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Abbreviations

COP	code of practice
DA	disturbance area
EIA	environmental impact assessment
EIS	Environmental Impact Statement
FDC	Flow Duration Curves
GSD	grain size distribution
HRU	Hydrological Response Unit
HYFRAN+	Hydrologic Frequency Analysis Plus
LAA	local assessment area
PDA	project development area
PDL	permanent diversion licence
RAA	regional assessment area
SSC	suspended sediment concentration
SSRB	South Saskatchewan River Basin
the Project	Springbank Off-stream Reservoir Project
ToR	Terms of Reference
TSS	Total Suspended Sediment
VC	valued component
WNA	Western North America
WSC	Water Survey of Canada

6.0 ASSESSMENT OF POTENTIAL EFFECTS ON HYDROLOGY

Hydrology encompasses the occurrence and movement of fresh water on, and beneath (see Volume 3a, Section 5), the surface of the earth, and through the atmosphere. Included in the definition of hydrology used here is the transport of sediment. Sediment transport is included as changes in discharge, as a surrogate for shear stress or stream power. These forces largely determine whether sediment entrainment, transport, and deposition occurs so that any modification of hydrology in a river system will also modify sediment transport. Springbank Off-stream Reservoir Project (the Project) construction and dry operations can affect the hydrology (i.e., surface water quantity) of watercourses, which are defined as rivers, creeks and streams, as well as sediment transport patterns. These changes can affect water quality, aquatic life and other ecological and human receptors.

6.1 SCOPE OF THE ASSESSMENT

6.1.1 Regulatory and Policy Setting

The hydrology assessment follows the requirements of the federal Environmental Impact Statement (EIS) Guidelines and provincial Terms of Reference (ToR) issued for the Project. Concordance tables, demonstrating where EIS Guidelines and ToR requirements are addressed are provided in Volume 4, Appendix A.

6.1.1.1 *Alberta Water Act*

The *Alberta Water Act* supports and promotes the conservation and management of water. Works in and around watercourses and waterbodies are regulated under the *Water Act* (2000), and it applies to an activity, as defined in the Act, that causes, may cause or may become capable of causing an adverse effect on the aquatic environment.

Under the *Water Act*, a code of practice (COP) sets out the regulatory mechanism to govern prescribed activities included in the overall scope of the Act. The codes of practice, including the COP for Watercourse Crossings (ESRD 2013b) are incorporated in the Water Act Water (Ministerial) Regulation (1998) under the authority of the *Water Act*. The COPs establish the objectives, standards and conditions to be met when undertaking a designated activity within the Water (Ministerial) Regulation.

6.1.1.2 Elbow River Basin Water Management Plan

The vision of the Elbow River Basin Water Management Plan is to provide "ample clean water for the benefit of all, while maintaining the integrity of the aquatic environment" (Elbow River Watershed Partnership 2009). The purpose of this plan is to provide guidance for decisions where those decisions may impact the protection, restoration and/or maintenance of water quality in the Elbow River. Water quantity is explicitly not assigned to the Elbow River Basin Water Management Plan because it is covered under the South Saskatchewan Regional Plan.

6.1.1.3 Approved Water Management Plan for the South Saskatchewan River Basin (SSRB)

The SSRB plan reflects a balance between water allocation in the SSRB and the need to protect the aquatic environment (AENV 2006). The SSRB recommendations included establishing water conservation targets, storage of peak flows and cessation of issuance of new water applications (AENV 2006; Pertnitsky and Guy 2010). The recommended water conservation objective for the Bow River watershed, which includes the Elbow River, is either 45% of the natural rate of flow, or the existing instream objective increased by 10%, whichever is the greater at any point in time.

6.1.2 Engagement and Key Concerns

Alberta Transportation has consulted with industry, adjacent lease owners, landowners, public stakeholders, and Indigenous groups about the Project. Key concerns raised during open houses included potential Project effects related to sediment deposition in the reservoir following draining, effects on the unnamed tributary used as the low-level outlet, and hydrological effects on the Elbow River channel.

Alberta Transportation's engagement with Indigenous groups began in 2014 with five Indigenous communities. In June 2016, an additional eight Indigenous communities were engaged as outlined in the CEA Agency guidelines. Indigenous engagement has been ongoing prior to and through the Environmental Impact Assessment (EIA) process and will continue until a decision is made by Natural Resources Conservation Board (NRCB). Detailed information regarding the Indigenous Engagement program is presented in Volume 1, Section 7 and Volume 4, Appendix B.

Traditional Land and Resource Use (TLRU) information was gathered through Project-specific traditional use studies (TUS) conducted by potentially affected Indigenous groups and through the results of Alberta Transportation's Indigenous Engagement program. At the time of writing of this assessment, Alberta Transportation had received a Project-specific TUS report from Piikani Nation, as well as a joint interim TUS report from Kainai First Nation and Siksika Nation. In addition to Project-specific sources, publicly-available literature was reviewed for TLRU information relevant to the Project. Secondary source materials reviewed include:

- TUS studies conducted by Indigenous groups
- TLRU assessments, supplemental filings, and hearing evidence for other developments
- government reports and databases
- legal proceedings
- historical and ethnographic literature
- relevant internet sources (such as Indigenous community websites and the Indigenous and Northern Affairs Canada website)

TLRU information was considered during the preparation of all aspects of the EIA, including both methodology and analysis, as stipulated by the CEA Agency project guidelines. TLRU information contributed to the understanding of the existing conditions and informed the assessment of potential Project effects. While this information did not directly affect the significance definition it has been incorporated into the analysis of effects on which the significance determination was based. This applies equally to effects assessed for construction, dry operations, flood operations and post-flood operations. Generally, issues and concerns related to effects of industrial development on hydrology, as reported by Indigenous groups through the review of Project-specific and publicly-available TLRU information, include:

- permanent alteration of flow in Elbow River
- increase of sedimentation in Elbow River

These issues and concerns, which are summarized below, have been considered in the assessment of potential project effects. More detailed information regarding TLRU in relation to hydrology is discussed in the TLRU assessment (see Section 14).

Water is important to Samson Cree Nation and waterbodies have been affected by industrial development. Samson Cree Nation members used to melt snow, collect rain water and drink water from rivers, but no longer do so (EEP 2016b).

Samson Cree Nation stated that the quality of water has decreased since the establishment of industrial development and agricultural leases (grazing leases, linear access limitation etc.) (SCN 2015a).

The water quality within Samson Cree Nation traditional territory has been adversely affected by pollution and contamination, which has in turn affected Samson Cree Nation's ability to undertake traditional practices. Samson Cree Nation wants all water sources protected (Enbridge 2012a).

Samson Cree Nation has witnessed water sources and water ways where there are no wild game tracks because of polluted waters. Samson Cree Nation explained that these animals now have to travel greater distances to get good water (TMP 2014).

Through the Project-specific Indigenous Engagement program, Tsuut'ina Nation expressed concerns that the Project would permanently alter the flow of the Elbow River and result in flooding of portions of Tsuut'ina Nation traditional territory. Tsuut'ina Nation noted the potential for flood water, including any debris or contamination it contains, to spill over the floodplain berm and on to the Tsuut'ina Nation 145 Reserve. They mentioned the potential for methylmercury contamination both upstream and downstream. More frequent floods and higher flood volumes than those predicted in the project description may occur as a result of global warming.

Tsuut'ina Nation noted that the Project would result in increased sedimentation in the Elbow River, especially during construction, but also during operation. The Nation stated that community members rely on the Elbow River for drinking water and noted concern regarding effects of the Project on Tsuut'ina Nation's ability to use the river as a water source. Tsuut'ina Nation depends on the groundwater in the Elbow River Alluvial Aquifer for the reserve's drinking water. Tsuut'ina Nation explained that the project doesn't plan to line the reservoir, so any contaminants would likely seep into the groundwater system. "Any potential contamination or change to the flow of the Elbow River is therefore likely to contaminate our aquifer."

The Tsuut'ina requested an opportunity to review the Breach Analysis Report and the draft hydrology report before they are submitted to the regulatory agencies.

Through the Project-specific engagement program, Piikani Nation voiced concern regarding silt build up in the Elbow River as well as the in the proposed Springbank Reservoir due to flood cessation. Piikani Nation used the example of the Oldman Dam and the silt shadow that has developed. The Piikani also expressed concerns about effects upstream and downstream of the Project.

Through the Project-specific engagement program, Stoney Nakoda Nations (SNN) stated that the proposed Springbank Off-Stream Reservoir project poses many environmental effects including the areas of health of the Stoney Nakoda Nations and the current use of the lands and resources that would be impacted by the Project. Stoney Nakoda Nations noted that the waters that flow through the traditional lands have sustained the Stoney Nakoda Nations since time immemorial. Furthermore, "When Treaty 7 was signed, the SNN neither surrendered their Aboriginal title to water within their traditional territory nor surrendered any other interests pursuant to an associated Aboriginal right. The SNN continue to hold these rights. Therefore, the SNN are concerned that the project will impact these rights and traditional use of lands in the Project area." The Stoney Nakoda Nations stated "Stoney Nakoda Nation[s] feel[s] a Cultural Use Study and a Stoney Hydrology report is required." The Stoney Nakoda Nations expressed concerns about the changes in hydrology in the area of the Project; particularly, for effects on Elbow River and groundwater.

In an email to the Canadian Environmental Assessment Agency, Métis Nation British Columbia noted the potential for the Project to affect Métis land use, and effects on water due to the proximity of the Project to the Alberta and British Columbia border; where a long history of Métis land use is documented in the Kootenay region.

The Siksika Nation noted "They [impacts to TLRU] can be expected to include both upstream and downstream impacts during the construction and operation of the SR1 control structure. Given that the Elbow River is a major transport corridor for Siksika members and has been for millennia, is expected that the impacts on Siksika traditional use and sites will be substantial."The Siksika Nation noted "the seepage area between the reservoir and the Elbow River situated between the intake and discharge channels, that will likely become impacted by water seeping from the reservoir, access channel or discharge channel and by project construction activities, the downstream waters and riparian areas that will be impacted by instream project construction activity … and, upstream high bank riparian impacts resulting from the rapid rise in upstream flood waters above levels that would otherwise occur when the flood control structure is raised during a floor to divert waters to the reservoir."

The Siksika Nation noted "During the construction period, there will be substantial instream project work as the control structure and access channels are built. This …will have obvious instream and riparian impacts on Siksika Traditional Use in areas A [off-stream storage dam], C [downstream Elbow River]and D [upstream high bank riparian impacts] …."

The Siksika Nation noted "During a major flood there may be an initial upstream surge of water as the gates are raised on the control structure to divert water to the reservoir. This upstream surge may flood high bank riparian areas that would not otherwise be impacted if the flood were permitted to proceed naturally."

The Kainai First Nation expressed concern about impact on wetlands and upstream and downstream effects. The Kainai First Nation also expressed concern about debris and sediment that may be left in the reservoir as a result of a flood. Kainai First Nation expressed concerns that instream work within Elbow River will impact fish and there could be temporary downstream impacts from project construction.

No project-specific intangible concerns were identified with respect to hydrology.

6.1.3 Potential Effects, Pathways and Measurable Parameters

The potential effects, pathways and measurable parameters for hydrology are presented in Table 6-1.

Table 6-1 Potential Effects, Pathways and Measurable Parameters for Hydrology

Potential Environmental Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
• Change in hydrological regime[1] beyond the range evident in the historical record • Change in sediment transport dynamics	• Interactions between the Project and hydrology (i.e., surface water quantity) can result in changes in hydrological regime and sediment transport dynamics	• Stream discharge - continuous site-specific data and longer term estimates of high, average and low flow existing conditions using applicable data • Change in waterbody water level • Flow in m^3/s or volumes in dam^3 • Flow duration curves • Sediment concentrations and loads

NOTES:

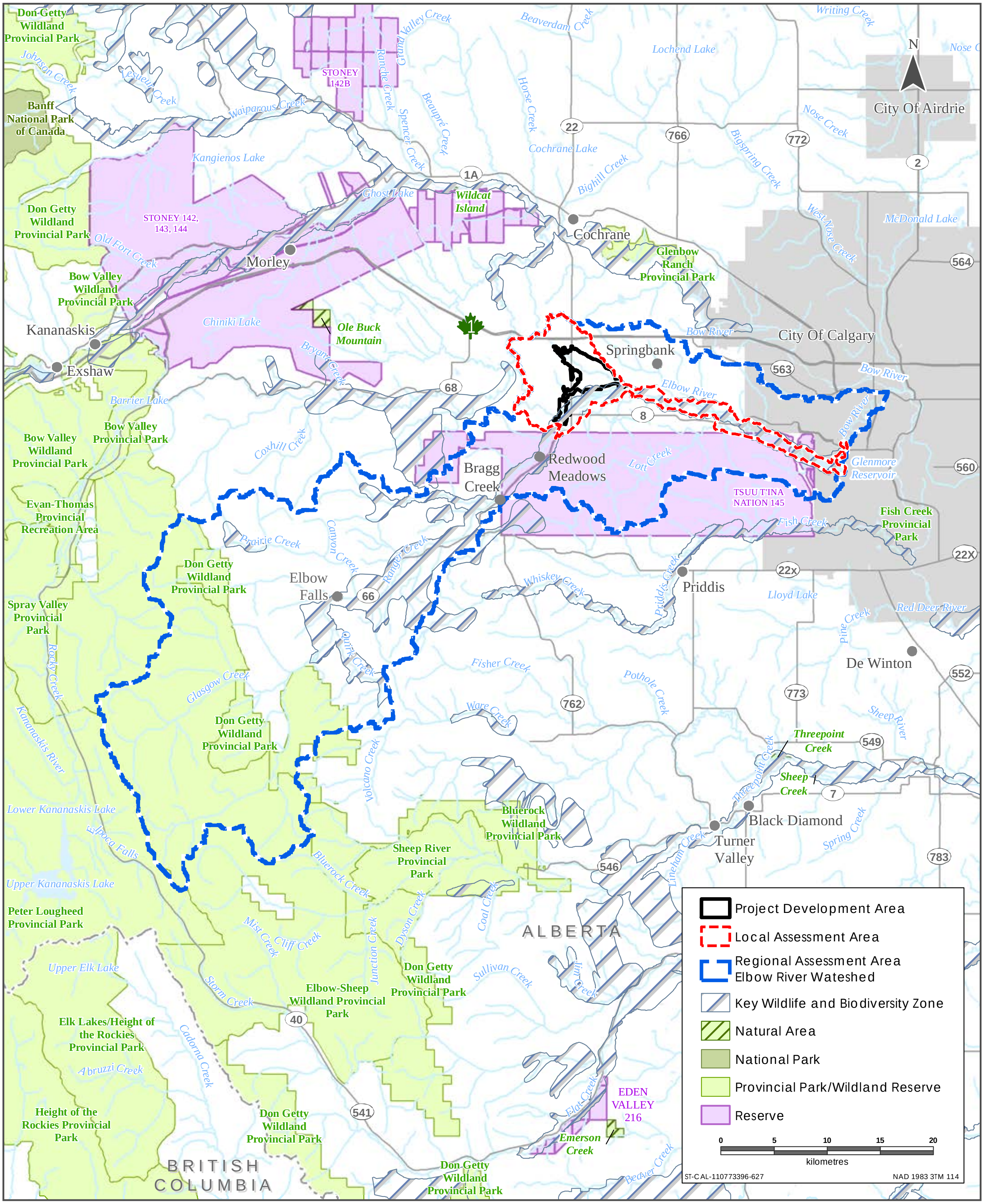
[1] Hydrological regime is defined here as the relationship between precipitation inputs and watercourse outputs in a watershed across a range of temporal and spatial scales.

[2] A flow duration curve is a graph that shows the percentage time a specific flow rate is equaled or exceeded.

6.1.4 Boundaries

6.1.4.1 Spatial Boundaries

Assessment areas for hydrology are at both regional and local scales to examine the potential cumulative changes to watercourses resulting from the Project and other development in the watershed. The local assessment area (LAA) included the project development area (PDA) and the Elbow River from Redwood Meadows to the inlet of Glenmore Reservoir, including the proposed dam, reservoir, diversion channel, and low-level outlet (i.e., the unnamed creek that runs through the off-stream reservoir). The regional assessment area (RAA) is the Elbow River watershed from headwaters to Glenmore Dam. Figure 6-1 presents the spatial boundaries for the hydrology assessment.



Sources: Base Data - ESRI, Natural Earth, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Hydrology Spatial Boundaries

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 6-1

6.1.4.2 Temporal Boundaries

Project construction would take place over a 36-month period. Assuming regulatory approval by Q4 2018, construction would commence in Q1 2019. By Q4 2020, the Project would be able to accommodate a 1:100 year flood. Construction would be complete by Q1 2022 at which time the Project would be able to accommodate water volumes equal to the 2013 flood. Dry operations of the Project will occur indefinitely (i.e., permanent installation) after construction, with periods of dry operations alternating with flood and post-flood phases.

6.1.5 Residual Effects Characterization

The characterization of residual effects on hydrology is presented in Table 6-2.

Table 6-2 Characterization of Residual Effects on Hydrology

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	Positive – a residual effect that changes measurable parameters in a direction beneficial to hydrology relative to existing conditions. Adverse – a residual effect that changes measurable parameters in a direction detrimental to hydrology relative to existing conditions. Neutral – no net change in measurable parameters for hydrology relative to existing conditions.
Magnitude	The amount of change in measurable parameters or the variable relative to existing conditions	Negligible – little to no variation predicted in measurable parameters, with variations that are less than 10% relative change from existing condition values. Low – small variation predicted in measurable parameters, with variations that are between 10% and 15% relative change from existing conditions. Moderate – modest variation predicted in measurable parameters, with variations that are between 15% and 30% relative change from existing conditions. High – large variation predicted in measurable parameters, with variations that are greater than 30% relative change from existing conditions
Geographic Extent	The geographic area in which a residual effect occurs	PDA (disturbance area) – residual effects are restricted to the PDA LAA – residual effects extend into the LAA RAA – residual effects interact with those of other project or development in the RAA

Table 6-2 Characterization of Residual Effects on Hydrology

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	Single event Multiple irregular event – occurs at no set schedule Multiple regular event – occurs at regular intervals Continuous – occurs continuously
Duration	The period of time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured or otherwise perceived	Short-term – residual effect that lasts for several days Medium-term – residual effect that extends through several months Long-term – residual effect that extends through more than one year
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	Reversible – the residual effect is likely to be reversed after activity completion and reclamation Irreversible – the residual effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	Undisturbed – area is relatively undisturbed or not adversely affected by human activity Disturbed – area has been substantially previously disturbed by human development or human development is still present
Timing	Periods of time where residual effects from Project activities could affect the VC	Seasonality – residual effect is greater in one season than another (e.g., spring/summer vs. fall/winter) Time of day – residual effect is greater during daytime or nighttime Regulatory – provincial or federal restricted activity periods or timing windows (e.g., migration, breeding, spawning) related to the VC Not applicable - the residual effect of Project activities will have the same effect on the VC, regardless of timing

The definitions for magnitude of effects on hydrology, including sediment transport is further defined as follows:

1. A low magnitude change (<15%): Variations in hydrology and sediment transport that are <15% change from existing conditions are likely not measurable within reasonable accuracy or detected by environmental receptors. A 15% reduction in flow is generally used as a maximum threshold for maintenance of instream flow needs in Alberta watercourses (Locke and Paul 2011).
2. A moderate magnitude change (15-30%): Variations in hydrology and sediment transport that are between 15% to 30% relative change from existing conditions may be observable, measurable, and detectable by environmental receptors, depending on frequency and duration. Measurable effects on water levels and flow velocities may occur with associated changes in sediment transport and potential changes in channel morphology.
3. A high magnitude change (>30%): Variations in hydrology and sediment transport that relate to a change in streamflow greater than 30% from existing conditions are likely detectable by environmental receptors, depending on frequency and duration. Measurable effects on water levels and flow velocities most likely occur with changes in sediment transport and associated changes in channel morphology.

6.1.6 Significance Definition

A significant adverse residual effect on hydrology (i.e., surface water quantity) and sediment transport is defined as a measurable change that:

- does not meet established instream flow needs or
- contravenes a watershed management target

In the absence of specific targets, thresholds were developed based on professional judgment, understanding of hydrological and sediment transport processes and physical measurability.

Because of the dependence of sediment transport on hydrology, the same significance thresholds are applied. As sediment transport is a (discontinuous) function of water flow interacting with a deformable boundary, discharge is used as a surrogate measure of the flow forces that mobilize, transport and deposit sediment. Although the relationship between discharge and sediment transport is complex and non-linear, the relationship in a general sense is strong enough that environmental significance thresholds can be equally applied.

6.2 EXISTING CONDITIONS FOR HYDROLOGY

6.2.1 Methods

Hydrology data sources and methods for the description of existing hydrological conditions in the assessment areas are provided in Volume 4, Appendix J, Hydrology Technical Data Report.

6.2.2 Overview

The geological and climate setting, basin characteristics, hydrology and ice dynamics are discussed in the following sections. Sediment characteristics, more germane to the hydrological modelling and assessment of the flood and post-flood effects are presented in Section 6.2 of Volume 3B.

6.2.2.1 Geological Setting

The Elbow River watershed, and subsequent runoff regime and fluvial sediment supply, is strongly influenced by its geological structure. Three structural provinces comprise the underlying geology: 1) the Front Ranges; 2) the Foothills of the eastern margin of the Cordillera and 3) the Plains of the Alberta syncline (Hudson 1983). The PDA lies within the eastern portion of the 40 km wide Foothills Belt that marks the transition between the Rocky Mountains and the Plains (Osborn et al. 2006). The Front Ranges and Foothills are underlain by marine limestone and dolomite rock of Paleozoic origin that are thrust northeast to produce a series of imbricated, northwest striking, southwest dipping locally folded and faulted thrust sheets (Seagel 1971). These thrust sheets are typically steep to near vertical where they are exposed (Hudson 1983). As a result, the mountains and foothills area of the Elbow River watershed have structurally-determined high relief, ridge and valley topography. Valleys are typically U-shaped with cirques and horns reflecting erosional modification by multiple periods of glacial activity. Wisconsin related glacial erosion and deposition have resulted in extensive deposits of colluvium over bedrock. The colluvial material is dominated by gravel sized material (Hudson 1983). The bedrock units are subject to failure from mechanical weathering and mass movement (Hudson 1983). Tills and alluvial material in the Front Ranges predominantly originate from the Wisconsin Glaciation and reworking during subsequent advances (Jackson 1980, Moran 1986). Alluvial deposits in the Front Ranges are dominated by gravel sized material deposited in alluvial fans and fluvial and glaciofluvial plains and terraces in valley bottoms (Hudson 1983).

The Foothills are dominated by colluvium but with less prominent bedrock outcrops (Hudson 1983). The underlying bedrock reflects six different Mesozoic shale and sandstone formations that underlay the Elbow River from the confluence of the Elbow and Little Elbow rivers to the Highway 22 bridge and are highly erodible (Hudson 1983). The Bow Valley till is the major till unit in this area along with significant alluvial deposits along valley bottoms. The mid- and lower-Foothills are dominated by thick deposits of colluvial and morainic material with valleys infilled with glaciolacustrine deposits or alluvium.

Downstream of Highway 22, the Plains zone is characterized by highly erodible Pleistocene glaciolacustrine material overlying the folded Tertiary quartz, feldspar and chert/calcareous matrix of the Paskapoo Formation (Moran 1986). The glaciolacustrine material was deposited in Glacial Lake Bragg during the retreat of ice in the Elbow and Bow Valleys at the end of the Erratics Train Glaciation (Hudson 1983). Upon draining of the Glacial Lake Bragg and Glacial Lake Calgary, the Elbow River likely began flowing in its present course (Hudson 1983).

6.2.2.2 Climate Setting

Environment Canada climate normal data for Springbank Airport (ID 303F0PP), approximately 9 km north of the PDA for period 1981 to 2010 indicate an average annual air temperature of 3.1 °C. The warmest month is July with an average temperature of 14.8 °C and the coldest is January with a mean temperature of -8.2 °C. The average annual precipitation is 469 mm of which 366 is rainfall. June has the highest rainfall of 106.7 mm.

Although the Springbank Airport is suitable for characterizing the immediate area of the Project, the values do not reflect the entire Elbow River watershed. There are significant differences in climate introduced by changes in elevation and orographic uplift effects on precipitation patterns (Flesch and Reuter 2012). To account for this difference, for this assessment Elbow River watershed is divided into an upper and lower watershed, reflecting differences between the high gradients of the Front Ranges and the low gradient of the Plains. The demarcation between the two zones is approximately at Maclean Creek where gradients start to increase. The upper watershed has an area of approximately 812 km^2 and the lower watershed, 425 km^2.

For the upper watershed, elevation decreases air temperature and increases snow-water equivalent and rainfall, which result in an annual average precipitation of approximately 762 mm, of which approximately 45% is attributed to snow (Figure 6-2). Maximum snow-water equivalent occurs in April and maximum rainfall in June. For the lower watershed, mean annual precipitation is approximately 473 mm, of which 19% is attributed to snow. Maximum snow-water equivalent occurs in March and maximum rainfall in June. The earlier maximum snow-water equivalent occurs in the lower watershed due to snow melt occurring progressively from lower to higher elevations (Hudson 1983). As a result, winter conditions typically persist in the upper watershed until May or June. When these winter conditions are combined with intense rainfall in the upper watershed during May and June, the potential for generation of large flood events increases (Pomeroy et al. 2016), as occurred in 2013.

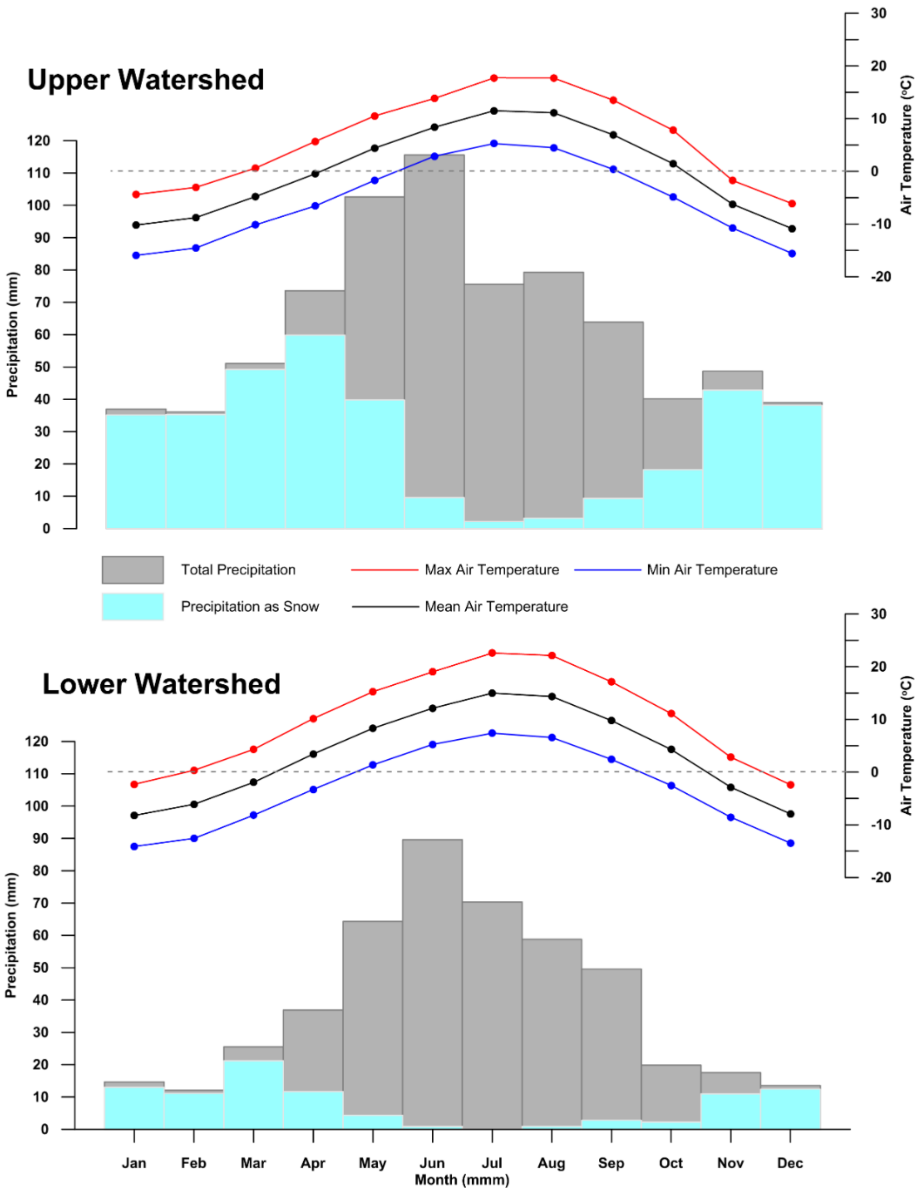


Figure 6-2 Climate Normals for Upper and Lower Elbow River Watershed based on Climate WNA data

Evaporation data is not available for Springbank Airport. However, data for Calgary International Airport suggests that shallow lake evaporation and potential evaporation average 728 mm and 992 mm annually, respectively (AESRD 2013). Highest evaporation occurs in July with a shallow lake evaporation of 154 mm (AESRD 2013). Shallow lake evaporation historical averages are shown in Figure 6-3.

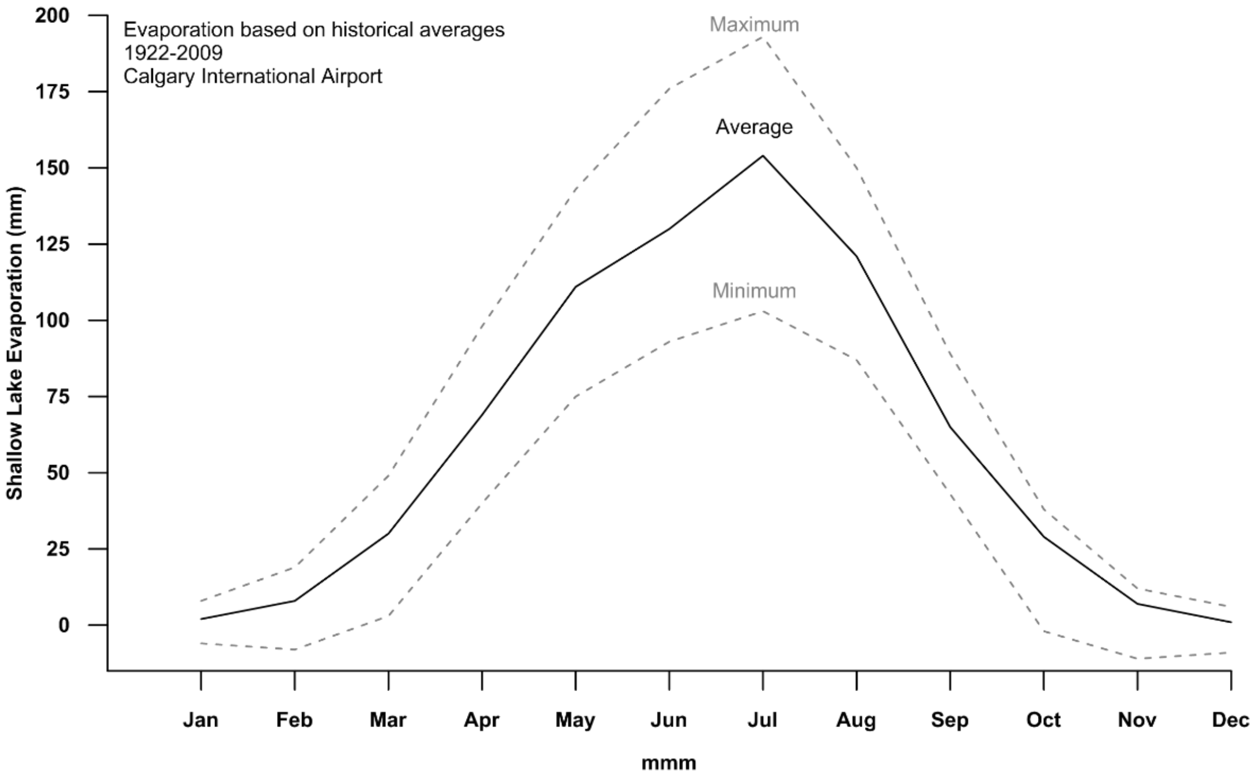


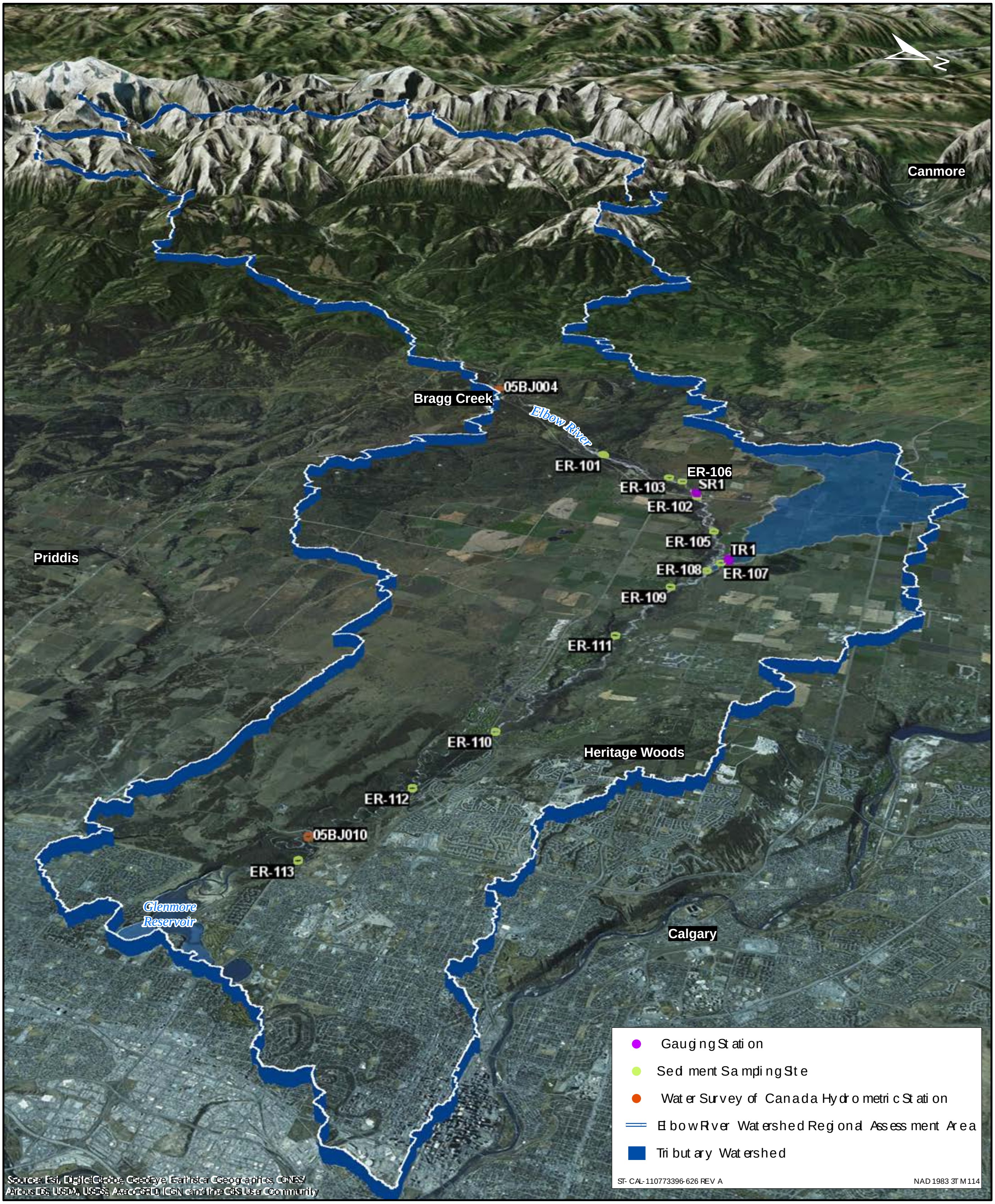
Figure 6-3 Historical Shallow Lake Evaporation Estimates for Calgary International Airport

6.2.2.3 Basin Characteristics

The Elbow River and its tributaries have a total watershed area of approximately 1,238 km^2 (Figure 6-4). From its source in the Front Ranges of the Rocky Mountains, Elbow Lake, at an elevation of 2,085 m asl, the river flows approximately 113 km through foothills and plains to the inlet to Glenmore Reservoir in the City of Calgary at an elevation of 1,080 m asl (Beers and Sosiak 1993). The Elbow River flows through the City of Calgary downstream of the Glenmore Reservoir dam to its confluence with the Bow River at an elevation of 1,000 m asl (Figure 6-4). The upper watershed has a minimum elevation of 1,282 m asl and a maximum of 3,212 m asl, a range of 1,929 m. Mean elevation is 1,923 m asl. The minimum elevation in the lower watershed range is 1,026 m asl, and the maximum is 1,461 m asl for a range of 434 m. Mean elevation is 1,199 m asl. The wide range in elevations results in a large gradient variation between the upper and lower watersheds.

The Elbow River is one of the steepest rivers in Alberta (Kellerhals et al. 1972). The overall gradient is approximately 0.9% (Figure 6-5). However, gradients in the headwaters upstream from Elbow Falls are considerably higher, at approximately 1.54%. Gradients of the Elbow Rivers two main headwater tributaries, the Little Elbow and Canyon Creeks are also steep with headwater gradients of 5.42% and 4.11%, respectively. Between Elbow Falls and Bragg Creek, the Elbow River gradient reduces to less than 0.8%. Where the Elbow River transitions to the Alberta Plains, gradients reduce to 0.4% and further reduce to approximately 0.2% where the Elbow River enters Glenmore Reservoir (Figure 6-5).

In contrast to headwater tributaries, tributaries in the LAA tend to have much lower gradients for most of their lengths. Gradients typically increase as tributary channels incise through glaciolacustrine/till terraces to their confluence with the Elbow River. For example, the unnamed tributary (a portion of which is in the PDA) has a low gradient of 0.2 % for most of its 19-km length (Figure 6-6). The channel planform in the upper reaches is sinuous and the channel is diffuse in places. Where channelization exists, widths and depths and typically less than 1.0 m. However, the gradient steepens at approximately 17 km from the headwaters where the channel drops approximately 20 m in 2 km to its confluence with the Elbow River, a gradient of 0.81%. This increase in gradient and associated stream power has resulted in the channel being confined to a single channel with incision of up to 3.0 m through the overlying glaciolacustrine material. This incision pattern is observed for all tributaries in the LAA.



Sources: Base Data - ESRI, Natural Earth. Thematic Data - ERBC, Stantec

Elbow River Watershed Overview

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 6-4

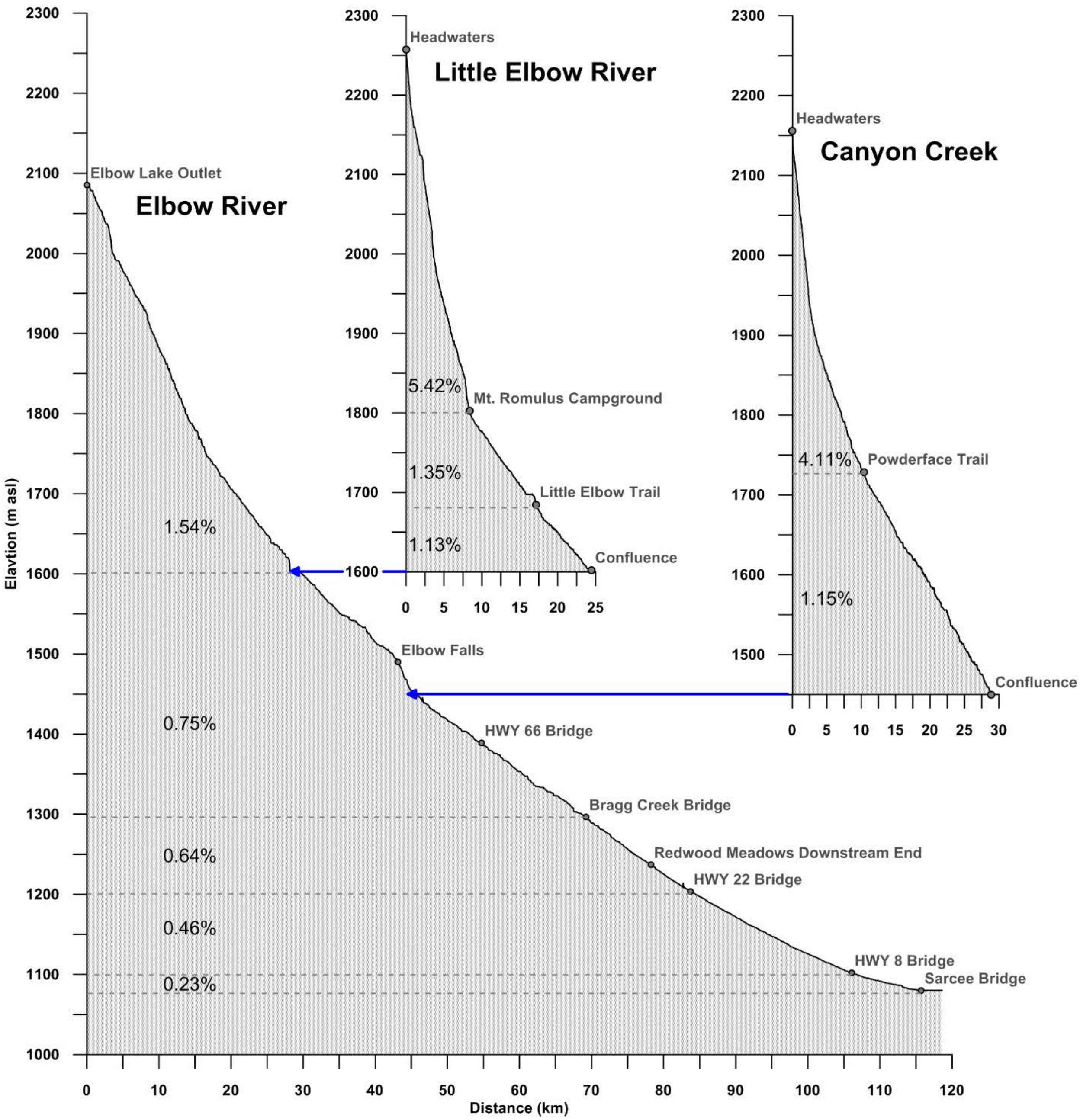


Figure 6-5 Longitudinal 3D Gradients of the Elbow River and Select Tributaries

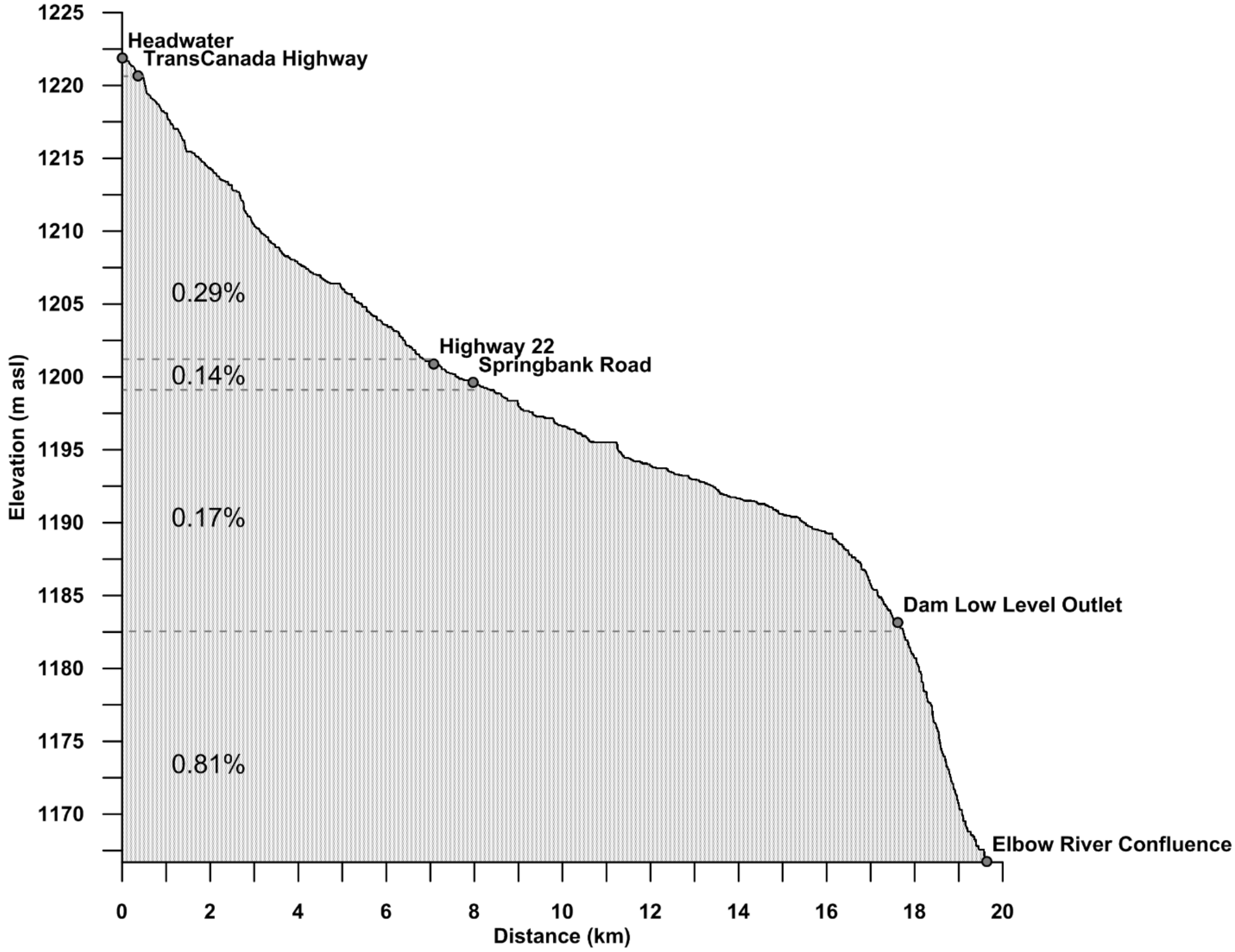


Figure 6-6 Longitudinal 3D Gradient of the Unnamed Tributary

Because of these marked gradient changes, the Elbow River and its tributaries transition from a steep, generally single channel mountain stream with pool-riffle sequences to a weakly braided/wandering pattern contained within broad floodplain with low gradients and typically poorly defined tributaries as the Elbow flows towards Glenmore Reservoir. The river is occasionally confined by limited bedrock canyons in the foothills and flows predominantly over gravel and cobble size alluvium for its entire length (Hudson 1983). These gradient changes also reflect the physical characteristics of the Elbow River watershed. These physical characteristics are assessed here using a hydrological response unit (HRU) approach applied to the Elbow River watershed.

An HRU analysis provides context for understanding the relative influence of catchment structure on runoff response as well as sediment supply (Buttle 2006; Jensco and McGlynn 2011). HRUs are landscape units that can be defined as having a similar hydrological response to a climatic input, for example, a rainfall event (Devito et al. 2005). These landscape units are commonly defined as a combination of slope, surficial geology, and land cover because these components largely determine the magnitude and timing of the hydrological response of a watershed to precipitation or snow (Devito et al. 2005; Jensco and McGlynn 2011). The HRU classifications are presented here to identify potential first order controls on runoff controls in the Elbow River watershed. The HRU results are summarized in Table 6-3 and in Figure 6-7.

The HRU results show marked differences in surficial geology, slope and landcover between the upper and lower watersheds. The upper watershed is dominated by slope gradients greater than 10% combined with bedrock and coarse grained surficial material and with a high percentage of alpine landcover. This combination suggests that runoff response to precipitation is rapid in areas with large areas of bedrock but less in areas with coarse surficial material and forest cover. The high slope gradients also suggest that gravitational and cryogenic processes dominate sediment generation and transport (Church and Ryder 2010). Gravitational processes include rock avalanches and debris flows, all of which deliver large quantities of sediment to valley bottoms for transport. These processes suggest that mountain sediment yields contribute sediment from surface wash of colluvium within tributary basins, with occasional inputs from mass movement where they intersect with the active channel (Hudson 1983). However, sediment derived from channel and riparian erosion of colluvium and till in both the tributaries and the Elbow River dominates suspended sediment sources, with considerable spatial variation (Hudson 1983).

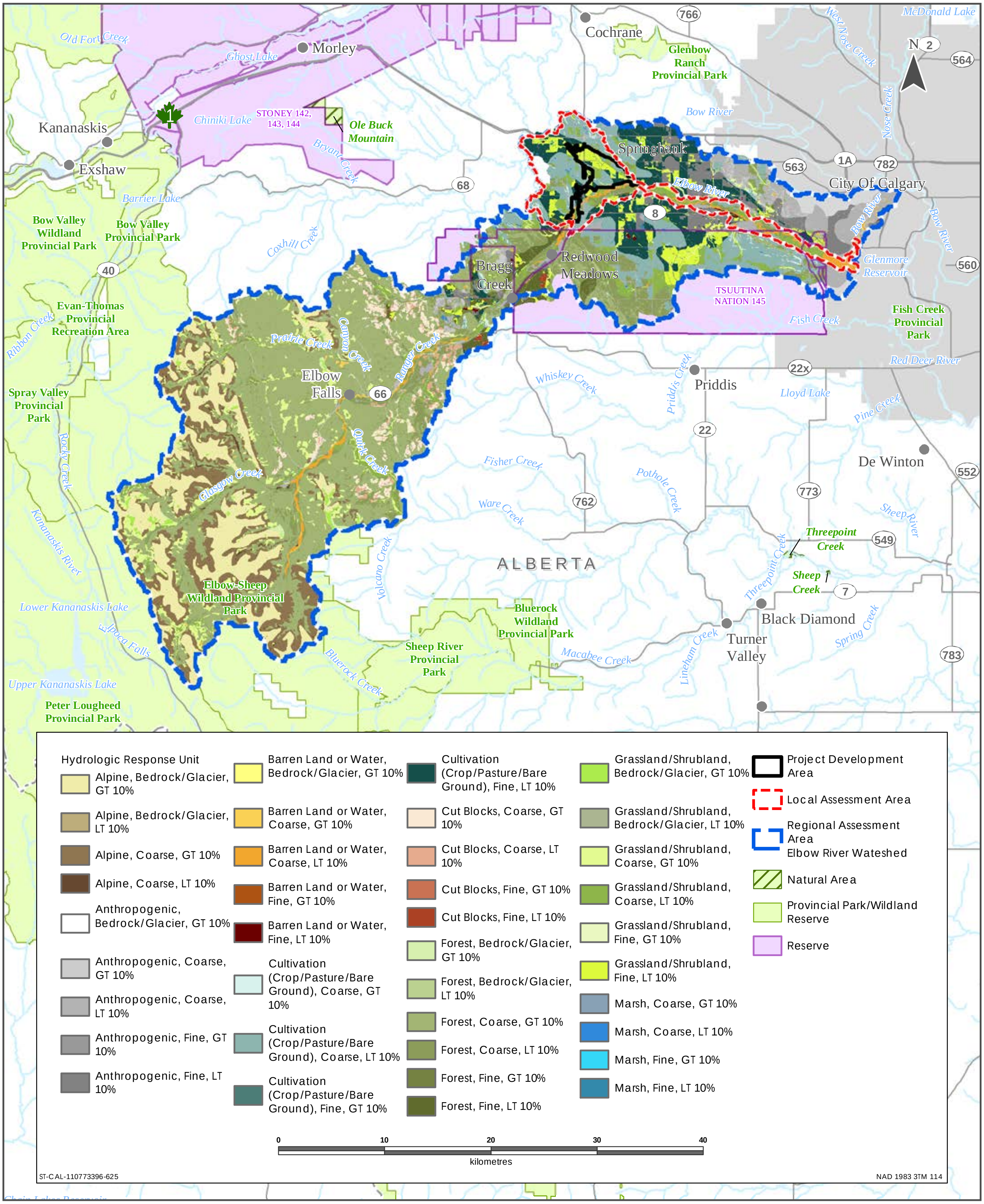
Table 6-3 Surficial Geology and Landcover of the Elbow River Watershed

		Upper Watershed		Lower Watershed		Combined Area (km²)
		Area (km²)	%	Area (km²)	%	
SURFICIAL GEOLOGY	Bedrock/Glacier	138.8	17	0.0	0	138.8
	Coarse material[1]	654.3	81	264.0	62	918.3
	Fine material[2]	18.5	2	160.8	38	179.2
	Total	811.5	100	424.8	100	1236.3
SLOPE	Greater than 10%	696.7	86	48.3	11	744.9
	Less than 10%	114.8	14	376.6	89	491.4
	Total	811.5	100	424.8	100	1236.3
LANDCOVER	Alpine	239.8	30	0.0	0	239.8
	Anthropogenic	22.7	3	98.4	23	121.1
	Barren Land or Water	8.5	1	12.5	3	21.1
	Cultivation (Crop/Pasture)	5.5	1	151.2	36	156.7
	Cut Blocks	31.0	4	0.6	0	31.6
	Forest	429.7	53	81.3	19	511.0
	Grassland/Shrubland	73.7	9	77.0	18	150.7
	Marsh	0.6	0	3.9	1	4.4
	Total	811.5	100	424.8	100	1236.3

NOTES:

[1] Includes colluvial deposits; fluvial deposits; fluted moraine; glaciofluvial deposits; ice-thrust moraine; preglacial fluvial deposits; stagnant ice moraine

[2] Includes eolian deposits; glaciolacustrine deposits; lacustrine deposits; organic deposits



Sources: Base Data - ESRI, Natural Earth, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Hydrological Response Unit Distribution in the Elbow River Watershed

Figure 6-7

In contrast, HRUs in the lower watershed are dominated by slope gradients less than 10% with a higher percentage of fine grained surficial material and cultivated/anthropogenic landcover classes. In the lower watershed, sediment sources for the Elbow River are dominated by channel and riparian erosion with silt, clays and gravels laterally eroded from valley walls where there is contact and flow levels are high enough to access the walls (Hudson 1983). Sediment sources in the tributaries are limited to channel and riparian areas with occasional inputs from minor rilling and gullying of limited areas (Hudson 1983). Runoff in these tributaries is largely intermittent in often poorly organized channels on low gradient surfaces. Generation of runoff is primarily through either prolonged rainfall events or early spring rainfall on partially frozen ground (see Section 6.2.2.4).

In summary, the modulation of climatic inputs by surficial geology, landcover and watershed physiography in the Elbow River watershed results in a distinct change in hydrology between the upper and lower watersheds. These differences are primarily driven by elevation effects on precipitation.

6.2.2.4 Hydrology

Elbow River

Two Water Survey of Canada stations on the Elbow River provide long-term flow data relevant to this assessment. These two stations are Elbow River at Bragg Creek (ID 05BJ004), upstream of the PDA, and Elbow River at Sarcee Bridge (ID 05BJ010), downstream of the PDA (see Figure 6-4 for their locations). The attributes of these stations are summarized in Table 6-4 and flow data are listed in Table 6-5.

Table 6-4 Relevant Hydrometric Stations Historical Data

Station ID	Watershed Area (km^2)	Mean Daily Flow Record		Instantaneous Peak Flow Record		Hourly Flow/Stage Record		15-min Flow/Stage Record		Record
		From	To	From	To	From	To	From	To	
05BJ004 Elbow River at Bragg Creek	790.8	May 1935	Dec 2016[1]	June 1950	June 2012	Jan 1999	Oct 2016[1]	Jan 2013[1]	Dec 2013[1]	Partial
05BJ010 Elbow River at Sarcee Bridge	1189.3	April 1979	Dec 2016[1]	May 1979	June 2012	Mar 2006	Oct 2016[1]	-	-	Partial

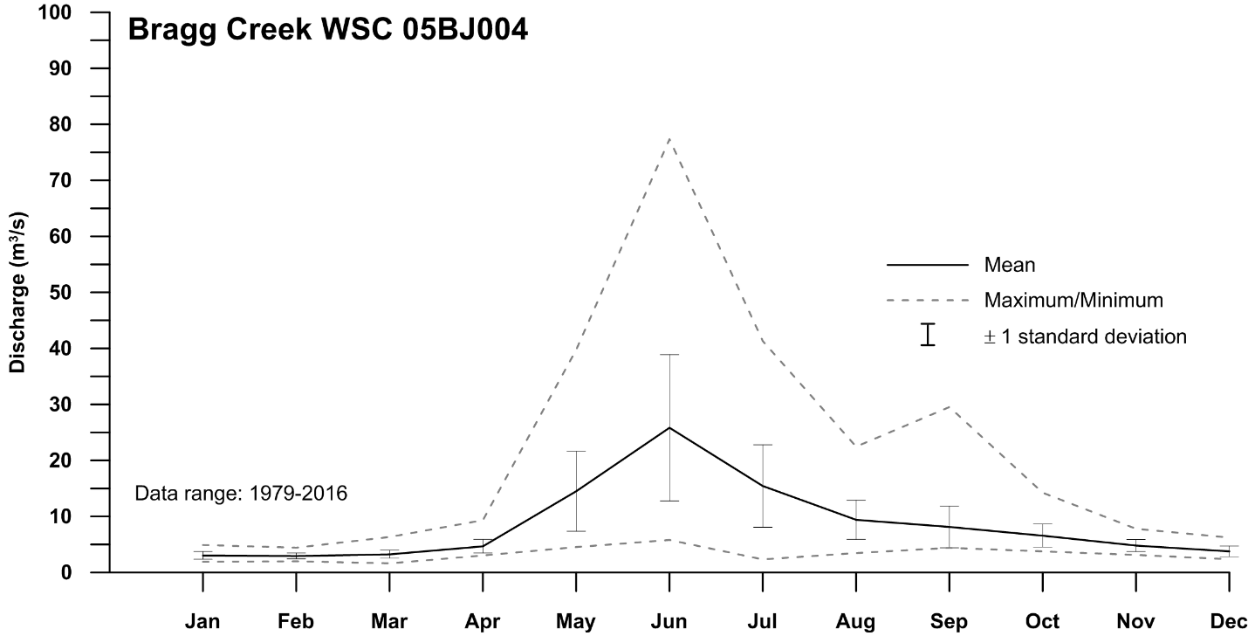
NOTE:
[1] Discharge and stage data is provisional for 2014, 2015 and 2016 and subject to change

Table 6-5 Summary of mean monthly flows for Bragg Creek and Sarcee Bridge 1979-2016

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Mean flow (m^3/s) (standard deviation in brackets)											
05BJ004 Elbow River at Bragg Creek	3.0 (0.7)	2.9 (0.5)	3.2 (0.7)	4.7 (1.2)	14.5 (7.1)	25.8 (13.1)	15.4 (7.4)	9.4 (3.5)	8.1 (3.7)	6.6 (2.1)	4.8 (1.1)	3.8 (0.9)
05BJ010 Elbow River at Sarcee Bridge	3.7 (0.4)	3.6 (0.3)	4.2 (0.8)	5.4 (1.5)	14.8 (8.7)	29.5 (19.4)	15.5 (7.2)	9.7 (3.8)	8.5 (3.9)	6.7 (2.1)	5.4 (0.6)	4.2 (0.5)

The Elbow River has a typical high-latitude runoff regime with low winter discharges with most of runoff derived from snowmelt (Church 1974). However, mean monthly flows for the period 1979 to 2014 for Bragg Creek and Sarcee Bridge show distinct patterns that reflect their position in the Elbow River watershed (Figure 6-8, Table 6-5). At both stations, winter flows are low in response to below freezing air temperatures and precipitation falling predominantly as snow. The slightly higher flows and standard deviations for the Sarcee station during January and February likely reflect periods of warm temperatures and enhanced melt on the Plains associated with orographically reinforced chinook winds that are common during winter (Hudson 1983). Spring flows increase first at Sarcee Bridge in March/April, which reflects local inputs of runoff over partially frozen ground with snow melt occurring at progressively higher elevations in the upper basin as spring progresses. This pattern results in the Plains snowpack being removed before the influx of most of the annual flow from the upper watershed in May, June and July.

Approximately 54% of the annual flow volume occurs during May, June and July in the Elbow River watershed. Of this percentage, 25% of the annual flow typically occurs in June alone. The higher variability evident in June reflects that this is the primary month for flood occurrence. Approximately 94% of the annual runoff is sourced from the watershed upstream of Bragg Creek with 6% contributed from the Plains over the year (Figure 6-9). In some months, there is a net loss of up to 1.0% between Bragg Creek and Sarcee Bridge, as also noted by Hudson (1983). This loss is likely due to infiltration into the alluvium of the Elbow River valley floor (Hudson 1983). Summer recession begins in June with a rapid decline towards October and November. Over the long term, the increase in discharge between Bragg Creek and Sarcee Bridge during the summer recession is likely a result of groundwater inflows, rather than rainfall inputs on the plains (Hudson 1983).



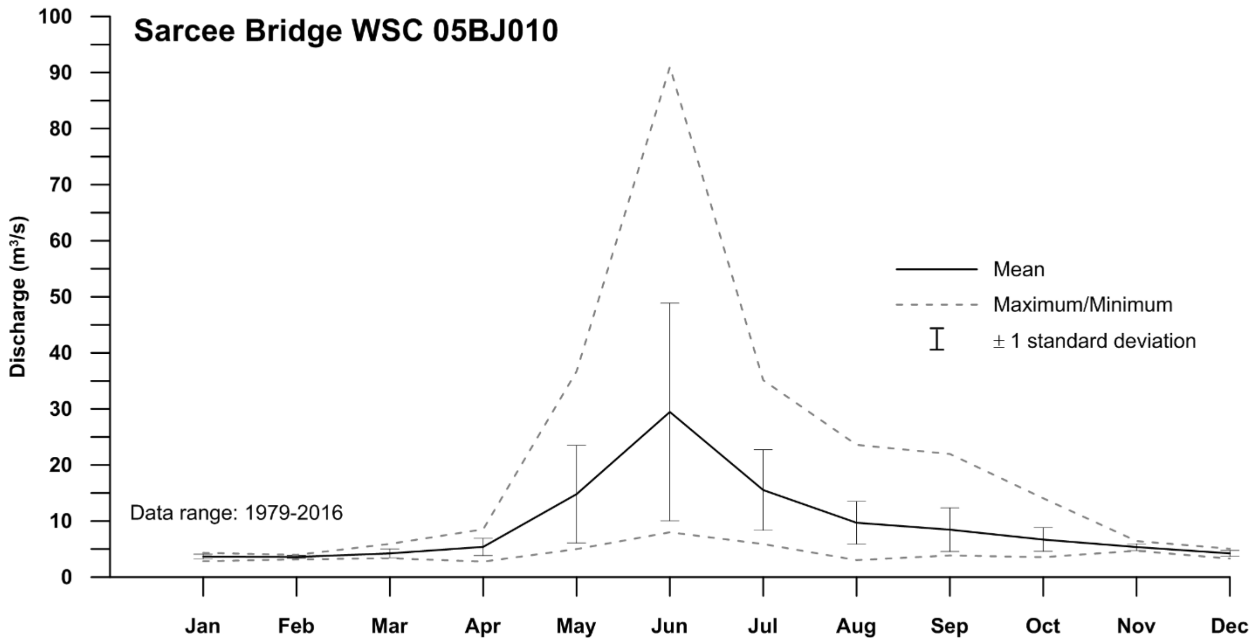


Figure 6-8 Mean, Minimum and Maximum Monthly Flows for Bragg Creek and Sarcee Bridge

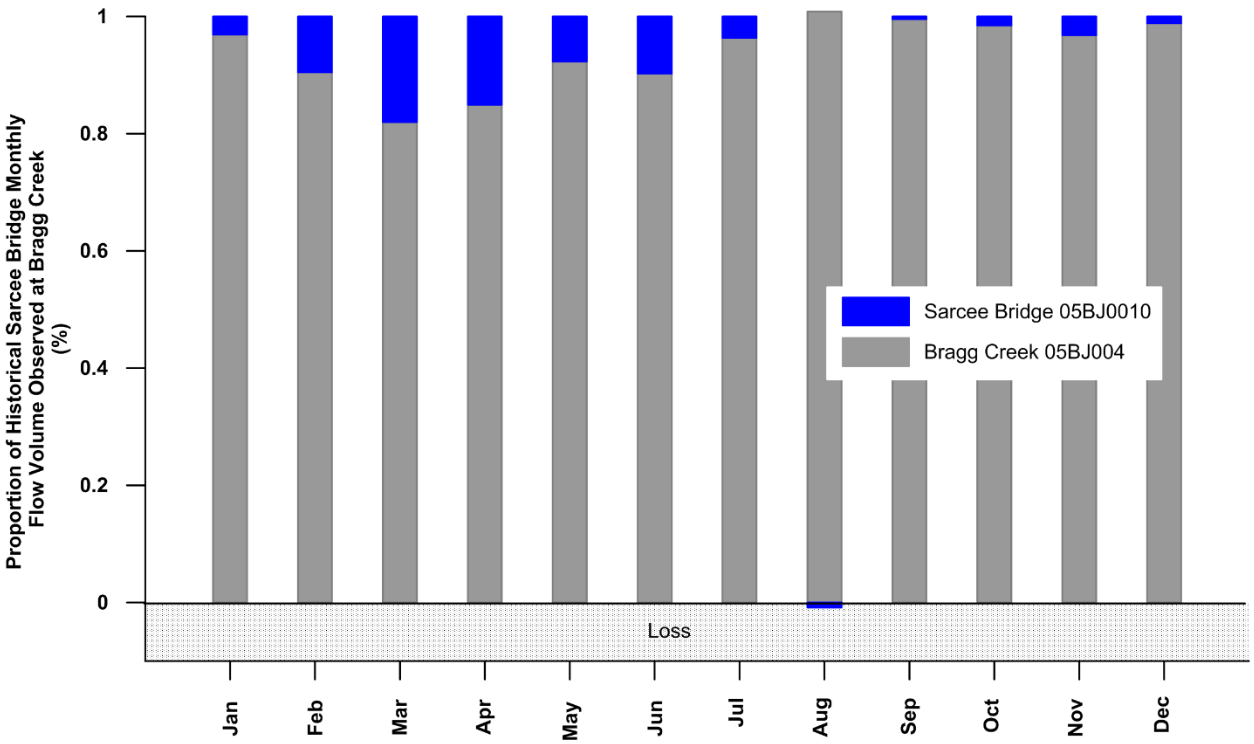


Figure 6-9 Proportion of Sarcee Bridge Monthly Flow Observed at Bragg Creek

However, sustained rainfall from stationary frontal systems over the foothills and plains can markedly increase runoff during the summer months. For example, field data collected from the Elbow River at Highway 22 during 2015 and 2016 showed marked differences in flow volumes between the two years, as a function of snowpack and rainfall differences (Figure 6-10). In 2015, the flow volume for May and June were 17% and 23% of the total annual flow, with July at 13%. Flow volumes in 2016 were 17% of the total annual flow in May, 15% in June and 24% in July. The increase in flow during July 2016 was a result of approximately 206 mm of rain falling over the month, as recorded at Calgary International Airport. This rainfall amount represents a 208% increase over the 1981-2010 climate normal rainfall of 66.9 mm. This example illustrates that the timing and generating mechanism of flow events in the Elbow River can be quite variable.

Although intra- and inter-annual flows can vary considerably depending on driving mechanisms, flow duration curves (FDC) for Bragg Creek and Sarcee Bridge show that the Elbow River is typically a low flow system for the majority of the year. Based on the FDCs, Bragg Creek and Sarcee Bridge have median discharges of 6.3 m^3/s and 7.5 m^3/s, respectively (Figure 6-11). The mean annual flood for Bragg Creek (recurrence interval of 2.33 years) is estimated at 80 m^3/s (Stantec 2015a). This flow, which is important for downstream sediment transport and fish habitat maintenance is only equaled or exceeded 0.3% of the time, approximately 1 day per year, on average.

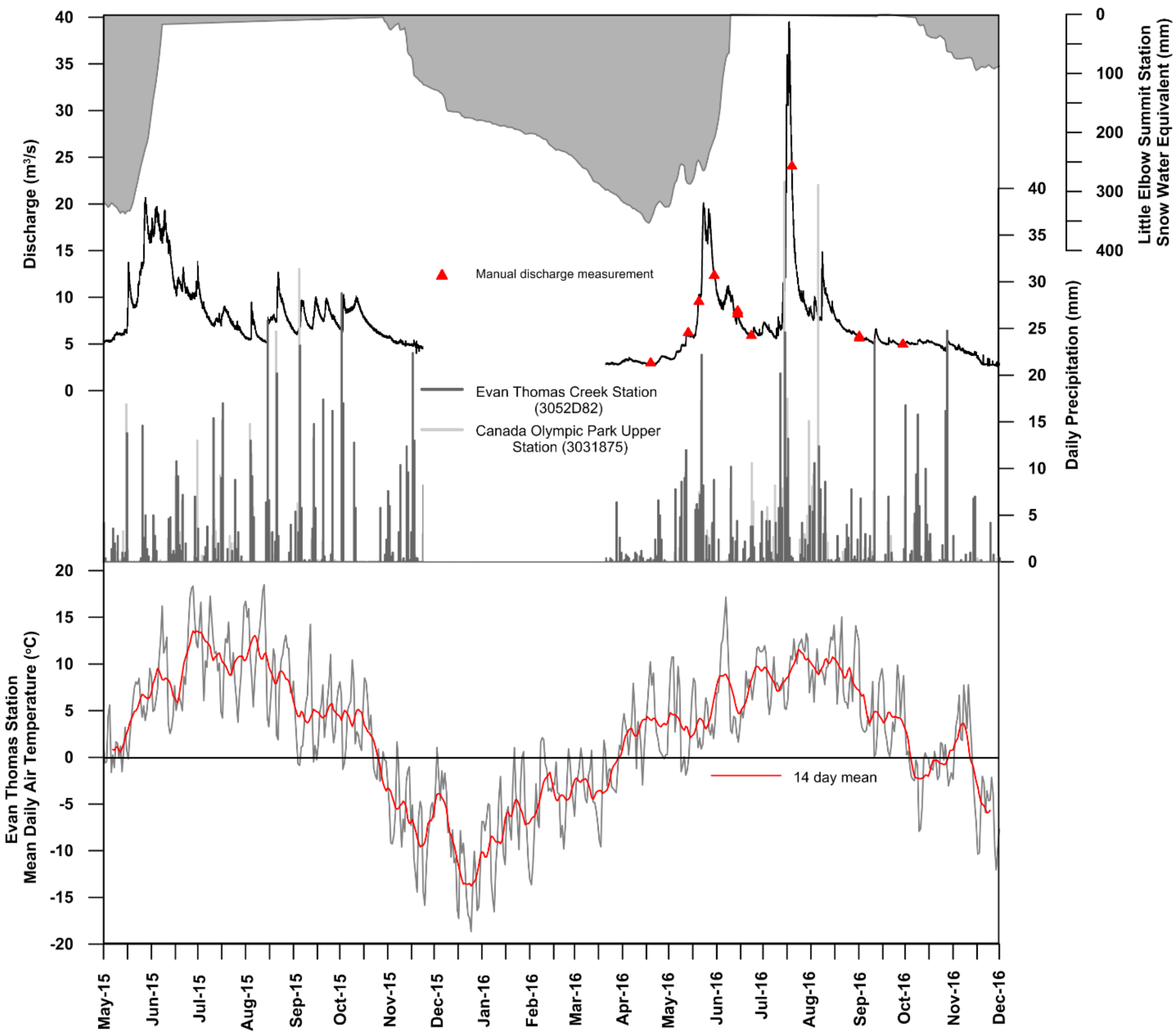


Figure 6-10 Hydrometeorology of the Elbow River at Highway 22, 2015 and 2016

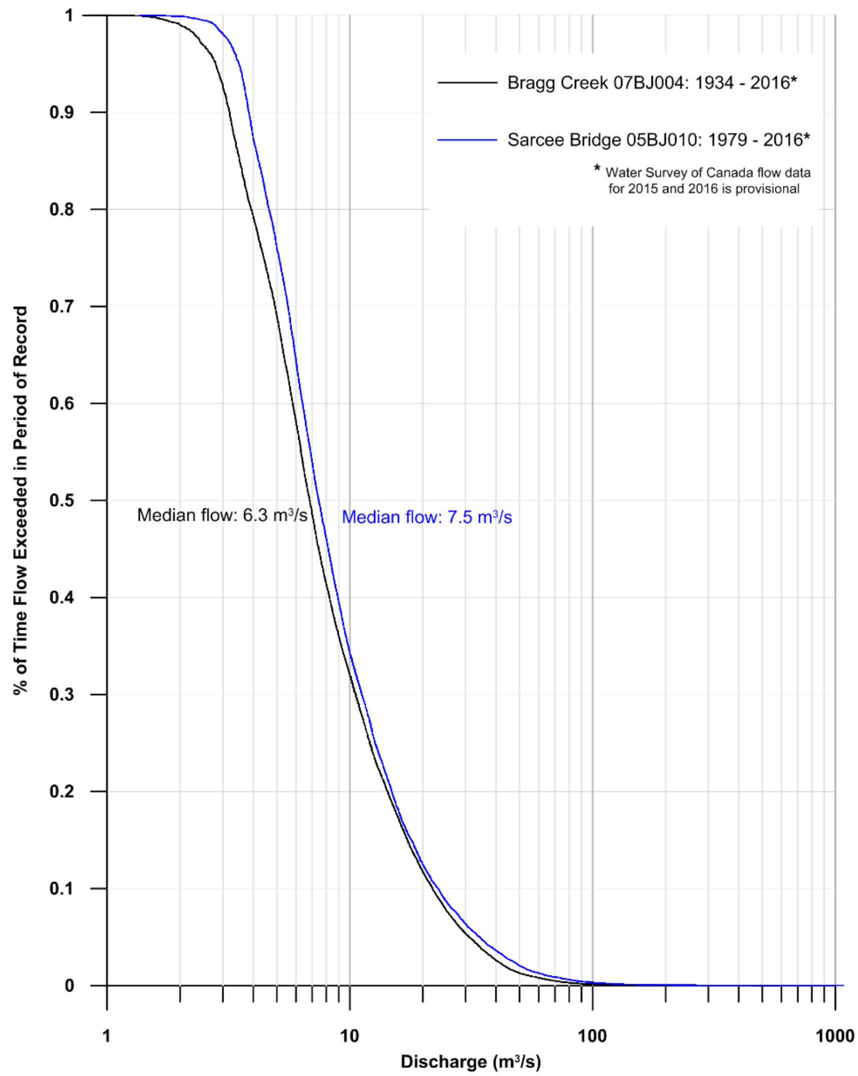


Figure 6-11 Flow Duration Curves for Bragg Creek and Sarcee Bridge

Generation of high flow events in the Elbow River Basin are complex with changes in magnitude reflecting different combinations of driving mechanisms. Early spring floods driven by snowmelt alone are typically small and occur soon after ice break-up (Hudson 1983). Increasing flood magnitudes reflect an increasing rainfall contribution in the upper watershed with additional inputs from the lower watershed (Hudson 1983). High magnitude events occur when substantial rainfall occurs during spring melt when higher elevation snowpack is isothermal, or close to isothermal. For example, in June 2013, heavy rainfall and rapidly melting snowpack in the Front Ranges of the Canadian Rocky Mountains resulted in widespread flooding in multiple watersheds, including the Elbow River. Over 200 mm and as much as 350 mm of precipitation fell in watershed headwaters between June 19th and June 22nd (Pomeroy et al. 2016).

The intensity of the 2013 storm event was the result of coupling between upper and lower circulation systems. This coupling resulted in upslope winds from the east that were warm and moist, raising the freezing level and resulting in rainfall rather than snowfall at high elevations (Pomeroy et al. 2013). Snowmelt over partially frozen soil at higher elevations may have increased runoff by up to 30%, in some areas (Pomeroy et al. 2016). The system persisted for over 36 h (Pomeroy et al. 2016). Localized pockets of high intensity convection driven rainfall over the foothills and plains, as well as in the upper Elbow River watershed, also contributed to extreme runoff conditions. Pomeroy et al. (2016) concluded that the generation of high magnitude floods in the Elbow River watershed typically requires a combination of snowmelt, rainfall and rain-on-snow.

A detailed flood frequency analysis was undertaken using peak instantaneous flows at the Bragg Creek Station, for the period 1934 to 2013, and downstream stations, for the period 1908 to 2013 (Stantec 2015). Data from the downstream stations was amalgamated into a Combined Station on the basis of minor differences in watershed area and distances between stations. The combined logarithmic and power curves were then used to estimate recurrence intervals for instantaneous peak, 7-day and 56-day flow volumes, summarized in Table 6-6.

Table 6-6 Estimated Flood Frequencies for the Elbow River at the Diversion Site

Recurrence Interval (years)	Instantaneous Peak Discharge (m^3/s)	7-Day Volume (dam^3)	56-Day Volume (dam^3)
500	1,800	174,000	371,000
200	1,110	132,000	322,000
100	765	107,000	290,000
50	530	86,600	260,000
20	330	65,600	226,000
10	200	53,100	203,000
5	140	38,100	172,000
2	70	20,000	105,000

Based on a combination of mean daily flow and peak instantaneous flow values (Table 6-7), if the Project had been built in 1934, the Project would have potentially diverted floods 12 times since then.

Although the Project has been designed to start water diversion from Elbow River when the flow rate in the river reaches 160 m^3/s of flow in the Elbow River, actual operation would be determined by a number of factors at the time of diversion. These include, for example, the forecasted likelihood of a large flood based on weather conditions or the possibility of two back-to-back floods.

Table 6-7 Floods Greater than 160 m^3/s since 1934

Date		Mean Daily Flow (m^3/s)	Annual Peak Instantaneous Flow (m^3/s)	Diversion Time (days)
Year	Month/Day			
1948	May 23	183	-	1
1953	June 13	118	181	1
1963	June 30	141	268	1
1967	May 31	185	283	1
1969	June 29	139	170	1
1974	June 29	66	170	1
1990	May 26	129	172	1
1995	June 7	190	377	1
2005	June 7	230	308	1
2005	June 18	195	-	1
2008	May 24	125	204	1
2013	June 20-23	581, 357, 200, 197	1170	4

Flows in the Elbow River are typically at their lowest in February. Mean monthly flow data show a steady recession from fall flows into winter, with a consistent low variance of 0.5 m^3/s around the mean values over most of the winter period (November to February) (Table 6-5 and Figure 6-8). The majority of the low flow during winter is sourced from the watershed upstream of Bragg Creek with between 2% and 5% of the mean monthly flow supplied by the lower watershed. As noted by Hudson (1983), winter discharge at Bragg Creek is primarily sourced from the upper Elbow River watershed upstream of Elbow Falls. Lows in discharge correspond to prolonged periods of cold temperatures with higher low flows corresponding to increases in air temperature above freezing during, for example, chinook events (Hudson 1983). Seven day average low flows (7Q) estimated for various recurrence intervals for Bragg Creek and Sarcee Bridge are summarized in Table 6-8. Low flow estimates are shown for the open water season (March to October) and winter (November to April).

Table 6-8 Estimated 7-day Low Flows for the Elbow River at Bragg Creek and Sarcee Bridge

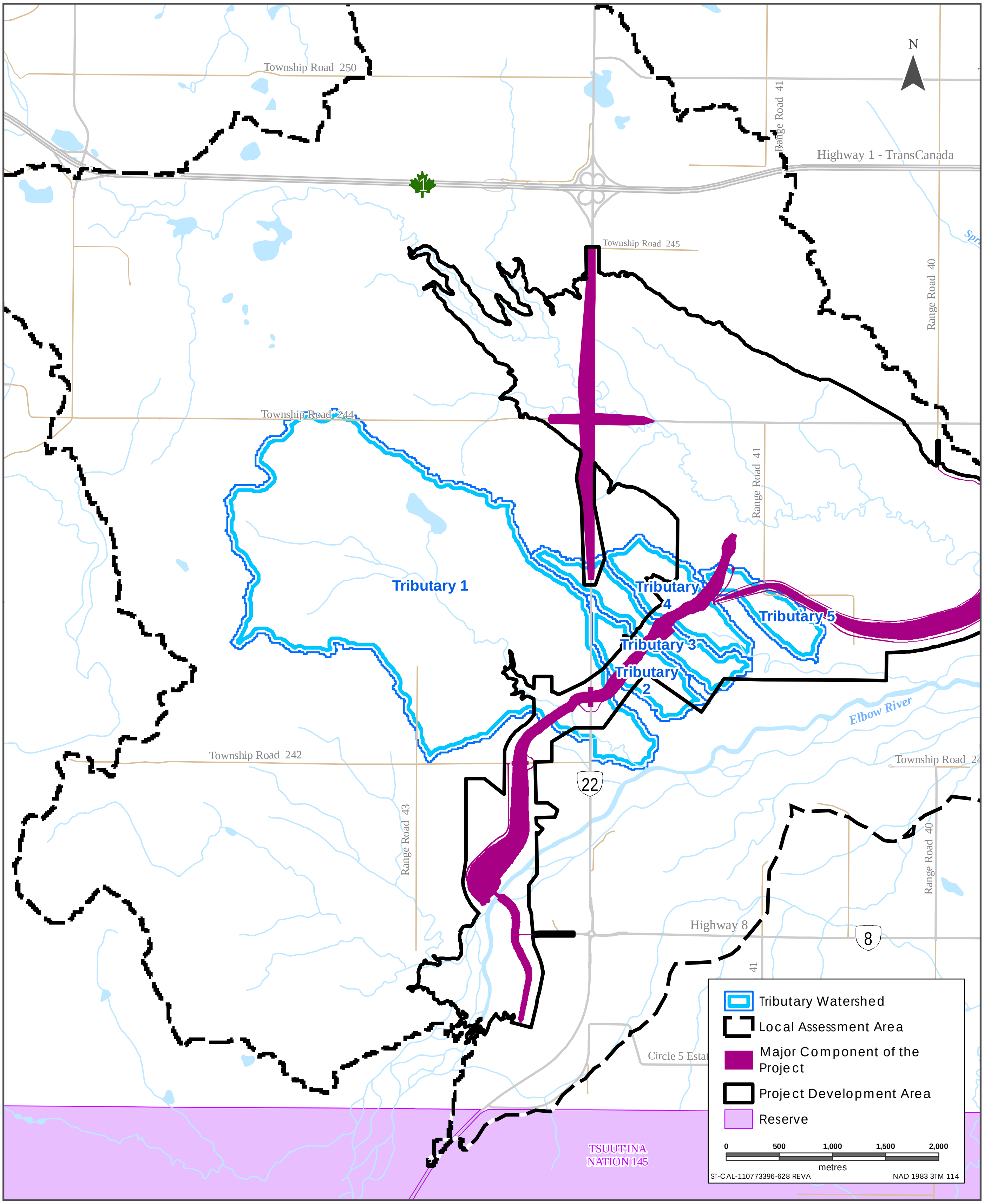
	Season	$7Q_2$ (m^3/s)	$7Q_{10}$ (m^3/s)	$7Q_{20}$ (m^3/s)	$7Q_{100}$ (m^3/s)
BRAGG CREEK	**Open Water**	3.40	2.38	2.08	1.53
	Winter	2.24	1.60	1.40	1.04
SARCEE BRIDGE	**Open Water**	3.87	2.76	2.42	1.80
	Winter[1]	2.71	1.91	1.67	1.23

NOTE:
[1] Sarcee Bridge winter values are based on only eight years of data and should be treated with caution

Tributaries

The LAA contains several tributaries to the Elbow River that contribute flow from the plains (Figure 6-12). Based on field collected data from the 36.4 km^2 watershed of the unnamed tributary stream that will form the low-level outlet for the Project, the hydrological regime of small tributaries in the LAA is typically intermittent (Figure 6-13).

Although limited to one year of continuous observation, mean flow in the unnamed tributary is approximately 30 L/s (0.03 m^3/s) or 0.83 L/s/km^2 (0.00083 m^3/s/km^2), when flow is present. The peak flow recorded was 791 L/s after a period of prolonged rainfall in July 2016 (Figure 6-13). Based on visual observations during this peak event, bankfull discharge is in the order of 1.0 m^3/s. The field data collected to date suggests that surface flow is only initiated in tributaries either after prolonged rainfall (resulting in high antecedent moisture conditions) or when rain falls on partially frozen ground (enhancing runoff during early spring precipitation events). Rainfall events in late spring do not appear to result in similar magnitude runoff responses. This suggests that increased ground infiltration and spring vegetation growth substantially attenuate runoff (Figure 6-13). Snowmelt does not appear to play a major role in runoff generation for the data record. During winter and for periods during the summer months, there is no surface flow. However, specific electrical conductivity values of 1.2 mS/cm to 1.7 mS/cm (1200 to1700 µS/cm) and substantive dilution of electrical conductivity during rainfall events suggests that baseflow in the unnamed tributary is, in part, maintained by springs (Figure 6-14). Other tributaries in the area surrounding the PDA have been observed to be spring fed and to maintain flow year-round.



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Tributary Watersheds in the Local Assessment Area

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 6-12

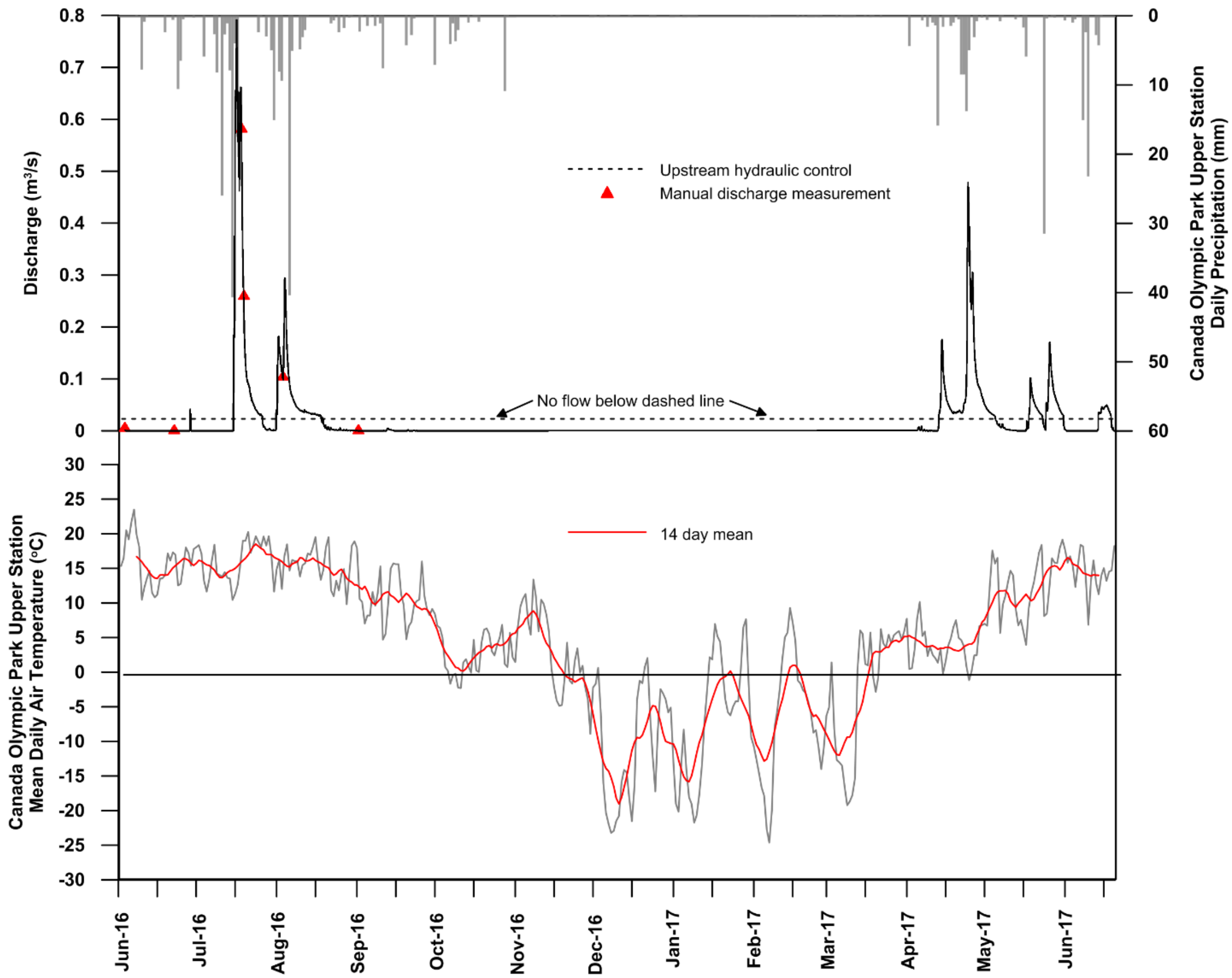


Figure 6-13 Hydrometeorology of the Unnamed Tributary, 2016-2017

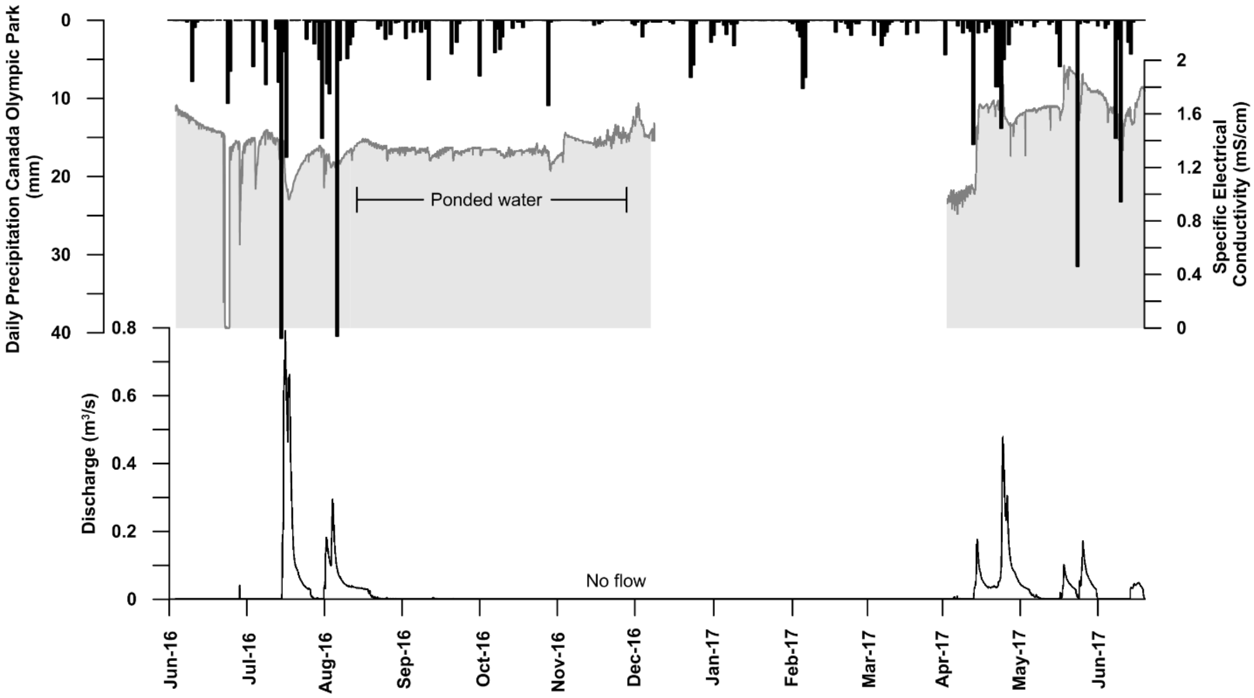


Figure 6-14 Response of Electrical Conductivity to Rainfall Events in the Unnamed Tributary

Waterbodies

There are several small, naturally occurring waterbodies in the PDA. These waterbodies are primarily fed by the low-level outlet and its tributaries. As a result, runoff contributions will be intermittent and result in fluctuating water levels.

6.2.2.5 Ice Dynamics

Semi-quantitative observations of ice build-up and decay on the Elbow River near the Highway 22 bridge are used as an analog for potential ice dynamics near the Project diversion structures. Remote camera and continuous water level data show that freeze-up was rapid and occurred in less than 24 hours (Figure 6-15). This ice layer remained in place until the start of in situ thermal degradation in March 2017, prior to the onset of spring melt from the upper watershed (Figure 6-16). No backwater effects due to ice jamming were observed during this thermal degradation.

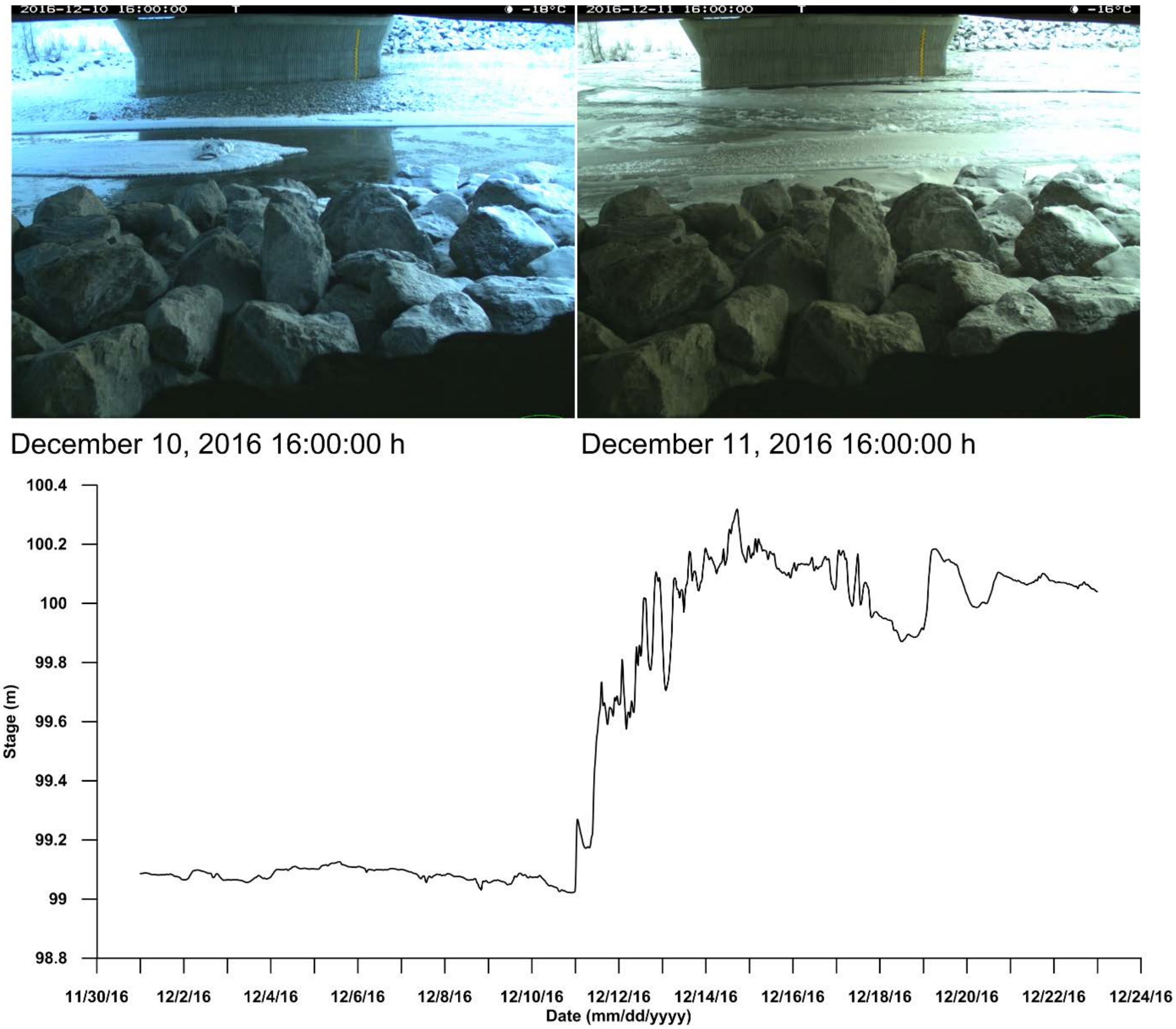


Figure 6-15 Ice Freeze up at Highway 22 Bridge, December 10-11, 2016

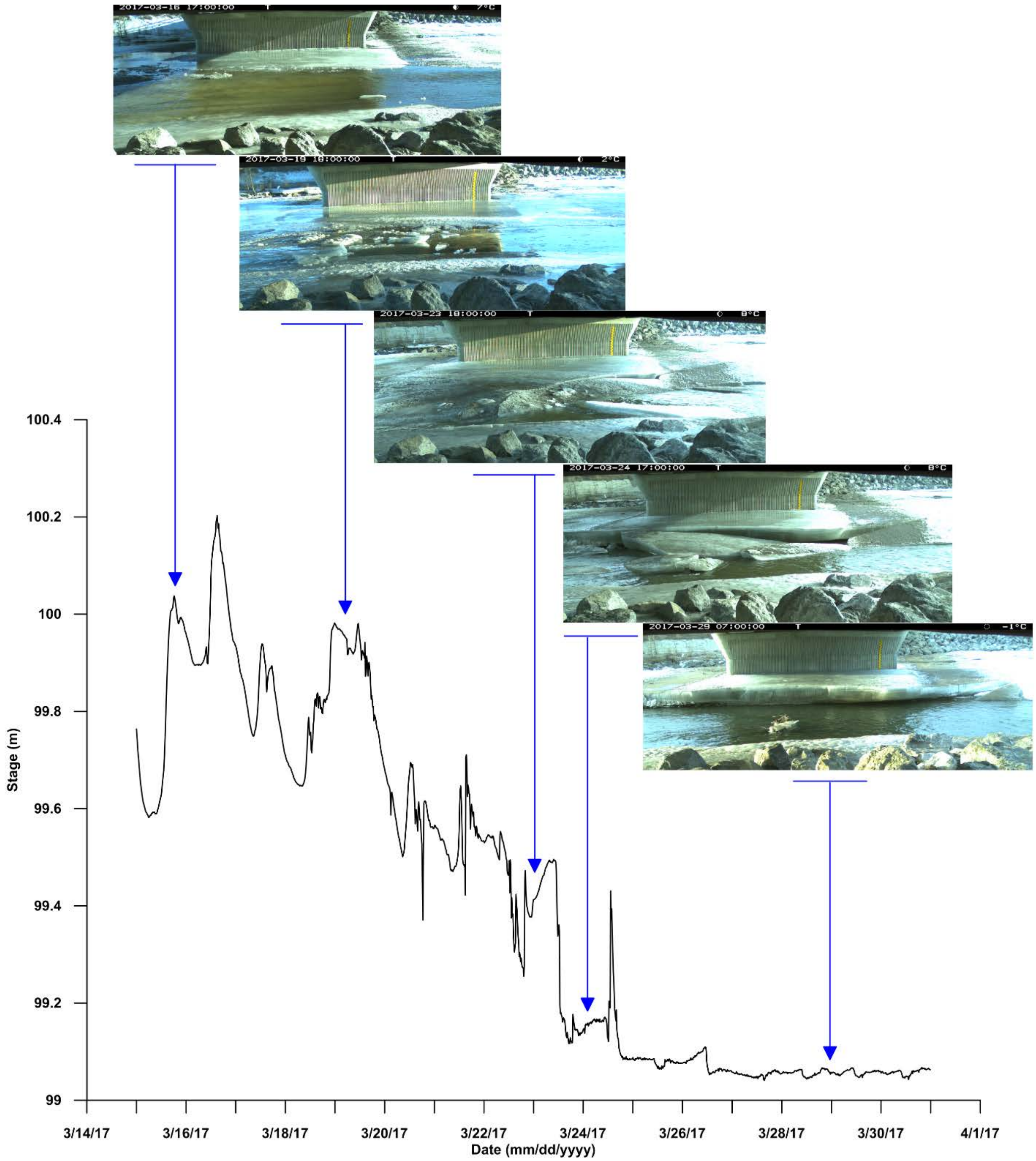


Figure 6-16 Ice Break-up at Highway 22 Bridge, March 14 – April 1, 2017

6.2.2.6 Water Licences

Water licences allocated within the LAA and associated volumes are summarized in Table 6-9 (J. Yan. pers. comm., April 4, 2017)

Table 6-9 Surface Water Withdrawal Licences in LAA

Source	Number of Licences	Licensed Volume (dam^3)
Elbow River	33	111,251.0
Cullen Creek	2	94.0
Lott Creek	4	10,567.0
Pirmez Creek	5	2.73
Springbank Creek	1	2.47
Surface Runoff	7	0.90
Unnamed Lake	1	0.11
Unnamed Stream	12	4.59
	Total	121,922.80

6.3 PROJECT INTERACTIONS WITH HYDROLOGY

Table 6-10 identifies the interaction of project activities with hydrology. These interactions are discussed in detail in Section 6.5 in the context of effects pathways, standard and project-specific mitigation, and residual effects. A justification for no interaction is provided following the table.

Table 6-10 Project-Environment Interactions with Hydrology

Project Components and Physical Activities	Environmental Effects	
	Change in hydrological regime	Change in sediment transport dynamics
Construction		
Clearing	✓	✓
Channel excavation	✓	✓
Water diversion construction	–	✓
Dam and berm construction	–	✓
Outlet works construction	–	✓
Road construction	–	✓

Table 6-10 Project-Environment Interactions with Hydrology

Project Components and Physical Activities	Environmental Effects	
	Change in hydrological regime	Change in sediment transport dynamics
Bridge construction	–	✓
Lay down areas	–	–
Borrow extraction	–	✓
Reclamation	–	–
Dry Operations		
Physical structures	✓	✓
Maintenance	–	✓
Ice Jamming	–	–
NOTES: ✓ = Potential interaction – = No interaction		

6.3.1 Construction

All instream works will be completed in a manner that allows for water conveyance. Therefore, hydrology in the Elbow River and low-level outlet will not interact during construction of the water diversion structure, dam and berm, and low-level outlet structure and are not assessed further. Hydrology in the Elbow River and associated tributaries in the PDA will not interact with other Project activities such as road and bridge construction, laydown, borrow areas, or reclamation and are not assessed further. Sediment transport will not interact with Project laydown or reclamation as these will be located away from watercourses and are not assessed further.

6.3.2 Dry Operations

The dry operations phase of the Project occurs following construction and when there are no floods that require the diversion of portions of the Elbow River flow into the reservoir. As flow is unimpeded in the Elbow River and low-level outlet during dry operations, no interaction with hydrology is anticipated during maintenance activities and is not assessed further.

Survey and field observations from the Highway 22 bridge indicate that no upstream flooding occurs because of structure induced ice jamming during spring and as a result, no measurable interaction with sediment transport (see Volume 4, Appendix J, Hydrology Technical Data Report). Given the similarities in the design of the Project's control structures bounding the Elbow

River channel at the diversion point, a similar effect to that at the bridge is expected and ice dynamic effects on hydrology and sediment transport are not assessed further.

6.4 MITIGATION

Potential effects of erosion and sedimentation on watercourses during construction would be avoided or mitigated through:

- All applicable regulatory notifications, permits, and authorizations including the *Environmental Protection and Enhancement Act*, *Water Act* and the federal *Fisheries Act* and *Navigable Waters Protection Act,* will be obtained before the start of any instream construction.
- Instream work areas will be isolated from the main river flow by using cofferdams, silt fences and turbidity barriers. TSS will be monitored and measured in conformance with Alberta Transportation's Turbidity and Monitoring specifications.
- Clean granular fill with less than 5% fines passing the 80um sieve size will be used for instream work such as cofferdams, causeways, access ramps, Bailey bridges, river channel diversions. Fine grained soils may be used, provided only clean granular fill is exposed to the river at any time during construction and restoration operations.
- Sediment and erosion control measures as detailed in Section 8 Aquatic Ecology will be used
- Bank and riparian areas disturbed during construction will be reclaimed and re-vegetated. Silt fences, turbidity barriers and riprap materials will be used to prevent future bank erosion.
- All applicable regulatory notifications, permits, and authorizations, if required, would be obtained before the start of any instream construction.
- Bank and riparian areas disturbed during construction will be rehabilitated and re-vegetated. Silt fences, turbidity barriers and riprap materials will be used to prevent future bank erosion. bank erosion, including revegetation.

More detail on instream mitigations is provided in Section 8 Aquatic Ecology.

6.5 ASSESSMENT OF RESIDUAL ENVIRONMENTAL EFFECTS ON HYDROLOGY

6.5.1 Analytical Assessment Techniques

This effects assessment is primarily based on semi-quantitative assessment techniques because of the limited nature of the potential Project interactions with hydrology and sediment transport that could occur during these phases of the Project.

6.5.2 Change in Hydrological Regime

The Project has the potential to change hydrology during construction and dry operation because alteration of surfaces adjacent to the Elbow River tributaries. Clearing, grading and construction of the diversion channel, dam and floodplain berm may change the runoff response to precipitation events. Increased compaction of surfaces would result in less infiltration and the potential for enhanced runoff. Similarly, removal of vegetation may also increase runoff because of lowered surface roughness. However, changes in hydrology because of enhanced runoff require hydrological connection to the Elbow River or the low-level outlet. Given the distance of most of the PDA from active channels, increases in runoff are unlikely to be measurable within the larger hydrological regime of the Elbow River.

Permanent diversion of five small tributaries intersected by the diversion channel and the dam would affect the input of flow from these tributaries into the Elbow River. However, using the gauged data from the low-level outlet and, assuming that the hydrodynamics measured are representative, direct flow input to the Elbow River from the five intersected tributaries is likely to be negligible. Estimates of the potential flow input as a function of watershed area from these tributaries, using June 2016 to June 2017 as an example, are summarized in Table 6-11. No visible tributaries are intersected by the floodplain berm.

Table 6-11 Project Intersected Tributary Discharge Estimates

	Tributary 1	Tributary 2	Tributary 3	Tributary 4	Tributary 5	Low-level Outlet[2]
Watershed Area (km^2)	7.21	0.52	0.65	0.67	0.43	36.2
Estimated Mean Flow 2016 – 2017 (L/s)[1]	5.99	0.43	0.54	0.56	0.36	30

NOTES:

[1] Estimated flows are based on the unit area flow of 0.83 L/s/km^2 recorded in the low-level outlet between June 2016 and June 2017. Note that this value is based on intermittent flow and assumes a similar response in the ungauged tributaries to precipitation inputs, including any groundwater input. As a result, the values presented are a guide only and should not be interpreted as perennial flow.

[2] The low-level outlet's flow is not impeded or diverted during dry operations and is included here for context only.

The flow estimates from the five intersected tributaries are extremely low, likely intermittent and are already affected by roads, cultivation, and dugouts. Therefore, the residual effect on the hydrology of the Elbow River watershed is unlikely to be measurable. However, the diversion of flow from Tributary 1, which has direct hydrological connectivity with the Elbow River in its lower reaches may change the channel form at the confluence.

Under existing conditions in the Elbow River, the current tributary channel form may function as a backwater "clear water" refugia for fish. This type of refugia assumes that there is enough runoff from the tributary to counteract the turbidity contained in backwater from the Elbow River during floods. Post construction and under dry operations, the tributary channel would no longer function as a clear water refugia as upstream flow would be diverted into the diversion channel. However, the lower reaches of the tributary channel would still be available as a velocity refugia for fish during floods in the Elbow River. See Section 8 Aquatic Ecology for more detail.

During dry operations, there is a potential for increased flows in the low-level outlet through the intersection of the diversion channel with shallow groundwater seepage. Groundwater that seeps into the diversion channel may either infiltrate back into the groundwater system, evaporate or—if antecedent moisture conditions prevent infiltration—it may flow as surface flow into the reservoir. This surface flow would then become part of the low-level outlet drainage system with input into the Elbow River. The spatial extent of groundwater seepage would be determined by the depth of local water tables (see Volume 3B, Section 5 for more detail). Similarly, any excess runoff from rainfall in the diversion channel would either infiltrate, evaporate or become part of the low-level outlet drainage with input into the Elbow River.

The residual effects on the hydrology of the Elbow River, because of tributary drainage diversion and groundwater intersection, during dry operation can be characterized by the following:

- Direction is neutral because primary flow in the Elbow River and the low-level outlet would not be impeded and intermittent flow from the diverted small tributaries, including any potential groundwater seepage, is unlikely to be measurable at the LAA scale.
- Magnitude is negligible with little to no variation from existing conditions in the Elbow River and the low-level outlet.
- Geographic extent of the effects is limited to the PDA area due to scale limiting any transfer of effects into the Elbow River in a measurable way.
- Frequency of the effect is continuous given the permanent nature of the Project.
- The duration of the effect is long-term given the permanent nature of the Project.
- The effects are irreversible, given the permanent nature of the Project.
- The ecological and socio-economic context is disturbed because the PDA has been previously disturbed by human development.
- Timing is seasonality for the watershed

6.5.3 Change in Sediment Transport

Construction activities may result in the release of suspended sediment and bedload-sized material into the Elbow River and the low-level outlet. However, best management practices and implementation of erosion and sediment control plans would mitigate this release. Similarly, any sediment released during maintenance would be mitigated by best management practices.

During dry operation, localized changes in hydraulics around the diversion structures in the Elbow River may result in shifts in the location of channel scour and deposition of bedload material. However, these effects would be very localized and are unlikely to have a measurable effect on downstream sediment transport.

The apparent lack of sediment transport measured in the low-level outlet under existing conditions and the intermittent flow regime suggest that dry operations is unlikely to have any measurable effect on sediment transport. The residual effects on sediment transport in the Elbow River, because of localized hydraulic changes during dry operation, can be characterized by the following:

- Direction is neutral because primary flow in the Elbow River and the low-level outlet would not be impeded and effective discharge ranges for suspended sediment and bedload are unaltered at the LAA scale.

- Magnitude is negligible with little to no variation from existing conditions in the Elbow River and the low-level outlet.
- Geographic extent of the effects is limited to the PDA area due to scale limiting any transfer of effects up- or downstream of the Elbow River and the low-level outlet in a measurable way.
- Frequency of the effect is continuous, given the permanent nature of the Project.
- The duration of the effect is long-term, given the permanent nature of the Project.
- The effects are irreversible, given the permanent nature of the Project.
- The ecological and socio-economic context is disturbed because the PDA has been previously disturbed by human development.
- Timing is not applicable because effects from Project activities would be similar regardless of season or other timing characteristics

6.5.4 Summary of Project Residual Effects

The residual environmental effects on hydrology during construction and dry operations are summarized in Table 6-12.

Table 6-12 Project Residual Effects on Hydrology during Construction and Dry Operations

Residual Effect	Residual Effects Characterization								
	Project Phase	Timing	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological and Socio-economic Context
Change in Hydrology	C, DO	S	N	N	PDA	LT	C	I	D
Change in Sediment Transport	C, DO	N/A	N	N	PDA	LT	C	I	D

KEY

See Table 6-2 for detailed definitions

Project Phase
C: Construction
DO: Dry Operation

Timing consideration
S; Seasonality
T: Time of day
R: Regulatory

Direction:
P: Positive
A: Adverse
N: Neutral

Magnitude:
N: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Duration:
ST: Short-term;
MT: Medium-term
LT: Long-term

N/A: Not applicable

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Ecological/Socio-Economic Context:
D: Disturbed
U: Undisturbed

6.6 DETERMINATION OF SIGNIFICANCE

The effects of the Project on hydrology during construction and dry operations, given mitigation measures and monitoring during construction in the PDA, are not significant. Variations in hydrology and sediment transport are expected to have a <15% change from existing conditions and as a result, are likely not measurable within reasonable accuracy or detected by environmental receptors. Should an increase in suspended sediment concentrations occur, it would be mitigated immediately or the work halted until mitigation is in place.

6.7 PREDICTION CONFIDENCE

Prediction confidence of construction effects on hydrology is high because the effects on hydrology from construction involving earthworks and instream work are generally known and the mitigation measures are well established. Because Elbow River flows are unaltered during dry operations, the prediction confidence of dry operation effects on hydrology is also high. Prediction confidence of construction effects on sediment transport is high because effects from construction involving earthworks and instream work are generally known and the mitigation measures are well established.

Prediction confidence of dry operations on sediment transport is moderate because of the spatial and temporal variability in sediment transport and data limitations. The influence of historical large floods, such as 2013, on sediment availability and caliber, as well the influence of debris transport during high flows can alter sediment transport dynamics beyond what has been observed. Overall, the prediction confidence for sediment transport is moderate to reflect this variability.

6.8 CONCLUSIONS

6.8.1 Change in Hydrology

Changes in hydrology (water quantity) and sediment transport during construction and dry operations of the Project were evaluated at the LAA and RAA scale. Due to the limited nature of Project interactions with hydrology during these phases, the residual effects on hydrology have been assessed to be not significant with a high degree of confidence.

6.8.2 Change in Sediment Transport

Changes in sediment transport during construction and dry operations of the Project were evaluated at the RAA (watershed) scale. Due to the limited nature of Project interactions expected with sediment transport during these phases, the residual effects on sediment transport have been assessed to be not significant with a moderate degree of confidence.

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