

Field Evidence of Nested Groundwater Flow Along the Little Smoky River, West-Central Alberta

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B.D. Smerdon, L.A. Atkinson, G.M.D. Hartman,
T.L. Playter and L.D. Andriashek

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Alberta Energy Regulator
Alberta Geological Survey
4th Floor, Twin Atria Building
4999 – 98th Avenue
Edmonton, AB T6B 2X3
Canada

Tel: 780.638.4491
Fax: 780.422.1459
E-mail: AGS-Info@aer.ca
Website: ags.aer.ca

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Abstract

As part of the Alberta Geological Survey project “Hydrogeological Characterization of the Fox Creek Area, West-Central Alberta,” three boreholes were drilled into the upper part of the Paskapoo Formation near Fox Creek, Alberta. The boreholes intersect lithologies that are typical of the Sunchild aquifer and Lacombe aquitard. Detailed lithological descriptions and an associated suite of downhole geophysical logs collected from these boreholes will help inform a new hydrostratigraphic model for this region.

At two of the borehole locations, vibrating wire piezometers were installed to four depths measuring vertical hydraulic heads adjacent to the Little Smoky River. Combined with water level data from the Alberta Water Well Information Database, these data indicate that the Little Smoky River occurs within a localized groundwater flow system that is nested within a larger-scale system at this location. The prevailing groundwater flow direction appears to be downwards in the Paskapoo Formation (i.e., recharge condition), except for the localized flow system providing base flow to the Little Smoky River (i.e., a gaining river). In this regard, the Little Smoky River may be contained within a localized groundwater flow system extending approximately three kilometres away from the river.

1 Introduction

In west-central Alberta, the oil and gas industry has started to develop the liquids-rich shale gas plays in the Duvernay and Montney formations using horizontal multistage fractured wells. This approach to development uses nonsaline water for hydraulic fracturing, which is often sourced from surface water and shallow groundwater in the region surrounding Fox Creek, Alberta. To regulate oil and gas developments, including sources of nonsaline water for enhanced recovery operations, the Alberta Energy Regulator (AER) and Alberta Environment and Parks (EP) have indicated that there is a need for managing cumulative effects at a regional scale. Such a regional scale approach is inherent to the AER's play-based regulation (PBR) pilot program (Alberta Energy Regulator, 2015) and EP's regional strategic assessments (e.g. Johnson et al., 2011). Support of these cumulative effects management initiatives will rely on scientifically defensible geoscience at a scale that is comparable to regulation.

The Alberta Geological Survey (AGS) has recently initiated a project that will advance the understanding of the near-surface hydrogeology within the Fox Creek area (the Hydrogeological Characterization of the Fox Creek Area, West-Central Alberta Project [the characterization project]). Part of this project will be developing a conceptual model of groundwater circulation for the region surrounding Fox Creek, Alberta. This conceptualization includes a three-dimensional hydrostratigraphic framework constructed to assist further characterization of the interaction between nonsaline groundwater and surface water. Several approaches exist for characterizing the connectivity between groundwater and surface water (Winter et al., 1998), and many rely on knowing the spatial distribution of hydraulic heads compared to surface water (i.e., conditions leading to gaining or losing streams). In the region surrounding Fox Creek, Alberta, shallow hydraulic head information is typically determined from water wells, the majority of which were simply installed to supply water and not designed for characterizing the interaction between groundwater and surface water.

The objective of this study was to characterize hydraulic head conditions near the Little Smoky River and interpret connectivity between groundwater and surface water. In the process of drilling boreholes and installing nested piezometers, high-quality lithological and downhole geophysical data were obtained that will be incorporated into AER, AGS, and EP projects.

2 Methods

2.1 Study Area

The study area for the characterization project is located in the vicinity of Fox Creek, approximately 260 km northwest of Edmonton, and spans portions of the Peace River and Athabasca River basins. The southwest margin of the study area is bounded by the Cordilleran deformation belt, and all other boundaries are aligned with sub-basin drainage boundaries (Figure 1). The study area is approximately 22 000 km² and encompasses the AER PBR pilot area (Alberta Energy Regulator, 2015).

Heterogeneous Neogene-Quaternary sediments overlie the bedrock. The Upper Cretaceous–Paleogene bedrock formations consist of the Paskapoo, Scollard, and Battle formations and Wapiti Group (listed in reverse stratigraphic order), which all subcrop towards the northern portion of the study area, with the exception of the Battle Formation (Figure 1). Across the southern half of study area, Neogene-Quaternary sediments are relatively thin (less than 20 m thick; MacCormack et al., 2015) and the Upper Cretaceous Paskapoo Formation is eroded by the major rivers. The Paskapoo Formation contains three stratigraphic subdivisions (Demchuck and Hills, 1991): Dalehurst Member (sandstone, mudstone, coal), Lacombe Member (siltstone, mudstone), and Haynes Member (predominantly sandstone). Furthermore, three hydrostratigraphic units have been proposed (Lyster and Andriashek, 2012) that differ somewhat from

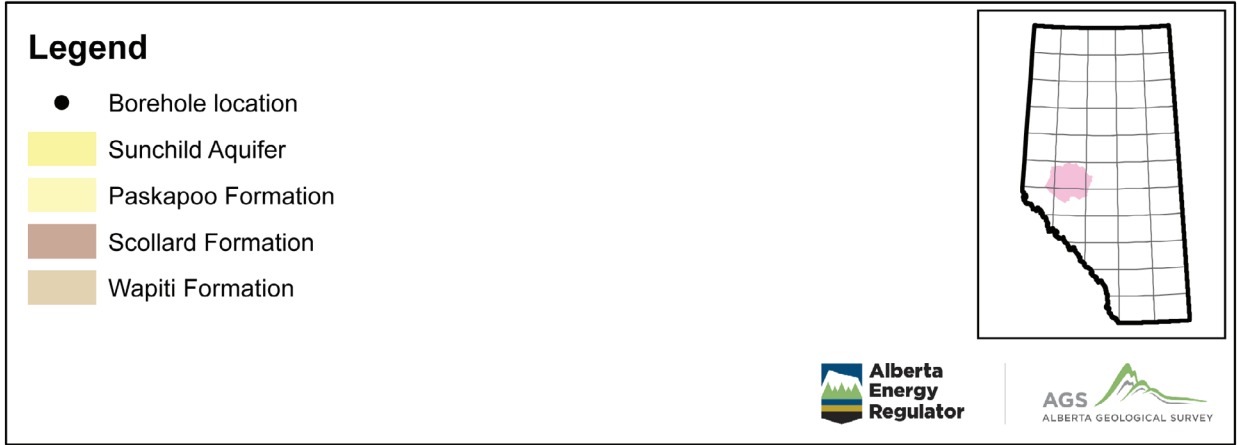
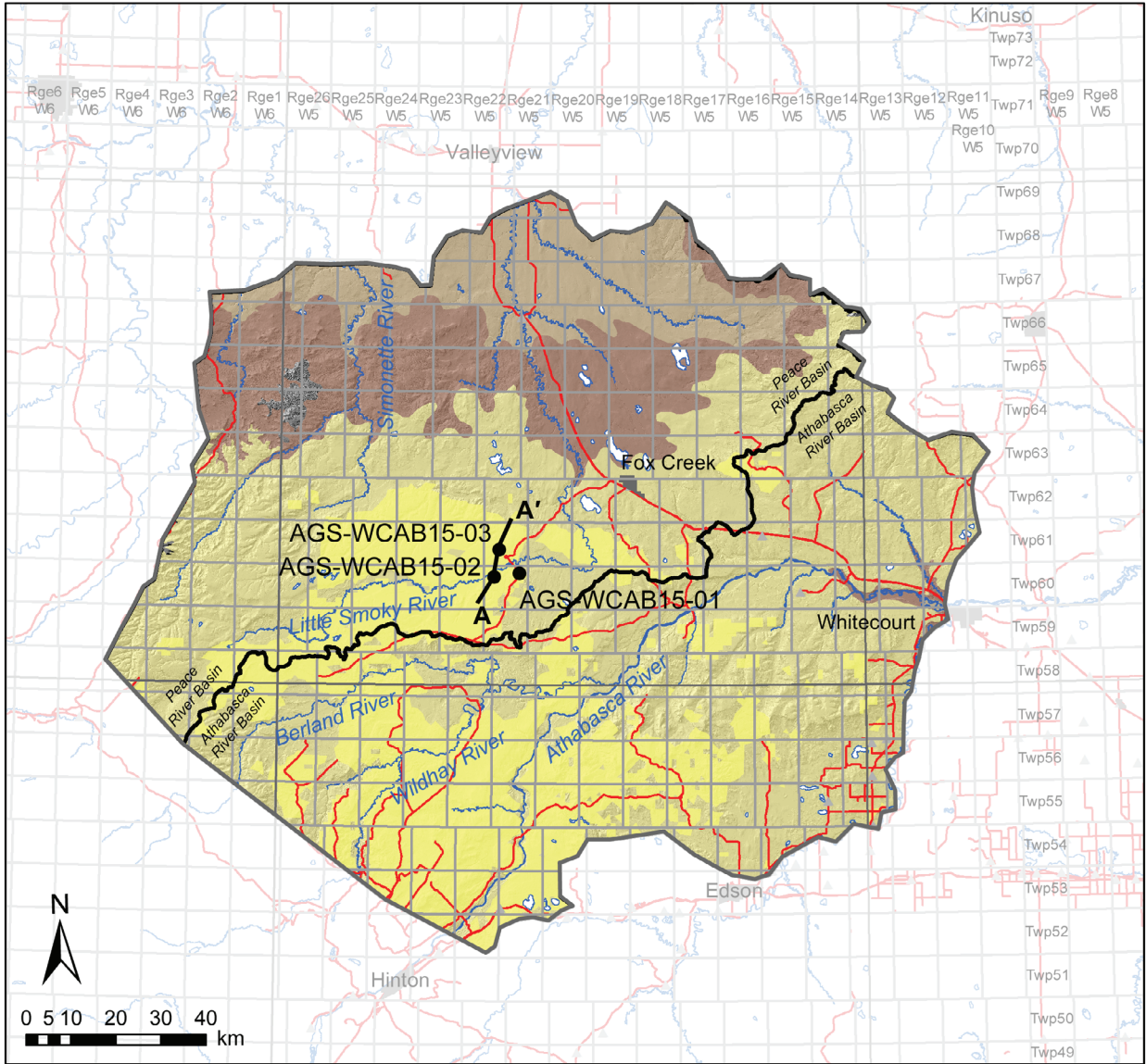


Figure 1. Location and bedrock geology of the study area.

the stratigraphic subdivisions but which represent a regional framework for conceptualizing groundwater: Sunchild aquifer, Lacombe aquitard, and the Haynes aquifer. Within the study area, the distribution of the Sunchild aquifer (Figure 1) generally corresponds with higher ground surface elevations.

2.2 Borehole Drilling and Downhole Geophysical Logging

Borehole locations were selected on Crown land to coincide with the margin of the Sunchild aquifer and occur in close proximity to the Little Smoky River (Figure 1). The three borehole locations are named AGS-WCAB15-01 through AGS-WCAB15-03 (boreholes 1–3).

Boreholes were drilled in March 2015 with an air-rotary drill rig (Atlas Copco T3-W) operated by Ashburn Drilling Ltd. At each location, surface casing was used to maintain the integrity of the upper portion of the borehole where unconsolidated sediments were present. The surface casing was removed at borehole 1 but remained at boreholes 2 and 3 to facilitate installation of vibrating wire piezometers. The boreholes were drilled using standard drilling techniques (Figure 2a) with sufficiently large cuttings for visual examination. Observations of drill cuttings included the sediment or rock type, colour, reaction to 10% HCl (indicating presence of carbonates), mineralogy, and approximate grain size and grain angularity.

Upon completion of borehole drilling, geophysical logging was completed from surface to the bottom of each borehole by Datalog Technology Inc. The suite of downhole logs included natural-gamma, resistivity, neutron-density, sonic, caliper, and dip meter. These logs were collected for the complete borehole depth at each location, except for the sonic and dip meter logs at borehole 2, which were unable to proceed past an obstruction at a depth of 97 m.

Table 1 shows the location (latitude-longitude), ground elevation, total depth, and Dominion Land Survey (DLS) location of each borehole.

Table 1. Location of borehole sites.

Borehole Number	Land Use	Latitude	Longitude	Elevation (masl)*	Borehole Depth (m)	DLS
AGS-WCAB15-01	Forest cut block	54.2235	-117.17834	1019.75	150	16-26-060-22W5M
AGS-WCAB15-02	Gravel pit	54.2169	-117.26418	981.00	150	06-29-060-22W5M
AGS-WCAB15-03	Gravel pit	54.2711	-117.24745	1040.74	121	04-16-061-22W5M

* metres above sea level; ground elevation determined from LiDAR DEM

2.3 Vibrating Wire Piezometer Installation

Each borehole was abandoned by pumping a cement-bentonite grout mixture through a tremie pipe until the borehole was filled to surface. At boreholes 2 and 3, four vibrating wire piezometers (Slope Indicator VW Piezometer) were fastened to the tremie pipe and grouted into the borehole to measure pore pressure (Figure 2b). At borehole 2, the piezometers were set to depths of 7, 32, 74, and 102 m, while at borehole 3, the piezometers were set to depths of 30, 54, 77, and 110 m. At each location the vibrating wire piezometers were connected to a data logger (Slope Indicator VW Quattro Logger; Figure 2c), which recorded subsurface pressure and temperature at 60-minute intervals. Barometric pressure was also recorded at the same time interval at borehole 3.



Figure 2. (a) Drill rig and AGS field trailer at site AGS-WCAB15-03; (b) Vibrating wire piezometer attached to tremie pipe; (c) Data logger installation at site AGS-WCAB15-02.

Measuring the pore pressure of a geological formation through a fully grouted borehole may seem counterintuitive. However, embedding a piezometer within a fully grouted borehole (i.e., without a sand pack) is a long-established practice, having first been described over 40 years ago by Vaughan (1969). Recently, this method has been used in hydrogeological studies (McKenna, 1995; Smith et al., 2013; Smerdon et al., 2014). Compared to a standpipe piezometer, the installation of an embedded piezometer is simplified (Contreras et al., 2008). Additionally, there are no sand packs present that would promote vertical movement of groundwater. The vibrating wire piezometers used in this method will detect changes in pore pressure through a grouted borehole within minutes (Simeoni, 2012). Application in the present study was intended to generate knowledge of the vertical pore pressure distribution (i.e., hydraulic head gradient) in the vicinity of a river within the study area. Because the borehole is completely filled with grout, the instruments at surface can be removed at a future time by simply cutting the wiring and surface casing.

3 Results

Borehole striplogs that include lithology and results of the geophysical logging are located in Appendix 1, and detailed notes from each borehole are located in Appendix 2. This report provides a basic description of the lithology encountered in each borehole. More detailed characterization of the Paskapoo Formation, including a hydrostratigraphic model, will be developed as part of the characterization project.

Borehole drilling intersected the top of the Cretaceous bedrock surface at depths of 11.7, 4.9, and 16.8 m, respectively, for boreholes 1 through 3. The sediment type immediately overlying the bedrock varied with location: till was encountered above the bedrock at borehole 1 and sandy gravel at boreholes 2 and 3. At borehole 3, approximately 3 m of diamicton (till) was observed over the sandy gravel and in the exposed gravel pit adjacent to the drill site.

Bedrock lithologies comprised mudstone, siltstone, and sandstone of the Paskapoo Formation. These rocks were found to vary spatially, as is characteristic of the Paskapoo Formation (i.e., highly heterogeneous; Grasby et al., 2008). At borehole 1, mudstone with some sandstone beds and bentonitic coal beds were found from 11.7 to 68.6 m, and interbeds of siltstone and sandstone (with some mudstone) from 68.6 to 150 m. There was no appreciable thickness of sandstone in borehole 1. In contrast, at borehole 2, considerable thicknesses of sandstone were encountered from 4.9 to 33.5 m (medium-grained sandstone) and 33.5 to 59.4 m (fine-grained sandstone with mudstone interbeds). Mudstone with some siltstone and coal interbedding was found between 59.4 and 89.9 m in borehole 2. The lower portion of borehole 2 encountered fine-grained sandstone with mudstone interbeds from 89.9 to 115.8 m and siltstone from 115.8 to 150 m. At borehole 3, siltstone was observed from 16.8 to 80.8 m, with some mudstone beds between 18.8 and 30.5 m. This was followed by a thick sequence of sandstone with minor coal beds from 44 to 80.8 m, underlain by a fine- to medium-grained sandstone from 80.8 to 112.8 m siltstone from 112.8 to 121.3 m.

The pore pressure measurements were converted to hydraulic head relative to mean sea level (using the surface elevation at each location) and assuming a fluid density of 1000 kg/m³. The resultant time series of hydraulic head (Figures 3a and b) illustrates a short equilibration period (less than 1 day) following borehole closure by grouting, with the exception of the deepest piezometer at borehole 2. This period of rapid recovery reflects the high permeability of sandstone encountered in boreholes 2 and 3. The more gradual equilibration period (approximately 75 days) observed at 110 m depth in borehole 2 reflects the presence of mudstone noted in the lower portion of the borehole.

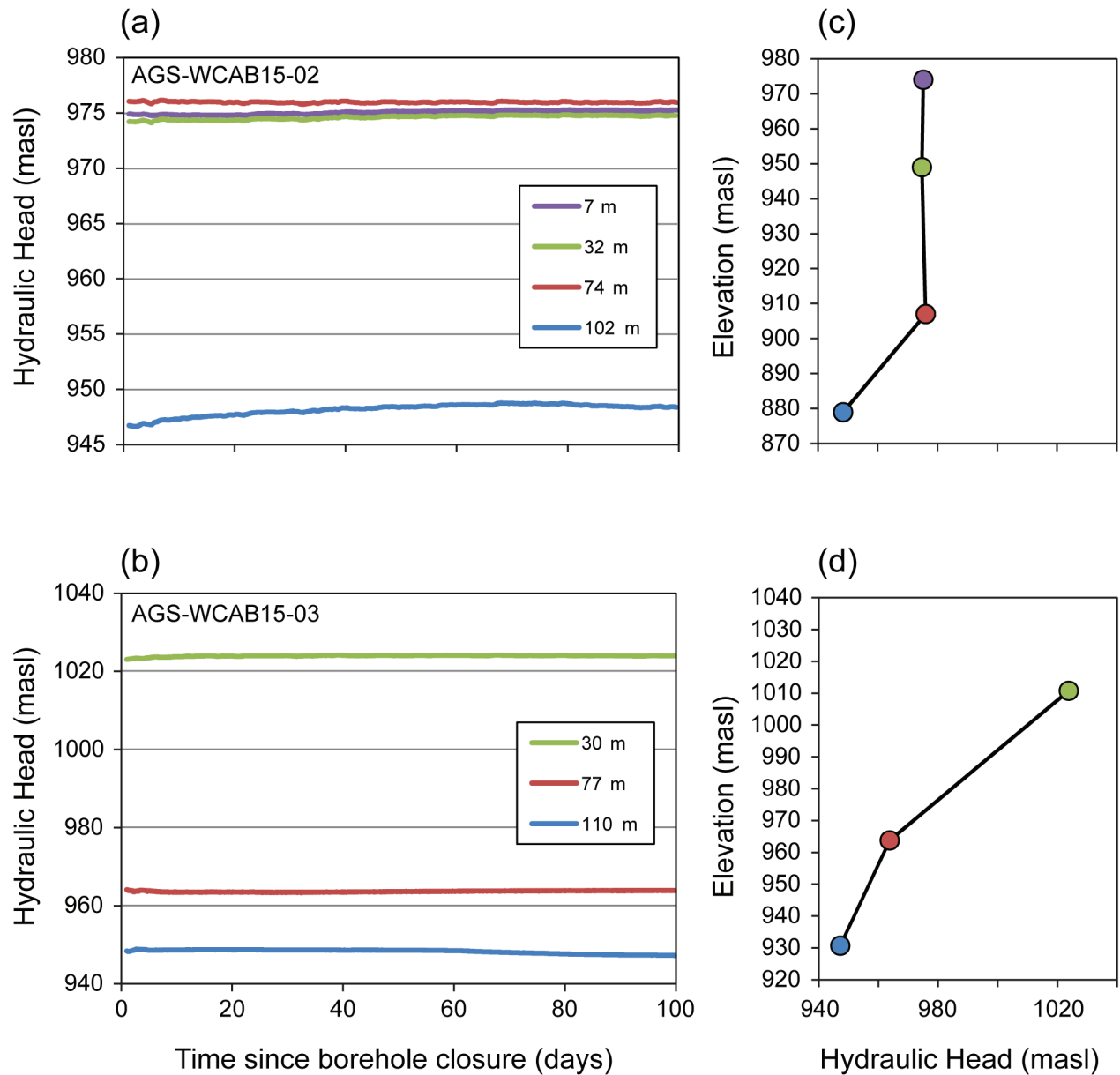


Figure 3. Time series of hydraulic head at (a) site AGS-WCAB15-02 and (b) site AGS-WCAB15-03. Hydraulic head profiles at (c) site AGS-WCAB15-02 and (d) site AGS-WCAB15-03 with colour coordinated points for the depths shown on the time series.

At borehole 2, hydraulic head values were similar at depths of 7, 32, and 74 m (Figure 3c), indicating the absence of a vertical gradient. Considering the presence of sandstone encountered at these depths, and the close proximity of the Little Smoky River (approximately 1 km north), there is likely a dominance of horizontal groundwater flow. At greater depth in borehole 2, hydraulic head decreases, indicating a potential for downward flow (i.e., groundwater recharge). At borehole 3, the hydraulic heads decrease with depth, also indicating a potential for downward flow.

4 Groundwater-River Interaction

Understanding the connectivity between groundwater and surface water is a fundamental step when developing a conceptual model of shallow groundwater circulation. For tributaries of the major rivers emanating from the Canadian Rockies, peak river flow occurs in the spring and early summer months as a result of melting snowpacks at higher elevations. The amount of base flow—water released from groundwater storage—is what sustains the necessary environmental conditions of in-river aquatic habitat and is available for other uses (e.g., water source for industrial development). Although there are numerous techniques to quantify the characteristics of base flow, it is also important to understand the source of base flow within a hydrogeological context, especially when evaluating the integrated effect of multiple uses (i.e. cumulative effects).

To extend the findings of vertical hydraulic head profiles determined in this study, additional well records from the Alberta Water Well Information Database (AWWID; Table 2) were used to develop a hydrogeological cross-section (Figure 4) perpendicular to the Little Smoky River (A–A' shown on Figure 1). With the exception of two flowing shot holes drilled in 1986, these wells were drilled between 1990 and 2009 as nonsaline water sources for industry (e.g., camps and deep drilling activity). Most of the AWWID wells used for the cross-section were completed as pairs in close proximity (indicated by the same owner in the AWWID record) and are shown on the cross-section as coincident locations to represent a pseudo-vertical gradient. Hydraulic head values were calculated from the static water

Table 2. Water wells from the Alberta Water Well Information Database used to develop cross-section.

EP Groundwater Information Centre Well ID	Well Completion Interval (m)	Hydraulic Head (masl)
1035263	18.3–24.4	1065.80
1035352	18.3–36.6	1053.00
354685	19.8–30.5	1068.40
354686	12.2–24.4	1072.95
351325	22.9–42.7	1063.20
351326	31.4–61.0	1048.90
351327	19.5–54.9	1066.25
400124	12.2–24.4	1049.30
400125	36.6–48.8	1029.50
427262	Flowing shot hole (~9 m)	1005.00
427265	Flowing shot hole (~9 m)	1012.00
1665341	29.9	1006.50
1665847	18.3	1028.70
1665842	18.3	918.50

level and estimated ground surface elevation from a digital elevation model (DEM) derived from light detection and ranging (LiDAR) data, assuming that the monitoring point was the midpoint of the completion interval. Although the static water levels span a 20-year period, they are assumed to reflect the regional groundwater conditions.

The hydraulic head contours shown in Figure 4 were created by interpolating AWWID well data (Table 2), the vibrating wire data (Figures 3c and d), and elevation of the Little Smoky River (approximately 970 masl where intersected by the hydrogeological cross-section).

The pattern of hydraulic head contours in cross-section indicates that the Little Smoky River is a gaining river and may be contained within a localized groundwater flow system extending approximately 3 km away from the river. The broad pattern of hydraulic head contours may better represent the groundwater flow system at a regional scale, which dominantly appears to be a recharge condition in this area. This larger-scale system appears to extend across 10 km or more. In this regard, localized groundwater conditions near the Little Smoky River are nested within a larger groundwater regime (e.g., Tóth, 1963).

The field evidence shown on Figure 4 suggests that portions of the Little Smoky River may be a local drainage feature for shallow groundwater. Further examination of this phenomenon is needed to characterize the nature of groundwater and surface water interaction in other parts of the study area. However, the data collected in this study confirm that local hydrogeological conditions (i.e., a small gaining river within a more regional recharge area) have an effect on interaction between groundwater and surface water.

Presence of nested groundwater flow along the tributaries of the major rivers in the study area will have implications for water management in this region. Based on the findings of this study, rivers such as the Little Smoky River are hypothesized to have a combination of water sources: annual snowmelt runoff and relatively shallow groundwater within a few kilometres of the river. Extraction of river water or shallow groundwater should be considered within the hydrogeological context proposed in Figure 4. It is also hypothesized that the more prevalent direction of groundwater flow within the Paskapoo Formation in this area is downward. Further examination of hydraulic head data will be completed as part of the characterization project to develop a broader understanding of groundwater flow patterns and interaction with rivers.

5 Summary

As part of the AGS's Hydrogeological Characterization of the Fox Creek Area, West-Central Alberta Project, three boreholes were drilled into the upper part of the Paskapoo Formation near Fox Creek, Alberta. The boreholes intersect lithologies that are typical of the Sunchild aquifer and Lacombe aquitard. Detailed lithological descriptions and an associated suite of downhole geophysical logs will help inform a new hydrostratigraphic model for this region.

At two of the borehole locations, vibrating wire piezometers were installed to four depths to measure the vertical hydraulic head profile adjacent to the Little Smoky River. Combined with water level data from the AWWID, these data indicate that the Little Smoky River exists within a localized groundwater flow system that is nested within a larger-scale system at this location. The prevailing groundwater flow direction appears to be downward (i.e., recharge condition) in the Paskapoo Formation, except for the localized flow system providing base flow to the Little Smoky River. In this regard, the Little Smoky River is a gaining river and may be contained within a localized groundwater flow system extending approximately three kilometres away from the river.

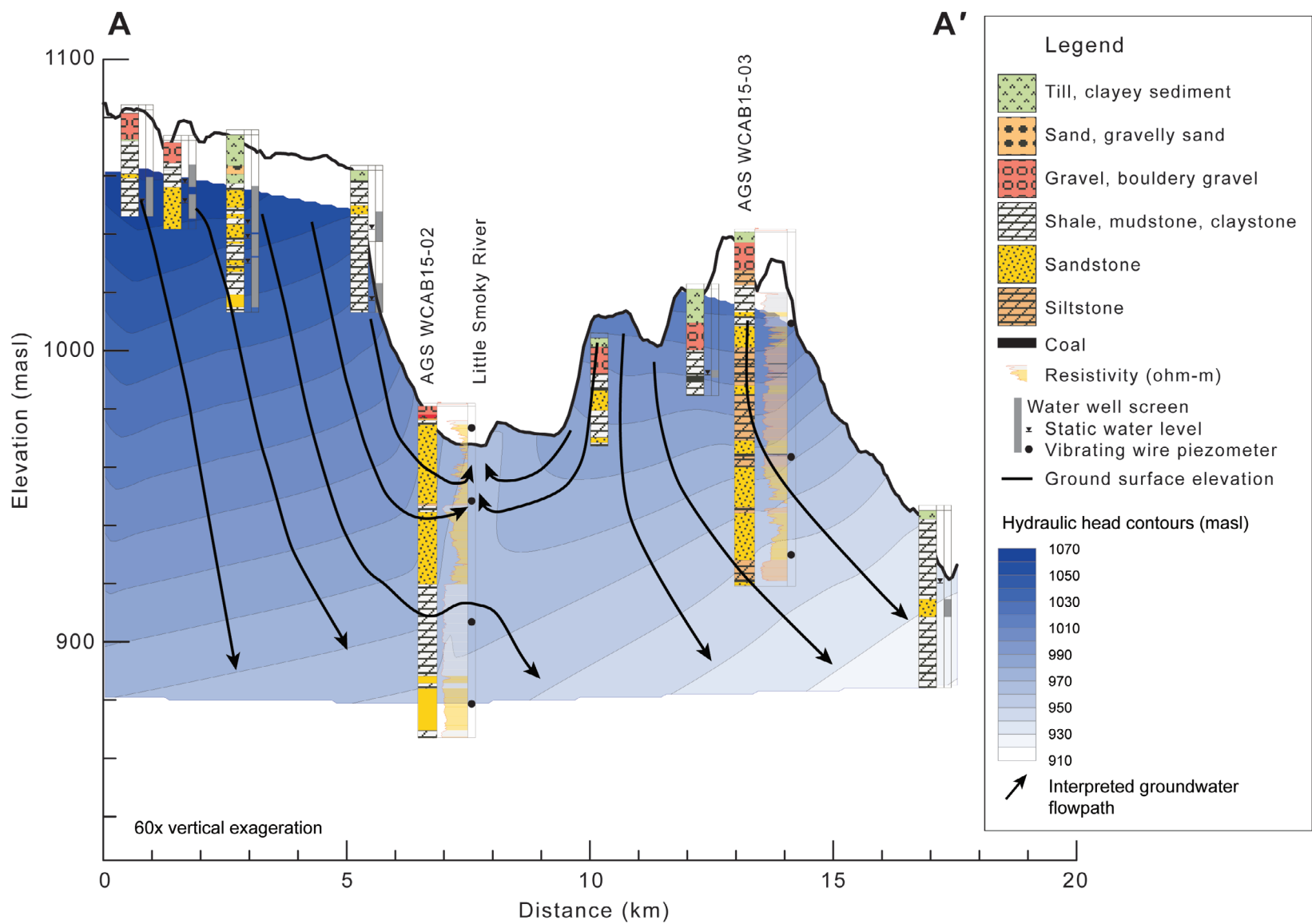


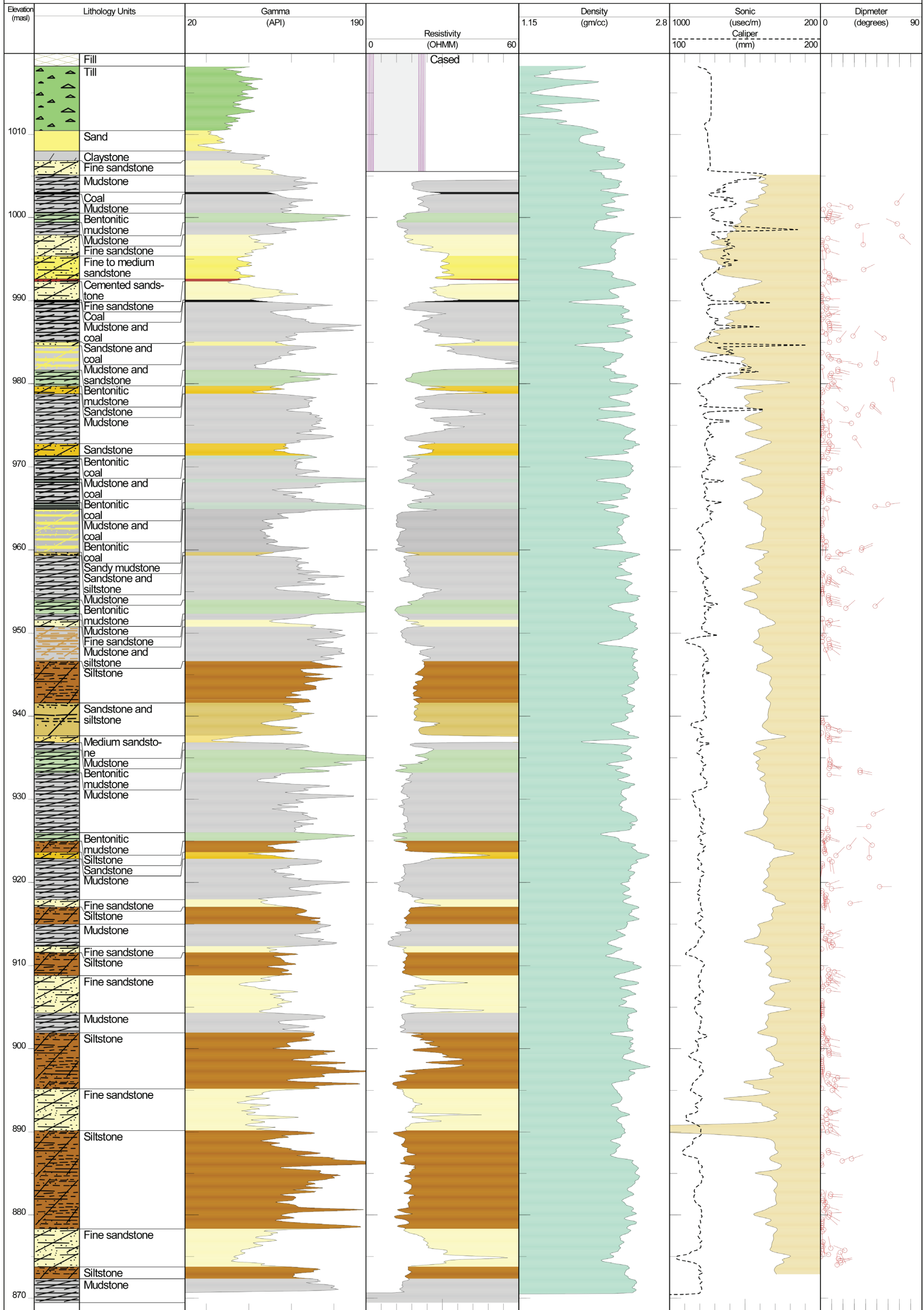
Figure 4. Hydrogeological cross-section perpendicular to the Little Smoky River with contoured hydraulic heads and interpreted groundwater flow paths. Cross-section location shown on Figure 1.

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Appendix 1 – Borehole Striplogs

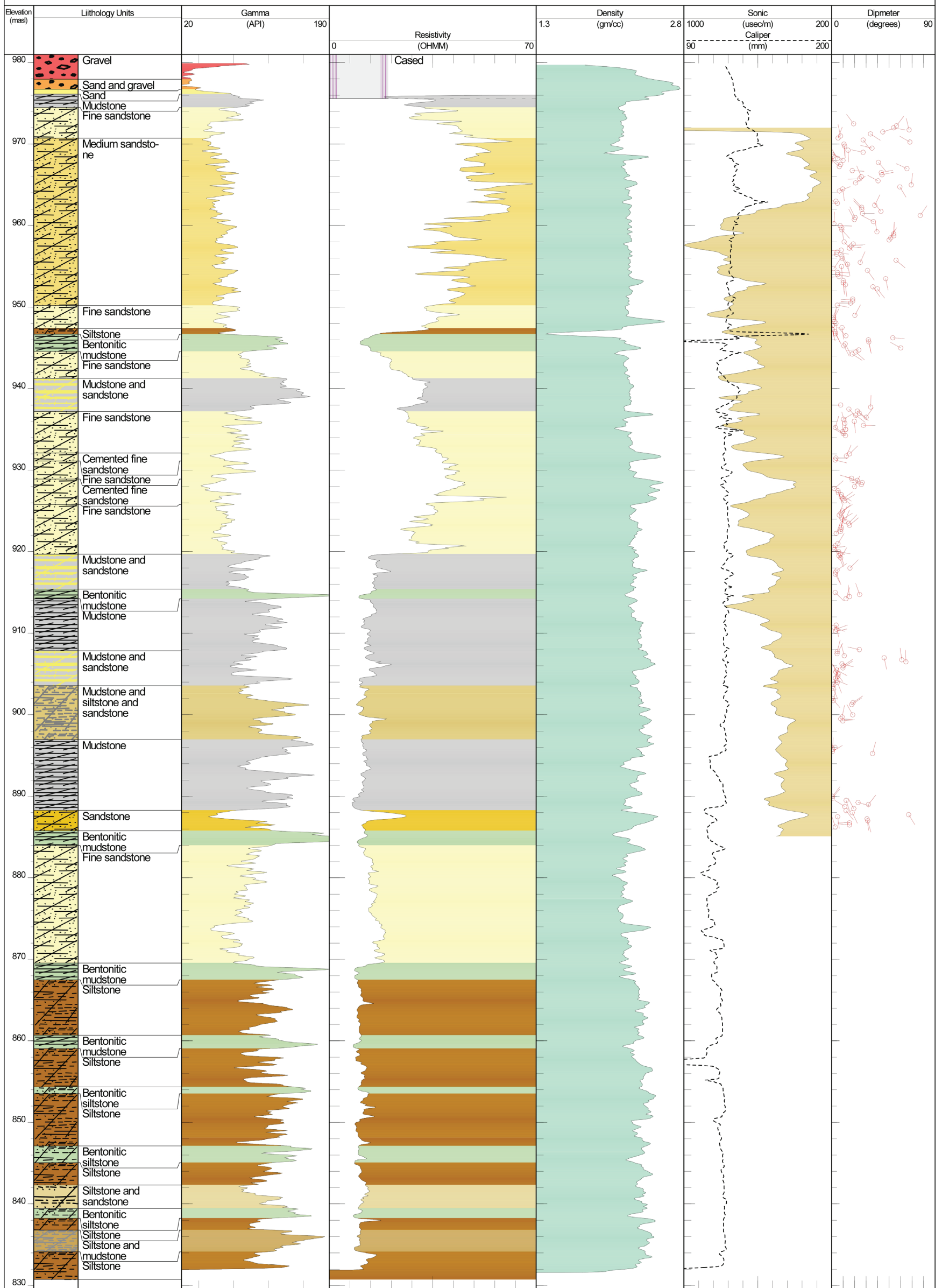
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 Latitude 54.22354° Longitude 117.17834°
 Reference: Ground Surface - 1019.75 masl



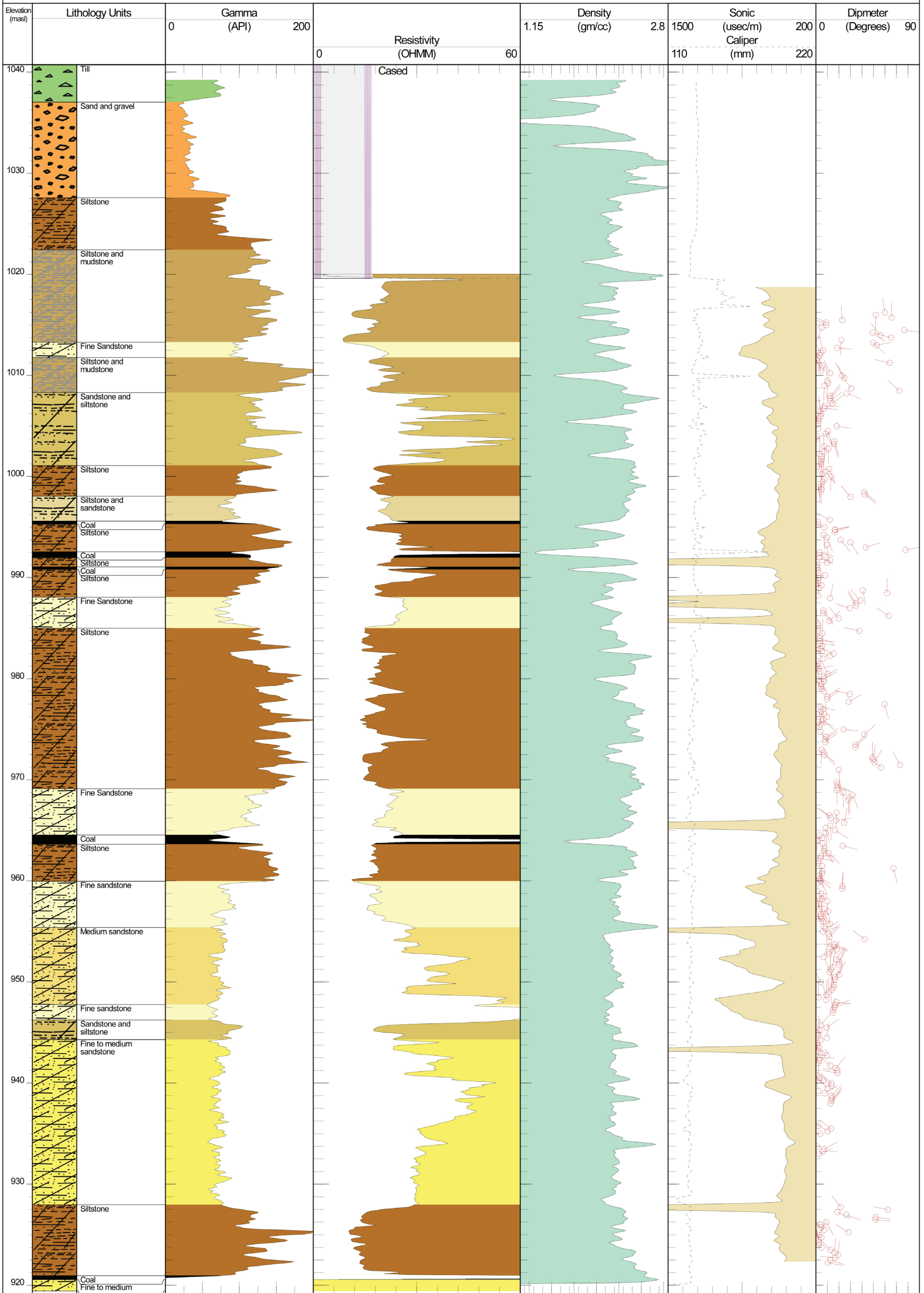
Well Name: AGS-WCAB15-02

Latitude 54.21690⁰ Longitude 117.26418⁰

Reference: Ground Surface - 981 masl



Well Name: AGS-WCAB15-03
 Latitude 54.27107° Longitude 117.24745°
 Reference: Ground Surface - 1040.74 masl



Appendix 2 – Detailed Borehole Lithological Descriptions

Table 3. Borehole WCAB-15-01.

Top Depth (m bgs)	Bottom Depth (m bgs)	Top Elevation (m asl)	Bottom Elevation (m asl)	Description
0.00	1.52	1019.75	1018.23	Minor iron staining, pebbles, some iron concretions, moist, soft, noncalcareous, 2.5Y 4/4, cl-sa-si. The abundance of wood fragments suggests that this is disturbed material.
1.52	1.83	1018.23	1017.92	at 6ft there was a colour change, sand (20%)-clay (20%)-loam (60%), 5Y3/2, no more twigs, moist, noncalcareous, no pebbles, no Fe oxidation, very little sand
1.83	3.05	1017.92	1016.70	cl-sa-si, 2.5Y4/3, pebbles (metaquartzite), coal fragments, some oxidized small pebbles, crumbly (dry), calcareous (strong reaction), 2 size fractions (less than 1cm and greater than 1 cm)
3.05	4.57	1016.70	1015.18	cl-sa-si, calcareous (strong reaction), 5Y3/2, pebbles (rounded metaquartzite, dark chert, purple/mauve sandstone), crumbly, very minor coal fragments (?), very minor oxidation, soft
4.57	5.79	1015.18	1013.96	local bedrock is coating till grains with a powder, but getting clay-rich (possibly shale)
5.79	6.10	1013.96	1013.65	cl-sa-si, 5Y4/2, pebbles (purple sandstone, black cemented siltstone, dark sandstone), calcareous, dry
6.10	7.62	1013.65	1012.13	cl-sa-si, 5Y4/2, crumbly, moderate to strong calcareous reaction, pebble fragments (rounded, white to yellow metaquartzite), coal fragments
7.62	8.53	1012.13	1011.22	as above
8.53	9.14	1011.22	1010.61	lithology change, now in sand. Cl-si-sa, 2.5Y3/2, moist sand, no/few pebbles or fragments, highly calcareous, fine to very fine sand
9.14	10.36	1010.61	1009.39	No Sample
10.36	10.67	1009.39	1009.08	cl-si-sa, 5Y3/2 (dark olive grey), wet fine sand, highly calcareous, pebbles (~1-2 cm diameter; tan metaquartzite)
10.67	11.73	1009.08	1008.02	39ft hit bedrock
11.73	12.19	1008.02	1007.56	claystone, 5Y2.5/1 (black), noncalcareous, some small quartz fragments (possibly from drilling), reddish-brown carbonaceous plant debris with striations and a regular structure
12.19	13.72	1007.56	1006.03	mudstone 5Y3/1 (very dark grey), iron oxide fragments (soft and woody; plant debris?), organic rich particles, carbonaceous debris, noncalcareous, wet outside, dry inside
13.72	14.63	1006.03	1005.12	lithology change to muddy, fine sandstone. Out of the sandstone by 48 ft, 5Y5/1 (grey)

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO₃, density/hardness, moisture
14.63	15.24	1005.12	1004.51	mudstone, 5Y 2.5/1 (black), noncalcareous, occasional small, round iron oxide pebble but rare (less than 5mm diameter), hard
15.24	16.46	1004.51	1003.29	changes from mudstone to coal at around 54 feet. The mudstone is 5y3/1 (very dark grey), noncalcareous.
16.46	16.61	1003.29	1003.14	coal seam runs from roughly 54-54.5 feet and is vitreous
16.61	16.76	1003.14	1002.99	mudstone 5Y4/1 (dark grey), calcareous, fragmented, rare small angular, pale tan pebbles
16.76	18.29	1002.99	1001.46	mudstone 5Y3/1 (very dark grey), calcareous, fragmented (~2cm diameter or less), small angular rock fragments (tan/white quartz), carbonaceous debris
18.29	19.20	1001.46	1000.55	light grey bentonite, coal, black mudstone, rich in carbonaceous debris, after 65 feet, no bentonite
19.20	19.81	1000.55	999.94	minor bentonite, black mudstone, noncalcareous, some clay-rich, unconsolidated/poorly lithified mud that is calcareous (5Y42; olive grey)
19.81	21.34	999.94	998.41	no bentonite, mudstone, 5Y2.5/1, noncalcareous, small fragments (less than 1cm diameter), very minor carbonaceous debris
21.34	22.56	998.41	997.19	as above
22.56	22.86	997.19	996.89	poorly lithified sand, salt and pepper (avg colour is 5Y4/1), noncalcareous, fine sand, uniform grain size
22.86	24.38	996.89	995.37	No Sample
24.38	25.91	995.37	993.84	salt and pepper sand (poorly lithified), avg colour 5Y4/1, noncalcareous, fine to medium (probably more on the fine end), uniform grain size
25.91	27.13	993.84	992.62	as above
27.13	27.43	992.62	992.32	sandstone, very fine to fine, consolidated, hard, calcareous, 5Y3/1 (very dark grey), very small black chert, rare mudstone flakes
27.43	27.74	992.32	992.01	as above
27.74	28.96	992.01	990.79	fine sandstone, soft, calcareous, 5Y4/1 (dark grey), salt and pepper, minor carbonaceous debris
28.96	29.57	990.79	990.18	as above
29.57	29.87	990.18	989.88	coal with minor bentonite, water flowing clear (no silt), minor sandstone fragments (salt and pepper)
29.87	30.48	989.88	989.27	mudstone, 5Y3/1 (very dark grey), noncalcareous, small fragments (~2-5mm)

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
30.48	32.00	989.27	987.75	mudstone, 5Y3/1 (very dark grey), calcareous, very small fragments, rare carbonaceous debris
32.00	32.61	987.75	987.14	coal with bentonite, noncalcareous
32.61	33.53	987.14	986.22	mudstone, 5Y3/1 (very dark grey), calcareous
33.53	35.05	986.22	984.70	minor coal, 5Y4/1 (dark grey), calcareous mudstone
35.05	36.58	984.70	983.17	coal fragments, calcareous, 5Y31 (very dark grey)
36.58	38.10	983.17	981.65	mixed mudstone, coal fragments and sandstone clasts, but mudstone dominant, calcareous, average colour 5Y41
38.10	39.62	981.65	980.13	bentonite with mudstone, 5Y3/1, calcareous
39.62	40.54	980.13	979.21	sandstone, salt and pepper, 5Y4/1, calcareous, very minor carbonaceous debris, consolidated, moderately hard
40.54	41.15	979.21	978.60	mudstone with minor carbonaceous debris, 5Y3/1, calcareous, minor sandstone clasts (salt and pepper)
41.15	42.67	978.60	977.08	mudstone, rare coal fragments, 5Y4/1, calcareous
42.67	44.20	977.08	975.55	mudstone with very small coal fragments, 5Y41, moderately calcareous
44.20	45.72	975.55	974.03	mudstone with rare coal fragments, 5Y4/1, calcareous
45.72	47.24	974.03	972.51	mudstone with minor coal fragments, minor soft, tan fragments, 5Y41, calcareous, minor sandstone fragments (salt and pepper)
47.24	48.16	972.51	971.59	No Sample
48.16	48.77	971.59	970.98	coal with bentonite, noncalcareous
48.77	50.29	970.98	969.46	mudstone with minor coal flecks, 5Y3/1, calcareous, minor small, soft, tan fragments (silt?)
50.29	51.82	969.46	967.93	mudstone with minor carbonaceous debris and minor coal, 5Y4/1, weakly calcareous
51.82	53.04	967.93	966.71	coal rich mudstone, calcareous, 5Y4/1, minor sandstone clasts (salt and pepper)
53.04	53.34	966.71	966.41	mudstone, coal, bentonite, 5Y4/1, calcareous
53.34	54.26	966.41	965.49	coal with bentonite, mudstone clasts, 5Y2.5/1, noncalcareous mudstone
54.26	54.86	965.49	964.89	mudstone with minor coal flecks, 5Y4/1, noncalcareous
54.86	56.39	964.89	963.36	very fine sandstone with mudstone clasts (sandy mudstone), possible minor bentonite, weakly calcareous, salt and pepper sandstone
56.39	57.91	963.36	961.84	very fine muddy sandstone with minor coal fragments, 5Y4/1, noncalcareous
57.91	59.44	961.84	960.31	mudstone with bentonite 5Y3/1, weakly calcareous

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
59.44	60.05	960.31	959.70	sandstone with siltstone and mud, 5Y4/1, minor coal flecks, hard, tan chips with carbonaceous debris, calcareous, hard overall
60.05	60.35	959.70	959.40	very fine sandstone and siltstone
60.35	60.96	959.40	958.79	soft mudstone, minor bentonite, minor coal, 5Y2.5/1, calcareous
60.96	62.48	958.79	957.27	mudstone with minor coal and carbonaceous debris, 5Y31, calcareous
62.48	64.01	957.27	955.74	mudstone with very fine sandstone clasts (salt and pepper), very minor coal, calcareous
64.01	65.53	955.74	954.22	mudstone, 5Y4/1, calcareous, very minor coal
65.53	67.06	954.22	952.69	mudstone with bentonite and minor coal, 5Y4/1, minor carbonaceous debris, noncalcareous
67.06	68.28	952.69	951.47	No Sample
68.28	68.58	951.47	951.17	very fine sandstone with mudstone clasts, minor coal, 5Y4/3, to 5Y3/1, calcareous, brittle
68.58	69.80	951.17	949.95	silt
69.80	70.10	949.95	949.65	mudstone with very minor sandstone clasts, 5Y3/1, weakly calcareous
70.10	71.63	949.65	948.12	mudstone with minor coal, calcareous, 5Y2.5/1
71.63	73.15	948.12	946.60	mudstone and siltstone with minor coal, calcareous, 5Y4/1
73.15	74.68	946.60	945.07	siltstone and mudstone (dominated by siltstone) with very minor coal and some very fine sand, 5Y2.5/1, calcareous
74.68	76.20	945.07	943.55	muddy siltstone with minor coal, 5Y2.5/1, calcareous
76.20	77.72	943.55	942.03	muddy siltstone, very minor carbonaceous debris, 5Y3/2 (dark olive grey), calcareous, minor very fine sand (salt and pepper)
77.72	79.25	942.03	940.50	muddy siltstone to very fine sandstone, minor coal, 5Y4/2 (olive grey), calcareous (moderate to weakly)
79.25	80.77	940.50	938.98	siltstone to very fine sandstone, minor coal, carbonaceous debris (minor), 5Y3/1, calcareous (moderately)
80.77	81.84	938.98	937.91	medium sandstone, salt and pepper with coal debris, 5Y4/1, calcareous
81.84	82.30	937.91	937.45	silty mudstone with coal (minor), 5Y4/1, calcareous
82.30	83.82	937.45	935.93	silty mudstone with coal (minor), 5Y4/1, calcareous
83.82	85.35	935.93	934.40	mudstone with bentonite and minor coal, 5Y4/1, noncalcareous
85.35	86.87	934.40	932.88	carbonaceous mudstone with bentonite, some siltstone, waxy cuttings (with some white), 5Y2.5/2, noncalcareous

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
86.87	88.39	932.88	931.36	hard, silty mudstone with carbonaceous clasts, 5Y2.5/2, minor coal fragments, noncalcareous
88.39	89.92	931.36	929.83	mudstone with very minor coal flecks, 5Y3/1, weakly calcareous
89.92	91.44	929.83	928.31	mudstone, hard, minor coal, 5Y4/1 (dark grey), calcareous
91.44	92.97	928.31	926.78	mudstone, hard, very minor coal, very minor bentonite, 5Y3/1, noncalcareous
92.97	94.49	926.78	925.26	silty mudstone, bentonite, 5Y3/1, very weakly calcareous, very minor coal
94.49	96.01	925.26	923.74	siltstone, some very fine sand, hard, some soft, dark, carbonaceous clasts, minor coal fragments, 5Y4/1, calcareous
96.01	96.93	923.74	922.82	hard, muddy siltstone/silty mudstone, 5Y4/1, weakly calcareous, very minor coal, very minor bentonite
96.93	97.54	922.82	922.21	mudstone (5Y2.5/1) with claystone (5Y4/2) interbeds, mudstone noncalcareous, claystone weakly calcareous
97.54	99.06	922.21	920.69	mudstone, 5Y3/1, single white quartzite fragment, mudstone is hard, weakly calcareous, minor coal flecks visible
99.06	100.59	920.69	919.16	mudstone/siltstone, 5Y3/1, minor bentonite and coal, weakly to moderately calcareous, hard
100.59	101.80	919.16	917.95	as above
101.80	102.11	917.95	917.64	fine sandstone, salt and pepper, bentonite, minor coal fragments, 5Y3/2, calcareous
102.11	103.63	917.64	916.12	siltstone, 5Y3/1, noncalcareous
103.63	105.16	916.12	914.59	carbonaceous siltstone, 5Y2.5/1, coal fragments, calcareous
105.16	106.68	914.59	913.07	mudstone siltstone, 5Y5/1, coal fragments and abundant bentonite, noncalcareous
106.68	108.21	913.07	911.54	very fine sandstone, 5Y5/1, minor coal, sandstone relatively soft, moderately calcareous, salt and pepper
108.21	109.73	911.54	910.02	siltstone with minor coal and bentonite (moderately abundant), 5Y2.5/2 (black), moderately calcareous (calcareous reaction varies with lithology; bentonite weakly calcareous, some siltstone nonreactive)
109.73	110.64	910.02	909.11	No Sample
110.64	111.25	909.11	908.50	fine sandstone, salt and pepper, bentonite, minor coal, minor mudstone, 5Y4/2, highly calcareous, sandstone is hard
111.25	112.17	908.50	907.58	fine sandstone, salt and pepper, mudstone fragments, minor coal flecks, 5Y4/1, highly calcareous

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
112.17	112.78	907.58	906.97	siltstone with minor fine sandstone fragments (salt and pepper), some pale mudstone flecks (bentonite?), but not overly soft, very minor coal, calcareous
112.78	114.30	906.97	905.45	fine sandstone, salt and pepper, some mudstone (pale) fragments, sandstone soft, some mudstone and minor bentonite, 5Y3/1, moderately calcareous, very minor coal fragments
114.30	115.83	905.45	903.92	fine sandstone (weakly calcareous), salt and pepper, siltstone (noncalcareous), minor bentonite, very minor coal, 5Y2.5/1,
115.83	117.35	903.92	902.40	mudstone, coal, bentonite (minor), 5Y4/1, moderately calcareous
117.35	118.87	902.40	900.88	siltstone, 5Y4/1, minor coal, minor bentonite, highly calcareous
118.87	120.40	900.88	899.35	siltstone, 5Y3/1, minor very fine sandstone (salt and pepper), minor bentonite, rare coal flecks, calcareous
120.40	121.92	899.35	897.83	siltstone, 5Y4/1, coal fragments, carbonaceous debris, minor bentonite
121.92	123.45	897.83	896.30	siltstone, 5Y2.5/1, minor coal, moderate bentonite, noncalcareous
123.45	124.97	896.30	894.78	fine sandstone, salt and pepper, coal fragments, 5Y3/2, noncalcareous
124.97	125.88	894.78	893.87	same as above
125.88	126.49	893.87	893.26	fine sandstone, moderate-weakly calcareous, salt and pepper, minor carbonaceous mud clasts (noncalcareous), minor coal, minor bentonite (calcareous), 5Y31
126.49	128.02	893.26	891.73	fine sandstone (salt and pepper), minor siltstone fragments, minor coal, sandstone moderately calcareous, siltstone weakly calcareous, 5Y 2.5/1
128.02	129.39	891.73	890.36	No Sample
129.39	129.54	890.36	890.21	siltstone, 5Y2.5/2, minor bentonite (30%), noncalcareous
129.54	131.07	890.21	888.68	siltstone (weakly calcareous), 5Y2.5/1, rare carbonaceous mudstone (noncalcareous), very minor coal, rare bentonite
131.07	132.59	888.68	887.16	siltstone, rare mudstone fragments, minor salt and pepper sandstone fragments, very minor bentonite, very weakly calcareous, 5Y2.5/1
132.59	134.11	887.16	885.64	hard siltstone, soft carbonaceous mudstone fragments, minor coal, single quartzite fragment, iron oxide-stained fragment of pale siltstone, minor bentonite, siltstone is moderately calcareous, mudstone is noncalcareous, 5Y31
134.11	135.64	885.64	884.11	siltstone with minor/rare coal, carbonaceous mudstone, minor bentonite, hard brittle fragments of siltstone, 5Y3/1, moderately calcareous
135.64	137.16	884.11	882.59	siltstone, rare hard mudstone fragments, rare coal, rare bentonite, 5Y2.5/1, moderate to highly calcareous

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO₃, density/hardness, moisture
137.16	138.69	882.59	881.06	soft, silty mudstone, bentonite, 5Y2.5/1, noncalcareous, rare carbonaceous mud clasts (soft), minor siltstone fragments
138.69	140.21	881.06	879.54	silty mudstone clasts (hard and brittle), discrete large chunks of bentonite but bentonite overlay is minor in occurrence, carbonaceous mudstone fragments are rare, minor coal, 5Y2.5/1, weakly calcareous
140.21	141.73	879.54	878.02	fine sandstone (salt and pepper), abundant siltstone, carbonaceous mudstone fragments, minor coal, one iron-stained quartzite fragment (probably from above), minor bentonite but it occurred as a large discrete fragment, 5Y3/1, weakly calcareous, sandstone is soft, siltstone is hard and brittle
141.73	143.26	878.02	876.49	mudstone, brittle, large fragments, carbonaceous-rich mudstone fragments, bentonite, coal, 5Y3/1
143.26	144.78	876.49	874.97	fine sandstone (salt and pepper), with mudstone, carbonaceous mudstone fragments, sandstone fragments, small mudstone fragments, large minor coal, bright green clay (small fragments, rare), iron oxide quartz (2 fragments, from above), moderately calcareous
144.78	146.00	874.97	873.75	as above
146.00	146.31	873.75	873.44	bentonitic mudstone, carbonaceous (dark) mudstone, coal, large chunks of bentonitic mudstone, 5Y4/1, non-calcareous
146.31	147.83	873.44	871.92	siltstone with large mudstone clasts, carbonaceous mudstone clasts (large), siltstone is small, fragmented and brittle, mudstone soft but still fairly competent, minor bentonite, 5Y2.5/1, noncalcareous
147.83	149.35	871.92	870.40	mudstone with minor small siltstone fragments, mudstone fragments are large and hard (but breakable), rare iron oxide coarse quartzite, carbonaceous rich mud clasts, minor coal, large bentonitic fragments, avg:5Y3/1
149.35	149.96	870.40	869.79	mudstone, soft large fragments and carbonaceous, large clasts (dark), quartzite fragments and grass suggests contamination, coal, avg colour: 5Y4/2, moderately calcareous

Table 4. Borehole WCAB-15-02.

Top Depth (m bgs)	Bottom Depth (m bgs)	Top Elevation (m asl)	Bottom Elevation (m asl)	Description
0.00	1.52	981.00	979.48	gravelly sand: fine to medium sand, pebble-sized gravel, some coarse sand and some cobbles, trace to no silt; 2.5Y 5/3 colour; poorly sorted; sand is composed of white quartz and black chert grains, gravel is quartzite; noncalcareous (sand fraction); loose; moist
1.52	3.05	979.48	977.95	gravelly sand; medium sand, ~5% pebble content, no silt present; 2.5Y4/3 colour; sand is composed of white quartz with some black chert grains, pebbles are quartzite with occasional siltstone; noncalcareous; loose; moist
3.05	4.88	977.95	976.12	sand or gravelly sand: similar to above but unsampled; water table at 3.66 m; bedrock top at 4.88 m
4.88	6.10	976.12	974.90	mudstone to v. fine sandy mudstone: silt and clay with some v. fine sand; 5Y4/2 colour; noncalcareous; consolidated but weak to very weak rock
6.10	7.62	974.90	973.38	v. fine-grained sandstone: 5Y4/1 colour; well sorted; quartz and chert grains, more quartz than chert
7.62	9.14	973.38	971.86	muddy v. fine-grained sandstone: 5Y4/1 colour; moderately sorted; quartz and chert grains; consolidated but weak to very weak rock
9.14	10.67	971.86	970.33	fine-grained sandstone: 5Y4/2 colour; well sorted; quartz and chert grains, more quartz than chert; moderately calcareous
10.67	12.19	970.33	968.81	medium to f. grained sandstone: 5Y4/2 colour; heterolithic subangular to rounded grains; strongly calcareous; some carbonaceous debris
12.19	13.72	968.81	967.28	medium to f. grained sandstone: 5Y4/2 colour; heterolithic subangular to subrounded grains; harder light grey unit at 12.50 m to 12.80 m (not sampled)
13.72	15.24	967.28	965.76	medium-grained sandstone: 5Y4/2 colour; heterolithic subangular to subrounded grains; moderately calcareous; weak (soft) rock (driller's comment)
15.24	16.76	965.76	964.24	medium-grained sandstone: as above
16.76	18.29	964.24	962.71	medium-grained sandstone: 5Y3/1 colour; dominantly quartz and chert grains, more quartz than chert, grains are rounded to subrounded; moderately calcareous
18.29	19.81	962.71	961.19	medium-grained sandstone: as above
19.81	21.34	961.19	959.66	fine-grained sandstone: 5Y3/1 colour; quartz and chert grains, more quartz than chert, some pink opaque grains as well, subrounded to rounded grains; moderately calcareous; soft weak rock

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
21.34	22.86	959.66	958.14	medium-grained sandstone: 5Y3/1 colour; quartz and chert grains with some tan grains, grains are subrounded to rounded with occasional subangular grains; rock is weak (although driller reports slightly harder drilling); moderately calcareous
22.86	24.38	958.14	956.62	fine to medium-grained sandstone: 5Y3/1 colour; quartz and chert grains, more quartz than chert, some tan, brown and pink grains as well, grains are subrounded to rounded; moderately calcareous; weak rock
24.38	25.91	956.62	955.09	medium-grained sandstone: 5Y3/2 colour; white (quartz) with some black (chert) grains, grains are subrounded to rounded; strongly calcareous; weak rock
25.91	27.43	955.09	953.57	medium-grained sandstone: some coarse grains; 5Y3/2 colour; quartz and chert grains, more quartz than chert, some tan, brown and pink grains as well, grains are subrounded to rounded; occasional flakes or nodules of bentonite-type clay; moderately calcareous; weak rock
27.43	28.96	953.57	952.04	medium-grained sandstone: occasional coarse grains; 5Y3/2 colour; quartz and chert (white and black) grains with some other coloured grains (green, tan and pink); moderately calcareous
28.96	30.48	952.04	950.52	medium-grained sandstone: as above; driller's report harder drilling
30.48	32.00	950.52	949.00	medium-grained sandstone: 5Y2.5/1 colour; quartz and chert (white and black) grains with some other coloured grains (green, tan and pink), rounded to subrounded grains; moderately calcareous
32.00	33.53	949.00	947.47	fine-grained sandstone: 5Y2.5/1 colour; white and black (quartz and chert) with some other coloured grains (green, tan and pink), rounded to subrounded grains; moderately calcareous; weak rock
33.53	35.05	947.47	945.95	siltstone: 5Y3/2 colour; bentonitic; noncalcareous
35.05	36.58	945.95	944.42	mudstone: clay and silt; 5Y3/2 colour; noncalcareous
36.58	38.10	944.42	942.90	fine-grained sandstone: 5Y4/1 colour; quartz and chert grains, with some tan and pink grains; bentonitic nodules; weak rock
38.10	39.62	942.90	941.38	fine-grained sandstone: 5Y3/1 colour; white and black coloured grains (quartz and chert) with some other coloured minerals; weakly calcareous; black carbonaceous nodules present in trace occurrence; weak rock
39.62	41.15	941.38	939.85	fine-grained sandstone: 5Y4/1 colour; white and black (quartz and chert) grains, with some to trace other coloured minerals; bentonitic nodules present as trace; carbonaceous nodules up to coarse sand size present as trace; weakly calcareous; weak rock

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
41.15	42.67	939.85	938.33	fine-grained sandstone and mudstone: 1) sandstone description: white (quartz) and black (chert) grains; 2) mudstone description: silt and clay only - no sand; 3) undifferentiated sample description: 5Y4/1 colour; weakly calcareous; possibly mudstone and sandstone interbedded
42.67	44.20	938.33	936.80	mudstone and sandstone: 1) mudstone description: silt and clay, no sand; 5Y3/1 colour; no structure observable in chips; noncalcareous; 2) sandstone description: fine to medium grained; white and black (quartz and chert) with some other minerals; 5Y3/2 colour; occasional coal fragments; trace bentonite nodules; 3) undifferentiated sample description: may be interbedded mudstone / sandstone / coal or occasional finer bed, or mudstone may have fallen from 42.67 m
44.20	45.72	936.80	935.28	fine-grained sandstone: 5Y4/1 colour; white and black (quartz and chert) grains; weakly calcareous; weak rock; carbonaceous nodules
45.72	47.24	935.28	933.76	fine-grained sandstone: described as above; mudstone chips present (describes as 42.67 m depth above); driller's comment: mudstone chips may have fallen from 42.67 m depth; alternatively - interval may be sandstone / mudstone interbeds
47.24	48.77	933.76	932.23	fine-grained sandstone and mudstone chips: both lithologies described as above; driller's comment: mudstone chips may have fallen from 42.67 m depth; alternatively - interval may be sandstone / mudstone interbeds
48.77	50.29	932.23	930.71	fine-grained sandstone with mudstone (as interbeds?): 1) sandstone description: 5Y4/1 colour; quartz and chert grains with trace other minerals; weakly calcareous; weak rock; 2) mudstone description: clay and silt; 5Y3/2 colour; mudstone present as small chips in sample
50.29	51.82	930.71	929.18	fine-grained sandstone: 5Y3/2 colour; white and black (quartz and chert) grains with trace other minerals; weakly calcareous; weak rock
51.82	53.34	929.18	927.66	fine to medium-grained sandstone with mudstone (as interbeds?): 5Y3/2 colour; white and black (quartz and chert) grains with trace other minerals; strongly calcareous; mudstone chips may represent interbeds of mudstone; coal fragments; bentonite nodules
53.34	54.86	927.66	926.14	fine-grained sandstone with mudstone (as interbeds?): 1) sandstone description: 5Y4/1 colour; white and black (quartz and chert) grains; strongly calcareous; weak rock; 2) mudstone description: clay and silt
54.86	56.39	926.14	924.61	fine-grained sandstone with mudstone (as interbeds?): sandstone described as above; mudstone described as: 5Y3/2 colour; some larger chips (small pebble size)
56.39	57.91	924.61	923.09	sandstone with mudstone (as interbeds?): described as above; however, some trace coal fragments present

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
57.91	59.44	923.09	921.56	fine-grained sandstone: 5Y3/2 colour; quartz and chert grains with trace other minerals, rounded and mature grains; moderately calcareous; weak rock; trace mudstone fragments present
59.44	60.96	921.56	920.04	mudstone / siltstone / fine-grained sandstone (as interbeds?): two types of chips (mudstone and siltstone) dispersed evenly in a matrix of disaggregated sandstone; mudstone colour 5Y3/2; siltstone colour 5Y4/1; sandstone colour 5Y3/2; some coal fragments present
60.96	62.48	920.04	918.52	sandstone and mudstone (interbedded?): 1) sandstone description: very fine grained; 5Y4/1 colour; quartz and chert grains; moderately calcareous; sandstone chips (not disaggregated - rock is stronger than typical disaggregated sandstone); 2) mudstone description: silt and clay; noncalcareous
62.48	64.01	918.52	916.99	mudstone: silt and clay; noncalcareous; chips up to pebble size
64.01	65.53	916.99	915.47	mudstone: silt and clay at near equal proportions, some sand; 5Y3/2 colour; weakly calcareous; trace coal fragments
65.53	67.06	915.47	913.94	mudstone: silt and clay; 5Y3/1 colour; noncalcareous
67.06	68.58	913.94	912.42	mudstone: described as above; note in this sample and in last: chips of slightly lighter, grittier and slightly darker, less gritty mudstone could indicate alternating beds of siltier and less silty mudstone
68.58	70.10	912.42	910.90	mudstone: silt and clay; 5Y3/1 colour; noncalcareous; trace bentonite as flakes (may exist as thin beds in formation)
70.10	71.63	910.90	909.37	mudstone: silt and clay with some fine sand; 5Y4/1 colour; trace to some bentonite present as thin flakes
71.63	73.15	909.37	907.85	mudstone: silt and clay; 5Y3/1 colour; noncalcareous
73.15	74.68	907.85	906.32	mudstone / sandstone (interbedded?): 1) mudstone description: silt and clay composition; 5Y3/1 colour; noncalcareous; 2) sandstone description: v. fine grained; 5Y4/1 colour; moderately calcareous; 3) undifferentiated sample description: both lithologies present as chips possibly indicating that sandstone is stronger than typical disaggregated sample; siltstone present as trace; coal fragments present as trace
74.68	76.20	906.32	904.80	mudstone / sandstone / siltstone / coal (interbedded?): 1) mudstone description: silt/clay composition; 5Y3/2 colour; noncal-careous; 2) sandstone description: f. grained; 5Y4/1 colour; white and black (quartz and chert) grains; weakly calcareous; 3) siltstone description: little to no clay; 5Y5/1 colour; 4) undifferentiated sample description: some coal fragments
76.20	77.72	904.80	903.28	mudstone / sandstone / siltstone / coal (interbedded?): described as above
77.72	79.25	903.28	901.75	siltstone: silt with trace clay; 5Y4/1 colour; moderately calcareous; carbonaceous debris; trace coal chunks

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
79.25	80.77	901.75	900.23	mudstone and siltstone (interbedded?): siltstone is 5Y4/1 colour; mudstone is 5Y3/1 colour; bentonite flakes
80.77	82.30	900.23	898.70	siltstone: silt with trace to no clay, trace v. fine sand present; 5Y4/1 colour; trace coal nodules; trace bentonite flakes
82.30	83.82	898.70	897.18	mudstone: clay and silt; 5Y3/2 colour; trace carbonaceous debris; trace bentonite; weak rock
83.82	85.34	897.18	895.66	mudstone: clay and silt; 5Y3/1 colour; noncalcareous; some coal
85.34	86.87	895.66	894.13	siltstone: silt with some v. fine sand; 5Y4/1 colour; some mudstone chips; mudstone is silt and clay composition, and it weaker than siltstone
86.87	88.39	894.13	892.61	mudstone: silt and clay composition; 5Y3/2 colour; noncalcareous; trace siltstone flakes
88.39	89.92	892.61	891.08	silty sandstone: v. fine-grained sand; 5Y4/1 colour; some mudstone chips may indicate mudstone interbeds or material derived from overlying intervals (83.82, 85.34), mudstone described as in 83.82 m and 85.34 m intervals; trace coal chunks present
89.92	91.44	891.08	889.56	mudstone: silt and clay composition; 5Y3/1 colour; noncalcareous; bentonite present as flakes; trace siltstone flakes, bentonite may be present as distinct bed; carbonaceous debris
91.44	92.96	889.56	888.04	siltstone and mudstone (siltstone with mudstone interbeds?): 1) siltstone description: 5Y4/1 colour; noncalcareous; 2) mudstone description: 5Y3/1 colour; noncalcareous
92.96	94.49	888.04	886.51	mudstone: silt and clay; GLEY2 3/10BG colour; weakly calcareous
94.49	96.01	886.51	884.99	v. fine-grained sandstone: silty; 5Y 4/2 colour; white and black (quartz and chert) grains; weakly calcareous; bentonite present as chunks; some mudstone chips may indicate mudstone present as interbeds
96.01	97.54	884.99	883.46	siltstone and mudstone (interbedded?): 1) siltstone description: siltstone; silt with some clay; GLEY1 4/10GY colour; noncal-careous; 2) mudstone description: silt and clay; 5Y3/2 colour
97.54	99.06	883.46	881.94	fine-grained sandstone: silty; 5Y4/2 colour; white and black (quartz and chert) grains; strongly calcareous; some mudstone chips may indicate mudstone present as interbeds
99.06	100.58	881.94	880.42	sandstone: as described above
100.58	102.11	880.42	878.89	sandstone and mudstone (interbedded?): 1) sandstone description: fine grained and silty; 5Y4/1 colour; white and black (quartz and chert) grains; strongly calcareous; 2) mudstone description: silt and clay; 5Y3/1 colour; noncalcareous; 3) undifferentiated sample description: rare chips of oxidized mudstone
102.11	103.63	878.89	877.37	sandstone and mudstone: described as above

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
103.63	105.16	877.37	875.84	sandstone: fine grained; 5Y4/2 colour; white and black (quartz and chert) grains; weakly calcareous; disaggregated to small flakes in sample; some mudstone chips, silt and clay composition, 5Y3/1 colour, may exist as interbeds in sandstone
105.16	106.68	875.84	874.32	sandstone and mudstone (interbedded?): 1) sandstone description: fine grained; 5Y4/1 colour; white and black (quartz and chert) grains; moderately calcareous; disaggregated and in small flakes in sample; 2) mudstone description: silt and clay; 5Y2.5/1 colour; noncalcareous; 3) undifferentiated sample description: some sandy bentonite chips
106.68	108.20	874.32	872.80	sandstone: fine grained; 5Y3/2 colour; white and black (quartz and chert) grains; moderately calcareous; trace bentonite nodules; some mudstone chips may indicate mudstone present as interbeds; trace oxidized fragment (oxidized siltstone or ironstone?)
108.20	109.73	872.80	871.27	sandstone: described as above; some nodules of bentonitic sandstone; mudstone / siltstone chips common in sample but driller reports that these have fallen from higher in borehole
109.73	111.25	871.27	869.75	sandstone: fine grained, clean - no silt; 5Y3/2 colour; white and black (quartz and chert) grains with trace other minerals; moderately calcareous; siltstone chips, GLEY1 3/10GY colour, noncalcareous; formation may be interbedded sandstone and siltstone (or siltstone fell from above?)
111.25	112.78	869.75	868.22	sandstone / siltstone / mudstone (interbedded?): 1) sandstone description: silty and fine grained; white and black (quartz and chert) grains; 2) siltstone description: GLEY1 3/5 colour; 3) mudstone description: silt and clay, 5Y3/1 colour; 4) undifferentiated sample description: trace chips of oxidized sandstone
112.78	114.30	868.22	866.70	sandstone: fine grained; 5Y3/1 colour; white and black (quartz and chert) grains; moderately calcareous; trace small mudstone chips; some larger bentonite chips may represent distinct bed(s) of bentonite
114.30	115.82	866.70	865.18	mudstone and siltstone (interbedded?): 1) mudstone description: silt and clay composition; 5Y3/1 colour; 2) siltstone description: GLEY1 4/10GY; 3) undifferentiated sample description: trace bentonite flakes; noncalcareous
115.82	117.35	865.18	863.65	siltstone: GLEY1 3/5GY colour; very weakly calcareous; trace oxidized sandstone nodules
117.35	118.87	863.65	862.13	siltstone: GLEY1 3/5GY colour; noncalcareous; bentonite nodules present as trace; some mudstone chips, 5Y2.5/1 coloured mudstone
118.87	120.40	862.13	860.60	silty to very silty sandstone (or interbedded siltstone and sandstone?): texture is siltstone chips in sand matrix (disaggregated sandstone?) - likely indicates thin beds of each lithology; GLEY1 3/5 colour; weakly calcareous

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
120.40	121.92	860.60	859.08	mudstone: silt and clay with some v. fine sand; GLEY1 4/5GY colour; noncalcareous; disaggregated sand distributed around siltstone / mudstone chips - may be interbeds or washed from overlying formations; bentonite present as trace nodules
121.92	123.44	859.08	857.56	siltstone: with trace to some sand; GLEY1 3/5GY colour; bentonite present as trace nodules
123.44	124.97	857.56	856.03	siltstone: described as above except single small calcite vein found between 123.44 m and 124.97 m depth
124.97	126.49	856.03	854.51	siltstone (with sandstone as interbeds or sandy siltstone?): siltstone is GLEY1 3/5GY colour; weakly calcareous
126.49	128.02	854.51	852.98	siltstone: some sand (possibly as interbeds?); sand is distributed around outside of siltstone flakes, so may be from independent beds; GLEY1 3/5GY colour; trace oxidized sandstone chips
128.02	129.54	852.98	851.46	siltstone: described as above
129.54	131.06	851.46	849.94	siltstone / bentonite: GLEY1 3/5GY; bentonitic, some bentonite nodules, distinct bentonite bed is expected; some sand in sample, but may be washed in from other formations
131.06	132.59	849.94	848.41	siltstone: as described above
132.59	134.11	848.41	846.89	siltstone and sandstone (interbedded?): GLEY 1 3/5GY; sandstone is v. fine grained; some coal fragments present as very hard, vitreous coal chips
134.11	135.64	846.89	845.36	siltstone: GLEY1 3/5GY; carbonaceous chips - coal or carbonaceous siltstone
135.64	137.16	845.36	843.84	siltstone: GLEY1 3/10GY colour
137.16	138.68	843.84	842.32	siltstone: GLEY1 3/5GY colour; some coal fragments present
138.68	140.21	842.32	840.79	siltstone: GLEY1 3/5GY; hard, vitreous coal fragments; occasional mudstone fragments, mudstone is darker than siltstone
140.21	141.73	840.79	839.27	siltstone: GLEY1 2.5/5GY; trace fragments of bentonitic sandstone
141.73	143.26	839.27	837.74	siltstone: GLEY1 3/10Y colour; trace to some bentonitic sandstone flakes present; trace flakes of oxidized sandstone; trace coal fragments
143.26	144.78	837.74	836.22	siltstone: GLEY1 3/5GY colour, occasional lighter grey siltstone flakes; trace coal or carbonaceous siltstone flakes; trace bentonite nodules
144.78	146.30	836.22	834.70	siltstone: GLEY1 3/5GY
146.30	147.83	834.70	833.17	siltstone: with some sandstone and some mudstone chips (may represent interbeds?); siltstone colour GLEY1 3/5GY; mudstone colour 5Y3/1; moderately calcareous sandstone; noncalcareous siltstone/mudstone

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
147.83	149.35	833.17	831.65	siltstone: with some sandstone (possibly as interbeds?); siltstone colour GLEY1 3/5GY; sandstone colour 5Y3/2; moderately calcareous sandstone, noncalcareous siltstone; occasional coal fragments
149.35	149.96	831.65	831.04	siltstone: as described above

Table 5. Borehole WCAB-15-03.

Top Depth	Bottom Depth	Top Elevation	Bottom Elevation	Description
(m bgs)	(m bgs)	(m asl)	(m asl)	Grain size, colour (including Munsell Colour Systems codes), structure, inclusions, petrology, CaCO ₃ , density/hardness, moisture
0	1.52	1040.74	1039.22	cl-sa-si, 2.5Y 4/3, trace gravel, gravel size less than 5 mm, may be fill at surface, small root-lets, slight carbonaceous material, no reaction with HCL, soft, damp
1.52	3.65	1039.22	1037.09	cl-sa-si, 2.5Y 3/2, fine-medium sand, some gravel, gravel includes small granites 2-10 mm in size, trace carbonaceous material, strong reaction with HCL, soft, damp
3.65	4.88	1037.09	1035.86	gr-si-sa, 10YR 4/6, medium-coarse sand, sand is predominantly quartz and oxidized tan grains, gravel includes quartzite <20 mm in size, gravel mostly broken up by drilling method, no reaction with HCL, loose, dry
4.88	6.1	1035.86	1034.64	gr-si-sa, 10YR 4/6, medium-coarse sand, sand is predominantly quartz and oxidized tan grains, gravel includes pale pink, tan and dark green quartzite 2-25 mm in size, gravel mostly broken up by drilling method, no reaction with HCL, loose, dry
6.1	7.62	1034.64	1033.12	gr-si-sa, 10YR 4/6, fine-medium sand, sand is predominantly quartz and chert, black and tan colours, oxidized, gravel includes pale pink, white, tan, and dark green quartzite, gravel mostly broken up by drilling method, no reaction with HCL, loose
7.62	8.84	1033.12	1031.9	gr & si-sa, 10 YR 4/6, coarse-very coarse sand, sand is oxidized, gravel includes pale pink, tan, white, and dark grey quartzite, gravel mostly broken up by drilling method, no reaction with HCL, loose, dry
8.84	9.14	1031.9	1031.6	gr & si-sa, 10 YR 4/6, fine-medium sand, sand is oxidized, gravel has the same lithologies as above 5-30 mm in size (measurement for intact pieces), no reaction with HCL, loose, damp (no water in drilling process, water from formation)
9.14	10.67	1031.6	1030.07	gr & si-sa, 10YR 4/6, medium-very coarse sand, sand is oxidized, sand is predominantly quartz and tan and black grains, gravel includes quartzite of 2-20 mm in size, gravel mostly broken up by drilling method, no reaction with HCL, loose, damp

Top Depth (m bgs)	Bottom Depth (m bgs)	Top Elevation (m asl)	Bottom Elevation (m asl)	Description
10.67	11.28	1030.07	1029.46	gr & si-sa, 10YR 4/6, medium-very coarse sand, sand is oxidized, gravel includes pale pink, tan, and black quartzite and chert 2-20 mm in size, gravel mostly broken up by drilling method, no reaction with HCL, loose, wet (now drilling with water)
11.28	13.1064	1029.46	1027.64	gr & si-sa, 2.5Y 5/4, fine sand, sand is oxidized, gravel includes quartzite and chert 2-25 mm in size, gravel mostly broken up by drilling method, no reaction with HCL, loose
13.1064	16.76	1027.64	1023.98	siltstone, GLEY 1 2.5/10Y, no reaction with HCL, siltstone is loose and pulverized by drilling. Drillers comment: gr & si-sa in samples taken at 13.72 m and 15.24 m is brought down the sides of the borehole from above sand/ gravel
16.76	18.29	1023.98	1022.45	same as above
18.29	19.81	1022.45	1020.93	siltstone/mudstone, GLEY 1 2.5/N, some carbonaceous material, no reaction with HCL, loose due to drilling method, some very coarse sand/gravel in sample is from higher up in the borehole
19.81	21.34	1020.93	1019.4	mudstone, GLEY 1 2.5/5GY, waxy, small mudstone pieces are very hard, no reaction with HCL, some very coarse sand/gravel in sample is from higher up in the borehole, trace amount of bentonite dispersed in sample from drilling
21.34	22.86	1019.4	1017.88	mudstone, GLEY 1 2.5/ 10Y, no reaction with HCL, trace amount of bentonite dispersed in sample could be from drilling method. Drillers comment: casing down to 21.34 m
22.86	24.38	1017.88	1016.36	predominantly siltstone and less amounts of mudstone, GLEY 1 2.5/10Y, gritty feeling when cut, some of oxidized material, trace carbonaceous material, reaction with HCL
24.38	25.91	1016.36	1014.83	mudstone, GLEY 1 2.5/N, waxy, trace carbonaceous material, trace flakes of bentonite, no reaction with HCL, trace oxidized sand/gravel in sample is from higher up in the borehole
25.91	27.43	1014.83	1013.31	siltstone with some mudstones, 5Y 4/1, waxy, trace carbonaceous material, no reaction with HCL, trace oxidized sand/gravel in sample is from higher up in the borehole
27.43	28.96	1013.31	1011.78	sandstone, 5Y 3/1, fine, sandstone grains are salt and pepper, some siltstone, trace bentonite flakes, very slight HCL reaction, loose from drilling method
28.96	30.48	1011.78	1010.26	mudstone, GLEY 1 2.5/10Y, some very fine sandstone, some carbonaceous material, reaction with HCL, loose from drilling method
30.48	32	1010.26	1008.74	siltstone, GLEY 1 4/N, trace oxidized material, trace carbonaceous material, very slight reaction with HCL
32	33.53	1008.74	1007.21	siltstone, GLEY 1 3/5GY, some oxidized material, reaction with HCL, loose from drilling method
33.53	35.05	1007.21	1005.69	siltstone, 5Y 4/1, some very fine sandstone, some oxidized material, reaction with HCL, loose from drilling method

Top Depth (m bgs)	Bottom Depth (m bgs)	Top Elevation (m asl)	Bottom Elevation (m asl)	Description
35.05	35.97	1005.69	1004.77	siltstone, 5Y 3/1, coal as small fragments throughout due to thin coal at 35.96 m, some oxidized material, no reaction with HCL
35.97	36.58	1004.77	1004.16	siltstone, 5Y 4/1, trace carbonaceous material, trace small flakes of oxidized siltstone or claystone, reaction with HCL
36.58	38.1	1004.16	1002.64	siltstone and sandstone, 5Y 3/2, very fine- fine sandstone, sandstone grains are salt and pepper, some carbonaceous material (could be coal), trace small flakes of oxidized siltstone, trace flakes of bentonite, reaction with HCL
38.1	39.62	1002.64	1001.12	siltstone, 5Y 4/1, some very fine sandstone, trace oxidized siltstone, trace carbonaceous material, trace bentonite flakes, strong reaction with HCL
39.62	41.15	1001.12	999.59	siltstone, 5Y 3/2, some very fine sandstone, trace hard white claystone, trace carbonaceous material, reaction with HCL
41.15	42.67	999.59	998.07	siltstone, 5Y 2.5/1, trace very fine sandstone, trace carbonaceous material, reaction with HCL. Drillers comment: easy to drill through, very soft.
42.67	45.138	998.07	995.602	siltstone and sandstone, 5Y 3/2, very fine-fine sandstone, sandstone grains are salt and pepper, trace carbonaceous material, trace hard nodules of white claystone, moderate reaction with HCL
45.138	45.447	995.602	995.293	coal, black in colour, hard and platy
45.447	47.24	995.293	993.5	siltstone, 5Y 3/2, some very fine sandstone, bentonite at 46.32 m, trace carbonaceous material, trace hard and white nodules of claystone, strong reaction with HCL
47.24	48.46	993.5	992.58	siltstone, 5Y 3/2, bentonite at 48.16 m, some carbonaceous material, slight reaction with HCL
48.46	48.77	992.58	991.97	coal, black in colour, hard and platy
48.77	49.99	991.97	991.063	siltstone, 5Y 3/2, some carbonaceous material, slight reaction with HCL
49.99	50.29	991.063	990.857	coal, black in colour, hard and platy
50.29	51.82	990.857	988.07	siltstone, 5Y 3/2, some very fine sandstone, some coal, trace bentonite flakes, very slight reaction with HCL
51.82	52.67	988.07	987.4	sandstone, 5Y 3/2, very fine-fine sandstone, sandstone grains are salt and pepper, trace carbonaceous material (probably coal), trace oxidized siltstone, moderate reaction with HCL
52.67	55.47	987.4	985	sandstone, 5Y 3/2, very fine-fine sandstone, sandstone grains are salt and pepper, some siltstone, trace carbonaceous material, slight reaction with HCL
55.47	56.39	985	984.35	siltstone, 5Y 2.5/2, some very fine sandstone, trace carbonaceous material, trace oxidized siltstone, trace flakes of bentonite, slight to moderate reaction with HCL

Top Depth (m bgs)	Bottom Depth (m bgs)	Top Elevation (m asl)	Bottom Elevation (m asl)	Description
56.39	57.91	984.35	982.83	siltstone, 5Y 2.5/2, some carbonaceous material/coal, trace bentonite flakes, moderate to strong reaction with HCL
57.91	59.44	982.83	981.3	siltstone and sandstone, GLEY 1 2.5/10Y, very fine sandstone, sandstone grains are salt and pepper, some carbonaceous material/coal, trace oxidized siltstone, moderate reaction with HCL. Drillers comment: hard drilling for 57.91-59.44 m interval.
59.44	60.66	981.3	980.08	siltstone, 5Y 4/1, trace white nodules of claystone, trace bentonite intermixed, no reaction with HCL
60.66	60.96	980.08	979.78	coal, black in colour, hard and platy
60.96	62.48	979.78	978.26	siltstone, 5 Y 2.5/2, some very fine sandstone, some carbonaceous material/coal, trace oxidized siltstone, moderate reaction with HCL. Drillers comment: coal in sample may be from above coal seam at 60.66 m.
62.48	64.01	978.26	976.73	siltstone, 5Y 4/1, some carbonaceous material/coal, some bentonite flakes/nodules, strong reaction with HCL. Drillers comment: coal in sample may be from above coal seam at 60.66 m.
64.01	65.53	976.73	975.21	siltstone, GLEY 1 3/10Y, trace carbonaceous material, trace bentonite flakes, no reaction with HCL
65.53	67.1	975.21	973.68	siltstone and sandstone, 5Y 2.5/1, very fine sandstone, sandstone grains are salt and pepper, some carbonaceous material, trace bentonite flakes, trace weathered siltstone, strong reaction with HCL
67.66	68.28	973.68	972.16	siltstone, 5Y 3/2, reaction with HCL
68.28	68.58	972.46	972.16	coal, black in colour, hard and platy
68.58	70.1	972.16	970.64	siltstone, GLEY 1 4/5 GY, some carbonaceous material/coal, trace oxidized siltstone, no reaction with HCL
70.1	71.63	970.64	969.11	siltstone and sandstone, 5Y 4/1, very fine sandstone, sandstone grains are salt and pepper, trace bentonite flakes, slight to moderate reaction with HCL, loose from drilling method
71.63	73.15	969.11	967.59	sandstone, 5 Y 3/2, very fine sandstone, sandstone grains are salt and pepper, some siltstone, some carbonaceous material/coal, moderate reaction with HCL
73.15	74.68	967.59	966.06	sandstone, 5 Y 3/1, very fine-fine sandstone, sandstone grains are salt and pepper, some siltstone, some carbonaceous materials/coal, trace oxidized sandstone, slight to moderate reaction with HCL
74.68	76.2	966.06	964.54	sandstone, 5Y 3/2 colour, fine sandstone, sandstone grains are salt and pepper, trace carbonaceous material/coal, trace bentonite flakes, trace oxidized sandstone, moderate reaction with HCL
76.51	77.11	964.54	963.63	coal, black in colour, hard and platy, trace bentonite flakes

Top Depth (m bgs)	Bottom Depth (m bgs)	Top Elevation (m asl)	Bottom Elevation (m asl)	Description
77.11	77.72	963.63	963.02	siltstone, 5Y 3/2, some very fine sandstone, some carbonaceous material, trace oxidized siltstone, moderate reaction with HCL.
77.72	79.25	963.02	961.49	siltstone, 5Y 3/2, some carbonaceous material, trace oxidized siltstone, trace bentonite flakes, moderate reaction with HCL
79.25	80.47	961.49	960.27	siltstone, 5Y 4/1, some bentonite chips, moderate reaction with HCL
80.47	80.77	960.27	959.97	coal, black in colour, hard and platy, trace bentonite flakes
80.77	82.3	959.97	958.44	sandstone, 5Y 3/2, fine sandstone, sandstone grains are salt and pepper, trace carbonaceous material, trace bentonite flakes, slight reaction with HCL. Drillers comment: coal in sample is from higher up in the boreholes (seam at 80.47 m).
82.3	83.82	958.44	956.92	sandstone, 5Y 3/2, fine sandstone, sandstone grains are salt and pepper, trace bentonite flakes, slight reaction with HCL. Drillers comment: coal in sample is from higher up in the boreholes (seam at 80.47 m).
83.82	85.34	956.92	955.4	sandstone, 5Y 3/1, fine sandstone, sandstone grains are salt and pepper, strong reaction with HCL. Drillers comment: coal in sample is from higher up in the boreholes (seam at 80.47 m).
85.34	86.87	955.4	953.87	sandstone, 5Y 3/1, medium sandstone, sandstone grains are salt and pepper, trace carbonaceous materials/coal, trace bentonite flakes, moderate to strong reaction with HCL
86.87	88.39	953.87	952.35	sandstone, 5Y 2/1, fine-medium sandstone, sandstone grains are salt and pepper, trace carbonaceous materials, trace siltstone (could be from higher up in the borehole), strong reaction with HCL
88.39	89.92	952.35	950.82	same as above
89.92	91.44	950.82	949.3	sandstone, 5Y 3/1, medium sandstone, sandstone grains are salt and pepper, some carbonaceous material/coal, some siltstone fragments, trace bentonite flakes, trace oxidized siltstone, moderate to strong reaction with HCL
91.44	92.96	949.3	947.78	sandstone, 5 Y 3/1, medium sandstone, sandstone grains are salt and pepper, trace carbonaceous material, moderate to strong reaction with HCL
92.96	94.49	947.78	946.25	sandstone, 5 Y 3/2, fine sandstone, sandstone grains are salt and pepper, intermixed with some siltstone, some coal and some bentonite chips, some mudstone, trace oxidized siltstone, very slight reaction with HCL
94.49	96.44	946.25	944.297	sandstone and siltstone, 5Y 3/1, fine-medium sandstone, sandstone grains are salt and pepper, sandstone is the dominant lithology, coal and siltstone intermixed with sandstone, trace bentonite flakes, moderate reaction with HCL
96.44	99.06	944.297	941.68	sandstone, 5Y 3/2, medium sandstone, sandstone grains are salt and pepper, trace coal/carbonaceous materials, trace siltstone, trace oxidized siltstone, moderate reaction with HCL

Top Depth (m bgs)	Bottom Depth (m bgs)	Top Elevation (m asl)	Bottom Elevation (m asl)	Description
99.06	100.58	941.68	940.16	sandstone, 5Y 3/2, fine sandstone, sandstone grains are salt and pepper, trace carbonaceous material, moderate reaction with HCL
100.58	102.11	940.16	938.63	sandstone, 5Y 3/2, medium sandstone, sandstone grains are salt and pepper, trace carbonaceous material, moderate to strong reaction with HCL
102.11	103.63	938.63	937.11	sandstone, 5Y 3/1, fine-medium sandstone, sandstone grains are salt and pepper, intermixed with some coal and siltstone, trace bentonite flakes, moderate reaction with HCL
103.63	105.16	937.11	935.58	sandstone, 5Y 3/1, fine-medium sandstone, sandstone grains are salt and pepper, trace carbonaceous material, moderate to strong reaction with HCL
105.16	106.68	935.58	934.06	sandstone, 5Y 3/1, fine-medium sandstone, sandstone grains are salt and pepper, trace siltstone, trace oxidized siltstone, moderate to strong reaction with HCL
106.68	108.2	934.06	932.54	sandstone, 5Y 3/1, fine-medium sandstone, sandstone grains are salt and pepper, trace carbonaceous material/coal, trace siltstone, trace bentonite, strong reaction with HCL
108.2	109.73	932.54	931.01	sandstone, 5Y 3/1, fine-medium sandstone, sandstone grains are salt and pepper, trace carbonaceous material, trace siltstone, moderate reaction with HCL
109.73	111.25	931.01	929.49	sandstone, 5Y 3/1, fine-medium sandstone, sandstone grains are salt and pepper, trace carbonaceous material, trace siltstone, trace oxidized siltstone, trace bentonite flakes, moderate reaction with HCL
111.25	112.78	929.49	927.96	sandstone, 5Y 3/1, fine-medium sandstone, same as above
112.78	114.3	927.96	926.44	siltstone, GLEY 1 2.5/N, some very fine-fine sandstone, some carbonaceous material/coal, trace bentonite flakes, no reaction with HCL
114.3	115.82	926.44	924.92	siltstone, GLEY 1 2.5/10Y, some carbonaceous material/coal, some bentonite intermixed, trace oxidized siltstone, no reaction with HCL
115.82	117.35	924.92	923.39	siltstone, GLEY 1 2.5/10Y, some carbonaceous material/coal, some bentonite intermixed, trace oxidized siltstone, trace hard white claystone, no reaction with HCL
117.35	118.87	923.39	921.87	siltstone, GLEY 1 2.5/10Y, some very fine-fine sandstone, trace carbonaceous material/coal, trace bentonite, no reaction with HCL
118.87	119.79	921.87	920.95	siltstone and coal, GLEY 1 4/10Y, coal is black in colour, hard and platy, trace bentonite, trace oxidized siltstone, no reaction with HCL
119.79	120.19	920.95	920.554	coal, black in colour, hard and platy, trace bentonite flakes
120.19	121.31	920.554	919.43	sandstone, 5Y 3/1, fine-medium sandstone, sandstone grains are salt and pepper, trace carbonaceous materials/coal, trace siltstone, trace oxidized siltstone, strong reaction with HCL