TOWN OF BLACKFALDS NORTHWEST AREA MASTER STORMWATER MANAGEMENT PLAN

Prepared for:
Town of Blackfalds

Prepared by:
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EXECUTIVE SUMMARY

The Town of Blackfalds has retained Stantec Consulting Ltd. to prepare a Master Stormwater Management Plan for the Town's Northwest Area. This study provides a conceptual design for the overall Northwest Area storm drainage system which ensures that future development within Northwest Blackfalds will have an adequate outlet, and also forms part of the Water Act Application 001-00387959.

In 2013, MPE Engineering Ltd. was commissioned by Lacombe County, Ponoka County, City of Lacombe, and Town of Blackfalds to complete a Master Drainage Plan (MDP) study for the Wolf Creek and Whelp Brook Watersheds. Several land owners located along Wolf Creek and Whelp Brook had voiced concerns about perceived conveyance capacity limitations along these water courses; therefore, Alberta Environment and Parks (AEP) requested that the municipalities undertake the MDP study. The final report for Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds, was generated by MPE Engineering Ltd. on August 31, 2014. Water Act Approval No. 00358426-00-00 was granted to the municipalities on August 24, 2015 to carry out the drainage improvements identified by the MDP.

The Wolf Creek and Whelp Brook Watersheds Master Drainage Plan prescribes pre-development release rates of 0.11 L/s/ha, 0.28 L/s/ha, and 2.0 L/s/ha for the 1:2 year, 1:5 year, and 1:100 year storm events, respectively. This report demonstrates that the Northwest Area Storm System will meet these pre-development release rates.

Additional Whelp Brook modeling was completed in 2017 to support the Lacombe Intermunicipal Development Plan, 2017 Servicing Study. The City of Lacombe and Lacombe County Whelp Brook Flood Hazard Mapping Study was completed by MPE in September 2017. Given that the southern limit of the 2017 Whelp Brook modeling was Highway 12, the MPE study did not verify whether Lacombe Lake, nor Whelp Brook upstream of Highway 12, could provide sufficient conveyance for upstream development areas. However, the continuous simulation results provided within this report demonstrate that the difference between long term pre and post development runoff volumes in Whelp Brook is only approximately 6.8%. The single event modeling also shows that the 1:100 year unit area release rate from Lacombe Lake is 0.48 L/s/ha. Therefore, the resulting post-development release rates are well below the 1:100 year pre-development flow rate and as such, no impact will occur to the downstream environment.

The pre-development catchment area for rural undeveloped lands draining to Lacombe Lake is estimated to be 1,300 ha. The pre and post development catchment area for rural undeveloped lands draining to Whelp Brook located on the north side of Lacombe Lake where the brook crosses Range Road 272 is estimated to be 3,697 ha. The Northwest Area gross development area is 512 ha, but 490.58 ha of the Northwest

Area is assumed to have no overland drainage to Lacombe Lake for pre-development conditions due to the high rate of infiltration in the Northwest Blackfalds Area.

The Northwest Area is characterized by knob and kettle topography with numerous wet low areas that do not have an effective overland spill route/outlet for pre-development conditions. However, as elaborated on in the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment" dated May 28, 2018 and provided in Appendix D, the local hydrogeology is such that there is significant sub-surface flow towards the north, which is intercepted by Lacombe Lake. Additional findings from this letter report include:

- The natural wetlands and proposed stormwater management ponds should behave similarly based on the proposed unlined stormwater management facility (SWMF) design, allowing interaction between surface water features and the groundwater environment;
- The long-term average for rates of groundwater recharge, and eventual discharge to Lacombe Lake should remain similar to pre-development conditions and the overall volume of water entering Lacombe Lake should not change significantly between pre and post development conditions; and
- High infiltration rates are expected based on surficial geology descriptions and lithological records. Infiltration rates are expected to range from 1.1 - 45 mm/hour depending on soil texture as determined from geotechnical grain-size analysis and analytical permeability calculations (10mm/hour is considered a reasonable and realistic rate of infiltration).

In approximately 1972 a diversion structure was constructed on Whelp Brook at Range Road 272, such that when the sluice gate was closed, as portion of the Whelp Brook flows could be diverted towards Lacombe Lake through the previously described ditch/culvert system. Lacombe County holds the existing license (No. 1450 in the North Saskatchewan River Basin) that permits water to be diverted from Whelp Brook to Lacombe Lake. However, our understanding is that the County's long-term intent is to leave the Whelp Brook diversion structure open, such that **no** intentional diversion from Whelp Brook to Lacombe Lake occurs.

The single event modeling results show that under the existing configuration for pre-development conditions that Whelp Brook would begin to back up into Lacombe Lake during an event that exceeds the 1:10 design storm event, and this would occur when the sluice gate on the Whelp Brook control structure at Range Road 272 is left completely open. The occurrence of Whelp Brook backing up into Lacombe Lake would result from existing conveyance capacity limitations of Whelp Brook at Range Road 272, rather than a result of any specific interventions or operational schemes.

The single event analysis results provided in the report body estimate that the difference between pre and post development Lacombe Lake water levels for the 1:100 year design storm event is 0.09 m, and the 1:100 year unit area discharge rate from the lake is only 0.48 L/s/ha. These results assume no changes to the existing conveyance infrastructure at the outlet to Lacombe Lake or on Whelp Brook at Range Road 272.

Continuous simulation modeling over a 23 year period estimates the difference between pre and post development average annual runoff volumes at the Lacombe Lake outlet is increased approximately 35%, and the difference between pre and post development average annual runoff volumes in Whelp Brook is increased 6.8%.

This report provides results from a sediment removal analysis, which demonstrates that the SWMF proposed for the Northwest Area Storm System will provide water quality improvement that exceeds the Alberta Environment and Parks (AEP) criteria for removing 85% of Total Suspended Solids (TSS), for sediment particles 75 microns and larger. The expected level of removal of other contaminants such as phosphorus was also analyzed and is included in this document.

Based on the results of the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment", the expected regional average stormwater management facility infiltration rate of 10 mm/hour, results in only 3% of the total stormwater management facility inflows being discharged offsite.

The single event and continuous simulation analyses provided in this report demonstrate a negligible impact to downstream water bodies, and that Lacombe Lake and Whelp Brook are capable of providing an adequate outlet.

The Town of Blackfalds is committed to preserving wetlands and other natural water bodies through their incorporation into proposed developments and regional storm systems. The Town, through their consultants, are designing storm systems to work with existing topography and natural systems. This report is in alignment with this commitment by preserving existing water bodies and wetlands, and by utilizing existing drainage routes for stormwater conveyance.

The Town of Blackfalds has committed funding to the development of an Environmental Stewardship/Master Plan which will guide internal and external stakeholders on policies and Best Management Practices (BMPs) for items such as, but not limited to, roadway deicer usage, fertilizer and pesticide usage, water and energy conservation, air quality, waste management and composting, and pharmaceutical disposal. The Environmental Stewardship/Master Plan is a living document that facilitates policies and BMPs evolving over time to meet the changing demands of the community and environment.

RECOMMENDATIONS

The following items are respectfully recommended for AEP's consideration:

A. The Northwest Storm Trunk is proposed to drain from the north end of Pond 'A' through approximately 420 m of 900 mm diameter storm trunk, where it will outlet to the south end of Pond 'C'. After conveying through Pond 'C' it will drain through approximately 40 m of 900 mm diameter storm trunk under Township Road 40-0, continue through the proposed system approximately 370 m northwest through a constructed linear wetland, and then outfall to a natural drainage course that further drains north to Lacombe Lake. Although the analysis shows very low release rates, this trunk is sized to accommodate the 1:100 year event with no SWMF infiltration because stormwater management facilities should not be designed to rely on infiltration alone.

B. The Town of Blackfalds is committed to applying the specific Best Management Practices (BMPs) of oil and grit separators for potential "hot spots", the hybrid stormwater management facilities proposed in this report, and an increased topsoil thickness to a total of 25 cm to 30 cm (local supply permitting).

C. Hybrid stormwater management facilities, which include both permanently wet and semi-wet wetland areas within the facility, are universally proposed for the Northwest Area. The hybrid storm pond parameters defined in this report outline the required ratio of semi-wet (infiltration) pond areas to permanently wet pond areas, for which subsequent analyses have quantified the resulting infiltration (runoff volume control) and water quality improvement performance for a facility with these design parameters.

D. It is recommended that water quality data be collected as part of the Northwest Area Water Act Approval. This data will provide valuable information that will help to guide the evolution of the Town's Environmental Stewardship Plan; thus, providing a means to tailor the policies and BMPs that provide protection to the users located downstream of the Blackfalds Northwest Area.

E. The proposed Northwest Area drainage project will provide the future development area with an adequate stormwater outlet. Therefore, it is recommended that the pending Water Act approval for the Northwest Area Master Stormwater Management Plan be approved based on the results provided in this study/analysis.

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Acronyms Table

Number	Acronym	Meaning
1	AEP	Alberta Environment and Parks
2	AIS	Aquatic Invasive Species
3	AT	Alberta Transportation
4	BMP	Best Management Practice
5	County	Lacombe County
6	HWL	High Water Level
7	LID	Low Impact Development
8	MDP	Master Drainage Plan
9	MSMP	Master Stormwater Management Plan
10	NW	Northwest
11	NWL	Normal Water Level
12	OGS	Oil and Grit Separator
13	PCSWMM	Computer model used for analysis
14	SC#	Sub-catchment ID
15	SWMF	Stormwater Management Facility
16	Town	Town of Blackfalds
17	TES	Total Energy Services, Inc. Industrial Park
18	TSS	Total Suspended Solids
19	QE2	Queen Elizabeth II Highway

1.0 Background

1.1 INTRODUCTION

The Town of Blackfalds has retained Stantec Consulting Ltd. to prepare a Master Stormwater Management Plan for the Town's Northwest Area. The Town of Blackfalds is located approximately 8 km north of the City of Red Deer, and the existing Town is approximately divided in half by Highway 2A. Please see Figure 1.0 - Study Area, located at the end of this report section. The Northwest Area gross development area is approximately 512 ha; however, the net developable area is approximately 455 ha. Of the 512 ha total area, Lacombe County wishes to contribute approximately 35.8 ha of future development which is located on the west side of Highway QE2, and Highway QE2 also contributes 20.70 ha. Therefore, the Town lands gross development area is approximately 456 ha, and the net developable area is approximately 419 ha. The primary areas proposed for development are located the following quarter sections:

Town Lands

- Section 34, Range 39, Township 27, W4M,
- W1/2, Section 35, Range 39, Township 27, W4M
- SE Quarter, Section 35, Range 39, Township 27, W4M
- NW Quarter, Section 26, Range 39, Township 27, W4M
- W1/2, Section 27, Range 39, Township 27, W4M

County Lands

- NE Quarter, Section 28, Range 39, Township 27, W4M
- SE Quarter, Section 33, Range 39, Township 27, W4M
- SE Quarter, Section 35, Range 39, Township 27, W4M.

This study will provide a conceptual design for the overall Northwest Area storm drainage system, and also forms part of a Water Act application for the approval of a Master Stormwater Management Plan. A preliminary design for the Northwest Area Storm Trunk is also being completed in conjunction with this study. The conceptual/preliminary designs will provide a valuable blueprint to be followed during subsequent planning and development activities, and will facilitate the development of funding mechanisms.

The Town of Blackfalds is committed to preserving wetlands and other natural water bodies through the incorporation into proposed developments and regional storm systems. The Town, and their consultants, are designing storm systems to work with existing topography by preserving existing water bodies and wetlands, and by utilizing existing drainage routes for stormwater conveyance.

1.2 EXISTING CONDITIONS

The future development areas within the Town are bound by Queen Elizabeth II Highway and Lacombe County on the west side, Highway 2A on the east side, Township Road 40-0 on the north side, and the existing town extents on the south side. Township Road 40-0 also forms the boundary between the Town of Blackfalds and Lacombe County. The Aurora Heights, Aspen Lake West, and Valley Ridge are the active developments located on the leading edge of the north side of Town.

The future development areas are currently used for farming operations that include hay, pasture, and small grain agriculture. During the planning of the Aurora Heights Development the existing natural waterbody Pond 'A' was claimed as Public Lands, and Pond 'B' was not. It is also our understanding that the existing wetland located north of the Valley Ridge development and east of Highway QE2 was also claimed as a Crown waterbody.

On February 2, 2017 Stantec submitted a letter to AEP entitled, "Supporting information for Blackfalds NW Project Water Boundary Review within portions of NE 34-39-27 W4M and SE 3-40-27 W4M. On May 30, 2017 AEP informed the Town and their consultants that both Pond 'C' (W2) and the natural wetland (W1) located immediately north of Township Road 40-0 (Pond 'D') would be claimed as public waterbodies. The relatively small wetland (W3) located between Pond 'C' and Pond 'A' was not claimed. A figure identifying the above mentioned waterbodies, and the May 30, 2017 response from AEP is provided in Appendix F.

Similar to the rest of the Town of Blackfalds, the Northwest Area is characterized by knob and kettle topography with numerous wet low areas that do not have an effective overland spill route/outlet for pre-development conditions. However, as elaborated on in the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment" dated May 28, 2018 and provided in Appendix D, the local hydrogeology is such that there is significant sub-surface flow towards the north, including Lacombe Lake.

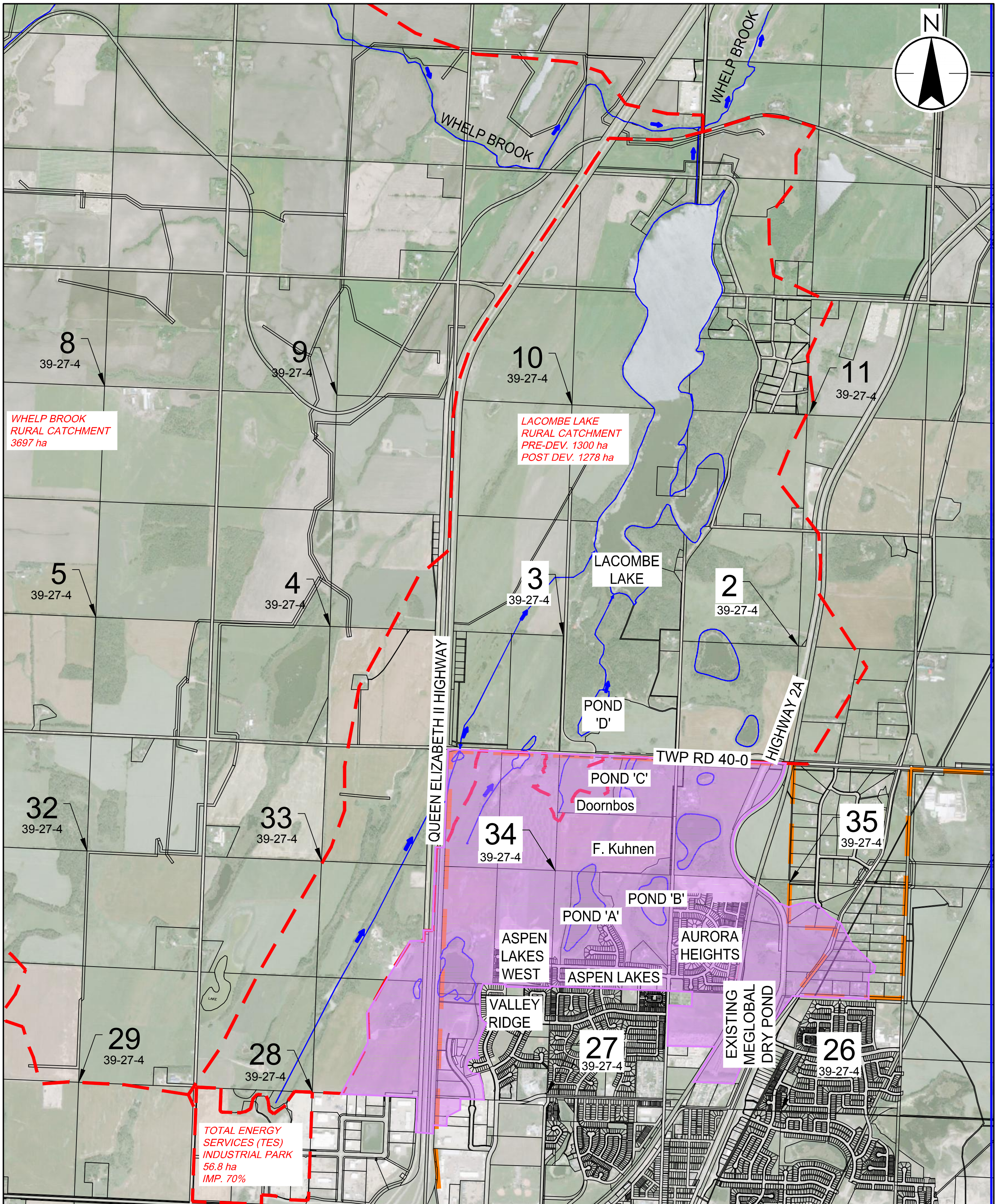
1.3 EXISTING STUDIES

In 2013 MPE Engineering Ltd. was commissioned by Lacombe County, Ponoka County, City of Lacombe, and Town of Blackfalds to complete a Master Drainage Plan study for the Wolf Creek and Whelp Brook Watersheds. Several land owners located along Wolf Creek and Whelp Brook had voiced concerns about perceived conveyance capacity limitations along these water courses; therefore, Alberta Environment and Parks (AEP) requested that the municipalities undertake the study. The final report for Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds, was generated by MPE Engineering Ltd. on August 31, 2014. Water Act Approval No. 00358426-00-00 was granted to the municipalities on August 24, 2015.

Additional Whelp Brook modeling was completed in 2017 to support the Lacombe Intermunicipal Development Plan, 2017 Servicing Study. The southern extent of the additional modeling was Highway 12. The City of Lacombe and Lacombe County Whelp Brook Flood Hazard Mapping Study was completed by MPE in September 2017. Given that the southern limit of the 2017 Whelp Brook modeling was Highway 12, the MPE study did not verify whether Lacombe Lake, nor Whelp Brook upstream of Highway 12, could provide sufficient conveyance for upstream development areas.

The Aurora Heights Stormwater Management Report was submitted on behalf of Aurora Heights Inc. by Stantec Consulting Ltd. On July 14, 2014. However, continued development of the Aurora Heights development has been delayed because AEP has concerns over the Blackfalds Northwest Area not currently having an adequate outlet.

The Aspen Lake West Stormwater Management Report was submitted on behalf of Aspen Lake West Development Inc. by Stantec Consulting Ltd. on June 30, 2015. However, continued development of the Aspen Lake West development has been delayed because AEP has concerns over the Blackfalds Northwest Area not currently having an adequate outlet, and that was the original impetus for this report.



NOT TO SCALE

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LEGEND:
- NATURAL DRAINAGE COURSES/WATER BODIES
- RURAL CATCHMENT AREA
- NW AREA STORM SUB-CATCHMENTS
- TOWN OF BLACKFALDS BOUNDARY

FIGURE 1.0
LOCAL STUDY AREA
TOWN OF BLACKFALDS NORTHWEST AREA MASTER STORMWATER MANAGEMENT PLAN

2.0 Methodology and Input Data

2.1 STUDY OBJECTIVES

The active developments located on the north side of the Town of Blackfalds are currently being restricted because the Northwest Area does not currently have an adequate outlet in terms of storm drainage.

This study will provide a conceptual design for the overall Northwest Area Storm System. The study will provide preliminary storage volumes, discharge rates, land requirements, and design elevations of proposed stormwater management facilities. It will also provide preliminary alignments, dimensions, design elevations, and design flow rates of the proposed Northwest Area Storm Trunk. Preliminary design drawings for the Northwest Area Storm Trunk are also being completed in conjunction with this study, under separate cover.

The primary objective of this study is to provide a storm system design and framework that will ultimately provide an adequate outlet for the Northwest Area, and subsequently facilitate regulatory approvals and further development in the area. The conceptual/preliminary designs will provide detailed plan to be followed during subsequent planning and development activities and will facilitate the development of funding mechanisms.

As previously mentioned, the Town of Blackfalds is committed to preserving wetlands and other natural water bodies through their incorporation into proposed developments and regional storm systems. The Town, through their consultants, are designing a storm system to work with existing topography by preserving existing water bodies and wetlands, and by utilizing existing drainage routes for stormwater conveyance.

The ultimate goal is to demonstate an adequate stormwater outlet for the Northwest Blackfalds area and obtain an approval from AEP for this Master Stormwater Management Plan report, so that the proposed Northwest Area Storm System can be constructed, such that development can occur in this area.

2.2 PRE-DEVELOPMENT DISCHARGE RATE

The project area falls within the study area of the Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds (MPE, August 2014), and as such must meet the pre-development release rate of 2.0 L/s/ha for the 1:100 year storm event, as outlined in the previously named study. Water Act Approval No. 00358426-00-00 was granted to the municipalities on August 24, 2015 for the Master Drainage Plan (MDP). Please also note that the Master Drainage Plan prescribes pre-development release rates of 0.11 L/s/ha and 0.28 L/s/ha for the 1:2 year and 1:5 year storm events, respectively.

2.3 COMPUTER MODELING

The PCSWMM computer model (Version 5.0.022) was used in this study to perform single event and continuous simulation analyses. PCSWMM has a proprietary graphical user interface developed by Computational Hydraulics, Inc. (CHI) in Guelph, Ontario, but is based on the EPA SWMM5 computational engine.

The PCSWMM can utilize steady state, kinematic wave or full dynamic wave routing methods which considers various hydrologic processes, such as: precipitation; evaporation; snow accumulation and melting. By providing input data on rainfall and land use, the PCSWMM model can be used to generate runoff for specific catchments. Algorithms in PCSWMM can then be used to model the conveyance of runoff through pipes or in open channels, and reservoir routing can also be done to represent the attenuating effects of storage found in traplows and/or stormwater management facilities.

2.4 DESIGN STORM

Chicago design storms with 1:2, 1:5, 1:10, 1:25, and 1:100 year return periods, 24 hour durations, and 5 minute time increments, were used to analyze the proposed storm system.

Rainfall intensities for the Chicago distribution were determined from an *intensity-duration-frequency* (IDF) relationship that is described as

$$i = a / (t + b)^c \qquad [1]$$

Where i is intensity (mm/hr), a, b and c are IDF parameters and t is the time duration (minutes). The time to storm peak is determined by

$$t_p / t_d = r \qquad \text{or} \qquad t_p = r(t_d) \qquad [2]$$

Where t_p is the time to peak and r is the ratio of time to peak versus storm duration, t_d.

The following parameters were used to generate the Chicago design storm, and these parameters were developed from the Environment Canada IDF data for the Red Deer Airport (3025480), with data from 1959 – 2012. Please refer to Appendix B for a graphical representation of the 1:100 year Chicago design storm utilized.

a = 248.1	b = 2.27	c = 0.679	r = 0.30 (1:2 year, 24 hour duration)
a = 354.2	b = 1.77	c = 0.684	r = 0.30 (1:5 year, 24 hour duration)
a = 423.5	b = 1.65	c = 0.686	r = 0.30 (1:10 year, 24 hour duration)
a = 513.1	b = 1.49	c = 0.688	r = 0.30 (1:25 year, 24 hour duration)
a = 644.6	b = 1.41	c = 0.689	r = 0.30 (1:100 year, 24 hour duration)

2.5 CONTINUOUS SIMULATION

Continuous simulation modeling was completed to assess potential changes to pre versus post development runoff volumes, the potential effects of back to back storms on Lacombe Lake, and also to complete a sediment removal performance analysis for the type of stormwater management facilities proposed for the Northwest Area.

Continuous simulation analysis was completed using daily rainfall totals recorded at the Environment Canada Lacombe CDA2 (3023722) precipitation gauge, over a 23 year period from 1995 to 2017.

3.0 Hydrology

3.1 SUB-CATCHMENT DELINEATION

The pre-development sub-catchments for the Town of Blackfalds Northwest Area were delineated based upon the DEM topographical data that was collected in 2016, and as shown in Figure 3.0 - Northwest Area Pre-development Storm Sub-catchments, located at the end of this report section. Land ownership considerations resulted in slightly revised post-development sub-catchment boundaries, which can be seen on Figure 3.1 – Northwest Area Storm System, also located at the end of this report section.

The pre-development catchment area for rural undeveloped lands draining to Lacombe Lake is estimated to be 1,300 ha. Please see Figure 3.2 - Lacombe Lake Rural Catchment Area, located at the end of this report section. The existing Total Energy Services, Inc. Industrial Park (TES), located in the SW Quarter, Section 28, Range 39, Township 27, W4M, has an industrial/commercial land use, a development area of 56.8 ha, and drains through the Lacombe Lake rural catchment area via natural drainage courses. It was developed prior to the adoption of the Wolf Creek and Whelp Brook Watershed Master Drainage Plan (MPE 2014). The TES development has a stormwater management system that meets a pre-development release rate of 3.1 L/s/ha for the 1:100 year design storm event, but does not meet pre-development rates for any of the lesser design storm events, as does the Wolf Creek and Whelp Brook Master Drainage Plan.

The pre and post development catchment area for rural undeveloped lands draining to Whelp Brook located on the north side of Lacombe Lake where the brook crosses Range Road 272 is estimated to be 3697 ha. Please see Figure 3.3 – Whelp Brook Rural Catchment Area, located at the end of this report section.

The Northwest Area gross development area is 512 ha, but the net developable area is closer to 455 ha once the wetlands and environmental reserves are subtracted. Due to the local knob and kettle geography, 512 ha – 21.42 ha (sub-catchment areas SC20 & SC22) = 490.58 ha of the Northwest Area is assumed to **not** have overland drainage to Lacombe Lake for pre-development conditions. For post development conditions the entire Northwest Area catchment of 512 ha drains to Lacombe Lake, but with substantial treatment prior to discharge. The catchment area for rural undeveloped lands draining to Lacombe Lake for post development conditions is reduced slightly from 1300 ha to 1300 ha – 21.42 ha (SC20 & SC22) = 1278 ha, due to the ultimate development of sub-catchments SC20 and SC22.

A field inspection of culverts crossing Township Road 40-0 was completed on November 29, 2017. A 750 mm diameter concrete culvert, in good condition, was found to be providing an outlet at the north end of SC 22. No other culverts were found crossing

Township Road 40-0. Please see Figure 3.1 at the end of this report section. While we did not find a culvert at the north end of SC20, it is recommended that SC20 be considered as contributing to the pre-development condition. Prior to the construction of Township Road 40-0, SC20 was definitely part of the pre-development catchment area, and if that road were to be built today, a culvert would most likely be provided at that location. There does not appear to be frequent ponding on the south side of Township Road 40-0; therefore, the resulting sub-catchment runoff may be flowing/seeping underneath the roadway embankment.

3.2 SUB-CATCHMENT PARAMETERS

Tables 3.0 and 3.1 on the following pages provide the hydrologic parameters used in the PCSWMM stormwater modeling to complete and then compare pre versus post development configurations and results. The single event modeling was also used to determine the required storm pond storage volumes for the 24 hour, 1:100 year design storm event, and also for preliminary design of the proposed Northwest Area Storm Trunk. The PCSWMM modeling data files can be provided upon request.

The PCSWMM computer modeling estimated the infiltration over pervious surfaces based on Horton's Method. Horton's equation is defined as follows:

$$f = f_c + (f_o - f_c)\, e^{-k(t)}$$

Where,

f = infiltration rate at time t (mm/hr)
f_c = final infiltration rate (mm/hr)
f_o = initial infiltration rate at the start of the storm (mm/hr)
k = decay rate (t^{-1})
t = time since initial infiltration rate

Table 3.0 Northwest Area Hydrologic Parameters

Parameter	Unit	Value
Infiltration		
Initial Rate	mm/hr	75
Final Rate	mm/hr	7.5
Decay Factor	(1/hr)	4.14
Depression Storage		
Pervious Area	mm	3.2
Impervious Area	mm	1.6
Manning's Coefficient		
Pervious Area	n/a	0.25
Impervious Area	n/a	0.015

Table 3.1 Rural Undeveloped Hydrologic Parameters

Parameter	Unit	Value
Infiltration		
Initial Rate	mm/hr	40
Final Rate	mm/hr	1.2
Decay Factor	(1/hr)	4.14
Depression Storage		
Pervious Area	mm	1.0
Impervious Area	mm	N/A
Manning's Coefficient		
Pervious Area	n/a	0.25
Impervious Area	n/a	0.015

The CentralAB_SurficialMaterials_UTM12N shape files, which is a digital representation of the AGS Map 213 'Quaternary Geology, Central Alberta' (1987), were overlaid on the study area to gain insight into the regional surficial soils patterns. The Quaternary Geology mapping suggests that the Lacombe Lake (Figure 3.2) and Whelp Brook (Figure 3.3) rural undeveloped catchment areas are comprised of glacial till and lacustrine deposits which are expected to have relatively low stormwater infiltration rates. Whereas, the Northwest Area has surficial soils comprised of coarse-grained glaciolacustrine type deposits that are high in sand and gravel content, and consequently are expected to have relatively high stormwater infiltration rates. Appendix F contains some published hydrologic parameters which were also referenced to help select representative hydrologic parameters for the study area, and which are summarized in Tables 3.0 and 3.1 above. For additional information on regional hydrogeology, please also consult the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment" dated May 28, 2018, which has been provided in Appendix D.

The PCSWMM model computes evaporation losses from two sources; depression storage on the catchment surface and the water surface in storage locations. Monthly evaporation values obtained from the document Evaporation and Evapotranspiration in Alberta (April 2013, Alberta Government) for Lacombe Lake was converted to daily evaporation values for use in the PCSWMM model. The evaporation data is summarized in Appendix F.

The sub-catchment area and impervious surface ratio parameters have the greatest impact upon the stormwater runoff rate and volume resulting from **developed** areas. Proposed land use data, as shown on Map 5 in Appendix A, was used to develop the impervious surface ratio for each sub-catchment located within the Northwest Area, and these values are provided in Tables 3.2 to 3.4 on the following pages. Table 3.2, Table 3.3, and Table 3.4 also provide the modeled runoff depths resulting from the 1:5 year and 1:100 year design storm events, and from continuous simulation modeling over a 23 year period.

Table 3.2 Sub-catchment Hydrologic Characteristics 1:5 Year

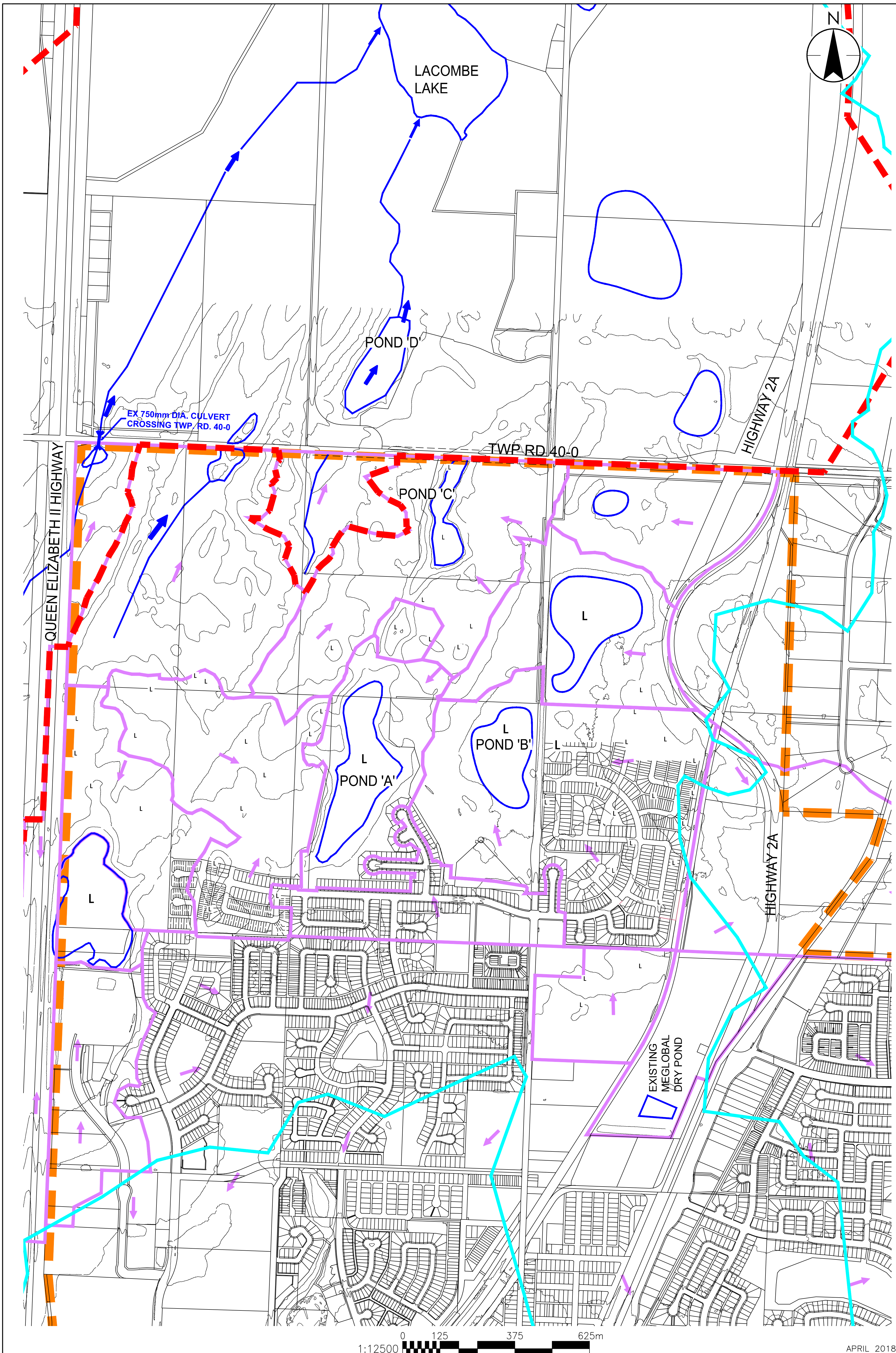
Catchment Area	Catchment Area Description	Design Rainfall Event Return Period and Duration	Rainfall Amount (mm)	Catchment Area (ha)	% Imperv.	Runoff Depth (mm)
SC_1	Residential	1:5 yr, 24 hr	58.7	19.84	64	38.1
SC_2	Residential/ER/MR	1:5 yr, 24 hr	58.7	21.82	54	32.4
SC_3	Residential	1:5 yr, 24 hr	58.7	65.58	63	37.6
SC_4	Residential/Industrial	1:5 yr, 24 hr	58.7	37.46	60	35.9
SC_5	Residential	1:5 yr, 24 hr	58.7	9.98	57	34.1
SC_6	Residential	1:5 yr, 24 hr	58.7	29.89	57	34.1
SC_7	Residential	1:5 yr, 24 hr	58.7	14.19	57	34.1
SC_8A	ER/MR	1:5 yr, 24 hr	58.7	9.29	90	52.7
SC_8B	Industrial	1:5 yr, 24 hr	58.7	22.82	75	44.3
SC_8C	Residential/Industrial	1:5 yr, 24 hr	58.7	24.30	75	44.3
SC_9	Residential/Industrial	1:5 yr, 24 hr	58.7	19.52	65	38.7
SC10	ER/MR	1:5 yr, 24 hr	58.7	5.59	40	24.4
SC11	Residential/Commercial	1:5 yr, 24 hr	58.7	14.13	75	44.3
SC12	Residential/Commercial	1:5 yr, 24 hr	58.7	22.21	75	44.3
SC20	Residential/Industrial	1:5 yr, 24 hr	58.7	12.87	75	44.3
SC21	Residential/Industrial	1:5 yr, 24 hr	58.7	48.00	70	41.5
SC22	Residential/Industrial	1:5 yr, 24 hr	58.7	8.55	75	44.3
SC23	Industrial (County)	1:5 yr, 24 hr	58.7	35.80	75	44.3
SC24	Highway QE2 (AT)	1:5 yr, 24 hr	58.7	20.70	35	21.0
SC30	Residential/Commercial	1:5 yr, 24 hr	58.7	69.45	65	38.3
	NW Area sub-total:			512		
	NW Area developable:			455		
TES development	Commercial/Industrial	1:5 yr, 24 hr	58.7	56.8	70	**48.2**
Pre-dev. Lacombe Lake	Pre-development/ Agriculture	1:5 yr, 24 hr	58.7	1180	0	**25.4**
Post-dev. Lacombe Lake	Pre-development/ Agriculture	1:5 yr, 24 hr	58.7	1158	0	**25.4**
Lacombe Lake Wetted Area	Lake surface	1:5 yr, 24 hr	58.7	120	100	**59.8**
Whelp Brook	Pre-development/ Agriculture	1:5 yr, 24 hr	58.7	3697	0	**25.4**

Table 3.3 Sub-catchment Hydrologic Characteristics 1:100 Year

Catchment Area	Catchment Area Description	Design Rainfall Event Return Period and Duration	Rainfall Amount (mm)	Catchment Area (ha)	% Imperv.	Runoff Depth (mm)
SC_1	Residential	1:100 yr, 24 hr	103.0	19.84	64	74.5
SC_2	Residential/ER/MR	1:100 yr, 24 hr	103.0	21.82	54	66.3
SC_3	Residential	1:100 yr, 24 hr	103.0	65.58	63	73.7
SC_4	Residential/Industrial	1:100 yr, 24 hr	103.0	37.46	60	71.3
SC_5	Residential	1:100 yr, 24 hr	103.0	9.98	57	68.8
SC_6	Residential	1:100 yr, 24 hr	103.0	29.89	57	68.8
SC_7	Residential	1:100 yr, 24 hr	103.0	14.19	57	68.8
SC_8A	ER/MR	1:100 yr, 24 hr	103.0	9.29	90	95.2
SC_8B	Industrial	1:100 yr, 24 hr	103.0	22.82	75	83.4
SC_8C	Residential/Industrial	1:100 yr, 24 hr	103.0	24.30	75	83.4
SC_9	Residential/Industrial	1:100 yr, 24 hr	103.0	19.52	65	75.3
SC10	ER/MR	1:100 yr, 24 hr	103.0	5.59	54	54.7
SC11	Residential/Commercial	1:100 yr, 24 hr	103.0	14.13	75	83.4
SC12	Residential/Commercial	1:100 yr, 24 hr	103.0	22.21	75	83.4
SC20	Residential/Industrial	1:100 yr, 24 hr	103.0	12.87	75	83.4
SC21	Residential/Industrial	1:100 yr, 24 hr	103.0	48.00	70	79.4
SC22	Residential/Industrial	1:100 yr, 24 hr	103.0	8.55	75	83.4
SC23	Industrial (County)	1:100 yr, 24 hr	103.0	35.80	75	83.4
SC24	Highway QE2 (AT)	1:100 yr, 24 hr	103.0	20.70	35	47.8
SC30	Residential/Commercial	1:100 yr, 24 hr	103.0	69.45	65	74.2
	NW Area sub-total:			512		
	NW Area developable:			455		
TES development	Commercial/Industrial	1:100 yr, 24 hr	103.0	56.8	70	**91.5**
Pre-dev. Lacombe Lake	Pre-development/ Agriculture	1:100 yr, 24 hr	103.0	1180	0	**65.0**
Post-dev. Lacombe Lake	Pre-development/ Agriculture	1:100 yr, 24 hr	103.0	1158	0	**65.0**
Lacombe Lake Wetted Area	Lake surface	1:100 yr, 24 hr	103.0	120	100	**104.4**
Whelp Brook	Pre-development/ Agriculture	1:100 yr, 24 hr	103.0	3697	0	**65.0**

Table 3.4 Sub-catchment Hydrologic Characteristics Continuous Simulation

Catchment Area	Catchment Area Description	Design Rainfall Event Return Period and Duration	Rainfall Amount (mm)	Catchment Area (ha)	% Imperv.	Runoff Depth (mm)/yr.
SC_1	Residential	1995-2017	9930.0	19.84	64	149.2
SC_2	Residential/ER/MR	1995-2017	9930.0	21.82	54	126.0
SC_3	Residential	1995-2017	9930.0	65.58	63	146.9
SC_4	Residential/Industrial	1995-2017	9930.0	37.46	60	139.9
SC_5	Residential	1995-2017	9930.0	9.98	57	133.0
SC_6	Residential	1995-2017	9930.0	29.89	57	133.0
SC_7	Residential	1995-2017	9930.0	14.19	57	133.0
SC_8A	ER/MR	1995-2017	9930.0	9.29	90	209.3
SC_8B	Industrial	1995-2017	9930.0	22.82	75	174.6
SC_8C	Residential/Industrial	1995-2017	9930.0	24.30	75	174.6
SC_9	Residential/Industrial	1995-2017	9930.0	19.52	65	151.5
SC10	ER/MR	1995-2017	9930.0	5.59	40	93.5
SC11	Residential/Commercial	1995-2017	9930.0	14.13	75	174.6
SC12	Residential/Commercial	1995-2017	9930.0	22.21	75	174.6
SC20	Residential/Industrial	1995-2017	9930.0	12.87	75	174.6
SC21	Residential/Industrial	1995-2017	9930.0	48.00	70	163.1
SC22	Residential/Industrial	1995-2017	9930.0	8.55	75	174.6
SC23	Industrial (County)	1995-2017	9930.0	35.80	75	174.6
SC24	Highway QE2 (AT)	1995-2017	9930.0	20.70	35	81.5
SC30	Residential/Commercial	1995-2017	9930.0	69.45	65	150.5
	NW Area sub-total:			512		
	NW Area developable:			455		
TES development	Commercial/Industrial	1995-2017	9930.0	56.8	70	162.9
Pre-dev. Lacombe Lake	Pre-development/ Agriculture	1995-2017	9930.0	1180	0	3.5
Post-dev. Lacombe Lake	Pre-development/ Agriculture	1995-2017	9930.0	1158	0	3.5
Lacombe Lake Wetted Area	Lake surface	1995-2017	9930.0	120	100	271.0
Whelp Brook	Pre-development/ Agriculture	1995-2017	9930.0	3697	0	3.5



LEGEND:

- WHELP BROOK SUBWATERSHED BOUNDARY, MPE 2014
- TOWN OF BLACKFALDS BOUNDARY
- LACOMBE LAKE RURAL CATCHMENT AREA
- NW AREA STORM SUB-CATCHMENTS
- NATURAL DRAINAGE COURSES/WATER BODIES
- L NATURAL LOW AREA

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FIGURE 3.0

NORTHWEST AREA PRE-DEVELOPMENT STORM SUB-CATCHMENTS

TOWN OF BLACKFALDS NORTHWEST AREA MASTER STORMWATER MANAGEMENT PLAN

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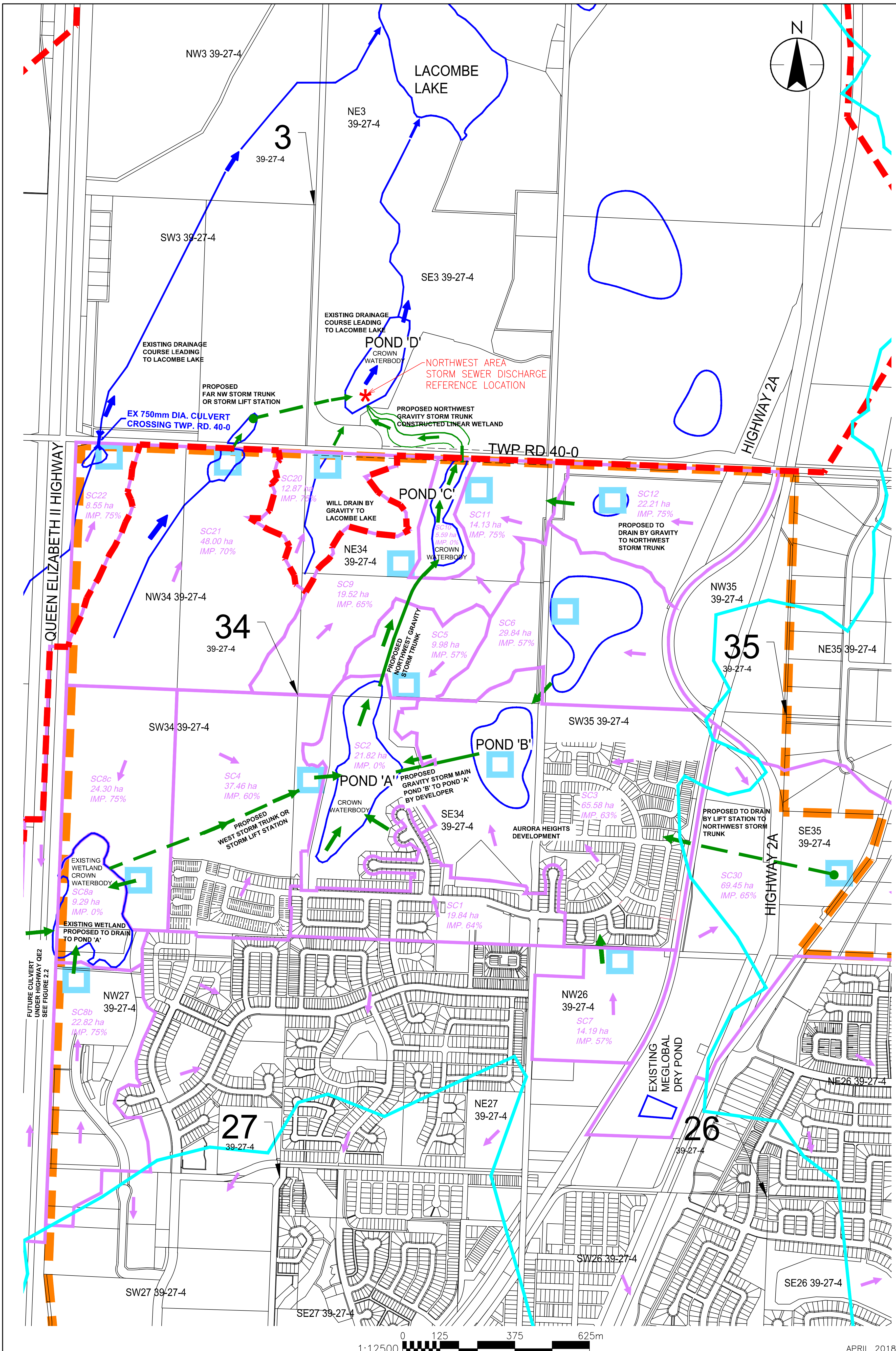


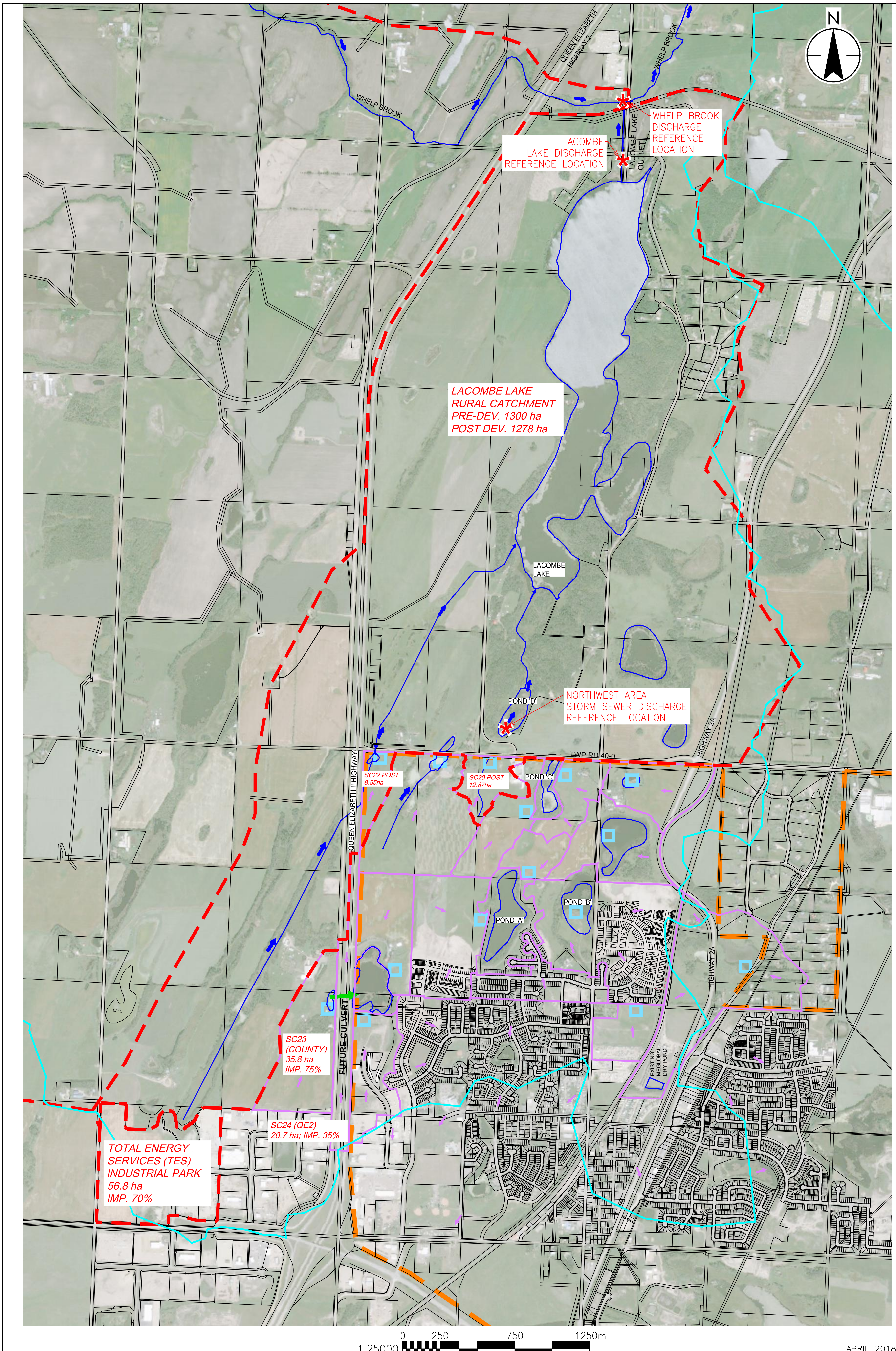
LEGEND:

- WHELP BROOK SUBWATERSHED BOUNDARY, MPE 2014
- TOWN OF BLACKFALDS BOUNDARY
- LACOMBE LAKE RURAL CATCHMENT AREA
- NW AREA STORM SUB-CATCHMENTS
- NATURAL DRAINAGE COURSES/WATER BODIES
- PROPOSED STORMWATER MANAGEMENT FACILITIES
- REGIONAL DRAINAGE INFRASTRUCTURE/ROUTES

Stantec

FIGURE 3.1
NORTHWEST AREA STORM SYSTEM

TOWN OF BLACKFALDS NORTHWEST AREA MASTER STORMWATER MANAGEMENT PLAN



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LEGEND:
- WHELP BROOK SUBWATERSHED BOUNDARY, MPE 2014
- TOWN OF BLACKFALDS BOUNDARY
- NW STORM SUB-CATCHMENTS
- RURAL CATCHMENT AREA
- PROPOSED STORMWATER MANAGEMENT FACILITIES
- NATURAL DRAINAGE COURSES/WATER BODIES

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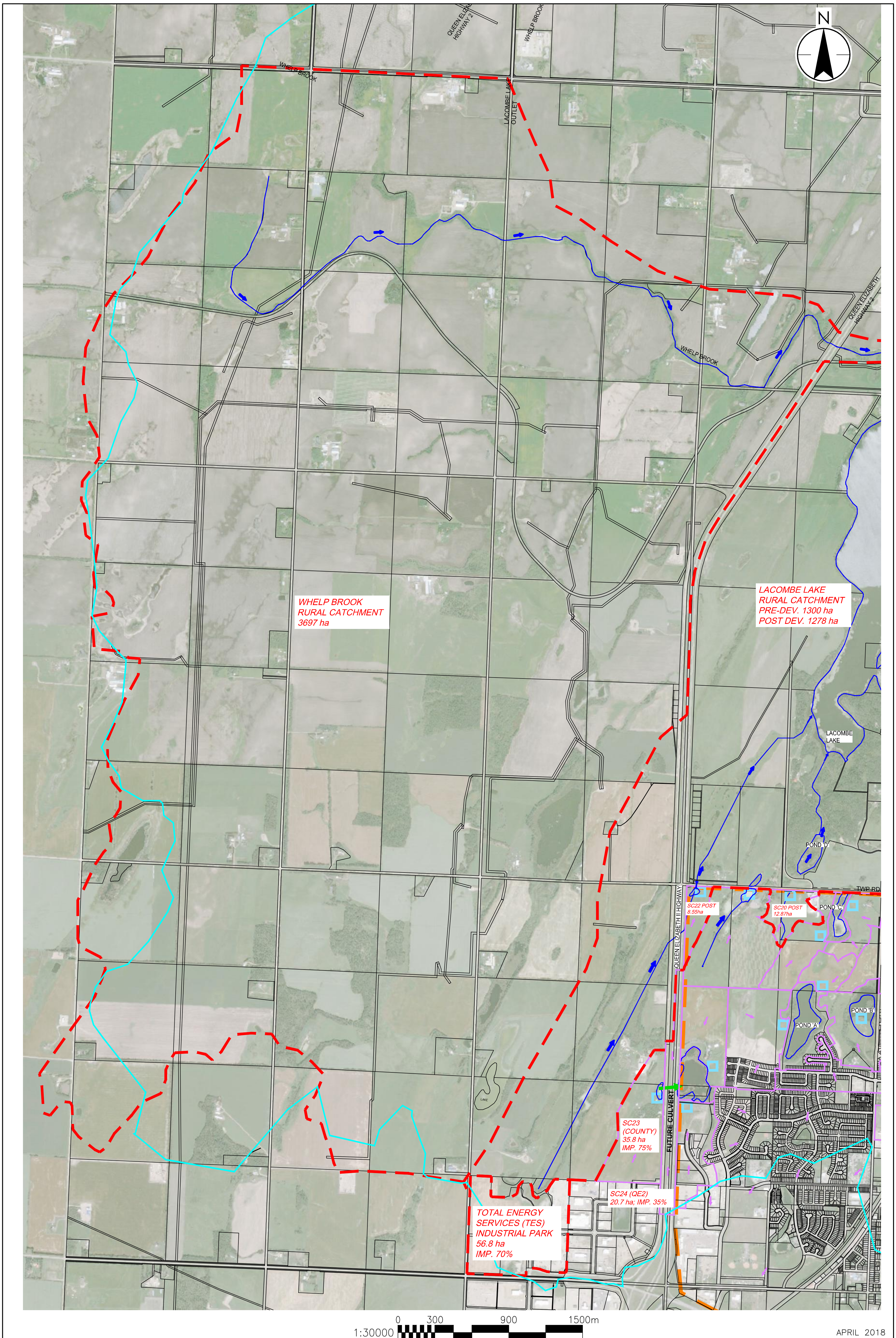
FIGURE 3.2

LACOMBE LAKE RURAL CATCHMENT AREA

TOWN OF BLACKFALDS NORTHWEST AREA MASTER STORMWATER MANAGEMENT PLAN



LEGEND:

- WHELP BROOK SUBWATERSHED BOUNDARY, MPE 2014
- TOWN OF BLACKFALDS BOUNDARY
- RURAL CATCHMENT AREA
- PROPOSED STORMWATER MANAGEMENT FACILITIES
- NW AREA STORM SUB-CATCHMENTS
- NATURAL DRAINAGE COURSES/WATER BODIES

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FIGURE 3.3
WHELP BROOK RURAL CATCHMENT AREA

TOWN OF BLACKFALDS NORTHWEST AREA MASTER STORMWATER MANAGEMENT PLAN

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2018/05/31 8:39 AM By: McAleese, Meagan

4.0 Proposed Northwest Area Storm System

4.1 STORMWATER MANAGEMENT FACILITIES

The Northwest Area Master Stormwater Management Plan provides conceptual designs for stormwater management facilities (SWMF) required for development within the study area. Please see the previously provided Figure 3.1 - Northwest Area Storm System, for the location of proposed stormwater management facilities, which are also referred to as storm ponds.

Hybrid stormwater management facilities are universally proposed in the Northwest Area which include both permanently wet and semi-wet wetland areas within the overall facility. Figure B2 in Appendix B provides the details of this typical hybrid storm pond design. The hybrid storm pond parameters defined in this report outline the required ratio of semi-wet (infiltration) pond areas to permanently wet pond areas, for which subsequent analyses will quantify the resulting infiltration (runoff volume control) and water quality improvement performance for a facility with these design parameters. All storm ponds within the Northwest Area will be designed and constructed according to these parameters. The typical facility is shown with a square configuration; however, facilities will ultimately be given curvilinear shapes to provide more aesthetically pleasing amenities for the community.

Stormwater management facilities were universally assumed to have active depths of 1.8 m and 5:1 side slopes above the normal water level (NWL). The typical facility is shown with a wet sediment forebay at the location of storm system inflows. A wet ponding area is also located at the outlet of the facility, and this facilitates a submerged piped outlet which results in detainment of floatable pollutants such as potential hydrocarbons and refuse. The above mentioned wet areas will be provided with an impermeable liner to contain potential stormwater contaminants, and to ensure that a permeant water depth of 2.0 m can be maintained. The combined permanently wetted areas are proposed to have a NWL area that is 20% of the overall facility high water level (HWL) area.

The SWMF wetland areas will be designed to facilitate infiltration; thus, will not have impermeable linings. The wetland areas will be wetted on a regular basis; therefore, appropriate vegetation will be selected by our vegetation specialists to endure the moisture conditions. Vegetation will be unmanicured, and may include natural grass varieties, sedges, and/or wetland vegetation. The wetland areas are envisioned to have a shallow permeant channel that meanders through the wetland; thus, providing a lengthy "low flow" route through the facility.

The proposed stormwater management facilities are expected to have an average infiltration rate of 10 mm/hour. However, the facility infiltration rate can be a challenging variable to predict and/or control; therefore, to ensure adequate flood protection, all storm facilities will be provided with a piped outlet which is sized for the 1:100 year pre-development release rate, and assuming that no infiltration is available in the facility.

As elaborated on in the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment" dated May 28, 2018 and provided in Appendix D, the local hydrogeology is such that there is significant sub-surface flow towards the north, including Lacombe Lake. Additional findings from this letter report include:

- The natural wetlands and proposed stormwater management ponds should behave similarly based on the proposed unlined stormwater management facility (SWMF) design, allowing communication between surface water features and the groundwater environment,
- The long-term average for rates of groundwater recharge, and eventual discharge to Lacombe Lake should remain similar to pre-development conditions and the overall volume of water entering Lacombe Lake should not change significantly between pre and post development conditions.

Through the Town's permitting and development approvals process, this area will undergo detailed design of each of the stormwater management facilities. This design review will ensure that there are no adverse effects, caused by the introduction of facility infiltration, to any adjacent structures or infrastructure.

As required by the Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds (MPE, August 2014), each of the SWMF is proposed to have a vaulted control structure containing three individual orifices. Figure B3 in Appendix B provides a typical storm pond control structure. Each of the orifices is specifically designed to meet one of the pre-development discharge rates associated with either the 1:2 year, 1:5 year, or 1:100 year design storms, respectively. There may be an opportunity to eliminate the orifice associated with the 1:2 year event, if the facility can be designed so that it does not discharge in a 1:2 year event. The elimination of the 1:2 year orifice would more closely replicate the pre-development condition because of the reduction in the amount of discharge to the receiving watercourse. The 1:2 year orifices are extremely small and will pose an operational challenge, so the elimination of them would mitigate some of the long-term operation and maintenance of these facilities.

The Northwest Area storm ponds shall be designed such that ponds can be drained completely dry for routine maintenance of the SWMF forebays and outlet control structures. The design of the facilities will result in the forebays freezing during winter in the permanent pool of the forebay. Annual freezing of the facility may not penetrate to full depth (2.0m) but will help to control some Aquatic Invasive Species (AIS), but will not be the sole management strategy. An operational procedure shall be developed that conforms to fish salvage/rescue requirements and that all appropriate permits are in place if an aquatic invasive species are identified in the SWMF.

Table 4.1 on the following page summarizes the sub-catchment area, permissible release rate, proposed active storage volume, approximate facility footprint, and preliminary design elevations, for each of the stormwater facilities that were modeled for the Northwest Area Storm System. To be conservative, all of the single event analysis estimates of the required SWMF storage assume that there is **no** infiltration occurring in any of the proposed SWMF. Estimates for SWMF footprints were also assumed to include a 15 m buffer beyond the facility high water level (HWL) which includes freeboard area, berming, backsloping, and perimeter landscaping.

This is a planning level study; therefore, the provided drainage patterns and storm pond catchment areas should not be considered as final. During the ultimate development process, the developers' consultants may develop alternate drainage patterns and storm pond catchment areas that work equally well. However, if drainage patterns are changed then the ultimate stormwater management facilities must still demonstrate that they meet the criteria and overall intent of this report. The proposed SWMF criteria provided above is a template for a particular facility's required active storage volume and approximate footprint area associated with a given development area.

Table 4.1 Proposed Stormwater Management Facility Characteristics

Pond #	Serviced Area (ha)	1:100 Year Pre-Development Discharge Rate (L/s)	Active Storage Volume (m^3)	Approximate Facility Foot Print (ha)	Preliminary NWL Elevation (m)	Preliminary HWL Elevation (m)
Pond'B' (SC3)	65.60	131.2	43,900	3.91	867.80	869.60
4	37.46	74.9	24,300	2.48	871.00	872.80
5	9.98	20.0	6,000	0.97	871.50	873.30
6	29.84	59.7	18,500	2.03	868.00	869.80
7	14.00	28.0	8,900	1.24	871.50	873.30
8b	22.82	45.6	17,700	1.97	869.50	871.30
8c	24.30	48.6	18,700	2.05	869.50	871.30
9	19.52	39.0	13,300	1.61	873.50	875.30
11	14.13	28.3	10,800	1.40	867.50	869.30
12	22.21	44.4	17,200	1.93	866.50	868.30
20	12.87	25.7	10,000	1.33	867.00	868.80
21	48.00	96.0	33,900	3.19	865.00	866.80
22	8.55	17.1	6,700	1.04	867.50	869.30
23	35.80	71.6	27,900	2.75	867.00	868.80
30	69.45	138.9	46,700	4.11	879.50	881.30

4.2 SEDIMENT REMOVAL ANALYSIS OF PROPOSED SWMF

Sediment settling calculations were performed for post development conditions using the PCSWMM computer model. The sediment settling calculations are based on continuous simulation modeling which utilizes actual historical precipitation data for the study area; thus, considers the potential effects of back to back rain storms on system performance for both water quantity and quality (sediment settling).

The PCSWMM sediment removal analysis requires input data for pollutant build-up, pollutant wash off, and storm pond settling velocities, which was based on data provided in the City of Calgary 2011 Stormwater Management & Design Manual (SMDM), Tables 7-2 and 7-3. As no local information is available on the required parameters, the City of Calgary values were used.

The procedure used in the PCSWMM model for pollutant simulation is as follows:

- Pollutants are identified and given certain attributes. For this sediment simulation modelling, Total Suspended Solids (TSS) was listed for five size ranges as noted in the City of Calgary manual; (1) 0-10 µm, (2) 10-20 µm, (3) 20-50 µm, (4) 50-150 µm and (5) > 150 µm.

- A fraction of total sediment is assigned to these sediment sizes as noted in the City of Calgary 2011 SMDM, Table 7-3.

- Land uses are identified, each with a set of buildup and washoff parameters. For this study the land uses identified include (1) residential, (2) commercial, and (3) industrial.

- Removal efficiencies for the source control BMPs, used in addition to the proposed SWMFs, can be assigned for each land use, but for this analysis an efficiency of 0 % was used as a conservative assumption. Essentially the results of this sediment removal analysis are only relying on the proposed SWMFs.

- Removal of TSS in the SWMFs is simulated by turning on the PCSWMM treatment flag, and assigning a removal expression based on the settling velocities for each of the TSS particle sizes, as provided in the City of Calgary 2011 SMDM, Table 7-3.

The sediment removal modeling was completed on a representative hybrid stormwater management facility, which are proposed for the Northwest Area, with a 100 ha total catchment area, and an impervious surfaces ratio of 70% of the total catchment area. The catchment area was assumed to be comprised of 50% residential land use, 25% commercial land use, and 25% industrial land use. Table 4.2 below provides the results of the sediment removal analysis, which demonstrates that the SWMFs proposed for the Northwest Area will provide water quality improvement that exceeds the Alberta Environment and Parks (AEP) criteria for removing 85% of Total Suspended Solids (TSS), for sediment particles 75 microns and larger. Appropriate erosion and sediment control measures shall also be employed during the buildout of the development area.

Table 4.2 SWMF Sediment Removal Performance

Particle Size (microns)	Total Sediment Inflow (kg/yr)	Sediment Outflow (kg/yr)	Removed Sediment (kg/yr)	Sediment Removal (%)
<10	12634.174	1443.435	11190.739	88.58%
10 - 20	4940.478	93.174	4847.304	98.11%
20 - 50	7165.783	21.517	7144.265	99.70%
50 - 100	12634.174	4.802	12629.372	**99.96%**
>150	17574.696	0.583	17574.112	100.00%
Total	54949.304	1563.511	53385.793	97.15%

To be conservative, the above sediment removal analysis results assume that there is no facility infiltration. However, in addition to meeting the pre-development release rates for the 1:2 year, 1:5 year and 1:100 year events, the proposed stormwater management facilities will also be designed to provide significant infiltration of stormwater. Table 4.3

below provides the modeled long-term average stormwater management facility disposal rates for various mechanisms for a range of facility infiltration rates. Based on the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment", which has been provided in Appendix D, the expected regional average stormwater management facility infiltration rate of 10 mm/hour, results in only 3% of the total stormwater management facility inflows being discharged offsite.

Table 4.3 Stormwater Management Facility Long-term Disposal Quantities

Facility Infiltration Rate (mm/hr.)	Ratio of Evaporation to Facility Inflow (%)	Ratio of Facility Infiltration to Facility Inflow (%)	Ratio of Outfall Discharge to Facility Inflow (%)	Facility Drawdown Time from Full (days)
0	14%	0%	86%	60
2	8%	73%	19%	24
10	5%	92%	3%	7

Sediment settling performance (physical treatment) is also considered a proxy for the treatment of other stormwater contaminants because the sediment settling performance is largely a function of facility detention times which is also a critical factor in the other biological and chemical treatment processes that are associated with wet stormwater management facilities. Report Section 5.4 and Appendix C provide additional discussion of water quality improvement.

4.3 STORMWATER BEST MANGEMENT PRACTICES (BMP)

The regular occurrence of sand and gravel layers found within the native sub-soils in the Blackfalds Northwest area results in moderate to high infiltration rates of stormwater runoff. This puts the Town of Blackfalds in the enviable position of having site conditions that are conducive to the use of "Source Control" Best Management Practices (BMPs) and Low Impact Development (LID). Source Control BMPs use a variety of practical techniques to manage and dispose of stormwater close to its source, i.e. where the rain falls. Potential BMPs that facilitate and promote infiltration include, but not limited to, vegetated swales, bio-retention areas, minimized development impervious area, and any other landscaping features that promote infiltration. These and other BMPs will be encouraged by the Town of Blackfalds. The implementation of these BMPs will be balanced against other factors such as infrastructure lifespan, and operation and maintenance costs.

The Town of Blackfalds also commits to the specific Best Management Practices (BMPs) of oil and grit separators for potential "hot spots", the hybrid stormwater management facilities as outlined in report Section 4.1, and an increased topsoil thickness to a total of 25 cm to 30 cm (local supply permitting).

Oil and grit separators (OGS) are below grade vaulted structures that are designed to provide enhanced sedimentation in a relatively smaller footprint. OGS units in Alberta have typically relied upon sedimentation which due to the smaller footprint typically do not provide as high of performance as stormwater management facilities that include wet cells. The Town of Blackfalds already requires oil and grit separators in developments that are potential "hot spots" for stormwater contaminants. An example of a development which requires their own oil and grit separator is a gas station.

Increased topsoil thickness generally reduces runoff from developments located in areas with impervious sub-soils, but may not be as effective in reducing runoff in areas with higher permeability sub-soils such as the Northwest Area. Regardless, increased topsoil thickness is considered an effective BMP because this extra material can potentially reduce the quantity of fertilizer and/or pesticides that are often applied to landscaped areas. The Town of Blackfalds will require residential developments located in the Northwest Area to have a topsoil thickness of 25 cm to 30 cm in landscaped areas; however, this requirement will be dependent on the local supply of topsoil found within a particular subdivision. Alternative measures to an increased topsoil thickness may also be entertained, provided they are reviewed and approved by the Town.

4.4 ENVIRONMENTAL STEWARDSHIP PLAN

The Town of Blackfalds has also committed funding to the development of an Environmental Stewardship/Master Plan. The study is just being initiated, and the development of the plan is envisioned to take approximately 3 years. The Environmental Stewardship Plan will guide internal and external stakeholders on policies and Best Management Practices (BMPs) for items such as, but not limited to, roadway deicer usage, fertilizer and pesticide usage, water and energy conservation, air quality, waste management, composting, and pharmaceutical disposal.

The Environmental Stewardship/Master Plan is a living document that facilitates policies and BMPs evolving over time to meet the ever changing demands of the community and environment. The water quality data collected as part of the Northwest Area Master Stormwater Management Plan will provide valuable information that will help to guide the evolution of the Environmental Stewardship Plan. Thus, providing a means to tailor the policies and BMPs that provide protection to the users located downstream of the Blackfalds Northwest Area, and the Town as a whole.

4.5 NORTHWEST STORM TRUNK

The Northwest Storm Trunk is proposed to convey stormwater from the north end of Pond 'A' through approximately 420 m of 900 mm diameter storm trunk where it will outlet to the south end of Pond 'C'. After flowing through Pond 'C' it will flow through approximately 40 m of 900 mm diameter storm trunk under Township Road 40-0, drain approximately 370 m northwest through a constructed linear wetland, and then outfall to a natural drainage course that further drains north into Lacombe Lake, Whelp Brook, and then Wolf Creek. Please refer to the previously provided Figure 3.1 - Northwest Area Storm System.

Natural waterbodies Pond 'A' and 'C' are Crown claimed, and are proposed to be kept in their current condition and preserved from development. While Ponds 'A' and 'C' are not proposed to provide stormwater management for surrounding developments, they are proposed to form part of the overall conveyance system. As such, their elevations will rise slightly during significant rainfall events, and then draw down to their normal water level shortly after the event passes.

Tables 4.4 and 4.5 below summarize the natural water body characteristics for post development conditions for the 1:2 year, 1:5 year, and 1:100 year design storm events, respectively. Table 4.6 provides the Northwest Area Storm System post development discharge rates for the same design storm events. Figures H.1 to H.3, provided in Appendix H, show the post development hydrographs at the outlet of the Northwest Area Storm System (location shown on Figure 3.1) for the for the 1:2 year, 1:5 year, and 1:100 year design storm events, respectively.

Pre-development characteristics and hydrographs were not provided for Ponds 'A' and 'C', nor for the outlet of the Northwest Area system because as previously described, the knob and kettle topography of this area results in no overland discharge for the pre-development condition. However, the local hydrogeology is such that for pre-development conditions there is significant sub-surface flow towards the north, including Lacombe Lake. These and other findings were elaborated on in the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment" dated May 28, 2018, which has been provided in Appendix D.

Please note that the post development discharge from SC21 is also included in Table 4.6 and Figures G.1 to G.3 because the future Far Northwest Storm Trunk is also expected to discharge to the natural environment in essentially the same location as the currently proposed Northwest Storm Trunk.

Table 4.4 Pond A Post Development Characteristics

Description	Elevation (m)	Active Ponding Depth (m)	Surface Area (m^2)
*Lower Stage	865.30	-0.30	70,000
NWL	865.60	0.00	72,000
*Elevated Stage	866.40	0.80	78,000
Modeled 1:2 Year	865.67	0.07	
Modeled 1:5 Year	865.71	0.11	
Modeled 1:100 Year	866.00	0.40	

*Lower and Elevated Stages used for modeling to define water body stage/area curve

Table 4.5 Pond C Post Development Characteristics

Description	Elevation (m)	Active Ponding Depth (m)	Surface Area (m^2)
*Lower Stage	864.20	-0.30	21,000
NWL	864.50	0.00	23,000
*Elevated Stage	865.30	0.80	29,000
Modeled 1:2 Year	864.56	0.06	
Modeled 1:5 Year	864.60	0.10	
Modeled 1:100 Year	864.91	0.41	

*Lower and Elevated Stages used for modeling to define water body stage/area curve

Table 4.6 Northwest Area Storm System Post Development Discharge Rates

Design Storm Event	Catchment Area (ha)	Discharge Rate (L/s)	Unit Area Release Rate (L/s/ha)
Modeled 1:2 Year	511.90	56.00	0.11
Modeled 1:5 Year	511.90	119.00	0.23
Modeled 1:100 Year	511.90	742.00	1.45

As can be seen in the above results, the water level increase for a 1:100 year design storm event has a minimal impact on the Pond 'A' and Pond 'C' water levels, and the levels will draw down to their normal water level within approximately 6 days of the storm passing. The proposed Northwest Area Storm System also meets the pre-development discharge rates of 0.11 L/s/ha, 0.28 L/s/ha, and 2.0 L/s/ha, for the 1:2 year, 1:5 year, and 1:100 year design storm events, respectively, as required by the Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds (MPE, August 2014).

Please note that all of the single event analysis results assume that there is **no** infiltration occurring in any of the SWMFs proposed for the Northwest Area. However, all of the single event modeling assumes that the natural water bodies of Pond ‘A’, Pond ‘C’, and Pond SC8a provide an infiltration rate of 2 mm/hour over their ponded area.

The proposed Northwest Area storm system will provide an appropriate level of service to developed areas and the natural environment, as well as provide appropriate flood protection for the Northwest Area and all areas located downstream.

4.6 WETLAND PRESERVATION CONSIDERATIONS

The analysis results provided in this report, namely the post development water level fluctuations for Ponds ‘A’ and ‘C’, and the pre and post development comparisons for Lacombe Lake and Whelp Brook, assume that Pond ‘A’, Pond ‘C’, Pond SC8a, and Pond ‘D’ are the only natural waterbodies in the Northwest Area that will be preserved in their current form. Additional natural waterbodies may ultimately be preserved, but to provide a conservative analysis, these are the only three bodies assumed to be preserved under this study. Stormwater attenuation in all the other study area sub-catchments is assumed to occur in man-made stormwater management facilities that will meet the pre-development release rates outlined in the Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds (MPE, August 2014). Therefore, the stormwater analysis was undertaken in such a way, so that the decision of whether or not to preserve other wetlands found within the study area can be left until the subdivision development stage.

5.0 Downstream Considerations

As previously summarized, the pre-development catchment area for rural undeveloped lands draining to Lacombe Lake is estimated to be 1,300 ha. Please see the previously provided Figures 3.0 to 3.3. The catchment area for rural undeveloped lands draining to Lacombe Lake for post development conditions is reduced slightly from 1,300 ha to 1,278 ha, due to the ultimate development of sub-catchments SC20 and SC22.

The existing Total Energy Services, Inc. Industrial Park (TES)has a development area of 56.8 ha and drains through the Lacombe Lake rural catchment area via natural drainage courses.

The pre and post development catchment area for rural undeveloped lands draining to Whelp Brook located on the north side of Lacombe Lake where the brook crosses Range Road 272 is estimated to be 3,697 ha.

Due to the local knob and kettle geography the majority of the Northwest Area is assumed to **not** have overland drainage to Lacombe Lake for pre-development conditions. For post development conditions the entire Northwest Area catchment of 512 ha drains to Lacombe Lake, but with substantial treatment prior to discharge.

5.1 DOWNSTREAM SYSTEM

As part of the stormwater analysis for the Blackfalds Northwest Area Storm Project, Alberta Environment and Parks (AEP) requested that Stantec quantify the potential effects of the proposed development on Lacombe Lake and downstream waterbodies. The assumed Lacombe Lake stage/area characteristics for both pre and post development conditions are summarized in Table 5.1 below.

Table 5.1 Lacombe Lake Characteristics

Description	Elevation (m)	Active Ponding Depth (m)	Surface Area (m^2)
*Lower Stage	857.43	-0.15	1,189,000
NWL	857.58	0.00	1,201,000
*Elevated Stage	858.58	1.00	1,278,000

*Lower and Elevated Stages used for modeling to define water body stage/area curve

Lacombe Lake has a control structure located at the north end which is comprised of a concrete weir that is 1.5 m in length and is housed in a concrete vault. A 750 mm diameter smooth wall steel pipe (~36 m long) drains from the vault to a trapezoidal ditch. The trapezoidal ditch drains north for approximately 220 m, and then drains under the railway tracks through twin 900 mm and 1200 mm diameter corrugated steel pipes that are approximately 15 m in length. The railway culverts essentially outlet into Whelp Brook, which then flows an additional 30 m east where it crosses the Range Road 272. Please see Figure 5.1 – Downstream Conveyance Infrastructure provided on the following page.

The 1.5 m long concrete weir that provides the lake outlet flow control also has a 600 mm diameter pipe through the weir that has an invert that is approximately 0.6 m below the top of weir elevation. The original control structure design had a sluice gate installed on the 600 mm diameter pipe, which was presumably to remain closed during normal operations. At some point this sluice gate was removed; however, the 600 mm diameter pipe has typically been observed to be significantly obstructed by beaver debris. Therefore, for the purposes of this analysis, the 1.5 m long concrete weir has been assumed as providing the lake outlet flow control, as well as the elevation control for the lake's targeted minimum water level.

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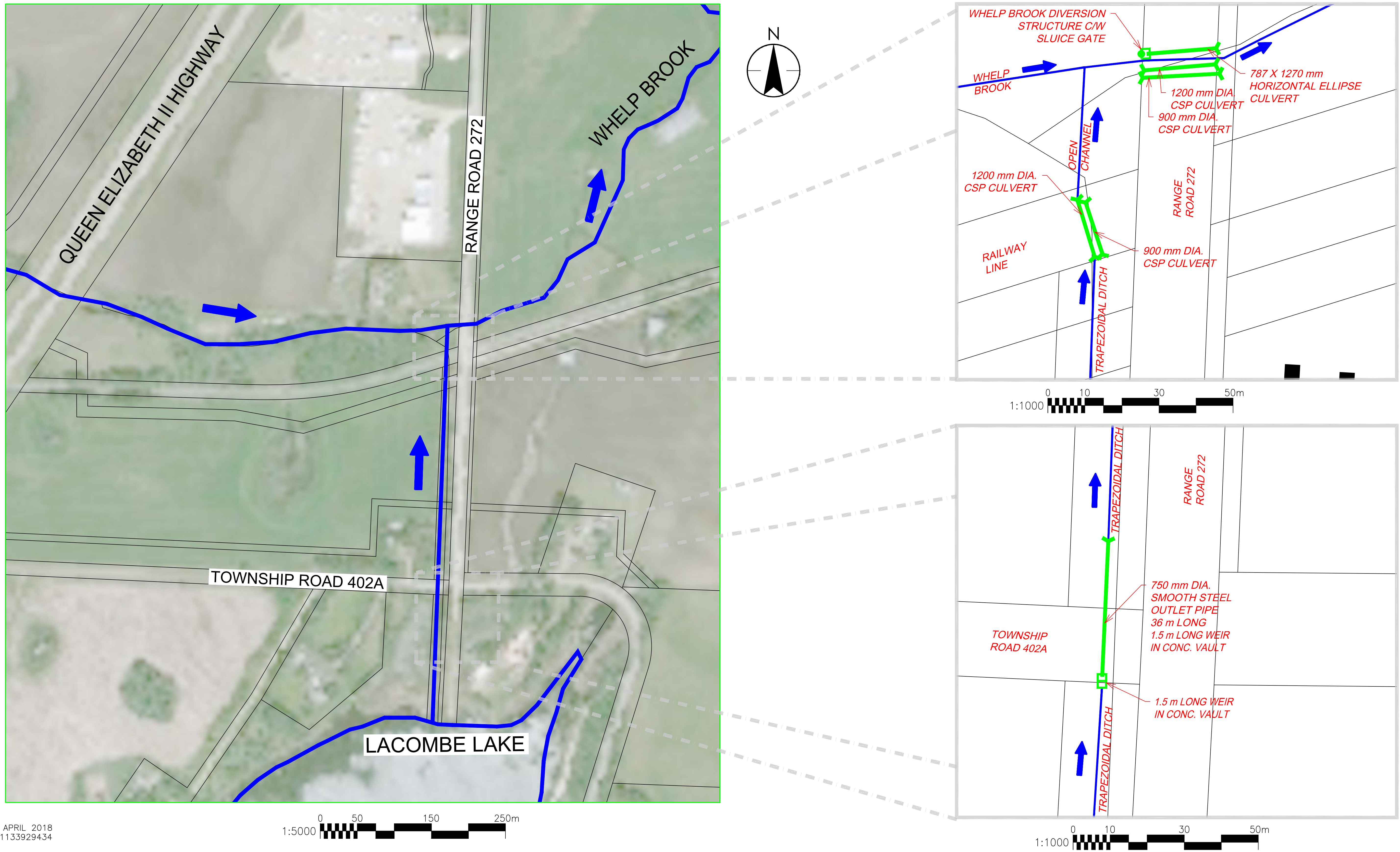

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LEGEND:
- LACOMBE LAKE RURAL CATCHMENT AREA
- NATURAL DRAINAGE COURSES/WATER BODIES
- STRUCTURES

Stantec

FIGURE 5.1
DOWNSTREAM CONVEYANCE INFRASTRUCTURE
TOWN OF BLACKFALDS NORTHWEST AREA
MASTER STORMWATER MANAGEMENT PLAN

The current 750 mm diameter smooth wall steel pipe was originally installed in approximately 1972 as a 900 mm diameter corrugated steel pipe. However, in 2017 Lacombe County performed maintenance to this pipe, and it was decided to line the original pipe with the current 750 mm diameter smooth wall steel pipe. The pipe downsizing was necessary to maintain an existing gas line that is crossing the lake outlet pipe.

In approximately 1972 a diversion structure was constructed on Whelp Brook at Range Road 272, such that when the sluice gate was closed, a portion of the Whelp Brook flows could be diverted towards Lacombe Lake through the previously described ditch/culvert system. Lacombe County holds the existing license (No. 1450 in the North Saskatchewan River Basin) that permits water to be diverted from Whelp Brook to Lacombe Lake. However, our understanding is that the County's long-term intent is to leave the Whelp Brook diversion structure open, such that **no** intentional Whelp Brook diversion to Lacombe Lake occurs. Please see the attached letter in Appendix E from Lacombe County to AEP dated July 24, 2008, and also the follow up email from Lacombe County to Stantec dated September 14, 2016.

The conveyance works installed in 1972 on Whelp Brook at Range Road 272 included a primary horizontal ellipse culvert with dimensions 0.787 m x 1.27 m. A concrete vault with a 600 mm diameter sluice gate on the inlet side was also installed at the inlet of the horizontal ellipse culvert, and this configuration allowed the aforementioned diversion from Whelp Brook to Lacombe Lake when the sluice gate was closed. The 1972 conveyance works at Range Road 272 also included a secondary 900 mm diameter corrugated steel pipe culvert which was installed approximately 900 mm higher in elevation than the primary horizontal ellipse culvert, and this pipe was to function as an emergency overflow. Sometime between the original 1972 installation and the writing of this report, an additional 1200 mm diameter corrugated steel pipe culvert was installed at approximately the same elevation as the original primary ellipse culvert. This additional culvert does not have any flow control measures on its inlet; thus, it will reduce the ability of the original structure to divert flow from Whelp Brook into Lacombe Lake.

On November 29, 2017 Stantec performed topographic survey of all of the above described infrastructure, and the various PCSWMM computer models were also updated to reflect that which currently exists in the field. The topographic survey was completed using the NAD 1983 datum, and the GSD95AB geoid.

The modeling results provided in this report assume that all of the structures and culverts located between the Lacombe Lake outlet and Whelp Brook at Range Road 272 are sufficiently maintained, and essentially free of any plugging. However, it is our understanding that the existing Lacombe Lake outlet structure requires regular removal of beaver debris by Lacombe County maintenance staff. Therefore, the occurrence of beaver debris could result in Lacombe Lake levels that are elevated beyond that which is estimated by this report.

5.2 SINGLE EVENT ANALYSIS

To quantify the potential effects of the proposed development on Lacombe Lake and downstream waterbodies, Stantec has completed single event pre and post development analyses of Lacombe Lake and Whelp Brook, for which the results are shown in Table 5.2 provided at the end of this report sub-section. In the interest of being conservative, all of the single event analysis results assume that there is **no** infiltration occurring in any of the SWMF proposed for the Northwest Area. However, all of the single event modeling assumes that the natural water bodies of Pond 'A', Pond 'C', and Pond SC8a provide an infiltration rate of 2 mm/hour over their ponded area. Please also note that the catchment area at the Lacombe Lake outlet is 1,847 ha.

The single event modeling results show that under the existing configuration for pre-development conditions that Whelp Brook would begin to back up into Lacombe Lake for something between a 1:10 and 1:25 year design storm event, and this would occur when the sluice gate on the Whelp Brook control structure at Range Road 272 is left completely open. The phenomenon of Whelp Brook backing up into Lacombe Lake would result from existing conveyance capacity limitations of Whelp Brook at Range Road 272, rather than resulting from any specific interventions or operational schemes.

Figures H.4 to H.6 provided in Appendix H show the Lacombe Lake outflow/inflow hydrographs, for pre and post development conditions, that result for the 1:2 year, 1:5 year, and 1:100 year design storm events, respectively.

The single event analysis results provided in Table 5.2 estimate that the difference between pre and post development Lacombe Lake water levels for the 1:100 year design storm event is 0.09 m, and the 1:100 year unit area discharge rate from the lake is only 0.48 L/s/ha. These results assume no changes to the existing conveyance infrastructure at the outlet to Lacombe Lake, nor on Whelp Brook at Range Road 272.

However, the last column in the Table 5.2 is also provided to demonstrate the difference between pre and post development conditions for the proposed Northwest Area development, and assuming that the restrictions (culverts) on Whelp Brook at Range Road 272 are improved to such a degree that there are no backwater effects on Lacombe Lake. These results are similar to the previous iteration of this Master Stormwater Management Report because those analyses did not try to model the culverts on Whelp Brook at Range Road 272, and essentially assumed that Whelp Brook provided a free outfall.

Table 5.2 Single Event Downstream Hydraulic Characteristics

	Scenario					
Description	1:2 Year Single Event	1:5 Year Single Event	1:10 Year Single Event	1:25 Year Single Event and current lake outlet configuration	1:100 Year Single Event and current lake outlet configuration	1:100 Year Single Event and Whelp Brook restrictions at RR272 removed for post dev.
Lacombe Lake Weir Elevation (m)	857.58	857.58	857.58	857.58	857.58	857.58
Starting Lake Elevation (m)	857.58	857.58	857.58	857.58	857.58	857.58
Starting Lake Water Level Above Weir (m)	0.00	0.00	0.00	0.00	0.00	0.00
Modeled Pre-Development Max. Elev. (m)	857.66	857.73	857.78	857.87	**858.07**	858.07
Modeled Pre-Development lake Max. outflow (m3/s)	0.055	0.147	0.231	0.407	0.753	0.753
Modeled Post-Development Max. Elev. (m)	857.66	857.74	857.80	857.91	**858.16**	858.04
Modeled Post-Development lake Max. outflow (m3/s)	0.060	0.163	0.268	0.497	0.881	0.774
Modeled Post-Development lake unit area discharge rate (L/s/ha)	0.032	0.088	0.145	0.269	**0.477**	0.419
Post Development Max. level fluctuation (m)	0.08	0.16	0.22	0.33	0.58	0.46
Pre vs Post Dev. change in Max. water level (m)	**0.00**	**0.01**	**0.02**	**0.04**	**0.09**	-0.03

5.3 CONTINUOUS SIMULATION ANALYSIS

Continuous simulation modeling was completed to assess the potential changes to pre versus post development runoff volumes, and also to assess the potential effects of back to back storms on Lacombe Lake.

As previously mentioned, continuous simulation analysis was completed using daily rainfall totals recorded at the Environment Canada Lacombe CDA2 (3023722) precipitation gauge, over a 23 year period from 1995 to 2017.

The 1971-2000 climate normals for the Lacombe CDA (3023720) precipitation gauge state the annual average precipitation at 446 mm. The maximum annual precipitation for the Lacombe CDA2 gauge for the 1995-2017 data set was 663 mm, and this occurred in 1996. The annual precipitation at the same gauge for 1995 was also above average at 502 mm. Therefore, the significantly high precipitation years of 1995 and 1996 in the data set should do well at representing the potential effects of consecutive wet years on Lacombe Lake and other downstream waterbodies. The year 2010 had the second highest precipitation total at 569 mm.

Table 5.3, provided at the end of this report sub-section, provides computer modeled annual maximum Lacombe Lake water elevations for various pre and post development scenarios for the 23 year continuous simulation period. Table 5.4 provides a summary of the annual maximum water levels for Lacombe Lake, and also provides a summary of pre and post development runoff volumes for the same suite of scenarios.

The following suite of pre and post development scenarios were analyzed and provided to show the potential effects of various BMP combinations:

1. Pre-development: Assumes there is no runoff contribution from the Northwest Area for pre-development conditions. This is a conservative assumption because it will result in a larger difference when comparing pre and post development discharge rates and volumes. However, the local hydrogeology is such that for pre-development conditions there is significant sub-surface flow (discharge) towards the north, including Lacombe Lake. It is also assumed that the Lacombe Lake outlet and Whelp Brook culverts are in their current configuration.

2. Post development: Storm ponds with no infiltration capacity and providing discharge rate control for only the 1:100 year event, and assuming that the Northwest Area has low infiltration rates which is typical of the clay/till sub-soils found predominately in central Alberta. It is also assumed that the Lacombe Lake outlet and Whelp Brook culverts are in their current configuration.

3. Post development: Storm ponds with no infiltration capacity and providing discharge rate control for only the 1:100 year event, and assuming that the Northwest Area has moderate to high infiltration rates which are more reflective

of the local sandy/gravely sub-soils. It is also assumed that the Lacombe Lake outlet and Whelp Brook culverts are in their current configuration.

4. Post development: Storm ponds with no infiltration capacity and providing discharge rate control for the 1:2, 1:5, and 1:100 year events, and assuming that the Northwest Area has moderate to high infiltration rates which are reflective of the local sandy/gravely sub-soils. It is also assumed that the Lacombe Lake outlet and Whelp Brook culverts are in their current configuration.

5. Post development: Storm ponds providing infiltration at 2 mm/hr. over 80% of their surface area, providing discharge rate control for the 1:2, 1:5, and 1:100 year events, and assuming that the Northwest Area has moderate to high infiltration rates which are reflective of the local sandy/gravely sub-soils. It is also assumed that the Lacombe Lake outlet and Whelp Brook culverts are in their current configuration.

6. Post development: Storm ponds providing infiltration at 10 mm/hr. over 80% of their surface area, providing discharge rate control for the 1:2, 1:5, and 1:100 year events, and assuming that the Northwest Area has moderate to high infiltration rates which are reflective of the local sandy/gravely sub-soils. It is also assumed that the Lacombe Lake outlet and Whelp Brook culverts are in their current configuration.

7. Post development: Storm ponds providing infiltration at 10 mm/hr. over 80% of their surface area, providing discharge rate control for the 1:2, 1:5, and 1:100 year events, and assuming that the Northwest Area has moderate to high infiltration rates which are reflective of the local sandy/gravely sub-soils. Under this scenario it is also assumed that the natural water bodies of Pond 'A', Pond 'C', and Pond SC8a provide an infiltration rate of 0.5 mm/hour over their ponded area.

The results in Table 5.4 provide a sensitivity analysis which shows how the various Best Management Practices (BMPs) proposed for the Northwest Area Storm System result in progressively less impact to downstream waterbodies as compared to a more traditional storm system with little to no infiltration in the stormwater management facilities. Please also note that the continuous simulation modeling was primarily completed to quantify the potential changes to runoff volumes for pre and post development conditions; therefore, to ensure a proper accounting of Lacombe Lake outflows for pre and post development conditions, the continuous simulation modeling was configured such that Whelp Brook could **not** back up into Lacombe Lake.

The Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment" dated May 28, 2018 and provided in Appendix D, completed a desktop analysis of potential stormwater management facility infiltration rates based on grain size distribution methods, which result in a range of 1.13 mm/hour to 45 mm/hour.

The modeled annual maximum Lacombe Lake water elevations would reach their highest level in the year 2010 for all scenarios. Table 5.4 shows that under the proposed development **Scenario 6**, the maximum difference between pre and post development annual maximum Lacombe Lake water elevations is 0.031 m, and the difference between the **mean** pre and post development annual maximum Lacombe lake water elevations is only 0.008 m.

Table 5.4 also provides a comparison of total runoff volumes for the various pre and post development scenarios. The values provided for Whelp Brook is located at Range Road 272, and the values provided for Lacombe Lake is at the lake outlet. Table 5.4 shows that under the proposed development **Scenario 6**, the difference between pre and post development runoff volumes at the Lacombe Lake outlet is approximately 35%, and the difference between pre and post development runoff volumes in Whelp Brook is only 6.8%. The BMPs applied as part of the Northwest Area Storm System under Scenario 6 will result in a total runoff volume that is approximately 25 times less than what would be experienced for a more traditional storm system with little to no infiltration in the stormwater management facilities.

Please note that for Scenarios 2 – 6, the annual maximum Lacombe Lake elevations and pre versus post development runoff volume comparisons are considered to be conservative because they assume that the natural water bodies of Pond ‘A’, Pond ‘C’ and Pond SC8a do **not** have any infiltration losses for post development conditions.

Scenario 7 is provided to demonstrate that the difference between pre versus post development runoff volumes is reduced dramatically with a relatively small amount of infiltration in the natural water bodies of Pond ‘A’, Pond ‘C’, and Pond SC8a. Scenario 7 assumes that the natural water bodies of Pond ‘A’, Pond ‘C’, and Pond SC8a provide an infiltration rate of 0.5 mm/hour over the ponded area. However, this report is primarily quoting the results of Scenario 6, which assumes an infiltration rate of zero, because we are less confident in our ability to predict the resulting infiltration rates of these natural water bodies, as compared to the infiltration rates for the proposed stormwater management facilities which are engineered facilities.

The single event and continuous simulation analyses provided in this report demonstrate a negligible impact to downstream water bodies, and that Lacombe Lake and Whelp Brook are capable of providing an adequate outlet.

Table 5.3 Lacombe Lake Annual Maximum Water Levels

	Pre-Dev. Annual Maximum Lake Level (m)	Post-Development Annual Maximum Lake Level (m)					
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Year	NW Area does not contribute for pre-development; Lacombe Lake and Whelp Brook rural catchments assumed to have impervious sub-soils for all scenarios, and having current Lacombe Lake outlet configuration	NW Area has low infiltration, traditional ponds, and current lake outlet configuration	NW Area has moderate infiltration, traditional ponds, and current lake outlet configuration	NW Area has moderate infiltration, multi pre-dev. rate control, and current lake outlet configuration	NW Area has moderate infiltration, multi pre-dev. rate control, pond infiltration at 2mm/hr, and current lake outlet configuration	NW Area has moderate infiltration, multi pre-dev. rate control, pond infiltration at 10mm/hr, and current lake outlet configuration	NW Area has moderate infiltration, multi pre-dev. rate control, storm pond infiltration at 10mm/hr, and natural water bodies Pond A, Pond C, and Pond SC8a at 0.5 mm/hr. of infiltration
1995	857.636	857.699	857.699	857.682	857.658	857.647	857.636
1996	857.603	857.745	857.745	857.713	857.644	857.624	857.604
1997	857.623	857.685	857.685	857.681	857.646	857.635	857.623
1998	857.616	857.734	857.734	857.699	857.631	857.623	857.616
1999	857.629	857.743	857.743	857.701	857.647	857.636	857.629
2000	857.523	857.664	857.663	857.642	857.580	857.530	857.523
2001	857.485	857.614	857.614	857.619	857.494	857.485	857.485
2002	857.506	857.617	857.617	857.614	857.521	857.506	857.506
2003	857.505	857.626	857.626	857.623	857.517	857.505	857.505
2004	857.503	857.602	857.602	857.603	857.507	857.504	857.504
2005	857.515	857.637	857.637	857.630	857.536	857.515	857.515
2006	857.485	857.644	857.644	857.644	857.524	857.491	857.485
2007	857.553	857.815	857.808	857.780	857.692	857.613	857.557
2008	857.483	857.630	857.630	857.627	857.553	857.486	857.483
2009	857.475	857.576	857.576	857.582	857.483	857.475	857.475
2010	857.769	858.076	858.045	858.000	857.883	857.800	857.784
2011	857.608	857.707	857.700	857.649	857.619	857.611	857.608
2012	857.499	857.626	857.626	857.621	857.529	857.499	857.499
2013	857.524	857.638	857.638	857.639	857.552	857.525	857.525
2014	857.554	857.656	857.656	857.649	857.591	857.556	857.555
2015	857.542	857.652	857.652	857.643	857.579	857.546	857.542
2016	857.494	857.629	857.629	857.624	857.510	857.495	857.494
2017	857.521	857.633	857.633	857.630	857.558	857.528	857.522

Table 5.4 Continuous Simulation Downstream Hydraulic Characteristics

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Scenario	NW Area does not contribute for pre-development; Lacombe Lake and Whelp Brook rural catchments assumed to have impervious sub-soils for all scenarios, and having current Lacombe Lake outlet configuration	NW Area has low infiltration, traditional ponds, and current lake outlet configuration	NW Area has moderate infiltration, traditional ponds, and current lake outlet configuration	NW Area has moderate infiltration, multi pre-dev. rate control, and current lake outlet configuration	NW Area has moderate infiltration, multi pre-dev. rate control, pond infiltration at 2mm/hr, and current lake outlet configuration	NW Area has moderate infiltration, multi pre-dev. rate control, pond infiltration at 10mm/hr, and current lake outlet configuration	NW Area has moderate infiltration, multi pre-dev. rate control, storm pond infiltration at 10mm/hr, and natural water bodies Pond A, Pond C, and Pond SC8a at 0.5 mm/hr. of infiltration
Maximum Lake Annual Max. Elevation (m)	857.769	858.076	858.045	858.000	857.883	857.800	857.784
Maximum Lake Annual Max. Elevation (m) change over Pre-development	---	0.307	0.276	0.231	0.114	**0.031**	0.015
Mean Lake Annual Max. Elevation (m)	857.550	857.680	857.678	857.665	857.585	857.558	857.551
Mean Lake Annual Max. Elevation (m) change over Pre-development	---	0.130	0.128	0.115	0.035	**0.008**	0.001
Northwest Area Storm System Discharge Volume per year; Depth over catchment (mm)	---	119.7	118.9	110.4	23.5	**4.6**	1.0
Lacombe Lake Discharge Volume per yr. (m3)x10^3	32	350	344	327	78	43	33
Discharge Volume Percentage Increase (%) over Pre-development	---	1007.1%	987.9%	931.6%	145.9%	**35.0%**	4.5%
Whelp Brook Discharge Volume per yr. (m3)x10^3	159	478	474	452	205	170	160
Discharge Volume Percentage Increase (%) over Pre-development	---	200.5%	197.8%	184.2%	29.0%	**6.8%**	0.8%

5.4 WATER QUALITY DOWNSTREAM OF THE PROPOSED DEVELOPMENT

Stantec has prepared a water quality report as supplemental information to support this document, which is provided in Appendix C. The water quality report provides the background context for traditional stormwater management within the urban context, evaluates the existing background water quality conditions in Lacombe Lake and Whelp Brook/Wolf Creek; discusses the difference between urban and agricultural runoff; discusses removal rates from typical wet ponds; and provides a water and mass balance analysis for nutrient loading. The report makes the comparison of water quality to the Environmental Quality Guidelines for Alberta Surface Waters and cumulative impacts. The proposed SWMFs within the proposed development provide a cumulative enhancement of water quality as water is conveyed through the development. Cumulative impacts on Lacombe Lake are expected to be negligible. It is expected that with improved conveyance and regular discharge to Whelp Brook that the downstream receiving environment nutrient loading will improve with the additional flow.

6.0 Conclusions and Recommendations

6.1 CONCLUSIONS

The following conclusions are drawn from the above analysis and study:

1. The Town of Blackfalds has retained Stantec Consulting Ltd. to prepare a Master Stormwater Management Plan for the Town's Northwest Area. This study provides a conceptual design for the overall Northwest Area storm drainage system which ensures that future development within Northwest Blackfalds will have an adequate outlet, and also forms part of the Water Act Application 001-00387959.

2. In 2013, MPE Engineering Ltd. was commissioned by Lacombe County, Ponoka County, City of Lacombe, and Town of Blackfalds to complete a Master Drainage Plan (MDP) study for the Wolf Creek and Whelp Brook Watersheds. Several land owners located along Wolf Creek and Whelp Brook had voiced concerns about perceived conveyance capacity limitations along these water courses; therefore, Alberta Environment and Parks (AEP) requested that the municipalities undertake the MDP study. The final report for Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds, was generated by MPE Engineering Ltd. on August 31, 2014. Water Act Approval No. 00358426-00-00 was granted to the municipalities on August 24, 2015 to carry out the drainage improvements identified by the MDP.

3. The Wolf Creek and Whelp Brook Watersheds Master Drainage Plan prescribes pre-development release rates of 0.11 L/s/ha, 0.28 L/s/ha, and 2.0 L/s/ha for the 1:2 year, 1:5 year, and 1:100 year storm events, respectively. This report demonstrates that the Northwest Area Storm System will meet these pre-development release rates.

4. Additional Whelp Brook modeling was completed in 2017 to support the Lacombe Intermunicipal Development Plan, 2017 Servicing Study. The City of Lacombe and Lacombe County Whelp Brook Flood Hazard Mapping Study was completed by MPE in September 2017. Given that the southern limit of the 2017 Whelp Brook modeling was Highway 12, the MPE study did not verify whether Lacombe Lake, nor Whelp Brook upstream of Highway 12, could provide sufficient conveyance for upstream development areas. However, the continuous simulation results provided within this report demonstrate that the difference between long term pre and post development runoff volumes in Whelp Brook is only approximately 6.8%. The single event modeling also shows that the 1:100 year unit area release rate from Lacombe Lake is 0.48 L/s/ha. Therefore, the resulting post-development release rates are well below the 1:100

year pre-development flow rate and as such, no impact will occur to the downstream environment.

5. The pre-development catchment area for rural undeveloped lands draining to Lacombe Lake is estimated to be 1,300 ha. The pre and post development catchment area for rural undeveloped lands draining to Whelp Brook located on the north side of Lacombe Lake where the brook crosses Range Road 272 is estimated to be 3,697 ha. The Northwest Area gross development area is 512 ha, but 490.58 ha of the Northwest Area is assumed to have no overland drainage to Lacombe Lake for pre-development conditions due to the high rate of infiltration in the Blackfalds Northwest Area.

6. The Northwest Area is characterized by knob and kettle topography with numerous wet low areas that do not have an effective overland spill route/outlet for pre-development conditions. However, as elaborated on in the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment" dated May 28, 2018 and provided in Appendix D, the local hydrogeology is such that there is significant sub-surface flow towards the north, which is intercepted by Lacombe Lake. Additional findings from this letter report include:

   - The natural wetlands and proposed stormwater management ponds should behave similarly based on the proposed unlined stormwater management facility (SWMF) design, allowing interaction between surface water features and the groundwater environment;

   - The long-term average for rates of groundwater recharge, and eventual discharge to Lacombe Lake should remain similar to pre-development conditions and the overall volume of water entering Lacombe Lake should not change significantly between pre and post development conditions; and

   - High infiltration rates are expected based on surficial geology descriptions and lithological records. Infiltration rates are expected to range from 1.1 - 45 mm/hour depending on soil texture as determined from geotechnical grain-size analysis and analytical permeability calculations (10mm/hour is considered a reasonable and realistic rate of infiltration).

7. In approximately 1972 a diversion structure was constructed on Whelp Brook at Range Road 272, such that when the sluice gate was closed, as portion of the Whelp Brook flows could be diverted towards Lacombe Lake through the previously described ditch/culvert system. Lacombe County holds the existing license (No. 1450 in the North Saskatchewan River Basin) that permits water to be diverted from Whelp Brook to Lacombe Lake. However, our understanding is that the County's long-term intent is to leave the Whelp Brook diversion structure open, such that **no** intentional diversion from Whelp Brook to Lacombe Lake occurs.

8. The single event modeling results show that under the existing configuration for pre-development conditions that Whelp Brook would begin to back up into Lacombe Lake during an event that exceeds the 1:10 design storm event, and this would occur when the sluice gate on the Whelp Brook control structure at Range Road 272 is left completely open. The occurrence of Whelp Brook backing up into Lacombe Lake would result from existing conveyance capacity limitations of Whelp Brook at Range Road 272, rather than a result of any specific interventions or operational schemes.

9. The single event analysis results provided in the report body estimate that the difference between pre and post development Lacombe Lake water levels for the 1:100 year design storm event is 0.09 m, and the 1:100 year unit area discharge rate from the lake is only 0.48 L/s/ha. These results assume no changes to the existing conveyance infrastructure at the outlet to Lacombe Lake or on Whelp Brook at Range Road 272.

10. Continuous simulation modeling over a 23 year period estimates the difference between pre and post development average annual runoff volumes at the Lacombe Lake outlet is increased approximately 35%, and the difference between pre and post development average annual runoff volumes in Whelp Brook is increased 6.8%.

11. This report provides results from a sediment removal analysis, which demonstrates that the SWMFs proposed for the Northwest Area Storm System will provide water quality improvement that exceeds the Alberta Environment and Parks (AEP) criteria for removing 85% of Total Suspended Solids (TSS), for sediment particles 75 microns and larger. The expected level of removal of other contaminants such as phosphorus was also analyzed and is included in this document.

12. Based on the results of the Stantec letter report, "Blackfalds Northwest Area Desktop Hydrogeological Assessment", the expected regional average stormwater management facility infiltration rate of 10 mm/hour, results in only 3% of the total stormwater management facility inflows being discharged offsite.

13. The single event and continuous simulation analyses provided in this report demonstrate a negligible impact to downstream water bodies, and that Lacombe Lake and Whelp Brook are capable of providing an adequate outlet.

14. The Town of Blackfalds is committed to preserving wetlands and other natural water bodies through their incorporation into proposed developments and regional storm systems. The Town, through their consultants, are designing storm systems to work with existing topography and natural systems. This report is in alignment with this commitment by preserving existing water bodies and wetlands, and by utilizing existing drainage routes for stormwater conveyance.

15. The Town of Blackfalds has committed funding to the development of an Environmental Stewardship/Master Plan which will guide internal and external stakeholders on policies and Best Management Practices (BMPs) for items such as, but not limited to, roadway deicer usage, fertilizer and pesticide usage, water and energy conservation, air quality, waste management and composting, and pharmaceutical disposal. The Environmental Stewardship/Master Plan is a living document that facilitates policies and BMPs evolving over time to meet the changing demands of the community and environment.

6.2 RECOMMENDATIONS

The following items are respectfully recommended for AEP's consideration:

A. The Northwest Storm Trunk is proposed to drain from the north end of Pond 'A' through approximately 420 m of 900 mm diameter storm trunk, where it will outlet to the south end of Pond 'C'. After conveying through Pond 'C' it will drain through approximately 40 m of 900 mm diameter storm trunk under Township Road 40-0, continue through the proposed system approximately 370 m northwest through a constructed linear wetland, and then outfall to a natural drainage course that further drains north to Lacombe Lake. Although the analysis shows very low release rates, this trunk is sized to accommodate the 1:100 year event with no SWMF infiltration because stormwater management facilities should not be designed to rely on infiltration alone.

B. The Town of Blackfalds is committed to applying the specific Best Management Practices (BMPs) of oil and grit separators for potential "hot spots", the hybrid stormwater management facilities proposed in this report, and an increased topsoil thickness to a total of 25 cm to 30 cm (local supply permitting).

C. Hybrid stormwater management facilities, area which include both permanently wet and semi-wet wetland areas within the facility, are universally proposed for the Northwest Area. The hybrid storm pond parameters defined in this report outline the required ratio of semi-wet (infiltration) pond areas to permanently wet pond areas, for which subsequent analyses will quantify the resulting infiltration (runoff volume control) and water quality improvement performance for a facility with these design parameters.

D. It is recommended that water quality data be collected as part of the Northwest Area Water Act Approval. This data will provide valuable information that will help to guide the evolution of the Town's Environmental Stewardship Plan; thus, providing a means to tailor the policies and BMPs that provide protection to the users located downstream of the Blackfalds Northwest Area.

E. The proposed Northwest Area Drainage project will provide the future development area with an adequate stormwater outlet. Therefore, it is recommended that the pending Water Act approval for the Northwest Area Master Stormwater Management Plan be approved based on the results provided in this study/analysis.

7.0 References

Stormwater Management Guidelines for the Province of Alberta, Alberta Environmental Protection, January 1999.

Evaporation and Evapotranspiration in Alberta, Alberta Government, April 2013.

Municipal Policies and Procedures Manual, Alberta Environmental Protection, April 2001.

PCWMM – Water System Models, User's Guide to SWMM5, CHI, Guelph, Ontario, Canada 2008.

The City of Red Deer – Engineering Services Design Guidelines, 2013.

The City of Calgary - Wastewater and Drainage - Stormwater Management and Design Manual, December 2000.

AGS Map 213, Quaternary Geology, Central Alberta, I. Shetsen 1987, digitized to CentralAB_SurficialMaterials_UTM12N shape files.

Final report for: Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds, prepared for Lacombe County, Ponoka County, City of Lacombe, and Town of Blackfalds, by MPE Engineering Ltd., August 31, 2014.

City of Lacombe and Lacombe County Whelp Brook Flood Hazard Mapping Study, by MPE Engineering Ltd., September 2017.

Aurora Heights Stormwater Management Report, for Aurora Heights Inc., by Stantec Consulting, July 14, 2014.

Total Energy Services, Inc. Industrial Park SW-28-39-W.4, by Stantec Consulting, April 10, 2013.

Aspen Lake West Stormwater Management Report, for Aspen Lake West Development Inc., by Stantec Consulting, June 30, 2015.

Blackfalds Northwest Area Desktop Hydrogeological Assessment, by Stantec Consulting, May 28, 2018.

Water Quality Downstream of the Proposed Development, by Stantec Consulting, May 28, 2018.

8.0 Corporate Authorization

This document entitled "Town of Blackfalds Northwest Area Master Stormwater Management Report" was prepared by Stantec Consulting Ltd. on behalf of the Town of Blackfalds. The material in it reflects Stantec Consulting Ltd.'s best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or reliance on or decisions made based on it, are the responsibilities of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

PERMIT TO PRACTICE
STANTEC CONSULTING LTD.

Signature
Date May 31 2018

PERMIT NUMBER: P 0258
The Association of Professional Engineers
Geologists and Geophysicists of Alberta

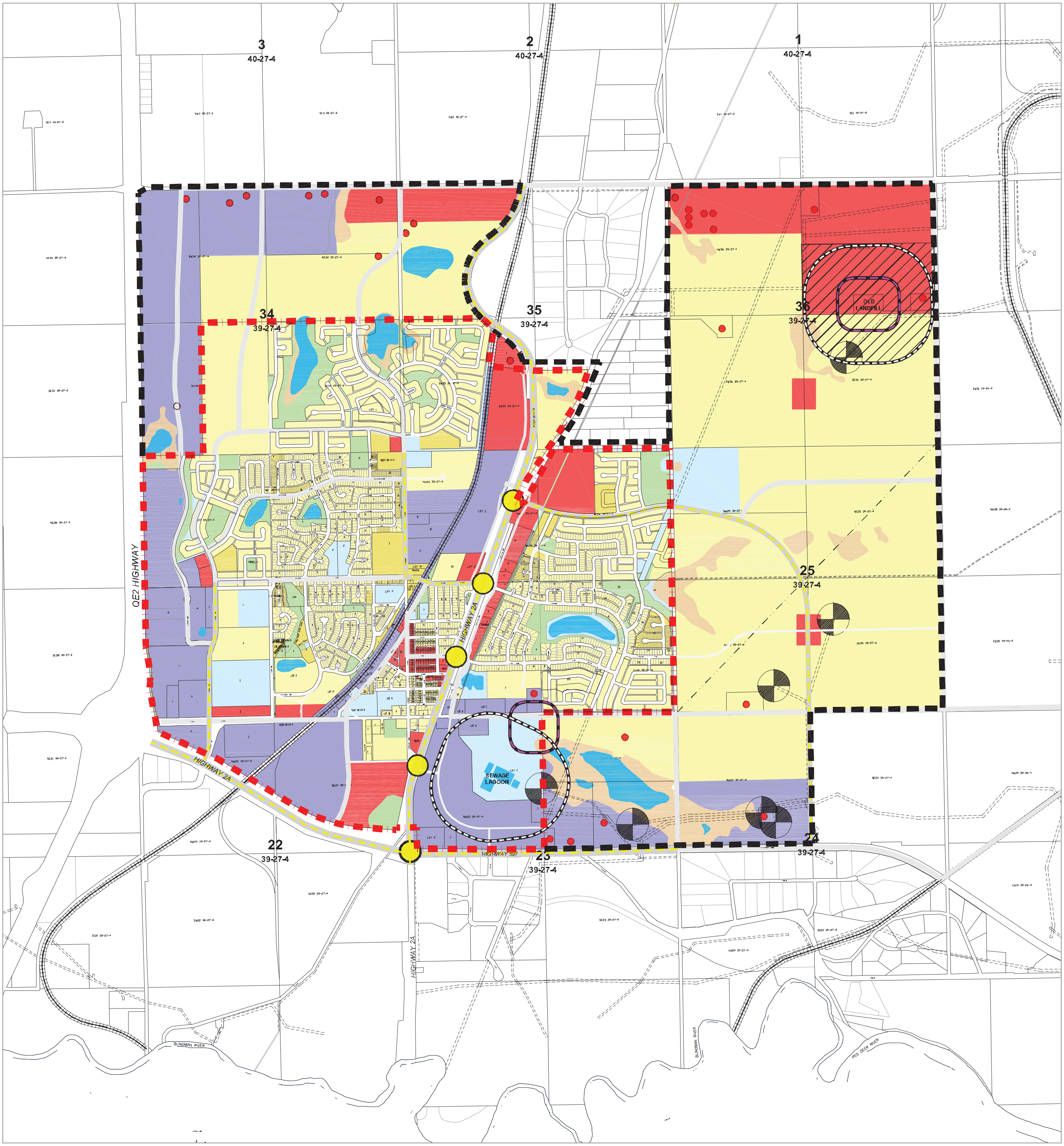
CORPORATE AUTHORIZATION

PROFESSIONAL ENGINEER
BRAD DARDIS
ALBERTA

May 30, 2018

RESPONSIBLE ENGINEER

Appendix A
Map 5 – Future Land Use & Roadways from Town of Blackfalds 2007 Master Plan for Annexation



TOWN OF

BLACKFALDS

2007 Proposed Annexation

EXISTING TOWN BOUNDARY	INDUSTRIAL	OVERHEAD POWER LINE
PROPOSED ANNEXATION BOUNDARY	PUBLIC / INSTITUTIONAL	300m SETBACK
ARTERIAL ROADWAY	RESIDENTIAL	100m SETBACK
COLLECTOR ROADWAY	RESIDENTIAL MULTI-FAMILY	BUILDING
LOCAL ROADWAY	WATER BODY	OIL / GAS WELL (100m setback)
SIGNALIZED INTERSECTION	SLOUGH / WETLAND	OIL / GAS / GLYCOL PIPELINE R-of-W
COMMERCIAL	SPECIAL STUDY AREA	RAILWAY
OPEN SPACE		

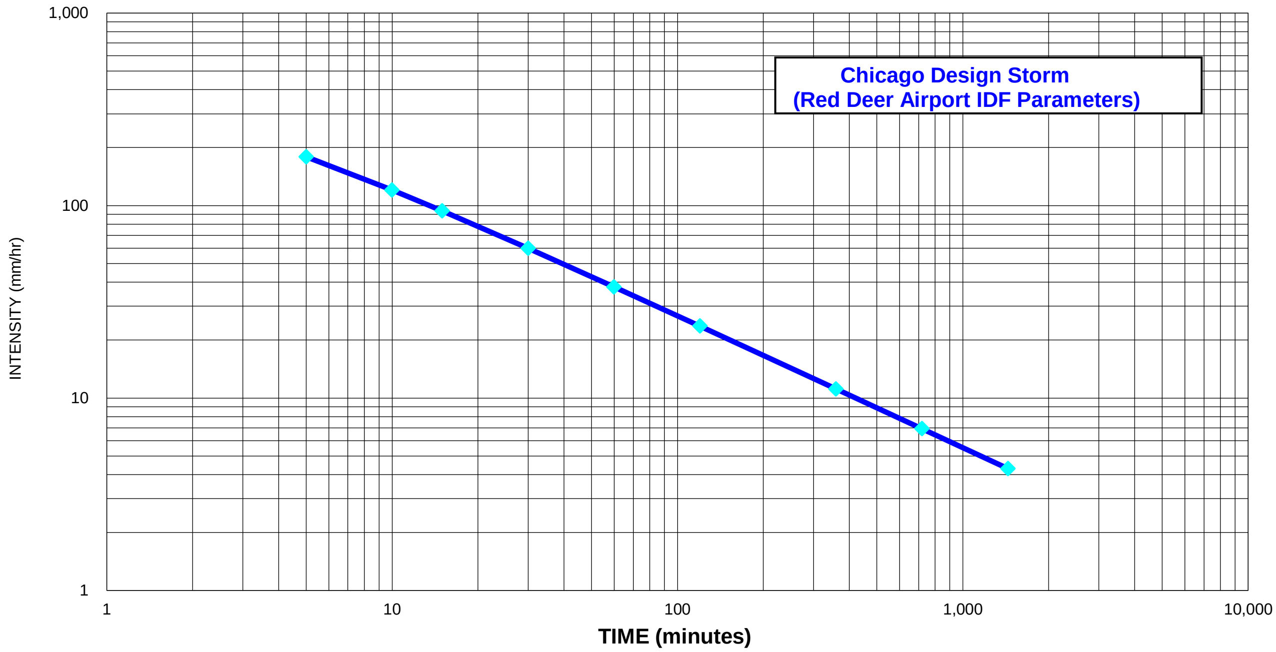
MAP 5

FUTURE LAND USE & ROADWAYS

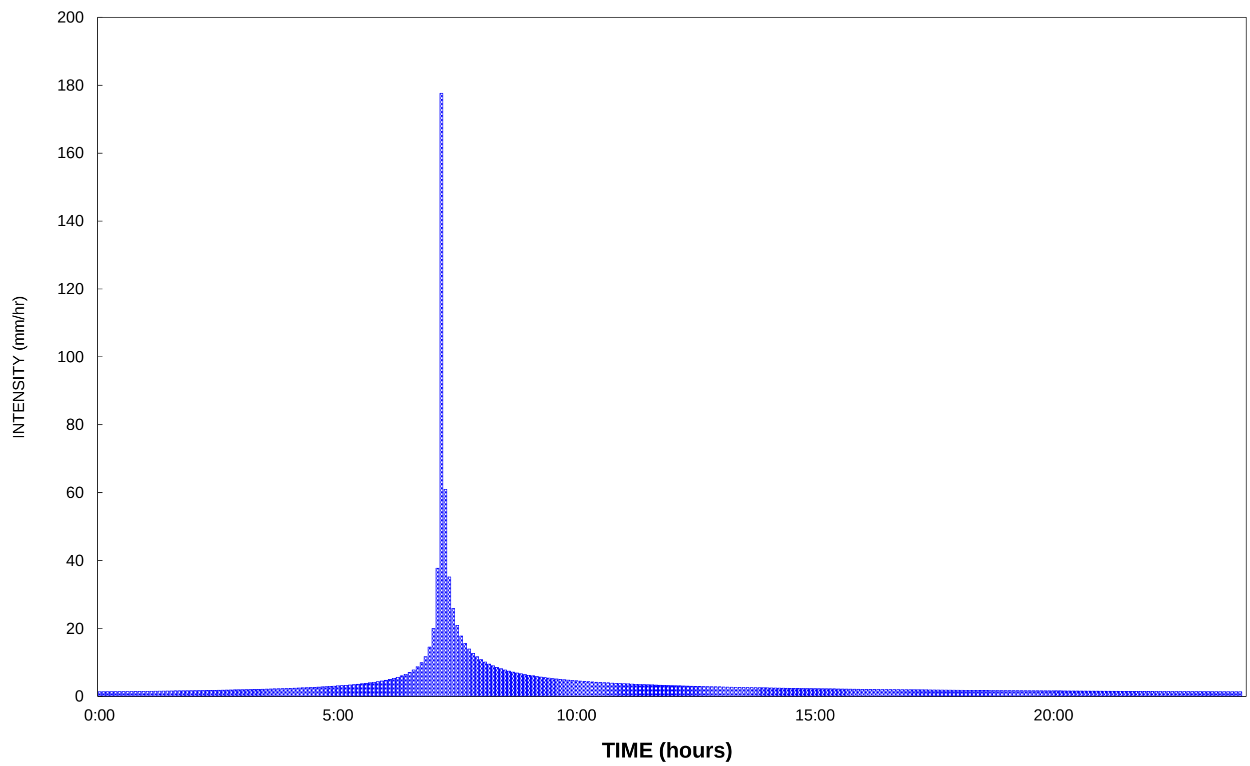
OCTOBER 2007

PARKLAND COMMUNITY PLANNING SERVICES

Appendix B
Figure B1 Chicago Design Storm
Figure B2 Typical Storm Pond
Figure B3 Typical Storm Pond Control Structure



(a) Intensity-Duration Relationship



(b) Distribution of Intensity Versus Time

A: 644.6
B: 1.41
C: 0.689
r: 0.3

Stantec

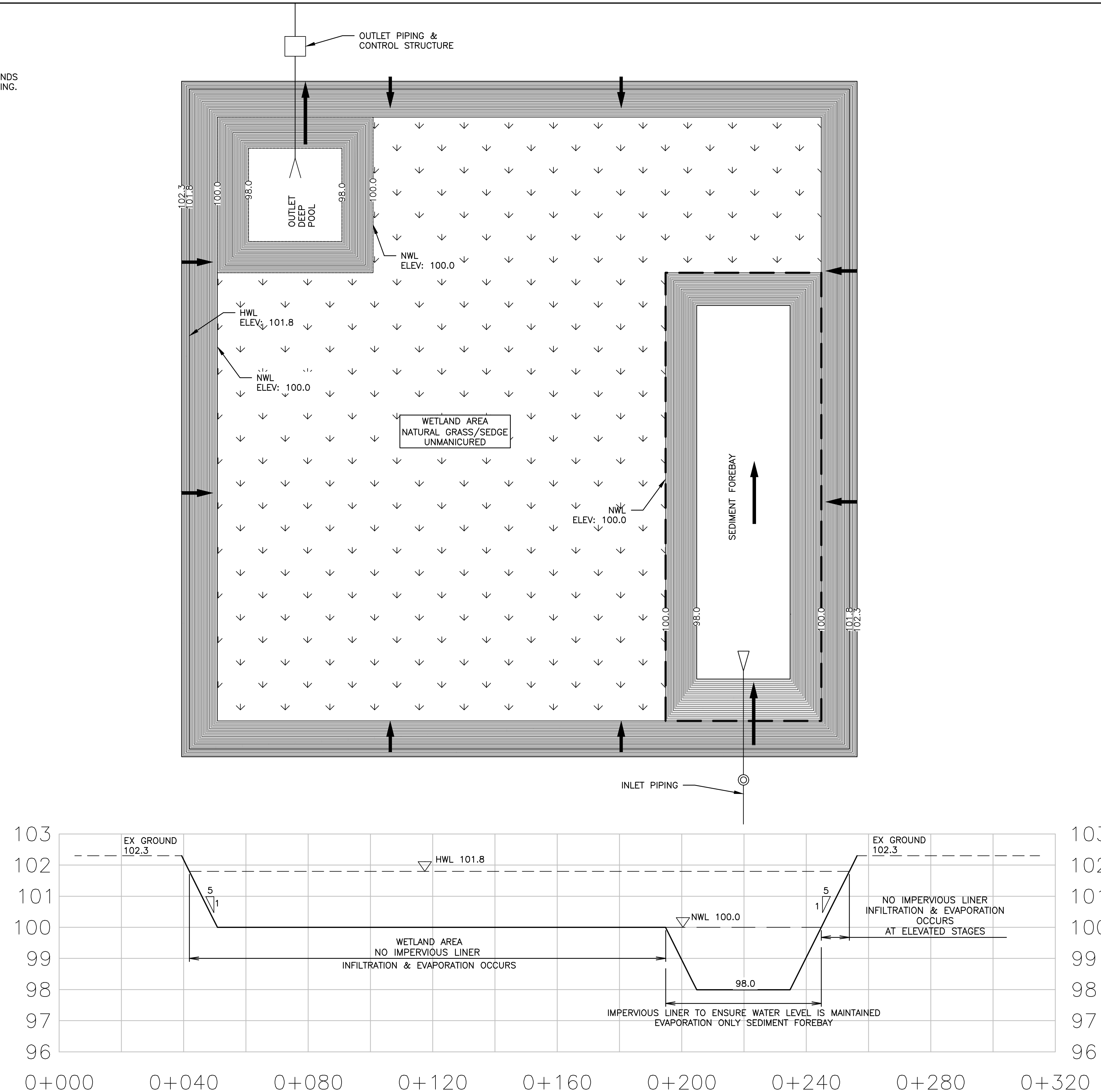
Client/Project
Town of Blackfalds
Northwest Area
Master Stormwater Management Report

Figure No.
B1

Title
Chicago Design Storm
24 Hour, 1:100 Year

chicago_CRD_2012data.xls

NOTES:
1. POND CONFIGURATION AND DIMENSIONS ARE GENERIC IN NATURE. MOST PONDS WILL BE GIVEN A MORE NATURAL SHAPE TO BE MORE ESTHETICALLY PLEASING.
2. POND CATCHMENT AREA ASSUMED TO BE 100ha AND 70% IMPERVIOUS; REQUIRED ACTIVE STORAGE VOLUME ~70,000m³.
3. SEDIMENT FOREBAY HAS A NWL FOOTPRINT AREA THAT IS ~20% OF THE OVERALL FACILITY HWL FOOTPRINT AREA.



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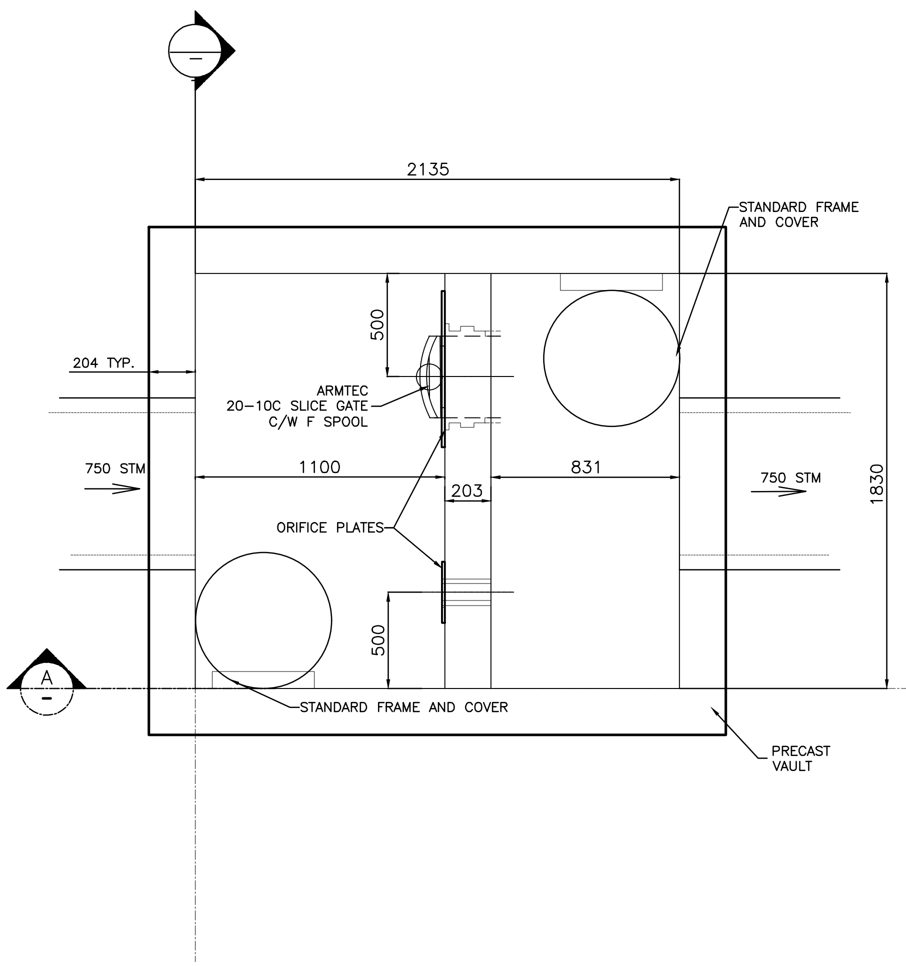
2018/04/25 2:46 PM By: McAleese, Meagan

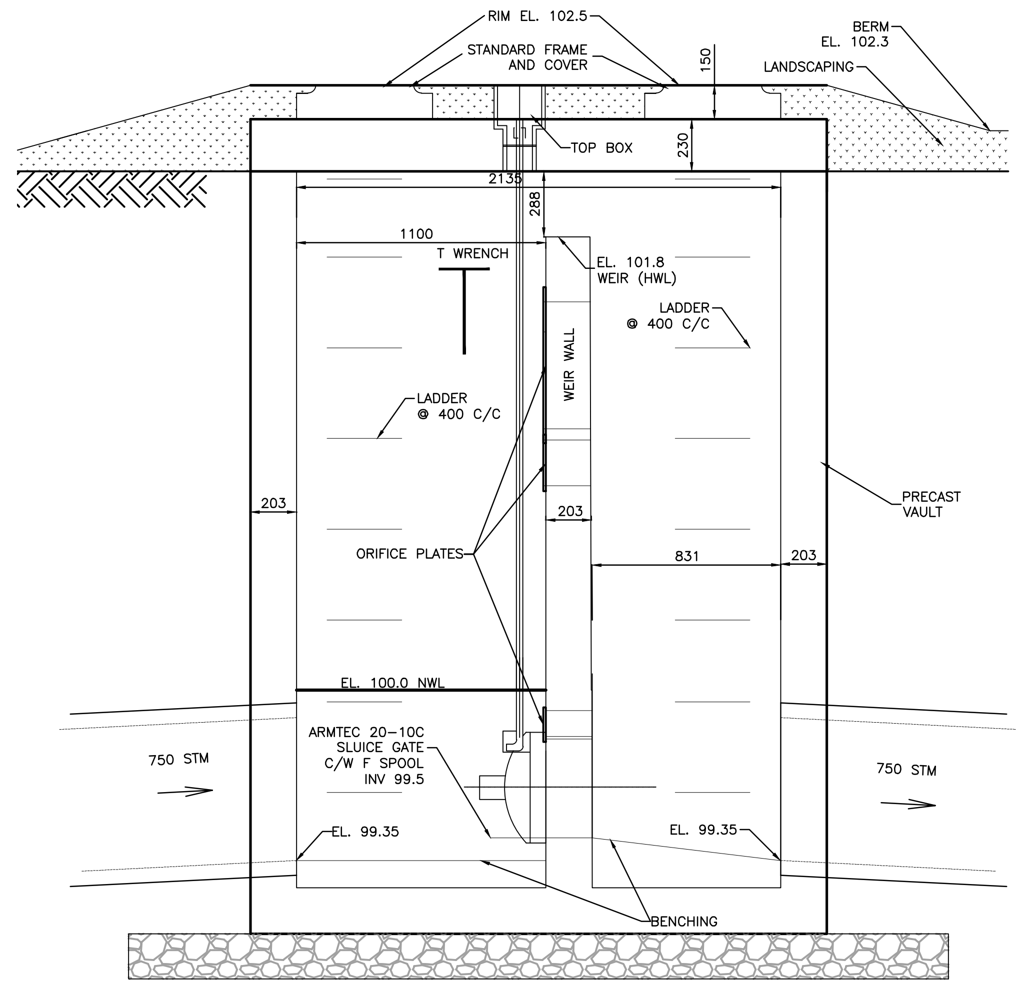
FIGURE B2 GENERIC STORM POND

Stantec

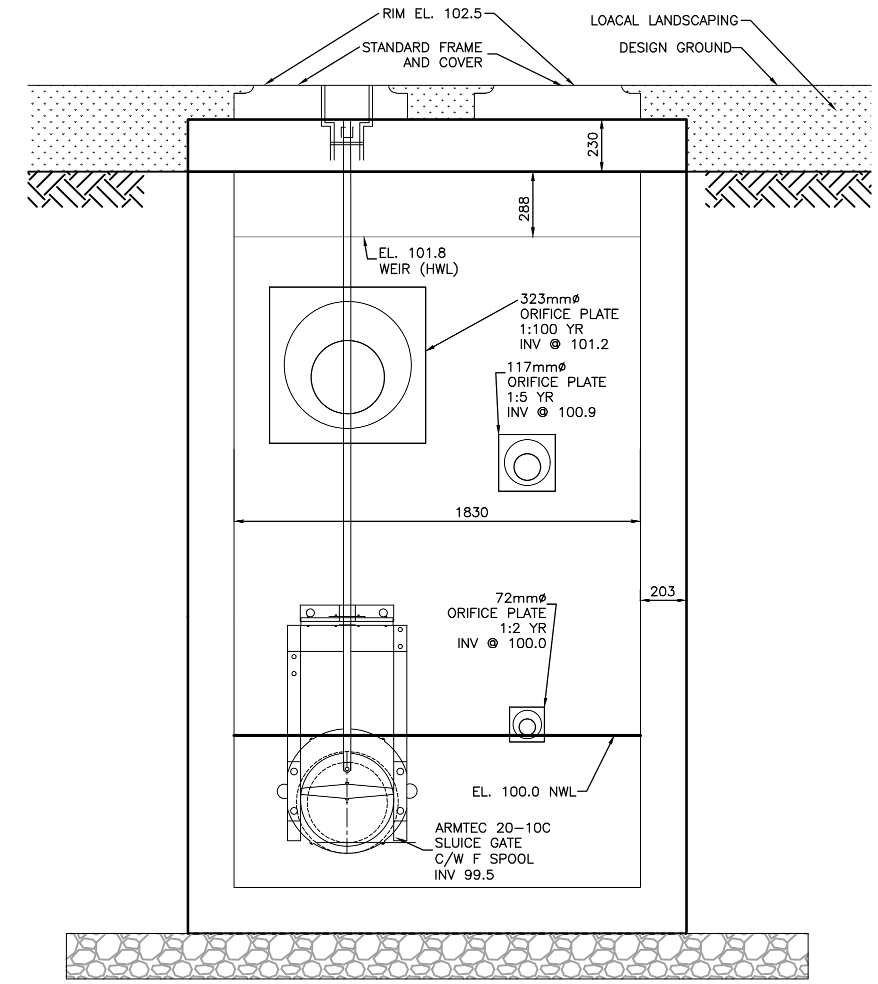
BLACKFALDS NW AREA
TOWN OF BLACKFALDS, ALBERTA



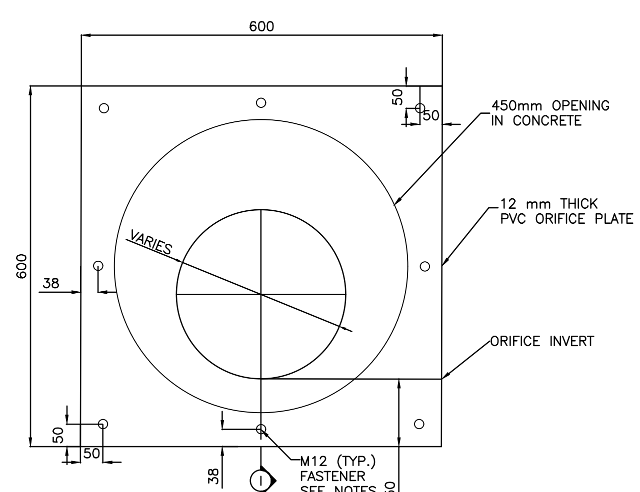
PLAN–CONTROL STRUCTURE CS–1
NOT TO SCALE



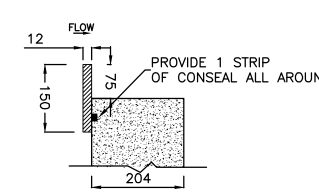
A
CJ–101
SECTION–CONTROL STRUCTURE CS–1
NOT TO SCALE



B
CJ–101
SECTION–CONTROL STRUCTURE CS–1
NOT TO SCALE



2
TYPICAL ORIFICE PLATE DETAIL
NOT TO SCALE



1
SECTION
NOT TO SCALE

1. DIMENSIONS ARE IN MILLIMETRES, STATIONS AND ELEVATIONS ARE IN METRES, UNLESS OTHERWISE NOTED.

2. THERE MAY BE AN OPPORTUNITY TO ELIMINATE THE ORIFICE ASSOCIATED WITH THE 1:2 YEAR EVENT IF IT CAN BE DEMONSTRATED THAT THE INFILTRATION CAPABILITY OF A PARTICULAR FACILITY CAN FULLY MANAGE THE RUNOFF ASSOCIATED WITH A 1:2 YEAR EVENT. THE POTENTIAL ELIMINATION OF THE 1:2 YEAR ORIFICE IS SEEN AS BENEFICIAL BECAUSE IT WOULD MORE CLOSELY REPLICATE THE PRE-DEVELOPMENT CONDITION.

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2018/04/25 2:46 PM By: McAleese, Meagan

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FIGURE B3 GENERIC STORM POND CONTROL STRUCTURE

BLACKFALDS NW AREA
TOWN OF BLACKFALDS, ALBERTA

Appendix C
Water Quality Downstream of the Proposed Development

Stantec

Stantec Consulting Ltd.
500–311 Portage Avenue Winnipeg MB R3B 2B9

May 28, 2018
File: 113929434

Attention: Mr. Preston Weran, Director of Infrastructure and Property Services
Town of Blackfalds
Box 220, 5018 Waghorn Street.
Blackfalds, AB T0M 0J0

Dear Mr. Weran,

Reference: Water Quality Downstream of the Proposed Development

1.0 Introduction

The sections below summarize information gathered to support the proposed Master Stormwater Management Plan (MSMP) for the town of Blackfalds as a part of the Blackfalds Northwest Area Stormwater Project Response to Supplemental Information Request (SIR) #1, Item 3(b) and 3(d), Water Act File 00387959.

This report will:

- Outline the background water quality of various water bodies and compare to objectives for areas:
  - Downstream of the development, such as Lacombe Lake and Whelp Brook; and
  - Other water bodies, such as Wolf Creek and Battle River.
- Characterize the water quality from various urban and non-urban land uses including agricultural use (and the atmosphere) for current and future land uses within the Lacombe Lake Basin.
- Review available literature to gain an understanding of potential removal rates of wet ponds for nutrients and contaminant loadings.
- Develop a water balance of the various sub-watersheds of the Lacombe Lake basin and Whelp Brook watershed using the PC-SWMM modelling results.
- Develop a pre- and post-development project mass balance for total phosphorus, for the various sub-watersheds of the Lacombe Lake basin and Whelp Brook watershed, using:
  - The storm water modelling results;
  - Runoff characterization;
  - Atmospheric loadings;
  - An understanding of the location of the proposed ponds and existing wetlands within the drainage area; and
  - Assumed removal rate for ponds for specific nutrients.

These results are then used to develop an understanding of cumulative impacts and inform the proposed monitoring program.

2.0 Background Water Quality

2.1 Lacombe Lake

In the State of the Environment report issued by Lacombe County in 2013, water quality in Lacombe Lake was characterized as "fair" based on analysis of nutrients (total phosphorus and total nitrogen) and bacteria (total coliform bacteria) (Lacombe County 2013). Lacombe Lake is a relatively shallow lake with a maximum depth of 2.9 m, and the surrounding land use is predominantly agricultural. Water quality monitoring between May 2008 and October 2011 determined that total Kjeldahl nitrogen and total phosphorus exceeded the Alberta guideline values of 1.0 mg/L and 0.05 mg/L, respectively (Figure 1). It should be noted that these guidelines were eligible during the monitoring period of the study but have now been withdrawn and narrative statements have been developed. No increases in total nitrogen or phosphorus over existing conditions are expected to occur (ESRD 2014). Increase of total phosphorus and total nitrogen concentration in Lacombe Lake was attributed to diversion of Whelp Brook through a weir system that controls and diverts water from Whelp Brook to Lacombe Lake during periods of high flow. As a result of excess nutrients, there has been excess macrophyte growth observed in the lake.

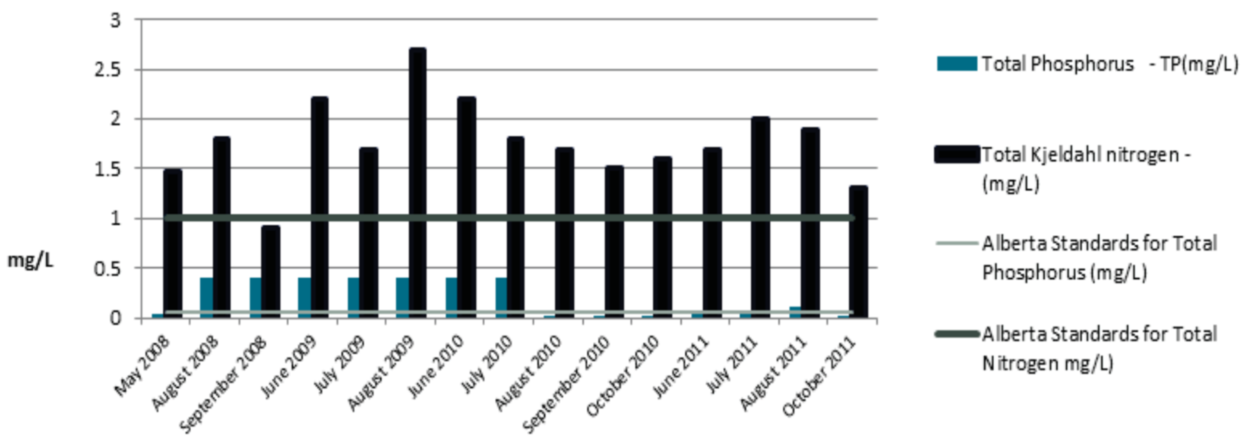
Analysis of 23 water quality parameters in Lacombe Lake by Alberta Environment and Parks (AEP) in 2014-2017 (AEP 2018a) (Table 1) showed very few exceedances of guidelines. Only two parameters showed exceedances with total alkalinity over the long-term Alberta Environmental Quality Guidelines for Protection of Aquatic Life (AB EQG-PAL) (20 mg/L) and dissolved fluoride over the Canadian Environmental Quality Guidelines for Protection of Aquatic Life (CEQG-PAL) (0.12 mg/L). The reported pH values in the lake are slightly alkaline (maximum 8.92) and approaching the upper limit of the guideline pH range (9.00).

Lacombe Lake has an average total phosphorus concentration of 0.21 mg/L. Based on CEQG-PAL guideline framework for phosphorus (CCME 2004), Lacombe Lake can be classified as mesotrophic (0.010 to 0.020 mg/L TP) to meso-eutrophic (0.020 to 0.035 mg/L TP) (Table 1).

Lacombe County's survey in 2013 was negative for the presence of invasive species (Lacombe County 2013).

Reference: **Water Quality Downstream of the Proposed Development**

Figure 1 Total Phosphorus and Total Nitrogen in Lacombe Lake 2008-2011 (Lacombe County 2013)



Stantec

Reference: **Water Quality Downstream of the Proposed Development**

Table 1 Detailed Lake Water Quality Data – Lacombe Lake by Alberta Environment and Parks (AEP 2018a)

Parameter	Units	**AB EQG-PAL, long-term**	CEQG-PAL, long-term	Jun-14	Jul-14	Aug-14	Sep-14	Jun-15	Jul-15	Aug-15	Aug-15	Sep-15	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Jun-17	Jul-17	Aug-17	Sep-17	Mean	Min	Max
Alkalinity, Total $CaCO_3$	mg/L	20	n/a	**230**	**233**	**220**	**235**	**210**	**210**	**210**	**220**	**210**	**220**	**210**	**230**	**230**	**230**	**210**	**220**	**220**	**230**	**221**	**210**	**235**
Ammonia, Total	mg/L	Equation	Equation	n/a	n/a	n/a	n/a	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05	0.14	0.055	L0.05	L0.05	L0.015	0.02	0.026	L0.015	0.060	0.020	0.140
Carbon, Dissolved Organic	mg/L	n/a	n/a	n/a	n/a	n/a	n/a	20	16	16	17	15	14	11	16	15	17	15	15	15	16	16	11	20
Chloride Dissolved	mg/L	120	120	20.3	20.3	22	21.8	24	24	25	25	25	24	25	25	25	25	26	26	27	28	24	20	28
Coliforms, Fecal	No/100 mL	100	100	L10	n/a	10	L10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	10	10	10
Fluoride, Dissolved	mg/L	n/a	0.12	**0.153**	**0.183**	**0.231**	**0.166**	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**0.183**	**0.153**	**0.231**
Hardness, Total (Calcd) $CaCO_3$	mg/L	n/a	n/a	197	179	204	203	180	190	190	180	170	190	190	200	200	180	190	200	170	180	189	170	204
Nickel, Total Recoverable	µg/L	82	143	0.08	n/a	n/a	L0.008	n/a	n/a	0.045	0.137	0.144	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.102	0.045	0.144
Nitrogen, Nitrite	mg/L	0.20	0.06	n/a	n/a	n/a	n/a	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003
Nitrogen, NO_3 & NO_2	mg/L	n/a	13	n/a	n/a	n/a	n/a	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005	L0.0042	L0.0042	L0.0042	L0.005	L0.005	L0.005
Nitrogen, Total (Calcd)	mg/L	No increase over existing conditions	n/a	n/a	n/a	n/a	n/a	1.3	1.3	1.4	1.4	1.4	1.3	1.5	1.3	1.2	1.2	1.2	1.3	1.4	1.2	1.3	1.2	1.5
Nitrogen Total Kjeldahl	mg/L	No increase over existing conditions	n/a	1.3	1.25	1.37	1.25	1.3	1.3	1.4	1.4	1.4	1.3	1.5	1.3	1.2	1.2	1.2	1.3	1.4	1.2	1.3	1.2	1.5
Nitrogen, Nitrate	mg/L	n/a	13	n/a	n/a	n/a	n/a	L0.003	L0.003	L0.003	L0.003	L0.003	0.0036	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	L0.003	0.003	0.003	0.003	0.004
pH (Lab)	pH unit	6.5-9.0 (and < 0.5-unit change from background)	6.5-9.0	8.34	8.52	8.46	8.63	8.9	8.78	8.92	8.66	8.65	8.66	8.62	8.69	8.45	8.66	8.51	8.42	8.58	8.6	8.61	8.34	8.92
Phosphorus, Total	mg/L	No increase over existing conditions	Guidance Framework	0.0271	0.0276	0.0198	0.0186	0.016	0.025	0.021	0.017	0.017	0.013	0.018	0.015	0.011	0.022	0.017	0.052	0.017	0.019	0.021	0.011	0.052
Phosphorus, Total Dissolved	mg/L	n/a	n/a	0.0058	0.006	0.0048	0.0037	0.007	0.009	0.004	0.005	0.005	L0.003	0.004	L0.003	L0.003	0.005	0.0038	0.0041	0.0045	0.0052	0.0051	0.0037	0.009
Specific Conductance (Lab)	µS/cm	n/a	n/a	485	497	508	520	470	480	470	490	480	480	470	510	510	480	500	510	510	540	495	470	540
Sulphate, Dissolved	mg/L	309 and higher (varies dep on hard)	n/a	15.4	13.3	14.2	13.5	16	17	17	15	14	16	14	14	14	13	12	12	15	14	14	12	17
Temperature, Air	Deg C	n/a	n/a	12	12	22	15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	17	17	21	12	16	12	22
Total Dissolved Solids (Calcd)	mg/L	500 to 3500	500 to 3500	275	273	278	284	260	270	270	270	260	270	270	290	290	280	270	280	270	290	275	260	290
Total Water Depth	m	n/a	n/a	3.5	3.7	2.8	3.5	3.5	3.8	3.7	3.8	3.8	3.5	3.2	3.5	3.4	3.4	3.7	3.8	3.1	3.4	3.5	2.8	3.8
Turbidity	NTU	8 NTUs from backgr for 24-h and 2 NTUs from backgr for 30-d	8 NTUs from backgr for 24-h and 2 NTUs from backgr for 30-d	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.6	2.6	2.6
Zinc, Total Recoverable	µg/L	30	30	n/a	0.7	n/a	n/a	2.0	1.2	0.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.2	0.7	2.00

Notes: AB EQG-PAL – Alberta Environmental Quality Guidelines for Protection of Aquatic Life (ESRD 2014), CEQG-PAL Canadian Environmental Quality Guidelines for Protection of Aquatic Life (CCME 2014); Parameter values exceeding long-term AB EQG-PAL guidelines are bolded and long-term CEQG-PAL guidelines are double underlined, long-term AB EQG-PAL and CEQG-PAL guideline values were used as the most stringent guidelines; Irrigation AB EQG and CEQG guidelines are used for Fecal Coliform (*E.coli*) and total dissolved solids; Most stringent long-term AB EQG-PAL and CEQG-PAL guidelines at the lowest hardness (min 170 mg/L) are used for total nickel; A long-term AB EQG-PAL (30-d average) at chloride greater than 10 mg/L is used for total nitrite; Calcd – Calculated; L0.006 – below a detection limit, which is 0.006 mg/L for L0.006.

2.2 Whelp Brook

An extensive 6-year research project was conducted under the direction by Alberta Agriculture and Rural Development (PEWC and AB Agriculture and Rural Development 2014) from 2007 to 2012. The project called the Nutrient Beneficial Management Practices Evaluation Project (BMP Project) was directed on evaluation of the effectiveness of Best Management Practices (BMPs) at field and watershed scales in Alberta. As a part of this project, water quality and contaminant loadings were evaluated for Whelp Creek (also called Whelp Brook and is Whelp Brook hereafter) located within the Whelp Creek (WHC) Sub-watershed (center at 52.43° N, 113.85° W and area is 5056 ha or 50.56 km^2). The WHC Sub-watershed stretches from the origin of Whelp Brook and its south tributaries to the confluence of Whelp Brook and the discharge from Lacombe Lake. The confluence is located downstream of the Lacombe Lake, and the stream flow from Whelp Brook will back up into Lacombe Lake during periods of high flow. The weir system was constructed by the Prairie Farm Rehabilitation Association (PFRA) in the 1960s to divert water from Whelp Brook to Lacombe Lake during periods of high flow to prevent flooding of the landscape (Lacombe county 2013).

Land cover and land use information recorded during driving surveys using AgCapture software showed that the primary land use in WHC Sub-watershed was agriculture (approx. 86.7% of land), including cultivated crops, hay crops and pasture, and livestock production (dairy and beef operations) (PEWC and AB Agriculture and Rural Development 2014). In addition, residential, commercial, industrial, transportation, and idle land occupied 3.8%, and forest, grass land, water bodies, and wetlands occupied 9.2%. The WHC Sub-watershed was categorized as a high intensity agriculture watershed by the Alberta Environmentally Sustainable Agriculture (AESA) Program, during which the outlets of 23 watersheds were monitored for 8 years from 1999 to 2006. Total nitrogen (median 3.6 mg/L) and total phosphorus (median 0.7 mg/L) concentrations for the 5-year dataset (n=96) for the WHC Sub-watershed outlet was higher than median concentrations (TN 1.9 mg/L and TP 0.2 mg/L) of the AESA watersheds.

The Nutrient Water Quality Sub-index (NWQS-I) based on the Alberta Agricultural Water Quality Index (Wright et al. 2003) showed that all monitoring sites at the WHC Sub-watershed and in all years were rated as poor. The sub-index is calculated using the number of objectives (seven nutrient water quality objectives for WHC Sub-watershed) that were not met, the frequency with which the objectives were not met, and the amount by which the objectives were not met. Index scores were grouped into five categories: poor (0-40), marginal (41-55), fair (56-70), good (71-85), and excellent (86-100).

The average annual NWQS-I scores were similar during the monitoring period showing that BMPs were unable to improve water quality at the watershed scale. Intermittent characteristics of the brook and its tributaries, which typically flow after snowmelt or heavy rainfall events, and shallow water table enables producers to cultivate through portions of the Whelp Brook in some years.

Water quality data recorded at the outlet from Whelp Brook (located at Highway 2) showed that 77% of nitrogen was in the form of organic nitrogen (ON) and phosphorus was mainly in the dissolved form (TDP) (Table 2). Mean overall concentrations of total nitrogen (3 mg/L), nitrate (0.59 mg/L), ammonia (0.1 mg/L), total phosphorus (0.59 mg/L), total dissolved phosphorus (0.52 mg/L), chloride (67.6 mg/L), and electrical conductivity (755 µS/cm) at the WHC Sub-watershed outlet were greater than those at Lacombe Lake in approximately 2, 84, 5, 28, 92, 3, and 1.5 folds (Table 1 and 2). Mean pH values were similar with 8.08 pH units at the WHC Sub-watershed outlet and 8.65 pH units at Lacombe Lake.

Based on CEQG-PAL guideline framework for phosphorus, Whelp Brook can be classified as eutrophic (0.035 to 0.100 mg/L TP) with total mean phosphorus varying from 0.048 to 0.078 mg/L (Table 2).

Reference: Water Quality Downstream of the Proposed Development

Mean overall concentration of *E. coli* (4,536 mpn/100 mL) exceeded the Alberta (100 mpn/100 mL) and the Canadian (100 mpn/100 mL) Irrigation guidelines for the Protection of Agriculture in approximately 45 folds (Table 2). Mean concentration of *E. coli* was below the guidelines only in 2009 (9 mpn/100 mL) and 2012 (58 mpn/100 mL). These exceedances were attributed to wildlife activities, domestic animals, and manure application.

Table 2 Mean Parameter Concentrations at The Whelp Brook Sub-watershed Outlet from 2008 to 2012

Year	Unit	2008	2009	2010	2011	2012	All
n	n/a	31	4	24	24	13	96
TN	mg/L	3.14	3.74	2.19	3.26	3.43	3
ON	mg/L	2.57	2.39	1.98	2.24	2.3	2.3
NO_3-N	mg/L	0.5	1.21	0.13	0.85	0.95	0.59
NH_3-N	mg/L	0.05	0.11	0.05	0.16	0.18	0.1
TP	mg/L	0.48	0.56	0.56	0.78	0.56	0.59
TDP	mg/L	0.41	0.52	0.5	0.68	0.49	0.52
PP	mg/L	0.07	0.04	0.06	0.1	0.08	0.08
TSS	mg/L	9	3	8	17	13	11
Cl	mg/L	36.8	76.7	114	30.4	50.3	67.6
E. coli	mpn/100 mL	147	9	7,069	10,121	58	4,536
EC	µS/cm	787	696	945	542	722	755
pH	pH unit	8.07	8.44	8.15	7.97	8.06	8.08

Notes: TN - total nitrogen; ON- organic nitrogen; NO_3-N - nitrate nitrogen; NH_3-N - ammonia nitrogen; TP - total phosphorus; TDP - total dissolved phosphorus; PP - particulate phosphorus; TSS - total suspended solids; Cl - chloride; *E. coli* - Escherichia coli; EC - electrical conductivity; pH - potential hydrogen; n/a - not available; *E. coli* guidelines are Irrigation guidelines for the Protection of Agriculture; mpn – most probable number.

Regression analysis showed no relationship between flow and concentrations of water quality parameters but a strong relationship between all parameters and flow. Annual flow was the main parameter influencing annual loadings (shown in Table 3). Annual loadings of total phosphorus and total nitrogen varied from 17 and 94 kg/yr, respectively, during low flow conditions to 5,522 and 25,432 kg/yr, respectively, during high flow conditions.

Table 3 Annual Mass Load of Parameters (kg/yr) and Annual Flow (m^3/yr) at the Whelp Brook Sub-watershed Outlet from 2008 to 2012

Parameter	2008	2009	2010	2011	2012
TP	168	17	655	5,522	860
TDP	144	15	585	4,924	724
PP	24	2	70	598	136
TN	1,173	94	1,523	25,432	5,997
ON	969	58	1,288	12,895	3781
DIN	204	36	235	12,615	1869
TSS	3,122	74	7,976	95,831	22,398
Flow	355,999	25,319	644,966	5,896,213	1,686,658

Notes: TP - total phosphorus; TDP - total dissolved phosphorus; PP - particulate phosphorus; TN - total nitrogen; ON - organic nitrogen; DIN - dissolved inorganic nitrogen (NO3-N plus NH3-N); TSS - total suspended solids.

2.3 Other Waterbodies

This section describes water quality conditions at other waterbodies, including Wolf Creek and Battle River. After crossing Highway 2, Whelp Brook continues to flow north until it confluences with Wolf Creek, which flows north and empties into the Battle River near Ponoka, Alberta.

Analysis of 22 water quality parameters in Wolf Creek by Alberta Environment and Parks in 2013-2014 (AEP 2018b) (Table 4) showed exceedances of total alkalinity (mean 317 mg/L) over the long-term AB EQG-PAL (20 mg/L) in ~x15 times, fecal coliform (mean 106 No/100 mL and max 260 No/100 mL) over irrigation AB EQG and CEQG, dissolved fluoride (mean 0.29 mg/L) over the CEQG-PAL (0.12 mg/L) in ~x2 times, and occasionally dissolved oxygen over the AB EQG-PAL for mid-May to end-June (8.3 mg/L) and for larval fish developing within gravel beds (9.5 mg/L). The reported pH values in the lake are slightly alkaline varying from 7.91 to 8.42.

Reference: Water Quality Downstream of the Proposed Development

Table 4 Wolf Creek Stations Near HWY 2 at TWP RD 425 from 2013 to 2014

Station_No Sample_Datetime	Unit	**AB EQG-PAL, long-term**	CEQG-PAL, long-term	AB05FA0080 Aug-13	AB05FA0080 Oct-13	AB05FA0080 Jan-14	Mean	Min	Max
Alkalinity Total ($CaCO_3$)	mg/L	20	n/a	**290**	**290**	**370**	**317**	**290**	**370**
Ammonia Total	mg/L	Equation	Equation	0.066	L0.05	0.28	0.17	0.066	0.28
Carbon Total Organic (TOC)	mg/L	n/a	n/a	18	10	6.4	11	6.4	18
Chloride Dissolved	mg/L	120	120	56	92	37	62	37	92
Coliforms Fecal	No/100 mL	100	100	**<u>260</u>**	54	3	**106**	3	**260**
Fluoride Dissolved	mg/L	n/a	0.12	**0.28**	**0.35**	**0.23**	**0.29**	**0.23**	**0.35**
Hardness Total (Calcd) $CaCO_3$	mg/L	n/a	n/a	330	390	400	373	330	400
Nitrogen Nitrite	mg/L	0.20	0.06	0.0052	0.049	L0.01	0.027	0.0052	0.049
Nitrogen NO_3+NO_2	mg/L	n/a	13	0.18	0.43	0.77	0.46	0.18	0.77
Nitrogen Total (Calcd)	mg/L	No increase over existing conditions	n/a	1.8	2.1	1.7	1.9	1.7	2.1
TKN	mg/L	No increase over existing conditions	n/a	1.6	1.7	0.89	1.4	0.89	1.7
Nitrogen, Nitrate	mg/L	n/a	13	0.17	0.38	0.77	0.44	0.17	0.77
Oxygen Dissolved (Field)	mg/L	6.5; 8.3 (mid-May to end-Jun); 9.5 (larval fish)	6.0 - 9.5	**6.8**	11.9	**8.7**	9.1	6.8	11.9
pH (Field)	pH units	6.5-9.0 (and < 0.5-unit change from background)	6.5-9.0	8.4	8.42	7.91	8.24	7.91	8.42
Phosphorus Total (P)	mg/L	No increase over existing conditions	Guidance Framework	0.51	0.25	0.058	0.27	0.058	0.51
Phosphorus Total Dissolved	mg/L	n/a	n/a	0.48	0.085	0.016	0.19	0.016	0.48
Specific Conductance (Field)	µS/cm	n/a	n/a	826	955	869	883	826	955
Sulphate Dissolved	mg/L	309 and higher (varies dep on hard)	n/a	89	160	120	123	89	160
Temperature Water	Deg C	n/a	n/a	16.6	4.5	0.4	7.2	0.4	16.6
Total Dissolved Solids	mg/L	500 to 3500	500 to 3500	412	478	434	441	412	478
Turbidity (Field) NTU	NTU	8 NTUs from backgr for 24-h and 2 NTUs from backgr for 30-d	8 NTUs from backgr for 24-h and 2 NTUs from backgr for 30-d	8.72	7.65	2.1	6.2	2.1	8.72
Water Depth	m	n/a	n/a	0.75	0.75	0.3	0.6	0.3	0.75

Notes: AB EQG-PAL – Alberta Environmental Quality Guidelines for Protection of Aquatic Life (ESRD 2014), CEQG-PAL Canadian Environmental Quality Guidelines for Protection of Aquatic Life (CCME 2014); Parameter values exceeding long-term AB EQG-PAL guidelines are bolded and long-term CEQG-PAL guidelines are double underlined, long-term AB EQG-PAL and CEQG-PAL guideline values were used as the most stringent guidelines; Irrigation AB EQG and CEQG guidelines are used for total dissolved solids; A long-term AB EQG-PAL (30-d average) at chloride greater than 10 mg/L is used for total nitrite; Most stringent 6.0 is for warm water biota and early life stages, 9.5 is for cold water biota and early life stages; Calcd – Calculated; L0.05 – below a detection limit, which is 0.05 mg/L for L0.05.

Some historical data was available to support the Fisheries Assessment of Wolf Creek conducted by Palliser Environmental Services Ltd. (2013), but these were limited, and samples were collected between 1984 and 1990. While the system might have changed considerably in the interim, the 1984 to 1990 data suggest that Wolf Creek was enriched in nutrients, including total nitrogen and total phosphorus, and had elevated concentrations of cadmium, iron, and arsenic. Wolf Creek experienced periods of oxygen depletion where conditions would not meet guidelines for supporting fish and other aquatic biota (Palliser Environmental Services Ltd. 2013, as cited in MPE Engineering Ltd. 2014).

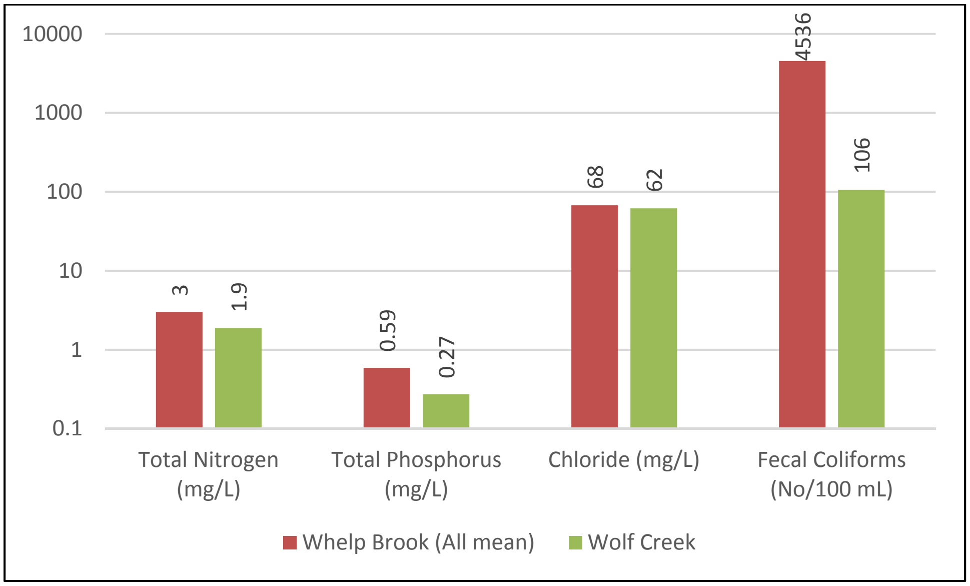
Water quality data collected in 2004 to 2005 and 2007 to 2009 in Battle River indicate that generally the river has fair water quality (as an average index rating) (Government of Alberta 2014). Specifically, sub-index values for nutrients were marginal in 2007 to 2008 and poor in 2008 to 2009, which was consistent with reports of elevated TP and TN in 2004 to 2005. Sub-index values for metals were good to excellent in both years, while bacteria loads were fair to good in 2007 to 2008 and fair to excellent in 2008 to 2009. In 2004 to 2005, guidelines for ammonia and nitrite were exceeded rarely and guidelines for fecal coliforms, DO, and pH were exceeded occasionally. Phosphorus was identified as the parameter most likely responsible for degraded water quality in the Battle River, causing excess algal growth and consequent oxygen depletion (Government of Alberta 2014).

2.4 Comparison of Water Quality in Lacombe Lake, Whelp Brook, and Wolf Creek

Comparison of the mean values of total nitrogen, total phosphorus, chloride, and fecal coliforms from Table 2 and 4 showed that concentrations of all these parameters were higher in Whelp Brook than in Wolf Creek (Figure 2).

Concentrations of these parameters in Lacombe Lake were lower than in both Whelp Brook and Wolf Creek (Table 1 and Figure 2). However, it should be noted that this comparison is not adequate because Whelp Brook and Wolf Creek represent small streams characterized by small flows and, consequently, often higher concentrations of water quality parameters as oppose to Lacombe Lake representing a much larger waterbody with limnological characteristics of a lake.

Figure 2 **Total Nitrogen, Total Phosphorus, Chloride, and Fecal Coliforms in Whelp Brook and Wolf Creek**



Note: Figure 2 is based on the water quality data from Table 2 and 4.

3.0 Characterization of Urban and Agricultural Runoff

3.1 Urban Runoff

A literature review was undertaken to compile data from studies characterizing urban runoff water quality parameters in Alberta or other Canadian and North American jurisdictions. Below are three studies describing urban runoff of a similar type for the current land use zoning in the Blackfalds NW development. Water quality from nonpoint source urban runoff can vary considerably from location to location and between storm events.

3.1.1. Calgary, Alberta

The City of Calgary has conducted water quality monitoring in the last decade. The data sets collected by the water monitoring program for baseflow, first flush, stormwater runoff, and snowmelt for sub-catchments of each land use type during 2001-2005 were selected for further analysis (Shrestha and He 2017).

The sub-catchments included the following:

- Two commercial sub- catchments (Eau Claire and Rundle);
- Two industrial sub-catchments (Bonnybrook and Wigmore East);
- Three on-going development sub-catchments (69th St. West, Cranston, and Crestmont West); and
- Five residential sub-catchments (68th St. East, 68th St. West, 69th St. East, Rocky Ridge Inlet, and McKenzie Towne).

The original water quality data sets were not shown by Shrestha and He (2017). Instead, box-whisker plots of event mean concentrations of stormwater runoff, baseflow and snowmelt for TSS, TP, ammonia, TDP, nitrate plus nitrite, TKN, and BOD.

In terms of flow events, all measured parameters, except TDP and nitrate/nitrite, were significantly higher under storm and snow melt conditions than baseflow. Strictly comparing stormwater flows from the four land use types, on-going development areas had the greatest concentrations of TP, TKN, and TSS, and lowest levels of TDP and BOD. Residential areas had the lowest levels of TP, TKN, TSS, and BOD, and the highest levels of TDP and ammonia. When data was pooled for all urban land use types, median concentrations of parameters of interest in stormwater runoff were as follows: TSS – 108 mg/L; TP – 0.3 mg/L; ammonia – 0.13 mg/L; TDP – 0.06 mg/L; nitrate/nitrite – 0.9 mg/L; TKN – 1.125 mg/L; and BOD – 10.4 mg/L (Shrestha and He 2017).

Commentary on the study: The study does not define the sampling locations or provide any context to the sampling locations, such as sampled from a manhole or outfall. The author notes in the conclusions that more detailed characteristics of land surface and other factors that govern stormwater runoff should be taken into consideration. We assume, based on the data presented, that the sample locations were in traditional stormwater systems without any pre-treatment from a stormwater pond or other Best Management Practice.

3.1.2. Saskatoon, Saskatchewan

In 2001, Saskatchewan Environment initiated a study of urban runoff from the City of Saskatoon into the South Saskatchewan River (McLeod et al. 2006). Samples were collected in four drainage catchments, each with a different land use type – light industrial (Sturgeon), new residential (Silverwood), old residential (Taylor), and commercial (Avenue B). The mean concentrations for each catchment area are shown in Table 5. As demonstrated by these results, the residential areas generally had higher concentrations of parameters of interest. However, due to higher flows in the commercial area, runoff from the commercial site had higher loadings than residential sites.

Table 5 Average Concentrations for Each Study Catchment

Parameter	Unit	Sturgeon	Silverwood	Taylor	Avenue B
TSS	(mg/L)	3	4.5	4.1	8.9
TKN	(mg/L)	0.99	1.4	1.8	4
TP	(mg/L)	0.13	0.25	0.22	0.54
COD	(mg/L)	41.8	34.9	28.7	34.6
Chloride	(mg/L)	54.4	47.9	81.9	101

3.1.3. USEPA Nationwide Urban Runoff Program (NURP)

USEPA Nationwide Urban Runoff Program (NURP) study was used for modeling of phosphorus loadings to the proposed stormwater ponds into Lacombe Lake. The NURP was a nationwide research program conducted by the US Environmental Protection Agency (USEPA) from 1978 to 1983 (USEPA 1999). Samples were collected at 81 sites during over 2,300 storm events to characterize urban runoff and assess effectiveness of management practices for controlling contaminants loading to the environment. Runoff samples were analyzed for TSS, BOD, COD, TP, soluble P, TKN, nitrate plus nitrite, total copper, total lead, and total zinc.

Sites were categorized as residential, mixed use, commercial, and open/non-urban, allowing for comparisons between different land use types (USEPA 1999). For all measured parameters, except total zinc, the highest event mean concentrations were measured in runoff from residential areas. Generally, the three urban land use types had similar contaminant profiles, but the non-urban runoff nearly always had the least concentration of a measured parameter and differed from the other land use types. This was particularly true in the case of nutrients (TKN, total and soluble phosphorus) and lead. The values for lead may be out of date as since that time (1983) lead has been phased out of gasoline and therefore a major reduction of a source has occurred. A summary of median event mean concentrations in the four land use types is presented in Table 6 below.

Reference: **Water Quality Downstream of the Proposed Development**

Table 6 Median event mean concentrations of parameters of interest in stormwater from different urban land uses and open/non-urban land.

Parameter	Units	Residential	Mixed Use	Commercial	Open/ Non-Urban
		Median	Median	Median	Median
BOD	mg/L	10	7.8	9.3	n/a
COD	mg/L	73	65	57	40
TSS	mg/L	101	67	69	70
Total Kjeldahl Nitrogen	mg/L	1.9	1.3	1.2	0.97
Nitrate plus Nitrite	mg/L	0.74	0.56	0.57	0.54
Total Phosphorus	mg/L	0.38	0.26	0.20	0.12
Soluble Phosphorus	mg/L	0.14	0.056	0.080	0.026
Total Lead	µg/L	144	114	104	30
Total Copper	µg/L	33	27	29	n/a
Total Zinc	µg/L	135	154	226	195

Source: Nationwide Urban Runoff Program (USEPA 1983), as cited in USEPA 1999.
Notes: "Event mean" concentration for a particular sampling point is concentration in a composite sample collected by using automatic samplers, or by collecting a series of discrete samples and manually compositing.
Total lead concentrations might be elevated compared to modern levels of lead due to lead additives in motor vehicle gasoline that were prohibited on 1 Jan 1996 (The final stage of the lead drawdown campaign in US) (Resources for the future 2003).

3.2 Agricultural Runoff

Agricultural runoff within the study area is represented by water quality data for Whelp Brook collected as a part of the six-year BMP Project conducted under the direction of Alberta Agriculture and Rural Development from 2007 to 2012 (see Section 2.2).

4.0 Nutrient and Contaminant Loadings

The section provides a review of available literature to demonstrate the potential for wet ponds to remove nutrients and metals and develop a water and mass balance of the study area.

4.1 Wet Pond Contaminant Removal

Based on model results calculated by Stantec using PCSWMM (Appendix G) for a representative pond in the Blackfalds NW area, greater than 85% removal of sediment particles larger than 75 µm is expected in the proposed stormwater facility (see Table 7).

Reference: **Water Quality Downstream of the Proposed Development**

Table 7 Contaminant removal modeled by Stantec using PCSWMM

Particle size (µm)	Removal efficiency (%)
<10	99.5
10-20	100
20-50	100
50-100	**100**
>150	100
Total	99.9

In terms of TSS and other parameters of interest in stormwater, review of the literature provides information about typical removal efficiency for these parameters in other constructed wetland and wet pond systems in Canada and the United States (summarized in Table 8). For example, a wet pond facility in Markham, Ontario, was assessed for performance efficiency in removing pollutants during summer and fall. The wet pond was dominated by cattails (*Typha* spp.) (85-90% of plant coverage), with reed canary grass (*Phalaris arundinacea*) comprising most of the balance (8-13%). During wet weather, removal efficiencies were estimated at 100%, 96%, and 84% for sand, silt, and clay-sized particles, respectively. The median particle size was reduced from 3.8 µm in influent to the storm water facility to approximately 2.0 µm in wet pond effluent (SWAMP 2002).

The National Pollutant Removal Performance Database compiles data from 139 best management practice studies published in the U.S. until 2006. Of the 139 studies, 46 studies examined efficiency of wet ponds in removing pollutants; specifically, TSS, TP, soluble P, TN, nitrate plus nitrite, copper, zinc, and bacteria (CWP 2007). Likewise, AEP reports literature means and ranges for removal efficiencies in *Stormwater Management Guidelines for the Province of Alberta* (AEP 1999), incorporating between 7 and 18 literature values per parameter in wet ponds.

Table 8 Literature-reported removal efficiency (%) for parameters of interest from constructed wet ponds

Parameter		Wet pond (AEP 1999)	Wet pond (SWAMP 2002)	Wet pond (CWP 2007)
TSS	Mean	60	92	80
	Range	-30 to 91	n/a	-33 to 99
COD	Mean	40	n/a	n/a
	Range	5 to 90	n/a	n/a
Ammonia	Mean	n/a	44	n/a
	Range	n/a	n/a	n/a
Total Kjeldahl Nitrogen	Mean	n/a	48	n/a
	Range	n/a	n/a	n/a
Total nitrogen	Mean	35	n/a	31
	Range	5 to 85	n/a	-12 to 76
Total Phosphorus	Mean	45	83	52

Parameter		Wet pond (AEP 1999)	Wet pond (SWAMP 2002)	Wet pond (CWP 2007)
	Range	10 to 85	n/a	12 to 91
Phosphate	Mean	n/a	76	n/a
	Range	n/a	n/a	n/a
Bacteria	Mean	n/a	97 to 99	70
	Range	n/a	97 to 99	-6 to 99
Copper	Mean	n/a	84	57
	Range	n/a	n/a	1 to 95
Chromium	Mean	n/a	80	n/a
	Range	n/a	n/a	n/a
Lead	Mean	75	n/a	n/a
	Range	10 to 85	n/a	n/a
Nickel	Mean	n/a	65	n/a
	Range	n/a	n/a	n/a
Zinc	Mean	80	87	64
	Range	10 to 95	n/a	13 to 96

4.2. Water and Mass Balance for Lacombe Lake and Whelp Brook Basins

4.2.1 Approach to Analysis

In order to understand the loadings from the Northwest Area, the information from various sources was used to develop a water and mass balance of the development area and other agricultural or non-urban areas. The water and mass balance analysis was developed for total phosphorus (TP) and is shown in Table 9.

The water and mass balance analysis was developed based on:

- The water balance for each catchment area was developed using the storm water model PCSWMM as discuss in the MSMP. The average annual runoff for each catchment area was calculated using the output from 23 years of modelling.
    - The water balance assumes that all water entering a pond will pass through the pond with the exception of evaporation. No infiltration of pond water into the ground was considered. There is a high likelihood that infiltration will occur, thus reducing the water (and associated loads) passing downstream towards Lacombe Lake.
- To estimate the TP concentrations for a catchment area, the median event runoff concentration from Table 6 were used as follows:
    - Type 1 Residential TP = 0.38mg/L

- Type 2 Mixed Use TP = 0.26 mg/L
- Type 3 Commercial TP = 0.20 mg/L
- Type 4 -Open/ Non-Urban TP = 0.12 mg/L

- These concentrations are selected from the US EPA Nationwide Urban Runoff Program (USEPA 1983). This program developed the concentrations based on a large data set covering a large number of sites and events, providing a better overall assessment of TP concentration than any local data available in Canada. The local agricultural runoff TP, as discussed earlier in Section 2, indicate that Whelp Brook likely has higher concentrations of TP (**mean 0.59 mg/L**) than NURP open/non-urban runoff (0.12mg/L). Therefore, this analysis may underestimate the relative impact of agricultural loads in this watershed and over predict the relative impact of the NW area development on Lacombe Lake.
- The mass load from each catchment area was calculated by multiplying average annual flow times water quality for each land use (Table 9).
- The development runoff as designed will pass through newly developed detention ponds and existing natural ponds or wetlands. The removal rates could vary, however, based on the literature values discussed earlier (Table 8) removal rates of 50% for each pond was assumed. All of the development catchment areas will pass through at least one pond and many will pass through three ponds before being discharged to Lacombe Lake.
- The water balance shows that direct rainfall accounts for a major portion of water to Lacombe Lake. Direct loading of TP from the atmosphere will also contribute to Lacombe Lake. Annual loading rates ($mg/m^2/yr$) were estimated from the literature for on atmospheric deposition of phosphorus in Central Alberta (Shaw et. al 1989). Estimates for the atmospheric loading phosphorus are 20 $mg/m^2/yr$.

4.2.2. Water and Mass Balance Results

A summary of the results is shown in Tables 10 and 11. The flow leaving Lacombe Lake is 222 x 10^3 m^3 before the development and will increase to 524 x 10^3 $m^3$with the development. The NW area development will increase the flow 2-3 times the existing flow to Lacombe Lake.. This is assuming that there is no infiltration occurring within the development, a conservative approach to the calculations to follow. The concentration of TP from the NW will be reduced by 80% on average, from the typical residential runoff, before reaching Lacombe Lake. This high reduction rate is based on the assumed removal rate of 50% per pond and that many of the ponds are connected in series. The average concentration of TP to Lacombe Lake predicted from the development runoff, after removal of loads from the ponds, is 0.07 mg/L. These TP concentrations are similar to the concentration expected in rainfall and lower that agricultural or non-urban runoff.

The water and mass balance calculations show a small decrease in expected concentrations of TP in Lacombe Lake. It is unlikely that any cumulative load and change in water quality will be measurable. This analysis also shows that the NW area project loads will increase the TP loads to the watershed downstream of Lacombe Lake on Whelp Brook, however, the concentration of TP will decrease (Table 11).

The analysis presented here does not account for potential infiltration of water from the detention pond into the ground water. This would decrease the flow and load of TP to Lacombe Lake. The low rate out outflow for the 1:2 year and 1:5 year events, increased the detention time of the surface water as it passes through the pond. The increased detention time would lead to better removal rates, therefore further reduce the impacts downstream. The increase in detention time has not been accounted for in the modelling.

In addition, a linear wetland is proposed to be located at the downstream edge of the NW area development just before Pond D. The removal of TP from this facility was not considered in the mass balance model, however would provide additional reduction of the TP load. This wetland adds another level of protection for downstream waterbodies, such a Lacombe Lake.

As the review of the literature has determined, there is uncertainty in runoff concentrations and removal rates from ponds for phosphorus. However, the analysis does show that the proposed design with multiple ponds in series before discharge to Lacombe Lake, will provide protection to the lake.

There is less information of runoff concentrations, removal rates, and atmospheric deposition for other nutrients and metals such that it does not allow a similar mass balance to be developed. The removal rates of wet ponds for other parameters such as nitrogen and metals are similar to phosphorus, therefore the relatively high rates of removal for ponds in series could also be expected for these parameters.

Considering the uncertainty inherent in this type of analysis, it is important to monitor both the quantity and quality of water discharge from the site as the development progresses. The selection of nutrient sequestering native vegetation will also enhance the removal rates within detention ponds. The planned design of the ponds will introduce wetland and native plants that not only tolerate nutrient loading, but uptake nutrients from the water for their biological processes.

Reference: **Water Quality Downstream of the Proposed Development**

Table 9 Total Phosphorus Loads from Northwest Area and Agricultural Runoff

Catchment Area	Catchment Area Description	Land Use Type	Catchment Area (ha)	Annual Sub-catchment Runoff (m³)x10³	WQ (mg/L)	WQ Load (kg/year) to Pond	Number of Ponds in Series before Lake	Cumulative Pond Removal rate	Load to Lake (kg/yr)	Flow to Lake (m³)x10³	WQ to Lake (mg/L)
SC_1	Residential	1	19.84	30	0.38	11	2	75%	2.8	26	0.11
SC_2	Residential/ER/MR	4	21.82	27	0.12	3	2	75%	0.8	24	0.03
SC_3	Residential	1	65.58	96	0.38	37	3	88%	4.6	72	0.06
SC_4	Residential/Industrial	2	37.46	52	0.26	14	3	88%	1.7	40	0.04
SC_5	Residential	1	9.98	13	0.38	5	3	88%	0.6	10	0.06
SC_6	Residential	1	29.89	40	0.38	15	3	88%	1.9	30	0.06
SC_7	Residential	1	14.2	19	0.38	7	**3**	88%	0.9	14	0.06
SC_8A	ER/MR	4	9.3	19	0.12	2	**3**	88%	0.3	8	0.03
SC_8B	Industrial	3	22.8	40	0.20	8	**3**	88%	1.0	30	0.03
SC_8C	Residential/Industrial	2	24.3	42	0.26	11	**3**	88%	1.4	32	0.04
SC_9	Residential/Industrial	2	19.5	30	0.26	8	**2**	75%	1.9	25	0.08
SC10	ER/MR	4	5.6	5	0.12	1	**1**	50%	0.3	5	0.06
SC11	Residential/Commercial	2	14.1	25	0.26	6	**2**	75%	1.6	21	0.08
SC12	Residential/Commercial	2	22.2	39	0.26	10	**2**	75%	2.6	33	0.08
SC20	Residential/Industrial	2	12.9	22	0.26	6	**1**	50%	3.0	20	0.15
SC21	Residential/Industrial	2	48.0	78	0.26	21	**1**	50%	10.3	68	0.15
SC22	Residential/Industrial	2	8.6	15	0.26	4	**1**	50%	2.0	13	0.15
SC23	Industrial (County)	3	35.8	63	0.20	13	**3**	88%	1.6	47	0.03
SC24	Highway QE2 (AT)	3	20.7	17	0.20	3	**3**	88%	0.4	7	0.06
SC30	Residential/Commercial	2	69.5	105	0.26	27	**3**	88%	3.4	78	0.04
	NW Area sub-total:		**512.0**	**777**	**0.27**	**213**		**80%**	**43**	**605**	**0.07**
	NW Area developable:		**454.6**	**708**	**0.29**	**204**		**80%**	**41**	**560**	**0.07**
TES development	Commercial/Industrial	3	56.8	93	0.20	19	**1**	50%	9	79	0.12
Pre-dev. Lacombe Lake	Pre-development/ Agriculture	4	1180.0	41	0.12	5	**0**	0%	5	41	0.12
Post-dev. Lacombe Lake	Pre-development/ Agriculture	4	1158.0	40	0.12	5	**0**	0%	5	40	0.12
Lacombe Lake Wetted Area	Lake surface	4	120.0	325	20	24	**0**	0%	24	325	0.07
Whelp Brook	Pre-development/ Agriculture	4	3697.0	128	0.12	15	**0**	0%	15	128	0.12

Reference: **Water Quality Downstream of the Proposed Development**

Table 10 Runoff Water Quantity and Quality: Total Phosphorus

Component	Land Use Type	Cumulative Pond Removal Rate	Load to Lake (kg/yr)	Flow to Lake $(m^3)x10^3$	WQ (mg/L)	Comment
NW Area Development		80%	43	605	0.07	
TES development	Commercial/Industrial	50%	9	79	0.12	
Pre-dev. Lacombe Lake	Pre-development/ Agriculture	0%	5	41	0.12	
Post-dev. Lacombe Lake	Pre-development/ Agriculture	0%	5	40	0.12	
Lacombe Lake Wetted Area	From atmosphere to Lake surface	0%	24	325	0.07	20 $mg/m^2/yr$ P from atmosphere - Central Alberta
Whelp Brook	Pre-development/ Agriculture	0%	15	128	0.12	

Table 11 Water Quality Pre and Post Development: Total Phosphorus

Component	Load (kg/yr)	Flow to Lake $(m^3)x10^3$	Water Quality (mg/L)	Comment
Pre-Development Totals				
Pre-dev. Lacombe Lake Watershed	38	445	0.086	Natural WQ inflow to Lake
Lacombe Lake (includes Evaporation & Settling)	5	222	0.021	TP in Monitored in Lake = 0.021 mg/L
Downstream of Whelp Brook	20	572	0.035	Add in Whelp Brook
Post Development Totals				
Post-dev. Lacombe Lake+NW Area	81	1049	0.078	Natural WQ inflow to Lake
Lacombe Lake (includes Evaporation & Settling)	10	524	0.019	After Settling
Downstream of Whelp Brook	25	1176	0.021	Add in Whelp Brook
Pond Removal =	50%			
Lacombe Lake Removal =	88%			

4.3. Rationale for Parameter Selection and Potential Further Mitigation

The previous section shows how the proposed and existing ponds will have reduced loads of nutrient and contaminants. Table 12 below presents the range of parameters of interest in urban runoff and additional mitigation measures that could further enhance water quality. Some of these mitigation measures include additional linear wetlands, enhanced plant growth in proposed detention basins and public education to reduces contaminants at the source.

Table 12 Summary of parameters of interest and potential further mitigation

Parameters of interest	Rational for choosing a parameter	Further mitigation, if needed
pH	Ammonia guideline calculations/PAL	Combined mitigation used for other parameters of interest
T	Ammonia guideline calculations	Not needed
Hardness	Metal guideline calculations	Combined mitigation used for other parameters of interest
TSS	Potential impact from agricultural and urban runoff (winter maintenance activities)	Enhance plant growth in wet ponds and/or construct wetland and potential regulation
Conductivity/TDS (half of conductivity)	Shows total concentration of all dissolved ions (salts, dissolved meals)	Combined mitigation for dissolved nutrients, dissolved metals, and chloride, i.e. Enhance plant growth in wet ponds and/or construct wetland
DO	PAL (Could be impacted by chemical or biological demand)	Combined mitigation for organic compounds and ammonia, i.e. Enhance plant growth in wet ponds and/or construct wetland between ***
BOD	Potential impact on DO from agricultural and urban runoff	
COD	Potential impact on DO from agricultural and urban runoff	
P species:		
Total phosphorus	Potential impact from agricultural and urban runoff	Enhance plant growth in wet ponds and/or construct wetland
Phosphate		
N species:		
N-Tot	Potential impact from agricultural and urban runoff	Enhance plant growth in wet ponds and/or construct wetland
TKN		
NO3+NO2		
NO3-N		
Chloride	Potential impact from urban runoff (winter maintenance activities)	Source reduction: Public education and potential regulation (MPCA 2016)

Reference: Water Quality Downstream of the Proposed Development

Parameters of interest	Rational for choosing a parameter	Further mitigation, if needed
Potential Metals:		
Aluminum	Potential impact from urban runoff	Enhance plant growth in wet ponds and/or construct wetland
Copper		
Chromium		
Lead		
Nickel		
Zinc		
Bacteria (Coliform or Coliform fecal)	Potential impact from agricultural and urban runoff	Enhance plant growth in wet ponds and/or construct wetland
Synthetic organic compounds	Potential impact from urban runoff (pesticides, herbicides)	Source reduction: Public education and potential regulation. Enhance plant growth in wet ponds and/or construct wetland. Natural degradation through hydrolysis and photolysis in ponds and wetlands (USEPA 1999).

5.0 Summary and Conclusions

In the State of the Environment report issued by Lacombe County in 2013, water quality in Lacombe Lake was characterized as “fair” based on analysis of nutrients (total phosphorus and total nitrogen) and bacteria (total coliform bacteria) (Lacombe County 2013). It is a relatively shallow lake with a maximum depth of 2.9 m, and the land use surrounding the lake is predominantly agricultural. Water quality monitoring between May 2008 and October 2011 determined that total Kjeldahl nitrogen and total phosphorus exceeded the Alberta guideline values of 1.0 mg/L and 0.05 mg/L, respectively (Figure 1). It should be noted that these guidelines were eligible during the monitoring period of the study but have now been withdrawn and narrative statements have been developed. No increase in total nitrogen or phosphorus over existing conditions should occur (ESRD 2014).

Analysis of 23 water quality parameters in Lacombe Lake by Alberta Environment and Parks in 2014-2017 (AEP 2018a) (Table 1) showed very few exceedances of guidelines. Only two parameters showed exceedances to any guidelines, total alkalinity and dissolved fluoride.

Lacombe Lake has an average total phosphorus concentration of 0.21 mg/L. Based on CEQG-PAL guideline framework for phosphorus, Lacombe Lake can be classified as mesotrophic (0.010 to 0.020 mg/L TP) to meso-eutrophic (0.020 to 0.035 mg/L TP) (Table 1).

An extensive 6-year research project was conducted under the direction by Alberta Agriculture and Rural Development (PEWC and AB Agriculture and Rural Development 2014) from 2007 to 2012. The project called the Nutrient Beneficial Management Practices Evaluation Project (BMP Project) was directed on evaluation of the effectiveness of BMPs at field and watershed scales in Alberta. As a part of this project, water quality and contaminant loadings were evaluated for Whelp Brook. The Nutrient Water Quality Sub-index (NWQS-I) based on the Alberta Agricultural Water Quality Index (Wright et al. 2003) showed that all monitoring sites at the WHC Sub-watershed and in all years were rated as poor.

USEPA Nationwide Urban Runoff Program (NURP) study was used for modeling of phosphorus loadings to the proposed stormwater ponds into Lacombe Lake. NURP program is a nationwide research conducted by the US Environmental Protection Agency (USEPA) from 1978 to 1983 (USEPA 1999).

The National Pollutant Removal Performance Database compiles data from 139 best management practice studies published in the U.S. until 2006. Of the 139 studies, 46 studies examined efficiency of wet ponds in removing pollutants; specifically, TSS, TP, soluble P, TN, nitrate plus nitrite, copper, zinc, and bacteria (CWP 2007). Likewise, AEP reports literature means and ranges for removal efficiencies in Stormwater Management Guidelines for the Province of Alberta (AEP 1999), incorporating between 7 and 18 literature values per parameter in wet ponds. While the species and conditions present in the referenced systems might vary from those in the proposed Blackfalds NW system, the performance efficiencies reported here provide some insight into what is achievable and could be expected. Overall, ponds have moderate to good TSS removal, good to excellent bacteria removal, moderate to good metals removal, and moderate to good nutrient removal. When ponds are located in series the removal rate will compound and performance of the system can improve greatly.

To understand the loadings from the Northwest Area, the information from various sources was used to develop a water and mass balance of the development area and other agricultural or non-urban areas. The water and mass balance was developed for total phosphorus (TP).

The Northwest area development will increase flows by 2-3 times the existing flow to Lacombe Lake and add total phosphorus using the modeling scenario where no infiltration is occuring. The concentration of total phosphorus from the Northwest area will be reduced by 80% on average, from the typical residential runoff, before reaching Lacombe Lake. This high reduction rate is based on the assumed removal rate of 50% per pond and that many of the ponds are in series. The average concentration of total phosphorus to Lacombe Lake predicted from the development runoff, after removal of loads from the ponds, is 0.07 mg/L. These total phosphorus concentrations are similar to the concentration expected in rainfall and lower than agricultural or non-urban runoff.

The water and mass balance calculations show a small decrease in expected concentrations of total phosphorus in Lacombe Lake. It is unlikely that any cumulative load and change in water quality will be measurable.

There is less information on runoff concentrations, removal rates, and atmospheric deposition for other nutrients and metals that does not allow a similar mass balance to be developed. Since the removal rates of wet pond for other parameters such as nitrogen and metals are similar to phosphorus, the relatively high rates of removal for ponds in series could also be expected. Infiltration from the detention basins, which could potentially be high, could further reduce loads to the downstream lakes.

Some of mitigation measures that could further enhance water quality include additional linear wetlands, enhanced plant growth in proposed detention basins and public education to reduce contaminants at the source.

Considering the uncertainty inherent in this type of analysis, it is important to monitor both the quantity and quality of water discharge from the site as the development progresses. In addition, to be able to define the provincial (AB EQG-PAL) and federal (CEQG-PAL) water quality guidelines for the receiving waterbodies (Lacombe Lake, Whelp Brook, Wolf Creek) the following parameters should be recorded during the pre-development period:

- Temperature and pH for calculations of ammonia guideline;
- Hardness for calculation of hardness dependent guidelines (metals, sulphate);
- Total phosphorus and total nitrogen since no increase over existing conditions is recommended;

Reference: Water Quality Downstream of the Proposed Development

- Turbidity for which a certain increase is allowed over background conditions that should be documented prior the development; and
- Chloride, which determines the Alberta guideline for nitrite.

Future monitoring and assessments may be confounded by diversion of Whelp Brook into Lacombe Lake for flood control. Monitoring data for Whelp Brook water quality has indicated that nutrient concentrations and loads are high. These loads may increase nutrient concentrations within Lacombe Lake and this could be mistakenly attributed to upstream development such as the Blackfalds Northwest Area Development.

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Regards,

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Appendix D
Desktop Hydrogeological Assessment

Stantec Consulting Ltd.
10160 - 112 Street, Edmonton, AB T5K 2L6

May 28, 2018
File: 113929434.501

Attention: Mr. Preston Weran, Director of Infrastructure and Property Services
Town of Blackfalds
Box 220, 5018 Waghorn St
Blackfalds, AB T0M 0J0

Dear Mr. Weran,

Reference: Blackfalds Northwest Area Desktop Hydrogeological Assessment

INTRODUCTION

Stantec Consulting Ltd. (Stantec) has been retained by the Town of Blackfalds (the Town) to complete a desktop hydrogeological assessment of the proposed development area on the north side of town, south of Lacombe Lake. The objective for this preliminary assessment was to add a groundwater or hydrogeological component to the proposed master stormwater management plan (MSMP). Based on this desktop assessment, conclusions and recommendations are made below to address to the extent possible, the role groundwater plays in the surface water management plan, and how it may interact with Lacombe Lake.

BACKGROUND AND LITERATURE REVIEW

The northwest portion of Blackfalds, which is South of Lacombe Lake, is an important short and long term growth area for the community. The area slated for development is currently used for either agricultural land use or is in the process of being graded for sub-urban development. The issuance of the Town of Blackfalds Northwest Area Master Stormwater Management Plan (Stantec, April 19, 2017) made residents of Lacombe Lake aware of the proposal to use Lacombe Lake as a flow through for treated urban stormwater. Despite several conceptual elements in the surface water management plan to mitigate the potential effects to the water quality and quantity of the Lake, residents have made several Statement of Concerns (SOCs) regarding the effects to the Lake.

The objective of the desktop analysis was to determine, to the extent possible, the hydrogeological inputs to the lake and the extent and nature of the groundwater-surface water interaction in the development area. To complete this desktop analysis, several publicly available data resources were used to interpret the hydrogeological framework of the Project Area, including Lacombe Lake. Key references cited in this analysis are listed below and other references are also listed in the References section below. It should be noted that the Atlas of Alberta Lakes (Mitchel and Prepas, 1990) did not contain any information on Lacombe Lake, but information on nearby Lakes (i.e., Gull, Sylvan, and Buffalo) was considered.

Key hydrogeological references used for the summary and interpretation herein include:

- Hydrogeological map of the Red Deer area, Alberta, NTS 83A (LaBretton and Green, 2005)
- Earth Science Report 1971-01 - Hydrogeology of the Red Deer Area, Alberta (Toth, 1977)
- Edmonton-Calgary Corridor Groundwater Atlas (Barker et al., 2011)
- Geostatistical Rendering of the Architecture of Hydrostratigraphic Units within the Paskapoo Formation, Central Alberta (Lyster and Andriashek, 2012)
- Locations of Alberta Springs (Stewart, 2009)

Other publicly available digital data was also used in both geographic information system and 3D geological modeling software to further interpret the geospatial data available for the desktop analysis.

REGIONAL HYDROGEOLOGICAL SETTING

To assess the groundwater characteristics of the study area, a relatively large, regional area was modeled to be able to ascertain the groundwater catchment area and determine that Lacombe Lake has a connection to regional groundwater flow systems. Figure 1 presents the modeled area, with the Project Area highlighted in approximately the middle of the domain. The orange lines indicate the mapped thalwegs (or deepest alignment) of known buried channels or paleo-valleys.

TOPOGRAPHY AND HYDROLOGY OF THE DEVELOPMENT AREA

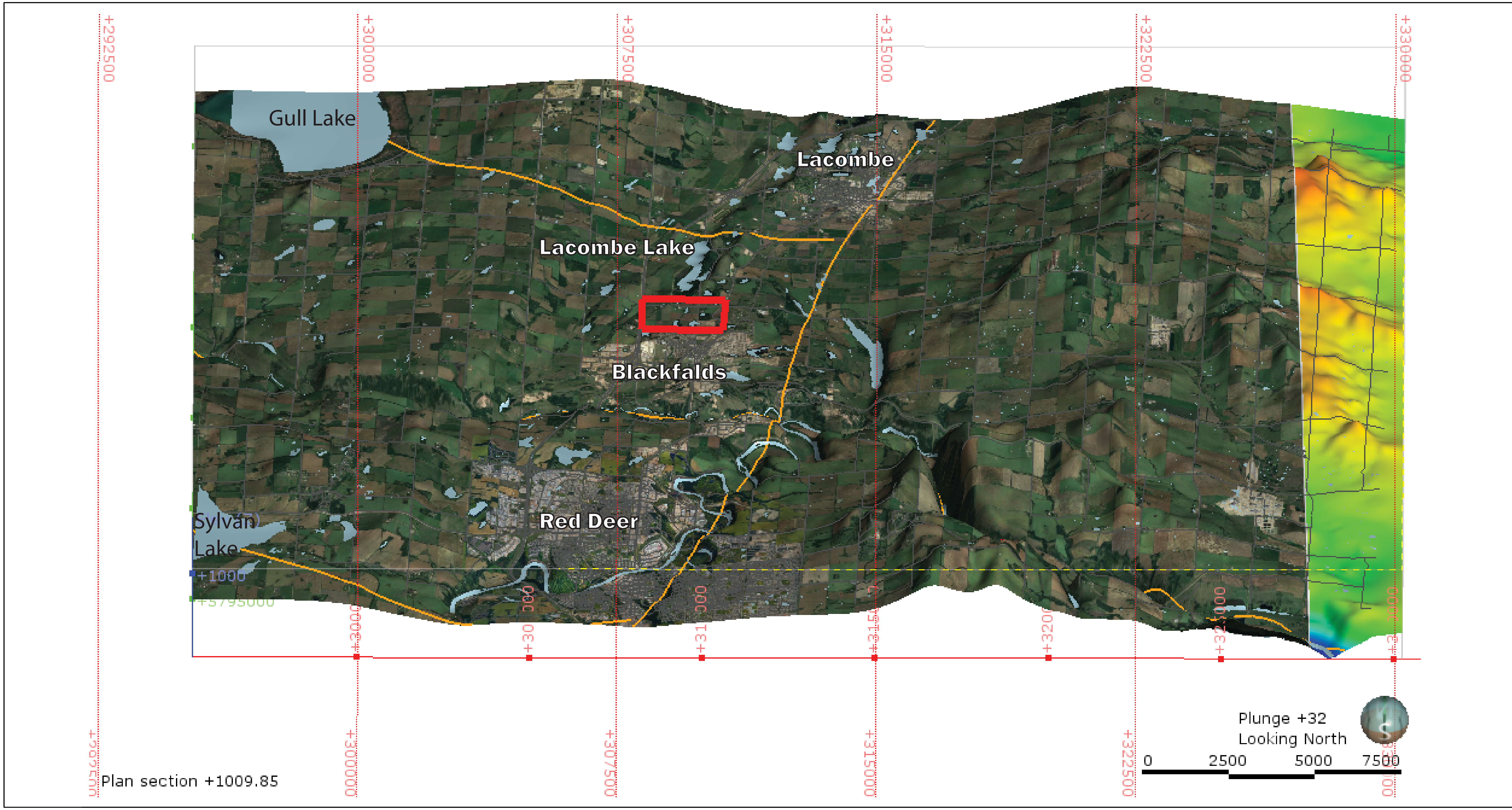
The development area is situated in a regional topographic low area created by both modern (i.e., the Red Deer River) and paleo river systems (i.e., pre- and post-glacial fluvial processes) that are no longer present. The land surface topography has been sculpted over time by glacial and fluvial erosion processes. Both of these processes eroded the upper bedrock surface and left both pre-glacial (sand and gravel) and glacial material (i.e., till, glaciofluvial and glaciolacustrine sediment) on the bedrock surface as the glaciers receded.

The upper bedrock surface has a strong control on the regional topography with generally thin unconsolidated sediment above bedrock with thinner sediment cover overlying bedrock topographic highs. A series of wetlands, ponds, and small lakes such as Lacombe Lake are found in the north-south trending paleo valley north of the Red Deer and Blindman River Valleys. These hydrological features situated between bedrock ridges to the east and to the west that create topographic flow divides for both surface water and groundwater resulting in drainage towards the paleo valley in which Lacombe Lake, Blackfalds Lake, and the numerous smaller wetlands features are located. Despite a fluted moraine landform to the west of Lacombe Lake on the west side of the paleo-valley, the surface water drainage pattern is poorly defined, likely as result of the widespread, highly permeable substrate (sandy soils) that are present at surface. At a local scale, the study area is hummocky with small depressions occupied by wetlands and there is a distinct ridge to the east of Lacombe Lake.

GEOLOGY ABOVE BEDROCK

Lacombe Lake and many smaller hydrological features occupy linear landscape features on the fluted moraine landform that the lake is situated on. The lake itself is located on the flank of the fluted moraine feature on till/diamicton (Figure 2; below). To the west and south of Lacombe Lake, the surficial geology transitions to glaciolacustrine sediments deposited in a glacial lake environment adjacent to the fluted moraine to the west. Glaciolacustrine sediments therefore cover much of the development area south of Lacombe Lake with some eolian sand and silt located in the eastern portion of the study area.

The till of the fluted moraine is generally fine-grained sediment and has hydraulic characteristics such as low permeability, low infiltration rates and low hydraulic conductivity. The glaciolacustrine material is generally fine grained but can vary locally to contain coarse-grained material such as beach (i.e., sand) deposits. Lithology data from public water well records indicate sand and gravel sediment above bedrock ranges from approximately 22 to 45 m in thickness above the upper bedrock surface. This suggests that the glaciolacustrine material is a thin veneer overlying pre-glacial sand and gravel layers present directly above bedrock. As is commonly observed in Alberta, these permeable sediments constitute an unconsolidated, unconfined aquifer overlying bedrock. Wetlands located on the glaciolacustrine in the paleo-valley are thought to receive depression focused runoff and slowly recharge the groundwater environment after periods of water surplus. Depending on the bathymetry of these wetlands, some may intersect the water table and receive local-scale groundwater flow from small catchment areas related to the hummocky topography.



ORIGINAL SHEET - ANSI A - COLOR

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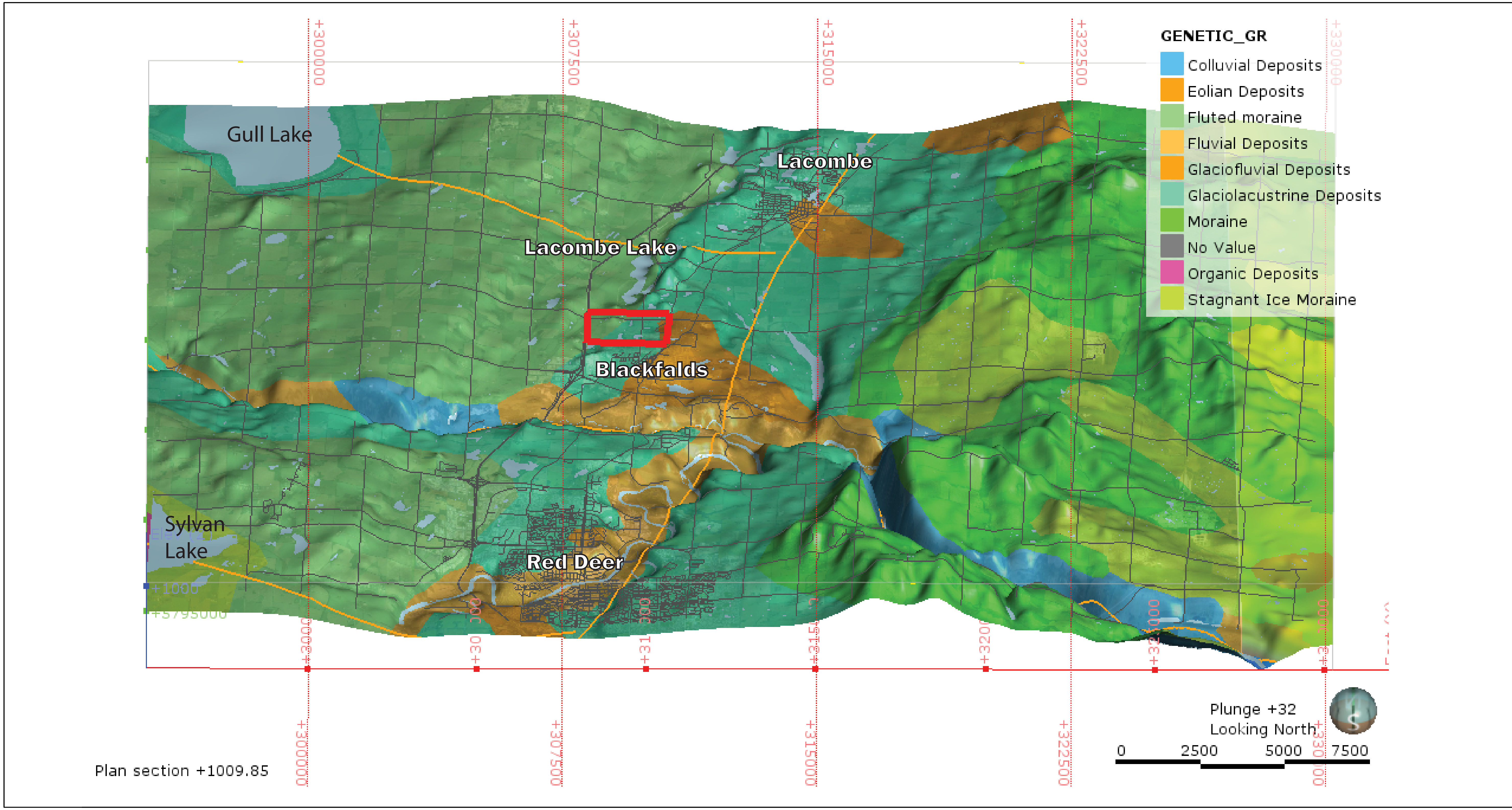
Northwest Development Area

Burried Channel Thalwegs

Client/Project
Town of Blackfalds
Blackfalds Northwest Area Desktop
Hydrogeological Assessment
Blackfalds, Alberta

Figure No
1

Title
Regional 3D CSM Study Area



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Northwest Development Area

Burried Channel Thalwegs

Client/Project
Town of Blackfalds
Blackfalds Northwest Area Desktop
Hydrogeological Assessment
Blackfalds, Alberta

Figure No
2

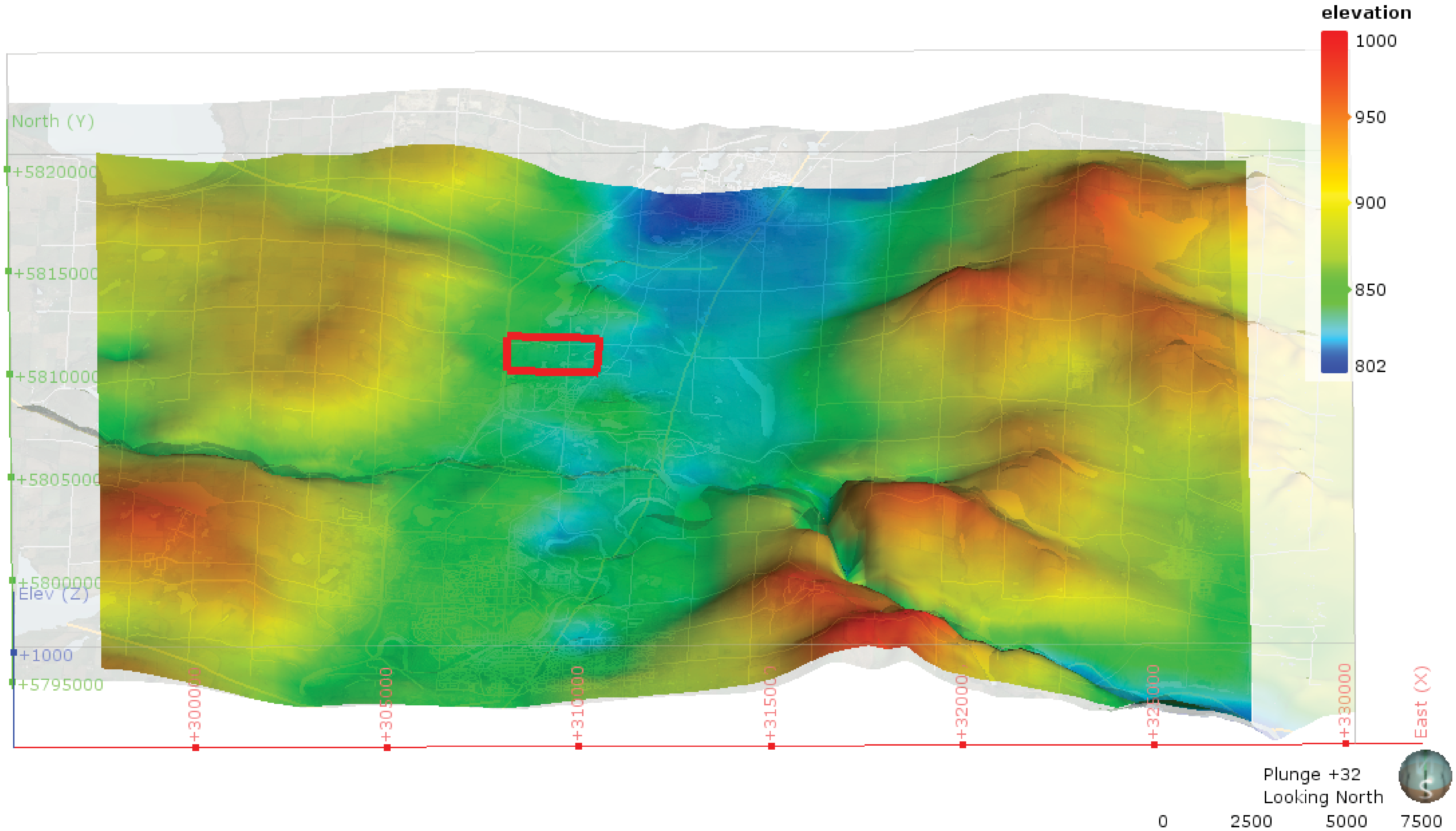
Title
Regional Surficial Geology shown
in 3D CSM

Reference: Blackfalds Northwest Area Desktop Hydrogeological Assessment

BEDROCK GEOLOGY AND HYDROSTRATIGRAPHY

The upper bedrock surface at the site is the Lacombe Member of the Paskapoo Formation. The position of Lacombe Lake relative to the internal architecture of the Paskapoo Formation has significant hydrogeological implications in assessing the possible connection to bedrock hosted regional groundwater flow systems. The Paskapoo Formation is composed of three Members. From the base of the formation, the Haynes Member is a thick medium to coarse-grained sandstone unit commonly used as an aquifer, followed by the Lacombe Member which is a mudstone/siltstone dominated interval in the Paskapoo Formation considered a regional aquitard. The Dalehurst Member of the Paskapoo does not exist in the study area as it is highly eroded with its zero-edge (i.e., completely eroded) situated west of Sylvan Lake with only thin erosional remnants of this member in the vicinity of the study area.

The Paskapoo Formation is approximately 200 m thick in the study area with up to 160 m of the formation thickness being composed of the Lacombe Member aquitard as the Haynes member is either not present or thin in the study area. Gull Lake and Sylvan Lake to the west are situated above the Haynes Member and are known to receive regional groundwater discharge from the Haynes aquifer supporting their lake water balances. Conversely, Lacombe Lake likely receives little regional-scale groundwater discharge as the Lacombe Member acts as a confining unit to the Haynes Member and the lake bathymetry is unlikely to intersect the upper bedrock surface.



ORIGINAL SHEET - ANSI A - COLOR

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Northwest Development Area

Burried Channel Thalwegs

Client/Project

Town of Blackfalds
Blackfalds Northwest Area Desktop
Hydrogeological Assessment
Blackfalds, Alberta

Figure No

3

Title

Regional Topography of 3D CSM

REGIONAL HYDROGEOLOGY

The publicly available data was sufficient to develop an understanding of the regional geological/ hydrogeological setting of the study area. The study area sits within a paleo valley, with the thalweg (or deepest part of a river channel) located approximately 3 km east of Lacombe Lake. A smaller tributary to the main thalweg of the Red Deer paleo-valley runs just north of the lake. The unconsolidated sediment above bedrock is composed of coarse-grained sand and gravel deposits. The surficial mapping indicates glaciolacustrine sediment, though it appears to be a thin veneer of finer grained sediment covering the pre-glacial and post-glacial fluvial sand and gravel deposits. A total of eight well records from the Alberta Water Well Information Database (AWWID) had lithological data within the development area, all of which indicated 30 to 36 m of sand and gravel above the upper bedrock surface. This indicates that the sand and gravel compose a thick (up to 36 m) unconfined aquifer covered by less than 5 m of glaciolacustrine sediment. Well records indicate the sediment immediately overlying bedrock has higher gravel content, and at shallower depths, sand lithologies dominate.

The Alberta Groundwater Springs Inventory (Stewart, 2009) does not indicate any observed groundwater springs south of Lacombe Lake in the study area. However, this does not mean that there are no groundwater springs, rather only that none have been mapped. Given the Edmonton-Calgary Corridor (ECC) Groundwater Atlas (Barker et al., 2011) has several lines of evidence to suggest minimal interaction of deep, regional groundwater flow with surface water features, any springs present would be supported from local-scale groundwater flow from within the local scale groundwater catchment area. The ECC Groundwater Atlas is largely based on geospatial analysis of public water well records and is the most comprehensive resource to evaluate regional hydrogeological characteristics of central Alberta. The various thematic maps in the ECC Groundwater Atlas indicate the Site has the following hydrogeological attributes:

- Both semi-regional and regional analysis of vertical hydraulic head gradients indicate near-neutral to recharge gradients (i.e., downward component to groundwater flow). This is important as it indicates that Lacombe Lake is not likely supported by regional groundwater discharge.
- Water wells in the area typically produce 6 – 10 Imperial gallons per minute. This is intuitive given the presence of thick saturated sand and gravel deposits and sandstone intervals in the Paskapoo Formation.
- Recharge values are moderate with 76 – 100 mm of deep groundwater recharge per year.

The Atlas of Alberta Lakes (Mitchell and Prepas, 1990) indicates that Lakes in the Red Deer River Basin demonstrate significant natural variability in lake water levels. Although these lakes were not studied in detail herein, and their geological/hydrogeological settings vary in nature, the data indicate strong climatic and seasonal influences on lake levels. Lake level data indicates the water levels of the following lakes varied significantly over time with:

- Gull Lake levels have varied 2.0 m from the mid 1930’s to 1987, however, the Gull Lake Watershed Society (http://www.gulllakewater.net/gulllakewater.net/LAKE_LEVELS.html) provides a longer time series indicating 3.0 m of lake level variation from 1924 (pre-management of levels) to 2012. Since 1965 until 2012 The lake demonstrates approximately 1.0 m of level variation.

- Sylvan Lake levels have varied 1.2 m from 1955 to 1987. Water level collected at for Sylvan Lake (05CC003) are similar indicating 1.3 m of lake level variation measured from 1918 to 2014 (https://wateroffice.ec.gc.ca/report/historical_e.html?stn=05CC003).
- Buffalo Lake levels have varied 1.75 m from 1955 to 1987. Water level collected at for Sylvan Lake (05CD005) indicate the same range 1.75 m of lake level variation measured from 1965 to 2018 (https://wateroffice.ec.gc.ca/report/historical_e.html?stn=05CD005).

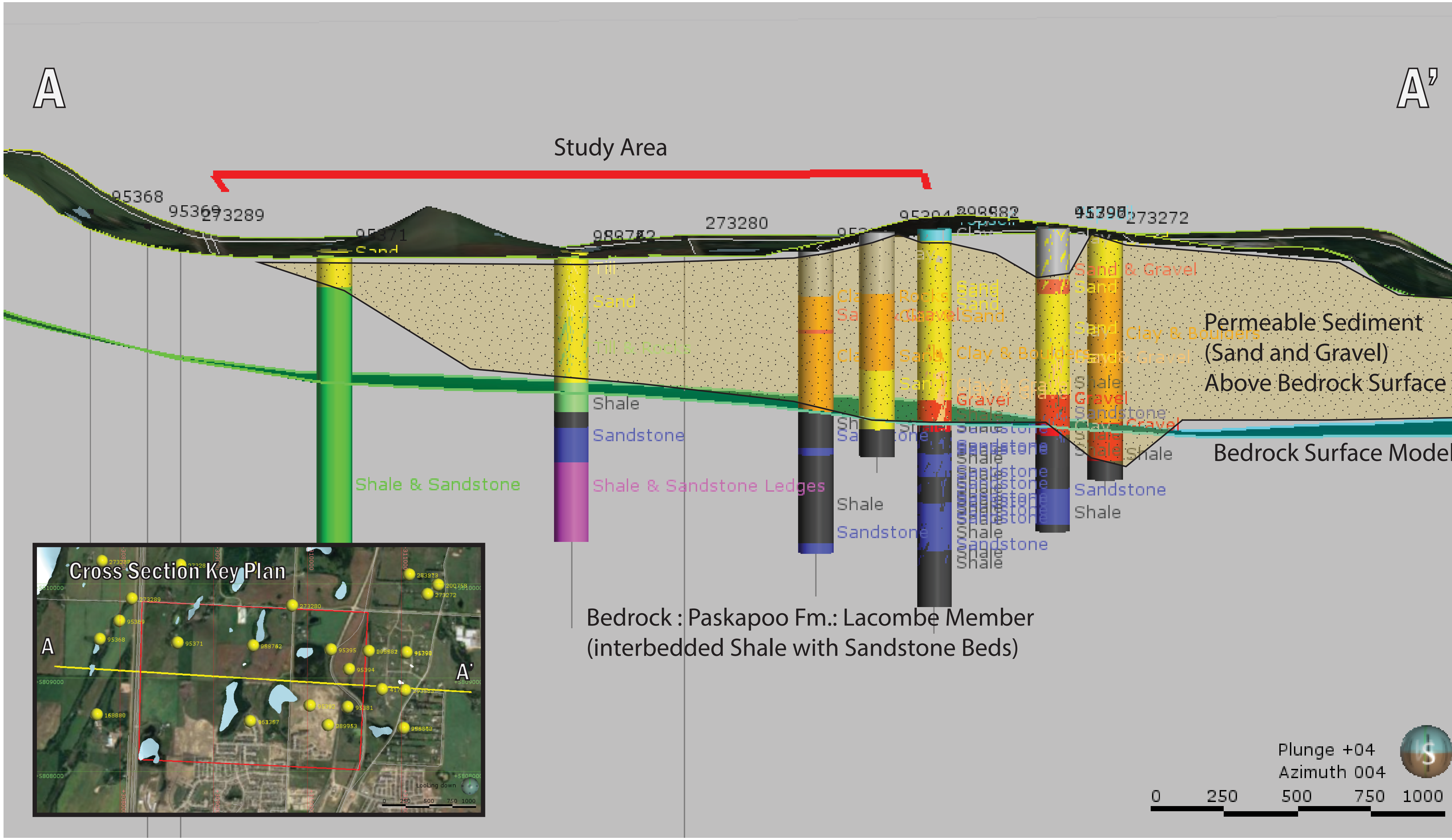
Though Lacombe Lake was not detailed in the Atlas (Mitchell and Prepas, 1990), these large lakes in the area demonstrate that lakes in central Alberta are prone to level variation due to climatic variability. The extent of variability in a given lake is dependent on many factors including connection to regional groundwater flow systems, catchment area, anthropogenic activities etc. However, determination of the factors influencing Lacombe Lake levels was beyond the scope of this analysis.

3D CSM AND INTERPRETATION OF LOCAL (SITE-SCALE) HYDROGEOLOGICAL SETTING

The integration of the available public data allowed the physical hydrological setting of the development area, Lacombe Lake and the surrounding area to be interpreted. The data available from the AWWID and regional mapping products allowed the geological/hydrogeological framework and the following salient hydrogeological characteristics to be assessed:

- Both the NW development area and Lacombe Lake are in a continuous geological and hydrogeological setting.
- The Project Area is in a paleo-valley with up to 30 m of sand and gravel overlying bedrock (Figure 4). The lithological data from public water wells within the study area agrees with mapping and geophysical interpretation of the distribution of coarse-grained sediments in the area (Barker *et al*., 2011).
- A geostatistical rendering of the regional water table surface indicates a shallow water table and continuity of groundwater flow throughout the base of the paleo valley (Figure 5).
- The regional water table model overpredicted groundwater elevations (Figure 5) confirming that the area, and particularly the wetland areas act as recharge areas for the groundwater flow system, which agrees with the regional assessment in the ECC Groundwater Atlas (Barker *et al*., 2011).
- Based on the regional water table model, the groundwater catchment area for Lacombe Lake is estimated to be approximately 58.7 km^2, as shown on Figure 6.

- The development area constitutes a small portion (approximately 12 percent) of the overall groundwater catchment.
- The bedrock topography (Figures 3 and 4) created by the paleo-valley and the generally low permeability bedrock characteristics of the Lacombe Member of the Paskapoo indicates that there is not significant regional groundwater contribution to the lake. **Rather the inputs to the lake are from within the local-scale groundwater catchment created by the paleo-valley.**
- The proposed storm trunks will emulate the behavior of the natural swales or low areas between wetlands that convey excess water between wetlands during times of surplus.
- **Lacombe Lake receives local-scale groundwater flow from the development area so maintaining some form of infiltration capacity in the proposed Stormwater Management Facilities (SWMF) ponds will retain the hydrological/hydrogeological function that the natural wetlands provide and reduce storm flow magnitudes.**



ORIGINAL SHEET - ANSI A - COLOR

Stantec

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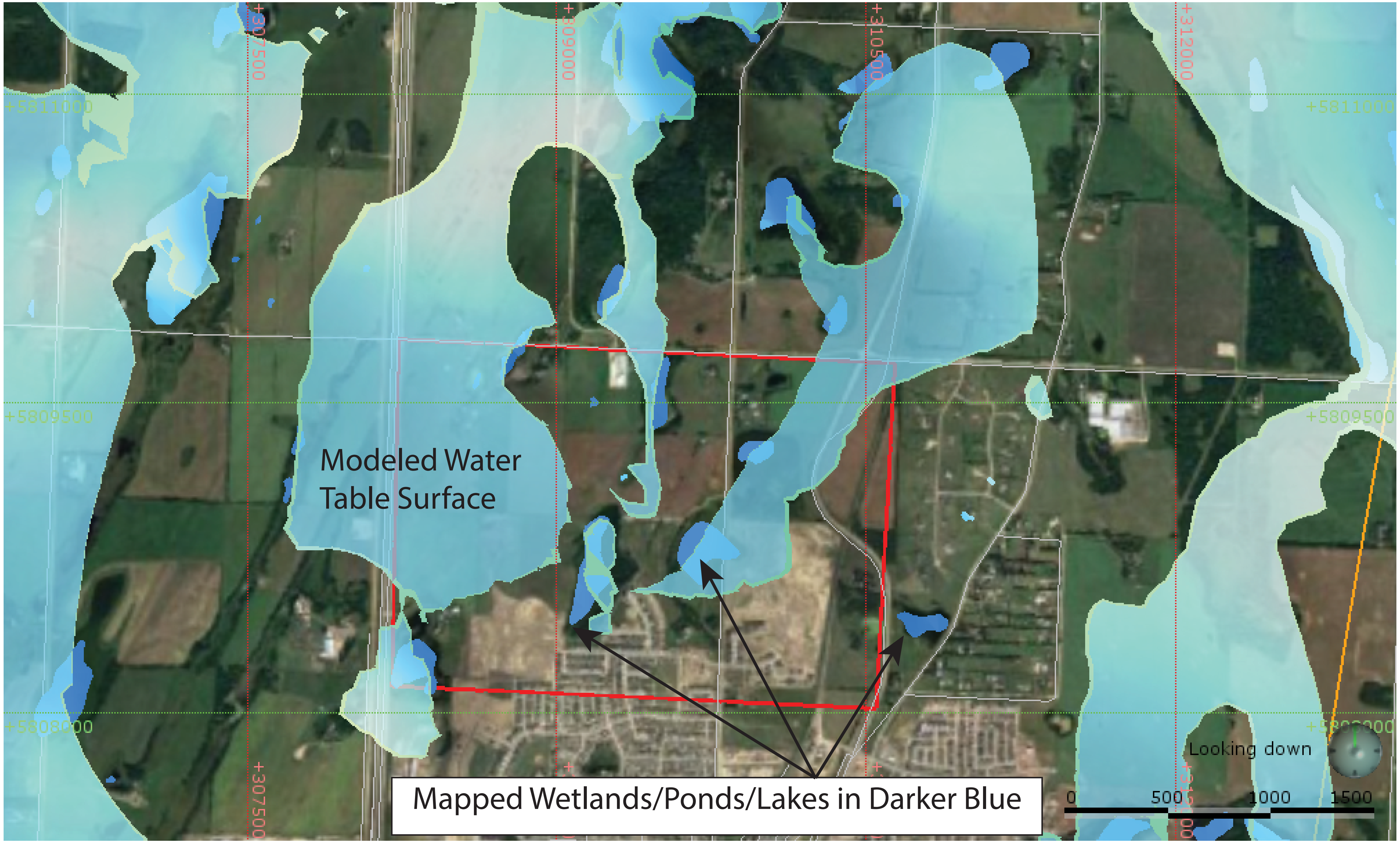
Town of Blackfalds
Blackfalds Northwest Area Desktop
Hydrogeological Assessment
Blackfalds, Alberta

Figure No
4

Title
3D CSM Cross Section through
Northwest Development Area with
AWWID Geological Data



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Town of Blackfalds
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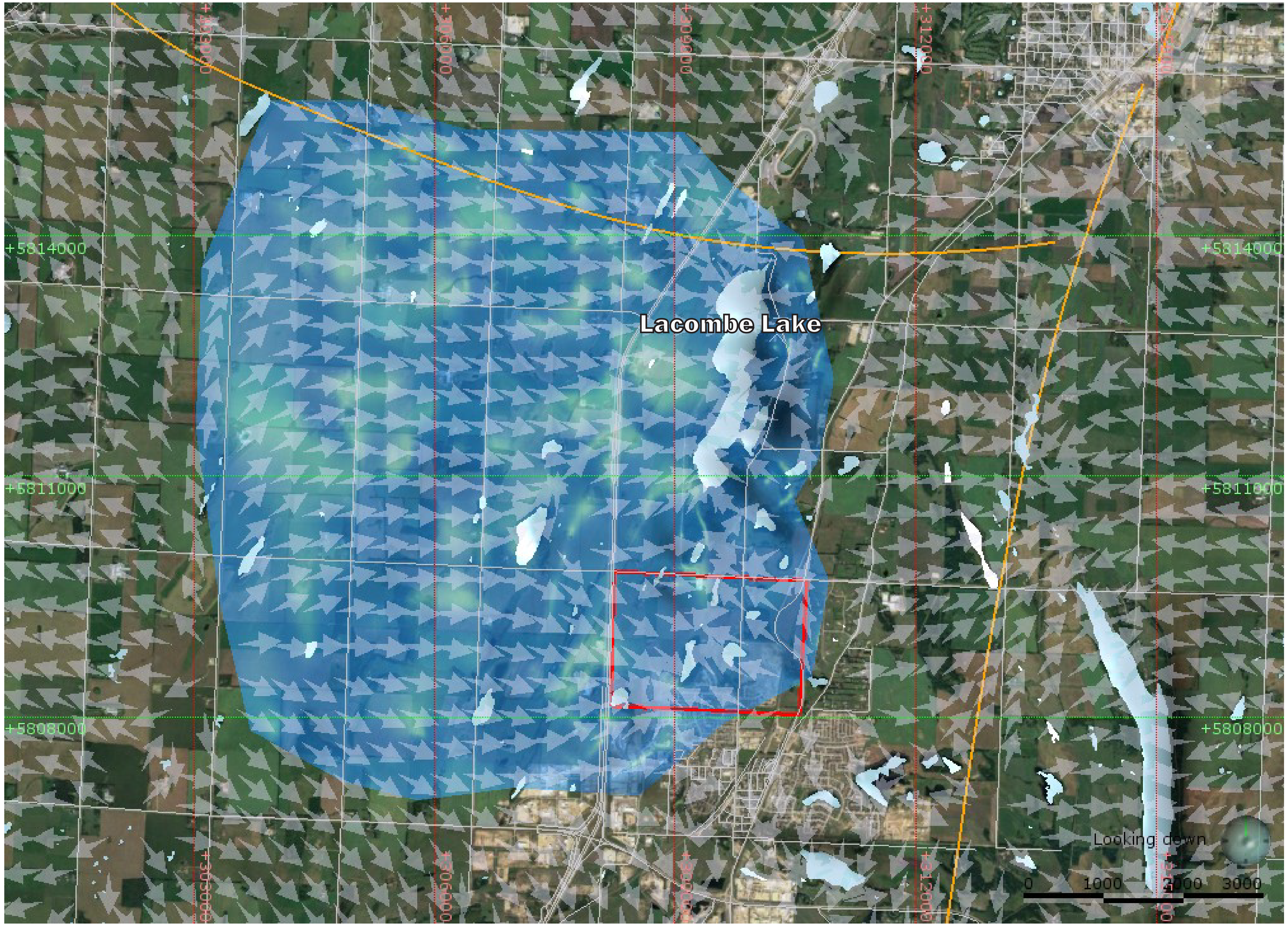
Hydrogeological Assessment
Blackfalds, Alberta

Figure No
5

Title
Regional Water Table
Elevation Model and
Permanent Water Features



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Groundwater FLow Vector (based on regional water table model)

Estimated Lacombe Lake Groundwater Catchment

Northwest Development Area

Burried Channel Thalwegs

Client/Project

Town of Blackfalds
Blackfalds Northwest Area Desktop
Hydrogeological Assessment
Blackfalds, Alberta

Figure No

6

Title

Estimated Lacombe Lake Groundwater
Catchment Area shown in Regional
3D CSM

Typically, there is a need to evaluate two components of the SWMF including the quantity of water (or alterations to the volume of water) received by Lacombe Lake, and the quality of the stormwater that enters Lacombe Lake. The analysis completed herein provides a framework to address the physical hydrogeology of the study area. Site-scale physical groundwater data and groundwater quality data would be required to accurately quantify effects to quantity and quality but potential effects to the water quantity in Lacombe Lake are addressed at a high level below based on the physical hydrogeological framework developed from regional-scale, publicly available data.

POTENTIAL EFFECTS TO WATER QUANTITY

The analysis completed above indicates that the groundwater catchment area of Lacombe Lake based on vector analysis of the water table model is 58.7 km^2. Further, the development area is contained within the groundwater catchment area as shown on Figure 6. Given the proposed unlined stormwater pond design, they will act similarly to the natural wetlands which collect depression focused recharge lying within the local-scale catchment area of the lake. As such, it is unlikely that the overall water quantity entering the lake would change appreciably as the stormwater ponds will emulate the behavior of the natural wetlands and the atmospheric water input in the development area will not be affected.

The natural wetlands and farmland south of the lake constitute a small percentage (approximately 12 percent) of the overall groundwater catchment area. Most of the atmospheric water input in this portion of the groundwater catchment is infiltrated save for evaporation/evapotranspiration, and potential overland flow (runoff) during storm events, which subsequently enters the groundwater flow system and flows into the lake. As such, the long-term average of inflows to the lake should not change significantly if stormwater continues to infiltrate into the groundwater environment from the proposed SWMFs. However, the time of concentration for the atmospheric input to enter the lake in periods of surplus may decrease when storm trunks are activated.

CONCLUSIONS AND RECOMMENDATIONS

The desktop analysis described herein is based on publicly available regional to sub-regional data and as such, the uncertainty at this scale is somewhat limited. However, the geology of the Red Deer paleo-valley is well documented to contain significant sand and gravel above bedrock in the eroded upper bedrock surface. This allows the sub-regional geological and hydrogeological framework to be determined with some degree of certainty. Further, the interpretation of the hydrogeology provided above for the site is in-keeping with the available data resources though as with any desktop hydrogeological analysis. As site development proceeds the data collected will allow the interpretation herein to either be validated or highlight the need for more study based on site specific physical characterization data.

Specific conclusions with respect to the Master Stormwater Management Plan include the following:

- Lacombe Lake receives groundwater flow from the development area between the current development limit on the north side of the Town of Blackfalds and south of Lacombe Lake.

- High infiltration rates are expected based on surficial geology descriptions and lithological records. Infiltration rates are expected to range from 1.13 to 45 mm/hour depending on soil texture as determined from geotechnical grain-size analysis and analytical permeability calculations (see attached Memo).
- Low groundwater flow velocities are expected despite to high transmissivity saturated sediments due to very low lateral hydraulic head gradients. Differences in wetland/lake elevations and the distance between features indicate a horizontal hydraulic head gradient of less than 1% across the study area. Based on the hydraulic conductivities determined from the grain-size analysis of selected lithologies on site (Parkland Geo, 2013), long-term average linear groundwater flow velocities would range from 0.5 to 100 m per year.
- Induced gradients due to surface water impoundment and/or storm events could lead to higher gradients (i.e., up to 3 percent) and groundwater mounding resulting in groundwater velocities adjacent to SWMFs up to 300 m per year in permeable, coarse-grained media.
- The development area constitutes approximately 6.75 km^2 or 12% of the groundwater catchment area.
- Wetlands in the area act as depression focused recharge features allowing impounded runoff to infiltrate into the groundwater environment.
- A shallow and laterally well-connected water table are expected based on the water table model completed in this analysis.
- The natural wetlands and proposed stormwater management ponds should behave similarly based on the unlined SWMF design, allowing communication between surface water features and the groundwater environment.
- The long-term average for rates of groundwater recharge, and eventual discharge to Lacombe Lake should remain similar to pre-development conditions and the overall volume of water entering Lacombe Lake should not change significantly between pre and post development conditions.

Given the analysis completed, Stantec strongly recommends that as development proceeds confirmation of this desktop study may occur along with the required geotechnical field work. Completing a field program to reduce uncertainty, support the MSMP, and provide defensible site characterization data to answer follow-up concerns from the regulator and public. A field program would be designed to:

- Assess lateral and vertical hydraulic head gradients;
- Assess in-situ hydraulic conductivity of the near surface geological materials;
- Assess average linear groundwater flow velocity;
- Assess extent of surface water-groundwater interaction;
- Determine areas within the development with near surface groundwater elevations;

Reference: Blackfalds Northwest Area Desktop Hydrogeological Assessment

- Determine where potential for groundwater interaction, dewatering and potential approvals are required within development area;
- Collect monitoring data to evaluate seasonal trends in groundwater elevation and groundwater/surface water chemistry.

Regards,

Stantec Consulting Ltd.

Joseph Riddell
Hydrogeologist, Environmental Services
Phone: 587-756-6233
Joseph.Riddell@Stantec.com

Attachment: Grain size distribution based Hydraulic Conductivity/Infiltration Rate Calculations and Summary; Northwest Stormwater Management Project, Blackfalds, AB

c. Gordon Ludtke, Alberta Environment and Parks
Todd Simenson, Stantec
Brad Vander Heyden, Stantec
Meghan Chisholm, Stantec

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Stantec

Memo

To:	Brad Dardis Red Deer (Stantec)	From:	Joe Riddell Edmonton (Stantec)
File:	113929434	Date:	May 24, 2018

Reference: Grain Size Distribution Based Hydraulic Conductivity/Infiltration Rate Calculations and Summary; Northwest Stormwater Management Project, Blackfalds, AB

Introduction

Based on a request from the surface water engineering project team, site-specific geotechnical data from borehole drilling (ParklandGeo, 2013, ParklandGeo, 2017) was used to estimate saturated hydraulic conductivity values such that reasonable, defensible infiltration rate data could be provided as an input for surface water models. To estimate the hydraulic characteristics of the near surface geological media, two different grain-size distribution methods were implemented using cumulative distribution function data from sieve analysis appended with the borehole data in the geotechnical reports.

The Hazen Method and the Gustafson Method were both applied as the preliminary analysis using the Hazen Method proved to be somewhat un-representative of site conditions given its original application to determine filter sand permeability. However, the Gustafson Method was more applicable for natural geological media and produced good estimates of saturated hydraulic conductivity and by extension, infiltration rates. While the actual field-observed infiltration rates are uncertain due to other physical hydrogeological conditions such as water table position, shape of pond, potential macro-porosity etc. The Gustafson derived infiltration rates are reasonable figures for preliminary design estimates. Further, a spreadsheet tool that can be used in conjunction with the infiltration rates provided can assist in a prior determination of infiltration capacities of SWMFs when additional data becomes available.

Assumptions

The following assumptions were made such that the grain-size method could be applied:

- The samples obtained from the geotechnical drilling programs were dominantly sand and if not, had a high proportion of sand.
- Samples with little to no sand were omitted from the analysis table as presented below.
- Due to the ex-situ analysis technique, samples were disturbed with no way to evaluate potential anisotropy (i.e., the ratio of saturated horizontal hydraulic conductivity to saturated vertical hydraulic conductivity). As such, it is assumed that the hydraulic conductivity rates and infiltration rates are isotropic (1:1 K_h:K_v).
- Given the geological information available, some of the glaciolacustrine material may have lower vertical hydraulic conductivity or infiltration rates if significant clay is present.
- Weathering and macropore development may significantly increase infiltration rates (K_v) compared to the tabulated results.
- As mentioned in the introduction above, this analysis of infiltration rates does not consider in-situ hydraulic conditions such as ambient water table position, infiltration surface area, depth of impounded water etc.
- When some of the previous bullets characteristics become available a spreadsheet tool can be used to provide accurate estimates of infiltration rates and volumes.

Discussion and Tabulated Results

The results of the Hazen Method were not reasonable due to the natural heterogeneity present in the geological media. This method works well for naturally homogeneous geological media and or pre-sieved media to restrict the grain size distribution and create a well-sorted material. As such, the Hazen Results are of limited utility and seem to systemically overestimate hydraulic conductivity/infiltration rates.

Reference: Grain Size Distribution Based Hydraulic Conductivity/Infiltration Rate Calculation

The Gustafson method was applied to the grain size data given it considers the sorting though a uniformity coefficient (d_{60}/d_{10}) and is better suited to naturally deposited materials. The range of values produced by the Gustafson method indicates reasonable infiltration rates for the well sorted fine sand samples though the poorly sorted material may be underestimated in some cases. However, this is simply a limitation of ex-situ grain-size data derived estimation techniques. (See Table 1 attached)

Conclusions

- The results of the Hazen Method were not reasonable are of limited utility and seem to systemically overestimate hydraulic conductivity/infiltration rates.
- The Gustafson method is better suited to naturally deposited materials. The range of values produced by the Gustafson method indicates reasonable infiltration rates for the well sorted fine sand samples though the poorly sorted material may be underestimated in some cases.
- The maximum infiltration rate was 6,420 mm/day in a clean, well-sorted fine sand and the minimum in a fine sand sample was 0.43 mm/day demonstrating a significant range of values even in a sandy substrate.
- The harmonic mean (i.e., a fundamentally conservative vertically averaging the various sediment types) which is infiltration rates omitting select the maximum and minimum calculated rates is 0.31 mm/day
- The harmonic mean of the infiltration rates omitting none of the samples is 0.21 mm/day
- The arithmetic mean of the infiltration rates omitting highest values (from clean, well sorted sand sediment) is 1.13 mm/hour and is up to 45 mm/hour if the highest values associated with the clean, well sorted sand are retained in the average.
- Given the size/volume of the samples sieved, it is possible that there is a need to spatially average more samples over a larger area to get representative values.
- The geotechnical data indicate occasional clay layers that will significantly impair vertical infiltration where present, particularly where clay dominated strata is encountered at shallow depths.
- Where there is well sorted sandy material, the infiltration rates should be high, and a viable means of managing stormwater in the environment.

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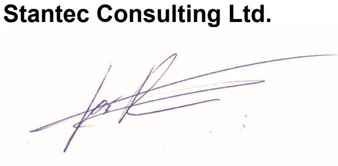


Joseph Riddell
Hydrogeologist

Phone: (587) 756-6233
Joseph.Riddell@stantec.com

Attachment: Table 1 – Hazen and Gustafson Method Derived Infiltration Rates
Imperial Infiltration Calculation Tool (applied after additional site data acquired)

c. Preston Weran, Town of Blackfalds
Brad Vander Heyden, Stantec Consulting Ltd.

Table 1 - Grain-size based Saturated Hydraulic Conductivity and Infiltration Rate Analysis Results

Site	Borehole	Sample Depth (m)	Material	Sorting	Hazen Method		d10(mm)	d60(mm)	Cu	K (Hazen)	Gustafson Method			K (Gustafson)	Infiltration Rate (mm/day)
					Cmin	*Cmax*					*E*	*g(Cu)*	*E(Cu)*		
AH Subdivision	BH-2	2.5	Sandy Silt	Poor	40	80	0.001	0.09	90	4.00E-05	0.09	1.64	2448.68	2.45E-09	0.21
AH Subdivision	BH-3	1.0-2.0	Fine Sand	Poor	40	80	0.001	0.24	240	4.00E-05	0.07	1.63	1382.50	1.38E-09	0.12
AH Subdivision	BH-8	3.0-3.5	Fine Sand	Poor	40	80	0.01	0.15	15	4.00E-03	0.14	1.89	7330.16	7.33E-07	63.33
AH Subdivision	BH-12	1.5-2.0	Silt	Well	40	80	0.0008	0.045	56.25	2.56E-05	0.10	1.66	3252.91	2.08E-09	0.18
AH Subdivision	BH-17	1.0-4.5	Fine Sand	Poor	40	80	0.0015	0.16	106.6667	9.00E-05	0.09	1.63	2213.31	4.98E-09	0.43
AH Subdivision	BH-21	1.1-2.1	Sandy Silt	Medium	40	80	0.0005	0.08	160	1.00E-05	0.08	1.63	1745.10	4.36E-10	0.04
AH Subdivision	BH-22	0.5	Fine Sand	Well	40	80	0.001	0.2	200	4.00E-05	0.08	1.63	1534.28	1.53E-09	0.13
AH Subdivision	BH-22	1.1-1.5	Fine Sand	Well	40	80	0.001	0.17	170	4.00E-05	0.08	1.63	1684.87	1.68E-09	0.15
AH Subdivision	20G1	?	Fine Sand	Well	40	80	0.08	0.21	2.625	2.56E-01	0.24	3.22	11610.42	7.43E-05	6420.10
AH Subdivision	18D2	?	Fine Sand	Well	40	80	0.01	0.4	40	4.00E-03	0.11	1.70	4011.31	4.01E-07	34.66
NW SWP	BH6	6	Fine Sand	Well	40	80	0.018	0.41	22.77778	1.30E-02	0.13	1.79	5686.04	1.84E-06	159.17
NW SWP	BH4	6	Fine Sand	Well	40	80	0.01	0.3	30	4.00E-03	0.12	1.74	4794.13	4.79E-07	41.42
NW SWP	BH2	1.5	Fine Sand	Well	40	80	0.08	0.205	2.5625	2.56E-01	0.25	3.26	11428.52	7.31E-05	6319.51

Appendix E
Letter from Lacombe County to AEP, dated July 24, 2008
Email from Lacombe County to Stantec, Dated September 14, 2016

LACOMBE COUNTY

July 24, 2008

David Helmer
Acting Regional Approvals Manager
Approvals , Alberta Environment
3rd fl Provincial Building
4920 - 51 Street
Red Deer, AB T4N 6K8

Dear Mr. Helmer:

Re: Lacombe Lake Stabilization Project

At the July 24, 2008 regular meeting of Council the following motions were passed:

Moved that Lacombe County refrain from diverting water into Lacombe Lake until the results of the Alberta Agriculture project are understood; unless extreme low lake levels are occurring, and further, upon completion of this project Lacombe County will re-evaluate the diversion and prepare an appropriate action plan.

Carried Unanimously.

Moved that current owners of property affected by the diversion of water into Lacombe Lake be contacted to provide input into the future of this lake stabilization project.

Carried Unanimously.

While we have operated this diversion structure in accordance with our existing license, we feel that is prudent to refrain from diverting water until the findings of Alberta Agriculture's Whelp Creek Study are released. At this time we will review the findings and develop a strategy for Lacombe Lake that will be in the best interests of all those involved.

Should conditions exist that that cause a significant drop in the lake level, we will consider diverting, but will not undertake any diversion without consultation with your department.

In addition we will consult with affected property owners around the lake to inform them of the current situation, and solicit input regarding their wishes for the lake.

Regarding your suggestion for sampling the water quality in the lake and the creek, we are planning to move forward with testing the lake water, but feel that the water quality in the creek will be better determined by the efforts of the Whelp Creek Project.

RR 3, Lacombe, Alberta T4L 2N3 (Tel) 403.782.6601 (Fax) 403.782.3820 www.lacombecounty.com

I would request that you respond to this letter regarding the review of diversion licenses. It is our hope that you will allow us time, (5 to 7) years without diversion to allow the Whelp Creek Study to be completed and for us to review the diversion.

Sincerely,

Keith Boras
Manager of Environmental and Protective Services
Lacombe County

From: Keith Boras [mailto:kboras@lacombecounty.com]
Sent: Wednesday, September 14, 2016 2:17 PM
To: Dardis, Brad <Brad.Dardis@stantec.com>
Subject: RE: Blackfalds NW storm project letter to county on Whelp Brook diversion structure

Brad,

That is somewhat correct. Lacombe County has agreed to not divert into the lake, and would only consider any diversion regardless of lake level after consultation with lakeshore owners.

Keith

From: Dardis, Brad [mailto:Brad.Dardis@stantec.com]
Sent: September-14-16 2:08 PM
To: Keith Boras
Cc: Myron Thompson ; Terry Hager ; Vander Heyden, Brad ; Phil Lodermeier ; Preston Weran
Subject: RE: Blackfalds NW storm project letter to county on Whelp Brook diversion structure

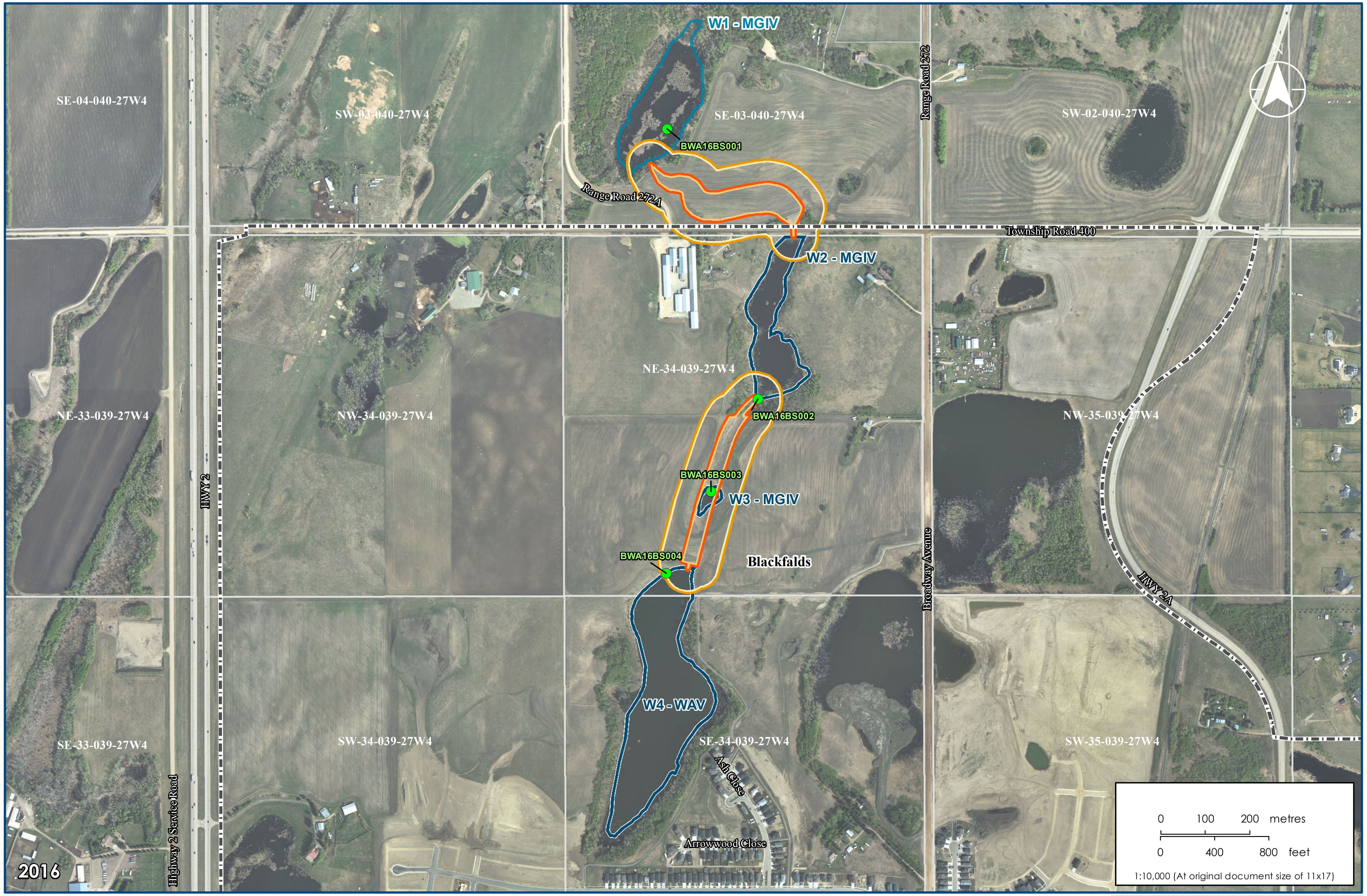
Hi Keith. Further to the previous emails, can you please confirm the following:

As part of the stormwater analysis for the Blackfalds Northwest Area Storm Project, Alberta Environment and Parks (AEP) has requested that we quantify the potential effects of the proposed development on Lacombe Lake water levels. As you are aware, Lacombe County has an existing license to divert water from Whelp Brook to Lacombe Lake. To ensure that we are representing the Lacombe Lake/ Whelp Brook system appropriately, we respectfully request that the County confirm that their long term intent is to leave the Whelp Brook diversion structure open, such that **no** Whelp Brook diversion occurs to Lacombe Lake for typical years, but that the County is still leaving the option open to divert water to the lake during drought periods?

Thanks

Appendix F
Crown Waterbody Determinations

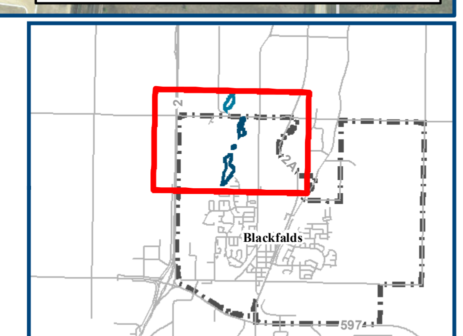
FIGURE A-2. BLACKFALDS NW AREA STORM PROJECT - WETLAND AREA MAP



Source: Imagery from City of Lacombe, 2016. Base data Geogratis, ©Department of Natural Resources Canada, All rights reserved.

Stantec

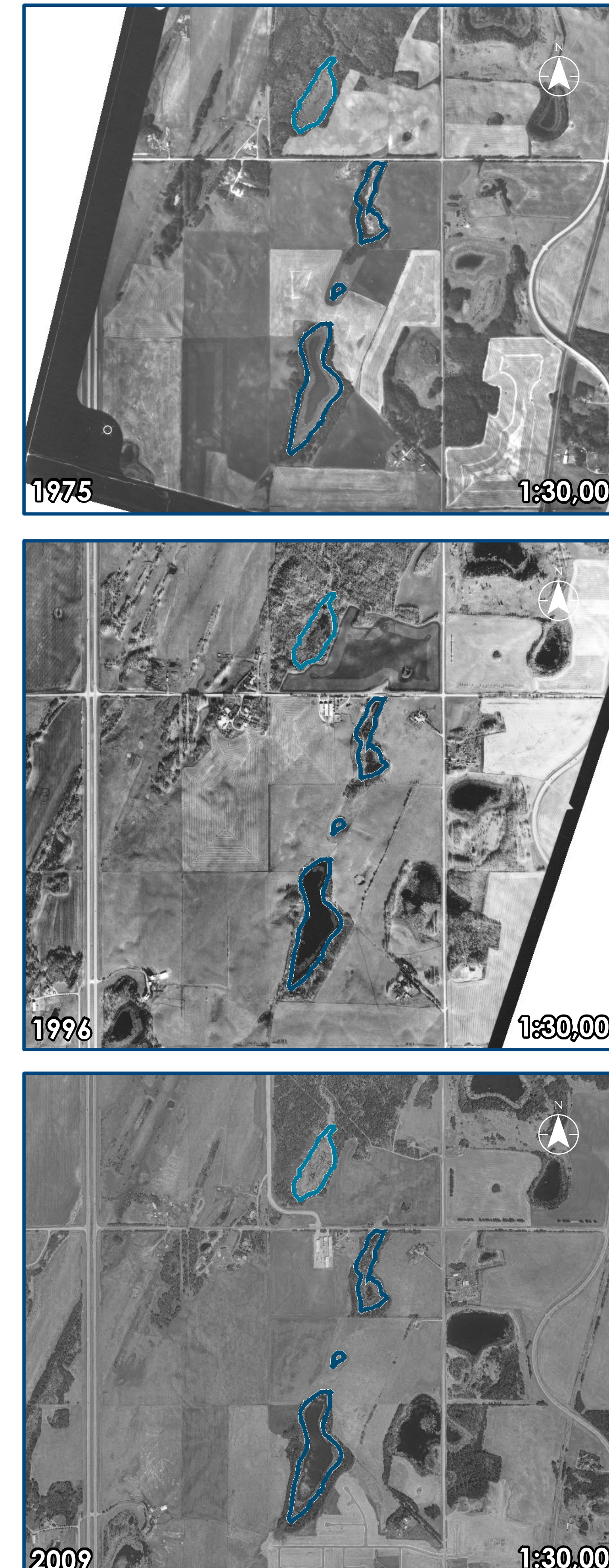
- Vegetation Survey Site
- Intersected Wetland
- Surrounding Wetland
- Project Footprint
- Study Area
- Municipal Boundary
- Quarter Section



Page 01 of 01

Location Map

HISTORICAL AIR PHOTOS



From: Sid Parseyan
Sent: May-30-17 9:35 AM
To: Stantec
Subject: RE: Permanence Assessment (113929258)

Hi Ben,

Please be advised that a review of historical photos of 32 different years (from 1950 to 2016) especially the last 30 years indicates a reasonably persistent presence of open water within wetlands which are identified in your report as "W1" and "W2". As such, under Section 3 of *Public Lands Act* the Crown in right of Alberta asserts a claim to the bed and shore of naturally occurring and permanent bodies of water within those two wetlands. Note that the naturally occurring body of water within the third wetland which is identified as "W3" in your report does not meet the criteria of permanency. Therefore, it does not have a Crown claimable bed and shore.

This assessment is not a permission to alter any of the existing wetlands in that area. Local environmental office and/or the Water Act Approval authorities must be contacted before planning any action which may affect any of the identified wetlands.

If you need any further clarifications and/or have any questions or comments on this matter, please do not hesitate to contact us.

Thank you,

Sid

Sid Parseyan, B.Sc. M.Sc.
Senior Waterbody/Boundary Research Analyst
Provincial Wetlands & Water Boundaries Unit
Operations Division
Alberta Environment and Parks

Appendix G
Tabulated Modeling Parameters

Blackfalds Northwest Area Master Stormwater Management Plan
PCSWMM Tabulated Modeling Parameters

Table G1 Post Development Sub-catchment Parameters

Catchment	Area (ha)	Length (m)	Slope (%)	Impervious (%)	Manning 'n'		Depression Storage (mm)		Zero Imperv. (%)	Subarea Routing	Amount Routed (%)	Horton Parameters			
					Imperv.	Perv.	Imperv.	Perv.				Max Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)	Drying Time (Days)
SC_1	19.8	150	1	64	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_2	21.8	150	1	54	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_3	65.6	150	1	63	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_4	37.5	150	1	60	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_5	10.0	150	1	57	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_6	29.9	150	1	57	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_7	14.2	150	1	57	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_8A	9.3	150	1	90	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_8B	22.8	150	1	75	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_8C	24.3	150	1	75	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC_9	19.5	150	1	65	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC10	5.6	150	1	40	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC11	14.1	150	1	75	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC12	22.2	150	1	75	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC20	12.9	150	1	75	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC21	48.0	150	1	70	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC22	8.6	150	1	75	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC23	35.9	150	1	75	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC24	20.5	350	1	35	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC30	69.5	350	1	65	0.015	0.25	1.6	3.2	0	OUTLET	100	75	7.5	4.14	7
SC-LAC-LAKE	1158	350	1	0	0.015	0.25	1.0	1.0	100	OUTLET	100	40	1.2	4.14	7
SC-LL-WET	120	50	1	100	0.015	0.25	1.0	1.0	100	OUTLET	100	40	1.2	4.14	7
SC-TES	56.8	350	1	70	0.015	0.25	1.6	3.2	0	OUTLET	100	40	1.2	4.14	7
SC-WHELP	3697	350	1	0	0.015	0.25	1.0	1.0	100	OUTLET	100	40	1.2	4.14	7

Table G2 Evaporation Parameters

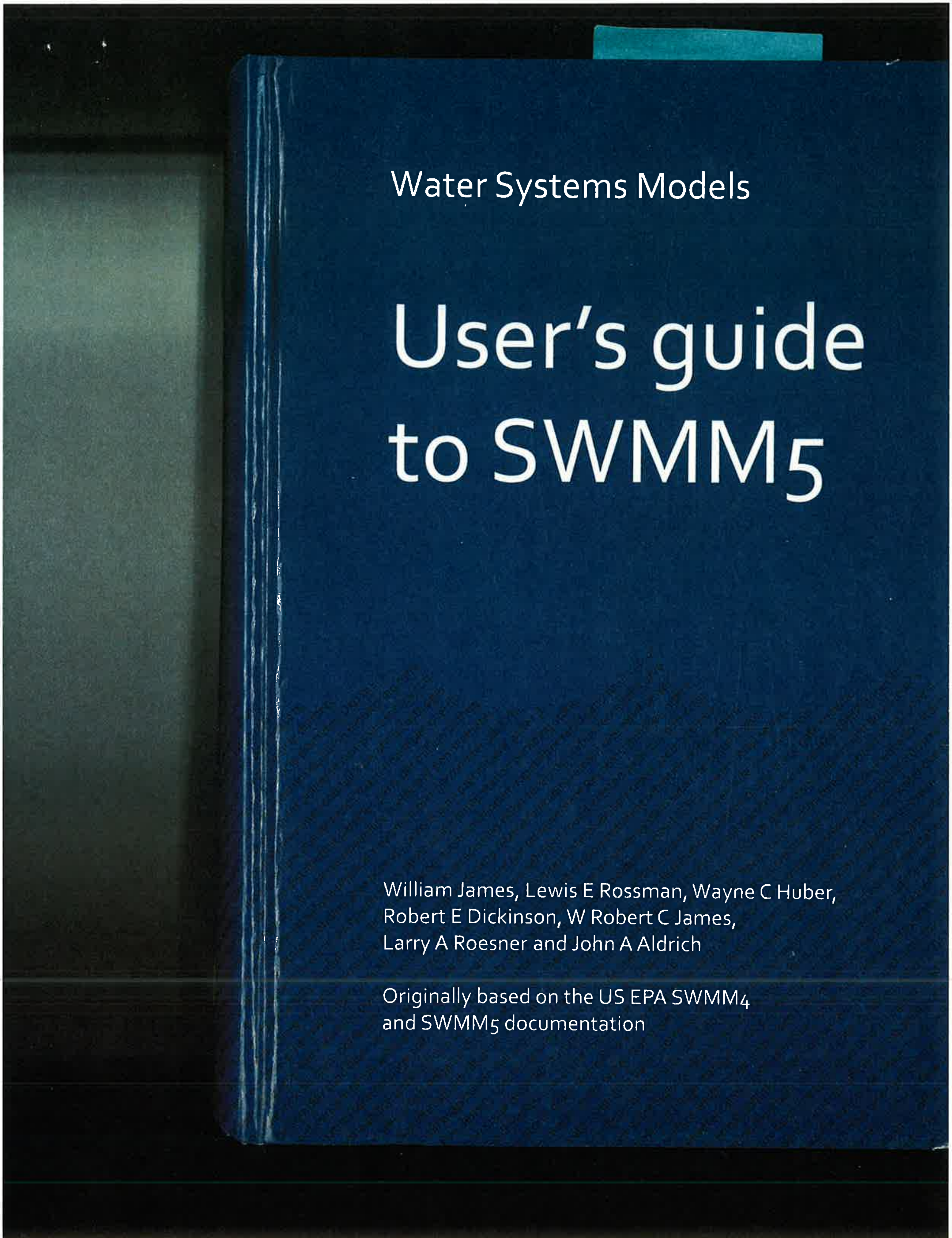
Month	Monthly (mm)	Daily (mm)
January	-2.0	-0.06
February	0.0	0.00
March	21.0	0.66
April	70.0	2.35
May	115.0	3.72
June	132.0	4.40
July	147.0	4.76
August	117.0	3.79
September	63.0	2.12
October	27.0	0.87
November	2.0	0.07
December	-3.0	-0.10

Table G3 TSS Buildup & Washoff

Residential Land Use										
Parameter	Particle Size (μm)	Fraction (%)	Buildup				Washoff			
			Function	Max. (kg/ha)	Rate (kg/ha)	Power/Sat. Constant	Function	Coefficient (mg/L)	Exponent	BMP Effic. (%)
TSS010	< 10	23	POW	460	1.26	0.95	EMC	102	1	0
TSS020	10-20	9	POW	180	0.493	0.95	EMC	40	1	0
TSS050	20-50	13	POW	260	0.712	0.95	EMC	58	1	0
TSS150	50-150	23	POW	460	1.26	0.95	EMC	102	1	0
TSS500	> 150	32	POW	640	1.753	0.95	EMC	142	1	0
Commercial Land Use										
Parameter	Particle Size (μm)	Fraction (%)	Buildup				Washoff			
			Function	Max. (kg/ha)	Rate (kg/ha)	Power/Sat. Constant	Function	Coefficient (mg/L)	Exponent	BMP Effic. (%)
TSS010	< 10	23	POW	460	1.26	0.95	EMC	41.4	1	0
TSS020	10-20	9	POW	180	0.493	0.95	EMC	16.2	1	0
TSS050	20-50	13	POW	260	0.712	0.95	EMC	23.4	1	0
TSS150	50-150	23	POW	460	1.26	0.95	EMC	41.4	1	0
TSS500	> 150	32	POW	640	1.753	0.95	EMC	57.6	1	0
Industrial Land Use										
Parameter	Particle Size (μm)	Fraction (%)	Buildup				Washoff			
			Function	Max. (kg/ha)	Rate (kg/ha)	Power/Sat. Constant	Function	Coefficient (mg/L)	Exponent	BMP Effic. (%)
TSS010	< 10	23	POW	460	1.26	0.95	EMC	85	1	0
TSS020	10-20	9	POW	180	0.493	0.95	EMC	33	1	0
TSS050	20-50	13	POW	260	0.712	0.95	EMC	48	1	0
TSS150	50-150	23	POW	460	1.26	0.95	EMC	85	1	0
TSS500	> 150	32	POW	640	1.753	0.95	EMC	118	1	0

Table G4 TSS Removal from Storage

Parameter	Particle Size (μm)	Settling Velocity (m/s)	Treatment Expression
TSS010	< 10	0.00000592	C=TSS010*exp(-0.00000592*DT/DEPTH)
TSS020	10-20	0.0000473	C=TSS020*exp(-0.0000473*DT/DEPTH)
TSS050	20-50	0.000283	C=TSS050*exp(-0.000283*DT/DEPTH)
TSS150	50-150	0.00195	C=TSS150*exp(-0.00195*DT/DEPTH)
TSS500	> 150	0.0124	C=TSS500*exp(-0.0124*DT/DEPTH)


Water Systems Models
User's guide to SWMM5
William James, Lewis E Rossman, Wayne C Huber, Robert E Dickinson, W Robert C James, Larry A Roesner and John A Aldrich
Originally based on the US EPA SWMM4 and SWMM5 documentation

meters) (set to zero

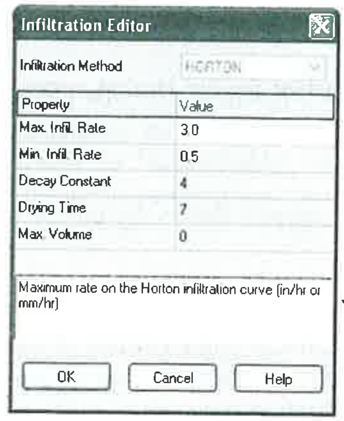
any ground water
node's invert

are consistent with
for metric units.

the difference in
water and Surface
Groundwater Flow
Surface Water Flow
Coefficient

parameters that
soil zone in a
the Infiltration
on which
or Curve
editing the

project's Simulation Options (see Chapter 11 *Running a Simulation*, section 11.1) or by changing the project's Default Properties (see Chapter 8 *Working with Projects*, section 8.4).



fo = Initial Infil
fc = Final Infil

fo = Initial Infiltration rate

Horton Infiltration Parameters

The following data fields appear in the Infiltration Editor for Horton infiltration:

Max. Infil. Rate
Maximum infiltration rate on the Horton curve (in/hr or mm/hr). Representative values are as follows:

1. DRY soils (with little or no vegetation):
   - Sandy soils: 5 in/hr
   - Loam soils: 3 in/hr
   - Clay soils: 1 in/hr
2. DRY soils (with dense vegetation):
   - Multiply values in A. by 2
3. MOIST soils:
   - Soils which have drained but not dried out (i.e., field capacity):
   - Divide values from A and B by 3.
   - Soils close to saturation:
   - Choose value close to min. infiltration rate.
   - Soils which have partially dried out:
   - Divide values from A and B by 1.5 - 2,5.

fo for rural areas 40 mm/hr.
fo for N areas = 75 mm/hr.

26.2 Soil Characteristics

Soil Texture Class	K	Ψ	φ	FC	WP
Sand	4.74	1.93	0.437	0.062	0.024
Loamy Sand	1.18	2.40	0.437	0.105	0.047
Sandy Loam	0.43	4.33	0.453	0.190	0.085
Loam	0.13	3.50	0.463	0.232	0.116
Silt Loam	0.26	6.69	0.501	0.284	0.135
Sandy Clay Loam	0.06	8.66	0.398	0.244	0.136
Clay Loam	0.04	8.27	0.464	0.310	0.187
Silty Clay Loam	0.04	10.63	0.471	0.342	0.210
Sandy Clay	0.02	9.45	0.430	0.321	0.221
Silty Clay	0.02	11.42	0.479	0.371	0.251
Clay	0.01	12.60	0.475	0.378	0.265

K = saturated hydraulic conductivity, in/hr
Ψ = suction head, in.
φ = porosity, fraction
FC = field capacity, fraction
WP = wilting point, fraction

fc = 7.5 mm/hr for NW area

Source: Rawls, W.J. et al., (1983). J. Hyd. Engr., 109:1316.

26.3 NRCS Hydrologic Soil Group Definitions

fc = final Infilitration Rate

Group	Meaning	Saturated Hydraulic Conductivity (in/hr)
A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels.	≥ 0.45
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures. E.g. shallow loess, sandy loam.	0.30 - 0.15
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. E.g., clay loams, shallow sandy loam.	0.15 - 0.05
D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay-pan or clay layer at or near the surface, and shallow soils over nearly impervious material.	0.05 - 0.00

fc ~ 0.05 in/hr = 1.2 mm/hr.

Rural areas

United States
Environmental Protection
Agency

EPA/600/R-15/162A | January 2016 | www2.epa.gov/water-research

Storm Water Management Model Reference Manual

Volume I – Hydrology (Revised)

Office of Research and Development
Water Supply and Water Resources Division

Separate values of depression storage can be used for the pervious and impervious subareas within a subcatchment. Representative values for the latter can probably be obtained from the European data just discussed. Pervious area measurements are lacking; most reported values are derived from successful simulation of measured runoff hydrographs. Although pervious area values are expected to exceed those for impervious areas, it must be remembered that the infiltration loss, often included as an initial abstraction in simpler models, is computed explicitly in SWMM. Hence, pervious area depression storage might best be represented as an interception loss, based on the type of surface vegetation. Many interception estimates are available for natural and agricultural areas (Linsley et al., 1949; Maidment, 1993; Viessman and Lewis, 2003). For grassed urban surfaces a value of 0.10 inches (2.5 mm) may be appropriate.

As mentioned earlier, several studies have determined depression storage values in order to achieve successful modeling results. For instance, Hicks (1944) in Los Angeles used values of 0.20, 0.15 and 0.10 inches (5.1, 3.8, 2.5 mm) for sand, loam and clay soils, respectively, in the urban area. Tholin and Keifer (1960) used values of 0.25 and 0.0625 inches (6.4 and 1.6 mm) for pervious and impervious areas, respectively, for their Chicago hydrograph method. Brater (1968) found a value of 0.2 inches (5.1 mm) for three basins in metropolitan Detroit. Miller and Viessman (1972) give an initial abstraction (depression storage) of between 0.10 and 0.15 inches (2.5 and 3.8 mm) for four composite urban catchments. The American Society of Civil Engineers (1992) suggests depression storage of 1/16 inch for impervious areas and 1/4 inch for pervious areas. The Denver Urban Drainage and Flood Control District (UDFCD, 2007) recommends depression storage losses of 0.1 inches for large paved areas and flat roofs, 0.05 inches for sloped roofs, 0.35 inches for lawn grass, and 0.4 inches for open fields.

In SWMM, depression storage may be treated as a calibration parameter, particularly to adjust runoff volumes. If so, extensive preliminary work to obtain an accurate a priori value may be unnecessary since the value will be changed during calibration anyway. Depression storage is most sensitive for small storms; as the depth increases it becomes a smaller and smaller relative component of the water budget.

Ia used for Rural areas = 1.0 mm based on model calibration

3.8.8 Parameter Sensitivity

Sensitivity of surface runoff volume and peak flow estimates to key surface runoff parameters is listed in Table 3-6. The influence of storm depth is not represented in the table.

Appendix H
Pre and Post Development Hydrographs

Figure H.1 Northwest Area Storm System Post-development Hydrograph 1:2 Year

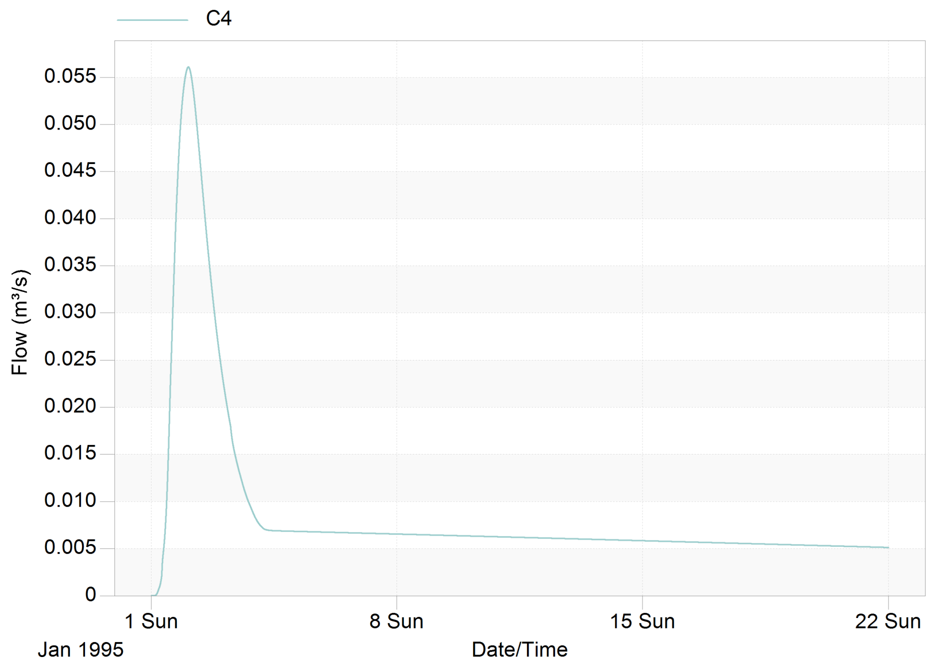


Figure H.2 Northwest Area Storm System Post-development Hydrograph 1:5 Year

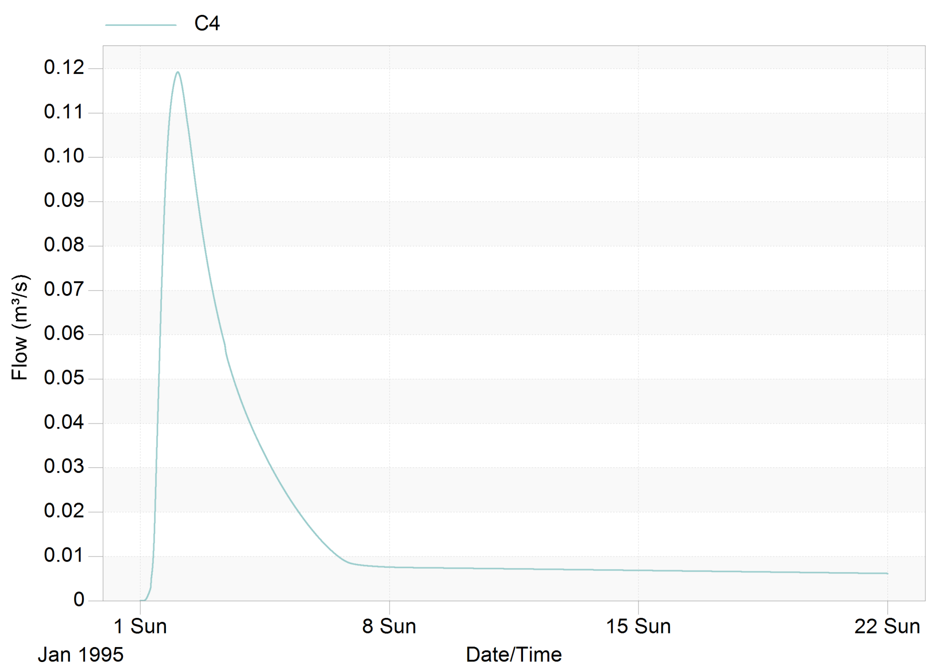


Figure H.3 Northwest Area Storm System Post-development Hydrograph 1:100 Year

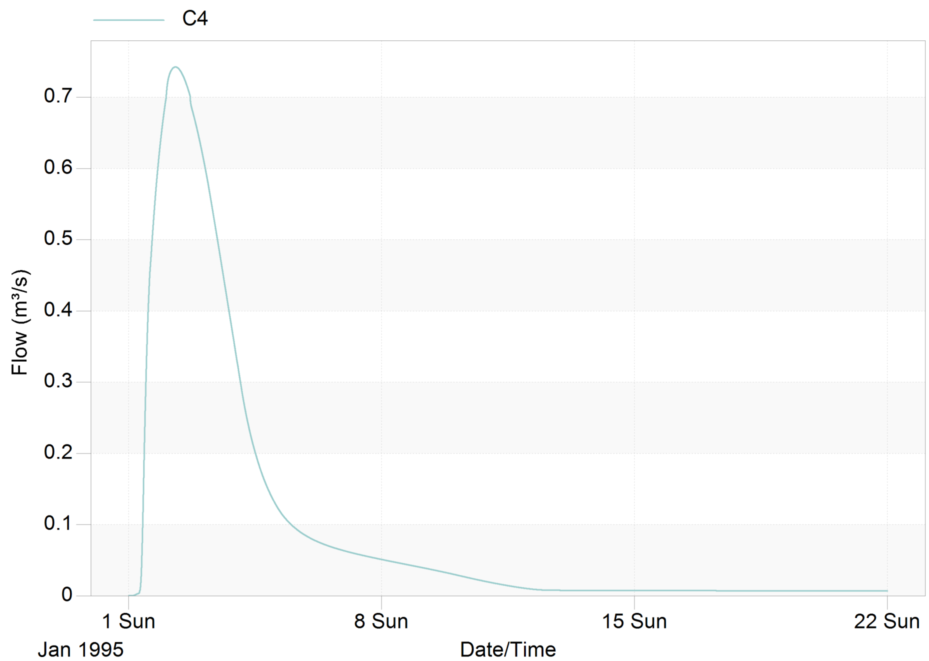


Figure H.4 Lacombe Lake Pre/Post Development Outflow 1:2 Year Event

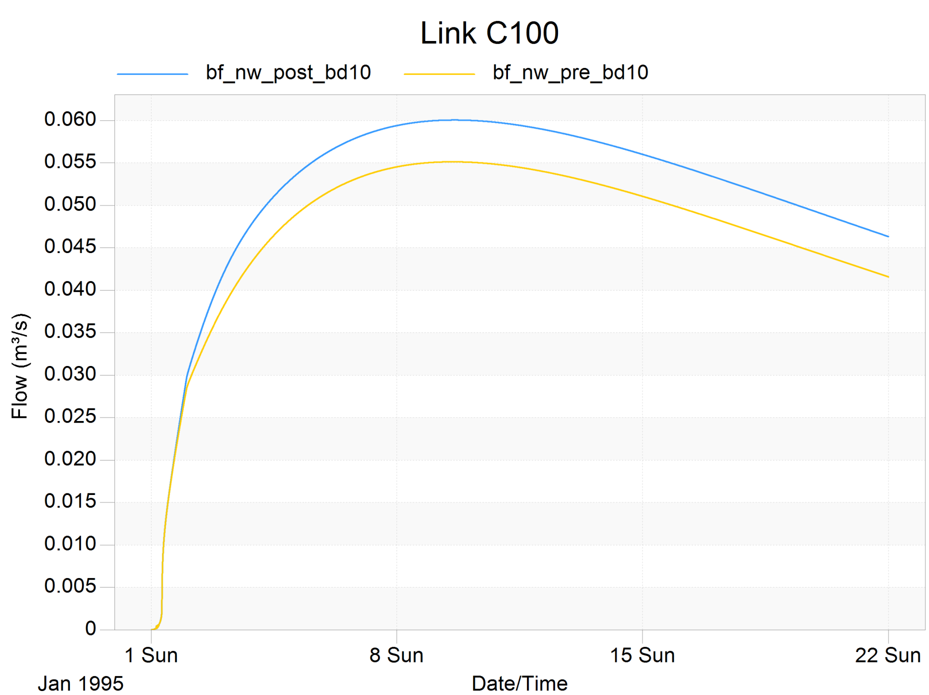


Figure H.5 Lacombe Lake Pre/Post Development Outflow 1:5 Year Event

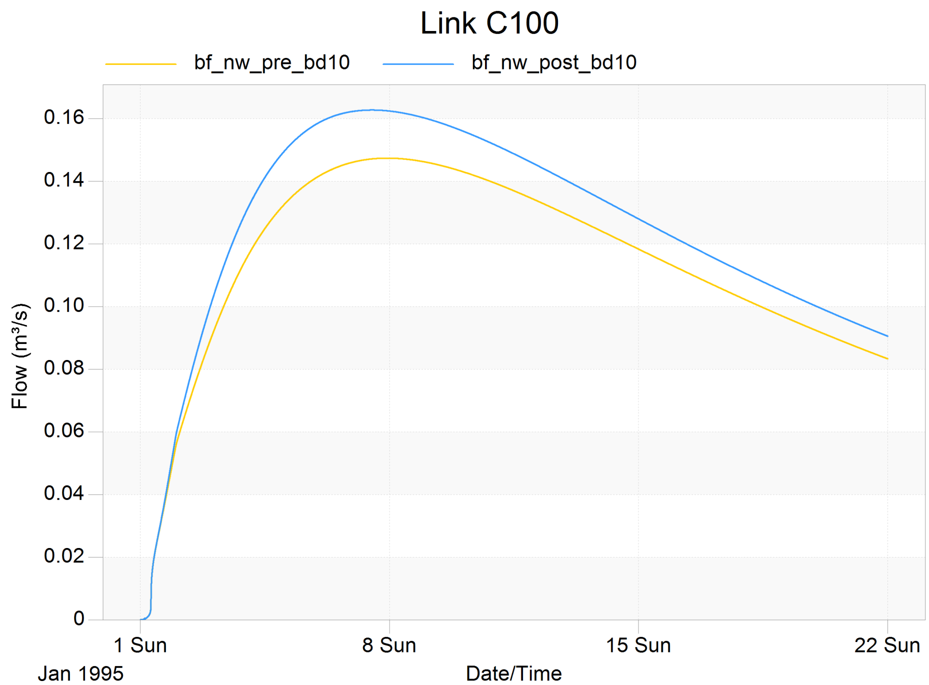


Figure H.6 Lacombe Lake Pre/Post Development Outflow 1:100 Year Event