



Collaborative approaches to groundwater knowledge acquisition in Québec: Inter-regional characterization

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ABSTRACT

Seven regional groundwater characterization projects are currently being funded by the Quebec *Ministère du Développement durable, de l'Environnement et des Parcs*. These projects are led by research teams from six Quebec universities, and have been carried out collaboratively since their inception in 2009. Collaborative efforts have included the pooling of equipment and services, exchanges of dedicated research staff, co-supervision of graduate students, and the development of protocols and methodologies common to all teams. These have been complemented by applied research carried out in response to region-specific problems and needs.

RÉSUMÉ

Sept projets de caractérisation régionale sont présentement subventionnés par le *Programme d'acquisition de connaissances sur les eaux souterraines (PACES)* du ministère du Développement durable, de l'Environnement et des Parcs du Québec (MDDEP). Ces projets sont menés par des chercheurs de six universités québécoises et leur équipe de recherche. Les projets sont réalisés en partenariat depuis le tout début en 2009. Les efforts de collaboration incluent la mise en commun d'équipements et de services, l'échange de personnel de recherche, la codirection d'étudiants aux cycles supérieurs et le développement de protocoles communs de réalisation des travaux. Des projets de recherche complémentaires touchant des problématiques spécifiques à chacune des régions s'ajoutent aux projets PACES.

1 INTRODUCTION

As is the case elsewhere in Canada and internationally, Québec's groundwater resources have been increasingly under pressure of potential overexploitation and contamination as the province's population increases and as industrial and agricultural activities expand and intensify. Over the past decade, Québec has taken a number of initiatives with regards to the management and protection of its water resources, particularly through the submission of an extensive report in 2000 by the Commission on Water Management in Québec of the Bureau d'audiences publiques sur l'environnement (BAPE, 2000). This was followed by the development of the Québec Water Policy under the mandate of the *Ministère du Développement durable, de l'Environnement et des Parcs* (MDDEP, 2002) leading to the enactment of the *Act to affirm the collective nature of water resources and provide for increased water resource protection*.

The establishment and call for proposals within the Groundwater Knowledge Acquisition Program (*Programme d'acquisition de connaissances sur les eaux*

souterraines – PACES) by the MDDEP (MDDEP, 2008) further highlights recognition of the importance of this vital resource for the Québec society, and attempts to address the limited and fragmented state of knowledge on groundwater resources available in Québec. This investment in groundwater research and knowledge acquisition has created an unprecedented opportunity in the province, in terms of both the rate and scope of applied groundwater research.

Funding through the PACES program for university-based regional groundwater characterization, \$7.5 million for a duration of three years (2009 – 2012), was initially announced in September, 2008, with a second call for projects funded from 2010-2013 made in September, 2009. Seven projects were funded in 2009 and 2010. These are being managed and carried out by research teams from six universities in collaboration with regional, provincial, and federal partners. Interuniversity collaborative efforts made within the framework of the PACES projects, as well as advantages and spin-offs thereof, are described in the following sections.

2 REGIONAL PROJECTS

Seven regional groundwater characterization (PACES) projects, to be completed by March, 2013, are currently underway in Québec in the following regions: Abitibi-Témiscamingue, the Bécancour basin in central Québec, the Metropolitan Community of Québec, Mauricie, Montérégie East, Outaouais, and Saguenay-Lac-Saint-Jean (Fig. 1). Further information on each of the regional projects, including sub-projects, and specific methodologies and results are presented in other sessions of the Geohydro2011 meeting.

The general objective of the PACES projects is to provide a portrait of the resource by enhancing knowledge about groundwater in an effort to better protect and sustainably manage groundwater resources in the covered regions. Four main priorities have been identified: (1) to create a detailed portrait of the state of groundwater resources in terms of quality, quantity, use, vulnerability, etc., (2) to maintain and develop partnerships with regional and provincial stakeholders, (3) to provide the knowledge required for science based recommendations favoring sustainable management and planning decisions; and (4) to train students and personnel.

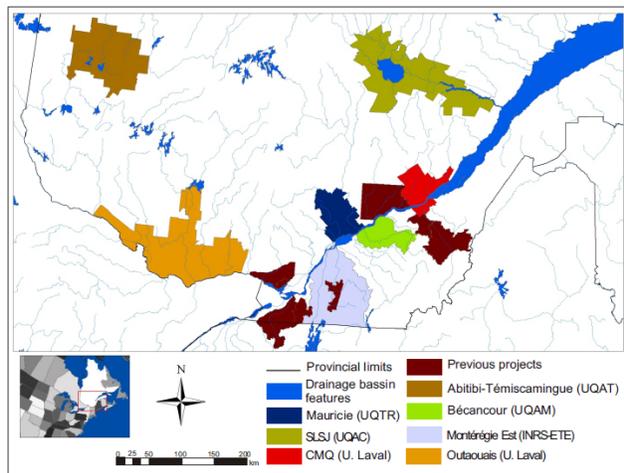


Figure 1. PACES and previous groundwater characterization projects.

2.1 Territory covered

The seven PACES projects cover a total area of 54 247km² (Table 1). Combined with four previous characterization projects (Fig. 1), the PACES projects cover 50% of southern Québec, leaving 50% remaining to be characterized upon their completion in 2013. A population of over 2.2 million people resides in the areas currently being characterized (Table 1). This is an impressive number considering that much of the covered area lies in a rural setting.

Table 1. Area and population covered by the PACES projects.

Project	Population	
	Area (km ²)	(1 000 people)
Abitibi-Témiscamingue	9,188	69.8
Bassin Bécancour (Centre-du-Québec)	2,924	52.1
Mauricie	3,350	223.5
Metropolitan Community of Québec	3,051	715.0
Montérégie Est	9,036	587.8
Outaouais	13,488	341.1
Saguenay-Lac-Saint-Jean	13,210	277.0
TOTAL	52,247	2,266.3

2.2 Project partners

Each project has established partnership with its Regional Conference of Elected Officials (*Conférence régionale des élus – CRÉ*), which has the general mandate of advising the provincial government on important regional issues and concerns, and establishing projects delegated to them by the government. A total of 31 Regional County Municipalities (Municipalités régionales de comtés – MRC) and cities, more than 21 watershed organizations (*organismes de bassin versant*) and other interested groups (e.g the *Société de l'eau souterraine Abitibi-Témiscamingue*, the *Conseil régional de l'environnement de la Montérégie*, etc.) have also formed partnerships with the researchers in the context of the current projects.

The direct links that have been established between each research team and their regional partners have allowed for the development of regional poles of expertise where researchers already familiar with a given region covered by the PACES projects are well equipped to respond to local concerns regarding issues specific to that region.

At the provincial level, in addition to the MDDEP, the following Québec ministries are also involved: MAPAQ (*ministère de l'Agriculture, des Pêcheries et de l'Alimentation*), MRNF (*ministère des Ressources naturelles et de la Faune*), and the *Centre d'expertise hydrique du Québec*. At the federal level, Geological Survey of Canada (GSC) researchers are also extensively involved in the projects. The large number and diversity of partners is testimony to the great interest in the PACES program, as well as to the cooperation fostered by the research teams, which has been invaluable to the success of each of the projects to date. Partners have also committed to providing monetary and in-kind contributions. These exceed 1.9 million \$, or approximately 20% of the programme funding from the MDDEP (total spending > 9.7 million \$).

2.3 Project phases and timelines

Projects are to be completed in three phases, (1) gathering and compilation of existing data; (2) field work and completion of data sets; and (3) data analysis, interpretation, and production of research reports (Figure 2).

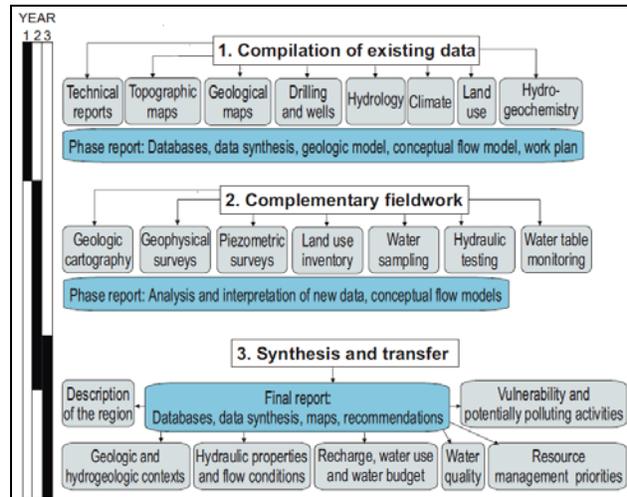


Figure 2. Research activities, products, and timelines associated with each of the three PACES project phases (derived from MDDEP, 2008).

During the first phase of the projects, *gathering and compilation of existing data*, regional data were collected from a variety of sources (mainly private sector consulting firm reports prepared for municipalities, and various ministries and government organizations) and organized to identify missing data. Validation of the quality of existing data for each project (quality control) was also important at this phase, and usable data were organized in integrated data bases.

Data compiled during Phase 1 were complemented with data acquired during Phase 2, *field work and completion of data sets*. Given the disparity in the quality, extent and sources of existing data within and between regional projects, different projects were faced with different requirements in order to complete their data sets, in terms of collecting original data generated by fieldwork. Section 2.4 below provides a brief description of the different thematic data types and field work.

Phase 3, *data analysis and interpretation*, involves the synthesis of data acquired through both Phase 1 and Phase 2. Data interpretation through the production of thematic maps, technical and general information documents will take place during this phase, with an emphasis on transferring summarized and practical knowledge acquired during the project to regional and provincial partners to be used in management and planning decisions.

At the end of each phase, research teams submit their phase report to the MDDEP (Ayotte *et al*, 2011; Cloutier *et al*, 2011; Larocque *et al*, 2011; Leblanc *et al*, 2011; Lefebvre *et al*, 2011; Therrien *et al*, 2011; Walter *et al*, 2011). Generally these reports consist of description of

the region, geologic and hydrogeologic contexts, hydrologic budgets, vulnerability and polluting activities, sustainability of groundwater resources, and eventually recommendations for groundwater management and monitoring. Table 2 details the specific products to be produced during phase 3 of the projects.

All seven PACES projects have now completed Phase 1, with the Metropolitan Community of Québec and Outaouais projects (which started in 2010) now beginning Phase 2 while the other projects (which started in 2009) are entering Phase 3.

Table 2. Specific products to be produced by the PACES projects

Thematic maps and texts describing the following information:

1. Topography
2. Roads, municipal limits, and place names
3. Digital elevation model (DEM)
4. Surface slope
5. Hydrography
6. Watershed and sub-bassin limits
7. Land cover
8. Vegetation cover
9. Wetlands (ecological zones of interest)
10. Land use (activity)
11. Pedology
12. Quaternary geology
13. Bedrock geology
14. Stratigraphic and hydrostratigraphic cross-sections
15. Thickness of hostrock
16. Topography of bedrock
17. Hydrogeological contexts
18. Thickness and boundaries of regional aquifers
19. Piezometry in shallow aquifers
20. Bedrock piezometry
21. Hydrogeologic parameters (K, T, S, porosity, etc.)
22. Aquifer vulnerability (using the DRASTIC method)
23. Potentially polluting activities
24. Quality (for drinking)
25. Quality (esthetic parameters)
26. Water use
27. Location of meteorological and hydrometric stations, and water table monitoring
28. Preferential recharge and resurgence zones

2.4 Sub-projects

Within the context of the PACES projects, a number of sub-projects are being carried out to contribute to the general hydrogeologic assessment. These include characterization of bedrock and surface deposits, Quaternary mapping, hydrogeochemistry, meteorology, hydrologic water balance, land use characterization, identification of recharge zones and areas vulnerable to contamination, groundwater-surface water interactions,

piezometry, hydraulic testing and for some projects characterization of wetland-groundwater interaction.

3 INTER-REGIONAL RESEARCH TEAM

More than 22 professors, 23 research technicians, professionals and assistants, eight doctoral candidates and 19 masters students are involved in the current PACES projects, in addition to the more than 62 regional and provincial partners listed above, as well numerous undergraduate level students are involved as interns each field season.

The organizational structure of the inter-regional characterization projects is presented in Figure 2. Each regional project is led by one or more coordinator who are also professors from an associated university. In general, the coordinators are responsible within each of the projects for (1) assuring the regional projects are carried out; (2) supervising research staff comprising their teams; (3) organizing the sharing of resources and infrastructure within the interregional projects; (4) supervising and following-up related graduate-level research projects; (5) ensuring the integration of results and data into maps and reports; and (6) liaising with regional project partners.

The coordinators also make up the *Scientific Committee*, which as a whole is responsible for (1) defining general and specific approaches used, as well as the format of different research products (maps, etc); (2) coordinating the use of equipment, material, and research professionals between regional projects; and (3) advancing the projects and related products in collaboration. The Scientific Committee serves as the contact with the MDDEP for all scientific and technical, as well as administrative questions. The inter-university group approach facilitates the direct implication of the Ministry, by allowing consensus to be reached more quickly and easily regarding common methodology and formatting issues, etc.

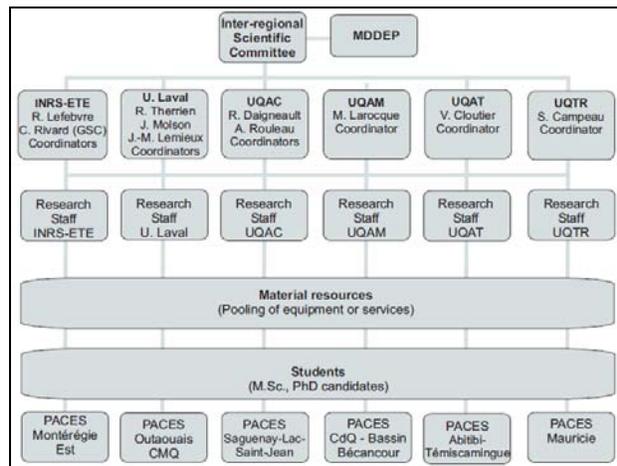


Figure 3. Inter-regional organizational structure of the PACES projects.

4 COLLABORATIVE FEATURES

Collaborative efforts have been made between the coordinating researchers and members of the research teams since the inception of the projects to ensure uniform research products, comparable over space and time. The main collaborative features and some specific examples are elaborated below.

4.1 Pooling of research equipment, analyses, and services

No individual research team has all of the necessary equipment to carry out all aspects of their regional characterization project. However each one possesses equipment, infrastructure or facilities that the others do not. The collaborative approach of pooling resources taken by the researchers has (1) ensured that all teams and projects have access to widest possible pool of equipment and (2) reduced the potential cost of the projects by optimizing the use of existing resources and new investments, and by offering inter-project access at reduced (internal) costs in most instances.

Existing infrastructure and equipment available for shared use between the participating universities include: a *Geotech 605D* geotechnical drilling rig and geophysical equipment (electric tomography (*Syscal*), georadar, Time Domain ElectroMagnetic induction (TDEM)), major ion analyses (INRS), a mobile hydraulic testing laboratory (UQAC), thermoluminescence sediment dating (LUX Laboratory-UQAM), rare gas (He, Ne, Ar, Kr, Xe) analyses in fluids and rocks (GRAM Laboratory-UQAM), hydrogen (¹H, ²H), oxygen (¹⁶O, ¹⁸O) and carbon (¹²C, ¹³C), and nitrogen (¹⁴N, ¹⁵N) isotope analyses (GEOTOP-UQAM and DeltaLab-GSC), Electrical resistivity tomography (ERT-INRS); mineralogical characterization of sediments (X-Ray Diffraction (XRD), scanning electron microscope) (UQAT and UQAM), a Roto-Sonic drill and High Resolution Seismic Reflection (GSC). Joint calls for proposals for hydrogeochemical laboratory analyses and for well drilling were submitted.

4.2 Collaborative research staff

In addition to sharing experts and technicians for the equipment listed above, dedicated research personnel have been hired for each of the regional projects. The interregional project collaboration enabled complementary professional profiles to be designed and sought out for these positions. Research staff from each of the teams has collaborated to develop protocols and methodologies common to all projects, as well as to establish and add data to an integrated database which has been developed by specialized staff from INRS.

4.3 Co-supervision of students

Many graduate and bachelor level students are involved directly in the PACES projects, either through thesis research or student internships. Students have also benefited from the increased exchange between researchers and universities resulting from the

collaborative PACES projects through co-supervision on other projects (e.g. funded by the *Fonds québécois de la recherche sur la nature et les technologies*; FQRNT), and internship and exchange possibilities, and also participate in other activities organized by the research group.

4.4 Other joint activities

Upon initial funding of the PACES projects, the coordinating researchers formed the Inter-university Groundwater Research Group (*Groupe de recherche interuniversitaire sur les eaux souterraines* – GRIES; www.gries.uqam.ca). The establishment of GRIES and the hiring of a dedicated Scientific Coordinator have facilitated the coordination of activities common to the participating universities. The GRIES has since been expanded to include groundwater researchers from other Québec universities not directly involved in the PACES projects.

Several joint activities have been organized as part of the collaborative PACES projects since 2009, either in direct response to project needs (e.g., specific training sessions, group meetings, etc.), or as more indirect spin-offs from the increasing communication and collaboration between research teams.

The GRIES participated in the public debate on shale gas by submitting a memoir to the BAPE (GRIES, 2010). Training workshops have been held in conjunction with general research meetings to optimize the travel time and resources involved. These have taken place twice a year since 2009 and have included topics such as water sampling and analysis, data base management and the development of protocols and methodologies.

The first annual *Groundwater in Quebec* conference was organized by the GRIES and held in Saguenay on the UQAC campus in October, 2010. In addition to presentations of the PACES projects and sub-projects, other relevant research projects were also presented, and participants (approximately 120) represented a range of governmental, academic, private sector and non-governmental organizations.

A partnership with the Canadian National Chapter of the International Association of Hydrogeologists has resulted in the GRIES – AIH-CNC Quebec Groundwater Seminar Series. These seminars (audience of 40-50 for each of ten conferences), which take place in one of the GRIES universities, are video-linked to the others, enabling further inter-university networking and joint activity, and diversifying the scientific discussion within and between research teams.

5 CONCLUSION

The inter-university collaborative approach taken in the PACES projects has facilitated not only the acquisition and organization of data, but also the transfer of knowledge and skills between research teams and to research partners. The overall result is that projects are more efficient in terms of human, material and financial resources, and that research products such as maps, databases, and reports will have uniform production methods and presentation format, enabling their

comparability between project areas. The collaborative dynamic established through the joint PACES projects has also led to further joint activities, notably through the establishment and consolidation of the GRIES research group.

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