Penobscot River 2001 Data Report
May 2002

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DEPLW-0484

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Introduction

The Penobscot River Basin is the largest river basin lying entirely within the state of Maine. It has a drainage area of 8592 square miles at its mouth. The river segment of interest on the Penobscot River begins in Millinocket below Ferguson Lake as the West Branch, where after 10 miles it joins with the East Branch. It then flows an additional 72 miles before reaching the site of the former Bangor dam, and then over 21 additional miles of tidal waters to Bucksport. In this 103 mile segment, there are 15 point source discharges, 12 dams, 11 of which are retrofitted for hydropower, and 9 tributaries that have a drainage area of over 100 square miles.

In the summer of 2001, the DEP had planned a basin wide sampling effort on the 103 miles of river from Millinocket to Bucksport, which is a follow up to a similar data collection effort in 1997. In the spring of 2001, the DEP met with many stakeholders in the river basin who participated in both the planning and actual field sampling, similarly to 1997. Participants in the study included representatives from Maine DEP, Penobscot Nation, USEPA, Great Northern Paper Co, Champion International Paper Co, Lincoln Sanitary District and Georgia Pacific Corp of Old Town. An ambitious sampling effort was planned once again including the Penobscot River, major tributaries, and point sources.

The purpose of the 2001 sampling effort is to collect a second data set, which in conjunction with the 1997 data will be used for calibration and verification of a water quality model. Collection of a second data set in 2001 was recommended in the Penobscot Modeling Report (DEPLW2000-11, June 2000). The modeling report also stated that the collection of an additional data set in the summer of 2001 will be used to re-assess attainment / non-attainment status of dissolved oxygen criteria and trophic state of the Penobscot River.

The summer of 2001 proved to be a rather dry summer in which suitable river flow conditions were reached for the study. The overall quality of the data is considered to be excellent. A brief description of this effort will follow.

Technical Design of Study

The technical design of this study is explained in detail in the <u>Penobscot River Basin Work Plan</u> (Maine DEP, June 2001). Some of the highlights are repeated here for convenience. The sampling that was undertaken involved one three-day intensive survey collected on Tuesday, Wednesday, and Thursday. The three day sampling event for the Penobscot was tentatively targeted in three weeks of the summer of 2001 (July 24, 25, and 26; August 7, 8, and 9; or August 21, 22, and 23) and was constrained upon achievement of a satisfactory low flow condition. The first week of late July was determined to be unsatisfactory due to rapidly changing flow conditions from runoff received from recent precipitation events. The second targeted week resulted in satisfactory low flow conditions. The sampling hence occurred from August 7th to 9th.

Dissolved oxygen and temperature (all locations), and salinity (tidal locations only) were sampled twice daily at thirty main stem locations (table 1), and ten tributary locations (table 2). In addition, samples were collected for nutrient analysis (NH3-N, TKN, NO2+NO3-N, TP, and PO4-P); chlorophyll a, and ultimate BOD (all) and secchi depth (where depth allows) at eighteen main stem locations (table 1) and ten tributary locations (table 2). Composite samples were collected for fifteen point sources inputs (table 3) for nutrient, ultimate BOD, and BOD5 analysis.

The data collection effort also resulted in the placement of continuous recording equipment for dissolved oxygen and temperature in three locations (above Rockabema dam, North Lincoln, and above West Enfield dam). In addition, core samples were collected for sediment oxygen demand analysis at twelve locations in the fall of 2001.

Table 1
Penobscot River Sampling Locations

Station Code	Station Location	Chemical Parameters
West Branch Penobscot		
WBP1	Ferguson Lake Outlet	All
WBP2	Dolby Pond Inlet	All
WBP3	Above Dolby Dam	All
WBP4	Above Mill Dam 2	DO / Temp
WBP5	Above Rockabema Dam	All
Main Stem Penobscot		
Pn1	Above Weldon Dam	All
Pn2	Winn	DO / Temp
Pn3	North Lincoln	All
Pn4	South Lincoln	All
Pn5	Above West Enfield Dam	All
Pn6	Passadumkeag	DO / Temp
Pn7	Greenbush	DO / Temp
Pn8	Costigan	DO / Temp
Pn9	Milford Dam	All
Pn10	Great Works Dam	DO / Temp
Pn11	Orono near Water Co.	DO / Temp
Pn12	Above Veazie Dam	All
Pn13	Above Bangor Dam	All
DupR	River Duplicate	All
Tidal		
PnE1	Bangor Rte 9 / 1a Bridge	DO/Temp/Sal
PnE2	South Brewer	All
PnE3	North Orrington (ledges)	DO/Temp/Sal
PnE4	Orrington (near PERC)	DO/Temp/Sal
PnE5	Orrington Center	All
PnE6	Bald Hill Cove	DO/Temp/Sal
PnE7	South Orrington	All
PnE8	North Bucksport	DO/Temp/Sal
PnE9	Winterport	All
PnE10	Confluence Marsh Stream	DO/Temp/Sal
PnE11	Harriman Cove	DO/Temp/Sal
PnE12	Fort Knox	All
DupE	Estuary Duplicate	All

Table 2
Tributary Sampling Locations

Station Code	Station Location	Chemical Parameters
MiS	Millinocket Stream	All
EBPn	East Branch Penobscot	All
MaR	Matawamkeag River	All
PiR	Piscataquis River	All
StR	Stillwater River	All
DupT	Tributary Duplicate	All
PaR	Passadumkeag River	All param. day 2, only
PuS	Pushaw Stream	
KeS	Kenduskeag Stream	
SoS	Soudabascook Stream	DO / Temp all 3 days
MaS	Marsh Stream	

Table 3
Effluent Sampling Locations

Station Code	Station Location	No. Days Sampled
GNPW	Great N. Paper West	3
Mill	Millinocket	3
GNPE	Great N. Paper West	3
EPL	Eastern Paper, Lincoln	3
Linc	Lincoln	1
Howl	Howland	1
OldT	Old Town	3
GPOT	Georgia Pacific Old T.	3
Oron	Orono	3
Veaz	Veazie	1
Bang	Bangor	3
Brew	Brewer	3
Wint	Winterport	1
Buck	Bucksport	1
IPB	Inter. Paper Bucksport	3

Note: Effluents were collected as composite samples and analyzed for BOD5, ultimate BOD, TP, PO4-P, TKN, NH3-N, and NO2+ NO3-N.

Hydrologic Data

River flow data is available at a number of locations on the Penobscot River and some limited tributaries. There is a USGS gage at West Enfield ; flow estimates from Great Northern Paper Co. on the West Branch at Dolby dam, the East Branch of the Penobscot, and Weldon dam; and flow estimates from Bangor Hydro Co. at Milford and the Stillwater Branch. There is also tributary gaging data from USGS on the Piscataquis River at Dover Foxcroft and Medford and the Mattawamkeag River at Mattawamkeag.

Trigger flows were established utilizing the USGS gage in West Enfield as a determination whether or not flow was sufficiently low enough to make the sampling effort worthwhile. For the three-day survey a 90% flow duration (4400 cfs) was set as the ideal target trigger flow but flows up to 75% flow duration (5600 cfs) were still considered acceptable. The three day average flow of 3400 cfs at West Enfield when sampling was undertaken is lower than the lower target flow (figure 1) indicating ideal low flow conditions occurred. The three day survey was sampled at a 97% flow duration and low flow approached a five year recurrence. A similar low flow occurred in the 1997 data collection effort (actually about 100 cfs higher in 1997). A ten year low flow is used by DEP as a worse case low flow.

The continuous flow data can be used as an indication of whether or not significant runoff occurred prior to the sampling dates. This runoff would indicate non point source loading could have influenced sampling results. A large storm event occurred two week prior to sampling, but peaks flows were reached around July 27th. Hence both the tributary and West Enfield gaging data indicate that significant runoff did occur from storms ten days prior to sampling. It is generally desirable not to have runoff during and prior to the model calibration data sets, due to the facts that the runoff pollution is difficult to quantify and lack of runoff is desirable for worse case conditions of low flow. Hence it is concluded that the three day intensive survey data from 2001 was sampled under ideal hydrologic conditions for re-calibrating the water quality model. A similar conclusion was reached with the 1997 three day intensive survey (see Penobscot Data Report, April 1998).

Ambient Chemical Data

The chemical data collected for the three day intensive survey were dissolved oxygen (D.O.), temperature, salinity in tidal waters, total phosphorus (TP), orthophosphorus (PO4-P), total kjeldhal nitrogen (TKN), ammonia nitrogen (NH3-N), nitrite plus nitrate nitrogen (NO2+NO3-N), chlorophyll a (chl a), and ultimate BOD (TBODu). All of these parameters were measured in the early morning hours and, in addition, mid afternoon readings of D.O., temperature, and salinity were made to capture diurnal effects. Secchi depth measurements were made on one day of the three day surveys.

For the three day surveys it is desirable to sample the river under steady state conditions of flow and water chemistry, i.e. conditions remaining constant with time. Not only is it easier to interpret the data under steady conditions, but is also essential for application of the water quality model, which assumes steady state. Hence readings of flow, water chemistry, and waste discharge should be relatively similar when comparing all three days of the survey. An examination of the data reveals that the data was very constant from day to day and its quality is therefore considered good for application with the model.

Dissolved Oxygen, Temperature, and Salinity

Dissolved oxygen and temperature were measured with YSI portable meters. Meters were calibrated in the early morning and checked frequently during sampling. In addition, meters were cross checked with other meters from adjacent sampling teams both prior to and after sampling.

The D.O. readings on the Penobscot River in from August 7th to 9th failed to meet D.O. criteria at a number of locations (figure 2). Class C minimum D.O. criteria of 5 ppm and 60% of saturation were met at all 7 sampling locations that are classified C (five locations on West Branch, and 1 each above Weldon, and West Enfield impoundments). However on class B segments, where there are fourteen sampling locations, only four locations (Costigan, and above Milford, Veazie and Bangor dams) met minimum class B criteria of 7 ppm and 75% of saturation. D.O. readings of sampling locations, which didn't meet class B minimum criteria, ranged from 6.1 to 6.9 ppm. In the estuary, minimum class SC D. O. criteria of 75% of saturation was met at all nine sampling locations.

Diurnal dissolved oxygen is the range of dissolved oxygen measured at a specific sampling location over a given day. Large diurnal D.O. fluctuations indicate the presence of algal activity and a productive system. One disadvantage of a productive system is low early morning dissolved oxygen, which typically occurs after an extended period of nighttime respiration. The daily minimum D.O. usually occurs in the early morning and daily maximum D.O. in mid to late afternoon. The difference between early morning and mid afternoon D.O. readings in any given day are used to estimate the diurnal D.O. range at various sampling locations (figure 3).

The average diurnal D.O. is as high as 2 ppm at some sampling locations (Winn, North Lincoln, Orono) and often under 0.5 ppm at other locations. It can be observed that at the four sampling locations where class B minimum criteria were met (Costigan, and above Milford, Veazie and Bangor dams), the average minimum diurnal D.O. fluctuation is 0.5 ppm or less. At the locations (Winn, North Lincoln, South Lincoln, and Orono) where the minimum D.O. approached the lowest observed D.O. (6.1 ppm), the diurnal D.O. fluctuation is the highest.

Dissolved oxygen and temperature were monitored continuously utilizing data sondes at three locations (Rockabema, North Lincoln, and West Enfield). The continuous data gives a good indication when the minimum and maximum readings for dissolved oxygen and temperature occurs over any given day, and are compared with the instantaneous readings taken with field meters (figure 4). At North Lincoln, the continuous readings indicate that daily minimum and maximum D.O. readings typically occur at 6 AM and 4 PM, respectively. Instantaneous sampling with field meters was within two hours of these times and the D.O. did not usually vary more than 0.2 ppm within theses two hours except on one occasion when the readings were 0.4 ppm different. The field meter readings, when compared with the continuous readings averaged about 0.4 ppm lower. No corrections were employed to the continuous monitor readings here.

When the continuous monitor readings at Rockabema dam are compared to the meter readings, the meter readings indicate that the data sonde was reading low for both DO and temperature by 1.7 ppm and 0.2 ^{o}C, respectively. A correction of +1.7 ppm was employed to the continuous DO monitor readings. Both the instantaneous meter readings taken twice daily and continuous readings indicate that there was not a strong diurnal pattern of DO observed at this site.

When the continuous monitor readings at the West Enfield dam are compared to the meter readings, the meter readings indicate that the data sonde was reading low for both DO and temperature. Since the low temperature readings were consistent, a temperature correction of + 1.3 ^{o}C was employed to all continuous temperature readings. The continuous DO readings were within 0.3 ppm during the first half of the three day period but the readings drifted to 0.7 ppm low by the end of the three days. A correction factor of up to +0.7 ppm was employed to the second one-half of the data. Both the instantaneous meter readings taken twice daily and continuous readings indicate that there was also not a strong diurnal pattern of DO observed at this site.

Water temperatures on the Penobscot in 2001 during the sampling period were very high compared to most summers. The data was collected during an extended heat wave in which air temperatures typically exceeded 90 ^{o}F during the afternoon sampling run. Penobscot River temperature generally was lowest at the upstream boundary or most inland station (Ferguson Lake outlet) and increased in the downstream direction reaching the maximum temperature in the Bangor area. The three-day average temperature for all riverine sampling locations varied form a low of 25 ^{O}C at Ferguson Lake outlet to a high of 27.3^{O}C at Bangor (figure 5).

In the estuary, temperatures were highest at the most landward stations in the Bangor area and decreased in the seaward direction reaching the minimum at the downstream boundary station at Fort Knox. Temperatures were also lower at high tide conditions when compared to low tide conditions. Both of these effects are due to the influence of the cooler ocean water. The three-day average temperature for all estuarine sampling locations varied form a high of 26.8 ^{O}C in Bangor to a low of 16.2 ^{O}C at Fort Knox.

There is usually negligible salinity from Bangor to South Brewer. The first quantifiable salinity is observed at the North Orrington site. The average salinity observed were 5 ppt at the Orrington site near PERC, 10 ppt at Bald Hill Cove, 16 ppt at Winterport, and 23 ppt at Fort Knox (figure 6).

Ultimate BOD

The ultimate biochemical oxygen demand (BODu) procedure follows the overall BOD5 test of standard methods with some modifications. The tests are run for a duration of 60 days or more with a requirement that there is no more significant depletion of dissolved oxygen when the test is stopped. Ambient samples are run with no additions of any reagents. When samples readings for D.O. approach 2 ppm, the samples are reaerated. A minimum of 10 to 12 readings of dissolved oxygen are preferred over the duration of the test.

The final result first requires an estimation of ultimate or final BOD (BODu) and then a partitioning of carbonaceous and nitrogenous portions. The BODu is estimated from a plot of BOD (D.O. consumed) Vs time curve and is typically a "leveling off" of the curve or where no additional oxygen is consumed over time. This value is not necessarily the last BOD reading of the test and is typically estimated with a model. A two stage model accounting for both the carbonaceous and nitrogenous fractions was employed to estimate CBODu.

If the final nitrate reading (taken after commencement of test) is larger than the initial nitrate reading, it can be deduced that ammonia nitrogen has oxidized to nitrate nitrogen, consuming oxygen in the process as nitrogenous BOD (NBOD). An estimation of NBODu is made by the difference of initial and final nitrate readings times 4.33, the stoichiometric coefficient of nitrogen, i.e. amount of O2 consumed per nitrogen converted.

A plot of the BODu vs river mile (figure 7) reveals that the majority of the BODu (usually > 80%) is carbonaceous. Average NBODu levels were always less than 1 ppm and CBODu levels ranged from 3 to 4 ppm. The observed BODu of the Penobscot River are typical values seen on rivers with low levels of pollution.

Total ultimate BOD for tributary locations on Millinocket Stream, East Branch Penobscot, Piscataquis River, Stillwater River, Kenduskeag Stream, and Souadabscook Stream ranged from 2.5 to 4 ppm. Total ultimate BOD at tributary locations on the Mattawamkeag River, Passadumkeag River, and Pushaw Stream averaged 4.8, 5.0, and 5.8 ppm, respectively.

Phosphorus Series

Average total phosphorus observed below point source discharges was usually in-between 20 and 30 ppb on the riverine sample stations with the exception of the sampling location above Rockabema dam, which had levels approaching 70 ppb (figure 8). TP ranges of 20 to 30 ppb are indicative of moderate nutrient enrichment, and 70 ppb a high level of nutrient enrichment. In the estuary, total phosphorus values increased in the seaward direction until levels ranging from 40 to 50 ppb were reached at the four most seaward sampling locations. It is concluded that this increase in phosphorus is due primarily to a switch in nutrient limitation for algae production from phosphorus in fresh waters to nitrogen in tidal waters.

Orthophosphorus (OPO4-P) was usually under 10 ppb at riverine locations, except above Rockabema dam where TP levels were 40 ppb. Similarly to TP, OPO4-P values increased in the seaward direction in the estuary, reaching a maximum value of over 20 ppb at Fort Knox. Tributary stations had low levels of phosphorus that all were within a range of 7 to 22 ppb. The highest TP levels were measured at Pushaw Stream (22 ppb) and lowest at the East Branch Penobscot and Millinocket Stream locations (7 ppb).

Nitrogen Series

Average TKN for all riverine and estuarine locations ranged from 0.2 to 0.4 ppm (figure 9). Average ammonia nitrogen was less than 0.02 ppm at all locations, except two West Branch locations where average values up to 0.04 ppm were observed. Average nitrite plus nitrate nitrogen for all riverine and estuarine stations ranged from 0.01 to 0.06 ppm. These values represent relatively low levels of nitrogen and are consistent with the reported low NBODu levels. Tributary stations had similar low nitrogen levels, except TKN levels on two occasions was 0.5 ppm.

Chlorophyll A

Chlorophyll a is used as an indicator of the amount of algal biomass in a water body. Higher values are generally undesirable and can result in a poor aesthetic quality from green tainted waters, dissolved oxygen depletion in deeper waters, and low early morning D.O. readings. The algae produce oxygen during daylight hours which often results in supersaturated dissolved oxygen in the afternoon and consume oxygen during night time hours resulting in minimum D.O. readings at dawn.

Chlorophyll a levels at seven of the ten stations on the Penobscot ranged from 2 to 3 ppb indicating low levels of algae (figure 10). Chlorophyll a was similarly low on all of the tributary stations. At Dolby, Rockabema and Weldon dams chlorophyll a values ranged from 8 to 13 ppb and represent conditions approaching mild blooms. Chlorophyll a in the tidal portion gradually increased in the seaward direction reaching levels indicative of mild bloom conditions (8 ppb) at Orrington Center and South Orrington locations. It can be concluded that eutrophication on the Penobscot, although not severe, could be approaching levels of concern and may prove to be an issue in the future.

Secchi Depth

Secchi depth is a measure of water transparency or clarity that is accomplished by lowering a black and white disk on a chain into the water column by an observer in a boat. Secchi depth was measured on a minimum of one day at all locations with sufficient depth. All values ranged from 1.7 to 4.2 meters (figure 11). The lowest readings occur in the estuary at Orrington and South Orrington, which also had high chlorophyll a levels. Transparency readings on the upper end of this range were observed at the following sampling location; Ferguson Lake outlet, Dolby inlet, Veazie dam, and Bangor dam. Transparency readings on the low end of this range would be considered poor readings for lakes, but are not necessarily a cause for concern in rivers. Besides being more turbid than lakes, rivers often have high color that influence transparency. Data taken by the DEP in the late 1980's indicated that the Penobscot River and its tributaries have a moderately elevated color of natural origin that is further elevated by both paper mill and non point source discharges.

E Coli

E Coli levels on the Penobscot main stem, West Branch, and estuary ranged from 0 to 26 ct/100ml indicating low bacterial contamination (figure 12). The E Coli levels on some of the tributaries were elevated. In particular, levels on Millinocket Stream ranged from 141 to 461 ct/100ml; on the Mattawamkeag River ranged from 55 to 461 ct/100ml; and Souadabscook Stream was at 137 ct/100ml.

Effluent Chemical Data

Effluent chemical data collected included composite samples of BOD5, BODu, total phosphorus, orthophosphorus, total kjeldhal nitrogen, ammonia nitrogen, and nitrite plus nitrate nitrogen. In addition, BOD5 data and treatment plant flow information was available as discharge monitoring data from the point source discharges on the Penobscot. Effluent total ultimate BOD results are summarized in plots of average load and concentration experienced during the three-day intensive survey (figure 13). The loads are more indicative of potential impact to the river and concentrations more indicative of the waste strength. The lower concentrations are also better treated waste.

It can be seen that, although both Bucksport and Winterport have much higher waste strength when compared to other discharges, their low flow volume results in a small pollutant load. The higher waste strength is expected since both of these towns have primary treatment compared to secondary treatment of the other discharges. Many of the discharges sampled during the survey had very low concentrations of BOD indicating good treatment. Of particular merit were Great Northern Paper East Millinocket, Georgia Pacific Paper Co., Orono, Bangor, Brewer, and

International Paper, Bucksport. International Paper reported that a secondary clarifier was out of service for a complete refurbish job during the three day study and loads for BOD5 and TSS were about 2.6 and 3.5 times higher, respectively than under normal mill operation.

Point source discharges are licensed as BOD5. Actual loads discharged are plotted comparatively as mass (lb/day) and a percentage of allowable licensed loads (figure 14). This is another test for a worse case scenario in which it is assumed point sources are discharged at their allowable licensed load. This indicates that on the average, point sources collectively were only at about 17% of their permitted allowable daily maximum load. As to be expected, the paper mill discharges have the highest mass loading of BOD5 due to their large volume of flow.

Nutrients as total phosphorus and total nitrogen (TKN + NO2+NO3-N) are also plotted and compared (figures 15,16). When considering nutrient sources for eutrophication, phosphorus is generally the limiting nutrient in fresh water systems, and conversely nitrogen in estuarine systems. The discharges of Great Northern Paper Millinocket and East Millinocket contributed the most phosphorus (each about 270 ppd) during the intensive survey. Bangor and Georgia Pacific also had high phosphorus load inputs (each about 170 ppd). Great Northern Paper's Millinocket mill and Bangor contributed the most nitrogen (about 1200 and 800 ppd, respectively) during the intensive surveys.

Penobscot River Sediment Analysis

Sediment samples were collected in the fall of 2001 from 10/30 to 11/15 over a period of several days. In most sample locations of the Penobscot, it was difficult to collect sediment samples in the main channel, due to the lack of adequate sediments. There is, no doubt, great scouring of sediments in a large river such as the Penobscot occurs during high flow periods. Sediment samples were collected in known depositional areas that were often outside the main channel. Sediment samples were analyzed for oxygen demand, mercury, total organic carbon, and grain size (table 4).

Table 4 Penobscot River Sediment Analysis

Location	Station Code	SOD $g/m^2 day$	Total Organic Content (%)	TOC	Grain Size			Mercury
				%	Gravel %	Sand %	Silt + Clay %	ug/g(ppm)
Dolby Pond	WBP3	1.4	52.4	24.6	0.0	73.6	26.4	0.88
Mill Dam 2	WBP4	3.0		28.9				
Rockabema	WBP5	2.3	48.3	16.9	0.0	68.4	31.6	1.50
Weldon	PN1	1.5	24.4	13.2	0.0	30.1	69.8	0.66
West Enfield	PN5	3.4	5.6	3.1	5.4	68.5	26.1	0.12
Milford	PN9	3.1	14.7	5.5	4.1	72.7	23.2	0.08
Veazie	PN12	2.5	6.1	4.3	14.5	60.6	24.8	0.10
Bangor	PN13	3.8	13.9	9.5	4.7	76.6	18.7	0.36
South Brewer	PNE2	3.1	9.0	3.8	3.5	19.4	77.1	0.43
Orrington Center	PNE5	2.0	15.2	7.4	1.0	10.4	88.7	1.10
South Orrington	PNE7	1.7	5.6	2.6	6.0	43.8	50.2	0.52
Winterport	PNE9	2.5	6.2	2.7	0.5	34.7	64.8	0.54

The sediment oxygen demand ranged from 1.4 to 3.8 gm/m^2-day and averaged 2.5 gm/m^2-day (figure 17). The mercury results ranged from 0.36 to 1.50 ug/g and averaged 0.57 ug/g. When compared collectively, elevated mercury samples were observed above Rockabema dam and at the Orrington Center location in tidal waters.

Quality Control

Proper quality control is essential for any sampling effort to assure data collected is good data. Quality control procedures were practiced in both field sampling and the laboratory analysis of various parameters. Dissolved oxygen meters were calibrated prior to and frequently during sampling. In addition, meters were cross checked amongst adjacent sampling teams to assure consistency and accuracy of results. The D.O. meters were cross checked after initial morning calibration and again after commencement of sampling . This procedure was repeated for the afternoon sampling run. If meters did not agree favorable after commencement of sampling, meters were re calibrated and rechecked.

The work plan specified that dissolved oxygen readings amongst sampling teams should be within 0.3 ppm and temperature within 2 ^{o}C when cross checking readings. A column plot of crosscheck for the D.O. meters indicates that this criteria was met (figures 18-20).

Field duplicate samples were collected for all parameters at a river, estuary, tributary, and effluent station each day during the intensive survey. When the results for some of various parameters are compared graphically for ambient (figures 21-28) and effluent (Figure 29) samples, good agreements occurs for most of the samples. An examination of the deviation of the duplicate from the actual sample indicates the following

Table 5 Duplicate Sample Deviation

Parameter	Number	Ave Deviation	% with Deviation < 10%	% with Deviation < 20%
Dissolved Oxygen	28	0.8%	100%	100%
Temperature	28	0.2%	100%	100%
Total Phosphorus	12	7.2%	92%	92%
Ultimate BOD	12	7.7%	67%	100%
Chlorophyll a	9	15%	55%	78%
Total Kjeldhal Nitrogen	12	7.8%	84%	84%
Nitrite + Nitrate Nitrogen	12	0.4%	100%	100%
Totals	113	3.2%	89%	96%

It can be concluded from table 4 that the average deviation of 113 duplicate samples is 3.2%. Also 89% of all duplicates were within a 10% deviation and 96% were within a 20% deviation. Temperature was the most accurate reading with an average deviation of 0.2%. Nitrate + Nitrite nitrogen and dissolved oxygen were also very accurate with deviations of 0.4% and 0.8%, respectively. Chlorophyll a was the least accurate with an average deviation of 15%.

The favorable quality control results and consistency of the data results in a conclusion that the data is good and adequate for re-calibration of the water quality model.

Location Maps

Ambient Dissolved Oxygen, Temperature, and Salinity Results

Ambient and Effluent BOD, Nutrients, and Chlorophyll A Results

BOD Spreadsheets and Calculations

Responses to Comment

Great Northern Paper Inc.

Page 9 of Report – Comment: Why weren't the continuous monitor readings for dissolved oxygen that were within 0.3 ppm not corrected?
Response: The monitoring of DO is accurate to within 0.3 ppm. DEP's protocol for cross checking DO meters, for example, is for meters to be within 0.3 ppm of each other. Hence any of the readings that fall within 0.3 ppm require no adjustment due to the fact that this is within the measurement error of instrumentation. Readings of greater than 0.3 ppm error should be corrected, since this infers that a problem of instrumentation occurred.

Appendix- Water Quality Data – Comment: TP and PO4-P effluent values should be in ppb not ppm for those reported.
Response: Agreed. This will be changed in the final report.