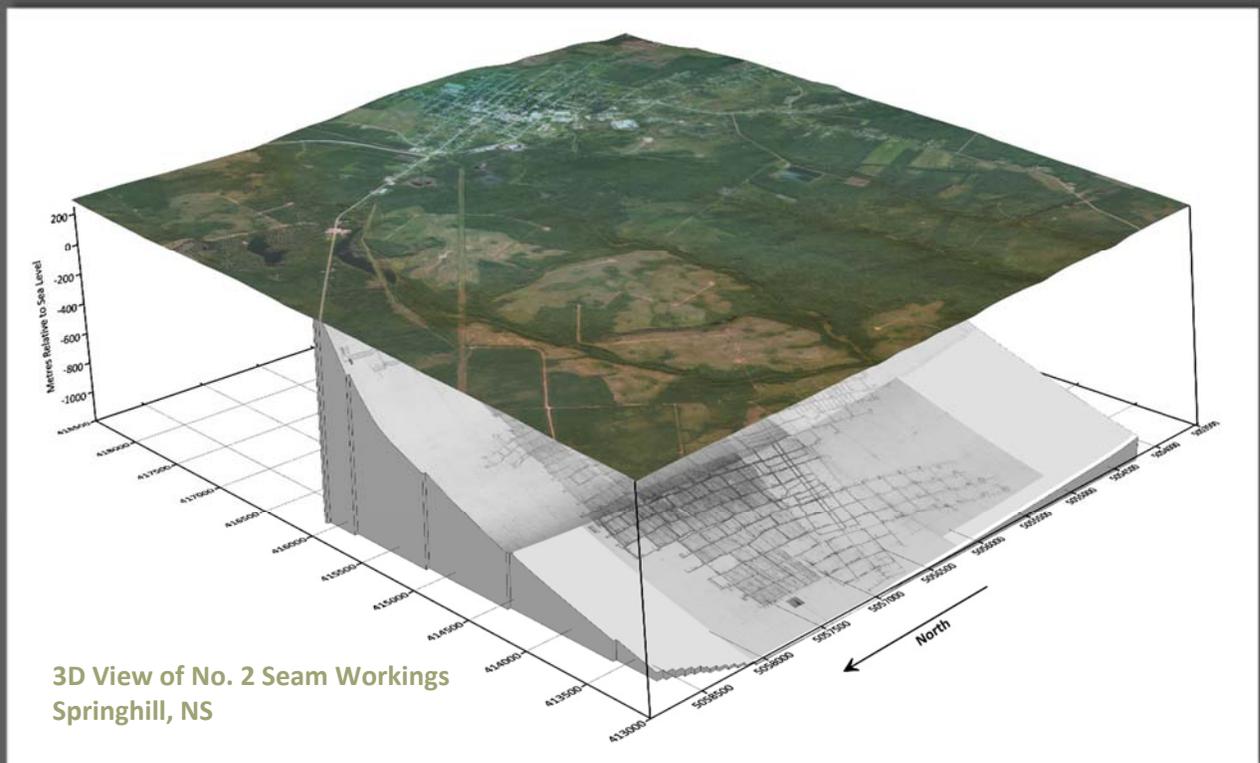


Mine Workings Spatial Analysis Review And Deep Well Test Boreholes

Springhill, NS



3D View of No. 2 Seam Workings
Springhill, NS

172437.00 • Report • March 2017

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Prepared for:
**Municipality of
Cumberland**

Prepared by:



CBCL LIMITED
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March 28, 2018

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Dear Mr. Waugh-Cress

*RE: Report - Mine Workings Spatial Review and
Deep Well Test Boreholes – Springhill, Nova Scotia*

CBCL Limited (CBCL) was retained by the Cumberland Energy Authority (CEA) for provision of professional services associated with the Request for Proposal (RFP) RFP-CEA16-01 Mine Water Geothermal Study Mine Workings Spatial Analysis Review and Deep Well Test Boreholes, Springhill Community.

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The purpose of the review was to conduct a spatial analysis review of the abandoned underground coal mine workings at Springhill and provide recommendations and technical assistance for deep well test boreholes. The spatial review involved checking the accuracy of previously geo-referenced mine workings while the borehole component included assisting CEA with locating, drilling, geotechnical logging, and testing boreholes drilled into the mine workings. The project was initiated in May 2017, with drilling taking place in January and February 2018.

All key deliverables were provided previously to CEA on-going through the project. This report summarizes what work was completed and the methods used.

Thank you for the opportunity to work with you on this very interesting project. Please do not hesitate to call if you require clarification of any of the issues discussed.

Yours very truly,

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**Solving
today's
problems
with
tomorrow
in mind**

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CHAPTER 1 INTRODUCTION

CBCL Limited (CBCL) was retained by the Cumberland Energy Authority (CEA) for provision of professional services associated with the Request for Proposal (RFP) *RFP-CEA16-01 Mine Water Geothermal Study Mine Workings Spatial Analysis Review and Deep Well Test Boreholes, Springhill Community*.

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The spatial review involved checking the accuracy of previously geo-referenced mine workings while the borehole component included assisting CEA with locating, drilling, geotechnical logging, and testing boreholes drilled into the mine workings. The project was initiated in May 2017, with drilling taking place in January and February 2018.

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CHAPTER 2 SITE HISTORY

The Springhill coal reserves were originally leased to the General Mining Association (GMA) by the Duke of York in 1825. To facilitate larger commercial development of the reserves, the Springhill Mining Company was formed in 1870, and with the expansion of the railway in 1884, the Cumberland Railway and Coal Company was formed from various independent operators. From that time, large scale coal mining continued uninterrupted by them and their successors until October 1958.

The Springhill coal resource consisted of seven (7) coal seams that maintain a constant thickness of between 1.4 and 3 m. The seams outcrop at surface, and typically dip at 30 degrees near surface to 11 degrees at depth. Over the life of the operations, underground mining extended a distance of over 4,400 m to the west and reached a vertical depth of 1,320 m (No. 2 Seam). Mining methods progressed from Room and Pillar to Room and Pillar Extraction to Long Wall Advance to Long Wall Retreat. Continuous large scale production continued until a major rock burst closed the No. 2 Mine in 1958 (Springhill Mine Disaster).

Since their abandonment in 1958, the workings flooded. In the late 1980s and early 1990s, their value as a geothermal energy source was realized and a number of boreholes were drilled to tap the energy source. Some of the original wells, and a number of new wells, are still being utilized as a mine water geothermal energy source. All the geothermal wells have been drilled in the upper portions of the mine workings.

CHAPTER 3 SCOPE OF WORK AND APPROACH

The following sections list the tasks associated with project, the methodology and approach for the review and how key deliverables were produced.

3.1 Phase 1 - Geo-Reference Mines Plans, Site Plans and Aerial Photographs

CEA identified that geo-reference work was required for mine plans for workings on seams No's. 1, 2, 3, 4, 6 and 7 in the Springhill Coalfield. The following sections list the tasks associated with project, the methodology and approach for the review and how key deliverables were produced.

CBCL first reviewed the CEA supplied documents and mine plans to see what data was available and also what information gaps existed. Table 1 lists the digital imagery provided and summarizes what georeferencing was completed. CBCL used Golden Software mapping products <http://www.goldensoftware.com/> for the georeferencing conversion and mapping. All images were referenced to NAD83 CSRS UTM Zone 20 (UTM).

Base Mapping

The first step that CBCL undertook in the geo-reference mapping process was to obtain mapping of the coalfield geology and associated mining. This information is provided on NSDNR map "Map 95-1 Geology Map of the Springhill Coalfield, Cumberland County, Nova Scotia, J.H. Calder" and comes already georeferenced to UTM, NAD83 zone 20. This map would serve as a reference base when assembling the more detailed larger scale mine plans. In addition, a request was made to Nova Scotia Department of Natural Resources (NSDNR) to see if they had any new information that might aid mine plan geo-referencing; from that request, they provided CBCL their most current Abandoned Mine Openings database. The database provides NSDNR's current interpretation of former mine opening positions, including those in Springhill.

In addition, to aid with georeferencing, provincial topographic mapping (1:10,000 scale) was obtained from GeoNova. This provided the position of road, streets, highways, railway lines, water bodies, topography and infrastructure.

Aerial Photographs

Historic aerial photographs from 1939, 1951, 1954, 1964 and 2014 were next added to the mapping layers. Years 1939, 1954 and 1964 were purchased for this project. The 1939, 1951, 1954, and 1964 photos were georeferenced-based on features common on the 2014 photo (which was already georeferenced) and provincial geographic details shown on 1:10,000 scale mapping. Historic aerial photos are important georeference sources as they show features that often are included on mine plans such as bankheads, hoists, buildings, railway lines and streets. All georeferenced aerial photographs were submitted previously to CEA.

Surface Plans

Several surface plans that show mining features were also provided to CBCL by CEA. Three (3) that were considered important to the project were:

1. Subsidence Post Plan
2. General Layout (No. 2 Mine Site and surrounding area)
3. Surface Plan of No 6 Mine

Georeferencing for these plans was completed using modern sub-metre surveys (by CEA) of remnant surface features that are shown on the plans and also through features that are common on the historic aerial photos. All georeferenced surface plans were submitted previously to CEA.

Mine Plans

CEA provided CBCL twenty-six (26) mine plan sheets in digital form. The initial review showed that two (2) separate local survey grids were in use during the mining period covered by the plans. The older (1920s) grid was in use for mining operations at No. 6 and No. 7 Mines. The grid origin appears to be the portal for the Cumberland Railway & Coal Company Ltd. (CR&CCL) No.6 Hoisting Slope and the "0" north line runs through the centerline of the slope; which places the 1920 grid north approximately 14⁰ west of the UTM grid. The grid drawn on the original plans has a 1000-foot spacing.

Georeferencing for No. 6 and No. 7 Mines:

1. The No. 6 Mine plan image was first georeferenced to the original 1920s grid. This was necessary so as to make the plan symmetrical to the local grid. This process removes any spatial errors induced by previous blue printing, photo copying, scanning or sheet stitching.
2. The plan image was then digitally stretched to scale so that ground distances on the image equate to distances within the UTM system.
3. The mine plan was then rotated and moved into position such that two (2) features shown on the plan match the same two (2) points for which UTM grid coordinates have been established; those points being the No. 6 Hoist structure, which was positioned during georeferencing of the Surface Plan of No. 6 and the CR&CCL No. 2 Main Slope, which was positioned using several sources that includes surveys of nearby structures, aerial photographs and the Surface Plan.
4. With the plan in its correct position, UTM grid coordinates could then be calculated for the local 1920 grid intersections. Using these points the image was then georeferenced to UTM.

5. Because No. 7 Mine shares the same local grid with No. 6, georeferencing was completed directly using the UTM positions established for the local 1920 grid.

The geo-referencing accuracy of the No. 6 and 7 plans is estimated to be about three (3) metres.

Georeferencing for No. 2 Mine Plan and other plans using the same 1950's grid.

CEA provided CBCL the No. 2 Mine plan georeferenced to UTM in digital form. Georeferencing was conducted by an NSDNR cartographer an unknown number of years ago (personal communication with NSDNR). CBCL's initial review noted that the plan appeared to be approximately in the correct position but the local grid was not symmetrical. Measurements between plan grid lines were off in some places ten (10) metres or more. Therefore, it was decided to make the plan symmetrical with the local grid and then establish UTM coordinates for the local 1950s grid using the same procedure as described above for No. 6 Mine.

For the No. 2 Plan, the two (2) anchor points with known UTM coordinates used to position the plan were the CR&CCL No. 2 Main Slope, described above, and the CR&CCL Aberdeen Slopes. Coordinates for the Aberdeen Slopes were collected recently by NSDNR when the slopes were uncovered during the excavation of a coal bulk sample. With the plan in its correct position, UTM grid coordinates were then calculated for the local 1950s grid intersections. Using these points the image was then georeferenced to UTM. This method of georeferencing provides a plan that is very accurate spatially with the best accuracy close to and in between the two (2) anchor points (accuracy estimate is 2 to 3 metres). In this case, the anchor points are approximately 2 km apart which provides a reasonable plan rotation angle, however even a very small change in rotation can impact plan accuracy away from the anchor points and therefore the western, northern and southern extents of the mine plan, which are up to 3.6 km from the anchor points, may only have a georeferenced accuracy of 10 to 15 metres.

All other mine plans with the 1950s grid were subsequently georeferenced using the UTM coordinates established for the 1950s grid.

Comments on the 1950's Local Grid Origin.

The No. 2 Mine plan georeferencing placed the 1950's grid origin within 2 to 3 metres of a survey point identified as "corner" on the Subsidence Post plan (E 416997.4, N 5055500.9). The point is shown on several plans and on some plans, lines extending from the point are referred to as "COAL AREA LINE". CEA personnel examined the area in the field and found a bent over, flattened metal pipe buried under approximately 0.30 metres of coal mine waste rock at E 416995.2, N 5055502.7. This evidence suggests that the "corner" survey point may be the grid origin. The pipe may have once marked the "corner" survey point; however its exact original position is not known as it had been disturbed. All georeferenced mine plans were submitted previously to CEA.

Geo-reference Comparison

As part of the georeferencing procedure, CBCL was asked to provide a series of Northing's and Easting's of mine plan locations that can be compared to the same points on the Municipality of

Cumberland geo-referenced plans. The locations were tabulated so that a measured relative difference could be calculated by CEA.

CBCL created comparisons plans on each of the five (5) major seams and one (1) for the Subsidence Post Plan. Four (4) representative locations within the plans were chosen. To aid in locating each point, CBCL created a key image of the overall mine plan, and close ups images of each point. This information was submitted previously to CEA.

Recommendations

To improve the accuracy of the georeferencing procedure, CBCL recommends searching for documents that describe the derivation of the local grids used at Springhill during mining. From that a direct transformation from local grids to UTM could be produced. The plans could then georeferenced to the accuracy provided by the original surveying and drafting.

3.2 Phase 2 –Drilling

Drilling Contractor Tender

CBCL assisted the CEA in the selection of a drilling contractor by reviewing and commenting on the drilling contractor tender document. In addition, CBCL reviewed all tender submissions and provided recommendations regarding selection of the drilling contractor; final contractor selection was completed by CEA.

Identify Potential Borehole Locations

Using the new geo-referenced mine plans, CBCL was asked to identify several potential borehole locations within the mine workings that would assist in the assessment of the geothermal resource at deeper elevations (200 to 300 metres below ground surface). As part of this task, CBCL first constructed structure contours (seam elevation relative to sea level) for each seam. When planning drilling programs, accurate seam structure is necessary for determining borehole depths.

Normally the best elevation data are the spot elevations posted on the originally mine plans. In this case, elevations were sparse and often not available in the earlier mined shallower areas. Lack of mine plan elevation data required obtaining the information from other sources such as: Recent well drilling logs, historic borehole logs, NSDNR mapping, seam grade information, coal seam outcrop positions, mine plan geometry and exploration reports. The compiled information was reviewed and new digital structure contours were developed. CBCL has previously provided CEA with CBCL's interpretation of the seam structure contours for No 1, 2 and 3 Seams in both feet and metres in SHP file format.

Working with CEA staff, CBCL recommended several new well locations. Targets were chosen that would be approximately 250-metres deep and that would have the best probability of encountering mine water while avoiding potential trouble areas. After several iterations, it was mutually decided that two (2) potential drill targets would be as follows:

Hole 1 would be drilled at UTM coordinate E 461,233 N 5,055,256, with the intention of intersecting Seam No. 3 workings at approximately 250 metres depth.

Hole 2 would be drilled at UTM coordinate E 416,522 N 5,055,372256, with the intention of intersecting Seam No. 1 or No. 2 Seam workings at approximately 220 and 265 metres depth respectively.

Borehole Logging and Assessment

The initial schedule had drilling commencing in the fall of 2017; however, drilling contractor availability pushed the start of drilling to the end of January 2018. CBCL was asked to have a geologist present during drilling, to provide geologic assessments, and to collect rock chip samples to determine rock type, occurrence of fracture zones and staining which may indicate the presence of mine water in the strata. CBCL was on-site to monitor drilling at Hole 1 for drilling depths between 18 and 174 metres. The hole was stopped short of the target depth due to excessive groundwater inflow estimated at approximately 1.5 m³/minute (400 gal/min). Water producing aquifers were encountered at depths 40, 55, 82, 90 and 110 metres below ground surface.

An attempt was made to start the second hole however surface ground conditions (freeze / thaw) prohibited the drill from being able to set up a stable base so CEA decided that drilling would be postponed until ground conditions improved.

CHAPTER 4 **CONCLUSION**

Thank you for the opportunity to work with you on this very interesting project. Please do not hesitate to call if you require additional information or clarification of any of the issues discussed.

Table 1 List of Digital Imagery
Mine Workings Spatial Review and Deep Well Test Boreholes – Springhill NS

Image Category	Plan Title	Seam	Original Scale	Date	Comment	Original file name	GR File Name	Number of images in mosaic	Number of GR images
Aerial Photograph	1939 Aerial Photograph	NA	NA	26/06/1939	GR using locations common to 2014 airphoto and mine plan surface features	A-6612-85.tif	A6612_085v2.jpg	1	1
	1951 Aerial Photograph	NA	NA	1951	GR mosaic of two photos using locations common to 2014 airphoto and mine plan surface features	Springhill_1951_18.tif Springhill_1951_19.tif Springhill_1951_20.tif	1951_18-20v2.jpg	2	2
	1964 Aerial Photograph	NA	NA	1954	GR mosaic of two photos using locations common to 2014 airphoto and roads and street from provincial mapping	A14010_012.tif A14289_132.tif	1954 mosaic.jpg	2	3
	1964 Aerial Photograph	NA	NA	1964	GR mosaic of two photos using locations common to 2014 airphoto and roads and street from provincial mapping	18577_025_048.tif 18577_140_047.tif	1964 A18577_025-140.jpg	2	4
Surface Plan	Subsidence Post Plan	NA	1" = 100'	Post September 1952	Surface plan that has several field surveyed features that enabled the plan to be accurately GR. It includes the "Corner" survey marker which has been identified as the 0,0 point for the 1950s local grid.	HPSC0227.tif	SubsidencePosts_1-100.tif	1	5
	General Layout	NA	1" = 50'	Unknown	GR using several survey surface features and historic aerial photos. General Surface Layout of No. 2 Bankhead area	Mine_Site_Surface_Plan.tif	SurfacePlanNo2_1-50.tif	1	6
	Surface Plan of No 6 Mine	NA	1" = 50'	Unknown	GR using best fit and survey of features thought to be No. 6 hoist and bankhead	HPSC0232.tif	SurfacePlanNo6Mine_1-50.tif	1	7
Mine Workings Plans	Workings in Top Coal No. 1 Seam	No. 1	1" = 200'	1950s	GR using 1950 grid. One sheet. Best for detail in deeper area. Missing shallow area	HPSC0230.tif	No1_Top_1-200.tif	1	8
	Plan of Workings in No. 1 Seam	No. 1	1" = 400'	1950s	GR using 1950 grid. One sheet. Shows outline of shallow area	HPSC0225.tif	No1_Top_1-400.tif	1	9
	Plan of No. 1 WKGS	No. 1	1" = 2 chn	1924	GR using No. 2 bankhead and deeper connections with No. 2, Aberdeen Slope, NSDNR No. 1 slope position and NSDNR shaft to the south. Shows near surface workings.	No_1_Seam_Workings.tif	No1_1-2chn.tif	1	10
	No. 1 Seam Showing Workings in Bottom Coal	No. 1 Bottom	1" = 200'	1954	GR using 1950 grid. Small detail area. Near No. 2 Main slope. Has 1950s grid	HPSC0237.tif	No1_Bot_1-200.tif	1	11
	Plan of No. 2 Mine	No. 2	1" = 200'	Appears to be final plan. Date on longwall is Nov 1958	1. Plan was initially GR and scaled to local grid but was missing near surface grid lines. Stretched to scale and rotated so as to position No. 2 slopes and Aberdeen Slopes. 2. Plan was then GR to UTM grid based on step 1. 3. Grid lines for the near surface area was provided. The 1950s grid was established using the new information and converted to UTM; the plan was GR again to this grid.	No_2_Mine_Plan.tif	No2_1-200.tif	1	12
	Geological Projection of the No. 3 Top Seam in No. 3 Colliery	No. 3	Not Shown 1" = 400'?	Unknown	GR using 1950 grid. One sheet	No_3_Top_Seam_Workings.tif	No3_Top_1-400.tif	1	13
	Plan of No. 6 Mine	No. 6	1" = 100'	1930?	GR to old grid and stretched to scale. Made Negative of blue print. Positioned plan based on No. 2 bankhead and surveyed No. 6 hoist structure and slope structure.	No_6_Mine_Workings.tif	No6_1-100.tif	1	14
	Plan of No. 6 Seam	No. 6	1" = 200'	1950s	GR using 1950 grid. Stitched two sheets. Shows both early shallow workings and deeper workings from No. 4 mine.	HPSC0235.tif HPSC0236.tif	No6_1-200.tif	2	15
	Plan of No. 7 Mine	No. 7	1" = 100'	1933	GR to old grid established for No. 6 Mine. Made Negative of blue print and stitched 3 images together to make mosaic.	No_7_Mine_Workings.tif No_7_Mine_Workings_1.tif No_7_Mine_Workings_3.tif	No7_1-100.tif	3	16
	Plan of Workings in No. 7 Seam No. 4 Mine	No. 7	1" = 200'	1950s	GR using 1950 grid. Shows both shallow southerly workings and deeper workings from No. 4. Does not show shallow early No. 7 workings to the north.	HPSC0239.tif	No7_1-200.tif	1	17
No name	No. 7	1" = 200'	1950s	GR using 1950 grid. Shows deep No. 7 Seam workings not shown on other plans.	HPSC0240.tif	No7_1-200_deep.tif	1	18	
Reviewed but not Georeferenced	Plan of Workings in Top Coal No. 1 Seam	No. 1	1" = 2 chn	Unknown	Not GR. Small detail area. Near Aberdeen slopes.	HPSC0231.tif			
	Plan of No. 1 WKGS	No. 1	1" = 200'	1924	Not GR. Only northern part. Similar to No_1_Seam_Workings.tif	No_1_Seam_Workings_4.tif			
	Workings in Top Coal No. 1 Seam	No. 1	1" = 200'	Unknown	Not GR. Very similar to HPSC0230.tif	No_1_Seam_Workings_1.tif			
	Plan of No. 3 Slope Workings	No. 3	1" = 2 chn	Unknown	Not GR. Maybe better detail surface than plan "Geological Projection of the No. 3 Top Seam in No. 3 Colliery" but plan is partial.	No_3_Slope_Workings.tif			