

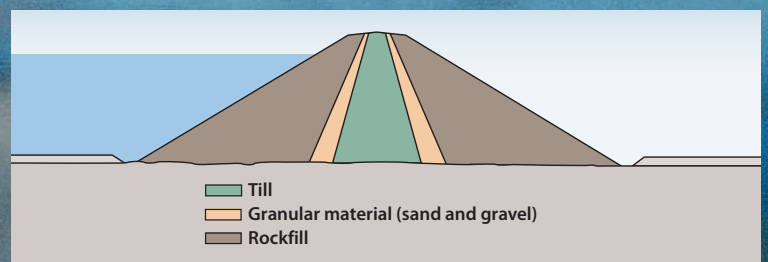
In spring 1971, an ambitious project was launched to develop the hydroelectric potential of the Baie-James territory, home to some of the largest rivers in the province. The “project of the century” produced impressive results: today, the La Grande complex generates almost half of all the electricity in Québec.

In the Heart of the Taiga

The La Grande Complex



The Baie-James territory covers 350,000 km², or one-fifth the area of Québec. It extends from the 49th to the 55th parallel, and from the Otish Mountains in the east to Baie James (James Bay) and the Ontario border in the west. Approximately 15% of this vast area is water.



Retaining structures

A dam is built across a river bed to close off the flow, raise the water level and create a “head,” or drop. To prevent the now higher water from escaping through secondary valleys, dikes are built around the reservoir.

The majority of the dikes and dams in the La Grande complex are embankment structures, that is, made of natural materials excavated for the project. The Baie-James territory is rich in borrow materials: rocks, sand, gravel and till. Till comes from moraine deposits created by the movement of glaciers. Its near-impervious nature makes it the ideal material for dam and dike cores.

Water, a natural treasure

Several large rivers, including the Grande Rivière (800 km), the Nottaway (720 km) and the Eastmain (720 km), flow from their source on the western slopes of the Otish Mountains to empty into Baie James.

The headwaters of the La Grande complex are contained in Caniapiscau reservoir (4,275 m²). It, too, eventually discharges into the bay through an elaborate network of waterways.

A work of *gigantic* proportions

The La Grande complex is 800 km long. The “project of the century” was the largest construction site in the world for almost 25 years. Because of its mammoth scale, the project was built in three phases.

Phase I (1973–1985) comprises these activities:

- Partial diversion of the Eastmain, the Opinaca and the Petite Rivière Opinaca (EOL diversion), as well as the Rivière Caniapiscau, to increase the flow of the Grande Rivière
- Creation of five reservoirs: La Grande 2,* La Grande 3, La Grande 4, Opinaca and Caniapiscau
- Construction of three generating stations: La Grande-2 (largest underground generating station in the world), La Grande-3 and La Grande-4

* The entire La Grande-2 site was renamed Robert-Bourassa in 1996.

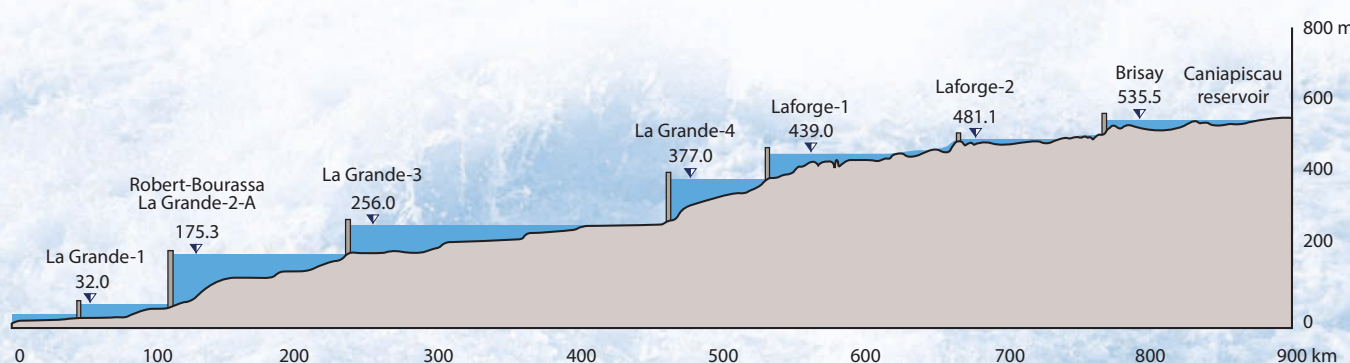
Phase II (1987–1996) comprises these activities:

- Creation of three reservoirs: La Grande 1, Laforge 1 and Laforge 2
- Construction of five generating stations: La Grande-1, La Grande-2-A, Laforge-1, Laforge-2 and Brisay

Phase III (2002–2013) comprises these activities:

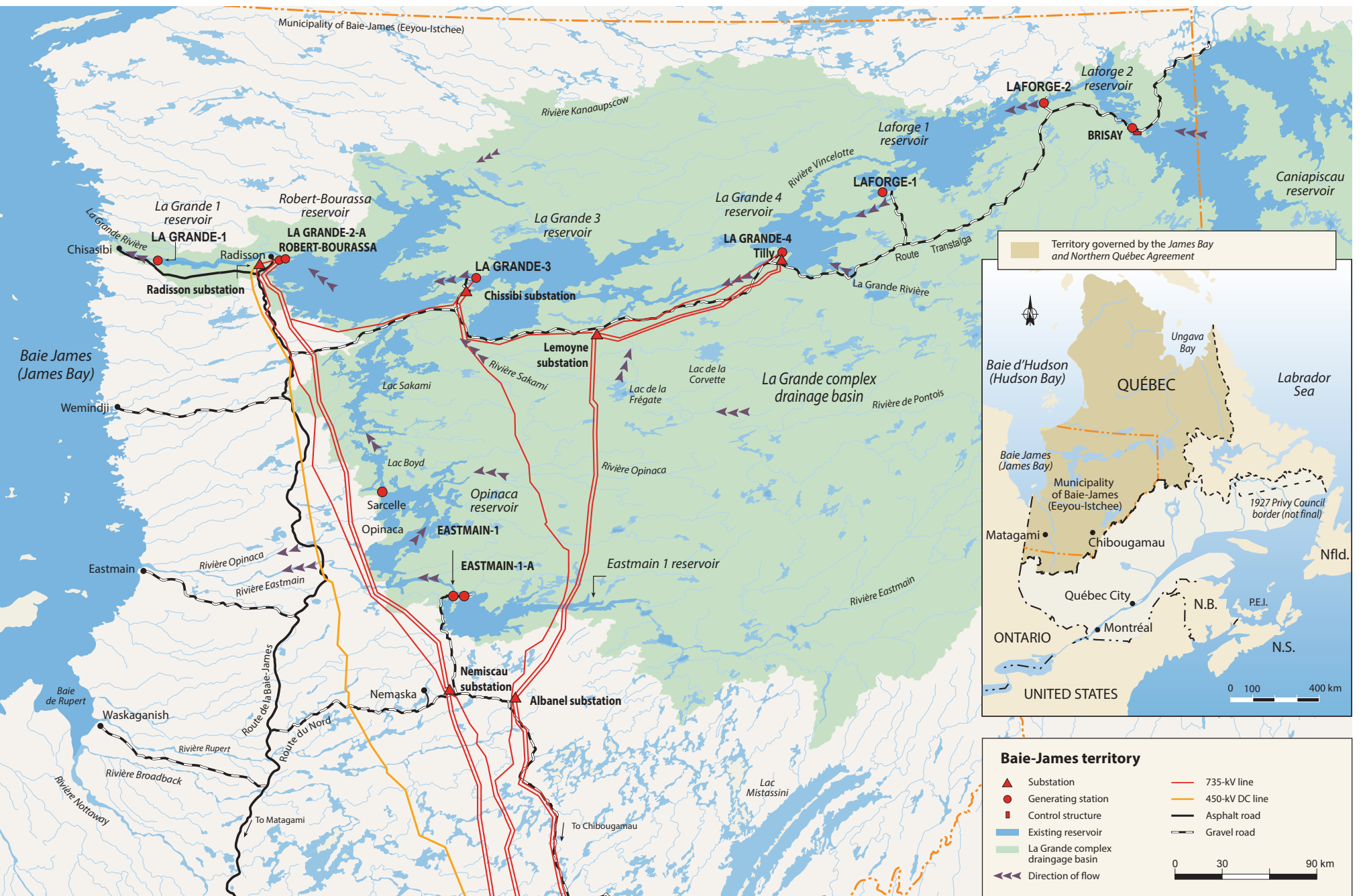
- Creation of one reservoir: Eastmain 1
- Construction of three generating stations: Eastmain-1, Eastmain-1-A and Sarcelle
- Construction of five dams, some ninety dikes and two spillways
- Partial diversion of the Rivière Rupert

Today, the La Grande complex accounts for close to half of Hydro-Québec’s generating capacity—with a non-polluting, renewable energy source.



Hydrographic profile of phases I and II of the La Grande complex

Two ideal conditions make development of the Grande Rivière particularly worthwhile: a high rate of flow and a significant “head,” or drop in elevation, along its course.



History in the making

The James Bay and Northern Québec Agreement (JBNQA) was signed on November 11, 1975, by seven parties: the Crees, the Inuit, Hydro-Québec, Société d'énergie de la Baie James, Société de développement de la Baie James and the governments of Québec and Canada.

One of the 30 chapters deals with the Crees and the Inuit, who received financial compensation, land rights, and specific rights in a variety of areas including local government, harvesting of wildlife, pursuit of traditional activities, economic development, administration of justice, health care, social services, education and environmental protection.

With the coming of the new millennium, it was no longer a question of how to live as neighbors, but rather of partnership. In 2002, the Government of Québec signed a nation-to-nation agreement with the Grand Council of the Crees, known as the Paix des Braves.

That same year, Hydro-Québec, Société d'énergie de la Baie James and the Cree Nation signed the Nadoshtin Agreement (Eastmain-1) and the Boumhounan Agreement (Eastmain-1-A/Sarcelle/Rupert). The latter agreement covered issues such as further development of the territory's hydroelectric potential, Cree training and Cree employment opportunities at the La Grande complex.



High-voltage transmission, a made-in-Québec innovation

In 1977, Hydro-Québec started construction of the Baie-James transmission system. The system consists of six AC lines operating at 735 kV, a technology developed in Québec in 1965 for the Manic-Outardes project. These lines run a combined distance of more than 6,000 km on approximately 14,000 towers, often through areas with few access roads. The Baie-James transmission system also includes the world's only multiterminal direct current link. This ± 450 -kV line runs from Radisson substation to Nicolet substation in Québec and then all the way to Sandy Pond, near Boston. In addition to supplying the Québec system, it is used for power interchanges with the United States.

Multiple uses

The Baie-James territory has a population of 33,000. There are approximately 17,000 Crees, who live in eight villages scattered along the coast of Baie James and inland. Non-Natives are concentrated in six southern communities and one more northerly one, Radisson.



According to archaeological digs, the first human settlements in the area date back 4,000 years. The ancestors of today's Native inhabitants hunted large game, like caribou and bison.

Part of the Canadian Shield

The Baie-James region is an ancient formation. Its eroded topography is the result of repeated attacks by glaciers, the last one retreating 10,000 years ago. From west to east, the landscape consists of a coastal plain, a mottled plateau flecked with lakes, and finally the more rugged terrain of the Otish Mountains.

Under the Northern Lights

The continental climate of the Baie-James region is characterized by a long, harsh winter. The temperature averages -4°C , but can dip as low as -50°C . The seasons are very different, with the sun setting around 10:00 p.m. in summer and before 4:00 p.m. in winter.

Flora

The taiga is a zone of subarctic forest that extends from the 52nd to the 55th parallel. The underlying bedrock is about two billion years old. Most of it is covered with an overburden of glacial origin, mainly till.

The taiga forest, interspersed with many peat bogs, consists mainly of black spruce, jack pine and larch. Willow, aspen, colorful flowers, berries and abundant lichen, the main source of food for caribou, are also found.

Fauna

There are 39 species of land animals in the region. Three of them are of economic or sporting interest: moose, caribou and beaver.

The whole Baie James coast offers a wide range of habitats suitable for migratory birds such as the Canada goose and snow goose. There are also some forty species of fish, some for Native use exclusively (e.g., sturgeon, whitefish and burbot).



Radisson is the only non-Native village north of the 53rd parallel accessible by road. A veritable oasis in the heart of the taiga, it totals just over 400 inhabitants.



For the past 45 years, Hydro-Québec has invested enormous effort in protecting the environment. To reduce the impact of its activities on the affected area, it develops and implements mitigation, compensation and enhancement measures.



Right at home

Because an osprey nest can be as large as 1 m in diameter, it sometimes happens that its branches touch power lines. Platforms have therefore been installed on some poletops for ospreys to nest on. This protects the birds and prevents system outages.

Respect for nature

Protected ecosystems

Four weirs were built on the Eastmain and Opinaca rivers to raise the water to its levels under natural conditions. This has benefited waterfowl and certain fur-bearing animals by preventing the exposure of riverbanks.

A bountiful hunting ground

Goose ponds were created on the coast and inland. Geese are now more plentiful, and Cree hunters have been more successful.

A wealth of fish and birds

Close to La Grande-1 generating station, 14 small islands were created in the Baie d'Upichiwuun to attract waterfowl and muskrat. Visitors can spot a dozen bird species including osprey, Canada goose and greater yellowlegs.

A dike was built to protect a bay in Robert-Bourassa reservoir from fluctuations in the water level. Above a certain level, the water in the bay flows into the reservoir rather than flooding the banks. The dike also has a fishway that allows migration from the reservoir into the bay during spawning season.

No trace of waste

Sound waste management practices are followed at Hydro-Québec workcamps and facilities. Dry materials are buried, and scrap metal and hazardous waste such as used oil are recovered.

A treat for the eyes

All the hydroelectric development sites have been enhanced by lookouts and observation points from which to admire the surrounding countryside.

Reservoir history

Hydro-Québec monitored water quality and fish populations, conducted archaeological digs before impounding, studied waterfowl habitats before and after impounding, and performed any necessary clearing of the reservoir periphery to facilitate navigation.



La Grande complex generating stations

Number of generating stations . . 11
 Number of generating units 74
 Installed capacity* 17,418 MW
 Number of reservoirs 9

Note: Reservoir creation entailed the flooding of 11,505 km² of land, which is 6.5% of the Grande Rivière drainage basin or 2.9% of traditional Cree hunting grounds.

** In this document, installed capacity is stated at 5°C.*

Robert-Bourassa hydroelectric 7,722 MW

Robert-Bourassa 5,616 MW



Robert-Bourassa
112 km from Baie James

Generating station

Installed capacity 5,616 MW
 Number of generating units 16
 Unit capacity 351 MW
 Type of turbine Francis
 Net rated head 137.2 m
 Commissioning 1979–1981

Reservoir

Area at maximum level 2,835 km²

Dam

Crest length 2.8 km
 Maximum height 162 m

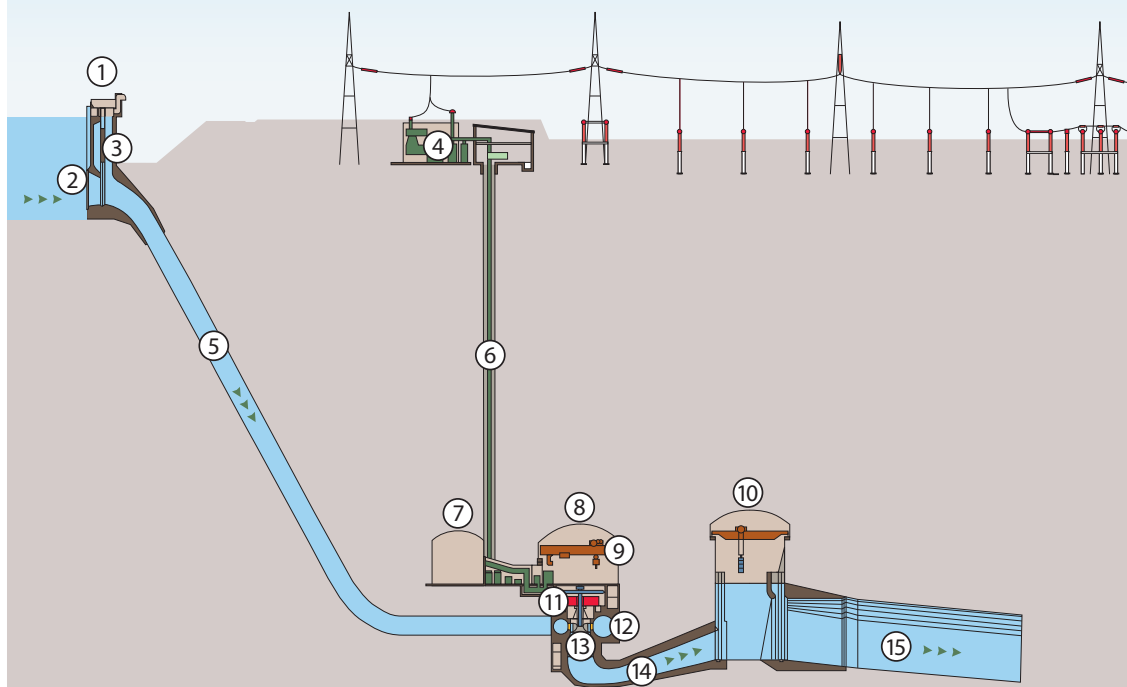
Dikes

Number 29
 Total crest length 23.8 km

Spillway

Number of gates 8
 Discharge capacity 16,280 m³/s

Cross-section of the generating station



- | | | |
|-----------------|------------------------------|---------------------|
| 1. Intake | 7. Service tunnel | 12. Spiral case |
| 2. Trash rack | 8. Machine hall | 13. Francis turbine |
| 3. Gate | 9. Overhead travelling crane | 14. Draft tube |
| 4. Transformer | 10. Surge chamber | 15. Tailrace tunnel |
| 5. Penstock | 11. Generator | |
| 6. Busbar shaft | | |



La Grande-2-A
111 km from Baie James

Generating station

Installed capacity2,106 MW
 Number of generating units6
 Unit capacity351 MW
 Type of turbine Francis

Net rated head138.5 m
 Commissioning1991-1992

Dikes

Number2
 Total crest length1 km

Built in the early 1970s, the **Robert-Bourassa hydroelectric generating facilities** include the following structures:

- **Robert-Bourassa generating station**, located 137 m underground in the depths of the Canadian Shield. From an intake in a secondary valley, the water enters the 16 penstocks that channel the water to the 16 turbines. The machine hall is four storeys tall and 483 m long.
- A dam the height of a 53-storey building. The dam and 29 dikes hold back the waters of the Grande Rivière to create the head needed to drive the turbines.
- A reservoir almost three times the size of Lac Saint-Jean. It occupies about 1% of the complex area and has a storage capacity of 61.7 billion m³.
- A spillway, nicknamed “the giant’s staircase” because of its 10 steps, each 10 m high. It is 1.5 km long and can discharge 16,280 m³/s of water, or twice the flow of the Fleuve Saint-Laurent (St. Lawrence River) at Montréal.

La Grande-2-A generating station was built to add capacity to Robert-Bourassa. It provides 2,106 MW, a significant amount when energy demand is at its peak. It draws its water from Robert-Bourassa reservoir.

This addition to the Robert-Bourassa facilities required the building of an intake, six penstocks, two tailrace tunnels and a headrace canal flanked by two dikes.

Mari-Québec

Installed in the cavernous machine hall, the impressive sculpture pays tribute to the men and, in particular, the women who built the Robert-Bourassa hydroelectric generating facilities. The 900-kg bronze statue was created by Marc-André Parisé, one of the workers at the site. The statue was unveiled on October 27, 1979, by then Premier René Lévesque and Bertrand Guérette, master tinsmith.



A unanimous gesture of recognition

In 1971, Robert Bourassa used the convincing argument, “Never let it be said that we shall live like paupers on a land this rich,” to support his dream of a hydroelectric development project. For the young Québec premier, developing the rivers of Baie-James meshed perfectly with his goals of economic recovery and job creation, while also being the most logical energy choice.

Convinced of the soundness of his project, Bourassa lived to see his dream come true. He died just as Phase II was being completed. On October 4, 1996, two days after his death, the Québec government announced that the whole La Grande-2 development (dam, generating station and reservoir) would be renamed Robert-Bourassa.



Restoring the land to its beauty

As soon as La Grande-2-A generating station was completed, 750,000 green alders were planted, part of the total 18.4 million trees planted during the first two phases of the complex. Other examples of Hydro-Québec’s mitigation measures for the environment include the following:

- Carrying out archaeological digs and inventories
- Building a new drinking-water intake and filtration plant for the village of Chisasibi
- Installation of minidikes on the coast of Baie-James to attract waterfowl

La Grande-1

1,436 MW



La Grande-1 37 km from Baie James

Generating station

Installed capacity	1,436 MW
Number of generating units	12
Unit capacity	119.7 MW
Type of turbine	Fixed-blade propeller
Net rated head	27.5 m
Commissioning	1993–1995

Reservoir

Area at maximum level	70 km ²
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Dikes

Number	2
Total crest length	2.6 km

Spillway

Number of gates	8
Discharge capacity	16,280 m ³ /s

La Grande-1 generating station, a run-of-river facility that receives all the water flowing through Robert-Bourassa and La Grande-2-A, is the last to turbine the water before it empties into Baie James. Despite its low head of 27.5 m, the rate of flow is sufficient to run its 12 generating units.

Built directly over the river, the generating station does double duty as a dam. Its construction required 640,000 m³ of concrete—or the same amount as a sidewalk stretching from Montréal to Miami—as well as 6,000 km of steel rods for reinforcement.

The spillway has the same capacity as the Robert-Bourassa spillway, at 16,280 m³/s. There are also two concrete gravity dams, each extended by a dike, that form a small 70-km² reservoir.



More productive hunting and fishing for the Crees

La Grande-1 is located on the traditional fishing, hunting and trapping grounds of the Chisasibi Crees. A number of measures were carried out to minimize the impact of the development on the environment:

- **For hunting:** Creation of a marsh near the generating station to attract waterfowl and muskrat; selective cutting on the bank to attract hare, ptarmigan, waterfowl and moose
- **For safer navigation:** Additional clearing of the reservoir

La Grande-3

2,417 MW



La Grande-3 238 km from Baie James

Generating station

Installed capacity	2,417 MW
Number of generating units	12
Unit capacity	201.5 MW
Type of turbine	Francis
Net rated head	79.2 m
Commissioning	1982–1984

Reservoir

Area at maximum level	2,420 km ²
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Dam

Crest length	4.3 km
Maximum height	93 m

Dikes

Number	68
Total crest length	21.8 km

Spillway

Number of gates	5
Discharge capacity	10,000 m ³ /s

A rocky island divides the Grande Rivière into two branches at the site chosen for **La Grande-3 generating station**, which was built right into a 200 m by 50 m cut in the pre-Cambrian rock. It is the third-largest generating station in Québec.

The dam is the longest dam in Québec, higher and longer than the Jacques-Cartier Bridge. Its reservoir is formed by the dam and a ring of 68 dikes over 60 km.

A distant 100 km from the site, the flow of the Sakami River is diverted by the small but significant Frégate dike, which increases the generating station's capacity by 4%.

The magnificent spillway is considered an engineering feat as well as an aesthetic achievement. Built like a ski jump, it projects the water high into the air; the water then falls into the stilling basin before resuming its normal course. The spillway has a discharge capacity of 10,000 m³/s, or the flow of the Fleuve Saint-Laurent (St. Lawrence River) at its mouth.



An island for a base

This small island is an integral part of the development. The spillway, which stands in the middle of the island, marks the dividing point between the north and south dams. So that the structure could be built in the dry, the water of the Grand Rivière was temporarily diverted under the island.

La Grande-4

2,779 MW



La Grande-4

463 km from Baie James

Generating station

Installed capacity 2,779 MW
 Number of generating units 9
 Unit capacity 308.8 MW
 Type of turbine Francis
 Net rated head 116.7 m
 Commissioning 1984–1986

Reservoir

Area at maximum level 765 km²

Dam

Crest length 4 km
 Maximum height 125 m

Dikes

Number 10
 Total crest length 5 km

Spillway

Number of gates 4
 Discharge capacity 7,335 m³/s

La Grande-4 generating station is the second most powerful in Québec in terms of installed capacity. The powerhouse was built right into the heart of the mountain. The excavation was done in tiers, leaving behind the three huge steps that give the structure its unique appearance.

The dam closes off an encased valley. The intake structure sits in the reservoir itself, 50 m upstream from the dam, and is linked to the dam by a bridge.

The spillway is carved into the side of the mountain. Before discharging into the Grande Rivière, the water slows down in Lac Jean in a breathtaking spray.

Laforge-1

878 MW



Laforge-1

531 km from Baie James

Generating station

Installed capacity 878 MW
 Number of generating units 6
 Unit capacity 146.3 MW
 Type of turbine Francis
 Net rated head 57.3 m
 Commissioning 1993–1994

Reservoir

Area at maximum level 1,288 km²

Dikes and dams

Number of dams 2
 Number of dikes 80
 Total crest length 23.5 km

Spillway

Number of gates 2
 Discharge capacity 2,510 m³/s

Laforge-1 generating station lies on the Laforge diversion, which channels water from the upper watershed of the Caniapiscou into the Grande Rivière watershed. Laforge-1 is the only Phase II project that required the creation of a large reservoir.

In Phase I, the Rivière Laforge, a tributary of the Grande Rivière, was diverted. Phase II saw the construction of a 985-m-long dam on the Laforge River and a 1,178-m-long dam on the Rivière Vincelotte. A network of 80 dikes was also built to contain the shallow reservoir.

The spillway is located 4 km from the powerhouse.



In times immemorial

The area reveals the traces of nomadic hunters. On an island in Lac Vincelotte, archaeologists have discovered work areas and a cache of finely worked tools (knives, cutters, scrapers and drills), dating back to 950 BCE.



Highly diversified wildlife habitats

A network of dikes—the Vincelotte retaining structure—was built to keep the Rivière Vincelotte apart from the flooded areas and protect its land animals and waterfowl.

Laforge-2

319 MW



Brisay

469 MW



Laforge-2

713 km from Baie James

Generating station

Installed capacity	319 MW
Number of generating units	2
Unit capacity	159.5 MW
Type of turbine	Kaplan
Net rated head	27.4 m
Commissioning	1996

Reservoir

Area at maximum level	260 km ²
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Dikes

Number	3
Total crest length	2 km

Spillway

Number of gates	2
Discharge capacity	2,350 m ³ /s

Brisay

767 km from Baie James

Generating station

Installed capacity	469 MW
Number of generating units	2

Unit capacity	234.5 MW
Type of turbine	Kaplan
Net rated head	37.5 m
Commissioning	1993

Reservoir

Area at maximum level	4,275 km ²
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Laforge-2 generating station, which forms a dam across the river, is the first to receive the water turbined at Brisay. It is the smallest generating station in the complex as regards installed capacity.

The run-of-river powerhouse and its built-in spillway are located at the outlet of the Fontanges basin (renamed Laforge 2 reservoir), created 50 km from Caniapiscou reservoir during Phase I. It takes its water directly from the reservoir through a gap in a dike immediately upstream.

The other major structures include a spillway and two dikes (one for flood protection and the other to close off the reservoir) that together are more than 1,000 m long.

Brisay generating station is located at the head of the La Grande complex. Built at the outlet of Caniapiscou reservoir, it also serves as a control structure to regulate the flow into the Grande Rivière.

Its two Kaplan turbines are among the largest in the world, with a runner diameter of 8.6 m and a weight of 275 t each. The rotors weigh in at 710 t each. The penstock, which directs the water to the turbines, is 12 m in diameter.

Dams, dikes, and a spillway were built in Phase I to contain Caniapiscou reservoir, the largest body of fresh water in Québec. Intake from the reservoir is adjusted according to the requirements of the various generating stations and the load on the power system.



Beauty survives

During simulated spillway operation, it was noted that the discharged water would erode, and potentially inundate, an island in its path. A dike along the edge of the island was therefore redesigned to encircle the area vulnerable to erosion.



Power from the North

A 166-km line transmits the electricity generated at Brisay, Laforge-2 and Laforge-1 to Tilly substation, near La Grande-4. This substation steps up the voltage from 315 kV to 735 kV and takes over transmission of power to major load centres.

Eastmain-1

480 MW



Eastmain-1

Generating station

Installed capacity 480 MW
 Number of generating units 3
 Unit capacity 160 MW
 Type of turbine Francis
 Net rated head 66 m
 Commissioning 2006

Spillway

Discharge capacity approx. 5,500 m³/s

Reservoir

Area at maximum level 603 km²

Dam

Number 1
 Crest length 870 m

Dikes

Number 32

The **Eastmain-1 development** is made up of various structures including a generating station, a dam, some 30 dikes to close off the reservoir and a spillway.

To transmit the electricity, a 70-km, 315-kV line connects Eastmain-1 to Nemiscau substation. A permanent 85-km road links the future dam to the substation.

Eastmain-1-A

768 MW



Eastmain-1-A

Generating station

Installed capacity 768 MW
 Number of generating units 3
 Unit capacity 256 MW

Type of turbine Francis
 Net rated head 63 m
 Commissioning 2011–2012

Spillway

Discharge capacity approx. 3,630 m³/s

Sarcelle

150 MW



Sarcelle

Generating station

Installed capacity 150 MW
 Number of generating units 3
 Unit capacity 50 MW
 Type of turbine bulb

Net rated head 10.8 m
 Commissioning 2012–2013

Control structure

Discharge capacity approx. 1,305 m³/s

Reservoir

Area at maximum level 1,040 km²



Concrete actions

Cree workers participate in the lake sturgeon spawning follow-up on the Rupert.

Picture these numbers...

During tours of the facility, our host guides use a variety of colorful comparisons to illustrate the sheer magnitude of the **Robert-Bourassa hydroelectric generating facilities**. Here are some of them:

- A generating unit has a rated flow of 270 m³/s, or the equivalent of 15,000 18-L bottles.
- Each turbine can develop 454,000 hp—the equivalent of 2,500 car engines or 70,000 lawn mower engines.
- At 483 m long, the machine hall is almost as big as five football fields.
- The height of the dam (162 m) corresponds to a 53-storey building; in comparison, Montréal's Place Ville-Marie is only 43 storeys tall.
- The dam was built with 23 million m³ of fill, or enough to cover the four lanes of Highway 20 between Montréal and Québec City in 7 m of rubble.
- It would take about two million 10-wheel trucks, each with a capacity of 11 m³, to carry the fill used to build the dam (23,000,000 m³). If these trucks were driving down the highway, the convoy would stretch one and a half times around the globe.
- With a surface area of 2,835 m², the reservoir is almost three times larger than Lac Saint-Jean.
- The capacity of the reservoir is 61.7 billion m³. If the water were put into one-litre bottles, there would be 10,000 bottles for each of the approximately six billion people on the planet.
- The rated output of the Robert-Bourassa generating facilities is 37 billion kilowatthours per year. This same quantity of energy could power a 100-W light bulb for 42 million years!



How to get to Baie-James:

By car

- Route de la Baie-James (620 km paved), starting from Matagami. 1,400 km from Montréal.
- Route du Nord (430 km gravel), starting from Chibougamau. 1,350 km from Québec City.

By air

Several airlines serve the area with flights from Montréal and Val-d'Or.

Tours

Please reserve 48 hours in advance.
1 800 291-8486

Robert-Bourassa hydroelectric generating facilities

Open year round.

La Grande-1 generating station

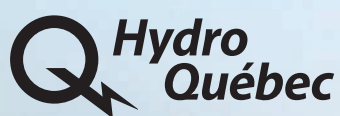
Open from mid-June until Labor Day.

Units of measure

°C	degree Celsius
GWh	gigawatt hour or one billion watthours
hp	horsepower
km	kilometre
km ²	square kilometre
kV	kilovolt or one thousand volts
L	litre
m	metre
m ³	cubic metre
m ³ /s	cubic metre per second
MW	megawatt or one million watts
t	tonne
W	watt
Wh	watthour

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