

Valorization of Shallow to Deep Inactive Gas Well Infrastructures in Low Enthalpy Sedimentary Basins, Quebec, Canada*

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Search and Discovery Article #80690 (2019)**

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Abstract

Quebec's sedimentary basins have been the focus of some oil and gas exploration efforts over the past 150 years. The public data directories contain just over 900 oil-related works (SIGPEG, 2019). In parallel, two regional studies of the geothermal potential of certain sectors of these basins have been carried out (SNC-SOQUIP, 1979; INRS, 2016). Aside from electricity generation, geothermal energy offers considerable economic potential in the cold and temperate regions of the northern hemisphere. With average temperatures ranging from -35°C to 25°C on annual basis, Québec needs a variety of energy- efficient and environmentally friendly sources to reduce the pressure on its electrical network during periods of high heating (wintertime) and air conditioning (summertime) demand. Geothermal can be used to meet these needs for institutional, commercial and industrial users. The use of certain methods of exploration of the oil and gas industry will make it possible to obtain more success in the search for geothermal deposits. Past exploration and geoscience information in public databases (SIGPEG, SIH or SIGEOM) can be used to identify reservoir areas, the nature of the fluids in place, and the presence of thermal anomalies. Adding this information to recent geothermal data (Bédard et al., 2018, Raymond, 2018) promoted by new research facilities (Pasquier, 2017, Raymond et al., 2017) will help identify the best development sectors in relation to inactive wells infrastructures and potential customers. The economic development of geothermal energy affects the sensitive areas of energy and natural resources; however, the concept receives a positive reception and its social acceptance is favorable to Quebec (Moutenet et al, 2014, Malo et al., 2016). Although the conversion of conventional geothermal energy into electricity does not appear to be viable in the short term in low enthalpy sedimentary basins in Quebec, there are several very interesting development options for developing deep stored energy. The use of available knowledge, expertise and infrastructure in the oil and gas sector is an asset in bringing projects to sustainable levels of profitability. An effective geothermal exploration methodology based on this approach will be presented in this paper. In this context, a pre-feasibility study was also conducted to identify the potential of a converted inactive hydrocarbon well to provide heating energy to a nearby greenhouse. In addition, the proposed document will present the technical choices and financial results achieved so far.

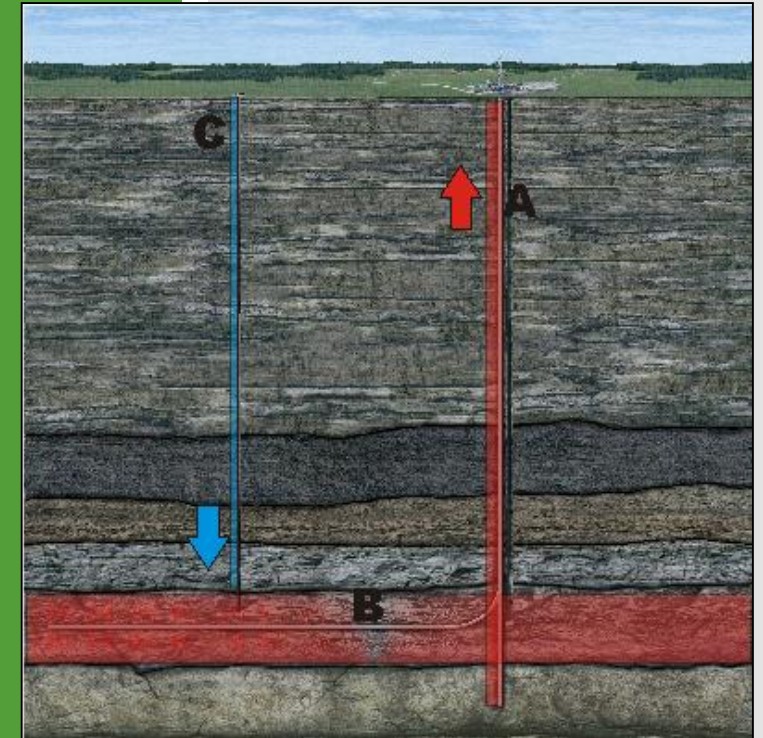
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Jean-Sébastien Marcil
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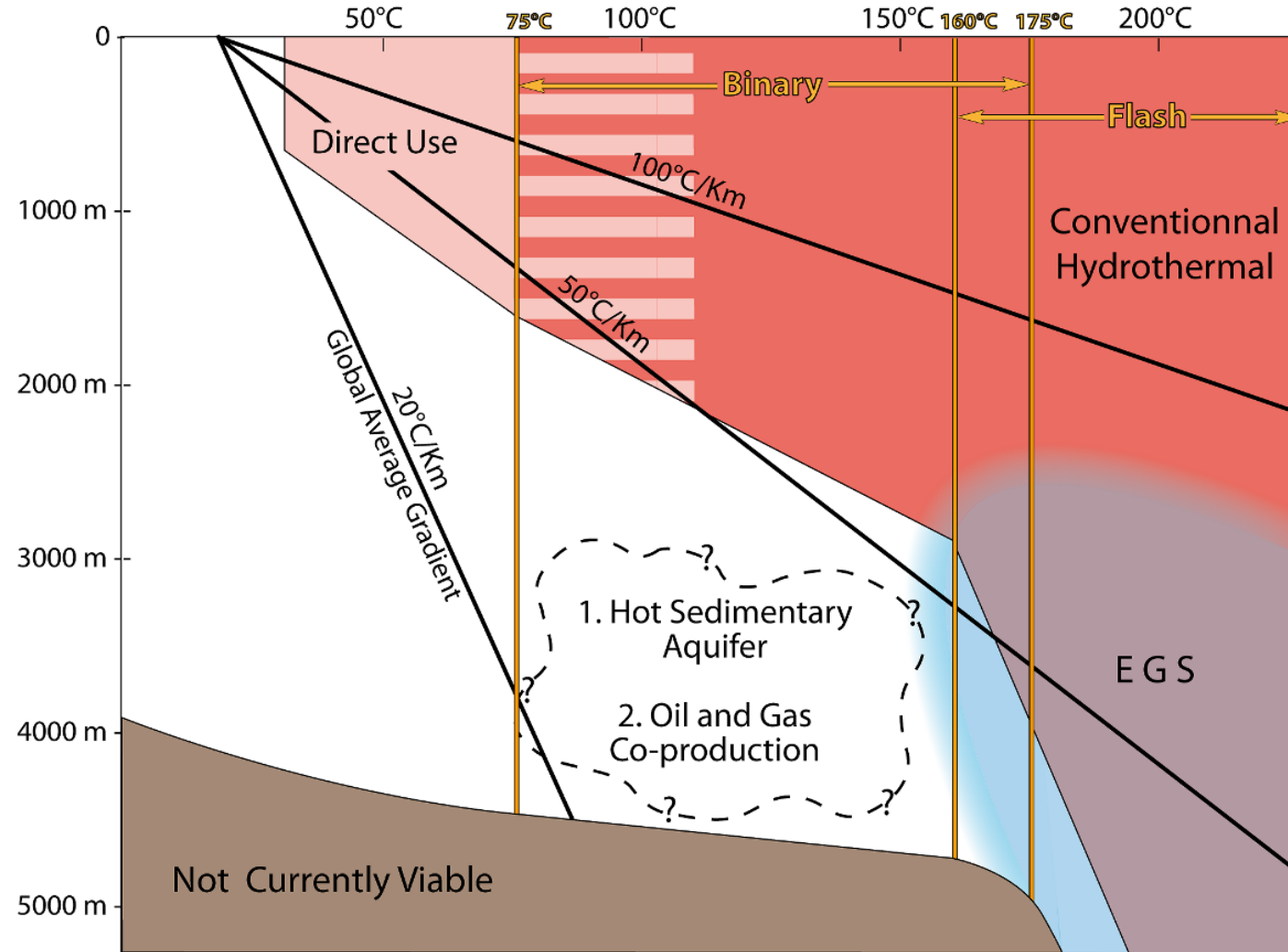
AAPG 3rd Hydrocarbon – Geothermal Cross Over Technology Workshop, *An AAPG Europe - IGA Event*

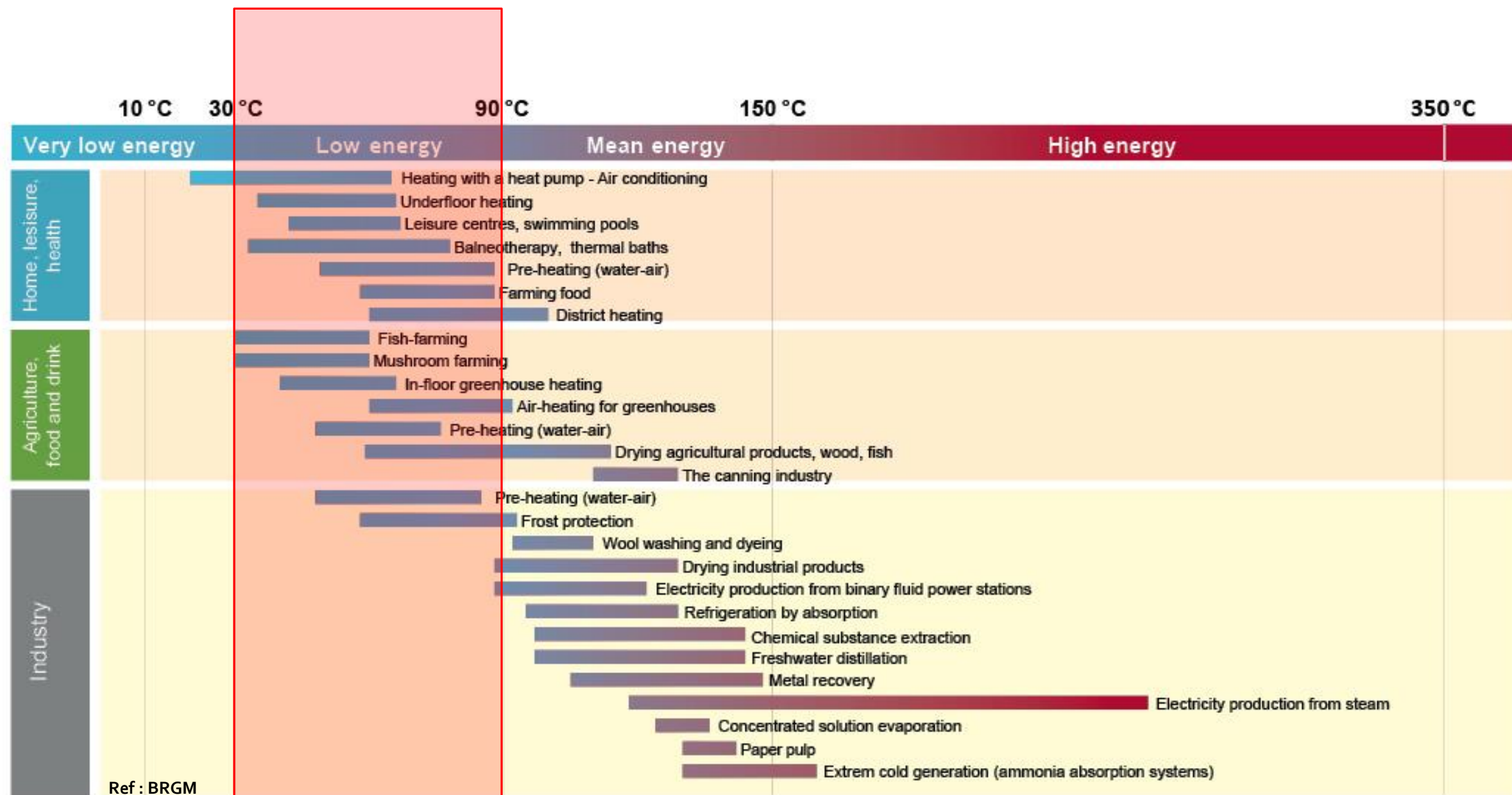


Low Enthalpy Medium Depth Geothermal Energy

Extraction of energy from rock layers located between 500 and 1500 meters deep. Can be used for heat production as well as air conditioning. Medium-depth geothermal energy can be from "low" to "medium" temperature in Quebec. In any case, the geothermal resource remains a form of renewable energy, depending on how it is exploited.

Schematic Depth-Temperature Plot for Geothermal Resources

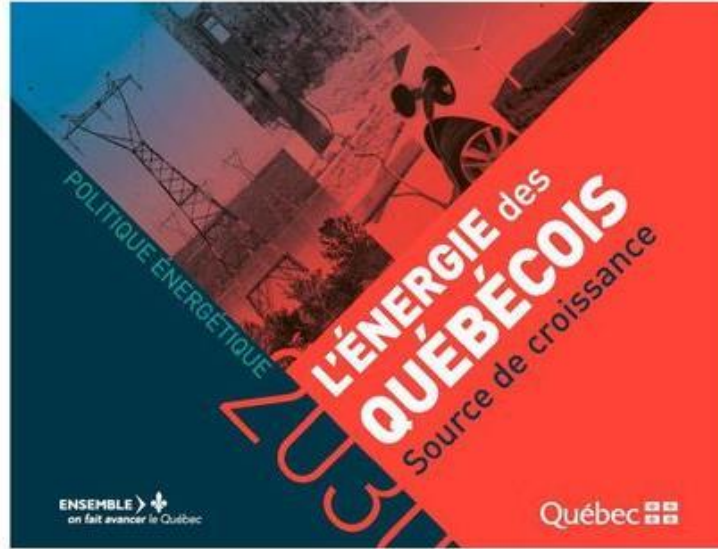




Current Energy Situation in Quebec

Medium-depth geothermal energy can play a role in improving energy efficiency, increasing renewable energy production and reducing GHG emissions.

Projects to extract geothermal energy can be greatly enhanced by the use of techniques borrowed from the oil industry such as horizontal drilling and hydraulic fracturing, as well as the use of a more systematic exploration strategy.



- Improve by 15% the energy efficiency;
- Reduce by 40% the consumption of petroleum products);
- Eliminate the use of thermal coal;
- Increase by 25% renewable energy production.

Currently, Québec, like many regions of the world, is seeking to develop renewable and sustainable energy sectors. One of these sectors is geothermal energy, especially deep geothermal energy. Geothermal energy is the energy recovered from the heat of the deep layers of the earth, which is then used to produce electricity. Through an EGS-stimulated deep geothermal power plant, the heat energy of the rock formations is transformed into mechanical energy, which in turn will be transformed into electrical energy. According to Hydro-Québec, in southeastern Quebec, geothermal power plants could be supplied by reservoirs located more than 6 or 7 km underground on an area covering 10 to 15% of the territory. The temperatures of the tanks would be around 150 °C, and the installed capacity could be 2 to 5 MW per production site.

Geothermal and Hydrocarbon Energy

Geothermal for Valorization of Hydrocarbon Wells

The extraction of geothermal energy to valorized low productive oil or gas wells, or depleted fields is not a new idea but, with the advent of new technologies (low cost horizontal drilling and completion techniques, higher efficiency heat pumps), there is now a renewed interest in this possibility of energy production.

August 2018 – Production Engineering

Review and investigations on geothermal energy extraction from abandoned petroleum wells

D. Sui¹ · E. Wiktorski¹ · M. Røksland¹ · T. A. Basmoen¹

February 2018 - Renewable and Sustainable Energy Reviews

Insights into geothermal utilization of abandoned oil and gas wells

Yong-Le Nian, Wen-Long Cheng*

Open Journal of Yangtze Gas and Oil, 2017, 2, 191-200

Future Electricity Production from Geothermal Resources Using Oil and Gas Wells

Asif Mehmood*, Jun Yao, Dong Yan Fun

Exemple

North Dakota's first successful commercial enterprise to co-produce electricity using geothermal water from hydrocarbon production in the Williston Basin. Source: Kirby Baier of Continental Resources

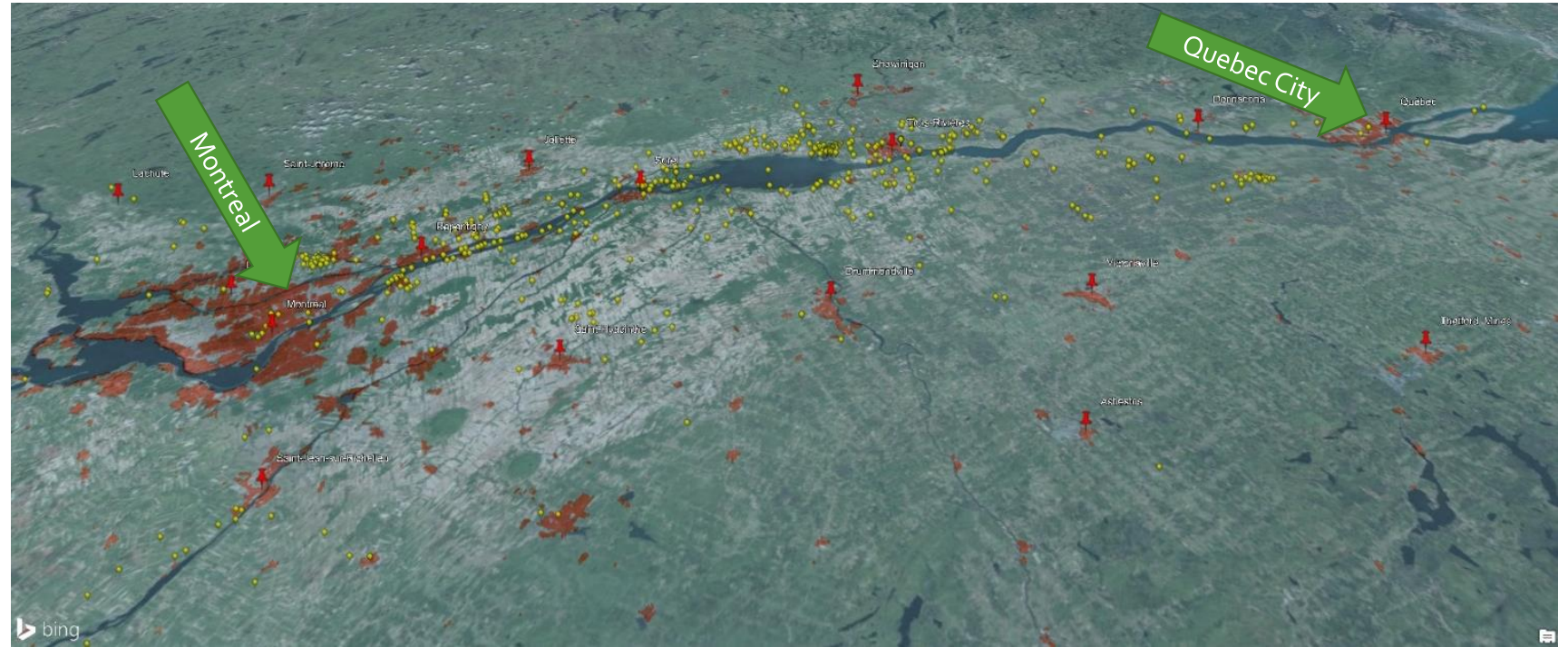


Geothermal development proposal in a low enthalpy basin

Inactive Hydrocarbon Wells Valorization

Quebec's Saint Lawrence Lowlands Ordovician sedimentary basin have been the focus of some oil and gas exploration efforts over the past century. According to the public data directories over 680 oil-related works have been realized in this basin (SIGPEG, 2019). From this number, 90% can be considered "inactive wells".

Location of the Oil and Gas Wells drilled in the St. Lawrence Lowlands Basin



- **More Science** : Improve the assessment of the geothermal potential with deep equilibrium temperature measurements - Collaboration (Gas Cies, INRS and GSC);
- **Pilot Project** : Evaluate the feasibility of using certain wells located in urban or industrial areas for the installation of permanent column geothermal (PCP) wells.

Geothermal development proposal in a low enthalpy basin

Inactive Hydrocarbon Wells Valorization

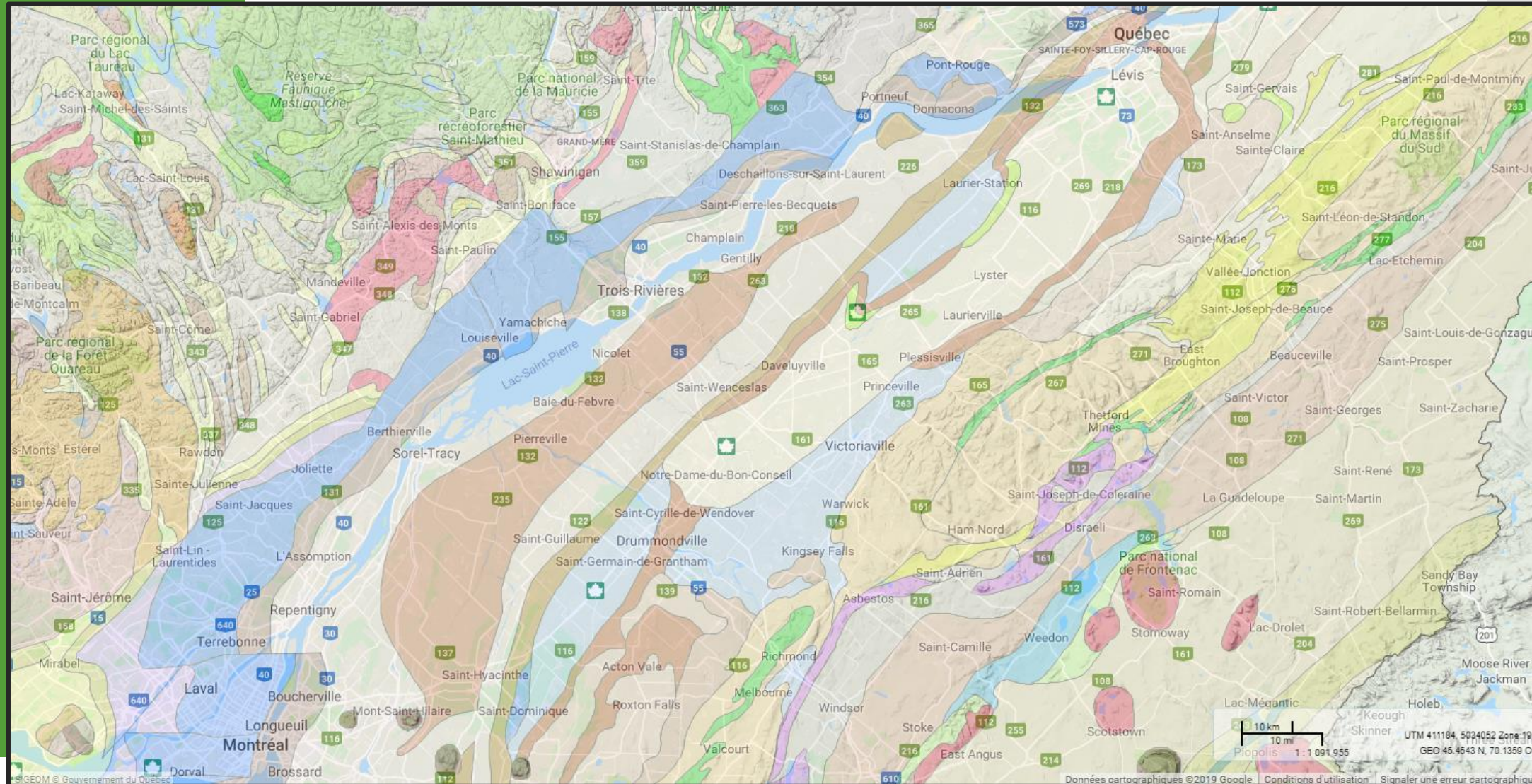
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Medium Depth Geothermal Energy

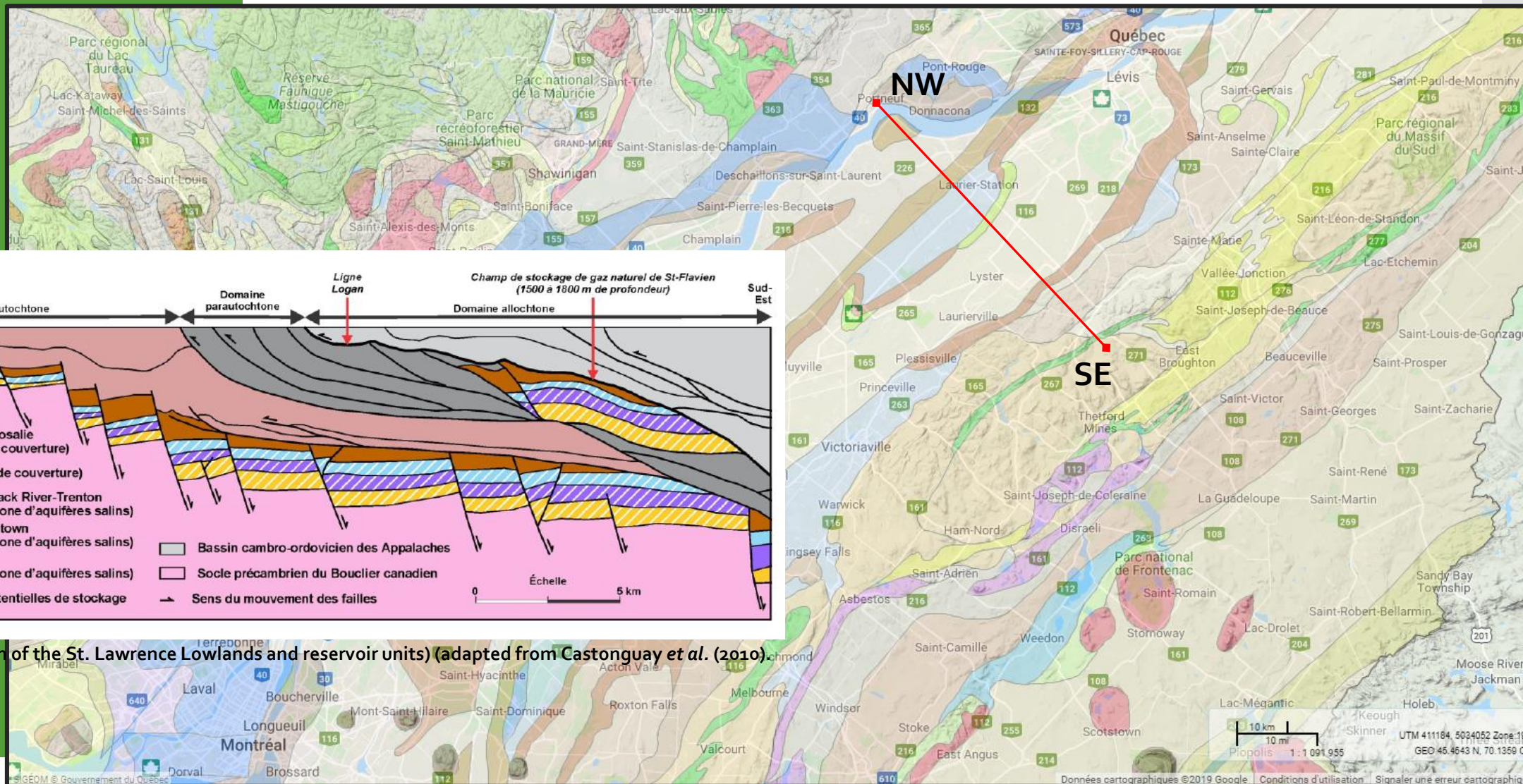
- Valuing inactive oil and gas wells as infrastructure that can be used for geothermal energy production;
- Look for "reservoir" zones;
- Use and enhance public data (SIGPEG, SIGEOM and SIH);
- Characterize reservoir fluids at all depths;
- Invest in pilot projects;
- Promote ongoing initiatives;
- The discussion is open and several good ideas are coming.

Map of the St. Lawrence region showing the distribution of 12 fish species. The map includes the St. Lawrence River, Gulf of St. Lawrence, and surrounding areas like Terre-Neuve-et-Labrador, Saint-Pierre-et-Miquelon, and Nouvelle-Écosse. A scale bar indicates 100 km. The map is titled "Répartition des espèces de poissons".

Southern Quebec Geology



Southern Quebec Geology



Geological cross-section of the St. Lawrence Lowlands and reservoir units (adapted from Castonguay *et al.* (2010))

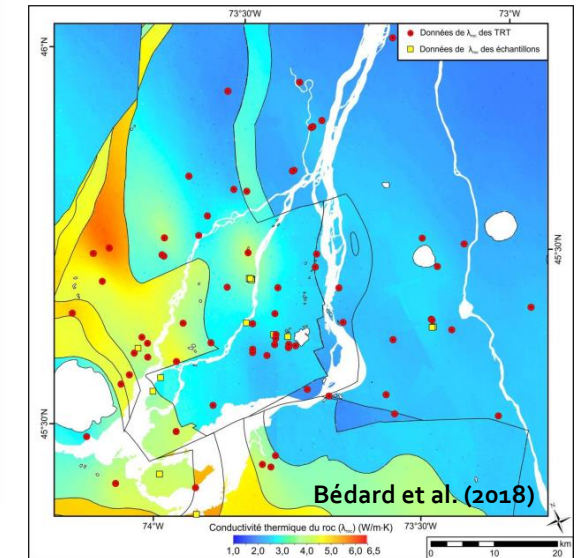
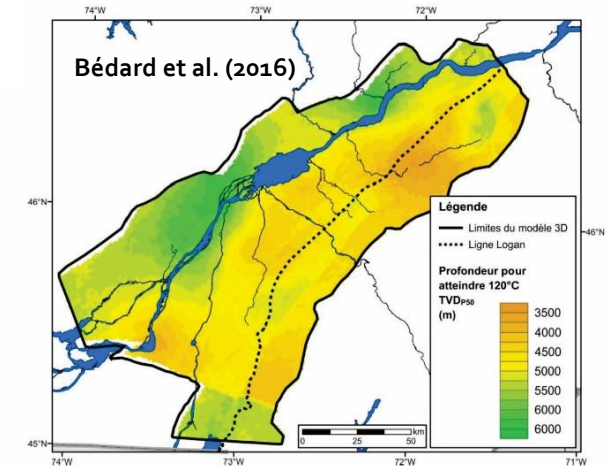
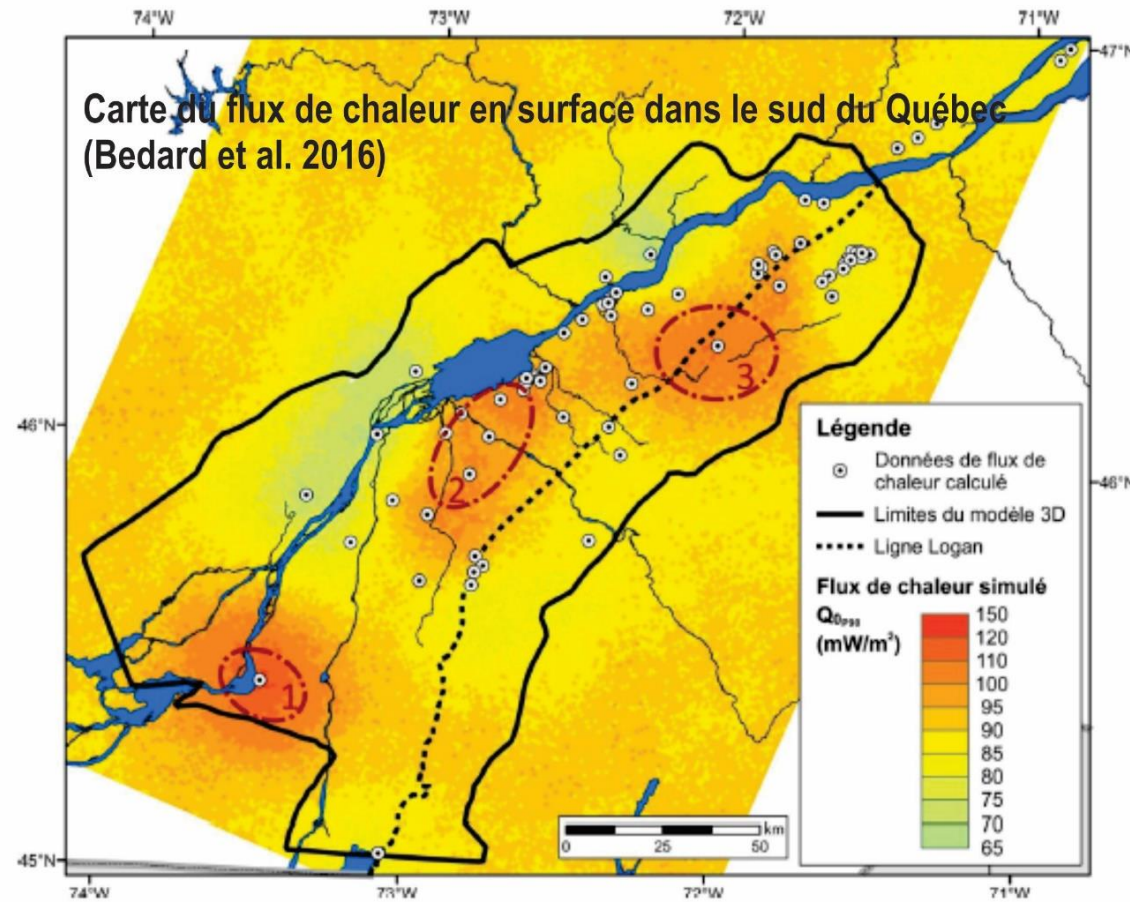
Knowledge Available on Deep Geothermal Energy in Southern Quebec

Current research

Improving the assessment of the geothermal potential of the Lowlands with down-hole temperature measurements (INRS and CGC)

Explore shallow aquifers by coupling them with new available data.

Create maps of geothermal prospectivity



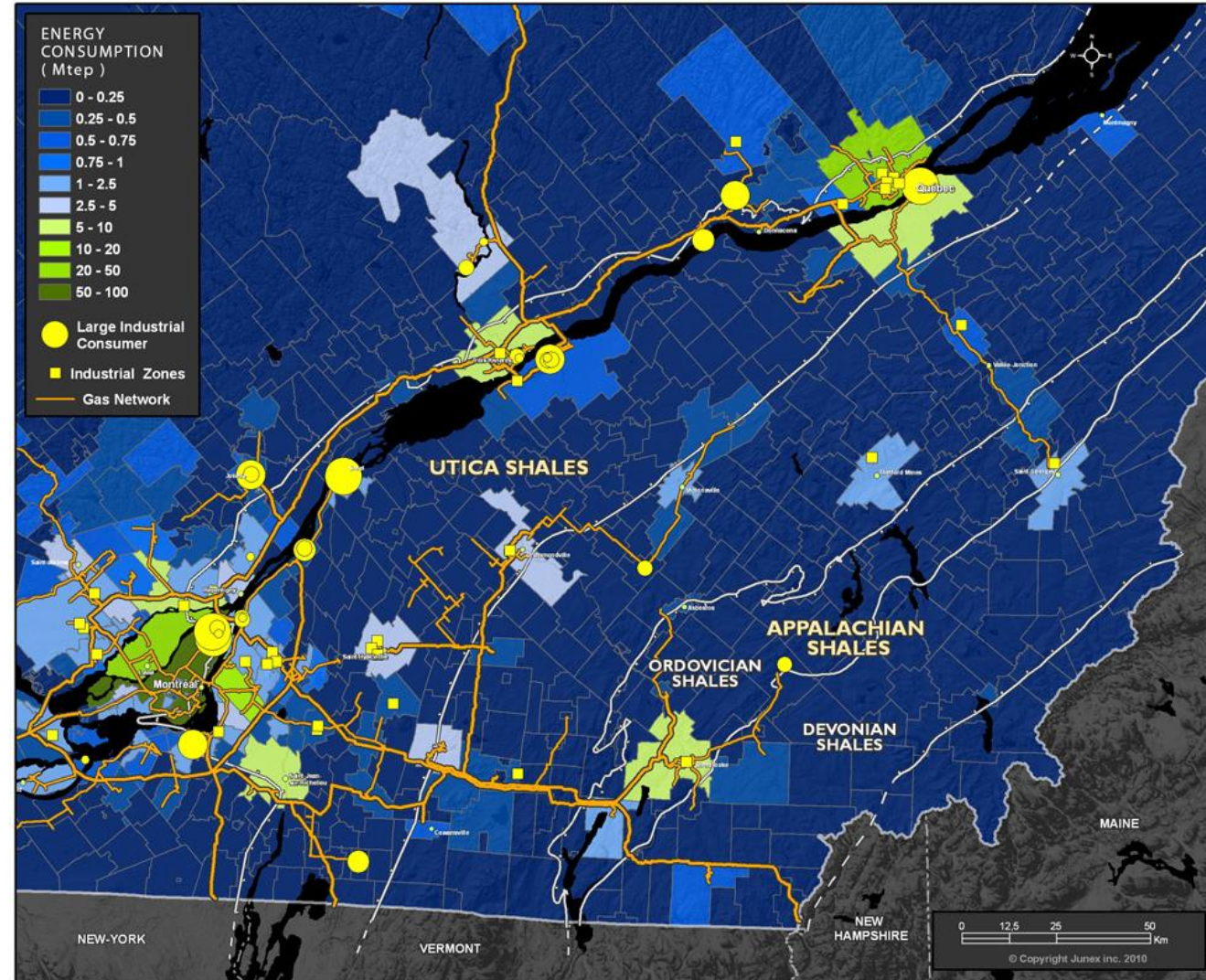
Geothermal Energy Development

Exploring for energy around areas where energy is needed

Land Management Considerations

Population Density & Basin Geology

Agricultural and Soil qualities

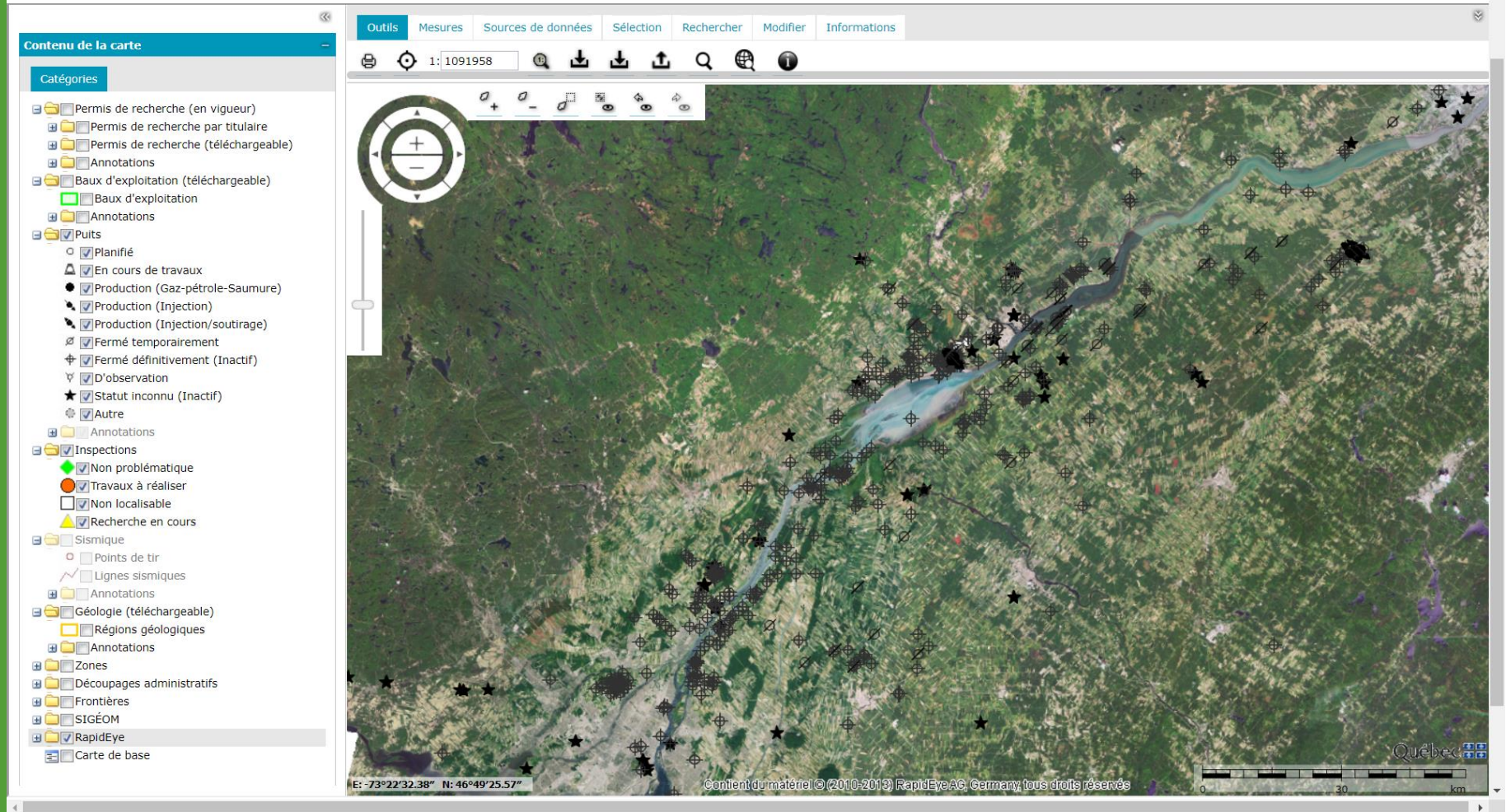


Area with the strongest energy consumption are in green colors

Marcil et al. (2012)

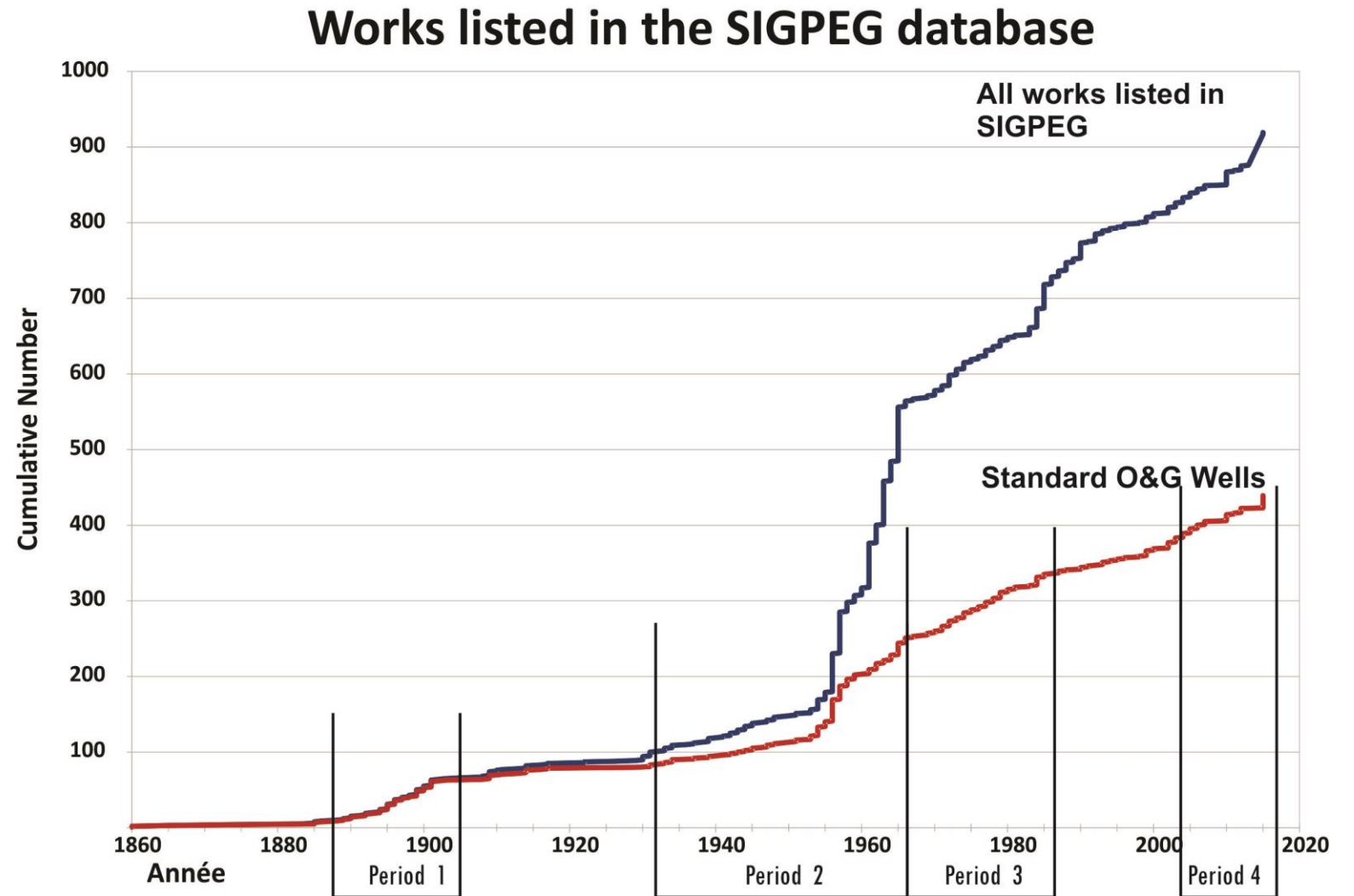
Hydrocarbon Wells Location

SIGPEG database



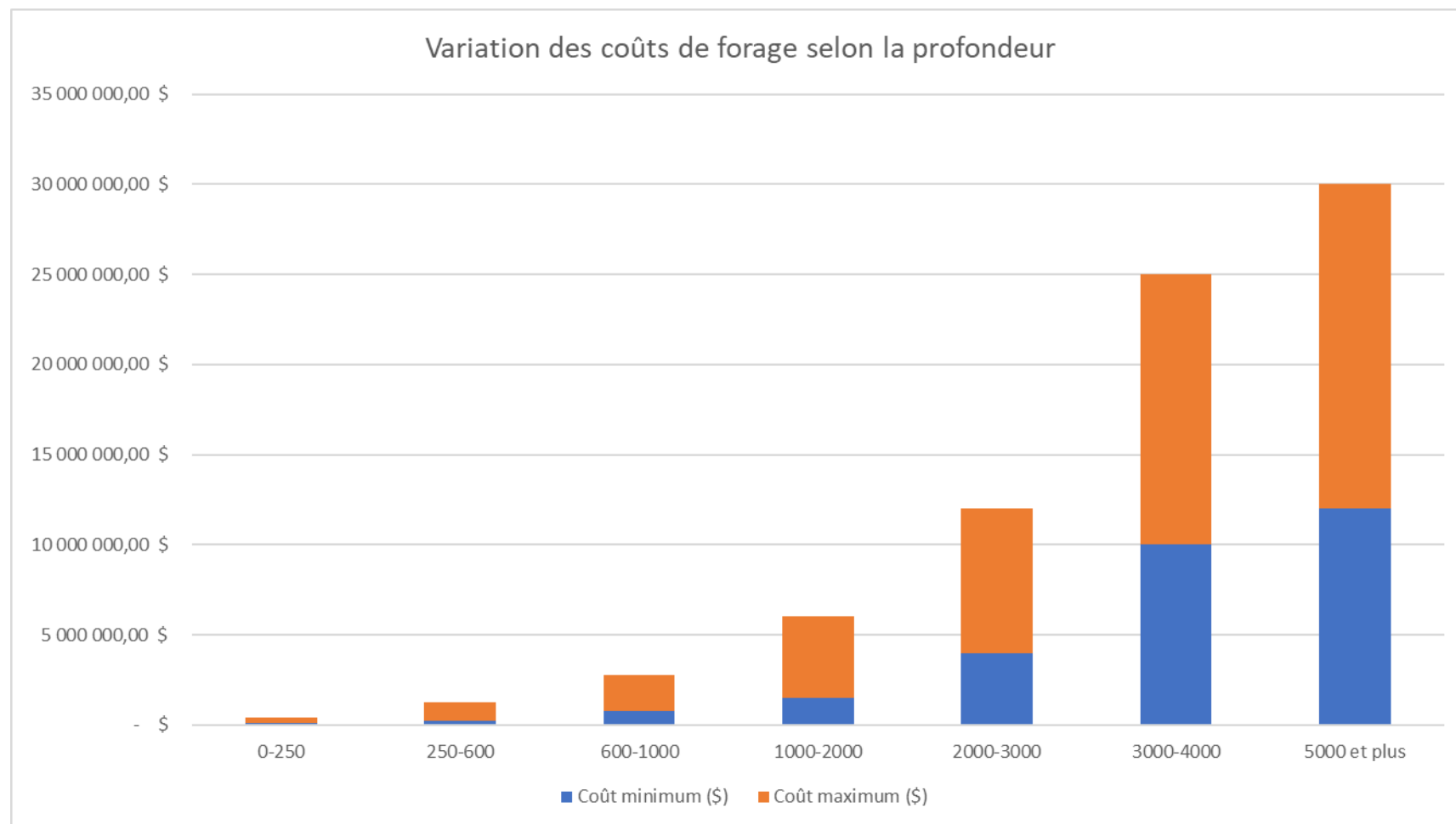
Inactive O&G Wells

Around 900 wells are listed in the SIGPEG database. Half of this number can be considered as standard hydrocarbon wells with associated drilling information. The remaining wells stay interesting for underground information and maybe more as an already drilled borehole for geothermal energy extraction.



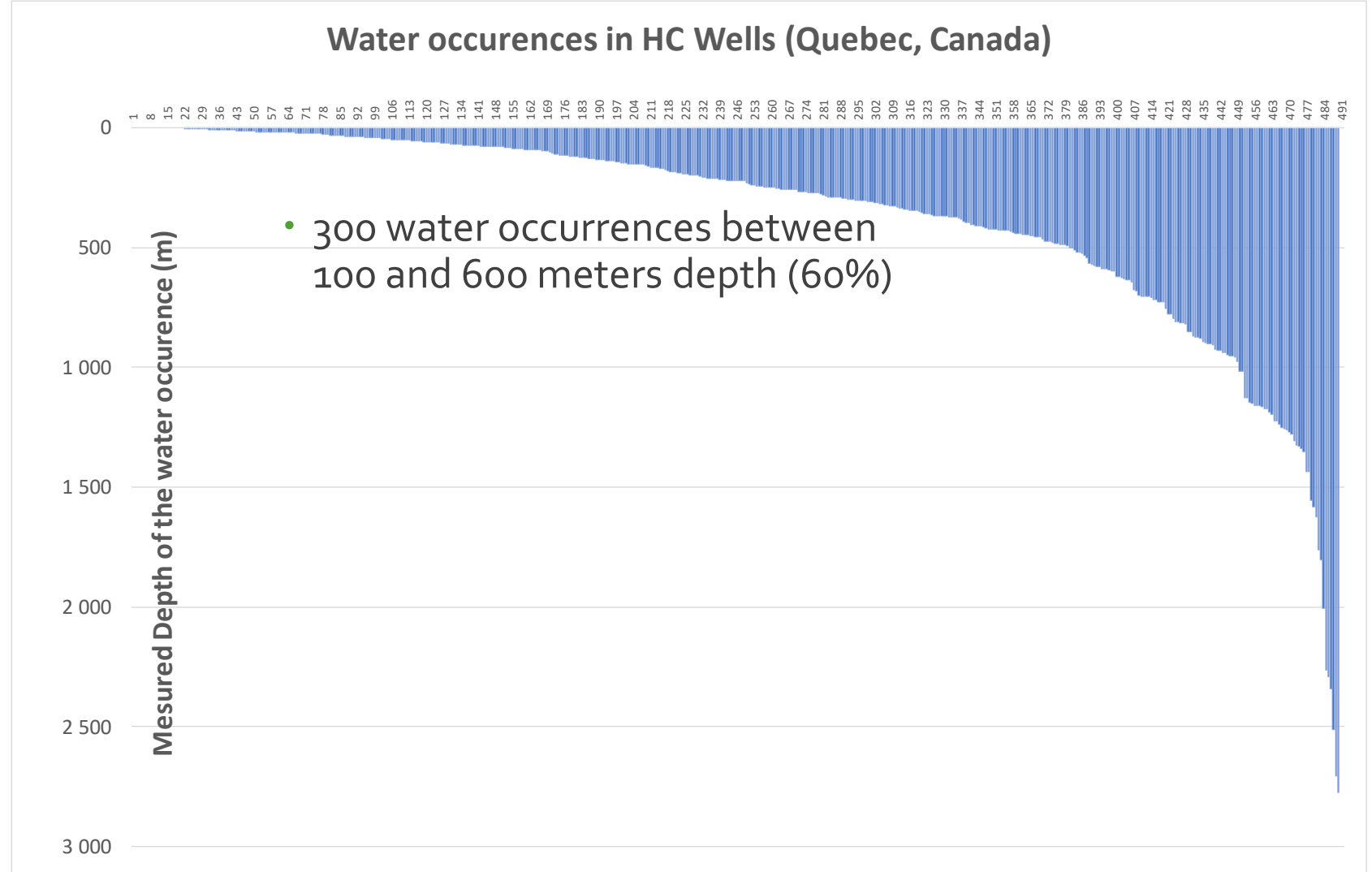
An Outstanding Infrastructure Value to Valorized

Drilling a well from 1000 to 2000 meters can requires an investment as high as \$ 5 million due to high mob/demob costs. It is an investment that is very difficult to make profitable in the Quebec energy context (low cost of electricity and natural gas). The estimated cost to redrill all inactive wells in Quebec exceeds \$ 1.16 billion.



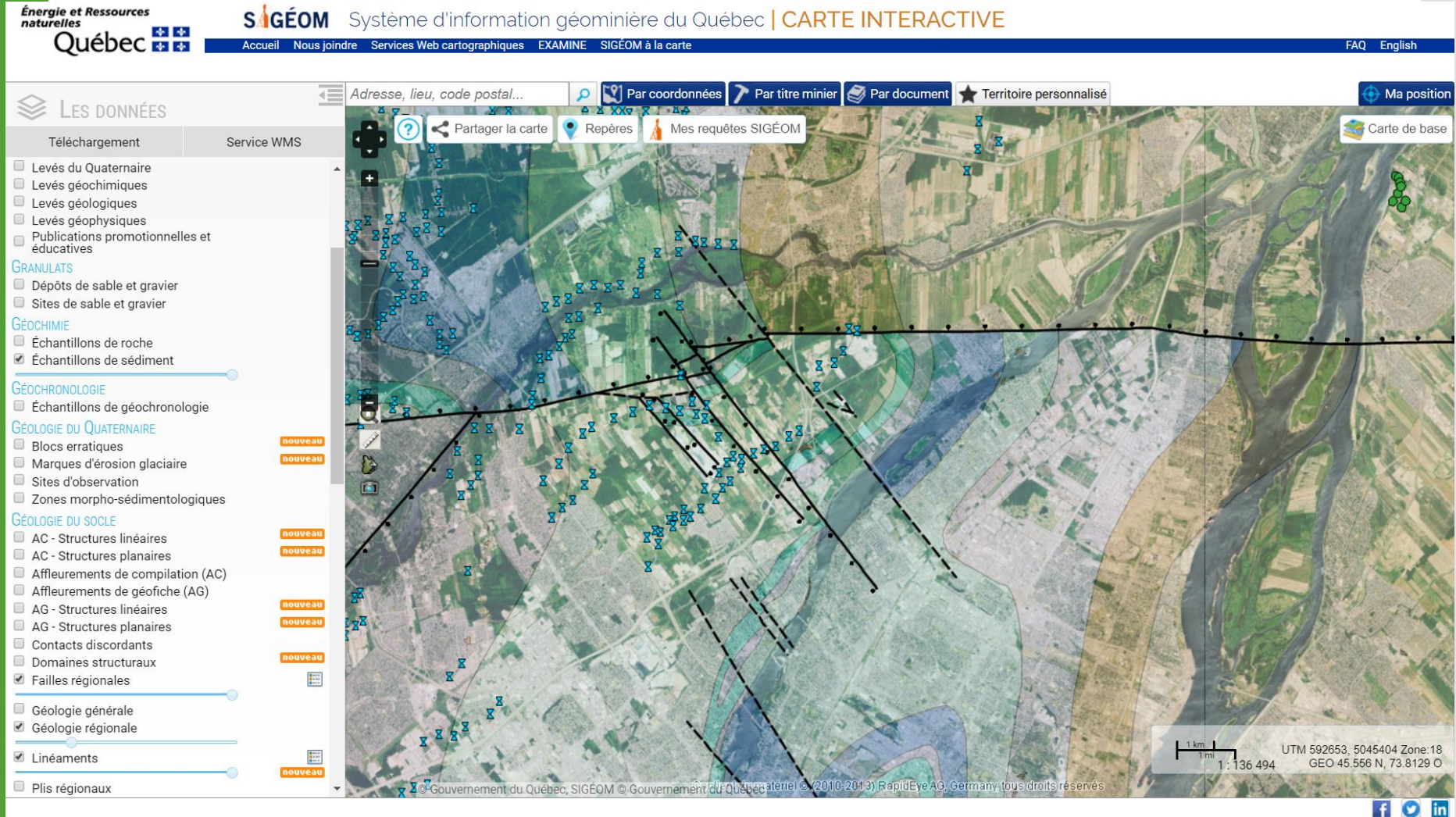
Research for Permeable Zones

Five hundred occurrences of water have been noted in well drilled in Quebec. This water is mainly salty or brine water (non potable water). Majority of the occurrences are shallower than 600 meter from surface.



Geoscience Information

Surface geology and Underground Water Geochemistry in the SIGEOM database;
Water Well Information in the Système d'information hydrogéologique (SIH) database;

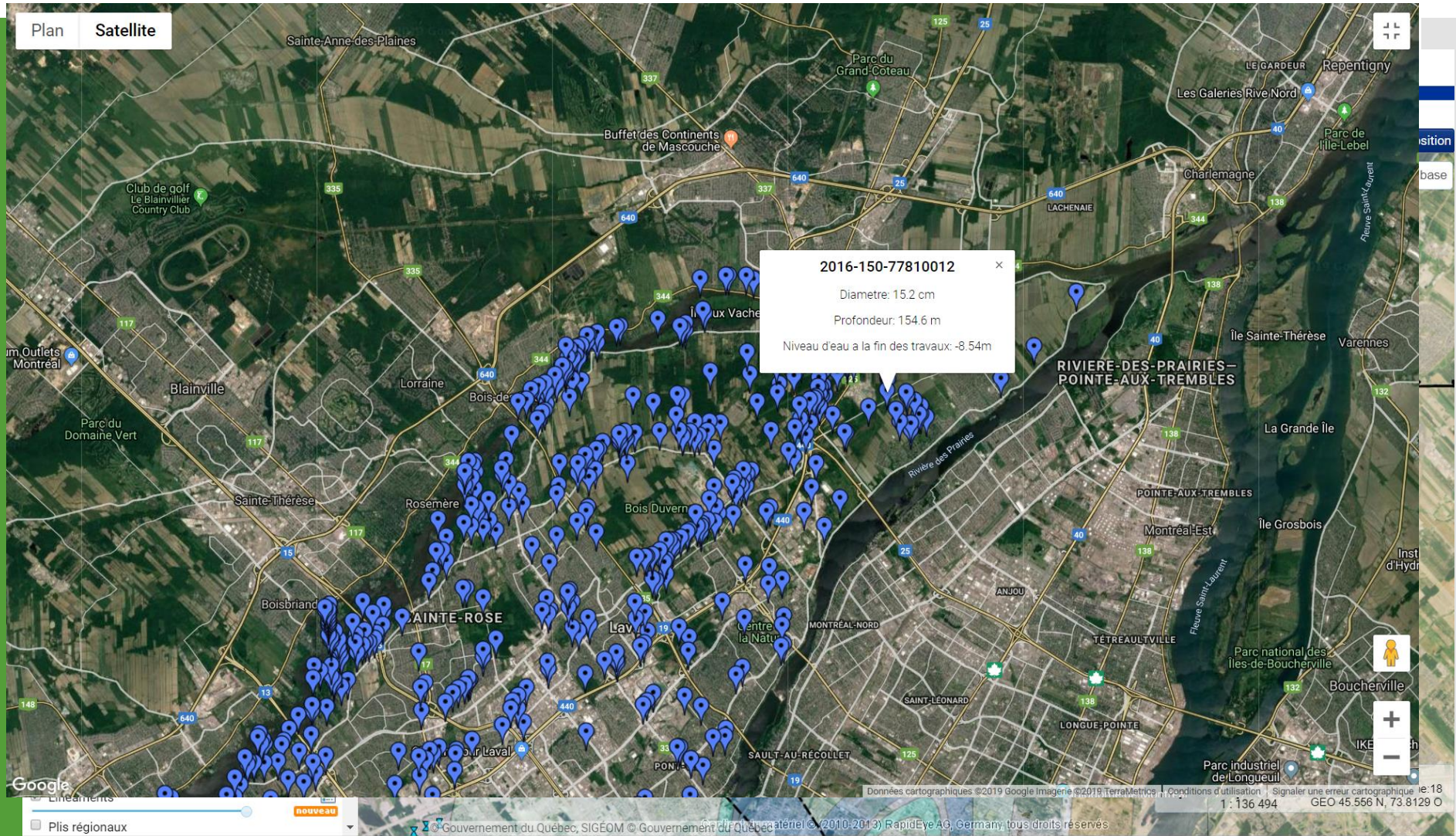


Surface geology and Underground
Water Geochemistry in the SIGEOM
database;
Water Well Information in the
Système d'information
hydrogéologique (SIH) database;

Échantillons de sédiment		1 de 1
Numéro feuillet SNRC	: 31H12	Localisation sur la carte
Numéro document	: DP-98-02 , DV 84-14 , DV 84-15 , tous	
Type échantillon sédiment	: Eau de forage dans le roc	
Numéro projet sédiment	: 1982069	
Numéro échantillon unique	: 1982080622	
Date échantillon	: 1982-07-27	
Estant	: 606579	
Nordant	: 5058023	
Fuseau	: 18	
Précision localisation	: Précision de localisation élevée	
Profondeur	: 27.43	
Commentaire échantillon sédiment	:	
Intensité couleur sédiment	:	
Couleur sédiment	:	
Intensité couleur nodules ou oxydation	:	
Couleur nodules ou oxydation	:	
Contamination	:	
pH	: 8.5	
Poids initial échantillon tamisé	:	
Poids fraction légère	:	
Poids fraction lourde	:	
Poids fraction lourde magnétique	:	
Poids fraction lourde non magnétique	:	
Grosseur maille tamis	:	
Date de diffusion	: 19820727	

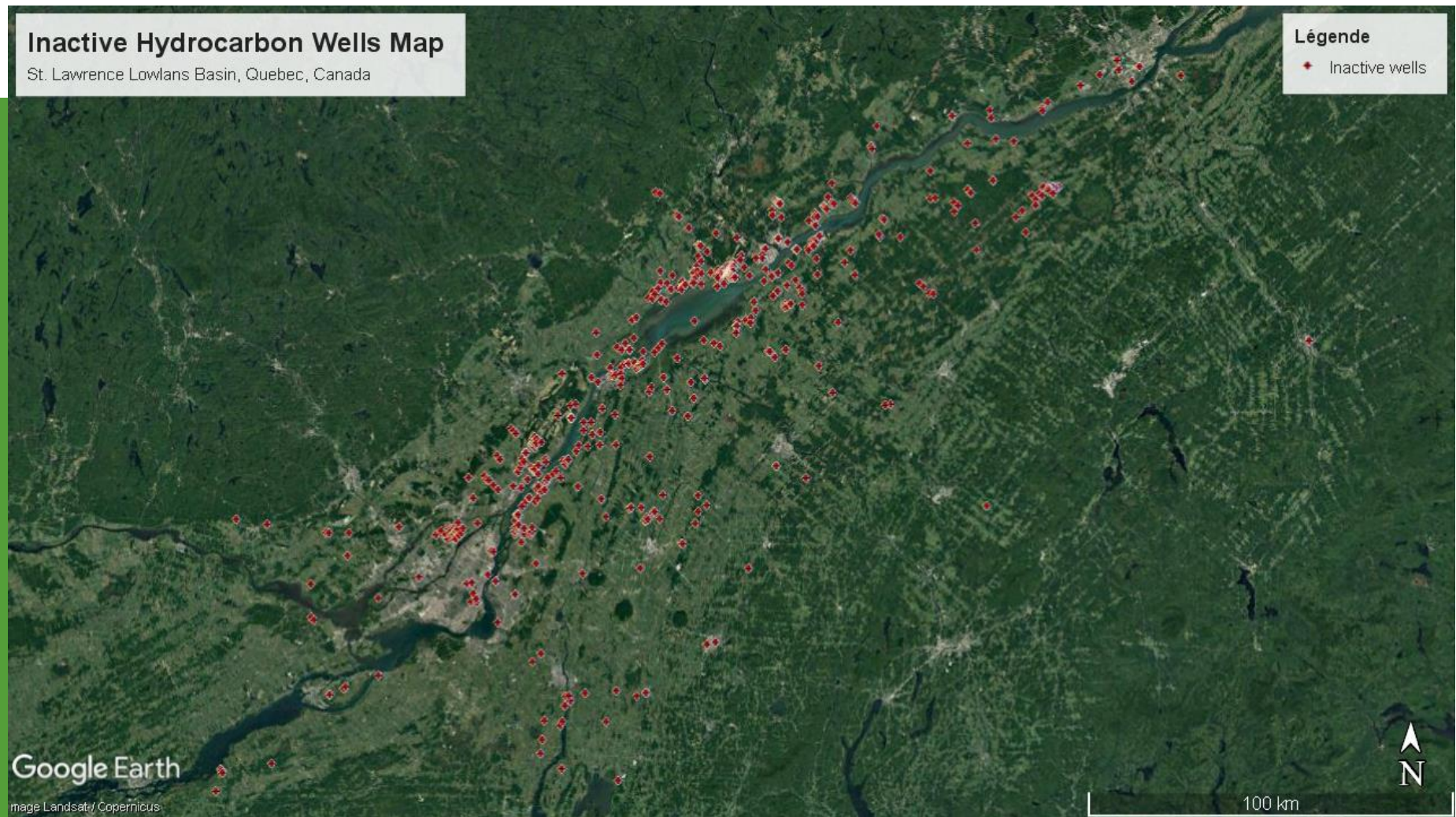
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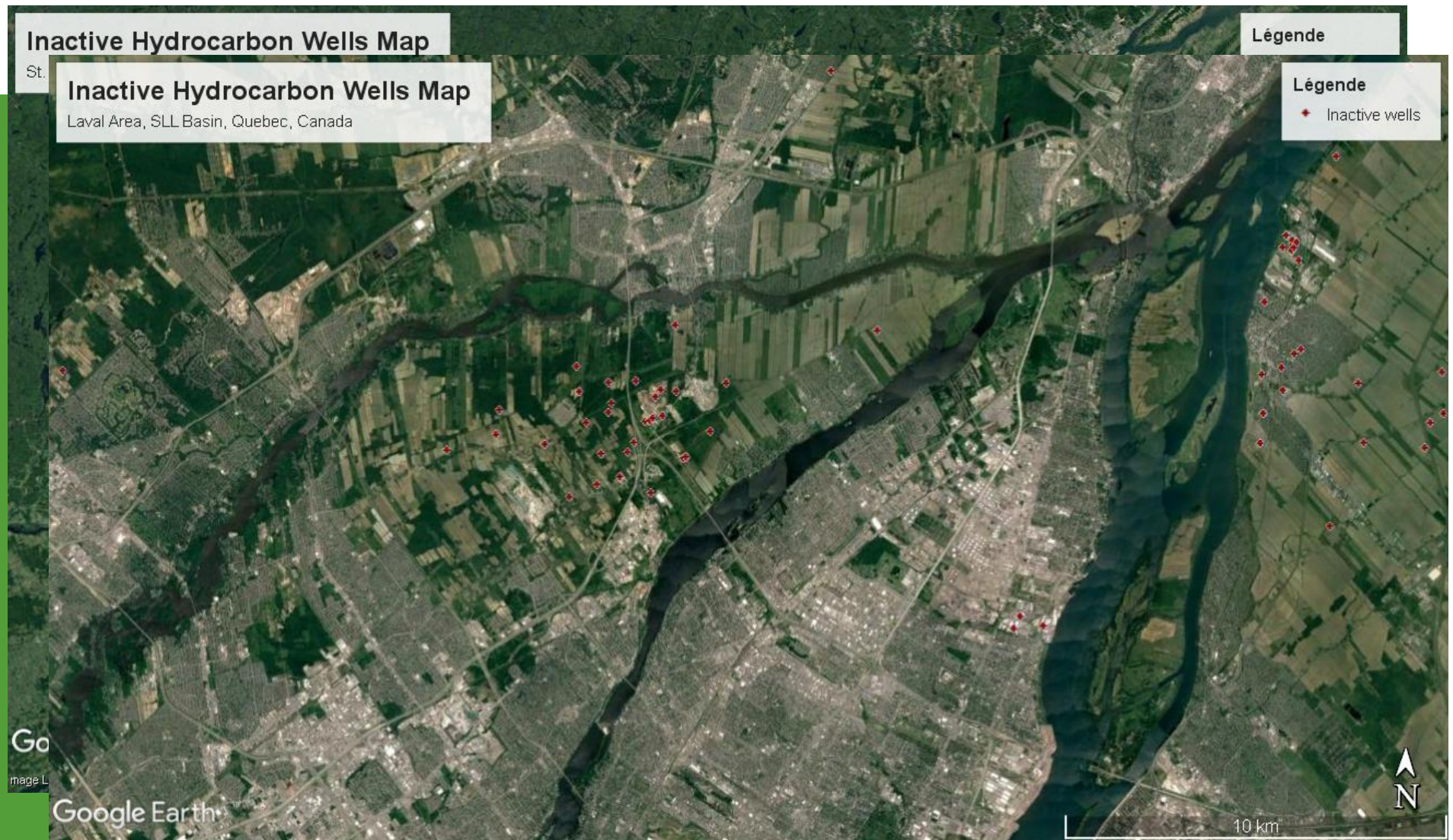
Zone of Interest Example

Looking for Industrial Area with inactive wells drilled in vicinity (distance of 100 m)



Zone of Interest Example

Looking for Industrial Area with inactive wells drilled in vicinity (distance of 100 m)



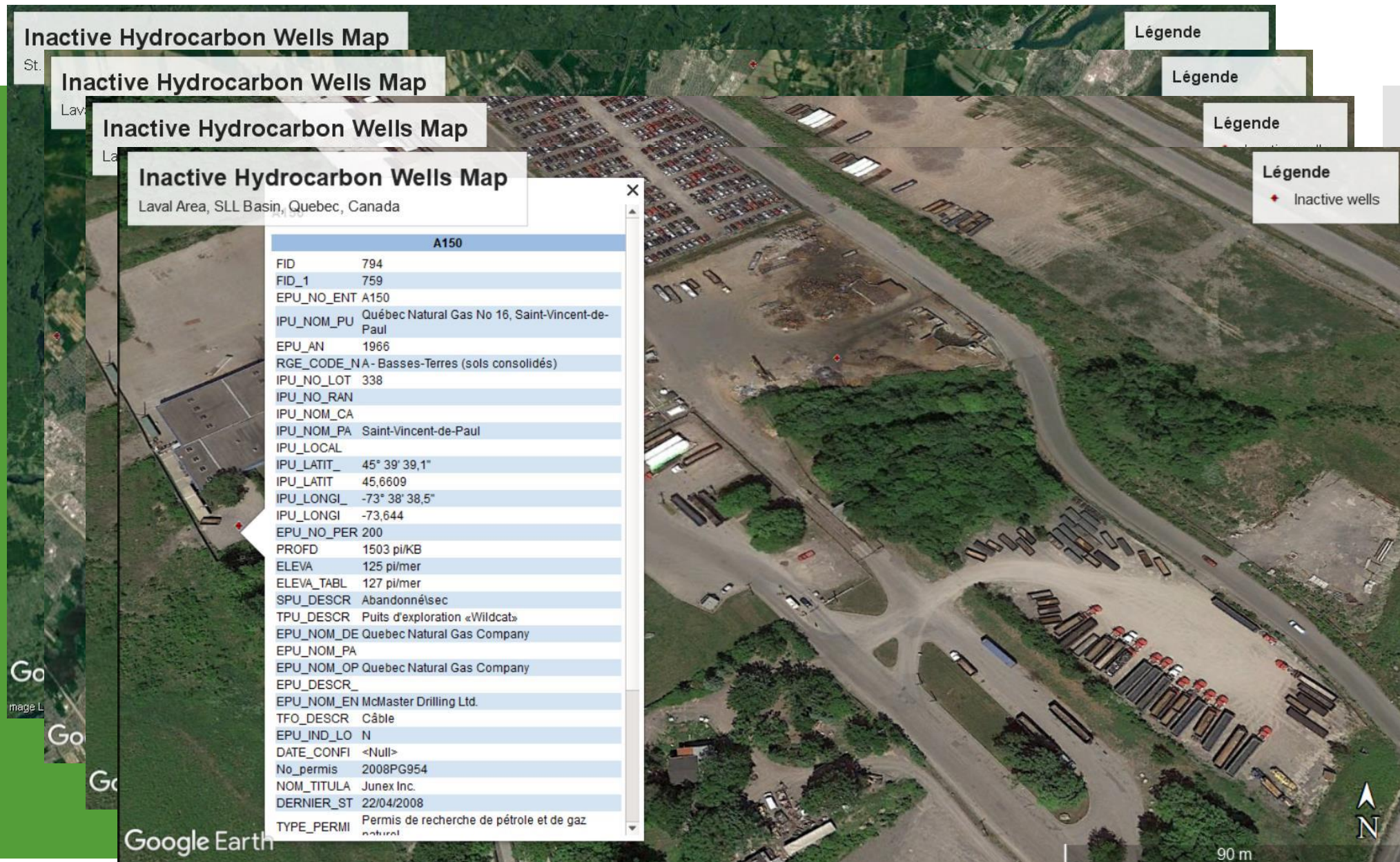
Zone of Interest Example

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Zone of Interest Example

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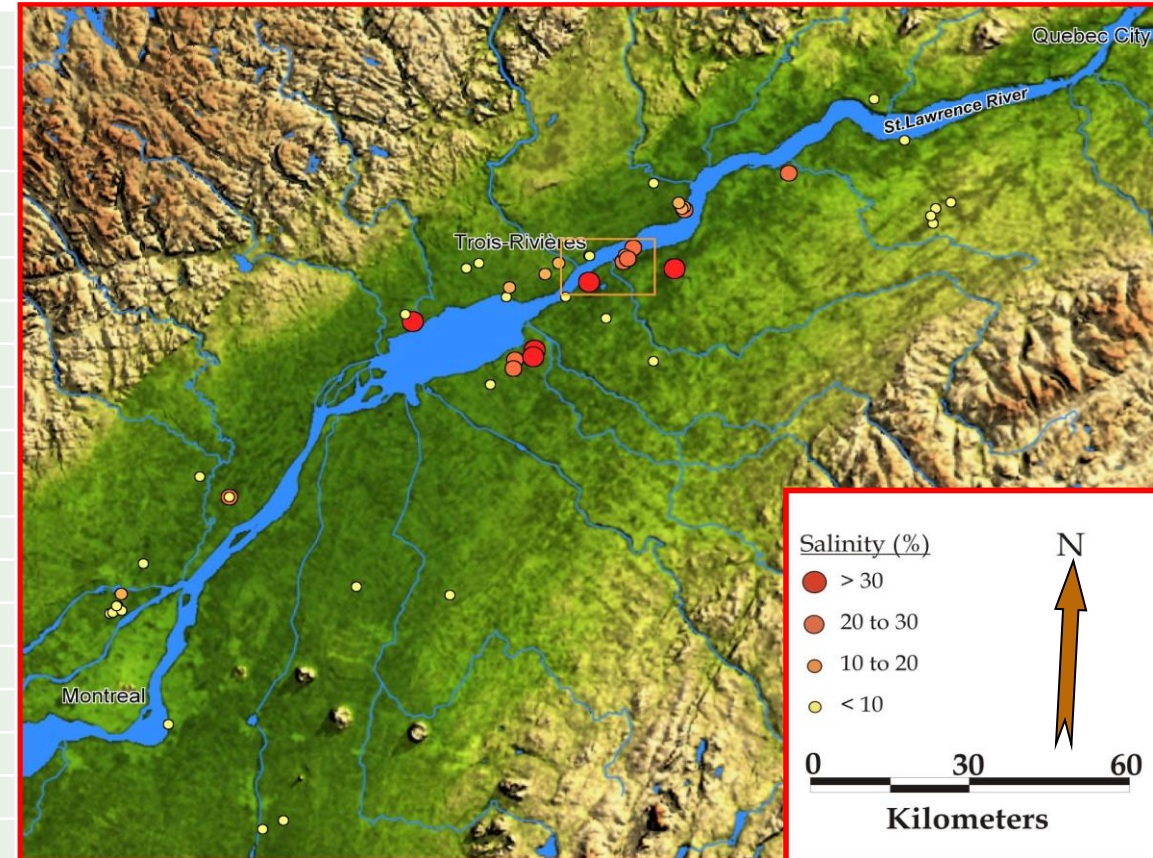
Becancour Brine - Geothermal Case Study

Natural Brine in Quebec

In Quebec, natural hypersaline brine is found only in the Center-du-Québec / Mauricie region, in an area between the Du Chêne and Saint-François rivers. In particular, the hypersaline brine has been identified in Bécancour, Nicolet and Louiseville.

Natural Brine Discovery in Southern Quebec

Wells	Salinity
Bald Mountain, Batiscan no. 5	12%
Bald Mountain, Louiseville no. 2	34%
Caprive, Trois-Rivières no. 3	14%
Laduboro, La Baie-Yamaska no. 5	27%
Imperial Lowlands no. 1	20%
Okalta Oilmont no. 2	11%
Laduboro C.I.G., Nicolet no. 1	30%
Laduboro C.I.G., Yamaska no. 1	28%
Laduboro Bald Mountain-Intercity No 2, Trois-Rivières	16%
Laduboro Verchères Saint-Pierre No 22, Pointe-du-Lac	10%
Louvicourt - Métal l'Assomption No 8	22%
Husky, Gentilly No 1	34%
Canac BP Sisque Brossard No 1	15%
Husky, Bruyères No 1	28%
C.S. SOQUIP Laduboro, Nicolet No 1 et No 1a	34%
SOQUIP Pétrifina, Bécancour No 1	22%
SOQUIP Pétrifina, Bécancour No 2	27%



Becancour Hypersaline Brine

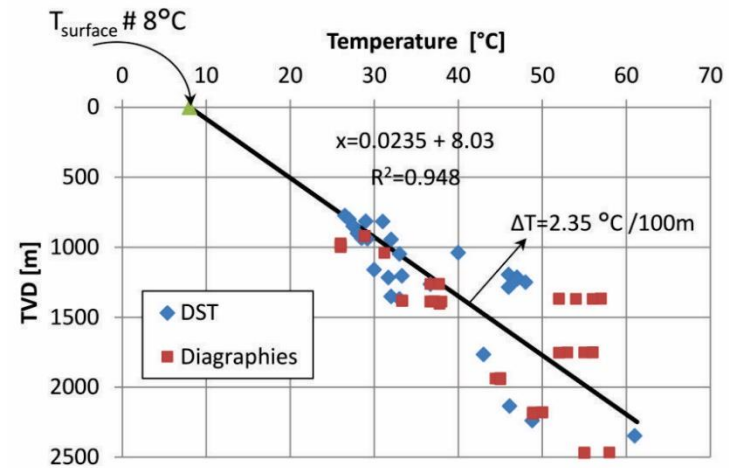
Two Major Geothermal Properties

Its thermal capacity and thermal conductivity are lower than those of fresh water;

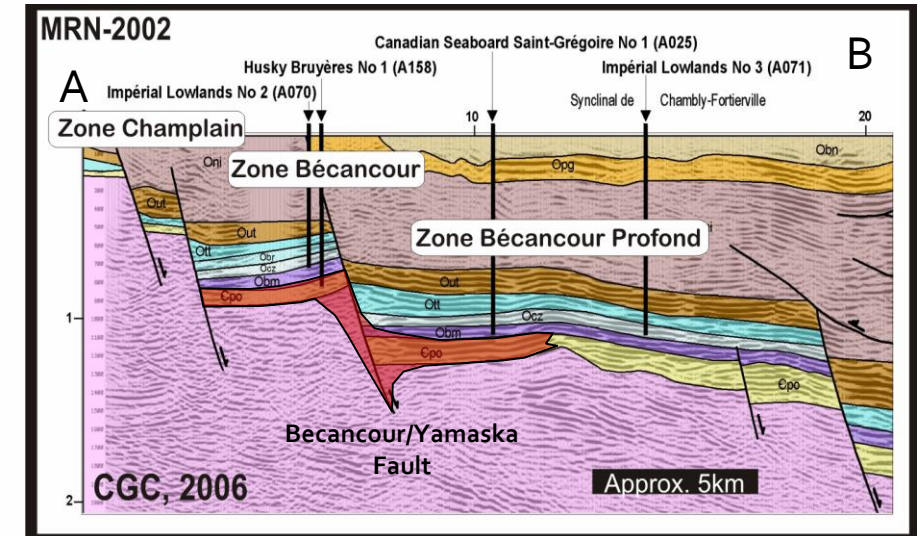
For the same reservoir temperature, the amount of recoverable thermal energy is greater than that of fresh water since the energy extraction is still possible under zero °C due to its low freezing point.

There are few references to geothermal deposits of hypersaline aquifers. Some points will need to be further studied.

- The natural brine is of underground origin, rich in salts in the form of chlorides. It was extracted, by pumping, from three wells.
- The salinity of the brine increases according to its stratigraphic position. The brines recovered in Cambrian sandstone ($> 300 \text{ g / L}$) are saltier than those in dolomites ($\pm 270 \text{ g / L}$) and Ordovician limestones ($\pm 220 \text{ g / L}$)
- The brines are in the form of a dense liquid (1.18 to 1.23 kg / L), odorless and colorless. Their freezing point, as pumped, is of the order of -20°C . Their salinity is 8 to 10 times higher than that of seawater, which is 35 g / L of dissolved solids.
- The temperature of the brine in the reservoir is on average 30°C .



Graphique des températures en fonction de la profondeur à Bécancour (Bedard et al. 2016)



A new way to look at Becancour Reservoir

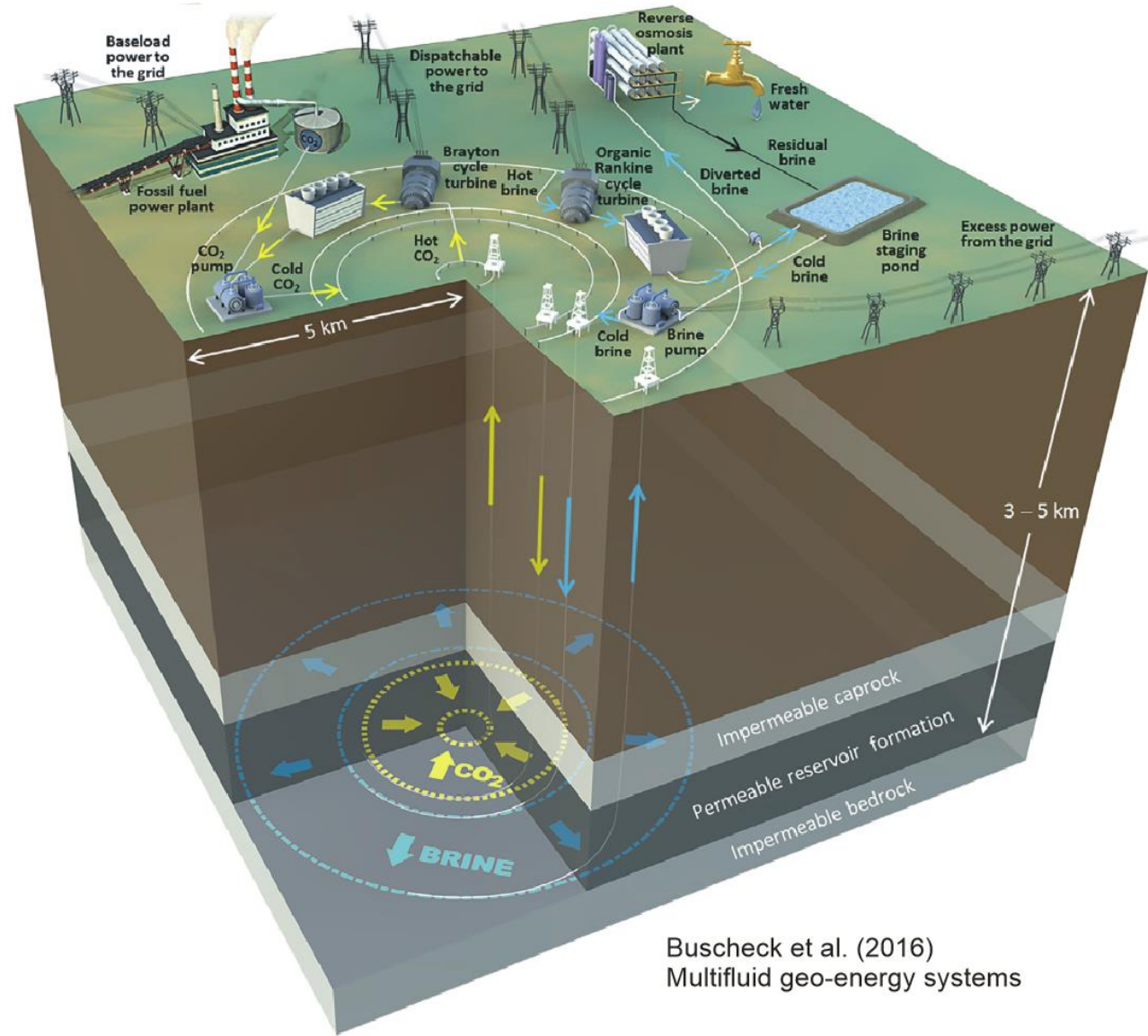
Simultaneous storage and heat generation
(Multi-fluid geo-energy systems)

Injection of natural gas or CO₂ into the aquifer;

Production of natural brine;

Extraction of the energy contained in the brine and in the associated gas;

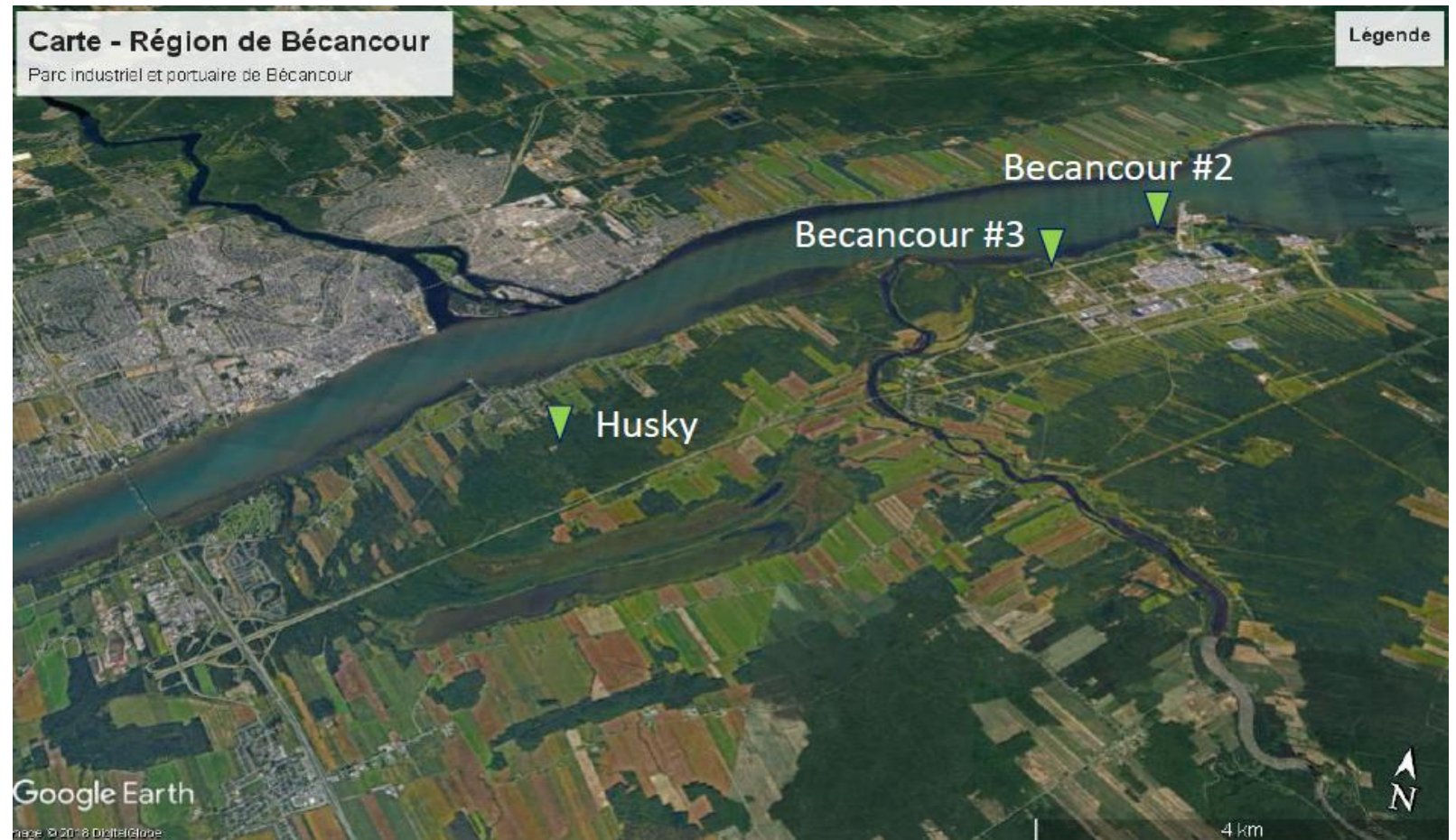
Sale of bulk brine or extraction of value-added items.



Pre-feasibility study for geothermal greenhouse heating

Polytechnique Montréal from data shared by Junex inc.

- Junex Bécancour n°3 – Gas exploration well turned as a brine producing well
- Around 2 millions m³ of Na-Ca-Cl brine in-place
- Salinity between 210 and 350 g/L TDS

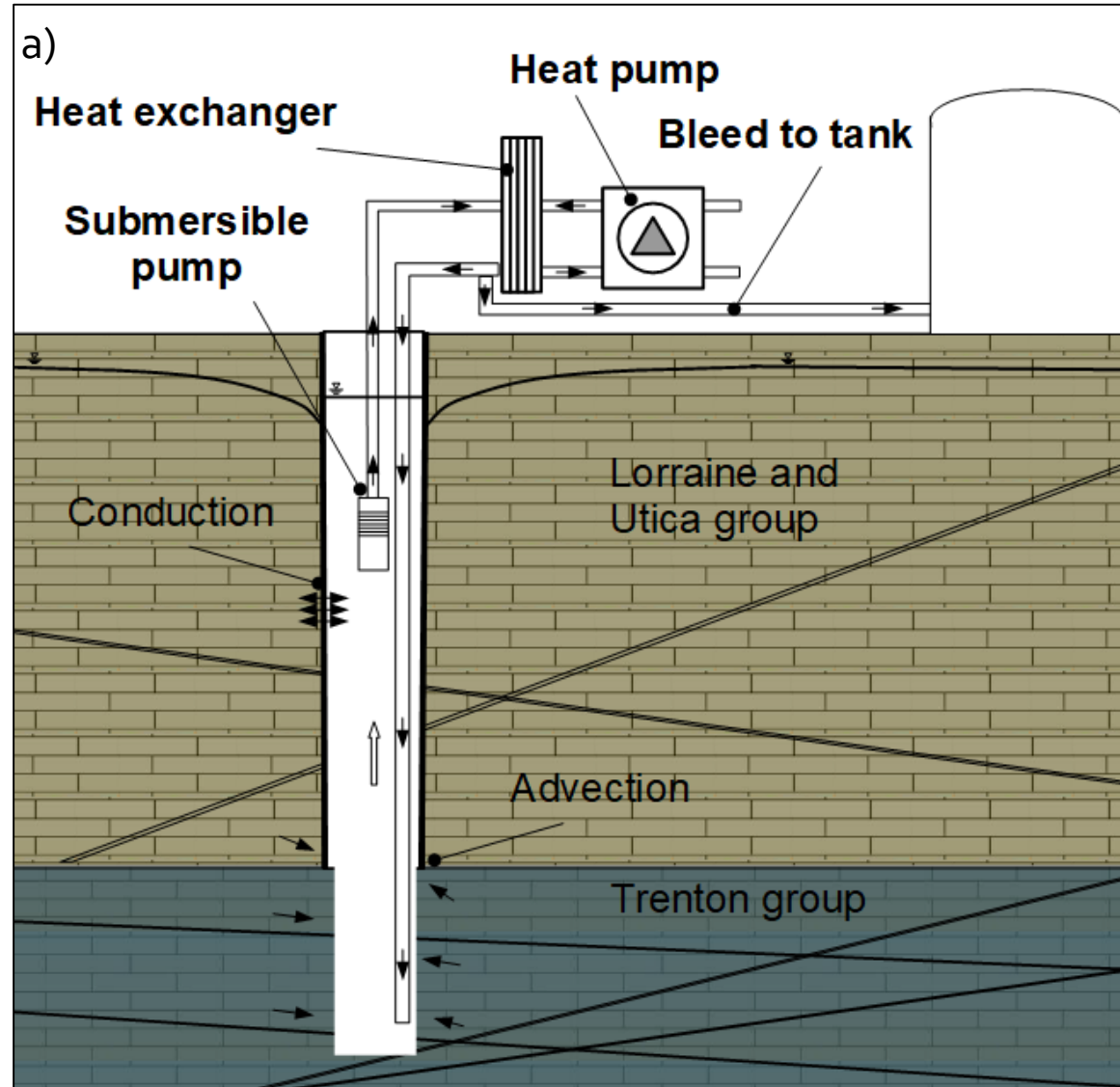


Masse-Dufresne, Cerclet et Fortier-Morissette (2018)

Development Perspectives

Standing Column Well

Evaluate the feasibility of using certain abandoned oil wells located in urban or industrial areas for the installation of standing column wells (SCW)



- a) Standing column well
- b) Polytechnique geothermal laboratory
- c) Heat pump

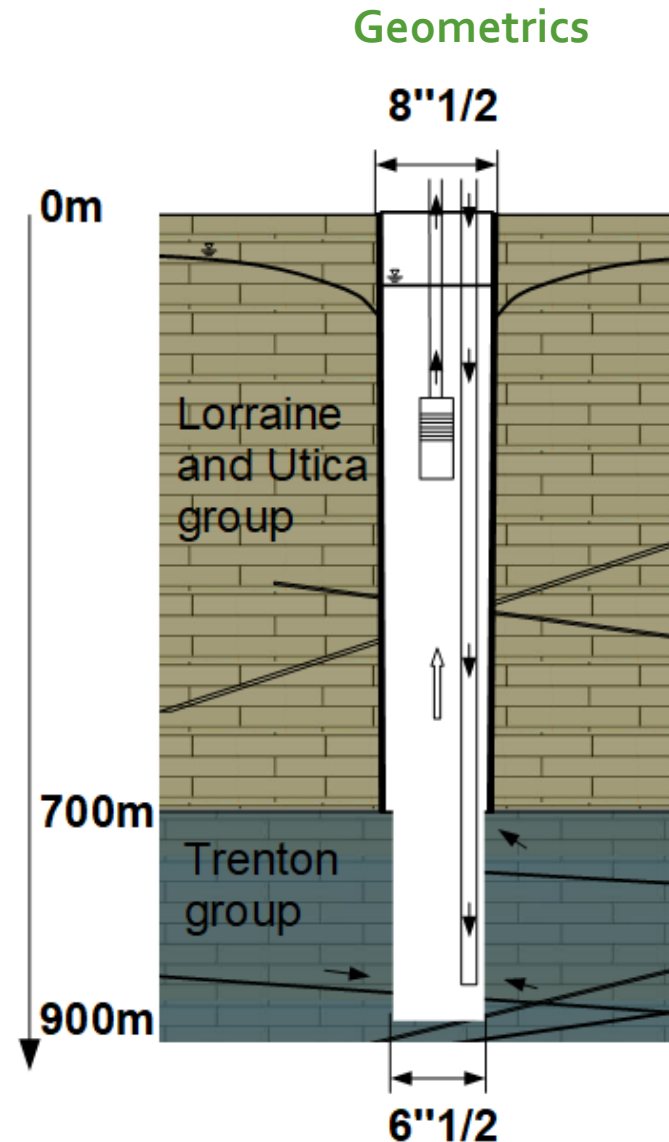
Pre-feasibility study

Drilled in 2003

Brine exploitation for several years

Diverse revalorisation possibilities

Freezing point of hypersaline brine is interesting for geothermal energy



Thermal and hydraulic parameters

	Parameter	Value	Reference
Hydraulic	Lorraine and Utica group		
	Permeability	$4 \cdot 10^{-4} mD$	Ngoc, T (2011)
	Porosity	0,003944	Ngoc, T (2011)
	Anisotropy factor	10	Ngoc, T (2011)
	Hydraulic compressibility	$5 \cdot 10^{-5} Pa^{-1}$	
	Trenton group		
	Permeability	100mD	Junex (2011)
	Porosity	0,0034	Ngoc, T (2011)
	Anisotropy factor	10	Ngoc, T (2011)
	Hydraulic compressibility	$5 \cdot 10^{-5} Pa^{-1}$	
Thermic	Lorraine and Utica group		
	Thermal conductivity	$2,8 W/(m \cdot K)$	
	Density	$2700 kg/m^3$	Ngoc, T (2011)
	Specific thermal capacity	$851 J/(kg \cdot K)$	
	Trenton group		
	Thermal conductivity	$2,8 W/(m \cdot K)$	Naser, (2016)
	Density	$2700 kg/m^3$	Ngoc, T (2011)
	Specific thermal capacity	$866 J/(kg \cdot K)$	Naser, (2016)

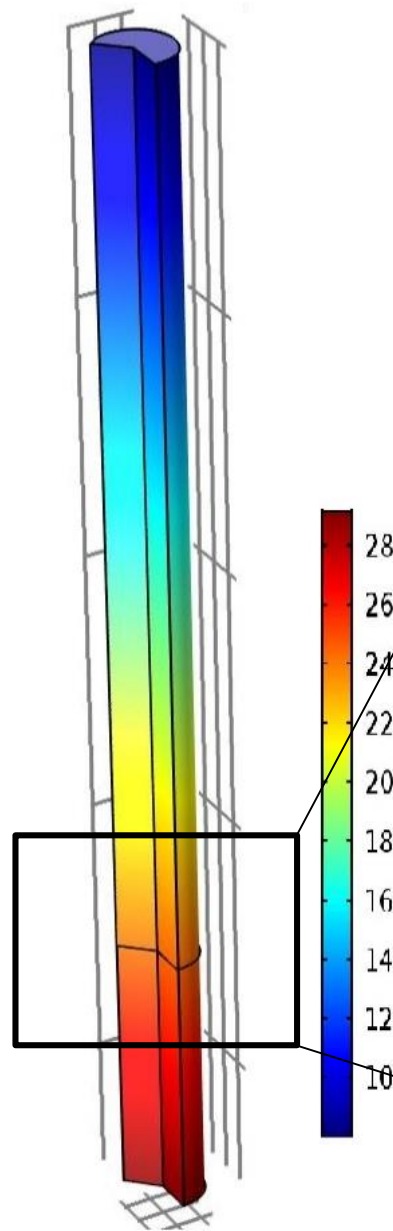
Numerical simulation

Two simulations :

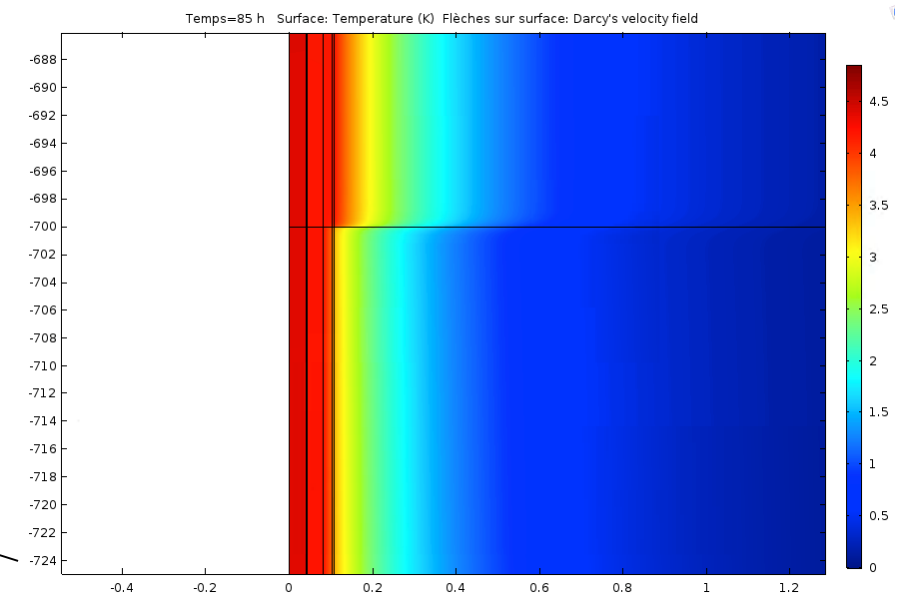
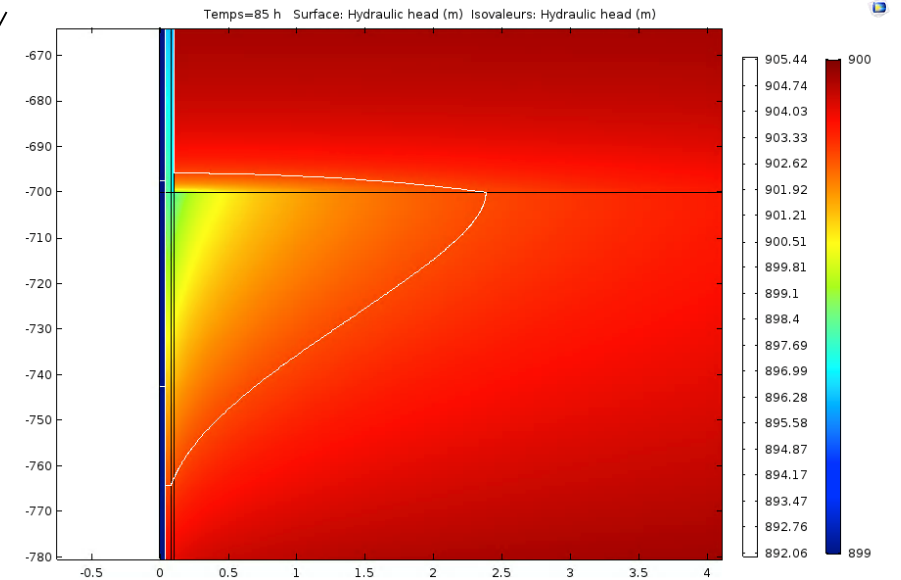
1. Gradient uniformisation at 18.14
 - 2.1 . Advection in contact of Trenton and Utica group in model
 - 2.2. Conduction on long the tube well

Masse-Dufresne, Cerclet et
Fortier-Morissette (2018)

1. Influence of thermal gradient



2. Impact of geology on hydraulic and thermal responses

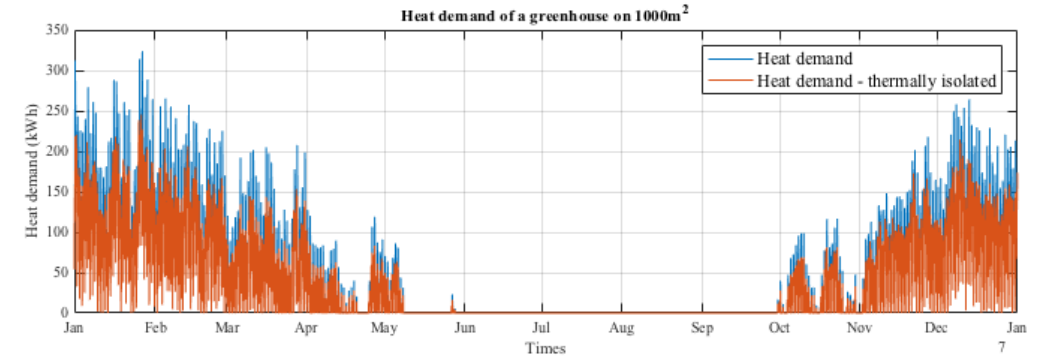


Results

To determine the maximal area of a greenhouse.

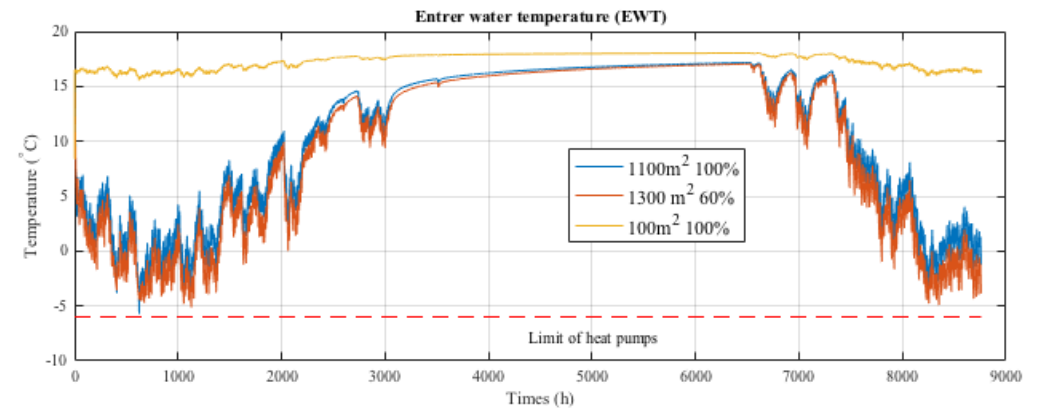
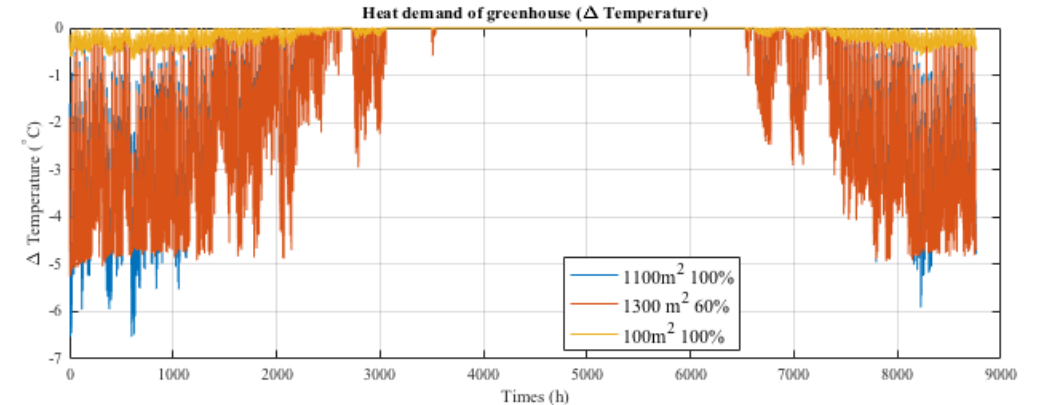
Estimation of the heat demand

- Green house size of 100 m x 10 m x 3 m
- 85% windows
- Thermally isolated



Maximal area for heat demand

- Heat pumps can operate as low as -6.6 °C
- Maximal area is 1300m² (with geothermal energy covering 60% of the peak heat demand)



Financial analysis

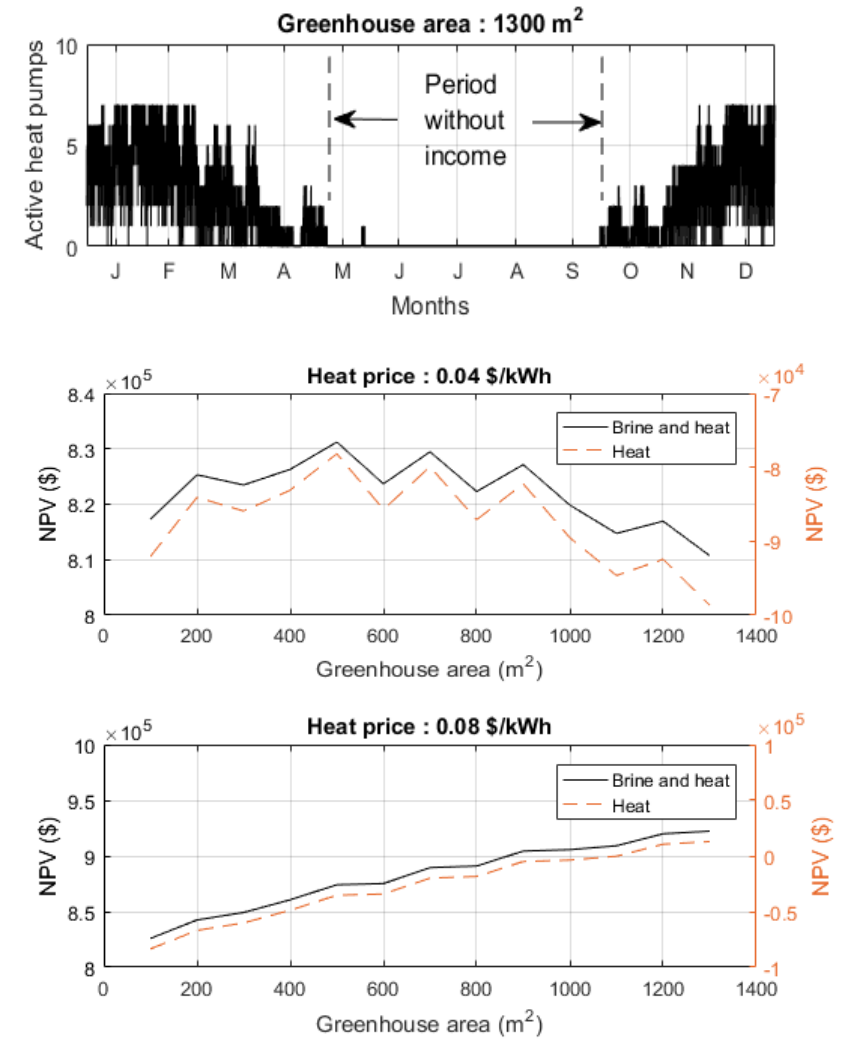
To determine the optimal area of a greenhouse heated by geothermal energy by maximizing the NPV (Net Present Value)

Scenarios

- Greenhouse area (100 m² to 1300 m²)
- Heat selling price (0,02 to 0,08 \$/kWh)
- Heat pump size (6 BTU or 12 BTU)
- Coverage of peak demand (100% or 60%)

Key factors

- Climatisation
- Optimisation of the number of active heat pump
- Heat selling price
- Business model



Masse-Dufresne, Cerclet et Fortier-Morissette (2018)

Legal framework and Public Perceptions

Transfer of operating rights for
inactive wells

Protection of water resources

- It should be noted that, according to a publication by the INRS (2014), 67% of Quebecers are favorable to development of deep geothermal energy and in Center-du-Québec, 70% were in favor of a deep geothermal project in their area. From the moment the respondents were informed that deep geothermal energy can required the use of hydraulic fracturing, support for the project remained at 56% (stay a majority favorable opinion). The main fear identified by the survey participants was groundwater contamination. The survey results indicate that Quebecers are clearly in favor of studying the deep geothermal potential of sedimentary basins in Quebec.
- Faced with this situation, the legal authorities must find a way to adapt or modify the regulations in force to allow pilot projects to be put into operation for the commercial development of geothermal energy on a larger scale.

Reference :

Connaissance et perception des Québécois à l'égard de la géothermie profonde - Moutenet et al. (2014) - Colloque sur la géothermie au Québec

Conclusions

Some recommendations for developing Québec's geothermal potential

- Invest and test innovative energy production concepts;
- Collaborate available expertise;
- Develop greater usability for technical research in geoscience databases;
- Exit the current paradigm that does not sufficiently consider oil knowledge and expertise in the evaluation of geothermal resources;
- Pursue the development of Québec expertise in deep drilling;
- Generate electricity by EGS with a pilot project by assessing and controlling the associated risks;
- Maintain scientific teams to analyze the technical, environmental, economic and social feasibility of the projects;
- Respect the priorities of the current energy strategy :
 - *increase by 25% the total production of renewable energies;*
 - *increase investment in renewable energy;*
 - *support research and development to propel innovative technologies;*
 - *build on the strength of partnership in model energy choices.*

References

Research Groups:

GRREBS (INRS)

GEOTOP (UQAM)

ÉTS Montréal

Polytechnique Montréal

CGC (Québec)

- SNC-SOQUIP (1979) – Rapport sur le potentiel en énergie géothermique de basse énergie dans les Basses Terres du St-Laurent.
- Junex (1999 à 2013) – Rapports internes et publics de la compagnie
- INRS (2010 et 2013) – Potentiel de stockage de CO₂ dans l'aquifère salin de Bécancour
- Marcil et al. (2012) - Utica and Other Ordovician Shales: Exploration History in the Quebec Sedimentary Basins, Eastern Canada
- INRS (2016) - Évaluation des ressources géothermiques du bassin des Basses-Terres du Saint-Laurent
- Pasquier (2016) - Un programme de recherche pour l'étude des puits à colonne en milieu nordique
- Bedard et Raymond (2018) - Cartographie de la conductivité thermique des Basses-Terres du Saint-Laurent
- INRS (2018) - Cartographie de la conductivité thermique des Basses-Terres du Saint-Laurent
- Malo, Marcil et Séjourné (2018) – L'exploration pétrolière au Québec : histoire et potentiel
- Masse-Dufresne, Cerclet et Fortier-Morissette (2018) - Étude de préfaisabilité pour le chauffage d'une serre par géothermie

Derena Geosciences thanks *Junex inc.* and *Polytechnique Montréal* for permission to use certain images and information.

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Thank you for listening
and for this exchange opportunity about
deep geothermal energy.



Jean-Sébastien Marcil, ing. M.Sc.

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Cellulaire : 418-254-1286

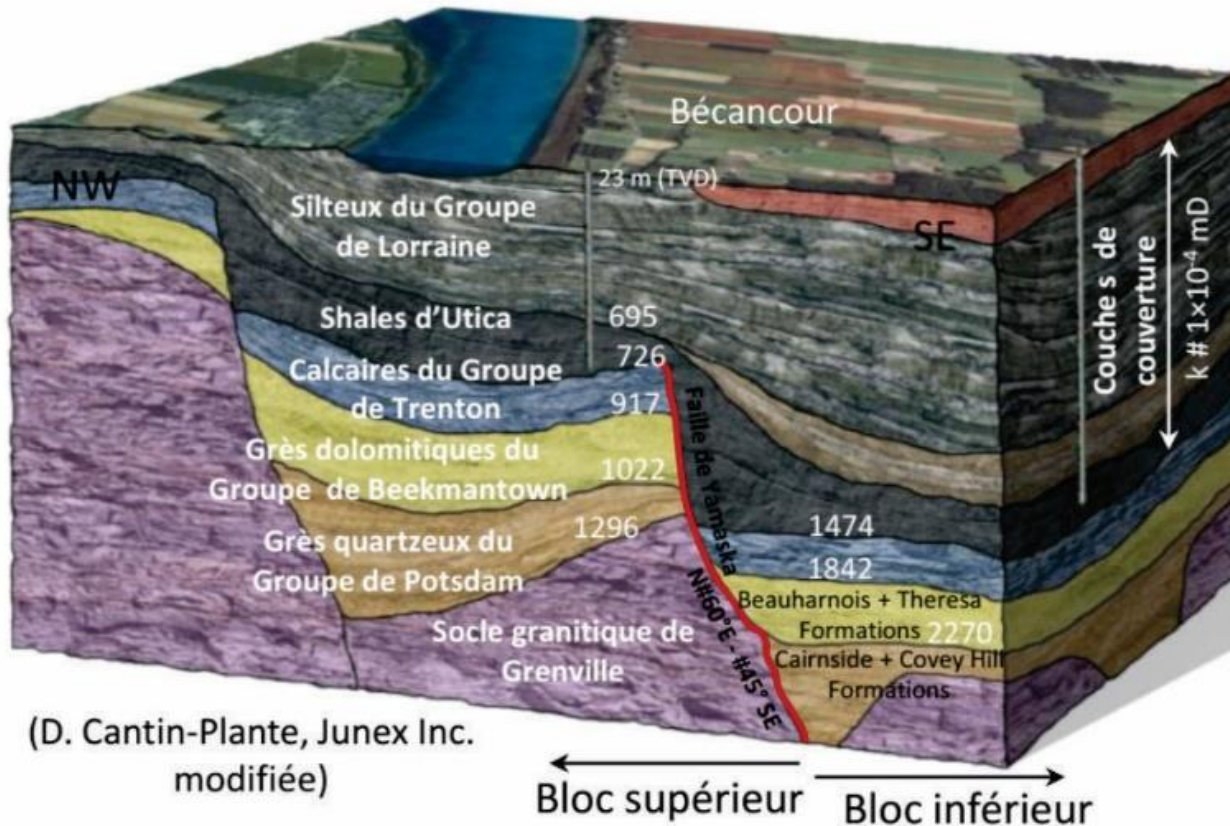
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Connaissance – Compétence - Innovation

St. Lawrence Lowlands Petroleum Geology

Reservoir Rocks

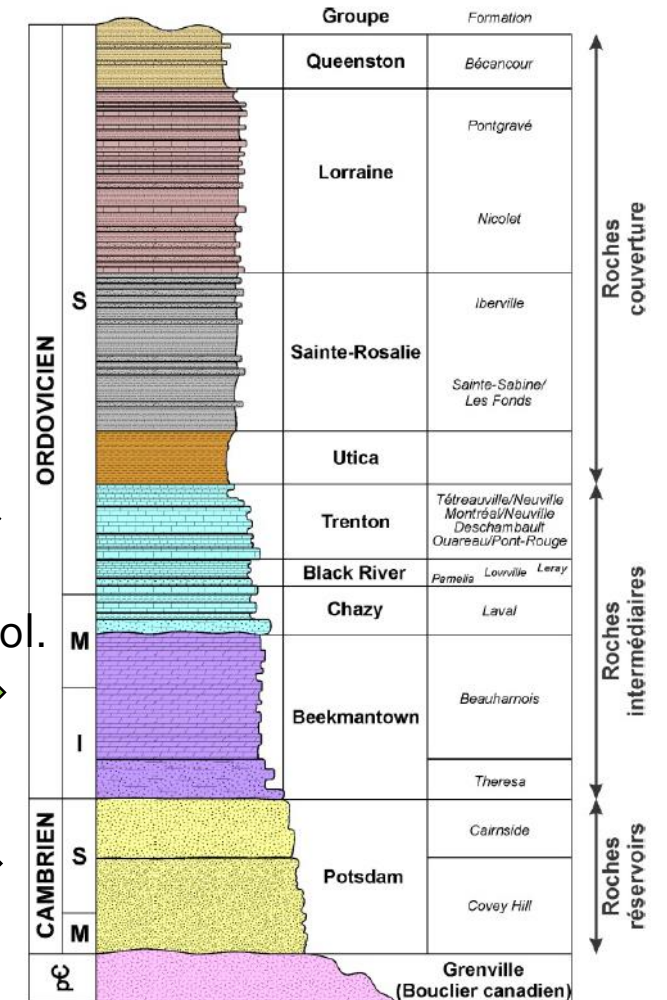


Trenton Ls. →

Beekmantown Dol. →

Covey Hill Arkose →

Granite Wash →



Colonne stratigraphique des Basses-Terres du Saint-Laurent. Adaptée de Hofmann (1972), Globensky (1987), Salad Hersi et al. (2003) et Comeau et al. (2004)

Additional Information on Deep Geothermal Potential

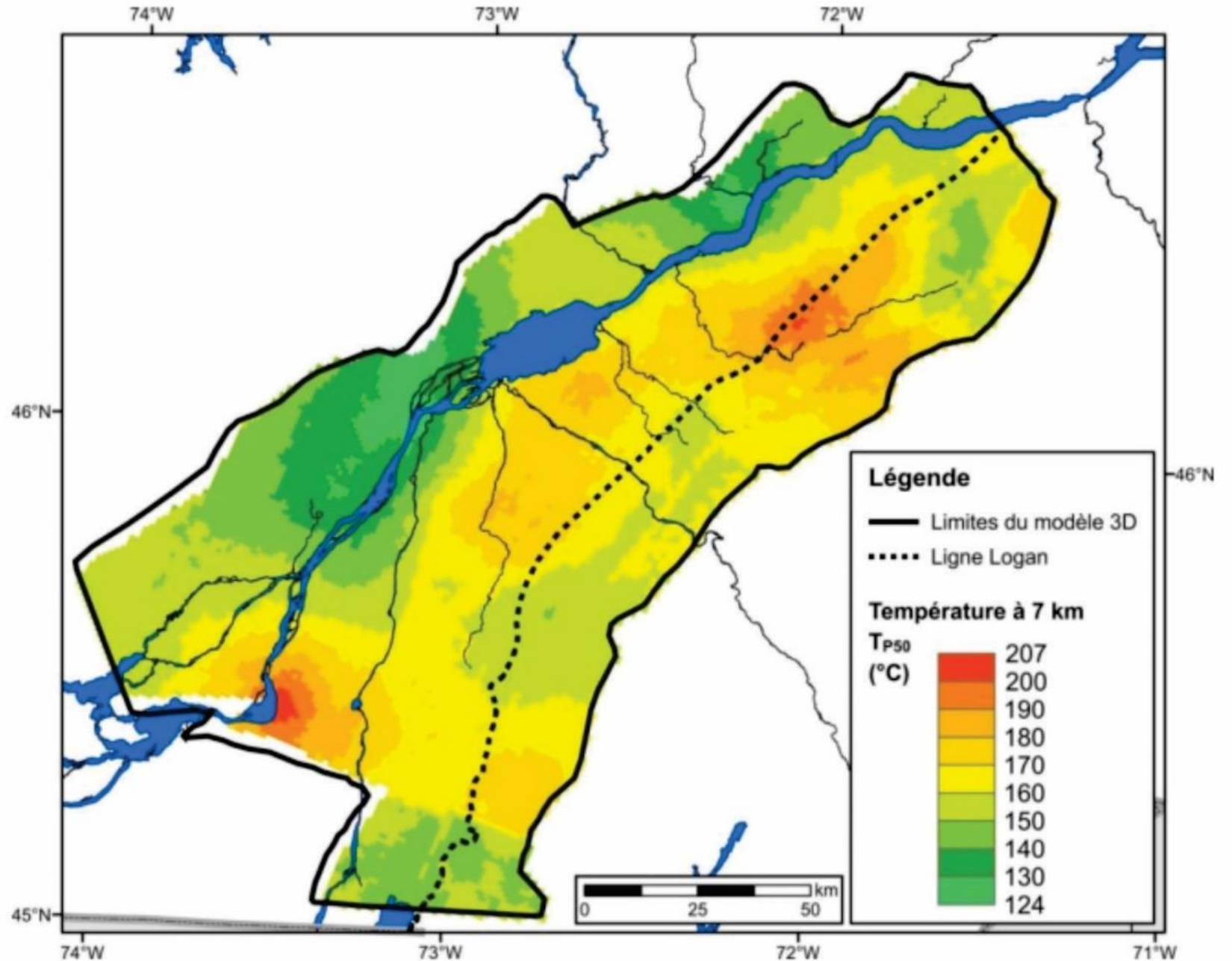
Area of higher temperature at depth have been identified in the St. Lawrence Lowlands. It is possible that these areas may one day be exploited to extract energy from the success of technological developments in the field of deep geothermal energy.

Starting in 2009, the INRS, through its Research Group on Sedimentary Basin Energy Resources, conducted a number of studies on the basins of the St. Lawrence and Anticosti Lowlands, and the Gaspé. The funding granted for the Chair on geological sequestration of CO₂ (2008 to 2013) allowed to model the basins and from 2013, research on geothermal energy was added to the work of GRREBS. The integration of deep temperature data into 3D modeling of the Lower Terrestrial Basin demonstrates the existence of at least two large regional geothermal anomalies. The main temperature anomaly is that of Arthabaska-Érable located near Villeroy in the Lotbinière region. The temperatures of 120 and 150 °C are encountered in the sedimentary rocks of this anomaly from 4000 meters up to 5000 meters deep.

Assessment of Geothermal Resources in the Lower St. Lawrence Basin - Bédard et al. (2016) - Research Report #1659 submitted to IREQ on October 19, 2016

Additional Information on Deep Geothermal Potential

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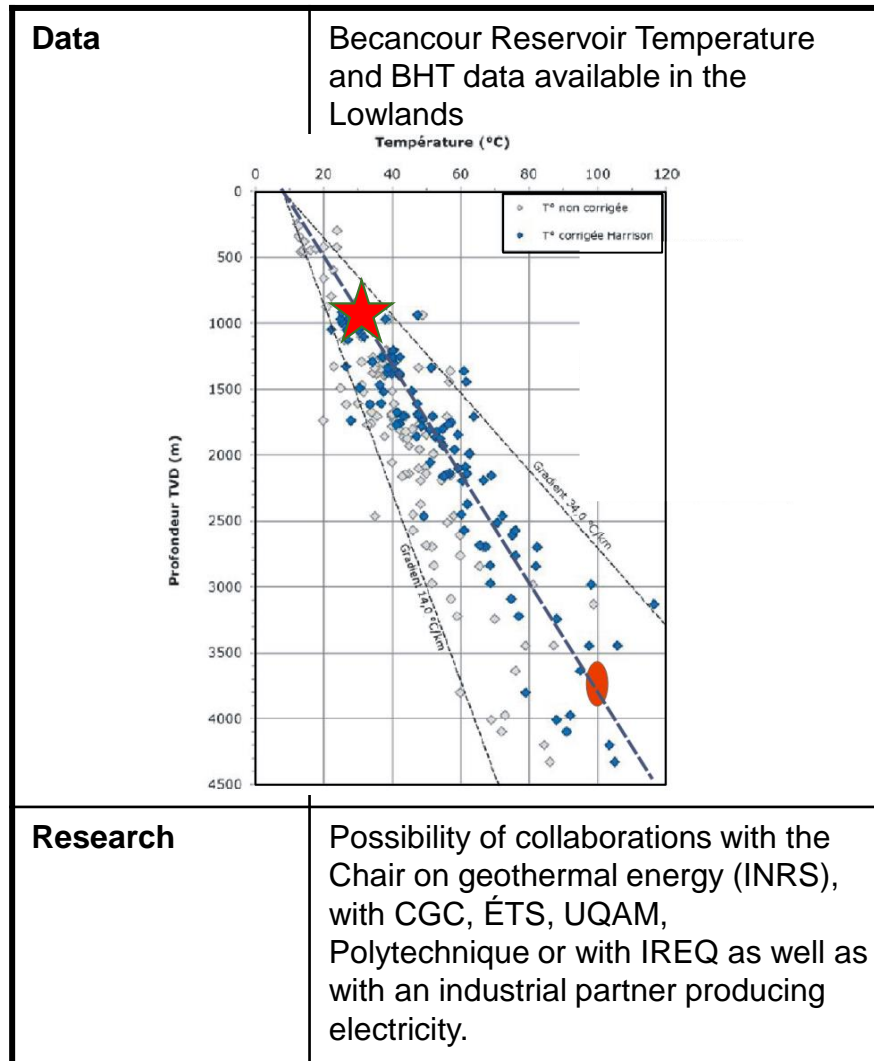
Development Perspectives

Additional Information on Deep Geothermal Potential

Data Acquisition

Research & Development

Drilling and Pilot Project



- A. Pumping hot brine to the surface and using its heat
- B. Drilling a horizontal well to increase the extraction capacity
- C. Drilling an injection well to create a loop circuit

