DRUMHELLER RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING REPORT

Prepared for:

Alberta

16 June 2022

NHC Ref. No. 1003877

nhc
northwest hydraulic consultants
water resource specialists

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FINAL REPORT

Prepared for:

Alberta Environment and Parks
Edmonton, Alberta

Prepared by:

Northwest Hydraulic Consultants Ltd.
Edmonton, Alberta

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DISCLAIMER

This report has been prepared by Northwest Hydraulic Consultants Ltd. (NHC) in accordance with generally accepted engineering practices, for the benefit of Alberta Environment and Parks for specific application to the Drumheller River Hazard Study in Alberta. The information and data contained herein represent the best professional judgment of NHC, based on the knowledge and information available to NHC at the time of preparation.

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EXECUTIVE SUMMARY

Alberta Environment and Parks retained Northwest Hydraulic Consultants Ltd. in June 2018 to complete a river hazard study for the Town of Drumheller and surrounding areas of Kneehill County, Starland County, Wheatland County, and Special Area No. 2. The river hazard study area includes 56.1 km of the Red Deer River, 7.9 km of Kneehills Creek, 5.3 km of Michichi Creek, 10.7 km of the Rosebud River, and 3.0 km of Willow Creek. The study is being conducted under the provincial Flood Hazard Identification Program; the overall objectives are to enhance public safety and to reduce future flood damages and disaster assistance costs.

The Drumheller River Hazard Study is comprised of six major project components. This report summarizes the work of the third component: ***Hydraulic Modelling and Flood Inundation Mapping***. This component includes construction and calibration of the hydraulic model, a sensitivity analysis, computation of flood frequency water levels and the associated inundation mapping.

The hydraulic model was calibrated by adjusting channel roughness and other model parameters so that the computed flood levels agreed well with the observed flood levels for recorded floods. The Red Deer River was calibrated to the 2005 and 2013 flood events. Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek were calibrated to the April 2018 flood event. Computed stage-discharge rating curves were compared to the published rating curves and associated data for Water Survey Canada (WSC) gauge stations located along the study reaches. The computed rating curves agreed well with the published rating curves.

Supplementary planned flood control structure information provided by the Town of Drumheller was incorporated into the calibrated hydraulic model, which was used to calculate water surface profiles for the 13 regulated flood frequency return periods. The computed flood frequency levels were then used to determine the extent of inundation for all return periods. The results of the inundation analysis are presented as the open water flood inundation map library, provided as an appendix to this report. A total of 13 flood scenarios based on the calibrated open water flood frequency profiles were mapped individually for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year regulated events. It is worth noting that if flood control structure plans change, this report may not reflect accurate future conditions.

The open water flood inundation maps provide information that can be used by provincial and local authorities to assist in emergency preparedness planning for future flood events.

CREDITS AND ACKNOWLEDGEMENTS

Northwest Hydraulic Consultants Ltd. would like to express appreciation to Alberta Environment and Parks for initiating this project, making extensive background information available, and providing the project team with valuable technical input throughout the project. Mr. Peter Bezeau and Ms. Jane Eaket managed and directed the Drumheller River Hazard Study on behalf of Alberta Environment and Parks (AEP). Thanks are also expressed to Dr. Jennifer Nafziger and other members of AEP for providing relevant information and valuable comments throughout the course of the work.

The following NHC personnel were part of the study team and participated in the hydraulic modelling and flood inundation mapping component of the study:

- Robyn Andrishak (Project Manager) – responsible for the overall direction of the project and hydraulic model development and calibration work.
- Agata Hall (Hydraulic Modelling Specialist) – authored this report and was responsible for hydraulic model development, calibration, and model sensitivity analysis.
- Rebecca Himsl (GIS Analyst) – responsible for development of inundation mapping and GIS deliverables.
- Sarah North (GIS Analyst) – responsible for review of inundation mapping and GIS deliverables.
- Gary Van Der Vinne (Senior Technical Reviewer) – provided senior review input and advice.

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1 INTRODUCTION

1.1 Study Background

The Drumheller River Hazard Study was initiated by Alberta Environment and Parks (AEP) to identify and assess river and flood hazards along the Red Deer River, Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek within the Town of Drumheller and surrounding areas of Kneehill County, Starland County, Wheatland County, and Special Area No. 2. A flood hazard mapping study was previously completed for the Drumheller area by Matrix Solutions (2007); however, the present study covers an expanded study reach and represents a significant update to the prior work.

Results from this study are designed to inform local land use planning decisions, flood mitigation projects, and emergency response planning. This study is being undertaken as part of the Flood Hazard Identification Program (FHIP) with the intent of enhancing public safety and reducing future flood damages within the Province of Alberta.

This river hazard study is comprised of six major study components:

1) Survey and Base Data Collection
2) Open Water Hydrology Assessment
3) Hydraulic Modelling and Flood Inundation Mapping
4) Design Flood Hazard Mapping
5) Flood Risk Assessment and Inventory
6) Channel Stability Investigation

Each component includes a separate report and associated deliverables for that portion of the study.

1.2 Study Objectives

This report summarizes the work of the third component: ***Hydraulic Modelling and Flood Inundation Mapping***. The primary tasks, services, and deliverables associated with this report are:

- Documentation of open water flood history.
- Creation, calibration, and validation of a HEC-RAS hydraulic model.
- Simulation of selected return-period floods and creation of water surface profiles throughout the study reach.
- A sensitivity analysis of the model inputs.

- Production of flood inundation maps.

The development of the hydraulic model and the production of the inundation maps are foundational to the overall study and are required for the identification of flood hazard areas along the study reach.

1.3 Study Area and Reach

The Town of Drumheller is located along the Red Deer River, approximately 100 km northeast of the City of Calgary and 115 km southeast of the City of Red Deer. **Figure 1** shows the location and boundaries of the river hazard study area and provides an overview of the upstream watershed boundaries. The study area includes the following river reaches and Alberta Township System quarter section boundaries:

- 56.1 km of the Red Deer River from the northern boundary of NW/NE-27-29-21-W4M to the southern boundary of SW/SE-3-27-17-W4M
- 7.9 km of Kneehills Creek from the western boundary of SE-15-29-21-W4M to the Red Deer River
- 5.3 km of Michichi Creek from the eastern boundary of SE-13-29-20-W4M to the Red Deer River
- 10.7 km of the Rosebud River from the southern boundary of SW-7-28-19-W4M to the Red Deer River
- 3.0 km of Willow Creek from the eastern boundary of NE-7-28-18-W4M to the Red Deer River

River cross section surveys extended beyond these boundaries to accommodate hydraulic modelling and inundation mapping requirements. Local authorities within the study area include the Town of Drumheller, Kneehill County, Starland County, Wheatland County, and Special Area No. 2.

The contributing watershed covers a total area of about 29,970 km^2, extending from the headwaters of the Red Deer River in the Rocky Mountains to the downstream boundary of the river hazard study area. The Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek sub-basins account for 2,440, 1,170, 4,360, and 400 km^2 of the total watershed area, respectively. Floods are typically derived from rapid spring snowmelt augmented by heavy rainfall events, although the nature and timing of flooding on the tributary reaches is typically unique and independent of those experienced by the Red Deer River.

Flows in the Red Deer River have been regulated since 1983 by Dickson Dam which impounds Gleniffer Reservoir located about 50 km upstream of Red Deer. The drainage area upstream of the reservoir (5,590 km^2) accounts for about 22% of the area upstream of Drumheller.

2 FLOOD HISTORY

2.1 General Information

A detailed description of local flood history has been prepared to provide context for the hydraulic modelling and flood inundation mapping efforts. This flood history documentation includes observations from open water flooding.

2.2 Open Water Floods

Most of the runoff conveyed by the Red Deer River is typically derived from the Rocky Mountain and foothills portions of the basin. Annual peak flows usually occur in June, while heavy rainfall in summer can also result in large flood events. Floods generated from spring runoff in the tributaries tend to occur earlier than those along the Red Deer River.

2.2.1 Historic and Observed Floods

Historic floods refer to major floods that occurred prior to the period of hydrometric data collection and systematic recording of water level and discharge. In some cases, the magnitude of a historic flood can be estimated based on observations or even anecdotal information. The period of record for each key hydrometric station is summarized in **Table 1**.

Table 1 List of hydrometric gauges supporting model creation and calibration

Station Name (ID)	Period of Record
Red Deer River at Drumheller (05CE001)	1916-1931, 1959-2018
Kneehills Creek near Drumheller (05CE002)	1921-1931, 1935-1936, 1957-2014, 2015-2018
Michichi Creek at Drumheller (05CE020)	1979-2014, 2015-2018
Rosebud River at Redland (05CE005)	1951-2018

The Red Deer River at Drumheller (05CE001) gauge station was established by Water Survey of Canada (WSC) in November 1915. Prior to systematic recording, the flood events which occurred in 1901 and 1915 are the two largest known events on the Red Deer River (Alberta Department of the Environment, 1975). Two other flood events were observed in 1952 and 1954, while the gauge station was not being operated. This information is documented in the ***Open Water Hydrology Assessment*** provided under separate cover (NHC, 2020a).

Kneehills Creek near Drumheller (05CE002) has been gauged since 1921. The historic flood of June 1902 has no associated discharge estimate (NHC, 2008). Three other significant flooding events occurred in June 1931, April 1948, and April 1952. However, direct discharge measurements are not available for any of these and there is insufficient data available to produce estimates (NHC, 2008).

Photos of 23 April 1948 flooding in the Hamlet of Wayne, on the Rosebud River, were provided by AEP showing open water flooding of various structures in low-lying areas and road crossings. The railway does not appear to have been overtopped during this event. There is also recorded evidence of flooding along the Rosebud River from circa 1917 at the Town of Didsbury (located far upstream of the present study area); however, neither a specific date nor an estimated discharge are available for that event.

No historic flood information is available for Michichi Creek and Willow Creek, as documented by NHC (2020a).

The available historic observations of open water floods are summarized in **Table 2**. There are insufficient details on discharges and water levels to use these historic flood data for model calibration.

Table 2 Historic and observed open water floods in the study area

Watercourse	Date	Details
Red Deer River	1901	The 1901 flood was reported to be as large as, or larger than, the 1915 flood; however, no definite indication of its magnitude could be found by Alberta Department of the Environment (AENV).[1]
	1915	"The 1915 open water flood reached a maximum elevation of 684.43 m at the gauge in Drumheller corresponding to an instantaneous discharge of approximately 2,020 m^3/s; The Towns of Midlandvale and Newcastle were severely flooded, while Nacmine, Drumheller, Rosedale and Cambria had minor flooding in the low lying sections near the river".[2]
	1952	"The 1952 flood reached a maximum elevation of 682.51 m at Drumheller gauge corresponding to an instantaneous discharge of approximately 1,360 m^3/s; The flood produced some flooding in Midlandvale and Newcastle".[2]
	1954	"The 1954 flood peak recorded a maximum elevation of 682.75 m (at Drumheller gauge), corresponding to an instantaneous discharge of approximately 1,530 m^3/s; The flood produced some flooding in Midlandvale and Newcastle".[2]
Kneehills Creek	1902	Large flood; however, no definite indication of its magnitude could be found by AENV.[3]
	1931	Bridge at Hesketh (upstream of study reach) was washed out[4] and west approach of Highway 575 Bridge was washed out.[5]
	1948	Highwater level 0.3 m above deck of Range Road 211A Bridge recorded in April 1948.[6]
	1952	Highwater level 0.6 m above deck of Range Road 211A Bridge and damage to east abutment recorded in April 1952.[6] Highwater level 0.3 m below deck of Highway 575 Bridge recorded in April 1952.[5]
Rosebud River	c.1917	Flooding recorded in the Town of Didsbury (located far upstream of the present study area).[7]
	1948	Photos of 23 April 1948 flooding in the Hamlet of Wayne were found in AEP archives.

Notes:

1. Alberta Department of the Environment, Environmental Engineering Support Services, Technical Services Division. 1975. Floodplain Study of the Red Deer River through Drumheller. July 1975.
2. Matrix Solutions Inc. 2007. Drumheller Flood Risk Mapping Study. February 2007.
3. Northwest Hydraulic Consultants. 2008. Carbon Flood Hazard Mapping Study Kneehills Creek. January 2008.
4. Alberta Transportation, Bridge File 08856.
5. Alberta Transportation, Bridge File 13486.
6. Alberta Transportation, Bridge File 13182.
7. Northwest Hydraulic Consultants. 2008. Town of Didsbury Flood Risk Mapping Study. February 2006.

2.2.2 Recent and Recorded Floods

A list of the WSC gauges supporting model creation and calibration as well as their respective periods of record was presented in **Table 1**. The Red Deer River at Drumheller (05CE001) gauge is located downstream of the Kneehills Creek and Michichi Creek confluences and upstream of the Rosebud River and Willow Creek confluences. Kneehills Creek near Drumheller (05CE002) is located approximately 20 km from the Red Deer River confluence. Michichi Creek at Drumheller (05CE020) is located approximately 1 km upstream of the mouth of Michichi Creek. Rosebud River at Redland (05CE005) is located approximately 37 km upstream of the mouth of the Rosebud River. Willow Creek is ungauged. **Table 3** summarizes the recent and recorded open water floods pertinent to the study area.

On the Red Deer River, there are two significant recorded open water flood events with corroborating water level measurements: 2005 and 2013. The flood events which occurred along the four tributaries in April of 2018 ranged from the highest flood on record (Kneehills Creek) to within the 5 highest recorded events (Michichi Creek). As Willow Creek is ungauged, the magnitude of flooding along this creek is unknown. Corresponding highwater marks along each tributary were measured by AEP. **Table 4** lists the recorded flood peak discharges for the large open water floods. Salient information describing each recent and recorded flood event is provided in the sections that follow. **Appendix A** contains a compilation of photo documentation for each of these three flood events.

Table 3 Recent and recorded open water floods observations in the study area

Watercourse	Date	Details
Red Deer River	21 June 2005	Highest recorded event (approximate return period of 20 years) with peak instantaneous discharge of 1,450 m^3/s at WSC gauge for Red Deer River at Drumheller (05CE001).
	23 June 2013	Second highest recorded event (approximate return period of 10 to 20 years) with peak instantaneous discharge of 1,270 m^3/s at WSC gauge for Red Deer River at Drumheller (05CE001).
Kneehills Creek	25 April 2018	Highest recorded event (approximate return period of 50 years) with peak instantaneous discharge of 158 m^3/s at WSC gauge for Kneehills Creek near Drumheller (05CE002).
Michichi Creek	21 April 2018	Within the 5 highest recorded events (approximate return period of 5 to 10 years), with peak instantaneous discharge of 27.3 m^3/s at WSC gauge for Michichi Creek at Drumheller (05CE020).
Rosebud River	23 April 2018	Within the 3 highest recorded events (approximate return period of 20 to 35 years), with peak instantaneous discharge of 160 m^3/s at WSC gauge for Rosebud River at Redland (05CE005).

Table 4 Associated peak discharges published by Water Survey of Canada for recent and recorded open water floods on Red Deer River and its tributaries

Year	Flood peak discharge (m^3/s) on date and time indicated			
	Red Deer River at Drumheller	Kneehills Creek near Drumheller	Michichi Creek at Drumheller	Rosebud River at Redland
2005	1,450 21 June 00:45	n/a	n/a	n/a
2013	1,270 23 Jun 18:30	n/a	n/a	n/a
2018	n/a	158 25 April 00:50	27.3 21 April 21:45	160 23 April 05:06

2005 Flood on Red Deer River

The 2005 event is the largest flood to occur since the continuous systematic collection of gauge data was initiated along the Red Deer River at Drumheller in November 1915. Two rain events, occurring west of Sundre between June 6-9 and June 16-19, produced 100 mm and 150 mm of precipitation, respectively. Flood warnings prompted the construction of 7 km of temporary diking within the Town of Drumheller for the protection of flood prone areas (Matrix, 2007). WSC published a peak instantaneous flow of 1,450 m^3/s at the gauge in Drumheller. AEP collected the location and elevations of highwater marks.

In total, 85 homes were flooded or incurred water or wastewater damage during the 2005 event. This included the following areas: west and east of 9th Street in Nacmine, low lying areas between the hospital and Michichi Creek in north Drumheller, upstream of Rosedale, Starmine area of Rosedale, upstream of Highway 10 Bridge in Cambria, and the entire community of Lehigh (Matrix, 2007).

Several of the permanent dikes were overtopped. Midland dike was overtopped by 0.34 m at 25th Street, 0.25 m at 19th Street, and the highwater level was 0.01 m below the dike at 1st Avenue. The Newcastle dike was overtopped by 0.03 m at Riverside Avenue and 2nd Avenue. The dike along the east side of Michichi Creek was not overtopped and served to protect developments on both sides of Highway 56. In central Drumheller and Riverside, permanent and temporary diking was not overtopped; however, the freeboard was as little as 0.15 m in some areas (Matrix, 2007).

2013 Flood on Red Deer River

Between 19 and 21 of June 2013, southern Alberta experienced heavy rainfall that resulted in rapid and extensive flooding. This resulted in the second largest flood event since the continuous systematic collection of gauge data was initiated along the Red Deer River at Drumheller. As in 2005, flood warnings caused the residents to mobilize and take precautions, which included temporary diking and local evacuations. WSC published a peak instantaneous flow of 1,270 m^3/s at the gauge in Drumheller. AEP collected the location and elevation of highwater marks along the flooded area as well as aerial photography. As reported by a local news source, "water spilled the banks in a few areas throughout the valley, with most damage localized to Lehigh" (The Drumheller Mail, 2013).

2018 Floods on Tributaries

Spring conditions in 2018 caused flooding along the Red Deer River tributaries at Drumheller. Cold temperatures and snowfall in late-March and early-April led to an above-average late-winter snow pack in the Red Deer River basin (Drumheller Online, 2018). A sudden increase in temperatures, which occurred between April 19 and 20, caused rapid snowmelt and high water levels along Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek. A mandatory evacuation and state of emergency was declared for the community of Wayne and all residents along Highway 10X near the Rosebud River.

2.3 Ice Affected Floods

Ice affected flooding can occur in the study area when rapid snowmelt runoff occurs in the spring. Some of the significant floods identified by Town of Drumheller (2020), such as the events in 1948, 1997, and 2018, have occurred in April when ice was present in the channels.

The 1948 event is the only one reported to involve an ice jam on the Red Deer River. Alberta Department of the Environment (1975) reported that: *"The location of the jam was at East Coulee just upstream from the existing bridge. Apparently, ice became hung up on the bridge causing minor flooding. The bridge causing the problem was dynamited and the ice jam broke up almost immediately. Since that time, no further major ice jams have occurred."* The mechanism of the 1948 ice jam event was further clarified through conversations between AEP and Town of Drumheller flood management personnel. During spring breakup along the Red Deer River in 1948, ice flowing freely on the river damaged the East Coulee bridge, causing it to collapse into the river. When the bridge collapsed, it arrested the flowing ice and caused an ice jam to form. The bridge was subsequently dynamited, and the ice jam released.

Matrix (2007) characterized the 1997 flood arising from a combination of very high early spring flows, low Red Deer River levels and the sudden release of an ice jam resulting in extraordinarily high velocities in the Rosebud River upstream of its mouth.

The magnitude of ice affected floods that have been observed and recorded are less severe than documented open water floods. Therefore, the current study does not examine ice jam flood hazards in further detail.

3 AVAILABLE DATA

Data pertinent to the development of a calibrated hydraulic model include: basin hydrology, current high-resolution terrain data representing the floodplain, survey data, existing hydraulic models, highwater marks, gauge data and rating curves, and flood photographs. The data available for this study are summarized below.

3.1 Hydrology Summary

Basin hydrology, documented in ***Open Water Hydrology Assessment*** provided under separate cover (NHC, 2020a), determined estimates of flood frequencies for a range of return periods, from the 2-year up to the 1000-year at the following locations:

- Red Deer River above Kneehills Creek
- Red Deer River above Michichi Creek
- Red Deer River at Drumheller (WSC Station No 05CE001)
- Red Deer River below Rosebud River
- Red Deer River below Willow Creek
- Kneehills Creek near Drumheller (WSC Station No. 05CE002)
- Michichi Creek at Drumheller (WSC Station No. 05CE020)
- Rosebud River at the mouth
- Willow Creek at the mouth

The hydrology assessment recommended that the flood frequency estimates for WSC Station 05CE001 be used for all the ungauged sites on the Red Deer River, including Red Deer River above Kneehills Creek, above Michichi Creek, below Rosebud River and below Willow Creek. Flood frequency estimates for the study sites on Kneehills Creek, Michichi Creek and the Rosebud River were based on measured peak discharges on these streams, while regional analysis was performed to develop flood frequency estimates for Willow Creek at the mouth.

Table 5 summarizes the flood frequency discharges for the 2- to 1000-year floods, with associated annual probabilities of exceedance, for the Red Deer River and its tributaries.

Table 5 Flood frequency discharge estimates for the Red Deer River and its tributaries

Return Period (Years)	Probability of Exceedance in Any Given Year (%)	Flood Frequency Discharge (m^3/s)					
		Red Deer River at Drumheller(1) (05CE001)		Kneehills Creek near Drumheller (05CE002)	Michichi Creek at Drumheller (05CE020)	Rosebud River at the mouth	Willow Creek at the mouth
		Naturalized	Regulated				
1,000	0.10	3,820	3,820(2)	286	103	641	66
750	0.13	3,600	3,580(3)	274	99	586	62
500	0.20	3,300	3,170(3)	256	93	515	58
350	0.29	3,050	2,900(3)	241	87	458	54
200	0.50	2,680	2,450(3)	216	79	377	49
100	1.0	2,260	1,850(3)	186	68	292	41
75	1.3	2,090	1,670(3)	173	64	260	40
50	2.0	1,870	1,430(3)	155	58	220	35
35	2.9	1,690	1,240(3)	140	52	188	31
20	5.0	1,410	869(4)	116	44	145	26
10	10	1,100	702(4)	87	33	99	19
5	20	807	542(4)	58	23	63	13
2	50	448	330(4)	22	10	27	5

Notes:

1. The estimates are applicable for Red Deer River at Drumheller (WSC Station 05CE001), above Kneehills Creek, above Michichi Creek, below Rosebud River, and below Willow Creek.
2. The 1000-year naturalized peak discharge has been adopted as the estimate for the regulated flow condition.
3. The adopted value is from the synthetic flood hydrograph routing.
4. The adopted value is from the flood frequency curve for the regulated peak discharges of Red Deer River at Drumheller.

3.2 Digital Terrain Model Data

A digital terrain model (DTM) based on LiDAR data was supplied by AEP for this study. The LiDAR data were collected by Airborne Imaging in May 2018 (Airborne Imaging, 2018). A complete description of the digital terrain model data, including a comparison to ground survey data, is provided in the ***Survey and Base Data Collection Report*** under separate cover (NHC, 2020b).

3.3 Survey Data

The development of the hydraulic model required extensive surveys of the river cross sections, bridges, and flood control structures. Control points were also established to validate the DTM and facilitate the extension of the river cross sections through the overbank beyond the expected flood inundation limits. The majority of the survey program was conducted between July and September of 2018, with some additional surveying conducted in January of 2019, as is documented in the ***Survey and Base Data Collection Report*** submitted as part of this study.

A total of 444 cross sections were surveyed: 210 on the Red Deer River, 60 on Kneehills Creek, 41 on Michichi Creek, 120 on Rosebud River, and 13 on Willow Creek. The cross section locations were selected to capture changes in key hydraulic parameters such as the width and depth and at the location of islands. The cross section spacing varied based on the size of the water body, with the mean spacing being 269 m on the Red Deer River, 132 m on Kneehills Creek, 129 m on Michichi Creek, 89 m on the Rosebud River, and 223 m on Willow Creek.

Cross sections were surveyed immediately upstream and downstream of bridges and culverts to facilitate the calculation of the energy losses and water surface elevations through the structures and, in high flow conditions, over the embankments. Additional cross sections were surveyed one channel width upstream and downstream of these cross sections. Model bridge geometry was derived from available bridge design drawings and survey data. The profile of the approaches and embankments was extracted from the DTM.

3.4 Existing Hydraulic Models

Several hydraulic models exist for the Drumheller area. AENV carried out the Floodplain Study of the Red Deer River through Drumheller in 1975. This was followed by the Drumheller Floodplain Study carried out by AENV in 1984. A recent hydraulic model was developed as part of the 2007 Drumheller Flood Risk Mapping Study. This model used survey data from the AENV 1984 study, including 127 cross sections along the Red Deer River, 30 along Michichi Creek, and 11 along Rosebud River.

3.5 Highwater Marks

Highwater mark observations provide documentation of the peak water levels that occurred at a given location for a particular flood of interest. These data are used for hydraulic model calibration and validation by comparing simulated water levels to the observed highwater mark elevations along the study reach. For this study, highwater marks were provided by AEP. Highwater marks are available on the Red Deer River for the floods which occurred in 2005 and 2013. Highwater marks are available for 2018 floods along Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek. All of these highwater marks occurred during open water flood events.

The location of the available highwater mark data are depicted in **Figure 2**. **Table 6** provides a summary of the open water highwater mark data available for each flood event.

Table 6 Summary of open water highwater marks

Location Name	Highwater Mark ID	River Station (m)	Event Date	Highwater Mark Elevation (m)
Red Deer River				
Nacmine (NW-8-29-20-W4)	05-RD-31	46451	21-Jun-05	685.036
Nacmine (NW-8-29-20-W4)	05-RD-31	46451	21-Jun-05	685.010
Newcastle CPR bridge (SE-9-29-20-W4)	05-RD-32	44443	21-Jun-05	684.440
Newcastle (SW-10-29-20-W4)	05-RD-33	43324	21-Jun-05	684.083
Newcastle park (SE-10-29-20-W4)	05-RD-34	41983	21-Jun-05	683.480
Drumheller WSC gauge at Hwy 9 (NE-11-29-20-W4)	05-RD-35	40804	21-Jun-05	682.820
Drumheller near old Hospital (NW-1-29-20-W4)	05-RD-36	39129	21-Jun-05	681.863
Composite High School (SE-1-29-20-W4)	05-RD-37	37819	21-Jun-05	681.510
Rosedale Bridge Crossing (SW-28-28-19-W4)	05-RD-38a	32484	21-Jun-05	680.070
Rosedale Bridge Crossing (SW-28-28-19-W4)	05-RD-38b	32484	21-Jun-05	679.930
Rosedale Swinging Bridge (SE-28-28-19-W4)	05-RD-39a	31198	21-Jun-05	679.440
Rosedale Swinging Bridge (SE-28-28-19-W4)	05-RD-39b	31198	21-Jun-05	679.370
Nacmine (5th St and 3rd Ave)	2013-RD-31a	46451	23-Jun-13	-
Newcastle CPR bridge	2013-RD-32a	44443	23-Jun-13	683.464
Newcastle Dr and Riverside Ave	2013-RD-33a	43324	23-Jun-13	-
Newcastle Park [Ball diamond #2]	2013-RD-34a	41983	23-Jun-13	683.101
Drumheller, WSC gauge at Hwy 9	2013-RD-35A-a	40832	23-Jun-13	-
Hwy 9 Bridge, Drumheller	2013-RD-35A-a-wl	40832	23-Jun-13	-
Hwy 9 Bridge, Drumheller	2013-RD-35B-a	40832	23-Jun-13	682.320
Riverside Dr across from Rotary Pleasure Pathways sign	2013-RD-36a	39129	23-Jun-13	-
Riverside Dr, Secondary School	2013-RD-37a	37819	23-Jun-13	681.129
Rosedale Bridge Crossing	2013-RD-38a	32484	23-Jun-13	679.188
Rosedale Swinging Bridge	2013-RD-39a	31198	23-Jun-13	678.822
Rosedale Swinging Bridge	2013-RD-39b	31207	23-Jun-13	678.861
Kneehills Creek				
Highway 575 Bridge	KH-1-HWM1	1498	25-Apr-18	688.437

Table 6 Summary of open water highwater marks (continued)

Location Name	Highwater Mark ID	River Station (m)	Event Date	Highwater Mark Elevation (m)
Highway 575 Bridge	KH-1-HWM2	1581	25-Apr-18	688.732
Highway 575 Bridge	KH-1-HWM2	1581	25-Apr-18	688.731
Range Road 211A	KH-2-HWM1	3013	25-Apr-18	691.052
Range Road 211A	KH-2-HWM2	3013	25-Apr-18	690.878
Range Road 211A	KH-2-HWM2	3013	25-Apr-18	690.886
House located on right bank of Kneehills Creek, u/s of Highway 575 Bridge	KH-3-HWM1	1854	25-Apr-18	689.273
House located on right bank of Kneehills Creek, u/s of Highway 575 Bridge	KH-3-HWM3	2010	25-Apr-18	689.489
House located on right bank of Kneehills Creek, u/s of Highway 575 Bridge	KH-3-HWM2	1929	25-Apr-18	689.353
Michichi Creek				
North Dino Trail Bridge	Mich-1-HWM1	987	21-Apr-18	682.225
North Dino Trail Bridge	Mich-1-HWM2	990	21-Apr-18	682.263
North Dino Trail Bridge	Mich-1-HWM3	987	21-Apr-18	682.220
Highway 56 Culvert	Mich-2-HWM1	1364	21-Apr-18	682.970
Rosebud River				
Highway 10/56, most d/s bridge on Rosebud River	Rose-0.5-HWM1	519	23-Apr-18	679.529
Highway 10/56, most d/s bridge on Rosebud River	Rose-0.5-HWM2	526	23-Apr-18	679.458
Highway 10/56, most d/s bridge on Rosebud River	Rose-0.5-HWM2	526	23-Apr-18	679.629
Highway 10/56, most d/s bridge on Rosebud River	Rose-0.5-HWM3	535	23-Apr-18	679.402
11 Bridges Campground, u/s of Highway 10/56 Bridge and d/s of camp office	Rose-0.6-HWM1	644	23-Apr-18	679.816
11 Bridges Campground, farther u/s of Highway 10/56 Bridge and camp office	Rose-0.7-HWM1	826	23-Apr-18	679.952
Highway 10X Bridge No. 1	Rose-1-HWM1	1197	23-Apr-18	680.839
Highway 10X Bridge No. 1	Rose-1-HWM2	1110	23-Apr-18	680.396
Highway 10X Bridge No. 2	Rose-2-HWM3	2106	23-Apr-18	682.662

Table 6 Summary of open water highwater marks (continued)

Location Name	Highwater Mark ID	River Station (m)	Event Date	Highwater Mark Elevation (m)
Highway 10X Bridge No. 2	Rose-2-HWM2	2124	23-Apr-18	682.667
Highway 10X Bridge No. 2	Rose-2-HWM1	2158	23-Apr-18	683.080
Highway 10X Bridge No. 3	Rose-3-HWM1	4526	23-Apr-18	688.163
Highway 10X Bridge No. 3	Rose-3-HWM2	4508	23-Apr-18	688.115
Highway 10X Bridge No. 5	Rose-5-HWM1	5464	23-Apr-18	689.806
Highway 10X Bridge No. 5	Rose-5-HWM1	5464	23-Apr-18	689.807
Highway 10X Bridge No. 6	Rose-6-HWM1	5867	23-Apr-18	690.420
Highway 10X Bridge No. 6	Rose-6-HWM1	5867	23-Apr-18	690.421
Highway 10X Bridge No. 7	Rose-7-HWM1	6398	23-Apr-18	691.335
Highway 10X Bridge No. 7	Rose-7-HWM1	6398	23-Apr-18	691.329
Highway 10X Bridge No. 7	Rose-7-HWM2	6367	23-Apr-18	691.133
Highway 10X Bridge No. 8	Rose-8-HWM1	7312	23-Apr-18	692.878
Highway 10X Bridge No. 8	Rose-8-HWM2	7314	23-Apr-18	693.007
Highway 10X Bridge No. 8	Rose-8-HWM2	7314	23-Apr-18	693.011
Highway 10X Bridge No. 9	Rose-9-HWM1	7932	23-Apr-18	693.987
Highway 10X Bridge No. 9	Rose-9-HWM2	7981	23-Apr-18	694.268
Last Chance Saloon	Rose-9.5-HWM1	8564	23-Apr-18	695.181
Last Chance Saloon	Rose-9.5-HWM1	8564	23-Apr-18	695.184
Last Chance Saloon	Rose-9.5-HWM4	8567	23-Apr-18	695.119
Last Chance Saloon	Rose-9.5-HWM2	8541	23-Apr-18	695.127
Last Chance Saloon	Rose-9.5-HWM3	8477	23-Apr-18	695.060
Highway 10X Bridge No. 10	Rose-10-HWM1	8687	23-Apr-18	697.202
Highway 10X Bridge No. 10	Rose-10-HWM2	8717	23-Apr-18	695.736
Highway 10X Bridge No. 10	Rose-10-HWM3	8795	23-Apr-18	695.795
Highway 10X Bridge No. 11	Rose-11-HWM1	9576	23-Apr-18	697.217
Highway 10X Bridge No. 11	Rose-11-HWM2	9553	23-Apr-18	697.130
Willow Creek				
Highway 10 Bridge	Will-1-HWM1	838	Apr-18	676.661
Highway 10 Bridge	Will-1-HWM2	846	Apr-18	676.860
Highway 10 Bridge	Will-1-HWM3	831	Apr-18	676.769
Highway 10 Bridge	Will-1-HWM4	841	Apr-18	676.789
Highway 10 Bridge	Will-1-HWM5	873	Apr-18	677.133

3.6 Gauge Data and Rating Curves

Water level (stage) records and rating curves from WSC hydrometric gauging stations in and near the study area were obtained and used to support creation and calibration of the hydraulic model. **Table 1** (in **Section 2.2.1**) lists the gauging stations for which data were examined and their respective periods of record.

3.7 Flood Imagery

Details of available aerial orthoimagery captured near the 2005 Red Deer River flood peak and provided by AEP are provided in **Table 7**.

Table 7 Available flood imagery from Alberta Environment and Parks

Dates	Area	Details	Comment
20-Jun-2005 to 22-June 2005	Town of Drumheller, Kneehill County, Starland County, Wheatland County, Special Area No. 2	Resolution: 0.25 m Number of tiles: 6 Products: orthorectified panchromatic (BW) aerial imagery	Daily Average Flow at Drumheller: 20-Jun-2005 = 1040 m^3/s 21-Jun-2005 = 1260 m^3/s 22-Jun-2005 = 826 m^3/s

3.8 Planned Flood Control Structures

The Town of Drumheller has planned flood control structure upgrades which are to be constructed beginning in 2022. Crest alignment and elevation profiles for seven proposed flood control structures were provided to NHC by AEP on 24 September 2021. The Town of Drumheller provided the dike details to AEP, via their consultants, between 20 July 2021 and 13 August 2021. Although the proposed upgrades were not complete at the time of this report, it is expected that they will be completed in the near future, so it was deemed appropriate to include their hydraulic impact on the flood inundation maps and water surface profiles in this report. This will ensure the information are relevant when the upgrades are complete and for future planning. It is worth noting that if flood control structure plans change, this report may not reflect accurate future conditions.

4 RIVER AND VALLEY FEATURES

4.1 General Description

Within the study area, the Red Deer River flows through the Western Alberta Plains physiographic region (Government of Alberta and University of Alberta, 1969). The Red Deer River valley walls are comprised of eroded shales and sandstones (Edmonton Formation) overlain by till and lacustrine deposits, and often referred to as "Badlands." In this region, the Red Deer River is partially entrenched and flows through a deep, stream-cut valley. Lateral development is confined by low terraces, alluvial fans, or valley walls (Kellerhals et al, 1972).

The main population centre consists of the following neighbourhoods located within the Town of Drumheller: North Drumheller, Central Drumheller, and Riverside. This region is located on a continuous low terrace (Kellerhals et al, 1972). The Town of Drumheller also includes the following neighbourhoods: Nacmine, Midland, Newcastle, Rosedale, Wayne, Cambria, Lehigh, and East Coulee. Several other localities or hamlets exist within the study area but outside of the Town of Drumheller, including: Dunphy (Kneehill County), Kirkpatrick (Kneehill County), and Dorothy (Special Area No. 2).

4.2 Red Deer River

4.2.1 Channel Characteristics

The study area includes 56.1 km of the Red Deer River, which is represented by five sub-reaches that are deemed to be morphologically similar. The area includes the following Town of Drumheller neighborhoods situated along the Red Deer River: Nacmine, Midland, Newcastle, North Drumheller, Central Drumheller, Riverside, Rosedale, Cambria, Lehigh, and East Coulee. The area also includes the locality of Kirkpatrick (Kneehill County) and the Hamlet of Dorothy (Special Area No. 2), located near the upstream and downstream boundary of the Red Deer River, respectively. The Red Deer River channel follows a sinuous meander pattern with occasional islands and side bars. The channel shape is partly entrenched and confined by the valley. The channel bed material consists of shallow gravel over easily erodible shale; bank materials consist of gravel overlain by silt, silt and sand, and easily erodible rock (Kellerhals et al, 1972). The reach-averaged channel slope based on the bathymetric survey is 0.00036 m/m. Based on 2-year peak flow conditions, the average top width through the Red Deer River is approximately 120 m and the mean cross section depth is approximately 2.8 m.

4.2.2 Floodplain Characteristics

The floodplain of the Red Deer River is generally fragmented, narrow, and covered in shrubby vegetation. There are two levels of terraces within a deep, stream cut valley exhibiting Badland topography. The terrain of the surrounding valley is mainly cultivated plain among lacustrine and till deposits (Kellerhals et al, 1972).

4.3 Significant Tributaries

The four modelled tributaries include: Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek.

4.3.1 Kneehills Creek

The study area includes the lower 7.9 km of Kneehills Creek up to the confluence with the Red Deer River. Kneehill County localities of Dunphy and Kirkpatrick exist along this reach of Kneehills Creek. The channel pattern of Kneehills Creek consists of irregular meanders with a pool and riffle sequence. There is presence of beaver activity as evidenced by beaver dams. The channel shape is partly entrenched and confined, with lateral stability described as moderately unstable. The channel bed material consists of predominantly gravel which form notable alternating diagonal bars; bank materials consist of silt, sand, gravel, and easily erodible rock (Kellerhals et al, 1972). The reach-averaged channel slope based on the bathymetric survey is 0.0028 m/m. Based on 2-year peak flow conditions, the average top width of Kneehills Creek is approximately 20 m and the mean cross section depth is approximately 1.5 m.

The floodplain of Kneehills Creek is generally covered in shrubs and is not cultivated. There is one continuous level of terrace within a stream cut valley with almost bare valley walls. The terrain of the surrounding valley is mainly cultivated till plain (Kellerhals et al, 1972).

4.3.2 Michichi Creek

The study area includes the lower 5.3 km of Michichi Creek up to the confluence with the Red Deer River. The Town of Drumheller neighborhood of North Drumheller is situated near this confluence. The channel pattern of the upper 3 km of Michichi Creek consists of irregular meanders. The floodplain in this portion is generally vegetated and does not appear to be cultivated. The lower 2 km of Michichi Creek has previously been channelized. The lower 1 km of Michichi Creek was channelized in 1951, and a combination of earthen dikes and timber retaining walls were constructed on both sides of the channel. In addition, the lower several hundred meters of the creek was channelized as part of Dike B construction in 2001. As a result, the confined channel is incised and has experienced significant degradation. The channel bed material consists of predominantly gravel, with some boulders; bank materials consist of silt and shale. Rock riprap has been installed to provide erosion protection at bends along the lower channelized portion of the reach. Dike side slopes are generally well vegetated with grasses and shrubs (Matrix, 2007). The reach-average channel slope based on the bathymetric survey is 0.0024 m/m. Based on 2-year peak flow conditions, the average top width of Michichi Creek is approximately 10 m and the mean cross section depth is approximately 1.2 m.

4.3.3 Rosebud River

The study area includes the lower 10.7 km of Rosebud River up to the confluence with the Red Deer River. The Town of Drumheller neighborhoods of Wayne and Rosedale exist along this reach of the Rosebud River. Rosebud River follows an irregular channel pattern, with tortuous meanders and a pool and riffle sequence. The channel shape is partly entrenched and frequently confined, with lateral stability described as moderately unstable. The channel bed material consists of predominantly gravel which form notable alternating diagonal bars; bank materials consist of silt, sand, gravel, and moderately erodible rock (Kellerhals et al, 1972). The reach-average channel slope based on the bathymetric survey is 0.0017 m/m. Based on 2-year peak flow conditions, the average top width of Kneehills Creek is approximately 19 m and the mean cross section depth is approximately 1.5 m.

The Rosebud River floodplain is mainly cultivated. There are several continuous levels of terrace within a stream cut valley, with occasional slumps and grass covered valley walls. The terrain of the surrounding valley is mainly cultivated till plain (Kellerhals et al, 1972).

4.3.4 Willow Creek

The study area includes the lower 3.0 km of Willow Creek up to the confluence with the Red Deer River. The channel pattern of Willow Creek consists of irregular meanders. The channel appears to be partly entrenched and confined within the valley. Based on the survey, the channel bed material consists of predominantly gravel and cobbles; bank materials consist of silt, sand, gravel, and easily erodible rock. The reach-average channel slope based on the bathymetric survey is 0.0054 m/m. Based on 2-year peak flow conditions, the average top width of Willow Creek is approximately 8.3 m and the mean cross section depth is approximately 0.5 m. The floodplain of Willow Creek is well vegetated with grasses, shrubs, and occasional trees.

4.4 Hydraulic Structures

The study area of the Drumheller River Hazard Study contains a total of 35 bridges and one culvert. The descriptions and locations with respect to the established river stationing of the hydraulic structures are provided in **Table 8**. Detailed information concerning the bridge configurations can be found in Appendix C of the ***Survey and Base Data Collection Report*** provided under separate cover.

Table 8 Hydraulic structures located within the study area

Reach	Description	River Station (m)	Structure Type
Red Deer River	Newcastle Mine Railway Bridge	44,430	Railway Bridge
	Highway 56 Bridge at Drumheller	40,815	Highway Bridge
	Roper Road Bridge at Rosedale	32,502	Road Bridge
	Star Mine Suspension Bridge	31,204	Pedestrian Bridge
	Abandoned Piers (Railway Bridge)	28,264	Abandoned Piers
	Abandoned Piers (Highway Bridge)	28,204	Abandoned Piers
	Highway 10 Bridge 8 km SE of Drumheller	27,931	Highway Bridge
	Atlas Coal Mine Railway Bridge	16,778	Railway Bridge
	Highway 10 Bridge at East Coulee	16,259	Highway Bridge

Table 8 Hydraulic structures located within the study area (continued)

Reach	Description	River Station (m)	Structure Type
Red Deer River (continued)	Highway 848 Bridge at Dorothy	3,897	Highway Bridge
Kneehills Creek	Range Road 211A Bridge	3,017	Road Bridge
	Highway 575 Bridge near Nacmine	1,591	Highway Bridge
Michichi Creek	Local Road (Unnamed Road) Bridge	2,583	Road Bridge
	Private Road Access Bridge	2,435	Private Bridge
	Highway 9 over Michichi Creek at Drumheller	1,326	Culvert
	Highway 838 Bridge in Drumheller	1,009	Highway Bridge
Rosebud River	Abandoned Railway Bridge 9	9,609	Railway Bridge
	Highway 10X (Historical Bridge No. 11)	9,562	Highway Bridge
	Highway 10X (Historical Bridge No. 10)	8,697	Highway Bridge
	Abandoned Railway Bridge 8	8,668	Railway Bridge
	Abandoned Railway Bridge 7	8,069	Railway Bridge
	Highway 10X (Historical Bridge No. 9)	7,947	Highway Bridge
	Highway 10X (Historical Bridge No. 8)	7,315	Highway Bridge
	Abandoned Railway Bridge 6	7,233	Railway Bridge
	Abandoned Railway Bridge 5	6,458	Railway Bridge
	Highway 10X (Historical Bridge No. 7)	6,370	Highway Bridge
	Abandoned Railway Bridge 4	5,892	Railway Bridge
	Highway 10X (Historical Bridge No. 6)	5,863	Highway Bridge
	Highway 10X (Historical Bridge No. 5)	5,461	Highway Bridge
	Highway 10X (Historical Bridge No. 4)	4,988	Highway Bridge
	Highway 10X (Historical Bridge No. 3)	4,518	Highway Bridge
	Abandoned Railway Bridge 3	4,490	Railway Bridge
	Abandoned Railway Bridge 2	2,245	Railway Bridge
	Highway 10X (Historical Bridge No. 2)	2,125	Highway Bridge
	Highway 10X (Historical Bridge No. 1)	1,140	Highway Bridge
	Highway 10 Bridge at Rosedale	542	Highway Bridge
	Abandoned Railway Bridge 1	340	Railway Bridge
Willow Creek	Highway 10 Bridge 10.5 km NW of East Coulee	856	Highway Bridge

4.5 Flood Control Structures

At the time of survey in 2018, there were seven dedicated flood control structures (berms and dikes) within the study reach (**Table 9**). All of these are located along the Red Deer River, with one (Dike B) also extending into Michichi Creek. The locations and extents of surveyed flood control structures are illustrated in **Figure 3**. Profiles of the crest elevation and cross sections at representative locations were surveyed along the flood control structures. Where the dikes included concrete barriers above the earthen embankment, both the top of the barrier and the crest of the earthen embankment were surveyed. Detailed information concerning the flood control structures can be found in Appendix D of the ***Survey and Base Data Collection Report*** provided under separate cover.

Table 9 Flood control structure summary

Name and Description	Owner	Stream	River Station (m)		Crest Length (m)
			Start	End	
Midland Dike North side of Red Deer River, adjacent to Midland	AEP	Red Deer River	44,420	42,942	1,610
Newcastle Dike South side of Red Deer River, adjacent to Newcastle	AEP	Red Deer River	43,452	41,856	1,541
Hospital Dike North side of Red Deer River, adjacent to Drumheller Heath Centre	AHS	Red Deer River	42,341	41,734	511
Dike B East side of Michichi Creek and north side of Red Deer River, west of Bridge Street (Highway 56)	AEP	Red Deer River	41,346	40,844	962
	AEP	Michichi Creek	535	0	
Dike C North side of Red Deer River, east of Bridge Street (Highway 56)	AEP	Red Deer River	40,796	40,528	326
Dike D South side of Red Deer River from the Aquaplex to 5 Street E, north of 4 Avenue E	AEP	Red Deer River	40,712	39,549	1,063
East Coulee Dike North side of Red Deer River between 9 Street and 4 Street in East Coulee	AEP	Red Deer River	18,440	17,640	902

4.6 Other Features

The majority of major infrastructure and populated areas within the study area are located in North Drumheller, Central Drumheller, and Riverside. Other features of note within the study area are highlighted below.

- Highways 838, 575, and 10, as well as the railway, parallel the Red Deer River, and in some locations, the embankments and side slope armoring encroach on the river channel. These linear features also behave like dikes during high flow events.
- A 500 m long reach of riprap erosion protection located adjacent to a 500 m long reach of river engineering training works are present along the left bank of the Red Deer River between the communities of Lehigh and East Coulee.
- Range Road 211A and an old railway line parallel Kneehills Creek and in some locations, the embankments and side slope armoring encroach on the river channel. These linear features also behave like dikes during high flow events.
- Highway 576 and a local road parallel Michichi Creek. These linear features behave like dikes during high flow events.
- As mentioned in **Section 4.3.2**, the lower 2 km of Michichi Creek has been channelized and a combination of earthen dikes and timber retaining walls exist on both sides of the channel.
- Highway 10X and an old railway line parallel Rosebud River and in some locations, the embankments and side slope armoring encroach on the river channel. These linear features also behave like dikes during high flow events and heavily influence hydraulics.
- The steep and high valley walls along the Red Deer River and the four tributaries encroach on the channel in some locations.

5 MODEL CONSTRUCTION

5.1 HEC-RAS Program

The U.S. Army Corps of Engineers *Hydrologic Engineering Center-River Analysis System* (HEC-RAS) computer program (Version 5.0.6, November 2018) was used to calculate flood levels along the study reach. The basic inputs required by HEC-RAS are a series of cross sections with known distances between sections, roughness coefficients for the channel and overbank areas at each cross section, inflow discharge at the upstream limits of each reach, and a prescribed water level at the downstream outflow boundary.

5.1.1 Theoretical Aspects

HEC-RAS can perform one-dimensional (1D), two-dimensional (2D), or combined 1D and 2D hydraulic calculations for a network of channels and hydraulic structures. For this study, a 1D model was constructed to calculate water surface profiles for steady state gradually varied flow. The computational procedure for steady flow calculations are based on the solution of the 1D energy equation. Energy losses between river sections are calculated as friction losses (using Manning's equation) and expansion/contraction losses. The momentum equation is used by the model where rapidly varied flow conditions arise, for the hydraulics through bridges, and for evaluating water surface profiles at stream junctions. The analytical approach employed by HEC-RAS has the following assumptions and potential limitations:

- Flow is gradually varied and boundary friction losses between cross sections are estimated by Manning's equation using section-average parameters.
- The geometry is assumed to be fixed; therefore, changes in the channel and floodplain geometry that may occur during a flood are not accounted for.
- Each model cross section is apportioned into three separate conveyance components representing the main channel, left overbank, and right overbank; the water level is assumed to be constant across all three conveyance components.
- The flow is one-dimensional.

5.1.2 General Model Setup

Geometric Layout

The following describes the approach for developing the key components comprising the geometric layout of the model.

- Channel centrelines were created along the middle of the main channel of the Red Deer River and its four tributaries: Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek. The centreline was digitized using GIS tools and visual interpretation of the DTM and aerial imagery. A single continuous centreline was created to represent each individual model reach.

- The Red Deer River is represented by five sub-reaches that are named in relation to the modelled tributaries in this study. These sub-reaches, which are separated by modelled junctions, have the following names: *Abv Kneehills*, *Blw Kneehills*, *Blw Michichi, Blw Rosebud,* and *Blw Willow*.
- Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek are represented by single channel centerlines and denoted by the reach name *Main*.

- Model cross section lines were drawn at each surveyed river cross section. The cross sections were aligned perpendicular to the flow across the main channel at the river bed and bank survey point locations. Cross section elevation values from the survey were projected onto these cross section lines. The cross sections were then extended into the left and right overbank (floodplain) areas. The overbank portions were projected beyond the 1000-year flood inundation extents, except where impractical to do so based on adjacent cross sections and local terrain. Elevation data in the overbank areas was extracted from the supplied DTM along the extended cross section lines.
- The location of the left and right banks (bank stations) were determined from the cross section survey data and examination of the DTM. The channel "banks" demarcate the extent of the left overbank, main channel, and right overbank portions of the model cross section.
- Overbank and main channel flow path lines were digitized to represent the length of the flow path in the main channel and left and right overbanks. These lengths are used to compute energy losses between cross sections within in the left overbank, main channel, and right overbank.

A schematic model layout, as shown in **Figure 4**, includes the reach names described above, as well as the locations of junctions. The sub-reaches of the HEC-RAS model are summarized in **Table 10.**

Table 10 Summary of Model Sub-Reaches

Stream Name	HEC-RAS Model Sub-Reach	Upstream River Station (m)	Flow Zone Name
Red Deer	Abv Kneehills	56,139	Red Deer River above Kneehills Creek
	Blw Kneehills	51,563	Red Deer River below Kneehills Creek
	Blw Michichi	41,263	Red Deer River below Michichi Creek
	Blw Rosebud	32,344	Red Deer River below Rosebud River
	Blw Willow	22,842	Red Deer River below Willow Creek
Kneehills	Main	7,869	Kneehills Creek
Michichi	Main	5,335	Michichi Creek
Rosebud	Main	10,702	Rosebud River
Willow Cr	Main	2,970	Willow Creek

Channel and Overbank Roughness

Manning's roughness values were used to represent roughness in the modelled reaches. Roughness values were varied horizontally across each cross section, to represent changes in river and floodplain characteristics. A minimum of three (one channel and two overbank) roughness values were used within each cross section. The number of roughness values used was dependent on the complexity of the channel and the presence of distinct features, such as bars and islands.

Manning's roughness is used to account for an array of energy losses that may vary with respect to discharge. Due to the complexity and length of the model and the limited spatial distribution of calibration data, roughness values were assumed to be constant with discharge. As discussed in **Section 4.3.4**, at the locations where rating curve data are available, using a single roughness value for all discharges provided reasonable results. Roughness values were set for the overbank areas based on inspection of the land cover information deduced from survey photographs, aerial imagery, and the DTM.

Expansion and Contraction Coefficients

The effects of abrupt flow expansions or contractions between successive cross sections are accounted for in HEC-RAS using coefficients, which range from 0.10 for gradual transitions to 0.80 for abrupt transitions (Brunner, 2016). The default values of 0.1 and 0.3 (for expansion and contraction, respectively) were applied at each cross section throughout the hydraulic model. Expansion and contraction coefficient values were increased to 0.3 and 0.5, respectively, for cross sections located near bridges where the abutments are expected to cause a more rapid flow transition.

Boundary Conditions

Boundary conditions are required at the inflow and outflow boundaries of the model and at river junctions (i.e. confluences). The model junctions divide the streams into sub-reaches; therefore, a discharge is required by the model at the upstream end of each sub-reach.

Each junction within the model domain represents internal boundaries through which the discharge of the upstream sub-reaches pass into the downstream sub-reach. The momentum equation, which calculates the energy losses through the junction using the internal angle between the upstream sub-reaches, was selected as to calculate the hydraulics at the junctions.

A normal depth water level approximation was assigned as the boundary condition at the downstream boundary of the Red Deer River. The normal depth slope was 0.00050 m/m which was determined from the reach-averaged energy grade line slope near the downstream limit of the study reach.

5.2 Geometric Database

The geometric database consists of a geodatabase and ArcMap project file which contains all the components of the HEC-RAS model geometry. This information includes associated points, polylines, and polygons representing model cross sections, reach lengths, channel and overbank centrelines, bank stations and banklines, ineffective flow area stations and polygons, bridges, culverts, and flood control structures. The following sections describe these components and the methods taken to develop model geometry. The resulting geometric database is provided as part of the electronic deliverables of the study.

5.2.1 Cross Section Data

Cross section alignments were established following the general path of the topographic and hydrographic survey points for each of the surveyed cross sections (refer to **Section 3.3**), as well as the anticipated flow path along the left and right overbanks to an elevation beyond the anticipated 1,000-year flood level. As a result, cross section elevations were derived from a combination of topographic and hydrographic survey data, as well as DTM data. The steps taken to generate cross section data were as follows:

1. The cross section alignments were defined as described above.
2. Two distinct station-elevation data sets were created for each cross section.
    a. The first data set was created from topographic and hydrographic survey data projected onto the cross section line.
    b. The second data set was created from the DTM by extracting elevation values along the cross section lines.
3. The survey-based and DTM-based cross sections were combined and the number of elevation points were reduced within the overbanks so as not to exceed 500 points per cross section.

Distances between each cross section along the channel centerline and along the central flow path of the left and right overbank areas were established within the HEC-RAS model. Cross section details based on NHC's surveys are provided in **Appendix B**.

5.2.2 Bridges, Culverts and Weirs

The modelled reach includes 35 bridge crossings and one culvert. **Table 8** provides a summary of bridges and culverts included in the analysis. Key design information which was incorporated into the model is tabulated in **Appendix B** (**Table B-2 and Table B-3**). Culverts in the study area that convey only local drainage are not relevant to the hydraulic computations and were therefore not represented in the model.

The alignment and location of each bridge structure were established based on the survey data and available design drawings. Key components include abutments, high and low chord defining the bridge deck and superstructure, and the arrangement, shape and dimensions of piers. The bridge cross section line was extended to include the approach roadway on both banks using DTM data along the road centerline.

For low flow, each of the bridges were modelled using the energy and momentum methods, taking the highest energy result from these two methods. For bridges crossing the Red Deer River, the energy method was adopted for high flow. The pressure and/or weir method was not considered to be applicable for these structures because the bridge decks are relatively high and roadway approaches are too low. For bridges crossing the tributary reaches, the appropriate high flow method was selected individually for each structure, based on flood levels in relation to the bridge and roadway approach elevations.

5.2.3 Flood Control Structures

Profiles of the top of flood control structures (berms and dikes) were surveyed during the field program. These data, in conjunction with the DTM, were used to inform the specification of levees in the HEC-RAS model. Levees in HEC-RAS restrict the wetted portion of the channel to the area inside the levees until the simulated water level exceeds a specified elevation. Generally, the levee elevation at a model cross section corresponds to the crest elevation of the flood control structure where the cross section intersects the flood control structure. However, consideration was given to overtopping points upstream and downstream of the model cross section to best represent streamwise conditions along the crest (including between model sections) where water overtops and inundates areas behind the structure. The adopted levee elevation values were assigned at each model cross section to define dry areas behind the flood control structure. The surveyed crest elevations and the corresponding effective elevation used for model calibration are provided in **Table 11**. Supplementary planned flood control structure information used to generate flood frequency profiles and produce flood inundation mapping is contained in **Section 5.5**.

Table 11 Modelled flood control structure details for calibration

Name and Description	Stream	River Station (m)	Surveyed Crest Elevation (m)	Effective Modelled Elevation (m)
Midland Dike North side of Red Deer River, adjacent to Midland	Red Deer River	44,420	684.93	684.93
		44,290	684.84	684.84
		44,005	684.77	684.77
		43,798	684.75	684.75
		43,527	684.76	684.76
		43,209	684.20	684.20
		42,942	684.17	684.17
Newcastle Dike South side of Red Deer River, adjacent to Newcastle	Red Deer River	43,209	684.15	684.15
		42,942	684.10	684.00
		42,779	684.08	684.00
		42,558	683.98	683.98
		42,341	683.87	683.87

Table 11 Modelled flood control structure details for calibration (continued)

Name and Description	Stream	River Station (m)	Surveyed Crest Elevation (m)	Effective Modelled Elevation (m)
		42,214	683.98	683.87
		41,996	684.02	683.87
Hospital Dike North side of Red Deer River, adjacent to Drumheller Heath Centre, North Drumheller	Red Deer River	42,341	685.75	685.75
		42,214	685.91	685.75
		41,996	683.32	683.32
		41,823	683.14	683.14
Dike B East side of Michichi Creek and north side of Red Deer River, west of Bridge Street (Highway 56), North Drumheller	Red Deer River	41,263	684.17	684.17
		41,074	684.21	684.15
	Michichi Creek	506	684.14	684.11
		412	684.16	684.11
		334	683.95	683.99
		194	684.13	683.99
Dike C North side of Red Deer River, east of Bridge Street (Highway 56), North Drumheller	Red Deer River	40,804	683.56	683.56
		40,748	683.59	683.56
		40,606	683.46	683.46
Dike D South side of Red Deer River from the Aquaplex to 5 Street E, north of 4 Avenue E, Central and Riverside Drumheller	Red Deer River	40,606	683.29	683.29
		40,517	683.50	683.29
		40,322	683.10	683.10
		40,132	683.23	683.10
		39,912	683.12	683.10
		39,774	682.74	682.74
		39,619	682.68	682.68
East Coulee Dike North side of Red Deer River between 9 Street and 4 Street in East Coulee	Red Deer River	18,440	675.86	675.86
		18,219	676.20	675.86
		18,020	676.09	675.86
		17,745	675.86	675.86

5.2.4 Other Features

Four confluences exist along the study reach of the Red Deer River. These include that of Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek. The approach for selecting the cross section alignment within the Red Deer River floodplain took into account hydraulically significant features adjacent to the tributary, hydraulic capacity at cross sections, and inundation mapping requirements.

Kneehills Creek Confluence

The portion of Kneehills Creek located downstream of the Highway 575 Bridge is located within the Red Deer River floodplain. A total of nine cross sections (not including those bounding the bridge) were originally surveyed in an effort to represent this portion of the model. Of these, seven cross sections (RS 416 through RS 1532) were used as part of the model. The right endpoints of each of these seven cross sections extend back to Highway 575 (high ground) and the left ends terminate within the Red Deer River floodplain. The two downstream-most surveyed cross sections were not used in the model due to the orientation of the channel and adjacent cross sections on the Red Deer River. Also of note is that the cross sections at RS 416 on Kneehills Creek and RS 51689 on the Red Deer River abut one another for convenience.

Michichi Creek Confluence

The portion of Michichi Creek located downstream of the Highway 838 Bridge is located within the Red Deer River floodplain. A total of seven cross sections (not including those bounding the bridge) were surveyed and used in the model to represent this portion of the channel. Based on preliminary model runs, Michichi Creek is able to convey its own 1000-yr flow without overtopping its banks, assuming no significant concurrent highwater on the Red Deer River. This substantial capacity is a result of channelization and diking along several kilometres of the downstream portion of Michichi Creek. While flooding of the Michichi Creek confluence area will be dominated by flooding on the Red Deer River, the flow contained within the channelized reach of the Red Deer River floodplain can be reasonably represented using cross sections extending only to the edge of the top of the channel banks or flood control structure embankments.

Rosebud River Confluence

The portion of Rosebud River located downstream of the abandoned railway bridge is located within the Red Deer River floodplain. All of the surveyed cross sections were used in the model. Each cross section was extended to high ground on both edges.

Willow Creek Confluence

The portion of Willow Creek located downstream of the Highway 10 Bridge is located within the Red Deer River floodplain. Three cross sections (not including those bounding the bridge) were surveyed in an effort to represent this portion of the channel; however, the preferred approach based on an analysis of channel capacity was to exclude these Willow Creek cross sections within Red Deer River floodplain and instead represent the area using the Red Deer River cross sections.

5.3 Model Calibration

5.3.1 Methodology

Model calibration involved the selection of modelling parameters to simulate observed water levels along the study reach for both high and low flow conditions. The modelling parameters that were calibrated included:

- Manning's roughness coefficient for the channel, islands, and floodplain.
- Friction slope associated with the downstream normal depth boundary condition.
- Ineffective flow areas at each model cross section.
- Expansion and contraction coefficients between cross sections.

Of the above, the primary calibration parameters were the Manning's roughness coefficients for the main channel, which were selected for each cross section by comparing the simulated water surface profile elevations to observed water levels and highwater marks. The challenges or limitations that are typical to the calibration process include:

- The accuracy of the highwater mark elevations.
- Improper identification of highwater marks.
- Uncertainties in estimates of the flood peak discharge.
- Insufficient channel geometry data.

The type of land cover was used to help characterize roughness in the floodplain areas and along islands. Using orthophotography, four distinct land cover types were identified for this study and they are described in **Table 12**. Each land cover type was assigned a constant value of roughness coefficient based on values provided in reference literature (Chow, 1959).

The hydraulic model was calibrated for both low and high flow conditions using available data. These data included surveyed water levels, highwater marks provided by AEP, as well as WSC hydrometric gauge data and rating curves.

Table 12 Description of floodplain land cover types within the study reach

Land Cover Type	Description
Light vegetation	Agricultural crops or pastureland within the overbank with grasses with a general height of one meter or less
Medium vegetation	Small size trees and shrubs with height less than the depth during the design event
Dense vegetation	Medium to large size trees and shrubs with height greater than the depth during the design event
Urban	Developed urban areas composed of numerous residential, commercial, and industrial buildings

5.3.2 Low Flow Calibration

Red Deer River

The bathymetric survey was completed during low flow conditions. Corresponding measured water levels and WSC gauged discharges were available to calibrate the Red Deer River reach within the HEC-RAS model. **Table 13** summarizes the model cross sections surveyed on each day and associated discharge estimates used for the Red Deer River low flow model calibration.

Table 13 Cross section survey sequence and corresponding discharges used in the low flow model calibration along the Red Deer River

Dates (2018)	River Station (m)	Discharge (m^3/s)	
		Range	Average
10 July to 13 July	0 to 5,828; 30,696 to 40,134	64.6 to 69.7	67.6
17 July to 25 July	6,283 to 30,480; 40,322 to 51,970	43.5 to 55.7	50.8
26 July to 27 July	16,777 to 17,162; 52,365 to 56,141	39.1 to 40.1	39.6

Flow conditions along the Red Deer River at the time of survey were approximately 10% of the 2-year flood discharge estimate. Results of the low flow calibration are provided in **Section 5.3.5**.

Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek

Water level data was also collected along each of the tributaries during the bathymetric survey; however, corresponding gauged discharges were either very low or there was no measurable flow. Therefore, a low flow calibration was not possible along the four tributaries.

5.3.3 High Flow Calibration

Red Deer River

The June 2005 and June 2013 floods were the two largest floods to occur since the continual systematic collection of gauge data along the Red Deer River. These floods were of comparable magnitude, with estimated peak discharges of 1,450 m^3/s and 1,270 m^3/s for the 2005 and 2013 floods, respectively. Emphasis was placed on calibrating computed water levels to the observed highwater marks for these two events. Highwater mark observations for these two floods extended over a significant portion of the study reach and the flood magnitudes are considered to be representative of a high flow condition. The high flow calibration was completed using highwater marks provided by AEP, as well as WSC hydrometric gauge data and measurements. The number and location of highwater marks are described in **Section 3.5**. The majority of the highwater marks are located along developed areas within Drumheller. The discharges used for the high flow calibration are summarized in **Table 4**. Results of the model calibration are provided in **Section 5.3.5**.

Kneehills Creek, Michichi Creek, and Rosebud River

The 2018 flood was selected for calibration of Kneehills Creek, Michichi Creek, and Rosebud River. This was the highest flood on record for Kneehills Creek and among the top five highest on record for Michichi Creek and Rosebud River. Extensive highwater mark information was obtained by AEP for each of these tributaries to the Red Deer River during this flood event. The model calibration was completed using the aforementioned highwater marks, as well as WSC hydrometric gauge data and measurements. The number and location of highwater marks are described in **Section 3.5**. The discharges used for the high flow calibration are summarized in **Table 4**. Results of the high flow calibration are provided in **Section 5.3.5**.

Willow Creek

Since there is no corresponding peak discharge estimate available to carry out calibration of the Willow Creek reach, a calibration of discharge was carried out for the 2018 flood event. Highwater mark information was obtained by AEP in the area of the Highway 10 Bridge during the 2018 flood event, as described in **Section 3.5**. The roughness values calibrated for Michichi Creek and Rosebud River were adopted for Willow Creek, as the three creeks have very similar characteristics. Results of this discharge calibration are provided in **Section 5.3.5**.

5.3.4 Gauge Data and Rating Curves

Red Deer River

The WSC gauge for the Red Deer River at Drumheller (05CE001) is located at the Highway 56 Bridge. WSC publishes revised rating curves for each gauge as new data records become available. The HEC-RAS model was used to generate simulated rating curves both upstream and downstream of the bridge for discharges from 448 m^3/s to 2,260 m^3/s. **Figure 5** shows the simulated rating curve from the calibrated model as compared with the current WSC gauge rating curve and 1990-2019 measurements. Overall, good agreement was attained between the simulated and current WSC gauge rating curve. This comparison verifies the Manning's roughness factors over a range of discharges and provides confidence in the ability of the model to simulate water levels over a range of flows along the reach of the Red Deer River located within the study area.

Michichi Creek

WSC also operates a gauging station (05CE020) on Michichi Creek at Highway 838. **Figure 6** illustrates the simulated rating curve from the calibrated model as compared with the current WSC gauge rating curve and 1988-2019 measurements. The gauge site on Michichi Creek can be influenced by backwater from the Red Deer River during high flows; however, high flows on Michichi Creek are often not concurrent with significant backwater from the Red Deer River. The simulated rating curve is slightly higher as a result of model calibration to the 2018 highwater mark data. Overall, good agreement was attained between the HEC-RAS model, current WSC gauge rating curve, and water level measurements.

Kneehills Creek, Rosebud River, and Willow Creek

WSC also operates gauging stations along Kneehills Creek (05CE002) and Rosebud River (05CE005); however, the available rating curves cannot be compared with corresponding simulated rating curves from the calibrated model as these stations are located outside of the model boundary. Willow Creek is ungauged.

5.3.5 Calibration Results

Red Deer River

The high flow calibration for the Red Deer River was carried out using highwater marks collected from the June 2005 and June 2013 flood events (**Section 5.3.3**). **Figure 7** shows the comparison between simulated water surface profiles and observed HWMs for each event, offering a good visual fit. A tabular summary of the high flow calibration is provided in **Table 14**. The mean absolute error between observed highwater marks and simulated water levels was 0.15 m for the 2005 flood event, which was selected as the primary calibration event. Similarly, the mean absolute error for the 2013 flood event was 0.27 m. In addition, good correlation was observed when conducting a visual comparison of 2005 simulated inundation extents with flood imagery (**Section 3.7**). It should be noted that flood control structures within the calibration model (and as shown on **Figure 7**) represent existing dikes as of the time of this study. Several dikes were upgraded and extended following the 2005 flood. Additionally, significant dike upgrades within the Town of Drumheller are expected to begin in 2022. The flood frequency profiles and flood inundation mapping contained in this report will include the supplementary planned flood control structure information received, as described in **Section 5.5**.

The low flow calibration for the Red Deer River was carried out using water level data collected during the bathymetric survey carried out in July 2018 (**Section 5.3.2**). As described in **Table 13**, three distinct flow conditions (13 July 2018, 25 July 2018, and 27 July 2018) were modelled for comparison with surveyed water levels. A known (surveyed) water surface elevation was used as the downstream boundary condition for these model runs. **Figure 7** includes the comparison between simulated water surface profiles and surveyed water levels for each flow condition. Over 200 points were used in this comparison and a tabular statistical summary for the low flow calibration is provided in **Table 15**. The mean absolute error between observed highwater marks and simulated water levels was 0.10 m, 0.14 m, and 0.10 m for the flows modelled on 13 July 2018, 25 July 2018, and 27 July 2018, respectively.

Table 14 Calibration results for Red Deer River – high flow conditions

Highwater Mark ID	River Station (m)	Event Date	Discharge (m^3/s)	Observed Highwater Mark (m)	Simulated Water Level (m)	Simulated Minus Observed
05-RD-31	46451	21-Jun-05	1,450	685.04	684.95	-0.09
05-RD-31	46451	21-Jun-05	1,450	685.01	684.95	-0.06
05-RD-32	44443	21-Jun-05	1,450	684.44	684.25	-0.19
05-RD-33	43324	21-Jun-05	1,450	684.08	683.74	-0.34
05-RD-34	41983	21-Jun-05	1,450	683.48	683.23	-0.25
05-RD-35	40804	21-Jun-05	1,450	682.82	682.85	0.03
05-RD-36	39129	21-Jun-05	1,450	681.86	682.13	0.27
05-RD-37	37819	21-Jun-05	1,450	681.51	681.62	0.11
05-RD-38a	32484	21-Jun-05	1,450	680.07	680.1	0.03
05-RD-38b	32484	21-Jun-05	1,450	679.93	680.1	0.17
05-RD-39a	31198	21-Jun-05	1,450	679.44	679.55	0.11
05-RD-39b	31198	21-Jun-05	1,450	679.37	679.55	0.18
2013-RD-31a	46451	23-Jun-13	1,270	-	-	-
2013-RD-32a	44443	23-Jun-13	1,270	683.46	683.8	0.34
2013-RD-33a	43324	23-Jun-13	1,270	-	-	-
2013-RD-34a	41983	23-Jun-13	1,270	683.10	682.76	-0.34
2013-RD-35A-a	40832	23-Jun-13	1,270	-	-	-
2013-RD-35A-a-wl	40832	23-Jun-13	1,270	-	-	-
2013-RD-35B-a	40832	23-Jun-13	1,270	682.32	682.39	0.07
2013-RD-36a	39129	23-Jun-13	1,270	-	-	-
2013-RD-37a	37819	23-Jun-13	1,270	681.13	681.19	0.06
2013-RD-38a	32484	23-Jun-13	1,270	679.19	679.69	0.50
2013-RD-39a	31198	23-Jun-13	1,270	678.82	679.13	0.31
2013-RD-39b	31207	23-Jun-13	1,270	678.86	679.13	0.27

Table 15 Statistical Summary of calibration results for Red Deer River – low flow conditions

13 July 2018 Simulated Minus Observed Water Level (m)			25 July 2018 Simulated Minus Observed Water Level (m)			27 July 2018 Simulated Minus Observed Water Level (m)		
Min	Max	Average	Min	Max	Average	Min	Max	Average
-0.57	0.09	-0.09	-0.46	0.08	-0.13	-0.15	0.11	-0.07

Kneehills Creek

The high flow calibration for Kneehills Creek was carried out using highwater marks collected from the April 2018 event (**Section 5.3.3**). A known water level was used as the downstream boundary, based on the surveyed highwater mark elevation. **Figure 8** shows the comparison between the simulated water surface profile and observed HWMs for the April 2018 event. A tabular summary of the high flow calibration for Kneehills Creek is provided in **Table 16**. The mean absolute error between observed highwater marks and simulated water levels was 0.12 m.

Table 16 Calibration results for Kneehills Creek – high flow conditions

Highwater Mark ID	River Station (m)	Event Date	Discharge (m^3/s)	Observed Highwater Mark (m)	Simulated Water Level (m)	Simulated Minus Observed
KH-1-HWM1	1498	25-Apr-18	158	688.44	688.62	0.18
KH-1-HWM2	1581	25-Apr-18	158	688.73	688.69	-0.04
KH-1-HWM2	1581	25-Apr-18	158	688.73	688.69	-0.04
KH-2-HWM1	3013	25-Apr-18	158	691.05	691.38	0.33
KH-2-HWM2	3013	25-Apr-18	158	690.88	691.00	0.12
KH-2-HWM2	3013	25-Apr-18	158	690.89	691.00	0.11
KH-3-HWM1	1854	25-Apr-18	158	689.27	689.27	0.00
KH-3-HWM3	2010	25-Apr-18	158	689.49	689.59	0.10
KH-3-HWM2	1929	25-Apr-18	158	689.35	689.51	0.16

Michichi Creek

The high flow calibration for Michichi Creek was carried out using highwater marks collected from the April 2018 event (**Section 5.3.3**). A known water level was used as the downstream boundary, based on surveyed highwater mark elevations. **Figure 8** shows the comparison between simulated water surface profiles and observed HWMs for the April 2018 event. A tabular summary of the high flow calibration for Michichi Creek is provided in **Table 17**. The mean absolute error between observed highwater marks and simulated water levels was 0.03 m.

Table 17 Calibration results for Michichi Creek – high flow conditions

Highwater Mark ID	River Station (m)	Event Date	Discharge (m^3/s)	Observed Highwater Mark (m)	Simulated Water Level (m)	Simulated Minus Observed
Mich-1-HWM1	987	21-Apr-18	27.3	682.22	682.26	0.04
Mich-1-HWM2	990	21-Apr-18	27.3	682.26	682.3	0.04
Mich-1-HWM3	987	21-Apr-18	27.3	682.22	682.26	0.04
Mich-2-HWM1	1364	21-Apr-18	27.3	682.97	682.96	-0.01

Rosebud River

The high flow calibration for Rosebud River was carried out using highwater marks collected from the April 2018 event (**Section 5.3.3**). A known water level was used as the downstream boundary, based surveyed highwater mark elevations. **Figure 8** shows the comparison between simulated water surface profiles and observed HWMs for the April 2018 event. A tabular summary of the high flow calibration for Rosebud River is provided in **Table 18**. The mean absolute error between observed highwater marks and simulated water levels was 0.21 m.

Table 18 Calibration results for Rosebud River – high flow conditions

Highwater Mark ID	River Station (m)	Event Date	Discharge (m^3/s)	Observed Highwater Mark (m)	Simulated Water Level (m)	Simulated Minus Observed
Rose-0.5-HWM1	519	23-Apr-18	160	679.53	679.63	0.10
Rose-0.5-HWM2	526	23-Apr-18	160	679.46	-	-
Rose-0.5-HWM2	526	23-Apr-18	160	679.63	-	-
Rose-0.5-HWM3	535	23-Apr-18	160	679.40	679.68	0.28
Rose-0.6-HWM1	644	23-Apr-18	160	679.82	679.77	-0.05
Rose-0.7-HWM1	826	23-Apr-18	160	679.95	-	-
Rose-1-HWM1	1197	23-Apr-18	160	680.84	680.78	-0.06
Rose-1-HWM2	1110	23-Apr-18	160	680.40	680.52	0.12
Rose-2-HWM3	2106	23-Apr-18	160	682.66	682.86	0.20
Rose-2-HWM2	2124	23-Apr-18	160	682.67	682.89	0.22
Rose-2-HWM1	2158	23-Apr-18	160	683.08	682.92	-0.16
Rose-3-HWM1	4526	23-Apr-18	160	688.16	687.99	-0.17
Rose-3-HWM2	4508	23-Apr-18	160	688.12	687.80	-0.32
Rose-5-HWM1	5464	23-Apr-18	160	689.81	689.63	-0.18
Rose-5-HWM1	5464	23-Apr-18	160	689.81	689.63	-0.18
Rose-6-HWM1	5867	23-Apr-18	160	690.42	690.20	-0.22
Rose-6-HWM1	5867	23-Apr-18	160	690.42	690.20	-0.22
Rose-7-HWM1	6398	23-Apr-18	160	691.34	691.28	-0.06
Rose-7-HWM1	6398	23-Apr-18	160	691.33	691.28	-0.05

Table 18 Calibration results for Rosebud River – high flow conditions (continued)

Highwater Mark ID	River Station (m)	Event Date	Discharge (m^3/s)	Observed Highwater Mark (m)	Simulated Water Level (m)	Simulated Minus Observed
Rose-7-HWM2	6367	23-Apr-18	160	691.13	691.19	0.06
Rose-8-HWM1	7312	23-Apr-18	160	692.88	692.97	0.09
Rose-8-HWM2	7314	23-Apr-18	160	693.01	693.08	0.07
Rose-8-HWM2	7314	23-Apr-18	160	693.01	693.08	0.07
Rose-9-HWM1	7932	23-Apr-18	160	693.99	693.93	-0.06
Rose-9-HWM2	7981	23-Apr-18	160	694.27	693.99	-0.28
Rose-9.5-HWM1	8564	23-Apr-18	160	695.18	695.42	0.24
Rose-9.5-HWM1	8564	23-Apr-18	160	695.18	695.42	0.24
Rose-9.5-HWM4	8567	23-Apr-18	160	695.12	695.4	0.28
Rose-9.5-HWM2	8541	23-Apr-18	160	695.13	695.39	0.26
Rose-9.5-HWM3	8477	23-Apr-18	160	695.06	695.19	0.13
Rose-10-HWM1	8687	23-Apr-18	160	697.20	695.48	-1.72
Rose-10-HWM2	8717	23-Apr-18	160	695.74	695.71	-0.03
Rose-10-HWM3	8795	23-Apr-18	160	695.80	695.82	0.02
Rose-11-HWM1	9576	23-Apr-18	160	697.22	697.47	0.25
Rose-11-HWM2	9553	23-Apr-18	160	697.13	697.40	0.27

Willow Creek

A discharge calibration for Willow Creek was carried out using highwater marks collected from the April 2018 event (**Section 5.3.3**) and the same roughness as calibrated for Michichi Creek. The creek junction was used as the downstream boundary, as backwater from the Red Deer River is not expected to affect the bridge location at this flow condition. **Figure 8** shows the comparison between simulated water surface profiles and observed HWMs for the April 2018 event using a discharge of 26 m^3/s, which corresponds to a 20-year return period for Willow Creek (**Table 5**). A tabular summary of the high flow calibration for Willow Creek is provided in **Table 19**. The mean absolute error between observed highwater marks and simulated water levels was 0.12 m.

Table 19 Calibration results for Willow Creek – high flow conditions

Highwater Mark ID	River Station (m)	Event Date	Discharge (m^3/s)	Observed Highwater Mark (m)	Simulated Water Level (m)	Simulated Minus Observed
Will-1-HWM1-4 (average)	839	Apr-18	26	676.77	676.55	-0.22
Will-1-HWM5	873	Apr-18	26	677.13	677.11	-0.02

5.4 Model Parameters and Options

The following sections describe the key model parameters and options adopted in the calibrated HEC-RAS model. These include Manning's roughness coefficients for the channel and overbank areas, contraction and expansion loss coefficients, ineffective flow areas, and geometric configuration around flow splits, islands, and diversions.

5.4.1 Manning's Roughness Values

Computations in HEC-RAS are based on quantifying the friction loss between cross sections using Manning's roughness equation. The Manning's roughness coefficient is a parameter that accounts for losses attributed to river bottom and bank material size and shape, floodplain conditions, and variations in the general river planform. A description of the channel and floodplain roughness values adopted in the model follows.

Channel Roughness

Table 20 summarizes the calibrated channel roughness at each model cross section within the given reach based on the model calibration. Model calibration determined that a single channel roughness value for each modelled stream resulted in satisfactory agreement between simulated water levels and observed highwater marks. There was no compelling evidence to suggest that there should be any notable variation in roughness along any of the Red Deer River sub-reaches. The adopted channel roughness values for the Red Deer River are comparable to those determined in the previous flood hazard study (Matrix 2007). The channel roughness values calibrated for Michichi Creek and Rosebud River were adopted for Willow Creek, as the three creeks have very similar characteristics.

Table 20 Adopted Manning's roughness values for the channel based on model calibration

Reach Description	Channel Roughness
Red Deer River above Kneehills Creek	0.026
Red Deer River below Kneehills Creek	0.026
Red Deer River below Michichi Creek	0.026
Red Deer River below Rosebud River	0.026
Red Deer River below Willow Creek	0.026
Kneehills Creek	0.060
Michichi Creek	0.052
Rosebud River	0.052
Willow Creek	0.052

Overbank Roughness

Table 21 shows the adopted overbank roughness values for the land cover types identified within the study area. The overbank roughness values were applied based on consideration of land cover composition using aerial imagery and literature guidance (Chow, 1959).

Table 21 Adopted Manning's roughness values for the overbank areas

Land cover type	Overbank Roughness
Light vegetation	0.040
Medium vegetation	0.060
Dense vegetation	0.080
Urban	0.100

The calibrated channel roughness and prescribed overbank roughness values along the Red Deer River are comparable to the values found in the 2007 Study, as well the 1975 and 1984 studies. The calibrated roughness value for Michichi Creek is comparable to that assumed for Michichi Creek in the 2007 study. The calibrated roughness value for the Rosebud River is slightly higher than that assumed for the Rosebud River in the 2007 Study.

5.4.2 Expansion and Contraction Coefficients

To account for the effect of flow contraction or expansion on the energy balance between successive cross sections, HEC-RAS multiplies the absolute difference in velocity head by a coefficient. Coefficients range from 0.10 for gradual transitions to 0.80 for abrupt transitions (Brunner, 2016).

Contraction and expansion coefficients were set to 0.3 and 0.5, respectively for cross sections located near culverts and bridges where the piers and abutments could lead to a rapid contraction of the flow. The default values of 0.1 and 0.3 for contraction and expansion loss coefficients were used at all other cross sections.

5.4.3 Obstructions and Ineffective Flow Areas

Blocked Obstructions

Blocked obstructions in the floodplain, such as buildings, walls, storage tanks, or elevated foundations were not specified in the HEC-RAS model. Obstructions associated with bridge piers and structural members were modelled using the standard bridge editor specifications in HEC-RAS.

Ineffective Flow Areas

Ineffective flow areas were specified at cross sections in the HEC-RAS model based on a review of the local terrain and floodplain features both at and between cross sections. Ineffective flow areas can be specified within portions of cross sections where water is expected to pond, and where the velocity of that water, in the downstream direction, is expected to be close to or equal to zero (Brunner, 2016). The downstream direction is taken relative to the cross section lines defined in the model, so the orientation of cross sections was considered when specifying ineffective flow areas.

Ineffective flow areas in the model may be specified as either permanent or non-permanent. Permanent ineffective flow areas apply regardless of the water surface elevation, whereas non-permanent ineffective flow areas become effective above a defined elevation. The configuration of permanent and non-permanent ineffective flow areas were specified depending on site-specific circumstances and engineering judgement.

General Criteria Used to Define Ineffective Areas

The general principles for determining ineffective flow areas were as follows:

- Non-permanent ineffective flow areas were used to "fill" local depressions on the floodplain that are obstructed by higher ground upstream or downstream. These areas were assumed to become engaged in the active flow area (or effective) once the water level exceeded the elevation of the adjacent ground.
- Permanent ineffective flow areas were used to permanently "fill" relic channels, tributary channels or excavated holes that would otherwise have incorrectly added flow area to the cross section.
- Permanent ineffective flow areas were defined where flow patterns were likely to be influenced by nearby bridge abutments and roadway embankments crossing the floodplain. These types of obstructions tend to direct flows towards the bridge opening. Several site-specific factors were taken into account when configuring ineffective flow areas at bridges and culverts in the study area, including: distance from the cross section to the bridge, terrain features, bridge geometry, and skew of the bridge opening relative to the river.
- Ineffective flow areas behind railroad and highway embankments were assessed on a case by case basis. Aerial imagery, LiDAR, and historic information were used to determine if there were indications of flow behind and/or above embankments. Areas behind and below the height of the embankment were modelled as effective flow only if there was no downstream obstruction or if there was an indication of flow moving in the downstream direction. Otherwise, permanent ineffective flow areas were set to the top of embankment elevation, allowing areas behind embankments (assumed permeable) to be shown as wet and isolated but not conveying flow. Areas above embankments generally conveyed flow once the embankment was overtopped, unless an upstream or downstream obstruction was present causing local ponding or dead zones with limited flow.
- Ineffective flow areas near encroaching river valley wall features or river engineering training works were also assessed on a case by case basis, using aerial imagery and LiDAR, similar to the approach described above.

5.4.4 Flow Splits, Islands and Diversions

The study reaches were adequately represented without flow splits around islands. Where a cross section intersected an island, the HEC-RAS model assumed equal water level on both sides of an island based on the composite channel conveyance properties and computed energy losses. This assumption is most valid once flood magnitudes increases and the island becomes inundated.

Diversions may include avulsion channels or flow paths that reduce the total discharge carried by the main channel along a portion of the study reach. There were no such diversions encountered within the study area, and all flood flows were confined to the cross sections modelled along the study reaches.

5.5 Flood Frequency Profiles

The Town of Drumheller has proposed seven flood control structure upgrades which are planned for construction beginning in 2022. This includes the following projects: Nacmine, Midland, Newcastle, Dike A, Dike B and C, Dike D, and Willow Estates. Centreline crest elevation profiles for each proposed flood control structure were provided to NHC by AEP on 24 September 2021, and this information is shown in **Figure 9**. These data, in conjunction with the DTM, were used to inform or update the specification of levees in the HEC-RAS model. The crest elevations and the corresponding effective elevation used for modelling are provided in **Table 22.** It should be noted that Midland and Newcastle dikes each contain a portion of dike that will not be permanently raised. In the event of a flood, temporary fill will be placed to the design flood levels. The model geometry corresponds with permanent dike structures only and does not include segments relying on temporary fill.

Table 22 Modelled flood control structure details for flood frequency profiles

Name and Description	Stream	River Station (m)	Design Crest Elevation (m)	Effective Modelled Elevation (m)
Nacmine Dike South side of Red Deer River, adjacent to Nacmine	Red Deer River	47,010	686.97	686.97
		46,672	686.79	686.79
		46,395	686.72	686.72
		46,221	686.66	686.66
		46,039	686.56	686.56
		45,748	686.46	686.46
Midland Dike North side of Red Deer River, adjacent to Midland	Red Deer River	44,420	686.05	686.05
		44,290	686.05	686.05
		44,005	684.77*	684.77
		43,798	684.75*	684.75
		43,527	685.39	685.39
		43,209	685.30	685.30

Table 22 Modelled flood control structure details for flood frequency profiles (continued)

Name and Description	Stream	River Station (m)	Design Crest Elevation (m)	Effective Modelled Elevation (m)
		42,942	685.10	685.10
Newcastle Dike South side of Red Deer River, adjacent to Newcastle	Red Deer River	43,209	684.15*	684.15
		42,942	685.19	685.19
		42,779	685.19	685.19
		42,558	685.19	685.19
		42,341	685.19	685.19
		42,214	685.19	685.19
		41,996	684.94	684.94
Hospital Dike North side of Red Deer River, adjacent to Drumheller Heath Centre, North Drumheller	Red Deer River	42,341	685.75*	685.75
		42,214	685.91*	685.75
Dike A North side of Red Deer River and west side of Michichi Creek, extension of dike adjacent to Drumheller Heath Centre, North Drumheller	Red Deer River	41,996	684.95	684.95
		41,823	684.89	684.89
		41,644	684.78	684.78
Dike B East side of Michichi Creek and north side of Red Deer River, west of Bridge Street (Highway 56), North Drumheller	Red Deer River	41,263	684.70	684.70
		41,074	684.68	684.68
		40,832	685.29	684.67
	Michichi Creek	506	684.14*	684.11
		412	684.16*	684.11
		334	683.95*	683.99
		194	684.13*	683.99
Dike C North side of Red Deer River, east of Bridge Street (Highway 56), North Drumheller	Red Deer River	40,804	684.66	684.66
		40,748	684.62	684.62
		40,606	684.52	684.52
Dike D South side of Red Deer River from the Aquaplex to 4 Avenue E, east of 5 Street E, Central and Riverside Drumheller	Red Deer River	40,804	684.42	684.42
		40,748	684.42	684.42
		40,606	684.39	684.39
		40,517	684.36	684.36
		40,322	684.05	684.05
		40,132	684.00	684.00
		39,912	683.92	683.92

Table 22 Modelled flood control structure details for flood frequency profiles (continued)

Name and Description	Stream	River Station (m)	Design Crest Elevation (m)	Effective Modelled Elevation (m)
		39,774	683.94	683.94
		39,619	683.86	683.86
		39,538	683.86	683.86
Willow Estates Dike South side of Red Deer River, adjacent to Willow Estates	Red Deer River	37,829	683.18	683.18
		37,633	683.18	683.18
		37,484	683.25	683.25
East Coulee Dike North side of Red Deer River between 9 Street and 4 Street in East Coulee	Red Deer River	18,440	675.86*	675.86
		18,219	676.20*	675.86
		18,020	676.09*	675.86
		17,745	675.86*	675.86

* Indicates elevation surveyed during the field program in 2018.

The proposed flood control structures were added to the calibrated hydraulic model geometry and this was used to generate flood frequency profiles for the thirteen regulated coincident open water floods of varying magnitude listed in **Table 5**. The computed flood frequency water levels at each surveyed cross section on the Red Deer River, Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek are provided in **Appendix B**. These results are plotted in **Figure 10** for the Red Deer River and **Figure 11** for the tributaries.

The flood frequency profiles show that water levels begin to reach the low chord of rail bridges and road bridges crossing the Red Deer River at the 75-year and 200-year flood levels, respectively. The Star Mine Suspension Bridge is affected at the 50-year flood level. Dikes along the Red Deer River begin overtopping at the 100-year flood level. Water levels begin to reach the low chord of bridges along Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek at the 75-year, 100-year, 50-year, and 500-year flood levels, respectively. The culvert along Michichi Creek exceeds capacity at the 75-year flood level due to backwater from the Red Deer River.

It should be noted that several water levels along Kneehills Creek, Rosebud River, and Willow Creek were adjusted to eliminate the crossing of profiles (i.e., a water level from a smaller flood event being higher than a water level for a larger flood event). This was carried out by looking at the flood frequency profile above and below as well as the cross section upstream and downstream to determine an appropriate water level substitution. A footnote reference using an asterisk is included at every occurrence of this within the tables in **Appendix B**. In addition, computed flood frequency water levels near the mouth of Kneehills Creek were adjusted where Red Deer River water levels governed the profile. The adjusted values are denoted with a double asterisk in **Appendix B**.

5.6 Model Sensitivity

The sensitivity of water levels computed by the calibrated open water hydraulic model to adjustments in boundary conditions and Manning's roughness values was evaluated. Variation in these parameters affects the computed water surface profiles, and consequently, flood depths and inundation limits. The sensitivity analysis provides an indication of the plausible range of error in the model results and identifies the relative sensitivity of the model to variations in each parameter. The 100-year naturalized flood was used along the Red Deer River and the 100-year flood was used along the tributaries as the baseline for the sensitivity analyses.

A summary of the sensitivity analysis results is provided below. Detailed tabulated results are provided in **Appendix C**.

5.6.1 Boundary Conditions

Downstream Boundary

The hydraulic model requires a downstream water level and an upstream discharge as boundary conditions for each river reach. The adopted downstream boundary condition in the calibrated model was a normal depth, which was computed by specifying an estimate of the energy grade slope of 0.00050 m/m at the most downstream cross section of the Red Deer River. At the baseline discharge, this corresponds to a water surface elevation of 668.20 m at the downstream boundary. A plausible range of uncertainty in this elevation is ±0.5 m, which corresponds to energy grade slopes for normal depth conditions of 0.000637 m/m (downstream water level of 667.7 m) and 0.000376 m/m (downstream water level of 668.70 m). The results are presented in **Table C-1** in **Appendix C**.

The water surface elevation profiles (calibrated, low downstream water level case, and high downstream water level case) for Red Deer River are illustrated in **Figure 12**. The variation from the calibrated profile falls below 0.1 m upstream of RS 5356 m for the low water level case and RS 5018 m for the high water level case. None of the tributaries (Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek) are impacted by changes to the downstream boundary condition.

Inflow Boundary

The sensitivity of the upstream discharge boundary conditions were evaluated by varying the adopted discharge values by ±20%. This was carried out concurrently for the Red Deer River and the tributaries using the values summarized in **Table 23**. The results are presented in **Table C-2** in **Appendix C**. The water surface elevation profiles (calibrated, low, and high discharge values) are plotted on **Figure 13** for the Red Deer River and on **Figure 14** for the tributaries. A summary of the sensitivity results for discharge on flood levels is provided in **Table 24**. The Red Deer River water levels are more sensitive to changes in discharge than the tributaries.

Table 23 Discharge values used in sensitivity analysis

Stream	Reach	Discharge (m^3/s)		
		Baseline Value	Low (-20%)	High (+20%)
Red Deer River	All	2260	1810	2710
Kneehills Creek	-	186	149	223
Michichi Creek	-	68	54	82
Rosebud River	-	292	234	350
Willow Creek	-	41	33	49

Table 24 Sensitivity analysis results for variation in discharge

Stream	Difference from Baseline Profile (m)					
	Low Discharge (-20%)			High Discharge (+20%)		
	Max	Avg	Min	Max	Avg	Min
Red Deer River	-1.16	-0.86	-0.75	1.02	0.75	0.60
Kneehills Creek	-0.86	-0.32	-0.14	0.72	0.29	0.12
Michichi Creek	-0.84	-0.48	-0.20	0.81	0.46	0.16
Rosebud River	-0.82	-0.46	-0.19	0.78	0.39	0.13
Willow Creek	-0.83	-0.31	-0.05	0.73	0.29	0.06

5.6.2 Manning's Roughness

The sensitivity of the calibrated model to Manning's roughness was examined for all the modelled reaches. Channel roughness was examined independently of overbank roughness. The results of the sensitivity analyses are discussed below.

Channel Roughness

The calibrated channel roughness on the Red Deer River was 0.026 for all reaches. A plausible range of channel roughness for the modelled length of the South Saskatchewan River was considered to be approximately 0.022 to 0.030, which corresponds to a ±15% range. Therefore, the channel roughness value was adjusted by ±15% for the low and high roughness sensitivity runs. The same ±15% range was applied to the roughness values in Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek. The sensitivity analysis was run concurrently for the Red Deer River and the tributaries using the values listed in **Table 25**.

Table 26 summarizes the average difference between the baseline flood levels and those computed using the low and high roughness values. Water surface elevations for each stream are presented in **Table C-3** in **Appendix C** and profiles are illustrated in **Figure 15** through **Figure 16.** On average, the Red Deer River reaches are more sensitive to changes in channel roughness than the tributaries.

Table 25 Channel roughness values used in sensitivity analysis

Stream	Reach	Channel Roughness Values		
		Calibrated Value	Low Roughness (-15%)	High Roughness (+15%)
Red Deer River	All	0.026	0.022	0.030
Kneehills Creek	-	0.060	0.051	0.069
Michichi Creek	-	0.052	0.044	0.060
Rosebud River	-	0.052	0.044	0.060
Willow Creek	-	0.052	0.044	0.060

Table 26 Sensitivity analysis results for variation in main channel roughness

Stream	Difference from Baseline Profile (m)					
	Low Channel Roughness (-15%)			High Channel Roughness (+15%)		
	Max	Avg	Min	Max	Avg	Min
Red Deer River	-0.65	-0.44	-0.29	0.49	0.39	0.27
Kneehills Creek	-0.41	-0.13	-0.04	0.36	0.11	0.03
Michichi Creek	-0.37	-0.23	-0.09	0.41	0.23	0.08
Rosebud River	-0.27	-0.12	0.00	0.31	0.13	0.06
Willow Creek	-0.31	-0.13	0.00	0.30	0.13	0.00

Overbank Roughness

The sensitivity of computed flood levels to variations in overbank roughness were evaluated by varying the adopted overbank roughness values by ±20%. A higher range was selected for this parameter since it was not calibrated. The values adopted for the tests are listed in **Table 27**. **Table 28** presents a summary of the results of the sensitivity analysis for variation in overbank roughness. Water surface elevations for each case are presented in **Table C-4** in **Appendix C** and profiles are plotted on **Figure 17** through **Figure 18**. On average, the streams are more sensitive to changes in channel roughness than in overbank roughness.

Table 27 Overbank roughness values used in sensitivity analysis

Landcover Type	Overbank Roughness Values		
	Adopted Value	Low Roughness (-20%)	High Roughness (+20%)
Light vegetation	0.040	0.032	0.048
Medium vegetation	0.060	0.048	0.072
Dense vegetation	0.080	0.064	0.096
Urban	0.100	0.080	0.120

Table 28 Sensitivity analysis results for variation in overbank roughness

Stream	Difference from Baseline Profile (m)					
	Low Overbank Roughness (-20%)			High Overbank Roughness (+20%)		
	Max	Avg	Min	Max	Avg	Min
Red Deer River	-0.22	-0.10	-0.04	0.17	0.07	0.01
Kneehills Creek	-0.16	-0.12	-0.08	0.14	0.09	0.02
Michichi Creek	-0.13	-0.05	0.01	0.09	0.05	0.01
Rosebud River	-0.15	-0.07	0.07*	0.19	0.08	-0.10*
Willow Creek	-0.14	-0.06	0.00	0.11	0.05	0.00

Note: * Simulated water surface profile crosses the base case near bridges.

6 FLOOD INUNDATION MAPS

Flood inundation mapping shows areas of ground that could be covered by water under one or more flood scenarios for existing conditions. For this study, one flood inundation map series was created for each of the 13 regulated flood frequency return periods from the 2-year through 1000-year scenarios. Additional information concerning the flood inundation map production is provided below.

6.1 Methodology

The methodology used to create the flood inundation maps from the computed flood frequency profiles (**Section 5.5**) followed four basic steps.

- Create a water surface elevation (WSE) triangular irregular network (TIN) representing a contiguous flood level profile along the modelled river reaches.
- Generate a WSE grid with the same grid geometry as the underlying DTM. Assign elevation values to each grid cell based on the corresponding value taken from the WSE TIN.
- Generate a depth grid (with the same grid geometry as the WSE grid) by subtracting elevation values from the underlying DTM from the corresponding WSE grid value. Negative depth values represent dry cells and were assigned a value of *NoData*.
- Generate inundation polygons based on the depth grids by converting depths greater than 0 m into inundation polygons.

The inundation polygons were further processed by smoothing, filtering out wetted areas there were isolated and not directly inundated, and removing very small dry areas (or “holes”). These inundation polygons were then used to clip the WSE grids and depth grids to the full inundation extent. All of the WSE TINs, WSE grids, depth grids, and inundation polygons are in standard Esri file format and were created using standard ArcGIS tool sets.

6.2 Flood Impacts

6.2.1 Direct Flood Inundation Areas

Areas affected by direct inundation are described in the sections that follow. Detailed inundation maps are provided in **Appendix D**.

Town of Drumheller (along the Red Deer River)

- Residential areas in the community of Nacmine would be flooded starting at the 200-year flood.
- Residential areas in the community of Midland would be flooded starting at the 100-year flood.

- Residential areas in the community of Newcastle would be flooded starting at the 100-year flood. At the 350-year flood, portions of the highway and some industrial areas south of the highway would begin to be impacted.
- In North Drumheller, the residential area along 9th Street and Michichi Drive would be impacted starting at the 50-year flood. Other areas south of Highway 838 would be impacted starting at the 75-year flood. The Drumheller Health Centre, located on the west side of 9th Street and south of Highway 838 would be fully inundated at the 350-year flood.
- Central Drumheller would begin to be impacted at the 200-year flood. At the 350-year flood and larger, most of the developed area between the river and Railway Avenue would be flooded. This area includes the Town Hall, Fire Department, Royal Canadian Mounted Police (RCMP) Detachment, and Miner's Memorial Park as well as the Rotary Spray Park, Aquaplex, Memorial Arena, Badlands Community Facility, and Drumheller Public Library.
- Riverside is situated on higher ground; Willow Estates (east of 17th Street) would be flooded starting at the 200-year flood. The remainder of the community would also be impacted at this flow, with portions of Riverside Drive flooding first.
- The Drumheller Wastewater Treatment plant and lagoons are situated above the 1000-year flood and are not expected to be impacted.
- Rosedale would be impacted starting at the 50-year flood, with portions of Railway Avenue and areas south of the suspension bridge park being flooded. The 11 Bridges Campground would become inundated starting at the 35-year flood.
- Cambria would begin to flood at the 75-year flood, with the areas north of the Highway 10 bridge being impacted first. Residential areas south of the bridge would be more significantly impacted starting at the 200-year flood. The large RV campground on the north side of the river just east of Cambria would be inundated starting at the 50-year flood.
- Lehigh would begin to flood at the 35-year flood and be completely inundated up to the highway at the 50-year flood.
- East Coulee would be affected by flooding starting at the 100-year flood and mostly inundated starting at the 200-year flood. Significant flooding near the Atlas Coal Mine on the south side of the river would not be expected until the 200-year or larger floods.

Town of Drumheller (along Rosebud River)

- Residential properties in Wayne start to become impacted by inundation from the Rosebud River at the 20-year flood.

Dorothy

- The Hamlet of Dorothy is situated on relatively high ground above the 1000-year flood level; however, a ranch/farmstead south of Highway 10 adjacent to the river would be impacted starting at the 200-year flood.

Dunphy

- Residential buildings along Kneehills Creek in Dunphy would be impacted starting at the 20-year flood. At the 200-year flood, portions of Range Road 211A would become inundated.

Kirkpatrick

- Inundation from the Red Deer River and Kneehills Creek begin to impact residential properties in and around Kirkpatrick at the 50-year flood.

6.2.2 Potential Flood Control Structure Failure

Areas affected by potential flood control structure failure inundation are described in the following sections.

Nacmine Dike

- Low-lying residential areas behind the Nacmine Dike in Nacmine would potentially be flooded at the 50-year flood if the structure failed. Additionally, some areas to the east of 9th Street would potentially be flooded if the structure failed at the 35-year flood. At the 200-year flood and above, the dike would be overtopped resulting in direct inundation.

Midland Dike

- Low-lying residential areas behind the Midland Dike in Midland would potentially be flooded at the 50-year flood if the structure failed. Additionally, some areas along 14th and 15th streets south of 1st Avenue would potentially be flooded if the structure failed at the 35-year flood. At the 100-year flood and above, the dike would be overtopped resulting in direct inundation. It is understood that adaptive measures may be used along lower portions of the dike and that this may be successful in protecting the community to a higher flood level; however, the impact of these adaptive measures are not reflected in this study.

Newcastle Dike

- The Newcastle Dike in Newcastle would be overtopped at the 100-year flood event. This level may be increased if adaptive measures are implemented effectively. Failure of the dike would result in potential inundation of residential areas along Newcastle Road, Riverside Avenue, 1st Avenue W, and 2nd Avenue W at the 50-year flood. At the 35-year flood, potential flood impacts would be limited to the baseball diamond and a portion of 1st and 2nd Avenue W.

Hospital Dike / Dike A

- Dike A is an extension of the Hospital Dike and extends up the west side of Michichi Creek. Direct inundation is expected behind the dike beginning at the 200-year flood. Beginning at the 50-year flood level, portions of 9 Street NW and Michichi Drive would become inundated along Michichi Creek as a result of backwater from the Red Deer River. The Drumheller Health Centre is built on higher ground. Mapping shows the helipad and west parking lot would become inundated at the

200-year flood. The main building as well as all access routes to it would be inundated at the 350-year flood.

Dike B

- Dike B is located along the north side of the Red Deer River, west of Highway 9. Low-lying areas of North Drumheller between this dike and Michichi Creek would potentially be flooded at the 35- and 50-year floods if the structure failed. This area includes various residential buildings, some commercial buildings on the west side of Highway 9, and a campground. At the 75-year flood, the dike would either be outflanked or overtopped resulting in direct inundation.

Dike C

- Dike C is located along the north side of the Red Deer River, east of Highway 9. The commercial-industrial area would potentially be flooded at the 50-year flood if the structure failed. There is no significant potential flooding at the 35-year and lower events; at the 75-year flood, the dike would be outflanked.

Dike D

- Dike D is located within the park behind the Drumheller Aquaplex and Memorial Arena, connecting with Riverside Drive to the east and ending between 3rd and 4th Avenue E. At the 35- year flood, low-lying areas east of 2nd Street E, including the ball diamond and residential properties at Riverside Drive and 3rd Avenue E would potentially be flooded if the structure failed. A larger area along Riverside Drive would be potentially affected at the 50-year flood, including the areas surrounding the Memorial Arena and Visitor Information Centre. Starting at the 200-year flood, portions of the dike would be overtopped and a large area along Riverside Drive would become directly inundated.

Willow Estates Dike

- Willow Estates Dike is located at the eastern-most portion of Riverside Drive. Low-lying residential areas behind the Willow Estates Dike would potentially be flooded at the 75-year flood if the structure failed. At the 200-year flood and above, the dike would be overtopped resulting in direct inundation.

East Coulee Dike

- The East Coulee Dike extends from 4th Street to the west end of East Coulee. At the 35-year flood, the area behind the dike from River Drive to 2nd Ave, east of 6th Street, and River Drive to 1st Ave, west of 6th Street, would potentially be impacted if the dike failed. Starting at the 100- year flood, the dike would be outflanked at the downstream end and the areas noted above would become directly inundated, along with additional areas of East Coulee to the east of 4th Street.

7 CONCLUSIONS

The objectives of this study were to assess river flood-related hazards along the Red Deer River and local tributaries (Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek) in the Drumheller area. Municipalities within the study area include the Town of Drumheller, Kneehill County, Starland County, Wheatland County, and Special Area No. 2. The Drumheller River Hazard Study was divided into six major project components. This report summarizes the work of the ***Hydraulic Modelling and Flood Inundation Mapping*** component. A hydraulic model was developed using the HEC-RAS computer program from the U.S. Army Corps of Engineers. River bathymetry and digital terrain data from the ***Survey and Base Data Collection*** component, as well as flood frequency estimates from the ***Open Water Hydrology Assessment*** component, were used to develop, calibrate, and apply the hydraulic model as described throughout this report. The reports for the two previous work components mentioned above should be read in conjunction with this report, as they provide additional background information.

The largest recorded flood events on the Red Deer River were the June 2005 flood (peak discharge 1,450 m^3/s) followed by June 2013 flood (peak discharge 1,270 m^3/s). Both of these events were adopted for model calibration. The simulated water surface profiles agreed well with the measured highwater marks with a mean absolute error of 0.15 m for the 2005 flood event and 0.27 m for the 2013 flood event. Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek were calibrated to the April 2018 flood event, which was the only event with sufficient highwater mark data to facilitate calibration along these reaches. The simulated water surface profiles agreed well with the measured 2018 highwater marks with a mean absolute error of 0.12 m for Kneehills Creek, 0.03 m for Michichi Creek, 0.21 m for Rosebud River, and 0.12 m for Willow Creek. In addition, the sensitivity of simulated water levels to various model parameters was investigated.

Supplementary planned flood control structure information was provided by the Town of Drumheller and incorporated into the calibrated hydraulic model. Water surface profiles were calculated for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year regulated open water flood frequency return period discharges. These profiles showed that water levels begin to reach the low chord of rail bridges and road bridges crossing the Red Deer River at the 75-year and 200-year flood levels, respectively. The Star Mine Suspension Bridge is affected at the 50-year flood level. Dikes along the Red Deer River begin overtopping at the 100-year flood level. Water levels begin to reach the low chord of bridges along Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek at the 75-year, 100-year, 50-year, and 500-year flood levels, respectively. The culvert along Michichi Creek exceeds capacity at the 75-year flood level due to backwater from the Red Deer River.

Flood inundation maps were created for the 13 regulated flood frequency return periods from the 2-year through 1000-year scenarios. Areas affected at the 20-year flood level include: Wayne and Dunphy. Lehigh is affected at the 35-year flood level. Areas affected at the 50-year flood level include: North Drumheller, Rosedale, and Kirkpatrick. Cambria is affected at the 75-year flood level. Midland, Newcastle, and East Coulee are affected at the 100-year flood level, while Nacmine, Central Drumheller, Riverside (Willow Estates), and Dorothy are affected at the 200-year flood level.

8 REFERENCES

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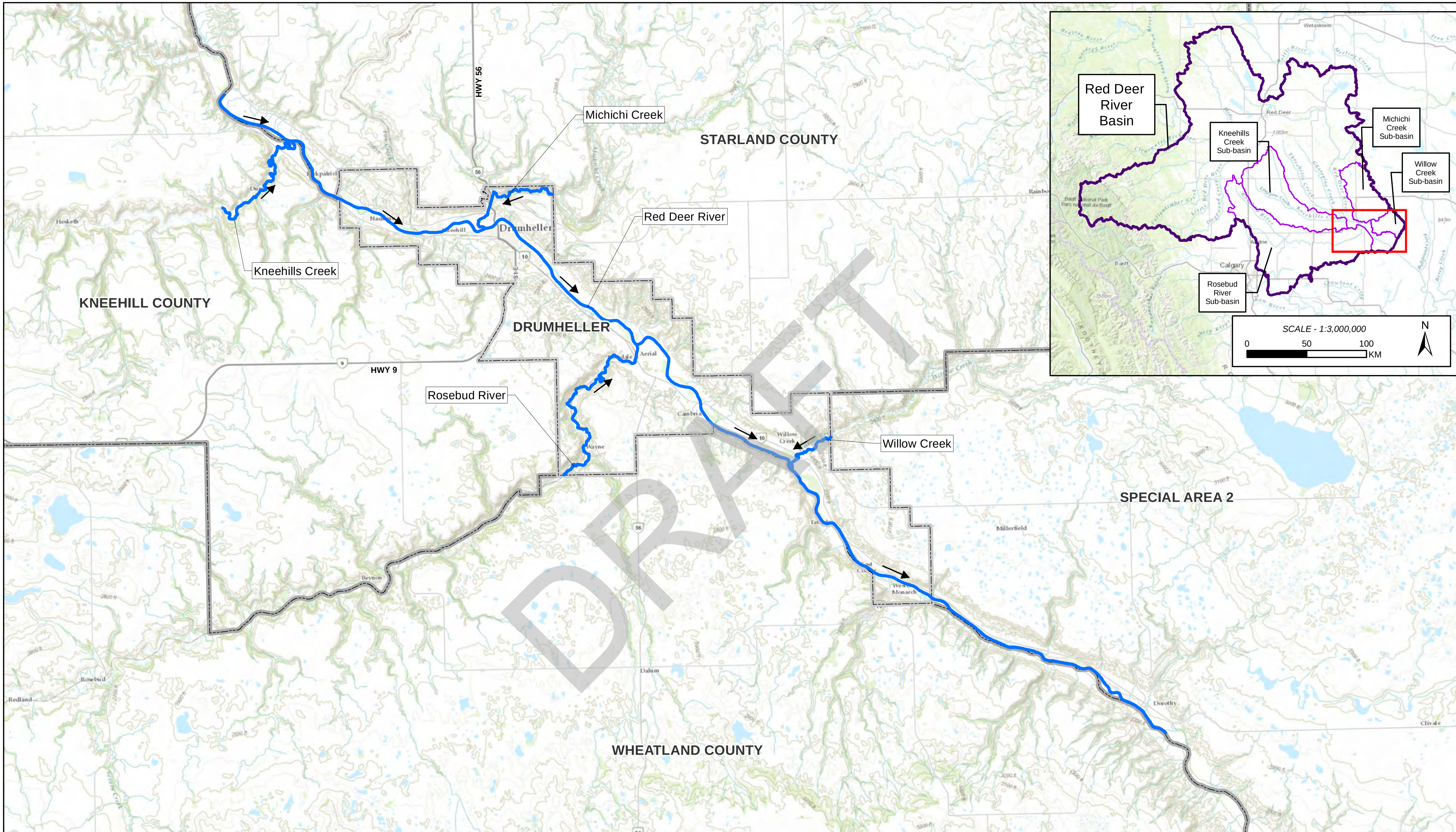
Figures



FLOW DIRECTION
STUDY REACH
MUNICIPAL BOUNDARY

Alberta

nhc northwest hydraulic consultants

DATA SOURCES: Basemap from Esri & NRCan.

SCALE - 1:150,000
0 2 4 6 KM
N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877

Date: 21-FEB-2020

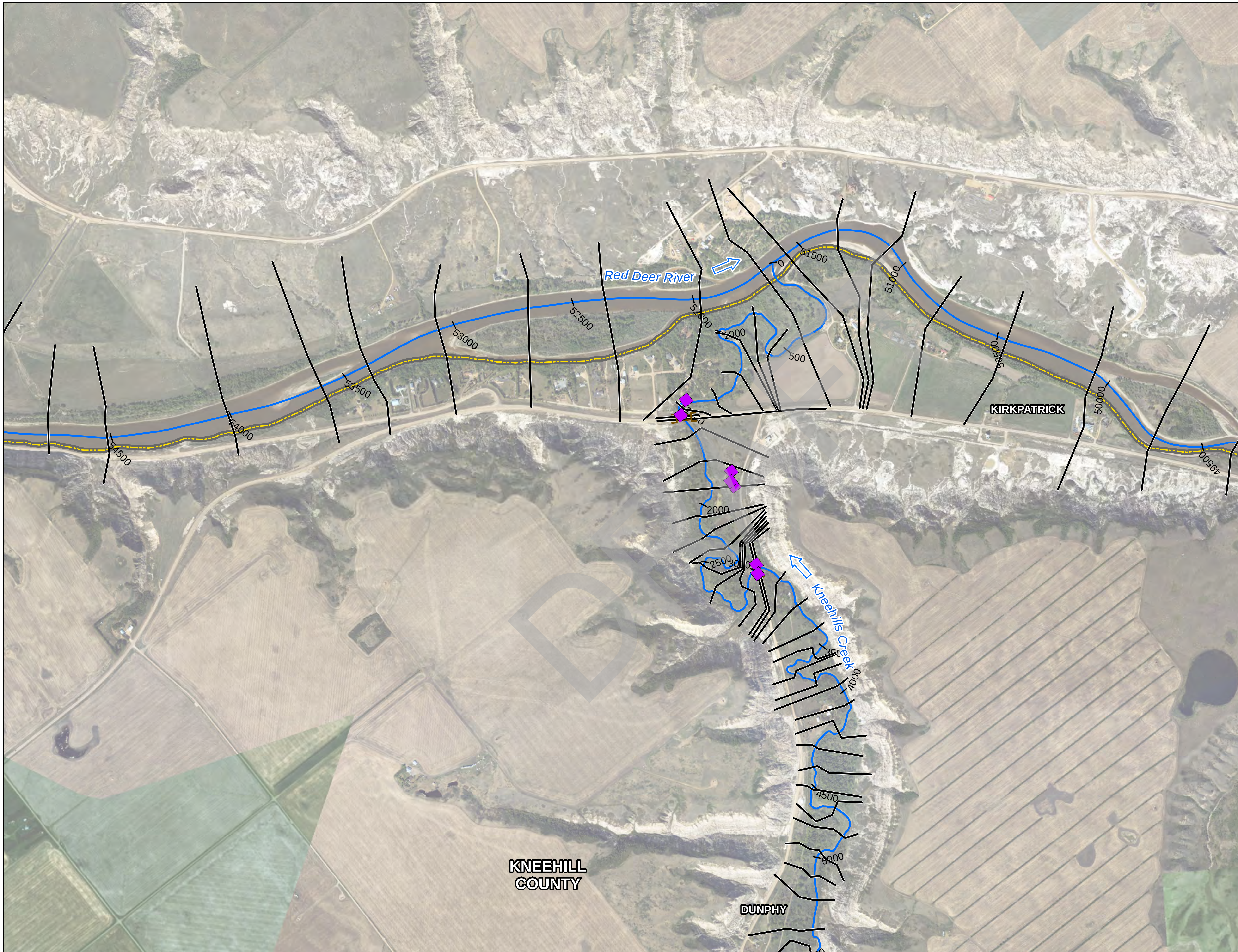
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND
FLOOD INUNDATION MAPPING

STUDY AREA

FIGURE 1

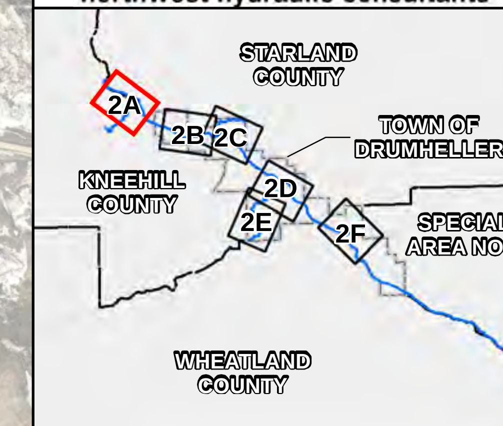
REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig01_StudyArea_R0.mxd

Classification: Public



Alberta

nhc
northwest hydraulic consultants



FLOW DIRECTION
STUDY REACH
BRIDGE
CULVERT
FLOOD CONTROL STRUCTURE
STUDY LIMIT
MODEL CROSS SECTION
MUNICIPAL BOUNDARY

HIGHWATER MARK

YEAR

2005
2013
2018

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater Marks from Alberta Environment and Parks.

SCALE - 1:15,000
0 250 500 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer AMH	*GIS* REH	*Reviewer* RBA

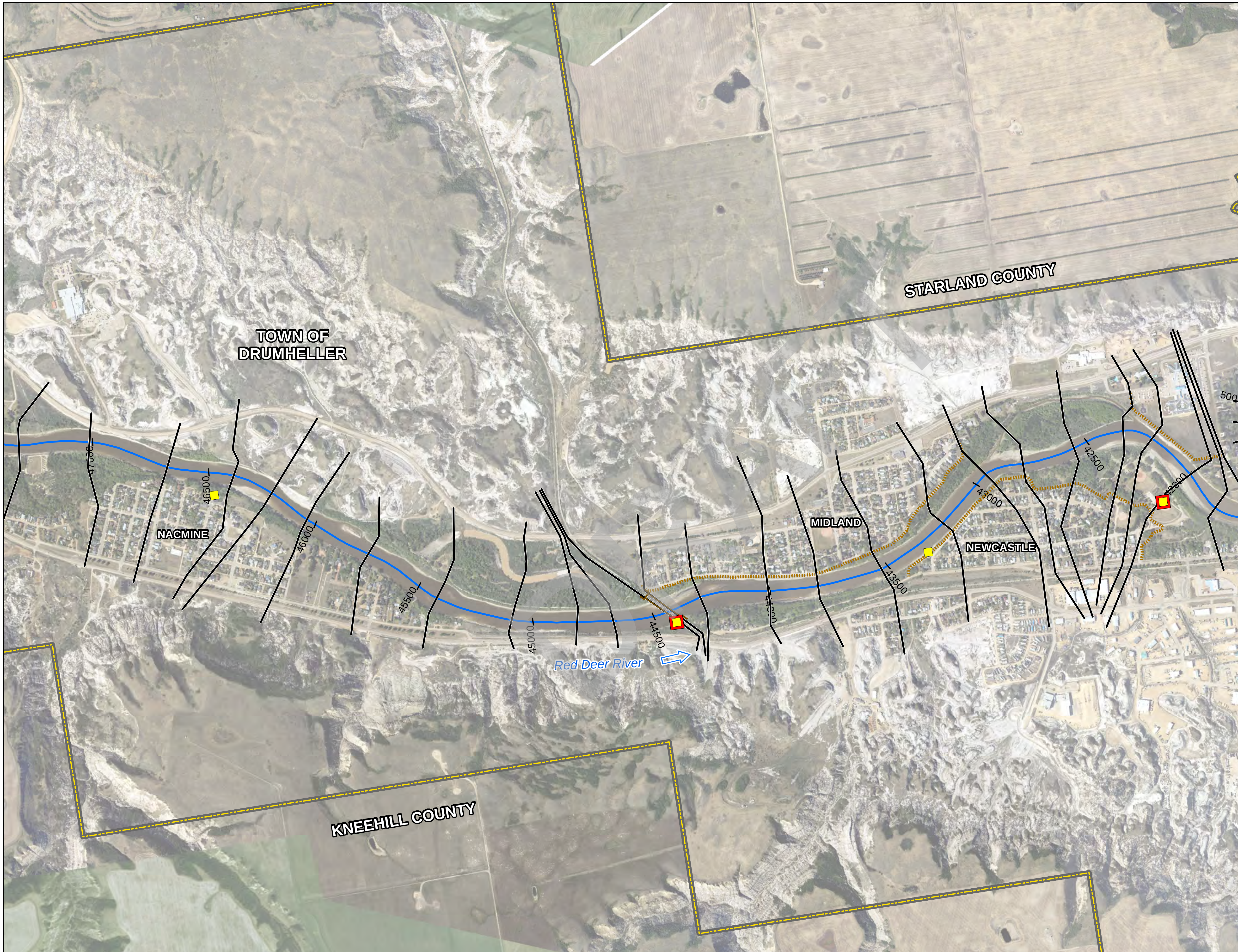
Job: 1003877 | *Date: 09-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS: Kneehills Creek

FIGURE 2A

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig2A_2C_HWM.mxd



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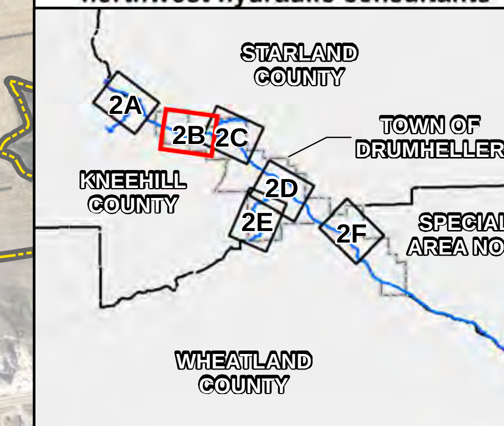
northwest hydraulic consultants



FLOW DIRECTION
STUDY REACH
BRIDGE
CULVERT
FLOOD CONTROL STRUCTURE
STUDY LIMIT
MODEL CROSS SECTION
MUNICIPAL BOUNDARY

HIGHWATER MARK

YEAR

2005
2013
2018

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater Marks from Alberta Environment and Parks.

SCALE - 1:15,000
0 250 500 M
N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
AMH	REH	RBA

Job: 1003877 | *Date: 09-MAR-2020*

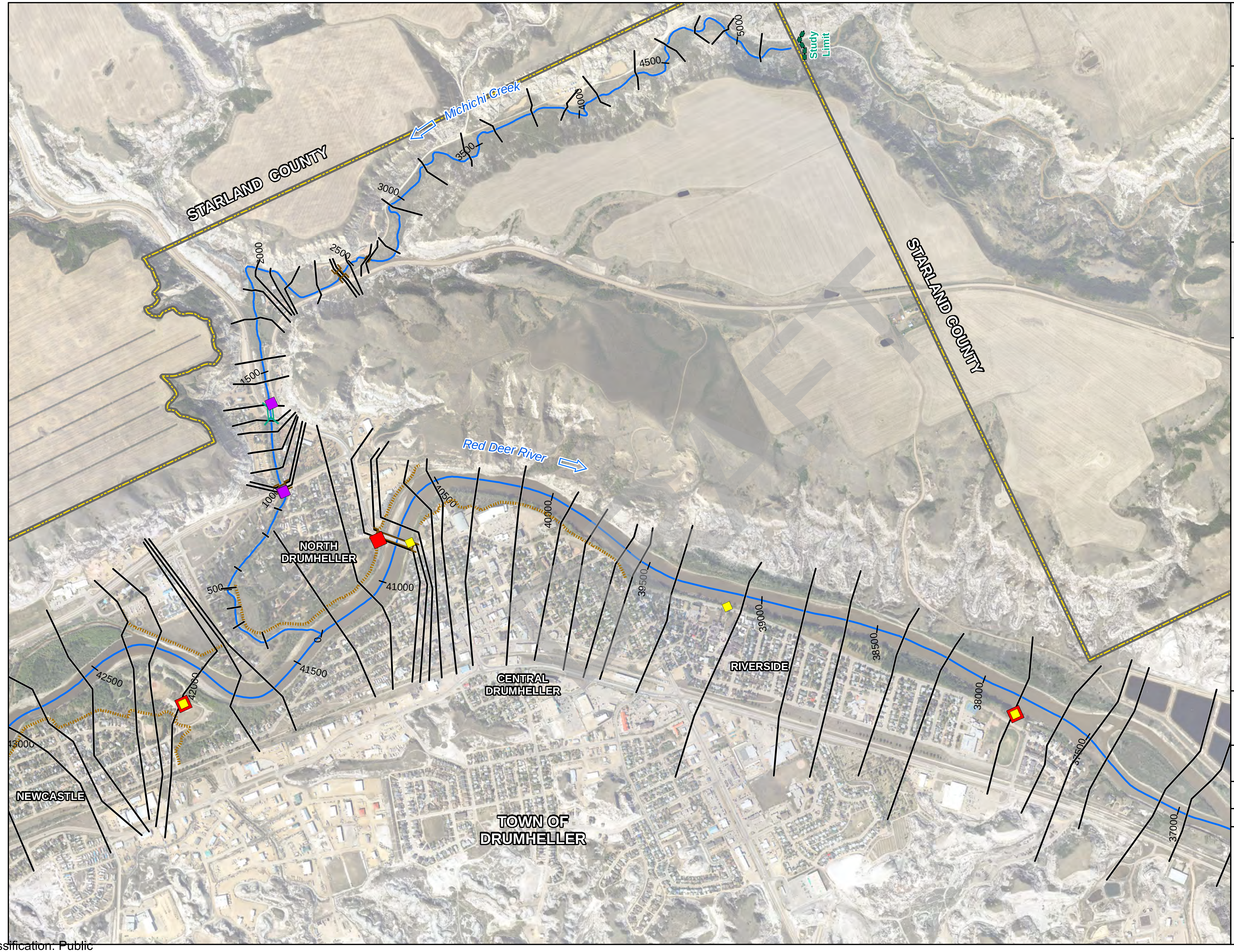
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS: Red Deer River

FIGURE 2B

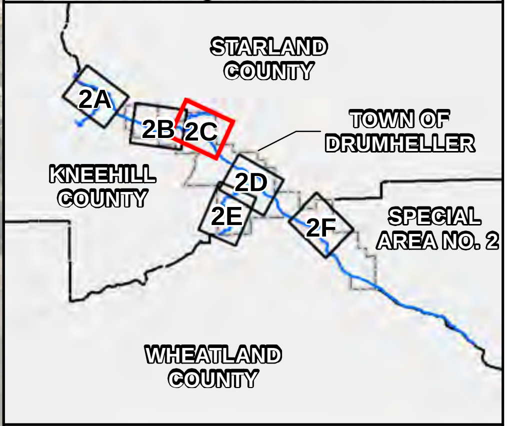
REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig2A_2C_HWM.mxd

Classification: Public



Alberta

nhc
northwest hydraulic consultants



FLOW DIRECTION
STUDY REACH
BRIDGE
CULVERT
FLOOD CONTROL STRUCTURE
STUDY LIMIT
MODEL CROSS SECTION
MUNICIPAL BOUNDARY

HIGHWATER MARK

YEAR

- 2005
- 2013
- 2018

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater Marks from Alberta Environment and Parks.

SCALE - 1:15,000
0 250 500 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
AMH	REH	RBA

Job: 1003877 | *Date: 09-MAR-2020*

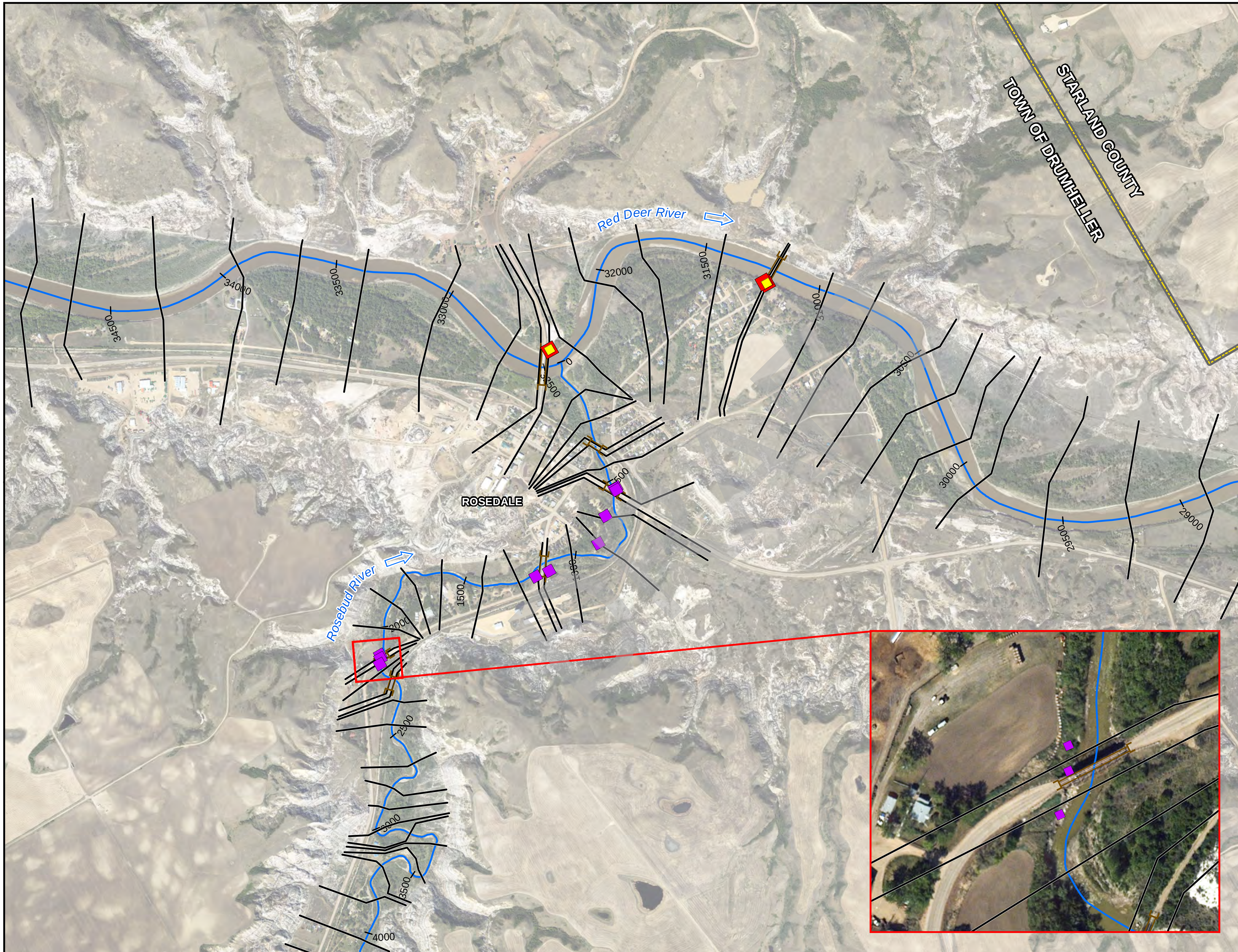
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS: Michichi Creek & Red Deer River

FIGURE 2C

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig2A_2C_HWM.mxd

Classification: Public



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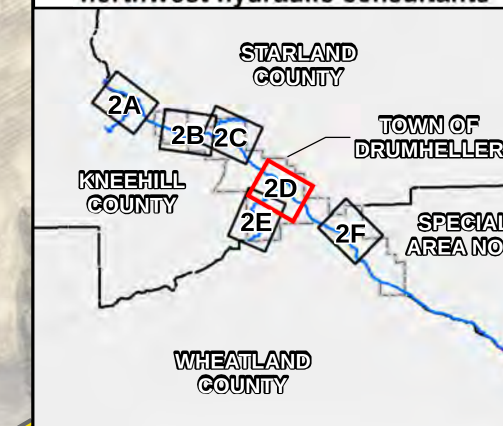
northwest hydraulic consultants



FLOW DIRECTION
STUDY REACH
BRIDGE
CULVERT
FLOOD CONTROL STRUCTURE
STUDY LIMIT
MODEL CROSS SECTION
MUNICIPAL BOUNDARY

HIGHWATER MARK

YEAR

- 2005
- 2013
- 2018

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater Marks from Alberta Environment and Parks.

SCALE - 1:15,000

0 250 500 M

N

Coordinate System: NAD 1983 CSRS 3TM 114
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer AMH	*GIS* REH	*Reviewer* RBA

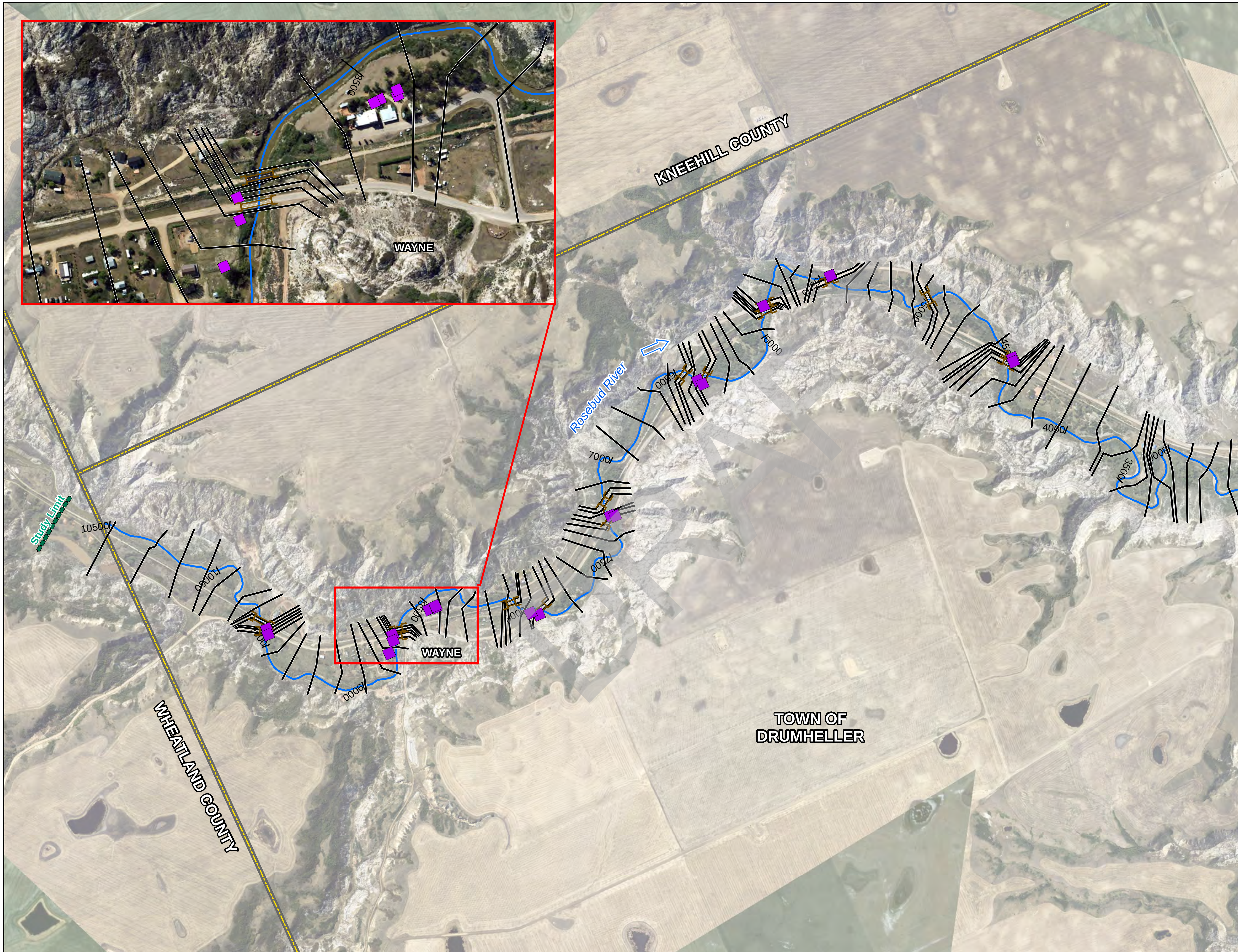
Job: 1003877 | *Date: 09-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS: Rosebud River & Red Deer River

FIGURE 2D

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig2D_HWM.mxd



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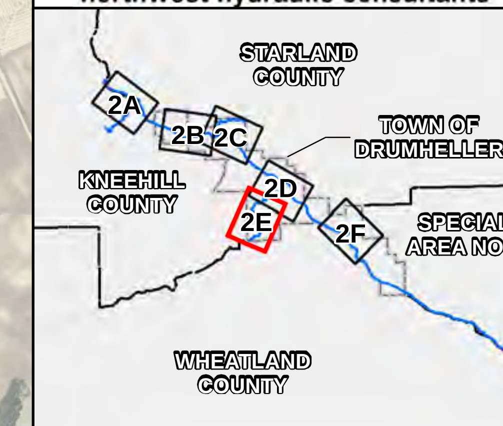


FLOW DIRECTION
STUDY REACH
BRIDGE
CULVERT
FLOOD CONTROL STRUCTURE
STUDY LIMIT
MODEL CROSS SECTION
MUNICIPAL BOUNDARY

HIGHWATER MARK

YEAR

- 2005
- 2013
- 2018

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater Marks from Alberta Environment and Parks.

SCALE - 1:15,000
0 250 500 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer AMH	*GIS* REH	*Reviewer* RBA

Job: 1003877 *Date: 09-MAR-2020*

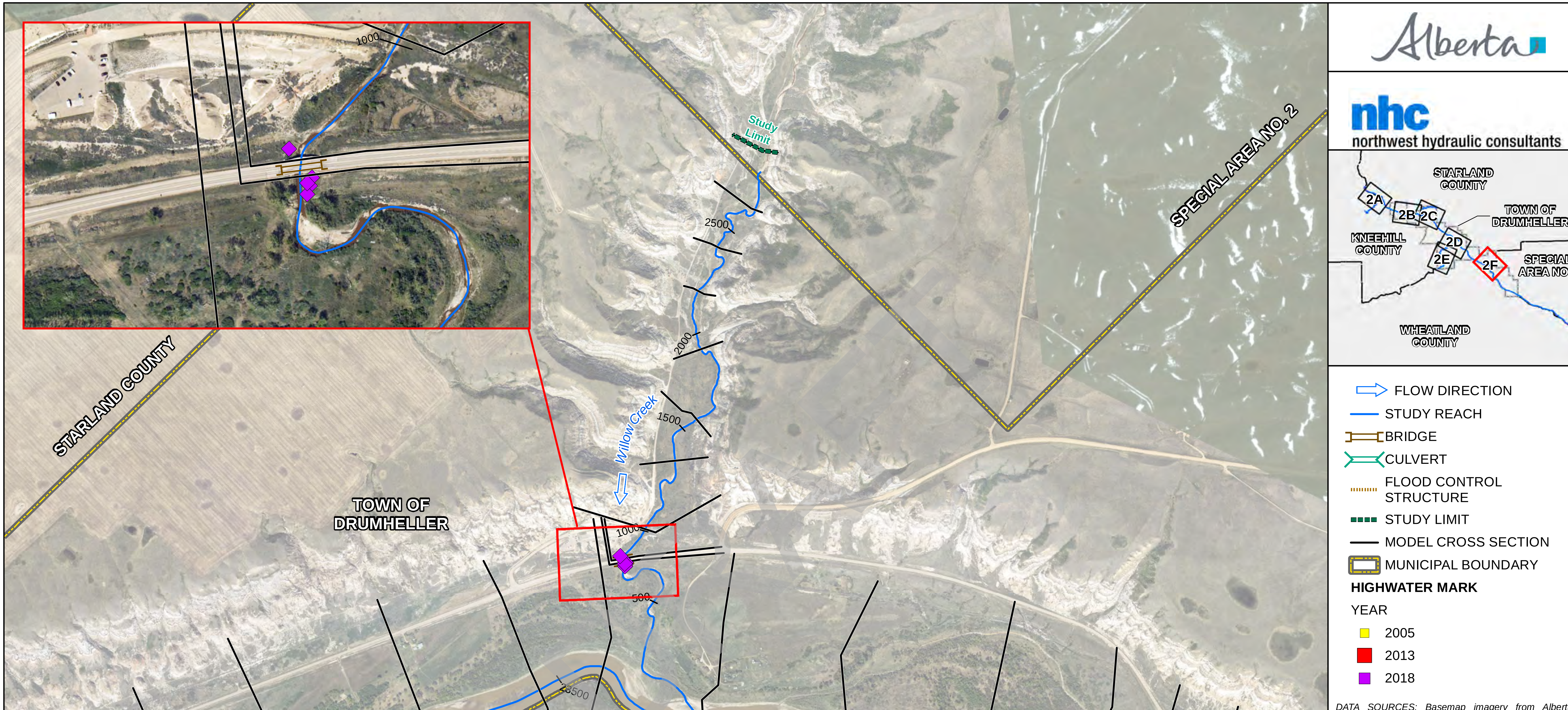
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS: Rosebud River

FIGURE 2E

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig2E_HWM.mxd

Classification: Public



Alberta

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DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater Marks from Alberta Environment and Parks.

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
AMH	REH	RBA

Job: 1003877 | Date: 09-MAR-2020

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS: Willow Creek

FIGURE 2F

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig2F_HWM.mxd

Alberta

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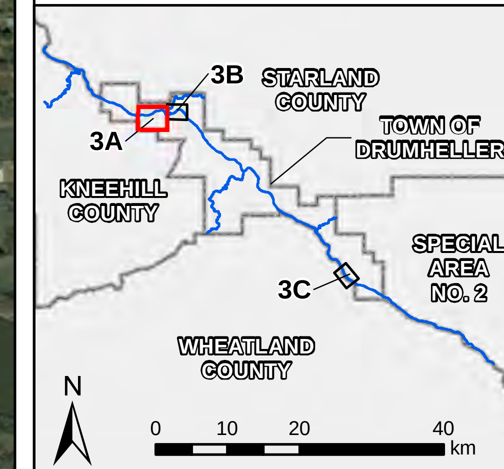

FLOW DIRECTION
IMAGE LOCATION
FLOOD CONTROL STRUCTURE
BRIDGE

1

89°E (T) ● 12 U 377837 5703044 ±5m ▲ 686m

2

106°E (T) ● 12 U 378192 5703046 ±5m ▲ 685m

3

266°W (T) ● 12 U 378721 5703032 ±5m ▲ 684m

4

253°W (T) ● 12 U 379173 5703122 ±5m ▲ 689m

5

122°SE (T) ● 12 U 379650 5703159 ±5m ▲ 682m

6

67°NE (T) ● 12 U 379894 5702889 ±5m ▲ 684m

7

153°SE (T) ● 12 U 379922 5703462 ±5m ▲ 688m

8

230°SW (T) ● 12 U 380230 5703336 ±5m ▲ 684m

DATA SOURCES: Basemap from Esri and NRCan

SCALE - 1:7,500

0 125 250 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 | *Date: 24-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

MIDLAND, NEWCASTLE & HOSPITAL DIKES

FIGURE 3A

DRAFT

REH, \\nhcfile-edm\P-drive_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig3A_FloodControlStructures_R0.mxd

Classification: Public

Alberta

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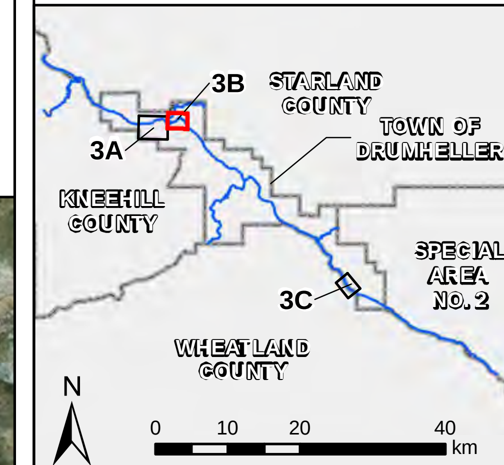

FLOW DIRECTION

IMAGE LOCATION

FLOOD CONTROL STRUCTURE

BRIDGE

DATA SOURCES: Basemap from Esri and NRCan

SCALE - 1:5,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 | *Date: 21-FEB-2020*

DRUMHELLER RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

DIKES B, C & D

FIGURE 3B

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig3B_FloodControlStructures_R0.mxd

Classification: Public

Alberta

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3A
3B
3C
STARLAND COUNTY
TOWN OF DRUMHELLER
KNEEHILL COUNTY
SPECIAL AREA NO. 2
WHEATLAND COUNTY
N
0 10 20 40 km

FLOW DIRECTION
IMAGE LOCATION
FLOOD CONTROL STRUCTURE
BRIDGE

DATA SOURCES: Basemap from Esri and NRCan

SCALE - 1:5,000
0 100 200 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 | Date: 21-FEB-2020

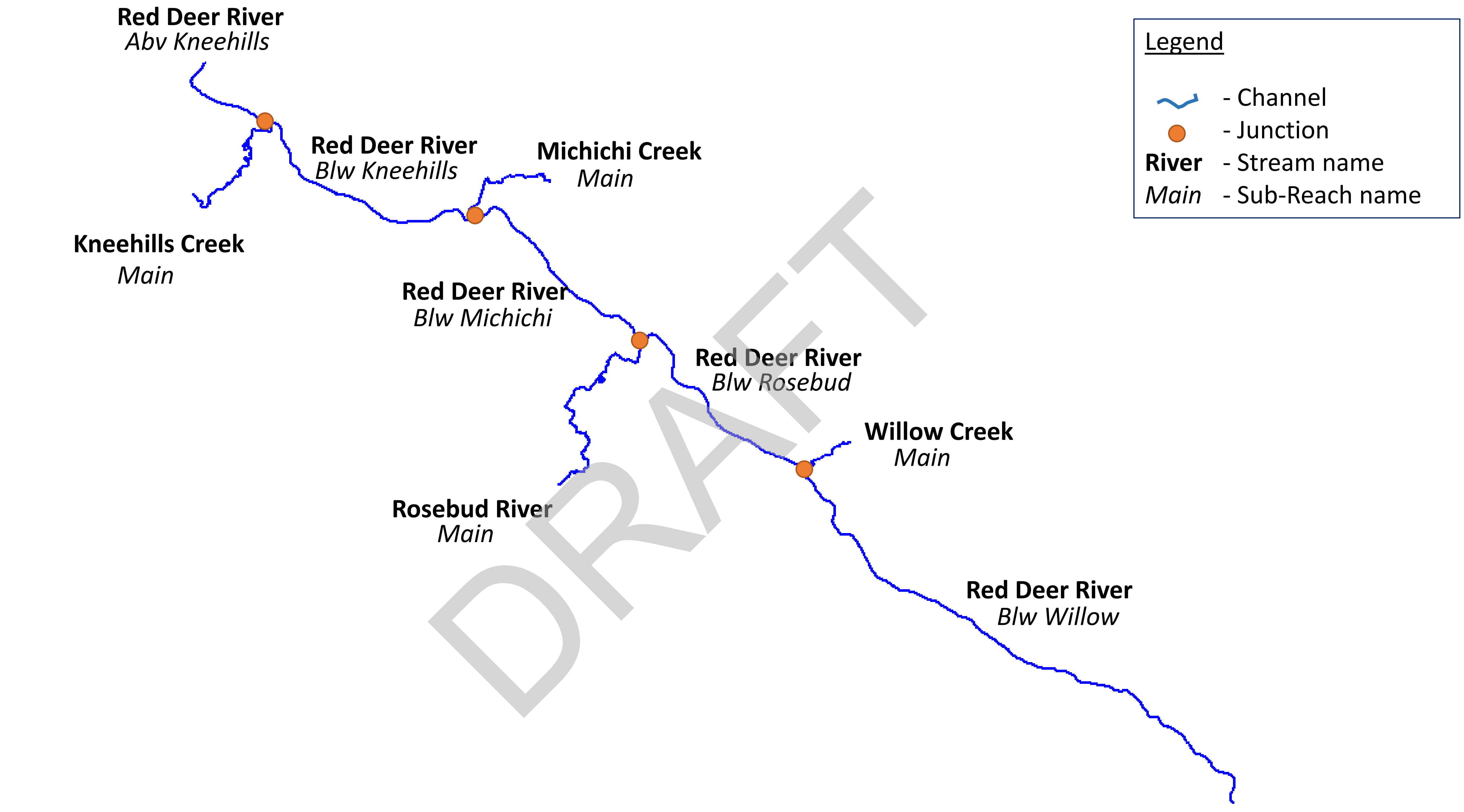
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

EAST COULEE DIKE

FIGURE 3C

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1003877_T300_Fig3C_FloodControlStructures_R0.mxd

Classification: Public



Alberta

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northwest hydraulic consultants

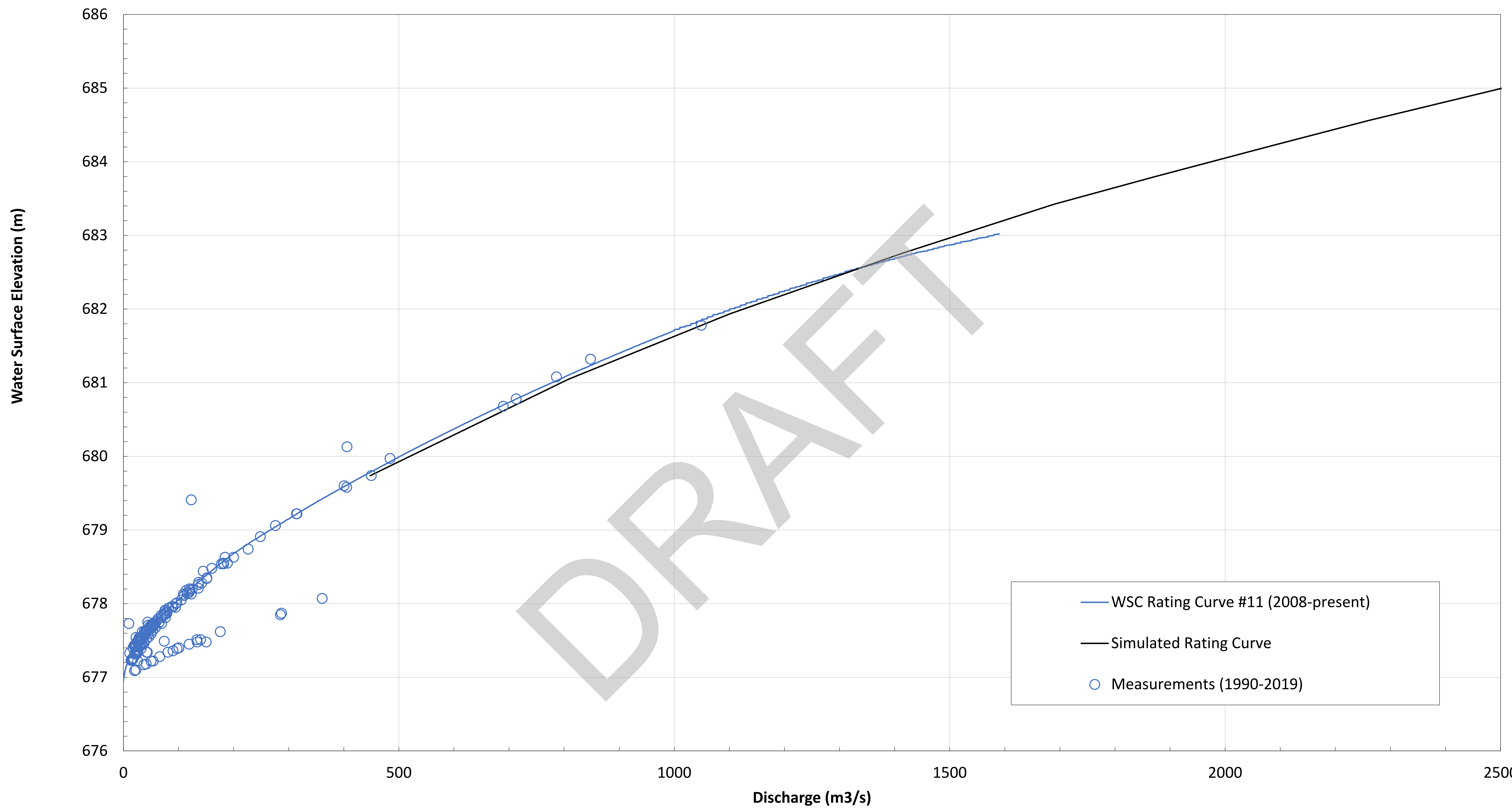
Job: 1003877

Date: 25-MAR-2020

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

SCHEMATIC LAYOUT OF MODEL REACHES

FIGURE 4



Alberta

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SCALE – AS SHOWN

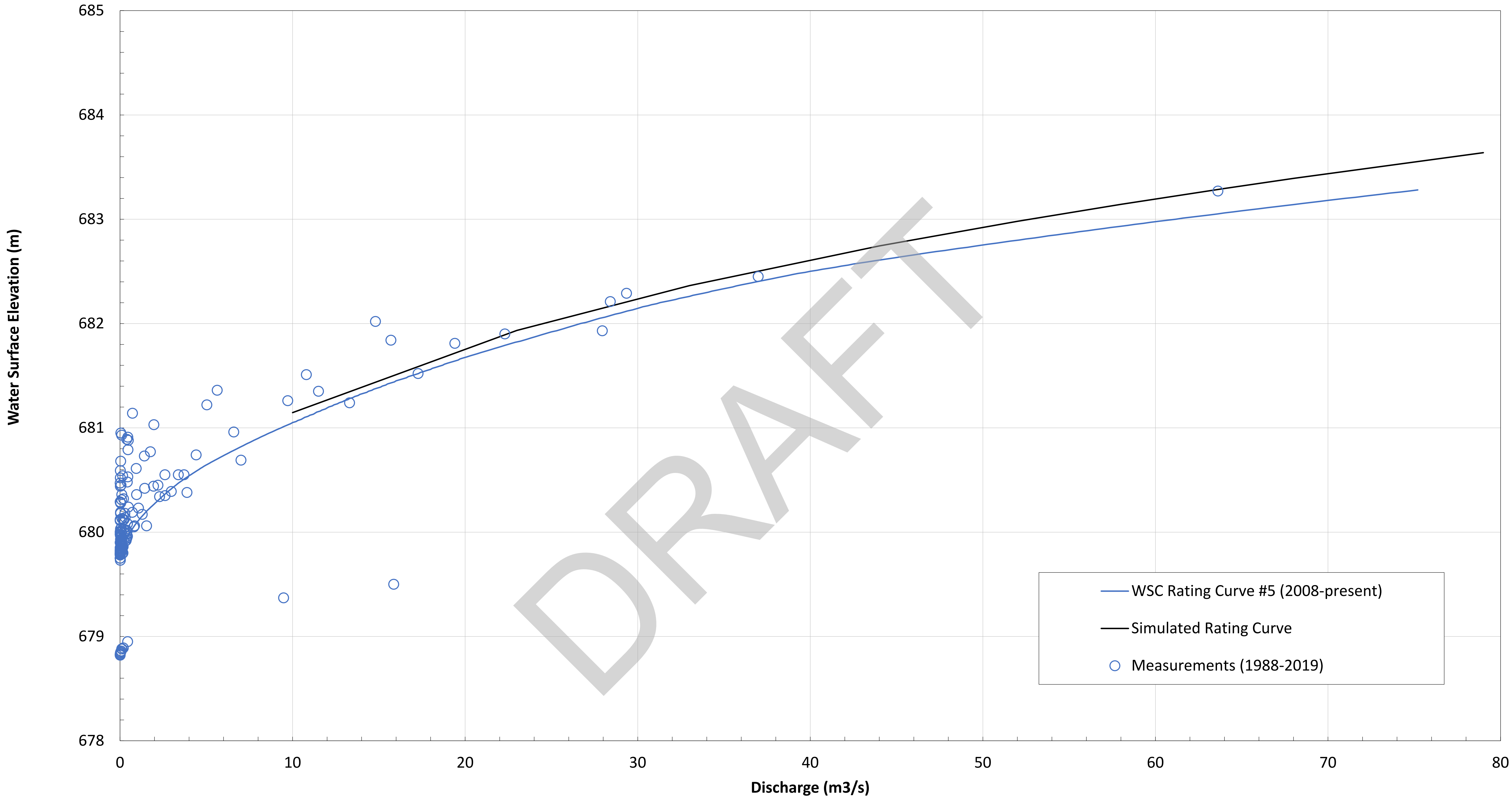
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | Date: 15-DEC-2021

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING
COMPARISON OF SIMULATED RATING CURVE TO WSC RATING CURVE AT RED DEER RIVER AT DRUMHELLER (WSC STATION 05CE001)

FIGURE 5

RBA P:_Projects (Active)\1003877 Drumheller River Hazard Study\05 Reporting\0100 Survey and Base Data Collection\00 DRAFT\Figures\Figure 3-DRAFT.pptx



Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

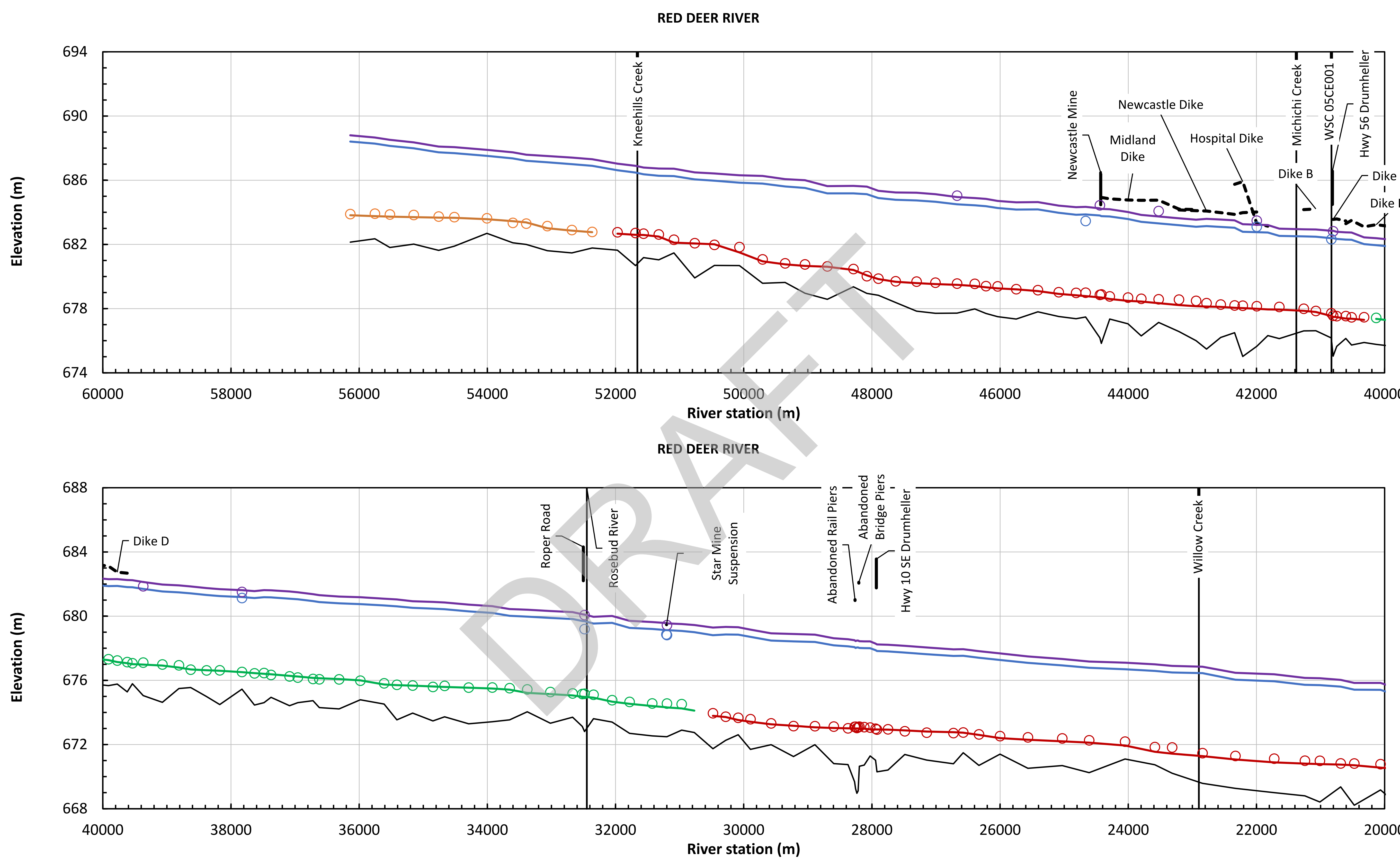
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877

Date: 15-DEC-2021

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING
COMPARISON OF SIMULATED RATING CURVE
TO WSC RATING CURVE
AT MICHICHI CREEK AT DRUMHELLER (WSC STATION 05CE020)

FIGURE 6



Alberta

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northwest hydraulic consultants

LEGEND

- 2005 Model Results
- 2013 Model Results
- 13 July 2018 Model Results
- 25 July 2018 Model Results
- 27 July 2018 Model Results
- Dikes
- Thalweg
- 2005 Observations
- 2013 Observations
- 13 July 2018 Observations
- 25 July 2018 Observations
- 27 July 2018 Observations
- Profile Features

SCALE – AS SHOWN

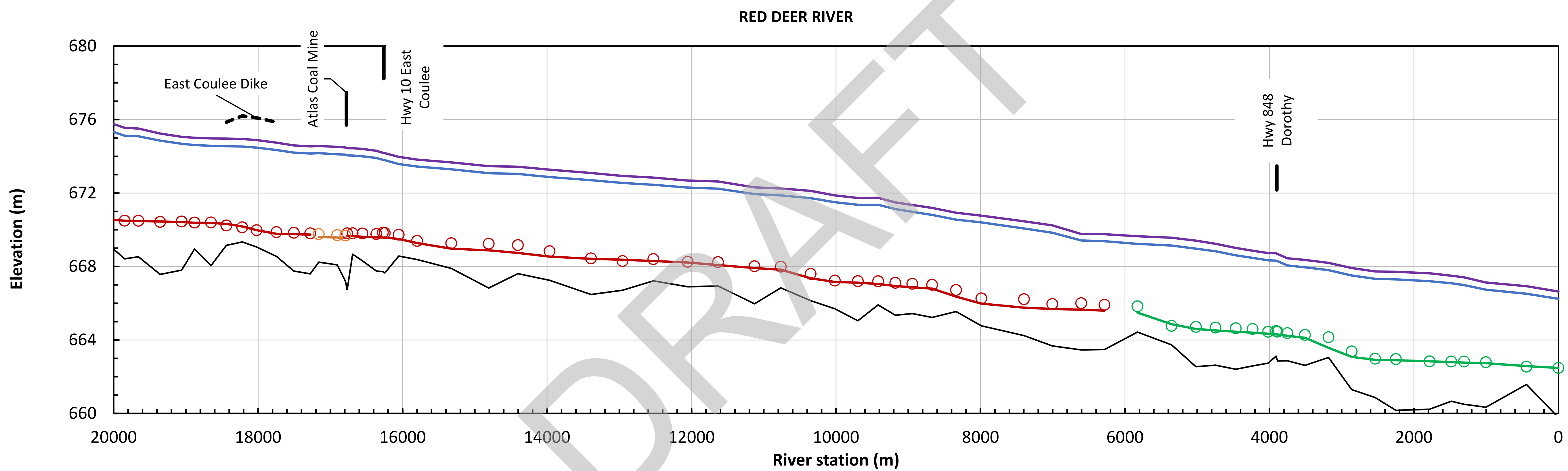
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

WATER SURFACE PROFILE CALIBRATION
RED DEER RIVER

FIGURE 7A



LEGEND

- 2005 Model Results
- 2013 Model Results
- 13 July 2018 Model Results
- 25 July 2018 Model Results
- 27 July 2018 Model Results
- Dikes
- Thalweg
- 2005 Observations
- 2013 Observations
- 13 July 2018 Observations
- 25 July 2018 Observations
- 27 July 2018 Observations
- Profile Features

Alberta

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SCALE – AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

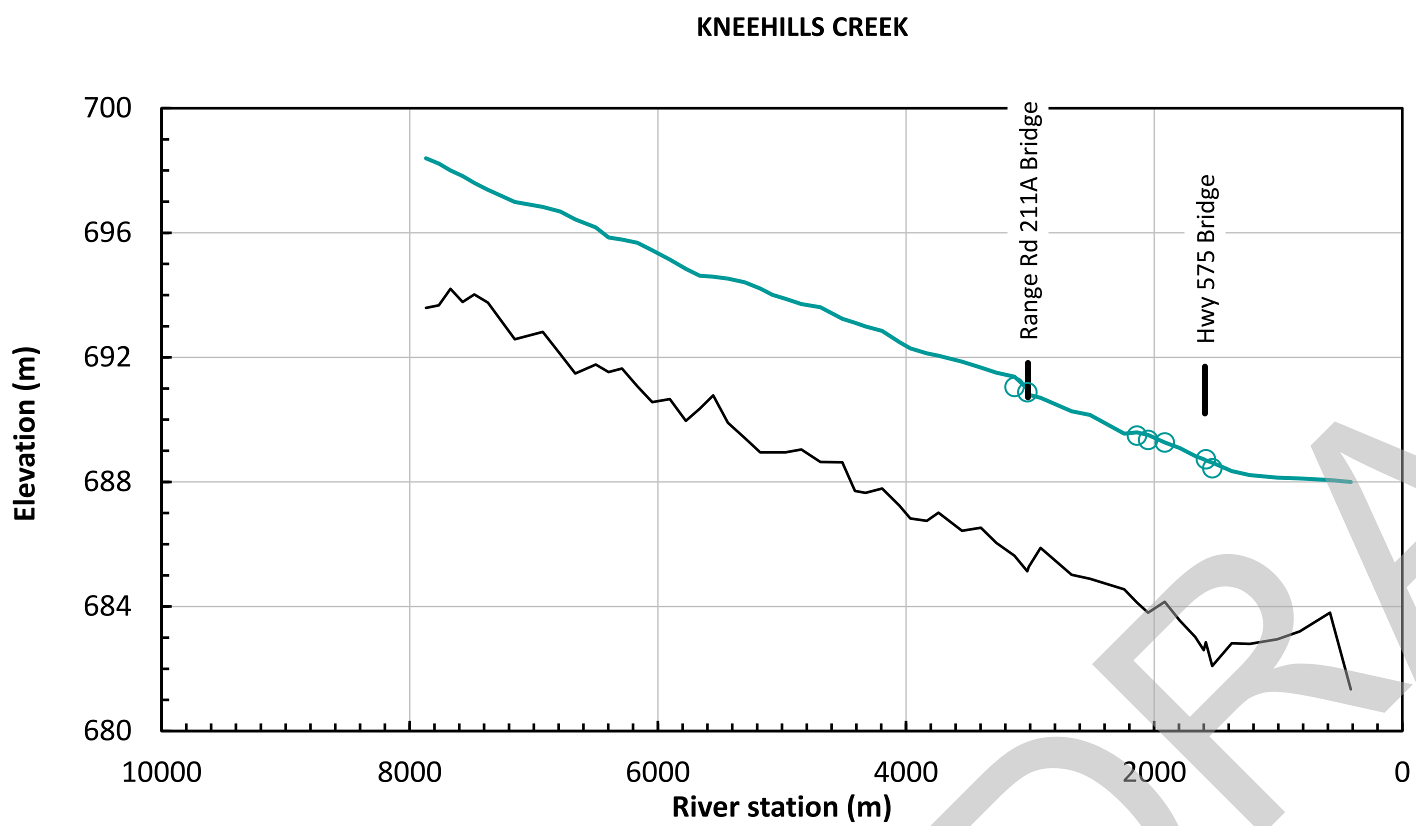
Job: 1003877 | Date: 25-MAR-2020

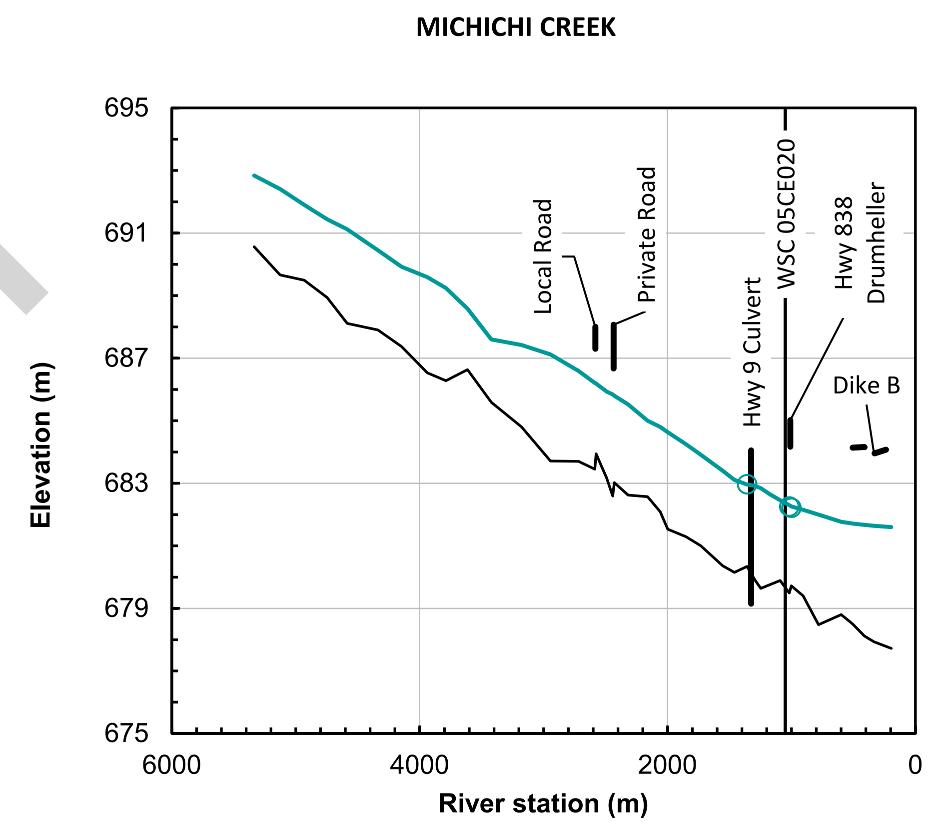
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

WATER SURFACE PROFILE CALIBRATION
RED DEER RIVER

FIGURE 7B

RBA P:_Projects (Active)\1003877 Drumheller River Hazard Study\05 Reporting\0100 Survey and Base Data Collection\00 DRAFT\Figures\Figure 3-DRAFT.pptx





DRAFT

LEGEND

- 2018 Model Results
- 2018 Observations
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | *Date: 25-MAR-2020*

Alberta

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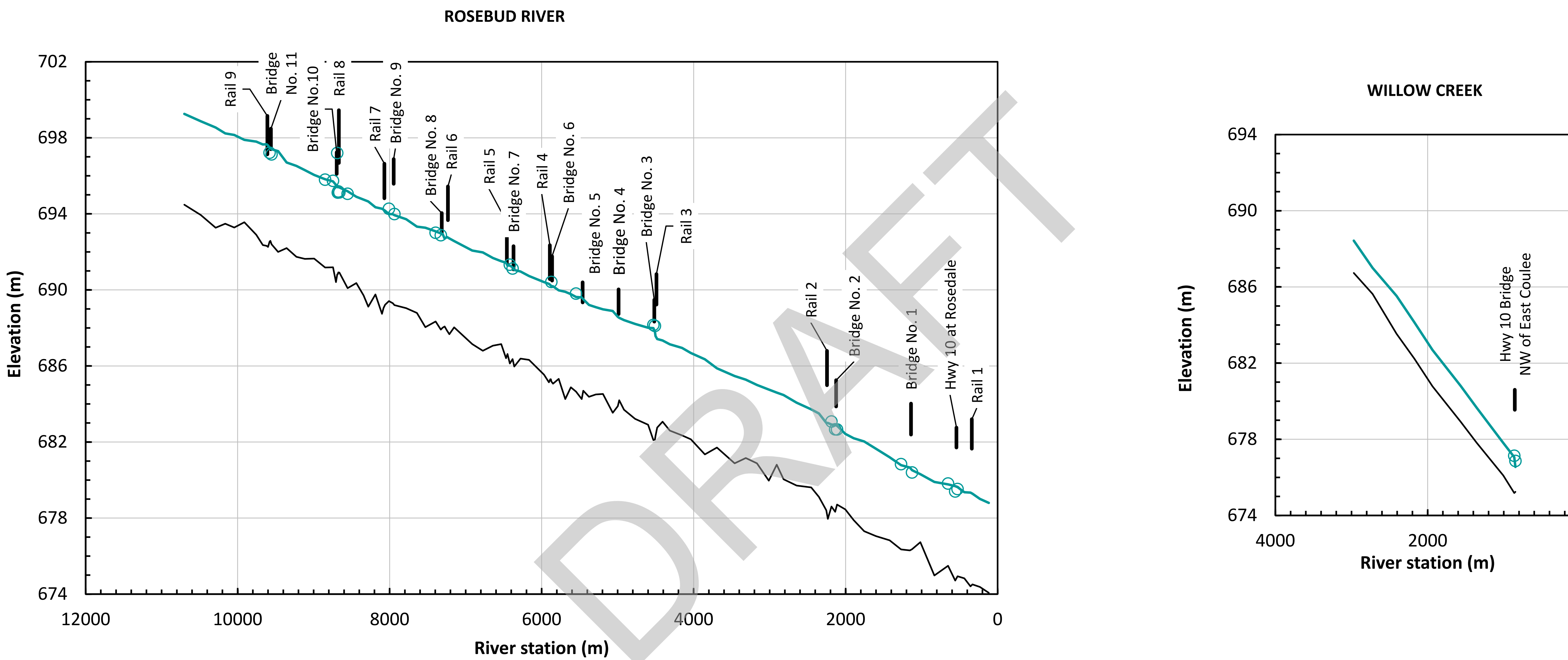
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

WATER SURFACE PROFILE CALIBRATION
KNEEHILLS CREEK, MICHICHI CREEK

FIGURE 8A



LEGEND

- 2018 Model Results
- 2018 Observations
- Dikes
- Profile Features
- Thalweg

Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

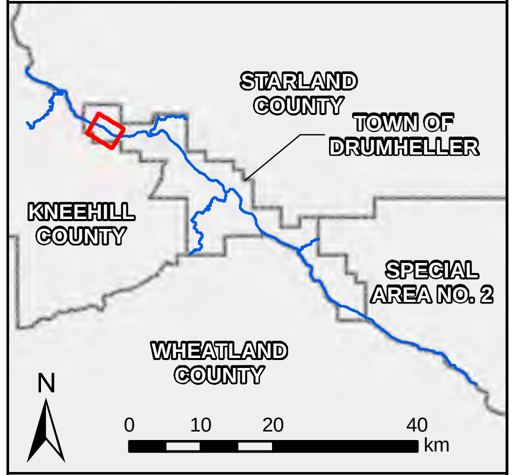
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

WATER SURFACE PROFILE CALIBRATION
ROSEBUD RIVER, WILLOW CREEK

FIGURE 8B



FLOW DIRECTION

PLANNED FLOOD CONTROL STRUCTURE

MODEL CROSS SECTION

Notes

1. Planned flood control structure data were provided to NHC by Alberta Environment and Parks on 24 September 2021.

2. Existing flood control structure (2018) data were surveyed by NHC in 2018.

SCALE - 1:7,500

0 125 250 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 | *Date: 04-FEB-2022*

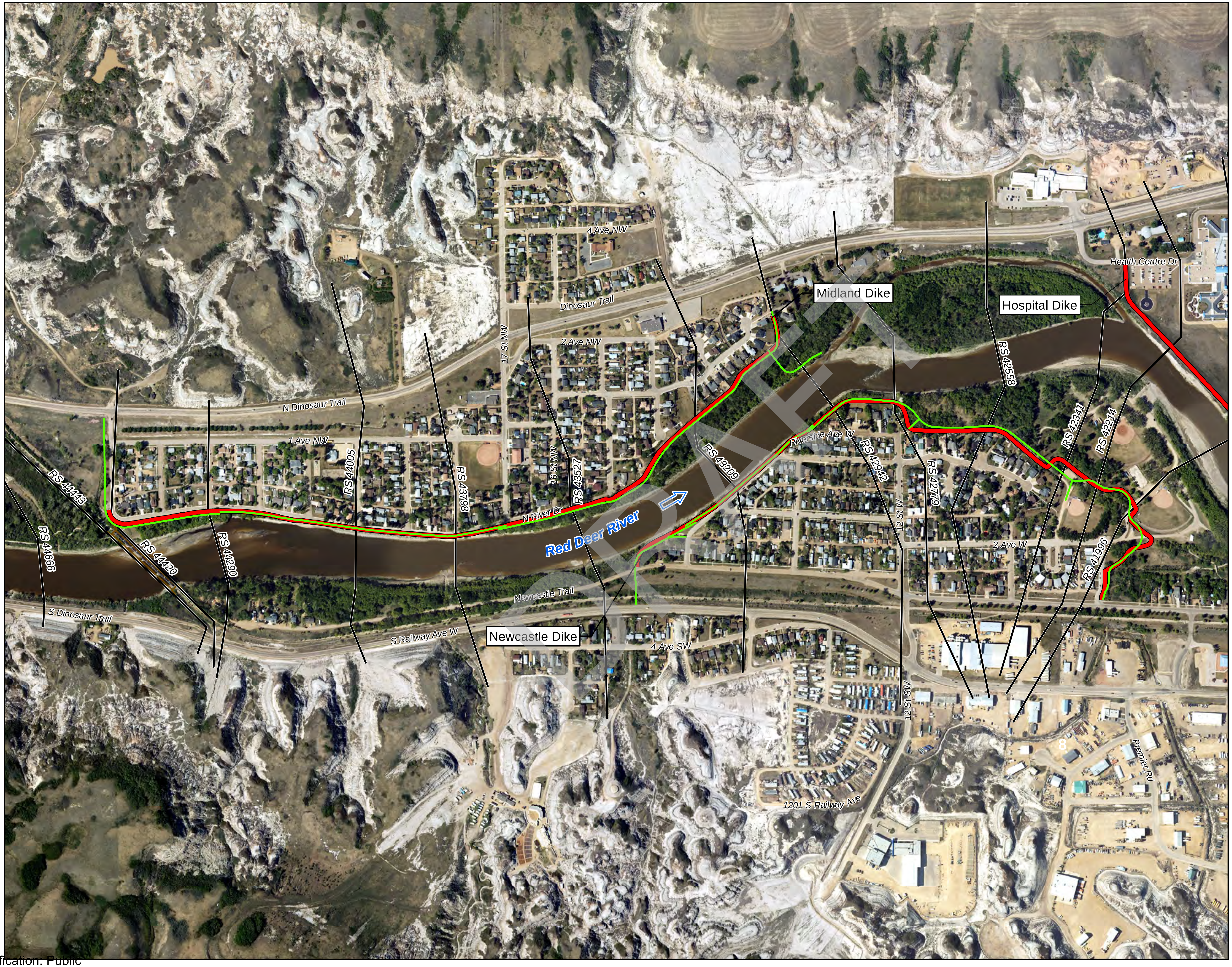
DRUMHELLER RIVER HAZARD STUDY HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

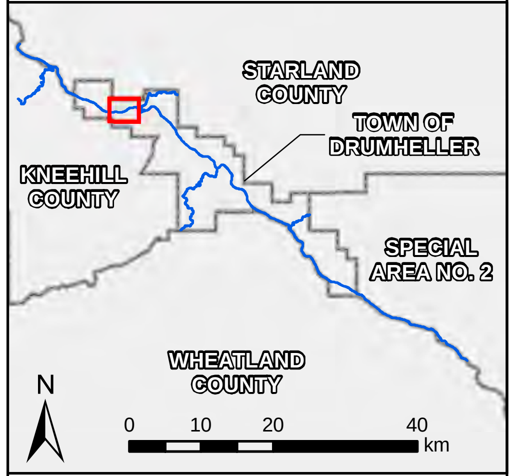
NACMINE DIKE

FIGURE 9A

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1006302_T300_Fig9A_FCS_Nacmine.mxd

Classification: Public





FLOW DIRECTION

PLANNED FLOOD CONTROL STRUCTURE

EXISTING FLOOD CONTROL STRUCTURE (2018)

BRIDGE

MODEL CROSS SECTION

Notes

1. Planned flood control structure data were provided to NHC by Alberta Environment and Parks on 24 September 2021.

2. Existing flood control structure (2018) data were surveyed by NHC in 2018.

SCALE - 1:7,500

0 125 250 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 | *Date: 18-MAR-2022*

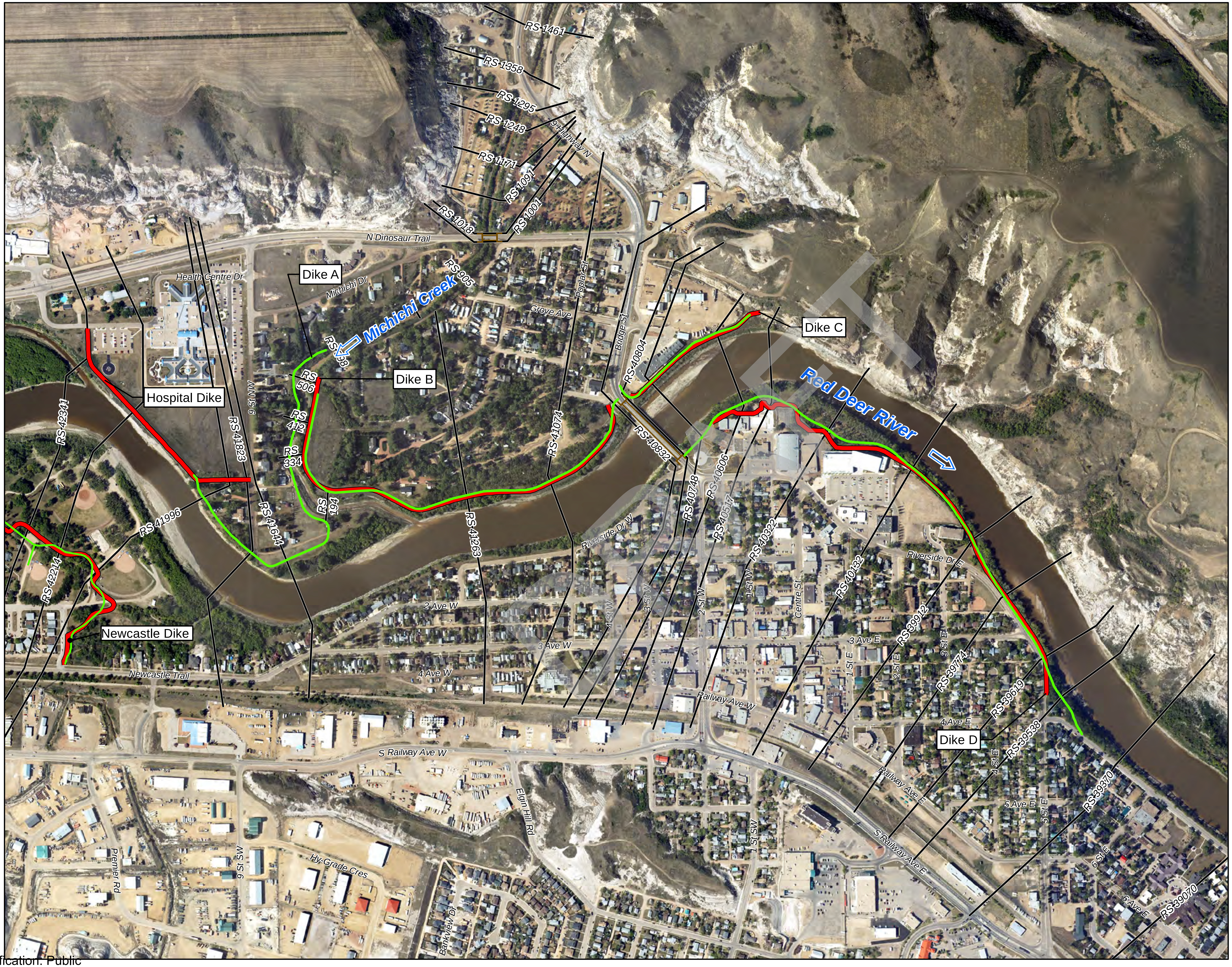
DRUMHELLER RIVER HAZARD STUDY HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

MIDLAND AND NEWCASTLE DIKES

FIGURE 9B

REH, \\mainfile-edm\Projects_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1006302_T300_Fig9B_FCS_MidlandNewcastle.mxd

Classification: Public



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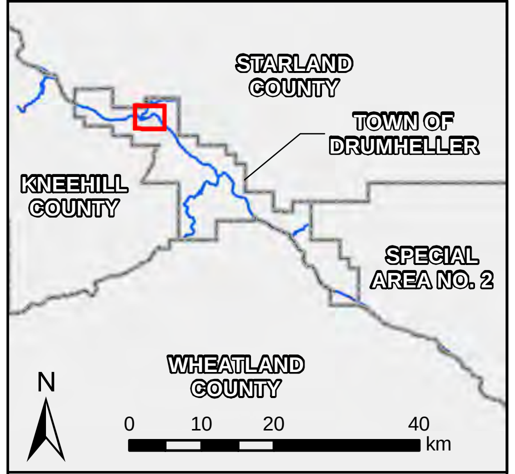

FLOW DIRECTION
PLANNED FLOOD CONTROL STRUCTURE
EXISTING FLOOD CONTROL STRUCTURE (2018)
BRIDGE
MODEL CROSS SECTION

Notes
1. Planned flood control structure data were provided to NHC by Alberta Environment and Parks on 24 September 2021.
2. Existing flood control structure (2018) data were surveyed by NHC in 2018.

SCALE - 1:7,500
0 125 250 M
N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877	Date: 18-MAR-2022

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

DIKES A, B, C & D

FIGURE 9C

REH \\van\file-edm\Projects_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1006302_T300_Fig9B_FCS_ABCD.mxd

Classification: Public

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FLOW DIRECTION
PLANNED FLOOD CONTROL STRUCTURE
MODEL CROSS SECTION

Notes

1. Planned flood control structure data were provided to NHC by Alberta Environment and Parks on 24 September 2021.
2. Existing flood control structure (2018) data were surveyed by NHC in 2018.

SCALE - 1:7,500
0 125 250 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877	Date: 04-FEB-2022

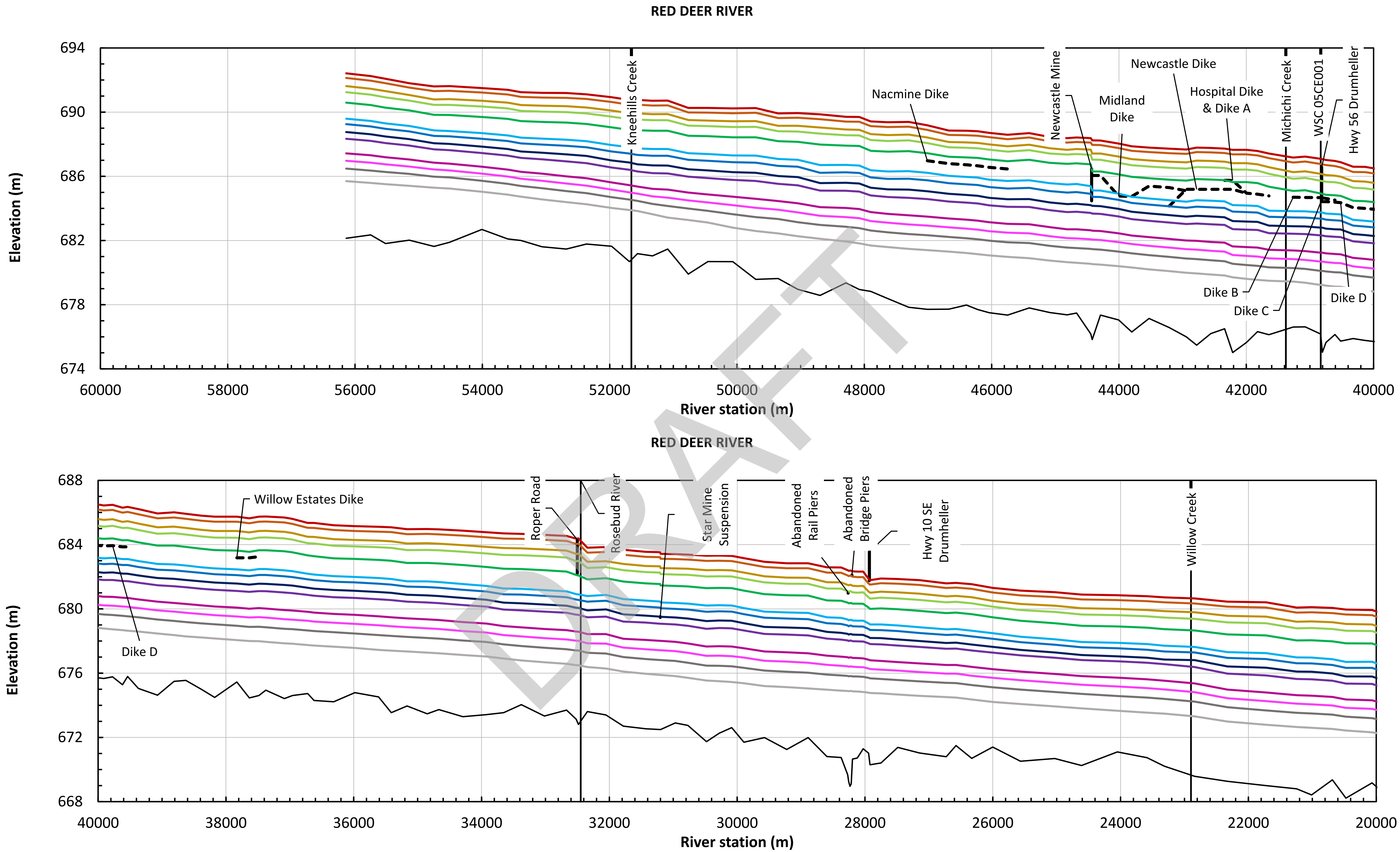
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND
FLOOD INUNDATION MAPPING

WILLOW ESTATES DIKE

FIGURE 9D

REH, P:_Projects (Active)\1003877 Drumheller River Hazard Study\90 GIS\1006302_T300_Fig9D_FCS_Willow_F.mxd

Classification: Public



LEGEND

1000-year	750-year	500-year
350-year	200-year	100-year
75-year	50-year	35-year
20-year	10-year	5-year
2-year	Dikes	Profile Features
Thalweg		

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SCALE – AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

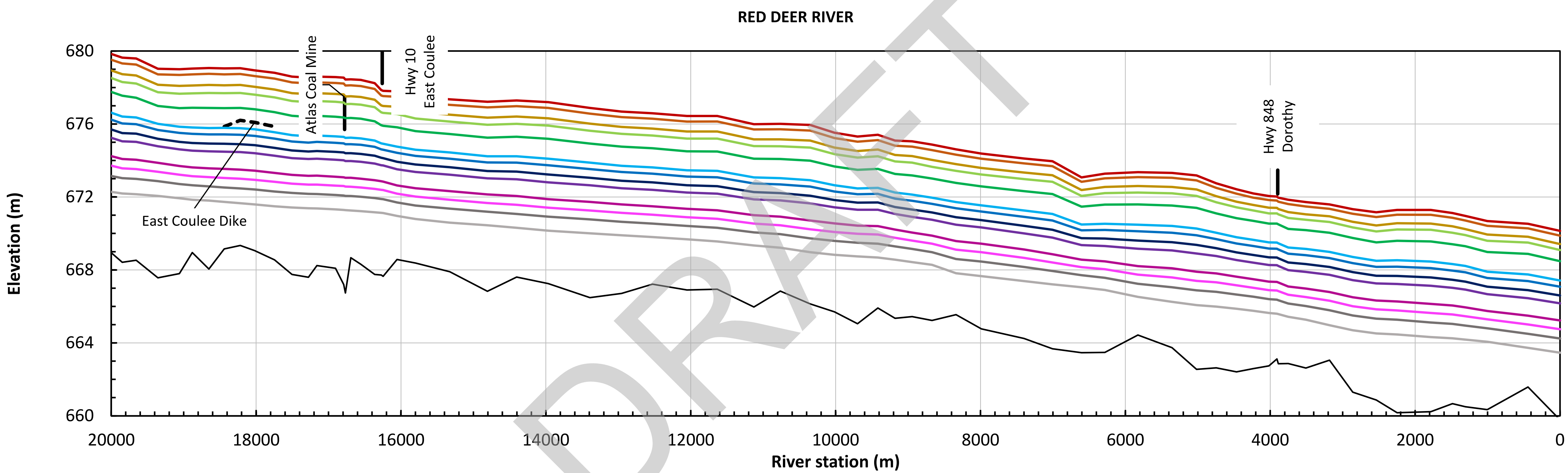
Job: 1003877

Date: 15-DEC-2021

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

RED DEER RIVER FLOOD FREQUENCY PROFILES

FIGURE 10A



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LEGEND

1000-year, 750-year, 500-year, 350-year, 200-year, 100-year, 75-year, 50-year, 35-year, 20-year, 10-year, 5-year, 2-year, Dikes, Profile Features, Thalweg

SCALE – AS SHOWN

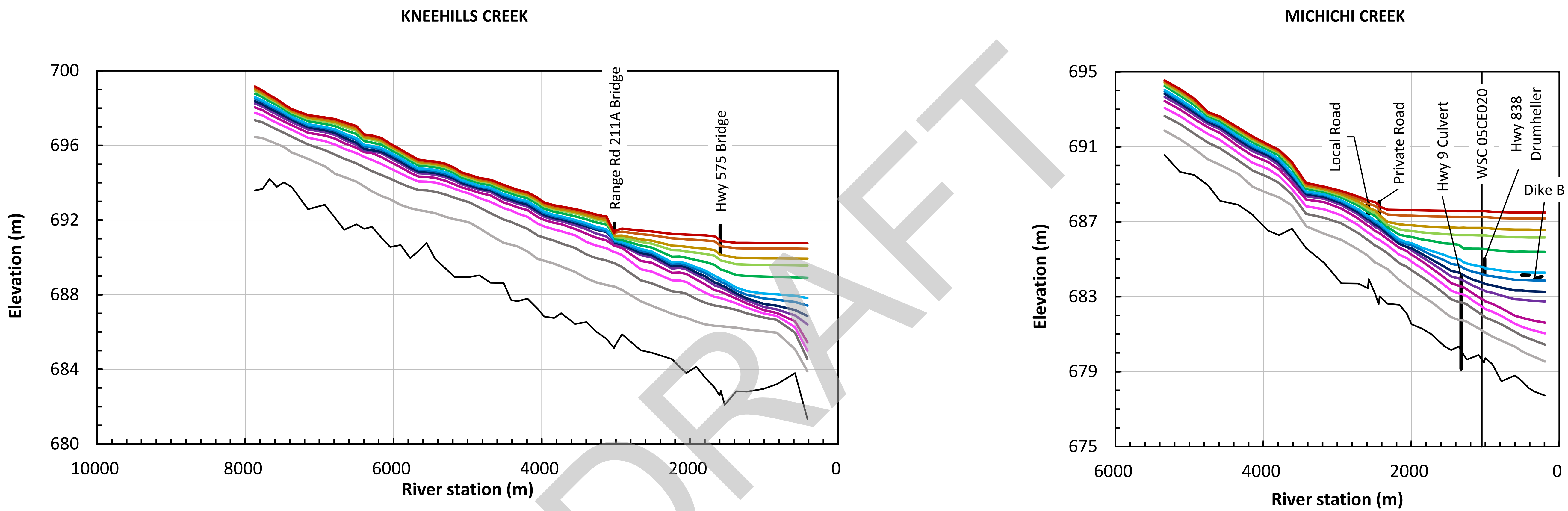
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 *Date: 15-DEC-2021*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

RED DEER RIVER FLOOD FREQUENCY PROFILES

FIGURE 10B



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LEGEND

- 1000-year
- 750-year
- 500-year
- 350-year
- 200-year
- 100-year
- 75-year
- 50-year
- 35-year
- 20-year
- 10-year
- 5-year
- 2-year
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

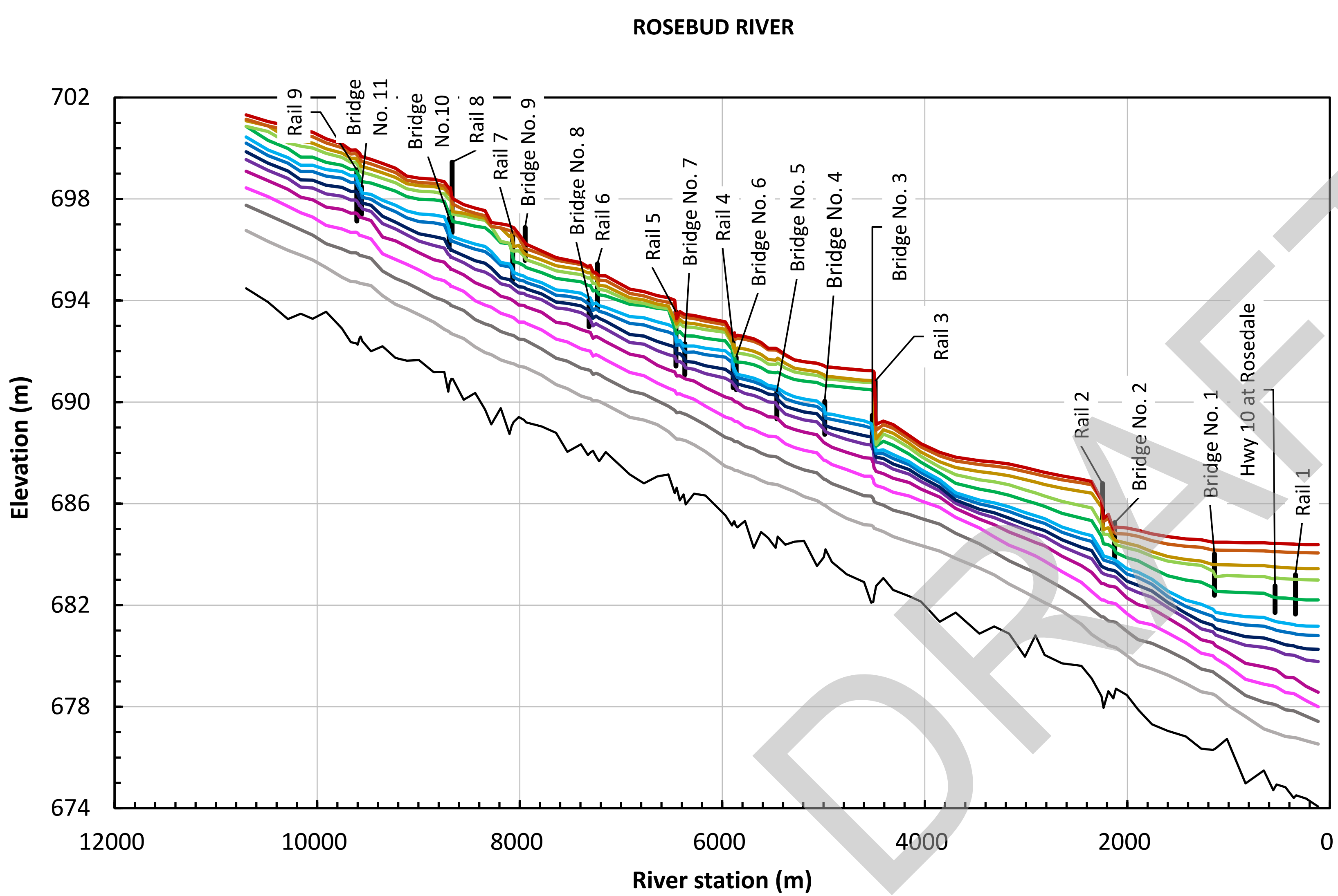
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

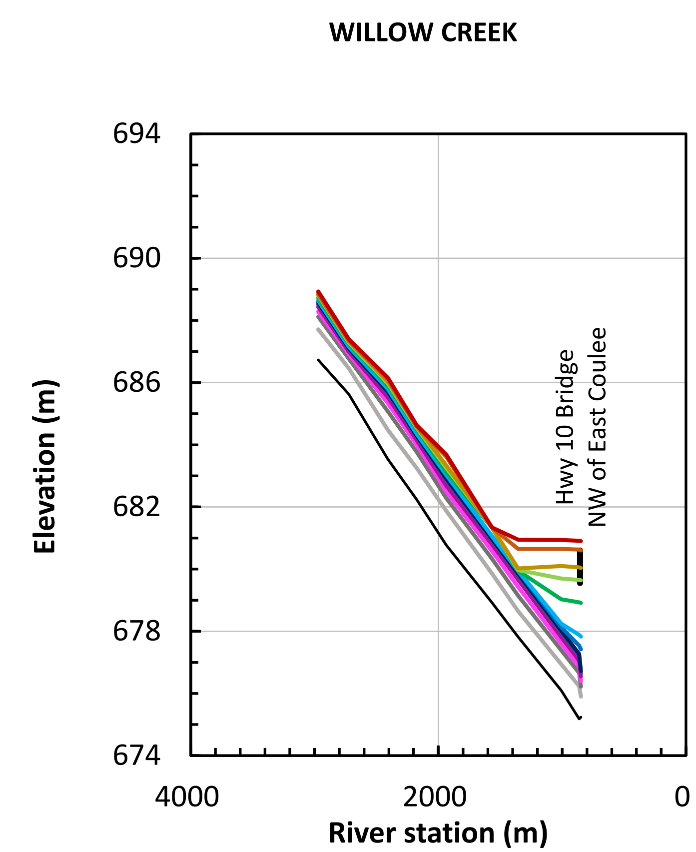
Job: 1003877 | *Date: 15-DEC-2021*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

KNEEHILLS CREEK, MICHICHI CREEK
FLOOD FREQUENCY PROFILES

FIGURE 11A





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LEGEND

1000-year	750-year	500-year
350-year	200-year	100-year
75-year	50-year	35-year
20-year	10-year	5-year
2-year	Dikes	Profile Features
Thalweg		

SCALE – AS SHOWN

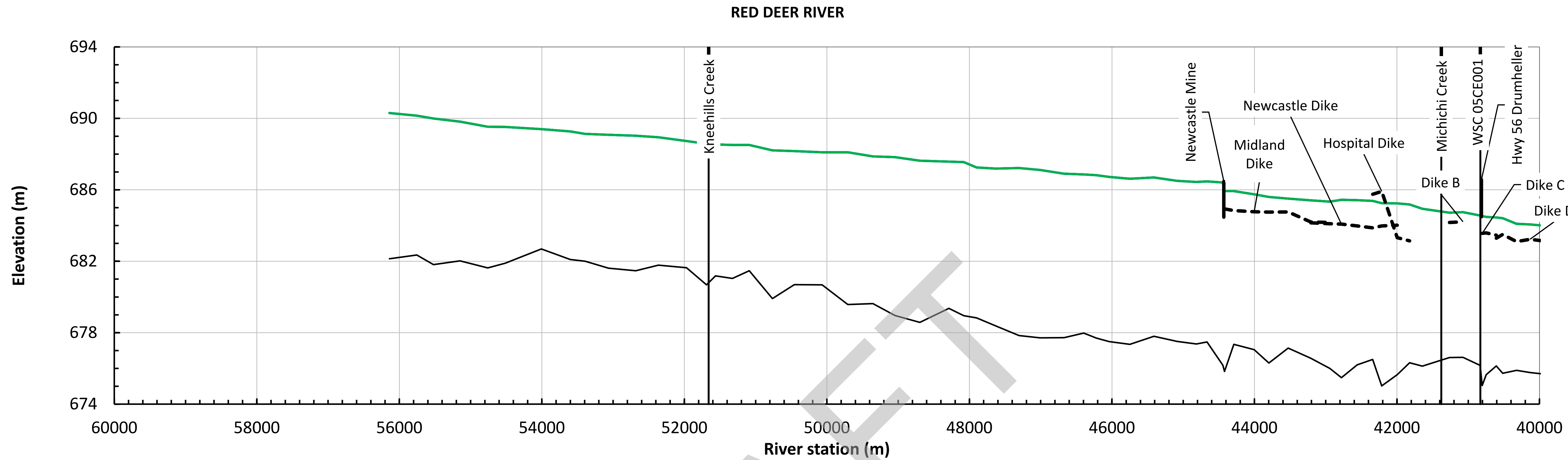
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

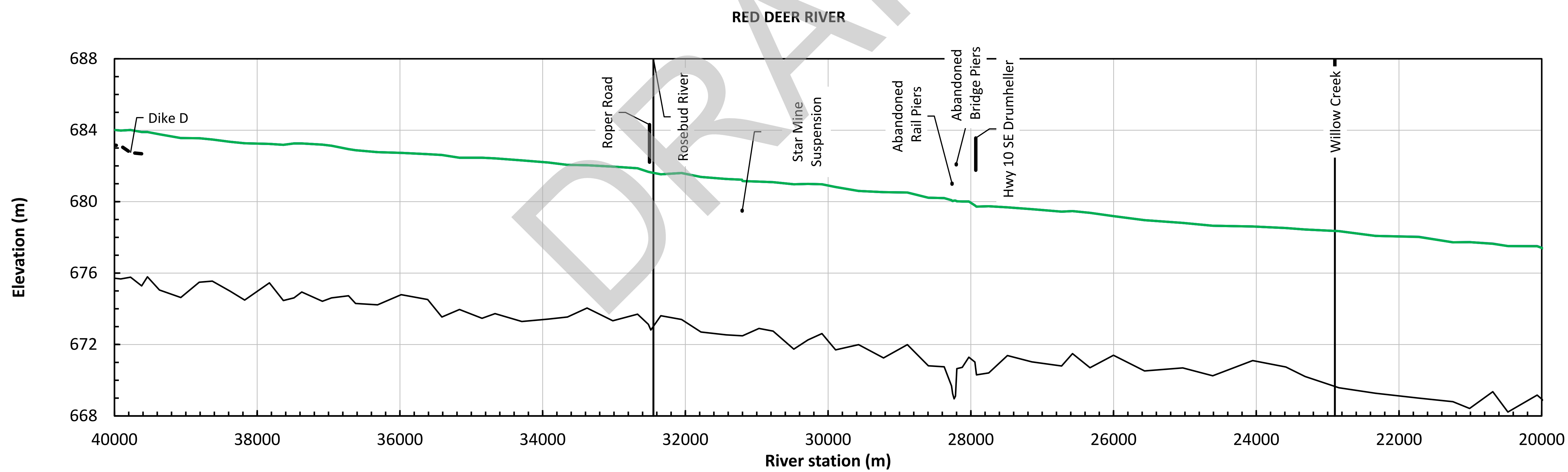
Job: 1003877 | *Date: 15-DEC-2021*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

ROSEBUD RIVER, WILLOW CREEK
FLOOD FREQUENCY PROFILES

FIGURE 11B





DRAFT

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LEGEND

- High Downstream Boundary (s = 0.000376 m/m)
- Calibrated
- Low Downstream Boundary (s = 0.000637 m/m)
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

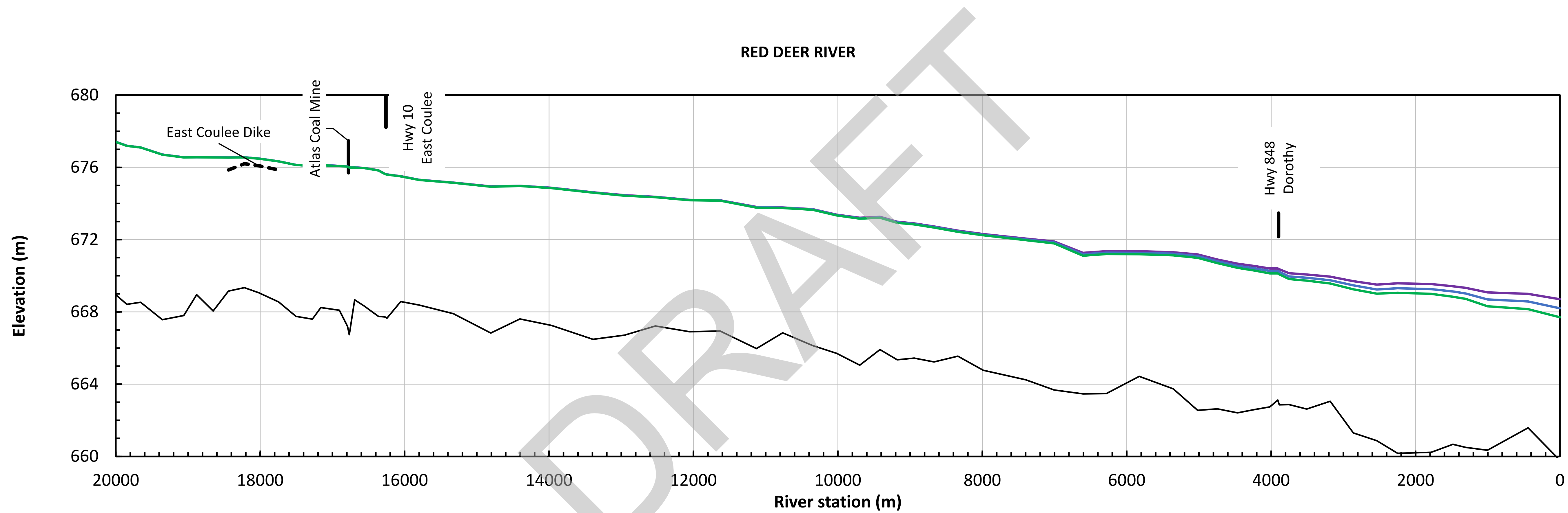
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO DOWNSTREAM BOUNDARY CONDITION – RED DEER RIVER

FIGURE 12A



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LEGEND

- High Downstream Boundary (s = 0.000376 m/m)
- Calibrated
- Low Downstream Boundary (s = 0.000637 m/m)
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

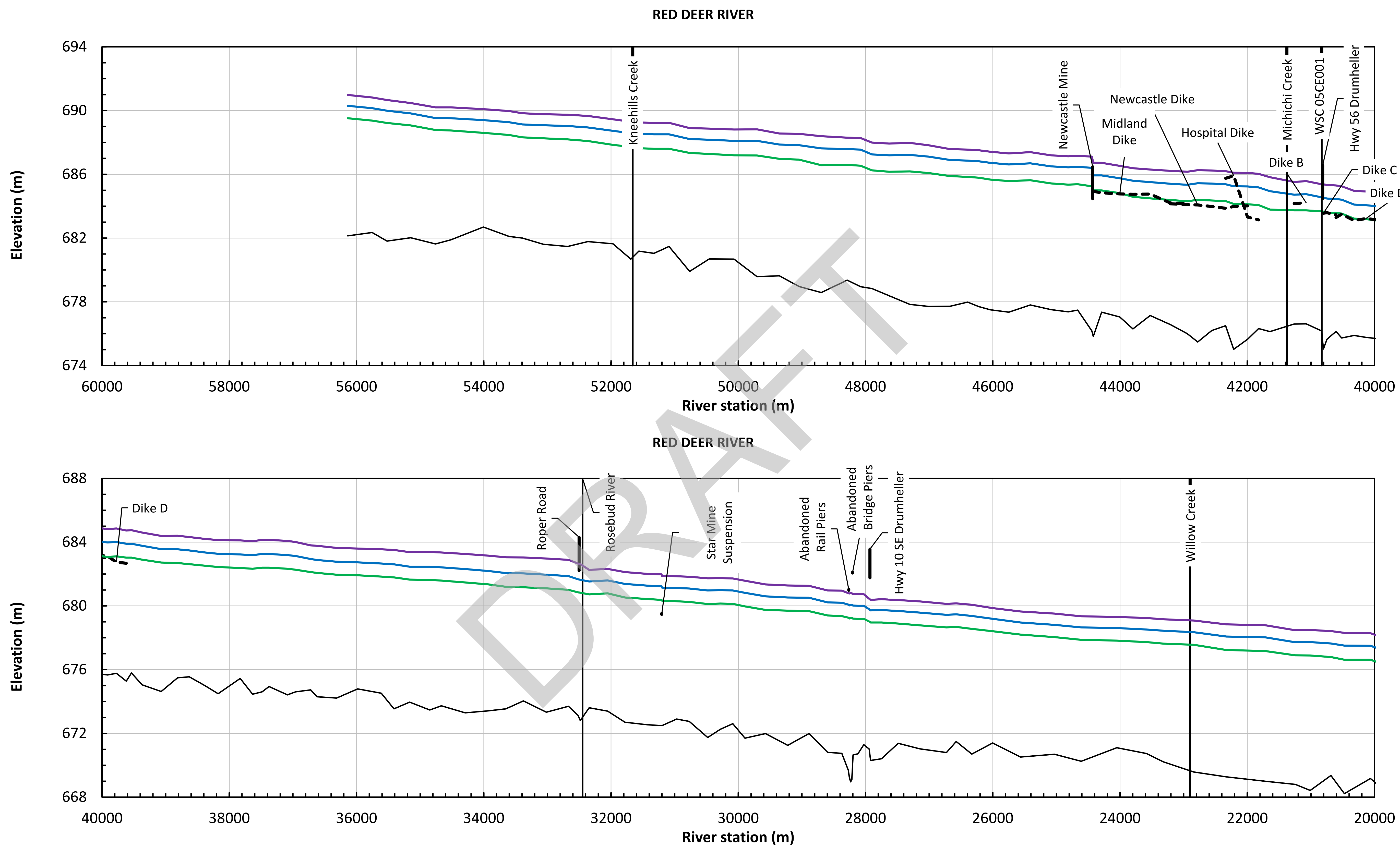
Job: 1003877 | *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO DOWNSTREAM BOUNDARY CONDITION – RED DEER RIVER

FIGURE 12B

RBA P:_Projects (Active)\1003877 Drumheller River Hazard Study\05 Reporting\0100 Survey and Base Data Collection\00 DRAFT\Figures\Figure 3-DRAFT.pptx



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LEGEND

- High Discharge
- Calibrated
- Low Discharge
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

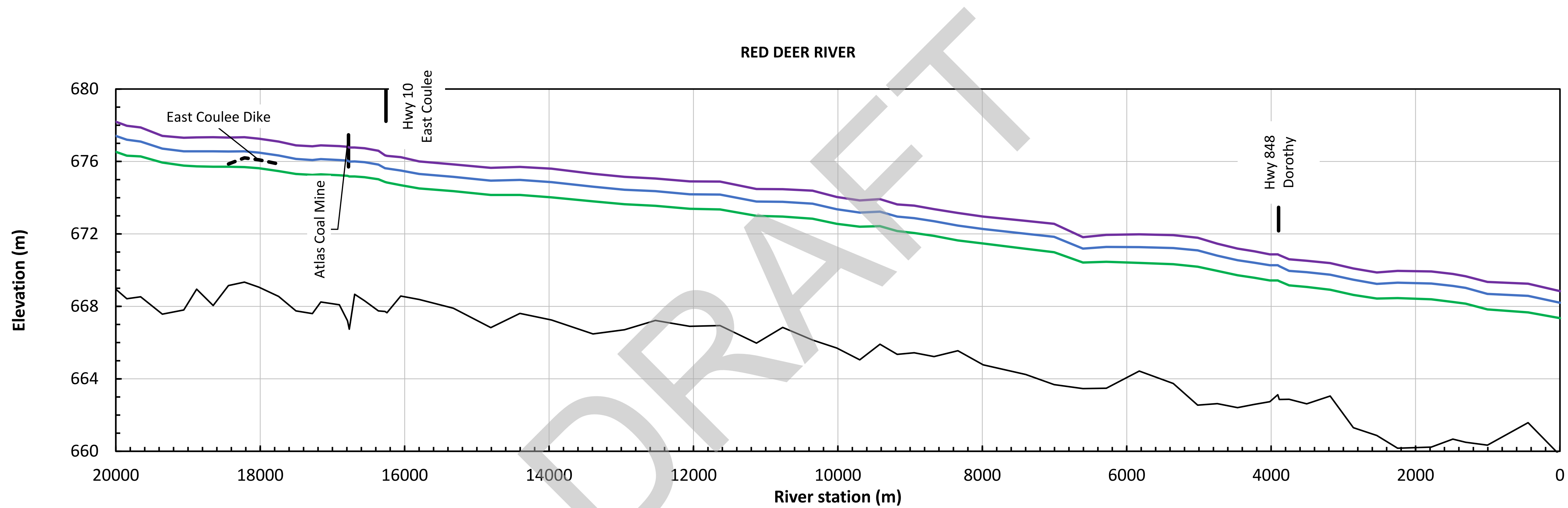
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | Date: 25-MAR-2020

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO DISCHARGE – RED DEER RIVER

FIGURE 13A



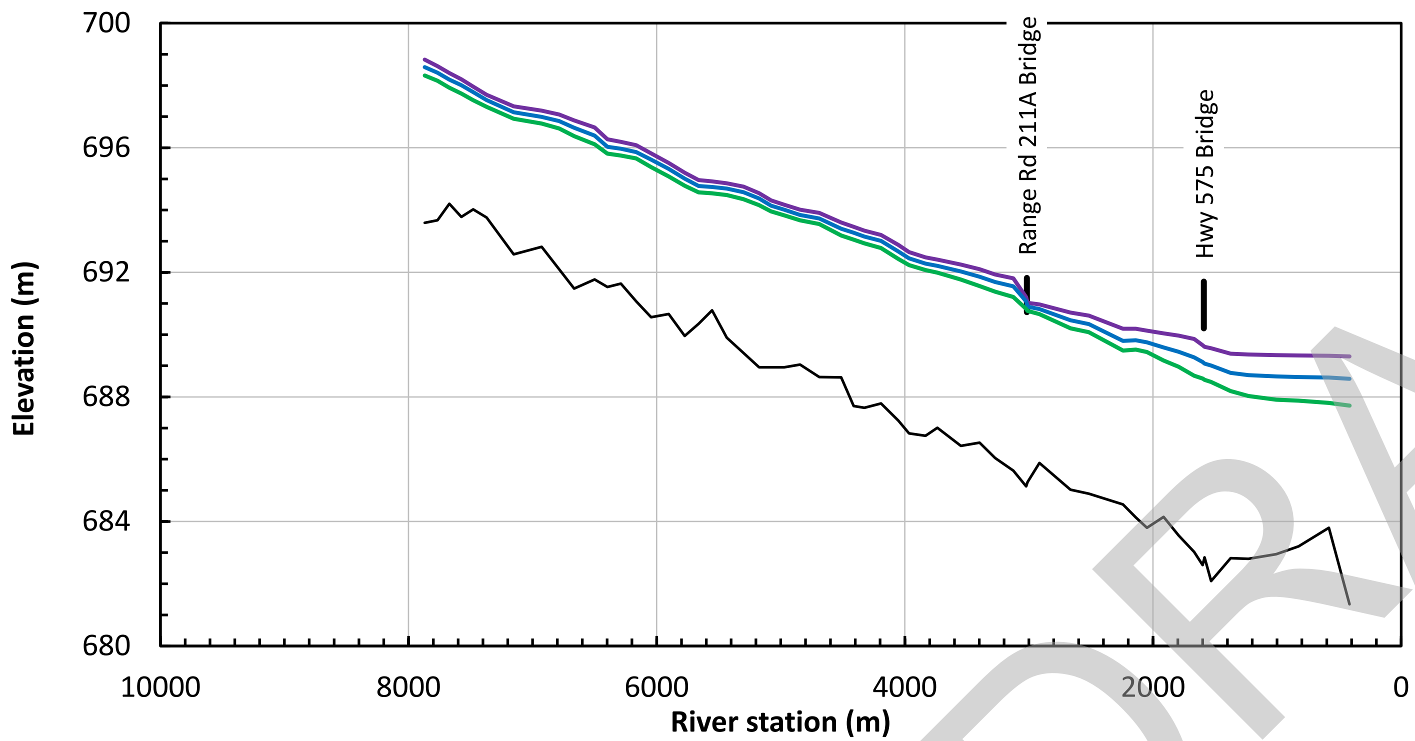
Alberta nhc northwest hydraulic consultants	**LEGEND** High Discharge Calibrated Low Discharge Dikes Profile Features Thalweg	SCALE – AS SHOWN Elevation Datum: CGVD28 (HTv2.0) Units: As Shown *Job: 1003877* *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

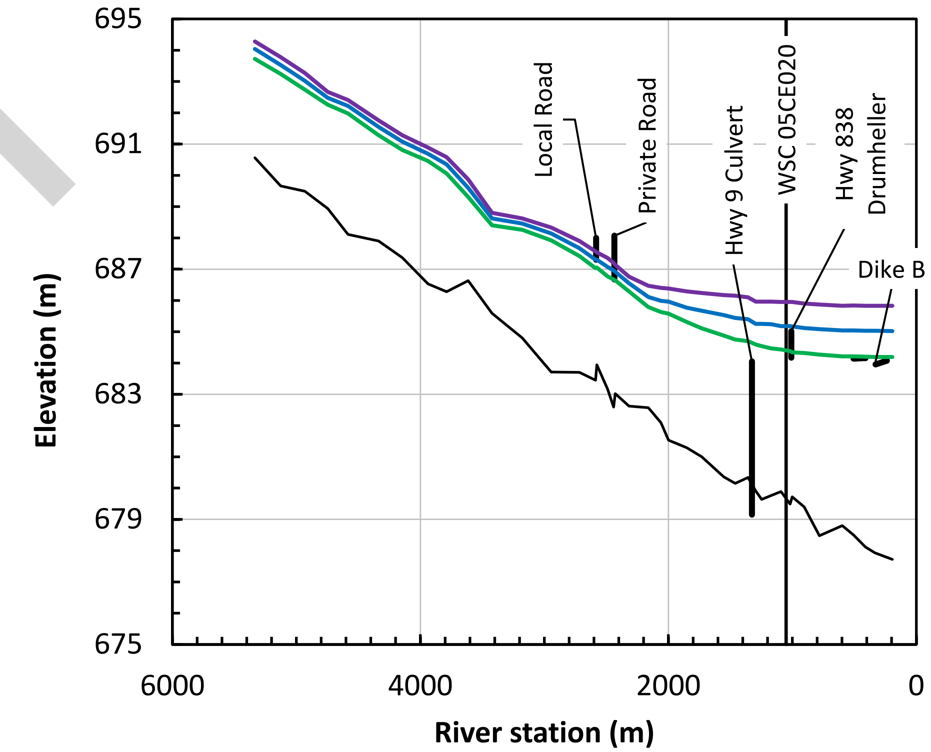
COMPUTED WATER SURFACE PROFILE SENSITIVITY TO DISCHARGE – RED DEER RIVER

FIGURE 13B

KNEEHILLS CREEK



MICHICHI CREEK



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LEGEND

- High Discharge
- Calibrated
- Low Discharge
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

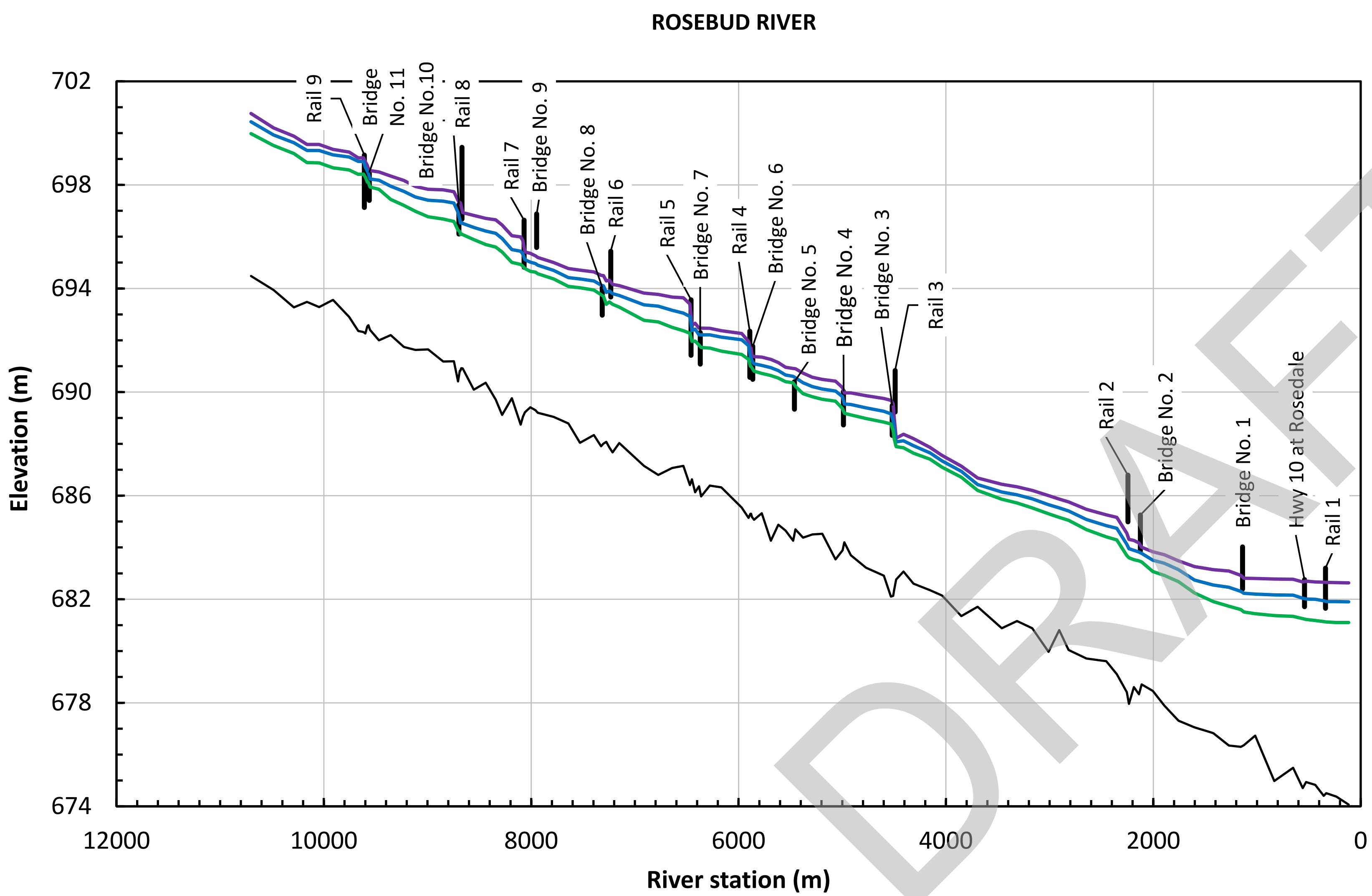
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

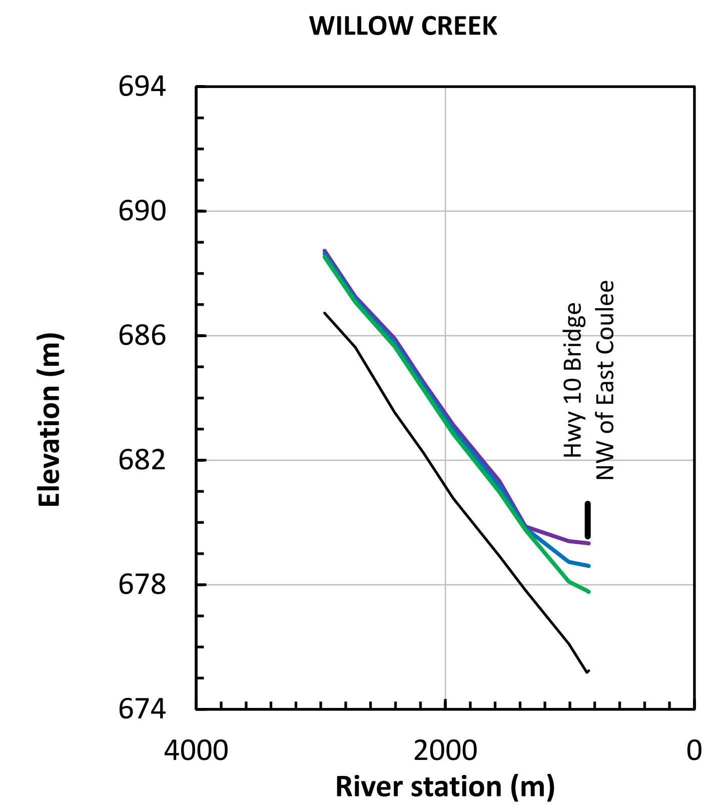
Job: 1003877 *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO DISCHARGE – KNEEHILLS CREEK, MICHICHI CREEK

FIGURE 14A





LEGEND
- High Discharge
- Calibrated
- Low Discharge
- Dikes
- Profile Features
- Thalweg

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SCALE – AS SHOWN

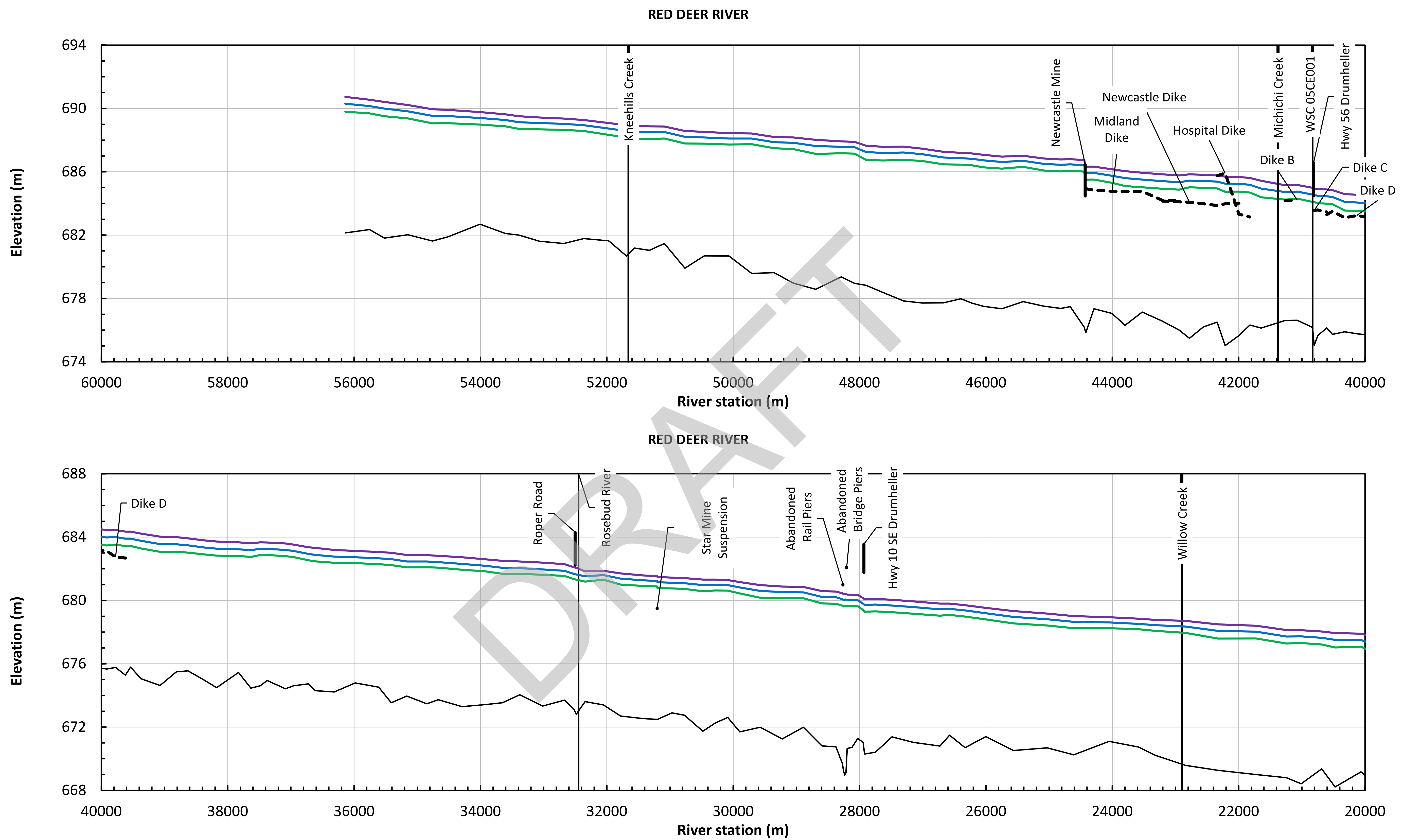
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO DISCHARGE – ROSEBUD RIVER, WILLOW CREEK

FIGURE 14B



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LEGEND

- High Channel Roughness
- Calibrated
- Low Channel Roughness
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

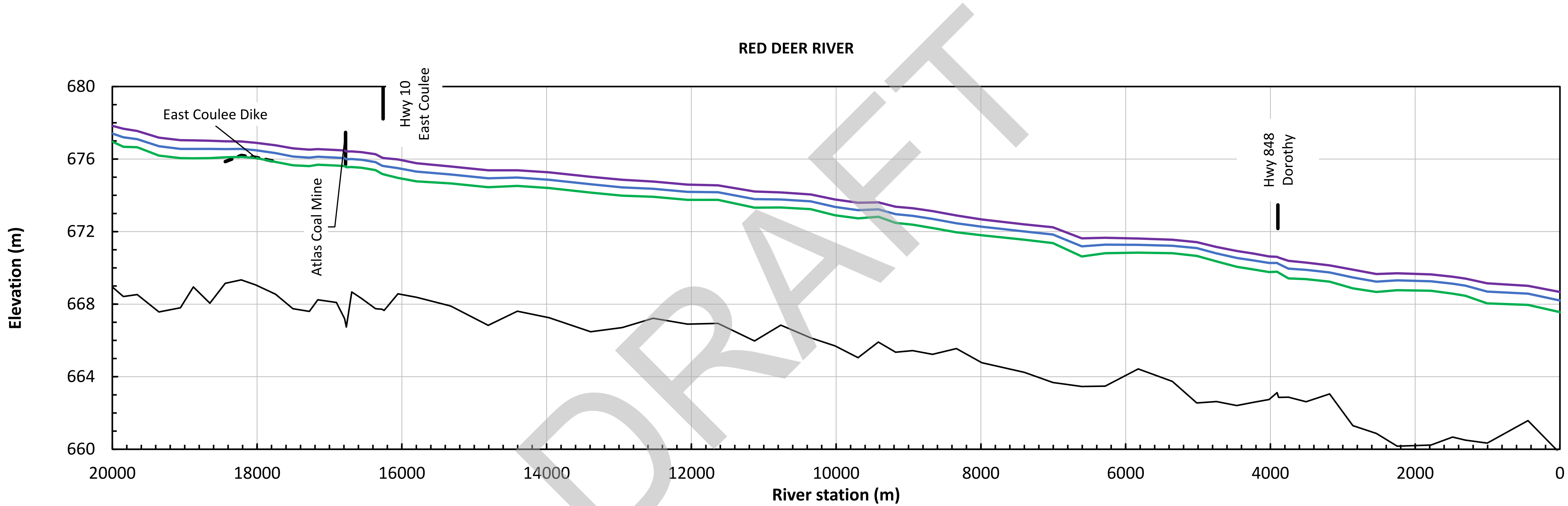
Job: 1003877

Date: 25-MAR-2020

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO CHANNEL ROUGHNESS – RED DEER RIVER

FIGURE 15A



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LEGEND
- High Channel Roughness
- Calibrated
- Low Channel Roughness
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

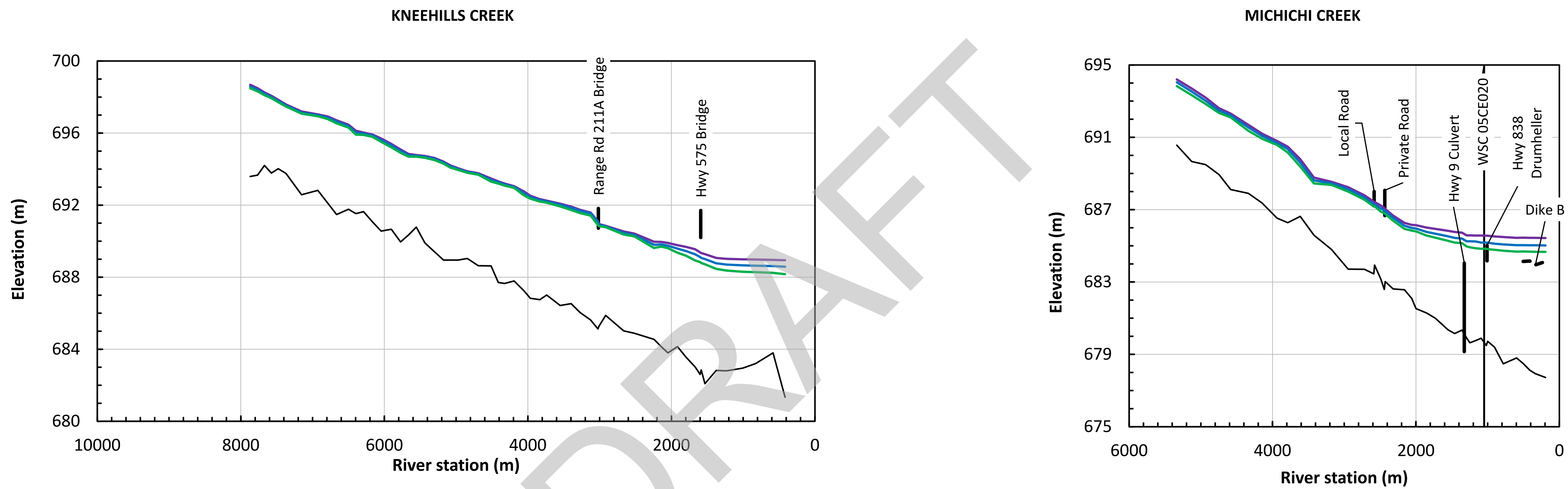
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | Date: 25-MAR-2020

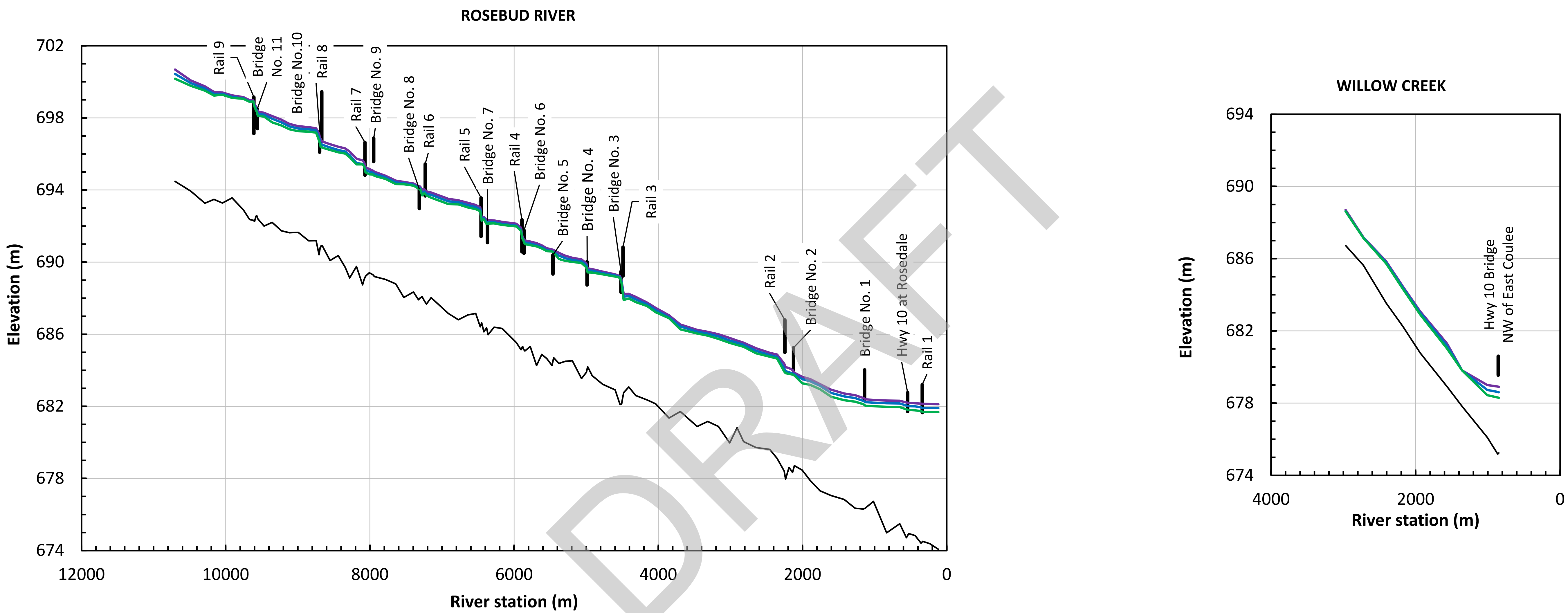
DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO CHANNEL ROUGHNESS – RED DEER RIVER

FIGURE 15B



Alberta nhc northwest hydraulic consultants	LEGEND High Channel Roughness Calibrated Low Channel Roughness Dikes Profile Features Thalweg	SCALE – AS SHOWN Elevation Datum: CGVD28 (HTv2.0) Units: As Shown Job: 1003877 / Date: 25-MAR-2020	*DRUMHELLER RIVER HAZARD STUDY* *HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING* *COMPUTED WATER SURFACE PROFILE SENSITIVITY TO CHANNEL ROUGHNESS – KNEEHILLS CREEK, MICHICHI CREEK* *FIGURE 16A*



LEGEND

- High Channel Roughness
- Calibrated
- Low Channel Roughness
- Dikes
- Profile Features
- Thalweg

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SCALE – AS SHOWN

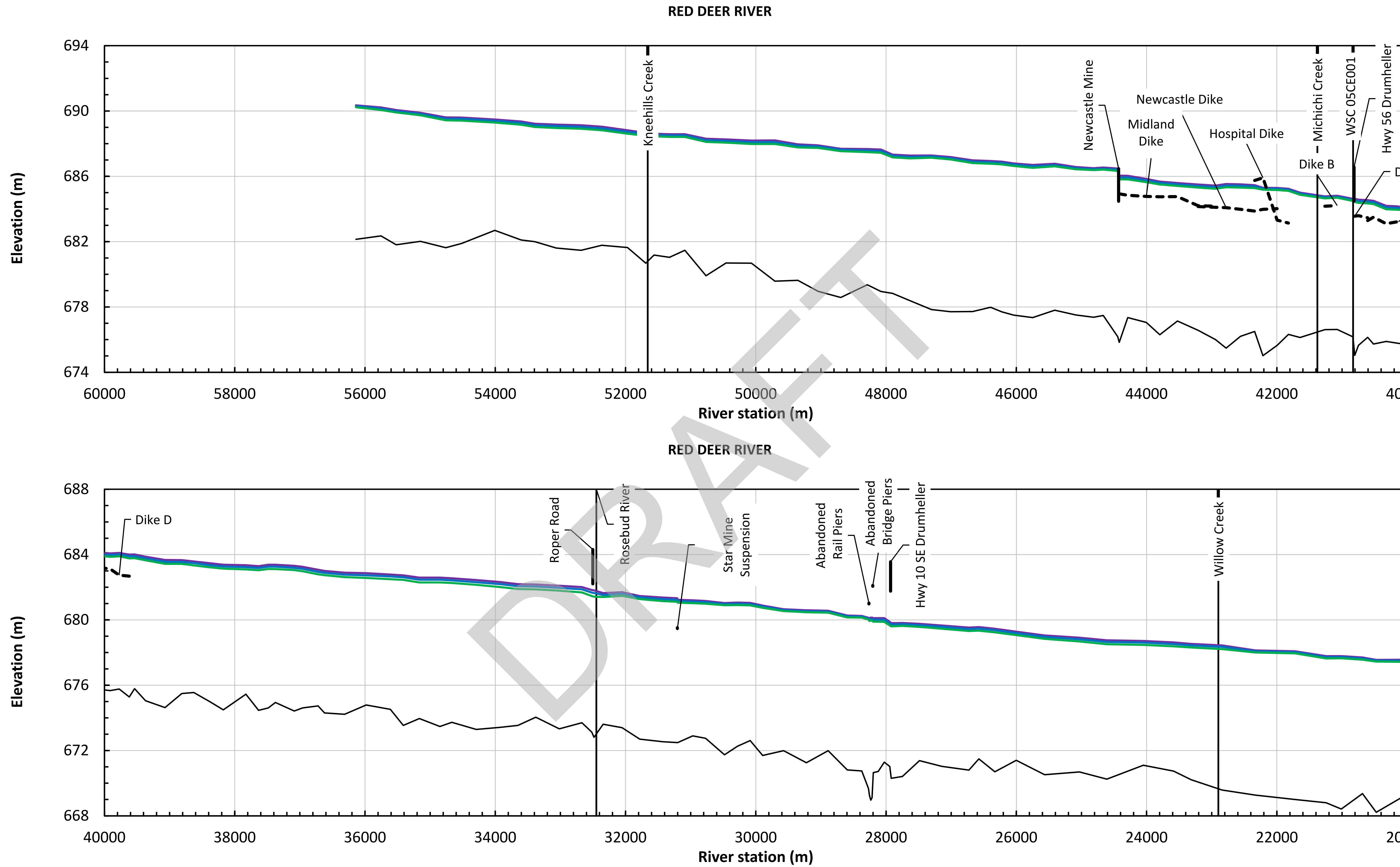
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | Date: 25-MAR-2020

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO CHANNEL ROUGHNESS – ROSEBUD RIVER, WILLOW CREEK

FIGURE 16B



LEGEND

- High Overbank Roughness
- Calibrated
- Low Overbank Roughness
- Dikes
- Profile Features
- Thalweg

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SCALE – AS SHOWN

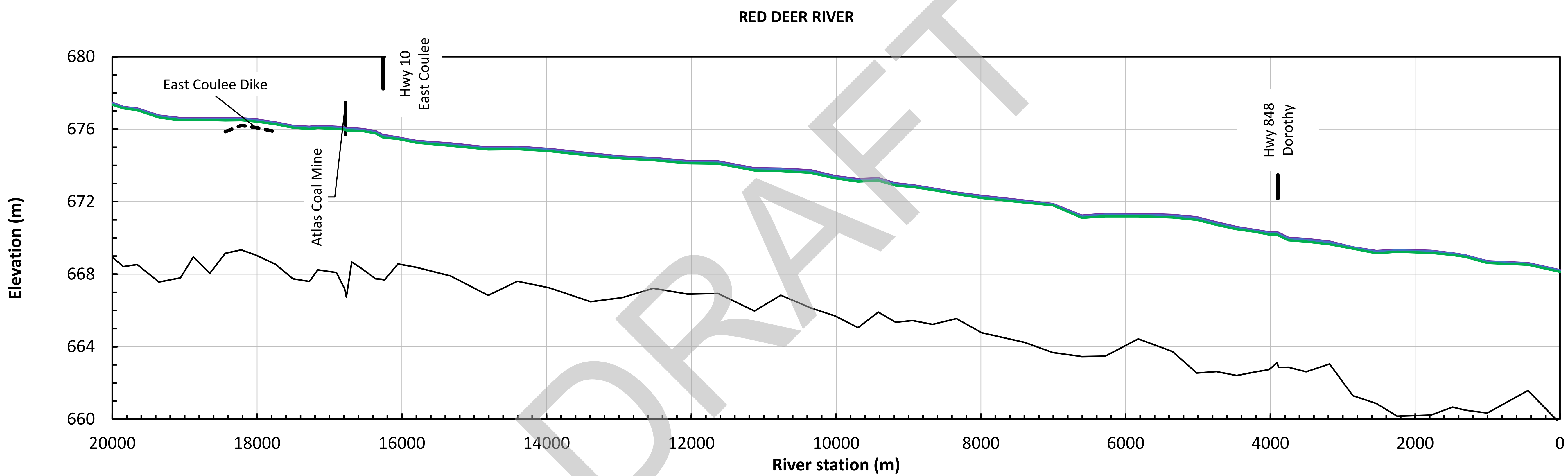
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO OVERBANK ROUGHNESS – RED DEER RIVER

FIGURE 17A



LEGEND

- High Overbank Roughness
- Calibrated
- Low Overbank Roughness
- Dikes
- Profile Features
- Thalweg

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SCALE – AS SHOWN

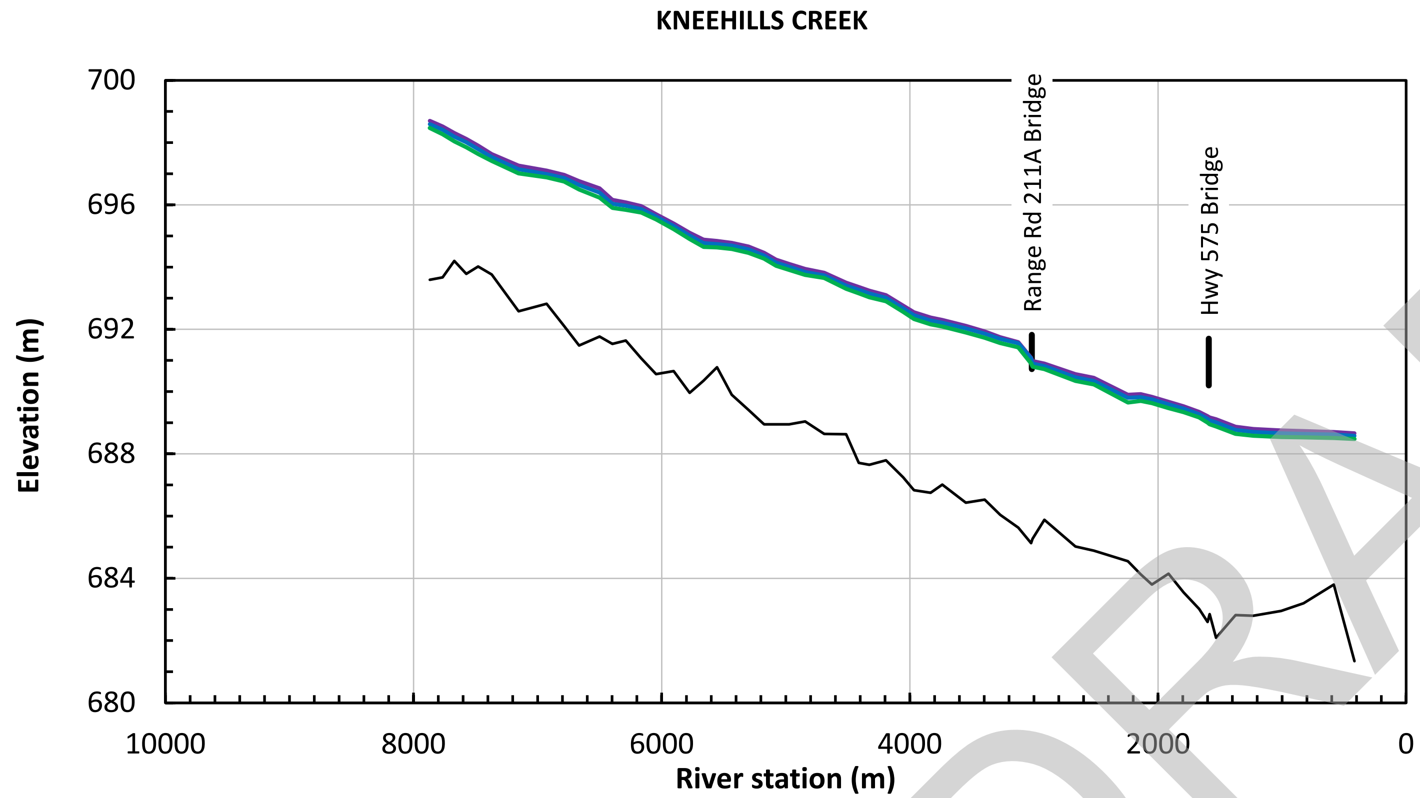
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

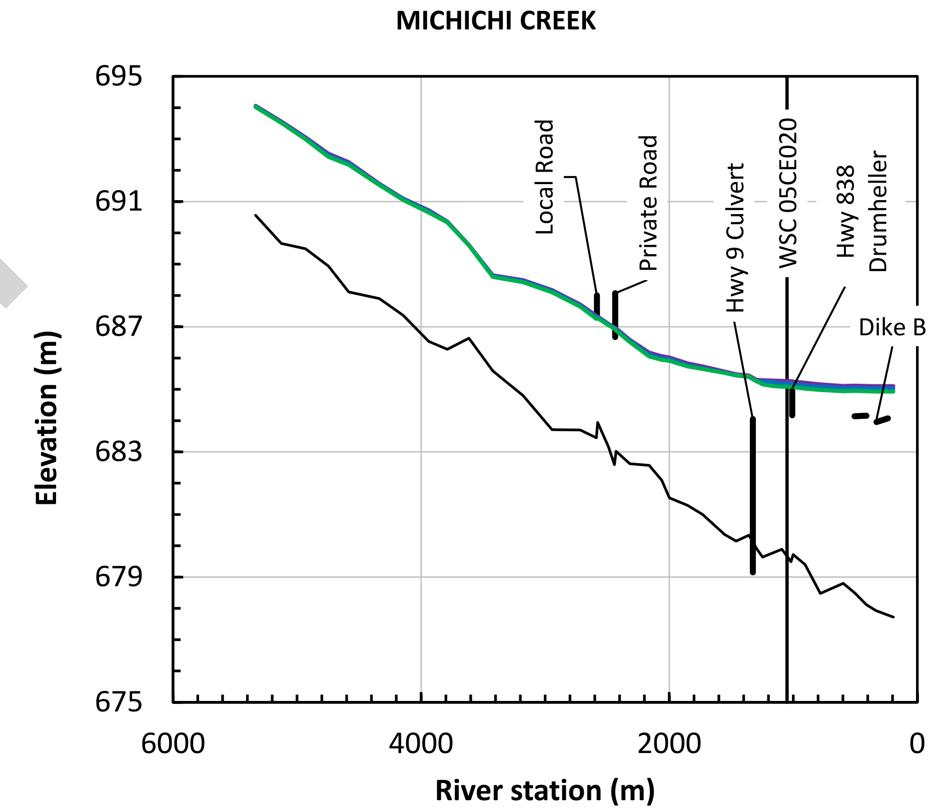
Job: 1003877 | Date: 25-MAR-2020

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO OVERBANK ROUGHNESS – RED DEER RIVER

FIGURE 17B





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LEGEND

- High Overbank Roughness
- Calibrated
- Low Overbank Roughness
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

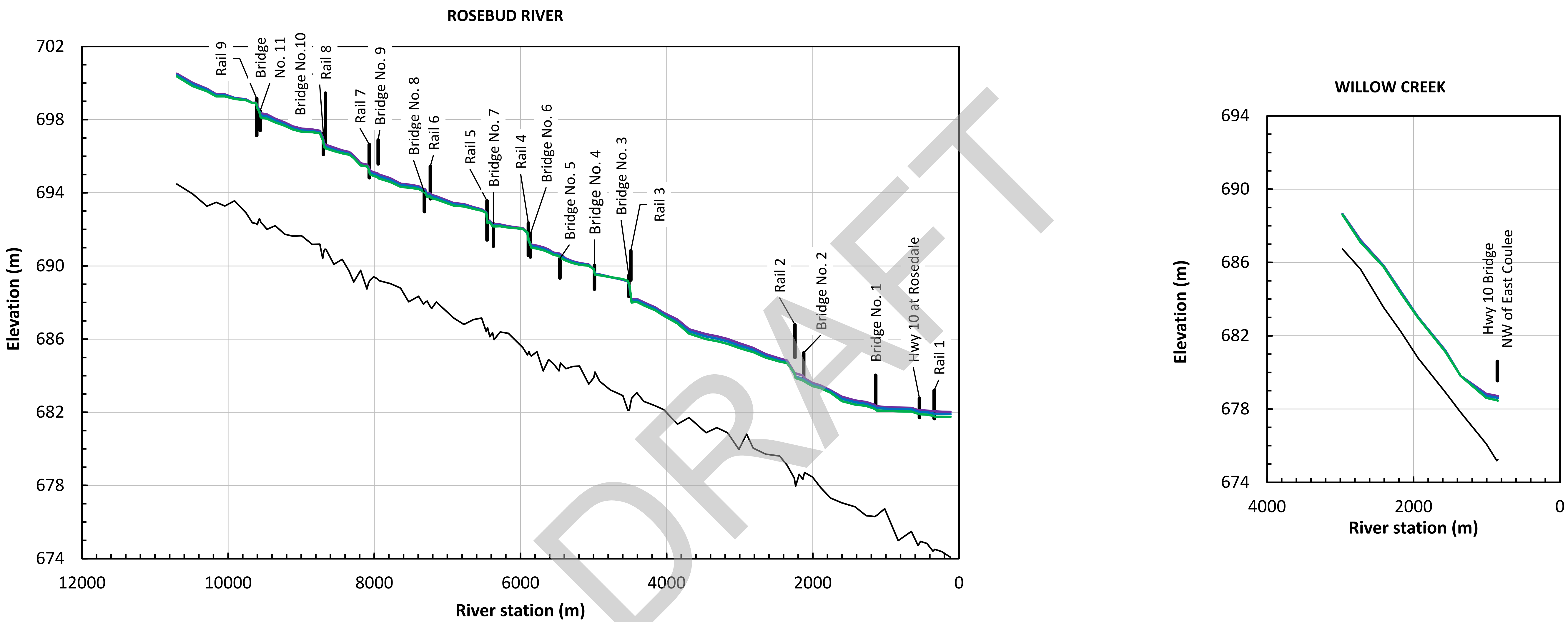
Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO OVERBANK ROUGHNESS – KNEEHILLS CREEK, MICHICHI CREEK

FIGURE 18A



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LEGEND

- High Overbank Roughness
- Calibrated
- Low Overbank Roughness
- Dikes
- Profile Features
- Thalweg

SCALE – AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 | *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

COMPUTED WATER SURFACE PROFILE SENSITIVITY TO OVERBANK ROUGHNESS – ROSEBUD RIVER, WILLOW CREEK

FIGURE 18B

RBA P:_Projects (Active)\1003877 Drumheller River Hazard Study\05 Reporting\0100 Survey and Base Data Collection\00 DRAFT\Figures\Figure 3-DRAFT.pptx

Appendix A
Flood History Photo Documentation

1. Flooding upstream of Kirkpatrick and the Town of Drumheller.

2. Highwater in Kirkpatrick, upstream of the Town of Drumheller.

3. Flooding in the Nacmine area of the Town of Drumheller.

4. Newcastle Mine Railway Bridge in the Town of Drumheller.

5. Temporary dike at 18th Street in the Midland area of the Town of Drumheller.

6. Flooding in the Lehigh area of the Town of Drumheller.

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Notes:

- Photos 1 though 5 provided by Alberta Environment and Parks, Water Management Operations.
- Photo 6 provided by the Town of Drumheller.

Job: 1003877

Date: 25-MAR-2020

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

JUNE 2005 FLOOD PHOTOGRAPHS – RED DEER RIVER

FIGURE A-1

1. Newcastle Mine Railway Bridge in the Town of Drumheller.

2. Highway 56 Bridge in the Town of Drumheller.

3. Star Mine Suspension Bridge in the Town of Drumheller.

4. View from Newcastle Mine Railway Bridge in the Town of Drumheller.

5. Surveying HWM near Newcastle Mine Railway Bridge in the Town of Drumheller.

6. Red Deer River in the Town of Drumheller, with Newcastle Mine Railway Bridge in the background.

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Notes:

- Photo 1 from The Drumheller Mail, *2013 Flood Timeline*, 26 June 2013.
- Photo 2 from The Drumheller Mail, *Water flow appears to have leveled*, 24 June 2013.
- Photo 3 from Drumheller Online, *Kneehill Declares Emergency*, 22 June 2013.
- Photos 4-6 provided by Alberta Environment and Parks, taken 27 June 2013.

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DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

JUNE 2013 FLOOD PHOTOGRAPHS – RED DEER RIVER

FIGURE A-2

1. Surveying HWM at Highway 575 Bridge along Kneehills Creek.

2. Surveying HWM downstream of Highway 838 Bridge along Michichi Creek.

3. Flooding along Rosebud River near the community of Wayne within the Town of Drumheller.

4. Flooding along Rosebud River near the community of Wayne within the Town of Drumheller.

5. Flooding along Rosebud River near the community of Wayne within the Town of Drumheller.

6. Surveying HWM upstream of Highway 10 Bridge along Willow Creek.

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Notes:

- Photos 1, 2 and 6 provided by Alberta Environment and Parks, taken 26 through 28 April 2018.
- Photo 3 from The Drumheller Mail (DM), *The Mail's most read stories of 2018,* 31 December 2018.
- Photo 4 from The DM, *State of Emergency remains in effect*, 24 April 2018.
- Photo 5 from The DM, *Evacuation order for Wayne lifted*, 25 April 2018.

Job: 1003877 *Date: 25-MAR-2020*

DRUMHELLER RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

APRIL 2018 FLOOD PHOTOGRAPHS – TRIBUTARIES

FIGURE A-3

Appendix B
Detailed Model Data

Table B-1 Cross section details

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Red Deer River						
1	56,139	Abv Kneehills	survey/DTM	682.14	75.45	Upstream model limit
2	55,755	Abv Kneehills	survey/DTM	682.35	100.06	
3	55,521	Abv Kneehills	survey/DTM	681.81	90.62	
4	55,149	Abv Kneehills	survey/DTM	682.02	96.98	
5	54,759	Abv Kneehills	survey/DTM	681.63	93.22	
6	54,516	Abv Kneehills	survey/DTM	681.89	107.16	
7	54,007	Abv Kneehills	survey/DTM	682.69	137.81	
8	53,602	Abv Kneehills	survey/DTM	682.10	156.84	
9	53,393	Abv Kneehills	survey/DTM	682.00	128.37	
10	53,064	Abv Kneehills	survey/DTM	681.61	151.99	
11	52,682	Abv Kneehills	survey/DTM	681.47	273.40	
12	52,364	Abv Kneehills	survey/DTM	681.78	248.81	
13	51,970	Abv Kneehills	survey/DTM	681.64	155.76	
14	51,689	Abv Kneehills	survey/DTM	680.68	108.06	
15	51,563	Blw Kneehills	survey/DTM	681.18	94.59	
16	51,326	Blw Kneehills	survey/DTM	681.04	115.02	
17	51,089	Blw Kneehills	survey/DTM	681.47	165.78	
18	50,765	Blw Kneehills	survey/DTM	679.91	113.94	
19	50,457	Blw Kneehills	survey/DTM	680.69	140.14	
20	50,067	Blw Kneehills	survey/DTM	680.68	149.39	
21	49,706	Blw Kneehills	survey/DTM	679.58	266.41	
22	49,354	Blw Kneehills	survey/DTM	679.63	118.43	
23	49,045	Blw Kneehills	survey/DTM	678.96	75.82	
24	48,695	Blw Kneehills	survey/DTM	678.58	83.81	
25	48,288	Blw Kneehills	survey/DTM	679.36	138.55	
26	48,079	Blw Kneehills	survey/DTM	678.95	157.02	
27	47,899	Blw Kneehills	survey/DTM	678.83	93.38	
28	47,630	Blw Kneehills	survey/DTM	678.38	86.87	
29	47,303	Blw Kneehills	survey/DTM	677.84	87.21	
30	47,010	Blw Kneehills	survey/DTM	677.71	93.67	
31	46,672	Blw Kneehills	survey/DTM	677.72	91.97	
32	46,395	Blw Kneehills	survey/DTM	677.98	106.24	
33	46,221	Blw Kneehills	survey/DTM	677.70	107.54	
34	46,039	Blw Kneehills	survey/DTM	677.50	108.81	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Red Deer River						
35	45,748	Blw Kneehills	survey/DTM	677.35	105.75	
36	45,410	Blw Kneehills	survey/DTM	677.80	126.69	
37	45,086	Blw Kneehills	survey/DTM	677.51	143.32	
38	44,815	Blw Kneehills	survey/DTM	677.37	305.23	
39	44,666	Blw Kneehills	survey/DTM	677.48	255.65	
40	44,443	Blw Kneehills	survey/DTM	676.18	148.07	Upstream of Newcastle Mine Railway Bridge
41	44,420	Blw Kneehills	survey/DTM	675.83	208.71	Downstream of Newcastle Mine Railway Bridge; Midland Dike on left bank
42	44,290	Blw Kneehills	survey/DTM	677.35	151.11	Midland Dike on left bank
43	44,005	Blw Kneehills	survey/DTM	677.05	114.92	Midland Dike on left bank
44	43,798	Blw Kneehills	survey/DTM	676.30	84.39	Midland Dike on left bank
45	43,527	Blw Kneehills	survey/DTM	677.14	95.72	Midland Dike on left bank
46	43,209	Blw Kneehills	survey/DTM	676.57	100.44	Midland Dike on left bank; Newcastle Dike on right bank
47	42,942	Blw Kneehills	survey/DTM	676.00	197.75	Midland Dike on left bank; Newcastle Dike on right bank
48	42,779	Blw Kneehills	survey/DTM	675.48	219.53	Newcastle Dike on right bank
49	42,558	Blw Kneehills	survey/DTM	676.20	261.21	Newcastle Dike on right bank
50	42,341	Blw Kneehills	survey/DTM	676.50	156.76	Hospital Dike on left bank; Newcastle Dike on right bank
51	42,214	Blw Kneehills	survey/DTM	675.02	332.64	Hospital Dike on left bank; Newcastle Dike on right bank
52	41,996	Blw Kneehills	survey/DTM	675.65	108.64	Hospital Dike on left bank; Newcastle Dike on right bank
53	41,823	Blw Kneehills	survey/DTM	676.32	108.69	Hospital Dike on left bank
54	41,644	Blw Kneehills	survey/DTM	676.13	96.49	
55	41,263	Blw Michichi	survey/DTM	676.61	130.07	Dike B on left bank
56	41,074	Blw Michichi	survey/DTM	676.62	123.48	Dike B on left bank
57	40,832	Blw Michichi	survey/DTM	676.17	111.72	Upstream of Highway 56 Bridge at Drumheller (BF06615)
58	40,804	Blw Michichi	survey/DTM	675.04	123.68	Downstream of Highway 56 Bridge at Drumheller (BF06615)
59	40,748	Blw Michichi	survey/DTM	675.65	135.25	Dike C on left bank
60	40,606	Blw Michichi	survey/DTM	676.14	130.85	Dike C on left bank; Dike D on right bank
61	40,517	Blw Michichi	survey/DTM	675.73	113.19	Dike D on right bank

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Red Deer River						
62	40,322	Blw Michichi	survey/DTM	675.89	90.26	Dike D on right bank
63	40,132	Blw Michichi	survey/DTM	675.77	92.51	Dike D on right bank
64	39,912	Blw Michichi	survey/DTM	675.67	115.81	Dike D on right bank
65	39,774	Blw Michichi	survey/DTM	675.77	114.20	Dike D on right bank
66	39,619	Blw Michichi	survey/DTM	675.28	110.50	Dike D on right bank
67	39,538	Blw Michichi	survey/DTM	675.79	123.37	
68	39,370	Blw Michichi	survey/DTM	675.05	97.49	
69	39,070	Blw Michichi	survey/DTM	674.63	104.30	
70	38,812	Blw Michichi	survey/DTM	675.49	107.57	
71	38,629	Blw Michichi	survey/DTM	675.55	109.50	
72	38,381	Blw Michichi	survey/DTM	674.99	96.05	
73	38,176	Blw Michichi	survey/DTM	674.49	91.15	
74	37,829	Blw Michichi	survey/DTM	675.45	120.50	
75	37,633	Blw Michichi	survey/DTM	674.46	106.11	
76	37,484	Blw Michichi	survey/DTM	674.61	190.58	
77	37,376	Blw Michichi	survey/DTM	674.94	96.35	
78	37,086	Blw Michichi	survey/DTM	674.42	241.46	
79	36,958	Blw Michichi	survey/DTM	674.61	133.00	
80	36,721	Blw Michichi	survey/DTM	674.73	124.04	
81	36,621	Blw Michichi	survey/DTM	674.30	107.66	
82	36,313	Blw Michichi	survey/DTM	674.22	118.08	
83	35,982	Blw Michichi	survey/DTM	674.79	134.18	
84	35,611	Blw Michichi	survey/DTM	674.52	130.28	
85	35,412	Blw Michichi	survey/DTM	673.54	106.98	
86	35,165	Blw Michichi	survey/DTM	673.96	112.27	
87	34,850	Blw Michichi	survey/DTM	673.47	111.98	
88	34,667	Blw Michichi	survey/DTM	673.73	113.30	
89	34,292	Blw Michichi	survey/DTM	673.29	104.97	
90	33,924	Blw Michichi	survey/DTM	673.42	105.95	
91	33,653	Blw Michichi	survey/DTM	673.54	97.64	
92	33,378	Blw Michichi	survey/DTM	674.04	119.11	
93	33,017	Blw Michichi	survey/DTM	673.33	99.43	
94	32,670	Blw Michichi	survey/DTM	673.70	128.84	
95	32,519	Blw Michichi	survey/DTM	673.13	117.57	Upstream of Roper Road Bridge at Rosedale (BF07329)

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
			Red Deer River			
96	32,484	Blw Michichi	survey/DTM	672.81	117.93	Downstream of Roper Road Bridge at Rosedale (BF07329)
97	32,344	Blw Rosebud	survey/DTM	673.61	95.05	
98	32,054	Blw Rosebud	survey/DTM	673.40	123.31	
99	31,781	Blw Rosebud	survey/DTM	672.70	81.83	
100	31,429	Blw Rosebud	survey/DTM	672.54	96.58	
101	31,207	Blw Rosebud	survey/DTM	672.49	109.12	Upstream of Star Mine Suspension Bridge (BF74796)
102	31,198	Blw Rosebud	survey/DTM	672.49	109.12	Downstream of Star Mine Suspension Bridge (BF74796)
103	30,968	Blw Rosebud	survey/DTM	672.90	113.72	
104	30,771	Blw Rosebud	survey/DTM	672.75	112.70	
105	30,480	Blw Rosebud	survey/DTM	671.74	99.21	
106	30,282	Blw Rosebud	survey/DTM	672.26	125.86	
107	30,086	Blw Rosebud	survey/DTM	672.61	141.84	
108	29,895	Blw Rosebud	survey/DTM	671.70	121.14	
109	29,573	Blw Rosebud	survey/DTM	671.99	85.21	
110	29,224	Blw Rosebud	survey/DTM	671.25	110.44	
111	28,890	Blw Rosebud	survey/DTM	671.99	126.38	
112	28,595	Blw Rosebud	survey/DTM	670.81	82.40	
113	28,373	Blw Rosebud	survey/DTM	670.75	86.11	
114	28,271	Blw Rosebud	survey/DTM	669.68	98.13	Upstream of Abandoned railway bridge (piers only)
115	28,255	Blw Rosebud	survey/DTM	669.25	85.02	Downstream of Abandoned railway bridge (piers only)
116	28,234	Blw Rosebud	survey/DTM	668.96	88.38	
117	28,215	Blw Rosebud	survey/DTM	669.11	91.18	Upstream of Abandoned Highway 10 Bridge (piers only)
118	28,196	Blw Rosebud	survey/DTM	670.65	93.96	Downstream of Abandoned Highway 10 Bridge (piers only)
119	28,120	Blw Rosebud	survey/DTM	670.72	95.40	
120	28,028	Blw Rosebud	survey/DTM	671.29	117.62	
121	27,943	Blw Rosebud	survey/DTM	671.02	91.75	Upstream of Highway 10 Bridge, 8 km SE of Drumheller (BF73277)
122	27,921	Blw Rosebud	survey/DTM	670.30	80.73	Downstream of Highway 10 Bridge, 8 km SE of Drumheller (BF73277)
123	27,749	Blw Rosebud	survey/DTM	670.41	82.70	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Red Deer River						
124	27,487	Blw Rosebud	survey/DTM	671.38	105.69	
125	27,145	Blw Rosebud	survey/DTM	671.03	101.87	
126	26,728	Blw Rosebud	survey/DTM	670.80	101.13	
127	26,576	Blw Rosebud	survey/DTM	671.49	136.76	
128	26,330	Blw Rosebud	survey/DTM	670.70	94.26	
129	26,001	Blw Rosebud	survey/DTM	671.40	120.99	
130	25,566	Blw Rosebud	survey/DTM	670.52	96.08	
131	25,030	Blw Rosebud	survey/DTM	670.69	112.70	
132	24,611	Blw Rosebud	survey/DTM	670.25	111.90	
133	24,051	Blw Rosebud	survey/DTM	671.10	136.75	
134	23,586	Blw Rosebud	survey/DTM	670.74	132.79	
135	23,316	Blw Rosebud	survey/DTM	670.21	111.65	
136	22,842	Blw Willow	survey/DTM	669.58	106.56	
137	22,328	Blw Willow	survey/DTM	669.27	62.27	
138	21,724	Blw Willow	survey/DTM	669.00	88.21	
139	21,245	Blw Willow	survey/DTM	668.80	105.21	
140	21,011	Blw Willow	survey/DTM	668.42	109.39	
141	20,686	Blw Willow	survey/DTM	669.36	106.40	
142	20,474	Blw Willow	survey/DTM	668.22	86.24	
143	20,065	Blw Willow	survey/DTM	669.17	139.04	
144	19,848	Blw Willow	survey/DTM	668.42	81.42	
145	19,656	Blw Willow	survey/DTM	668.53	85.68	
146	19,356	Blw Willow	survey/DTM	667.57	78.28	
147	19,059	Blw Willow	survey/DTM	667.80	96.09	
148	18,881	Blw Willow	survey/DTM	668.95	89.48	
149	18,652	Blw Willow	survey/DTM	668.05	89.82	
150	18,440	Blw Willow	survey/DTM	669.15	140.80	East Coulee Dike on left bank
151	18,219	Blw Willow	survey/DTM	669.34	169.66	East Coulee Dike on left bank
152	18,020	Blw Willow	survey/DTM	669.06	140.23	East Coulee Dike on left bank
153	17,745	Blw Willow	survey/DTM	668.55	162.66	East Coulee Dike on left bank
154	17,505	Blw Willow	survey/DTM	667.75	100.77	
155	17,278	Blw Willow	survey/DTM	667.60	104.95	
156	17,161	Blw Willow	survey/DTM	668.24	140.26	
157	16,904	Blw Willow	survey/DTM	668.09	139.92	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Red Deer River						
158	16,791	Blw Willow	survey/DTM	667.20	137.58	Upstream of Atlas Coal Mine Railway Bridge
159	16,767	Blw Willow	survey/DTM	666.74	138.61	Downstream of Atlas Coal Mine Railway Bridge
160	16,692	Blw Willow	survey/DTM	668.67	154.89	
161	16,555	Blw Willow	survey/DTM	668.31	151.31	
162	16,363	Blw Willow	survey/DTM	667.75	252.00	
163	16,272	Blw Willow	survey/DTM	667.72	114.68	Upstream of Highway 10 Bridge at East Coulee (BF73077)
164	16,246	Blw Willow	survey/DTM	667.65	117.40	Downstream of Highway 10 Bridge at East Coulee (BF73077)
165	16,054	Blw Willow	survey/DTM	668.57	103.53	
166	15,799	Blw Willow	survey/DTM	668.38	106.71	
167	15,326	Blw Willow	survey/DTM	667.90	121.10	
168	14,807	Blw Willow	survey/DTM	666.83	107.37	
169	14,404	Blw Willow	survey/DTM	667.61	225.78	
170	13,966	Blw Willow	survey/DTM	667.25	196.26	
171	13,392	Blw Willow	survey/DTM	666.48	133.76	
172	12,955	Blw Willow	survey/DTM	666.71	126.56	
173	12,528	Blw Willow	survey/DTM	667.22	150.13	
174	12,053	Blw Willow	survey/DTM	666.90	139.40	
175	11,633	Blw Willow	survey/DTM	666.94	229.14	
176	11,128	Blw Willow	survey/DTM	665.97	116.99	
177	10,764	Blw Willow	survey/DTM	666.84	154.45	
178	10,351	Blw Willow	survey/DTM	666.14	207.18	
179	10,016	Blw Willow	survey/DTM	665.70	113.11	
180	9,697	Blw Willow	survey/DTM	665.05	108.32	
181	9,417	Blw Willow	survey/DTM	665.91	157.85	
182	9,179	Blw Willow	survey/DTM	665.35	130.45	
183	8,943	Blw Willow	survey/DTM	665.44	110.12	
184	8,669	Blw Willow	survey/DTM	665.23	101.32	
185	8,338	Blw Willow	survey/DTM	665.55	129.77	
186	7,988	Blw Willow	survey/DTM	664.77	105.03	
187	7,398	Blw Willow	survey/DTM	664.24	102.52	
188	7,006	Blw Willow	survey/DTM	663.68	95.08	
189	6,606	Blw Willow	survey/DTM	663.46	94.26	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Red Deer River						
190	6,283	Blw Willow	survey/DTM	663.48	130.77	
191	5,827	Blw Willow	survey/DTM	664.43	314.11	
192	5,356	Blw Willow	survey/DTM	663.74	433.65	
193	5,018	Blw Willow	survey/DTM	662.55	248.28	
194	4,746	Blw Willow	survey/DTM	662.63	131.51	
195	4,466	Blw Willow	survey/DTM	662.41	98.08	
196	4,233	Blw Willow	survey/DTM	662.59	100.35	
197	4,018	Blw Willow	survey/DTM	662.74	99.91	
198	3,908	Blw Willow	survey/DTM	663.12	115.96	Upstream of Highway 848 Bridge at Dorothy (BF71085)
199	3,888	Blw Willow	survey/DTM	662.86	112.92	Downstream of Highway 848 Bridge at Dorothy (BF71085)
200	3,752	Blw Willow	survey/DTM	662.87	97.77	
201	3,508	Blw Willow	survey/DTM	662.62	113.12	
202	3,182	Blw Willow	survey/DTM	663.05	119.92	
203	2,861	Blw Willow	survey/DTM	661.30	81.18	
204	2,536	Blw Willow	survey/DTM	660.87	98.63	
205	2,249	Blw Willow	survey/DTM	660.17	98.06	
206	1,783	Blw Willow	survey/DTM	660.23	159.59	
207	1,484	Blw Willow	survey/DTM	660.67	482.15	
208	1,306	Blw Willow	survey/DTM	660.50	312.27	
209	1,004	Blw Willow	survey/DTM	660.34	98.91	
210	442	Blw Willow	survey/DTM	661.58	132.00	
211	0	Blw Willow	survey/DTM	659.78	99.50	
Kneehills Creek						
212	7,869	Main	survey/DTM	693.59	23.30	Upstream model limit
213	7,766	Main	survey/DTM	693.67	19.58	
214	7,671	Main	survey/DTM	694.20	15.54	
215	7,574	Main	survey/DTM	693.78	15.86	
216	7,479	Main	survey/DTM	694.02	17.00	
217	7,370	Main	survey/DTM	693.76	27.62	
218	7,153	Main	survey/DTM	692.58	18.53	
219	6,927	Main	survey/DTM	692.82	8.16	
220	6,786	Main	survey/DTM	692.10	18.75	
221	6,665	Main	survey/DTM	691.48	17.17	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Kneehills Creek						
222	6,500	Main	survey/DTM	691.77	13.96	
223	6,397	Main	survey/DTM	691.53	11.86	
224	6,289	Main	survey/DTM	691.64	8.67	
225	6,165	Main	survey/DTM	691.07	10.27	
226	6,045	Main	survey/DTM	690.56	7.47	
227	5,903	Main	survey/DTM	690.66	8.42	
228	5,774	Main	survey/DTM	689.96	14.14	
229	5,662	Main	survey/DTM	690.35	15.07	
230	5,554	Main	survey/DTM	690.78	37.26	
231	5,435	Main	survey/DTM	689.90	9.79	
232	5,300	Main	survey/DTM	689.41	14.06	
233	5,175	Main	survey/DTM	688.95	18.31	
234	5,078	Main	survey/DTM	688.95	13.94	
235	4,972	Main	survey/DTM	688.95	10.94	
236	4,844	Main	survey/DTM	689.04	16.93	
237	4,690	Main	survey/DTM	688.64	10.41	
238	4,513	Main	survey/DTM	688.63	10.14	
239	4,412	Main	survey/DTM	687.71	15.49	
240	4,326	Main	survey/DTM	687.65	11.25	
241	4,192	Main	survey/DTM	687.79	11.26	
242	4,053	Main	survey/DTM	687.24	10.69	
243	3,966	Main	survey/DTM	686.83	15.22	
244	3,833	Main	survey/DTM	686.75	13.01	
245	3,738	Main	survey/DTM	687.01	13.34	
246	3,549	Main	survey/DTM	686.43	11.31	
247	3,397	Main	survey/DTM	686.53	11.53	
248	3,272	Main	survey/DTM	686.04	14.51	
249	3,126	Main	survey/DTM	685.63	14.97	
250	3,023	Main	survey/DTM	685.13	13.53	Upstream of Range Road 211A Bridge (BF13182)
251	3,011	Main	survey/DTM	685.27	14.87	Downstream of Range Road 211A Bridge (BF13182)
252	2,916	Main	survey/DTM	685.88	34.80	
253	2,665	Main	survey/DTM	685.02	16.66	
254	2,517	Main	survey/DTM	684.89	16.06	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Kneehills Creek						
255	2,242	Main	survey/DTM	684.55	16.50	
256	2,139	Main	survey/DTM	684.13	14.99	
257	2,049	Main	survey/DTM	683.80	17.69	
258	1,915	Main	survey/DTM	684.15	11.03	
259	1,794	Main	survey/DTM	683.55	18.79	
260	1,669	Main	survey/DTM	683.02	19.20	
261	1,600	Main	survey/DTM	682.60	20.65	Upstream of Highway 575 Bridge near Nacmine (BF13486)
262	1,584	Main	survey/DTM	682.85	18.73	Downstream of Highway 575 Bridge near Nacmine (BF13486)
263	1,532	Main	survey/DTM	682.09	20.92	
264	1,375	Main	survey/DTM	682.82	18.09	
265	1,231	Main	survey/DTM	682.80	14.94	
266	1,007	Main	survey/DTM	682.95	27.76	
267	827	Main	survey/DTM	683.20	10.35	
268	583	Main	survey/DTM	683.80	14.49	
269	416	Main	survey/DTM	681.34	15.86	
Michichi Creek						
270	5,335	Main	survey/DTM	690.56	19.13	Upstream model limit
271	5,127	Main	survey/DTM	689.66	11.14	
272	4,932	Main	survey/DTM	689.49	11.30	
273	4,747	Main	survey/DTM	688.94	11.02	
274	4,584	Main	survey/DTM	688.11	12.21	
275	4,337	Main	survey/DTM	687.90	10.68	
276	4,146	Main	survey/DTM	687.37	14.21	
277	3,938	Main	survey/DTM	686.53	12.66	
278	3,788	Main	survey/DTM	686.28	7.46	
279	3,614	Main	survey/DTM	686.63	12.15	
280	3,422	Main	survey/DTM	685.59	14.52	
281	3,178	Main	survey/DTM	684.80	8.60	
282	2,945	Main	survey/DTM	683.71	8.21	
283	2,718	Main	survey/DTM	683.70	8.85	
284	2,587	Main	survey/DTM	683.45	9.51	Upstream of Local Road (Unnamed Road) Bridge (BF07522)
285	2,577	Main	survey/DTM	683.94	9.95	Downstream of Local Road (Unnamed Road) Bridge (BF07522)

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Michichi Creek						
286	2,491	Main	survey/DTM	683.17	11.55	
287	2,442	Main	survey/DTM	682.59	8.88	Upstream of Private Road Access Bridge
288	2,429	Main	survey/DTM	683.02	8.74	Downstream of Private Road Access Bridge
289	2,318	Main	survey/DTM	682.62	9.66	
290	2,161	Main	survey/DTM	682.57	12.05	
291	2,059	Main	survey/DTM	682.09	11.20	
292	1,999	Main	survey/DTM	681.53	7.19	
293	1,852	Main	survey/DTM	681.29	6.99	
294	1,731	Main	survey/DTM	681.00	6.86	
295	1,554	Main	survey/DTM	680.36	6.20	
296	1,461	Main	survey/DTM	680.15	7.25	
297	1,358	Main	survey/DTM	680.34	15.12	Upstream of Highway 56 Culvert/Highway 9 over Michichi Creek at Drumheller (BF07524)
298	1,295	Main	survey/DTM	679.91	9.63	Downstream of Highway 56 Culvert/Highway 9 over Michichi Creek at Drumheller (BF07524)
299	1,248	Main	survey/DTM	679.64	6.41	
300	1,171	Main	survey/DTM	679.76	6.54	
301	1,091	Main	survey/DTM	679.89	10.92	
302	1,018	Main	survey/DTM	679.49	8.91	Upstream of Highway 838 Bridge in Drumheller (BF08584)
303	1,001	Main	survey/DTM	679.72	15.06	Downstream of Highway 838 Bridge in Drumheller (BF08584)
304	905	Main	survey/DTM	679.40	15.10	
305	782	Main	survey/DTM	678.48	7.69	
306	598	Main	survey/DTM	678.80	8.95	
307	506	Main	survey/DTM	678.50	39.27	Dike B on left bank
308	412	Main	survey/DTM	678.12	25.56	Dike B on left bank
309	334	Main	survey/DTM	677.93	26.24	Dike B on left bank
310	194	Main	survey/DTM	677.72	11.68	Dike B on left bank
Rosebud River						
311	10,702	Main	survey/DTM	694.48	11.73	Upstream model limit
312	10,485	Main	survey/DTM	693.94	13.54	
313	10,289	Main	survey/DTM	693.27	13.74	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Rosebud River						
314	10,163	Main	survey/DTM	693.48	21.91	
315	10,045	Main	survey/DTM	693.28	22.10	
316	9,912	Main	survey/DTM	693.56	18.83	
317	9,755	Main	survey/DTM	692.90	28.36	
318	9,668	Main	survey/DTM	692.36	19.24	
319	9,618	Main	survey/DTM	692.32	36.90	Upstream of Abandoned Railway Bridge 9
320	9,600	Main	survey/DTM	692.26	29.99	Downstream of Abandoned Railway Bridge 9
321	9,580	Main	survey/DTM	692.54	18.02	
322	9,570	Main	survey/DTM	692.58	22.67	Upstream of Highway 10X (Historical Bridge No. 11) (BF09315)
323	9,554	Main	survey/DTM	692.40	18.69	Downstream of Highway 10X (Historical Bridge No. 11) (BF09315)
324	9,468	Main	survey/DTM	692.00	17.82	
325	9,355	Main	survey/DTM	692.20	15.55	
326	9,227	Main	survey/DTM	691.74	13.47	
327	9,116	Main	survey/DTM	691.63	20.87	
328	8,994	Main	survey/DTM	691.65	19.99	
329	8,849	Main	survey/DTM	691.18	20.86	
330	8,745	Main	survey/DTM	691.19	17.88	
331	8,706	Main	survey/DTM	690.41	15.52	Upstream of Highway 10X (Historical Bridge No. 10) (BF08934)
332	8,689	Main	survey/DTM	690.82	16.63	Downstream of Highway 10X (Historical Bridge No. 10) (BF08934)
333	8,682	Main	survey/DTM	690.83	13.58	
334	8,675	Main	survey/DTM	690.92	14.45	Upstream of Abandoned Railway Bridge 8
335	8,661	Main	survey/DTM	690.91	15.57	Downstream of Abandoned Railway Bridge 8
336	8,553	Main	survey/DTM	690.09	21.49	
337	8,439	Main	survey/DTM	690.36	14.25	
338	8,343	Main	survey/DTM	689.71	15.46	
339	8,281	Main	survey/DTM	689.12	15.67	
340	8,187	Main	survey/DTM	689.76	14.72	
341	8,101	Main	survey/DTM	688.74	14.82	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Rosebud River						
342	8,080	Main	survey/DTM	689.05	20.28	Upstream of Abandoned Railway Bridge 7
343	8,060	Main	survey/DTM	689.22	28.70	Downstream of Abandoned Railway Bridge 7
344	8,009	Main	survey/DTM	689.41	19.99	
345	7,958	Main	survey/DTM	689.30	31.18	Upstream of Highway 10X (Historical Bridge No. 9) (BF08935)
346	7,937	Main	survey/DTM	689.20	22.91	Downstream of Highway 10X (Historical Bridge No. 9) (BF08935)
347	7,783	Main	survey/DTM	689.04	13.63	
348	7,641	Main	survey/DTM	688.79	20.05	
349	7,530	Main	survey/DTM	688.04	23.89	
350	7,395	Main	survey/DTM	688.34	12.50	
351	7,326	Main	survey/DTM	687.91	18.48	Upstream of Highway 10X (Historical Bridge No. 8) (BF70514)
352	7,303	Main	survey/DTM	688.01	20.69	Downstream of Highway 10X (Historical Bridge No. 8) (BF70514)
353	7,276	Main	survey/DTM	688.08	13.36	
354	7,246	Main	survey/DTM	687.86	33.77	Upstream of Abandoned Railway Bridge 6
355	7,215	Main	survey/DTM	687.67	26.63	Downstream of Abandoned Railway Bridge 6
356	7,151	Main	survey/DTM	688.03	18.23	
357	6,913	Main	survey/DTM	687.15	20.68	
358	6,774	Main	survey/DTM	686.80	22.49	
359	6,641	Main	survey/DTM	687.07	14.19	
360	6,532	Main	survey/DTM	687.15	22.13	
361	6,469	Main	survey/DTM	686.41	10.77	Upstream of Abandoned Railway Bridge 5
362	6,450	Main	survey/DTM	686.63	12.69	Downstream of Abandoned Railway Bridge 5
363	6,419	Main	survey/DTM	686.13	23.12	
364	6,382	Main	survey/DTM	686.36	19.45	Upstream of Highway 10X (Historical Bridge No. 7) (BF70513)
365	6,361	Main	survey/DTM	685.97	23.03	Downstream of Highway 10X (Historical Bridge No. 7) (BF70513)
366	6,278	Main	survey/DTM	686.39	18.08	
367	6,166	Main	survey/DTM	686.32	17.27	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
			Rosebud River			
368	5,969	Main	survey/DTM	685.54	13.15	
369	5,904	Main	survey/DTM	685.14	17.03	Upstream of Abandoned Railway Bridge 4
370	5,886	Main	survey/DTM	685.30	18.78	Downstream of Abandoned Railway Bridge 4
371	5,879	Main	survey/DTM	685.30	18.75	
372	5,872	Main	survey/DTM	685.18	17.40	Upstream of Highway 10X (Historical Bridge No. 6) (BF70774)
373	5,851	Main	survey/DTM	685.07	21.08	Downstream of Highway 10X (Historical Bridge No. 6) (BF70774)
374	5,776	Main	survey/DTM	685.32	16.68	
375	5,689	Main	survey/DTM	684.26	17.36	
376	5,616	Main	survey/DTM	684.88	12.58	
377	5,547	Main	survey/DTM	684.65	15.59	
378	5,473	Main	survey/DTM	684.26	26.14	Upstream of Highway 10X (Historical Bridge No. 5) (BF70773)
379	5,452	Main	survey/DTM	684.70	24.11	Downstream of Highway 10X (Historical Bridge No. 5) (BF70773)
380	5,378	Main	survey/DTM	684.38	13.45	
381	5,288	Main	survey/DTM	684.50	16.28	
382	5,193	Main	survey/DTM	684.53	29.74	
383	5,065	Main	survey/DTM	683.54	23.55	
384	4,997	Main	survey/DTM	683.89	13.90	Upstream of Highway 10X (Historical Bridge No. 4) (BF70512)
385	4,980	Main	survey/DTM	684.20	20.89	Downstream of Highway 10X (Historical Bridge No. 4) (BF70512)
386	4,917	Main	survey/DTM	683.70	22.04	
387	4,771	Main	survey/DTM	683.22	24.31	
388	4,599	Main	survey/DTM	682.91	18.38	
389	4,530	Main	survey/DTM	682.10	28.71	Upstream of Highway 10X (Historical Bridge No. 3) (BF70511)
390	4,509	Main	survey/DTM	682.13	15.88	Downstream of Highway 10X (Historical Bridge No. 3) (BF70511)
391	4,501	Main	survey/DTM	682.33	10.33	Upstream of Abandoned Railway Bridge 3
392	4,480	Main	survey/DTM	682.76	16.01	Downstream of Abandoned Railway Bridge 3
393	4,409	Main	survey/DTM	683.07	23.83	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
			Rosebud River			
394	4,313	Main	survey/DTM	682.60	17.27	
395	4,153	Main	survey/DTM	682.35	27.13	
396	4,037	Main	survey/DTM	682.14	16.08	
397	3,852	Main	survey/DTM	681.35	22.03	
398	3,694	Main	survey/DTM	681.71	14.32	
399	3,461	Main	survey/DTM	680.88	22.91	
400	3,314	Main	survey/DTM	681.16	15.56	
401	3,167	Main	survey/DTM	680.88	23.14	
402	3,011	Main	survey/DTM	679.97	29.50	
403	2,907	Main	survey/DTM	680.81	24.32	
404	2,817	Main	survey/DTM	680.04	13.44	
405	2,645	Main	survey/DTM	679.71	15.74	
406	2,454	Main	survey/DTM	679.61	20.33	
407	2,352	Main	survey/DTM	679.11	14.50	
408	2,255	Main	survey/DTM	678.41	19.30	Upstream of Abandoned Railway Bridge 2
409	2,235	Main	survey/DTM	677.96	21.99	Downstream of Abandoned Railway Bridge 2
410	2,187	Main	survey/DTM	678.61	20.71	
411	2,138	Main	survey/DTM	678.33	27.66	Upstream of Highway 10X (Historical Bridge No. 2) (BF70510)
412	2,113	Main	survey/DTM	678.71	29.35	Downstream of Highway 10X (Historical Bridge No. 2) (BF70510)
413	2,005	Main	survey/DTM	678.46	13.12	
414	1,894	Main	survey/DTM	677.89	15.00	
415	1,757	Main	survey/DTM	677.31	26.40	
416	1,602	Main	survey/DTM	677.05	17.10	
417	1,422	Main	survey/DTM	676.83	19.26	
418	1,271	Main	survey/DTM	676.35	18.88	
419	1,155	Main	survey/DTM	676.30	30.64	Upstream of Highway 10X (Historical Bridge No. 1) (BF70817)
420	1,127	Main	survey/DTM	676.36	25.98	Downstream of Highway 10X (Historical Bridge No. 1) (BF70817)
421	1,017	Main	survey/DTM	676.73	25.49	
422	833	Main	survey/DTM	674.98	19.03	
423	652	Main	survey/DTM	675.49	39.21	

Table B-1 Cross section details (Continued)

No	River Station (m)	HEC-RAS Model Sub-Reach	Source data for Main Channel/ Floodplain	Thalweg Elevation (m)	Channel Width (m)	Notes
Rosebud River						
424	559	Main	survey/DTM	674.71	26.10	Upstream of Highway 10 Bridge at Rosedale (BF08719)
425	527	Main	survey/DTM	674.94	29.18	Downstream of Highway 10 Bridge at Rosedale (BF08719)
426	438	Main	survey/DTM	674.83	15.75	
427	357	Main	survey/DTM	674.41	23.83	Upstream of Abandoned Railway Bridge 1
428	332	Main	survey/DTM	674.51	24.86	Downstream of Abandoned Railway Bridge 1
429	234	Main	survey/DTM	674.38	15.23	
430	116	Main	survey/DTM	674.07	16.82	
Willow Creek						
431	2,970	Main	survey/DTM	686.73	6.98	Upstream model limit
432	2,723	Main	survey/DTM	685.63	31.73	
433	2,408	Main	survey/DTM	683.54	8.15	
434	2,174	Main	survey/DTM	682.23	10.64	
435	1,937	Main	survey/DTM	680.78	19.07	
436	1,566	Main	survey/DTM	678.92	12.60	
437	1,356	Main	survey/DTM	677.82	8.31	
438	1,007	Main	survey/DTM	676.10	10.40	
439	863	Main	survey/DTM	675.18	14.40	
440	848	Main	survey/DTM	675.24	16.20	
441	584	Main	survey/DTM	673.98	10.50	
442	422	Main	survey/DTM	672.53	9.85	Upstream of Highway 10 Bridge 10.5 km NW of East Coulee (BF08584)
443	301	Main	survey/DTM	672.56	7.34	Downstream of Highway 10 Bridge 10.5 km NW of East Coulee (BF08584)

Table B-2 Bridge details

Stream Name	River Station (m)	Description	Type of Bridge	Design Drawing /Info	Span (m)	Width (m)	Number of Piers	Pier Width (m)	Model Skew (°)	High Chord	Low Chord	Pier Shape	Pier Type	Low Flow Modelling Approach	High Flow Modelling Approach
Red Deer River	44,430	Newcastle Mine Railway Bridge	Railway Bridge	No	167.8	5.8	3	2.6	30	686.47	684.47	Circular	Concrete	Highest Energy Answer	Pressure and/or Weir
	40,815	Highway 56 Bridge at Drumheller - BF06615	Highway Bridge	Yes	158.2	15.2	4	1.15	0	686.57	684.49	Circular	Concrete	Highest Energy Answer	Pressure and/or Weir
	32,502	Roper Road Bridge at Rosedale - BF07329	Road Bridge	Yes	153.6	9.5	4	1.55 - 1.88	0	684.31	682.21	Circular with Slope	Concrete	Highest Energy Answer	Pressure and/or Weir
	31,204	Star Mine Suspension Bridge - BF74796	Pedestrian Bridge	Yes	125.3	1.4	0	N/A	0	679.52	679.47	N/A	N/A	Highest Energy Answer	Energy Only (Standard Step)
	28,264	Abandoned Piers (U/S)	Abandoned Piers	No	N/A	6.9	4	3	0	N/A	N/A	Triangular	Concrete	Highest Energy Answer	Energy Only (Standard Step)
	28,204	Abandoned Piers (D/S)	Abandoned Piers	No	N/A	3.9	1	2.8	0	N/A	N/A	Triangular with Slope	Concrete	Highest Energy Answer	Energy Only (Standard Step)
	27,931	Highway 10 Bridge 8km SE of Drumheller - BF73277	Highway Bridge	Yes	167.3	8.5	4	0.90 - 1.8	10	683.56	681.76	Triangular with Slope	Concrete	Highest Energy Answer	Pressure and/or Weir
	16,778	Atlas Coal Mine Railway Bridge	Railway Bridge	No	226.3	11.8	15	0.3 (7), 3.2 (1), 4.2 (1), 2.8 (2), 3.6 (1), 0.3 (3)	10	677.47	675.97	Variable	Concrete and Timber	Highest Energy Answer	Pressure and/or Weir
	16,259	Highway 10 Bridge at East Coulee - BF73077	Highway Bridge	Yes	170	11.5	2	1.8	15	681.17	678.22	Circular	Concrete	Highest Energy Answer	Pressure and/or Weir
	3,897	Highway 848 Bridge at Dorothy - BF71085	Highway Bridge	Yes	161.7	6.2	2	1.25 - 1.70	0	673.47	672.17	Circular with Slope	Concrete	Highest Energy Answer	Pressure and/or Weir
Kneehills Creek	3,017	Range Road 211A Bridge - BF13182	Road Bridge	No	38.1	6.3	0	N/A	0	691.82	690.72	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	1,591	Highway 575 Bridge near Nacmine - BF13486	Highway Bridge	Yes	48.8	10.8	2	0.41	0	691.70	690.20	Circular	Steel Pile	Highest Energy Answer	Pressure and/or Weir
Michichi Creek	2,583	Local Road (Unnamed Road) Bridge - BF07522	Local Road	No	21.2	6	0	N/A	0	688.00	687.30	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	2,435	Private Road Access Bridge	Private Bridge	No	30.4	4.8	1	0.32	0	688.07	686.67	Square	Timber Pile	Highest Energy Answer	Pressure and/or Weir
	1,009	Highway 838 Bridge in Drumheller - BF08584	Highway Bridge	Yes	30.2	11.1	2	0.3	0	685.02	684.17	Circular	Steel Pile	Highest Energy Answer	Pressure and/or Weir
Rosebud River	9,609	Abandoned Railway Bridge 9	Railway Bridge	No	63	5.3	8	0.30 (5), 1.9 (3)	0	699.15	697.13	Square	Concrete	Highest Energy Answer	Pressure and/or Weir
	9,562	Highway 10X (Historical Bridge No. 11) - BF09315	Highway Bridge	No	30.2	8	0	N/A	0	698.48	697.40	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	8,697	Highway 10X (Historical Bridge No. 10) - BF08934	Highway Bridge	No	30.5	7.9	0	N/A	0	697.24	696.10	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	8,668	Abandoned Railway Bridge 8	Railway Bridge	No	28.9	5.5	0	N/A	0	699.45	696.68	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	8,069	Abandoned Railway Bridge 7	Railway Bridge	No	35.6	5.5	1	1.87	0	696.64	694.82	Circular	Concrete	Highest Energy Answer	Pressure and/or Weir

Table B-2 Bridge details (Continued)

Stream Name	River Station (m)	Description	Type of Bridge	Design Drawing /Info	Span (m)	Width (m)	Number of Piers	Pier Width (m)	Model Skew (°)	High Chord	Low Chord	Pier Shape	Pier Type	Low Flow Modelling Approach	High Flow Modelling Approach
Rosebud River	7,947	Highway 10X (Historical Bridge No. 9) - BF08935	Highway Bridge	Yes	49.4	5.8	0	N/A	0	696.88	695.58	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	7,315	Highway 10X (Historical Bridge No. 8) - BF70514	Highway Bridge	No	29.9	6	0	N/A	0	694.04	692.97	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	7,233	Abandoned Railway Bridge 6	Railway Bridge	No	35.2	5.4	1	1.9	0	695.44	693.67	Triangular	Concrete	Highest Energy Answer	Pressure and/or Weir
	6,458	Abandoned Railway Bridge 5	Railway Bridge	No	36.9	5.6	1	1.7	0	693.56	691.42	Square	Concrete	Highest Energy Answer	Pressure and/or Weir
	6,370	Highway 10X (Historical Bridge No. 7) - BF70513	Highway Bridge	No	30.3	6.4	1	1.27	0	692.3	691.08	Square	Timber Box	Highest Energy Answer	Pressure and/or Weir
	5,892	Abandoned Railway Bridge 4	Railway Bridge	No	41.1	5.2	1	2.48	0	692.35	690.57	Square	Concrete	Highest Energy Answer	Pressure and/or Weir
	5,863	Highway 10X (Historical Bridge No. 6) - BF70774	Highway Bridge	No	40.8	6.3	0	N/A	0	691.77	690.49	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	5,461	Highway 10X (Historical Bridge No. 5) - BF70773	Highway Bridge	No	30.4	6.3	0	N/A	0	690.4	689.34	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	4,988	Highway 10X (Historical Bridge No. 4) - BF70512	Highway Bridge	Yes	49.4	6.3	1	1.25	0	690.03	688.73	Square	Timber Box	Highest Energy Answer	Pressure and/or Weir
	4,518	Highway 10X (Historical Bridge No. 3) - BF70511	Highway Bridge	No	30.4	6.3	0	N/A	0	689.48	688.33	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	4,490	Abandoned Railway Bridge 3	Railway Bridge	No	30.8	5.4	1	1.48	0	690.83	689.23	Triangular	Concrete	Highest Energy Answer	Pressure and/or Weir
	2,245	Abandoned Railway Bridge 2	Railway Bridge	No	49.1	6	2	1.9	0	686.79	684.99	Triangular	Concrete	Highest Energy Answer	Pressure and/or Weir
	2,125	Highway 10X (Historical Bridge No. 2) - BF70510	Highway Bridge	No	41.1	6.3	0	N/A	0	685.25	683.87	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	1,140	Highway 10X (Historical Bridge No. 1) - BF70817	Highway Bridge	Yes	61.6	8.9	0	N/A	0	684.02	682.39	N/A	N/A	Highest Energy Answer	Pressure and/or Weir
	542	Highway 10 Bridge at Rosedale - BF08719	Highway Bridge	Yes	49.5	10.9	2	1.3	0	682.76	681.71	Circular	Concrete	Highest Energy Answer	Pressure and/or Weir
	340	Abandoned Railway Bridge 1	Railway Bridge	No	53.1	4.8	2	1.35	0	683.20	681.65	Circular with Slope	Concrete	Highest Energy Answer	Pressure and/or Weir
Willow Creek	856	Highway 10 Bridge 10.5 km NW of East Coulee - BF71746	Highway Bridge	Yes	33	13.5	2	0.61	0	680.60	679.55	Circular	Steel Pile	Highest Energy Answer	Pressure and/or Weir

Table B-3 Culvert details

Stream Name	River Station (m)	Description	Design Drawing/Info	Culvert Shape	Culvert Type	Entrance Condition	Number of Barrel	Barrel Length (m)	Diameter, Rise, or Height (m)	Span or Width (m)	Upstream Invert Elev (m)	Downstream Invert Elev (m)	Low Flow Modelling Approach	High Flow Modelling Approach
Michichi Creek	1326	Highway 9 Bridge over Michichi Creek at Drumheller - BF07524	Yes	Vertical Ellipse/Arch	Concrete	Headwall with Wingwall	1	48	4.9	9.0	679.24	679.15	Highest Energy Answer	Pressure and/or Weir

Table B-4 Computed flood frequency water levels – Red Deer River

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
56,139	685.70	686.48	686.97	687.43	688.34	688.76	689.25	689.59	690.59	691.24	691.62	692.13	692.42
55,755	685.59	686.36	686.85	687.31	688.21	688.62	689.11	689.45	690.44	691.09	691.46	691.96	692.25
55,521	685.51	686.27	686.75	687.19	688.07	688.48	688.96	689.30	690.28	690.92	691.31	691.80	692.08
55,149	685.41	686.15	686.61	687.05	687.92	688.32	688.80	689.14	690.11	690.72	691.07	691.53	691.80
54,759	685.29	685.98	686.43	686.85	687.68	688.06	688.52	688.86	689.83	690.45	690.79	691.31	691.60
54,516	685.24	685.93	686.37	686.79	687.63	688.02	688.49	688.82	689.82	690.45	690.81	691.33	691.62
54,007	685.04	685.72	686.17	686.60	687.45	687.85	688.34	688.69	689.70	690.35	690.71	691.22	691.50
53,602	684.86	685.53	685.99	686.42	687.29	687.70	688.20	688.55	689.58	690.23	690.59	691.10	691.39
53,393	684.73	685.40	685.85	686.28	687.15	687.55	688.05	688.41	689.44	690.08	690.44	690.95	691.24
53,064	684.56	685.26	685.72	686.17	687.06	687.47	687.98	688.35	689.39	690.03	690.40	690.91	691.20
52,682	684.39	685.08	685.55	686.00	686.93	687.37	687.90	688.28	689.35	690.00	690.37	690.89	691.19
52,364	684.26	684.95	685.42	685.88	686.82	687.27	687.81	688.19	689.26	689.92	690.29	690.82	691.11
51,970	684.03	684.70	685.17	685.62	686.55	686.99	687.55	687.95	689.05	689.72	690.10	690.63	690.93
51,689	683.90	684.55	685.00	685.45	686.41	686.86	687.42	687.82	688.90	689.56	689.93	690.46	690.76
51,563	683.84	684.47	684.92	685.36	686.30	686.75	687.33	687.74	688.87	689.54	689.92	690.46	690.76
51,326	683.64	684.28	684.75	685.22	686.20	686.68	687.28	687.70	688.84	689.50	689.87	690.41	690.71
51,089	683.43	684.15	684.67	685.17	686.18	686.67	687.28	687.70	688.84	689.50	689.88	690.42	690.72
50,765	683.28	683.99	684.50	684.99	685.98	686.44	687.03	687.44	688.53	689.16	689.51	689.98	690.26
50,457	683.12	683.85	684.37	684.87	685.89	686.37	686.97	687.39	688.50	689.13	689.47	689.97	690.26
50,067	682.80	683.64	684.20	684.73	685.78	686.26	686.88	687.30	688.43	689.07	689.43	689.93	690.23
49,706	682.59	683.46	684.04	684.60	685.71	686.22	686.85	687.29	688.43	689.08	689.44	689.96	690.25
49,354	682.44	683.34	683.92	684.46	685.53	686.02	686.65	687.08	688.19	688.81	689.15	689.63	689.92
49,045	682.27	683.14	683.75	684.32	685.44	685.95	686.60	687.03	688.15	688.79	689.15	689.65	689.94
48,695	682.11	682.97	683.54	684.08	685.11	685.58	686.22	686.70	687.98	688.66	689.04	689.56	689.86
48,288	681.94	682.86	683.46	684.03	685.10	685.60	686.25	686.71	687.91	688.56	688.92	689.41	689.71
48,079	681.82	682.77	683.39	683.96	685.05	685.55	686.21	686.67	687.89	688.55	688.90	689.40	689.70
47,899	681.69	682.62	683.21	683.77	684.81	685.29	685.93	686.38	687.59	688.26	688.63	689.13	689.42
47,630	681.59	682.51	683.11	683.66	684.71	685.19	685.84	686.30	687.54	688.20	688.57	689.07	689.37
47,303	681.48	682.40	683.00	683.57	684.66	685.17	685.85	686.32	687.57	688.24	688.60	689.09	689.39
47,010	681.40	682.33	682.93	683.49	684.58	685.07	685.75	686.22	687.44	688.07	688.42	688.89	689.18
46,672	681.31	682.22	682.82	683.37	684.43	684.91	685.57	686.03	687.22	687.81	688.14	688.58	688.85
46,395	681.22	682.14	682.74	683.30	684.36	684.84	685.50	685.96	687.18	687.78	688.11	688.56	688.84
46,221	681.15	682.08	682.68	683.24	684.31	684.79	685.46	685.92	687.15	687.75	688.08	688.53	688.81
46,039	681.07	681.99	682.58	683.14	684.19	684.66	685.33	685.79	687.05	687.66	687.99	688.44	688.71
45,748	680.98	681.89	682.49	683.04	684.10	684.57	685.24	685.71	686.94	687.54	687.87	688.31	688.59
45,410	680.90	681.84	682.45	683.01	684.09	684.58	685.28	685.75	687.03	687.63	687.97	688.42	688.69

Table B-4 Computed flood frequency water levels – Red Deer River (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
45,086	680.75	681.67	682.27	682.83	683.89	684.37	685.08	685.57	686.84	687.42	687.75	688.18	688.45
44,815	680.65	681.56	682.15	682.70	683.77	684.27	684.99	685.49	686.78	687.36	687.65	688.10	688.38
44,666	680.61	681.53	682.13	682.70	683.79	684.29	685.02	685.52	686.81	687.39	687.70	688.14	688.42
44,443	680.55	681.48	682.08	682.64	683.72	684.20	684.91	685.39	686.75	687.34	687.66	688.10	688.38
44,420	680.53	681.46	682.06	682.61	683.68	684.16	684.72	685.12	686.30	687.04	687.42	687.96	688.24
44,290	680.50	681.43	682.03	682.59	683.66	684.14	684.71	685.11	686.30	687.03	687.42	687.95	688.23
44,005	680.40	681.31	681.90	682.45	683.50	683.97	684.53	684.92	686.12	686.84	687.23	687.76	688.04
43,798	680.32	681.20	681.78	682.31	683.33	683.79	684.34	684.72	685.97	686.69	687.07	687.59	687.87
43,527	680.20	681.09	681.67	682.21	683.23	683.69	684.24	684.62	685.88	686.61	686.99	687.51	687.79
43,209	680.09	680.98	681.56	682.10	683.12	683.58	684.13	684.51	685.79	686.53	686.91	687.44	687.72
42,942	679.99	680.88	681.46	682.00	683.03	683.49	684.04	684.42	685.73	686.48	686.87	687.40	687.67
42,779	679.95	680.84	681.43	681.98	683.06	683.54	684.11	684.51	685.83	686.58	686.98	687.51	687.79
42,558	679.88	680.77	681.36	681.91	683.01	683.50	684.07	684.48	685.80	686.56	686.96	687.49	687.77
42,341	679.82	680.71	681.31	681.87	682.97	683.45	684.03	684.44	685.76	686.52	686.91	687.45	687.73
42,214	679.71	680.55	681.10	681.63	682.71	683.21	683.80	684.21	685.64	686.42	686.82	687.37	687.65
41,996	679.61	680.47	681.04	681.59	682.68	683.18	683.77	684.18	685.64	686.42	686.82	687.37	687.65
41,823	679.55	680.42	681.00	681.56	682.66	683.16	683.74	684.15	685.58	686.35	686.75	687.30	687.58
41,644	679.49	680.33	680.89	681.42	682.46	682.93	683.48	683.86	685.35	686.16	686.57	687.13	687.42
41,263	679.44	680.28	680.84	681.38	682.42	682.89	683.44	683.83	685.09	685.85	686.26	686.86	687.17
41,074	679.37	680.23	680.79	681.34	682.40	682.88	683.43	683.82	685.13	685.90	686.31	686.92	687.23
40,832	679.23	680.11	680.69	681.24	682.32	682.80	683.36	683.75	684.93	685.72	686.15	686.77	687.09
40,804	679.23	680.11	680.69	681.24	682.31	682.80	683.36	683.74	684.90	685.70	686.13	686.74	687.07
40,748	679.19	680.07	680.65	681.20	682.27	682.74	683.30	683.68	684.85	685.66	686.08	686.70	687.02
40,606	679.13	680.02	680.60	681.16	682.23	682.70	683.26	683.65	684.82	685.63	686.04	686.64	686.96
40,517	679.12	680.01	680.59	681.14	682.21	682.69	683.24	683.63	684.78	685.57	685.98	686.56	686.88
40,322	678.97	679.83	680.39	680.92	681.95	682.40	682.93	683.29	684.48	685.29	685.70	686.27	686.60
40,132	678.88	679.75	680.31	680.85	681.88	682.34	682.87	683.23	684.45	685.25	685.67	686.26	686.59
39,912	678.78	679.65	680.22	680.76	681.80	682.25	682.79	683.15	684.36	685.12	685.54	686.13	686.44
39,774	678.73	679.62	680.20	680.75	681.80	682.27	682.81	683.18	684.39	685.17	685.58	686.16	686.48
39,619	678.68	679.57	680.15	680.70	681.74	682.20	682.73	683.10	684.27	685.04	685.42	685.99	686.30
39,538	678.64	679.54	680.13	680.68	681.73	682.19	682.73	683.10	684.28	685.05	685.46	686.04	686.35
39,370	678.59	679.48	680.05	680.59	681.63	682.08	682.61	682.98	684.14	684.91	685.31	685.89	686.21
39,070	678.47	679.34	679.91	680.45	681.47	681.92	682.44	682.80	683.94	684.68	685.08	685.64	685.94
38,812	678.37	679.25	679.83	680.37	681.41	681.87	682.40	682.77	683.94	684.71	685.12	685.69	686.01
38,629	678.29	679.18	679.76	680.31	681.35	681.80	682.33	682.70	683.86	684.63	685.04	685.61	685.92
38,381	678.22	679.10	679.68	680.22	681.25	681.71	682.24	682.59	683.74	684.51	684.92	685.49	685.80
38,176	678.16	679.04	679.61	680.15	681.19	681.64	682.16	682.52	683.66	684.44	684.85	685.43	685.74

Table B-4 Computed flood frequency water levels – Red Deer River (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
37,829	678.06	678.95	679.53	680.08	681.12	681.58	682.10	682.46	683.63	684.43	684.85	685.43	685.74
37,633	678.00	678.88	679.47	680.01	681.06	681.51	682.04	682.40	683.55	684.34	684.76	685.33	685.64
37,484	677.99	678.89	679.49	680.05	681.11	681.57	682.11	682.48	683.65	684.44	684.85	685.43	685.74
37,376	677.95	678.86	679.46	680.02	681.10	681.56	682.11	682.48	683.65	684.45	684.86	685.44	685.75
37,086	677.86	678.76	679.36	679.93	681.02	681.49	682.03	682.40	683.59	684.39	684.80	685.38	685.69
36,958	677.83	678.74	679.33	679.90	680.98	681.45	681.98	682.35	683.52	684.31	684.72	685.29	685.60
36,721	677.75	678.66	679.26	679.82	680.87	681.32	681.84	682.19	683.33	684.09	684.49	685.05	685.35
36,621	677.72	678.62	679.21	679.77	680.82	681.26	681.79	682.14	683.28	684.07	684.48	685.04	685.35
36,313	677.65	678.55	679.14	679.69	680.73	681.18	681.69	682.04	683.15	683.93	684.34	684.91	685.21
35,982	677.57	678.47	679.07	679.63	680.68	681.13	681.65	681.99	683.11	683.89	684.29	684.85	685.15
35,611	677.45	678.37	678.98	679.54	680.60	681.05	681.57	681.92	683.05	683.84	684.25	684.81	685.11
35,412	677.40	678.32	678.92	679.48	680.55	681.00	681.51	681.86	683.00	683.80	684.21	684.78	685.08
35,165	677.35	678.26	678.86	679.41	680.45	680.88	681.39	681.72	682.86	683.66	684.07	684.65	684.96
34,850	677.28	678.19	678.79	679.35	680.40	680.84	681.36	681.71	682.86	683.67	684.09	684.67	684.97
34,667	677.24	678.15	678.75	679.31	680.36	680.80	681.32	681.67	682.83	683.65	684.06	684.64	684.95
34,292	677.13	678.03	678.62	679.18	680.24	680.68	681.19	681.55	682.73	683.56	683.97	684.56	684.87
33,924	677.04	677.94	678.53	679.09	680.14	680.57	681.08	681.43	682.61	683.45	683.86	684.46	684.77
33,653	676.91	677.79	678.37	678.93	679.96	680.39	680.91	681.27	682.50	683.36	683.79	684.38	684.70
33,378	676.79	677.69	678.29	678.85	679.91	680.35	680.89	681.25	682.48	683.34	683.77	684.36	684.67
33,017	676.68	677.58	678.18	678.75	679.83	680.27	680.81	681.17	682.41	683.28	683.70	684.30	684.61
32,670	676.58	677.49	678.10	678.68	679.76	680.20	680.73	681.09	682.32	683.20	683.63	684.23	684.54
32,519	676.50	677.41	678.02	678.59	679.64	680.07	680.58	680.92	682.11	682.97	683.42	684.04	684.37
32,484	676.49	677.41	678.01	678.58	679.63	680.06	680.56	680.90	682.08	682.99	683.44	684.06	684.39
32,344	676.38	677.27	677.86	678.43	679.48	679.91	680.45	680.80	681.84	682.55	682.93	683.50	683.81
32,054	676.29	677.22	677.84	678.43	679.52	679.97	680.51	680.87	681.91	682.60	682.97	683.54	683.85
31,781	676.10	677.00	677.59	678.14	679.21	679.66	680.23	680.61	681.70	682.41	682.80	683.37	683.68
31,429	675.96	676.88	677.49	678.07	679.15	679.58	680.14	680.52	681.59	682.29	682.67	683.24	683.55
31,207	675.89	676.82	677.43	678.01	679.08	679.52	680.08	680.46	681.55	682.26	682.65	683.22	683.53
31,198	675.89	676.82	677.43	678.01	679.08	679.51	680.04	680.40	681.46	682.17	682.54	683.12	683.43
30,968	675.82	676.76	677.37	677.95	679.03	679.47	680.00	680.37	681.43	682.14	682.52	683.10	683.41
30,771	675.71	676.65	677.27	677.85	678.95	679.40	679.96	680.33	681.40	682.12	682.50	683.07	683.38
30,480	675.54	676.47	677.08	677.66	678.76	679.24	679.82	680.21	681.29	682.02	682.41	682.99	683.31
30,282	675.50	676.46	677.09	677.68	678.81	679.28	679.85	680.23	681.31	682.03	682.42	683.00	683.32
30,086	675.45	676.43	677.06	677.66	678.79	679.26	679.83	680.21	681.29	682.02	682.40	682.98	683.30
29,895	675.37	676.33	676.97	677.55	678.66	679.11	679.67	680.05	681.14	681.87	682.26	682.84	683.16
29,573	675.20	676.16	676.77	677.35	678.44	678.88	679.45	679.83	680.92	681.65	682.03	682.61	682.93
29,224	675.13	676.09	676.72	677.30	678.40	678.84	679.40	679.78	680.85	681.57	681.95	682.53	682.84

Table B-4 Computed flood frequency water levels – Red Deer River (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
28,890	675.05	676.03	676.65	677.24	678.35	678.80	679.36	679.75	680.83	681.56	681.94	682.53	682.84
28,595	674.97	675.91	676.52	677.09	678.15	678.57	679.11	679.48	680.53	681.27	681.66	682.26	682.59
28,373	674.91	675.86	676.46	677.03	678.09	678.51	679.06	679.44	680.51	681.26	681.65	682.25	682.58
28,271	674.89	675.83	676.43	676.99	678.04	678.45	678.97	679.34	680.39	681.09	681.49	682.08	682.41
28,255	674.88	675.81	676.40	676.96	678.00	678.40	678.92	679.29	680.35	681.07	681.47	682.04	682.37
28,234	674.89	675.82	676.42	676.98	678.03	678.43	678.96	679.32	680.36	681.10	681.50	682.07	682.39
28,215	674.89	675.82	676.42	676.98	678.02	678.43	678.96	679.32	680.37	681.08	681.49	682.06	682.38
28,196	674.87	675.80	676.40	676.95	677.99	678.40	678.92	679.28	680.33	681.03	681.44	682.01	682.34
28,120	674.86	675.79	676.38	676.94	677.98	678.39	678.91	679.27	680.33	681.01	681.42	681.98	682.32
28,028	674.83	675.77	676.37	676.92	677.97	678.38	678.90	679.27	680.32	681.03	681.43	681.98	682.32
27,943	674.79	675.71	676.29	676.84	677.86	678.25	678.75	679.10	680.08	680.72	681.08	681.58	681.87
27,921	674.77	675.68	676.26	676.80	677.81	678.19	678.69	679.03	680.00	680.64	681.01	681.51	681.79
27,749	674.74	675.64	676.22	676.76	677.79	678.18	678.68	679.03	680.03	680.70	681.07	681.60	681.89
27,487	674.67	675.57	676.16	676.69	677.72	678.10	678.62	678.97	679.98	680.65	681.03	681.57	681.86
27,145	674.59	675.49	676.07	676.61	677.63	678.00	678.50	678.86	679.88	680.56	680.95	681.49	681.79
26,728	674.51	675.40	675.97	676.51	677.52	677.88	678.38	678.73	679.74	680.41	680.78	681.30	681.59
26,576	674.48	675.38	675.97	676.51	677.53	677.90	678.40	678.75	679.77	680.44	680.81	681.33	681.62
26,330	674.36	675.26	675.84	676.39	677.41	677.78	678.29	678.64	679.67	680.35	680.73	681.25	681.54
26,001	674.21	675.12	675.71	676.25	677.28	677.64	678.14	678.49	679.48	680.14	680.50	681.02	681.31
25,566	674.08	674.98	675.56	676.10	677.11	677.45	677.93	678.27	679.26	679.93	680.31	680.84	681.14
25,030	673.93	674.83	675.41	675.95	676.96	677.29	677.77	678.11	679.11	679.81	680.20	680.74	681.04
24,611	673.81	674.71	675.28	675.82	676.82	677.13	677.61	677.94	678.95	679.65	680.04	680.59	680.89
24,051	673.66	674.58	675.17	675.72	676.74	677.05	677.55	677.89	678.91	679.61	680.00	680.55	680.85
23,586	673.54	674.48	675.07	675.62	676.65	676.96	677.46	677.81	678.83	679.54	679.93	680.48	680.79
23,316	673.48	674.40	674.99	675.53	676.56	676.85	677.35	677.71	678.74	679.46	679.86	680.41	680.72
22,842	673.31	674.23	674.82	675.36	676.38	676.81	677.29	677.63	678.66	679.38	679.79	680.34	680.65
22,328	672.99	673.88	674.44	674.98	675.97	676.42	676.95	677.31	678.41	679.16	679.57	680.14	680.45
21,724	672.79	673.68	674.26	674.80	675.86	676.34	676.88	677.25	678.35	679.11	679.52	680.09	680.41
21,245	672.65	673.53	674.10	674.63	675.64	676.10	676.62	676.98	678.04	678.79	679.20	679.77	680.08
21,011	672.60	673.49	674.06	674.60	675.62	676.09	676.61	676.97	678.05	678.81	679.22	679.79	680.11
20,686	672.53	673.42	673.99	674.52	675.53	675.98	676.51	676.87	677.98	678.75	679.17	679.74	680.06
20,474	672.43	673.29	673.84	674.36	675.35	675.80	676.33	676.70	677.86	678.64	679.06	679.65	679.96
20,065	672.32	673.20	673.78	674.31	675.33	675.79	676.33	676.71	677.85	678.62	679.03	679.61	679.93
19,848	672.19	673.03	673.57	674.08	675.05	675.50	676.03	676.41	677.55	678.30	678.73	679.32	679.64
19,656	672.15	672.99	673.53	674.04	675.02	675.47	675.99	676.36	677.44	678.22	678.66	679.26	679.59
19,356	672.06	672.87	673.38	673.87	674.78	675.19	675.67	676.01	676.99	677.74	678.15	678.72	679.03
19,059	671.93	672.71	673.22	673.70	674.61	675.02	675.51	675.85	676.87	677.66	678.09	678.69	679.00

Table B-4 Computed flood frequency water levels – Red Deer River (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
18,881	671.85	672.64	673.14	673.62	674.54	674.96	675.46	675.81	676.89	677.68	678.11	678.72	679.04
18,652	671.80	672.58	673.09	673.57	674.50	674.93	675.43	675.78	676.88	677.70	678.14	678.75	679.07
18,440	671.73	672.52	673.04	673.54	674.48	674.92	675.43	675.79	676.87	677.69	678.12	678.72	679.05
18,219	671.66	672.47	673.00	673.50	674.46	674.89	675.41	675.77	676.88	677.70	678.14	678.74	679.06
18,020	671.59	672.41	672.94	673.44	674.40	674.84	675.35	675.71	676.81	677.61	678.04	678.63	678.94
17,745	671.49	672.30	672.83	673.32	674.26	674.69	675.20	675.55	676.65	677.46	677.89	678.49	678.81
17,505	671.42	672.22	672.73	673.21	674.13	674.55	675.04	675.39	676.45	677.26	677.69	678.28	678.60
17,278	671.38	672.17	672.68	673.16	674.08	674.49	674.98	675.33	676.39	677.20	677.64	678.23	678.54
17,161	671.37	672.16	672.68	673.17	674.10	674.52	675.02	675.37	676.45	677.26	677.69	678.28	678.60
16,904	671.32	672.11	672.62	673.11	674.04	674.47	674.97	675.32	676.40	677.22	677.65	678.25	678.57
16,791	671.29	672.08	672.60	673.08	674.01	674.44	674.94	675.29	676.36	677.18	677.62	678.22	678.54
16,767	671.28	672.06	672.57	673.05	673.97	674.40	674.89	675.24	676.32	677.09	677.51	678.11	678.44
16,692	671.26	672.05	672.56	673.05	673.97	674.40	674.89	675.25	676.33	677.10	677.52	678.12	678.45
16,555	671.22	672.01	672.52	673.00	673.93	674.36	674.86	675.21	676.29	677.06	677.48	678.08	678.42
16,363	671.16	671.94	672.44	672.92	673.83	674.26	674.75	675.09	676.15	676.92	677.33	677.92	678.24
16,272	671.13	671.89	672.39	672.86	673.74	674.15	674.61	674.94	675.93	676.64	677.02	677.56	677.86
16,246	671.12	671.88	672.38	672.84	673.73	674.13	674.59	674.92	675.90	676.61	676.99	677.53	677.82
16,054	670.96	671.70	672.18	672.63	673.52	673.93	674.42	674.76	675.82	676.55	676.94	677.49	677.79
15,799	670.79	671.53	672.02	672.48	673.37	673.78	674.25	674.59	675.61	676.30	676.67	677.22	677.52
15,326	670.59	671.36	671.85	672.32	673.22	673.63	674.10	674.44	675.45	676.13	676.51	677.05	677.35
14,807	670.45	671.19	671.67	672.14	673.02	673.42	673.89	674.23	675.25	675.96	676.35	676.91	677.22
14,404	670.31	671.07	671.57	672.05	672.97	673.39	673.88	674.23	675.30	676.01	676.41	676.98	677.29
13,966	670.15	670.92	671.41	671.88	672.80	673.23	673.74	674.10	675.19	675.91	676.31	676.88	677.20
13,392	670.01	670.77	671.26	671.73	672.64	673.05	673.53	673.88	674.93	675.63	676.02	676.57	676.88
12,955	669.90	670.64	671.13	671.59	672.48	672.89	673.37	673.71	674.76	675.46	675.84	676.38	676.68
12,528	669.80	670.54	671.03	671.49	672.39	672.80	673.28	673.62	674.67	675.37	675.75	676.29	676.59
12,053	669.68	670.41	670.89	671.35	672.24	672.64	673.12	673.46	674.50	675.20	675.59	676.13	676.44
11,633	669.56	670.31	670.80	671.27	672.18	672.59	673.08	673.43	674.49	675.20	675.59	676.14	676.44
11,128	669.34	670.06	670.54	671.00	671.87	672.27	672.74	673.07	674.10	674.79	675.16	675.70	675.99
10,764	669.22	669.96	670.45	670.92	671.81	672.21	672.69	673.03	674.08	674.78	675.16	675.71	676.01
10,351	668.97	669.73	670.23	670.71	671.65	672.07	672.57	672.92	673.99	674.71	675.09	675.64	675.95
10,016	668.83	669.59	670.08	670.55	671.43	671.83	672.30	672.64	673.67	674.35	674.71	675.23	675.52
9,697	668.74	669.49	669.98	670.43	671.30	671.69	672.15	672.47	673.49	674.16	674.52	675.03	675.31
9,417	668.68	669.44	669.94	670.40	671.30	671.70	672.17	672.50	673.54	674.23	674.60	675.12	675.41
9,179	668.56	669.29	669.76	670.21	671.07	671.45	671.91	672.24	673.26	673.95	674.30	674.81	675.09
8,943	668.43	669.15	669.61	670.05	670.91	671.31	671.79	672.13	673.18	673.88	674.24	674.76	675.05
8,669	668.28	668.97	669.44	669.88	670.75	671.15	671.62	671.96	673.01	673.65	674.03	674.57	674.87

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Table B-4 Computed flood frequency water levels – Red Deer River (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
8,338	667.82	668.60	669.11	669.58	670.48	670.89	671.38	671.72	672.77	673.43	673.80	674.32	674.61
7,988	667.66	668.46	668.97	669.44	670.33	670.73	671.20	671.54	672.58	673.23	673.59	674.10	674.38
7,398	667.39	668.16	668.66	669.12	670.00	670.42	670.91	671.26	672.32	672.98	673.34	673.84	674.11
7,006	667.21	667.94	668.41	668.86	669.77	670.20	670.71	671.07	672.16	672.83	673.19	673.69	673.96
6,606	667.05	667.71	668.15	668.56	669.36	669.74	670.17	670.49	671.47	672.06	672.38	672.83	673.07
6,283	666.90	667.57	668.04	668.47	669.31	669.72	670.19	670.53	671.58	672.21	672.55	673.02	673.28
5,827	666.52	667.24	667.74	668.21	669.16	669.61	670.12	670.48	671.59	672.24	672.60	673.09	673.36
5,356	666.25	667.05	667.59	668.09	669.07	669.52	670.04	670.41	671.53	672.20	672.55	673.05	673.32
5,018	666.07	666.88	667.40	667.90	668.90	669.37	669.90	670.27	671.40	672.06	672.41	672.91	673.18
4,746	665.99	666.80	667.32	667.81	668.76	669.19	669.69	670.04	671.10	671.71	672.04	672.50	672.75
4,466	665.87	666.65	667.16	667.63	668.54	668.96	669.45	669.79	670.84	671.43	671.74	672.18	672.42
4,233	665.76	666.53	667.02	667.49	668.40	668.82	669.31	669.65	670.69	671.26	671.56	671.96	672.19
4,018	665.64	666.40	666.89	667.36	668.27	668.69	669.17	669.51	670.54	671.10	671.41	671.83	672.05
3,908	665.60	666.37	666.87	667.34	668.26	668.68	669.16	669.50	670.54	671.10	671.40	671.80	672.02
3,888	665.58	666.34	666.84	667.31	668.22	668.64	669.12	669.46	670.50	671.05	671.34	671.74	671.96
3,752	665.43	666.16	666.64	667.09	667.99	668.41	668.89	669.23	670.25	670.85	671.17	671.61	671.85
3,508	665.27	666.02	666.51	666.98	667.89	668.32	668.81	669.15	670.18	670.75	671.05	671.48	671.72
3,182	664.97	665.79	666.31	666.79	667.73	668.16	668.65	668.99	670.04	670.63	670.94	671.35	671.59
2,861	664.69	665.50	666.01	666.50	667.44	667.88	668.37	668.71	669.75	670.33	670.64	671.08	671.33
2,536	664.52	665.33	665.84	666.32	667.26	667.68	668.17	668.50	669.51	670.11	670.44	670.90	671.16
2,249	664.46	665.27	665.78	666.27	667.23	667.67	668.18	668.53	669.60	670.22	670.56	671.03	671.29
1,783	664.32	665.12	665.64	666.14	667.13	667.59	668.10	668.46	669.56	670.20	670.54	671.02	671.29
1,484	664.25	665.04	665.56	666.05	667.02	667.46	667.96	668.32	669.41	670.04	670.39	670.86	671.12
1,306	664.18	664.95	665.46	665.95	666.92	667.36	667.87	668.22	669.30	669.91	670.24	670.71	670.96
1,004	664.06	664.80	665.29	665.75	666.67	667.08	667.56	667.90	668.98	669.60	669.94	670.42	670.68
442	663.73	664.50	665.01	665.49	666.45	666.89	667.39	667.75	668.88	669.50	669.82	670.28	670.53
0	663.46	664.24	664.75	665.23	666.17	666.60	667.08	667.42	668.48	669.09	669.42	669.88	670.14

Table B-5 Computed flood frequency water levels – Kneehills Creek

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
7,869	696.45	697.35	697.75	698.04	698.25	698.37	698.51	698.59	698.78	698.93	699.01	699.10	699.16
7,766	696.39	697.24	697.61	697.89	698.08	698.20	698.33	698.41	698.59	698.72	698.79	698.88	698.94
7,671	696.23	697.05	697.40	697.67	697.86	697.98	698.11	698.19	698.36	698.49	698.56	698.64	698.69
7,574	696.08	696.85	697.21	697.48	697.67	697.80	697.93	698.01	698.17	698.28	698.35	698.43	698.48
7,479	695.92	696.68	697.03	697.29	697.46	697.59	697.72	697.79	697.94	698.04	698.10	698.17	698.21
7,370	695.62	696.46	696.83	697.08	697.25	697.37	697.47	697.53	697.67	697.77	697.83	697.90	697.94
7,153	695.28	696.05	696.41	696.68	696.86	696.97	697.07	697.14	697.30	697.42	697.49	697.57	697.63
6,927	694.88	695.75	696.23	696.53	696.71	696.81	696.92	696.99	697.15	697.28	697.36	697.45	697.50
6,786	694.48	695.50	696.04	696.36	696.56	696.66	696.78	696.86	697.03	697.17	697.26	697.35	697.41
6,665	694.31	695.29	695.82	696.12	696.30	696.41	696.55	696.64	696.83	696.99	697.09	697.19	697.25
6,500	694.06	695.04	695.59	695.87	696.03	696.14	696.29	696.39	696.61	696.78	696.87	696.97	697.04
6,397	693.81	694.83	695.39	695.64	695.73	695.81	695.95	696.03	696.23	696.37	696.44	696.54	696.59
6,289	693.54	694.62	695.22	695.59	695.68	695.75	695.89	695.97	696.15	696.31	696.38	696.47	696.53
6,165	693.29	694.42	695.01	695.38	695.59	695.65	695.78	695.86	696.04	696.18	696.26	696.34	696.40
6,045	693.11	694.22	694.77	695.12	695.32	695.42	695.55	695.62	695.78	695.90	695.97	696.05	696.09
5,903	692.81	693.96	694.50	694.83	695.02	695.12	695.24	695.32	695.47	695.60	695.66	695.73	695.78
5,774	692.64	693.76	694.25	694.54	694.72	694.82	694.94	695.01	695.17	695.28	695.35	695.43	695.48
5,662	692.53	693.61	694.07	694.33	694.51	694.60	694.70	694.77	694.93	695.04	695.11	695.19	695.24
5,554	692.46	693.59	694.06	694.32	694.49	694.57	694.67	694.74	694.89	695.00	695.06	695.13	695.18
5,435	692.36	693.52	694.01	694.26	694.43	694.52	694.62	694.69	694.83	694.94	695.01	695.08	695.13
5,300	692.18	693.37	693.86	694.11	694.30	694.39	694.49	694.57	694.72	694.83	694.89	694.97	695.02
5,175	692.04	693.19	693.67	693.91	694.10	694.20	694.30	694.37	694.51	694.62	694.68	694.76	694.80
5,078	691.97	693.07	693.54	693.75	693.91	693.99	694.09	694.14	694.28	694.38	694.44	694.51	694.55
4,972	691.86	692.94	693.41	693.63	693.78	693.86	693.95	694.01	694.14	694.25	694.31	694.37	694.42
4,844	691.57	692.68	693.18	693.46	693.62	693.70	693.79	693.84	693.98	694.08	694.14	694.21	694.26
4,690	691.18	692.36	692.97	693.32	693.50	693.59	693.67	693.73	693.87	693.98	694.04	694.11	694.16
4,513	690.78	692.03	692.64	692.94	693.12	693.21	693.33	693.40	693.56	693.68	693.75	693.84	693.89
4,412	690.68	691.90	692.51	692.81	692.99	693.09	693.20	693.27	693.42	693.54	693.61	693.69	693.74**
4,326	690.59	691.75	692.35	692.68	692.87	692.97	693.08	693.15	693.30	693.42	693.49	693.57	693.62**
4,192	690.32	691.53	692.17	692.53	692.72	692.82	692.94	693.01	693.17	693.29	693.36	693.44	693.49**
4,053	689.91	691.17	691.80	692.16	692.36	692.47	692.59	692.67	692.84	692.97	693.05	693.14	693.19**
3,966	689.82	691.06	691.66	692.01	692.18	692.27	692.37	692.45	692.61	692.74	692.80	692.89	692.94**
3,833	689.66	690.90	691.50	691.85	692.01	692.11	692.20	692.27	692.44	692.57	692.64	692.73**	692.79**
3,738	689.51	690.75	691.40	691.78	691.94	692.04	692.12	692.20	692.37	692.50	692.57	692.66**	692.72**
3,549	689.22	690.51	691.18	691.52	691.72	691.84	691.93	692.01	692.20	692.35	692.43	692.52**	692.59**

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.
** Indicates adjusted values where Red Deer River water levels govern the profile.

Table B-5 Computed flood frequency water levels – Kneehills Creek (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
3,397	688.88	690.16	690.83	691.27	691.51	691.65	691.73	691.83	692.04	692.20	692.27**	692.37**	692.44**
3,272	688.67	689.97	690.64	691.07	691.29	691.49	691.55	691.65	691.88	692.03**	692.11**	692.22**	692.30**
3,126	688.52	689.83	690.49	690.91	691.12	691.36	691.40	691.50	691.76	691.91**	691.99**	692.10**	692.19**
3,023	688.43	689.68	690.28	690.63	690.76	690.92*	690.92	690.98	691.17	691.22**	691.23**	691.26**	691.32**
3,011	688.42	689.67	690.28	690.62	690.73	690.79	690.85	690.90	690.99	691.08**	691.16**	691.33**	691.44**
2,916	688.26	689.48	690.13	690.50	690.63	690.69	690.76	690.82	690.93**	691.06**	691.17**	691.38**	691.54**
2,665	687.65	688.77	689.36	689.81	690.12	690.24	690.36	690.45	690.64**	690.83**	690.97**	691.25**	691.44**
2,517	687.41	688.61	689.24	689.71	690.00	690.12	690.24	690.32**	690.53**	690.74**	690.90**	691.19**	691.39**
2,242	686.98	688.18	688.77	689.17	689.40	689.52	689.63	689.73**	690.04**	690.39**	690.63**	691.02**	691.26**
2,139	686.84	688.14	688.76	689.19	689.44	689.56	689.67	689.76**	690.05**	690.38**	690.61**	691.00**	691.24**
2,049	686.76	688.05	688.68	689.11	689.35	689.47	689.58	689.67**	689.98**	690.32**	690.57**	690.97**	691.22**
1,915	686.55	687.77	688.36	688.81	689.06	689.19	689.35	689.47**	689.85**	690.25**	690.51**	690.94**	691.20**
1,794	686.41	687.57	688.11	688.55	688.83	688.98	689.15**	689.29**	689.75**	690.19**	690.47**	690.91**	691.18**
1,669	686.33	687.42	687.88	688.24	688.50	688.66	688.85**	689.02**	689.60**	690.09**	690.39**	690.86**	691.13**
1,600	686.32	687.38	687.84	688.18	688.42	688.56	688.74**	688.88**	689.40**	689.88**	690.18**	690.67**	690.95**
1,584	686.31	687.37	687.81	688.15	688.38	688.51	688.68**	688.83**	689.34**	689.83**	690.13**	690.60**	690.87**
1,532	686.29	687.33	687.75	688.07	688.29	688.43	688.60**	688.74**	689.29**	689.79**	690.10**	690.57**	690.85**
1,375	686.23	687.19	687.54	687.79	687.96	688.07**	688.22**	688.38**	689.05**	689.63**	689.98**	690.49**	690.78**
1,231	686.14	687.00	687.30	687.53	687.69	687.80**	687.99**	688.19**	689.00**	689.61**	689.97**	690.48**	690.78**
1,007	686.04	686.78	687.00	687.18	687.35**	687.51**	687.80**	688.06**	688.97**	689.59**	689.95**	690.48**	690.77**
827	685.96	686.65	686.86	687.02	687.21**	687.41**	687.73**	688.02**	688.95**	689.59**	689.95**	690.47**	690.77**
583	685.08	685.96	686.26	686.57**	686.89**	687.18**	687.61**	687.94**	688.93**	689.58**	689.94**	690.47**	690.77**
416	683.90**	684.55**	685.00**	685.45**	686.41**	686.86**	687.42**	687.82**	688.90**	689.56**	689.93**	690.46**	690.76**

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.
** Indicates adjusted values where Red Deer River water levels govern the profile.

Table B-6 Computed flood frequency water levels – Michichi Creek

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
5,335	691.86	692.64	693.07	693.44	693.66	693.82	693.96	694.04	694.24	694.35	694.43	694.50	694.54
5,127	691.40	692.21	692.64	692.99	693.20	693.33	693.45	693.53	693.73	693.86	693.95	694.03	694.08
4,932	690.88	691.69	692.13	692.48	692.69	692.83	692.95	693.02	693.22	693.34	693.43	693.51	693.56
4,747	690.33	691.22	691.68	692.03	692.22	692.33	692.42	692.48	692.63	692.71	692.77	692.82	692.85
4,584	690.03	690.91	691.36	691.73	691.93	692.05	692.15	692.22	692.36	692.46	692.52	692.57	692.61
4,337	689.55	690.27	690.66	691.01	691.23	691.37	691.49	691.55	691.71	691.83	691.90	691.97	692.01
4,146	688.87	689.73	690.15	690.53	690.76	690.90	691.01	691.08	691.24	691.35	691.43	691.50	691.55
3,938	688.52	689.39	689.82	690.19	690.42	690.54	690.64	690.69	690.84	690.95	691.02	691.08	691.12
3,788	688.30	689.07	689.44	689.79	690.00	690.15	690.27	690.35	690.53	690.65	690.72	690.79	690.83
3,614	687.87	688.45	688.75	689.06	689.26	689.39	689.52	689.60	689.81	689.95	690.05	690.13	690.18
3,422	686.76	687.42	687.82	688.18	688.36	688.47	688.56	688.62	688.76	688.86	688.93	689.00	689.07
3,178	686.36	687.21	687.66	688.04	688.22	688.32	688.41	688.46	688.59	688.67	688.74	688.81	688.87
2,945	686.03	686.91	687.34	687.70	687.89	687.99	688.08	688.14	688.29	688.39	688.46	688.55	688.64
2,718	685.52	686.39	686.82	687.17	687.38	687.50	687.61	687.67	687.86	687.98	688.08	688.22	688.34
2,587	685.19	686.02	686.42	686.78	686.99	687.12	687.22	687.29	687.52	687.66	687.78	687.98	688.13
2,577	685.14	686.00	686.41	686.78	687.00	687.13	687.24	687.30	687.49	687.63	687.74	687.95	688.12
2,491	684.82	685.73	686.15	686.51	686.72	686.85	686.98	687.06	687.30	687.46	687.60	687.85	688.04
2,442	684.74	685.64	686.05	686.41	686.63	686.75	686.87	686.95	687.15	687.28	687.42	687.69	687.91
2,429	684.70	685.60	686.02	686.39	686.60	686.72	686.84	686.91	687.09	687.21	687.34	687.59	687.80
2,318	684.46	685.31	685.73	686.07	686.27	686.35	686.47	686.54	686.70	686.83	686.99	687.38	687.64
2,161	683.88	684.78	685.24	685.61	685.81	685.82	685.95	686.05	686.31	686.59	686.86	687.34	687.63
2,059	683.59	684.59	685.05	685.43	685.65*	685.65	685.80	685.90	686.22	686.53	686.82	687.32	687.61
1,999	683.39	684.41	684.87	685.25	685.48	685.59	685.75	685.86	686.19	686.51	686.81	687.32	687.61
1,852	683.02	684.03	684.49	684.87	685.10	685.27	685.47	685.61	686.05	686.43	686.76	687.30	687.60
1,731	682.72	683.69	684.15	684.53	684.80	684.99	685.23	685.45	685.98	686.39	686.73	687.28	687.59
1,554	682.18	683.16	683.62	684.02	684.34	684.60	684.94	685.23	685.85	686.34	686.70	687.27	687.58
1,461	681.91	682.86	683.32	683.72	684.08	684.38	684.75	685.08	685.82	686.32	686.69	687.26	687.57
1,358	681.75	682.71	683.17	683.58	683.97	684.28	684.68	685.02	685.77	686.28	686.67	687.26	687.57
1,295	681.73	682.67	683.11	683.50	683.86	684.15	684.52	684.84	685.57	686.28	686.68	687.25	687.57
1,248	681.66	682.59	683.02	683.39	683.76	684.05	684.44	684.77	685.57	686.28	686.67	687.25	687.56
1,171	681.48	682.37	682.80	683.18	683.59	683.91	684.33	684.69	685.56	686.28	686.67	687.25	687.56
1,091	681.31	682.15	682.59	682.98	683.46	683.81	684.26	684.63	685.56	686.27	686.67	687.25	687.56
1,018	681.13	681.95	682.40	682.81	683.33	683.71	684.17	684.56	685.55	686.27	686.67	687.25	687.56
1,001	681.08	681.89	682.34	682.75	683.29	683.67	684.14	684.50	685.54	686.27	686.67	687.25	687.56
905	680.87	681.74	682.20	682.62	683.21	683.60	684.09	684.46	685.49	686.23	686.63	687.22	687.53
782	680.65	681.52	681.97	682.38	683.06	683.48	684.01	684.39	685.45	686.20	686.60	687.19	687.51

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.

Table B-6 Computed flood frequency water levels – Michichi Creek (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
598	680.33	681.12	681.55	681.98	682.86	683.33	683.90	684.30	685.40	686.17	686.58	687.17	687.49
506	680.09	680.91	681.39	681.88	682.84	683.33	683.90	684.31	685.41	686.17	686.58	687.18	687.49
412	679.91	680.77	681.27	681.78	682.80	683.29	683.88	684.29	685.40	686.16	686.58	687.17	687.49
334	679.78	680.65	681.18	681.71	682.78	683.28	683.87	684.28	685.40	686.16	686.57	687.17	687.49
194	679.54	680.44	681.04	681.61	682.75	683.26	683.86	684.28	685.39	686.16	686.57	687.17	687.49

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.

Table B-7 Computed flood frequency water levels – Rosebud River

River Station (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Flood Return Period – Water Surface Elevation (m)												
10,702	696.76	697.75	698.44	699.09	699.55	699.86	700.20	700.44	700.86*	700.86	701.08	701.14	701.31
10,485	696.33	697.37	698.09	698.72	699.13	699.41	699.71	699.93	700.31	700.66	700.88	700.88	701.05
10,289	695.98	697.02	697.71	698.38	698.81	699.10	699.41	699.63	699.99	700.21	700.39	700.71	700.88
10,163	695.79	696.79	697.46	698.07	698.47	698.75	699.08	699.33	699.65	700.08	700.28	700.53	700.71
10,045	695.60	696.58	697.29	697.97	698.43	698.74	699.08	699.33	699.65	700.01	700.20	700.45	700.63
9,912	695.30	696.24	696.96	697.68	698.20	698.54	698.90	699.16	699.44	699.80	699.98	700.21	700.37
9,755	694.92	696.03	696.82	697.59	698.11	698.46	698.82	699.08	699.33	699.64	699.81	700.02	700.17
9,668	694.75	695.88	696.68	697.44	697.96	698.30	698.65	698.91	699.16	699.44	699.60	699.77	699.92
9,618	694.74	695.88	696.69	697.45	697.96	698.31	698.66	698.91	699.16	699.45	699.60	699.79	699.93
9,600	694.72	695.85	696.66	697.40	697.88	698.20	698.51	698.68	698.99	699.34	699.51	699.71	699.87
9,580	694.68	695.78	696.56	697.28	697.73	698.02	698.36	698.53	698.87	699.22	699.42	699.63	699.80
9,570	694.67	695.77	696.56	697.28	697.72	698.02	698.29	698.44	698.71	699.08	699.30	699.52	699.70
9,554	694.66	695.76	696.54	697.26	697.61	697.84	698.06	698.23	698.68	699.05	699.27	699.48	699.66
9,468	694.59	695.66	696.43	697.15	697.51	697.75	697.99	698.18	698.63	698.96	699.18	699.38	699.56
9,355	694.19	695.16	695.84	696.50	697.03	697.32	697.71	697.95	698.48	698.81	699.03	699.22	699.40
9,227	693.85	694.87	695.62	696.35	696.82	697.09	697.50	697.75	698.31	698.64	698.85	699.04	699.21
9,116	693.67	694.69	695.43	696.13	696.59	696.86	697.26	697.53	698.09	698.40	698.60	698.74	698.90
8,994	693.44	694.45	695.20	695.88	696.34	696.63	697.11	697.41	697.99	698.31	698.52	698.65	698.82
8,849	693.15	694.14	694.89	695.61	696.17	696.52	697.06	697.37	697.97	698.28	698.49	698.62	698.78
8,745	692.87	693.99	694.78	695.51	696.07	696.43	696.98	697.30	697.90	698.20	698.40	698.52	698.68
8,706	692.79	693.90	694.66	695.34	695.82	696.12	696.62	696.94	697.51	698.01	698.22	698.30	698.47
8,689	692.75	693.86	694.63	695.30	695.78	696.08	696.45	696.66	697.42	697.96	698.15	698.22	698.39
8,682	692.71	693.81	694.56	695.23	695.70	695.98	696.34	696.53	697.45	698.00	698.19	698.27	698.44
8,675	692.70	693.80	694.56	695.24	695.71	696.00	696.37	696.56	697.29	697.76	697.97	697.97	698.15
8,661	692.67	693.78	694.54	695.21	695.68	695.96	696.33	696.51	697.11	697.40	697.50	697.80	698.01
8,553	692.50	693.61	694.36	695.01	695.49	695.77	696.17	696.36	697.03	697.33	697.44	697.58	697.78
8,439	692.17	693.25	693.99	694.70	695.23	695.57	696.02	696.22	696.93	697.23	697.32	697.44	697.64
8,343	691.95	693.08	693.82	694.54	695.12	695.47	695.93	696.13	696.87	697.16	697.24	697.34	697.54
8,281	691.87	693.00	693.74	694.45	694.98	695.28	695.75	695.93	696.67	696.91	696.92	696.92*	697.07
8,187	691.66	692.78	693.50	694.17	694.66	694.90	695.39	695.50	696.28	696.33	696.86	696.86*	697.02
8,101	691.55	692.66	693.39	694.08	694.58	694.82	695.33	695.44	696.23	696.26	696.52	696.76	696.96
8,080	691.53	692.64	693.36	694.03	694.52	694.76	695.25	695.32	695.97*	695.97	696.59	696.72	696.90
8,060	691.51	692.62	693.32	693.98	694.45	694.68	694.92	695.11	695.53	695.95	696.12	696.68	696.87
8,009	691.41	692.48	693.15	693.82	694.30	694.54	694.81	695.02	695.48	695.96	696.17	696.49	696.62
7,958	691.38	692.46	693.15	693.81	694.28	694.52	694.77	694.96	695.37	695.75	695.86	696.09	696.33
7,937	691.35	692.42	693.10	693.75	694.22	694.46	694.71	694.90	695.30	695.61	695.81	696.04	696.22

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.

Table B-7 Computed flood frequency water levels – Rosebud River (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
7,783	691.06	692.09	692.84	693.54	694.03	694.26	694.51	694.70	695.10	695.40	695.60	695.82	695.95
7,641	690.69	691.73	692.48	693.14	693.71	693.94	694.21	694.42	694.87	695.17	695.37	695.59	695.69
7,530	690.53	691.61	692.37	693.08	693.66	693.89	694.17	694.37	694.81	695.10	695.30	695.51	695.60
7,395	690.24	691.34	692.10	692.86	693.52	693.79	694.07	694.29	694.74	695.02	695.22	695.42	695.49
7,326	690.16	691.27	692.03	692.77	693.37	693.63	693.89	694.13	694.60	694.88	695.09	695.28	695.33
7,303	690.14	691.25	692.01	692.75	693.25	693.57	693.84	694.10	694.60	694.90	695.11	695.32	695.39
7,276	690.05	691.09	691.81	692.51	693.00	693.30	693.61	693.85	694.38	694.67	694.90	695.09	695.14
7,246	690.06	691.13	691.87	692.59	693.09	693.39	693.69	693.91	694.40	694.67	694.88	695.06	695.09
7,215	690.03	691.09	691.81	692.53	693.01	693.30	693.58	693.80	694.23	694.44	694.60	694.80	694.98
7,151	689.90	690.93	691.66	692.38	692.88	693.18	693.50	693.73	694.18	694.40	694.57	694.79	694.97
6,913	689.40	690.44	691.17	691.89	692.35	692.66	693.10	693.37	693.85	693.97	694.11	694.28	694.45
6,774	689.29	690.31	691.04	691.78	692.28	692.60	693.04	693.32	693.80	693.89	694.02	694.18	694.35
6,641	689.11	690.05	690.75	691.45	692.03	692.39	692.87	693.16	693.69	693.74	693.86	694.01	694.19
6,532	688.84	689.84	690.55	691.27	691.87	692.25	692.76	693.05	693.65	693.68	693.78	693.93	694.11
6,469	688.61	689.68	690.45	691.19	691.80	692.17	692.65	692.92	692.92*	693.24	693.24*	693.82	694.01
6,450	688.54	689.58	690.32	691.03	691.60	691.90	692.23	692.37	692.68	692.95	693.07	693.21	693.29
6,419	688.54	689.60	690.33	691.04	691.60	691.91	692.28	692.43	692.78	693.10	693.26	693.45	693.57
6,382	688.50	689.54	690.25	690.95	691.50	691.77	692.04	692.21	692.61	692.97	693.13	693.34	693.47
6,361	688.48	689.52	690.23	690.91	691.35	691.60	691.96	692.21	692.61	692.96	693.12	693.33	693.45
6,278	688.32	689.35	690.11	690.83	691.29	691.57	691.97	692.21	692.60	692.94	693.09	693.29	693.41
6,166	688.05	689.10	689.84	690.57	691.12	691.43	691.87	692.12	692.51	692.85	693.00	693.19	693.31
5,969	687.47	688.61	689.41	690.20	690.94	691.29	691.77	692.02	692.41	692.75	692.87	693.05	693.16
5,904	687.38	688.53	689.33	690.12	690.79	691.10	691.56	691.79	692.07	692.32	692.37	692.62	692.70
5,886	687.33	688.47	689.27	690.06	690.69	690.89	691.22	691.33	691.80	692.00	692.11	692.51	692.62
5,879	687.32	688.45	689.25	690.03	690.66	690.87	691.21	691.32	691.86	692.10	692.25	692.62	692.73
5,872	687.31	688.44	689.24	690.01	690.64	690.83	691.13	691.22	691.59	691.82	691.96	692.47	692.58
5,851	687.30	688.44	689.23	690.00	690.48	690.72	690.96	691.09	691.58	691.93	692.13	692.51	692.63
5,776	687.17	688.26	689.02	689.78	690.34	690.63	690.89	691.03	691.55	691.89	692.09	692.47	692.58
5,689	687.06	688.15	688.92	689.69	690.26	690.55	690.80	690.94	691.47	691.81	692.00	692.39	692.49
5,616	686.91	687.99	688.77	689.57	690.15	690.45	690.69	690.83	691.36	691.69	691.88	692.26	692.35
5,547	686.80	687.88	688.66	689.42	690.01	690.32	690.55	690.66	691.19	691.50	691.68	692.06	692.12
5,473	686.76	687.85	688.64	689.40	689.98	690.28	690.50	690.61	691.16	691.48	691.65	692.05	692.12
5,452	686.74	687.82	688.60	689.34	689.83	690.11	690.41	690.55	691.18	691.54	691.73	692.02	692.08
5,378	686.62	687.63	688.36	689.05	689.53	689.83	690.13	690.36	691.02	691.34	691.53	691.84	691.87
5,288	686.48	687.47	688.21	688.92	689.41	689.72	690.01	690.21	690.89	691.19	691.34	691.66	691.66*
5,193	686.28	687.33	688.10	688.82	689.30	689.61	689.91	690.12	690.83	691.12	691.27	691.59	691.59*

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.

Table B-7 Computed flood frequency water levels – Rosebud River (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
5,065	686.12	687.21	688.00	688.71	689.22	689.54	689.83	690.04	690.77	691.05	691.20	691.53	691.53*
4,997	685.95	686.97	687.71	688.41	688.94	689.25	689.62	689.82	690.66	690.96	691.08	691.44	691.44*
4,980	685.92	686.95	687.70	688.37	688.83	689.07	689.37	689.54	690.64	690.90	691.01	691.39	691.39*
4,917	685.73	686.79	687.54	688.22	688.72	688.98	689.32	689.52	690.64	690.90	691.00	691.37	691.37*
4,771	685.42	686.57	687.34	688.02	688.53	688.84	689.20	689.39	690.58	690.84	690.93	691.31	691.31*
4,599	685.17	686.31	687.08	687.81	688.35	688.68	689.06	689.26	690.51	690.78	690.86	691.25	691.25*
4,530	685.15	686.30	687.08	687.79	688.31	688.63	688.98	689.16	690.49	690.77	690.85	691.24	691.24*
4,509	685.10	686.20	686.95	687.61	688.10	688.38	688.69	688.89	690.43	690.75	690.82	691.22	691.22*
4,501	685.03	686.08	686.80	687.41	687.85	688.13	688.42	688.65	689.97	690.00	690.00*	691.18	691.18*
4,480	685.00	686.03	686.71	687.27	687.64	687.83	687.98	688.08	688.26	688.33	688.55	688.89	689.13
4,409	684.90	685.94	686.63	687.18	687.57	687.78	687.97	688.12	688.46	688.74	688.91	689.11	689.25
4,313	684.70	685.74	686.45	687.00	687.36	687.56	687.78	687.93	688.30	688.58	688.77	688.97	689.11
4,153	684.49	685.58	686.30	686.83	687.16	687.34	687.53	687.65	687.95	688.20	688.37	688.55	688.68
4,037	684.35	685.42	686.11	686.57	686.87	687.04	687.22	687.34	687.63	687.86	688.03	688.23	688.36
3,852	684.13	685.19	685.85	686.26	686.50	686.65	686.83	686.94	687.20	687.44	687.65	687.88	688.02
3,694	683.84	684.83	685.46	685.81	686.01	686.14	686.30	686.43	686.80	687.14	687.42	687.68	687.83
3,461	683.46	684.42	685.04	685.39	685.62	685.78	685.99	686.14	686.57	686.94	687.26	687.54	687.69
3,314	683.19	684.09	684.69	685.17	685.45	685.64	685.86	686.03	686.47	686.86	687.19	687.48	687.64
3,167	682.83	683.75	684.36	684.88	685.21	685.43	685.69	685.87	686.33	686.74	687.10	687.40	687.56
3,011	682.51	683.46	684.12	684.64	684.97	685.19	685.46	685.65	686.13	686.54	686.95	687.26	687.42
2,907	682.29	683.28	683.94	684.47	684.82	685.05	685.33	685.52	686.01	686.42	686.85	687.17	687.32
2,817	682.10	683.07	683.74	684.34	684.70	684.94	685.22	685.41	685.89	686.30	686.75	687.08	687.23
2,645	681.77	682.68	683.32	683.93	684.31	684.58	684.87	685.08	685.62	686.09	686.61	686.94	687.09
2,454	681.25	682.21	682.90	683.56	683.99	684.28	684.62	684.84	685.43	685.92	686.48	686.82	686.96
2,352	680.85	681.84	682.54	683.29	683.83	684.15	684.51	684.74	685.33	685.83	686.41	686.74	686.87
2,255	680.59	681.54	682.21	682.85	683.29	683.53	683.91	684.12	684.70	685.17	685.86	686.13	686.14
2,235	680.57	681.54	682.21	682.85	683.24	683.49	683.78	683.94	684.42	684.80	684.98	685.30	685.42
2,187	680.42	681.38	682.11	682.76	683.17	683.41	683.72	683.88	684.38	684.78	685.05	685.42	685.58
2,138	680.36	681.35	682.08	682.73	683.13	683.37	683.66	683.81	684.26	684.57	684.63	684.91	685.00
2,113	680.33	681.32	682.05	682.71	683.10	683.33	683.61	683.76	684.07	684.39	684.54	684.82	685.08
2,005	680.02	680.97	681.67	682.29	682.69	682.95	683.23	683.44	683.87	684.26	684.44	684.80	685.04
1,894	679.67	680.64	681.35	682.02	682.50	682.78	683.09	683.30	683.75	684.15	684.33	684.71	684.95
1,757	679.49	680.50	681.23	681.87	682.31	682.56	682.82	683.02	683.46	683.93	684.11	684.54	684.81
1,602	679.25	680.22	680.91	681.50	681.91	682.11	682.34	682.56	683.16	683.74	683.92	684.41	684.70
1,422	678.91	679.86	680.52	681.07	681.48	681.68	681.95	682.20	682.99	683.63	683.80	684.32	684.61
1,271	678.59	679.49	680.11	680.64	681.07	681.36	681.72	682.04	682.91	683.57	683.74	684.28	684.58

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.

Table B-7 Computed flood frequency water levels – Rosebud River (Continued)

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
1,155	678.50	679.38	680.01	680.53	680.95	681.21	681.56	681.84	682.69	683.34	683.60	684.17	684.48
1,127	678.44	679.29	679.90	680.40	680.82	681.08	681.43	681.72	682.55	683.12	683.60	684.17	684.48
1,017	678.08	678.98	679.63	680.17	680.66	680.95	681.34	681.64	682.52	683.17	683.59	684.16	684.48
833	677.61	678.44	679.08	679.71	680.42	680.76	681.22	681.55	682.49	683.14	683.57	684.15	684.46
652	677.13	678.18	678.89	679.57	680.34	680.71	681.17	681.52	682.47	683.13	683.56	684.14	684.46
559	677.00	678.10	678.82	679.48	680.26	680.60	681.06	681.39	682.32	683.04	683.51	684.11	684.43
527	676.96	678.06	678.77	679.44	680.21	680.56	681.01	681.35	682.29	683.07	683.50	684.11	684.43
438	676.83	677.88	678.56	679.17	680.06	680.44	680.94	681.29	682.28	683.04	683.48	684.09	684.42
357	676.79	677.84	678.52	679.14	680.03	680.40	680.89	681.24	682.25	683.02	683.46	684.08	684.41
332	676.77	677.80	678.47	679.08	679.99	680.36	680.86	681.21	682.23	683.01	683.45	684.07	684.40
234	676.66	677.63	678.24	678.80	679.84	680.28	680.82	681.18	682.21	683.00	683.44	684.07	684.39
116	676.53	677.42	678.00	678.57	679.78	680.26	680.80	681.17	682.21	682.99	683.44	684.06	684.39

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.

Table B-8 Computed flood frequency water levels – Willow Creek

River Station (m)	Flood Return Period												
	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
	Water Surface Elevation (m)												
2,970	687.71	688.12	688.28	688.43	688.51	688.57	688.63	688.64	688.73	688.80	688.83	688.87	688.93
2,723	686.46	686.77	686.92	687.00	687.06	687.10	687.15	687.16	687.25	687.29	687.33	687.36	687.40
2,408	684.48	685.08	685.34	685.53	685.63	685.71	685.79	685.81	685.91	685.98	686.04	686.11	686.16
2,174	683.24	683.76	683.99	684.14	684.23	684.28	684.34	684.35	684.49	684.54	684.58	684.58	684.62
1,937	681.88	682.29	682.50	682.69	682.82	682.92	683.02	683.05	683.14	683.26	683.34	683.62	683.69
1,566	679.86	680.33	680.58	680.79	680.90	680.97	681.05	681.06	681.33	681.34	681.34*	681.34*	681.34*
1,356	678.65	679.15	679.43	679.66	679.78	679.85	679.93	679.95	679.95*	679.97	680.02	680.65	680.95
1,007	676.94	677.39	677.60	677.81	677.92	678.02	678.13	678.25	679.03	679.70	680.10	680.65	680.94
863	676.23	676.66	676.86	677.06	677.18	677.27	677.54	677.88	678.93	679.65	680.06	680.63	680.91
848	675.90	676.22	676.39	676.55	676.65	676.72	677.42	677.83	678.91	679.64	680.04	680.60	680.90

* Indicates values that have been manually adjusted to eliminate the crossing of profiles.

Appendix C
Sensitivity Analysis Results

Table C-1 Sensitivity analysis results for downstream boundary condition

River Station (m)	Flood Levels (m) for varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.000637 m/m	Adopted Normal Depth S= 0.00050 m/m	0.5 m Above Adopted S = 0.000376 m/m
Red Deer River			
56,139	690.30	690.30	690.30
55,755	690.15	690.15	690.15
55,521	689.99	689.99	689.99
55,149	689.82	689.82	689.82
54,759	689.53	689.53	689.53
54,516	689.52	689.52	689.52
54,007	689.40	689.40	689.40
53,602	689.27	689.27	689.27
53,393	689.13	689.13	689.13
53,064	689.08	689.08	689.08
52,682	689.03	689.03	689.03
52,364	688.94	688.94	688.94
51,970	688.73	688.73	688.73
51,689	688.58	688.58	688.58
51,563	688.54	688.54	688.54
51,326	688.51	688.51	688.51
51,089	688.51	688.51	688.51
50,765	688.21	688.21	688.21
50,457	688.17	688.17	688.17
50,067	688.10	688.10	688.10
49,706	688.10	688.10	688.10
49,354	687.87	687.87	687.87
49,045	687.83	687.83	687.83
48,695	687.63	687.63	687.63
48,288	687.58	687.58	687.58
48,079	687.55	687.55	687.55
47,899	687.25	687.25	687.25
47,630	687.19	687.19	687.19
47,303	687.22	687.22	687.22
47,010	687.11	687.11	687.11
46,672	686.90	686.90	686.90
46,395	686.86	686.86	686.86
46,221	686.82	686.82	686.82
46,039	686.72	686.72	686.72
45,748	686.62	686.62	686.62
45,410	686.69	686.69	686.69

Table C-1 Sensitivity analysis results for downstream boundary condition (continued)

River Station (m)	Flood Levels (m) for varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.000637 m/m	Adopted Normal Depth S= 0.00050 m/m	0.5 m Above Adopted S = 0.000376 m/m
Red Deer River			
45,086	686.50	686.50	686.50
44,815	686.44	686.44	686.44
44,666	686.47	686.47	686.47
44,443	686.41	686.41	686.41
44,420	685.93	685.93	685.93
44,290	685.93	685.93	685.93
44,005	685.75	685.75	685.75
43,798	685.60	685.60	685.60
43,527	685.51	685.51	685.51
43,209	685.41	685.41	685.41
42,942	685.34	685.34	685.34
42,779	685.44	685.44	685.44
42,558	685.42	685.42	685.42
42,341	685.38	685.38	685.38
42,214	685.25	685.25	685.25
41,996	685.24	685.24	685.24
41,823	685.18	685.18	685.18
41,644	684.94	684.94	684.94
41,263	684.72	684.72	684.72
41,074	684.75	684.75	684.75
40,832	684.56	684.56	684.56
40,804	684.53	684.53	684.53
40,748	684.48	684.48	684.48
40,606	684.45	684.45	684.45
40,517	684.41	684.41	684.41
40,322	684.09	684.10	684.10
40,132	684.06	684.06	684.06
39,912	683.98	683.98	683.98
39,774	684.01	684.01	684.01
39,619	683.90	683.90	683.90
39,538	683.90	683.90	683.90
39,370	683.77	683.77	683.77
39,070	683.56	683.56	683.56
38,812	683.55	683.55	683.55
38,629	683.48	683.48	683.48
38,381	683.35	683.35	683.35

Table C-1 Sensitivity analysis results for downstream boundary condition (continued)

River Station (m)	Flood Levels (m) for varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.000637 m/m	Adopted Normal Depth S= 0.00050 m/m	0.5 m Above Adopted S = 0.000376 m/m
Red Deer River			
38,176	683.27	683.27	683.27
37,829	683.23	683.23	683.23
37,633	683.18	683.18	683.18
37,484	683.26	683.26	683.26
37,376	683.26	683.26	683.26
37,086	683.19	683.19	683.19
36,958	683.13	683.13	683.13
36,721	682.94	682.94	682.94
36,621	682.88	682.88	682.88
36,313	682.77	682.77	682.77
35,982	682.73	682.73	682.73
35,611	682.66	682.66	682.66
35,412	682.61	682.61	682.61
35,165	682.46	682.46	682.46
34,850	682.46	682.46	682.46
34,667	682.42	682.42	682.42
34,292	682.31	682.31	682.31
33,924	682.19	682.19	682.19
33,653	682.06	682.06	682.06
33,378	682.04	682.04	682.04
33,017	681.96	681.96	681.96
32,670	681.87	681.87	681.87
32,519	681.67	681.67	681.67
32,484	681.64	681.64	681.64
32,344	681.53	681.53	681.53
32,054	681.60	681.60	681.60
31,781	681.38	681.38	681.38
31,429	681.27	681.27	681.27
31,207	681.23	681.23	681.23
31,198	681.15	681.15	681.15
30,968	681.12	681.12	681.12
30,771	681.09	681.09	681.09
30,480	680.97	680.97	680.97
30,282	680.99	680.99	680.99
30,086	680.97	680.97	680.97
29,895	680.82	680.82	680.82

Table C-1 Sensitivity analysis results for downstream boundary condition (continued)

River Station (m)	Flood Levels (m) for varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.000637 m/m	Adopted Normal Depth S= 0.00050 m/m	0.5 m Above Adopted S = 0.000376 m/m
Red Deer River			
29,573	680.60	680.60	680.60
29,224	680.53	680.53	680.53
28,890	680.51	680.51	680.51
28,595	680.22	680.22	680.22
28,373	680.20	680.20	680.20
28,271	680.08	680.08	680.08
28,255	680.03	680.03	680.03
28,234	680.06	680.06	680.06
28,215	680.06	680.06	680.06
28,196	680.02	680.02	680.02
28,120	680.01	680.01	680.01
28,028	680.01	680.01	680.01
27,943	679.79	679.79	679.79
27,921	679.72	679.72	679.72
27,749	679.74	679.74	679.74
27,487	679.68	679.68	679.68
27,145	679.58	679.58	679.58
26,728	679.44	679.44	679.44
26,576	679.47	679.47	679.47
26,330	679.37	679.37	679.37
26,001	679.19	679.19	679.19
25,566	678.96	678.96	678.96
25,030	678.81	678.81	678.81
24,611	678.65	678.65	678.65
24,051	678.61	678.61	678.61
23,586	678.52	678.52	678.52
23,316	678.44	678.44	678.44
22,842	678.35	678.35	678.35
22,328	678.08	678.08	678.08
21,724	678.02	678.03	678.03
21,245	677.72	677.72	677.72
21,011	677.73	677.73	677.73
20,686	677.64	677.64	677.65
20,474	677.51	677.51	677.51
20,065	677.50	677.50	677.51
19,848	677.19	677.20	677.20

Table C-1 Sensitivity analysis results for downstream boundary condition (continued)

River Station (m)	Flood Levels (m) for varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.000637 m/m	Adopted Normal Depth S= 0.00050 m/m	0.5 m Above Adopted S = 0.000376 m/m
Red Deer River			
19,656	677.10	677.10	677.10
19,356	676.70	676.71	676.71
19,059	676.55	676.56	676.56
18,881	676.56	676.56	676.57
18,652	676.55	676.56	676.56
18,440	676.54	676.55	676.55
18,219	676.55	676.56	676.56
18,020	676.48	676.49	676.49
17,745	676.33	676.33	676.33
17,505	676.13	676.14	676.14
17,278	676.07	676.08	676.08
17,161	676.12	676.13	676.13
16,904	676.07	676.08	676.08
16,791	676.04	676.05	676.05
16,767	675.99	675.99	676.00
16,692	675.99	676.00	676.00
16,555	675.96	675.96	675.97
16,363	675.83	675.83	675.84
16,272	675.63	675.63	675.64
16,246	675.60	675.61	675.61
16,054	675.50	675.50	675.51
15,799	675.30	675.31	675.31
15,326	675.15	675.15	675.16
14,807	674.93	674.94	674.95
14,404	674.97	674.98	674.98
13,966	674.85	674.86	674.87
13,392	674.60	674.61	674.62
12,955	674.43	674.44	674.46
12,528	674.35	674.36	674.37
12,053	674.18	674.19	674.20
11,633	674.16	674.17	674.18
11,128	673.77	673.79	673.81
10,764	673.75	673.77	673.78
10,351	673.65	673.67	673.69
10,016	673.34	673.36	673.38
9,697	673.16	673.18	673.21

Table C-1 Sensitivity analysis results for downstream boundary condition (continued)

River Station (m)	Flood Levels (m) for varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.000637 m/m	Adopted Normal Depth S= 0.00050 m/m	0.5 m Above Adopted S = 0.000376 m/m
Red Deer River			
9,417	673.21	673.23	673.26
9,179	672.93	672.96	672.99
8,943	672.84	672.87	672.90
8,669	672.67	672.70	672.73
8,338	672.43	672.46	672.50
7,988	672.24	672.27	672.31
7,398	671.97	672.01	672.06
7,006	671.79	671.84	671.90
6,606	671.11	671.19	671.27
6,283	671.20	671.28	671.36
5,827	671.19	671.27	671.36
5,356	671.13	671.22	671.30
5,018	670.99	671.09	671.18
4,746	670.70	670.80	670.90
4,466	670.44	670.55	670.67
4,233	670.29	670.41	670.54
4,018	670.13	670.27	670.40
3,908	670.13	670.27	670.40
3,888	670.08	670.22	670.36
3,752	669.82	669.96	670.14
3,508	669.73	669.89	670.07
3,182	669.57	669.75	669.95
2,861	669.25	669.47	669.70
2,536	669.01	669.24	669.51
2,249	669.06	669.31	669.58
1,783	669.00	669.26	669.54
1,484	668.84	669.13	669.42
1,306	668.72	669.02	669.33
1,004	668.31	668.69	669.08
442	668.15	668.58	669.00
0	667.70	668.20	668.70

Table C-2 Sensitivity analysis results for discharge values

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Red Deer River			
56,139	689.52	690.30	690.98
55,755	689.37	690.15	690.82
55,521	689.22	689.99	690.66
55,149	689.07	689.82	690.47
54,759	688.78	689.53	690.20
54,516	688.75	689.52	690.20
54,007	688.60	689.40	690.09
53,602	688.47	689.27	689.97
53,393	688.32	689.13	689.83
53,064	688.26	689.08	689.77
52,682	688.19	689.03	689.74
52,364	688.09	688.94	689.66
51,970	687.85	688.73	689.45
51,689	687.72	688.58	689.30
51,563	687.64	688.54	689.26
51,326	687.60	688.51	689.22
51,089	687.60	688.51	689.23
50,765	687.34	688.21	688.90
50,457	687.28	688.17	688.87
50,067	687.19	688.10	688.81
49,706	687.18	688.10	688.82
49,354	686.97	687.87	688.56
49,045	686.92	687.83	688.54
48,695	686.57	687.63	688.39
48,288	686.59	687.58	688.30
48,079	686.54	687.55	688.28
47,899	686.25	687.25	687.99
47,630	686.16	687.19	687.93
47,303	686.18	687.22	687.97
47,010	686.08	687.11	687.82
46,672	685.89	686.90	687.58
46,395	685.84	686.86	687.55
46,221	685.79	686.82	687.51
46,039	685.67	686.72	687.42
45,748	685.58	686.62	687.31
45,410	685.63	686.69	687.39

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Red Deer River			
45,086	685.43	686.50	687.19
44,815	685.35	686.44	687.13
44,666	685.38	686.47	687.16
44,443	685.25	686.41	687.11
44,420	685.00	685.93	686.73
44,290	684.99	685.93	686.72
44,005	684.82	685.75	686.53
43,798	684.59	685.60	686.38
43,527	684.49	685.51	686.30
43,209	684.39	685.41	686.22
42,942	684.31	685.34	686.16
42,779	684.40	685.44	686.26
42,558	684.36	685.42	686.24
42,341	684.32	685.38	686.20
42,214	684.14	685.25	686.10
41,996	684.12	685.24	686.09
41,823	684.07	685.18	686.03
41,644	683.79	684.94	685.82
41,263	683.74	684.72	685.52
41,074	683.74	684.75	685.57
40,832	683.68	684.56	685.38
40,804	683.66	684.53	685.37
40,748	683.60	684.48	685.33
40,606	683.57	684.45	685.30
40,517	683.54	684.41	685.25
40,322	683.22	684.10	684.96
40,132	683.19	684.06	684.92
39,912	683.07	683.98	684.82
39,774	683.11	684.01	684.86
39,619	683.03	683.90	684.73
39,538	683.03	683.90	684.75
39,370	682.90	683.77	684.60
39,070	682.72	683.56	684.39
38,812	682.69	683.55	684.40
38,629	682.62	683.48	684.32
38,381	682.52	683.35	684.20

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Red Deer River			
38,176	682.44	683.27	684.13
37,829	682.38	683.23	684.11
37,633	682.33	683.18	684.06
37,484	682.40	683.26	684.14
37,376	682.40	683.26	684.14
37,086	682.33	683.19	684.08
36,958	682.27	683.13	684.01
36,721	682.12	682.94	683.80
36,621	682.07	682.88	683.77
36,313	681.96	682.77	683.64
35,982	681.92	682.73	683.60
35,611	681.84	682.66	683.55
35,412	681.79	682.61	683.51
35,165	681.65	682.46	683.37
34,850	681.63	682.46	683.38
34,667	681.59	682.42	683.35
34,292	681.47	682.31	683.26
33,924	681.35	682.19	683.15
33,653	681.20	682.06	683.05
33,378	681.17	682.04	683.04
33,017	681.10	681.96	682.97
32,670	681.01	681.87	682.89
32,519	680.85	681.67	682.66
32,484	680.83	681.64	682.63
32,344	680.72	681.53	682.26
32,054	680.79	681.60	682.32
31,781	680.53	681.38	682.12
31,429	680.43	681.27	682.01
31,207	680.38	681.23	681.98
31,198	680.33	681.15	681.88
30,968	680.29	681.12	681.86
30,771	680.25	681.09	681.83
30,480	680.12	680.97	681.73
30,282	680.15	680.99	681.74
30,086	680.13	680.97	681.72
29,895	679.97	680.82	681.58

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Red Deer River			
29,573	679.75	680.60	681.35
29,224	679.70	680.53	681.28
28,890	679.67	680.51	681.26
28,595	679.40	680.22	680.97
28,373	679.36	680.20	680.96
28,271	679.26	680.08	680.80
28,255	679.21	680.03	680.78
28,234	679.25	680.06	680.80
28,215	679.24	680.06	680.79
28,196	679.20	680.02	680.73
28,120	679.19	680.01	680.74
28,028	679.19	680.01	680.73
27,943	679.02	679.79	680.45
27,921	678.96	679.72	680.38
27,749	678.96	679.74	680.42
27,487	678.89	679.68	680.37
27,145	678.78	679.58	680.28
26,728	678.65	679.44	680.13
26,576	678.68	679.47	680.16
26,330	678.56	679.37	680.07
26,001	678.41	679.19	679.86
25,566	678.20	678.96	679.65
25,030	678.04	678.81	679.52
24,611	677.87	678.65	679.35
24,051	677.82	678.61	679.31
23,586	677.73	678.52	679.24
23,316	677.63	678.44	679.16
22,842	677.56	678.35	679.08
22,328	677.23	678.08	678.84
21,724	677.17	678.03	678.79
21,245	676.90	677.72	678.47
21,011	676.89	677.73	678.49
20,686	676.79	677.64	678.42
20,474	676.62	677.51	678.31
20,065	676.62	677.50	678.29
19,848	676.32	677.20	677.97

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Red Deer River			
19,656	676.28	677.10	677.88
19,356	675.94	676.71	677.41
19,059	675.77	676.56	677.31
18,881	675.73	676.56	677.33
18,652	675.71	676.56	677.34
18,440	675.71	676.55	677.32
18,219	675.69	676.56	677.34
18,020	675.63	676.49	677.26
17,745	675.47	676.33	677.10
17,505	675.31	676.14	676.89
17,278	675.26	676.08	676.84
17,161	675.29	676.13	676.89
16,904	675.24	676.08	676.85
16,791	675.21	676.05	676.81
16,767	675.17	675.99	676.77
16,692	675.17	676.00	676.77
16,555	675.13	675.96	676.73
16,363	675.02	675.83	676.59
16,272	674.87	675.63	676.34
16,246	674.84	675.61	676.31
16,054	674.69	675.50	676.24
15,799	674.51	675.31	676.00
15,326	674.36	675.15	675.84
14,807	674.15	674.94	675.65
14,404	674.15	674.98	675.70
13,966	674.02	674.86	675.60
13,392	673.80	674.61	675.32
12,955	673.64	674.44	675.15
12,528	673.55	674.36	675.06
12,053	673.39	674.19	674.90
11,633	673.35	674.17	674.89
11,128	673.00	673.79	674.48
10,764	672.96	673.77	674.47
10,351	672.84	673.67	674.39
10,016	672.56	673.36	674.04
9,697	672.40	673.18	673.85

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Red Deer River			
9,417	672.43	673.23	673.92
9,179	672.16	672.96	673.63
8,943	672.05	672.87	673.56
8,669	671.89	672.70	673.37
8,338	671.64	672.46	673.16
7,988	671.47	672.27	672.96
7,398	671.18	672.01	672.72
7,006	670.99	671.84	672.56
6,606	670.42	671.19	671.82
6,283	670.46	671.28	671.95
5,827	670.40	671.27	671.98
5,356	670.33	671.22	671.93
5,018	670.19	671.09	671.79
4,746	669.96	670.80	671.46
4,466	669.72	670.55	671.19
4,233	669.58	670.41	671.04
4,018	669.43	670.27	670.87
3,908	669.43	670.27	670.87
3,888	669.39	670.22	670.83
3,752	669.16	669.96	670.60
3,508	669.07	669.89	670.52
3,182	668.92	669.75	670.39
2,861	668.63	669.47	670.09
2,536	668.43	669.24	669.87
2,249	668.46	669.31	669.96
1,783	668.39	669.26	669.93
1,484	668.24	669.13	669.79
1,306	668.15	669.02	669.66
1,004	667.83	668.69	669.35
442	667.67	668.58	669.25
0	667.35	668.20	668.84
Kneehills Creek			
7,869	698.32	698.59	698.83
7,766	698.15	698.41	698.62
7,671	697.93	698.19	698.40
7,574	697.74	698.01	698.20

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Kneehills Creek			
7,479	697.53	697.79	697.96
7,370	697.31	697.53	697.70
7,153	696.93	697.14	697.33
6,927	696.78	696.99	697.19
6,786	696.62	696.86	697.07
6,665	696.37	696.64	696.88
6,500	696.11	696.39	696.65
6,397	695.81	696.03	696.27
6,289	695.75	695.97	696.19
6,165	695.66	695.86	696.08
6,045	695.38	695.62	695.82
5,903	695.08	695.32	695.51
5,774	694.78	695.01	695.20
5,662	694.57	694.77	694.96
5,554	694.54	694.74	694.92
5,435	694.48	694.69	694.86
5,300	694.35	694.57	694.75
5,175	694.16	694.37	694.54
5,078	693.96	694.14	694.31
4,972	693.83	694.01	694.17
4,844	693.67	693.84	694.01
4,690	693.55	693.73	693.91
4,513	693.18	693.40	693.60
4,412	693.05	693.27	693.46
4,326	692.93	693.15	693.34
4,192	692.78	693.01	693.20
4,053	692.43	692.67	692.88
3,966	692.23	692.45	692.65
3,833	692.07	692.28	692.48
3,738	691.99	692.21	692.41
3,549	691.77	692.03	692.25
3,397	691.56	691.86	692.10
3,272	691.38	691.69	691.93
3,126	691.21	691.55	691.81
3,023	690.83	691.07	691.20
3,011	690.76	690.90	691.02

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Kneehills Creek			
2,916	690.66	690.82	690.97
2,665	690.20	690.46	690.71
2,517	690.08	690.34	690.61
2,242	689.49	689.80	690.19
2,139	689.52	689.82	690.19
2,049	689.44	689.75	690.13
1,915	689.17	689.59	690.04
1,794	688.97	689.45	689.97
1,669	688.68	689.27	689.86
1,600	688.59	689.12	689.66
1,584	688.55	689.07	689.61
1,532	688.48	689.01	689.56
1,375	688.19	688.77	689.39
1,231	688.03	688.70	689.36
1,007	687.91	688.66	689.34
827	687.88	688.64	689.33
583	687.81	688.62	689.32
416	687.72	688.58	689.30
Michichi Creek			
5,335	693.72	694.04	694.28
5,127	693.24	693.53	693.78
4,932	692.74	693.02	693.27
4,747	692.26	692.48	692.67
4,584	691.98	692.22	692.41
4,337	691.28	691.55	691.76
4,146	690.81	691.08	691.28
3,938	690.46	690.69	690.89
3,788	690.06	690.35	690.58
3,614	689.31	689.60	689.87
3,422	688.40	688.62	688.80
3,178	688.26	688.46	688.62
2,945	687.92	688.14	688.33
2,718	687.42	687.67	687.90
2,587	687.03	687.30	687.57
2,577	687.05	687.30	687.54
2,491	686.77	687.07	687.36

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Michichi Creek			
2,442	686.67	686.96	687.20
2,429	686.64	686.92	687.14
2,318	686.29	686.55	686.76
2,161	685.79	686.11	686.47
2,059	685.63	685.99	686.40
1,999	685.58	685.96	686.38
1,852	685.31	685.77	686.29
1,731	685.11	685.67	686.24
1,554	684.88	685.53	686.17
1,461	684.75	685.44	686.15
1,358	684.70	685.40	686.10
1,295	684.59	685.25	685.96
1,248	684.54	685.25	685.96
1,171	684.47	685.24	685.96
1,091	684.43	685.18	685.95
1,018	684.38	685.18	685.95
1,001	684.34	685.17	685.95
905	684.32	685.12	685.90
782	684.27	685.08	685.87
598	684.21	685.04	685.83
506	684.21	685.04	685.84
412	684.20	685.03	685.83
334	684.19	685.03	685.83
194	684.19	685.02	685.83
Rosebud River			
10,702	699.98	700.44	700.76
10,485	699.52	699.93	700.20
10,289	699.21	699.63	699.88
10,163	698.86	699.33	699.56
10,045	698.85	699.33	699.56
9,912	698.66	699.16	699.37
9,755	698.58	699.08	699.27
9,668	698.41	698.91	699.04
9,618	698.42	698.91	699.05
9,600	698.30	698.68	698.90
9,580	698.11	698.53	698.75

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Rosebud River			
9,570	698.10	698.44	698.63
9,554	697.92	698.23	698.55
9,468	697.83	698.18	698.50
9,355	697.44	697.95	698.34
9,227	697.21	697.75	698.17
9,116	696.98	697.53	697.94
8,994	696.77	697.41	697.83
8,849	696.68	697.37	697.81
8,745	696.59	697.30	697.74
8,706	696.25	696.94	697.40
8,689	696.20	696.66	697.28
8,682	696.09	696.53	697.31
8,675	696.11	696.56	697.18
8,661	696.08	696.51	696.93
8,553	695.89	696.36	696.82
8,439	695.70	696.22	696.71
8,343	695.60	696.13	696.65
8,281	695.41	695.93	696.45
8,187	695.01	695.50	696.04
8,101	694.93	695.44	695.99
8,080	694.86	695.32	695.84
8,060	694.77	695.11	695.41
8,009	694.66	695.02	695.36
7,958	694.63	694.96	695.26
7,937	694.57	694.90	695.20
7,783	694.37	694.70	695.00
7,641	694.08	694.42	694.77
7,530	694.03	694.37	694.71
7,395	693.94	694.29	694.64
7,326	693.76	694.13	694.51
7,303	693.70	694.10	694.50
7,276	693.39	693.85	694.29
7,246	693.48	693.91	694.32
7,215	693.39	693.80	694.16
7,151	693.28	693.73	694.11
6,913	692.77	693.37	693.82

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Rosebud River			
6,774	692.71	693.32	693.77
6,641	692.50	693.16	693.67
6,532	692.37	693.05	693.64
6,469	692.27	692.92	693.40
6,450	691.96	692.37	692.58
6,419	691.97	692.43	692.66
6,382	691.82	692.21	692.47
6,361	691.72	692.21	692.47
6,278	691.70	692.21	692.46
6,166	691.58	692.12	692.37
5,969	691.45	692.02	692.26
5,904	691.26	691.79	691.95
5,886	691.00	691.33	691.65
5,879	690.99	691.32	691.69
5,872	690.94	691.22	691.41
5,851	690.81	691.09	691.37
5,776	690.72	691.03	691.35
5,689	690.64	690.94	691.26
5,616	690.54	690.83	691.14
5,547	690.40	690.66	690.96
5,473	690.36	690.61	690.91
5,452	690.22	690.55	690.90
5,378	689.94	690.36	690.73
5,288	689.82	690.21	690.57
5,193	689.72	690.12	690.49
5,065	689.65	690.04	690.42
4,997	689.36	689.82	690.17
4,980	689.18	689.54	689.97
4,917	689.12	689.52	689.97
4,771	688.98	689.39	689.86
4,599	688.84	689.26	689.75
4,530	688.77	689.16	689.68
4,509	688.50	688.89	689.54
4,501	688.23	688.65	689.09
4,480	687.89	688.08	688.22
4,409	687.85	688.12	688.37

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Rosebud River			
4,313	687.64	687.93	688.20
4,153	687.41	687.65	687.86
4,037	687.10	687.34	687.55
3,852	686.71	686.94	687.14
3,694	686.20	686.43	686.68
3,461	685.86	686.14	686.44
3,314	685.72	686.03	686.34
3,167	685.53	685.88	686.20
3,011	685.30	685.65	686.00
2,907	685.16	685.53	685.87
2,817	685.05	685.41	685.76
2,645	684.69	685.08	685.47
2,454	684.41	684.84	685.26
2,352	684.29	684.74	685.16
2,255	683.69	684.12	684.55
2,235	683.60	683.95	684.31
2,187	683.53	683.89	684.27
2,138	683.48	683.82	684.17
2,113	683.44	683.77	684.01
2,005	683.07	683.51	683.83
1,894	682.92	683.39	683.72
1,757	682.68	683.14	683.48
1,602	682.24	682.74	683.26
1,422	681.91	682.55	683.14
1,271	681.73	682.46	683.09
1,155	681.60	682.30	682.92
1,127	681.51	682.23	682.81
1,017	681.44	682.20	682.80
833	681.37	682.17	682.78
652	681.34	682.16	682.77
559	681.25	682.04	682.67
527	681.22	682.01	682.70
438	681.18	682.00	682.67
357	681.14	681.94	682.66
332	681.12	681.91	682.65
234	681.10	681.91	682.64

Table C-2 Sensitivity analysis results for discharge values (continued)

River Station (m)	Flood Levels (m) for varying Discharge Value		
	Low Discharge (-20%)	Adopted Discharge	High Discharge (+20%)
Rosebud River			
116	681.10	681.90	682.63
Willow Creek			
2,970	688.53	688.63	688.73
2,723	687.08	687.16	687.25
2,408	685.66	685.79	685.91
2,174	684.26	684.38	684.49
1,937	682.85	683.00	683.14
1,566	680.98	681.17	681.33
1,356	679.76	679.81	679.87
1,007	678.10	678.73	679.40
863	677.81	678.62	679.34
848	677.77	678.60	679.33

Table C-3 Sensitivity analysis results for channel roughness

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Red Deer River			
56,139	689.80	690.30	690.73
55,755	689.69	690.15	690.55
55,521	689.51	689.99	690.41
55,149	689.37	689.82	690.22
54,759	689.06	689.53	689.95
54,516	689.07	689.52	689.91
54,007	688.98	689.40	689.77
53,602	688.87	689.27	689.63
53,393	688.71	689.13	689.51
53,064	688.68	689.08	689.43
52,682	688.65	689.03	689.36
52,364	688.58	688.94	689.27
51,970	688.33	688.73	689.08
51,689	688.17	688.58	688.94
51,563	688.08	688.54	688.92
51,326	688.07	688.51	688.87
51,089	688.10	688.51	688.86
50,765	687.79	688.21	688.58
50,457	687.78	688.17	688.52
50,067	687.72	688.10	688.44
49,706	687.74	688.10	688.42
49,354	687.49	687.87	688.20
49,045	687.43	687.83	688.17
48,695	687.13	687.63	688.02
48,288	687.17	687.58	687.92
48,079	687.15	687.55	687.89
47,899	686.76	687.25	687.65
47,630	686.71	687.19	687.58
47,303	686.76	687.22	687.59
47,010	686.68	687.11	687.46
46,672	686.47	686.90	687.26
46,395	686.45	686.86	687.20
46,221	686.41	686.82	687.16
46,039	686.28	686.72	687.07
45,748	686.20	686.62	686.96
45,410	686.31	686.69	687.01

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Red Deer River			
45,086	686.08	686.50	686.84
44,815	686.02	686.44	686.78
44,666	686.07	686.47	686.80
44,443	686.01	686.41	686.73
44,420	685.50	685.93	686.33
44,290	685.51	685.93	686.32
44,005	685.30	685.75	686.16
43,798	685.10	685.60	686.04
43,527	685.02	685.51	685.94
43,209	684.93	685.41	685.84
42,942	684.87	685.34	685.77
42,779	685.02	685.44	685.84
42,558	684.99	685.42	685.81
42,341	684.95	685.38	685.77
42,214	684.74	685.25	685.69
41,996	684.75	685.24	685.67
41,823	684.69	685.18	685.61
41,644	684.39	684.94	685.43
41,263	684.24	684.72	685.15
41,074	684.31	684.75	685.17
40,832	684.10	684.56	684.99
40,804	684.09	684.53	684.95
40,748	684.01	684.48	684.91
40,606	683.99	684.45	684.88
40,517	683.96	684.41	684.84
40,322	683.55	684.10	684.59
40,132	683.54	684.06	684.55
39,912	683.47	683.98	684.45
39,774	683.53	684.01	684.45
39,619	683.43	683.90	684.35
39,538	683.44	683.90	684.35
39,370	683.28	683.77	684.22
39,070	683.07	683.56	684.03
38,812	683.08	683.55	684.00
38,629	683.02	683.48	683.92
38,381	682.91	683.35	683.80

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Red Deer River			
38,176	682.83	683.27	683.72
37,829	682.81	683.23	683.67
37,633	682.75	683.18	683.61
37,484	682.87	683.26	683.67
37,376	682.87	683.26	683.66
37,086	682.80	683.19	683.60
36,958	682.74	683.13	683.53
36,721	682.54	682.94	683.36
36,621	682.47	682.88	683.32
36,313	682.38	682.77	683.19
35,982	682.36	682.73	683.13
35,611	682.29	682.66	683.06
35,412	682.23	682.61	683.01
35,165	682.09	682.46	682.87
34,850	682.10	682.46	682.86
34,667	682.07	682.42	682.82
34,292	681.94	682.31	682.73
33,924	681.84	682.19	682.60
33,653	681.68	682.06	682.50
33,378	681.68	682.04	682.46
33,017	681.62	681.96	682.39
32,670	681.55	681.87	682.29
32,519	681.34	681.67	682.09
32,484	681.32	681.64	682.06
32,344	681.19	681.53	681.84
32,054	681.31	681.60	681.87
31,781	681.00	681.38	681.71
31,429	680.92	681.27	681.58
31,207	680.89	681.23	681.54
31,198	680.78	681.15	681.48
30,968	680.76	681.12	681.44
30,771	680.73	681.09	681.41
30,480	680.58	680.97	681.32
30,282	680.63	680.99	681.32
30,086	680.62	680.97	681.29
29,895	680.44	680.82	681.16

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Red Deer River			
29,573	680.17	680.60	680.97
29,224	680.15	680.53	680.88
28,890	680.14	680.51	680.85
28,595	679.81	680.22	680.59
28,373	679.79	680.20	680.56
28,271	679.67	680.08	680.45
28,255	679.62	680.03	680.40
28,234	679.67	680.06	680.41
28,215	679.67	680.06	680.41
28,196	679.63	680.02	680.37
28,120	679.63	680.01	680.36
28,028	679.63	680.01	680.35
27,943	679.39	679.79	680.14
27,921	679.29	679.72	680.09
27,749	679.31	679.74	680.10
27,487	679.26	679.68	680.04
27,145	679.16	679.58	679.94
26,728	679.04	679.44	679.80
26,576	679.09	679.47	679.80
26,330	678.98	679.37	679.70
26,001	678.80	679.19	679.53
25,566	678.55	678.96	679.33
25,030	678.42	678.81	679.17
24,611	678.25	678.65	679.01
24,051	678.25	678.61	678.94
23,586	678.18	678.52	678.85
23,316	678.08	678.44	678.77
22,842	677.95	678.35	678.71
22,328	677.59	678.08	678.49
21,724	677.60	678.03	678.40
21,245	677.28	677.72	678.13
21,011	677.31	677.73	678.12
20,686	677.22	677.64	678.04
20,474	677.03	677.51	677.94
20,065	677.08	677.50	677.90
19,848	676.68	677.20	677.67

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Red Deer River			
19,656	676.65	677.10	677.55
19,356	676.19	676.71	677.18
19,059	676.05	676.56	677.04
18,881	676.04	676.56	677.03
18,652	676.05	676.56	677.01
18,440	676.10	676.55	676.98
18,219	676.12	676.56	676.97
18,020	676.06	676.49	676.90
17,745	675.84	676.33	676.76
17,505	675.66	676.14	676.59
17,278	675.61	676.08	676.52
17,161	675.69	676.13	676.55
16,904	675.64	676.08	676.50
16,791	675.61	676.05	676.47
16,767	675.55	675.99	676.42
16,692	675.56	676.00	676.42
16,555	675.52	675.96	676.38
16,363	675.39	675.83	676.27
16,272	675.18	675.63	676.08
16,246	675.15	675.61	676.05
16,054	674.96	675.50	675.98
15,799	674.77	675.31	675.77
15,326	674.66	675.15	675.59
14,807	674.45	674.94	675.38
14,404	674.52	674.98	675.38
13,966	674.40	674.86	675.27
13,392	674.15	674.61	675.02
12,955	673.98	674.44	674.86
12,528	673.92	674.36	674.76
12,053	673.75	674.19	674.59
11,633	673.75	674.17	674.55
11,128	673.32	673.79	674.21
10,764	673.33	673.77	674.16
10,351	673.24	673.67	674.05
10,016	672.90	673.36	673.77
9,697	672.73	673.18	673.59

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Red Deer River			
9,417	672.82	673.23	673.61
9,179	672.48	672.96	673.37
8,943	672.38	672.87	673.29
8,669	672.20	672.70	673.13
8,338	671.96	672.46	672.89
7,988	671.80	672.27	672.67
7,398	671.55	672.01	672.40
7,006	671.37	671.84	672.24
6,606	670.63	671.19	671.63
6,283	670.81	671.28	671.66
5,827	670.84	671.27	671.62
5,356	670.81	671.22	671.55
5,018	670.66	671.09	671.42
4,746	670.36	670.80	671.15
4,466	670.06	670.55	670.93
4,233	669.91	670.41	670.79
4,018	669.77	670.27	670.63
3,908	669.79	670.27	670.61
3,888	669.74	670.22	670.57
3,752	669.42	669.96	670.39
3,508	669.38	669.89	670.29
3,182	669.24	669.75	670.14
2,861	668.87	669.47	669.90
2,536	668.67	669.24	669.66
2,249	668.77	669.31	669.70
1,783	668.74	669.26	669.64
1,484	668.58	669.13	669.51
1,306	668.46	669.02	669.41
1,004	668.04	668.69	669.15
442	667.96	668.58	669.01
0	667.56	668.20	668.67
Kneehills Creek			
7,869	698.49	698.59	698.68
7,766	698.32	698.41	698.49
7,671	698.11	698.19	698.26
7,574	697.94	698.01	698.07

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Kneehills Creek			
7,479	697.72	697.79	697.85
7,370	697.47	697.53	697.59
7,153	697.08	697.14	697.20
6,927	696.94	696.99	697.04
6,786	696.78	696.86	696.92
6,665	696.54	696.64	696.71
6,500	696.31	696.39	696.47
6,397	695.92	696.03	696.13
6,289	695.90	695.97	696.03
6,165	695.79	695.86	695.92
6,045	695.52	695.62	695.70
5,903	695.21	695.32	695.40
5,774	694.91	695.01	695.09
5,662	694.69	694.77	694.84
5,554	694.69	694.74	694.78
5,435	694.63	694.69	694.73
5,300	694.50	694.57	694.62
5,175	694.30	694.37	694.42
5,078	694.08	694.14	694.20
4,972	693.96	694.01	694.05
4,844	693.80	693.84	693.88
4,690	693.69	693.73	693.77
4,513	693.31	693.40	693.48
4,412	693.20	693.27	693.32
4,326	693.09	693.15	693.20
4,192	692.96	693.01	693.05
4,053	692.54	692.67	692.76
3,966	692.36	692.45	692.52
3,833	692.20	692.28	692.33
3,738	692.14	692.21	692.25
3,549	691.93	692.03	692.08
3,397	691.73	691.86	691.92
3,272	691.56	691.69	691.74
3,126	691.42	691.55	691.59
3,023	690.89	691.07	691.10
3,011	690.84	690.90	690.95

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Kneehills Creek			
2,916	690.78	690.82	690.85
2,665	690.37	690.46	690.54
2,517	690.27	690.34	690.42
2,242	689.62	689.80	689.97
2,139	689.70	689.82	689.96
2,049	689.61	689.75	689.90
1,915	689.36	689.59	689.78
1,794	689.19	689.45	689.68
1,669	688.93	689.27	689.55
1,600	688.84	689.12	689.38
1,584	688.79	689.07	689.34
1,532	688.72	689.01	689.28
1,375	688.46	688.77	689.07
1,231	688.37	688.70	689.02
1,007	688.30	688.66	688.99
827	688.28	688.64	688.98
583	688.24	688.62	688.96
416	688.17	688.58	688.94
Michichi Creek			
5,335	693.83	694.04	694.20
5,127	693.33	693.53	693.70
4,932	692.84	693.02	693.19
4,747	692.35	692.48	692.61
4,584	692.10	692.22	692.31
4,337	691.36	691.55	691.69
4,146	690.92	691.08	691.20
3,938	690.58	690.69	690.80
3,788	690.16	690.35	690.48
3,614	689.38	689.60	689.79
3,422	688.45	688.62	688.77
3,178	688.37	688.46	688.54
2,945	688.00	688.14	688.24
2,718	687.55	687.67	687.79
2,587	687.17	687.30	687.44
2,577	687.19	687.30	687.42
2,491	686.89	687.07	687.23

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Michichi Creek			
2,442	686.80	686.96	687.09
2,429	686.76	686.92	687.04
2,318	686.39	686.55	686.67
2,161	685.94	686.11	686.27
2,059	685.84	685.99	686.16
1,999	685.80	685.96	686.14
1,852	685.57	685.77	686.01
1,731	685.45	685.67	685.94
1,554	685.28	685.53	685.83
1,461	685.18	685.44	685.77
1,358	685.15	685.40	685.73
1,295	684.97	685.25	685.58
1,248	684.92	685.25	685.58
1,171	684.87	685.24	685.57
1,091	684.84	685.18	685.57
1,018	684.84	685.18	685.56
1,001	684.82	685.17	685.56
905	684.78	685.12	685.52
782	684.73	685.08	685.49
598	684.68	685.04	685.44
506	684.69	685.04	685.45
412	684.68	685.03	685.44
334	684.67	685.03	685.44
194	684.67	685.02	685.43
Rosebud River			
10,702	700.17	700.44	700.68
10,485	699.78	699.93	700.08
10,289	699.51	699.63	699.75
10,163	699.24	699.33	699.44
10,045	699.28	699.33	699.41
9,912	699.11	699.16	699.25
9,755	699.06	699.08	699.15
9,668	698.89	698.91	698.98
9,618	698.91	698.91	698.97
9,600	698.61	698.68	698.75
9,580	698.42	698.53	698.64

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Rosebud River			
9,570	698.35	698.44	698.55
9,554	698.12	698.23	698.36
9,468	698.07	698.18	698.28
9,355	697.75	697.95	698.10
9,227	697.58	697.75	697.90
9,116	697.37	697.53	697.67
8,994	697.26	697.41	697.54
8,849	697.24	697.37	697.49
8,745	697.18	697.30	697.42
8,706	696.74	696.94	697.13
8,689	696.53	696.66	696.81
8,682	696.38	696.53	696.84
8,675	696.41	696.56	696.77
8,661	696.35	696.51	696.69
8,553	696.22	696.36	696.54
8,439	696.09	696.22	696.40
8,343	696.02	696.13	696.31
8,281	695.82	695.93	696.13
8,187	695.42	695.50	695.74
8,101	695.42	695.44	695.64
8,080	695.32	695.32	695.53
8,060	694.98	695.11	695.25
8,009	694.87	695.02	695.17
7,958	694.86	694.96	695.07
7,937	694.78	694.90	695.01
7,783	694.61	694.70	694.79
7,641	694.33	694.42	694.52
7,530	694.32	694.37	694.45
7,395	694.24	694.29	694.36
7,326	694.08	694.13	694.22
7,303	694.05	694.10	694.19
7,276	693.70	693.85	694.02
7,246	693.82	693.91	694.04
7,215	693.69	693.80	693.92
7,151	693.57	693.73	693.86
6,913	693.22	693.37	693.51

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Rosebud River			
6,774	693.20	693.32	693.43
6,641	693.03	693.16	693.29
6,532	692.94	693.05	693.17
6,469	692.82	692.92	693.03
6,450	692.30	692.37	692.47
6,419	692.37	692.43	692.51
6,382	692.11	692.21	692.34
6,361	692.14	692.21	692.33
6,278	692.15	692.21	692.31
6,166	692.06	692.12	692.23
5,969	691.98	692.02	692.13
5,904	691.74	691.79	691.91
5,886	691.30	691.33	691.43
5,879	691.29	691.32	691.42
5,872	691.20	691.22	691.30
5,851	691.00	691.09	691.20
5,776	690.94	691.03	691.14
5,689	690.87	690.94	691.05
5,616	690.76	690.83	690.93
5,547	690.61	690.66	690.77
5,473	690.59	690.61	690.70
5,452	690.53	690.55	690.67
5,378	690.17	690.36	690.51
5,288	690.07	690.21	690.35
5,193	690.01	690.12	690.24
5,065	689.95	690.04	690.15
4,997	689.70	689.82	689.92
4,980	689.43	689.54	689.65
4,917	689.42	689.52	689.61
4,771	689.32	689.39	689.47
4,599	689.20	689.26	689.32
4,530	689.13	689.16	689.22
4,509	688.81	688.89	688.99
4,501	688.53	688.65	688.75
4,480	687.90	688.08	688.23
4,409	687.98	688.12	688.24

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Rosebud River			
4,313	687.78	687.93	688.07
4,153	687.56	687.65	687.75
4,037	687.22	687.34	687.46
3,852	686.89	686.94	687.05
3,694	686.27	686.43	686.54
3,461	686.04	686.14	686.24
3,314	685.92	686.03	686.13
3,167	685.74	685.88	686.00
3,011	685.52	685.65	685.79
2,907	685.40	685.53	685.65
2,817	685.30	685.41	685.53
2,645	684.94	685.08	685.22
2,454	684.75	684.84	684.97
2,352	684.65	684.74	684.87
2,255	683.93	684.12	684.37
2,235	683.84	683.95	684.18
2,187	683.80	683.89	684.12
2,138	683.76	683.82	684.02
2,113	683.71	683.77	683.86
2,005	683.28	683.51	683.64
1,894	683.19	683.39	683.51
1,757	682.95	683.14	683.23
1,602	682.53	682.74	682.92
1,422	682.34	682.55	682.71
1,271	682.26	682.46	682.62
1,155	682.12	682.30	682.46
1,127	682.03	682.23	682.39
1,017	682.01	682.20	682.35
833	681.97	682.17	682.32
652	681.96	682.16	682.31
559	681.83	682.04	682.21
527	681.80	682.01	682.19
438	681.78	682.00	682.17
357	681.73	681.94	682.15
332	681.69	681.91	682.14
234	681.69	681.91	682.13

Table C-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	Flood Levels (m) for varying Channel Roughness		
	Low Channel Roughness (-15%)	Adopted/Calibrated Roughness	High Channel Roughness (+15%)
Rosebud River			
116	681.68	681.90	682.12
Willow Creek			
2,970	688.62	688.63	688.70
2,723	687.14	687.16	687.18
2,408	685.73	685.79	685.85
2,174	684.31	684.38	684.44
1,937	682.91	683.00	683.08
1,566	681.02	681.17	681.30
1,356	679.81	679.81	679.81
1,007	678.44	678.73	679.00
863	678.31	678.62	678.92
848	678.29	678.60	678.90

Table C-4 Sensitivity analysis results for overbank roughness

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Red Deer River			
56,139	690.23	690.30	690.35
55,755	690.06	690.15	690.22
55,521	689.91	689.99	690.06
55,149	689.74	689.82	689.89
54,759	689.43	689.53	689.61
54,516	689.41	689.52	689.60
54,007	689.29	689.40	689.48
53,602	689.16	689.27	689.36
53,393	689.02	689.13	689.22
53,064	688.96	689.08	689.17
52,682	688.91	689.03	689.13
52,364	688.82	688.94	689.04
51,970	688.61	688.73	688.82
51,689	688.48	688.58	688.66
51,563	688.45	688.54	688.61
51,326	688.41	688.51	688.58
51,089	688.41	688.51	688.58
50,765	688.11	688.21	688.30
50,457	688.06	688.17	688.26
50,067	687.98	688.10	688.19
49,706	687.98	688.10	688.20
49,354	687.77	687.87	687.96
49,045	687.74	687.83	687.90
48,695	687.54	687.63	687.69
48,288	687.48	687.58	687.67
48,079	687.44	687.55	687.64
47,899	687.16	687.25	687.33
47,630	687.10	687.19	687.27
47,303	687.14	687.22	687.28
47,010	687.03	687.11	687.18
46,672	686.81	686.90	686.98
46,395	686.77	686.86	686.94
46,221	686.73	686.82	686.90
46,039	686.63	686.72	686.79
45,748	686.52	686.62	686.70
45,410	686.61	686.69	686.77

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Red Deer River			
45,086	686.43	686.50	686.57
44,815	686.38	686.44	686.50
44,666	686.41	686.47	686.54
44,443	686.33	686.41	686.48
44,420	685.81	685.93	686.04
44,290	685.81	685.93	686.03
44,005	685.64	685.75	685.84
43,798	685.50	685.60	685.68
43,527	685.41	685.51	685.59
43,209	685.31	685.41	685.50
42,942	685.24	685.34	685.43
42,779	685.33	685.44	685.53
42,558	685.31	685.42	685.51
42,341	685.28	685.38	685.46
42,214	685.18	685.25	685.30
41,996	685.16	685.24	685.29
41,823	685.11	685.18	685.24
41,644	684.87	684.94	685.00
41,263	684.65	684.72	684.77
41,074	684.69	684.75	684.81
40,832	684.49	684.56	684.62
40,804	684.43	684.53	684.62
40,748	684.37	684.48	684.57
40,606	684.34	684.45	684.54
40,517	684.30	684.41	684.50
40,322	683.98	684.10	684.19
40,132	683.95	684.06	684.16
39,912	683.86	683.98	684.07
39,774	683.89	684.01	684.10
39,619	683.77	683.90	684.00
39,538	683.78	683.90	684.01
39,370	683.65	683.77	683.87
39,070	683.43	683.56	683.67
38,812	683.43	683.55	683.66
38,629	683.34	683.48	683.58
38,381	683.22	683.35	683.47

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Red Deer River			
38,176	683.14	683.27	683.38
37,829	683.09	683.23	683.35
37,633	683.04	683.18	683.29
37,484	683.12	683.26	683.38
37,376	683.11	683.26	683.38
37,086	683.05	683.19	683.31
36,958	682.98	683.13	683.25
36,721	682.79	682.94	683.07
36,621	682.74	682.88	683.00
36,313	682.62	682.77	682.89
35,982	682.57	682.73	682.86
35,611	682.49	682.66	682.78
35,412	682.45	682.61	682.73
35,165	682.29	682.46	682.59
34,850	682.29	682.46	682.59
34,667	682.26	682.42	682.55
34,292	682.15	682.31	682.44
33,924	682.01	682.19	682.32
33,653	681.89	682.06	682.19
33,378	681.87	682.04	682.17
33,017	681.79	681.96	682.09
32,670	681.68	681.87	682.01
32,519	681.46	681.67	681.83
32,484	681.42	681.64	681.81
32,344	681.40	681.53	681.64
32,054	681.47	681.60	681.70
31,781	681.27	681.38	681.46
31,429	681.15	681.27	681.37
31,207	681.11	681.23	681.33
31,198	681.05	681.15	681.23
30,968	681.02	681.12	681.20
30,771	680.99	681.09	681.16
30,480	680.90	680.97	681.03
30,282	680.91	680.99	681.06
30,086	680.89	680.97	681.04
29,895	680.74	680.82	680.88

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Red Deer River			
29,573	680.54	680.60	680.65
29,224	680.47	680.53	680.59
28,890	680.44	680.51	680.56
28,595	680.15	680.22	680.27
28,373	680.14	680.20	680.24
28,271	680.02	680.08	680.13
28,255	679.93	680.03	680.11
28,234	679.96	680.06	680.14
28,215	679.95	680.06	680.14
28,196	679.89	680.02	680.11
28,120	679.89	680.01	680.11
28,028	679.88	680.01	680.11
27,943	679.66	679.79	679.88
27,921	679.60	679.72	679.80
27,749	679.63	679.74	679.81
27,487	679.57	679.68	679.76
27,145	679.46	679.58	679.66
26,728	679.32	679.44	679.53
26,576	679.34	679.47	679.56
26,330	679.24	679.37	679.46
26,001	679.07	679.19	679.28
25,566	678.84	678.96	679.05
25,030	678.68	678.81	678.91
24,611	678.51	678.65	678.75
24,051	678.47	678.61	678.71
23,586	678.38	678.52	678.62
23,316	678.31	678.44	678.53
22,842	678.21	678.35	678.44
22,328	678.00	678.08	678.13
21,724	677.95	678.03	678.08
21,245	677.64	677.72	677.78
21,011	677.65	677.73	677.78
20,686	677.56	677.64	677.70
20,474	677.45	677.51	677.55
20,065	677.43	677.50	677.56
19,848	677.15	677.20	677.22

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Red Deer River			
19,656	677.05	677.10	677.14
19,356	676.64	676.71	676.75
19,059	676.49	676.56	676.61
18,881	676.51	676.56	676.61
18,652	676.50	676.56	676.59
18,440	676.48	676.55	676.60
18,219	676.49	676.56	676.60
18,020	676.42	676.49	676.54
17,745	676.27	676.33	676.37
17,505	676.08	676.14	676.18
17,278	676.01	676.08	676.13
17,161	676.06	676.13	676.18
16,904	676.01	676.08	676.13
16,791	675.98	676.05	676.09
16,767	675.93	675.99	676.05
16,692	675.93	676.00	676.05
16,555	675.90	675.96	676.01
16,363	675.77	675.83	675.89
16,272	675.56	675.63	675.69
16,246	675.53	675.61	675.67
16,054	675.46	675.50	675.54
15,799	675.25	675.31	675.35
15,326	675.08	675.15	675.21
14,807	674.88	674.94	674.99
14,404	674.90	674.98	675.03
13,966	674.79	674.86	674.91
13,392	674.54	674.61	674.66
12,955	674.38	674.44	674.49
12,528	674.29	674.36	674.41
12,053	674.12	674.19	674.24
11,633	674.10	674.17	674.22
11,128	673.72	673.79	673.84
10,764	673.69	673.77	673.82
10,351	673.59	673.67	673.73
10,016	673.29	673.36	673.41
9,697	673.11	673.18	673.24

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Red Deer River			
9,417	673.16	673.23	673.29
9,179	672.89	672.96	673.01
8,943	672.81	672.87	672.91
8,669	672.65	672.70	672.73
8,338	672.41	672.46	672.50
7,988	672.20	672.27	672.32
7,398	671.95	672.01	672.06
7,006	671.80	671.84	671.87
6,606	671.11	671.19	671.23
6,283	671.19	671.28	671.33
5,827	671.19	671.27	671.33
5,356	671.13	671.22	671.27
5,018	671.00	671.09	671.14
4,746	670.72	670.80	670.86
4,466	670.48	670.55	670.60
4,233	670.35	670.41	670.45
4,018	670.19	670.27	670.31
3,908	670.18	670.27	670.31
3,888	670.13	670.22	670.28
3,752	669.87	669.96	670.01
3,508	669.80	669.89	669.94
3,182	669.65	669.75	669.80
2,861	669.41	669.47	669.48
2,536	669.16	669.24	669.28
2,249	669.24	669.31	669.34
1,783	669.18	669.26	669.29
1,484	669.06	669.13	669.15
1,306	668.96	669.02	669.04
1,004	668.62	668.69	668.71
442	668.52	668.58	668.61
0	668.13	668.20	668.22
Kneehills Creek			
7,869	698.47	698.59	698.70
7,766	698.27	698.41	698.52
7,671	698.04	698.19	698.31
7,574	697.85	698.01	698.12

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Kneehills Creek			
7,479	697.63	697.79	697.90
7,370	697.41	697.53	697.63
7,153	697.01	697.14	697.26
6,927	696.88	696.99	697.10
6,786	696.75	696.86	696.96
6,665	696.49	696.64	696.76
6,500	696.23	696.39	696.53
6,397	695.90	696.03	696.16
6,289	695.84	695.97	696.08
6,165	695.75	695.86	695.96
6,045	695.53	695.62	695.70
5,903	695.22	695.32	695.40
5,774	694.90	695.01	695.10
5,662	694.65	694.77	694.88
5,554	694.63	694.74	694.84
5,435	694.58	694.69	694.78
5,300	694.46	694.57	694.66
5,175	694.27	694.37	694.46
5,078	694.04	694.14	694.24
4,972	693.91	694.01	694.10
4,844	693.75	693.84	693.94
4,690	693.65	693.73	693.82
4,513	693.30	693.40	693.50
4,412	693.16	693.27	693.36
4,326	693.03	693.15	693.24
4,192	692.90	693.01	693.10
4,053	692.56	692.67	692.76
3,966	692.33	692.45	692.55
3,833	692.16	692.28	692.38
3,738	692.09	692.21	692.30
3,549	691.90	692.03	692.11
3,397	691.73	691.86	691.93
3,272	691.56	691.69	691.75
3,126	691.42	691.55	691.59
3,023	690.91	691.07	691.09
3,011	690.80	690.90	690.98

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Kneehills Creek			
2,916	690.72	690.82	690.90
2,665	690.34	690.46	690.56
2,517	690.23	690.34	690.44
2,242	689.65	689.80	689.90
2,139	689.70	689.82	689.92
2,049	689.63	689.75	689.83
1,915	689.47	689.59	689.67
1,794	689.34	689.45	689.53
1,669	689.17	689.27	689.35
1,600	689.00	689.12	689.21
1,584	688.95	689.07	689.17
1,532	688.88	689.01	689.11
1,375	688.64	688.77	688.87
1,231	688.58	688.70	688.80
1,007	688.54	688.66	688.75
827	688.53	688.64	688.73
583	688.51	688.62	688.70
416	688.48	688.58	688.66
Michichi Creek			
5,335	694.02	694.04	694.06
5,127	693.51	693.53	693.56
4,932	692.99	693.02	693.05
4,747	692.43	692.48	692.53
4,584	692.17	692.22	692.26
4,337	691.53	691.55	691.57
4,146	691.05	691.08	691.10
3,938	690.65	690.69	690.72
3,788	690.33	690.35	690.36
3,614	689.60	689.60	689.61
3,422	688.59	688.62	688.64
3,178	688.42	688.46	688.49
2,945	688.10	688.14	688.17
2,718	687.64	687.67	687.71
2,587	687.25	687.30	687.35
2,577	687.27	687.30	687.33
2,491	687.05	687.07	687.09

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Michichi Creek			
2,442	686.94	686.96	686.98
2,429	686.88	686.92	686.95
2,318	686.51	686.55	686.58
2,161	686.05	686.11	686.17
2,059	685.94	685.99	686.06
1,999	685.91	685.96	686.02
1,852	685.73	685.77	685.83
1,731	685.65	685.67	685.73
1,554	685.52	685.53	685.57
1,461	685.45	685.44	685.48
1,358	685.41	685.40	685.44
1,295	685.26	685.25	685.30
1,248	685.16	685.25	685.29
1,171	685.11	685.24	685.28
1,091	685.08	685.18	685.27
1,018	685.08	685.18	685.26
1,001	685.07	685.17	685.25
905	685.02	685.12	685.21
782	684.98	685.08	685.16
598	684.94	685.04	685.11
506	684.95	685.04	685.12
412	684.94	685.03	685.11
334	684.93	685.03	685.10
194	684.93	685.02	685.10
Rosebud River			
10,702	700.36	700.44	700.51
10,485	699.83	699.93	700.01
10,289	699.55	699.63	699.69
10,163	699.27	699.33	699.39
10,045	699.27	699.33	699.38
9,912	699.13	699.16	699.19
9,755	699.06	699.08	699.11
9,668	698.91	698.91	698.92
9,618	698.91	698.91	698.93
9,600	698.62	698.68	698.74
9,580	698.48	698.53	698.58

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Rosebud River			
9,570	698.38	698.44	698.51
9,554	698.12	698.23	698.35
9,468	698.05	698.18	698.28
9,355	697.85	697.95	698.05
9,227	697.67	697.75	697.85
9,116	697.46	697.53	697.63
8,994	697.34	697.41	697.51
8,849	697.31	697.37	697.46
8,745	697.25	697.30	697.39
8,706	696.90	696.94	697.05
8,689	696.59	696.66	696.78
8,682	696.48	696.53	696.65
8,675	696.51	696.56	696.67
8,661	696.42	696.51	696.62
8,553	696.28	696.36	696.47
8,439	696.16	696.22	696.32
8,343	696.08	696.13	696.23
8,281	695.90	695.93	696.03
8,187	695.50	695.50	695.61
8,101	695.45	695.44	695.54
8,080	695.33	695.32	695.45
8,060	695.01	695.11	695.21
8,009	694.92	695.02	695.12
7,958	694.86	694.96	695.07
7,937	694.78	694.90	695.00
7,783	694.59	694.70	694.80
7,641	694.33	694.42	694.50
7,530	694.28	694.37	694.45
7,395	694.21	694.29	694.36
7,326	694.06	694.13	694.20
7,303	694.00	694.10	694.19
7,276	693.78	693.85	693.92
7,246	693.83	693.91	693.99
7,215	693.70	693.80	693.88
7,151	693.64	693.73	693.81
6,913	693.30	693.37	693.44

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Rosebud River			
6,774	693.25	693.32	693.38
6,641	693.12	693.16	693.21
6,532	693.02	693.05	693.10
6,469	692.90	692.92	692.95
6,450	692.34	692.37	692.42
6,419	692.39	692.43	692.48
6,382	692.17	692.21	692.27
6,361	692.16	692.21	692.29
6,278	692.17	692.21	692.27
6,166	692.10	692.12	692.17
5,969	692.03	692.02	692.06
5,904	691.82	691.79	691.81
5,886	691.34	691.33	691.37
5,879	691.33	691.32	691.35
5,872	691.23	691.22	691.27
5,851	691.00	691.09	691.17
5,776	690.95	691.03	691.11
5,689	690.86	690.94	691.02
5,616	690.75	690.83	690.90
5,547	690.61	690.66	690.73
5,473	690.54	690.61	690.68
5,452	690.44	690.55	690.64
5,378	690.29	690.36	690.41
5,288	690.16	690.21	690.26
5,193	690.07	690.12	690.16
5,065	690.01	690.04	690.08
4,997	689.82	689.82	689.81
4,980	689.51	689.54	689.57
4,917	689.49	689.52	689.54
4,771	689.39	689.39	689.40
4,599	689.28	689.26	689.24
4,530	689.18	689.16	689.15
4,509	688.94	688.89	688.85
4,501	688.72	688.65	688.55
4,480	688.00	688.08	688.15
4,409	688.04	688.12	688.20

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Rosebud River			
4,313	687.85	687.93	688.01
4,153	687.57	687.65	687.73
4,037	687.27	687.34	687.43
3,852	686.86	686.94	687.07
3,694	686.30	686.43	686.54
3,461	686.00	686.14	686.27
3,314	685.89	686.03	686.16
3,167	685.74	685.88	686.01
3,011	685.52	685.65	685.78
2,907	685.39	685.53	685.64
2,817	685.29	685.41	685.52
2,645	684.99	685.08	685.18
2,454	684.77	684.84	684.94
2,352	684.69	684.74	684.83
2,255	684.17	684.12	684.19
2,235	683.87	683.95	684.13
2,187	683.81	683.89	684.07
2,138	683.74	683.82	684.01
2,113	683.68	683.77	683.86
2,005	683.43	683.51	683.60
1,894	683.32	683.39	683.47
1,757	683.07	683.14	683.20
1,602	682.61	682.74	682.85
1,422	682.42	682.55	682.65
1,271	682.35	682.46	682.56
1,155	682.19	682.30	682.41
1,127	682.10	682.23	682.33
1,017	682.08	682.20	682.29
833	682.05	682.17	682.26
652	682.04	682.16	682.24
559	681.92	682.04	682.12
527	681.89	682.01	682.11
438	681.87	682.00	682.09
357	681.81	681.94	682.07
332	681.76	681.91	682.05
234	681.76	681.91	682.03

Table C-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	Flood Levels (m) for varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted/Calibrated Roughness	High Overbank Roughness (+20%)
Rosebud River			
116	681.75	681.90	682.02
Willow Creek			
2,970	688.61	688.63	688.65
2,723	687.10	687.16	687.22
2,408	685.76	685.79	685.82
2,174	684.33	684.38	684.42
1,937	682.98	683.00	683.02
1,566	681.13	681.17	681.20
1,356	679.81	679.81	679.81
1,007	678.61	678.73	678.83
863	678.48	678.62	678.72
848	678.46	678.60	678.71

Appendix D
Open Water Flood Inundation Map Library

(provided under separate cover)