Mine Closure 2011 — A.B. Fourie, M. Tibbett and A. Beersing (eds)
© 2011 Australian Centre for Geomechanics, Perth, ISBN 978-0-9870937-1-4
doi:10.36487/ACG_rep/1152_98_Plante

# Improving fish habitat productivity through controlled dam removals and fishway construction as part of a reclamation plan

**F. Plante** *Department of Fisheries and Oceans, Canada*

**M. Clément** *Department of Fisheries and Oceans, Canada*

**D. Caissie** *Department of Fisheries and Oceans, Canada*

## Abstract

*Mining sites are frequently equipped with dams and reservoirs for water supply. At the time of closure, the dam decommissioning represents an important component of reclamation programmes. Several small dams in North America are reaching the end of their lifespan and the removal process is becoming an increasingly popular technique in the restoration of fish habitats.*

*During the reclamation process at the Heath Steele Mine (NB, Canada), approximately 90 km$^2$ of drainage basin area has been reopened to fish migration in the North Branch of the Miramichi River system through dam removals and modifications to existing obstructions.*

*It was difficult to attribute any changes in the water temperature regime to the dam removal because data were only available after the dam was removed. Nonetheless, no major impact on water temperature was detected as a result of the dam removal. An increase in water temperature was observed in only one branch of the newly formed stream (draining within the old reservoir). Water temperature in other branch remained cold (and similar to its upstream site), suggesting the presence of groundwater seepage. The mean monthly water temperature increased by a maximum of 2.2ºC at the site located downstream of the decommissioned dam. However, water temperature at the mouth of the Little South Branch Tomogonops River (10.5 km downstream of the decommissioned dam) returned to values similar to those recorded at the inlet of the old reservoir. This decrease in water temperature can be attributed to the forest canopy (stream shading), groundwater seepage or colder tributaries flowing into the main stem in this section of the river. Brook trout abundance in the newly formed stream within the reservoir section was low (<0.04 individual/m$^2$) compared to the downstream site (<1.2 individual/m$^2$) but was within densities frequently observed in other streams of the province of New Brunswick.*

*Another dam removal project was conducted in White Rapids Brook (Miramichi River) in 2006. Although sediment transport was present at some sites following the removal, the impacts were low, localised, and of short duration. Atlantic salmon recolonised the newly accessible habitat within one year of the dam removal. The planned work sequence and proper mitigative techniques were key components in protecting fish habitat in these projects. Moreover, results showed that when proper techniques were implemented, negative impacts were minor and localised compared to the long-term benefits.*

*These projects represented a unique opportunity for researchers and habitat managers to study the recovery of fish habitat following dam removals, and to better understand river restoration processes. Such studies dealing with river restoration will permit the development of procedures, methods and guidelines for decision-making in future dam removal projects.*

## 1 Introduction

Mining sites are frequently equipped with dams and reservoirs for water supply. At the time of closure, the dam decommissioning planning is often neglected despite the fact they represent an important component of reclamation programmes. Knowledge of the potential effects of dam removals on rivers e.g. effects on water temperature regime, downstream movement of fine sediments stored in the reservoir, etc., as well as the ecological and morphological processes following dam removals are often lacking (Bednarek, 2001; Pizzuto, 2002). It is therefore crucial to have a more thorough understanding of the potential impacts (both negative and positive) of dam removal on river systems.

Noranda Inc., Heath Steele Mine, operated a base metal mining and milling operation in north-central New Brunswick, Canada (Figure 1). The mine is located within the headwaters of the Tomogonops River, a tributary of the Northwest Miramichi River. This site has a long history of mining. For instance, the mine and mill facilities were first developed in 1955. The mine closed in November 1999. Both prior to closure and following the closure, extensive rehabilitation activities have been undertaken. Heath Steele Mine is currently owned by Xstrata.

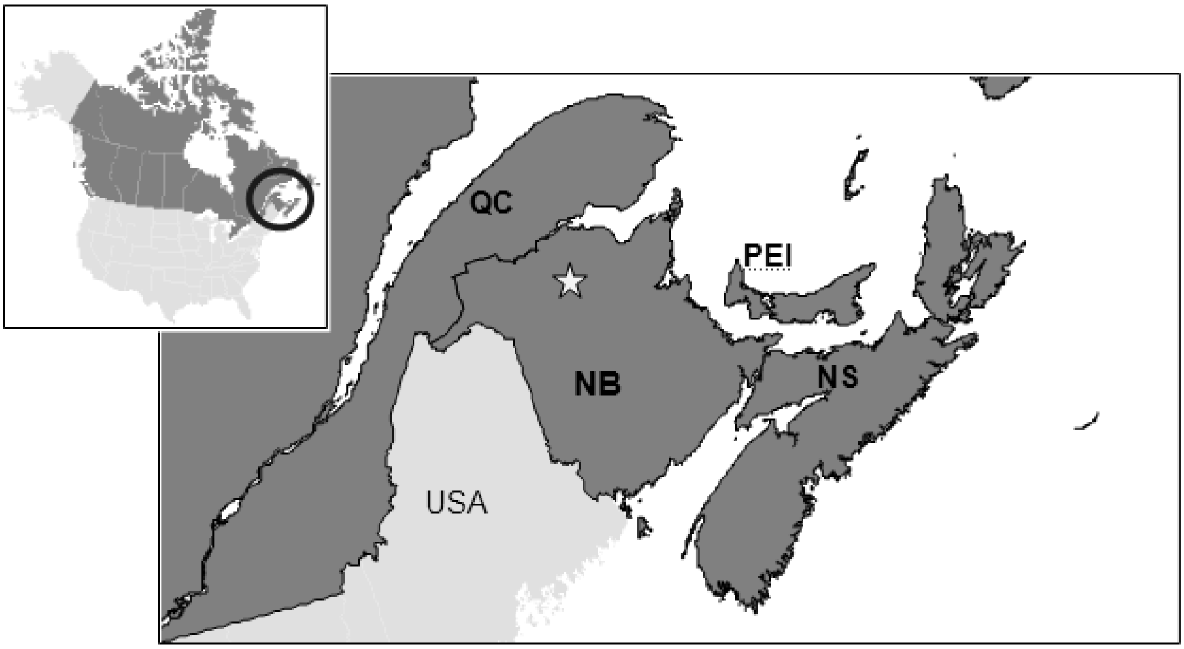


**Figure 1 Location of Heath Steele Mine, New Brunswick, Canada**

Two dams, North Little River Reservoir and McCormack Reservoir, as well as three culverts were removed in addition to the construction of four fishways (fw1 to fw4) as part of reclamation works at Heath Steele Mine (Figure 2). These structures were identified as complete obstruction to fish passage and were impacting approximately 90 km$^2$ of drainage area on tributaries of the Northwest Miramichi River. By mid August, 2005, reservoirs were drained and fish salvaged. At these locations, dams were removed and fishways were constructed. Brook sections were reconstructed and realigned to reconnect downstream sections to formerly flooded habitat. Other obstructions were removed or modified to provide fish passage.

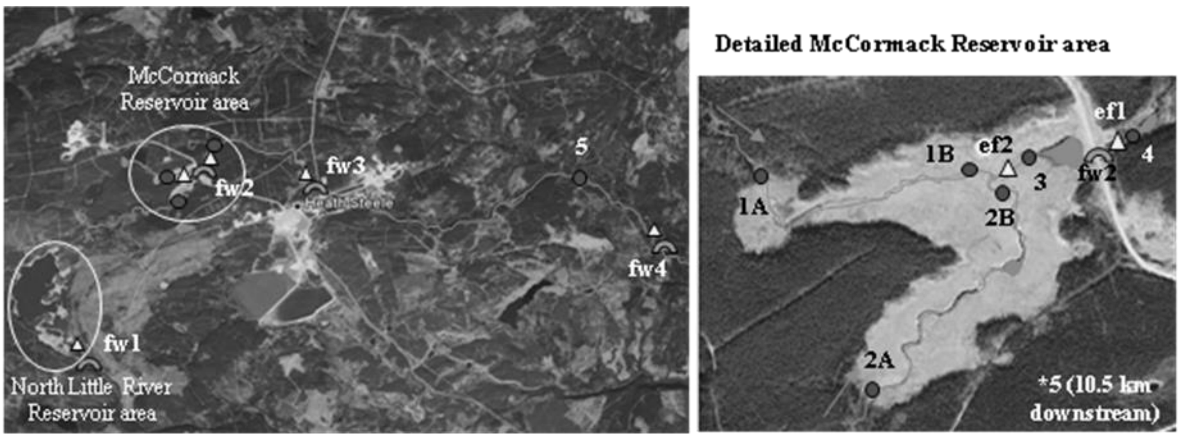


**Figure 2 Experimental sites location at Heath Steele Mine, New Brunswick, Canada (circles: temperature probes; triangles: electrofishing sites; arches: new fishways – map modified from Google earth™)**

# 2 Methodology

By mid August 2005, the McCormack Reservoir was completely drained. Water was siphoned over the remaining dam through a settling pond, and then this water was released in the surrounding vegetation adjacent to the natural brook (in order to keep the water free of sediment during the decommissioning operations). Seines and trap nets were used to salvage fish from the reservoir. Dip nets and electrofishers were used to rescue stranded fish from isolated pools. Water tanks equipped with aerators were used to relocate captured fish in nearby watercourses and to ensure that fish habitat was not oversaturated. Water temperature was monitored during two years after the dam decommission activities.

Water quality (Total Suspended Sediment (TSS)) was monitored and tested by the proponent twice daily during the decommissioning operations. As a condition of the permit, TSS in the receiving environment had to be kept under 50 mg/L.

In autumn 2006 to 2009, electrofishing was conducted at two sites (50 m in length). One site was located upstream (ef1) whereas the other site was located downstream (ef2) of the former dam (Figure 2). Additional electrofishing surveys were conducted at these sites, as well as in and around the 4 newly constructed fishways. Trout density (number of fish per square metre), was calculated and compared to trout density within the reservoir prior to dam removal.

In 2006 and 2007, 5 thermographs (8 bit Minilog TR 16K, Vemco™) were installed from June to October in the newly formed stream upstream of the removed dam (Figure 2). A thermograph was installed 30 m downstream the decommissioned dam (site 4) and at the mouth of the Little South Branch Tomogonops River (Site 5, 10.5 km downstream the decommissioned dam, Figure 2). In 2006, all thermographs were installed on 12 June except at Site 5 (28 June 2006). The mean water temperature in June 2006 (all sites except Site 5) was based on 19 days partial data series. Thermographs were installed prior to 1 June 2007 and mean water temperatures were calculated for the entire month at different locations upstream and downstream of McCormack dam study site. In the present study, the Duncan's multiple range (DMR) test was used to differentiate the differences in water temperatures among sites (SAS 9.1.3™). This test evaluates the statistical significance of ranges in the sorted sample for each pair of means using the studentised range statistic.

# 3 Results

## 3.1 Water temperature

Data from some thermographs could not be retrieved as they were malfunctioning, which prevented a full comparison of the mean monthly water temperatures. Nonetheless, in 2007, water temperatures were similar between Sites 1A and 1B (maximum difference of 0.5ºC in July 2007, $p > 0.05$; Figure 3). In contrast, water temperatures were significantly warmer at Site 2B compared to Site 2A from June to September (2006 and 2007, $p < 0.05$) (maximum difference of 2.2ºC was observed in July 2007). In the main stem of the Little South Branch Tomogonops River, water temperatures recorded at Site 4 were warmer than Site 3 (maximum difference of 1.2ºC recorded in July 2006 and 2007) but the difference was not statistically significant ($p > 0.05$). Water temperatures at Site 5 were significantly colder than Site 4 from June to September in 2006 and 2007 (maximum difference of 2.0ºC in September 2006, $p < 0.05$; Figure 3). However, water temperatures at Site 5 were similar to those recorded at Site 3, Sites 1A and 2A ($p > 0.05$), suggesting a recovery in comparison to Site 4. In October 2006 and 2007, no significant differences in water temperatures were observed between sites ($p > 0.05$).

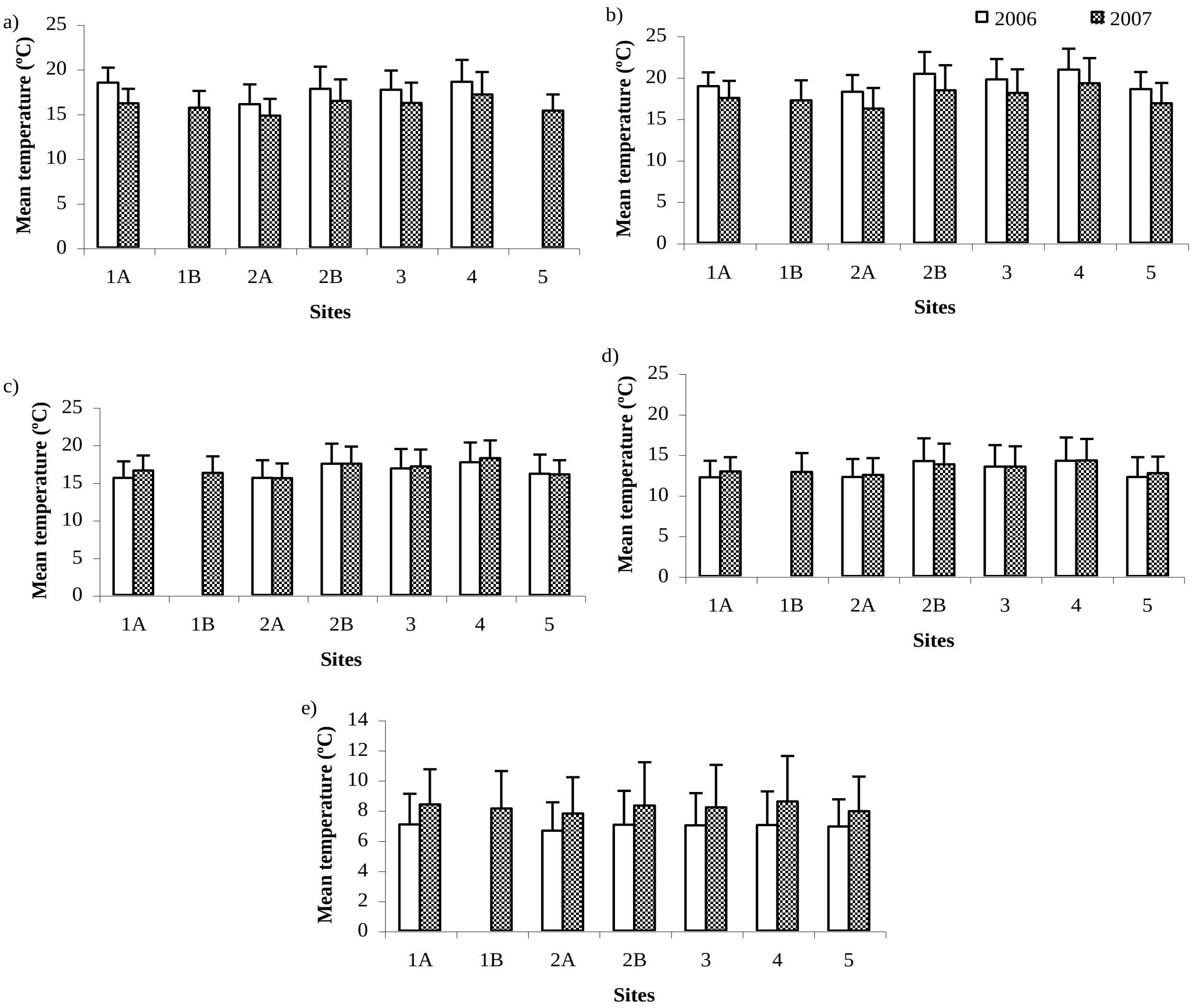


**Figure 3 Mean monthly water temperature for a) June b) July, c) August, d) September and e) October (2006 and 2007) at different study sites at Heath Steele Mine (Sites 1 to 3 were located in the drained reservoir. Sites 4 and 5 were located downstream of the dam)**

## 3.2 Fish abundance

The fish salvage operations collected a total of 54,276 White suckers, chubs, and daces in the whole reservoir as well as 166 Brook trout. According to the size of the reservoir, Brook trout density was estimated at 0.0005 individual/m$^2$. Following the dam removal, trout densities were lower (<0.04 individual/m$^2$) in the site located upstream of the former dam (ef1; Figure 2 for site location) compared to the downstream site (ef2; <1.2 individual/m$^2$; Figure 4). Nonetheless, densities in the newly formed stream were much higher than the trout density in the former reservoir although they represent totally different habitats.

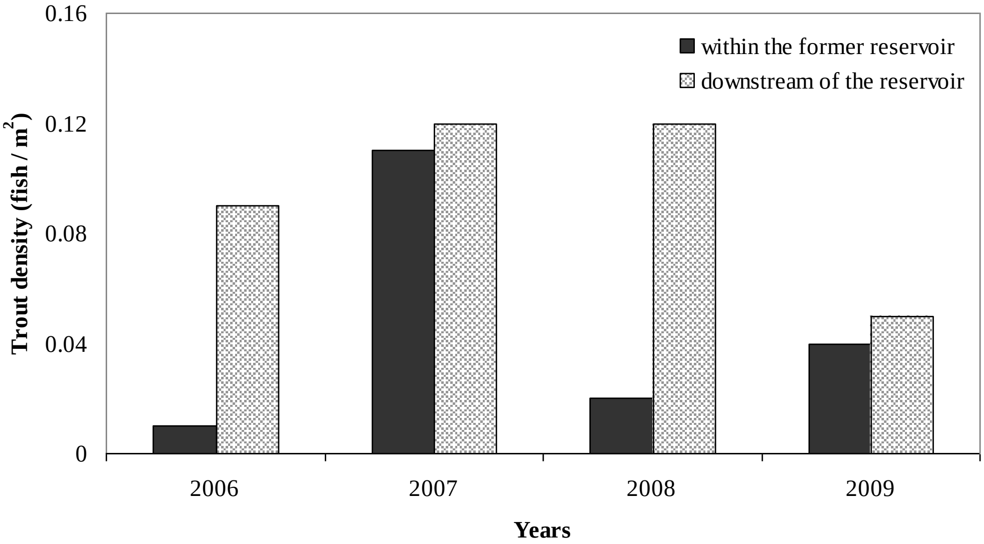


**Figure 4 Brook trout density within and downstream of the former McCormack Reservoir at Heath Steele Mine**

Electrofishing surveys were also conducted in and around the 4 newly built fishways. At every site, Brook trout have been captured in the fishway. Furthermore, 3 years after the project, Atlantic salmon of 3 different age classes have been identified upstream of the fishway located on the Tomogonops River (fw4; Figure 2 for location).

### 3.3 Suspended sediment

For each working site, TSS was monitored and tested onsite by a technical staff twice daily during the duration of decommissioning operations. During the morning of 1 September 2006, the limit of 50 mg/L sets within the permit was exceeded for the first time (80 mg/L) following a heavy rain of 50 mm in 12 hours (SNC-Lavalin, 2006). This event was the remnant of hurricane Katrina. Samples collected in the afternoon that day yielded a concentration of 35 mg/L, a concentration well below the allowable limit and work continued thereafter.

On 17 September 2005, after the work was completed, the cofferdam upstream of the dam was removed, allowing water to flow through the newly installed fishway. Water samples were collected in the morning, after the removal of the cofferdam, and a TSS concentration of 55 mg/L was observed. The sample collected in the afternoon yielded a TSS concentration of 34 mg/L, indicating that the water quality returned under the allowable limit.

## 4 Discussion

### 4.1 Water temperature

It was difficult to attribute any changes in the water temperature regime to the dam removal, because data were only available after the dam was removed. Nonetheless, no major impact on water temperature was detected when looking at increases in temperatures in newly created streams within the older reservoir area. The lack of increase in water temperature from Sites 1A to 1B can be attributed to the presence of groundwater seepage in the newly formed stream. In contrast, water temperature increased between Site 2B and Site 2A (during the warmer months, June to September) which can be attributed to absence of canopy cover along the bank of the newly formed stream. Although not statistically significant, the increase in water temperature recorded at Site 4 (site located downstream of the decommissioned dam) can be attributed to the presence of 2 small pond formed upstream and downstream of the constructed fishway. Nonetheless, this increase in water temperature was localised and water temperature at the mouth of the Little South Branch

Tomogonops River (Site 5, located 10.5 km downstream of decommissioned dam) returned to upstream values (i.e. similar to those recorded at the inlet of the former reservoir, Sites 1A and 2A). Water temperature generally increases in a downstream direction, especially in small streams (Caissie, 2006). In the main stem of the Little South Branch Tomogonops River, canopy cover, groundwater seepage and colder tributaries emptying into the main stem may all have contributed to cooling water temperature downstream of Site 4.

## 4.2 Fish abundance

During the fish salvage operation, Brook trout density in the reservoir was estimated to 0.0005 individual/m$^2$. This low abundance of salmonid suggests a warmer environment than expected in this portion of the province. From 2006 to 2009, trout densities within the newly formed stream were approximately 100 times higher than the trout density in the former reservoir. Although trout densities were slightly lower within the former reservoir (<0.04 individual/m$^2$) compared to the downstream site (<1.2 individual/m$^2$), trout densities in the newly formed stream returned to values frequently observed in other streams of New Brunswick. For example, mean trout densities varied between 0.02 to 0.27 individual/m$^2$ in Catamaran Brook (a tributary located in the nearby area) (Mitchell et al., 2004). Delays in recolonisation and population rehabilitation are frequently observed following dam removals (Pess et al., 2008). Trout may recolonise this stream section with time. Trout were observed in all fishways, which suggests that these structures are providing access to upstream available fish habitat.

## 4.3 Suspended sediment

Although this project had a well planned construction sequence ,backed-up by a series of sediment control structures implemented to mitigate the anticipated disturbance, it was not possible to completely eliminate TSS related to the construction activities. However, it was observed that in both cases where higher than allowable TSS concentration was experienced at the McCormack site, these events did not impact water quality further downstream. In fact, water samples collected simultaneously at the other working site approximately 3.5 km downstream (fw3) yielded a TSS concentration of only 2 mg/L in both instances (SNC-Lavalin, 2006).

## 4.4 Similar projects

In 2006, another dam was decommissioned in the nearby area. Although the reservoir in White Rapids Brook was smaller (6,400 m$^2$) compared to Heath Steele Mine, this project represented an opportunity to conduct a full study to evaluate and quantify the impacts of a dam removal and the effectiveness of mitigative measures implemented at Heath Steele Mine. The White Rapids Brook (drainage basin of approximately 20 km$^2$) is also located in the Miramichi drainage basin and is located 60 km south of the Heath Steele Mine. Observations and electrofishing surveys confirmed aggregation of adult Atlantic salmon downstream of the dam during the spawning migration (Norman Stewart, White Rapids Brook Enhancement Association, pers. comm., 2005). The dam was identified as a complete obstruction to fish passage for 90% of the stream length.

By mid August 2006, the reservoir at With Rapids Brook was completely drained. Approximately 300 m$^3$ of sediment accumulated upstream of the dam was removed using excavators and transported offsite. The existing brook was rerouted through a temporary plastic lined diversion channel along the south side of the former reservoir, keeping the water free of sediment during the decommissioning operations and providing for fish passage. A sedimentation pond was built to catch sediment laden runoffs, and then this water was pumped into the surrounding vegetation. The dam was removed and a new channel ,approximately 250 m in length, was constructed and stabilised within the reservoir section. A culvert located 30 m downstream of the dam was also removed. Rock riprap and vegetation bundles were used to stabilise the banks and the area of the former reservoir was covered with mulch. It was determined that restoration of the channel within the reservoir was only required for a length of 250 m due to smaller quantities of sediments accumulated in the upper portion of the old reservoir (Plante et al., 2009).

A before, during and after study design was used to quantify the effects of the White Rapids dam removal. TSS concentrations were recorded and sedimentation was quantified using sediment traps. TSS was generally below 100 mg/L at the sites located upstream and downstream of the dam. Two events of high TSS

(>650 mg/L) were recorded downstream of the dam during the decommission activities but these events were brief (<7 hrs) and were associated with the stream diversion into the reconstructed channel during the removal of the dam and with the culvert removal. In general, it was judged that the potential impacts associated with sedimentation were small in White Rapids Brook.

The electrofishing surveys confirmed that Atlantic salmon parr are using habitats previously inaccessible after the dam removal. Evidences of spawning or presence of young of the year has been confirmed within newly accessible habitats (Marie Clément, Department of Fisheries and Oceans, unpublished data). It is expected that fish will recolonise the entire watercourse within a few years.

# 5 Conclusion

The dam removal in both Heath Steele Mine and White Rapids Brook induced minor negative impacts during the decommission activities. Previous studies showed that dam removals can induce significant impacts to aquatic habitat and biota located downstream (Bogan, 1993; Sethi et al., 2004). The success in removing these dams without introducing significant negative impacts can be attributed to 1) a progressive and slow drainage of the reservoir, 2) the management of accumulated sediments from the reservoir prior removing the dam, and 3) the use of sedimentation pond which trapped sediments during decommissioning operations.

Normally, water temperature increases slightly in rivers in the downstream direction due to heat exchange with atmospheric conditions (Caissie, 2006). In the Little South Branch Tomogonops River it was not the case downstream of Site 4. The highest temperature was recorded at the site located downstream of the former dam (Site 4). This could be attributed to the fact that there were small impoundments immediately above Site 4 which could have contributed to some of the heating. Water temperature increased as water flowed through one branch of the newly formed stream (from Sites 2A and 2B). This section of the brook offered very little in terms of protection against solar heating. In contrast, the brook section between Sites 1A and 1B appeared to be cooled by groundwater seepage. Water temperature at the mouth of the Little South Branch Tomogonops River returned to values similar to those recorded at the inlet of the former reservoir. Water temperature in reservoirs upstream of dams frequently reaches values well above 25ºC, especially at the surface. Prior to the dam removal, water spilling over the dam most likely warmed up water temperature (above 27ºC) in fish habitats located downstream of the McCormack Reservoir (Norman Morris, Xstrata, pers. comm., 2006). Therefore, it was concluded that dam removal was beneficial and it is expected that natural water temperature regime within the former reservoir will be re-established as vegetation along the bank of the newly formed stream will be re-established.

The dam removal at Heath Steele Mine induced minor TSS events during the decommission activities. Only brief events of high TSS were recorded downstream of the site. These events occurred following a high rainfall event and during the reconnection of the river to its newly constructed bed. Sediment transport is a major concern related to dam removals. Previous studies showed that dam removals can induce significant impacts to aquatic habitat and biota located downstream (Bogan, 1993; Sethi et al., 2004). As observed in a previous study (Plante et al., 2009), the substrate below the White Rapids Brook dam was deficient in cobble, gravel, and fine sediments prior to decommissioning the dam. In some instance, a small amount of sediment caused by a dam removal can re-established sediments transport process downstream and the substrate composition should reflect more natural conditions within this section in the future (Shuman, 1995).

Planned work sequence and proper mitigation techniques were key components in the success of this dam removal project. Results showed that when proper techniques were implemented, negative impacts were minor compared to the long-term benefits such as providing access to migratory fish to upstream reaches, which could translate into increased fish production.

# Acknowledgements

Authors thank Richard C. Schwenger (regional reclamation manager, Xstrata) and Norman Morris (site manager, Xstrata) for facilitating site accessibility during this research project and monitoring programme. We also thank Denis Haché (Department of Fisheries and Oceans) for the engineering review prior dam decommissioning and Peter Hardie (Department of Fisheries and Oceans) for data collection and his participation during electrofishing surveys.

## References

Bednarek, A.T. (2001) Undaming Rivers: A Review of the Ecological Impacts of Dam Removal, Environmental Management, Vol. 27, pp. 803–14.

Bogan, A.E. (1993) Freshwater Bivalve Extinctions (Mollusca: Unionoida): A Search for Causes, American Zoologist, Vol. 33, pp. 599–609.

Caissie, D. (2006) The thermal regime of rivers: a review. Freshwater Biology, Vol. 51, pp. 1389–1406.

Mitchell, S., Fraser, A., Hardie, P. and Cunjack, R.A. (2004) Electrofishing data summaries from Catamaran Brook, New Brunswick, 1990–2002, Canadian Data Report of Fisheries and Aquatic Sciences, p. 1130.

Pess, G.R., McHenry, M.L., Beechie, T.J. and Davies, J. (2008) Biological impacts of the Elwha River dams and potential salmonid responses to dam removal, Northwest Science, Col. 82, pp. 72–90.

Pizzuto, J. (2002) Effects of dam removal on river form and process, BioScience, Vol. 52, pp. 683–92.

Plante, F., Clément, M. and Caissie, D. (2009) Positive impacts on fish habitat from a controlled dam removal project, Proceedings 2009 IAHR Congress, 2009 – Water Engineering for a Sustainable Environment, 9–14 August 2009, Vancouver BC, Canada.

Sethi, S.A., Selle, A.R., Doyle, M.W., Stanley, E.H. and Kitchel, H.E. (2004) Response of Unionid Mussels to Dam Removal in Koshkonong Creek, Wisconsin (USA), Hydrobiologia, Vol. 525, pp. 157–165.

Shuman, J.R. (1995) Environmental considerations for assessing dam removal alternatives for river restoration, Regulated Rivers: Research & Management 11, pp. 249–261.

SNC-Lavalin (2006) Heath Steele Closure Project, Freshwater dams closure and repairs, 2005 construction, as-built report 334384, 125 p.