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The design of one of Canada's first deep direct-use geothermal doublets

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INTRODUCTION

The City of Regina (CoR) in Saskatchewan, Canada, is developing a new, indoor aquatic facility (IAF). The vision for the IAF is an accessible, inclusive and sustainable destination that will serve Regina for generations to come. It is planned to heat the facility utilising a deep geothermal heating system. The system in Regina which will comprise a geothermal doublet with one production well and one injection well. The production well is anticipated to produce 60°C geothermal brine from the sedimentary Winnipeg and Deadwood aquifers (collectively referred to as the Basal Clastic Unit or BCU) at depths of 2,030 to 2,200 m. The geothermally heated brine will be cycled through multiple heat exchangers to provide heating to the IAF. The heat-depleted brine will then be returned to the BCU aquifer via the geothermal disposal well. The IAF has an estimated peak heating demand of 7.3 MW which requires a flow requirement of up to 50 L/s assuming an injection temperature of around 20°C.

It is planned to drill the wells in mid-2026. The wells will be drilled in a heavily urbanised setting and will need to be designed for a lifetime of at least 30 years. Significant effort has been made to prepare a design best suited for the BCU aquifer and brine conditions to minimise the number amount of interventions required post-construction. This abstract summarises the design basis for the geothermal wells.

1 PRECEDENT FACILITIES

Direct-use of geothermal heat is being utilised for district and industrial heating around the world but is often overlooked. An extensive review of precedent facilities including site visits was undertaken to ensure that the design integrates international best practice. Similar facilities are found in the Netherlands – where comparable sedimentary aquifers are being used to provide heating for the greenhouse industry. In Paris, France, direct-use geothermal has been used since the 1970's for district heating and in Perth, Australia, more than a dozen geothermal systems have been installed for the purpose of heating local aquatic facilities.

The design of the Regina IAF geothermal system is heavily supported by learnings and advancements from these projects, which consider:

- The importance of prediction of aquifer performance in relation to electrical-submersible pump (ESP) setting and injection pump sizing.
- Well trajectory and subsurface targets to manage geothermal plume development, fault reactivation risk and maximise aquifer exposure.
- Management of dissolved gases by either degassing in case of hydrocarbons (Netherlands) or operating a pressurised system in case of H_2S (Paris) and management and mitigation against formation of scale and highly corrosive brines.
- Consideration of the risk of migration of sediment resulting in excessive fine production and screen or aquifer plugging.

2 GEOLOGY

Regina overlies the northern portion of the Williston Basin, a major intra-cratonic sedimentary basin with deposits aging from the Cambrian to Tertiary. The Williston Basin can be considered a tectonic and stratigraphic domain within the larger Western Canadian Sedimentary Basin (WCSB) which extends from the Rocky Mountains in British Columbia to the Canadian Shield in Saskatchewan and Manitoba (Figure 1). Precambrian structures are derived from gravity, magnetic and seismic survey data and surface lineaments (Penner & Cosford, 2006).

It is planned for the wells to intersect the full thickness of the Williston Basin before reaching the Ordovician – Cambrian targets of the Winnipeg and Deadwood formations, which directly overlie the Precambrian Basement.

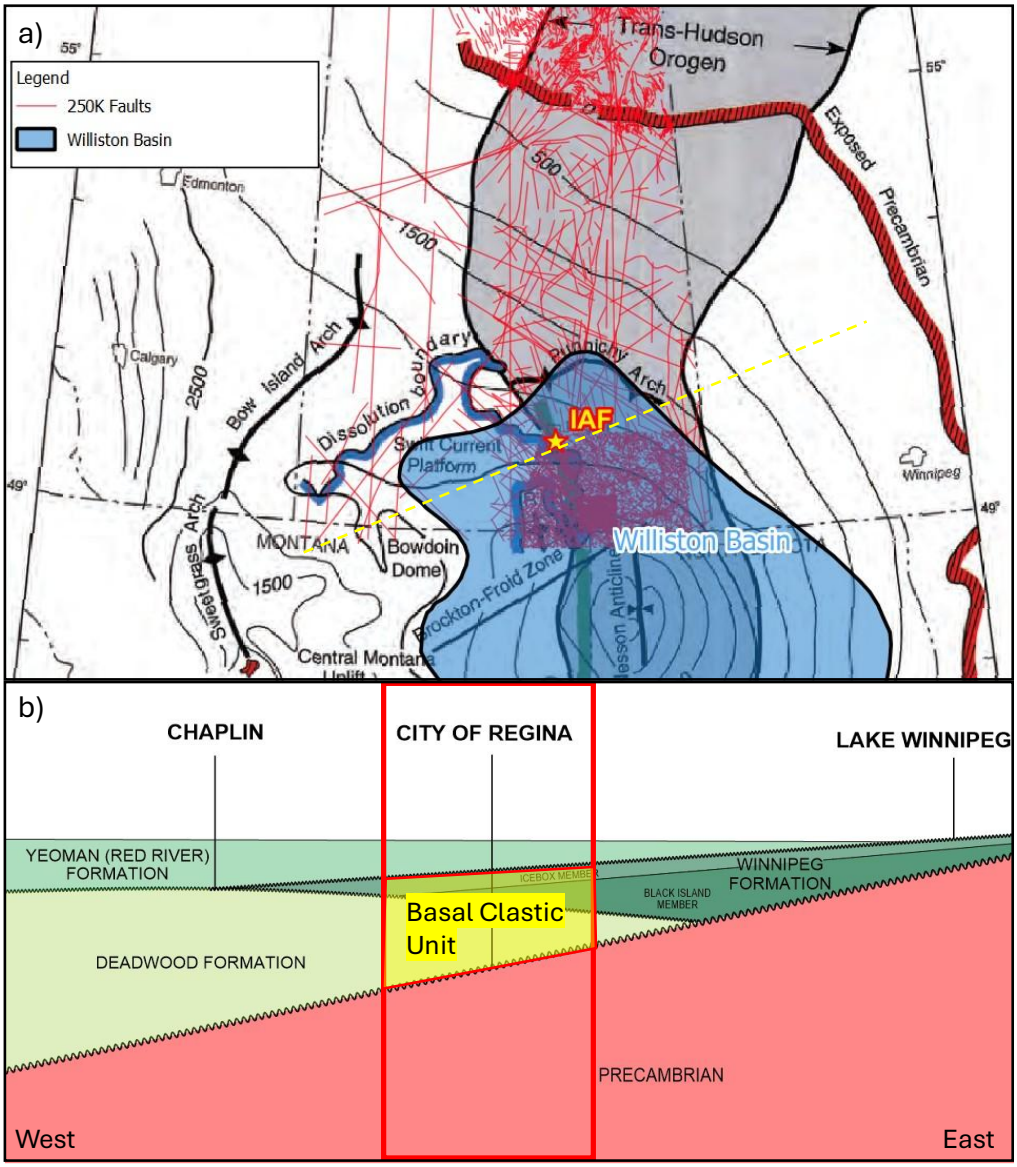


Figure 1 a) structural features of the Williston Basin (after Fenton et al., 1994) b) schematic drawing of the erosional surface between the Deadwood and Winnipeg Formations – not to scale

3 AQUIFER CHARACTERISTICS

The target formations are the fluvio-deltaic Cambrian Deadwood Formation and Ordovician Winnipeg Formations, which host the Deadwood and Winnipeg aquifers, respectively. Both have been used for brine and sour water disposal in the area and are expected to be suitable aquifers for this project.

The best estimate of the formation and brine characteristics needs to be made to determine the expected operating conditions and to prepare the best suited design given the available data. Offset data is derived from the University of Regina (5 km to the southeast), the Co-op refinery complex (5.5 km to the northeast) and several exploration and disposal wells further away. Expected ranges for key hydraulic parameters are presented in Table 1.

Table 1: Interpreted aquifer parameters

Unit	Parameter	Min	Med	Max
Black Island Member	Gross thickness (m)	26	31	32
	N/G (dec)	0.95	0.98	1
	Average Permeability (mD)	150	248	438
	Porosity (-)	0.17		
	Temperature (°C)	58		
	Salinity	111,000	123,000	131,000
	Kh/Kv	1		
	Top Depth (mTVD)	2025 - 2030		
Deadwood Formation	Gross thickness (m)	125	127	131
	N/G (dec)	0.82	0.84	0.85
	Average Permeability (mD)	86	129	250
	Porosity (-)	0.14		
	Temperature (°C)	60		
	Salinity (ppm)	116,000	130,000	143,000
	Kh/Kv	1		
	Top Depth (mTVD)	2,065 – 2,066		
Total thickness (m)		151	158	163
Average N/G		0.84	0.87	0.88
Average Permeability (mD)		98	155	292
Average salinity (ppm TDS)		115,000	128,000	140,000
Average temperature (°C)		59		

3.1 Prediction of aquifer and well losses

The minimum, expected and maximum aquifer parameters were used in TNO's DoubletCalc 1.4.3 (Veldkamp et al., 2015) in conjunction with Gudrun v2.3 by Seequent to estimate the expected aquifer and well losses anticipated in the production and injection wells. The results are translated to an expected ESP installation depth and injection pump pressure requirements. For a flow-rate of 40 to 56 L/s, P50 results suggest that the ESP would need to be installed between 450 and 550 m depth and injection pressures could be between 2.3 and 3.3 MPa for the current design configuration. P10 results suggest an ESP between 500 and 600 m depth and injection pressure up to 4.3 MPa. It should be noted that injection performance is difficult to predict as there are dynamic processes to consider such as screen clogging which decrease the performance of injection wells. as seen in the Netherlands and Australia.

3.2 Prediction of scaling and corrosion

Thermochemical equilibrium in a solution is very sensitive to variations of temperature, pH and redox potential. Precipitation of dissolved materials (scaling) could potentially occur in the geothermal loop due to variations of the aquifer temperature and pressure which will modify the equilibrium conditions of the geothermal fluid composition. The casing material and downhole infrastructure may also corrode.

Geochemical simulations were performed with PHREEQC version 3.8.6 (Parkhurst and Appelo, 2000) to predict the evolution of the brine as it circulates through the geothermal system and is reintroduced to the aquifer. The results suggest that barium-sulphate ($BaSO_4$) has the highest potential to form scale. Barium-sulphate scale can cause major long-term operational difficulties as sulfate mineral deposits are difficult to overcome with standard clean-in-place methods.

Additionally, the brine has a high salinity (up to 140,000 ppm TDS) with potentially a low concentration of H_2S. Experience with operation in these conditions from the Netherlands shows that significant corrosion can be expected. The use of corrosion inhibitor was originally indicated to have good outcome (TNO, 2015), however, in more recent consultation with operators that produce high-salinity brine, the use of corrosion inhibitor has been noted to have mixed results.

4 DESIGN CONSIDERATIONS

4.1 Performance and pump sizing

A production hole diameter of 8½" with 7" low-friction tubing has been selected for the design. This configuration reflects a balance between cost, hydraulic efficiency, and operational performance. While larger-diameter wells offer reduced friction and pressure losses, thereby lowering the risk of underperformance and minimising the energy requirement on the ESP and injection pumps, they also incur significantly higher drilling and completion costs. Given the uncertainty surrounding aquifer losses, the selected design represents a practical compromise between hydraulic performance and overall project cost.

4.2 Subsurface planning

The proposed geothermal doublet at Regina will draw water through the matrix porosity of the target aquifers and the wells are planned to be oriented in a NW-SE direction parallel to the prevailing trend of mapped structures. This orientation of the wells will reduce the likelihood of the wells being completed in isolated aquifer intervals.

Due to the uncertainty of aquifer losses, inclined penetration of up to 60° is preferred to increase the exposure to the aquifer (Figure 2). Additionally, drilling and constructing the wells at the planned inclination will increase the subsurface separation to minimise thermal breakthrough of the cold water plume (Pujol et al., WGC 2026).

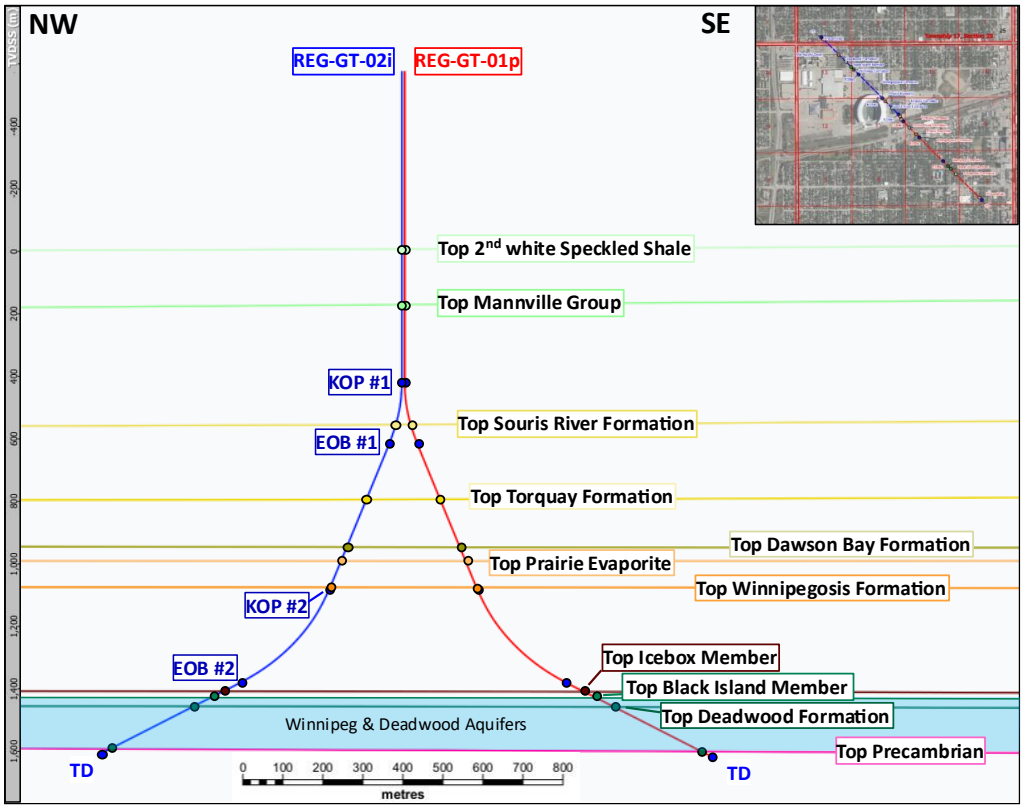


Figure 2 Proposed well trajectories to allow for sufficient subsurface separation and increased penetration angles through the target aquifers.

4.3 Corrosion and scale formation

Because of the tendency for scale formation, bench test/trials should be undertaken with inhibitors to determine the most appropriate strategy to prevent sulfate mineral scaling (including barium-strontium-calcium sulfate) in the geothermal system. It is expected that scale formation can be partially mitigated by scale inhibitors or reinjecting at a higher reinjection temperature and running at a higher flow rate, however this would decrease the efficiency of the geothermal system. It should be noted that water chemistry is based on a single data point from 1979. Further sampling and associated modelling will be undertaken to confirm this risk.

Corrosion is expected to be mitigated by implementing a double-barrier well design, similar to the new Dutch geothermal standard (Geothermie Nederland, 2021), with internally applied corrosion-resistant coating is proposed for the IAF wells to limit the occurrence of corrosion and provide a protective barrier for the outer casing. The cost of internal tubing is expected to outweigh the costs of running corrosion inhibition and other

required maintenance over the lifetime of the wells. Surface piping is expected to be GRE with limited use of stainless steel except in filter barrels and valves. Any potential de-gassing of the brine is expected to be effectively managed by operating a pressurised system of up to 10 bar.

4.4 Mobilization of fine materials

The Winnipeg and Deadwood formations have significant amounts of fine material (below 100 µm) which can be detrimental especially to injection well operation. Wire-wrapped screens with optimal retention will be selected for both the production and injection well. Surface filtration down to 1 µm is typical prior to the heat exchanger. At the Regina IAF, post-heat exchanger filtration is also proposed to catch any scale that forms as the temperature of the brine is reduced.

Fluctuations in flow regime, and especially completely stopping and restarting the system, are known to mobilise fines in both production and injection wells. Running at a constant rate will limit the amount of fines and filter changes required as demonstrated in Australian, Dutch and French geothermal systems. Other design decisions include a wide-range ESP to run at a lower consumption, and the use of thermal buffering within the facility or the use of an external thermal buffer to reduce the amount of variations in the flow regime.

5 CONCLUSIONS

The proposed geothermal doublet system for the Regina IAF represents a technically robust and sustainable design solution for meeting the facility's long-term heating requirements. The design integrates international best practice, drawing on extensive experience from successful geothermal developments in Europe and Australia, while being tailored to the specific geological and geochemical characteristics of the Winnipeg and Deadwood aquifers. Key design elements, including optimised well diameter, inclined trajectories, corrosion-resistant materials, and fine-material management strategies, aim to ensure reliable long-term operation with minimal maintenance intervention. Although uncertainties remain regarding aquifer performance and geochemical behaviour, these have been mitigated through conservative design assumptions and flexibility in system configuration. It is hoped that the project will demonstrate the viability of direct-use geothermal energy in the Canada and provides a model for future low-emission district or industrial heating applications in Regina and beyond.

Acknowledgements

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