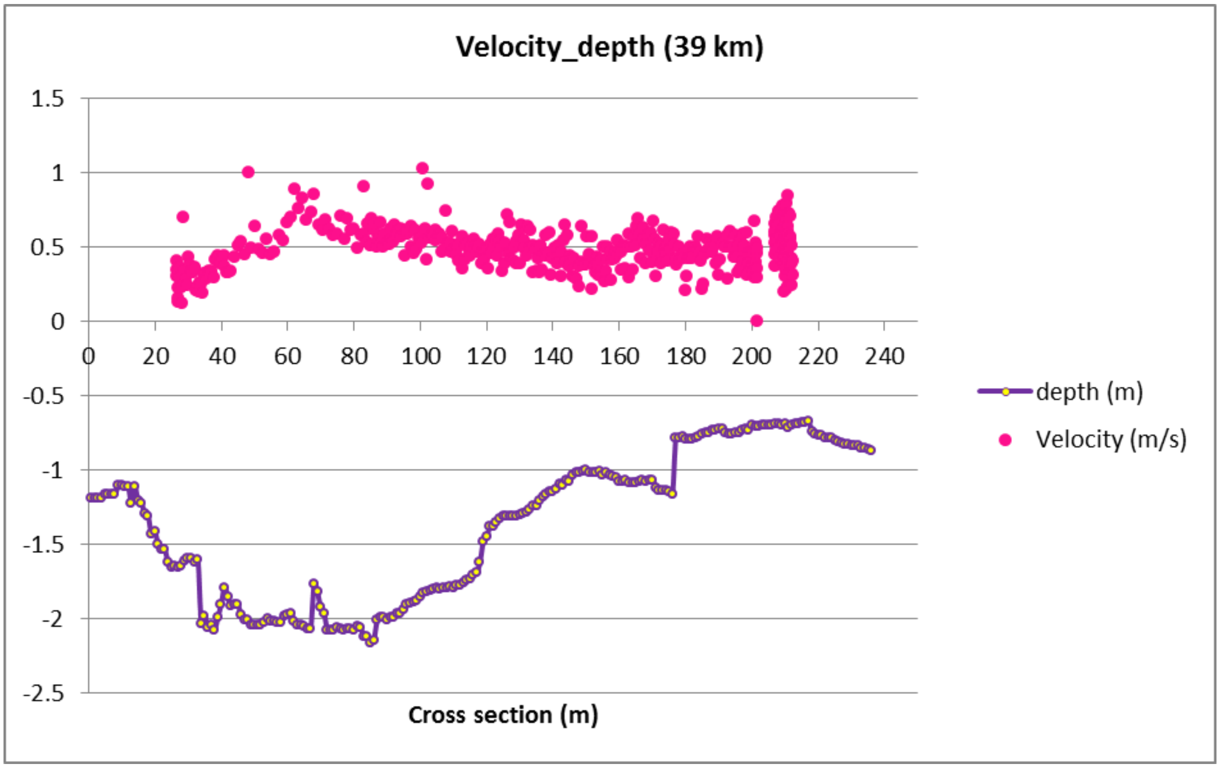
Velocity 39km_4



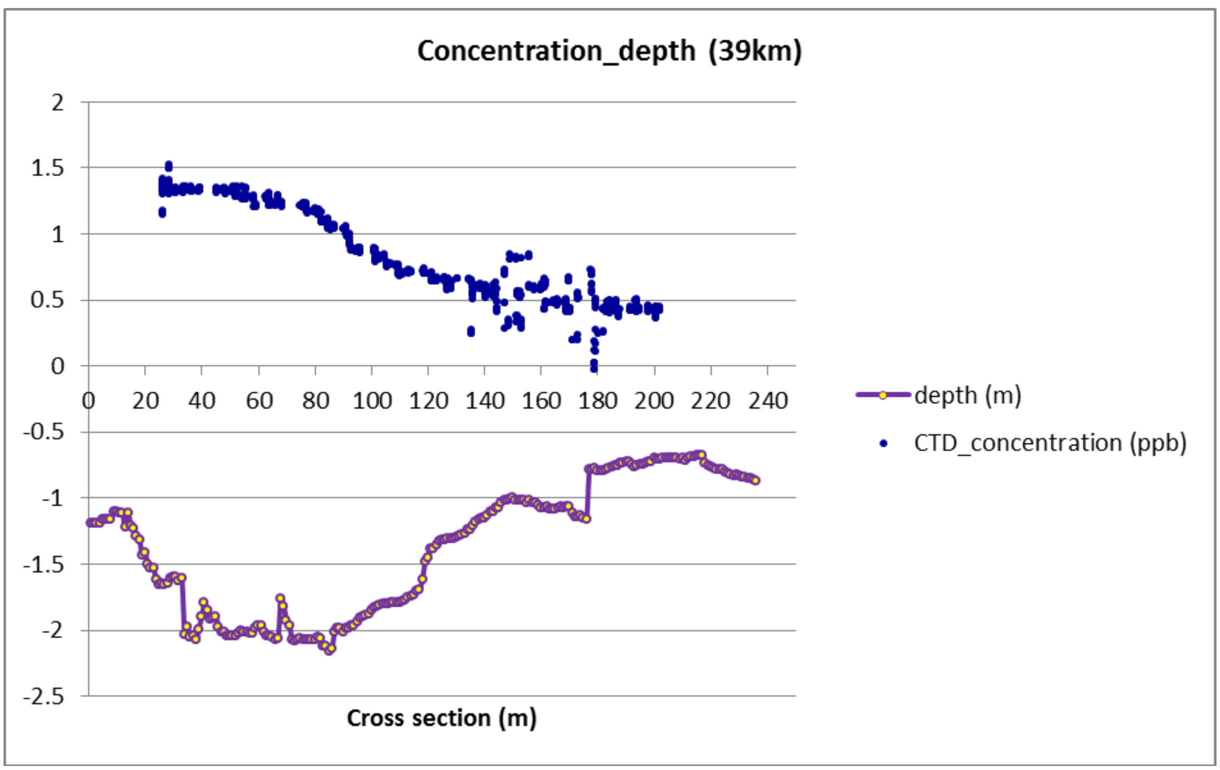
Concentration 39km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	1.33	1.33	1.33
0.2-0.3	1.20	1.23	1.22
0.3-0.4	0.83	0.87	0.85
0.4-0.5	0.66	0.68	0.67
0.5-0.6	0.55	0.58	0.56
0.6-0.7	0.47	0.52	0.50
0.7-0.8	0.45	0.46	0.45
0.8-0.9	0.42	0.43	0.42
0.9-1			
Approximate width(m)	214.42		
Approximate distance from outfall(km)	39		
Time and date	17:29:38	Oct 27 2011	



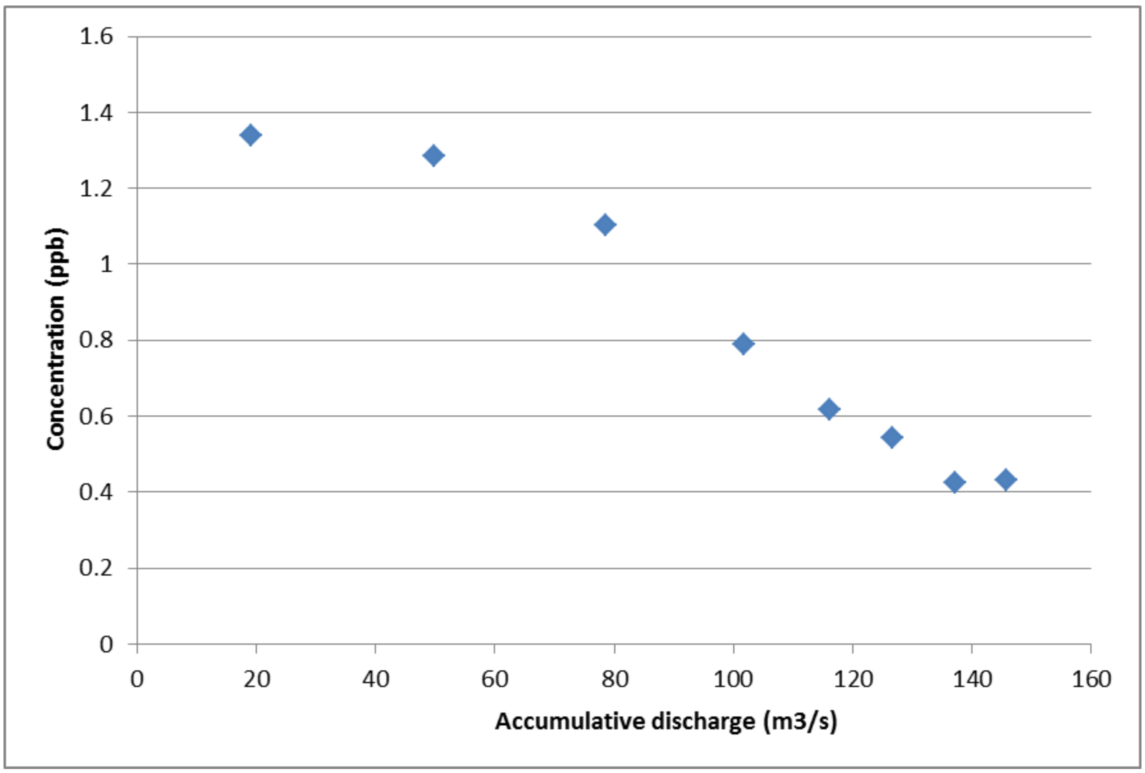


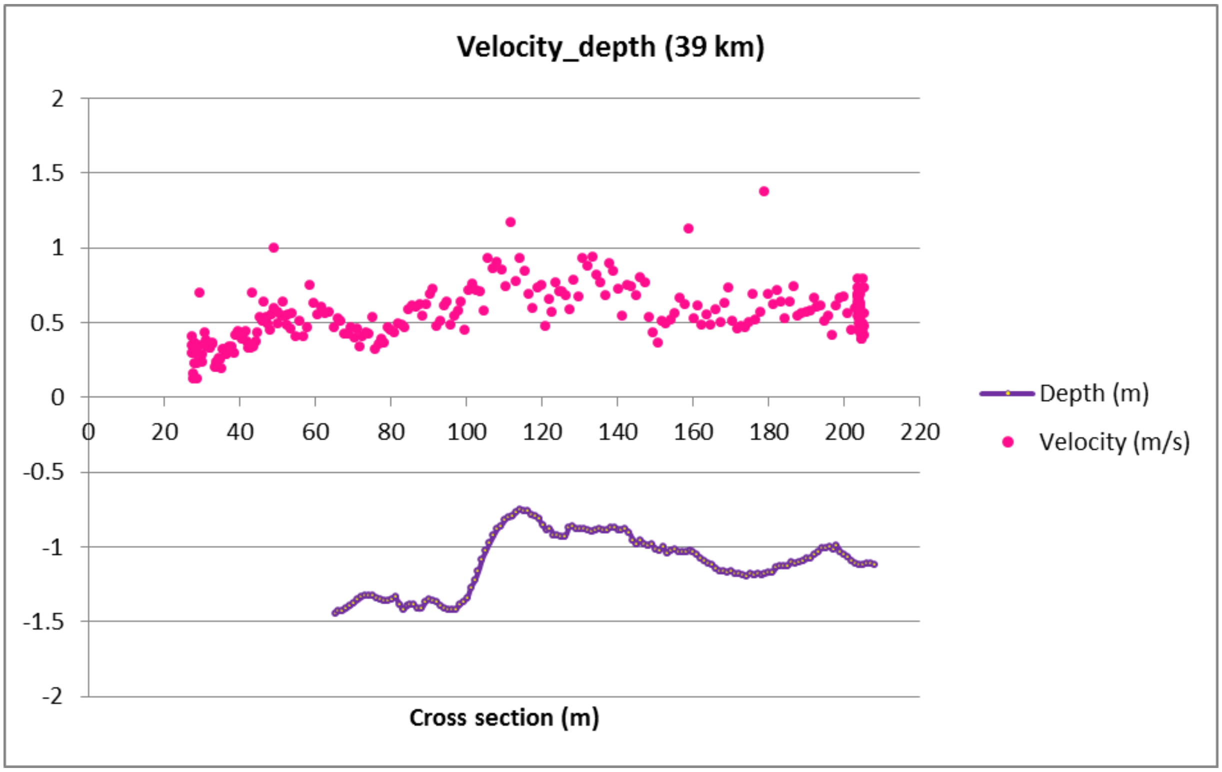
Velocity 39km_5



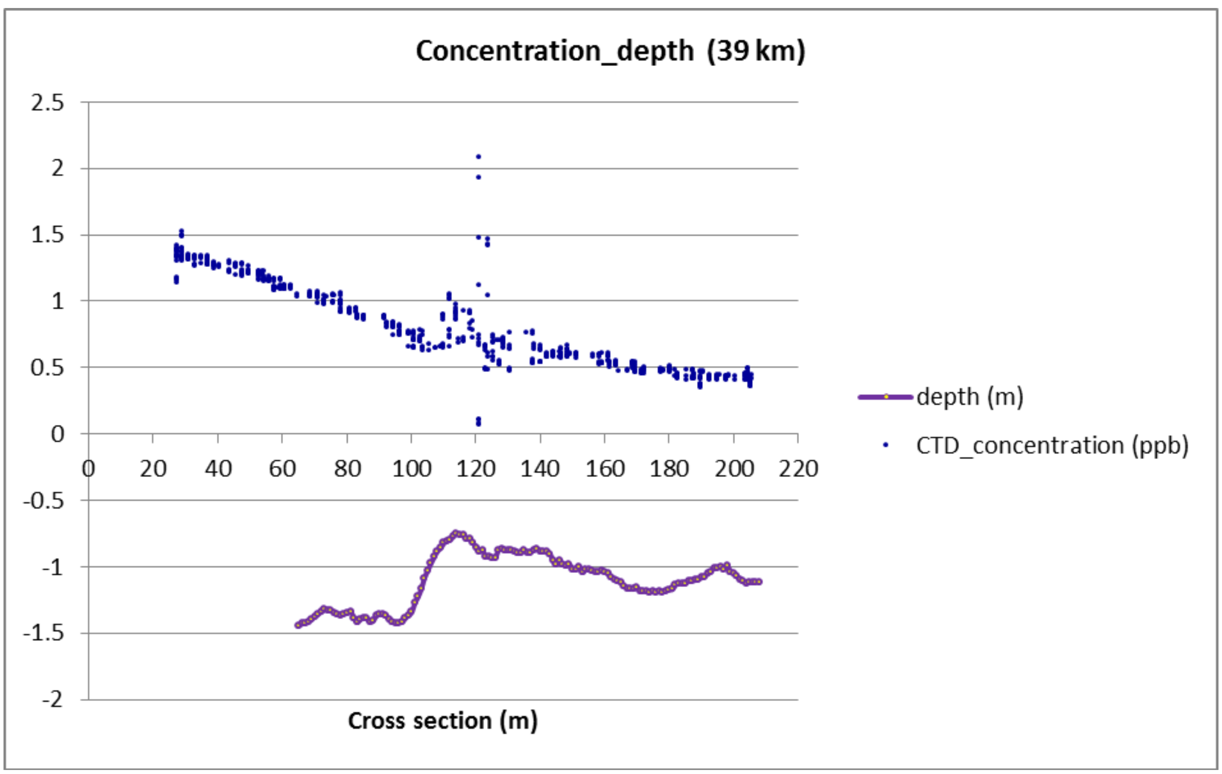
Concentration 39km_5

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	1.33	1.35	1.34
0.2-0.3	1.27	1.29	1.28
0.3-0.4	1.08	1.12	1.10
0.4-0.5	0.77	0.80	0.79
0.5-0.6	0.60	0.63	0.62
0.6-0.7	0.52	0.57	0.54
0.7-0.8	0.40	0.45	0.42
0.8-0.9	0.43	0.44	0.43
0.9-1			
Approximate width(m)	236.27		
Approximate distance from outfall(km)	39		
Time and date	17:29:38	Oct 27 2011	



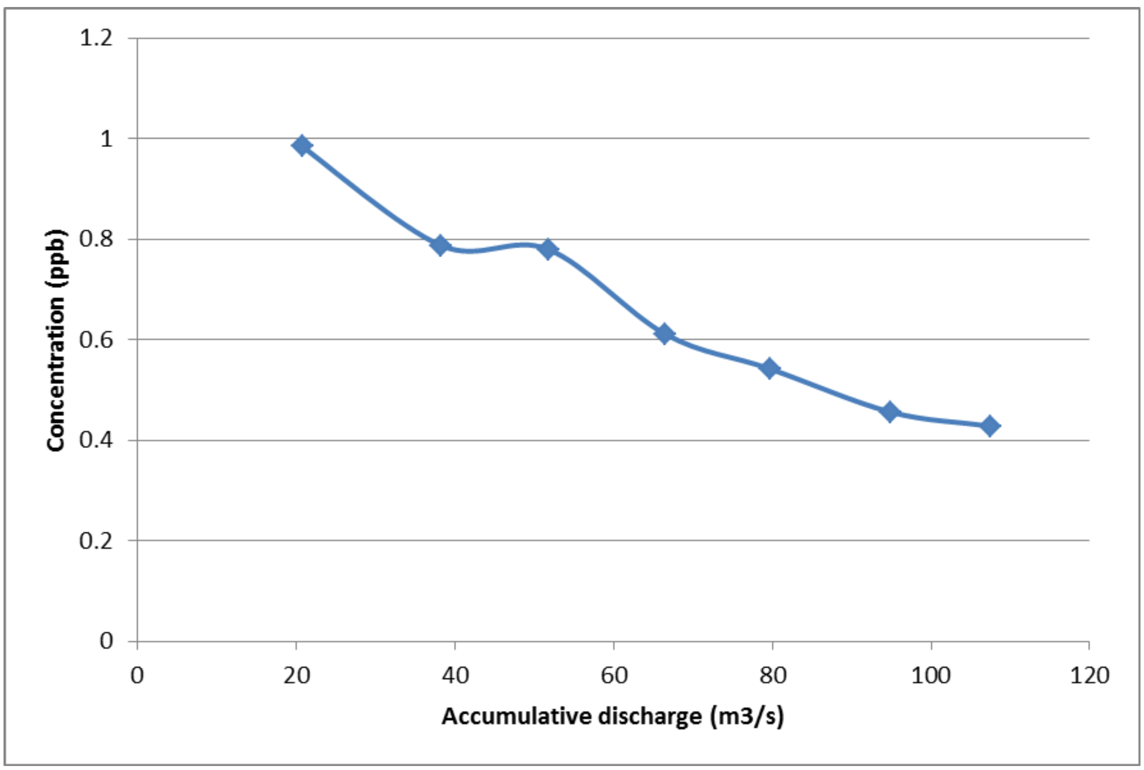


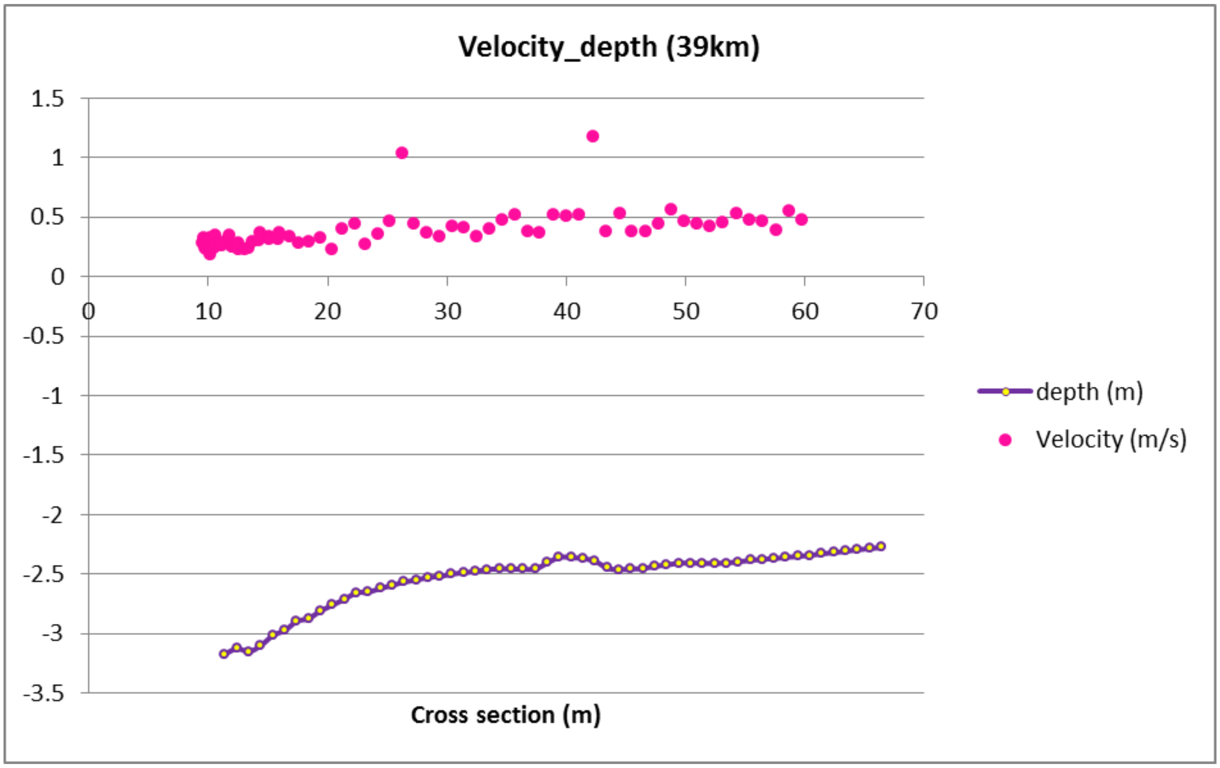
Velocity 39km_6



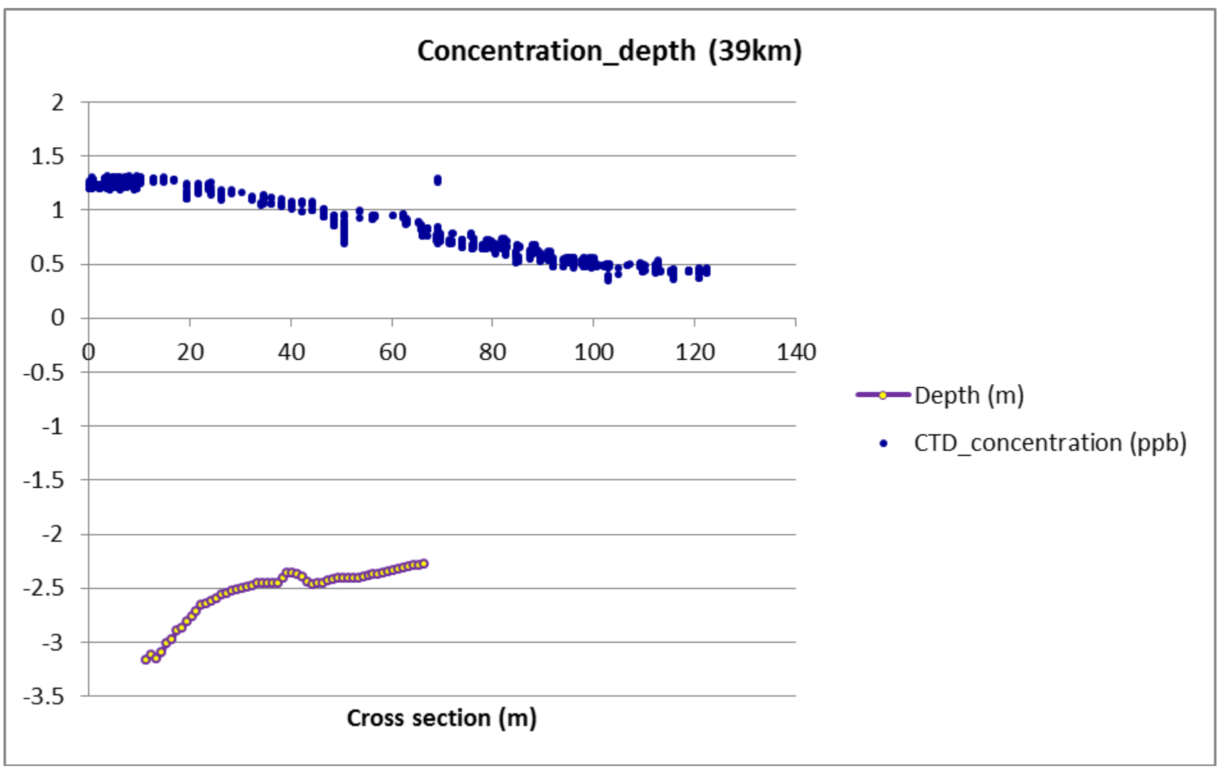
Concentration 39km_6

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	1.31	1.34	1.32
0.2-0.3	1.16	1.19	1.18
0.3-0.4	0.97	1.00	0.98
0.4-0.5	0.77	0.80	0.79
0.5-0.6	0.71	0.85	0.78
0.6-0.7	0.60	0.62	0.61
0.7-0.8	0.53	0.55	0.54
0.8-0.9	0.45	0.46	0.46
0.9-1	0.42	0.43	0.43
Approximate width(m)	213.44		
Approximate distance from outfall(km)	39		
Time and date	17:29:38	Oct 27 2011	



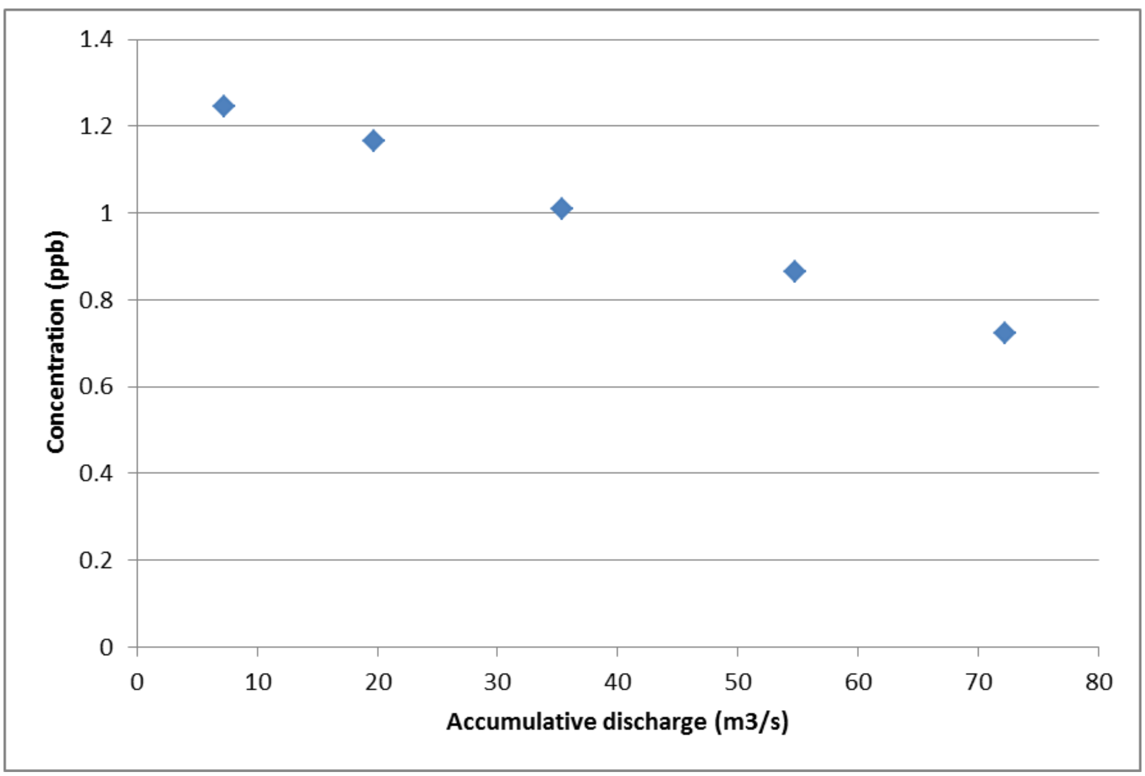


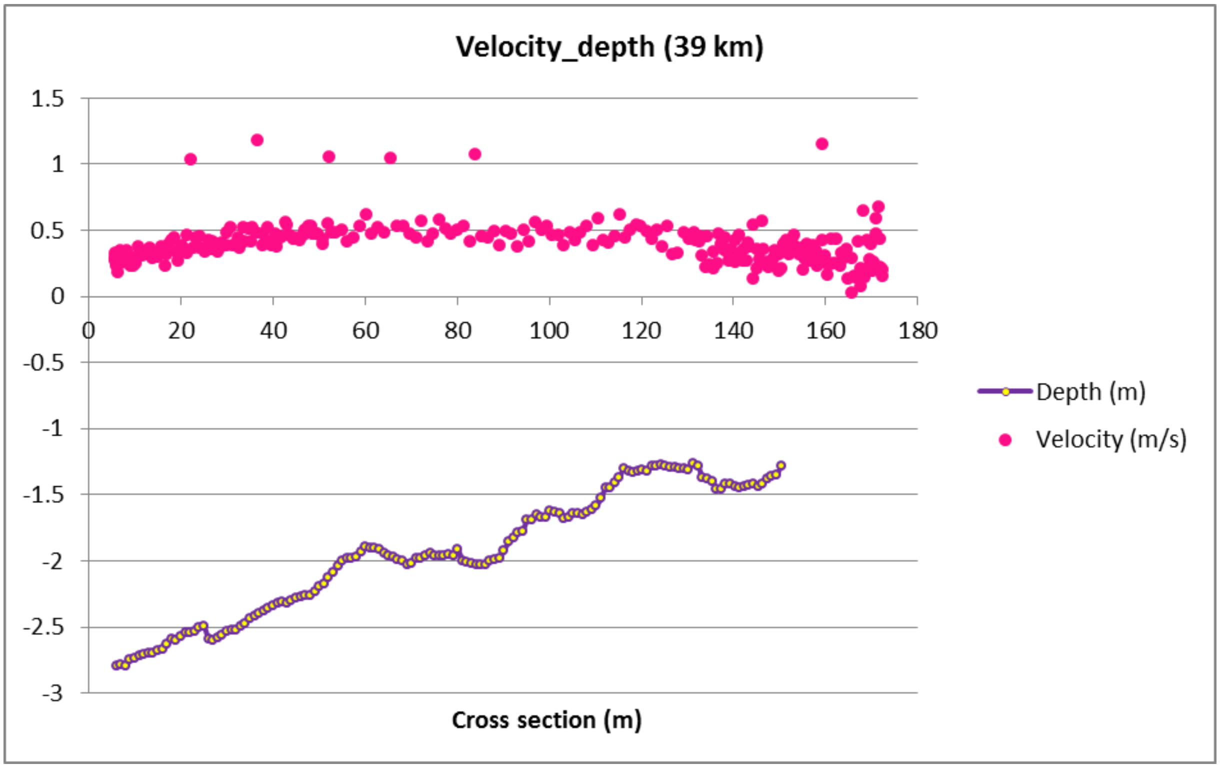
Velocity 39km_7



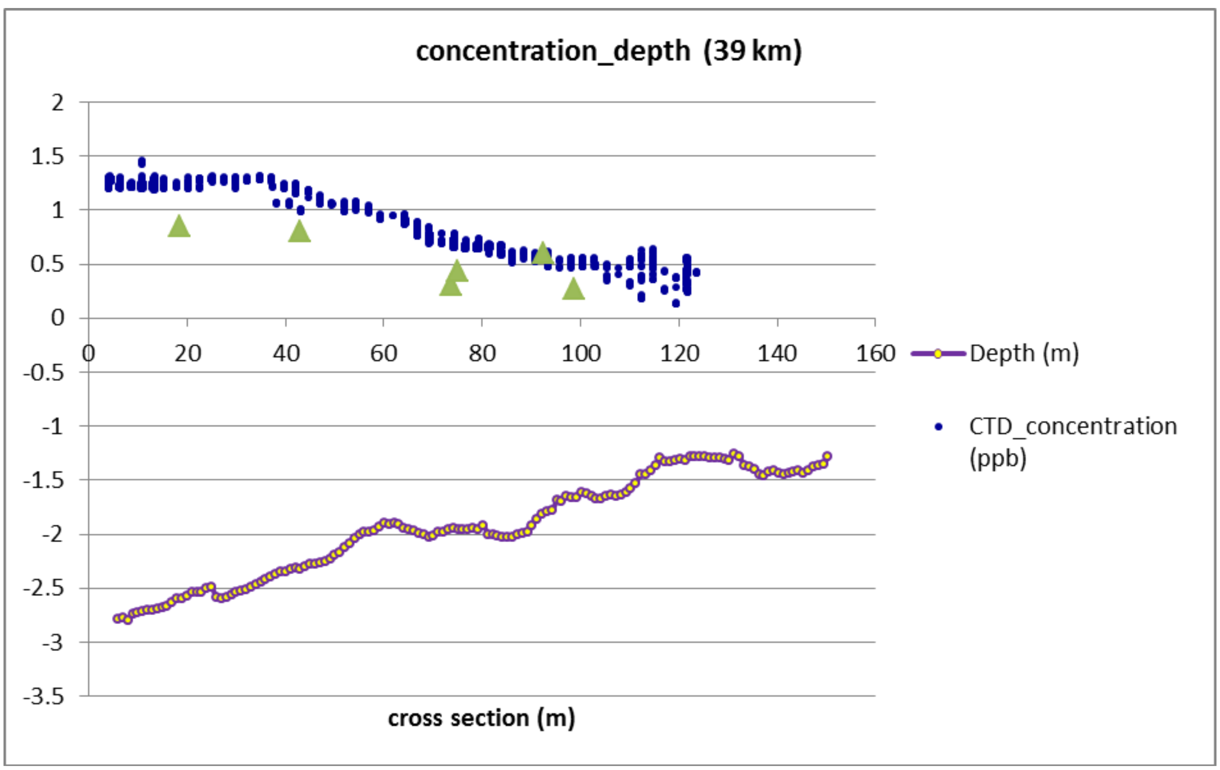
Concentration 39km_7

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.24	1.25	1.25
0.1-0.2	1.16	1.18	1.17
0.2-0.3	0.99	1.02	1.01
0.3-0.4	0.85	0.88	0.87
0.4-0.5	0.71	0.74	0.72
0.5-0.6	0.57	0.59	0.58
0.6-0.7	0.48	0.49	0.48
0.7-0.8	0.42	0.43	0.42
0.8-0.9			
0.9-1			
Approximate width(m)	163.13		
Approximate distance from outfall(km)	39		
Time and date	12:53:46	Oct 27 2011	



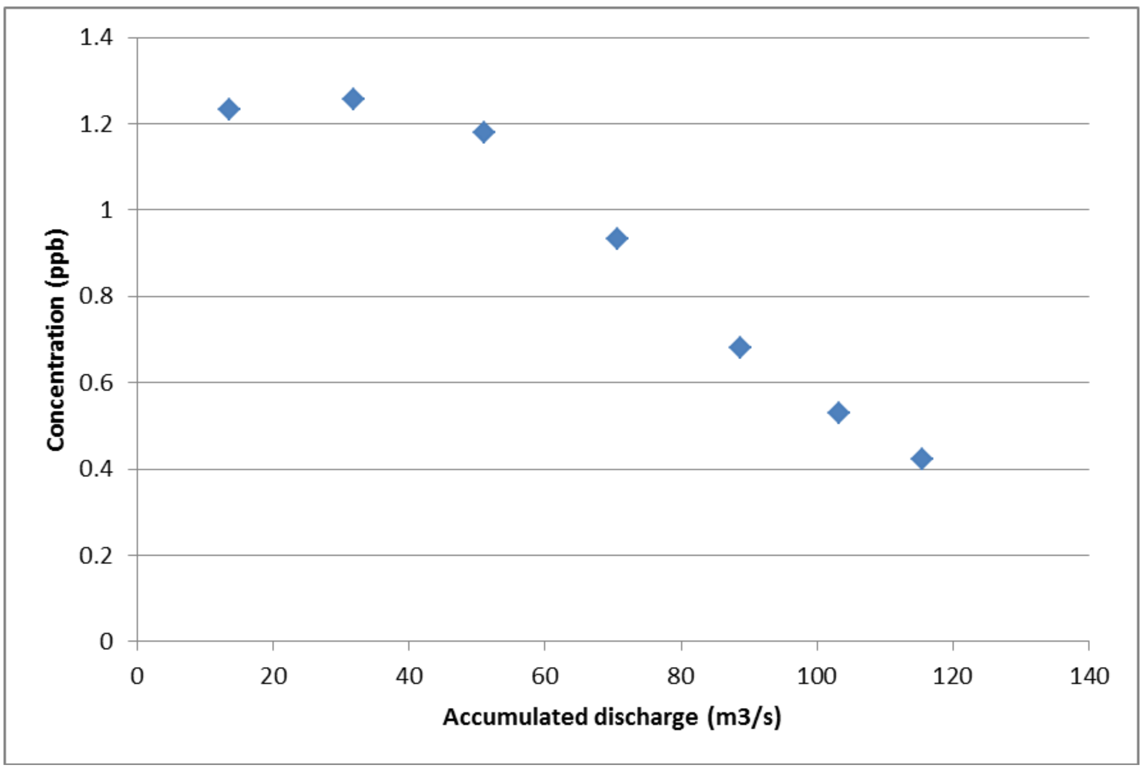


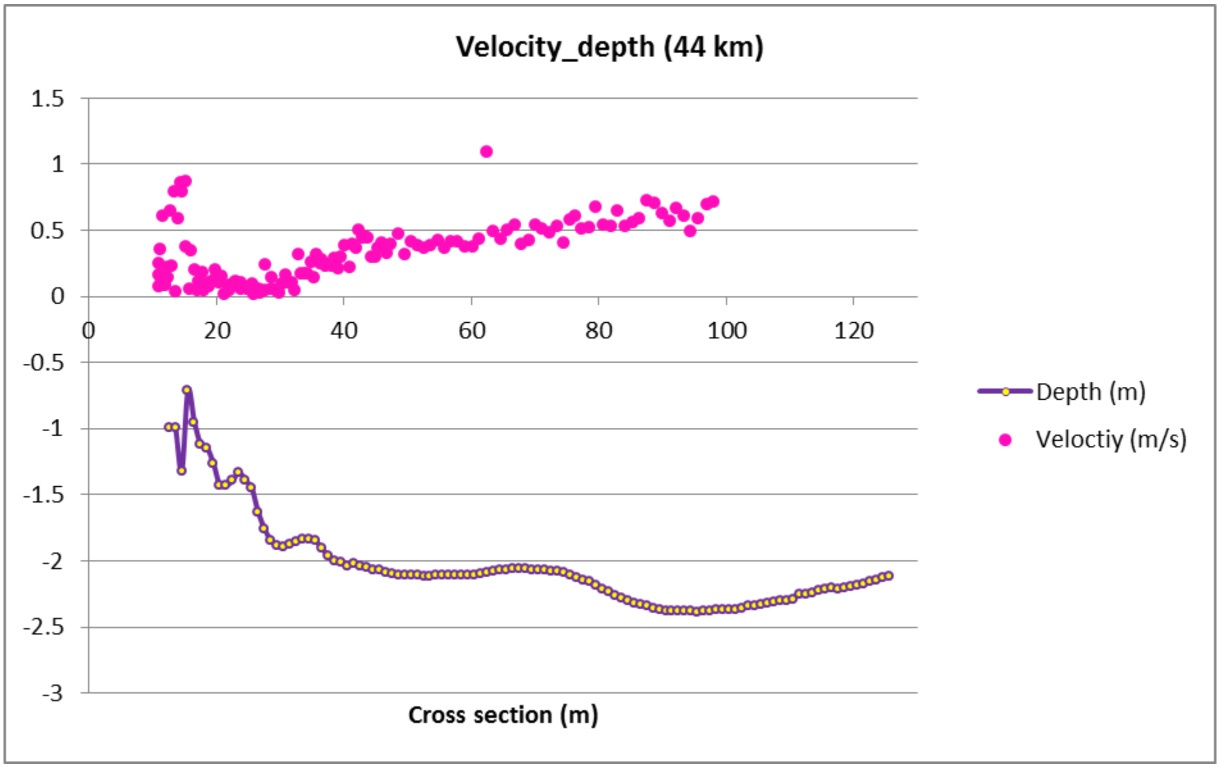
Velocity 39km_8



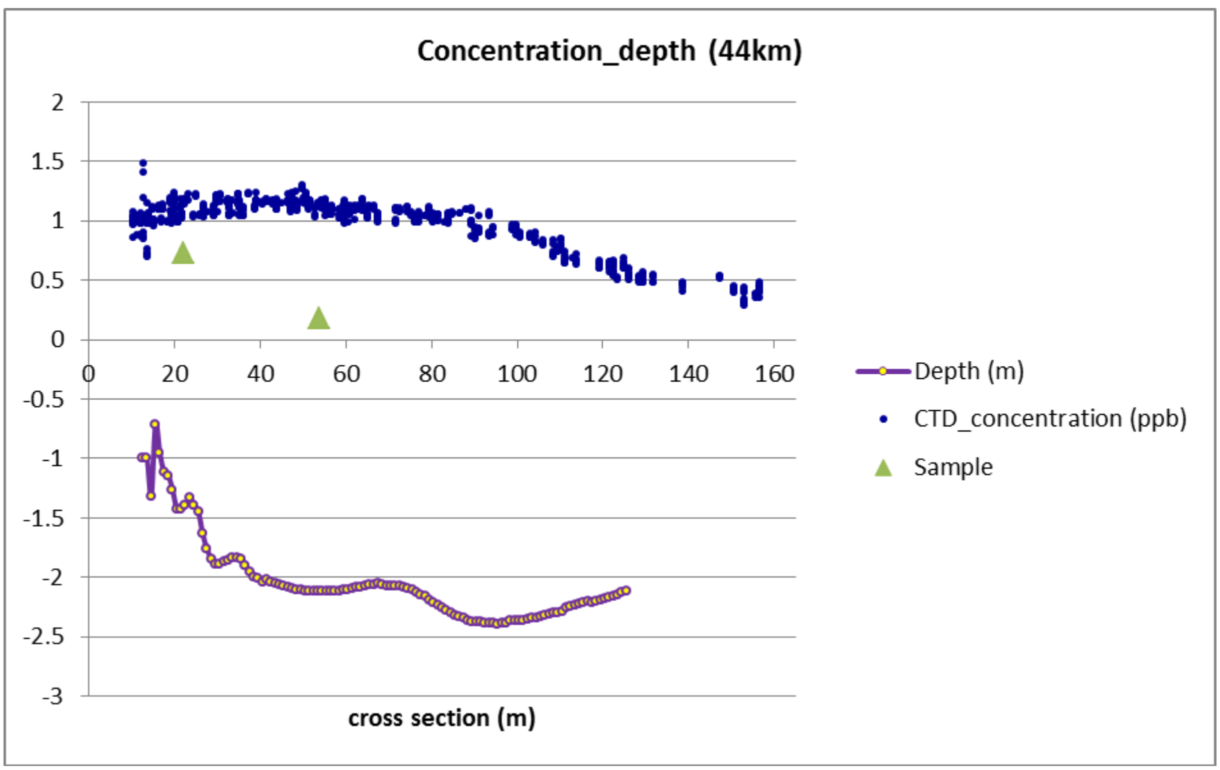
Concentration 39km_8

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.23	1.24	1.23
0.1-0.2	1.25	1.26	1.26
0.2-0.3	1.16	1.19	1.18
0.3-0.4	0.92	0.95	0.93
0.4-0.5	0.68	0.69	0.68
0.5-0.6	0.52	0.54	0.53
0.6-0.7	0.40	0.45	0.42
0.7-0.8	0.37	0.42	0.40
0.8-0.9			
0.9-1			
Approximate width(m)	171.81		
Approximate distance from outfall(km)	39		
Time and date	12:53:46	Oct 27 2011	



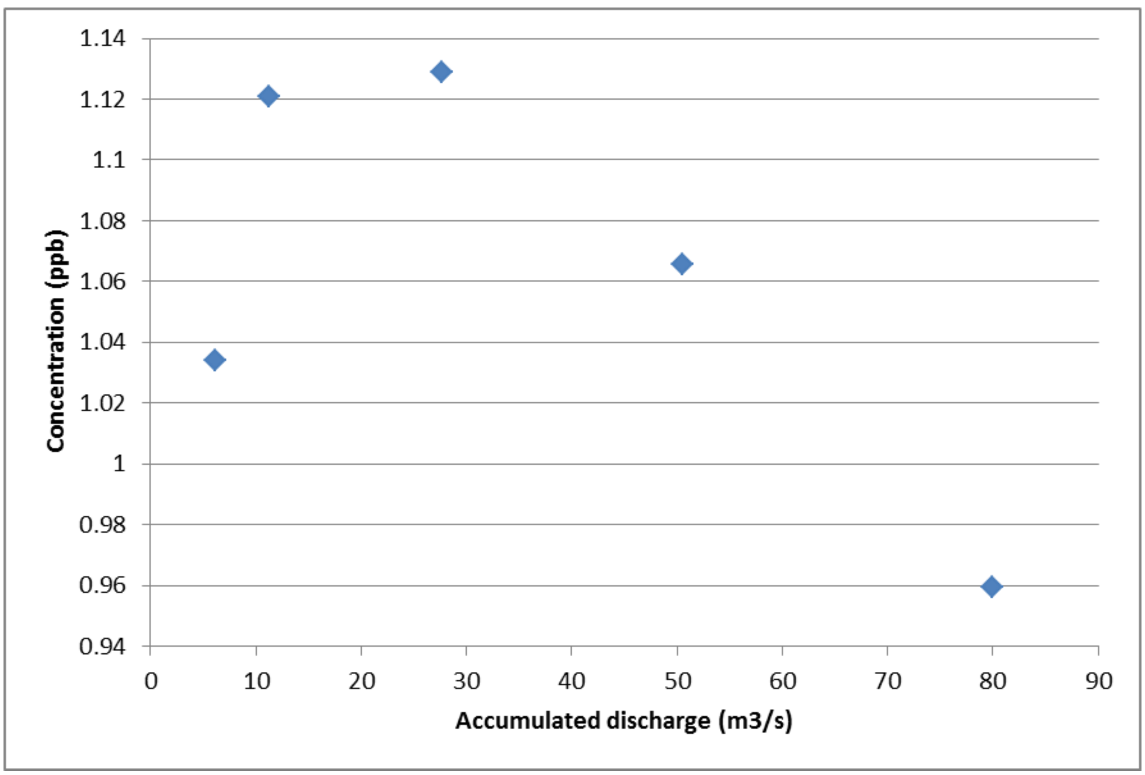


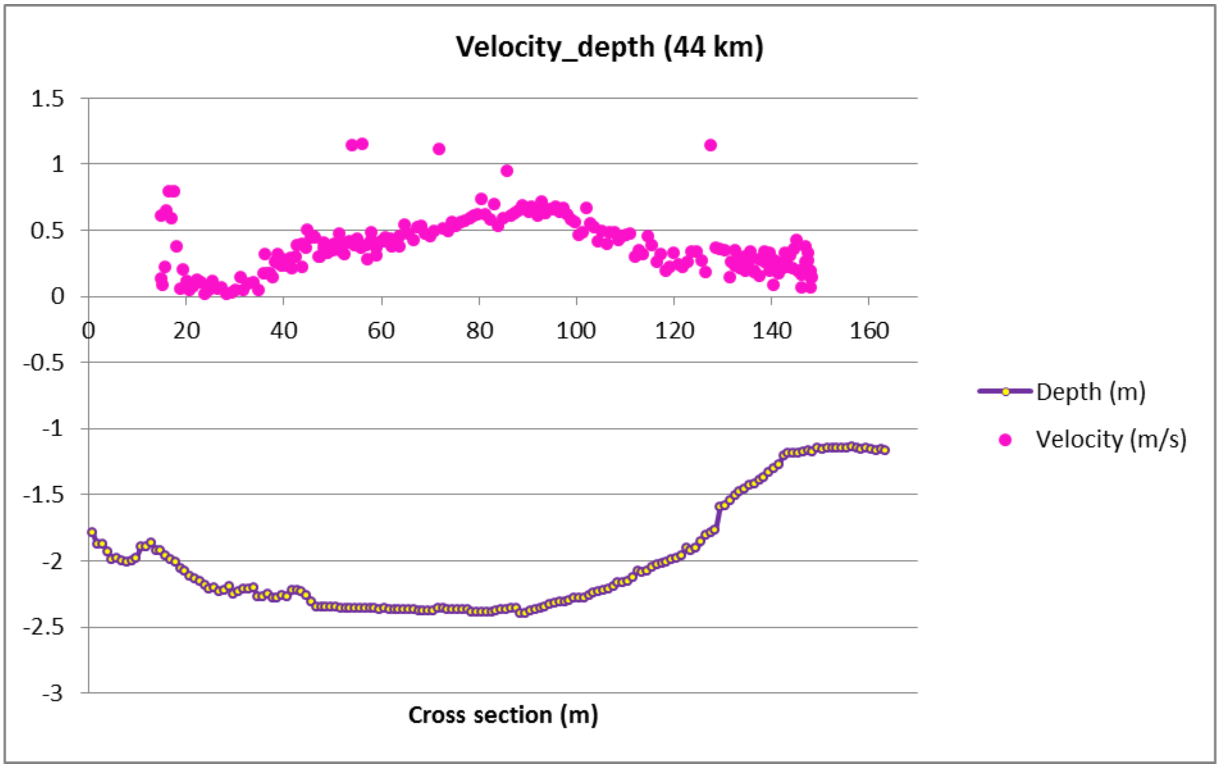
Velocity 44km_1



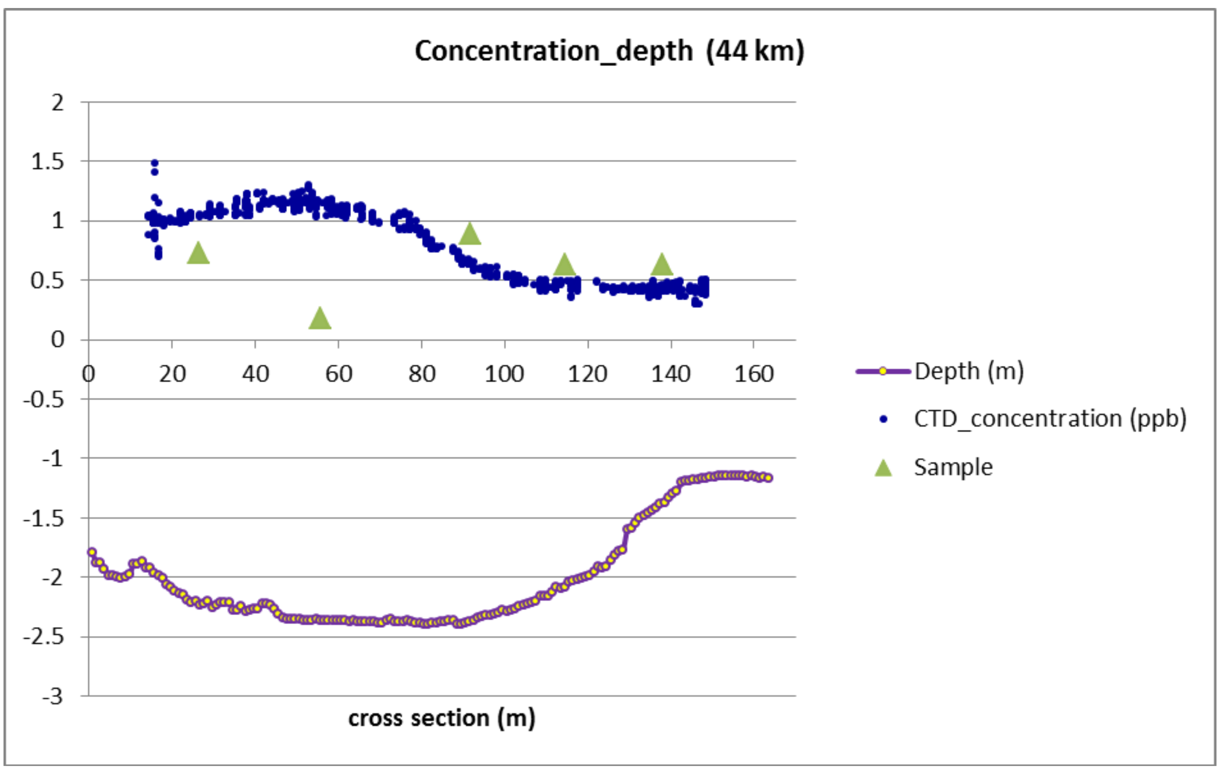
Concentration 44km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.02	1.05	1.03
0.1-0.2	1.11	1.13	1.12
0.2-0.3	1.12	1.14	1.13
0.3-0.4	1.06	1.07	1.07
0.4-0.5	0.94	0.98	0.96
0.5-0.6	0.71	0.76	0.73
0.6-0.7	0.52	0.56	0.54
0.7-0.8	0.39	0.43	0.41
0.8-0.9			
0.9-1			
Approximate width(m)	203.67		
Approximate distance from outfall(km)	44		
Time and date	17:05:48	Oct 27 2011	



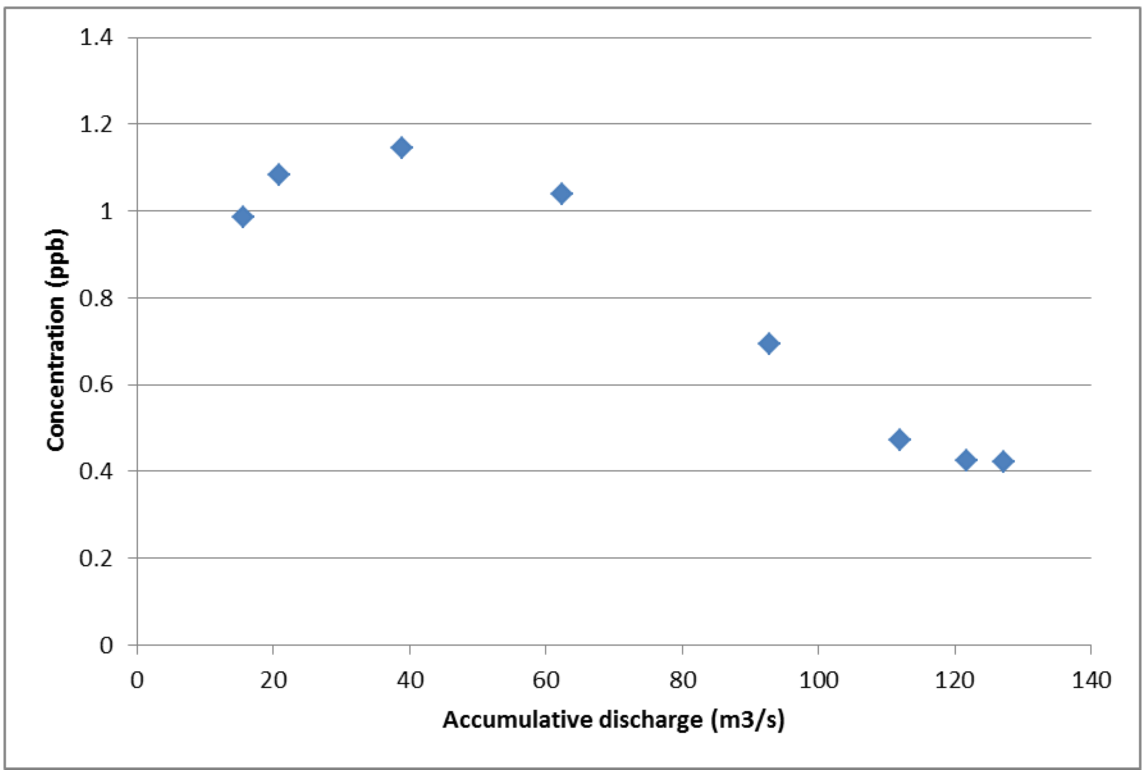


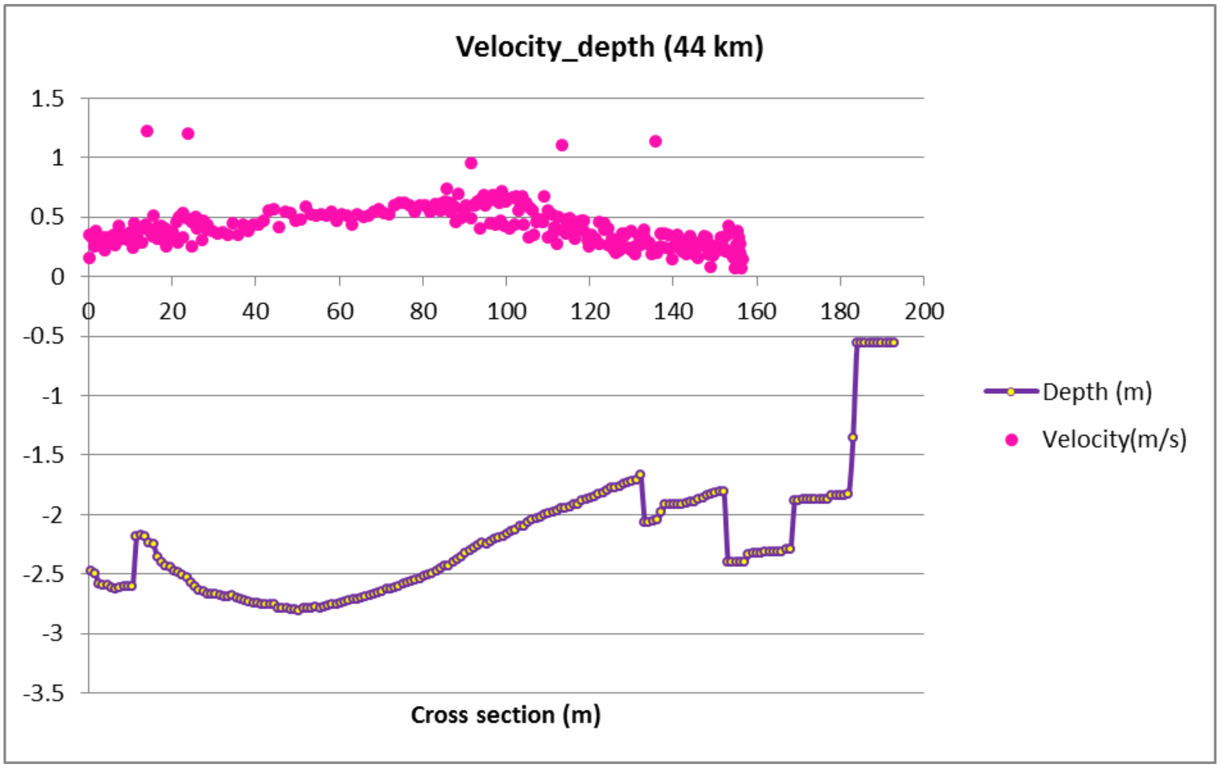
Velocity 44 km_2



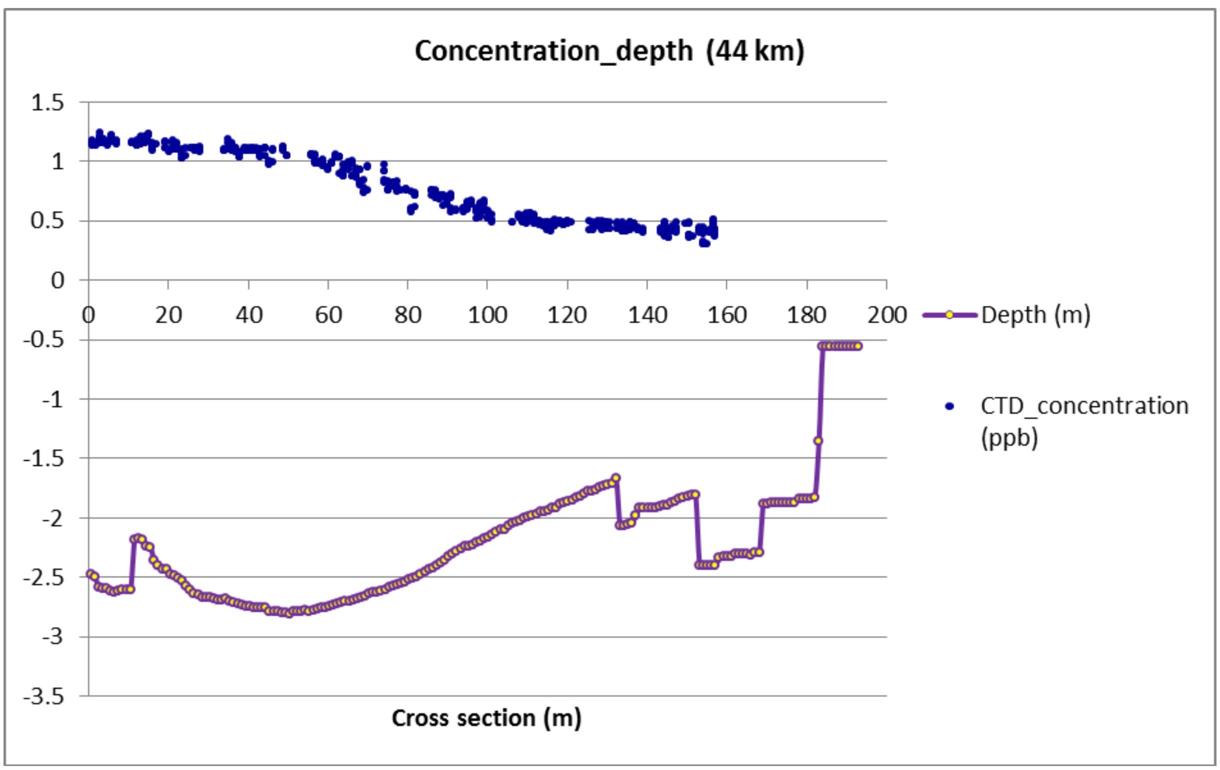
Concentration 44km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.95	1.02	0.99
0.1-0.2	1.07	1.09	1.08
0.2-0.3	1.14	1.15	1.15
0.3-0.4	1.03	1.05	1.04
0.4-0.5	0.67	0.72	0.69
0.5-0.6	0.46	0.48	0.47
0.6-0.7	0.42	0.43	0.42
0.7-0.8	0.42	0.43	0.42
0.8-0.9			
0.9-1			
Approximate width(m)	197.18		
Approximate distance from outfall(km)	44		
Time and date	17:05:48	Oct 27 2011	



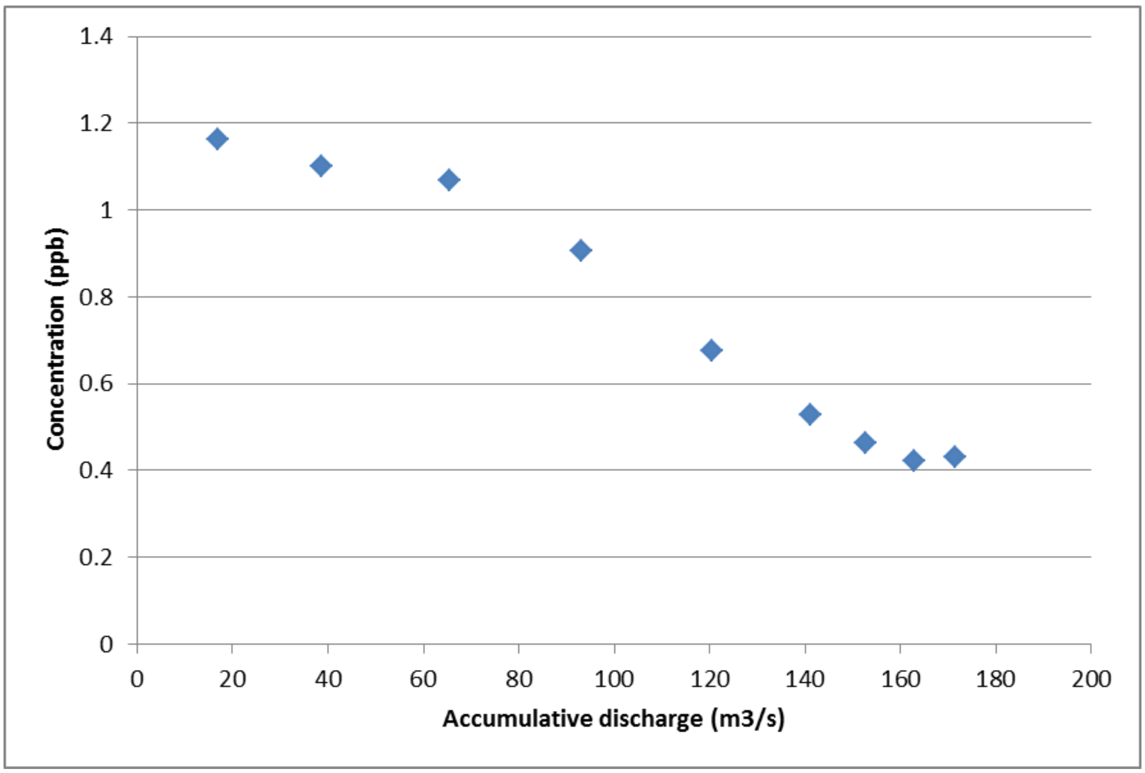


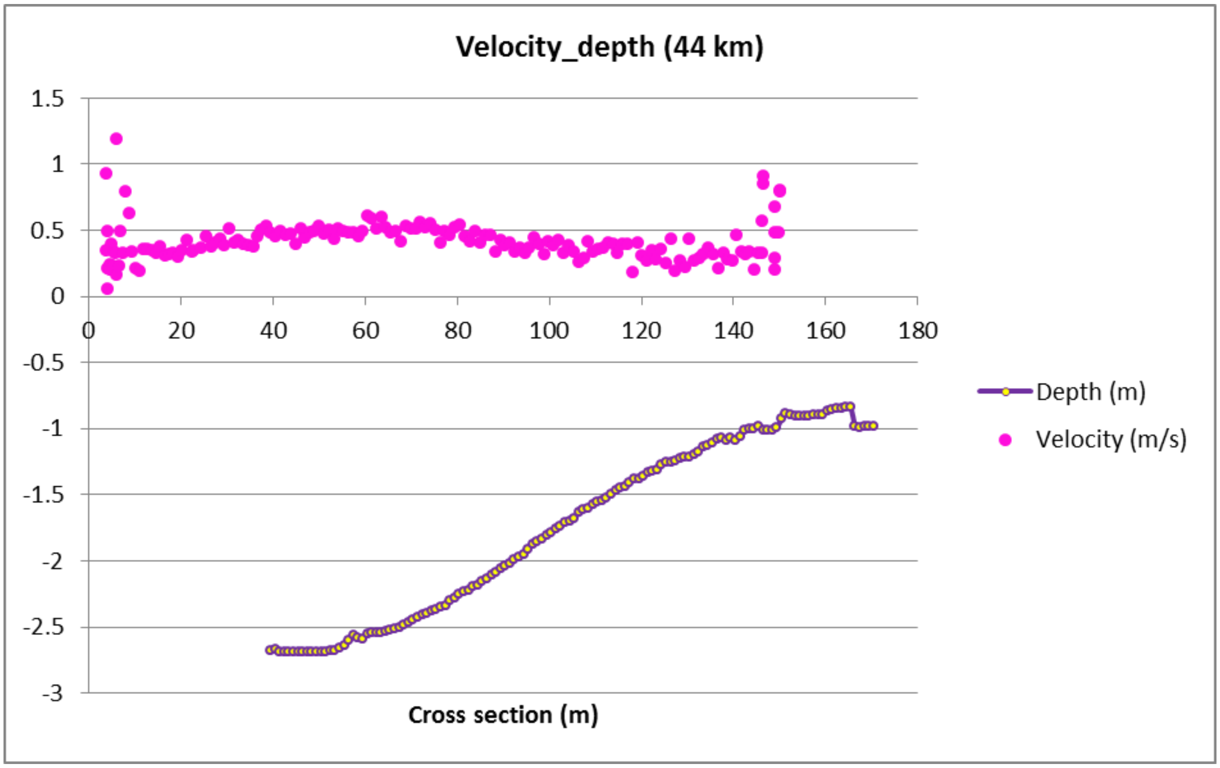
Velocity 44km_3



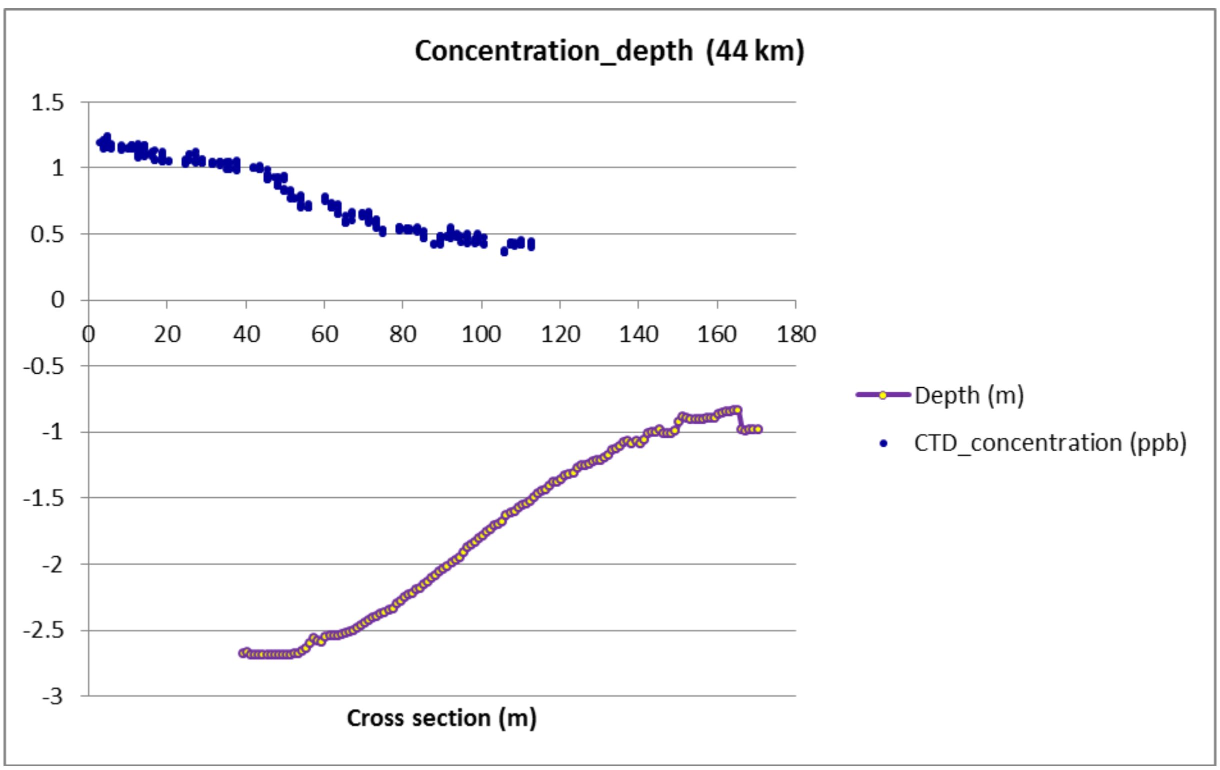
Concentration 44km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.16	1.17	1.16
0.1-0.2	1.09	1.11	1.10
0.2-0.3	1.06	1.08	1.07
0.3-0.4	0.88	0.93	0.91
0.4-0.5	0.66	0.69	0.67
0.5-0.6	0.52	0.54	0.53
0.6-0.7	0.46	0.47	0.46
0.7-0.8	0.41	0.43	0.42
0.8-0.9	0.41	0.45	0.43
0.9-1			
Approximate width(m)	193.23		
Approximate distance from outfall(km)	44		
Time and date	17:05:48	Oct 27 2011	



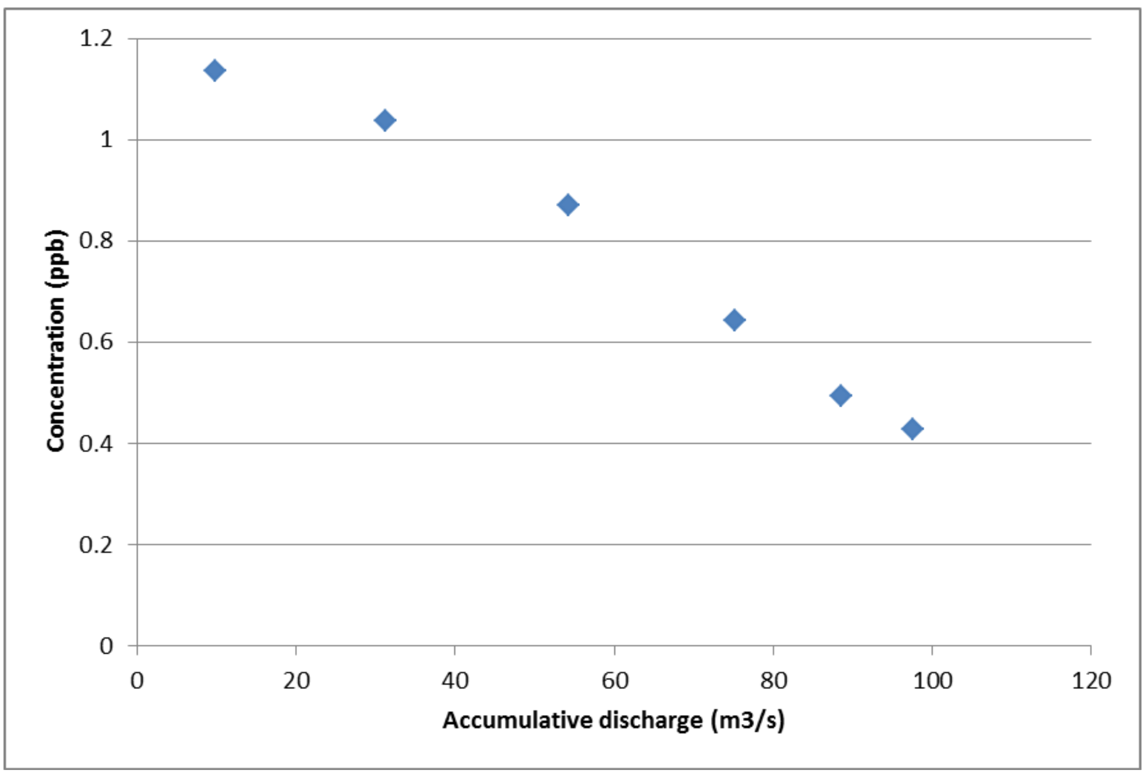


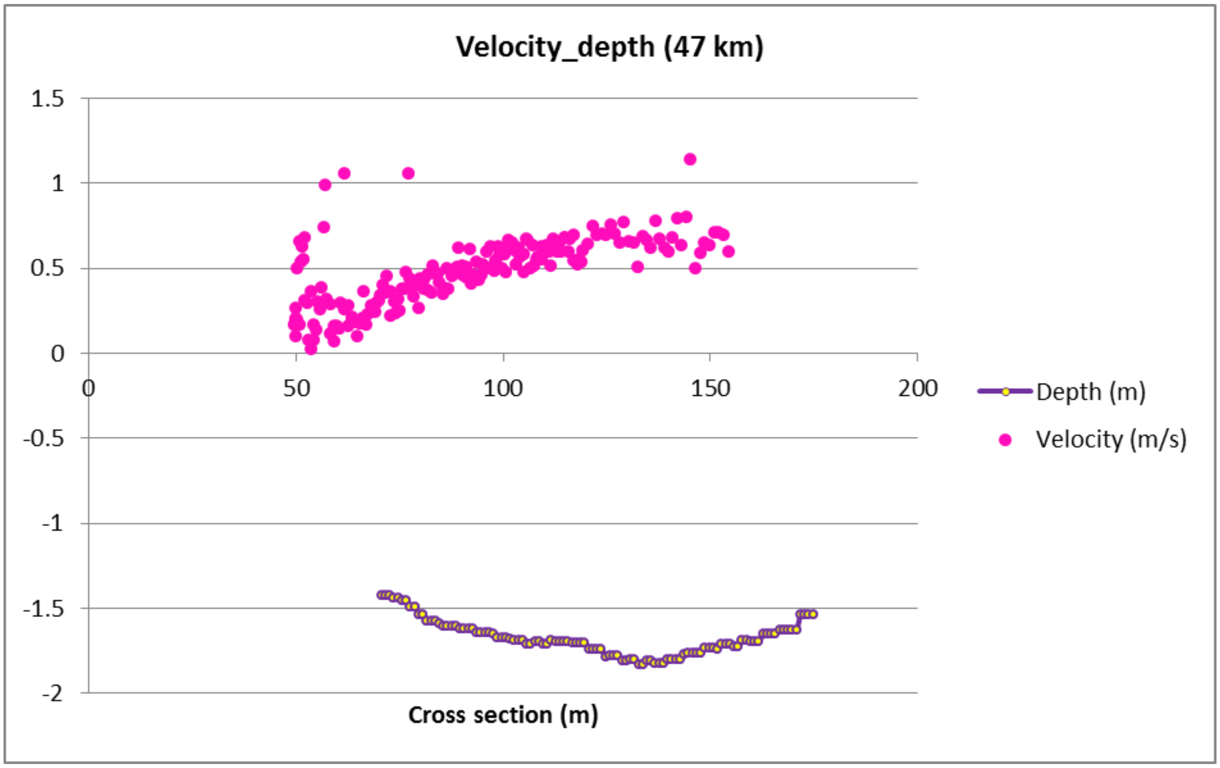
Velocity 44km_4



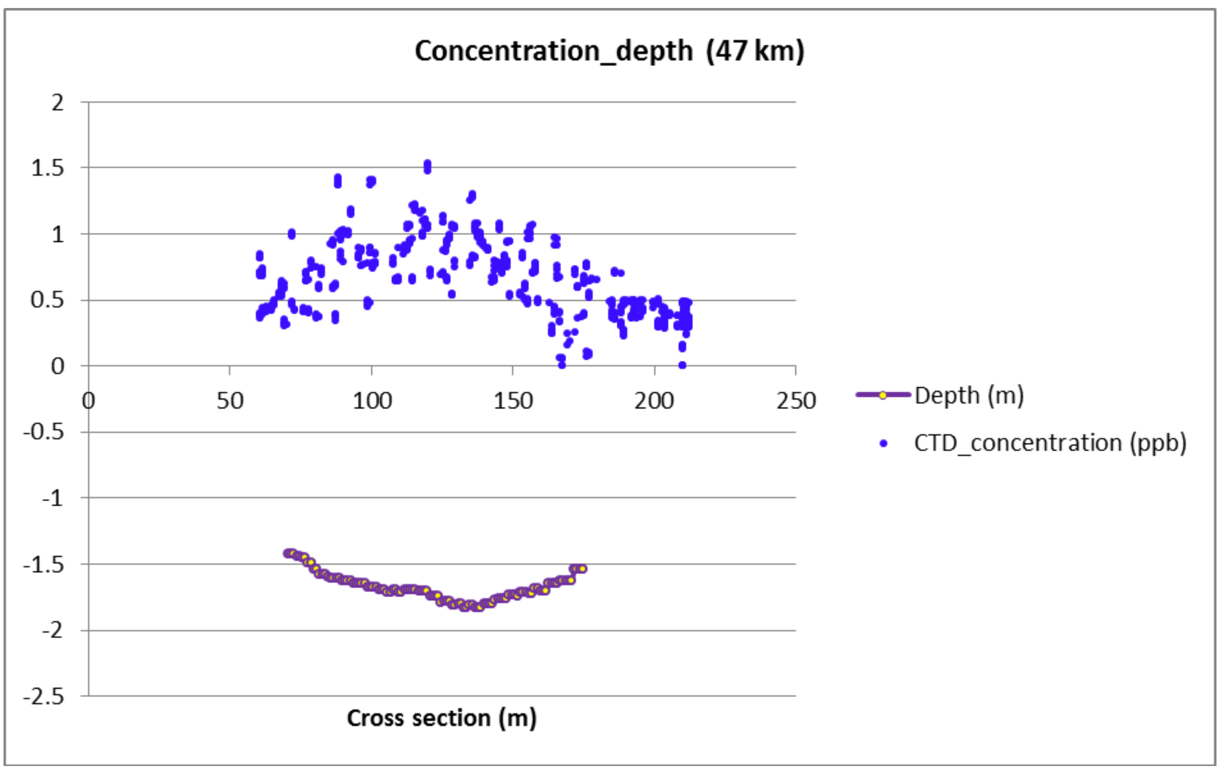
Concentration 44km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	1.13	1.14	1.14
0.1-0.2	1.03	1.04	1.04
0.2-0.3	0.85	0.89	0.87
0.3-0.4	0.63	0.66	0.64
0.4-0.5	0.49	0.50	0.49
0.5-0.6	0.42	0.44	0.43
0.6-0.7			
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	194.89		
Approximate distance from outfall(km)	44		
Time and date	17:05:48	Oct 27 2011	



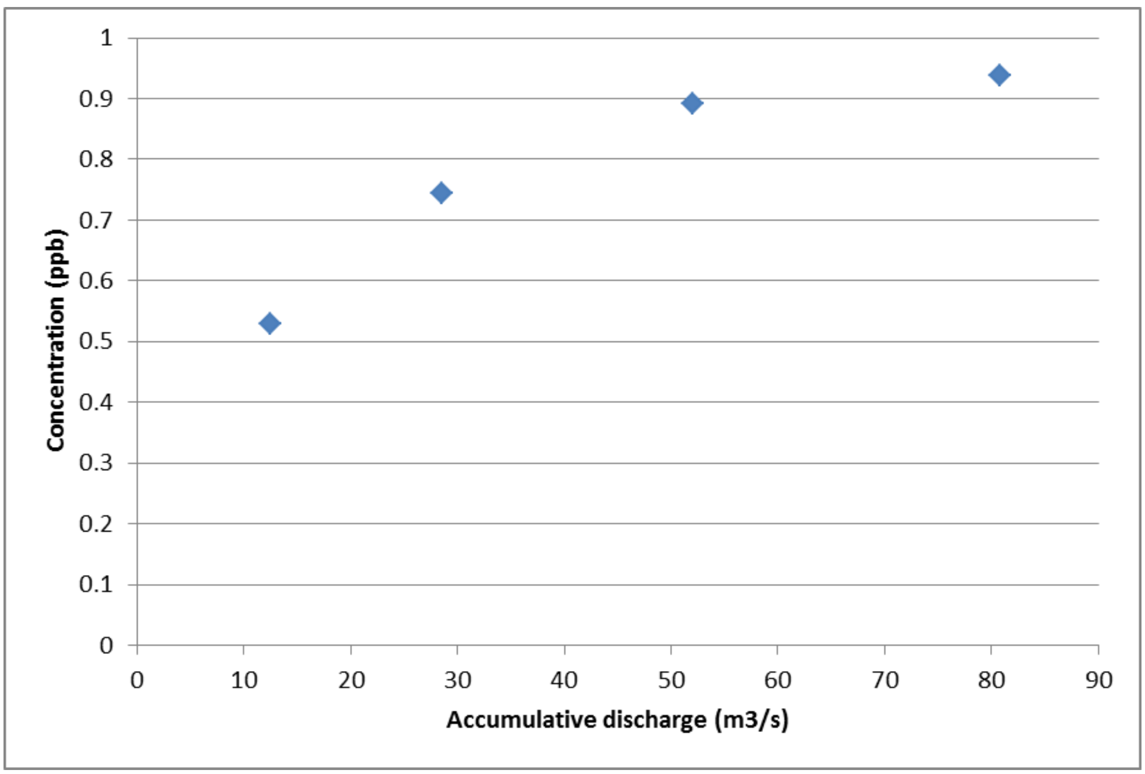


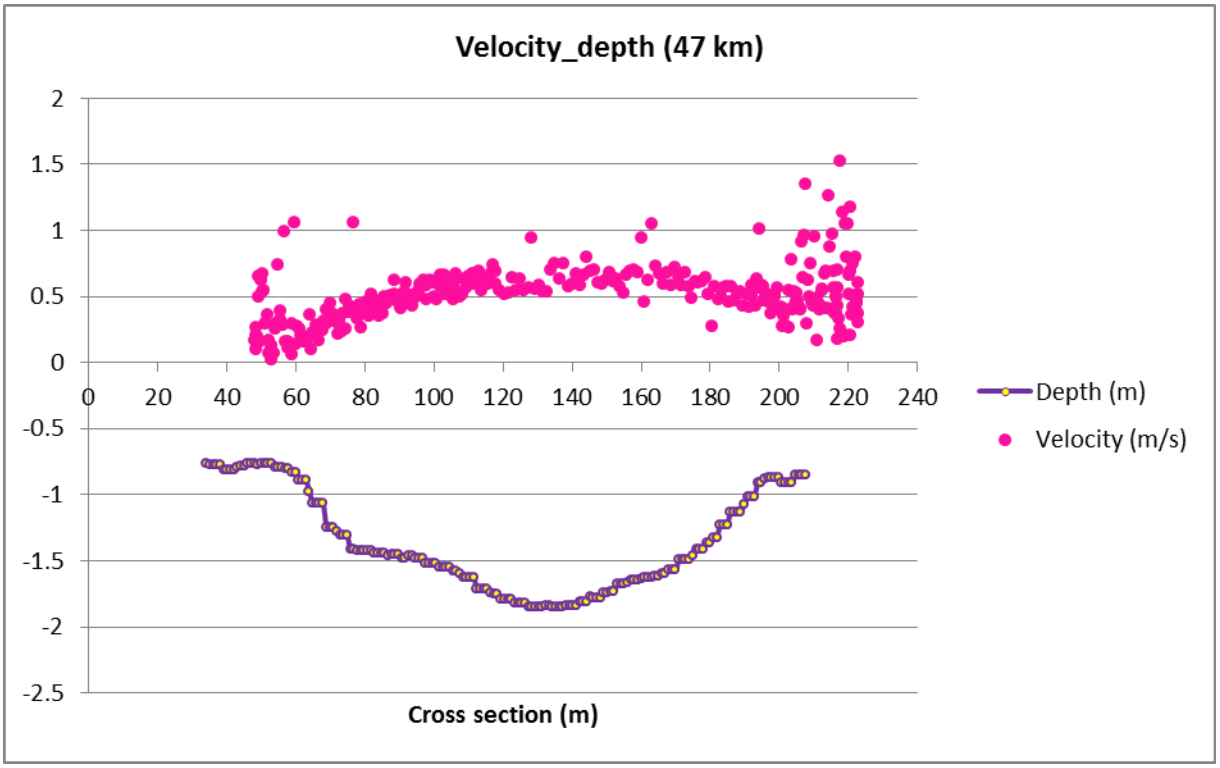
Velocity 47km_1



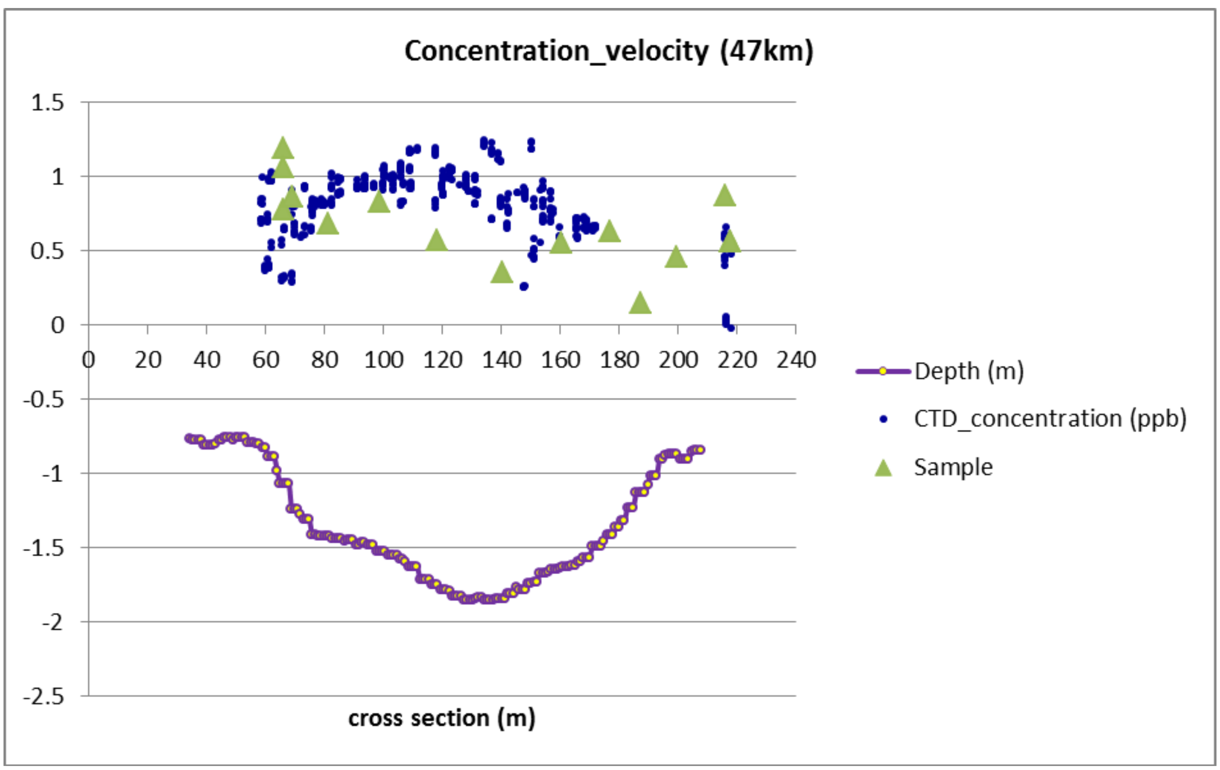
Concentration 47km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	0.49	0.57	0.53
0.3-0.4	0.68	0.81	0.75
0.4-0.5	0.85	0.94	0.89
0.5-0.6	0.89	0.99	0.94
0.6-0.7	0.65	0.75	0.70
0.7-0.8	0.41	0.50	0.45
0.8-0.9	0.35	0.39	0.37
0.9-1			
Approximate width(m)	238.28		
Approximate distance from outfall(km)	47		
Time and date	13:44:08	Oct 27 2011	



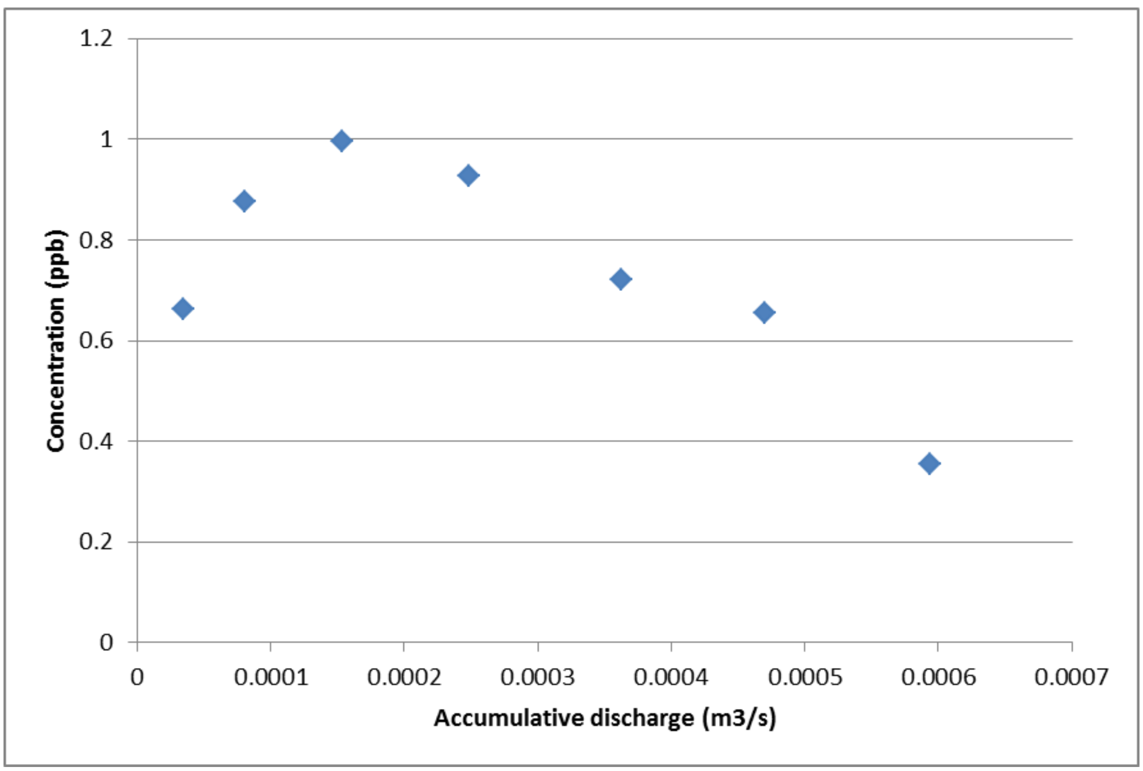


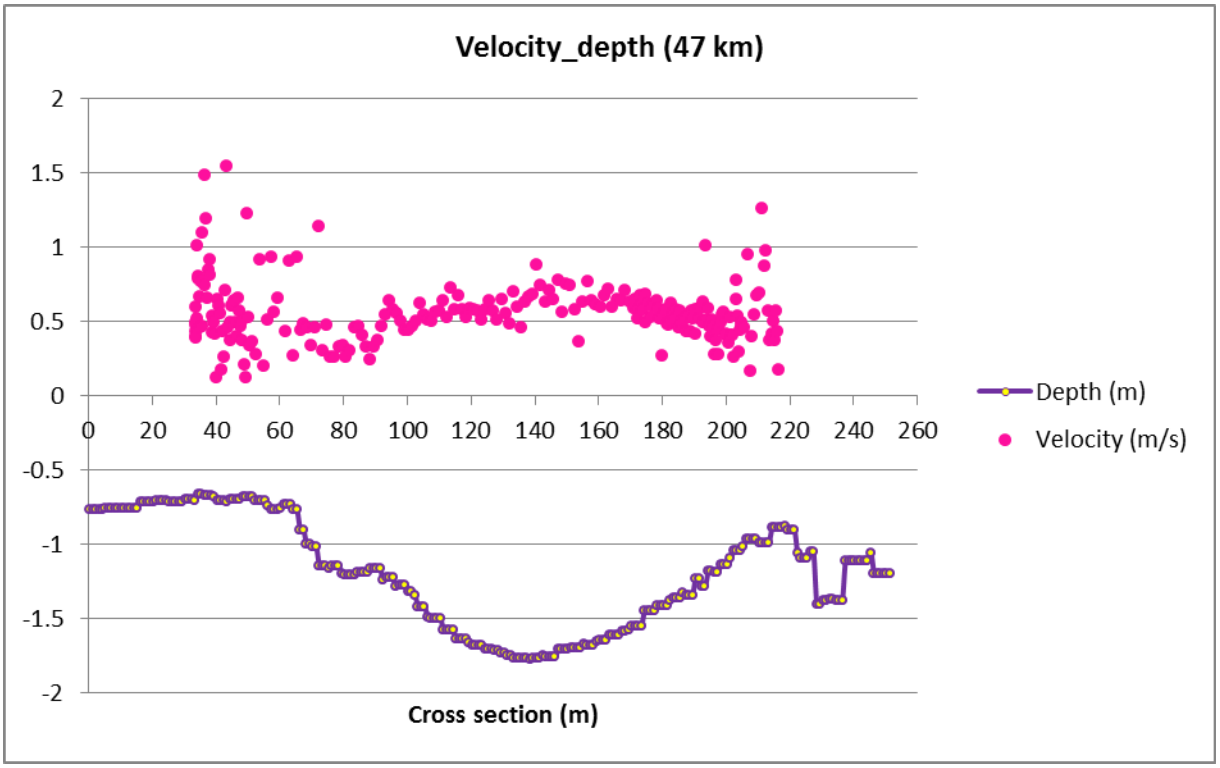
Velocity 47km_2



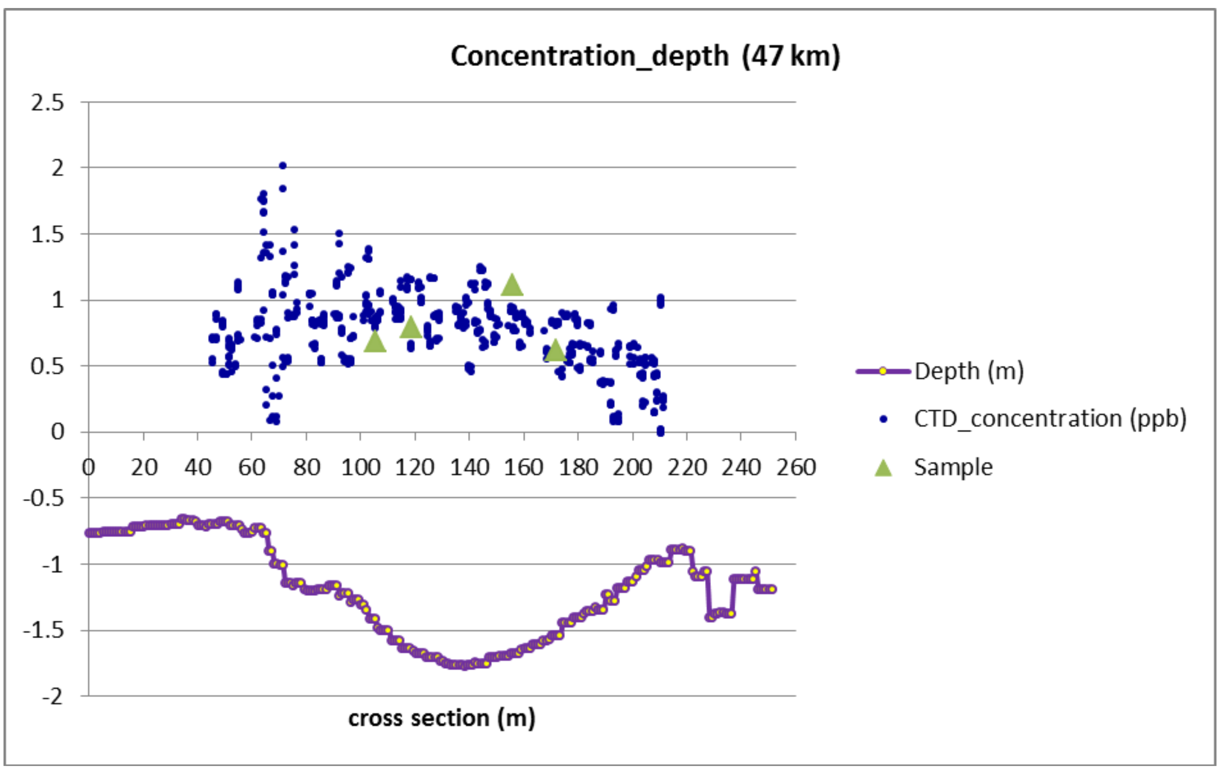
Concentration 47km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	0.61	0.71	0.66
0.3-0.4	0.86	0.89	0.88
0.4-0.5	0.98	1.01	1.00
0.5-0.6	0.89	0.96	0.93
0.6-0.7	0.69	0.75	0.72
0.7-0.8	0.65	0.66	0.65
0.8-0.9	0.21	0.50	0.35
0.9-1			
Approximate width(m)	245.43		
Approximate distance from outfall(km)	47		
Time and date	13:44:08	Oct 27 2011	



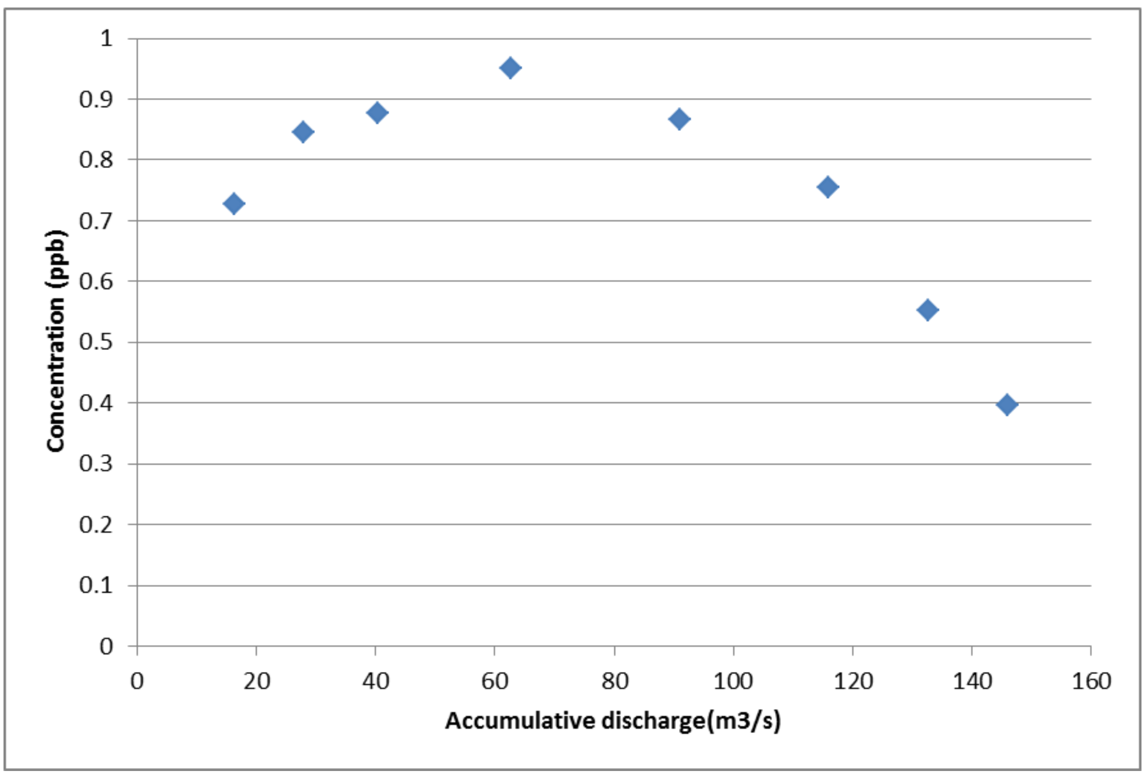


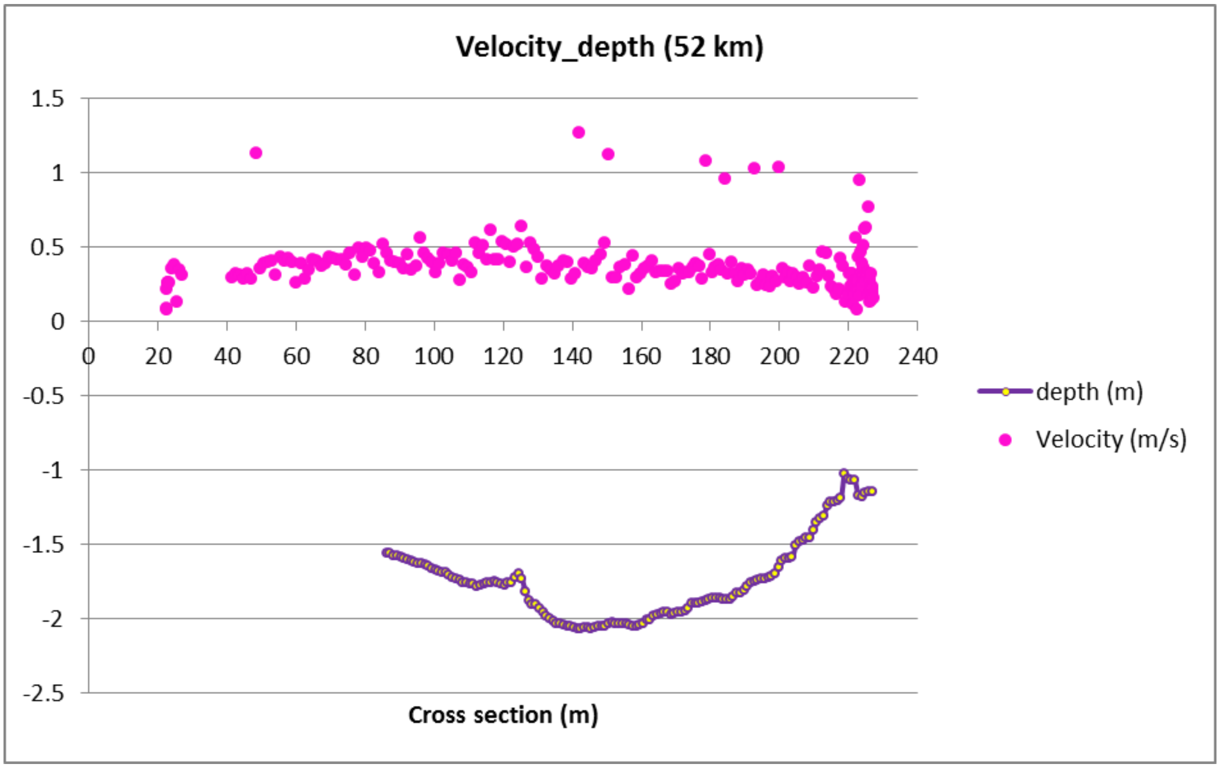
Velocity 47km_3



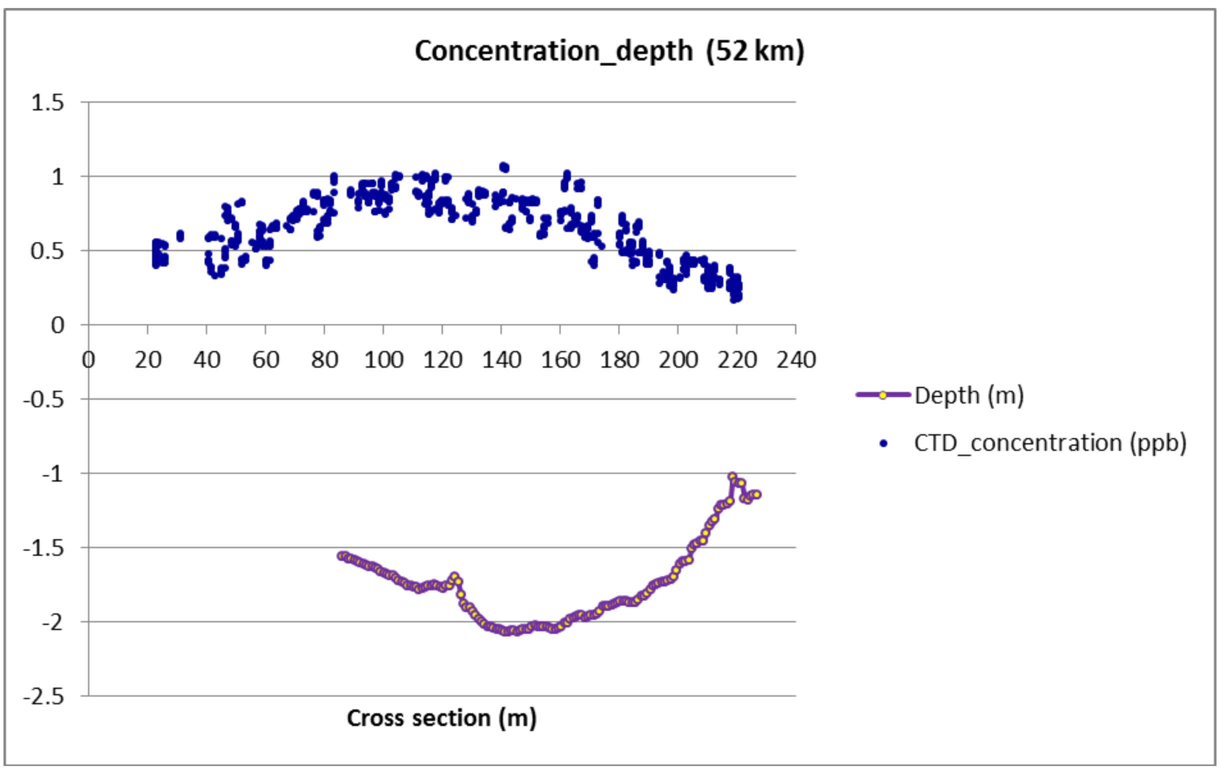
Concentration 47km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.65	0.80	0.73
0.2-0.3	0.75	0.93	0.84
0.3-0.4	0.82	0.93	0.88
0.4-0.5	0.92	0.99	0.95
0.5-0.6	0.83	0.91	0.87
0.6-0.7	0.72	0.79	0.75
0.7-0.8	0.50	0.60	0.55
0.8-0.9	0.34	0.46	0.40
0.9-1			
Approximate width(m)	251.95		
Approximate distance from outfall(km)	47		
Time and date	13:44:08	Oct 27 2011	



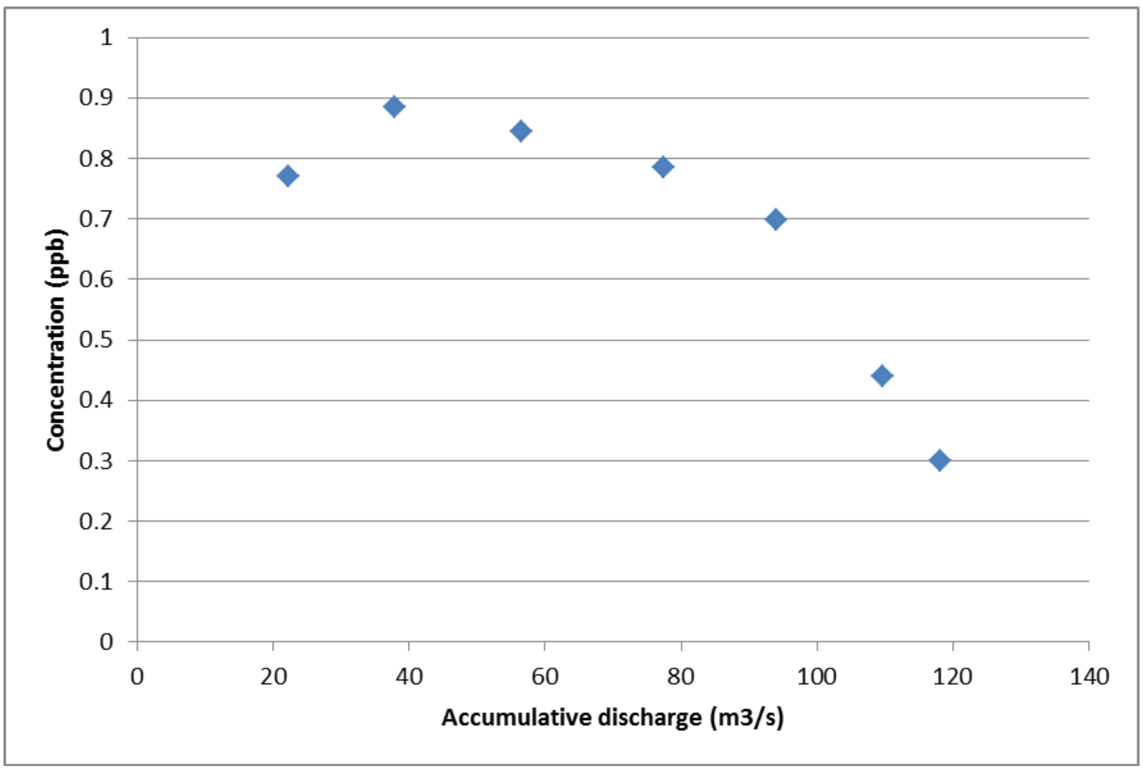


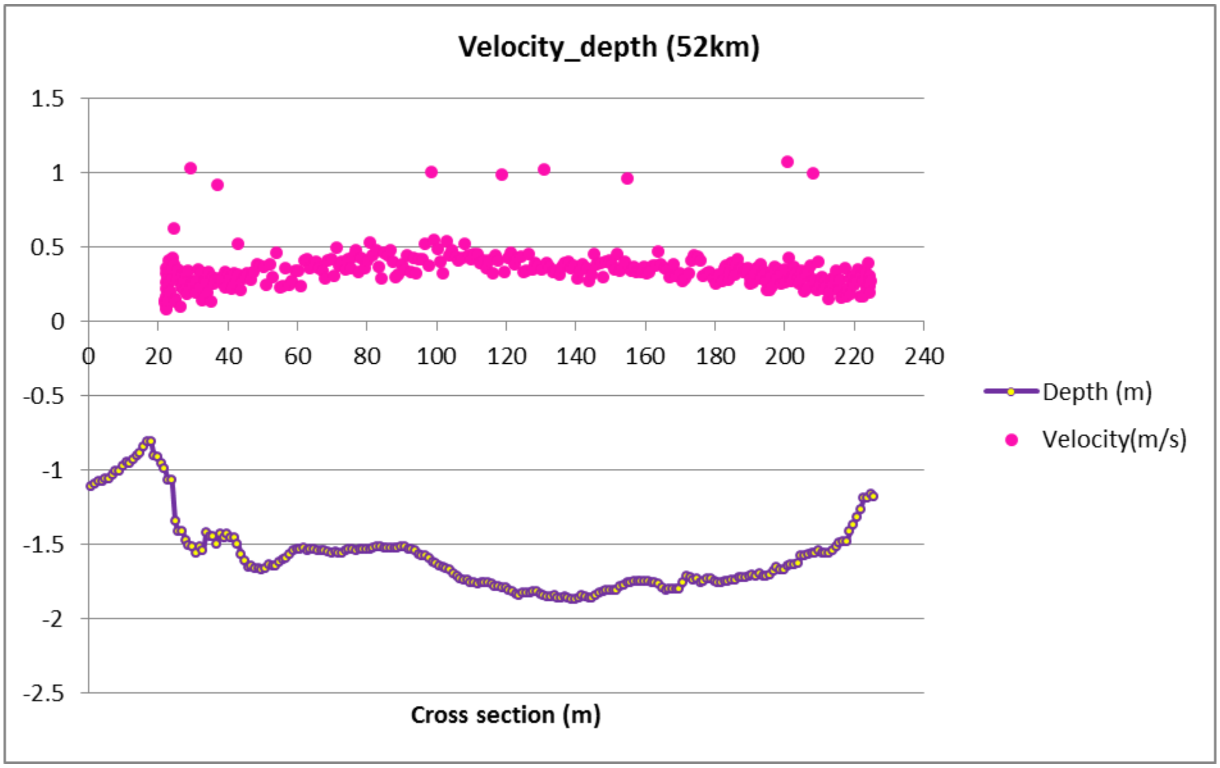
Velocity 52km_1



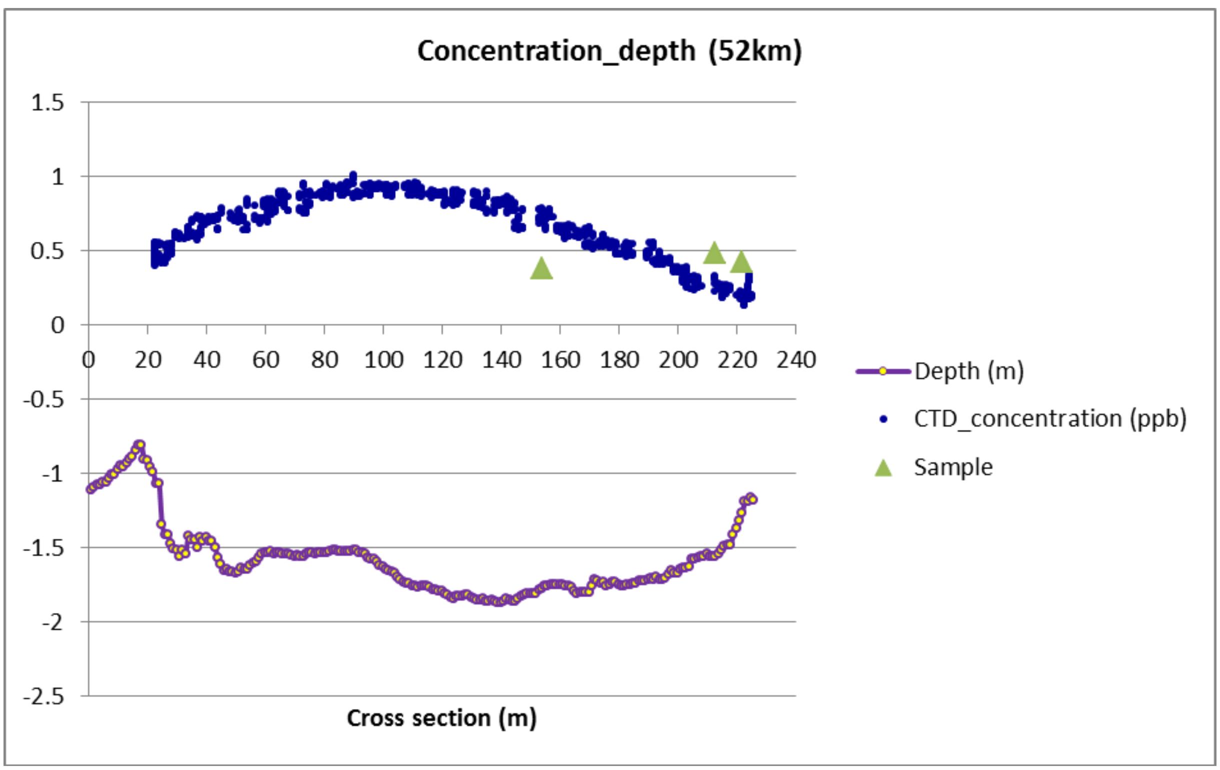
Concentration 52km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.47	0.50	0.49
0.2-0.3	0.57	0.62	0.60
0.3-0.4	0.75	0.79	0.77
0.4-0.5	0.87	0.90	0.88
0.5-0.6	0.83	0.86	0.84
0.6-0.7	0.76	0.81	0.79
0.7-0.8	0.67	0.73	0.70
0.8-0.9	0.42	0.46	0.44
0.9-1	0.29	0.31	0.30
Approximate width(m)	227.29		
Approximate distance from outfall(km)	52		
Time and date	16:10:21	Oct 27 2011	



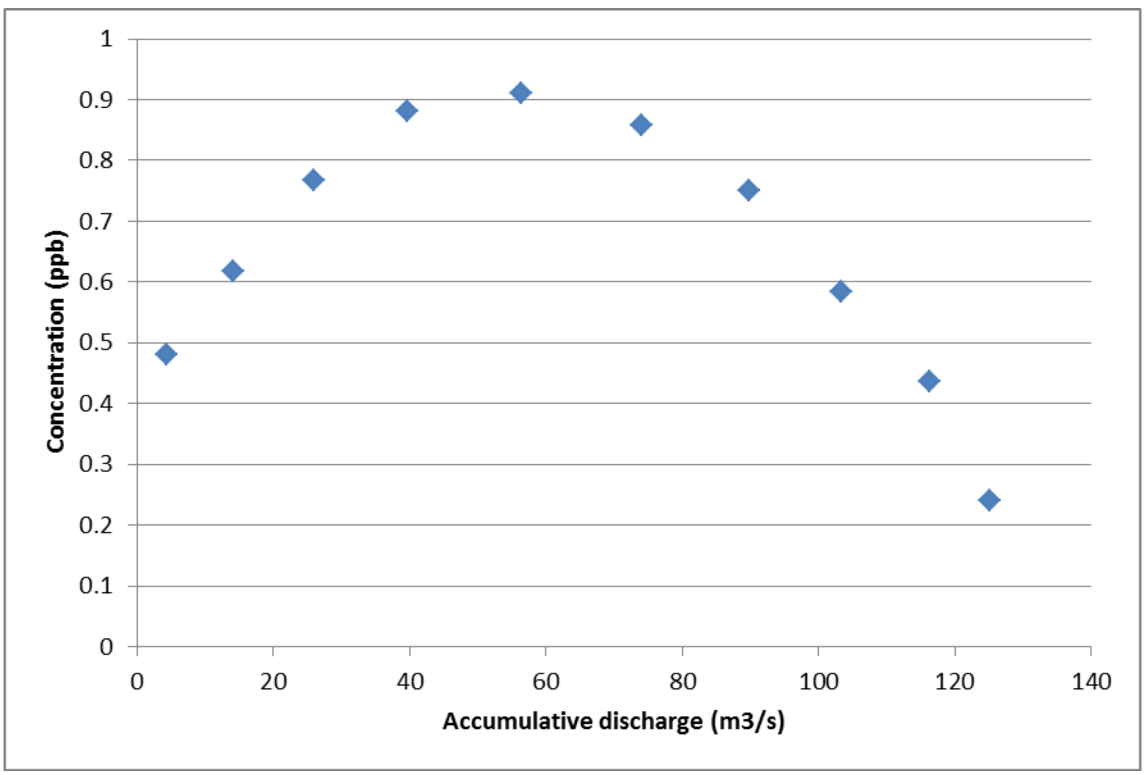


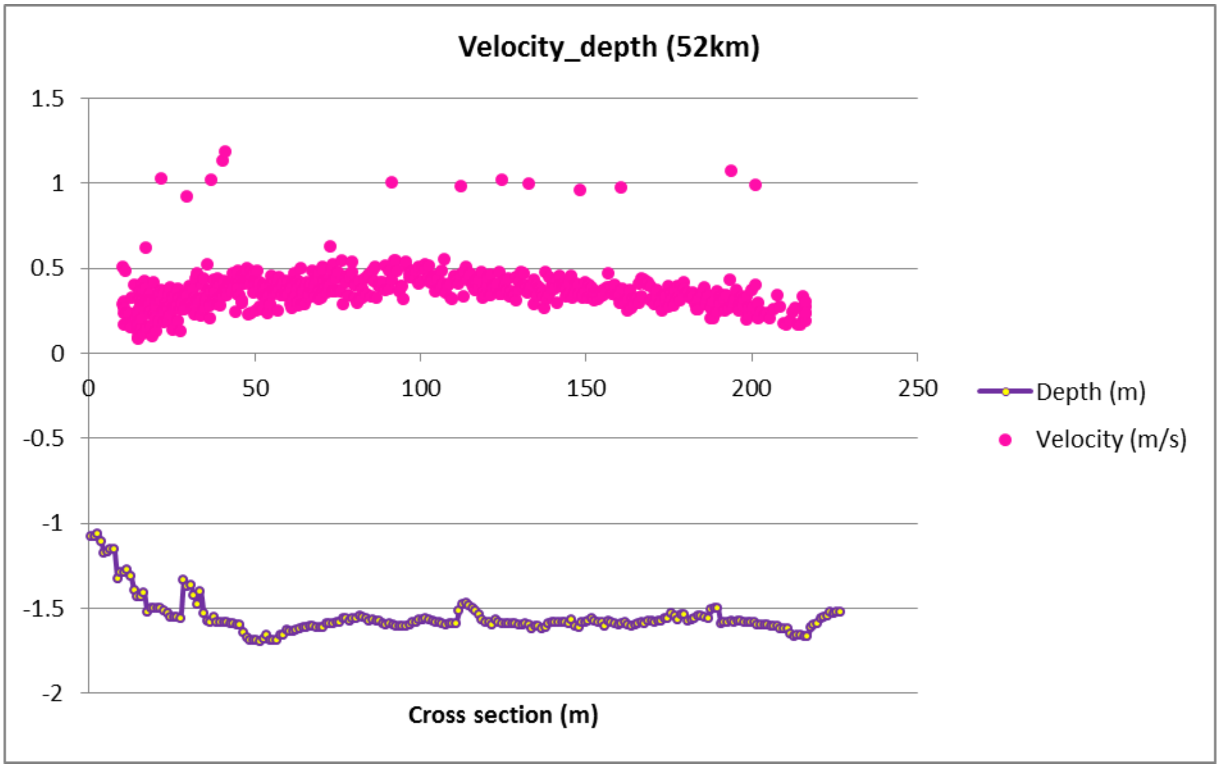
Velocity 52km_2



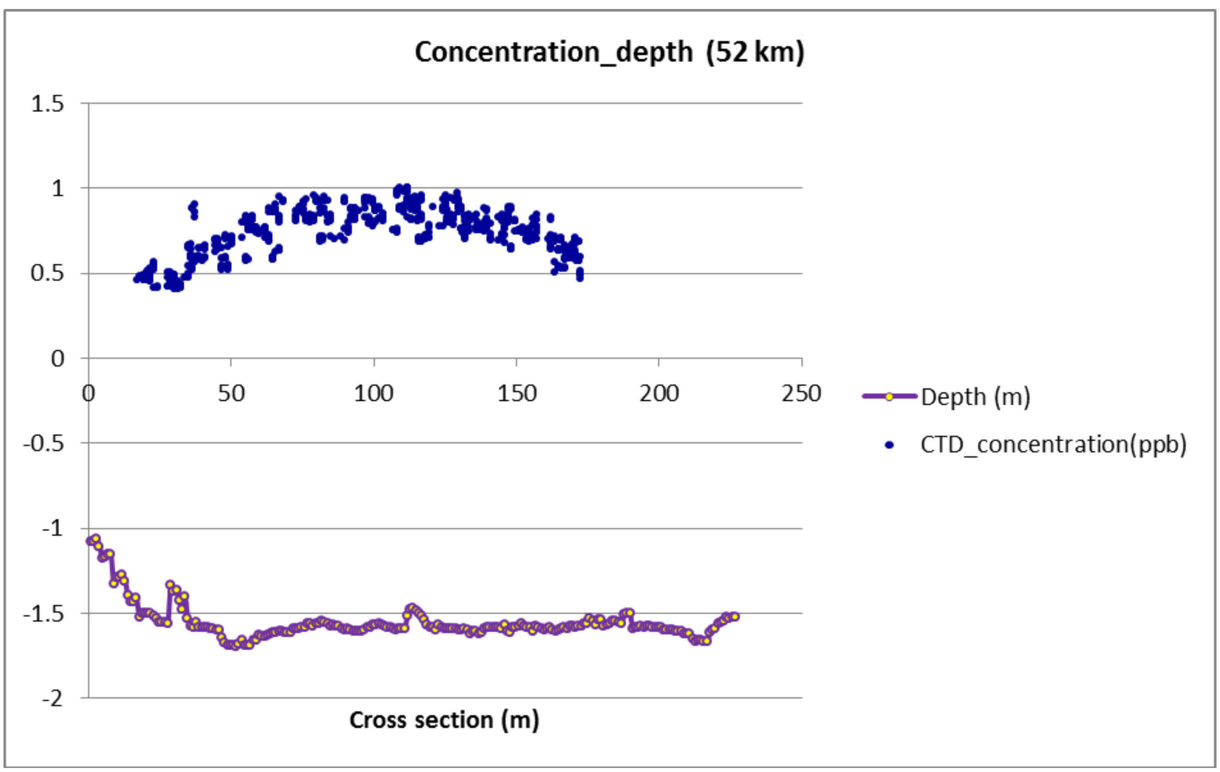
Concentration 52km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.47	0.49	0.48
0.1-0.2	0.60	0.63	0.62
0.2-0.3	0.76	0.78	0.77
0.3-0.4	0.87	0.89	0.88
0.4-0.5	0.91	0.92	0.91
0.5-0.6	0.85	0.87	0.86
0.6-0.7	0.74	0.76	0.75
0.7-0.8	0.57	0.59	0.58
0.8-0.9	0.42	0.45	0.44
0.9-1	0.23	0.25	0.24
Approximate width(m)	226.78		
Approximate distance from outfall(km)	52		
Time and date	16:10:21	Oct 27 2011	



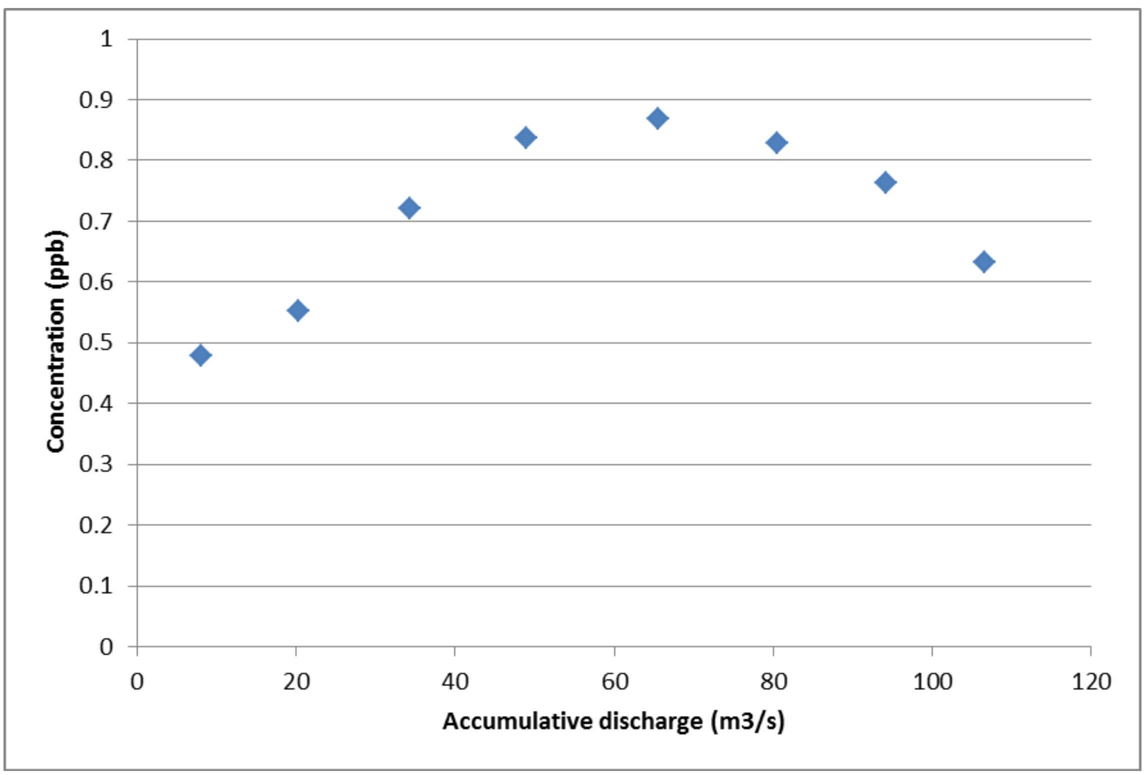


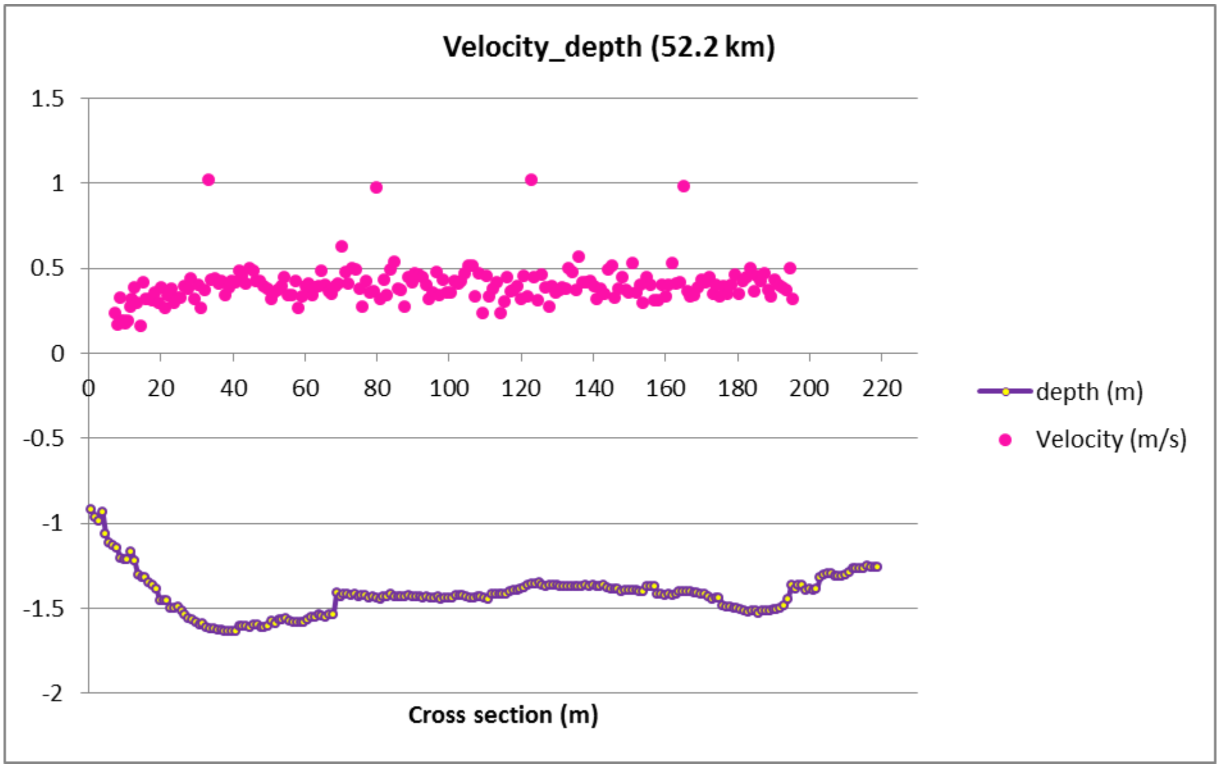
Velocity 52km_3



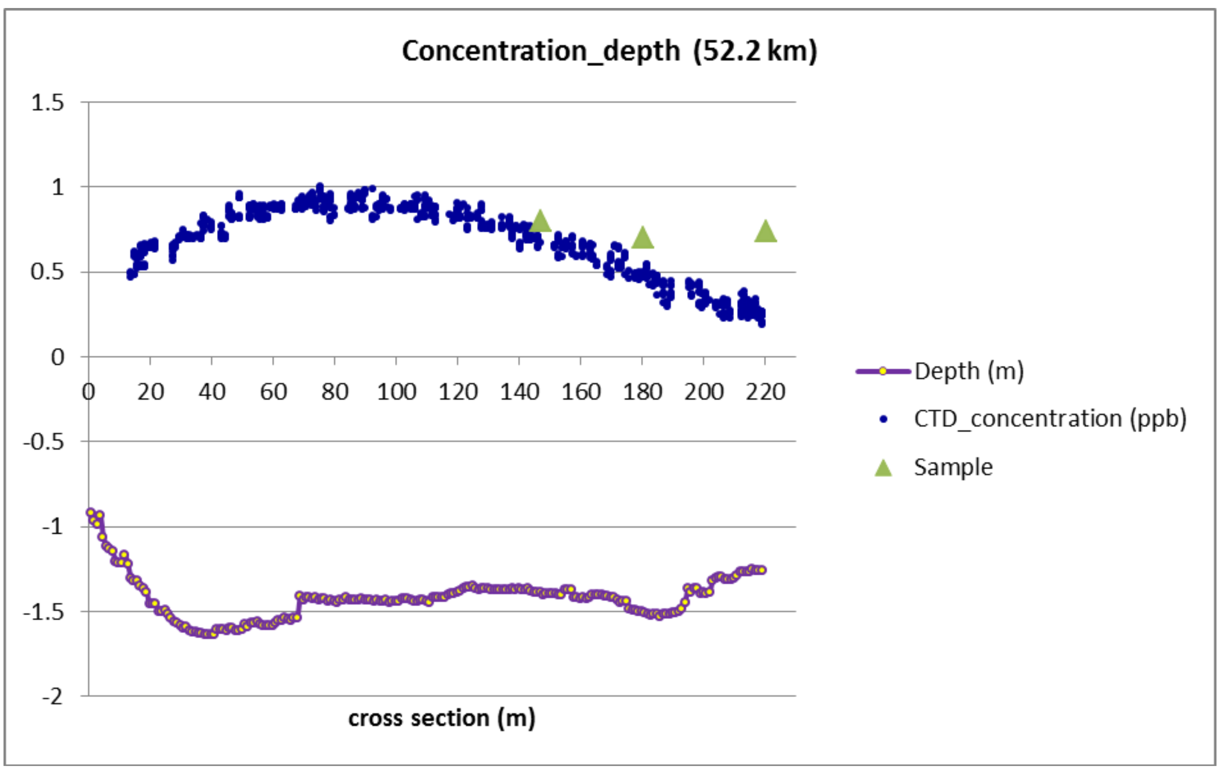
Concentration 52km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.47	0.48	0.48
0.1-0.2	0.53	0.58	0.55
0.2-0.3	0.70	0.74	0.72
0.3-0.4	0.82	0.85	0.84
0.4-0.5	0.86	0.88	0.87
0.5-0.6	0.81	0.84	0.83
0.6-0.7	0.75	0.77	0.76
0.7-0.8	0.61	0.65	0.63
0.8-0.9			
0.9-1			
Approximate width(m)	227.17		
Approximate distance from outfall(km)	52		
Time and date	16:10:21	Oct 27 2011	



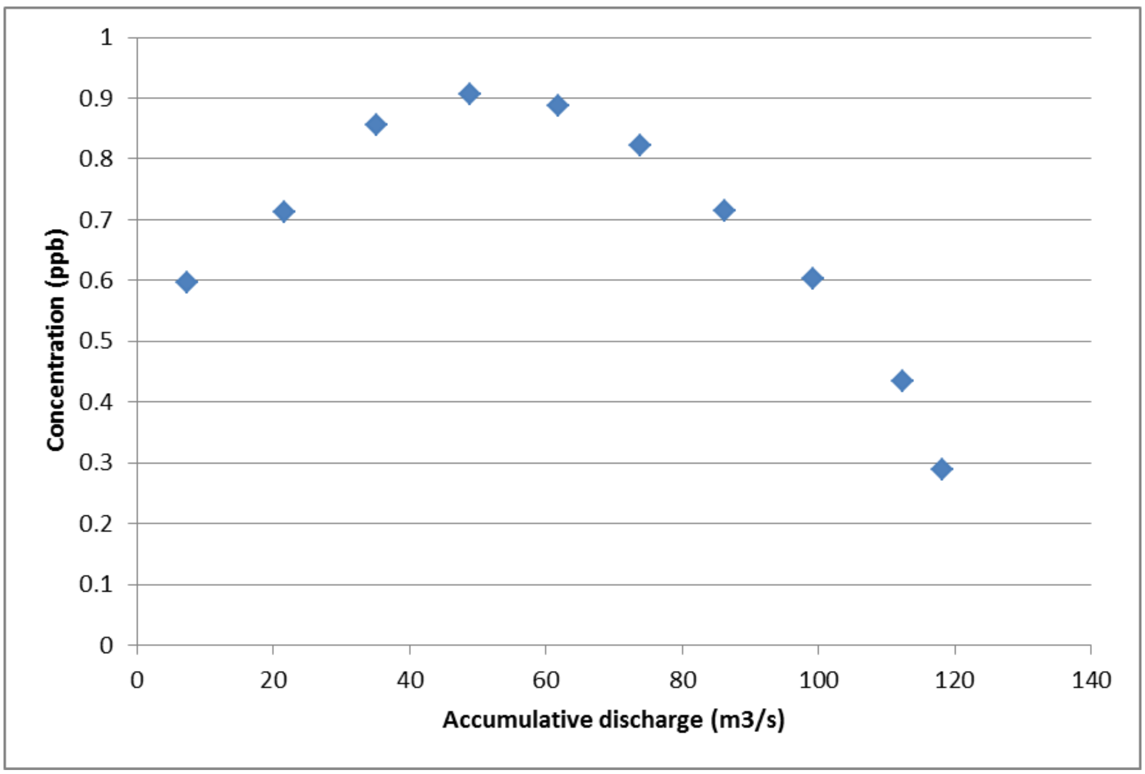


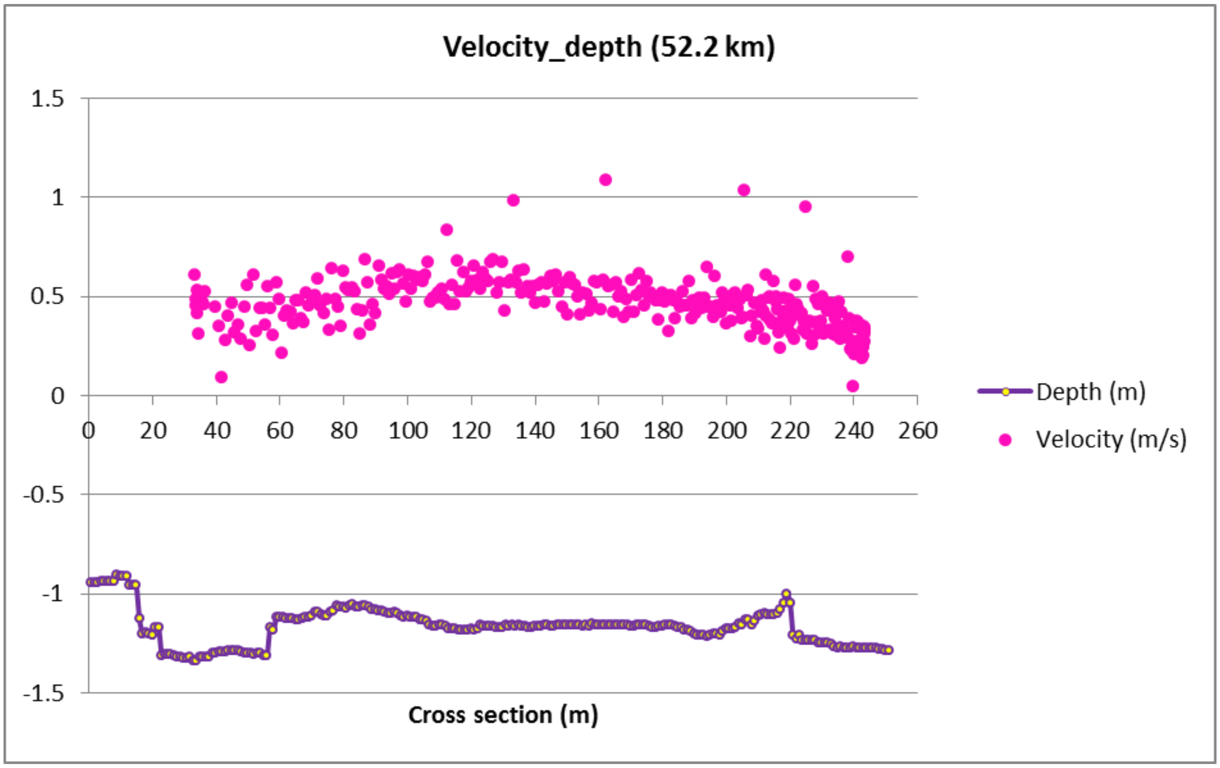
Velocity 52.2km_4



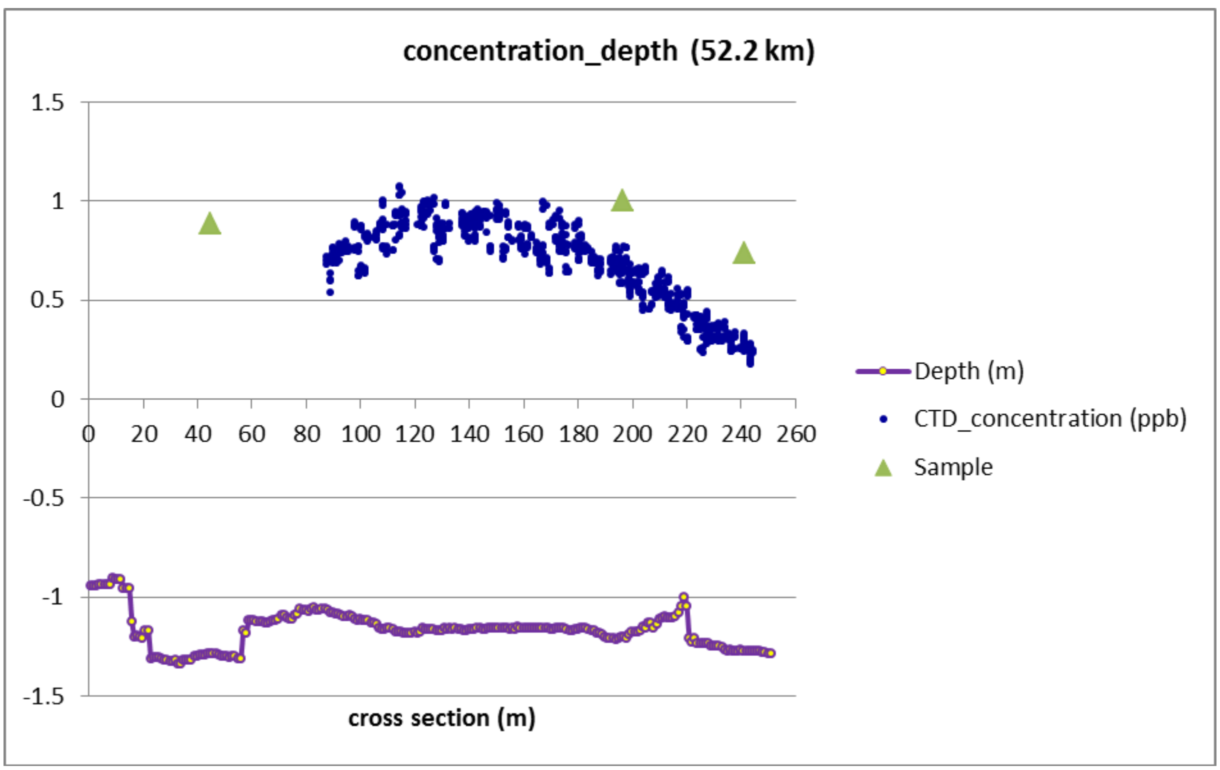
Concentration 52.2km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.58	0.61	0.60
0.1-0.2	0.70	0.72	0.71
0.2-0.3	0.85	0.87	0.86
0.3-0.4	0.90	0.92	0.91
0.4-0.5	0.88	0.90	0.89
0.5-0.6	0.81	0.83	0.82
0.6-0.7	0.70	0.73	0.71
0.7-0.8	0.59	0.61	0.60
0.8-0.9	0.42	0.45	0.43
0.9-1	0.28	0.30	0.29
Approximate width(m)	220.03		
Approximate distance from outfall(km)	52.2		
Time and date	16:10:21	Oct 27 2011	



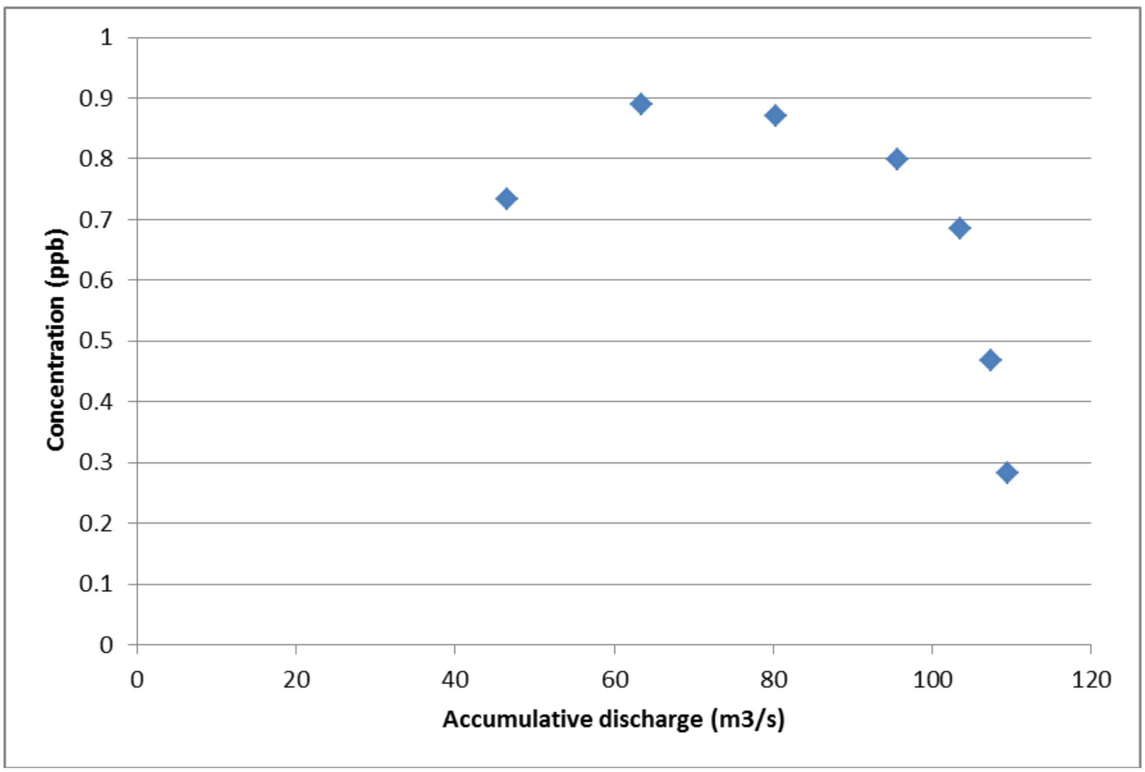


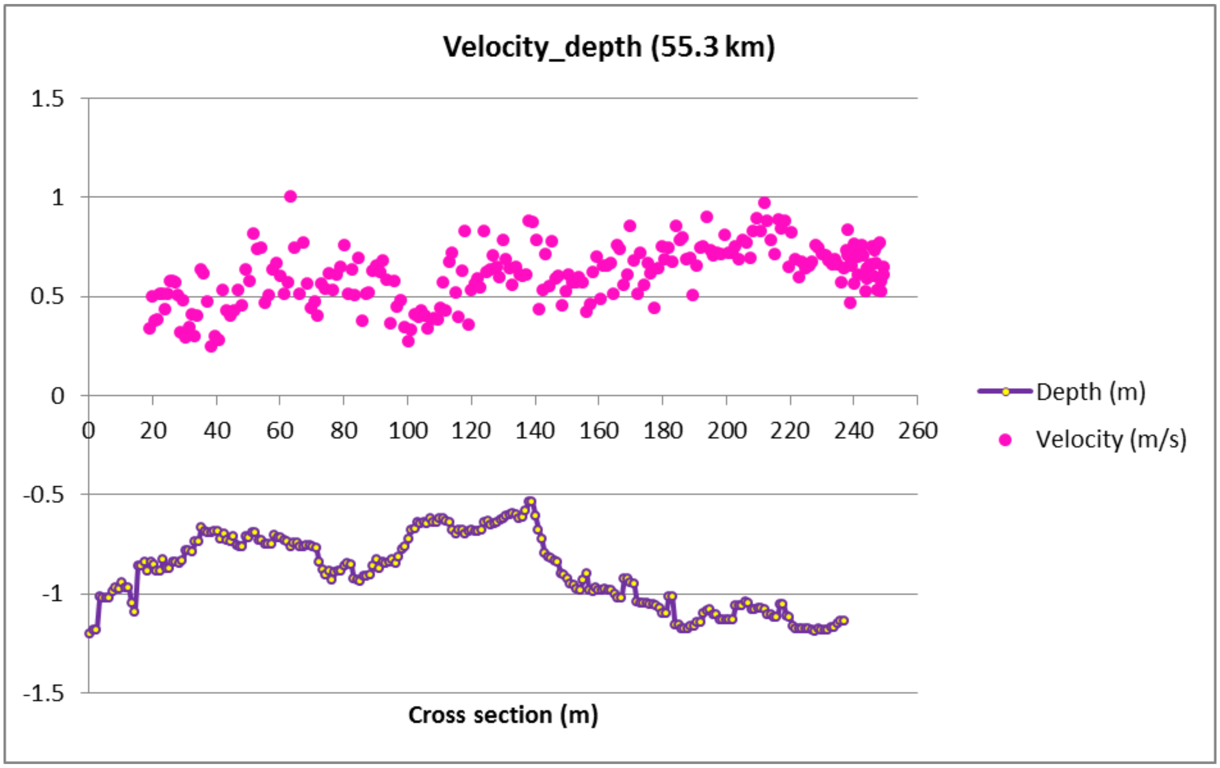
Velocity 52.2km_5



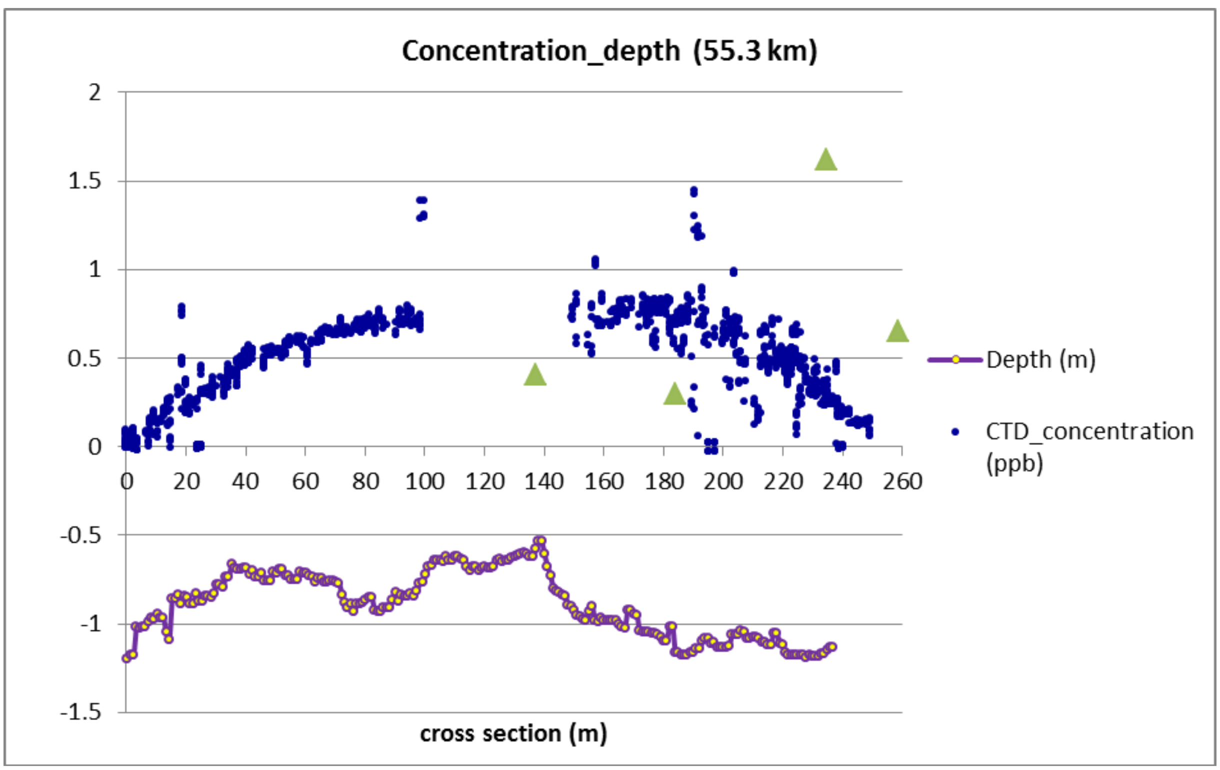
Concentration 52.2km_5

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3			
0.3-0.4	0.72	0.75	0.73
0.4-0.5	0.88	0.90	0.89
0.5-0.6	0.86	0.88	0.87
0.6-0.7	0.78	0.81	0.80
0.7-0.8	0.67	0.70	0.68
0.8-0.9	0.45	0.48	0.47
0.9-1	0.27	0.29	0.28
Approximate width(m)	254.24		
Approximate distance from outfall(km)	52.2		
Time and date	16:10:21	Oct 27 2011	



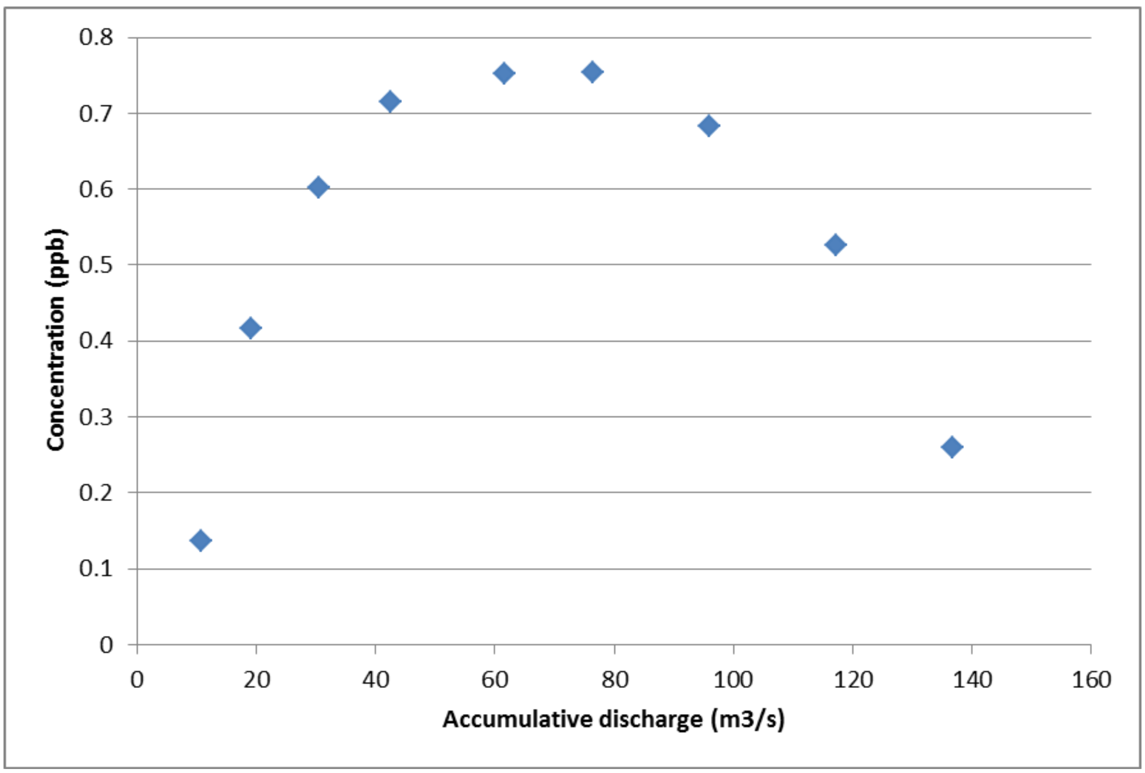


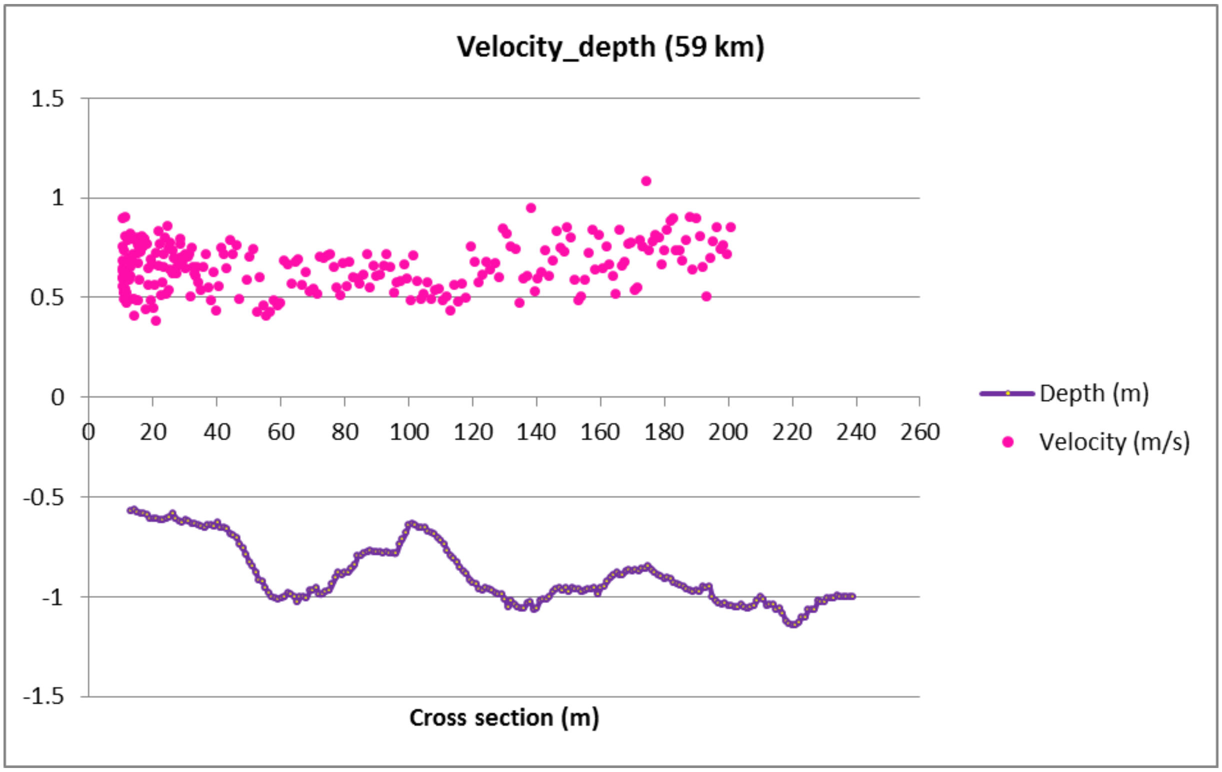
Velocity 55.3km_1



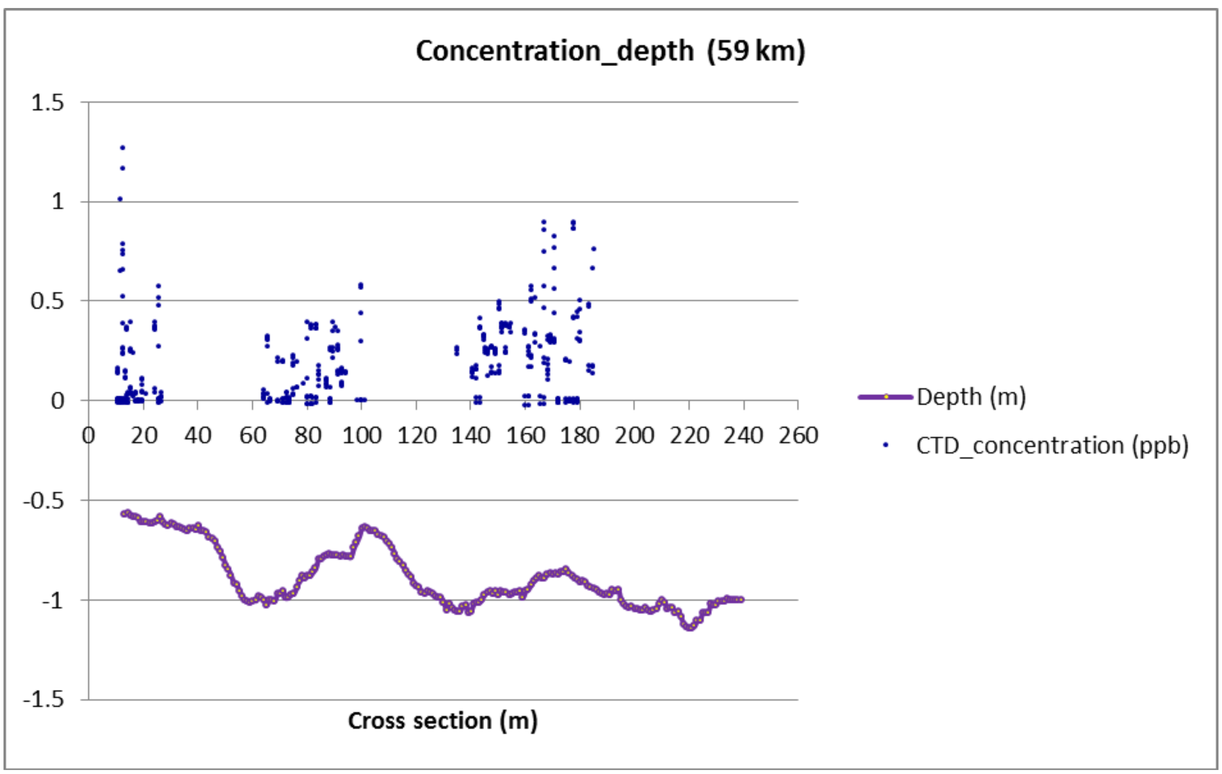
Concentration 55.3km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.11	0.16	0.14
0.1-0.2	0.40	0.43	0.42
0.2-0.3	0.59	0.61	0.60
0.3-0.4	0.70	0.73	0.72
0.4-0.5			
0.5-0.6	0.72	0.79	0.75
0.6-0.7	0.73	0.77	0.75
0.7-0.8	0.65	0.72	0.68
0.8-0.9	0.51	0.55	0.53
0.9-1	0.24	0.28	0.26
Approximate width(m)	249.61		
Approximate distance from outfall(km)	55.3		
Time and date	15:44:56	Oct 27 2011	



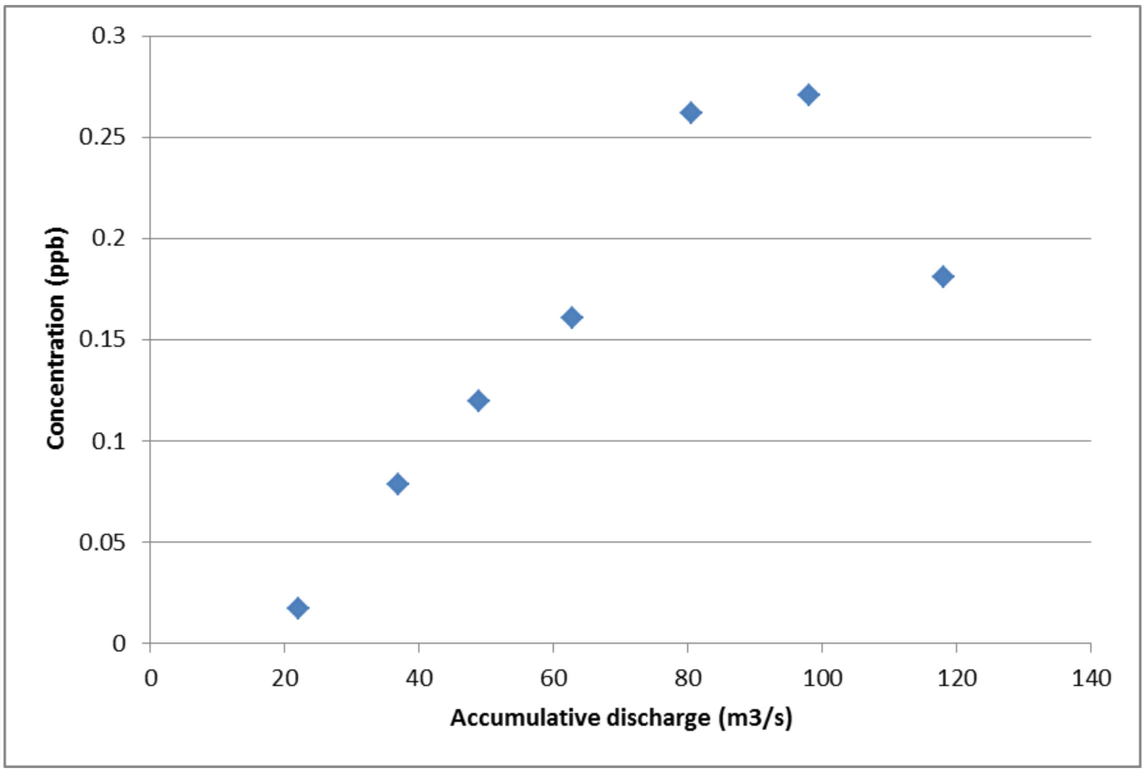


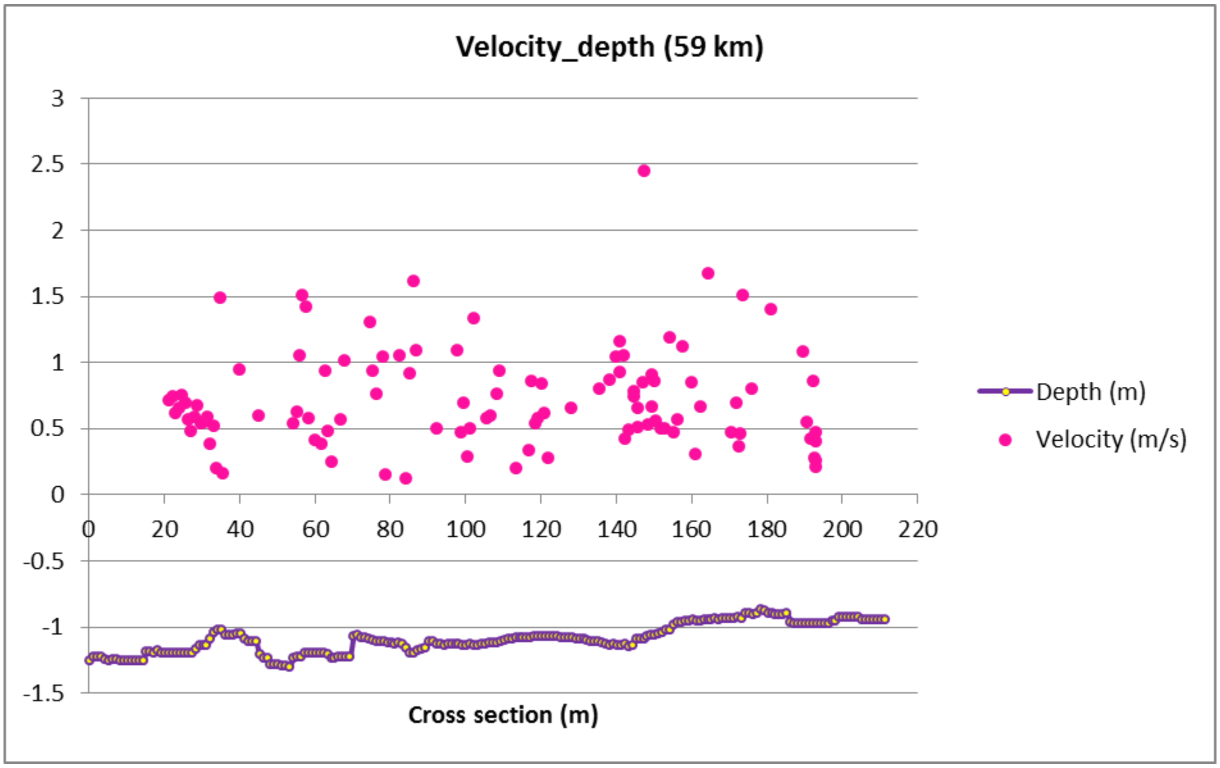
Velocity 59km_1



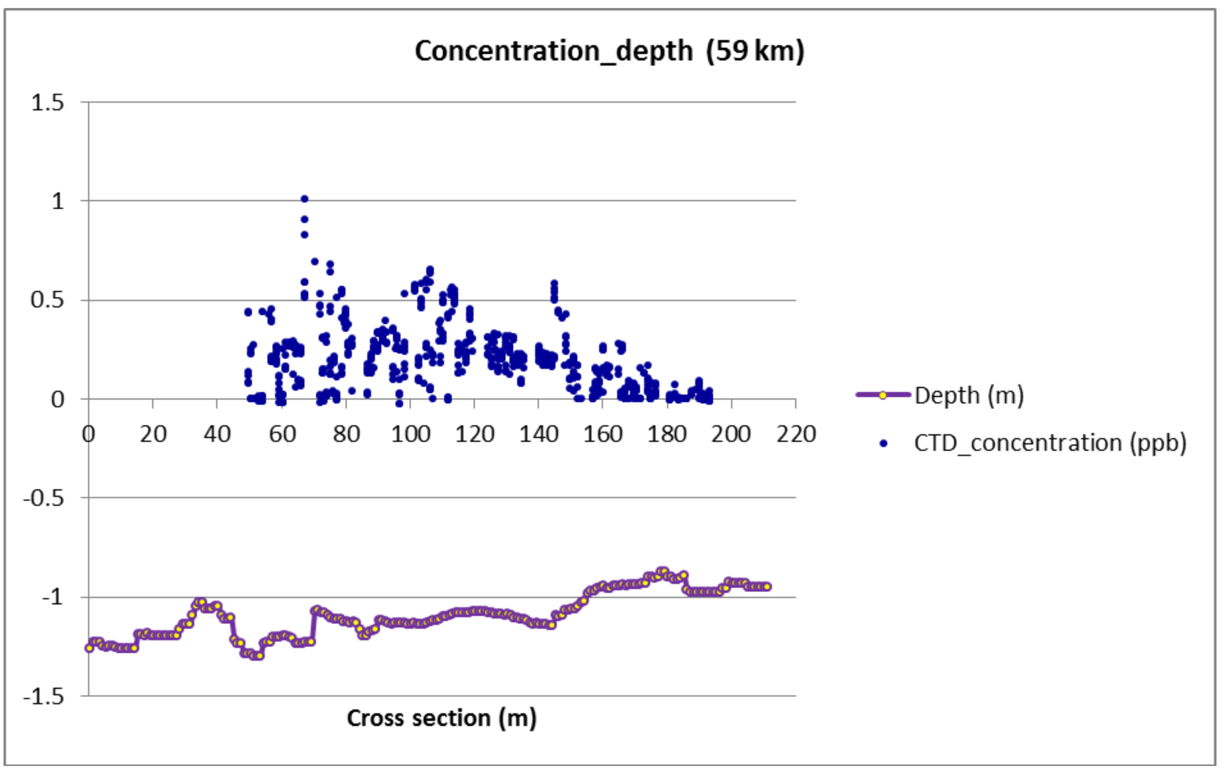
Concentration 59km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.08	0.15	0.11
0.1-0.2	-0.01	0.04	0.02
0.2-0.3	0.05	0.11	0.08
0.3-0.4			
0.4-0.5	0.13	0.20	0.16
0.5-0.6	0.24	0.29	0.26
0.6-0.7	0.22	0.32	0.27
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	264.33		
Approximate distance from outfall(km)	59		
Time and date	15:16:08	Oct 27 2011	



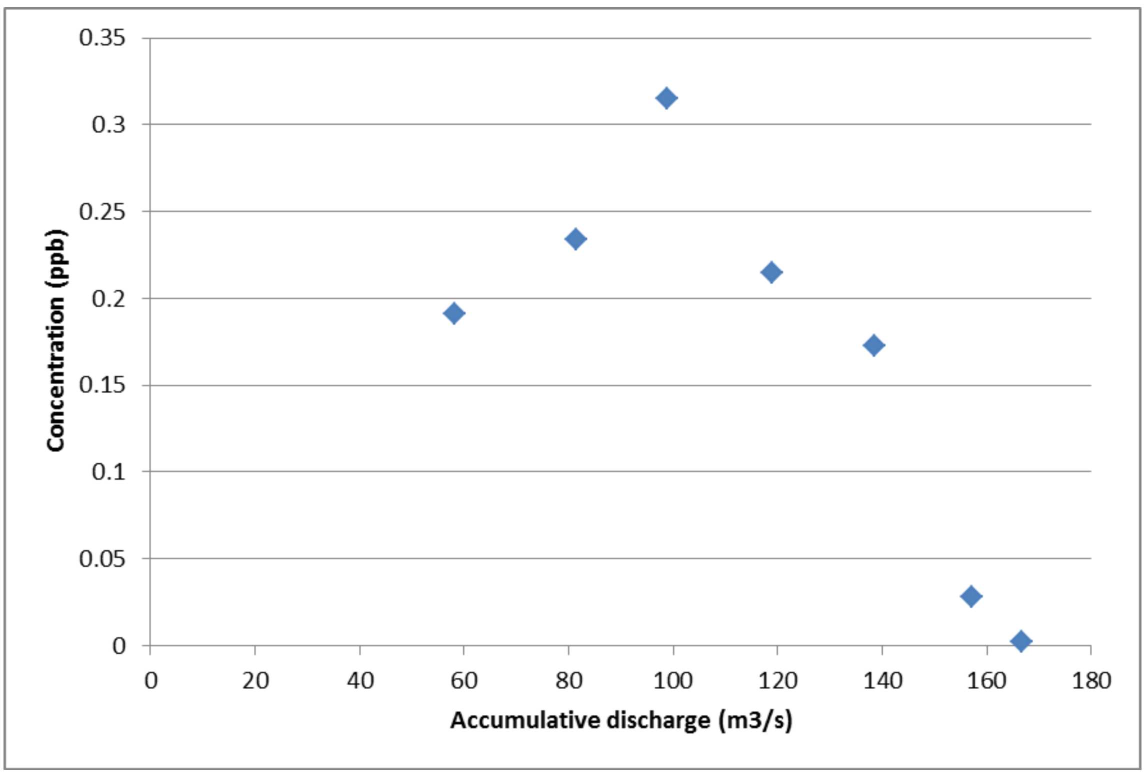


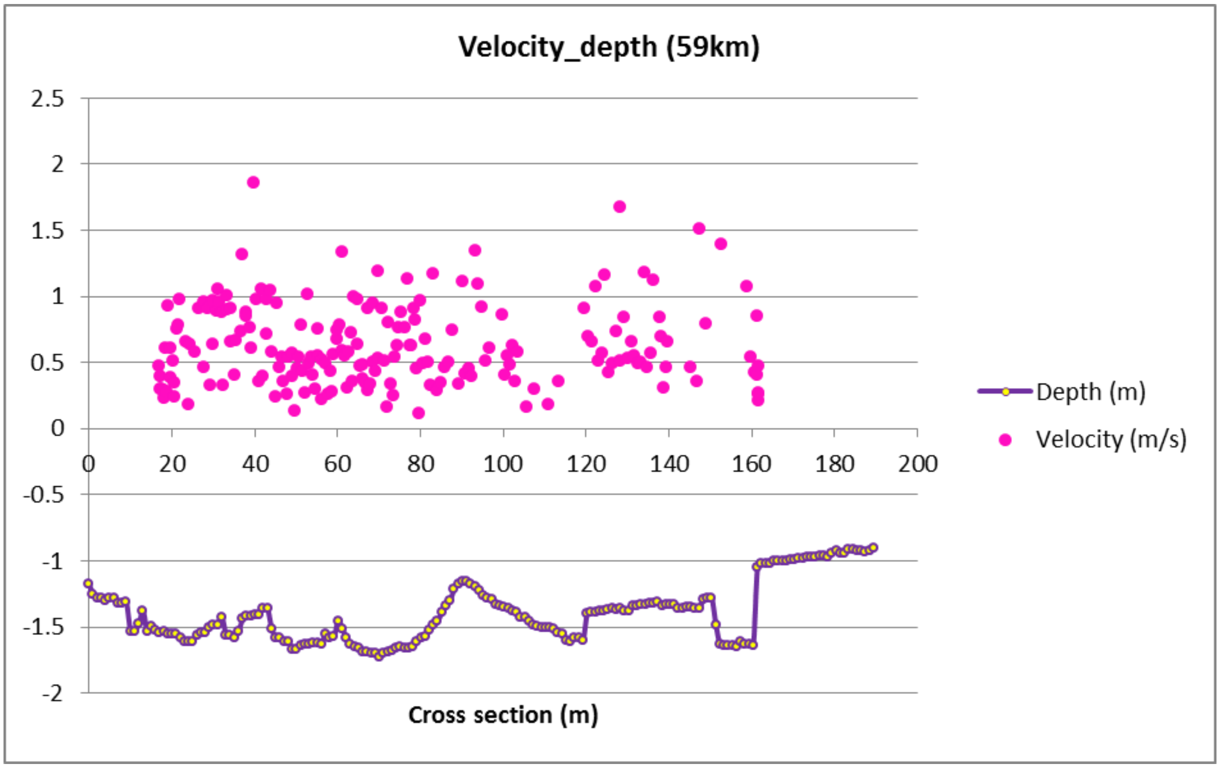
Velocity 59km_2



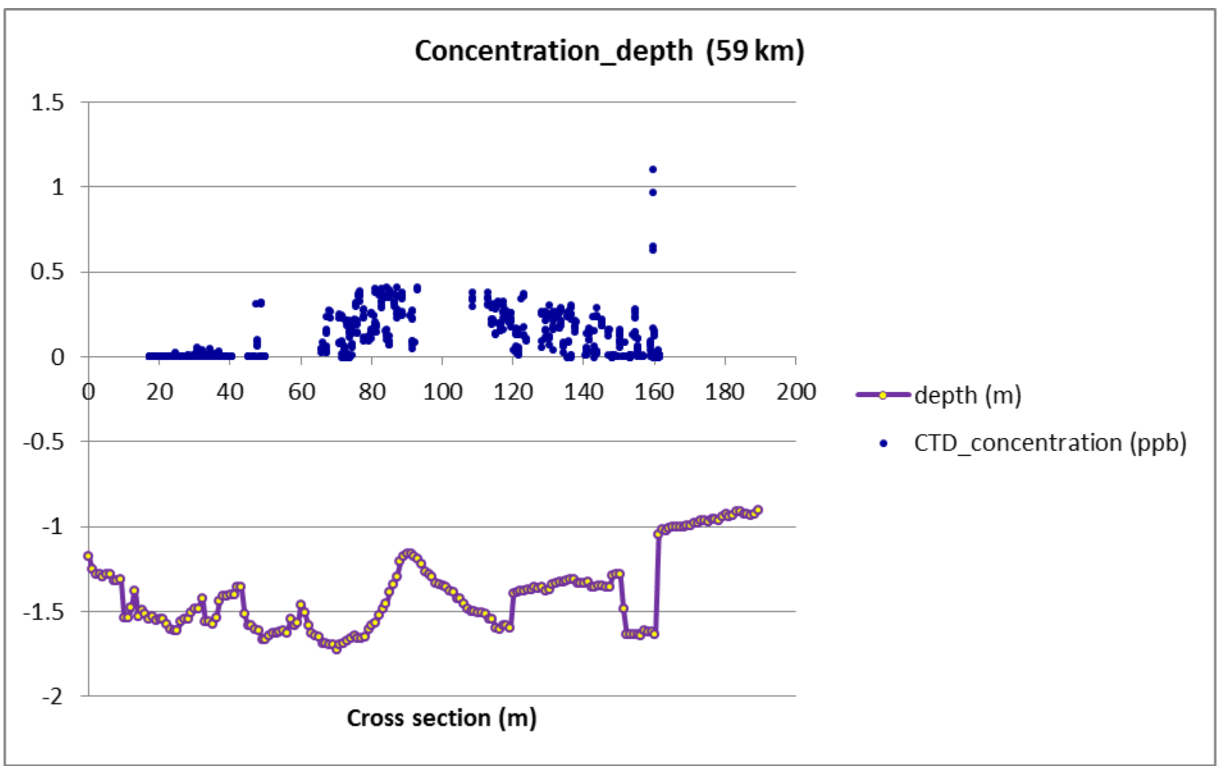
Concentration 59km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	0.15	0.23	0.19
0.3-0.4	0.21	0.26	0.23
0.4-0.5	0.28	0.35	0.31
0.5-0.6	0.20	0.23	0.21
0.6-0.7	0.14	0.20	0.17
0.7-0.8	0.02	0.04	0.03
0.8-0.9	0.00	0.00	0.00
0.9-1			
Approximate width(m)	238.14		
Approximate distance from outfall(km)	59		
Time and date	15:16:08	Oct 27 2011	



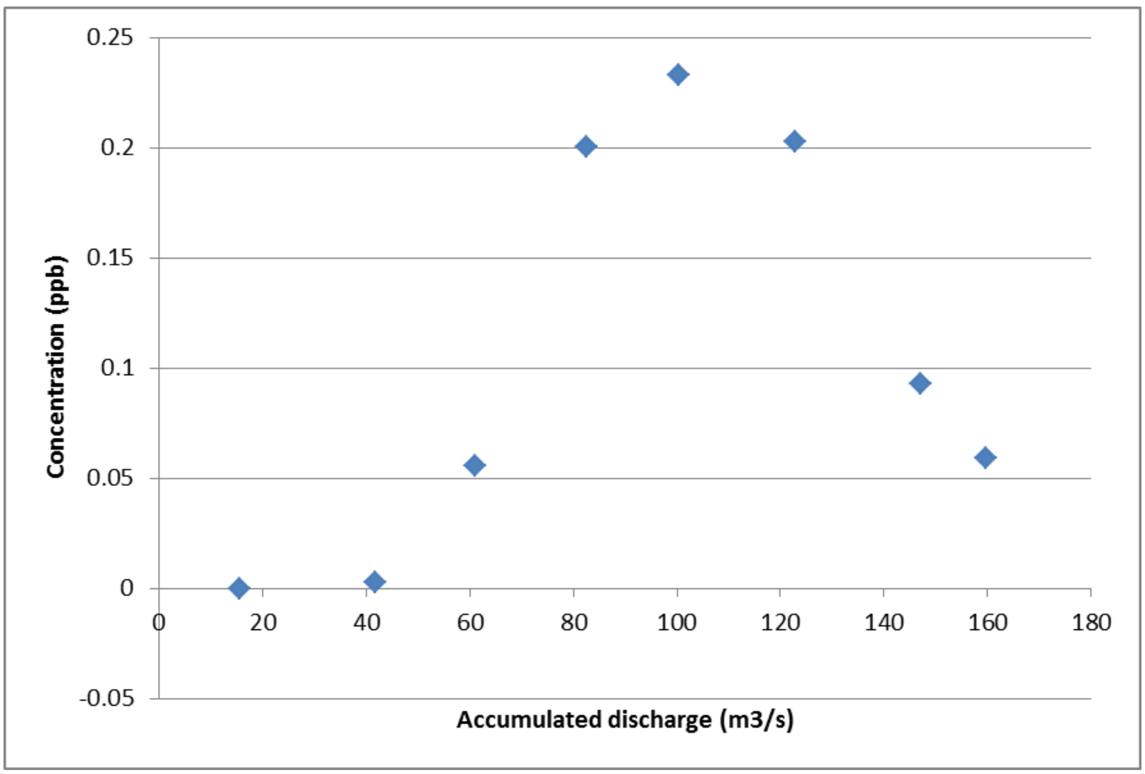


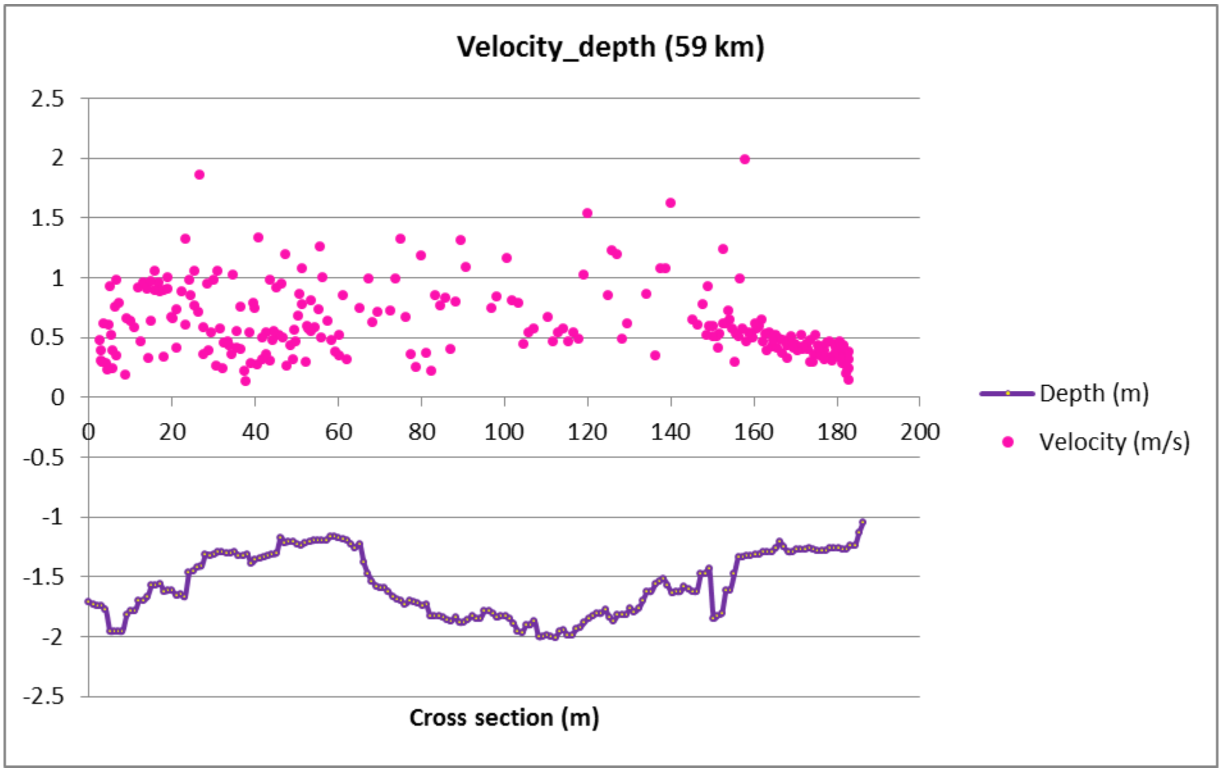
Velocity 59km_3



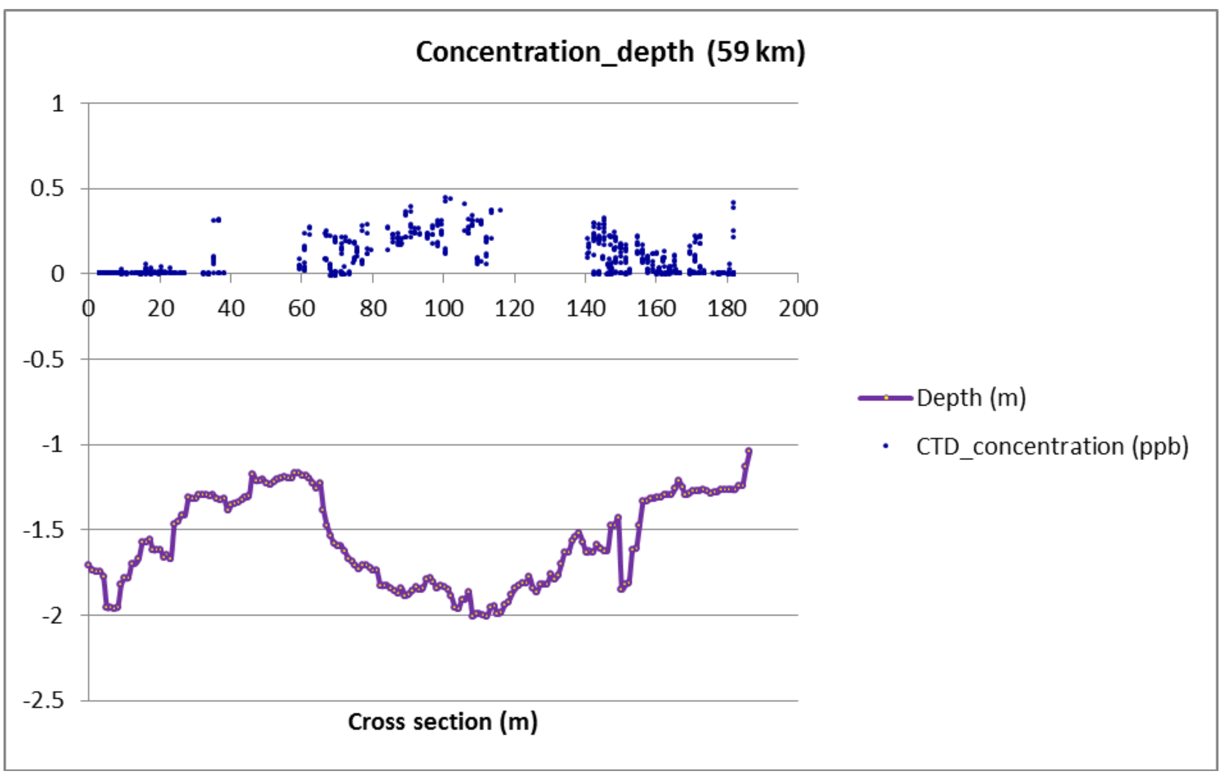
Concentration 59km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.00	0.00	0.00
0.1-0.2	0.00	0.00	0.00
0.2-0.3	0.02	0.09	0.06
0.3-0.4	0.18	0.22	0.20
0.4-0.5	0.17	0.30	0.23
0.5-0.6	0.19	0.22	0.20
0.6-0.7	0.08	0.11	0.09
0.7-0.8	0.01	0.10	0.06
0.8-0.9			
0.9-1			
Approximate width(m)	223.28		
Approximate distance from outfall(km)	59		
Time and date	15:16:08	Oct 27 2011	



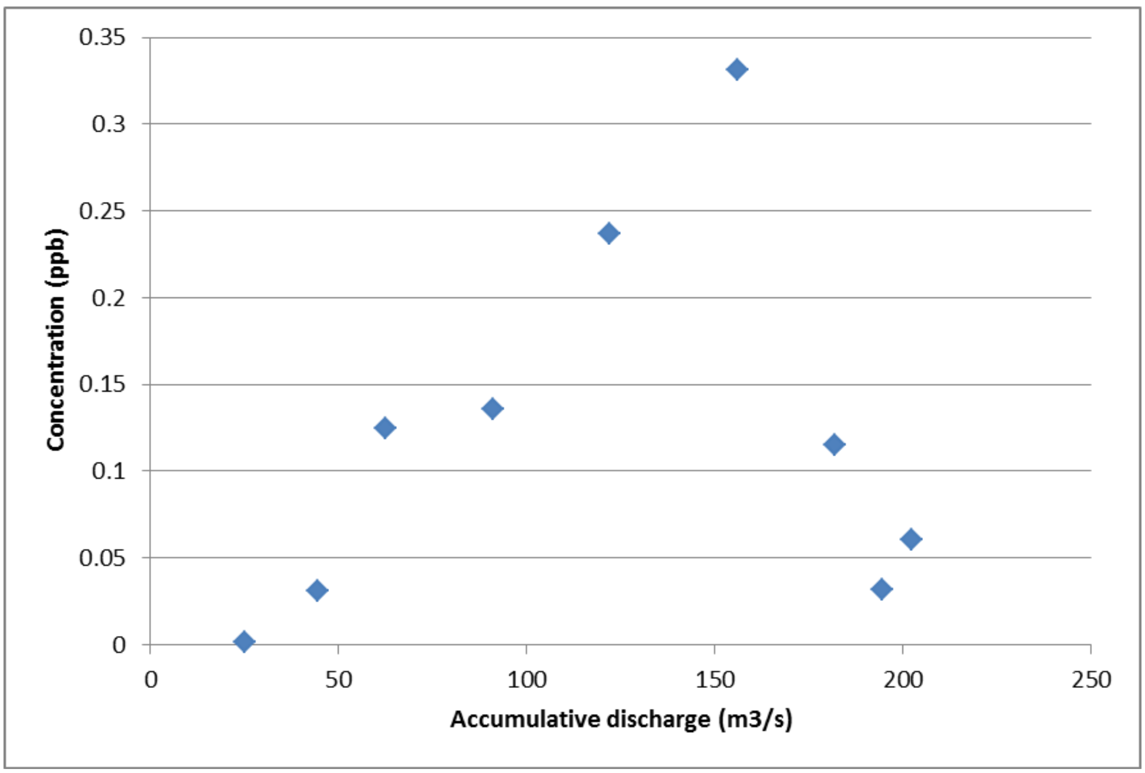


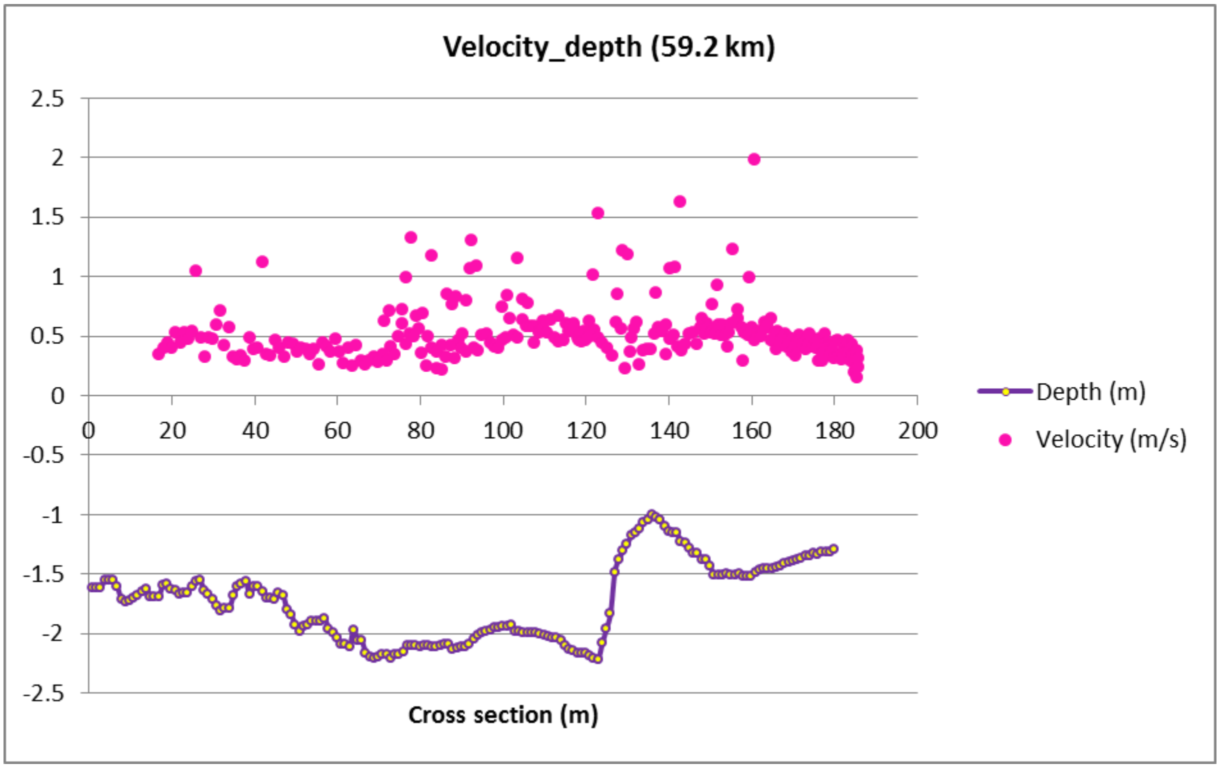
Velocity 59km_4



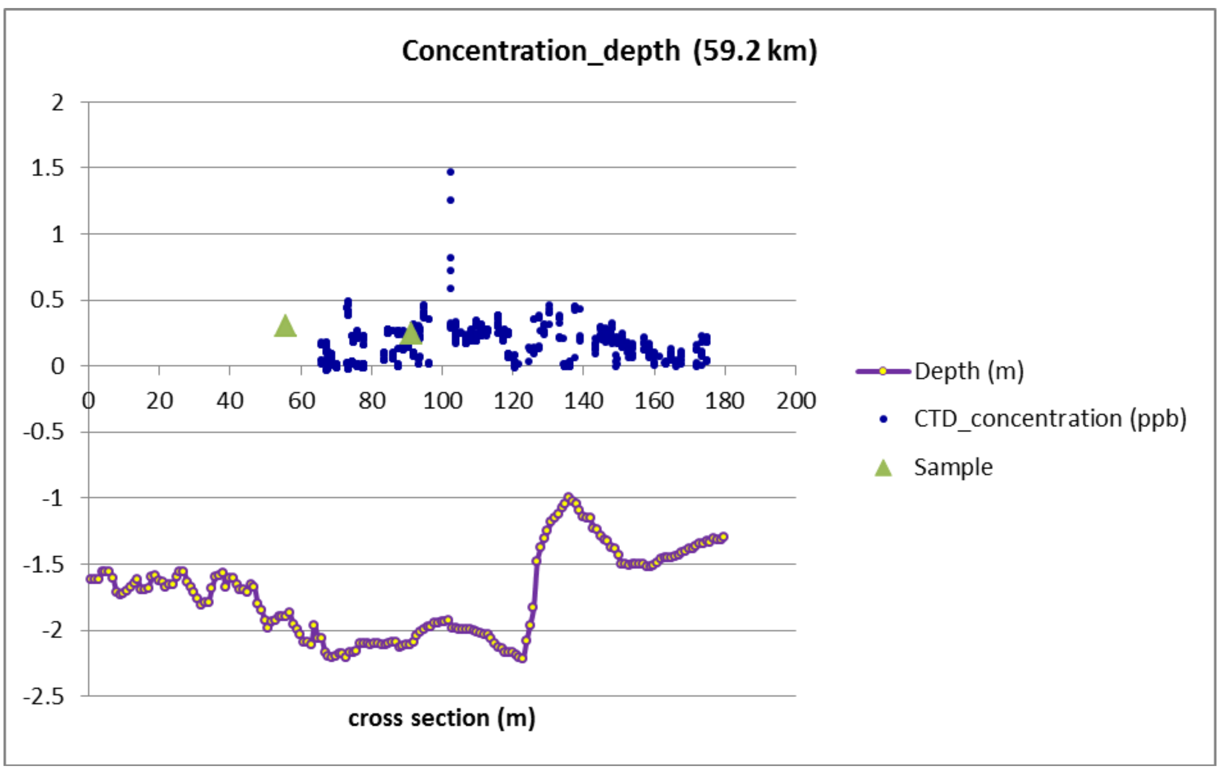
Concentration 59km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.00	0.00	0.00
0.1-0.2	0.01	0.05	0.03
0.2-0.3	0.09	0.16	0.12
0.3-0.4	0.12	0.16	0.14
0.4-0.5	0.22	0.26	0.24
0.5-0.6	0.25	0.41	0.33
0.6-0.7	0.10	0.13	0.12
0.7-0.8	0.02	0.04	0.03
0.8-0.9	0.00	0.12	0.06
0.9-1			
Approximate width(m)	227.00		
Approximate distance from outfall(km)	59		
Time and date	15:16:08	Oct 27 2011	



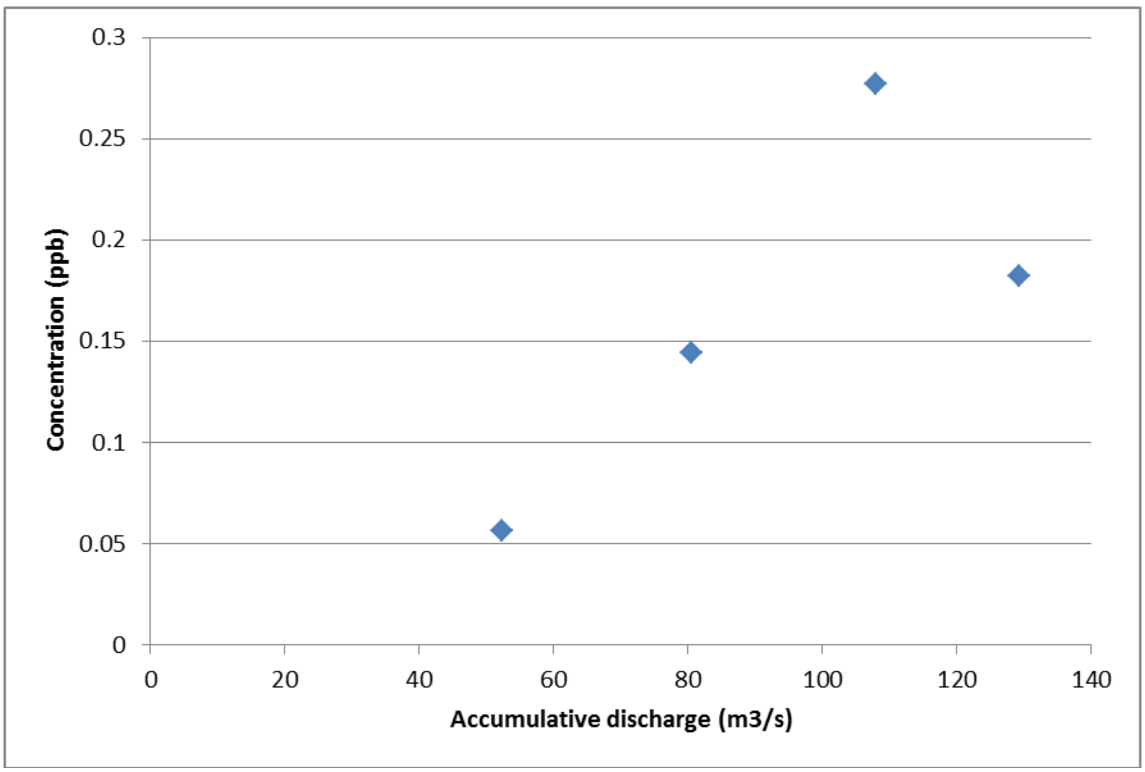


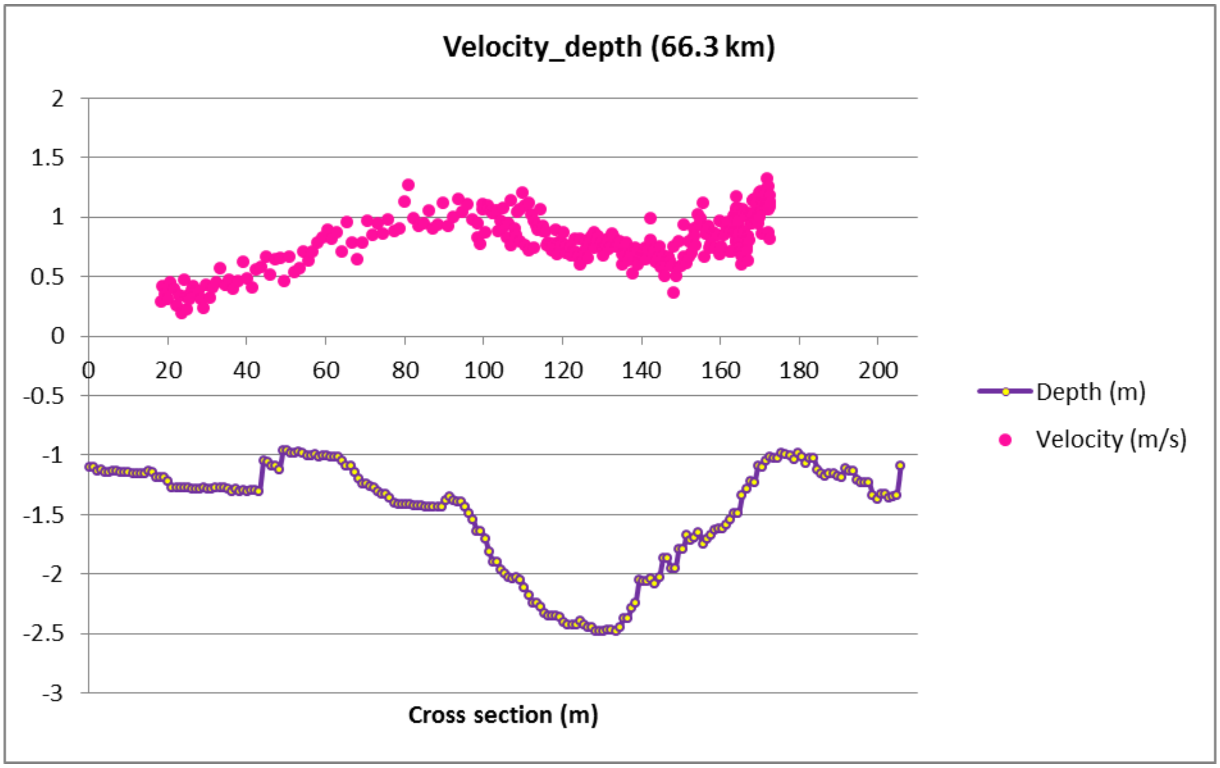
Velocity 59.2km_5



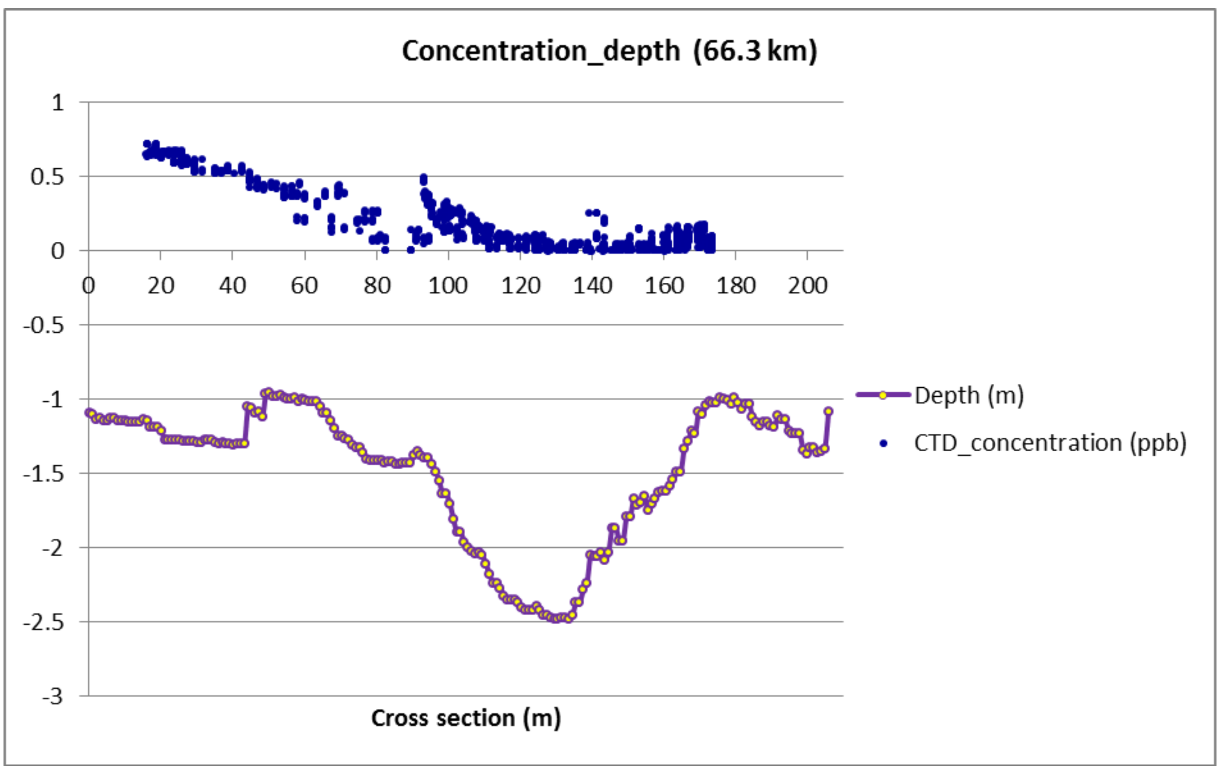
Concentration 59.2km_5

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	0.04	0.07	0.06
0.3-0.4	0.13	0.16	0.14
0.4-0.5	0.25	0.30	0.28
0.5-0.6	0.16	0.21	0.18
0.6-0.7	0.14	0.17	0.15
0.7-0.8	0.06	0.09	0.07
0.8-0.9			
0.9-1			
Approximate width(m)	232.98		
Approximate distance from outfall(km)	59.2		
Time and date	15:16:08	Oct 27 2011	



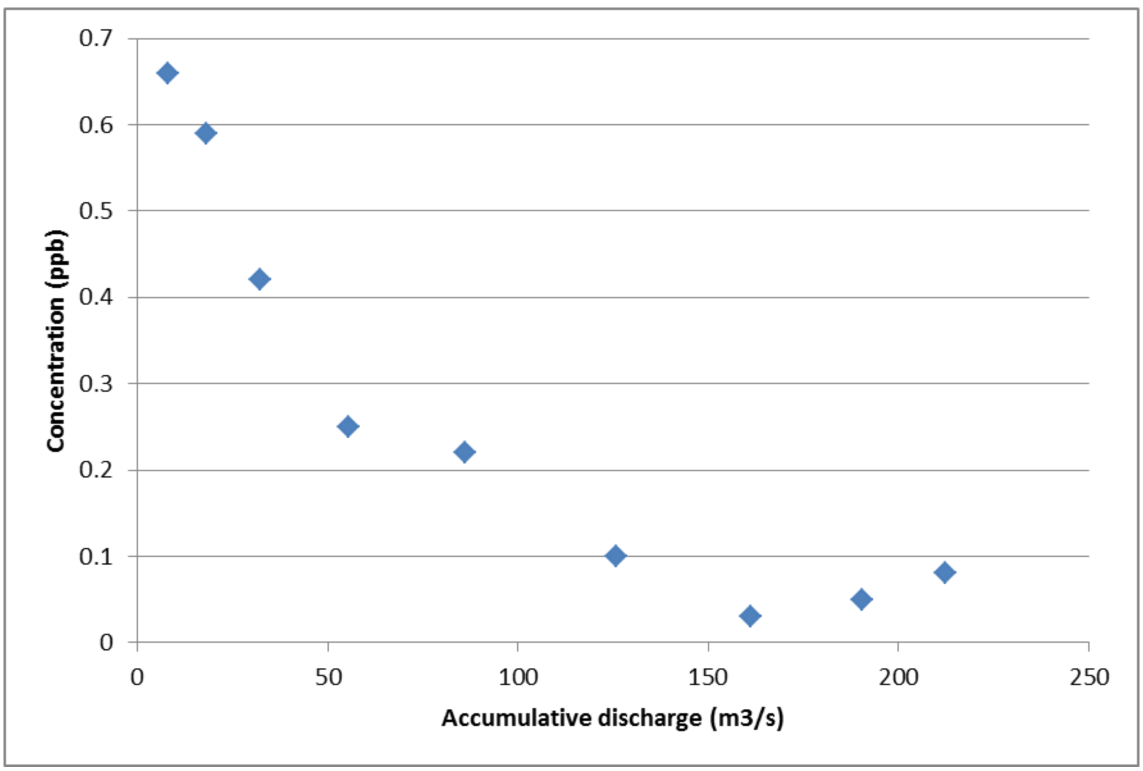


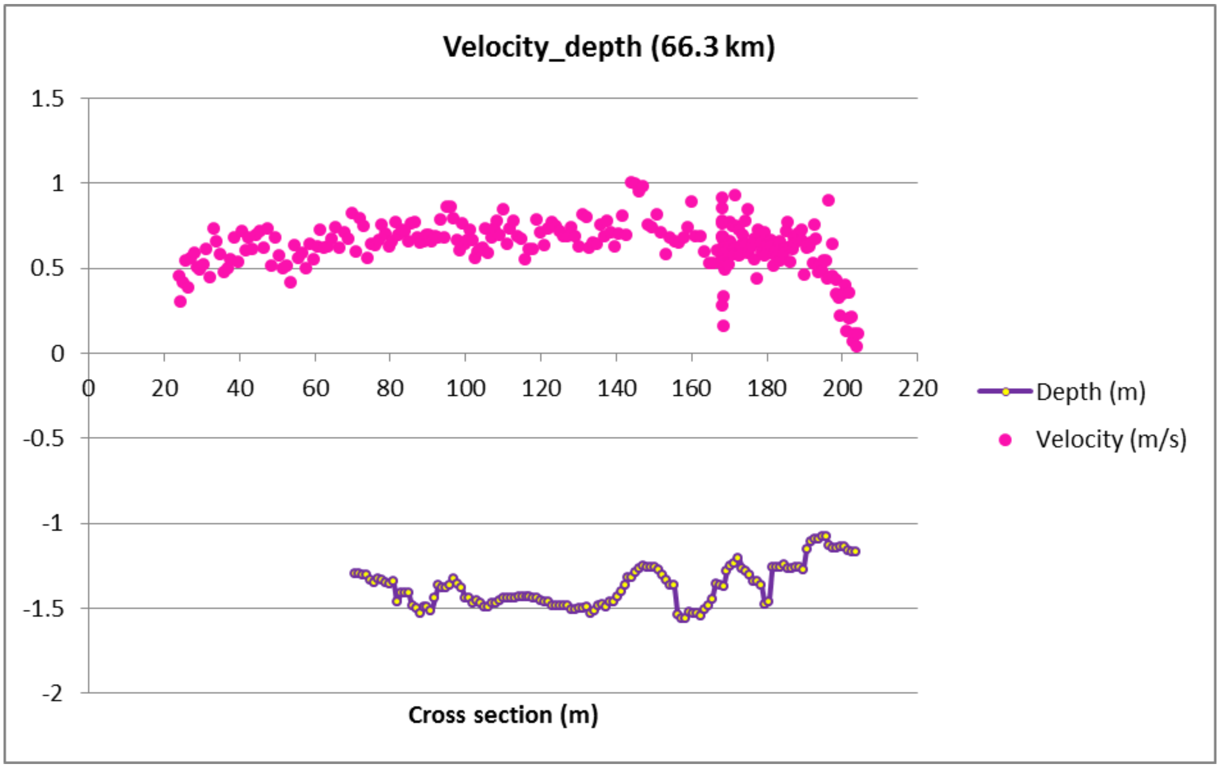
Velocity 66.3km_1



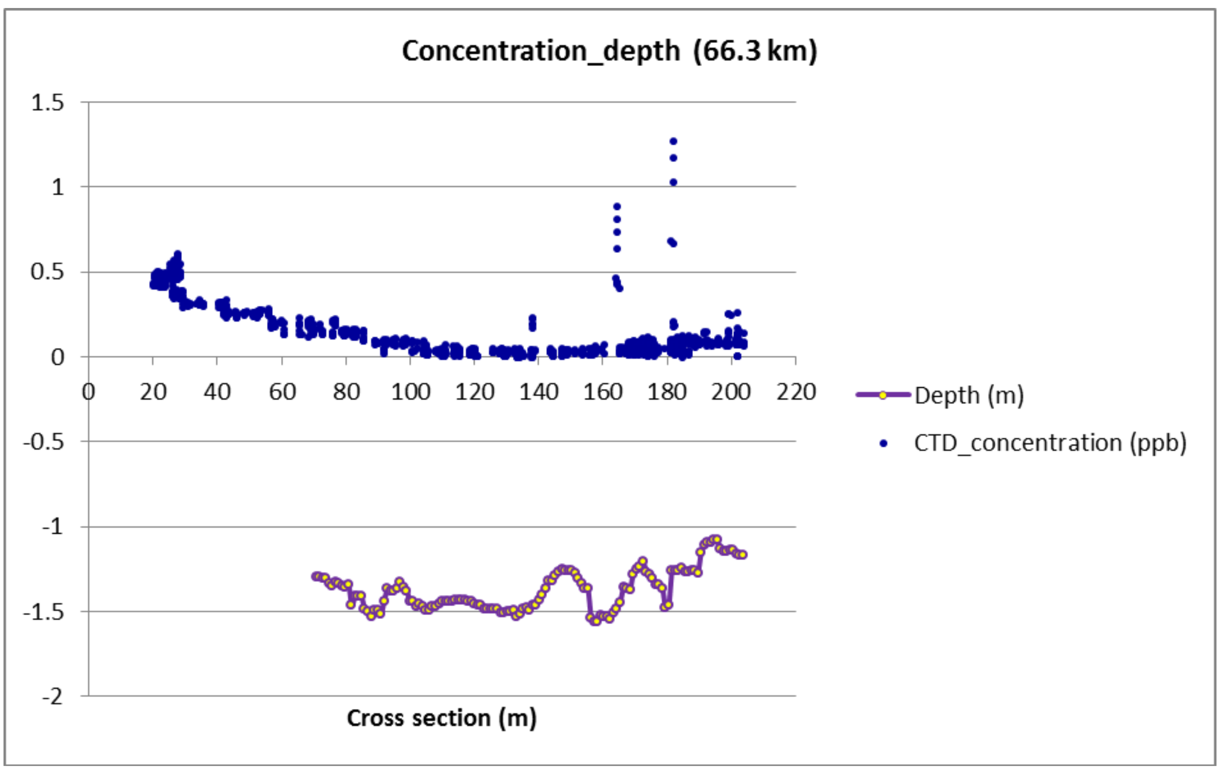
Concentration 66.3km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.66	0.67	0.66
0.1-0.2	0.58	0.60	0.59
0.2-0.3	0.40	0.43	0.42
0.3-0.4	0.22	0.28	0.25
0.4-0.5	0.20	0.24	0.22
0.5-0.6	0.09	0.11	0.10
0.6-0.7	0.03	0.04	0.03
0.7-0.8	0.04	0.05	0.05
0.8-0.9	0.08	0.09	0.08
0.9-1			
Approximate width(m)	205.94		
Approximate distance from outfall(km)	66.3		
Time and date	14:17:35	Oct 28 2011	



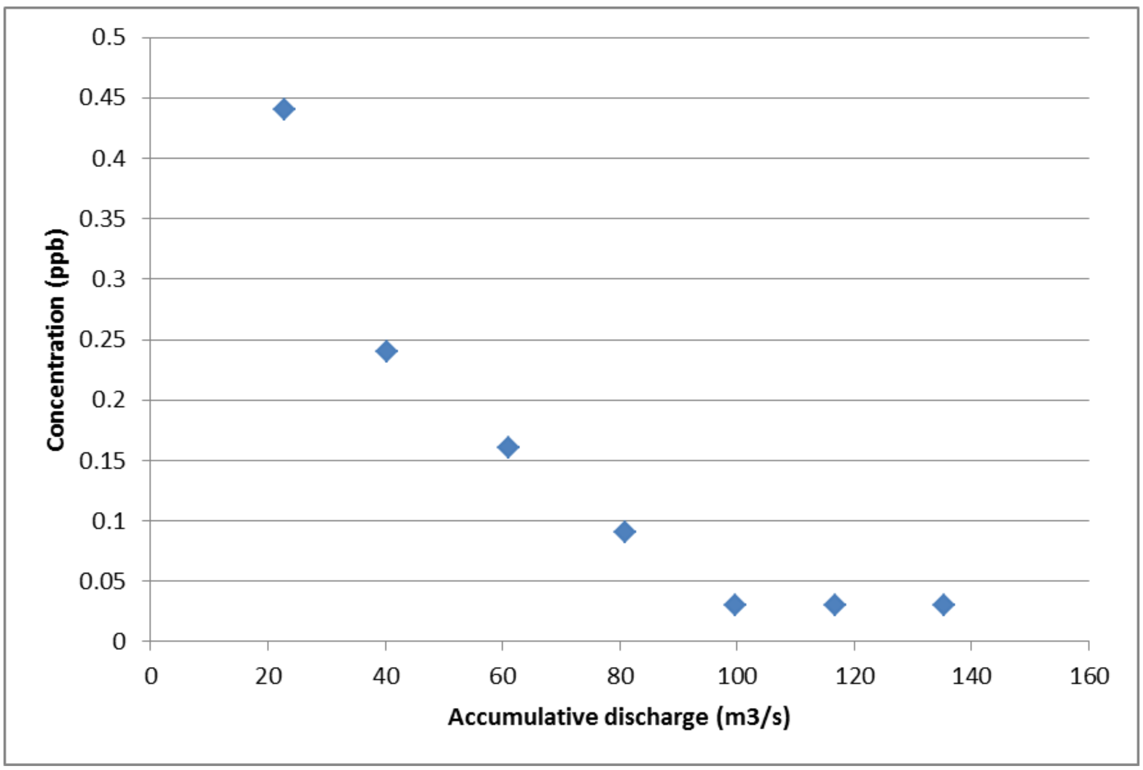


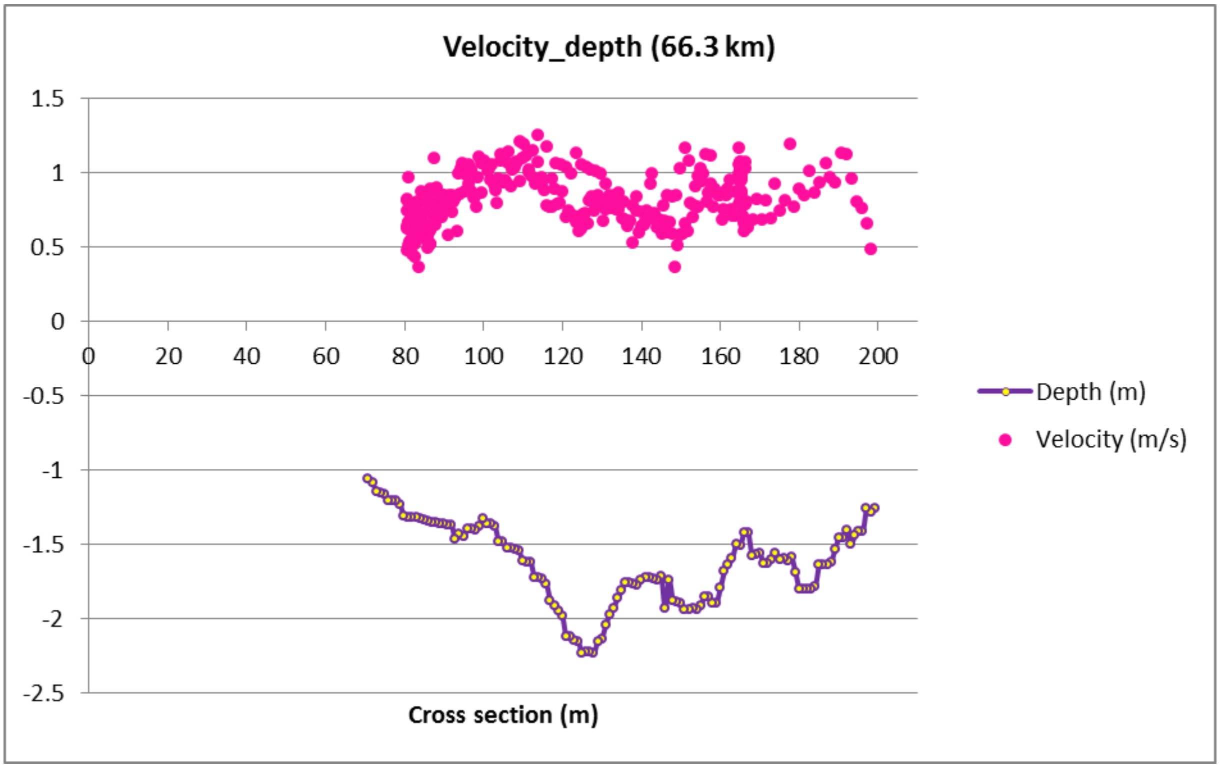
Velocity 66.3km_2



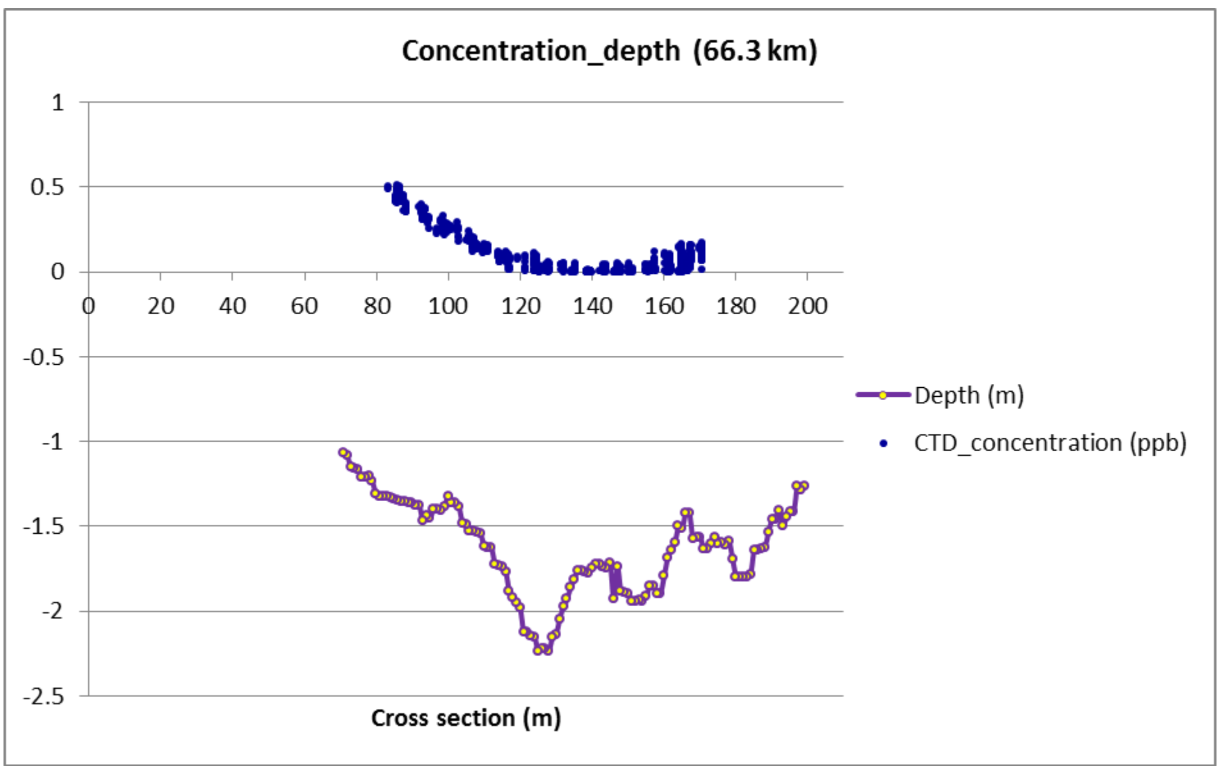
Concentration 66.3km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.41	0.43	0.42
0.1-0.2	0.43	0.45	0.44
0.2-0.3	0.23	0.25	0.24
0.3-0.4	0.15	0.17	0.16
0.4-0.5	0.09	0.10	0.09
0.5-0.6	0.02	0.03	0.03
0.6-0.7	0.02	0.04	0.03
0.7-0.8	0.02	0.03	0.03
0.8-0.9	0.07	0.12	0.09
0.9-1	0.08	0.09	0.08
Approximate width(m)	204.18		
Approximate distance from outfall(km)	66.3		
Time and date	14:17:35	Oct 28 2011	



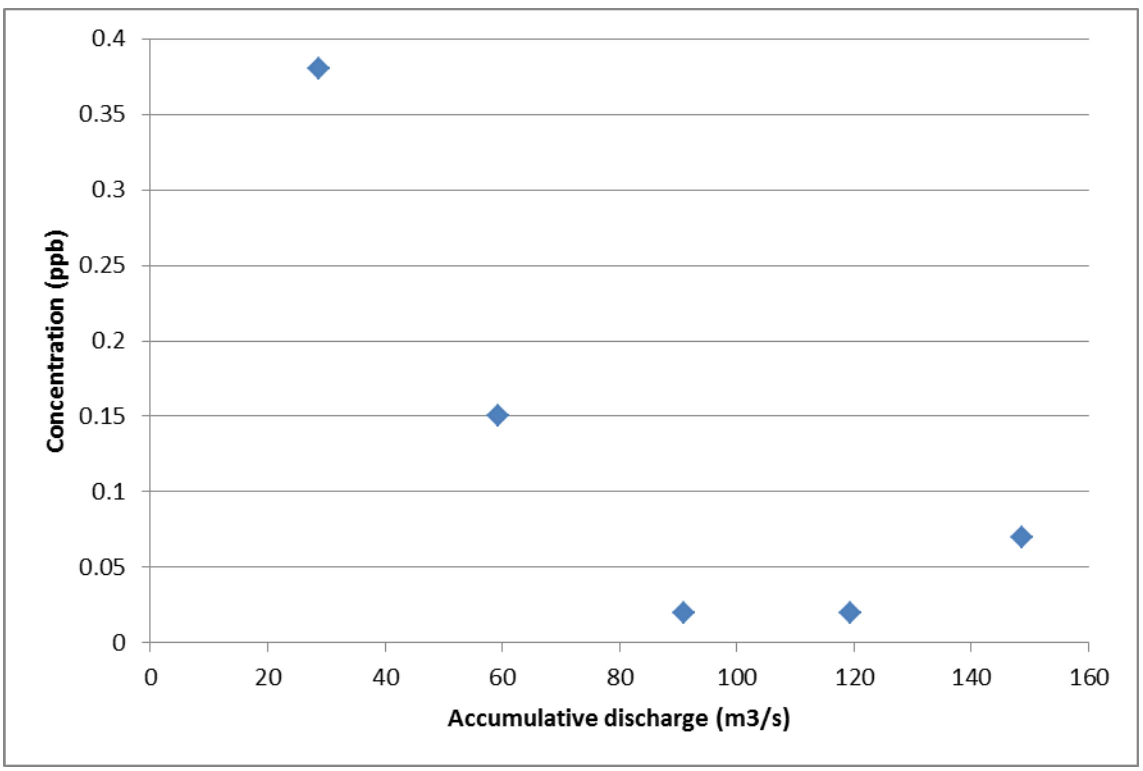


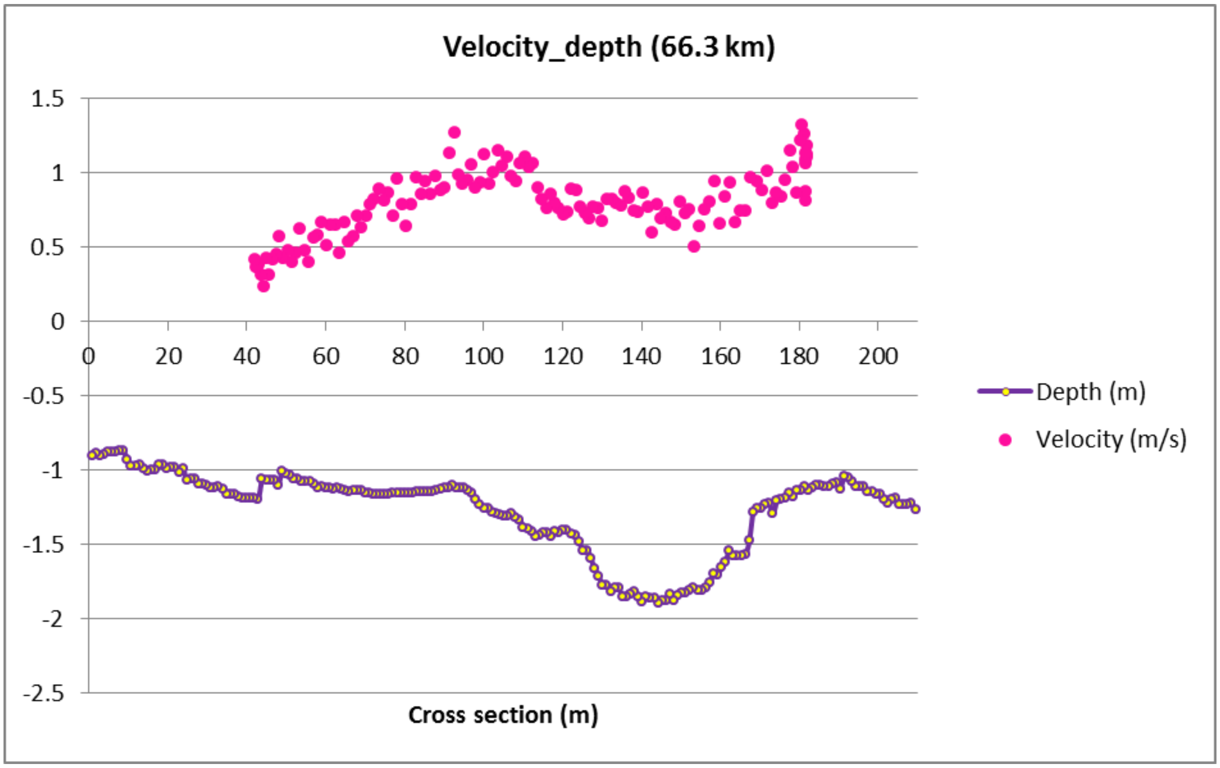
Velocity 66.3km_3



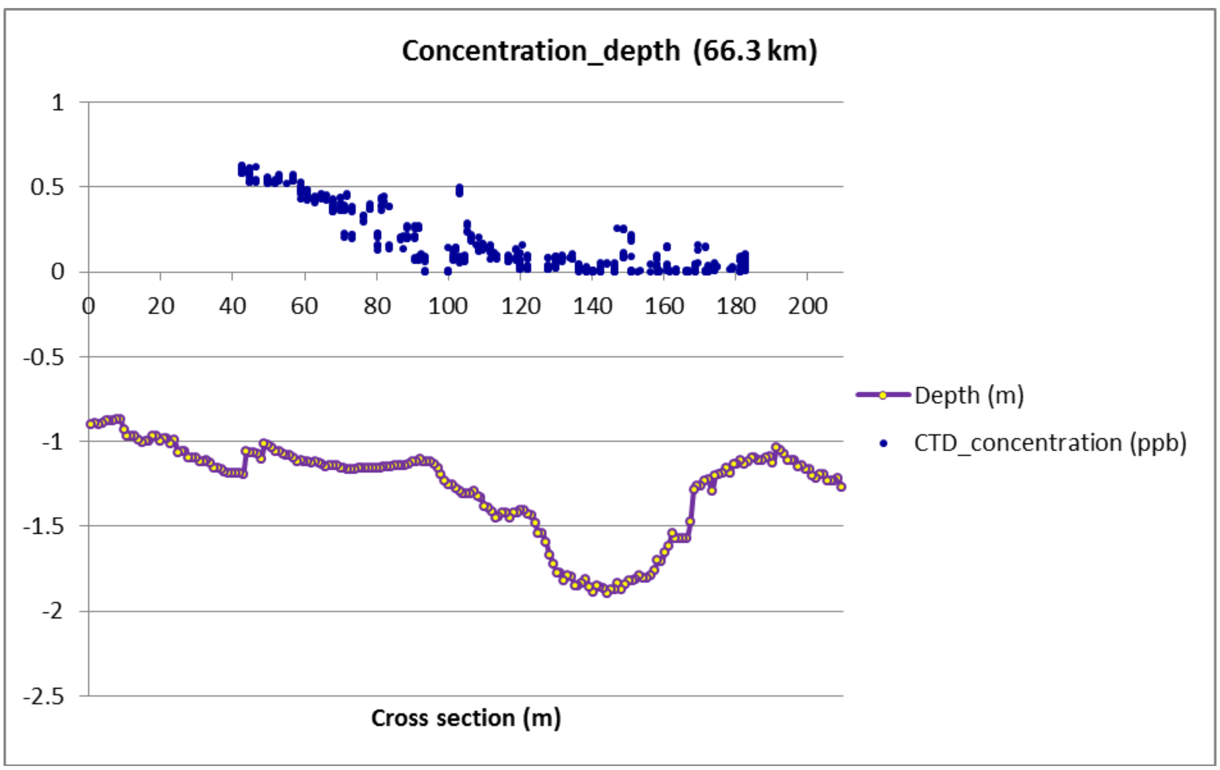
Concentration 66.3km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3			
0.3-0.4			
0.4-0.5	0.36	0.39	0.38
0.5-0.6	0.13	0.16	0.15
0.6-0.7	0.02	0.03	0.02
0.7-0.8	0.01	0.02	0.02
0.8-0.9	0.07	0.08	0.07
0.9-1			
Approximate width(m)	199.26		
Approximate distance from outfall(km)	66.3		
Time and date	14:17:35	Oct 28 2011	



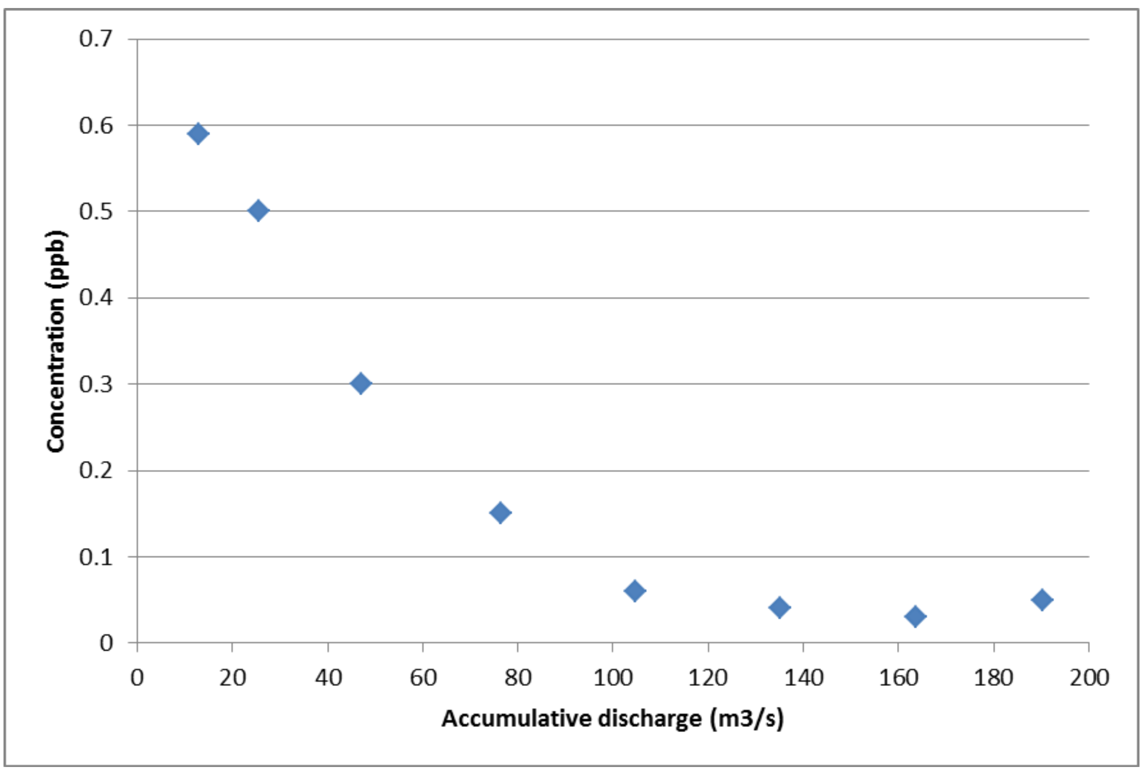


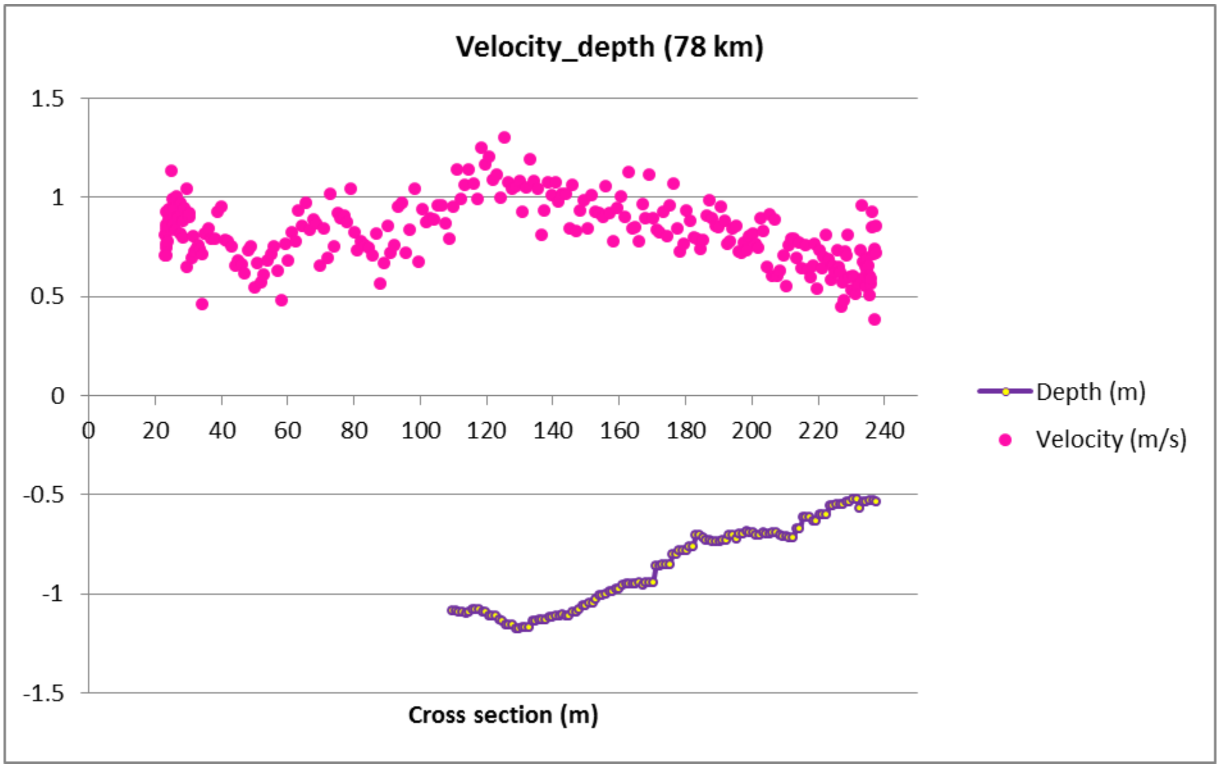
Velocity 66.3km_4



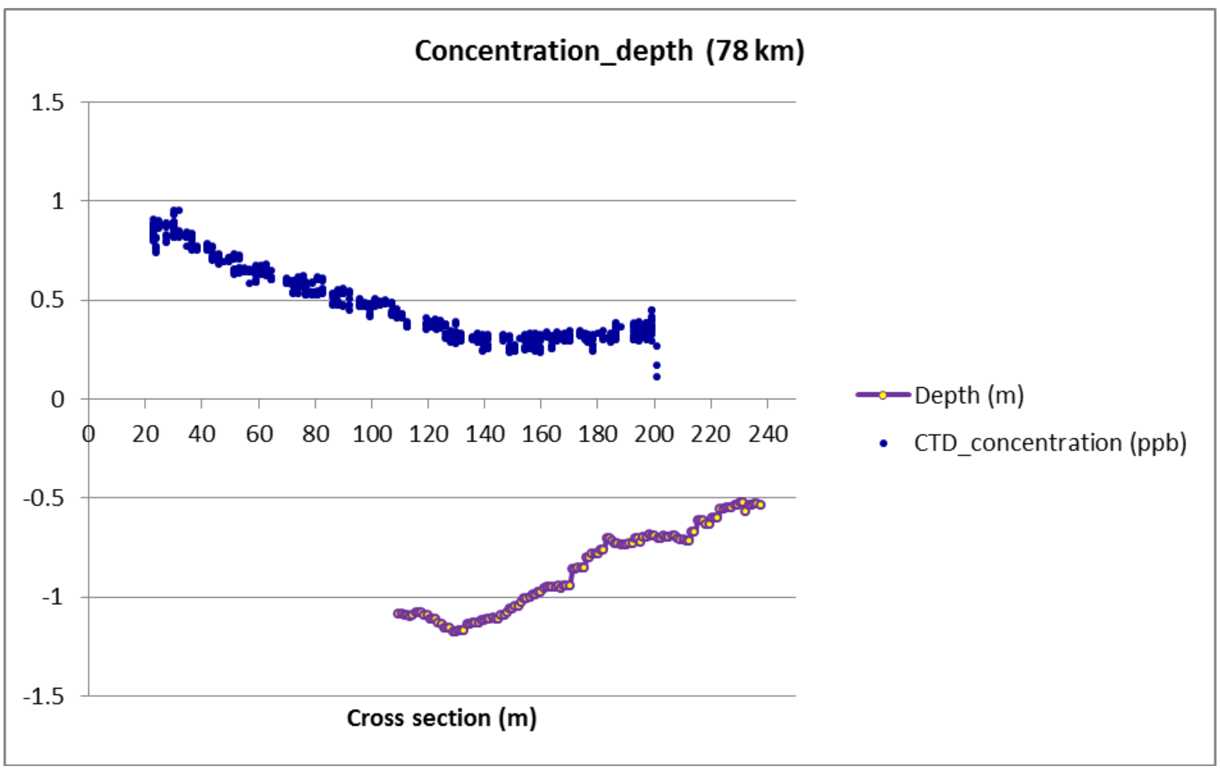
Concentration 66.3km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.58	0.59	0.59
0.2-0.3	0.49	0.51	0.50
0.3-0.4	0.28	0.32	0.30
0.4-0.5	0.12	0.17	0.15
0.5-0.6	0.06	0.07	0.06
0.6-0.7	0.03	0.06	0.04
0.7-0.8	0.02	0.04	0.03
0.8-0.9	0.04	0.06	0.05
0.9-1			
Approximate width(m)	226.98		
Approximate distance from outfall(km)	66.3		
Time and date	14:17:35	Oct 28 2011	



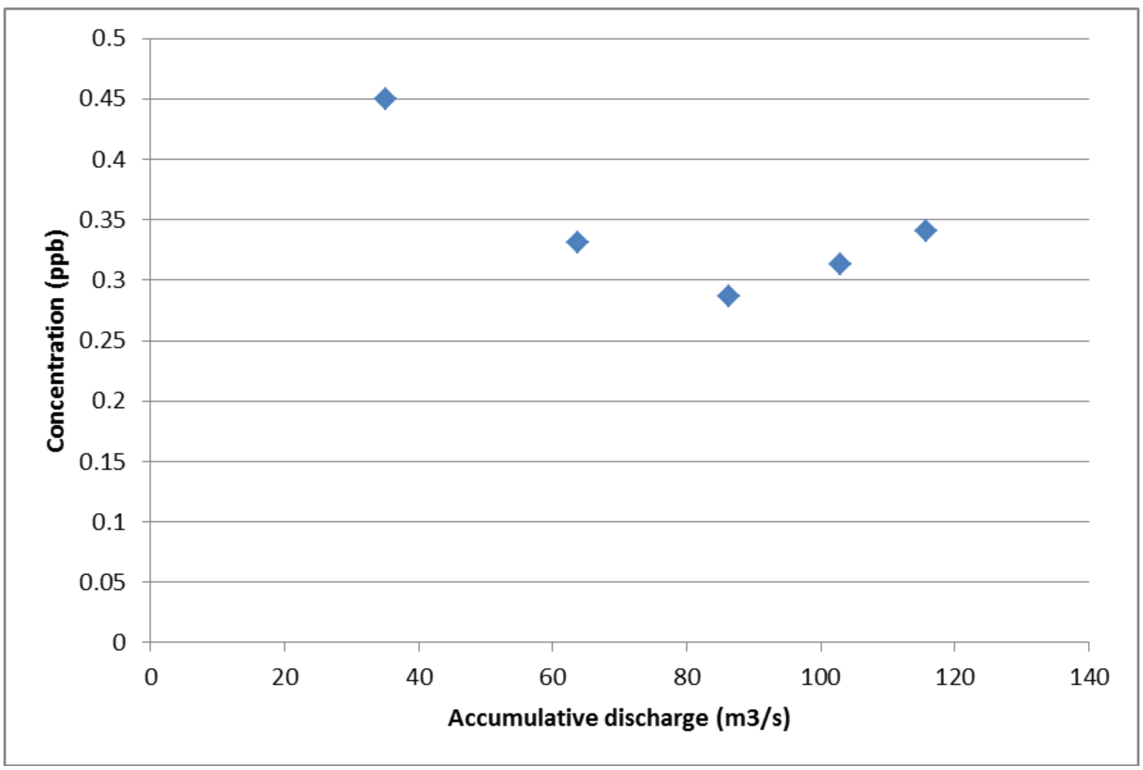


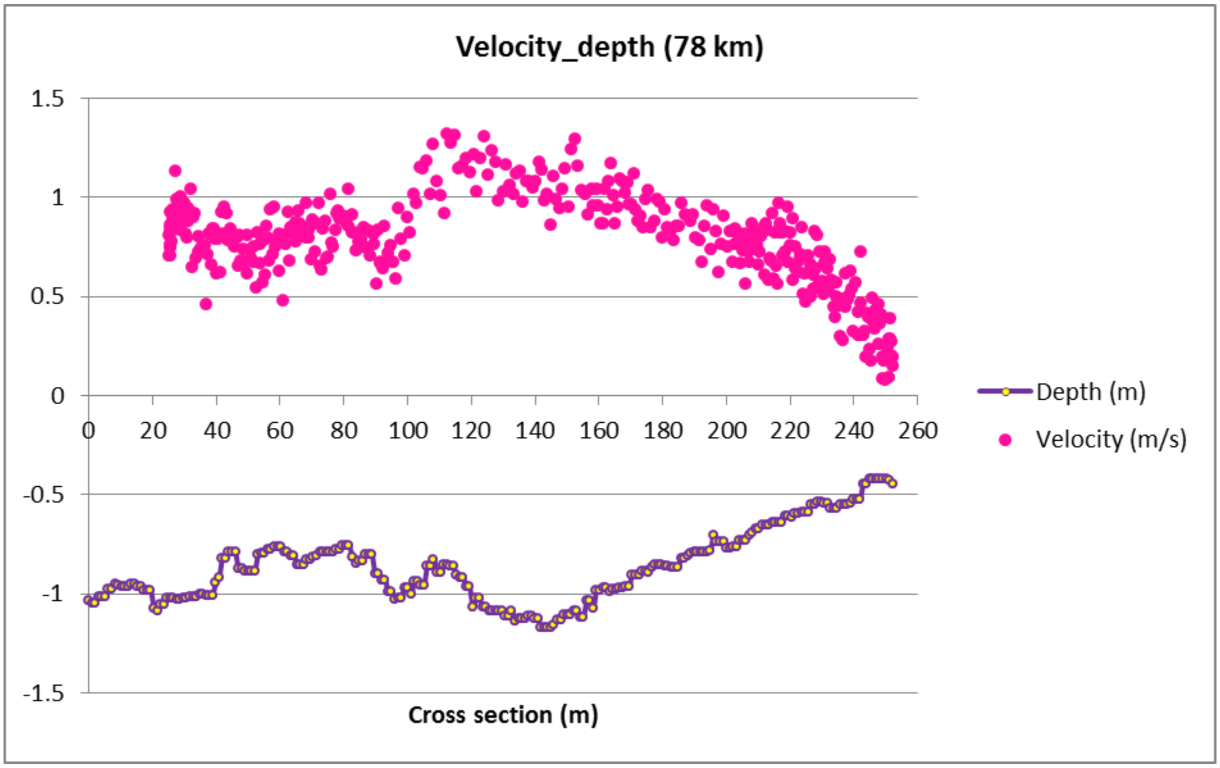
Velocity 78km_1



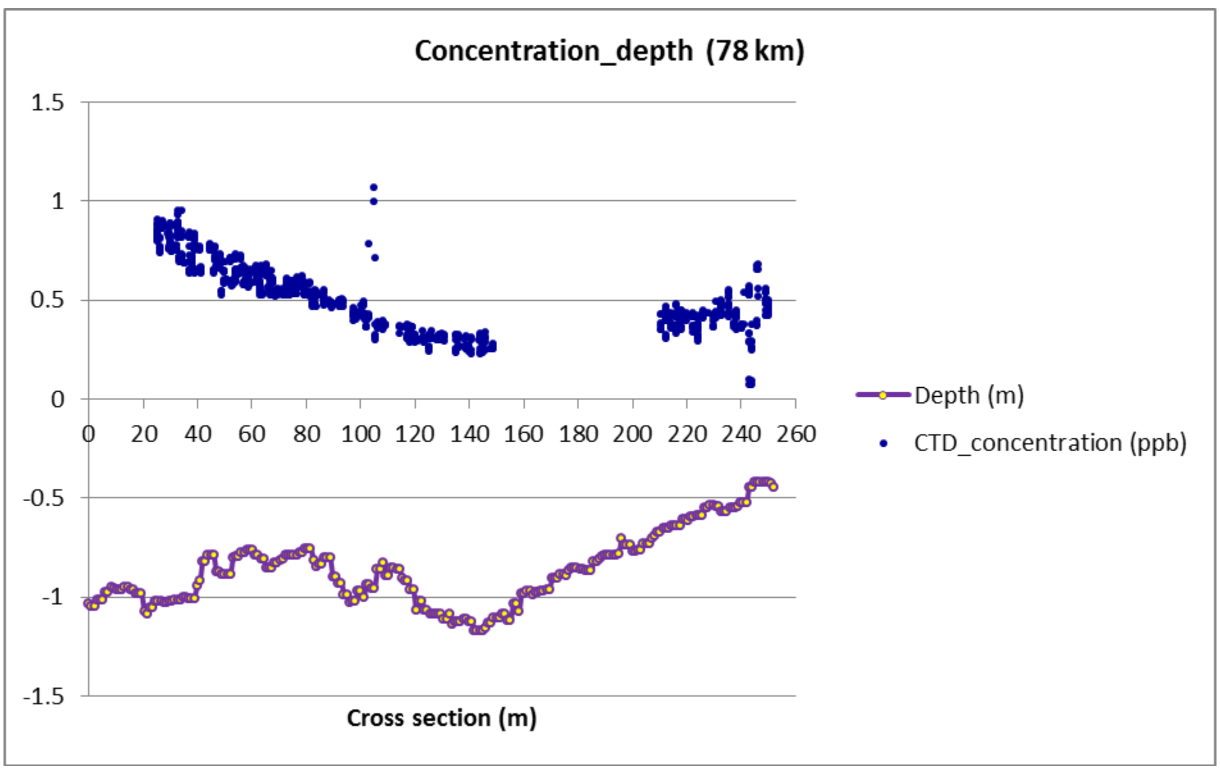
Concentration 78km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.82	0.83	0.83
0.1-0.2	0.79	0.81	0.80
0.2-0.3	0.64	0.66	0.65
0.3-0.4	0.54	0.56	0.55
0.4-0.5	0.44	0.46	0.45
0.5-0.6	0.32	0.34	0.33
0.6-0.7	0.28	0.29	0.29
0.7-0.8	0.31	0.32	0.31
0.8-0.9	0.33	0.35	0.34
0.9-1			
Approximate width(m)	237.66		
Approximate distance from outfall(km)	78		
Time and date	15:28:13	Oct 28 2011	



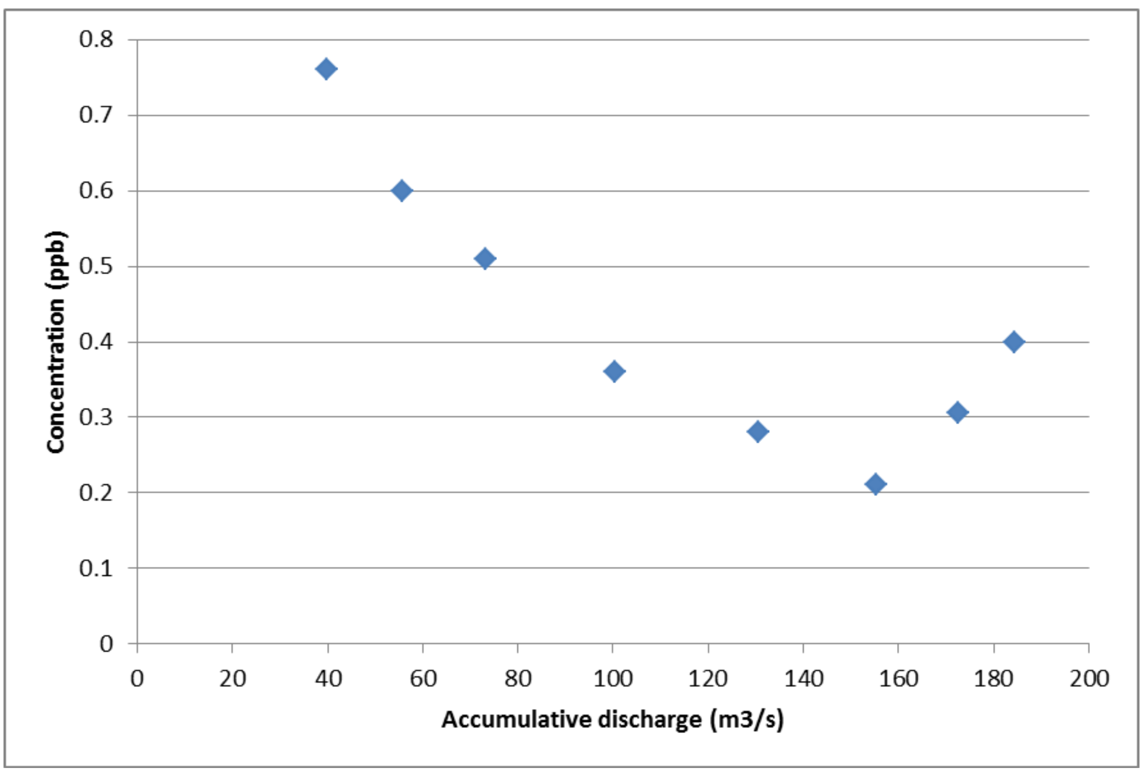


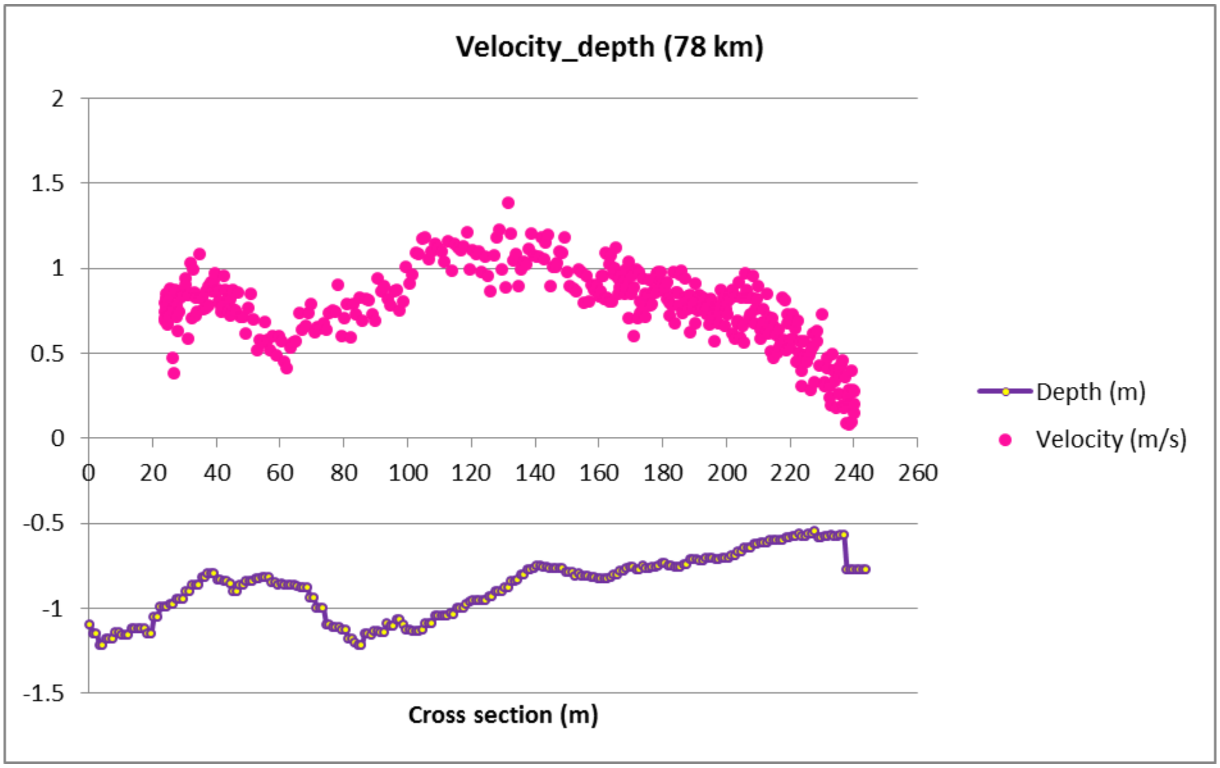
Velocity 78km_2



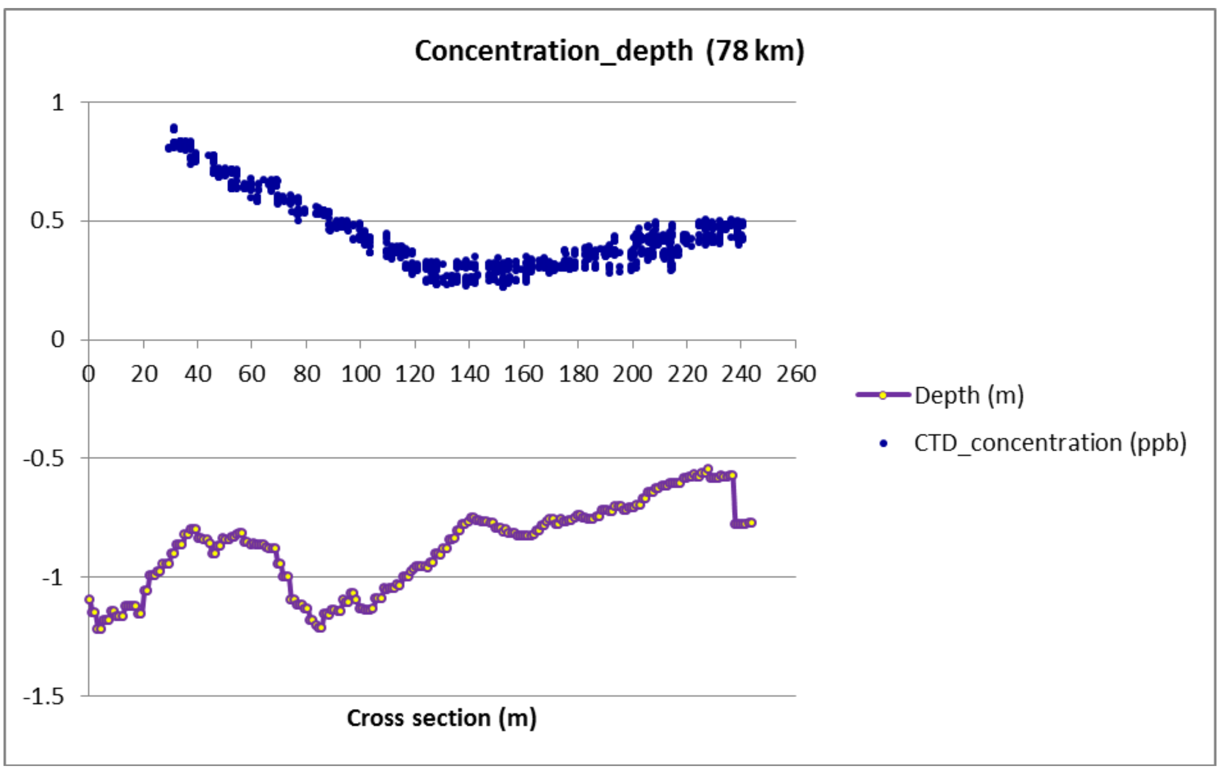
Concentration 78km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.75	0.77	0.76
0.2-0.3	0.59	0.61	0.60
0.3-0.4	0.50	0.52	0.51
0.4-0.5	0.34	0.39	0.36
0.5-0.6	0.28	0.29	0.28
0.6-0.7			
0.7-0.8			
0.8-0.9	0.33	0.47	0.40
0.9-1	0.48	0.50	0.49
Approximate width(m)	252.93		
Approximate distance from outfall(km)	78		
Time and date	15:28:13	Oct 28 2011	



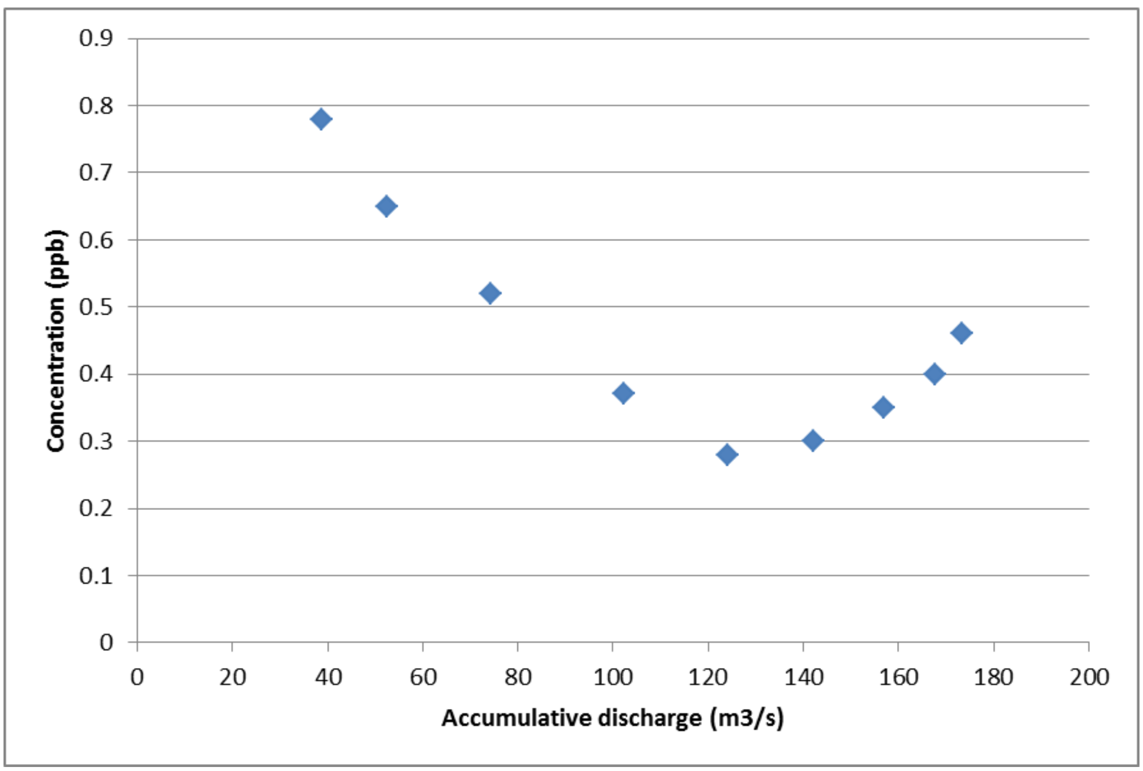


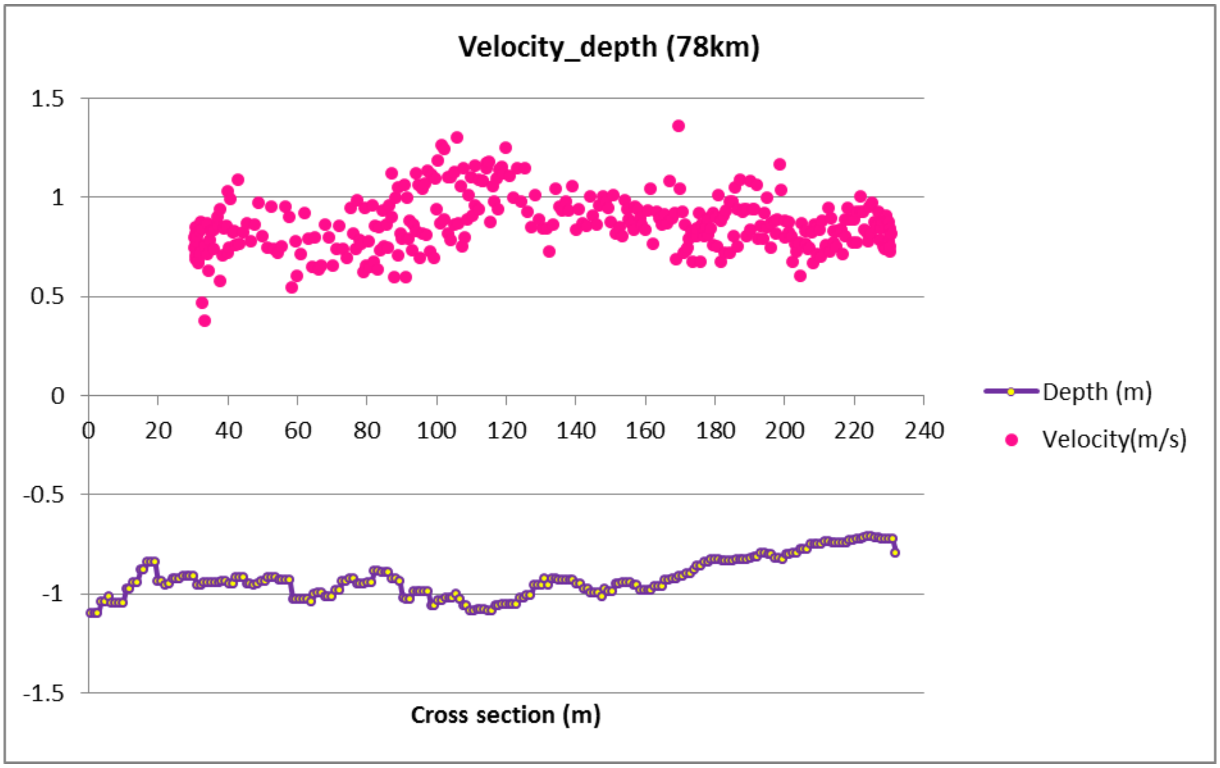
Velocity 78km_3



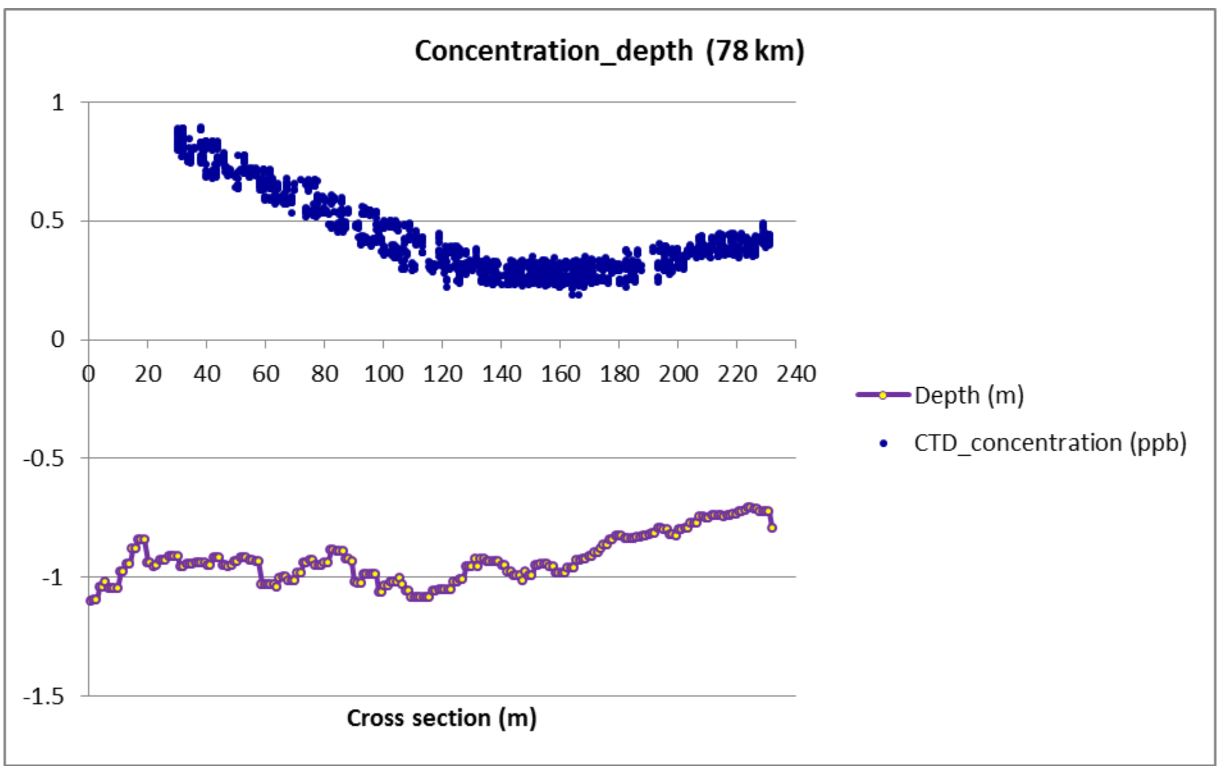
Concentration 78km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.77	0.79	0.78
0.2-0.3	0.64	0.65	0.65
0.3-0.4	0.51	0.52	0.52
0.4-0.5	0.36	0.38	0.37
0.5-0.6	0.27	0.28	0.28
0.6-0.7	0.29	0.30	0.30
0.7-0.8	0.34	0.35	0.35
0.8-0.9	0.39	0.41	0.40
0.9-1	0.45	0.46	0.46
Approximate width(m)	248.70		
Approximate distance from outfall(km)	78		
Time and date	15:28:13	Oct 28 2011	



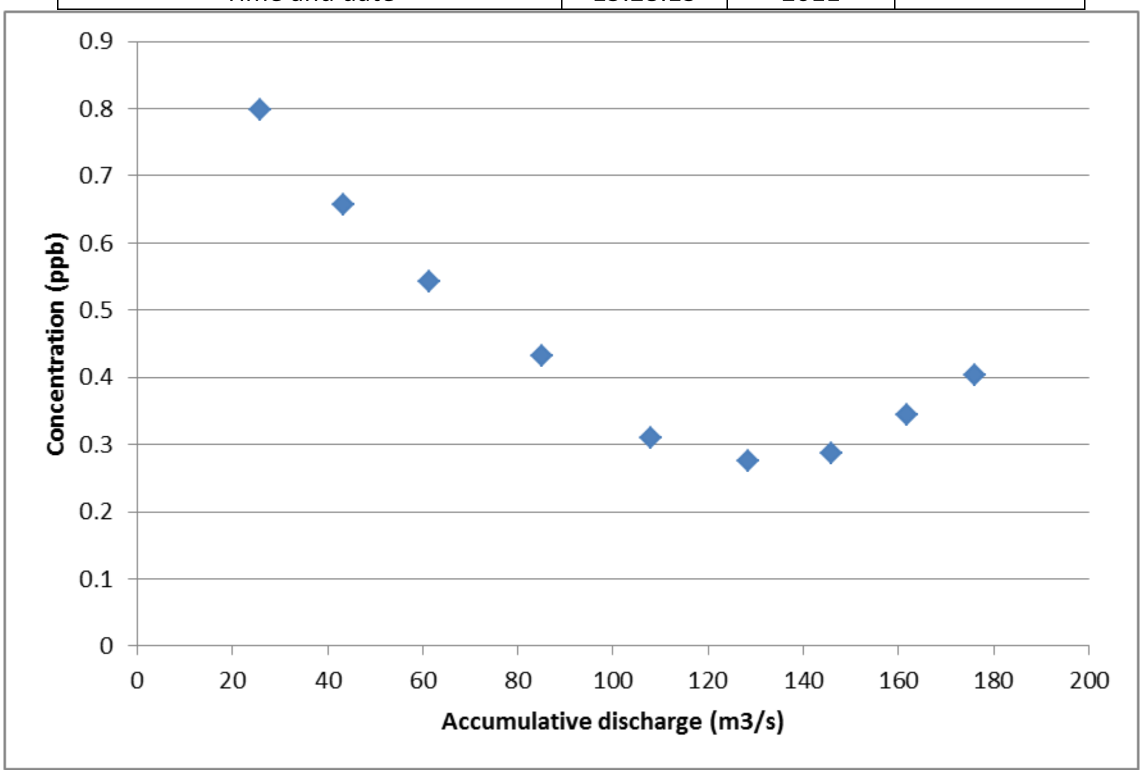


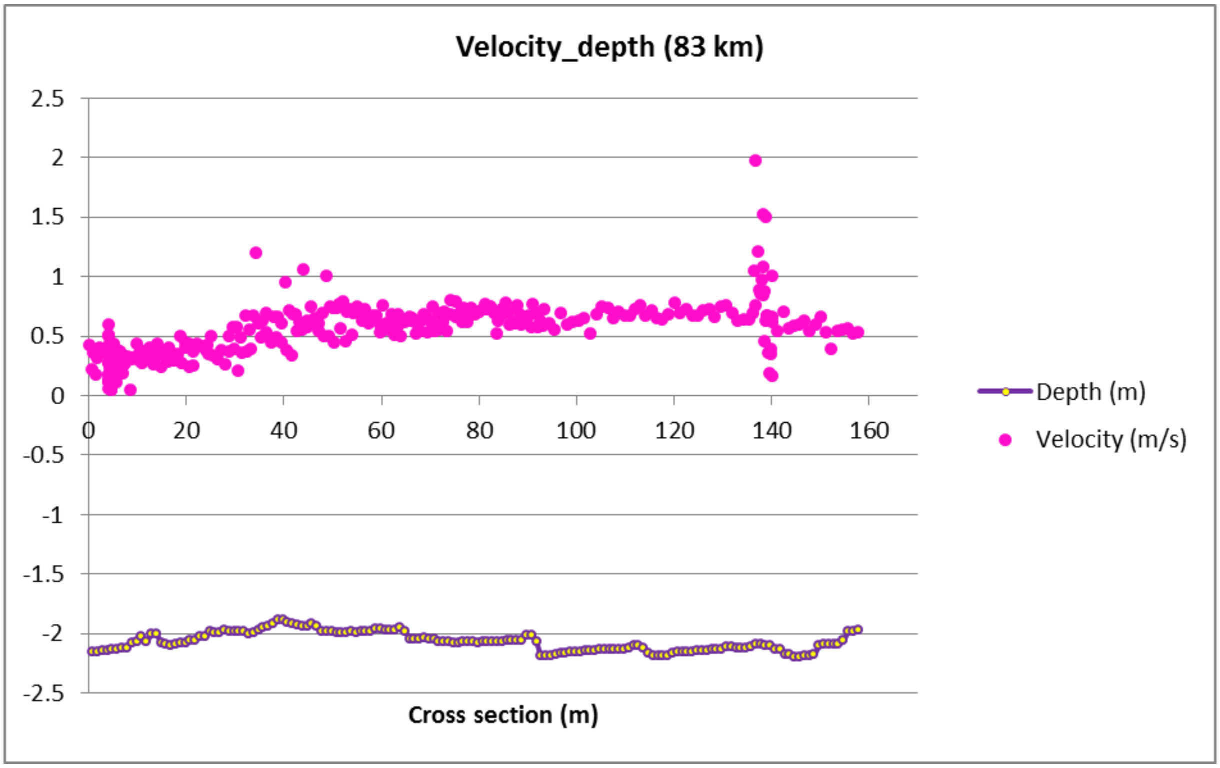
Velocity 78km_4



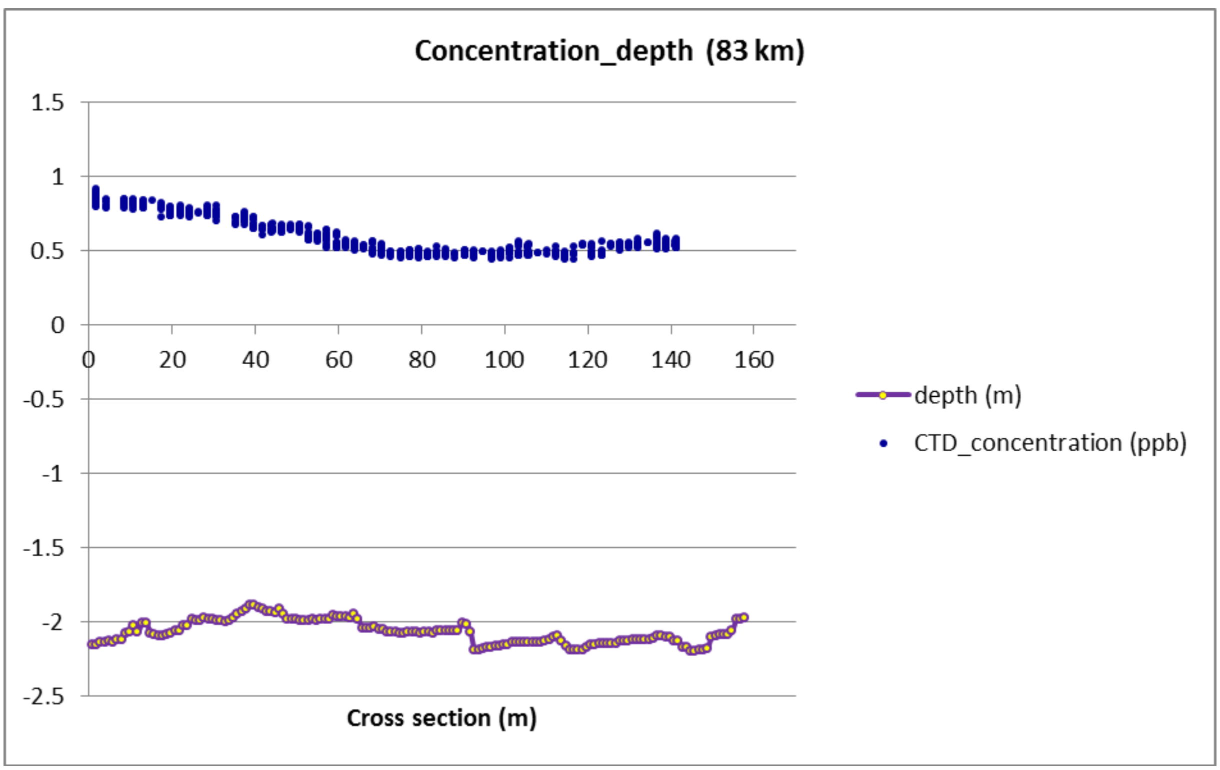
Concentration 78km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.79	0.80	0.80
0.2-0.3	0.65	0.66	0.66
0.3-0.4	0.53	0.55	0.54
0.4-0.5	0.42	0.44	0.43
0.5-0.6	0.30	0.31	0.31
0.6-0.7	0.27	0.28	0.27
0.7-0.8	0.28	0.29	0.29
0.8-0.9	0.34	0.35	0.34
0.9-1	0.40	0.41	0.40
Approximate width(m)	232.09		
Approximate distance from outfall(km)	78		
Time and date	15:28:13	Oct 28 2011	



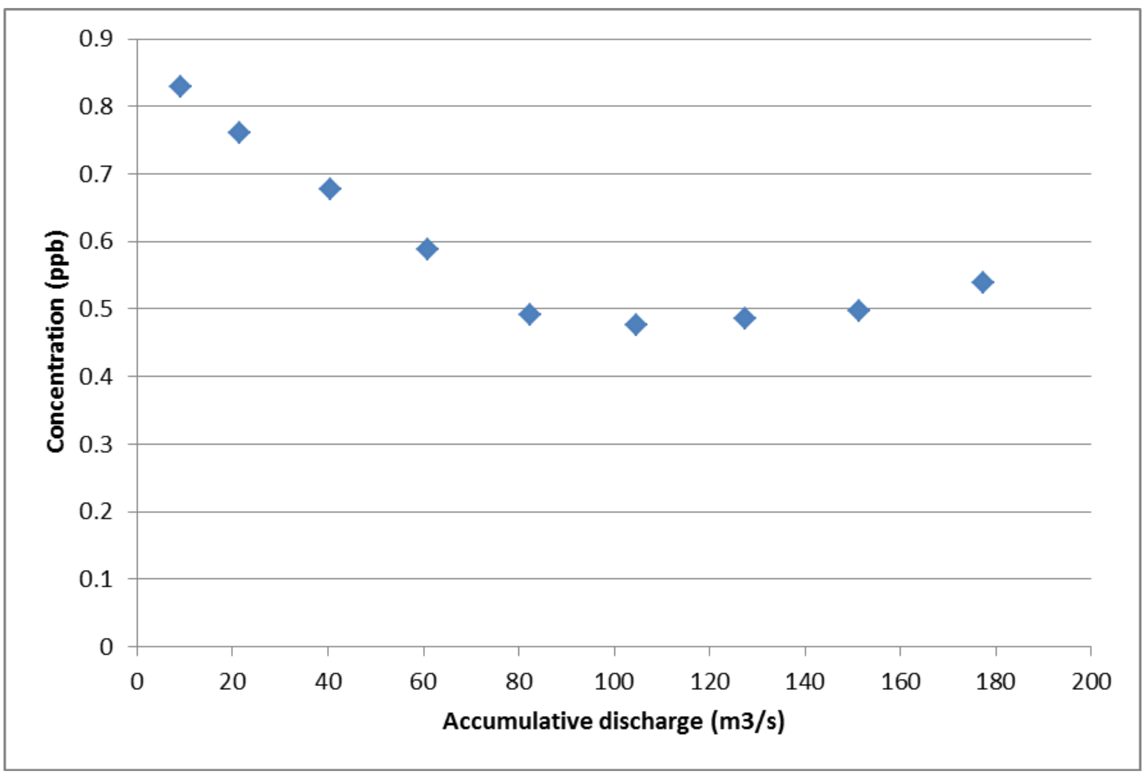


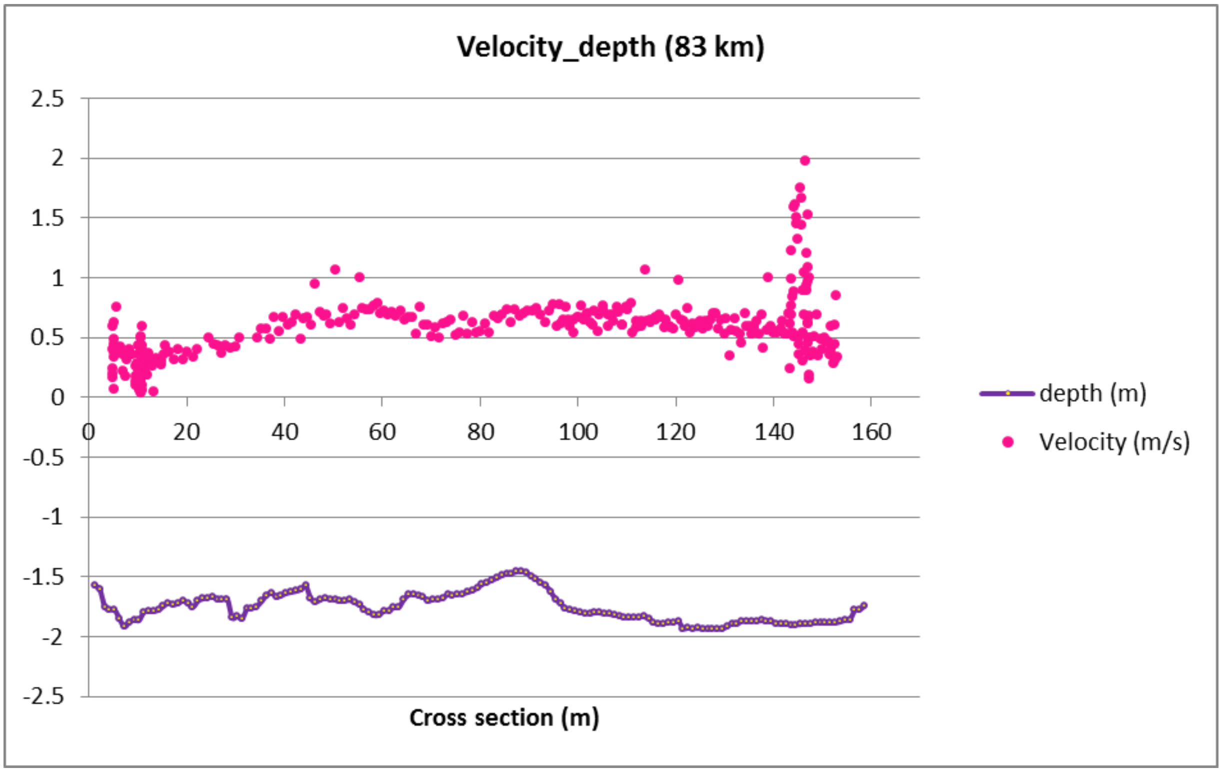
Velocity 83km_1



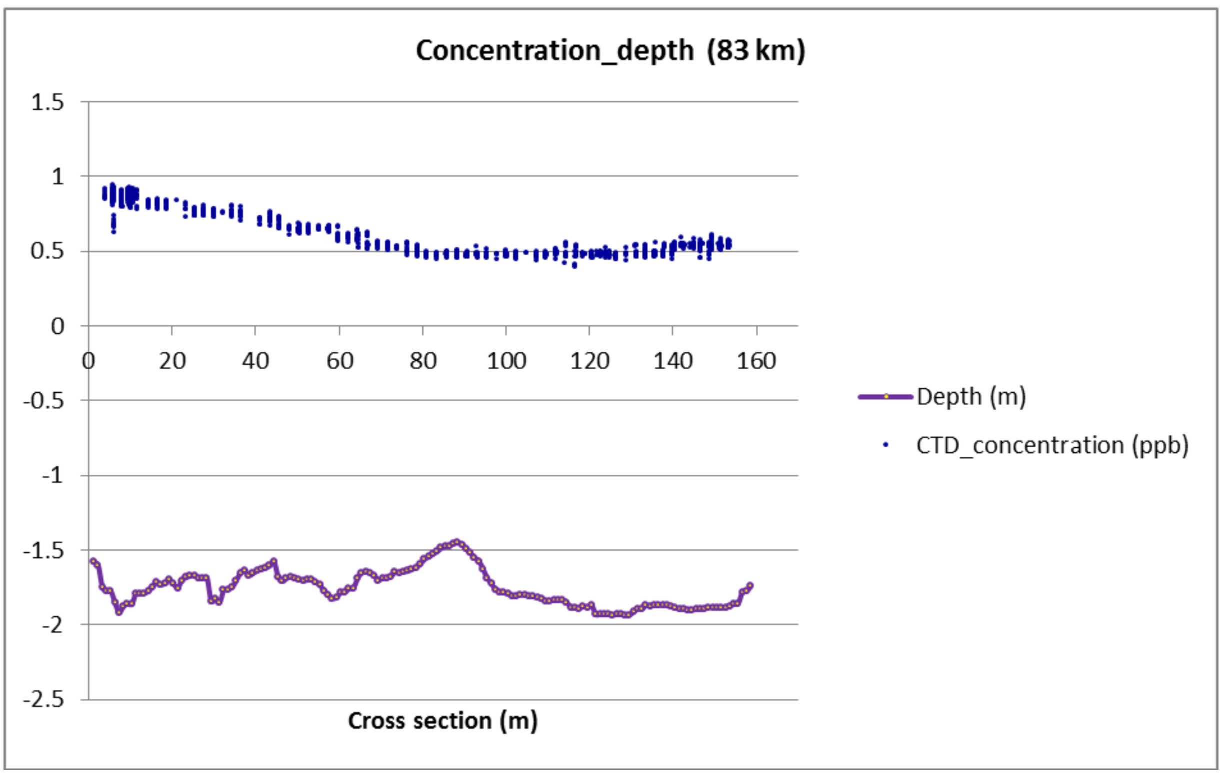
Concentration 83km_1

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.82	0.84	0.83
0.1-0.2	0.75	0.77	0.76
0.2-0.3	0.67	0.69	0.68
0.3-0.4	0.58	0.60	0.59
0.4-0.5	0.49	0.50	0.49
0.5-0.6	0.47	0.48	0.48
0.6-0.7	0.48	0.49	0.48
0.7-0.8	0.49	0.50	0.50
0.8-0.9	0.53	0.54	0.54
0.9-1			
Approximate width(m)	160.89		
Approximate distance from outfall(km)	83		
Time and date	16:00:38	Oct 28 2011	



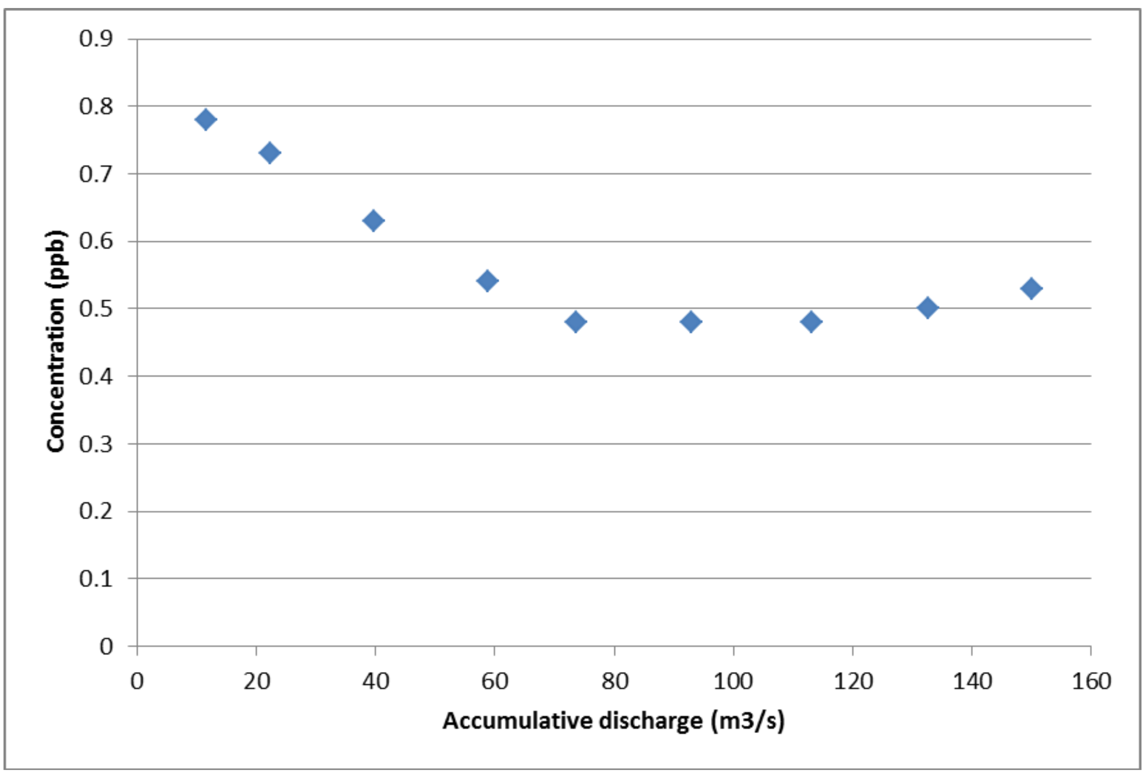


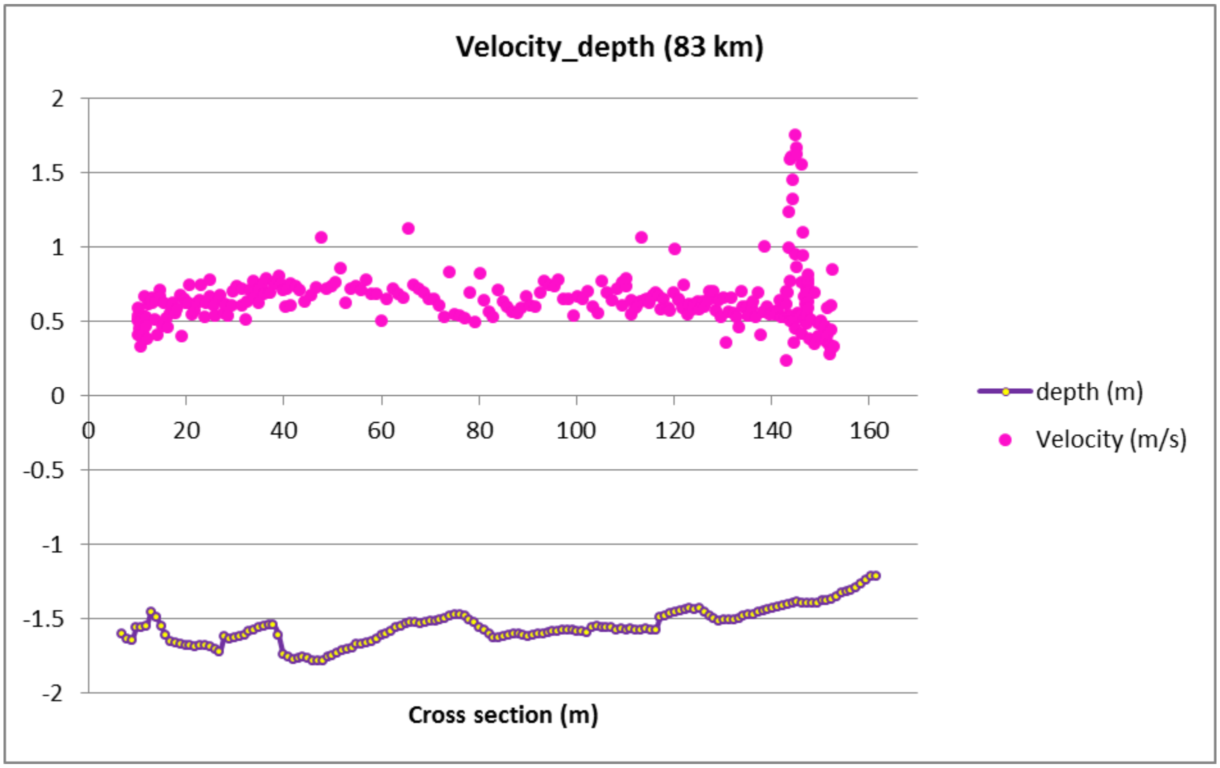
Velocity 83km_2



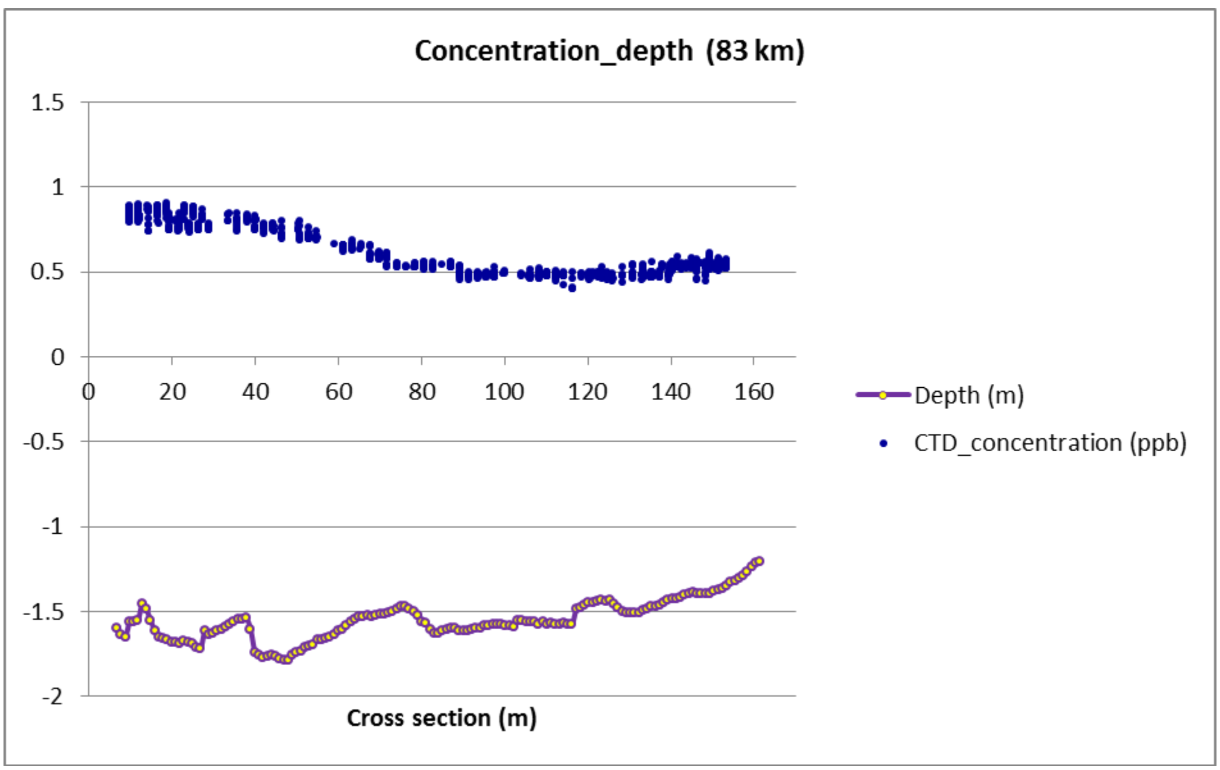
Concentration 83km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.85	0.86	0.86
0.1-0.2	0.77	0.79	0.78
0.2-0.3	0.72	0.74	0.73
0.3-0.4	0.63	0.64	0.63
0.4-0.5	0.53	0.55	0.54
0.5-0.6	0.47	0.48	0.48
0.6-0.7	0.47	0.48	0.48
0.7-0.8	0.48	0.49	0.48
0.8-0.9	0.49	0.50	0.50
0.9-1	0.53	0.54	0.53
Approximate width(m)	159.35		
Approximate distance from outfall(km)	83		
Time and date	16:00:38	Oct 28 2011	



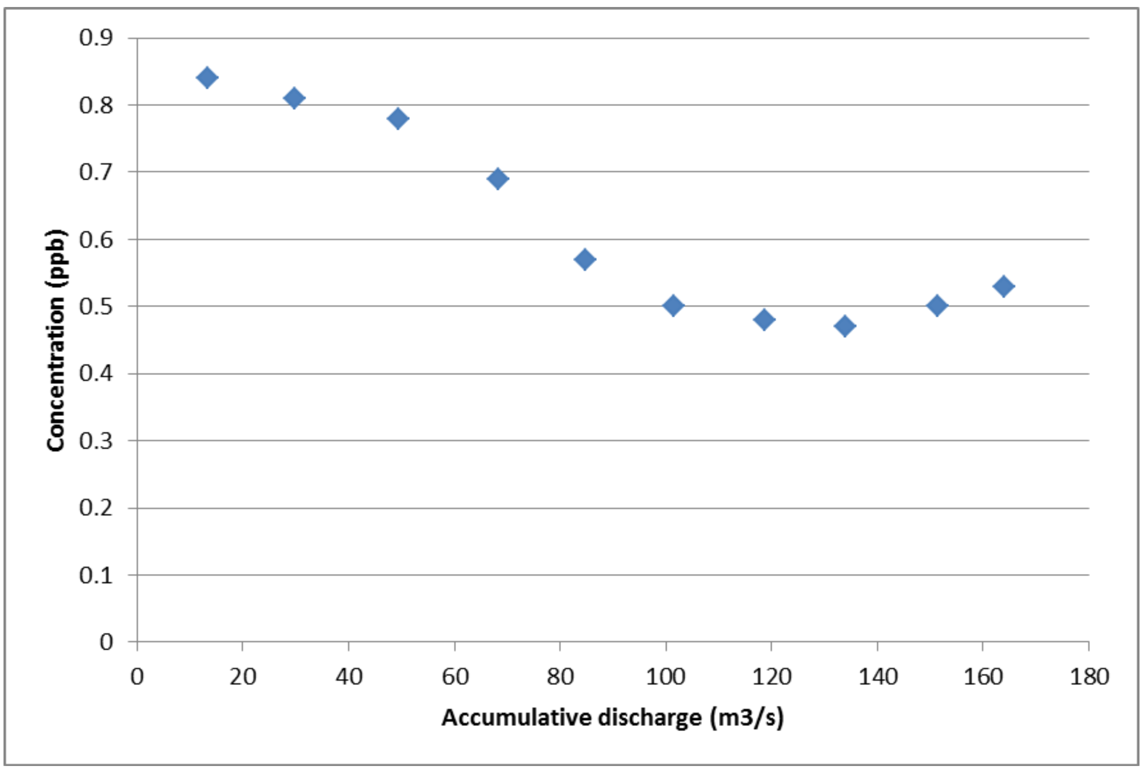


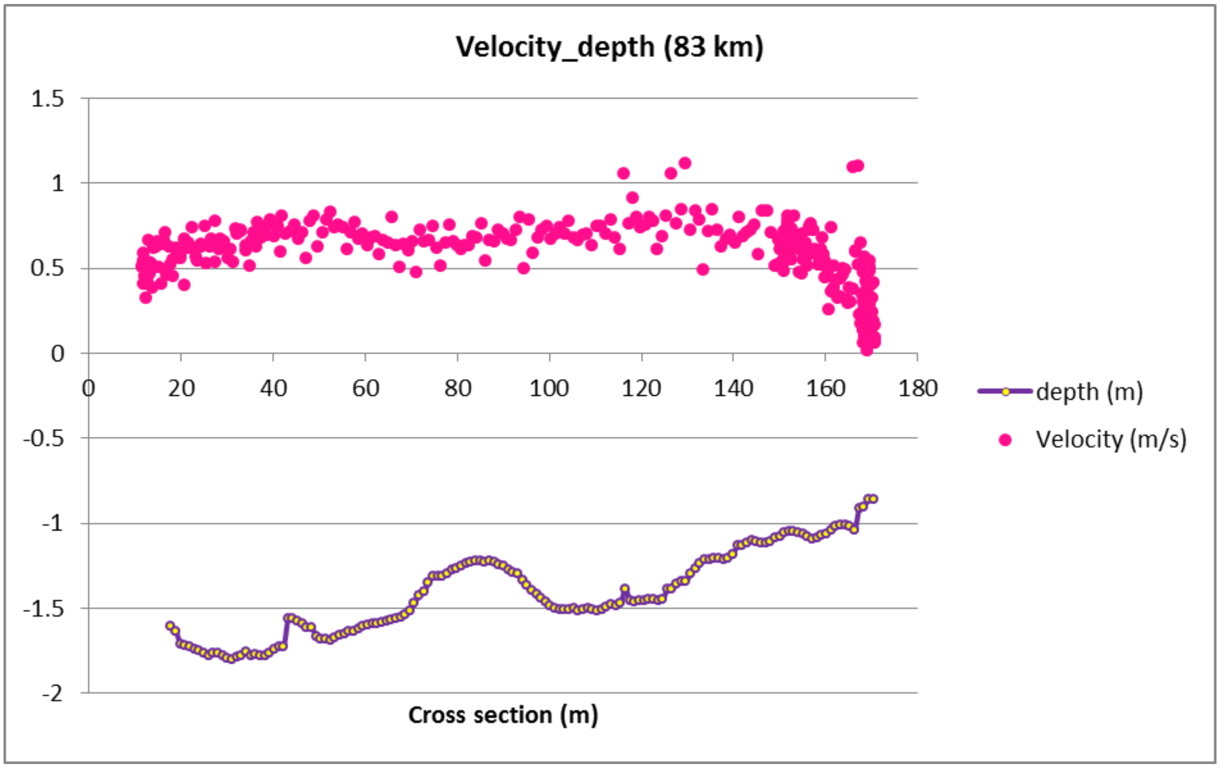
Velocity 83km_3



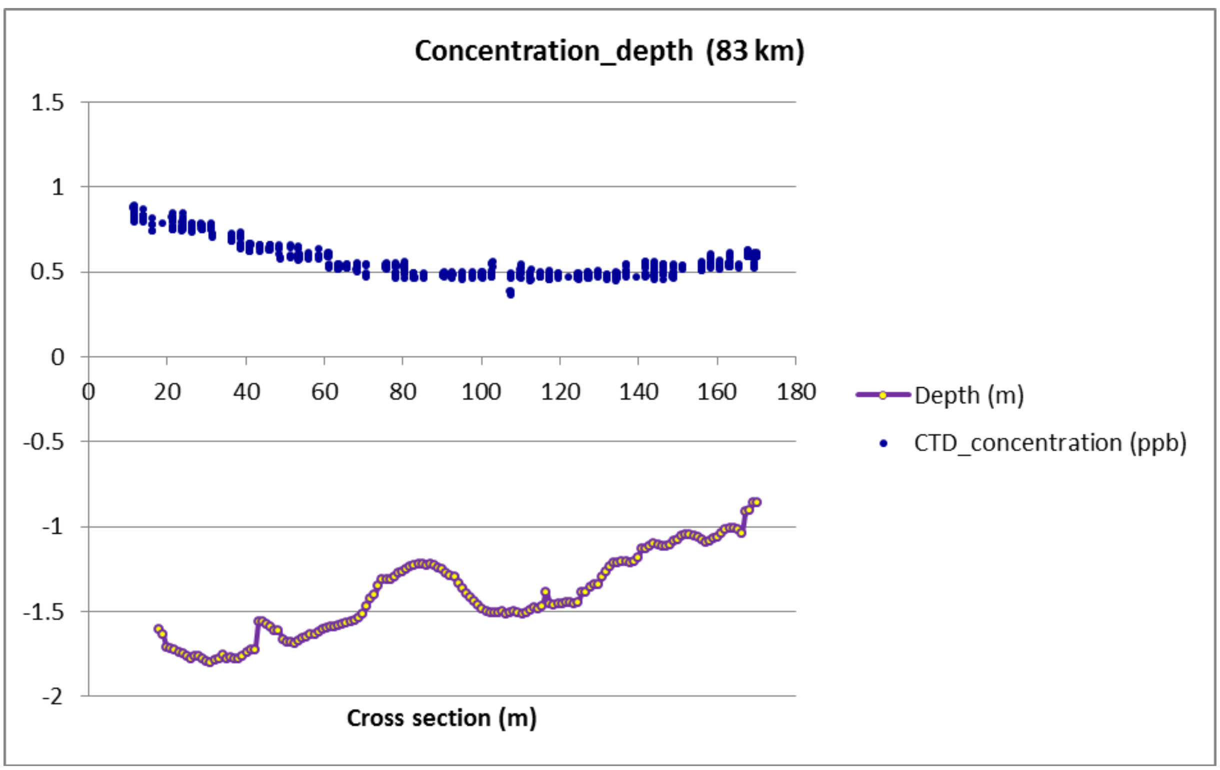
Concentration 83km_3

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.84	0.85	0.84
0.1-0.2	0.80	0.82	0.81
0.2-0.3	0.77	0.79	0.78
0.3-0.4	0.68	0.70	0.69
0.4-0.5	0.56	0.58	0.57
0.5-0.6	0.50	0.51	0.50
0.6-0.7	0.48	0.49	0.48
0.7-0.8	0.47	0.48	0.47
0.8-0.9	0.50	0.51	0.50
0.9-1	0.53	0.54	0.53
Approximate width(m)	162.31		
Approximate distance from outfall(km)	83		
Time and date	16:00:38	Oct 28 2011	



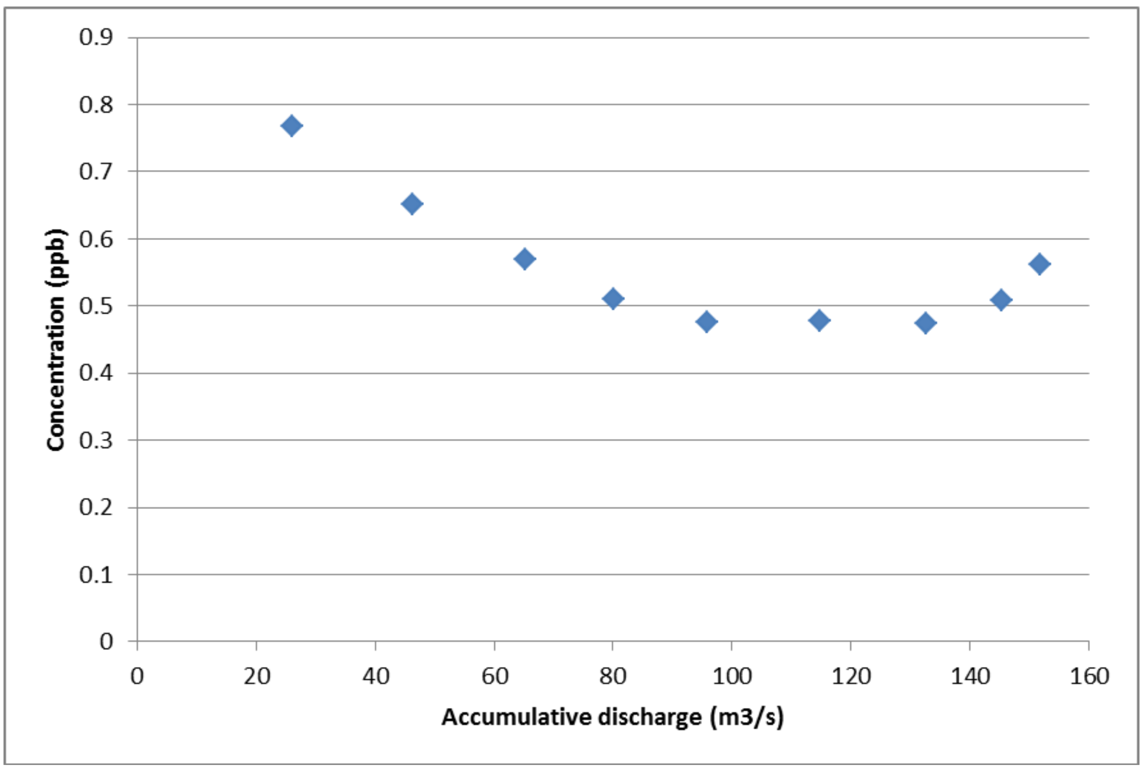


Velocity 83km_4

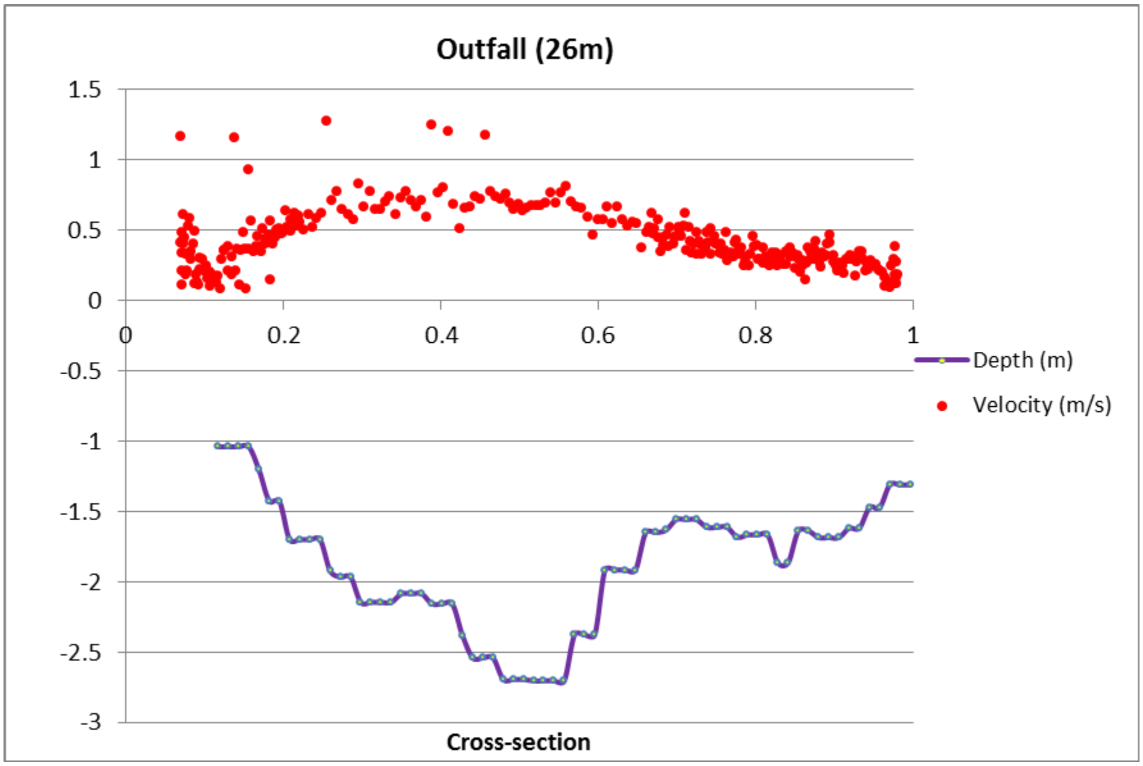


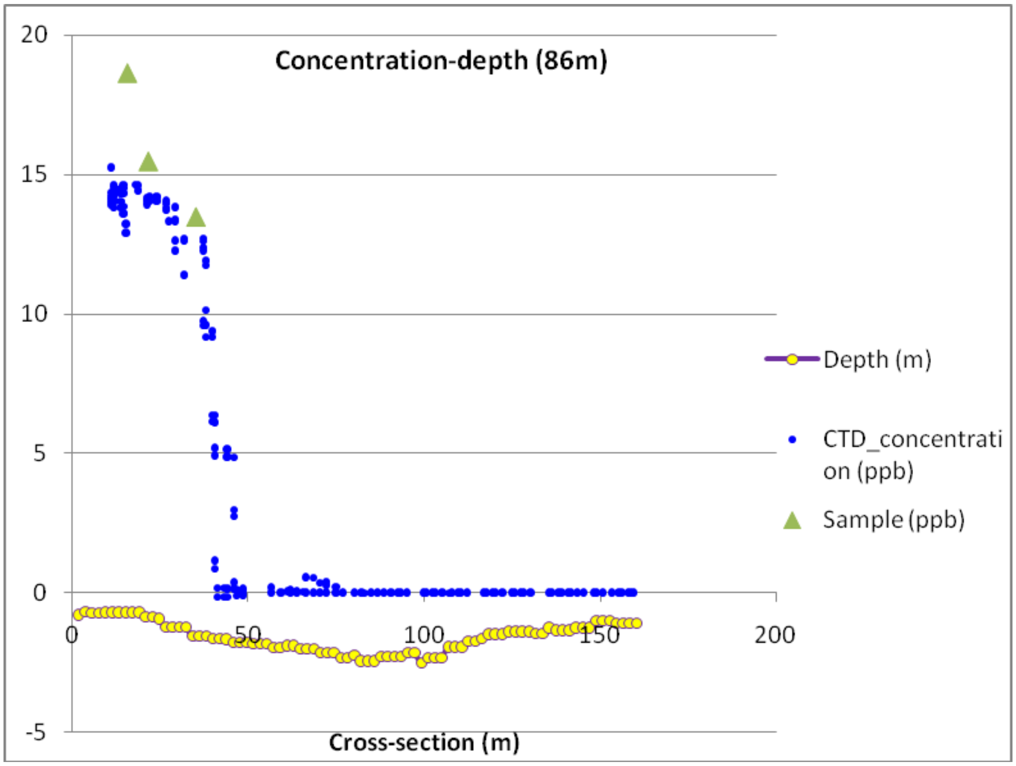
Concentration 83km_4

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.83	0.84	0.83
0.1-0.2	0.76	0.77	0.77
0.2-0.3	0.64	0.66	0.65
0.3-0.4	0.56	0.58	0.57
0.4-0.5	0.50	0.52	0.51
0.5-0.6	0.47	0.48	0.48
0.6-0.7	0.47	0.48	0.48
0.7-0.8	0.47	0.48	0.47
0.8-0.9	0.50	0.51	0.51
0.9-1	0.56	0.57	0.56
Approximate width(m)	170.82		
Approximate distance from outfall(km)	83		
Time and date	16:00:38	Oct 28 2011	

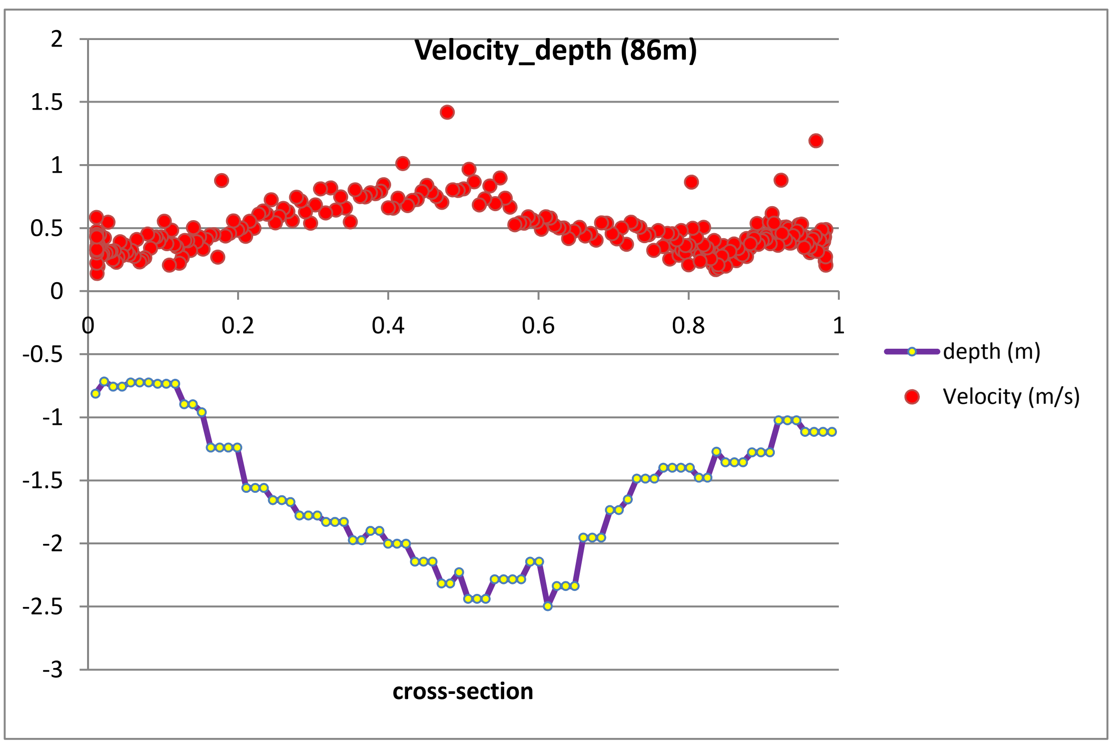


Appendix C: Goldbar WWTP Results



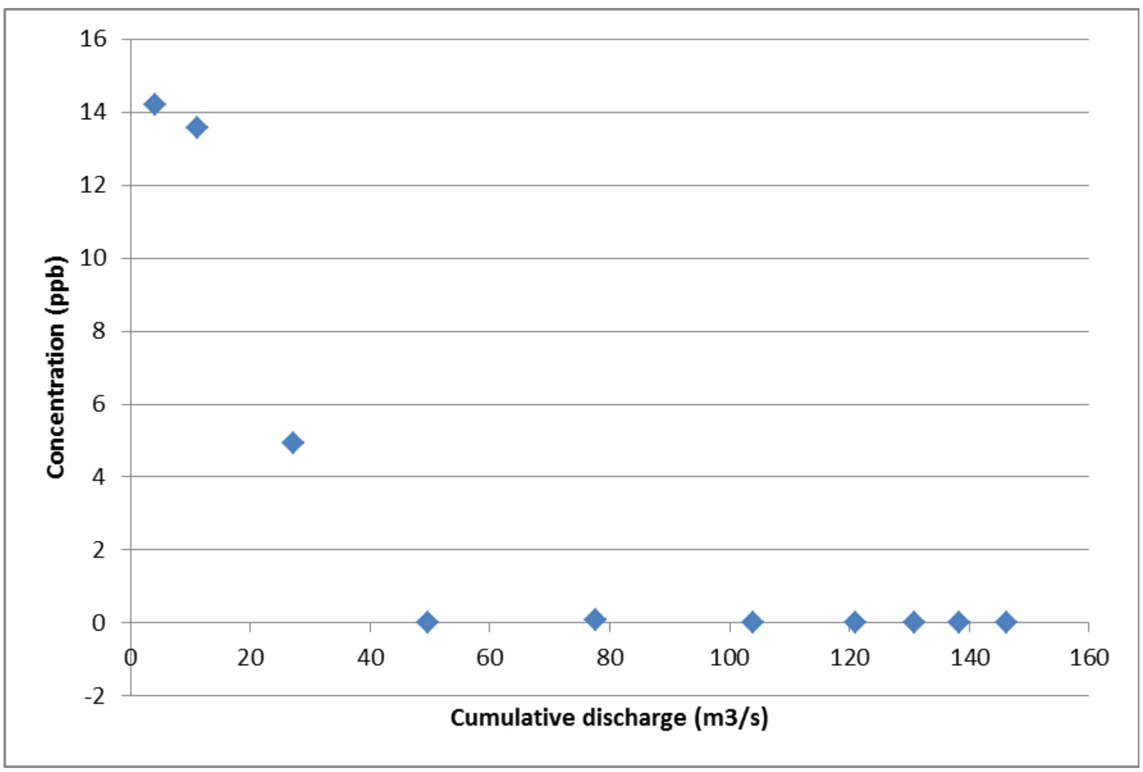


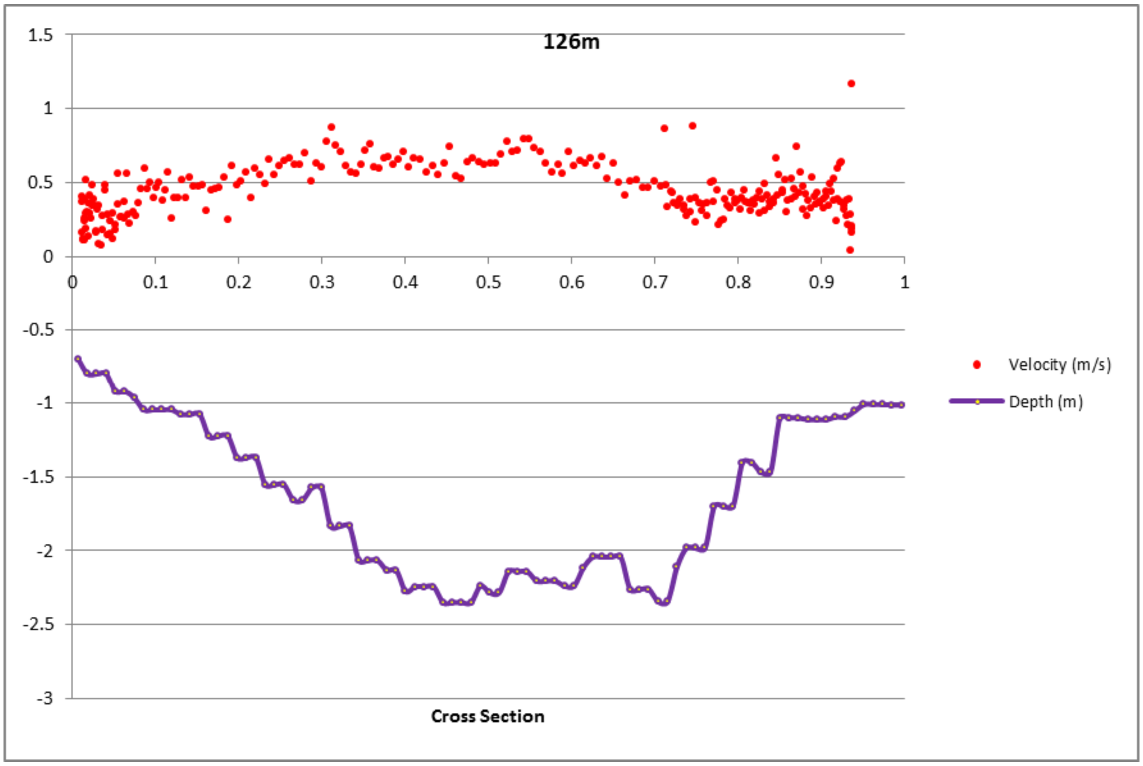
Concentration 86m

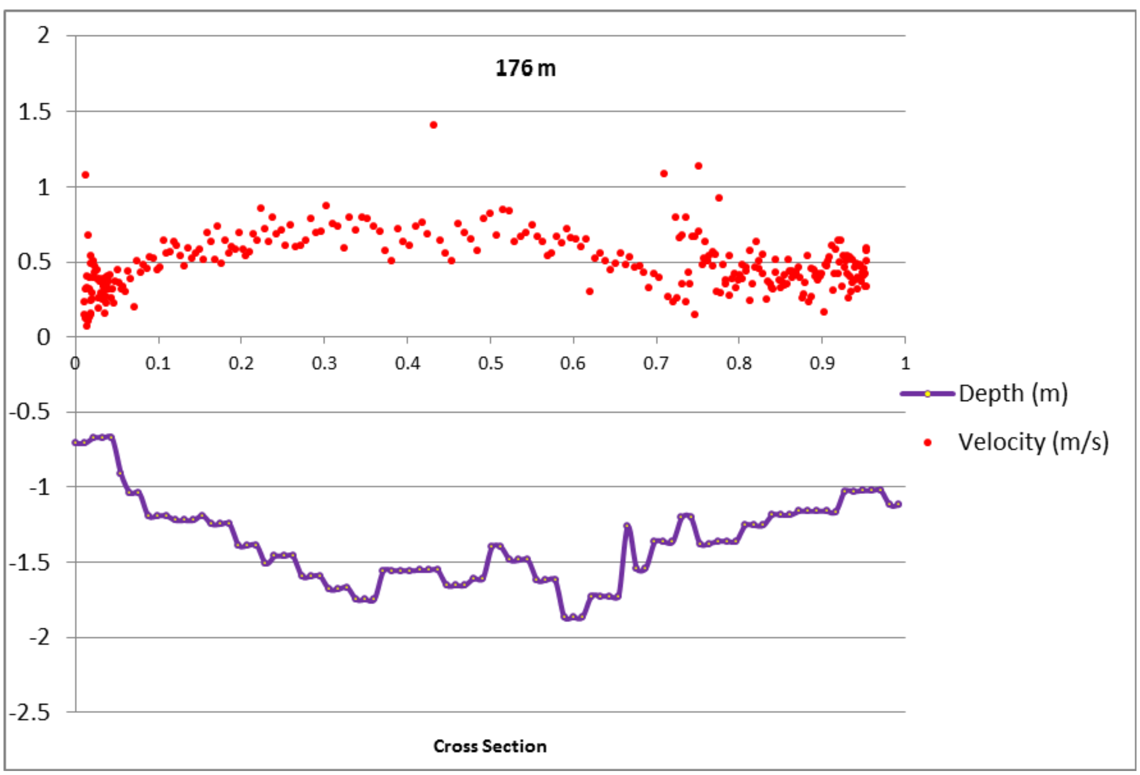


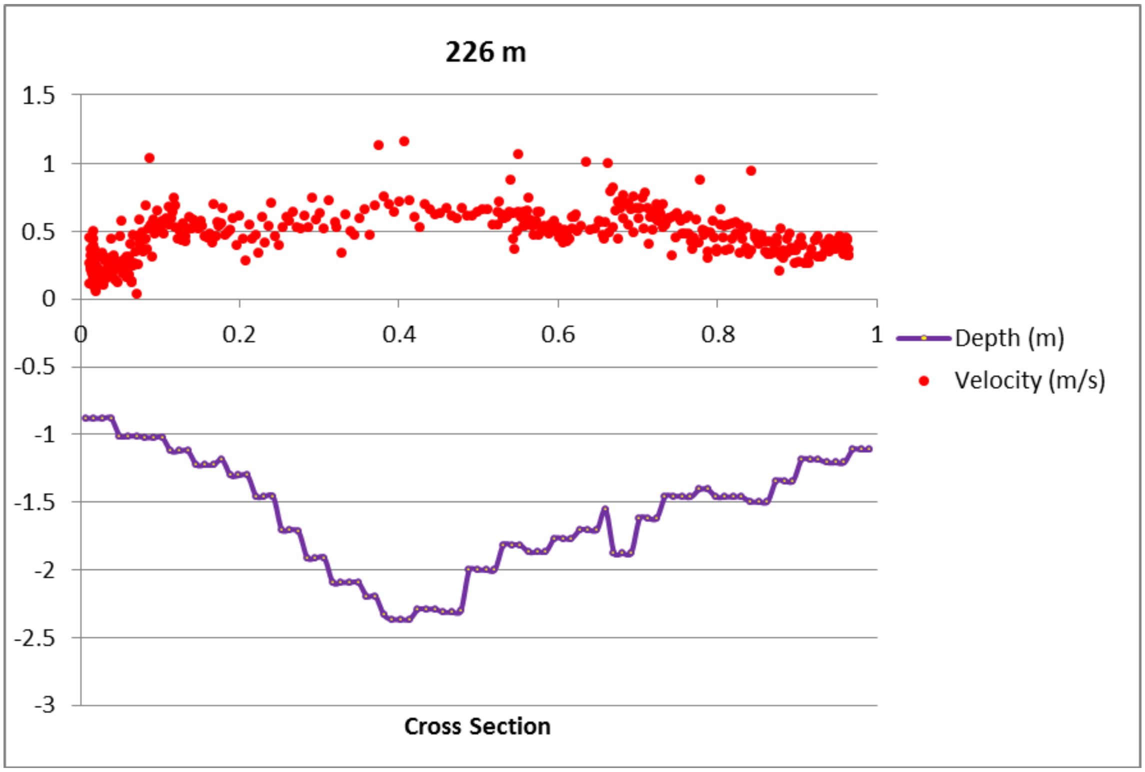
Velocity 86m

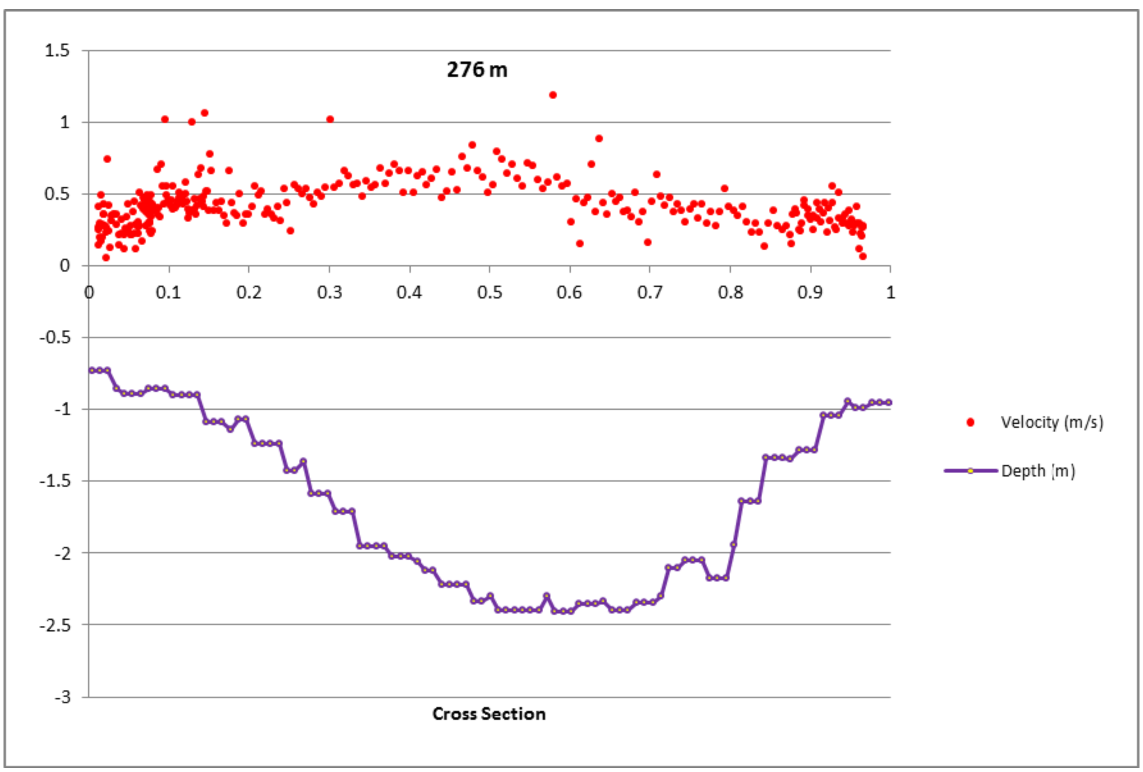
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	14.08	14.27	14.18
0.1-0.2	13.38	13.78	13.58
0.2-0.3	3.74	6.11	4.93
0.3-0.4	0.00	0.03	0.02
0.4-0.5	0.05	0.15	0.10
0.5-0.6	0.00	0.00	0.00
0.6-0.7	0.00	0.00	0.00
0.7-0.8	0.00	0.00	0.00
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	161.80		
Approximate distance from outfall(km)	0.86		
Time and date	11:41:36	Oct 29 2011	

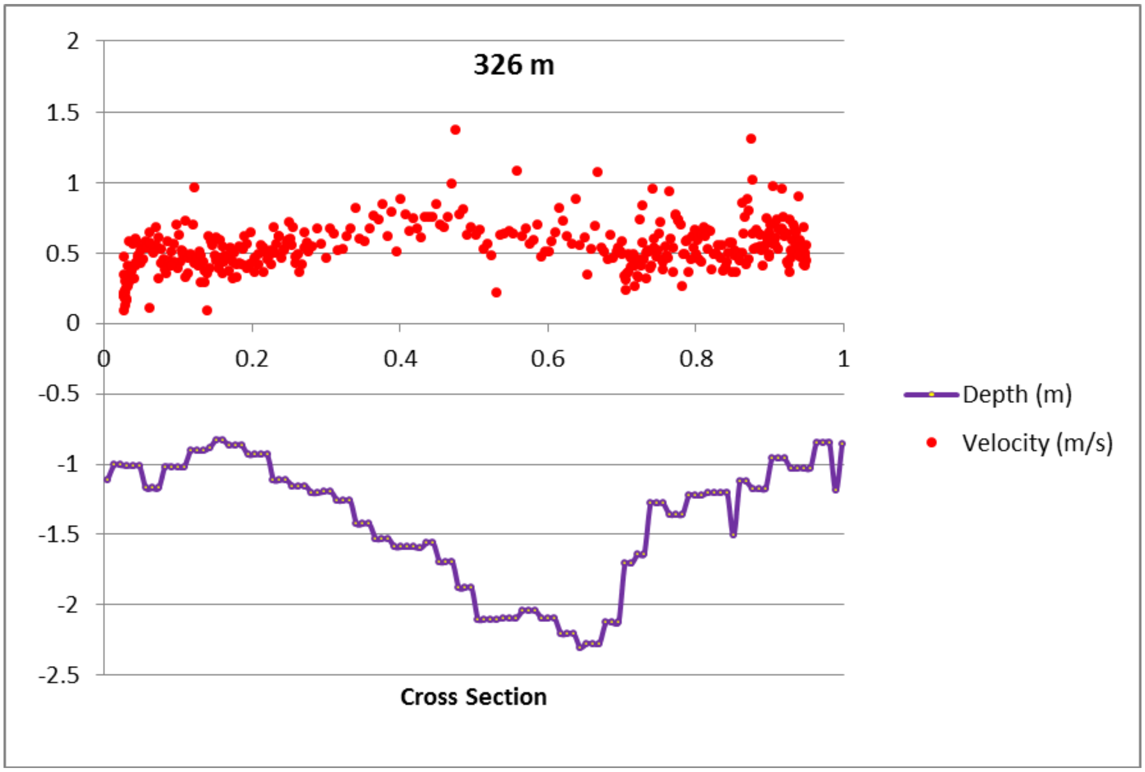


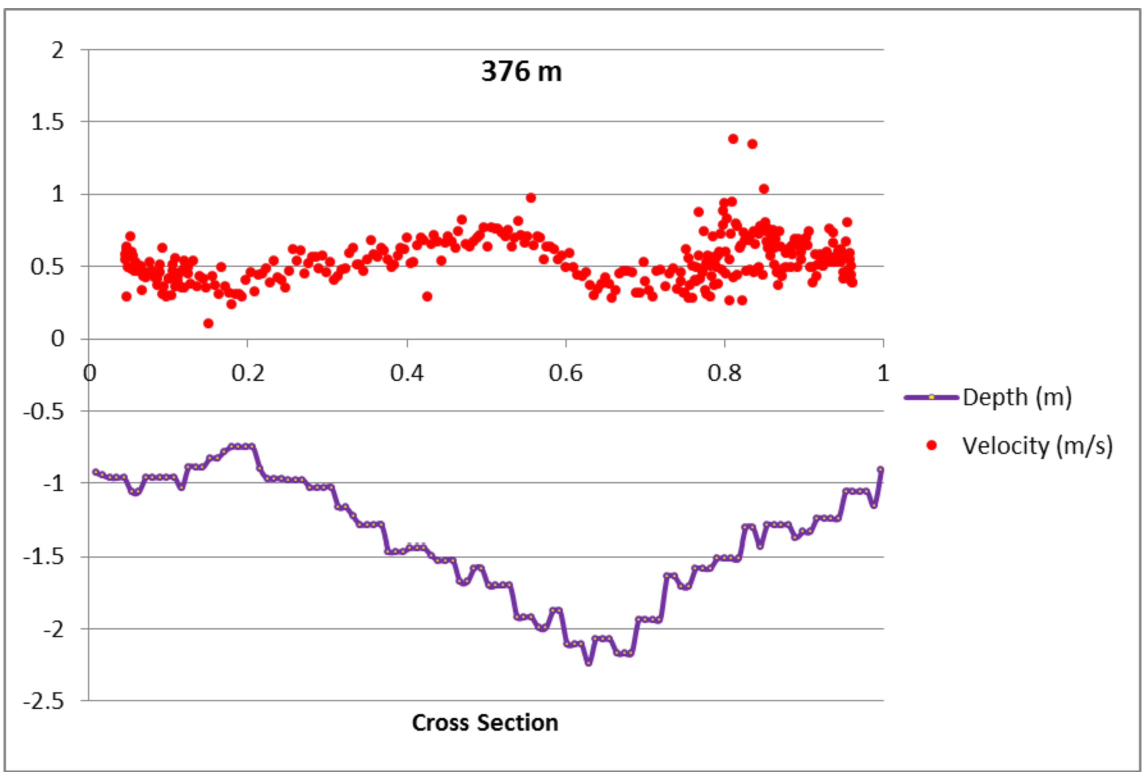

126m
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Velocity (m/s)
Depth (m)
Cross Section

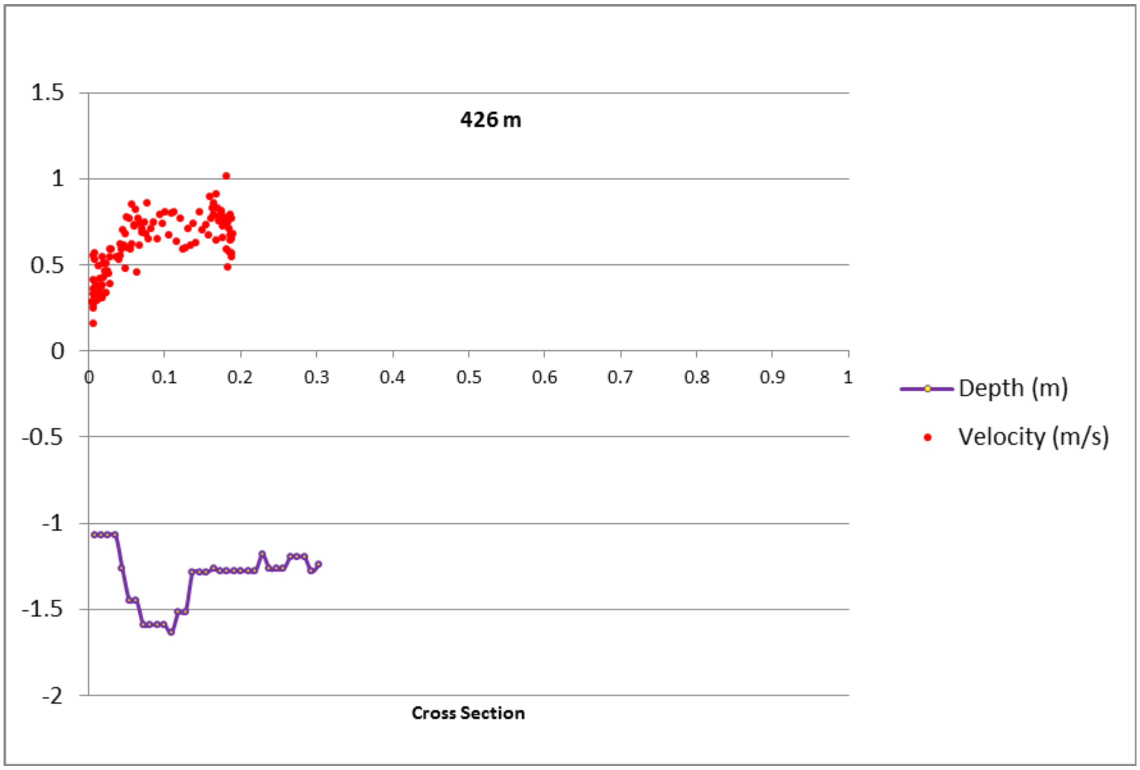

176 m
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Depth (m)
Velocity (m/s)
Cross Section

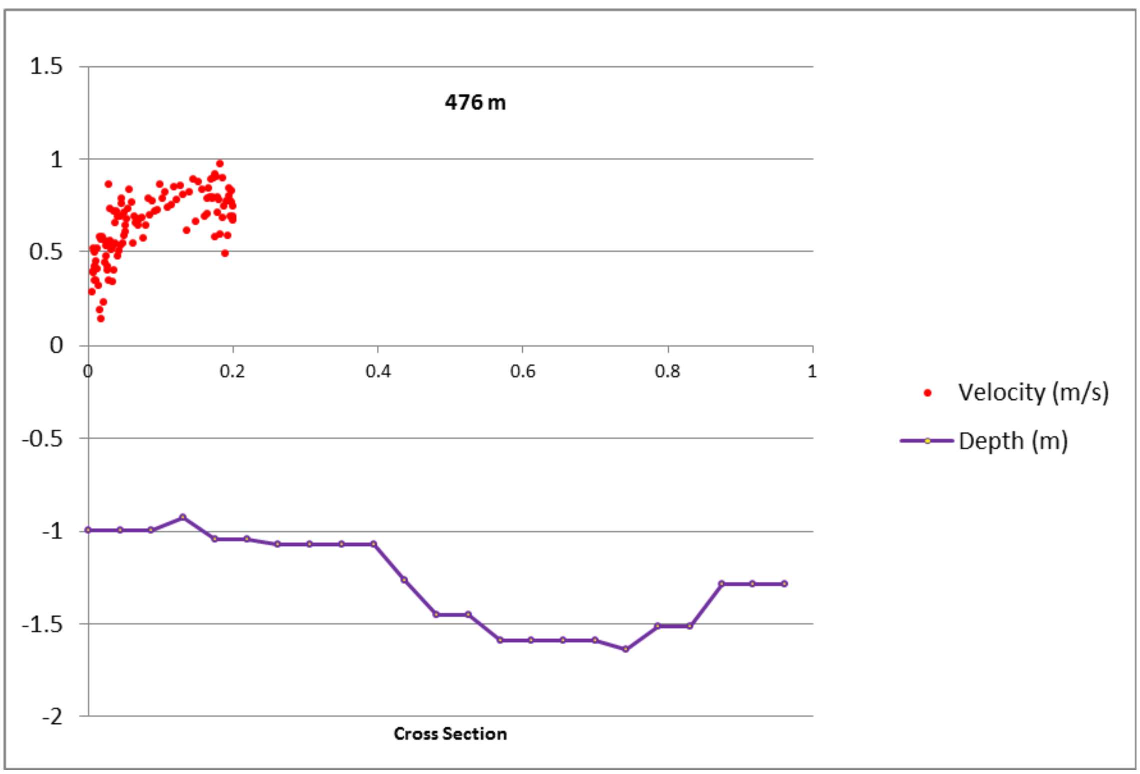

226 m
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
0.2
0.4
0.6
0.8
1
Depth (m)
Velocity (m/s)
Cross Section

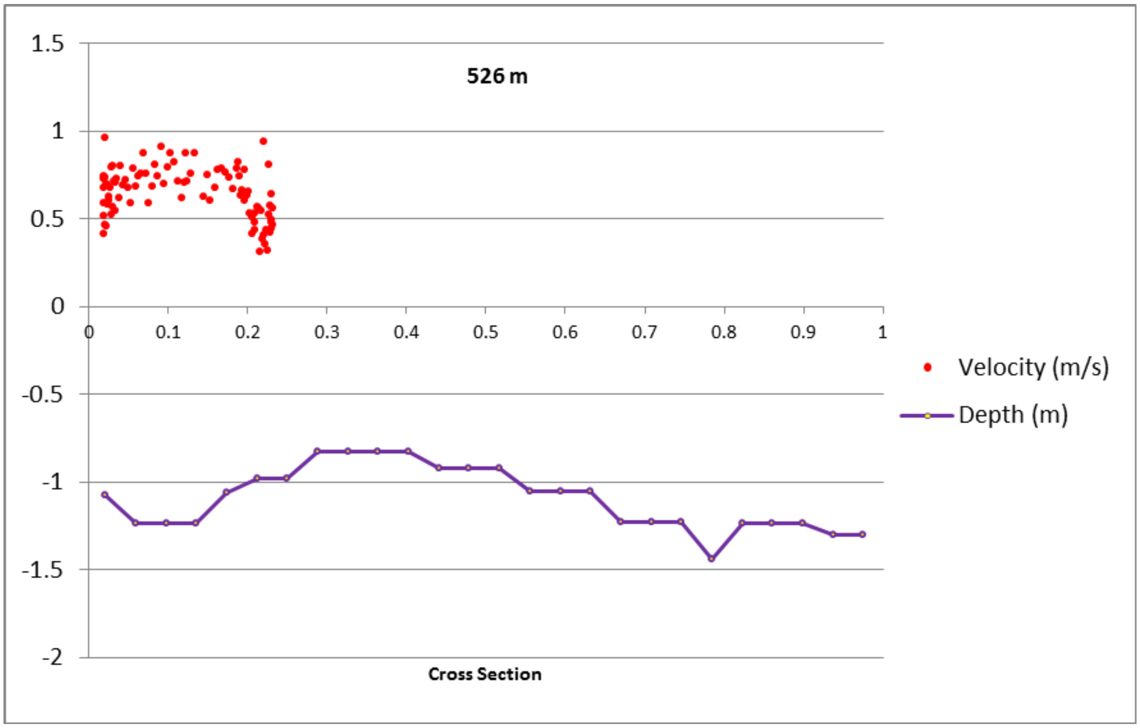

276 m
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Velocity (m/s)
Depth (m)
Cross Section

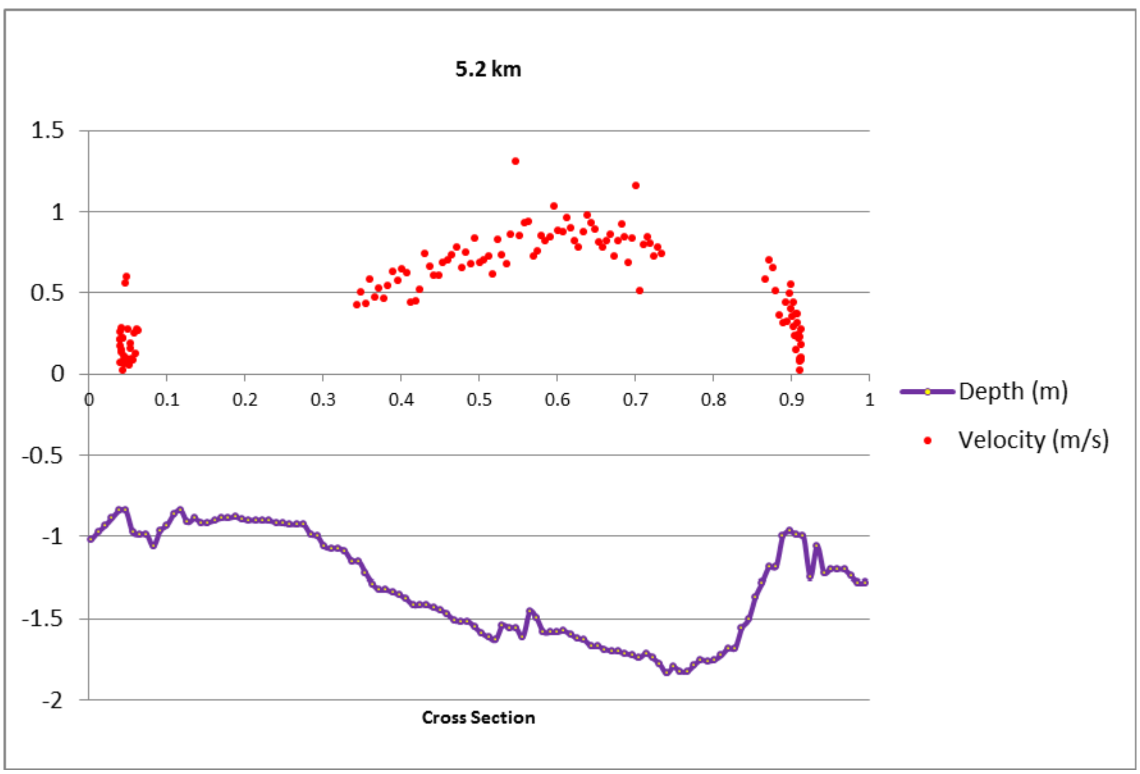

326 m
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
0.2
0.4
0.6
0.8
1
Cross Section
Depth (m)
Velocity (m/s)

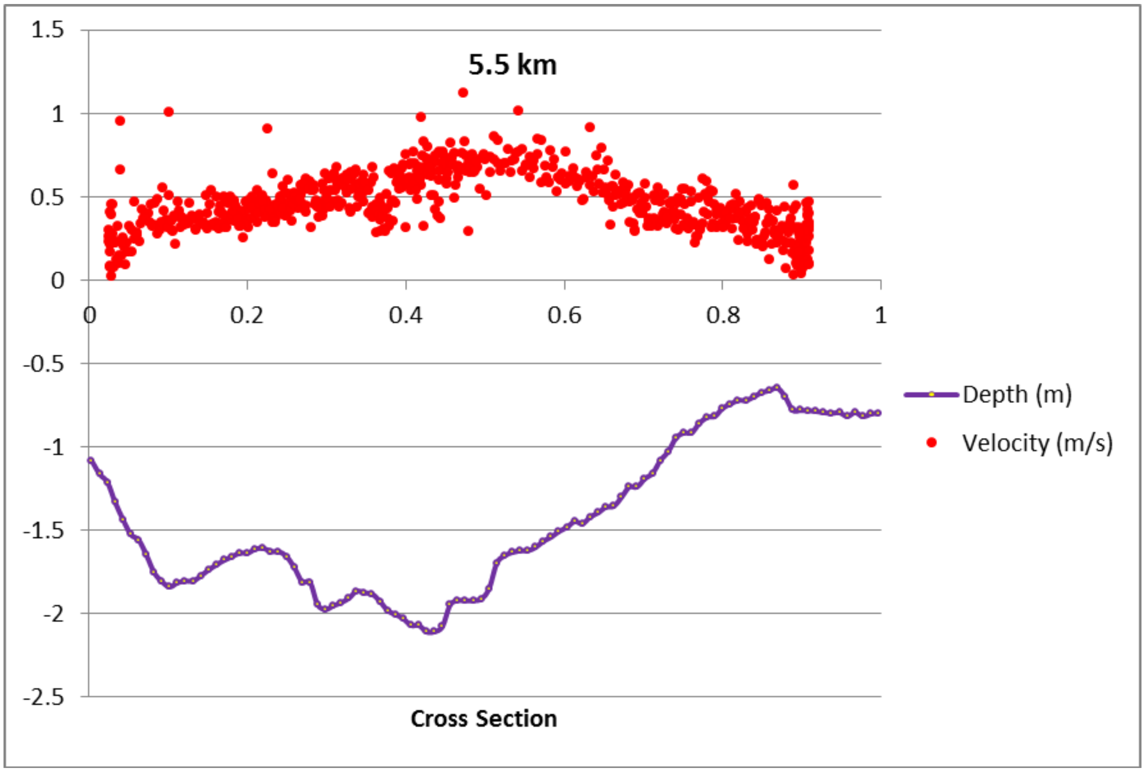

376 m
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
0.2
0.4
0.6
0.8
1
Cross Section
Depth (m)
Velocity (m/s)

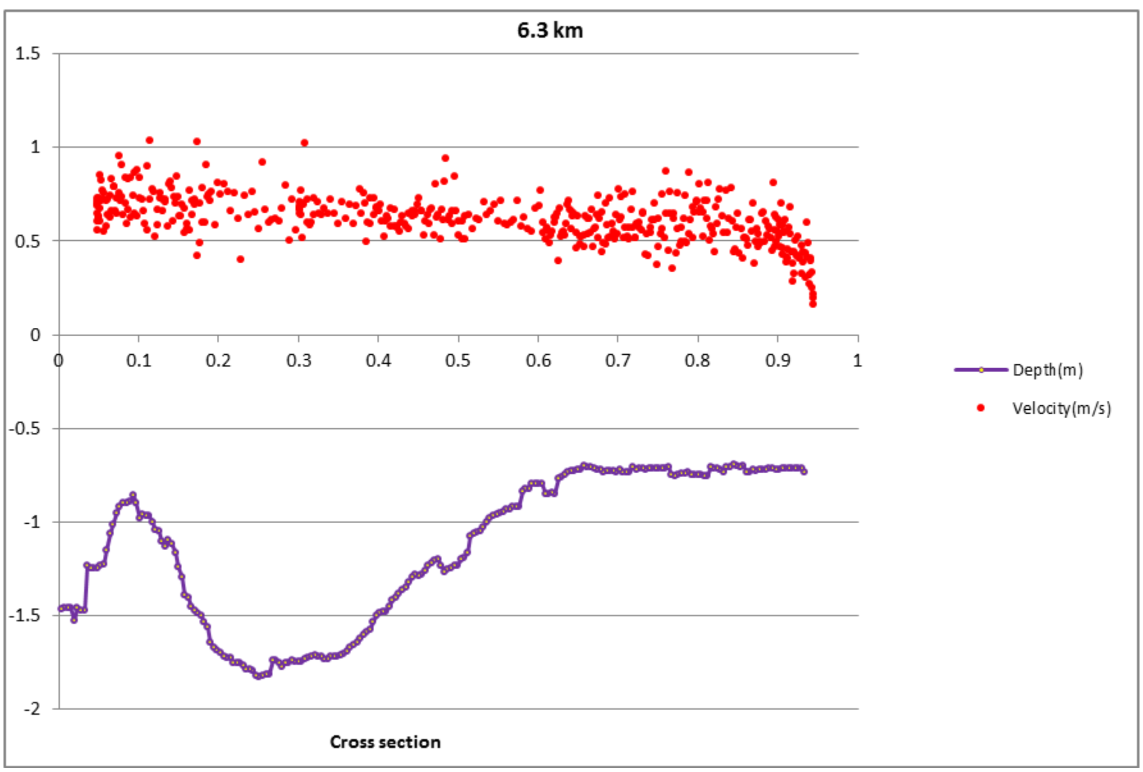

426 m
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Cross Section
Depth (m)
Velocity (m/s)

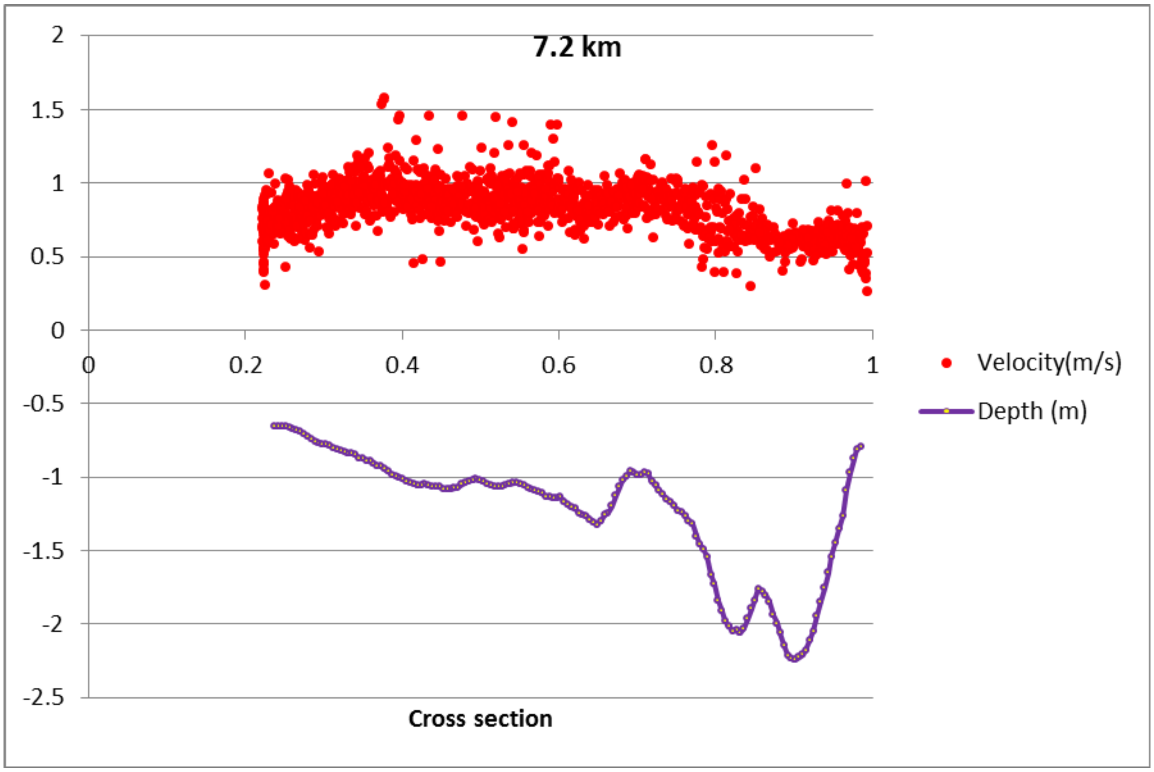

476 m
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.2
0.4
0.6
0.8
1
Cross Section
Velocity (m/s)
Depth (m)

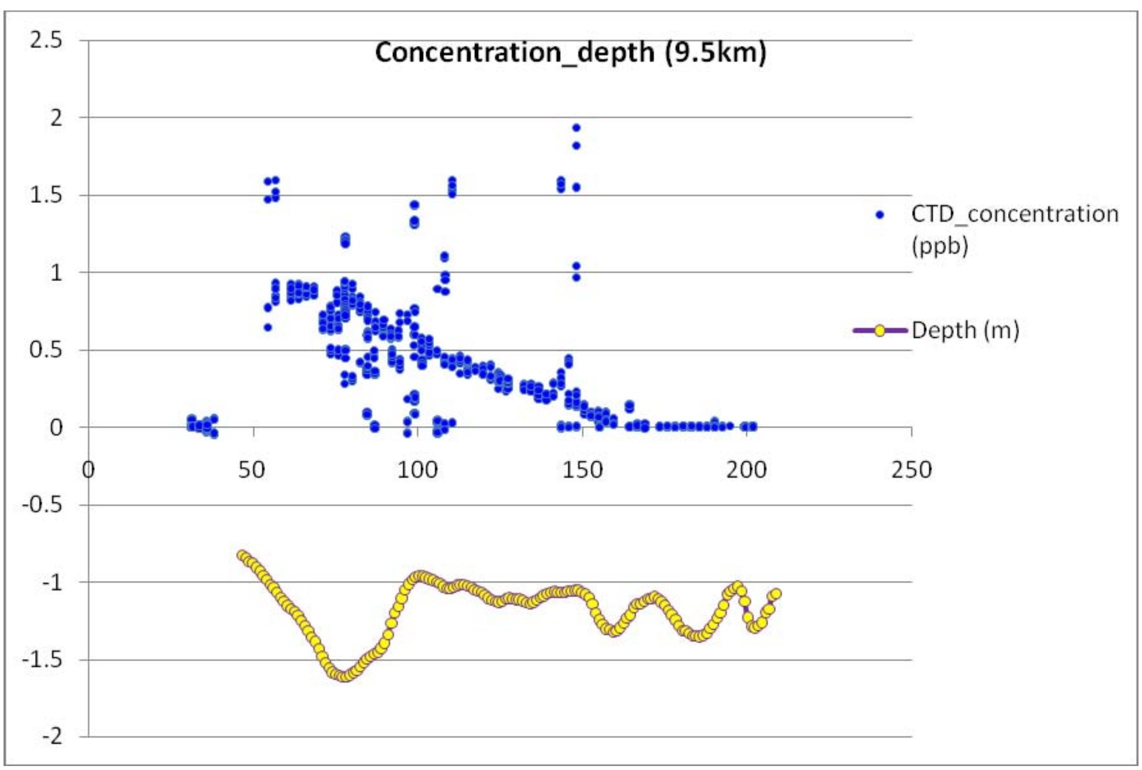

526 m
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Velocity (m/s)
Depth (m)
Cross Section


5.2 km
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Depth (m)
Velocity (m/s)
Cross Section

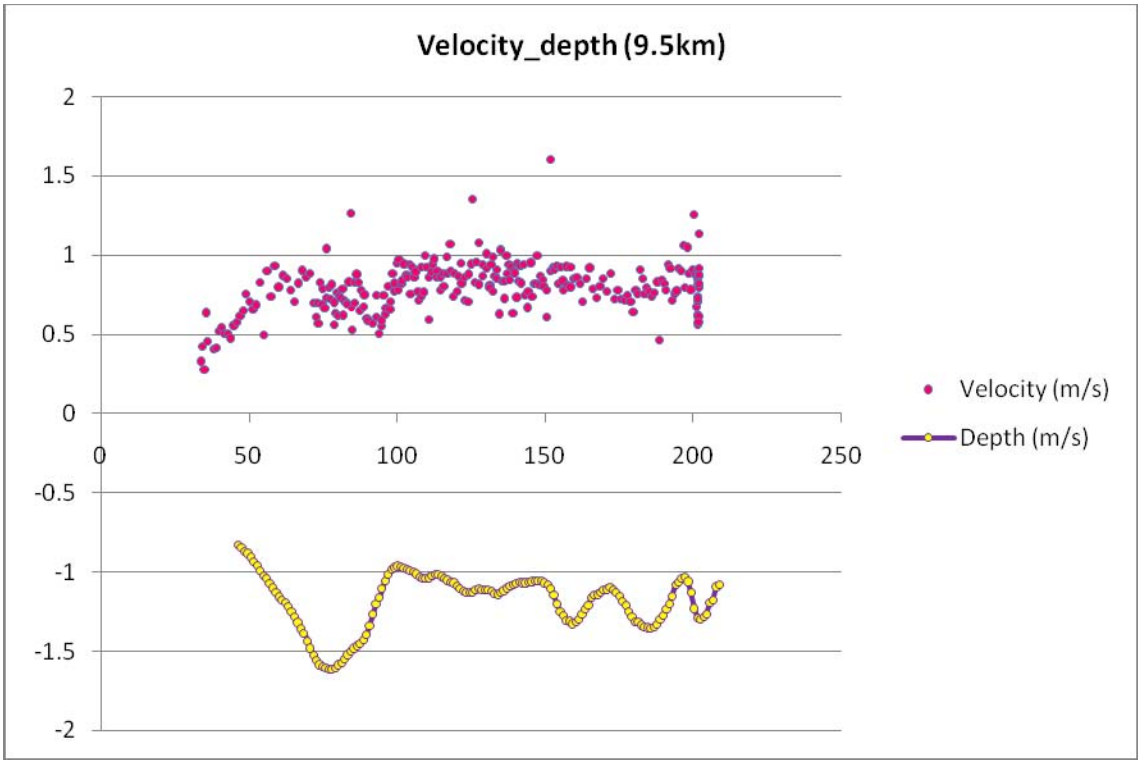

5.5 km
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
0.2
0.4
0.6
0.8
1
Depth (m)
Velocity (m/s)
Cross Section


6.3 km
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Depth(m)
Velocity(m/s)
Cross section



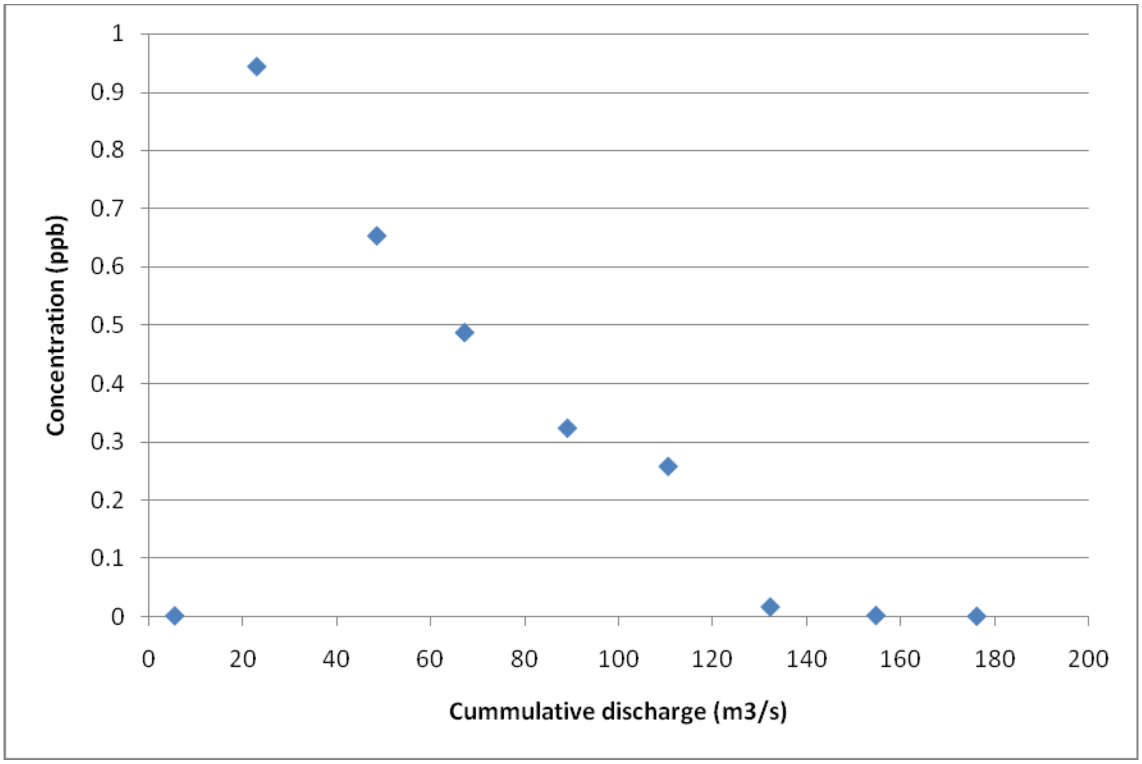


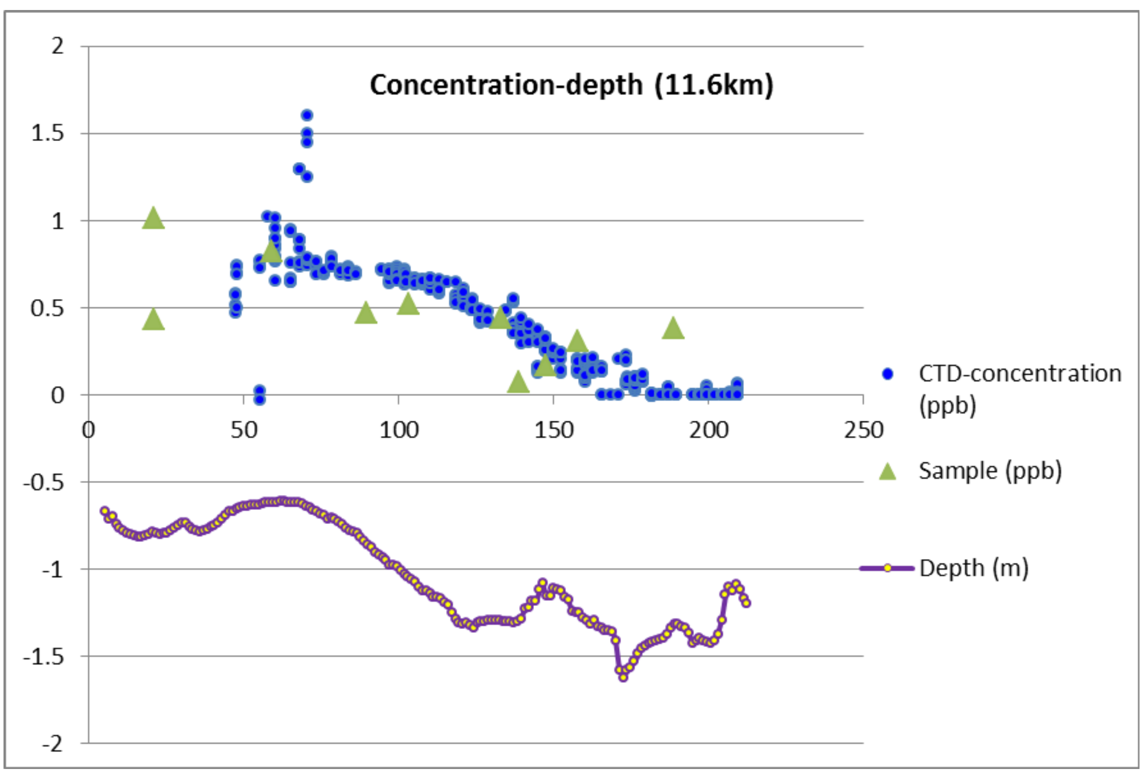
Concentration 9pt5km



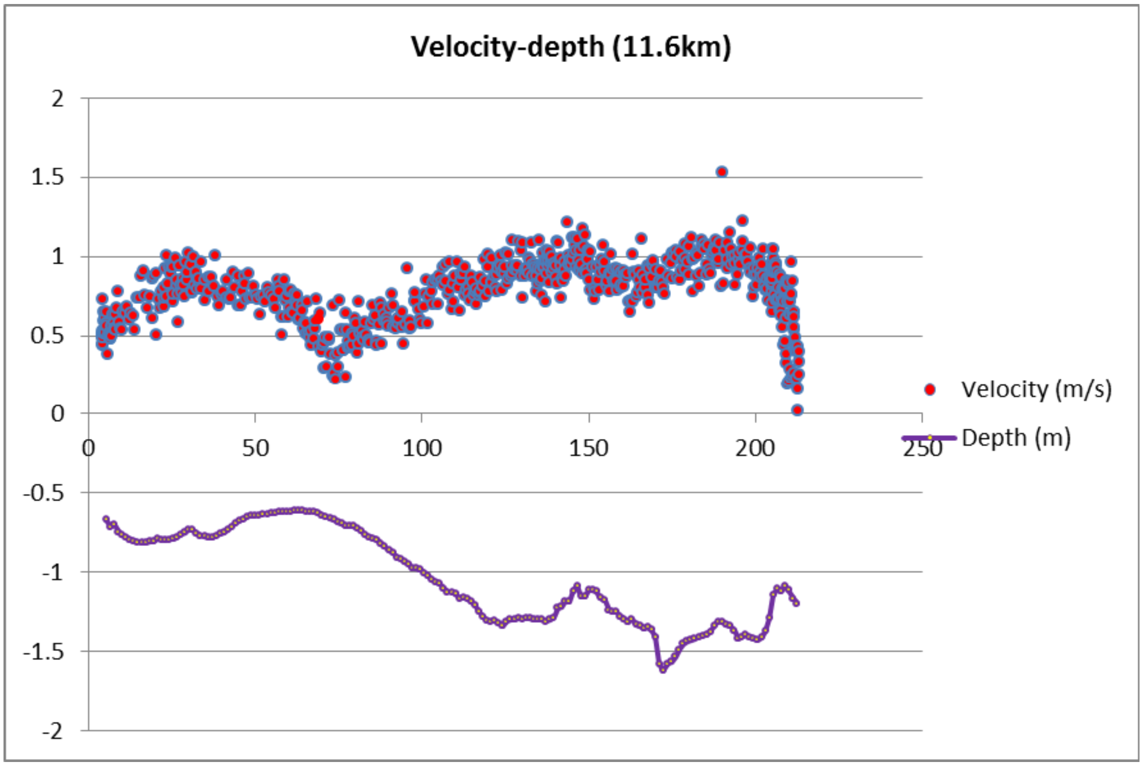
Velocity 9pt5km

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.00	0.00	0.00
0.2-0.3	0.87	1.01	0.94
0.3-0.4	0.62	0.69	0.65
0.4-0.5	0.43	0.54	0.49
0.5-0.6	0.31	0.34	0.32
0.6-0.7	0.18	0.34	0.26
0.7-0.8	0.01	0.02	0.02
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	224.24		
Approximate distance from outfall(km)	9.5		
Time and date	16:09:24	Oct 29 2011	


Concentration (ppb)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
140
160
180
200
Cummulative discharge (m3/s)

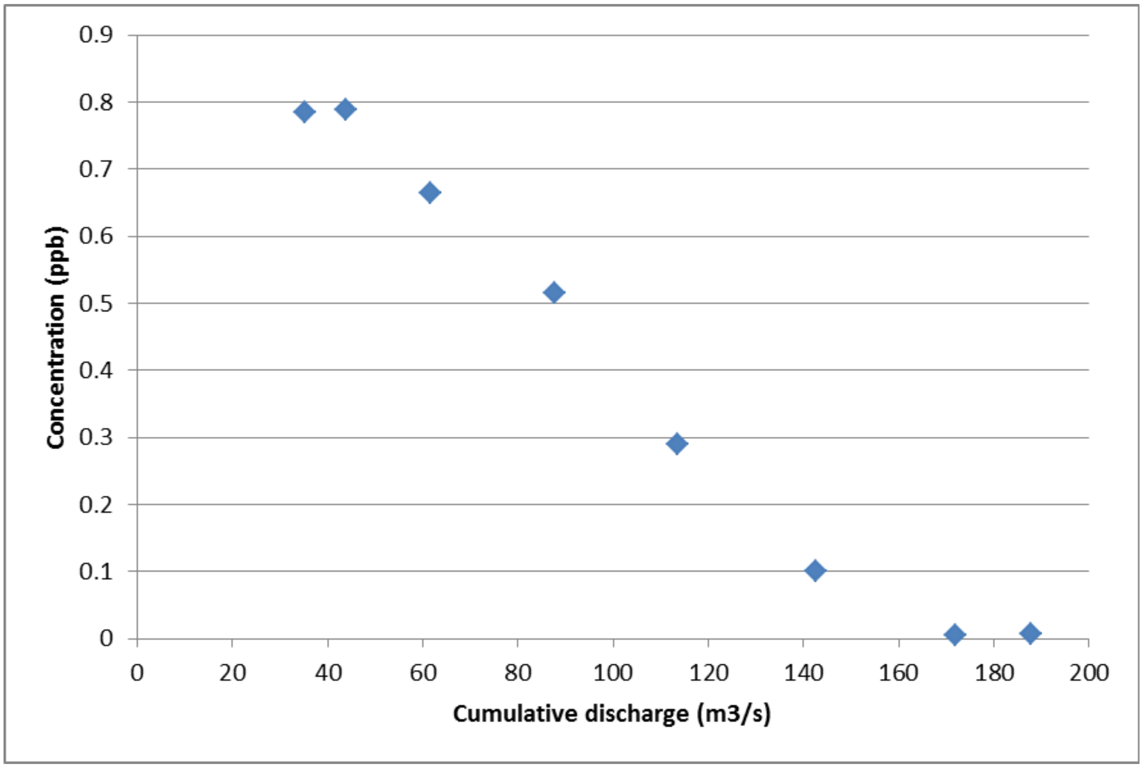

Concentration-depth (11.6km)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
50
100
150
200
250
CTD-concentration (ppb)
Sample (ppb)
Depth (m)

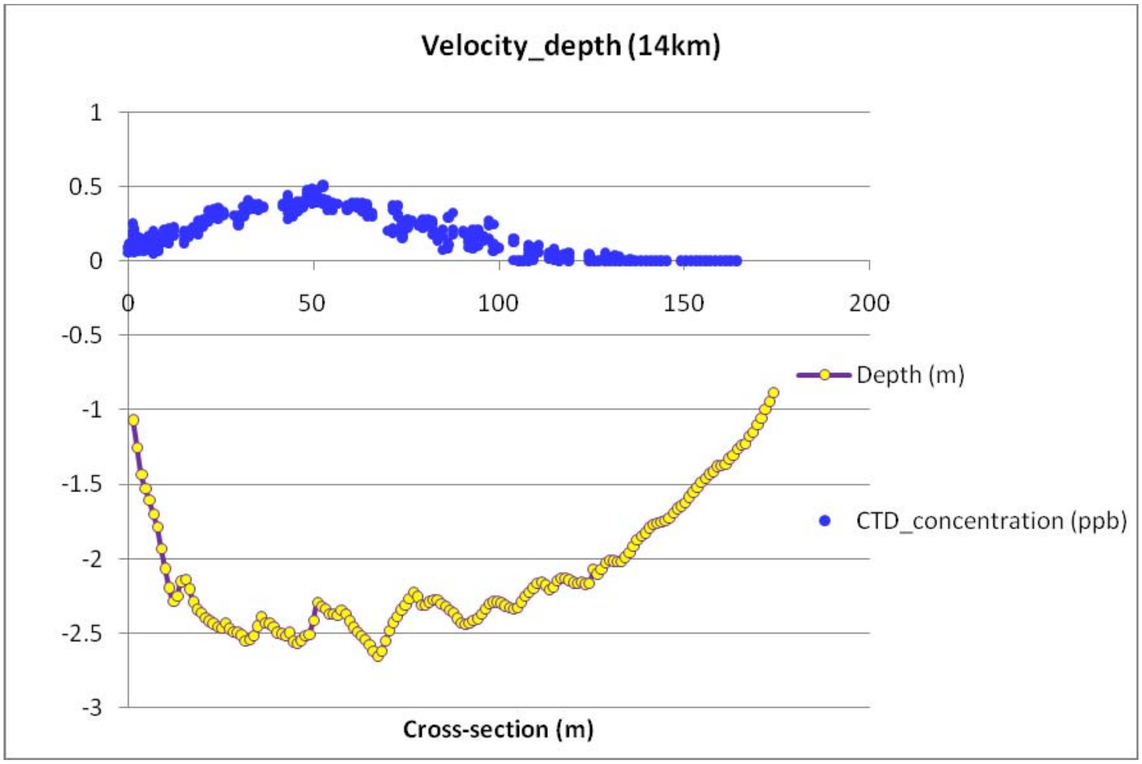
Concentration 11pt6km

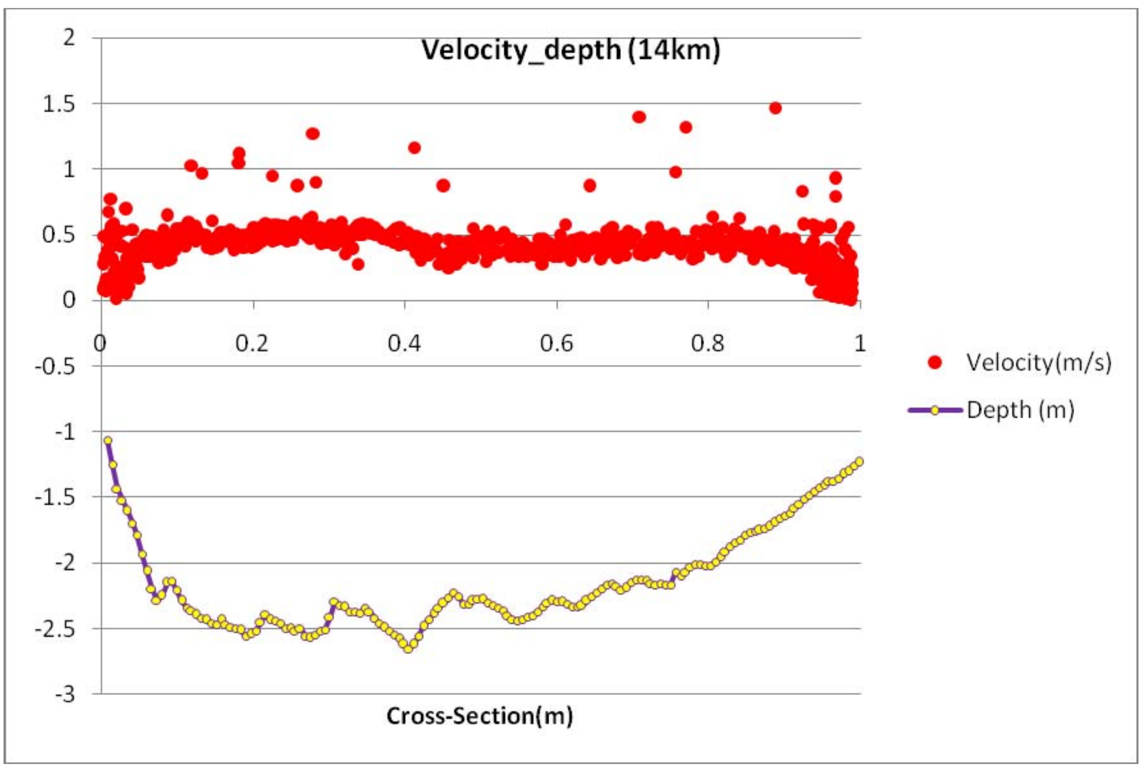


Velocity 11pt6km

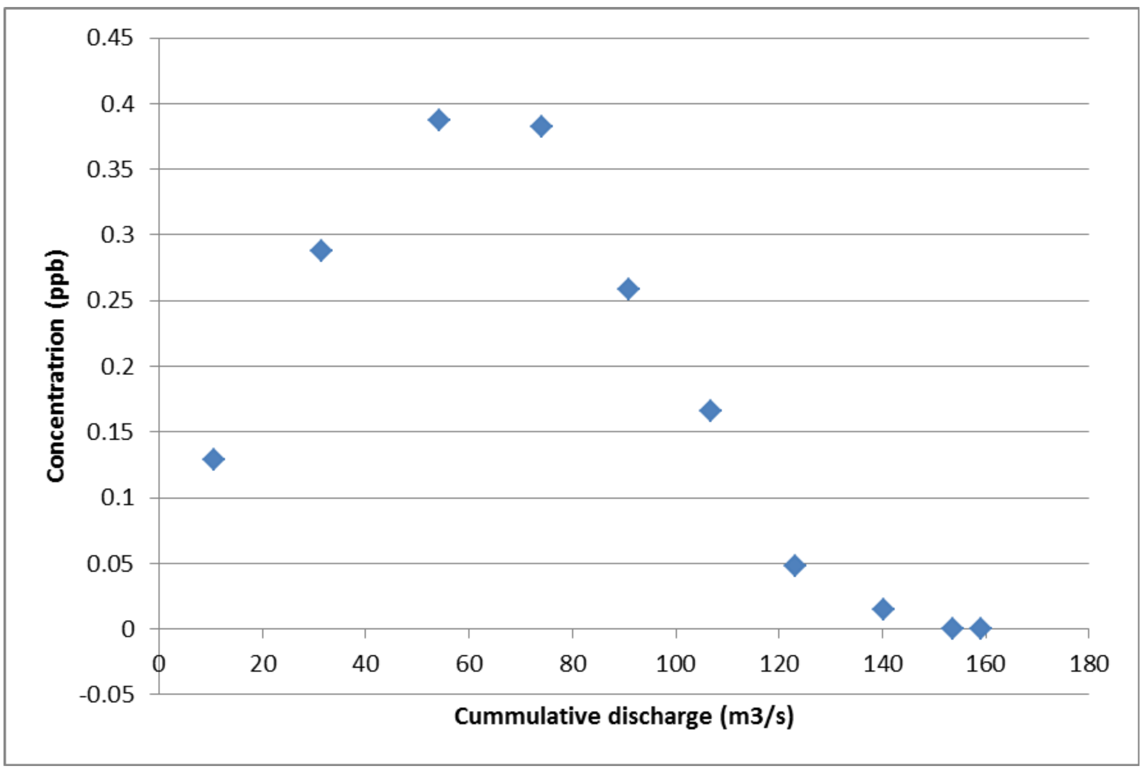
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	0.71	0.86	0.78
0.3-0.4	0.73	0.85	0.79
0.4-0.5	0.65	0.67	0.66
0.5-0.6	0.49	0.54	0.51
0.6-0.7	0.26	0.32	0.29
0.7-0.8	0.08	0.12	0.10
0.8-0.9	0.00	0.01	0.00
0.9-1	0.00	0.01	0.01
Approximate width(m)	228.32		
Approximate distance from outfall(km)	11.6		
Time and date	16:26:04	Oct 29 2011	

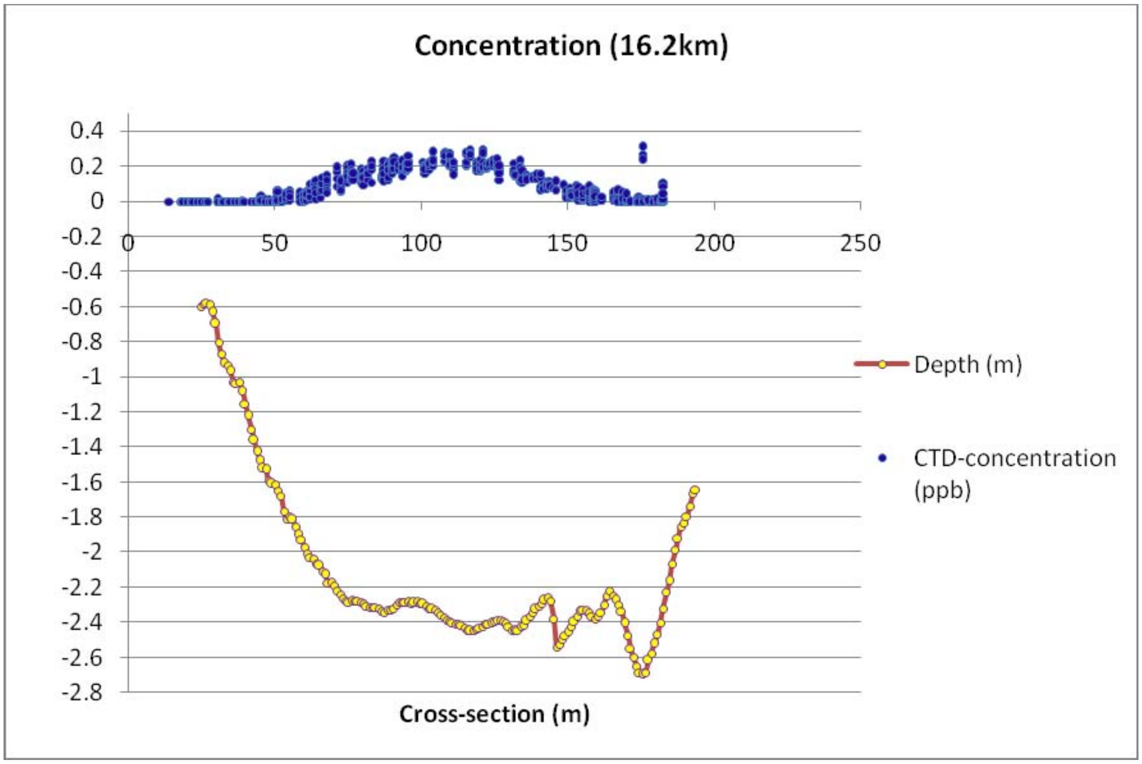

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Concentration (ppb)
0
20
40
60
80
100
120
140
160
180
200
Cumulative discharge (m3/s)


Velocity_depth (14km)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
50
100
150
200
Depth (m)
CTD_concentration (ppb)
Cross-section (m)

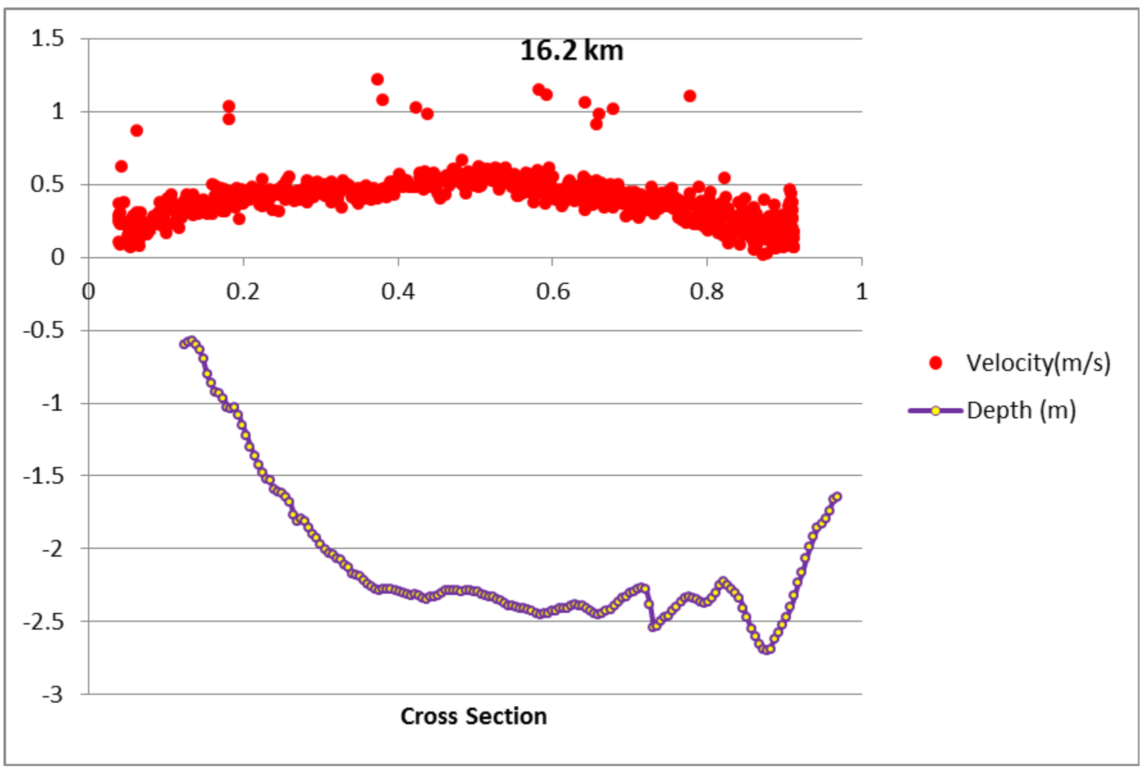

Velocity_depth (14km)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
0.2
0.4
0.6
0.8
1
Velocity(m/s)
Depth (m)
Cross-Section(m)

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.12	0.14	0.13
0.1-0.2	0.27	0.30	0.29
0.2-0.3	0.37	0.40	0.39
0.3-0.4	0.37	0.39	0.38
0.4-0.5	0.24	0.27	0.26
0.5-0.6	0.15	0.18	0.17
0.6-0.7	0.03	0.06	0.05
0.7-0.8	0.01	0.02	0.01
0.8-0.9	0.00	0.00	0.00
0.9-1	0.00	0.00	0.00
Approximate width(m)	165.95		
Approximate distance from outfall(km)	14		
Time and date	16:53:18	Oct 29 2011	



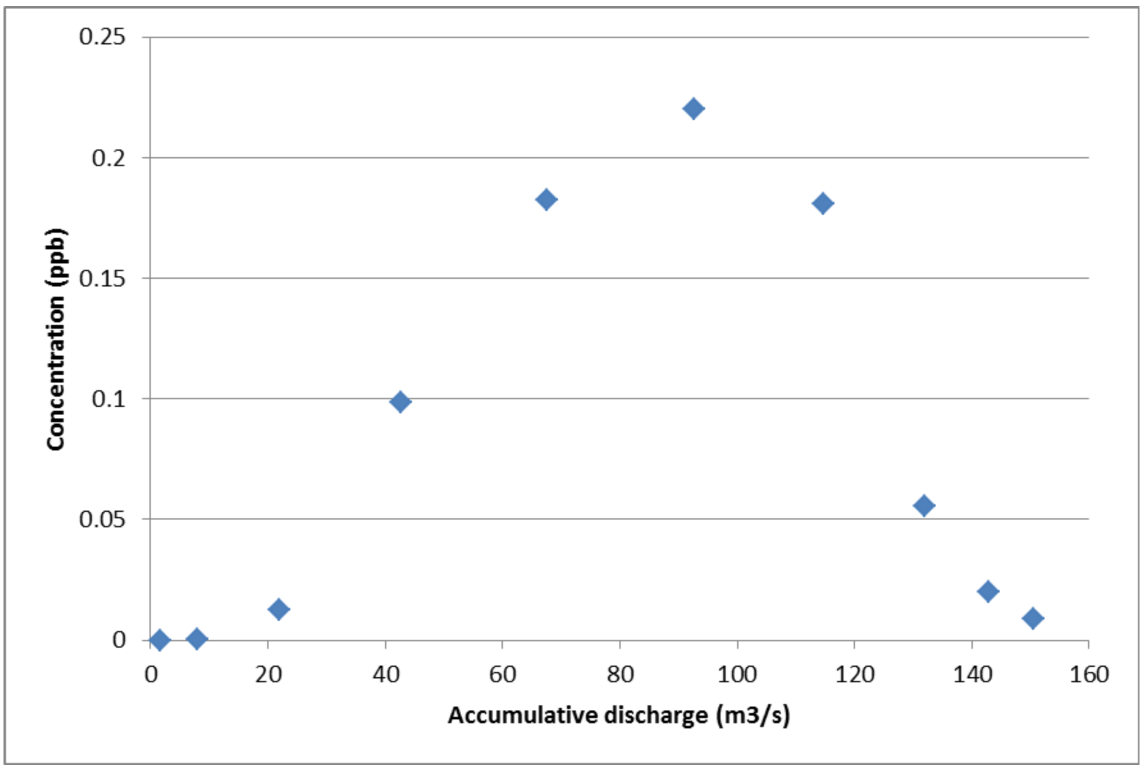


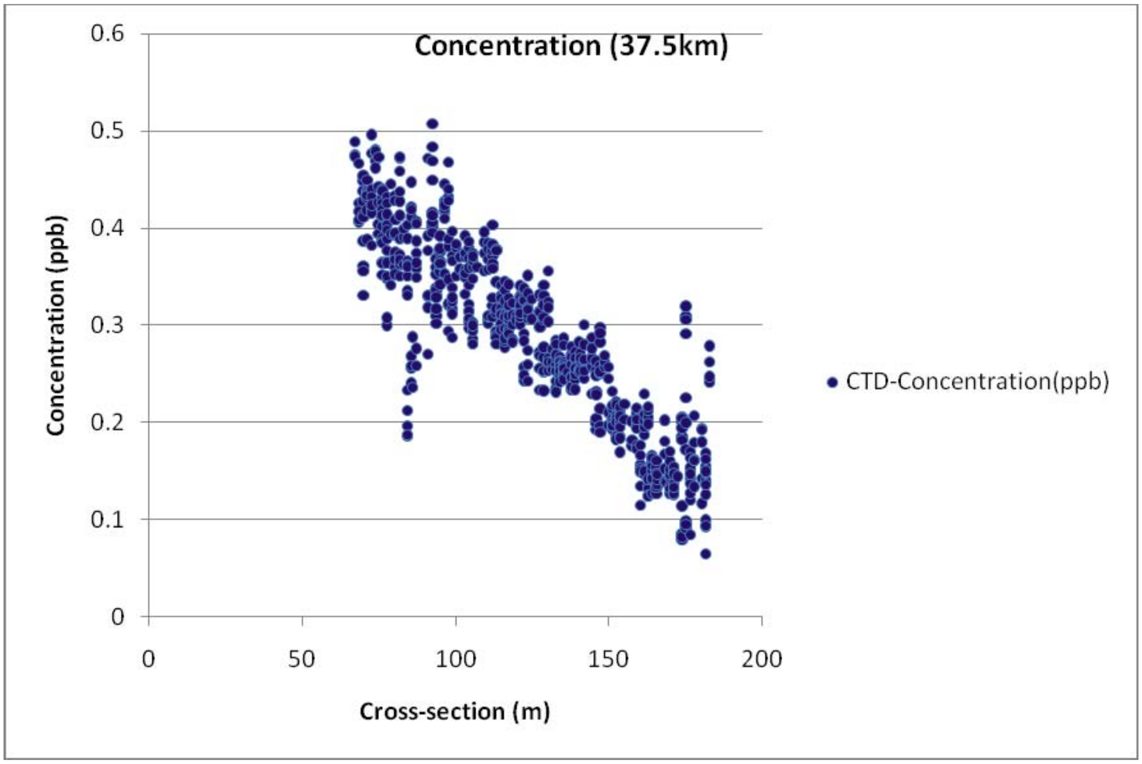
Concentration 16pt2km



Velocity 16pt2km

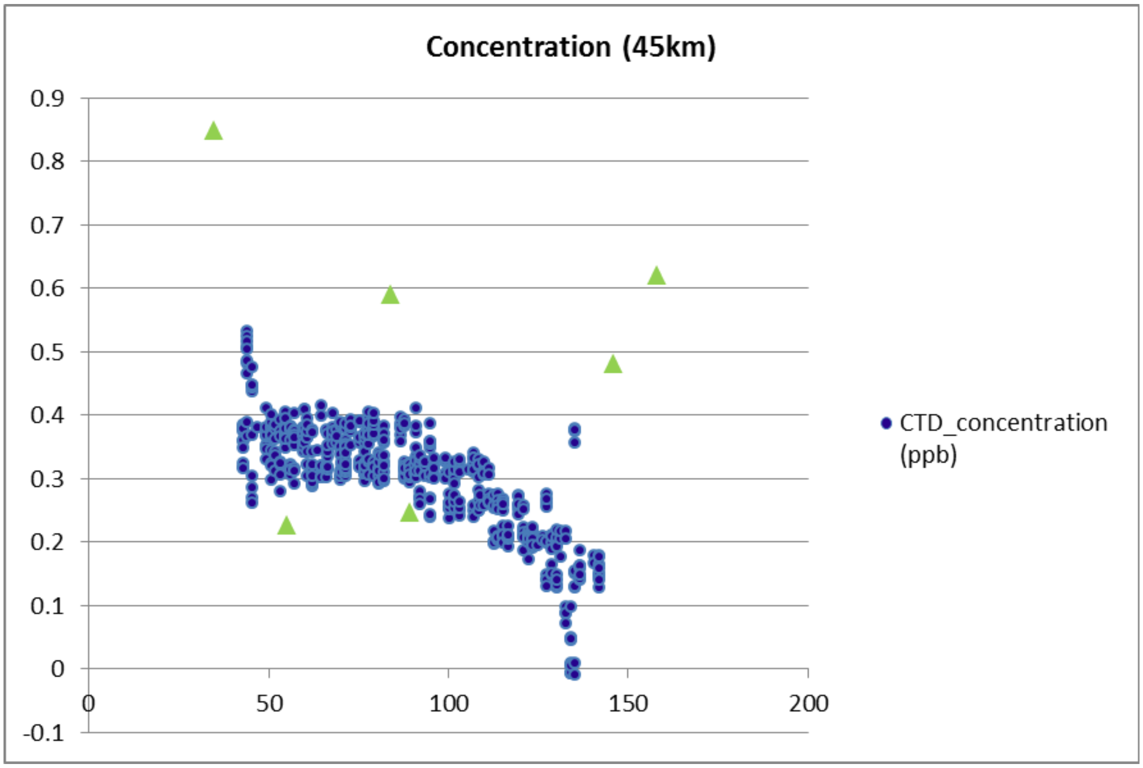
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.00	0.00	0.00
0.1-0.2	0.00	0.00	0.00
0.2-0.3	0.01	0.02	0.01
0.3-0.4	0.09	0.11	0.10
0.4-0.5	0.18	0.19	0.18
0.5-0.6	0.21	0.23	0.22
0.6-0.7	0.17	0.19	0.18
0.7-0.8	0.05	0.06	0.06
0.8-0.9	0.01	0.03	0.02
0.9-1	0.00	0.02	0.01
Approximate width(m)	199.98		
Approximate distance from outfall(km)	16.2		
Time and date	17:18:15	Oct 29 2011	





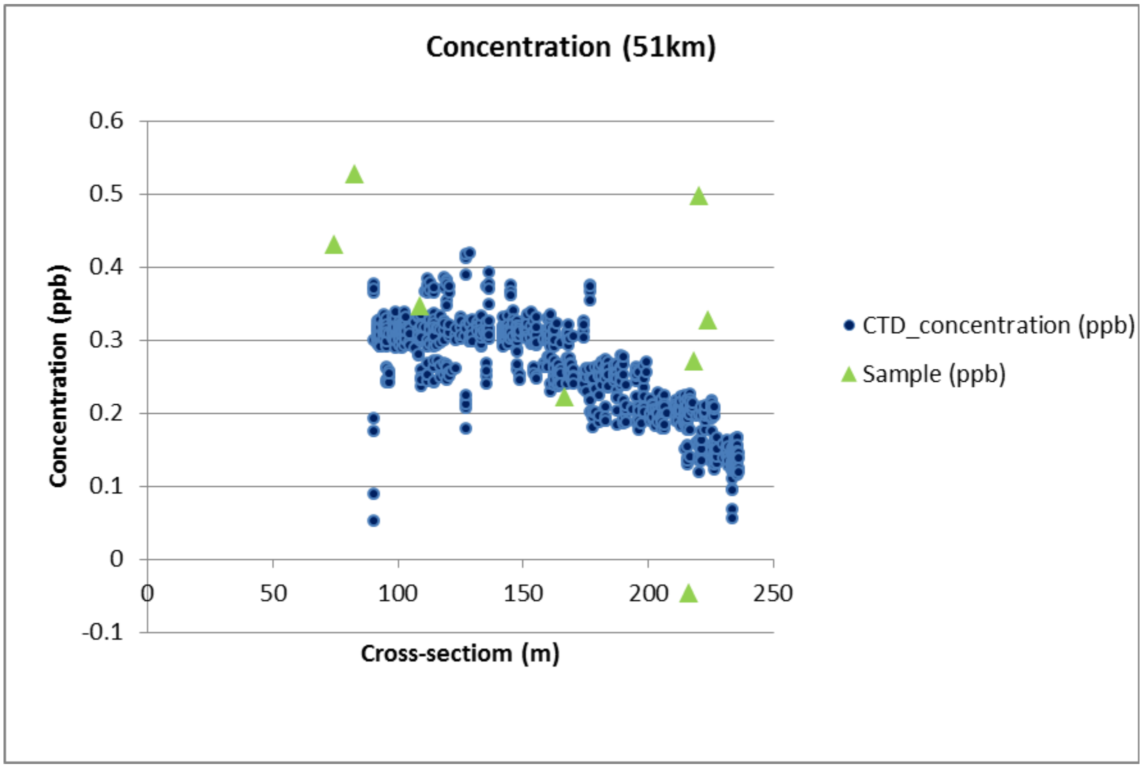
Concentration 37pt5km

cross-section	Lower(ppb)	Upper(ppb)	Average(ppb)
0.05			
0.15			
0.25			
0.35	0.40	0.42	0.41
0.45	0.35	0.38	0.37
0.55	0.32	0.34	0.33
0.65	0.27	0.28	0.28
0.75	0.21	0.22	0.21
0.85	0.15	0.17	0.16
0.95			
Approximate width (m)	201.14709		
Approximate distance from outfall(km)		37.5km	
Time and date		13:50:27	Oct 30 2011



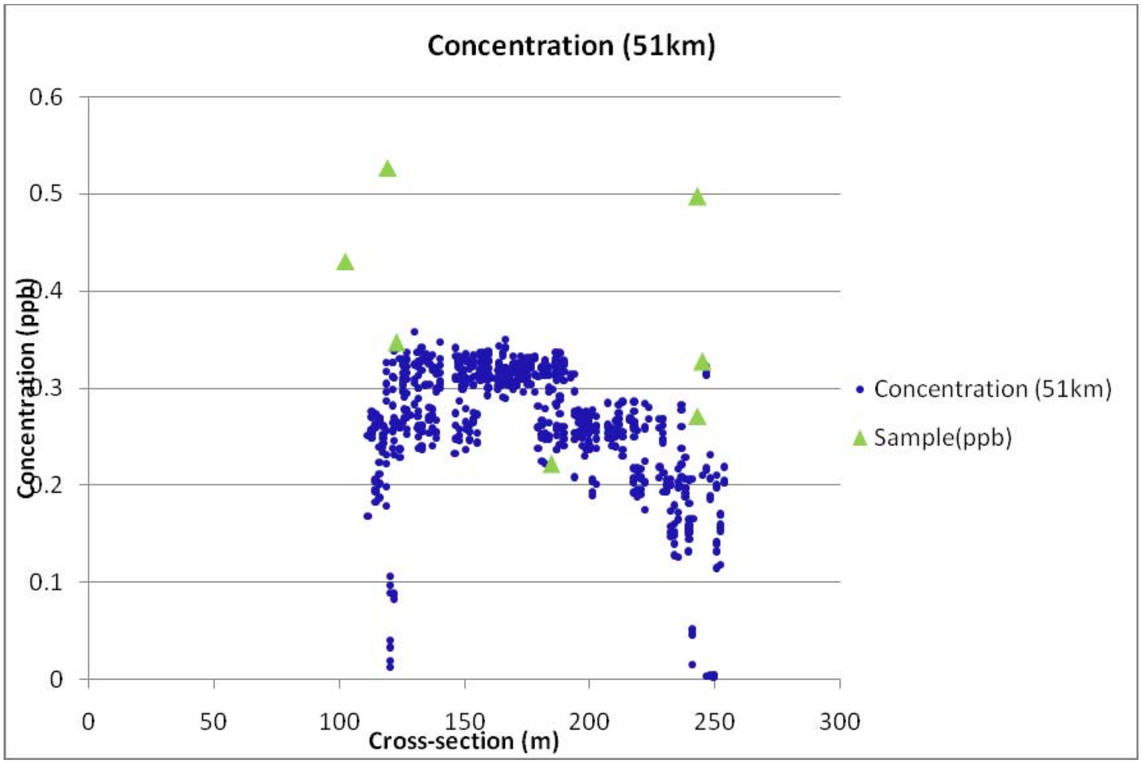
Concentration 45km

cross-section	Lower(ppb)	Upper(ppb)	Average(ppb)
0.25	0.36	0.39	0.38
0.35	0.34	0.36	0.35
0.45	0.34	0.35	0.34
0.55	0.30	0.31	0.30
0.65	0.23	0.25	0.24
0.75	0.13	0.17	0.15
Approximate width (m)	180.34		
Approximate distance from outfall(km)	45km		
Time and date	14:27:19	30-Oct-11	



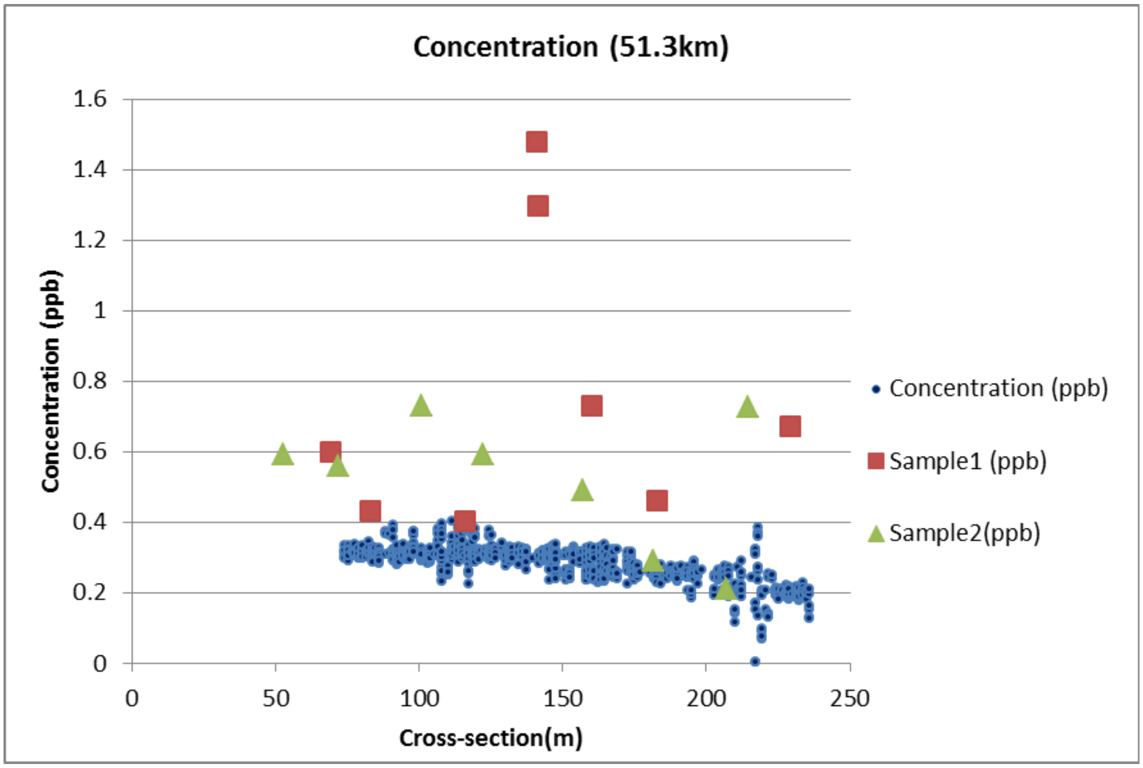
Concentration 51km_1

cross-section	Lower(ppb)	Upper(ppb)	Average(ppb)	
0.05				
0.15				
0.25				
0.35		0.30	0.31	0.30
0.45		0.30	0.32	0.31
0.55		0.30	0.31	0.31
0.65		0.26	0.27	0.27
0.75		0.21	0.22	0.22
0.85		0.16	0.17	0.16
0.95				
Approximate width (m)	263.75			
Approximate distance from outfall(km)	51.00			
Time and date	15:41:12	Oct 30 2011		



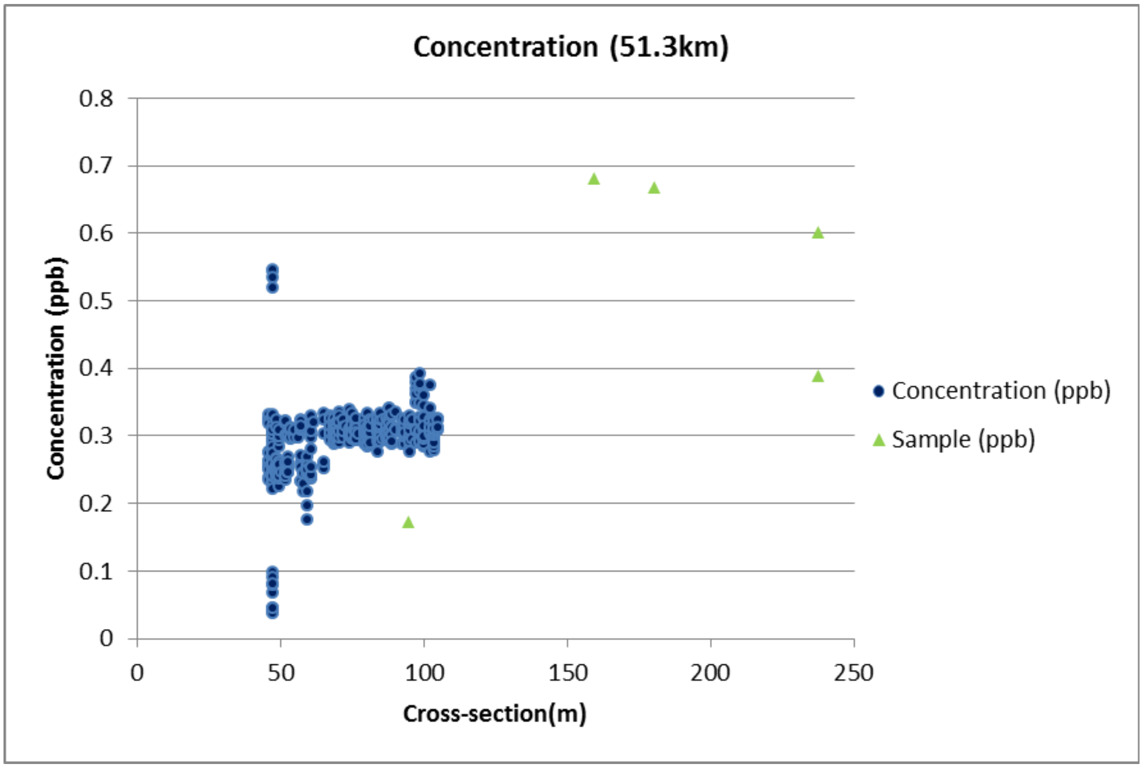
Concentration 51km_2

Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3			
0.3-0.4			
0.4-0.5	0.25	0.28	0.26
0.5-0.6	0.30	0.31	0.30
0.6-0.7	0.30	0.31	0.31
0.7-0.8	0.26	0.27	0.26
0.8-0.9	0.19	0.21	0.20
0.9-1	0.11	0.17	0.14
Aproximate width(m)	269.00		
Approximate distance from outfall(km)	51.00		
Time and Date	15:11:46	Oct30 2011	



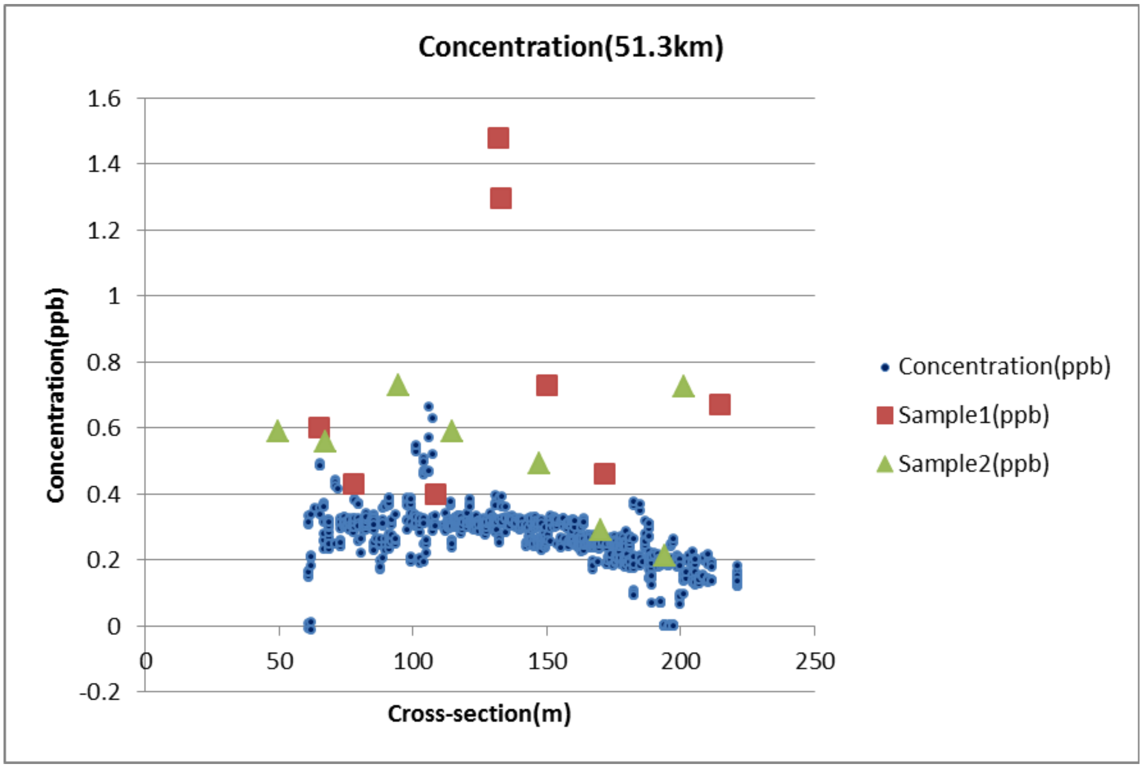
Concentration 51pt3km_1

cross-section	Lower(ppb)	Upper(ppb)	Average(ppb)
0.05			
0.15			
0.25	0.31	0.31	0.31
0.35	0.31	0.31	0.32
0.45	0.32	0.31	0.32
0.55	0.30	0.29	0.30
0.65	0.27	0.27	0.28
0.75	0.24	0.23	0.24
0.85	0.20	0.19	0.21
0.95			
Approximate width (m)	264.63		
Approximate distance from outfall(km)	51.3		
Time and date	16:19:21	Oct 30 2011	



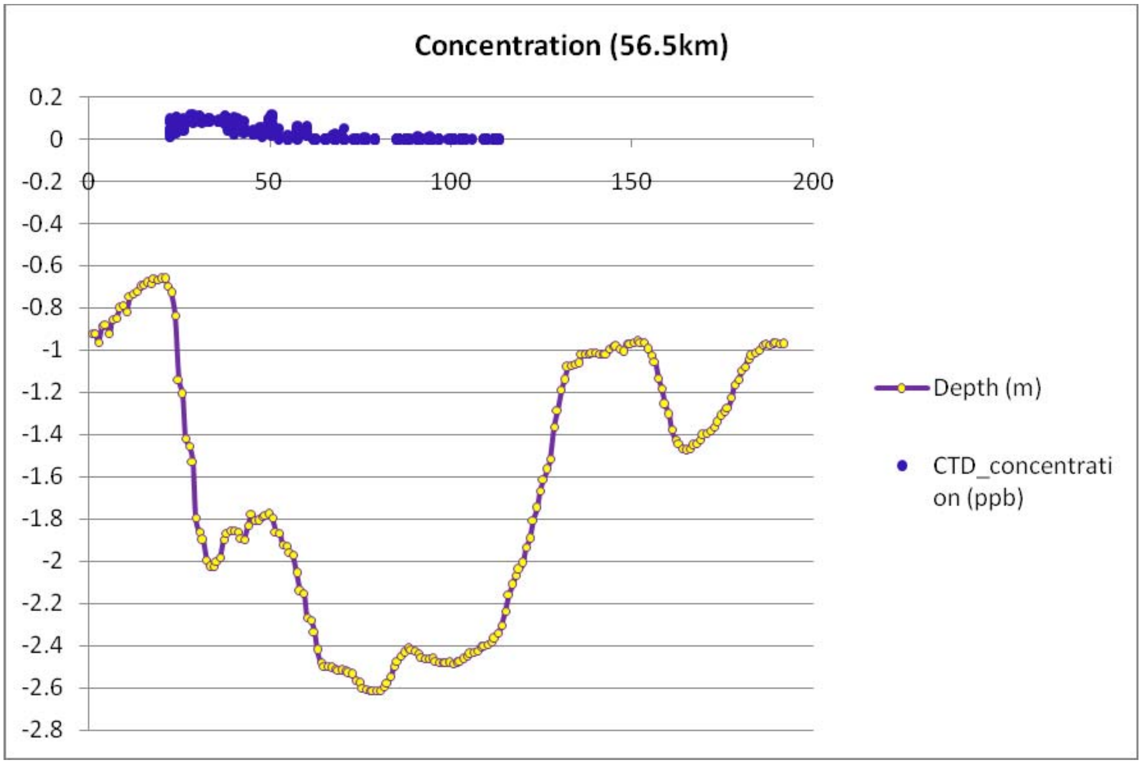
Concentration 51pt3km_2

cross-section	Lower(ppb)	Upper(ppb)	Average(ppb)
0.05			
0.15	0.25	0.27	0.26
0.25	0.29	0.30	0.30
0.35	0.31	0.32	0.31
0.45			
0.55			
0.65			
0.75			
0.85			
0.95			
Approximate width (m)	266.94		
Approximate distance from outfall(km)	51.30		
Time and date	17:00:52	Oct 30 2011	

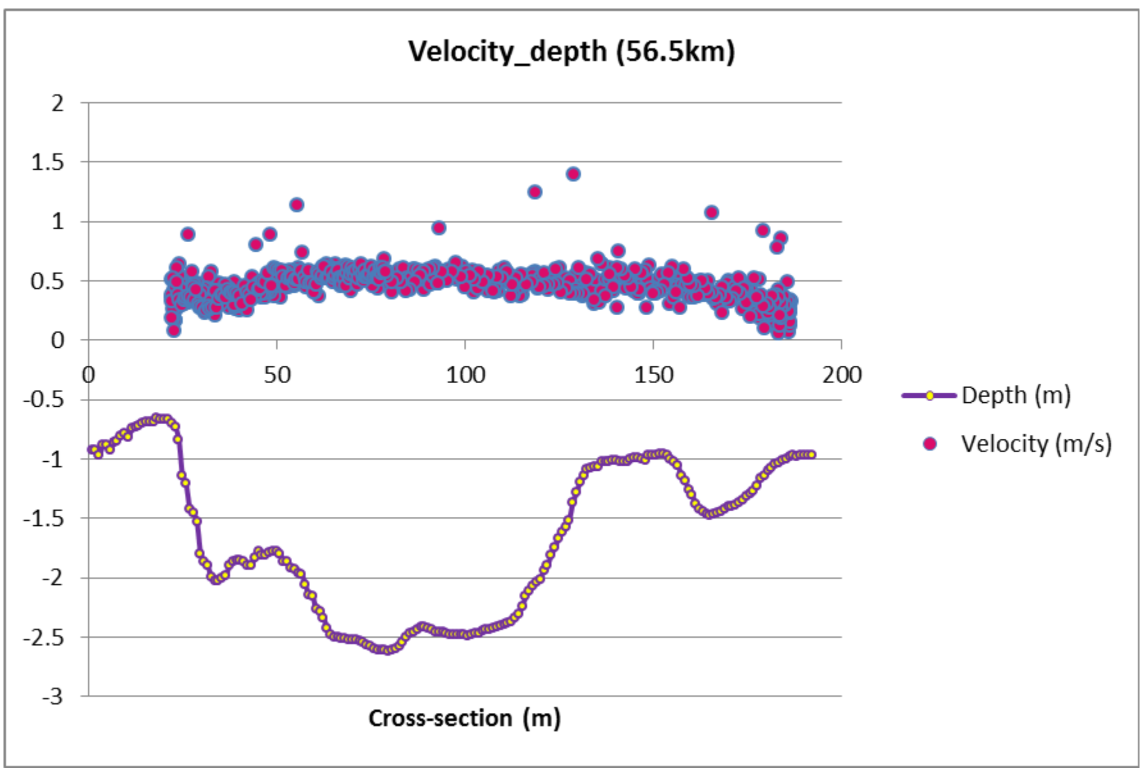


Concentration 51pt3km_3

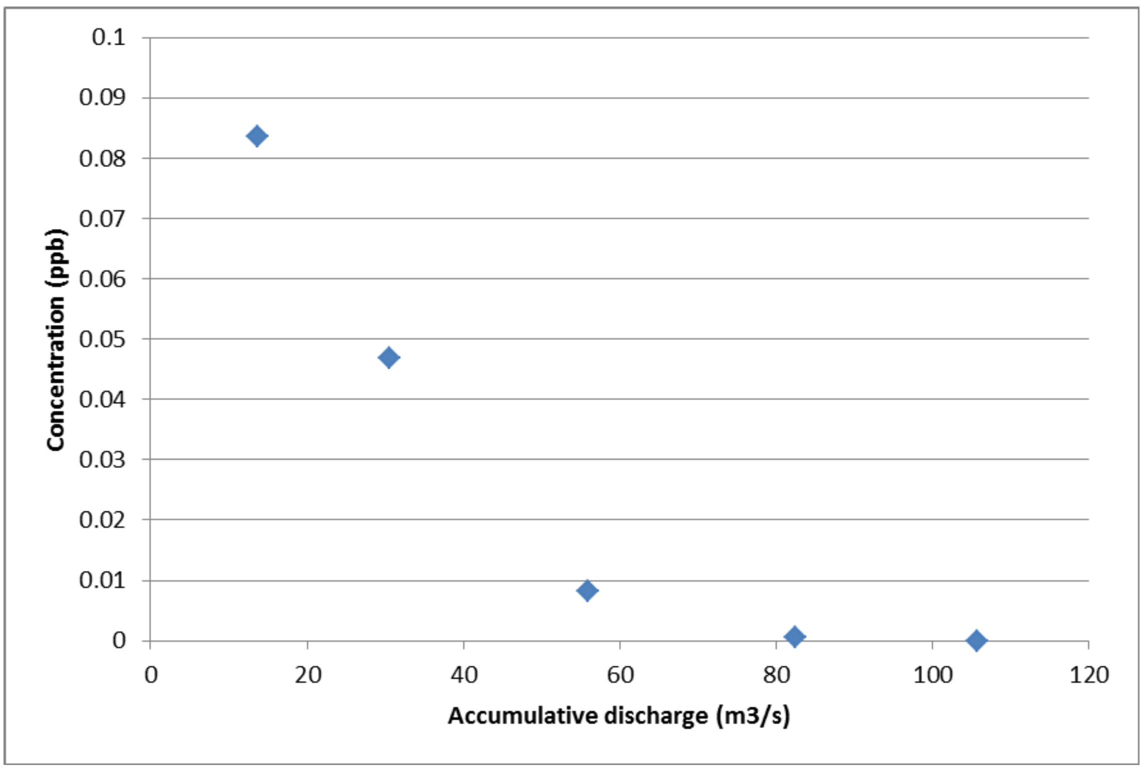
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	0.27	0.31	0.29
0.3-0.4	0.30	0.31	0.30
0.4-0.5	0.32	0.34	0.33
0.5-0.6	0.30	0.31	0.30
0.6-0.7	0.26	0.27	0.27
0.7-0.8	0.18	0.20	0.19
0.8-0.9	0.15	0.17	0.16
0.9-1			
Aproximate width(m)	247.88		
Approximate distance from outfall(km)	51.30		
Time and Date	16:19:21	Oct 30 2011	

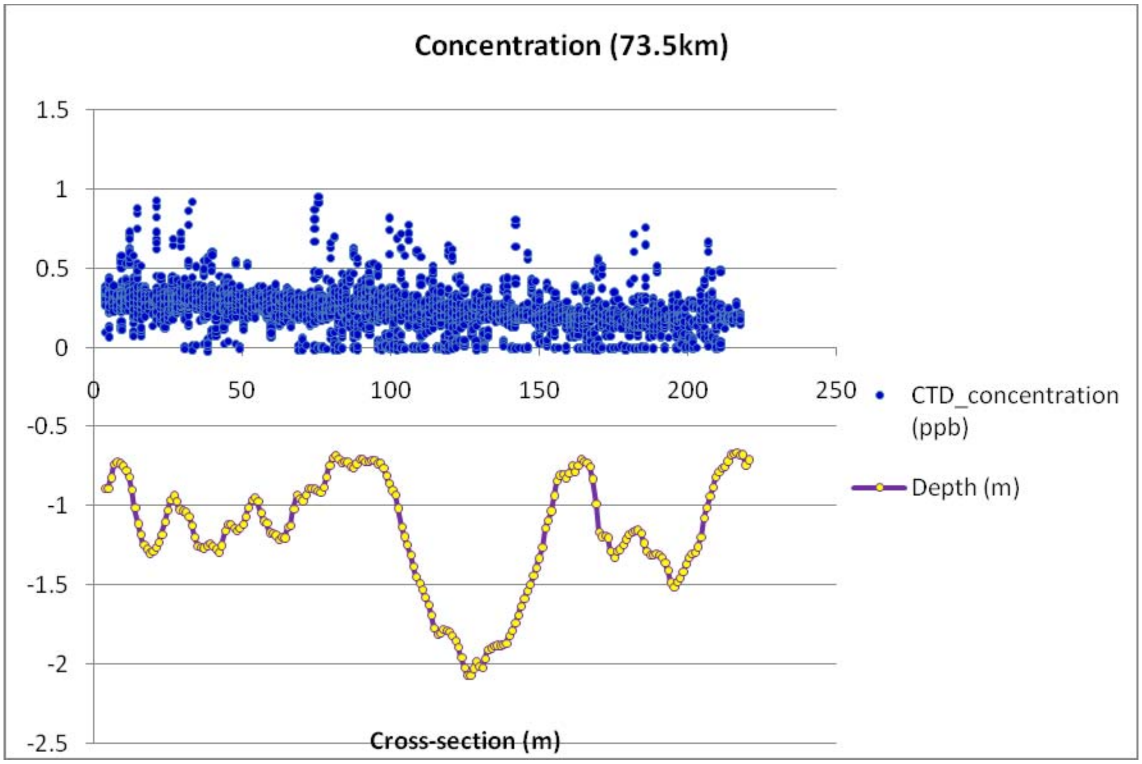


Concentration 56pt5km

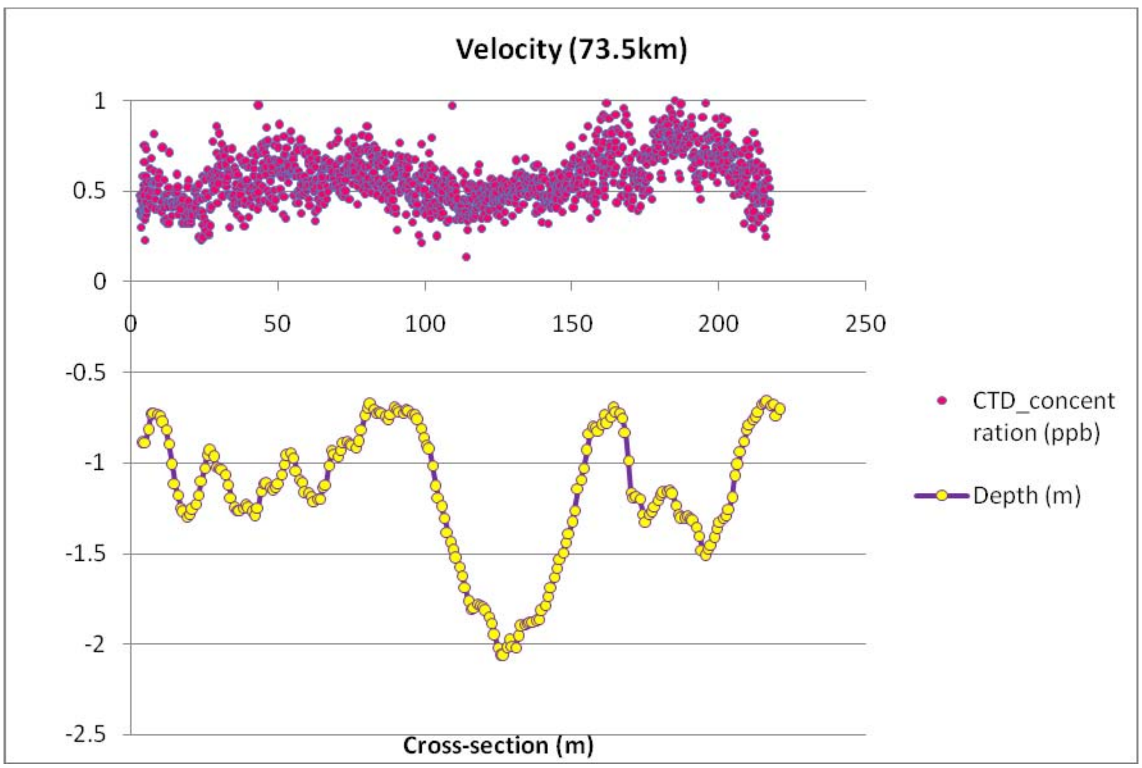


Cross-section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.08	0.09	0.08
0.2-0.3	0.04	0.05	0.05
0.3-0.4	0.00	0.01	0.01
0.4-0.5	0.00	0.00	0.00
0.5-0.6	0.00	0.00	0.00
0.6-0.7			
0.7-0.8			
0.8-0.9			
0.9-1			
Approximate width(m)	192.64		
Approximate distance from outfall(km)	56.5		
Time and date	10:04:40	Oct 31 2011	

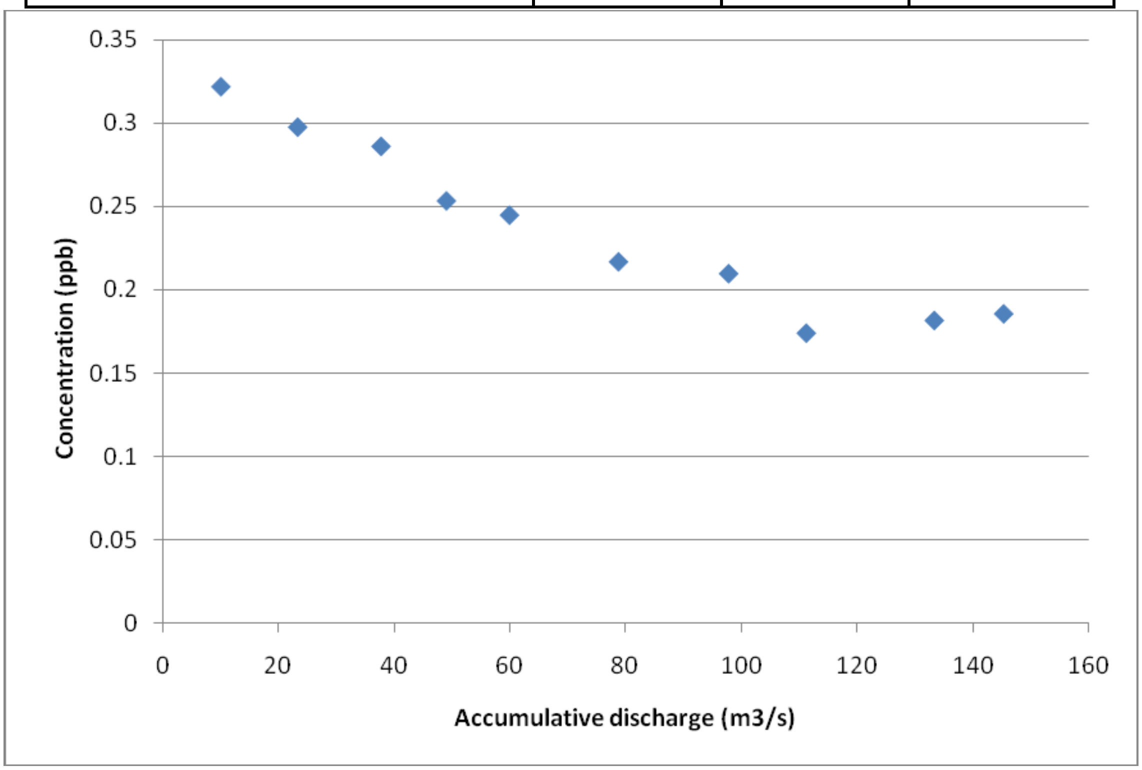


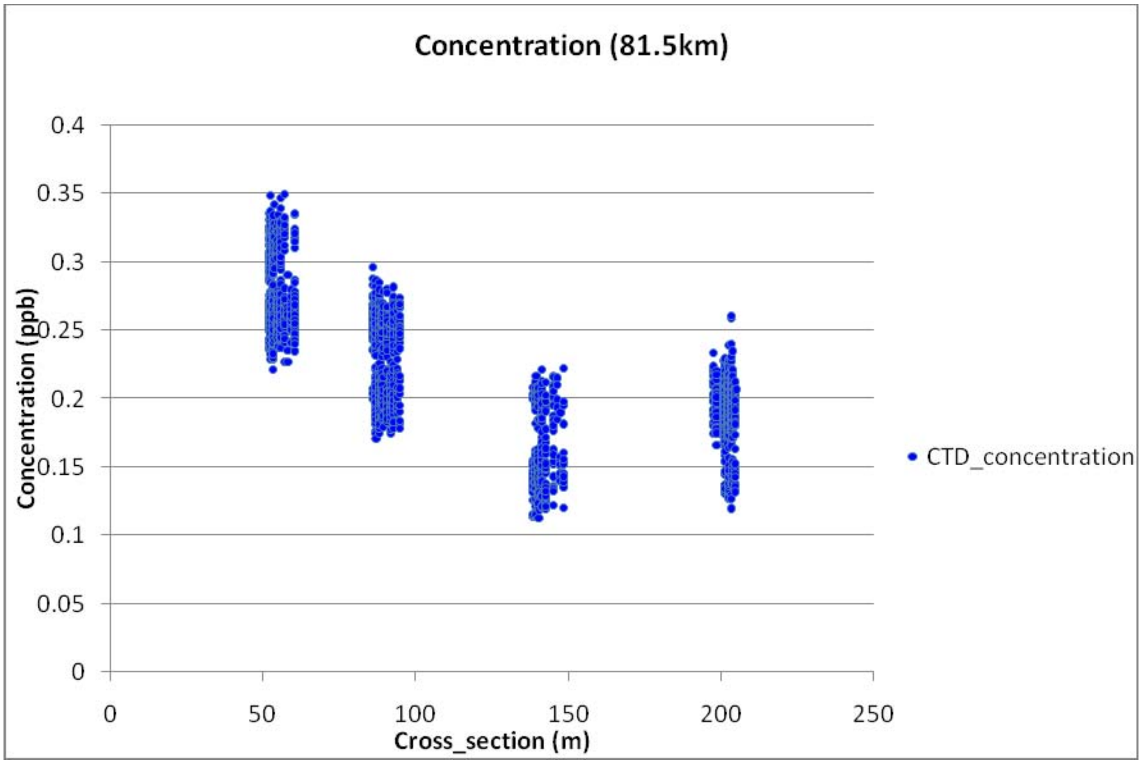


Concentration 73pt5km



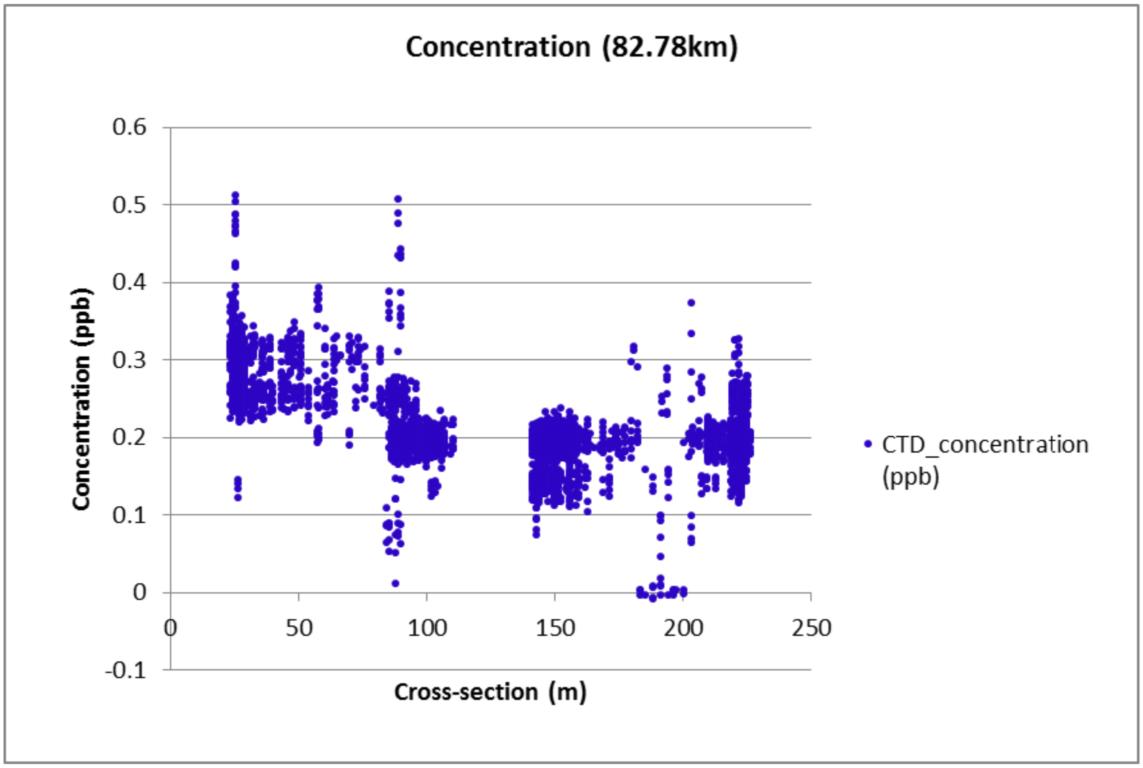
Cross-section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1	0.31	0.33	0.32
0.1-0.2	0.29	0.31	0.30
0.2-0.3	0.28	0.29	0.29
0.3-0.4	0.24	0.26	0.25
0.4-0.5	0.23	0.26	0.24
0.5-0.6	0.21	0.23	0.22
0.6-0.7	0.20	0.22	0.21
0.7-0.8	0.17	0.18	0.17
0.8-0.9	0.17	0.19	0.18
0.9-1	0.17	0.20	0.19
Approximate width(m)	220.51		
Approximate distance from outfall(km)	73.5		
Time and date	10:44:49	Oct 31 2011	





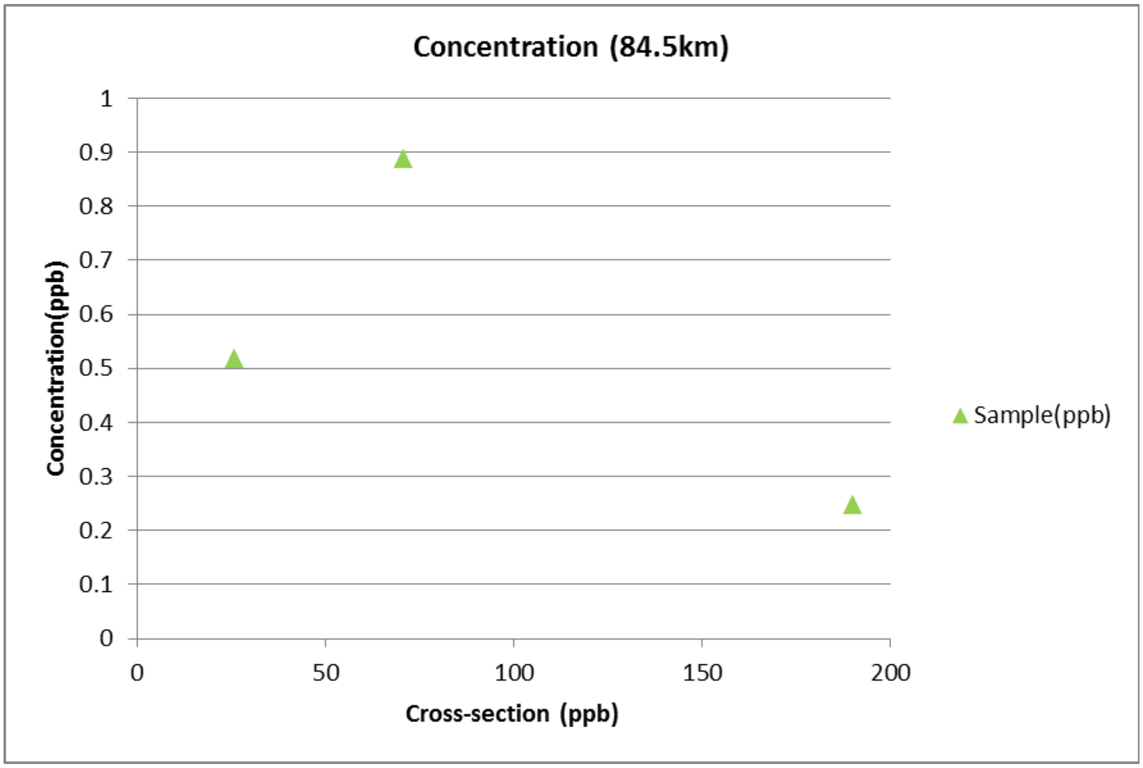
Concentration 81pt5km

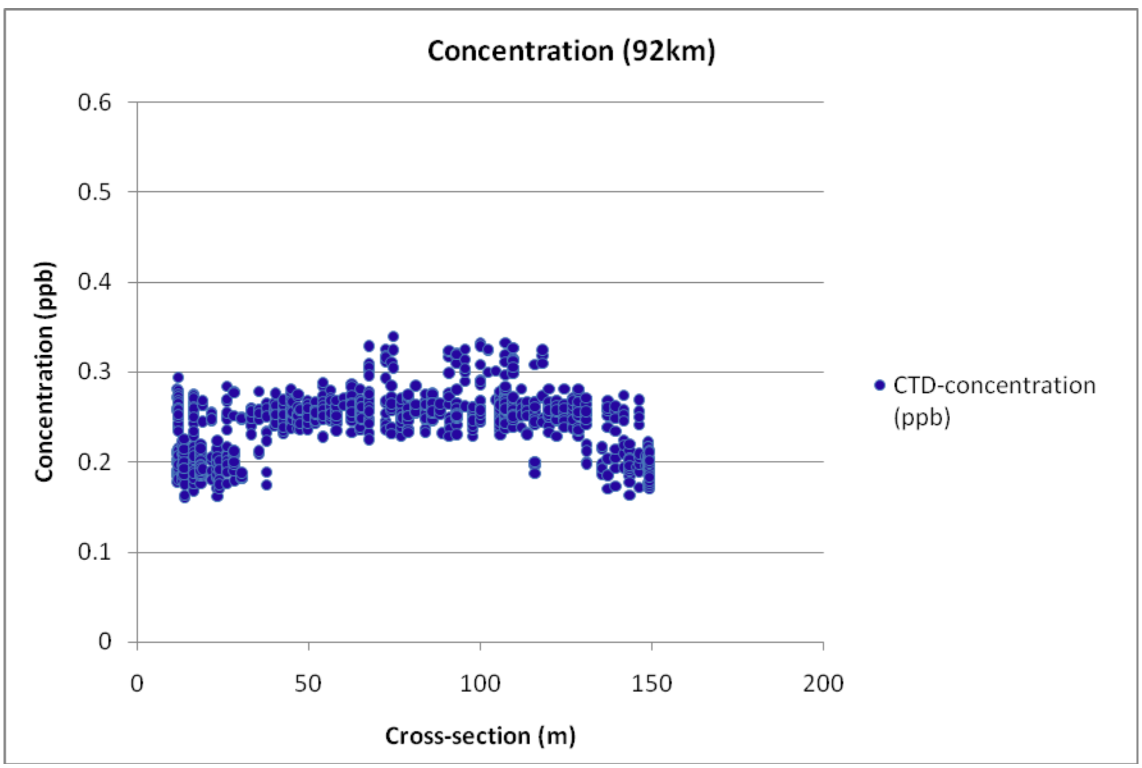
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2			
0.2-0.3	0.27	0.28	0.28
0.3-0.4	0.23	0.24	0.24
0.4-0.5	0.23	0.24	0.23
0.5-0.6	0.14	0.15	0.15
0.6-0.7	0.16	0.16	0.16
0.7-0.8			
0.8-0.9	0.19	0.19	0.19
0.9-1			
Aproximate width(m)	231.86		
Approximate distance from outfall(km)	81.50		
Time and date	14:25:23	31-Oct-11	



Concentration 82pt78km

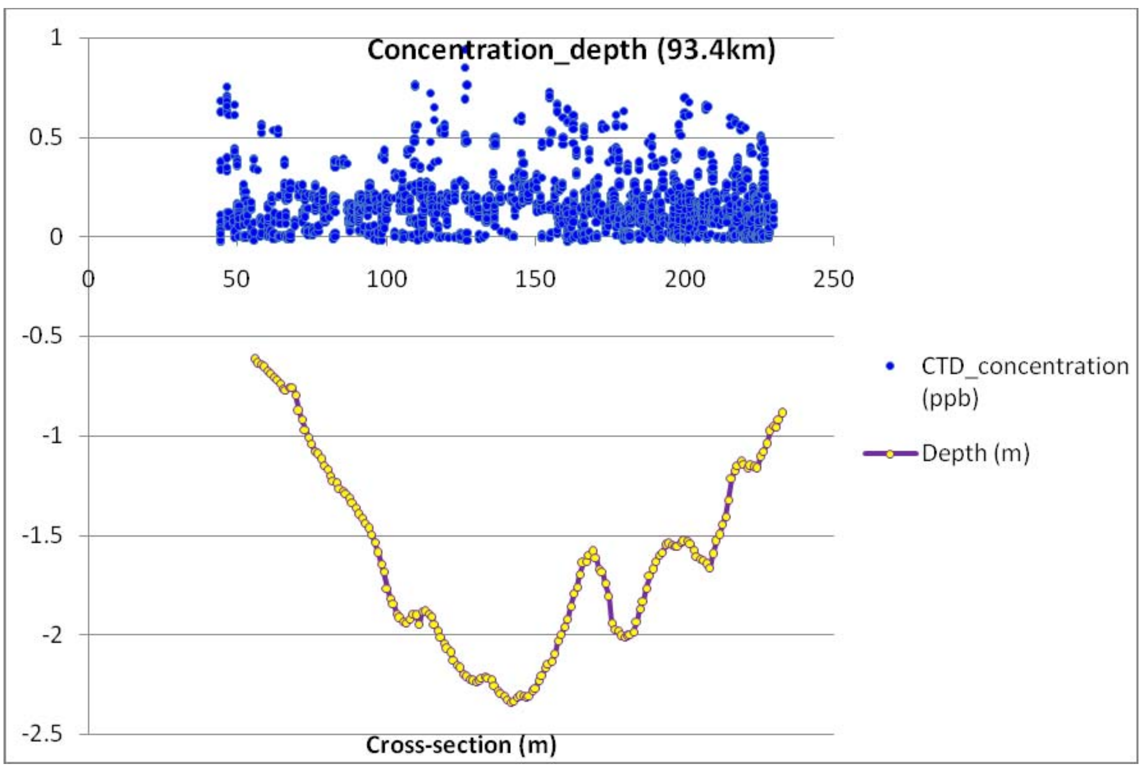
Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.29	0.29	0.29
0.2-0.3	0.27	0.29	0.28
0.3-0.4	0.22	0.23	0.22
0.4-0.5	0.20	0.20	0.20
0.5-0.6	0.18	0.18	0.18
0.6-0.7	0.18	0.20	0.19
0.7-0.8	0.10	0.15	0.13
0.8-0.9	0.20	0.20	0.20
0.9-1			
Aproximate width(m)	228.66		
Approximate distance from outfall(km)	82.78		
Time and date	15:01:07	Oct 31 2011	



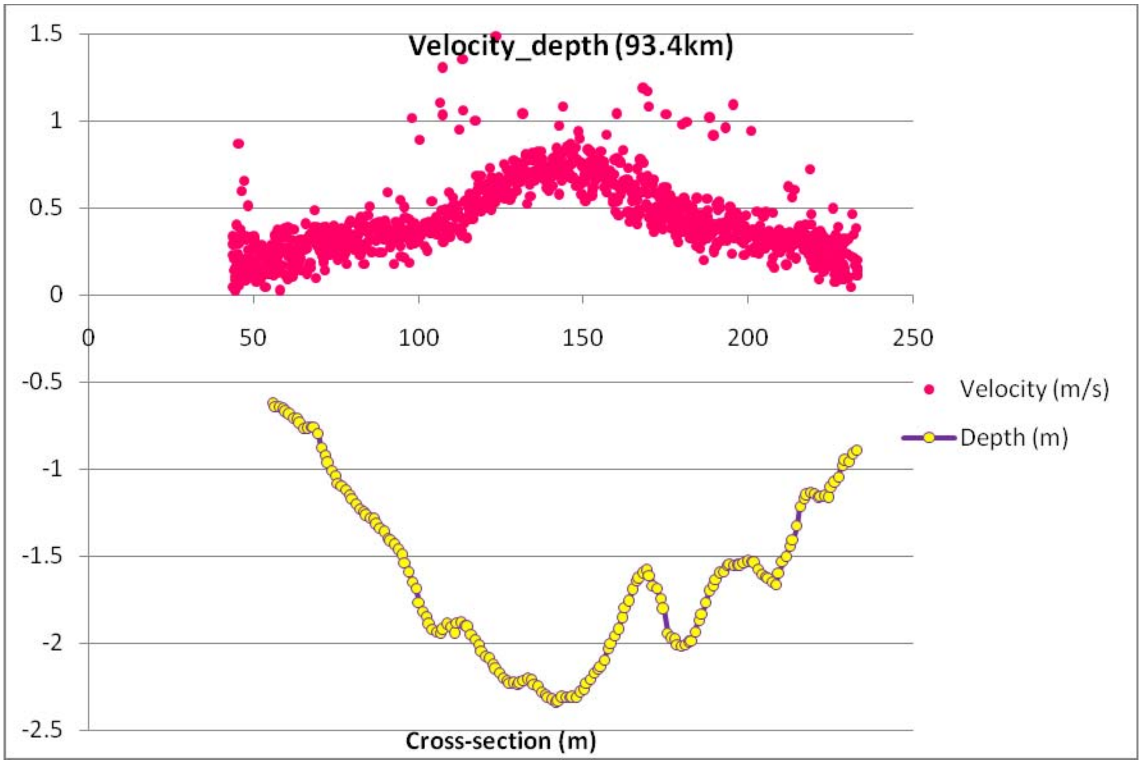


Concentration 92km

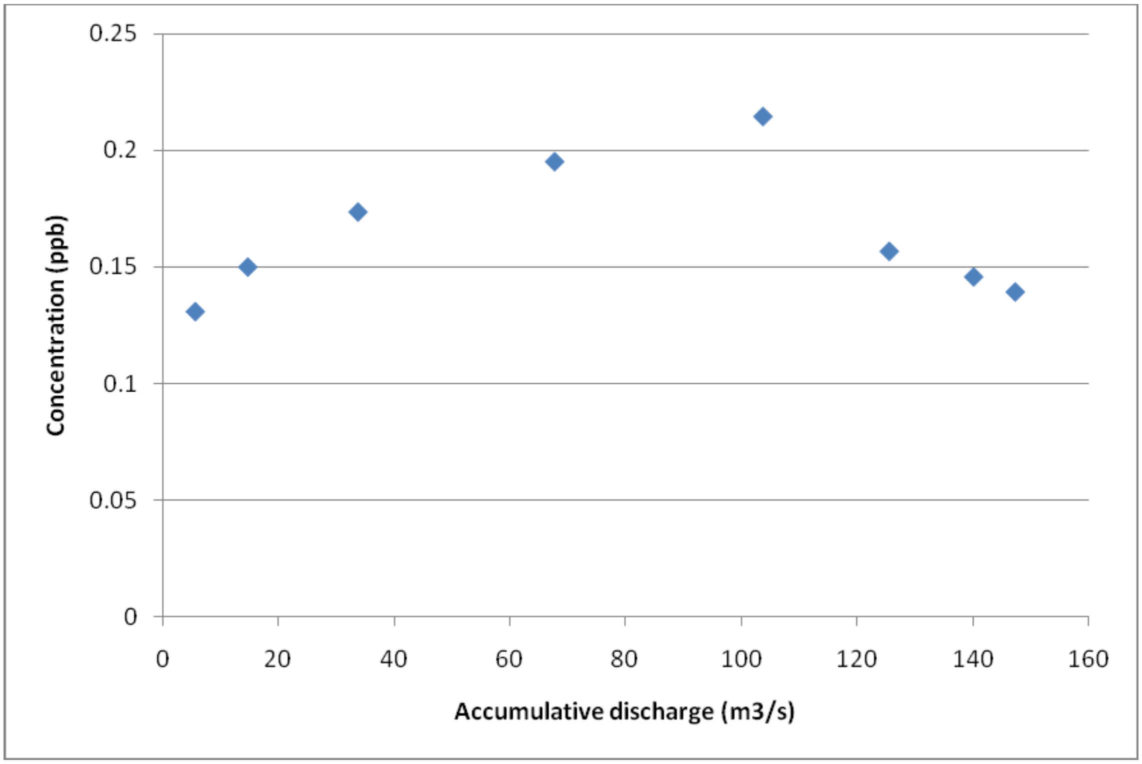
cross-section	Lower(ppb)	Upper(ppb)	Average(ppb)
0.05	0.21	0.21	0.21
0.15	0.21	0.22	0.22
0.25	0.25	0.25	0.25
0.35	0.26	0.26	0.26
0.45	0.26	0.26	0.26
0.55	0.26	0.27	0.27
0.65	0.25	0.26	0.25
0.75	0.22	0.23	0.22
0.85	0.19	0.20	0.19
0.95			
Approximate width (m)	184.03		
Approximate distance from outfall(km)	92.00		
Time and date	15:38:44	Oct 31 2011	

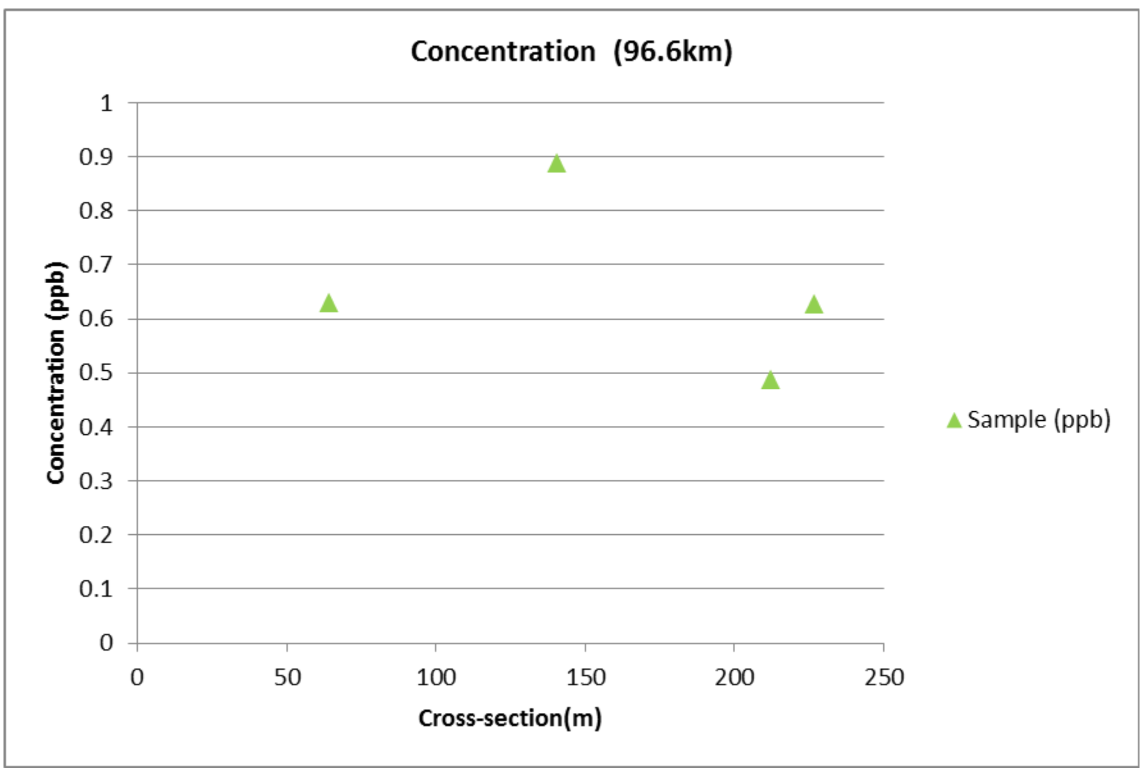


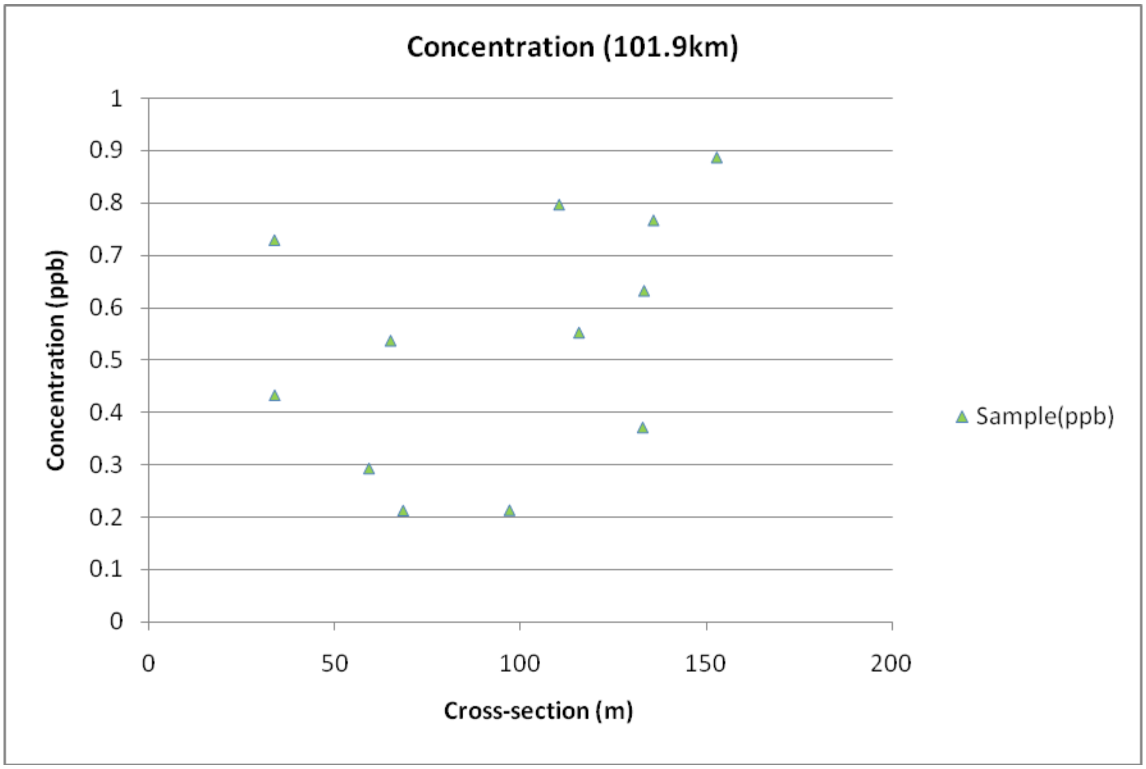
Concentration 93pt4km



Cross Section	Lower (ppb)	Upper(ppb)	Average(ppb)
0-0.1			
0.1-0.2	0.28	0.28	0.28
0.2-0.3	0.13	0.13	0.13
0.3-0.4	0.15	0.15	0.15
0.4-0.5	0.17	0.17	0.17
0.5-0.6	0.19	0.20	0.20
0.6-0.7	0.21	0.21	0.21
0.7-0.8	0.16	0.16	0.16
0.8-0.9	0.15	0.15	0.15
0.9-1	0.14	0.14	0.14
Approximate width(m)	233.11		
Approximate distance from outfall(km)	93.40		
Time and date	11:59:52	31-Oct-11	


0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
160
Concentration (ppb)
Accumulative discharge (m3/s)


Concentration (96.6km)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
Concentration (ppb)
Cross-section(m)
Sample (ppb)


Concentration (101.9km)
Concentration (ppb)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
Cross-section (m)
Sample(ppb)

Appendix D: Importance of Wind on Observed Mixing

Wind Shear in the Governing Equations

Wind shear stress is a source term in the shallow water governing equations (Eq. 1 , 2).

$$\frac{\partial(hu)}{\partial t}+\frac{\partial(hu^2+\frac{1}{2}gh^2)}{\partial x}+\frac{\partial(huv)}{\partial y}=\nu(\frac{\partial h}{\partial x}(\frac{\partial u}{\partial x})+\frac{\partial h}{\partial y}(\frac{\partial u}{\partial y}))-gh\frac{\partial}{\partial x}(Z)+\frac{\tau_{wx}}{\rho} \qquad \textbf{(1)}$$

$$\frac{\partial(hv)}{\partial t}+\frac{\partial(hv^2+\frac{1}{2}gh^2)}{\partial y}+\frac{\partial(huv)}{\partial x}=\nu(\frac{\partial h}{\partial x}(\frac{\partial u}{\partial x})+\frac{\partial h}{\partial y}(\frac{\partial v}{\partial y}))-gh\frac{\partial}{\partial y}(Z)+\frac{\tau_{wx}}{\rho} \qquad \textbf{(2)}$$

In the above equations ***u*** and ***v*** are depth averaged water velocity in x- and y- direction respectively, ***Z*** is the bed elevation, ***h*** the water depth, ***g*** the gravitational acceleration and ***ρ*** the water density.

Wind shear stresses are τ_{wx} and τ_{wy} in –x and –y direction respectively.

$$\tau_{wx}=\rho C_w w_x\sqrt{w_x{}^2+w_y{}^2} \qquad \textbf{(3)}$$

$$\tau_{wy}=\rho C_w w_y\sqrt{w_x{}^2+w_y{}^2} \qquad \textbf{(4)}$$

Where W = (w_x , w_y) is the wind velocity at 10m above water surface. C_w is the coefficient of wind friction and usually defined by [1]:

$$C_w=(0.75+0.067\sqrt{w_x{}^2+w_y{}^2})*10^{-3} \qquad \textbf{(5)}$$

The density (ρ) in Equations 3-5 is air density.

Note that wind is usually measured at 10 m above ground level. Our anemometer was situated at approximately 2 m above ground level. Velocity at 10 m as a function of measured velocity at 2 m will depend on local surface roughness, but can be approximated using the typical 1/7 power law [6].

$$\frac{W_{z2}}{W_{z1}}=\left(\frac{z_2}{z_1}\right)^{1/7} \qquad \textbf{(6)}$$

There are other formulas for calculating wind shear stress. In RMA2 User Guide [7], Wu's equation 6 is presented for calculating wind shear stress.

$$\tau = \rho k_w W^2 \tag{7}$$

τ : Wind shear stress exerted on the water surface by the wind (units of g/[cm.s^2])

ρ : mass density of the air (0.001225 g/cm^3)

W : sustained wind speed in cm/s at a 10 m elevation above the water surface

k_w : =1.25/((Wind Speed/100)$^{0.2}$* 0.001 { Wind speed less than 100 cm/s }

= ((Wind Speed/100)$^{0.5}$ * 0.001/2 { 100 cm/s <Wind speed<1500 cm/s }

= 0.0026 { Wind speed greater than 1500 cm/s }

In the 3D Navier-Stokes equation (Eq. 8 & 9), wind shear is implemented as a boundary condition at the water surface.

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \nu \frac{\partial^2 u_i}{\partial x_j \partial x_j} + g_i \tag{8}$$

$$\frac{\partial u_i}{\partial x_i} = 0 \tag{9}$$

Without wind, the stress at the free surface is zero but in presence of wind, the wind shear stress is applied on the water surface boundary condition as follows

$$\nu \frac{\partial u}{\partial y} = \frac{1}{\rho}\left|\overrightarrow{\tau_w}\right| \cos(\theta) \tag{10}$$

$$\nu \frac{\partial v}{\partial y} = \frac{1}{\rho}\left|\overrightarrow{\tau_w}\right| \sin(\theta) \tag{6}$$

where θ is the angle between the wind stress vector and the local direction.

Wind-Generated Waves

From a physical point of view, wind can generate waves. All of the available relationships for calculating wind generated wave height and period are empirical. But the main parameters in all of them are fetch length and duration of wind blowing.

For the case that fetch length and blowing duration would be long enough, the fully developed wave height can be represented as:

$$H_\infty = \frac{\lambda_5 u^2}{g} \tag{12}$$

Where

H_∞ = fully developed wave height
λ_5 =dimensionless coefficient (approximately equal to 0.27)
u = wind speed

In a meandering river, as the river path continuously changes, even if it is assumed that a wind blows with essentially constant direction, over a fetch for sufficient time, the fetch length would not be long enough to reach fully developed condition.
The required time (t_{xu}) for wave crossing fetch length of length ***x*** under a wind of velocity ***u*** to become fetch limited is

$$t_{x,u} = 77.23 \frac{X^{0.67}}{u^{0.34} g^{0.33}} \tag{13}$$

Using (13), it can be found if the wind duration is long enough to reach fully developed wave conditions for a given fetch length. If the wind duration is not long enough, the wind generated wave is considered within the "growing with fetch" category.

The governing equations of wave growth with fetch are:

$$\frac{gH_{mo}}{u_*^{\,2}} = 4.13 \times 10^{-2} * \left(\frac{gX}{u_*^{\,2}} \right)^{\frac{1}{2}} \tag{7}$$

$$\frac{gT_p}{u_*} = 0.751 * \left(\frac{gX}{u_*^{\,2}} \right)^{\frac{1}{3}} \tag{8}$$

$$C_D = \left(\frac{u_*^{\,2}}{U_{10}^{\,2}} \right) \tag{9}$$

$$C_D = 0.001(1.1 + 0.035 U_{10}) \tag{10}$$

X = straight line fetch distance over which the wind blows (units of m)

H_{m0} = energy-based significant wave height (m)

C_D = drag coefficient

U_{10} = wind speed at 10 m elevation (m/sec)

u_* = friction velocity (m/sec)

More details can be found in [5].

Fully developed wave conditions in these equations are also given as:

$$\frac{gH_{mo}}{u_*^{\,2}} = 2.115 \times 10^2 \tag{11}$$

$$\frac{gT_p}{u_*} = 2.398 \times 10^2 \tag{12}$$

The equation for wind growth with fetch could be written as wave growth with wind duration by converting duration to equivalent fetch as :

$$\frac{gX}{u_*^{\,2}} = 5.23 \times 10^{-3} \left(\frac{gt}{u_*}\right)^{\frac{3}{2}} \tag{13}$$

Relevance for North Saskatchewan River Mixing Study

Wind speed and direction were measured during the mixing study. These data were collected to be available in the unlikely event that wind speed and direction were sufficient to influence mixing processes in the river. The North Saskatchewan River between Goldbar WWTP and the Agrium plant flows NE along an average axis of 51°. Wind during the deployment generally blew from the SW, with average daily wind directions ranging from 211° to 277°. Thus, wind was generally from the upstream direction, and relatively straight portions of the study reach could have had sufficient fetch for wind-generated waves. The average daily wind speeds during the deployment ranged from 1.20 m/s to 3.51 m/s. Note that these wind speeds were measured at the location of the anemometer, which was situated about 2 m above ground in the vicinity of the respective outfall (not on the water surface). Using Equation 11, a wind speed of 3 m/s in an infinite fetch would generate a wave height of about 0.25 m. However, wind-generated waves were not observed during the deployment. Thus, it is reasonable to conclude that river meandering sufficiently minimized fetch, and/or wind speed in the valley bottom was sufficiently weak, to preclude generation of wind waves.

In terms of wind shear on the water surface, Equation 6 suggests wind of 3 m/s at 2 m above the water surface would have been equivalent to about 3.76 m/s at 10 m above the water surface. Using Equations 3-5 or Equation 7, wind shear on the water surface would have been about 0.02 N/m^2. This wind shear is much less than the bed shear. The measured mean channel depth and depth-averaged velocity were 1.42 m and 0.52 m/s, respectively. Assuming a Manning's *n* roughness coefficient of 0.025 to 0.03 for the North Saskatchewan River [3], and converting *n* to a friction coefficient, calculated bed shear ranges from 3 to 4 N/m^2. While these values may be biased high by lack of depth and velocity measurements in shallow areas, they do suggest that bed shear was 10 to 20 times greater than surface wind shear. Thus, wind shear likely had minimal influence on mixing processes in the river.

References:

[1] A. Bermudez, C. Rodrıguez, and R. Vilar, M.A. Solving Shallow Water Equations by a Mixed Implicit Finite Element Method. IMA J. Numer. Anal., 11:79–97, 1991.

[2] Coastal Engineering Manual, U.S. Army Corps of Engineers, 2006, II-2-44.

[3] Dow, K.E., Steffler, P.M., Zhu, D.Z. (2009). Case study: Intermediate field mixing for a bank discharge in a natural river. J. Hydraulic Eng., 135(1):1-12.

[4] Delft3D-FLOW,User Manual, Version: 3.15, Revision: 17474, 24 June 2011

[5] Demirbilek, Z., Bratos, S. M., and Thompson, E. F. 1993."Wind Products for Use in Coastal Wave and Surge Models,"Miscellaneous Paper CERC-93-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

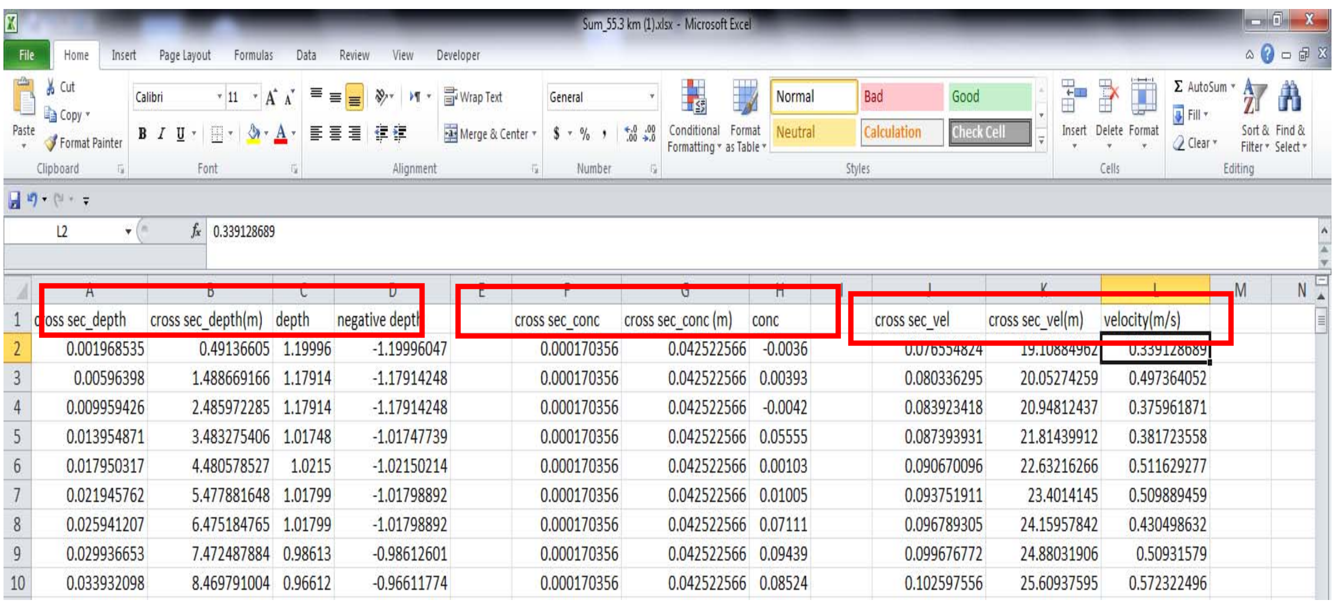
[6] Hutchinson, M.F., Kalma, J.D., Johnson, M.E. (1984). Monthly estimates of wind speed and wind run for Australia, J. Climatology, **VOL**. 4, 311-324 (1984) 551.553.6(94).

[7] U.S. Army Corps of Engineers Waterways Experiment Station (1996), Users Guide to RMA2 Version 4.3, Vicksburg, MS, June 28, 1996, pp. 118-119.

Appendix E: Data Set Structure

This is a brief description of the format of the summary files provided for each investigated plant in the report. The summary files are categorised in separate folders for each plant. The general file name format is SUM_xxptxkm_x in which xxptx shows the approximate distance of the surveyed section from outfall (e.g., for capital region SUM_55pt3 contains the collected data from section at about 55.3km from outfall). In some sections, the data have been extracted along more than one line. The _x part of the file name shows the number of the extract line in the specific section (e.g., SUM_55pt3_1 is the data for extract line 1 in section at about 55.3km from the outfall). The numbering of the extract line is based on the order of the extract line in the surveyed path.

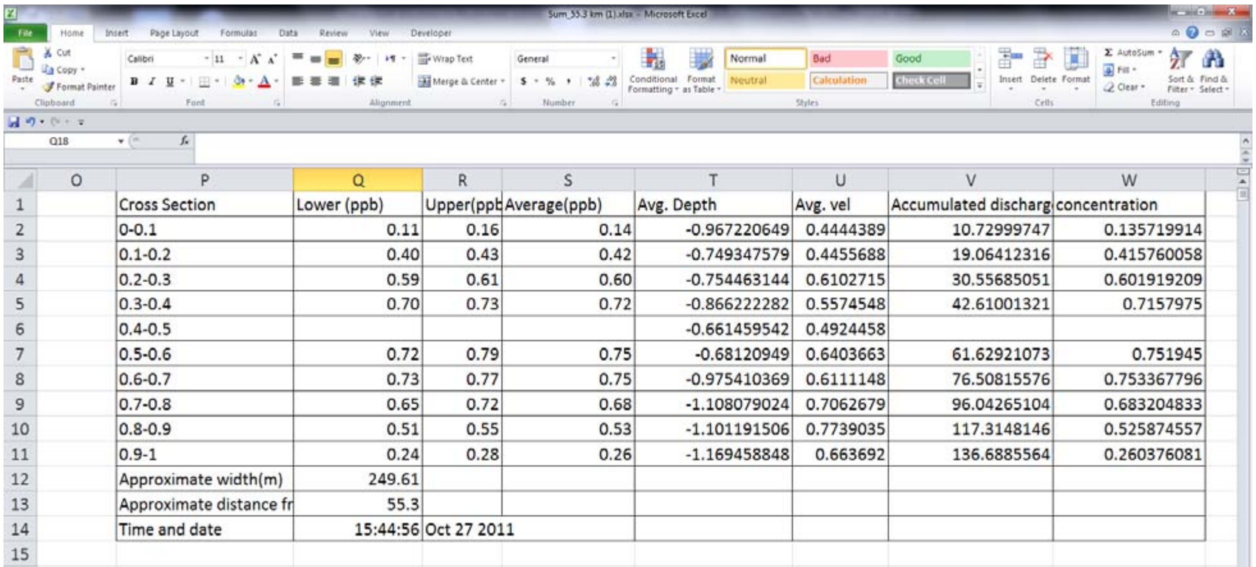
For each section the summary file contains depth averaged velocity, depth and concentration across the section. For each mentioned parameter the data are provided in three columns (Figure 1). The rightmost column for a given parameter contains the measured value. The middle column contains the distance (m) of the specific measurement location along the cross-section from the outfall bank side. The leftmost column contains normalized distance (distance divided by channel width) of the measurement location from the outfall bank side. For each column, a header is also provided (Figure1).



	A	B	C	D	E	F	G	H	I	J	K	L
1	cross sec_depth	cross sec_depth(m)	depth	negative depth		cross sec_conc	cross sec_conc (m)	conc		cross sec_vel	cross sec_vel(m)	velocity(m/s)
2	0.001968535	0.49136605	1.19996	-1.19996047		0.000170356	0.042522566	-0.0036		0.076554824	19.10884962	0.339128689
3	0.00596398	1.488669166	1.17914	-1.17914248		0.000170356	0.042522566	0.00393		0.080336295	20.05274259	0.497364052
4	0.009959426	2.485972285	1.17914	-1.17914248		0.000170356	0.042522566	-0.0042		0.083923418	20.94812437	0.375961871
5	0.013954871	3.483275406	1.01748	-1.01747739		0.000170356	0.042522566	0.05555		0.087393931	21.81439912	0.381723558
6	0.017950317	4.480578527	1.0215	-1.02150214		0.000170356	0.042522566	0.00103		0.090670096	22.63216266	0.511629277
7	0.021945762	5.477881648	1.01799	-1.01798892		0.000170356	0.042522566	0.01005		0.093751911	23.4014145	0.509889459
8	0.025941207	6.475184765	1.01799	-1.01798892		0.000170356	0.042522566	0.07111		0.096789305	24.15957842	0.430498632
9	0.029936653	7.472487884	0.98613	-0.98612601		0.000170356	0.042522566	0.09439		0.099676772	24.88031906	0.50931579
10	0.033932098	8.469791004	0.96612	-0.96611774		0.000170356	0.042522566	0.08524		0.102597556	25.60937595	0.572322496

Figure -1: Measured parameters across a section

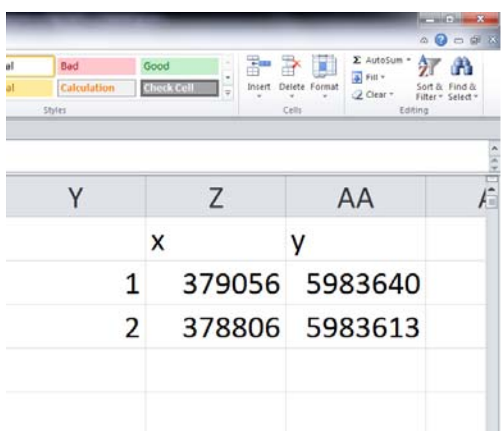
Figure1 is from Capital Region SUM_55pt3_1 file, column A shows the distance from the outfall bank side which has been normalised by the average cross section width. The absolute distance of the point from the outfall bank side is provided in column B. Column C shows the depth value and column D is the negative value of column C. Concentration data (ppb) and depth averaged velocity (m/s) are provided in the same format as depth in column H and L respectively. In addition, a table (see Figure 2) is provided that summarizes the presented data in columns A-L by giving the lower and upper limit with 95% confidence probability, average concentration, average depth (T), average velocity (U), accumulative discharge (V) and concentration (W) in 0.1 width increments across the section. The date and time of collection of the presented data as well as approximate width of surveyed section and the distance from the outfall location are also provided in the table.



	O	P	Q	R	S	T	U	V	W
1		Cross Section	Lower (ppb)	Upper(ppb	Average(ppb)	Avg. Depth	Avg. vel	Accumulated discharg	concentration
2		0-0.1	0.11	0.16	0.14	-0.967220649	0.4444389	10.72999747	0.135719914
3		0.1-0.2	0.40	0.43	0.42	-0.749347579	0.4455688	19.06412316	0.415760058
4		0.2-0.3	0.59	0.61	0.60	-0.754463144	0.6102715	30.55685051	0.601919209
5		0.3-0.4	0.70	0.73	0.72	-0.866222282	0.5574548	42.61001321	0.7157975
6		0.4-0.5				-0.661459542	0.4924458		
7		0.5-0.6	0.72	0.79	0.75	-0.68120949	0.6403663	61.62921073	0.751945
8		0.6-0.7	0.73	0.77	0.75	-0.975410369	0.6111148	76.50815576	0.753367796
9		0.7-0.8	0.65	0.72	0.68	-1.108079024	0.7062679	96.04265104	0.683204833
10		0.8-0.9	0.51	0.55	0.53	-1.101191506	0.7739035	117.3148146	0.525874557
11		0.9-1	0.24	0.28	0.26	-1.169458848	0.663692	136.6885564	0.260376081
12		Approximate width(m)	249.61						
13		Approximate distance fr	55.3						
14		Time and date	15:44:56	Oct 27 2011					
15									

Figure 02: Average of collected data in 0.1 increments across the section

The file also contains the coordinates of the two end points of the extraction line. The coordinate is provided by (x,y) as (utme,utmn) (Figure 3).



Y	Z	AA
	x	y
1	379056	5983640
2	378806	5983613

Figure 3: Coordinate of extract line two end points

For Goldbar WWTP, a few sections had only concentration measurements available. For these sections, the concentration value has been graphed across the section and the related summary file contains only concentration values.