Baseline Water Quality in Rivers of Eastern Manitoba: 2007

A Project Report to Manitoba Conservation-Forestry Branch
and the Manitoba Model Forest

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Summary

As part of an on-going Manitoba Model Forest project to document baseline water quality conditions in rivers in eastern Manitoba and to examine the potential impacts of forest harvesting, wildfire and beaver activity on water quality, monitoring was conducted on a monthly basis in 5 rivers of the Manitoba Model Forest area in eastern Manitoba from May to September 2007. The rivers included the O'Hanly River at Hwy 304, Black River at Hwy 304, Manigotagan River at Hwy 304, Wanipigow River at the Rice River Road, Manigotagan River at Hwy 314, Black River at Hwy 314 and Rabbit River at Hwy 314. Parameters monitored included river discharge, cations (calcium, magnesium, potassium and sodium), sulphate, pH, alkalinity, alkalinity, major nutrients (forms of phosphorus and nitrogen), dissolved organic carbon (color), turbidity, suspended solids, dissolved oxygen and conductivity. This report compares and contrasts water quality among the rivers and describes the seasonal trends for some of the parameters in 2007. The information is helping to establish a long-term database on water quality for several important rivers in the Manitoba Model Forest area. The report also summarizes the work undertaken to date to select an area of the Tembec Forest Management License (FML) in which to implement experimental watershed-scale timber harvesting trials in order to assess the effects of timber harvest on water quality. Discussions with Tembec so far suggests that the proposed Kaneshoot operating area likely represents the most ideal location of a study to examine the impacts of timber harvest on water quality.

Introduction

Very little data exists on the water quality of rivers, streams and creeks in the Manitoba Model Forest area of eastern Manitoba, and indeed for most of Eco-region 90 (EBM Science Team Report, 2002). Of the historical data that has been collected, sampling was restricted to only a few of the major rivers (e.g., Pigeon, Bloodvein, Manigotagan, Black, Winnipeg), and almost all of these monitoring programs ended in the 1980s (an exception being the Winnipeg River, for which limited monitoring continues as part of a larger monitoring network to examine nutrient loading to Lake Winnipeg). Virtually no data exists on water quality in smaller rivers, streams and creeks in the Model Forest area. In addition to this lack of baseline data, our understanding of what watershed features (e.g., soils, forest type) influence water quality on a regional basis, or how natural disturbances (e.g., fire, beaver) or anthropogenic disturbances (e.g., timber harvesting, roads, agriculture) affect water quality is limited.

In 2004, the Manitoba Model Forest initiated a regional water quality monitoring project in order to assess baseline water quality in 22 rivers, streams and creeks in the Manitoba Model Forest area (eastern Manitoba). In addition to baseline data collection, the water quality data that was collected was combined with GIS-based watershed information to assess the influence of watershed characteristics (such as major soil type and forest type), agriculture, fire and timber harvesting on water quality (Kotak et al, 2005). From May to September or October in 2004-2006, water quality samples were collected at a frequency of once per month. In the smaller streams and creeks, water velocity was also measured, and was used to calculate discharge. In addition, sampling also occurred during the winters of 2003/04 and 2004/05 to assess water quality when the rivers, streams and creeks are ice-covered. The results of this research showed that water quality in the region's rivers, streams and creeks is highly influenced by the type of soils found in each watershed, as well as disturbance history. In particular, peatlands had a significant effect on water quality, and permanent removal of forest cover for agriculture affected water quality much more dramatically than fire or timber harvest (Kotak et al., 2005). In addition, the affects and the magnitude of the effects of fire and timber harvesting on water quality were not always the same. While it was difficult to tease apart the separate influences of soil type and disturbance history on water quality for each watershed, it appeared that little change in water quality was detectable in the study rivers, streams and creeks until a significant proportion of the watershed was disturbed. Finally, in a subsequent study which examined the spatial variation in water quality in the Manigotagan, Black and O'Hanly rivers from close to the Ontario border to

Lake Winnipeg, beaver activity was found to have a substantial effect on water quality along certain segments of the Black and O'Hanly rivers, compared to fire or timber harvest (Kotak, 2006).

Based on these results, two recommendations were made to the Manitoba Model Forest with respect to water quality studies in eastern Manitoba. Firstly, due to the paucity of long-term water quality data, some form of baseline water quality monitoring should continue, but on a much more limited extent. As such, a scaled-down monitoring program was implemented in 2007 (which forms the basis of this report), in which monthly monitoring continued from May to August and which focussed on 5 rivers of regional importance (O'Hanly, Black, Manigotagan, Wanipigow and Rabbit). A second recommendation was made to plan and execute a series of experimental watershed-scale timber harvesting experiments in order to validate the results of previous research which examined the effects of timber harvest on water quality.

This report describes the results of the baseline water quality monitoring conducted in 2007, and describes the preliminary work undertaken to select a general area of the Tembec Forest Management License (FML) for the experimental timber harvesting experiment.

Methods

The water quality in 5 rivers was monitored on a monthly basis from May to August in 2007. The rivers were: O'Hanly River, Black River (two sites), Manigotagan River (two sites), Wanipigow River and the Rabbit River. The locations of the rivers and monitoring sites are shown in Figure 1. Table 1 provides a general indication of the size of each river (i.e., bank-full width) and location at each sampling station. Figure 2 shows the watershed size (calculated from the point from which water quality samples were taken).

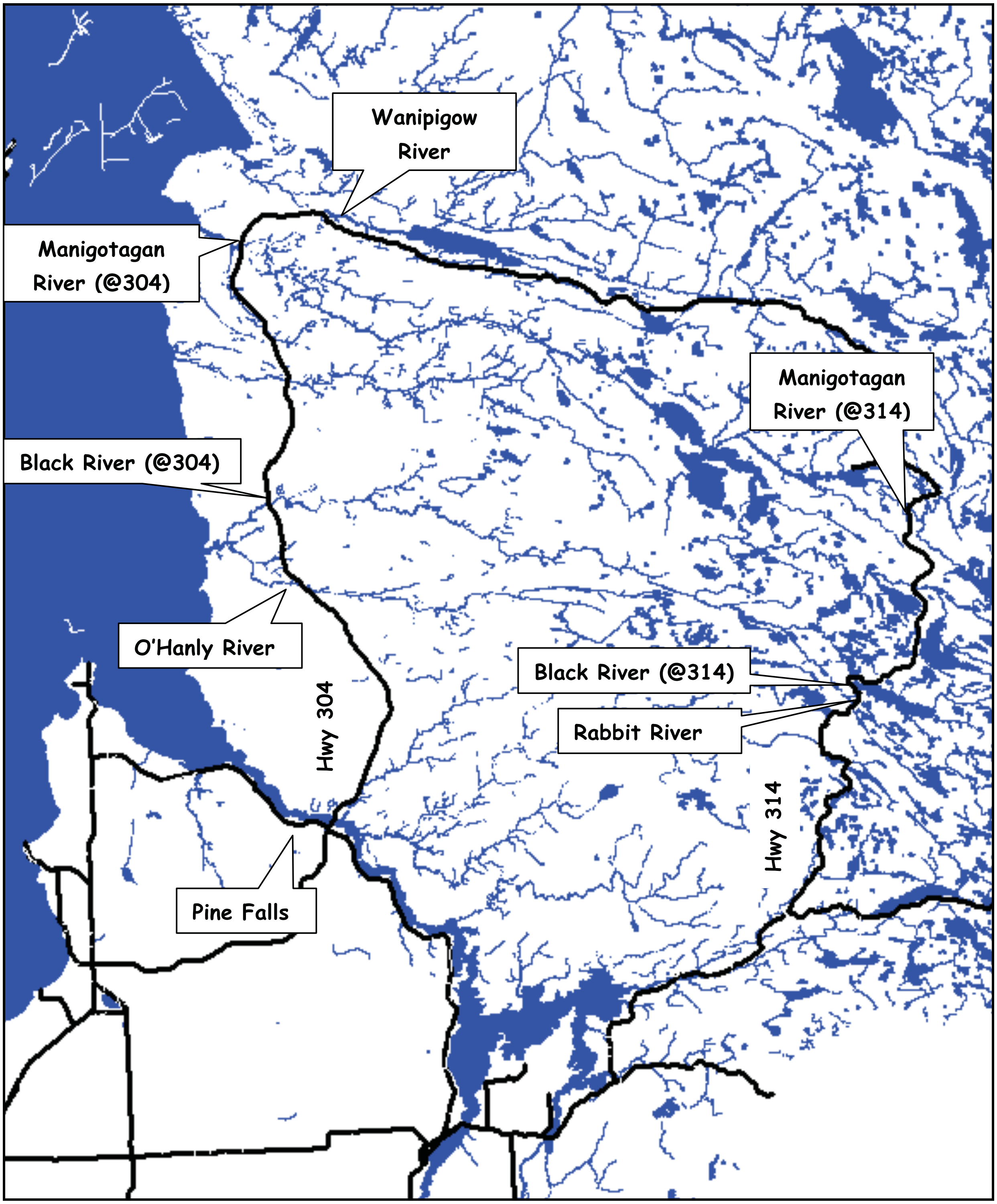

Figure 1. Map showing location of study rivers and sampling stations in the Manitoba Model Forest area.

Table 1. Bank full width of each study stream and GPS location of the study sites where water quality and/or flow measurements were made.

Stream Site	Bank full width (m)	GPS Coordinates[*1]
Rabbit River at Hwy 314	5.6	N 50 39.090 W 95 24.377
Black River at Hwy 314	5.6	N 50 39.572 W 95 23.549
O'Hanly River at Hwy 304	14.0	N 50 47.081 W 96 12.336
Black River at Hwy 304	18.0	N 50 51.448 W 96 15.165
Manigotagan River at 304[*2]	20.5	N 51 06.049 W 96 16.597
Wanipigow River at Rice River Road[*2]	22.5	N 51 07.971 W 96 10.628
Manigotagan River at Hwy 314[*2]	29.4	N 50 48.020 W 96 21.013

*1 Coordinates are the location where water velocity and/or water quality samples were collected. The sampling sites were located upstream of highways/roads.
*2 Bank full width estimated from GIS.

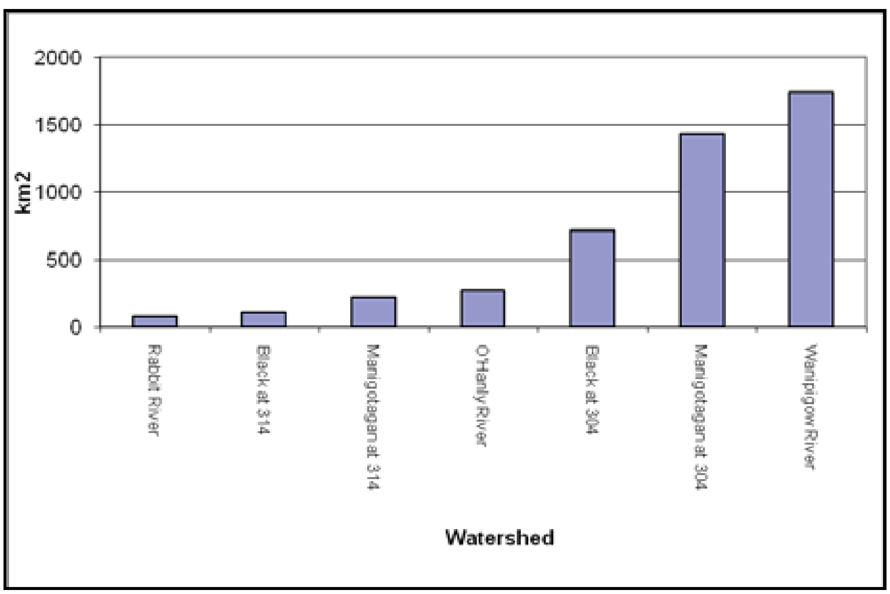

Figure 2. Watershed size (in km^2) for the study rivers.

On each sampling date, surface water (upper 10-50 cm) samples were collected by wading into the rivers (when possible) and collecting the water samples directly into the bottles provided by the analytical laboratory. Sample bottles were double rinsed with the river water prior to collecting the sample. In instances where wading into the rivers would create a large disturbance to the bottom sediments and possibly contaminate the sample (e.g., in rivers with slow moving water and a mud bottom), samples were collected from the shoreline using a metal scoop on a long handle. Water samples collected for dominant ions (calcium, magnesium, etc.) were acidified in the field with 20% nitric acid. Water samples were placed in a cooler on ice until transport to the analytical laboratory (usually the next day).

Water chemistry analysis was conducted by ALS Laboratories (formerly Envirotest), Winnipeg. Water samples were analyzed for pH, alkalinity, conductivity, total phosphorus, total dissolved phosphorus, ammonia, nitrate (includes nitrite), sulphate, dissolved organic carbon, cations (calcium, magnesium, potassium, sodium), chloride, total suspended solids and turbidity. Values for total dissolved solids and hardness were calculated.

Water velocity was only measured in the rivers which were safe to wade across. In some of the larger rivers (e.g., Manigotagan, Wanipigow), flow was too great at all times to safely allow for water velocity measurements. In some of the other rivers (e.g., Black River, O'Hanly River), velocity measurements were only possible during lower flow periods. Therefore, velocity and depth information (and thus, stream discharge – discussed below) is not available for all rivers at all sampling periods.

To measure water velocity, a line transect (tape measure) was stretched across the river from bank to bank (Figure 3). Water depth and velocity was measured every 1m across the width of the river. Water velocity was measured using an AquaSensa RC-2 Water Velocity Meter equipped with an electromagnetic RV4 mini probe. As velocity varies with water depth, velocity was always measured at 0.6 times the water depth, in order to obtain an average velocity reading.

Figure 3. Summer student Daniel Dupont measuring water velocity (in foreground) and Matthew Doering measuring water temperature and dissolved oxygen.

Discharge was calculated using a macro in an Excel spreadsheet, based on the following theory: a cross sectional diagram of each river was created using the depth information collected along each transect. Water velocity (m/sec) at each point on the transect was multiplied by the cross sectional area (m^2) calculated between the points along each transect. The product for each measurement was then summed across the entire river width to produce a discharge value (m^3/sec).

Dissolved oxygen concentration and water temperature in the rivers were measured using a YSI Model 550A Temperature/Dissolved Oxygen Meter. Prior to use each day, the meter was calibrated. Membranes and KCl solution were also regularly changed to ensure accuracy of the measurements. Dissolved oxygen was measured *in situ*, within the upper 50 cm of the water column. Care was taken to ensure that the bottom sediments were not disturbed when taking oxygen measurement, as this would affect dissolved oxygen concentrations by mixing anoxic (low oxygen) water of the sediments into the overlying water column. Measurements were always taken on the upstream side when wading in the rivers.

Results and Discussion

General Considerations of the Effects of Climatic Variability on Water Quality

Climatic factors such as air temperature, and especially precipitation, can have s significant effect on many processes occurring in watersheds, and thus have a major effect on water quality. For example, unusually warm temperatures in spring can cause rapid snowmelt, little infiltration of runoff into the still-frozen soils, and a dilution effect in rivers, as runoff water contains less constituents (e.g., nutrients) than that present in the rivers. Conversely, unusually cool air temperatures during the spring may cause an extended period of time for snowmelt, lead to greater infiltration of runoff into the soils, and a large export of constituents from soils to rivers. Rain storm events during the summer can not only increase river discharge significantly, but will cause a large influx of constituents (such as dissolved nutrients, dissolved organic carbon or DOC ([which imparts the frequently observed dark brown color to rivers in the boreal shield] and particulates [and thus increasing turbidity]) into the rivers. Conversely, periods of little precipitation throughout the summer will reduce runoff, reduce river discharge and reduce the export of constituents from the land to the water. For constituents such as DOC, extended periods of little precipitation throughout the summer will not only reduce concentrations in the rivers because of reduced runoff through soils, but the increased residence time of DOC (the amount of time spent in the river) due to reduced water flow will allow for a greater breakdown of the color by sunlight. Thus, some brown-colored rivers will become less colored during periods of extended dry periods. As observed in the Black River and O'Hanly River in 2005 (Kotak, 2006), periods of low precipitation and thus reduced river discharge, can also have some unexpected consequences on water quality. In the above-noted study, significantly reduced river discharge in the fall of 2005 resulted in substantially heightened beaver activity, as the animals desperately attempted to dam up the little available water in preparation for the winter. Back-flooding of riparian forests and soils, along with soil erosion caused by beaver activity on river bank resulted in greatly elevated nutrient levels and turbidity, even through river flow was very low.

Regional Climate in 2007

Daily maximum air temperature, from Pinawa, Manitoba (one of the few sites in the Manitoba Model Forest where complete climatic records are kept by Environment Canada) are shown in Figure 4a. There is almost a 2 week period at the beginning of May for which data from Environment Canada is not available. Overall, the average temperature in each month of the study in 2007 (based on the daily maximums), was not significantly different from the long-term mean calculated from 1971 to 2000 (Figure 5a).

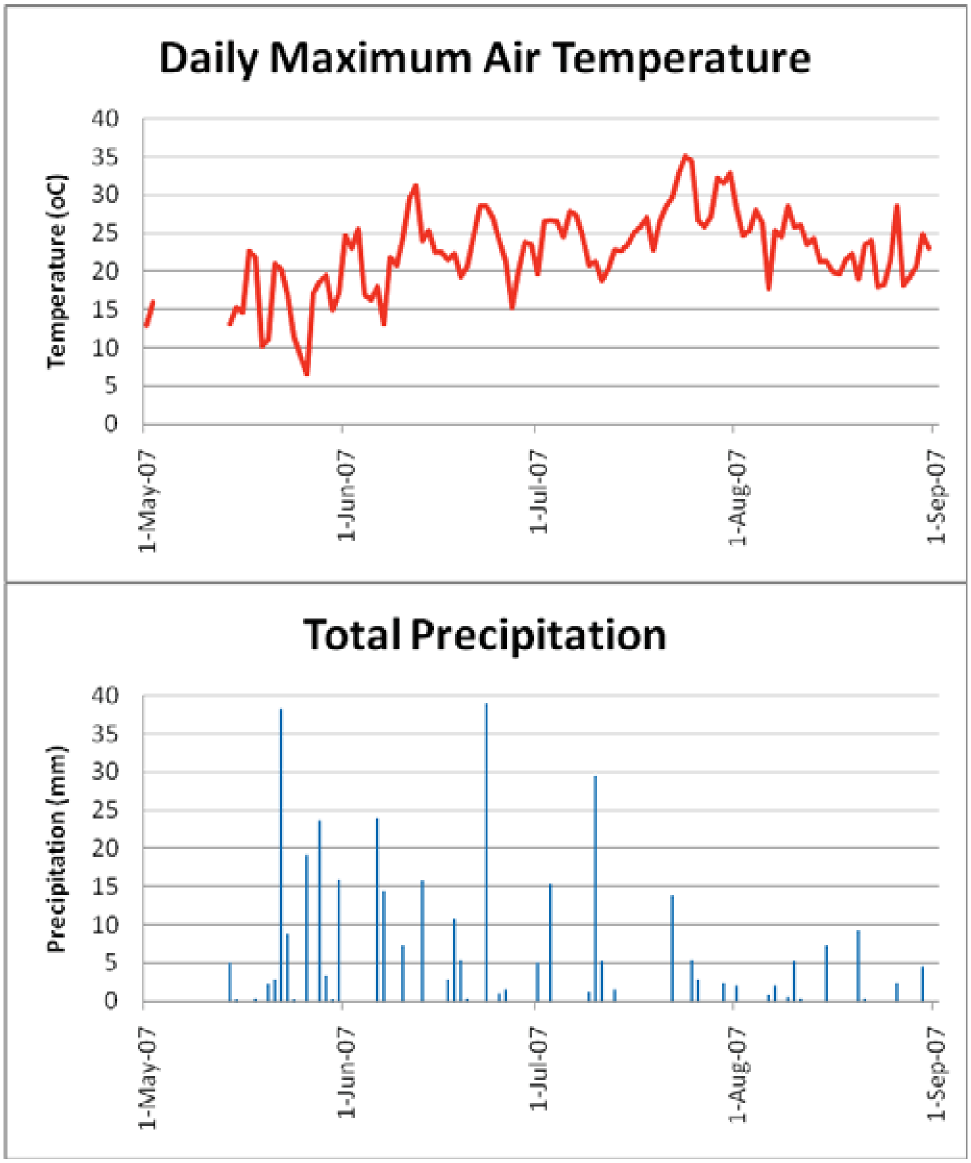

Figure 4. A) Daily maximum air temperature and B) daily total precipitation observed at Pinawa, Manitoba for 2007 (Data source: Environment Canada).

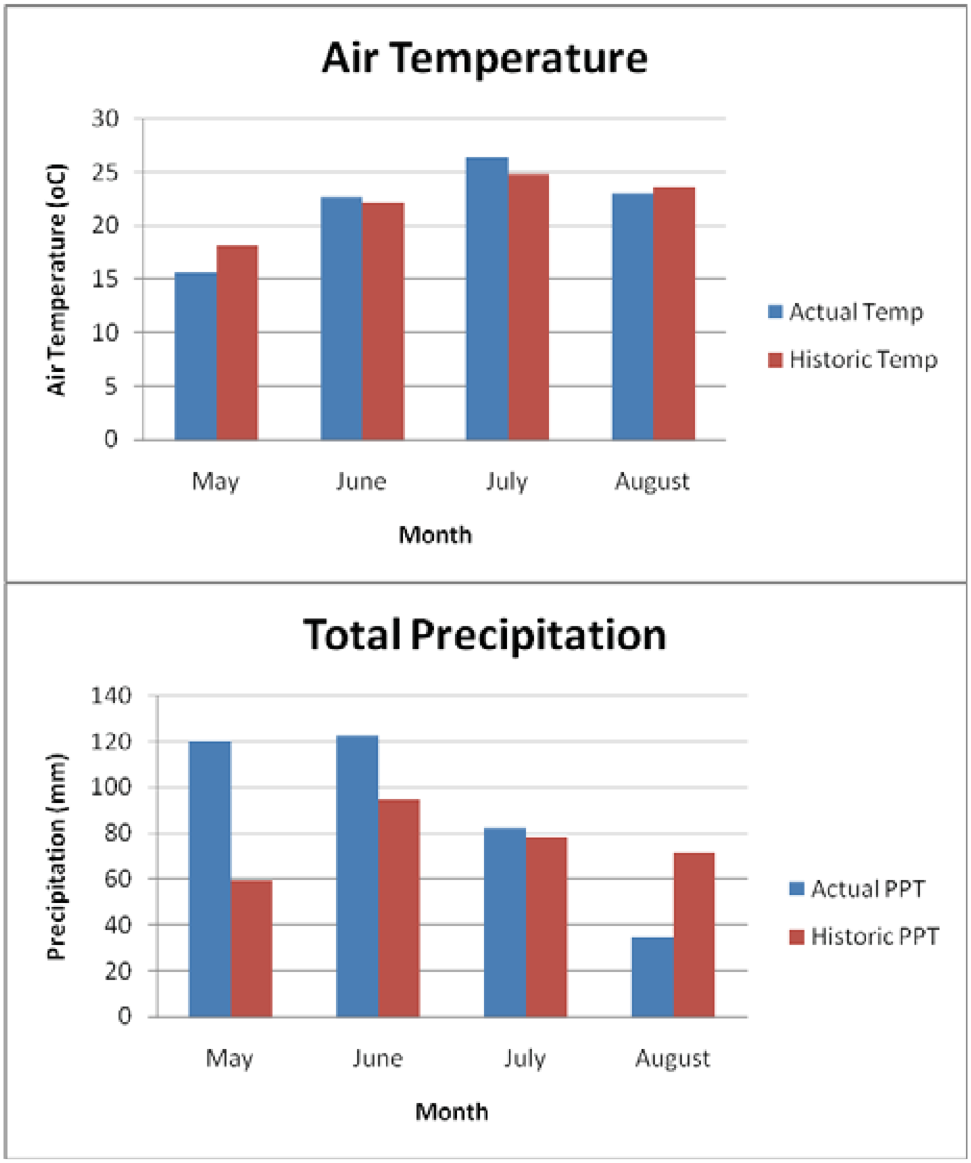

Figure 5. Comparison of 2007 A) daily maximum air temperature and B) total precipitation observed at Pinawa, Manitoba compared to historical averages (Data source: Environment Canada)

Significant trends were observed in the timing and amount of precipitation in 2007. Large rainfall events were observed in May, June and early July (Figure 4a). For example, rainfall of 38.2, 39.0 and 29.6 mm were recorded for May 22, June 23 and July 10. Several other rainstorms containing less precipitation were also noted in these months. These trends can also be easily seen in the river discharge data (discussed later). The total precipitation for May and June were significantly higher than the long-term average (Figure 5b).

Total precipitation in July was only marginally higher than the long-term average. As can be observed in Figure 4a, very little precipitation occurred after about July 10. Conditions were quite dry for the majority of the period from July 11 to the end of August. Precipitation in August was significantly lower than the historical average (Figure 5b). As a result, river discharge was quite low in August (discussed later).

Comparison of Water Quality Among Rivers in 2007

As has been noted in earlier studies (Kotak et al., 2005; Kotak, 2006), there are marked differences in water quality between the study rivers. The differences can be attributed to a number of features of the watersheds, including main soil type, forest type, as well as disturbance history (fire, logging). In general, logging and fire history have less influence on water quality than does soil type (Kotak et al., 2005). Logging or fire impacts were only observed in very small watersheds (i.e.., watersheds much smaller than that of the O'Hanly, Black, Manigotagan or Wanipigow rivers which were studied in 2007), and only when a significant proportion of a watershed was disturbed. As noted previously, the magnitude of these impacts were much lower to those observed for watersheds containing agriculture. In smaller rivers (including sections of the O'Hanly and Black), beaver activity may play a more important role in shaping water quality.

Although a complete description of each water quality parameter monitored in the study rivers cannot be accomplished in this report, a selection of parameters were chosen as they either are important from a water quality perspective, or because they demonstrate key differences in water quality (or in the watersheds) between the rivers.

The pH of water in the rivers varied from a seasonal average of 6.5 in the Rabbit River to 7.8 in the Wanipigow River (Figure 6). pH is a measure of amount of hydrogen ions in solution. The more hydrogen ions, the lower the pH, and the more acidic the water. For rivers in the boreal forest, pH is highly dependent on soil type and also the amount of peatlands in the watershed. The relatively low pH of water in the Rabbit, O'Hanly and Black rivers are likely the result of the thin Canadian Shield-type bedrock soils which are naturally acidic, the presence of peatlands and the lack of more calcium-rich clay-based soils in these watersheds. In contrast, the higher pH water found in the Manigotagan and Wanipigow rivers is likely due to a higher proportion of clay-based soils in their watersheds. A very similar trend was also observed in conductivity (Figure 7). Conductivity is a general measure of the amount of dissolved ions, and bedrock-based soils generally contribute few ions to rivers, compared to richer clay-based soils. The results for 2007 are almost identical to the trends observed in 2004 (Kotak et al., 2005).

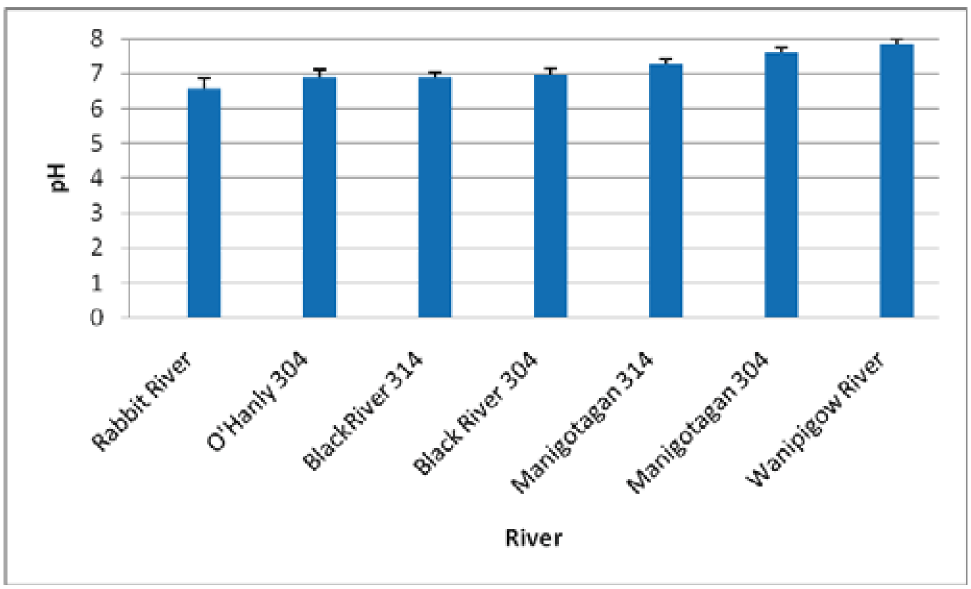

Figure 6. Seasonal average pH of water in study rivers in 2007. Vertical bars are the standard deviation of the mean.

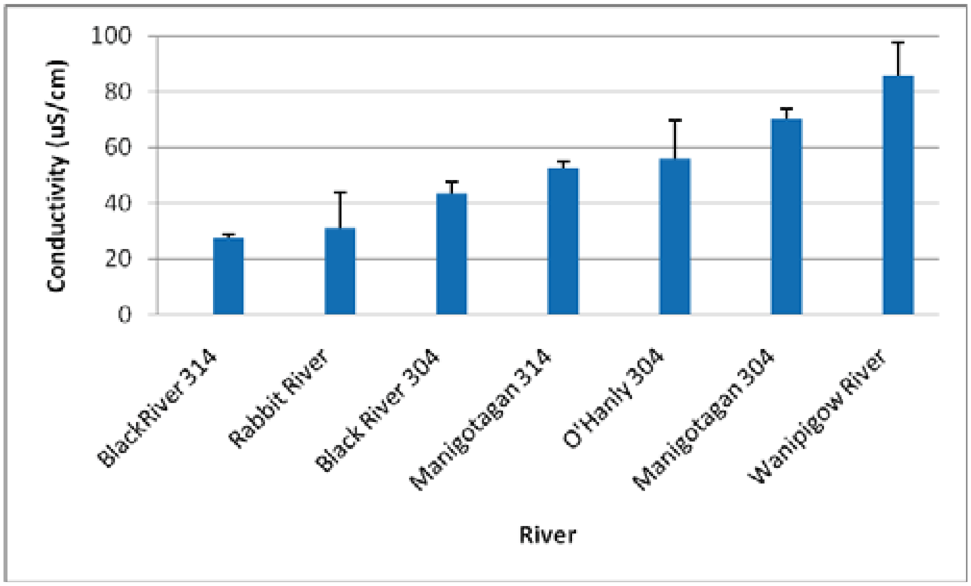

Figure 7. Seasonal average conductivity in the study rivers in 2007. Vertical bars are the standard deviation of the mean.

There were also marked differences between the rivers in the concentration of total phosphorus (TP). On average, rivers such as the Black (at Hwy 314 in Nopiming Park), Manigotagan and Rabbit had much lower TP than did the Black River (at Hwy 304), Wanipigow and O'Hanly (Figure 8). The lower TP concentrations in Black River at Hwy 314 and Manigotagan River at Hwy 314 are likely due to the poor soils in this region of their watersheds. Higher average concentrations in the Black River at Hwy 304, and especially in the O'Hanly River, is likely a result of more nutrient-rich soils in the lower end of the watershed, but also due to a large increase noted in late August, likely due to beaver activity (see later section on seasonal variation).

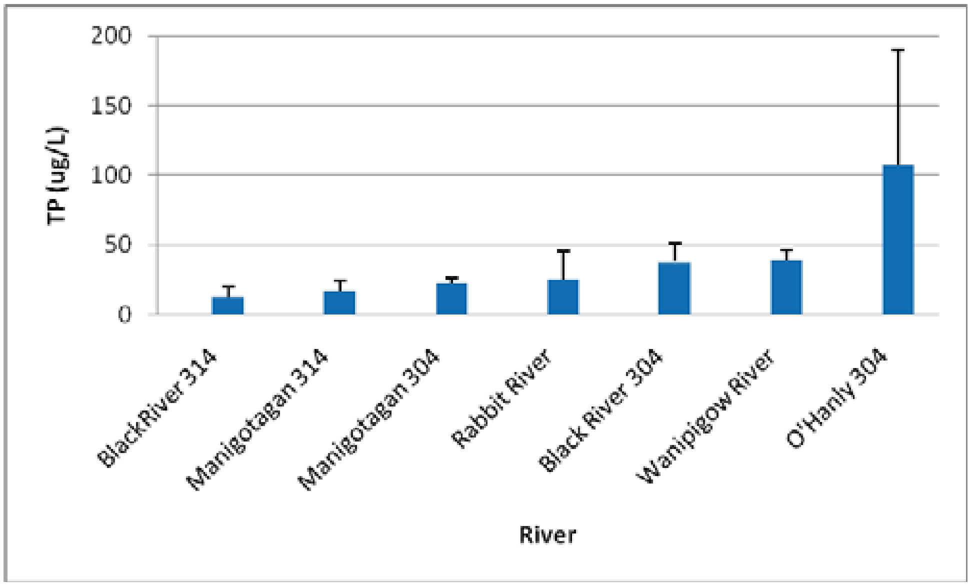

Figure 8. Seasonal average conductivity in the study rivers in 2007. Vertical bars are the standard deviation of the mean.

Dissolved organic carbon (DOC) is an important water quality parameter, particularly in boreal forest rivers, as this parameter has a significant influence on water color, light penetration, water temperature, and the mobility and solubility of other key constituents (such as metals and some nutrients). The level of DOC (water color) is largely a function of the occurrence of peatlands in a watershed. The lower DOC values for the Manigotagan River (at both site locations), the Black River at Hwy 314 and the Rabbit River (Figure 9) reflects a lower proportion of peatlands in their watersheds compared to the Black and O'Hanly Rivers at Hwy 304. Higher levels of DOC in the latter set of rivers may also be due to back-flooding of riparian forests and soils by beaver, and also from forest harvesting, as suggested in Kotak et al. (2005) and Kotak (2006).

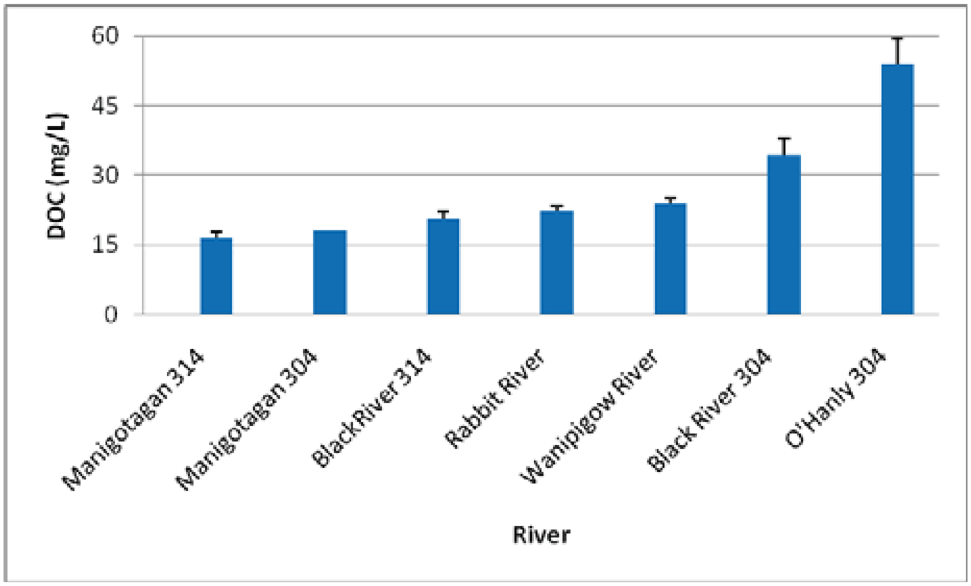

Figure 9. Seasonal average dissolved organic carbon (DOC) in the study rivers in 2007. Vertical bars are the standard deviation of the mean.

Finally, there were significant differences in the turbidity of water in the rivers during 2007. The Rabbit, Manigotagan (both sites) and Black River at Hwy 314 all have seasonal average turbidity values of less than 5 NTU (Nephalometric Turbidity Units), indicating very clear water (Figure 10). On the other hand, the Black River at Hwy 304, Wanipigow River and especially the O'Hanly River had much more turbid water. For the Black River at Hwy 304 and the O'Hanly River, the higher seasonal average values are driven largely by significant increases in turbidity in August. This turbidity likely originates from beaver activity and also due to dislodging of algae growing on rocks (described in more detail in the next section on seasonal variation). These trends are consistent with those observed in 2004 (Kotak et al., 2005).

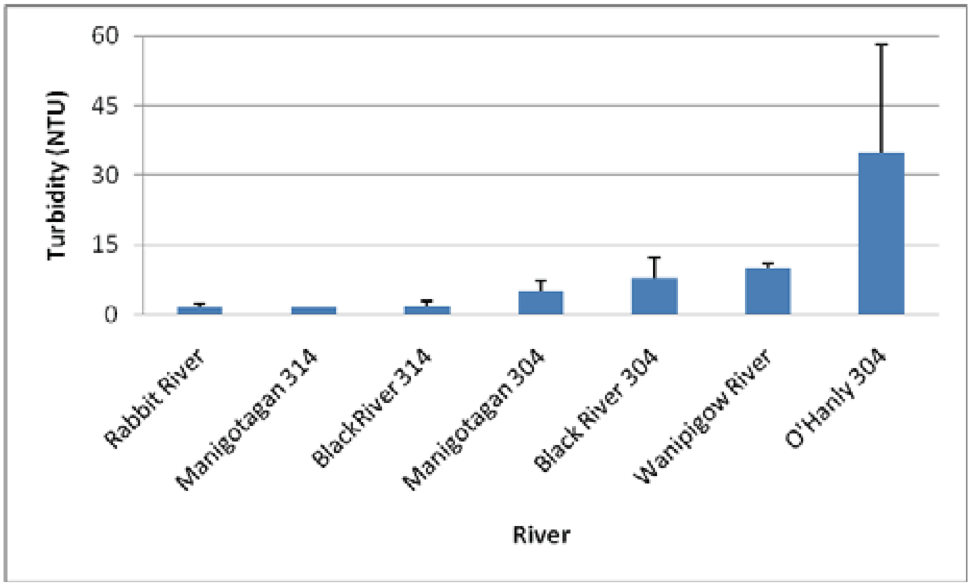

Figure 10. Seasonal average water turbidity in the study rivers in 2007. Vertical bars are the standard deviation of the mean.

<u>Seasonal Variation in Water Parameters in 2007</u>

River discharge was measured only in rivers where it was safe to wade across. This precluded measurements at both sites of the Manigotagan River, the Wanipigow River and Black River at Hwy 304. In addition, measurements of water velocity (used to calculate discharge) were made only on the remaining rivers (the O'Hanly River at Hwy 304, Black River at Hwy 314 and Rabbit River) when these rivers were safe to wade across. This was not always posible throughout the summer. Table 2 shows river discharge for those occasions when measurements could be made.

Generally, discharge was greatest in May and June in all three rivers and then decreased in July and August. However, this could not be quanitified easily, as often times flow was too great to attempt measurements. For example, while flow was high in May in the O'Hanly River, it was even higher in June and July, precluding measurements. Discharge in August in the O'Hanly River demonstrates the effects of the lack of rain in this month. For the Black River at Hwy 314, the highest discharge was likely in June, but this could not be quantified. As with the O'Hanly River, the effects of the lack of precipitation in August is easily observed on the river discharge during this month. In the Rabbit River, the increase in discharge from July to August (despite a lack of rain), could potentially be explained by a series of beaver dam breeches upstream of the sampling site. Elevations in other parameters (such as total phosphorus and conductivity) in August compared to July were also noted, further supporting this hypothesis.

Table 2. River discharge (m^3/sec) in the Black, O'Hanly and Rabbit rivers in 2007.

Date	O'Hanly	Black at Hwy 314	Rabbit
May 22, 2007	1.294	0.943	*b
June 25, 2007	*a	*a	1.573
July 18, 2007	*a	1.342	0.205
August 28, 2007	0.123	0.261	0.889

*a Water velocity and depth were too great to attempt measurements

*b No water quality data was collected in May

Seasonality was observed from May to August in many of the chemical water quality parameters, but only in some of the rivers. Generally, spring run-off, which occurs when the soils are still frozen, contains mostly snow meltwater and little nutrients or other chemical elements. This has the net effect of diluting the river water. Hence, concentrations of most ions are at their seasonal low at this time of the year and from there tend to increase as contituents in the watershed soils are exported from the land to the water following rainfall events. For example, calcium (Ca), magnesium (Mg), potasium (K) and sodium (Na), relatively inert consituents (and thus is a good element to look at as changes in the concentration are not confounded by biological uptake), generally increase in all rivers from spring to late summer (Figure 11).

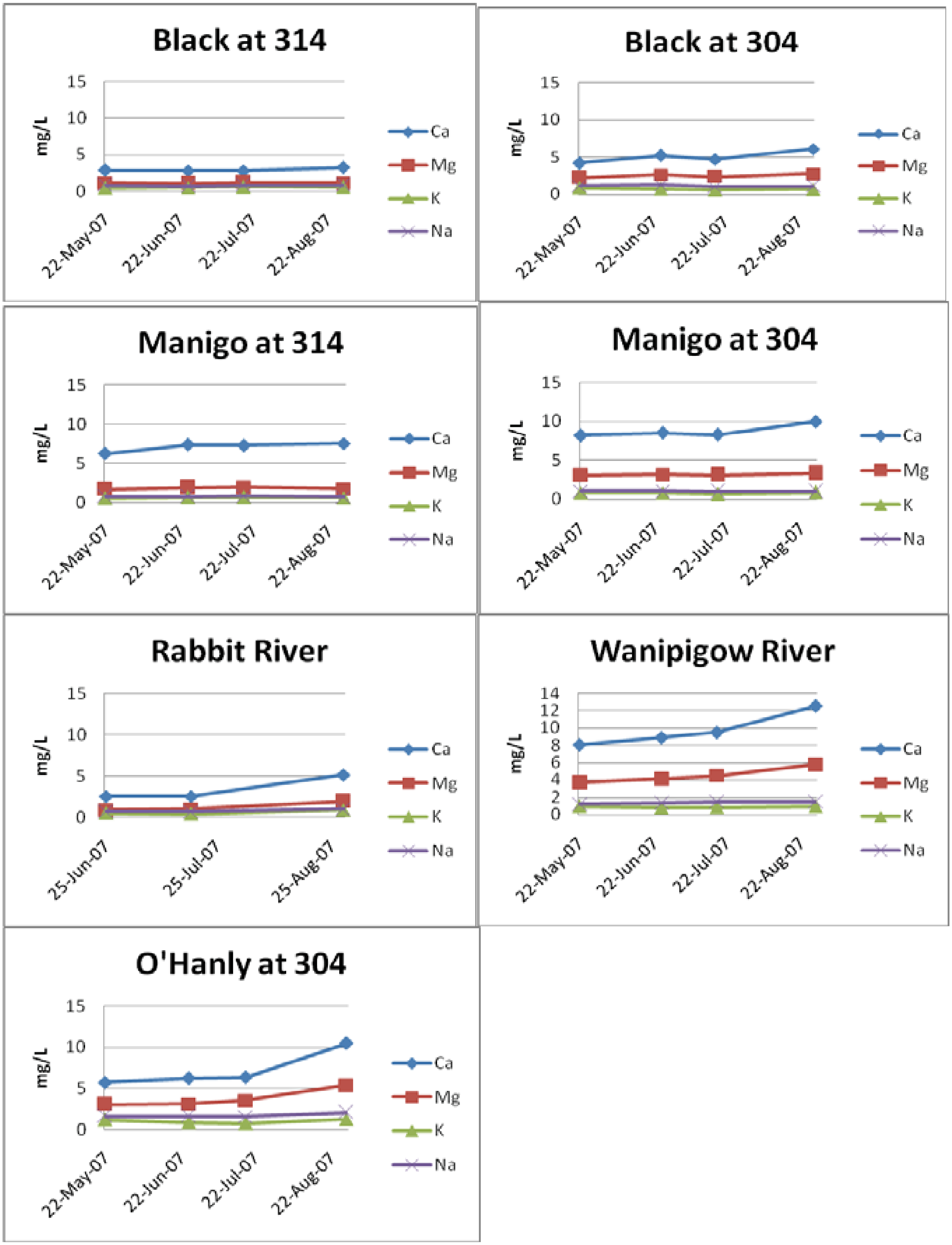

Figure 11. Seasonal changes in calcium (Ca), magnesium (Mg), potasium (K) and sodium (Na) in 2007.

Key nutrients such as phosphorus also varied seasonally, and the seasonal changes were most dramatic in the Black and O'Hanly rivers at Hwy 304, and also in the Rabbit River, where concentrations of total phosphorus were initially low in the spring and peaked in late summer (Figure 12). In both the Black and O'Hanly rivers at Hwy 304, this dramatic increase occurred during periods of reduced river flow over the summer. Thus, it appears that the increase in TP was due to internal processes, rather than export of TP from the larger watershed. One plausible explanation for this is that the reduced water flow allowed for the abundant growth of epilithic algae (algae growing on rocks). Following sufficient growth, the algae accumulating on rocks were then dislodged by the limited river flow, making the water more turbid and contributing to elevated phosphorus concentrations in the water (primarily as particulate phosphorus). This hypothesis is consistent with the significant increase in water turbidity measured throughout the summer in these two rivers (Figure 13). Dislodge algae could be easily seen in the water in August. This appears to be a natural phenomenon in these productive rivers as it occurs each year, and is not seen in rivers that are lower in phosphorus concentration (such as the Manigotagan). An additional reason for the large increase in phosphorus and water turbidity over the summer in the Black and O'Hanly rivers near Hwy 304 are the abundant beaver populations, which back-flood forested areas (releasing phosphorus from the flooded soils) and more noteably, by disturbing the clay-rich river banks in theses sections of the rivers. Beaver activity would also dislodge algae from the rocks in the river.

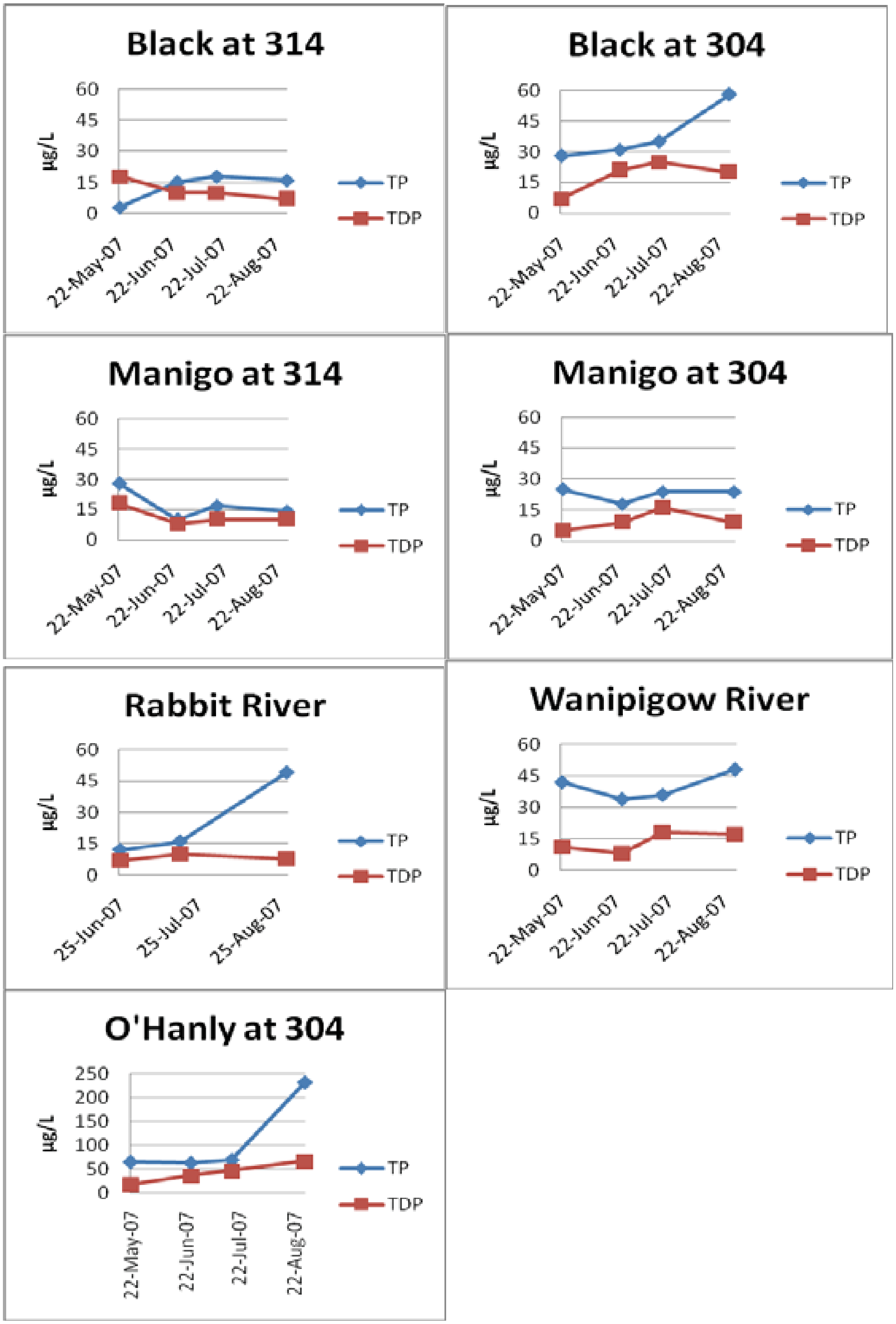

Figure 12. Seasonal changes in total phosphorus (TP) and total dissolved phosphorus (TDP) in 2007. Note difference in vertical axis scale for O'Hanly River.

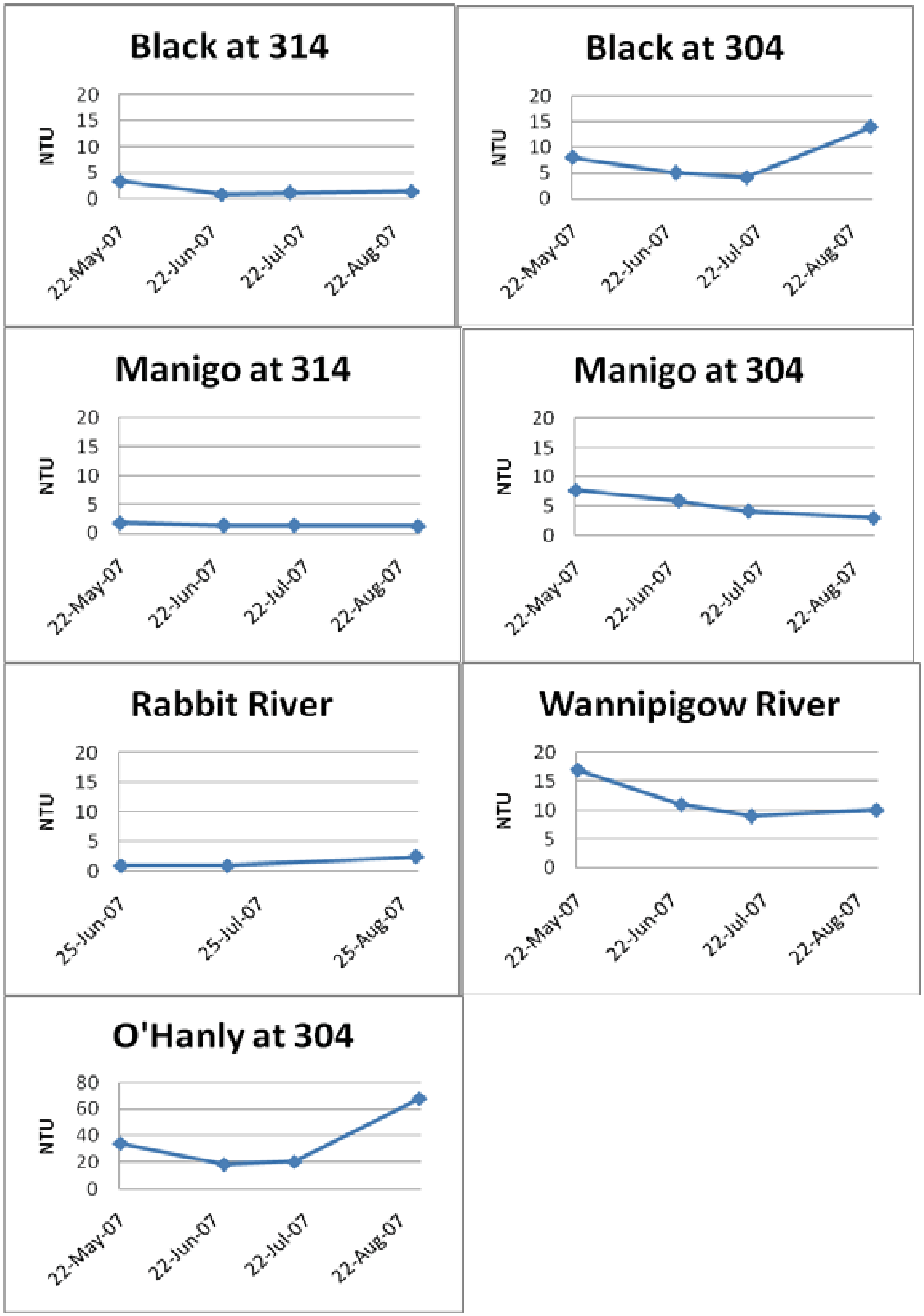

Figure 13. Seasonal changes in water turbidity in 2007. Note difference in vertical axis scale for O'Hanly River.

Identification of Experimental Watershed Areas in the Tembec FML

As mentioned earlier in this report, previous research on water quality in the Manitoba Model Forest area included the collection of water quality data and GIS-based data to examine the influence of watershed features (soil and forest type) and disturbance history (fire, timber harvest) on water quality. This was done in 22 river, stream and creek watersheds containing different soils types, forest types and disturbance histories (Kotak et a., 2005; Kotak, 2006). Preliminary results suggested that soils may have a significant influence on regional water quality, and that disturbances such as timber harvest may have a minimal (or no discernable) impact if the disturbance affects only a small proportion of a watershed. These studies, termed retrospective studies, rely on watersheds that have already experienced disturbances (whether timber harvest or fire). As many confounding factors are present in the above studies, it is advisable to test some of the assumptions and results in a more formal experimental design. As such, the Manitoba Model Forest will be initiating several watershed-scale experimental harvesting trials in the Tembec FML in order to assess in a more controlled manner, the effects of timber harvest on water quality.

To date, Miette Environmental Consulting has worked with Tembec to identify candidate areas in which to conduct the experimental harvests. Criteria for the selection of a location of the experimental watersheds included a) harvest scheduling that would allow for several years of pre-harvest data collection followed by several years of post-harvest data collection, b) some form of access to the area, c) little to no history of timber harvest, d) a uniform fire history, and e) relatively uniform soil types. The experimental will be based on a BACI design (Before After Control Impact), where some watersheds (or parts of watersheds) are subject to timber harvest, some of the watersheds are not (controls or reference watersheds), and monitoring occurs in both types before and after the harvest occurs. As much as feasibly possible, watersheds of both treatments (harvest, reference) are replicated.

Upon discussions with Tembec, it was evident that harvest scheduling was a driving factor in deciding where potential experimental watersheds could be located. Tembec is planning on opening up a new operating area known as the Kaneshoot area (Figure 14). Preliminary road construction into the area is scheduled for 2008 with harvesting not likely to begin several years after. This was one of the very few large areas on the FML where experimental watersheds could be chosen in which no previous timber harvesting has occurred, and which also fit in with the timelines needed for such a study. More detailed assessments will be conducted in 2008 to identify the appropriate experimental watersheds within the Kaneshoot operating area, conduct preliminary analysis of soil types and fire history, and to conduct some preliminary water quality sampling. This will allow for the final selection of watersheds and sampling locations, and more detailed harvest planning with Tembec's foresters. Pre-harvest monitoring will then begin in earnest in 2009.

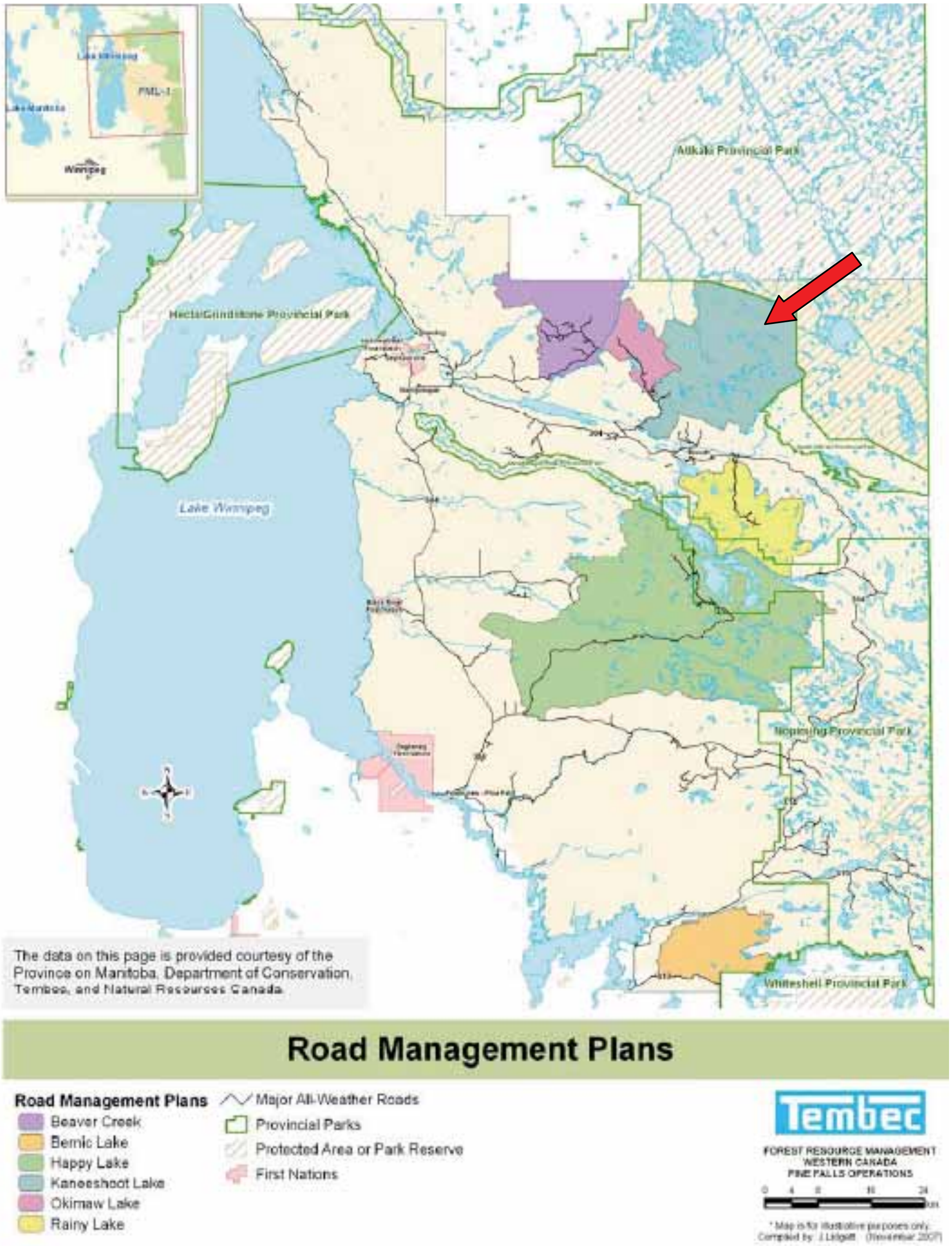

Figure 14. Map of Tembec FML showing location of location of Kaneshoot Operating area (red arrow) where watershed-scale timber harvesting/water quality experiments are proposed).

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