Research and Information Needs Assessment to Support Sustainable Watershed Management in the South Coast and West Coast Natural Resource Regions, British Columbia

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Research and Information Needs Assessment to Support Sustainable Watershed Management in the South Coast and West Coast Natural Resource Regions, British Columbia

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Watershed management issues are among the many challenges facing natural resource managers in British Columbia. The B.C. Ministry of Forests, Lands and Natural Resource Operations (FLNRO) conducted a research and information needs assessment survey to help identify specific knowledge gaps and develop strategic priorities for research to support sustainable water resource management in the South Coast and West Coast Natural Resource Regions of British Columbia. In total, 216 individuals who were familiar with surface water and/or groundwater issues in these two regions completed all or portions of the survey and identified priority topics for research, monitoring, data collection, and policy development. The survey was conducted from October 20 to November 30, 2015. This report is the third in a series of regional assessments that are being conducted across British Columbia. The first regional assessment was completed in northeastern British Columbia (Lapp et al. 2015); the second was completed in the Thompson–Okanagan Region (Scherer et al. 2016).

Survey respondents most frequently identified the following priority research and management needs:

- surface water quantity research on low-flow magnitude and timing, rainfall timing and rates, peak flow magnitude, and snow accumulation;
- climate change effects on all aspects of water quantity, water supply, and water quality. Also highlighted was the need to better understand how extreme events such as drought and floods will affect water quantity, water quality, aquatic ecosystems, and natural resource development hazards;
- understanding and management of cumulative effects and land-use effects on all aspects of surface water, groundwater, aquatic ecosystems, and natural resource development hazards;
- groundwater quantity research on surface water–groundwater interactions, and aquifer identification and characterization to quantify the availability, magnitude, and extent of groundwater resources;
- requirement for water budgets and water consumption/use data to improve the understanding of water availability/withdrawals to ensure the sustainable allocation of both surface water and groundwater; and
- environmental flow needs for fish-bearing streams, temperature-sensitive streams, and land-use activities in riparian areas.

More than 65% of the respondents identified online access to data, online access to georeferenced data, hydrometric monitoring data, and online access to analysis results/products as a high priority. Written responses also highlighted the need for increased hydrometric monitoring of surface waters as being very important.

Key policy and regulatory needs that were identified included groundwater regulation and groundwater resource inventory to determine resource availability and quality, and threats to sustainability. The following were also identified as key policy and regulatory issues:

- increased monitoring of water consumption and use to better allocate surface water and groundwater to support sustainable water supply;

- government funding to increase regulatory requirements and capacity to enforce regulations to protect water;
- additional information about the implementation of the *Water Sustainability Act* and how the Act will maintain and/or protect water sources;
- integrated and watershed-scale planning to ensure that land-use activities do not negatively affect community water supplies; and
- increased requirements for improved stormwater management to minimize land-use effects on water.

Respondents also identified the following as emerging pressures and issues:

- reducing uncertainty about climate change effects on water supply for both consumptive and aquatic ecosystem uses;
- identification of drought and water storage requirements;
- the need for increased government capacity and funding to improve resource management and monitoring;
- the need for improved groundwater regulation, licensing, and monitoring;
- implementation of the *Water Sustainability Act*; and
- the need for sustainable allocation of water supplies.

The survey results identified many of the same themes and topics that were identified in previous reports (e.g., Hollstedt 2000; Redding 2011; Brandes and O'Riordan 2014; Lapp et.al. 2015; Scherer et al. 2016). In addition to this report, a database of data sources, information sources, and relevant research projects and publications from British Columbia and adjoining jurisdictions was compiled. The database is intended to provide a first stop for researchers and managers in locating key water resource information of regional relevance. The database is available at www.bcwatertool.ca/info-sources/.

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INTRODUCTION

Project Purpose

Watershed management issues are among the many challenges facing natural resource managers in British Columbia. The B.C. Ministry of Forests, Lands and Natural Resource Operations (FLNRO) has conducted a research and information needs assessment to support sustainable water resource management in the South Coast and West Coast Natural Resource Regions of British Columbia (Figure 1). This report is the third in a series of regional assessments that has been conducted across British Columbia. The first regional assessment was completed in northeastern British Columbia in 2014 (Lapp et al. 2015); the second was completed in the Thompson–Okanagan Region in 2015 (Scherer et al. 2016).

An applied research strategy will be developed to support sustainable water resource management in the South Coast and West Coast Natural Resource Regions by using this assessment and other relevant research and data as its foundation. Individuals involved in water and natural resource management were asked to participate in a survey to help identify related research and information needs.

The survey was divided into seven main themes:

- surface water quantity;
- groundwater quantity;
- surface water quality;
- groundwater quality;
- groundwater–surface water interactions;
- aquatic ecosystems; and
- natural resource development hazards.

To support sustainable water management in the South Coast and West Coast Natural Resource Regions, survey respondents were asked to identify:

- key research questions and information needs;
- knowledge and data requirements;
- policy and regulatory needs;
- emerging pressures/issues and the expected new information required to address them; and
- current and planned water-related research activities that are directly relevant to water resource management in the regions.

The identification of these needs, issues, and research activities is intended to aid FLNRO in identifying future applied water research areas, monitoring requirements, and tools to support sustainable water resource management.

Report Format

This report presents the data collection methods used in the survey, a profile of the respondents, the ranking (high, medium, low, not applicable) of key research and information needs by topic area within each theme, and a summary of the written comments for each of the seven main themes.

Appendix 1 presents average priority rankings of responses in relation to the main group affiliations that were surveyed. Appendix 2 lists current and planned water-related research that was identified by the respondents. Appendix 3 presents the cover letter and survey questions that were sent to the respondents.

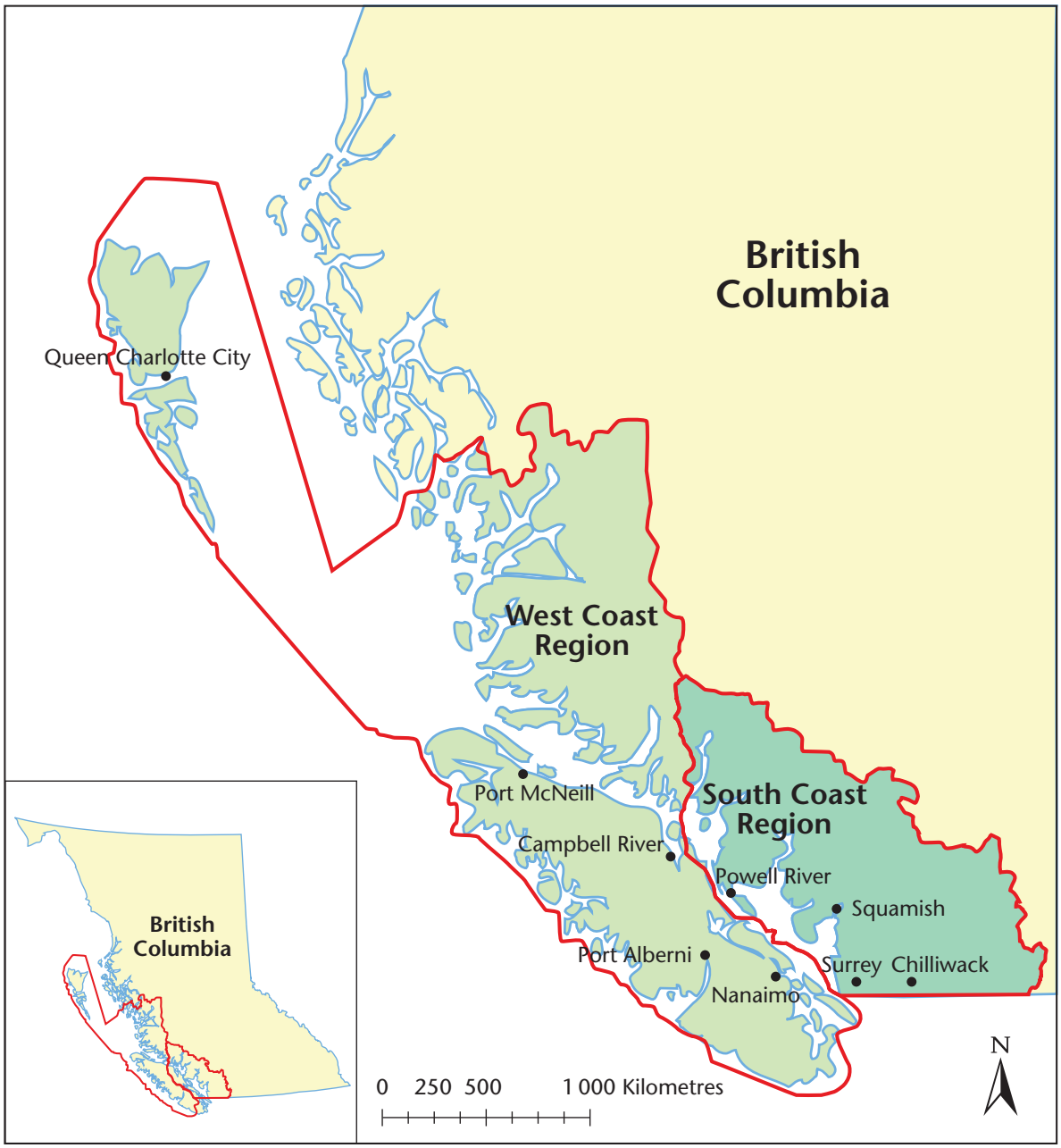

FIGURE 1 *Extent of the survey conducted within the South Coast and West Coast Natural Resource Regions (boundary of the two regions shown by red line) in British Columbia.*

A separate database of data sources, information sources, and relevant research projects and publications from British Columbia and adjoining jurisdictions was also compiled and is available at www.bcwatertool.ca/info-sources/. The database includes information on historic and current water projects and related publications, databases, and monitoring activities conducted within the South Coast and West Coast Natural Resource Regions that are directly relevant to water resource management in these regions.

METHODS

Study Design

A list of potential respondents was compiled and prioritized in conjunction with staff from FLNRO. Selection was based on the respondents' profession and their experience within their organizations. All respondents were familiar with surface water and/or groundwater issues in the South Coast and/or West Coast Natural Resource Regions of British Columbia.

Study Delivery

An introduction to the project and a link to the survey questions was sent by email to most respondents (Appendix 3). A small number of respondents was interviewed by telephone or in-person. The survey was conducted from October 20 to November 30, 2015. In some instances, respondents forwarded the survey to other people and these people also completed the survey (e.g., regional managers distributed the survey to staff members); therefore, the number of responses received is not consistent with the number of respondents contacted directly by the survey team (Table 1).

TABLE 1 *Number and affiliation of individuals contacted, and the number of respondents and the response rate by affiliation*

Sector/employment affiliation	Response count	Number contacted	Response rate (%)
Provincial government			
FLNRO	39	61	64
B.C. Ministry of Environment	21	41	51
B.C. Ministry of Energy and Mines	0	1	0
B.C. Ministry of Agriculture	0	0	–
Coastal Health Authority	4	13	31
Crown Corporation	1	5	20
Total	**65**	**121**	**54**
Consulting (incl. water, geoscience, environmental, and fisheries consultants)	47	88	53
Community/stewardship/NGO	30	97	31
Local/regional government	24	56	43
Academic	20	28	71
Federal government			
Environment Canada	0	3	0
Fisheries and Oceans Canada	14	44	32
Agriculture Canada	0	0	–
Total	**14**	**47**	**30**
Natural resource industry			
Forest industry	6	18	33
Mining industry	1	1	100
Total	**7**	**19**	**37**
Water purveyor	5	16	31
First Nations	4	17	24
Agriculture industry/producer	0	0	–
Total of all respondents	216	489	44

Study Limitations

This needs assessment is a qualitative, non-random survey of respondents who were identified as being interested or involved in water-related issues within the South Coast and West Coast Natural Resource Regions. This report does not offer any interpretation of the respondents' input; it only presents and summarizes the results collected in the survey.

RESULTS

Profile of Respondents

The identification of a respondent's affiliation or sector helped determine where geographically and in which sectors research is being conducted, what research or monitoring needs exist, and what opportunities for future collaboration are possible. In total, 489 individuals were contacted; 216 completed all or portions of the survey (a survey response rate of 44%). Table 1 lists the number of individuals contacted at each affiliation, and the number of responses. Most respondents were employed by the provincial government, followed by consulting firms, community and non-government organizations, local/regional government, and academia (Figure 2).

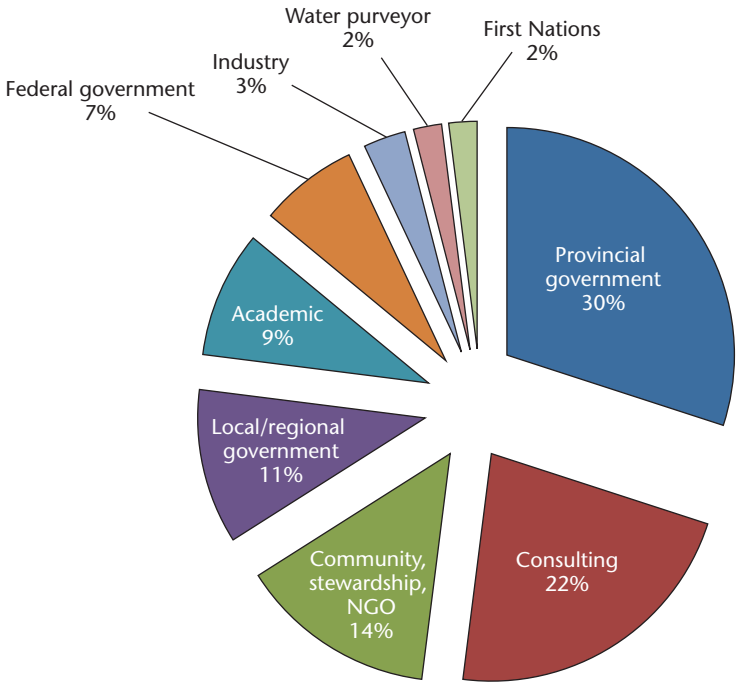

FIGURE 2 *Percentage of total responses (*n = *216) by sector affiliation. The survey targeted individuals with knowledge of surface water– or groundwater-related issues. Most respondents were provincial government employees, and their primary areas of practice were watershed management, fisheries and aquatic ecology, research, geoscience and engineering, and surface water and groundwater hydrology (Table 2). The least common areas of practice were oil and gas production, energy (e.g., hydropower, oil and gas, geothermal), and mining/mineral extraction.*

Many of the following tables list an "Other" category, which includes additional information that was not addressed in the original categories in the survey. The "Other" responses provided by respondents are listed below the respective tables.

TABLE 2 *Respondents' field/area of primary practice (n = 216). (Note: respondents were able to select a maximum of three responses.)*

Field/area of primary practice	Response (%)
Watershed management	37
Fisheries and aquatic ecology	30
Research	23
Geoscience and engineering	21
Surface water hydrology	20
Community/stewardship/NGO	18
Groundwater hydrology	13
Water purveyor	12
Policy development	12
Surface water management (allocation, licensing)	10
Natural resource hazards (e.g., mass movements, floods)	10
Forest management	9
Land-use planning	7
Groundwater management (allocation, licensing)	6
Wastewater management	6
Hydropower production	4
Mining and minerals extraction	3
Agriculture	2
Oil and gas production	1
Energy (e.g., oil and gas, hydropower, geothermal)	1
Mining and mineral extraction	1
Other[a]	15

a Other included hydrometrics; wildfire road/guard rehabilitation; groundwater chemistry/quality; karst resource assessments; previous employment as water purveyor; fisheries management; climatology; environmental monitoring; water utility regulation; regulation of private water utilities; groundwater protection; engineering officer; salmon enhancement; implement *Drinking Water Protection Act* and Drinking Water Protection Regulation, provide information and advice to water purveyors and local, provincial, and federal governments related to drinking water; storm and sanitary sewer systems; water conservation theory and practice; not fish, but amphibians (especially tailed frog); waste and water management related to mining, including tailings, dams, closure, baseline for groundwater, surface water, and mine waste; structured decision-making, decision analysis, and stakeholder participation; watershed restoration; conservation and protection (enforcement); public health and preventive medicine physician; stream non-government organization.

Respondents identified the primary areas of their professional practice (Table 3). The five most common responses were monitoring, stewardship and conservation, management, research, and operations. The least common responses were policy and regulation, remediation, allocation/licensing, and compliance and enforcement.

TABLE 3 *Respondents' primary water-related focus of professional practice (n = 216). (Note: respondents were able to select a maximum of three responses.)*

Field/area of primary practice	Response (%)
Monitoring (e.g., trend, baseline, compliance)	41
Stewardship and conservation	36
Management	33
Research	25
Operations	25
Data collection (e.g., well log data, consultant reports)	23
Planning	19
Policy and regulation	17
Remediation	10
Allocation/licensing	8
Compliance and enforcement	7
Other[a]	11

a Other included emergency response; karst planning and management for both the public and private sectors; water quality/quantity; oversight of operations and rates of privately owned community water systems; development and implementation of a watershed plan for the Lower Coquitlam River watershed; groundwater science; public health; design of stream offsetting; mostly forestry-related effects on amphibians; "I don't work on water management"; water quality and quantity; engagement of technical and public stakeholders in decision processes; restoration; exploration and usage; water supply assessment; restoration of degraded habitat; providing information to inform adaptation; strategic planning; education; research on governance; watershed assessment and hydrological assessment for forest management; prevention of landslides; slope stability.

Surface water quantity and fish and aquatic ecosystems ranked the highest of the seven themes related to the respondents' primary areas of practice, followed by surface water quality and groundwater–surface water interaction themes; groundwater quantity, groundwater quality, and natural resource hazards themes ranked the lowest (Table 4).

TABLE 4 *Respondents' ranking of water-related themes in terms of relevance to the respondents' primary areas of practice (n = 216)*

	Rank (Percent of respondents)			
Theme	High	Medium	Low	Not applicable or not answered
Surface water quantity	66	20	6	8
Fish and aquatic ecosystems	54	23	12	11
Surface water quality	53	25	12	10
Groundwater–surface water interactions	39	30	16	15
Groundwater quantity	39	22	20	19
Groundwater quality	35	25	21	19
Natural resource hazards	30	35	19	16

Most respondents addressed in this survey (Figure 1) practiced on southern Vancouver Island and/or the Gulf Islands, the lower Fraser Valley, and northern Vancouver Island. The least number of respondents practiced in the Central Coast, Haida Gwaii, and the North Coast regional areas. Ten percent of the respondents practiced province-wide (Table 5).

TABLE 5 *Regional area(s) within which respondents practice (n = 216). (Note: respondents could choose more than one regional watershed.)*

Regional area	Response (%)
Vancouver Island South and Gulf Islands (e.g., Port Alberni, Nanaimo, Victoria)	54
Lower Fraser Valley (Hope to Vancouver)	45
Vancouver Island North (e.g., Campbell River, Port McNeill)	40
Howe Sound and Sunshine Coast (Squamish, Powell River)	34
Central Coast (e.g., Bella Coola)	25
Haida Gwaii	18
North Coast (e.g., Prince Rupert)	17
Province-wide	10

Survey Response Summaries

Respondents were asked to rank their priority information needs as high, medium, or low with respect to improving their ability to do their job. Respondents selected "not applicable" if an answer was not currently applicable to their job. It should be noted that response rate varied between survey questions because not all respondents answered all the questions (i.e., *n* values varied from 216 to 169).

Categories in Tables 6–20 are ranked by the number of "high" responses in descending order.

Many of the following tables list an "Other" category, which includes additional information that was not addressed in the original categories in the survey. The "Other" responses provided by respondents are listed below the respective tables.

Figures 3–17 provide the FLNRO staff responses and the overall average rank of all responses for each category of survey questions. An average priority ranking was calculated by using the following numerical rankings: 3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered. This information was provided to highlight whether FLNRO staff responses differed from the combined overall response. Figures showing how responses varied between affiliations are also provided in Appendix 1.

Surface water quantity hydrologic processes Respondents identified low-flow magnitude and timing, rainfall timing and rates, peak flow magnitude, and snow accumulation and melt rates as the highest-priority information needs related to surface water quantity hydrologic processes (Table 6). The lowest-priority information needs included annual water yield, infiltration and soil moisture storage, and evaporation and transpiration rates.

FLNRO staff responses were similar to the overall average priority rankings; however, FLNRO ranked the priorities in a slightly different order, with rainfall timing and rates, snow accumulation and melt rates, low-flow magnitude, and peak flow magnitude identified as the top four priorities (Figure 3).

TABLE 6 *Respondents' priority rankings of key information needs related to surface water quantity hydrologic processes (n = 215)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Low-flow magnitude	56	21	12	11
Low-flow timing	52	24	14	10
Rainfall timing and rates	52	28	11	9
Peak flow magnitude	51	23	15	11
Snow accumulation and melt rates	47	28	14	11
Peak flow timing	44	30	15	11
Groundwater–surface water interaction	41	31	13	15
Groundwater recharge	36	27	20	17
Annual water yield	33	33	15	19
Infiltration and soil moisture storage	23	33	21	23
Evaporation and transpiration rates	19	31	27	23

a Other comments included surface water use and timing (monthly volumes); "granting water licenses on Goudie Creek upstream from our system intake"; sediment data; seasonal flows; watershed hydrology response to climate change; "mostly concerned with base flow conditions but also the linkage with groundwater and improving our ability to understand where stressful environmental conditions may occur"; "more hydrometric stations, especially for smaller watersheds (< 100 km²) since there are huge data gaps all over province"; clean drinking water for communities; protect and maintain fisheries resources; percent effective impermeable versus permeable surfaces in the Cougar Creek watershed.

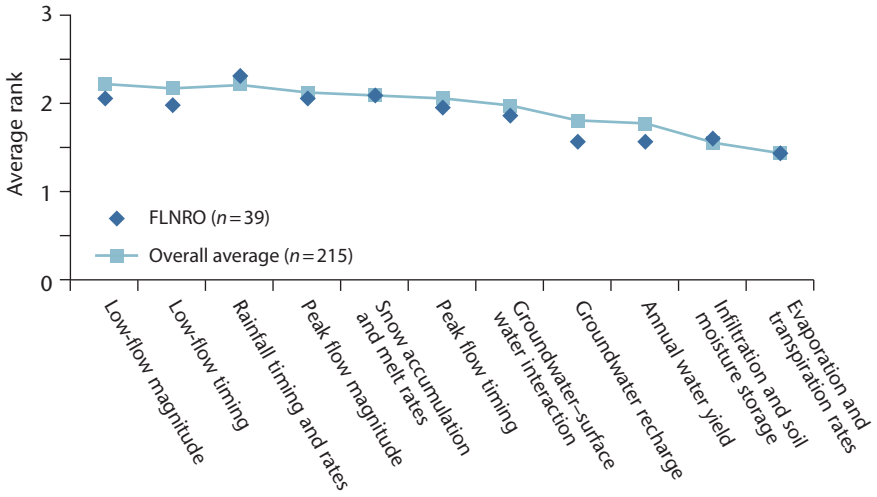

FIGURE 3 *Surface water quantity hydrologic processes: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff responses and all the combined individual responses for key information needs.*

Management of surface water quantity Respondents identified climate change effects on water supply, environmental flow needs, water availability/storage, cumulative hydrologic effects, and current allocation as the highest-priority information needs related to the management of surface water quantity (Table 7). Lower-priority information needs included hydropower generation, agricultural/range effects, mining effects, and recreational uses.

FLNRO staff responses were similar to or slightly lower than the overall average priority rankings (Figure 4).

TABLE 7 *Respondents' priority rankings of key information needs related to the management of surface water quantity (*n = *214)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Climate change effects on water supply	60	23	10	7
Environmental flow needs	56	22	10	12
Water availability/storage	53	23	12	13
Cumulative hydrologic effects	50	28	10	12
Current allocation	39	21	16	24
Forest management effects	30	34	23	13
Urban water management	23	29	25	23
Hydropower generation	18	26	27	29
Agricultural/range effects	17	29	27	27
Mining effects	11	30	31	28
Recreational uses	10	27	38	25

a Other comments included "Difficult to answer. Our role is acquiring and providing this information for management decisions"; conservation and restoration of urban forest and wetlands; percent effective impermeable versus permeable surfaces in North Delta/Surrey watersheds; sediment transport; "For those that I ranked 'medium'—it is because I find that we already have some information in those areas, and certainly more for agriculture effects than for cumulative effects for instance. So I ranked the gaps as higher needs"; and impacts on fisheries resources.

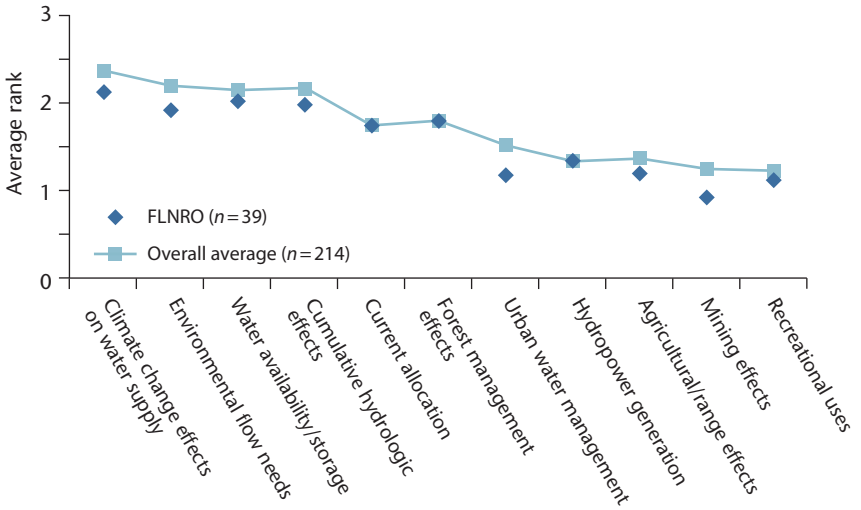

FIGURE 4 *Management of surface water quantity: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff responses and all the combined individual responses for key information needs.*

Groundwater quantity hydrogeologic processes Respondents identified water levels, groundwater–surface water interactions, aquifer mapping, recharge rates, and withdrawal amounts as the highest-priority information needs related to groundwater quantity hydrogeologic processes (Table 8).

Lower-priority information needs included lithology, flowing artesian conditions, and saltwater intrusion. FLNRO staff responses were similar to the overall average priority rankings but were slightly lower (Figure 5).

TABLE 8 *Respondents' priority rankings of key information needs related to groundwater quantity hydrogeologic processes (*n = *210)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Water levels	52	20	11	17
Surface water–groundwater interaction	49	26	10	15
Aquifer mapping	42	20	15	23
Recharge rates	41	24	14	21
Withdrawal amounts	40	21	14	25
Aquifer yield potential	35	21	19	25
Aquifer permeability and porosity	31	25	19	25
Flow direction	29	28	21	22
Aquifer "typing"	28	21	23	28
Storativity	27	25	21	27
Geological model	22	27	25	26
Lithology	22	22	25	31
Flowing artesian conditions	21	29	24	26
Saltwater intrusion	19	19	31	31

a Other comments included "no idea what this means"; "difficult to answer since our role is acquiring and providing this information for others to use"; conservation and restoration of urban forest and wetlands, percent effective impermeable versus permeable surfaces in North Delta/Surrey watersheds; "groundwater levels, lithology, and use are key. Also hydrometric data are important for assessing groundwater recharge/discharge areas. Database management and access is also important, as much data is difficult to locate and compile." "Our Watershed Plan does not really address groundwater to any great depth. Information on groundwater in our watershed would be very helpful"; and "Need to understand what should be used as a 'baseline' that will be used for before and after licensing in aquifers."

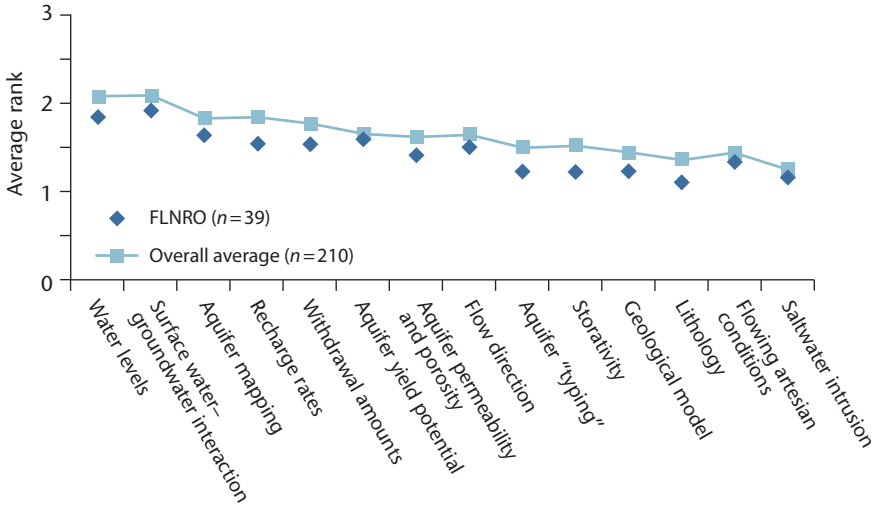

FIGURE 5 *Groundwater quantity hydrogeologic processes: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff responses and all the combined individual responses for key information needs.*

Management of groundwater quantity The highest-priority information needs related to the management of groundwater quantity were cumulative hydrologic effects, current groundwater availability, current groundwater withdrawals, climate change effects on water supply, and water well locations (Table 9). Urban water management, forest management effects, agricultural effects, and mining effects were the lowest-priority information needs. FLNRO staff responses were similar to the overall average priority rankings but were slightly lower (Figure 6).

TABLE 9 *Respondents' priority rankings of key information needs related to the management of groundwater quantity (*n = *211)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Cumulative hydrologic effects	45	26	11	18
Current groundwater availability	45	19	15	21
Current groundwater withdrawals	44	19	15	22
Climate change effects on water supply	43	28	11	18
Water well locations	40	21	16	23
Urban water management	24	26	25	25
Forest management effects	24	29	26	21
Agricultural effects	20	29	22	29
Mining effects	15	20	35	30

a Other comments included "difficult to answer since our role is acquiring and providing this information for management decisions"; conservation and restoration of urban forest and wetlands; percent effective impermeable versus permeable surfaces in North Delta/Surrey; and water table dynamics as a control on watershed biogeochemistry and constituent exports.

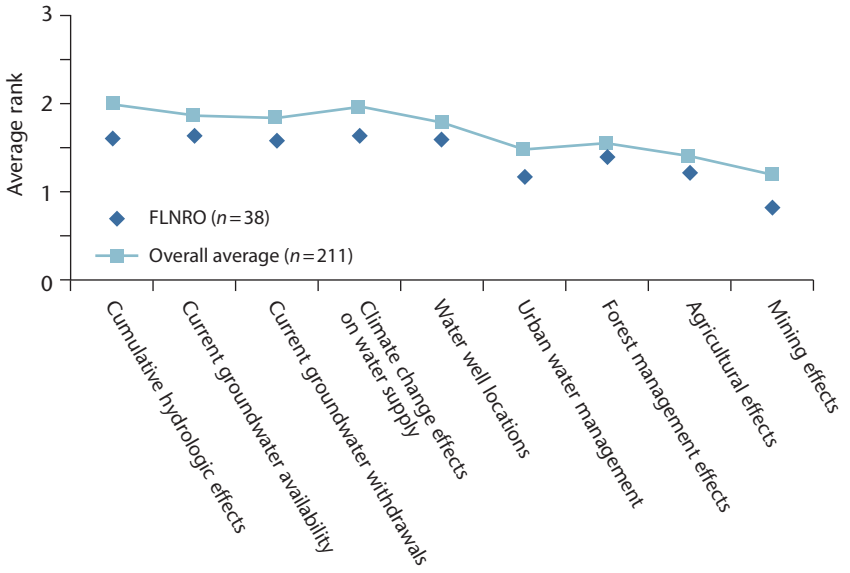

FIGURE 6 *Management of groundwater quantity: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff and all the combined individual responses for key information needs.*

Surface water quality Respondents identified sediment, turbidity, temperature, biological water quality, and nutrients as the highest-priority information needs related to surface water quality (Table 10). The lowest-priority information needs included organic chemicals, pharmaceuticals, and radiological agents. FLNRO staff responses were similar to but lower than the overall average priority rankings (Figure 7).

TABLE 10 *Respondents' priority rankings of key information needs related to surface water quality (*n = *205)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Sediment	53	23	8	16
Turbidity	52	24	9	15
Temperature	51	25	10	14
Biological water quality	48	20	16	16
Nutrients	39	28	12	21
Inorganic chemicals	34	26	16	24
Organic chemicals	27	28	22	23
Pharmaceuticals	15	15	33	37
Radiological agents	10	16	38	36

a Other comments included "everything is of high importance, but the overriding issue is getting more urban runoff infiltrating into the ground, which would greatly improve all issues of water quality"; stable isotopes of high water; "naturally occurring dissolved organic matter is our main focus; quantity effects on groundwater quality; water information is site/system specific over 900 systems in Island Health region"; dissolved metals; and "my focus is more on broad-scale indicators of watershed assessment, while of course these are all important, I'm not sure any would be directly relevant to my work. Any information on these would help to validate watershed level assessments."

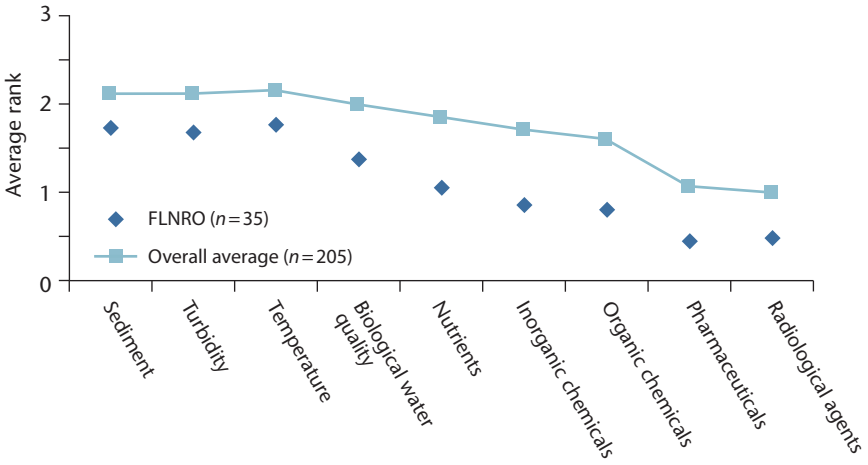

FIGURE 7 *Surface water quality: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff and all the combined individual responses for key information needs.*

Management of surface water quality Respondents identified activities in riparian areas, climate change effects, cumulative effects, aquatic ecosystem management, and activities in wetland areas as the highest-priority information needs related to the management of surface water quality (Table 11). The

lowest-priority information needs were saltwater intrusion, aquaculture effects, and range effects. FLNRO staff responses were similar to the overall average priority rankings; however, FLNRO staff ranked activities in wetlands and forest management effects as a higher priority than aquatic ecosystem management (Figure 8).

TABLE 11 *Respondents' priority rankings of key information needs related to the management of surface water quality (*n = *202)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Activities in riparian areas	57	23	5	15
Climate change effects	56	21	10	13
Cumulative effects	50	29	5	16
Aquatic ecosystem management	50	19	14	17
Activities in wetland areas	46	27	11	16
Forest management effects	40	25	22	13
Urban development effects	32	23	19	26
Agriculture effects	28	23	21	28
Mining effects	23	22	28	27
Oil and gas effects	21	16	27	36
Recreation	16	30	31	23
Saltwater intrusion	13	13	34	40
Aquaculture effects	11	16	28	45
Range effects	9	21	36	34

a Other comments included "Pacific Climate Impacts Consortium already does a great job on climate change"; oil effects due to urban runoff being piped directly into creeks; "we have so many questions about the effects of aggregate mining adjacent to the Coquitlam River. The City of Coquitlam has been advised to monitor turbidity above and below the mine sites using continuous monitoring equipment. The aggregate industry is represented on the Roundtable"; site/system specific; effects of independent power producers; and any information that would help to validate watershed level assessments.

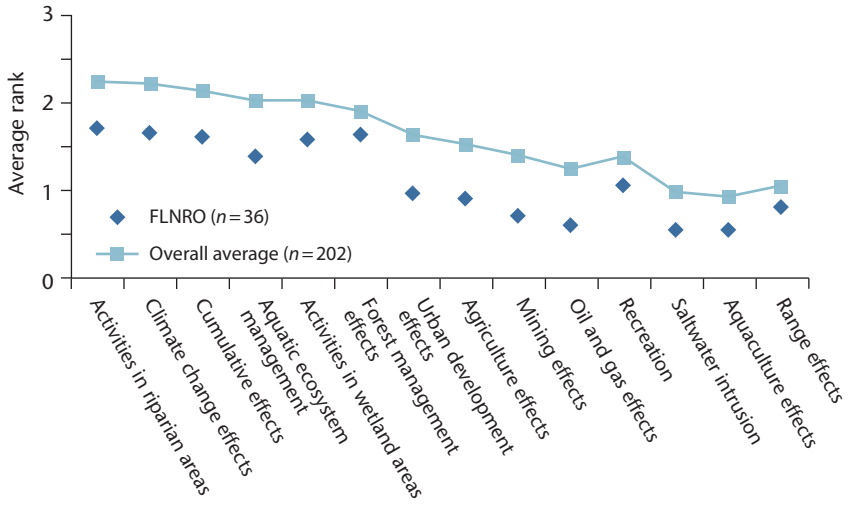

FIGURE 8 *Management of surface water quality: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff and all the combined individual responses for key information needs.*

Groundwater quality Respondents identified biological water quality, inorganic chemicals, nutrients, temperature, and organic chemicals as the highest-priority information needs related to groundwater quality (Table 12). The lowest-priority information needs were turbidity, sediment, radiological agents, and pharmaceuticals. FLNRO staff responses were similar to the overall average priority rankings, but the order of priority was different: biological water quality and temperature were ranked higher than nutrients and inorganic chemicals (Figure 9).

TABLE 12 *Respondents' priority rankings of key information needs related to groundwater quality (*n = *197)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Biological water quality	35	20	19	26
Inorganic chemicals	32	22	19	27
Nutrients	30	23	20	27
Temperature	25	20	30	25
Organic chemicals	24	25	24	27
Turbidity	20	17	27	36
Sediment	17	17	29	37
Radiological agents	11	17	32	40
Pharmaceuticals	9	17	34	40

a Other comments included stable isotopes of high water, and quantity effects on groundwater quality.

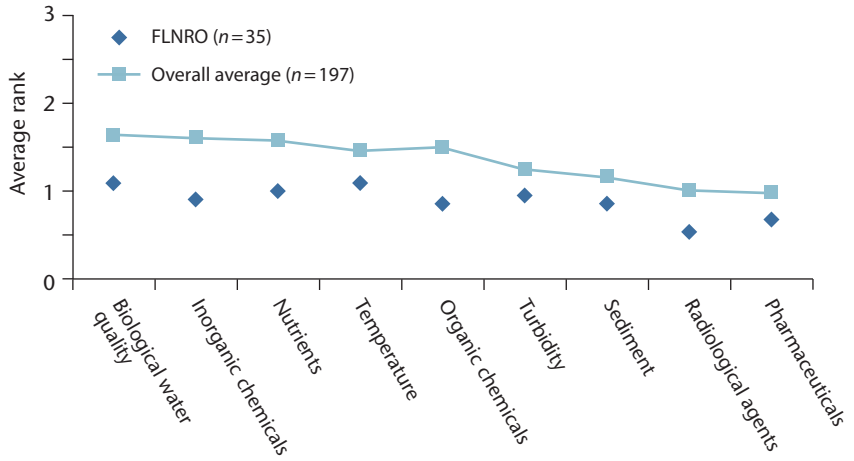

FIGURE 9 *Groundwater quality: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff responses and all the combined individual responses for key information needs.*

Management of groundwater quality Respondents identified cumulative effects, climate change effects, aquatic ecosystem management, urban development effects, and oil and gas effects as the highest-priority information needs related to the management of groundwater quality (Table 13). The lowest-priority information needs were range effects, aquaculture effects, and recreation. FLNRO staff responses were similar to the overall average priority rankings; however, FLNRO staff rated oil and gas effects as one of the lower priorities (Figure 10).

TABLE 13 *Respondents' priority rankings of key information needs related to the management of groundwater quality (*n = *189)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Cumulative effects	45	29	9	17
Climate change effects	41	28	13	18
Aquatic ecosystem management	29	25	21	25
Urban development effects	28	28	19	25
Oil and gas effects	28	16	23	33
Activities in wetland areas	26	30	20	24
Activities in riparian areas	26	27	21	26
Agriculture effects	25	26	21	28
Forest management effects	24	30	27	19
Mining effects	24	21	27	28
Saltwater intrusion	22	20	26	32
Range effects	10	22	38	30
Aquaculture effects	10	15	32	43
Recreation	8	21	44	27

a Other comments included "groundwater quality is not currently managed aside from adherence to contaminated sites regulations."

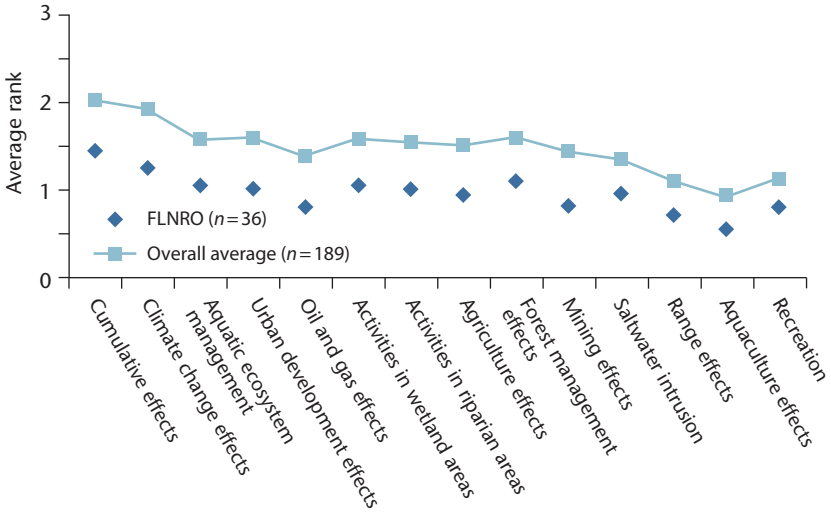

FIGURE 10 *Management of groundwater quality: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff responses and all the combined individual responses for key information needs.*

Groundwater–surface water interactions The highest-priority information needs related to groundwater–surface water interactions that were selected by respondents focussed on where the interactions occur and on seasonal variations and water quality (Table 14). FLNRO staff responses were similar to the overall average priority rankings; however, FLNRO ranked flux magnitudes and flux directions as a higher priority than water quality and pumping data (Figure 11).

TABLE 14 *Respondents' priority rankings of key information needs related to groundwater–surface water interactions (*n = *194)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Where do they occur	55	26	9	10
Seasonal variations	50	26	14	10
Water quality	43	29	14	14
Pumping data	37	16	22	25
Flux magnitudes	34	26	21	19
Flux directions	31	27	21	21

a Other comments included "I don't directly work with much of this data and I'm not aware of who in my branch uses this information"; hydrometric data, irrigation rates, aquifer data to support development of regional groundwater models; any interference effects; "what percent of stream flow is linked to groundwater in each watershed"; and measured effects on surface flows of shallow wells and high pump rates.

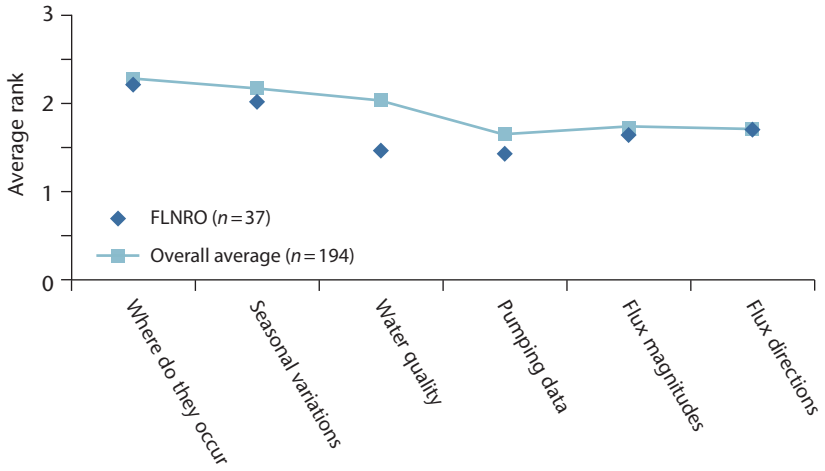

FIGURE 11 *Groundwater–surface water interactions: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff responses and all the combined individual responses for key information needs.*

Management of groundwater–surface water interactions Respondents identified climate change, water withdrawal, cumulative effects, aquatic ecosystem management, and activities in riparian areas as the highest-priority information needs related to the management of groundwater–surface water interactions (Table 15). The lowest-priority information needs were hydropower generation, mining, and range management. FLNRO staff responses were similar to the overall average priority rankings (Figure 12).

TABLE 15 *Respondents' priority rankings of key information needs related to the management of groundwater–surface water interactions (*n = *182)*

	Rank (Percent of respondents)			
Answer options	**High**	**Medium**	**Low**	**Not applicable or not answered**
Climate change	53	26	13	8
Water withdrawal	53	21	12	14
Cumulative effects	50	30	8	12
Aquatic ecosystem management	40	26	19	15
Activities in riparian areas	37	25	25	13
Activities in wetland areas	36	24	25	15
Roads and stream crossings	34	28	20	18
Forest management	32	24	28	16
Urban development	25	29	25	21
Agriculture	21	26	25	28
Hydropower generation	20	14	34	32
Mining	20	23	27	30
Range management	5	16	41	38

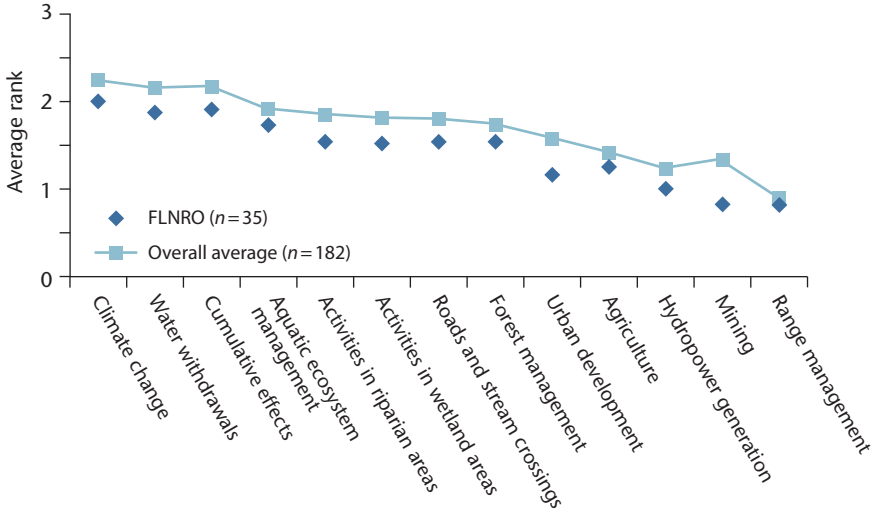

FIGURE 12 *Management of groundwater–surface water interactions: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff and all the combined individual responses for key information needs.*

Aquatic ecosystems Respondents identified environmental flow needs, activities in riparian areas, temperature-sensitive streams, and fish passage as the highest-priority information needs related to aquatic ecosystems (Table 16). The lowest-priority information needs were aquatic ecosystem health and activities in estuaries and coastal areas. FLNRO staff responses were similar to the overall average priority rankings; however, FLNRO staff ranked fish passage as a higher priority (Figure 13).

TABLE 16 *Respondents' priority rankings of key information needs related to aquatic ecosystems (*n = *198)*

	Rank (Percent of respondents)			
Answer options	**High**	**Medium**	**Low**	**Not applicable or not answered**
Environmental flow needs	57	21	9	13
Activities in riparian areas	49	25	10	16
Temperature-sensitive streams	48	23	11	18
Fish passage	48	18	14	20
Fish populations	47	18	16	19
Activities in wetland areas	41	26	16	17
Aquatic ecosystem health (e.g., biomonitoring)	41	18	19	22
Activities in estuaries and coastal areas	32	23	21	24

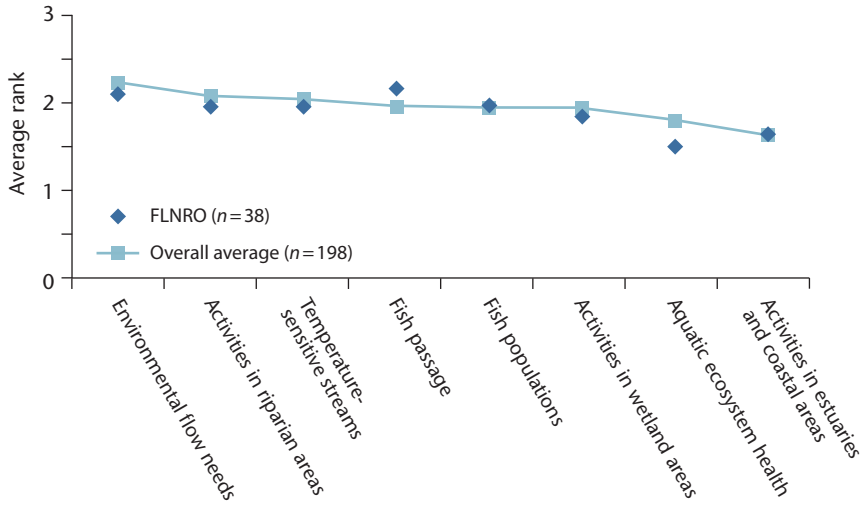

FIGURE 13 *Aquatic ecosystems: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff responses and all the combined individual responses for key information needs.*

Management of aquatic ecosystems Respondents identified aquatic ecosystem management, climate change, activities in riparian areas, cumulative effects, and water withdrawals as the highest-priority information needs related to the management of aquatic ecosystems (Table 17). The lowest-priority information needs were agriculture, mining, and range management. FLNRO staff responses followed a similar ranking order as the overall average priority rankings but were ranked slightly lower. Also, topics related to roads and stream crossings, activities in wetland areas, and forest management were ranked higher by FLNRO staff than was water withdrawal, which was ranked higher overall (Figure 14).

TABLE 17 *Respondents' priority rankings of key information needs related to the management of aquatic ecosystems (*n = *169)*

	Rank (Percent of respondents)			
Answer options	**High**	**Medium**	**Low**	**Not applicable or not answered**
Aquatic ecosystem management	52	17	13	18
Climate change	51	20	14	15
Activities in riparian areas	49	21	12	18
Cumulative effects	47	23	12	18
Water withdrawals	47	18	14	21
Roads and stream crossings	41	21	17	21
Activities in wetland areas	40	19	22	19
Forest management	37	19	23	21
Urban development	30	22	20	28
Hydropower generation	28	15	21	36
Agriculture	24	18	25	33
Mining	21	20	25	34
Range management	9	12	38	41

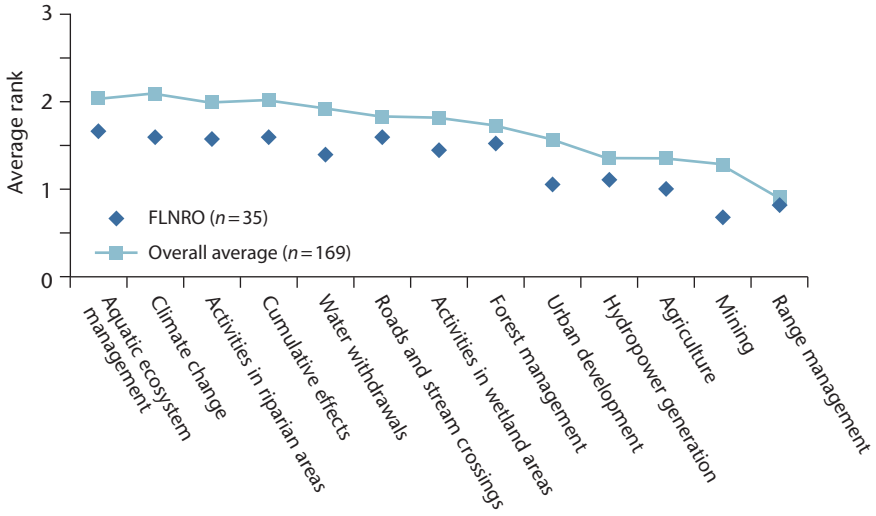

FIGURE 14 *Management of aquatic ecosystems: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff and all the combined individual responses for key information needs.*

Natural resource development hazards Respondents identified drought, floods, surface erosion, and slope mass movement as the highest-priority information needs related to natural resource development hazards (Table 18). The lowest-priority information needs were earthquake, karst, and snow avalanche. FLNRO staff responses were similar to the overall average priority rankings; however, FLNRO staff ranked slope mass movement slightly higher than surface erosion (Figure 15).

TABLE 18 *Respondents' priority rankings of key information needs related to natural resource development hazards (*n = *196)*

	Rank (Percent of respondents)			
Answer options[a]	**High**	**Medium**	**Low**	**Not applicable or not answered**
Drought	61	22	11	6
Floods	55	28	11	6
Surface erosion	47	24	17	12
Slope mass movements	39	23	24	14
Earthquake	20	21	39	20
Karst	18	19	33	30
Snow avalanche	15	21	40	24

a Other comments included all important hazards, site and context specific; storms and combination of hazards and how those interact and need to be managed; highest high tides plus increased magnitude of storms leaves questions about impacts on estuaries, aquaculture, etc.); and "would also add tsunamis for coastal regions and the risks that affect aquatic ecosystems if water and waste-water infrastructure is affected by a natural hazard."

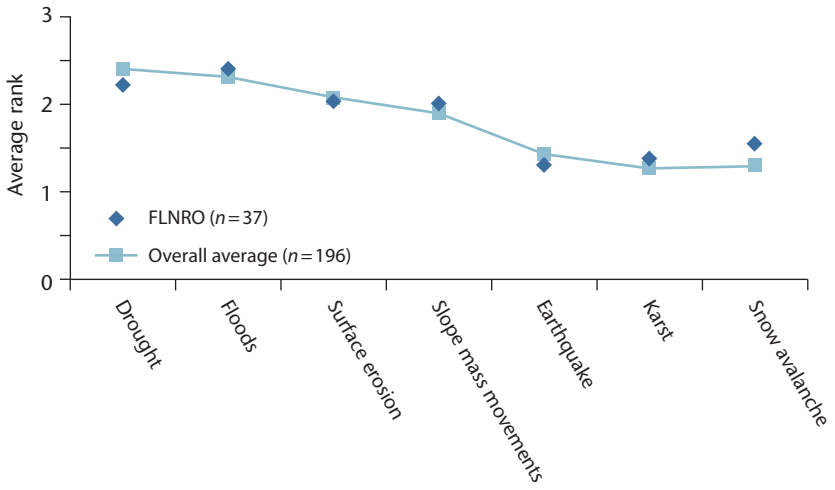

FIGURE 15 *Natural resource development hazards: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff and all the combined individual responses for key information needs.*

Management of natural resource development hazards Respondents identified climate change, activities in riparian areas, cumulative effects, roads and stream crossings, and forest management as the highest-priority information needs related to natural resource development hazards (Table 19). The lowest-priority information needs were hydropower generation, mining, agriculture, and range management. FLNRO staff responses were similar to the overall average priority rankings (Figure 16).

TABLE 19 *Respondents' priority rankings of key information needs related to the management of natural resource development hazards (*n = *169)*

	Rank (Percent of respondents)			
Answer options	**High**	**Medium**	**Low**	**Not applicable or not answered**
Climate change	46	20	12	22
Activities in riparian areas	41	17	17	25
Cumulative effects	40	25	11	24
Roads and stream crossings	38	19	15	28
Forest management	36	21	18	25
Activities in wetland areas	34	15	24	27
Aquatic ecosystem management	31	18	22	29
Water withdrawal	28	26	21	25
Urban development	22	21	25	32
Hydropower generation	19	19	20	42
Mining	18	26	19	37
Agriculture	13	18	30	39
Range management	7	14	33	46

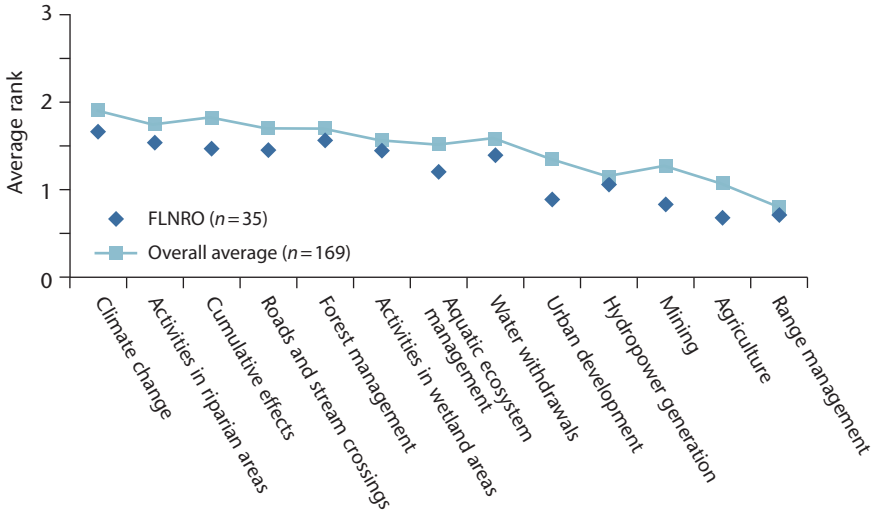

FIGURE 16 *Management of natural resource development hazards: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO staff and all the combined individual responses for key information needs.*

Data and information system needs Respondents identified a wide range of data and information system needs as a high priority. More than 65% of respondents identified online access to data, online access to georeferenced data, hydrometric monitoring data, and online access to analysis results/products (e.g., interpreted data) as the highest priorities (Table 20). Lower-priority information needs included snow survey data, chemical water quality monitoring data, high-elevation climate data, geologic data, water temperature monitoring data, and biological water quality monitoring data. Although high-elevation climate data were identified as a low-priority need, weather and climate monitoring, especially at high elevations, was identified as an important topic.

The general trend in FLNRO staff responses was similar to the overall average priority rankings (Figure 17) except that the need for hydrometric monitoring was identified as the highest priority. FLNRO staff also ranked several data/information needs lower than the overall average priority rankings, which may reflect FLNRO's existing access to data sources that may not be as accessible to other groups. These topics included water temperature monitoring data, online data repository, and physical, chemical, and biological water quality monitoring data.

TABLE 20 *Respondents' priority rankings of general data and information system needs (*n = *198)*

	Rank (Percent of respondents)			
Answer options	**High**	**Medium**	**Low**	**Not applicable or not answered**
Online access to data	73	18	5	4
Online access to georeferenced data	67	21	7	5
Hydrometric monitoring data	67	22	6	5
Online access to analysis results/products (e.g., interpreted data)	65	24	6	5
Climate monitoring data	59	29	8	4
Online data standards (e.g., to facilitate data sharing and use in GIS platforms)	57	25	12	6
Water temperature monitoring data	53	23	13	11
Online data repository (e.g., groups can upload data to share)	51	22	18	9
Physical water quality monitoring data	49	24	15	12
Water consumption/usage data	49	23	16	12
Groundwater-level monitoring data	49	19	20	12
Professional development opportunities (e.g., conferences, workshops)	45	38	14	3
Online analysis tools (e.g., statistical analysis, models)	45	29	21	5
Biological water quality monitoring data	45	21	17	17
Aquifer mapping and characterization	42	26	19	13
Snow survey data	41	30	19	10
Chemical water quality monitoring data	40	27	19	14
High-elevation climate data	40	23	22	15
Geologic data	28	30	31	11

a Other comments included "understandable data to convince local planners and engineers to get serious about stormwater infiltration—beyond pilot-project showpieces"; better spatial georeferenced data; "surficial geology data at 1:20 000 would be great!"; and systematic landslide inventories and documentation of extreme geohazard events.

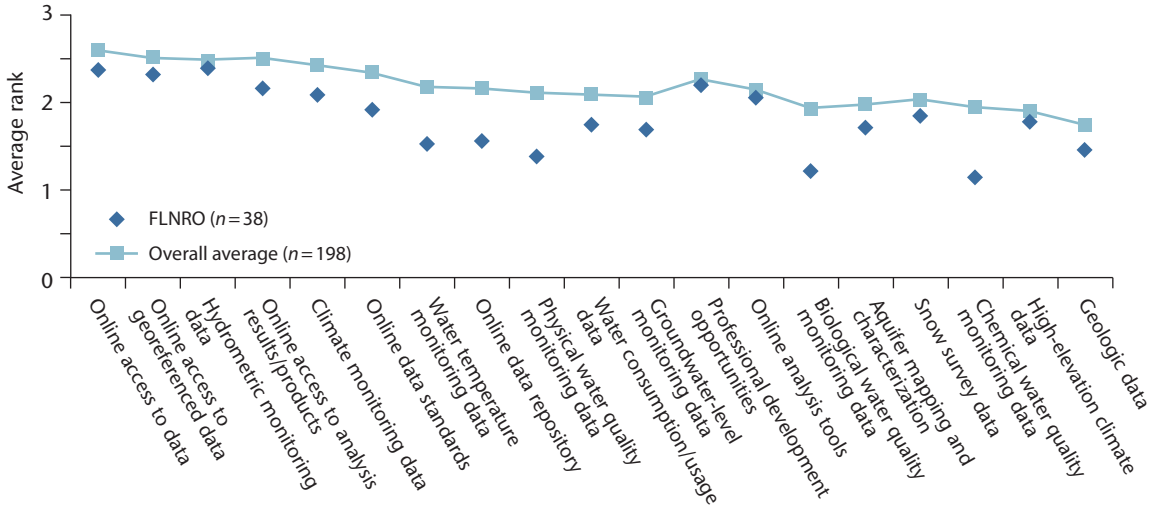

FIGURE 17 *General data and information systems needs: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for the FLNRO group affiliation and all the combined individual responses for key information needs.*

Research and Information Needs/ Questions

Responses to the open-ended questions about research and information needs to support sustainable water management in the South Coast and West Coast Natural Resource Regions were organized by theme (surface water quantity, groundwater quantity, surface water quality, groundwater quality, groundwater–surface water interactions, aquatic ecosystems, and natural resource development hazards) and were classified into research, extension, or monitoring/data needs. The following lists summarize the key needs identified. The lists are ordered by the frequency of responses. The number of responses that identified each need is shown in square brackets.

Surface water quantity

Research needs

- Climate change effects on water quantity, including changes in extreme events (especially floods and droughts) [23]
- Cumulative effects of land use on water quantity [9]
- Improved water budgets to determine water supply and to ensure that allocation is sustainable [6]
- Urban stormwater processes and management [5]
- Hydrologic model development and testing (examples of hydrologic models included Raven, NEWT, DHSVM) [5]
- Forest management (including equivalent clearcut area) and natural disturbance effects on streamflow changes [4]
- Quantification of evaporation from multiple sources [3]
- Glacier melt effects on streamflow regimes [3]
- Mining effects on water quantity (both surface and groundwater) [2]
- Updated watershed assessment procedures to account for cumulative effects [2]
- Management of water supplies during drought, and effects of building new storage [2]

- Effects of independent power producers and run-of-river hydropower [2]
- Testing whether the ecosystem-based management and land-use objectives on the coast are working to protect watershed values [1]
- Peak flow effects on stream channels [1]
- Effects of atmospheric rivers [1]
- Testing the efficacy of the "results-based" approach to resource management [1]
- Rain-on-snow effects [1]
- Effects of watershed restoration on water quantities [1]

Extension needs
- Data availability and access for professionals and the public [3]
- Public communication on watersheds, and watershed management to increase awareness of issues and constraints on water supply [1]
- An inventory of current research and contacts [1]

Monitoring and data needs
- Increased surface water hydrometric monitoring network [28]
- Weather and climate monitoring, especially at high elevations [18]
- Consumption/usage monitoring and reporting [7]
- Snow and glacier monitoring [6]
- Spatial data sets to support hydrologic modelling and analysis [6]
- Access to real-time data [4]
- Data archiving and access [2]
- Floodplain mapping and hazard analysis [1]
- Quality control of available hydrometric data [1]

Groundwater quantity

Research needs
- Aquifer mapping, characterization, and water budgets [19]
- Geologic mapping [5]
- Quantification of recharge rates [5]
- Climate change effects on groundwater [4]
- Development of hydrogeological models, both conceptual and numerical [2]

Extension needs
- Communication about the function of watersheds to increase the general population's awareness and knowledge [1]
- How many people get water supply from groundwater versus surface water [1]

Monitoring and data needs
- Increased Observation Well Network [14]
- Measurement and reporting of groundwater extraction and usage [10]
- Location data for existing wells, and corresponding well logs and geology [5]
- Quality control of available groundwater hydrometric data [1]

Surface water quality

Research needs
- Agriculture and water quality (especially related to nutrients) [5]
- Climate change effects on water quality (including the effects of climate extremes) [5]
- Road and crossing effects on water quality [4]
- Sediment management in the Lower Fraser Valley [3]
- Cumulative effects and land-use effects on water quality, including forest management and mining [2]
- Identification of point and non-point pollution sources, especially excess nutrients, to lakes and wetlands [1]
- Urbanization and water quality [1]
- Watershed restoration effects on water quality [1]
- Private land forest management effects on water quality [1]

Extension needs
- Develop field guidance to assess long-term health of infrastructure under climate change [1]

Monitoring and data needs
- Increased water quality monitoring data for streams, rivers, and lakes with a focus on community water sources. Identification of non-point pollution sources. Parameters to consider include nutrients, temperature, sediment, and biological pollutants. [13]

Groundwater quality

Research needs
- Agricultural impacts [3]
- Contaminant source identification [2]

Extension needs
- Aquifer vulnerability to pollution related to land use, low water levels, and recharge [3]

Monitoring and data needs
- Increased groundwater quality monitoring [8]
- Saltwater intrusion [5]

Groundwater–surface water interactions

Research needs
- Identification of where groundwater–surface water interactions are occurring [9]
- Modelling groundwater–surface water interactions [2]
- Effects of groundwater extraction on groundwater–surface water interactions and the potential effects on environmental flow needs [2]

Aquatic ecosystems

Research needs

- Determination of environmental flow needs for fish-bearing streams [14]
- Climate change effects on aquatic ecosystems [3]
- Cumulative effects of land management on aquatic ecosystems [3]
- Identification of temperature-sensitive streams [1]
- Role of wetlands in healthy watersheds [1]
- Prediction of windthrow in riparian buffers [1]
- Review of watershed restoration efforts in the 1990s—what worked and what did not? [1]

Monitoring and data needs

- Fish population surveys [4]

Natural resource development hazards

Research needs

- Climate change effects on hazards [2]
- Large-scale geohazard mapping [1]
- Identification and characterization of vulnerable karst areas [1]
- Wildfire effects on slope stability [1]
- Effects of drought on soil water repellency [1]

Monitoring and data needs

- LiDAR (light detection and ranging) data for mapping natural hazard assessment [1]
- Provincial landslide database [1]

Key Policy and Regulatory Needs

Respondents' feedback on key policy and regulatory needs to support sustainable water management in the South Coast and West Coast Natural Resource Regions was reviewed and summarized based on common issues raised. The following responses are ranked in order of frequency of response. The number of responses that identified each need is shown in square brackets.

- Groundwater regulation and groundwater resource inventory, including monitoring, data quality, and standards for modelling, and standards for aquifer characterization [33]
- Government funding to increase regulatory/enforcement and monitoring capacity [20]
- Water use monitoring and reporting to confirm water allocation and use (including agriculture and groundwater use) [17]
- Implementation of the *Water Sustainability Act* [13]
- Urban stormwater issues and mitigation [8]
- Environmental flow needs—determination and monitoring [7]
- Climate change [5]
- Cumulative effects [5]
- Groundwater–surface water interactions, including the connections between streams and aquifers [5]
- Regulation and inventory for landslide hazards is needed for development purposes [5]

- Improved co-ordination between all levels of government [5]
- Greater compliance and enforcement efforts by the provincial government, and a move away from a professional reliance model [5]
- Standards for data collection, archiving, and availability [4]
- Saltwater intrusion guidelines for development and extraction [4]
- Agriculture water quality and irrigation efficiency [4]
- Health guidelines [4]
- Watershed governance [4]
- Standards and guidelines for demonstrating water availability for development purposes [3]
- First Nations water rights and management [3]
- Regulation of independent power producers [2]
- Drought and water storage [2]
- Development of process that prioritizes water uses [2]
- Source water protection [2]
- Watershed assessment and habitat evaluation procedures [2]
- Riparian and wetland protection policy [2]
- Floods and floodplain management [2]
- Secure long-term funding to support research and monitoring programs [2]
- Water licence analysis to examine unused or underused allocations that could be directed toward environmental flow needs [1]
- Clean water for First Nations reserves [1]
- Karst management regulations [1]
- Private land forestry regulations [1]
- Dam safety [1]

Emerging Pressures/Issues

Respondents' feedback on emerging pressures/issues regarding sustainable water management in the South Coast and West Coast Natural Resource Regions is summarized by the common issues raised. The following emerging issues are ranked in order of frequency of response. The number of responses that identified each need is shown in square brackets.

- Climate change [13]
- Drought and water storage [12]
- Government capacity and funding for resource management and monitoring, including consistency in monitoring and measurement methods and data archiving [9]
- Groundwater regulations, licensing, and monitoring [9]
- Implementation of the *Water Sustainability Act*, including clarification of the government's roles and responsibilities (e.g., B.C. Ministry of Environment's role versus FLNRO's role) [9]
- Water licensing and allocation, including water use monitoring and reporting [9]
- Cumulative effects [7]
- Urban development effects on surface water and groundwater quantity and quality [7]
- Determination and management of environmental flow needs [7]
- Snow and glacier monitoring [5]
- Forest management effects on water, including effects on karst and the effects of logging second-growth forests [5]

- Sediment and roads [4]
- Status of fish populations and habitat, including the effects of land uses on flows for fish and on water temperature that can affect fish population and health [4]
- Saltwater intrusion into aquifers in the Gulf Islands [3]
- Agricultural water use [3]
- First Nations title and resource management [2]
- Sediment and habitat effects of Fraser River dredging [2]
- Groundwater and surface water interaction and water quality [2]
- Flood studies related to dam breaches (e.g., is the 200-year design flood the appropriate hazard to consider?) [2]
- Population growth and water demand management [2]
- Invasive species [2]
- Information sharing among all levels of government, industry, and stewardship groups [1]
- Transborder water issues and monitoring between Canada and the United States [1]
- Wetland protection [1]

SUMMARY

The intent of this needs assessment survey was to identify specific knowledge gaps and provide guidance in the development of strategic priorities for water research and management in the South Coast and West Coast Natural Resource Regions in British Columbia. These results are meant to be informative, not directive, and to prioritize future research and address knowledge gaps within the FLNRO mandate.

This section includes two main subsections. The first summarizes the research and monitoring needs identified under the seven main themes of the survey: surface water quantity, groundwater quantity, surface water quality, groundwater quality, groundwater–surface water interactions, aquatic ecosystems, and natural resource development hazards. The second subsection provides a synthesis of the re-occurring and key research, policy, and monitoring needs that were consistently identified in the survey.

Research and Monitoring Needs

Surface water quantity The highest-priority research and information needs related to surface water quantity were low-flow magnitude and timing, rainfall timing and rates, peak flow magnitude, and snow accumulation. In the management of surface water quantity, the highest-priority topics identified were climate change effects on water supply, environmental flow needs, water availability/storage, cumulative hydrologic effects, and current allocation.

These priorities were also emphasized in the written responses. The most frequently identified research needs referred to climate change effects on water quantity, which included the need for research related to changes in extreme events (e.g., floods and drought), cumulative effects of land use on water quantity, improved water budgets to determine water supply and to ensure that allocation is sustainable, and urban stormwater processes and management.

Monitoring priorities commonly identified included the need for hydrometric monitoring data, weather and climate monitoring data (especially at high elevations), and better reporting/tracking of water consumption and use.

Groundwater quantity The highest-priority research and information needs related to groundwater quantity were water levels, groundwater–surface water interactions, aquifer mapping, recharge rates, and withdrawal amounts. Information needs for the management of groundwater quantity were related to cumulative hydrologic effects, current groundwater availability, current groundwater withdrawals, climate change effects on water supply, and water well locations. Written responses emphasized the need for improved understanding of the location and characterization of groundwater sources (i.e., aquifer mapping) and better understanding of water budgets/allocation of groundwater sources. Monitoring and data needs included the need for an increased network of observation wells, more information about the measurement and reporting of groundwater extraction and usage, and location data for existing wells and corresponding well logs and geology.

Surface water quality The highest-priority needs for surface water quality were research on sediment, turbidity, temperature, biological water quality, and nutrients. In the management of surface water quality, key information needs were related to activities in riparian areas, climate change effects, cumulative effects, aquatic ecosystem management, and activities in wetland areas. Written responses emphasized the need for understanding the effects of agriculture on water quality (especially related to nutrients), climate change effects on water quality (including the effects of climate extremes), and the effects of roads and crossings on water quality. Numerous written responses also stressed the need for increased water quality monitoring data for streams, rivers, and lakes, with a focus on community water sources and identification of non-point pollution sources.

Groundwater quality The highest-priority research and information needs for groundwater quality were related to biological water quality, inorganic chemicals, nutrients, temperature, and organic chemicals. The highest-priority information needs for the management of groundwater quality were related to cumulative effects, climate change effects, aquatic ecosystem management, urban development effects, and oil and gas effects. Only a few written responses were provided; they related to agricultural impacts and identification of contaminant sources. Monitoring and data needs included the need for increased groundwater quality monitoring and monitoring of saltwater intrusion into groundwater sources.

Groundwater–surface water interactions The highest-priority research and information needs related to groundwater–surface water interactions focussed on where the interactions occur, and on seasonal variations and water quality. The highest-priority information needs for the management of groundwater–surface water interactions were related to climate change, water withdrawal, cumulative effects, aquatic ecosystem management, and activities in riparian areas. Written responses highlighted the need for better identification of where groundwater–surface water interactions are occurring.

Aquatic ecosystems The highest-priority research and information needs for aquatic ecosystems were related to environmental flow needs, activities in riparian areas, temperature-sensitive streams, and fish passage. The highest-priority needs for the management of aquatic ecosystems were related to aquatic ecosystem management, climate change, activities in riparian areas, cumulative effects, and water withdrawals. Written responses emphasized the need for better determination of environmental flow needs for fish-bearing streams, climate change effects on aquatic ecosystems, and cumulative effects of land management on aquatic ecosystems. Monitoring and data needs included the need for more fish population surveys.

Natural resource development hazards The two highest-priority research needs for natural resource development hazards were related to drought and floods, followed closely by surface erosion and slope mass movements. Climate change, activities in riparian areas, cumulative effects, roads and stream crossings, and forest management were the highest-priority needs related to the management of natural resource development hazards. Written responses emphasized the need for more research on climate change and/or wildfire effects on natural resource development hazards, large-scale mapping and use of LiDAR for geohazard mapping, and identification and characterization of vulnerable karst areas.

Key Priority Research, Policy, and Management Needs

In summary, the survey respondents most frequently identified the following key priority research and management needs:

- surface water quantity research on low-flow magnitude and timing, rainfall timing and rates, peak flow magnitude, and snow accumulation;
- climate change effects on all aspects of water quantity, water supply, and water quality. Also highlighted was the need to better understand how extreme events such as drought and floods will affect water quantity, water quality, aquatic ecosystems, and natural resource development hazards;
- management and understanding of cumulative effects and land-use effects on all aspects of surface water, groundwater, aquatic ecosystems, and natural resource development hazards;
- groundwater quantity research on groundwater–surface water interactions, and aquifer identification and characterization to quantify the availability and extent of groundwater resources;
- water budgets and water consumption/usage data are required to improve the understanding of water availability/withdrawals to ensure the sustainable allocation of both surface water and groundwater; and
- environmental flow needs for fish-bearing streams, temperature-sensitive streams, and land-use activities in riparian areas.

More than 65% of the respondents identified online access to data, online access to georeferenced data, hydrometric monitoring data, and online access to analysis results/products as a high priority. Written responses also highlighted the need for increased hydrometric monitoring of surface waters as being very important.

Key policy and regulatory needs included the following:

- increased groundwater regulation and groundwater resource inventories that provide improved standards for monitoring and data collection. Respondents also highlighted the need for improved identification of the location of aquifers so that the risks of land development to aquifers could be better characterized and managed.
- increased monitoring of water consumption and usage, and improved regulation to more effectively allocate water to ensure that environmental flow needs are met.
- increased government funding to improve regulatory requirements to protect surface water and groundwater, and increased government capacity to enforce regulations and protect water resources.
- more information about the implementation of the *Water Sustainability Act* and how the Act will maintain and/or protect water sources.
- more integrated and watershed-scale planning to ensure that land-use activities do not negatively affect community water supplies.
- increased requirements for improved stormwater management that minimizes land-use effects on water quality, water quantity, and aquatic ecosystems.

The following were identified as emerging pressures and issues:

- reducing uncertainty about climate change effects on water supply for both consumptive and aquatic ecosystem uses;
- identification of drought and water storage requirements;
- increased government capacity and funding for resource management and monitoring;
- improved groundwater regulation, licensing, and monitoring;
- implementation of the *Water Sustainability Act*; and
- sustainable allocation of water supplies.

The results of the survey identified many of the same themes and topics that were identified in previous reports (e.g., Hollstedt 2000; Redding 2011; Brandes and O'Riordan 2014; Lapp et.al. 2015; Scherer et al. 2016). In addition to this report, a database of data sources, information sources, and relevant research from British Columbia and adjoining jurisdictions has been compiled. The database is intended to provide a first stop for researchers and managers in locating key water resource information of regional relevance. The database is available at www.bcwatertool.ca/info-sources/.

Brandes, O.M. and J. O'Riordan. 2014. A blueprint for watershed governance in British Columbia. POLIS Project on Ecological Governance. Univ. Victoria, Victoria, B.C. poliswaterproject.org/sites/default/files/POLIS-Blueprint-web.pdf

Hollstedt, C. 2000. Science, innovation, and sustainability: investing in British Columbia's knowledge based natural resource sector. Southern Interior Forest Extension and Research Partnership, Kamloops, B.C. SIFERP Ser. 2.

Lapp, S., T. Redding, K. Ronneseth, and D. Wilford. 2015. Research and information needs assessment to support sustainable watershed management in northeast British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 090. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr090.htm

Redding, T. 2011. A summary of recent British Columbia watershed management information needs assessments. Streamline Watershed Manag. Bull. 14(2):20–23.

Scherer, R., T. Redding, K. Ronneseth, and D. Wilford. 2016. Research and information needs assessment to support sustainable watershed management in the Thompson–Okanagan Natural Resource Region, British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 095. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr095.htm

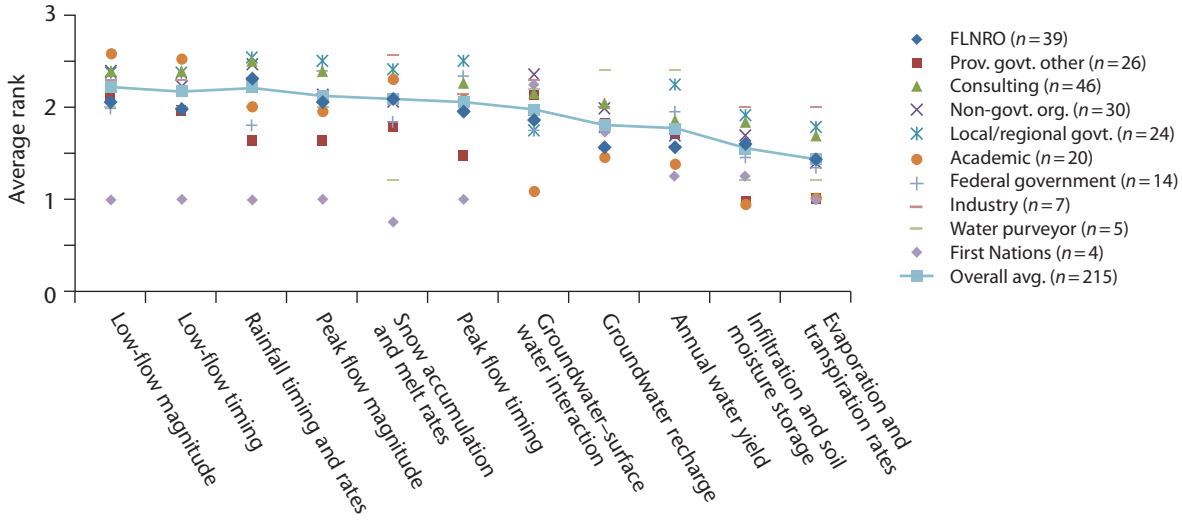

FIGURE A1 *Surface water quantity hydrologic processes: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

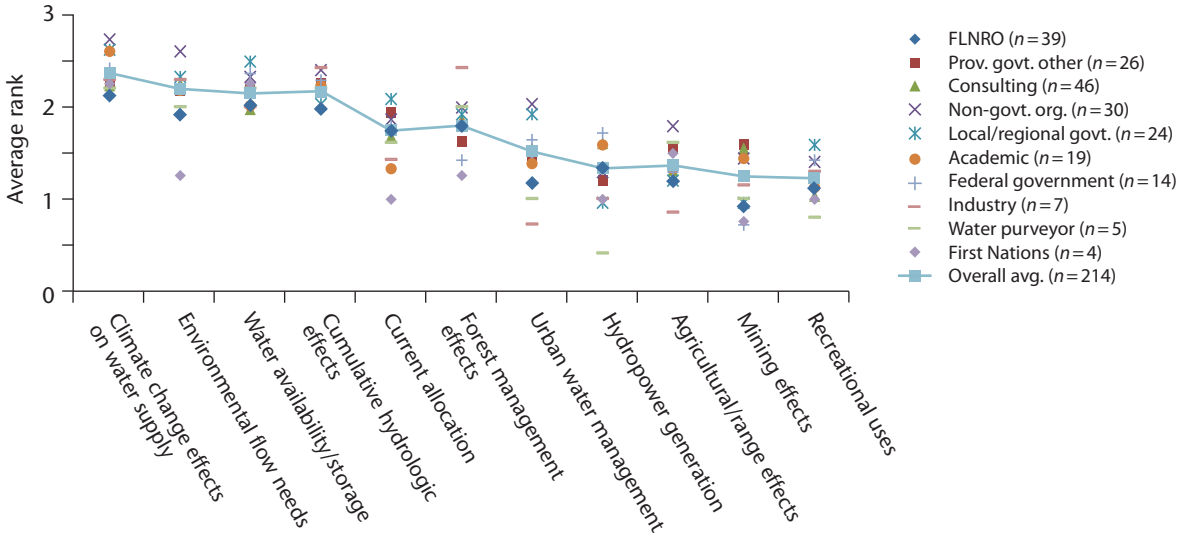

FIGURE A2 *Management of surface water quantity: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

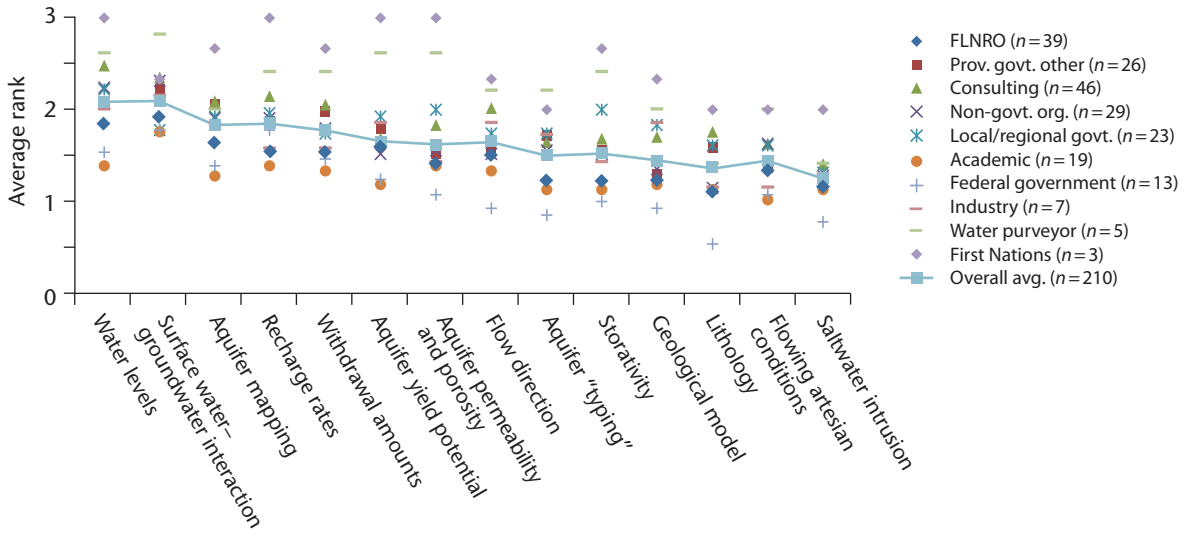

FIGURE A3 *Groundwater quantity hydrogeologic processes: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

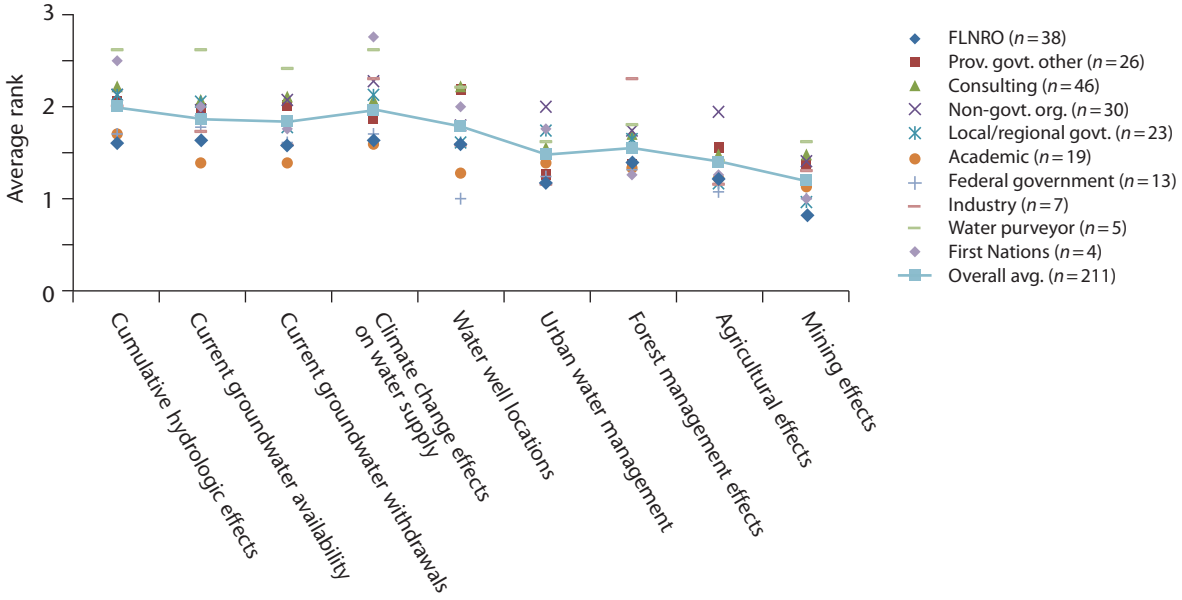

FIGURE A4 *Management of groundwater quantity: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

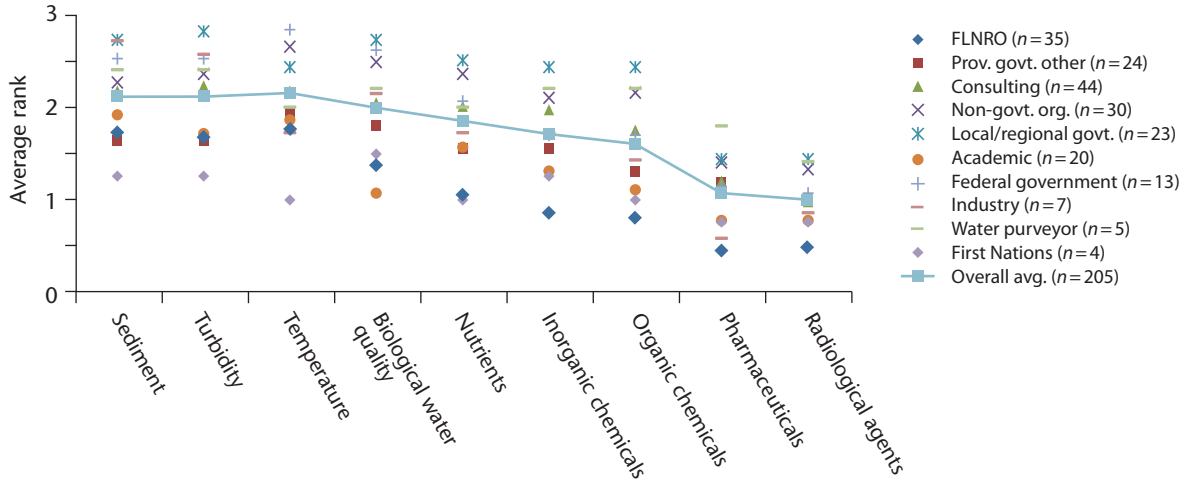

FIGURE A5 *Surface water quality: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

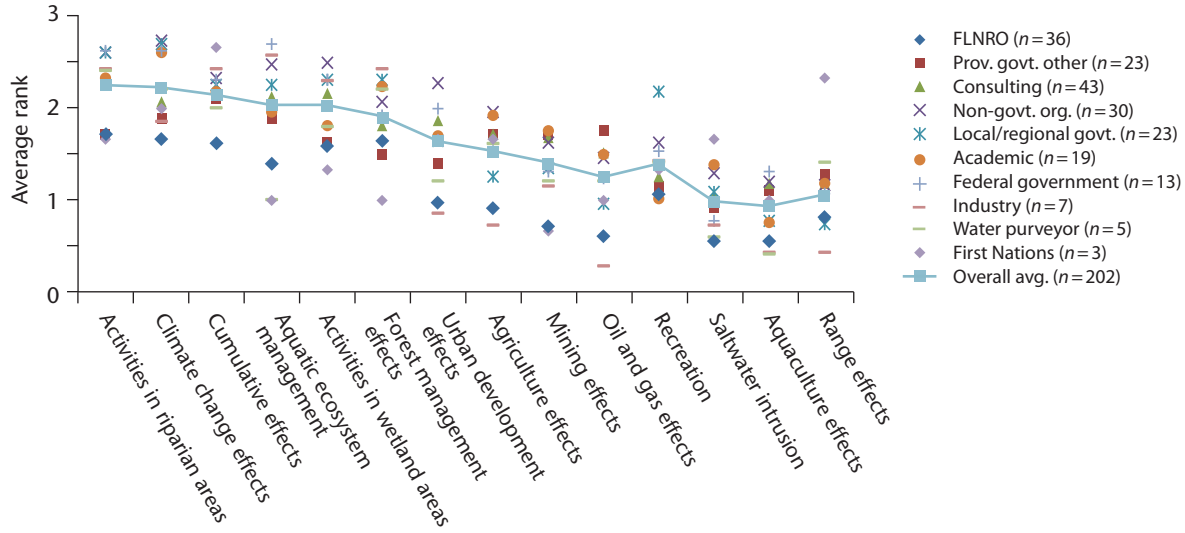

FIGURE A6 *Management of surface water quality: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

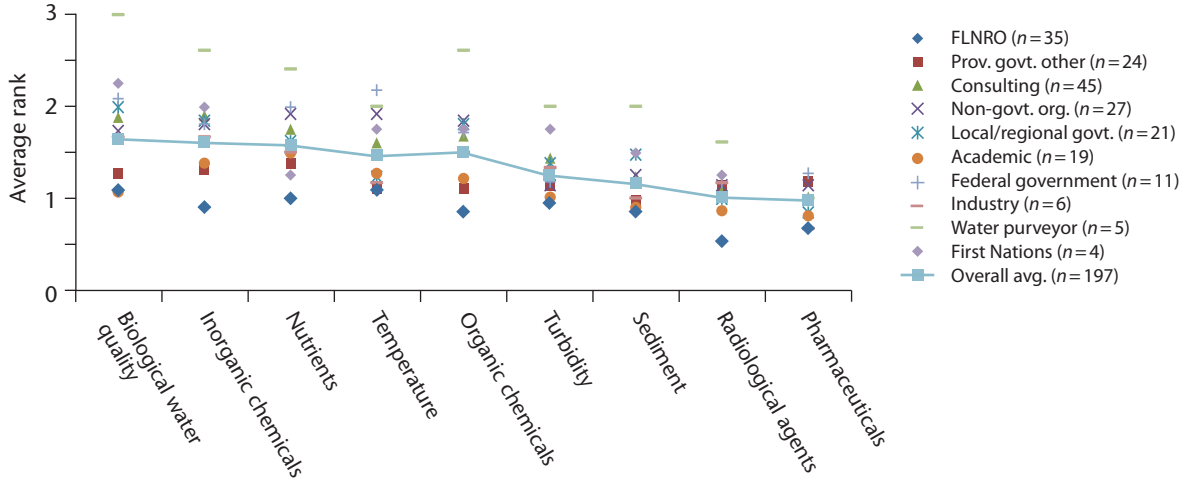

FIGURE A7 *Groundwater quality: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

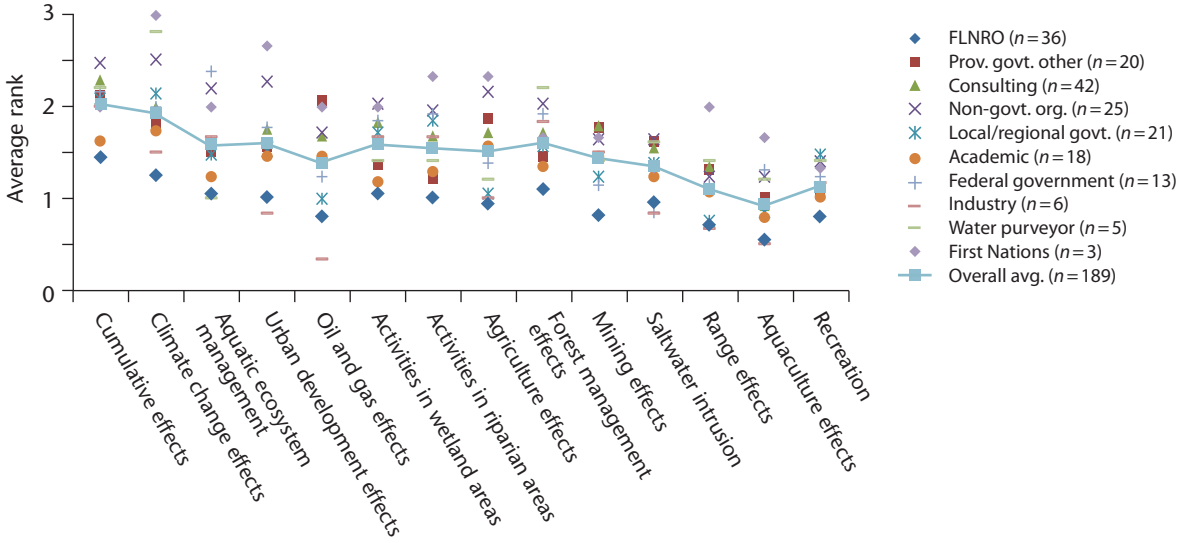

FIGURE A8 *Management of groundwater quality: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

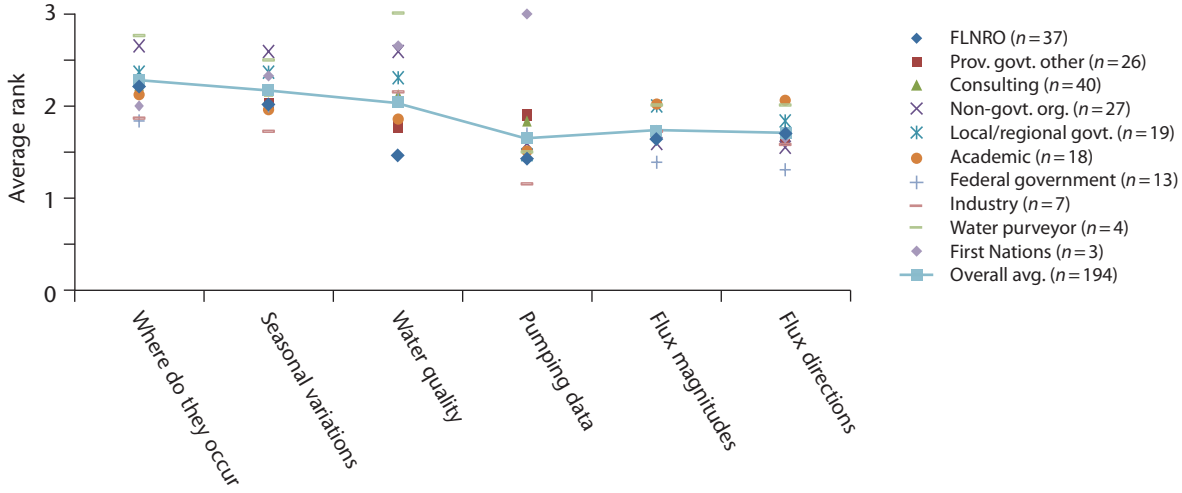

FIGURE A9 *Groundwater–surface water interactions: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

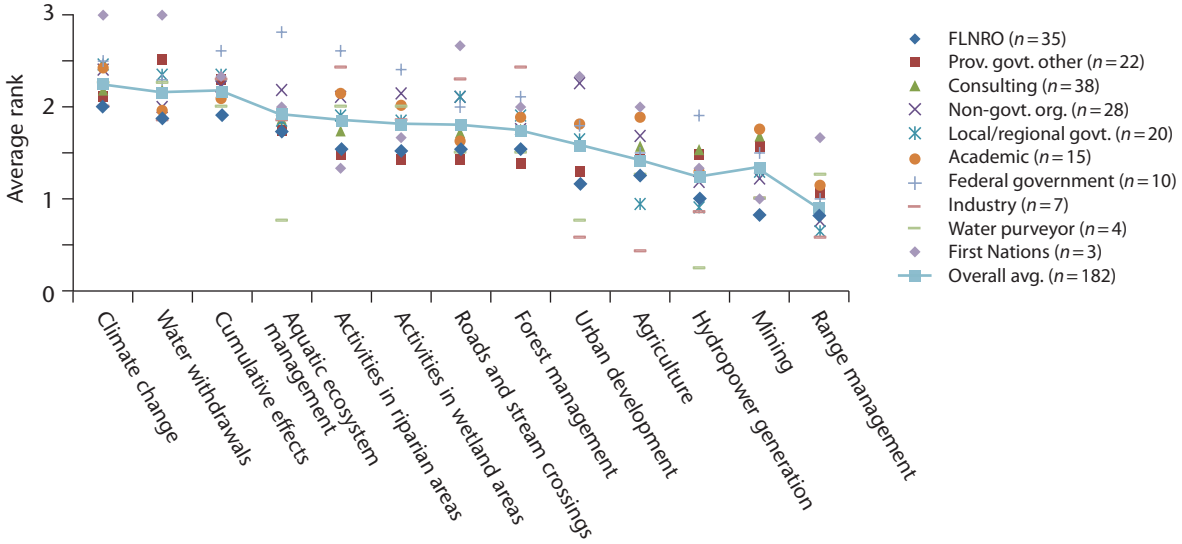

FIGURE A10 *Management of groundwater–surface water interactions: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

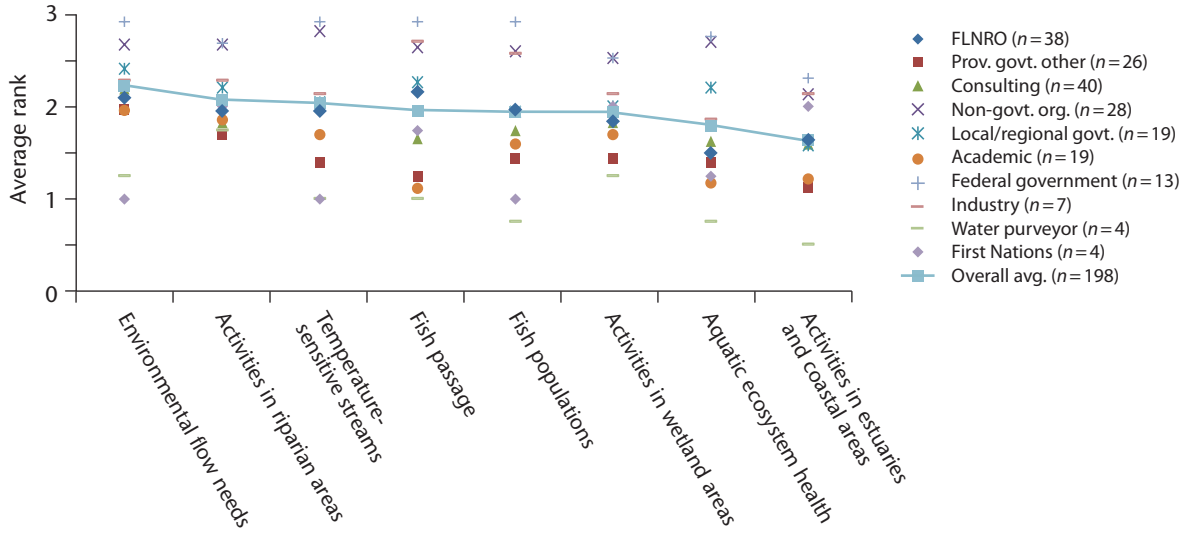

FIGURE A11 *Aquatic ecosystems: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

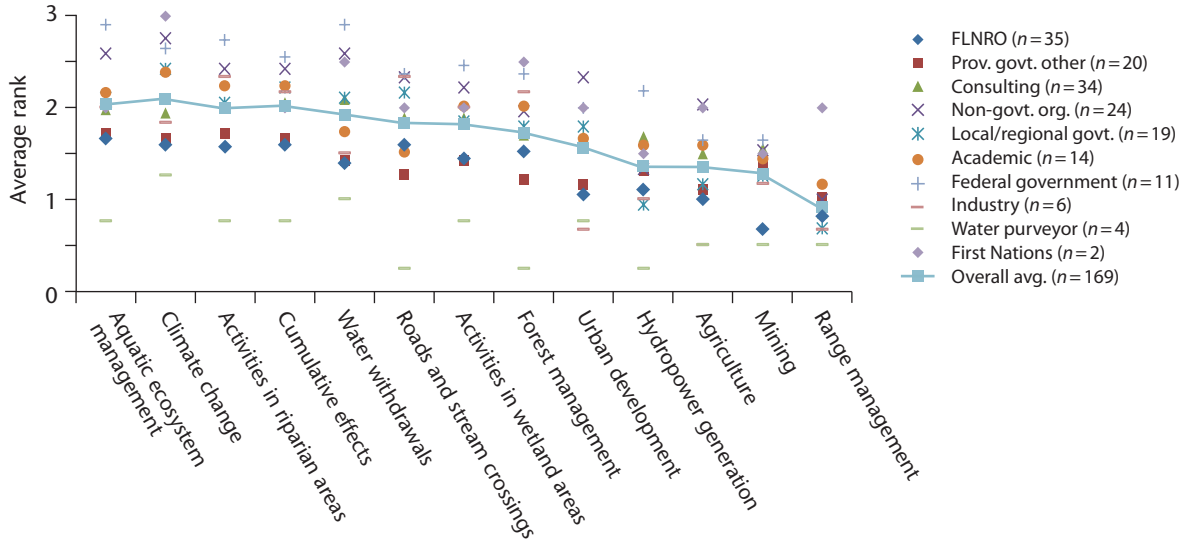

FIGURE A12 *Management of aquatic ecosystems: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

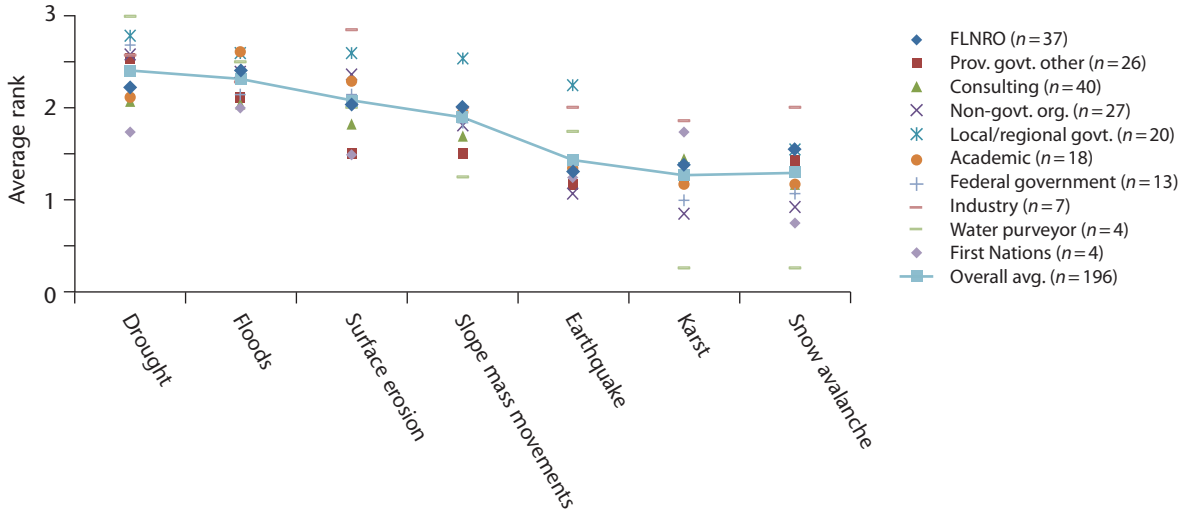

FIGURE A13 *Natural resource development hazards: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

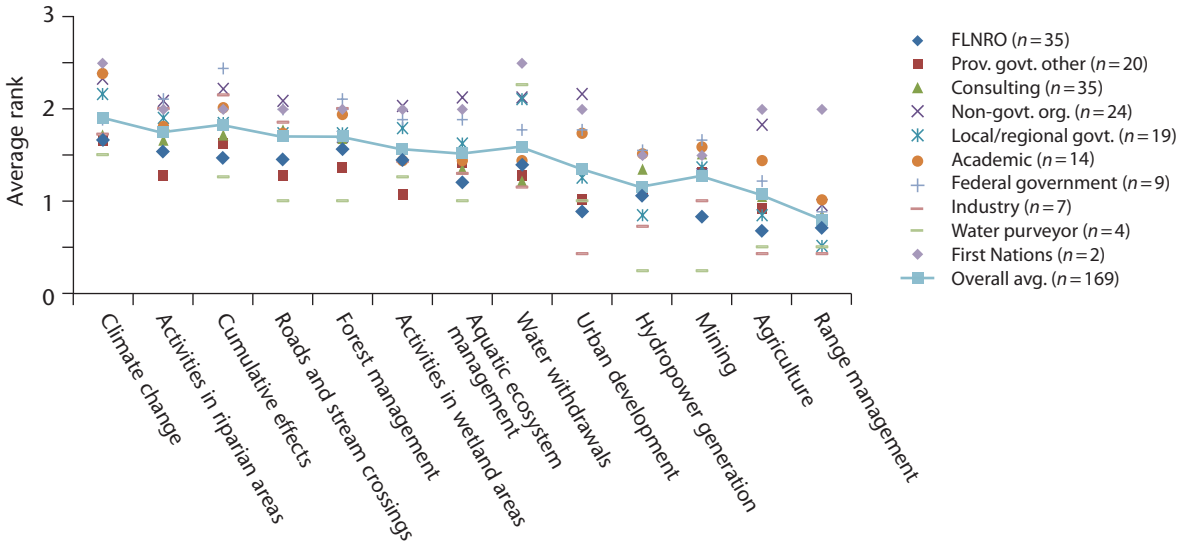

FIGURE A14 *Management of natural resource development hazards: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

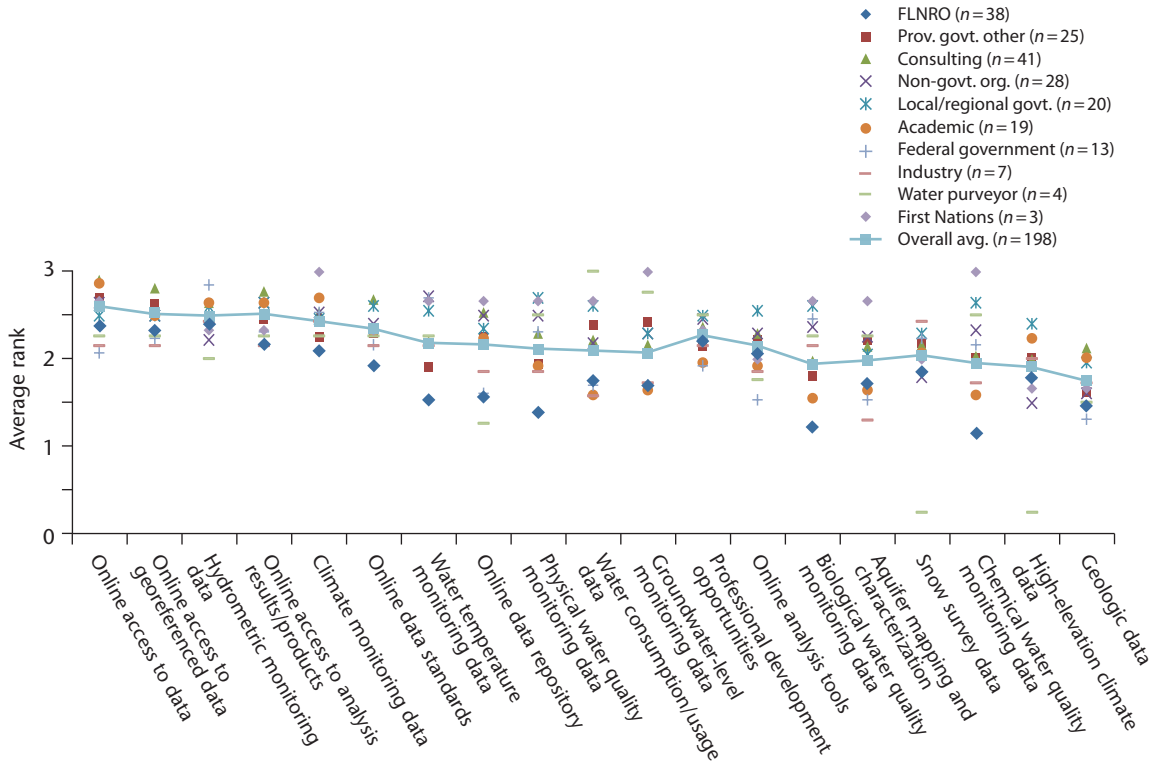

FIGURE A15 *General data and information systems needs: average priority rankings (3 = high, 2 = medium, 1 = low, 0 = not applicable or not answered) for each of the respondent group affiliations and key information needs. The overall average priority ranking for all individual responses is also provided.*

Respondents were asked to identify current and planned water-related research undertaken by their organization, by a partner organization, or in their local area. Comments from different respondents are separated by a line. This list should not be considered as an exhaustive account of all research being conducted in the South Coast and West Coast Natural Resource Regions.

As already noted, in addition to this report and appendices, a database of data sources, information sources, and relevant research projects and publications from British Columbia and adjoining jurisdictions was compiled. The database is intended to provide a first stop for researchers and managers in locating key water resource information of regional relevance. The database is available at www.bcwatertool.ca/info-sources/.

- Preliminary water budgets for two aquifer areas in British Columbia. Contact: Klaus Rathfelder (B.C. Ministry of Environment [MOE])
- Utilization of low-impact development technology and green infrastructure to enhance urban ecological outcomes. Case-study research project currently underway. Contact: Amy Greenwood (Fraser Basin Council)

- The Hydrologic Impacts (HI) theme of the Pacific Climate Impacts Consortium is developing an updated version of the Variable Infiltration Capacity macro-scale hydrologic model for all watersheds flowing in or out of British Columbia, which includes a dynamic representation of glaciers. This model will be used to estimate daily streamflow out to 2100 for a range of climate scenarios from the 5th Coupled Modelling Inter-comparison Project (CMIP5). Methods of selecting climate scenarios or global climate models and statistical downscaling to bias correct these temperature and precipitation fields is being done in a way to improve our ability to project changes to hydrologic extremes, such as floods and droughts. Results from the CMIP3 models for the Campbell, Fraser, Peace, and Columbia River basins are available on our website, along with downscaled climate projections for Canada from CMIP5. The HI team includes Markus Schnorbus, Rajesh Shrestha, and Arelia Werner. Links to our data portal are as follows:
  www.pacificclimate.org/data/gridded-hydrologic-model-output
  www.pacificclimate.org/data/station-hydrologic-model-output
  www.pacificclimate.org/data/statistically-downscaled-climate-scenarios
  We also have several publications that are relevant for climate change pressures on streamflow in British Columbia:
  www.pacificclimate.org/resources/publications?tid%5B%5D=47&keys=

- Maintain more than 60 climate and hydrological stations for clients in British Columbia; undertake installation, calibration, and testing of climate and hydrometric stations; developed advanced telemetry and communications for remote stations; advanced data processing and modelling

- Due to concerns about the opening of a coal mine above our operation, we have budgeted ten thousand dollars to start water testing before they start their operation and after they begin. We have hired scientists to run the program. Contact: Charley Vaughan

- You have all my Ministry projects already listed. Majors are Honna Watershed, Russell Creek, and Ecosystem Based Management High Elevation Weather Station Network expansion on the central coast. I am heavily involved in the weather and hydrology component at the Hakai Institute on Calvert Island, a multidisciplinary project examining the linkages between terrestrial, aquatic, and marine ecosystems. Contact: Bill Floyd (FLNRO)
  www.hakai.org/research/kwakshua-watershed-program

- Limnological studies of reservoirs
- Source water quality studies
- Fish–drinking water relationships
- Impacts of climate change scenarios in terms of adaptation
- Corrosion control assessment underway
- Re-assessment of secondary disinfection in the region

- Masters study "Water availability and climate change for the Chapman Creek water system" by Monte Staats (Sunshine Coast Regional District [SCRD]). Installation of new weather station at Chapman Lake—Monte Staats. Re-instating snow surveys in the Chapman watershed—Monte Staats. Area A (Pender Harbour/Egmont) watershed hydrological monitoring program (on hold)—Bryan Shoji (SCRD General Manager Infrastructure Services)

- Cowichan Tribes sits on the Cowichan Watershed Board and its technical advisory group, in collaboration with the Cowichan Valley Regional District, the B.C. Ministry of Environment, Fisheries and Oceans Canada, Catalyst Paper, and the Pacific Salmon Commission. The Watershed Board has undertaken studies related to drought management, river flows throughout the Cowichan River, and the effect of these flows on our aquatic resources. More on information collected by the Watershed Board can be found at: www.cowichanwatershedboard.ca/
  Also see: http://poliswaterproject.org/sites/default/files/CWBCaseStudy_WebFINAL_o.pdf
- Q'ul-lhanumutsun
- Aquatic Resources Society has produced a report for Cowichan Tribes that looks at water quality as it relates to levels of contaminants in Chinook salmon occurring in the Cowichan River. Contact: Jordan Maher (Cowichan Tribes)

- Groundwater–surface water interactions
- Use of engineered and natural vegetated systems for treating stormwater and wastewater
- Low-impact development technologies for urban areas for treating stormwater (both quantity and quality)
- Developing vegetative buffers in riparian zones to treat pollution

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- Sedimentation in lower Fraser River. Contact: M. Church (University of British Columbia [UBC] Geography). See http://ibis.geog.ubc.ca/fraserriver/publications.html

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- We continue to work on provincial-scale fish habitat modelling as part of the Fish Passage Technical Working Group. We are currently finalizing Version 2 of this model. Contact: Craig Mount (B.C. Ministry of Environment);

Cumulative impacts assessments work (specifically aquatic ecosystems) is ongoing with people like Zaid Jumean, Richard Thompson, and Peter Tschaplinski (B.C. Ministry of Environment).
- Forest and Range Evaluation Program (FREP) watershed status evaluation reports are being carried out by folks like Lars Reese-Hansen, Richard Thompson, Peter Tschaplinski, and Craig Mount.

- The BC Conservation Foundation (BCCF) has spent the last 9 years investigating several opportunities for new licensed storage on small lakes and reservoirs on the east coast of Vancouver Island, to be used for provision of downstream conservation flows. This takes specialized expertise and a holistic, multidisciplinary approach to feasibility/design studies. A number of such projects were completed, but senior governments no longer wish to hold such licences owing to long-term liability and maintenance obligations. Consequently, projects have been indefinitely deferred for lack of an approved licensee and capital budgets for construction. Projects that were built include Cameron Lake (Little Qualicum River), Westwood Lake (Millstone River), Thetis Lake (Craigflower Creek), Crofton Lake (Richards Creek), and Keogh Lake (Keogh River). BCCF's Senior Project Manager, James Craig, AScT, in Lantzville.
- BCCF is also mentoring several east coast Vancouver Island (ECVI) community stewardship groups in streamflow and water quality monitoring techniques, following Resources Information Standards Committee and Water Survey of Canada standards. This project is multi-year, and information derived is shared with senior government water management agencies.
- Dendrohydrological reconstruction of stream and river discharge in the southern Coast Mountains
- Snow water equivalent and snow history reconstructions from tree rings in the southern Coast Mountains

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- Continued development of Aquarius system. Development of process for acquiring third party hydrometric data. Support for climate change adaptation.

- Currently my research in this coastal region of British Columbia focusses on two main topics: (1) risk to groundwater in coastal bedrock aquifers. The work is supported by Natural Resources Canada and is being done in partnership with the B.C. Ministry of Environment and FLNRO. That project ends in December 2016, and we will provide GIS maps of sea water intrusion vulnerability to the province. (2) We are also working on groundwater recharge modelling on Gabriola Island (as a case study area for the Gulf Islands)—impacts of climate change on recharge. Research is supported by Regional District of Nanaimo. Response of groundwater levels to heavy precipitation events. Research is based on the Gulf Islands, and we are using a combination of precipitation and seepage sampling (isotopes), groundwater-level data (hourly from the Observation Well Network), thermal infrared imaging, and numerical modelling to examine response times of groundwater level to these heavy rain events. Groundwater–surface water interactions. We just finished developing a watershed-scale model for the Cowichan—collaboration with FLNRO on a broader study in that watershed. Groundwater–surface water interaction in the Fraser Valley (stream temperature to understand exchanges—PhD student), a stream vulnerability assessment approach has been developed for groundwater-

dependent streams as part of this study. Groundwater–surface water interactions, in partnership with FLNRO in the Fraser Valley (Hoppington Aquifer)—pumping tests and monitoring of stream and groundwater conditions. Not sure what is on the horizon.

- Lithological controls on groundwater quality in the Gulf Islands. Identifying saltwater intrusion in coastal regions.
- Currently conducting meta-analysis on tailed frog data coast-wide in co-operation with FLNRO.
- Aquifer mapping, aquifer stress mapping, water budgets, etc. Final products will be available through www.env.gov.bc.ca/ecocat/ and iMapBC.
- Langley Environmental Partners Society (LEPS) Water Quality Sampling Program. Contact: Erin Enns. Our water quality sampling program area includes the Township and City of Langley, and nine out of 11 watersheds within these municipalities. Our staff and trained community volunteers have sampled surface water since 2013 to determine the health of our watersheds at 43 sites across Langley. We test for water temperature, pH, turbidity, dissolved oxygen, nutrients, and hydraulic conductivity, and compare them to the aquatic water guidelines of B.C. and Canada (depending on the parameter). LEPS hosts the database, and it is currently updated and organized by LEPS staff, which includes our data as well as historical data from various sources. The information is free to anyone; however, you need to contact LEPS for the water quality information as it is not yet available on the internet. We are currently in conversation with several other partners to host an online database to house our water quality data, where it would be free to anyone looking for the information. Only LEPS staff would have access to change or update the data, and permission would be needed to download the information. Our goal with the online database is to have a platform for residents to inquire about the health of their watersheds (educational tool), a way to start conversations about the importance of a healthy watershed, and to determine how much data we have, from where and current gaps in the data collection. This would also help with stewardship groups or local volunteers to determine where help is needed and to prevent doubling up on the data collection.
- Many water-related research projects in the federal government (Fisheries and Oceans Canada [DFO], Environment Canada) have been discontinued due to retirements, departures, and failures to replace research staff, as well as ongoing program funding cuts.
- I'm working with Scott Babakaiff right now to identify drought-sensitive streams in the South Coast Region. The question remains: Are streams that regularly drop below some threshold, for example 5% mean annual discharge, more sensitive to drought than streams that rarely do? To answer this question, long-term monitoring data are required. We are using available Water Survey of Canada data, but if there were a global archive of quality controlled third party data, that would be useful. Perhaps there already is, which I'm not aware of.
- Past study: Sakinaw Lake water balance study, MSc thesis, 2003, Grant McBain, DFO.

- Currently involved in irrigation water use in the Lower Fraser Valley, particularly in the Richmond/Delta area, and issues emerging with saltwater intrusions. Sunshine Coast domestic water management—supply and demand (with District) innovative stormwater management in the urban environment. Also: Domestic water supply and demand in the Columbia Basin (with Columbia Basin Trust). Contact: Hans Schreier (Faculty of Land and Food Systems, UBC).

- Effects of forest management and roads on groundwater.

- No research per se, though the following initiatives for provincial hydrometric network planning and optimization, and regional streamflow analyses are in play, led by MOE's Hydrology and Hydrometric Programs Unit. Contact: Heather Johnstone (B.C. Ministry of Environment).
- Camosun Capstone Network Operations Optimization project proposal to develop a software application for determining optimal "routes" or circuits for field operations of a network of monitoring stations within a given area. Initiated functional classification to apply to existing provincial hydrometric network to rectify previously identified network use issues; ensure all stations are effective, efficient, and unique; and explore operational flexibility. Initiated spatial analyses of existing provincial hydrometric network. Updating (Obedkoff) regional streamflow inventory analyses with reports completed for the following regions: Skeena (2013), Omineca–Northeast (2014), Cariboo (2015—report yet to be posted); analyses now underway for the West Coast and South Coast (anticipated completion in May 2016); anticipated completion of the Thompson/Okanagan and Kootenay/Boundary reports is in 2017.

- Long-term monitoring of seven watersheds that discharge into nearshore marine environments on the central coast. We monitor a range of stream constituents, with particular emphasis on dissolved organic matter, in addition to stream discharge. We monitor precipitation inputs to the watersheds. We monitor soil water tables and soil moisture, among other soil parameters.

- Acoustic detection of sediment flux in Fraser River at Mission. Geomorphic impacts of run-of-river hydroelectricity production. River Dynamics Laboratory, Simon Fraser University. Contact: Jeremy Venditti.

- Long-term monitoring of forest growth, mortality, and recruitment in the Greater Victoria Water Supply Area in a changing climate; contact: Joel Ussery (Capital Regional District). Soil moisture as an indicator of shifts in ecosystem processes and forest species composition with climate change in the CDFmm–CWHxm transition; contact: Sari Saunders at MFLNRO. Forest chronsequence and demographic monitoring plots; contact: Tony Trofymow (Canadian Forestry Service). Assessments of fish habitat, stream channel stability, and proper functioning condition in the streams within the Greater Victoria Water Supply Area; contact: Joel Ussery.

- We are continuing to develop automated flow measurement systems using salt dilution. These are designed to help build better rating curves and measure higher flows than is possible using manual methods, particularly where site access is difficult and/or costly. Measuring extreme flows is also

possible with this type of system. John Fraser or Gabe Sentlinger at Fathom Scientific Ltd. www.fathomscientific.com/

- Links between salmon and their ecosystems, with emphasis on nutrient transfers between freshwater and riparian zones. Contact: John Reynolds, Simon Fraser University.

- Nanoose Water Budget Study Phase 2—monitoring and analysis to support an understanding of supply and demand. Regional District of Nanaimo Drinking Water and Watershed Protection Program wetland inventory and monitoring: How do wetlands in our region contribute to aquifer recharge and water filtration? Regional District of Nanaimo Drinking Water and Watershed Protection Program and Vancouver Island University. For more details and other projects, contact Julie Pisani (Regional District of Nanaimo).

- Yellow Point–Cedar watershed modelling case study. The Cowichan Valley Regional District (CVRD) requested that a watershed modelling case study be conducted in the Yellow Point–Cedar watershed, located in the northeast corner of the CVRD. The project was designed to support the CVRD Environmental Initiatives Division in (1) protecting freshwater areas from degradation and contamination as a result of urbanization and land-use practices, (2) developing and testing the use of automated mapping to identify key surface water resources for protection, (3) developing and testing the use of automated mapping to identify critical ecological areas at risk or for restoration prioritization, and (4) educating decision-makers and the public about the importance of key ecological function and relationship to long-term sustainability. The study was completed through processing and analysis of LiDAR data provided by the CVRD for the study area, integrating with other existing mapping and GIS products, upgrading key ecosystem mapping, producing ecologic and predictive hydrologic maps, and working with community environmental groups to ground-truth these maps. The results included maps that showed areas with potential for contaminant loading in surface water to interact with groundwater based on zones of high interaction between groundwater and surface water and high human impact.

- MOE has undertaken a number of research projects to support implementation of the *Water Sustainability Act* and groundwater licensing. The project I am involved in is supporting the development of preliminary groundwater budgets in five high-priority areas of the province. The objectives of these studies are to (1) develop a conceptual model of groundwater movement in the study area, (2) develop preliminary estimates of groundwater inputs/outputs to the aquifer, and initial estimates of groundwater availability for allocation, and (3) identify data gaps and monitoring recommendations to support ongoing water budget calculations.

- Ongoing: FREP-based Watershed Status Evaluation Protocol development www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/integrated-resource-monitoring/forest-range-evaluation-program/frep-monitoring-protocols/fish-watershed

- In our area: Phase 2 of a water budget for one of the water regions in our area; this will include some aquifer characterization and groundwater–

surface water interaction assessments; climate station installation on Mount Arrowsmith, including a snow pillow; community watershed monitoring network, surface water quality monitoring by environmental stewardship organizations; volunteer observation well database and expansion of the provincial Observation Well Network in our region. Contact: Julie Pisani (Regional District of Nanaimo, Drinking Water and Watershed Protection Coordinator)

- Effectiveness of WSA regime, Aboriginal water rights and WSA indigenous water law and Canadian water law
- Modelling the hydrologic impacts of climate change for watersheds throughout British Columbia. Online access to model data, including climate data (historic and future)

- We are implementing the "Open Standards for the Practice of Conservation," an adaptive management approach to watershed governance that recognizes the linkages between ecosystem services and human well-being. We have completed the action plan and are looking to implement the actions plan—they address pressures relevant in the Coquitlam River watershed, such as development, stormwater, water extraction, invasive species, recreation, vandalism and illegal activities, mainstream cultural norms, and mining. www.coquitlamriverwatershed.ca/content/watershed-plan

- Alouette River Management Society, Stoney Creek Environment Committee, Sapperton Fish and Game Club, Coquitlam River Watershed Roundtable, Stave Valley Salmonid Enhancement Society, Hyde Creek Watershed Society, Hoy/Scott Watershed Society, Kanaka Environmental and Education Partnership Society, Metro Vancouver Regional District, BC Hydro, Brunette Basin Coordination Committee

North Salt Spring Waterworks District (NSSWD) has had the following documents completed by Kerr Wood Leidal Associates Ltd.:

- Sutherland, C. and W. Yao. 2015. St. Mary Lake watershed water availability and demand – climate change assessment. Kerr Wood Liedal Associates Ltd. www.northsaltspringwaterworks.ca/wordpress_water/wp-content/uploads/2015/06/St.-Mary-Lake-Hydrology-Study-Final-2015.pdf
- Climate and hydrological information continues to be collected. Sutherland, C. and W. Yao. 2015. Maxwell Lake, Rippon Creek and Larmour Creek watersheds water availability – climate change assessment. Kerr Wood Liedal Associates Ltd. www.northsaltspringwaterwork.ca/wordpress_water/wp-content/uploads/2015/06/Maxwell-Lake-Hydrology-Study-Final-2015.pdf
- Additional projects include: a technical memorandum on the 2015 drought for Maxwell Lake and St. Mary Lake, flood impacts of raising the Duck Creek weir and a water quality study (2014–15) and study and statement related to the hypo limnetic aeration of St. Mary Lake

- Peace River: effects of hydropower development. See Church, M. 2015. The regulation of Peace River. Wiley-Blackwell, Chichester, UK. Sediment transport and morphology of lower Fraser River: many research papers and reports; advice to B.C. Ministry of Justice, Attorney General; Ministry of Environment; and FLNRO.

- As an engineering and geology consulting firm, we seldom if ever undertake "pure research" but often complete "applied research" as part of the process of solving our clients' problems or designing water and wastewater systems and management plans. Some of these projects include monitoring of groundwater, including water levels, water quality, and pumping rates. This monitoring occurs over a relatively short duration of typically 3 months to 10 years, and at a small number of locations (wells), typically 2–10 locations. Most of this monitoring information is privately held, but some of this information could, potentially, be made public. If you would like to contact me about this, here are my contact details: Michael Payne, PEng, PGeo. (Payne Engineering Geology).
- Project title: Assessment of hydraulic connectivity related to groundwater extraction on selected sensitive steams in support of science-based allocation decision-making. Author: Michele Lepitre, M.Sc., P.Geo., Regional Hydrogeologist, South Coast Natural Resource Region
- Have research activities in Horn River Basin, Jordan River, Columbia River/Elk Valley, and province-wide initiatives. Contact Water, Innovation, and Global Governance Lab at UVic. www.uvic.ca/research/centres/globalstudies/projects/core-projects/wigg-lab/index.php
- Investigation of groundwater channel creation for fish habitat enhancement on Gold Creek in Golden Ears Park. Monitoring of flow and temperature on Gold Creek. Fish population assessment on Kawkawa Lake near Hope. Stream flow and water quality monitoring on inlet streams of Kawkawa Lake.
- For more information on the groundwater science projects for 2015/16 under the Water Protection and Sustainability Branch, please contact Michele Lepitre or Mike Wei (B.C. Ministry of Environment).
- Campbell River Water Use Plan long-term monitoring projects for BC Hydro–Ecofish Research and A-Tlegay Fisheries Society
- Groundwater–surface water interaction study in the Cowichan River watershed; sediment budget study in the San Juan River; drought monitoring program on Vancouver Island
- Catchment-based karst system management planning. Wildfire impacts on karst systems. Contact: Paul Griffiths
- 1. Carnation Creek watershed experiment: Multidisciplinary. Long-term study of the effects of historic practices and climate change on watershed hydrology, geomorphology, riparian ecosystems, stream form/function, aquatic habitats, and fish. Peter Tschaplinski, Robin Pike, and Jonathan Goetz (MOE); David Spittlehouse and David Wilford (FLNRO). www.for.gov.bc.ca/hre/ffip/CarnationCrk.htm
- 2. Russell Creek, Tsitika River studies; snow accumulation and melt studies—see William Floyd, FLNRO West Coast Region.
- The Managed Forest Council is looking into administrative and operational strategies employed by private managed forest landowners when working in and around individual water licences and licensed water intakes. Contact: Phil O'Connor (Managed Forest Council)

- Look at my research projects and publication list for examples of research and extension work conducted by my group. Contact: Dan Moore (www.geog.ubc.ca/~rdmoore)

- Groundwater–surface water interactions work Phase 2 wrapping up. Pat Lapcevic: Three-year water quality survey (baseline research wrapped up) need to follow up. Deb Epps: Water temperature and pumping opportunities need to be pursued. Why has the fishery crashed in Lake Cowichan? How can we bring back the spring run of Chinook in our Canadian heritage? Is it reasonable to invoke watering restrictions on users of our bountiful aquifer? Pilot study for new model of watershed governance that addresses senior government capacity issues. Revenue source models for water/watershed research.

- Many contacts in BC Hydro related to learning from the Water Use Planning and monitoring. Contact: Ron Ptolemy or Jordan Rosenfeld (B.C. Ministry of Environment)

- Currently partnering with DFO habitat restoration, provincial Ministry of Transportation and Infrastructure, and FLNRO to strategically accommodate protection of fisheries values in development planning.

- Chemical indicators of saltwater intrusion for the Gulf Islands, British Columbia. J. Klassen, D.M. Allen, and D. Kirste, Department of Earth Sciences, Simon Fraser University; Screening tool for guiding short-term groundwater curtailment during water scarcity. Klaus Rathfelder, MOE; Cumulative impacts of groundwater extraction on seasonal flows of a regulated stream, Cowichan River, B.C. Sylvia Barroso, FLNRO. *Water Sustainability Act:* factors, principles and reasoning governing legislative policy development related to the diversion and use of groundwater in B.C. Mike Wei, MOE.

- This work has been ongoing since 2005 in the Cowichan watershed. We have done many good things but need the final push to get local control of our water supply.

- In 2014–15, Fraser Basin Council completed a watershed health report for the Nechako River Basin and is now in the second phase of disseminating the report findings as well as initiating the development of a NechakoWatershed Strategy. We will be partnering with the Nechako Watershed Roundtable for this project. The Nechako Watershed Health Report can be found at www.fraserbasin.bc.ca/_Library/Water_BCWF/Nechako-Mar31-2015_FINAL.pdf
  Lead contact is Steve Litke, Senior Manager of the Watersheds and Water Resources Program.
- Fraser Basin Council is also facilitating a collaborative regional process to strengthen flood management throughout the entire Lower Mainland. This is a partnership with 26 local governments, federal and provincial agencies, and other entities. For more information, see www.fraserbasin.bc.ca/_Library/Media/backgrounder_lmfls.pdf

- Sediment supply analysis of the San Juan River. Forestry management effects on deep-seated landslides, Cascade Bay, Harrison Lake. Contact: Tom Millard (FLNRO)

Cover Letter:

Watershed management issues are among the many challenges facing natural resource managers in British Columbia. The B.C. Ministry of Forests, Lands and Natural Resource Operations (FLNRO) is conducting a needs assessment to identify specific information gaps in FLNRO's South Coast and West Coast regions of B.C. (refer to the following URL for the location of these two regions: https://www.for.gov.bc.ca/mof/maps/regdis/regdismap.pdf). This assessment will inform the development of an applied research strategy to support sustainable water resource management in the coast regions of B.C.*

We have compiled a list of key persons to participate in a survey to help identify these information needs. Participation in this survey will promote applied water research that is regionally focussed, resource efficient, strategic, and provides opportunities for collaboration. We are requesting your help in this process by completing the survey (link below).

To complete the survey, please click on this link or paste the following URL into your browser: https://www.surveymonkey.com/r/KHXVWN7.

The survey takes about 20 minutes to complete. Fill in only those sections relevant to your area of experience and practice. Your participation is greatly appreciated.

You can complete the survey online, or an in-person interview can be arranged by phone.

Please complete the survey by August 15, 2015.

If you have questions about this survey, please contact myself, Rob Scherer, at rascherer@okanagan.bc.ca, Todd Redding at TRedding@okanagan.bc.ca or Kevin Ronneseth at kevinronneseth@shaw.ca.

For more information about the development of the research strategy, please contact Dave Wilford (dave.wilford@gov.bc.ca) at the B.C. Ministry of Forests, Lands and Natural Resource Operations.

Thank you again for your participation.

* Similar assessments have been completed for northeast B.C. and the Thompson–Okanagan region. The NE report is available at www.bcwatertool.ca/info-sources (the link to the NE report can be found on the top right-hand portion of the website), and the T–O report is in review for publishing. A tool we used was a searchable database with information relevant to water in NE B.C. and the T–O region. The NE searchable database is available now (at the website above), and the T–O searchable database will be available soon. We will be doing the same thing for the coastal regions of B.C. Support to the project will help make the database for the coastal regions more complete.

Survey:

1. Name

2. Title

3. Affiliation (e.g., government ministry, company name)

4. Survey completion method

- ◯ Online individually
- ◯ Interview with survey team member

5. What is your primary employment affiliation? (Please select only one)

- ◯ Provincial government
- ◯ Federal Government
- ◯ Local/regional government
- ◯ First Nations
- ◯ Community/Stewardship/NGO
- ◯ Academic
- ◯ Water purveyor
- ◯ Industry
- ◯ Consulting

Other (please specify)

6. In Which field/area do you primarily practice? Select a maximum of 3.

- [ ] Surface water management (allocation, licensing)
- [ ] Surface water hydrology
- [ ] Groundwater management (allocation, licensing)
- [ ] Groundwater hydrology
- [ ] Watershed management
- [ ] Fisheries and aquatic ecology
- [ ] Forest management
- [ ] Geoscience and engineering
- [ ] Agriculture
- [ ] Water purveyor
- [ ] Mining and minerals extraction
- [ ] Oil and gas production
- [ ] Hydropower production
- [ ] Waste water management
- [ ] Land use planning
- [ ] Research
- [ ] Community/Stewardship/NGO
- [ ] Energy (e.g., oil & gas, hydro, geothermal)
- [ ] Natural resource hazards (e.g., mass movements, floods)
- [ ] Mining and mineral extraction
- [ ] Policy development

Other (please specify)

7. What is the primary water related focus of your professional practice? Select a maximum of 3.

- [ ] Management
- [ ] Allocation/licensing
- [ ] Monitoring (e.g., trend, baseline, compliance etc.)
- [ ] Remediation
- [ ] Operations
- [ ] Planning
- [ ] Policy and regulation
- [ ] Compliance and enforcement
- [ ] Research
- [ ] Data collection and inventory (e.g., well log data, consultant reports, etc.)
- [ ] Stewardship and conservation

Other (please specify)

8. Please rank the following themes in terms of their relevance to your primary areas of practice (as identified in Question #6).

	High	Medium	Low	Not Applicable
Surface water quantity	○	○	○	○
Surface water quality	○	○	○	○
Groundwater quantity	○	○	○	○
Groundwater quality	○	○	○	○
Groundwater–surface water interactions	○	○	○	○
Fish and aquatic ecosystems	○	○	○	○
Natural resource hazards	○	○	○	○

9. Please indicate the regional watersheds within which you practice; or the watersheds which contain the aquifers within which you practice. Please select all that apply.

- [ ] Haida Gwaii
- [ ] Lower Fraser (Hope to Vancouver)
- [ ] Howe Sound & Sunshine Coast (Squamish, Powell River)
- [ ] Central Coast (Bella Coola)
- [ ] North Coast (Prince Rupert)
- [ ] Vancouver Island South and Gulf Islands (Port Alberni, Nanaimo, Victoria)
- [ ] Vancouver Island North (Campbell River, Port McNeill)

Other (please specify)

10. Please rank the information needs with respect to improving your ability to do your job relating to surface water quantity hydrologic processes.

	High	Medium	Low	Not Applicable
Peak flow timing	○	○	○	○
Peak flow magnitude	○	○	○	○
Low flow timing	○	○	○	○
Low flow magnitude	○	○	○	○
Annual water yield	○	○	○	○
Evaporation and transpiration rates	○	○	○	○
Infiltration and soil moisture storage	○	○	○	○
Surface water–groundwater interactions	○	○	○	○
Rainfall timing and rates	○	○	○	○
Snow accumulation and melt rates	○	○	○	○
Groundwater recharge	○	○	○	○

Other (please specify)

11. Please rank the information needs with respect to improving your ability to do your job relating to <u>management for surface water quantity</u>.

	High	Medium	Low	Not Applicable
Current allocation	○	○	○	○
Water availability/storage	○	○	○	○
Climate change effects on water supply	○	○	○	○
Forest management effects	○	○	○	○
Environmental flow needs	○	○	○	○
Mining effects	○	○	○	○
Hydropower generation	○	○	○	○
Agricultural/range effects	○	○	○	○
Cumulative hydrologic effects	○	○	○	○
Urban water management	○	○	○	○
Recreational uses	○	○	○	○

Other (please specify)

12. Please rank the information needs with respect to improving your ability to do your job relating to ground water quantity hydrogeologic processes.

	High	Medium	Low	Not Applicable
Water levels	○	○	○	○
Aquifer yield potential	○	○	○	○
Recharge rates	○	○	○	○
Aquifer permeability and porosity	○	○	○	○
Storativity	○	○	○	○
Flow direction	○	○	○	○
Geological model	○	○	○	○
Aquifer mapping	○	○	○	○
Aquifer “typing”	○	○	○	○
Lithology	○	○	○	○
Withdrawal amounts	○	○	○	○
Surface water–groundwater interactions	○	○	○	○
Flowing artesian conditions	○	○	○	○
Saltwater intrusion	○	○	○	○

Other (please specify)

13. Please rank the information needs with respect to improving your ability to do your job relating to management of ground water quantity.

	High	Medium	Low	Not Applicable
Current groundwater withdrawls	○	○	○	○
Current groundwater availability	○	○	○	○
Water well locations	○	○	○	○
Climate change effects on water supply	○	○	○	○
Forest management effects	○	○	○	○
Mining effects	○	○	○	○
Agricultural effects	○	○	○	○
Cumulative hydrologic effects	○	○	○	○
Urban water management	○	○	○	○

Other (please specify)

14. Please rank the information needs with respect to improving your ability to do your job relating to surface water and ground water quality.

	Surface Water Quality	Groundwater Quality
Nutrients		
Organic chemicals		
Inorganic chemicals		
Temperature		
Sediment		
Turbidity		
Biological water quality		
Pharmaceuticals		
Radiological agents		

Other (please specify)

15. Please rank the information needs with respect to improving your ability to do your job relating to <u>management of surface and ground water quality</u> concering effects from:

	Surface Water Quality	Groundwater Quality
Climate change effects		
Forest management effects		
Mining effects		
Agriculture effects		
Range effects		
Cumulative effects		
Urban development effects		
Recreation		
Activities in riparian areas		
Activities in wetland areas		
Aquatic ecosystem management		
Oil and gas effects		
Saltwater intrusion		
Aquaculture effects		

Other (please specify)

16. Please rank the information needs with respect to improving your ability to do your job relating to ground water - surface water interactions.

	High	Medium	Low	Not Applicable
Where do they occur	○	○	○	○
Flux magnitudes	○	○	○	○
Flux directions	○	○	○	○
Water quality	○	○	○	○
Seasonal variations	○	○	○	○
Pumping data	○	○	○	○

Other (please specify)

17. Please rank the information needs with respect to improving your ability to do your job relating to aquatic ecosystems.

	High	Medium	Low	Not Applicable
Fish populations	○	○	○	○
Environmental flow needs	○	○	○	○
Activities in riparian areas	○	○	○	○
Activities in wetland areas	○	○	○	○
Activities in estuaries and coastal areas	○	○	○	○
Temperature-sensitive streams	○	○	○	○
Aquatic ecosystem health (e.g., biomonitoring)	○	○	○	○
Fish passage				

Other (please specify)

18. Please rank the information needs with respect to improving your ability to do your job relating to natural resource development hazards.

	High	Medium	Low	Not Applicable
Slope mass movements	○	○	○	○
Surface erosion	○	○	○	○
Floods	○	○	○	○
Drought	○	○	○	○
Snow avalanche	○	○	○	○
Karst	○	○	○	○
Earthquake	○	○	○	○

Other (please specify)

19. Please rank the information needs with respect to improving your ability to do your job relating to management for groundwater–surface water interactions, aquatic ecosystems, and natural resource development hazards as concerning the effects of:

	Groundwater–Surface Water Interactions	Aquatic Ecosystems	Natural Resource Development Hazards
Water withdrawal			
Aquatic ecosystem management			
Activities in riparian areas			
Activities in wetland areas			
Climate change			
Forest management			
Mining			
Agriculture			
Range management			
Hydropower generation			
Cumulative effects			
Urban development			
Roads and stream crossings			

20. Please rank the general data and information system needs with respect to improving your ability to do your job.

	High	Medium	Low	Not Applicable
Hydrometric monitoring data	○	○	○	○
Groundwater-level monitoring data	○	○	○	○
Climate monitoring data	○	○	○	○
High-elevation climate data	○	○	○	○
Snow survey data	○	○	○	○
Chemical water quality monitoring data	○	○	○	○

	High	Medium	Low	Not Applicable
Physical water quality monitoring data	○	○	○	○
Biological water quality monitoring data	○	○	○	○
Water temperature monitoring data	○	○	○	○
Geologic data	○	○	○	○
Aquifer mapping and characterization	○	○	○	○
Water consumption/usage data	○	○	○	○
Online data repository (e.g., groups can upload data to share)	○	○	○	○
Online access to data	○	○	○	○
Online access to analysis results/products (e.g., interpreted data)	○	○	○	○
Online access to geo-referenced data	○	○	○	○
Online data standards (e.g., to facilitate data sharing and use in GIS platforms)	○	○	○	○
Online analysis tools (e.g., statistical analysis, models etc.)	○	○	○	○
Professional development opportunities (e.g., conferences, workshops)	○	○	○	○

Other (please specify)

21. Please identify research and information needs/questions to support sustainable water management in the Coast region of BC. Provide as many as necessary and be as specific as possible.

22. Please identify key policy and regulatory needs to support sustainable water management in the Coast region of BC. Provide as many as necessary and be as specific as possible.

23. Please identify current and planned water-related research being undertaken either by your organization, a partner organization, or in your local area. Please provide a title, contact person, and contact information (e.g., email or web link) if possible.

24. Please identify any emerging pressures/issues, not captured in the survey questions, that you forsee requiring information to support sustainable water resource management (e.g., *Water Sustainability Act*) in the Coast region.

25. Please provide the names and contact information (if available) of colleagues or interested people who could provide further input to the survey.

Thank you for your time and assistance. If you have further questions, please contact Dr. Dave Wilford at the BC Ministry of Forests, Lands and Natural Resource Operations (dave.wilford@gov.bc.ca).