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Understanding the Types of Aquifers in the Canadian Cordillera Hydrogeologic Region to Better Manage and Protect Groundwater

Mike Wei, Diana Allen, Alan Kohut, Steve Grasby, Kevin Ronneseth, and Bob Turner

Introduction

Groundwater is often viewed as a mysterious and challenging resource to manage as it is hidden underground. Generally, the only obvious sign of groundwater to the public is water flowing from a spring or from a well. Where and how the groundwater got to the spring or well and how much is available are questions of interest when trying to protect the resource. Extending knowledge of groundwater and *aquifers*—permeable, water-bearing geological formations or deposits that transmit and store groundwater—to communities and land and water resource decision makers has been a challenge in British Columbia because of the general lack of comprehensive studies in many areas. If similar types of aquifers have similar characteristics, it may be reasonable to extrapolate knowledge from well-studied areas to predict properties of a specific aquifer where little is known. Although this inferred knowledge does not replace actual testing and assessment of the local aquifer, it can be useful, as a first step, to develop a working hypothesis about the local aquifer, especially in sparsely studied areas. This article describes a system of categorizing aquifers in the Canadian Cordillera Hydrogeologic Region (first described by Halstead [1967] and here referred to as the "Region" or "Cordillera") based on general hydrogeological characteristics (Figure 1). Categorizing aquifers promotes increased general knowledge and understanding of the characteristics of local aquifers in this Region, and thus supports the management and protection of local groundwater resources.

The Canadian Cordillera Hydrogeologic Region occupies the mountainous region that covers much of British Columbia (except the Peace River country), as well as the Rocky Mountain foothills of southwestern Alberta, the southern part of the Yukon Territory, and part of the Northwest Territories; it is the westernmost of Canada's hydrogeologic regions (Figure 1; Sharpe et al., in press). Aquifers in the Region supply water to an estimated 1 million persons for drinking water, as well as for irrigation, aquaculture, and industrial processing needs. The Region is physiographically diverse, comprising massive mountain ranges, highlands, foothills, plateaus, basins, and lowlands, with a total relief of over 4000 m (the greatest in Canada) and covering over 1 million km^2. The Region's climate varies widely from Mediterranean conditions along the southwest coast to polar conditions

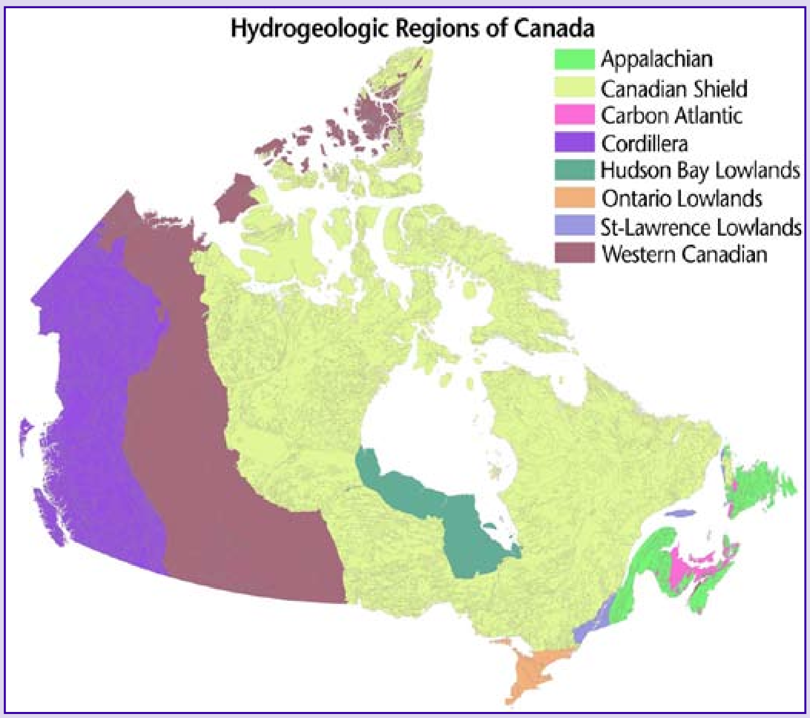

Figure 1. Hydrogeologic regions of Canada (Source: Rivera, in press; reproduced with permission of the Geological Survey of Canada).

at high mountain elevations and in the north. Mean annual precipitation generally decreases from west to east across the Region (following the general movement of the weather fronts), ranging, for example, from 3306 mm at Tofino on the west coast of Vancouver Island to 293 mm at Kamloops and 472 mm at Banff, Alberta. Annual precipitation also generally increases with elevation due to orographic effects.

Seasonal climatic variations control the annual quantity and form of precipitation, thereby affecting the timing and amount of runoff to streams and recharge to aquifers in the Cordillera. Coastal areas experience highest precipitation during the winter months, with much of it falling as rain, except at higher elevations where it may fall as snow. In these coastal areas, groundwater recharge mostly occurs during the winter months when the rate of evaporation and transpiration are at their seasonal lowest. Consequently, the natural groundwater levels in coastal areas show a seasonal high during winter or early spring, and decline from spring to late fall (see Figure 2a). In contrast, interior areas have their highest precipitation during the summer months, but much of this is evaporated or transpired and does not normally contribute to groundwater recharge. In the interior, snow accumulations during the winter months, and at higher elevations, are important for recharge during the spring and early summer when snowmelt occurs. Thus, groundwater levels in the interior generally are at a seasonal high in late spring or early summer and then decline over the summer and early fall. The groundwater level generally reaches a seasonal low during the winter months, when precipitation at the land surface is frozen (see Figure 2b).

Glacial history, surficial and bedrock geology, and tectonic history greatly influence the occurrence, distribution, and characteristics of aquifers in the Region. Most surficial

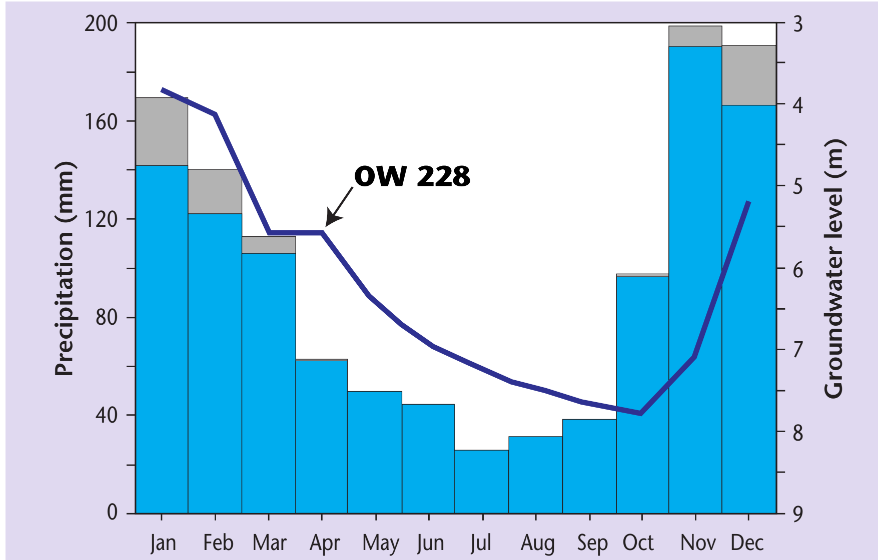

Figure 2a. Average monthly precipitation at Nanaimo (coastal setting: the blue bars represent rainfall and the grey bars represent snowfall). The mean annual precipitation at Nanaimo is 1163 mm. Also plotted (dark blue line) is the average monthly groundwater level from Observation Well No. 228. Groundwater level in the aquifer is recharged by rain falling during the fall and winter months (November to February).

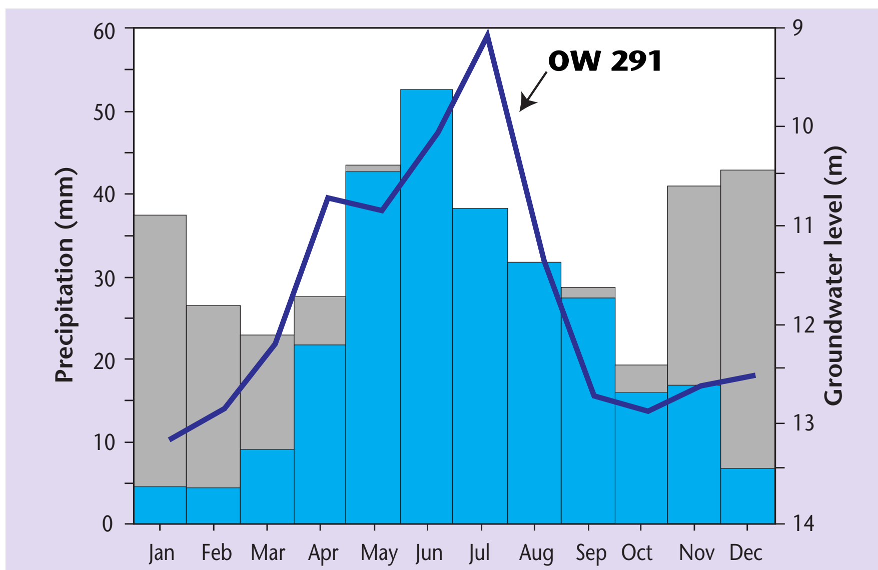

Figure 2b. Average monthly precipitation at Cranbrook (interior setting: the blue bars represent rainfall and the grey bars represent snowfall). The mean annual precipitation at Cranbrook is 411 mm. Also plotted (dark blue line) is the average monthly groundwater level from Observation Well No. 291. Groundwater level in the aquifer is recharged, not from the relatively high precipitation in May–June, but rather from snowmelt from the preceding winter months (November to March).

or unconsolidated aquifers are formed by deposition of sand and gravel in moving water under a fluvial or, if by moving water during glacial times, a glaciofluvial environment related to the last period of glaciation. Glacio-fluvial sand and gravel aquifers formed during ice advance tend to be overlain by till or glaciolacustrine clay and silt, and are lithologically confined. Glaciofluvial sand and gravel aquifers formed during the melting of the

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ice are commonly unconfined. The bedrock geology of the Cordillera is extremely varied and complex due to the Region's geologic, tectonic, and volcanic history. Holland (1976) generalized the bedrock geology of the Region into six main bedrock types:

1. intrusive igneous rocks;
2. flat-lying lava, and some sedimentary rocks;
3. flat or gently dipping sedimentary rocks;
4. folded sedimentary rocks;
5. folded and faulted volcanic and sedimentary rocks; and
6. foliated metamorphic rocks of various ages.

Despite the presence of different types of bedrock in the Cordillera, bedrock permeability exists mostly as a result of development of fractures or faults from tectonic forces or, in limestone, from development of dissolution cavities (karst). In the Cordillera, fractures and faults developed in igneous intrusive, foliated metamorphic, and folded and faulted volcanic and sedimentary rocks, give these types of rocks sufficient secondary permeability to form aquifers. The permeability, however, is often *anisotropic*[1] because the fractures or faults are discrete and have specific orientations in the bedrock. The porosity and *storativity*[2] of fractured or faulted bedrock are also very low (e.g., porosity of less than a few percent). Extensive areas of central British Columbia are underlain by relatively unaltered, flat-lying lava of Tertiary age (e.g., the Cariboo-Chilcotin area). These are mostly basalts and individual flows that can be hundreds of metres thick. This lava forms an important aquifer because groundwater typically occurs in joints, and in fractured and weathered contact zones between the lava flows.

The Province of British Columbia and the Canadian Government (through the Geological Survey of Canada and Environment Canada) have conducted groundwater studies in the Region since the 1950s. The Province of British Columbia has also been mapping and classifying developed aquifers in the Region since 1994 (for background on the BC Aquifer Classification System, see adjacent sidebar and Berardinucci and Ronneseth 2002). This work, and the resulting inventory, has enabled the identification of aquifer types within the Region and improved our understanding of their general hydrogeologic characteristics.

Major Aquifer Types in the Canadian Cordillera Hydrogeologic Region

In the Cordillera Hydrogeologic Region, aquifers generally fall into the following six categories (refer also to Figures 3a and 3b).

Unconsolidated Sand and Gravel Aquifers

1. *Unconfined*[3] fluvial or glaciofluvial aquifers along river or stream valleys
   a. Aquifers along major higher-order rivers, where the potential of hydraulic connection with the river exists,
   b. Aquifers along moderate-order rivers, where the potential of hydraulic connection with the river exists, or
   c. Aquifers along lower-order (< 3–4) streams in confined valleys, where aquifer thickness and lateral extent are more limited
2. Unconfined deltaic aquifers
3. Unconfined alluvial fan or colluvial aquifers
4. Aquifers of glacial or pre-glacial origin
   a. Unconfined glaciofluvial outwash or ice contact aquifers,
   b. *Confined*[4] aquifers of glacial or pre-glacial origin, or
   c. Confined aquifers associated with glaciomarine environments

Bedrock Aquifers

5. Sedimentary rock aquifers
   a. Fractured sedimentary bedrock aquifers, or
   b. Karstic limestone aquifers
6. Crystalline rock aquifers
   a. Flat-lying or gently-dipping volcanic flow rock aquifers, or
   b. Crystalline granitic, metamorphic, meta-sedimentary, meta-volcanic, and volcanic rock aquifers

The categories of aquifer types are based on geologic and hydrologic properties, as well as on practical considerations, such as data availability. The main geologic factors are the origin and type of the geologic deposit that comprise an aquifer (e.g., sand and gravel aquifer forming a delta at the mouth of a river or a plutonic granitic fractured bedrock aquifer). The origin and type of geologic deposit often governs an aquifer's hydraulic properties, such as the nature of the porous medium (porous sand and gravel, or fractured bedrock) and ability to transmit and store water. Another consideration is the hydraulic connection between an aquifer and a river, stream, or lake. A direct hydraulic connection can be advantageous for potential well yields because pumping could induce infiltration of surface water into those aquifers. A practical consideration, particularly for unconsolidated aquifers buried at depth, is that it is often difficult to identify the origin of these buried unconsolidated sand and gravel aquifers based on very limited well record data. Buried unconsolidated sand and gravel aquifers are grouped into confined, unconsolidated sand and gravel aquifers of glacial or pre-glacial origin (Type 4b). Descriptions of the aquifer types are presented directly below; many of the aquifer types are illustrated in Figures 3a and 3b, which represent aquifers in a coastal and interior setting, respectively.

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The BC Aquifer Classification System

The British Columbia Aquifer Classification System was developed in 1994 (Kreye and Wei 1994). Its objective was to interpret raw data (primarily well records and geologic mapping) to identify and classify aquifers, and thus:

- provide a framework to direct detailed aquifer mapping and characterization;
- provide a method of screening and prioritizing management, protection, and remedial efforts on a provincial, regional, and local level;
- identify the level of management and protection an aquifer requires;
- build an inventory of the aquifers in the province; and
- increase public knowledge and understanding of their local aquifer.

The aquifer classification system has two main components (Figure A-1):

a. classification component
b. ranking value component

The **classification component** classifies an aquifer on the basis its level of development and its vulnerability to contamination. The classification component categorizes an aquifer based on its current level of groundwater development and vulnerability to contamination (categories A, B, and C for high, moderate, and low vulnerability, respectively). The level of development (categories I, II, and III for high, moderate, and light development, respectively) compares the amount of groundwater withdrawn from an aquifer (demand) to the aquifer's inferred ability to supply groundwater for use (productivity). The level of vulnerability (categories I, II, and III for high, moderate, and low vulnerability, respectively) of an aquifer is based on whether or not an aquifer is confined.

The combination of the three development and three vulnerability categories results in nine aquifer classes. The nine aquifer classes have an implied priority from a general management and protection standpoint, from IIIC, which is the lowest priority, to IA, which is the highest (Figure A-2).

The **ranking value component** assigns a number value to indicate the relative importance of an aquifer. Assigned values are derived from the following criteria:

1. aquifer productivity;
2. aquifer vulnerability to surface contamination;
3. aquifer area or size;
4. demand on the resource;
5. type of groundwater use; and known documented groundwater concerns related to:
6. quality; and
7. quantity.

The ranking value is determined by summing the points for each criterion (Figure A-3): the lowest ranking value possible is 5, and the highest ranking value possible is 21. Generally, the aquifer with the greater ranking value has the greater priority. Figure A-3 shows the ranking values applied for each criterion.

The classification and ranking value components are determined for the aquifer as a whole, and not for parts of aquifers.

To promote the appropriate use of the aquifer classification system, a guidance document was produced to assist users in interpreting and using the aquifer maps. This document can be found at: ***www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/aquifers/reports/aquifer_maps.pdf***

The aquifer maps and other hydrological information are also available online at: ***www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html***

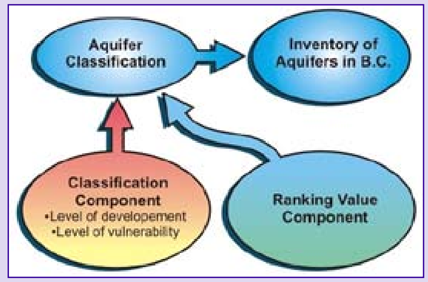

Figure A-1. The British Columbia Aquifer Classification System (Source: Rivera, in press; reproduced with permission of the Geological Survey of Canada).

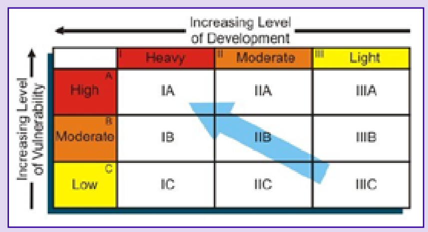

Figure A-2. Aquifer classes (Source: Rivera, in press; reproduced with permission of the Geological Survey of Canada).

Increasing ranking value →

	1	2	3
Productivity	low	moderate	high
Vulnerability	low	moderate	high
Area	< 5 km²	5 - 25 km²	> 25 km²
Demand	low	moderate	high
Type of use	non-drinking water	drinking water	multiple
Quality concerns	isolated	local	regional
Quantity concerns	isolated	local	regional

Figure A-3. Criteria and points for aquifer ranking value (Source: Rivera, in press; reproduced with permission of the Geological Survey of Canada).

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Type 1 – This category covers sand and gravel aquifers that are generally shallow, unconfined, and occur along river or stream valleys. Often both fluvial and glaciofluvial sand and gravel deposits form an aquifer along the river or stream valley bottom. Therefore, shallow sand and gravel aquifers underlying river or stream valleys—whether of fluvial or glaciofluvial origin—are categorized as the same general aquifer type. This category is further subdivided into the following three sub-categories.

- *Type 1a* – Aquifers found along major higher-order rivers with potential hydraulic connection to the river. These rivers are generally of low gradient and the depositional energy is relatively low to cause deposition of mostly sand, silt, some clay, and some gravel (e.g., the Chilliwack-Rosedale aquifer along the Fraser River near the City of Chilliwack).
- *Type 1b* – Unconfined sand and gravel aquifers found along moderate-order rivers with potential hydraulic connection to the river. These rivers have higher gradients compared to rivers of higher stream orders and the depositional energy is relatively high to cause deposition of mostly sand and gravel (e.g., the fluvial sand and gravel deposit along the Cowichan River on the east coast of Vancouver Island near the community of Duncan; the fluvial and terraced glaciofluvial sand and gravel deposits along the Kettle River at the Southern Interior community of Grand Forks).
- *Type 1c* – Sand and gravel aquifers found along lower-order (< 3–4) streams in confined valleys with floodplains of limited lateral extent, where aquifer thickness and size are more limited (e.g., fluvial or glaciofluvial deposits along a mountain stream).

Type 2 – This category covers sand and gravel aquifers that are shallow, unconfined, and which form deltas at the mouth of rivers and streams (e.g., the Scotch Creek aquifer at Shuswap Lake). Older deltas buried at depth below till, glaciolacustrine, or glaciomarine deposits have not been included here because it is generally difficult to identify buried sand and gravel as deltas based on limited data. These buried aquifers would be categorized under sand and gravel aquifers of glacial or pre-glacial origin (i.e., aquifer Type 4b).

Type 3 – This category covers sand and gravel aquifers that form alluvial fans or are of colluvial origin near the land surface. As with Type 2 aquifers, this category excludes older alluvial or colluvial aquifers buried at depth. The

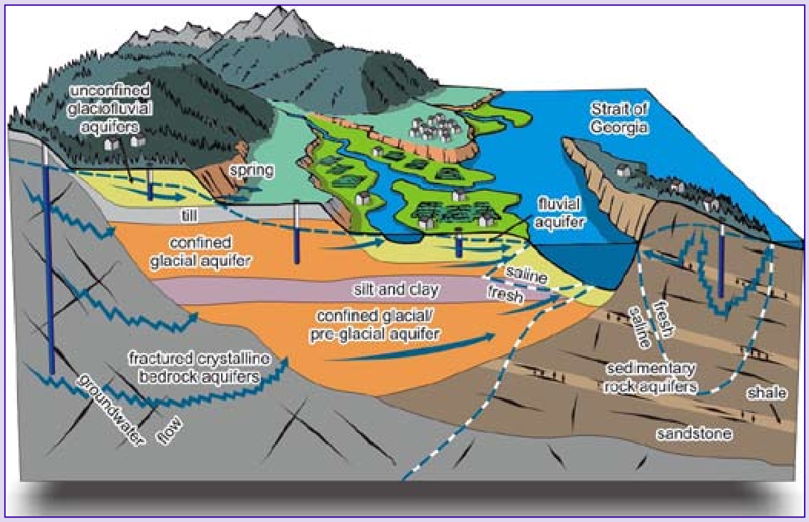

Figure 3a. Schematic diagram showing some of the different types of aquifers in the Region in a coastal setting (Source: Rivera, in press; reproduced with permission of the Geological Survey of Canada).

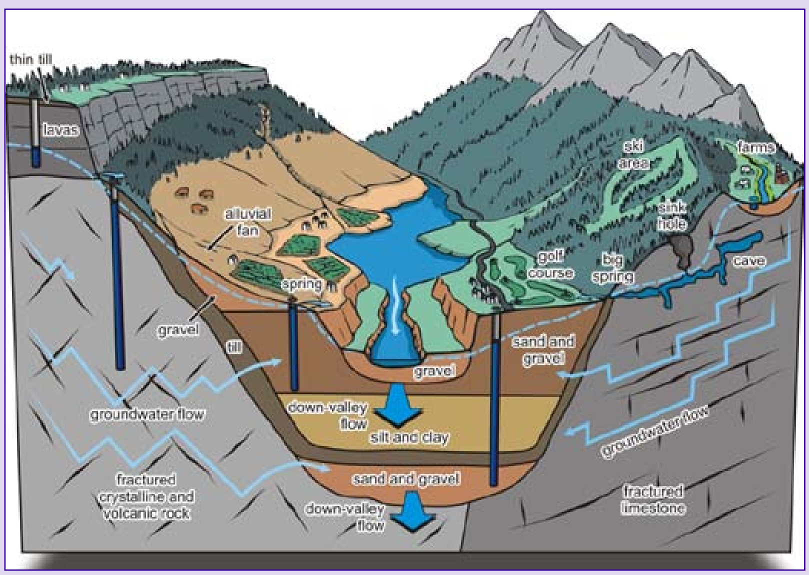

Figure 3b. Schematic diagram showing some of the different types of aquifers in the Region in an interior setting (Source: Rivera, in press; reproduced with permission of the Geological Survey of Canada).

Vedder River Fan aquifer at the City of Chilliwack is an example of this type of aquifer.

Type 4 – This category covers known glaciofluvial sand and gravel aquifers, as well as other sand and gravel aquifers identified in well records as occurring at depth, underneath till or glaciolacustrine deposits, and glaciomarine sand, sand and gravel aquifers. This category is further subdivided into the following three sub-categories.

- *Type 4a* – Unconfined glaciofluvial outwash or ice contact sand and gravel aquifers, generally formed near or at the end of the last period of glaciation. The Abbotsford-Sumas Aquifer is perhaps the most well-known and studied aquifer of this type in the Cordillera Region.
- *Type 4b* – Confined sand and gravel aquifers underneath till, in between till layers, or underlying glaciolacustrine deposits. The Quadra Sand, which occurs in the Georgia Depression on the east coast of Vancouver Island and along the southern mainland coast, is an excellent example of a confined glaciofluvial sand and gravel aquifer consisting of sand and gravel deposited as the glacier advanced south along the Georgia Depression. Other confined glaciofluvial sand and gravel aquifers occur between till layers, which is indicative of deposition during glaciation. Still other confined sand and gravel aquifers may be fluvial, alluvial, or colluvial deposits from a time prior to glaciation (and therefore lie underneath till or glaciolacustrine deposits). Unless a confined sand and gravel aquifer has been well studied, it is often difficult to determine its geologic origin and geomorphology based on limited data. Therefore, any water-bearing sand and gravel occurring underneath till, in between till layers, or under glaciolacustrine deposits is included in this sub-category.
- *Type 4c* – Sand and gravel aquifers that occur underneath known sand, silt, and clay deposited under a marine environment near the coast. Most of the few known aquifers in this category occur in the deep marine sediments at depth in low-lying areas in the Fraser Lowland, in Surrey and Langley, east of Vancouver.

Type 5 – This category is further subdivided into two sub-categories: (a) fractured sedimentary rocks and (b) karstic limestone rocks. The Nanaimo Group of fractured and faulted sedimentary rocks in the Gulf Islands and east coast of Vancouver Island is a classic example of the former sub-category. The limestone formations in the Rocky Mountains are an example of the latter sub-category. For fractured sedimentary rocks, groundwater flow occurs mostly along joints and in fractures and faults. Although this classification may also apply to karstic limestone, the major difference is that groundwater may flow in open dissolution channels and large cavities in karstic limestone aquifers.

Type 6 – This category is subdivided into two sub-categories: (a) flat-lying to gently dipping volcanic flow aquifers and (b) fractured crystalline rocks. Groundwater flow in flat-lying to gently dipping volcanic rocks can be through joints and fractures, but also in broken, weathered zones between flows. The large volcanic flow bedrock aquifer in the Central Interior of British Columbia near 70-Mile House is an example of this type of aquifer.

Groundwater flow in fractured crystalline rocks is mostly along joints, fractures, and faults. This sub-category includes igneous intrusive or metamorphic rocks (such as the fractured granodiorite aquifer underlying the Saanich Peninsula, north of Victoria). The meta-sedimentary, older volcanic, and meta-volcanic rocks are most similar in hydrogeological properties to granitic and metamorphic rocks and, therefore, have been included in this sub-category.

General Aquifer Characteristics

A summary of some of the characteristics for each category or sub-category of aquifer is presented in Table 1, including size, reported well depths and yields, representative *transmissivity*[5] values, and potential hydraulic connection to surface water. The summary information in Table 1 was compiled from available well records, attribute data associated with the classified aquifers, and available groundwater reports.

Generally, sand and gravel aquifers (Types 1–4) are of limited size (< 1 km^2 to over 100 km^2, with average sizes of a few to 10s of square kilometres). Their limited size reflects the variable topography and relief of the Canadian Cordillera Hydrogeologic Region. Bedrock aquifers can be larger, but even so, aquifers in the Cordillera are not typically considered "regional" aquifers.

Table 1 also shows that unconfined sand and gravel aquifers (Types 1, 2, 3, and 4a) are generally shallower (inferred from the well depth) than confined sand and gravel aquifers (Types 4b and 4c) and bedrock aquifers (Types 5 and 6). The shallower, unconfined sand and gravel aquifers (Types 1, 2, 3, and 4a) are considered highly vulnerable to contamination whereas the generally deeper, confined sand and gravel aquifers (Type 4b and 4c) are considered to have a moderate to low vulnerability. In the Region, widespread nitrate contamination from human activities is found in unconsolidated, unconfined aquifers (Types 1b, 2, 4a) where intense agricultural activity occurs or a high density of on-site sewerage systems and shallow water tables are present; these are the most vulnerable aquifers.

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Table 1. Summary of hydrogeologic characteristics of the major aquifer system types in the Cordillera Hydrogeologic Region (Source: Rivera in press; reproduced with permission of the Geological Survey of Canada).

Aquifer type	Range; average size (km^2)	Average range; average median well depths (m)	Average range; average median well yields (L/s)	Range; geometric mean transmissivity (m^2/d)	Hydraulic connections with surface water?	Examples of aquifer types
1. Unconfined aquifers of fluvial or glaciofluvial origin along river valley bottoms						
a. Aquifers along higher-order rivers	< 1–140; 27	12–83; 23	2–17; 3	350–22 000; 4500	Common	Agassiz, Chilliwack-Rosedale
b. Aquifers along moderate-order rivers	< 1–120; 15	11–53; 22	2–41; 6	1–36 000; 1300	Common	Grand Forks, Duncan, Chemainus, Nechako, Merritt
c. Aquifers along lower-order streams	< 1–23; 7	9–43; 19	1–22; 4	160–240; 200 (based on two values)		Cache Creek, Little Fort
2. Unconfined deltaic aquifers	< 1–19; 4	5–27; 12	2–15; 6	960–2390; 1500	Common	Scotch Creek near Chase
3. Unconfined alluvial, colluvial fan aquifers	< 1–54; 5	13–47; 24	2–23; 4	25–5600; 710	Common in aquifers adjacent to surface water	Vedder River Fan at Chilliwack
4. Aquifers of glacial or pre-glacial origin						
a. Unconfined glacio-fluvial aquifers	< 1–90; 8	12–59; 24	1–22; 3	2–89 000; 690	Common in aquifers adjacent to surface water	Abbotsford, Langley, Hopington
b. Confined glacial or pre-glacial aquifers	< 1–330; 13	20–83; 39	0.8–12; 2	1–120 000; 250		Quadra Sand aquifers in the Georgia Basin, Okanagan and Coldstream valleys
c. Confined glacio-marine aquifers	2–190; 32	23–180; 61	0.1–14; 0.6	45–410; 150	Limited	Nicomekl-Serpentine in Surrey and Langley
5. Sedimentary rock aquifers						
a. Fractured sedimentary rock aquifers	< 1–700; 24	22–140; 56	0.1–3; 0.3	0.1–480; 4	Limited	Nanaimo Group aquifers in the Gulf Islands and east coast of Vancouver Island
b. Karstic aquifers	2–36; 11	35–130; 75	0.1–1; 0.3	N/A	Unknown, but possible	Limestone aquifers in the Central Canadian Rockies, Sorrento, Fort St. James
6. Crystalline rock aquifers						
a. Flat-lying volcanic flow aquifers	< 1–6500; 420	21–130; 62	0.1–3; 0.3	11–47; 23 (based on three values)	Limited	Aquifer classification #124 around 70 Mile House
b. Fractured igneous intrusive, metamorphic, fractured volcanic, or metavolcanic aquifers	< 1–540; 31	28–150; 71	0.1–5; 0.4	0.2–400; 9	Limited	Saanich granodiorite, granitic aquifers along Sunshine Coast, metabasalt aquifer at Metchosin near Victoria

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Although some nitrate is also found in confined unconsolidated aquifers (Type 4b), windows may be present in the confining layers in those aquifers; nitrate found in Type 4b aquifers is usually isolated or localized. The vulnerability of bedrock aquifers (Types 5 and 6) in the Region is variable and depends to a large degree on the nature and thickness of overlying unconsolidated materials.

Shallow, unconfined sand and gravel aquifers are also expected to have the greatest potential of hydraulic connection to surface water. Public water supply wells completed into shallow Type 1, 2, and 3 aquifers have the potential to draw in surface water during pumping and may require an assessment to determine whether disinfection of the well water is required before distribution and use.

The productivity of aquifers, as reflected by the reported well yield and transmissivity, is generally greater for sand and gravel aquifers than bedrock aquifers. Despite their limited size, the sand and gravel aquifers in the Cordillera are actually some of the most productive in Canada (e.g., well yields of up to several 10s of litres per second and transmissivity values of up to 10s of thousands of square metres per day). The productivity of bedrock aquifers is generally lower, but bedrock can also be a viable source of domestic water supply where sand and gravel aquifers are not present.

Understanding and categorizing a local aquifer's general characteristics may allow decision makers to start developing broad management and protection strategies.

Conclusions

Knowledge of local aquifer characteristics is key to managing the local groundwater resource. To support local management and protection of groundwater, however, it may not be practical to conduct detailed aquifer characterization studies for each of the more than 900 developed aquifers known to exist in the Canadian Cordillera Hydrogeologic Region. Therefore, if an aquifer's type can be categorized through simpler assessment techniques such as interpretation of local well records and surficial and bedrock geologic mapping, then it may be possible to ascertain some general characteristics of the local aquifer (e.g., local extent, shallow or deep, expected productivity, potential connection to surface water, confined/unconfined) based on similar types of aquifers studied elsewhere. Understanding and categorizing a local aquifer's general characteristics may allow decision makers to start developing broad management and protection strategies. For example, it may be important for a drinking water officer to recognize the need to assess the potential connection between surface water and groundwater and to establish disinfection requirements for the operation of a public water supply well that is drilled into a Type 1, 2, or 3 aquifer. Where Type 1, 2, 3, and 4a aquifers exist and are relied upon as a water supply source, a local government may want to consider the use of more detailed vulnerability mapping to identify areas of high vulnerability or high risk to aid in planning or zoning land use. Finally, local governments may want to consider establishing more stringent pumping test requirements under water servicing by-laws for new subdivision developments where the source of water supply is from a fractured rock aquifer (Type 5b or Type 6 aquifer).

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Endnotes

1. Anisotropic means physical properties of an aquifer or a geologic formation, such as permeability, is not the same in all directions.
2. Storativity means the amount of water an aquifer will release or yield from its pores when the groundwater level is lowered as, for example, during pumping.
3. Unconfined means the aquifer is not overlain by a low permeable geological formation or deposit, such as clay or till
4. Confined means the aquifer is overlain by a low permeable geological formation or deposit, such as clay or till.
5. Transmissivity is the ability of an aquifer to transmit groundwater and is a product of the aquifer's hydraulic conductivity and thickness.

For further information, contact:

Mike Wei
BC Ministry of Environment,
Victoria, BC
Tel: (250) 356-5062
Email: Mike.Wei@gov.bc.ca

Diana Allen
Simon Fraser University
Email: dallen@sfu.ca

Alan Kohut
Hy-Geo Consulting
Email: apkohut@telus.net

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Steve Grasby
Geological Survey of Canada
Email: Steve.Grasby@nrcan-rncan.gc.ca

Kevin Ronneseth
BC Ministry of Environment
Email: Kevin.Ronneseth@gov.bc.ca

Bob Turner
Geological Survey of Canada
Email: Bob.Turner@nrcan-rncan.gc.ca

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