REPORT TO
CUMBERLAND ENERGY AUTHORITY

Researching the Geothermal Potential of the Former Springhill Mine

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1 Introduction

The Cumberland Energy Authority (CEA) entered into a collaborative research program with the Verschuren Centre for Sustainability in Energy and Environment at Cape Breton University (Verschuren Centre) to study the current use of the geothermal resource at the former Springhill Mine and summarize currently available information on the resource. The program was designed to provide a summary report that the CEA can use to move forward other components of the plan to commercialize the geothermal resource associated with the former Springhill Mine.

Exploiting the geothermal potential in the former Springhill Mine is not a new concept. For approximately 30 years, the resource has been studied, explored and used for heating and cooling of businesses in Springhill. While commercial users of the resource have come and gone, some users continue to benefit from using the resource to heat and cool their operations, saving money. How these users make use of the resource, and attempting to quantify the savings to their operations, is a current goal of the CEA and Verschuren Centre research.

2 Background

In many regions of the world, flooded mines are a potentially cost-effective option for heating and cooling using geothermal heat pump systems. There are now many former mining sites across the world that uses geothermal energy to provide heating and cooling for all types of buildings and industries (Watzlaf and Ackman, 2006). Springhill was the original world leader in championing the use of groundwater from flooded coal mine workings for heating and cooling buildings (since 1989), with many other attempts world-wide to follow the lead of Springhill.

Springhill is famed for having some of the deepest coal mines in North America, with depths reaching 1323 m. Coal mining became the primary industry for the town in 1849 and continued until a series of mining disasters forced the closure of the mines in 1958. This was the end of large scale coal mining in Springhill. Over the years, the mine tunnels started to flood with water, providing a valuable resource for the community. Various estimations of the volume of water in the workings have been produced over the years. Vaughan Engineering Associates Limited (1992) estimated that the No. 2 Seam could contain approximately 4,350,000 m^3 of water, while the No. 1 Seam held the potential for 1,058,400 m^3 of water. Brian Herteis (2006) undertook a much more detailed GIS analysis of the No. 2 Seam and estimated a total water storage volume of 5,583,000 m^3. In general, it can be concluded that the mine workings contain sufficient volume to supply the Town of Springhill.

Interest in the exploitation of this resource and the utilization of geothermal energy has been on-going since 1984 when Ralph Ross first proposed the possible uses of mine warm to help maintain existing industries in Springhill and also attract new industries due to the energy cost savings afforded by geothermal energy systems. The first application of mine water geothermal was made in 1989 at Ropak Can-Am Plastics through a system of heat pumps and wells. The system's first year of operation saved Ropak an estimated $15,103 on their energy expenses even though the factory was expanded from 35,000 square feet to 117,000 square feet. Today, there are multiple users of geothermal energy in Springhill, with many users satisfied with the benefits of their geothermal systems, which is being used for both heating and cooling purposes.

3 Methodology

This research program was divided into four primary components:

- Review and summary of existing research
- Interviews with currents users of the geothermal resource
- Collection of field data
- Mine water quality monitoring

Each of these project components is described in detail in the following four sections.

3.1 Literature Review

The CEA provided the Verschuren Centre research team with a large number of geothermal related documents dating back to the early 1980s. Our team reviewed the documents in detail and summarized the information that was determined valuable for the CEA moving their goals forward.

The documents included many well drilling reports, information on pumping tests that were conducted after well installations, student studies, consultant reports and provincial agency reports. Many previous reports include general information on geothermal energy or economic development, which is not the primary focus of this report. This report summarizes data specific to the former Springhill Mine that is available in previous studies to make future progress for the CEA as efficient as possible.

In addition to documents and reports available through the CEA, the Verschuren Centre conducted a thorough search of academic publication databases to identify research that focused on, or referenced, the former Springhill Mine. Information from these reports was included in the summary of existing research.

3.2 Geothermal User Survey

The research team approached each of the current mine water geothermal users in Springhill and conducted interviews with company personnel that had some understanding of the geothermal heating and cooling system(s). Interviews were conducted with the following representatives:

- Nova Scotia Community College – Darrin Embree
- Ropak Packaging – Wendell Crowley
- Fitness Centre
- Dr. Carson and Marion Murray Community Centre – Scott Munro
- Surette Battery
- Golden Opportunities Vocational Rehabilitation Centre (GOVRC) – Paul Williams

The information collected during the interviews is summarized in the results section of this report.

3.3 Field Data Collection

The field program was conducted over a period of two months and included two days of onsite data collection. On-site data collection events were conducted on July 15 and September 16, 2015. On-site data collection included a meeting with Brian Herteis, Capital Projects Engineer at Cumberland County, to (i) discuss the previous studies and consultant reports available for this project, (ii) meet with current users of the geothermal resource, (iii) obtain mine water samples, and conduct the following activities:

- Inspection of supply and return wells, both active and inactive
- Measurement of mine water levels
- Installation of temperature and pressure transducers in pumping wells to monitor mine water level and temperature over a two month period
- Inspection of general well integrity.

3.4 Mine Water Quality Monitoring

Mine water quality can have a direct effect on its potential use for geothermal energy. Low quality mine water will be acidic and contain high concentrations of dissolved metals, specifically iron. The acidic nature of the mine water will corrode geothermal infrastructure prematurely. High metals concentrations in mine water can result in precipitation of metals if oxygen is introduced. This precipitation will result in solids forming in the mine water, clogging geothermal infrastructure.

The quality of the mine water currently being pumped and used by active geothermal users was evaluated in several ways. During sample collection from operating systems, field parameters were collected, including the following:

- pH
- Temperature
- Electrical conductivity
- Total dissolved solids
- Dissolved oxygen
- Redox potential

The second step in mine water quality monitoring was the analytical testing of samples for general chemistry and total metals concentrations. In total, six mine water samples were collected from active systems for total metals analysis and two for general chemistry. Locations of these samples include:

- Ropak Packaging
- Town Loop (GOVRC)
- Nova Scotia Community College
- Dr. Carson and Marion Murray Community Centre
- Fitness Centre
- Surette Battery

4 Results

4.1 Literature Review

Detailed results of the literature review and references are provided in the annotated bibliography provided in **Appendix 2**. A summary of information relevant to this project is provided below.

In 1986, a report was prepared by Booth Engineering Limited. The Springhill Minewater Geothermal Heat Source presented the feasibility and value of using the mine water of the former mine for geothermal applications. It presented the information known at the time on the mine water resource, the technology available to exploit it and the economic benefit to ownership of, and rights to, the resource. The report included mine working plans and descriptions developed by Ross (1981) and proposals by Ross (1984) and Braybrooke (1985).

The first three geothermal wells in Springhill were drilled in 1987 (Jacques Whitford, 1987 and International Groundwater Symposium, 1988). One of the three wells (GTW-3) eventually went into use as the Town Loop supply well. The three wells were advanced into Seam 2 of the former mine with maximum depths of 84 m. One of the three wells did not hit open workings resulting in insufficient yield, and a second well hit caved workings or the edge of a pillar based on wood in the drill returns. GTW-3 provided sufficient yield for geothermal use and mine water temperatures observed during pump tests following drilling ranged from 9°C to 13°C. The borehole logs for these wells were the earliest record found of geothermal exploration at the former Springhill Mine. Warren (1993) developed temperature logs for these wells.

GTW-4 and GTW-5 were drilled in late 1987 for the Nova Scotia Power facility (Jacques Whitford, 1988), which is now the town Fitness Centre. One well hit pillars in both Seam 1 and Seam 2 so it could not be used as the supply well. GTW-5 was used as the supply well; but during drilling, was reportedly contaminated with inflowing groundwater. Water quality analysis supported this. Both wells were drilled through Seam 1 into Seam 2 with mine water temperatures of 11°C to 14°C. During a seven-day pumping test, a mine water temperature of 13°C was consistent with the groundwater intrusion suspected. Response in water level at other wells was observed during the pumping test. Difficult drilling conditions were recorded in this report due to fracturing and caving zones.

Geothermal wells drilled for ROPAK (GTW-6 and GTW-7) were drilled in 1988 into Seam 2 (GTW-6) and Seam 3 (GTW-7) (Ross, 1988). The supply well GTW-6 was drilled to a total depth of 137.5 m and required replacement in 2000 due to collapsed casing.

Surrette Battery had four wells drilled for their geothermal system. In February/March 1989, GTW-8, GTW-9 and GTW-10 were installed in Seams 1, 2 and 3, respectively. GTW-8 was the initial return well but required replacement in 2012. Well depths were 63 m into Seam 1 and 104 m into Seam 2. Water levels have been observed between 8.9 m and 34.6 m below ground with temperatures between 12 °C and 14 °C with over 300 gallons per minute (gpm) production capacity.

GTW-11 and GTW-12 are currently inactive, but were initially drilled for Pizza Delight/JBs Pub (Jessop, 1990). These wells were advanced in Seams 6 and 7, respectively, with total depths of 150 m and 119 m (Seam 6 is deeper than Seam 7). Interestingly, these two wells are only 7 m apart and appear to be the closest supply and return well set observed during this program. This project was considered a success that lead to the development of the District Heating Scheme (Town of Springhill, 1990b). Ten sites were identified as potential end users of a geothermal heating loop. GTW-13 and GTW-14 were proposed as part of that program. GTW-13 is a return well for the Town Loop (GTW-3) and was installed into Seam 2 in 1990 (Ross, 1992).

Expansion of the geothermal system in the Industrial Park continued in 1991 with the drilling of GTW-14 and GTW-15 for industrial park use (Ross and Kavanaugh, 1993). Information on these two wells is very limited; however, total depths were 49 m and 68 m, respectively. Similarly, GTW-16 was drilled into Seam 4, but little information is available on this well. GTW-17 and GTW-18 were drilled into Seam 6 for the Parkview Centre offices. GTW-19 was also drilled into Seam 6 with little information available.

In 1992, K. Arkay developed the Geothermal Energy from Abandoned Mines: A Methodology for an Inventory, and Inventory Data for Abandoned Mines in Quebec and Nova Scotia, Geological Survey of Canada Open File 3825, September 2000. He presented and summarized the major point identified in a 1993 report: First Springhill Geothermal Energy Conference, Springhill, Nova Scotia, 28-29 October 1992. Geological Survey of Canada Open File 2773, December 1993.

Brown's Funeral Home once operated on geothermal, with GTW-20 and GTW-21 installed into Seams 6 and 7 in 1994. Also in 1994, a three-month study was conducted with eight users of the geothermal resource to monitor mine water flow, incoming and outgoing temperatures, as well as incoming and outgoing air through the geothermal heat pumps systems (Bagnell, 1994). These resource use parameters have not been sufficiently monitored since that study.

One of the documents provided to the Verschuren Centre by the CEA is a Springhill Geothermal Resource 1994 Report Vol.1 in a white binder. This report provides a very useful summary of the work conducted in 1993 and 1994 to evaluate the geothermal resource at the former Springhill Mine. The Jessop (1993), Ross and Kavanaugh (1993) and Bagnell (1994) reports are included therein, as are DNR maps that were used for resource evaluation.

Jessop, MacDonald and Spence (1995) developed the report: Clean Energy from Abandoned Mines at Springhill, Nova Scotia, and presented at the World Geothermal Congress in Florence, Italy, in 1995. They studied two methods to estimate the volume of the flooded mines, terrestrial heat flow, geothermal gradients and physical processes within the flooded mines. This study reported on the operation of the ROPAK geothermal system between March 1989 and March 1990, including operational costs. This type of data collection is now required in order to quantify the savings being recognized by current users in order to support potential business plans.

The Dr. Caron and Marion Murray Community Centre have a total of six wells associated with its geothermal system. Most were drilled in 2003 (Seams 1 and 2) (Hy-Grade Geoscience, 2004) with a replacement return well (CC-R) drilled into Seam 3 in 2011. Two of the original well drillings were considered unsuccessful due to low yields or observed groundwater intrusion. These wells have since been considered observation wells. The initial return well was decommissioned upon replacement with CC-R.

Supply and return wells at the Nova Scotia Community Centre (NSCC) are installed into Seam 6 and no information could be identified for the inactive supply and return wells at the Fire Department or the Springhill Public Works facility.

Cumberland County Capital Project Engineer, Brian Herteis, generated a very detailed report (Herteis, 2006) for the Town of Springhill prior to joining the Public Works Department. This report includes temperature gradients of eight mine water wells and estimates the mine water capacity of the No.2 Seam based on mining practices in various areas of the mine. The data summarized in this report and the techniques employed should be considered for future research of the resource. Kavanaugh (2006) also developed similar estimates for the No. 6 Seam and No. 7 Seam.

In 2007, the Nova Scotia Department of Energy, Nova Scotia Department of Natural Resources and the Town of Springhill prepared the Evaluation of Geothermal Energy Potential in Springhill, Nova Scotia. This is a very robust report with (i) climate and geology information, (ii) categories of geothermal applications, (iii) a discussion on the importance of understanding subsurface conditions, (iv) references Mr. Ralph Ross as a local resource of geothermal knowledge and experience, (v) mine water temperatures at the Community Centre, (vi) a summary of previous capacity estimates and existing systems, and (vii) calculations of energy potential and critical issues impeding development of the resource.

Recommendations in the report include a GIS study of subsurface mine workings, exploratory drilling of deeper resources, pumping tests to determine interconnectivity, and an evaluation of system requirements to assist system capacity design.

Other documentation that relates to the project, but is essentially a summary or discussion of existing information, is described in **Appendix 2**.

4.2 User Interviews

Six users of the geothermal resource were interviewed as part of the data collection program. In general, the personnel that were interviewed were familiar with the geothermal system(s), but were not able to provide specific details on routine operations. Significant information collected during the interviews is presented in the following subsections.

4.2.1 Ropak Packaging

- Ropak operated in their location since the 1960s, but an expansion in 1989 led to the installation of the geothermal system for both new and existing buildings. Before geothermal, the buildings required approximately 1000 gallons of oil per month for heating purposes.
- Air conditioning is constant through the summers and indoor temperatures are self-regulated at 65°F during the winters. They do not use the geothermal resource for industrial purposes, solely climate control. The only backup system are some baseboard heaters in the front offices.

- They have experienced challenges with infrastructure failures. Their supply well collapsed in 2000 and required a replacement well to be drilled. They have experienced drops in heat pump efficiency due to clogging and ultimately replace these units. They installed five new heat pumps in 2013 and will be ordering another five to replace when the time comes. Approximately every 10 years, the water supply submersible pump requires replacement. This pump is operating at a depth of 240 feet in the well.
- They were not aware of the flow rate or incoming temperature of the mine water.

4.2.2 Nova Scotia Community College

- The system was installed at the NSCC in 2009/2010 and is a component of the refrigeration program at the school.
- It is used for just a portion of the building, specifically the back laboratories and offices. The remainder of the building uses oil furnaces. The operator believes that the system is sufficient to supply the entire building and some of the required infrastructure is already in place to make that transition.
- Their system includes two closed loop systems for instruction purposes. These systems do not use mine water.
- They have not experienced any significant challenges since the system began operation, with very little maintenance required.
- During the system installation, it was operating at 7-9 gpm. There is currently no measurement of flow, but is assumed to be in the same range. NSCC is considering the installation of monitoring equipment to develop a better understanding of system operation.

4.2.3 Surette Battery

- The building has been in place since the 1950s and the geothermal wells and system were brought online in 1989.
- They use approximately 80% of their geothermal resource draw for climate control and the remaining 20% for cooling during the manufacturing process.
- The geothermal resource is used for heating and cooling of the production floor and offices year round. They do not require additional sources for heating and cooling with the exception of small heaters in some offices.
- They have experienced some heat pump failures due to the mine water, but it has been seven to eight years since the last replacement. One water supply well (GTW-9) required pump replacement twice in three years, while their second supply well (GTW-10) has not required a pump replacement for more than five years. This suggests different water qualities in the two wells.

- Their system operates at approximately 100 gpm. This was recorded during the replacement of heat pumps or well pumps only, and is not monitored.
- The sample collection point was on the factory floor and part of the industrial cooling component of the system. The sample collected was 17.3 °C suggesting that it was already heated by the climate inside the building or had already been used for industrial cooling.

4.2.4 GOVRC

- This operation began in 1981 and the geothermal system came online around 1993. The current manager has only been in this position for a year, so his knowledge of the system is limited.
- There are three heat pump systems at GOVRC that operate on the Town Loop supply. One heat pump supplies the greenhouse, which requires oil furnace support in winter. A second and third heat pump supply heating and cooling to the main building. An extension for the woodworking operation uses an oil furnace with no source of air conditioning.
- They have experienced issues with system maintenance. As this is a non-profit society, maintenance costs can be an issue. They have experienced pipe leaks due to corrosion and have replaced some metal pipes with plastic.
- They are concerned with high electricity costs for operating the heat pumps; however, electric heat is also used in one building, so a more thorough review of their energy use at GOVRC is warranted.
- The manager had no way of knowing the flow rates that GOVRC was using or the temperature of the incoming mine water.

4.3 Field Data Collection

Field inspections of the mine water geothermal wells were conducted on July 15 and September 16, 2015 with the assistance of Brian Herteis. The following points summarize the activities (in addition to interviews and sample collections) undertaken at the well sites during those days, with relevant information provided in other reports sections as warranted. Field measurements are provided in **Table 1** and photographs of the geothermal wells inspected are provided in **Appendix 5**.

- Two inactive geothermal wells were inspected at the former Pizza Delight/JB's Pub. These two wells are located in a residential lot adjacent to the vacant commercial property. Mine water levels were collected (Table 2) and a data-logger was installed in the return well. A submersible pump remains installed in the supply well.
- The Dr. Carson and Marion Murray Community Centre utilizes the geothermal resource for heating and cooling purposes seasonally, making use of the cooling properties to manage heat generated by ice making for the

rink. During the site visit, the flow rate of mine water was recorded from an inline flow meter. Incoming and outgoing mine water temperatures were also available through system monitoring equipment. It was noted that a plate heat exchanger was used as part of the system.

- Golden Opportunities Occupation Rehabilitation Centre (GOVRC) is a government operated work environment for people with learning disabilities. This facility utilizes three geothermal heat pumps for climate control in three main sections of their facility, including a greenhouse. Management are pleased with the operation of the heat pumps, aside of maintenance costs. Due to inadequate plumbing during the first field event, a mine water sample was unavailable. Prior to the second field event, access points were installed for sample collection and monitoring of field parameters. Flow rate was not available. This facility operates on the Town Loop. The Town Loop well was monitored for depth to mine water and a data-logger was installed to monitor changes in water level and temperature. Information was collected from the electrical meter supplying the Town Loop well to estimate costs of operating the Town Loop.
- Two supply wells and one return well were monitored at the Surrette Battery facility. Water levels were measured and a data-logger installed in one of the supply wells (GTW-10). It was advised that a water level should not be collected from the return well because it has either sloughed in downhole, or was originally completed within a pillar, reducing its capacity for water discharge and resulting in abnormally high water levels. A sample was collected here during the second field event.
- Fitness Centre – This facility is a residence/small business that has made use of the geothermal resource for over 10 years for heating and cooling. The supply well was measured for water level, a mine water sample was collected for analysis, and field readings were collected.
- NSCC - The NSCC employs a three way geothermal system that includes mine water supply and return wells (in addition to two closed loop systems). Only a portion of the building is heated/cooled using this system. Mine water levels were measured, a mine water sample was collected for analysis, and field parameters were recorded.
- ROPAK Packaging – Both the supply and return wells of the ROPAK geothermal system were monitored for water level. The supply entering the building was sampled and monitored for field parameters.
- Springhill Public Works – This inactive well was monitored for water level only.
- Constituency Office – without prior authorization, our researchers located, but did not monitor this supply well.
- Funeral Home – without prior authorization, our researchers located, but did not monitor these supply and return wells.

- Fire Department – without prior authorization, our researchers located, but did not monitor these supply and return wells.

4.3.1 Mine Water Well Survey

Verschuren Centre researchers, with the assistance of Brian Herteis, conducted well inspections at as many supply and return wells as possible over the two-day field program. In total, 20 wells were visually inspected; of these, 12 were supply wells and seven were return wells with one well use unknown. Wells were inspected for general integrity, GPS location, mine water level (at locations where permission was obtained), total depth and general information. Of the 21 wells included in the survey, 12 of the wells were in active use and nine wells were inactive. Important information to note about the well systems includes:

- Mine water wells currently in use appear to be regular water well installations. Similarly, the submersible pumps are regular domestic well pumps.
- One active supply well (Community Centre) appears to be slightly damaged in its power supply (broken conduit).
- Several of the mine water wells (both active and inactive) are flush mount wells (flush with ground surface), whereas others have an above-ground section up to 1m above ground surface.

4.3.2 Mine Water Level Monitoring

Measured depths to mine water range from 1.9m below top of well casing, to 34.6m below top of well casing. The very shallow measurements are attributed to return flow being discharged back into the mine. The deeper measurements are attributed to, at least in part, higher elevations of the well installations (e.g., Ropak and Town Loop).

Water level data collected by the pressure transducers installed in GTW-3 and GTW-10 is presented in **Figure 2 and 3**, respectively. There are data anomalies in both of the figures with spikes in water level that cannot be attributed to rainfall events. These anomalies may be attributed to debris inside the wells that affected the operation of the transducers.

There are two interesting points to observe in the water level trends over this two-month period. Firstly, the water levels decreased over the period from July 15 to September 16. The decrease in water level is not significant (e.g., less than 1 m), but it is likely attributed to a decrease in the infiltration of surface water and shallow groundwater into the mines during low precipitation summer months.

A second interesting note is in the well that was installed at the Surette Battery facility. Upon inspection, it appears that the water level fluctuates on what could be interpreted as a five-day work week schedule. There appears to be fluctuations in the water level in cycles of five with short stable periods between them. This could appear as mine water level fluctuations during Surette's main production periods, with high demand for heating and/or cooling requirements, followed by "weekend" periods were demand drops off, allowing the mine water level at the supply well to stabilize.

This fluctuation is minor (0.25m) and is not considered a concern. Likewise, the decreasing mine water level over the summer period is not considered to be a concern at this time. But these observations confirm that the water level in the mine(s) fluctuates based both on infiltrating groundwater and surface water, as well as demand and recirculation time.

4.3.3 Mine Water Temperature Monitoring

The transducers that were used to monitoring fluctuations in groundwater level were also used to track changes in the temperature of the mine water over the same period. The transducers were installed within the wellbore of both wells and therefore represent the temperature of the water being extracted by the submersible pump and being used in heat pumps.

As shown in **Figure 4**, the temperatures of the mine water in wells GTW-3 and GTW-10 is very stable in the 12-14 °C range of the period of July 15 to September 16. It is interesting to note that the mine water temperature in both wells increased slightly over the period (somewhere in the range of 0.5 °C). It is possible that a decrease in the infiltration of surface water and shallow groundwater into the mine water during the summer months, may have decreased the cooling effect of this infiltration, thereby increasing the temperature of the mine water being extracted for geothermal use.

4.4 Water Quality Monitoring

4.4.1 Field Parameters

Six mine water samples were collected from active geothermal resource users. In each case, a sample location had to be identified upon the request. In the case of the GOVRC, a sample point had to be installed in the intake system in order to obtain a sample of the mine water.

With the exception of the Fitness Centre, each geothermal system was in full operation at the time of assessment. This means that each system was pumping and operating under normal conditions. In the case of the Fitness Centre, the pump system was activated and allowed to run for 10 minutes before the sample was collected, to ensure a representative mine water sample.

In each case, one sample of the mine water was bottled for water quality analysis, and a second sample was used for the measurement of field parameters. Field parameters measured in the mine water samples presented the following results:

- pH: 6.7 – 7.8
- Electrical Conductivity: 1153 – 5594 uS/cm
- Dissolved Oxygen: 12-70%
- Total Dissolved Solids: 1412 – 4721 ppm
- Redox Potential: -93.6 to 37.7 mV

4.4.2 Water Quality Analysis

During the initial field monitoring event (15 July 2015), two mine water samples were collected (Community Centre and Fitness Centre). These two samples were analyzed for general chemistry and total metals analysis. It should be noted that Maxxam Analytics Inc. of Sydney, Nova Scotia, conducted the general chemistry analysis. Maxxam also provided total metals analysis, which was also conducted by the Verschuren Centre.

It should be noted that Surette Battery uses two supply wells and we were unable to isolate the two wells for water sample collection. It is unclear if the water sample was provided from GTW-9, GTW-10 or a combination of the two.

4.4.2.1 Mine Water Acidity

The majority of acidity in mine water arises from free protons (manifested in low pH) and the mineral acidity arising from dissolved iron, aluminum, and manganese (Watzlaf et al., 2004). The acidity of a mine water sample is calculated from its pH and the sum of the milli-equivalents of the dissolved acidic metals. In many acid mine drainage investigations, the acidity is calculated as follows (Kirby and Cravotta, 2005; Park et al., 2015):

$$Acidity_{calc} = 50 \cdot \left\{ 2 \cdot \left[Fe \right] / 56 + 3 \cdot \left[Al \right] / 27 + 2 \cdot \left[Mn \right] / 55 + 1000 \cdot 10^{(-pH)} \right\}$$
(1)

Where: the concentrations of the metals Iron (Fe), Aluminum (Al), and Manganese (Mn) are given in units of mg/L, and 50 is the equivalent weight of $CaCO_3$, which converts the acidity in units of meq/L into units of mg/L of $CaCO_3$ equivalent. A number of studies have demonstrated the acidities estimated using Equation (1) are in good agreement with the measured acidities over a broad range of pH values (e.g., Watzlaf et al., 2004; Kirby and Cravotta, 2005).

Water with pH > 4.5 has acid neutralizing capacity and is said to contain alkalinity. The principal form of alkalinity in mine water is dissolved carbonate, which can exist in bicarbonate and carbonate form. Alkalinity and acidity are not mutually exclusive terms. When water contains both mineral acidity and alkalinity, a comparison between the two measurements results in a determination as to whether the water is net alkaline (alkalinity > acidity) or net acidic (acidity > alkalinity). Net alkaline water contains enough alkalinity to neutralize the mineral acidity represented by dissolved iron and manganese. Net acidic water means that the mineral acidity plus acidity generated by the oxidation and precipitation of metals exceeds the initial alkalinity. The calculated net acidity is presented as follows (Park et al., 2015):

$$NetAcidity_{calc} = Acidity_{calc} - Alkalinity$$
(2a)
$$NetAcidity_{calc} = 50 \cdot \left\{ 2 \cdot \left[Fe \right] / 56 + 3 \cdot \left[Al \right] / 27 + 2 \cdot \left[Mn \right] / 55 + 1000 \cdot 10^{(-pH)} \right\} - Alkalinity$$
(2b)

Where: alkalinity is measured in mg/L as $CaCO_3$.

Geochemical analysis was conducted on the groundwater samples collected from the Community Centre and Fitness Centre on 15th July 2015. It is evident from the geochemical properties of the water samples that the acidity in the water is relatively low. For instance, the concentrations of the metals Iron (Fe), Aluminum (Al) and Manganese (Mn) at both locations are low (<5 mg/L), with a corresponding pH of ~7.3. Using Equation 1, this equates to a calculated acidity of 3.98 mg/L for the Community Centre and 9.99 mg/L for the Fitness Centre. Furthermore, it is evident that both groundwater samples contain significant alkalinity (>400 mg/L) that will neutralize the acidity, resulting in net alkaline water.

5 Conclusions

The purpose of this study was to collect, review and summarize data that is currently available for the geothermal resource at the former Springhill Mine. The following conclusions can be made:

- The resource is currently being exploited in the shallow sections of the former mine.
- Mine water quality at the current geothermal installations is higher than expected. The water does not present high acidity or metals loadings; mine water factors that can negatively affect geothermal infrastructure.
- Mine water temperatures at the current geothermal installations are normally between 12 and 14 degrees Celsius. It is therefore not the high temperature of the mine water that makes it appealing for geothermal applications; it is the moderate temperature and high capacity.
- With the exception of the Dr. Caron and Marion Murray Community Centre, very little data is being collected from operating geothermal systems. The

NSCC plans to implement a monitoring program to record system data for training purposes.

- Though outside of the scope of work, it was noted that the electrical meter that supplies the town loop recorded 1108 kWh of power used by the Town Loop Submersible pump for a 60-day period. At current rates, this represents a cost of $166.

6 Recommendations

At this point in the project, the Verschuren Centre research team would like to recommend the following three activities.

6.1 Implementation of a data collection program

Most of the current users of the geothermal resource have little interest in the details of their geothermal systems. The systems are repaired as required, but these systems perform well and specifics are not required for these operations. The research team suggests an ongoing data collection program be implemented to collect one year of data from four-six users of the resource. Data can be collected monthly or quarterly to identify changes and trends in the data. Important information to collect:

- Incoming and outgoing mine water temperatures
- Flow rates
- Well pump and heat pump energy use
- Repairs or system maintenance

This information can be used to estimate energy capture and cost savings for each of these installations. When considered relative to one another, estimates could then be determined for proposed resource installations such as new businesses considering a relation to the Springhill area.

In addition to the collection of data from active geothermal systems, there are several inactive geothermal systems in Springhill that could be assessed for potential use. Well inspections and pumping tests could be conducted on these existing supply/return wells to determine the feasibility of putting them back into use.

6.2 GIS mapping of the former Springhill Mine

Brian Herteis of Cumberland County previously conducted an in-depth study of the former Springhill Mine workings and their locations relative to surface. The importance of this information cannot be overstated. In order to accurately install mine water wells to exploit the geothermal potential of the former mine, precise geographic information must be available prior to the initiation of any drilling program. Details on the mining method used in different areas of the mine and accurate representation of these areas is required in order to accurately locate a drilling site that will access open and flooded mine workings.

Geographic information systems (GIS) are a powerful tool that has been used to achieve this level of precision on the Sydney Coalfield. Our team recommends that the CEA undertake a GIS survey of the former Springhill Mine, making full use of the experience of Brian Herteis, to develop precise coordinates for future drilling. This exercise will also allow for additional study of the volume of open and flooded mine workings to allow for capacity determinations.

6.3 Exploration and Pilot Project

In order to attract business to the Springhill area, it will not be enough to showcase the current users of the resource. The resource must be explored to fully describe its future potential and secure investment from companies looking to save money on heating and cooling costs.

We propose an exploration program into deeper sections of the mine. This will allow for determination of mine water quality and temperatures at deeper depths, important information that is not currently available with the existing well network. With exploration wells, a pilot project could be implemented. The purpose of the pilot project will be to confirm the potential of the geothermal resource by applying a heating or cooling demand on a pilot system. For example, a greenhouse, temporary or fixed, could be installed for a local grower and make full use of the mine water geothermal energy. This installation would be closely monitored to collect data that supports the savings being recognized using geothermal versus conventional oil or electrical heat. This study would be a selling feature of the resource, demonstrating the economic benefit potential of using this resource efficiently to prospective commercial entities.

References (in addition to the annotated bibliography in Appendix 2)

Kirby, C.S., and Cravotta, C.A., III. (2005) Net alkalinity and net acidity 1: Theoretical considerations. Applied Geochemistry, 20, 1920-1940.

Park, D., Park, B., Mendinsky, J.J., Paksuchon, B., Suhataikul, R., Dempsey, B.A., and Cho, Y. (2015) Evaluation of acidity estimation methods for mine drainage, Pennsylvania, USA. Environmental Monitoring and Assessment, 187:4095.

Watzlaf, G.R., Schroeder, K.T., Kleinmann, R.L.P., Kairies, C.L., and Nairn, R.W. (2004) The Passive Treatment of Coal Mine Drainage. U.S. Department of Energy, DOE/NETL-2004/1202.

APPENDIX 1

Table 2 Mine Water Quality Analysis

APPENDIX 2
Literature Review

APPENDIX 3
Geothermal Mine Water Well Database

APPENDIX 4

Herteis (2006) - Town of Springhill NS Geothermal Assessment - No. 2 Seam

APPENDIX 5
Geothermal Well Monitoring Photographs