Springbank Off-stream Reservoir Project review

Review of hydrogeology, groundwater modelling, water quality & geochemistry, and climate considerations

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On behalf of:

The Springbank Concerned Landowners Group (SCLG)

For:

The Natural Resources Conservation Board
Application No. 1701

February 2021

Executive Summary

The flood of 2013 in southern Alberta was one of the most expensive weather events in history and resulted in significant disruption to people and property. Since then, the assessment of options to deal with flooding that occur on the Elbow River have been underway with the Springbank Off-stream Reservoir, or SR1, being identified as the most suitable option by the Alberta government. Unfortunately, the SR1 is located amongst country residential properties and valuable agricultural lands that have been in families for generations. The Springbank Concerned Landowners Group (SCLG) does not see the development of this large earthen dammed structure as a compatible land use, particularly given the risk posed to their community should there be a catastrophic failure of the large (up to 77,800,000 m3 of water) reservoir designed to contain, and eventually release captured flood water.

The concerns of the SCLG fall into four topic areas:

1. Knowledge of the hydrogeologic regime and its influence on the success of the SR1.
2. Efficacy of the groundwater modelling to allow an informed decision to be made regarding whether or not to approve the application.
3. Review of the geochemical and water quality issues that could arise if SR1 is constructed and operated as planned.
4. Climate change considerations including the impacts from extreme flood and drought conditions, and how that might affect the safe and efficient operation of the SR1.

With respect to topic area 1, the applicant has not provided sufficient information to understand the hydraulic properties of the surficial sediments. In fact, only 3 field measurements of the in-situ hydraulic conductivity of the surficial sediments have been conducted. Such a small number of measurements is insufficient to capture the range of conditions likely present across the large footprint of the SR1, and the role that fracturing of the sediments may play to degrade their containment properties. Evidence from monitoring wells hydrographs indicates that there is connectivity between the surficial deposits and the bedrock, but the model as set up does not convey that message. Similarly, there is no mineralogical information provided for the surficial sediments, which increases the risk if certain minerals, like swelling clays with low cohesion when hydrated, are present. There is evidence in the literature that the glacial sediments beneath the reservoir footprint contain a significant percentage of the mineral montmorillonite, which could pose a risk to the structural integrity of the SR1 under the right conditions.

As for topic area 2, there are concerns with the groundwater model and how the results have been reported. Only plan view maps of how hydraulic heads may change have been provided by the applicant. This does not help with understanding how pore pressures may change in the various surficial deposits beneath the SR1 and whether there may be a shear-slip risk within certain intervals or at the interface between distinct glacial formations. The limited amount of documented output showing how groundwater conditions and fluxes will change under the various scenarios run (including the sensitivity analysis runs) does not allow a rigorous assessment of the model efficacy to be performed. Provision of some targeted hydrographs to show pore pressure changes in various intervals (including interfaces between major formations), as well as modelled water balance outputs, would have been helpful.

Unfortunately, the subject of geochemistry (topic area 3) is the most overlooked. The applicant has conducted a baseline survey of monitoring wells installed in both the surficial deposits and the bedrock but that is as far as it goes. There has been no assessment of how natural contaminants, like the selenium and uranium identified in the water of the surficial deposits, might be mobilized down into the bedrock after SR1 is commissioned and put to use. This includes the impact to local residents that rely on the groundwater for their day-today needs. There is also no exploration of how other contaminants entrained in the flood water routed to the SR1 might pose a risk to local water users, or how the geochemical conditions beneath the structure might be changed, leading to other reactions that could exacerbate the release of natural contaminants from the surficial deposits.

And finally, there has been no exploration of how the climate conditions of the area will affect the success of the SR1 (topic area 4). The reliance of the applicant on the 2013 event as being the "design flood" is limiting to the SR1 design given the likelihood that larger flood events have occurred in the past. Unfortunately, the period of record for the Elbow River (i.e. 1903 – 2013) is not long enough to capture those events. Evidence in the paleo-records show that occurrence of wet and dry periods extending several years to decades have not been accommodated in the analysis completed by the applicant. Equally, the anticipated change in Spring precipitation and the shift in river flow characteristics to more flashy and peaked flow as a result of climate changes and how this has influenced the design and successful operation of the SR1 have not been sufficiently explored. Finally, the risks to the safe operation of the SR1 from extended drought conditions have not been assessed.

It is the responsibility of the applicant to address these concerns so that an informed decision on whether the SR1 can be approved, as is, can be made. At this point there are still too many unanswered question to provide the level of confidence necessary to move this project forward, even after several rounds of supplemental information requests and model and design updates.

Introduction

The flood of 2013 was significant. It caused major disruption and result in significant recovery costs. Although the Bow River conveyed the majority of water during the event, the flow volumes on the Elbow River were significant and resulted in overtopping of the Glenore dam and a backwater affect that impacted large areas of Calgary's downtown core, east village and along the Elbow River valley. Following that event, plans were developed to provide flood mitigation for future events that would inevitably occur in the future. Of the options put forward, the Springbank Off-stream Reservoir, or SR1, was identified as the most viable option.

The location proposed for this large infrastructure development is north of the Elbow River along Highway 8 about halfway between Elbow Valley and the Highway 22 interchange. The land where the SR1 is to be established is primarily used to support agricultural activities (grazing) and is surrounded by country residential developments. The plan for the SR1 is to commence diversion of water down an engineered channel to a dedicated dry reservoir area when the flow reaches 160 m^3/s. This diversion system is designed to divert up to 600 m^3/s of flow from the Elbow River and temporarily store up to 77, 800,000 m^3 of water in an earthen dammed reservoir covering up to 730 hectares of land. The goal of this strategy is to capture some of the flood peak from the Elbow River before it reaches the Glenmore reservoir, ultimately protecting downstream areas within the City of Calgary.

The Springbank Concerned Landowners Group (SCLG) is opposed to the SR1 given its proximity to existing country residential dwellings and the removal of valuable agricultural lands from use. A number of concerns have been expressed by the SCLG, some of which include the effect of a catastrophic failure of the reservoir and release of a large volume of water into the surrounding community. Others include the implications for local groundwater quality, the likely impacts to the aquatic environment in the Elbow River when the water from SR1 is eventually released, and the overall success of operations in achieving the intended goal of the project.

From a hydrogeological, geochemical, and climate perspective there are a number of challenges that remain unresolved or unmitigated with respect to this Project that need suitable clarification to avoid the risk of project failure. The concerns of the SCLG relate to the following topic areas:

1. Knowledge of the hydrogeologic regime and its influence on the success of the SR1.
2. Efficacy of the groundwater modelling to allow an informed decision to be made regarding whether or not to approve the application.
3. Review of the geochemical and water quality issues that could arise if SR1 is constructed and operated as planned.
4. Climate change considerations including the impacts from extreme flood and drought conditions, and how that might affect the safe and efficient operation of SR1.

The following sections address each of these topic areas and explore some of the continuing issues associated with the location and design of the SR1. The intent is to provide the Natural Resources Conservation Board (NRCB) panel members with additional information not specifically provided by the applicant (Alberta Transportation) so that an informed decision can be made whether or not to approve this project.

1. Knowledge of hydrogeological regime and its influences

According to borehole lithology logs provided by Stantec (2019)[1], the area for the proposed SR1 is blanketed by glaciolacustrine and stagnant undifferentiated glacial till deposits ranging from 2.5 metres to 25 metres thick. These glacial deposits overlie alternating layers of sandstone, siltstone, shale (with some coal layers), and mudstone of the Wapiabi, Brazeau, Coalspur, and Paskapoo formations. The glacial deposits were laid down roughly 25,000 years ago during the last continental glaciation and are believed by many to represent a hydraulic barrier between the surface and water-bearing intervals of the bedrock due to their predominantly clay-sized texture.

According to Morin (1986), in his review of surficial geology in the Calgary urban area, the glacial deposits in the immediate areas of the SR1 represent isolated surface deposits of fluvial gravel (Gg), followed by Calgary Formation deposits ranging from clay (Cc) to fluvial sand (Cs), and then till of the Spy Hill Formation (Lower Unit), which consists of 40-45% silt and 40-45% clay (Figure 1).

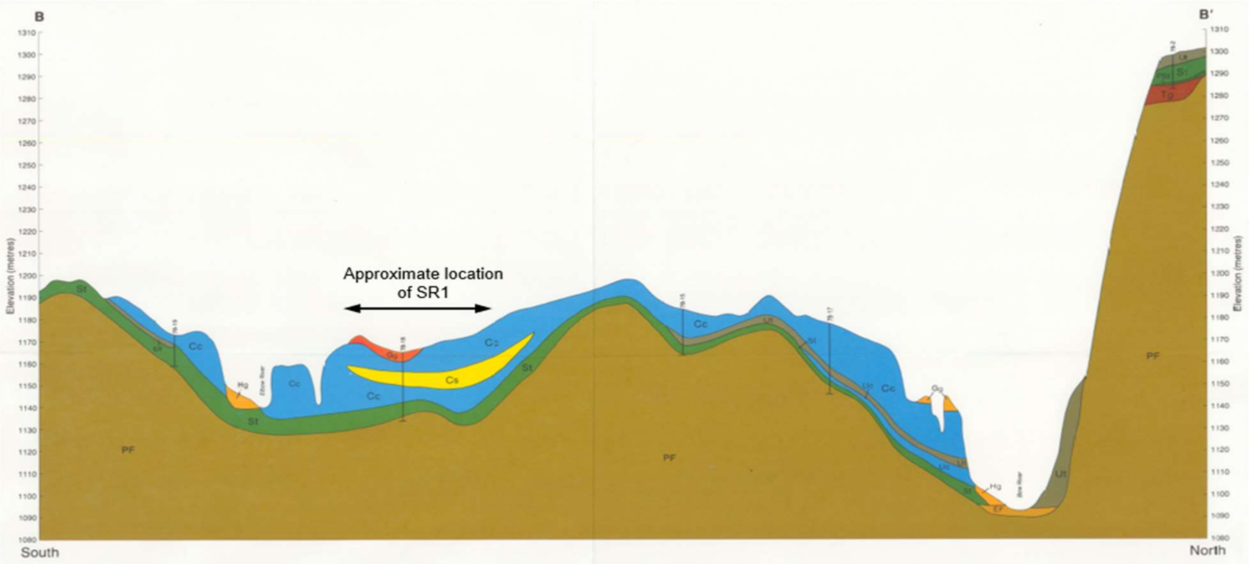

Figure 1. Geological cross-section through the SR1 area showing the disposition of glacial deposits over the bedrock. *(Note: Gg = fluvial channel gravel; Cc = Calgary Formation clayey lacustrine deposits; Cs = Calgary Formation fluvial channel sand; St = Spy Hill Formation till - Lower Unit; PF = Paskapoo Formation)*

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[1] Pdf pages 161-215 of Exhibit #110

The applicant has indicated in their submissions to the NRCB that the amount of leakage from the SRI, when full, will be minimal and on the order of 426 m^3/day. This value has been generated by the groundwater numerical model constructed to assess how this large earthen dammed structure will influence the local groundwater conditions under dry and filled configurations, if commissioned. The concern raised by the SCLG is the accuracy of this estimate given the lack of supporting evidence provided by the applicant.

To understand the hydraulic properties of deposits like the overlying glacial gravel (Gg), Calgary Formation lacustrine clays (Cc) and fluvial sands (Cs), and the Lower Spy Hill Formation till (St) the applicant conducted a number of field-based hydraulic conductivity (K) tests. These test are designed to measure the in-situ ability of the sediments to transmit water. A number of these tests were also conducted in the Paskapoo Formation bedrock to understand their water transmitting properties. Of the 46 tests performed, only three were conducted in the overlying surficial deposits, and only one in the uppermost surficial clay (i.e. the primary barrier to vertical flow beneath the SR1 reservoir area).

Three K tests, with only one in the primary barrier beneath the SR1 containment area is hardly enough to capture the range of values in the overlying sediments given their importance to seal off water leakage through the base of the structure into the underlying bedrock. Most of the area's residents have their water wells completed in the underlying bedrock and use that water for human consumption, livestock watering and other day-to-day needs. Concerns have been raised by the SCLG regarding how the operation of the SR1 reservoir will affect the water levels in their wells (i.e. will some become flowing artesian?) and the chemical quality of the water (i.e. will things change due to the introduction of contaminants?).

The modelled leakage through the base of SR1 reservoir is based on the thickness and K value of the surficial deposits mapped below the structure's proposed footprint. The three K values noted for the surficial sediments ranged from a low of 2.4 x 10^{-10} m/s to 2.2 x 10^{-7} m/s, with the lower K values predominating. The low K values noted are consistent with clay-dominated deposits, assuming that they are not significantly fractured. The one K value on the order of 10^{-7} m/s supports the occurrence of fractures in the surficial deposits based on studies of southern Alberta (Hendry 1982) and the glaciated plains of southern Canada (Keller et al. 1991). In those studies the researchers found that fractures in surficial deposits of glacial origin extended to depths of up to 30 m or so due to a much lower water table during an extended warm period following the last continental glaciation of North America. This les to the weathering, leaching, and desiccation of the mostly clay-rich deposits. Hydraulic conductivity values associated with the intact sediments were found to be very similar to the lower-end K values documented by Stantec (e.g. 10^{-10} m/s). However, the one in-situ test generating a K value on the order of 10^{-7} m/s is direct evidence that the deposits beneath the SR1 reservoir footprint are likely fractures.

Hydrographs from monitoring wells installed by the applicant during field investigation at the SR1 site provide evidence of hydraulic connectivity between the overlying glacial deposits and the bedrock intervals, further supporting the role of fractures in providing pathways for groundwater movement. Figure 2 is a comparison of hydrographs generated from wells completed in the surficial deposits and bedrock beneath the site. It is clear that the wells in both intervals are showing similar water level responses.

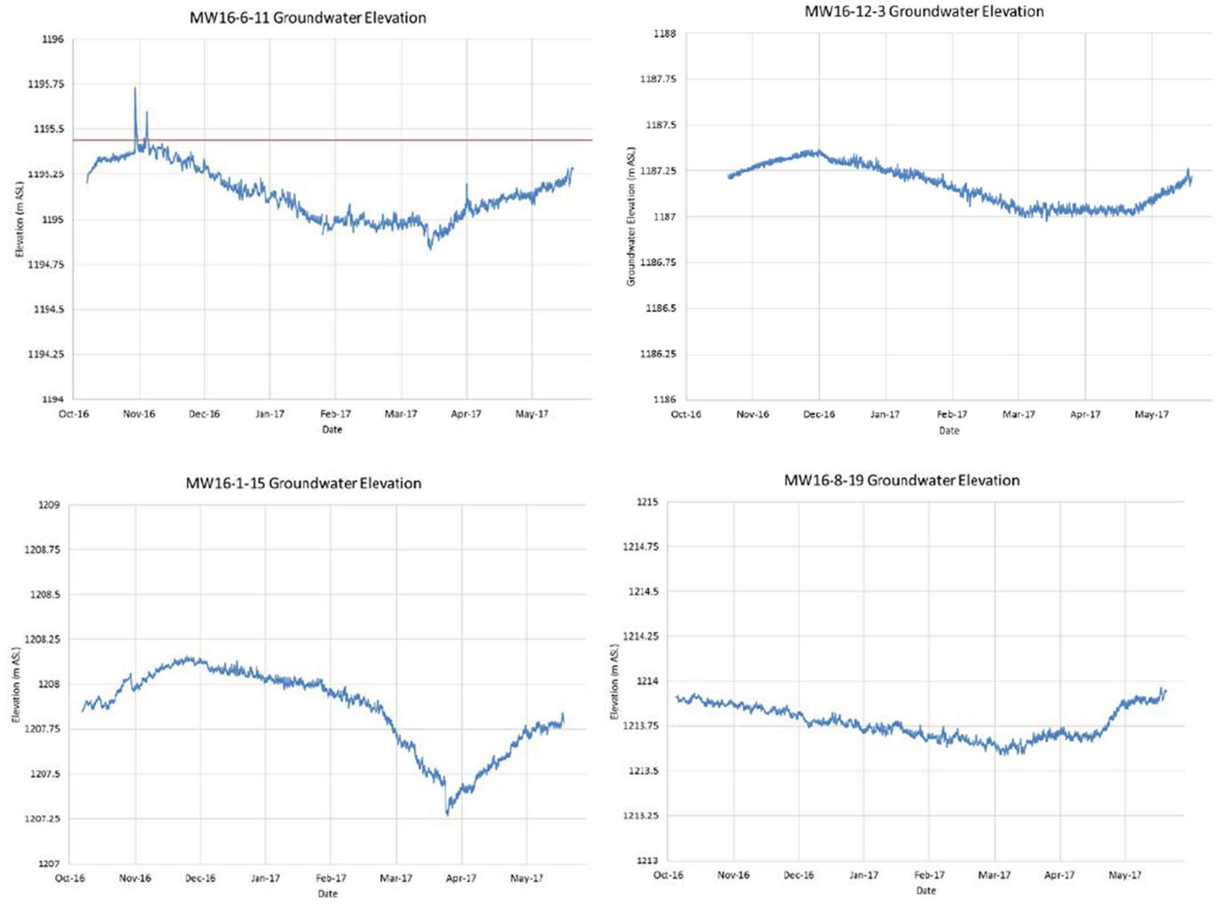

Figure 2. Similarity in water level responses in wells completed in the glacial deposits (upper graphs) and bedrock intervals (lower graphs).[2]

Another concern with the application materials filed by the applicant is the lack of information regarding mineralogy of the various glacial deposits. It is clear that the types of minerals present in the underlying soils will have an influence on geotechnical stability of the area when subjected to loading by a large earthen dam structure and the weight of water when the reservoir is partially or completely filled during a flood event. According to Moran (1986) the deposits of the Lower Spy Hill Formation contain a notable amount (i.e. up to 43% of the mineral clay fraction) of montmorillonite - a swelling clay similar to bentonite. When hydrated, these types of clay lose their cohesion and can create a shear-slip plane when placed under a load. The concern of the SLCG is that when the reservoir structure is in place, the added weight of the earthen

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[2] From pdf pages 78-79 of Exhibit #110

dam and water may cause the structure to move resulting in structural integrity issues, and possible catastrophic failure.

Further details regarding how the lack of understanding of hydraulic and mineralogical properties of the surficial sediments would influence the groundwater numerical model are discussed later. However, it is clear that the information provided is inadequate to constrain any modelling attempts (physical or chemical) and ultimately weakens the applicants understanding of how the placement and design of the SR1 will impact the underlying groundwater of area.

2. Efficacy of the groundwater model

In preparation of Alberta Transportation's application documents, Stantec developed a numerical model to better understand how the SR1 design would affect groundwater conditions in the project area. A subsequent update was provided following a number of supplemental information requests (Exhibit #110; Stantec 2019). The purpose of the model was to simulate the influence of the proposed infrastructure on hydraulic heads (i.e. groundwater levels and/or pore pressures) and flow conditions in the surficial and bedrock deposits. The model that was developed consists of seven (7) layers, each representing a certain interval of the underlying formations. As stated on pdf page 112 of Exhibit #110:

> *"The model layers were developed based on the 3D CSM and are consistent with the interpreted geologic contacts."*

In this case, CSM means the conceptual site model. The modelling code used was FEFLOW, a finite element simulator used to project changes in groundwater flow conditions based on perturbations of hydraulic head from dry "post-construction" conditions to full-flood containment (i.e. design flood of 2013). Although reasonably constructed, the model suffers from a number of limitations. The first is the hydraulic properties that have been attributed to the underlying glacial sediments beneath the SR1 reservoir footprint. As shown in Layers 1-5 in Figure 3, the underlying K value across much of the reservoir footprint is 7.2 x 10^{-8} m/s. This value is one order of magnitude, or more, lower than values expected for fractured till as reported by Hendry (1982) and Keller et al. (1991). The addition of a low permeability layer beneath the SR1 will influence the following:

i) The ability of water to leak through the base of the structure and create increased pore pressures in the underlying sediments than can lead to geotechnical issues along planes of weakness within and between differing sediment horizons.

ii) Flushing of the natural sediments under an increased hydraulic head, and movement of harmful trace elements from the surficial deposits into the bedrock intervals used by local residents.

iii) The possibility of contaminants entrained in the flood waters being introduced into the subsurface when the SR1 contains water.

iv) Introduction of well-oxygenated surface water into the subsurface leading to increased mineral weathering reactions and the further release of harmful trace elements to the groundwater.

It is clear that the increased head of water (up to 24 m at its deepest point near the Low Level Outlet) will serve to increase the vertical hydraulic gradient and effectively push water through the surficial deposits down to the bedrock. Unfortunately, this aspect has not been assessed beyond the following statement on pdf page 151 of Exhibit #110 (Stantec 2019):

> *"An estimate of seepage out of the reservoir area when full and just prior to commencement of release (when seepage rates out of the reservoir area would be at their maximum) was obtained through examination of the flux values at each of the nodes within the reservoir. Summation of the net fluxes yielded an estimated seepage rate of 426 m^3/day out of the reservoir."*

Again, this seepage rate has been estimated based on the hydraulic conductivity values used in the model, which are arguably too low when considering the presence of fractures in the overlying surficial deposits. It is quite possible that this flux value may be an order of magnitude, or more, higher. That being the case, the additional leakage of water through the base of the SR1 reservoir down into the bedrock is a concern. In addition to the possible translocation of natural contaminants from the surficial sediment into the bedrock, there is the risk of contaminants picked up by the flood waters upstream of the site (i.e. from Redwood Meadows and Bragg Creek) migrating down into the bedrock intervals when the reservoir is containing flood water.

There is also an issue related to how well the groundwater model is representing simulated hydraulic heads. The statement is made on pdf page 127 of Exhibit #110 (Stantec 2019) that:

> *"Systemic bias in the simulations can be also evaluated by comparing the residuals to the simulated water levels. Figure 4-15 presents a plot of the residual values at each of the calibration points versus its simulated head. The plot indicates that residuals are distributed both above and below the zero line, again indicating no systemic bias in the calibration."*

From a review of Figure 4, taken from the Stantec report (pdf page 127) there seems to be an error with that statement. Closer review indicates that the majority of residual values lie above the zero-line, which is a systemic bias. The simulation of "higher than observed" hydraulic heads will adversely affect the seepage estimates provided, making them lower than anticipated due to less of a vertical gradient downward through the surficial deposits towards the bedrock.

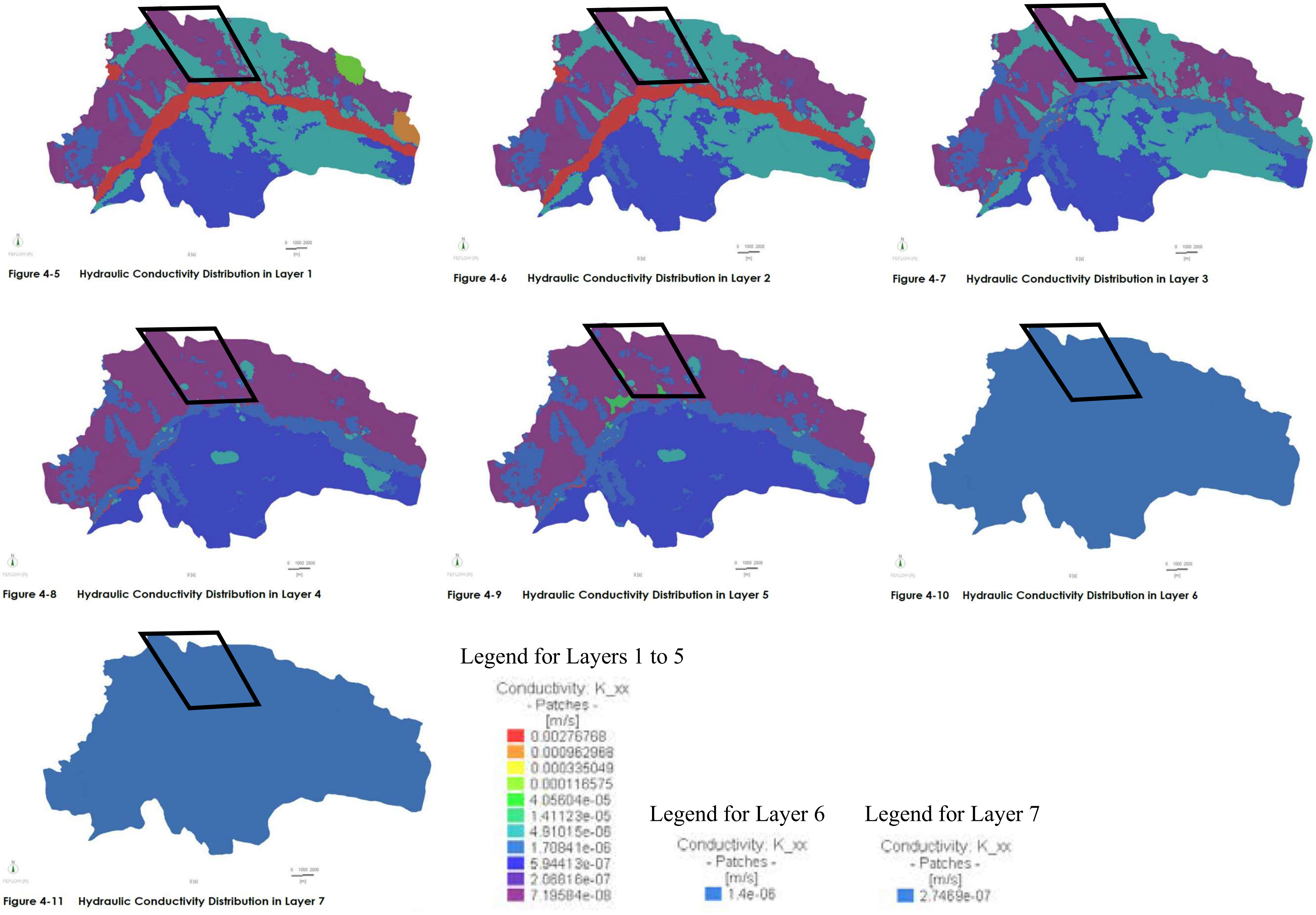


Figure 4-5 Hydraulic Conductivity Distribution in Layer 1

Figure 4-6 Hydraulic Conductivity Distribution in Layer 2

Figure 4-7 Hydraulic Conductivity Distribution in Layer 3

Figure 4-8 Hydraulic Conductivity Distribution in Layer 4

Figure 4-9 Hydraulic Conductivity Distribution in Layer 5

Figure 4-10 Hydraulic Conductivity Distribution in Layer 6

Figure 4-11 Hydraulic Conductivity Distribution in Layer 7

Figure 3. Distribution of hydraulic conductivity (K) values in various Stantec model layers (Stantec 2019). *(Note: black trapezoid shows approximate location of reservoir footprint)*

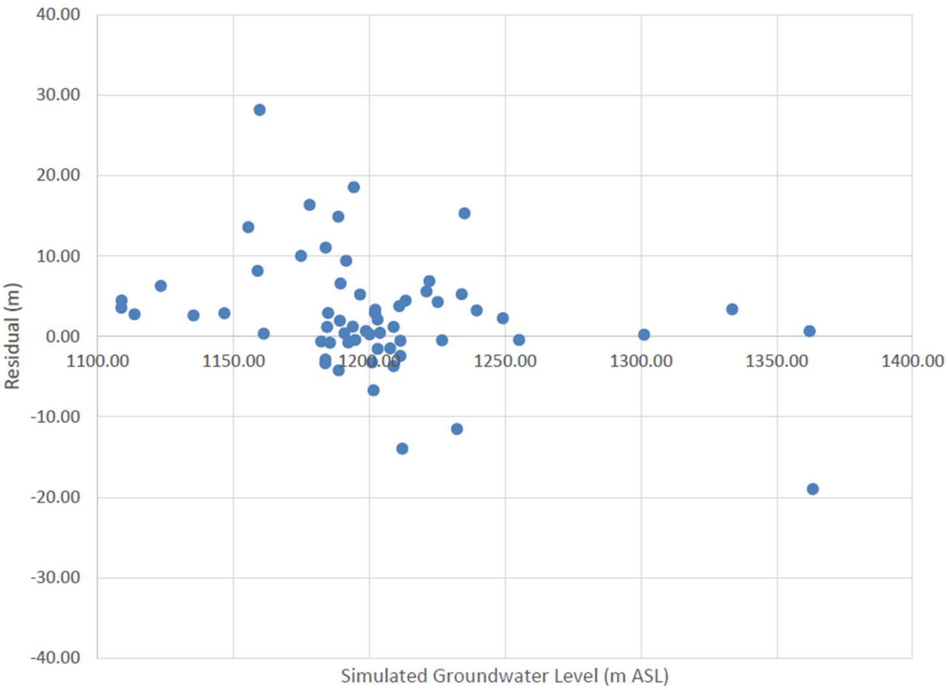


Figure 4. Graph of residual values from groundwater numerical model showing positive bias between simulated versus measured hydraulic heads.

Another issue is the lack of information provided by the applicant showing how, and to what degree, hydraulic head conditions might change in the various model layers beneath the project area, particularly the SR1 reservoir. Provision of some simulated hydrographs for targeted "Points of Interest Used for Interpretation of Time-Series Evaluation" (displayed in Figure 5-4 on pdf page 135 of Exhibit #110) in the various clay, till, and bedrock intervals would have provided a better understanding of the potential change in pore pressure conditions at critical depths (e.g. formation interfaces), vertical gradient conditions, and migration potential for contaminants.

It is obvious from the model results that the simulated net change in hydraulic head conditions is generally confined to the immediate area around the reservoir. This is noted when comparing the project effects for the design flood basis (PXX1/EXX1) to the baseline condition (PXX0/EXX0) with no water in the SR1 reservoir. This is shown in Figures 5 to 7 for various sensitivity scenarios listed in Table E.11-1 on pdf page 472 of Exhibit #110.

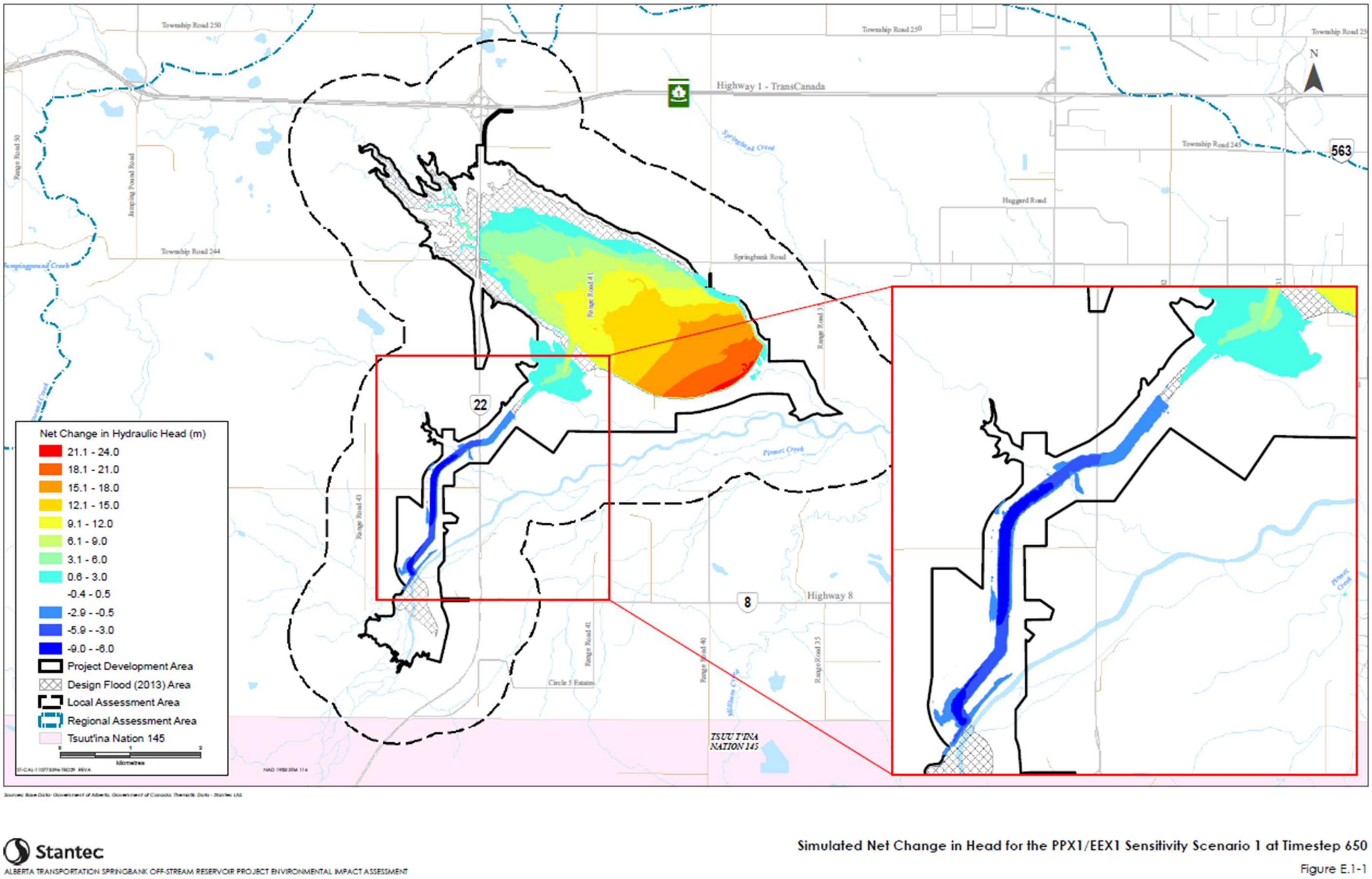


Figure 5. From pdf page 477 of Exhibit #110 (Stantec 2019)

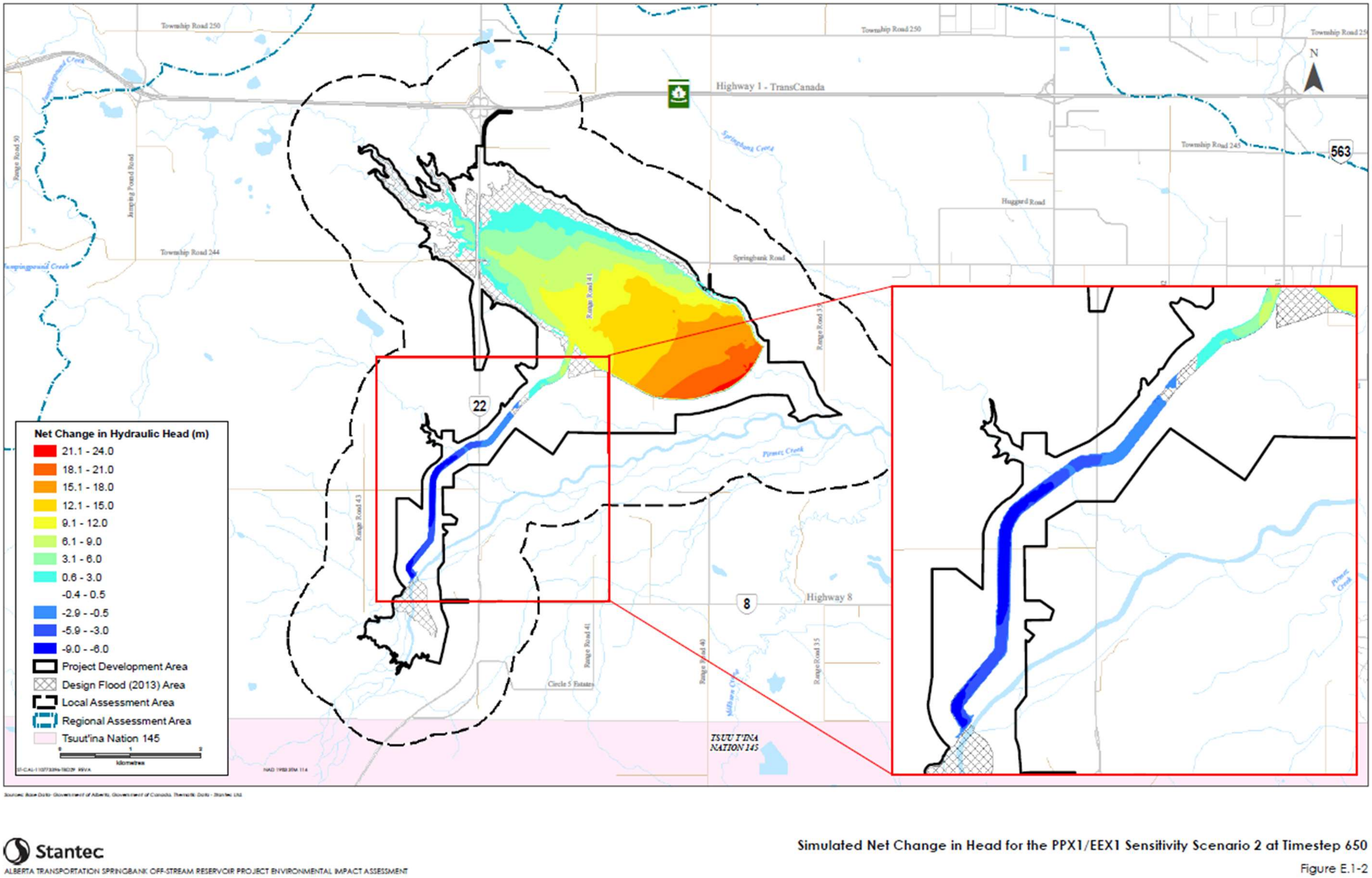
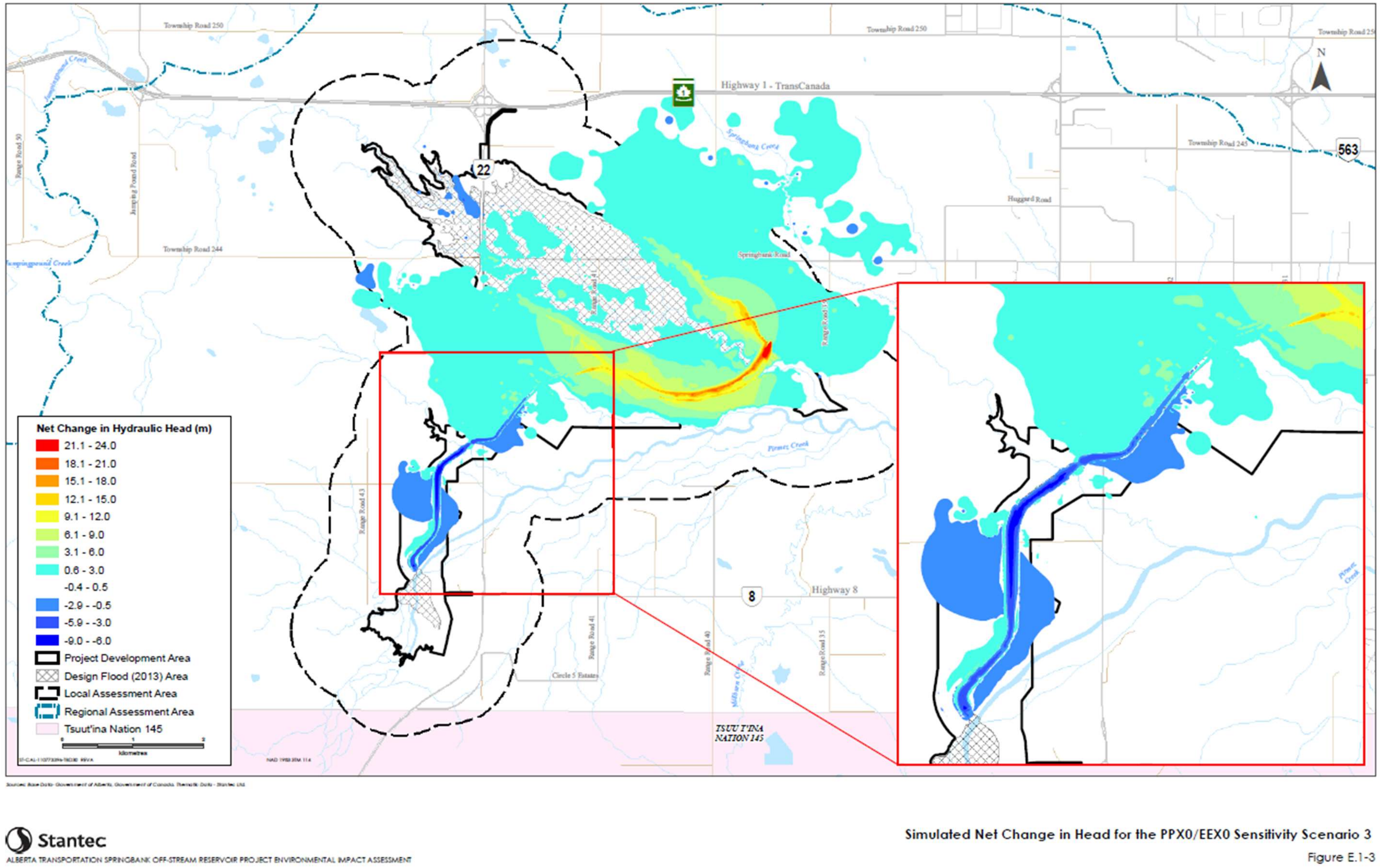


Figure 6. From pdf page 478 of Exhibit #110 (Stantec 2019)



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

Figure 7. From pdf page 479 of Exhibit #110 (Stantec 2019)

It clear that the three order of magnitude increase in hydraulic conductivity values for the till in Sensitivity Scenario 1 has little effect. It is also clear that Sensitivity Scenario 2 (with an increase in storativity and specific yield) has little effect. The difference is shown in the baseline case where increased hydraulic head conditions up to 9 m or so extending outwards for the footprint of the earthen dam.

Although the maps provided in Figures 5-7 are useful to some degree, what is lacking is a full accounting of the resulting changes <u>within or between</u> the model layers under the various scenarios (i.e. water balance and fluxes). However, all that is provided by the applicant is a summary table on pdf page 125 of Exhibit #110 (Table 4-2: Residual Statistics from Steady-State Calibration) indicating that the model results are acceptable. This in no way clarifies whether there are issues in certain parts of the model domain versus others and is just an average of entire model domain. The considerable difference in observed versus simulated head of -18.98 to +28.14 metres, as indicated in Table 4-1 on pdf page 123 of Exhibit #110 (i.e. Observed versus Simulated Heads and Calculated Residuals) and shown in the preceding Figure 3 of this submission, is a clear indication of the issue with accurately simulating observed conditions. This is to be expected, because models are a gross simplification of actual conditions and are based on the input parameters uses. As such, they rarely provide accurate and precise answers.

The lack of information provided by the applicant unfortunately does not allow a comprehensively assessment of model efficacy to be performed, particularly with respect to how water is moving through the various geologic layers and impacting others, both under dry condition and when the reservoir is containing diverted flood water. The geotechnical risk associated with higher pore pressures anticipated in the underlying sediments therefore remains in question.

3. Lack of review for geochemical issues and water quality

The proponent has conducted baseline surveys of the groundwater beneath the SR1 project area. The results of this assessment are communicated in the Table 3-4: Summary of Groundwater Analytical Laboratory Results on pdf pages 93-97 of Exhibit #100 (Stantec 2019). A comparison of the groundwater sampled from the glacial deposits with that in the underlying bedrock was made by the applicant and the results are provided in Figure 8. It is clear from a review of that figure that the groundwater sampled from the surficial deposits is chemically similar to the groundwater sampled from the upper bedrock. This is another indication of hydraulic communication between the two intervals - this time chemically versus physically, as previously noted in Figure 2.

Further review of the baseline water quality reveals some other interesting aspects. With respect to trace elements, the presence elevated selenium (Se) and uranium (U) concentrations in the groundwater sampled from the clay and till deposits has been noted. In fact, selenium values as high as 0.056 mg/L and uranium as high as 0.04 mg/L have been recorded. These concentrations are above the maximum acceptable concentration (MAC) for Canadian drinking water of 0.050 and 0.020 mg/L, respectively[3] based on health-related effect. The effects of exposure to elevated selenium include hair loss, tooth decay, weakened nails, and nervous system disturbances, while those for uranium (a radioactive element) include impact to the kidneys. The occurrence of these elements is most likely connected to natural processes, but nevertheless does indicate that the geochemical conditions are suitable for their mobility from the local sediments into the local groundwater.

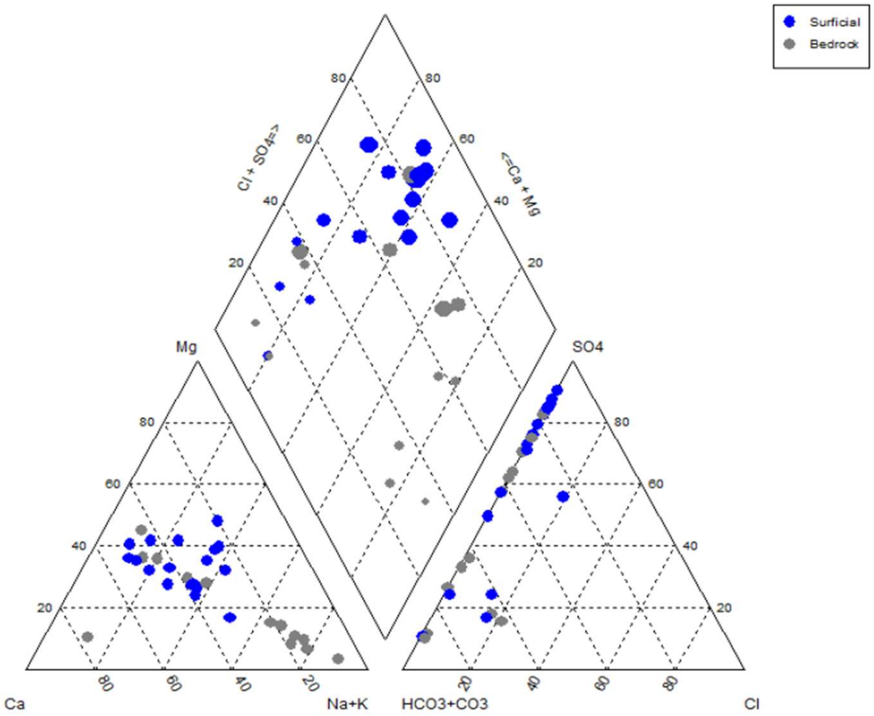


Figure 8. Piper plot showing major ion composition of the water contained in the surficial (glacial) deposits and the underlying bedrock.[4]

Further review of the baseline water quality data in Table 3-4 of Exhibit #110 also indicates the presence of elevated iron and manganese, as well as notable detections of ammonia and nitrite. This provides some indication of the oxidation-reduction potential (ORP) of the groundwater in the absence of field verification by the applicant. Figure 9 show Eh-pH diagrams for selenium and uranium with the red shaded areas indicating the anticipated conditions in the local groundwater. The dominant species identified in these figures are selenate (SeO_4^{2-}) and uranyl hydroxide (UO_2OH^+). These are relatively mobile constituents whose mobility could be enhanced by this project.

There are two major concerns related to these harmful trace elements and the location and operations of SR1. First, the operation of the reservoir under flood conditions will provide a large driving head of water

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[3] Health Canada 2020

[4] From pdf page 92 of Exhibit #110

at the base of the structure that will serve to flush these trace elements, and any other contaminants present in the flood accumulated flood waters, down into the bedrock, in effect compromising the water quality in that interval and impacting the drinking water supplies of local residents. Secondly, the introduction of well-oxygenated surface water accumulated in the reservoir may lead to additional release of selenium and uranium, and possibly other harmful trace elements, through various geochemical reactions (e.g. ion exchange, mineral dissolution, etc.). Unfortunately, the applicant has not assessed this risk or any other groundwater quality concerns that could arise from the construction and operation of the SR1.

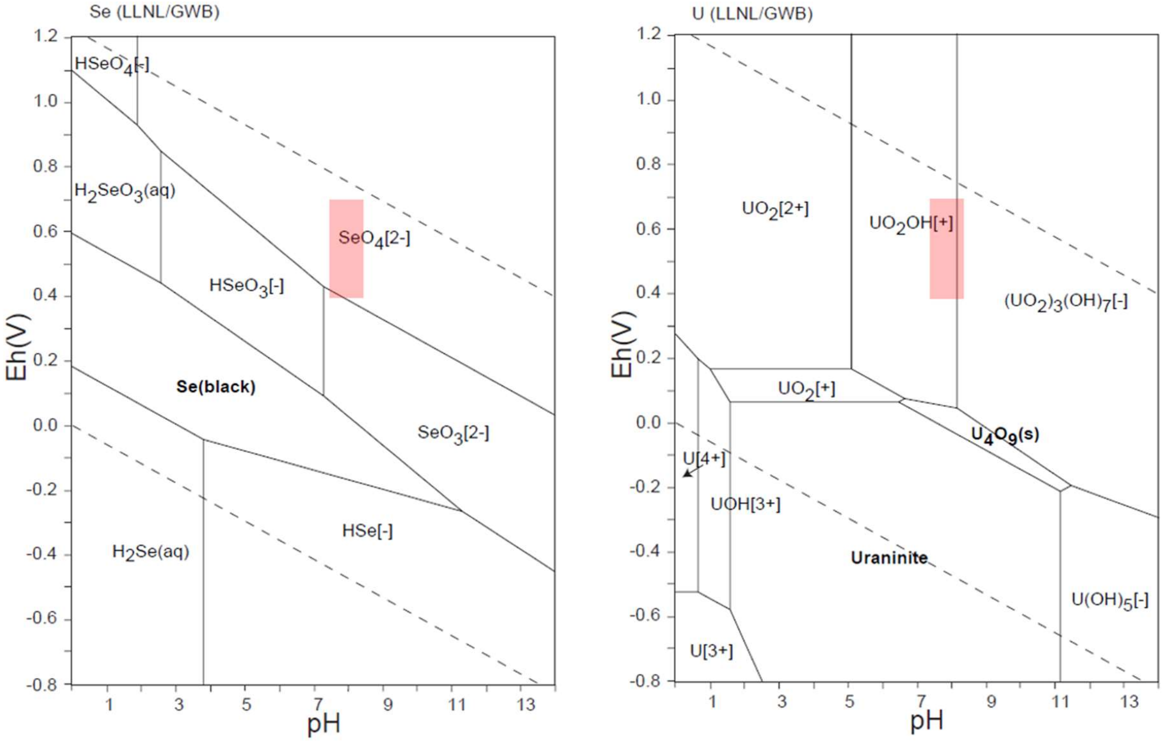

Figure 9. Eh-pH diagrams for selenium, left and uranium, right.[5] *(Note: red shaded areas represent conditions anticipated for the local groundwater conditions based on ammonia, iron, manganese and nitrite values)*

4. Climate change considerations (including variability)

The SCLG is concerned with how climate variability and climate change have been addressed in this application, or more precisely how they have not been addressed. The applicant has relied on instrumental flow records that span from the early 1900s for the Elbow River. This limited flow period is of greatest concern given the fact that larger flow events recorded in the neighbouring Bow River have not been documented for this river. It is therefore clear that the record of flow on the Elbow River has not captured the full range and magnitude of runoff events. This equates to the concern that the SR1 flood management

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[5] Geological Survey of Japan 2005

system has not been sufficiently designed to address the magnitude of flood events that have likely surpassed the design flood of 2013 and will likely occur in the future.

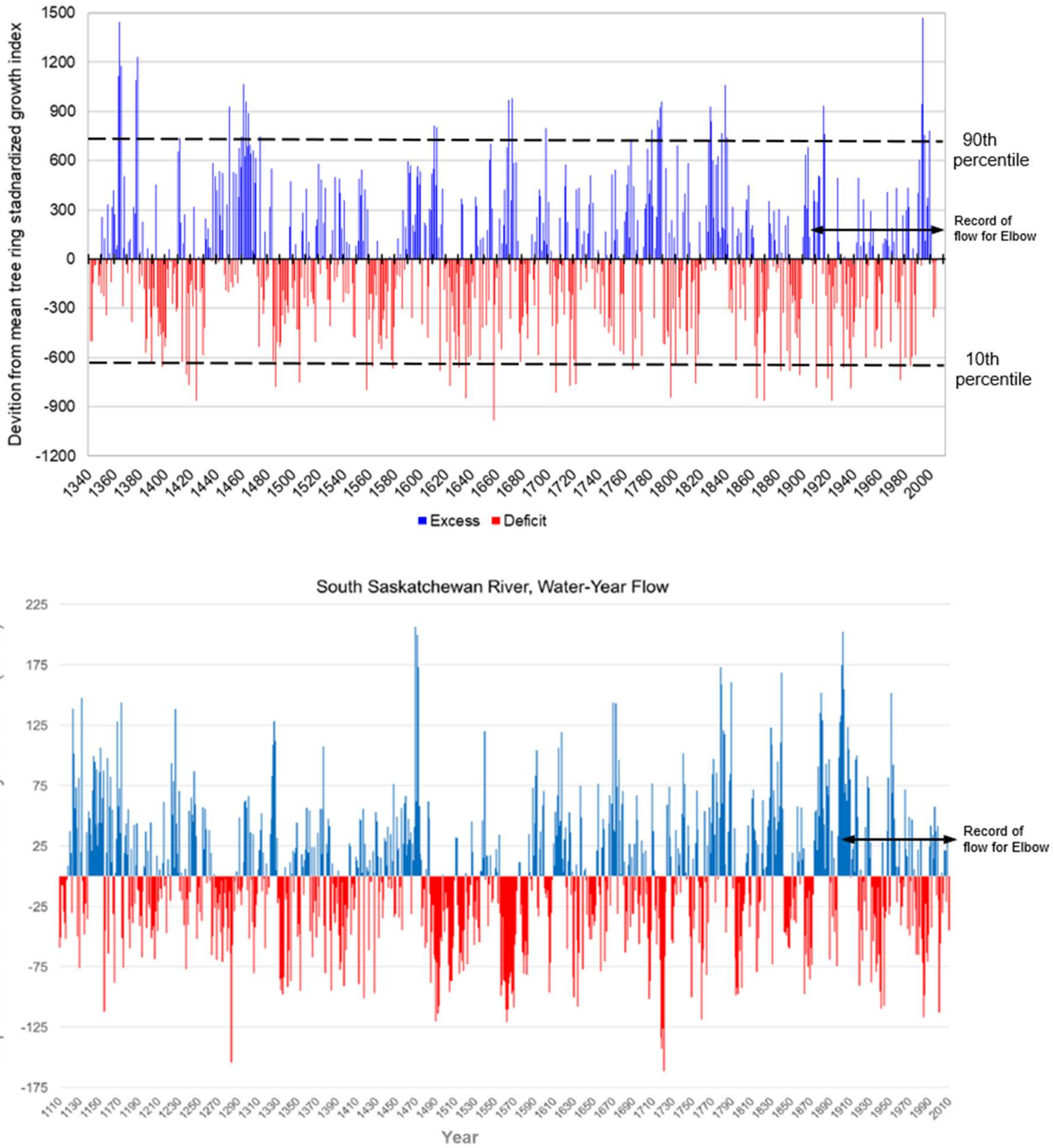

Figure 10. Reconstruction of past climate and flow conditions based on tree rings[6] with positive (blue) and negative (red) departures from mean conditions[7]

To better understand the range of variability in hydroclimatic conditions, scientists often use paleo-records such as age-dated sediment cores and tree-rings to give some idea of past temperature and moisture conditions in an area. With respect to tree rings, each year a tree grows it produces a new ring of wood. In

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[6] Axelson et al. 2009

[7] Sauchyn and Illich 2017

years with good growing conditions (wet) the thickness of these tree rings will be greater than the thickness of those produced during less favourable conditions (dry). Once standardized, the variability in tree ring width for each growth year can be used to reconstruct past climate conditions. By counting the tree rings back from the most recent to the core of the tree the age of the tree can be established. Going one step further, scientists have used this information to reconstruct river flow conditions back several hundreds of years.

The upper image in Figure 10 shows results for a tree core taken from a Douglas Fir located in the Wildcat Hills area approximately 30 kilometers northwest of the SR1. Reconstruction of the past climate over the last 660 years or so indicates highly variable conditions, shifting from periods of excess (flood potential) to periods of deficit (drought potential). The black dashed lines on that upper image identify the 90th and and 10th percentiles of the deviation from mean tree ring standardized growth index. These extremes are considered appropriate to describe potential flood and drought conditions, respectively. Of particular relevance is the number of times when the 90th percentile is exceeded and how these exceedances compare to the record of flow for the Elbow River.

The lower image in Figure 10 represents a reconstruction of streamflow for the South Saskatchewan River. Although this reconstruction includes both the Bow and Oldman watersheds, it does provide an indication of how streamflow conditions have changed in southern Alberta over the last 900 years. From a review of this figure It is apparent that there have been wet periods spanning several years to decades. When compared to the most recent flood events documented for Elbow River (Figure 11), it is would appear that the assessment of flood conditions has not captured the full range of conditions that could be expected.

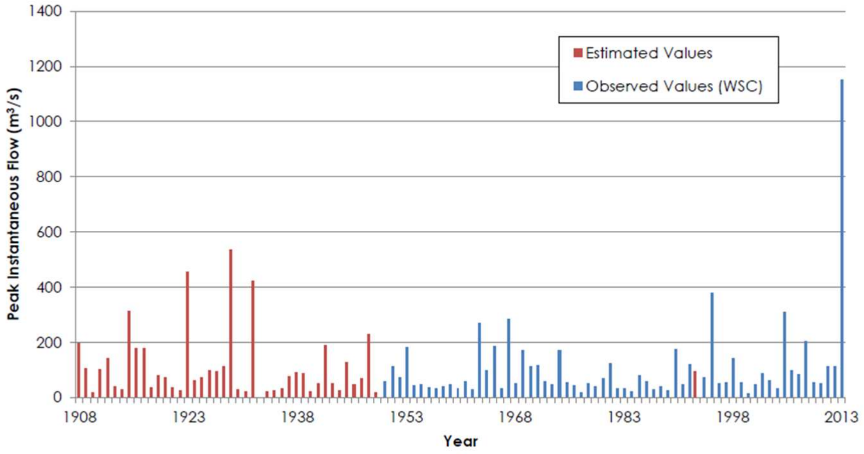

Figure 11. Observed and Estimated Peak Instantaneous Flows of Elbow River at Bragg Creek Station (1908-2013)[8]

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[8] From pdf page 28 of Exhibit #173 (Appendix B – Hydrology, September 25, 2020)

This type of reconstructive analysis provides a view into the past and an indication of what might happen in the future. Additionally, the global climate modelling community has produced a number of useful General Circulation Models (GCMs) to project future changes to temperature and precipitation conditions under varying greenhouse gas emissions and global warning scenarios. Based on the output of these GCMs, future precipitation in the Elbow River watershed is anticipated to increase up to 12% annually by the end of this century, and up to 34% during the Spring period[9]. The results of these projections are summarized in Figure 12. Timing of the freshet is also projected to shift to earlier in the year by approximately 1 month as the winter season shortens. A change in the magnitude and seasonality of precipitation and an increase in the magnitude of peak flows is also anticipated (Figure 13).

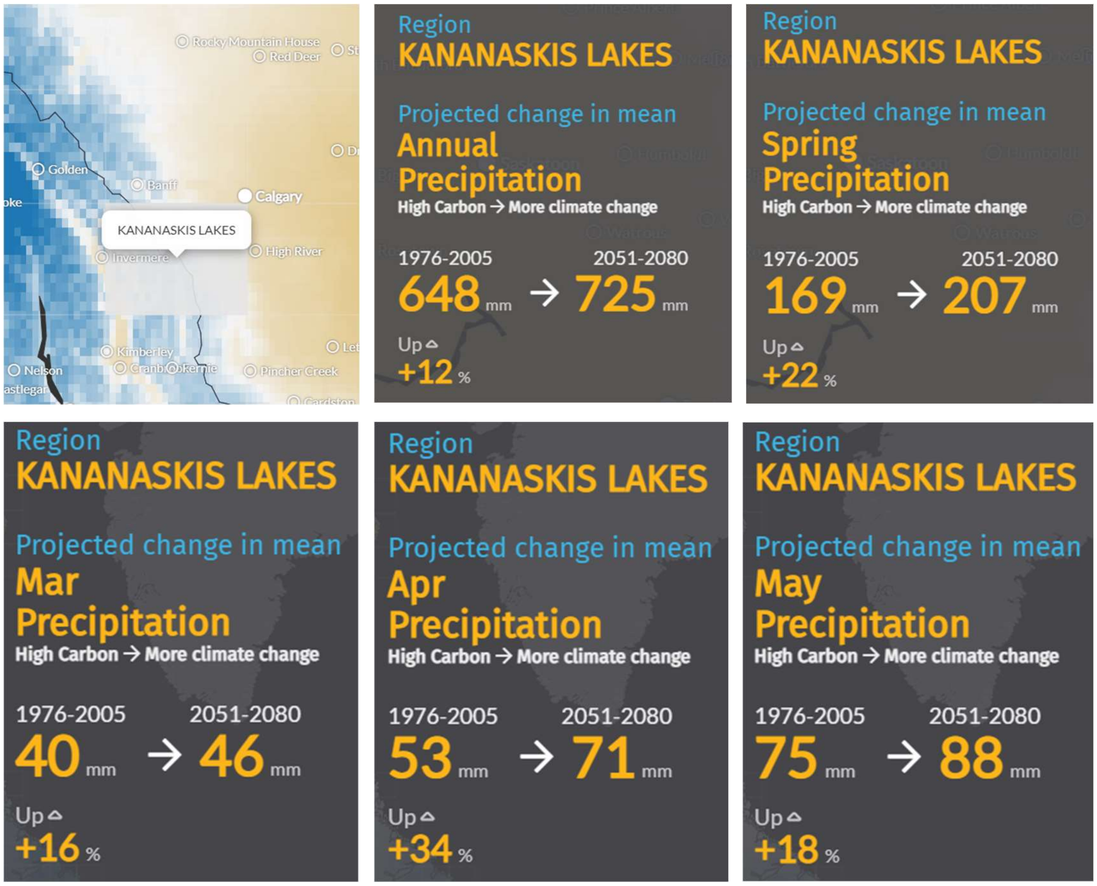

Figure 12. Projected changes to precipitation under the high-carbon (RCP 8.5) worst-case scenario for Elbow River watershed area.

The SCLG are concerned with how the applicant has assessed the flood risk to the Elbow River and how the projected increase in Spring precipitation, combined with an increased risk of rain-on-snow events, has been incorporated in their analysis. Figure 14 shows the historical records of snowpack for the Little Elbow Summit station located in the Elbow River watershed. Based in this historical record there is about a 50%

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[9] Climate Atlas of Canada, www.climateatlas.ca

chance in any given year of an above normal snowpack. Combined with the projection for increase amounts of Spring precipitation, this elevates the risk of higher magnitude flood events like 2013 or much worse.

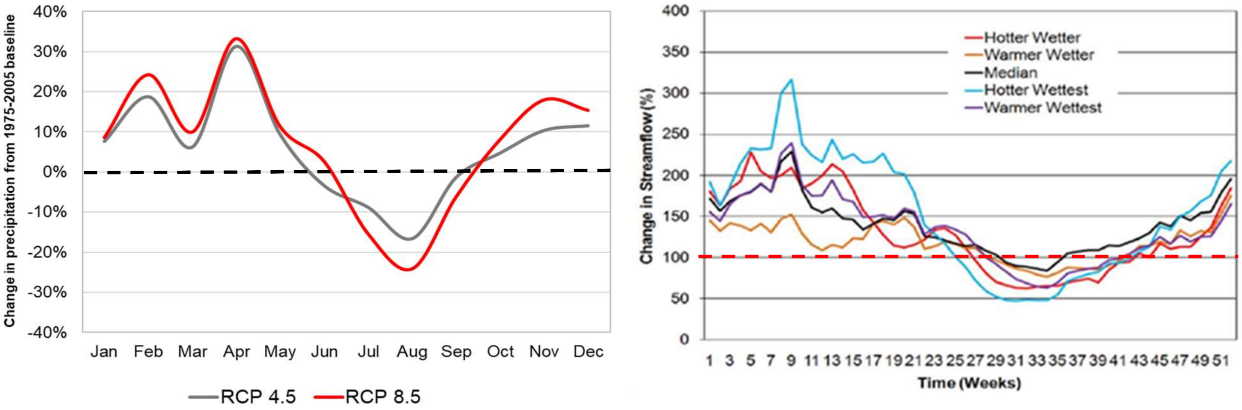

Figure 13. Projected change in seasonal precipitation under moderate (RCP 4.5) and extreme (RCP 8.5) climate change scenarios compared to the 1975-2005 period for the Elbow River watershed[10], and anticipated change in streamflow, as a percent change from the 1961-1990 baseline period (red dashed line), under various climate change scenarios for rivers draining the eastern front ranges of the Rocky Mountains[11].

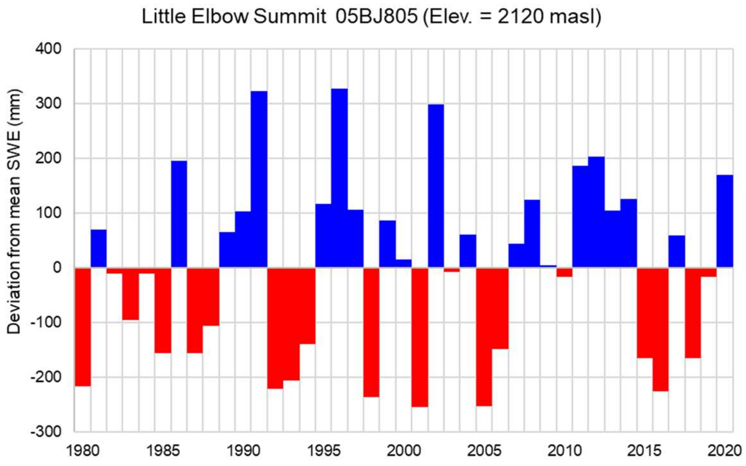

Figure 14. Historical deviation from mean snow water equivalent(SWE in mm) for the Little Elbow Summit monitoring station[12].

However, the applicant has only used the period of record for the Elbow River to indicate the highest magnitude flood for design purposes, which was the 2013 event. It is quite clear that higher magnitude events are likely, based on the instrumental records for the Bow River, but unfortunately the period of record for the Elbow does not capture those events. Therefore, use of the 2013 event as the design flood

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[10] Climate Atlas of Canada, www.climateatlas.ca

[11] Sauchyn et al. 2011

[12] Data from Alberta Environment and Parks

for SR1 has serious limitations given the common occurrence of large spring rainfall events associated with upslope conditions and falling on residual snowpacks[13].

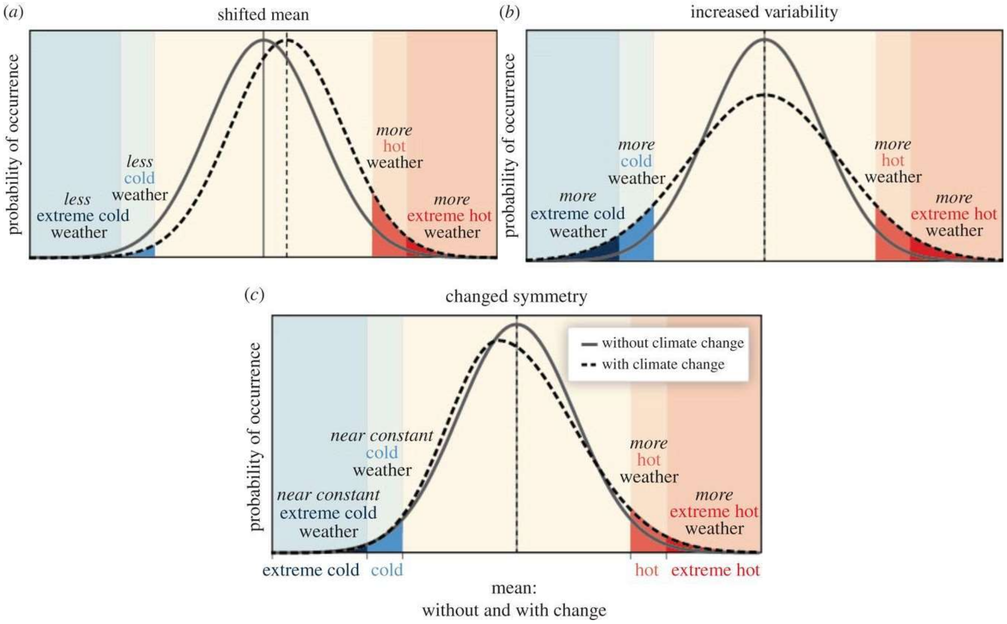

Figure 15. Change in the mean, variability, and symmetry of climate conditions and the impact on probability of extreme events[14]

The expectation, as the world continues to warm, is for the probability of extreme events to increase. This effect is shown in Figure 15 with the expected shift in the mean, variability, and symmetry of the climate (in this case temperature). Similar effects are expected for precipitation as well, with more frequent high magnitude events occurring. What can be expected is the occurrence of hotter weather and more heat waves leading to increased meteorological, agricultural, and/or hydrological drought, as well as an increase in more extreme precipitation events leading to increased flood risk. A shift in the intensity, duration and frequency, or IDF, of precipitation events is therefore anticipated. According to Kuo et al. (2015)[15], the following changes can be expected:

> *"Future IDF curves show a wide range of increased intensities especially for storms of short durations (≤1-h). Conversely, future* ***IDF curves are expected to shift upward*** *because of increased air temperature and precipitable water which are projected to be about 2.9 °C and 29 % in average by 2071–2100, respectively."*

All of this supports the concept that shifting temperature and precipitation conditions of the future will influence the hydroclimate of the Elbow River watershed beyond what we currently understand or believe. Simply using a design flood of 2013 when there is evidence that more extreme flood events have occurred

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[13] Pomeroy et al. 2015

[14] Ummenhofer and Meehl 2017

[15] Kuo et al. 2015

in the region is not reasonable enough, and certainly does not accommodate the worst-case scenario. And, if the worst-case scenario is not accommodated the risk of under-designing the flood mitigation system or having an operational approach that does not achieve the intended goals, is considerable.

Another factor is how return periods and magnitude of flows have been based on the data assessed, and that the applicant's projections are based on those these statistics. It is a known fact that flood statistics continue to change as events occur and are heavily influenced by the larger events. As such, the statistics are not static. For example, if annual daily maximum discharges for wet years are separated out from the entire period of record, the return periods and associated magnitudes of flow change. This effect is shown in Figure 16 for the Elbow River, based on data obtained from the Water Survey of Canada. Wet phases of the climate in Western Canada were separated out using historical records for the Pacific Decadal Oscillation[16].

Although there have been various flood statistics communicated by the applicant in their submissions, and the results shown in Figure 15 may differ from those due to the used of differing data sets, they have been provided for illustrative purposes. It should be noted that the flood event of 2013 has not been included because of its outlying nature and influence on the associated regression line for the "Wet phases" data. Despite not including the 2013 flood event it is clear that during wetter climatic conditions the return periods for events like a 1:100 or 1:200 flood become more frequent (e.g. a 1:100 event shifts to a 1:60, or so, return period). Equally, the magnitude of flow associated with typical 1:100 event during wetter climatic periods also increases.

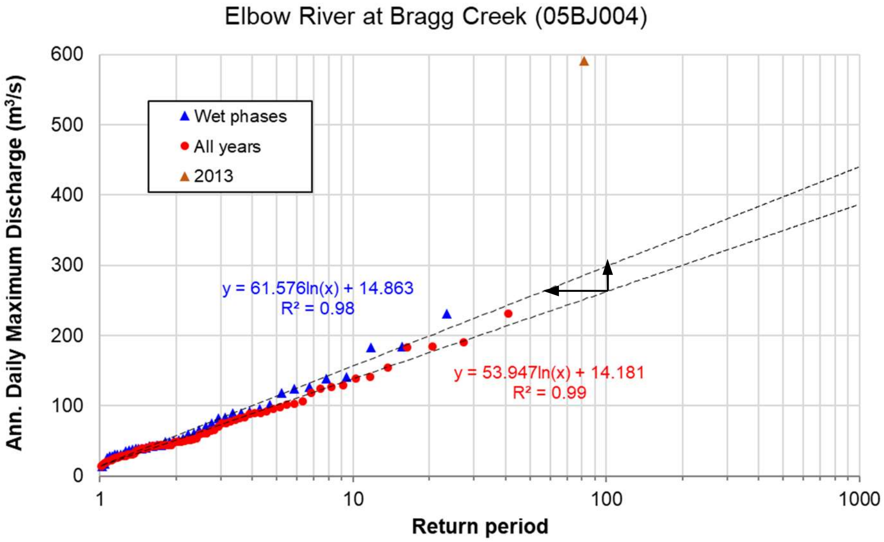

Figure 16. Difference in flood return periods and flow magnitudes when wet years area assessed separately from the entire period of record (using Log Pearson Type III method)[17].

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[16] Joint Institute for the Study of the Atmosphere and Ocean, JISAO, http://research.jisao.washington.edu/pdo/

[17] Data from the Water Survey of Canada website.

As noted previously, future projections from the global climate modelling community are for warmer and wetter conditions in Western Canada with an increase in the intensity, duration, and frequency of rainfall events. Although the applicant has tried to a capture this variability in their assessment, they have not conclusively demonstrated that the current evaluations, model simulations, and assumptions used to support the SR1 design and proposed operation have included the anticipated change in probability of extreme weather events. The applicant has simply stated that the scenarios provided will be conservative enough to adequately frame the anticipated range of conditions, with the 2013 flood being used as the extreme case.

There is also a complete lack of consideration for drought conditions, which have equally manifested themselves in the region over the past several hundreds of years (Figure 10). There has been no exploration of how extended drought conditions affect the viability of the SR1 management system. One consideration to keep in mind is the risk of wind-blown dust from accumulated sediments in the SR1 reservoir. There are likely others; however, this has not formed part of the applicant's assessment process and is therefore a notable gap. Although this is currently not the intended use of the SR1 reservoir, but if the decision were ever made to use the structure as a longer-term storage of water for City of Calgary drought mitigation, the feasibility of such a use would have to be assessed given the physical and geochemical concerns raised in this submission.

Closure

Siting of the SR1 reservoir and related diversion channels and outlet flows in the Springbank area, although convenient from an access perspective, creates some concerns and possible issues for the residents of that area. Not only is valuable agricultural land being taken out of service, but the construction of a large earthen dammed structure designed to contained up to 77,800,000 m^3 of water over a 730 hectare area is concerning from a hydrogeological and geochemical perspective (as well as geotechnical). Unfortunately, no exploration of the geochemical aspects has occurred beyond assessing baseline groundwater quality. The residents of Springbank obtain their drinking water from wells mostly completed in the underlying bedrock, yet there has been no assessment of how the existence of SR1 could impact that groundwater. The numerical model developed to assess how the construction of a large earthen dam and diversion channel is restricted to how hydraulic heads will be affected, but not how pore pressures in various internals (that may be subject to failure) or how movement of existing or introduced contaminants will be affected (or exacerbated).

It is the applicant's responsibility to alleviate the concerns of residents who will be directly-affected by this proposed development, and to assure them that if approved it will achieve the intended goals without placing their health and safety at risk. The establishment of a large off-stream reservoir in the Springbank area is not conducive with the country-residential development there. It also limits future develop to accommodate the recent trend of people moving from the crowded city environment to larger peripheral properties. Based on the information reviewed there are still questions that remain unanswered, including how the climate of the future will affect the design and successful operation of SR1 and the goal of downstream flood mitigation. At the very least this information should be brought forward and considered before any decision is made on this application.

Respectfully submitted by,

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