

Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization

Tibor Lengyel, Judit Deri-Takacs, Andrew Hinnell, and John J. Clague



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John. J. Clague 2002. An aerial view of the Peace River, north of the current study area.

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EXECUTIVE SUMMARY

Worley Canada Services Ltd., operating as Advisian, was retained by the Province of British Columbia (BC) to conduct aquifer mapping in the Kiskatinaw-Peace area, south of the Peace River, between the Pine River and the British Columbia-Alberta provincial border (Study Area). The purpose of the aquifer mapping study was to review and update the mapped aquifer boundaries and to identify previously unmapped aquifers to support the management of groundwater resources.

To meet these goals, a database of available information was compiled. The database includes water and research well records, bedrock and surficial geology maps, topography information, surface water bodies, and spring locations. Geology data were captured using key lithology terms to support subsurface interpretation. The depth of investigation was limited to 600 m below ground surface (mbgs) or, to the deeper of 300 mbgs and the Base of Fish Scales Marker where it was shallower than 600 mbgs. All but one of the wells with lithology information were shallower than 300 mbgs in the Study Area. Bedrock geology, bedrock groundwater level, surficial sediment thickness, and overburden groundwater level maps and seven geological cross-sections were prepared for the Study Area. The data were used to develop a conceptual model of the regional hydrogeological system to support identification of hydrostratigraphic units, map overburden and bedrock aquifers, and to infer hydraulic connections between the aquifers and surface water bodies.

Previously, 17 aquifers were identified within the Study Area or its immediate vicinity (i.e., within 5 km of the Study Area boundary). The extents of ten aquifers were adjusted by expanding them to interpreted physical and hydraulic boundaries (0589, 0590, 0591, 0592, 0593, 0594, 0595, 0596, 0598, and 0633). The study also identified an additional bedrock aquifer in the southern part of the Study Area (1275). Overburden aquifer 0597 was retired and superseded by aquifer 0594. Aquifers 0631 and 0634 were primarily outside of the Study Area and are recommended to be further reviewed as part of aquifer mapping north of the current Study Area. Aquifer updates used regional-scale physical and hydraulic boundaries (e.g., groundwater divides, streamlines, and surface water bodies) to delineate aquifer boundaries and to support water management efforts. Mapped aquifers may extend beyond areas where registered wells currently exist; therefore, there is uncertainty in aquifer boundaries and properties, particularly at distance from areas of development.

The vulnerability of the mapped aquifers has been assessed as high (0598), moderate (0589, 0590, 0591, 0592, 0593, 0595, 0633, 0851, 0903), and low (0594, 0596, 1275).

Aquifers 0589, 0593, 0594, 0596, and 1275 likely extend well beyond the Study Area buffer of 5 km. The descriptions provided here are based on information reviewed within the Study Area (including the 5 km buffer). We recommend that the aquifer mapping be extended to allow for a more rigorous mapping of these new aquifers beyond the Study Area.

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1. BACKGROUND

1.1 Water Management

Water for domestic purposes in northeast British Columbia (BC) is primarily sourced from surface water. While surface water resources are available in northeast BC, water allocation notations (including possible water shortage restrictions, application refused, and office reserve notations) already exist for several rivers and creeks in the region (e.g., Kiskatinaw River and its tributaries, and Pouce Coupé River). Existing water diversion allocations have also been temporarily suspended in response to drought conditions. Furthermore, due to changes in precipitation patterns, irrigation will likely be increasingly required for agriculture in northeast BC (BC Agriculture and Food Climate Action Initiative 2013). Most agricultural land in the region is located well above the floors of river valleys, thus irrigation from surface water sources involves technical and economic challenges (BC Agriculture and Food Climate Action Initiative 2013). Hence, groundwater is expected to be increasingly used as the region continues to develop.

Aquifers have been previously mapped in northeast BC (Lowen Hydrogeology Consulting Ltd. [LHC] 2011) in support of GeoScience BC's Montney Water Project. However, ongoing water licensing highlighted the need for further refinement of aquifer boundaries. Groundwater studies carried out in the region since LHC's 2011 aquifer mapping study (e.g., Baye et al. 2016, Goetz 2021) provide additional information for interpreting groundwater conditions in the region. As part of a hydrogeologic interpretation and aquifer mapping series in northeast BC, Advisian completed mapping in the Peace-Beaton study area (Lengyel et al. 2022). The current study is part of the same aquifer mapping series. Mapping aquifers and improved understanding of the groundwater system (including connection to surface water) is important for these areas as they are increasingly expected to rely on groundwater.

1.2 Scope of Study

Worley Canada Services Ltd. (operating as Advisian) was retained by the Province of British Columbia to conduct a desktop regional aquifer mapping study south of the Peace River in northeast BC for 16 British Columbia Geographic System (BCGS) 1:20,000 map sheets (the Peace-Kiskatinaw Study Area, Figure 1):

093P075, 093P076, 093P077, 093P078, 093P079, 093P080, 093P085, 093P086, 093P087, 093P088, 093P089, 093P090, 093P097, 093P098, 093P099, and 093P100.

The vertical limit of the study was 600 m below ground surface (mbgs), or the deeper of 300 mbgs and the Base of Fish Scales marker where this marker was shallower than 600 mbgs (defined as Deep Groundwater) (Government of British Columbia 2021, BCOGC 2022). All but one of the wells with lithology information were shallower than 300 mbgs. The Base of Fish Scales marker corresponds to the top of the Lower Cretaceous. The depth of the Base of Fish Scales Marker varies between less than 300 mbgs in the north of the Study Area toward Fort St John, and deeper than 600 mbgs in the south toward Pouce Coupe (Athanasopoulos, Pana, 2023, email comm.). Examination of the hydraulic properties of this boundary and mapping of deep groundwater resources were outside the scope of the current study.

2. METHODS

2.1 Data Sources

Key studies reviewed prior to preparation of this report as well as spatial data sources used to facilitate hydrogeologic interpretations include: Baye et al. (2016), Berardinucci and Ronneseth (2002), Cui et al. (2019), Goetz (2021), Hartman and Clague (2008), Hartman et al. (2018), Hickin and Best (2013), Hickin et al. (2016), Lengyel et al. (2022), LHC (2011), Monahan et al. (2018), and Reimchen (1980).

2.2 Data Processing

2.2.1 Well Depth

Well depths reported in the Provincial Groundwater Wells database (GWELLS) in the Study Area range from 1.5 to 334.1 mbgs, with an average well depth of 54.3 mbgs. Reported depths for wells assigned to overburden aquifers in the current study range from 1.5 to 155.5 mbgs, and depths for wells assigned to bedrock aquifers range from 3.7 to 334.1 mbgs.

2.2.2 Lithology Standardization

GWELLS includes lithological descriptions of the subsurface sediments encountered during water well drilling. Lithological descriptions are presented over a series of intervals penetrated during drilling and may include both lithologies (e.g., clay, shale, till) and sediment physical properties (e.g., blue, hard, silty). The quality of information and the status of data in GWELLS have not been field-verified. Quality of lithologic information is variable and typically based on the drilling method, the type of samples collected, experience of field personnel, and the purpose of drilling. The quality of the lithological logs may limit detailed geologic interpretation of subsurface conditions.

Semi-automated methods were used to standardize lithologic units. Data preparation included removal of lithologic data for wells with interval errors, text cleaning (e.g., making all text lowercase, correcting spelling errors, and using consistent terminology), and standardization of lithologic units based on material classification. Material descriptions may not be standardized for all entries due to ambiguous terminology (e.g., “rock”), lack of material descriptors (e.g., only colour is described), or the use of material descriptors that are unlikely to be correct (e.g., ash). GWELLS does not include elevation data for many wells. In the absence of available Light Detection and Ranging (LiDAR) data, each well was assigned a ground surface elevation based on the TRIM digital elevation model (DEM, 25 m resolution) to convert interval data from depth to elevation values.

Standardized lithologic units were based on the size and composition of sediment particles using the American Association for Testing and Materials (ASTM) modified Unified Soil Classification System (USCS). However, the units are generally more simplified (e.g., one category for silt) and include additions such as till and bedrock, and consider boulder and cobble grain sizes. This level of detail in the classification scheme was deemed appropriate given the reliance on water well records and the regional nature of the study. Standardized lithologic units were manually reviewed and edited based on a review of bedrock depth, screen material, and water levels.

Lithological information was also obtained from scientific studies describing the installation of new monitoring wells (Goetz 2021) and scientific reviews of water well and oil and gas data (Hickin 2013).

2.2.3 Bedrock Depth

Bedrock depth was calculated by taking the minimum depth of material classified as bedrock within a borehole to ensure consistency with processed lithology data. This calculated depth was then compared with bedrock depth information available from other studies (e.g., Monahan et al. 2018). Where the bedrock picks calculated from the processed lithology data and bedrock picks available from scientific studies were inconsistent, bedrock picks from scientific studies were chosen.

2.2.4 Screen Material

Screen material (overburden or bedrock) was determined from standardized lithologic units that overlap with screen interval data. Screen material determined this way was used to quality-control the aquifer lithology code available from GWELLS during data processing. Manual review and edits to standardize lithologic units or screen material were made based on quality assurance/quality control checks.

2.2.5 Water Levels

Water levels for wells in GWELLS that are assigned a screen material were used to prepare cursory groundwater contour maps for both overburden and bedrock units. Quality assurance/quality control checks included manual review and editing (as necessary) of water levels that were reported to be deeper than the total depth of the well.

Ground surface elevations determined from the DEM were used to convert water level depths to elevations. Groundwater contours were interpolated using kriging in Surfer®. Groundwater levels were constrained to be at or below ground surface. Although groundwater levels may locally be above the ground surface where artesian conditions exist, artesian conditions do not appear to be widespread in the Study Area and wells with artesian conditions were individually reviewed (see Section 4.4).

2.2.6 Geologic Cross-Sections

Seven cross-sections were prepared to improve understanding of the subsurface geology in the Study Area. Cross-section locations were selected to provide spatial coverage of the Study Area with a focus on understanding potential buried paleo-valleys and aquifer extents, and to identify potential surface water/groundwater interactions.

Standardized lithologic units were grouped and included in cross-section profiles to interpret hydrogeologic units (HGU). HGUs were identified based on inferred permeability and depositional environment (e.g., fluvial, glaciofluvial, glacial, glacial [sand and gravel]).

2.2.7 Aquifer Mapping Approach

Aquifers were delineated using physical and hydraulic boundaries where possible (e.g., geologic contacts, major surface water bodies, and groundwater divides or streamlines). Regional groundwater management goals (i.e., the division of large, spatially continuous aquifers into smaller units, more practical for licensing purposes) were also considered when defining aquifer extents. Mapped aquifers may extend beyond, or include areas, where there currently are no registered wells. Aquifers may also exist outside of mapping extents where information is limited. Therefore, there is some uncertainty in aquifer boundaries and properties, particularly for confined and bedrock aquifers.

Mapping of bedrock aquifers was primarily based on hydraulic boundaries. As such, surface water licensing watershed boundaries and inferred groundwater divides were used as aquifer boundaries. In the case where a major geographical feature was present (i.e., the Kiskatinaw River) two separate flow systems were mapped. Geological boundaries between bedrock aquifers were reviewed, however, consistent with Berardinucci and Ronneseth (2002) they were not used to delineate boundaries due to:

- observations indicating that secondary, fracture generated porosity and permeability is dominant in the Study Area, which included:
 - no apparent correlations between geological units and well yields; and
 - large variation of well yields over short distances.

Overburden aquifers were delineated based on an understanding of the glacial history of the area as well as topography, surficial geology mapping, and overburden thickness. The overburden aquifers are typically associated with heterogeneous glacial deposits with uncertainty in the lateral and vertical extent of permeable units.

Existing aquifer mapping reports have been reviewed, with relevant information incorporated into mapping report templates provided by the Province.

Aquifer attributes were assigned using statistics calculated for wells correlated to an aquifer based on location and screen material. Wells with no lithologies or unknown screen material were not assigned to a specific aquifer. Wells with lithologic information may not be correlated to mapped aquifers due to interval errors, lack of screen information, or material descriptions that could not be standardized using automated methods or during manual reviews as part of quality assurance/quality control. This results in some wells that were previously assigned to an aquifer not being assigned to the current mapped aquifers due to missing information in the well records. Wells with no lithology information that had available aquifer designation from the licence (i.e., bedrock or unconsolidated) were assigned to new aquifers following the aquifer material identified in the licence.

Vulnerability of aquifers to surface contamination was assessed based on the thickness and extent of geologic materials above the aquifer, depth to the water table (or top of confined aquifer), and type of aquifer material.

3. OVERVIEW OF GEOLOGY

3.1 Bedrock Geology

The Peace-Kiskatinaw Study Area is located about 20 km east of the Rocky Mountain Foothills on the Alberta Plateau of the Interior Plains physiographic region. The Interior Plains in BC form the western edge of the Western Canada Sedimentary Basin (WCSB) and include some of the thickest (over 3 km) Phanerozoic sedimentary rocks within the basin (Wright et al. 1994). The region is characterized by flat to gently rolling topography that is deeply incised by the valleys of the Pouce Coupé, Kiskatinaw, and Pine rivers and their tributaries (Reimchen 1980).

The conceptual model for the geology and hydrogeology of the Study Area is presented in Figure A and described below.

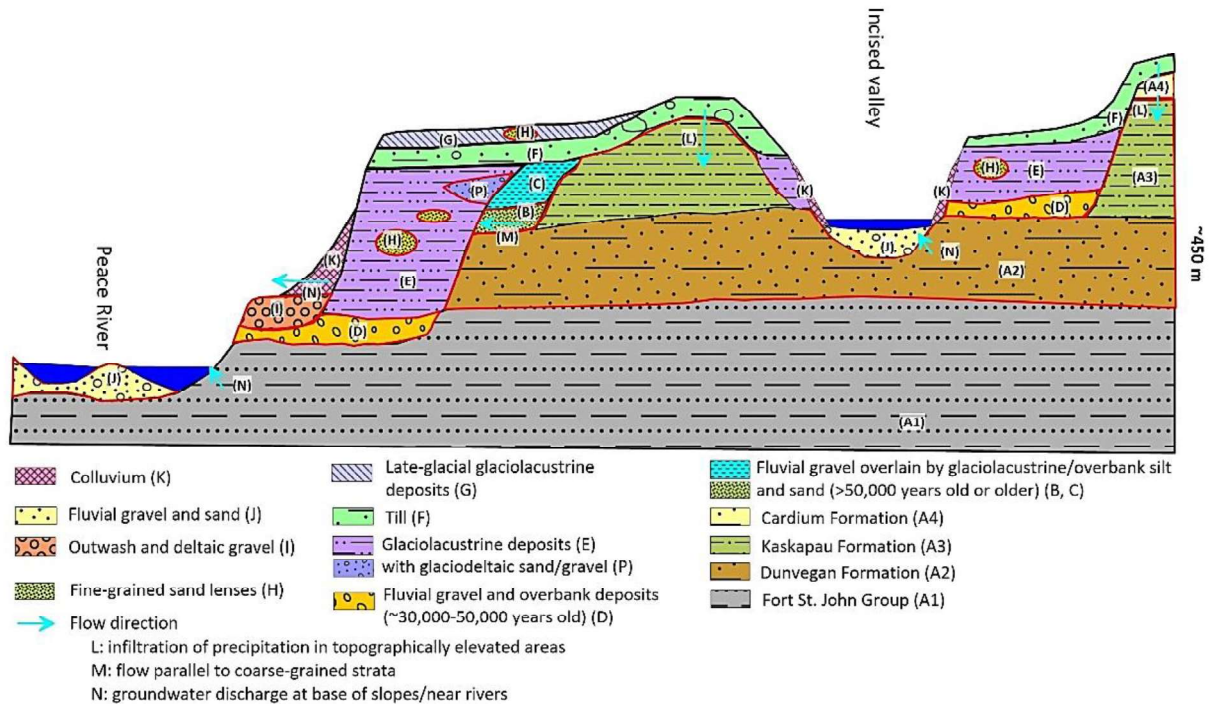


Figure A Conceptual model of the geology and hydrogeology of the Study Area, modified after Monahan et al. (2018) and Lengyel et al. (2022); no horizontal scale is intended; red outlines identify potential aquifers

The Fort St. John Group is primarily fine-grained (i.e., dark marine shale), but may be interbedded with coarser-grained sediment (Figure A - Unit A1). The interbedded coarser-grained sediments may be water-bearing. Although the Fort St. John Group forms the bedrock surface near the Peace River and groundwater from its water-bearing sediments may discharge into the river, it is not considered further in this study because it is covered by younger bedrock units in the Study Area. In addition, wells installed in the bedrock are interpreted to be completed above the Fort St. John Group.

The Upper Cretaceous Dunvegan, Kaskapau and Cardium formations (Figure A – Units A2, A3, and A4) form the bedrock of interest in the Study Area. The Dunvegan and Cardium formations consist of sandstone (Cui et al. 2019, Figure 2), whereas the Kaskapau Formation consists mainly of shale, except for the Pouce Coupe and Doe Creek members, which are dominated by sandstone (Cui et al. 2019, LHC 2011, Figure 2).

No major faults are reported in the bedrock within the Study Area (Figure 2). However, major faults are present within the Rocky Mountain Foothills nearby, thus bedrock in the Study Area, which has been uplifted since deposition, is likely fractured. Fractured bedrock has been described in several monitoring wells.

3.2 Quaternary Geology

Quaternary sediment thickness, based on borehole data, is shown in Figure 3. Thickness appears to be greatest (more than 50 m) along river terraces and valley floors of the Kiskatinaw and the Pouce Coupé rivers, and least (less than 10 m) in the gently rolling terrains between valleys (paleo and recent). These observations are generally consistent with the most recent depth-to-bedrock map published for the Study Area by Monahan et al. (2018).

Thick Quaternary sediments (Monahan et al. 2018) have also been reported where paleo-valleys have been identified in the Study Area (Hickin and Best 2013). Hartman (2005) and Hartman and Clague (2008) identified “upper” and “lower” buried valleys in the Peace River valley, which they differentiated on the basis of elevations. The buried valley floors contain fluvial gravels. The “lower” buried valleys have been dated to the Middle Wisconsinan (ca. 30,000-50,000 years; Hartman et al. 2018). The “upper” buried valleys have not been dated, although the lower buried valley is inset into a glaciolacustrine unit that overlies the upper buried valley, thus, the upper buried valley must be older than the lower buried valley (Hartman et al. 2018).

The Quaternary geology of the Kiskatinaw-Peace Study Area, similar to the area northwest of Fort St. John discussed in Lengyel et al. (2022), is a product of glaciation originating both east (Laurentide Ice Sheet) and west (Cordilleran Ice Sheet and Rocky Mountain glaciers) of the area (Reimchen 1980, Hartman and Clague 2008; LHC 2011; Hickin et al. 2016; and Hartman et al. 2018,). Due to the complex interplay of glaciers, the nature, type, and thickness of surficial sediments strongly depend on location: closer to the Rocky Mountains (e.g., near the Pine and Murray river valleys), there are multiple tills associated with montane glaciers or the Cordilleran Ice Sheet; whereas farther east tills appear to be either of Laurentide origin or mixed Laurentide/Cordilleran provenance (Hickin et al. 2016). Based on Mathews (1978), Reimchen (1980), Hartman and Clague (2008), Hickin et al. (2016), and Hartman et al. (2018), the general Quaternary sediment sequence in the Study Area is comprised, from oldest to youngest, of the following units:

- 1) Early Wisconsinan (>50,000 years old) or older fluvial gravel overlain by glaciolacustrine/overbank silt and sand (i.e., “upper paleovalley sediments”, Figure A - Units B and C);
- 2) Early Wisconsinan or older glacial sediments (expected only in the western part of the Study Area, not illustrated in Figure A):
 - a. Ice-advance glaciofluvial gravels within paleo-valleys;
 - b. Till deposited in front of and beneath glaciers advancing from the west;
 - c. Ice-retreat glaciolacustrine sediments within paleo-valleys;
- 3) Middle Wisconsinan (non-glacial, ca. ~30,000-50,000 years old) fluvial gravel and overbank deposits (“lower paleovalley sediments”, Figure A – Unit D);
- 4) Late Wisconsinan (11,000~30,000 years old) glacial sediments:
 - a. Ice-advance, mainly fine-grained glaciolacustrine, deposits within paleo-valleys, associated with Glacial Lake Mathews, which was impounded by the Laurentide Ice Sheet advancing from the east. Ice-advance sediments comprise of laminated and bedded clay, silt, sand (Figure A – Unit E). Locally, glaciodeltaic sediments (Figure A – Unit P), consisting of fine- to coarse- grained sand and gravel, occur near the top of the ice-advance glaciolacustrine sequence.
 - b. Till deposited beneath Rocky Mountain glaciers and the Cordilleran Ice Sheet in the west, the Laurentide Ice Sheet in the east, and possibly beneath the zone of coalescence of the Cordilleran and Laurentide ice sheets in the central portion of the Study Area. Interbeds of sand and gravel may be present within till (Figure A – Unit F);
 - c. Late-glacial glaciolacustrine deposits consisting of stratified and massive clay, silt, and sand associated with Glacial Lake Peace. These sediments were deposited near the end of the Pleistocene Epoch about 11,000-13,000 years ago, before the present river system became established (Figure A – Unit G);
 - d. Glaciofluvial and deltaic gravels deposited on river terraces near the end of Pleistocene (Figure A – Unit I; these sediments are younger than those shown in Figure A – Unit G);

- 5) Holocene or postglacial (11,000 years old to present):
- Fluvial gravel and sand associated with the channels and floodplains of rivers (Figure A – Unit J);
 - Colluvium (landslide deposits, talus, slope deposits, Figure A – Unit K).

Glacial sediments are locally overlain by alluvial, colluvial, and eolian sediments deposited during the Holocene. Hickin et al. (2016) concluded that landforms in the Dawson Creek map-area are Late Wisconsinan and Holocene in age (Figure 4).

4. HYDROGEOLOGY

4.1 Updated Conceptual Model of Hydrogeology

The conceptual hydrogeological model for the Study Area is presented in Figure A and generally follows the geological conceptual model. Bedrock is the lowest unit in the conceptual hydrogeology model. Bedrock comprises Cretaceous siliciclastic sedimentary rocks, primarily of the Cardium, Kaskapau, and Dunvegan formations (Figure A – Unit A2, A3, A4).

The Cardium Formation is fine-to-coarse grained (i.e., sandstone, conglomerate, and shale). It is restricted to the southeast part of the Study Area and is not considered a major bedrock aquifer in the area.

The Kaskapau and Dunvegan formations form the principal bedrock aquifers in the Study Area. The Kaskapau Formation, forming the bedrock throughout most of the Study Area (Figure 2), is primarily fine grained (i.e., marine shale) with sandstone units near the bottom. The Dunvegan Formation, limited to near the northwestern limit of the Study Area, is mainly coarse-grained (i.e., sandstone). While no bedrock faults have been reported in the Study Area (Figure 2), fractures have likely formed during uplift of the Rocky Mountains, as well as the long-term mechanical weathering caused by glacial erosion (Goetz, 2021). Fractures in the Kaskapau and Dunvegan formations are expected to increase their primary porosity and permeability and create secondary porosity and permeability, and, where fractures are present, they are expected to be hydraulically connected. As per the observations presented in Section 2.2.7, secondary porosity and permeability was inferred to be more important for groundwater flow than the primary porosity and permeability. Thus, the Kaskapau and Dunvegan formations were inferred to form a single aquifer system.

The lowermost aquifers above bedrock occur in the Early Wisconsinan or older fluvial and glaciofluvial paleo-valley sediments (“upper paleovalley sediments”, Figure A - Unit B). These sediments have limited areal extents. They may be hydraulically connected to bedrock aquifers (if they overlie Dunvegan Formation or Kaskapau Formation). Where overlying Early Wisconsinan glaciolacustrine sediments or till (Figure A – Unit C) do not inhibit hydraulic continuity, they also may form stacked aquifer systems with younger permeable sediments. Middle to Late Wisconsinan fluvial gravels are expected to form regionally extensive aquifers (Figure A – Unit D “lower paleovalley sediments”). Ice-advance glaciolacustrine sediments associated with Glacial Lake Mathews (Figure A – Unit E), till (Figure A – Unit F), and ice-retreat glaciolacustrine sediments associated with Glacial Lake Peace (Figure A - Unit G), which overlie glaciofluvial gravel, are generally fine-grained regionally. Coarser grained units could be present within these fine-grained deposits:

- fine- to medium-grained sand at the base of the Glacial Lake Mathews glacial lake sequence (these could not be distinguished from Unit D in the Study Area);
- discontinuous, massive or horizontally bedded, fine-grained sand lenses in both the Glacial Lake Mathews and Glacial Lake Peace sequences (Figure A - Unit H),

- intra-till sand lenses, and
- glaciodeltaic sediments, consisting of fine-to coarse-grained sand and gravel, occur near the top of the Glacial Lake Mathews and Peace sequences.

Glaciodeltaic sediments appear to form regionally significant overburden aquifers within the Study Area.

Where coarse-grained glaciodeltaic sediments are not present, Units E to G are expected to have lower permeability and thus may limit groundwater infiltration from the surface into underlying fluvial and glaciofluvial sediments, protecting lower aquifers from surface contamination. Based on surficial mapping by Reimchen (1980) and Monahan et al. (2018) and the inferred limited extent of such fine-grained sediments in the gently rolling uplands in the Study Area, aquifers in these areas may be more vulnerable to contamination by surface infiltration. Late-glacial glaciofluvial outwash and deltaic gravel deposited in Glacial Lake Peace (Mathews 1978, Figure A - Unit I), and fluvial sand and gravel (Figure A – Unit J) may also form aquifers. These shallow unconfined aquifers are typically more vulnerable to surface contamination than aquifers in older fluvial and glaciofluvial sediments.

Eolian sand and glaciofluvial gravel near the Pine River within the areas of thick sediments mapped by Monahan et al. (2018) (Figure 4) may also be water-bearing. The potential of these units to be productive aquifers is not understood due to a limited number of wells within them. Additional production or monitoring wells drilled into these deposits are required to assess if they are regionally significant aquifers.

Groundwater recharge in the Study Area is by infiltration of precipitation and snowmelt in topographically elevated areas (Figure A – Unit L). Groundwater is expected to flow largely parallel to coarse-grained strata (Figure A – Unit M). Groundwater may discharge at the base of slopes (as springs) or near the rivers/lakes occupying valley bottoms (Figure A – Unit N). Groundwater recharge may also occur from surface water bodies.

4.2 Bedrock Aquifers

Bedrock aquifers in the Study Area have been previously delineated based on areas of well development, topography, geological formation boundaries, and water bodies. Previous aquifer mapping reports highlight the uncertainties associated with delineating bedrock aquifers by presenting their boundaries as dashed lines (see Berardinucci and Ronneseth 2002).

Bedrock aquifer extents have been revised in the current study by extending the aquifers beyond areas with known well installations based on mapped and interpreted geological and hydrogeological conditions. Boundaries of aquifers delineated within the Dunvegan and Kaskapau formations follow major water bodies (deemed significant enough to impact bedrock groundwater flow) and watershed boundaries (based on inferred alignments between surface water and groundwater flow systems).

Details for each aquifer are provided in aquifer mapping reports (Appendix A).

Portions of previously mapped nine bedrock aquifers were mapped to extend in the Study Area and its immediate vicinity:

- East Pine (0589)¹;
- East Pine - Groundbirch (0591)¹;
- Valley View - Dawson Creek (0593)¹;
- Sunset Prairie (0595)¹;
- South of Pouce Coupe, north of Tate Creek and west of Tupper River - Peace River Land District (0622);

- South of the Peace River, west of confluence with Kiskatinaw River – Peace River Land District (0631)
- Sweetwater (0633)¹;
- South of the Peace River near Taylor (0634)¹; and
- Near East Pine (0917)¹.

The extents of seven bedrock aquifers (0589, 0591, 0593, 0595, 0631, 0633, and 0634) have been revised as part of the current study. Two previously mapped bedrock aquifers (0622 and 0917) are mainly south and west of the Study Area, respectively. As there were no additional data available for these two aquifers within the Study Area, their extents and descriptions were not revised. An aquifer mapping report was prepared for an additional, newly described bedrock aquifer, named the Arras-Fellers Heights¹ (1275).

The extents of aquifers 0589, 0591, 0593, 0595, and 0633 were adjusted based on inferred groundwater flow systems (represented by water licensing watershed boundaries), and surface water bodies (Figure 1). Aquifer 0595 encompasses the southern portions of previously delineated aquifers 0631 and 0634. As a result, the southern extents of aquifers 0631 and 0634 were adjusted to follow the extent of the revised 0595. It is expected that aquifer 0631 and 0634 may be continuous beyond their currently mapped extents. Review of aquifers 0631 and 0634 was not part of this study and will need to be undertaken as part of aquifer mapping north of the current Study Area.

Aquifer 1275 is a newly delineated aquifer. It is bound by watershed boundaries in the north and west, and by the Kiskatinaw River in the east. It follows the Study Area boundary in the south. As the extent of the aquifer is likely to continue well beyond the Study Area, it is recommended that its extent be reviewed in future studies.

There are four active bedrock provincial observation wells within the Study Area:

- OW 416 (Well Tag Number [WTN] 104707) – aquifer 0595,
- OW 417 (WTN 104708) – aquifer 0595,
- OW 418 (WTN 104709) – aquifer 0633, and
- OW 420 (WTN 104711) – aquifer 0593.

Water levels in OW 416 and 420 are relatively stable and reflect seasonal fluctuations. Water levels at OW 417 show a slight increase (~ 1 m) since installation and remain stable since 2020. Water levels at OW 418 show a visually decreasing trend in water levels dropping by about 2.5 m since 2014.

Based on data from wells OW 416, OW 417, OW 418, and OW 420, Baye et al. (2016) concluded that precipitation is likely a major source of recharge for these aquifers, with aquifer 0633 being less responsive to direct recharge than aquifer 0593 due to the relatively thick confining layer in the area.

4.3 Overburden Sediment Aquifers

Geologic cross-sections were prepared to assist with reviewing and delineating overburden aquifers (Figure 1, Figures 5A-5G).

Previously, eight overburden aquifers were mapped in the Study Area:

- Groundbirch Buried Valley (0590)¹;
- Sunset Creek (0592);

¹ Aquifer was not previously named. Aquifer names are assigned in this study for ease of reference and may not be reflective of initial location.

- Kiskatinaw Buried Channel (0594);
- Kiskatinaw Glaciodeltaic (0596);
- Arras, Dawson Creek, South Peace River District (0597);
- Pouce Coupe (0598)¹;
- Dawson Creek (0851)¹; and
- East of Dawson Creek (0903).

The extents of aquifers 0590, 0592, 0594, and 0596 were revised based on the extents of buried channel boundaries presented by Hickin and Best (2013) and overburden thickness, presented by Monahan et al (2018). Aquifers 0590, 0592, 0594, and 0596 consist of fine, medium, and coarse sand and gravel and are interpreted to be associated with Middle- (0594) and Late Wisconsinan (0590, 0592, 0596) glacio(fluvial) and glaciolacustrine (glaciodeltaic) depositional environments. The buried-channel fluvial sediments of aquifer 0597 have been incorporated into aquifer 0594 and aquifer 0597 has been retired.

The extent of aquifer 0598 was revised based on the extent of the alluvial sediments along the Pouce Coupé River.

Based on borehole lithologies (Figure 5A and 5B), aquifer 0851 was interpreted as primarily low conductivity unit comprised of glaciolacustrine clay/glacial till with discontinuous coarse-grained sediments that may locally support lower intensity groundwater production from low yield wells.

The boundaries of aquifer 0903 was retained as no additional data were available that supported adjusting the boundaries.

Based on the conceptual model, other aquifers are possibly present in the alluvial sediments of the Pine and the Murray rivers, and in the Pouce Coupe buried channel (Figures 3 and 4); however insufficient data was available to delineate aquifers in these areas.

There is one active overburden provincial observation well (OW 445 [WTN 106675] – aquifer 0590) within the Study Area. Water levels in well OW 445 are stable, and changes reflect seasonal fluctuations.

4.4 Groundwater Flow

Interpolated groundwater levels for bedrock and overburden in the Study Area are presented in Figures 6 and 7. Water-level maps are inferred to represent average regional groundwater conditions in the Study Area. Water levels were interpolated from water levels recorded in GWELLS. Water levels recorded in GWELLS are typically measured at the time of well installation (data are available between 1920 and 2021) and in wells with different screened intervals. Static water levels are reported in GWELLS with an elevation datum at the top of casing. Because not all static water levels had associated reference elevations, all water levels were referenced to the DEM ground elevation for consistency. Groundwater elevation from these wells includes an error equal to the distance from top of casing to ground surface. Obvious outliers were excluded from the interpolation.

Water levels in overburden were interpolated across the entire Study Area where data were available. However, where the Study Area is covered by fine-grained till or glaciolacustrine veneers and the overburden is interpreted being thinner than 15 m (Monahan et al. 2018), the flow in the overburden may be more discontinuous than indicated in Figure 7. As rivers are deeply incised, flow in buried valleys coinciding with modern rivers may be a combination of flow towards the center of the valley (driven by the topography) and flow parallel to the valley (along its dropping thalweg). Depending on the nature (i.e., coarse-grained vs fine-grained), the continuity and the thickness of the sediments separating the buried valley sediments from the modern rivers, the rivers and the buried valley sediments may be hydraulically connected.

Groundwater surface elevations in overburden and bedrock aquifers in the Study Area appear to mimic topography, with highest groundwater surface elevations in the uplands (where wells were available) and the lowest along the major rivers (the Kiskatinaw, Pouce Coupé and Pine rivers). This is consistent with the higher areas acting as regional recharge areas and the major water bodies acting as regional discharge areas. The limited thickness of unconsolidated sediments in the upland areas (as indicated by the overburden veneers on Figures 6 and 7) is expected to facilitate recharge to the buried valley aquifers and underlying bedrock aquifers (Korus et al. 2017). Lakes, as well as wetlands in the rolling uplands, are inferred to recharge regional-scale groundwater flow via direct seepage. However, they may be perched and/or seasonal and thus the relation between lake levels and groundwater levels is uncertain.

4.4.1 Groundwater Flow in the Bedrock Aquifers

The Pine/Murray, Kiskatinaw, and Pouce Coupé rivers were used to delineate boundaries of bedrock aquifers. Local- to regional-scale groundwater flow systems are expected to discharge into these rivers (Section 4.1, Figure 6).

Monahan et al. (2018) mapped thick overburden along the Kiskatinaw, Pouce Coupé and Pine rivers. Therefore, bedrock aquifers in the Dunvegan and Kaskapau formations are inferred to be hydraulically connected to these surface water bodies via the overburden separating them.

Artesian conditions do not appear to be common in the bedrock aquifers of the Study Area. Six bedrock wells are reported to be artesian (WTNs 17941, 75478, 75480, 118215, 104710, and EERI²-11). For WTN 17941, however, static water level was reported to be at 0.3 mbgs. Static water levels were not reported for the other wells (except for EERI-11). The static water level below the ground surface at WTN 17941 is inconsistent with artesian conditions, indicating potential reporting errors.

Springs often occur along geologic boundaries of Dunvegan and Cardium formations and are interpreted to indicate discharge from localized fractures.

² Energy and Environment Research Initiative

4.4.2 Groundwater Flow in the Overburden Aquifers

Groundwater surface elevations in overburden appear to be a subdued replica of the topography. Local- to regional-scale groundwater flow systems in overburden are expected to discharge into the Pine, Kiskatinaw and Pouce Coupé rivers. General flow directions in the area between the Kiskatinaw and Pouce Coupé rivers appear to be consistent with other studies (e.g., Baye et al. 2016). However, further studies are required to confirm the direction of flow between surface water bodies and underlying aquifers, especially since flow between the aquifers and surface water bodies may vary seasonally. Surface water-groundwater interactions in the Stewart Creek region, near the northwest boundary of the Study Area, are studied as part of a Coordinated Groundwater, Surface Water and Climate Monitoring Program by the British Columbia Ministry of Land, Water, and Resource Stewardship, contributing to better understanding hydraulic dynamics between surface water and overburden aquifers (Lapp 2022, Rathfelder 2022).

East of the Kiskatinaw River, groundwater within overburden is generally expected to flow north and west, towards the Kiskatinaw River or east - southeast towards the Pouce Coupé River (Figure 7). West of the Kiskatinaw River, groundwater is generally expected to flow east towards the Kiskatinaw River or west - northwest towards the Pine River. Locally, the flow is expected to deviate towards the valleys associated with the tributaries of the Pine, Kiskatinaw, and Pouce Coupé rivers.

Two overburden wells (WTN 80273 and EERI-1) were reported to be artesian within the study area. EERI-1 is in the Sunset buried valley (0592), between two topographic highs. Conceptually, the well is expected to be artesian due to the combination of the steep slope providing a high driving force for groundwater movement and the confining capabilities of the overlying fine-grained sediments.

4.5 Vulnerability

Aquifer vulnerability has been qualitatively assessed as part of the review of aquifer extents based on the methods described by Berardinucci and Ronneseth (2002). Factors considered in assessing aquifer vulnerability included:

- depth of the aquifer;
- depth of the water table;
- presence or absence of low permeability confining layers above an aquifer;
- integrity of the overlying confining units (i.e., if fractured or not); and
- velocity of expected seepage (including porosity).

The vulnerability of the mapped aquifers has been assessed as high (0598), moderate (0589, 0590, 0591, 0592, 0593, 0595, 0633, 0851, 0903), and low (0594, 0596, 1275) (Table A).

Table A Aquifer Vulnerability Assessment

Aquifer Number	Aquifer Name	Subtype	Depth of the Water Table	Permeability	Confining Units	Vulnerability
0589	East Pine Bedrock Aquifer	5a	Shallow to moderately shallow	Low to medium, except high where fractured	Present with variable thickness; surface material: clay, till, at places sand (<15 - >70 m)	Moderate
0590	Groundbirch Buried Valley	4b	Shallow to moderately deep	High	Present with variable thickness; Surface material: clay, at places sand, silt (>15 m)	Moderate (High)
0591	East Pine - Groundbirch Bedrock Aquifer	5a	Shallow to moderately deep	Low to medium, except high where fractured	Present with variable thickness, with thin veneer in east and west; Surface material: till, clay, sand (<3 - ~140 m)	Moderate
0592	Sunset Creek Overburden Aquifer	4b	Shallow to moderately shallow	High	Present with variable thickness, Surficial material: clay, till (>15 m)	Moderate
0593	Valley View - Dawson Creek Bedrock Aquifer	5a	Shallow to deep	Low to medium, except high where fractured	Present with variable thickness, with potential windows; Surficial material: clay and till, with lesser amount of sand (<3 - >100 m)	Moderate (high)
0594	Kiskatinaw Buried Channel	4b	Shallow to moderately deep	High	Present with variable thickness; Surficial material: clay, till, colluvium (>15 m)	Low
0595	Sunset Prairie Bedrock Aquifer	5a	Shallow to deep	Low to medium, except high where fractured	Present with variable thickness, with thin veneer in north; Surficial material: till, clay (<3 - >200 m)	Moderate
0596	Kiskatinaw Glaciodeltaic Overburden Aquifer	4b	Shallow to moderately deep	Moderate to high	Present with variable thickness; Surficial material: clay, till, colluvium (>15 m)	Low

Aquifer Number	Aquifer Name	Subtype	Depth of the Water Table	Permeability	Confining Units	Vulnerability
0598	Pouce Coupe Overburden Aquifer	1a	Shallow	Moderate to high	No confining units	High
0633	Sweetwater Bedrock Aquifer	5a	Shallow to deep	Low to moderate, except high where fractured	Present with variable thickness, with potential windows; Surficial material: clay, till (<3 - ~80 m)	Moderate
0851	Dawson Creek Overburden Aquifer	4b	Shallow to deep	Medium ¹	Present with variable thickness; surface material: clay, till (<15 - >100 m)	Moderate
0903	Pouce Coupe Overburden Aquifer	4b	Shallow to moderately deep	High	Present with variable thickness; Surficial material: clay, till (<3 - >30 m)	Moderate
1275	Arras-Fellers Heights Bedrock Aquifer	5a	Shallow to deep	Low to moderate, except high where fractured	Present with variable thickness; Surficial material: clay, till (<3 - >30 m)	Low

¹ The permeability of the aquifer is expected to be medium where discontinuous sand units are present (fine- to medium-sand) and low in the fine-grained material surrounding the coarse-grained lenses.

5. DATA GAPS AND UNCERTAINTY

Mapped aquifers extend beyond areas with registered wells (Figure 8), therefore there is uncertainty in aquifer boundaries, properties and interpreted water levels. Specific areas of uncertainties are highlighted in the individual aquifer mapping reports (Appendix A). Areas with uncertainties due to data gaps include:

- the horizontal extent of aquifer 1275 in the south where the aquifer may be continuous further south;
- the horizontal extents of 0590 and 0592 in the east where they coincide with the boundary of aquifer 0596, as there is no information on the potential hydraulic connectivity between aquifers 0592, 0594, and 0596;
- the horizontal extent of aquifers 0594 and 0596 in the west, where hydraulic connection between coarse-grained fluvial sediments of the Kiskatinaw paleovalley and those of the Groundbirch and Sunset paleo-valleys are unknown;
- the horizontal continuity of the coarse-grained sediments within overburden aquifers 0590, 0592, 0594, and 0596. Due to glacial erosion, the coarse-grained sediments of these aquifers may be discontinuous and not be present throughout the buried channels;
- the horizontal extent of aquifer 0594 and 0596 in the north and south, as the aquifers are likely to extend beyond the Study Area boundaries;
- potential aquifers in alluvial and buried channel sediments of the Pine, Murray, and Pouce Coupé rivers, where insufficient data was available to delineate aquifers in these areas; and
- analysis of shallow groundwater use in dugouts was not considered in this study; future analysis of this information could be used to understand shallow groundwater use within the study area.

Uncertainties in overburden thickness also exist. The historical surficial geological mapping by Reimchen (1980) indicates that the southeast portion of the Study Area is covered by thin glaciolacustrine sediments (veneers), implying the presence of bedrock within a few meters of the surface. More recent studies, however, indicate that buried valleys (Hickin and Best 2013) and thick unconsolidated sediments (up to 30 m, Monahan et al. 2018) are present. The thickness and the nature of unconsolidated sediments may have implications for both aquifer vulnerability and recharge.

Uncertainties also exist in groundwater levels due to different measurement dates, screened intervals, and aquifers. Static water levels at one well (WTN 17941) were below ground surface, but the well was also reported to be artesian. The interpolated groundwater surface elevations are expected to represent regional trends, but local groundwater surface elevations are uncertain and may vary from those measured at the time of drilling which are represented in this report.

Uncertain groundwater surface elevations may influence interpretation of potential surface water/groundwater interactions. Surface water/groundwater interactions can also be influenced by variable levels of surface water bodies (e.g., due to the spring freshet). Uncertainties in surface water/groundwater interactions also follow from limited information on local variations in the hydraulic conductivity of streambed sediments and underlying geology.

6. CONCLUSIONS AND RECOMMENDATIONS

Thirteen aquifers were mapped in the Kiskatinaw-Peace Study Area (six bedrock and seven overburden aquifers). One aquifer (0597) was retired. Mapped aquifers are summarized in Table B below.

Table B Summary of Mapped Aquifers

Aquifer Name	Recommended Action
0589	Revised extent
0590	Revised extent
0591	Revised extent
0592	Revised extent
0593	Revised extent
0594	Revised extent
0595	Revised extent
0596	Revised extent
0597	Retired aquifer
0598	Revised extent
0633	Revised extent
0851	Updated description – no change to extent
0903	Updated description – no change to extent
1275	Introduced as new aquifer

As various observations (see Section 2.2.7) indicated the secondary fracture generated porosity and permeability is dominant in the Study Area, aquifers in the Dunvegan and Kaskapau formations (0589, 0591, 0593, 0595, 0633, 1275) were inferred to be the part of the same geological/hydrostratigraphical unit. These aquifers were separated along groundwater divides. Current provincial systems do not allow for handling of aquifer management units representing portions of a continuous aquifer, only separate aquifers. As development of groundwater resources near groundwater divides may require assessment of groundwater conditions on both sides of a divide, it is recommended that current provincial systems be revised for handling aquifer management units within aquifers.

Aquifers 0593, 0598, and 0903 likely extend beyond the British Columbia-Alberta provincial boundary. It is recommended that data on both sides of the provincial boundary be reviewed to assess the full extent of these aquifers.

The vulnerability of the mapped aquifers has been assessed as low (buried valley aquifers 0594 and 0596, and bedrock aquifer 1275), moderate (bedrock aquifers 0589, 0591, 0593, 0595, and 0633, overburden aquifers 0590, 0592, 0851, and 0903), and high (0598 – alluvial aquifer).

There are four active bedrock provincial observation wells within the Study Area, two in aquifer 0595, one in aquifer 0593, and one in aquifer 0633. There is one active overburden provincial observation well in aquifer 0590 within the Study Area.

Recommendations to advance understanding of hydrogeological conditions in the Study Area include the following:

- Refine the southern extent of aquifer 1275 by conducting an aquifer mapping study south of the Study Area;
- Extend aquifer mapping north of the Study Area to update the extents of aquifers 0631 and 0634;

- Conduct detailed surficial geological/terrain mapping, particularly in areas where more recent studies (Monahan et al. 2018) report thick sediments where previous surficial mapping (Reimchen 1980) indicated the presence of sediment veneers (i.e., thin sediments). This could provide further information on aquifer vulnerability, recharge, and aquifer extents, particularly in the area west of Pouce Coupé River, between the Pouce Coupé and Kiskatinaw rivers, along and south of highway 97 (Figures 3 and 4);
- Target wells for inspections, water level verification, and/or downhole geophysical logging to verify lithological interpretations and to document well status. Targets could include: 1) the artesian well with static water level below ground surface to confirm their artesian nature, and 2) high yielding wells within bedrock aquifers to confirm if they are producing from the Dunvegan or the Kaskapau formations;
- Review potential surface water/groundwater interactions through localized targeted studies (e.g., Lapp et al. 2022). Unconfined aquifers may be hydraulically connected with the surrounding surface water bodies; for example, potential interaction between aquifer 0589 and surface water bodies in the north;
- Collect additional data to better understand hydraulic connections between coarse-grained sediments in aquifers 0590, 0592, 0594, and 0596;
- Expand the provincial observation monitoring well network to include nested/clustered wells in the bedrock to facilitate understanding regional groundwater flow;
- Evaluate the presence of a potential buried channel aquifer in the Pouce Coupé River paleo-valley. Hickin and Best (2013) described a paleo-valley in the area, and coarse-grained sediments appear present at depth (Figure 5D), however no wells were installed in the potential aquifer; and
- Review water quality data in detail to advance understanding on potential water quality concerns (Chelton van Geloven, pers. comm., 2022).

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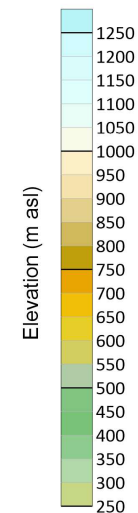
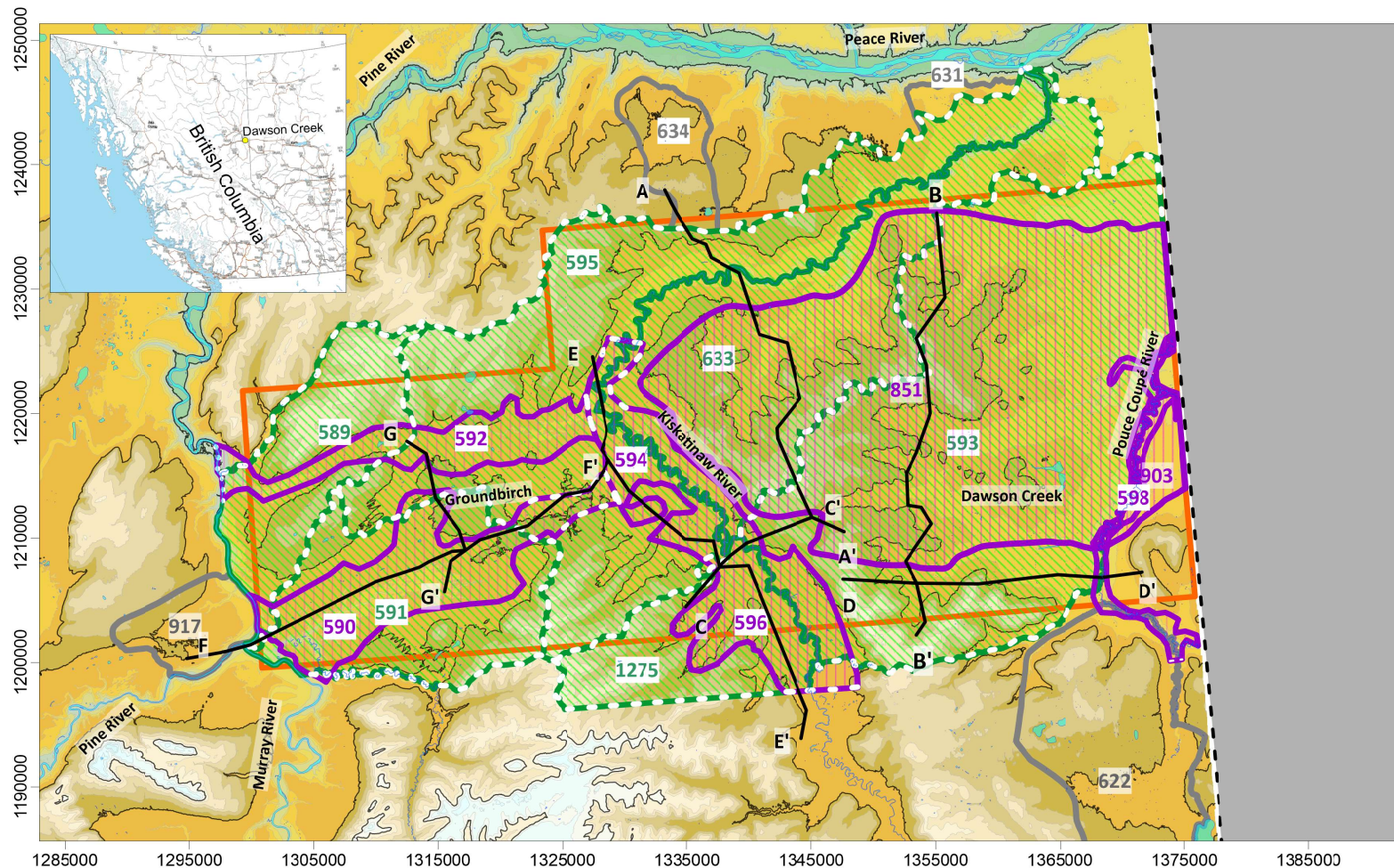
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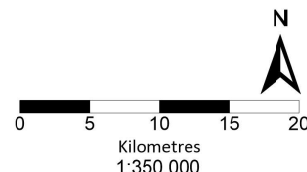
FIGURES



- A Cross-Section Lines
- 451 Bedrock Aquifers
- 444 Overburden Aquifers
- Study Area
- - - Uncertain Aquifer Boundary (Bedrock)
- - - Uncertain Aquifer Boundary (Overburden)
- Aquifers not mapped

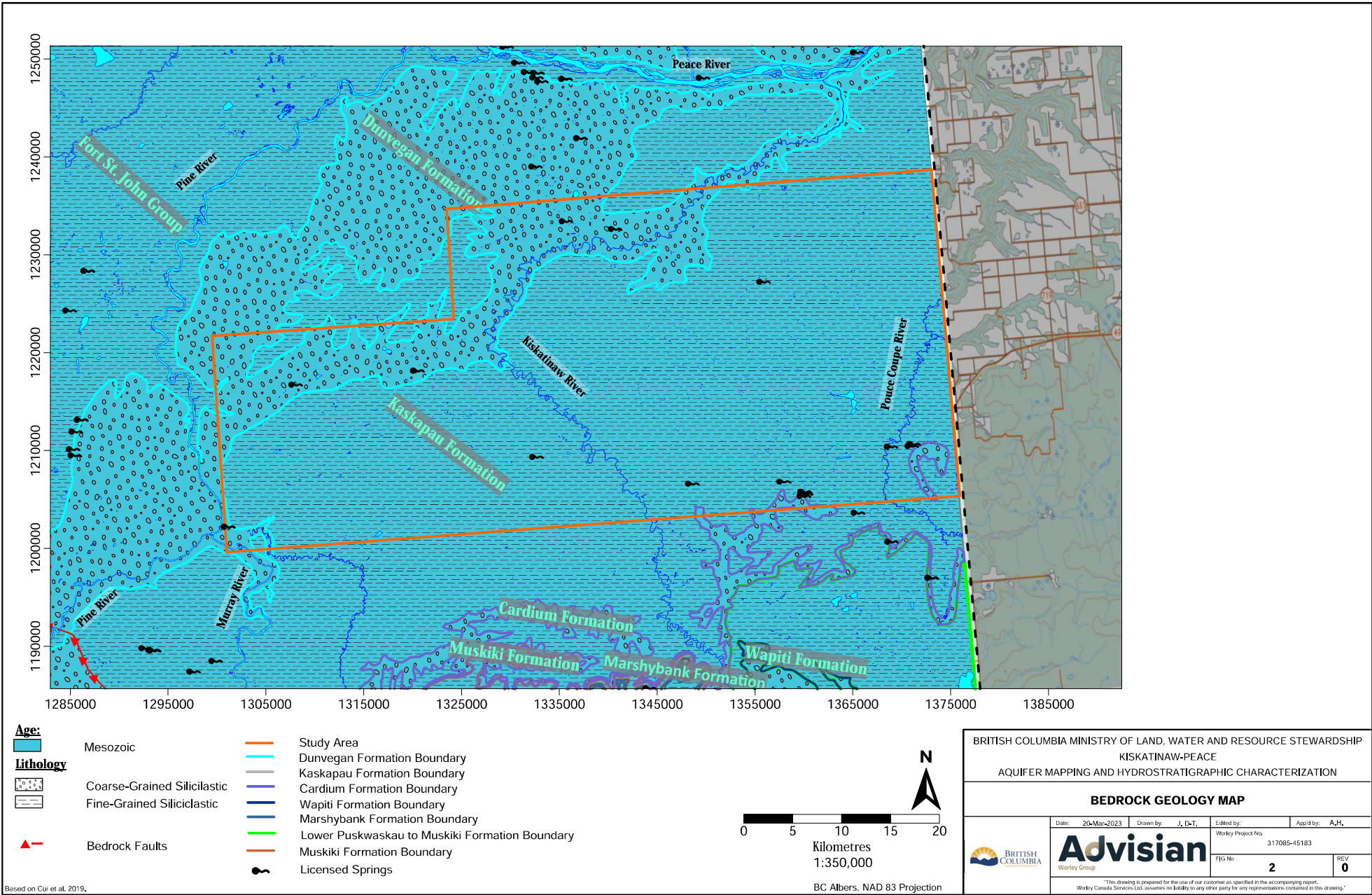
Notes:
Based on the conceptual model, other aquifers are possibly present in the alluvial sediments of the Pine and the Murray rivers, and in the Pouce Coupe buried channel; however insufficient data was available to delineate aquifers in these areas.

Topographic Data Source: Terrain Resource Information Management (TRIM),
B.C. Ministry of Land, Water and Resource Stewardship

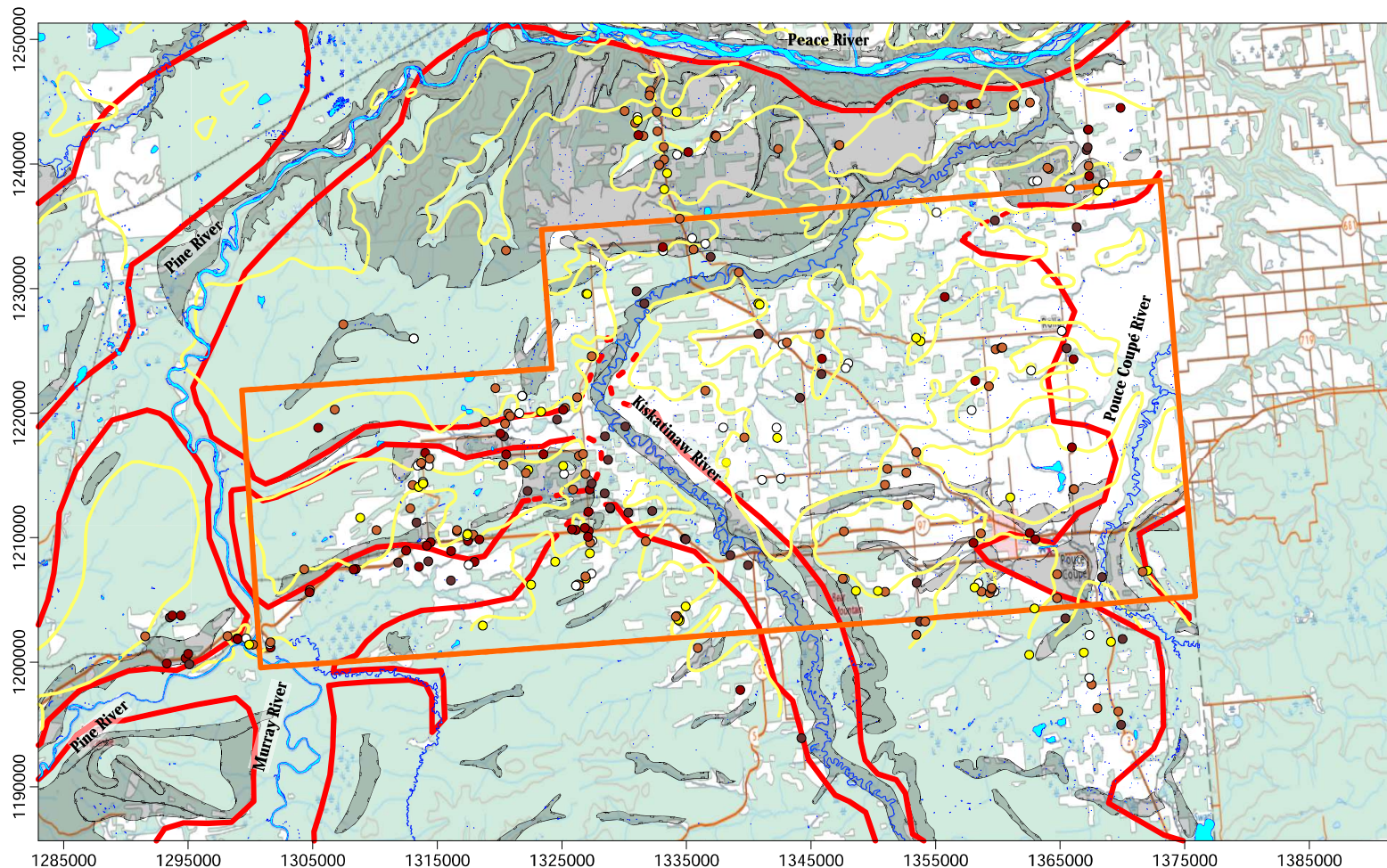


BC Albers, NAD 83 Projection

BRITISH COLUMBIA MINISTRY OF LAND, WATER AND RESOURCE STEWARDSHIP			
KISKATINAW-PEACE			
AQUIFER MAPPING AND HYDROSTRATIGRAPHIC CHARACTERIZATION			
LOCATION MAP AND MAPPED AQUIFERS			
Date: 17-Mar-2023	Drawn by: J. D-T.	Edited by:	App'd by: A.H.
Worley Project No. 317085-45183		Worley Group	
FIG No. 1		REV 0	
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Based on Cui et al. 2019.



Overburden Veneer and Colluvium (Bedrock near Surface)

Overburden Thickness (m)*

- 0 to 5
- 5 to 10
- 10 to 25
- 25 to 50
- 50 to 166.1

* based on GWELLS records

- Study Area
- Paeovalley (Hickin and Best 2013)
- Depth to Bedrock - 15 m (Monahan et al. 2018)

0 5 10 15 20
Kilometres
1:350,000

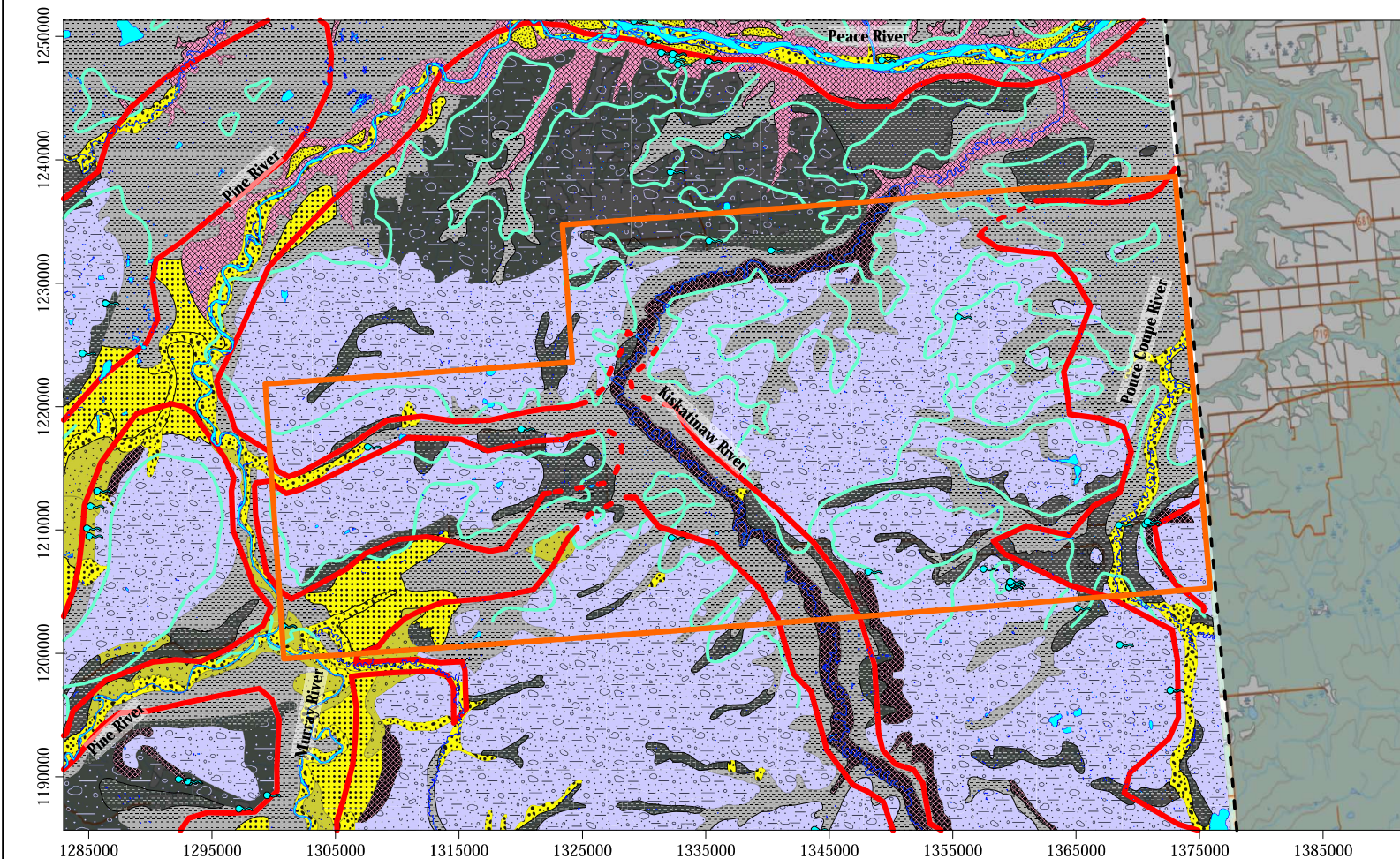


BC Albers, NAD 83 Projection

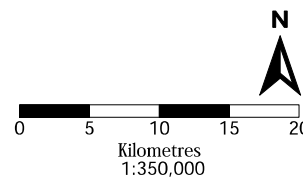
BRITISH COLUMBIA MINISTRY OF LAND, WATER AND RESOURCE STEWARDSHIP			
KISKATINAW-PEACE			
AQUIFER MAPPING AND HYDROSTRATIGRAPHIC CHARACTERIZATION			
OVERBURDEN THICKNESS			
Date: 20-Mar-2023	Drawn by: J. D.T.	Edited by:	App'd by: A.J.H.
Workley Project No.		317085-45183	
FIG No.		3	
REV		0	

Surficial geology based on information compiled by Monahan et al. 2018
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- Study Area
- Paleovalley (Hickin and Best 2013)
(dashed line indicates uncertain extent)
- Depth to Bedrock - 15 m (Monahan et al. 2018)
- Licensed Springs
- Alluvial (Fluvial)/Eolian - Holocene
- Eolian - Holocene
- Colluvial Veneer - Holocene
- Colluvial - Holocene
- Glaciofluvial - Late Wisconsinan
- Glaciolacustrine - Late Wisconsinan
- Glaciolacustrine Veneer - Late Wisconsinan
- Till - Late Wisconsinan
- Till Veneer - Late Wisconsinan



BC Albers, NAD 83 Projection

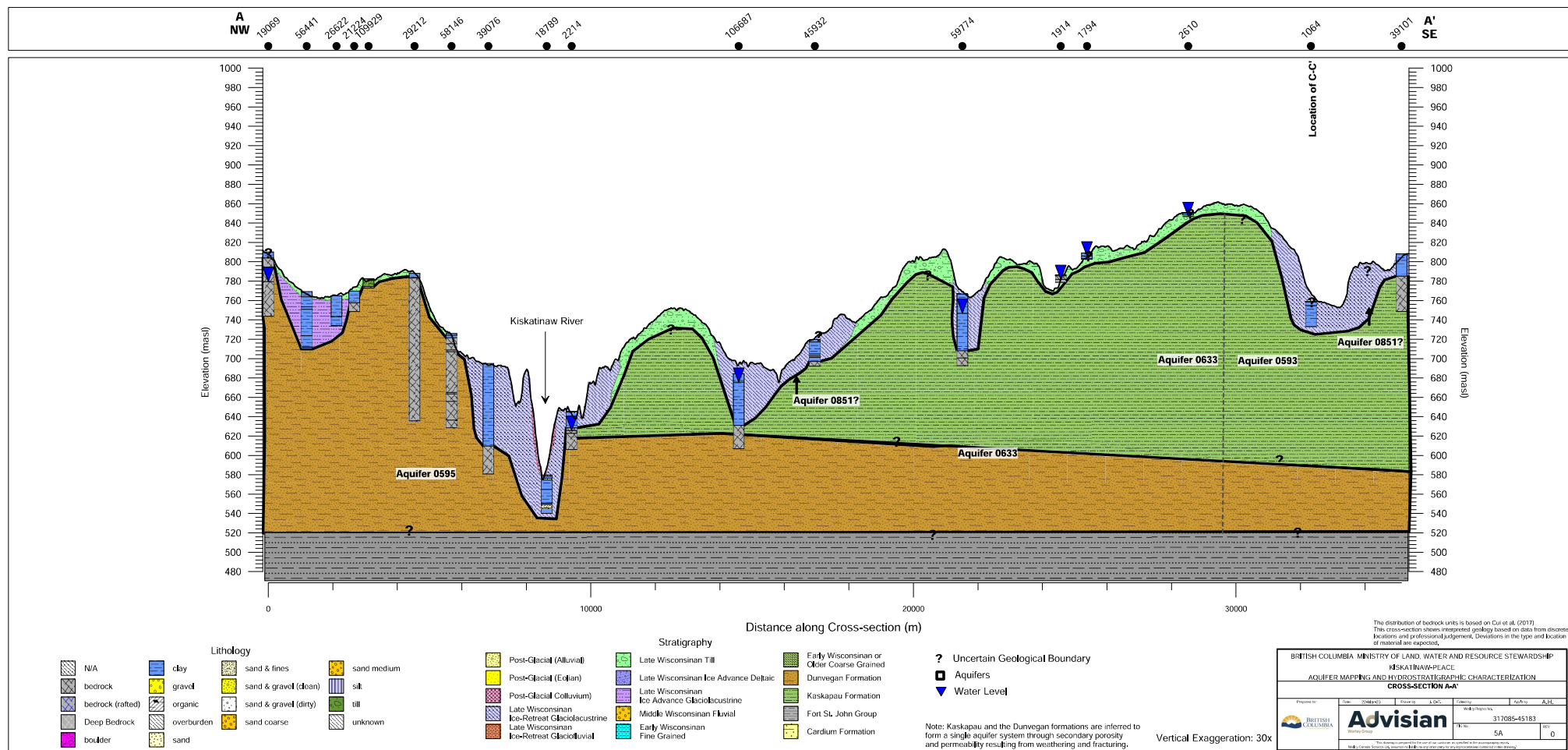
BRITISH COLUMBIA MINISTRY OF LAND, WATER AND RESOURCE STEWARDSHIP			
KISKATINAW-PEACE			
AQUIFER MAPPING AND HYDROSTRATIGRAPHIC CHARACTERIZATION			
SURFICIAL GEOLOGY			
Date: 20-Mar-2023	Drawn by: J. D.T.	Edited by:	App'd by: A.J.H.
		Workley Project No. 317085-45183	
		FIG No. 4	
		REV 0	

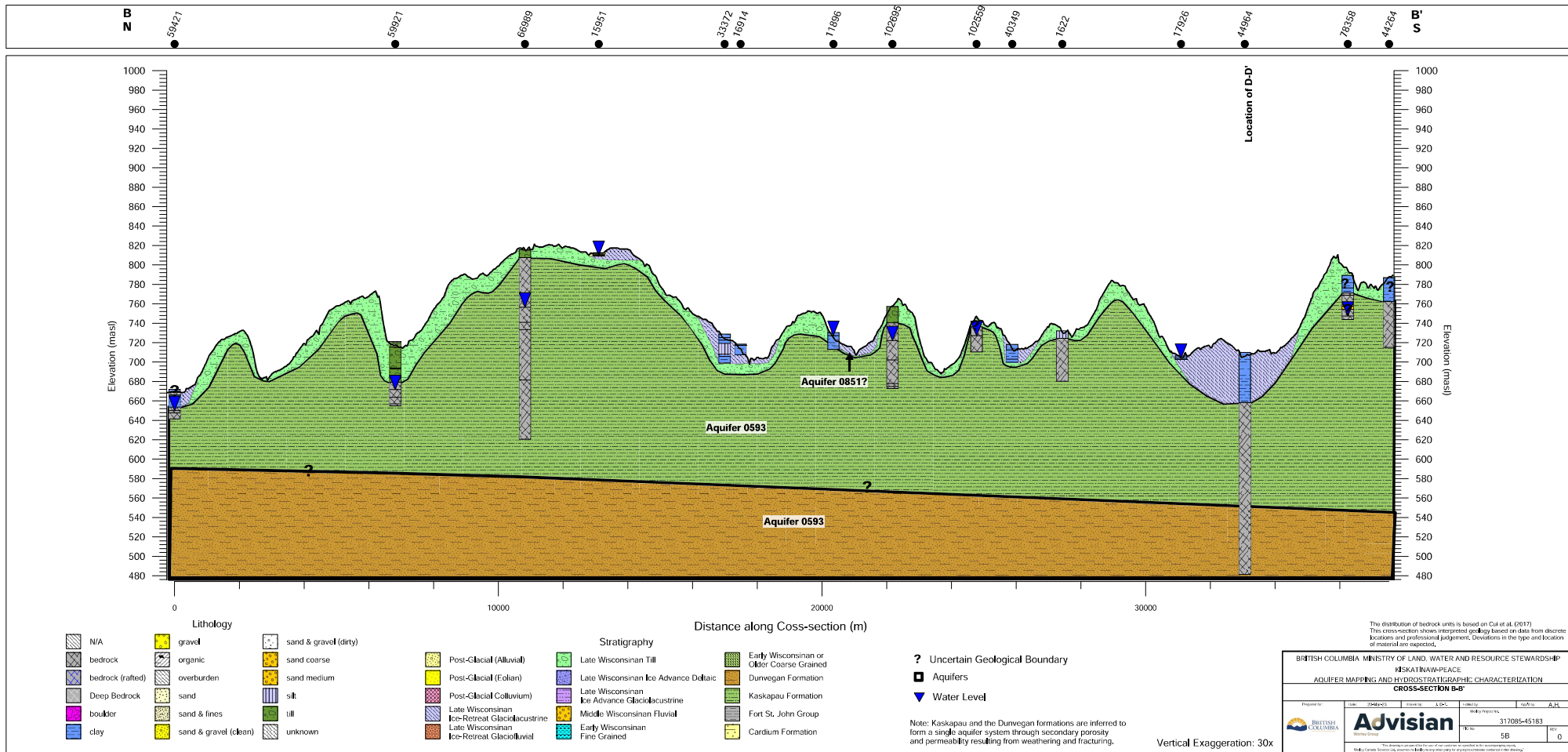
Advisian

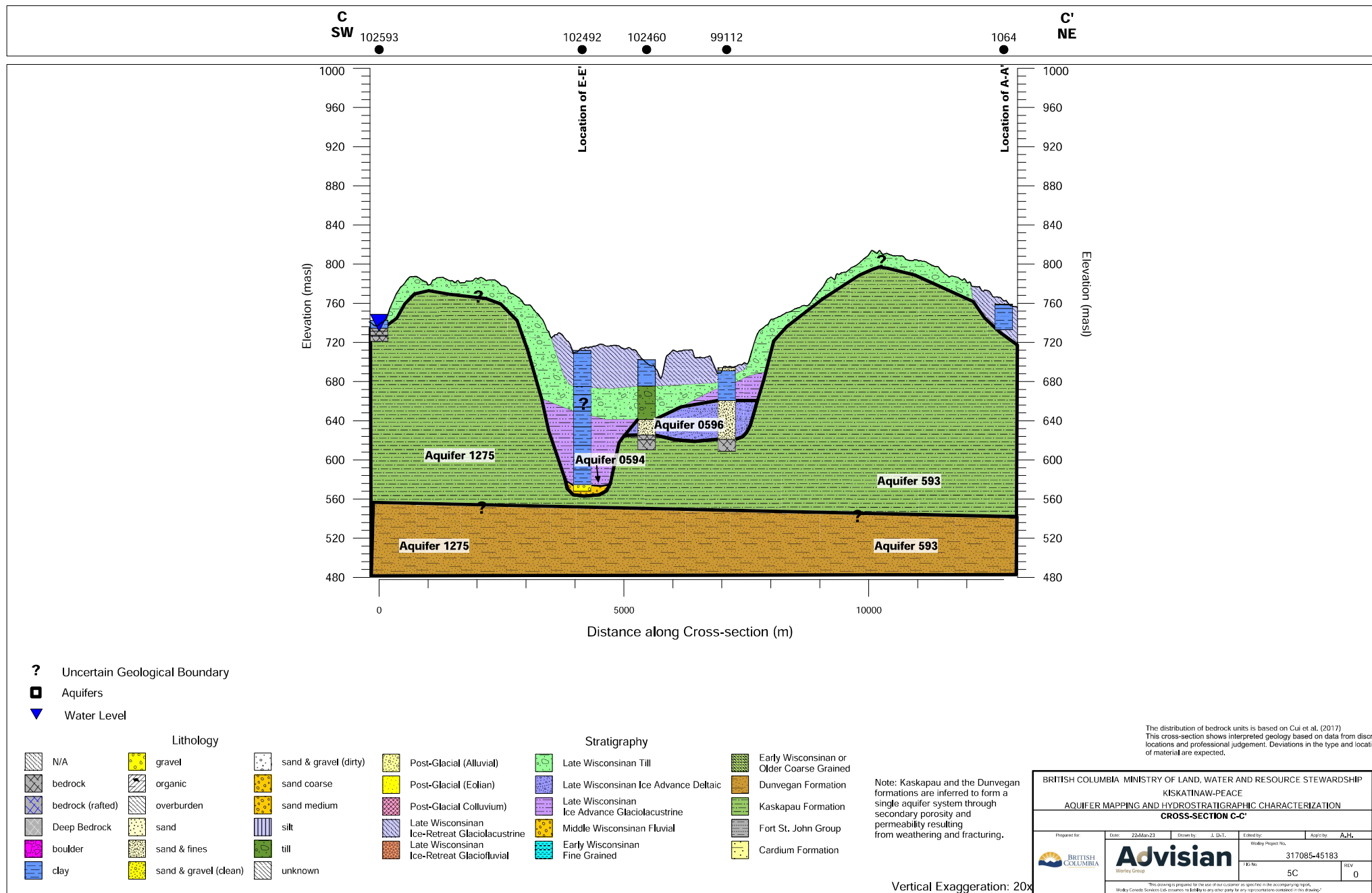
Worley Group

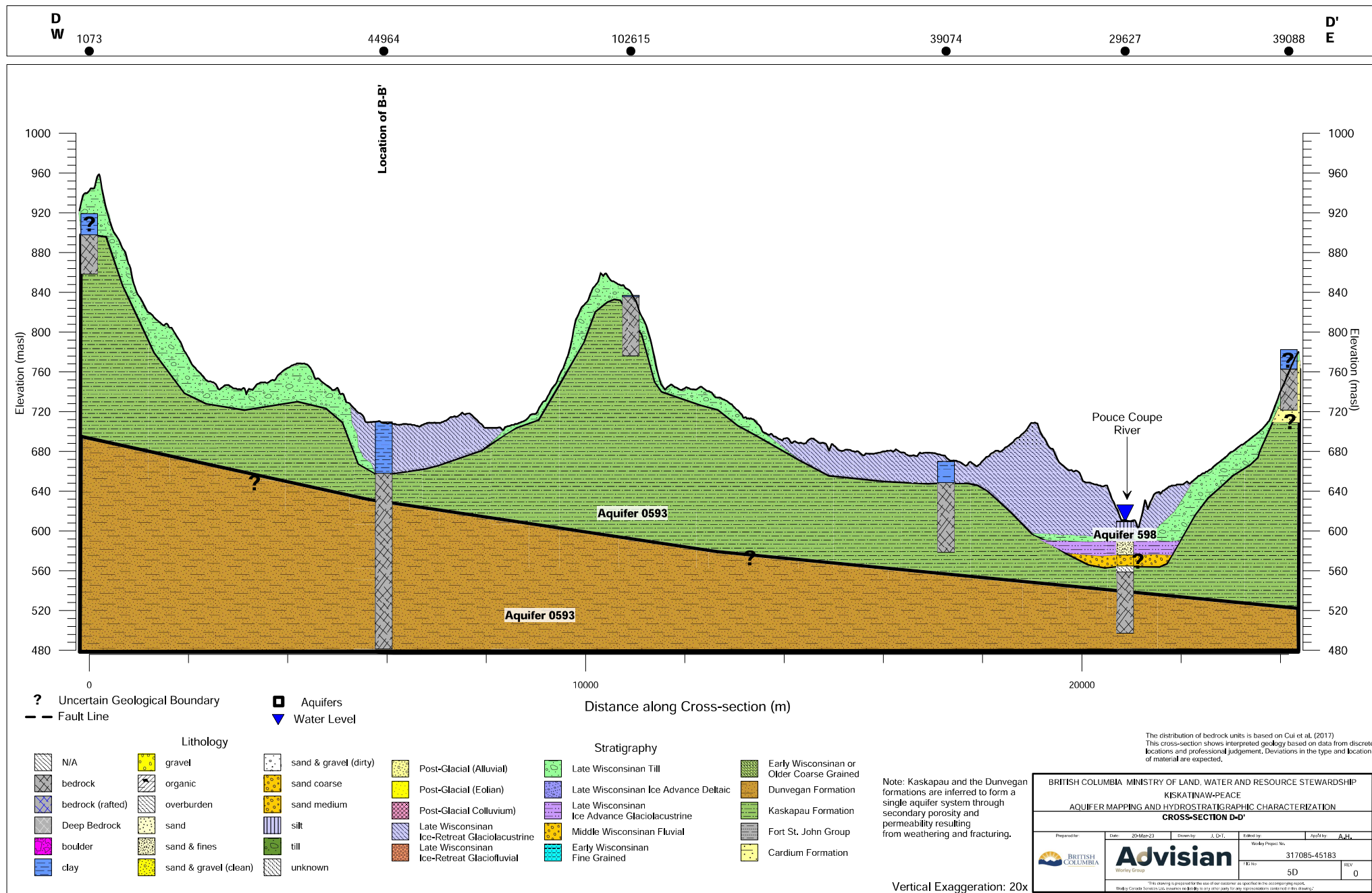
"This drawing is prepared for the use of our customer as specified in the accompanying report.
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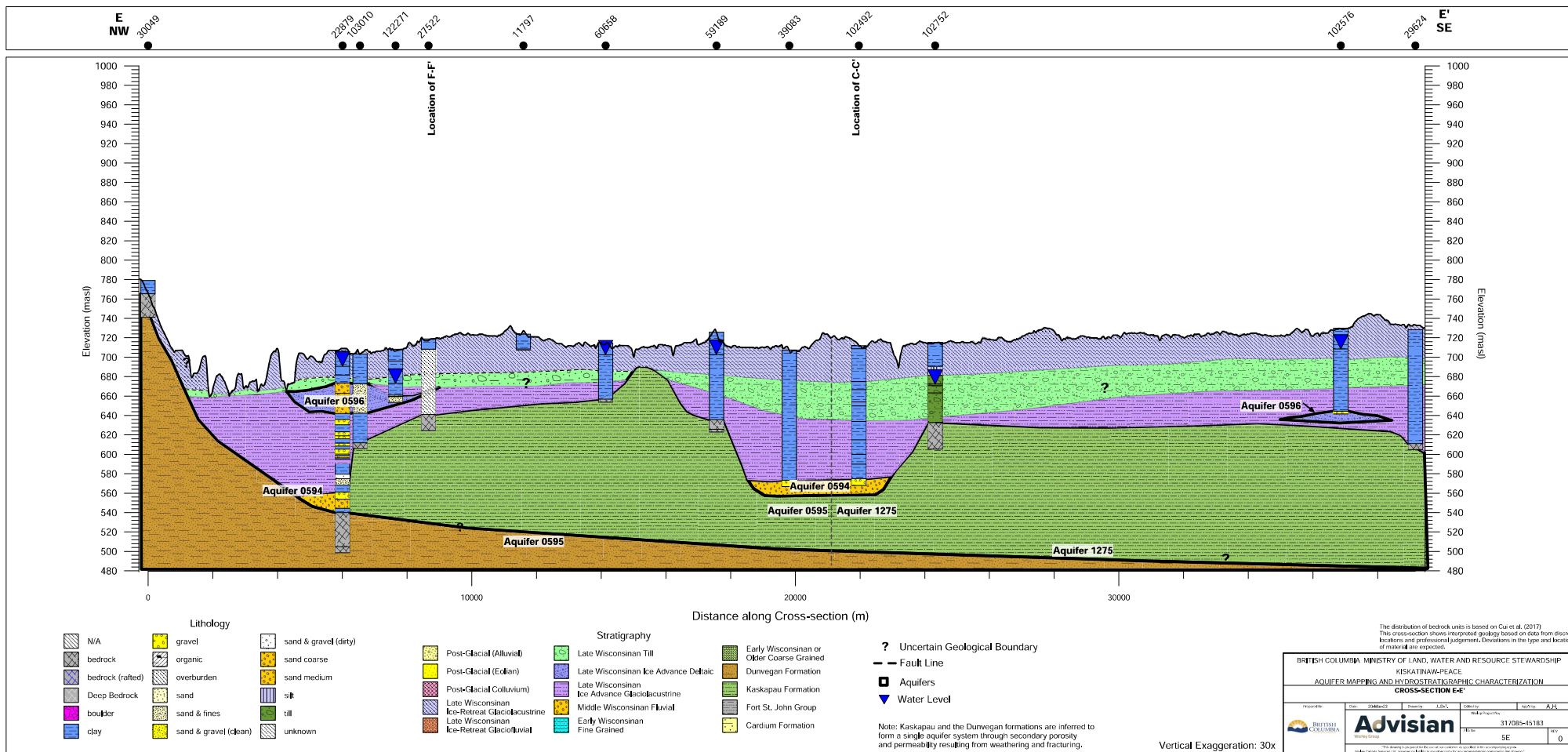
Surficial geology based on information compiled by Monahan et al 2018
 Contains information licensed under the Open Government Licence – Canada.

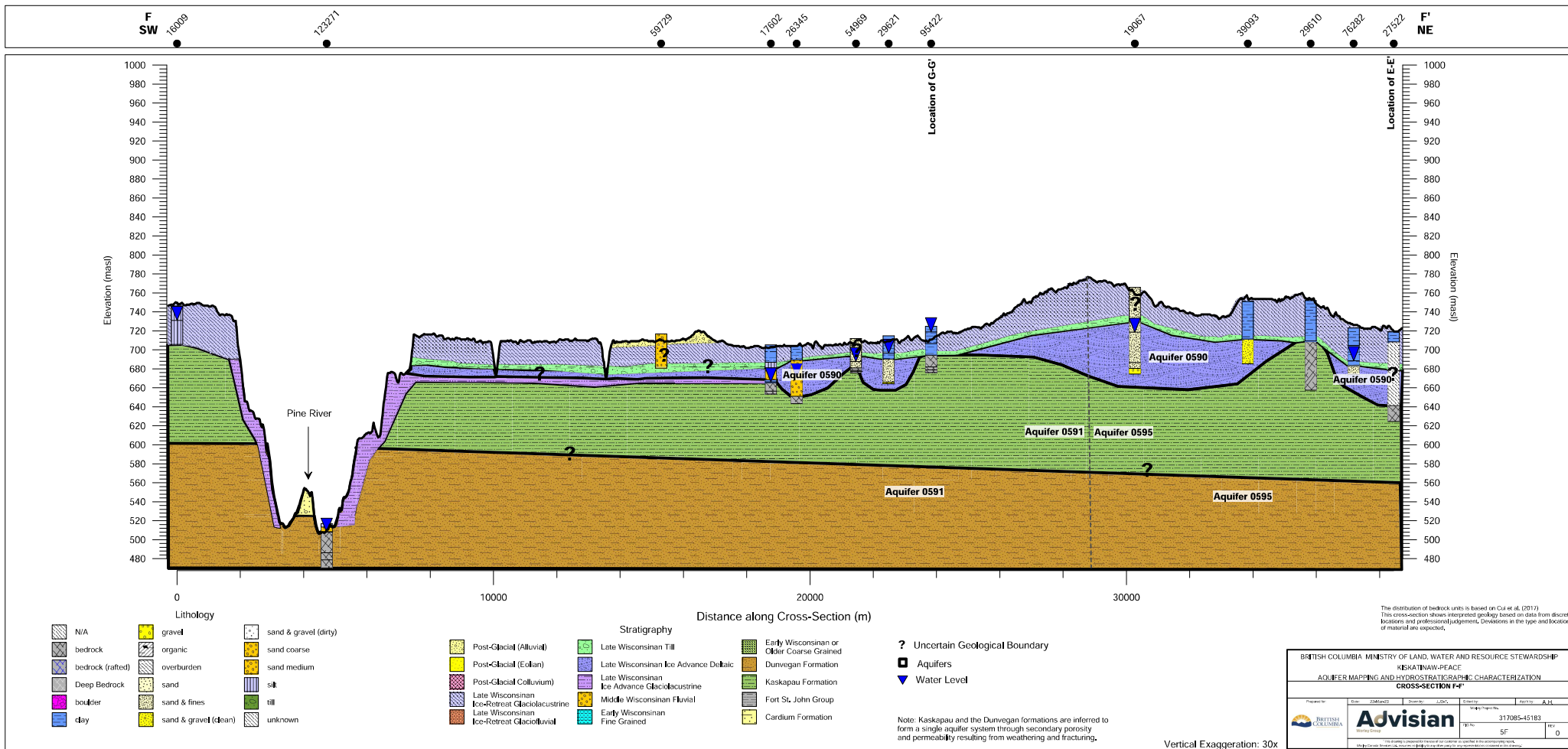












G
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53418

17378

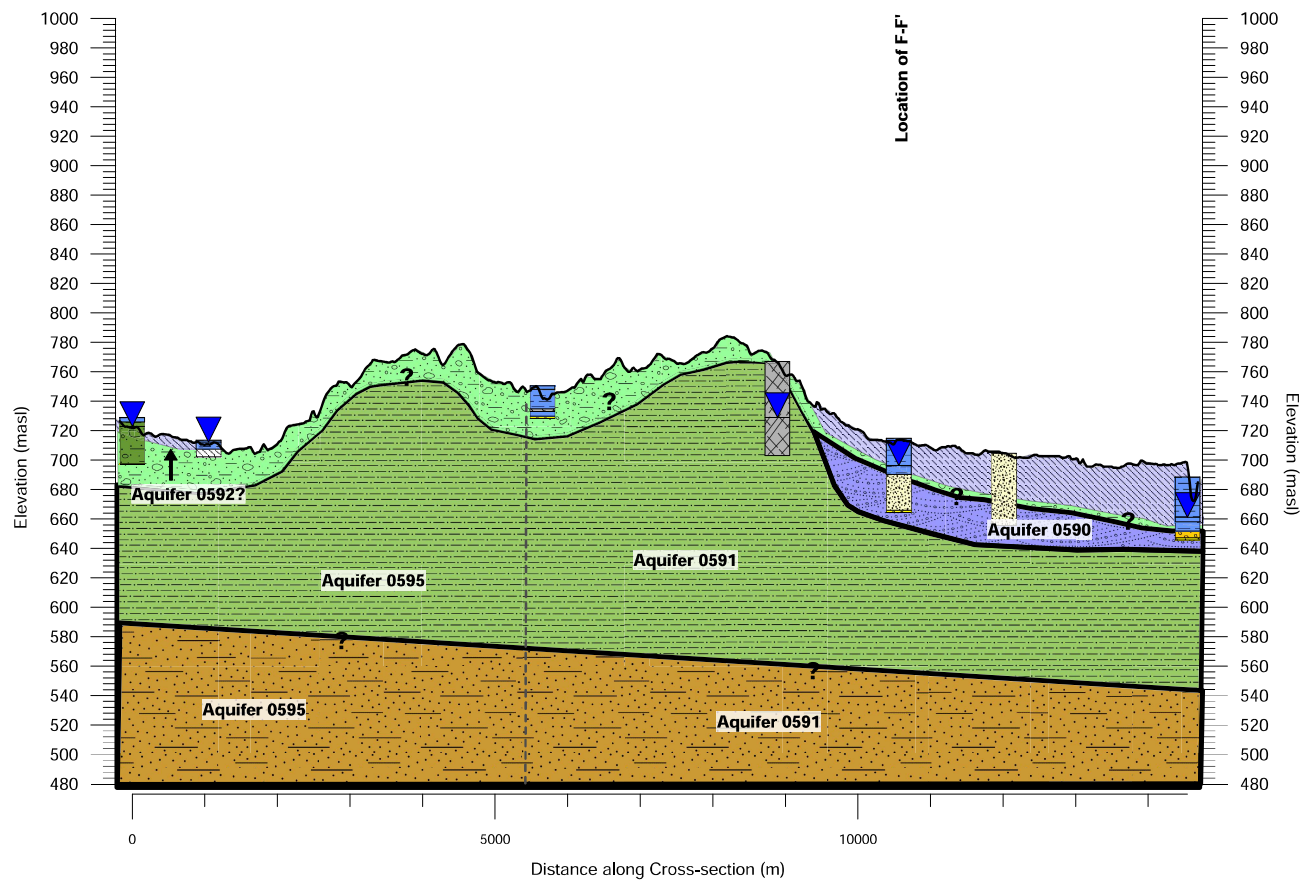
57708

11925

29621

103017

54974

G'
S

? Uncertain Geological Boundary

□ Aquifers

▼ Water Level

Lithology

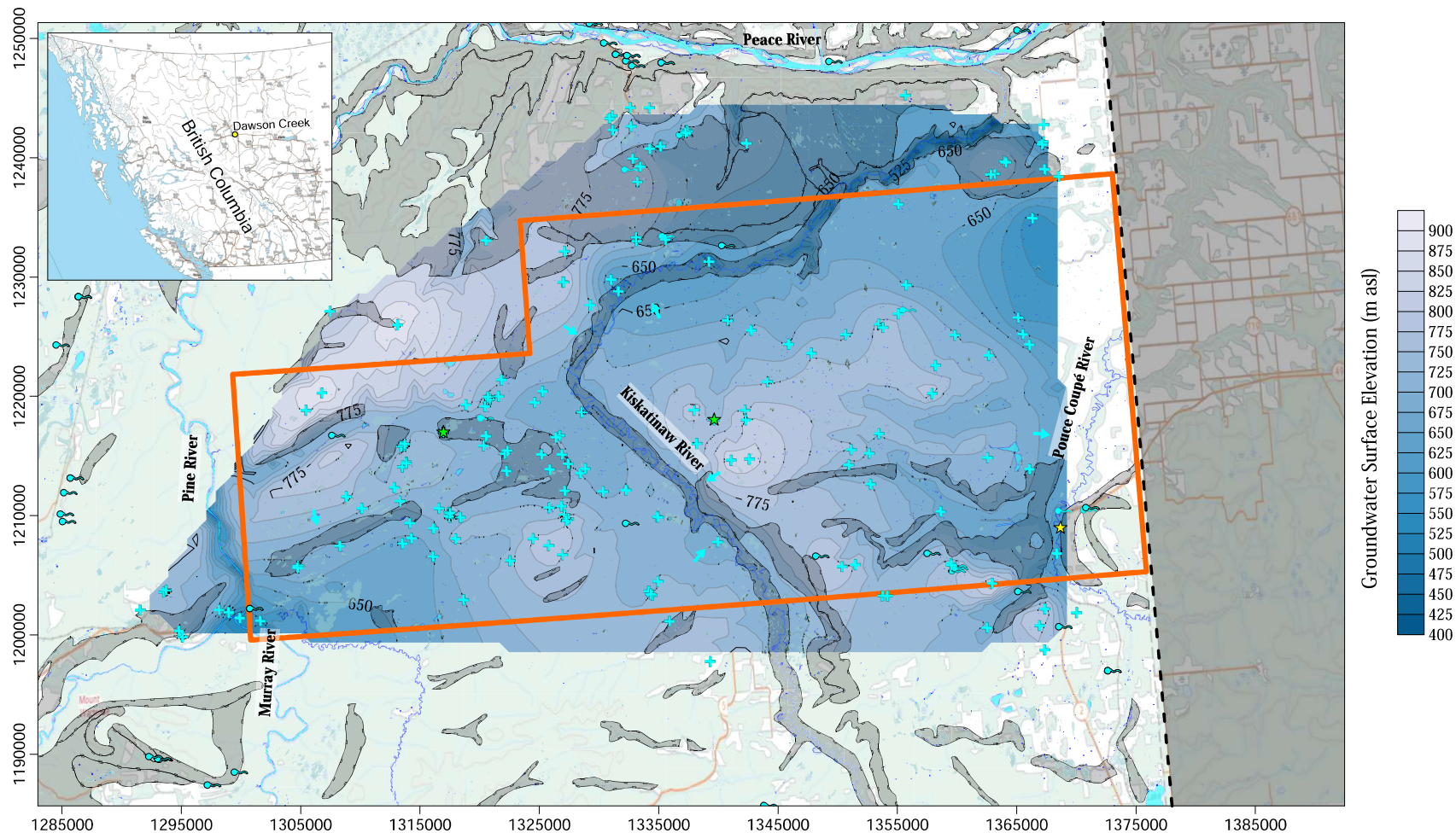
Stratigraphy

Note: Kaskapau and the Dunvegan formations are inferred to form a single aquifer system through secondary porosity and permeability resulting from weathering and fracturing.

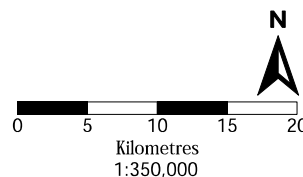
Vertical Exaggeration: 20x

The distribution of bedrock units is based on Cui et al. (2017). This cross-section shows interpreted geology based on data from discrete locations and professional judgement. Deviations in the type and location of material are expected.

BRITISH COLUMBIA MINISTRY OF LAND, WATER AND RESOURCE STEWARDSHIP					
KISKATINAW-PEACE					
AQUIFER MAPPING AND HYDROSTRATIGRAPHIC CHARACTERIZATION					
CROSS-SECTION G-G'					
Prepared for	Date	20-Mar-23	Drawn by	J. G. L.	Edited by
					Agg/By
					A.H.
Workshop Project No.		317085-45183			
TBS No.		5G		REV	
				0	



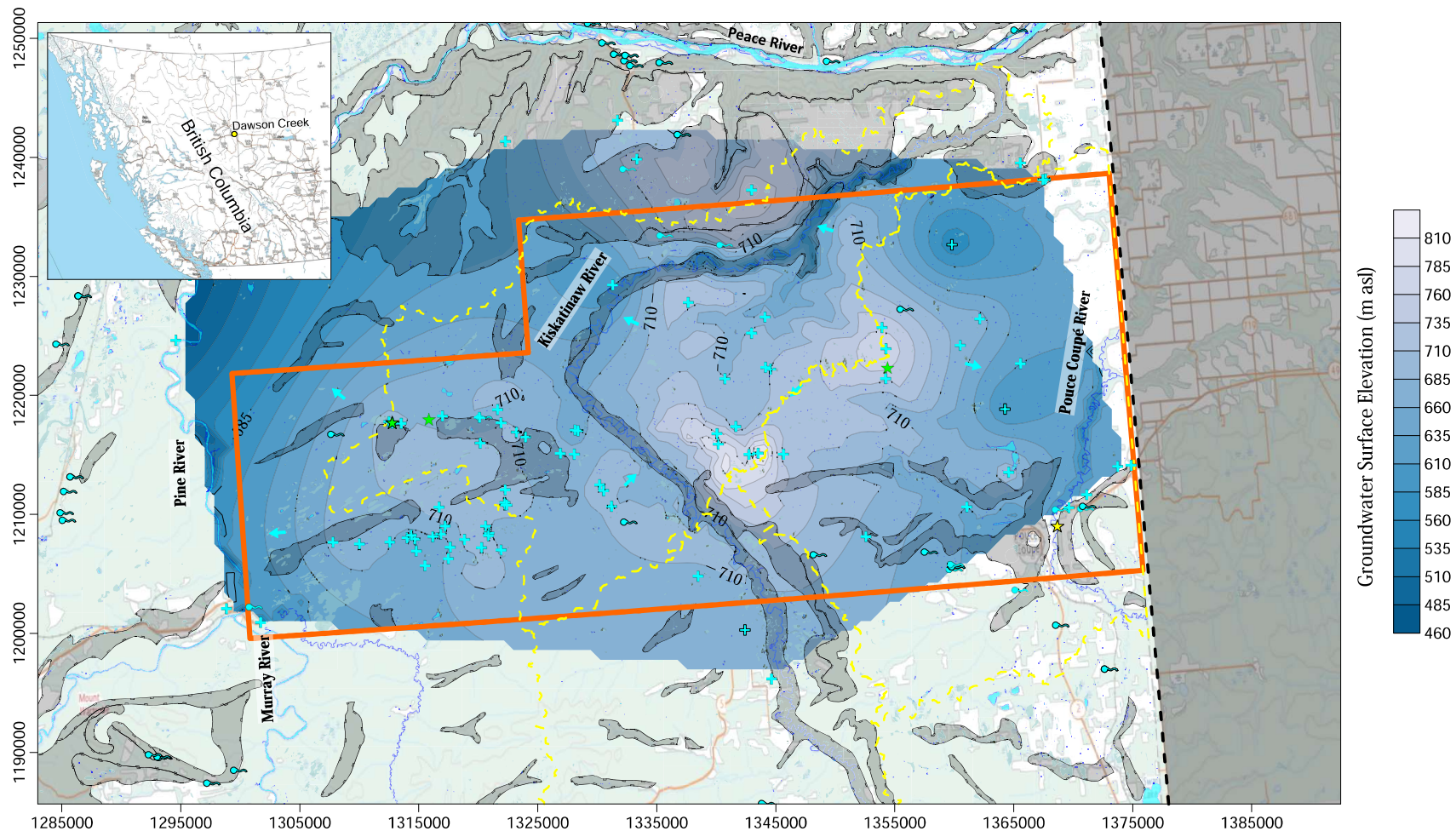
- Study Area
- + Groundwater Surface Elevation Measurement in Wells (Bedrock)
- Inferred Groundwater Flow Direction (Bedrock)
- ★ Artesian (Aquifer type unknown)
- ★ Artesian (Bedrock)
- Licensed Springs
- Overburden Veneer and Colluvium (Bedrock near Surface)



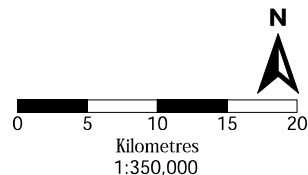
BRITISH COLUMBIA MINISTRY OF LAND, WATER AND RESOURCE STEWARDSHIP			
KISKATINAW-PEACE			
AQUIFER MAPPING AND HYDROSTRATIGRAPHIC CHARACTERIZATION			
GROUNDWATER SURFACE ELEVATION - BEDROCK			
Date: 20-Mar-2023	Drawn by: J. D.T.	Edited by:	App'd by: A.J.H.
Workley Project No.		317085-45183	
FIG No.		6	
REV		0	

Advisian
Worley Group

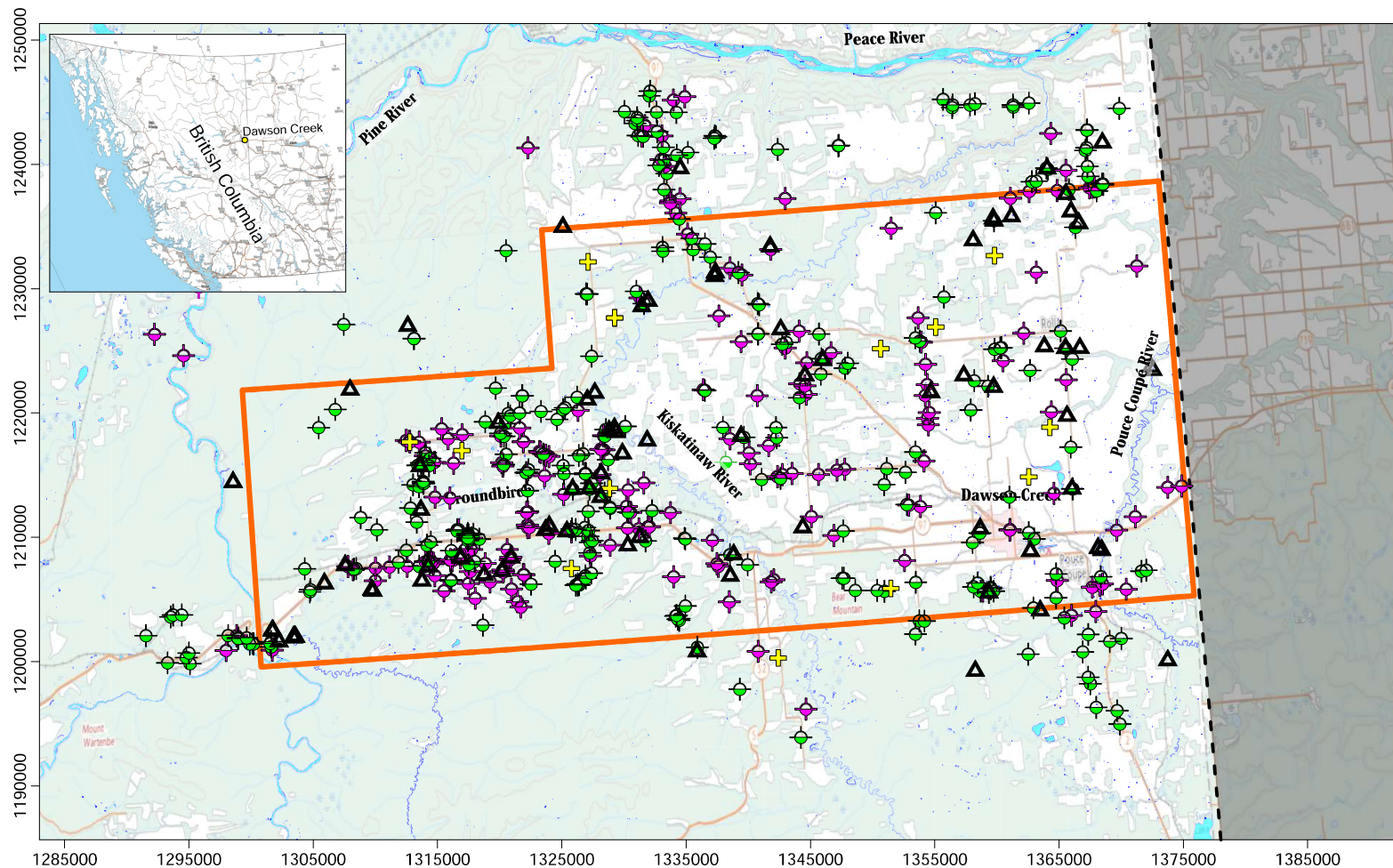
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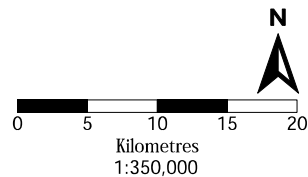
- Study Area
- - - Water Licensing Watershed Boundaries
- + Groundwater Surface Elevation Measurement in Wells (Overburden)
- Inferred Groundwater Flow Direction (Overburden)
- ★ Artesian (Aquifer Type Unknown)
- ★ Artesian (Overburden)
- Licensed Springs
- Overburden Veneer and Colluvium (Bedrock near Surface)



BRITISH COLUMBIA MINISTRY OF LAND, WATER AND RESOURCE STEWARDSHIP			
KISKATINAW-PEACE			
AQUIFER MAPPING AND HYDROSTRATIGRAPHIC CHARACTERIZATION			
GROUNDWATER SURFACE ELEVATION - OVERBURDEN			
Date: 20-Mar-2023	Drawn by: J. D.T.	Edited by:	App'd by: A.J.H.
Workley Project No.		317085-45183	
FIG No.		7	
REV		0	



- Study Area
- ◆ GWELLS (Undefined)
 - ◆ GWELLS (Bedrock)
 - ◆ GWELLS (Overburden)
 - ✚ Goetz (2021)
 - △ Hickin (2013)



BC Albers, NAD 83 Projection

BRITISH COLUMBIA MINISTRY OF LAND, WATER AND RESOURCE STEWARDSHIP			
KISKATINAW-PEACE			
AQUIFER MAPPING AND HYDROSTRATIGRAPHIC CHARACTERIZATION			
DATA DISTRIBUTION			
Date: 20-Mar-2023	Drawn by: J. D.T.	Edited by:	App'd by: A.J.H.
Workley Project No.		317085-45183	
Workley Group		FIG No.	REV
		8	0
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APPENDIX A: AQUIFER MAPPING REPORTS

0589	EAST PINE BEDROCK AQUIFER
0590	GROUND BIRCH OVERBURDEN AQUIFER
0591	EAST PINE -GROUND BIRCH BEDROCK AQUIFER
0592	SUNSET CREEK OVERBURDEN AQUIFER
0593	VALLEY VIEW – DAWSON CREEK BEDROCK AQUIFER
0594	KISKATINAW BURIED CHANNEL OVERBURDEN AQUIFER
0595	SUNSET PRAIRIE BEDROCK AQUIFER
0596	KISKATINAW GLACIO DELTAIC OVERBURDEN AQUIFER
0598	POUCE COUPE OVERBURDEN AQUIFER
0633	SWEETWATER BEDROCK AQUIFER
0851	DAWSON CREEK OVERBURDEN AQUIFER
0903	POUCE COUPE OVERBURDEN AQUIFER
1275	ARRAS-FELLERS HEIGHTS BEDROCK AQUIFER

Aquifer Name: East Pine Bedrock Aquifer

Aquifer Number: 0589

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0589

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is located east of the Pine River. It was delineated based on watershed boundaries in the east and the south, the Pine River in the west, and Stewart Creek in the north (Lengyel et al. 2023, Figure 1). The aquifer boundary is uncertain where it follows Stewart Creek in the north. The aquifers to the east and south of the aquifer (0591 and 0595) are part of the same geological/hydrostratigraphical unit.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by till, glaciolacustrine, and alluvial deposits. Four out of the five wells associated with the aquifer reported fine-grained material (clay, till) on the surface. The thickness of the overlying material ranges from less than 15 to more than 70 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 5A FRACTURED SEDIMENTARY ROCK

The bedrock aquifer comprises sediments of the Upper Cretaceous Dunvegan and Kaskapau formations. The Dunvegan Formation is interpreted to be a regionally continuous hydrostratigraphic unit. The Dunvegan Formation consists of massive conglomerate, fine- to coarse-grained sandstone, and carbonaceous shale (Massey et al. 2005), while the Kaskapau Formation mostly consists of shale, siltstone, and sandstone. The deepest well associated with the aquifer is 98.1 m deep.

Permeability is associated with both the primary and the secondary porosity (through fractures) of the formations. The Dunvegan and Kaskapau formations are described in further detail by Lengyel et al. (2023).

The aquifer is interpreted to be a confined aquifer based on the overlying materials.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to moderately shallow. While the permeability of the aquifer was not tested, it is expected to be low to medium based on the type of aquifer material (shale, sandstone) and high where fractures are present. Surficial mapping by Reimchen (1980) and borehole logs indicate that the bedrock aquifer is covered by fine-grained materials of variable thickness. The

overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be moderate.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels recorded in the provincial groundwater wells database (GWELLS) range from shallow (9.1 m) to moderately shallow (18.3 m). No active provincial monitoring wells and no wells with artesian conditions exist in the aquifer.

The groundwater surface is interpreted to be a subdued representation of the topography, based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily towards the Pine River and its tributaries.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt through the thin overburden (Baye et al. 2016). Much of the recharge is expected to occur in the spring associated with snowmelt. The aquifer may also be recharged by the overlying minor tributaries of the Pine River and/or regional groundwater flow in the bedrock units. However, the spatial and temporal understanding of these recharge pathways as well as vertical flow potential within the bedrock are uncertain and further investigation is required to be evaluated.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater in the aquifer is in direct hydraulic connection with its neighbouring bedrock Aquifers 0591 and 0595. Aquifer boundaries are defined based on inferred groundwater flow paths within the Dunvegan and Kaskapau formations (continuous hydrostratigraphic units) rather than by structural boundaries. Groundwater may also be hydraulically connected with the overlying buried valley aquifer (0592).

Groundwater in the aquifer may also be in direct hydraulic connection with minor tributaries of the Pine River and wetlands in the east, where the thickness of the overburden separating them is thin.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported exceedances for iron, manganese, and hardness in some of the bedrock wells within the area of aquifer 0589. Stated yields in the well records range from 0.63 to 1.26 L/s, with geometric mean of 0.98 L/s indicating moderate productivity. Groundwater is used primarily for domestic and commercial water supply purposes (3 out of 5 wells), based on the GWELLS database.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

Baye et al. (2016) concluded that recharge occurs in upland areas by precipitation percolating through the till, however the exact recharge source of the regional bedrock aquifer is currently unclear and requires further investigation.

Aquifer 0589 is part of the Dunvegan Formation. Bedrock aquifers in the weathered and fractured Dunvegan and Kaskapau formations in the Study Area (0589, 0591, 0593, 0595, 0633, and 1275) are inferred to be part of the same hydrostratigraphic unit and are interpreted to be continuous on a regional scale (see Lengyel et al. 2023). The aquifer is differentiated from adjacent aquifers (0591 and 0595) based on regional groundwater flow paths. Water management decisions for the aquifer may require assessment of adjacent aquifers, especially where development is near the aquifer boundaries.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grouse areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

Geographic datasets from the BC Data Catalogue, accessed November 2022 <https://data.gov.bc.ca/>.

Lengyel, T., Deri-Takacs, J., Hinnell, A. C. & Clague, J. J. 2023. Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization. Victoria, B.C.

Massey, N.W.D., MacIntyre, D.G., Desjardins, P.J. & Cooney, R.T. 2005. Geology of British Columbia. Ministry of Energy and Mines, BC Geological Survey, Geoscience Map 2005-3.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011
02/10/2023	2	Major	Remapping of aquifer	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Groundbirch Buried Valley Aquifer

Aquifer Number: 0590

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0590

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is in the Groundbirch area, between the Pine and Kiskatinaw rivers. The aquifer is bound to the north, south, and east by a combination of the Groundbirch paleovalley extent (Hickin and Best 2013) and the 15 m depth-to-bedrock contour line (Monahan et al. 2018). The western boundary follows the 640 m topographic elevation contour east of the Pine and Murray rivers where the glaciofluvial coarse sediments were inferred to pinch out (Lengyel et al. 2023, Figures 1 and 5F). The aquifer is not expected to be continuous through the valley of the Pine River. The boundary is uncertain in the northeast and southeast as the boundaries of the buried channel are uncertain here. The eastern boundary of the aquifer is uncertain due to lack of information on the hydraulic connection between aquifers 0590, 0594, and 0596. The coarse-grained sediments may not be continuous throughout the entire aquifer extent due to glacial erosion.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by eolian, glaciolacustrine, alluvial, and glaciofluvial sediments in the west, and by glaciolacustrine deposits in the east. Eolian sediments consists of sand and silt, alluvial and glaciofluvial sediments consist of sand, silt, and gravel, and glaciolacustrine sediments consist of silt and clay. Twenty-seven of the 41 wells associated with the aquifer reported low-permeability, fine-grained material (clay, silt, till), four reported medium-permeability (sand with fines), and four reported high-permeability (coarse-grained sand, gravel) sediments at surface.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 4B CONFINED GLACIOFLUVIAL

The aquifer consists of fine- to medium-grained sand and gravel interpreted to be of Late Wisconsinan glaciodeltaic origin.

The aquifer is interpreted to be a confined aquifer, with “windows” in the confining layer where sediments are relatively coarse-grained.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to moderately deep. The permeability of the aquifer has not been tested, but it is expected to be high based on the type of the dominant aquifer material (sand and gravel). Permeability could be spatially variable. Surficial mapping by Reimchen (1980) and borehole logs

indicate that the glaciodeltaic aquifer is covered by fine-grained and medium- to coarse-grained materials of variable thickness. The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be moderate, except where overlying materials are relatively coarse-grained and thus the aquifer vulnerability is interpreted to be high.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static water levels recorded in the provincial groundwater wells database (GWELLS) range from shallow (2.4 m) to moderately deep (53.9 m). There is one active provincial observation well (OW-445, Well Tag Number [WTN] 106675) and one inactive provincial observation well (OW-110, WTN 22824).

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily toward the Kiskatinaw, Pine, and Murray rivers.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt particularly where the aquifer is in a topographically elevated position (i.e., eastern portion of the aquifer) and where coarse-grained materials occur at the surface. Baye et al. (2016) concluded that groundwater in the aquifer is recharged by precipitation (typically occurring in the spring and fall seasons). The aquifer may also be recharged by the overlying minor tributaries of the Kiskatinaw and Pine rivers; however, the spatial and temporal understanding of these recharge pathways are uncertain and further investigation is required to evaluate these hydraulic connections.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater may be hydraulically connected with minor tributaries of the Kiskatinaw and Pine rivers, as well as with wetlands located in the western portion of the aquifer extent, however, further investigation is required to confirm the magnitude and level hydraulic connectivity. Groundwater is also inferred to be hydraulically connected with the underlying bedrock aquifers (0591 and 0595), where these are fractured, and where they are not separated by layers of fine-grained sediment. The aquifer may also be hydraulically connected to overburden aquifer 0596.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported exceedances for arsenic, iron, manganese, and hardness in some of the overburden wells within the extent of aquifer 0590. Stated yields in the well records range from 0.007 to 6.3 L/s, with a geometric mean of 0.5 L/s indicating moderate productivity with localized zones of both low and high productivity. Groundwater is used primarily for domestic purposes (28 of 41 wells), based on the GWELLS database.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

No water availability or water budget studies have been completed in the area.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grouse areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

Geographic datasets from the BC Data Catalogue, accessed November 2022 <https://data.gov.bc.ca/>.

Hickin, A. S., Best, M. E. 2013. Mapping the Geometry and Lithostratigraphy of a Paleovalley with a Time-domain Electromagnetic Technique in an Area with Small Resistivity Contrasts, Grouse, British Columbia, Canada, Journal of Environmental and Engineering Geophysics, 18(2):119-135, doi: 10.2113/JEEG18.2.119.

Lengyel, T., Deri-Takacs, J., Hinnell, A. C. & Clague, J. J. 2023. Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization. Victoria, B.C.

Monahan, P.A., Levson, V.M., Hayes, B.J., Dorey, K., Mykula, Y., Brenner, R., Clarke, J., Galambos, B., Candy, C., Krumbiegel, C. & Calderwood, E. 2018. Mapping the Susceptibility to Amplification of Seismic Ground Motions in the Montney Play Area of Northeast British Columbia. Geoscience BC Report 2018-16.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011
02/10/2023	2	Minor	Aquifer boundaries updated to reflect aquifer extent based on updated conceptual model	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: East Pine - Groundbirch Bedrock Aquifer

Aquifer Number: 0591

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.SC., P.Geo, Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0591

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is between the Pine and Kiskatinaw rivers near the community of Groundbirch. It is a bedrock aquifer delineated based on water licensing watershed boundaries and surface water bodies within a regionally extensive geological/hydrostratigraphic unit. The aquifer is bound by watershed boundaries in the northwest, west, and east, and by the Murray River, the Coldstream Creek, and an unnamed tributary in the south and southwest (Lengyel et al. 2023, Figure 1). The aquifer boundary is uncertain in the south where it follows the Coldstream Creek and its unnamed tributary. To the north and west the aquifer abuts aquifers (0589 and 0595) that are part of the same geological/hydrostratigraphical unit.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by glaciolacustrine, alluvial, eolian, and glaciofluvial deposits. Thirty out of the 38 wells associated with the aquifer reported fine-grained material (clay, silt, till) overlying the aquifer. Of the other wells, two reported sand and fines (silty sand), and two reported coarser grained (medium sand) sediments on the surface. The thickness of the overlying material ranges from less than 3 to more than 70 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 5A FRACTURED SEDIMENTARY ROCK

The bedrock aquifer comprises sediments of the Kaskapau Formation. The Kaskapau Formation mostly consists of shale, siltstone, and sandstone. Permeability is interpreted to be associated with secondary porosity (through fractures and erosion). The Kaskapau Formation is described in further detail by Lengyel et al. (2023). The aquifer is interpreted to be confined based on the overlying materials.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to moderately deep. While the permeability of the aquifer has not been tested, it is expected to be low to medium based on the type of aquifer material (shale and sandstone), and high where fractures are present. Surficial mapping by Reimchen (1980) and borehole logs indicate that the bedrock aquifer is covered by fine- to coarse-grained materials of variable thickness. The overall vulnerability of the aquifer to surface contamination has been interpreted to be moderate.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static water levels recorded in the provincial groundwater wells database (GWELLS) range from shallow (3.0 m) to moderately deep (50.7 m). No active provincial monitoring wells and no wells with artesian conditions exist within the aquifer extent. There is an inactive provincial monitoring well (OW-421) within the extents of the aquifer. The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily towards the Kiskatinaw and Pine rivers and their tributaries.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt through the thin overburden (Baye et al. 2016). Much of the recharge is expected to occur in the spring associated with snowmelt. The aquifer may also be recharged by the overlying minor tributaries of the Pine and Murray rivers and/or regional groundwater flow in the bedrock units. However, the spatial and temporal understanding of these recharge pathways as well as vertical flow potential within the bedrock are uncertain and further investigation is required to be evaluated.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater in the aquifer is in direct hydraulic connection with the groundwater in the neighbouring bedrock aquifers 0589 and 0595. Aquifer boundaries are defined based on inferred groundwater flow paths within the Dunvegan and Kaskapau formations rather than by structural boundaries. Hydraulic connection may also exist between aquifer 0591 and overlying buried channel aquifer (Goetz 2021, i.e., aquifer 0590).

Groundwater in the aquifer may also be in direct hydraulic connection with the minor tributaries of the Pine and Murray rivers and wetlands in the northwest due the limited thickness and locally coarse-grained texture of the overburden separating them.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Two wells reported a water quality concern (WTN 39099 and 47816), representing isolated water quality concerns. Well 17365 noted poor quantity. Baye et al. (2016) reported exceedances for arsenic, iron, manganese, and hardness in some of the bedrock wells within the extent of aquifer 0591. Stated yields in the well records range from 0.06 to 1.5 L/s, with geometric mean of 0.42 L/s indicating moderate productivity. Groundwater is used primarily for domestic purposes (20 of 37 wells).

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

The regional groundwater flow model developed for the Sunset paleo-valley area (Goetz 2021) concluded that the weathered bedrock aquifer, underlying the Sunset buried channel, is the main source of groundwater recharge to the buried channel aquifer. Similarly, aquifer 0591 may recharge the overlying buried channel aquifer (i.e., 0590) which may guide management actions.

Aquifer 0591 is part of the Kaskapau Formation. Bedrock aquifers in the weathered and fractured Dunvegan and Kaskapau formations in the Study Area (0589, 0591, 0593, 0595, 0633, and 1275) are inferred to be part of the same hydrostratigraphic unit and are interpreted to be continuous on a regional scale (see Lengyel et al. 2023). The aquifer is differentiated from adjacent aquifers (0589 and 0595) based on regional groundwater flow paths. Water management decisions for the aquifer may require assessment of adjacent aquifers, especially where development is near the aquifer boundaries.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grounrbirch areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

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Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011.
02/10/2023	2	Major	Aquifer boundaries updated to include hydraulically connected geologic formations (merged with Aquifer 0589)	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Sunset Creek Overburden Aquifer

Aquifer Number: 0592

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0592

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is in the Sunset Creek area, north of Groundbirch, between the Pine and Kiskatinaw rivers. The aquifer is bound to the north by a combination of the extent of the Sunset paleovalley (Hickin and Best 2013) and the 15 m depth-to-bedrock contour line (Monahan et al. 2018). The western boundary follows the Pine River, while the southern boundary was based on the 15 m depth-to-bedrock contour (Monahan et al. 2018) (Lengyel et al. 2023, Figure 1). The eastern boundary of the aquifer is uncertain due to lack of information on the hydraulic connection between aquifers 0592, 0594, and 0596.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by glaciolacustrine sediments and till. Fourteen of the 18 wells associated with the aquifer reported low-permeability, fine-grained material (clay, silt) on the surface, and three reported high-permeability, coarse-grained (sand, gravel) sediments. The thickness of the overlying material is generally more than 15 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 4B CONFINED GLACIOFLUVIAL

The aquifer consists of fine- to medium-grained sand and gravel interpreted to be Late Wisconsinan glaciodeltaic origin. The aquifer is interpreted to be a confined aquifer based on the overlying material thickness. The coarse-grained sediments may not be continuous throughout the entire aquifer extent due to glacial erosion.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to moderately shallow. Hydraulic conductivity was estimated to range between 60 and 130 m/d at well EERI-1 (Goetz 2021). Surficial mapping by Reimchen (1980) and borehole logs indicate that the glaciodeltaic aquifer is covered by fine-grained sediments in the east and medium- to coarse-grained materials of variable thickness in the west. The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be moderate.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels recorded in the provincial groundwater wells database (GWELLS) range from shallow (1.2 m) to moderately shallow (21.3 m). Artesian conditions were encountered at research well EERI-1 (Goetz 2021). No provincial observation wells are within the aquifer extents.

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily toward the Kiskatinaw and Pine rivers.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt particularly where the aquifer is in a topographically elevated position and/or where coarse-grained materials associated with the aquifer occur at the surface. Groundwater in the aquifer is recharged by precipitation (mainly occurring in the spring and fall seasons) within the aquifer area (Baye et al. 2016). Goetz (2021) delineated recharge and discharge areas and concluded that these are consistent with the hypothesis that topographically elevated areas are recharge areas, whereas valleys are discharge areas. The aquifer may also be recharged by the overlying minor tributaries of the Kiskatinaw and Pine rivers; however, the spatial and temporal understanding of these recharge pathways are uncertain and further investigation is required to evaluate these hydraulic connections.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater is inferred to be hydraulically connected with the underlying bedrock aquifers (0589 and 0595) where they are not separated by layers of fine-grained sediment. The aquifer may also be hydraulically connected to overburden aquifer 0596, which is located east of 0592.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported exceedances for arsenic, iron, manganese, sulphate, and hardness in some of the overburden wells within the extent of aquifer 0592. Stated yields in the well records range from 0.3 to 2.5 L/s, with a geometric mean of 0.7 L/s indicating moderate productivity. Groundwater is used primarily for domestic purposes (12 of 18 wells), based on the GWELLS database.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

Goetz (2021) concluded that the buried-valley aquifer receives 99% of its inflow from the weathered bedrock, and that groundwater in the aquifer exits through the Kiskatinaw River.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Groudbirch areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

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Hickin, A. S., Best, M. E. 2013. Mapping the Geometry and Lithostratigraphy of a Paleovalley with a Time-domain Electromagnetic Technique in an Area with Small Resistivity Contrasts, Groudbirch, British Columbia, Canada, Journal of Environmental and Engineering Geophysics, 18(2):119-135, doi: 10.2113/JEEG18.2.119.

Lengyel, T., Deri-Takacs, J., Hinnell, A. C, & Clague, J. J. 2023. Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization. Victoria, B.C.

Monahan, P.A., Levson, V.M., Hayes, B.J., Dorey, K, Mykula, Y, Brenner, R., Clarke, J., Galambos, B, Candy, C., Krumbiegel, C. & Calderwood, E. 2018. Mapping the Susceptibility to Amplification of Seismic Ground Motions in the Montney Play Area of Northeast British Columbia. Geoscience BC Report 2018-16.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011.
02/10/2023	2	Minor	Aquifer boundaries updated to reflect aquifer extent based on updated conceptual model	Tibor Lengyel, M.SC., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Valley View - Dawson Creek Bedrock Aquifer

Aquifer Number: 0593

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0593

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is located between the Kiskatinaw River and the Pouce Coupe River. It is a bedrock aquifer delineated based on water licensing watershed boundaries and surface water bodies within a regionally extensive geological/hydrostratigraphic unit. The aquifer is bound to the north and northwest by water licensing watershed boundaries, to the east by the Pouce Coupe River and the provincial boundary between British Columbia and Alberta, to the south by the Bisette Creek, and tributaries of Bisette Creek and the Kiskatinaw River and to the west by the Kiskatinaw River, (Lengyel et al. 2023, Figure 1). The aquifer extent is uncertain in the south where it follows the Bisette Creek and the unnamed tributaries of Bisette Creek and Kiskatinaw River. It is also uncertain in the east where it follows the provincial boundary as the aquifer likely extends into Alberta. The aquifer to the north of the aquifer (0633) is part of the same geological/hydrostratigraphical unit.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is primarily overlain by variable thickness of till and glaciolacustrine sediments, with more limited extents of alluvial and colluvial sediments. Fifty-six of the 60 wells associated with the aquifer reported fine-grained material (clay, till, silt) on the surface and four reported bedrock material extending to surface. The thickness of the overlying material ranges from 0 to more than 70 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 5A FRACTURED SEDIMENTARY ROCK

The bedrock aquifer is primarily comprised of sediments of the Kaskapau Formation with a limited extent of Cardium Formation near the southern margin of the aquifer. The Kaskapau Formation mostly consists of shale, siltstone, and sandstone, while the Cardium Formation consists of sandstone, conglomerate, and shale (Monahan et al. 2018). Permeability may be associated with primary and secondary porosity (through fracturing) of the Kaskapau and Cardium formations. The Kaskapau and Cardium formations are described in further detail by Lengyel et al. (2023). The aquifer is interpreted to be a confined aquifer except where it outcrops.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to deep. At provincial observation wells OW-419 (Well Tag Number [WTN] 104710), a pumping test analysis estimated the transmissivity at 13.5 m²/d and the hydraulic conductivity at 0.53 m/d (Baye et al. 2016). Surficial mapping by Reimchen (1980) and

borehole logs indicate that most of the bedrock aquifer is covered by fine-grained materials of variable thickness, with limited areas where the aquifer unit outcrops at surface (WTN 1052, 1924, 38945, and 103013). The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be moderate except high where it outcrops at the surface.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static water levels recorded in the provincial groundwater wells database (GWELLS) and in research wells (Goetz 2021) range from shallow (1.8 m) to deep (85.3 m). Flowing artesian conditions were encountered at two wells (WTN 118215 and 104710). There is one active and one inactive bedrock provincial observation well within the aquifer extents, OW-420 (WTN 104711) and OW-419 (WTN 104710), respectively.

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily towards the Kiskatinaw and Pouce Coupé rivers and their tributaries.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt through areas of thin overburden (Baye et al. 2016) with direct recharge in spots where the aquifer outcrops at surface. Much of the recharge is expected to occur in the spring associated with snowmelt. The aquifer may also be recharged by the overlying minor tributaries of the Kiskatinaw and Pouce Coupé rivers and/or regional groundwater flow in the bedrock units. However, the spatial and temporal understanding of these recharge pathways as well as vertical flow potential within the bedrock are uncertain and further investigation is required to be evaluated.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater in the aquifer is in direct hydraulic connection with its neighbouring bedrock aquifer 0633. Aquifer boundaries are defined based on inferred groundwater flow paths within the Kaskapau and Cardium formations within a continuous hydrostratigraphic unit.

Hydraulic connection may exist between aquifer 0593 and the coarse-grained sediments in aquifer 0851, where they are not separated by thick fine-grained sediments. Groundwater in the aquifer may also be in direct hydraulic connection with the Kiskatinaw and Pouce Coupe rivers and their tributaries.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported elevated concentrations of arsenic, iron, sulphate, total dissolved solids (TDS), and hardness in some of the bedrock wells within the extent of aquifer 0593. Some wells report poor to very poor quality (mainly due to excessive iron concentrations). Stated yields in the well records

range from 0.02 to 3.15 L/s, with a geometric mean of 0.3 L/s indicating low/moderate productivity. Several wells were reported dry. Where the purpose of groundwater use is recorded, it is primarily reported as domestic use. In addition, wells with observation and unknown purposes were also recorded in GWELLS.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

Baye et al. (2016) concluded that recharge occurs in upland areas by precipitation percolating through the till, however the recharge pathways to the regional bedrock aquifer are currently uncertain and require further investigation.

Aquifer 0593 is part of the Kaskapau Formation. Bedrock aquifers in the weathered and fractured Dunvegan and Kaskapau formations in the Study Area (0589, 0591, 0593, 0595, 0633, and 1275) are inferred to be part of the same hydrostratigraphic unit and are interpreted to be continuous on a regional scale (see Lengyel et al. 2023). The aquifer is differentiated from adjacent aquifers (0633 and 1275) based on regional groundwater flow paths and major geographic features. Water management decisions for the aquifer may require assessment of adjacent aquifers, especially where development is near the aquifer boundaries.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grounmbirch areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

Geographic datasets from the BC Data Catalogue, accessed November 2022 <https://data.gov.bc.ca/>.

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Monahan, P.A., Levson, V.M., Hayes, B.J., Dorey, K, Mykula, Y, Brenner, R., Clarke, J., Galambos, B, Candy, C., Krumbiegel, C. & Calderwood, E. 2018. Mapping the Susceptibility to Amplification of Seismic Ground Motions in the Montney Play Area of Northeast British Columbia. Geoscience BC Report 2018-16.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011.
02/10/2023	2	Major	Aquifer boundaries updated to include hydraulically connected geologic formations	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Kiskatinaw Buried Channel

Aquifer Number: 0594

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0594

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is along the Kiskatinaw River. The boundaries in the north, west, and east were based on a combination of the Kiskatinaw paleovalley extent (Hickin and Best 2013) and the 15 m depth-to-bedrock contour line (Monahan et al. 2018) (Lengyel et al. 2023, Figure 1). The southern boundary is uncertain as the aquifer is likely continuous toward the south. The aquifer boundaries are uncertain in the north as the boundaries of the buried channel here are uncertain. The western boundary of the aquifer is uncertain due to lack of information on the hydraulic connection between aquifers 0590, 0594 and 0596. The coarse-grained sediments may not be continuous throughout the entire aquifer extent due to glacial erosion.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by glaciolacustrine and glaciodeltaic sediments, till, and colluvial deposits. Glaciolacustrine sediments consist of silt and clay. Glaciodeltaic sediments consist of gravel, sand, and silt. Till mainly consists of poorly-sorted clasts in a clay to sand matrix. Fifteen out of the 16 wells associated with the aquifer reported low-permeability, fine-grained material (clay, silt) on the surface, one reported high-permeability, coarse-grained sediment (sand). The thickness of the overlying material is more than 100 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 4B CONFINED GLACIOFLUVIAL

The buried-channel sediments, interpreted to be of Middle-Wisconsinan fluvial origin, consist of gravel and sand. Based on the thickness and type of overlying sediments, the aquifer is interpreted to be likely confined.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to moderately deep. The permeability of the aquifer has not been tested, but it is expected to be high based on the type of the dominant aquifer material (sand and gravel). Surficial mapping by Reimchen (1980) and borehole logs indicate that the buried-channel aquifer is primarily covered by fine-grained materials of variable thickness. The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be low.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels recorded in the provincial groundwater wells database (GWELLS) and the EERI research wells (Goetz 2021) range from shallow (2.1 m) to moderately deep (35.1 m). There are no active provincial observation wells in the aquifer extents, however there is one inactive provincial observation well (OW-113, Well Tag Number [WTN] 22906). There are no wells with artesian conditions within the aquifer extents.

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily toward the Kiskatinaw River with a northerly component corresponding to the regional slope of the river valley.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt. The aquifer may also be recharged from surrounding weathered bedrock (Goetz 2021) (i.e., aquifers 0593, 0595, 0633, and 1275); however, the spatial and temporal understanding of these recharge pathways are uncertain and further investigation is required to confirm these hydraulic connections.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater is inferred to be hydraulically connected with the underlying bedrock aquifers (0593, 0595, 0633, and 1275) where the aquifers are not separated by layers of fine-grained sediment. The aquifer may also be hydraulically connected to the overlying overburden aquifer (0596).

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported exceedances for arsenic, iron, manganese, and hardness in some of the overburden wells within the area of aquifer 0594. Stated yields in the well records range from 3.2 to 4.7 L/s, with a geometric mean of 3.8 L/s indicating high productivity. Groundwater is used for domestic, commercial, and monitoring purposes, based on the GWELLS database.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

No water availability or water budget studies have been completed in the area.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Groudbirch areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

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Goetz, A. M. 2021 Regional Groundwater Conditions in Northeast BC: Results from a Monitoring Well Network in an Area of Historical and Ongoing Unconventional Natural Gas Development. M.Sc. Thesis, University of British Columbia, Vancouver

Hickin, A. S., Best, M. E. 2013. Mapping the Geometry and Lithostratigraphy of a Paleovalley with a Time-domain Electromagnetic Technique in an Area with Small Resistivity Contrasts, Groudbirch, British Columbia, Canada, Journal of Environmental and Engineering Geophysics, 18(2):119-135, doi: 10.2113/JEEG18.2.119.

Lengyel, T., Deri-Takacs, J., Hinnell, A. C, & Clague, J. J. 2023. Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization. Victoria, B.C.

Monahan, P.A., Levson, V.M., Hayes, B.J., Dorey, K, Mykula, Y, Brenner, R., Clarke, J., Galambos, B, Candy, C., Krumbiegel, C. & Calderwood, E. 2018. Mapping the Susceptibility to Amplification of Seismic Ground Motions in the Montney Play Area of Northeast British Columbia. Geoscience BC Report 2018-16.

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A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011
02/10/2023	2	Minor	Aquifer boundaries updated to reflect aquifer extent based on updated conceptual model	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Sunset Prairie Bedrock Aquifer

Aquifer Number: 0595

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0595

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is along the Kiskatinaw River on its western and northern side, between the community of Progress and the confluence of the Kiskatinaw River and the Peace River. It is a bedrock aquifer delineated based on water licensing watershed boundaries and surface water bodies within a regionally extensive geological/hydrostratigraphic unit. The aquifer is bounded by the Kiskatinaw River to the east and water licensing watershed boundaries in the other directions (Lengyel et al. 2023, Figure 1). The bedrock aquifers to the north, west and south of the aquifer (589, 591, 0631, 0634, and 1275) are part of the same geological/hydrostratigraphical unit.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by variable thickness of till and glaciolacustrine deposits with areas reporting veneers only. Seventy of the 91 wells associated with the aquifer reported fine-grained material (clay, till), three reported sand and fines (silty sand), and two reported coarse-grained material (sand and gravel) on the surface. The thickness of the overlying material ranges from 1.2 to more than 200 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 5A FRACTURED SEDIMENTARY ROCK

The bedrock aquifer is comprised of sediments of the Dunvegan and Kaskapau formations. The Dunvegan Formation and Kaskapau Formation are interpreted to be a regionally continuous hydrostratigraphic unit. The Dunvegan Formation consists of massive conglomerate, fine- to coarse-grained sandstone, and carbonaceous shale (Massey et al. 2005), while the Kaskapau Formation mostly consists of shale, siltstone, and sandstone.

Permeability may be associated with both the primary and the secondary porosity (through fractures) of the formations. The Dunvegan and Kaskapau formations are described in further detail by Lengyel et al. (2023).

The aquifer is interpreted to be a confined aquifer based on the thickness and type of overlying materials.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to deep. Pumping test derived estimates for transmissivity and hydraulic conductivity are 69 m²/d and 7.7 m/d, respectively, at provincial observation well OW-416

(Well Tag Number [WTN] 104707), and 16 m²/d and 0.8 m/d, respectively, at provincial observation well OW-417 (WTN 104708) (Baye et al. 2016). Surficial mapping by Reimchen (1980) and borehole logs indicate that the bedrock aquifer is primarily covered by fine-grained materials of variable thickness (see Section A.1.3). The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be moderate.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels recorded in the provincial groundwater wells database (GWELLS) and in reviewed research wells (Goetz 2021) range from shallow (0.6 m) to deep (85.3 m). Flowing artesian conditions were encountered at three wells (WTN 75478 and 75480, and EERI-11). There are two active bedrock provincial observation, OW 416 (WTN 104707) and OW 417 (WTN 104708) and two inactive provincial observation wells, OW-111 (WTN 22879) and OW-112 (WTN 22892) within the extents of the aquifer.

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow towards the Kiskatinaw River and its tributaries.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt through the thin overburden (Baye et al. 2016). Much of the recharge is expected to occur in the spring associated with snowmelt. The aquifer may also be recharged by the overlying minor tributaries of the Kiskatinaw River and/or regional groundwater flow in the bedrock units. However, the spatial and temporal understanding of these recharge pathways as well as vertical flow potential within the bedrock are uncertain and further investigation is required to be evaluated.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater in the aquifer is in direct hydraulic connection with its neighbouring bedrock aquifers 0589, 0591, 0631, 0634, and 1275 that are all part of a continuous hydrostratigraphic unit. Hydraulic connection may also exist between aquifer 0595 and overlying overburden aquifers (i.e., 0592, 594, and 596) where the intervening sediments are permeable.

Groundwater in the aquifer may also be in direct hydraulic connection with the minor tributaries of the Kiskatinaw River and wetlands in the west and north, where the thickness of the overburden separating them is thin.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Three wells reported elevated iron and hardness content for wells WTN 54157, 39097, and 39092, with additional comment on hydrogen-sulfide smell of water in well 54157. Baye et al. (2016) reported exceedances for arsenic, iron, manganese, sulphate, TDS, and hardness in some of the bedrock wells within the area of aquifer 0595. Stated yields in the well records range from 0.03 to 6.3 L/s, with a geometric mean of 0.54 L/s indicating moderate productivity with localized zones of both low and high productivity. Groundwater is used commonly for domestic purposes (52 out of 91 wells). In addition, wells with observation, commercial, and unknown purposes were also recorded in GWELLS.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

Baye et al. (2016) concluded that recharge occurs in upland areas by precipitation percolating through the till, however the exact recharge source of the regional bedrock aquifer is currently uncertain and requires further investigation.

Aquifer 0595 is part of the Dunvegan and Kaskapau formations. Bedrock aquifers in the weathered and fractured Dunvegan and Kaskapau formations in the Study Area (0589, 0591, 0593, 0595, 0633, and 1275) are inferred to be part of the same hydrostratigraphic unit and are interpreted to be continuous on a regional scale (see Lengyel et al. 2023). The aquifer is differentiated from adjacent aquifers (0589, 0591, 0633, 1275) based on regional groundwater flow paths and major geographic features. Water management decisions for the aquifer may require assessment of adjacent aquifers, especially where development is near the aquifer boundaries.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grounbirch areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

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Lengyel, T., Deri-Takacs, J., Hinnell, A. C, & Clague, J. J. 2023. Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization. Victoria, B.C.

Massey, N.W.D., MacIntyre, D.G., Desjardins, P.J. & Cooney, R.T. 2005. Geology of British Columbia. Ministry of Energy and Mines, BC Geological Survey, Geoscience Map 2005-3.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011
02/10/2023	2	Major	Aquifer boundaries updated to include hydraulically connected geologic formations	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Kiskatinaw Glaciodeltaic Overburden Aquifer

Aquifer Number: 0596

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0596

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is located along the Kiskatinaw River. The boundaries in the north, west, and east were based on the combination of the Kiskatinaw paleovalley extent (Hickin and Best 2013) and the 15 m depth-to-bedrock contour (Monahan et al. 2018) (Lengyel et al. 2023, Figure 1). The southern boundary is uncertain as the aquifer is likely continuous towards the south. The aquifer boundaries are uncertain in the north as the boundaries of the buried channel here are uncertain. The western boundary of the aquifer is uncertain due to lack of information on the hydraulic connection between aquifers 0590, 0594 and 0596. The coarse-grained sediments may not be continuous throughout the entire aquifer extent due to glacial erosion.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by glaciolacustrine sediments, till, and colluvium. Glaciolacustrine sediments consist of silt and clay; the till mainly consists of poorly sorted clasts in a clay to sand matrix. Thirteen out of the 14 wells associated with the aquifer reported low-permeability, fine-grained material (clay, silt) on the surface, and one reported high-permeability, coarse-grained material (sand). The thickness of the overlying material is more than 15 meters (Monahan et al. 2018).

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 4B CONFINED GLACIOFLUVIAL

The aquifer material, interpreted to be Late Wisconsinan ice-advance glaciodeltaic origin, consists of silt, fine- to medium-grained sand, and gravel. Based on the thickness and the type of overlying material, the aquifer is interpreted to be a confined aquifer.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to moderately shallow. The permeability of the aquifer has not been tested, but it is expected to be moderate to high based on the type of the dominant aquifer material (silt, sand, and gravel). Surficial mapping by Reimchen (1980) and borehole logs indicate that the glaciodeltaic aquifer is covered by fine-grained materials of variable thickness. The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be low.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels recorded in the provincial groundwater wells database (GWELLS) range from shallow (2.1 m) to moderately deep (35.1 m). There are no active provincial observation wells within the aquifer extents but there is one inactive provincial observation well (OW-113, Well Tag Number [WTN] 22906). There are no wells with artesian conditions in the aquifer.

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily toward the Kiskatinaw River with a northerly component corresponding to the regional slope of the river valley.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt. The aquifer may be recharged from surrounding weathered bedrock (Goetz 2021) (i.e., aquifers 0593, 0595, 0633, and 1275). The aquifer may also be recharged by the Kiskatinaw River; however, the spatial and temporal understanding of these recharge pathways are uncertain and further investigation is required to evaluate these hydraulic connections.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater may be hydraulically connected with the Kiskatinaw River, as well as with wetlands located in the southern portion of the aquifer extent, however, further investigation is required to evaluate the magnitude and level of hydraulic connectivity. Groundwater may also be hydraulically connected with the underlying bedrock aquifers (0593, 0595, 0633, and 1275) where bedrock aquifers are fractured, and where the aquifers are not separated by layers of fine-grained sediment.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported exceedances for arsenic, iron, manganese, and hardness in some of the overburden wells within the area of aquifer 0596. Stated yields in the well records range from 1.1 to 3.2 L/s, with a geometric mean of 1.7 L/s indicating moderate productivity with localized zones of high productivity. Groundwater is used for domestic, commercial, and monitoring purposes based on the GWELLS database.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

No water availability or water budget studies have been completed in the area.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grounrbirch areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

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Hickin, A. S., Best, M. E. 2013. Mapping the Geometry and Lithostratigraphy of a Paleovalley with a Time-domain Electromagnetic Technique in an Area with Small Resistivity Contrasts, Grounrbirch, British Columbia, Canada, Journal of Environmental and Engineering Geophysics, 18(2):119-135, doi: 10.2113/JEEG18.2.119.

Lengyel, T., Deri-Takacs, J., Hinnell, A. C, & Clague, J. J. 2023. Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization. Victoria, B.C.

Monahan, P.A., Levson, V.M., Hayes, B.J., Dorey, K, Mykula, Y, Brenner, R., Clarke, J., Galambos, B, Candy, C., Krumbiegel, C. & Calderwood, E. 2018. Mapping the Susceptibility to Amplification of Seismic Ground Motions in the Montney Play Area of Northeast British Columbia. Geoscience BC Report 2018-16.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011.
02/10/2023	2	Minor	Aquifer boundaries updated to reflect aquifer extent based on updated conceptual model	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Pouce Coupe Overburden Aquifer

Aquifer Number: 0598

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0598

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is along the Pouce Coupé River and bound by the extent of the alluvial sediments to the east and west (Reimchen 1980). The boundaries are uncertain in the northeast, where they follow the provincial boundary, and south, as the aquifer likely extends further south (Lengyel et al. 2023, Figure 1). The aquifer extends across the provincial border but has been truncated to the provincial boundary for management reasons.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

Based on Reimchen (1980) and borehole lithology, the alluvial deposits which form the aquifer consist of silt and sand. The aquifer is considered unconfined to semi-confined.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 1B UNCONFINED FLUVIAL

Sand, gravel, and silt associated with recent fluvial depositional environment.

A.1.4 VULNERABILITY

Depth to groundwater is shallow. The permeability of the aquifer has not been tested, but it is expected to be high based on the type of the dominant aquifer material (sand and gravel). Permeability of silt is expected to be moderate. The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be high.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels are shallow (0.6 to 2.1 m, LHC 2011). There are no active provincial observation wells or wells with artesian conditions within the extents of the aquifer.

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily

towards the Pouce Coupé River with a north-easterly component corresponding to the regional slope of the river valley.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt as the aquifer is exposed at surface. The aquifer is inferred to be hydraulically connected to the Pouce Coupé River and therefore may be recharged by the Pouce Coupé and its smaller tributaries. However, the spatial and temporal understanding of these recharge pathways are uncertain and further investigation is required to evaluate these hydraulic connections.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater is inferred to be hydraulically connected to the Pouce Coupé River and its tributaries. The aquifer may also be hydraulically connected with the underlying bedrock aquifer (0593) where intervening sediments are absent, thin, or permeable.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

The yield, based on one well record, is 10.1 L/s, indicating high productivity. Groundwater is used for domestic purposes, based on the GWELLS database.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

No water availability or water budget studies have been completed in the area.

A.4 AQUIFER REFERENCES

Geographic datasets from the BC Data Catalogue, accessed November 2022 <https://data.gov.bc.ca/>.

Lengyel, T., Deri-Takacs, J., Hinnell, A. C. & Clague, J. J. 2023. Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization. Victoria, B.C.

LHC (Lowen Hydrogeology Consulting Ltd.) 2011. Aquifer Classification Mapping in the Peace River Region for the Montney Water Project. File No. 1026. June 2011.

Monahan, P.A., Levson, V.M., Hayes, B.J., Dorey, K, Mykula, Y, Brenner, R., Clarke, J., Galambos, B, Candy, C., Krumbiegel, C. & Calderwood, E. 2018. Mapping the Susceptibility to Amplification of Seismic Ground Motions in the Montney Play Area of Northeast British Columbia. Geoscience BC Report 2018-16.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011.
02/10/2023	2	Minor	Aquifer boundaries updated to reflect aquifer extent based on alluvial sediments along Poucé Coupe River	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo

Aquifer Name: Sweetwater Bedrock Aquifer

Aquifer Number: 0633

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0633

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is located south and west of the Kiskatinaw River. It is a bedrock aquifer delineated based on water licensing watershed boundaries and surface water bodies within a regionally extensive geological/hydrostratigraphic unit. The aquifer is bound to the west and north by the Kiskatinaw River, to the south and east by water licensing watershed boundaries (Lengyel et al. 2023, Figure 1). The aquifer to the south of the aquifer (0593) is part of the same geological/hydrostratigraphical unit.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is primarily overlain by till and glaciolacustrine, and colluvial sediments near the Kiskatinaw River. Twenty-two of the 29 wells associated with the aquifer reported fine-grained material (clay, till) on the surface and three reported bedrock. The remaining wells did not specify surficial lithology. The thickness of the overlying material ranges from 0 to more than 79 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 5A FRACTURED SEDIMENTARY ROCK

The bedrock aquifer primarily comprises sediments of the Upper Cretaceous Kaskapau Formation, with sediments of the Dunvegan Formation limited to near the Kiskatinaw River. The Dunvegan Formation consists of massive conglomerate, fine to coarse-grained sandstone, and carbonaceous shale (Massey et al. 2005), and the Kaskapau Formation mostly consists of shale, siltstone, and sandstone. Permeability may be associated with both the primary and the secondary porosity (through fracturing) of the formations. The Dunvegan and Kaskapau formations are described in further detail by Lengyel et al. (2023).

Based on the thickness and type of the overlying material, the aquifer is interpreted to be a confined aquifer.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to deep. Baye et al. (2016) reported relatively stable water levels for August 2014-July 2015 and extremely low well yield at provincial observation well OW-418 (Well Tag Number [WTN] 104709). While the permeability of the aquifer has not been tested, it is expected to be low in shale, moderate in sandstone, and high where fractures are present. Surficial mapping by Reimchen (1980) and borehole logs indicate that most of the bedrock aquifer is covered by

fine-grained materials of variable thickness, with potential windows where bedrock is on surface. The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be moderate.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels recorded in the provincial groundwater wells database (GWELLS) and in reviewed research wells (Goetz 2021) range from shallow (0.3 m) to moderately deep (76.8 m). Flowing artesian conditions were encountered at one well (WTN 17941). There is one active bedrock provincial observation well within the aquifer extents, OW-418 (WTN 104709).

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow toward the Kiskatinaw River and its tributaries.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt through the overburden (Baye et al. 2016). Much of the recharge is expected to occur in the spring associated with snowmelt. The aquifer may also be recharged by the overlying minor tributaries of the Kiskatinaw River and/or regional groundwater flow in the bedrock units. However, the spatial and temporal understanding of these recharge pathways as well as vertical flow potential within the bedrock are uncertain and further investigation is required to be evaluated.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater in the aquifer is in direct hydraulic connection with its neighbouring bedrock aquifer 0593. Hydraulic connection may exist between aquifer 0633 and the coarse-grained sediments in aquifer 0851, where they are not separated by thick fine-grained sediments. Groundwater in the aquifer may also be in direct hydraulic connection with the minor tributaries of the Kiskatinaw River where the thickness of the overburden is limited.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported elevated concentrations for arsenic, iron, sulphate, total dissolved solids (TDS), and hardness in some of the bedrock wells within the extent of aquifer 0633. Stated yields in the well records range from 0.02 to 5.55 L/s, with a geometric mean of 0.42 L/s indicating moderate productivity with localized zones of both low and high productivity. Several wells were reported as dry. Where identified, groundwater is primarily used for domestic purposes. Commercial and industrial purpose is also reported at one well in the aquifer based on GWELLS.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

Baye et al. (2016) concluded that recharge occurs in upland areas by precipitation percolating through the till, however the exact recharge source of the regional bedrock aquifer is currently uncertain and requires further investigation.

Aquifer 0633 is part of the Kaskapau Formation and, where present, the Dunvegan Formation. Bedrock aquifers in the weathered and fractured Dunvegan and Kaskapau formations in the Study Area (0589, 0591, 0593, 0595, 0633, and 1275) are inferred to be part of the same hydrostratigraphic unit and are interpreted to be continuous on a regional scale (see Lengyel et al. 2023). The aquifer is differentiated from adjacent aquifers (0593 and 0595) based on regional groundwater flow paths and major geographic features. Water management decisions for the aquifer may require assessment of adjacent aquifers, especially where development is near the aquifer boundaries.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-GrounDbirch areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

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Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011
02/10/2023	2	Major	Aquifer boundaries updated to include hydraulically connected geologic formations	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Dawson Creek Overburden Aquifer

Aquifer Number: 0851

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0851

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is between the Kiskatinaw River and the Pouce Coupé River. It was delineated based on well log records and is bounded by rivers in rolling uplands away from the incised river valleys. The rolling uplands were mapped as glacial and glaciolacustrine sediments of generally lower thickness (<15 m, see Figure 4 in Lengyel et al. 2023). The boundaries are not well defined and were adjusted to include all unconsolidated wells (Lowen Hydrogeology Consultants Ltd. [LHC] 2011).

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by till, glaciolacustrine and alluvial deposits. Forty-four of the 47 wells associated with the aquifer reported fine-grained material (clay, till), while three reported coarse-grained sediments (gravel) on the surface. The thickness of the overlying material ranges from less than 3 meters to more than 30 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) – 4B - CONFINED GLACIOFLUVIAL AQUIFER

Aquifer 0851 is primarily a low conductivity unit comprised of glaciolacustrine clay/glacial till with localized discontinuous coarse-grained sediments (fine- to medium-grained sand) that may locally support lower intensity groundwater production from low yield wells (Lengyel et al., 2023 Figure 1 and Figure 5A, B).

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to deep. The permeability of the aquifer has not been tested, but it is expected to be medium where discontinuous sand units are present (fine- to medium-sand). The permeability of the fine-grained material surrounding the coarse-grained lenses is expected to be low. The sand lenses are expected to be the main producing zone within the aquifer. Surficial mapping by Reimchen (1980) and borehole logs indicate that the aquifer material is dominantly covered by fine-grained material (clay, till). The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be moderate.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels recorded in the provincial groundwater wells database (GWELLS) range from shallow (0.5 m) to deep (98.5 m¹). There is one well reported with artesian flow conditions (WTN 80273). No active provincial monitoring wells exist in the aquifer.

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily towards the Kiskatinaw and Pouce Coupé rivers.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt through the thin overburden (Baye et al 2016). Much of the recharge is expected to occur in the spring associated with snowmelt. The aquifer may also be recharged by the overlying minor tributaries of the Kiskatinaw and Pouce Coupé rivers; however, the spatial and temporal understanding of these recharge pathways are uncertain and further investigation is required to evaluate these hydraulic connections.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater may be hydraulically connected with minor tributaries of the Kiskatinaw and Pouce Coupé rivers, however, further investigation is required to evaluate the magnitude and level of hydraulic connectivity. Groundwater is also inferred to be hydraulically connected with the underlying bedrock aquifers (0593 and 0633) where they are not separated by layers of fine-grained sediment.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported exceedances for arsenic, iron, manganese, sulphate, and hardness in some of the overburden wells within the area of aquifer 0851. Stated yields in the well records range from 0.09 to 1.8 L/s, with a geometric mean of 0.34 L/s indicating moderate productivity with pockets of low productivity. Groundwater is used primarily for domestic purposes, where the purpose is reported in GWELLS.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

No water availability or water budget studies have been completed in the area.

¹ Based on a research well (see Goetz 2021, EERI-27).

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grouse areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

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LHC (Lowen Hydrogeology Consulting Ltd.) 2011. Aquifer Classification Mapping in the Peace River Region for the Montney Water Project. File No. 1026. June 2011.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011
02/10/2023	2	Major	Update to the conceptual understanding of the aquifer	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Pouce Coupe Overburden Aquifer

Aquifer Number: 0903

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 0903

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is located east of the Pouce Coupé River. It was delineated based on well log records (Lowen Hydrogeology Consulting Ltd. [LHC 2011]) between the Pouce Coupé River in the west and the provincial boundary in the east. The boundaries are not well defined and were adjusted to include all unconsolidated wells (LHC 2011). The aquifer is likely to extend further to the east.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by till, glaciolacustrine sediment and, at places, coarse-grained alluvial deposits (Reimchen 1980). All wells associated with the aquifer reported fine-grained material (clay, till) on the surface. The thickness of the overlying material ranges from less than 3 meters to more than 30 meters.

A.1.3 GEOLOGIC FORMATION (AQUIFER) –4B CONFINED GLACIOFLUVIAL

The overburden aquifer is comprised of glaciolacustrine sand and gravel. The aquifer is considered semi-confined (LHC 2011). Based on the review of the conceptual model (Lengyel et al. 2023) the aquifer is interpreted to consist of localized, discontinuous sediments that may locally support groundwater production from low yield wells.

A.1.4 VULNERABILITY

Depth to groundwater varies from shallow to moderately deep. The permeability of the aquifer has not been tested, but it is expected to be high based on the type of the dominant aquifer material (sand and gravel). Surficial mapping by Reimchen (1980) and borehole logs indicate that the aquifer material is covered by fine-grained material (clay, till) and by coarser-grained alluvial sediments. The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be moderate.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static water levels recorded in the provincial groundwater wells database (GWELLS) range from shallow (3.0 m) to moderately deep (30.5 m). No active provincial monitoring wells or wells with artesian conditions exist in the aquifer.

The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily towards the Pouce Coupé River.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt through the thin overburden (Baye et al. 2016). Much of the recharge is expected to occur in the spring associated with snowmelt. The aquifer may also be recharged by the overlying minor tributaries of the Pouce Coupé River; however, the spatial and temporal understanding of these recharge pathways are uncertain and further investigation is required to evaluate these hydraulic connections.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater may be hydraulically connected with minor tributaries of the Pouce Coupé River; however, further investigation is required to evaluate the magnitude and level of hydraulic connectivity.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

Baye et al. (2016) reported exceedances for iron, sulphate, and hardness in some of the overburden wells within the area of aquifer 0903. Yields were not reported for the wells associated with the aquifer; in the absence of data, it was interpreted to be of low productivity (LHC 2011). Groundwater is used primarily for domestic purposes, where the well purpose is recorded in GWELLS.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

No water availability or water budget studies have been completed in the area.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grouse areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

Geographic datasets from the BC Data Catalogue, accessed November 2022 <https://data.gov.bc.ca/>.

Lengyel, T., Deri-Takacs, J., Hinnell, A. C, & Clague, J. J. 2023. Kiskatinaw-Peace Aquifer Mapping and Hydrostratigraphic Characterization. Victoria, B.C.

LHC (Lowen Hydrogeology Consulting Ltd.) 2011. Aquifer Classification Mapping in the Peace River Region for the Montney Water Project. File No. 1026. June 2011.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
2011	1	Major	Initial mapping of aquifer	Lowen Hydrogeology Consulting Ltd. 2011
20230210	2	Major	Update to the conceptual understanding of the aquifer	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

Aquifer Name: Arras-Fellers Heights Bedrock Aquifer

Aquifer Number: 1275

Date of Mapping: February 10, 2023

Authors: Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., and Andrew Hinnell, Ph.D., P.Geo.

A. AQUIFER DESCRIPTION FOR AQUIFER 1275

A.1 CONCEPTUAL UNDERSTANDING OF HYDROSTRATIGRAPHY

A.1.1 AQUIFER EXTENTS

The aquifer is located south of Peace River, between the Pine and Kiskatinaw rivers. It was delineated based on surface water bodies and water licensing watershed boundaries. The aquifer is bound by watershed boundaries in the north, west, by the Kiskatinaw River in the east, and by the Study Area boundary in the south (Lengyel et al. 2023, Figure 1). The aquifer boundaries are uncertain in the south, as the aquifer is likely to extend further south. The aquifer to the north of the aquifer (0595) is part of the same geological/hydrostratigraphical unit.

A.1.2 GEOLOGIC FORMATION (OVERLYING MATERIALS)

The aquifer is overlain by variable thickness of till and glaciolacustrine deposits (with some veneers). All nine wells associated with the aquifer reported fine-grained material (clay, silt, till) on the surface. The thickness of the overlying material ranges from 6 to more than 90 meters.

A.1.1 GEOLOGIC FORMATION (AQUIFER) – 5A FRACTURED SEDIMENTARY ROCK

The bedrock aquifer is comprised of sediments of the Kaskapau Formation. The Kaskapau Formation mostly consists of shale, siltstone, and sandstone. Permeability is interpreted to be associated with secondary porosity (through fractures). The Kaskapau Formation is described in further detail by Lengyel et al. (2023).

The aquifer is interpreted to be a confined aquifer based on the thickness and the type of overlying material.

A.1.2 VULNERABILITY

Depth to groundwater varies from shallow to deep. While the permeability of the aquifer has not been tested, it is expected to be low in shale, moderate in sandstone, and high where fractures are present. Surficial mapping by Reimchen (1980) and borehole logs indicate that the bedrock aquifer is covered by fine-grained materials of variable thickness. The overall vulnerability of the aquifer to surface contamination has been qualitatively assessed to be low.

A.2 CONCEPTUAL UNDERSTANDING OF FLOW DYNAMICS

A.2.1 GROUNDWATER LEVELS AND FLOW DIRECTION

Static groundwater levels recorded in the provincial groundwater wells database (GWELLS) range from shallow (6.7 m) to deep (103.6 m). No active provincial monitoring wells within the aquifer extent. Artesian conditions have not been observed in the aquifer. The groundwater surface is interpreted to be a subdued representation of the topography based on regional interpolation of groundwater surface elevations. Groundwater is interpreted to flow primarily to the east.

A.2.2 RECHARGE

Recharge to the aquifer could occur via distributed infiltration of precipitation and snowmelt through areas with thin overburden (Baye et al. 2016). Much of the recharge is expected to occur in the spring associated with snowmelt. The aquifer may also be recharged by the overlying minor tributaries of the Kiskatinaw River and/or regional groundwater flow in the bedrock units. However, the spatial and temporal understanding of these recharge pathways, as well as vertical flow potential within the bedrock are unknown and further investigation is required to be evaluated.

A.2.3 POTENTIAL FOR HYDRAULIC CONNECTION

Groundwater in the aquifer is in direct hydraulic connection with the groundwater in the neighbouring bedrock aquifer 0595. Hydraulic connection may exist between aquifer 1275 and overlying overburden aquifers (Goetz 2021, i.e., 0594 and 0596). Groundwater in the aquifer may also be in direct hydraulic connection with the minor tributaries of the Kiskatinaw River where there is limited thickness of the overburden.

A.3 WATER MANAGEMENT

A.3.1 ADDITIONAL INFORMATION ON WATER USE AND MANAGEMENT

No water quality concern has been reported in the aquifer. Stated yields in the well records range from 0.12 to 0.95 L/s, with a geometric mean of 0.27 L/s indicating low productivity with pockets of moderate productivity. Groundwater is used primarily for domestic purposes (seven of the nine wells), based on GWELLS well purposes.

A.3.2 ADDITIONAL ASSESSMENTS OR MANAGEMENT ACTIONS

The regional groundwater flow model developed for the Sunset paleo-valley area (Goetz 2021) concluded that the weathered bedrock aquifer, underlying the Sunset buried channel, is the main source of groundwater recharge to the buried channel aquifer. Similarly, aquifer 1275 may recharge the overlying buried channel aquifers (0594 and 0596), which may guide management actions.

Aquifer 1275 is part of the Kaskapau Formation. Bedrock aquifers in the weathered and fractured Dunvegan and Kaskapau formations in the Study Area (0589, 0591, 0593, 0595, 0633, and 1275) are

inferred to be part of the same hydrostratigraphic unit and are interpreted to be continuous on a regional scale (see Lengyel et al. 2023). The aquifer is differentiated from adjacent aquifers (0593 and 0595) based on regional groundwater flow paths and major geographic features. Water management decisions for the aquifer may require assessment of adjacent aquifers, especially where development is near the aquifer boundaries.

A.4 AQUIFER REFERENCES

Baye, A., Rathfelder, K., Wei, M., and Yin, J., 2016. Hydrostratigraphic, hydraulic and hydrogeochemical descriptions of Dawson Creek-Grounjbirch areas, Northeast BC. Victoria, Prov of B.C. Water Science Series 2016-04.

Geographic datasets from the BC Data Catalogue, accessed November 2022 <https://data.gov.bc.ca/>.

Goetz, A. M., 2021. Regional groundwater conditions in northeast BC: Results from a monitoring well network in an area of historical and ongoing unconventional natural gas development. M.Sc. Thesis, University of British Columbia, Vancouver, B.C.

Massey, N.W.D., MacIntyre, D.G., Desjardins, P.J. & Cooney, R.T. 2005. Geology of British Columbia. Ministry of Energy and Mines, BC Geological Survey, Geoscience Map 2005-3.

Reimchen, T.H.F, 1980. Surficial Geology Dawson Creek; Geological Survey of Canada, Map 1467A, 1:250000 scale map.

A.5 REVISION HISTORY

Date	Version	Revision Class	Comments	Author
02/10/2023	1	Major	Initial mapping of aquifer	Tibor Lengyel, M.Sc., P.Geo., Judit Deri-Takacs, Ph.D., Andrew Hinnell, Ph.D., P.Geo.

APPENDIX B: AQUIFER SUMMARY

Table 1 Summary of Aquifer Properties

#	Name	Lithostratigraphic Unit	Descriptive Location	Vulnerability*	Subtype*	Material*	Quality Concerns*	Productivity*	Artesian Conditions Noted	Obs. Wells	Changes to the Aquifer
0589	East Pine Bedrock Aquifer	Dunvegan and Kaskapau formations	Bedrock area east of the confluence of the Pine River and the Murray River.	Moderate	5a	Bedrock	Isolated	Moderate	No	No	Revised extent
0590	Groundbirch Buried Valley	Late Wisconsinan glaciodeltaic sand and gravel	Groundbirch, BC (Peace River District)	Moderate (High)	4b	Sand and Gravel	Isolated	Moderate	No	Yes OW 445 OW 110 (inactive)	Revised extent
0591	East Pine - Groundbirch Bedrock Aquifer	Kaskapau Formation	Eat of Pine River, Groundbirch	Moderate	5a	Bedrock	Isolated	Moderate	Yes	Yes OW 421 (inactive)	Revised extent
0592	Sunset Creek Overburden Aquifer	Late Wisconsinan glaciodeltaic sand and gravel	Groundbirch and Willow Valley, BC	Moderate	4b	Sand and Gravel	Isolated	Moderate	Yes	No	Revised extent
0593	Valley View - Dawson Creek Bedrock Aquifer	Kaskapau Formation	Between the Kiskatinaw and Pouce Coupé rivers, Dawson Creek, Arras, BC	Moderate (High)	5a	Bedrock	Isolated	Low/Moderate	Yes	Yes OW 420 OW-419 (inactive)	Revised extent
0594	Kiskatinaw Buried Channel	Middle Wisconsinan fluvial sand and gravel	South of Peace River, Lower Kiskatinaw River Valley, Sunset Prairie, Arras, BC	Low	4b	Sand and Gravel	Isolated	High	No	Yes OW-113 (inactive)	Revised extent
0595	Sunset Prairie Bedrock Aquifer	Dunvegan and Kaskapau formations	Along the Kiskatinaw River on its western and northern side, between the community of Progress and the confluence of the Kiskatinaw River and the Peace River.	Moderate	5a	Bedrock	Isolated	Moderate	Yes	Yes OW 416 OW 417 OW 111 (inactive) OW 112 (inactive)	Revised extent
0596	Kiskatinaw Glaciodeltaic Overburden Aquifer	Late Wisconsinan glaciodeltaic sand and gravel	South of Peace River, Lower Kiskatinaw River Valley, Sunset Prairie, Arras, BC	Low	4b	Sand and Gravel	Isolated	Moderate	No	Yes OW 113 (inactive)	Revised extent
0598	Pouce Coupe Overburden Aquifer	Alluvial sand and gravel	Alluvial sediments along Pouce Coupé River	High	1a	Sand and gravel	None	High	No	No	Revised extent
0633	Sweetwater Bedrock Aquifer	Dunvegan and Kaskapau formations	South and East of Kiskatinaw River, Sunrise Valley, Sweetwater, BC	Moderate	5a	Bedrock	Isolated	Moderate	Yes	Yes OW 418	Revised extent

#	Name	Lithostratigraphic Unit	Descriptive Location	Vulnerability*	Subtype*	Material*	Quality Concerns*	Productivity*	Artesian Conditions Noted	Obs. Wells	Changes to the Aquifer
0851	Dawson Creek Overburden Aquifer ⁴	Intra-till/Glaciolacustrine sands ⁴	Between the Kiskatinaw and the Pouce Coupé rivers, BC	Moderate	4b	Sand ⁴	Isolated	Moderate ⁴	Yes	No	Updated description – no change to extent
0903	Pouce Coupe Overburden Aquifer	Glaciolacustrine sand and gravel	East of Pouce Coupé River	Moderate	4b	Sand and Gravel	Isolated	Low	No	No	Updated description – no change to extent
1275	Arras-Fellers Heights Bedrock Aquifer	Kaskapau Formation	South of Groundbirch and Progress, BC	Low	5a	Bedrock	None	Low	No	No	Newly introduced

Notes:

Parameters defined according to Berardinucci and Ronneseth, 2002

1 Aquifer subtype description available through the BC Data Catalogue <https://catalogue.data.gov.bc.ca>.

2 Based on available information. A more detailed review of water quality data would be required to understand water quality concerns.

3 Aquifers 0622, and 0917 were not revised, thus they are not included in Appendix B.

⁴ Aquifer 0851 consists of primarily low conductivity glaciolacustrine clays and/or glacial tills with localized discontinuous coarse-grained sediments (fine- to medium-grained sand). Material description refers to the coarse-grained sediment lenses.

APPENDIX C: AQUIFER SHAPEFILES

Digital files attached

APPENDIX D: AQUIFER-WELL CORRELATIONS

Digital files attached

APPENDIX E: WELL STRATIGRAPHY

Digital files attached