DIVERSION OF THE RIVIÈRE AU RENARD [Fox River] — GASPÉ

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BACKGROUND

The Ministry of Transportation of Quebec (MTQ) had, since 1979, been planning to rebuild a portion of Highway 197 linking two areas of the City of Gaspé, namely Saint-Majorique and Rivière-au-Renard. This project also included replacing the Denis Bridge located approximately 7.4 km from the mouth of the Rivière au Renard on the Gulf of St. Lawrence. The area earmarked for reconstruction had very sharp curves that adversely affected users' safety.

This highway is bordered on the south by Forillon National Park and follows or crosses the Rivière au Renard, known for being very active and unstable in the valley sector, especially during high-water periods. Many personal accounts and documents pointed to the existence of serious river degradation problems that occurred with every high-water period.

After the valley sector underwent considerable deforestation between 1950 and 1970, the Rivière au Renard experienced high water levels in the spring of 1954 that widened its riverbed and flooded several houses and properties. Extensive work was subsequently carried out between 1956 and 1974 to repair, divert and enstone the river and to install wattle. Then, in 1975, the Ministry of Public Works constructed a sedimentation basin to reduce the amount of sediment reaching the fishing harbour at the mouth of the river.

From May to July 1980, the river ran exceptionally high. In May, three bridges located downstream from the reconstruction project were carried away. In order to eliminate the need for two bridges, the MTQ was forced to divert the river by enstoning the new channel (bed and banks). Although this new channel withstood the high water in July, considerable damage ensued upstream, i.e. significant erosion, the formation of meanders, and the destruction of a power line, a house, and nearly 35 metres of road (to the centre line) upstream from the Denis Bridge. The MTQ had to intervene, backfilling nearly a nearly fifty-metre section with stone. For its part, the Ministry of Environment and Fauna repaired the river at several locations following the July 1980 high water.

HISTORY OF THE MTQ's HIGHWAY PROJECT

As previously mentioned, the MTQ had, as of 1979, a project in mind to reconstruct Highway 197 along the Rivière au Renard and to replace the Denis Bridge. This project was part of a series of projects designed to correct the geometrical alignment and vertical profile of the roadway, to increase the number of passing zones, and to replace the existing steel-wood structures on the highway.

Between 1981 and 1984, modifications were made to the route to limit the expropriation of houses and to reconstruct an urban section of the highway. From that point on, the route necessitated diverting a section of the river.

After conducting hydrological and hydraulic studies and drafting plans and specifications, the Ministry split the initial project in 1997 to speed up the reconstruction of two bridges that had reached the end of their useful lives. However, the requirements of an environmental impact study on the diversion of the river led to the suspension of the project in September of that same year. Then, in the spring of 1998, the MTQ considered a potential route through Forillon National Park.

1998 HIGH WATER

In October of 1998, a subsequent occurrence of extremely high water forced the evacuation of 30 families, destroyed the Denis Bridge, and caused serious river damage above and below the bridge, namely serious erosion of the banks, the formation of large meanders, shifting, and the creation of secondary channels that threatened several residences located near the river. The MTQ therefore had to construct a temporary bridge with the same alignment as the former Denis Bridge. It henceforth became essential to rebuild Highway 197 and the Denis Bridge.

The MTQ then analysed three options:

1. The **diversion option**: building Highway 197 in a direct line behind the residences affected by the flooding, i.e. along the north shore of the river, which would involve building a bridge upstream and diverting the river downstream along a nearly 300-metre section.
   - Length of the project: 1,910 metres
   - Cost: $2,970,000 (excluding costs for river-related work)
2. The **bold option**: a route located more to the north of the river involving the construction of a bridge upstream but no diversion of the river (this was the first route considered by the MTQ in 1979 but rejected due to excessive expropriation of properties).
   - Length of the project: 1,915 metres
   - Cost: $3,770,000 (excluding costs for river-related work)
3. The **Forillon Park option**: a route south of the river in Forillon National Park necessitating the construction of a bridge downstream from the section in question. This route would have crossed a vertical drop (hill of rock).
   - Length of the project: 2,665 metres
   - Cost: $4,245,000 (excluding costs for river-related work)

To minimize the government resources required, a meeting was held in December to work toward achieving concerted action by all the agencies that had been involved in dealing with the last high-water period, namely the City of Gaspé, the Ministry of Environment and Fauna (MEF), the Ministry of Public Safety (MSP), and the MTQ. This meeting saw option 1 emerge as the priority route; diverting the river would involve expropriating six residences on the section of highway to be abandoned. Indeed, the choice of the diversion option was justified by the urgency of the situation, the state of the riverfront residences along the highway, the conservation character of Forillon National Park that limited allowable work within its boundaries, and, finally, the pressing obligation to protect the highway infrastructure and some residences from the risk that the meanders would grow and shift, which could occur during the next high-water period. As well, diverting the river and relocating the new highway would protect other residences on the north side facing a medium-term threat from actively eroding banks.

However, the MTQ had to conduct hydraulic and environmental impact studies before the final route could be adopted. Furthermore, given the urgency of the situation, the Ministry of Public

Safety prepared to request a special protection order for two residences, and the MEF agreed to issue an emergency order concerning the environmental approval, conditional upon the required studies.

PLAN TO DIVERT THE RIVER

An in-depth analysis of the river was conducted (with input from an international expert in this field) that examined its hydrological, hydraulic, geotechnical, morphological and wildlife aspects.

The overall findings of the studies were more alarming than expected, revealing that the river was degrading along the section of Highway 197 earmarked for reconstruction. The studies indicated that there was a significant risk of high water reoccurring, that further river instability was to be expected in the short term if the stabilization work were not carried out, and that the banks of the river were significantly more vulnerable to erosion than the riverbed, which increased the risk that the watercourse's meanders would expand and place the private residences at greater risk.

Against this background, the work could not have as its sole objective the reconstruction of the highway and bridge but also had to seek morphological balance and to reduce the amount of sediment and debris arriving downstream; by the same token, this meant having a positive impact on the environment. Regardless of the final highway route selected, the new river profile had to follow the curves upstream and downstream on each side of the affected section. Corrective work within the section would also be essential to protect the river dwellers, the highway and the bridge. However, intervention could not be restricted to the section in question due to the instability observed further downstream.

The "diversion" option was superior to the other options with respect to the technical and economic criteria as well as the hydraulic, environmental and social criteria. From the outset, it must be pointed out that this option involved the total reconfiguration of 1.3 km of Highway 197, including the construction of a new, wider bridge and the relocation of the bed of the Rivière au Renard along a 700-metre section. Once completed, the new section of river would be 870 metres long and come with a $6.8 million price tag.

In addition to guaranteeing stability over the short, medium, and long term, the techniques used to design the work to be carried out on the river had to fully respect the watercourse's natural equilibrium with respect to gravel and pebbles, a stable route, and a natural geometry. The plan therefore included well-configured repair and stabilization work that involved creating pools and sills, a main riverbed, a minimum-flow channel for fish migration, a dominant channel to handle moderately high water and ice, and a flood plain to handle extremely high water.

These multiple objectives would allow the entire physical and dynamic environment, even of the river, to benefit from the work. Over the medium term, the river could thus recover a totally stable morphology and gradually meld into the landscape.

By taking advantage of the reconstruction of Highway 197 and the replacement of the Denis Bridge to correct a section of the river, the “diversion” option would:

- Satisfactorily meet the objectives of the highway reconstruction project;
- Protect the residences;
- Improve physical security in the short, medium and long term;
- Re-establish the river’s morphological equilibrium profile in the sector above the bridge;
- Halt the ongoing erosion process and expansion of the meanders;
- Reduce the risk of flooding and protect the residences on the north shore;
- Improve and stabilize the flow conditions below the affected section so as to restore the waters to the equilibrium route of the years 1963 and 1977 (positive impact on the unstable downstream sections);
- Recreate flow conditions supportive of wildlife needs and thus improve the wildlife habitat in the sector;
- Reduce the amount of sediment and various debris arriving downstream (positive impact on the fishing harbour);
- Lead to expropriation of residences on the south shore.

Conversely, performing only temporary and partial work would have necessitated periodic monitoring and maintenance costs that could have proved more onerous than configuring a new riverbed, which would, in addition, have provided stronger all-round guarantees.

STEPS IN PERFORMING THE WORK

To achieve the aforementioned objectives, the work on the river could be summarized as follows:

- Reprofiling of the river’s dominant channel (2-year flood) in a equilibrium route similar to that of 1977, i.e. identical to the 1963 and 1965 routes;
- Construction of a flood plain (100-year flood) from the channels created by the 1998 high water;
- Diversion of the downstream part of the route (approximately 300 metres) to allow the construction of the roadway;
- Creation of pools in the diversion and upstream for wildlife purposes;
- Stabilization of the dominant channel with rock fill in high-risk areas (e.g. concave banks);
- Stabilization of the concave banks with rock fill at the end of the affected section in order to safely and permanently restore the downstream waters, as per the years 1963, 1965 and 1977;
- Stabilization of the flood plain using gentler methods (vegetation guard);
- Joint highway-riverbank protection (rock fill) where the highway and river were adjacent.

Since diverting a river is not an everyday occurrence and this type of intervention is only allowed as a last recourse to address specific situations, extensive environmental requirements apply. To obtain the targeted results, many restrictions related to the techniques for executing the work were stipulated in the plans and specifications, both for the riverbed and riverbanks.

Thus, very clear parameters were set out with respect to the work to be conducted on the river. In general, it was clearly established that, given the torrential nature of the river and the proximity of Forillon National Park, the contractor was to limit the work corridor to the strict minimum, that no traffic or activity was allowed in the park, and that under no circumstances was work to be conducted in white water. Furthermore, the contractor had to advise the MTQ's representative of the method he intended to use to avoid spilling demolition materials into the watercourse.

As well, to avoid damaging permanent and temporary infrastructure and impacting fish fauna during the work, the contractor was to implement the following attenuation measures:

- Removing the machinery from the flood plain outside work hours, during suspension of work, and during periods of heavy rain;
- Mechanically protecting the temporary diversion channels, temporary infrastructure along the river, and areas along the river subject to erosion, through enstonement or any other work approved by the work supervisor;
- Mechanically protecting the storing or setting aside of excavated materials near the river through enstonement or any other infrastructure able to handle sudden changes in the river's water level;
- Ensuring that the planned enstonement was completed before opening the diversion to water, only opening the diversion during a period of minimum water flow, and submitting the method for approval before starting work;
- Preserving the vegetation and woods in some specific areas.

In addition, all cutting of trees was strictly prohibited before August 1, i.e. during birds' nesting period.

<u>Work on the riverbed</u>

The work on the riverbed was supposed to restore the river's historical geometry and morphology. However, it is important to specify that the objective was to create channels with mobile beds and not fixed ones, thereby allowing the river to adjust on its own and provide a greater diversity of wildlife habitats.

From the hydro-morphological perspective, it was important for the redevelopment to meet the general conditions for equilibrium, i.e. with convergence of currents in the concave banks and transfer of flow from one concave bank to the other.

To provide a supportive environment for fish fauna, it was agreed that the bottom of the minor channel should have a "V" shape in the straight sections (allowing water to flow at the centre of the river during minimum-flow periods) and that four pools should be placed at the curves.

The special setting in which the contractor was hired to work necessitated including some specifications concerning work on the riverbed. Under no circumstances was the right shore of the river to be modified, and the riverbanks outside the limits of the project were to be left intact.

Also with the goal of returning the river to its most natural state possible, the contractor was required to re-use a set quantity of stone from the existing enstonement and to construct a protection lock. Similarly, to recreate natural conditions on the watercourse, the sand covering the existing riverbed was to be excavated, set aside, and then placed back on the riverbed. During excavation, the contractor was to recover the maximum volume of sand and to limit its contamination as much as possible. If the amount of natural sand recovered was insufficient to cover the bed of the new channel to the required depth, the additional granular fill used was to have the same characteristics as the natural river sand. It was also strictly prohibited to produce the additional material by crushing.

To provide fish fauna with an appropriate ecosystem around the rock fill transitions, hydraulic clogging of the rocky pores with fine gravel was performed in the rapids as well as at the top of the bank enstonements. Filling the gaps in the rapids was performed using a non-cohesive material with a specific maximum diameter. As well, during application, large quantities of the material was sprayed to fill the gaps fully. This technique allowed the watercourse to flow over the enstonements and not through their gaps, even during minimum-flow periods, thus eliminating barriers preventing both young and adult fish from migrating. As for filling the gaps at the top of the bank enstonements, the contractor was to fill the cavities so that the levelling material did not penetrate the gaps.

Finally, some additional specifications were set out with respect to the enstonement of some portions of the bank and to full protection of other sections of the riverbank or riverbed.

<u>Work to stabilize the slopes and conduct revegetation</u>

As previously mentioned, the studies conducted for this project clearly demonstrated that the riverbanks were significantly more vulnerable to erosion that the riverbed itself. Also, special attention had to be paid to stabilizing the slopes and to performing revegetation. This work took place over a period of approximately six weeks (October 1 to November 10, 2001).

Various types of work were performed, namely the stabilization and revegetation of the slopes unprotected by enstonements, the revegetation of the slopes protected by enstonements, the placing of plants at the top of the banks, and, finally, the revegetation of the enstonements.

Much preparatory work was required, including the placement of a rigid metal grill upstream to prevent any fish from entering the work area until the river was diverted and a sedimentation basin built downstream from the work. In addition, as was the case for work on the riverbed, the existing arable soil on the site was recovered, sifted and enriched based on the analyses conducted.

The revegetation of slopes unprotected by enstonements was achieved by planting willow seedlings and clumps of dogwood, planting rooted and unrooted cuttings, and spreading seed without fertilizer.

The clumps of dogwood, cuttings, and willow seedlings were gathered from the surrounding area, transported to the site in a sheeted vehicle to protect them from the sun and from drying out, and then stored using methods appropriate to each species.

The initial work consisted of preparing the slopes by profiling them and placing stone mounds at the base of the slopes to be revegetated so as to provide the riverbanks with solid support. A bed was prepared for the clumps and seedlings. The mounds created in the riverbed were covered with a thin layer of compacted soil, then encased within a membrane of woven coconut fibre. Soil was also placed on this last membrane before it was folded over, stretched, and fixed with temporary stakes to form a “mattress” designed to receive the clumps and seedlings. The clumps of dogwood were then placed on the inside slope of the bed and the stems directed in such as way as to reach beyond the mound; the seedlings were then introduced through the dogwood stems. The extremities of the dogwood and willow stems were pointed downstream at angles varying from 30° to 45°. Finally, soil was scattered on the bed to fill the gaps and protect the roots from drying out; the base of the bed was then compacted slightly.

A final levelling of the slope was performed and manual seeding and spreading of natural phosphate was performed under the membrane. Then work designed to anchor the membrane on the slope was carried out using stakes and cedar pickets and, at the extremities of the membrane, enstonement. Finally, rooted and unrooted cuttings were planted on the slope.

As for the top of the banks and the slopes protected by enstonements, the answer was simply to plant grass and different species of varying formats. More than 16,600 plants in pots and multi-compartment containers were planted at a rate of one plant per square metre.

The enstonements were also revegetated. The gaps in the enstonements were identified and filled manually with soil. More than 700 plants were then transferred onto these same enstonements.

Planting the remaining clumps of dogwood in a trench upstream from the new bridge was the last stage in the stabilization and revegetation. The stems of these dogwood plants were flattened to help them take.

PROJECT MONITORING

To check the river’s condition after the work was completed, a monitoring program was carried out over three years, i.e. 2002, 2003 and 2004. This monitoring, which centred on the technical and environmental aspects, the landscaping, and the fish habitat, was designed to validate the compliance of the new segment of the river by checking the physical characteristics of the environment (stability of the habitats, success of the revegetation, water levels, current speed, etc.), especially during minimum-flow periods.

<u>Technical and environmental monitoring</u>

More specifically, the technical and environmental monitoring was designed to achieve the following goals:

- To check, from a morpho-sedimentary perspective, whether the geometrical shape of the channel was meeting the technical and environmental expectations;
- To check, from a hydro-morphological perspective, whether the diverted and redeveloped section of river was generating dynamic equilibrium conditions, i.e. with

currents converging in the curves and the flow transferring from one concave bank to the other in the straight sections;

- To validate the hydraulic behaviour of the rock-filled transition zones;
- To check the technical stability conditions of the work in its entirety, especially in the upstream and downstream start and end zones, in the curves, and around the transitions;
- To check whether the hydraulic conditions in minimum-flow periods were providing aquatic wildlife with an appropriate ecosystem.

The monitoring conducted over the three years following completion of the work indicated that, in general, the MTQ's diversion of a section of the river was clearly meeting the prior technical and environmental expectations from all perspectives (hydrological, hydraulic, morphological, and sedimentological).

From the morpho-sedimentary perspective, the dominant channel has undergone no noteworthy changes since the diversion work was completed; it has retained its geometric and morphological characteristics in their entirety regardless of the flow level (minimum flow or high water). No areas of erosion or major deposits have been observed on the banks. As well, the shifting riverbed designed to allow the river to self-adjust is plainly observable on the minimum-flow bed. The superficial washing away of fine material has left an excellent paved bed made up of polydispersed gravel and pebbles as well as a morphological configuration that provides a rich hydro-biological diversity (well-defined curves, pools, rapids, gravel islands, spreading out of the water, etc.).

In hydro-morphological terms, the entire redeveloped section meets the general equilibrium conditions well, with convergence of currents in the concave curves and transfer of flow from one bank to the other throughout the redeveloped segment. The equilibrium conditions attained as of the 2002 high-water period remain omnipresent. In other words, the bottom of the dominant channel and especially the bottom of the minimum-flow channel, although still shifting, have remained practically unchanged, with pools, shoals, gravel banks, secondary channels, spawning grounds, etc. One of the great successes of the technical operations has been that, from the outset, the hydraulic clogging of the four rock-fill transitions with sand and fine gravel produced the expected results. The water always flows over the bottom surface, both in the transitions and in all the other redeveloped segments, thereby allowing fish to transit throughout the diversion quite freely.

With respect to technical stability, all the work exhibits great stability around the various channels (minimum-flow, dominant, and high water), even after four high-water periods. The enstonements, concave banks, flood plains and vegetation guards (dogwood hedges) have remained stable. Moreover, the rapid and continuing growth of indigenous plants in the flood plains ($Q_{2\text{-}100\ years}$) serves to enhance this stability.

Monitoring the landscaping

The planting work that accompanied the river diversion is meeting the success rate stipulated in the submission documents. It appears that the objective of restoring the natural setting around the new section of river has been achieved through the quality of the measures taken over the years. The revegetation is maintaining a high rate of growth and herbaceous plants are even naturally colonizing areas where no planting took place, namely the part of the flood plain between the riverbed and the foot of the banks.

As well, the stabilization work has also proved very resistant in the face of spring floods and summer flash floods.

However, despite an excellent rate of survival and growth of the plantings near the river, it will take at least two or three years before the plant mass is more visible. Over the long term, this work will contribute to restoring a natural setting equivalent to the natural portions of the river.

Monitoring the fish habitat

As part of the project, the MTQ obtained permission to destroy 7,200 m^2 of fish habitat, conditional upon (among other things) creating pools and rapids on the new section of river and monitoring its fish potential for three years. The three years of monitoring have led to the following conclusions.

The redeveloped portion of the river was colonized by fish, especially brook trout, as of the first year, and their population continually increased over the three-year monitoring. As well, the habitats have created have a good potential for salmonid fish and are relatively stable and functional; no particular problems have been observed related to residual overflow water or the free movement of fish. Finally, the brook trout appear to have been using the sills and bank enstonements as areas of refuge near the pools, to compensate for the temporary lack of plant cover on the banks.

Thus, the results of the monitoring have been very positive and even confirm the existence of an improved ecosystem, for fish migration and habitats, compared to the conditions existing prior to the redevelopment of this portion of the river.