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Abbreviations

3D	three-dimensional
3D CSM	three-dimensional conceptual site model
AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
AGS	Alberta Geologic Survey
AWWID	Alberta Water Well Information Database
BGL	below ground level
BGP	base of groundwater protection
BTEX	benzene, toluene, ethylbenzene, xylenes
CEA Agency	Canadian Environmental Assessment Agency
EPEA	Environmental Protection and Enhancement Act
GCDWQ	Guideline for Canadian Drinking Water Quality
GSC	Geological Survey of Canada
HCL	Hydrogeological Consultants Ltd.
LAA	local assessment area
m asl	metres above sea level
NRCB	Natural Resource Conservation Board
PDA	project development area
PFRA	Prairie Farm Rehabilitation Administration
RAA	regional assessment areas
TDS	total dissolved solids
VC	valued component

5.0 ASSESSMENT OF POTENTIAL EFFECTS ON HYDROGEOLOGY

Groundwater is an integral part of the hydrologic system and serves as a water resource that supports both the ecologic function within a watershed, and a variety of human land uses including residential, agricultural, commercial and industrial uses. Groundwater can be used as a source of raw water for domestic supply, and many rural landowners who are not serviced by municipal supplies rely on groundwater to meet their water demands. Groundwater also interacts with surface water resources in the vicinity of rivers, lakes, or wetlands and can serve as baseflow contributions to their water balances throughout the hydrologic year.

5.1 SCOPE OF THE ASSESSMENT

5.1.1 Regulatory and Policy Setting

In Alberta, groundwater resources are generally regulated under provisions of the *Water Act*, which outlines the process for licensing of consumptive non-saline groundwater use, and under provisions of the *Environmental Protection and Enhancement Act* (EPEA), which includes means to protect groundwater resources through approvals issued for industrial, municipal, or other developments. Numerous other regulations, policies, directives, and guidelines also exist that serve to promote sustainable use and management of groundwater resources. Some policies, directives, and guidelines are under the purview of Alberta Environment and Parks (AEP), while others fall under the regulatory authority of other Government of Alberta agencies or boards. Many of these policies, directives, and guidelines are specific to a particular type of development (e.g. energy developments in the case of the Alberta Energy Regulator directives; livestock operations in the case of Natural Resource Conservation Board (NRCB) guidelines) and may not be directly applicable to the Project. Nevertheless, these policies, directives, and guidelines serve to provide best management practices or hydrogeological assessment guidance in the spirit of groundwater resource protection.

The scope of the hydrogeology assessment has been developed in accordance with the terms of reference issued by AEP for an environmental assessment of the Project. Specifically, Section 3.3 of the terms of reference addresses requirements for hydrogeology.

The scope of the hydrogeology assessment has also been developed in accordance with the guidelines for an environmental impact statement issued by the Canadian Environmental Assessment Agency (CEA Agency) for the Project. Specifically, Sections 6.1.4 and 6.2.2 of the guidelines address requirements for the hydrogeology assessment.

5.1.2 Engagement and Key Concerns

Alberta Transportation carried out an engagement and consultation program for the Project with both the public and Indigenous communities. Engagement summaries are presented in Volume 1, Section 6 and Section 7. .

Issues and key concerns related to hydrogeology raised by the public include the following:

- protection of groundwater resources is of importance to local landowners due to their reliance on groundwater for potable and agricultural uses.
- the potential for the Project to interact with groundwater resources is cause for concerns related to effects on water well yields, groundwater quality, springs, wetlands, agricultural productivity and interaction with surface water resources.

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 Canadian Environmental Assessment Agency (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.

The Tsuut'inna Nation raised concerns related to SR1 on Tsuut'ina's ground and surface water.

The Stoney Nakoda Nations noted that "that they used to listen to the bison moving. There are pockets of underground streams, and they listened to the vibration. The oral history told us about the water table and flood plain". The Stoney Nakoda Nations expressed concerns about the hydrology of the SR1 area, particularly with the Elbow River and potential ground water impacts.

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. In addition to project-specific sources, publicly-available literature was reviewed for TLRU information relevant to the Project.

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 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 hydrogeology, as reported by Indigenous groups and through the review of Project-specific and publicly-available TLRU information, include:

- the potential for the Project to affect groundwater quality within the alluvial deposits in the Elbow River Valley
- the potential for effects on shallow groundwater levels near the Project during flood events
- the potential for the Project to affect the availability of groundwater for domestic use

As of January 1, 2018, no project-specific intangible concerns were identified with respect to hydrogeology.

5.1.3 Potential Effects, Pathways and Measurable Parameters

The value of groundwater resources can be broadly evaluated through two characteristics: groundwater quantity and groundwater quality. Groundwater quantity refers to the availability of groundwater at a given rate for production and use, and it varies widely depending upon the local geologic setting, hydrogeological conditions and past/current groundwater use. Groundwater quality refers to the chemical composition of groundwater and its suitability for various uses and also varies widely depending upon the local geologic setting, hydrogeological conditions, and past/current land use practices that may contribute to anthropogenic effects.

In evaluating effects on groundwater resources, both quantity and quality need to be considered together. For example, abundant groundwater (i.e., high quantity) may not be of meaningful value if its quality precludes its use. Similarly, high quality groundwater may not be of meaningful value if it is not available in sufficient quantity for a given use.

Effect pathways describe the mechanism through which the Project can cause a potential effect on groundwater resources through physical infrastructure or associated activities. Effects pathways can change throughout the phases of the Project, depending upon the activities and physical infrastructure present within a given timeframe. As such, effect pathways discussed in this section are limited to those that are relevant during the construction and dry operations phases of the Project.

Measurable parameters are a means through which change in groundwater quantity or quality can be characterized. The measurable parameter for a change in groundwater quantity is the potentiometric head (measured as an elevation above sea level) in a given hydrostratigraphic unit. Potentiometric head controls the movement of groundwater in the subsurface and is directly related to the availability of groundwater for use. Potentiometric head can be readily measured in water wells and can be interpreted to understand potential spatial or temporal variation in groundwater quantity.

Changes in groundwater quality can be assessed through examination of a wide range of water quality parameter concentrations. Parameter concentrations can readily be determined from laboratory analysis of groundwater samples collected from water wells and the analysis results can be used to understand spatial and temporal variation in groundwater quality.

Table 5-1 presents the potential effects, pathways and measurable parameters for the hydrogeology.

Table 5-1 Potential Effects, Effects Pathways and Measurable Parameters for Hydrogeology

Potential Environmental Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in groundwater quantity	Interactions between the Project and groundwater quantity can include: • groundwater withdrawals for construction dewatering • groundwater seepage into open excavations • groundwater seepage into the diversion channel when dry	Potentiometric head (measured in metres above sea level)
Change in groundwater quality	Interactions between the Project and groundwater quality can include: • changes to groundwater quantity or flow patterns that can in turn affect groundwater quality • groundwater contamination related to construction activities	Various water quality parameters (variable units of measure, including aqueous concentrations, pH units, conductivity, and others)

5.1.4 Boundaries

The following spatial and temporal boundaries are used in the assessment.

5.1.4.1 Spatial Boundaries

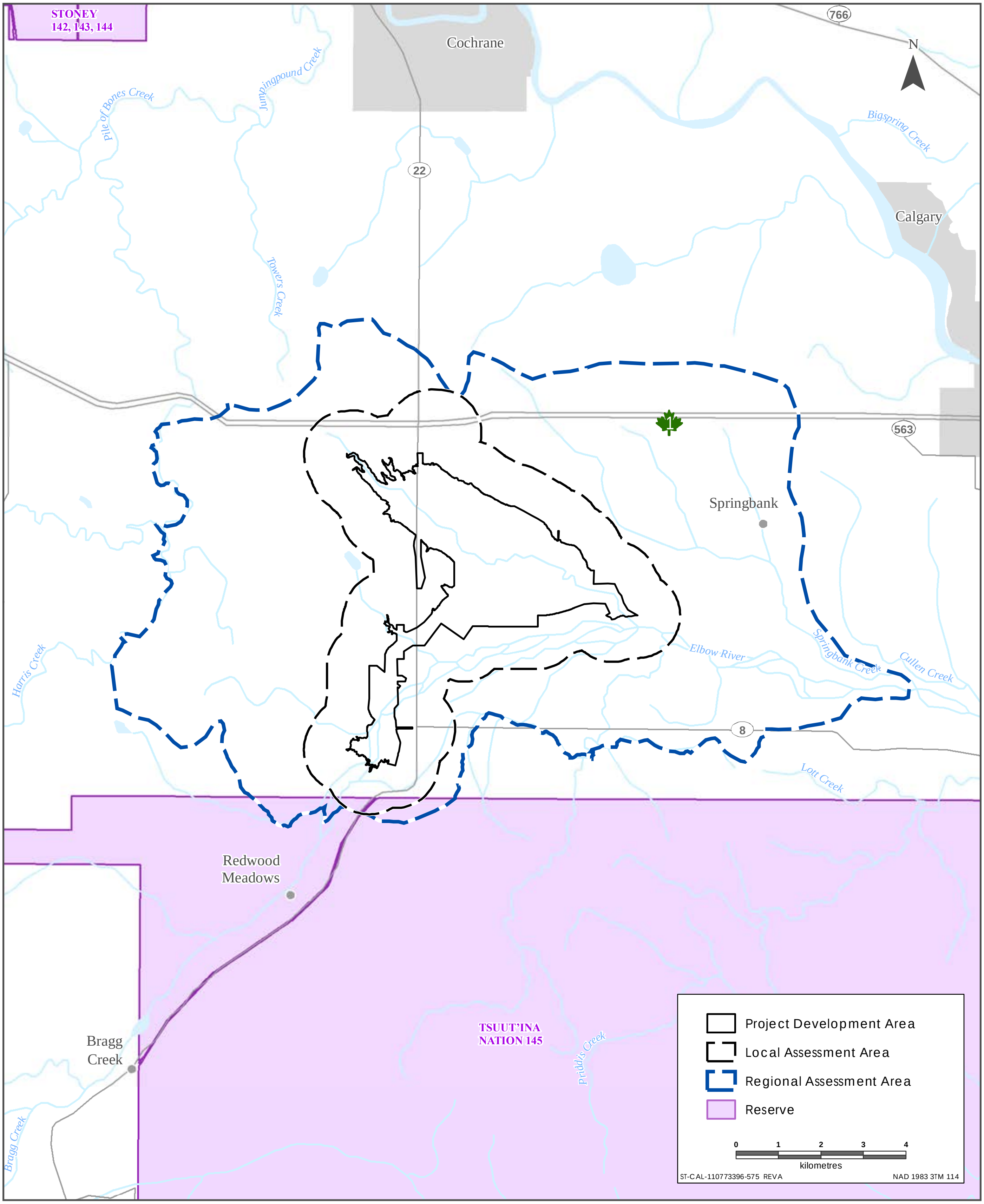
The groundwater resources assessment areas are defined as follows and are depicted in Figure 5-1:

- The project development area (PDA) for hydrogeology is the immediate area of Project activities. The PDA is limited to the anticipated area of physical disturbance associated with the construction and operation of the Project. The PDA is approximately 1,438 ha and includes:
  - the diversion structure (0.36 ha)
  - diversion channel (64.23 ha)

  - off-stream dam (42.47 ha)
  - low-level outlet works (0.04 ha)
  - off-stream reservoir (816.03 ha, the maximum possible backflooding area)
  - internal access roads and borrow areas
- The local assessment area (LAA) includes the PDA and a nominal one kilometre buffer surrounding the PDA to address potential localized hydrogeological effects, such as water level and water quality changes near to the construction areas and localized seepage into the diversion channel during dry operations. The LAA is reduced where the buffer extends outside of the floodplain and terrace of the Elbow River to the south.
- The regional assessment areas (RAA) is 14,000 ha and is based on the regional hydrogeological conditions and boundary conditions for the numerical groundwater model. Lateral extent of the RAA is bounded by:
  - a surface and shallow groundwater flow divide in the north
  - a boundary to the northwest to encompass the subwatershed of three small tributaries to the Elbow River
  - the floodplain and terrace of the Elbow River to the south
  - Jumpingpound Creek to the west

5.1.4.2 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.



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

Hydrogeology Spatial Boundaries

Figure 5-1

5.1.5 Residual Effects Characterization

Table 5-2 presents definitions for residual environmental effects on hydrogeology. These terms are used in this effects assessment to characterize and describe the nature of potential residual effects on groundwater resources.

Table 5-2 Characterization of Residual Effects on Hydrogeology

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 groundwater resources relative to baseline. adverse – a residual effect that changes measurable parameters in a direction detrimental to groundwater resources relative to baseline. neutral – no net change in measurable parameters for groundwater resources relative to baseline.
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	Negligible – no measurable change in potentiometric head or groundwater quality parameters Low – a measurable change in potentiometric head or groundwater quality parameters, but within the range of expected natural variability Moderate – measurable change groundwater quantity as measured by the potentiometric head beyond the range of expected natural variability, but does not materially alter groundwater flow patterns or lead to an exceedance of an applicable water quality guideline High – measurable change of in potentiometric head beyond the range of expected natural variability that materially alters groundwater flow patterns or a measurable change in groundwater quality parameters beyond the range of expected natural variability that directly leads to and exceedance of an applicable water quality guideline for those parameters which did not exceed the guideline under baseline conditions
Geographic Extent	The geographic area in which a residual effect occurs	PDA – residual effects are restricted to the PDA LAA – residual effects extend into the LAA RAA – residual effects potentially interact with those of other projects in the RAA

Table 5-2 Characterization of Residual Effects on Hydrogeology

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 – occurs once 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 restricted to 36 months (construction phase) or less Medium-term – residual effect extends through the construction phase but not beyond one year following construction Long-term – residual effect extends beyond the construction phase and for the life of the project
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

5.1.6 Significance Definition

A significant adverse residual effect on groundwater quantity is defined as a measurable change in groundwater quantity that decreases the yield from an existing and otherwise adequate groundwater supply well to the point where it is inadequate for its intended use.

A significant adverse residual effect on groundwater quality is one where the quality of groundwater from an otherwise adequate water supply well that meets guidelines deteriorates to the point where it becomes non-potable or cannot meet the Guidelines for Canadian Drinking Water Quality (Health Canada 2012) for a consecutive period exceeding 30 days.

Residual effects on groundwater resources can in turn cause effects on other VCs. For example, long term changes in the groundwater table could lead to changes in the soil moisture profile, or changes in surface water interactions near wetland features. Where residual effects on groundwater resources could lead to secondary effects on other VCs, the significance determination for those secondary effects are presented in their respective VC sections.

5.2 EXISTING CONDITIONS FOR HYDROGEOLOGY

This section provides an overview of hydrogeological conditions in the project area based on previously available hydrogeological information available for the region, historical reports available for the PDA, and the results of a hydrogeological field program completed specifically to support this effects assessment.

A more detailed description of the methodologies used to develop the hydrogeological framework, the hydrogeological field program executed for this Project, and interpretation of results is presented in Volume 4, Appendix I, Hydrogeology Baseline Technical Data Report (TDR).

5.2.1 Methods

The first step in developing the hydrogeological framework for the RAA involved the compilation of hydrogeological data available from publicly accessible sources. Report and mapping products and online data available from the Alberta Geological Survey (AGS), former Alberta Research Council, Prairie Farm Rehabilitation Administration (PFRA), AEP, the Geological Survey of Canada (GSC) and other published papers were reviewed and relevant hydrogeological information for the RAA was extracted. Additional information from previous hydrogeological and geotechnical studies conducted for the Project were also included in the historical information review. This information was compiled into a centralized geodatabase and was used to develop a preliminary conceptual model of the hydrogeological framework for the study area and identify data gaps that could be addressed by a hydrogeological field program.

The hydrogeological field program was developed to address data gaps noted during the historical data review in consideration of the project description, preliminary engineering designs and operational procedures. The planned geotechnical field program was also reviewed to reduce redundancies in drilling locations such that information from both investigations (hydrogeological and geotechnical focused) could be better leveraged.

A total of 32 boreholes and monitoring wells were completed over the course of the hydrogeological field program. An additional 125 boreholes were completed during the geotechnical field program and that information was also incorporated into hydrogeological interpretations. The shallower monitoring wells were installed with screened intervals within the first water-bearing unit encountered. The deeper (bedrock) monitoring wells were installed in the first water-bearing bedrock unit, excluding the weathered upper portion of the bedrock, which was generally in hydraulic communication with the unconsolidated deposits.

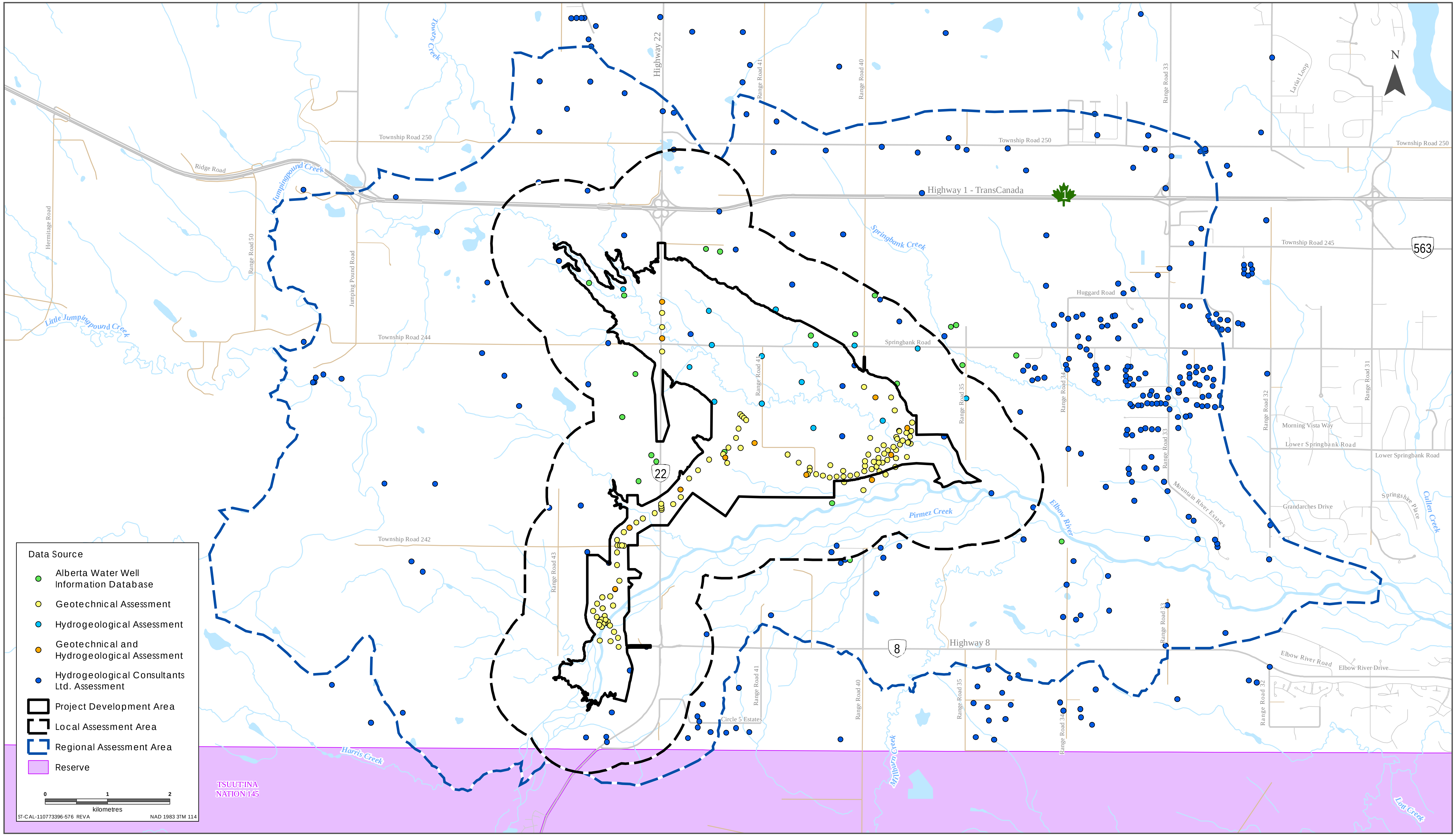
Following drilling and monitoring well completion, field testing for hydraulic conductivity by single well response tests was completed on 15 monitoring wells. In addition to the single well response tests, packer testing was completed as part of the geotechnical drilling program. A total of 37 single packer permeability tests were conducted in five boreholes to determine the permeability of the bedrock interval.

Groundwater monitoring and sampling was completed on 31 of the new monitoring wells installed. Thirty-three groundwater samples were collected for analysis of a broad suite of analytical parameters including routine major ions, dissolved metals, nutrients, various organic parameters including benzene, toluene, ethylbenzene, xylenes (BTEX) and F1 to F2 fraction hydrocarbons, and bacteriological parameters.

Data logging pressure transducers were installed in 10 monitoring wells during the groundwater monitoring program to record pressure data. One barometric pressure transducer was also deployed to record atmospheric pressure required to correct the pressure data from the other transducers. All loggers were set to record pressure data on an hourly basis.

After the hydrogeological field program was completed, the information was compiled with the geotechnical investigation results and previously existing hydrogeological information. All sources of hydrogeological information were then used to develop a three-dimensional conceptual site model (3D CSM) using Leapfrog Hydro geomodelling software. The 3D CSM allows for more effective conceptualization and illustrates the relationships between the geology, hydrogeology, monitoring wells and other physical features of the RAA. Modelling information and results are presented in the Hydrogeology Modelling TDR (Volume 4, Appendix I).

Figure 5-2 presents the distribution of the monitoring wells, Alberta Water Well Information Database (AWWID) drilling records and Hydrogeological Consultants Ltd. ([HCL] 2002) bedrock picks across the 3D CSM domain.



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

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Lithological Data Used in the 3D CSM

Figure 5-2

5.2.2 Overview of Existing Hydrogeological Conditions

5.2.2.1 Hydrostratigraphic Framework

The following is a summary of the baseline hydrogeological conditions from Volume 4, Appendix I, Hydrogeology Baseline TDR.

A regional stratigraphic column presenting the generalized stratigraphy beneath the RAA is presented in Figure 5-3. Brief descriptions of each of the stratigraphic units along with discussion of the additional salient features of the model are presented below.

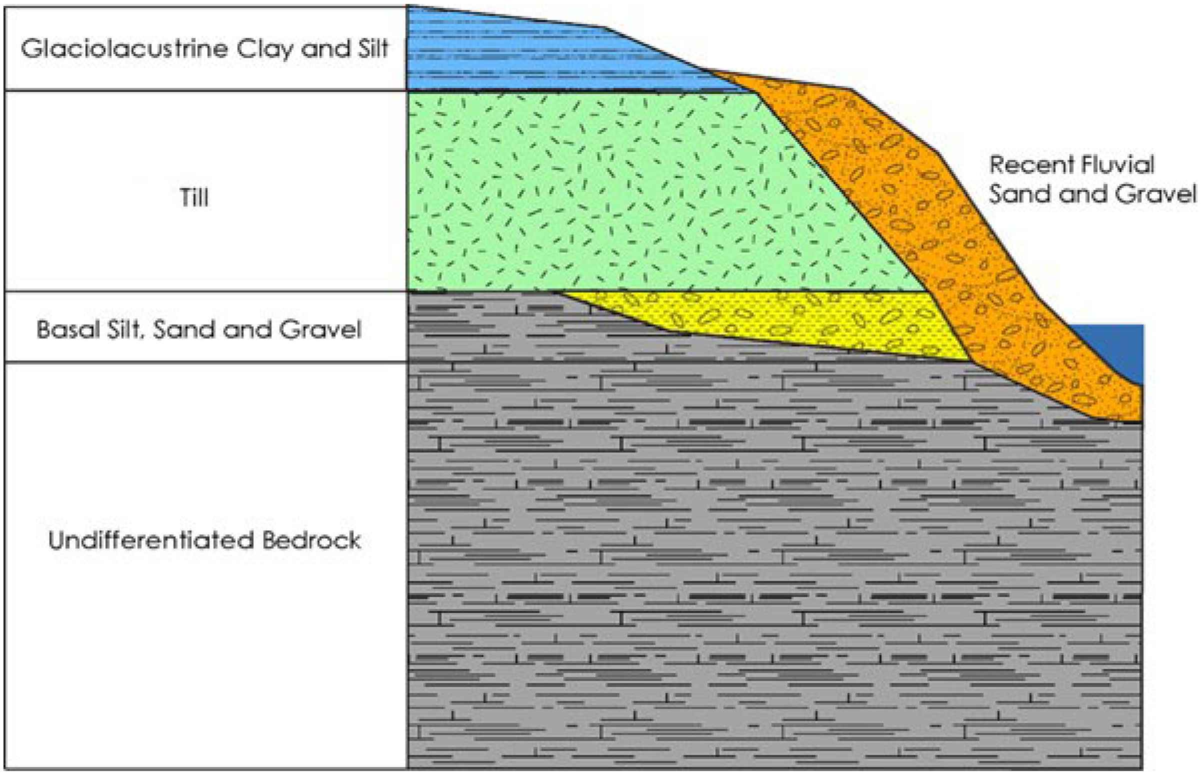


Figure 5-3 Regional Stratigraphic Column

Bedrock

The RAA is located in the "disturbed belt" of Alberta, which forms a transitional zone (foothills) between the Rocky Mountains to the west and prairie to the east. Bedrock topography is presented in Figure 5-4. The approximate subcrop boundaries of the bedrock units presented in Figure 5-4 are based on regional mapping by Pana and Elgr (2013).

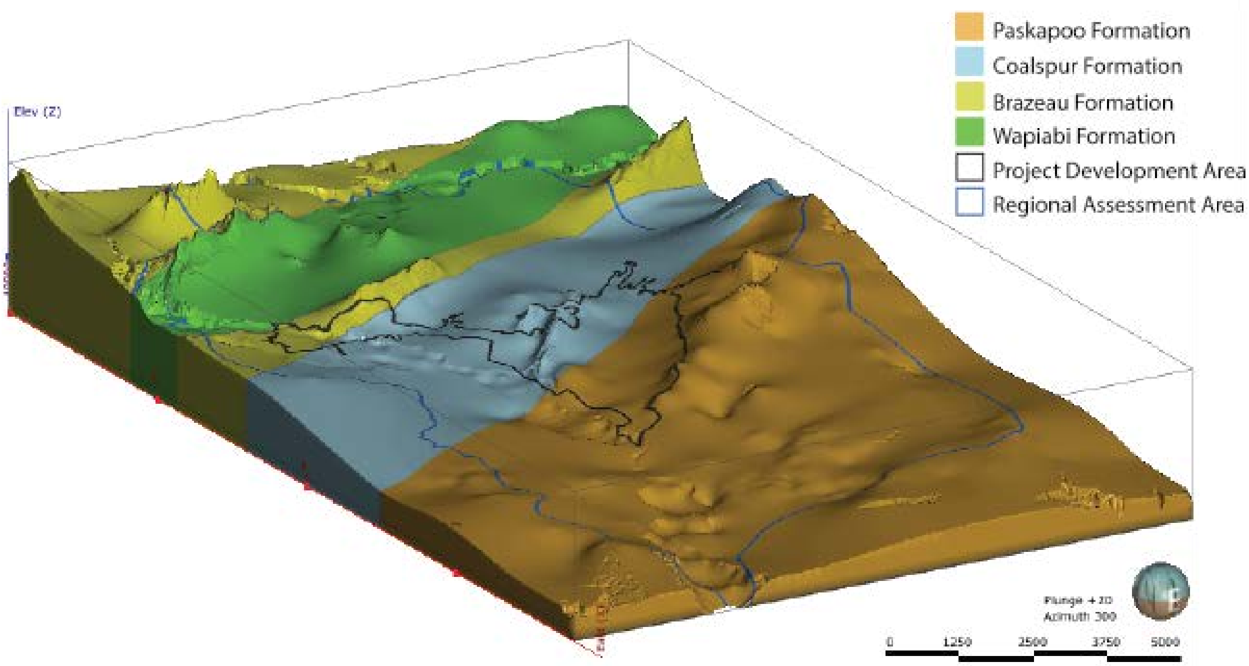


Figure 5-4 Bedrock Topography and Subcrop Formations

The bedrock units encountered beneath the Quaternary deposits from west to east (also oldest to youngest) across the RAA are:

- The Wapiabi Formation—The Upper Cretaceous aged Wapiabi Formation of the Alberta Group is generally composed of shale and mudstone with minor siltstone with the exception of the Chungo and Marshybank members, which are sandstone dominated (Pana and Elgr 2013).
- The Brazeau Formation—The Upper Cretaceous aged Brazeau formation is primarily composed of sandstone and laminated siltstone along with olive green mudstone and granule to pebble conglomerate in the lower part. The upper part is composed of greenish-grey to dark grey mudstone, siltstone and greenish grey sandstone. Thin coal and coaly shale beds and thin bentonite layers are also found in the upper part (Prior et al. 2013). In the foothills, the Brazeau is the approximate lateral equivalent of the Scollard Formation on the plains (Hamblin 2010).

- The Coalspur Formation—This Upper Cretaceous to Tertiary aged deposit formed as a marginal marine fluvial infill of the foreland basin. The Coalspur Formation is composed of thinly bedded to massive sandstone, siltstone, light grey to olive green mudstone, shale, coaly shale, coal seams and minor volcanic tuff in the lower portions (Pana and Elgr 2013).
- The Paskapoo Formation—The Tertiary aged Paskapoo Formation is made up of thick tabular sandstone, siltstone and mudstone (Glass 1990). The sandstones are fine to coarse grained and cliff forming. The Paskapoo Formation also contains a significant amount of shale, carbonaceous shale, siltstone, rare coals seams, and shell beds (Pana and Elgr 2013). In the central Rocky Mountains and foothills the Paskapoo is dominated by recessively weathering; grey to greenish-grey mudstone and siltstone with subordinate pale grey, thick- to thin-bedded and commonly cross-stratified sandstone; and minor conglomerate, mollusc coquina (soft porous limestone composed of broken shells), and coal (Prior et al. 2013). The Paskapoo Formation is the primary bedrock aquifer in the Elbow River watershed. Due to the stratigraphy of the layers of sandstone and shale present within this formation, multiple aquifers can be found at various depths in the rock (Waterline 2011). In the RAA, the yield value for the Paskapoo Formation aquifer is 35 m^3/day -175 m^3/day (Waterline 2011).

Unconsolidated Deposits Above Bedrock

Unconsolidated deposits above the bedrock surface in the RAA include till, glaciolucustrine deposits, and recent fluvial deposits. A brief description of these unconsolidated units is presented below. A more detailed description of each of these units, together with isopach maps and geologic cross sections is presented in Volume 4, Appendix I, Hydrogeological Baseline TDR.

Based on the field observations and laboratory grain size analyses completed as part of the geotechnical drilling program, the till is composed of a heterogeneous mixture of approximately equal parts clay and silt, a lower proportion of sand, and minor gravel. Silt and sand lenses are also present within the heterogeneous matrix. The till is described as generally stiff to very stiff or hard, medium to high plastic clay with silt and more minor sand.

In some portions of the LAA, there is a coarser grained unit at the base of the till. This unit is most prominent near the Elbow River Valley and consists of a mixture of sand, silt and gravel. It is thought that these deposits are of preglacial or subglacial fluvial origin.

Glaciolacustrine clay overlies the till in the low lying areas of the LAA. Within the LAA, the glaciolacustrine clay averaged 5.3 m thick in the boreholes where is was encountered. Based on the field observations and laboratory grain size analyses, the glaciolacustrine clay in the LAA is generally composed of 50%-70% clay, 30%-40% silt and a minor proportion of sand. Typical of a lacustrine deposit, the clay was found to be laminated with silt and fine sand. This layering has resulted in relatively high hydraulic conductivities compared to the underlying till.

Post-glacial fluvial channel sediments can be found within the Elbow River valley in the southern part of the RAA and the Jumpingpound Creek in the west. These sediments developed as the rivers exported eroded material from upstream areas and deposited coarse alluvium (sand and gravel) on their floodplains. The deposition of alluvium over Quaternary deposits or bedrock in the valleys resulted in formation of alluvial aquifers.

Figure 5-5 presents an overview of the distribution of the unconsolidated deposits in the RAA, based on the 3D CSM. More detailed figures presenting the distribution of each of the unconsolidated units, isopach maps, and geologic cross sections across the RAA are presented in Volume 4, Appendix I, Hydrogeological Baseline TDR.

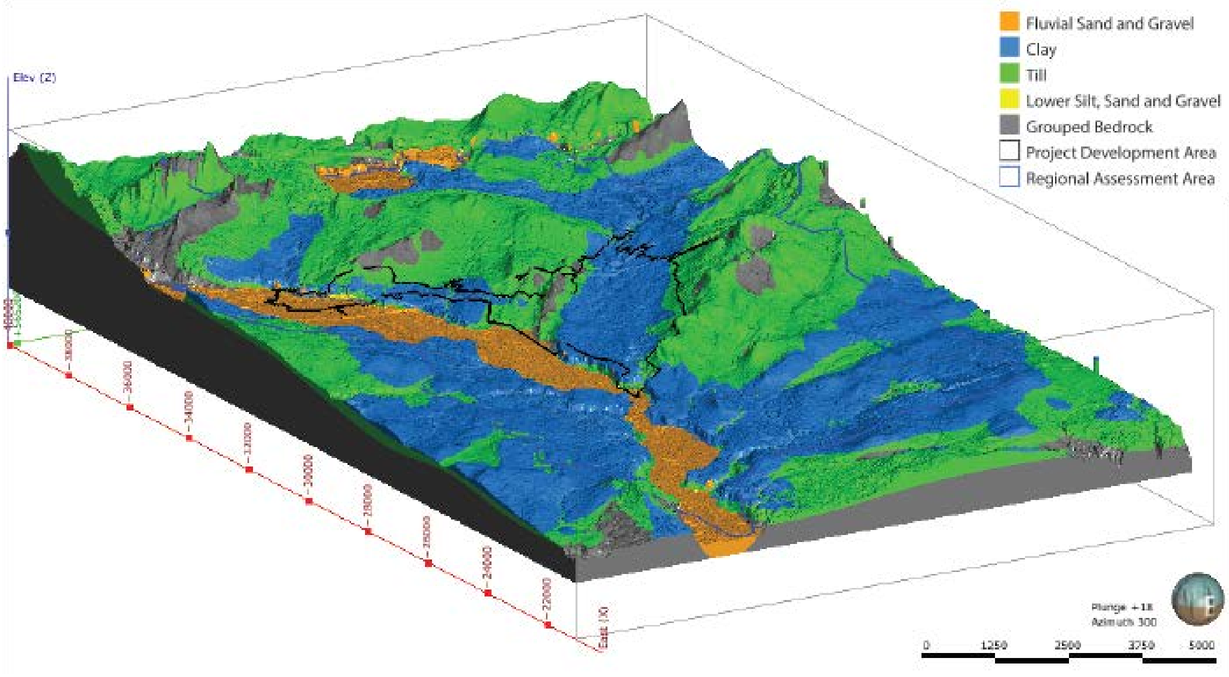
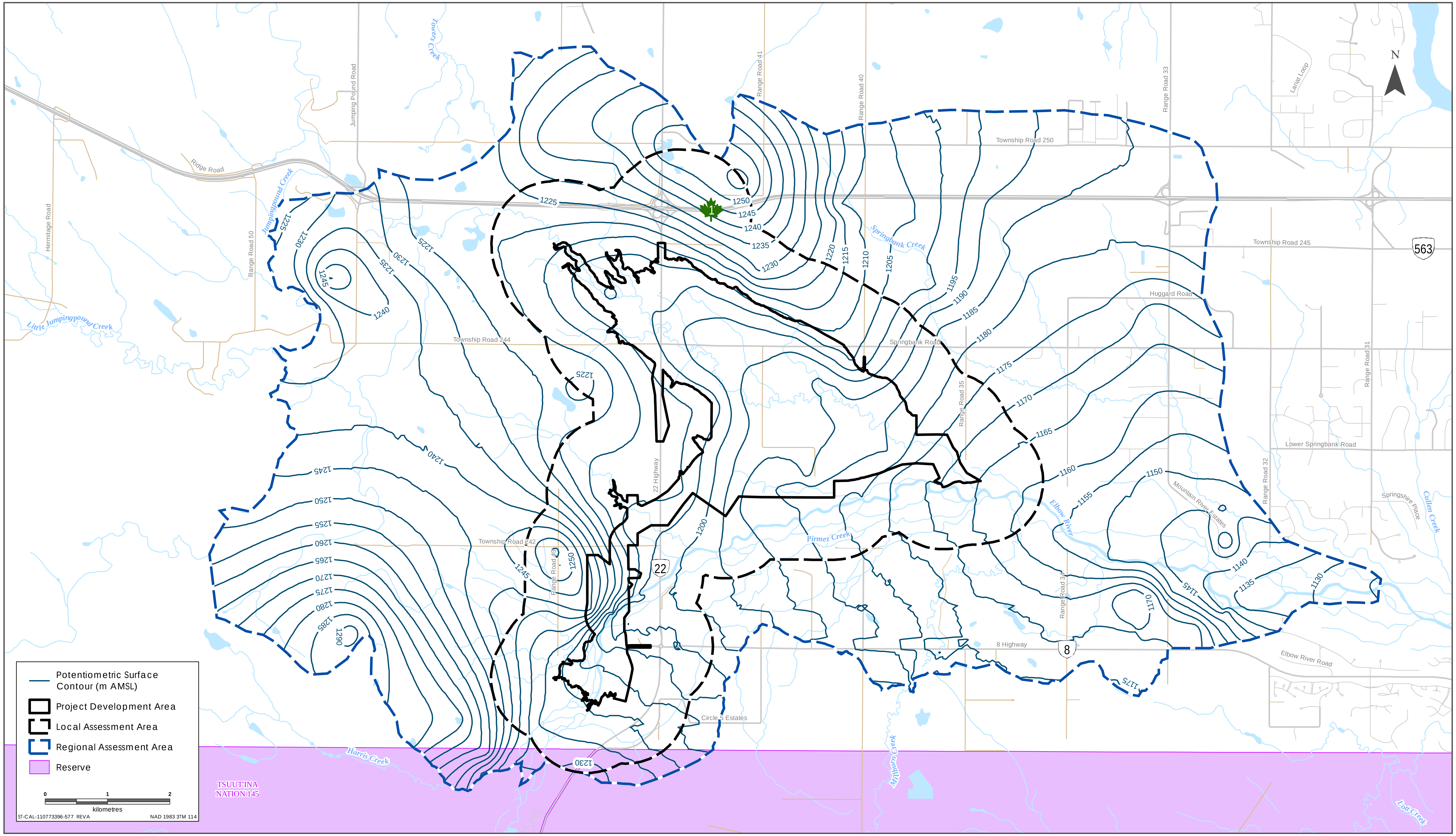


Figure 5-5 Distribution of Unconsolidated Deposits in the RAA

5.2.2.2 Groundwater Flow in the RAA

Groundwater Flow in the Unconsolidated Deposits

The potentiometric surface of the unconsolidated surficial aquifer is presented in Figure 5-6. Groundwater elevations within the surficial aquifer generally follow the topography and range from approximately 1,290 m asl in the southwest to 1,125 m asl along the eastern boundary of the RAA. Groundwater depths measured in monitoring wells completed in the unconsolidated deposits ranged for ground surface to 8.0 m below ground level (BGL).



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

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Potentiometric Surface of the Unconsolidated Deposits

Figure 5-6

Groundwater flow direction in the unconsolidated deposits is interpreted to be toward the Elbow River across the majority of the RAA, with the exception of areas in the northwest where shallow groundwater flows west toward Jumpingpound Creek and areas along the north side of the RAA across the flow divide and in the Bow River watershed where groundwater flows north. Apparent horizontal gradients beneath the LAA range from 0.003 in the central portion of the proposed reservoir to 0.1 in the southern portion of the LAA adjacent to the Elbow River near the proposed diversion structure.

A number of potential springs were identified based upon visual examination of the air photos combined with the surface topographic layer in the 3D CSM. These potential springs (blue dots) were identified along the northeast side of the reservoir area (outlined in black) as indicated in Figure 5-7. Based on the drilling program, these springs are interpreted to be contact springs with groundwater flow in the unconsolidated deposits discharging where the underlying low permeability bedrock material is near surface along the valley wall. As groundwater flows along this contact, downward flow is limited and the water discharges along the toe of the slope, forming the springs. The elevation of these springs ranges from approximately 1,205 m asl in the southeast to 1,225 m asl further northwest along the valley wall. At least one contact spring was also identified in the field along the southwest valley wall of the reservoir. This spring location is plotted in Figure 5-7 and is at an elevation of approximately 1,211 m asl. Further downslope from the contact springs, gravity springs also occur where the potentiometric surface intersects the ground surface.

The average linear groundwater velocity in the unconsolidated glaciolacustrine deposits and till is estimated to range from less than 1 cm/yr to approximately 230 cm/yr. However, flow velocities through sand lenses within, or at the base of the till could be higher.

Groundwater Flow in the Upper Bedrock Aquifers

The potentiometric surface of the bedrock aquifer is presented in Figure 5-8. The hydraulic head data points used in the interpretation are also presented in the figure. Potentiometric surface elevations range from approximately 1,300 m asl in the southwest to 1,123 m asl along the eastern boundary of the RAA.

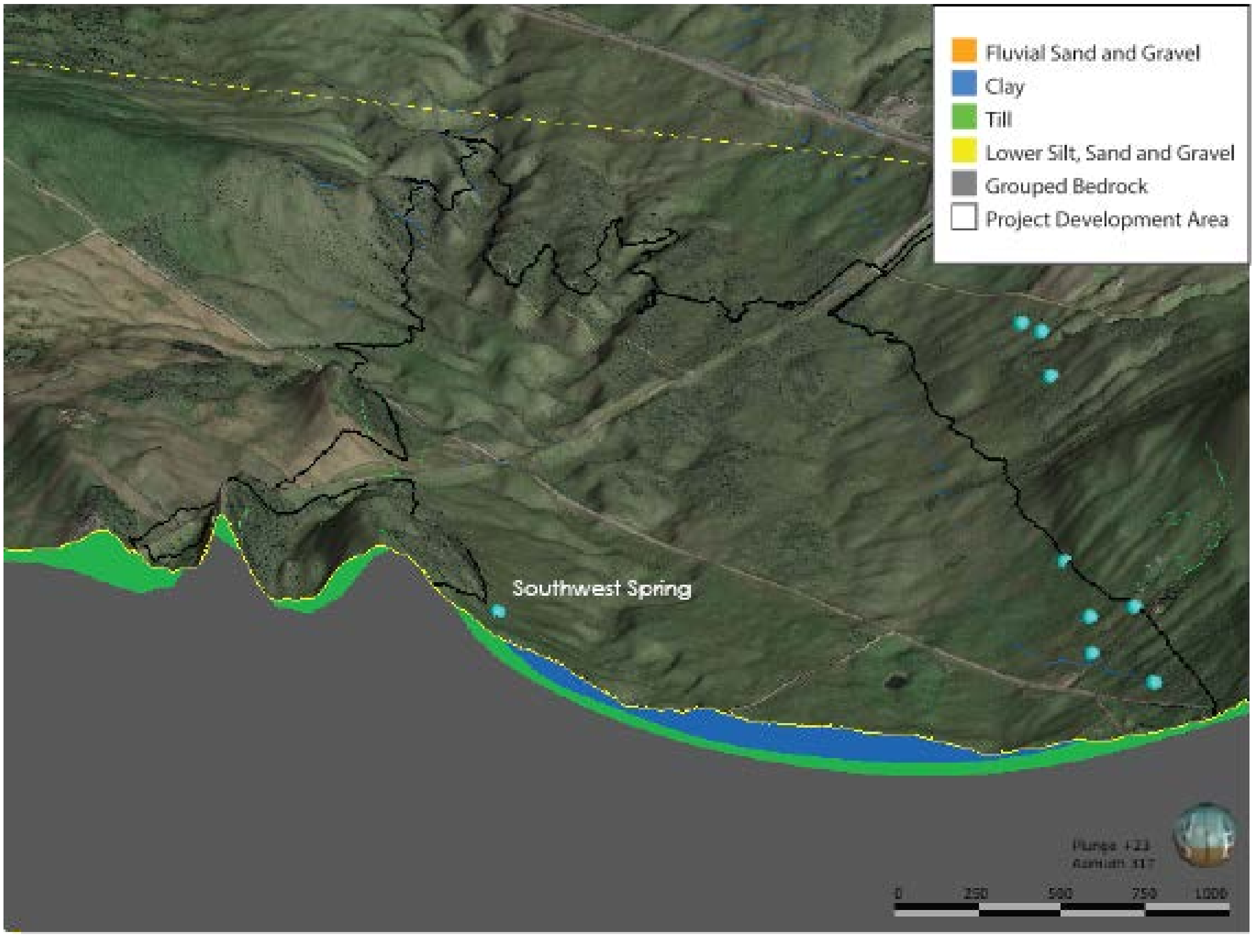
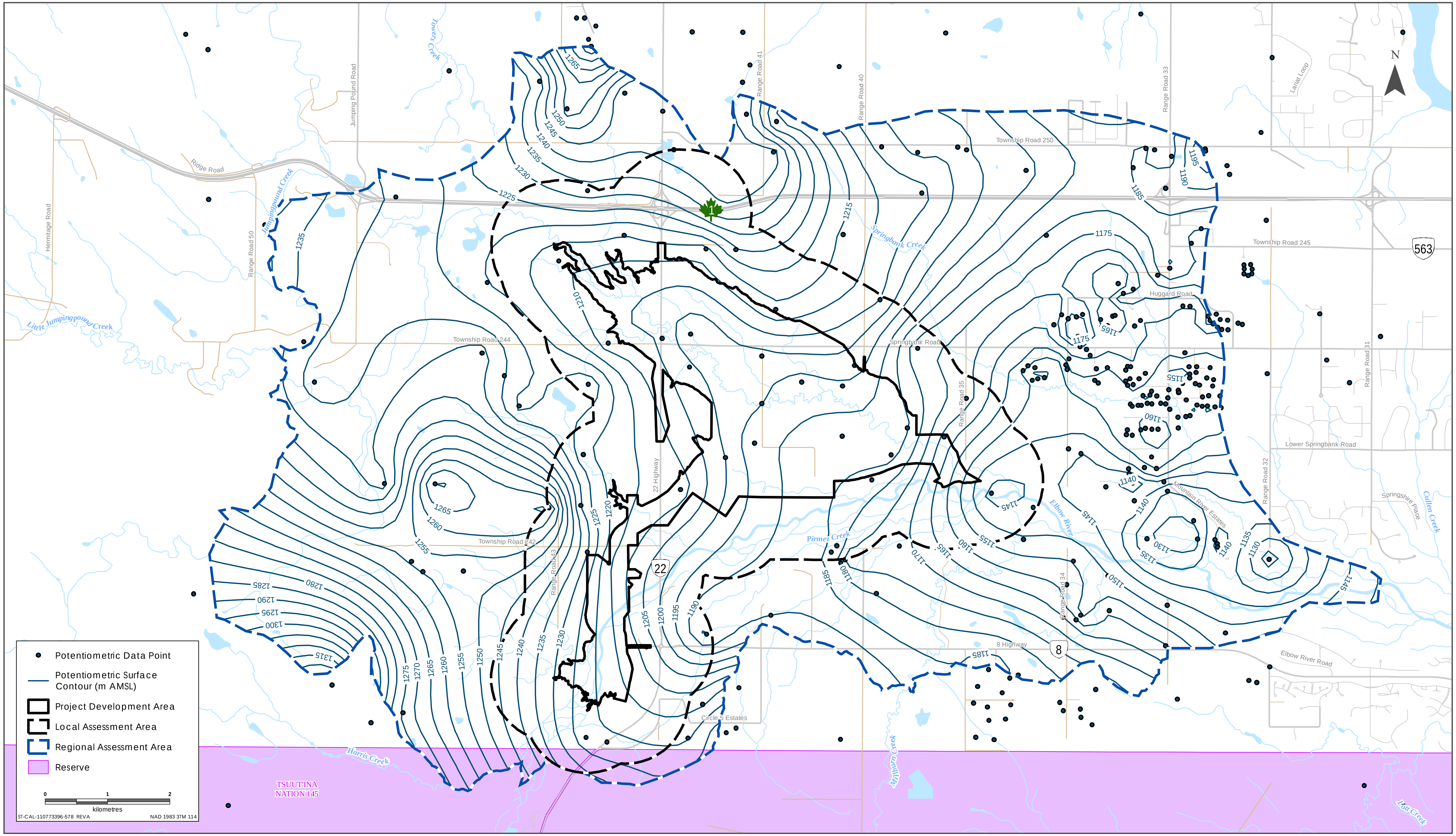


Figure 5-7 Suspected Spring Locations



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

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Potentiometric Surface of the Upper Bedrock

Figure 5-8

Groundwater flow direction in the bedrock is also toward the Elbow River across the majority of the RAA. Groundwater elevations within the upper bedrock generally follow the topography although the relationship is more muted compared to the potentiometric surface of the unconsolidated deposits. Apparent horizontal gradients in the upper bedrock aquifers beneath the LAA range from 0.005 in the central portion of the proposed reservoir to 0.02 in the southern portion of the LAA, adjacent to the Elbow River near the diversion structure.

The average linear groundwater velocity in the shallow bedrock is estimated to range from less than 1 cm/yr in the unfractured portions of the claystone bedrock to approximately 3,000 cm/yr in the more permeable sandstone in the areas of higher hydraulic gradient near the Elbow River.

5.2.2.3 Groundwater Quality

The following sections present a summary of groundwater quality results for the RAA. Detailed discussion of groundwater is presented in Volume 4, Appendix I. Hydrogeology Baseline TDR. The results of chemical analysis of groundwater samples have been compared to the Guideline for Canadian Drinking Water Quality (Health Canada 2012) and the Alberta Tier 1 Soil and Groundwater Remediation Guidelines (Alberta Environment and Parks 2016).

Groundwater Chemistry of the Unconsolidated Deposits

Seventeen groundwater samples were collected from wells completed in the unconsolidated deposits in the LAA. The TDS concentrations in the unconsolidated deposits ranged from 640 to 6,900 mg/L with an average concentration of 2,381 mg/L. These TDS concentrations exceed both referenced guidelines and are considered slightly to moderately saline. At three locations, the TDS concentrations exceeded the definition of “fresh water” (TDS<4,000 mg/L) under the Alberta’s Water (Ministerial) Regulation.

Based on the groundwater analysis results, there is no dominant cation characteristic of the unconsolidated deposits. Sodium concentrations are relatively high with 10 of 17 samples exceeding the 200 mg/L guidelines. Sulphate is the dominant anion in 12 samples with bicarbonate dominating the remaining five. The average sulphate concentration was 1,444 mg/L with the majority of samples exceeding referenced guidelines (500 mg/L). Chloride concentrations were low in the majority of samples, ranging from 1.6 to 17 mg/L with two exceptions (230 mg/L and 72 mg/L). These values are below the guideline value of 250 mg/L.

Nutrient concentrations including ammonia, nitrate, nitrite, phosphate and total Kjeldahl nitrogen were analyzed because they are contaminants of potential concern in agricultural settings. Nutrient concentrations were low in all samples with the exception of one monitoring well reporting nitrite-nitrogen above the Alberta Tier 1 Guideline. The nitrite concentration was 0.17 mg/L-N compared to a guideline value of 0.06 mg/L-N.

Dissolved metals were generally within the range of expected concentrations for monitoring wells completed in glacial deposits in southern Alberta. Iron concentrations exceeded the 0.3 mg/L guideline at three locations with a maximum concentration 0.5 mg/L. Manganese concentrations ranged from 0.025 to 2.3 mg/L exceeding the referenced guidelines (0.05 mg/L) in all but one sample. Selenium concentrations exceeded the 0.001 mg/L Alberta Tier 1 Guideline in seven samples and exceeded the 0.05 mg/L GCDWQ in one sample. Uranium concentrations ranged from 0.0044 to 0.04 mg/L, exceeding the 0.01 mg/L guidelines in 10 of 17 samples. Single exceedances of arsenic and copper were also noted with concentrations marginally exceeding referenced guidelines.

Dissolved mercury was below the 0.002 µg/L laboratory detection limit in 14 of 17 samples. Concentrations in the remaining three samples were marginally above the detection limit with values ranging from 0.002 to 0.0036 µg/L.

Hydrocarbon concentrations were below their respective guideline concentrations at all but one of the monitoring wells where benzene and ethylbenzene marginally exceeded guidelines with concentrations of 0.0055 and 0.0034 mg/L, respectively. The source of the hydrocarbon impacts is not known. Dissolved organic carbon concentrations ranged from 1.8 to 9.2 mg/L.

Bacteriological parameters including Escherichia coli (E. Coli), fecal coliform, total coliforms and heterotrophic plate counts (HPC) were enumerated for all samples. As with the mercury analyses described above, sediment in the samples also affected the detection limits for the bacteriological parameters due to the dilution of samples required by the laboratory (which leads to an associated increase in sample detection limits). While the sample detection limits were not low enough to determine if the water is safe for human consumption in the majority of samples, it does provide general information on the bacteriological levels and potential for pre-existing impacts in the shallow groundwater.

HPC’s were included in the analytical suite to provide information on the level of bacteriological activity across the LAA. HPC concentrations varied from 920 cfu/100 ml to 56,000 cfu/100 mL. No spatial or depth correlation was evident in the HPC data. E. coli concentrations were below the detection limits in all samples but one that registered an E. coli concentration of 63 mpn/100 mL, compared to the GCDWQ of 0 mpn/100 mL. Total coliform bacteria ranged from <100 to 9,300 mpn/100 mL. Fecal coliform bacteria were below the detection limit in all but one sample which reported a concentration of 100 mpn/100 mL.

Groundwater Chemistry of the Upper Bedrock Aquifers

Fourteen groundwater samples were collected from Project related monitoring wells completed in bedrock within the LAA. Samples collected from domestic water wells were also available from the domestic well testing program completed in April 2016.

The TDS concentrations in the bedrock deposits ranged from 440 to 4,700 mg/L with an average concentration of 1,444 mg/L. The bedrock TDS concentrations are significantly lower than in the unconsolidated deposits but still exceed both referenced guidelines in 12 of the 14 samples and are considered slightly saline. The TDS exceeded the 4,000 mg/L Water (Ministerial) Regulation criteria for fresh water in one sample. TDS concentrations were lower in the 12 domestic wells sampled by Stantec with an average concentration of 761 mg/L.

Sodium is the dominant cation in 8 of the 14 bedrock samples with the remaining samples having no dominant cation. Sodium concentrations exceed the referenced 200 mg/L guideline in 12 of the 15 samples with an average concentration of 222 mg/L. Bicarbonate is the dominant anion in 7 of the 14 samples with sulphate dominating the remaining. The average sulphate concentration was 564 mg/L which is lower than in the unconsolidated deposits. Chloride concentrations were low in the majority of samples ranging from <1 to 78 mg/L with one exception with a concentration of 110 mg/L. Similar chloride concentrations were noted in the domestic water wells with an average concentration of 59 mg/L.

Nutrient concentrations were low in all bedrock groundwater samples with the exception of one nitrate-nitrogen Alberta Tier 1 Guideline exceedance. The nitrite concentration at this monitoring well was 4.8 mg/L-N compared to a guideline value of 3 mg/L-N. Nitrate and nitrite concentrations were low and below the referenced guidelines in all domestic wells sampled.

Dissolved metals concentrations in the bedrock aquifers were relatively consistent across the LAA and similar to the surficial deposits with one exception which reported elevated barium (3.8 mg/L), iron (68 mg/L) and manganese (14 mg/L) concentrations. Iron concentrations exceeded the 0.3 mg/L guideline at three other locations with a maximum concentration 2.6 mg/L. Manganese concentrations exceeded the referenced guidelines (0.05 mg/L) in 12 of 14 samples. Selenium concentrations exceeded the 0.001 mg/L Alberta Tier 1 Guideline in four samples. Manganese and selenium exceedances were also noted in a number of domestic water wells sampled. Uranium concentrations were lower than in the unconsolidated deposits with only one exceedance of the 0.01 mg/L guidelines where a concentration of 0.012 mg/L was measured.

Dissolved mercury was below the 0.002 µg/L laboratory detection limit in 13 of 14 samples. Concentrations in the remaining monitoring well was marginally above the detection limit with a value of 0.0029 µg/L. Total mercury concentrations were below the detection limits (0.1 to 20 µg/L) in all samples. Samples from the domestic wells also reported mercury concentrations that were below the laboratory detection limits in 11 of 12 samples and marginally above the detection limit with a concentration of 0.0025 µg/L in the remaining sample.

No hydrocarbon concentration exceedances were noted in any of the bedrock groundwater samples. Dissolved organic carbon concentrations ranged from 1.2 to 5.1 mg/L.

HPC concentrations were generally lower than in the unconsolidated deposits as expected, ranging from 39 cfu/100 ml to 44,000 cfu/100 mL. Lower HPC concentrations were generally found in deeper bedrock wells. E. coli concentrations were below the detection limits in all but one sample which reported an E. coli concentration of 11 mpn/100 mL, compared to the GCDWQ of 0 mpn/100 mL. Total coliform bacteria ranged from <1 to 2,400 mpn/100 mL. Fecal coliform bacteria were below the detection limit in all samples except one which reported a concentration of 5.1 mpn/100 mL. Total coliform bacteria in the domestic wells were low, ranging from <1 to 24 mpn/100 ml in all samples except one which reported a concentration of 2,400 mpn/100 mL. E. Coli concentrations were below the detection limit in all domestic well samples.

5.2.2.4 Groundwater Use in the RAA

The base of groundwater protection (BGP) is an estimate of the elevation of the base of the geological formation in which the groundwater is deemed useable with a total dissolved solids (TDS) concentration of less than 4,000 mg/L. West of the RAA, the BGP is defined as the base of the Paskapoo Formation; however, because the RAA lies within the disturbed belt of the Rocky Mountains, the AGS has set an arbitrary BGP of 600 m.

Groundwater use in the RAA is primarily from shallow bedrock aquifers with some wells also completed in the recent fluvial deposits along the Elbow River. Regional mapping by HCL (2002) indicates apparent yields from the bedrock aquifers in the disturbed belt range from 10 m^3/day to 75 m^3/day in the RAA. Yields from wells completed in the recent fluvial deposits along the Elbow River are expected to range from 175 m^3/day to 2,500 m^3/day (Waterline 2011).

Drillers' records for groundwater wells completed in the RAA were queried from the AWWID. A total of 594 unique well records were identified in the RAA. A number of well record types were screened from the raw data, such as abandoned test holes, dry holes, piezometers, chemistry only records, and seismic test holes. These categories are not reflective of groundwater use. A total of 392 water well drilling records remained after screening the data. The proposed uses of the wells, as was reported in the AWWID, were:

- 277 for domestic use
- 50 for stock use
- 31 for domestic and stock use
- 7 for industrial purposes
- 2 for irrigation purposes

- 5 for municipal use
- 20 for unknown use

Water well depths ranged from 5 m to 200 m BGL. Figure 5-9 is a histogram of the total depth recorded on the drilling records.

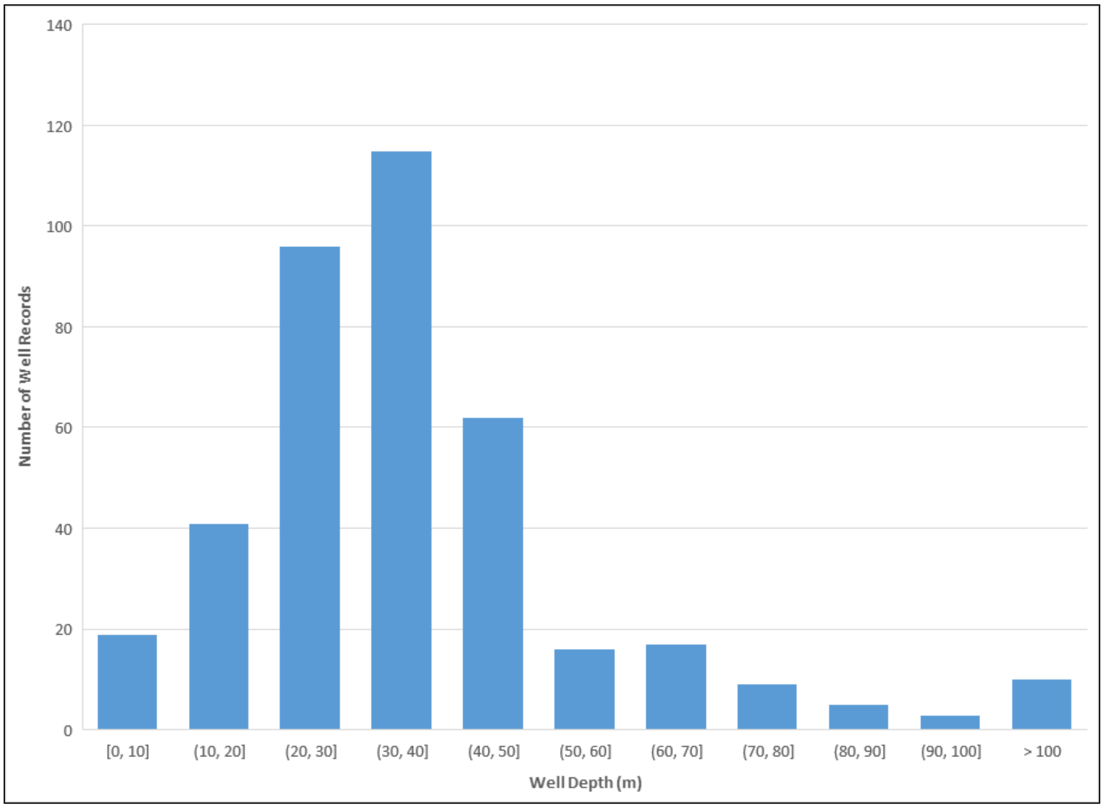


Figure 5-9 Histogram of Water Well Depth in the RAA

5.3 PROJECT INTERACTIONS WITH HYDROGEOLOGY

Table 5-3 identifies the project components and physical activities that might interact with hydrogeology. These interactions are discussed in Section 5.4 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 5-3 Project-Environment Interactions with Hydrogeology during Construction and Dry Operations

Project Components and Physical Activities	Environmental Effects	
	Change in Groundwater Quantity	Change in Groundwater Quality
Construction		
Clearing	–	–
Channel excavation	✓	✓
Water diversion construction	–	–
Dam and berm construction	✓	✓
Outlet works construction	✓	✓
Road construction	–	–
Bridge construction	✓	✓
Lay down areas	–	✓
Borrow extraction	✓	✓
Reclamation	–	–
Dry Operations		
Maintenance	✓	✓

NOTES:
✓ = Potential interaction
– = No interaction

During Project construction, clearing activities are not expected to interact with groundwater resources because these activities occur at or above the ground surface and above the water table except where it is at surface (e.g. springs).

The construction or dry operation of the water diversion structure is not anticipated to interact with groundwater resources because the structure is situated in the Elbow River floodplain and within the regional discharge area for shallow groundwater.

Road construction activities are not expected to interact with groundwater resources because these activities occur at the ground surface and above the water table.

Lay down areas are not expected to interact with groundwater quantity such that effects on groundwater quantity result, because lay down activities occur at the ground surface and above the water table. Lay down areas could potentially interact with groundwater resources such that groundwater quality is affected (e.g., incidental spills).

Reclamation activities related to restoration of constructed areas (e.g., roads, dam and berm) are not expected to interact with groundwater resources because these activities occur at or above the ground surface and above the water table.

5.4 ASSESSMENT OF RESIDUAL ENVIRONMENTAL EFFECTS ON HYDROGEOLOGY

5.4.1 Assessment Techniques

The effects assessment for hydrogeology during the construction and dry operations phase of the Project uses both quantitative and qualitative techniques.

Quantitative modeling for the construction and dry operation phase focused on the activity predicted to result in the greatest effect on groundwater from the Project, thus representing the most conservative approach. The greatest effect on groundwater during this phase is predicted to occur due to the permanent presence of the dry diversion channel during dry operations. The effects from operation of the channel would be higher in magnitude, longer in duration, and greater in geographic extent than other activities during this phase. A qualitative assessment was completed for all other activities during the phase.

For the quantitative assessment, a numerical flow model was selected for use over other potential analytical solution methods due to the size of the RAA, complex geologic framework, time-variable boundary conditions, and irregular geometry of the physiographic setting and project components. A numerical solution technique was favoured over analytical methods in order to minimize the number of simplifying assumptions, thus yielding a more detailed depiction of the hydrogeologic setting and system response within the RAA.

The development and calibration of the numerical groundwater flow model used for this hydrogeology effects assessment is presented in Volume 4, Appendix I, Hydrogeology Numerical Modelling TDR. The finite element subsurface flow and transport system (FEFLOW) is a numerical groundwater modelling system that is capable of modelling three-dimensional (3D) groundwater flow and mass transport. FEFLOW was used for the groundwater flow model in combination with the 3D CSM developed with Leapfrog Hydro (Volume 4, Appendix I, Baseline TDR).

5.4.2 Change in Groundwater Quantity

5.4.2.1 Dry Operations

The Project has the potential to change groundwater quantity through groundwater seepage into the diversion channel when dry. Groundwater that seeps into the diversion channel (when dry) would infiltrate back into the groundwater system at a downstream location that is not saturated, or continue to flow by gravity down the diversion channel and into the off-stream reservoir. Once there, groundwater seepage collected in the diversion channel may infiltrate back into the ground (returning to the groundwater system) or, where the local infiltration capacity is exceeded, continue to flow overland toward existing surface water drainage courses. There, groundwater seepage would become part of the surface water system, eventually draining through the outlet structure. Groundwater seepage into the dry diversion channel would occur only in some areas where the local groundwater table is near ground surface and where the diversion channel has been cut to an elevation below the water table.

In order to simulate the potential effects of dry operations on groundwater quantity, two FEFLOW simulation runs were completed to represent hydrogeologic conditions with and without the addition of the Project. Both simulations were run with an average flow condition (i.e. non-flood condition) in the Elbow River. The “EE0” simulation run represents the hydrogeologic system in the RAA under an average flow scenario prior to construction of the Project (i.e., existing conditions). The “PP0” simulation run represents the hydrogeologic system in the RAA under an average flow scenario with the major project features (diversion channel, off-stream reservoir) represented in the model.

Following each of the simulation runs, output files from FEFLOW were exported for post-processing and interpretation. Each of the output files model simulated potentiometric heads at each of the model nodes at each time step of the simulation. These output files were examined using spatial analysis tools to generate interpolated 3D potentiometric surfaces (at various timesteps in the simulation) that were then imported into the 3D CSM for latter evaluation and interpretation.

Figure 5-10 presents the simulated potentiometric head distribution yielded from the EE0 simulation of the water table across the RAA under existing conditions (without the Project) and with average (i.e., non-flood) flow conditions in Elbow River. Groundwater levels range from approximately 1,338 m ASL in the southwestern areas of the RAA, to approximately 1,147 m ASL in the eastern edge of the RAA within the Elbow River valley. In general, the groundwater flow patterns exhibit a predominance of topographic control over the flow regime, with upland areas along ridges driving flow toward low lying areas, including local drainage features, the Elbow River valley, and the off-stream reservoir area. The Elbow River valley is a hydraulic divide for shallow groundwater, with flow directions on either side of the valley directed inward towards it.

Figure 5-11 presents the simulated potentiometric head distribution yielded from the PP0 simulation of the water table across the RAA following construction of project components, and with average flow conditions in the Elbow River. Similar to Figure 5-10, groundwater levels range from approximately 1,338 m ASL in the southwestern areas of the RAA, to approximately 1,147 m ASL in the eastern edge of the RAA within the Elbow River valley. The groundwater flow patterns are almost the same as was the case for the existing conditions (EE0) simulation, indicating that at the scale of the RAA, changes in groundwater flow patterns are almost imperceptible.

In order to evaluate potential change in groundwater quantity resulting from the Project, it is necessary to identify groundwater level change that is result of construction and dry operations. This was accomplished by comparing the EE0 run and the PP0 run results under average flow conditions in Elbow River in order to calculate the net change in groundwater level. Figure 5-12 presents the net change in groundwater levels that could be attributable to dry operations. This distribution of net change in groundwater levels was obtained through grid calculations performed on the FEFLOW output files for each of the EE0 and PP0 simulation runs. Positive net change in head represent increased groundwater levels attributable to construction and dry operations. Negative change in head represent decreased groundwater levels attributable to construction and dry operations. The net change in head values are then interpolated and plotted within the 3D CSM to depict the spatial distribution of changes in potentiometric head that could be attributable to the Project.

From Figure 5-12, net change in potentiometric heads that could be attributable to dry operations are generally limited to areas of the diversion channel. In southwestern areas of the diversion channel (near the inlet structure), net negative changes in groundwater levels of up to 5.5 m are predicted due to the incision of the diversion channel into the ground surface below the original groundwater table level. This diversion channel incision, and resulting seepage face, causes a localized lowering of the groundwater table as groundwater is allowed to discharge into the dry channel. In northeastern areas of the diversion channel (near its outlet into the off-stream reservoir), net positive changes in groundwater levels of up to 6 m are predicted due to the additional infiltration of water into this area. This infiltration locally raises the groundwater table as additional seepage water that is conveyed in the diversion channel (when not in operation) is allowed to infiltrate back into the ground near this location. In either area of net negative or positive change, the extent of the changes in potentiometric head are limited to near the diversion channel and well within the LAA.

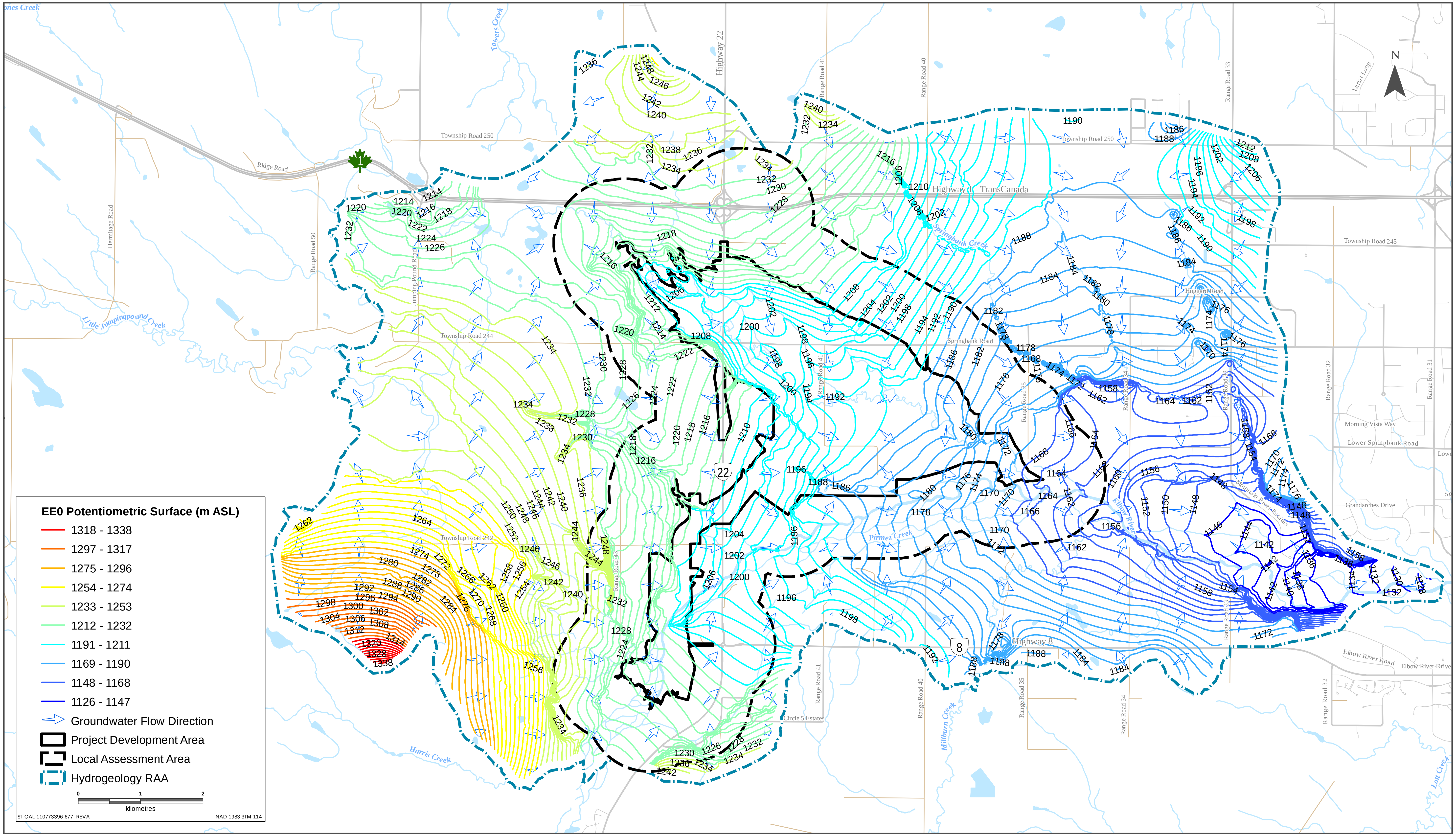
5.4.2.2 Construction Dewatering

The Project has the potential to change groundwater quantity in and near the PDA as a result of local, shallow and temporary subsurface dewatering that might be required to facilitate construction of the diversion channel, dam and floodplain berm, outlet works, bridge, excavation of borrow pits, and utility realignments, although with the construction mitigation measures presented in Section 5.4.2.3, these effects are expected to be low in magnitude.

The need for temporary construction dewatering will be evaluated during the construction planning for the Project and will be determined based on the construction method to be employed at a given location, local water table conditions at the time of construction, the timeframe for construction, and the locations and depth of excavations (or other subsurface disturbance) required. In general, topographically upland areas situated away from surface water features or groundwater recharge areas have less potential to require dewatering during construction. Conversely, topographically low areas near surface water features or areas of groundwater discharge to surface are more likely to require dewatering during construction due to the relatively shallow depth of the water table expected in these areas.

Dewatering outside the PDA is not expected to be required for construction. Where construction dewatering occurs, local water table elevations would be temporarily lowered, and a localized interaction between the Project and groundwater resources would occur.

Effects on groundwater quantity could be expected as a result of construction dewatering. Dewatering creates a “cone of depression” (lowering) in groundwater levels that are greatest near the pumping location, and gradually rise back toward static (non-pumping) groundwater levels with increasing distance away from the pumping location. The maximum depth of this cone of depression would depend upon the depth of excavation required (groundwater levels would normally be lowered slightly below the depth of excavation in order to keep the excavation dry). The lateral extent of the cone of depression is dependent upon the pumping rate and hydraulic properties of the hydrostratigraphic unit that is being dewatered.



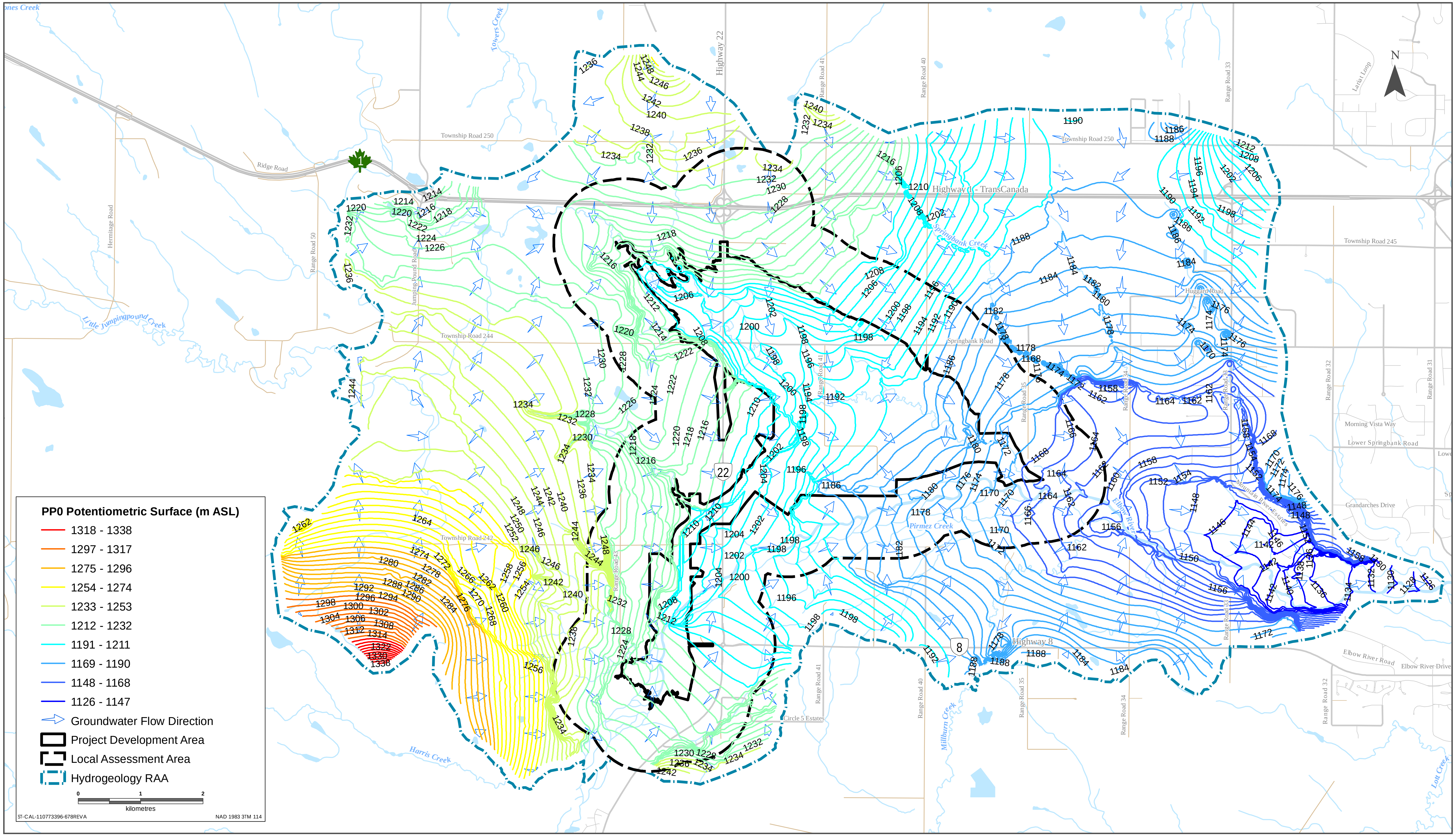
Sources: Base Data - Government of Alberta, Government of Canada. Thematic Data - Stantec Ltd.

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Potentiometric Head Distribution Under Average Flow Conditions (EE0)

Figure 5-10



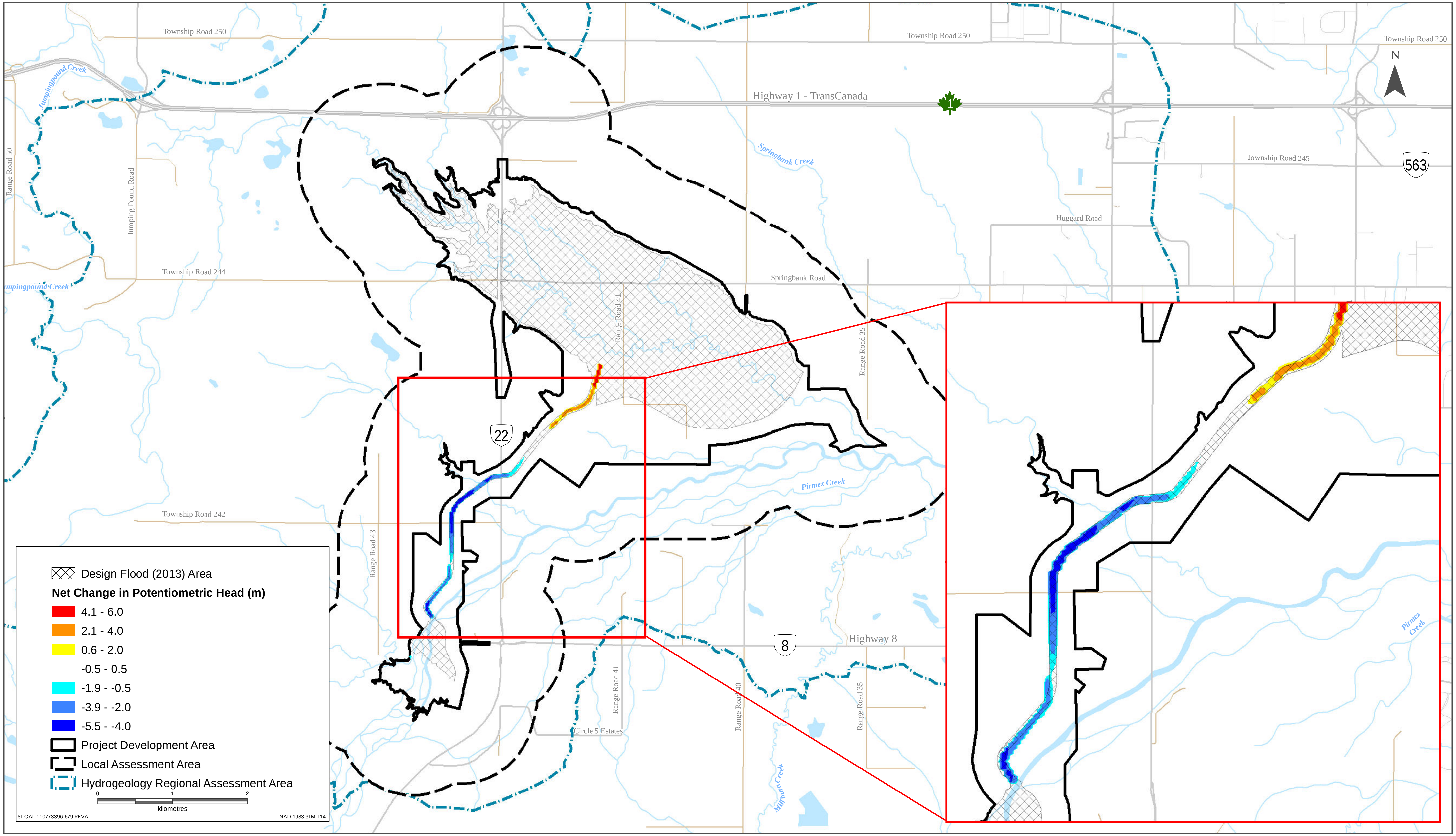
Sources: Base Data- Government of Alberta, Government of Canada. Thematic Data - Stantec Ltd.

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Potentiometric Head Distribution Under Average Flow Conditions (PP0)

Figure 5-11



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

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Net Change in Potentiometric Head Under Average Flow Conditions (PP0-EE0)

Figure 5-12

5.4.2.3 Mitigation

Construction dewatering, if required, would be done locally and according to the terms and conditions of dewatering licences issued by AEP (where applicable and if required) and best management practices. This would be included as part of the ECO Plan (Environmental Construction Operation Plan) prepared by the contractor. Standard construction dewatering methods will be used, including methods to cut off excessive seepage where trenches extend below the water table in order to mitigate preferential flow paths. Other mitigation measures are as follows:

- Water will be discharged in a manner to avoid erosion by the use of turbidity barriers, containment berms and settling ponds. Construction dewatering, if required, will be in accordance with the terms and conditions of the *Environmental Protection and Enhancement Act* approval conditions, and *Water Act* approval and the federal *Fisheries Act* and *Navigable Waters Protection Act*.
- A Care of Water Plan will include using cofferdams, pumping systems, sumps, pipelines, channels, flumes, drains, and other dewatering works to permit construction of the work in the dry.
- TSS levels will be controlled and reduced by the use of silt fences and turbidity barriers so that the water quality from care of water system discharges is made equal to or better than the initial water quality. TSS levels will be monitored by carrying out frequent water quality testing.
- Construction dewatering will be limited through diligent construction planning.
- Existing water wells within the reservoir footprint will be decommissioned and plugged off to prevent groundwater contamination.
- Regional-scale effects on groundwater quantity can be mitigated by allowing seepage in the dry diversion channel to infiltrate back into the subsurface, or flow back into the Elbow River through surface water drainage pathways. Silt fences and turbidity barriers will be used as required to control TSS so that the water quality from care of water system discharges is made equal to or better than the initial water quality by carrying out frequent water quality testing.

Effects on groundwater quantity as a result of construction dewatering would not be entirely mitigated at a local scale, since dewatering deliberately seeks to temporarily lower the groundwater table in the PDA in order to facilitate construction. The amount of time required for construction dewatering can be minimized through diligent construction planning. Groundwater that is collected during dewatering would be returned to the local water shed to mitigate regional-scale effects on groundwater quantity.

Groundwater that would seep into the diversion channel (when dry) would remain within the watershed, although potentially travelling through a more tortuous route. Regional-scale effects on groundwater quantity can be mitigated by allowing seepage in the dry diversion channel to infiltrate back into the subsurface, or flow back into the Elbow River via surface water drainage pathways.

5.4.2.4 Project Residual Effects

The potential residual effects on groundwater quantity related to construction dewatering can be characterized as follows:

- Direction would be adverse because the localized lowering of groundwater levels would reduce the availability of groundwater within the cone of depression.
- Magnitude would be moderate because groundwater levels could be reduced lower than expected seasonal lows. Groundwater flow patterns are not expected to be materially affected due to the limited extent of the cone of depression and limited duration of the effect, which limits lateral growth of the cone of depression.
- Geographic extent of the effects would be limited to the LAA due to the relatively low rate of pumping that is expected for dewatering excavations. This evaluation is based on the predominantly low permeability shallow sediments in the PDA.
- Frequency of the effect due to dewatering would be a single event at a given location because once construction is completed at a given location, dewatering would no longer be required.
- The duration of the effect due to construction dewatering would be short term because it would be limited to construction.
- The effects due to construction dewatering would be reversible because it is expected that once pumping ceases, groundwater levels would recover to pre-disturbance conditions.
- The ecological and socio-economic context is disturbed since the PDA has been previously disturbed by human development.
- Timing was found to be not applicable as effects from Project activities would be similar regardless of season or other timing characteristics

The potential effects on groundwater quantity related to groundwater seepage into the diversion channel (when dry) can be characterized as follows:

- Direction would be neutral because the localized seepage of groundwater would reduce the availability of groundwater within the area of influence of the diversion channel; however, seepage would also increase the availability of groundwater in downstream areas where this seepage derived groundwater re-infiltrates back into the subsurface.

- Magnitude would be moderate because groundwater levels could be reduced lower than expected seasonal lows. Groundwater flow patterns are not expected to be materially affected due to the limited extent of the area of influence and limited spatial occurrences of seepage.
- Geographic extent of the effects would be limited to the LAA due to the relatively low rate of seepage that is expected. Further, effects are only expected in limited areas where the groundwater table is near ground surface.
- Frequency of the effect due to seepage into the diversion channel would be continuous at locations where the existing water table is near the ground surface.
- The duration of the effect due to seepage into the diversion channel would be long term because it would extend for the life of the Project.
- The effects due to seepage into the diversion channel would be irreversible because it is expected that the diversion channel would be in place indefinitely and the potential for seepage into the diversion channel would persist indefinitely.
- 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

5.4.3 Change in Groundwater Quality

5.4.3.1 Project Pathways

As is described in the previous section, the Project has the potential to affect groundwater levels and flow patterns as a result of construction (dewatering) and dry operations (seepage into the diversion channel). Since groundwater quality is dependent upon its flowpath through the subsurface, flow velocities, and recharge/discharge relationships with surface water (notwithstanding other anthropogenic alterations of groundwater quality), alterations to the baseline groundwater flow regime can create secondary effects on groundwater quality.

The Project has the potential to change groundwater quality as a result of groundwater seepage into the diversion channel when dry. Groundwater that seeps into the diversion channel (when dry) is anticipated to infiltrate back into the groundwater system at a downstream location within the diversion channel where the subsurface is not saturated, or continue to flow by gravity down the diversion channel and into the off-stream reservoir. Once in the off-stream reservoir, groundwater seepage may infiltrate back into the ground (returning to the groundwater system) or, where the local infiltration capacity is exceeded, continue to flow overland toward existing surface water drainage courses. There, it would become part of the surface water system, eventually draining out of the off-stream reservoir through the outlet structure. As a result, natural groundwater flowpaths can be disturbed at a local scale, potentially resulting in changes in groundwater quality.

5.4.3.2 Mitigation

As was the case for effects on groundwater quantity, the secondary effects on groundwater quality related to changes in groundwater flow patterns would not be entirely mitigated, since dewatering activities deliberately seek to lower the water table (and in turn affect groundwater flowpaths, potentially resulting in changes in groundwater quality). The amount of time required for construction dewatering can be minimized through diligent construction planning which in turn would limit the duration of the residual effects. Other mitigation measures will be completed as follows:

- A Care of Water Plan will be developed to manage dewatering and discharge of water on the construction site.
- At locations where flows from Care of Water operations are discharged into waterbodies, water quality will be tested at discharge locations and TSS monitored to confirm that the water quality is made equal to or better than the initial water source.
- Construction dewatering may be reduced through diligent construction planning.

5.4.3.3 Project Residual Effects

The potential secondary residual effects on groundwater quality related to changes in groundwater levels caused by construction dewatering can be characterized as follows:

- Direction would be neutral because the localized changes in groundwater quality could result in less mineralized (fresher) groundwater or could result in higher mineralized groundwater.
- Magnitude would be low because groundwater levels naturally vary seasonably under baseline conditions and, as a result, groundwater quality is also subject to seasonal variability. Further, due to the relatively short period of dewatering required, the magnitude of secondary changes in groundwater quality can be limited because the time required to affect changes in groundwater quality may be insufficient for a change to be noticeable.
- Geographic extent of the effects would be limited to the LAA because changes in groundwater levels and flow patterns are also limited to the LAA.
- Frequency of the effect due to dewatering would be a single event at a given location because after construction is completed at a given location, dewatering would no longer be required.
- The duration of the effect due to construction dewatering would be short term because it would be limited to construction.

- The effects due to construction dewatering would be reversible because it is expected that after pumping ceases, groundwater levels would recover, flow patterns would return to existing conditions and, in turn, groundwater quality would return to pre-disturbance conditions.
- 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

The potential effects on groundwater quality related to groundwater seepage into the diversion channel (when dry) can be characterized as follows:

- Direction would be neutral because the changes in groundwater quality could sometimes result in higher quality (less mineralized, fresher) water being introduced into the groundwater system. However, in other cases, it could result in lower quality water being introduced into the groundwater system.
- Magnitude would be moderate because groundwater quality could change beyond the range of expected natural variability.
- Geographic extent of the effects would be limited to the LAA because potential seepage into and out of the diversion channel is limited to the LAA.
- Frequency of the effect due to seepage into the diversion channel would be continuous at locations where seepage collected within the diversion channel re-infiltrates into the subsurface.
- The duration of the effect on groundwater quality due to seepage into the diversion channel would be long term because it would extend beyond one year following construction.
- The effects on groundwater quality due to seepage into the diversion channel would be irreversible because it is expected that the diversion channel would be in place indefinitely and, therefore, the potential for seepage into the diversion channel would persist indefinitely.
- 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

5.4.4 Summary of Project Residual Effects

Table 5-4 summarizes the residual environmental effects on hydrogeology during construction and dry operations.

Table 5-4 Project Residual Effects on Hydrogeology during Construction and Dry Operations

Residual Effect	Residual Effects Characterization								
	Project Phase	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological and Socio-economic Context**	**Timing**
Change in groundwater quantity (construction dewatering)	C	A	M	LAA	ST	S	R	D	N/A
Change in groundwater quantity (seepage into dry diversion channel)	O	N	M	LAA	LT	C	I	D	N/A
Change in groundwater quality (construction dewatering)	C	N	L	LAA	ST	S	R	D	N/A
Change in groundwater quality (seepage into dry diversion channel)	O	N	M	LAA	LT	C	I	D	N/A

KEY

See Table 5-2 for detailed definitions

Project Phase
C: Construction
O: Operation (Dry)

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

5.5 DETERMINATION OF SIGNIFICANCE

Based on the effects assessment, the residual effects on groundwater quantity during construction and dry operation phases of the Project are assessed as not significant because they would not decrease the yield of groundwater supply wells to the point where they can no longer be used.

Based on the effects assessment the residual effects on groundwater quality during construction and dry operation phases of the Project are assessed as not significant because changes in groundwater quality would not deteriorate to the point where it becomes non-potable or cannot meet the Guidelines for Canadian Drinking Water Quality for a consecutive period exceeding 30 days (for those parameters which don’t already, under existing conditions, exceed those guidelines).

5.6 PREDICTION CONFIDENCE

The level of confidence in the effects assessment for hydrogeology is moderate due to the site-specific nature of the Project interactions with groundwater resources, natural heterogeneity of the subsurface materials, preliminary nature of the construction dewatering requirements, and mitigation measures. Because potential effects on groundwater quality arise from changes in groundwater levels, predictions for these effects are also subject to similar constraints and, in turn, the prediction confidence is also moderate for effects on groundwater quality.

5.7 CONCLUSIONS

5.7.1 Change in Groundwater Quantity

Changes in groundwater quantity during construction and dry operations of the Project were evaluated in the context of the hydrogeological framework of the RAA and in consideration of Project infrastructure and activities occurring during these phases. Due to the limited interaction of the Project with groundwater resources, the residual effects on groundwater quantity would be not significant, with a moderate degree of confidence.

5.7.2 Change in Groundwater Quality

Changes in groundwater quality during construction and dry operations of the Project are related to secondary effects associated with changes in groundwater levels, whereby alterations of the existing flow regime affect change in groundwater quality due to alteration of groundwater flowpaths or interactions with surface water. Due to the limited interaction of the Project with groundwater resources the residual effects on groundwater quality would be not significant, with a moderate degree of confidence.

5.8 REFERENCES

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