6.0 CONCLUSIONS AND RECOMMENDATIONS

The 2006 RAMP monitoring program results have been discussed in detail, in Section 5. The following section provides a brief summary of overall conclusions specific to each monitoring component of RAMP, followed by general comments and recommendations for consideration by the RAMP Technical Program Committee and the RAMP Steering Committee.

6.1 CONCLUSIONS

6.1.1 Climate and Hydrology Component

The outlet 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. A summary of the hydrologic assessment for the watersheds in the RAMP FSA for 2006 is provided below in Table 6.1-1. A number of assumptions have been made in these assessments; these are described in the relevant watershed report within Section 5 and are not repeated here. Most of the hydrologic assessments are rated as negligible with the exception of the Muskeg, Tar, and Poplar watersheds, as well as winter Athabasca River hydrology. Specific water withdrawals and releases, and water diversions, were the focal project activities with the greatest influence in 2006 on hydrologic conditions in these watersheds, including:

- Effects of water withdrawals from the Athabasca River on winter flows;
- Discharges via the Aurora Clean Water Diversion into Stanley Creek and on into the Muskeg River; and
- Increased flows into Poplar Creek via the Beaver Creek diversion and Poplar Creek spillway.

Table 6.1-1 Summary of 2006 hydrologic assessment for RAMP FSA watersheds.

Watershed	Hydrologic Measurement Endpoint			
	Mean Open-Water Season Discharge	Mean Winter Discharge	Annual Maximum Daily Discharge	Minimum Open-Water Season Discharge
Athabasca River	negligible	low	negligible	negligible
Muskeg	low	high	low	high
Steepbank	negligible	*not measured*	negligible	negligible
Tar	low-moderate	low-moderate	low-moderate	low-moderate
MacKay	negligible	*not measured*	negligible	negligible
Calumet	negligible	*not measured*	*not measured*	negligible
Ells	negligible	negligible	negligible	negligible
Firebag	negligible	negligible	negligible	negligible
Christina	No assessment: there is no hydrometric monitoring station at the mouth of the Christina River			
Hangingstone	negligible	*not measured*	*not measured*	negligible
Poplar	high	*not measured*	high	*not measured*
Fort Creek	negligible	negligible	negligible	negligible

Assessments based on comparisons of estimated incremental %change in hydrologic measurement endpoints with criteria used in oil sands EIAs (RAMP 2005b).

"not measured" means hydrologic information was not obtained for times of year for which the measurement endpoint is applicable

Activities that caused land change resulting in closed-circuited areas were the focal project activities that had the second greatest influence on hydrologic conditions in 2006 in RAMP FSA watersheds; these land change activities were as important an effect on hydrologic conditions in the Muskeg River in 2006 as the Aurora Clean Water Diversion.

Activities that caused land change resulting in areas that were not closed-circuited were focal project activities that generally had minor effects on hydrologic conditions in RAMP FSA watersheds in 2006 with the exception of the Tar River.

The cumulative hydrologic effects of focal project activities plus all other active oil sands projects in the RAMP FS 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 2006, was a relatively simple process and provided useful results.

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.

There are a number of minor weaknesses in the network:

- The location of station S15 (Tar River near the Mouth) which is actually located some distance upstream of the mouth and therefore does not measure all of the impacts in the Tar River watershed. Consideration is being given to moving the station downstream in 2007;
- Lack of winter monitoring on the Tar River, Calumet River and Steepbank River; and
- Lack of a hydrometric station at the mouth of the Christina River.

6.1.2 Water Quality Component

Results of the 2006 water quality component suggest that focal project activities had no measurable effects on water quality in almost all surveyed watersheds, as assessed using the methods detailed in this report.

In fall 2006, concentrations of ions and some dissolved metals (e.g., boron) were relatively high at many stations (both reference and potentially influenced) relative to previous years, likely due to low water levels in many streams in summer and fall 2006, and associated changes in the relative contribution of surface water to total flow in these streams.

Effects of focal project activities were indicated in 2006 on water quality in Stanley Creek (a tributary to the Muskeg River) and in the Tar River.

With respect to the Muskeg River, elevated conductivity and high concentrations of dissolved solids and various ions were observed in Stanley Creek in fall 2006, with total dissolved solids, calcium, and sulphate concentrations greater than the 95th percentile of regional baseline concentrations. Water quality in this creek likely was affected by muskeg dewatering and clean surficial water discharged by the Aurora North development; similar high concentrations of total dissolved solids in 2003 and 2005 were attributed to Aurora North's Clean Water Discharge in those years. Water quality at the lower Muskeg River (station MUR-1) did not appear to be affected by changes in water quality in Stanley Creek, given TDS and ion water quality measurement endpoints at this station were within or below historical ranges and between the 5th and 95th percentile of regional baseline concentrations. The only exception to these overall results is the larger proportion of selected water quality measurement endpoints measured at stations designated as *potentially influenced* that was either below the 5th or greater than the 95th percentile of their regional baseline concentrations than at stations designated as *reference*, similar to 2004 and 2005 conditions.

With respect to the Tar River, total nitrogen concentration in the lower Tar River in fall 2006 exhibited a large increase relative to previous years, comprised largely of nitrate and nitrite, which was over seven times higher than previously observed at TAR-1. The high inorganic nitrogen concentration was attributed to discharge of treated sewage into the Tar River.

Exceedances of water quality guidelines occurred in every season of sampling, in both reference and potentially influenced watersheds. Guideline exceedances for several water quality variables (e.g., total aluminum, total iron, total phosphorus) were related to particulate metals in suspended materials, which generally would not be bioavailable. Total phenols commonly exceeded guidelines in all seasons. At station CAR-2 (upper Calumet River, reference station), dissolved oxygen was below the relevant guideline for the protection of freshwater aquatic life during summer sampling. This result is likely related to high organic matter content and the lentic/slow-flowing nature of this site, which is characterized by numerous beaver ponds.

6.1.3 Benthic Invertebrate Communities and Sediment Quality Component

The strength of the RAMP Benthic Invertebrate Community component is the development of baseline data from multiple watercourses in a reference 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 reaches designated as *reference* and *potentially influenced*. Because statistical power is very high, subtle effects that are consistent with operations are inevitable, and were detected with 2006 data. The regional baseline data, however, typically showed that the significant time trends or spatial variations were subtle in comparison to natural background variability.

Of the river reaches that were considered in an operational condition, benthic invertebrate communities of the lower reach of the Tar River provided the most compelling evidence of effects related to operations. Abundance, richness, diversity and evenness have declined in this reach since 2003, and those changes were consistent with degrading habitat quality. The absence of mayflies, caddisflies, and stoneflies in 2006 (like 2005) indicated habitat degradation.

Benthic invertebrate communities in Isadore's Lake (one of two lakes sampled for benthic invertebrates in 2006 that was designated as *potentially influenced*) had a lower number of taxa, diversity and evenness, with the average evenness falling outside the normal range of variation observed in reference lakes (Kearl, McClelland). This 2006 inventory was the first time Isadore's Lake had been sampled within RAMP. Future inventories are planned and will be used to confirm the nature and degree of effect on the benthic community in that lake.

Benthic invertebrate communities in the Muskeg, Mackay and Steepbank rivers were in good condition relative to natural background conditions characterized from regional reference reaches.

Stream slope (gradient) was measured as part of field inventories in 2006. Slope did not relate well to indices of benthic community composition, likely because the instrument used to measure slope had high variability. Based on the 2006 results, it is recommended that stream slope not be measured in the field, but instead be determined from a digital elevation model (DEM).

The sediment quality component was integrated with the benthic invertebrate component for the first time in fall 2006. Sediment quality was sampled at the most downstream benthic replicate in each depositional reach in order to provide supporting habitat data for interpretation of benthic invertebrate community results.

Sediment quality in 2006 was similar to historical sediment quality observed at stations within or near the sampled benthic reaches. In general, concentrations of small hydrocarbons (CCME fractions 1 and 2) were low, while larger hydrocarbons (F3, F4) were more abundant. PAHs were highest in the lower Ells River reach (*reference*), and a high proportion of dibenzothiophenes indicates a petrogenic source of these compounds. Overall, sediment quality monitoring did not suggest any influences of focal project activities.

Relationships among sediment quality variables and between sediment quality variables and benthic invertebrate community metrics were assessed using Spearman's rank correlation analysis. Relationships among sediment quality variables were as expected (e.g., strong correlation between total hydrocarbons and the F3 and F4 hydrocarbon fractions). Moderate correlations found between benthic invertebrate community metrics and sediment quality variables were related to associations of benthic invertebrate fauna with particular habitats (e.g., a negative correlation between % EPT taxa and % silt).

6.1.4 Fish Populations Component

The 2006 RAMP Fish Population component included several core elements in the following watersheds:

- Fish inventories on the Athabasca and Clearwater rivers;
- Fish tissue collection and chemical analysis in the Clearwater River;
- Full-span fish fence program on the Muskeg River;
- Sentinel fish species monitoring on the following Athabasca River tributaries: Muskeg, Steepbank, Horse and Dunkirk rivers; and
- Sentinel fish species reconnaissance program on the MacKay River.

Assessing potential effects of focal projects and other oil sands developments on fish populations is an ongoing challenge due to the limited temporal database (many program elements are not conducted on an annual basis) and alterations to the sampling design between years for some elements. These factors make it difficult to establish the level of natural variability associated with effects or measurement endpoints defined for the Fish Population component. Recognizing these limitations, the Fish Population component is continually being refined in terms of establishing standardized protocols and methodologies. As well, non-lethal sampling approaches are being incorporated to allow greater frequency of sampling while minimizing fish mortality.

Fish Inventory

In 2006, further efforts were made to standardize the analysis of Athabasca River fish inventory data by restricting the calculations of catch-per-unit-effort and composition to fish captured, rather than combining captured and observed fish as in previous years. Standardized current and historical fish inventory data from the Athabasca River indicate some level of species-specific variability in designated measurement endpoints (i.e., relative abundance, length-frequency distribution, and condition factor). However, preliminary statistical analysis of the inventory data thus far have demonstrated limited significant differences among years with no clear trends. Additional inventory data gathered in a standardized fashion are needed to allow for appropriate trend analysis. To date, there is little evidence to suggest that characteristics of key indicator fish populations in the Athabasca River have changed during increasing oil sands and related development in the Athabasca oil sands region.

2006 was the fourth successive year a fish inventory was conducted on the Clearwater River. The fish community in the Clearwater River appears to be similar to that found in the Athabasca River. Preliminary comparisons and analysis of the designated inventory measurement endpoints (e.g., relative abundance and condition factor) have been made using the four-year dataset. However, additional inventory data needs to be gathered in a standardized fashion for assessment of natural variability and to allow for appropriate detailed analysis. As was the case in the two previous years of the inventory, no lake whitefish were captured during the fall sampling. This adds further support to the idea that this species does not use the Clearwater River for spawning or as a migration route, as they do in the Athabasca River.

Fish Tissue

In 2006, potential effects on human health were assessment from individual and composite fish tissue samples collected from the Clearwater River. Results for northern pike analyzed from the Clearwater River indicate that, due to elevated concentrations of mercury and arsenic, there is potential risk from human consumption. Mercury concentrations of Clearwater River northern pike indicate a potential risk for subsistence consumers due to exceedance of mercury relative to the corresponding guideline. The potential human health risks based on arsenic concentrations pertain to both recreational and subsistence consumers, as levels exceeded the Health Canada and US EPA guidelines.

Currently, there is no ASRD Consumption Advisory for northern pike from the Clearwater River. However, there is an ASRD Consumption Advisory for Athabasca River walleye that applies to women of childbearing age and children under the age of 15.

Other metals and tainting compounds did not appear to pose any human health risks. Although mercury concentrations in Clearwater River northern pike tissues exceeded Health Canada and USEPA guidelines, comparison with historical data from the

Athabasca and Muskeg rivers, as well as other fish populations illustrates that these concentrations fall within the natural range of concentrations observed in this region of Alberta.

Effects on fish palatability were not predicted by the 2006 data, given that concentrations of all measured tainting compounds were below detection limits and well below screening values.

Fish Fence

The 2006 fish fence was operational for a complete month, and resulted in the total enumeration of 1,256 fish, 200 more fish than were captured in 2003. Seven fish species representing five families were captured at the Muskeg River fish fence in 2006, two fewer species than captured during the 2003 fish fence operation.

Although some differences as well as similarities are present in the two years of fish fence data (2003 and 2006), any influence by focal project activities on fish utilizing the Muskeg River during the spring spawning season remains largely undetectable and unknown. The tributary system continues to be utilized by populations of multiple fish species during spring, with some evidence to suggest that sucker populations return to the Muskeg River in multiple spawning events. The acquisition of additional data will help in the assessment of natural variability.

Sentinel Fish Species Monitoring

The non-lethal sampling methodology, introduced during the 2004 sentinel program on the Athabasca tributaries, was repeated in 2006. Based on the results of the 2004 program and difficulties in distinguishing between slimy sculpin, (the designated sentinel species), and spoonhead sculpin (a species of special concern) a field identification card was developed and utilized during the 2006 program.

The 2006 sentinel species results for the Steepbank River *potentially influenced* site may indicate one or a combination of the following:

- Limited reproductive capacity in adults;
- Elevated early life history mortality;
- Limited resource availability (e.g. food, preferred habitat); and/or
- Increased competition.

The 2006 sentinel species results for the Muskeg River *potentially influenced* site may indicate one or a combination of the following:

- Increased early life history recruitment; and/or
- Elevated mortality with increased age.

Some of the 2006 results correspond with those of the 2004 non-lethal program, as well as the 2001 lethal program, while others do not. Based on the current three-year cycle, the Athabasca tributaries sentinel species program is scheduled again for 2009. This will provide additional information on the natural variability of reference populations and potential response patterns of potentially influenced slimy sculpin populations.

Sentinel Fish Species Reconnaissance

Based on the reconnaissance sampling program results, the MacKay River appears to be a poor candidate for non-lethal sentinel fish species monitoring. Slimy sculpin abundance is expected to be too low to serve as an appropriate sentinel species because it was captured at only one of the two sites. Longnose dace numbers were also relatively low. In addition to the marginal fish sampling results, an additional potential barrier to the successful implementation of sentinel species program on the MacKay River is the possibility of high water levels that may persist into the month of August. Reliable field conditions are necessary in order to maintain sampling continuity between sampling years.

6.1.5 Acid-Sensitive Lakes Component

As a population, there have been only minor changes in the chemistry of the 50 RAMP ASL lakes over the five years of monitoring. Changes in a small number of variables 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.

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 2006 ranged from -0.177 keq H^+/ha/y to 1.192 keq H^+/ha/y with a median value of 0.291 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 -0.136 keq H+/ha/y to 1.484 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 2006 were 33% (16 of 50 RAMP ASL lakes) using hydrometrically-derived runoff estimates and 40% (20 of 50 RAMP 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 selecting the study lakes where the most poorly buffered lakes were preferentially selected for study. The rates of critical load exceedance in the RAMP ASL lakes were similar 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 to detect changes that might indicate incipient acidification. Analytical error was incorporated in the interpretation of the trend analysis. Most of the significant trends were inconsistent with any reasonable acidification scenario, indicating there is no definitive evidence to suggest that there have been any significant acidification-related changes in lake chemistry over the length of ASL monitoring conducted under RAMP.

6.2 RECOMMENDATIONS

From a sampling design and technical point of view, the three primary objectives of RAMP are:

- To monitor aquatic environment in the Athabasca oil sands region to detect and assess cumulative effects and regional trends;
- To collect baseline data to characterize variability in the Athabasca oil sands region; and
- To collect and compare data against which predictions contained in environmental impact assessments (EIAs) can be assessed.

The recommendations listed below, by RAMP component, are presented for consideration for continued, ongoing strengthening of the program.

6.2.1 Climate and Hydrology Component

- Develop and regularly update an overall plan of the RAMP FSA north of Fort McMurray, showing anticipated progress of mining development and reclamation. The map would be used for planning changes to the climate and hydrologic monitoring network;
- Enhancing the hydrologic monitoring network by moving RAMP station 15 (Tar River near the Mouth) downstream, conducting winter monitoring on the Tar River, Calumet River and Steepbank River; and installing a hydrometric station at the mouth of the Christina River; and
- Continue quantification of areas of land change using satellite imagery.

6.2.2 Water Quality Component

- Continue to focus RAMP water quality sampling in fall, as it is broadly representative of water quality observed in other seasons;
- Continue to assess seasonal water quality at newly established stations or stations with insufficient seasonal data for potential impact characterization, per the existing RAMP water quality design; and
- Establish a new mid-Christina River station, to provide a more representative reference station for CHR-1 (i.e., downstream of saline water inputs to the Christina River) to that at CHR-1; this station will be established in 2007.

6.2.3 Benthic Invertebrate Community and Sediment Quality Component

- Continue to sample sediment quality in conjunction with the benthic invertebrate component;
- Determine slope from a digital elevation model (DEM); and
- Develop strategies for accessing Athabasca River delta sites during periods of low water levels that restrict boat access.

6.2.4 Fish Population Component

- The non-lethal approach to sentinel species monitoring should be continued in the Athabasca River tributaries. Currently, condition factor is the only measurement endpoint that has an assigned impact criterion. Implementation of further non-lethal sentinel species programs under RAMP will help to provide the basis for formulation of impact criteria for other proposed measurement endpoints associated with fish growth, survival and reproduction;
- Non-lethal sentinel species monitoring should be expanded to include the Athabasca River using trout-perch as the sentinel species, and is scheduled to occur in 2007;
- Continued efforts are needed to standardize field data collection procedures/methods and data analysis for the fish inventory program, particularly on the Athabasca River;
- Continued application of a non-lethal sampling approach for the RAMP fish tissue program has been successful based on results from pilot studies conducted in 2004, 2005 and 2006 results. Efforts should be made to further expand, refine and apply the non-lethal approach to tissue collection for individual mercury analysis; and
- Comparative testing of hydroacoustic fish sampling methods should be undertaken during a future Muskeg River fish fence program (possibly as early as the spring of 2007). This would be done as a cooperative venture between Fisheries and Oceans Canada (DFO) and RAMP.

6.2.5 Acid-Sensitive Lakes Component

- In order to track the origin and fate of sulphate (the principal source of acidification) in the RAMP lakes, it is recommended that the RAMP water samples be analyzed for isotopic species of sulphur for comparison with isotopic ratios in the stack gases; and
- It is recommended to incorporate the results of the zooplankton data from the RAMP lakes available from Environment Canada. The data would be used to identify zooplankton species assemblages and potential changes in these assemblages indicative of acidification.