Aroostook River Data Report

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Introduction

The Aroostook River Basin is the largest sub basin of the St John River, lying almost entirely within the state of Maine. It has a drainage area of 2,353 square miles at the international border with Canada. The Aroostook River segment addressed in this study begins in Washburn (RM 39) and extends downstream through; Presque Isle (RM 30), Caribou (RM 16), Fort Fairfield (RM 4) and eventually the international border (RM 0). In Canada, after an additional 4.6 miles, the Aroostook joins with the St John River. A location map is shown in Appendix A.

A water quality study was completed on the river in 2001. From those data a water quality model was constructed in 2003 to simulate the water quality condition of the river under critical water quality conditions of low flow, high temperature and maximum licensed discharge from point source dischargers; the final model report was published in 2004. That model report stated the Aroostook River met water quality criteria for dissolved oxygen, but observed pH readings exceeded criterion. Modeled and observed chlorophyll-a levels exceeded limits indicative of algal blooms. The report concluded that high phosphorus loadings were the cause and performed a component analysis to recommend specific total phosphorus discharge limits from the two highest contributing dischargers; Presque Isle Sewer District and McCain Foods USA Inc.. The report also discussed the forthcoming EPA required Nutrient Criteria and made phosphorus limit recommendations if proposed limits were incorporated into the criteria.

Since 2004 there have been changes in the discharges to the river:

- Presque Isle Sewer District has removed their outfall from Presque Isle Stream, now discharging directly to the Aroostook River, and has reduced their total phosphorus loading.
- The Loring Development Authority combined flows with the Limestone Water and Sewer District and their combined discharge, licensed to the District, was removed from the Little Madawaska River and relocated to the same outfall pipe as the Caribou Utility District discharging to the Aroostook River.
- In Fort Fairfield a major industrial user who discharged to the Utility District has gone out of business and the plant demolished.
- A final draft Nutrient Criteria has been developed with numeric limits for in-stream total phosphorus and response indicators; pH, chlorophyll-a, percent benthic algae cover, aquatic life criteria and bacteria and fungi.

These changes justified another field survey for recalibration of the model and to have current values available for water quality classification and permit renewal.

In the spring of 2012 the stakeholders on the river were contacted; the towns of Washburn, Presque Isle, Caribou, Limestone and Fort Fairfield; McCain Foods; the Aroostook Band of MicMacs; and other interested members of the public. A formal study plan was developed, and a stakeholder meeting was held on July, 19, 2012. A three-day survey of the lower Aroostook River was undertaken during the week of July 23, 2012.
In addition, since diurnal variability in dissolved oxygen and pH generated by algal kinetics will fluctuate with nutrient concentration and temperature, continuous monitoring of this process over an extended period will provide valuable information. Therefore, two sondes were placed in the river for the month of August 2012.

The DEP's Northern Maine Regional Office (NMRO) staff has a program of monitoring non-point sources of pollution within the region and in particular, the Aroostook River Watershed. Agricultural non-point sources have always been identified as a contributor of excessive nutrients and sediment to the Aroostook River. The water quality model used in 2003 was run at steady-state, low-flow conditions and licensed flows from point sources. Non-point sources contribute to the system during high flow events and the model assumes when stormwater flow recedes that the effect from non-point sources is minimal. Under low flow conditions it is assumed all minor tributaries are at low stage of flow and rainfall is low resulting in minimal direct runoff which is not accounted for in the model. Accounting for these non-point contributions is a limitation of the model. The 2004 study plan and model report acknowledged this, and in an effort to at least rank some of the named tributary streams to the Aroostook for non-point contribution, a subsequent wet weather survey was conducted. From these data a simple mass balance analysis was conducted and a three stage (low, medium and high) ranking of these tributaries was presented in the 2004 report. As part of ongoing non-point source monitoring program, the data gathered from the 2001 study as well as from this one shall be used with data gathered in the non-point program to evaluate the water quality of the entire lower river basin.

Technical Design of Study

Details of the technical design of the Aroostook River data collection effort of 2012 are explained in the Aroostook River Work Plan (MDEP, June 2012). Some of the highlights more important elements are repeated here for convenience. The data collection effort involved an intensive survey over three consecutive days. The dates in which this sampling took place were July 24, 25 and 26 of 2012. The 2004 water quality model demonstrated that the Ashland discharge has minimal influence upon downstream water quality and was therefore excluded from this study. The survey began at the public boat launch in Washburn and extending downstream to the international border.

Major point source discharges addressed in this study and their licensed flows are as follows: Washburn (0.28 mgd), Presque Isle (2.3 mgd), McCain Foods (2.5 mgd), Caribou (1.7 mgd), Limestone (1.3 mgd), and Fort Fairfield (0.6 mgd).

For consistency, the majority of the sample stations for the survey were at the same locations as in the 2001 survey. Station AR6 was moved upstream of the Caribou/Limestone outfall because the of the relocation of the Limestone discharge it was not necessary to bracket the Little Madawaska River. Stations AR7 and AR8 were shifted upstream from their 2001 locations to capture representative flow sections downstream of Caribou/Limestone outfall and the Little Madawaska River, see Table 1. Coordinates of all sample stations in decimal degrees are shown in Table 2.

Table 1 Aroostook River Sampling Station Location and Parameter Frequency 2012

Station Code	River/ Stream Mile	Location	DO / Temp/ pH	Nitrogen TN, NH3-N/ NO2,3-N init./ NO2,3-N final	Phosphorus Total P/ PO4-P	Chl a	Ultimate BOD
AR1	38.9	River Rd Bridge in Washburn	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR1a	35.6	Crouseville	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR2	30.1	0.5 mil upstream of Rte 1 bridge	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR3	21.3	Mayesville	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR4	18.3	McGraw	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR5	15.9	Above Caribou Dam	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR6	11.5	Above Caribou POTW outfall	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR7	9.9	Adjacent Grimes Mill Road	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR8	5.8	Stevensville	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR9	3.1	Rte 1A Bridge Fort Fairfield	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days
AR10	0.5	0.5 miles from US/Can Border	2/day - 3 days	1/day - 3 day	1/day 3 days	1/day 3 days	1/day 3 day
PIS	0.6	Presque Isle Stream at Rte 163 Bridge	2/day - 3 days	1/day - 3 day	1/day 3 days	1/day 3 day	1/day 3 day
CS	0.1	Caribou Stream near confluence	2/day - 3 days	1/day - 3 day	1/day 3 days	1/day 3 day	1/day 3 day
LMR	0.3	Little Madawaska River Grimes Rd Bridge	2/day - 3 days	1/day - 3 days	1/day 3 days	1/day 3 days	1/day 3 days

		Effluents	DO / Temp	Nitrogen	Phosphorus	BOD5	BODU
WAS	37.7	Washburn Water and Sewer District	1/day- 3 days	24 hr. composite 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days
PRI	29.2	Presque Isle Sewer District	1/day - 3 days	24 hr. composite 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days
MCC	27.9	McCain Foods Easton	1/day - 3 days	24 hr. composite 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days
CAR	11.6	Caribou Utility District	1/day - 3 days	24 hr. composite 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days
LIM	11.6	Limestone Water and Sewer	1/day - 3 days	24 hr. composite 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days	24 hr. comp. 3 days
FTF	3.9	Fort Fairfield Utilities District	1/day - 3 days	24 hr. composite 3 days	24 hr. comp. 2 days	24 hr. comp. 2 days	24 hr. comp. 2 days

Table 2 Station Coordinates		
Station	Location (Decimal Degrees)	
AR1	46.776210	-68.154768
AR1a	46.755978	-68.115486
AR2	46.713563	-68.018737
AR3	46.776075	-67.969139
AR4	46.814863	-67.984853
AR5	46.847424	-68.000618
AR6	46.850654	-67.954884
AR7	46.833209	-67.931323
AR8	46.800759	-67.865259
AR9	46.773959	-67.833499
AR10	46.791423	-67.797734
CS	46.856890	-68.003877
LMR	46.846931	-67.944095
PIS	46.698818	-68.018015
WAS	46.763400	-68.139400
PRI	46.850200	-67.954800
MCC	46.696400	-67.983600
CAR	46.850100	-67.955000
LIM	46.850100	-67.955000
FTF	46.779100	-67.843000

When collecting data for model calibration, it is essential that adequate critical conditions approaching low flow and high water temperature occur and that flow in the river remains steady throughout the three-day survey. It is desirable not to have significant runoff occur during the survey and up to two weeks prior to the survey. In June the Department was informed that McCain Foods Inc. would be temporarily stopping production for approximately one month in the beginning of August. This would require the survey to occur by the end of July. Acceptable conditions were met during the third week of July and the survey was undertaken during the week of July 24-26.

The low flow three-day sampling event extended from the public boat launch at the River Road Bridge in Washburn to one-half mile upstream of the Canadian border and occurred daily, Tuesday through Thursday at 11 river stations and 3 tributary stations (Table 1). Dissolved oxygen, temperature and pH were sampled twice per day, before 8:00AM and again early to mid-afternoon. In addition, phosphorus series (TP, PO4-P); nitrogen series (TN, NH3-N, NO2-N, NO3-N), chlorophyll-a, and ultimate BOD were collected in the AM for laboratory analysis. Three-day effluent composite samples for the six point-sources discharges (Table 1) were drawn hourly for 24 hours in the early AM the day prior (Monday through Wednesday) to collection of ambient river samples. This accounted for travel time lags in the river. They were sampled for N-series, P-series, and BODu / BOD5. Each treatment plant tracked their own discharge flow as part of monitoring requirements. These data will be used to help compute pollutant load inputs for each point source.

Hydrologic Data

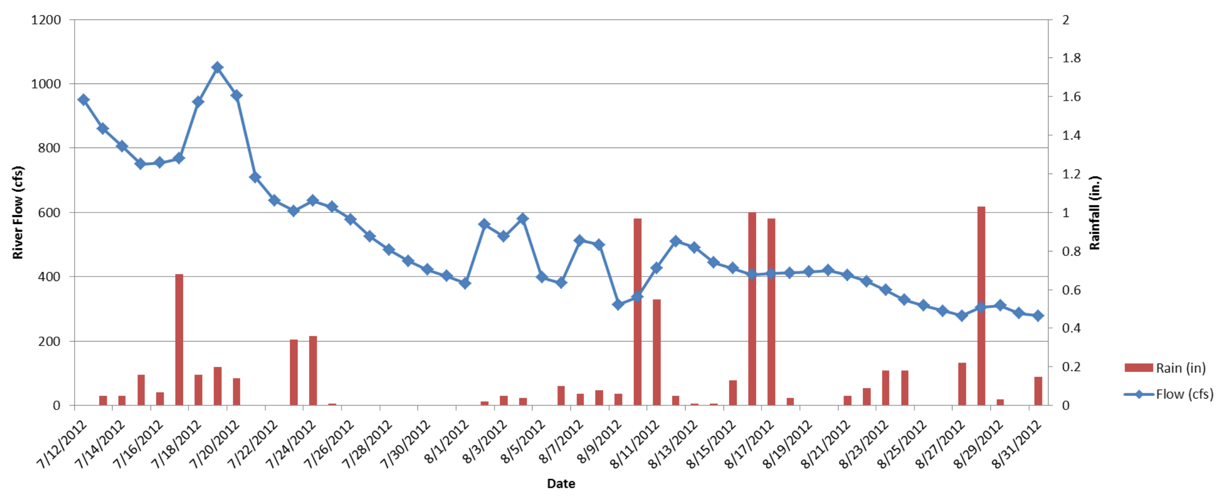
For critical low flow analysis, calibration and validation sample data sets are required to be taken at a satisfactory low flow condition. The flows which initiate sampling are referred to as "trigger flows." Two trigger flows were targeted for the Aroostook River study; the first of which was the satisfactory low flow trigger or 80% flow duration, and the second of which was the ideal low flow trigger or 90% flow duration. The USGS gage at Washburn *USGS 01017000 Aroostook River* was examined on Fridays in July to determine whether or not sampling should be initiated beginning the Monday of the following week. The first and second trigger flows at the USGS gage in Washburn are 560 cfs and 390 cfs, respectively. Both 2001 field surveys were ideal flows.

As noted in the previous section, McCain Foods would cease production in the second week of August, so during the third week of July flows at Washburn approached the 80% flow duration the decision was made to do the survey the following week. Although flows were slightly above the desired low flow trigger of 80% duration (560 cfs); weighing schedule, logistics, and flow trends for the summer it was decided to go forward with the survey during the week of July 23rd. Flows during the 2012 three-day study period (07/24-26/2012) ranged from 538 to 634 cfs with an average flow of 596 cfs, which was determined to be the 79% flow duration for the river. Figure 1 plots average daily flow from the Washburn gage and rainfall from the Crown Weather Service Station in Caribou, ME.

In a low flow survey, a steady river flow is as important as low flow conditions. The lack of runoff two weeks prior to the low flow surveys should also be targeted. Unfortunately there was a 0.7 inch rain event on July 17th, and 0.34 inches on the morning of July23rd, but it was felt that the effects from those rain events were minimal.

Significant runoff during the sampling effort which results in greater than 50% flow deviations should be boundaries defining when sampling should cease due to excessive runoff. On the morning of July 24th, just as the first survey day began, there was another 0.36 inch thunderstorm that did not affect river flows but did generate a stormwater flow event and turbidity was still seen in the lower river stations on the second day.

Figure 1 - 2012 Average Daily River Flow (cfs) and Rainfall (inches)



Additional Monitoring

Measurements are taken for each station at various times during a three hour survey run, yet there is no assurance that the time it is taken is at the peak of the diurnal curve. In order to get a more accurate measurement of each of these curves, two data sondes were placed in the river at stations AR3 and AR7 for extended deployments in the month of August, 2012.

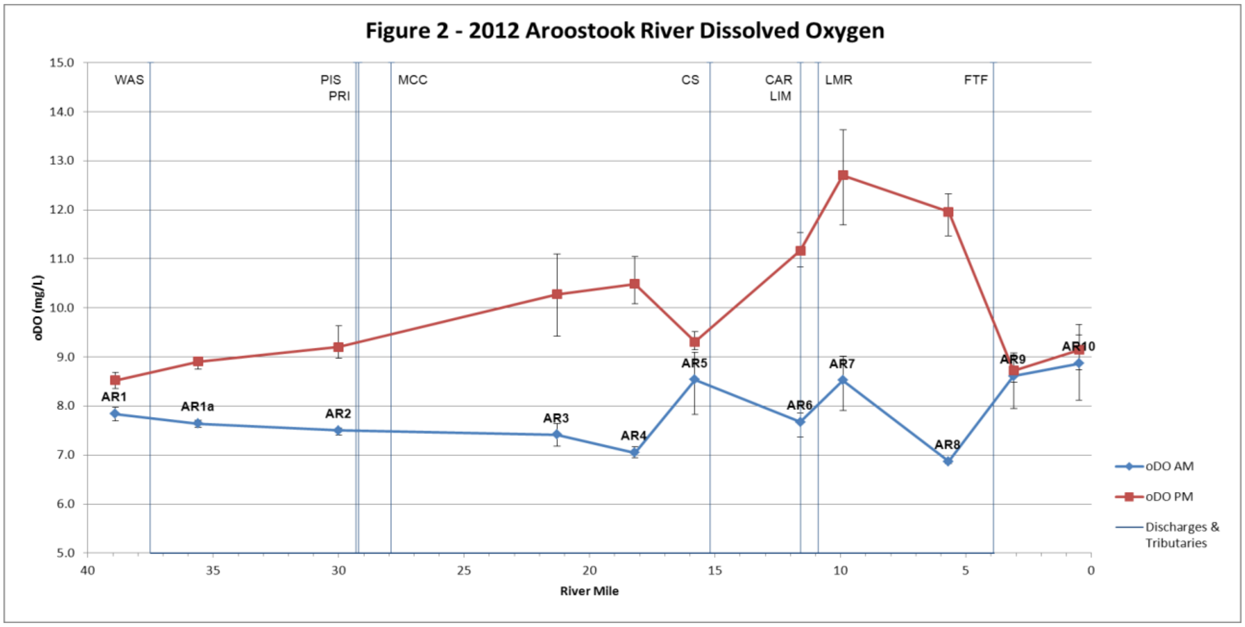
In the month of August flows remained within the target low flow range. With McCain Foods stopping production for approximately a month it was decide take some additional water quality samples for total phosphorus and orthophosphate at two stations, one upstream and the other downstream of Presque Isle and McCain Food's outfall, once a week for four weeks. These stations are AR2 (River Mile 30.0) and AR3 (RM 21.3). See "August Phosphorus Samples" for results.

Ambient River Data

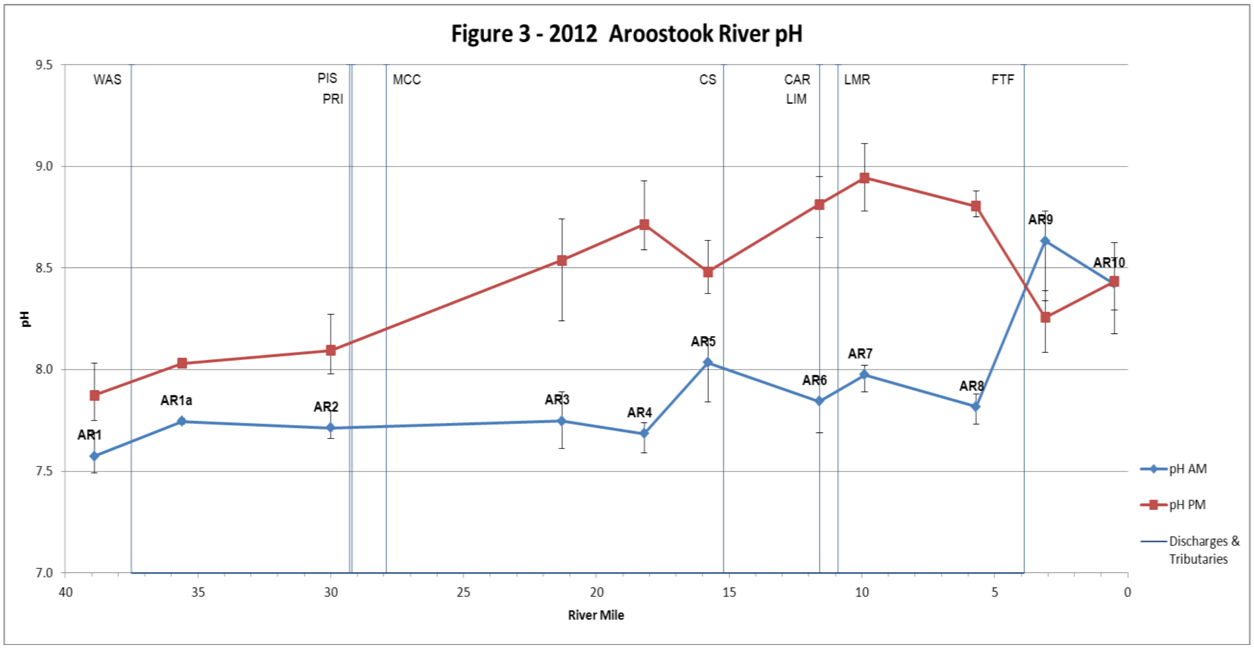
Dissolved Oxygen, Temperature and pH

Dissolved oxygen (DO), temperature, and pH were sampled twice daily on each of the three-day survey days, in the morning, before 8:00 AM and in mid afternoon. The average sample time for all morning stations was 6:29 AM and for afternoon stations it was 2:14 PM. See Appendix B.

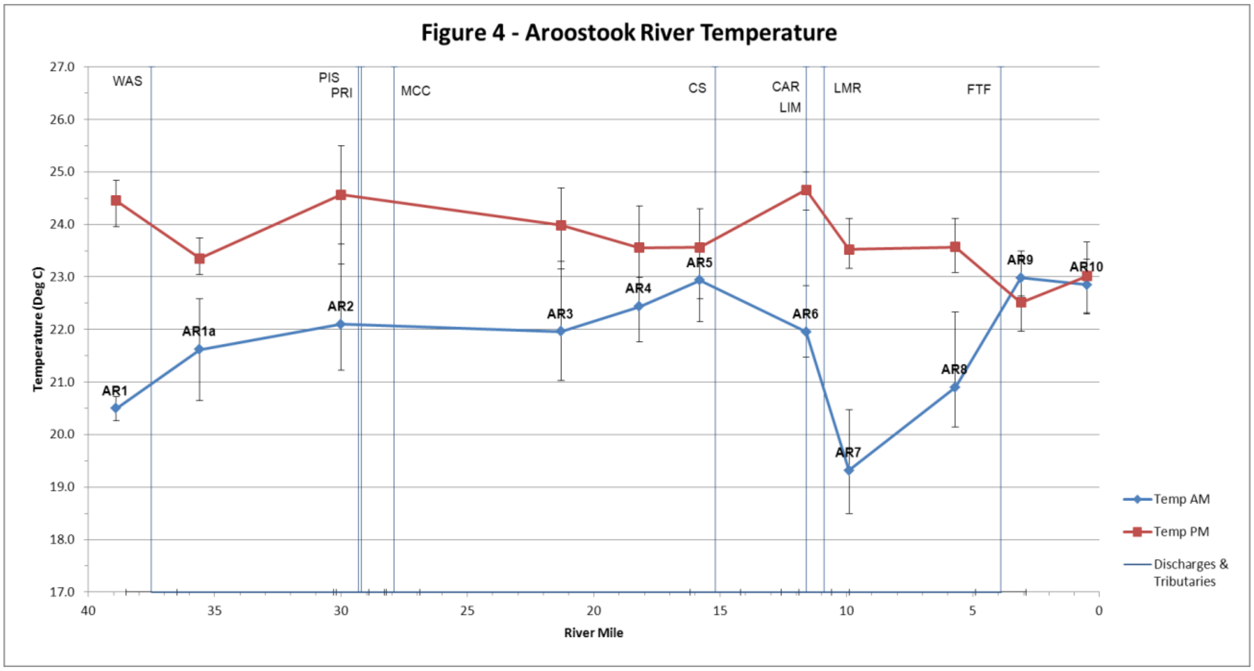
Diurnal fluctuations in DO concentration is an indicator of the presence of algae, both free-floating (phytoplankton) and bottom-attached (periphyton). The early morning DO readings are typically the daily minimum due to algal respiration (which consumes oxygen) occurring at night. During the daytime, oxygen production from photosynthesis results in a daily maximum DO in mid to late afternoon. Large diurnal fluctuations (swing) in DO correlate to the proliferation of these algae. Algal growth responds to nutrient content and there is corresponding widening of the diurnal fluctuation as can be seen at stations AR1a, AR 3 and AR7 which are all downstream of point source discharges, see Figure 2 (note abbreviations at the top of the graph mark river mile stations for discharges and tributaries, see table 1).



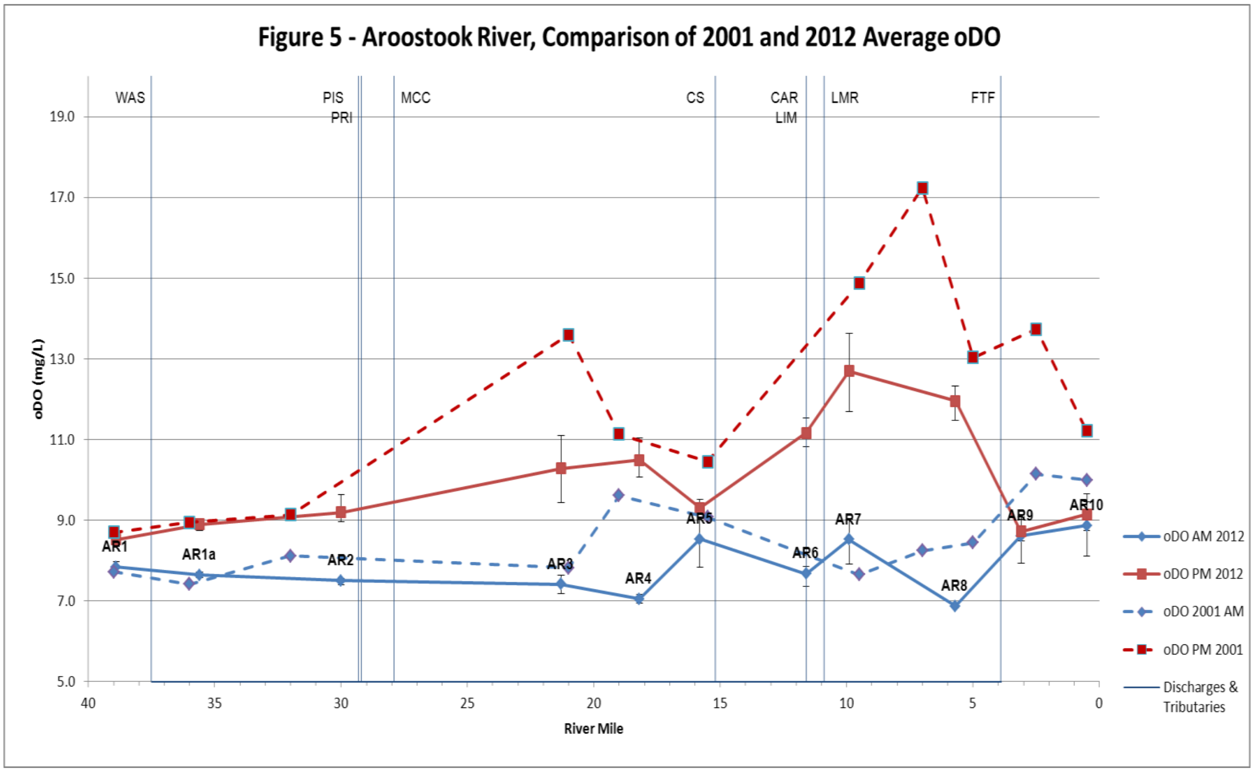
The pH is governed by the amount of carbon dioxide in the water. Photosynthesis consumes carbon dioxide and respiration produces it. The extent of diurnal fluctuation in pH is an indication of algal metabolism and will correspond with the relative fluctuation in DO. This can be shown by comparing the trends from station to station of Figure 2 and Figure 3.



Water temperature typically follows the same pattern of dissolved oxygen with lower readings in the early morning and higher readings in the afternoon due to sunlight and mixing with ambient air temperatures at the water surface. Shallow reaches will have more mixing with the ambient air and less volume to heat up from solar radiation, therefore they will have a wider fluctuation in diurnal temperature (Figure 4).



Maintaining adequate dissolved oxygen levels becomes increasing difficult at higher water temperatures because as temperature rises the oxygen saturation in water decreases and the decay of organic matter increases, both of which lower dissolved oxygen. Temperature and DO were measured each of the three-days of the intensive survey. Comparing the results with the 2001 survey (see figure 5) shows a similar trend in diurnal fluctuation, with a narrow range above Presque Isle, widening below the Presque Isle and McCain Foods discharges through the shallow reaches down to the Caribou dam impoundment, narrowing again in the impoundment, widening from the dam to the Caribou/Limestone discharges, increasing with the addition of the discharges down to the beginning of the Tinker dam impoundment where it again narrows. Note that the flows during the 2012 sample period were approximately four times those of the 2001 survey, this may account for the broader range in DO fluctuation. This will be investigated in the water quality model.



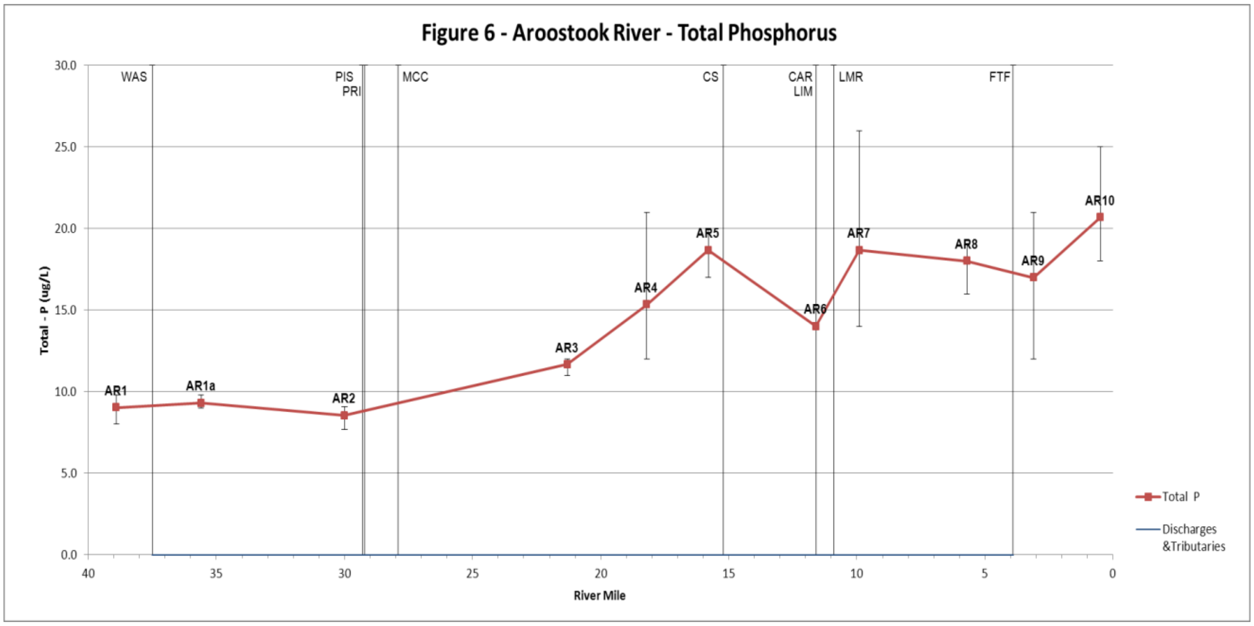
Data Sondes

Data sondes were deployed at stations AR3 and AR7 for extended periods in the month of August, 2012. Data plots of DO, temperature, and pH are presented in Appendix E. At both sample sites the data confirm the response of the three parameters to the diurnal photoperiod; they have approximately the same response frequency. Variations in the river temperature would correspond to ambient air temperature, cloud cover, and runoff events. This is shown from the period August 10th – 13th where records from the Crown Weather Service Station in Caribou show on August 10th the daily high air temperature dropped from 25.6°C to 18.9ºC and 0.5 inches of rain fell; also there was extensive cloud cover until the 13th. There was a direct response in river temperature with the DO and pH following the trend to the lesser degree.

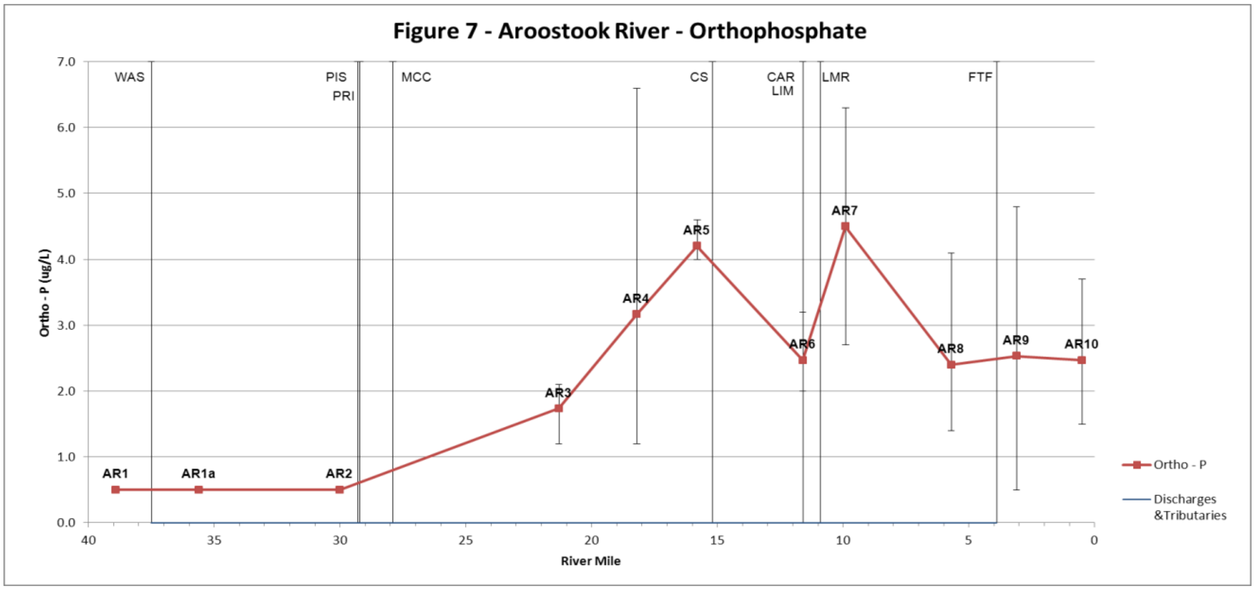
Nutrients

Nitrogen and phosphorus are the primary nutrients that could be controlling factors for plant growth and the development of excessive growth. Moderate levels of nutrients and algae are desirable and, in fact, are a vital component of the food chain. It is only when nutrients reach an excessive threshold where they may result in an algal bloom and become water quality concern. Appendix C has all the chemistry results from the three-day survey.

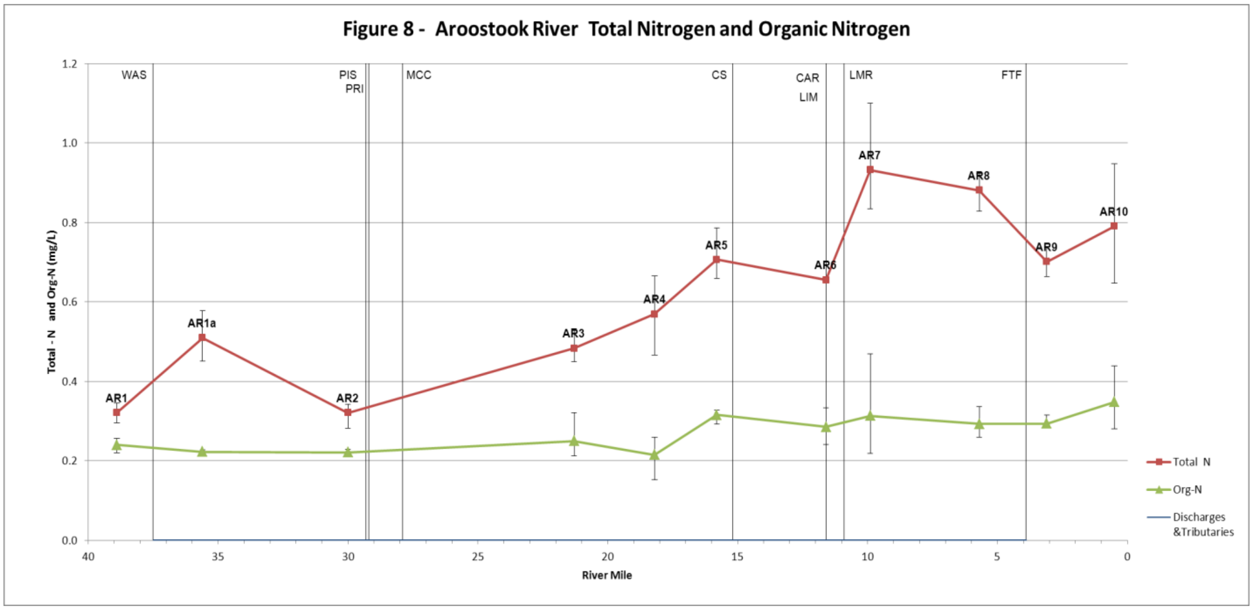
Total phosphorus (TP) and orthophosphates (Ortho-P) were measured at each ambient river station over the three-day survey. The average TP value for each station is plotted in Figure 6. Total phosphorus remained below 10 ppb above Presque Isle showing a slight increase below the Washburn discharge, then again downstream of the Presque Isle and McCain Foods discharges. It then steadily rises in the Caribou impoundment, peaking at 18.7 ppb at the dam. Decreasing to 14 ppb above Caribou/Limestone discharges, rising sharply immediately downstream and maintaining a level between 17 and 20.7 ppb to the border.



Orthophosphate levels follow a similar consistent trend as TP in the reaches above Presque Isle with all readings below the detection level of 1.0 ppb. (According to convention they were plotted as 0.5 ppb). Below Presque Isle and in the Caribou impoundment they rise, dramatically peaking at 4.2 ppb at the dam. Similar to TP, Ortho P dropped to 2.5 ppb above Caribou/Limestone discharge, rose to 4.5 ppb below the discharges and then dropped again to approximately 2.5 ppb through the Tinker dam impoundment.



Total nitrogen (TN) is composed of organic nitrogen (Org-N), nitrate and nitrite nitrogen, (NO2-N, NO3-N) and ammonia (NH3). In the lower Aroostook River the majority of the NH3 has been oxidized, leaving the Org-N and NO3-N as the two primary components. Figure 8 is a plot of TN and Org-N and it shows that Org-N is fairly constant throughout the river, ranging from 0.22 to 0.35 mg/L with only slight increases within the dam impoundments. Contributions from point discharges increase the NO3-N to the river as can be seen with spikes below Washburn and Caribou/Limestone of 0.25 and 0.58 mg/L respectively.



Chlorophyll-a

Samples were collected in the morning and analyzed for chlorophyll-a (Chl-a) to determine levels of phytoplankton in the water column. A reading of 8.0 mg/L or greater is indicative of eutrophic conditions and would be expected to occur in impounded reaches. Average readings for the three-day study were all below 5.0 mg/L with only one at AR9 (Day 2) exceeding the 8.0 mg/L threshold (Figure 9). Levels were below 2 mg/L for all stations above the Caribou/Limestone discharge and steadily climbed to 5.0 mg/L at AR9, then dropping to 4.3 mg/L at station AR10. It is unclear why Chl-a values rose through AR7 and AR8. These are free flowing reaches and relatively shallow and would not be expected to have higher readings than the Caribou impoundment. Chlorophyll-A is not a reliable indicator of periphyton growth, but during the three-day survey, clumps of detached periphyton were observed floating throughout the water column and this could be a reason for this increase.

Secchi depth measurements were made at impoundment locations; AR4, AR5, AR9, and AR10. In the Caribou dam impoundment three Secchi depth readings were made; two were to the bottom and the third was 3.8 meters. In the Tinker impoundment four Secchi depth readings were made; three averaged 1.6 meters and the forth at AR10 was to the bottom at 3.0 meters. It was noted that the shallowest reading 1.1 meters at AR9 was made on Day 2, the day after a morning rain where sediment was evident in the water column.

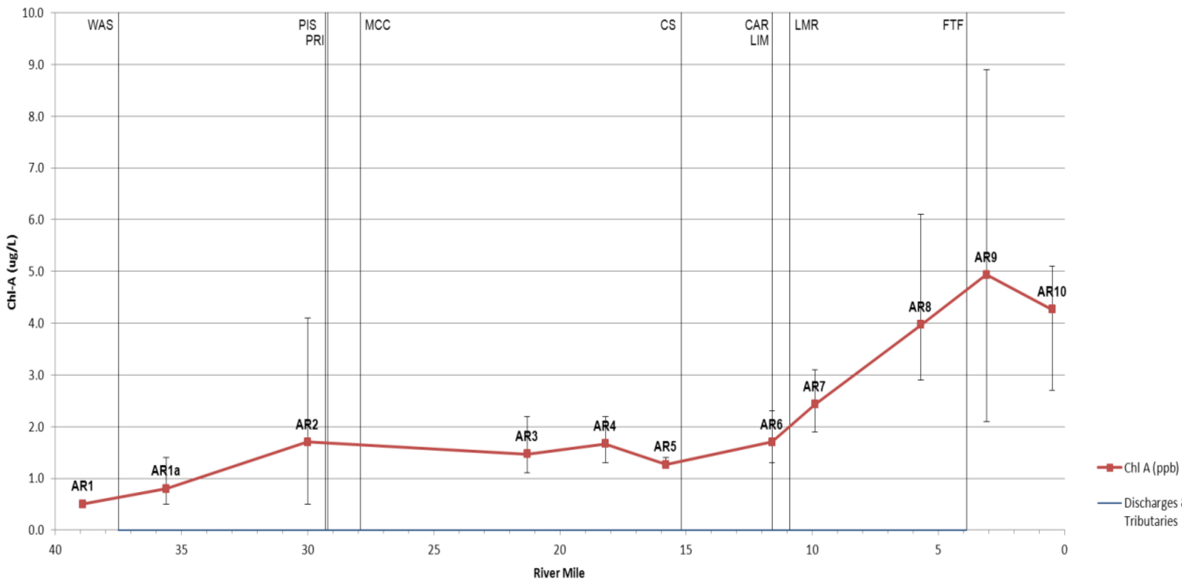


Figure 9 - Aroostook River - Chlorophyll -A

Ultimate BOD

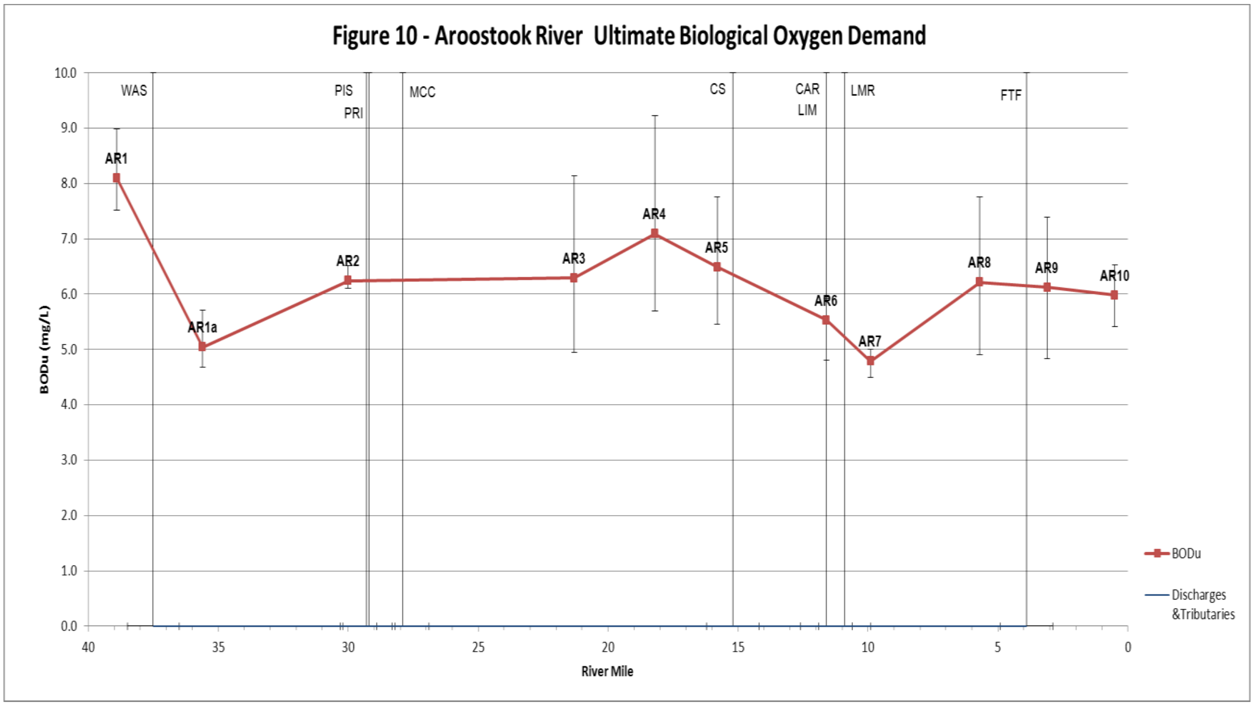
Samples were collected for ultimate BOD analysis in the morning. Ultimate BOD (BODu) samples are run in the laboratory for a period of 60 days or more and DO depletion observed for several readings within this period. A curve of DO depletion vs. time is fit onto the data using a least squares regression equation as indicated by the following:

$BOD_t = BOD_u\,(1-e^{-kt})$ where;

BOD_t = BOD level in ppm at time t
BOD_u = ultimate BOD in ppm
K = first order reaction rate in units of /day
t = time in days

The nitrogenous component of the BOD is obtained from a difference of initial and final nitrate nitrogen times a stoichiometric factor of 4.33. The carbonaceous component of BOD is obtained from a difference of total BOD and nitrogenous BOD.

The range of BODu readings for the Aroostook River was approximately 5.0 to 8.0 mg/L throughout the lower Aroostook River (Figure 10). These values are typical of areas with low to moderate pollution. It was expected that the BODu concentrations would increase below point source discharges, but there is a significant decrease below Washburn and Caribou /Limestone and no increase below Presque Isle/McCain Foods and Fort Fairfield. Tributary BODu readings were Presque Isle Stream – 6/5 mg/L, Caribou Stream – 5.4 mg/L, and Little Madawaska River - 5.3 mg/L. The BODu of the Aroostook River samples was comprised, on the average, of 81% carbonaceous and 19% nitrogenous. The BOD bottle, or laboratory, decay rate was 0.026 /day for the three-day river survey. River decay rates and the laboratory decay rates are not necessarily the same but the laboratory rates establish a lower boundary for the actual river decay rate which is of interest within the water quality model.



August Phosphorus Samples

Additional ambient samples for TP and Ortho-P were taken at AR2 and AR3 for three weeks while McCain Foods discontinued production (8/15-29) and once after production resumed (9/5). Table 3 shows those results and includes the average readings taken during the three-day survey (7/25).

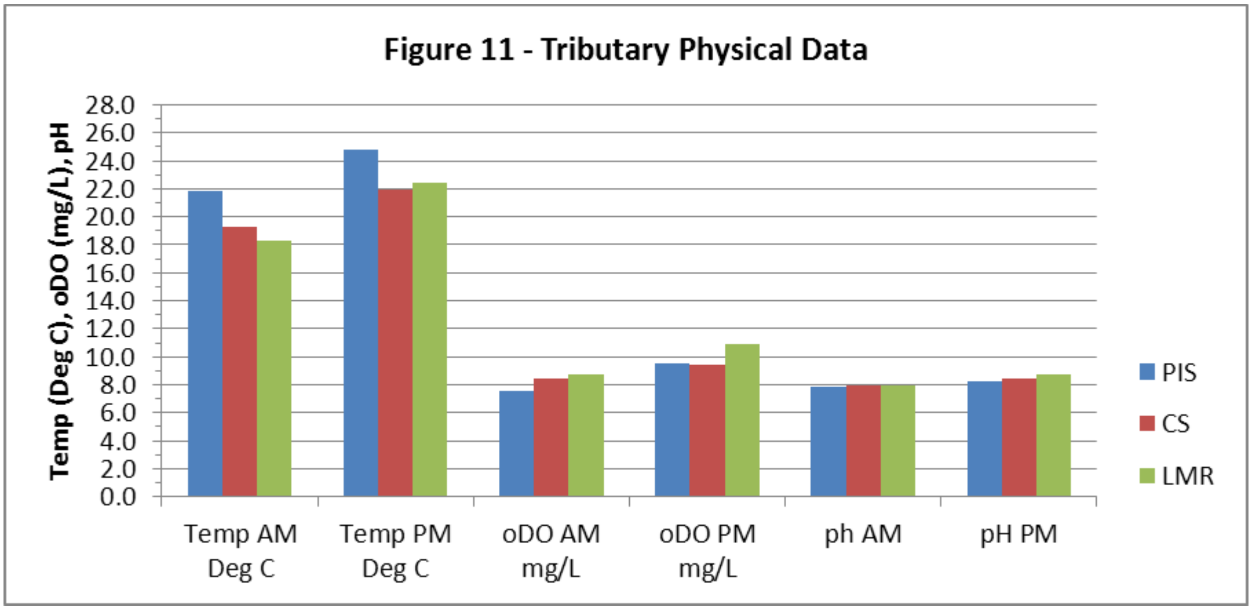
Table 3 - Aroostook August Total Phosphorus and Ortho Phosphate

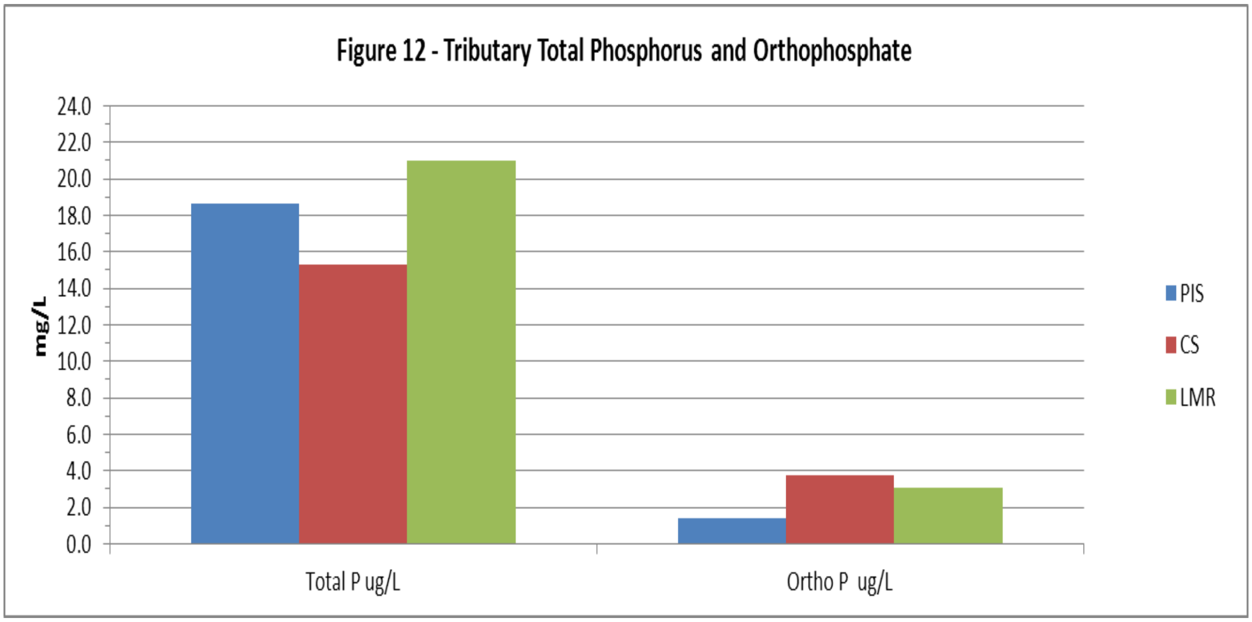
	Station AR2		Station AR3	
Date	Ortho-P (µg/L)	Total P (µg/L)	Ortho-P (µg/L)	Total P (µg/L)
7/25/2012	0.5	8.5	1.7	11.7
8/15/2012	3.2	7.9	3.8	12.0
8/21/2012	1.1	8.7	4.3	14.0
8/29/2012	<1	6.9	1.0	9.8
9/5/2012	2.6	8.7	10.0	21.0

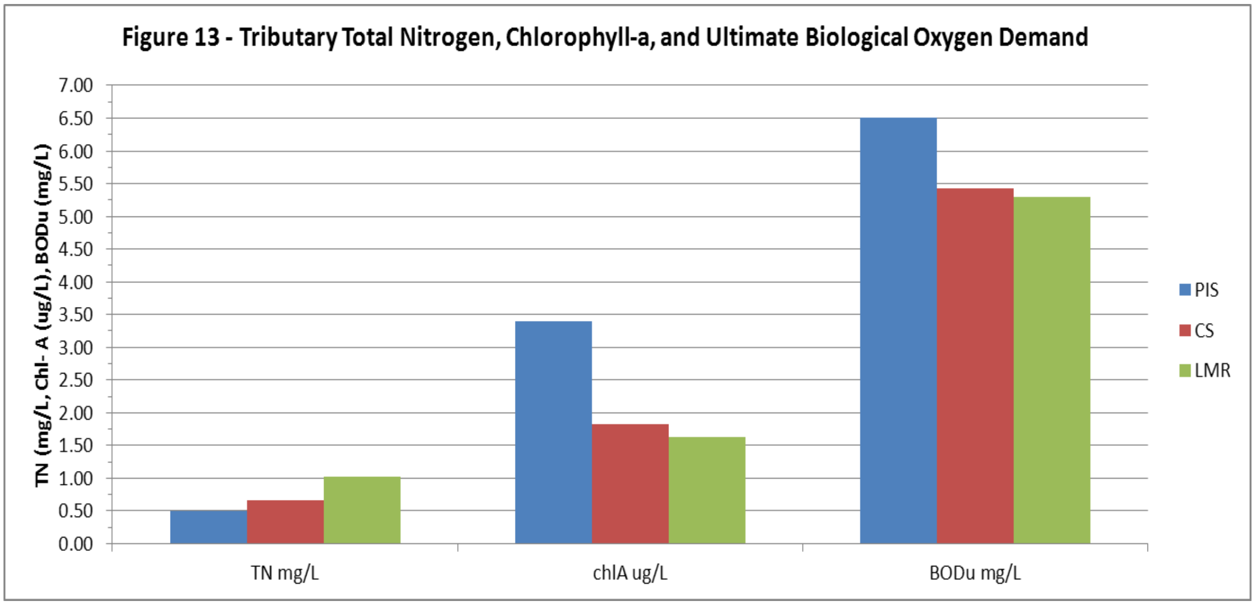
Ambient Tributary Data

In the 2001 survey, Presque Isle Stream and the Little Madawaska River both had up-steam sample stations because they had major point discharges to them. With the relocation of the Presque Isle Sewer District discharge and the Limestone Water and Sewer District discharge directly to the Aroostook River, these major tributaries will be treated as point loads in the water quality model. Sample stations for the 2012 survey were taken directly above the confluences with the Aroostook.

The following figures (11-13) show the average values for the three-day survey. When compared to the main stem Aroostook River data they were similar.



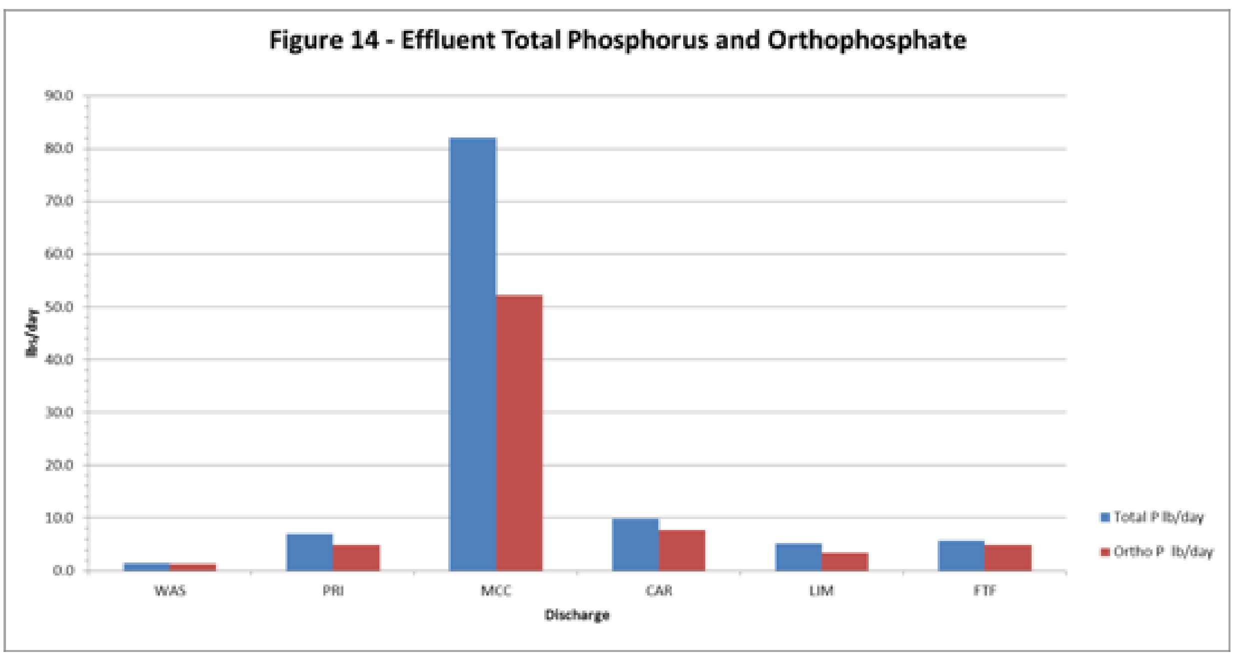




Effluent Data

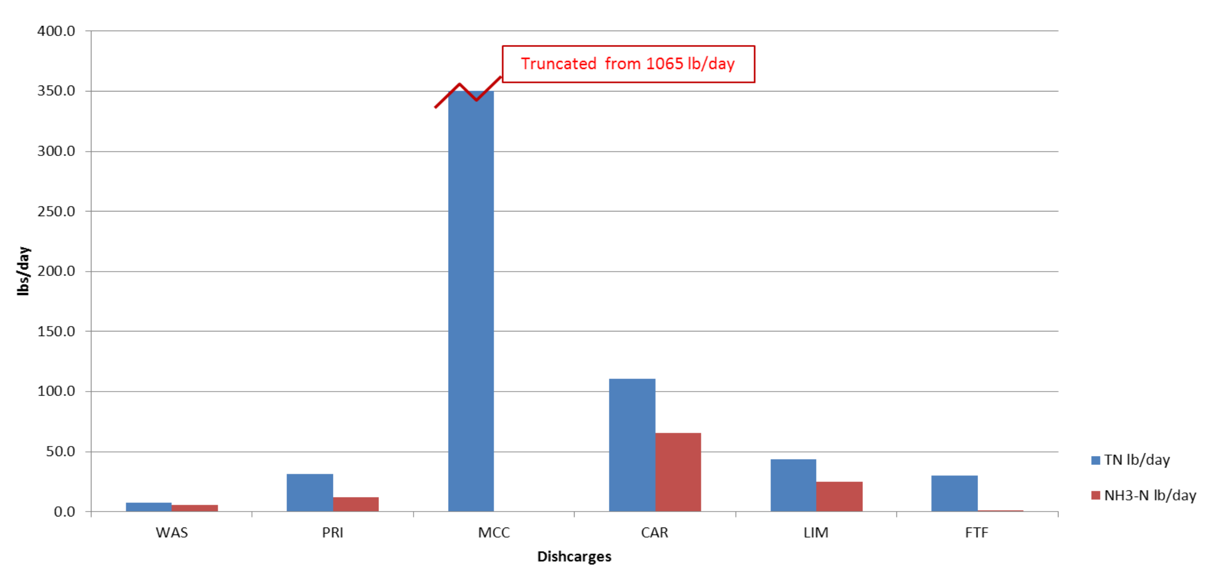
Samples from six point source discharges were collected as 24-hour composite samples on the day prior to the each ambient sampling. Discharge flow rates were also measured on the day of sampling. Average loads were calculated for total phosphorus and orthophosphate, total nitrogen and ammonia, and ultimate BOD. Although samples were taken at their respective facilities, Caribou and Limestone share the same outfall pipe. When the sample data are used for model calibration they will be combined. See Appendix D for effluent data.

Effluent total phosphorus (TP) and orthophosphate (Ortho-P) loadings in lbs./day are shown in Figure 14. For the three-day survey McCain Foods discharged the largest load of TP and Ortho-P.



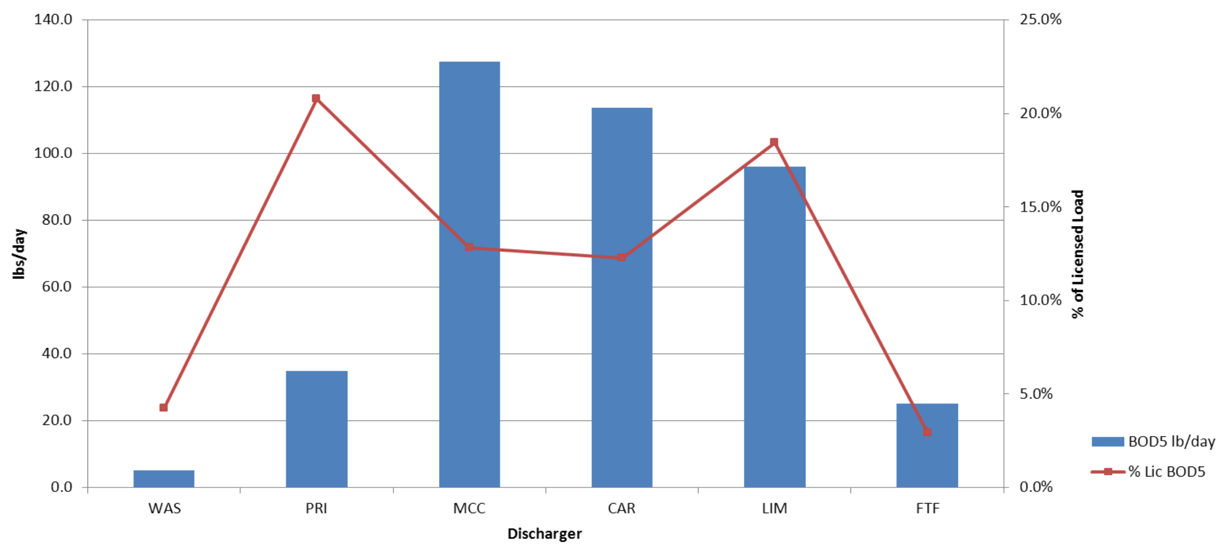
Effluent total nitrogen (TN) and ammonia (NH3) loading in lbs./day are shown in Figure 15. The column for TN load for McCain Foods was truncated from 1065 lbs./day to fit on the graph. As confirmed in the Appendix D table, there is essentially no organic-N and the majority of the TN discharge is nitrate/nitrite nitrogen.

Figure 15 - Effluent Total Nitrogen and Ammonia



When effluent BOD5 loads are compared to allowable licensed amounts (Figure 16) all plants were discharging under 21% of their licensed BOD5 load during the low flow survey. Both Washburn and Fort Fairfield were discharging below 5% of their licensed load. Collectively, the dischargers were at 11.2% of their licensed BOD5 loads.

Figure 16 - Effluent BOD5 and As Percent of Licensed Load



Quality Control

Proper quality control is essential for any sampling effort to assure data collected are good data. Quality control procedures were practiced in both field sampling and the laboratory analysis of various parameters. Data sondes have probes for dissolved oxygen, temperature, pH and depth. Three sondes were used during the study and were calibrated in the laboratory before the survey began in accordance with the manufacturer's QAPP and SOP. At the end of each survey day the sondes were cross checked.

The work plan specified that dissolved oxygen readings amongst sampling teams should be within 0.3 ppm and temperature should be within 1.0 ºC when cross checking readings. Table 4 shows those results and that these criteria were met. All readings were within a maximum difference of 1.0%.

Table 4- Sonde Calibration

Day	7/24/12				7/25/12				7/26/12			
Sonde	1	2	3	Max % Diff.	1	2	3	Max % Diff.	1	2	3	Max % Diff.
TIME	4:59:30	4:54:11	4:57:40		4:54:46	4:55:04	4:55:23		4:47:20	4:46:20	4:48:53	
Temp deg C	24.02	24	23.97	**0.2%**	23.15	23.11	23.09	0.3%	22.69	22.71	22.73	0.2%
HDO %Sat	99.6	99.7	99.9	**0.3%**	100.2	100.4	99.8	0.6%	99.8	100.2	99.9	0.4%
HDO mg/l	8.36	8.38	8.31	**0.8%**	8.33	8.35	8.31	0.5%	8.36	8.4	8.37	0.5%
pH units	8.19	8.16	8.19	**0.4%**	8.48	8.48	8.53	0.6%	8.44	8.39	8.42	0.6%
SpCond uS/cm	411.1	408.7	410.6	**0.6%**	414.8	412.6	414.3	0.5%	422.4	420.4	423	0.6%
Salinity PSS	0.19	0.19	0.19	**0.0%**	0.2	0.19	0.2	0.0%	0.2	0.2	0.2	0.0%

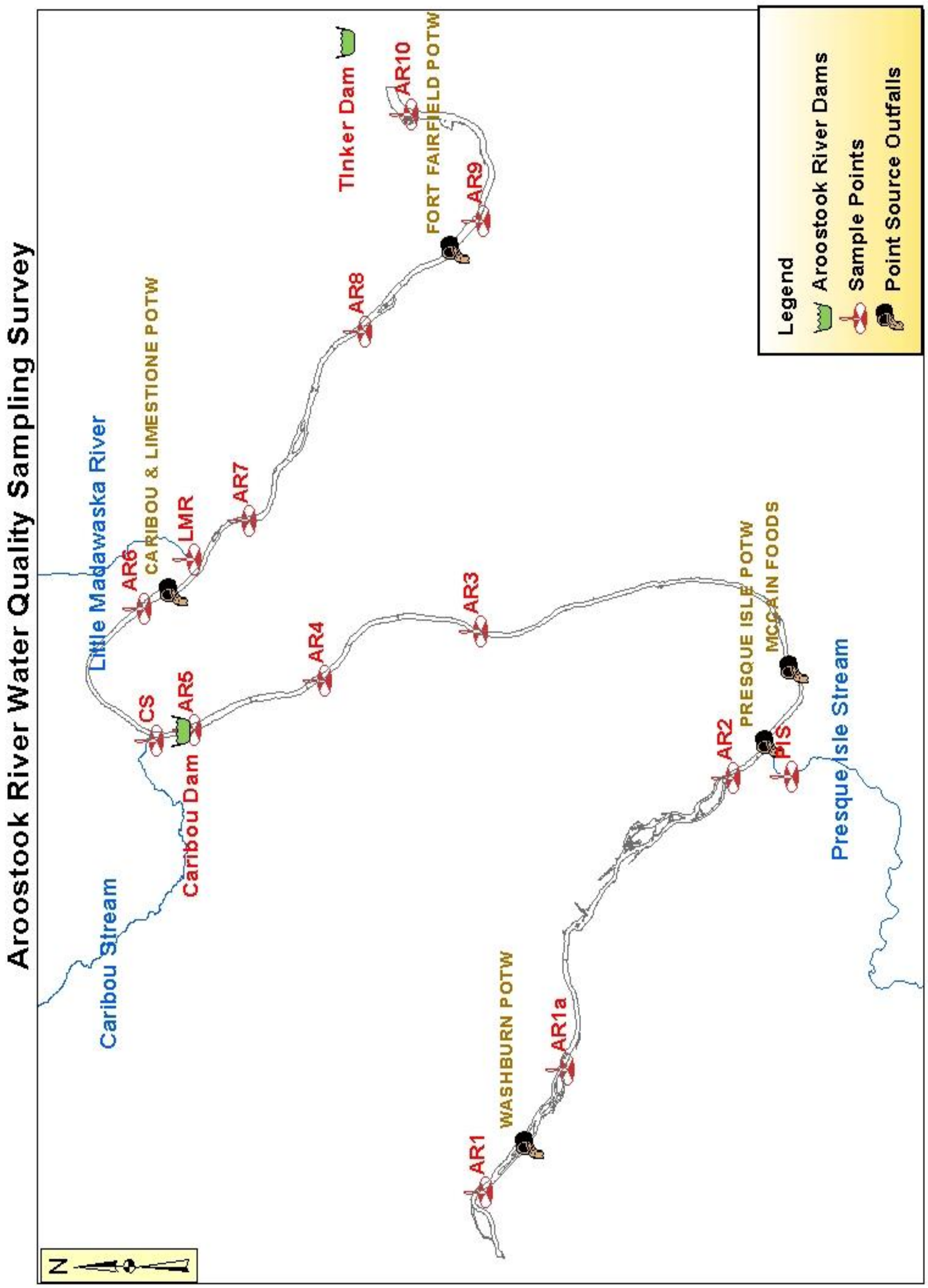
Field duplicate water quality samples were collected for all parameters at the river, tributaries and effluent station each day during the intensive survey. Duplicate samples for this study included three ambient river samples, one tributary sample, and two effluent samples. Table 5 shows the results of the river/tributary sampling. The results were satisfactory; 91% of the river/tributary duplicate measurements were within 20% and 78% were within 10% of the sample results. There is a concern with the Presque Isle Stream (PIS) duplicate, which will be evaluated when using these data in the model calibration.

Table 6 has the effluent sample results. Effluent duplicate results were also satisfactory. Of the fourteen samples taken only one, Washburn BOD5 differed by more than 10% but was within 20%.

Table 5 - Ambient River/Tibutary Duplicate Sample Analysis									
		Chl a ©	orthoP	TP	NOx-N	NH3-N	TN	NOx (60)	BOD60
Station	Date	mg/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
AR1	07/25/2012	<0.001	<1	0.009	0.03	<0.08	0.32	0.312	4.2
AR1D	07/25/2012	<0.001	<1	0.007	0.03	<0.08	0.32	0.298	5.1
MAXIMUM % DIFFERENCE		NA	NA	22.6%	0.4%	NA	2.5%	4.5%	19.7%
AR5	07/25/2012	0.0012	4.0	0.019	0.42	<0.08	0.79	0.691	5.4
AR5D	07/25/2012	0.0015	4.4	0.016	0.41	<0.08	0.73	0.713	5.9
MAXIMUM % DIFFERENCE		25.0%	10.0%	15.8%	3.3%	NA	7.4%	3.2%	8.1%
AR6	07/26/2012	0.0015	3.2	0.014	0.33	<0.08	0.65	0.577	4.3
AR6D	07/26/2012	0.0015	3.5	0.014	0.33	<0.08	0.62	0.534	4.3
MAXIMUM % DIFFERENCE		0.0%	9.4%	0.0%	2.1%	NA	5.1%	7.5%	0.7%
PIS	07/24/2012	<0.001	1.2	0.017	0.24	<0.08	0.56	0.500	4.6
PISD	07/24/2012	0.0041	1.5	0.019	0.24	<0.08	0.61	0.722	7.6
MAXIMUM % DIFFERENCE		NA	25.0%	11.8%	2.9%	NA	9.0%	44.4%	64.9%

Table 6 - Effluent Duplicate Sample Analysis									
		River	orthoP	TP	NOx-N	NH3-N	TKN	BOD60	BOD5
Station	Date	Mile	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
LIM	07/25/2012	11.6	560	0.94	1.30	5.20	6.90	45.0	25.0
LIMD	07/25/2012	11.6	560	0.96	1.30	5.20	7.20	45.0	27.0
MAXIMUM % DIFFERENCE			0.0%	2.1%	0.0%	0.0%	4.2%	0.0%	7.4%
WAS	07/26/2012	37.5	2800	3.20	1.00	13.00	15.00	81.0	8.1
WASD	07/26/2012	37.5	2800	3.20	1.00	13.00	15.00	78.0	10.0
MAXIMUM % DIFFERENCE			0.0%	0.0%	0.0%	0.0%	0.0%	3.8%	19.0%

Appendix A. Location Map



Appendix B. Ambient Aroostook River Survey Field Data (DO, temperature, pH)

Station	Date	oDO AM mg/L	oDO PM mg/L	oDO AM % Sat	oDO PM %Sat	Temp AM Deg C	Temp PM Deg C	pH AM	pH PM
AR1	7/24/2012	7.69	8.36	90.40	103.70	------	24.84	7.49	7.75
	7/25/2012	7.97	8.68	90.50	106.00	20.26	23.96	7.69	7.84
	7/26/2012	7.86	8.52	90.10	105.20	20.73	24.57	7.54	8.03
AR1a	7/24/2012	7.57	8.75	87.70	106.30	22.59	23.74	7.73	8.02
	7/25/2012	------	8.99	------	107.80	------	23.05	------	8.02
	7/26/2012	7.71	8.97	88.30	108.00	20.65	23.27	7.76	8.05
AR2	7/24/2012	7.41	8.97	87.60	111.50	23.62	24.95	7.66	8.03
	7/25/2012	7.55	9.00	87.90	108.40	21.46	23.25	7.80	7.98
	7/26/2012	7.54	9.63	87.40	121.00	21.22	25.50	7.68	8.27
AR3	7/24/2012	7.18	9.43	84.30	115.50	23.30	24.12	7.61	8.24
	7/25/2012	7.42	10.31	86.50	123.90	21.55	23.15	7.89	8.63
	7/26/2012	7.64	11.10	88.10	137.40	21.03	24.69	7.74	8.74
AR4	7/24/2012	6.94	10.08	82.70	123.93	23.57	24.36	7.59	8.62
	7/25/2012	7.03	11.04	82.73	132.33	21.98	22.99	7.72	8.93
	7/26/2012	7.17	10.36	83.90	124.90	21.76	23.33	7.74	8.59
AR5	7/24/2012	9.09	9.27	108.25	113.85	23.54	24.30	8.15	8.37
	7/25/2012	7.83	9.52	94.04	115.88	23.12	23.81	7.84	8.63
	7/26/2012	8.69	9.14	102.44	108.78	22.15	22.59	8.11	8.44
AR6	7/24/2012	7.85	10.83	91.40	134.10	22.83	24.71	7.69	8.65
	7/25/2012	7.37	11.14	85.80	136.80	21.48	24.27	7.89	8.84
	7/26/2012	7.80	11.54	91.00	143.60	21.55	25.00	7.95	8.95
AR7	7/24/2012	7.91	11.69	88.00	140.90	20.48	23.29	7.89	8.78
	7/25/2012	8.63	12.79	94.70	153.80	18.50	23.17	8.02	8.94
	7/26/2012	9.02	13.63	99.90	166.80	18.96	24.11	8.01	9.11
AR8	7/24/2012	6.89	11.47	80.20	140.40	22.34	24.12	7.73	8.75
	7/25/2012	6.90	12.32	78.30	147.90	20.14	23.08	7.88	8.88
	7/26/2012	6.82	12.08	77.50	146.30	20.21	23.51	7.84	8.78
AR9	7/24/2012	7.94	8.49	94.50	102.37	23.50	23.30	8.34	8.08
	7/25/2012	9.02	9.08	107.70	106.73	22.81	21.96	8.78	8.39
	7/26/2012	8.88	8.58	105.70	101.45	22.64	22.29	8.78	8.30
AR10	7/24/2012	9.46	9.66	112.15	117.33	23.34	23.66	8.54	8.62
	7/25/2012	8.11	9.03	97.03	108.50	22.89	23.09	8.18	8.29
	7/26/2012	9.04	8.74	106.95	103.33	22.33	22.30	8.55	8.38
PIS	7/24/2012	7.57	9.12	88.20	111.50	22.87	24.04	7.81	8.11
	7/25/2012	7.54	9.51	87.40	117.40	21.26	24.56	7.98	8.24
	7/26/2012	7.42	9.92	86.10	125.40	21.32	25.84	7.86	8.40
CS	7/24/2012	8.23	9.03	91.40	107.30	20.36	22.51	7.88	8.29
	7/25/2012	8.63	9.67	94.10	112.40	18.19	21.38	7.98	8.47
	7/26/2012	------	9.63	------	113.30	------	21.99	------	8.43
LMR	7/24/2012	8.28	10.26	91.00	121.20	19.86	22.22	7.97	8.55
	7/25/2012	8.75	11.07	94.30	131.20	17.58	22.38	7.94	8.74
	7/26/2012	9.05	11.27	97.00	134.60	17.36	22.81	8.01	8.87

Appendix C. Ambient Aroostook River Chemistry (Nutrients, Chlorophyll–a, and BOD)

Station	Date	Chl-A © ug/l	orthoP ug/l	TP ug/l	NOx-N mg/l	NH3-N mg/l	TN mg/l	NOx(60) mg/l	Org-N mg/l	BODu mg/l
AR1	07/24/2012	0.5	0.5	8.0	0.03	<0.08	0.30	0.30	0.22	9.0
	07/25/2012	0.5	0.5	9.3	0.03	<0.08	0.32	0.31	0.26	7.5
	07/26/2012	0.5	0.5	9.8	0.06	<0.08	0.35	0.25	0.24	7.8
AR1a	07/24/2012	0.5	0.5	9.5	0.31	<0.08	0.58	0.53	0.23	4.7
	07/25/2012	1.4	0.5	9.8	0.24	<0.08	0.50	0.47	0.22	4.7
	07/26/2012	0.5	0.5	9.0	0.18	<0.08	0.45	0.35	0.23	5.7
AR2	07/24/2012	4.1	0.5	9.1	0.07	<0.08	0.34	0.31	0.23	6.5
	07/25/2012	0.5	0.5	8.8	0.08	<0.08	0.34	0.27	0.22	6.1
	07/26/2012	0.5	0.5	7.7	0.03	<0.08	0.28	0.16	0.22	6.1
AR3	07/24/2012	2.2	2.1	12.0	0.17	<0.08	0.53	0.50	0.32	5.8
	07/25/2012	1.1	1.9	11.0	0.22	<0.08	0.47	0.43	0.21	4.9
	07/26/2012	1.1	1.2	12.0	0.19	<0.08	0.45	0.42	0.22	8.1
AR4	07/24/2012	1.3	1.7	13.0	0.28	<0.08	0.58	0.53	0.26	6.4
	07/25/2012	2.2	6.6	21.0	0.47	<0.08	0.67	0.69	0.15	5.7
	07/26/2012	1.5	1.2	12.0	0.19	<0.08	0.47	0.41	0.23	9.2
AR5	07/24/2012	1.4	4.6	20.0	0.34	<0.08	0.67	0.63	0.29	7.8
	07/25/2012	1.2	4.0	19.0	0.42	<0.08	0.79	0.69	0.33	6.3
	07/26/2012	1.2	4.0	17.0	0.29	<0.08	0.66	0.62	0.33	5.5
AR6	07/24/2012	2.3	2.0	14.0	0.29	<0.08	0.66	0.63	0.33	5.9
	07/25/2012	1.3	2.2	14.0	0.37	<0.08	0.65	0.60	0.24	4.8
	07/26/2012	1.5	3.2	14.0	0.33	<0.08	0.65	0.58	0.28	5.9
AR7	07/24/2012	3.1	6.3	26.0	0.59	<0.08	1.10	1.06	0.47	4.9
	07/25/2012	1.9	4.5	16.0	0.60	<0.08	0.86	0.90	0.22	4.5
	07/26/2012	2.3	2.7	14.0	0.54	<0.08	0.84	0.79	0.25	5.0
AR8	07/24/2012	6.1	1.7	19.0	0.51	<0.08	0.89	0.85	0.34	6.0
	07/25/2012	2.9	4.1	19.0	0.60	<0.08	0.92	0.85	0.28	7.8
	07/26/2012	2.9	1.4	16.0	0.53	<0.08	0.83	0.74	0.26	4.9
AR9	07/24/2012	3.8	2.3	18.0	0.38	<0.08	0.70	0.69	0.28	6.2
	07/25/2012	8.9	4.8	21.0	0.38	<0.08	0.74	0.76	0.32	7.4
	07/26/2012	2.1	0.5	12.0	0.34	<0.08	0.66	0.60	0.28	4.8
AR10	07/24/2012	5.1	1.5	18.0	0.33	<0.08	0.65	0.62	0.28	6.5
	07/25/2012	5.0	3.7	25.0	0.47	<0.08	0.95	0.83	0.44	6.0
	07/26/2012	2.7	2.2	19.0	0.41	<0.08	0.78	0.76	0.33	5.4
PIS	07/24/2012	<1.0	1.2	17.0	0.24	<0.08	0.56	0.50	0.28	6.3
	07/25/2012	3.8	1.3	18.0	0.24	<0.08	0.36	0.50	0.08	7.0
	07/26/2012	3.0	1.8	21.0	0.24	<0.08	0.59	0.47	0.32	6.3
CS	07/24/2012	2.8	5.7	16.0	0.30	<0.08	0.73	0.77	0.38	5.2
	07/25/2012	1.2	2.8	16.0	0.35	<0.08	0.65	0.63	0.26	5.9
	07/26/2012	1.5	2.7	14.0	0.33	<0.08	0.59	0.56	0.22	5.2
LMR	07/24/2012	1.1	5.1	32.0	0.64	<0.08	1.17	1.19	0.49	4.4
	07/25/2012	2.0	2.5	17.0	0.71	<0.08	0.95	0.90	0.21	5.9
	07/26/2012	1.8	1.5	14.0	0.70	<0.08	0.94	0.92	0.21	5.6

Appendix D. Effluent Chemistry (Nutrients, and BOD)

Station	Date	orthoP mg/l	TP mg/l	NOx-N mg/l	NH3-N mg/l	TKN mg/l	NOx(60) mg/l	Org-N mg/l	BOD5 mg/l	BODu mg/l
WAS	07/24/2012	2.80	3.20	0.94	13.00	16.00	14.00	3.00	19.0	86.9
	07/25/2012	2.90	3.20	0.91	13.00	15.00	14.00	2.00	6.6	75.0
	07/26/2012	2.80	3.20	1.00	13.00	15.00	14.00	2.00	8.1	83.2
PRI	07/24/2012	0.52	0.73	2.60	0.19	1.20	3.70	1.01	4.2	11.2
	07/25/2012	0.65	0.89	0.24	1.90	2.80	2.50	0.90	4.1	13.7
	07/26/2012	0.26	0.46	0.19	1.40	2.30	2.50	0.90	2.0	15.5
MCC	07/24/2012	3.90	5.60	80.00	0.05	<0.1	75.00	0.00	11.0	15.7
	07/25/2012	4.00	6.60	78.00	0.04	<0.1	72.00	0.00	10.0	21.9
	07/26/2012	3.70	6.00	78.00	0.05	<0.1	76.00	0.00	7.3	22.3
CAR	07/24/2012	1.10	1.50	4.10	10.00	12.00	14.00	2.00	32.0	73.5
	07/25/2012	1.40	1.70	6.20	12.00	14.00	18.00	2.00	11.0	80.6
	07/26/2012	1.50	1.90	7.20	12.00	14.00	19.00	2.00	16.0	77.6
LIM	07/24/2012	0.55	0.77	2.30	2.20	3.40	5.50	1.20	14.0	22.7
	07/25/2012	0.56	0.94	1.30	5.20	6.90	7.10	1.70	25.0	45.2
	07/26/2012	0.53	0.73	1.30	4.30	5.50	6.20	1.20	6.5	30.6
FTF	07/24/2012	3.20	3.80	16.00	0.80	3.70	38.00	2.90	22.0	44.9
	07/25/2012	2.90	3.40	15.00	0.50	3.50	15.00	3.00	15.0	36.5
	07/26/2012	2.90	3.40	15.00	0.50	3.20	17.00	2.70	10.0	36.5

Appendix E. Continuous Sonde Data