Technical Data Report

Hydrology

ENBRIDGE NORTHERN GATEWAY PROJECT

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Abbreviations

7Q10 .... seven-day 1:10 year return period event
7Q2 .... seven-day 1:2 year return period event
ESA .... environmental and socio-economic assessment
IDF .... intensity-duration-frequency
KP .... kilometre post
m asl .... metres above sea level
NCD .... non-classified drainage
NVC .... no visible channel
PEAA .... project effects assessment area
the Project .... Enbridge Northern Gateway Project
RoW .... right-of-way
TDR .... technical data report
WSC .... Water Survey of Canada

Glossary

1:100-year peak discharge	Maximum instantaneous discharge that will be equalled or exceeded once every 100 years on the long-term average.
7Q10 discharge	1:10-year return period, seven-day low flow. The flow below which the average seven-day flow will drop one year out of 10 on the long-term average. Benchmark flow for surface water resources effects assessment.
bankfull	The elevation on the bank where flooding begins. Commonly associated with the top-of-bank level.
channel	A watercourse. Includes rivulets, streams, creeks and rivers. Distinguished from drainage swales by having a defined bed and banks.
channel depth	The vertical distance between the deepest portion of the channel and the top of the channel banks.
channel geomorphology	The study of the origins, development and characteristics of watercourses.
channel cross-section	The shape of a channel along a line perpendicular to the banks and the direction of flow.
drainage area	The measurement of the area of a watershed draining to a specified point along a watercourse or on a water body.
erosion	The wearing away of stream banks by water as a result of detachment and movement of soil and rock particles.
evapotranspiration	Total water removed from an area through plant transpiration (evaporation from plant leaves and surfaces) and direct evaporation from soil, water and snow surfaces.
freshet	Spring runoff resulting from snowmelt or from combined rainfall and snowmelt runoff.
hydrological zone	A geographical area within which watercourses have similar hydrological characteristics and respond similarly to precipitation and climatic factors.
infiltration	The movement of water through the soil surface and into the soil.
reach	Longitudinal section of channel between two specified points. A reach may also be defined based on relative uniformity with respect to width, depth velocity and slope.
scour	Erosive action of water resulting in channel enlargement or channel bed lowering by the removal of material.

silt	Fine mineral particles with particle sizes ranging from 0.002 to 0.05 mm in diameter, i.e., between those of fine sand and clay.
surface storage	Water retained in surface depressions and puddles that does not contribute to surface runoff.
surficial geology	The geology of surficial materials, including soils and bedrock at or near the ground surface.
swale	A shallow depression that acts as a drainage path and conveys flow seasonally or intermittently.
watershed	A topographically defined region of land within which water flows to a specific water body or series of water bodies and from which all flow is discharged through a single downstream outlet.

1 Introduction

Surface water resources include existing watercourses, lakes and other natural surface water bodies encountered or approached by the project right-of-way (RoW). Surface water resources are discussed in the context of hydrology and surface water quality. This technical data report (TDR) addresses hydrology. Water quality is presented in the Surface Water and Sediment Quality Technical Data Report (Touchinski et al. 2010).

1.1 Objectives

This TDR describes the baseline characteristics of the biophysical elements assessed in the environmental and socio-economic assessment (ESA) for the Enbridge Northern Gateway Project (Project). This information will be used to identify construction and operational mitigation measures needed to reduce or avoid environmental effects on biophysical elements. It will also be used as a basis against which environmental effects on hydrology will be assessed.

1.2 Setting

Surface water hydrology is the movement of water over land, into and through surface water bodies such as wetlands, lakes and watercourses. Hydrology involves the interactions between precipitation, surface storage, evaporation, evapotranspiration, infiltration, surface runoff and groundwater. Surface runoff is the primary mechanism for transporting sediment from land into watercourses and surface water bodies. Surface water hydrology is directly linked with other aquatic resources, such as fisheries and water quality, as well as groundwater systems.

The hydrology baseline for the Project was prepared using information generated from existing literature sources and field surveys for the following key data categories:

- mean seasonal and mean annual total flow volumes
- 1:10 and 1:100 year return period peak flows
- drought (low) flows
- freeze-up and breakup timing and average duration of ice cover
- climate data (specifically rainfall)
- channel dimensions (width, depth and gradient)
- channel bed and bank materials

The geomorphology of a channel is a function of streamflow, sediment load, surficial geology and channel geometry (principally width, depth and gradient). The process of bed and bank erosion, sediment transport and sediment deposition are in balance in a stable channel for the local streamflow and sediment supply regimes. Changes to any of the three basic variables of streamflow, sediment load or channel geometry can affect the geomorphology of the watercourse.

In addition to the hydrological parameters listed above, the hydrology baseline summarizes data gathered during the hydrology and fisheries field studies on channel geometric properties. Baseline sediment data are presented in the water quality baseline report.

2 Methods

2.1 Study Area Boundaries

2.1.1 Hydrological Zones

The Project will extend approximately 1,172 km from an initiating station near Bruderheim, Alberta to the Kitimat Terminal south of Kitimat, British Columbia. The pipelines will cross six distinct hydrological zones (see Figures 2-1 and 2-2).

The hydrological zones were differentiated based on topography (i.e., elevation, relief, basin gradient and drainage density) and climate (principally precipitation and temperature) and confirmed by differences in surface runoff and hydrological characteristics. The six hydrological zones are:

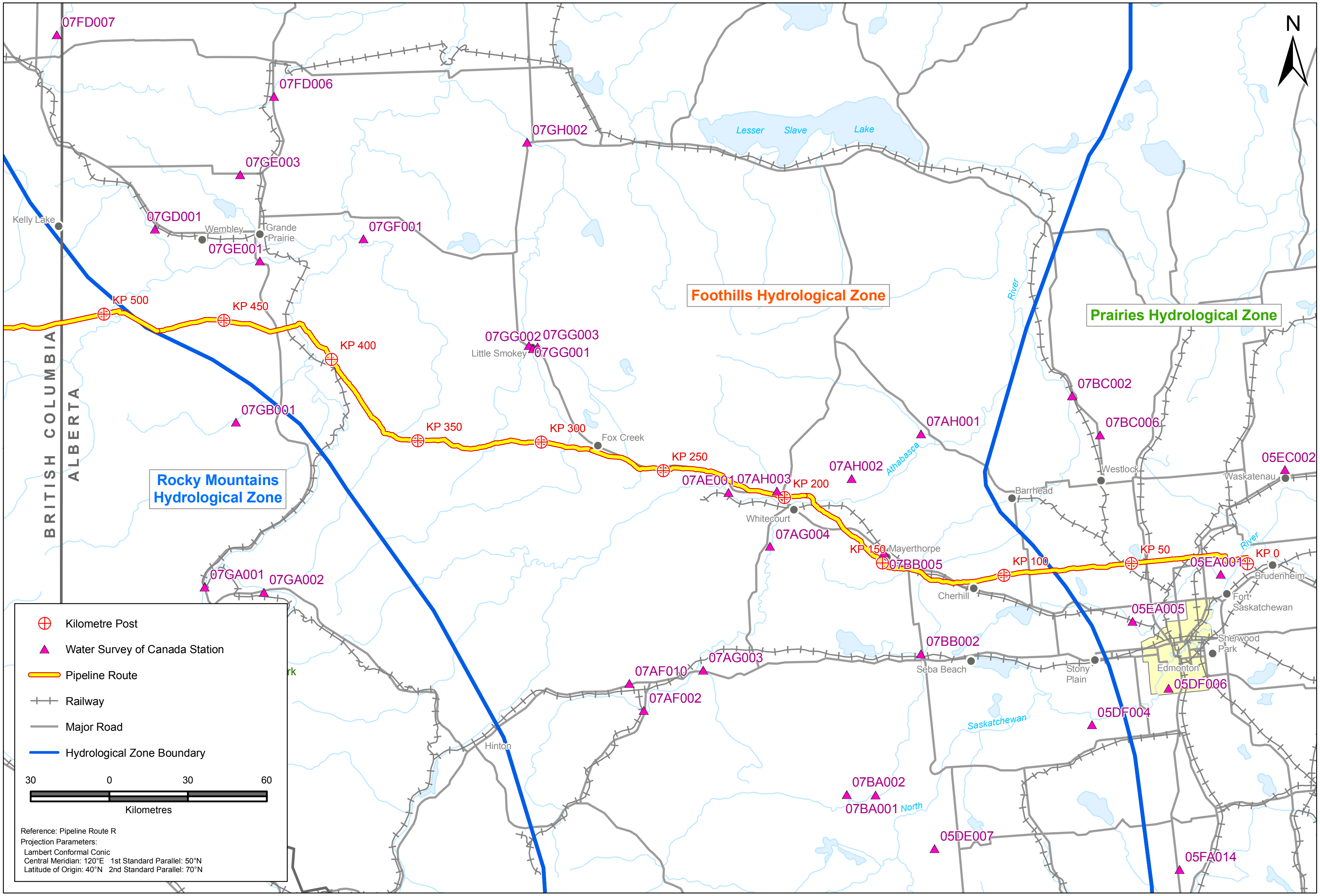
- Prairies (initiating station near Bruderheim to approximately Kilometre Post [KP] 81)
- Foothills (KP 81 to KP 485)
- Rocky Mountains (KP 485 to 714)
- Central Interior (KP 714 to 915)
- Central Mountains (KP 915 to KP 1054)
- Coastal Mountains (KP 1054 to the Kitimat Terminal)

2.1.2 Watercourse Crossings

About 1,300 watercourse crossings were identified from mapping and field investigations along the pipeline RoW. At more than 500 of these crossings, there was no visible channel (NVC) or the crossing was deemed a non-classified drainage (NCD) by the fisheries field assessment teams. There are approximately another 773 defined watercourse crossings. The majority of these crossing sites (about 82% of all defined watercourse crossings) are streams with drainage areas of less than 10 km^2.
See Table 2-1 for a list of watercourses by watershed drainage area and hydrological zone.

2.1.3 Study Area for Existing Data Review

There are a limited number of locations along the pipeline RoW for which baseline hydrological data are available. To assemble a sufficiently representative dataset, baseline hydrological data were gathered for an approximately 200-km-wide area along the pipeline RoW. The baseline data were used to describe the characteristics of the six hydrological zones.



REFERENCES: AB SRD, Enbridge, ESRI, Spatial Data Warehouse Ltd., Water Survey of Canada.

PREPARED BY:	PREPARED FOR:		FIGURE NUMBER:		DATE:
amec	ENBRIDGE NORTHERN GATEWAY PIPELINES	**ENBRIDGE NORTHERN GATEWAY PROJECT**	2-1		20091217
			SCALE: 1:2,000,000	AUTHOR: JNB	APPROVED BY: MW
		Hydrological Zones and Water Survey of Canada Stations, Alberta	PROJECTION: LCC	DATUM: NAD 83	

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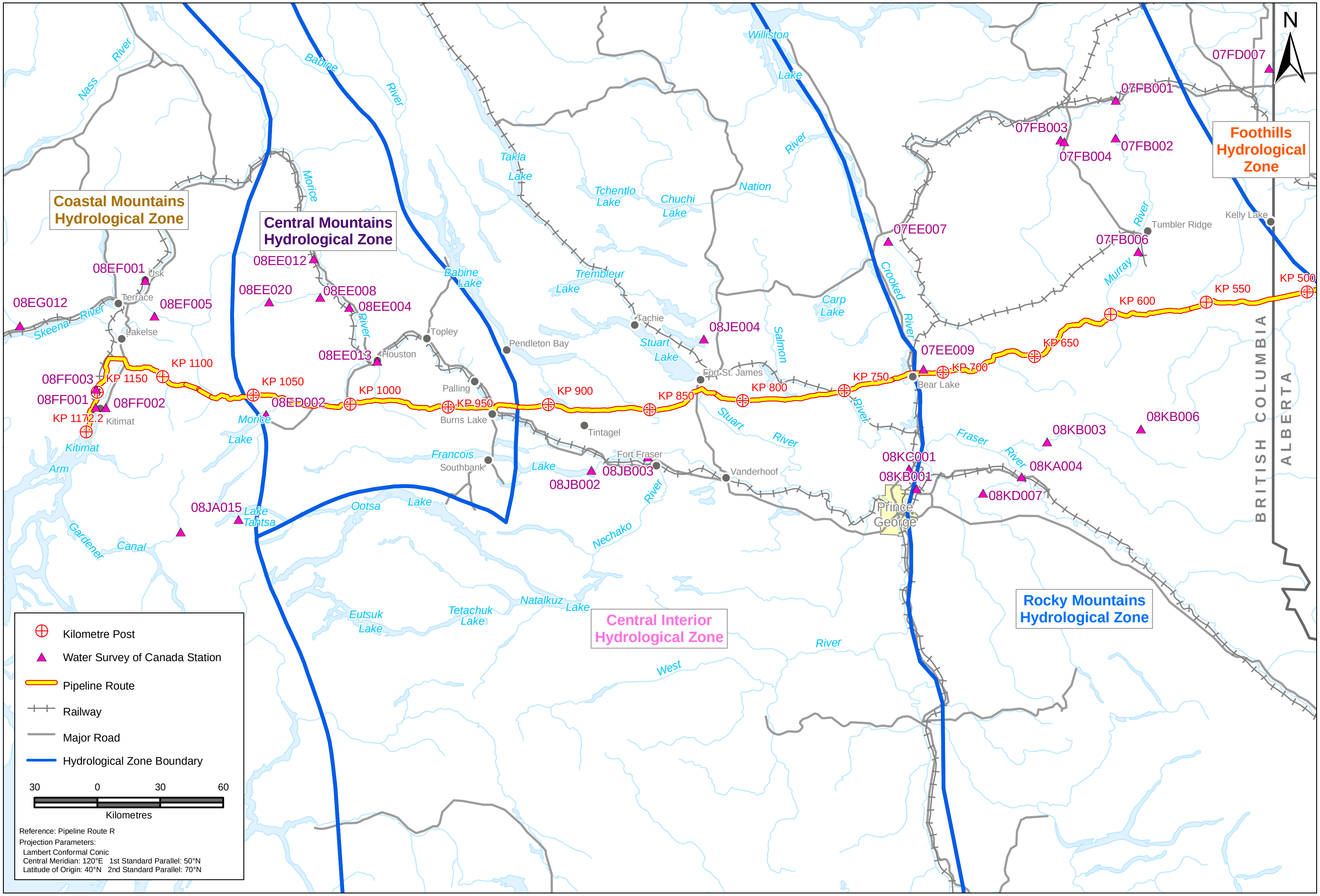

REFERENCES: BC_MOE, BC_MOF, Enbridge, ESRI, Spatial Data Warehouse Ltd., Water Survey of Canada.

PREPARED BY:	PREPARED FOR:		FIGURE NUMBER:	DATE:
amec	ENBRIDGE NORTHERN GATEWAY PIPELINES	**ENBRIDGE NORTHERN GATEWAY PROJECT**	2-2	20091217
		Hydrological Zones and Water Survey of Canada Stations, British Columbia	SCALE: 1:2,500,000	AUTHOR: JNB / APPROVED BY: MW
			PROJECTION: LCC	DATUM: NAD 83

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Table 2-1 Watercourse Crossings by Hydrological Zone

Drainage Area (km²)	Number of Watercourse Crossings by Hydrological Zone						Total Number of Crossings
	Prairies	Foothills	Rocky Mountains	Central Interior	Central Mountains	Coastal Mountains	
<1	0	39	158	59	37	88	381
1 to 10	9	68	65	39	35	39	255
10 to 100	12	25	19	14	11	8	89
100 to 1,000	2	13	7	3	6	5	36
1,000 to 10,000	0	3	3	1	1	0	8
>10,000	1	2	0	1	0	0	4
Total Defined Watercourse crossings	24	150	252	117	90	140	773
Crossings per km of pipeline	0.3	0.4	1.1	0.6	0.7	1.2	-
NVC or NCD	9	67	182	195	43	30	52
Total watercourse crossings	33	217	434	312	133	170	1,299

NOTES:
NVC – no visible channel
NCD – non-classified drainage

2.1.4 Study Area for Field Surveys

The baseline hydrology field study area is a 1-km-wide corridor. The PEAA for the hydrology assessment includes the channel reach between the project-affected point of interest on the watercourse (i.e., the upstream extent of any project-related environmental effects, usually the watercourse crossing) and the confluence with the next downstream watercourse or, where applicable, the inlet to a mapped lake (as shown on available 1:30,000 scale mapping). Such a downstream boundary is considered to be the point at which measurable environmental effects of the Project will be difficult to distinguish from natural changes in the hydrological and hydraulic characteristics of the watercourse downstream from the confluence.

Applicable data (i.e., channel geometry) from the fisheries discipline baseline assessment of potential watercourse crossings along the pipelines were also used by the hydrology discipline.

2.2 Review of Existing Data Sources

2.2.1 Streamflow Data

Streamflow data were obtained from the Water Survey of Canada (WSC), a division of Environment Canada, for stations within 100 km of the pipeline RoW (WSC 2008, Internet site). Almost 180 streamflow monitoring stations were identified in the 200-km-wide baseline data review study area. In addition to providing direct information on gauged streams crossed by the pipelines, a portion of the streamflow station dataset were used to define hydrological characteristics of streams crossed by the pipelines that are not gauged. The stations were screened before inclusion in the baseline database for:

- lake influences – Streamflows recorded at stations located downstream of large lakes will not be representative of streamflows in most watersheds being crossed by the RoW and were excluded from the baseline assessment (e.g., WSC Station 08JB008 – Nadina River at Outlet of Nadina Lake).
- flow regulation – Streamflows recorded on a regulated channel (i.e., dam or flow controls upstream of station) will not be representative of natural streamflows in most watersheds being crossed by the RoW.
- period of record – Only stations with a minimum 30-year (British Columbia) or 35-year (Alberta) period of record were included in the baseline database. Because of the generally shorter available periods of record for stations in British Columbia, the shorter period of record was accepted for stations in that province, to allow a sufficient number of representative stations to be included in the study.

After the screening process, 63 stations were accepted for the regional hydrology baseline. Of these, 32 stations are in Alberta and 31 stations are in British Columbia.

The majority of the stations are operated by the WSC. Some stations are also operated by provincial authorities (Alberta Environment and British Columbia Ministry of Environment). All the data are published through the WSC (Environment Canada 2003).

The stations used in this baseline study are listed in Table 2-2 and their locations are shown on Figures 2-1 and 2-2.

Streamflow data (i.e., recorded monthly mean, annual mean, annual peak and annual low flow data) were used to delineate six distinct hydrological zones along the pipeline RoW. These data were also used to develop regional relationships for annual, seasonal, peak and drought flows. The relationships were used to estimate hydrological parameters for ungauged basins. The results of these investigations were compared with available regional hydrological assessments done in British Columbia (Coulson and Obedkoff 1998).

Table 2-2 Streamflow Monitoring Stations

Station Number	Station Name	Drainage Area (km^2)	Available Period of Record[1]
Prairies Hydrological Zone			
05DF006	Whitemud Creek near Ellerslie	330	1969 to 2007 (S)
05EA001	Sturgeon River near Fort Saskatchewan	3,310	1914 to 1923 (C) 1928 to 1930 (C) 1935 to 2007 (S)
05EA005	Sturgeon River near Villeneuve	1,910	1972 to 2007 (C)
05EC002	Waskatenau Creek near Waskatenau	131	1966 to 2007 (S)
05FA014	Maskwa Creek No. 1 above Bearhills Lake	79.1	1972 to 2007 (S)
07BC002	Pembina River at Jarvie	13,100	1957 to 1961 (S) 1962 to 2007 (C)
07BC006	Dapp Creek at Highway No. 44	605	1973 to 2007 (S)
Foothills Hydrological Zone			
05DE007	Rose Creek near Alder Flats	559	1972 to 2007 (S)
05DF004	Strawberry Creek near the mouth	592	1966 to 2007 (S)
07AE001	Athabasca River near Windfall	19,600	1961 to 1978 (C) 1979 to 2007 (S)
07AF002	McLeod River above Embarras River	2,560	1954 to 2007 (C)
07AF010	Sundance Creek near Bickerdike	178	1972 to 2007 (S)
07AG003	Wolf Creek at Highway No. 16a	826	1954 to 2007 (C)
07AG004	McLeod River near Whitecourt	9,100	1968 to 1970 (C) 1971 to 2007(S)
07AH001	Freeman River near Fort Assiniboine	1,660	1965 to 2007(S)
07AH002	Christmas Creek near Blue Ridge	424	1973 to 2007(S)
07AH003	Sakwatamau River near Whitecourt	1,140	1973 to 2007(S)
07BA002	Rat Creek near Cynthia	605	1972 to 2007 (S)
07BB002	Pembina River near Entwistle	4,420	1915 to 1922 (C) 1955 to 2007(C)
07BB005	Little Paddle River near Mayerthorpe	298	1963 to 2007(S)
07FD006	Saddle River near Woking	538	1967 to 2007 (S)
07FD007	Pouce Coupe River below Henderson Creek	2,850	1971 to 2007 (C)
07GD001	Beaverlodge River near Beaverlodge	1,610	1968 to 1979 (S) 1980 to 1987 (C) 1988 to 2007 (S)
07GE001	Wapiti River near Grande Prairie	11,300	1961 to 2007(C)

Table 2-2 Streamflow Monitoring Stations (cont'd)

Station Number	Station Name	Drainage Area (km^2)	Available Period of Record[1]
Foothills Hydrological Zone (cont'd)			
07GE003	Grande Prairie Creek near Sexsmith	140	1969 to 2007 (S)
07GF001	Simonette River near Goodwin	5,040	1969 to 1970 (S) 1971 to 1986 (C) 1987 to 2007 (S)
07GG001	Waskahigan River near the mouth	1,040	1968 to 1969 (S) 1970 to 2007 (C)
07GG002	Little Smoky River at Little Smoky	3,010	1967 to 2007 (S)
07GG003	Iosegun River near Little Smoky	1,950	1969 to 2007 (S)
07GH002	Little Smoky River near Guy	11,100	1959 to 2007 (C)
Rocky Mountains Hydrological Zone			
07EE007	Parsnip River above Misinchinka River	4,900	1968 to 2007 (C)
07EE009	Chuchinka Creek near the mouth	311	1976 to 2007 (C)
07FB001	Pine River at East Pine	12,100	1961 to 1964 (S) 1965 to 2007 (C)
07FB002	Murray River near the mouth	5,550	1977 to 2007 (C)
07FB003	Sukunka River near the mouth	2,590	1977 to 2007 (C)
07FB004	Dickebusch Creek near the mouth	82.1	1978 to 2007 (C)
07FB006	Murray River above Wolverine River	2,370	1977 to 2007 (C)
07GA001	Smoky River above Hells Creek	3,870	1968 to 1986 (C) 1987 to 2007 (S)
07GA002	Muskeg River near Grande Cache	703	1972 to 1986 (C) 1987 to 2007 (S)
07GB001	Cutbank River near Grande Prairie	842	1970 to 2007 (S)
08KA004	Fraser River at Hansard	18,000	1952 to 2007 (C)
08KB001	Fraser River at Shelley	32,400	1950 to 2007 (C)
08KB003	McGregor River at Lower Canyon	4,780	1960 to 2007 (C)
08KB006	Muller Creek near the mouth	103	1977 to 2007 (C)
08KD007	Bowron River below Box Canyon	3,420	1977 to 2007 (C)
Central Interior Hydrological Zone			
08JB002	Stellako River at Glenannan	3,600	1961 to 2007 (C)
08JB003	Nautley River near Fort Fraser	6,030	1952 to 2007 (C)
08JE004	Tsilcoh River near the mouth	414	1976 to 2007 (C)
08KC001	Salmon River near Prince George	4,300	1953 to 2007 (C)

Table 2-2 Streamflow Monitoring Stations (cont'd)

Station Number	Station Name	Drainage Area (km²)	Available Period of Record[1]
Central Mountains Hydrological Zone			
08ED002	Morice River near Houston	1,900	1961 to 2007 (C)
08EE004	Bulkley River at Quick	7,350	1930 to 1945 (S) 1946 to 2007 (C)
08EE008	Goathorn Creek near Telkwa	126	1960 to 2007 (C)
08EE012	Simpson Creek at the mouth	13.2	1969 to 1974 (S) 1975 to 2007 (C)
08EE013	Buck Creek at the mouth	566	1973 to 2007 (C)
08EE020	Telkwa River below Tsai Creek	368	1976 to 2007 (C)
Coastal Mountains Hydrological Zone			
08EF001	Skeen River at Usk	42,300	1928 to 1931 (C) 1937 to 2007 (C)
08EF005	Zymoetz River above O.K. Creek	2,920	1964 to 2007 (C)
08EG012	Exchamsiks River near Terrace	370	1962 to 2007 (C)
08FE003	Kemano River above powerhouse tailrace	583	1972 to 2007 (C)
08FF001	Kitimat River below Hirsch Creek	1,990	1967 to 2007 (C)
08FF002	Hirsch Creek near the mouth	347	1967 to 2007 (C)
08FF003	Little Wedeene River below Bowbyes Creek	182	1967 to 2007 (C)
08JA015	Laventie Creek near the mouth	86.5	1976 to 2007 (C)

NOTE:
[1] S indicates seasonal data collection (typically March or April to October). C indicates continuous (year-round) data collection.

Although additional streamflow data were available for some water quality sampling sites in British Columbia and Alberta, these data were not included in the streamflow database because they are typically discrete (one-time) flow measurements.

Freeze-up, breakup and ice thickness data (see Figures 3-1 and Figures 3-3 to 3-7) were also gathered from WSC and publications (Allen 1977) for the stations listed in Table 2-2.

2.2.2 Climate Data

Hydrological modelling was not done for the baseline component of the study, but storm water runoff was modelled during the environmental effects assessment for the Project. This modelling was used to assess the environmental effects of the Project on local hydrology including runoff rates and timing. The data needed to support storm water runoff modelling included rainfall intensity-duration-frequency (IDF) data, which were available at a few locations between Bruderheim and Kitimat. Available IDF data were obtained for towns that were reasonably close to the RoW, including Edmonton, Edson, Hendrickson

Creek, Prince George, Fort St. James, Burns Lake, Quick, Terrace and Kitimat (Environment Canada 2008, Internet site).

2.2.3 Geomorphological Data

Geomorphological data assembled for the baseline study included channel size (width and depth) and gradient measurements taken at select watercourse crossings during the hydrology and fisheries field programs. Channel size, gradient and bed and bank material composition data were also obtained from reports for existing watercourse crossings along the RoW, namely reports from the Alliance Pipeline Project and other published documents (Kellerhals et al. 1972; Shaw and Kellerhals 1982).

2.3 Field Surveys

To assess the potential environmental effects of the Project on hydrology, information on relevant flow-related parameters was collected during baseline investigations. The measurable hydrological parameters for this investigation included annual total flow volumes (or runoff), peak discharges and drought (low) discharges. For selected watercourses crossed by the RoW, information was gathered on channel characteristics, including channel geometry, water levels, velocities and total suspended sediment concentrations. Channel cross-sectional data can be used to assess qualitatively the downstream changes to the stream hydraulic parameters (water depth and velocity) resulting from changes to the measurable hydrological parameters.

2.3.1 Open-Water Surveys

Open-water field investigations for the baseline hydrological investigation took place in September and October 2005 (AMEC 2005). Detailed field assessments were done at 33 sites, including 11 sites in Alberta and 22 sites in British Columbia as shown in Figure 2-3. The sites were selected to include representative small channels (drainage areas of less than 100 km^2) and to provide additional data for areas along the RoW with limited data sets. Data gathering at each site (where the channel could be waded safely) included:

- manual streamflow measurements
- a site survey to obtain a channel cross-section, as well as channel gradient, bed and bank material size characterizations
- qualitative observations of channel debris potential
- photographs of the site

Data gathering was limited at some locations where water depths were greater than 1.4 m or where channel velocities were greater than 1 to 1.2 m/s. For the crossings that were difficult to access, no site survey was done and flow measurements were taken at alternate locations either upstream or downstream of the study corridor. Streamflow measurements followed the standard methodology established by the WSC.

The results of the open-water hydrology field surveys are summarized in Table 2-3.

Table 2-3 Data Summary – Hydrology Open-Water Field Surveys, September to October 2005

Crossing	Channel	Drainage Area (km²)	Channel Dimensions[1] Wetted Width (m)	Average Depth (m)	Bankfull Width (m)	Bankfull Depth (m)	Gradient (%)	Measured Discharge[1] (m³/s)	Bed Materials	Bank Materials
Prairies Hydrological Zone										
15-A1[2]	Unnamed	1.5	3.0	0.18	3.6	0.33	0.6	0.033 (O)	silt, some organics	silt, some organics
26	Rivière Qui Barre	104	1.6	0.13	8.4	0.23	0.3	0.001 (O)	silt and clay with organics	silt and clay with organics
28	Unnamed	1.8	0.0	0.00	3.1	0.18	0.4	0.000 (O)	silt and clay with organics and topsoil	silt and clay with organics and topsoil
Foothills Hydrological Zone										
45	Unnamed	1.9	0.0	0.00	4.4	0.29	0.9	0.000 (O)	silt and topsoil	silt and topsoil
120	Sakwatamau River	1,213	18.8	0.48	29.7	0.93	0.7	3.470 (O)	cobbles to 200 mm over gravel and sand	cobbles, silt and organic cover
138	Unnamed	3.5	NA	0.10	NA	NA	NA	0.004 (E, O)	silt and clay	silt and clay
157	Unnamed	22.9	4.3	0.35	5.2	0.49	1.5	0.046 (O)	silt with some boulders to 400 mm	silt with organics; some boulders
180-A1[2]	Unnamed	81.3	7.0	0.45	14.4	1.30	1.2	0.394 (O)	silt, sand, trace organics	silt and organics
204-A1[2]	Unnamed	35.0	3.4	0.11	13.6	2.33	1.4	0.024 (O)	silt and fine sand	silt and sand with organics

Table 2-3 Data Summary – Hydrology Open-Water Field Surveys, September to October 2005 (cont'd)

Crossing	Channel	Drainage Area (km^2)	Channel Dimensions[1] Wetted Width (m)	Average Depth (m)	Bankfull Width (m)	Bankfull Depth (m)	Gradient (%)	Measured Discharge[1] (m^3/s)	Bed Materials	Bank Materials
Foothills Hydrological Zone (cont'd)										
221-A1[2]	Unnamed	1.4	1.1	0.05	5.6	0.69	4.0	0.001 (O)	cobbles, gravel, sand, occasional boulder	silts, sands and organics
233-A1[2]	Stony Creek	64.9	8.8	0.27	13.0	1.13	0.8	0.001 (O)	silty with many cobbles to 300 mm	silt, sands and organics
Rocky Mountains Hydrological Zone										
269-A1[2]	South Red Willow River	164	8.0 (E)	1.6 to 2.0	14.0 (E)	4.0	0.2	NA (S)	sandy silt, organics	boulders overlain by sand and silt
446	Unnamed	12.4	5.20	0.38	12.00	1.10	4.2	0.619 (S)	cobbles and gravel. Numerous falls and bedrock outcrops.	cobbles, gravel, sand and silt with organics
480	Unnamed	1.0	6.80	0.27	7.10	0.32	2.7	0.979 (S)	coarse gravel and sand and no cobbles	sand, fine gravel, silt, organics
619	Unnamed	2.5	0.55	0.02	2.80	0.56	4.5	0.001 (O)	coarse gravel and small cobbles to 100 mm	silt till

Table 2-3 Data Summary – Hydrology Open-Water Field Surveys, September to October 2005 (cont'd)

Crossing	Channel	Drainage Area (km^2)	Channel Dimensions[1] Wetted Width (m)	Average Depth (m)	Bankfull Width (m)	Bankfull Depth (m)	Gradient (%)	Measured Discharge[1] (m^3/s)	Bed Materials	Bank Materials
Rocky Mountains Hydrological Zone (cont'd)										
665	Angusmac Creek	115	6.00	0.21	15.20	0.70	0.7	0.439 (S)	bedrock outcrop on right bank and coarse gravel and cobbles	right bank fractured and weathered bedrock, overlain with sand and silt
Central Interior Hydrological Zone										
710	Unnamed	4.9	2.00	0.10	9.80	0.26	1.4	0.001 (S)	silt and organics	silt and organics
773	Unnamed	26.2	3.30	1.10	3.50	1.10	0.6	0.000 (S)	silts and organics and debris over gravel	silt and organics
835-A1[2]	Unnamed	5.7	1.60	0.26	2.30	0.56	1.2	0.001 (S)	silty sand over sand and gravel	silt and organics
849-A1[2]	Pitka Creek	132	5.50	0.59	10.5 (E)	1.80	2.0	0.123 (S)	gravel and cobbles	silt, sand, fine gravel and organics
918	Unnamed	2.6	0.00	0.00	3.20	0.43	5.0	0.000 (S)	silt, sand and gravel with some organics	silt, sand and organics
957	Unnamed	3.9	3.00	2.00	3.50	2.20	1.7	0.001 (S)	silt, sand and organics	silt, sand and organics

Table 2-3 Data Summary – Hydrology Open-Water Field Surveys, September to October 2005 (cont'd)

Crossing	Channel	Drainage Area (km²)	Channel Dimensions[1] Wetted Width (m)	Average Depth (m)	Bankfull Width (m)	Bankfull Depth (m)	Gradient (%)	Measured Discharge[1] (m³/s)	Bed Materials	Bank Materials
Central Interior Hydrological Zone (cont'd)										
985	Tintagel Creek	6.7	1.40	0.10	3.00	1.10	0.1	0.006 (S)	coarse gravel, sand and cobbles with occasional boulders	gravel, fine sand and silt
Central Mountains Hydrological Zone										
1024	Unnamed	3.9	1.30	0.12	3.40	0.36	3.1	0.008 (S)	gravel, small cobbles and coarse sand	gravel, small cobbles, sand and silt
1052	Parrott Creek	13.0	1.90	0.07	5.40	0.63	2.1	0.007 (S)	gravel with small cobbles	sand till with gravel and cobbles
1065-A1[2]	Unnamed	2.2	0.70	0.00	6.70	0.81	8.0	0.000 (S)	coarse gravel and small cobbles and few fines	sandy till with gravel and cobbles
1084-A1[2]	Thautil River	933	12.70	0.73	102.00	2.50	0.2	3.703 (S)	cobbles over gravel and sand	sand, coarse gravel and cobbles
Coastal Mountains Hydrological Zone										
1111	Gosnell Creek	102	6.40	0.24	38.20	0.37	1.7	1.212 (S)	gravel and cobbles to 300 mm	sand, gravel and small cobbles with organic surface layer

Table 2-3 Data Summary – Hydrology Open-Water Field Surveys, September to October 2005 (cont'd)

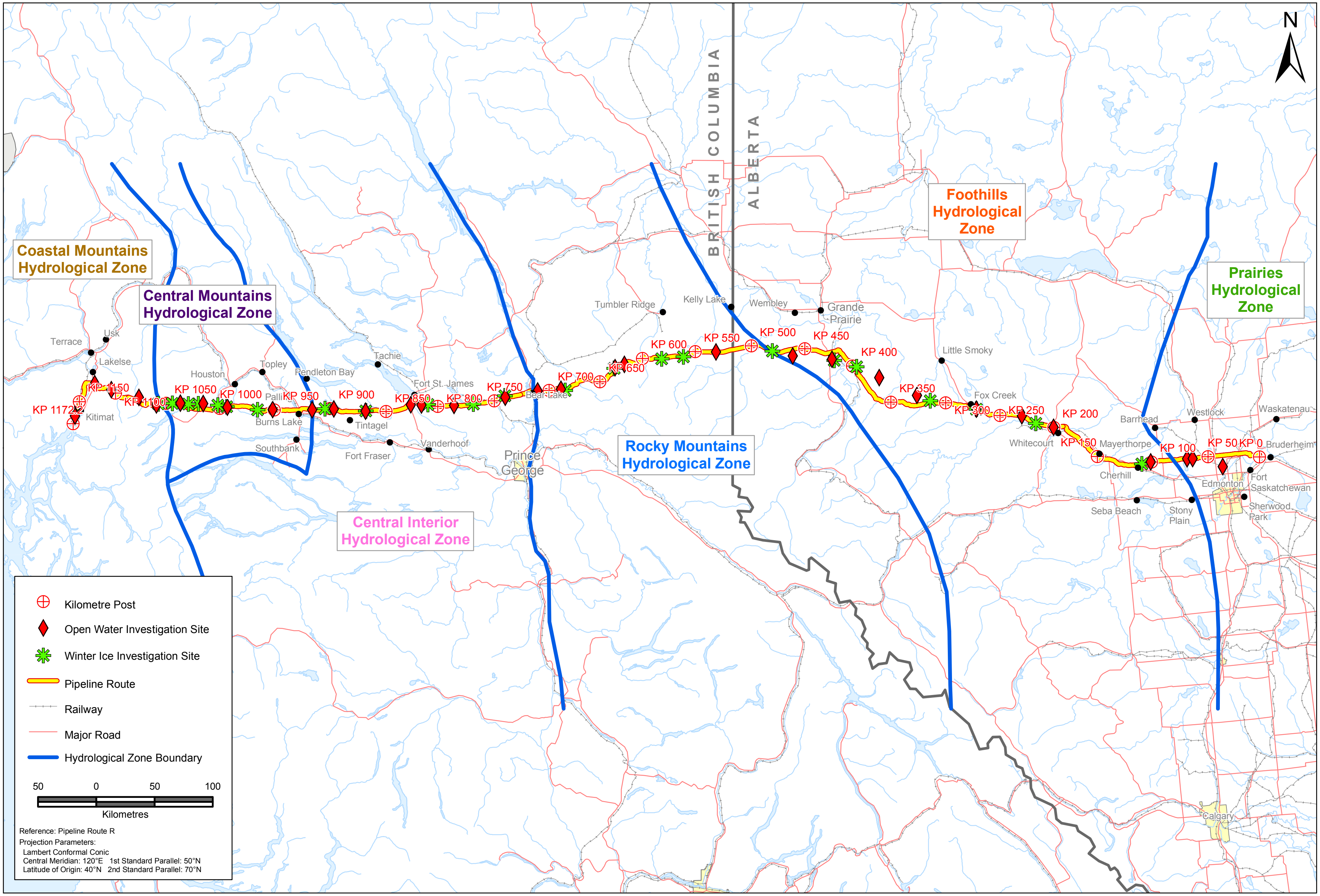
Crossing	Channel	Drainage Area (km^2)	Channel Dimensions[1] Wetted Width (m)	Average Depth (m)	Bankfull Width (m)	Bankfull Depth (m)	Gradient (%)	Measured Discharge[1] (m^3/s)	Bed Materials	Bank Materials
Coastal Mountains Hydrological Zone (cont'd)										
1139-A1[2]	Unnamed	1.0	2.70	0.16	4.00	0.80	12.5	0.049 (S)	cobbles to 250 mm and gravel and sand	fractured rock, gravel and sand with thin organic surface layer
1191	Unnamed	4.8	3.60	0.25	3.50	0.50	20.5	0.265 (S)	sand, gravel, cobbles and boulders. Bedrock controls.	bedrock outcrop on left bank, gravel and fractured cobbles with organic surface layer on right bank
1222	Chist Creek	161	20 (E)	0.60	35 (E)	1.50	1.7	12 (E, S)	cobbles and boulders	coarse gravel, sand, small cobbles
1274	Anderson Creek	37.4	27.00	0.60	39 (E)	3.00	4.1	16.3 (E, S)	N/A	N/A
1275	Moore Creek-A1[2]	14.3	13.80	0.37	25 (E)	3.60	7.7	2.8 (S)	N/A	N/A

NOTES:
[1] (E) = estimated data. (S) = field surveys done from September 11 to 20, 2005 or (O) October 3 to 7, 2005.
[2] Sites with an -A1 suffix are not directly on the pipeline route, but are included as representative regional information.

2.3.2 Winter Ice Survey

A winter streamflow and ice thickness survey was done in March 2006. The purpose of this survey was to determine the drainage areas in each hydrological zone below which zero winter flows could be expected during winter construction (i.e., channels that will likely be either dry or frozen to the bed over the winter period).

During the ice investigation, ice thicknesses, water depths and other relevant data were accumulated for 23 sites along the RoW as shown in Figure 2-3. The survey focused on watercourse crossings with drainage areas around the threshold of zero winter flow areas identified in Section 3. The results of the winter ice investigation are summarized in Table 2-4.



REFERENCES: BCMOE, BCMOF, Enbridge, ESRI, Spatial Data Warehouse Ltd.

PREPARED BY: amec

PREPARED FOR: ENBRIDGE NORTHERN GATEWAY PIPELINES

ENBRIDGE NORTHERN GATEWAY PROJECT

Hydrology Field Investigation Sites

FIGURE NUMBER: 2-3	DATE: 20091217	
SCALE: 1:4,500,000	AUTHOR: JNB	APPROVED BY: MW
PROJECTION: LCC	DATUM: NAD 83	

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Table 2-4 Data Summary – Hydrology Winter Ice Field Survey, March 2006

Field Investigation Site	Crossing	Drainage Area (km^2)	Elevation at Site (m asl)	Basin Aspect (Facing)	Channel Gradient (%)	Ice Thickness (m)	Depth of Water Below Ice (m)	Dry or Frozen to the Bed?	Comments
Foothills Hydrological Zone									
1	60-A1[1]	33.5	700	North	1.0	0.15	0.0	Yes	
2	133	181	769	Southeast	2.2	0.74	0.0	Yes	
3	168	22.9	840	North	2.0	0.35	0.0	Yes	
4	182-A1[1]	9.2	778	Northeast	0.5	0.56	0.0	Yes	
5	212-A1[1]	18.1	784	South	0.8	0.43	0.21	No	
6	220-A1[1]	28.1	767	North	0.2	0.31	0.0	Yes	
7	244-A1[1]	1.0	745	North	0.0	0.64	0.42	No	Water ponded because of beaver dams
8	Upstream of 315	15.6	1,065	North	3.5	0.10	0.26	No	
Rocky Mountains Hydrological Zone									
9	363-A1[1]	38.0	1,037	South	3.5	0.23	0.0	Yes	
10	Within PEAA	3.9	1,332	Southeast	7.6	0.10	0.0	No	No flow – slush, not ice, in channel
11	Downstream of 626 and 627	8.8	885	South	0.0	0.13	0.37	No	Water ponded because of beaver dams

Table 2-4 Data Summary – Hydrology Winter Ice Field Survey, March 2006 (cont'd)

Field Investigation Site	Crossing	Drainage Area (km²)	Elevation at Site (m asl)	Basin Aspect (Facing)	Channel Gradient (%)	Ice Thickness (m)	Depth of Water Below Ice (m)	Dry or Frozen to the Bed?	Comments
Central Interior Hydrological Zone									
12	734	4.9	768	South	1.2	0.17	0.01	No	No visible flow
13	778	56.3	793	Northwest	0.5	1.18	0.43	No	
14	863	18.5	795	Southwest	2.0	0.09	0.10	No	
15	958	1.0	920	South	5.0	0.02	0.0	Yes	
Central Mountains Hydrological Zone									
16	Downstream of 1028 and 1029	10.4	1,140	Northwest	3.0	0.08	0.0	Yes	
17	Downstream of 1100	12.2	1,319	East	0.5	0.22	0.11	No	
Coastal Mountains Hydrological Zone									
18	1116	13.4	946	West	5.0	0.40	0.20	No	
19	Outside PEAA	1.0	948	Southeast	1.5	0.10	0.0	Yes	
20	Outside PEAA	11.3	792	South	0.15	0.20	.12	No	No visible flow
21	Outside PEAA	35.4	739	South	0.75	0.10	0.28	No	
22	1156	48.1	834	North	2.0	0.10	0.25	No	Some open water
23	1170	5.6	824	North	1.0	1.20	0.03	No	Ice frozen almost to bottom

NOTE:
[1] Sites with an -A1 suffix are not directly on the pipeline route, but are included as representative regional information.

3 Baseline Investigations

Baseline conditions were evaluated for each of the six hydrological zones crossed by the RoW. Regional correlations between drainage area and baseline hydrological parameters were developed to characterize the hydrology of ungauged channels along the RoW. Specifically, annual and seasonal total flow volumes, 1:10 year and 1:100 year peak and drought (low) discharges were computed. Drought discharges are typically assessed over seven days for a 1:10 year return period event (7Q10); this event was used to define a benchmark drought discharge for the baseline investigation.

Periods of ice cover were examined for streamflow monitoring stations included in the regional assessment to assess the ranges of minimum and maximum duration ice cover on watercourses.

Channel size and gradient were qualitatively compared on the basis of drainage area and annual mean discharge. The limited bed and bank material data were also compared on the basis of channel size, gradient and annual mean discharge.

Baseline conditions are discussed separately for each of the hydrological zones.

3.1 Methods for Baseline Analyses

3.1.1 Hydrological Assessments

Standardized hydrological parameters were determined from recorded streamflow data for each station included in the regional analysis. The computed parameters from all the stations were compared and used in the delineation of hydrological zones along the pipeline RoW. In each hydrological zone, the computed parameters were used to develop regional relationships for estimating hydrological parameters at ungauged watercourses.

3.1.1.1 Annual and Seasonal Total Flow Volume

Annual total flow volume data were gathered for all stations in the baseline study area with continuous (year round) monitoring operations. Seasonal (May to October) total flow volume data were prepared for stations that recorded seasonal streamflow data.

For this study, seasonal and annual mean total flow volumes (dam^3)[1] are also expressed as seasonal and annual mean discharge (m^3/s) and as seasonal and annual total runoff (or yield, measured in mm). Seasonal or annual total flow volumes are expressed as seasonal or annual mean discharge (m^3/s) by dividing the total flow volume (in m^3) by the duration (in seconds) of the season or calendar year. Similarly, seasonal and annual total flow volumes are expressed as water yield or runoff (mm) by dividing the seasonal or annual total flow volume (dam^3) by the drainage area of the watershed (km^2).

Mean monthly, mean seasonal and annual discharges and mean seasonal and annual runoff data are presented in Appendix A (Table A-1) for the stations listed in Table 2-2.

[1] 1 dam^3 = 1 cubic decameter = 1,000 m^3

Seasonal or annual total flow volumes were correlated separately for each hydrological zone based on drainage area to yield regional curves relating flow volume to watershed drainage area. Best fit lines were fitted to the data using the following equation:

$$V = C \times A^b$$

where: V is the total flow volume (dam^3) for the season or calendar year
A is the watershed drainage area
C and b are coefficients

3.1.1.2 Peak Discharges

Flood frequency analyses were performed on annual maximum daily discharges for each streamflow monitoring station in the baseline study area. The computed flood magnitudes for the 1:10 year and 1:100 year return period peak flow events are presented in Appendix A (Table A-1) for each streamflow monitoring station. In each hydrological zone, the results of the frequency analyses were correlated based on drainage area to yield regional curves relating flood discharge to watershed drainage area. Best fit lines were fitted to the data using the following equation:

$$Q_x = C \times A^b$$

where: Q_x is the flood discharge (m^3/s) for return period x (years)
A is the watershed drainage area
C and b are coefficients

3.1.1.3 Drought Discharges

Daily discharge data from the open-water period (typically April to October) were used to compute running seven-day mean discharges over the period of record for each station in the baseline study area. For each year of record, the minimum seven-day flow was identified and drought (low) discharge frequency analyses were performed on the resulting data sets. The 1:10 year, seven-day (7Q10) drought discharge was used as the standard drought reference discharge for this study and the 1:2 year return period seven-day (7Q2) drought discharge is presented for comparison. The computed 7Q10 and 7Q2 discharges for the streamflow monitoring stations listed in Table 2-2 are presented by hydrological zone in Appendix A.

The results of the drought (low) discharge frequency analyses for streamflow monitoring stations in each hydrological zone were correlated based on drainage area to yield a regional curve relating the drought discharge to watershed drainage area. Best fit lines were fitted to the data using the following equation:

$$7QX = C \times A^b$$

where: 7QX is the seven-day drought discharge for a drought return period of X (2 or 10) years
A is the watershed drainage area
C and b are coefficients

3.1.2 Channel Geomorphology Assessments

Field data gathered during the hydrology and fisheries field investigations were used as the basis for estimating baseline geomorphological characteristics of channels crossing the RoW. The field data were supported with available published data (Kellerhals et al. 1972). Channel size and gradient were qualitatively compared on the basis of drainage area and annual mean discharge. The limited bed and bank material data were also compared based on channel size, gradient and annual mean discharges. Channel stability and factors affecting stability were qualitatively addressed.

3.1.3 Freeze-Up and Breakup Assessments

Data on channel freeze-up and breakup were obtained from WSC records and published reports (Allen 1977). The dates on which the WSC recorded gauge operations as being ice-affected were extracted for each year of the station period of record. The earliest freeze-up and latest breakup dates were used to show the maximum recorded period of ice cover at a station. The latest recorded freeze-up date and earliest breakup date were used to define the minimum recorded period of ice cover on the channel.

Ice thickness data were obtained from WSC records of manual streamflow measurements taken over winter. These data were supplemented with data gathered during the winter ice field survey in March 2006.

3.2 Regional Baseline Hydrological Characterizations

Based on the comparison of hydrological parameters computed for the WSC stations included in the baseline database, the six hydrological zones along the pipeline RoW are described below.

3.2.1 Prairies Hydrological Zone

The Prairies hydrological zone includes the flat agricultural lands adjacent to and immediately west of Edmonton, Alberta. The average annual total precipitation in this zone is between 400 and 500 mm, of which about 27% occurs as snow. The Prairies hydrological zone receives less precipitation than the other hydrological zones crossed by the pipeline RoW.

The regional hydrological characterization for the Prairies hydrological zone is discussed below.

3.2.1.1 Discharges

Annual and Seasonal Total Flow Volumes

Of the seven streamflow monitoring stations in the Prairies hydrological zone, four record data on a seasonal basis only (April to October), and three have partial continuous (January to December) and partial seasonal (April to October) records. Based on this data availability, only seasonal total flow volume relationships were estimated for this zone. The results of the seasonal total flow volume analyses are presented in Figure 3-1. The regional seasonal total flow volume correlation coefficient is presented in Table 3-1.

Table 3-1 Seasonal Total Flow Volume Correlation Coefficient – Prairies

Period	Coefficient		Correlation Coefficient R^2
	C	b	
Seasonal (April to October)	12.55	0.135	0.96

Baseline seasonal total flow volume in the Prairies hydrological zone varies directly with watershed drainage area. The correlation between seasonal total flow volume and drainage area in the Prairies hydrological zone is high.

Data from the stations with continuous (year-round) periods of record were used to estimate that about 85% of the annual total flow volume in larger watersheds in the Prairies hydrological zone runs off between March and October. This proportion could be greater in smaller watersheds where flows may cease over the winter (see discussion under Drought Discharges).

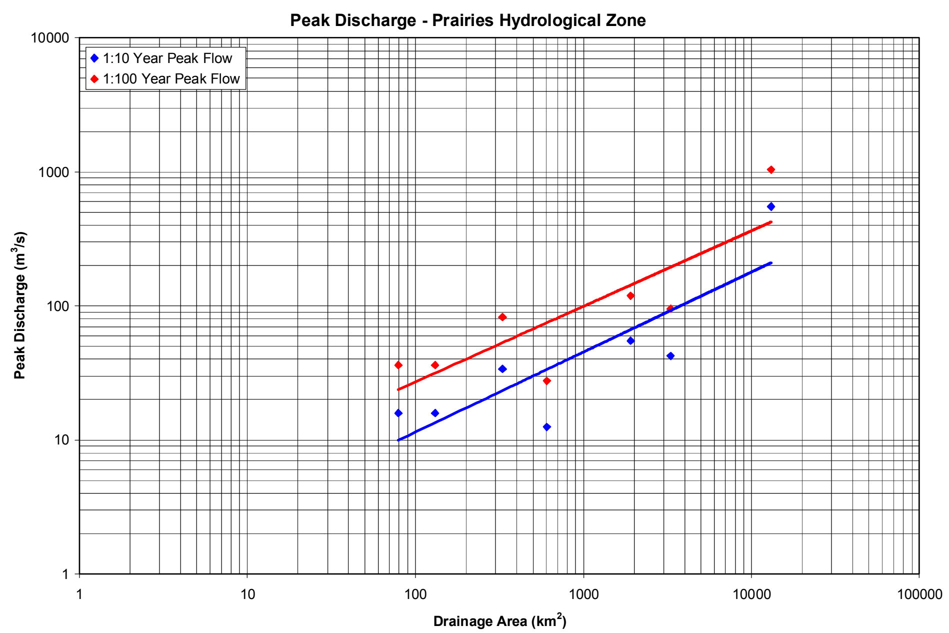
Peak Discharges

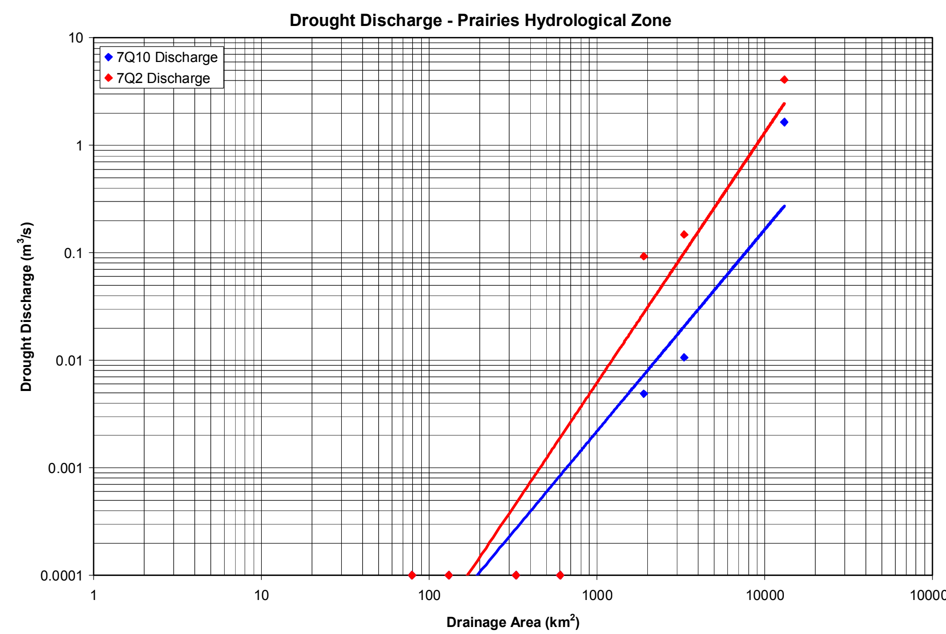
The regional peak discharge correlation coefficients developed for the Prairies hydrological zone are shown in Table 3-2 and Figure 3-1.

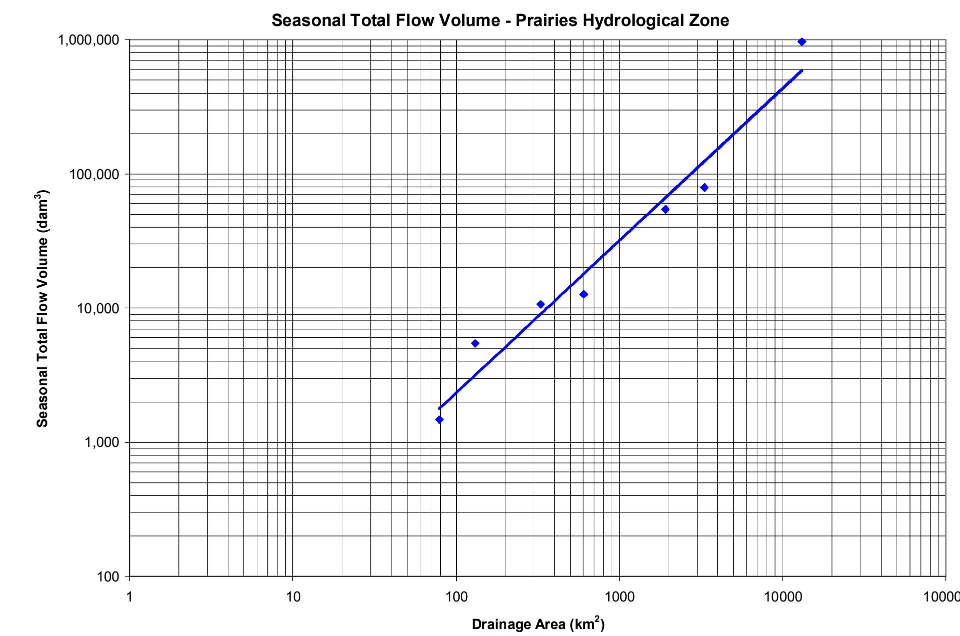
Table 3-2 Peak Discharge Correlation Coefficients – Prairies

Flood Return Period (years)	Coefficient		Correlation Coefficient R^2
	C	b	
10	0.731	0.597	0.71
100	2.020	0.564	0.70

Peak discharges in the Prairies hydrological zone are directly proportional to and correlate moderately well to watershed drainage areas. Unit discharges for peak discharge events (peak discharge divided by drainage area) are higher for smaller watersheds than for larger watersheds.

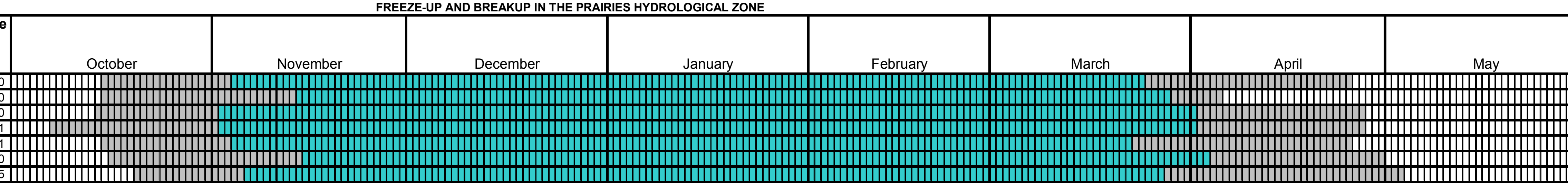






FREEZE-UP AND BREAKUP IN THE PRAIRIES HYDROLOGICAL ZONE

ID	Name	Drainage Area (km^2)
05DF006	WHITEMUD CREEK NEAR ELLERSLIE	330
05EA001	STURGEON RIVER NEAR FORT SASKATCHEWAN	3,310
05EA005	STURGEON RIVER NEAR VILLENEUVE	1,910
05EC002	WASKATENAU CREEK NEAR WASKATENAU	131
05FA014	MASKWA CREEK NO. 1 ABOVE BEARHILLS LAKE	79.1
07BC002	PEMBINA RIVER AT JARVIE	13,100
07BC006	DAPP CREEK AT HIGHWAY NO. 44	605



Maximum Period of Recorded Ice Cover (earliest freeze-up to latest breakup)
Minimum Period of Recorded Ice Cover (latest freeze-up to earliest breakup)

PREPARED BY: amec	PREPARED FOR: ENBRIDGE NORTHERN GATEWAY PIPELINES	CONTRACTOR: AMEC DATE: 20090811 AUTHOR: MC — APPROVED BY: MW	FIGURE NUMBER: 3-1 SCALE: NTS PROJECTION: NA — DATUM: NA

ENBRIDGE NORTHERN GATEWAY PROJECT

Hydrological Characteristics - Prairies Hydrological Zone

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Drought Discharges

The results of the drought discharge analyses for the Prairies hydrological zone are presented in Figure 3-1. The derived regional drought discharge correlation coefficients are presented in Table 3-3.

Table 3-3 Drought Discharge Correlation Coefficients – Prairies

Drought Event	Coefficient		Correlation Coefficient R^2
	C	b	
7Q2 (2-year return period)	6×10^{-10}	2.326	0.87
7Q10 (10-year return period)	5×10^{-9}	1.877	0.85

The correlations between drought discharges and drainage area in the Prairies hydrological zone are strong. For drought discharge events, the regional data show that zero discharge events commonly occur in watersheds with drainage areas less than 100 km^2 for the 7Q10 drought event during the March to October period and in watersheds with drainage areas up to 600 km^2 during the November to February period.

3.2.1.2 Freeze-Up and Breakup

Freeze-up and breakup data were limited in small watersheds in the Prairies hydrological zone because many streamflow monitoring stations cease operations in October, before the formation of an ice cover, and resume operations in April after the ice cover has melted out. This is because many small channels in the Prairies hydrological zone freeze to the bed over winter.

In the Prairies hydrological zone, all the channels with WSC data developed an ice cover in the fall that remained over winter. Freeze-up and breakup data for this zone are summarized in Figure 3-1. Freeze-up and breakup dates varied with channel discharge, gradient, elevation and climate conditions.

Freeze-up in the Prairies hydrological zone occurred for most channels during the first week of November. By November 15, all channels examined were ice-covered. About half of the channels in this zone began to break up in the second half of March. By the first week of April, most channels were ice-free.

Freeze-up and breakup could extend well beyond the typical ice-covered period described here. Freeze-up could occur before mid-October and breakup could be as late as the last week of April.

According to data from WSC, ice thickness varied among channels and years, depending on climatic and hydrological conditions. Average ice thicknesses varied from 0.12 to 0.62 m, with a mean of 0.34 m for all sites. Ice thickness extremes ranged from 0.05 to 0.80 m. Mean maximum ice thickness reported in Allen (1977) is about 0.88 m for this area.

Channels with small upstream drainage areas could freeze to the bed over the winter period. Based on the published regional data on winter discharges and ice thickness, it is expected that most channels with drainage areas less than 600 km^2, or more than 95% of the defined watercourses in the Prairies hydrological zone, could be dry or frozen to the bed during winter.

3.2.1.3 Channel Geomorphology

Channel Dimensions

Channel dimensions were available for 12 sites in the Prairies hydrological zone. In this zone, the basic channel dimensions – bankfull channel width and bankfull depth – vary directly with watershed drainage area. (This is as expected because discharge also varies directly with drainage area and higher discharges need a larger channel area to convey the flow.) The channel gradient, as measured at the watercourse crossings, was generally less than 2%. Typical channel bankfull widths, bankfull depths and gradients in the Prairies hydrological zone are summarized in Table 3-4 and Figure 3-2.

Table 3-4 Channel Dimensions at Watercourse Crossings – Prairies

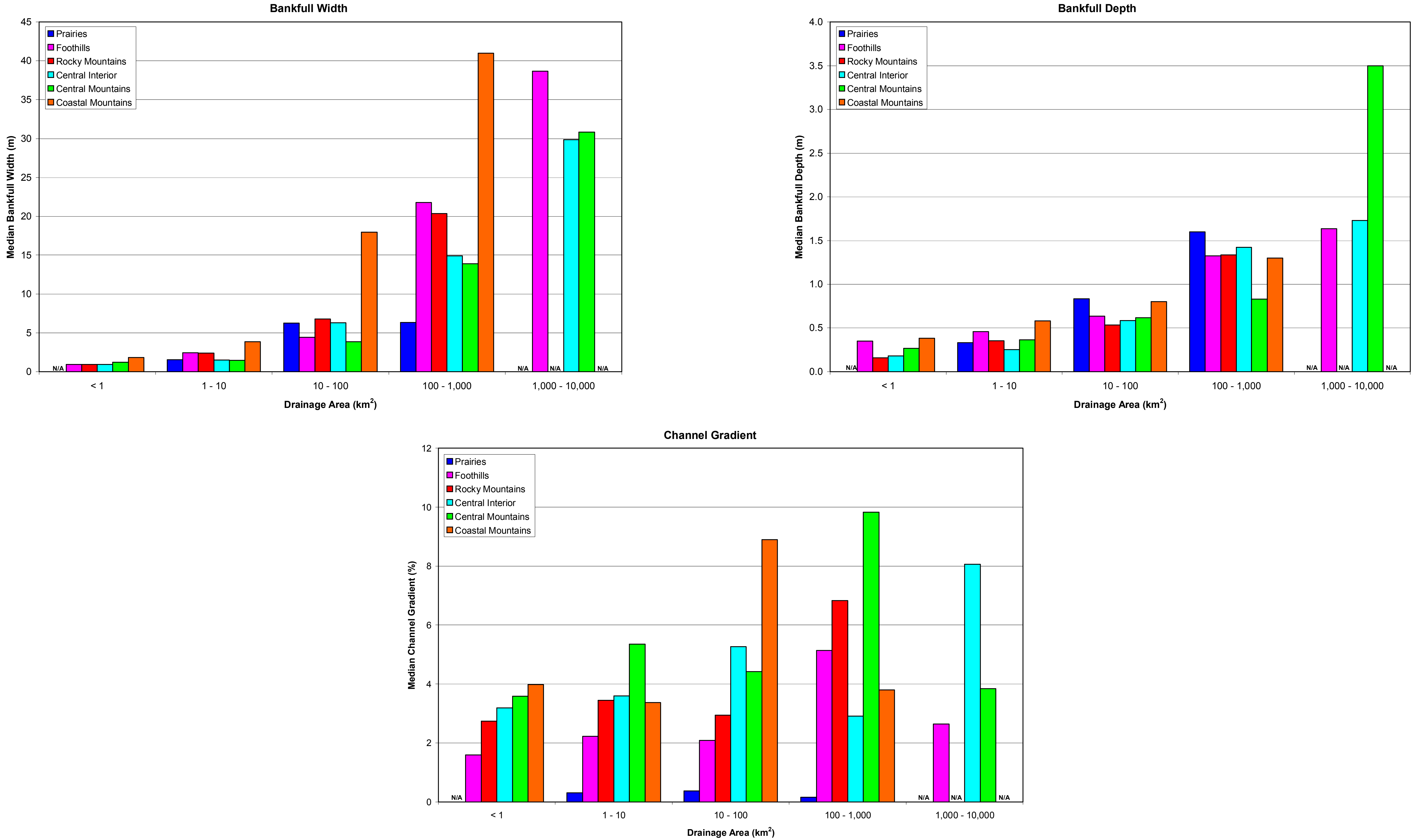
Drainage Area (km^2)	**Number of Crossings on RoW**	**Channel Width** (m)		**Channel Depth** (m)		**Channel Gradient** (%)	
		Median	**Observed Range**	**Median**	**Observed Range**	**Median**	**Observed Range**
<1	2	N/A	N/A	N/A	N/A	N/A	N/A
1 to 10	10	1.5	1.4 to 12.2	0.3	0.2 to 0.5	0.3	0.2 to 1.3
10 to 100	12	6.2	4.4 to 12.8	0.8	0.3 to 0.9	0.4	0.2 to 1.6
100 to 1,000	2	6.3	N/A	1.6	N/A	0.2	N/A
1,000 to 10,000	0	N/A	N/A	N/A	N/A	N/A	N/A

Channel Bed and Bank Material Characterization

The available bed and bank material data for the Prairies hydrological zone were assembled and compared. Overall, channel bed and bank materials were relatively fine-grained (i.e., clays, silts and organics). Gravel beds were observed only in the larger channels. The observed bed and bank materials are consistent with the generally low channel gradients characteristic of this zone and are consistent with published bed material size data (Kellerhals et al. 1972; Shaw and Kellerhals 1982).

Channel Stability

Channel stability is a site-specific condition. Bank erosion was observed in some channels (as expected in unconfined meandering channels), but overall bank erosion appeared to be balanced by deposition and bar formation. Disturbance to channel beds and banks from cattle was observed at several sites.



PREPARED BY:	PREPARED FOR:	CONTRACTOR: AMEC	ENBRIDGE NORTHERN GATEWAY PROJECT	FIGURE NUMBER: 3-2
amec	ENBRIDGE NORTHERN GATEWAY PIPELINES	DATE: 20090811	Typical Channel Dimensions in the Hydrological Zones	SCALE: NTS
		AUTHOR: MC / APPROVED BY: MW		PROJECTION: NA / DATUM: NA

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3.2.2 Foothills Hydrological Zone

The Foothills hydrological zone has slightly higher annual precipitation amounts (500 to 600 mm) and greater topographical relief than the Prairies hydrological zone. Because of higher elevations in this zone, approximately 35% of the annual total precipitation occurs as snowfall.

The regional hydrological characterization for the Foothills hydrological zone is discussed below.

3.2.2.1 Discharges

Annual and Seasonal Total Flow Volumes

Of the 23 streamflow monitoring stations in the Foothills hydrological zone, 14 record data on a seasonal (April to October) basis only and 9 have continuous (January to December) data over part of, or the entire period of the record. Based on this data availability, only seasonal total flow volume relationships were estimated for the Foothills hydrological zone. The results of the seasonal total flow volume analyses are presented in Figure 3-3. The regional seasonal total flow volume correlation coefficient is presented in Table 3-5.

Table 3-5 Seasonal Total Flow Volume Correlation Coefficient – Foothills

Period	Coefficient		Correlation Coefficient R^2
	C	b	
Seasonal (April to October)	20.97	1.232	0.94

Baseline seasonal total flow volume in the Foothills hydrological zone varies directly with watershed drainage area. The correlation between seasonal total flow volume and drainage area in this zone is high.

The Foothills hydrological zone shows similar flow patterns to the Prairies hydrological zone although total flow volumes are higher in the Foothills hydrological zone. Data from the stations with continuous (year-round) periods of record were used to estimate that about 95% of the annual total flow volume in larger watersheds in the Foothills hydrological zone runs off between March and October. This proportion could be greater in smaller watersheds where flows may cease over the winter (see discussion under Drought Discharges).

Peak Discharges

The regional peak discharge correlation coefficients developed for the Foothills hydrological zone are summarized in Table 3-6 and Figure 3-3.

Table 3-6 Peak Discharge Correlation Coefficients – Foothills

Flood Return Period (years)	Coefficient		Correlation Coefficient R^2
	C	b	
10	0.144	0.972	0.91
100	0.306	0.956	0.84

Peak discharges in the Foothills hydrological zone are directly proportional to and correlate well with drainage areas. Unit discharges for peak discharge events (flood discharge divided by drainage area) are similar for all watershed sizes. Compared with the Prairies hydrological zone, peak discharges in the Foothills hydrological zone were higher, which reflects both greater amounts of precipitation in this zone and the overall greater topographical relief in its watersheds.

Drought Discharges

The results of the drought discharge analyses for the Foothills hydrological zone are presented in Figure 3-3. The derived regional drought discharge correlation coefficients are presented in Table 3-7.

Table 3-7 Drought Discharge Correlation Coefficients – Foothills

Drought Event	Coefficient		Correlation Coefficient R^2
	C	b	
7Q2 (2 year return period)	1×10^{-7}	1.958	0.52
7Q10 (10 year return period)	1×10^{-8}	2.138	0.57

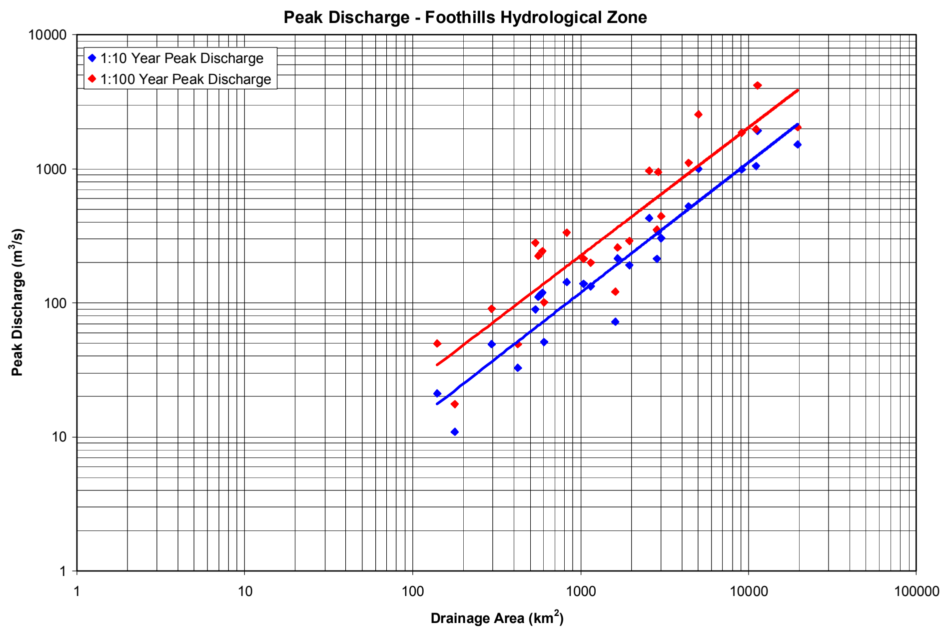
Drought discharges in the Foothills hydrological zone correlate moderately well with drainage area. For drought discharge events, regional data show that zero discharges with durations up to seven days are likely to occur in watersheds with drainage areas less than 70 km^2 during March to October and in watersheds with drainage areas up to 100 km^2 during November to February. Seven-day zero discharge events have been recorded in watersheds with drainage areas up to 1610 km^2 in this zone. Computed 7Q10 drought discharges in the Foothills hydrological zone were greater than in the Prairies hydrological zone for all watershed areas.

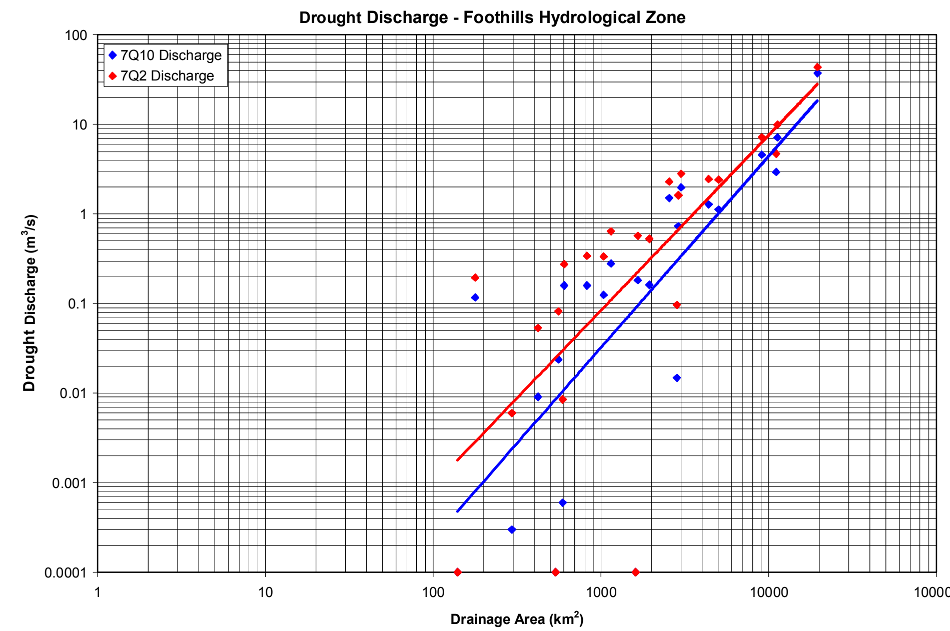
3.2.2.2 Freeze-Up and Breakup

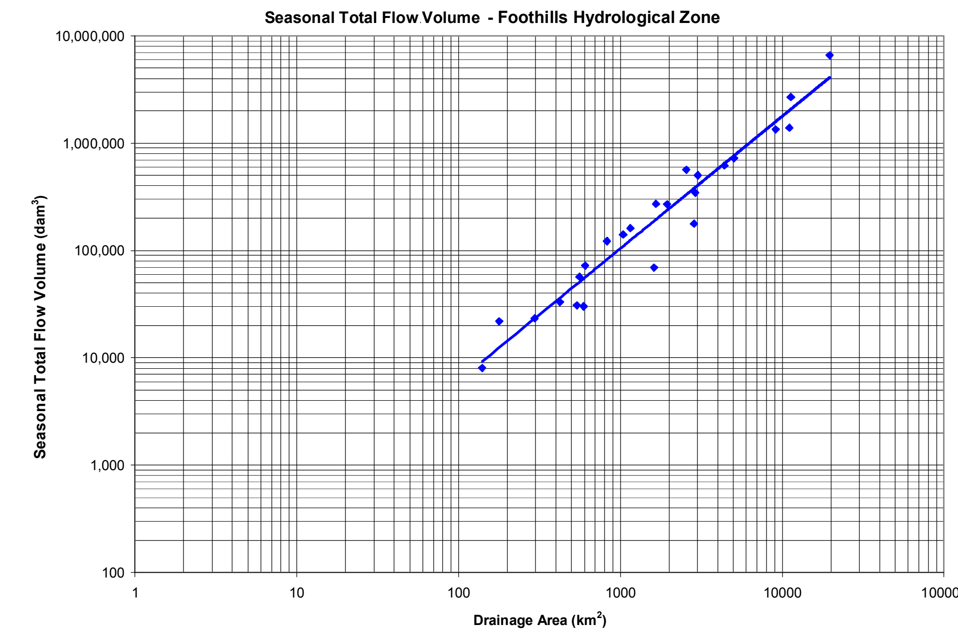
In the Foothills hydrological zone, all the channels with WSC data developed an ice cover that remained over winter. Freeze-up and breakup data for this zone are summarized in Figure 3-3. Freeze-up and breakup dates varied with channel discharge, gradient, elevation and climate conditions.

Freeze-up in the Foothills hydrological zone ranges from the first week of November for watersheds with drainage areas up to 600 km^2, to late November for the larger watersheds (see Figure 3-3). Breakup occurs in late March and early April. Freeze-up and breakup could extend well beyond the typical ice-covered period. In most channels, freeze-up has occurred as early as mid-October and breakup as late as the beginning of May.

According to data from WSC, ice thickness varied among channels and years, depending on climatic and hydrological conditions. Average ice thicknesses, which ranged from 0.07 to 0.71 m, with a mean of 0.43 m for all sites in the Foothills hydrological zone, were similar to the Prairies hydrological zone. Mean maximum ice thicknesses of up to 1.84 m are reported by Allen (1977).

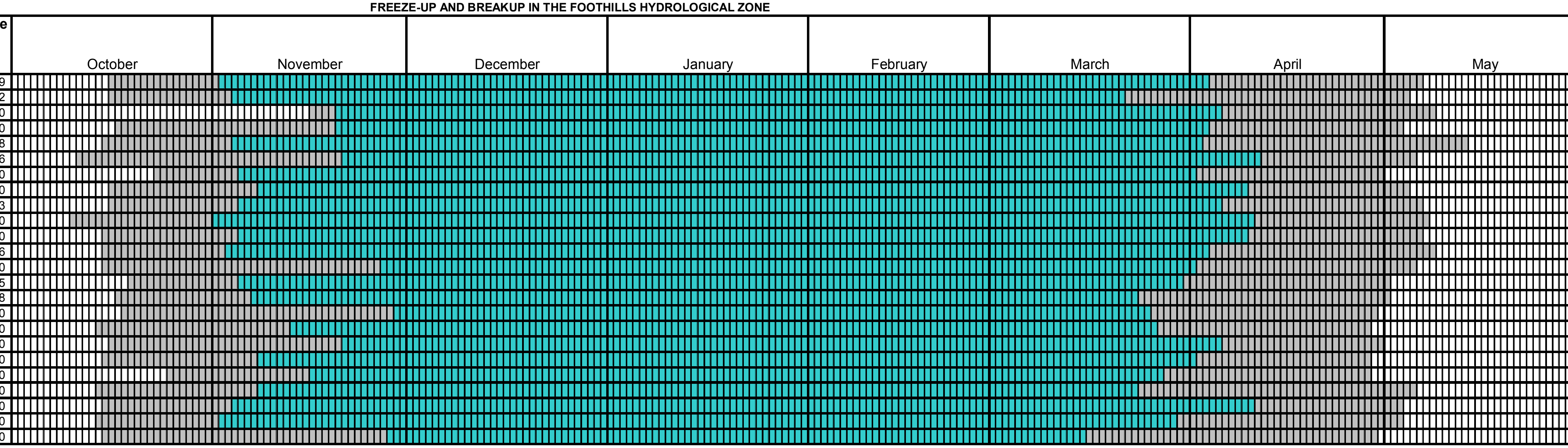






FREEZE-UP AND BREAKUP IN THE FOOTHILLS HYDROLOGICAL ZONE

ID	Name	Drainage Area (km^2)
05DE007	ROSE CREEK NEAR ALDER FLATS	559
05DF004	STRAWBERRY CREEK NEAR THE MOUTH	592
07AE001	ATHABASCA RIVER NEAR WINDFALL	19,600
07AF002	MCLEOD RIVER ABOVE EMBARRAS RIVER	2,560
07AF010	SUNDANCE CREEK NEAR BICKERDIKE	178
07AG003	WOLF CREEK AT HIGHWAY NO. 16A	826
07AG004	MCLEOD RIVER NEAR WHITECOURT	9,100
07AH001	FREEMAN RIVER NEAR FORT ASSINIBOINE	1,660
07AH002	CHRISTMAS CREEK NEAR BLUE RIDGE	423
07AH003	SAKWATAMAU RIVER NEAR WHITECOURT	1,150
07BA001	PEMBINA RIVER BELOW PADDY CREEK	2,900
07BA002	RAT CREEK NEAR CYNTHIA	606
07BB002	PEMBINA RIVER NEAR ENTWISTLE	4,400
07BB005	LITTLE PADDLE RIVER NEAR MAYERTHORPE	295
07FD006	SADDLE RIVER NEAR WOKING	538
07FD007	POUCE COUPE RIVER BELOW HENDERSON CREEK	2,850
07GD001	BEAVERLODGE RIVER NEAR BEAVERLODGE	1,610
07GE001	WAPITI RIVER NEAR GRANDE PRAIRIE	11,300
07GE003	GRANDE PRAIRIE CREEK NEAR SEXSMITH	140
07GF001	SIMONETTE RIVER NEAR GOODWIN	5,040
07GG001	WASKAHIGAN RIVER NEAR THE MOUTH	1,040
07GG002	LITTLE SMOKY RIVER AT LITTLE SMOKY	3,010
07GG003	IOSEGUN RIVER NEAR LITTLE SMOKY	1,950
07GH002	LITTLE SMOKY RIVER NEAR GUY	11,100



Maximum Period of Recorded Ice Cover (earliest freeze-up to latest breakup)
Minimum Period of Recorded Ice Cover (latest freeze-up to earliest breakup)

PREPARED BY:	amec
PREPARED FOR:	ENBRIDGE NORTHERN GATEWAY PIPELINES
CONTRACTOR:	AMEC
DATE:	20090811
AUTHOR:	MC
APPROVED BY:	MW
FIGURE NUMBER:	3-3
SCALE:	NTS
PROJECTION:	NA
DATUM:	NA

ENBRIDGE NORTHERN GATEWAY PROJECT

Hydrological Characteristics - Foothills Hydrological Zone

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Channels with small upstream drainage areas could freeze to the bed over the winter period. Based on the results of the winter ice investigation and published regional data on winter flows and ice thickness, it is expected that most channels with drainage areas less than 30 km^2, or as many as 90% of the crossings in this hydrological zone, could be dry or frozen to the bed in the winter.

3.2.2.3 Channel Geomorphology

Channel Dimensions

Channel dimensions were available for 76 sites in the Foothills hydrological zone. Compared with the Prairies hydrological zone, the Foothills channels are generally deeper and steeper. Channels in the Foothills hydrological zone are typically wider and deeper than channels in the Prairies hydrological zone. These results reflect the higher runoffs generated by the steeper terrain and confined valleys of the Foothills hydrological zone. Channel widths and depths are directly proportional to drainage area, and channel gradients are inversely proportional to drainage area. Typical channel widths, depths and gradients in the Foothills hydrological zone, as measured at the watercourse crossings, are summarized in Table 3-8 and Figure 3-2.

Table 3-8 Channel Dimensions of Watercourse Crossings – Foothills

Drainage Area (km^2)	Number of Crossings on RoW	Channel Width (m)		Channel Depth (m)		Channel Gradient (%)	
		Median	Observed Range	Median	Observed Range	Median	Observed Range
<1	56	0.9	0.4 to 1.7	0.4	0.1 to 0.6	1.6	0.2 to 3.4
1 to 10	68	2.4	0.5 to 14.7	0.5	0.1 to 2.3	2.2	0.3 to 8.3
10 to 100	25	4.4	1.3 to 10.5	0.6	0.2 to 2.5	2.1	0.2 to 6.4
100 to 1,000	13	21.8	13.8 to 55.2	1.3	0.7 to 2.5	5.1	1.5 to 7.7
1,000 to 10,000	3	38.7	9.3 to 93.6	1.6	1.2 to 2.3	2.7	2.2 to 3.0

Channel Bed and Bank Material Characterization

The available bed and bank material data for the Foothills hydrological zone were assembled and compared. Bed material gradations were a function of channel gradient. Bed materials in low gradient channels (slopes less than two percent) generally were relatively fine-grained (i.e., silts and fine sands). In channels with slopes of about two to four percent, bed materials were composed of coarser sand and gravel; bed materials in the steepest channels were dominated by coarse gravel, cobbles and boulders. The beds of the steeper channels and large channels such as the Sakwatamau River were armoured to some extent with cobbles and boulders. Bank materials varied with location, from fine-grained silt with organics to coarser granular materials including boulders. The observed bed and bank materials were consistent with the overall steeper channel gradients of the Foothills hydrological zone and with published bed material data (Kellerhals et al. 1972; Shaw and Kellerhals 1982).

Channel Stability

Channel stability is a site-specific condition. Most channels in the Foothills hydrological zone have a high to very high potential for waterborne debris (both wood and sediment), and debris jams play a greater role in channel geomorphology than in the Prairies hydrological zone. Debris jams can form during a single flood event and can dramatically affect local scour, bank erosion and overall channel alignment. Considerable beaver activity is also observed in this zone. Beaver dams create impoundments that trap and settle out silt and result in wide flooded areas that can attenuate peak discharges. Beaver dam failures during a flood event can affect channel stability because of the added debris and water and can result in bed degradation and bank instability.

3.2.3 Rocky Mountains Hydrological Zone

Annual total precipitation in the Rocky Mountains hydrological zone is the second highest among the six hydrological zones along the RoW, exceeded only by the Coastal Mountains hydrological zone. Annual total precipitation varies from 600 to 1,600 mm, of which as much as 60% can occur as snowfall.

The regional hydrological characterization for the Rocky Mountains hydrological zone is discussed below.

3.2.3.1 Discharges

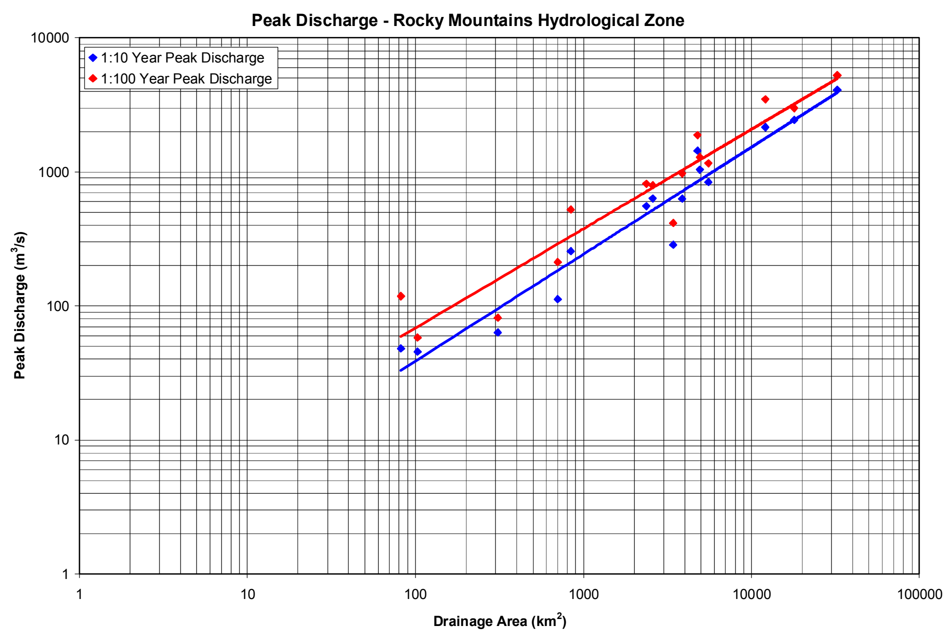
Annual and Seasonal Total Flow Volumes

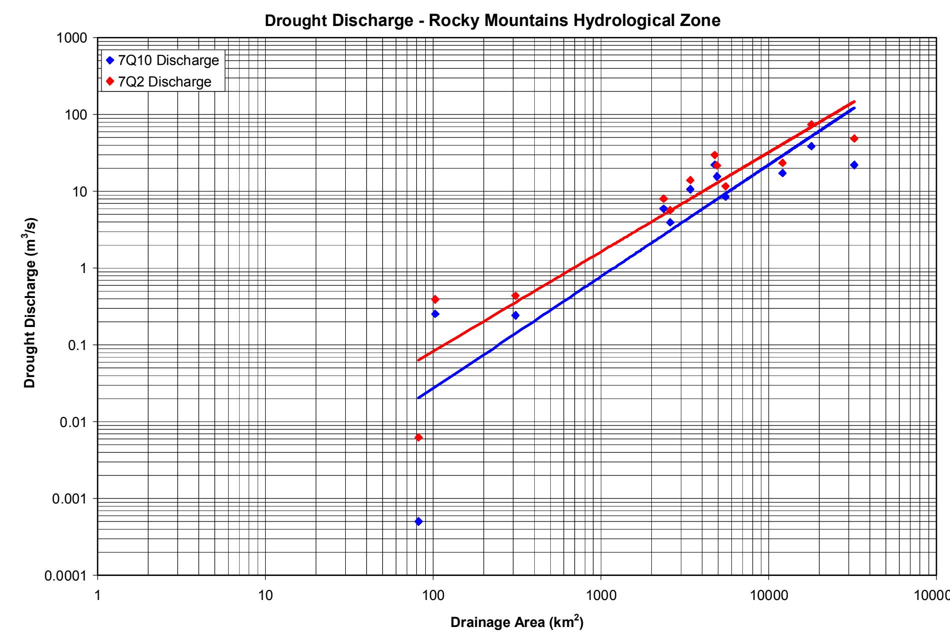
Of the 15 streamflow monitoring stations in the Rocky Mountains hydrological zone, 14 have continuous (January to December) data over at least part of the period of record. Based on this data availability, both seasonal and annual total flow volume relationships were estimated for the Rocky Mountains hydrological zone. The results of the seasonal and annual total flow volume analyses are presented in Figure 3-4. The regional seasonal and annual total flow volume correlation coefficients are presented in Table 3-9.

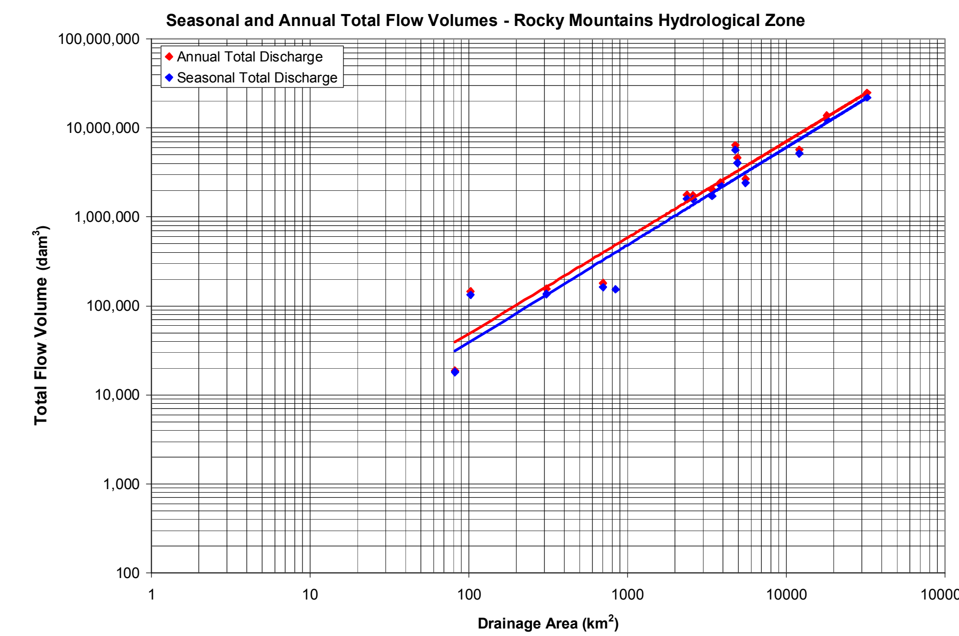
Table 3-9 Seasonal and Annual Total Flow Volume Correlation Coefficients – Rocky Mountains

Period	Coefficient		Correlation Coefficient R^2
	C	b	
Seasonal (April to October)	247.13	1.097	0.93
Annual (January to December)	332.87	1.081	0.94

Baseline seasonal and annual total flow volumes in the Rocky Mountains hydrological zone vary directly with watershed drainage area. The correlation between both seasonal and annual total flow volumes and drainage area in the Rocky Mountains hydrological zone is high.

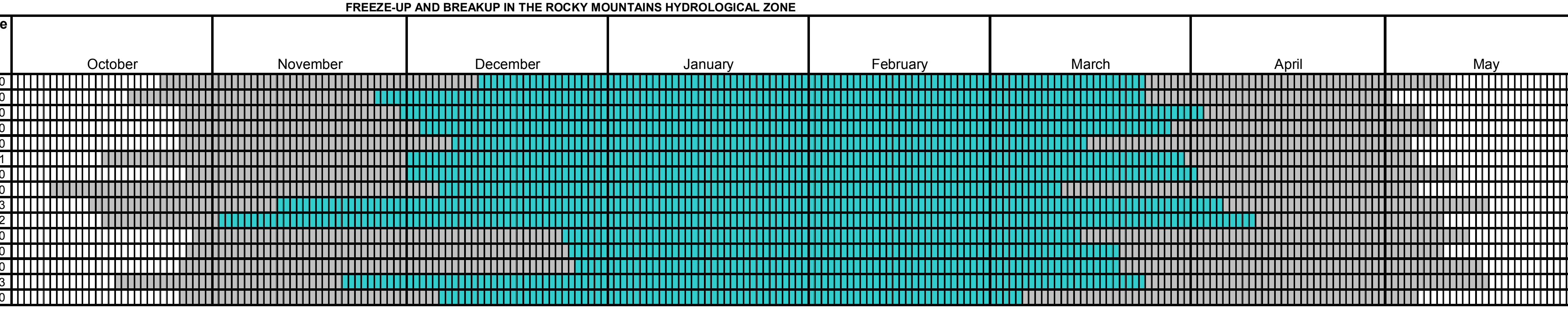






FREEZE-UP AND BREAKUP IN THE ROCKY MOUNTAINS HYDROLOGICAL ZONE

ID	Name	Drainage Area (km^2)
07EE007	PARSNIP RIVER ABOVE MISINCHINKA CREEK	4,930
07EE009	CHUCHINKA CREEK NEAR THE MOUTH	310
07FB001	PINE RIVER AT EAST PINE	12,100
07FB002	MURRAY RIVER NEAR THE MOUTH	5,550
07FB003	SUKUNKA RIVER NEAR THE MOUTH	2,590
07FB004	DICKEBUSCH CREEK NEAR THE MOUTH	82.1
07FB006	MURRAY RIVER ABOVE WOLVERINE	2,370
07GA001	SMOKY RIVER ABOVE HELLS CREEK	3,870
07GA002	MUSKEG RIVER NEAR GRANDE CACHE	703
07GB001	CUTBANK RIVER NEAR GRANDE PRAIRIE	842
08KA004	FRASER RIVER AT HANSARD	18,000
08KB001	FRASER RIVER AT SHELLEY	32,400
08KB003	MCGREGOR RIVER AT LOWER CANYON	4,780
08KB006	MULLER CREEK NEAR THE MOUTH	103
08KD007	BOWRON RIVER BELOW BOX CANYON	3,420



Maximum Period of Recorded Ice Cover (earliest freeze-up to latest breakup)
Minimum Period of Recorded Ice Cover (latest freeze-up to earliest breakup)

PREPARED BY:	PREPARED FOR:	CONTRACTOR: AMEC	ENBRIDGE NORTHERN GATEWAY PROJECT	FIGURE NUMBER: 3-4
amec	ENBRIDGE NORTHERN GATEWAY PIPELINES	DATE: 20090811	Hydrological Characteristics - Rocky Mountains Hydrological Zone	SCALE: NTS
		AUTHOR: MC / APPROVED BY: MW		PROJECTION: NA / DATUM: NA

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The Rocky Mountains hydrological zone shows similar flow patterns to the Prairies and Foothills hydrological zones, although total flow volumes are higher in the Rocky Mountains hydrological zone. Data from the stations with continuous (year-round) periods of record were used to estimate that about 90% of the annual total flow volume in larger watersheds runs off between March and October, reflecting the high proportions of water stored over the winter months as snowfall and released during spring snowmelt.

Peak Discharges

The regional peak discharge correlation coefficients developed for the Rocky Mountains hydrological zone are summarized in Table 3-10 and Figure 3-4.

Table 3-10 Peak Discharge Correlation Coefficients – Rocky Mountains

Flood Return Period (years)	**Coefficient**		**Correlation Coefficient R^2**
	C	**b**	
10	0.978	0.798	0.94
100	2.242	0.742	0.91

Peak discharges in the Rocky Mountains hydrological zone are directly proportional to and correlate well with drainage area. Compared with the Prairies and Foothills hydrological zones, peak discharges in the Rocky Mountains hydrological zone are higher, which reflects the greater amounts of precipitation, overall greater terrain relief in the watersheds, and greater winter snowpacks in this zone.

Drought Discharges

The results of the drought discharge analyses for the Rocky Mountains hydrological zone are presented in Figure 3-4. The derived regional drought discharge correlation coefficients are presented in Table 3-11.

Table 3-11 Drought Discharge Correlation Coefficients – Rocky Mountains

Drought Event	**Coefficient**		**Correlation Coefficient R^2**
	C	**b**	
7Q2 (2 year return period)	0.0002	1.296	0.86
7Q10 (10 year return period)	3×10^{-5}	1.456	0.77

Drought discharges in the Rocky Mountains hydrological zone also correlate reasonably well with drainage area. Unlike the hydrological zones to the east, regional data do not show a high likelihood of zero discharge events. Zero flows over periods of seven days or more were observed at only one station within this zone. This means that even in small channels with drainage areas in excess of about 100 km^2, some flow is expected year-round. It is possible that channels with smaller drainage areas could be dry or frozen to the bed over the winter months.

3.2.3.2 Freeze-Up and Breakup

In the Rocky Mountains hydrological zone, all the channels with WSC data developed an ice cover that remained over winter. Freeze-up and breakup data for this zone are summarized in Figure 3-4. Freeze-up and breakup dates varied with channel discharge, gradient, elevation and climate conditions.

The onset of freeze-up in the Rocky Mountains hydrological zone ranges from the first week of November for watersheds located along the eastern edge of the zone to late December for the larger watersheds (see Figure 3-4). Breakup occurs between early March and early April. Freeze-up and breakup could extend well beyond the typical ice-covered period. In most channels, freeze-up has occurred as early as mid-October and breakup as late as the first week of May.

According to data from WSC, ice thickness varies among channels and years, depending on climatic and hydrological conditions. Average ice thicknesses ranges from 0.36 to 0.57 m, with a mean of 0.46 m for all sites. Mean maximum ice thicknesses of up to 1.0 m are reported by Allen (1977).

Based on the results of the winter ice investigation and published regional data on winter streamflows and ice thickness, it is unlikely that many streams in this zone will freeze to the bed over the winter period. All but the smallest channels are expected to be wet (with ponded or flowing water) all winter.

3.2.3.3 Channel Geomorphology

Channel Dimensions

Channel dimensions are available for 207 sites in the Rocky Mountains hydrological zone. Compared with the Prairies and Foothills hydrological zones, watercourses in the Rocky Mountains zone are generally deeper, narrower and steeper, reflecting the typically steeper terrain and confined valleys of this zone. Typical channel widths, depths and gradients in the Rocky Mountains hydrological zone, as measured at the watercourse crossings, are summarized in Table 3-12 and Figure 3-2.

Table 3-12 Channel Dimensions of Watercourse Crossings – Rocky Mountains

Drainage Area (km^2)	Number of Crossings on RoW	Channel Width (m)		Channel Depth (m)		Channel Gradient (%)	
		Median	Observed Range	Median	Observed Range	Median	Observed Range
<1	157	0.9	0.3 to 4.5	0.2	0.1 to 0.8	2.7	0.3 to 14.8
1 to 10	65	2.4	0.6 to 8.0	0.4	0.1 to 1.1	3.5	0.7 to 14.1
10 to 100	19	6.8	2.7 to 8.3	0.5	0.2 to 1.3	2.9	1.0 to 16.3
100 to 1,000	7	20.3	16.7 to 27.2	1.3	0.4 to 1.5	6.8	0.9 to 12.5
1,000 to 10,000	3	N/A	N/A	N/A	N/A	N/A	N/A

Channel Bed and Bank Material Characterization

The available bed and bank material data for the Rocky Mountains hydrological zone were assembled and compared. Bed material gradations were determined to be a function of channel gradient. Bed materials in low gradient channels with bed slopes less than two percent are relatively fine-grained (i.e., silts and fine sands). In channels with slopes of about two to four percent, bed materials are composed of coarser sand and gravel; bed materials in the steepest channels are dominated by coarse gravel and cobbles. Bedrock outcrops are visible along the bed and bank of many channels. Bank materials vary with location, from silt and fine-grained sand with organics, to coarser granular materials including cobbles. The observed bed and bank materials are consistent with the steeper channel gradients typical of this zone.

Channel Stability

Channel stability is a site-specific condition. Most channels in the Rocky Mountains hydrological zone have a very high potential for waterborne debris (both wood and sediment). Debris jams and bedrock outcrops play a greater role in channel geomorphology here than in the Prairies and Foothills hydrological zones. Debris jams can form during a single flood event and can dramatically affect local scour, bank erosion and overall channel alignment. Bedrock outcrops can control the channel bed profile as well as the lateral configuration of the channel.

3.2.4 Central Interior Hydrological Zone

Annual total precipitation in the Central Interior hydrological zone (averaging 500 mm) is slightly greater than in the Prairies hydrological zone but less than in the remaining hydrological zones that were assessed. About 55% of the total annual precipitation in this zone occurs as snow over the winter. Its terrain is similar to that of the Prairies hydrological zone, and similar agricultural land uses are in place.

The regional hydrological characterization for the Central Interior hydrological zone is discussed below.

3.2.4.1 Discharges

Annual and Seasonal Total Flow Volumes

Only four streamflow monitoring stations are available in the Central Interior hydrological zone, but all have continuous (January to December) data over the entire period of record. Based on this data availability, both seasonal and annual total flow volume relationships were estimated for the Central Interior hydrological zone. The results of the seasonal and annual total flow volume analyses are presented in Figure 3-5. The regional seasonal and annual total flow volume correlation coefficients are presented in Table 3-9.

Baseline seasonal and annual total flow volumes in the Central Interior hydrological zone vary directly with watershed drainage area. The correlation between both seasonal and annual total flow volumes and drainage area in this zone is very high.

Table 3-13 Seasonal and Annual Total Flow Volume Correlation Coefficients – Central Interior

Period	Coefficient		Correlation Coefficient R^2
	C	b	
Seasonal (April to October)	196.58	0.961	0.99
Annual (January to December)	212.05	0.968	0.98

The Central Interior hydrological zone shows flow patterns very similar to those observed in the Foothills hydrological zone, although total flow volumes are slightly higher in the Central Interior hydrological zone. Based on the streamflow records, approximately 87% of the annual total flow volume is estimated to run off between March and October.

Peak Discharges

The regional peak discharge correlation coefficients developed for the Central Interior hydrological zone are summarized in Table 3-14 and Figure 3-5.

Table 3-14 Peak Discharge Correlation Coefficients – Central Interior

Flood Return Period (years)	Coefficient		Correlation Coefficient R^2
	C	b	
10	0.871	0.622	0.74
100	0.549	0.736	0.84

Peak discharges in the Central Interior hydrological zone are directly proportional to and correlate well with drainage area. Peak discharges in this zone were the lowest among all the hydrological zones for watersheds with drainage areas between 10 and 2,000 km^2.

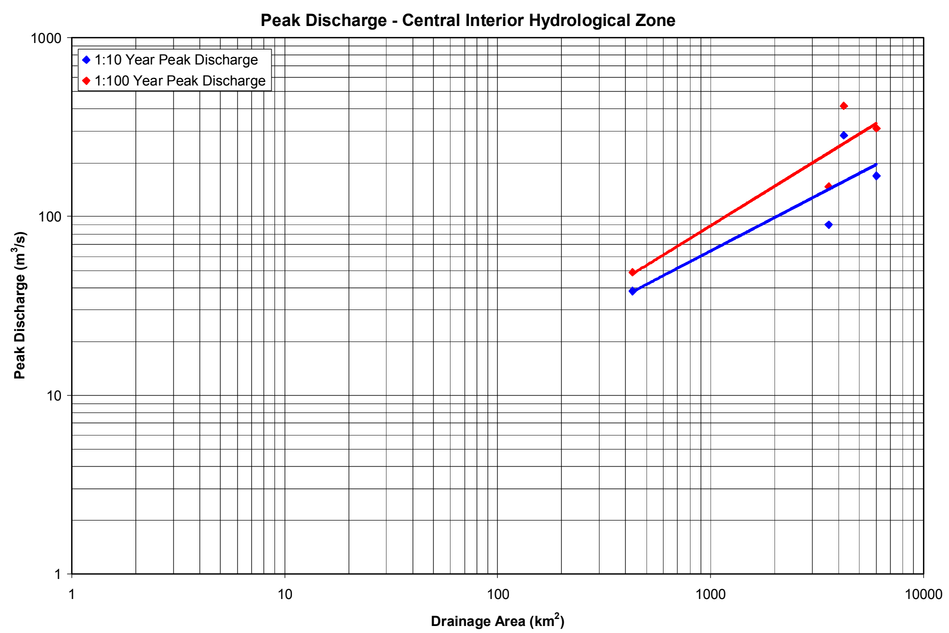
Drought Discharges

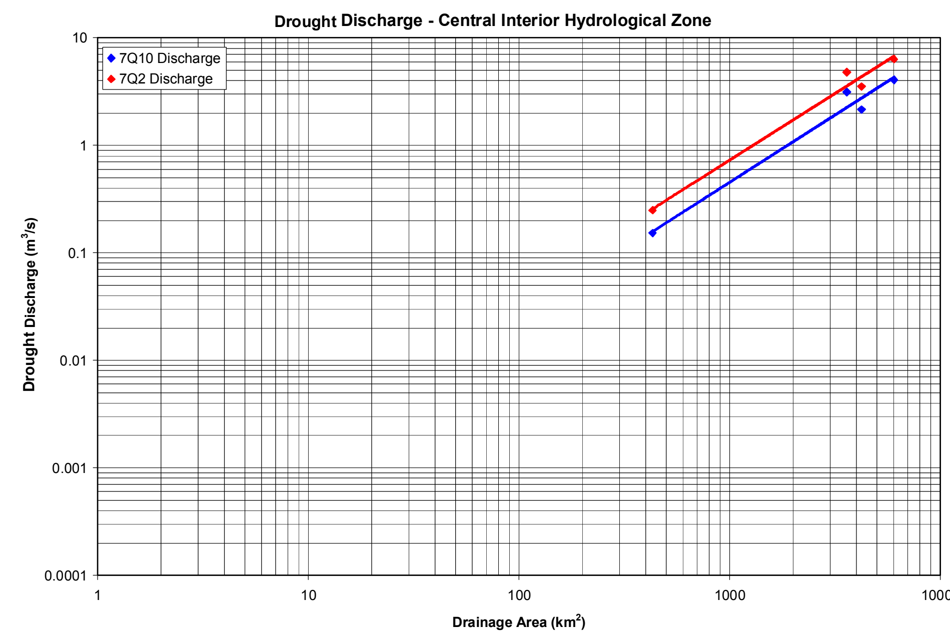
The results of the drought discharge analyses for the Central Interior hydrological zone are presented in Figure 3-5. The derived regional drought discharge correlation coefficients are presented in Table 3-15.

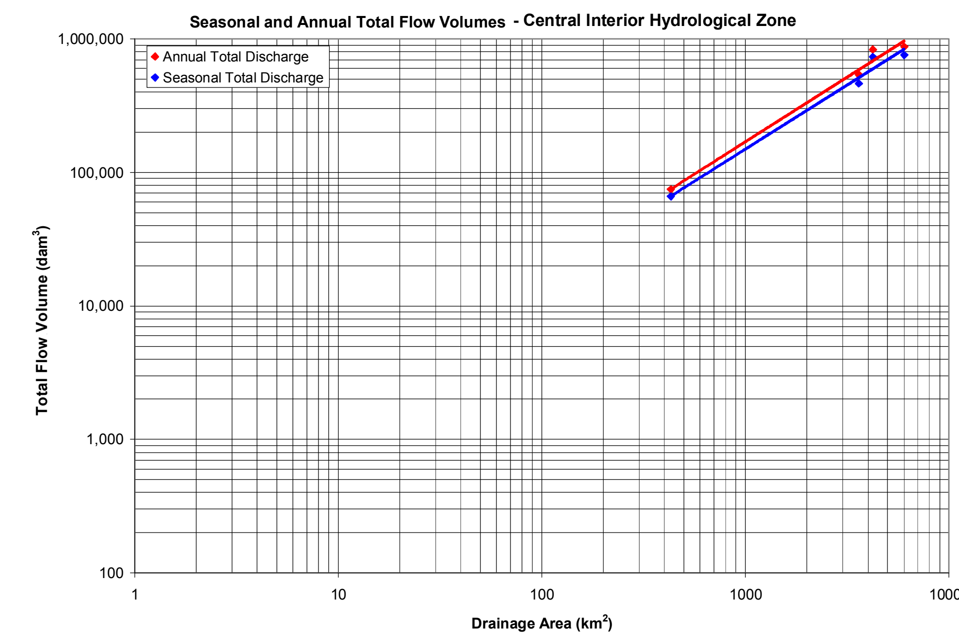
Table 3-15 Drought Discharge Correlation Coefficients – Central Interior

Drought Event	Coefficient		Correlation Coefficient R^2
	C	b	
7Q2 (2 year return period)	0.0001	1.240	0.98
7Q10 (10 year return period)	8×10^{-5}	1.252	0.97

Drought discharges in the Central Interior hydrological zone correlate very well with drainage area. Unlike the Prairies and Foothills hydrological zones to the east, regional data do not show a high probability of zero discharge events, and some flow is expected year-round in most channels. However, streamflow data were available only for streams with drainage areas greater than 400 km^2, and extrapolations to smaller watershed areas are unconfirmed.







FREEZE-UP AND BREAKUP IN THE CENTRAL INTERIOR HYDROLOGICAL ZONE

ID	Name	Drainage Area (km²)	October	November	December	January	February	March	April	May
08JB002	STELLAKO RIVER AT GLENANNAN	3,600								
08JB003	NAUTLEY RIVER NEAR FORT FRASER	6,030								
08JE004	TSILCOH RIVER NEAR THE MOUTH	431								
08KC001	SALMON RIVER NEAR PRINCE GEORGE	4,230								

Maximum Period of Recorded Ice Cover (earliest freeze-up to latest breakup)
Minimum Period of Recorded Ice Cover (latest freeze-up to earliest breakup)

PREPARED BY: amec

PREPARED FOR: ENBRIDGE NORTHERN GATEWAY PIPELINES

CONTRACTOR: AMEC

DATE: 20090811

AUTHOR: MC

APPROVED BY: MW

ENBRIDGE NORTHERN GATEWAY PROJECT

Hydrological Characteristics - Central Interior Hydrological Zone

FIGURE NUMBER: 3-5

SCALE: NTS

PROJECTION: NA

DATUM: NA

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3.2.4.2 Freeze-Up and Breakup

In the Central Interior hydrological zone, all channels with WSC data developed an ice cover that remained over winter. Freeze-up and breakup data for this zone are summarized in Figure 3-5.

Freeze-up in the Central Interior hydrological zone ranges from the last week of November for the smallest watershed to mid-January for the largest watershed (see Figure 3-5). The duration of ice cover on the largest watershed (Salmon River) is generally short. For other basins, breakup generally occurs between mid-March and early April. Freeze-up and breakup could extend well beyond the typical ice-covered period. In most channels, freeze-up has occurred as early as the third week of October and breakup as late as the first week of May.

According to WSC data, ice thickness varied among channels and years, depending on climatic and hydrological conditions. Average ice thicknesses ranged from 0.28 to 0.48 m, with a mean of 0.39 m for all sites. Mean maximum ice thicknesses of up to 1.6 m are reported by Allen (1977).

Based on the results of the winter ice investigation and published regional data on winter streamflows and ice thickness, it is unlikely that channels with substantial drainage areas will freeze to the bed over the winter period, when all but the smallest channels are expected to remain wet.

3.2.4.3 Channel Geomorphology

Channel Dimensions

Channel dimensions are available for 88 sites in the Central Interior hydrological zone. Watercourses in this zone are generally comparable to those of the Foothills and Rocky Mountains hydrological zones. Channel widths and gradients are similar to those observed in the Rocky Mountains hydrological zone. Typical channel widths, depths and gradients in the Central Interior hydrological zone, as measured at the watercourse crossings, are summarized in Table 3-16 and Figure 3-2.

Table 3-16 Channel Dimensions of Watercourse Crossings – Central Interior

Drainage Area (km^2)	Number of Crossings on RoW	Channel Width (m)		Channel Depth (m)		Channel Gradient (%)	
		Median	Observed Range	Median	Observed Range	Median	Observed Range
<1	67	0.9	0.3 to 18.3	0.2	0.1 to 0.6	3.2	0.4 to 12.9
1 to 10	38	1.5	0.4 to 6.1	0.3	0.1 to 0.9	3.6	1.8 to 18.0
10 to 100	14	6.3	1.4 to 40.3	0.6	0.1 to 1.2	5.3	1.3 to 7.7
100 to 1,000	3	14.9	14.5 to 15.3	1.4	1.1 to 1.8	2.9	1.6 to 4.2
1,000 to 10,000	1	29.8	N/A	1.7	N/A	8.1	N/A

Channel Bed and Bank Material Characterization

The available bed and bank material data for the Central Interior hydrological zone were assembled and compared. Bed material gradations were found to be a function of watershed area (and therefore peak discharges). Bed materials in watercourses with drainage areas less than 30 km^2 are relatively fine-grained (i.e., silts and fine sands with organics). In channels with drainage areas of more than 100 km^2, bed materials are coarser (up to coarse gravel in size); bed materials in the steepest channels are dominated by coarse gravel, cobbles and occasional boulders. Bank materials sizes generally range from silt and fine-grained sand with organics to coarser gravel.

Channel Stability

Channel stability is a site-specific condition. Most channels in the Central Interior hydrological zone have a lower potential for waterborne debris than the hydrological zones to the east. Bank erosion was observed in some channels (as expected in unconfined, meandering channels similar to those in the Prairies and Foothills hydrological zones), but overall bank erosion appears to be balanced by deposition and bar formation.

3.2.5 Central Mountains Hydrological Zone

The Central Mountains hydrological zone receives much less precipitation (averaging 530 mm annually) than the Coastal Mountains hydrological zone to the west. Approximately 50% of the annual total precipitation in the Central Mountains hydrological zone occurs as snow that contributes to streamflows during the spring freshet.

The regional hydrological characterization for the Central Mountains hydrological zone is discussed below.

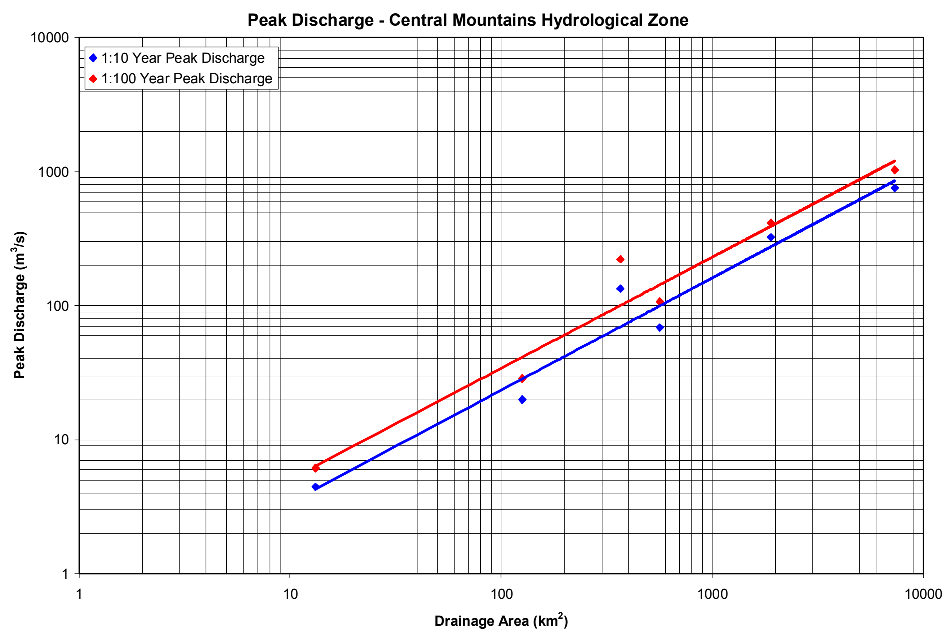
3.2.5.1 Discharges

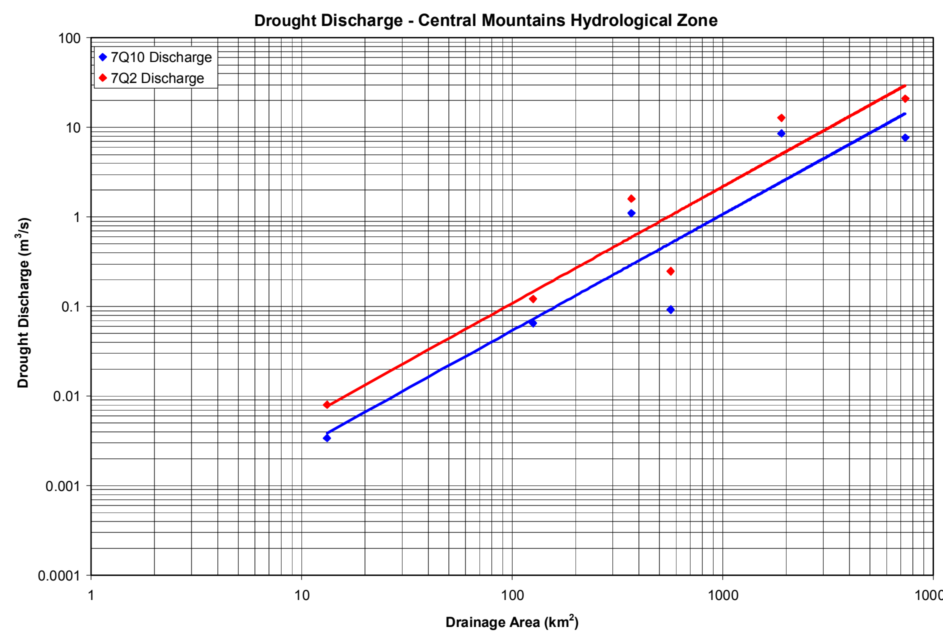
Annual and Seasonal Total Flow Volumes

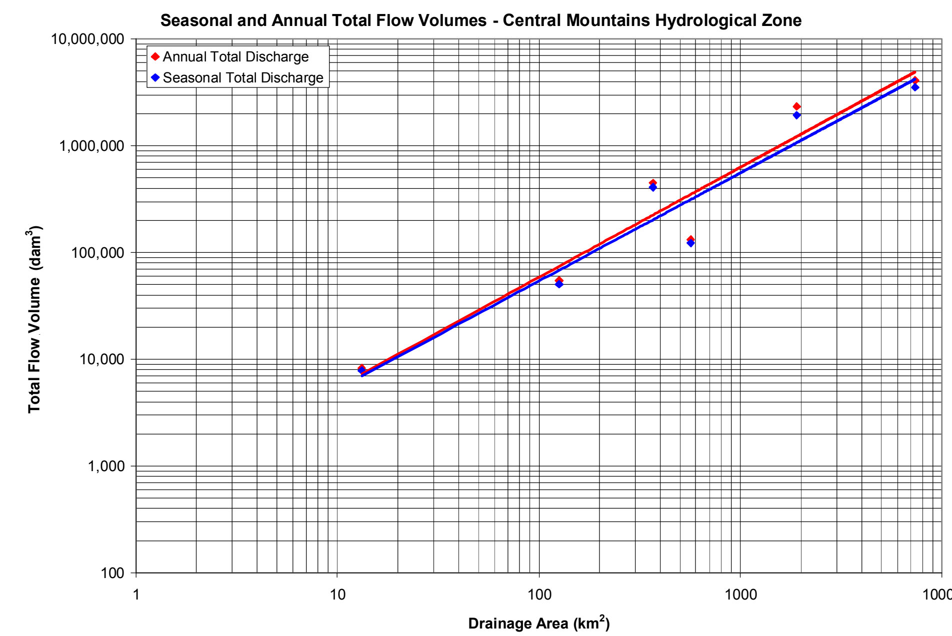
All six streamflow monitoring stations in the Central Mountains hydrological zone have continuous (January to December) data over the entire period of record. Based on this data availability, both seasonal and annual total flow volume relationships are estimated for this zone. The results of the seasonal and annual total flow volume analyses are presented in Figure 3-6. The regional seasonal and annual total flow volume correlation coefficients are presented in Table 3-17.

Table 3-17 Seasonal and Annual Total Flow Volume Correlation Coefficients – Central Mountains

Period	Coefficient		Correlation Coefficient R^2
	C	b	
Seasonal (April to October)	511.42	1.013	0.93
Annual (January to December)	511.31	1.030	0.93







FREEZE-UP AND BREAKUP IN THE CENTRAL MOUNTAINS HYDROLOGICAL ZONE

ID	Name	Drainage Area (km^2)	October	November	December	January	February	March	April	May
08ED002	MORICE RIVER NEAR HOUSTON	1,900								
08EE004	BULKLEY RIVER AT QUICK	7,350								
08EE008	GOATHORN CREEK AT TELKWA	126								
08EE012	SIMPSON CREEK AT THE MOUTH	13.2								
08EE013	BUCK CREEK AT THE MOUTH	566								
08EE020	TELKWA RIVER BELOW TSAI CREEK	368								

Maximum Period of Recorded Ice Cover (earliest freeze-up to latest breakup)
Minimum Period of Recorded Ice Cover (latest freeze-up to earliest breakup)

PREPARED BY:	PREPARED FOR:	CONTRACTOR: AMEC	ENBRIDGE NORTHERN GATEWAY PROJECT	FIGURE NUMBER: 3-6
amec	ENBRIDGE NORTHERN GATEWAY PIPELINES	DATE: 20090811	Hydrological Characteristics - Central Mountains Hydrological Zone	SCALE: NTS
		AUTHOR: MC / APPROVED BY: MW		PROJECTION: NA / DATUM: NA

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Baseline seasonal and annual total flow volumes in the Central Mountains hydrological zone vary in direct proportion to watershed drainage area. The correlation between both seasonal and annual total flow volumes and drainage area in the Central Mountains hydrological zone is very high.

The Central Mountains hydrological zone shows flow patterns very similar to those observed in the Rocky Mountains hydrological zone, and both seasonal and annual total flow volumes are similar in magnitude. Based on streamflow records, approximately 90% of annual total flow volume in the Central Mountains hydrological zone is estimated to run off between March and October.

Peak Discharges

The regional peak discharge correlation coefficients developed for the Central Mountains hydrological zone are summarized in Table 3-18 and Figure 3-6.

Table 3-18 Peak Discharge Correlation Coefficients – Central Mountains

Flood Return Period (years)	**Coefficient**		**Correlation Coefficient R^2**
	C	**b**	
10	0.493	0.838	0.96
100	0.746	0.830	0.95

The correlation between peak discharges and drainage areas in the Central Mountains hydrological zone is very strong. The magnitude of flood discharges is directly proportional to drainage area. Unit discharges for peak discharge events (peak discharge divided by drainage area) are higher for smaller watersheds than for larger watersheds. Peak discharges in this zone are slightly lower than in the Rocky Mountains hydrological zone.

Drought Discharges

The results of the drought discharge analyses for the Central Mountains hydrological zone are presented in Figure 3-6. The derived regional drought discharge correlation coefficients are presented in Table 3-19.

Table 3-19 Drought Discharge Correlation Coefficients – Central Mountains

Drought Event	**Coefficient**		**Correlation Coefficient R^2**
	C	**b**	
7Q2 (2 year return period)	0.0003	1.30	0.91
7Q10 (10 year return period)	0.0001	1.30	0.86

Drought discharges in the Central Mountains hydrological zone correlate very well with drainage area. The Central Mountains hydrological zone shows flow patterns very similar to those observed in the Rocky Mountains hydrological zone, and the 7Q2 and 7Q10 drought discharges in the two hydrological zones are both similar in magnitude. Regional data do not show a high probability of zero discharge events and some flow is expected year-round in most channels, although zero discharge events could still occur in small watersheds.

3.2.5.2 Freeze-Up and Breakup

In the Central Mountains hydrological zone, the development and duration of channel ice cover vary widely (see Figure 3-6). Freeze-up and breakup dates vary with channel discharge, gradient, elevation and climate conditions.

Two of the WSC sites in the Central Mountains hydrological zone (Morice River and Telkwa River) often had years with no ice covered. Typical freeze-up dates for the remaining stations vary from the last week of November to the beginning of February. Breakup occurs any time between mid-February and mid-March, depending on the channel. Freeze-up and breakup could extend well beyond the typical ice-covered period. At almost all the sites, freeze-up has occurred by the end of October and breakup as late as the end of April to early May.

Ice thickness data for the Central Mountains hydrological zone is very limited. Based on the available data, average ice thickness is estimated to vary between 0.15 and 0.40 m, with a mean thickness of 0.28 m. Mean maximum ice thicknesses of 0.45 m are reported by Allen (1977).

Based on the results of the winter ice investigation and published regional data on winter discharges and ice thickness, it is unlikely that streams in this zone will freeze to the bed over the winter period, and all but the smallest channels are expected to remain wet.

3.2.5.3 Channel Geomorphology

Channel Dimensions

Channel dimensions are available for 73 sites in the Central Mountains hydrological zone. Channel widths in the hydrological zone are similar to those observed in the Central Interior, but watercourses tended to be deeper and steeper. Average channel widths, depths and gradients in the Central Mountains hydrological zone are shown in Table 3-20 and Figure 3-2.

Table 3-20 Channel Dimensions of Watercourse Crossings – Central Mountains

Drainage Area (km^2)	Number of Crossings on RoW	Channel Width (m)		Channel Depth (m)		Channel Gradient (%)	
		Median	Observed Range	Median	Observed Range	Median	Observed Range
<1	41	1.2	0.5 to 3.0	0.3	0.1 to 0.5	3.6	0.8 to 8.8
1 to 10	35	1.4	0.4 to 6.5	0.4	0.1 to 0.7	5.4	1.4 to 15.1
10 to 100	11	3.8	1.4 to 14.9	0.6	0.3 to 1.3	4.4	0.9 to 17.7
100 to 1,000	6	13.9	7.6 to 15.3	0.8	0.7 to 1.1	9.8	8.9 to 10.7
1,000 to 10,000	1	30.8	N/A	3.5	N/A	3.8	N/A

Bed and Bank Material Characterization

The available bed and bank material data for the Central Mountains hydrological zone were assembled and compared. Bed material gradations were typically a function of watershed area and thus of peak discharges. Bed materials in smaller watercourses consist mainly of coarse sand, fine gravel and small cobbles. In watercourses with larger drainage areas, the bed materials are correspondingly coarser (coarse gravel and cobbles) with a reduced component of fine-grained material. Bank materials generally comprise sand, gravel and cobbles, with silt also observed at some locations.

Channel Stability

Channel stability is a site-specific condition. Most channels have a high to very high potential for waterborne debris (both wood and sediment). Debris jams play a greater role in the channel geomorphology of this zone than in the Central Interior and Prairies hydrological zones. Debris jams can form during a single flood event and can dramatically affect local scour, bank erosion and overall channel alignment. Debris torrents are also possible at confined narrow mountain channels conveying high sediment loads, as well as at alluvial fan crossings.

3.2.6 Coastal Mountains Hydrological Zone

The Coastal Mountains hydrological zone receives more precipitation than any other hydrological zone along the pipeline RoW. Annual total precipitation ranges from 800 to 2,400 mm, of which approximately 35% occurs as snow during the winter period.

The regional hydrological characterization for the Coastal Mountains hydrological zone is discussed below.

3.2.6.1 Discharges

Annual and Seasonal Total Flow Volumes

All eight streamflow monitoring stations in the Coastal Mountains hydrological zone have continuous (January to December) data over the entire period of record. Based on this data availability, both seasonal and annual total flow volume relationships were estimated for the Coastal Mountains hydrological zone. The results of the annual and seasonal analyses are presented in Figure 3-7. The regional seasonal and annual total flow volume correlation coefficients are presented in Table 3-21.

Table 3-21 Seasonal and Annual Total Flow Volume Correlation Coefficients – Coastal Mountains

Period	Coefficient		Correlation Coefficient R^2
	C	b	
Seasonal (April to October)	7044.1	0.780	0.96
Annual (January to December)	8818.3	0.772	0.96

Baseline seasonal and annual total flow volumes in the Coastal Mountains hydrological zone vary directly with watershed drainage area. The correlation between both seasonal and annual total flow volumes and drainage area in this zone is very high. However, seasonal and annual total runoff (total flow volume divided by drainage area) varies inversely with drainage area, because the watersheds that drain directly off the mountain slopes typically have less surface storage capacity than the larger watersheds encompassing the broad valley floors. Extrapolating regional data to watersheds with drainage areas of less than 100 km^2 overestimates annual total runoff and annual total flow volumes. Hence, average annual total runoff was assumed to peak at 3,000 mm per year for these watersheds.

The Coastal Mountains hydrological zone has higher seasonal and annual total flow volumes than any other hydrological zone identified along the RoW. Based on the streamflow records, approximately 84% of its annual total flow volume is estimated to run off between March and October.

Peak Discharges

The regional peak discharge correlation coefficients developed for the Coastal Mountains hydrological zone are summarized in Table 3-22 and Figure 3-7.

Table 3-22 Peak Discharge Correlation Coefficients – Coastal Mountains

Flood Return Period (years)	**Coefficient**		**Correlation Coefficient R^2**
	C	**b**	
10	7.643	0.657	0.93
100	15.921	0.614	0.93

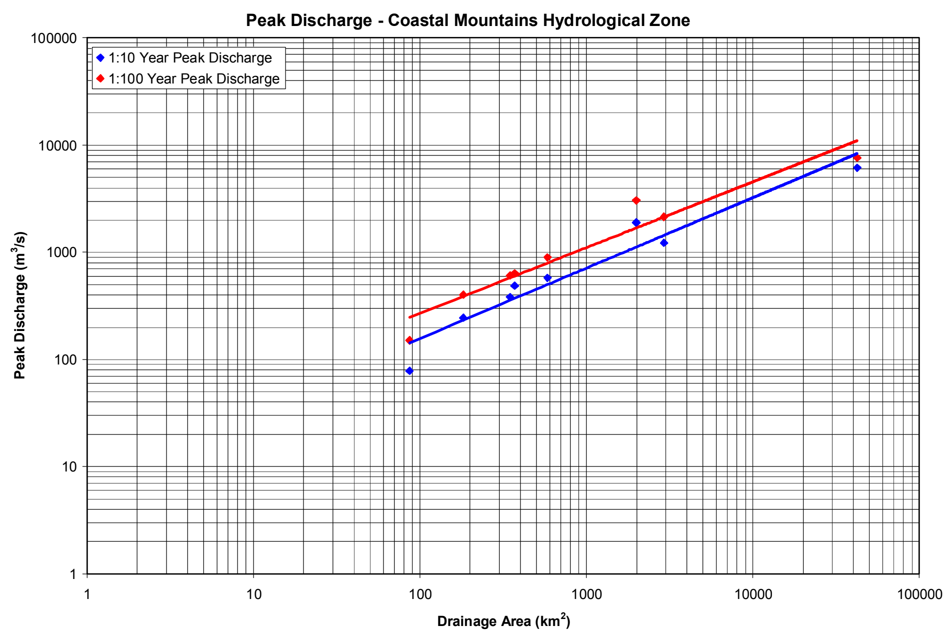
The correlation between peak discharges and drainage areas in this zone is very strong. The magnitude of flood discharges is directly proportional to drainage area, with greater unit flood peaks expected in the smaller watersheds. Peak discharges for comparably sized watersheds are higher in the Coastal Mountains hydrological zone than in all other hydrological zones.

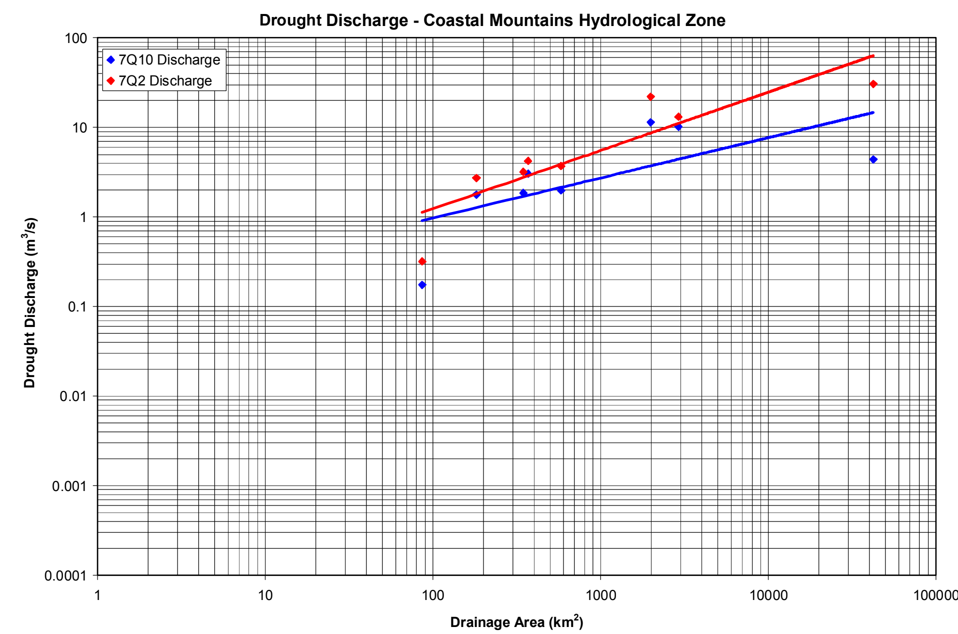
Drought Discharges

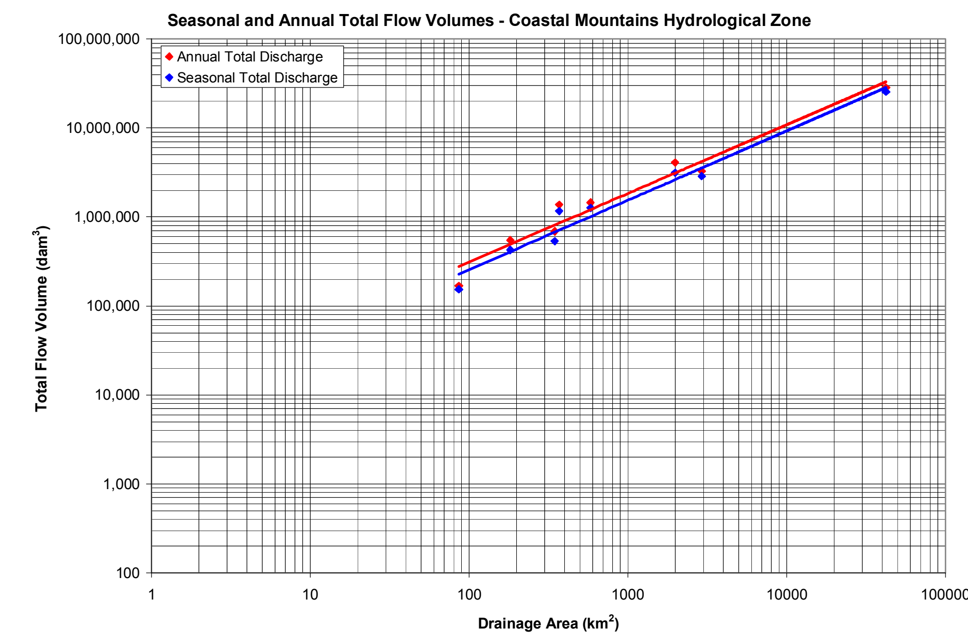
The results of the drought discharge analyses for the Coastal Mountains hydrological zone are presented in Figure 3-7. The derived regional drought discharge correlation coefficients are presented in Table 3-23.

Table 3-23 Drought Discharge Correlation Coefficients – Coastal Mountains

Drought Event	**Coefficient**		**Correlation Coefficient R^2**
	C	**b**	
7Q2 (2 year return period)	0.0612	0.651	0.77
7Q10 (10 year return period)	0.123	0.449	0.45







FREEZE-UP AND BREAKUP IN THE COASTAL MOUNTAINS HYDROLOGICAL ZONE

ID	Name	Drainage Area (km^2)	October	November	December	January	February	March	April	May
08EF001	SKEEN RIVER AT USK	42,300								
08EF005	ZYMOETZ RIVER ABOVE OK CREEK	2,920								
08EG012	EXCHAMSIKS RIVER NEAR TERRACE	370								
08FE003	KEMANO RIVER ABOVE POWERHOUSE TAILRACE	583								
08FF001	KITIMAT RIVER BELOW HIRSCH CREEK	1,990								
08FF002	HIRSCH CREEK NEAR THE MOUTH	347								
08FF003	LITTLE WEDEENE RIVER BELOW BOWBYES CREEK	182								
08JA015	LAVERTIE CREEK NEAT THE MOUTH	86.5								

Maximum Period of Recorded Ice Cover (earliest freeze-up to latest breakup)
Minimum Period of Recorded Ice Cover (latest freeze-up to earliest breakup)

PREPARED BY:	PREPARED FOR:	CONTRACTOR: AMEC	ENBRIDGE NORTHERN GATEWAY PROJECT	FIGURE NUMBER: 3-7
amec	ENBRIDGE NORTHERN GATEWAY PIPELINES	DATE: 20090811	Hydrological Characteristics - Coastal Mountains Hydrological Zone	SCALE: NTS
		AUTHOR: MC / APPROVED BY: MW		PROJECTION: NA / DATUM: NA

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The correlations in the Coastal Mountains hydrological zone between drought discharges and drainage area are moderate for low return period events (1:2 year event) and weak for less common events (1:10 year return period). Regional data show that zero discharge events are not expected to occur even in very small watersheds (less than 1 km^2) and drought discharges are greater than in any other hydrological zone.

3.2.6.2 Freeze-Up and Breakup

In the Coastal Mountains hydrological zone, the development and duration of channel ice cover vary widely (see Figure 3-7).

Ice has been reported at all eight of the streamflow monitoring stations used in this zone. Data from four of the sites show that ice cover occurs infrequently over the winter period. At three of the sites that normally develop an ice cover, ice duration is typically less than three weeks. The longest duration ice cover occurs at the smallest watercourse (Laventie Creek) and typically lasts from about mid-December to early March. Freeze-up and breakup could extend well beyond the typical ice-covered period. At most of the sites, freeze-up has occurred by the beginning of November; one site has had freeze-up occur as early as the second week of October. Although breakup generally occurs by mid-April, breakups as late as mid-May have been reported at one station.

Mean maximum ice thicknesses reported by Allen (1977) ranged from 0 to 0.50 m for this hydrological zone.

3.2.6.3 Channel Geomorphology

Channel Dimensions

The drainage areas of channels along the RoW in the Coastal Mountains hydrological zone are all less than 1,000 km^2. Channel dimensions are available for 105 sites in this zone. Channels with drainage areas up to 1,000 km^2 are generally wider and slightly deeper than channels in the other hydrological zones. Channel gradients are comparable to those in the two other mountainous hydrological zones: Rocky Mountains and Central Mountains. Average channel widths, depths and gradients in the Coastal Mountains zone, as measured at the crossings, are summarized in Table 3-24 and Figure 3-2.

Channel Bed and Bank Material Characterization

The available bed and bank material data for the Coastal Mountains hydrological zone were assembled and compared. The majority of channels along the RoW are steep, with gradients greater than four percent. Most channels are draining off the upper mountain slopes and through narrow valleys. Alluvial fans form where the high gradient, high energy mountain tributaries emerge from their confining valleys and enter the broader valley of the main channel. Depending on their location relative to the mouths of these tributary channels, the pipelines could cross numerous alluvial fans. Fans are at risk for sudden channel avulsions, particularly during extreme flood events when high sediment and debris loads are mobilized and transported onto the fans.

Table 3-24 Channel Dimensions of Watercourse Crossings – Coastal Mountains

Drainage Area (km^2)	Number of Crossings on RoW	Channel Width (m)		Channel Depth (m)		Channel Gradient (%)	
		Median	Observed Range	Median	Observed Range	Median	Observed Range
<1	94	1.8	0.6 to 5.8	0.4	0.1 to 1.5	4.0	0.2 to 131
1 to 10	39	3.9	0.9 to 13.6	0.6	0.2 to 2.3	3.4	0.2 to 9.7
10 to 100	8	17.9	6.8 to 68.0	0.8	0.6 to 3.2	8.9	3.6 to 15.8
100 to 1,000	5	41.0	23.0 to 67.2	1.3	1.2 to 1.7	3.8	2.6 to 5.0
1,000 to 10,000	0	N/A	N/A	N/A	N/A	N/A	N/A

Bed material gradations in the Coastal Mountains hydrological zone generally comprise coarse granular material ranging in size from gravel to boulders. Bedrock outcrops are encountered along the valley walls. The beds of the steeper channels are self-armoured to some extent with cobbles and boulders. Bank materials vary with location, but typically consist of sand, gravel and cobbles overlain by an organic surface layer. The observed bed and bank materials are in keeping with the steeper mountainous terrain of this zone.

Channel Stability

Channel stability is a site-specific condition. Most channels in the Coastal Mountains hydrological zone have a high to very high potential for waterborne debris. Channels on alluvial fans can trigger debris flows during extreme flood events.

3.2.7 Summary

Using published data from established streamflow monitoring stations with 30 to 35 years of continuous records, six distinct hydrological zones were established along the RoW and regional relationships were developed between seasonal or annual total discharge, peak discharges, low discharges and watershed drainage areas.

3.2.7.1 Discharges

The Foothills hydrological zone shows similar flow patterns to the Prairies hydrological zone although discharges are higher for all assessed parameters. Mean annual runoff in the Rocky Mountains hydrological zone is 3 to 10 times higher than in the Foothills hydrological zone, and 15 to 20 times higher than in the Prairies hydrological zone, depending on watershed area. Runoff in the Central Interior hydrological zone is up to 20 times greater than in the Foothills hydrological zone for drainage areas of up to 4,000 km^2 but is lower than in either the Rocky Mountains or the Central Mountains hydrological zones. Runoff is greatest in the Coastal Mountains hydrological zone because much more precipitation occurs in that zone.

Peak discharges in all the hydrological zones (specifically the 1:100-year return period discharges) follow a similar trend toward flood magnitude increasing proportionally with drainage area. The Prairies and Central Interior hydrological zones display the lowest peak discharges. Peak discharges in the Foothills and Central Mountains hydrological zones are greater than in the flatter Prairies and Central Interior hydrological zones. The greatest peak discharges occur in the Rocky Mountains and Coastal Mountains hydrological zones.

Computed 7Q10 drought discharges are dependent on drainage area in all of the hydrological zones. The lowest 7Q10 discharges are observed in the Prairies and Foothills hydrological zones, which receive the lowest annual precipitation along the pipeline RoW. The computed 7Q10 discharges in the Rocky Mountains, Central Interior and Central Mountains hydrological zones are similar to or greater than those in the eastern-most hydrological zones. The computed 7Q10 discharges in the Coastal Mountains are greater than in all other hydrological zones for watershed drainage areas less than about 3,000 km^2. In larger watersheds, the 7Q10 discharges in the Coastal Mountains hydrological zone are lower than in the Rocky Mountains and Central Mountains hydrological zones.

3.2.7.2 Freeze-Up and Breakup

Most watercourses along the RoW will develop a winter ice cover. However, the timing of ice cover formation (freeze-up) and dissipation (breakup), as well as the thickness of the ice cover, vary between hydrological zones.

In the Prairies and Foothills hydrological zones, freeze-up occurs for most channels during the first week of November. Breakup starts in the second half of March and by mid-April and channels are generally open. Channels with small upstream drainage areas could freeze to the bed over the winter period. Based on the published regional data on winter discharges and ice thickness, it is expected that in the Prairies hydrological zone most channels with drainage areas less than 600 km^2 could be dry or frozen to the bed during winter. Similarly, in the Foothills hydrological zone most channels with drainage areas less than 30 km^2 could be dry or frozen to the bed in the winter.

In the Rocky Mountains hydrological zone, all channels with available data develop an ice cover that remain over winter. Freeze-up ranges from the first week of November for watersheds located along the eastern edge of the zone to late December for the larger watersheds. Breakup occurs between early March and early April.

Freeze-up in the Central Interior hydrological zone ranges from the last week of November for the smallest watershed to mid-January for the largest watershed. Breakup generally occurs between mid-March and early April. The duration of ice cover on the largest watershed (Salmon River) is generally short.

In the Central Mountains hydrological zone, the development and duration of channel ice cover varies widely, and some sites often do not develop a winter ice cover at all. Typical freeze-up dates for the watercourses that do ice over vary from the last week of November to the beginning of February. Breakup may occur any time between mid-February and mid-March, depending on the channel.

Similarly, the development of channel ice cover and the duration of the ice-cover period vary widely in the Coastal Mountains hydrological zone. Many channels develop ice covers infrequently, and ice covers are generally of short duration (less than three weeks).

Recorded average ice thickness varies from a low of 0.07 m (Foothills hydrological zone) to 0.71 m in the Prairies hydrological zone. The greatest mean average ice thickness (0.46 m) was recorded on the Rocky Mountains hydrological zone.

3.2.7.3 Geomorphology

The geomorphology of a watercourse is a function of streamflows, surficial geology, sediment loads and channel geometry (principally width, depth and gradient). In a stable channel, the processes of bed and bank erosion, sediment transport and sediment deposition are in balance for the local streamflow regime. Changes to any of the three basic variables of streamflow, sediment load or channel geometry can affect the geomorphology of a watercourse.

For watercourses along the RoW, the basic dimensions of channel width and bankfull depth are observed to vary in direct relation to watershed drainage area in all the hydrological zones. This is as expected, as discharge also varies directly with drainage area and higher discharges need a larger channel area to convey the flow. Although channel gradient is expected to vary inversely with drainage area, the sample data are inconclusive in this regard.

Bankfull channel depths in the Prairies, Rocky Mountains and Central Interior hydrological zones are similar for each of the drainage area ranges considered and are the lowest of all the hydrological zones. Channel depths in the Foothills and Central Mountains hydrological zones tend to be greater than in the Prairies, Rocky Mountains and Central Interior hydrological zones for drainage areas greater than about 10 km^2. Bankfull channel depths tend to be greatest in the Coastal Mountains hydrological zone over all drainage area ranges. For example, for channels with drainage areas between 1 and 10 km^2, average channel depths vary from 0.4 m in the Prairies, Rocky Mountains and Central Interior hydrological zones to 0.7 m in the Coastal Mountains hydrological zone.

Similarly, channel widths in the Coastal Mountains hydrological zone tend to be greater than in the other hydrological zones, followed by the Prairies, Central Interior and Rocky Mountains hydrological zones. Data from the Foothills and Central Mountains hydrological zones show a trend toward narrower channels. For example, for channels with drainage areas between 1 and 10 km^2, average channel widths vary from less than 2 m in the Central Mountains hydrological zone to more than 4 m in the Coastal Mountains hydrological zone.

4 Additional Surveys

No additional hydrological field investigations are needed or proposed for the preparation of the ESA.

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Appendix A Baseline Hydrological Data

Table A-1 Baseline Hydrological Data for Regional Streamflow Monitoring Stations

WSC Station Number	WSC Station Name	Drainage Area (km^2)	Mean Monthly Discharge (m^3/s)												Mean Seasonal Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	Seasonal (Mar-Oct) Total Runoff (mm)	Annual Total Runoff (mm)	7Q10 Low Flows (m^3/s)		7Q2 Low Flows (m^3/s)		High Flows (m^3/s) for Return Period Flood Event				
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec					Year-Round	Seasonal (Mar-Oct)	Year-Round	Seasonal (Mar-Oct)	100 Year	50 Year	10 Year	5 Year	2 Year
Prairies Hydrological Zone																											
05DF006	Whitemud Creek near Ellerslie	330			0.767	2.19	0.215	0.202	0.413	0.110	0.126	0.038			0.507		32.3			0.000		0.000	82.5	66.2	33.7	22.3	9.45
05EA001	Sturgeon River near Fort Saskatchewan	3310			1.61	10.5	7.53	3.04	3.91	2.43	1.81	1.83			4.088		23.9			0.011		0.148	95.0	76.9	42.4	30.3	15.8
05EA005	Sturgeon River near Villeneuve	1910	0.480	0.460	1.63	7.33	3.03	2.49	2.81	1.26	1.14	0.961	0.798	0.569	2.582	1.914	28.5	34.3	0.022	0.005	0.049	0.093	119	98.6	54.9	38.3	18.3
05EC002	Waskatenau Creek near Waskatenau	131			0.044	1.35	0.249	0.177	0.082	0.046	0.081	0.060			0.260		41.6		0.000	0.000	0.000	0.000	36.2	31.3	15.8	8.37	1.24
05FA014	Maskwa Creek No. 1 above Bearhills Lake	79.1			0.074	0.296	0.052	0.034	0.059	0.020	0.013	0.011			0.070		18.6		0.000	0.000	0.000	0.000	36.2	31.3	15.8	8.37	1.24
07BC002	Pembina River at Jarvie	13100	4.97	4.32	10.2	67.0	69.2	61.3	74.1	38.8	26.5	19.4	11.1	6.70	45.817	32.801	73.9	86	1.211	1.64	3.07	4.08	1040	883	550	415	231
07BC006	Dapp Creek at Highway no. 44	605			0.112	1.73	1.15	0.405	0.526	0.369	0.243	0.260			0.599		20.9		0.000	0.000	0.000	0.000	27.5	23.2	12.5	7.86	2.53
Foothills Hydrological Zone																											
05DE007	Rose Creek near Alder Flats	559			0.537	3.79	4.91	3.95	4.84	1.51	1.20	0.753			2.69		101.6			0.024		0.082	224	191	111	76.3	32.9
05DF004	Strawberry Creek near the mouth	592			1.65	4.21	1.54	1.01	2.37	0.27	0.23	0.145			1.43		50.9			0.001		0.009	243	204	119	84.1	36.7
07AE001	Athabasca River near Windfall	19600			51.39	103.93	285.63	593.80	594.09	425.23	277.00	167.51			312.32		337.1			37.4		43.6	2,040	1,900	1,520	1,340	1,050
07AF002	McLeod River above Embarras River	2560	2.76	2.53	3.15	13.74	40.45	51.94	42.32	26.53	20.80	14.44	6.79	3.96	26.67	19.12	220.3	236.6	1.10	1.51	1.83	2.31	969	784	429	303	152
07AF010	Sundance Creek near Bickerdike	178			0.283	0.945	1.64	1.58	1.66	0.863	0.723	0.578			1.03		122.8			0.12		0.20	17.6	15.6	10.9	8.74	5.54
07AG003	Wolf Creek at Highway No. 16a	826	0.59	0.58	0.85	5.72	9.31	8.69	10.55	4.77	3.75	2.49	1.25	0.766	5.77	4.11	147.7	157.7	0.157	0.16	0.34	0.34	334.0	270.0	143.0	97.0	44.5
07AG004	McLeod River near Whitecourt	9100			10.32	52.50	97.92	106.30	104.67	58.23	45.34	32.77			63.51		147.6			4.60		7.22	1,860	1,590	989	745	412
07AH001	Freeman River near Fort Assiniboine	1660			0.977	12.41	23.58	19.42	22.59	11.91	7.62	4.48			12.87		164.1			0.18		0.57	258	250	215	186	122

Table A-1 Baseline Hydrological Data for Regional Streamflow Monitoring Stations (cont'd)

WSC Station Number	WSC Station Name	Drainage Area (km^2)	Mean Monthly Discharge (m^3/s)												Mean Seasonal Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	Seasonal (Mar-Oct) Total Runoff (mm)	Annual Total Runoff (mm)	7Q10 Low Flows (m^3/s)		7Q2 Low Flows (m^3/s)		High Flows (m^3/s) for Return Period Flood Event				
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec					Year-Round	Seasonal (Mar-Oct)	Year-Round	Seasonal (Mar-Oct)	100 Year	50 Year	10 Year	5 Year	2 Year
Foothills Hydrological Zone (cont'd)																											
07AH002	Christmas Creek near Blue Ridge	423			0.170	1.99	2.94	2.31	2.68	1.19	0.713	0.489			1.56		78.0			0.01		0.05	49.0	44.5	32.8	26.8	16.8
07AH003	Sakwatamau river Near Whitecourt	1150			0.965	9.89	14.98	11.47	10.78	5.85	4.19	3.04			7.65		140.5			0.28		0.64	199	182	133	107	65.3
07BA001	Pembina River below Paddy Creek	2900			3.33	17.5	27.1	21.7	27.3	13.8	11.1	8.68			16.3		15.1			0.73		1.62	946	767	340	180	35.5
07BA002	Rat Creek near Cynthia	606			0.610	3.69	5.70	5.20	5.87	2.58	2.21	1.42			3.41		15.1			0.16		0.28	101	85	51	38	19.8
07BB002	Pembina River near Entwistle	4400	2.88	2.71	4.72	27.1	44.9	45.0	53.8	26.3	19.4	13.6	6.61	3.77	29.353	20.899	141.1	150.6	1.02	1.28	1.94	2.47	1,110	924	526	371	179
07BB005	Little Paddle River near Mayerthorpe	295			0.599	2.71	1.59	1.33	1.55	0.588	0.326	0.175			1.109		79.3			0.000		0.006	90.5	78.4	49.1	36.1	18.6
07FD006	Saddle River near Woking	538			0.575	4.66	3.03	1.70	0.879	0.380	0.419	0.113			1.470		57.5			0.000		0.000	281	213	89.3	51.1	15.5
07FD007	Pouce Coupe River below Henderson Creek	2850	0.217	0.232	0.758	17.6	20.0	9.21	10.2	3.16	4.57	1.96	0.789	0.390	8.426	5.753	62.4	63.9	0.005	0.015	0.046	0.097	351	313	213	164	90.7
07GD001	Beaverlodge river Near Beaverlodge	1610	0.062	0.070	1.30	10.4	7.45	3.31	1.66	1.23	0.626	0.438	0.151	0.221	3.306	2.246	43.2	44		0.000		0.000	121	107	72.4	56.1	30.5
07GE001	Wapiti River near Grande Prairie	11300	13.9	12.0	14.9	80.5	237.4	287.6	178.0	89.7	70.0	59.2	30.1	18.3	127.153	90.964	237.8	254.9	7.01	7.14	9.09	9.94	4,190	3,430	1,920	1,370	688
07GE003	Grande Prairie Creek near Sexsmith	140			0.068	1.55	0.908	0.470	0.244	0.073	0.068	0.018			0.425		57.3			0.000		0.000	49.6	40.1	21	14.1	6.23
07GF001	Simonette River near Goodwin	5040	3.00	2.76	4.54	44.2	66.4	53.5	42.2	32.6	18.4	12.2	6.78	3.60	34.263	24.188	143.7	152		1.12		2.42	2,550	2,010	1,000	661	288
07GG001	Waskahigan River near the mouth	1040	0.453	0.413	0.687	9.4	14.0	10.5	8.48	4.60	3.56	1.95	1.07	0.575	6.649	4.642	135	141.3	0.091	0.125	0.264	0.334	213	192	139	113	71.4
07GG002	Little Smoky River at Little Smoky	3010			3.769	22.8	45.9	36.0	35.7	19.9	15.7	10.0			23.717		166.7			1.97		2.81	443	404	304	253	169
07GG003	Iosegun River near Little Smoky	1950			1.1	17.3	26.4	20.3	17.6	9.26	6.22	4.07			12.776		138.4			0.162		0.528	290	261	191	158	103
07GH002	Little Smoky River near Guy	11100	5.54	5.24	8.46	86.9	130	105	89.6	49.9	35.1	23.4	11.7	6.98	66.038	46.480	125.7	132.6	1.51	2.94	3.66	4.72	1,980	1,690	1,050	797	457

Table A-1 Baseline Hydrological Data for Regional Streamflow Monitoring Stations (cont'd)

WSC Station Number	WSC Station Name	Drainage Area (km^2)	Mean Monthly Discharge (m^3/s)												Mean Seasonal Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	Seasonal (Mar-Oct) Total Runoff (mm)	Annual Total Runoff (mm)	7Q10 Low Flows (m^3/s)		7Q2 Low Flows (m^3/s)		High Flows (m^3/s) for Return Period Flood Event				
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec					Year-Round	Seasonal (Mar-Oct)	Year-Round	Seasonal (Mar-Oct)	100 Year	50 Year	10 Year	5 Year	2 Year
Rocky Mountains Hydrological Zone																											
07EE007	Parsnip River above Misinchinka Creek	4930	44.06	37.99	43.82	158.61	432.66	419.69	160.18	77.20	99.97	139.92	99.26	56.86	191.51	147.52	820.5	946.1	15.65		21.78		1,290	1,220	1,040	946	796
07EE009	Chuchinka Creek near the mouth	310	1.31	1.21	1.89	14.45	20.84	5.90	2.15	1.20	1.58	3.74	3.47	1.78	6.47	4.96	439.6	504.5	0.243		0.439		81.5	76.5	63.2	56.2	43.9
07FB001	Pine River at East Pine	12100	34.21	30.36	36.19	117.49	528.30	607.30	281.07	129.00	121.35	139.27	97.15	50.17	245.00	180.99	427.8	473.4	17.25		23.49		3,470	3,050	2,150	1,780	1,280
07FB002	Murray River near the mouth	5550	18.75	16.97	19.88	54.27	211.72	270.19	149.29	75.11	66.76	66.32	42.87	26.11	114.19	84.85	434.8	483.8	8.46		11.66		1,160	1,070	839	728	552
07FB003	Sukunka River near the mouth	2590	10.38	9.56	11.67	41.59	182.35	182.67	74.36	28.83	34.09	43.97	30.20	14.02	74.94	55.31	611.4	675.7	3.95		5.66		794	751	634	572	459
07FB004	Dickebusch Creek near the mouth	82.1	0.043	0.030	0.055	0.618	1.87	1.63	1.34	0.627	0.429	0.265	0.126	0.065	0.85	0.59	220.0	228.4	0.00		0.01		118	94.8	48.1	30.7	9.09
07FB006	Murray River above Wolverine	2370	12.06	10.32	11.41	31.20	138.13	183.21	100.21	50.93	45.67	45.24	30.86	16.38	75.75	56.30	675.4	751.8	5.96		7.99		817	738	555	474	352
07GA001	Smoky River above Hells Creek	3870	14.50	11.41	11.81	21.41	117.32	243.03	204.20	128.22	81.94	51.10	25.91	16.91	107.38	77.31	586.8	633.0		7.67		9.63	972	864	630	535	404
07GA002	Muskeg River near Grande Cache	703	1.30	1.10	1.18	3.73	10.9	14.8	13.1	7.64	5.81	4.29	2.62	1.76	7.68	5.68	231.1	256.2		0.588		0.921	212	182	112	82.6	42.9
07GB001	Cutbank River near Grande Prairie	842			0.826	6.93	14.0	12.1	10.5	6.11	4.76	2.85			7.27		182.4			0.120		0.612	524	444	256	178	80.2
08KA004	Fraser River at Hansard	18000	106	98.4	114	283	787	1251	941	566	414	333	228	129	586	438	688.4	769.6	38.7		74.7		2,990	2,830	2,430	2,230	1,870
08KB001	Fraser River at Shelley	32400	207	191	239	774	1627	2056	1452	859	688	635	470	262	1041	788	679.2	769.8	22.0		49.0		5,240	4,910	4,090	3,690	3,030
08KB003	McGregor River at Lower Canyon	4780	45.6	39.6	45.5	164	442	551	352	210	193	191	122	65	269	202	1187.3	1335.7	22.2		29.8		1,880	1,750	1,440	1,290	1,050
08KB006	Muller Creek near the mouth	103	0.761	0.581	0.710	3.33	12.3	14.0	7.46	3.64	4.57	4.58	2.47	1.15	6.33	4.63	1298.3	1423.7	0.254		0.392		58	54.5	45.6	41.1	33.4
08KD007	Bowron River below Box Canyon	3420	22.0	20.2	24.2	77	171	162	81.7	39.6	46.3	51.9	46.1	28.1	81.7	64.1	504.4	592.9	10.6		14.0		414	376	286	245	183
Central Interior Hydrological Zone																											
08JB002	Stellako River at Glenannan	3600	6.83	6.47	6.19	9.17	35.8	48.3	34.8	20.7	12.6	8.78	7.96	7.21	22.0	17.1	129.5	150	3.13		4.801		147	129	90.1	73.8	50.9
08JB003	Nautley River near Fort Fraser	6030	10.2	9.71	9.81	20.0	71.0	76.1	52.4	28.0	17.0	13.2	13.1	11.5	35.9	27.7	126.1	145.3	4.07		6.347		311	265	169	131	81
08JE004	Tsilcoh River near the mouth	431	0.602	0.575	0.813	9.19	10.2	2.01	0.924	0.429	0.508	1.00	1.31	0.773	3.13	2.36	153.4	173	0.153		0.2486		48.7	45.9	38.3	34.1	26.5
08KC001	Salmon River near Prince George	4230	7.81	7.28	11.5	84.0	109	37.5	13.3	6.29	6.04	10.4	14.2	8.84	34.8	26.4	173.6	197	2.15		3.536		416	377	285	244	180

Table A-1 Baseline Hydrological Data for Regional Streamflow Monitoring Stations (cont'd)

WSC Station Number	WSC Station Name	Drainage Area (km²)	Mean Monthly Discharge (m^3/s)												Mean Seasonal Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	Seasonal (Mar-Oct) Total Runoff (mm)	Annual Total Runoff (mm)	7Q10 Low Flows (m^3/s)		7Q2 Low Flows (m^3/s)		High Flows (m^3/s) for Return Period Flood Event				
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec					Year-Round	Seasonal (Mar-Oct)	Year-Round	Seasonal (Mar-Oct)	100 Year	50 Year	10 Year	5 Year	2 Year
Central Mountains Hydrological Zone																											
08ED002	Morice River near Houston	1900	27.1	21.6	17.3	19.3	86.0	194	159	107	76.3	74.5	63.4	38.5	91.8	73.7	893.1	1224	8.558		12.83		413	387	323	291	239
08EE004	Bulkley River at Quick	7350	36.3	29.8	30.5	92.1	305	361	223	131	94.8	102	92.9	51.2	167	129.1	481.3	555.8	7.67		20.94		1030	949	756	668	534
08EE008	Goathorn Creek at Telkwa	126	0.222	0.174	0.210	1.40	4.87	5.26	3.11	1.67	1.21	1.35	0.857	0.326	2.38	1.72	400.2	432.8	0.065		0.122		28.6	26	19.9	17.1	12.7
08EE012	Simpson Creek at the mouth	13.2	0.019	0.016	0.035	0.128	0.579	0.966	0.586	0.271	0.216	0.188	0.106	0.036	0.371	0.262	593.7	628.5	0.003		0.008		6.14	5.66	4.43	3.81	2.77
08EE013	Buck Creek at the mouth	566	0.522	0.446	0.729	6.91	21.4	10.6	3.19	0.969	0.929	1.75	1.95	0.884	5.82	4.19	217.4	234.8	0.092		0.248		107	95.3	68.6	56.9	40.0
08EE020	Telkwa River below Tsai Creek	368	2.66	2.12	2.13	5.22	25.9	41.5	30.9	20.8	15.2	12.9	7.15	3.53	19.3	14.2	1109.6	1219	1.10		1.598		221	193	134	111	80.9
Coastal Mountains Hydrological Zone																											
08EF001	Skeen River at Usk	42300	193	167	188	523	1991	2824	1665	873	775	831	510	256	1209	900	603.9	673.1	4.38		30.64		7,630	7,210	6,160	5,620	4,710
08EF005	Zymoetz River above Ok Creek	2920	27.7	23.6	24.8	62.6	210	277	183	115	100	112	71.3	39.0	135.6	103.9	982.4	1126.5	10.2		13.1		2,140	1,850	1,220	963	622
08EG012	Exchamsiks River near Terrace	370	15.1	12.3	14.5	31.4	60.7	77.7	72.1	59.9	63.6	60.9	32.5	18.5	55.1	43.3	3151.1	3702.2	3.04		4.234		636	595	489	433	334
08FE003	Kemano River above powerhouse tailrace	583	12.8	10.7	11.6	25.2	66.7	101.8	95.0	68.0	57.7	53.9	31.1	16.0	60.0	45.9	2177.3	2493	1.98		3.704		895	804	578	471	308
08FF001	Kitimat River below Hirsch Creek	1990	76.8	65.7	68.1	112	196	230	168	110	126	174	141	90.3	147.9	129.8	1572.3	2061.3	11.4		22.06		3,050	2,690	1,890	1,550	1,050
08FF002	Hirsch Creek near the mouth	347	12.0	9.21	9.52	17.9	34.9	41.9	28.2	17.0	22.1	30.1	23.4	15.4	25.2	21.8	1535.6	1986	1.86		3.19		608	544	383	306	190
08FF003	Little Wedeene River below Bowbyes Creek	182	10.3	8.23	8.52	15.9	31.7	34.8	20.9	11.5	15.3	22.7	17.2	11.4	20.2	17.4	2344.6	3018.8	1.78		2.732		401	352	245	201	142
08JA015	Laventie Creek near the mouth	86.5	0.730	0.59	0.59	1.36	8.64	16.80	12.61	7.18	5.52	5.43	2.95	1.11	7.27	5.29	1776.4	1938.1	0.175		0.3181		151	126	78.5	60.9	39.2