Stage 1 Foundational Mapping

Hope, Moresby Island, Sunshine Coast, and Ucluelet, B.C.

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1. INTRODUCTION

WorleyParsons Canada Services Inc. (operating as Advisian) was retained by the Ministry of Environment and Climate Change Strategy (ENV) to conduct Stage I Aquifer Mapping in the following geographic areas (British Columbia Geographic System 1:20,000 mapsheet numbers are provided in brackets):

- Hope (92H033, 92H034, 92H043);
- Moresby Island (103G011, 103G012, 103G021, 103G022);
- Sunshine Coast (92G033, 92G041, 92G042, 92G043, 92G051, 92G052); and
- Ucluelet (92C092, 92C093, 92F002, 92F003).

Aquifer mapping in Hope, Moresby Island, and Ucluelet areas was undertaken to address recommendations from Hammond and Hinnell (April 2018). Key data sources used include Terrain Resource Information Management (TRIM) base data, Freshwater Atlas (mapped watersheds, freshwater resources), geologic mapping (bedrock, surficial materials, faults, geothermal), and the WELLS database. The Ecological Reports Catalogue (EcoCat) database and government websites were also searched to obtain additional information on water use and management.

Lithology information from the WELLS database was standardized into key lithologic units (gravel, sand and gravel, sand, silt, clay, sandstone, limestone, granite, etc.) and spatially reviewed using ArcGIS® and ArcScene® to inform aquifer mapping. Geologic cross-sections have been prepared to facilitate mapping of AQ560. The quality of information and the status of wells have not been field verified. Some well records have limited information or conflicting data. In the absence of well completion information, the well screen was assumed to be located in the lowest permeable unit based on well lithology data.

Aquifers were delineated based on available information with a focus on using physical and hydraulic boundaries where possible (e.g. groundwater divides or streamlines, geologic contacts and surface water bodies). Mapped aquifers may extend beyond or include areas where wells do not currently exist; therefore, there is some uncertainty in aquifer boundaries, particularly for confined unconsolidated aquifers and bedrock aquifers. Regional groundwater management efforts were also considered when defining aquifer extents.

The assessment of aquifer vulnerability to surface contamination was based on thickness and extent of materials with low permeability above the aquifer, depth to water table (or top of confined aquifer), and type of aquifer material (Berardinucci and Ronneseth 2002).

2. AQUIFER DESCRIPTIONS

A total of 15 aquifers were mapped, including eight bedrock and seven unconsolidated aquifers. For the Hope area, three bedrock aquifers were updated (AQ1008, 1009, 1188) and one new unconsolidated aquifer was mapped (AQ1189). Two new coastal aquifers were mapped on Moresby Island. A total of seven aquifers were updated and one new aquifer was mapped along the Sunshine Coast. Mapping of the Lost Shoe Aquifer (AQ0159), near Ucluelet, was also updated. An overview of the mapped aquifers is provided in Table 1. Aquifer mapping reports are provided in Appendix A.

Table 1 Aquifer Summary Table

Aquifer No.	Name	Area	Litho - Stratigraphic Unit	Vulnerability(1)	Subtype(2)	Primary Materials	Quality Concerns(3)	Quantity Concerns(4)	Artesian Conditions	Obs Well ID	Comment
1008	Haig	Hope	Hozameen Complex	B	5a	Sedimentary	Geothermal potential zone	Unknown			Updated
1009	Kawkawa Lake	Hope		B	6b	Crystalline Bedrock	Geothermal potential zone	Unknown			Updated
1188	Fraser Canyon	Hope	Custer Gneiss Formation	B	6b	Crystalline Bedrock	Geothermal potential zone	Unknown			Updated
1221	North Hope	Hope		A	2	Sand and Gravel	Unknown	Unknown			New
1222	Haans Creek to Blain Creek	Moresby Island		B	5a	Sedimentary	Unknown	Unknown			New
1223	Sandspit	Moresby Island		A	3	Sand	Unknown	Unknown		339 (inactive)	New
552	Langdale/ Hopkins Landing	Sunshine Coast	Quadra Sand or older Pre-Vashon	B	4b	Sand and Gravel	Unknown	Yes			Updated
555	Roberts Creek	Sunshine Coast		B	6b	Crystalline Bedrock	Some	Yes	Yes		Updated
560	Gibson/SCRD Grahams Landing/ Elphinstone	Sunshine Coast	Quadra Sand	B	4a/b	Sand and Gravel	None	Yes	Yes	460 (active)	Updated, includes former AQ0553 and AQ0554.
562	West Sechelt	Sunshine Coast		B	6b	Crystalline Bedrock	Some	Yes	Yes		Updated, includes former AQ0972

Aquifer No.	Name	Area	Litho - Stratigraphic Unit	Vulnerability[1]	Subtype[2]	Primary Materials	Quality Concerns[3]	Quantity Concerns[4]	Artesian Conditions	Obs Well ID	Comment
563	Sechelt, Wakefield Creek	Sunshine Coast		B	4b	Sand and Gravel	Unknown	Yes	Yes		Updated
564	East Porpoise Bay	Sunshine Coast		B	6b	Crystalline Bedrock	Some	Yes			Updated
566	East Sechelt	Sunshine Coast		A	4a/3	Sand and Gravel	Unknown	Yes			Updated, includes former AQ0556
1220	Eastern slope of Mount Elphinstone	Sunshine Coast		B	6b	Crystalline Bedrock	Some	Yes			New
0159	Lost Shoe	Ucluelet		A	4a	Sand and Gravel	Unknown	Yes		329 (active)	Updated

Notes:

1) A – high vulnerability, B – moderate vulnerability, C – low vulnerability to surface contamination.
2) Aquifer subtype description available through the BC Data Catalogue https://catalogue.data.gov.bc.ca
3) Based on available information. A more detailed review of water quality data would be required to understand water quality concerns.
4) Water budget studies are required to better understand water availability.

3. CONCLUSIONS AND RECOMMENDATIONS

A total of 15 aquifers have been mapped in the Hope, Moresby Island, Sunshine Coast, and Ucluelet areas and include eight bedrock aquifers and seven unconsolidated aquifers. The vulnerability of these aquifers has been assessed as either high (four aquifers) or moderate (eleven aquifers). Of the identified aquifers, two aquifers contain active provincial monitoring wells.

Recommendations to advance foundational aquifer mapping efforts based on the information provided in this report include the following:

- Available surficial geology mapping for the areas near Hope/Ucluelet (Fulton et al. 1982), Moresby Island (Brown 1968), and Sunshine Coast (McCammon 1977) could be updated and/or completed at a smaller scale to support aquifer mapping efforts.

- Aquifers mapped within areas of geothermal potential have been identified as having potential water quality concerns (e.g. Hope). Verification of these assumptions through further studies would better characterize potential water quality concerns for these aquifers.

- AQ0560 (Gibson/ Grahams Landing/ Elphinstone) has the potential for increased groundwater use in the future. Additional studies could be completed to better understand aquifer characteristics and connection with surface water features. This could include but is not limited to mapping of springs, surface geophysics (identify bedrock surface, investigate lateral continuity of lithologic units between well locations), drilling programs (e.g. sonic drill rig), and a field review of Pre-Vashon exposures.

- Periodic review of mapped aquifer boundaries as additional information becomes available is recommended to address uncertainty, particularly for aquifers that have been mapped based on limited information.

APPENDIX A AQUIFER WORKSHEETS

A1. Moresby Island

A2. Ucluelet

A3. Sunshine Coast

A4. Hope

A1. MORESBY ISLAND

1. AQUIFER MAPPING REPORT: AQUIFER 1222

Aquifer Name: Haans Creek to Blain Creek

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is in the Queen Charlotte Lowlands, on the northeast corner of Moresby Island within the Haida Gwaii archipelago. The aquifer is bound by the coastline along Hectate Strait. The aquifer extends inland and includes the lower watershed areas of Haans Creek and Blaine Creek (Freshwater Atlas). The northwestern and southeastern extents coincide with topographic divides (TRIM 1:20,000).

1.1.2 Geologic Formation (Overlying Materials)

Above an elevation of about 20 m, Quaternary deposits have not been mapped (Cui et al. 2017). At lower elevation, the overlying materials include primarily sand and gravel material with clay, till, or silt material reported in some lithological records.

1.1.3 Geologic Formation (Aquifer) – Sub-type 5a

Bedrock mapping indicates sedimentary (marine, conglomerate, coarse clastic) and volcanic rocks (Cui et al. 2017). A pluton of post-tectonic, undivided intrusive rocks has also been mapped within the aquifer extents (Southerland 1968). A northwest-southeast trending fault has been mapped within the aquifer extents (Cui et al. 2017).

1.1.4 Vulnerability - Moderate

Unconsolidated deposits exist at lower elevations and may include confining materials; however, most of the aquifer is assumed to have limited overlying materials. Water-bearing fracture zones are greater than 20 m deep. The permeability of the aquifer is assumed to be low but relatively quick movement of groundwater can occur along fractures. Based on this description, the vulnerability of the aquifer to surface contamination is moderate.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table is typically shallow (<15 m) based on limited water level data. Based on topography, groundwater is inferred to flow in a north-easterly direction towards the coastline through bedrock deformities like fractures and intergranular pore spaces (where sedimentary rocks are present). This interpretation assumes near-surface flow within the bedrock from areas of high to low elevation and ignores geologic complexities.

1.3 Recharge

Recharge primarily occurs where precipitation infiltrates into bedrock deformities (e.g. fractures). Precipitation that infiltrates through bedrock deformities in the surrounding mountainous areas may also contribute to recharge. Localized recharge from unconsolidated deposits or surface water features (e.g. wetlands) may occur at lower elevations.

1.3.1 Potential for Hydraulic Connection

The aquifer could potentially be hydraulically connected to unconsolidated aquifer AQ1223. The aquifer is likely hydraulically connected with the sea.

1.4 Additional Information on Water Use and Management

Drilling was advanced to bedrock at one location near the coastline (WTN 49395). The status of this well is unknown but appears to be abandoned because it encountered salty groundwater.

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

Geographic datasets from the BC Data Catalogue, accessed December 2018 https://data.gov.bc.ca/

Hammond, Z.M. and Hinnell, A.C., March 2019. Stage 1 Foundational Mapping: Hope, Moresby Island, Sunshine Coast, and Ucluelet. Prepared for the Ministry of Environment and Climate Change Strategy. Available through EcoCat (https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/ecocat).

Southerland, B. 1968. Geology of the Queen Charlotte Islands. British Columbia Department of Mines and Petroleum Resources, Bulletin No. 54, map, scale 1:125,000

1. AQUIFER MAPPING REPORT: AQUIFER 1223

Aquifer Name: Sandspit

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is in the Queen Charlotte Lowlands, on the northeast corner of Moresby Island within the Haida Gwaii archipelago. Most of the aquifer is bound by the coastline along Hecate Strait. The aquifer extends inland generally following the 20 metre elevation contour (TRIM 1:20,000) and coincides with the limits of mapped Quaternary deposits (Cui et. al. 2017). The western and southeastern extents coincide with mapped watershed boundaries (Freshwater Resource Atlas) with consideration of available well records. Limited well records were available to confirm the southeastern extent.

1.1.2 Geologic Formation (Overlying Materials)

Well lithology indicates primarily sand and gravel material. A few wells installed at deeper depths have overlying clay, till, or silt material.

1.1.3 Geologic Formation (Aquifer) – Sub-type 3

Based on available well lithology records, the aquifer is predominantly sand. The sand deposit is inferred to be a deposition bar or beach geomorphological landform.

1.1.4 Vulnerability - High

The overlying materials are typically permeable and provide limited protection from potential surface contamination. Many of the wells are dug (rather than drilled) and are generally less than 8 m deep. The depth to the water table is shallow (less than 6 m). Based on this description, the vulnerability of the aquifer to surface contamination is high.

The coastal aquifer is also vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table is shallow (<15 m) based on available well lithology records. Water level data from 1996 to 2000 is available for inactive Observation Well 339. Water levels are typically the lowest in winter and highest at the end of summer, fluctuating by approximately 1.5 m.

Groundwater is inferred to generally follow topography and flow in a northeast direction towards the coastline.

1.3 Recharge

Recharge is likely to occur where precipitation infiltrates into the subsurface as well as by mountain block recharge along the contact between bedrock and Quaternary deposits. There are several creeks and wetland features that may also contribute to recharge.

1.3.1 Potential for Hydraulic Connection

The aquifer is likely connected to bedrock aquifer AQ1222.

1.4 Additional Information on Water Use and Management

The aquifer has a high productivity based on well yields greater than 3.0 litres per second. Well records indicate a film on the water surface (WTN 38940 and 38930) but generally no taste or smell issues.

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

Geographic datasets from the BC Data Catalogue, accessed December 2018 https://data.gov.bc.ca/

Hammond, Z.M. and Hinnell, A.C, March 2019. Stage 1 Foundational Mapping: Hope, Moresby Island, Sunshine Coast, and Ucluelet. Prepared for the Ministry of Environment and Climate Change Strategy. Available through EcoCat (https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/ecocat).

Southerland, B. 1968. Geology of the Queen Charlotte Islands. British Columbia Department of Mines and Petroleum Resources, Bulletin No. 54, map, scale 1:125,000

A2. UCLUELET

1. AQUIFER MAPPING REPORT: AQUIFER 0159

Aquifer Name: Ucluelet, Lost Shoe

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The western extents of the aquifer are bound by the coastline along Florencia Bay. The remainder of the aquifer extents coincide with watershed mapping (Freshwater Atlas). The southeastern extent generally coincides with surficial geology boundaries between glaciofluvial deposits and till.

1.1.2 Geologic Formation (Overlying Materials)

Sand and gravel terraces and deltas were formed during the ice retreat drainage regime (Fulton et al. 1982). Well lithology records indicate stratified layers of gravel, sand, and silt. Overlying materials (unsaturated zone) are interpreted to be less than 5 m thick based on median water level depths.

1.1.3 Geologic Formation (Aquifer) – Sub-type 4a

The aquifer material is associated with glaciofluvial deposits (Fulton et al. 1982) and includes unconfined sand and gravel based on well lithology records. A clay/till unit noted in some well lithology records below the aquifer may confine the vertical extents. The aquifer is generally less than 20 m thick. Aquifer thickness may be under estimated since lithological records do not consistently intersect the bottom of the aquifer.

1.1.4 Vulnerability - High

The aquifer is unconfined and inferred to be less than 20 m thick. Overlying materials are permeable and provide limited protection from potential surface contamination. The depth to the water table is shallow (less than 10 m). Based on the above, the vulnerability of the aquifer to surface contamination is high.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from 0.6 to 9.1 m with a median of 5.4 m. Historical water level data from 1995 is available for active Observation Well 329. Water levels are typically the lowest in September and the highest in April, fluctuating by approximately 4 m.

Groundwater is inferred to flow in a westerly direction from areas of higher elevation towards the coastline.

1.3 Recharge

Recharge is likely to occur where precipitation infiltrates into the subsurface as well as by mountain block recharge along the contact between bedrock and Quaternary deposits. There are several creeks, lakes, and wetland features that may also contribute to recharge.

1.3.1 Potential for Hydraulic Connection

Hydraulic connection to unconsolidated aquifer AQ1179 is possible given the uncertainty in subsurface conditions. There are several lakes, wetlands, and creeks that could be hydraulically connected. In particular, surface water-groundwater interactions with Lost Shoe Creek may exist.

1.4 Additional Information on Water Use and Management

The aquifer is highly productive based on well records that indicate well yields typically greater than 3.0 litres per second. Groundwater is of sodium-chloride-bicarbonate type and is generally soft, low in mineralization, and slightly acidic (Hodge 1995b).

The Lost Shoe Creek Well Field, owned and operated by the District of Ucluelet, was developed in the 1990s as a water supply source for local residents and industry (fish processing plants). The well field has a total capacity of 120 litres per second. Recommendations on aquifer protection and management measures related to the well field have been developed (Badry 1994a).

Slides in the Mercantile Creek watershed resulted in discontinued use of Mercantile Creek as a water supply source by the District of Ucluelet in 2005. The District of Ucluelet now relies solely on groundwater from the Lost Shoe Creek Well Field. There are concerns about the sustainability of the aquifer in meeting local demands, particularly at the end of the dry season (Badry 1994a).

1.5 Additional Assessments or Management Actions:

Aquifer capacity evaluations have been completed using the water balance and numerical model methods as cited in Hodge (1995b). The original report by Badry (1994b) is not publicly available.

1.6 Aquifer References

Badry, A. 1994a. Completion Report Evaluation of Groundwater Potential of Lost Shoe Creek and Albion Aquifers to Supply the Village of Ucluelet. Pacific Hydrology Consultants Ltd. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=16378

Badry, A. 1994b. Groundwater Recharge Conditions at Lost Shoe Creek Aquifer at Ucluelet. Pacific Hydrology Consultants Ltd. Unpublished letter – report to Ministry of Municipal Affairs.

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

EBA Engineering Consultants Ltd. 2002. Assessment of Wellhead Protection Area, Lost Shoe Creek Aquifer, District of Ucluelet, BC.

Fulton R.J., Clague J.J., and Ryder J.M., 1982. Surficial Geology, Vancouver Island and adjacent Mainland, British Columbia, map, scale 1:1,000,000. Geological Survey of Canada, Open File 837.

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Hodge W.S. 1995a. Memo: Establishment of Observation Well No. 329 – Ucluelet http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=5206

Hodge W.S. 1995b. Memo: Village of Ucluelet – Lost Shoe Creek Aquifer http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=5207

A3. SUNSHINE COAST

1. AQUIFER MAPPING REPORT: AQUIFER 0552

Aquifer Name: Langdale/Hopkins Landing

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The eastern aquifer boundary primarily follows the coastline. The rest of the aquifer extents were defined based on surficial geology mapping and bedrock outcrops (McCammon 1977) with consideration of well extents. An aquifer system (e.g. multiple aquifer units) potentially exist within the mapped aquifer extents.

1.1.2 Geologic Formation (Overlying Materials)

A variety of overlying materials are inferred to exist primarily based on surficial geology mapping within the aquifer extents (McCammon 1977). Surficial Capilano Sediments of marine and glaciomarine origin, generally overlying till, have been mapped over the majority of the aquifer extents. However, Capilano Sediments do not exist along the banks of Langdale Creek based on mapping of Pre-Vashon exposures (McCammon 1977). The presence of Capilano Sediments may also be variable where Salish Sediments consisting of shore, deltaic, fluvial and swamp deposits along the lower reaches of Langdale Creek and Hutchinson Creek have been mapped.

1.1.3 Geologic Formation (Aquifer) – Sub-type 4b Confined Glaciofluvial

The primary aquifer material consists of sands and gravels inferred to be glaciofluvial Quadra Sands or potentially older Pre-Vashon deposits. There is potential for shallower groundwater to occur in deltaic Salish Sediments along the lower reaches of Langdale Creek and Hutchinson Creek. These have not been mapped as separate aquifer units due to limited information.

1.1.4 Vulnerability - Moderate

The aquifer is inferred to be primarily confined based on overlying clay, till, and silt material typically 10 m thick based on well record lithology; however, the spatial distribution of the lithology data is limited. Confining materials are likely limited or absent close to Langdale Creek and potentially limited or absent within the deltaic landforms along the coastline (e.g. where Langdale and Hutchinson Creeks discharge to the ocean). Based on this description, the overall vulnerability of the aquifer to surface contamination is moderate.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from shallow (<15 m) to deep (>60 m) and is typically moderately shallow (15 to 30 m) based on the median value of recorded depth to water. Undulating bedrock topography that is masked by the overlying unconsolidated material likely controls groundwater flow.

The overall groundwater flow is inferred from area of higher elevation towards the coastline (Shoal Channel and Thornbrough Channel).

1.3 Recharge

Recharge from the infiltration of precipitation through the confining material is inferred to be limited. Mountain block recharge along the bedrock contact with Quaternary deposits likely contributes to groundwater within the aquifer.

1.3.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with bedrock aquifer AQ1220. Erosion along the drainage feature of Langdale Creek that has exposed Pre-Vashon sediments could promote localized hydraulic connection with the aquifer and Langdale Creek. Additional studies are required to confirm or determine surface water/groundwater interactions with drainage features in the area. There is also potential for hydraulic connection with seawater.

1.4 Additional Information on Water Use and Management

The need to supplement surface water with groundwater as a reliable, long-term drinking water source is increasing groundwater demand in the area (SCRD, 2018). Groundwater protection planning was initiated by the Sunshine Coast Regional District in 1996 (Dayton & Knight Ltd., 1996). This was driven by the need to protect water supply sources, reduce surface water pollution, preserve land stability, and preserve land productivity.

Springs have been identified in the area and have historically been used as a water supply source (Foweraker 1964).

Dry well conditions or extremely low groundwater levels during the summer months have been noted in well records.

A study conducted in 1994 identified high arsenic concentrations in groundwater within the Sunshine Coast region (Carmichael and Clarkson 1994). In general, arsenic concentrations are variable both spatially and temporally with no significant correlation between arsenic levels and well depth. Mineralized deposits in fractures that are present in the bedrock are believed to be the source of arsenic (Mattu and Schreier 2000). Arsenic dissolves and becomes mobilized as groundwater flows through the fracture network. Dissolved arsenic was not detected in wells completed in unconsolidated material.

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

Carmichael V. and Clarkson L., 1994. Well Water Survey for Arsenic in the Powell River and Sunshine Coast Communities of British Columbia – March to June 1994. Prepared by the B.C. Ministry of Health. https://www.healthspace.ca/Clients/VCHA/CoastGaribaldi/CoastGaribaldi_Website.nsf

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

Dayton & Knight Ltd. 1996. Aquifer Protection Plan. Prepared for the Sunshine Coast Regional District. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=17038

Fairbanks, B.D., and Faulkner, R.L., 1992. Geothermal Resources of British Columbia. Geological Survey of Canada, Open File 2526, map, scale 1:2,000,000.

Foweraker, J.C. 1964. Groundwater Possibilities – Hopkins Landing Water Users Community. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=5984

Fulton R.J., Clague J.J., and Ryder J.M., 1982. Surficial Geology, Vancouver Island and adjacent Mainland, British Columbia, map, scale 1:1,000,000. Geological Survey of Canada, Open File 837.

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McCammon 1977. Surficial Geology and Sand and Gravel Deposits of Sunshine Coast, Powell River, and Campbell River Areas. Bulletin 65 Ministry of Energy, Mines, and Petroleum Resources. http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/BulletinInformation/BulletinsAfter1940/Pages/Bulletin65.aspx

Russell J.R.L. 1987. Crowston Lake Assessment. Reconnaissance report prepared for Fisheries Assessment and Improvement. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=5754

Sunshine Coast Regional District (SCRD) 2018. Regional Groundwater Task Force Consultation Report. Prepared for the Planning and Community Development Committee. http://www.scrd.ca/files/File/Infrastructure/Water/2018-MAR-08_Regional_Groundwater_Task_Force_Consultation_Report.pdf

1. AQUIFER MAPPING REPORT: AQUIFER 0555

Aquifer Name: Roberts Creek

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located along the Sunshine Coast on the western and southern slopes of Mount Elphinstone. Topographic divides were used to define the western and eastern boundaries (TRIM 1:20,000). The eastern extent also coincides with a geologic boundary between igneous and sedimentary rock types. The northern boundary is constrained by an elevation of 180 m generally based on where slopes become more steeply sloping. The southern boundary follows the coastline with the Strait of Georgia.

1.1.2 Geologic Formation (Overlying Materials)

Bedrock is overlain by varying thicknesses of glacial, glaciomarine, marine, and fluvial deposits (McCammon 1977). The thickest unconsolidated deposits exist to the east and west of Cliff Gilker Park/Roberts Creek (typically 20 m thick, up to 75 m thick) and within the Town of Gibsons (up to 200 m thick), suggesting localized bedrock depressions exist that are masked by the overlying deposits. Bedrock outcrops in the area are predominantly mapped along the coastline (east and west of the lower reach of Roberts Creek), in the areas of Cliff Gilker Park, southwest of Randall Lake, and the southeastern tip of the Town of Gibsons (McCammon 1977).

1.1.3 Geologic Formation (Aquifer) – Sub-type 6b Fractured Crystalline Rock

The bedrock consists of granodioritic and dioritic intrusive rocks (Cui et al. 2017). Well lithologies indicate predominantly granite described as white, pink, green, black, and grey bedrock. No faults have been mapped within the aquifer extents (Cui et al. 2017).

1.1.4 Vulnerability - Moderate

Confining materials include till and clay generally 5 m thick but are inferred to be laterally discontinuous. Multiple confining layers with more extensive coverage exists in the Town of Gibsons. Most water-bearing fracture zones are located at considerable depth (median well depth of 60 m). The permeability of the aquifer is assumed to be low but relatively quick movement of groundwater can occur along fractures. Based on this description, the vulnerability of the aquifer to surface contamination is moderate.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from flowing artesian to deep (>60 m) and is typically shallow (<15 m) based on the median value of existing water depths . Flowing artesian conditions have been noted for several wells (e.g. WTN 74692, 70651, 70651, 70654, 112346). Groundwater is inferred to flow predominantly to the west, towards the Strait of Georgia, through bedrock deformities like fractures. This assumes near-surface flow within the bedrock from areas of high to low elevation and ignores geologic complexities.

1.3 Recharge

Recharge likely occurs where precipitation infiltrates directly into bedrock deformities or from the overlying unconsolidated deposits. Precipitation that infiltrates through bedrock deformities in the surrounding mountainous areas and mountain block recharge along the bedrock contact with Quaternary deposits may also contribute to recharge.

1.3.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with unconsolidated aquifer AQ0566 in the Town of Gibsons area, bedrock aquifer AQ0564 to the west, and bedrock aquifer AQ1220to the east. Additional studies are required to confirm/determine surface water-groundwater interactions with drainage features in the area, particularly with Roberts Creek. The aquifer is likely hydraulic connected with the coastal waters of the Straight of Georgia.

1.4 Additional Information on Water Use and Management

The need to supplement surface water with groundwater as a reliable, long-term drinking water source is increasing groundwater demand in the area (SCRD, 2018). Groundwater protection planning was initiated by the Sunshine Coast Regional District in 1996 (Dayton & Knight Ltd., 1996). This was driven by the need to protect water supply sources, reduce surface water pollution, preserve land stability, and preserve land productivity.

A study conducted in 1994 identified high arsenic concentrations in groundwater within the Sunshine Coast region (Carmichael and Clarkson 1994). In general, arsenic concentrations are variable both spatially and temporally with no significant correlation between arsenic levels and well depth. Mineralized deposits in fractures that are present in the bedrock are believed to be the source of arsenic (Mattu and Schreier 2000). Arsenic dissolves and becomes mobilized as groundwater flows through the fractured network. Dissolved arsenic was not detected in wells completed in unconsolidated material.

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

Carmichael V. and Clarkson L., 1994. Well Water Survey for Arsenic in the Powell River and Sunshine Coast Communities of British Columbia – March to June 1994. Prepared by the B.C. Ministry of Health. https://www.healthspace.ca/Clients/VCHA/CoastGaribaldi/CoastGaribaldi_Website.nsf

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

Dayton & Knight Ltd. 1996. Aquifer Protection Plan. Prepared for the Sunshine Coast Regional District. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=17038

Fairbanks, B.D., and Faulkner, R.L., 1992. Geothermal Resources of British Columbia. Geological Survey of Canada, Open File 2526, map, scale 1:2,000,000.

Fulton R.J., Clague J.J., and Ryder J.M., 1982. Surficial Geology, Vancouver Island and adjacent Mainland, British Columbia, map, scale 1:1,000,000. Geological Survey of Canada, Open File 837.

Geographic datasets from the BC Data Catalogue, accessed February 2017 https://data.gov.bc.ca/

Hammond, Z.M. and Hinnell, A.C., March 2019. Stage 1 Foundational Mapping: Hope, Moresby Island, Sunshine Coast, and Ucluelet. Prepared for the Ministry of Environment and Climate Change Strategy. Available through EcoCat (https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/ecocat).

Mattu G. and Schreier H., 2000. An Investigation of High Arsenic Levels in Wells in the Sunshine Coast and Powell River Regions of B.C. Prepared for the Coast Garibaldi Community Health Services Society. https://www.healthspace.ca/Clients/VCHA/CoastGaribaldi/CoastGaribaldi_Website.nsf

McCammon 1977. Surficial Geology and Sand and Gravel Deposits of Sunshine Coast, Powell River, and Campbell River Areas. Bulletin 65 Ministry of Energy, Mines, and Petroleum Resources. http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/BulletinInformation/BulletinsAfter1940/Pages/Bulletin65.aspx

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1. AQUIFER MAPPING REPORT: AQUIFER 0560

Aquifer Name: Gibson/SCRD Grahams Landing/Elphinstone

Date of Mapping: March 2019

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located within the Georgia Lowland (Holland 1976). Bedrock within the aquifer footprint is interpreted to have an undulating surface masked by unconsolidated sediments but constrained laterally by local bedrock highs that have been used to define the western and eastern extents of the aquifer based McCammon (1977) and well lithology. The northern limit is based on the extent of surficial geology mapping (McCammon 1977) and roughly coincides with the maximum elevation where wells have been drilled. The southern and eastern boundaries of the aquifer follow the coastline of the Strait of Georgia.

Former AQ553 and AQ554 are included in the aquifer extents.

1.1.2 Geologic Formation (Overlying Materials)

Based on existing lithology and publicly available information, the Quaternary geology is complex. Four geologic cross-sections (A-A', B-B', C-C', and D-D') and a map showing their locations are attached to better understand subsurface conditions based on available information (Figures 1 to 5).

Generally, clay and pockets of fluvial sand and gravel of variable thickness inferred as Capilano Sediments occur below an elevation of 180 metres (McCammon 1977). Silty, blue-grey, thin-bedded clay at least 10 metres thick was observed in north and west Gibson (McCammon 1977). Glaciofluvial sands and gravels as well as till interpreted to be Vashon Drift units typically underlie Capilano Sediments. The Vashon till appears to be thicker to the north (A-A', D-D') and continuous along the western and eastern portions of the aquifer (A-A', B-B', C-C'). However, Vashon till is inferred to be absent based on thick sand and gravel deposits from wells lithologies along the central portion of the aquifer (D-D', B-B') between two local bedrock highs. Others have interpreted the Vashon till to be continuous in this area (Waterline 2013). Limitations with available lithology and the complex glacial setting contributes to the possibility of multiple interpretations. Actual presence or absence of confining material would need to be confirmed through intrusive investigation.

Exposures of Pre-Vashon sediments (McCammon 1977) and more recent Salish deposits are inferred at lower elevations (B-B', D-D'). These deposits vary from sand and gravel to till in the well records.

1.1.3 Geologic Formation (Aquifer) – Sub-type 4a Unconfined/4b Confined Glaciofluvial

The aquifer material consists primarily of sand and gravel inferred to be Quadra Sands. Organic/silt layers identified in well records have been used to infer underlying Pre-Olympia sediments (B-B', C-C') but additional studies are required to confirm interpretations. The Quadra Sands are interpreted to be relatively thick (approx. 40 m).

There are a large number of dug wells inferred to be completed in shallow, permeable deposits (D-D') inferred as Capilano Sediments. These wells have minimal information and are typically reported as dry or have limited seasonal use (e.g. dry in the summer). This suggests perched groundwater conditions may occur seasonally. The absence of the glaciomarine Capilano Sediments and Vashon till would allow vertical movement of groundwater and potentially explains why overlying permeable units have no/limited groundwater. Groundwater from these perched units likely contributes to the occurrence of springs in the area. This unit has not been explicitly mapped given its' limited potential for water use but should be considered as part of groundwater management efforts for the area.

Overall semi-confining conditions are inferred given the presence of springs and artesian well conditions.

1.1.4 Vulnerability - Moderate

Clay and till generally overlie the aquifer based on well records but potential windows exist, particularly where Pre-Vashon exposures have been mapped and where Vashon till is inferred to be absent (Figure 1, A-A', D-D'). Areas where Pre-Vashon deposits are exposed have a higher vulnerability to surface contamination assuming overlying low permeability material does not exist in these areas. Capilano Sediments are typically present where Vashon till is inferred to be absent. This provides protection from surface contamination; however, the absence of till would allow the downward movement of water. The depth to water varies from artesian to very deep (>60 m). Wells that have been dug have shallow water table depths (<15 m). The aquifer material is expected to have a high permeability. Based on this description, the aquifer is classified as having a moderate vulnerability to surface contamination.

The coastal setting of the aquifer makes it susceptible to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

Groundwater levels range from artesian to very deep (>60m). Artesian conditions are reported at several wells typically located along the toe of slope. Water level data is available for active Observation Well 460.

Bedrock topography that is masked by the overlying unconsolidated material likely controls groundwater flow from areas of high elevation to low elevation towards the coastline. Groundwater from perched units may discharge as groundwater seeps, infiltrate into the Quadra Sand unit, or flow towards local creeks (e.g. Chaster Creek as shown in B-B', C-C').

1.3 Recharge

Recharge from the infiltration of precipitation through confining material is inferred to be limited but could occur where confining materials are thin or absent (A-A', D-D'). This includes infiltration into the fluvial Vashon Drift that travels to the Quadra Sand where erosion of the Vashon till is inferred. Mountain block recharge along the bedrock contact with Quaternary deposits likely contributes to groundwater within the aquifer.

1.3.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with the underlying bedrock aquifer. Pre-Vashon sediments exposed along Chaster and Charman Creeks could promote hydraulic connection between the creeks and aquifer (See Figure 1, McCammon 1977). Deposits inferred as glaciofluvial Vashon Drift have the potential to be hydraulically connected to Chaster Creek (B-B', C-C'). Hydraulic connection between Gibsons Creek and Soames Creek with the aquifer is not inferred (A-A') given the thickness of low permeability material and lower water levels but connection at lower elevations or with overlying

Capilano Sediments could exist. Additional studies would be required to assess surface water-groundwater interactions with drainage features in the area.

There is also potential for hydraulic connection with seawater given the coastal setting of the aquifer. The bottom of the aquifer is inferred to extend below sea level (B-B’, D-D’).

1.4 Additional Information on Water Use and Management

The need to supplement surface water with groundwater as a reliable, long-term drinking water source is increasing groundwater demand in the area (SCRD, 2018). Groundwater protection planning was initiated by the Sunshine Coast Regional District in 1996 (Dayton & Knight Ltd., 1996). This was driven by the need to protect water supply sources, reduce surface water pollution, preserve land stability, and preserve land productivity. Aquifer protection planning has also been initiated by the Town of Gibsons, which relies on groundwater as a water supply (Waterline 2013).

Dry well conditions or extremely low groundwater levels during the summer months have been noted for dug wells.

A study conducted in 1994 identified high arsenic concentrations in groundwater within the Sunshine Coast region (Carmichael and Clarkson 1994). In general, arsenic concentrations are variable both spatially and temporally with no significant correlation between arsenic levels and well depth. Mineralized deposits in fractures that are present in the bedrock are believed to be the source of arsenic (Mattu and Schreier 2000). Arsenic dissolves and becomes mobilized as groundwater flows through the fracture network. Dissolved arsenic was not detected in wells completed in unconsolidated material.

1.5 Additional Assessments or Management Actions

No water availability or water budget studies have been completed. The following studies provide additional information to advance the hydrogeologic understanding of the area:

- Waterline Resources Inc., 2013. Aquifer Mapping Study: Town of Gibsons, British Columbia – includes hydrogeological assessment, hydrogeological model conceptualization, groundwater flow modeling, and climate change considerations.
- Associated Environmental, 2019. Sunshine Coast Regional District: Groundwater Investigation Phase 2 Project: Final Report and Preliminary Design of Production Wells at Dustry Rd, Mahan Rd, and Church Rd Well Sites – includes test well drilling, pumping tests, as well as hydraulic connection and water quality assessments.

At the time of mapping, these studies were publicly available on the SCRD website.

1.6 Aquifer References

Carmichael V. and Clarkson L., 1994. Well Water Survey for Arsenic in the Powell River and Sunshine Coast Communities of British Columbia – March to June 1994. Prepared by the B.C. Ministry of Health. https://www.healthspace.ca/Clients/VCHA/CoastGaribaldi/CoastGaribaldi_Website.nsf

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

Dayton & Knight Ltd. 1996. Aquifer Protection Plan. Prepared for the Sunshine Coast Regional District. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=17038

Fairbanks, B.D., and Faulkner, R.L., 1992. Geothermal Resources of British Columbia. Geological Survey of Canada, Open File 2526, map, scale 1:2,000,000.

Foweraker, J.C. 1964. Groundwater Possibilities – Hopkins Landing Water Users Community. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=5984

Fulton R.J., Clague J.J., and Ryder J.M., 1982. Surficial Geology, Vancouver Island and adjacent Mainland, British Columbia, map, scale 1:1,000,000. Geological Survey of Canada, Open File 837.

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Holland, S.S., 1976 (revised). Landform of British Columbia: A Physiographic Outline. British Columbia Geological Survey, Bulletin 48.

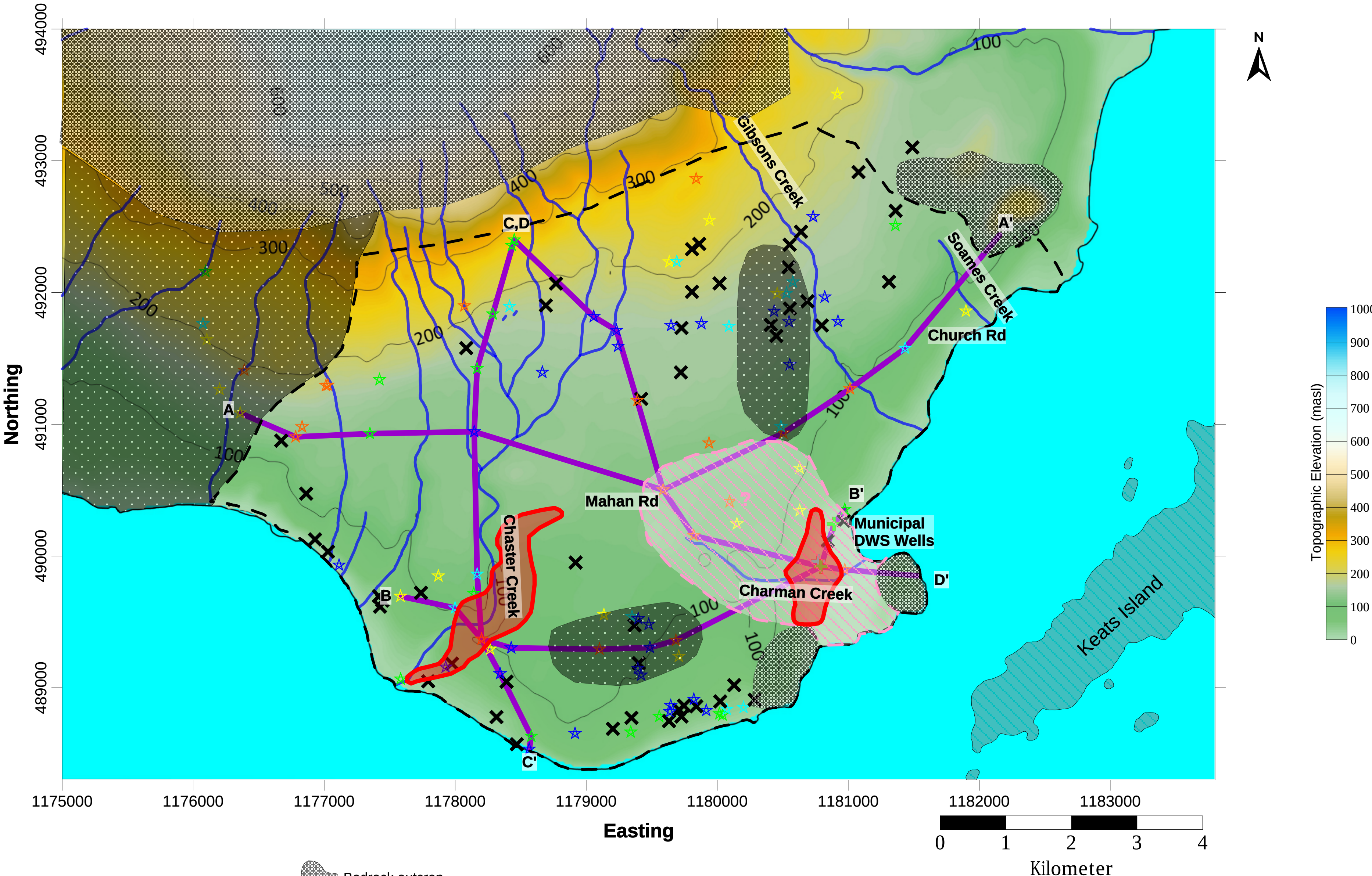
Mattu G. and Schreier H., 2000. An Investigation of High Arsenic Levels in Wells in the Sunshine Coast and Powell River Regions of B.C. Prepared for the Coast Garibaldi Community Health Services Society. https://www.healthspace.ca/Clients/VCHA/CoastGaribaldi/CoastGaribaldi_Website.nsf

McCammon 1977. Surficial Geology and Sand and Gravel Deposits of Sunshine Coast, Powell River, and Campbell River Areas. Bulletin 65 Ministry of Energy, Mines, and Petroleum Resources. http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/BulletinInformation/BulletinsAfter1940/Pages/Bulletin65.aspx

Sunshine Coast Regional District (SCRD) 2018. Regional Groundwater Task Force Consultation Report. Prepared for the Planning and Community Development Committee. http://www.scrd.ca/files/File/Infrastructure/Water/2018-MAR-08_Regional_Groundwater_Task_Force_Consultation_Report.pdf

1.7 Attachments

Figure 1	Location Map and Cross-Section Location Plan
Figure 2	Cross-Section A-A’
Figure 3	Cross-Section B-B’
Figure 4	Cross-Section C-C’
Figure 5	Cross-Section D-D’



Wells (Classified by Total Depth)

- 1-10
- 10-25
- 10-25 (Municipal Drinking Water Supply)
- 25-50
- 25-50 (Municipal Drinking Water Supply)
- 50-100
- 100+
- Depth/Lithology N/A

- Bedrock outcrop
- Key Bedrock Feature (masked by unconsolidated deposits)
- Exposed Pre-Vashon (High Vulnerability)
- Vashon Till Absent (Inferred) (Moderate to High Vulnerability)
- Rivers
- Ground Elevation Contour (masl)
- Cross-Section Line
- Inferred Aquifer Extent

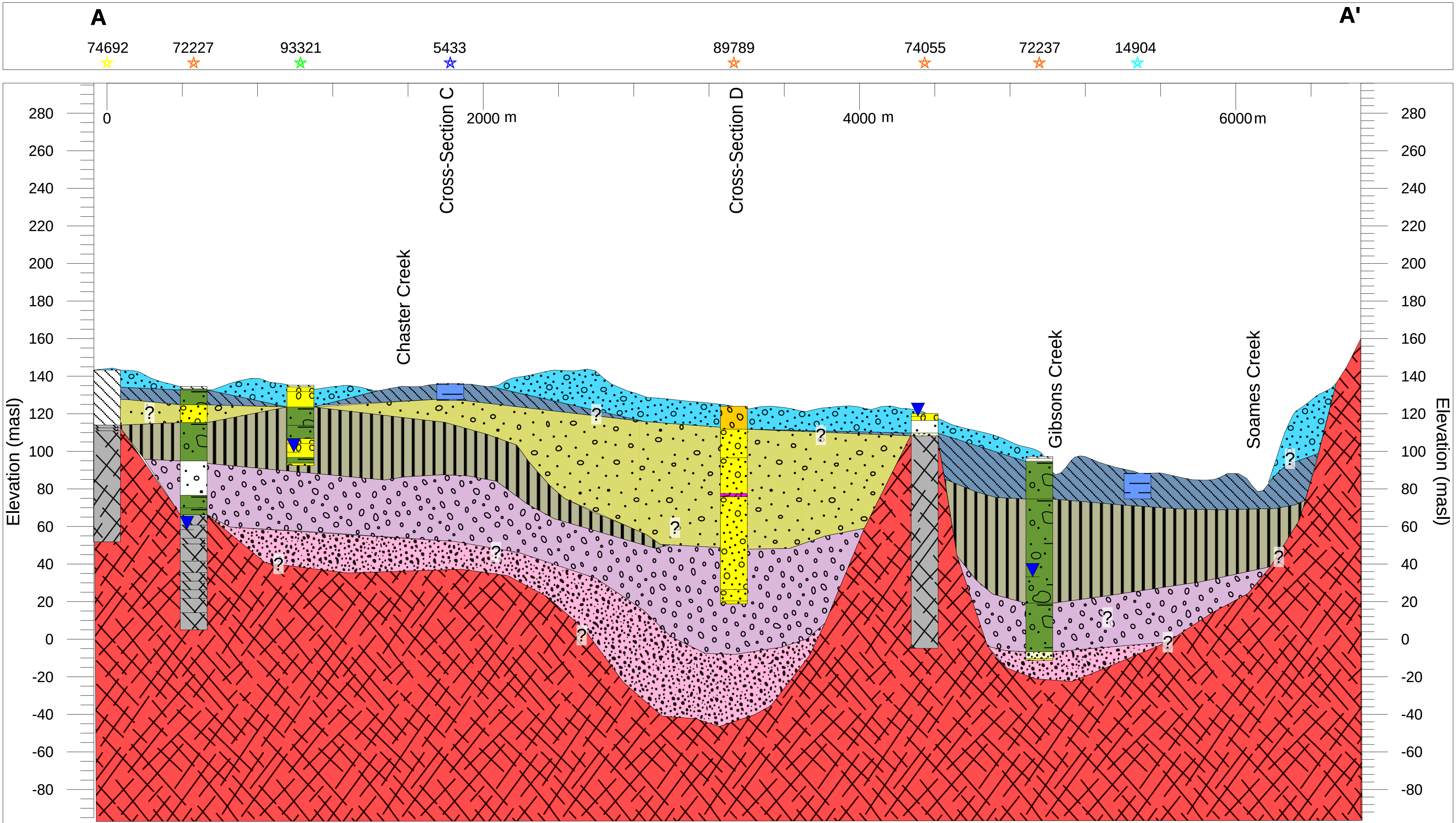
Data Sources:
Digital Elevation Model - 1:20,000 TRIM Data
Water Features - Freshwater Atlas
Bedrock Outcrops and Pre-Vashon Exposure: McCammon 1977
Key subsurface bedrock features inferred from available lithology information.

British Columbia Albers Projection, NAD83

MINISTRY OF ENVIRONMENT & CLIMATE CHANGE
2019 WINTER AQUIFER MAPPING
GIBSONS

LOCATION MAP AND LOCATION OF CROSS-SECTIONS

Date: 12-Mar-20	Drawn by: T.L.	Edited by: S.F.	App'd by: A.H.
BRITISH COLUMBIA	Advisian Worley Group	Worley Project No. 307071-01251	
		FIG No 1	REV 1



Vertical exaggeration: 10x

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.

Lithology

- bedrock
- boulder
- clay
- gravel
- organic
- overburden
- sand & fines
- sand & gravel clean
- sand & gravel dirty
- sand
- silt
- till
- undefined

Stratigraphy

- Salish/Capilano Sediments (fluvial)
- Capilano Sediments (glaciomarine)
- Vashon Drift (glaciofluvial)
- Vashon Drift (till)
- Pre-Vashon (Quadra?)
- Pre-Vashon
- Bedrock

Groundwater Surface Elevation

WTNs are used in the well header to identify locations. Legend for symbols - see Figure 1. Bedrock elevation interpreted based on well lithology and outcrops (McCammon 1977). Bedrock type not mapped, but typically described as igneous rock (granite) with minor occurrences of metamorphic and sedimentary elements based on well lithology.

MINISTRY OF ENVIRONMENT & CLIMATE CHANGE
2019 WINTER AQUIFER MAPPING
GIBSONS

CROSS-SECTION A-A'

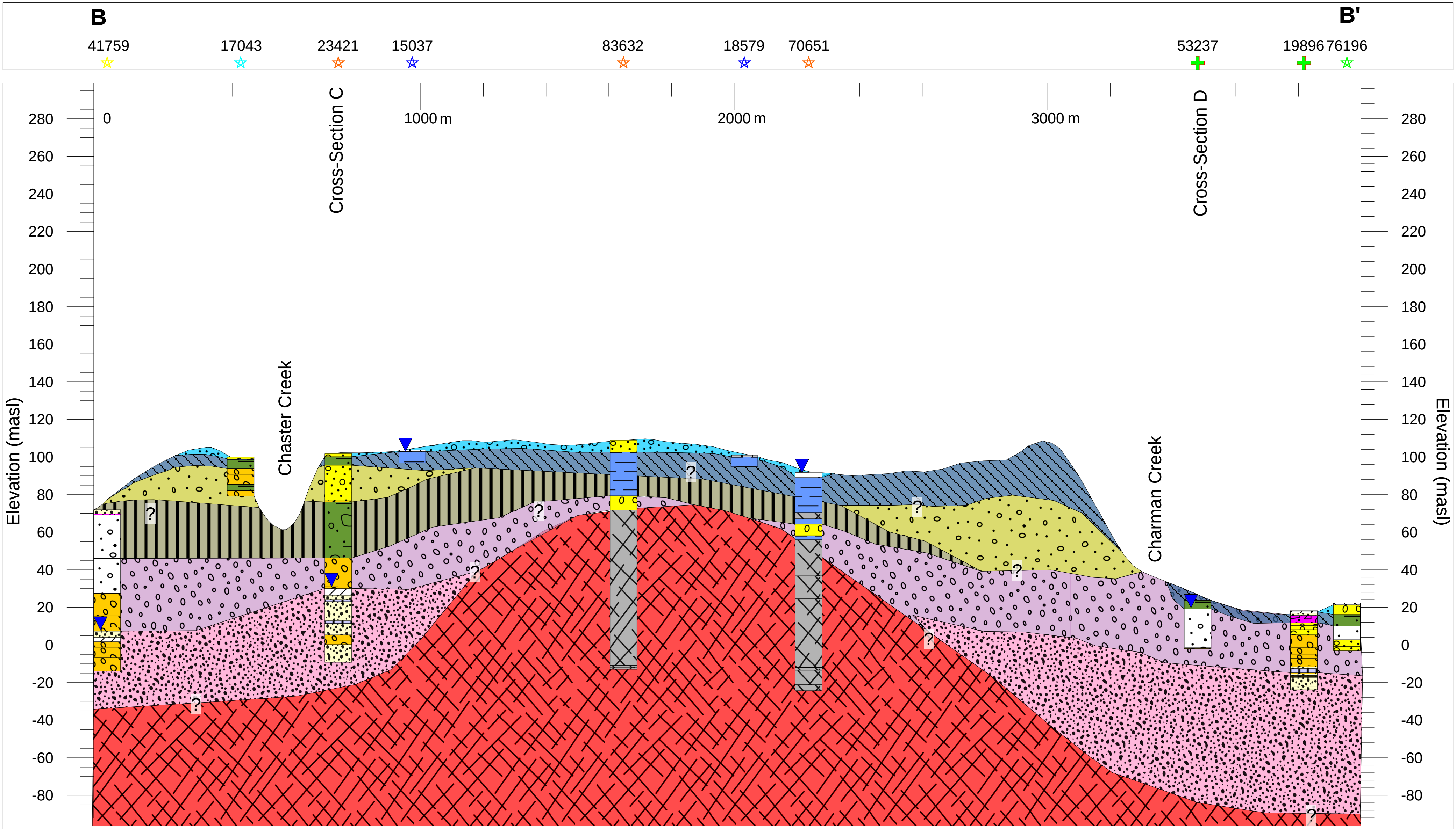
Date: 03-Mar-20	Drawn by: T.L.	Edited by: S.F.	App'd by: A.H.

BRITISH COLUMBIA

Advisian
Worley Group

Worley Project No. 307071-01251

FIG No 2 | REV 1



Vertical exaggeration: 6x

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.

Lithology

- bedrock
- boulder
- clay
- gravel
- organic
- overburden
- sand & fines
- sand & gravel clean
- sand & gravel dirty
- sand
- silt
- till
- undefined

Stratigraphy

- Salish/Capilano Sediments (fluvial)
- Capilano Sediments (glaciomarine)
- Vashon Drift (glaciofluvial)
- Vashon Drift (till)
- Pre-Vashon (Quadra?)
- Pre-Vashon
- Bedrock

Groundwater Surface Elevation

WTNs are used in the well header to identify locations. Legend for symbols - see Figure 1. Bedrock elevation interpreted based on well lithology and outcrops (McCammon 1977). Bedrock type not mapped, but typically described as igneous rock (granite) with minor occurrences of metamorphic and sedimentary elements based on well lithology.

MINISTRY OF ENVIRONMENT & CLIMATE CHANGE
2019 WINTER AQUIFER MAPPING
GIBSONS

CROSS-SECTION B-B'

Date: 03-Mar-20	Drawn by: T.L.	Edited by: S.F.	App'd by: A.H.

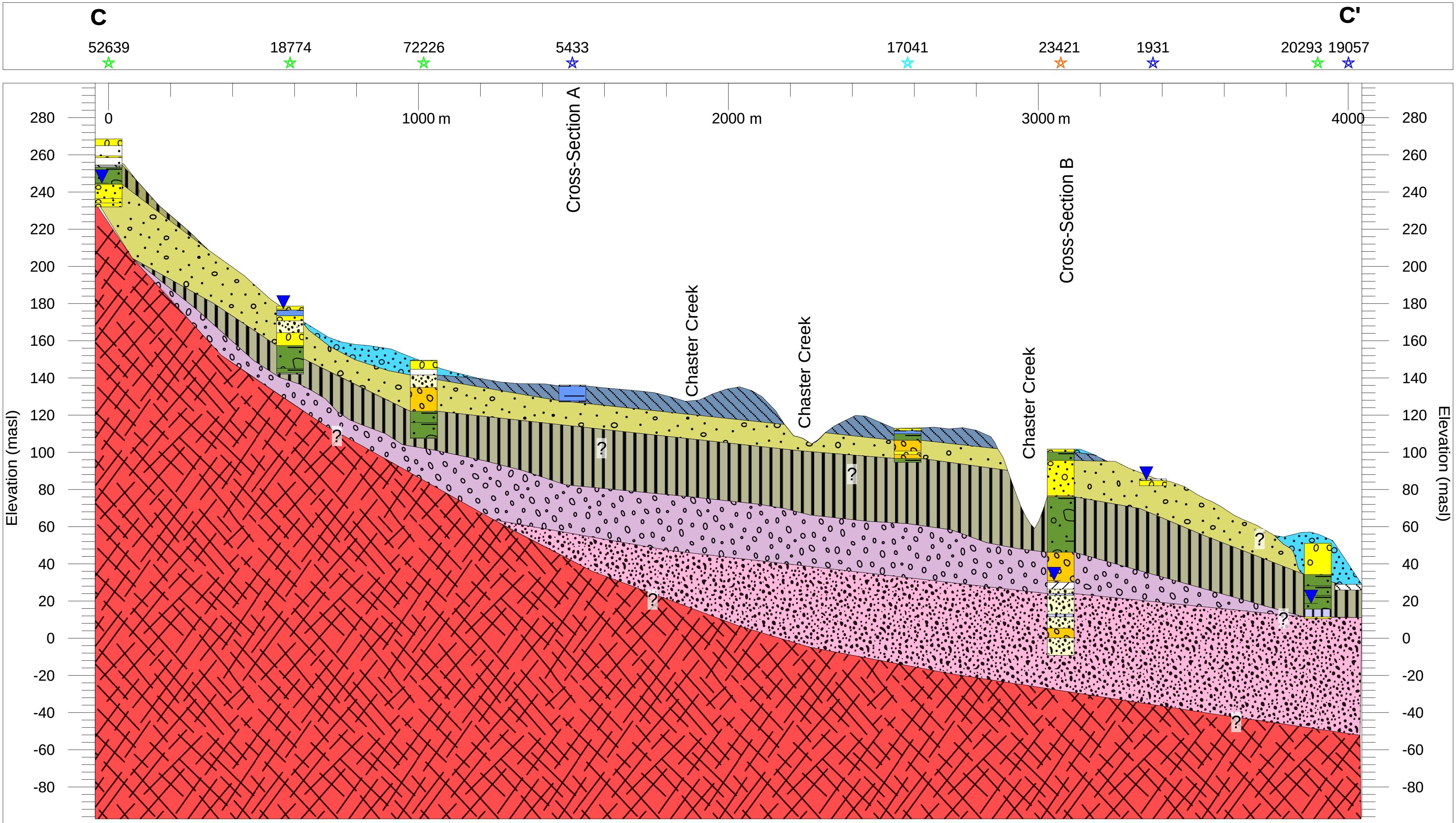
BRITISH COLUMBIA

Advisian
Worley Group

Worley Project No. 307071-01251

FIG No 3

REV 1



Vertical exaggeration: 6x

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.

Lithology

- bedrock
- boulder
- clay
- gravel
- organic
- overburden
- sand & fines
- sand & gravel clean
- sand & gravel dirty
- sand
- silt
- till
- undefined

Stratigraphy

- Salish/Capilano Sediments (fluvial)
- Capilano Sediments (glaciomarine)
- Vashon Drift (glaciofluvial)
- Vashon Drift (till)
- Pre-Vashon (Quadra?)
- Pre-Vashon
- Bedrock

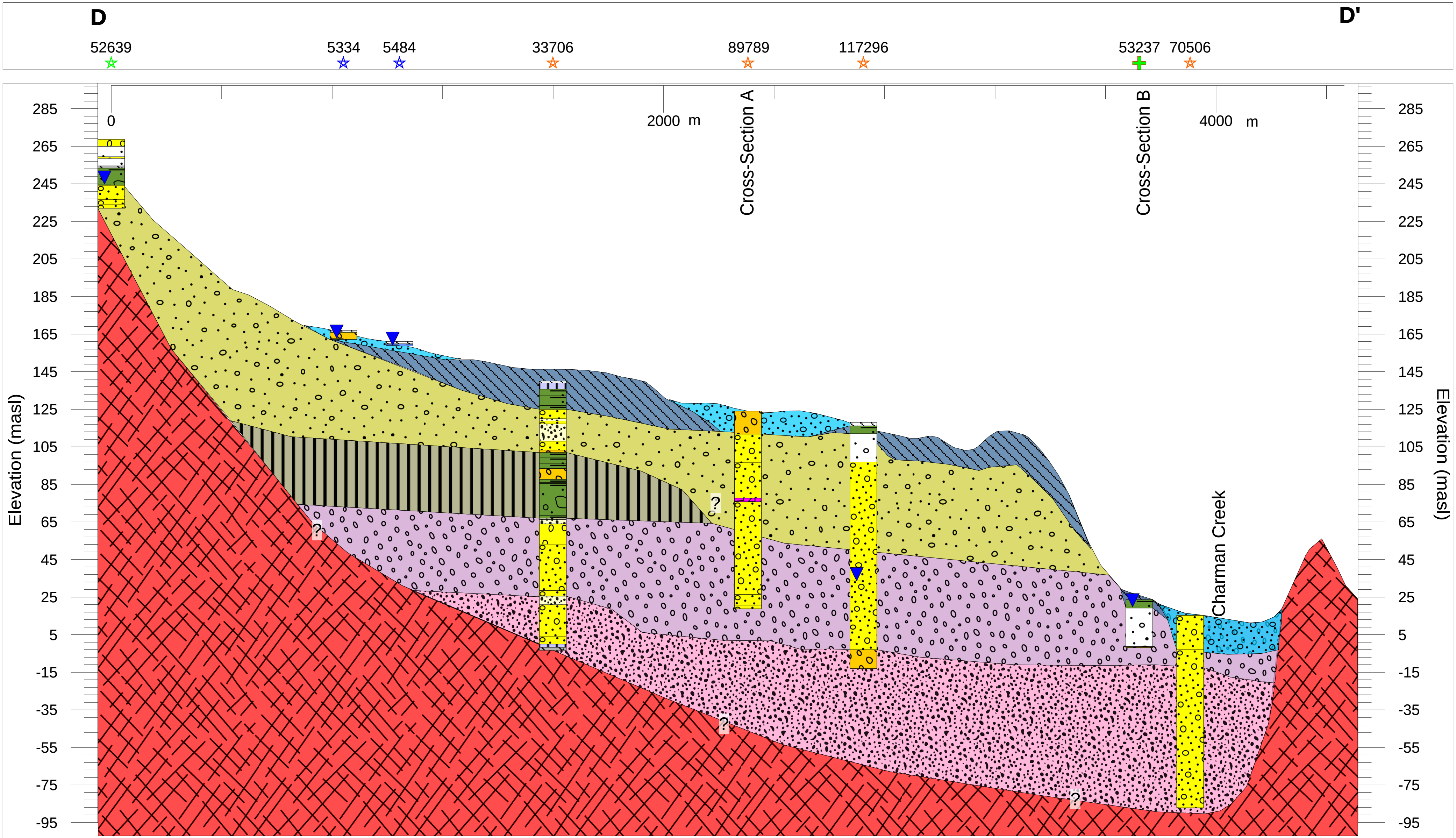
Groundwater Surface Elevation

WTNs are used in the well header to identify locations. Legend for symbols - see Figure 1. Bedrock elevation interpreted based on well lithology and outcrops (McCammon 1977). Bedrock type not mapped, but typically described as igneous rock (granite) with minor occurrences of metamorphic and sedimentary elements based on well lithology.

MINISTRY OF ENVIRONMENT & CLIMATE CHANGE
2019 WINTER AQUIFER MAPPING
GIBSONS

CROSS-SECTION C-C'

Date: 03-Mar-20	Drawn by: T.L.	Edited by: S.F.	App'd by: A.H.
British Columbia	Advisian Worley Group	Worley Project No. 307071-01251	
		FIG No 4	REV 1



Vertical exaggeration: 6x

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.

Lithology

- bedrock
- boulder
- clay
- gravel
- organic
- overburden
- sand & fines
- sand & gravel clean
- sand & gravel dirty
- sand
- silt
- till
- undefined

Stratigraphy

- Salish/Capilano Sediments (fluvial)
- Capilano Sediments (glaciomarine)
- Vashon Drift (glaciofluvial)
- Vashon Drift (till)
- Pre-Vashon (Quadra?)
- Pre-Vashon
- Bedrock

Groundwater Surface Elevation

WTNs are used in the well header to identify locations, except for 33706, which is a well plate number, as this well does not appear to be incorporated into the provincial groundwater wells database. Legend for symbols - see Figure 1. Bedrock elevation interpreted based on well lithology and outcrops (McCammon 1977). Bedrock type not mapped, but typically described as igneous rock (granite) with minor occurrences of metamorphic and sedimentary elements based on well lithology.
Pre-Vashon exposure inferred based on surifical McCammon 1977

MINISTRY OF ENVIRONMENT & CLIMATE CHANGE
2019 WINTER AQUIFER MAPPING
GIBSONS

CROSS-SECTION D-D'

Date: 03-Mar-20	Drawn by: T.L.	Edited by: S.F.	App'd by: A.H.
BRITISH COLUMBIA	Advisian Worley Group	Worley Project No. 307071-01251	
		FIG No 5	REV 1

1. AQUIFER MAPPING REPORT: AQUIFER 0562

Aquifer Name: West Sechelt

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located along the Sunshine Coast, between Sechelt and Halfmoon Bay. The western and southern extents of the aquifer follow the coastline. Topographic divides that coincide with mapped watershed boundaries near Halfmoon Bay and along the Sechelt Inlet were used to define the northern boundary (TRIM 1:20,000, Freshwater Resource Atlas). The upper part of the eastern boundary follows Sechelt Inlet while the lower eastern boundary is based on bedrock outcrops and where an erosional discontinuity is inferred.

The former extents of AQ0972 are contained within the updated aquifer boundary.

1.1.2 Geologic Formation (Overlying Materials)

The presence of overlying materials is variable. Marine deposits typically reach an elevation of 180 m (McCammon 1977). Above this, the bedrock is typically bare or covered by till varying in thickness from 2 to 20 m based on well lithology. Below an elevation of 180 m, bedrock outcrops still exist but the overlying material is more variable. Till is typically covered by variable deposits of glaciomarine, marine, and fluvial origin (McCammon 1977). The thickest unconsolidated deposits occur in the Sechelt area and west of Sargeant Bay.

1.1.3 Geologic Formation (Aquifer) – Sub-type 6b Fractured Crystalline Rock

The bedrock consists of granodioritic and dioritic intrusive rocks (Cui et al. 2017). Well lithologies indicate predominantly granite described as white, pink, green, black, and/or grey. A fault has been mapped north of the aquifer extents (Cui et al. 2017).

1.1.4 Vulnerability- Moderate

Overlying clay and till material exists but is inferred to be laterally discontinuous. Water-bearing fracture zones are typically 70 m deep based on the median depth of existing wells. The permeability of the aquifer is assumed to be low but relatively quick movement of groundwater can occur along fractures. Based on this description, the vulnerability of the aquifer to surface contamination is moderate.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from flowing to moderately deep (30 to 60 m) and is typically shallow (<15 m) based on the median value of existing water depths. Flowing artesian conditions were noted at one well (WTN 98338) located near the base of the mountain slope in the western Sechelt area.

Assuming near-surface flow within the bedrock and ignoring geologic complexities, groundwater flow is inferred to move from areas of higher elevation to areas of lower elevation. Groundwater flow is primarily towards the Strait of Georgia or Sechelt Inlet through bedrock deformities (e.g. fractures).

1.3 Recharge

Recharge is likely to occur where precipitation infiltrates directly into bedrock deformities or from the overlying unconsolidated deposits. Mountain block recharge along the bedrock contact with Quaternary deposits may also contribute to recharge. Lakes, such as Crowston Lake (Russell 1987), and wetland features in the upland region could be either or both local recharge or discharge zones.

1.3.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with unconsolidated aquifers AQ0563 and AQ0557 located at lower elevation in the Sechelt area and west of Sargeant Bay, respectively. Additional studies are required to confirm/determine surface water-groundwater interactions with drainage features in the area.

1.4 Additional Information on Water Use and Management

The need to supplement surface water with groundwater as a reliable, long-term drinking water source is increasing groundwater demand in the area (SCRD, 2018). Groundwater protection planning was initiated by the Sunshine Coast Regional District in 1996 (Dayton & Knight Ltd., 1996). This was driven by the need to protect water supply sources, reduce surface water pollution, preserve land stability, and preserve land productivity.

A study conducted in 1994 identified high arsenic concentrations in groundwater throughout the region (Carmichael and Clarkson 1994). In general, arsenic concentrations are variable both spatially and temporally with no significant correlation between arsenic levels and well depth. Mineralized deposits in fractures that are present in the bedrock are believed to be the source of arsenic (Mattu and Schreier 2000). Arsenic dissolves and becomes mobilized as groundwater flows through the fractured network.

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

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1. AQUIFER MAPPING REPORT: AQUIFER 0563

Aquifer Name: Sechelt, Wakefield Creek

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located along the Sunshine Coast, in the Village of Sechelt area. Part of the southern aquifer boundary follows the coastline. The rest of the aquifer boundary was based on surficial geology mapping and bedrock outcrops (McCammon 1977) with consideration of well lithology.

1.1.2 Geologic Formation (Overlying Materials)

Based on the limited number of well lithology records available, overlying material generally consists of till and clay layers with some silty sand. The presence of local gravel pits (TRIM 1:20,000) and shallow dug wells also indicates sands and gravels may be present at surface.

1.1.3 Geologic Formation (Aquifer) – Sub-type 4b Confined Glaciofluvial

The aquifer material consists of sands and gravels inferred to be glaciofluvial Quadra Sand deposits. There are several old, shallow, dug wells less than 10 m deep with limited lithology information. The status of these wells is unknown. These shallow wells may be installed in an upper, unconfined aquifer of limited lateral and vertical extent but insufficient information currently exists for further interpretation.

1.2 Vulnerability - Moderate

The primary aquifer is inferred to be confined based on overlying clay and till material generally 15 m thick that appears to be continuous; however, the spatial distribution of the lithology data is limited. The depth to the top of the confined aquifer is typically 20 m. Based on this description, the vulnerability of the aquifer to surface contamination is moderate.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.3 Conceptual Understanding of Flow Dynamics

1.3.1 Groundwater Levels and Flow Direction

The depth to the water table is shallow (<15 m). Flowing artesian conditions were noted at one well (WTN 5419).

Bedrock topography that is masked by the overlying unconsolidated material likely controls groundwater flow. Bedrock topographic highs are inferred along the western, northern, and eastern extents of the aquifer, resulting in groundwater flow to the south towards the coastline (Strait of Georgia).

1.4 Recharge

Limited recharge from the infiltration of precipitation through the confining material is inferred. Mountain block recharge along the bedrock contact with Quaternary deposits likely contributes to groundwater flow. The aquifer could also be recharged via hydraulic connection with surrounding bedrock aquifers. Wakefield Creek may also contribute to recharge.

1.4.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with bedrock aquifer AQ0555. Additional studies are required to confirm/determine surface water-groundwater interactions with drainage features in the area. There is also potential for hydraulic connection with the coastal waters of the Strait of Georgia and Sechelt Inlet.

1.5 Additional Information on Water Use and Management

The need to supplement surface water with groundwater as a reliable, long-term drinking water source is increasing groundwater demand in the area (SCRD, 2018). Groundwater protection planning was initiated by the Sunshine Coast Regional District in 1996 (Dayton & Knight Ltd., 1996). This was driven by the need to protect water supply sources, reduce surface water pollution, preserve land stability, and preserve land productivity.

Dry well conditions or extremely low groundwater levels during the summer months have been noted in well records.

A study conducted in 1994 identified high arsenic concentrations in groundwater within the Sunshine Coast region (Carmichael and Clarkson 1994). In general, arsenic concentrations are variable both spatially and temporally with no significant correlation between arsenic levels and well depth. Mineralized deposits in fractures that are present in the bedrock are believed to be the source of arsenic (Mattu and Schreier 2000). Arsenic dissolves and becomes mobilized as groundwater flows through the fracture network. Dissolved arsenic was not detected in wells completed in unconsolidated material.

1.6 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.7 Aquifer References

Carmichael V. and Clarkson L., 1994. Well Water Survey for Arsenic in the Powell River and Sunshine Coast Communities of British Columbia – March to June 1994. Prepared by the B.C. Ministry of Health. https://www.healthspace.ca/Clients/VCHA/CoastGaribaldi/CoastGaribaldi_Website.nsf

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1. AQUIFER MAPPING REPORT: AQUIFER 0564

Aquifer Name: East Porpoise Bay

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located along the Sunshine Coast, east of Porpoise Bay. The upper part of the western boundary follows Sechelt Inlet. The middle western boundary is based on bedrock outcrops where an erosional discontinuity is inferred. The southern boundary follows the coastline (Strait of Georgia). Topographic divides were used to define the south eastern and northern extents (TRIM 1:20,000). The eastern boundary is constrained by an elevation of 180 m generally based on where slopes become more steeply sloping. The elevation of 180 m also corresponds with the elevation limit for marine deposits (McCammon 1977).

1.1.2 Geologic Formation (Overlying Materials)

The bedrock is typically bare or covered by fluvial deposits that have formed deltas during glacial melt (McCammon 1977). Till is typically covered by glaciomarine, marine, and fluvial deposits at higher elevations. The thickest deposits occur near the base of the mountain slope where deltaic sands and gravels are more common.

1.1.3 Geologic Formation (Aquifer) – Sub-type 6b Fractured Crystalline Rock

The bedrock consists of granodioritic and dioritic intrusive rocks (Cui et al. 2017). Well lithologies indicate predominantly granitic rock. No faults have been mapped within the aquifer extents (Cui et al. 2017).

1.1.4 Vulnerability - Moderate

Bedrock outcrops exist predominantly in the northern portion of the aquifer. Till and clay act as confining materials at higher elevation in the southern half of the aquifer while permeable sand and gravel dominate as overlying materials at lower elevation. Water-bearing fracture zones are typically 120 m deep. The permeability of the aquifer is assumed to be low but relatively quick movement of groundwater can occur along fractures. Based on this description, the vulnerability of the aquifer to surface contamination is moderate.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from shallow (<15 m) to deep (>60 m) and is typically moderately shallow (15 to 30 m) based on the median value of existing water depths . Assuming near-surface flow within the bedrock and ignoring geologic complexities, groundwater flow is inferred to move from areas of higher elevation to areas of lower elevation. Groundwater flows predominantly to the west and southwest, towards the Strait of Georgia or Sechelt Inlet, through bedrock deformities like fractures.

1.3 Recharge

Recharge is likely to occur where precipitation infiltrates directly into bedrock deformities or from the overlying unconsolidated deposits.

1.3.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with unconsolidated aquifer AQ0566 and bedrock aquifer AQ0555. Additional studies are required to confirm/determine surface water-groundwater interactions with drainage features in the area. There is potential for hydraulic connection with the coastal waters of the Straight of Georgia and Sechelt Inlet.

1.4 Additional Information on Water Use and Management

The need to supplement surface water with groundwater as a reliable, long-term drinking water source is increasing groundwater demand in the area (SCRD, 2018). Groundwater protection planning was initiated by the Sunshine Coast Regional District in 1996 (Dayton & Knight Ltd., 1996). This was driven by the need to protect water supply sources, reduce surface water pollution, preserve land stability, and preserve land productivity.

A study conducted in 1994 identified high arsenic concentrations in groundwater within the Sunshine Coast region (Carmichael and Clarkson 1994). In general, arsenic concentrations are variable both spatially and temporally with no significant correlation between arsenic levels and well depth. Mineralized deposits in fractures that are present in the bedrock are believed to be the source of arsenic (Mattu and Schreier 2000). Arsenic dissolves and becomes mobilized as groundwater flows through the fracture network. Dissolved arsenic was not detected in wells completed in unconsolidated material.

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

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1. AQUIFER MAPPING REPORT: AQUIFER 0566

Aquifer Name: East Sechelt Delta

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located along the Sunshine Coast, east of Sechelt. The most westerly extents coincide with bedrock outcrop mapping (McCammon 1977). The aquifer boundary follows the coastlines along the Strait of Georgia as well as within the Sechelt Inlet. The eastern and northern boundaries of the aquifer are based on Capilano fluvial, deltaic deposits mapped by McCammon (1977) but are constrained at an elevation of about 100 m based on well lithology records.

The former AQ0556 is included within the current aquifer extents.

1.1.2 Geologic Formation (Overlying Materials)

Overlying materials include Capilano fluvial deposits that have formed a delta left by streams during glacial melt (McCammon 1977). The thickest deposits occur near the base of the mountain slope. Permeable deposits found at surface are underlain by till and clay in some areas; however, most wells within the mapped aquifer extents appear to have overlying fine sand based on well lithology records. Several gravel pits have been identified within the area (McCammon 1977).

1.1.3 Geologic Formation (Aquifer) – Sub-type 4a Unconfined Glaciofluvial/3 Alluvial Fan

The aquifer material consists of sands and gravels inferred as deltaic or glaciofluvial deposits. Unconfined conditions are inferred based on overlying materials that are predominantly fine sand.

1.1.4 Vulnerability - High

The aquifer is unconfined based on overlying materials that are predominantly fine sand. The water table depth is typically moderately shallow (See Section 1.2.1). Based on this description, the vulnerability of the aquifer to surface contamination is high.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from shallow (<15 m) to deep (>60 m) and is typically moderately shallow (15 to 30 m) based on the median value of existing water depths. Groundwater flow is inferred to move from areas of higher elevation to areas of lower elevation. Groundwater is assumed to flow in a west to southwest direction towards the Strait of Georgia or Sechelt Inlet.

1.3 Recharge

Recharge occurs primarily from precipitation infiltrating into the subsurface. Upgradient of the aquifer, perched groundwater conditions may exist within deposits overlying till or clay. This perched water may also contribute to recharge where the underlying till or clay layer becomes discontinuous.

1.3.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with bedrock aquifer AQ0564 as well as unconsolidated deposits upgradient of the aquifer mapped by McCammon (1977). The downstream end of Chapman Creek could also be hydraulically connected. Additional studies are required to confirm/determine surface-ground water interactions with drainage features in the area.

1.4 Additional Information on Water Use and Management

The need to supplement surface water with groundwater as a reliable, long-term drinking water source is increasing groundwater demand in the area (SCRD, 2018). Groundwater protection planning was initiated by the Sunshine Coast Regional District in 1996 (Dayton & Knight Ltd., 1996). This was driven by the need to protect water supply sources, reduce surface water pollution, preserve land stability, and preserve land productivity.

A study conducted in 1994 identified high arsenic concentrations in groundwater throughout the region (Carmichael and Clarkson 1994). In general, arsenic concentrations are variable both spatially and temporally with no significant correlation between arsenic levels and well depth. Mineralized deposits in fractures that are present in the bedrock are believed to be the source of arsenic (Mattu and Schreier 2000). Arsenic dissolves and becomes mobilized as groundwater flows through the fractured network. Dissolved arsenic was not detected in wells completed in unconsolidated material.

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

Carmichael V. and Clarkson L., 1994. Well Water Survey for Arsenic in the Powell River and Sunshine Coast Communities of British Columbia – March to June 1994. Prepared by the B.C. Ministry of Health. https://www.healthspace.ca/Clients/VCHA/CoastGaribaldi/CoastGaribaldi_Website.nsf

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1. AQUIFER MAPPING REPORT: AQUIFER 1220

Aquifer Name: Eastern slope of Mount Elphinstone

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located along the Sunshine Coast on the eastern slope of Mount Elphinstone between Witherby Point and Gibsons Creek. Topographic divides were used to define the southern and northern boundaries (TRIM 1:20,000). The southern extent also coincides with a geologic boundary between sedimentary and igneous rock types. The western boundary is constrained by an elevation of 180 m generally based on where slopes become more steeply sloping. The elevation of 180 m also corresponds with the elevation limit for marine deposits (McCammon 1977). The eastern boundary follows the coastline.

1.1.2 Geologic Formation (Overlying Materials)

Bedrock is overlain by varying thicknesses of glacial, glaciomarine, marine, and fluvial deposits ranging from 5 to over 80 m thick and typically 15 m thick based on median depth to bedrock values. Several bedrock outcrops have been mapped in the area (McCammon 1977), suggesting the bedrock surface is hummocky and is masked by overlying materials.

1.1.3 Geologic Formation (Aquifer) – Sub-type 6b Fractured Crystalline Rock

The majority of bedrock within the aquifer extents has been mapped as sedimentary rocks belonging to the Bowen Island Group from the Lower to Middle Jurassic (Cui et al. 2017). Typical rock types include argillite, greywacke, wacke, conglomerate turbidites. Granodioritic intrusive rocks have also been mapped near the northern and southern extents of the aquifer. Well lithologies indicate predominantly granite described primarily as white, green, black, and grey in colour. A fault has been mapped within the aquifer extents (Cui et al. 2017).

1.1.4 Vulnerability - Moderate

Confining materials include till and clay typically 10 m thick based on well lithologies that provide limited spatial coverage . Water-bearing fracture zones are typically over 80 m deep based on the median depth of existing wells. The permeability of the aquifer is assumed to be low but relatively quick movement of groundwater can occur along fractures. Based on this description, the vulnerability of the aquifer to surface contamination is moderate.

The coastal setting of the aquifer also makes it vulnerable to saltwater intrusion.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from shallow (<15 m) to moderately deep (30 to 60 m) and is typically moderately shallow (15 to 30) based on the median value of existing water depths. Groundwater is inferred to flow predominantly to the east, towards the coastline, through bedrock deformities (e.g. fractures) and intergranular pore spaces (where sedimentary rocks exist). This assumes near-surface flow within the bedrock from areas of high to low elevation and ignores geologic complexities. Springs have been identified in the area and are indicative of areas of groundwater discharge.

1.3 Recharge

Recharge likely occurs where precipitation infiltrates directly into bedrock deformities locally and in the surrounding mountainous areas or from the overlying unconsolidated deposits.

1.3.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with unconsolidated aquifers AQ0552 and AQ0560 as well as bedrock aquifer AQ0555. Additional studies are required to confirm/determine surface water-groundwater interactions with drainage features in the area. The aquifer is likely hydraulic connected to the coastal waters of Shoal Channel and Thornbrough Channel.

1.4 Additional Information on Water Use and Management

The need to supplement surface water with groundwater as a reliable, long-term drinking water source is increasing groundwater demand in the area (SCRD, 2018). Groundwater protection planning was initiated by the Sunshine Coast Regional District in 1996 (Dayton & Knight Ltd., 1996). This was driven by the need to protect water supply sources, reduce surface water pollution, preserve land stability, and preserve land productivity.

Springs have been identified in the area and have historically been used as a water supply source (Foweraker 1964).

A study conducted in 1994 identified high arsenic concentrations in groundwater within the Sunshine Coast region (Carmichael and Clarkson 1994). In general, arsenic concentrations are variable both spatially and temporally with no significant correlation between arsenic levels and well depth. Mineralized deposits in fractures that are present in the bedrock are believed to be the source of arsenic (Mattu and Schreier 2000). Arsenic dissolves and becomes mobilized as groundwater flows through the fracture network. Dissolved arsenic was not detected in wells completed in unconsolidated material.

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

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A4. HOPE

1. AQUIFER MAPPING REPORT: AQUIFER 1008

Aquifer Name: Haig

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

A portion of the aquifer boundary follows the shoreline of the Fraser River. The remainder of the aquifer boundary was based on topography and the extent of well development. The eastern aquifer boundary is based on a local topographic divide that roughly coincides with mapped geologic boundaries between metamorphic to sedimentary rock types. A fault line runs through the aquifer but was not used for delineation purposes due to insufficient information on the fault.

1.1.2 Geologic Formation (Overlying Materials)

Glacial, glaciofluvial and fluvial gravel, sand and clay, talus, and slope-wash deposits at the base of the mountain slope (Monger 1970). Lithology from well records indicates overlying sand and gravel deposits with some localized clay and till materials. Quaternary deposits are generally less than 10 metres thick and are absent in some locations.

1.1.3 Geologic Formation (Aquifer) – Subtype 5a

The aquifer is composed primarily of undivided sedimentary rocks from the Hozameen Complex. This includes undifferentiated chert, pelite, mafic volcanics, minor limestone, gabbro, and ultramafic rock (Cui et al. 2017). Some deep wells appear to be completed in intrusive rocks (e.g. granite).

1.1.4 Vulnerability - Moderate

Overlying clay and till material are generally limited in thickness and spatial extent. Water-bearing fracture zones are typically over 50 m deep based on the median depth of existing wells. The permeability of the aquifer is assumed to be low but relatively quick movement of groundwater can occur along fractures. Based on this description, the vulnerability of the aquifer to surface contamination is moderate.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from shallow (<15 m) to moderately deep (30 to 60 m) but is typically shallow based on the median value of existing records of depth to water . Assuming near-surface flow within the bedrock, groundwater is inferred to flow towards the Fraser River primarily through bedrock deformities like fractures with the potential for intergranular flow in the sedimentary units. Depending on the extent of bedrock deformities (e.g. fracture network), groundwater could potentially move vertically downward and join deeper groundwater flow systems.

1.3 Recharge

Recharge is likely to occur where precipitation infiltrates directly into bedrock deformities or from water that infiltrates into overlying unconsolidated deposits hydraulically connected to the bedrock. Mountain block recharge along the contact between bedrock and Quaternary deposits may also contribute to recharge. Recharge may occur through the base of Schkam Lake.

1.3.1 Potential for Hydraulic Connection

Groundwater could be hydraulically connected with bedrock aquifer AQ1188 to the north. Additional studies are required to confirm/determine surface water-groundwater interactions with drainage features including Schkam Lake. The influence of mapped faults in the area on groundwater flow is unknown.

1.4 Additional Information on Water Use and Management

Well record information indicates groundwater is primarily used for private domestic supply and to a much lesser extent for commercial/industrial and municipal purposes.

The aquifer is located within a region of moderate geothermal potential (Fairbank and Faulkner 1992) which may have an influence on groundwater quality (e.g. arsenic concentrations).

1.5 Additional Assessments or Management Actions:

Water availability or water budget studies have not been completed.

1.6 Aquifer References

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

Fairbanks, B.D., and Faulkner, R.L., 1992. Geothermal Resources of British Columbia. Geological Survey of Canada, Open File 2526, map, scale 1:2,000,000.

Fulton R.J., Clague J.J., and Ryder J.M., 1982. Surficial Geology, Vancouver Island and adjacent Mainland, British Columbia, map, scale 1:1,000,000. Geological Survey of Canada, Open File 837.

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Hammond, Z.M. and Hinnell, A.C, March 2019. Stage 1 Foundational Mapping: Hope, Moresby Island, Sunshine Coast, and Ucluelet. Prepared for the Ministry of Environment and Climate Change Strategy. Available through EcoCat (https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/ecocat).

Monger J.W.H., 1989. Geology, Hope, British Columbia. Geological Survey of Canada, Map 41-1989, sheet 1, scale 1:250 000.

1. AQUIFER DESCRIPTION FOR AQUIFER 1009

Aquifer Name: Kawkawa Lake

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is generally located within the lower catchment area of Kawkawa Lake. The south-western boundary follows the Coquihalla River. The northern and southern boundaries are defined along the margins of the valley bottom (approximate elevations of 180 to 260 m above sea level). The northwestern boundary roughly coincides where the rock type changes from metamorphic to sedimentary. The eastern boundary of the aquifer coincides with watershed mapping that could represent a groundwater divide for shallow groundwater in bedrock but more so distinguishes between different physiographic settings (catchment area of the lake versus the steep valley that contains Coquihalla River).The former AQ1189 is combined within the current aquifer extents of AQ1009.

1.1.2 Geologic Formation (Overlying Materials)

Based on well lithology records, till less than 5m thick overlies bedrock for wells installed at higher elevations. In some areas, bedrock is overlain by permeable sands and gravels. Southwest of Kawkawa Lake, the bedrock surface appears to drop-off and is covered by Quaternary deposits over 20m thick.

1.1.3 Geologic Formation (Aquifer) – Subtype 6b

The aquifer is composed of Granodioritic intrusive rocks from the Cenozoic era (Cui et. al. 2017).

1.1.4 Vulnerability - Moderate

Overlying till material is inferred to exist but may be discontinuous at higher elevations based on lithology from well records. Sands and gravels typically occur where the overlying material is the thickest (southwest of Kawkawa Lake). Water-bearing fracture zones are typically 72 m deep based on the median depth of existing wells. The permeability of the aquifer material is assumed to be low but relatively quick movement of groundwater can occur along fractures. Based on this description, the vulnerability classification of the aquifer is moderate.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from 3.6 to 48.8 m with a median of 22.9 m. Assuming near-surface flow within the bedrock, groundwater is inferred to flow towards Kawkawa Lake primarily through bedrock deformities like fractures. Groundwater in bedrock could also discharge into unconsolidated deposits southwest of Kawkawa Lake. Depending on the extent of bedrock deformities, groundwater could potentially move vertically downward and join regional groundwater flow systems.

1.3 Recharge

Recharge is likely to occur where precipitation infiltrates into bedrock deformities in the surrounding mountainous areas. The aquifer could also be recharged by overlying unconsolidated deposits as well as by mountain block recharge along the contact between bedrock and Quaternary deposits.

1.3.1 Potential for Hydraulic Connection

Camilos Creek, Kopp Creek, and Sucker Creek, and Kawkawa Lake are local drainage features. Groundwater is likely hydraulically connected with Kawkawa Lake as well as unconsolidated aquifer AQ1005 to the southwest of Kawkawa Lake. There is a potential for connection to sedimentary rock mapped to the west. Additional studies are required to confirm/determine surface-ground water interactions with drainage features in the area.

1.4 Additional Information on Water Use and Management

Water wells and surface water diversion licences are present within the footprint of the aquifer. Limited information on well use is available to differentiate groundwater uses.

The aquifer is located within a moderate geothermal potential region (Fairbank and Faulkner 1992) which may have an influence on groundwater quality (e.g. arsenic concentrations).

1.5 Additional Assessments or Management Actions:

Water availability or water budget studies have not been completed.

1.6 Aquifer References

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

Fairbanks, B.D., and Faulkner, R.L., 1992. Geothermal Resources of British Columbia. Geological Survey of Canada, Open File 2526, map, scale 1:2,000,000.

Fulton R.J., Clague J.J., and Ryder J.M., 1982. Surficial Geology, Vancouver Island and adjacent Mainland, British Columbia, map, scale 1:1,000,000. Geological Survey of Canada, Open File 837.

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Hammond, Z.M. and Hinnell, A.C, March 2019. Stage 1 Foundational Mapping: Hope, Moresby Island, Sunshine Coast, and Ucluelet. Prepared for the Ministry of Environment and Climate Change Strategy. Available through EcoCat (https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/ecocat).

Monger J.W.H., 1989. Geology, Hope, British Columbia. Geological Survey of Canada, Map 41-1989, sheet 1, scale 1:250 000.

1. AQUIFER MAPPING REPORT: AQUIFER 1188

Aquifer Name: Fraser Canyon, from Yale to Haig

Date of Mapping: December 2018

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located within the Fraser Canyon north of Hope to south of Yale and west of the Frazer River. The western extent of the aquifer is based on existing bedrock well locations and generally coincides with an elevation of 100 m. The western boundary of the aquifer could extend to a higher elevation but has been constrained for two reasons: 1) there is a low potential for development at higher elevation; and 2) the bedrock at a lower elevation has likely been more eroded by historical glacial activity; and therefore, has a greater potential to act as an aquifer. The eastern extent of the aquifer follows the Fraser River. The northern aquifer boundary is based on watershed mapping while the southern boundary is based on a local topographic divide that roughly coincides with mapped geologic boundaries (Cui et al. 2017). Several sub-watersheds exist within the mapped aquifer that were not used as boundaries given the uncertainty of how these watersheds influence groundwater flow in the valley bottom where Quaternary deposits exist.

1.1.2 Geologic Formation (Overlying Materials)

Channel and terrace deposits of sands and gravels commonly capped by silt to medium grained sand are found in the valley floor (Fulton et. al. 1982). Till deposits may be overlain by permeable deposits or may be located at or near the ground surface. Unconsolidated material is generally less than 10m thick.

1.1.3 Geologic Formation (Aquifer) – Subtype 6b

Bedrock from the Custer Gneiss Formation has been mapped within the footprint of the aquifer (Cui et. al. 2017). This formation consists of metamorphic rocks that typically includes granite gneiss with abundant pegmatite dikes, pelitic schist and amphibolite, minor marble and ultramafic rocks. Faults have been mapped to the east and west outside of the defined aquifer extents.

1.1.4 Vulnerability - Moderate

Overlying till material is inferred to exist but may be discontinuous based on lithology from well records. Water-bearing fracture zones are typically over 50 m deep based on the median depth of existing wells. The permeability of the aquifer material is assumed to be low but relatively quick movement of groundwater can occur along fractures. Based on this description, the vulnerability of the aquifer to surface contamination is moderate.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

The depth to the water table ranges from shallow (<15 m) to deep (>60 m) and is typically moderately shallow (15 to 30 m) based on the median value of existing water depths. Assuming near-surface flow within the bedrock, groundwater is inferred to flow predominantly to the east towards the Fraser River through bedrock deformities like fractures. Depending on the extent of bedrock deformities (e.g.

fracture network), groundwater could potentially move vertically downward and join deeper groundwater flow systems. The influence of mapped faults in the area on groundwater flow is unknown.

1.3 Recharge

Recharge is likely to occur where precipitation infiltrates into bedrock deformities in the mountainous areas to the west. The aquifer could also be recharged by overlying unconsolidated deposits as well as by mountain block recharge along the contact between bedrock and Quaternary deposits. The influence of mapped faults in the area on recharge is unknown.

1.3.1 Potential for Hydraulic Connection

The potential for hydraulic connection with creeks is unknown. The aquifer could be connected to AQ 1008, located to the south within a rock type mapped as sedimentary. Groundwater likely discharges to unconsolidated deposits within the valley floor and/or directly into the Fraser River. Additional studies are required to confirm/determine surface water-groundwater interactions with drainage features in the area.

1.4 Additional Information on Water Use and Management

Water wells and surface water diversion licences are present in the area. Limited information on water use is available.

The aquifer is located within a moderate geothermal potential region (Fairbank and Faulkner 1992) which may have an influence on groundwater quality (e.g. arsenic concentrations).

1.5 Additional Assessments or Management Actions:

No groundwater characterization studies are known to exist.

1.6 Aquifer References

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

Fairbanks, B.D., and Faulkner, R.L., 1992. Geothermal Resources of British Columbia. Geological Survey of Canada, Open File 2526, map, scale 1:2,000,000.

Fulton R.J., Clague J.J., and Ryder J.M., 1982. Surficial Geology, Vancouver Island and adjacent Mainland, British Columbia, map, scale 1:1,000,000. Geological Survey of Canada, Open File 837.

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Hammond, Z.M. and Hinnell, A.C., March 2019. Stage 1 Foundational Mapping: Hope, Moresby Island, Sunshine Coast, and Ucluelet. Prepared for the Ministry of Environment and Climate Change Strategy. Available through EcoCat (https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/ecocat).

Monger J.W.H., 1989. Geology, Hope, British Columbia. Geological Survey of Canada, Map 41-1989, sheet 1, scale 1:250 000.

1. AQUIFER DESCRIPTION FOR AQUIFER 1221

Aquifer Name: North Hope

Date of Mapping: December 2018Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

Authors: Zidra Hammond, P.Eng., Andrew Hinnell, P.Geo.

1.1 Conceptual Understanding of Hydrostratigraphy

1.1.1 Aquifer Extents

The aquifer is located east of the Coquihalla River, where the Coquihalla River empties into the Fraser River in northern Hope. The aquifer boundary follows the Fraser River and the Coquihalla River. The eastern boundary is constrained by topography, generally following an elevation of 80m. The northern boundary generally coincides with the extents of mapped Quaternary deposits (Cui et. al. 2017). The southern boundary follows a topographic divide and aligns with the boundary of unconsolidated aquifer AQ1005.

1.1.2 Geologic Formation (Overlying Materials)

No well lithology records are available and limited surficial mapping information is available. The overlying material likely consists of sands and gravels from a combination of fluvial, glacio-fluvial and deltaic origins.

1.1.3 Geologic Formation (Aquifer) – Subtype 2

Based on aerial photography, the aquifer is predominantly unconfined fluvial/deltaic sand and gravel.

1.1.4 Vulnerability - High

The permeability of the aquifer and overlying materials is assumed to be high. The water table is likely shallow. Based on this description, the vulnerability of the aquifer to surface contamination is high.

1.2 Conceptual Understanding of Flow Dynamics

1.2.1 Groundwater Levels and Flow Direction

Groundwater is inferred to flow from areas of higher elevation towards the Fraser River and the Coquihalla River.

1.3 Recharge

Recharge is likely to occur where precipitation infiltrates into the subsurface as well as by mountain block recharge along the contact between bedrock and Quaternary deposits.

1.3.1 Potential for Hydraulic Connection

Groundwater is likely hydraulically connected with the Fraser River and the Coquihalla River. Groundwater may discharge into the aquifer from the adjacent sedimentary bedrock (currently not mapped) that may be connected with bedrock aquifer AQ1009.

1.4 Additional Information on Water Use and Management

No well records were identified; however, groundwater may be used by the local golf course and for residential purposes.

The aquifer is located within a moderate geothermal potential region (Fairbank and Faulkner 1992) which may have an influence on groundwater quality (e.g. arsenic concentrations).

1.5 Additional Assessments or Management Actions:

No water availability or water budget studies have been completed.

1.6 Aquifer References

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p.

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Monger J.W.H., 1989. Geology, Hope, British Columbia. Geological Survey of Canada, Map 41-1989, sheet 1, scale 1:250 000.