BACKGROUND REPORT ON AQUATIC ECOSYSTEM HEALTH FOR THE PEACE RIVER WATERSHED

Hutchinson Environmental Sciences Ltd.

Aquatic Ecosystems – Peace River Watershed – February 12, 2014

EXECUTIVE SUMMARY

The purpose of this report is to provide in-depth information on data and results presented in the Mighty Peace State of the Watershed document regarding aquatic ecosystems. This report presents data sources, analysis methods, detailed results and interpretation of state of the watershed indicators and included metrics regarding surface-water quality, wetlands, riparian health, biological communities and invasive species. The status of these indicators was discussed by sub-basin, in the context of known landscape characteristics and human pressures, and was based on the data available at the time. Data gaps were identified, means to address them discussed, and priorities proposed.

Some major results of the status assessment are provided below by general indicator category.

Surface Water Quality

- There are a large variety of streams, rivers and lakes in the Peace Basin.
- Major rivers are mainly nutrient-poor during low-flow conditions and carry high sediment loads during high flows.
- An exception to this are the Wapiti and lower Smoky rivers due to the cumulative effects of point sources in the Wapiti River, resulting in nutrient enrichment effects, increased ion content, and larger diurnal oxygen fluctuations.
- Smaller rivers and streams with local watersheds are naturally nutrient-rich.
- Agricultural streams are further enriched with nutrients, an effect that increases in severity with increased agricultural intensity.
- Many lakes in the Peace Basin are naturally nutrient-rich, except in the uplands and the Slave sub-basin.
- Some lakes have shown increasing trends in total phosphorus in the past few decades.
- The highest nutrient and total dissolved solid concentrations were generally found in lakes of the Upper Peace Basin, with Central, Lower Peace, Wabasca and Slave having lower levels, and the Smoky-Wapiti and the Peace-Athabasca Delta lakes showing the largest variation in lake water quality.

Wetland Cover and Health

- The Wabasca sub-basin had the largest wetland cover in the Peace basin, at more than 50%.
- The Upper Peace sub-basin had the lowest wetland cover, at just over 10%.
- The largest proportion (80%) of disturbed wetlands was found in the Upper Peace sub-basin, with a large variety of disturbance types.
- Wetland disturbance was lower in partly or fully forested watersheds, but still substantial

in the presence of linear development by the energy sector (e.g., Smoky-Wapiti 75%, Wabasca sub-basin 30%).

- Wetland loss from 1985 to 2001 for the White Zone was estimated at 5%, but more wetlands were likely lost since settlement prior 1985.

Riparian Health

- Riparian land cover in the majority of sub-basins was primarily natural, with natural land cover of 90% to 100% (Central Peace, Wabasca, Lower Peace, Slave River).
- The Smoky/Wapiti and Upper Peace sub-basins displayed the greatest percentage of human land use (agriculture and development) in riparian areas compared with the other four sub-basins, with 75% human land use in the riparian areas of the Upper Peace and about 50% in the Smoky-Wapiti Sub-basin.
- Land cover in riparian areas correlated strongly with land cover in the entire sub- basins. Agricultural land use in the Upper Peace and Smoky-Wapiti sub-basins occurred preferentially in riparian areas. In the Central and Lower Peace, the proportion of agricultural cover was slightly lower in riparian areas than in the entire sub-basins.
- Individual riparian health assessments were scarce, with only three sites in the Upper Peace, and four sites in the Central Peace and 34 sites in the Smoky- Wapiti.
- The Smoky-Wapiti assessments resulted in about half of the sites assessed as healthy, 30% healthy with problems, and a quarter of the sites unhealthy.

Fish Populations

- There was a large variety of fish in the Peace Basin, thanks to a large variety of habitats and a good quantity of cool- and cold-water habitat.
- Generally, the status of fish species in large rivers was good, while densities in smaller rivers were moderate to low.
- Densities of sensitive species of smaller rivers, such as Arctic Grayling, were low in areas with increased water access or agricultural land use and/or linear disturbance, or possibly where habitats are less suitable. Local extirpations were reported in areas adjacent to Grande Prairie, including the Redwillow and Beaverlodge Rivers.
- Arctic Grayling occurs in high to moderate densities in headwater streams in remote, undeveloped areas and in the Little Smoky River, where the population has persisted at higher densities despite human land use, which is subject to fishery restrictions.
- Lake fish populations are stressed from fishing pressure and from anoxia in eutrophic lakes.
- There are many uncertainties about fish populations, particularly in the less-populated areas of the northeast of the Peace Basin.

Invasive Species

- Two exotic species in the Peace Basin were observed in all but the Wabasca and Slave River sub-basins.
- One invasive aquatic plant species of concern – Eurasian Milfoil - has been found once in the Wapiti watersheds.
- Invasive terrestrial plant species appear to be common in the riparian areas of the White Zone, but limited to 10 species and low percent-coverage values. More data are needed to confirm this trend.

The main data and knowledge gaps identified in this report are as follows:

Surface Water Quality

- Small- and medium-sized river and stream water quality
- Diurnal datasets for major rivers, except Wapiti River
- Long-term trends in water quality
- Instream flow needs
- Lake beach bacteria monitoring
- Synoptic river surveys
- Estimates of natural water quality in impacted areas
- Seasonal water quality objectives
- Site-specific water quality objectives
- Nutrient guidelines

Wetlands

- Extent and locations of wetland loss
- Wetland health

Riparian Health

- Better coverage of individual riparian health assessments
- Lake riparian health

Invasive Species

- Terrestrial invasive species in riparian areas

- Freshwater diatom algae Didymo (*Didymosphenia geminata*)
- Invasive species in wetlands

Fish Populations

- Population status of species that lack good data (Goldeye, Northern Pikeminnow, and Flathead Chub
- Population status for many fish in the Lower Peace, Central Peace (portions) and Wabasca sub-basins
- Stressor-Response relationships/thresholds of fish populations with
    - Cumulative human impacts
    - River regulation
    - Instream flow needs for habitat
- Standard survey techniques for data inclusion to the Fish Sustainability Index
- Differentiate habitat use (resident vs. migrant populations, spawning, rearing, overwintering
- Quantify fish barriers
- Review fish contaminants

Overall, the Peace Basin is rich in aquatic resources, both in terms of their number and diversity. The status of these ecosystems varies greatly across the basin. Aquatic ecosystem health is good in remote and protected areas, in particular in the Rocky Mountains and Foothills, as well as in the northeast, but a number of different human activities have had regionally significant impacts on water quality, biota, riparian areas and wetlands. Ongoing population and economic growth can potentially increase these impacts, but the lessons learned in this status assessment will help anticipate and mitigate future impacts.

The information presented in this report and the identified knowledge and data gaps, alongside the main SoW report, should provide a strong basis for future work towards a healthy and sustainable Mighty Peace watershed.

REPORT PURPOSE

This report was prepared as a technical document supporting the development of the State of the Watershed report of the Mighty Peace watershed. Its intent is to provide in-depth information on all data and results presented in the SoW regarding aquatic ecosystems, including source data, analysis methods, interpretation of results and a bibliography. Detailed sections covering the background information for the watershed and information on human pressures in the basin are provided in the SoW (CharettePellPoscente Environmental Corp. 2014) and were outside the scope of this document. Such subjects were only briefly discussed where required for interpretation of aquatic ecosystem data. A thorough understanding of the watershed features and human pressures on them, however, is necessary to fully grasp the significance of the results presented herein, and this document should not be read in isolation from, but in conjunction with the SoW report.

STATE OF THE WATERSHED INDICATORS

Aquatic Ecosystems

The Mighty Peace Watershed Alliance developed a set of indicators that were central to the SoW report. This set of indicators was the result of detailed reviews of existing information, consultation with stakeholders and the public, and discussion of the board. The indicators that fell within the scope of aquatic ecosystems were the subject of this report and guided its structure (Table 1).

Table 1. Overview of Indicators and Metrics for Aquatic Ecosystems considered in the Peace and Slave Rivers State of the Watershed Report

Indicator	Metric	Importance	Human Impacts
Surface Water Quality			
River water quality	Alberta River Water Quality Index	Overall description of water quality	Point and non-point source discharges
	E. coli	Recreational, irrigation and stock watering as well as drinking water uses	Municipal wastewater, livestock operations, manure application
	Phosphorus	Eutrophication and related impacts on aesthetics and aquatic life	Municipal and pulp mill wastewater, fertilizers, erosion
Lake water quality	*E. coli*	Recreational and drinking water quality	Municipal wastewater and livestock operations
	Algal blooms	Related impacts on aquatic life, drinking water quality and recreational uses	Fertilizers, erosion
	Anoxia		
	Salinity	Aquatic life, irrigation, stockwatering and drinking water quality	Municipal wastewater, climate change
Land Use and Land Cover			
Wetlands	Wetland cover and loss	Flood control, groundwater replenishment, water quality improvements, carbon storage, host biodiversity	Drainage, filling, cultivation
	Human disturbance in wetlands	Condition indicator for human impact in existing wetlands	Partial fill or drainage
	Invasive plant species in wetlands	Indicator of wetland health, see “invasive Species” below	Land clearance, introduction of weed species
Riparian health	Land cover in riparian areas	Habitat for many wildlife species, regulate hydrology,	Loss of natural cover by cultivation, linear or urban

Indicator	Metric	Importance	Human Impacts
	Individual health assessments	improve water quality	development
	Invasive plant species in riparian areas	Indicator of riparian health, see "invasive species" below	Land clearance, introduction of weed species
Biological Community			
Fish populations	Individual fish species density	Aquatic ecosystem health and recreational use	Habitat modification (removal of riparian vegetation) and fragmentation (stream crossings), water quality impacts
	Number of species (total, at risk)	Indicates biodiversity	
Invasive species	Presence of invasive species in wetlands, lakes, rivers or riparian areas	Displace or destroy native fauna and flora, impact biodiversity	Release of exotic bait fish, non-inspected boat transfer, other transports

Other descriptors of aquatic ecosystems are included in the discussion where deemed important to fully portray the effects of human activities on aquatic ecosystems. One of the lake water quality indicators, salinity, deserves additional explanation, as it is not related to any of the other indicators in an obvious way.

Salinity is an important indicator for lake water quality as changes in salinity can have major effects on aquatic biota and the human uses. Many freshwater algae, plants and animals are adapted to a narrow range of salinity (Wetzel 2001). Freshwaters can increase in ion content (measured as salinity, conductivity or total dissolved solids (TDS)) as a result of climatic factors (negative water balance), human alterations of the hydrological cycle (excessive water withdrawals) or as a result of point (wastewater) and non-point source (stormwater containing road salt) discharges.

Increases in TDS have been observed in many Alberta lakes, including lakes in the Peace Basin (Casey 2011). When freshwaters approach the limit to brackish waters (1000 mg/L TDS, Wetzel 2001), freshwater aquatic life that is not adapted to these conditions are subject to osmotic stress, which affects aquatic health. In this circumstance, organisms have to use more energy to maintain the required ion-water equilibrium within their bodies; energy is then unavailable for other life functions. The result is commonly a change in community composition in favour of species that are better adapted to higher salinities, which often is accompanied by a reduction in biodiversity (Williams 2001). In Alberta Lakes, Casey (2011) found that in some lakes with TDS concentrations larger than 500 mg/L, algal biomass was reduced below the level expected for their nutrient concentrations. On the other hand, naturally saline inland lakes represent valuable and rare ecosystems and their ecological integrity can be threatened by decreasing salinities associated with human activities in the watershed (Bowman and Sachs 2008).

METHODOLOGY

Surface Water Quality

Alberta River Water Quality Index data were obtained from the AESRD website and presented for the past ca. 10 years, if available, as an average for the period of record.

Other water quality information sources included the database held by AESRD, the Alberta Atlas of Alberta Lakes, university research and individual water quality assessments completed for a variety of rivers and purposes, such as environmental effects monitoring for pulp mills and compliance monitoring for wastewater treatment plants (as cited). A previously published synthesis of information about aquatic ecosystem health in the Peace Basin (CharettePellPoscente Environmental Corp. and Hutchinson Environmental Sciences Ltd. 2012) was another source consulted in the preparation of this report.

Summary statistics for river water quality were computed where larger datasets were available. We compared river water quality from upstream to downstream sites to describe spatial water quality differences and assess the influence of non-point and point source discharges. True synoptic datasets, where data were collected from the same time period in one year, were sparse.

A Wilcoxon Signed Ranks test was used to compare phosphorous concentrations at the two LTRN sites along the Peace River; Fort Vermilion and the site upstream of the Smoky River near Shaftesbury Crossing. Monthly total phosphorous and total dissolved phosphorous concentrations from September 2006 to March 2012 were used for the comparison.

Water quality data were available for about 100 lakes. For many of these lakes, there were only few measurements of varying parameters, the timing of which ranged from the 1980s to the 2000s. Given that lake water quality changes, if any, often occur gradually and that a broad overview of lake water quality was sought for the purpose of this report, we did not exclude any data for reason of age. We did select the data from the most recent year available for each lake in order to produce the most recent status description. We then selected lakes that had at least three measurements per year, including one made in the summer, which has been common practice in Alberta lake studies to correct for the high seasonal variability in lake water quality (Prepas et al. 2001a, b and Pinel-Alloul et al. 2002).

We calculated summary statistics by sub-watershed for lake phosphorus and TDS, based on average values from each lake. We have to stress that these statistics only represent approximations, with updated and correct statistics only possible through a synoptic-type lake sampling program over a few years. Some lakes are included in a more intensive sampling program by AESRD, with several visits per year, which allowed the presentation of long-term trends. The low number of these lakes, however, made them unsuitable for large spatial comparisons in terms of water quality trends.

Nutrient levels in lakes and rivers were discussed in relation to trophic status. Trophic status is a classification of surface waters in terms of nutrient (or algae) concentration. For lakes, we adopted the most commonly used classification internationally and in Alberta, that of the Organization of Economic Cooperation and Development (OECD 1982) (e.g., Casey 2011) (Table 2). For rivers, we used the most commonly used classification proposed by Dodds et al. (1998) for rivers and streams (Table 3).

TABLE 2. LAKE TROPHIC STATE CLASSIFICATION AFTER OECD (VOLLENWEIDER AND KEREKES 1982, IN NORTH/SOUTH CONSULTANTS 2007)

Trophic State Category	Phosphorus (mg/L)	Chlorophyll a (μg/L)
Oligotrophic	<10	< 2.5
Mesotrophic	0.01-0.035	2.5-8
Eutrophic	0.035 – 0.1	8-25
Hypertrophic	> 0.1	>25

TABLE 3. RIVER TROPHIC STATE CLASSIFICATION AFTER DODDS ET AL. (1998)

Trophic State Category	TP (mg/L)
Oligotrophic	0-20
Mesotrophic	20-70
Eutrophic	>70

To our knowledge, no bacteria data are available for lakes in the Peace Basin. The northernmost sites sampled through the recreational beach-monitoring program by Alberta Health are located in the vicinity of Edmonton.

Wetlands

Wetland Cover

Wetland cover was obtained from the latest combined wetland layer available from the Government of Alberta (AESRD 2013). This dataset depicts wetlands within the province of Alberta, Canada, for the period 1998 to 2012 classified according to the Canadian Wetland Classification System (CWCS) at the major class level (marsh, open water, bog, fen and swamp). This layer is a merged product of component wetland inventories, with differing specifications on how wetlands were captured and classified. The remote sensing techniques applied to generate this dataset were not used to distinguish between shallow and deep water, thus both open water wetlands and lakes were included in the open water category. This is important for the interpretation of total wetland cover, as lakes are not technically wetlands. We therefore presented the wetland cover distinguished by wetland type for each sub-watershed.

National parks were not covered by the GIS layer. The land area within sub-basins that comprise portions of any national park was therefore excluded from wetland cover analysis. We reported three metrics for wetland cover: total wetland area by sub-watershed, wetland area by wetland type and percentage wetland coverage of sub-watersheds.

Wetland Loss

Wetland loss is defined as the "measurable, anthropogenically created wetland basin alteration sufficient in magnitude to impose permanent effects to a wetland"s capacity to hold water and/or function as wetland habitat" (Watmough and Schmoll 2007). Wetland loss in the Peace River Basin has not yet been quantified. A thorough investigation for the entire prairie-parkland regions of Alberta, Saskatchewan and Manitoba, however, was completed by Watmough and Schmoll (2007). In consultation with the authors, we determined that the results of this report for the Aspen Parkland and Boreal Transition ecoregions are likely representative of wetland loss encountered in the White Zone (settled zone) of the Peace Basin. Agricultural practices are usually similar across the country and the only difference between the areas sampled by Wamough and Schmoll (2007) and the Peace Basin agricultural areas may be that the latter were settled somewhat later. Therefore the total wetland loss over the past century, which is generally less well know, is associated with a high degree of uncertainty, but the rate of wetland loss over the past few decades is likely similar to that observed in the Prairie study. We therefore present results on wetland loss from that report for each sub-watershed, based on the area that is under agricultural land use.

The methodology of Watmough and Schmoll (2007) consisted of estimating wetland extent in a number of quadrants along sample transects from 1985 false-colour infrared aerial imagery and then revisiting the same sites in 2001 by imagery and field investigations. In the Aspen Parkland, 59 transects were analyzed (0.53% of the ecoregion) and in the Boreal Transition, 13 transects were analyzed (0.2% of the ecoregion). The low sample size in Boreal Transition ecoregion reduced the reliability of the results for this region, but preliminary observations indicate that habitat change is likely higher than reported, especially in Alberta (Watmough and Schmoll 2007). This report also contained a literature review of estimated overall wetland loss since European settlement in the prairies, which is included in the SoW report.

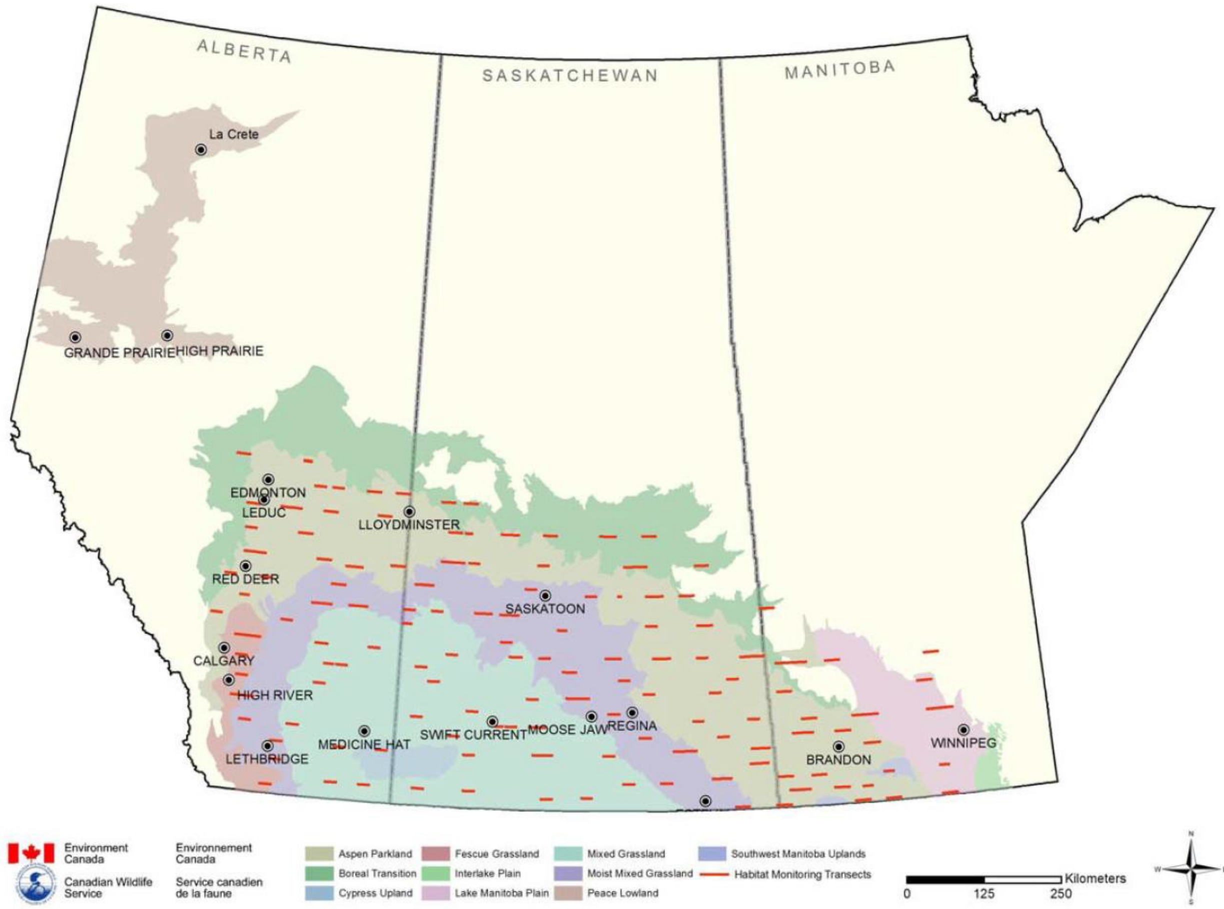

FIGURE 1: TRANSECTS ANALYZED IN THE PRAIRIE WETLAND LOSS STUDY BY WATMOUGH AND SCHMOLL (2007).

Wetland Health

Human disturbance in wetlands was assessed by analyzing data provided by the Alberta Biodiversity Monitoring Institute (ABMI). The ABMI dataset contains a category "level of disturbance" in the wetland survey results. These raw data were extracted for each sub-watershed using GIS.

We analyzed the data and summarized the level of disturbance in wetlands by sub-watershed. Calculated metrics were:

- number of surveyed wetlands where disturbance is present, and
- percentage of total surveyed wetlands that have a presence of disturbance.

Based on the number of ABMI sites with data, we discuss if the current ABMI dataset may be representative for a sub-basin, or if more data are needed to confirm trends.

Overall, while the GIS-based wetland inventory reports presence/absence only, the wetland disturbance adds qualitative information on a stressor for wetland health.

The sampling design of ABMI includes a grid of equidistant sample sites that covers the entire province and is therefore not biased by access or land use. Once data are available for all sites, results will be representative of the sub-watershed within which they were located due to the probabilistic[1] sample design. Only a portion of the sites has been sampled so far, with varying representation in the different Peace sub-basins, so the results presented in this report are preliminary.

Riparian Health

The most accurate way to determine riparian health is by field-based assessments. Due to the effort required, these are usually restricted to small areas. In the Peace River Basin, the Alberta Habitat Management Society (Cows and Fish) (Sikina and Ambrose 2013) have completed some riparian health assessments, but their number is small compared with the large surface area of the basin. The data therefore cannot be used to assess status of riparian health on a sub-basin basis. They do, however, provide snapshots of riparian health that may point to potential riparian health issues in surrounding areas or areas with similar land use.

In order to provide a basin-wide assessment of the status of riparian areas, a mapping exercise that was previously successfully applied in the Red Deer River watershed (O2 Planning + Design Inc. (O2) and LimnoLogic Solutions Ltd. 2013) was completed. Land cover in riparian areas was estimated by overlaying the ABMI land cover map on the Government of Alberta"s Digital Elevation Model (DEM) – Derived Lotic Riparian Dataset.

The riparian dataset provides a spatial representation of potential riparian areas associated with streams and rivers (lotic environments) but not isolated lakes. This riparian feature class consists of polygons representing the location of lotic riparian areas that have been generated from slopes derived from the Base Features Derived Partially Filled Hydrologically Corrected Digital Elevation Model grid using satellite imagery to determine thresholds for the floodplains (GeoDiscover Alberta 2014).

Through an accuracy assessment using high-resolution aerial photography in a small part of the dataset, the accuracy of riparian areas was estimated at 79% for the Boreal Natural Region (NR), at 87.4% for the Foothills NR and 71.4% for the Parkland NR.

The land cover dataset provided by ABMI was used to calculate percent cover of natural versus human-derived land cover by sub-watershed. This information will provides data on the extent of riparian areas and the level of human disturbance in these areas, which can be interpreted in terms of riparian health.

For agricultural areas in the Smoky/Wapiti and the Upper Peace sub-watersheds, the Agriculture Canada crop layer was used to distinguish between cropland and hay/pasture lands. These two types of agricultural use differ in the severity of effect on riparian areas, with perennial vegetation cover in hay and pasture lands resulting in less erosion than seasonally exposed bare soils in croplands. For the other sub-watersheds, this information was not available, as the crop layer

[1] Probabilistic sampling design is a design where all locations in an area have the same probability of being chosen for a sampling program that is conducted in that area.

only completely covered the agricultural lands in the Smoky/Wapiti and Upper Peace sub-basins.

Invasive Species

We scanned the wetland vegetation surveys conducted by ABMI in the Peace Basin for invasive plant species that are known to be present in other areas of Alberta. These results provide additional information on the status of wetland health, as invasive species are a type of human-cause disturbance to the natural ecosystem and therefore are potential indicators of wetland health (Wray and Bayley 2006).

Riparian Health Assessments summarized by Cows and Fish (Sikina and Ambrose 2013) included a section on the presence of invasive species. This information was used to describe invasive species occurrence in riparian areas.

Presence of exotic fish species was obtained from Johnson and Wilcox (2012). Information on invasive invertebrates was obtained from AESRD staff.

Fish Populations

Information on fish species presence, adult density and data uncertainty was taken from a report prepared by Johnson and Wilcox (2012), which was based on a detailed review of FWMIS information. In order to control for catch success in different methods, electro-fishing catch rate was used as the estimator for adult density for all focal species, in lotic systems. For lentic systems, a standardized gill-netting catch rate was used as the estimator (Johnson and Wilcox 2012). Adult density was reported on a tertiary-watershed basis, which is smaller landscape scale than the sub-basins defined by the MPWA. For example, in the Smoky-Wapiti sub-basin, there are nine tertiary watersheds for which different fish density data were available. We therefore reported ranges of fish densities found in the smaller landscape units for each sub-basin they were part of.

In addition, we consulted lake netting reports, stream inventories and individual fisheries assessments where available and where these provided additional information in areas of high data uncertainty in Johnson and Wilcox (2012).

SMOKY-WAPITI SUB-BASIN

Sub-Basin Description

The Smoky-Wapiti sub-basin is the largest sub-basin in the Peace Watershed and is the most diverse in terms of natural regions ranging from alpine in the Rocky Mountains, foothills, central and dry mixed-wood forests and parkland in lower reaches. As a result, the types of human uses of the natural resources are varied and also allowed the largest population growth in the Peace Basin. This sub-basin contains the largest number of large point source discharges and large agricultural areas, most of which are located in the Wapiti River catchment. The Smoky River catchment, by contrast, is mostly forested, with coal mining in the headwater regions, oil and gas and forestry operations in the foothills and some intense agriculture in the lower reaches of the sub-watershed.

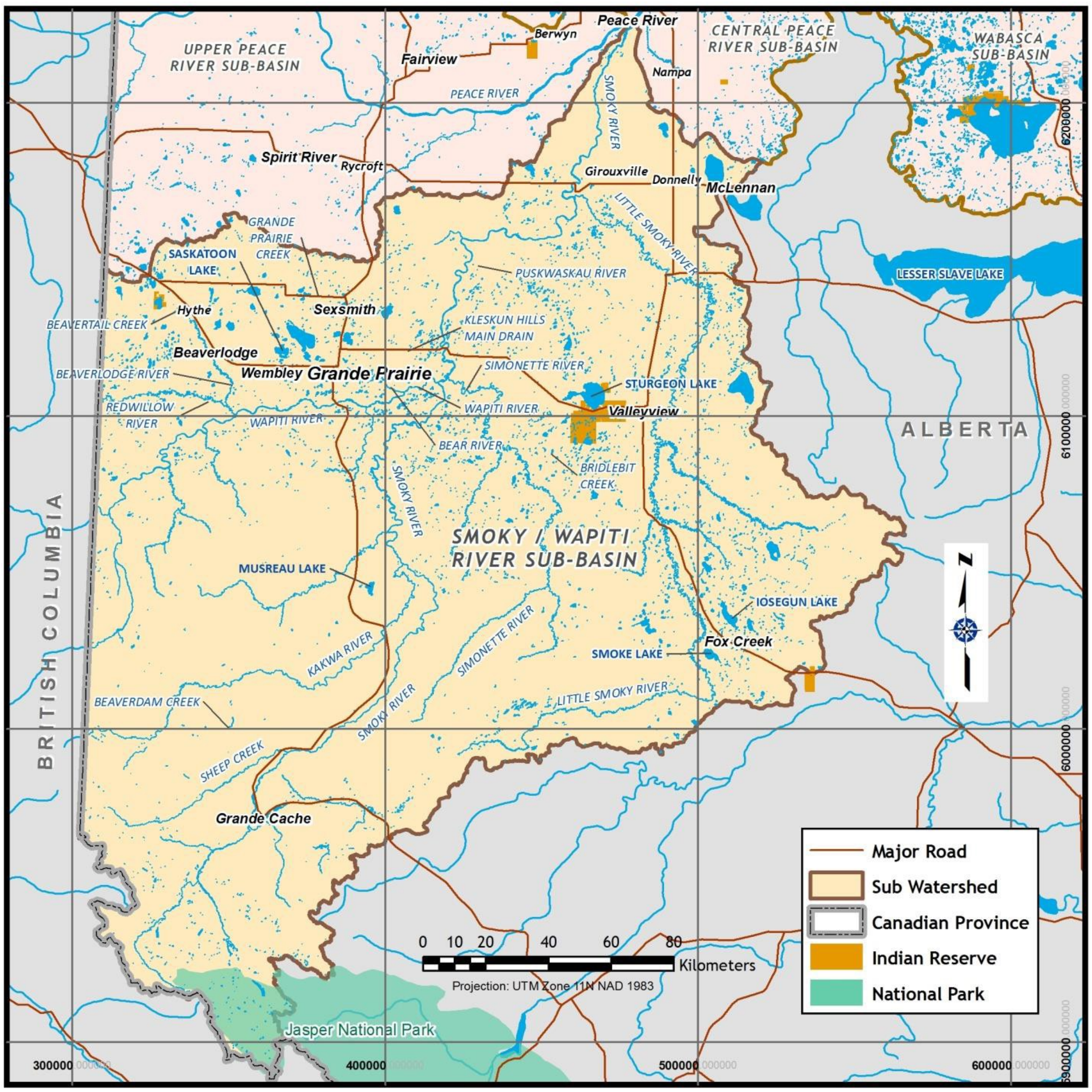

FIGURE 2. MAP OF SMOKY-WAPITI SUB-BASIN

Surface Water Quality

River and Stream Water Quality

Alberta River Water Quality Index

Three Long-term River Network (LTRN) sites are located within the Smoky-Wapiti River sub-basin, in the Wapiti River at Hwy 40 bridge, in the Wapiti River above the Smoky River confluence and in the Smoky River at Watino. There has been no update to ARWQI results available online since 2010.

Over the 10-year record, all three LTRN sites had an average overall water quality rating of "good" and the sub-indices for metals and pesticides were rated as "good" and "excellent," respectively.

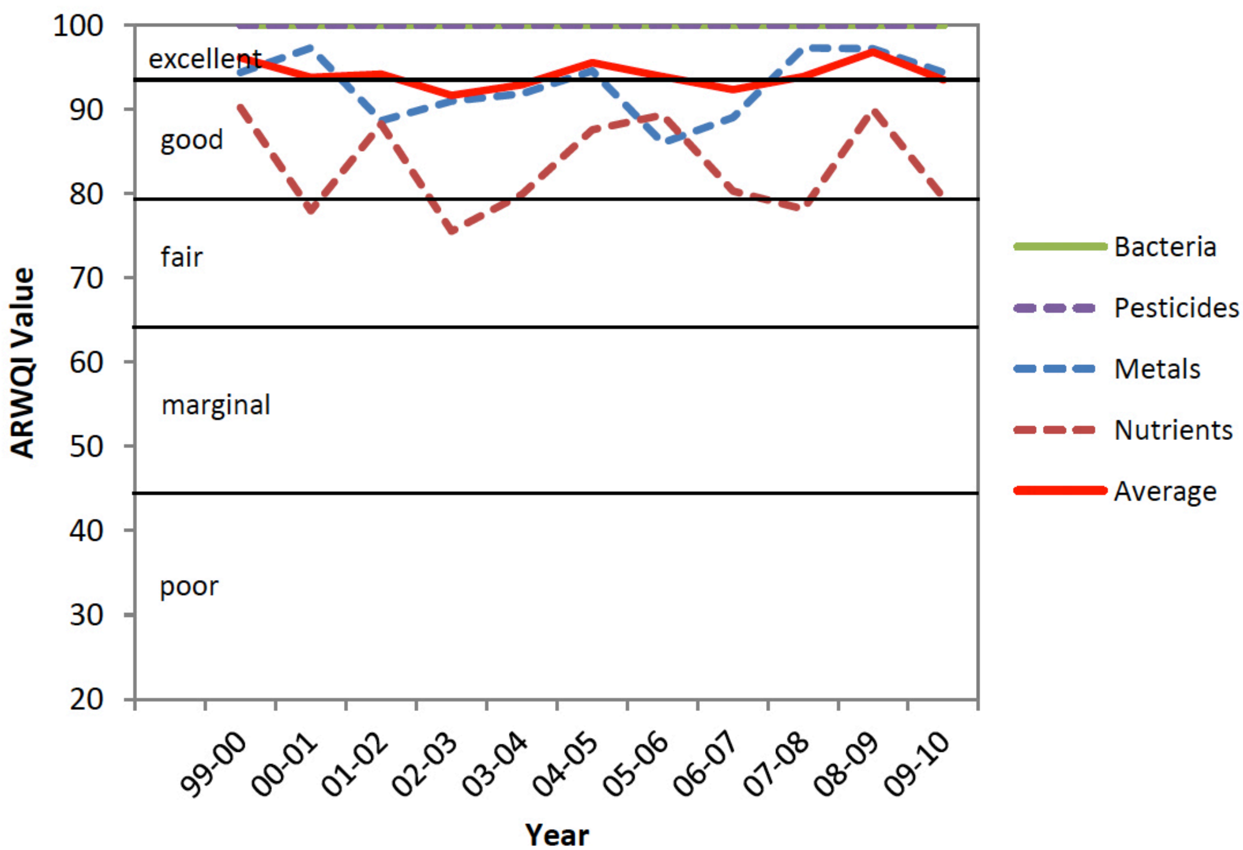

FIGURE 3. ARWQI FOR WAPITI RIVER AT HWY 40 BRIDGE.

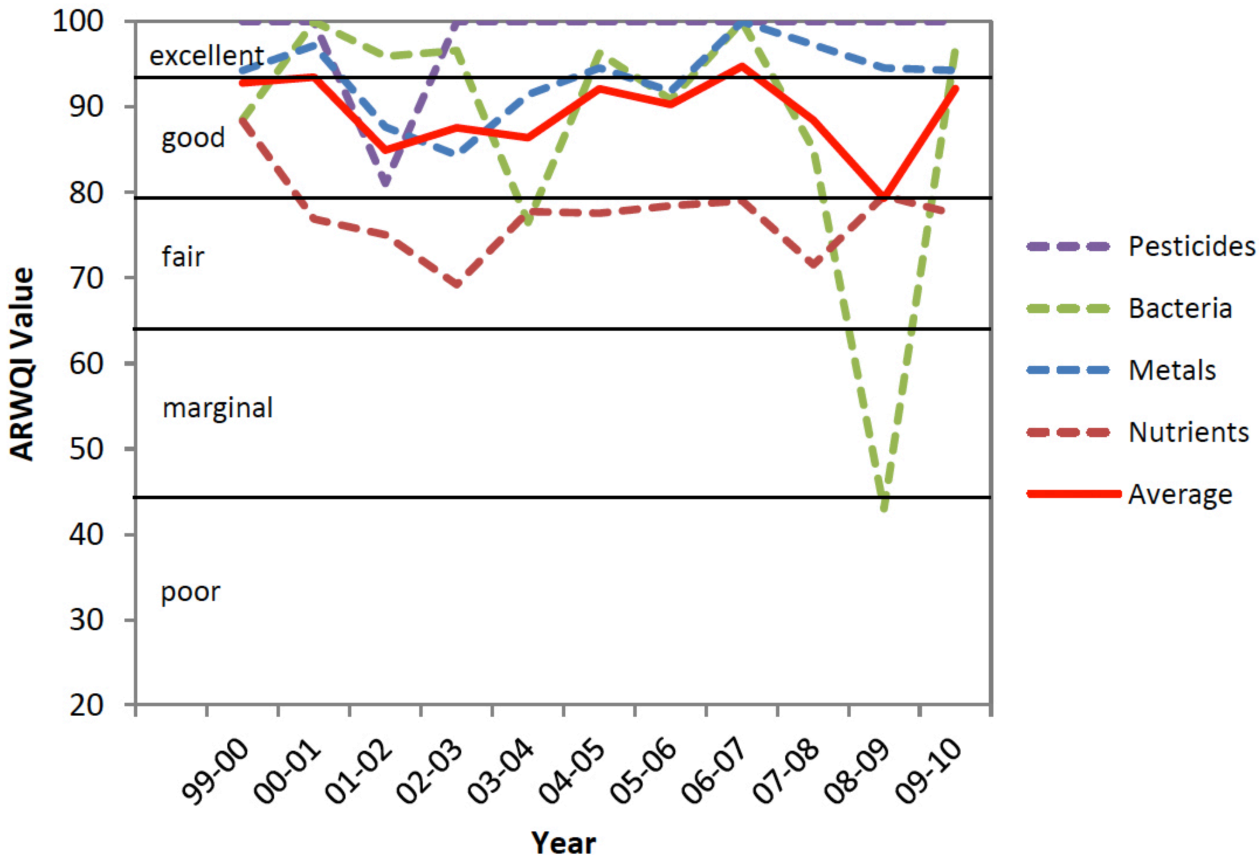

FIGURE 4. ARWQI FOR WAPITI RIVER ABOVE SMOKY RIVER.

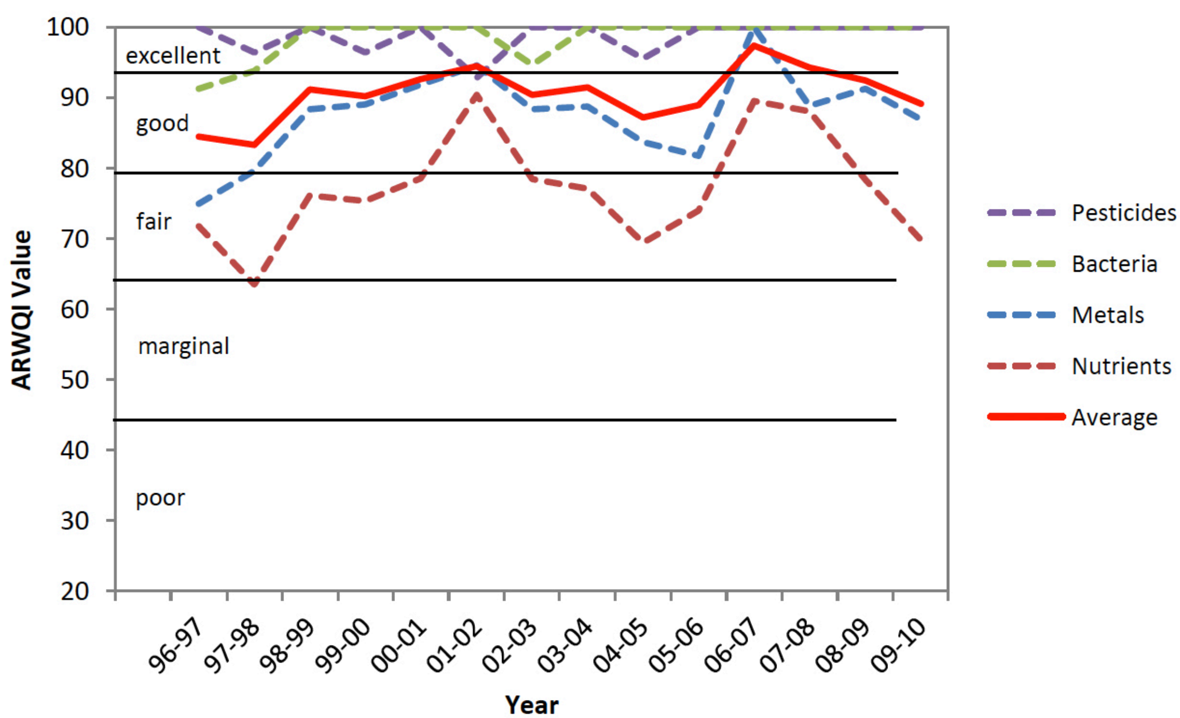

FIGURE 5. ARWQI FOR SMOKY RIVER AT WATINO.

At the Wapiti River at Hwy 40 Bridge site, which is located upstream of the WWTP and pulp mill discharges, the sub-indices for nutrients and bacteria were rated as “good” and “excellent,” respectively. At the site located on the Wapiti River above Smoky River, which is located downstream of both discharges and the confluence of Bear River that receives Grande Prairie stormwater, the sub-indices for nutrients and bacteria changed to “fair” and “good,” respectively.

At the Smoky River at Watino, downstream of the Smoky-Wapiti Rivers confluence, the sub-index rating for bacteria returned to “excellent,” likely due to dilution from the largely un-impacted waters of the Smoky River. “Fair” ratings for nutrients at the Smoky River at Watino site may in part be due to elevated TSS loads during high flow periods (North/South Consultants 2007), but are probably also a result of nutrient enrichment from point source discharges in the Wapiti River during low flow (HESL 2012).

Phosphorus

- *Major Rivers – Wapiti River*

Wapiti and Smoky Rivers are naturally nutrient poor, as indicated by upstream water quality data (Figures 6, 7 and 8). Total phosphorus levels are seasonally elevated during high-flow periods in spring and early summer due to elevated sediment transport (Figure 7).

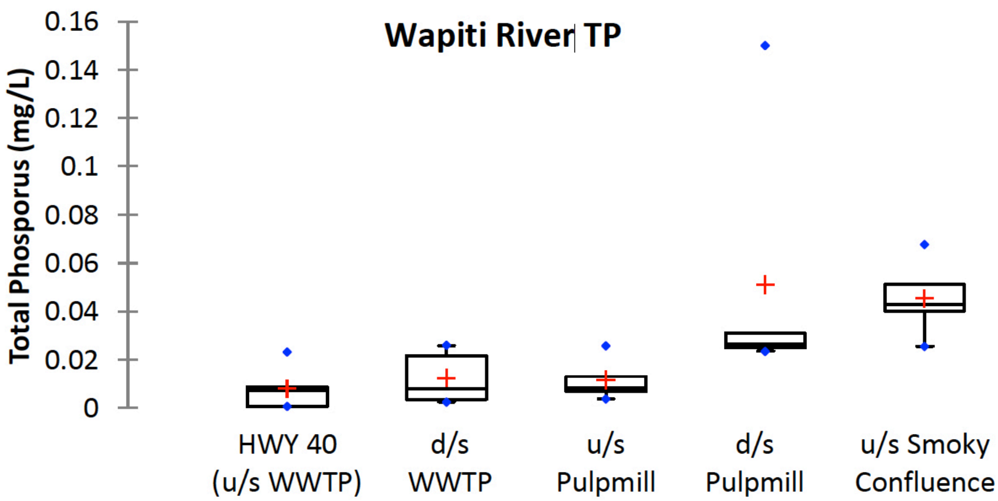

FIGURE 6. SPATIAL TP DIFFERENCES IN WAPITI RIVER DURING LOW FLOW (2011)

Eutrophication effects from increased total phosphorus (TP) are a concern for the Lower Wapiti River ecosystem during low flow (North/South Consultants 2007). Discharges of wastewater treatment plant effluent and pulp mill effluent increase TP concentrations significantly (Golder Associates Ltd. 2004, Hatfield Consultants 2008, HESL 2012).

While spring and early summer (high-flow) TP levels at the river mouth were similar to upstream concentrations in most years, concentrations at the mouth during low-flow periods, in particular in winter, were consistently higher by about an order of magnitude (Figures 7 and 8). This is mainly a result of reduced dilution capacity of the river during low flow.

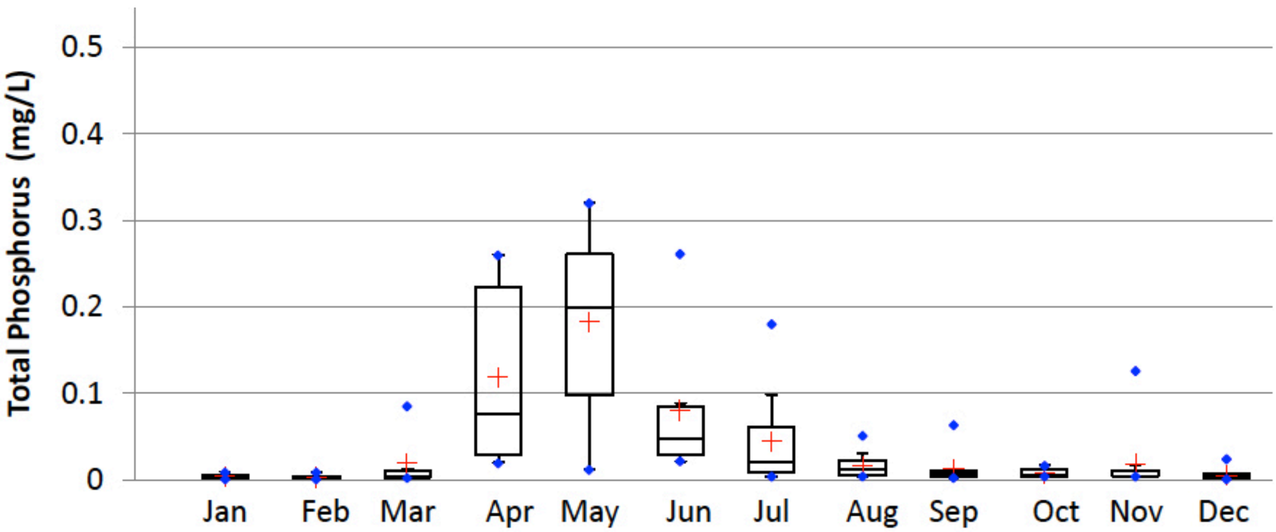

FIGURE 7. SEASONAL TP PATTERNS IN WAPITI RIVER AT HWY 40, UPSTREAM OF THE SMOKY RIVER CONFLUENCE 2003-2013

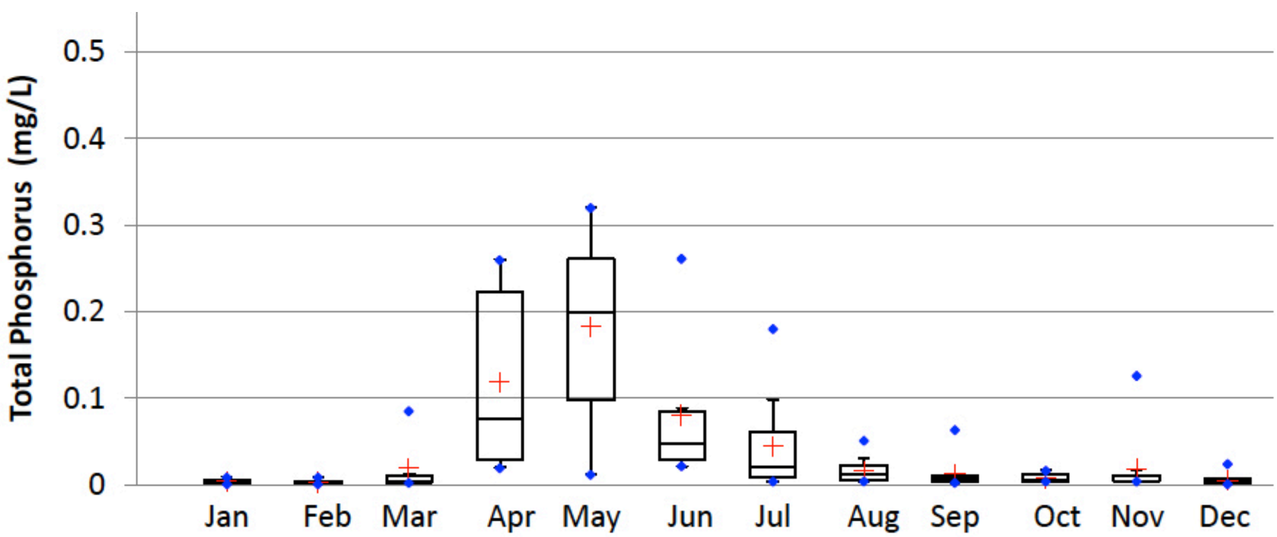

FIGURE 8. SEASONAL TP PATTERNS IN WAPITI RIVER UPSTREAM OF THE SMOKY RIVER CONFLUENCE 2003-2013

Elevated nutrient levels have also resulted in increased periphyton and benthic invertebrate productivity, lower benthic invertebrate diversity, increased the relative importance of blue-green algae in the periphyton community (HESL 2012) and resulted in better-nourished fish (Golder Associates Ltd. 2004). All these effects occur to a certain degree downstream of the WWTP and are enhanced downstream of the pulp mill.

Recently collected diurnal datasets for dissolved oxygen (DO) and pH showed consistently larger ranges in both parameters at a site downstream of the WWTP and more so at a site downstream of the pulpmill, compared to a site upstream of both discharges, in late summer and fall 2012 (Alina Wolanski, AESRD, pers. comm.). At the downstream sites, increased primary production of periphytic algae resulted in larger oxygen production from day-time photosynthesis in comparison to the upstream site, raising oxygen levels by up to ca. 1.5 mg/L. Larger oxygen consumption occurred at night due to algal respiration at the downstream sites, which reduced DO levels by up to 1 mg/L. DO levels, however, remained well above the 6.5 mg/L water quality guideline for the protection of aquatic life (AESRD 2013 (b)), so no negative effect on aquatic life is expected at any of the sites. Interestingly, there were week-to-week fluctuations in DO levels at the upstream site as well as the downstream sites, indicating upstream influences on DO levels in the Wapiti River. Overall, these results confirmed the productivity trends observed in biotic communities but provide a better picture of their effect on aquatic habitat.

AESRD data from Wapiti River demonstrated very low nutrient concentrations at locations upstream of the Redwillow River mouth in fall 1989 (TP = 0.002-0.004 mg/L). Data collected by Aquatera Utilities Inc. from the Wapiti River showed nutrient enrichment with distance downstream of the Grande Prairie WWTP and the Weyerhaeuser pulp mill discharges (Hutchinson Environmental Sciences Ltd. 2012, 2013, Figure Water Quality in the Wapiti River).

- *Major Rivers – Smoky River*

Seasonally elevated TP concentrations in Smoky River have been associated with high TSS concentrations during high flow (North/South Consultants 2007) and nutrient enrichment due to inputs from the Wapiti River (Hutchinson Environmental Sciences Ltd. 2012). Data from Smoky River upstream of the Wapiti River confluence are sparse, but generally indicate low phosphorus with low flow median TP concentrations at 0.001 mg/L in 2011 (mean 0.009 mg/L) and 0.011 mg/L (mean 0.048 mg/L, including a storm event) in 2012 (Hutchinson Environmental Sciences Ltd. 2012, 2013).

The average TP concentration at the Smoky River LTRN site at Watino, which is located downstream of the Wapiti River confluence, from March 1989 to March 2012 was 0.10 mg/L, with the highest concentrations usually occurring in April and May.

Low-flow data from Smoky River downstream of the Wapiti River confluence collected in 2011 showed increased phosphorus concentrations compared with upstream (Figure 9), confirming the nutrient enrichment effect from the Wapiti River. Comprehensive previous datasets collected by Golder Associates (2004) also showed nutrient enrichment effects in the Smoky River downstream of the Wapiti River confluence.

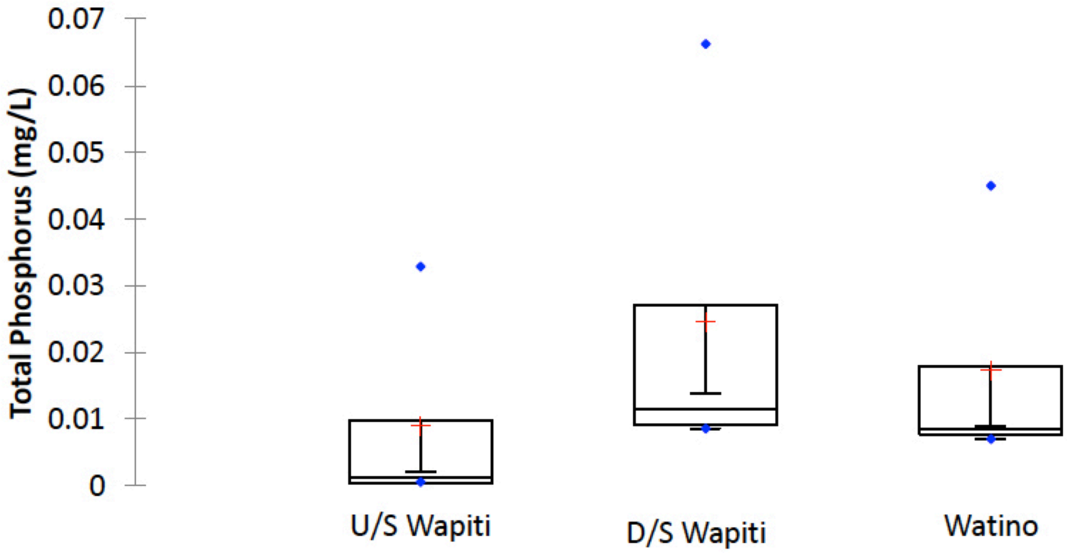

FIGURE 9. SPATIAL TP DIFFERENCES IN SMOKY RIVER DURING LOW FLOW (2011)
Data Sources: HESL (2012) and AESRD.

A synoptic survey of the lower Smoky River in 1983 indicated further increases in TP between Watino and the Smoky-Peace confluence (Figure 10). In this reach, there are no large point-discharges, but agricultural land use in this area was rated as "high intensity" by Alberta Agriculture and Food (Figure: Cultivation Intensity in the Peace Basin), which may contribute additional nutrients through tributaries in this reach. These synoptic data on the Smoky River are outdated, however, and therefore a synoptic survey of this river is recommended to asses current spatial patterns. The increasing patterns from Bezanson Bridge (corresponding to "d/s of Wapiti confluence" site in Figure Spatial Differences) to Watino were not observed in the recent data in 2011, and therefore require verification (Figure Spatial Differences Smoky River).

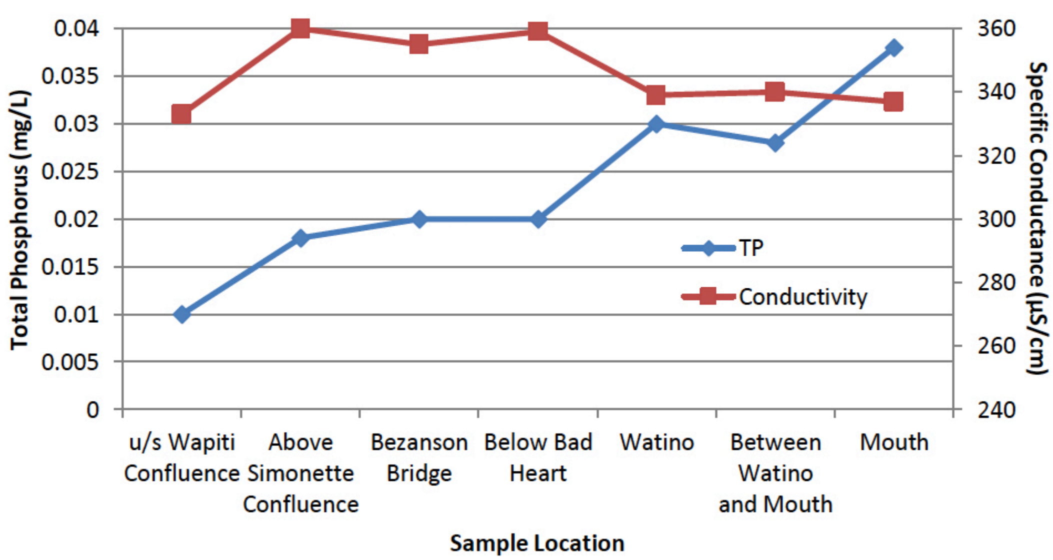

FIGURE 10. TP AND CONDUCTIVITY TRENDS IN THE SMOKY RIVER FROM THE WAPITI RIVER CONFLUENCE TO THE MOUTH IN 1983

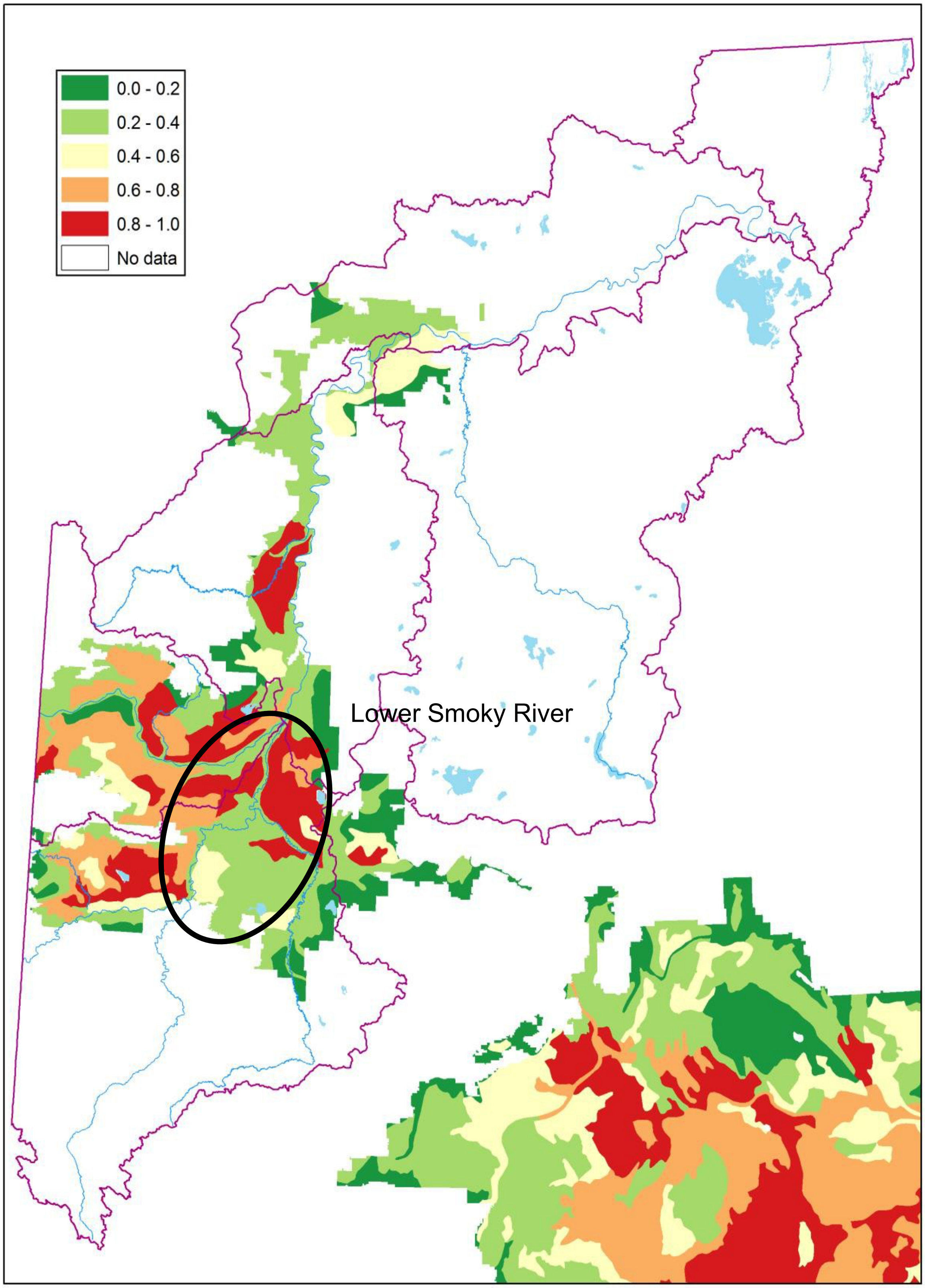

FIGURE 11. CULTIVATION INTENSITY IN THE PEACE BASIN AND LOCATION OF LOWER SMOKY RIVER
Source: Agriculture and Rural Development Alberta

Another effect of the Wapiti confluence is an increase in conductivity in the Smoky River. Conductivity decreased at Watino, likely due to the influence of the Little Smoky River, which - joins the Smoky River just upstream of Watino (Figure 2).

- *Small Rivers and Streams*

TP concentrations of two creeks in areas classified as moderately intense agriculture — Kleskun Drain (located east of Grand Prairie) and Grande Prairie Creek (located west of Grand Prairie) — exceeded the previous AWQG (Depoe and Westbrook 2003, in North/South Consulting 2007) between 1999 and 2002. In Grande Prairie Creek, TP concentrations exceeded former AWQG by three to 16 times at non-manure sites (Little et al. 2006). The Grande Prairie Creek and Kleskun Drain results were obtained part of a larger, Alberta-wide study into water quality of agricultural streams. One main finding of this study was that dissolved and total nutrient levels (phosphorus and nitrogen compounds) increased with agricultural intensity.

While these streams were located in high runoff watersheds, the concentrations of TSS were low compared with streams with similar runoff in other watersheds (AEH 2012) suggesting that erosion may be less problematic in Grand Prairie Creek.

Almost 90% of TP samples collected from the Beaverlodge River (Redwillow Watershed) between 1977 and 2007 were non-compliant with the previous AWQG of 0.05 mg/L (AECOM 2009). TP concentrations were high (0.1 to 0.5 mg/L) and highly variable along the length of the Beaverlodge River and among seasons (Figure 12).

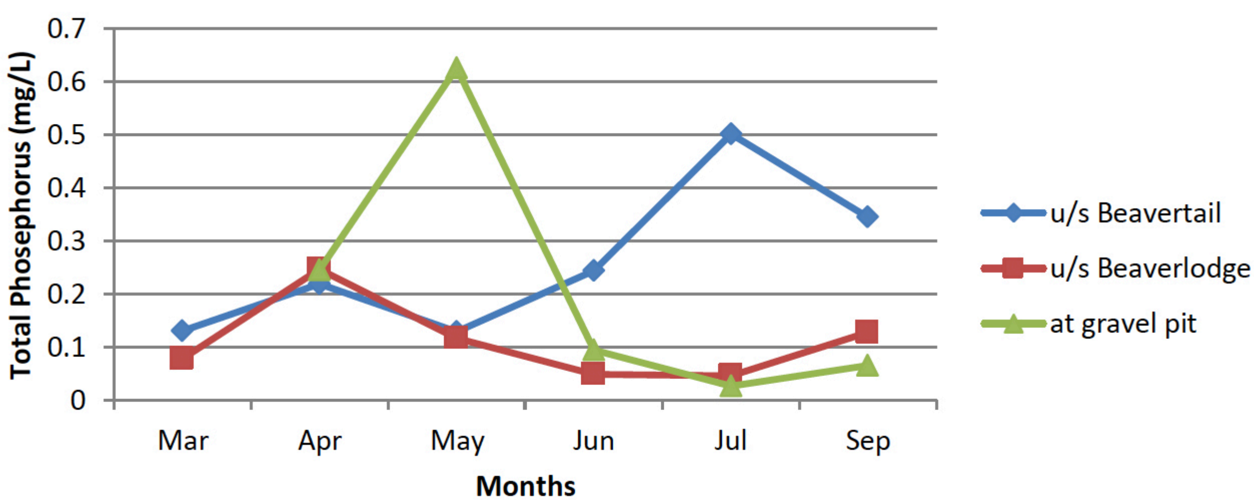

FIGURE 12. SEASONAL TP VARIATION AT THREE SITES ON THE BEAVERLODGE RIVER IN 2006

Given that risk to surface water quality from agriculture was rated as high up to the headwaters (Figure 11), it is likely that high nutrient concentrations in the Beaverlodge River were due to both intense land use with agricultural non-point sources along the upper and middle reaches of the river and naturally nutrient-rich soils that characterize this region. Data collected in 1994 and 1995 showed that total phosphorus concentrations decreased further downstream (Figure 13), which may reflect a strong influence of groundwater during low flow. Gravel extraction near the mouth of the Beaverlodge River indicates that highly porous surface deposits are concentrated in this area, promoting the discharge of groundwater to the river. Median and maximum TP concentrations measured in the 2000s, on the other hand, were higher near the mouth, indicating that sediment-derived TP observed during focused spring sampling in this study (AESA ref) increased between Beaverlodge and the river mouth.

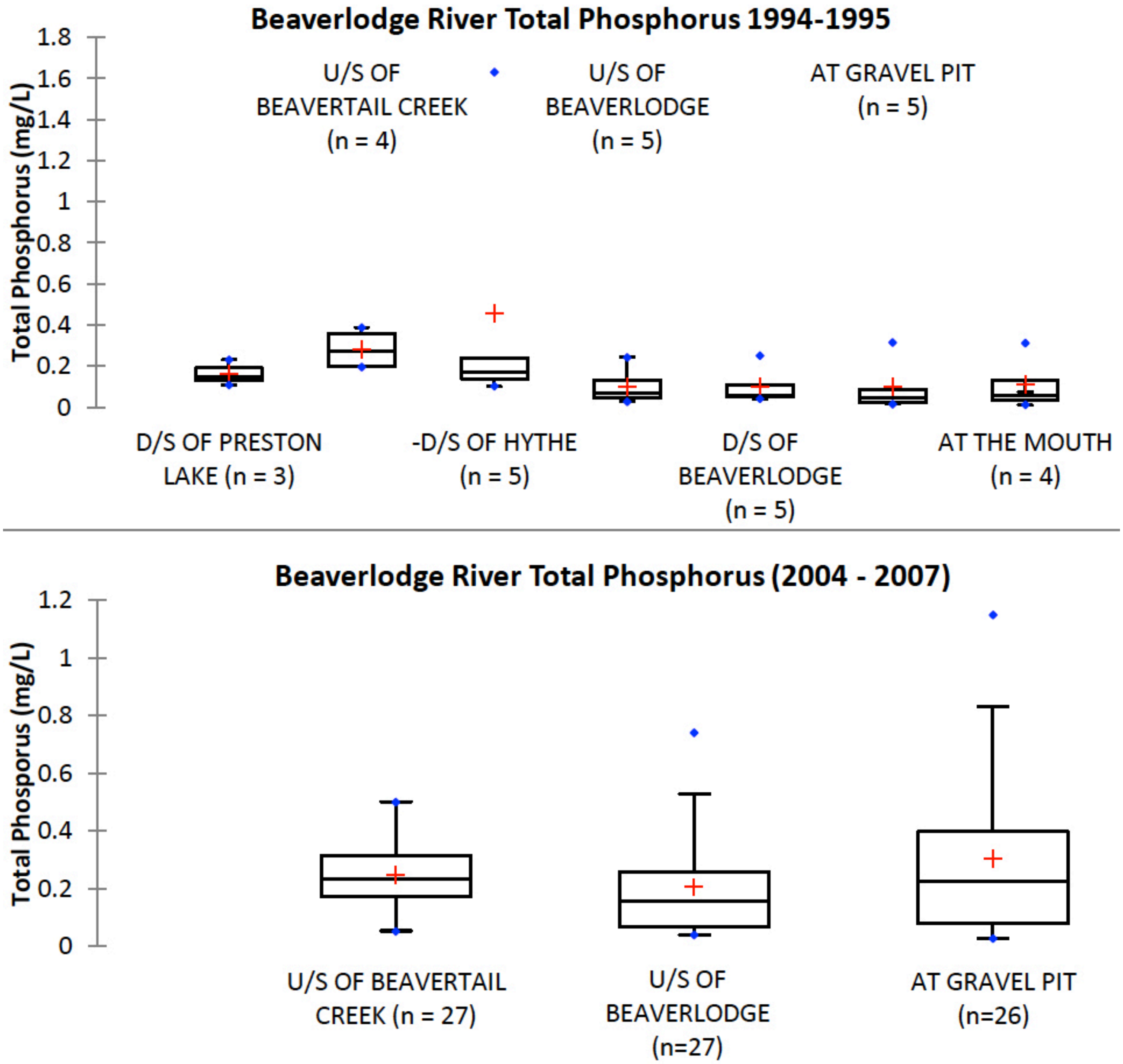

FIGURE 13. SPATIAL DIFFERENCES IN WATER QUALITY DATA FOR BEAVERLODGE RIVER 1994 – 1995.

Data Source: AESRD

High nutrient levels in the middle reaches, resulting in high algal productivity and elevated pH, in combination with an ammonia-enriched wastewater treatment plant discharge Town of Beaverlodge, were the likely cause of a fish kill in the Beaverlodge River in 2006. This demonstrates that cumulative effects of different human activities can be severe.

Although the relationship between agricultural intensity and stream water quality was well established by the AESA studies (Lorenz et al. 2008), water quality data for small, unimpacted streams in this ecoregion are scarce, representing a challenge to evaluate the exact degree of impairment of the studied agricultural streams compared to natural conditions. Water quality and health of aquatic biota comparisons of unimpacted with impacted streams within the same region, as demonstrated by Norris (2013), would be useful to better understand the range of natural variability and the impact of different land uses on stream ecosystems.

The Kakwa, Simonette and Little Smoky Rivers, which are larger than the streams discussed above and have mostly forested watersheds with some low-intensity agriculture (Little Smoky), had low TP (median TP range of 0.002 to 0.016 mg/L) (Table Water quality for other rivers in Smoky-Wapiti). Although the sample size is small and therefore does not give a complete representation of nutrient status of these rivers, the values were similar to those observed in the Smoky River upstream of the Wapiti River confluence and by an order of magnitude lower than minimum TP observed in the Beaverlodge River, indicating lower nutrient levels in these rivers. During the years 2011 and 2012, Simonette River was sampled near the mouth by Aquatera Utilities Ltd., confirming low TP with median low flow TP of 0.010 mg/L in 2011 and 0.014 mg/L in 2012 (Hutchinson Environmental Sciences Ltd. 2012 and 2013).

TABLE 4. AESRD WATER QUALITY DATA FOR OTHER RIVERS IN THE SMOKY-WAPITI SUB-BASIN.

Site Description	Data Range	n	TP (mg/L) median			n	TP (mg/L) median			n	E.coli (No./100 mL)		
			Med	Min	Max		Med	Min.	Max		Med	Min	Max
Kakwa River at Hwy 40	Jun 2010 - Feb 2011	3	0.004	0.003	0.008	3	0.008	0.001	0.003	1	10	10	10
Little Smoky River Near Mouth	Mar 1991 - Oct 1998	3	0.009	0.008	0.016	3	0.008	0.003	0.009	2	15.5	11	20
Simonette R. Near Mouth	Feb 1991 - Sep 1998	3	0.009	0.019	0.002	3	0.002	0.005	0.001	2	5.5	6	5

Coliforms & Pathogens

- *Major Rivers*

While fecal coliform levels did not exceed the AB guideline for recreation and aesthetics (200 CFU/mL) along Wapiti/Smoky Rivers, the Aquatera plant effluent was found to significantly increase levels in 2011 from less than 20 to over 80 CFU/100 ml (HESL 2012). Coliform counts remained elevated above background throughout the lower Wapiti River (Figure Spatial Differences in Fecal Coliform Counts in the Lower Wapiti River).

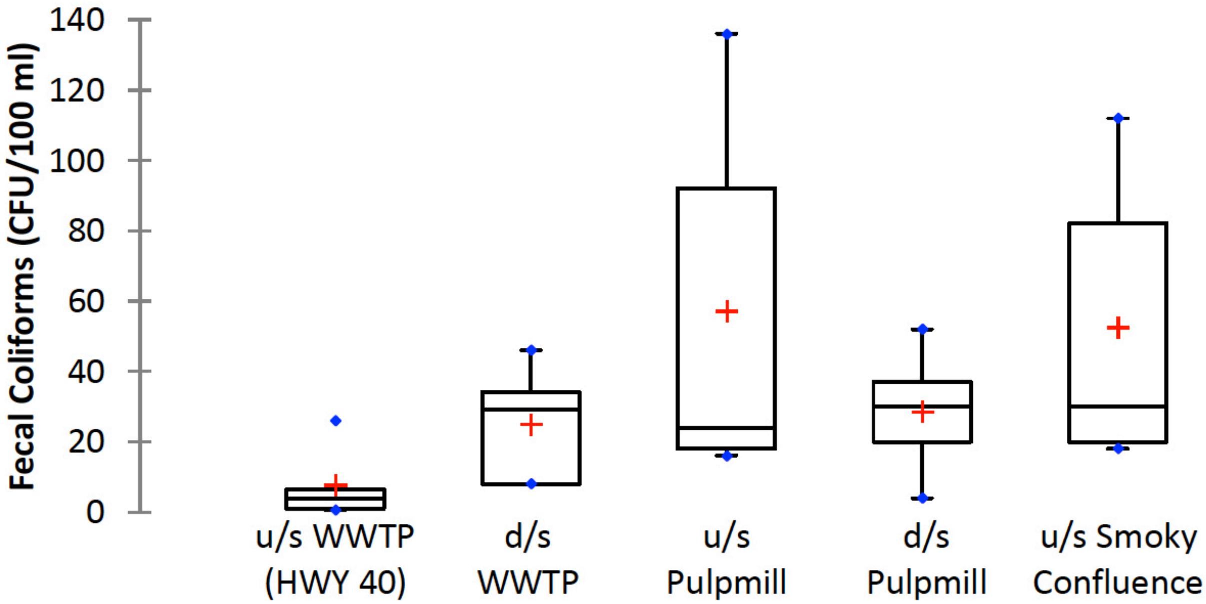

FIGURE 13. SPATIAL DIFFERENCES IN FECAL COLIFORM COUNTS DURING LOW FLOW IN THE LOWER WAPITI RIVER (2011)

Data Source: Hutchinson Environmental Sciences Ltd. 2012

Mean fecal coliform counts (1999-March 2012) from Wapiti River above the confluence with the Smoky River was below the Alberta guideline for recreation and aesthetics. Over the 13-year span, only eight occurrences exceeded this guideline, with the winters of 2003 and 2009 being particularly problematic periods (LTRN data, not shown).

- *Small Rivers and Creeks*

Between 1999 and 2006 both Grande Prairie Creek and Kleskun Drain had mean and median fecal coliform and *E. coli* concentrations <100 CFU/100 mL (AESA Volume 3). Grande Prairie Creek fecal coliform concentrations, however, varied substantially, with some individual measurements exceeding the guidelines. Between 1999 and 2006, mean annual compliance with recreational and irrigation guidelines was 59% for Grande Prairie Creek and 81% for Kleskun Drain (AESA Volume 3). Peaks in fecal bacteria most often occurred in summer months in association with peaks in discharge or suspended sediment (Lorenz et al. 2008). Fecal bacteria counts did not show an increasing pattern with increasing agricultural intensity.

The median *E. coli* concentration along Beaverlodge River ranged between 7.5 and 50 No./100 ml. The maximum concentrations reached 570 No./100 mL upstream of Beavertail Creek. In rural watersheds such as those discussed above, the main source of coliform bacteria are likely livestock operations and manure spreading (Lorenz et al. 2008).

Other Water Quality Concerns

Elevated selenium concentrations were found in aquatic environments downstream of coal mines on the Alberta Eastern Slopes and negative effects on fish embryos and fry and aquatic invertebrate communities were detected (Klaverkamp et al. 2005). Streams in the vicinity of coal mining activities in the headwaters of the Smoky River showed local increases in selenium and resulting deformities were detected in rainbow trout and brook trout larvae (Holm et al 2003). These effects diminished further downstream (North/South Consultants 2009) and are not detectable in the major rivers (BC Ministry of Environment and AENV 2009). Other environmental concerns associated with coal mines are acid mine drainage and cadmium.

The wastewater discharges in the lower Wapiti River have other effects beside nutrient enrichment. The pulpmill effluent is also rich in organic matter, as indicated by high total organic carbon content. Both discharges are higher in conductivity than the river, resulting in increased river conductivity, especially during low flow months (Figure 14). The effects of this conductivity increase are detectable in the Smoky River as well (HESL 2012, 2013), possibly until the mouth of the river (Figure 10).

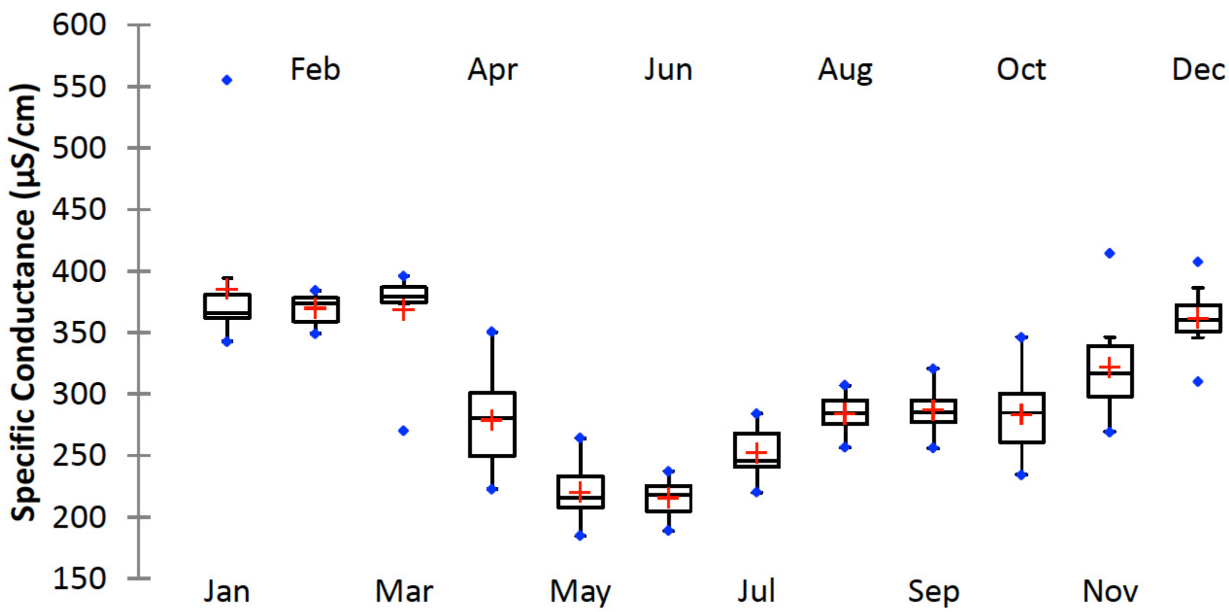

FIGURE 14. SEASONAL PATTERNS IN WAPITI RIVER CONDUCTIVITY AT HWY 40 AND ABOVE CONFLUENCE WITH THE SMOKY RIVER)

Lake Water Quality

Phosphorus

A large variety of phosphorus concentrations can be found in lakes of the Smoky-Wapiti sub-basin, ranging from mesotrophic (TP = 0.01 to 0.035 mg/L) to hypertrophic status (TP > 0.1 mg/L).

Saskatoon and Sturgeon Lakes are considered hypertrophic with mean TP concentrations of 0.80 mg/L and 0.104 mg/L, respectively. Saskatoon Lake concentrations are at the higher end of Alberta Lakes TP; as a comparison, the Grande Prairie Wastewater Treatment effluent had an annual average TP concentration of 0.8 mg/L in 2011 (Aquatera Utilities Inc. 2012).

Total phosphorus increased significantly in both lakes over the past 30 years (Casey 2011, Figure 15, Figure 16). Saskatoon Lake also had the lowest transparency out of 39 lakes studied in the Province of Alberta, with low transparency correlated with high chlorophyll a and phosphorus concentrations (Casey 2011). Saskatoon Lake is located in an agricultural watershed. In Sturgeon Lake, nutrient sources are agricultural runoff, wastewater effluent inputs and internal load from the sediments (Mitchell and Prepas 1990).

Iosegun and Smoke Lakes that have mostly forested watersheds are eutrophic and Musereau Lake is mesotrophic.

High algal productivity resulting from elevated nutrient levels has caused anoxia and fish kills in Saskatoon, Sturgeon and Smoke lakes.

Seasonal trends were seen with the open water season having higher TP and chlorophyll *a* concentrations and lower transparency. The highest TP concentrations usually occurred in late summer, however some lakes had high spring concentrations possibly related to internal phosphorus loading under ice (Casey 2011).

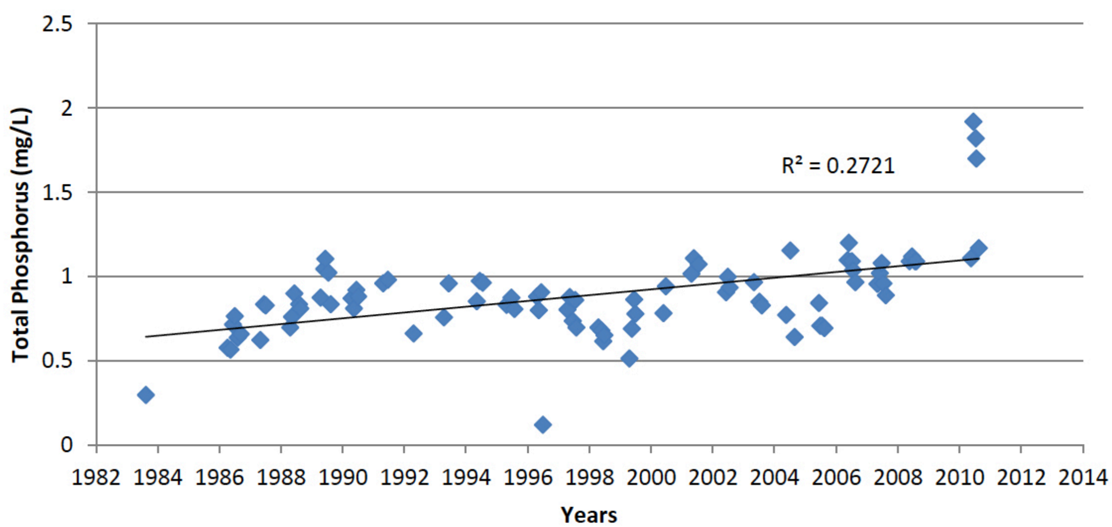

FIGURE 15. TP LONG-TERM TREND IN SASKATOON LAKE
DATA SOURCE: AESRD.

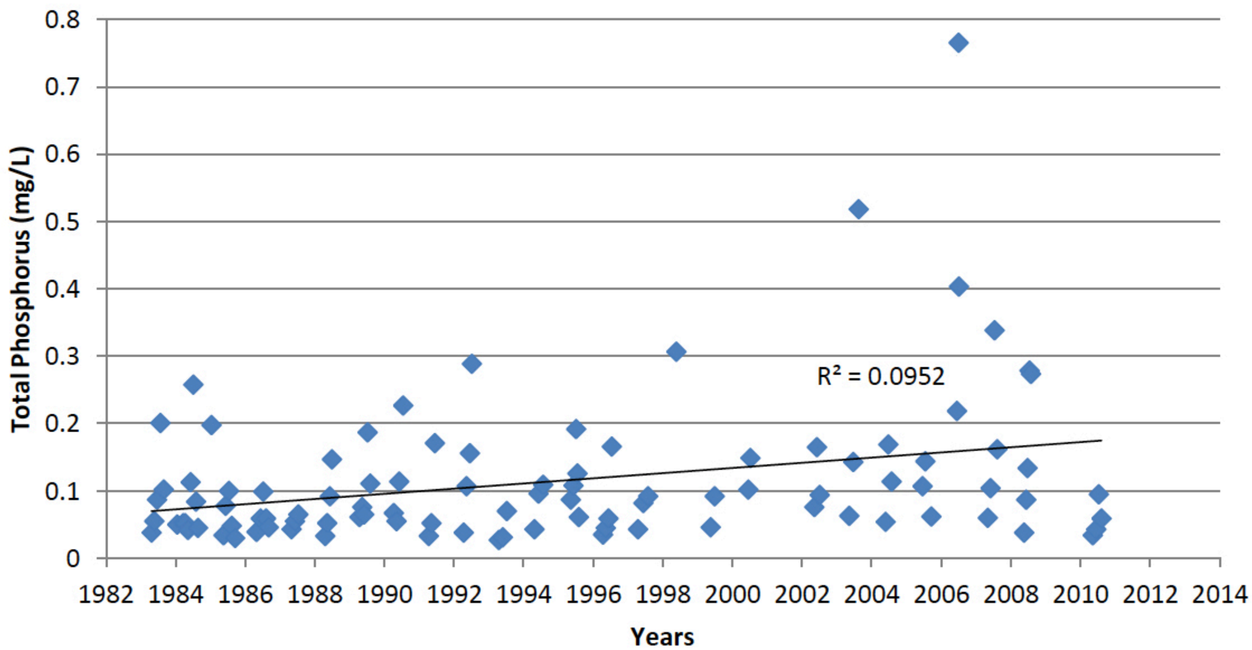

FIGURE 16. TP LONG-TERM TRENDS IN STURGEON LAKE
Data Source: AESRD.

Salinity

TDS concentrations in lakes of the Smoky Wapiti sub-basin are highly variable, ranging from 65.4 to 978.7 mg/L with a median concentration of 127.3 mg/L (Table 4). Most lakes in the sub-basin are freshwater lakes, but there are some naturally occurring slightly saline lakes due to the presence of saline soils in areas of the watershed. Another reason for high TDS concentrations is a negative water balance, which is common in prairie lakes, where evaporation exceeds precipitation. We did not have water balance data for most of the watershed, except for Beaverlodge (Figure 17), where precipitation always exceeded actual evaporation, but the difference between both declined, indicating a trend towards less water availability. It should be noted that these figures were based on climate data and do not take into account land use practices, which can significantly affect water balance in a watershed. Detailed investigations of local soils and water balance studies, possibly supported by stable isotope analysis to assess water balance, would be required to confirm the role of water balance in comparison with other sources of salinity in these lakes.

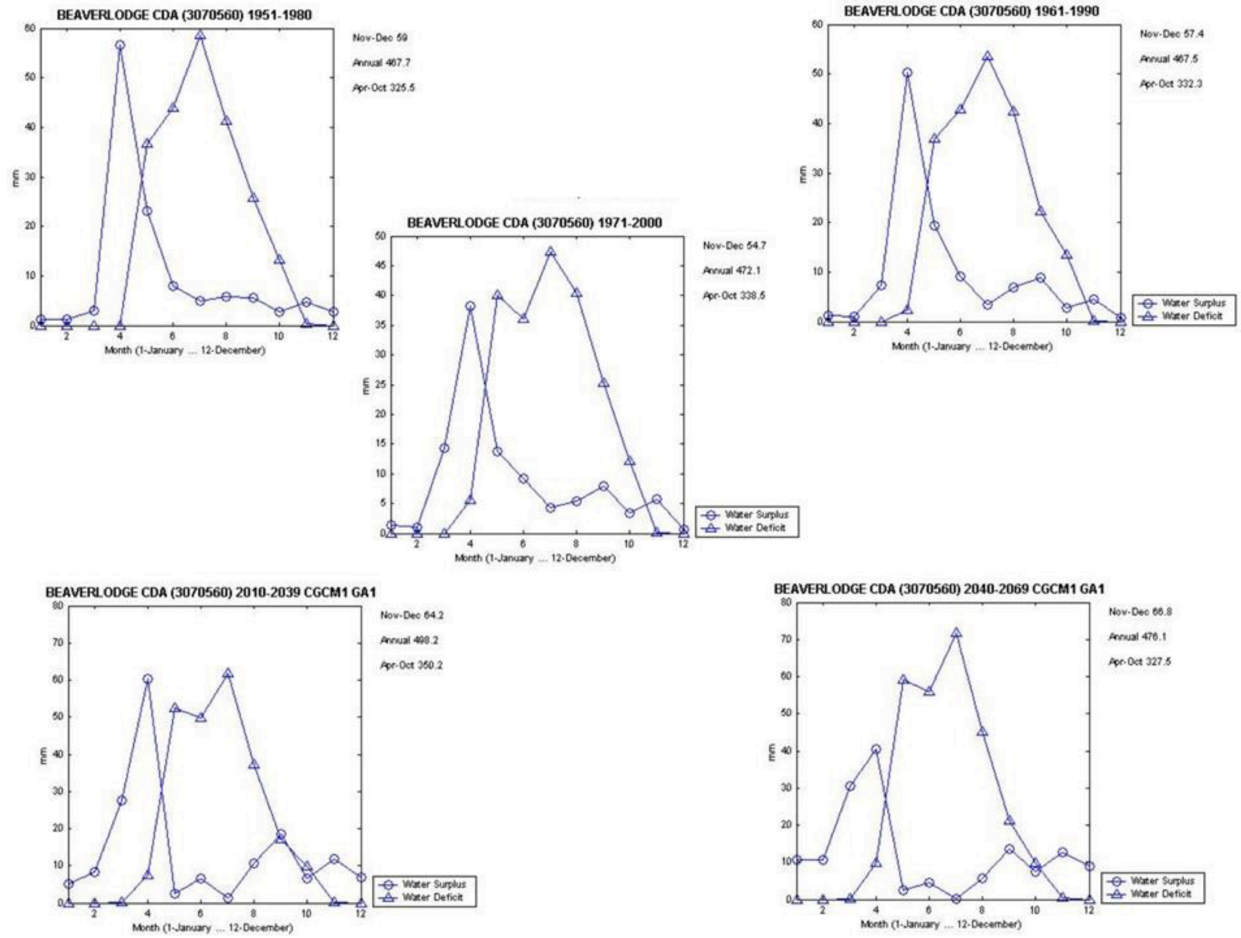

FIGURE 17. PAST OBSERVED AND FUTURE PREDICTED WATER SURPLUS AND DEFICIT AT BEAVERLODGE

Data Source: Canadian Institute of Climate Studies.
(http://www.cics.uvic.ca/scenarios/index.cgi?Bio-Climate_Profiles)

TDS concentrations have increased significantly in Sturgeon Lake over the past 30 years (Casey 2011, Figure 18) from an average of approximately 80 mg/L in the early 1980s to 127 mg/L in 2010. One reason for this increase could be the precipitation decrease in the region over the same time period, as demonstrated by the Simonette climate data, recorded at 77 km Distance to Sturgeon Lake (Figure 19). This trend has not been observed to this degree in any other lake in the Peace Basin with long-term data, indicating that local effects may have played a role as well. For example, a wastewater treatment plant discharges to Sturgeon Lake, which may be an additional source of increased ion concentrations.

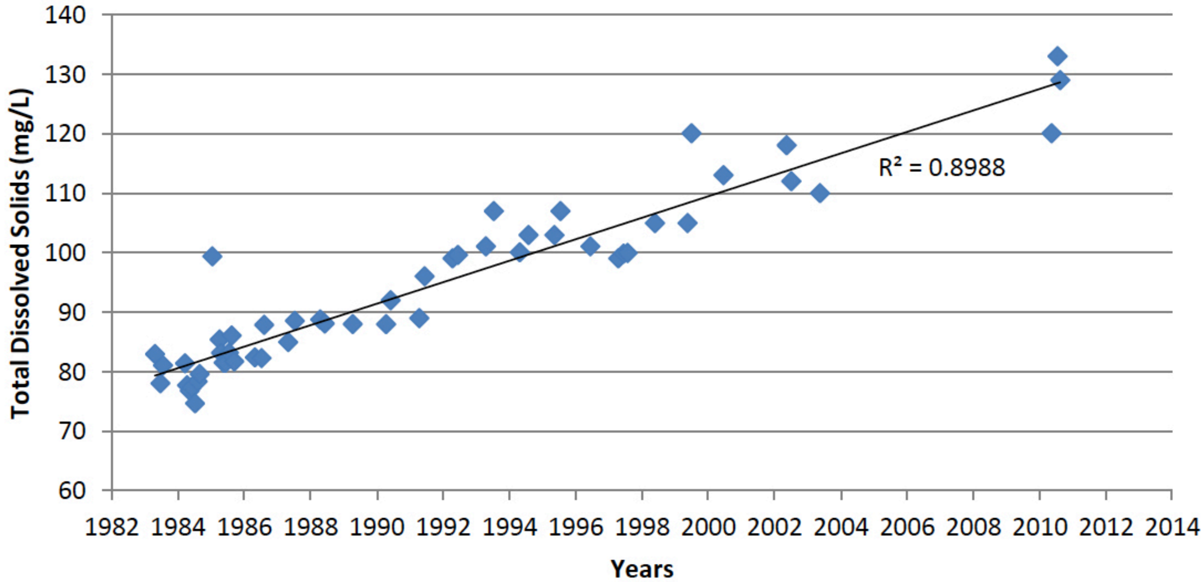

FIGURE 18. TDS LONG-TERM TRENDS IN STURGEON LAKE

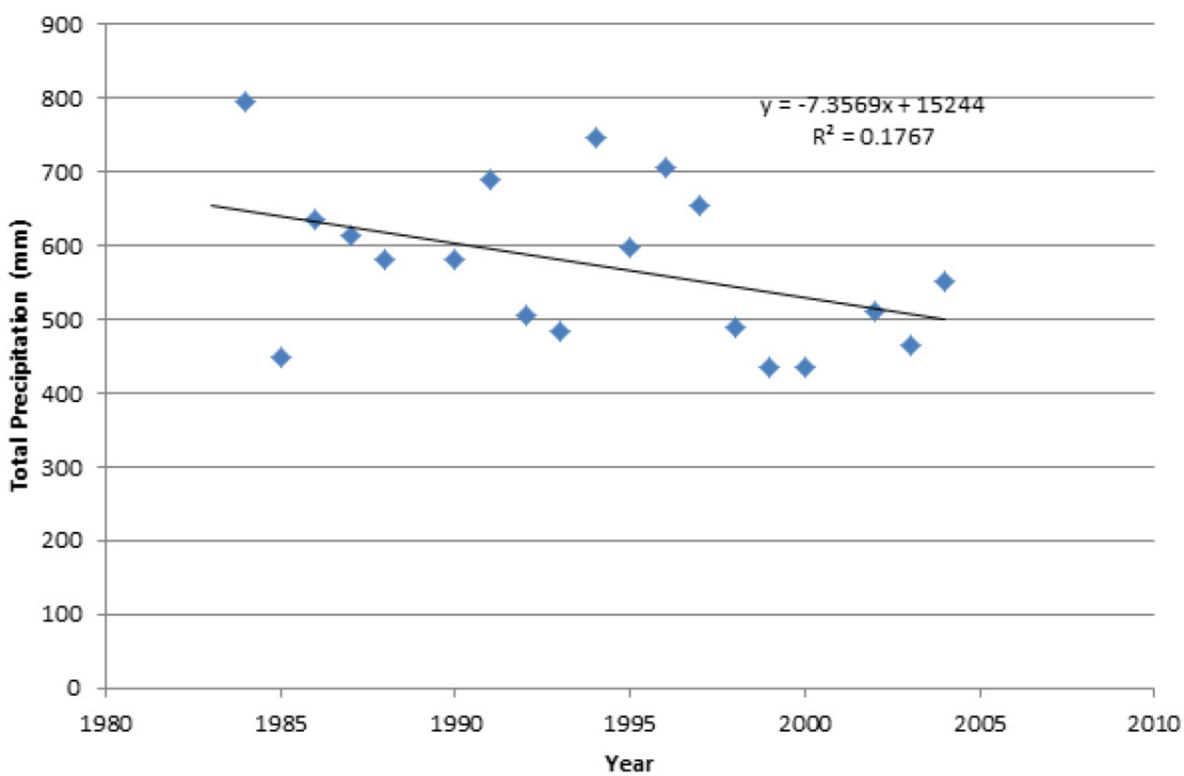

FIGURE 19. PRECIPITATION TREND IN SIMONETTE

Saskatoon Lake water is slightly saline with an average TDS concentration in 2010 of 978.7 mg/L (waters > 1000 mg/L TDS are considered brackish waters (Wetzel 2001)). Preliminary analysis of Saskatoon Lake data also suggests an increasing trend in TDS. This lake has shown large variations in TDS and the last three measurements in 2007-2008 showed significantly higher TDS than historically (Figure 20). It is possible that this lake is naturally subject to large TDS variations, as TDS varied on approximately decadal cycles. A longer record of salinity would be useful to better assess the causes of increased TDS in recent years for this lake, by the means of a paleolimnological investigation.

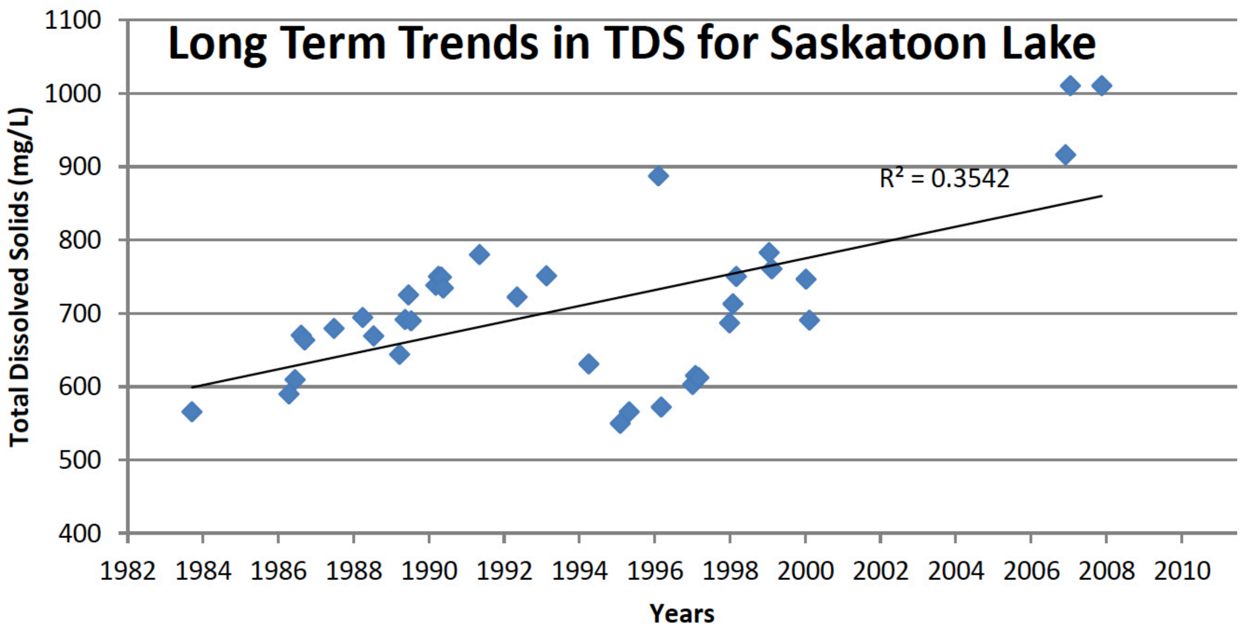

FIGURE LONG-TERM TREND IN TDS IN SASKATOON LAKE
Data Source: AESRD

TABLE 5. WATER QUALITY SUMMARY OF 23 LAKES WITHIN THE SMOKY WAPITI SUB-BASIN

Smoky Wapiti Sub-basin	Chlorophyll a (mg/m3)	Fecal Coliforms (No/100 mL)	*E. Coli* (No/100 mL)	TP (mg/L)	TDP (mg/L)	TDS (mg/L)
Median	21.1	5	5	0.065	0.029	127.3
Min	2.3	5	5	0.012	0.006	65.4
Max	269.4	5	5	1.54	0.933	978.7

Data Source: AESRD

Land Use And Land Cover

Wetland Area

Almost thirteen percent of the Smoky Wapiti sub-basin is covered with wetlands (Table 6), a third of which is represented by peatland-type wetlands (bogs and fens). While all wetlands act as carbon sinks, peat wetlands are able to sequester and store carbon for longer periods of time than marshes and swamps (Zoltai, Siltanen and Johnson, 2000).

TABLE 6. WETLAND COVER FOR THE SMOKY WAPITI SUB-BASIN

Smoky Wapiti	WS AREA	(WS-NP) AREA	Wetland Cover	Wetland Cover				
				Bog	Fen	Marsh	Swamp	Open Water
Area (km^2)	46,737	45,942	5,854	572	1475	198	2,953	657
Percentage of Land Cover		98.3%	12.7%	1.2%	3.2%	0.4%	6.4%	1.4%

Wetland Loss

Wetland loss is not only defined as the disappearance of wetlands, but also as the loss of function, even if some wetland features are still present. The wetland loss between 1985 and 2001 was estimated at 5% in the Canadian Aspen Parkland ecoregion and at 4% in the Canadian Boreal Transition ecoregion, the two ecoregions most similar to those found in the settled regions (White Zone) of the Smoky-Wapiti sub-basin (Watmough and Schmoll 2007). In addition, more wetland loss has likely occurred due to land clearing and cultivation since the time of European settlement prior to 1985.

For the Green Zone, no data on wetland loss are available, but some loss of wetland function due to linear disturbance is likely, as discussed below.

Wetland Health

Of the sub-basins where wetlands were surveyed by the ABMI, the Smoky Wapiti sub-watershed had the least number of wetlands inspected. Of these, the majority showed evidence of human disturbance (75%) (Table 7). In most cases this was a linear disturbance (e.g., cutline or pipelines), typically associated with the energy industry as these wetland sites are located in the southern, forested part of the sub-basin, where oil and gas and forestry are the main human land use activities.

TABLE 7. WETLAND DISTURBANCE IN ABMI-SURVEYED WETLANDS IN THE SMOKY WAPITI SUB-BASIN

	Number of wetlands assessed	Number of disturbed wetlands	Percent of wetlands with disturbance
Smoky-Wapiti	12	9	75%

Wetland Invasive Species

No invasive plant species were encountered in the twelve wetlands surveyed by ABMI in the Smoky-Wapiti sub-watershed.

Riparian Health

Individual Riparian Health Assessments

In the Smoky-Wapiti sub-basin, a total of 6.23 km lake and wetland riparian areas and a total of 17.31 km of stream and small river riparian areas was surveyed by Cows and Fish (Sikina and Ambrose 2013). About a quarter of these sites were rated as "unhealthy," almost half were "healthy" and 30% were "healthy, with problems." Given that the Cows and Fish surveys focus on the settled White Zone, it is promising that almost half of the sites were "healthy" within this heavily modified watershed. Given the large size of the sub-basin, however, these results cannot be extrapolated to the entire sub-basin.

TABLE 8. SMOKY-WAPITI SUB-BASIN – RIPARIAN HEALTH OVERVIEW

Health Category	Percentage of Sites	Number of sites
Healthy	47.1	16
Healthy, but with problems	29.4	10
Unhealthy	23.5	8

Land Cover in Riparian Areas

Natural land cover represents 73.1% of the riparian areas in the Smoky Wapiti sub- basin. This is the second-lowest percent of natural land cover in the Mighty Peace watershed. Disturbed land cover is predominantly agriculture (Table 9). While cropland, hay, and pastures are included in this general agriculture category in the ABMI dataset, they have been subdivided (as "Cropland" and "Hay/Pasture") to better explain their roles. Hay/Pasture lands retain grass ground cover (and thus topsoil) through the colder, unproductive months. Croplands, however, with their fallow soils exposed during winter and spring, experience greater amounts of erosion and thus exacerbate negative impacts on riparian habitat and surface waters. Cropland represents the majority of agricultural land cover in the Smoky-Wapiti sub-basin, representing 19.1% of riparian land cover (Table 10), and is therefore likely to adversely affect riparian health.

TABLE 9. RIPARIAN LAND COVER FOR SMOKY WAPITI SUB-BASIN

Smoky Wapiti	Developed	Agriculture	Natural
Area (km2)	280	1,793	5,640
Percentage	3.6%	23.2%	73.1%

TABLE 10. DISTRIBUTION OF CROPLAND AND HAY/PASTURE FOR AGRICULTURE LAND COVER OF SMOKY WAPITI SUB-BASIN

	Total Agriculture (km2)	Cropland	Hay/Pasture
Smoky Wapiti	1,924	19.1%	5.9%

Invasive species

Ten invasive plant species were encountered in the Cows and Fish riparian assessments, covering 1.5% of the surveyed area. The maximum coverage of invasive species (Canada Thistle and Caraganna) encountered at a specific site was 20% (Sikina and Ambrose 2013).

Biological Community Fish Populations

A total of 36 different fish species have been captured and documented in the Smoky Wapiti sub-basin. This is the highest number of species of all the sub-basins within the watershed, which may in part be due to the degree of development and therefore high catch effort, but also the large variety of habitats. Of the total species captured, 5 were non-native (including stocked and expansion from British Columbia), scoring one of the highest numbers in the watershed, and 2 out of these were exotic (Brown and Brook Trout). Three of the species found in the Smoky-Wapiti sub-basin were considered to be “species at risk” (Table 11).

TABLE 11. BREAKDOWN OF FISH SPECIES FOUND WITHIN THE SMOKY WAPITI SUB-BASIN.

Total Number of Fish Species captured	36
Species of management concern or species at risk	3
Non-native, naturalized, stocked or dispersal from BC	5

Data Source: Johnson &Wilcox (2013)

Arctic grayling were found in a wide range of densities, ranging from extirpated to high, with a similar varying degree of uncertainty in these numbers (Table Fish Density within the Smoky Wapiti Sub-Basin, Figure Arctic Grayling Density). Grayling is a cool-water species primarily found in boreal and foothills streams in the Athabasca, Peace and Hay River drainages. Presently, Arctic grayling are thought to be extirpated in several sub- watersheds of the Wapiti River watershed and declining in most although not all sub-watersheds (AECOM 2009). Subpopulations are estimated to have declined predominantly in the 1950s through the 1970s, with 50% of Alberta's subpopulations declining over 90% in abundance. These declines probably represent a range contraction of approximately 40% of the historical range (Walker 2005). A range of factors, acting in a cumulative fashion, have most likely led to the decline of many grayling populations, including high angling catchability coupled with a popular sport fishery, habitat fragmentation caused by improper road culverts, and increases in water temperature as a result of changing climate and land-use practices (Walker 2005).

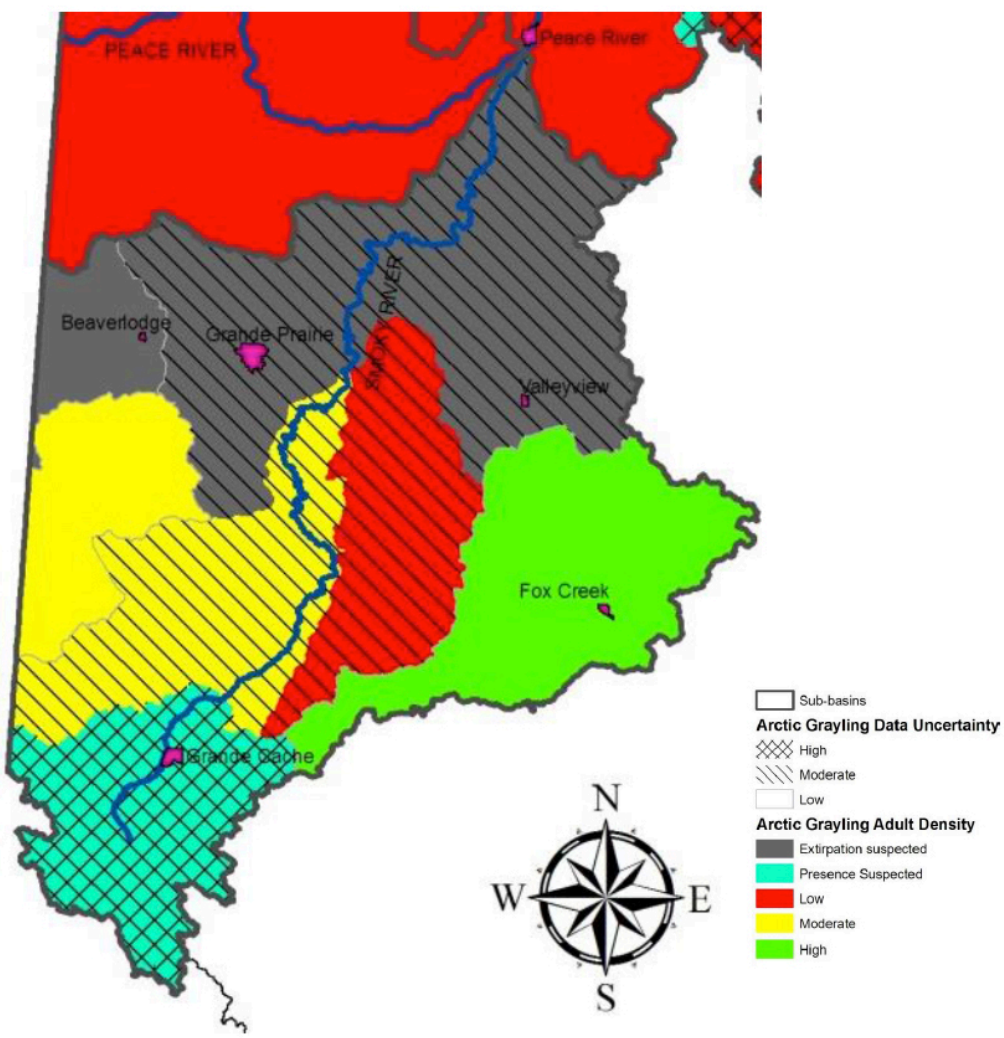

FIGURE 21. ARCTIC GRAYLING DENSITY IN THE SMOKY-WAPITI RIVER SUB-BASIN

A potential management option to restore lost grayling populations is to ensure that the habitat is suitable and then reintroduce grayling. Norris (2012) investigated the causes of their decline and disappearance by comparing water chemistry and land use data in watersheds where Arctic grayling is present with watersheds where it is extirpated and proposed a threshold based on phosphorus export increase. Fisheries regulations also appear effective, as the Little Smoky watershed, where a catch-and-release restriction for this area is in place, contained the highest Arctic grayling densities.

The Index of Biotic Integrity based on road density is a good proxy for cumulative stresses on fish habitat. The lowest integrity ratings in the Peace Basin were found in the lower Wapiti and Beaverlodge watersheds, where Arctic grayling is extirpated (Johnson and Wilcox 2009, Figure 22).

River Walleye ranged from low to high density with low to moderate uncertainty. Walleye was mostly found in the larger rivers, such as Smoky, Wapiti, Little Smoky and Simonette rivers. Lower densities were observed in the upper reaches and higher densities in the lower reaches, according to the habitat preference of this species for larger rivers.

A comprehensive study on fish communities and the factors that impact them was presented in a report on the Redwillow watershed, which includes the Beaverlodge watershed (AECOM 2009). The authors linked watershed disturbances to declining fish populations of Arctic grayling, northern pike, walleye, bull trout and mountain whitefish. They identified reduced stream flow, reduced water quality, obstruction of fish migration by weirs and direct damage to fish habitat and the riparian zone by agricultural activities as the main reasons for declining populations. This is a well-documented cause-and-effect study whose results are likely transferrable to other sub-basins where similar stressors are present (high road density, agriculture, water takings).

In summary, the Smoky-Wapiti River sub-basin has some of the greatest available data with regards to fish densities, but some of the lowest fish densities compared with other sub-basins due to the largest cumulative impacts of land use and fishery pressure, in particular in the White Zone.

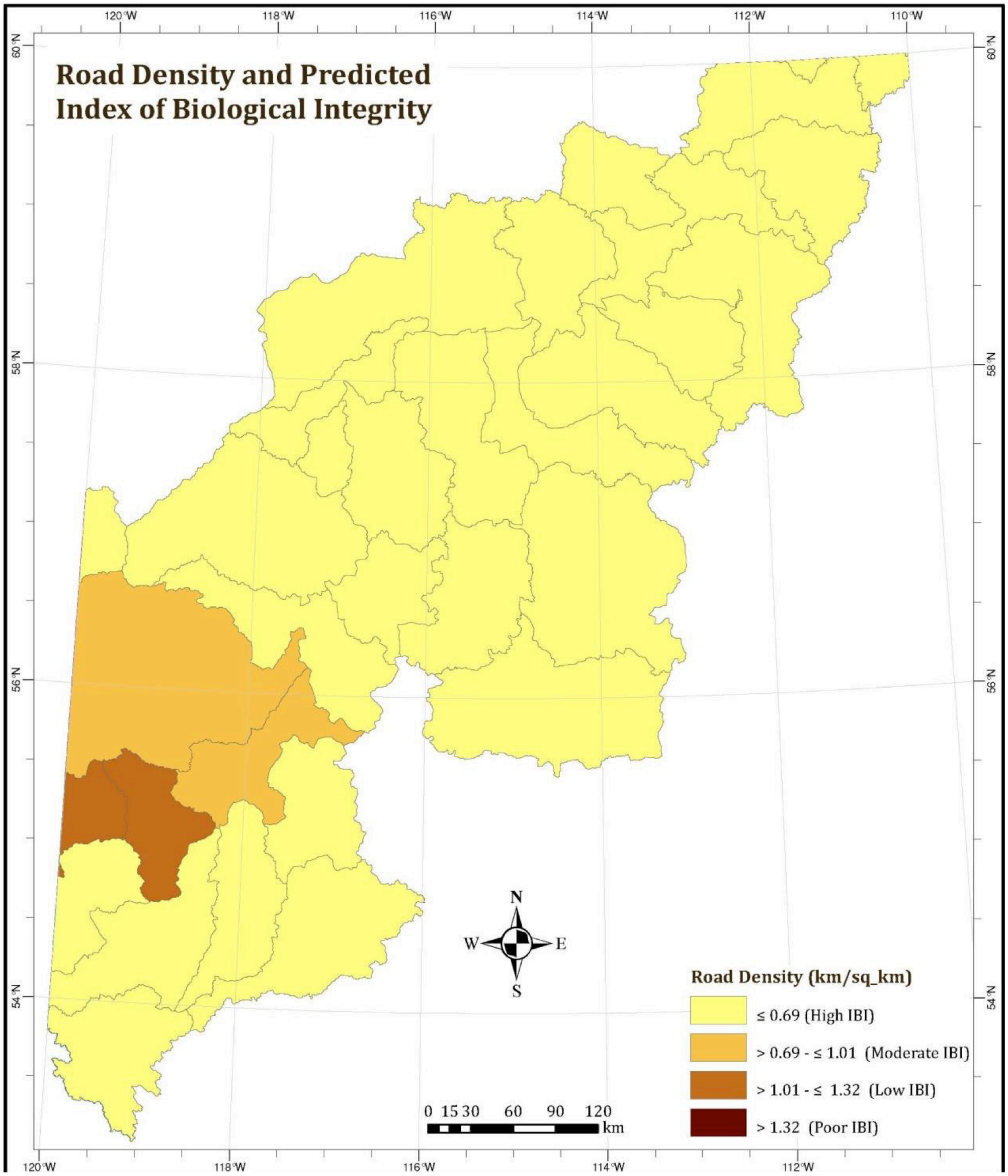

FIGURE 22. ROAD DENSITY IN THE PEACE BASIN AS INDICATOR FOR THE BIOTIC INDEX OF INTEGRITY (FROM CHARETTE PELL POSCENTE AND HUTCHINSON ENVIRONMENTAL SCIENCES LTD. 2012)

TABLE 12. FISH DENSITY WITHIN THE SMOKY WAPITI SUB-BASIN.

Fish Species	Habitat Type	Habitat Preference	Density	Data Uncertainty
Goldeye	Lotic (river)	Sizeable rivers, clay-induced turbidity of waters, rapid current (Government of Ohio).	Low	Low
Walleye	Lotic (river)	Sizeable rivers and or lakes, clear to slightly turbid water, bottoms are solid and comprised of various composition (e.g., gravel shoals, bedrock, reefs)	Low-High	Low- Moderate
Bull trout	Lotic (river)	Rivers of good water quality, cool with rapid current, substrate comprised of medium to large debris, favour pools and riffles (SCCP 2010)	Low-Moderate	High-Moderate
Arctic grayling	Lotic (river)	Cool rivers with ample pool habitats (U.S. Fish and Wildlife Services 1985.	Extirpated -high	Low-High
Walleye	Lentic (lake)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g., gravel shoals, bedrock, reefs)	No data-Moderate	Low

Data Source: Johnson &Wilcox (2013)

Invasive Aquatic Species

Zebra and Quagga mussels have not been detected in any Alberta lakes so far (Ron Zurawell, AESRD, personal comm.)

The wetland surveys conducted in the Peace Basin by the ABMI have not detected any invasive plant species. The invasive aquatic macrophyte Eurasian Milfoil (*Myriophyllum spicatum*) has only been reported at one location in the Peace Basin so far, and that was in the Wapiti River watershed (ABMI 2014).

The spiny water flea has not been reported in Peace Basin lakes.

Invasive algae species, such as *Didymosphenia geminata*, a nuisance-growth-forming diatom species, have not been reported in the basin. It has been reported in Saskatchewan, B.C. and the southern Albertan foothills, so it is possible that it is already present but went unnoticed.

UPPER PEACE SUB-BASIN

Sub-Basin Description

The Upper Peace Basin is small in size, but features natural regions ranging from foothills and boreal highlands to mixed-wood and parkland ecoregions. The Peace River mainstem at this point is already a sizeable river and most water quality and quantity characteristics are determined by upstream conditions. There are a number of tributaries in this sub-basin that drain forested and agricultural lands, the latter of which possibly have the largest impact on smaller rivers and streams. No major point sources are located in this sub-basin. Surface water is used for drinking water and livestock-watering in this region either from dugouts or streams. Lakes are used for recreation.

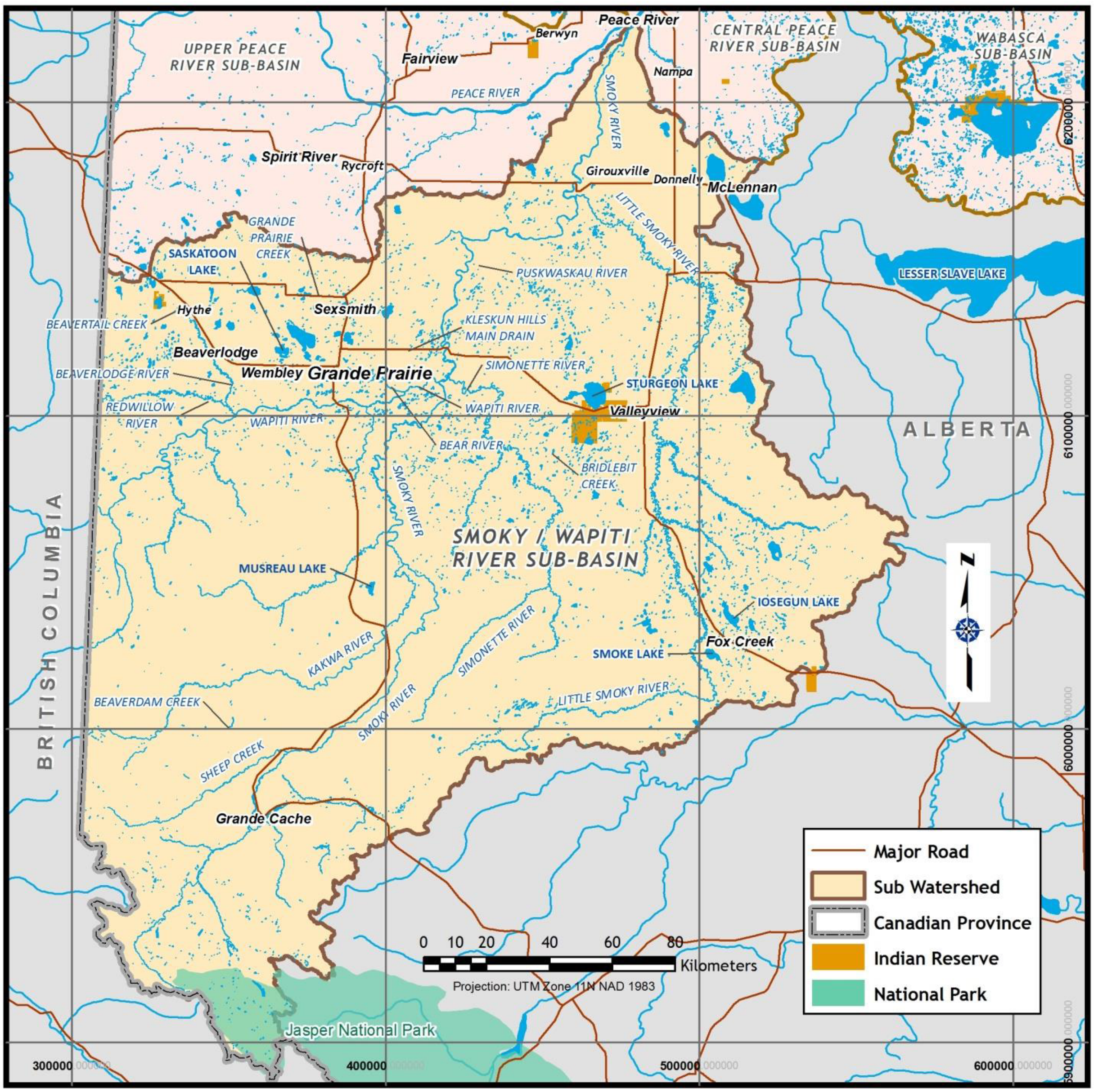

FIGURE 23. MAP OF UPPER PEACE SUB-BASIN.

Surface Water Quality

River and Stream Water Quality

- *Alberta River Water Quality Index*

From 2006 to 2008 the overall river water quality in the Peace River upstream of the Smoky River confluence was rated as "excellent." However, from 2008 to 2010 this rating dropped to "good" (Figure 24). This is due to the rating change in the metal and nutrients sub-indices from "excellent" to "good" and from "good" to "fair," respectively. Both bacteria and pesticide sub-indices are consistently rated as "excellent". The lower ratings for nutrients and metals are most likely due to elevated concentrations of suspended sediment during high flows from the drainage of agricultural and forested land with highly erodible soils in BC (North/South Consultants 2007). Data from more years are required to evaluate the significance of differences in water quality indices among these four years of data.

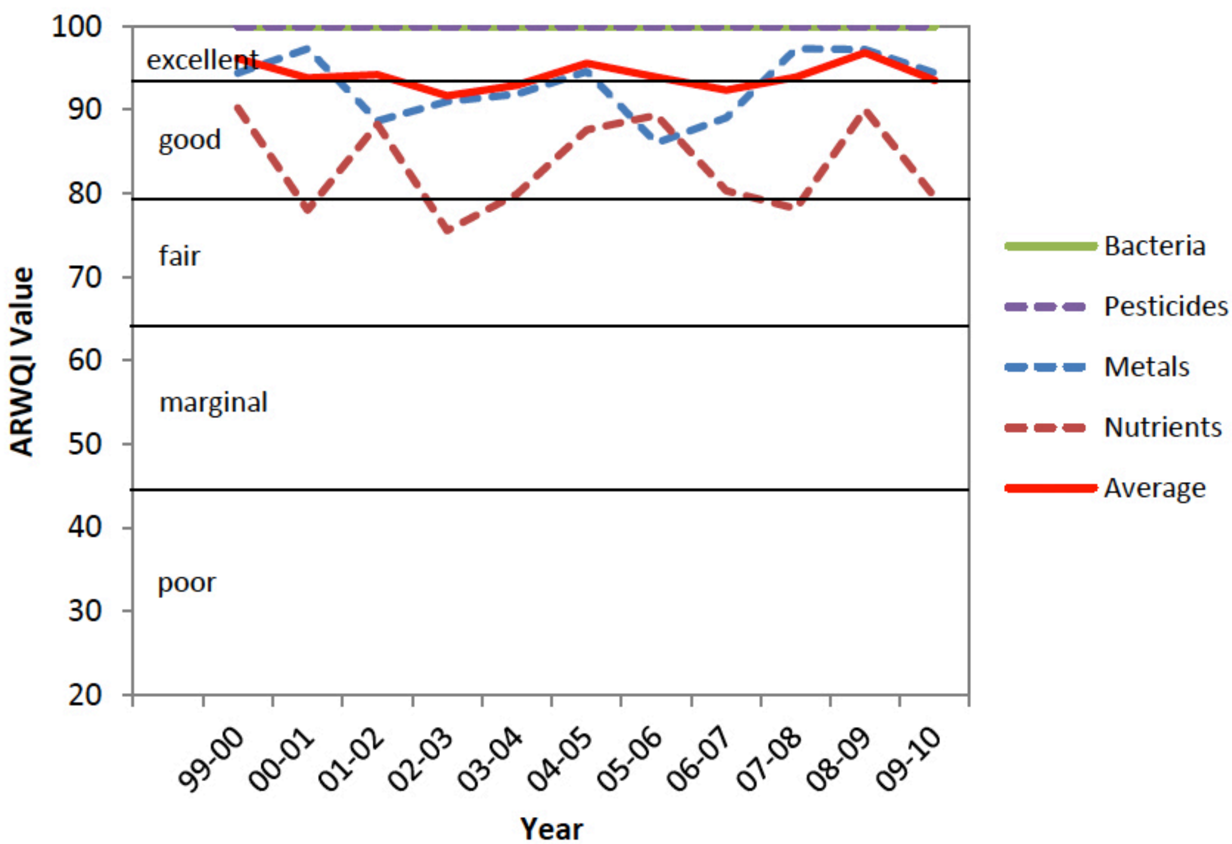

FIGURE 24. ARWQI FOR PEACE RIVER UPSTREAM OF SMOKY RIVER NEAR SHAFTESBURY CROSSING.

From 1999 to 2002 river water quality was rated as "fair" in the agricultural area of Hines Creek compared with Grande Prairie Creek and Kleskun Drain in the Smoky-Wapiti basin, which were rated as "poor," based on the Alberta Agriculture Water Quality Index (AAWQI). The better-rated water quality of Hines Creek is most likely due to its larger watershed area and lower intensity-agricultural practices (North/South Consultants 2007).

Phosphorus

- *Major Rivers (Peace Mainstem)*

Upstream of the Smoky River confluence the Peace River was classified as oligotrophic based on TP, but mesotrophic based on periphyton (North/South Consultants 2007). More recent LTRN data collected between April 2006 and March 2012 had an average TP concentration of 0.066 mg/L, biased by 13 incidences of elevated TP levels. Average concentrations during low flow (August-March) from 2006 to 2012 were 0.011 mg/L (AESRD data), indicating oligotrophic conditions.

- *Small Rivers and Creeks*

Hines Creek, which originates in forested uplands but flows through areas of moderately intense agriculture, is considered eutrophic based on average total nutrient concentrations.

For the Eureka, Clear and Montagneuse rivers, which flow through forested and low-intensity agricultural lands, total nutrient values were not available. However, orthophosphate (a fraction which makes up TP) was low to elevated, ranging from 0.008 to 0.070 mg/L (CHWI 2009).

Coliforms and Pathogens

In Clear Hills County where the Eureka, Clear and Montagneuse rivers are located, the urban areas are small and the watershed in general is healthy. However, there are concerns with the intensive livestock operations in the area (CHWI 2009). The Eureka, Clear and Montagneuse rivers exceeded the CCME water quality guidelines for total coliforms of 1000 CFU/100 mL, with most samples ~ 2000 CFU/100 mL (CHWI 2009). Natural bacteria, however, are also included in the total coliform count; therefore fecal coliforms or *E. coli* counts are better indicators of bacterial contamination.

The Clear and Eureka rivers also had *E. coli* numbers of 200/100mL and higher, with a maximum of 548 in Eureka (CHWI, 2008), which exceeds the recreational guideline of 400/100 mL for one-point measurements (Health Canada 2012) but more data are needed to assess if these levels are the rule or the exception. At the Peace River LTRN station fecal coliform levels were an average of 36 CFU/100 mL with most counts less than 10 CFU/100 mL between 2006 and 2012.

TABLE 13: AESRD WATER QUALITY DATA FOR THE PEACE RIVER IN THE UPPER PEACE SUB-BASIN

			TP (mg/L)				TP (mg/L)		
Site description	**Date Range**	**n**	**Med**	**Min**	**Max**	**n**	**Med**	**Min**	**Max**
U/S of Clear River	Jul 1980	1	0.525			0			
Dunvegan	Feb 1989	1	0.007			1	0.003	0.003	0.003
Below Shaftesbury R.	Feb 1989 - Mar 1991	2	0.028	0.007	0.590	2	0.005	0.002	0.11
Smoky RIver	Mar 1983 - Nov 1983	2	0.028	0.012	0.850				

Lake Water Quality

Phosphorus

Moonshine Lake is eutrophic and low oxygen events have led to fish kills, which initiated the use of an aeration system to improve oxygen levels and reduce the release of phosphorus from sediments under anoxic conditions (i.e., internal phosphorus loading) (Mitchel and Prepas 1990; in AEH). Long-term TP data collected in Moonshine Lake show a significant increasing trend (Casey 2011, Figure 25). Interestingly, the range of seasonal TP variation has increased over the years as well, which may indicate stronger internal phosphorus recycling in response to mixing events or larger availability of sediment phosphorus.

George Lake has similar water quality issues with frequent algae blooms (CHWI 2008; AEH), but long-term trends are unknown, as this lake is not included in the routine monitoring program by AESRD.

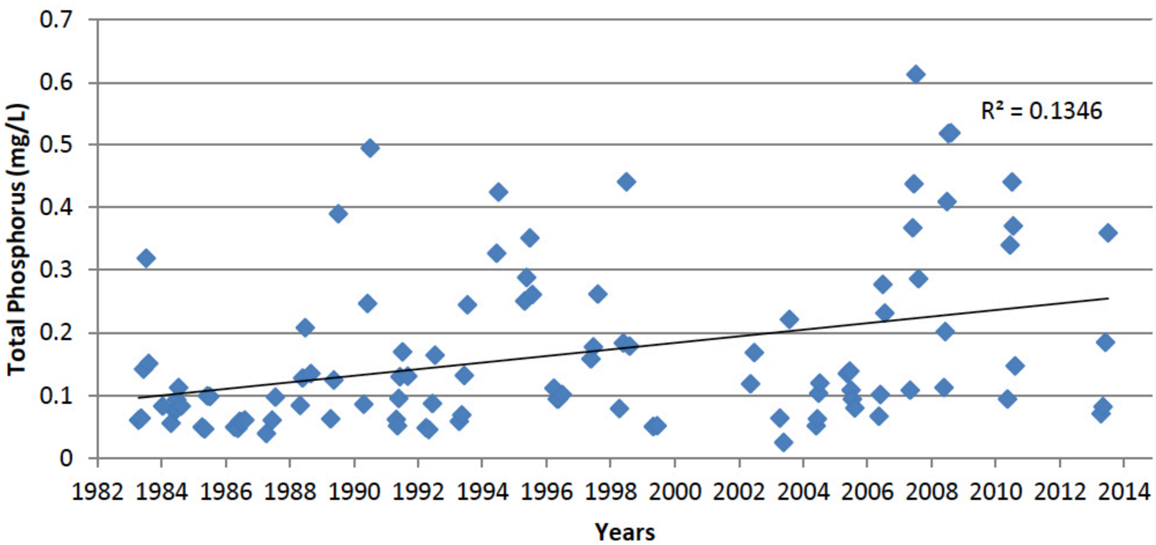

FIGURE 25. LONG-TERM TP TREND IN MOONSHINE LAKE

Salinity

The median TDS concentration for lakes in the Upper Peace Sub-basin is 190.7 mg/L, which is the highest median lake TDS concentration among all Peace sub-basins.

Moonshine Lake had the highest concentration in this sub-basin at 463 mg/L (Table 14). Statistical analysis of long-term data showed a significant decreasing trend in TDS in Moonshine Lake (Casey 2011), but similar to Saskatoon and Sturgeon Lakes, there were significant inter-annual variations with the highest values occurring in 2010 (Figure 25).

TABLE 14: WATER QUALITY SUMMARY OF 13 LAKES WITHIN THE UPPER PEACE SUB-BASIN

Upper Peace Sub-basin	Chlorophyll *a* (mg/m3)	TP (mg/L)	TDP (mg/L)	TDS (mg/L)
Median	36.8	0.100	0.059	191
Min	11.0	0.042	0.055	41
Max	85.9	0.439	0.090	463

Data Source: AESRD.

Land Use And Land Cover

Wetland Area

The Upper Peace sub-basin has a total wetland cover of 11.5%, the majority of which (10.4%) is bog, fen, marsh and swamp with peatland (bog + fen) constituting over half (Table 15). This is the lowest wetland cover for a sub-basin in the Peace River Basin and is likely related to a combination of relatively low precipitation and largest percent cover of agricultural areas, which are the major cause of wetland loss.

TABLE 15. WETLAND COVER FOR THE UPPER PEACE SUB-BASIN.

Upper Peace	WS AREA	(WS-NP) AREA	Wetland Cover	Wetland Cover				
				Bog	Fen	Marsh	Swamp	Open Water
Area (km^2)	17,593	17,593	2,024	425	530	55	825	189
% of Land Cover		100.0%	11.5%	2.4%	3.0%	0.3%	4.7%	1.1%

Wetland Health

A total of 16 wetlands have been surveyed for invasive species and human disturbance. Of these wetlands, 88% (Table 16) were found to be disturbed, which is the greatest percentage of disturbance of all the sub-basins within the surveyed wetlands. Note that this sub-basin is also the one with the largest percentage of watershed area in the “white zone,” that is, the settled areas. The Upper Peace sub-basin also had the greatest variation in disturbance type, including industrial facilities, livestock trails, roads and camping.

TABLE 16. WETLAND DISTURBANCE FOR THE UPPER PEACE SUB-BASIN

	Number of Wetlands	Number of disturbed	Percent of wetlands with disturbance
Upper Peace	16	14	88%

Wetland Loss

Wetland loss is not only defined as the disappearance of wetlands, but also as the loss of function, even if some wetland features are still present. The wetland loss between 1985 and 2001 was estimated at 5% in the Canadian Aspen Parkland ecoregion and at 4% in the Canadian Boreal Transition ecoregion, the two ecoregions most similar to those found in the settled regions (White Zone) of the Upper Peace sub-basin (Watmough, and Schmoll 2007). In addition, more wetland loss has likely occurred due to land clearing and cultivation since the time of European settlement prior to 1985.

For the Green Zone, no data on wetland loss are available.

Riparian Health

Individual Riparian Health Assessments

Cows and Fish (Sikina and Ambrose 2013) assessed three sites in the Upper Peace sub-basin, totalling 1 km of stream or small river riparian area. The riparian health assessments rated two sites as “healthy” and one site as “unhealthy”. Clearly, there is insufficient data for individual sites to extrapolate riparian health for the entire Upper Peace sub-basin.

TABLE 17. UPPER PEACE SUB-BASIN – RIPARIAN HEALTH OVERVIEW

Health Category	Percentage of Sites	Number of sites
Healthy	66.7%	2
Healthy, but with problems	0%	0
Unhealthy	33.3%	1

Land Cover in Riparian Areas

The Upper Peace sub-basin has the smallest riparian land area with just under 3,000 km^2, 41.9% of which is covered with agricultural lands (Table 18). This is the greatest percent of agricultural riparian land cover of all the sub-basins. However, due to its size, the Smoky Wapiti sub-basin contains a larger total with over 1,900 km^2 agricultural land cover in riparian areas.

The agriculture land was further divided into cropland and hay/pasture land cover to gain a greater understanding of this land cover’s influence on soil erosion. Cropland represents 34.9% of the riparian land cover; this would lead to greater erosion of soils in this area (Table 19). This is also the sub-basin with the greatest percent of development, representing 4.8% of riparian land cover. However, similar to the agricultural land cover, the larger Smoky Wapiti sub-basin has almost 150 km_2 more developed riparian land cover than the Upper Peace sub-basin.

TABLE 18. RIPARIAN LAND COVER FOR UPPER PEACE SUB-BASIN

Upper Peace	Developed	Agriculture	Natural
Area (km^2)	130	1,138	1,447
Percentage	4.8%	41.9%	53.3%

TABLE 19. AGRICULTURE LAND COVER FOR THE UPPER PEACE SUB-BASIN

	Total Agriculture (km^2)	Cropland	Hay/Pasture
Upper Peace	1197	34.9%	9.2%

From the GIS analysis, it appears that about half of the riparian areas in the Upper Peace sub-basin are impacted by human influence, mostly by agricultural land use.

Invasive Species in Riparian Areas

Three invasive plant species were encountered in the three riparian health assessments conducted by Cows and Fish (Sikina and Ambrose 2013). These species covered only 0.7% of the total area, with a maximum areal coverage of 10% per site (Canada Thistle).

Biological Community

Within the Upper Peace sub-basin, 34 species of fish have been captured. Three of these were species at risk and five were non-native (Table 20). Both goldeye and River walleye were found at moderate densities in this sub-basin while bull trout and Arctic graying were found at low densities. All these numbers were associated with a low amount of uncertainty (Table 21). In comparison with watersheds in the northern Smoky-Wapiti sub-basin, fish populations appear to persist, possibly due to better water quality from less intense agriculture and less habitat fragmentation due to lower road density. Road density is, on average, at a level that indicates a moderate index of biological integrity in the Upper Peace sub-basin (Figure Road Density in the Peace Basin as Indicator for the Biotic Index of Integrity – Smoky-Wapiti section).

TABLE 20. BREAKDOWN OF FISH SPECIES FOUND WITHIN THE UPPER PEACE SUB-BASIN

Total Number of Fish Species captured	34
Species of management concern or species at risk	3
Non-native, naturalized, stocked or dispersal from BC	5

TABLE 21. FISH DENSITY WITHIN THE UPPER PEACE SUB-BASIN

Fish Species	Habitat Type	Habitat Preference	Density	Data Uncertainty
Goldeye	Lotic (river)	Sizeable rivers, clay-induced turbidity of waters, rapid current (Government of Ohio).	Moderate	Low
Walleye	Lotic (river)	Sizeable rivers and or lakes, clear waters to low turbidity, bottoms are solid and comprised of various composition (e.g. gravel shoals, bedrock, reefs)	Moderate	Low
Bull Trout	Lotic (river)	Rivers of good water quality, cool with rapid current, substrate comprised of medium to large debris, favour pools and riffles (SCCP 2010)	Low	Low
Arctic Grayling	Lotic (river)	Cool rivers with ample pool habitats (U.S. Fish and Wildlife Services 1985.	Low	Mostly Low
Walleye	Lentic (lake)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g. gravel shoals, bedrock, reefs)	No data-low	High

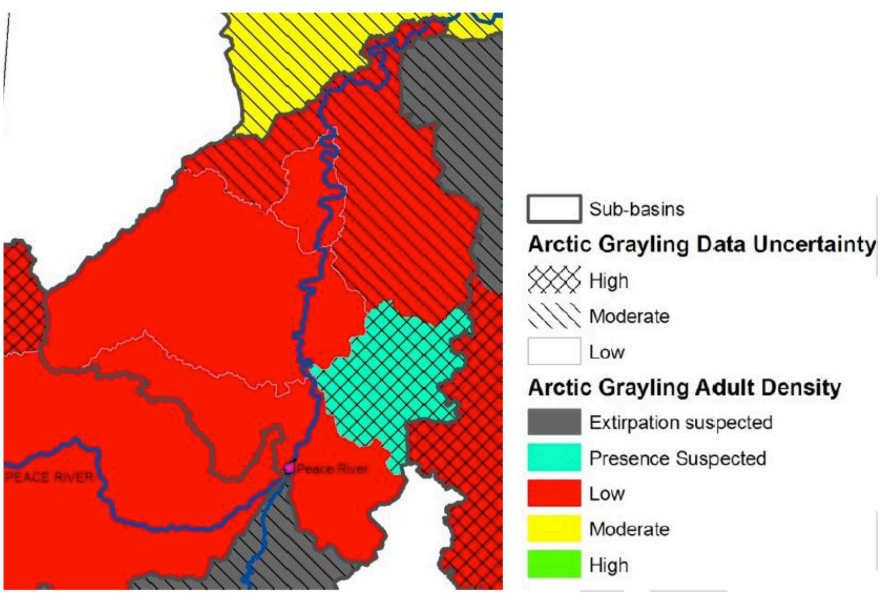

FIGURE 26: ADULT DENSITY OF ARCTIC GRAYLING IN THE UPPER PEACE SUB-BASIN.
Source: Johnson and Wilcox 2012

Invasive Species

Two exotic fish species were encountered in the Upper Peace sub-basin: brook trout and brown trout. The high level of confidence in data for other fish in this sub-basin indicates that this may be a realistic estimate.

CENTRAL PEACE SUB-BASIN

Sub-Basin Description

The Central Peace sub-basin includes the Peace River between the confluence of the Smoky River at the upstream end and Fort Vermillion at the downstream end and the area draining to this reach. Important tributaries in this sub-basin are the Whitemud, Notikewin and Heart Rivers. Major potential stressors in the Central Peace sub-basin include oil and gas exploration and extraction, forestry, agriculture, and wastewater effluents from both the town of Peace River and the pulp and paper mill operated by Daishowa-Marobeni International (DMI). In situ oil sands development occurs in this sub-basin and is expected to expand in the future. Notably, cutline density is highest in the tertiary watershed north-east of the town of Peace River, along with the neighbouring watershed in the Wabasca sub-basin CharettePellPoscente
and Hutchinson Environmental Sciences 2012).

In the Heart River watershed, there are a large number of developments within the watershed including agriculture, forestry, oil and gas and the village of Nampa. Until recently a major water withdrawal system operated at Nampa to service the village and Northern Sunrise County that resulted in low-water conditions in the lower reaches of the Heart River (Rees 2011).

Surface Water Quality

River and Stream Water Quality

- *Alberta River Water Quality Index*

Water quality data collected at the LTRN site Peace River at Fort Vermillion from 1996 to 2010 resulted in an overall ARWQI rating of “good” (Table 21). Bacteria and pesticide sub-indices have been primarily rated as “excellent” from 1996 to 2010 and the sub-index for metals has been rated as “good”.

The sub-index for nutrients has been rated as “fair” for most monitoring years. The lower ratings for nutrients are thought to be the result of spring freshet bringing high concentrations of TP. The large variation in total suspended solids (TSS) concentrations at the site and little nutrient influence by the DMI pulp mill supported the interpretation of elevated TP associated with suspended sediments (Stantec 2004).

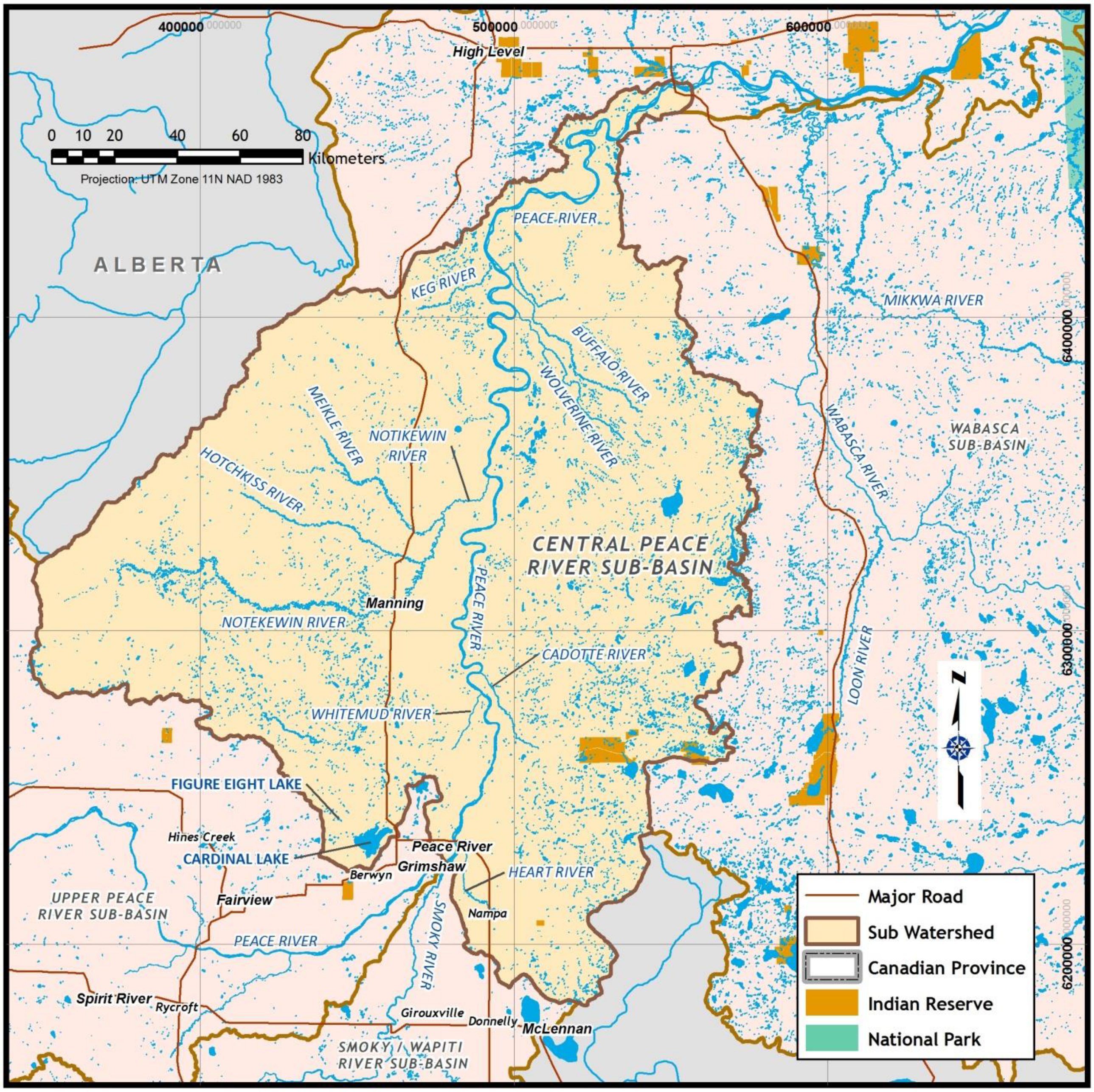

FIGURE 27. MAP OF CENTRAL PEACE SUB-BASIN

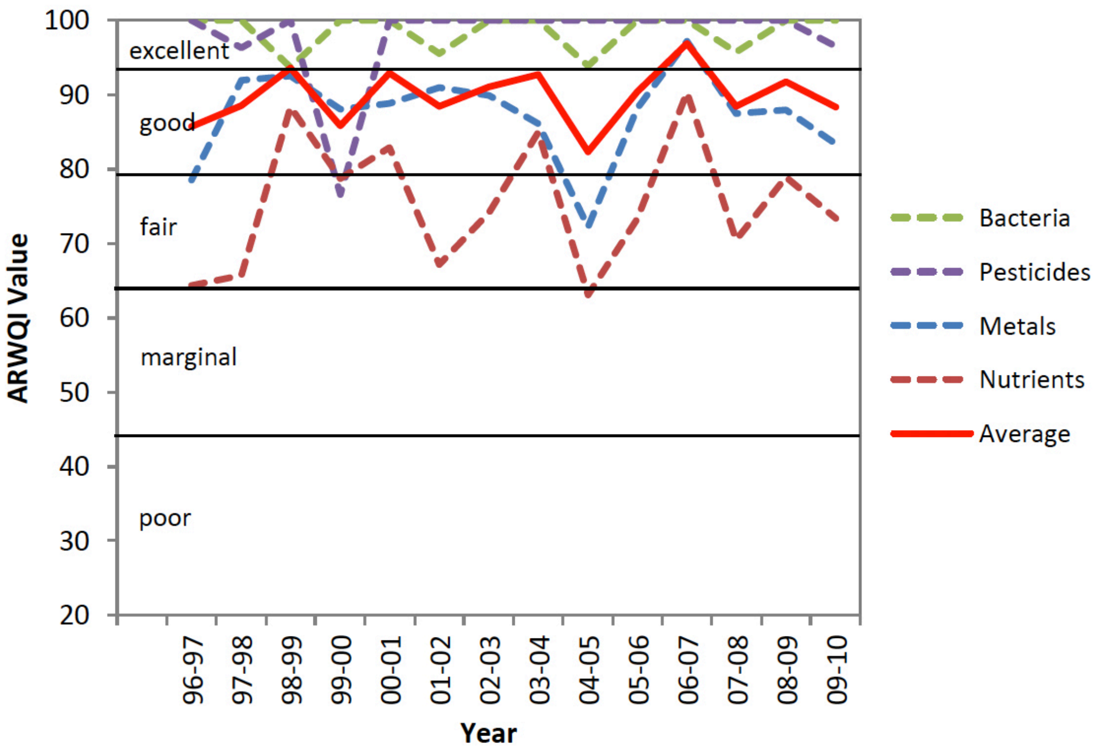

FIGURE 28. ARWQI FOR PEACE RIVER AT FORT VERMILION

Phosphorus

- *Major Rivers (Peace Mainstem)*

TP has frequently exceeded the former ABSWQG in the Peace River at Fort Vermilion, which is considered to be due to spring and summer high flow conditions. The low-flow (August to March) average TP concentrations at this site from 2006 to 2012 were 0.017 mg/L, which is considered oligotrophic for rivers. The average TP concentration for the LTRN site on the Peace River by Fort Vermillion from 1988 to March 2012 was 0.182 mg/L, with elevated concentrations usually occurring during the high-flow period between March and June. Data available for the Peace River in this sub-basin cover different years and seasons and so are not directly comparable. Synoptic studies during the main flow seasons would be required to assess differences between sites. Trend analysis on data collected from the LTRN site could provide more insight into recent changes in Peace River water quality in this reach.

- *Small Rivers and Creeks*

In Heart River and Myrtle Creek, nutrient concentrations are normally high in the spring and decrease in the summer, with the exception increases following rain events. From 2004 to 2009 average yearly TP concentrations at Heart River and Myrtle Creek exceeded the previous ABWQGs and had a significant positive relationship with turbidity (Aquality Environmental Consulting Ltd. 2010). The source of TP is believed to be located at the headwaters of Myrtle Creek, where recommendations have been made to examine current and past land use practices (Aquality Environmental Consulting Ltd. 2010).

In Notikewin River, TP concentrations were highest in the spring of 2012 at between 0.4 and 0.58 mg/L, with TDP making up only 6 to 8% of the TP (Aquality Environmental Consulting 2013a), indicating phosphorus associated with particulate matter. TP concentrations were below detection limits in summer 2012, with the exception of early in the season at one site. While the detection limit was not stated, other measurements were as low as 0.01 mg/L, indicating low TP concentrations in the Notikewin River and little impact on water quality from the agricultural activities in this watershed. These values were lower than the minima recorded by AESRD in the 1980s, when the lowest detected TP concentrations were at 0.027 mg/L (Table 21) and may either indicate an improvement in water quality or differing sampling procedures or lab detection limits. The better water quality in this river compared with other agricultural streams in the Peace Basin may be due to its forested headwaters and intact riparian areas (Aquality Environmental Consulting 2013b).

More recent data are required for tributaries in the Central Peace sub-basin, as the already sparse AESRD data are between 20 and 30 years old (Table 22). Also, the currently available data are inconclusive in terms of land use impacts on water quality.

TABLE 22. AESRD WATER QUALITY DATA FOR RIVERS IN THE CENTRAL PEACE SUB-BASIN

			TP (mg/L)				TP (mg/L)		
Site description	**Date Range**	**n**	**Med**	**Min**	**Max**	**n**	**Med**	**Min**	**Max**
Cadotte River NEAR THE MOUTH	May 1988 - Mar 1989	7	0.081	0.038	0.640	7	0.027	0.014	0.044
Keg River ABOVE PEACE RIVER CONFLUENCE	Jun 1988 to Mar 1989	6	0.062	0.040	0.275	6	0.019	0.010	0.033
Keg River NEAR THE MOUTH	Jul 1988 - Mar 1989	4	0.079	0.060	0.149	4	0.045	0.027	0.055
Notikewin River NEAR THE MOUTH	May 1988 - Mar 1989	7	0.070	0.027	0.660	7	0.019	0.013	0.029

Coliforms and Pathogens

The average fecal coliform concentration between May 1988 and March 2012 at the LTRN site on the Peace River by Fort Vermillion was 34 CFU/ 100 mL, which is below water quality guidelines. Fecal coliform levels at Heart River and Myrtle Creek were also below WQGs (Aquality Environmental Consulting Ltd. 2010).

In the Notikewin River, total coliforms and *E. coli* concentrations remained below their respective guidelines between the fall of 2011 and 2012, with the spring of 2012 having the highest concentrations of both bacteria indicators (Aquality Environmental Consulting Ltd. 2013(a)).

Other Water Quality Issues

In May 2005, low dissolved oxygen (DO) concentrations were measured in the Peace River under ice at Fort Vermillion and an investigation was completed in order to assess the likely causes. Results indicated that low DO was associated with a spring freshet peak from tributaries, mainly from the Smoky River. High spring temperatures caused early and high discharge containing high amounts of Biochemical Oxygen Demand, which consumed DO under ice in downstream Peace River (Charette and Friesenhan 2009, in CharettePellPoscente and Hutchinson Environmental Sciences Ltd. 2012). As accepted climate change scenarios for Alberta predict earlier spring thaw and increased extreme events, it is possible that a similar event will occur again.

Lake Water Quality

Phosphorus

The median TP concentrations of 24 lakes in the Central Peace sub-basin is 0.065 mg/L, indicating on average eutrophic conditions (Table 22). For example, Cardinal Lake is classified as hypereutrophic and Figure Eight Lake is classified as eutrophic (North/South Consultants 2007). In the 1970s, Figure Eight Lake experienced algae blooms and low oxygen concentrations. To reduce algae blooms and potential fish kills copper sulphate was added to the lake from 1980 to 84, followed by liming in 1986 and 87, and in 1986 an aerator was installed (Mitchell and Prepas 1990).

Six lakes in the Buffalo Head Hills are on the upper end of mesotrophic (Charette 2001); these lakes were included in the lake water quality summary (Table 23).

TABLE 23: WATER QUALITY SUMMARY OF 30 LAKES WITHIN THE CENTRAL PEACE SUB-BASIN

Central Peace Sub-basin	Chlorophyll a (mg/m^3)	TP (mg/L)	TDP (mg/L)	TDS (mg/L)
Median	10.0	0.045	0.019	141
Min	1.3	0.010	0.005	11
Max	185.4	0.520	0.083	1036

Long-term water quality data are available for Cardinal Lake. There is no unidirectional change in the lake, but both TP and TDS concentrations appear to fluctuate on multi- year cycles (Figures 29 and 30).

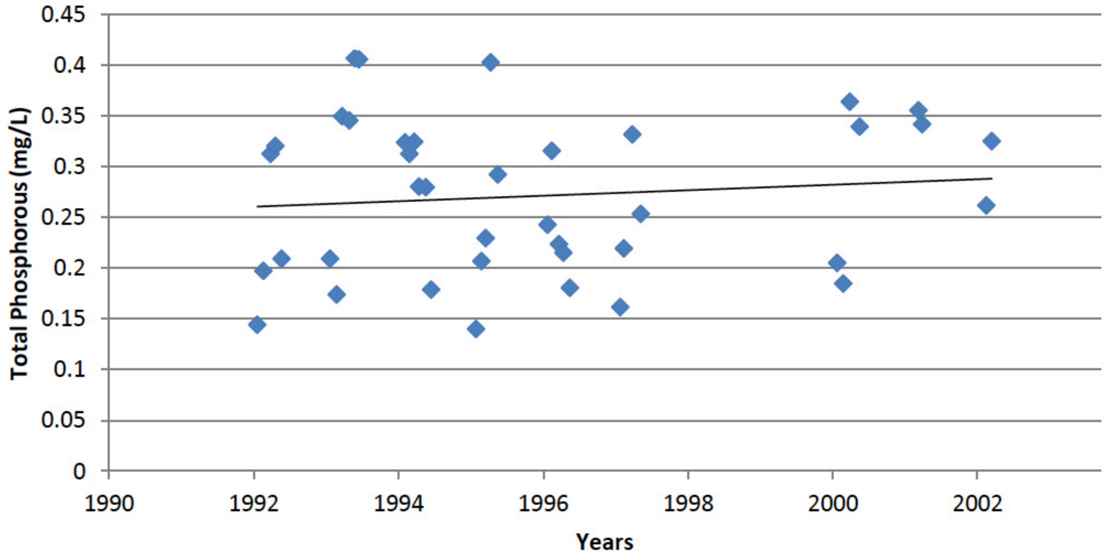

FIGURE 29. LONG-TERM TP TRENDS IN CARDINAL LAKE
Data Source: AESRD

Salinity

The median TDS for lakes in the Central Peace sub-basin is 141 mg/L ranging from 11.1 to 1036 mg/L. An unnamed lake had the highest TDS concentration of over 1000 mg/L, with the second-highest TDS levels measured at Deadwood Lake with a TDS concentration of 429 mg/L.

TABLE 24. WATER QUALITY SUMMARY OF 30 LAKES WITHIN THE CENTRAL PEACE SUB-BASIN

Central Peace Sub-Basin	Chlorophyll *a*	TP (mg/L>)	TDP (mg/L>)	TDS (mg/L>)
Median	10.0	0.045	0.019	141
Min	1.3	0.010	0.005	11
Max	185.4	0.520	0.083	1036

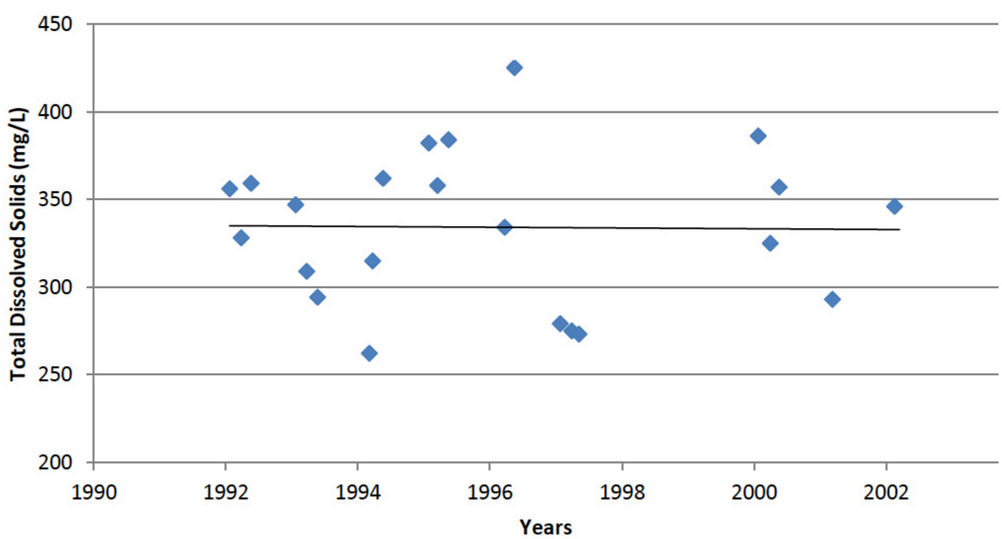

FIGURE 30: LONG-TERM TDS TRENDS IN CARDINAL LAKE

Land Use And Land Cover

Wetland Area

Over 25% of the Central Peace sub-basin is covered by wetlands. Swamp area cover comprises almost as much as bog and fen area cover combined (Table 25).

TABLE 25: WETLAND COVER FOR THE CENTRAL PEACE SUB-BASIN

Central Peace	WS AREA	(WS - NP) AREA	Wetland Cover	Wetland Cover				
				Bog	Fen	Marsh	Swamp	Open Water
Area (km_2)	35,374	35,374	9,113	2,376	1,704	598	3,716	721
% of Land Cover		100.0%	25.8%	6.7%	4.8%	1.7%	10.5%	2.0%

Wetland Loss

Wetland loss is not only defined as the disappearance of wetlands, but also as the loss of function, even if some wetland features are still present. The wetland loss between 1985 and 2001 was estimated at 5% in the Canadian Aspen Parkland ecoregion and at 4% in the Canadian Boreal Transition ecoregion, the two ecoregions most similar to those found in the settled regions (White Zone) of the Central Peace sub-basin (Watmough, and Schmoll 2007). In addition, more wetland loss has likely occurred due to land clearing and cultivation since the time of European settlement prior to 1985. The largest portion of the Central Peace Basin, however, has natural land cover (89%) and therefore overall wetland loss in the sub-basin is likely lower than in the Upper Peace sub-basin.

Riparian Health

Individual Riparian Health Assessments

Cows and Fish has visited four sites in the Central Peace sub-basin in 2007 and 2008, including 0.5 km of Peace River shoreline and 2.97 km of stream riparian area (SIkina and Ambrose 2013). The average assessment was healthy with some problems (Table 26). The surveyed sites represent only a very small portion of the total riparian area of 5,685 km^2 in the Central Peace Basin, and therefore may not be representative of the sub-basin (Sikina and Ambrose 2013).

TABLE 26. CENTRAL PEACE SUB-BASIN – RIPARIAN HEALTH OVERVIEW

Health Category	Percentage of Sites	Number of sites
Healthy	25%	1
Healthy, but with problems	50%	2
Unhealthy	25%	1

Land Cover in Riparian Areas

Most of the riparian land cover in the Central Peace sub-basin is natural (90.4%) (Table 27). This is in contrast with the individual assessments (Cows and Fish), which showed that three out of four assessed sites had some problems. One reason for the difference is likely that the Central Peace Basin contains a considerable area in the forested “Green Zone,” which is included in the GIS-based land cover analysis, while Cows and Fish riparian assessments are only conducted in the settled “White Zone”.

TABLE 27. RIPARIAN LAND COVER FOR CENTRAL PEACE SUB-BASIN

Central Peace	Developed	Agriculture	Natural
Area (km_2)	75	470	5,140
Percentage	1.3%	8.3%	90.4%

Invasive Species in Riparian Areas

Three invasive species were detected in the riparian health assessments conducted by Cows and Fish (Sikina and Ambrose 2013). In the four surveyed sites, they covered 10% of the total surveyed area, with a maximum coverage per site of 30% (Canada Thistle).

Biological Community

Thirty-one different species of fish have been captured in the Central Peace sub-basin (Table 26). There is a lack of data for lake walleye and bull trout. Arctic grayling densities are suspected to be low and a focused sampling effort in the Cadotte River was unsuccessful, making its extirpation in this watershed likely (Steenbergen and Wilcox 2013). The likely absence of Arctic grayling in the Cadotte River was in part attributed to the numerous beaver dams that slow flow and effectively remove stream habitat required for Arctic Grayling (Steenbergen and Wilcox 2013).

Both Goldeye and River Walleye are believed to have moderate to high densities in this region, likely from their occurrence in the Peace River. There is, however, a great deal of uncertainty associated with these numbers.

Walleye spawning movements are known to occur in larger tributaries of the Peace River, including Notikewin (Central Peace), Mikkwa (Lower Peace) and Beatton Rivers (British Columbia) (AMEC Earth & Environmental and LGL Ltd. 2008), but the role of smaller tributary systems for spawning is not well understood (Rees 2011). Based on an 11-day spring trap survey at the mouth of the Heart River in 2011, it is suggested small spawning runs do exist in Heart River for walleye, longnose suckers, and white suckers (Rees 2011). Walleye presence was also confirmed in Whitemud River, but it is uncertain if this represents a resident or spawning population (Sherburne et al. 2009).

An Arctic grayling survey in Whitemud River provided preliminary evidence of a range contraction, possibly due to angling, habitat fragmentation from poorly installed stream crossings, agricultural activity and increase in water temperature as a result of climate change and land-use practices (Sherburne et al. 2009). The Index of Biological Integrity based on road densities was rated as high in this basin, however, indicating that other factors or the cumulative effect of a number of human pressures may be responsible for low Arctic grayling numbers.

TABLE 28. FISH DENSITY WITHIN THE CENTRAL PEACE SUB-BASIN

Fish Species	Habitat Type	Habitat Preference	Density	Uncertainty
Goldeye	Lotic (river)	Sizeable rivers, clay-induced turbidity of waters, rapid current (Government of Ohio).	Moderate-High	Moderate-High
Walleye	Lotic (river)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g. gravel shoals, bedrock, reefs)	Moderate-High	Moderate-High
Bull Trout	Lotic (river)	Rivers of good water quality, cool with rapid current, substrate comprised of medium to large debris, favour pools and riffles (SCCP 2010)	No data-Low	
Arctic Grayling	Lotic (river)	Cool rivers with ample pool habitats (U.S. Fish and Wildlife Services 1985).	Presence Suspected - Low, Extirpation likely in Cadotte R.	Low-Moderate
Walleye	Lentic (lake)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g., gravel shoals, bedrock, reefs)	No data	

Notes: Data from Johnson and Wilcox (2012) and Steenbergen and Wilcox (2013)

TABLE 29: BREAKDOWN OF FISH SPECIES FOUND WITHIN THE CENTRAL PEACE SUB-BASIN.

Total Number of Fish Species captured	31
Species of management concern or species at risk	2
Non-native, naturalized, stocked or dispersal from BC	4

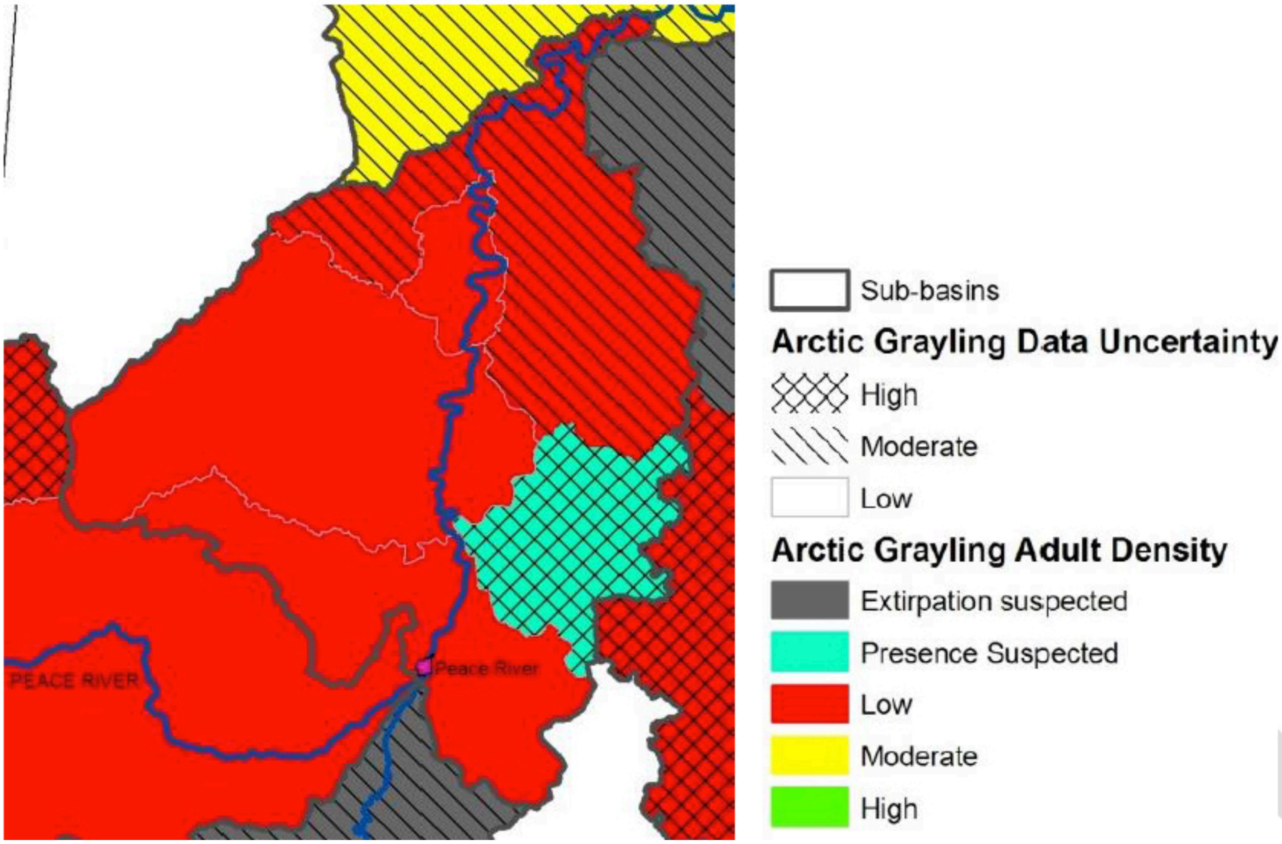

FIGURE 31. ADULT DENSITY OF ARCTIC GRAYLING IN THE CENTRAL PEACE SUB-BASIN.

Invasive Species

The central Peace sub-basin is home to at least two exotic fish species, Brown Trout and Brook Trout (Johnson and Wilcox 2012). This number is likely reliable given the relative large sampling efforts in this area, which is facilitated by the presence of an AESRD Fisheries Unit in the town of Peace River.

WABASCA SUB-BASIN

Sub-Basin Description

The Wabasca sub-basin is the largest sub-basin of the Peace watershed. It includes the drainage basins of the Peace tributaries Wabasca and Mikkwa Rivers as well as the Birch River that discharges to Lake Claire in the Peace-Athabasca Delta and a large number of lakes. The Wabasca sub-basin is mainly forested and land use is restricted to oil and gas exploration, forestry, recreation and traditional land uses by the predominantly Aboriginal population. The headwaters of this basin are underlain by the north-eastern part of the Athabasca Oil Sands Reserve, including the Wabasca Oil Field, which provides for an active oil and gas industry (CharettePellPoscente and Hutchinson Environmental Sciences Ltd. 2012).

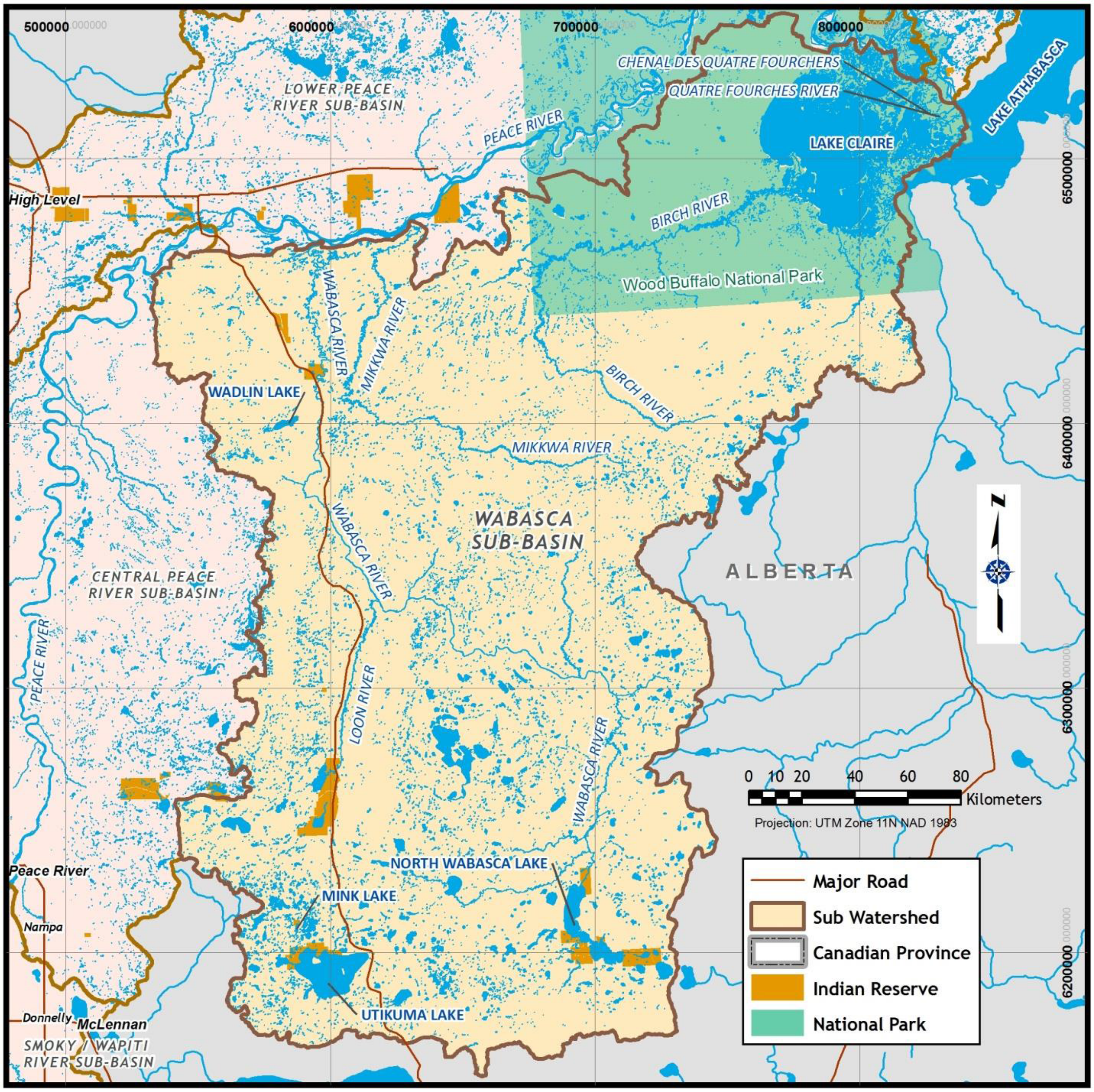

FIGURE 32: MAP OF THE WABASCA SUB-BASIN

Surface Water Quality

River and Stream Water Quality

No LTRN sites are located in this sub-basin and therefore no ARWQI results were available.

Phosphorus

The Wabasca and Birch Rivers contained higher concentrations of dissolved nutrients than the Peace River (Table 30), like other tributaries (Shaw 1990). Water quality data for this sub-basin are very sparse and outdated and no data were found for coliform bacteria.

TABLE 30. AESRD WATER QUALITY DATA FOR RIVERS IN THE WABASCA SUB-BASIN

Site Description	Date Range	n	TP (mg/L) median			n	TDP (mg/L)		
			Med	Min	Max		Med	Min	Max
Wabasca River ABOVE BEAR RIVER CONFLUENCE	May 1988 - Mar 1991	8	0.111	0.040	0.740	8	0.022	0.011	0.038
Birch River NEAR THE MOUTH	Mar - Aug 1993	2	0.138	0.120	0.138	2	0.049	0.025	0.049
Mikkwa River NEAR THE MOUTH	Jul 1988 - Mar 1989	4	0.079	0.060	0.149	4	0.045	0.027	0.055

Lake Water Quality

Phosphorus

The median TP concentration of 37 lakes in the Wabasca sub-basin was 0.063 mg/L, indicating on-average eutrophic conditions. Utikuma Lake is eutrophic to hypereutrophic, which, given the forested watershed, is likely natural. Peerless Lake has a diverse assemblage of algae indicative of a less eutrophic lake in comparison with other lakes in the Peace River Basin (Mitchell and Prepas 1990).

Salinity

The concentration of TDS in the Wabasca sub-basin ranges from 6.9 mg/L (very low ionic content) in Clayton Lake to 1350 mg/L in Nipisi Lake (very high ionic content, brackish lake). Mink Lake is also saline with a TDS concentration of 1315 mg/L which has increased from the 1980s, but it is unknown if this increase is significant or what its causes are. These are the only two lakes sampled in this sub-basin that have TDS concentrations above 220 mg/L.

TABLE 31. WATER QUALITY SUMMARY OF 37 LAKES WITHIN THE WABASCA SUB-BASIN

Wabasca Sub-basin	Chlorophyll *a*	TP (mg/L)	TDP (mg/L)	TDS (mg/L)
Median	16.2	0.063	0.0266	50.5
Min	2.3	0.020	0.0045	6.9
Max	112.5	0.495	0.1000	1350.0

Data Source: AESRD

Land Use And Land Cover

Wetland Area

The wetland cover in the Wabasca sub-basin is over 57%; this is the largest fraction of wetland cover in the entire Peace Basin (Table 32). Bog and fen wetlands make up the majority of the wetland cover. The largest portion of the wetland cover, however, is swamp (Table Wetland Cover for Wabasca). This is also the greatest percentage of swamp area cover of all the sub-basins. Wood- Buffalo National Park includes large wetland areas, but these are excluded from this assessment, and so wetland cover in the Wabasca sub-basin is even higher than the values presented here.

TABLE 32. WETLAND COVER FOR THE WABASCA SUB-BASIN

Wabasca	**WS AREA**	**(WS - NP) AREA**	**Wetland Cover**	**Wetland Cover**				
				Bog	Fen	Marsh	Swamp	Open Water
Area (km^2)	66,921	54,844	31,384	9,870	8,807	952	9,936	1,819
% of Land Cover		82.0%	57.2%	18.0%	16.1%	1.7%	18.1%	3.3%

Wetland Health

The Wabasca sub-basin has had the greatest number of wetlands surveyed for human disturbance (24). Of these wetlands, 29% were disturbed (Table 33). The disturbance type in all cases was linear features associated with the energy industry.

TABLE 33: WETLAND DISTURBANCE FOR THE WABASCA SUB-BASIN.

	Number of Wetlands Assessed	**Number of disturbed wetlands**	**Percent of wetlands with disturbance**
Wabasca Sub-basin	24	7	29%

Wetland Loss

For the Green Zone, no data on wetland loss are available. Given that the Wabasca sub-basin lies entirely within the Green Zone, wetland loss for this sub-basin is unknown. It can be assumed, however, that some function has been lost in portions of the 29% of disturbed wetlands, which is included in the definition of wetland loss (see section Methodology-Wetland Cover). More information is needed to assess the degree of wetland function impairment from linear developments.

Riparian Health

No individual riparian health assessments were available for the Wabasca sub-basin and therefore information on invasive species in riparian areas is lacking as well.

Land Cover in Riparian Areas

Of all the sub-basins, the Wabasca sub-basin contains the greatest amount of riparian area with over 21,000 km^2 as well as the second-largest percent of natural land cover in riparian areas (98.9%)(Table Riparian Land Cover for Wabasca Sub-Basin).

TABLE 34: RIPARIAN LAND COVER FOR WABASCA SUB-BASIN

Wabasca	Developed	Agriculture	Natural
Area (km^2)	132	104	20,819
Percentage	0.6%	0.5%	98.9%

Biological Community

The Wabasca sub-basin has the second-lowest number of species (24) captured in the entirety of the Mighty Peace Watershed. It also has the second-lowest number of non-native species (2) captured (Table 34). Given the lack of data for this basin, it is unknown whether these numbers represent lower catch effort or are in fact different from other Peace sub-basins. Data are lacking for both river and lake walleye, and bull trout in the Wabasca sub-basin. The species of fish observed in greatest densities was goldeye, though the certainty of these numbers varied greatly from low to high among tertiary watersheds (Table 35).

TABLE 35: BREAKDOWN OF FISH SPECIES FOUND WITHIN THE WABASCA SUB-BASIN

Total Number of Fish Species captured	24
Species of management concern or species at risk	2
Non-native, naturalized, stocked or dispersal from BC	2

The sensitive Arctic Grayling populations were observed in low densities in the southern end and are suspected to be extirpated in the lower reaches of the Wabasca River watershed. While the Index of Biotic Integrity was rated as high based on road density (Figure Road Density as Indicator of Index of Biological Integrity in the Peace Basin), there is a large density of linear disturbance in this watershed, as discussed in the wetland section of the Wabasca Sub-basin, and a significant area with agricultural land use in the lower reaches, which may have been the reason for low Grayling densities. More data are needed in this sub-basin to confirm the status of fish populations, as data uncertainty was, on average, moderate to high.

TABLE 36. FISH DENSITY WITHIN THE WABASCA SUB-BASIN

Fish Species	Habitat Type	Habitat Preference	Density	Uncertainty
Goldeye	Lotic (river)	Sizeable rivers, clay-induced turbidity of waters, rapid current (Government of Ohio).	Low-Moderate	Low-High
Walleye	Lotic (river)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g., gravel shoals, bedrock, reefs)	No data-Moderate	Low-High
Bull trout	Lotic (river)	Rivers of good water quality, cool with rapid current, substrate comprised of medium to large debris, favour pools and riffles (SCCP 2010)	No data	
Arctic grayling	Lotic (river)	Cool rivers with ample pool habitats (U.S. Fish and Wildlife Services 1985.	Extirpated-Low	Moderate-High
Walleye	Lentic (lake)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g., gravel shoals, bedrock, reefs)	No data, Low-High	Low-High

Note: Data from Johnson and Wilcox (2012), Brown and Wakeling (2013), Wakeling and Brown (2013), Lucko (2013)

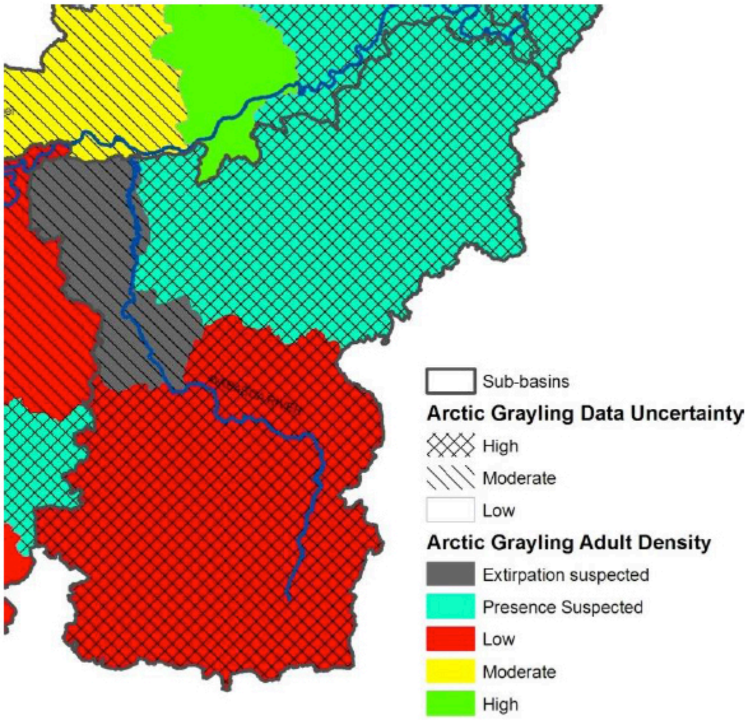

FIGURE 33. ADULT DENSITY OF ARCTIC GRAYLING IN THE WABASCA SUB-BASIN

Invasive Species

No invasive species have been reported for the Wabasca River sub-basin. This may in part be due to the remote nature of this basin, resulting in low probability of introduction and low catch effort, in the case of fish.

LOWER PEACE SUB-BASIN

Sub-Basin Description

The Lower Peace watershed includes the reach of the Peace River from Fort Vermillion to the Peace Athabasca Delta, where the confluence with Lake Athabasca outflow forms the Slave River. The headwaters of the Peace River tributaries, such as the Ponton and Wetzel Rivers, are located in the Caribou Mountains to the north. This reach of the Peace River also receives discharge from tributaries in the Wabasca sub-basin. The Lower Peace sub-basin is mainly forested, with the exception of some agricultural clearings to the north of the Peace River at Fort Vermillion stretching to High Level at the western end of the watershed and some cultivated fields around John D"Or Prairie. From satellite imagery it appears that there is ongoing forest harvesting in the central and eastern part of this sub-basin and oil and gas development in the western portion ear High Level (2012 Google Maps, in CharettePellPoscente and Hutchinson Environmental Sciences Ltd. 2012). High Level is the largest community and there are a few smaller communities, such as John D"Or Prairie, Beaver FN, Tallcree FN and Fox Lake scattered across the sub-basin.

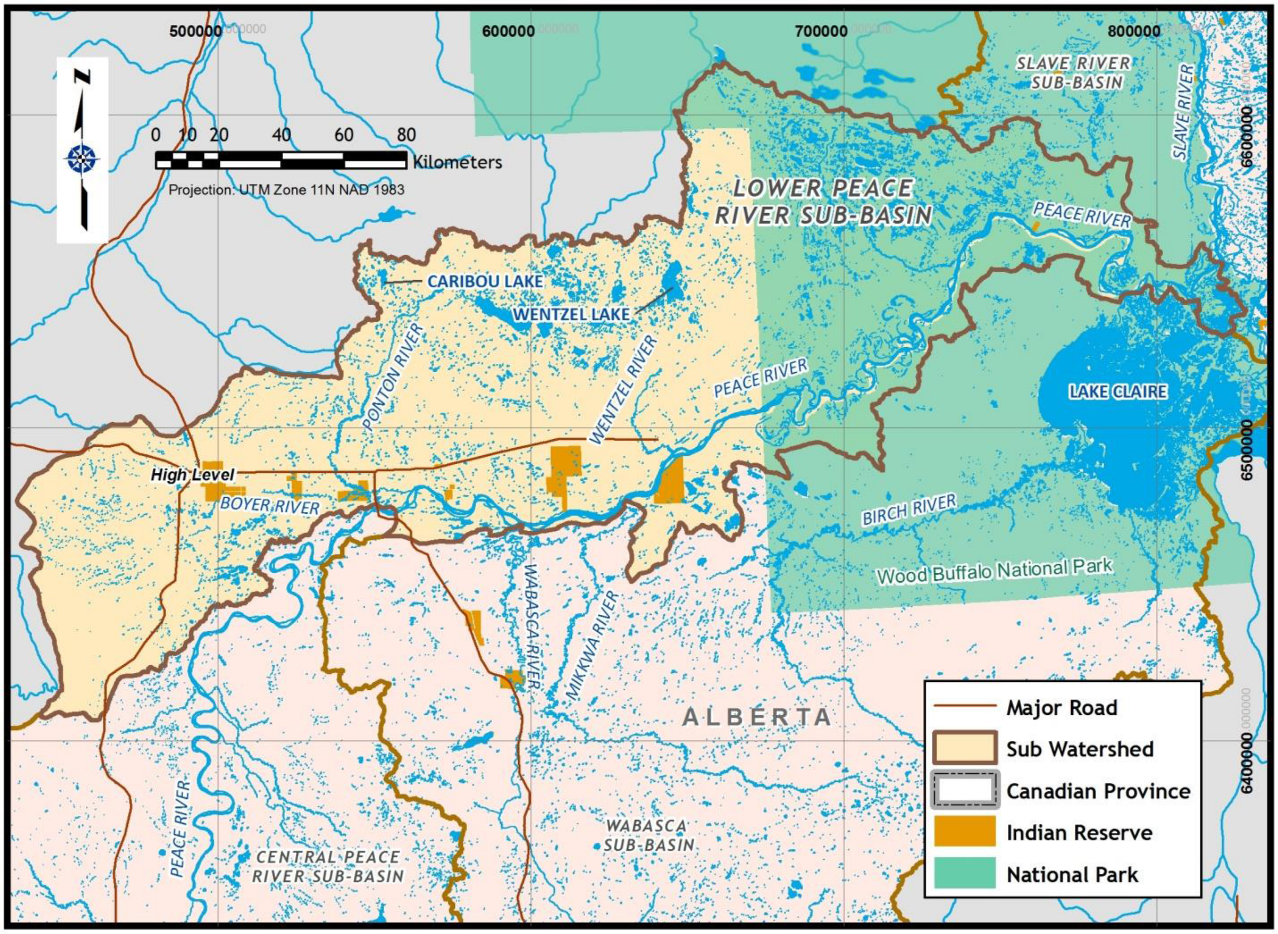

FIGURE 34: MAP OF THE LOWER PEACE SUB-BASIN

Surface Water Quality

River and Stream Water Quality

No Alberta River Water Quality Index ratings are available, as there is no LTRN site in the Lower Peace sub-basin. There is, however, a federal monitoring site on the Peace River in Wood-Buffalo Park, which provides good water quality data for the lower reach of the Peace River.

Phosphorus

- *Major Rivers (Peace Mainstem)*

The lower Peace River reach is characterized by seasonally high nutrient concentrations, especially during high flow events with high particulate transport (Shaw et al. 1990, Donald et al. 2004, Glozier 2009). The river is classified as mesotrophic, based on median phosphorus concentrations observed between 1989 to 2006 (North/South Consultants 2007), but high-flow data are included in these statistics, so they likely do not represent true aquatic productivity. From September 1974 to December 2010 the average TP concentration at Environment Canada"s monitoring station was 0.15 mg/L (hypertrophic) and the median was 0.046 mg/L (eutrophic).

A trend analysis of data collected at Peace Point from 1989 to 2006 indicated that water quality at this site has generally been stable, with the exception of increased dissolved nitrogen and oxygen concentrations (Glozier et al. 2009). Shaw et al. (1990) showed increasing concentrations of TDS, TSS and other constituents along the Peace River in 1988, with highest concentrations in the Lower Peace, but these trends have not been verified for the past 25 years.

- *Tributary Rivers and Creeks*

Data for rivers and creeks are scarce in this sub-basin, so we based our discussion on available river data from the 1980. The main rivers, Wentzel and Boyer Rivers, contained higher concentrations of TP than the Peace mainstem (Shaw 1990, Table 37). The Wentzel River, which has a mainly forested watershed, exhibited lower median and maximum TP concentrations than the Boyer River, which drains a large agricultural area and the community of High Level. These rivers are sizeable and therefore may contribute to the TP increase observed in the Peace River between Ft. Vermillion and Peace Point.

TABLE 37. AESRD WATER QUALITY DATA FOR LOWER PEACE SUB-BASIN RIVERS

Site Description	Date Range	n	TP (mg/L) median			n	TDP (mg/L)		
			Med	Min	Max		Med	Min	Max
Boyer River at HWY 67	May 1988 – Mar 1989	8	0.330	0.020	1.340	8	0.030	0.004	0.058
Wentzel River near the mouth	May 1988 – Mar 1989	5	0.058	0.020	0.100	5	0.012	0.002	0.028

No information on coliforms and pathogens was found for this sub-basin, but given the lack of intensive lifestock operations and large municipal discharges, the concern for coliform contamination is low.

Lake Water Quality

Phosphorus

Lakes in the Caribou Mountains were found to be naturally mesotrophic to eutrophic (0.032 mg/l of TP on average), with lakes affected by forest fire increasing phosphorus concentrations by 2.6-fold (McEachern 2002).

Salinity

Lakes in the Lower Peace basin were freshwater lakes with relatively low ion content, as indicated by mean TDS concentrations of 35.5 mg/L (Table 37).

TABLE 38: WATER QUALITY SUMMARY OF 39 LAKES WITHIN THE LOWER PEACE SUB-BASIN

Lower Peace Sub-basin	Chlorophyll *a* (mg/m^3)	TP (mg/L)	TDP (mg/L)	TDS (mg/L)
Median	9.4	0.036	0.019	35.5
Min	1.1	0.008	0.0070	18
Max	39.23	0.166	0.09	229

Data Source: AESRD and McEachern (2004)

Land Use And Land Cover

Wetland Area

The Lower Peace sub-basin contains the second largest wetland cover of all the sub- basins, with over 37% cover. The major wetland cover in this sub-basin is fen (12.1% cover) followed by swamp (11.2% cover).

TABLE 39: WETLAND COVER FOR THE LOWER PEACE SUB-BASIN

Lower Peace	WS AREA	(WS-NP) AREA	Wetland Cover	Wetland Cover				
				Bog	Fen	Marsh	Swamp	Open Water
Area (km^2)	29,088	19,511	7,329	1,436	2,368	676	2,179	669
Percentage		67.1%	37.6%	7.4%	12.1	3.5%	11.2%	3.4%

Wetland Loss

Wetland loss is not known for the Lower Peace Basin. The major cause of wetland loss in the Prairie wetland loss study by Watmough and Scholl (2008) was drainage for agricultural cultivation, which has likely occurred in the agricultural areas of the Lower Peace sub-basin. These clearings are younger compared with those in other sub-basins, however, and therefore more protective measures may have been taken to prevent wetland loss, although this remains to be confirmed.

No information on wetland health is currently available for the Lower Peace sub-basin, as no wetlands have been assessed by ABMI so far. There are sites in this sub-basin that are part of the ABMI sampling grid, however, so future sampling will show the degree of human disturbance in existing wetlands in the Lower Peace sub-basin. Linear development was a significant cause of wetland disturbance in the neighbouring Wabasca sub-basin with similar human pressures, suggesting that similar impacts on wetlands may have occurred in the Lower Peace sub-basin.

Riparian Health

No individual riparian health assessments have been completed in the Lower Peace sub-basin.

Land Cover in Riparian Areas

Land cover of the riparian areas in the Lower Peace sub-basin is primarily natural, measuring 97.4% (Table 40). This corresponds closely to the overall natural cover in the Lower Peace Basin of 96.6 % (data not shown).

TABLE 40: RIPARIAN LAND COVER FOR LOWER PEACE SUB-BASIN

Lower Peace	Developed	Agriculture	Natural
Area (km^2)	57	212	9,995
Percentage	0.6%	2.1%	97.4%

Biological Community

The total number of fish species captured in the Lower Peace (27) was lower than the number captured in the Upper Peace sub-basin, which may be related to lower catch efforts due to the remote nature of this sub-basin. The number of species at risk (2) and non-native species (4) was the same as in the Upper Peace sub-basin. Non-native fish species make up a larger fraction of fish species in the Lower Peace sub-basin (Table 41). Goldeye and river walleye have high densities in this sub-basin, however there is a great deal of uncertainty associated with these numbers (Table 42). Arctic grayling is found in moderate to high densities, with the moderate densities found in the western, agricultural areas, and higher densities in the eastern part, in the forested Wentzel River watershed and in Wood-Buffalo Park.

TABLE 41: BREAKDOWN OF FISH SPECIES FOUND WITHIN THE LOWER PEACE SUB-BASIN

Total Number of Fish Species captured	27
Species of management concern or species at risk	2
Non-native, naturalized, stocked or dispersal from BC	4

Note: Data from Johnson and Wilcox (2012)

TABLE 42: FISH DENSITY WITHIN THE LOWER PEACE SUB-BASIN.

Fish Species	Habitat Type	Habitat Preference	Density	Uncertainty
Goldeye	Lotic (river)	Sizeable rivers, clay-induced turbidity of waters, rapid current (Government of Ohio).	High	High
Walleye	Lotic (river)	sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g. gravel shoals, bedrock, reefs)	No data-High	Moderate
Bull trout	Lotic (river)	rivers of good water quality, cool with rapid current, substrate comprised of medium to large debris, favour pools and riffles (SCCP 2010)	No data	
Arctic grayling	Lotic (river)	Cool rivers with ample pool habitats (U.S. Fish and Wildlife Services 1985.	Presence Suspected-High	Low-High
Walleye	Lentic (lake)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g. gravel shoals, bedrock, reefs)	No data-Moderate	High

Note: Data from Johnson and Wilcox (2012)

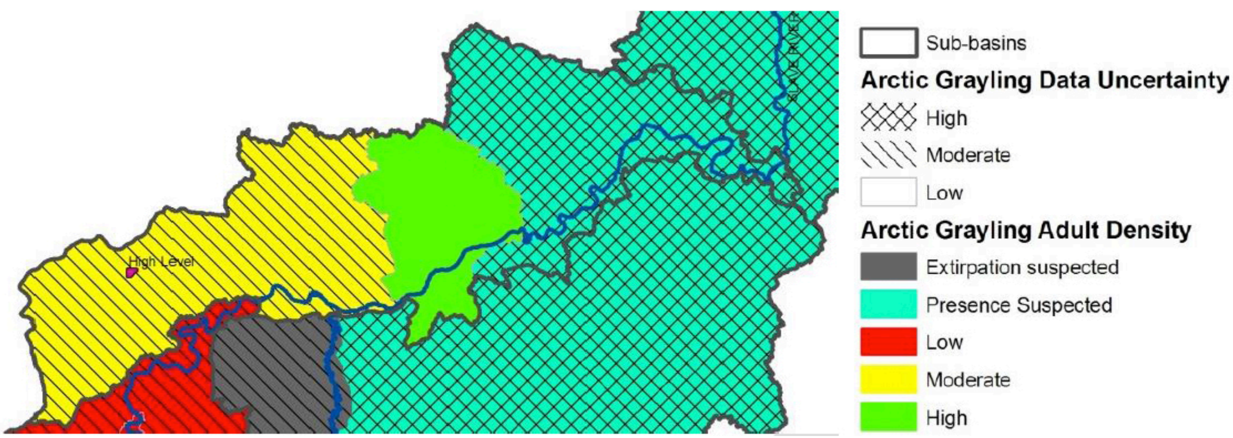

FIGURE 35. ADULT DENSITY OF ARCTIC GRAYLING IN THE LOWER PEACE SUB-BASIN

Invasive Species

The only exotic fish species considered exotic was caught in the lower Peace River Basin, which was Brook Trout (Johnson and Wilcox 2012). No information on other invasive species was available for the Lower Peace sub-basin.

SLAVE RIVER SUB-BASIN AND PEACE-ATHABASCA DELTA

Sub-Basin Description

The Slave River sub-basin is the most pristine of the sub-basins, with only a few roads and settlements along the Slave River and otherwise largely undisturbed areas in Wood-Buffalo National Park west of the Slave River and on the Canadian Shield east of the Slave River. The Peace Athabasca Delta (PAD) is located at the south end of the Slave River sub-basin and at the northeast end of the Wabasca sub-basin. The PAD is a large freshwater delta and wetland complex that is protected by National Park and RAMSAR wetland of significance designations. The largest potential human influences on the Slave River and the PAD are upstream pressures on the Peace and Athabasca Rivers. Among those, the oil sands industry in the Lower Athabasca Region is of most concern due to the potential effects of water use, air and water pollution on downstream ecosystems.

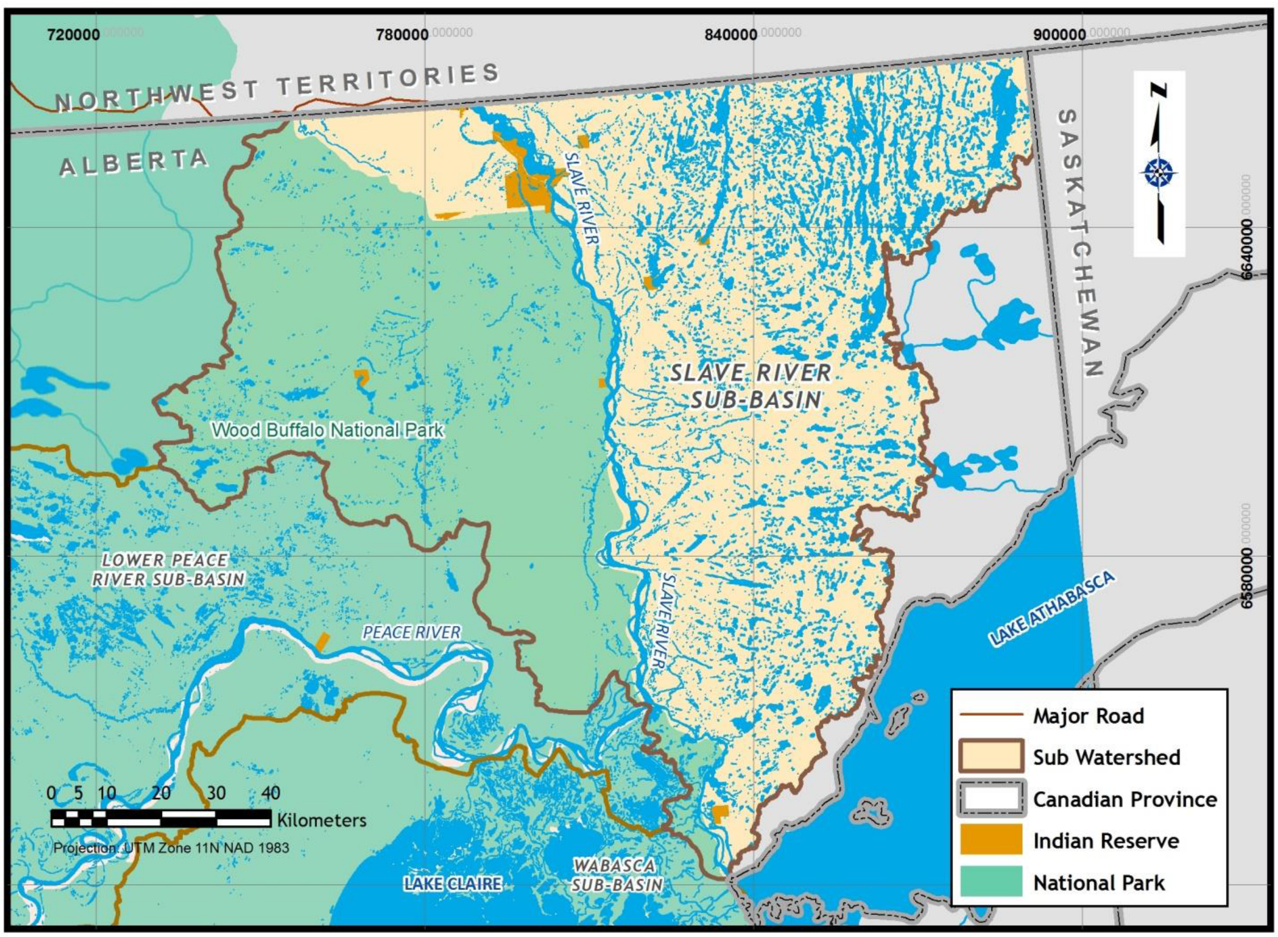

FIGURE 36. MAP OF THE SLAVE RIVER SUB-BASIN

Surface Water Quality

River and Stream Water Quality

Phosphorus

- *Major Rivers (Slave)*

Within Alberta, the Slave River is characterized by high concentrations of particulate phosphorus, especially during high flow events (AEH 2012). Such high TP concentrations during high flow events has led to the Slave River being classified as hyper-eutrophic (Environment Canada 2010), although the same report states that “these data demonstrate that classifying sites as hyper-eutrophic based on TP data alone can be misleading.” This is further supported by Glozier (2009), who reported that high TP and total nitrogen (TN) values in the river were associated with natural periods of high suspended sediment load.

TP and TDP in the Slave River displayed increasing trends for long-term datasets from both the Alberta site at Fitzgerald (Glozier 2009, 1989-2006) and the Fort Smith site in the Northwest Territories (AANDC 2012, 1974-2010), while the most recent dataset (1997-2006) did not show any trend (Glozier 2009). The confluence with the Athabasca River may be driving the observed increasing trend in Slave River phosphorus, given that the Athabasca River also showed increasing TP and TDP trends (EC 2010). These conflicting results may mean that the change is very subtle and therefore requires a large dataset to be detected by statistical methods or phosphorus concentrations may have stabilized in the recent decade after a period of increase. Step-trend analysis of the same dataset could resolve this question. Hebben (2009) conducted step-trend analysis for the Athabasca River data, with the step year defined as 1987, and did not find any trends in TP or TDP after 1987. Given the effluent quality improvements of large point sources of nutrients in the past two decades, including pulp and paper mills and wastewater treatment plants, this latter hypothesis seems likely.

To date no enrichment effect on biota (increased productivity) has been demonstrated by a scientific study and will be difficult to obtain due to the lack of baseline data. Informal observations of increasing algae on rocks and in fishing nets, however, have been reported (AANDC 2012). It may be helpful to implement a periphyton sampling program in order to monitor potential changes in nutrient status.

- *Small Rivers and Creeks*

There are no data for tributaries of the Slave River, except for some flowing waters in the PAD.

- *PAD River Water Quality*

In the Peace-Athabasca Delta, the Athabasca River water flows northwards towards the Peace River through a series of channels (e.g., Chenal des Quatres Fourches, Riviere des Rochers) but these can be assumed to be similar to Athabasca River water quality. Claire and Baril Lake are connected to the Peace River through the Claire and Baril Rivers, which would have water quality similar to the lakes (see section on PAD).

Lake Water Quality

Lake water quality data were available from the Peace Athabasca Delta, which is located at the southern end of the Slave River Basin, and from Wood Buffalo National Park in the central and western half of the Slave River basin. Lake water quality in the Peace Athabasca Delta is closely related to river water quality, due to frequent lake inundation during high spring and summer flows and ice jams on the Peace River that back up water and flood larger areas of this flat delta region. There is a large variety in lake hydrological connectivity, ranging from constantly river-connected lakes (open- drainage, Lake Claire and Mamawi), more or less frequently flooded lakes (most of PAD lakes, see Hall et al. 2004) to closed-drainage lakes.

Phosphorus

The lakes within the PAD are hydrologically strongly influenced by the rivers and their TP concentrations are directly linked with those of the rivers and affected by their degree of connectivity with the rivers. With exception of Lake Athabasca, lakes in the PAD are mainly shallow basins (median maximum depth 0.7 cm) and therefore can be classified as open-water wetlands (AECOM 2010).

Various water quality data were also collected from a large number of PAD rivers and lakes during the calibration exercise for the PAD Paleolimnology Study in 2000 (Hall et al. 2004). Total phosphorus concentrations in 57 PAD basins (excluding Lake Athabasca and Lake Claire) ranged from 0.019 mg/L to 0.4 mg/L, with a median TP of 0.084 mg/L, typical of mesotrophic to hypertrophic conditions (Hall et al. 2004).

Chlorophyll *a* concentrations ranged from 0.001 mg/L to 0.094 mg/L, with a mean of 0.016 mg/L. Sources that likely contribute high supplies of nutrients to the PAD include local catchments, which are easily leached deltaic and fluvial sediments, river-derived particulate nutrients associated with suspended sediments and dense waterfowl populations that utilize the productive wetlands of the PAD (Hall et al. 2004). Such high productivity levels are typical for delta environments and form the basis for the rich delta ecosystem for which this area is internationally recognized.

Lakes with continuous river connection, including Mamawi, Richardson, Athabasca, Claire and Blanche Lakes, had lower concentrations of dissolved nutrients, ions, phytoplankton biomass and higher turbidity than lakes having intermittent or no river influence. Strong relationships between water quality data and hydrological isotope indicators (oxygen and hydrogen stable isotopes) were found, indicating that hydrology strongly regulates water quality in the PAD. Lake Athabasca is a special case in that it receives about half of its annual inflow from the Athabasca River, which quickly flows to the nearby outlet, and the other half originates from the remainder of the lake, catchment, which is dominated by Canadian Shield. Most of Lake Athabasca is therefore low in nutrients and ions (Mitchell and Prepas 1990).

Lakes in the northern part of the Wood-Buffalo National Park (Alberta and Northwest Territories), outside the deltaic influences, were oligotrophic to mesotrophic, with the underlying geology determining most of their water chemistry (Moser et al. 1998). Total phosphorus concentrations ranged from 0.005 to 0.024 mg/L, with a mean TP of 0.012 mg/L and a mean Chlorophyll *a* concentration of 0.001 mg/L. On average, these lakes were 7 m deep and consisted of muskeg, sinkhole or shield lakes.

Salinity

In 1987 Lake Athabasca had a TDS concentration of 47 mg/L. The average TDS in 57 PAD lakes sampled by Hall et al. (2004) was 202 mg/L and ranged from 60 to 464 mg/L, and conductivity ranged from 120 µS/cm to 939 µS/cm. Conductivity in the lakes in the northern part of Wood Buffalo Park ranged from 18 µS/cm to 1030 µS/cm (Moser et al. 1998).

Land Use And Land Cover

Wetland Area

A large portion of the Slave River and PAD sub-basin lies within Wood Buffalo National Park and is therefore not included in the provincial wetland cover data presented here. Of the remaining land area in this sub-basin, 16.9% is wet, with the majority of this area being fen wetlands (Table Wetland Cover for the Slave River and PAD Sub-Basin). The portions of the Slave Basin located within the Peace-Athabasca Delta probably have a higher wetland cover, as it is recharged with water by periodic flooding; in fact, another GIS dataset (Reference of “Waterbody” layer) estimates 28 % of wetland cover in the Slave River Basin. Open-water cover, however, appears to be smaller, as the percent cover of lakes in the Slave River basin based on that same GIS dataset was estimated at 6% (Figure Percent Cover of lakes in the Peace Basin by sub-basin – summary section).

The portion north of the PAD, which is the area north of the Peace River and west of the Slave River, may have a different amount and types of wetland cover than the remainder of the basin, because lake types and natural regions are different as well, pointing to a different hydrological regime. Lakes on the eastern side of the Slave were described as shield lakes in the Kazan Uplands natural region and lakes on the western side of the Slave River, where Wood Buffalo National Park is located, are muskeg and sinkhole lakes in the Northern and Central Mixedwood regions (Moser et al. 1998).

TABLE 43. WETLAND COVER FOR THE SLAVE RIVER AND PAD SUB-BASIN

Slave River	WS AREA	(WS- NP) AREA	Wetland Cover	Wetland Cover				
				Bog	Fen	Marsh	Swamp	Open Water
Area (km^2)	13,252	7,976	2,240	11	821	118	297	993
%		60.2%	28.1%	0.1%	10.3%	1.5%	3.7%	12.5%

Wetland Health

A total of 19 wetland sites have been surveyed by the ABMI in the Slave PAD sub- basin; none of these have been influenced by human disturbance (Table Wetland Disturbance for the Slave PAD Sub-Basin).

TABLE 44. WETLAND DISTURBANCE FOR THE SLAVE PAD SUB-BASIN (ABMI DATA)

	Number of Wetlands	Number of disturbed	Percent of wetlands with disturbance
Slave	19	0	0%

Wetland Loss

Almost half of the Slave River Basin is covered by a National Park and the remainder is largely undeveloped territory. Therefore there has probably not been any or very little wetland loss in this sub-basin due to land use activities. The upstream regulation of the Peace River by the Bennett Dam, however, has had an effect on the seasonality of Peace River flows and possibly affected seasonal flooding of wetlands in the Peace Athabasca Delta. Periodic flooding of the delta is a major factor in maintaining the rich habitat and wildlife populations that the PAD supports, in particular the perched basins, those main water source are large floods (AECOM 2009).

Sediment studies of a number of PAD basins have shown that the frequency of flooding has varied substantially in the past due to climate phases, with the current flood frequency within the range of century-scale natural variability (Wolfe et al. 2006). On the other hand, a combination of increased freeze-up levels in the Peace River due to regulation and decreasing spring flows due to climate change has contributed to less frequent ice-jam flooding during the latter half of the 20th century (Beltaos et al. 2003) and therefore possibly caused drier conditions in parts of the delta compared to pre- dam conditions.

Riparian Health

Individual Riparian Health Assessments

No individual riparian health assessments were conducted in the Slave River basin. Riparian health can be assumed to be excellent due to the almost complete natural cover of riparian areas and the low human activity in this sub-basin.

Land Cover in Riparian Areas

In the Slave River and PAD sub-basin, 99.6% of riparian land cover is natural, with disturbed land cover representing less than 1%, which is exclusively related to road or residential development. This is the largest percent of natural land cover of all the sub-basins within the Mighty Peace watershed.

TABLE 45: RIPARIAN LAND COVER FOR SLAVE RIVER AND PAD SUB-BASIN

Slave River	Developed	Agriculture	Natural
Area (km^2)	14	0	3,222
Percentage	0.4%	0.0%	99.6%

Biological Community

Fish Population

With 18 different fish species captured, the Slave PAD sub-basin had the lowest number of captured fish species. It also had the fewest captured non-native species (1). This again may be the result of lower catch efforts, although the PAD does support regional commercial, domestic and sport fisheries for residents. It should be noted that a great deal of data are lacking from this sub-basin; no data exist for bull trout and data for walleye are only available for the PAD. Arctic grayling presence is suspected. The only species investigated with confidence in the densities was goldeye, and the numbers were low for this species (Table 46). The reason for low numbers has not been reported.

TABLE 46: BREAKDOWN OF FISH SPECIES FOUND WITHIN THE SLAVE PAD SUB-BASIN

Total Number of Fish Species captured	18
Species of management concern or species at risk	2
Non-native, naturalized, stocked or dispersal from BC	1

Note: Data from Johnson and Wilcox (2012)

Fish community composition in Mamawi and Claire Lakes has been constant and stable. Information on fish community structure in Mamawi – Claire Lakes has been documented since 1947 providing a good data source to use as a standard for assessing trends and conditions (AECOM 2009). Goldeye are the most abundant large fish in the delta and its abundance was assessed as good based on the catch per unit efforts documented (AECOM 2009).

Walleye is also an important fish species in the PAD and provides the greatest economic return. Based on the Walleye catch documented yearly since 1943, the catch limits identified for this species were being met and the walleye fish abundance was assessed as good with no detectable trend (AECOM 2009).

TABLE 47. FISH DENSITY WITHIN THE SLAVE SUB-BASIN (INCLUDING THE PAD)

Fish Species	Habitat Type	Habitat Preference	Density	Uncertainty
Goldeye	Lotic (river)	Sizeable rivers, clay-induced turbidity of waters, rapid current (Government of Ohio).	Low	Low
Walleye	Lotic (river)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g., gravel shoals, bedrock, reefs)	Rare, Present in large rivers of the PAD	
Bull trout	Lotic (river)	Rivers of good water quality, cool with rapid current, substrate comprised of medium to large debris, favour pools and riffles (SCCP 2010)	No data	
Arctic grayling	Lotic (river)	Cool rivers with ample pool habitats (U.S. Fish and Wildlife Services 1985.	Presence Suspected, found in an unnamed PADlocation	High
Walleye	Lentic (lake)	Sizeable rivers and or lakes, waters ranging through minimal turbidity, bottoms are solid and comprised of various composition (e.g., gravel shoals, bedrock, reefs)	Rare, Present in large lakes of thePAD	

Note: Data from Johnson and Wilcox (2012) and AECOM (2009)

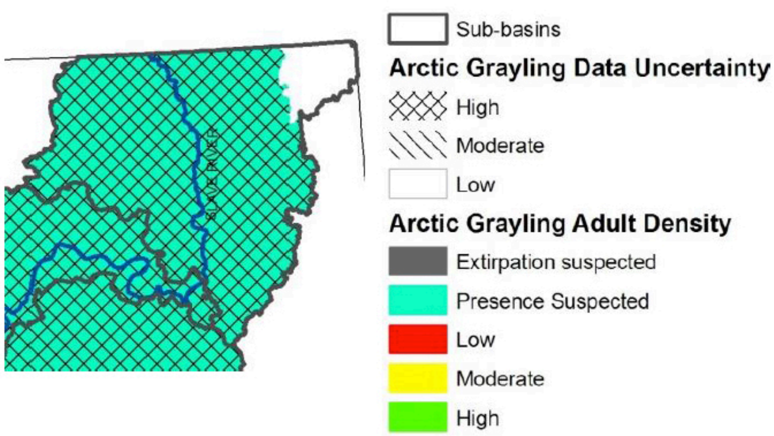

FIGURE 37. ADULT DENSITY OF ARCTIC GRAYLING IN THE SLAVE RIVER SUB-BASIN

Invasive Species

A total of 60 unique non-native species has been documented in Wood Buffalo National Park

(AECOM 2009). Four plant species have been studied in greater detail in conjunction with PAD vegetation studies and research projects. They are Canada thistle (*Cirsium arvense*) and perennial sow thistle (*Sonchus spp.*), which are both highly competitive, and broadleaved plantain (*Plantago major*) and Kentucky blue-grass (*Poa pratensis*), which invade disturbed areas. Observations of these species are lacking from surveys in the 1930s but have generally been increasing since the 1990s. The presence and establishment of invasive species in the PAD can be attributed to internal (e.g. bison activities) and external factors (e.g. northern expansion of agriculture) (AECOM 2009). We note that these species occupy terrestrial habitat and may not be a threat to aquatic ecosystems themselves. The fact that they have spread to the PAD, however, may indicate that aquatic invasive species may have spread to the area as well, following similar invading paths.

SUMMARY OF AQUATIC ECOSYSTEM STATUS ACROSS THE PEACE BASIN

In the previous sections, status of aquatic ecosystems in the Peace River Basin in Alberta was presented by sub-basin and the interactions between different landscape drivers and aquatic ecosystem indicators were discussed on relatively small scales. In this section, we will discuss the indicators in the context of the entire basin, compare sub-basins to each other and evaluate spatial patterns in indicator status in relation to large-scale distribution of natural conditions and human activities.

River Water Quality

There is a large variety of streams and rivers in the Peace Basin. They range from small headwater streams in forested and agricultural, lowland and mountainous regions to large rivers such as the Wapiti, Smoky and Wabasca, as well as large and wide river reaches in the lower Peace and Slave. Water source and quantity largely determines water quality and its susceptibility to human impacts in running waters in the Peace Basin. Seasonal flow patterns also influence seasonal water quality trends.

Large rivers such as the Peace, Wapiti and Smoky have their headwaters and major water source in high-elevation mountain regions, which are characterized by high precipitation, thin and poor soils and little development. They therefore carry large volumes of nutrient-poor waters. Only large human inputs, such as the point sources in the lower Wapiti River, have a significant impact on water quality. The impacts of the Grande Prairie sewage treatment plant and the Weyerhaeuser pulp mill on the lower Wapiti River are a well-studied example of cumulative effects of multiple discharges on a river. Historically, discharge of toxic dioxins and furans and high oxygen demand (BOD) were the main concerns in pulp mill effluent, but since reduction of these compounds following the introduction of effluent limits, toxic and DO effects have declined and nutrient effects are now the primary impact of concern. Multiple studies have shown nutrient enrichment leading to higher primary (algae) and secondary (animal) aquatic productivity, increased dissolved solids and increased organic matter as well as lower biodiversity and larger diurnal dissolved oxygen fluctuations (Alina Wolanski, pers. communication) in the lower Wapiti River. The Daishowa-Marubeni International (DMI) Kraft pulp mill discharges into the central Peace River reach, downstream of the town of Peace River, but Environmental Effects Monitoring did not detect a significant difference in nutrient and DO levels between sites upstream and downstream of the mill (North/South Consultants 2007). This difference in point-source effect may be due to the larger Peace River flow compared to the Wapiti River.

These rivers carry seasonally high flows in early summer, during peak snow melt in the mountains, when the rivers hold large amounts of sediments and associated substances, such as metals and nutrients. For example, TP concentrations are related to TSS concentrations in most rivers during high flows (Figure 38). During low flows, dissolved ion content is highest, due to larger relative importance of groundwater and, where applicable, increased impact of point-source discharges.

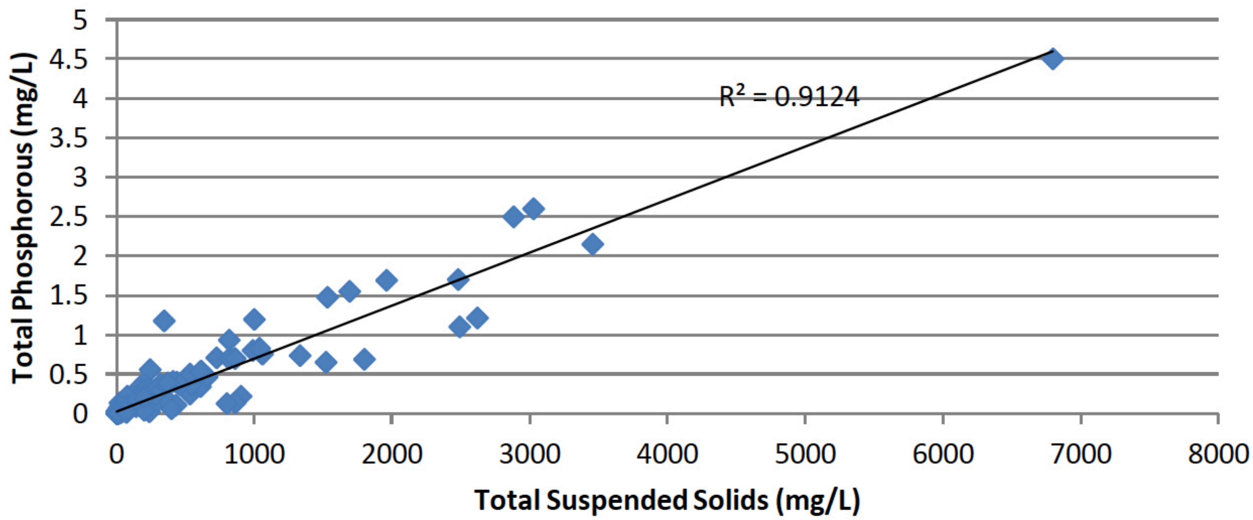

FIGURE 38. TSS-TP CORRELATION IN PEACE RIVER AT FT. VERMILION
Data source: LTRN data provided by AESRD.

The Peace River remains generally low in nutrients, but a synoptic survey conducted in 1988 showed that concentrations of total and dissolved constituents in the Peace River progressively increase from upstream to downstream, with relatively little increase of dissolved constituents and relatively high increase of particulate matter (Shaw et al.1990). These longitudinal data in the Peace River are outdated by 25 years now, however, and it is unclear if these trends have persisted after significant improvements of point-source effluent quality (e.g., pulp mills) and any trends in non-point sources that may have occurred.

Statistical comparison of LTRN data from low-flow periods (August – March) 2006-2012 upstream of the Smoky confluence and at Fort Vermilion, paired by sampling event, showed increases in TP and TDP, but only the TDP increase was statistically significant (Table 48). Both parameters show an increase in median, but the slightly higher variability in TP data (coefficient of variation for TP = 0.8 and 0.9, for TDP = 0.6) possibly reduced the power of the test to detect a significant difference.

TABLE 48. STATISTICAL COMPARISON OF LOW-FLOW TP AND TDP DATA BETWEEN LTRN SITES IN THE PEACE RIVER

	Low-Flow Median Upstream of Smoky	Low-Flow Median Fort Vermilion	Significance of Difference (p-value)*
TP	0.009	0.012	0.29
TDP	0.004	0.005	**0.012**

*P-values highlighted by bold type are statistically significant at alpha = 0.05, as estimated by a Wilcoxon signed rank test, the non-parametric equivalent of a paired t- test.

Data sets from Environment Canada monitoring stations upstream of the BC-AB border and at Peace Point in Wood-Buffalo National Park were much more scattered and did not provide much overlap with the LTRN data sets. Comparisons of TP and TDP for low-flow periods from August 2009 through December 2010 show that TP decreased from the border to the Smoky R.

confluence, then increased slightly downstream of the Smoky River confluence, with an additional, larger increase from Ft. Vermilion to Peace Point (Figure 39). Given the large volumes of Peace River in this reach and the absence of large point-source discharges, the reason for the latter increase is not clear. Main water sources in this reach include the Boyer River, which has its headwaters in wetland-rich areas and then drains most of the settled area north of the Peace River, including the community of High Level.

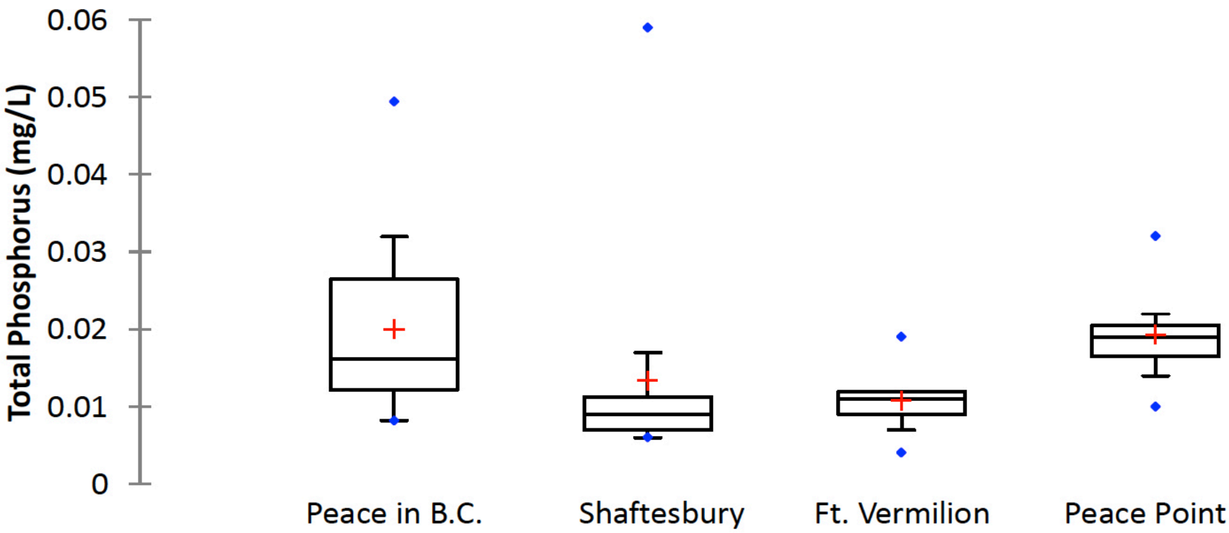

FIGURE 39. SPATIAL DIFFERENCES IN TOTAL PHOSPHORUS IN THE PEACE RIVER UNDER LOW FLOW (AUGUST 2009-DECEMBER 2010)

More data, in particular synoptic surveys during the three main flow seasons (winter, spring/summer, fall, Glozier et al. 2009), including monitoring of water quality of main tributaries, and a formal trend analysis on LTRN datasets, would be required to more accurately describe water quality changes along the Peace River from tributary, point- and non-point source inputs. The significant increase in TP from Ft. Vermillion to Peace Point requires verification and further study.

Water quality in small, forested streams in the Peace Basin is poorly known, but where data exist, they show generally nutrient-rich conditions in the absence of human impact, likely from the naturally-occurring nutrient-rich soils and large amount of wetlands in the basins. Streams located in agricultural watersheds in the upper and central Peace and the northern Smoky-Wapiti watersheds also have high nutrient concentrations and low oxygen levels (Lorenz et al. 2008, AECOM 2009), with higher nutrient levels and lower oxygen than in forested streams in the same ecoregion (Norris 2013). These changes, in conjunction with habitat deterioration from linear development, resulted in locally extirpated Arctic Grayling populations in the Beaverlodge River watershed (AECOM 2009, Johnson and Wilcox 2012). Water quality deterioration in highly developed watersheds in the Peace Basin is therefore locally established, but it is unknown how representative these patterns are for other developed areas. Given high natural nutrient levels in undeveloped streams, it is also unknown to what degree these changes have occurred and what the thresholds in terms of human stressors are that would turn a healthy into an unhealthy stream. Seasonal highs in flow occur naturally during spring runoff, resulting in higher particulate loads and hence nutrient concentrations.

Coliforms were generally low in the major rivers and more elevated in smaller rivers and streams. Similar to nutrient and other inputs from human activities as described above, large rivers have a large dilution capacity such that small inputs would not be detectable. Persistence of bacteria in the environment is favored by cool temperatures and high organic content, so under spring freshet conditions, high bacteria levels in small streams would mean a possible source of contaminants for downstream users of stream water.

LAKE WATER QUALITY

Lakes are an important feature of the landscape in the Peace Basin. The Peace basin is mostly covered by forested ecoregions, which are naturally rich in lakes, and small areas of parkland and delta ecoregions, which also host many lakes and ponds. The largest percentage cover of lakes can be found in the Wabasca and Slave River sub- basins, while the lowest percentage cover of lakes is located in the Upper Peace Basin (Figure 40), as indicated by a GIS analysis. There were about 70,000 lakes counted in total in the Peace basin, 0.2 % of which were included in the spatial comparisons in this section. Individual sub-basin representation ranged from 0.2 % in the Wabasca and Lower Peace sub-basins to 0.7 % in the Upper Peace sub-basin.

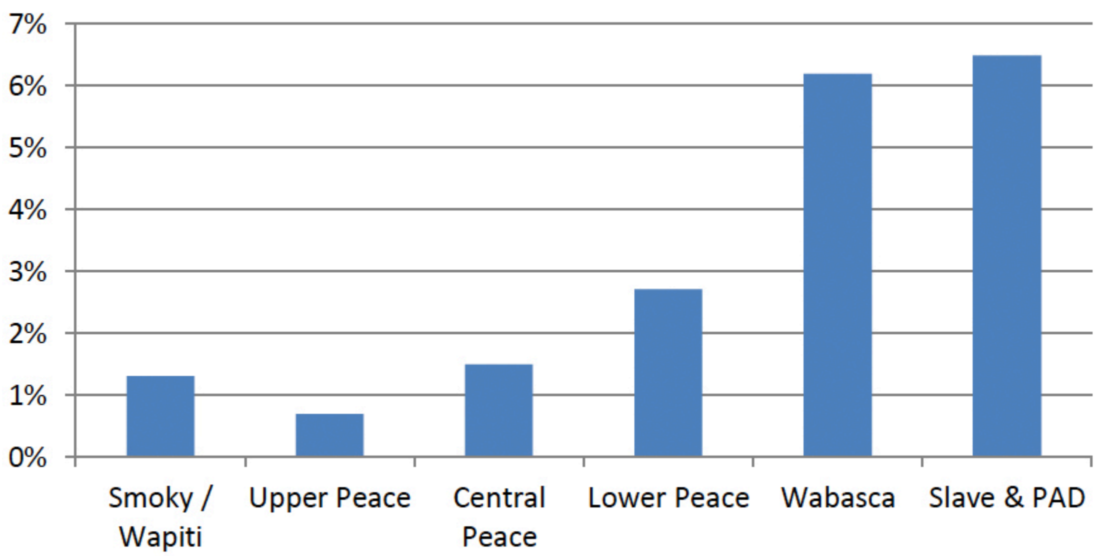

FIGURE 40. PERCENT COVER OF LAKES IN THE PEACE BASIN BY SUB-BASIN

Note: This information was derived from the MPWAC.shp (Peace River subbasins) and the BaseWaterbodyPolygon.shp layers provided by AESRD.

Lakes in the Upper Peace sub-basin had the highest mean concentrations of chlorophyll *a,* TP, TDP and TDS. This area is characterized by medium to high organic soils, saline soils, the longest frost-free season, and high agricultural intensity. High nutrient and salinity levels in soils causes naturally nutrient and ion-rich surface waters, their delivery to surface water bodies is accelerated by land use practices and their levels are increased by fertilizer and manure application and livestock operations. Long frost-free periods result in longer ice-free periods in lakes, prolonging time for aquatic productivity to occur and therefore for algae growth to proliferate. Therefore lake water quality reflects the combination of natural settings and land use in this sub-basin.

Lakes in the Smoky-Wapiti, Central Peace and Wabasca sub-basins were similar and had, on average, lower concentrations of TP, TDP and TDS. These sub-basins encompass larger areas of medium organic soils and average frost-free period (across sub-basins) as well as larger forested areas. The largest range in chlorophyll *a*, TP and TDP was observed in the Smoky-Wapiti sub-basin (Figures 41 to 44), reflecting the large variety of natural regions (montane, foothills, mixedwood to parkland) and degree of human impact (pristine to high density oil and gas and high agricultural intensity) in this sub-basin.

Lakes in the Central and Lower Peace sub-basin had the lowest mean concentrations of all parameters investigated, but the low sample size does not allow conclusions in terms of difference to other sub-basins. Lakes in the Slave River Basin have a variety of chemical characteristics, due to the variety of lake types encountered, including shield lakes, muskeg lakes, sinkhole (or karst) lakes and delta lakes.

Overall, the lakes with three or more samples showed the same spatial patterns as the datasets based on all lakes. The absolute values for the latter datasets, however, were often higher, indicating a sampling bias of lakes with higher nutrient and chlorophyll *a* concentrations. This may be due to easier access to affected sites in settled regions versus more difficult access to less affected sites in remote regions. These results indicate that while several samples per lake are preferable to describe that individual lake's water quality, larger datasets based on one or more samples per year are more representative of a region's lake population for the purpose of comparing water quality on a sub-basin scale.

When comparing sub-basin lake water quality averages with Peace basin averages, the general patterns described above remain, but the Smoky-Wapiti sub- basin has the highest values above average and the Wabasca sub-basin ranked among the sub-basins below average. Average values are highly influenced by extreme values, which occurred in the Smoky-Wapiti basin (e.g., Saskatoon Lake with very high TP, chl *a* and TDS). Therefore we use median values and percentiles in the lake datasets to draw conclusions that are representative for the majority of lakes.

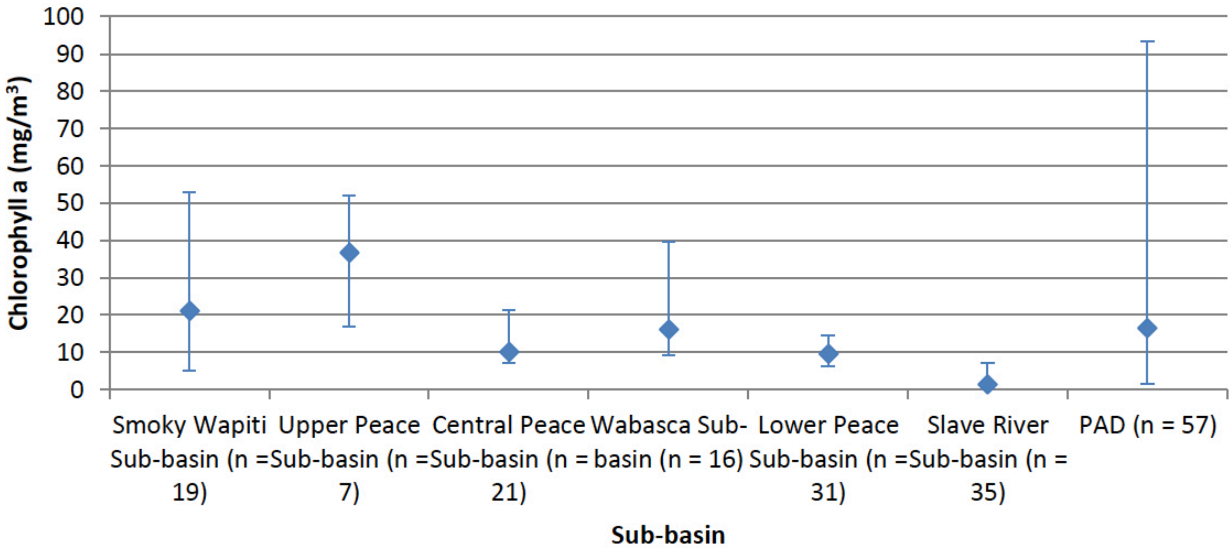

FIGURE 41. MEDIAN CHLOROPHYLL *a* CONCENTRATIONS OF LAKES BY SUB-BASIN – COMPLETE DATASET

Error bars represent 25th and 75th percentiles. Slave River and PAD values are means with error bars representing minimum and maximum values.

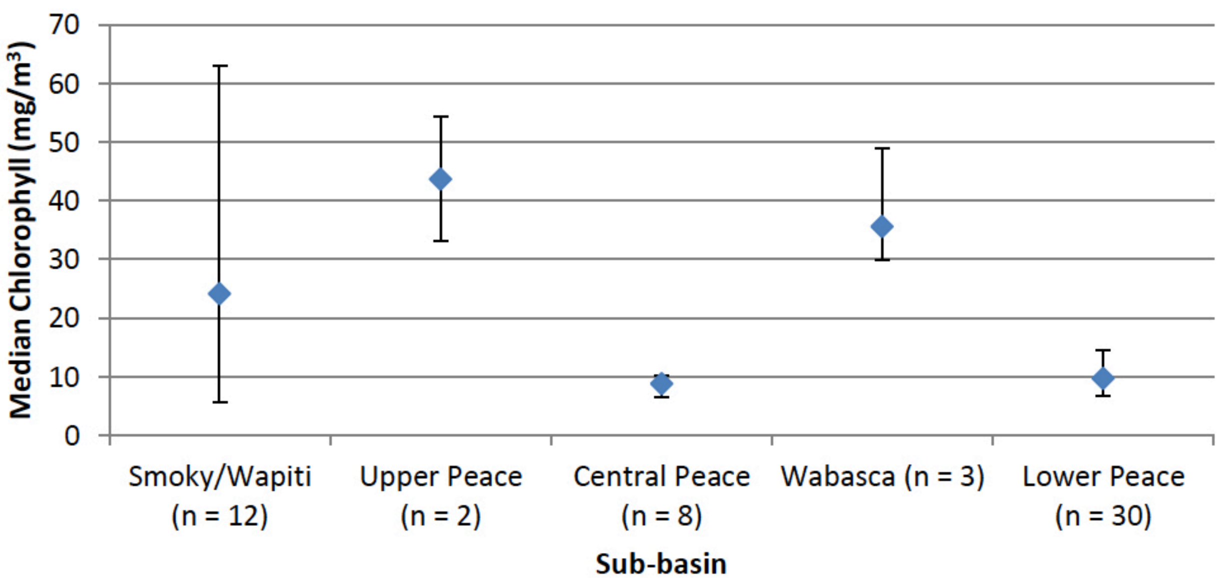

FIGURE 42. MEDIAN CHLOROPHYLL A CONCENTRATIONS OF LAKES BY SUB-BASIN – LAKES WITH AT LEAST THREE SAMPLES IN THE MOST RECENT SAMPLING YEAR

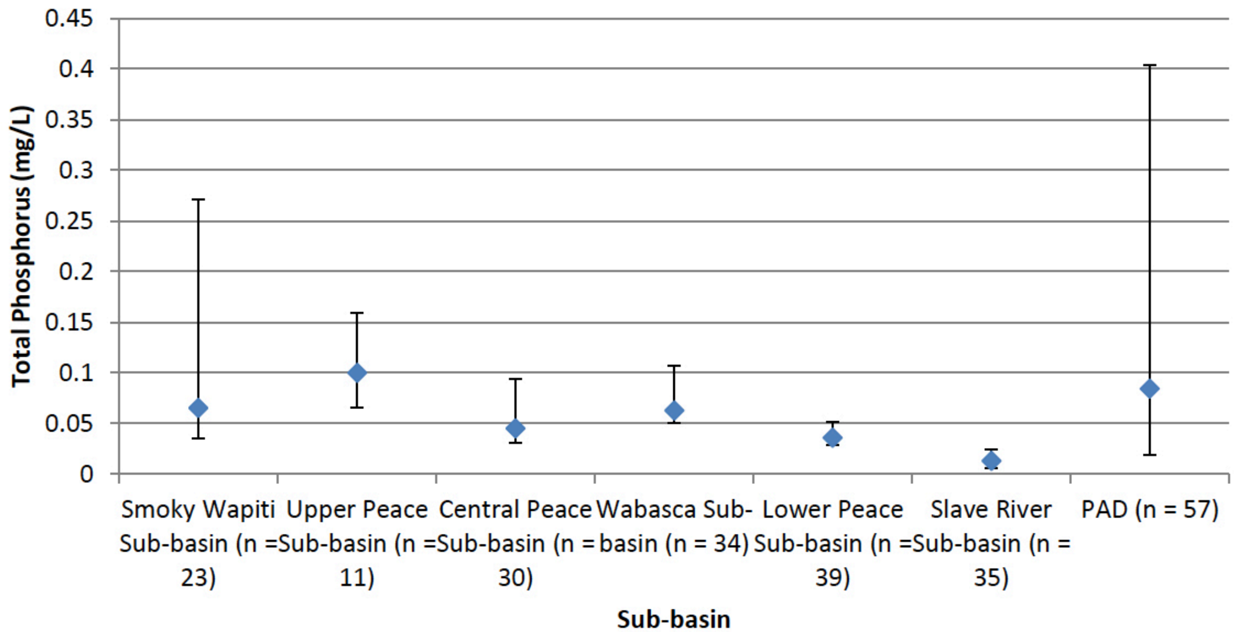

FIGURE 43. MEDIAN TOTAL PHOSPHORUS CONCENTRATIONS OF LAKES BY SUB-BASIN

Error bars represent 25th and 75th percentiles. Slave River and PAD values are means with error bars representing minimum and maximum values.

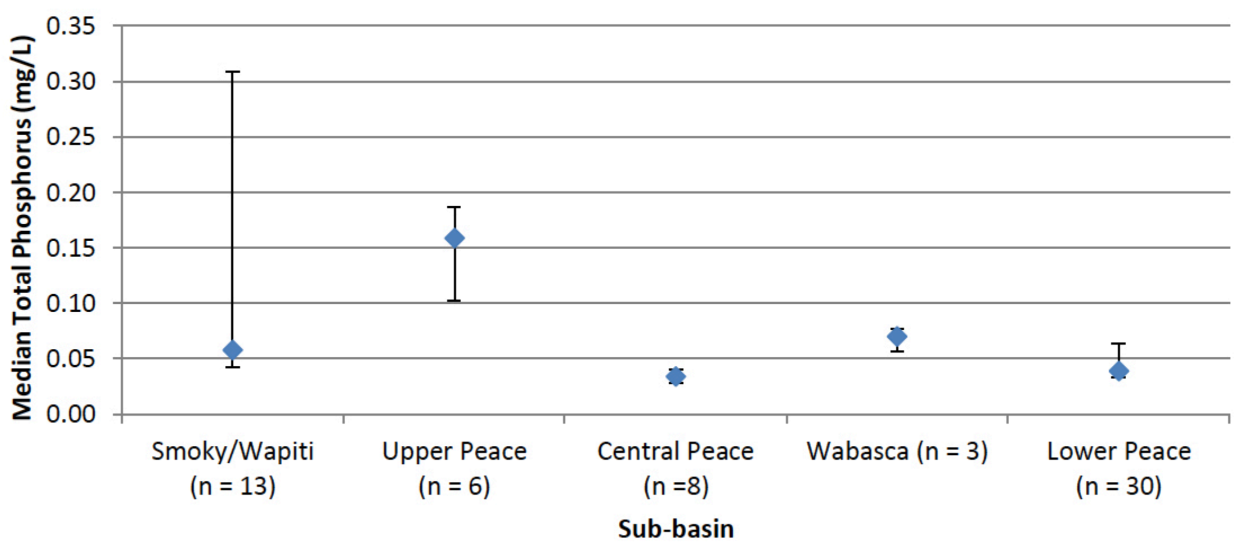

FIGURE 44: MEDIAN TOTAL PHOSPHORUS CONCENTRATIONS OF LAKES BY SUB-BASIN, ONLY LAKES WITH AT LEAST THREE MEASUREMENTS OVER THE YEAR

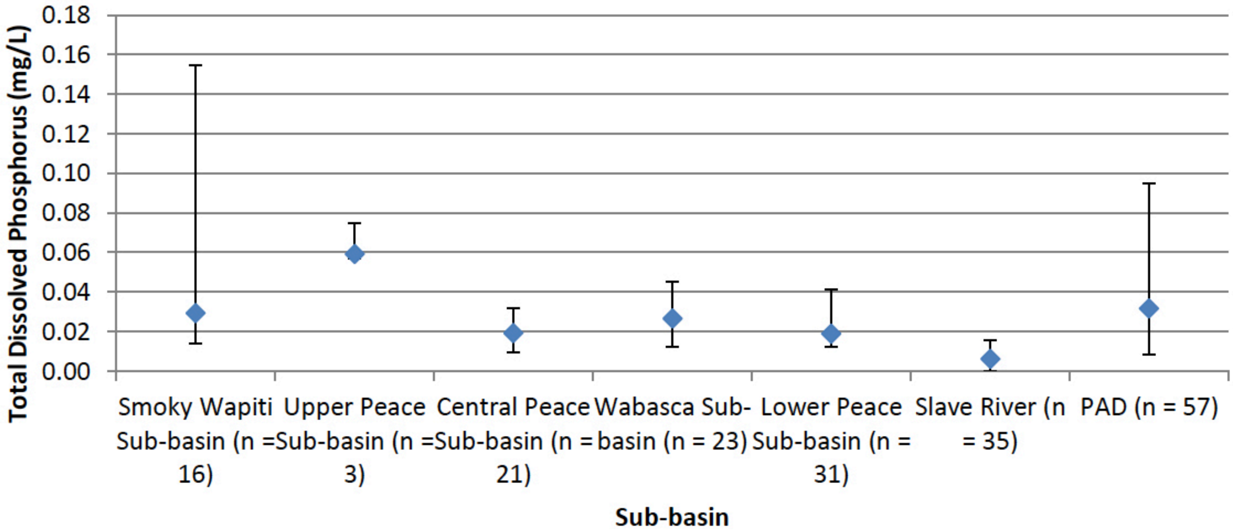

FIGURE 45: MEDIAN TOTAL DISSOLVED PHOSPHORUS CONCENTRATIONS OF LAKES IN EACH SUB-BASIN – COMPLETE DATASET

Error bars represent 25th and 75th percentiles. Slave River and PAD values are means with error bars representing minimum and maximum values.

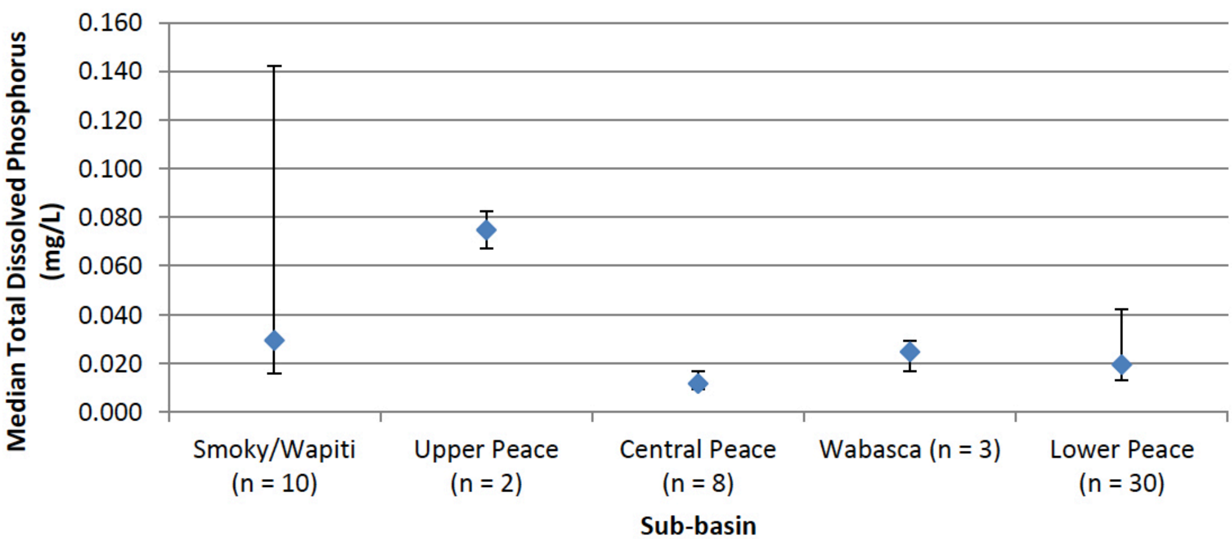

FIGURE 46. MEDIAN TOTAL DISSOLVED PHOSPHORUS CONCENTRATIONS OF LAKES IN EACH SUB-BASIN – LAKES WITH AT LEAST THREE SAMPLES

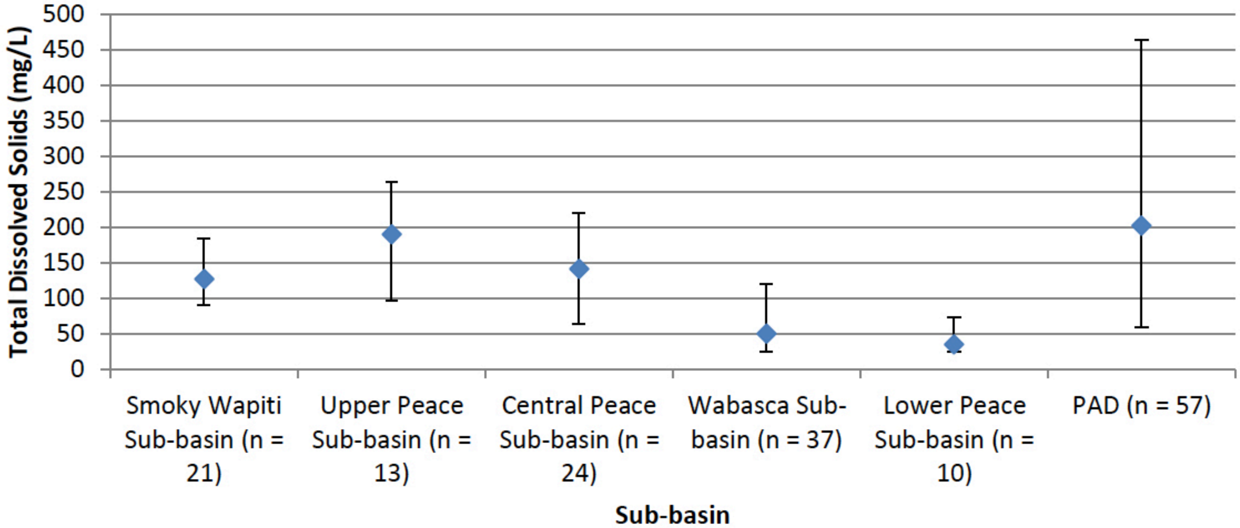

FIGURE 47. MEAN TOTAL DISSOLVED SOLIDS CONCENTRATIONS OF LAKES BY SUB-BASIN – COMPLETE DATASET.

Error bars represent 25th and 75th percentiles. PAD value is the mean with error bars representing minimum and maximum values.

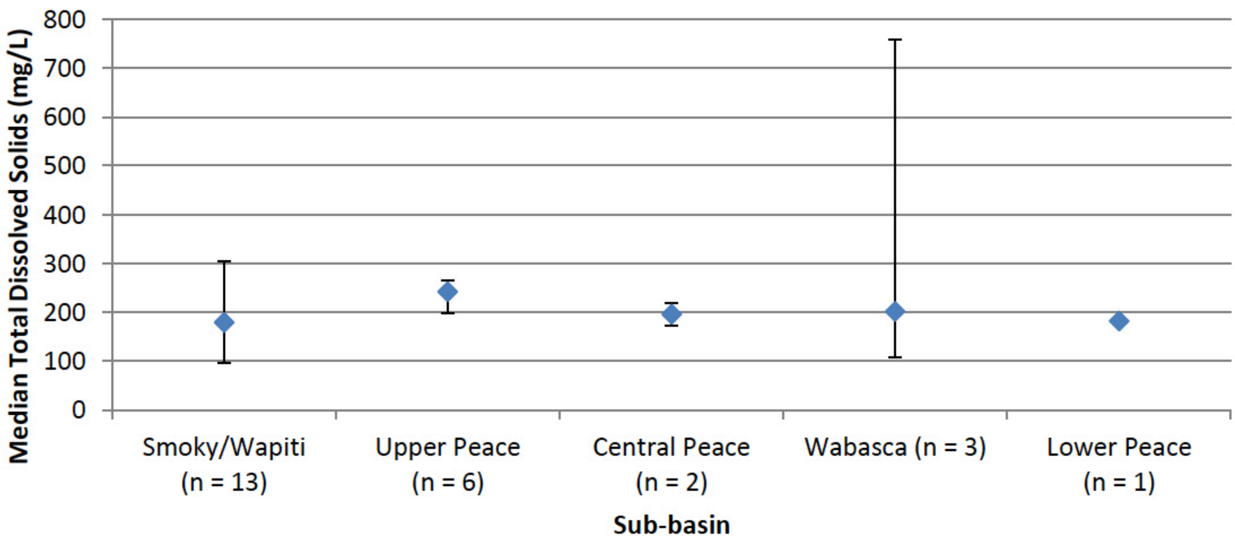

FIGURE 48. MEAN TOTAL DISSOLVED SOLIDS CONCENTRATIONS OF LAKES BY SUB-BASIN – LAKES WITH AT LEAST THREE SAMPLES IN MOST RECENT SAMPLING YEAR.

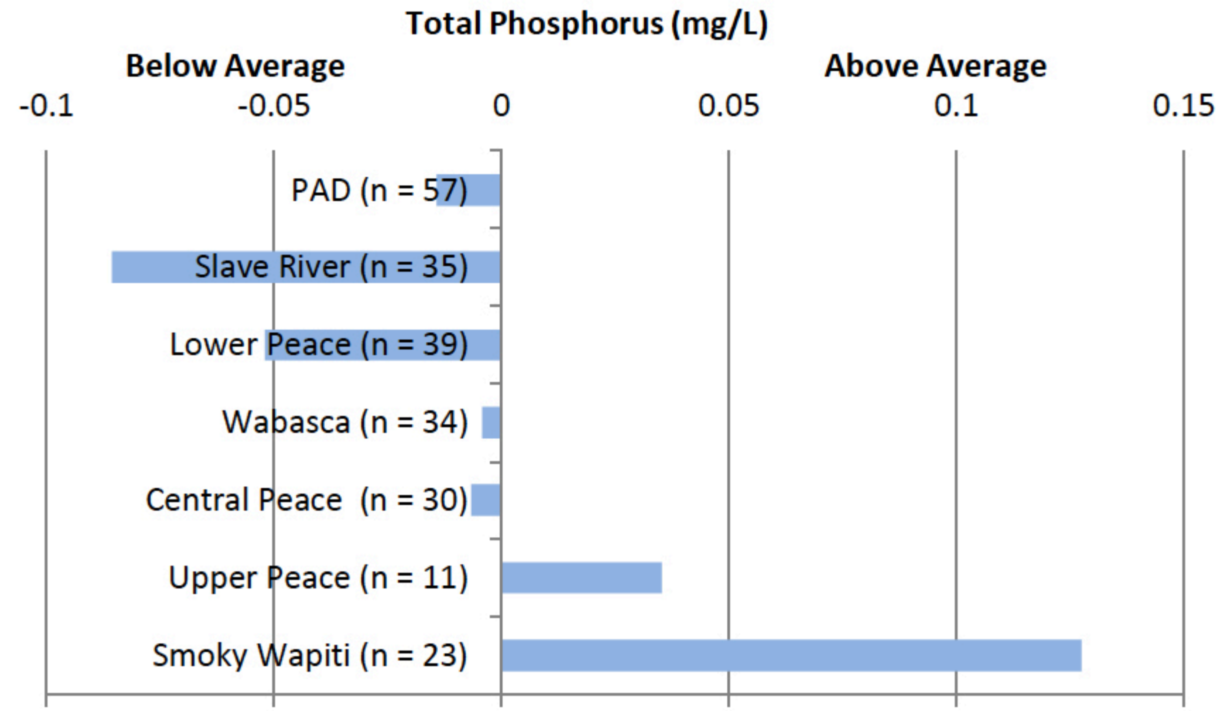

FIGURE 49. COMPARISON OF SUB-BASIN AVERAGE LAKE TP WITH PEACE BASIN AVERAGE LAKE TP (COMPLETE DATASET)

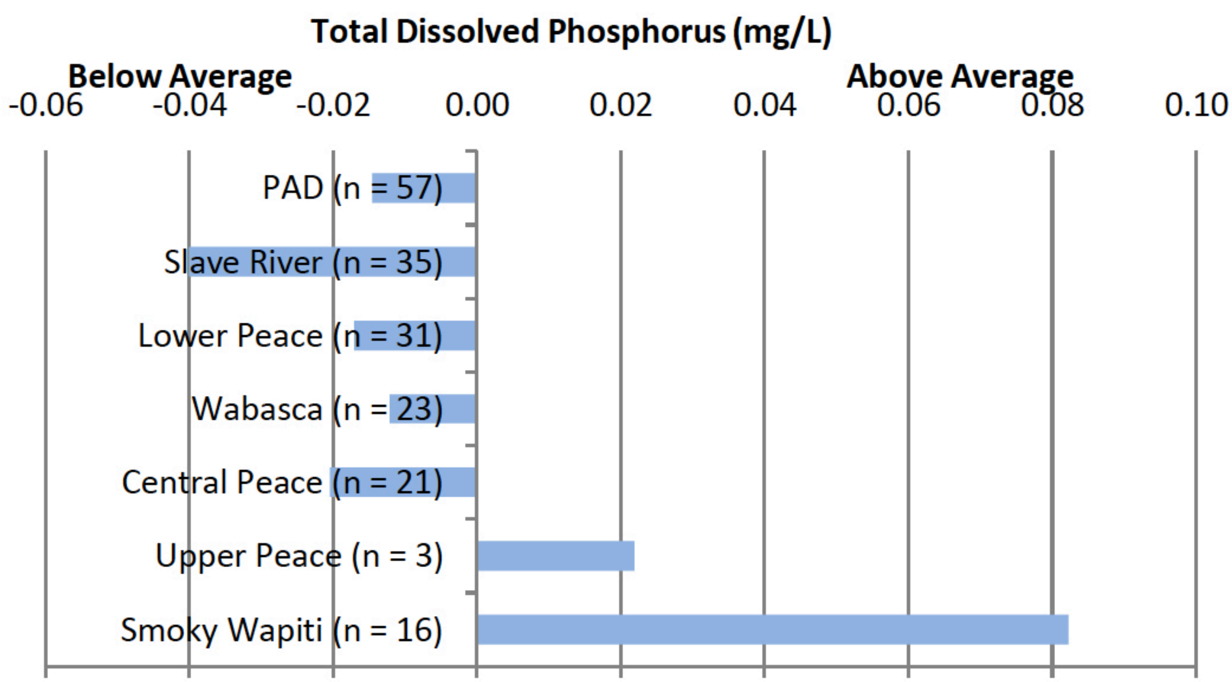

FIGURE 50. COMPARISON OF SUB-BASIN AVERAGE LAKE TDP WITH PEACE BASIN AVERAGE LAKE TDP (LAKES WITH THREE SAMPLES IN MOST RECENT YEAR ONLY)

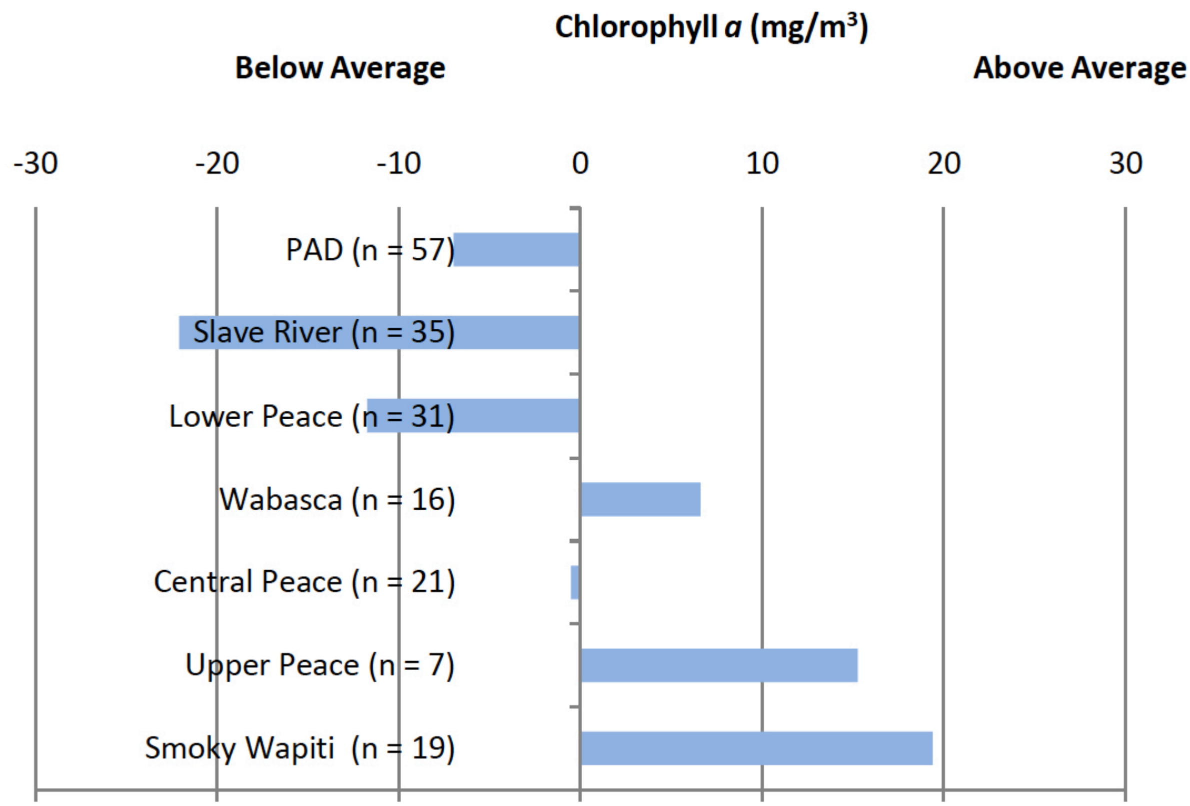

FIGURE 51. COMPARISON OF SUB-BASIN AVERAGE LAKE CHLOROPHYLL-A WITH PEACE BASIN AVERAGE LAKE CHLOROPHYLL A (COMPLETE DATASET)

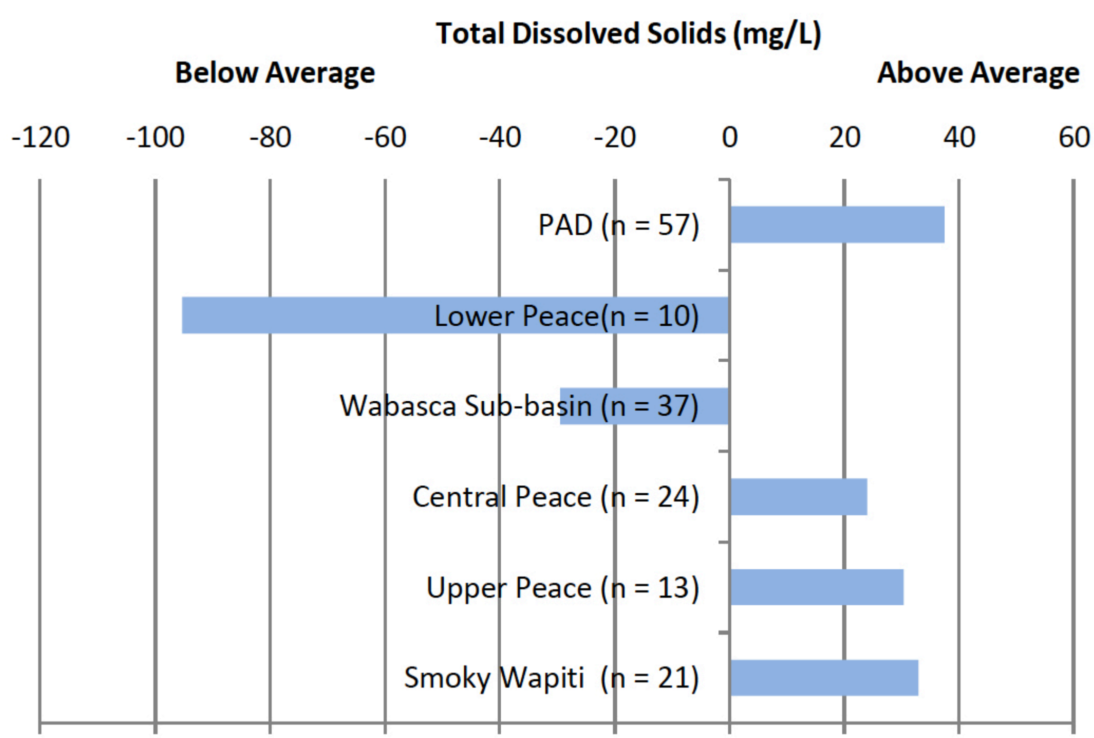

FIGURE 52. COMPARISON OF SUB-BASIN AVERAGE LAKE TDS WITH PEACE BASIN AVERAGE LAKE TDS (COMPLETE DATASET)

Wetland Cover And Health

The Wabasca sub-basin has the greatest percent of wetland cover, as well as the greater percent coverage of bog, fen and swamp wetland types. The Upper Peace has the lowest wetland coverage of all the sub-basins, likely because the largest portion of this watershed that has been cultivated, which is usually accompanied by significant wetland loss (Watmough and Scholl 2007). Swamp coverage comprises the greatest percent of wetland cover for all sub-basins with the exception of the Lower Peace and Slave River sub-basins. The Slave River sub-basin has the greatest percent of open water coverage, probably due to the large number of lakes and open-water wetlands in the Peace-Athabasca Delta (Figure 53).

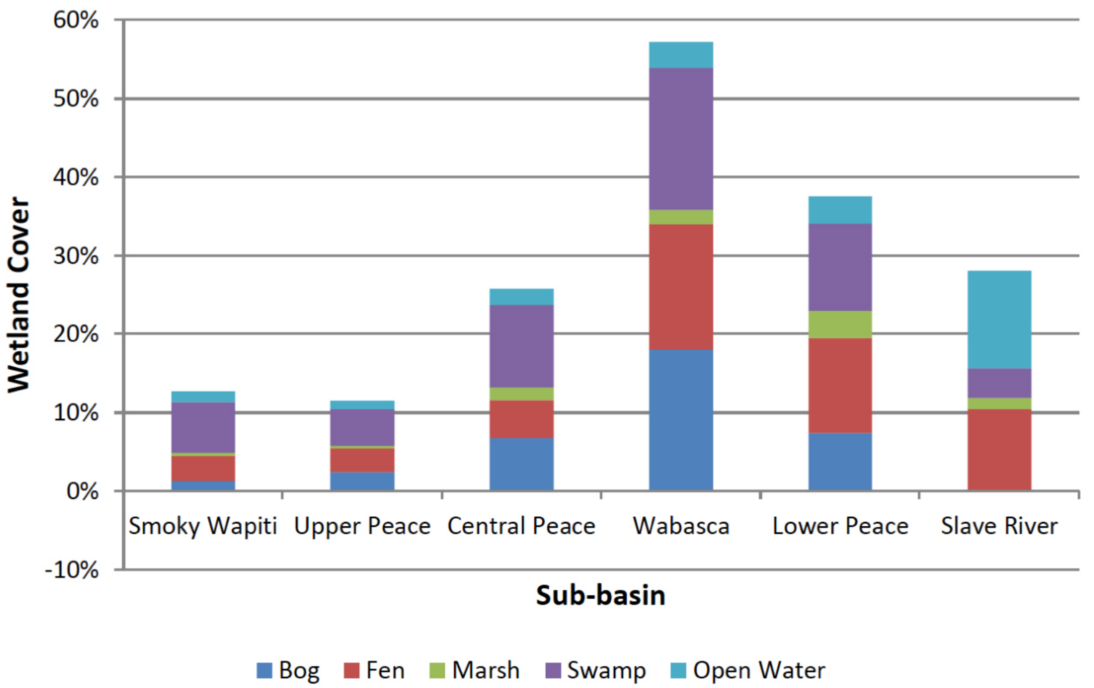

FIGURE 53. PERCENTAGE OF WETLAND COVER BY WETLAND TYPE AND SUB-BASIN

The Upper Central Peace sub-basin contained the greatest percentage of disturbed wetlands. Over 80% of the 16 wetlands surveyed in this sub-basin had been disturbed. Interestingly, the type of disturbance in this sub-basin consisted mainly of agriculture-related drainage, while linear disturbance related to energy sector activities dominated the 30% of wetlands that were found disturbed in the Wabasca sub-basin. The wetlands in the Smoky/Wapiti sub-basin have also encountered a large percentage of disturbance (75%), with linear disturbance from the energy sector dominating, but it should be noted that the ABMI sites monitored were all located in the south-central, forested part of the Smoky-Wapiti sub-basin. None of the Slave River wetlands surveyed experienced any disturbance (Figure 54).

Overall, both wetland cover and health appeared to correlate with human land use in the sub-basins. The ABMI wetland sites, however, are not equally distributed among sub-basins and within sub-basins, so it will be important to revisit these data once the complete sampling grid has been surveyed by the ABMI.

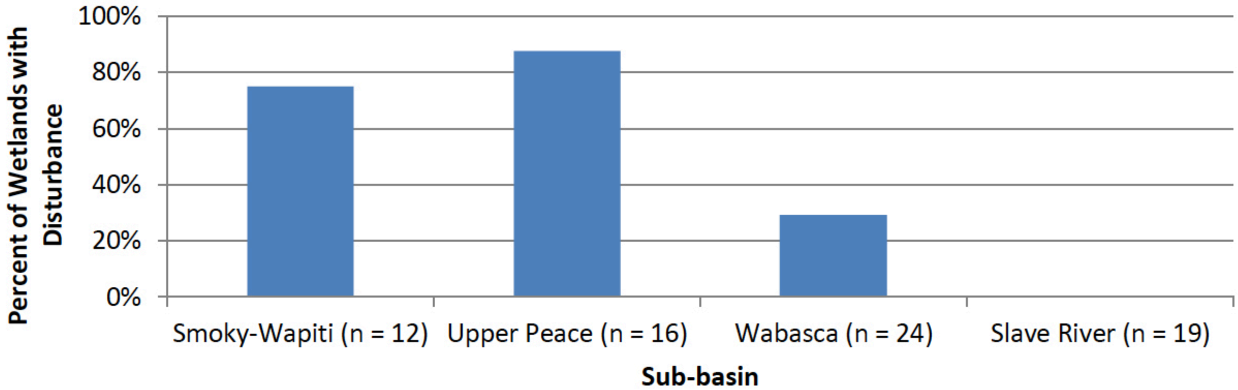

FIGURE 54. PERCENT OF WETLANDS WITH OBSERVED DISTURBANCE BY SUB-BASIN (DATA FROM ABMI).

Note: No data were available for the Central and Lower Peace sub-basins at the time of reporting.

Wetland loss is unknown in the Peace Basin, but a representative study of prairie regions in central and southern Alberta, Saskatchewan and Manitoba indicated that about 5% of wetlands were lost in these ecoregions from 1985 to 2001, which is likely representative for the White Zone in the Peace Basin. In addition, more wetland loss has likely occurred due to land clearing and cultivation since the time of European settlement prior to 1985. For the Green Zone, no direct data on wetland loss were available, but the wetland data collected by ABMI indicated widespread wetland disturbance and therefore likely loss of wetland function in the Wabasca and Smoky-Wapiti sub-basins from linear disturbance associated with the energy sector. Similar effects on wetlands in areas across the basin with similar disturbance patterns are likely. Basin-specific data are required to confidently assess the degree of wetland loss in the Peace basin.

Riparian health

Land cover in riparian areas in five out of the seven sub-basins was primarily natural (> 90% in the Central, Lower Peace, and Wabasca sub-basins and 100% in Slave River and PAD. This is largely a result of extensive remote forested areas in the Peace Basin and a large coverage of National Parks. Also, logging operations are subject to riparian setback regulations (e.g., the Forests Act and Timber Management Regulation, AESRD 2012), such that logging, one of the large-scale land disturbances in these areas, has limited effect on riparian areas.

The highest percentage of riparian disturbance, at almost 50%, was found in the Upper Peace sub-basin, followed by the Smoky-Wapiti sub-basin, where about a quarter of the sub-basin has agricultural or developed land cover. The majority of the agricultural land in these two sub-basins is cropland (Figure 55) and as such, impacts such as loss of natural vegetation, erosion and loss of hydrological function are likely more pronounced. In these two sub-basins, the percentage of agricultural land cover is higher in riparian areas than in the overall watershed (Figure 56) compared with sub- basin land cover), indicating that riparian areas may have been preferentially selected for agricultural practices, possibly due to their proximity to water.

In the Central and Lower Peace Basin, the agricultural cover in riparian areas was slightly lower than the overall sub-basin cover. This may indicate that in these basins, some riparian areas in agricultural regions have been left intact.

In conclusion, the spatial patterns of land use in riparian areas follow general land use patterns in the Peace Basin, similar to wetlands. While impacts of linear developments were observed in wetlands, riparian areas did not appear to be affected by linear development to the same degree in forested areas of the Peace Basin.

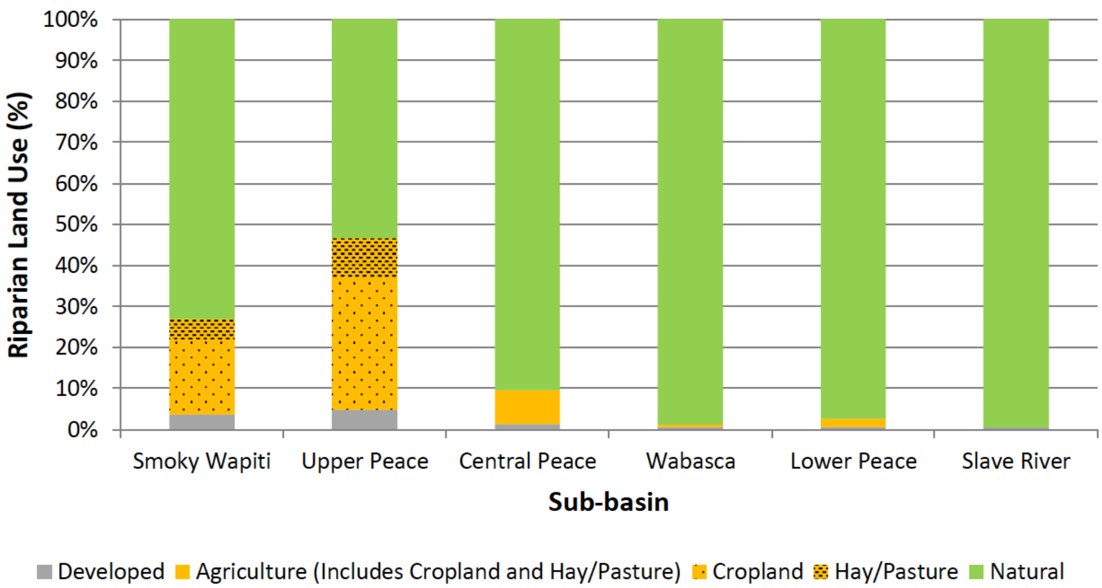

FIGURE 55. PERCENT OF RIPARIAN LAND USE BY SUB-BASIN

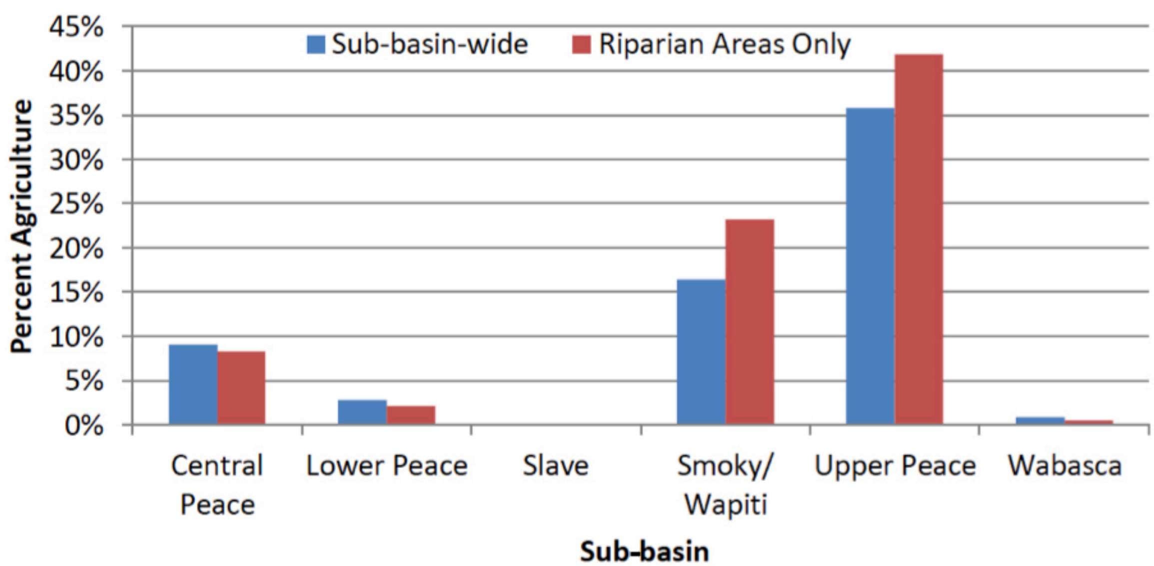

FIGURE 56. AGRICULTURAL LAND COVER IN RIPARIAN AREAS COMPARED TO SUB-BASIN LAND COVER

Fish Populations

In the previous sections, we summarized fish density and data uncertainty presented in Johnson and Wilcox (2012) by sub-basin in order to discuss fish occurrence in relation to the status of other aquatic ecosystem indicators. Basin-wide maps for the key focal species Arctic grayling, goldeye, walleye and bull trout were included in Johnson and Wilcox (2012). The maps of Arctic grayling and walleye density and associated data uncertainty are reproduced here as representative examples of spatial patterns in population health in relation to habitat preference and land use (Figures 57 and 58).

The estimated densities of adult Arctic grayling range from suspected extirpated to high densities (Figure 57), which is a result of the diversity of habitats in the basin and a large range of land uses. Arctic grayling have a preference for headwater streams, which coincide with remote, undeveloped areas. In these areas, high to moderate densities (i.e., low to moderate risk) were observed, with the exception of the population in the Little Smoky River, where the population has persisted at higher densities despite human land use, which may in part be due to fisheries regulations (catch and release for angling (2011 Alberta Sportfishing Regulations)). Populations of lower density were observed in areas with increased water access or land use, or possibly where habitats are less suitable. Local extirpations are suspected in the areas adjacent to Grande Prairie, including the Redwillow and Beaverlodge Rivers (AECOM 2009) in the Smoky-Wapiti sub-basin. These areas are subject to human impact on the landscape, including agriculture, forestry and oil and gas (AECOM 2009).

Walleye have been caught throughout most of the Peace Basin (Figure 58), except in the upper headwaters of the Smoky-Wapiti sub-basin and one relatively large portion of the Wabasca sub-basin. Walleye occupy both river and lake habitats and likely create the most significant sport fisheries in both habitat types. River walleye density appears to depend mostly on habitat availability, with moderate to high densities in lower reaches of the Wapiti and Little Smoky Rivers and all reaches of the Peace River and low densities in headwaters where smaller water bodies dominate. Lake walleye densities, on the other hand, occurred with low to moderate densities across all sub-basins, possibly showing a strong susceptibility to fishing pressure (Johnson and Wilcox 2012).

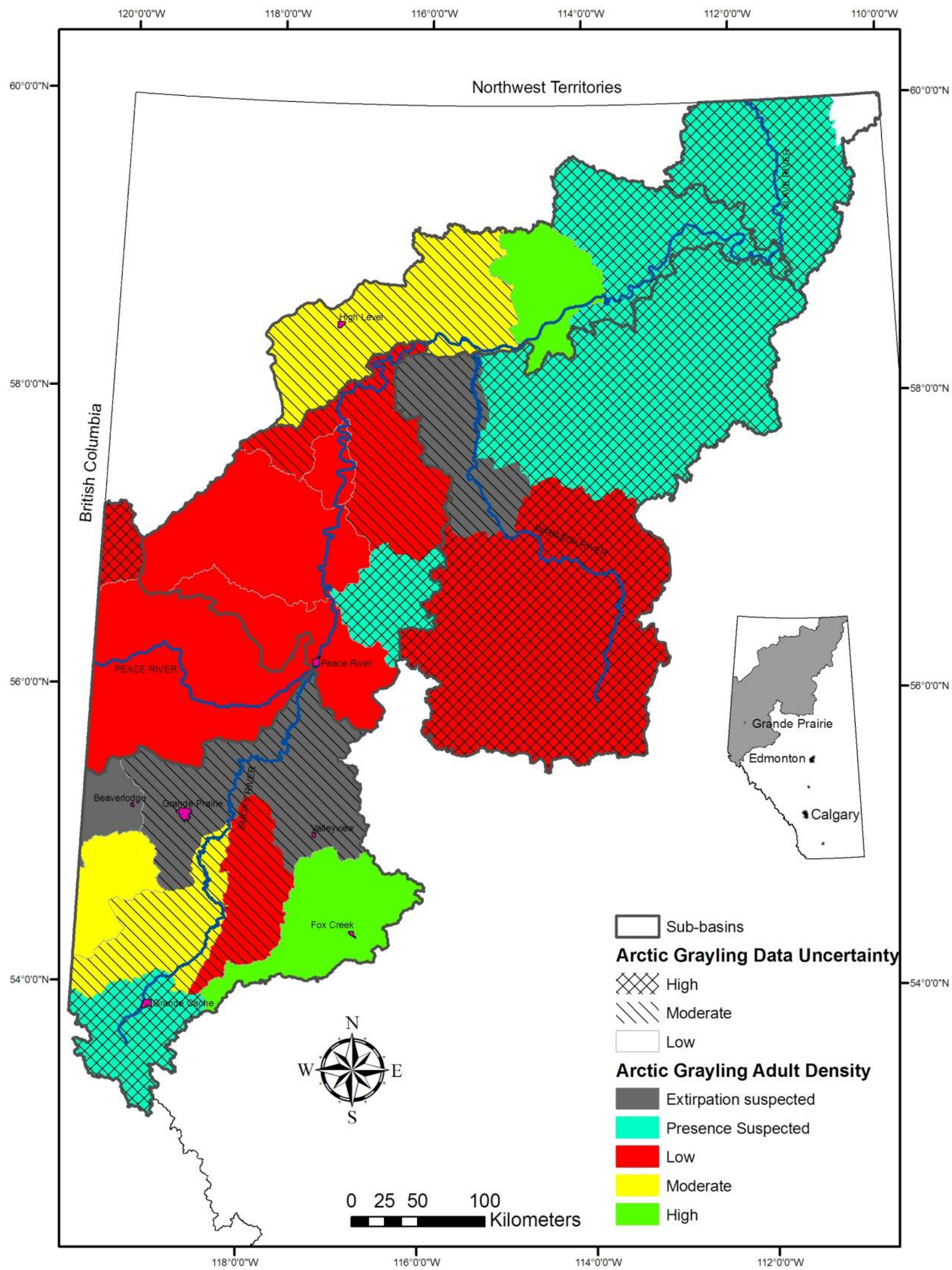

FIGURE 57. ESTIMATED AND CATEGORIZED DENSITIES OF ADULT ARCTIC GRAYLING (*THYMALLUS ARCTICUS*) IN RIVERS BY TERTIARY WATERSHED IN THE PEACE BASIN

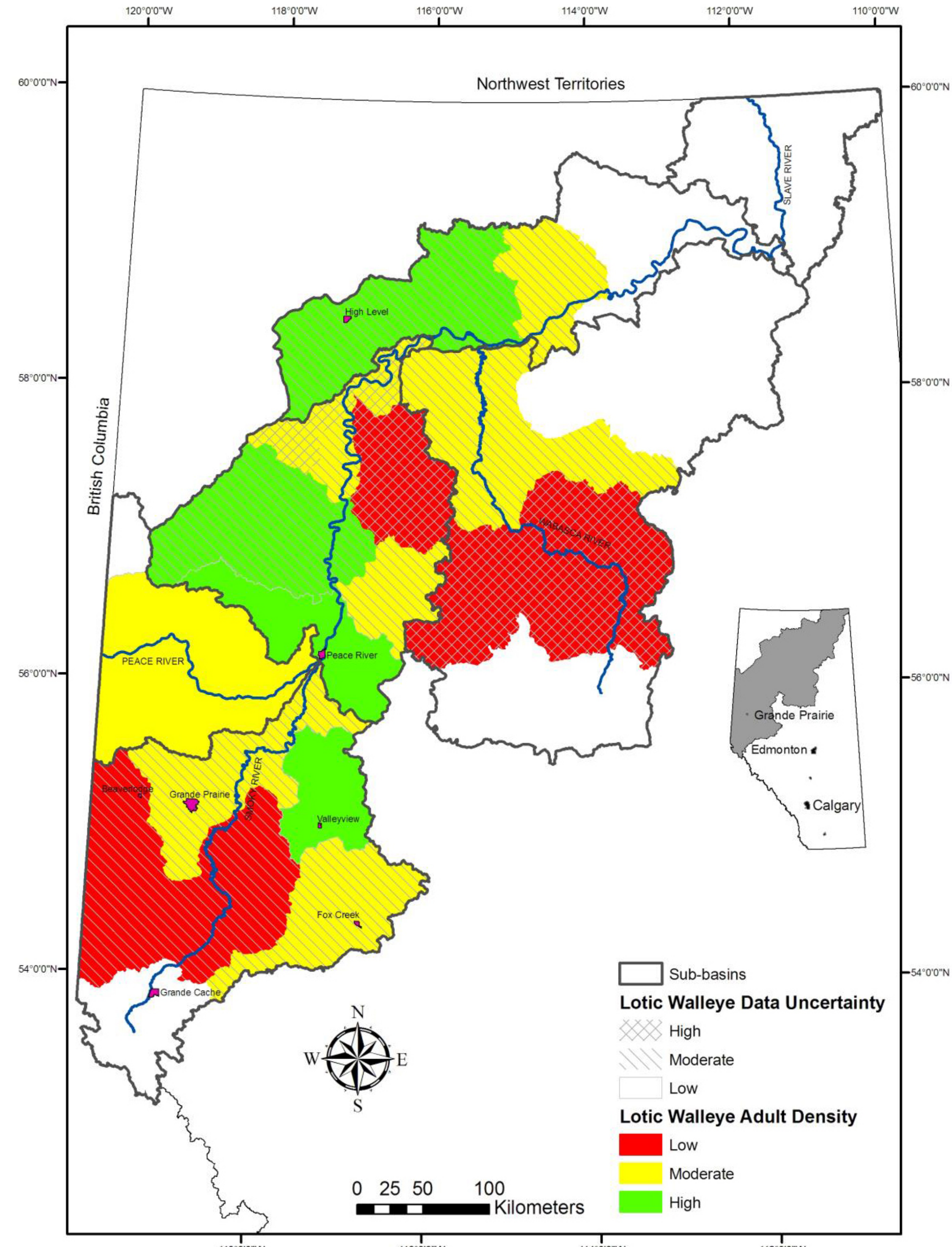

FIGURE 58. ESTIMATED AND CATEGORIZED DENSITIES OF ADULT WALLEYE (*SANDER VITREUS*) IN RIVER HABITATS (FROM JOHNSON AND WILCOX 2012)

In summary, fish populations in large rivers of the Peace Basin appear to be mainly healthy, fish populations in some lakes are under stress from fishing pressure and anoxia resulting from eutrophic conditions, and sensitive fish populations in smaller rivers are strongly affected by land use, with healthy populations only found in the Rocky Mountains and foothills in the South and remote forested areas near and in Wood Buffalo Park in the North-East.

Invasive Species

The freshwater algae *Didymosphenia geminata* (short: Didymo or Rock Snot) produces nuisance growth in rivers and streams of cold regions with low to moderate nutrient levels, and has been observed in Quebec, Saskatchewan, Alberta and British Columbia (B.C. Invasive Species Council 2014, Bothwell and Spaulding 2008). It has been found in many Alberta rivers, especially in the southern-eastern slopes of the Rocky Mountains, but we could not find any evidence for its occurrence in the Peace basin. Its effects on aquatic environments are reduced percentages of EPT (Ephemoptera, Plecoptera and Trichoptera), a group of invertebrates characteristic of good habitat quality and appears to increase benthic invertebrate abundance. Negative effects on fish populations have not been established (Bothwell and Spaulding 2008).

The Northern Crayfish (*Orconectes virilis*) has been observed in the Peace River, likely due to illegal introductions (Alberta Environment and Sustainable Resource Development 2007).

No exotic fish species were found in the Wabasca or Slave River sub-basins during fish surveys. These are also the two sub-basins with the least number of fish caught, so the absence of exotic species in the record may be an artifact of low sampling effort. The Central Peace sub-basin has the greatest percentage of invasive species caught (Figure 59). However the same two exotic species were also caught in the Smoky/Wapiti and Upper Peace sub- basins (Table 49).

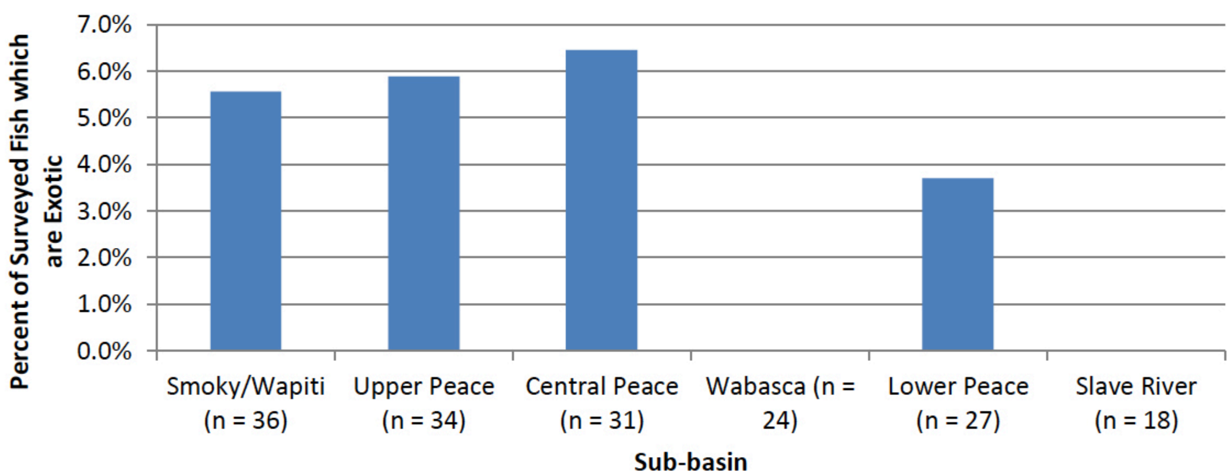

FIGURE 59. PERCENT OF SURVEYED FISH IN RIPARIAN AREAS CONSIDERED EXOTIC

TABLE 49. OVERVIEW OF EXOTIC FISH SPECIES FOUND IN EACH SUB-BASIN

Exotic/Alien Fish Species Found in Alberta		Sub-basins						
Scientific Name	**Common Name**	**Smoky/ Wapiti**	**Upper Peace**	**Central Peace**	**Wabasca**	**Lower Peace**	**Slave River**	**Total**
Gambusia affinis	Western							0
Gasterosteus aculeatus	Threespine							0
Hemichromis	African jewelfish							0
Micropterus dolomieu	Smallmouth bass							0
Oncorhynchus	Golden trout							0
Oncorhynchus nerka	Sockeye salmon							0
Poecilia latinpinna	Sailfin molly							0
Salmo trutta	Brown trout	x	x	x				3
Salvelinus fontinalis	Brook trout	x	x	x		x		4
Salvelinus malma	Dolly Varden							
Total		2	2	2	0	1	0	

The percent cover of invasive terrestrial plants in riparian areas was measured by Cowns and Fish as part of the riparian health assessments. The largest number of invasive species was observed in the Smoky-Wapiti sub-basin sites (Figure 60), but this was also the sub-basin with the highest sampling effort, so these results may be an artifact of sampling effort. The largest average cover of invasive species and the largest maximum cover were found in sites of the Central Peace sub-basin, but again, this result may not be representative, given the low number of sites (4) in this sub-basin (see section riparian health in Central Sub-basin Chapter). Clearly, more surveys are needed, especially in the Upper and Central Peace sub-basins, to better assess spatial differences in invasive plant cover of Peace Basin riparian areas.

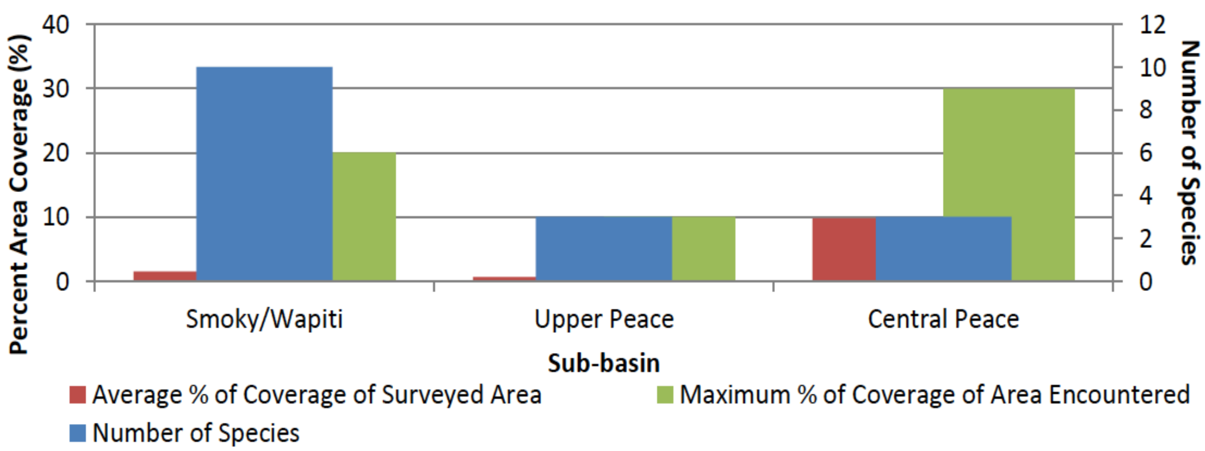

FIGURE 60: SUMMARY OF INVASIVE PLANT SPECIES IN RIPARIAN AREAS

GAP ANALYSIS

In this section we discuss data and knowledge gaps regarding the status of aquatic ecosystems and methods to assess them. We provide suggestions for filling these gaps and discuss their relative priority of addressing the gaps for the purpose of watershed planning activities. We sorted the data gaps by indicator, because certain indicators may be of more interest to groups of stakeholders than others. Also, the process of addressing several data gaps for an indicator may be combined into one project to be completed by the same specialists, which would increase efficiencies for the MPWA.

Water Quality

Data Gaps

Small and Medium Size River and Stream Water Quality

There is generally a large discrepancy between the amount and quality of water quality data available for the main rivers (Peace, Smoky, and Wapiti) and the smaller streams and rivers. The main rivers are well covered by the LTRN program, while the smaller rivers and streams were only monitored through isolated programs by different entities, which often differed in study design. To provide better information on the state of smaller rivers and streams and to allow comparison of data between sub-basins, we recommend taking efforts to harmonize any such sampling efforts. For example, monitoring recommendations or “standard procedures” could be developed for counties or other organizations that already conduct sampling, which should include parameters, detection limits, collection methods, timing and frequency, site selection, flow monitoring as well as data storage and statistical analysis of the results.

- *Diurnal Datasets*

Diurnal datasets, e.g., water quality data collected on hourly or shorter intervals, are largely missing in the Peace Basin. The Alberta long-term river network (LTRN) data are collected during the day and once a month, which is adequate for most water quality variables, but not for some parameters, which can fluctuate greatly between day and night and on a day-to day basis. For example, oxygen can fluctuate between high levels during the day and low levels during the night and early morning hours. This pattern mainly occurs in summer, when aquatic plants and attached algae produce oxygen during the day via photosynthesis and all aquatic biota consume oxygen during the night via respiration. Day-to-day changes can occur following storm events and due to varying flows and quality of point-source discharges. Instruments that measure oxygen and other parameters in short time intervals (e.g. 15 or 30 min), can be installed and left in the river to provide such data and have been proven very informative elsewhere (e.g., North Saskatchewan River, Bow River).

Datasonde data were recently collected for the lower Wapiti River, where large algae production occurs in the summer due to the nutrient enrichment effect of the pulp mill and sewage treatment plant discharges. Such monitoring could also be useful in other locations, where daily fluctuations in water quality could be expected, e.g., in the Smoky and Peace Rivers, during summer and in late winter, under ice.

- *Long-term Trends in River Water Quality*

No formal trend analysis has been conducted in the Peace Basin so far to assess the direction and degree of change in water quality, except for the Environment Canada site on the lower Peace River (Glozier et al. 2009). Observed improving trends can demonstrate management successes, while deteriorating trends can indicate management needs. The advantage of trend analysis on datasets that include a large number of variables, such as the LTRN datasets, is that unexpected trends may be found that can direct studies into emergent water quality problems. The LTRN datasets in the Peace Basin have been collected for a number of years and would likely be appropriate for trend analysis. Formal trend analysis needs to take into account the seasonality of water quality, its relationship with flow, serial autocorrelation and data distribution.

- *Instream Flow Needs*

Water quality is closely related to flow patterns in rivers and streams. If flow is altered significantly due to water allocations, the capacity of the rivers or streams to assimilate point and non-point source loadings changes. Instream flow-need studies assess which flows have to be maintained to protect water quality and fish habitat, but such studies are quite involved. Where there are large amounts of water takings in stream and river watersheds, instream-flow needs should be identified to help balance human and ecosystem needs in water quantity management.

- *Beach Bacteria Monitoring*

No lakes in the Peace Basin are currently monitored for bacterial contamination. In other parts of the province, popular beaches are monitored for bacteria levels, as these can seasonally exceed guidelines for contact recreation. Potential sources are bird (e.g., geese) feces, septic systems, urban runoff and livestock, which can enter the lake through agricultural streams, and these are usually most elevated after storm events. It would be useful to review which lake beaches in the Peace Basin are important for recreational use and work with Alberta Health to assess if they meet criteria to be included into the Alberta Health beach monitoring program.

- *Synoptic River Surveys*

For major rivers, synoptic surveys from the source to the mouth are useful to track water quality, including nutrient levels, from upstream to downstream and identify areas of high loadings. Often, tributaries and point sources, such as wastewater treatment plant effluents, are also sampled as part of such studies, and their flow measured, providing a "snapshot in time" of river water quality and all the loads its receives. Such surveys have been completed in 1988 in the Peace River and in 2004 in the Smoky River, as presented in this report; but no synoptic data from the past ten years are available to assess current spatial variation in water quality. It is therefore recommended to revisit the Peace and Smoky Rivers for synoptic surveys. The lower Wapiti River has been surveyed in a synoptic way through the EEM studies conducted by the Weyerhaeuser Company, operator of a pulp mill in 1998, 2002 and 2006, through Aquatic Assessments conducted by Aquatera, operator of Grande Prairie's wastewater treatment plant (2006, 2007, 2008 and 2009) and through the Coordinated Approach Monitoring Program (CMAP) conducted by Aquatera Ltd. in 2011, 2012. Water quality upstream of these point discharges was excellent compared to sites downstream of the discharges, but a large upstream portion of the river was not included due to the scope of these studies. Inclusion of sites further upstream in the Wapiti River for a complete synoptic survey would be helpful to assess all water quality influences, including tributaries that drain agricultural lands, such as the Redwillow River and its main tributary the Beaverlodge River.

- *Natural Water Quality*

Pre-disturbance, or natural water quality of lakes, streams and rivers in the Peace Basin is largely unknown, with the exception of some lakes and ponds in the Peace-Athabasca Delta. Many surface waters in the Peace Basin, including lakes and rivers, are naturally rich in nutrients and it is unknown to which degree nutrients are enriched from human activities and to which degree these levels are natural. It is therefore unknown if and to which degree the nutrient levels are manageable by addressing watershed sources, what realistic targets for managing surface water quality would be and how to correctly interpret monitoring data. Currently, our knowledge of the degree of human impact on waters stems from correlations with land use, existing scientific knowledge collected elsewhere and comparison with unimpacted systems, but is incomplete for many water bodies. We therefore suggest that inference of natural conditions should be attempted where possible.

For small streams, using the reference condition approach is a potential way to assess natural conditions. This would entail comparison of un-impacted and impacted streams in the same ecoregion. Alternatively, an assessment of natural versus current land cover and the use of export coefficients could be used, as demonstrate by Chambers et al. (2008) for the National Agricultural Environmental Standards Initiative (NAESI). This technique resulted in "ideal performance standards" and "best achievable conditions under current land use types, using BMPs" for streams and assist in identifying realistic targets for nutrient reductions. Using a similar approach in the Beaverlodge River watershed, Norris (2013) proposed a threshold of phosphorus export that would be protective of Arctic grayling populations. Synoptic studies as described above can also provide information on natural conditions through monitoring of un-impacted upstream reaches. The limit of this method is that water quality varies naturally from upstream to downstream and therefore cannot provide data on natural conditions in lower river reaches.

In lakes, natural background conditions can be inferred through paleolimnological studies, i.e., from sediment core analyses. Geochemical properties, fossil algae and invertebrate remains have been widely used to reconstruct natural conditions and the type and degree of human impact on water quality in lakes across Alberta and worldwide (Smol 2002). Fossil diatoms, an algae group, are particularly useful to reconstruct past patterns in salinity and nutrients. Chironomid (midge) fossils are indicators of deep-water oxygen conditions and algae pigments allow inferences about algae communities, such as the occurrence of blue-green algae dominance. Similar to rivers, the identification of natural conditions helps setting realistic lake management targets. Timing of water quality changes can be related to historically documented land use changes and thereby indicate causal factors, which can then be targeted for watershed management.

Assessment Methods

There are two natural characteristics of surface waters in the Peace Basin that complicate assessing the state of these waters and the degree to which they are impacted by human activities – high natural nutrient levels and high flow-based seasonal variability in water quality. Alternative, science-based assessment methods should be developed that take into account these characteristics. The outcome would be to greatly improve the capacity of water managers to evaluate the state of surface water quality in the Peace Basin.

Seasonal Water Quality Objectives

Water quality variables in rivers and streams of all sizes vary strongly on a seasonal basis due to the large seasonal flow variations. These patterns have historically biased the ARWQI ratings in large rivers, because high sediment load during high flow results in high TP and other variables associated with sediment transport. These elevated levels often exceeded guidelines and thereby reduced ARWQI ratings. A solution to this problem is to use seasonal indices, which is currently under development by AESRD (Eleanor Kneffel, AESRD Edmonton, pers. comm.). The caveat of that approach for nutrient assessment is that there is no longer a numeric nutrient guideline for protection from eutrophication effects in Alberta (AESRD 2013a). Another solution is to develop seasonal water quality objectives against which monitoring results can be evaluated, or to develop ecoregion-specific guidelines that take into account seasonality, as discussed below.

Site-Specific Water Quality Objectives

The government of Alberta is moving away from generic numerical nutrient guidelines and recommends a site-specific approach (Alberta Environment 2013). It is therefore preferable to develop site-specific water quality guidelines and objectives for the rivers and streams of the Peace Basin, the latter of which has been completed for other major rivers in Alberta, e.g., the North Saskatchewan, Red Deer, Bow and Athabasca. Such objectives make use of existing long-term datasets collected at LTRN sites and can take into account seasonal differences between high and low flow and the natural regional variation in nutrient levels. Datasets that are suitable to develop such objectives are available from the LTRN sites in the large rivers of the basin, Peace, Wapiti and Smoky rivers.

Nutrient Guidelines

For small rivers and streams, long-term datasets for objective development are not available. The reference condition approach, as described below, or an approach based on stressor-response relationships could be used to define desirable nutrient levels that are protective of healthy ecosystems for smaller streams and rivers in ecoregions of the Peace Basin. These would be nutrient guidelines that would also be applicable to other streams in the same ecoregion, and not limited to one site. Developing guidelines is a more involved process than objective setting as discussed above and is possibly best conducted under provincial coordination.

Wetland Cover

The main data gap for wetland cover in the Peace River Basin is the amount of wetland loss. Generic estimates for the entirety of Alberta"s agricultural areas range from 40 to 70%, which has limited use for watershed-based wetland management. Watershed-specific and local information on wetland loss that could inform restoration efforts is currently not readily available.

The ongoing work by Watmough and Scholl (2009) in this report includes a sample program in the Peace Parkland. It is anticipated that these data will be reported on in 2014/2015 (M. Watmough, personal communication). The results of this study will improve our understanding of wetland loss in the White Zone of the Smoky-Wapiti, Upper and Central Peace sub-basins.

Another way to inform decisions on wetland management is to develop a drained wetlands inventory. By identifying drained wetlands, the potential to restore drained wetlands is assessed. Drained wetland inventories have not been completed in the Peace Basin, but such inventories have been completed elsewhere. Ducks Unlimited Canada in conjunction with the Alberta Government has produced drained wetland inventories for some parts of the Province. The Canadian Wildlife Service is currently preparing a wetland-related ditching inventory for the Prairies that would make a good proxy for wetland loss. There are numerous small-area drained inventories completed by government agencies and conservation groups (M. Watmough, personal communication).

One way to identify potentially restorable wetlands is by merging two geographic datasets, a digital soil survey and a wetland inventory (Donelly 2001). This method relies on the assumption that areas indicated as wetlands would largely coincide with hydric soils in the digital soil survey. Where hydric soils exist, but do not coincide with wetlands, a drained wetland might exist. This information can be useful for regional planning and assessment of water and soil resources; however, using these data for site specific project planning is not recommended without additional onsite fieldwork (Donelly 2001).

Data collected by ABMI on human disturbance, which is an indicator of wetland health, have been proven useful to assess general trends across the basin. The full extent of the planned site location grid needs to be sampled to have a true statistical sample of the indicators across the basin and make more confident conclusions about wetland health. That will take a number or years to be complete. Wetland health is therefore poorly understood, but data are being collected on an ongoing basis and will be available in the near future.

Riparian Health

Field-based riparian health assessments are available, but limited to small distinct areas in the Smoky-Wapiti, Central and Upper Peace sub-basins. Given the large size of the Peace Basin and the small number of individual assessments completed, all sub-basins were considered as data deficient (Sikina and Ambrose, 2013). This implies that the detailed riparian health assessments in these sub-basins conducted by Cows and Fish are insufficient to extrapolate conditions to the entire sub-basins. Although the results are likely reflective of riparian health in the White Zone, more data are required to increase confidence in this assessment.

Data for riparian characteristics of lakes (soil/vegetation cover) are collected through the ABMI monitoring program. So far, however, only five lakes in the entire Peace basin have been assessed and it is unknown how many more will be assessed as part of the ABMI program. We therefore identify this indicator as a data gap, but assign lower priority compared with river and stream riparian surveys. Much less water is in direct contact with the riparian zone in lakes and it therefore has less importance than for rivers and streams. In order to address this data gap, GIS techniques can be used to assess land use in the riparian zone of lakes, which could be defined by a certain distance from shore. Such data could be ground-truthed by visual inspection, by AESRD staff that are already on the lakes for water quality monitoring, or by volunteers. The Alberta Lake Management Society engages lakeshore residents as volunteers for their water quality monitoring programs and stewardship initiatives and may be a good partner for any lake-related programs.

Invasive Species

The distribution of exotic fish species is well known as fisheries surveys record these species.

Monitoring for invertebrate aquatic invasive species has been historically sparse, but is receiving more attention and pro-active monitoring activities have recently been implemented by AESRD for some lakes. In addition, it would be useful to identify popular entry-point lakes in the watershed, e.g., where most boats are used from outside the watershed, and include them in the monitoring programs, for both fish and invertebrates. Reporting on invasive benthic invertebrates in rivers, to our knowledge, is not formalized as of yet.

There are no records of the invasive freshwater diatom algae Didymo (*Didymosphenia geminata*) in rivers and streams of the Peace Basin. It has been found in other parts of Alberta and neighboring Provinces, so it is likely that it is also present in the Peace basin. Existing periphyton surveys should be reviewed for this species" presence. Given its relatively distinct appearance, visual inspection for its potential occurrence could be implemented as part of other monitoring activities in streams of the foothills, where it would be most likely to find. Public education and invitation for website reporting can be another way to obtain indications of its presence, as has been done in British Columbia (bcinvasives.ca).

Monitoring for terrestrial invasive species is currently limited to the ABMI plant surveys of wetlands, and Cows and Fish Riparian Health Assessments. ABMI surveys will be complete in a few years, at which time analysis of the complete dataset is recommended. Cows and Fish Riparian Health Assessments are limited to small local areas and need to be continued to assess patterns of invasive species presence in riparian areas on a watershed scale. While most of the potential invasive species discussed were mainly found in the southern parts of the province, more systematic monitoring for their occurrence at likely entrance points to the Peace Basin water bodies (e.g., popular recreational lakes) may be necessary to address this potential threat to the integrity of aquatic ecosystems.

Fish Populations

Johnson and Wilcox (2012) completed a thorough analysis of fish population data for a number of focal species and as a result, developed a comprehensive list of data gaps regarding fish populations in the Peace Basin. Data gaps include population status in certain areas and for certain species, stressor-response relationships, with responses being fish populations or fish habitat, assessment techniques, stressor quantification, and details on fish ecology, as detailed below.

In terms of applicability to watershed planning, the gaps regarding stressor-response relationships and population status as well as assessment techniques are probably of highest priority, as only known population status using proper assessment techniques can inform the development of Fisheries Management Objectives and the association of population declines with human activities can direct the management actions to achieve those objectives.

Population Status

There are a number of data gaps regarding population status that became evident in the analysis of fish populations by Johnson and Wilcox (2012). These included areas with little data, species with little data and species and areas with high data uncertainty and large risk of impact from human pressures.

Sample areas where species presence is suspected but unknown and where extirpation is suspected but unknown need to be surveyed to determine either presence or estimate probability of extirpation. In the Peace River Basin, these are mostly areas in the Central and Lower Peace and Wabasca sub-basins.

Additional knowledge (e.g., life history, distribution, and population dynamics) of priority or key species is required where very little is known (examples include goldeye, northern pike minnow, and Flathead chub).

It is particularly important to update survey information in areas where data uncertainty is high and the risk to fish is considered high from human activities. These areas include smaller tributaries in the upper and lower Peace within watersheds of high linear disturbance, water use and agricultural activities. Targeted efforts in the Central Peace have been conducted in recent years (Sherburne et al. 2009, Rees 2011, Steenbergen and Wilcox, 2013) but need to continue to fill remaining data gaps.

We suggest developing a genetic database to determine whether meta-populations of fish exist in the Peace River watershed that may require a greater level of protection. This information will then help determine whether local extirpations could be re-colonized by meta-populations in nearby water bodies.

Stressor-Response Relationships

Relationships between anthropogenic stressors for fish populations (e.g., road densities, stream crossing densities) and fish status for each of the focal species discussed in Johnson and Wilcox (2012) as well as other species deemed “sensitive” but not included in that analysis are known but generally not quantified. While it is general agreed that negative relationships exist and have been quantified in some cases, this information is not readily available for most species found in the Peace Basin. Published threshold values for similar areas are rare; for example, negative impacts to water quality have been found at stream crossing densities of 0.4/km^2, and negative impacts to bull trout populations at stream crossing densities of 0.6/km^2 (BCF and BCE 1995). Norris (2012) proposed a threshold for Arctic grayling habitat suitability in terms of theoretical increase in phosphorus export from the watershed as estimated by export coefficients (three-fold), which in turn was related to winter oxygen levels and summer diurnal oxygen patterns.

A critical component of developing stressor-response relationships is to include populations where anthropogenic footprint or exploitation is low. This reinforces the need for data from natural or least-impacted areas, as described for water quality above, to fully understand the degree of human impact on aquatic ecosystems in developed areas. The value of reliable stressor-response relationships cannot be overstated, as they can also help manage stressors in watersheds where information on fish population or other ecosystem indicators itself is limited and help setting protection targets in healthy watersheds to prevent impacts from planned development.

Better understanding of water regulation effects on fish populations in the Peace River and other areas would improve the ability to provide proper input to hydroelectric development proposals, although effects on fish habitat are known to some degree.

Effects of the Bennett Dam on fish habitat include an altered water temperature regime, which can affect spawning, reduced capacity to transport sediment, which increased sediment deposition in downstream reaches of the Peace and thereby altered substrates and channel morphology, changes to the ice regime, and diurnal water level fluctuations (CPPEnv and HESL 2012). The amplitude of these effects is reduced with distance downstream because of the addition of unregulated tributary inputs. What effect these changes had on fish populations is unclear, given the limited fish population data from the time period prior dam erection (pre-1968).

Evaluating habitat availability under different flow regimes using flow modelling, including predicted flow regimes under future development scenarios, is a potential technique to use for assessing how much water can be allocated without negatively affecting fish habitat. This data gap relates to the data gap of instream-flow needs that are required for the protection of both physical fish habitat and water quality. Instream-flow need studies require a comprehensive suite of investigations of stream morphology, hydrology, water quality and biota and are therefore costly. They are likely only justified in watersheds where a large volume of water is allocated for human use. To our knowledge, the only instream-flow needs investigations in the Peace Basin so far have been initiated in the lower Wapiti River, in 2012.

Fishery Assessment Techniques

Standardized survey techniques for focal species are required that include a description of catchability for the technique and sampling conditions. The assessment of Johnson and Wilcox (2012) was only based on data using one standardized technique each for river and lake sampling. There are more data available that were collected using a variety of sampling techniques, for which efficiency of fish capture may vary and therefore may not be directly comparable in terms of resulting fish density estimates. Efforts of the Fish and Wildlife Management staff are ongoing to assess other collection methods for use in the FSI process.

Ecology

Johnson and Wilcox (2012) indicate that more needs to be known how and when fish use different locations, e.g. the mainstem of the Peace River and tributaries, at different times of the year and for different life stages (e.g., resident vs. migrant populations, spawning, rearing, overwintering). Such information would enhance the population status assessments and help distinguish locations that are critical for reproduction and survival from locations that are only used transiently. This in turn may help developing objectives and prioritizing management efforts.

Stressor Quantification

The location of barriers to fish movement in the watershed and what level of barrier they represent is not known on a watershed basis. Examples for barriers are weirs and road crossings. These may impede fish movement to different levels, depending on their height (weirs, bridges), diameter and drop height (culverts, Tchir et al. 2004) or general type (bridges representing the least barrier). One prominent example is the Vermillion Chutes, for which it is unknown whether they represent a fish barrier throughout the year. The location of potential barriers can be estimated by GIS analysis of stream and road networks, where intersections between these two features represent stream crossings. The level of barrier needs to be assessed in the field or from records on types of crossings, if available.

Fish Contaminants

Contaminants in fish are an important concern for human consumption. There are some consumption advisories in place for fish species in the Peace Basin and a number of reports exist on localized datasets. It would be useful to summarize all existing information on contaminants in fish tissue in order to identify data gaps and direct future monitoring activities in this field.

Summary of Data Gaps

Indicator	Data Gap	Strategies to Address Gaps	Priority	Importance for Watershed Management
River Water Quality	Small and medium size river water quality	prioritize rivers by ecological and human use significance or potential impact from land use (using GIS), implement monitoring	High	important habitat for aquatic life, vulnerable to effects of multiple stressors due to seasonally relatively low flow
	human non-point source nutrient loads to rivers	synoptic stream surveys, export coefficient modeling, reference condition approach	High	assess which regions require focussed land management efforts
	spatial patterns in river WQ	synoptic surveys, supported by estimates of all known point-source loads	Medium	assess which river reaches require focused load management efforts
	Tools to assess status on seasonal basis	site-specific, seasonal WQ objectives	High	Improve status assessments - avoid bias due to seasonal variation
	Tools to assess nutrient status	site-specific WQ objectives and ecoregion-specific nutrient guidelines	High	Improve status assessments - separate natural from human nutrient
	Instream Flow Needs to inform water allocation management	Flow needs studies, recognizing the anticipated effects of climate change on low-flow patterns	High	water quality and the capacity to assimilate point discharges is closely related to flow patterns.
	Long-term Trends	Complete proper trend analysis of WQ data from LTRN sites	Medium	Assess direction and degree of change in WQ, identify management successes and needs
Lake Water Quality	Long-term trends in nutrient and productivity status -natural versus human sources	Paleolimnological studies	High	required to inform lake and watershed management, nutrients are cause of severe effects in lake (e.g., fish kills, potentially toxic algae blooms)

Indicator	Data Gap	Strategies to Address Gaps	Priority	Importance for Watershed Management
	Long-term trends in salinity - human versus climate influence	Paleolimnological studies	Medium	required to inform water management
Wetland Cover	Wetland Loss	Drained Wetland Inventory	High	required to direct wetland restoration
	Wetland Health	Obtain and analyze continuous ABMI wetland survey data	Medium	useful for wetland restoration efforts
Riparian Health	Riparian Health for Rivers and Streams	Continue to work with Cows and Fish to conduct riparian health assessments	High	useful to direct riparian restoration efforts, riparian health important for flood protection, water quality protection, biodiversity
	Riparian Health for Lakes	GIS analysis/air photo interpretation of a ring around lakes	Medium	useful to direct riparian restoration efforts, riparian health important for water quality protection & biodiversity, but less than in rivers due to smaller portion of water adjacent to shore
Fish Populations	Effect of linear features on stream habitat quality	GIS analysis of stream and river crossings to assess barriers, field investigations for types, coupled with fish population status, and possibly synoptic WQ surveys	Medium	distinguish areas of high and low risk to fish populations from barriers
	Thresholds for Land Use and other stressors for fish habitat suitability	Compare low-impact to high-impact watersheds and assess stressor-response relationships (see Norris 2013)	High	threshold values for stressors can help setting restoration targets for impacted watersheds and preventing impacts from planned development in currently healthy watersheds

Indicator	Data Gap	Strategies to Address Gaps	Priority	Importance for Watershed Management
	Fish Population Status	targeted fisheries assessments in high-uncertainty and high-risk watersheds and for key species where little is known (Goldeye, Northern Pikeminnow, Flathead Chub)	High	Status of fish populations needs to be known to develop fisheries management objectives and fisheries management plans.
	Spawning Locations	Targeted surveys to confirm locations used for spawning	Medium	Suitable habitat for fish reproduction is critical to maintain populations
	Fish Contaminants	Summarize available reports and assess needs for further monitoring	Medium	Important concern for human consumption, advisories in place in PAD and several rivers in Peace basin
	Fish Density Assessment Techniques	establish catchability for a variety of methods and sampling conditions such that results are comparable among methods	Medium	density can be interpreted for a variety of collection methods, but more methods need to be assessed to be included in the standardized FSI assessment process
Invasive Species	Occurrence of *Didymosphenia geminata*	review existing periphyton community assessments, conduct rapid periphyton assessments in headwater streams, educate public and provide portal for public reporting	Low	Not a threat to aquatic ecosystems or of large concern for water uses

CONCLUSIONS

The purpose of this report was to provide in-depth information on data and results presented in the SoW regarding aquatic ecosystems. This report presented data sources, analysis methods, detailed results and interpretation of state of the watershed indicators and included metrics regarding surface water quality, wetlands, riparian health, biological communities and invasive species. The status of these indicators was discussed by sub-basin, in the context of known landscape characteristics and human pressures, and based on the data available at the time. Data gaps were identified, means to address them discussed and priorities proposed.

Overall, the Peace Basin is rich in aquatic resources both in terms of their number and diversity. The status of these ecosystems varies greatly across the basin. Aqautic ecosystem health is good in remote and protected areas, in particular in the Rocky Mountains and foothills as well as in the northeast, but a number of different human activities have had regionally significant impacts on water quality, biota, riparian areas and wetlands. Ongoing population and economic growth can potentially increase these impacts, but the lessons learned in this status assessment will help to anticipate and mitigate future impacts.

The information presented in this report and the identified knowledge and data gaps, alongside with the main SoW report, should provide a strong basis for future work towards a healthy and sustainable Mighty Peace watershed.

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