7.0 CONCLUSIONS AND RECOMMENDATIONS

The 2007 RAMP monitoring program results have been discussed in detail, in Section 5 and Section 6. The following section provides a brief summary of overall conclusions specific to each monitoring component of RAMP, as well as general comments and recommendations for consideration by the RAMP Technical Program Committee and the RAMP Steering Committee.

7.1 CLIMATE AND HYDROLOGY

The outlets of most major river basins in the RAMP Focus Study Area (FSA) are monitored, either by RAMP, by RAMP-member operators, or by federal or provincial governments, providing a good basis for assessing potential effects of focal projects and other oil sands developments. An increasing number of the hydrometric stations in the network monitor catchments in which development has occurred. Upstream monitoring locations are being added to compensate for this trend so that hydrometric data continues to be captured in natural watersheds for comparison.

In most of the watersheds, hydrologic impacts were assessed as negligible in 2007. Muskeg River, Tar River, Poplar Creek and Fort Creek were exceptions, with impacts ranging from low to high. High impacts were only observed in relation to increases in discharge; decreases in discharge had negligible or low impact.

Focal project activities with the greatest influence on hydrologic conditions in these watersheds in 2007 included:

- Hydrologic isolation of mine sites in the Muskeg River basin, resulting in reduced runoff;
- Clearing and drainage in the Tar River catchment, resulting in increased runoff;
- Water releases into Poplar Creek via the Beaver River diversion and Poplar Creek spillway, increasing the flow in Poplar Creek; and
- Muskeg dewatering in the Fort Creek catchment, increasing the flow in the creek.

The cumulative hydrologic effects of focal project activities plus all other active oil sands projects in the RAMP FSA are estimated to be only marginally greater than the hydrologic effects of the focal projects alone.

Measuring land use changes using satellite imagery, as was done for 2007, was a relatively simple process and provided useful results. However, there is some remaining uncertainty in defining catchment changes such as stream diversions and hydrologic isolation of developed areas.

The actual effects of the land changes considered are in fact more complex than what is represented in the current assessment approach, and low flows in particular are not well estimated using this simple approach. However, although the analytical approach used for the hydrologic data includes a number of simplifications, assumptions and unknowns, it does provide a useful indication of the potential magnitudes of changes in hydrologic measurement endpoints. A more detailed and rigorous assessment could be made using the same analytical approach supported by hydrologic modeling, particularly if the model was calibrated using a watershed that was largely cleared.

Obtaining useful hydrometric information from small, poorly-defined and beaver-inhabited streams continues to be a challenge.

Minor weaknesses in the hydrologic monitoring network include:

- Lack of a robust monitoring location on the Athabasca River;
- Lack of winter monitoring on the Tar River and Calumet River; and
- Lack of a hydrometric station at the mouth of the Christina River.

7.2 WATER QUALITY

Based on watershed-specific and regional analyses, the following waterbodies exhibited excursions from historical and/or regionally typical water quality in 2007:

- Lower Tar River: Increases in total nitrogen and changes in nitrogen speciation that suggest effects of the treated-sewage discharge from CNRL's Horizon project on water quality;
- Lower Beaver River: Regionally high concentrations of major anions (sulphate and chloride) that may be related to seepage from Syncrude's Mildred Lake site into this drainage, which had most of its flow diverted away to Poplar Creek in 1974; and
- Shipyard Lake: Increasing concentrations of several major ions, including sulphate, which in 2007 exhibited a concentration outside the regional range of natural variability, although relative ion balance has not changed over time toward one that would indicate influence of oil-sands process waters.

Aside from the above exceptions, water quality in the RAMP study area in 2007 did not indicate measurable influences of focal projects or other human activities on water quality.

For future RAMP programs, lower analytical detection limits for naphthenic acids should be pursued, given recent data have demonstrated that concentrations of naphthenic acids in natural waters of the lower Athabasca region are between approximately 0.2 and 0.8 mg/L (M. McKinnon, Syncrude Canada, *pers. comm.* 2008), below the current detection limit of 1 mg/L.

7.3 BENTHIC INVERTEBRATE COMMUNITIES AND SEDIMENT QUALITY

7.3.1 Benthic Invertebrate Communities

The strength of the RAMP Benthic Invertebrate Community component is the development of baseline data from multiple watercourses in a baseline condition. Replication within watercourses, and over time, is enabling RAMP the opportunity to extensively characterize the normal range of variability in common metrics of benthic community composition including abundance, richness, diversity, evenness and percent of the fauna such as sensitive mayflies, stoneflies and caddisflies. Rigorous statistical techniques can be used to test for subtle variations in time trends from before to after commencement of operations, or spatially between baseline and operational reaches. Because statistical power is very high, subtle effects that are consistent with operations are inevitable, and were observed with these 2007 data. The regional baseline data, however, typically showed that the significant time trends or spatial variations were subtle in comparison to natural background variability. Key findings from this 2007 inventory are provided in the bullets below.

- Athabasca River Delta: Benthic communities in the ARD were in generally good condition in 2007 with relatively high diversity for a shifting-sand environment; there was no evidence of undue deleterious effects on ARD benthic invertebrate communities.
- Muskeg River, Lower Reach: Indices of composition in the lower reach were well within the normal range of variation for reference erosional reaches, and without any indication that indices were trending in a fashion that they would, in the short term, be outside the normal range.
- Muskeg River, Middle Reach: The benthic community of the middle reach was diverse and contained a number of sensitive organisms including the mayfly *Leptophlebia*, and other organisms such as amphipods and fingernail clams (Bivalvia) that require stable (substrate) conditions. These data indicate no significant impacts in the middle reach of the Muskeg River.
- Fort Creek: Total numbers of organisms, number of taxa, evenness and percent EPT in 2007 were all at values consistent with observations prior to 2005 (i.e., previous to a local storm noted in 2005 [RAMP 2006]). The lack of statistically significant effects in 2007 can be attributed to a "recovery" from this natural disturbance.
- Steepbank River: The benthic community of the lower Steepbank River is presently in good condition relative to reference erosional reaches. There is some evidence, however, of changes over time. Continued monitoring of the lower Steepbank River will determine whether the observed trends are a function of degraded habitat quality or a part of the natural variation.
- Shipyard Lake: The benthic community of Shipyard Lake was diverse, and produced indices of composition that were within the normal range of conditions based on what has been observed at Kearl and McClelland lakes. The benthic community of Shipyard Lake is also tracking similarly to year-to-year variations in indices of composition in McCLelland and Kearl Lakes.
- Isadore's Lake: The benthic community has a low-diversity with the fauna being dominated by chironomids and nematodes. With the exception of percent EPT (which was lower in Isadore's Lake in both 2006 and 2007 relative to the two reference lakes), variations in indices of composition tended to fall within the normal range of variation for the two reference lakes.

The RAMP design has effectively characterized the natural background (baseline) conditions in lake and river (erosional and depositional) habitats. RAMP, to date, has not considered the benefits of characterizing the composition of the benthic community in "areas where impacts have been observed, and are known to be caused by focal projects". Such sites act as "negative references" against which to provide an additional piece of evidence that effects in reaches being monitored have or have not occurred. The RAMP benthic study design has been developed with the objective of fully characterizing natural variability, and the comparison of "test" reaches (or lakes) against the reference condition. A potential concern with that design is that variability is so high that it may be perceived to be difficult to detect effects when they occur. Many investigators in the US and Europe use negative references (or negative controls) because they help define the degree of deviation from a reference condition: that is, a benthic community may not be similar to the reference condition, but might also not be in a condition considered to be impaired. The concept of the negative reference was developed by Karr (1981) in the derivation of the Index of Biotic Integrity (IBI), and by others that followed in the derivation of like indices (e.g., Fore *et al.* 1996, Simon 1999). RAMP may wish to consider the addition of such negative controls for each of the major habitat classes (i.e., lake, depositional river, erosional river) to provide an additional frame of reference for the assessment locations being assessed through long-term monitoring.

7.3.2 Sediment Quality

Sediments in the RAMP study area naturally contain hydrocarbons and PAHs at concentrations that may exceed environmental-quality guidelines. Spatial and temporal comparisons of sediment quality over time since monitoring by RAMP began in 1997 did not indicate any consistent trends over time in concentrations of hydrocarbons or metals, any consistent differences in sediment quality between *reference* and *potentially influenced* stations, or any relationships between sediment chemistry and composition of benthic communities that would suggest a negative effect of chemicals in sediment on community structure. A consistent trend toward finer particle sizes in sediments of Fletcher Channel in the Athabasca River delta may reflect changes in geomorphology and hydrological characteristics of this specific delta channel; such trends are not apparent in any other delta channels (i.e., Goose Island, Big Point, or the Embarras River).

Future sediment-quality assessments should consider collection and analysis of sediment cores, particularly from the Athabasca River delta, to determine the concentrations of hydrocarbons, PAHs and other variables of potential concern in sediments deposited before the commencement of oil-sands development.

7.4 FISH POPULATIONS

The 2007 RAMP Fish Population component consisted of:

- Fish inventory – Athabasca River, Clearwater River;
- Fish tissue analysis – Clearwater River; Gregoire Lake, Namur Lake; and
- Sentinel species monitoring – Ells River, Athabasca River.

Assessing potential impacts on fish populations related to focal projects and other oil sands developments is an ongoing challenge due to limited temporal data (i.e., not all programs are conducted on an annual basis) and alterations in the program design between years. In addition to these challenges, large-bodied fish are highly migratory between and within rivers in this region rendering it difficult to determine differences between natural variability in fish populations versus changes due to focal projects and other oil sands developments. Recognizing these limitations, this component is continuously being refined in terms of methodologies and design. Assessments from external reviewers have been completed to assist in refining the component as appropriate.

7.4.1 Fish Inventory

In 2007, the analysis of the Athabasca River fish inventory focused on spatial trends over time of catch per unit effort, condition, and length-frequency distribution for large-bodied fish. Consistent with previous sampling years, analyses were completed only for captured fish and did not include observed records. Current and historical fish inventory data from the Athabasca River indicated some species-specific variability in designated measurement endpoints (i.e., relative abundance, length-frequency distribution, and condition factor). Statistical analyses of the inventory data indicated some significant differences between years due to fluctuations over time and not to clear increasing or decreasing trends that could be associated with focal projects.

2007 was the fifth year a fish inventory was conducted on the Clearwater River. The fish community on the Clearwater River was similar to the Athabasca River. Statistical analyses of the inventory data over time also indicated limited significant differences among years with no clear trends. Additional years of data gathering would be beneficial to more accurately define the natural variability in this reference watercourse.

In the Athabasca River, statistical differences over time were more evident in the spring inventory data than in the fall, particularly for condition factor. Given that spawning occurs during spring, it was difficult to interpret whether the differences were due to typical changes in condition related to spawning activities or potentially influenced by environmental stressors. Additional years of data collection should focus on sampling periods when fish populations are stable (i.e., resident individuals in summer following freshet) representing normal conditions. In addition a *reference* site on the Athabasca, perhaps upstream of Fort McMurray but certainly upstream of the Poplar Area, should be added to the program given all current areas are classified as *potentially influenced,* which would also aid in establishing natural variability versus population changes due to focal projects.

To date, there is little evidence to suggest that characteristics of key indicator fish populations in the Athabasca and Clearwater rivers have changed during increasing activities related to focal projects and other oil sands developments in the region.

7.4.2 Fish Tissue

In 2007, potential effects on human health were assessed from individual and composite fish muscle samples collected from the Clearwater River, Gregoire Lake and Namur Lake for northern pike, walleye, lake whitefish and lake trout. Northern pike and walleye showed potential risk to subsistence fishers given mercury concentrations were in exceedance of the Health Canada guideline 0.2 mg/kg. Lake whitefish showed no risk to consumers given all mercury concentrations were lower than the guidelines. Mercury concentrations in lake trout represented a risk to subsistence and general consumers (0.5 mg/kg) given most fish exceeded both Health Canada guidelines. However, mercury concentrations in fish muscle recorded in 2007 were within the regional range observed in fish from other waterbodies of northern Alberta, including those beyond the influence of focal projects and other oil sands developments.

Given mercury levels in fish are dependent on lake characteristics (i.e., food web structure and water and sediment chemistry) (INAC 2003, Ullrich *et al*. 2001), collection of supporting environmental data could be added to the program to provide further explanation of varying mercury levels in fish in regional waterbodies.

Other metals and tainting compounds that were detected did not appear to pose any human health risks. Effects on fish palatability were not predicted for the 2007 data, given that concentrations of all measured tainting compounds were below detection limits and well below screening values.

7.4.3 Sentinel Fish Species Monitoring

The non-lethal sampling methodology, introduced in 2004, was continued on the Athabasca River and the Ells River in 2007. Longnose dace, similar to 2005, was the sentinel species on the Ells River and trout-perch, similar to 1999 and 2002, was the sentinel species on the Athabasca River using condition factor as the measurement endpoint. At present the Ells River watershed is designated as *reference* and the 2007 results showed that condition factor was significantly lower at the Lower site relative to the Upper site, which was opposite to results documented in 2005. The results from the trout-perch sentinel program showed some significant differences in condition between the *reference* and *potentially influenced* sites, but with no clear pattern related to development. As well, the magnitude of difference in condition was always less than critical effect size of 10% (i.e., considered an ecologically-relevant level of change).

The young-of-year (YOY) cohort was difficult to determine for both trout-perch and longnose dace given both species are multiple spawners. A sampling program conducted prior to the spawning period would be beneficial to accurately determine the adult size range to differentiate between the young-of-year entering the population at a later time. This issue also influenced the ability to measure YOY growth, which may have also been affected by the limited time period between summer and fall surveys. By increasing the period between sampling programs, the growth rate of the YOY cohort could more easily be interpreted (i.e., sampling earlier in August).

Finally, the design of the sentinel species program on the Athabasca River takes into account the influence of the sewage treatment plant (STP) in Fort McMurray with a *reference* site downstream of the STP, but upstream of most focal projects. The design also includes a second *reference* site upstream of Fort McMurray. In future, two issues should be addressed when designing the Athabasca River sentinel species program, (i) the choice of reference site upstream of focal projects with habitat similar to the *potentially influenced* sites and (ii) determine the extent of the impact of the STP on the Athabasca River to assess if the changes in condition factor in fish at *potentially influenced* sites is due to wastewater from the STP or influenced by focal projects.

7.5 ACID-SENSITIVE LAKES

Based on established criteria, well over 50% of the lakes in the ASL component are considered highly sensitive or moderately sensitive to acidification. There have been only minor changes in the chemistry of the 50 ASL lakes as a whole over the previous six years of monitoring. Significant changes in a small number of variables observed in 2005 (including potassium, calcium and ammonia) were related to the high rates of precipitation and runoff to these lakes that occurred that year. Values returned to more normal levels in 2006 and 2007.

As in 2006, critical loads of acidity were calculated using the Henriksen critical load model modified to account for the contributions of both strong and weak organic acids. Critical loads were calculated using values of runoff derived both from traditional hydrometric methods and isotopic enrichment. Using the runoff derived hydrometrically, critical loads in 2007 ranged from -0.070 keq H+/ha/y to 1.333 keq H+/ha/y with a median value of 0.198 keq H+/ha/y. Lakes located in the upland regions (the Birch Mountains, the Caribou Mountains and the Stony Mountains) and in the Canadian Shield had the lowest critical load values. Using the runoff values derived from isotopic enrichment, critical loads ranged from -0.048 keq H+/ha/y to 1.781 keq

H+/ha/y. The mean and median critical loads were similar for the two methods. The critical loads of acidity were compared to modeled rates of acid deposition. Rates of critical load exceedance in 2007 were 39.6 % (19 of 48 ASL lakes) using hydrometrically-derived runoff estimates and 47.9 % (23 of 48 ASL lakes) using runoff estimates based on isotopic enrichment. These rates of exceedance are considerably higher than the rate of 8% reported for 399 lakes in a recent lake sensitivity report to the NOxSOx Management Working Group using the same model modifications (WRS 2006). The higher rates of critical load exceedance in the RAMP ASL lakes reflect a bias in the design that preferentially selected the most poorly buffered lakes for study. The rates of critical load exceedance in the RAMP ASL lakes were closer to rates observed in four sensitive regions in Ontario. A critical load exceedance does not necessarily mean that acidification of a lake is a certainty or imminent.

Mann-Kendall trend analysis was applied to key measurement endpoints on 31 individual lakes to detect changes that might indicate incipient acidification. Analytical error was incorporated in the interpretation of the trend analysis. As in previous years, most of the significant trends were inconsistent with any reasonable acidification scenario.

In general, there is no definitive evidence in the study lakes to suggest that there have been any significant acidification-related changes in lake chemistry over the length of monitoring conducted under RAMP.

As in previous years the following recommendations are proposed to improve the ASL component:

- In order to track the origin and fate of sulphate (the principal source of acidification) in the RAMP lakes, it is recommended that water samples from a subset of the lakes be analyzed for isotopic species of sulphur for comparison with isotopic ratios in the stack gases; and
- It is recommended that the results of the zooplankton collections from the RAMP lakes be incorporated in the ASL component analyses. The data would be used to identify zooplankton species assemblages and potential changes in these assemblages indicative of acidification. Incorporation of these data represents use of a biological variable (rather than strictly chemical variables) to study acidification-related changes.