City of Regina, Saskatchewan, Canada - Low Temperature Geothermal Infrastructure Project

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ABSTRACT

The geothermal potential of the sedimentary strata found below the City of Regina, Saskatchewan, Canada, was first identified in 1979 with the drilling of a geothermal exploration well on the University of Regina campus. This well indicated that the local geothermal gradient was approximately 30°C/km and temperatures at the top of the Precambrian basement were up to 62°C (143.6°F). While this well has long since been abandoned, the geothermal data collected during the drilling and testing of the well indicated there was potential for a low temperature thermal system. The City of Regina recently made the decision to use geothermal heat to provide the thermal energy needs for a public aquatic center, based on a detailed scoping analysis of the technical and financial aspects of the project. The space heating and pool energy needs will be met by providing 2.5 cubic meters (88.3 cubic feet) per minute of 60°C (140°F) geothermal brine from a depth of 2000-2200 m (6562-7218 ft) to a plate and frame heat exchanger. The equates to 22MBTU per hour heat delivered to the surface facility. An in-depth look at the subsurface for geothermal aquifers has been completed to provide the project with drilling plans, brine volumes, brine chemistry and flow rates. An investigation into the geothermal economics as compared to the baseline natural gas economics was also performed, with forecasting for both carbon and financial costs to 50 years. This project is slated to be the first large scale direct heat use geothermal project in Canada.

1.0 Introduction

The City of Regina is the capital of the Province of Saskatchewan, Canada. The City has a population of just under 230,000 residents and sits above the Western Canada Sedimentary Basin at its eastern margin (Figure 1). The City and its residents have been on the forefront of clean technologies and innovative thinking to invigorate and enliven life for the inhabitants of this prairie city. “Renewable Regina” is a phrase adopted by the City Council in 2018 to highlight its commitment to renewable energy and technologies, with a goal of being net-zero by 2050 (2022).

Regina has warm summers and cold, dry winters, prone to extremes at all times of the year (Table 1). Extremes in terms of winter temperatures are times when temperatures drop below minus 40°C (104°F) (Table 1). However, in compensation, the City has a high rate of sunshine (Table 1; almost 50%) and is one of the top three sunniest cities in Canada. Both outdoor and indoor activities are important for the City's residents. The facility will replace an existing structure with more pools and other amenities. It is part of the City's recreation masterplan and was priorized in 2022. In the City's planning for a new aquatic centre, they evaluated many options in order to determine the best energy source to reduce the greenhouse gas footprint of the new facility, in order to live up to the "Renewable Regina" pledge (2022).

The city is looking for \$128 million in infrastructure funding for the new facility. Of this funding, \$108 million goes towards the pool, and \$20 million goes towards a geothermal plant with a natural gas boiler as backup. "This aquifer-heated pool is the definition of a catalyst project," said Bob Hawkins while addressing City of Regina council members (Ratcliffe 2023). The current study was a precursor to a full Front-End Engineering and Design (FEED) analysis. This study was a scoping study and was taken as a preliminary step to confirm the technical and economic feasibility of the project and should be considered conceptual in nature. It was completed to support the proof-of-concept and Green Infrastructure Grant application of the City of Regina. The study was paid for by the City, and the Petroleum Technology Research Centre located in Regina was engaged to carry out the study. The subsurface work was completed by Terrapin Geothermics, based in Edmonton. Well design and well related aspects of the study was carried out by Remedy Engineering based in Calgary.

Table 1: Climate and sunshine data at the Regina International Airport, SK.

Climate data for Regina International Airport, 1981–2010 normals, extremes 1883–present [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	10.4 (50.7)	15.6 (60.1)	24.4 (75.9)	32.8 (91.0)	37.2 (99.0)	40.6 (105.1)	43.9 (111.0)	41.3 (106.3)	37.2 (99.0)	32.0 (89.6)	23.6 (74.5)	15.0 (59.0)	43.9 (111.0)
Average high °C (°F)	−9.3 (15.3)	−6.4 (20.5)	0.4 (32.7)	11.6 (52.9)	18.5 (65.3)	22.8 (73.0)	25.8 (78.4)	25.5 (77.9)	19.1 (66.4)	11.0 (51.8)	0.1 (32.2)	−7.1 (19.2)	9.3 (48.7)
Daily mean °C (°F)	−14.7 (5.5)	−11.7 (10.9)	−4.8 (23.4)	4.8 (40.6)	11.3 (52.3)	16.2 (61.2)	18.9 (66.0)	18.1 (64.6)	11.8 (53.2)	4.3 (39.7)	−5.2 (22.6)	−12.4 (9.7)	3.1 (37.6)
Average low °C (°F)	−20.1 (−4.2)	−17.0 (1.4)	−9.9 (14.2)	−2.0 (28.4)	4.1 (39.4)	9.5 (49.1)	11.9 (53.4)	10.7 (51.3)	4.6 (40.3)	−2.4 (27.7)	−10.5 (13.1)	−17.7 (0.1)	−3.2 (26.2)
Record low °C (°F)	−50.0 (−58.0)	−47.8 (−54.0)	−40.6 (−41.1)	−28.9 (−20.0)	−13.3 (8.1)	−5.6 (21.9)	−2.2 (28.0)	−5.0 (23.0)	−16.1 (3.0)	−26.1 (−15.0)	−37.2 (−35.0)	−48.3 (−54.9)	−50.0 (−58.0)
Average precipitation mm (inches)	15.3 (0.60)	9.4 (0.37)	19.7 (0.78)	24.1 (0.95)	51.4 (2.02)	70.9 (2.79)	66.9 (2.63)	44.8 (1.76)	32.8 (1.29)	24.5 (0.96)	14.2 (0.56)	15.7 (0.62)	389.7 (15.34)
Average rainfall mm (inches)	0.6 (0.02)	0.8 (0.03)	5.1 (0.20)	18.1 (0.71)	47.6 (1.87)	70.9 (2.79)	66.9 (2.63)	44.8 (1.76)	32.1 (1.26)	18.3 (0.72)	3.1 (0.12)	0.5 (0.02)	308.9 (12.16)
Average snowfall cm (inches)	19.4 (7.6)	11.4 (4.5)	18.8 (7.4)	6.9 (2.7)	3.6 (1.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.3)	6.9 (2.7)	13.0 (5.1)	19.5 (7.7)	100.2 (39.4)
Mean monthly sunshine hours	96.1	133.5	154.5	236.6	262.4	277.7	325.4	287.4	198.1	163.3	97.9	85.4	2,318.2
Percent possible sunshine	36.3	47.2	42.0	57.3	54.8	56.6	65.8	63.9	52.1	48.9	36.0	34.0	49.6

2.0 Climate Lens Study

In the City's planning for a new aquatic centre, they evaluated many options in order to determine the best energy source to reduce the greenhouse gas footprint of the new facility. Associated Engineering was engaged to complete a "Climate Lens" study and greenhouse gas emissions (GHG) cost evaluation (Binns 2023). Geothermal energy, along with electrical (grid and solar) and natural gas options for the heating and cooling of the building were evaluated. Geothermal energy was shown to be cost effective from a long-term financial perspective as well as from a GHG reduction standpoint. During the lifetime of the project, a geothermal energy source limits hydrocarbons usage and minimal grid energy is required, significantly reducing the fuel costs for the facility over its lifetime. Additionally, GHG emissions produced by using other sources of heating are avoided. As part of the economic and technical analysis, the Climate Lens study undertaken by Associated Engineering shows the long-term energy and GHG savings for the City of Regina in operating this facility are significant. These results are reported elsewhere (Binns 2023), but show significant benefits to developing and installing a geothermal heating system.

The advantages of a well-managed geothermal energy system that taps the deep (+2000 m or +6562 ft)) brines contained within the Basal Clastic Unit (Deadwood and Winnipeg Formations) is its baseload attributes, extremely long viability, very low OPEX (not subject to fluctuating fuel costs), and virtually no GHG emissions over the lifetime of the project. No other renewable energy source can claim the same low carbon footprint (Binns 2023) over such a long-life span as geothermal energy. This energy resource could serve the Citizens of Regina well into the next generation and beyond.

3.0 Subsurface Analysis

Terrapin's study was based solely on existing information available from a variety of sources. No new analytical work was carried out (such as brine geochemistry) (Hickson et al. 2023). The results are the best available efforts based on these data sets, the scope of the project deliverables and the time available to complete the investigations. Since much of the gathered data were reports from oil and disposal well (potash) operations in and around the City of Regina, it must be noted that this data was not gathered with a geothermal development lens in mind so the results must be modified for geothermal development scenarios (Hickson et al. 2021, 2023). The exception is the data from the University of Regina well completed in 1979 (Vigrass 1980). Although this was a purpose drilled geothermal well (and the results are extremely valuable for the analysis) the results are based on downhole tools and knowledge that are now more than 40 years old (Vigrass 1980, Vigrass et al. 1986). Despite these handicaps, enough understanding of the subsurface has been obtained to enable decision making.

The time frame for completion of this project was significantly compressed due to a number of factors, but most importantly the timeframe required for the City of Regina to submit a "Green Infrastructure Grant" proposal (2023). Due to these factors the Terrapin team was provided with a scenario to test for the suitability to provide heat at a minimum rate of 20.5 million BTU per hour to the surface facilities. The study results, (within the limits of the data as outlined in the report), determined, with a high level of confidence, that the deep geothermal resource below the project area is suitable for long-term production of hot brines to the surface, sufficient to provide 22.7 million BTUs per hour (MacPherson 2023) for a period of 70 years. Additionally, there is significant evidence, at a high level of confidence, to indicate that the resource may be robust enough to support a larger heating load. Testing the maximum potential of the resource will require more investigations, specifically modelling based on the result of this study.

4.0 Assumptions for the scenario-based feasibility study

- 60 ° C (140° F) bottom hole temperature
- Flow rate: 2.5 cubic meters per minute (2.5 m^3 per minute (2.5 m^3/min) 41.6 litres per second or 660 US gallons per minute)
- Input brine temperature to the heat exchanger of 58° C (136° F)
- Output temperature of the brine 18° C (65° F) for disposal
- 2000 m (6562 ft) separation between the wells in the aquifer
- Heated side of the heat exchanger fluid leaves at 54° C (130° F) and enters at 15° C (60° F)
- Heat delivery to the aquatic centre is at the rate of 22.7 million BTUs per hour, 80% of the time.

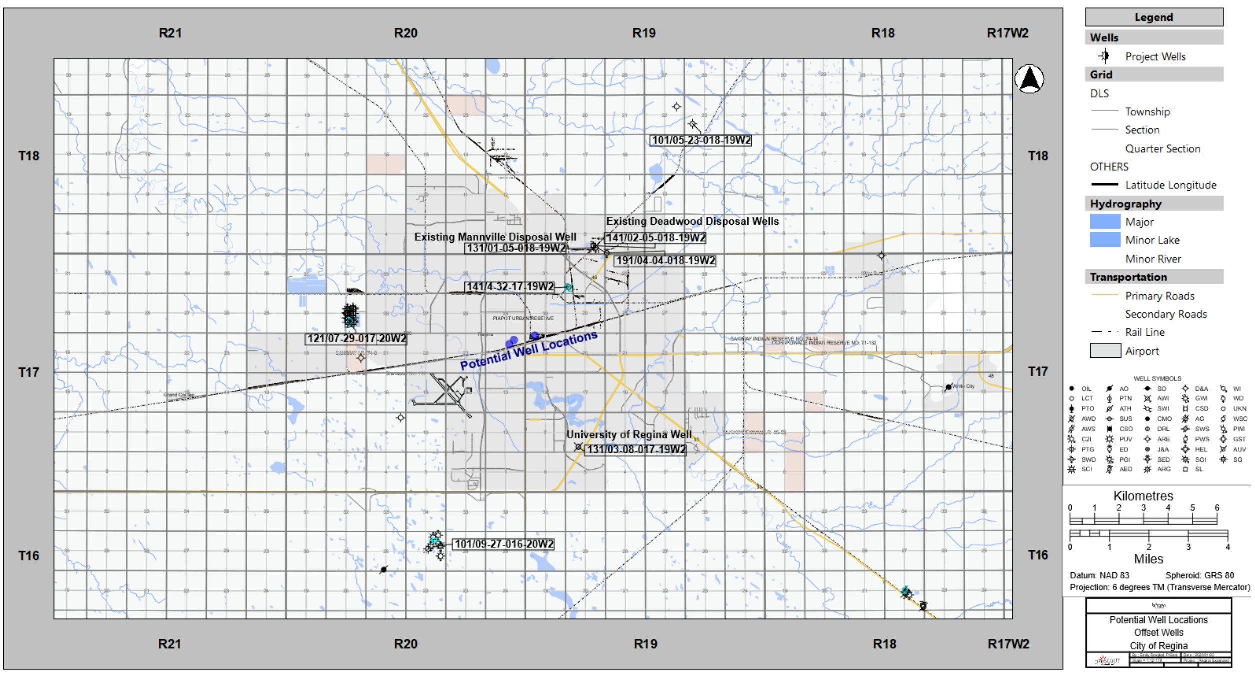

Figure 1: Map showing the City of Regina, Saskatchewan with the possible geothermal well locations and existing offset wells. The proposed drill locations for the geothermal well are in blue.

5.0 Summary Technical Results

Provided below is a summary of the technical results supported by the Terrapin study:

1. **Confirmation of aquifer suitability**: Within the limits of the data, it was determined that the deep geothermal resource below the project area is suitable for long-term production of hot brines to the surface. For the purposes of the analysis the three sites: (a) The Yards; (b) The Sportsplex; and (c) Former Taylor Field site (Figure 1); were considered together and the geothermal capacity is same for all three sites.

2. **Confirmation of the sustained temperature of the geothermal water at surface**: The assumption given was that the resource was 60° C (140°F); this was confirmed and used in the geotechnical and engineering considerations. The heat loss upon being pumped to the surface at a rate of 2.5 m^3/min is 0.98° C (1.76° F).
3. **Confirmation of the anticipated longevity of the geothermal resource:** Review of the available data on the Basal Clastic Unit (Winnipeg and Deadwood formations), gave the following parameters:
    a. Permeability = 155 mD
    b. Porosity = 13.8 %
    c. Thickness – 123 m (403.5 ft)
    d. Rock compressibility = 3.2e-10 1/Pa
    e. Transmissivity = 19,000 mD.m
    f. Pressure = 22 MPa (3190 psi)
    g. Thermal Conductivity – 2.5 W/(m.K)
    h. Estimated Temperature = 60° C (140 °F)
    i. Brine Density = 1058 m3/kg @60° C

   Using these parameters as inputs, the preliminary reservoir modelling showed more than 70 years production, without temperature loss, at a pump rate of 2.5 m^3/min (550 gpm).
4. **Confirmation of a base case water production rate of 2.5 m^3/min (550 gpm)**: Modelling and data analysis support the base case pump rate of 2.5 m^3/min and further, indicate that the 244.5mm (9 5/8" inch) completion well designs (optimized from the original base-case) will provide 32.1 million BTUs per hour @ 2.5 m^3/min (550 gpm).
5. **Consideration of the potential water production rate based on the well design tested**. The analysis of the well design and completions recommended confirm that the smallest completion (7") design for the vertical well will handle the flow rate of 2.5 m^3/min (550 gpm) given the Electrical Submersible Pump (ESP) specifications and a setting depth of 600 m (1968.5 ft). The maximum flow rate is calculated at 350 gpm with a minimum rate of 22 gpm (pump damage will occur at lower flow rates). The flow rate possible in the larger diameter wells with a completion of 9 5/8" (244.5mm) casing with the same ESP set depth is estimated at a maximum of 1,300 gpm and a minimum of 145 gpm.

Additionally, the study confirmed the following:

a) With a high level of confidence, the resource extraction from the Basal Clastic Unit (Deadwood and Winnipeg formations) is expandable beyond the 2.5 m^3/min (550 gpm) specifically modelled in the study. Optimizing the well designs (spacing distance), target zones (specific aquifers within the Basal Clastic Unit) and other operational characteristics will be required and would form part of the FEED study;

b) The study (Hickson et al. 2023) confirms, with a high level of confidence, that the resource, with a properly designed extraction system, is able to meet the minimum base load requirements of 20.5 Million BTUs per hour;

c) The previous studies on the geological character and depositional environment of the Basal Clastic Units (Deadwood and Winnipeg formations) in the Regina area (Vigrass et al. 1986, Vigrass et al. 2007, Lake 2022) have helped develop an initial 2D reservoir model and understanding of the geothermal resource;

d) As noted in (2) above, the heat loss upon being pumped to the surface at a rate of 2.5 m^3/min is 0.98° C (1.76° F). This is assessed with a high level of confidence.

e) The study (Hickson et al. 2023) confirms with a high level of confidence that the base case geothermal water production rate of 2.5 m^3 per minute (550 gpm) is sustainable for 70 years and capable of providing 22.7 million BTUs per hour to the heat exchangers.

f) Further, the study (Hickson et al. 2023) confirms (to a high level of confidence) that additional energy is available based on the investigated project design. As noted in (4) above, 32.1 million BTUs per hour per pound @ 2.5 m^3/min (550 gpm) is available with the system design modelled.

g) Modelling for the FEED study will provide additional insight into the behavior of the system given a higher energy output during the lifetime of the project. A project "Energy Demand Curve" (EDC) will be needed to complete the FEED analysis, but based on the available data, the system modelled in this study can already deliver 32.1 million BTUs per hour. A system delivering twice as much energy as considered (i.e., twice 22.7 Million BTUs per hour) is possible with a moderate level of confidence, but additional analysis and modification of well designs, targeting, pumping capacity and other factors would need to be evaluated to understand the system behaviour over a 70-year time frame. Reservoir engineering and the results of initial well testing and production will serve to validate the higher flow rates.

h) Geological analysis has optimized the well orientation; but confidence might be improved with an analysis carrying out a high-resolution seismic study over the project area.

i) The project design can be further optimized with an Energy Demand Curve and FEED level analysis of the system design with the goal of optimizing the energy output for the CAPEX (capital expenditure) investment. In the FEED analysis the details of the well design, targeting (spacing) pump capacity, piping, etc., will need to be further evaluated to optimize the CAPEX for the energy delivered to the surface.

This study strongly supports the resource potential of the Basal Clastic Unit (Winnipeg and Deadwood formations) in the greater Regina area (Hickson et al. 2023). Additionally, the robust resource provides opportunity for modification of the original project assumptions in terms of well designs, well spacing, pump sizing and other factors to enlarge the project scope to deliver more thermal energy to the surface for a larger development.

6.0 Next Steps

A Front-End Engineering Design (FEED) is required as the next step in project development. The current study was a scoping study, preliminary to a full Pre-FEED analysis as it was scenario based and not optimized for the resource and the size of the heating load . As part of the FEED study the well designs, spacing, pump size and characteristics, would all be reanalyzed to ensure that the project is "right sized" for the heat delivery required at surface for the length of time required.

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