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A Comprehensive Framework for Assessing Changes in Fish Habitat Productive Capacity Resulting From Large Hydroelectric Projects

Un protocole d'évaluation des changements de capacité de production de l'habitat du poisson lors de grands projets hydroélectriques

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ABSTRACT

The *Policy for the management of fish habitat* and its *No net Loss of habitat productive capacity* by the Department of Fisheries and Oceans (DFO) represents a challenge for the hydroelectric industry in general. Hydro-Québec presents to CSAS a general comprehensive framework to make big hydroelectric projects meet the objectives of the policy. This framework contains a short description of two examples of big projects (Eastmain 1-A Rupert diversion and Romaine), habitat and productive capacity considerations under an environmental impact assessment context, and detailed methods to assess productive capacity changes in rivers and lakes impacted. Habitat compensation principles are also proposed.

RÉSUMÉ

La *Politique de gestion de l'habitat du poisson* et son principe directeur d'*aucune perte nette de capacité de production* du Ministère des Pêches et Océans constituent un défi pour l'industrie hydroélectrique en général. Hydro-Québec présente au SCCS un protocole général visant à assurer l'atteinte des objectifs de la politique dans le cadre des grands projets hydroélectriques. Les projets Eastmain 1-A dérivation Rupert et Romaine y sont décrits brièvement en tant qu'exemples. Le protocole contient également une discussion sur la détermination de la productivité des habitats dans le cadre d'une étude d'impact ainsi qu'une proposition de méthodes détaillées pour l'évaluation de la productivité des habitats des lacs et cours d'eau touchés par ce projet. Des principes concernant la compensation d'habitats sont également proposés.

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1.0 Introduction

In 1986, the Department of Fisheries and Oceans (DFO) released a *Policy for the Management of Fish Habitat* in order to allow for clearer interpretation of the habitat protection provisions of the *Fisheries Act.* Within this policy, a concept of *no net loss of productive capacity of fish habitat* (NNL) was developed and presented as an objective for any future development. On a large scale, the policy even specifies that an overall gain in productive capacity of fish habitat should be the ultimate goal for this country. Over the years, the different regional offices of DFO and project proponents have tried in various ways to make proper fish habitat assessments and propose mitigation and compensation measures to attain NNL. Unfortunately, the concept of productive capacity, which is defined in the policy as "…the maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support or produce aquatic organisms upon which fish depend," involves some practical difficulties, not only in regard to determining baseline conditions, but also in establishing how habitat modifications can affect this productive capacity. In Minns et al. (1995), it is stated that "The assessment process has been plagued with inconsistency due to the lack of a clear set of information requirements with which to guide proposal development and a lack of a set of effects criteria to guide the review and decision process." Ten years later, we consider that this statement still holds very true.

For small-scale projects, such as culvert installations, bridge pillars or any type of embankment or filling, it is common practice and reasonable to express habitat modifications in terms of surface of habitat impacted, and propose compensation measures that relates to impacted surface. Generally speaking, compensation measures required for HADD (harmful alteration, disruption or destruction) authorization can vary in ratio from 1:1 to 3:1, based on the level of confidence that the newly created habitat will actually work. Using this approach, NNL is often achieved on the basis of a straight surface calculation, using minimal biological considerations such as limiting factors, or any other relationship between a habitat modification and the productive capacity of the system. We believe that this approach is practical and realistic for small, localized projects, since they do not involve a detailed impact study. Using this approach, an actual productive capacity estimate would not be useful for the purpose of achieving NNL.

For large hydroelectric projects, however, the situation is different. For the purpose of this document, large hydroelectric projects are defined as projects that involve creating a reservoir or making a significant change to the natural hydrograph. Large projects involve physical changes at the watershed level, which in turn, affect an entire ecosystem. In such cases, a detailed impact study is required, and since the implementation of the *Canadian Environmental Assessment Act* (CEAA), DFO has played a key role in the environmental impact assessment (EIA) process as the "Responsible Authority" (RA) for the federal government.

Over the years, DFO Quebec Region and Hydro-Québec (HQ) have entertained ongoing discussions on EIA related habitat assessment methodologies for various large hydroelectric projects. No agreement has been reached yet as to how habitat modifications or habitat productive capacity should be assessed and compensation hierarchy applied, and this highly complicates project assessments, both for HQ and DFO. Recently, a *Memorandum of Understanding* (MOU) was signed by the DFO and the *Canadian Electricity Association* (CEA) to clarify many aspects related to the application of the *Fisheries Act* within the context of existing hydroelectric operations, as well as new hydroelectric projects. Some joint DFO/CEA teams are now preparing *Interpretation Bulletins* for key issues like fish passage and instream flows for new projects, in order to provide guidance on these issues for both the proponent and the government. Unfortunately, a bulletin on fish habitat productive capacity assessment cannot be put together in the short term within the MOU context. Therefore, another context for discussion is necessary to settle this issue, especially since two major hydroelectric projects, namely, the Eastmain-1-A powerhouse and Rupert diversion project and the Romaine River project, are now subject to CEAA panel reviews. DFO proposed the DFO Science *National Advisory Process* to HQ with this in mind.

This document, which is divided into three sections, explains the comprehensive framework proposed by HQ for the assessment of habitat productive capacity changes resulting from large hydroelectric projects. The first section provides a very brief description of the Eastmain-1-A/Rupert and Romaine River projects, as examples to show the scale of these projects and the context in which the methodology is to be applied. The second section discusses habitat and productive capacity within an EIA context. The third section provides the proposed framework.

2.0 Brief description of the Romaine River complex and Eastmain-1-A/Rupert projects

This section provides some basic information on the two major projects to which the proposed methodology is to be applied. These projects are used as examples; the proposed framework is designed to be applicable to any future large projects.

2.1 Romaine River complex

The Romaine River complex involves the construction of a series of four dams and four powerhouses on a 300-km river on the North Shore of the St. Lawrence River. The source of the Romaine River is located on the Québec/Labrador border. It is frequented by salmon along its first 52 km from the sea. The first dam (Ro-1) is to be built at the site of a waterfall that blocks the upstream migration of salmon. The mean annual discharge at this site is 290 m^3/s. Although Ro-1 is a run-of-river powerhouse, the three other dams upstream will create reservoirs with large storage capacities. Therefore, the Ro-1 plant is not meant to operate on a natural flow regime, but rather on regulated flows, including peak flows. Over two thirds of the river will be transformed into reservoirs (214 km), and 42 lakes larger than 5 hectares will be flooded. The total surface area of the reservoirs is 273 km^2.

Each facility involves diverting a short river reach (0.7 km to 6 km) between the dam and powerhouse to maximize head. A general description of the project and the area is given in Appendix I. Some key characteristics of the project are summarized in the following table.

Table 1: Key characteristics of the Romaine River complex

	RO-1	RO-2	RO-3	RO-4	Total
Installed capacity	260 MW	610 MW	380 MW	250 MW	1,500 MW
Output	1.2 TWh	3.2 TWh	1.9 TWh	1.3 TWh	7.5 TWh
Watershed (km^2)	12 960	12 200	10 170	8 540	
Reservoir surface area (km^2)	12	83	38	140	273
Reservoir volume (hm^3)	139	3,357	1,762	2,668	7,926
Annual mean discharge (m^3/s)	290	272	223	185	
Portion of river flooded (km)	22	63	31	98	214
Maximum drawdown (m)	0	5	11.4	14.5	
Impoundment time	1 month	12 months	2 to 10 months	11 months	

2.2 Eastmain-1-A/Rupert project

Hydro-Québec Production plans to build Eastmain-1-A and Sarcelle powerhouses and divert part of the flow from the Rupert River into Eastmain 1 reservoir. The diverted flow will power the turbines at Eastmain-1 and Eastmain-1-A powerhouses and then those at Sarcelle powerhouse, before being channelled to the three existing generating stations in the La Grande complex: Robert-Bourassa, La Grande-2-A and La Grande-1 (see maps in Appendix II).

This will enable Hydro-Québec Production to increase its average annual output by about 8.5 TWh: 2.3 TWh from Eastmain-1-A, 0.9 TWh from Sarcelle, and 5.3 TWh from the increase at the three generating stations along the lower Grande Rivière.

The partial diversion of the Rupert River will require construction of a series of hydraulic and retaining structures, including a rockfill dam on the Rupert River and three sand and gravel dams, one on the Lemare River and two on the Nemiscau.

Construction of an approximately 2.9-km-long tunnel is also planned between the Lemare and Nemiscau watersheds, as well as 8 canals and 75 dikes, including one on Arques Creek, a tributary of the Nemiscau River. These structures will create two diversion bays, which will be connected by the tunnel and through which water will be channelled into Eastmain 1 reservoir (see Map 1.2). The diversion bays will increase the wetted surface area from 12,888 hectares to 26,419 hectares. The net mean annual diverted flow is estimated at 452.6 m^3/s and will not exceed 800 m3/s.

Downstream of Rupert dam, Hydro-Québec has planned an ecological instream flow regime to preserve fish stocks and river habitat. The instream flow, which will be released by the spillway, will average 181 m^3/s, or about 28% of the mean annual flow of the river at the release point. Hydro-Québec has also designed structures that will release the equivalent of the present flow of the Lemare and Nemiscau rivers, according to the mean natural hydrograph, to preserve the natural environment and the use of the rivers below the dams. In addition, eight hydraulic structures are planned between the dam and the mouth of the Rupert River to maintain the water level in nearly half of the river. The wetted surface area, which is now 25,425 hectares, will be reduced to 23,270 hectares. At the mouth of the Rupert River, the mean annual flow will be 423 m^3/s, which is 48.3% of the present mean annual flow.

3.0 Habitat and productive capacity within an environmental impact assessment context

An environmental impact assessment is based on the principle that at the end an informed judgement call has to be made on how much change to the environment is acceptable, considering the project submitted by the proponent. The EIA is a decision-making tool that is necessary to weigh the benefits and negative impacts of any given project. The *Policy on the Management of Fish Habitat*, and its supporting NNL principle, already states that residual losses of fish habitat productive capacity have to be compensated for. The Policy imposes a major challenge to the assessment of any project that modifies an aquatic ecosystem, such as a large hydroelectric project. Thus, the methodology to be used to assess fish habitat productive capacity is central to such project's EIA.

Pure habitat-surface assessment methods generally assume that maintaining productive capacity equals maintaining an equivalent number of square meters of lost habitat. This conservationist approach is suitable for small projects as stated earlier. Within the context of large projects, the analysis has to go further to include resulting impacts on fisheries, as always required by EIA guidelines. Impact on fisheries necessarily implies a relationship between habitat changes and productive capacity. As stated by Minns (1997), "Both HADD and NNL imply an ability to quantify the effects on fisheries of changes to habitat".

Square meters of habitat loss are not an expression of the impact on fish populations

Not all habitats are of equal value to fish. The Policy already recognizes that the level of protection to be given to any habitat has to reflect its ecological importance. It is a known fact that for some species, spawning sites are directly related to productivity and are thus limiting factors, while for others, this is not the case. For example, in Québec, the models used to calculate maximum sustainable yields for salmon and brook trout are based on the abundance of rearing habitats, given that spawning habitats generally do not limit productivity (LACHANCE and BÉRUBÉ. 1999, Picard 1998).

Habitat use depends not only on species, but on competition between species and on the relative availability of habitat. For example, it is well known that brook trout does not occupy the same habitat range when it is the only salmonid species in a river, as when it shares it with salmon. The wide range of spawning habitat conditions for this species is also an illustration of its response to different conditions of habitat availability.

It is possible to draw a map of fish habitat in a river as presented in Appendix III, based on water velocity, depth and substrate, as compared with textbook descriptions of fish species habitats. However useful as this may be, it cannot be considered as an exact description or quantification (in m^2) of habitat, and even less so, of habitat use by fish. Furthermore, if these square meters of habitat are to be added per species and per biological function, their total will largely exceed the total number of square meters in the river surface itself. For example, the same area can be used in the spring for walleye spawning, in the fall for whitefish spawning and in the summer as a feeding ground for many species. Calculating totals of square meters of habitat in pre- and post-project conditions is not necessarily a simple way of adding up HADDs.

For future reservoirs, calculating square meters of habitat per species and per life stage is an impossible task, considering not only the magnitude of these water bodies, but also the fact that little is known about the shift in the way these areas are used by the species, which may differ from that in natural lakes.

Therefore, fish-habitat maps and calculations of total square meters create an illusion of accuracy. They are at least as imprecise as productivity-related estimates, and square-meter balances are not an expression of the impact.

Most of our follow-up studies in reservoirs focus on CPUE and the biological characteristics of fish populations

The subject of how to measure the productivity or productive capacity of an aquatic ecosystem is certainly widely covered in the literature. This is mainly because productive capacity is the basic notion of interest to fisheries management specialists, who must provide guidance for sustainable fisheries operations. Absolute productive capacity, defined in the policy as "…the maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support or produce aquatic organisms upon which fish depend," cannot be determined in any large water body.

However, determining absolute productive capacity is not a requirement in the context of an EIA. What we are looking for is an index related to fisheries with which to compare future conditions to a baseline. For natural lakes and streams, it is generally possible to obtain the data required to estimate yields (biomass, CPUE, water quality criteria, bathymetry). Most of our follow-up data on reservoirs is in the form of catch per unit efforts (CPUE), which are used as input data for biomass and yield models. The relative abundance of fish species can be predicted from past experience, regardless of relative habitat availability. This is the basic knowledge on which we can base our impact prediction.

As for large rivers, habitat productivity is difficult to estimate, even indirectly, but the relative use of their various feeding habitats is measurable through CPUEs. Therefore, river reaches with modified flow can be compared before and after a project using habitat productivity indices, without having to determine global productivity in the river reach. This is a means of relating productivity changes to habitat changes, which is the basic principle underlying the habitat policy and the NNL concept.

Determining the difference between productive capacity and the actual productivity of an aquatic ecosystem

Within an EIA context, an impact is normally defined as a change when compared with present conditions, as opposed to ideal baseline conditions such as the “maximum natural capability of habitats to produce healthy fish.” Overfishing, pollution or other factors may have impaired fishing opportunities in the past, and it is arguable whether habitat modifications should be measured against theoretical conditions (productive capacity) or present conditions (production). We are of the opinion that the determination of impacts in relation to past ideal conditions, if made an important issue, should be discussed in the section on cumulative impacts of an EIA. Otherwise, for our purposes here, we will consider the present situation as our baseline, and will not differentiate between the actual production of a system and the productive capacity. In any case, since the majority of our projects are carried out in northern, pristine environments, productive capacity and actual productivity are similar (except for salmon).

4.0 Proposed comprehensive framework for assessing changes in fish habitat productive capacity resulting from large hydroelectric projects

The following section explains the different steps proposed to assess a project's habitat modification with regards to productive capacity and establish mitigation and compensation needs.

The proposal is divided into three parts: the first part explains the approach for the reservoir area (upstream of dams), the second explains the methodology for the downstream reaches, and the third discusses the overall upstream/downstream balance.

4.1 Proposed approach for the future reservoir area

The proposed approach is in four steps, as described below.

4.2 Baseline conditions

4.3 Detailed description of a sample of lakes, rivers and small streams

The first step is to choose a sample of the lakes, rivers and streams to be flooded and describe them in detail, in order to characterize the water bodies and their fish communities. This sample must represent the variety of habitat conditions encountered (small lakes, large lakes, small streams, rivers, etc.). To select and describe various types of water bodies, high-resolution digital imaging and aerial photographs are used. Important ecological features such as bathymetry, substrate, water quality and vegetation are described in detail for each water body or stream. Fishing with various types of gear is carried out to collect samples of all the species present, in order to describe the entire fish community and the way in which the different species use the habitat. Habitat is described per species and per biological function (e.g., spawning, rearing, adult feeding). Actual use of potential spawning sites is determined for target species. All data necessary to calculate fish-productivity estimates is also collected (temperature, depth, TDS, etc.).

4.4 Productivity-related estimates

The second step is to calculate fish-productivity estimates for all types of water bodies.

For lakes, the methods chosen are shown in table 1.

Table 1: Total yield and yield per species – Lakes

step	Equations	Data required
1	Yield (Y): log Y = 0.44 TEMP + log MEI + 0.021 (r^2 = 0.83) (Schlesinger and Regier, 1982)	• MEI = TDS/*z* – TDS: total dissolved solids – *z*: average depth (m) • TEMP: average annual temperature (ûC)
2	Species yield i (Y_i): $Y_i = Y \times M_iB_i \div \sum M_iB_i$ (Bruce, 1984)	See steps 3 and 4
3	Instant natural mortality rate (M_i): log M = -0.0066 – 2.790 log L_∞ + 0.6543 log K + 0.4630 T (Pauly, 1980)	Parameters of the von Bertalanffy equation when no data on mortality or catch curve methods when fish are aged
4	Relative biomass (B_i) (proportion)	Catches as biomass per unit effort (BPUE)

The Schlesinger and Regier (1982) equation is chosen here, because we think that this empirical relationship would suit most of our northern lakes conditions. The important thing to consider here is that we believe that although the morphoedaphic index (MEI) alone may be a controversial tool with which to estimate fish yields, the addition of temperature in a linear regression equation is a significant improvement that should be used. Whether this regression equation can be improved or adapted to a given range of conditions is to be considered.

Of course, partitioning the yield into species is a difficult task, but Bruce's 1984 suggestion, developed in the Smallwood reservoir and based on BPUE and mortality rates, is as close as we can get, and this method has the advantage of using data specific to local populations. It is recognized that some species-specific methods exist to determine maximum sustainable yields—for example, a method for lake trout (Olver et al., 1991) based on thermal habitat volume. Nevertheless, some preliminary trials led us to the conclusion that for some species, these estimates do not apply to our study area. Therefore, we prefer to start from a global yield estimate, and then partition it according to the relative abundance of species and to population characteristics.

For streams, the steps are as presented in table 2.

Table 2: Fish biomass in streams

Step	Equations	Data required
1	Estimate of electrofishing efficiency for the first fishing survey at closed stations using the Leslie model (King, 1995)	Results of electrofishing in the streams
2	Evaluation of the absolute density (D) of fish per unit of surface (fish/100 m^2)	Electrofishing efficiency (from Leslie's method)
3	biomass per species (B_0): $B_0 = D \times \varpi$	ϖ: mean weight per electrofishing catch in the streams in 2002 and 2003
4	Production: $\text{Log } P = 0.51 - 0.33 \log W + 0.89 \log B_0$ (Randall *et al.* 95)	Mean weight from electrofishing data

The maximum sustainable yield can then be expressed as a percentage of the production using Gulland's equation. It should be noted that in the case of the Rupert, only the biomass was estimated, as yields for small streams were not considered to be of interest. However, both yields and biomass can be determined from our field data.

For large rivers to be flooded, the situation is more complicated. Indeed, there is no agreement on how to assess overall fish productivity in rivers, as rivers differ from lakes by the fact that their productivity does not depend on primary production, but on yearly carbon intake, which, in turn, depends on many river characteristics such as flood regime, watershed area and substrate.

In fact, river productivity varies a great deal. Randall et al. (1995) tried to compare the productivity of lakes and rivers based on empirical data, but a direct comparison between lakes and rivers in temperate regions proved difficult, since a considerable amount of the available river data came from tropical regions. Follow-up surveys of the La Grande complex have indicated that rivers have yields equivalent to 70% of those in surrounding lakes (with similar water-quality characteristics), based on

CPUE data obtained with a standard set of gill nets (Lévesque et al., 1996). Gill nets are not as effective in rivers as in lakes, because fish in lakes have to move to get their food, whereas in rivers, many species can feed on the drift. Therefore, even if gill-net data from the La Grande studies was taken from lentic sections of the rivers, this 0.7 ratio may be too low an estimate. Nevertheless, if we need to pool all data from upstream water bodies (streams, lakes and large rivers) to make an overall balance for the flooded area, there is a need to agree on a given value, whether it is 0.7, or up to the same level of productivity as in surrounding lakes. We use this ratio in our EIAs, because it is the only estimate we can support with data; however, we are open to discussion regarding this aspect. We will see further that for the downstream reach, rather than estimate the overall productivity, we can estimate the relative contribution of habitats to productivity.

4.5 Extrapolation to the whole flooded area

The last step in determining baseline conditions is to extrapolate these yield estimates to the entire area impacted by the reservoir. This can be done with high resolution digital imagery, or simple aerial photograph interpretation (when digital imagery is not available). Very precise surface areas of the different types of water bodies can be calculated and multiplied by various productivity-related estimates.

4.6 Post-project conditions

Most of the time, the reservoir's future fishing yields can be calculated according to a predicted bathymetry with 2-m precision curves and water-quality predictions that will allow for the calculation of a future MEI, combined with temperature simulations. The same equation would then be used as for baseline conditions. This assumption takes into account the previous follow-up studies of various reservoirs, which have demonstrated that reservoirs have similar CPUEs to those in surrounding natural lakes (Therrien et al., 2002). The prediction of species relative abundance would also be based on CPUEs from previous follow-up studies.

This exercise is combined with what we call a “habitat analysis” based on hydraulic simulations of the future reservoir. The objective is to ensure that, based on current knowledge, the key species in the reservoir will be able to complete their life cycle under operating conditions—that is, taking into account the operating regime and the predicted water-level variations throughout the year. Access to spawning grounds in tributaries, for instance, would be assessed for species for which this is pertinent. It should be noted that previous follow-up studies suggest that habitat use changes in reservoirs for some species such as pike, when compared to natural lake conditions, since certain species maintain high abundance, even if their habitat has changed considerably. This will be taken into account, despite the fact that we do not have detailed information on habitat use in reservoirs.

Although estimates of fisheries yields based on temperature and MEI can be used for reservoirs, we understand that for very large reservoirs, this kind of estimate may be improved by separating littoral habitats from pelagic habitats. In large lakes, production in the littoral zone is known to be higher than in the pelagic zone (Randall et al., 1995). Since large reservoirs can replace a series of small lakes, it can happen that the ratio of littoral to pelagic habitat changes significantly. It can be argued that the MEI is too rough a measure to account for this on large reservoirs, and that estimates in such cases could be misleading. In such cases, one way to improve the method would be to estimate yields separately for the two types of habitat (littoral and pelagic), when the predicted bathymetry is precise enough. More detailed mapping of future fish habitat per species and per life stage in reservoirs is not possible, because there is no previous follow-up study that describes habitat use in reservoirs, and because detailed features like substrate and vegetation cannot be predicted to that level of accuracy.

4.7 Mitigation

What we would call mitigation in the context of an EIA is any work to either ensure access to habitat (such as a tributary mouth), or create new habitat (such as spawning areas for lake trout) *within* the limits of the future reservoir, in a way to ensure that predicted fisheries yields will be attained. This differs from the usual definition of mitigation as defined in the policy, in the sense that it may include what are usually called “compensation” measures (habitat creation). The reason for this is that we do not calculate an impact balance before and after mitigation for hydroelectric projects. The impact balance has to include mitigation, because the project necessarily involves mitigation measures. It is impractical and almost impossible to produce three impact balances for a project: one without mitigation, one with mitigation, and one with compensation. Mitigation measures are an integral part of a project; they can take all sorts of forms, including limited operation during certain periods, habitat access, instream flow and habitat creation.

If a species is included in the federal *Species at Risk Act* (SARA) lists, then the provisions of the Act apply, and mitigation or compensation takes into account any existing recovery plan.

4.8 Compensation

Compensation includes the creation of any habitat, or any fisheries project *outside* the boundaries of the reservoir. These measures are to be carried out if the overall productivity balance is not attained through the predicted productivity of the future reservoir (with mitigation measures). The need for compensation and the types of compensation measures are related to regional fisheries objectives. It is understood that if a key species for regional objectives is significantly affected by the creation of a reservoir, the predicted increased yields for other species cannot compensate for this impact unless they are also considered to be part of the regional fisheries objectives. In any case, compensation will be based on these objectives, and not on the technical possibility of recreating an impacted habitat, regardless of its significance in future conditions.

4.9 Follow-up programs

At the moment, most of our follow-up data is based on CPUEs. We intend to pursue further follow-up studies in order to complete our knowledge of habitat use by fish in reservoirs. Such knowledge will help to better predict the impact on fish communities for future projects.

5.0 Proposed approach for the assessment of modified flow river reaches

For a river reach downstream of a dam, fish habitat can be modified in many ways through changes in flow velocity, depth, sedimentation or temperature. Habitat access and the passage of fish can also be impaired. Modified-flow reaches are given a lot of attention in an EIA and the various impacts related to this part of a project are covered in detail. For the purpose of this document, the proposed methodology relates to determining the effects of modified flow on habitat productivity. The methodology is to be used mainly for downstream reaches where there is a net reduction in flow during the summer (feeding) period, either for long reaches, as is the case for diversion projects like Eastmain-1-A/Rupert, or for shortcut reaches between a dam and a tailrace, as is the case for the Romaine River complex. It may also be used for a downstream reach where productivity parameters such as temperature are subject to major changes under future conditions, even though there is little modification to summer flow, as will likely be the case in the Romaine River.

As stated above, river productivity estimates are difficult to make. In the case of a river reach subject to flow reduction, pre-and post-project conditions are both river conditions, as opposed to the upstream situation where a river reach becomes a man-made lake. It is thus less relevant to determine the overall productivity of the river reach than it is to assess the effects on productivity of qualitative and quantitative changes in various fish habitats. The proposed approach is to draw a fish mesohabitat map, use a habitat productivity index (HPI) to determine the contribution of the various habitats to productivity, simulate changes during summer operations using a hydraulic river model, and re-calculate post-project habitat areas as weighted by their respective HPIs.

5.1 Baseline conditions

The fish habitat in the river is mapped using high-resolution digital imagery. The flow facies, substrate and depth are the main characteristics traditionally used to separate habitat types. Then, fishing yields are used to correlate habitat types with species, and habitats are pooled into fewer classes of significance to fish.

At this point, it is important to explain that only fish feeding habitats are considered, as they are most closely related to productivity. Other important habitats such as spawning areas are inventoried as part of the overall impact assessment, but they are not subject to an HPI or any habitat preference index calculation designed to weigh habitat importance and compare pre- and post-project conditions.

This is because the approach is not to compare habitat *availability* before and after a project, but rather overall habitat *productivity*. The point of the exercise is not to establish general habitat indices for all species at all stages of life.

Ideally, feeding habitats should be divided into two classes for most species (juveniles and adults). However, this supposes that the relative abundance of juveniles and adults in various habitats can be determined using common fishing gear, which is difficult.

So habitats for juveniles were not computed in the Rupert project HPIs, but some trials will be conducted as part of the Romaine project to include young fish in the analysis, by using standard sets of various types of fishing gear (i.e., line, gill net and seine) at each fishing station in all types of habitat.

In large rivers, however, this will always be a major challenge and success in achieving this sort of sampling is not guaranteed. Another approach could be to simply use two different indices: one for young fish in shallow areas of the river using only a seine, and another for adults in deeper sections, using standard gill nets. The feasibility of these improvements is to be determined.

The BPUE in different types of habitat is used as the main input to determine contribution to productivity. It could be argued that BPUS (surface) should theoretically be used, but in large rivers, such data is impossible to get. Appendix IV gives the details of the HPI developed for the Rupert River and largely inspired by Randall and Minns (2000) and Minns et al. (1996), who introduced the idea of weighted suitable areas of habitat based on productivity indices. It should be noted that all the parameters are related to productivity in the following index equation:

$$S_i = BPUE \times (P \div B)_i \times e^{k_i t}$$

(Where k is the growth factor from the von Bertalanffy equation, t is temperature and P/B_i is the production-to-biomass ratio of a given species)

The equation also gives considerable importance to temperature, a factor most likely to be influenced by the presence of reservoirs. However, in the case of the Eastmain-1-A/Rupert project, the same index was used for pre- and post-project conditions, as temperature is not likely to change.

According to this index, all habitats are ranked on a scale of 0 to 1 for each species. Then, the habitat surface areas are multiplied by this “habitat preference” per species. It should also be noted that this gives equal importance to all species considered regardless of their relative overall abundance in the river.

As mentioned previously, this exercise is completed with a “habitat analysis” which describes the various types of habitat in the river for each species and the environmental conditions necessary for the species to complete their life cycle.

5.2 Post-project conditions

Post-project conditions are described using a hydraulic simulation of the river reach, which generates surface areas of the various types of habitat described in the baseline conditions.

The weighted area based on the indices described above is calculated again for the future summer conditions, and the difference constitutes the impact on a given species.

The significance of the impact with regard to the relative importance of the species is subject to expert opinion, as well as to the concerns of the local population regarding any particular species.

A habitat analysis completes the exercise; in particular, ecologically significant features such as fish passage and the availability of spawning and rearing habitats are examined.

For example, if the water level in a river reach during the spawning period were low enough to dry up all the spawning grounds, the results of the above-mentioned productivity balance would be considered invalid. The same would apply if spawning areas did not remain wet during the winter. Important spawning sites, for that matter, may be subject to 2-D habitat simulations as part of the study to determine instream flow. In any case, the post-project hydraulic simulation should take the future instream flow regime into account.

5.3 Mitigation

As for creation of the reservoir, all mitigation measures will be implemented on-site to ensure that productivity predictions are valid; this includes any work to create habitat, for the reasons previously explained.

5.4 Compensation

Compensation measures would be carried out off-site in accordance with regional fisheries objectives, also for the reasons explained in the previous reservoir section.

5.5 Follow-up programs

As for the creation of reservoirs, we have very little data on habitat use by various species in reduced-flow reaches, although we do have CPUE data. Further follow-up programs will focus on habitat use in modified-flow reaches, in order to improve future impact assessments.

6.0 Linking upstream and downstream assessments and establishing compensation priorities

In the proposed approach, the reservoir's productivity balance is expressed in fisheries yields while the downstream balance is based on weighted areas of habitat (based on productivity). Therefore, an overall balance of the project would involve estimating some yields for the downstream reach.

As seen above, previous follow-up surveys in the La Grande complex suggest that yields in large rivers are equivalent to approximately 70% of those in surrounding lakes. This could be used as a basis for establishing a balance of the whole project. The important thing is to use the same hypothesis for pre- and post-project conditions. The post-project overall productivity would be arrived at by multiplying this yield by the overall percentage of loss found through the HPI analysis.

However, with regard to the potential users of the resource, an overall productivity balance may only be of theoretical value in establishing compensation priorities, given the extensive geographical range of such projects. In fact, potential users of the project's downstream and upstream sections often differ. Populations affected by decreased fishing in a river are not likely to be “positively” impacted by increased fishing in a reservoir that may be located a few hundred kilometres upstream.

For this reason, separate upstream and downstream impact balances may be more useful in guiding further compensation needs. In all cases, any compensation should take the following four considerations into account:

1. Significance of the impact on fish populations
2. Geographical range of the impacted potential users of the resource
3. Regional fisheries management objectives (FMO) and local concerns
4. Conservation purposes, when required (SARA)

7.0 Conclusion

We believe that this ecosystem approach and its method for assessing fish habitat productive capacity changes is in compliance with the federal *Policy for the Management of Fish Habitat.* It is also adapted to the very nature of a hydroelectric project, which is a transformation of the watershed, and not simply an addition of gains and losses. This approach is based on biological concepts (productive capacity, limiting habitat, flexibility of species' habitat requirements) and takes into account the knowledge acquired in previous follow-up studies. Nevertheless, this proposal can be improved through our common work and in particular, through this advisory process.

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Appendix I

General Description of Romaine River Complex Project

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The **Romaine** Complex

Hydro-Québec plans to build a hydroelectric complex with an installed capacity of approximately 1,500 megawatts (MW) on the Romaine River in the Lower North Shore region, north of the municipality of Havre-Saint-Pierre. The complex would comprise four developments located between kilometre points 52 and 192 of the river.

General Information

March 2004

Justification

The project is in keeping with Hydro-Québec's *Strategic Plan 2004–2008*. The Company's main goals in carrying out this project are to increase generating capacity and to continue developing Québec's hydropower potential.

Studies will be carried out to gather essential data for decisions concerning the building of the complex. These studies will help define the characteristics of the developments, specify the technical concepts, determine the environmental impacts, develop mitigation and compensation measures, define the compliance monitoring and environmental follow-up programs and, finally, establish the project timetable and cost.

Project Description

The output of the complex's four generating stations will be 7.5 TWh per year, assuming average runoff. The table below shows the main characteristics of each development based on current projections. Each will have a rockfill dam, a generating station with two or three units, a spillway, and temporary by-pass structures during the construction phase.

The project will also involve construction of an access road about 10 km long that will link Highway 138 to the Romaine-1 development. This road will subsequently be extended approximately 150 km to Romaine-4.

Finally, the project will require the construction of workcamps whose number and location will be determined during the draft-design studies.

	Romaine-1	Romaine-2	Romaine-3	Romaine-4
Dam location	KP* 52.5	KP 90.4	KP 158.6	KP 192.0
Dam height	34 m	114 m	89 m	88 m
Reservoir area	12 km^2	83 km^2	38 km^2	140 km^2
Approximate length of reservoir	15 km	60 km	32 km	84 km
Installed capacity	260 MW	610 MW	380 MW	250 MW
Design flow	485 m^3/s	453 m^3/s	372 m^3/s	307 m^3/s
Head	61 m	151 m	116 m	93 m
Type of reservoir operation	Run-of-river	With drawdown	With drawdown	With drawdown

** KP: kilometre point on the river*

Related Projects

The electricity produced by the Romaine complex will be brought onto the Hydro-Québec TransÉnergie grid via new transmission lines whose voltage and connection points have yet to be determined. The switchyards to be built at the generating stations and the means for feeding the additional power into the transmission system will be the subject of a separate draft-design study.

Description of the Study Area

Situated in the North Shore administrative region, the project will be carried out entirely in Québec, more specifically in the RCM of Minganie and partially in the municipality of Havre-Saint-Pierre. This community, the largest in the region, has a population of 3,500 and is about 35 km from the southernmost structures planned at Romaine-1. The Innu community of Mingan, with a population of nearly 470, is located west of the mouth of the Romaine River, approximately 70 km from these structures, while the Innu community of Natashquan, home to almost 800 people, lies to the east of the river mouth, some 120 km away.

The lack of roads running inland has a major impact on land use in the area. Highway 138 is the main east-west access road. There is also a regional airport at Havre-Saint-Pierre, as well as a few seaplane bases. A railway line about 42 km long links the QIT-Fer et Titane mine with Havre-Saint-Pierre.

The biophysical survey area covers both sides of the Romaine River and the future access road to the structures and facilities. Downstream from the planned Romaine-1 generating station, the survey area extends two kilometres on either side of the river. North of Romaine-1, it stretches five kilometres west and east of the future reservoirs, and three kilometres from the road corridors being studied. This survey area will be the subject of detailed geological, vegetation and wildlife studies.

The reservoirs would be built in forests dominated by black spruce and balsam fir, with a few deciduous trees interspersed. The flat coastal terrain quickly changes into a landscape of hills and mountains, which in turn gives way to a plateau dotted with peatlands at the level of Romaine-4. Major fires and windthrow have considerably altered the forest since 2001.

The most prized wildlife resource of the Romaine River is the Atlantic salmon, which can swim 52 km upstream as far as the impassable waterfall of Grande Chute. The Puyjalon River, a major tributary of the Romaine at KP 13.5, is a vital salmon habitat. Although recreational fishing catches are low, Native people engage in subsistence net fishing on the Romaine River. Brook trout also populate the river over its entire length, becoming more abundant further north. Ouananiche, or landlocked salmon, are scarcer; sparse populations can be found throughout the river above Grande Chute (KP 52) and in larger numbers further north. Many lakes in the study area have lake trout populations.

Other wildlife resources in the study area are scarce. They include small mammals typically found in the region, such as beavers, martens and hares, as well as various species of waterfowl and other birds.

Large mammals include a sparse moose population and a small number of caribou in the northern part of the survey area. Wolves and lynx can also be seen on occasion.

Facing the mouth of the Romaine River is the Archipel-de-Mingan national park reserve, a 150-km-long chain of islands off the coast.

Studies of the human environment will focus on its key components: the regional economy, land development and use, logging operations and archaeology.

Primary Environmental Impacts

The proposed complex has four main environmental impact sources: the hydroelectric structures, the reservoirs, the access road to the sites, and the construction work. The impact sources as well as the project's effects on the biophysical and human environment will be examined during the studies, but we can already foresee that the primary issues will have to do with reservoir impoundment and with the economic spinoffs generated by the worksite and by local and regional hiring.

With the building of the reservoirs, the fish habitat, presently characterized by long stretches of flowing water, will be transformed into a predominantly lacustrine habitat. The distribution of species will be modified as a result. In the section of the river downstream from Romaine-1 dam, no decline in salmon productivity is expected, due to instream flow releases that will enable the salmon to reproduce by ensuring egg survival and smolt development.

Within the limits of the future reservoirs are forests whose economic value remains to be assessed. Merchantable timber recovery requirements and the clearing and clean-up plan for the future reservoirs will be specified during the studies.

The construction of a new road will increase access to the north, at least up to the future Romaine-4 generating station (KP 192). Issues relating to the opening of the territory and expansion of the land-use area primarily concern the development of new recreational sites, wildlife harvesting by both non-Native and Native communities and the potential development of natural resources, including the forest.

The project's economic spinoffs will be felt in all mid-North Shore communities and throughout the North Shore region. At the peak of construction, there may be almost 3,000 workers on the jobsite. Given its proximity, the municipality of Havre-Saint-Pierre is sure to benefit from the spinoffs.

Participation of the Host Community

Since it is essential that hydroelectric projects be favorably received by the local population, Hydro-Québec will implement a communication program that will enable the Company to carry out its studies in close collaboration with the host communities. It will organize information and discussion sessions with local representatives in order to take their concerns into consideration and incorporate them into the project design.

Hydro-Québec will also work out a financial partnership arrangement with the local communities affected by the project, i.e., the RCM of Minganie as well as the Innu communities of Mingan and Natashquan. When conducting its studies, the Company will make maximum use of local and regional labor, and regional suppliers of goods and services will be given priority.

Schedule of Activities

Hydro-Québec is now launching its draft-design studies. If these show that the project is economically viable and environmentally acceptable, and if the project is favorably received by the local communities, Hydro-Québec could file an environmental impact statement with the government authorities in fall 2006. If the Company obtains the necessary government approvals, construction could begin in 2008, and the generating stations could be commissioned between 2013 and 2015.

2004E114-A

Ce document est également publié en français.

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Appendix II

General Description of Eastmain-1-A Powerhouse and Rupert Diversion Project

Hydro Québec
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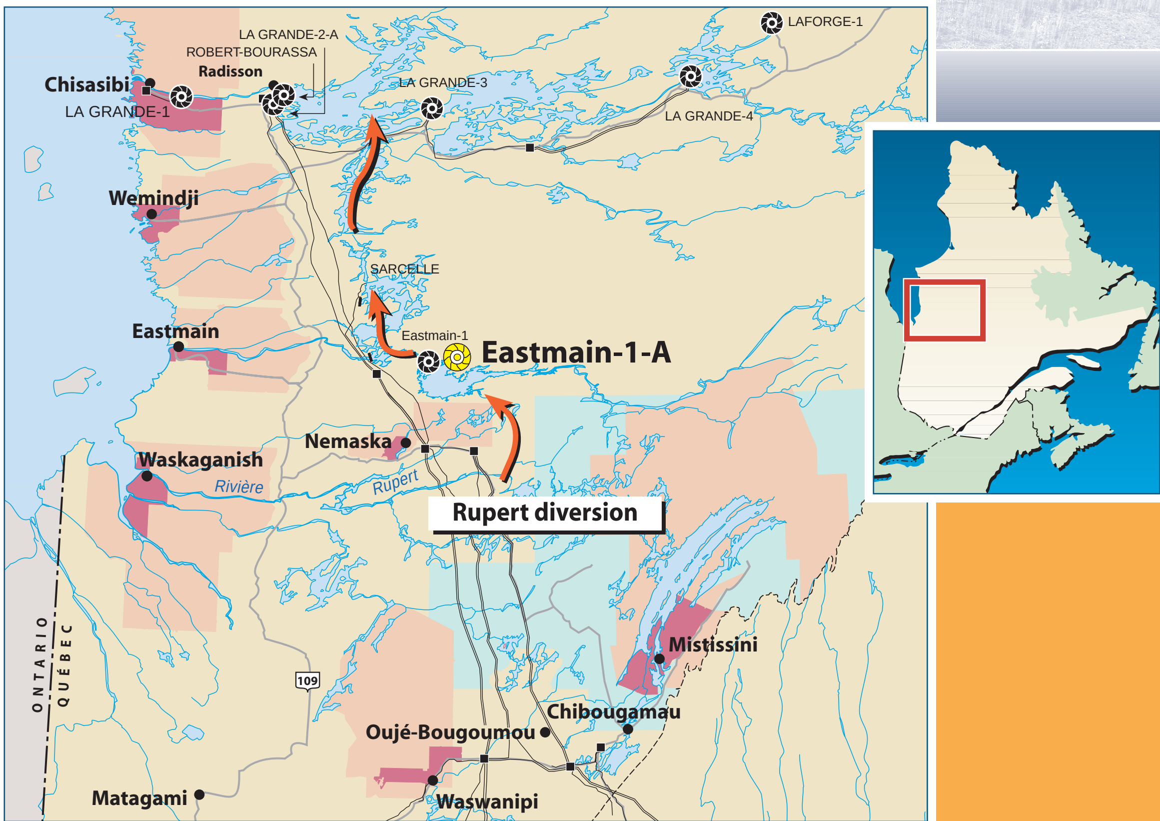
Eastmain-1-A Powerhouse and *Rupert Diversion*



Preliminary Information

October 2002

Rationale

The Eastmain-1-A powerhouse and Rupert diversion project is part of Hydro-Québec Production's commitment to continue to develop competitive hydroelectric projects, as stated in Hydro-Québec's* Strategic Plan 2002-2006*. This orientation reflects both the economic benefits of competitive hydroelectric projects and the environmental advantages of hydropower. The project aims to ensure the steady growth of electricity sales on wholesale markets and of Hydro-Québec Production's generating facilities in Québec.

Project Description

The project comprises the following:

- ***The Rupert diversion, which consists in redirecting some of the waters from the Rupert River watershed into the Eastmain watershed***
- ***The construction of an additional powerhouse (Eastmain-1-A) on Eastmain 1 reservoir***
- ***The addition of structures at the Sarcelle site, at the outlet of Opinaca reservoir***

The Rupert diversion
The diversion project involves diverting a portion of the flow from the Rupert River watershed into the Eastmain River using the following structures and facilities:

- Four dams, with the main dam located near kilometre 314 of the Rupert River
- A spillway on the Rupert River close to the dam
- About 50 dikes
- Two diversion bays (forebay and tailbay) with a total surface area of some 395 km^2
- A control structure between the Rupert River forebay and tailbay with a maximum capacity of 800 m^3/s
- A network of canals totaling approximately 12,000 metres in length to direct the flow into the various parts of the diversion bays
- Structures to restore some of the instream flow to the lower reaches of the Rupert, Lemare and Nemiscau rivers. Moreover, the Crees have the option of requesting that the project be designed to include an instream flow of at least 20% of the current average annual flow at the diversion point on the Rupert River. They have until April 1, 2003 to exercise this option.

The following measures will also be required to complete the diversion project:

- The relocation of some segments of the existing 735-kV transmission lines.
- The construction of permanent access roads from Albanel substation and an existing secondary road, as well as the installation of a permanent 25-kV transmission line from Albanel substation to the spillway on the Rupert River.

Studies will make it possible to define and optimize the project's characteristics.

The Eastmain-1-A powerhouse
The Eastmain-1-A powerhouse may have an installed capacity of up to 770 MW, and could include up to four turbines. Under average runoff conditions, the Eastmain-1 and Eastmain-1-A powerhouses, together with the Rupert River diversion, should produce an output of up to 5.6 TWh per year. Studies will clarify this data and help determine the location and capacity of the Eastmain-1-A powerhouse.

Sarcelle
The Crees have until April 1, 2003 to exercise their option to choose one of the following modifications to the Sarcelle site:

- The addition of a fourth gate to the Sarcelle control structure at the northern edge of Opinaca reservoir;

  or

- The construction of a powerhouse near the existing control structure, and the installation of a transmission line via Muskeg substation to the Eastmain-1 site.

Related Projects

Hydro-Québec Production will build a permanent access road running east-west between the existing Muskeg substation and the Eastmain-1 site, as well as two or three workcamps to accommodate the people working on the projects. The number and location of these workcamps will be determined during the studies.

Project Schedule

Hydro-Québec Production has begun its draft-design studies and plans to file an environmental impact assessment report with the concerned authorities in early 2004, in order to obtain the necessary government approvals. Once these approvals have been granted, construction work could begin in 2005. The diversion should be completed in late 2007 and Eastmain-1-A powerhouse could be commissioned by 2010.

TECHNICAL CHARACTERISTICS

Rupert Diversion

Main structures

• Dams (number)	4
• Dikes (number)	approx. 51
• Canals and transfer canal	approx. 12,000 m
• Rupert spillway (capacity)	approx. 3,630 m^3/s
• Control structure (capacity)	800 m^3/s
• Instream flow release structures	3 sites (Rupert/Lemare/Nemiscau)

Material

• Fill – excavated material	approx. 8,000,000 m^3
• Canal excavation	approx. 6,400,000 m^3
• Concrete	approx. 25,000 m^3

Impoundments (km²)

• Total area affected	approx. 395
• Land flooded	230
• Water level raised	165

Accommodations and access

• Workcamps	Nemiscau Cramoisy main camp Cramoisy secondary camp
• Roads	approx. 100 km (from Albanel substation)
• Airport used	Nemiscau

Eastmain-1-A

Main structures

• Powerhouse	
- Units	up to 4 turbines
- Capacity	up to 770 MW
- Design flow	up to 1,400 m^3/s

Accommodations and access

• Workcamps	Nemiscau Eastmain-1
• Airport used	Nemiscau

Sarcelle

Control structure (4th gate) or powerhouse

• An additional 4th gate is required at the Sarcelle control structure	
- Maximum flow	from 1,982 m^3/s to 2,770 m^3/s

OR

• A powerhouse with a transmission line to Eastmain-1 site through Muskeg	
- Maximum flow: Control structure plus powerhouse	from 1,982 m^3/s to 2,770 m^3/s

Accommodations and access

• Existing camp	km 381

ENERGY AND HYDROLOGICAL CHARACTERISTICS

Output with average inflows

• Eastmain-1 and Eastmain-1-A	up to 5.6 TWh/year
• Increase at Robert-Bourassa/La Grande-2-A and La Grande-1	up to 7.0 TWh/year
• Total	**up to 12.6 TWh/year**

Main hydrological data

Diverted flows (m^3/s)

• Mean diverted flow into Eastmain	up to 585.3
• Maximum diverted flow into Eastmain	up to 800.0

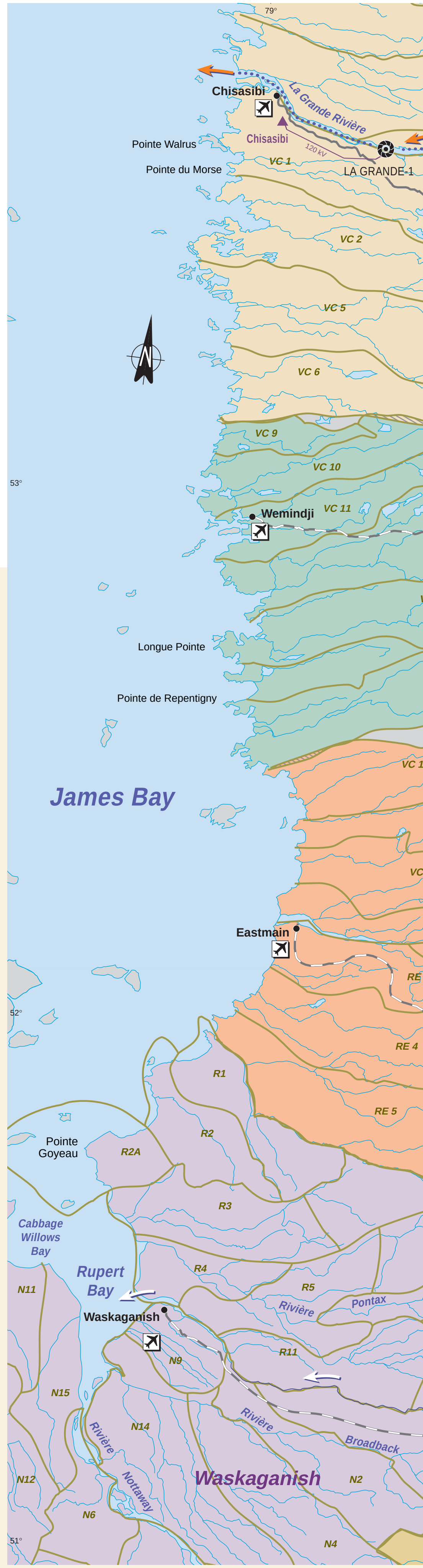
- Planned forebay and tailbay
- River with natural flow
- River with reduced flow
- Direction of flow
- Hydroelectric powerhouse
- Planned hydroelectric powerhouse
- Planned canal
- Dam or dike
- Planned dam or dike
- Control structure and spillway
- Planned control structure and spillway
- Instream flow release structure
- Transmission line (69 to 735 kV)
- Planned transmission line
- Substation (all voltage levels)

INFRASTRUCTURE

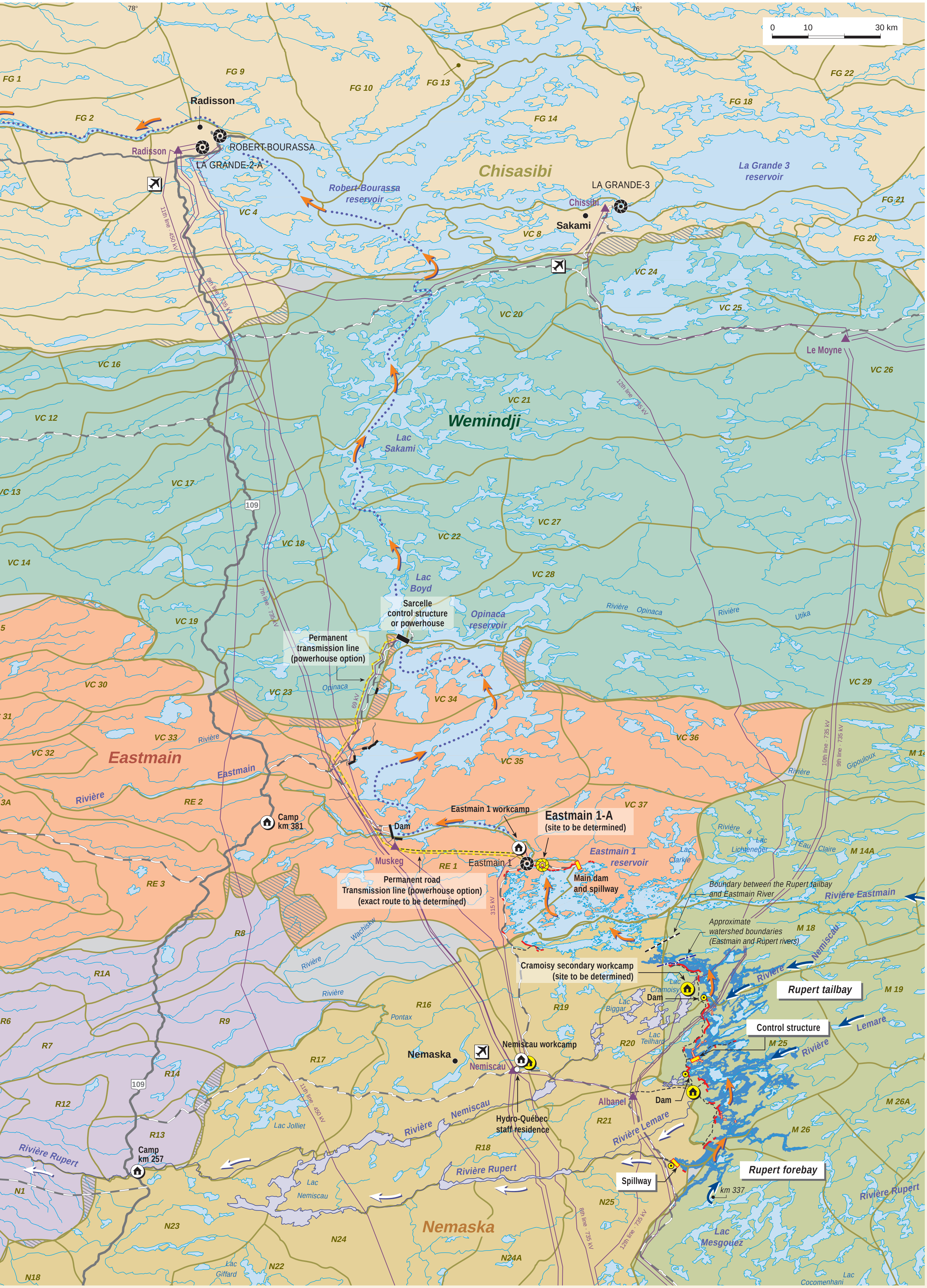
- Planned road (preliminary centre line)
- Existing road
- Secondary road
- Existing workcamp
- Planned workcamp
- Existing airport

CREE TRAPLINES

- Chisasibi
- Eastmain
- Mistissini
- Nemaska
- Waskaganish
- Waswanipi
- Wemindji
- Overlap
- Trapline limit



Eastmain-1-A Powerhouse and *Rupert Diversion*


0 10 30 km
Radisson
ROBERT-BOURASSA
LA GRANDE-2-A
Robert-Bourassa reservoir
Chisasibi
LA GRANDE-3
Sakami
La Grande 3 reservoir
Le Moyne
Wemindji
Lac Sakami
Lac Boyd
Sarcelle control structure or powerhouse
Opinaca reservoir
Permanent transmission line (powerhouse option)
Eastmain
Rivière Eastmain
Camp km 381
Eastmain 1 workcamp
Eastmain 1-A (site to be determined)
Dam
Muskeg
Eastmain 1
Eastmain 1 reservoir
Main dam and spillway
Permanent road
Transmission line (powerhouse option)
(exact route to be determined)
Boundary between the Rupert tailbay and Eastmain River
Approximate watershed boundaries (Eastmain and Rupert rivers)
Cramoisy secondary workcamp (site to be determined)
Rupert tailbay
Control structure
Nemaska
Nemiscau workcamp
Hydro-Québec staff residence
Albanel
Rivière Lemare
Rivière Nemiscau
Rivière Rupert
Camp km 257
Spillway
Rupert forebay
km 337
Lac Mesgouez
Nemaska

Study Area

The study area covers a sufficient portion of the Rupert, Eastmain and Grande Rivière watersheds to encompass all of the biophysical environments affected by the project, i.e.:

- The mid- and downstream segments of the Rupert River watershed and Rupert Bay
- Eastmain 1 and Opinaca reservoirs
- Lakes Boyd and Sakami
- Robert-Bourassa and La Grande 1 reservoirs
- The segment downstream of La Grande-1 generating station, as far as the mouth of the Grande Rivière
- The Grande Rivière estuary and its area of influence on the east coast of James Bay

Studies on the social environment will focus mainly on the four Cree communities of Waskaganish, Eastmain, Mistissini and Nemaska, as well as the municipality of Baie-James.

Agreements with the Cree Communities

On February 7, 2002, the Grand Council of the Crees, the Cree Regional Authority, the Eastmain Band, the Cree Nation of Mistissini, the Nemaska Band, the Waskaganish Band, Hydro-Québec and Société d'énergie de la Baie James signed the *Boumhounan Agreement*, which pertains specifically to the Eastmain-1-A and Rupert diversion project. This Agreement served to define the project and establish the commitments of the respective parties in relation to it.

The Agreement also provides for the future creation and allocation by Hydro-Québec of a regional development fund for the municipality of Baie-James, to be used for the specific purposes of the project.

Description of the Environment

The area under study is located on what is known as non-commercial forest land. It consists mainly of taiga containing a number of black spruce forests and scattered peat bogs that are particularly abundant on the coastal plain, especially south of the Rupert River.

Due to the harsh climate, the terrestrial fauna is somewhat sparse but diverse, with almost 40 species. Beaver, moose and caribou are of greatest interest and benefit to the local residents.

There are some 30 species of fish in the study area, the most abundant of which are lake cisco, walleye, lake whitefish, northern sucker, white sucker, northern pike, brook trout, lake sturgeon and lake trout. Areas of interest include Nemiscau Lake, where there is excellent potential for the development of lake whitefish and lake sturgeon, and the downstream reach of the Rupert River, which has a population of anadromous lake cisco.

The east coast of James Bay and Rupert Bay provide a wide range of excellent habitats for migratory birds, while the inland areas provide a less favorable environment for waterfowl. Canada geese and snow geese are found in abundance in the coastal region; during the autumn months, the snow-goose population at the southern tip of James Bay and in Rupert Bay numbers some one million individuals.

The entire study area is encompassed within the territory governed by the *James Bay and Northern Québec Agreement* (JBNQA), and the proposed development is located in Category III (public) lands. The area is accessible both by road (via the Route du Nord and the Matagami-Radisson-Chisasibi highway) and by air. The airport nearest to the construction site is at Nemiscau.

The development project mainly concerns four of the nine Cree communities. Mistissini and Nemaska are inland villages, while Waskaganish and Eastmain are located on the east coast of James Bay. The Crees have exclusive harvesting rights for certain species, including fur-bearing animals. Hunting, fishing and trapping are of great importance to the local residents and make up a large part of their activities. Wages in these communities are derived mainly from private service and government sector jobs, and most of the residents are under 24 years of age.

The non-Aboriginal population is concentrated in the southern portion of the territory covered by the JBNQA, in the two major municipalities of Baie-James and Chibougamau. Economic activity in this area is primarily related to mining, forestry and hydroelectricity. There is no forestry development in the study area, since its resources are of no commercial interest. Moreover, tourism and recreational activities have increased due to the opening of the Matagami-Radisson-Chisasibi highway and the Route du Nord. People who vacation in this area are mainly interested in visiting the hydroelectric facilities, hunting, sports fishing and ecotourism activities.

Impact Sources

The sources of impact from the Eastmain-1-A and Rupert diversion project are mainly related to the construction and use of the project's facilities and in particular, the following factors:

- The creation of a forebay and a tailbay for the partial diversion of the Rupert River
- Reduction in flow downstream of the partial diversion point on the Rupert and Lemare rivers, and in the Rupert River estuary
- The possible spilling of surplus water into the Rupert River
- The increase in the average annual flow in Eastmain 1 and Opinaca reservoirs, lakes Boyd and Sakami, Robert-Bourassa and La Grande 1 reservoirs, and in the Grande Rivière estuary
- The construction of new access roads
- Activities related to the construction of the various structures (dams, dikes, spillway, etc.) and their associated work sites
- The presence and activities of the workers

Issues

The issues associated with the project involve the following main elements:

Biophysical environment

- Change in terrestrial fauna and avifauna habitats
- Mercury concentrations in fish living in the Rupert River diversion bays and lakes Boyd and Sakami, and management of the health risk for users of this resource
- Management of sturgeon populations in the Rupert and Eastmain rivers
- Management of fish habitats in the Rupert, Nemiscau and Lemare rivers and fish migration patterns
- Management of fish and waterfowl habitats in the Rupert River estuary and Rupert Bay
- Maintaining most of the average annual flow and water levels in the Nemiscau River
- Maintaining water levels in Nemiscau Lake
- Stability of the riverbanks downstream of the Robert-Bourassa development, as far as the mouth of the Grande Rivière

Social environment

- Maintenance of the Rupert River as a navigation route
- Maintenance of the quality and quantity of drinking water from the Waskaganish water treatment plant
- Changes to the land and aquatic environments used by the Crees for hunting, fishing and trapping
- Development of the residual portion of the affected traplines to increase accessibility and the potential for supporting wildlife
- Maintenance of access routes to Rupert Bay and the Rupert River, and to various points along their banks in accordance with current Cree practices
- Development of new environments to include plans for clearing and management of wood debris
- Local and regional economic spinoffs
- Increased accessibility to the region
- Creation of partnerships with the community

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Eastmain-1-A Powerhouse and *Rupert Diversion*

This document was produced for
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2002G193A

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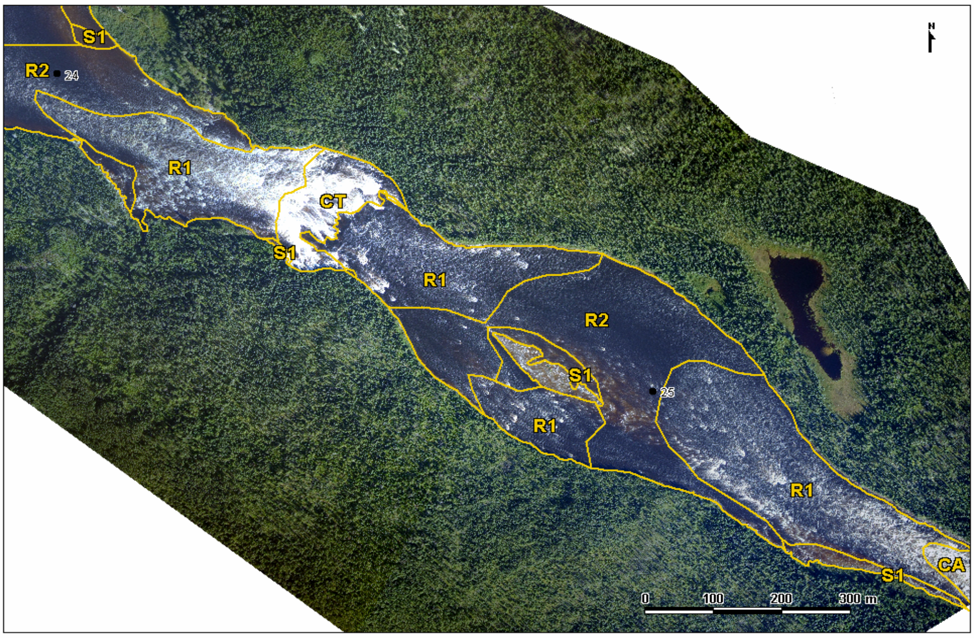
Appendix III

Example of Mapping Fish Habitat in a River Reach



Appendix IV

Proposed HPI Methodology for Eastmain-1-A/Rupert Project

Baseline conditions

An index was developed to quantify fish production in the Rupert River. It was largely inspired by the *weighted suitable area* (WSA) method introduced by Minns et al. (1996). This index was used to establish a baseline and to evaluate the project impacts.

For all types of habitat considered (i.e., Po1, Po2, Ch1, etc.), the index was calculated with the following equation:

$$WSA_i = \Sigma(A \times S_i)$$

where:

- WSA_i is the weighted suitable area for species i
- A is the area of the habitat in question
- S_i is the habitat preference index for species i

To obtain the total WSA for a given environment, the WSAs for each species were added up (Σ WSA_i). The method is shown in Table M10-16.

The habitat preference index (S) was calculated for each species with the biomass per unit effort (BPUE), the fish population replacement ratio (P/B) (Randall and Minns, 2000), the growth parameter k from the von Bertalanffy equation, and water temperature (t):

$$S_i = BPUE \times (P \div B)_i \times e^{k_i t}$$

A value S_i is then calculated for each of the five habitat type classes in the Rupert River.

The highest S_i value (S_i max) is then used to situate the S_i on a scale of 0 to 1 with the following formula:

$$S_{hi} = S_i \div S_i max$$

Table M10-16: Calculation of the weighted suitable area[1]

Habitats$_j$	Species 1	Species 2	Species i	WSA
h_1	$S_{1h1} \times A_{h1}$	$S_{2h1} \times A_{h1}$	$S_{ih1} \times A_{h1}$	$\sum_{i=1}^{n} (S_{ih1} \times A_{h1})$
h_2	$S_{1h2} \times A_{h2}$	$S_{2h2} \times A_{h2}$	$S_{ih2} \times A_{h2}$	$\sum_{i=1}^{n} (S_{ih2} \times A_{h2})$
h_j	$S_{1hj} \times A_{hj}$	$S_{2hj} \times A_{hj}$	$S_{ihj} \times A_{hj}$	$\sum_{i=1}^{n} (S_{ihj} \times A_{hj})$
Total	$\sum_{j=1}^{n} \frac{\left(S_1 \times A_{hj} \right)}{S_1 max}$	$\sum_{j=1}^{n} \frac{\left(S_1 \times A_{hj} \right)}{S_2 max}$	$\sum_{j=1}^{n} \frac{\left(S_{ihj} \times A_{hj} \right)}{S_i max}$	$\sum_{i=1}^{n} \left[\frac{\sum_{j=1}^{n} (S_{ij} \times A_{hj})}{S_i max} \right]$

[1]S= BPUE X P/B X e $^{k(t)}$, where S is the habitat preference index for each species, BPUE is the biomass of fish caught per unit of fishing effort,
P/B is the replacement rate of living matter in a fish population, P is production
B is instant biomass, k I s the growth factor for the species obtained with the von Bertalanffy model and it is the mean water temperature.
S_i max is the maximum valued of the species i preference index for all habitats j. A_h is the area of habitat h.

The resulting habitat preference index (S_{hi}) is then multiplied by the area of each habitat class (A_h) and the sum of the S_{hi} values gives the weighted suitable area for the species i (WSA_i). The total index for the river is thus obtained by adding up the WSA_i values.

The five habitat classes are actually a grouping of the 13 habitat types previously described. These groups were determined with Pearson correlation coefficients from the BPUEs obtained from gill and seine net fishing (see Table M10-17), and the various habitat types.

Table M10-17: Classes of habitat types used to calculate the WSA for rivers fished with gill nets in 2002

Class[1]	Flow type	Habitat type	Dominant substrate[2]	Subdominant substrate
1	Lentic	Lake	G, S	B, C, P
2	Lentic	Pool 1 Pool 2 Channel 2 Channel 3 Sill 3	G, S G, S P, G G, S C, P	B, C, P - S, C P C, S
3	Transition	Channel 1 Sill 1 Sill 2	C, B C, B C, G	P P B, G
4	Lotic	Rapids 1 Rapids 2	B, Bx C	C, R P, C, R
5	Lotic	Cascade Waterfall	R, Bx R	B Bx

Class 1 and 2 habitats (see Table M10-17) are lentic and suitable for species that prefer calm water and grass beds for feeding and shelter. Class 3 groups together the intermediate-flow habitats. Fast-flow zones are frequented by cold-water species with high dissolved-oxygen requirements.

Future conditions

The WSA in future conditions was calculated with the areas-per-habitat class obtained with the GIS after evaluation of the changes in the thirteen habitat types for an instream flow of Q20%. Only the areas change; fish preferences in future conditions will remain identical to those in the baseline conditions for each habitat type.

[1]Classes were established with a table of Spearman correlation coefficients.

[2]S = sand; G = gravel; P = pebbles; C = cobbles; B = boulders; Bx = large boulders.