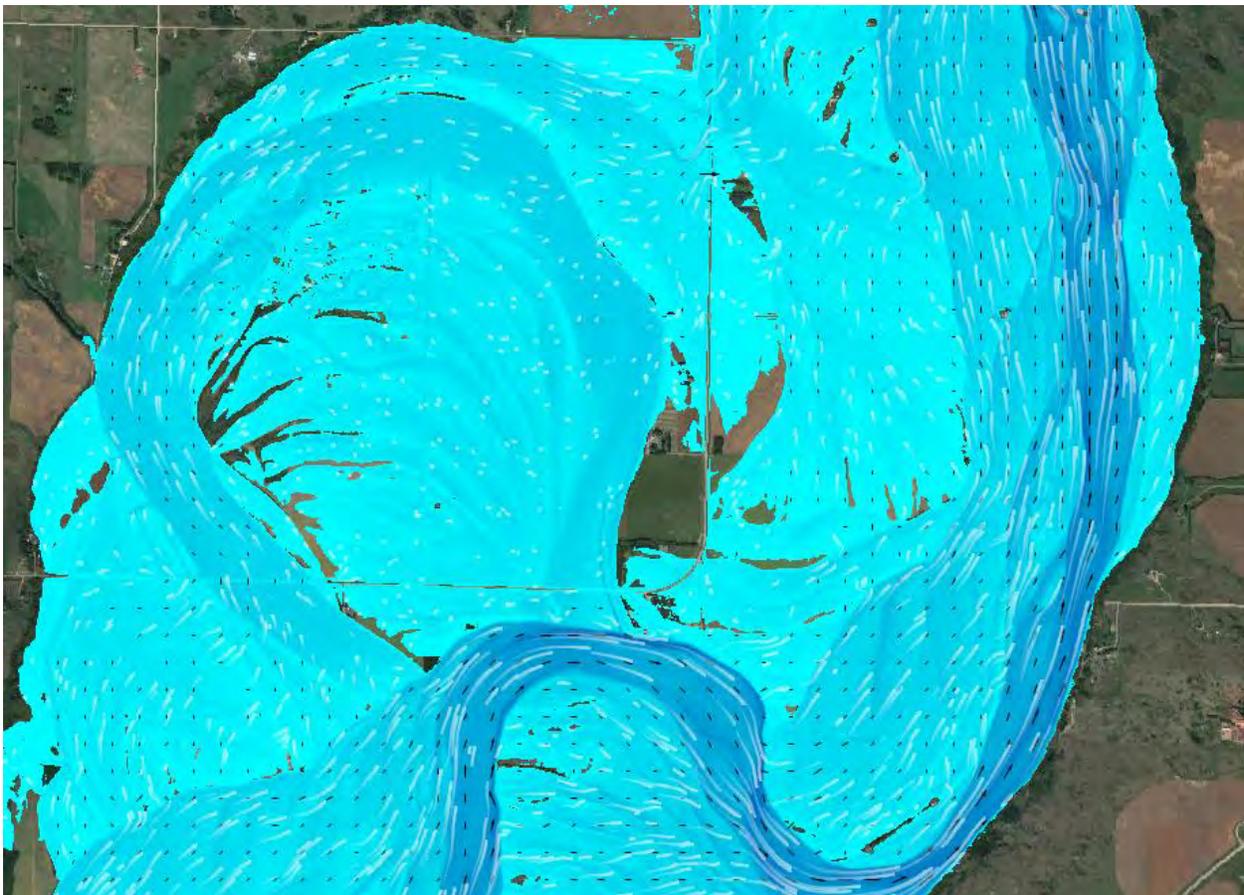


Hydraulic Modelling and Mapping Study

South Saskatchewan River Flood Plain

Prepared for
Rural Municipality of Corman Park No. 344, Saskatchewan

February 2019



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Certifications



Association of Professional Engineers & Geoscientists of Saskatchewan		
CERTIFICATE OF AUTHORIZATION		
Barr Engineering Co.		
Number C1130		
Permission to Consult held by:		
Discipline	Sk. Reg. No.	Signature
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_____	_____	_____

Acronyms and Abbreviations

Acronym	Description
1:XX	Average annual recurrence interval as represented by XX
AEP	Annual exceedance probability
cms	Cubic metres per second
CGVD28	Canadian Geodetic Vertical Datum of 1928
DTM	Digital terrain model
EGL	Energy grade line
HEC-RAS	Hydrologic Engineering Center River Analysis Software
LiDAR	Light detection and ranging
QA/QC	Quality assurance/quality control
R.M.	Rural municipality
SPI	Statements of Provincial Interest
UTM	Universal Transverse Mercator
WSA	The Water Security Agency
WSEL	Water surface elevation
WTP	Water Treatment Plant

Definitions

Annual exceedance probability – the probability that a specific flood event will be equaled or exceeded in any given year. Often the inverse of the return period (i.e., 1:500 year flood event is equal to a 0.2% annual exceedance probability).

Bathymetry data – the elevation data of the river bed, below the water surface.

Boundary condition – controls the model results at the edges of the model. Boundary conditions often control the rate of water entering the model at the upstream end, and control the water level at the downstream end, and the model determines the solution in between the boundaries.

Breaklines – a line used to connect data representing a distinct surface feature, like a ridge line, edge of pavement, toe of a slope, centreline of a road, or flowline of a ditch or stream.

Channel thalweg – a line drawn to join the lowest points along the entire length of a stream bed or valley in its downward slope, defining its deepest channel.

Erosion potential – the potential for erosion of sediment, given the flow conditions such as velocity and depth, and the resistive capacity of the sediment such as cohesion or weight.

Flood extent – the extent of land covered or inundated by a flood event. Often this is also called the flood plain for a specific flood event, such as the 1:500 year flood event.

Flood fringe – the portion of the flood plain where the waters in the 1:500 year flood are projected to be less than a depth of one metre or a velocity of one metre per second (reference [1]).

Flood plain – the area prone to flooding from a water body or watercourse that comprises the combined area of the flood way and flood fringe (reference [1]).

Flood proofed – a measure, or combination of structural and non-structural measures, incorporated into the design of a structure that reduces or eliminates the risk of flood damage to a defined elevation (reference [1]).

Floodway – the portion of the flood plain adjoining the channel where the waters in the 1:500 year flood are projected to meet or exceed a depth of one metre or a velocity of one metre per second (reference [1]).

Hydrograph – a graph showing the rate of flow (vertical axis) over a period of time (horizontal axis).

Manning's n roughness – a number used to represent the amount of frictional resistance water experiences when passing over land and channel features. Manning's n is a commonly used roughness coefficient with published numerical values. Smoother surfaces (concrete channel or clean straight rivers) have smaller numbers, and rougher surfaces (dense underbrush or fields of row crops) have higher numbers.

Regulatory flood – flood event recurrence interval used to regulate development in the flood plain.

Scroll bars – a topographic feature formed by meandering rivers. Scroll bars are the ridges of old deposited sand bars that are left as meandering rivers change course.

Velocity – a value that describes both the speed of water flow in a given direction.

Water surface elevation – the elevation of the water surface at a specific place and time.

Executive Summary

The hydraulic modelling and mapping study for a portion of the South Saskatchewan River through the Rural Municipality (R.M.) of Corman Park No. 344 (Corman Park) was done by Barr Engineering Co. (Barr) on behalf of Corman Park, in the province of Saskatchewan, and in consultation with representatives from the Water Security Agency of Saskatchewan and Government of Saskatchewan's Ministry of Government Relations (Community Planning). This study completed the technical analysis to define the expected velocities and depths of flooding during the regulatory 1:500 year flood event in order to produce accurate floodway delineation. Through provincial regulations, development is currently limited in the 1:500 year flood plain if the depth of flooding is greater than 1 metre or the velocity is greater than 1 metre per second (reference [1]).

The R.M. would like to consider development within areas of the 1:500 year flood plain at a density of up to five building sites per quarter section, or up to three building sites per 80 acres (reference [2]). Currently, densities are only allowed at two building sites per quarter section, or one building site per 80 acres (reference [3] and [4]). Properties in the 1:500 year flood plain are typically elevated on fill to at least 0.5 metres above the 1:500 year flood elevation (reference [1]).

Method

This study was built on previous efforts by the Water Security Agency (WSA) of Saskatchewan (reference [5]). The two-dimensional (2D) hydraulic modelling of the study area was completed using the Hydrologic Engineering Center River Analysis System (HEC-RAS), version 5.0.5. The hydraulic model was calibrated and validated to available water surface elevations, primarily at Moon Lake Pump Station. The hydraulic model was used to simulate the 1:50 year, 1:100 year, 1:200 year, and 1:500 year flood events. The model results were mapped to show inundation extents, flow depths, and velocities under existing conditions.

A future conditions hydraulic scenario was developed that assumed three building sites per 80 acres to assess the impacts of full development on flood elevations within the study area. The locations for elevated structures were selected to follow R.M. spacing requirements and to create a worst-case condition for flood impacts.

Findings

For the 1:500 year flood under existing conditions, velocities greater than 1 metre per second are largely confined to the main channel. However, roughly 75% of the flood plain has inundation depths greater than 1 metre. Despite the limited extents of regions of higher velocity, the greater extent of depths over 1 metre currently defines much of the flood plain as a floodway. Flood maps for existing conditions are in Attachment A.

Under the full development scenario, water surface elevations would increase by 1 to 2 cm throughout the vast majority of the flood plain, with the potential for isolated impacts of 2 to 5 cm near some rows of future houses. The velocity of water in the flood plain would largely remain the same. Flood maps for future conditions are in Attachment B.

Application of Results

The existing conditions velocity and depth mapping will be used by the R.M. to revise its development policy in a way that addresses flood risk to the community, protects existing property owners from adverse impacts caused by future development, and allows safe and responsible development. Once a consistent and technically sound policy is in place, property owners will have clear guidance on where and how they may develop.

1.0 Introduction and Purpose

This report documents the hydraulic modelling and flood inundation mapping of the South Saskatchewan River in the R.M. of Corman Park, located south of Saskatoon, Saskatchewan. The study developed a 2D hydraulic model and used that model to estimate flow depths and velocities in the river and flood plain for a range of flood events up to and including the 1:500 year flood event.

Overland flooding is a significant natural hazard for Corman Park. The Province of Saskatchewan's *Statements of Provincial Interest (SPIs) of 2012* (reference [1]) prohibits the development of new buildings and additions in the 1:500 year floodway. Within the flood fringe, flood-proofing of new buildings and additions to buildings is required, to an elevation 0.5 metres above the 1:500 year flood elevation of any watercourse (reference [1]). However, the current flood hazard maps show nearly the entire South Saskatchewan River flood plain as a floodway.

Corman Park's existing flood hazard mapping is based on results from a one-dimensional (1D) HEC-RAS model developed in 2009 (reference [6]). While the model establishes reasonable flood plain extents, it cannot simulate the complex flow paths needed to accurately define the floodway and flood fringe areas.

Corman Park commissioned this study to create the technical data needed to plan for safe and secure land development within the R.M. The 2D hydraulic model of a portion of the South Saskatchewan River simulates the complex flow pathways across road embankments and along abandoned meanders, making possible a more accurate floodway delineation. The results of this study make it possible to implement needed changes in land development policy and allow for responsible development in low-hazard portions of the flood plain.

1.1 Study Area Description

The study area consists of a portion of the reach of the South Saskatchewan River that passes through Corman Park and is upstream or south of the City of Saskatoon. A separate portion of the South Saskatchewan River north of the City of Saskatoon also passes through Corman Park and is a separate flood hazard area. The hydraulic modelling completed for the study extends to upstream and downstream of the Corman Park political boundaries. Figure 1-1 shows the study area and hydraulic model extents.

Upstream (south) of the City of Saskatoon, the South Saskatchewan River flows through a well-defined river valley that is up to 6 kilometres wide near Moon Lake. The main river channel has an average width of 300 to 400 metres. Aerial imagery shows evidence of significant meandering of the river channel within the valley walls. Much of the flood plain within the R.M. is on the west side of the river. The east side of the channel tends to flow along steep bluffs that rise above the flood plain. The Gardiner Dam is upstream of the study area and regulates flows in this reach of the South Saskatchewan River.

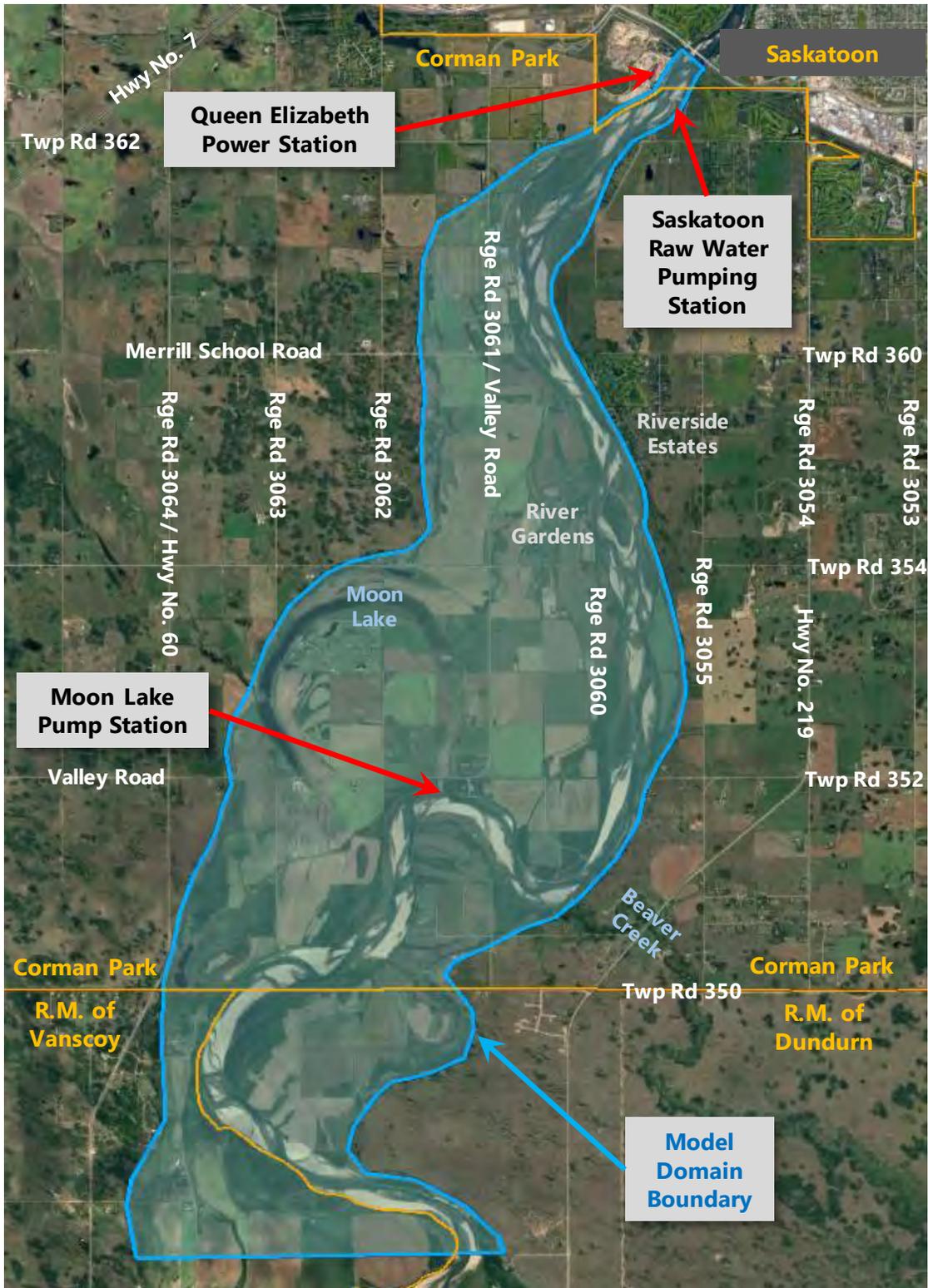


Figure 1-1 Study area and modelling extents for the South Saskatchewan River Flood Study for R.M. Corman Park, outlined in blue

2.0 Data Sources and Review

This section describes the different data sources that were provided and collected to build the 2D hydraulic model.

2.1 Previous Hydraulic Modelling Work

Hydraulic models have been created in the past for the South Saskatchewan River, including the portion (or reach) through Corman Park south of Saskatoon. The purpose of hydraulic modelling is to determine flow characteristics of interest for a given set of conditions (e.g., water surface elevation, flood extent, velocity, and erosion potential). Prior to this modelling work, hydraulic models used were 1D models created in the program HEC-RAS from the U.S. Army Corps of Engineers. In many situations, 1D models are of sufficient detail to provide the desired level of understanding. However, in some cases, the level of detail, particularly related to depth and velocity variation, is insufficient and more detailed modeling is required. Corman Park experienced this in 2012 when the R.M. drafted new bylaws but was unable to delineate the flood fringe and floodway using the existing 1D model; as a result, the proposed 2012 bylaw policy provisions have not been able to be implemented (reference [2] and [7]).

A 1D model was created in HEC-RAS in 2009, included surveyed bathymetry data from 2008, and was calibrated to a single flow rate of 1,800 cubic metres per second (cms) (reference [6]). In June of 2013, the flow in the South Saskatchewan River was the highest observed in recent history and was approximated as a 1:75 year event (about a 1.3% annual exceedance probability, or AEP). The 1D HEC-RAS model was further updated in 2016 and 2017 by the WSA to include, bridges, additional cross sections, and detail through Corman Park and to calibrate the model to the 2013 event among other flows (reference [5]). This most-recent calibrated 1D model by the WSA was the basis for some of the inputs to the current 2D modelling effort.

2.2 LiDAR Data

Light Detection and Ranging (LiDAR) data is used to define the topography in a study area. The LiDAR data covering this study area was collected by airplane in 2007 and provided by the WSA (reference [8]). The horizontal coordinate system of the data is Universal Transverse Mercator (UTM) Zone 13N (NAD83), the vertical datum is Canadian Geodetic Vertical Datum of 1928 (CGVD28), and the units are metres both horizontally and vertically. The vertical accuracy of the LiDAR data is not known to Barr because this specific information was not included with the data provided.

A few important notes about LiDAR are (1) it can penetrate vegetation and provide the topographic elevation in forested areas, (2) it returns a uniquely distinguishable signal when encountering buildings so that they can be removed from the topographic surface, and finally, (3) it cannot penetrate water. Therefore, wherever water is present, the LiDAR represents the water surface elevation at the time of the data collection and not the bottom of rivers or lakes. Section 2.4 discusses the collection of the river bathymetry, and Section 3.1 discusses the methods to merge the two datasets.

2.3 Past Events for Calibration

Three relatively large flood events have been observed on the South Saskatchewan River in recent history. Those are:

- June 2005 – ~1,830 cms approximated as a 1:38 year event (about 2.6% AEP).
- June 2009 – ~1,620 cms approximated as a 1:26 year event (about 3.8% AEP).
- June 2013 – ~2,300 cms approximated as a 1:75 year event (about 1.3% AEP).

The AEP, or annual exceedance probability, is the probability or chance that a given flood (defined by the flow rate) or one greater will happen in any year. Ignoring changing climate for a moment, in every year that goes by, the 1% AEP flood has the same probability of occurring, every year. Bigger floods are naturally rarer and therefore have lower AEPs. Because bigger floods have a lower chance of occurring in any given year, and smaller floods have a higher chance of occurring in any given year, smaller floods are observed more often and bigger floods are rarer. However, considering a rare, large flood event over a longer time frame than a year, such as over 30 years, the probability of even rare floods over a longer time span can drastically increase. Table 2-1 shows the impact of considering flood probabilities in one year versus over a longer time span. The chance of experiencing another flood event of the same magnitude as the recent 2013 flood event during the next 20 years is about one in four; during the next 50 years, the chance is about as good as getting “heads” on a coin flip.

Table 2-1 Probabilities of particularly rare flood events over periods of time longer than one year

Flood Event (1:Return Interval)	Percent chance of occurring in one year	Percent chance of occurring once in 5 years	Percent chance of occurring once in 10 years	Percent chance of occurring once in 20 years	Percent chance of occurring once in 30 years	Percent chance of occurring once in 50 years
1:25 year	4%	18.5%	33.5%	55.8%	70.6%	87.0%
1:50 year	2%	9.6%	18.3%	33.2%	45.5%	63.6%
1:75 year	1.33%	6.5%	12.6%	23.5%	33.1%	48.9%
1:100 year	1%	4.9%	9.6%	18.2%	26.0%	39.5%
1:200 year	0.5%	2.5%	4.9%	9.5%	14.0%	22.2%
1:500 year	0.2%	1.0%	2.0%	3.9%	5.8%	9.5%

The data Barr had for calibrating the model was limited to the data collected at the Moon Lake Pump Station. For these flood events, water surface elevations and flow rates were collected at the Moon Lake Pump Station at multiple times throughout the hydrograph, providing coinciding water surface elevation and flow rate data on both the rising and falling limb of the hydrograph and at or near the peak of the event. Additional water-level data were collected farther north (downstream) within Saskatoon and farther

south (upstream) near Pike Lake. All of that data was outside of the study area and outside of the LiDAR data Barr had for modelling.

Additionally, the WSA provided a hydrometric report on the South Saskatchewan River (reference [9]) which included water surface elevation hydrographs and flow hydrographs during the 2005, 2011, and 2013 flood events at the Moon Lake Pump Station. By associating flow rates at a given time during a flood event with water surface elevations at the same time from the published hydrographs for multiple large flood events (2005, 2011, and 2013) in the hydrometric report (reference [9]), Barr was able to estimate the water surface elevation for a variety of additional flow rates not directly collected during flood events. The relationship between water surface elevation and flow rate at the Moon Lake Pump Station developed from the data available is shown in Figure 2-1. During the project the WSA also provided the relationship they have at that location. It is included in Figure 2-1 to show how well it fits the data used to calibrate the model (reference [10]).

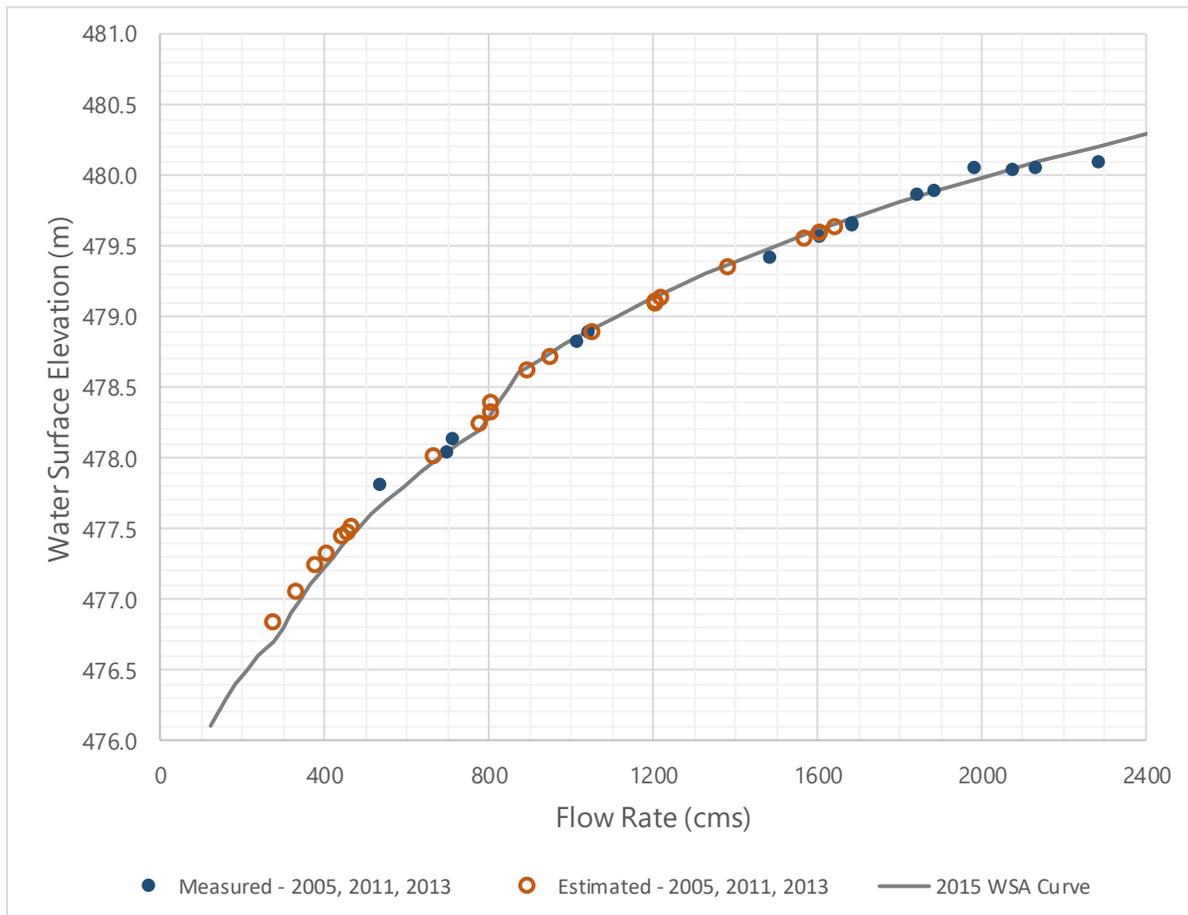


Figure 2-1 Rating curve (water surface elevation and flow relationship) at the Moon Lake Pump Station used for calibrating the model

2.4 Bathymetry Survey

Bathymetry data (river bottom elevation) in the South Saskatchewan River was required for this project to develop an accurate model. The river channel conveys the vast majority of a flood's flow. Therefore, accurately representing the conveyance area in the main channel is critical for creating a good hydraulic model. Barr used a subcontractor to collect the bathymetry data over a four-day period in May 2018 (May 15th through May 18th). Barr was present for an initial portion of the survey. The subcontractor collected 60 cross-sections throughout the 21 kilometres of river reach, averaging a spacing of about 350 metres. They also collected multiple cross sections in each of the larger side channels. At the point of collection, the bathymetry data accuracy is 1.0 centimetres. A map of the surveyed cross section locations is included in Attachment C as Figure C-1. Bathymetry data was also collected longitudinally along the river reach to provide additional information between cross sections and inform the channel thalweg. The processed survey data was provided to Barr as an electronic file of points with northing, easting, and elevation information. The horizontal coordinate system of the data is Universal Transverse Mercator (UTM) Zone 13N (NAD83), the vertical datum is Canadian Geodetic Vertical Datum of 1928 (CGVD28), and the units are metres both horizontally and vertically.

2.5 Field Reconnaissance

Barr staff conducted a field tour of the South Saskatchewan River valley within Corman Park to better understand the area, the land features and characteristics, the general use and roughness, and to understand expected flow patterns. Barr took measurements of culverts and ditches to identify potentially significant conveyance features. The larger culverts in the area are a part of the Moon Lake Irrigation Project. These culverts are commonly in line with weir structures (upstream) that create pools for irrigation (Figure 2-2). There are two other large culverts (120 cm diameter) that go through Valley Road near the Moon Lake Pump Station (Figure 2-3). These culverts are designed to drain local flooding and they have large flap gates on the river side to prevent flooding from events on the South Saskatchewan River that do not overtop Valley Road. Because these culverts have large flap gates and will not allow flow from the river into the overbank, these culverts were not included in the hydraulic model. Additional photos from the site visit are in Attachment D.



Figure 2-2 A pair of culverts, weir, and pump in the irrigation project



Figure 2-3 Flap gates on large culverts draining the flood plain around Moon Lake

Many of the other culverts, particularly running north-south through lateral roads off Valley Road are, damaged, entirely crushed at one end or the other, or largely plugged by vegetation and sediment (Figure 2-4). These culverts are not substantial conveyance structures, nor would they be if they were repaired to their original capacity. Therefore, they were not included in the hydraulic model.



Figure 2-4 Examples of the smaller and damaged culverts throughout the Corman Park flood plain

The ditches are sufficiently captured in the LiDAR data and additional elevation data to describe them was not collected or used to modify the topography in the model surface.

2.6 Other Supplied Data

Additional data was necessary for creating the hydraulic model for this project. Specifically, flow rates for specific flood recurrence intervals, Official Community Plan and Zoning Bylaws from Corman Park and the Corman Park – Saskatoon Planning District (District), and the SPIs.

2.6.1 Flow Rates for Specific Rare Events

The hydrologic analysis required for determining flows for specific flood events was previously performed by the WSA and provided through the 1D HEC-RAS model (reference [5]). The flows were largely determined by flooding upstream of the Gardiner Dam and the operation of the dam during flood events. The 1:500 year flood event (0.2% AEP) is the regulatory event. Additional events modelled for informational purposes were the 1:200 year (0.5% AEP), 1:100 year (1% AEP), and 1:50 year (2% AEP). The flow rates of these four large, rare events in order from largest (rarest) to smallest are 4,200 cms, 3,200 cms, 2,500 cms, and 2,000 cms, respectively.

2.6.2 Statements of Provincial Interest and R.M. Bylaws Governing Future Development

The SPIs (reference [1]), bylaws of Corman Park (reference [11]) and the Corman Park – Saskatoon Planning District (reference [12]) were used to guide the creation of a hypothetical future topography, representative of a fully developed condition. The definitions related to developing in flood-prone areas as defined in these documents, particularly in the SPIs, are as follows:

- A flood plain is flood-prone areas that are inundated with water during a flood event, specifically the 1:500 year event.
- A flood plain is divided into two distinct areas: the floodway and the flood fringe.
- The floodway is defined as the portion of the flood plain area where the water depth is greater than or equal to 1 metre or the flow velocity is greater than or equal to 1 metre per second.
- The flood fringe is defined as the portion of the flood plain area where the water depth is less than 1 metre or the flow velocity is less than 1 metre per second. However, through discussions with Corman Park, the WSA and Community Planning, and for the purposes of the study in determining developable areas within the flood plain, it is understood that the flood fringe definition ought to be an “and” statement, instead of “or”.
- Development of new buildings and additions to buildings is prohibited in the floodway of the 1:500 year flood elevation of any watercourse or water body.
- Development of new buildings and additions to buildings in the flood plain requires flood proofing to an elevation of 0.5 metres above the 1:500 year flood elevation of any watercourse or water body.

The SPIs (reference [1]) currently prohibit the development of new buildings or additions to buildings in the floodway and permit development in the flood fringe, provided they are properly floodproofed. The

current R.M. Zoning Bylaws do not contain as direct a statement and have not been updated since the SPI were adopted in 2012. Instead, the Corman Park Zoning Bylaws describe the floodway as the portion of a water body where the flow is the fastest and the potential for danger is greatest (reference [11]). The Corman Park Zoning Bylaw describes the flood fringe as the remaining portion of the flood plain (not floodway) where development will not create an excessive hindrance to the hydraulic efficiency of the watercourse and where most types of development may be accommodated subject to the application of proper flood proofing techniques (reference [11]). This implies that development is permitted in the flood fringe. The definitions of floodway and flood fringe and their implementation in municipal land use bylaws have been subject to agreement and feedback from the Province over the years, and a new policy framework is likely needed to properly apply the SPI moving forward.

3.0 Existing Conditions Modelling

The existing conditions hydraulic modeling was used to develop the technical data needed to define a floodway and flood fringe based on the current development conditions in the flood plain. This section describes the development of the existing-conditions model and the modelling results. A 2D hydraulic model was used for the study because it can calculate velocities and depths across a floodplain that is not characterised by uniform flows in one general direction. The software program HEC-RAS was used because it is a widely accepted model for flood plain mapping and it is in the public domain.

3.1 Terrain Development with Bathymetry

For a 2D hydraulic model, a digital terrain model (DTM) representing the ground surface over which water will flow is required. The 2007 LiDAR data was used as a basis for the majority of the DTM (reference [8]). As discussed in Section 2.2, the LiDAR does not include data below the water surface representing the river bottom. The bathymetry data collected was used to supplement the LiDAR data and replace the portion that was water surface along the river. The collected bathymetry data is accurate to 1.0 centimetres, where it was collected. Cross sections were created based on the collected bathymetry data and tied into the LiDAR where the data was collected (see the map Figure C-1 and cross-section data figures in Attachment C). A DTM was created based on the bathymetry cross sections with surface interpolation between cross sections. In the interpolated areas between cross sections of collected bathymetry data, the accuracy is unknown. The portion of the LiDAR DTM that was below water was replaced with the bathymetry DTM (Figure 3-1).

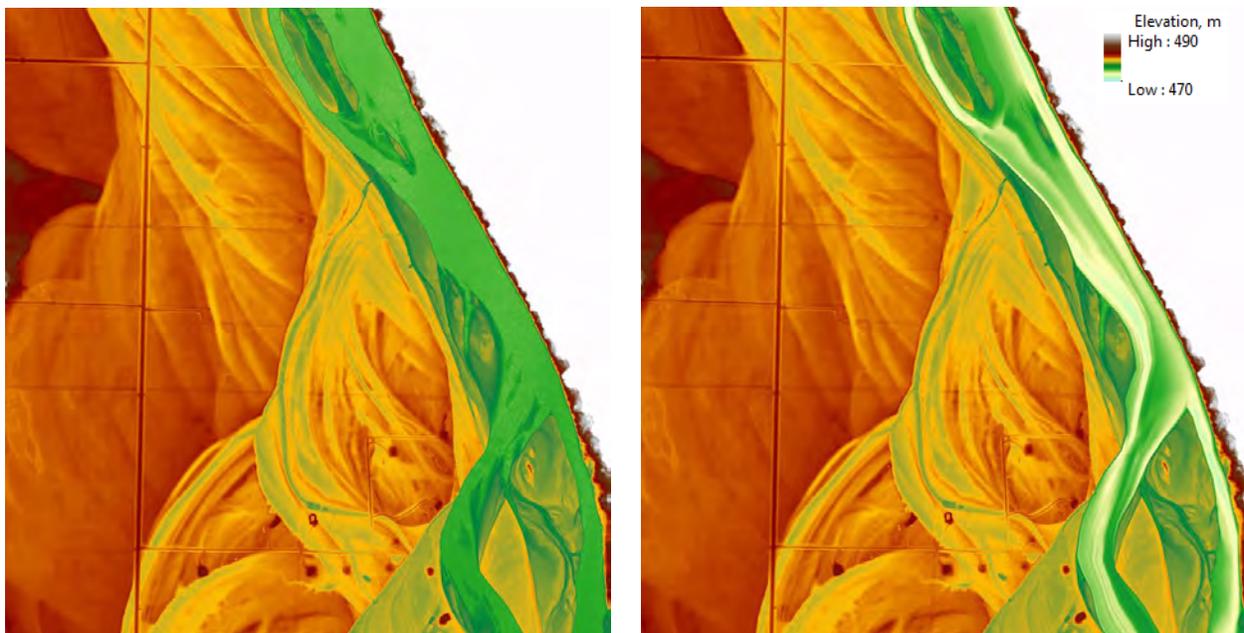


Figure 3-1 A comparison of the 2007 LiDAR DTM covering the South Saskatchewan River (left) and the same area with the river bathymetry tied into the DTM (right)

The Saskatoon Water Treatment Plant (WTP) Raw Water Intake/Pumping Station spur (WTP spur) extending out into the South Saskatchewan River (south of the Circle Drive Bridge and across from the

Queen Elizabeth Power Station) was updated in the terrain (Figure 3-2). This feature was built in 2010 and was, therefore, not captured in the 2007 LiDAR data. The WTP spur was created in the DTM based on a design drawing provided by the WSA (reference [13]). The incorporation of bathymetry data and the constructed WTP spur were the only changes made to the LiDAR to form the existing conditions surface. It is notable that, as expected, the sand bars throughout the South Saskatchewan River have moved since the LiDAR data was taken in 2007. Therefore, sandbars within the river that were surveyed and incorporated in the surface represent conditions in 2018 and the overall general structure of the river and its sandbars. Comparing the existing conditions surface to past photos or future surveys will likely show sandbars in different places.

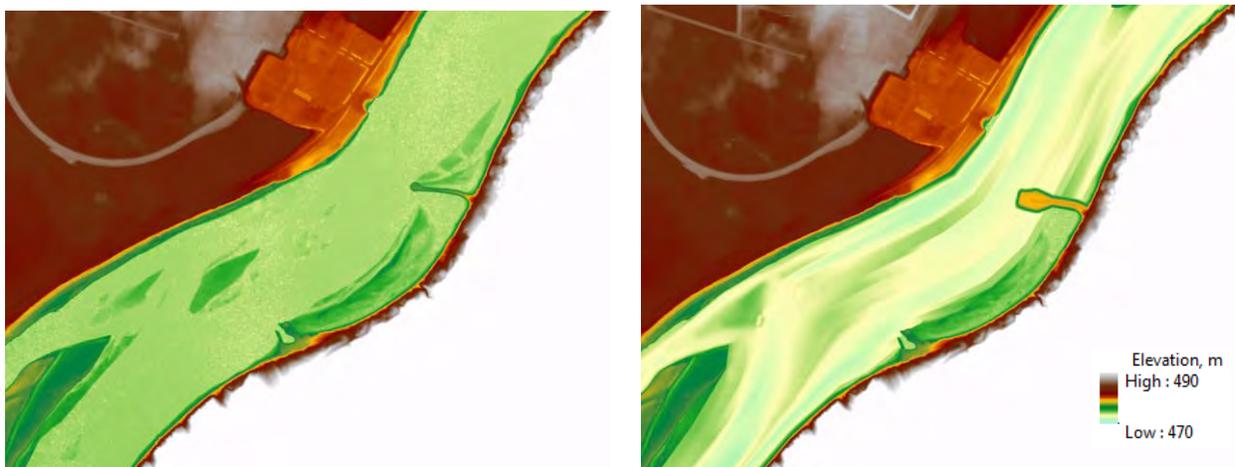


Figure 3-2 A comparison of the area around the WTP spur in the LiDAR DTM (left) and after the modification to include the design of the recent WTP spur construction (right)

3.2 Boundary Conditions

There are two boundary conditions specifically required for the 2D model: one at the downstream end and one at the upstream end of the model. For the slower-moving South Saskatchewan River, subcritical flow dominates the flow regime and a downstream water-level definition is required for the downstream boundary condition. For this project, the modeling incorporated a rating curve definition which relates the flow rate to a water surface elevation. The rating curve at the downstream end was developed from the most recently updated 1D HEC-RAS model (reference [5]). The cross-section upstream of the Circle Drive Bridge and the CN Railway Bridge was used (RS 308727 of the 1D model) and the rating curve is shown in Figure 3-3.

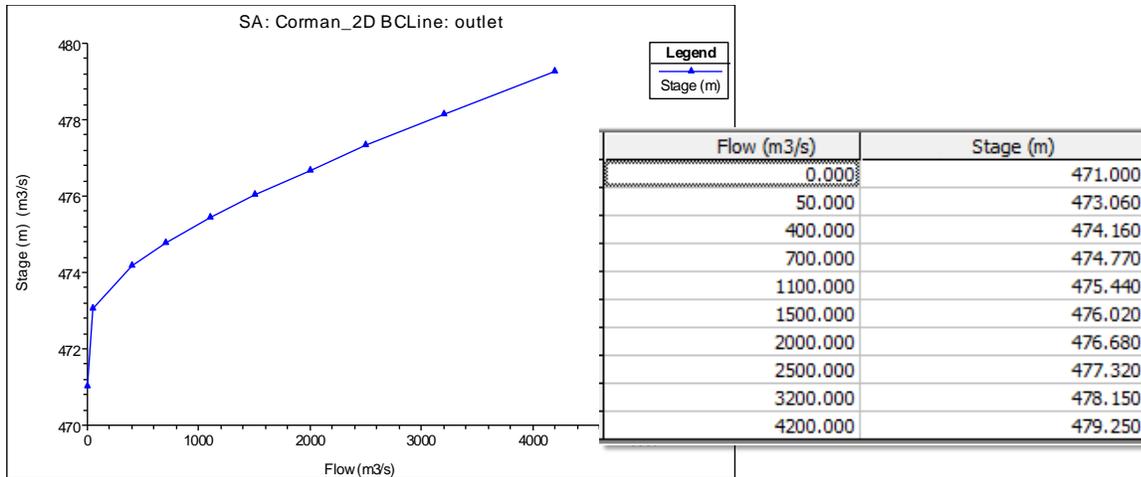


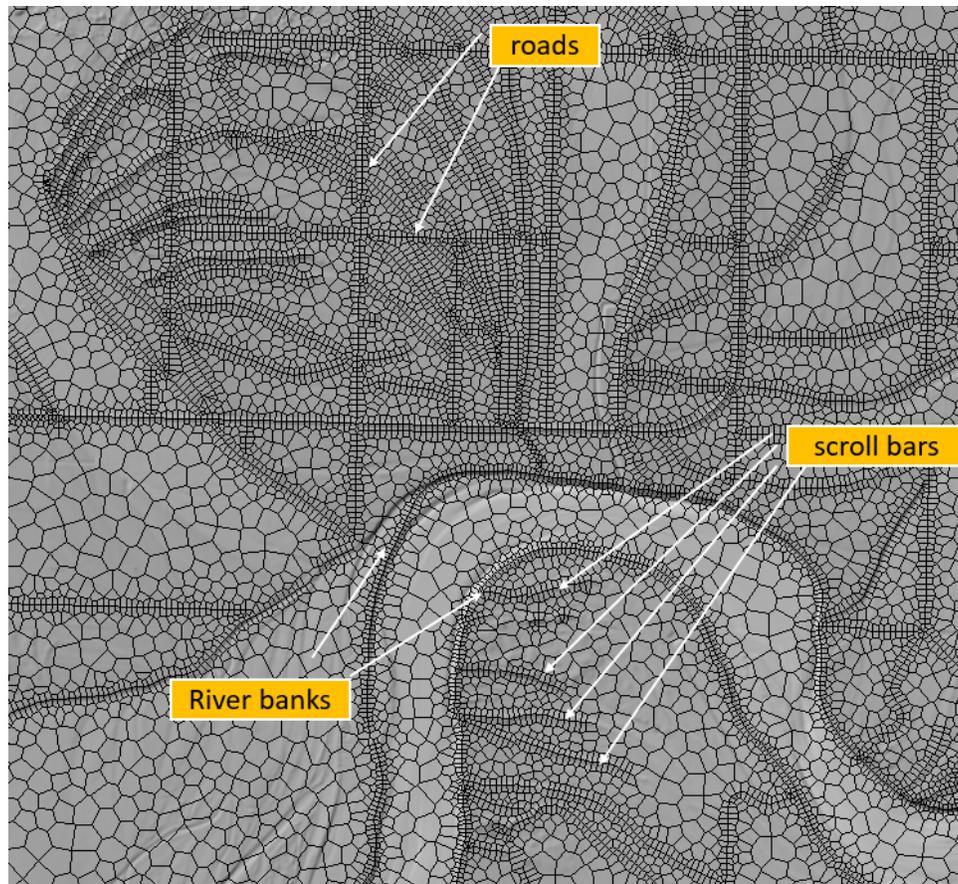
Figure 3-3 Rating curve at the downstream end of the model

At the upstream end of the 2D model, the flow rate into the model domain is specified. Steady (constant) flow rates were specified for a variety of events at the upstream end, including both the hypothetical design events and the observed historical events. In addition, for the flow to be distributed across the upstream boundary, an energy slope (energy grade line or EGL) is required. The EGL was specified as 0.0002 m/m based on an approximation of the channel bottom longitudinal slope (5 m per 25 km).

3.3 Numerical Mesh Generation

The “numerical mesh” of the 2D model is the definition of where hydraulic calculations will take place spatially and helps define the dependence of one area in the model on the neighboring areas. The numerical mesh is comprised of “cells” which are irregularly shaped polygons with no gaps and no overlapping cells. The numerical mesh was generated in GeoHECRAS v. 2.1.0 using an adaptive mesh scheme (Figure 3-4), rather than the default primarily Cartesian mesh generated in HEC-RAS. The adaptive mesh scheme generates a more efficient 2D mesh by “relaxing” the cells when possible (i.e., allowing them to be larger) and reduces the number of mesh cells. Since there are fewer 2D mesh cells and, therefore, fewer computational iterations, the overall process is faster and more efficient, and the software can converge to solutions more easily.

The model domain (numerical mesh domain) area was defined to contain the 1:500 year (0.2% AEP) flood extents. The cell sizes in the mesh range from about 20 metres squared (m^2) to 1,600 m^2 (roughly 4 m x 5 m cells to 40 m x 40 m cells), and average just under 500 m^2 . Breaklines are user-specified polylines used to force the alignment of mesh cell edges along particular features that are expected to control flow. Breaklines were added to capture flood plain features such as roads, river scroll bars, and river banks (Figure 3-4). The cell sizes are smaller along the breaklines to capture more detail of the flow patterns.



Note that this mesh is coarser than the mesh used in the modelling. This sample is shown strictly for visualization and for ease of seeing the cell boundaries and breaklines.

Figure 3-4 Numerical mesh sample near the Moon Lake Pump Station

3.3.1 Numerical Mesh Independence Check

Generally speaking, the greater the number of cells in a numerical mesh of a given area, the more accurate the results. However, a numerical mesh with a large number of cells will generally require simulations with long run times. In contrast, a numerical mesh with much fewer cells will run faster but will likely produce less accurate results. Because of this natural relationship between the number of cells covering an area, the simulation run time, and the accuracy of the results, a good practice is to determine the optimal number of cells using a mesh independence analysis. The optimal number of cells is defined as the minimum number of cells such that the resulting model solution is not significantly different than simulations with more cells.

A mesh independence analysis was conducted using five different numerical meshes. The properties of these meshes are shown in Table 3-1. The number of cells was controlled by adjusting the maximum cell area, the boundary cell spacing, and the breaklines cell spacing of the adaptive mesh scheme.

Table 3-1 Adaptive mesh definitions used for the mesh independence analysis

Mesh ID	Approximate Number of Cells	Minimum Element Angle (deg)	Maximum Cell Area (m ²)	Boundary Cell Spacing (m)	Maximum Element Angle (deg)	Breaklines Cell Spacing (m)
1	300,000	20	500	10	100	10
2	150,000	20	1000	15	100	15
3	100,000	20	1500	20	100	20
4	60,000	20	3000	20	100	20
5	40,000	20	15000	20	100	20

Examples of the numerical mesh cells for 40,000 cells (minimum number tested) and 300,000 cells (maximum number tested) are shown in Figure 3-5. These bounding numbers of cells were selected based on the resulting cell sizes, experience with 2D models, and the general flatness of the terrain and the expected velocity both in the channel and in the flood plain. Our expectation was that 300,000 cells would be more than sufficient to characterize the flood-prone areas.

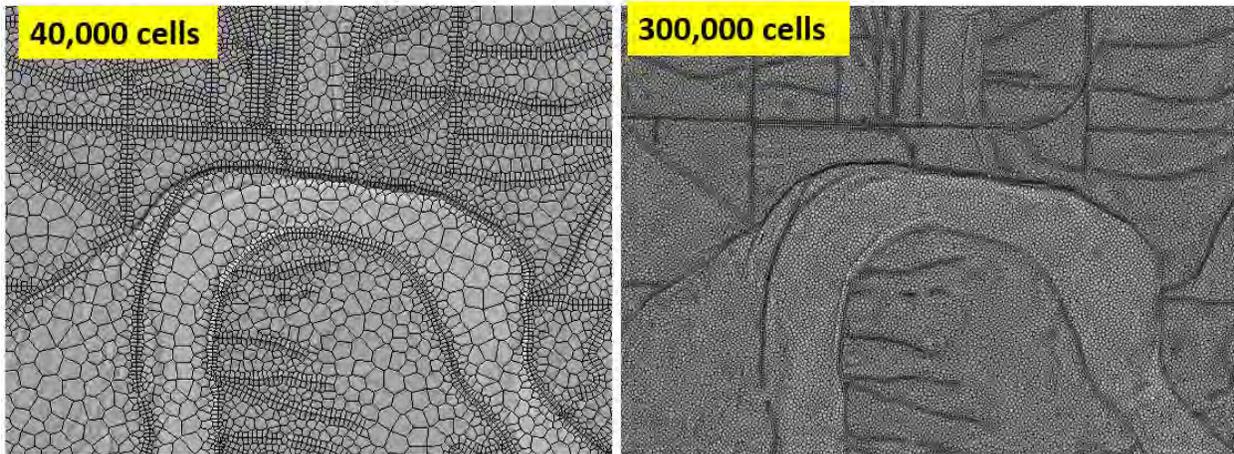


Figure 3-5 Numerical mesh comparison of 40,000 cells (approximate maximum size of 15,000 m²) to 300,000 cells (approximate maximum size of 500 m²).

The mesh independence analysis was conducted by simulating a flow of 2,100 cms in the river. This flow was approximated as the flow that best corresponds to the aerial imagery from the 2013 flood (reference [14]). Given the time it takes to develop aerial imagery and the sharp decline in flow rate over the two days of flight time, the flow is an approximation at best. In reality, the flow selection is arbitrary since the goal is to test the model solution as a function of the mesh, regardless of the modelling hydraulic parameters (as long as they are identical in all the simulations).

Eight observation points were located in the model domain as shown in Figure 3-6. The water surface elevation results from the simulation with mesh #1 (300,000 cells) was taken as the “assumed accurate baseline” for comparison purposes. The water surface elevation results from the simulations with meshes #2 through #5 were compared to those with mesh #1. The resulting water surface elevations at the

observation points and the water surface elevation differences are shown in Table 3-2 and Table 3-3, respectively.

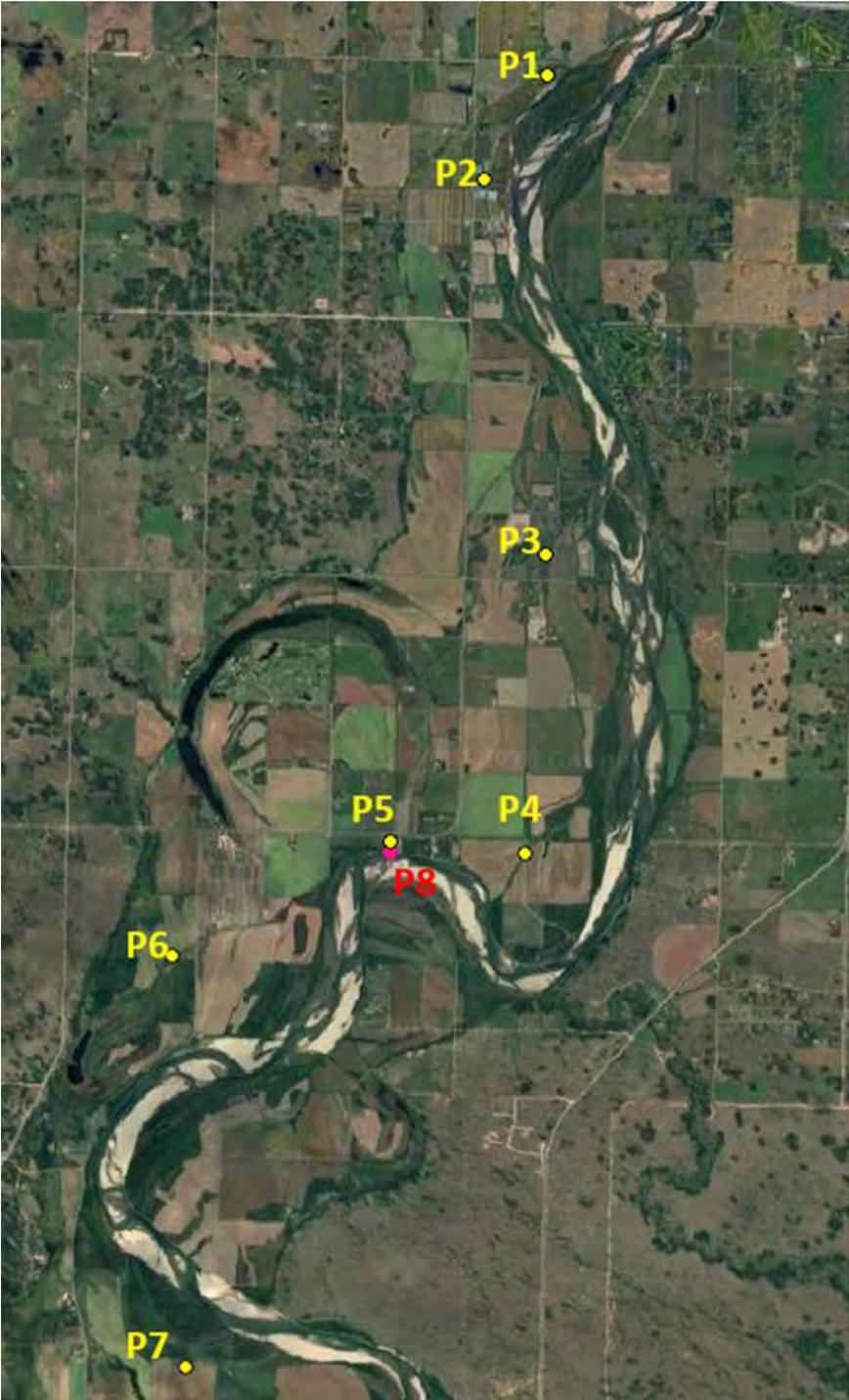


Figure 3-6 Observation points for the mesh independence analysis; the points are near the edge of water visible in the 2013 aerial imagery during the flood event

Table 3-2 Mesh independence analysis water surface elevation results at 2,100 cms

Observation Point	300,000 cells (m)	150,000 cells (m)	100,000 cells (m)	60,000 cells (m)	40,000 cells (m)
P1	477.63	477.69	477.41	477.42	477.43
P2	477.65	477.65	477.65	477.65	477.64
P3	478.71	478.70	478.71	478.73	478.75
P4	479.11	479.14	479.17	479.21	479.25
P5	480.08	480.08	480.08	480.10	480.11
P6	480.31	480.33	480.34	480.35	480.39
P7	481.43	481.45	481.45	481.46	481.49
P8 (Moon Lake Pump Station)	480.09	480.09	480.09	480.11	480.12

Table 3-3 Mesh independence analysis water surface elevation differences compared to the 300,000 cell mesh at 2,100 cms

Observation Point	300,000 cells (m)	150,000 cells (m)	100,000 cells (m)	60,000 cells (m)	40,000 cells (m)
P1	--	+0.06	-0.22	-0.21	-0.20
P2	--	0.00	0.00	0.00	-0.01
P3	--	-0.01	0.00	+0.02	+0.04
P4	--	+0.03	+0.06	+0.10	+0.14
P5	--	0.00	0.00	+0.02	+0.03
P6	--	+0.02	+0.03	+0.04	+0.08
P7	--	+0.02	+0.02	+0.03	+0.06
P8 (Moon Lake Pump Station)	--	0.00	0.00	+0.02	+0.03

For this analysis, a maximum water surface elevation difference of +/-5 cm was used as a target value to select the optimal number of cells. This value was selected since it represents half of the target value used for the calibration analysis, described in Section 3.4. Table 3-3 shows that mesh #5 with 40,000 cells has clear differences compared to mesh #1, particularly at observation points P1, P4, P6, and P7. Mesh #4 has improved results (similar model results to mesh #1) at P6 and P7, but still has large differences at P1 and P4. Mesh #3 has improved results at P4, very good results at P2, P3, and P5 through P8. However, similar to meshes #4 and #5, mesh #3 has large differences at P1. Mesh #2 showed very good results at P2, P3, and P5 through P8, further improved results at P4, and drastically improved results at P1. Despite the water surface elevation difference of 6 cm (just greater than our initial threshold of 5 cm), this difference

was accepted because this particular location includes a superelevated water surface near the observation point. Mesh #2 captured this feature and still had very similar results to mesh #1. Therefore, the mesh used for the calibration, validation, and modelling was the mesh with approximately 150,000 cells.

3.4 Calibration and Validation

The goal of the calibration process was to obtain a spatial distribution of roughness that resulted in a minimum error when comparing the model results to the observed water surface elevations. In the calibration process, the roughness values are refined to continue to improve the comparison of model results to observed data for a selected set of flow rates, as long as the roughness values are constrained to reasonable estimates. In the validation process, the roughness values are no longer altered, additional flow rates are modeled, and the results are compared to the observed data. If the validation process shows new unexpected errors, then the calibration process is re-started and the fundamental assumptions may be changed. The model is considered “calibrated” if the validation process shows continued good agreement between the model and the observed data.

As described in Section 2.3, the data available for calibration was primarily the data at the Moon Lake Pump Station (observation point P8 in Figure 3-6). Based on comments during the quality assurance/quality control (QA/QC) process, the one data point collected near Pike Lake was used as a validation point to check whether the model is providing a reasonable solution upstream of the Moon Lake Pump Station.

Initial calibration efforts focused on the main channel for flows between 400 cms and 1,100 cms using a single roughness value. The model results tended to be too high at 400 cms and too low at 1,100 cms. This led to the conclusion that roughness values varied by depth within the main channel. Channel roughness areas were separated into a portion that is less rough, where the flow is deeper and continuous, and a portion that is rougher (somewhat vegetated or covered with debris) with shallow flow and periodic inundation. These two portions identified by identifying the sandbars and point bars within the river channel using aerial imagery and the bathymetry survey data. This allowed the model to have lower roughness for lower flows and increasingly higher roughness as the flows increased and more of the sandbars and point bars were inundated. Several iterations were tested to determine the best Manning’s n values, resulting in 0.023 for the deeper, less rough portion, and 0.034 for the point bars, sandbars, and islands.

Table 3-4 shows the results of the main channel calibration process. The model was calibrated to within +0.08 m and -0.13 m at flows of 400 cms and 1,100 cms, respectively. The validation flows of 600 cms, 700 cms, and 900 cms were within -0.17 m to +0.01 m of the observed rating curve data (reference [9] and reference [10]).

Table 3-4 Results of the calibration of the main channel to the rating curve at the Moon Lake Pump Station

Flow Rate (cms)	Modeled Water Surface Elevation (m)	Observed Water Surface Elevation/Rating Curve (m)	Difference (m)
400	477.41	477.33	+0.08
600	477.87	477.93	-0.06
700	478.09	478.08	+0.01
900	478.48	478.65	-0.17
1100	478.84	478.97	-0.13

Notes:

The numerical mesh with 150,000 cells was used for the calibration, the validation, and the model runs.

The model was calibrated to flows of 400 cms and 1,100 cms and back-checked or validated at flows 600 cms, 700 cms, and 900 cms.

The roughness used for the main channel was 0.023 in the deeper portions and 0.034 in the areas of sandbars and point bars.

After the roughness values in the main channel were determined, the flood plain roughness was calibrated. The flood plain was divided into different land-use regions, as shown in Table 3-5. The land-use regions were initially identified through an automated classification process of aerial imagery in ArcMap. The land-use regions were then refined through a review process of the automated results.

During the June 2005 and June 2013 flood events, the observed peak discharges were 1,830 cms and 2,300 cms, respectively (reference [15]). The model was calibrated to the June 2013 event peak flow rate. The model was then validated to the June 2005 event and another intermediate flow of 1,500 cms, which represents a 1:25 year flood event. The Manning’s n roughness values in the flood plain (not the main channel nor the point bars/islands) were altered until an acceptable calibration was achieved. The altering of the roughness values was purposefully limited so that the values were both individually reasonable and reasonable relative to each other. The results of the flood plain calibration process are shown in Table 3-6 and the final Manning’s n values selected for the main channel and flood plain land-use regions are shown in Table 3-5. These values are generally consistent with the calibrated values from the 2009 1D model (reference [6]). The values in the 2D model are generally lower, which is common. Roughness values in 1D models have to account for energy loss due to form drag, whereas 2D models inherently include form drag and will use lower roughness values. The roughness value for “building footprint” is intentionally high at 0.500. The way in which buildings are represented in the model has a significant bearing on the specification of roughness. Where buildings or other major obstructions are not explicitly modeled, the impact of these features on losses can be incorporated into the roughness parameter, using a significantly higher value than would otherwise be the case.

Table 3-5 Calibrated **Manning's n** roughness values by land-use classification

Land-Use Classification	Manning's n Roughness
Main Channel	0.023
Point Bars/Islands	0.034
Forest	0.050
Roadway/Developed Urban	0.014
Agricultural or Grassed Field	0.035
Wetland	0.034
Building Footprint	0.500

Table 3-6 Results of the calibration of the flood plain to the rating curve at the Moon Lake Pump Station

Event	Flow Rate (cms)	Modeled Water Surface Elevation (m)	Observed Water Surface Elevation/ Rating Curve (m)	Difference (m)
Approximately 1:25 year	1,500	479.45	479.46	-0.01
June, 2005	1,830	479.85	479.86	-0.01
June, 2013	2,300	480.30	480.10	+0.20

The overall calibration and validation of the model to the data observed at the Moon Lake Pump Station is shown in Figure 3-7. The root mean square error of the eight calibration and validation data points is 11 cm, whether compared to the measured/estimated discrete points or the WSA curve from 2015 (reference [10]).

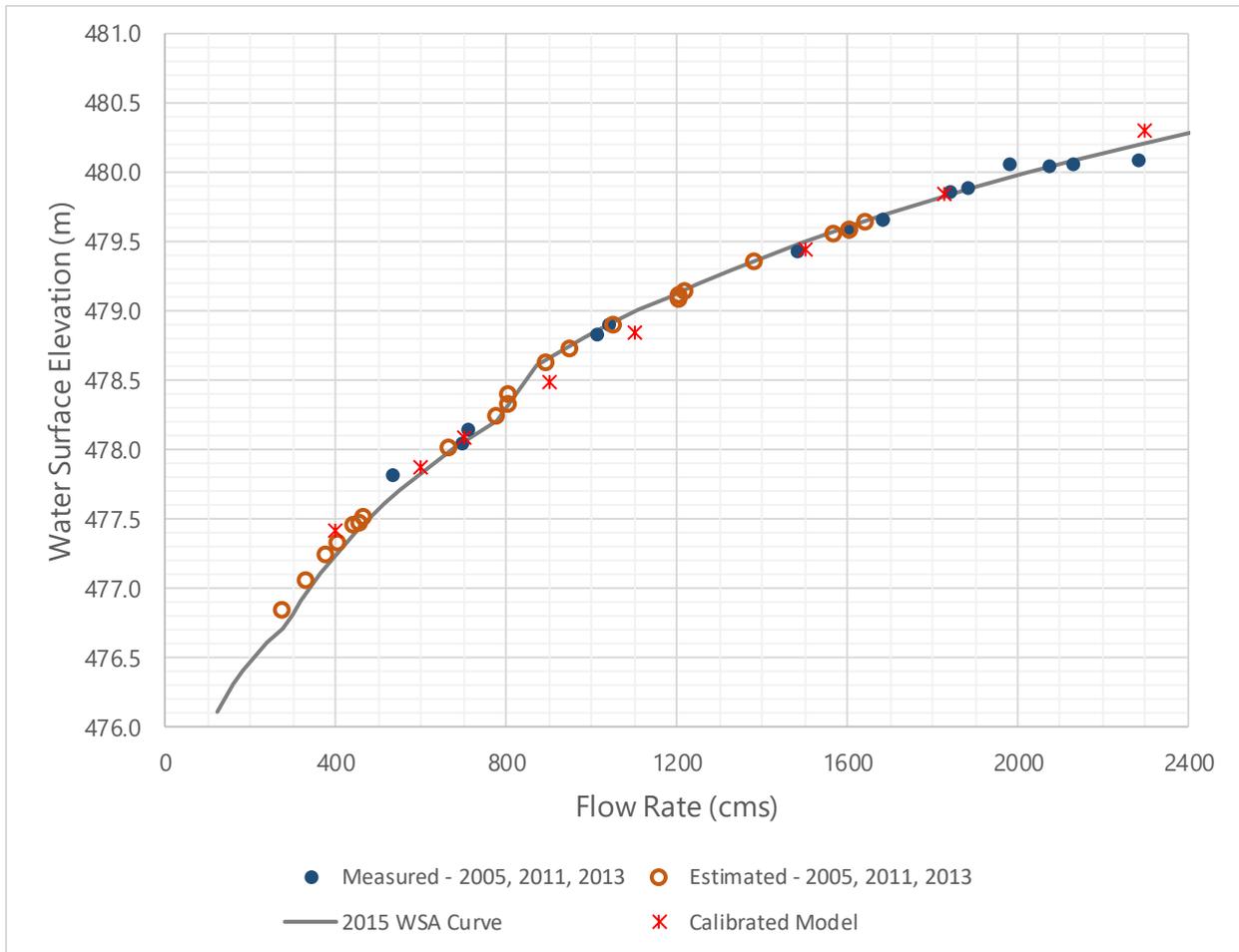


Figure 3-7 Calibrated model results compared to the rating curve at the Moon Lake Pump Station

3.4.1 Validation of the Model at Pike Lake

Observed data from the 2013 flood event was available at Pike Lake, approximately 7.5 kilometres upstream of the model domain. During the QAQC process, one of the comments questioned the model results upstream of the calibration point at the Moon Lake Pump Station. The comment was addressed by extrapolating the modeled water surface elevation profile upstream to the Pike Lake Pump Station observation. Figure 3-8 shows that the observed water surface elevation at the Pike Lake Pump Station is less than 0.2 metres different from the extrapolated modeled water surface profile for the 2013 flood event. This result gave us confidence in the model, particularly in the reach upstream of the Moon Lake Pump Station.

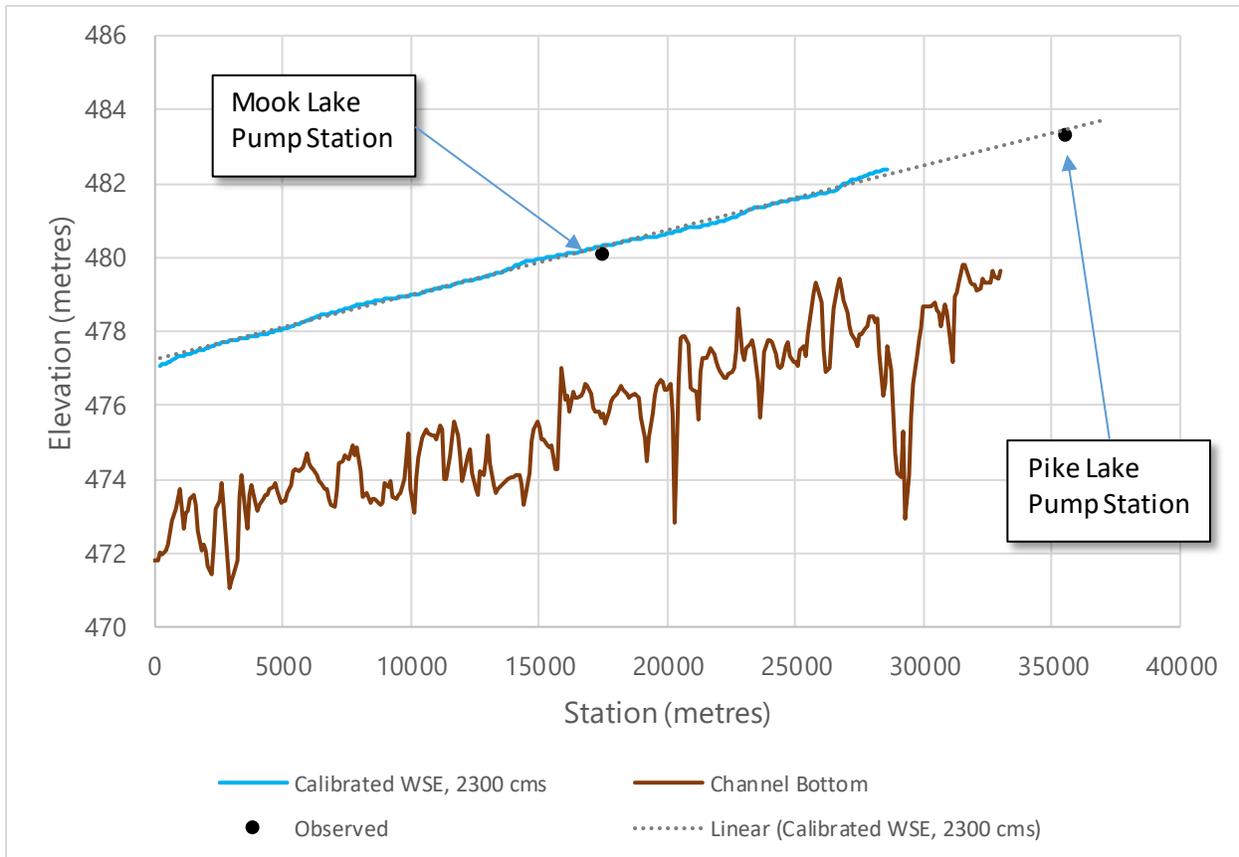


Figure 3-8 Profile plot of the calibrated model at 2,300 cms; extended to Pike Lake

3.4.2 Comparison of the 2D model to the 1D Model

The 2D model results were compared to the most recent 1D model results in order to understand the impact of different modeling efforts on policy and recent development in Corman Park. In particular, the water surface elevation profile from each model was compared along the modeled river reach (Figure 3-9). This comparison can help identify significant differences between past and current modeling and may identify issues with either of the modeling efforts. In this case, the results of the modeling for the regulatory flood event (1:500 year) are quite similar, with differences at any location of less than about 0.2 metres. The 2D modeling largely confirms the past work, gives confidence in development decisions that have been made in recent years (permitting development above the 1:500 year water surface elevation), and adds the critical velocity detail needed for future policy and residential development decisions. Additional comparisons at lower flow rates are included in Attachment E. The larger discrepancies at lower flows around 1D model station 315,000 are likely due to the contraction in the 1D model from a very wide flowing flood plain to a narrower section confined by the valley banks. Capturing the ineffective flow areas, contractions, and expansions in the 1D model is very difficult and likely is largely contributing to the differences. Updated bathymetry data in this area could additionally be contributing to the differences. The bathymetry changes are simply due to natural processes in the river as the bed changes over time.

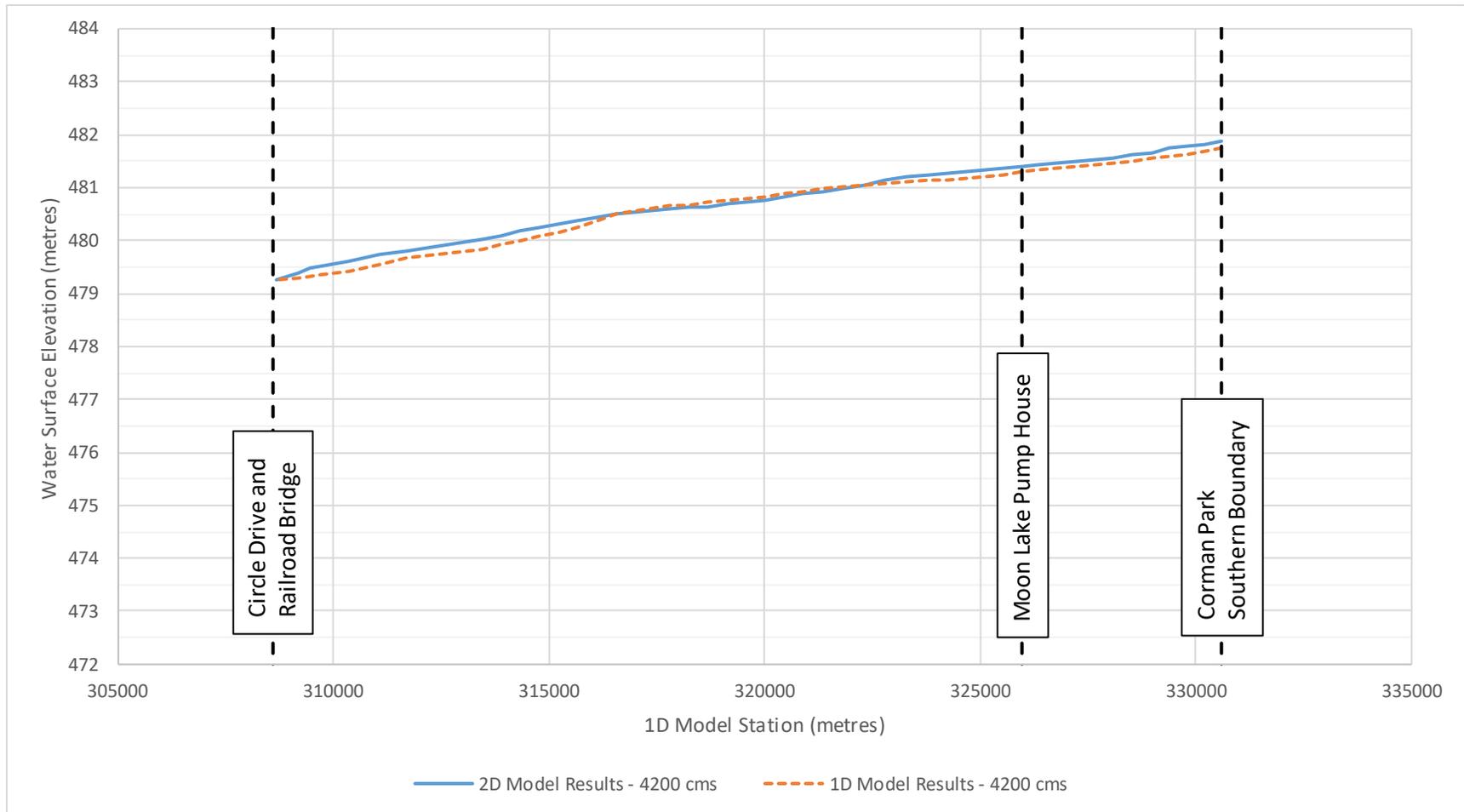


Figure 3-9 1:500 year flood event profile (4,200 cms); comparison of 1D and 2D model results

3.5 Sensitivity Model Runs

The sensitivity of the model results to the calibrated Manning's n roughness values was tested. In particular, the sensitivity of the predicted water surface elevation was tested. For the sensitivity analysis, the roughness values were both increased and decreased by 10% for all land use types. Manning's roughness values outside of this range (+/- 10% of the calibrated values) were considered unrealistic for the South Saskatchewan River and for the various land use types found in that area. Therefore, the sensitivity analysis provides reasonable uncertainty bounds on the model predictions.

Figure 3-10 shows the results of this sensitivity analysis at the Moon Lake Pump Station. Here, the comparison of the sensitivity results can be compared to the observed data and the rating curve. Figure 3-10 shows that a change of 10% in the Manning's roughness values will change the water surface elevation by less than 0.2 metres. Additionally, the flow range with the greatest sensitivity to Manning's roughness values is the range between about 800 cms and 2,000 cms. For flows greater than 2,000 cms, the sensitivity diminishes slightly. These results are important to understand the sufficiency of freeboard guidelines or limits for future development. Uncertainty in model predictions is one aspect of understanding the risks.

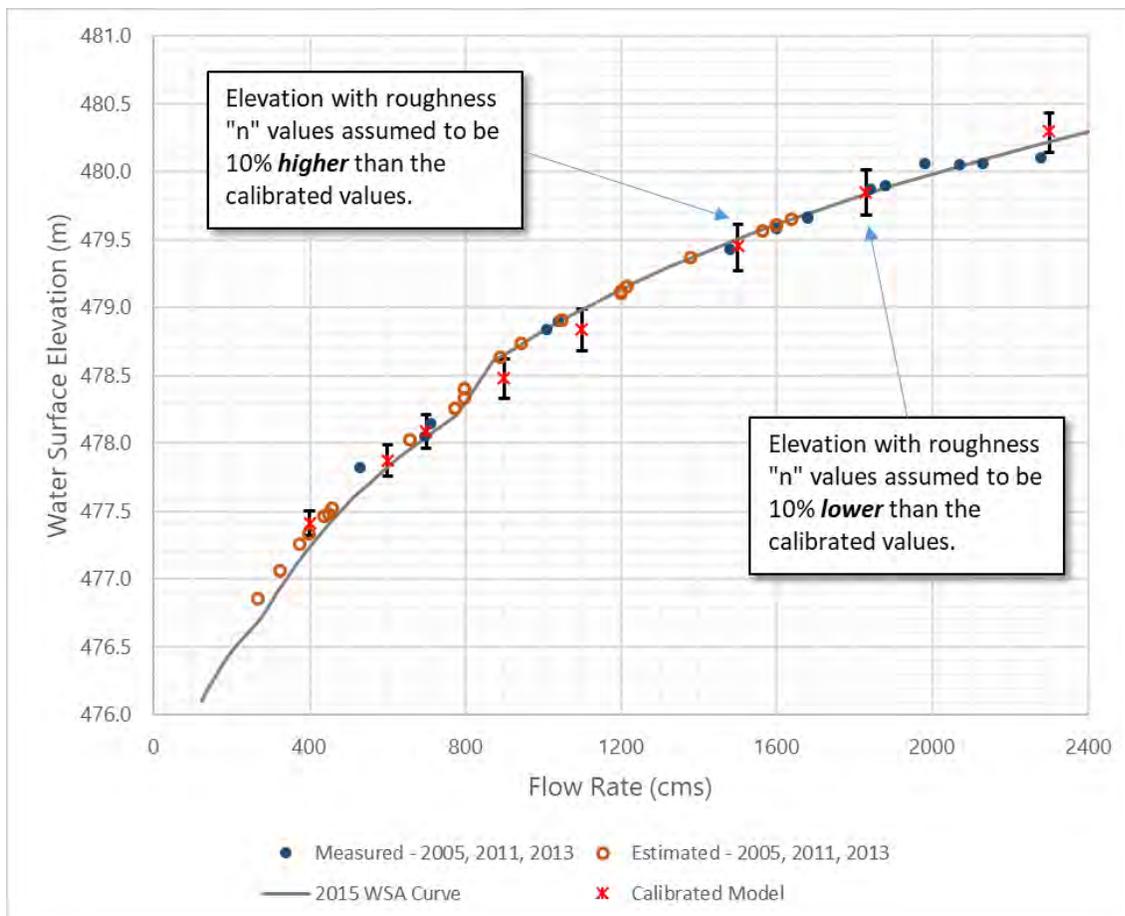


Figure 3-10 Sensitivity results compared to the rating curve at the Moon Lake Pump Station

An additional sensitivity analysis was performed on the downstream boundary condition by raising the water surface elevation at the downstream end of the model by 0.30 metres for each flow rate. The effects of this change to the downstream boundary condition tapered to 0.1 metres near Township Road 360 and 0.0 metres near Township Road 354. The effect of modifying the downstream boundary condition was limited to portions of the South Saskatchewan River north of Township Road 354. Even so, in areas where development may occur in the future, the sensitivity in the water surface elevation is less than 0.1 metres if the water surface elevation at Circle Drive Bridge is 0.30 metres higher than expected.

Given the limited sensitivity due to the downstream boundary condition (mostly less than 0.1 metres) and due to changes in roughness values (plus or minus 0.2 metres), the current requirements to elevate structures 0.5 metres above the regulatory water surface elevation are sufficient to account for the anticipated uncertainties.

3.6 Model QA/QC

The model development, calibration, and validation processes went through a formal internal QA/QC process. The most significant review comments, process outcomes, and the ways in which the comments were addressed were:

- Approval of the mesh chosen (approximately 150,000 cells) and, after review of the numerical mesh independence analysis, agreement that the mesh was appropriate for the study.
- Approval of the boundary conditions after some discussion of the upstream energy grade line (0.0002 m/m). This is primarily based on the understanding that the downstream and upstream boundary conditions are defined by others.
- Agreement that the culverts throughout the flood plain are not critical given the relatively small size, the current condition of most of them, and the large flap gates on the main culverts from the South Saskatchewan River into the Corman Park flood plain.
- A suggestion to validate the upstream portion of the model by plotting a profile and adding the observed data at Pike Lake. The model results are not available in that area because of the extent of the model, but a cursory review of the data can confirm or call into question the quality of the calibration. This is presented in Section 3.4.1.
- Agreement that the model is well calibrated to the data available.
- A suggestion to complete a sensitivity analysis of the model for the observed floods. At the time, it had not yet been completed. This is presented in Section 3.5.

3.7 Results

Results of the existing-conditions modelling are presented as large maps in Attachment A. Figure A-1 shows the water depth throughout the model domain during the peak of the regulatory event; the 1:500 year (0.2% AEP) flood event. Light blue areas are inundated with shallower depths of water and dark blue areas are areas of greater depth of water. Figures A-2, A-3, and A-4 show the water depth throughout the

model domain during the peak of the 1:200 year (0.5% AEP), 1:100 year (1% AEP), and 1:50 year (2% AEP) events, respectively.

Figure A-5 shows the flow velocity magnitude throughout the model domain during the peak of the regulatory event (1:500 year). Light blue areas are inundated with slow-moving water and red areas with the fastest flowing water. Figures A-6, A-7, and A-8 show the flow velocity magnitude throughout the model domain during the peak of the 1:200 year (0.5% AEP), 1:100 year (1% AEP), and 1:50 year (2% AEP) events, respectively.

Figure A-9 shows the classified water depth throughout the model domain during the peak of the regulatory event. The water depth is classified as either greater than or equal to 1 metre (red colour) or less than 1 metre (blue colour). Figure A-10 shows the classified flow velocity magnitude throughout the model domain during the peak of the regulatory event. The velocity is classified as either greater than or equal to 1 metre per second (red colour) or less than 1 metre per second (blue colour).

The figures in Attachment A, particularly in the 1:500 year flood event figures, show notable areas that are not inundated. They appear in the figure as a light green or brown colour because of the visible fields in the aerial imagery (see Figure 3-11). These areas are expected to be dry (not inundated) during the 1:500 year flood event because the topography is higher than the surrounding water surface elevation. This increased understanding is largely due to the use of the 2D model as opposed to the 1D model. Additional and smaller dry areas are more easily observed in Figure A-11 due to the use of brighter colours.

Within the domain of the 2D model, Valley Road is entirely open and usable during the 1:50 year flood event. At the peak of the 1:100 year flood event there are very short portions of Valley Road that could be inundated, particularly where Valley Road crosses over Moon Lake just east of Range Road 3063 (see Figure A-3 of Attachment A). Even still, Valley Road may be passable during this event. During the 1:200 year and 1:500 year flood events, Valley Road would not be usable for evacuation purposes (see Figure A-2 and A-1, respectively, in Attachment A).

For the regulatory event, the 2D model results are in good agreement with the results of the most recent updated 1D model (reference [5]). The water surface elevation of the 2D model along the entire reach of the study area is different from the 1D model by at most +19 cm/-7 cm (Figure 3-9) which is within the freeboard requirements for recently developed buildings and additions. This degree of difference is expected because we are using a different modeling approach that allows for more nuanced estimates of water surface elevations across the floodplain.

Similarly, the calculated velocities for the 2D model are within the expected range for the channel and for overbank areas. The regions of high velocity are primarily confined to the main river channel and smaller sparse areas of concentrated shallow flow in the flood plain. This level of detail for velocity estimates was one of the primary reasons for using a 2D model for this study. A 1D model can be used to calculate representative velocities across a typical cross section where flow is generally moving in a single direction. This is not the case for the 1:500 year flood event for the South Saskatchewan River.

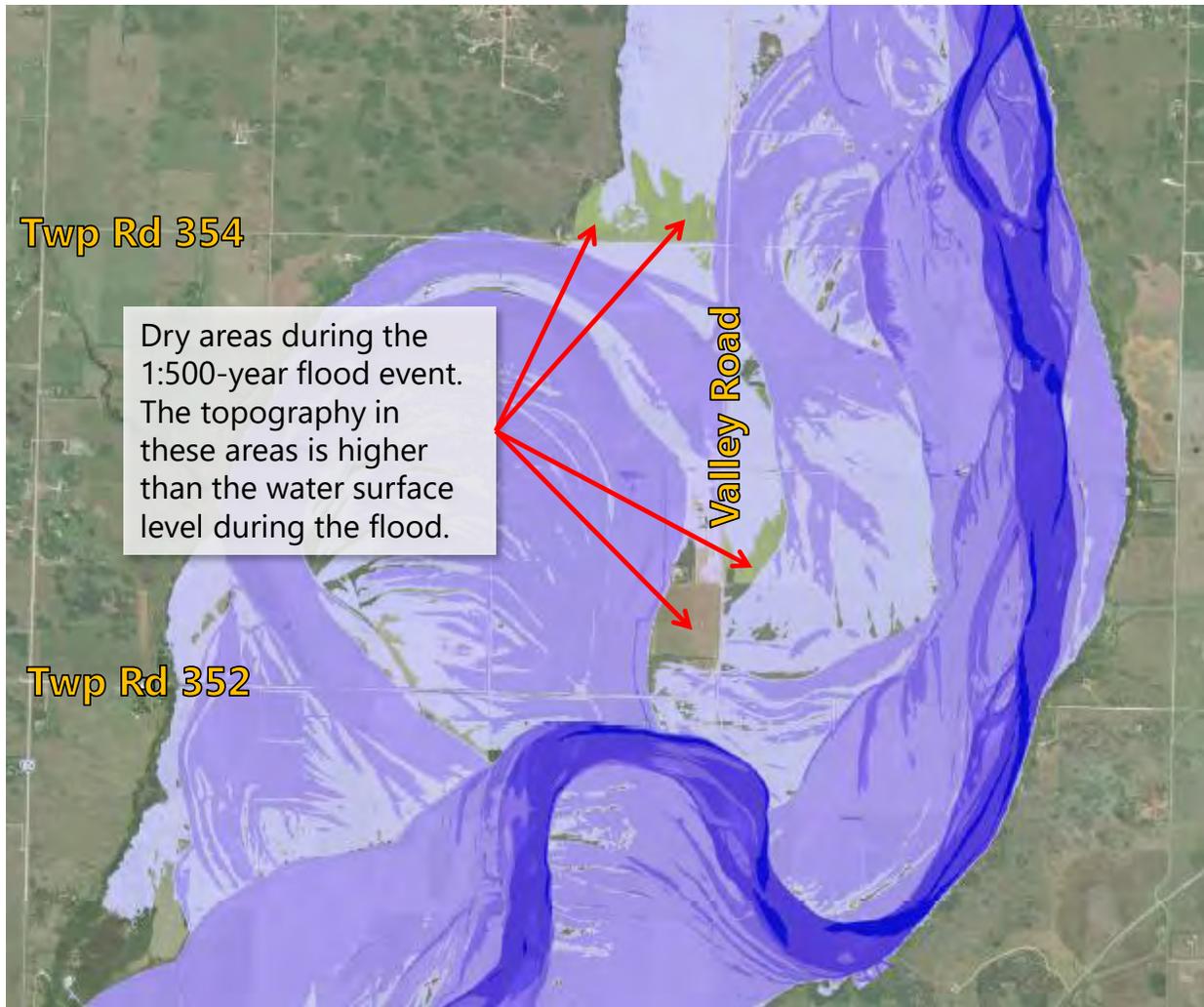


Figure 3-11 Notable dry areas in the flood-prone area previously thought to be inundated

3.7.1 Definition of Floodway and Flood Fringe for the Study Area

Finally, Figure A-11 shows the flood-prone areas throughout the model domain classified as either floodway or flood fringe, according to the SPIs, and the basis for the classification. The pink areas in the figure are classified as a floodway, where the velocity is greater than or equal to 1 metre per second and the depth is greater than or equal to 1 metre. The orange areas (very small portions) are also classified as floodway where the velocity is high (greater than or equal to 1 metre per second), and the depth is shallow (less than 1 metre). The yellow areas are classified as floodway where the depth is high (greater than or equal to 1 metre), and the velocity is low (less than 1 metre per second). Finally, the blue areas are classified as flood fringe where development is permitted according to the SPIs. These areas are where the depth is less than 1 metre, and the flow velocity is less than 1 metre per second. The areas in hectares for floodway and flood fringe are in Table 3-7. A breakdown of the floodway based on the depth and velocity regulatory triggers is provided in Table 3-8.

Table 3-7 Areas (hectares) of floodway and flood fringe in the study area

Classified Area	Colour in Figure A-11	Inundation Area (ha)	% of Flood Plain
Floodway	See Table 3-8	3,728	75%
Flood Fringe	Blue	1,238	25%
Total Flood Plain (1:500 year)	--	4,966	100%

Table 3-8 Areas (hectares) of floodway based on regulatory trigger

Floodway based on	Colour in Figure A-11	Area Covered (ha) (% of Floodway Area)
Floodway (depth and velocity)	Pink	488 (13%)
Floodway (velocity only)	Orange	2 (<0.1%)
Floodway (depth only)	Yellow	3,238 (87%)
Total Floodway Area	--	3,728

The WSA has noted that another method for calculating the floodway is to allow for encroachments in the flood fringe that collectively cause no more than a 0.30 metre increase in the regulatory flood elevation. This method, however, is not currently listed in the SPIs.

4.0 Full Residential Development Conditions Modelling

The full residential development conditions hydraulic modelling was used to explore how hydraulic conditions might change if the R.M. allowed full residential development throughout the flood plain. This section describes the creation of the full residential development conditions model and the modelling results.

4.1 Condition Definition

In Corman Park's bylaws, the fully developed agriculturally zoned parcels are defined as "three building sites per 80 acres" or "five building sites per quarter section" (reference [11] and [3]). Currently, there is an exclusion area in the R.M. Development Plan (reference [3]) that only permits "two building sites per quarter section" or "one building site per 80 acres". However, for the future conditions modelling the R.M. wanted to consider the potential of full residential development. Homes in the flood plain are required to be elevated at least 0.5 metres above the 1:500 year flood elevation. The R.M. and District Zoning Bylaws provide site development standards for flood proofing structures by elevating them on fill (reference [11] and [12]). This fill takes up a relatively small amount of storage within the floodplain, but it can also potentially impede flow in the floodplain. To create a worst-case hydraulic scenario, future homes were assumed to be constructed in locations that would maximize impacts to flood levels.

4.2 Terrain Development

A copy of the existing terrain model was modified to include the hypothetical residential structures built on earth mounds in the flood plain throughout the R.M. The modifications to the terrain were made based on the following guidelines and assumptions:

- Development occurs at "three building sites per 80 acres" plan (Figure 4-1) because it allows for more houses and more fill relative to the other option of "five building sites per quarter section" (Figure 4-2).
- It is recognized that other types of development are possible with the R.M. and District Zoning Bylaws, such as agri-tourism and other agriculturally-related commercial and industrial uses on Agricultural-zoned lands. It is also recognized that Agricultural-zoned lands are permitted to have additional accessory buildings on the 2.5-acre to 10-acre subdivisions. However, this study did not include that level of detail to presume which areas will be developed for agricultural residential versus other, non-residential land uses types. All building sites were assumed to be agricultural residential-type development for a consistent density of development throughout the model domain.
- Avoid development in areas such as Crown Land, recreation or park, golf courses, forested areas, areas that appear to be or are classified as wetlands.

-
- Represent development as mounds of fill (rather than homes on piles or piers) commonly employed in Corman Park, and because that will block or take up the most space from a hydraulic conveyance perspective.
 - Align the mounds of fill, rather than placing them randomly, as this creates the most restriction. The spacing is generally 100 metres between the centers of mounds.
 - Align the mounds of fill near existing roads, where possible, as this is more likely than development in the middle of a quarter-section or 80-acre parcel.
 - Placement of the mounds of fill is primarily driven by access, not based on the existing terrain elevation.
 - Set the mounds of fill back from the roads by at least 150 metres in either direction to maintain line-of-sight triangles, per the Draft R.M. Zoning Bylaw (reference [7]).
 - Mounds are circular shape at the top and 30 metres in diameter. Existing elevated structures are not built on necessarily circular or rectangular mounds but this is a simplifying assumption.
 - Mounds slope away from the top at 3.3% for 5 metres horizontally and then at 25% to the existing LiDAR terrain, according to the Draft R.M. Zoning Bylaw (reference [7]).
 - The tops of the mounds are set at between 0.5 and 0.6 metres above the existing condition 1:500 year flood level, wherever they are placed. This is to allow for at least 0.5 metres of freeboard (reference [1]), but not an excessive amount as developers will want to limit fill due to cost. Freeboard for future planning should be based on the sensitivity results presented in Section 3.5.
 - Hypothetical driveways are included in the full residential development future condition (one driveway per building site). The driveways are included as simple, straight lines to the nearest access road (either Township or Range Road). The driveways are assumed to be 10 metres wide. The elevation of the driveway was set through discussion with the R.M. and followed the logic routine in the bullet list below.
 - If the driveway is within the inundated area during the 1:100 year flood event, the driveway is set at the 1:100 year WSEL
 - If the existing ground is higher than the 100 year water surface elevation such that the driveway is not inundated during that event, then the driveway elevation is existing ground plus 0.3 metres.
 - In some instances where a nearby Township or Range Road did not exist, one was added along quarter section boundaries to provide access to the new hypothetical residential homes. These new Township or Range roads were added with the same elevation assumptions as the driveways, described in the bullet points above.

During the study, the WSA provided comments on the selected definition of future conditions. WSA reviewers had concerns about allowing development in the floodplain that only elevated structures and driveways and did not create an elevated roadway network that would allow for evacuation by vehicle without advanced forecasting. The R.M. is aware of this concern and will take it into future consideration.

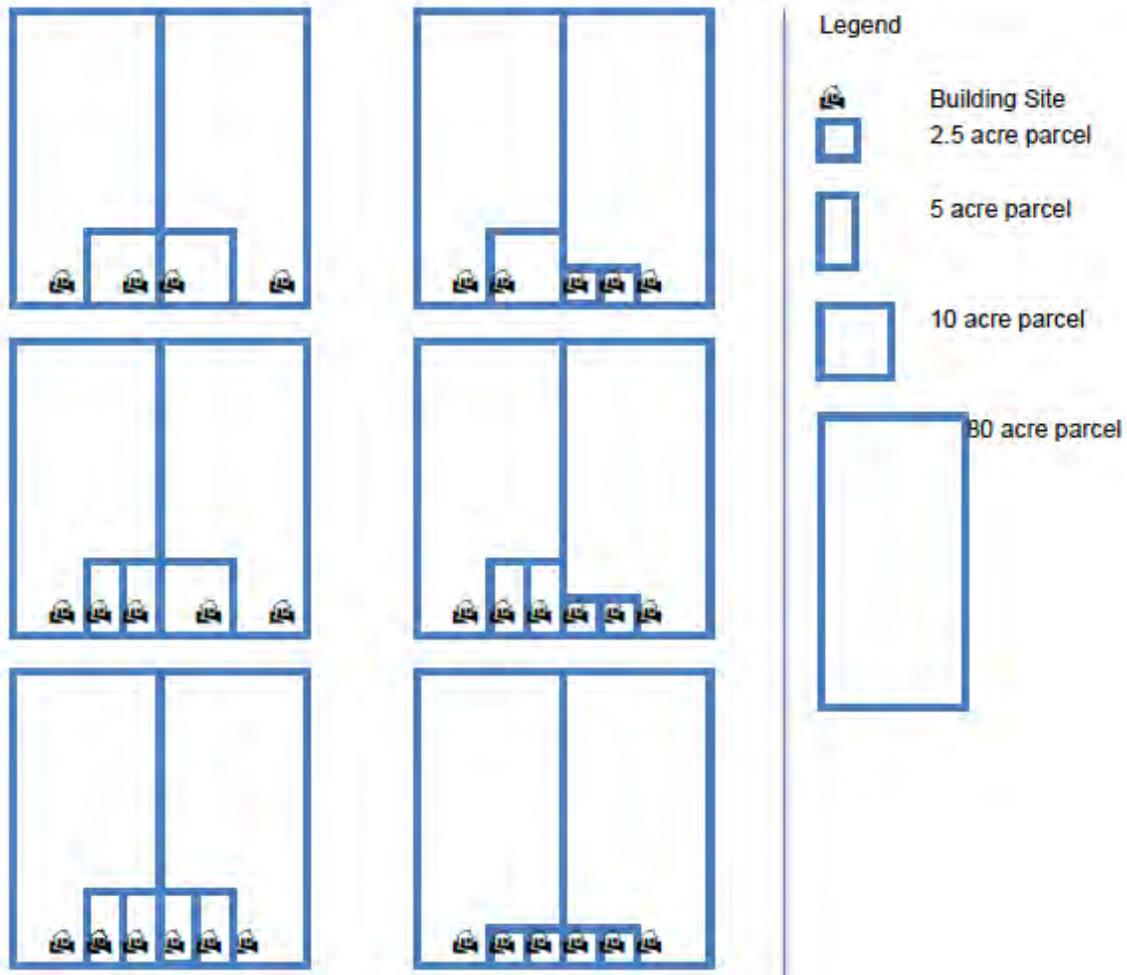


Figure 4-1 **Examples of proposed residential building site options at “3 per 80 acres”** provided by the R.M. of Corman Park (reference [16])

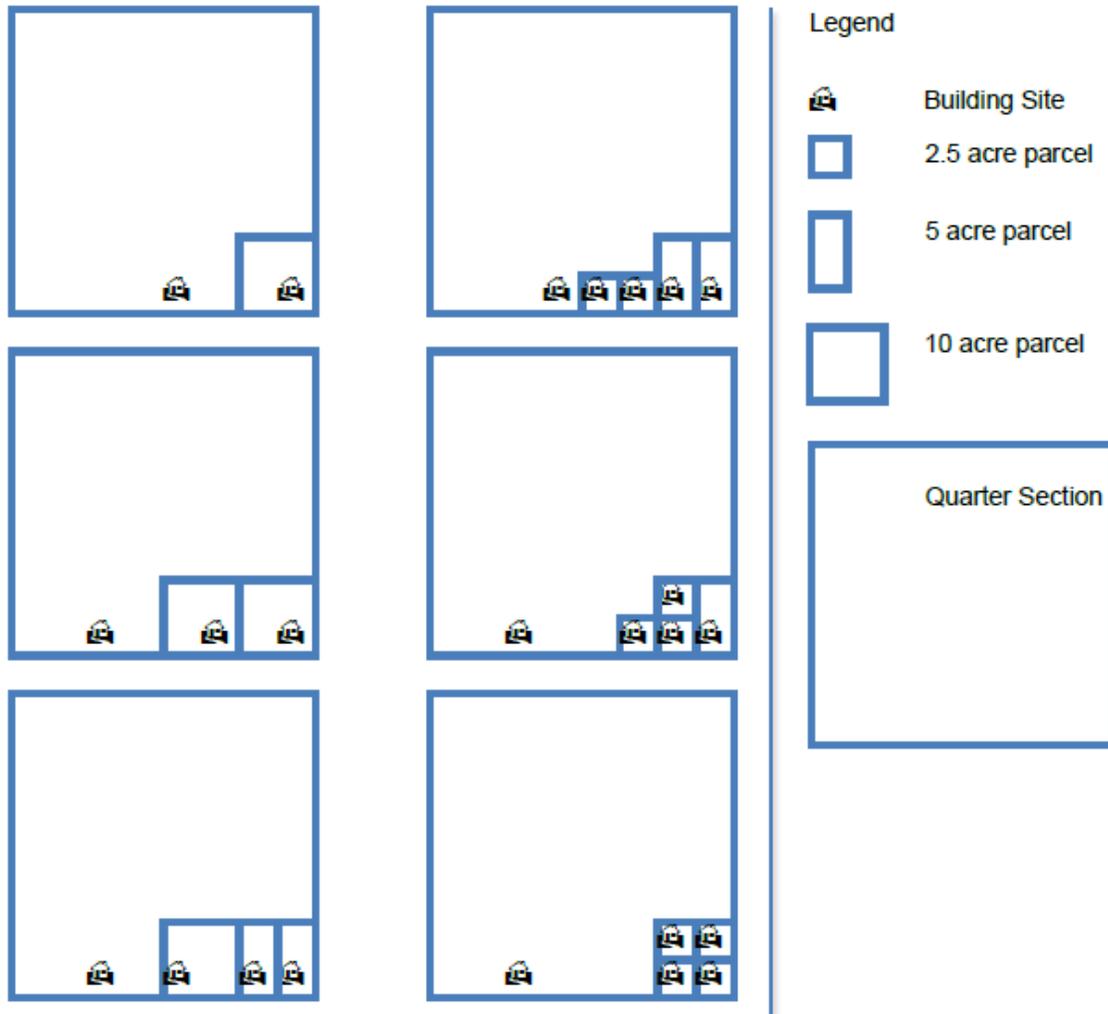


Figure 4-2 Examples of proposed residential building site options at “5 per ¼ section” provided by the R.M. of Corman Park (reference [17])

Following the guidelines and assumptions listed above, about 400 mounds of fill were hypothetically placed in the Corman Park study area, representing 400 new residences. This would nearly double the current number of residences within the study area (reference [2]). Figure 4-3 is an example comparison of the existing LiDAR and modifications to the terrain to represent one hypothetical future development condition. The mounds of fill appear in the terrain as small elevated bumps scattered throughout the area adjacent to the South Saskatchewan River.

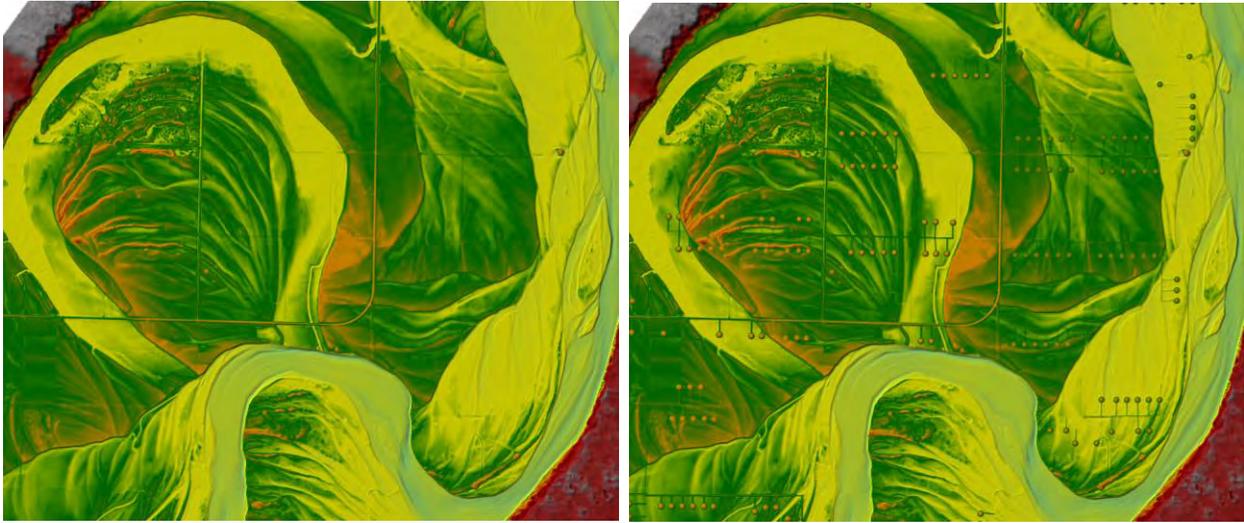


Figure 4-3 Comparison of the existing LiDAR terrain (left) and the terrain modification to represent one hypothetical fully developed future condition (right)

4.3 Boundary Conditions

The boundary conditions for the full residential development condition modelling were not changed from those for the existing-conditions modelling. Due to the mildly-sloping and low-velocity nature of the South Saskatchewan River, the proposed development in the Corman Park area will only potentially impact the water level and velocity within and upstream of Corman Park and will not impact areas downstream. Additionally, it was assumed that flood plain management policies within the City of Saskatoon will prevent development within Saskatoon from causing higher water levels within Corman Park for a given flood event. Therefore, the downstream rating curve boundary condition is not changed. Additionally, it was assumed that management of development within Corman Park, and the upstream Rural Municipalities of Dundurn and Vanscoy, will not substantially affect the flow rates of specific flood events which are largely driven by what is released from Gardiner Dam. Therefore, the upstream flow boundary condition is not changed either.

4.4 Mesh Generation

The numerical mesh used for the full residential development condition was not changed from the one used in the existing condition. The number of cells was approximately 150,000 cells ranging from 20 metres squared (m^2) to 1,600 m^2 , and averaging just under 500 m^2 .

4.5 Results

Results of the full residential development conditions modelling are presented as large maps in Attachment B. Figure B-1 shows the water depth throughout the model domain during the peak of the regulatory event: the 1:500 year (0.2% AEP) flood event. Light blue areas are inundated with shallower depths of water and dark blue areas are areas of greater depth of water. Figures B-2, B-3, and B-4 show the water depth throughout the model domain during the peak of the 1:200 year (0.5% AEP), 1:100 year (1% AEP), and 1:50 year (2% AEP) events, respectively.

In all of the figures of Attachment B, particularly in the 1:500 year flood event figures, there are notable areas that are not inundated. They appear in the figure as a light green or brown colour because of the visible fields in the aerial imagery (see Figure 3-11). Additionally, in the figures of Attachment B which represent the full residential development condition, small circles of dry areas are visible all throughout the flood plain. These small circles are the locations where the hypothetical mounds of fill were placed (above the 1:500 year WSEL) to represent residential development. These areas are expected to be dry (not inundated) during the 1:500 year flood event because the mounds are elevated above the surrounding water surface elevation.

Figure B-5 shows the flow velocity magnitude throughout the model domain during the peak of the regulatory event. Light blue areas are inundated with slow-moving water and red areas have the fastest flowing water. Figures B-6, B-7, and B-8 show the flow velocity magnitude throughout the model domain during the peak of the 1:200 year (0.5% AEP), 1:100 year (1% AEP), and 1:50 year (2% AEP) events, respectively. Floodway areas based on velocity considerations alone (greater than or equal to 1 metre per second) are confined to the main channel of the South Saskatchewan River and small, sparse areas of shallow, concentrated flow (i.e., south of Township Road 354 and west of the river).

Figure B-9 shows the classified water depth throughout the model domain during the peak of the regulatory event. The water depth is classified as either greater than or equal to 1 metre (red colour) or less than 1 metre (blue colour). Figure B-10 shows the classified flow-velocity magnitude throughout the model domain during the peak of the regulatory event. The velocity is classified as either greater than or equal to 1 metre per second (red colour) or less than 1 metre per second (blue colour).

4.5.1 Consideration of Sensitivity Run Results

Sensitivity runs were completed to quantify the level of uncertainty for the model results. The sensitivity model runs, which are discussed in Section 3.5, resulted in approximately a +/- 20 centimetre change in the water surface elevation due to uncertainty in roughness values. Additionally, the accuracy of the calibration presented in Section 3.4 is about 11 centimetres when considering all flow events modelled, and about 20 centimetres for the large flood event of 2013. The cumulative uncertainty of the calibration and model roughness values is less than the current minimum freeboard of 0.5 metres in the SPIs (reference [1]).

4.5.2 Impacts on the Flood Plain

Impacts to the flood plain are included in Attachment B as Figure B-11 (impact to water surface elevation) and Figure B-12 (impact on velocity). In general, regarding the impact to the water surface elevation as a result of full residential development, the water surface elevation increased by less than 2 centimetres throughout most of the floodplain, and less than 1 centimetre throughout most of the northern half of the floodplain. There are relatively small isolated regions where the water surface elevation rose by up to 5 centimetres due to the full residential development. The small isolated regions of the greater rise (up to 5 cm) are typically on the upstream side of a row of mounds, which caused a restrictive effect on the flow. In some areas, particularly in the northern part of the study area, on the downstream side of a row of mounds, the water surface elevation actually decreased due to the full residential development. This

makes sense hydraulically because the concentrated row of mounds caused the water to flow around them more than through them. However, this difference is small, on the order of a couple of centimetres.

The results of the impact analysis on the water surface elevation show that the impacts of a full residential development condition are well below the 30 centimetre encroachment criterion that has been used historically in Saskatchewan to define the floodway and flood fringe. The encroachment criterion is based on the premise that the cumulative impact of development in the floodplain should be less than 30 centimetres for the regulatory flood. Allowing this level of encroachment would still increase the flood risk of existing properties, but would be below the low floor elevation for structures built to at least the 1:500 year flood elevation plus 0.5 metres.

Regarding the impact on flow velocity, the vast majority of the South Saskatchewan River and its floodplain changed by between -0.1 and +0.1 metres per second (i.e., no significant change). In general, increases in velocity occurred in small localized areas between the mounds of fill, when the flow was concentrated between them. This happens when the flow direction in the flood plain is approximately perpendicular to the row of houses. Flow velocity decreases, also in small localized areas, on the upstream and downstream sides of the mounds, relative to the flow direction. This is because the mounds would block the flow, cause it to decelerate, and force the water around and between the mounds. The R.M. may want to consider future policies to guide placement of elevated structures so that local velocity effects are avoided. For example, as best can be managed, avoid placement of elevated structures in a row perpendicular to the general flow direction.

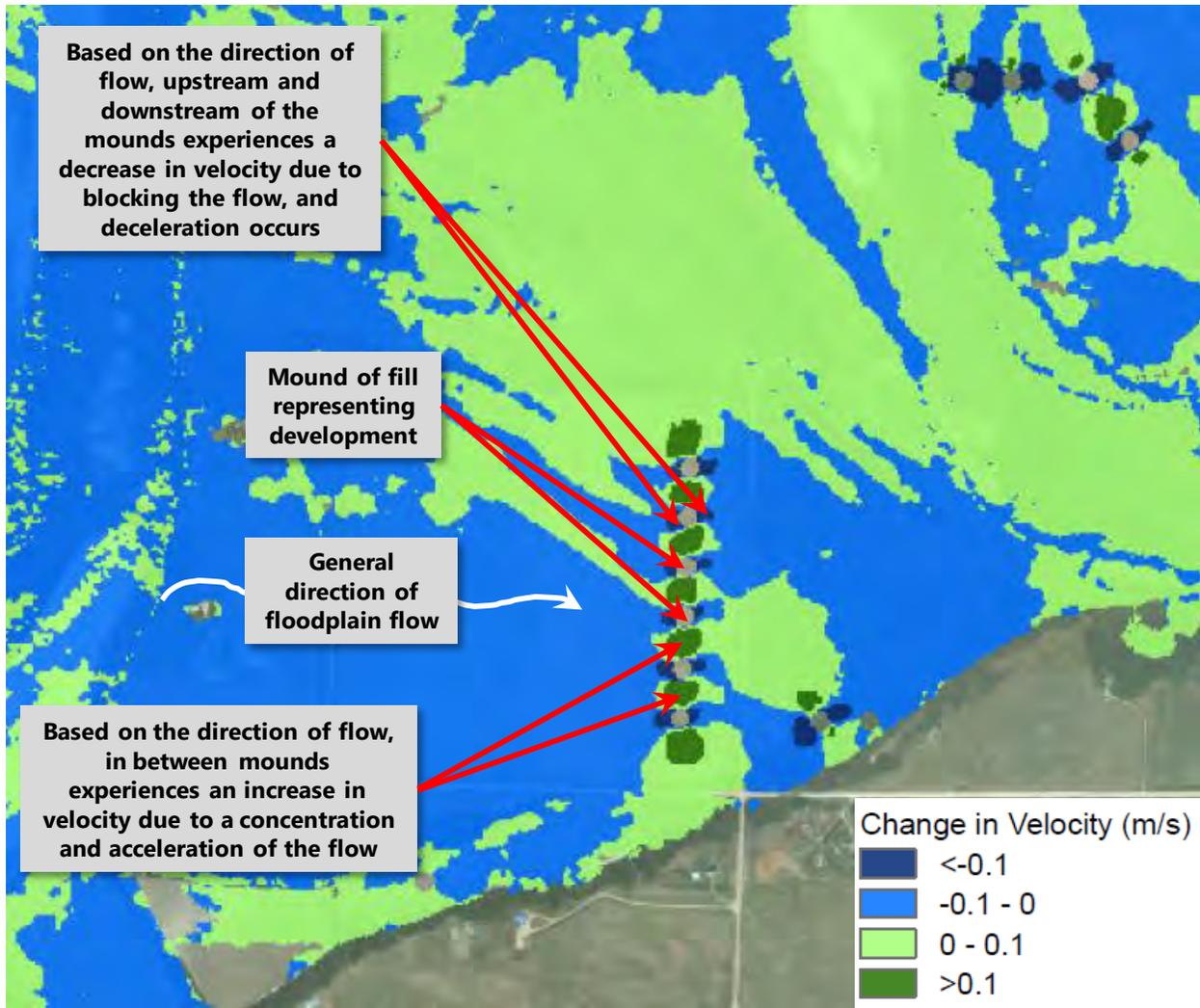


Figure 4-4 Explanation of the velocity impacts figure, Figure B-12, in Attachment B

Because the fully developed condition had so little impact on the water surface elevation, the flood events in which Valley Road (within the domain of the 2D model) is usable or not are essentially the same as for the existing condition, described in Section 3.7. In summary for the fully developed condition, Valley Road is entirely open and usable during the 1:50 year flood event. At the peak of the 1:100 year flood event there are very short portions of Valley Road that could be inundated, yet Valley Road may be passable during this event. During the 1:200 year and 1:500 year flood events, Valley Road would not be usable for evacuation purposes (see Figure B-2 and B-1, respectively, in Attachment B).

5.0 Conclusion

The development of a 2D hydraulic model of the South Saskatchewan River through Corman Park provides a more nuanced understanding of the range of flow depths and velocities in the flood plain for a range of events and allows for the delineation of the flood plain into floodway and flood fringe areas. This information will provide the technical basis for revising Corman Park's standards to mitigate flood risk while allowing for responsible and safe development within some areas of the flood plain.

The current provincial regulations define the floodway as any location where the 1:500 year velocity is greater than or equal to 1 metre per second or where the water depth is greater than or equal to 1 metre (reference [1]). Even with the 2D modelling, much of the flood plain (75%) would still be considered floodway based on the 1 metre depth restriction. There are areas throughout the floodplain that meet the current definition of the flood fringe under the provincial regulations and would permit development, subject to required flood-proofing measures. However, strictly adhering to the current provincial regulations would limit the extent of future development, and permitted locations would need to be carefully placed within the flood fringe areas.

A decision will likely need to be made regarding whether to keep the 1 metre depth restriction or to allow something less restrictive. When exploring alternative regulatory frameworks, Corman Park and provincial policymakers may want to research floodplain regulations for coastal communities in Canada or the United States, as they often allow elevated structures within the flood plain.

For this study area, elevating structures on mounds is a practical method for allowing development in the flood plain, while minimizing the potential for property damage. The proposed development density is dispersed enough that increases in regulatory flood elevations caused by constructing mounds and driveways would be localized and less than 0.10 metres. Calculated impacts to upstream water surface elevations for the R.M. of Dundurn are less than 0.02 metres. These changes in water surface elevations are shown in Figure B-11. In order to minimize localized and upstream effects of future full development in the flood plain (including in the flood fringe areas), Corman Park and provincial policymakers should consider the extent of permitted future development and permitted locations would need to be carefully placed within the flood fringe.

There would still be residual flood risk to persons and property in flood plain developments that are elevated to meet provincial SPIs and R.M. requirements. For example, homeowners who do not evacuate prior to a major flood event could be stranded in their home with limited ability to leave or receive emergency services. Without elevating the roadway network to higher than the 1:500 year water surface elevation, people who live within the flood plain would rely on advanced notice and evacuation to reduce risk. Drinking water wells may be at risk too if not properly protected from or elevated above flood waters.

Further study may be warranted to identify ways to reduce residual flood risk through improvements to development policy and emergency management processes. This could involve a review of current development requirements relative to those of other jurisdictions for things like wellhead protection and transportation access. Similarly, emergency management processes could be compared with those of

other jurisdictions to identify best practices for things like emergency communication channels, dissemination of flood forecast information, triggers for initiating voluntary and mandatory evacuations, and educational strategies for raising awareness of flood hazards within the community.

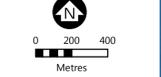
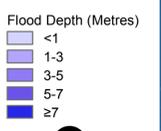
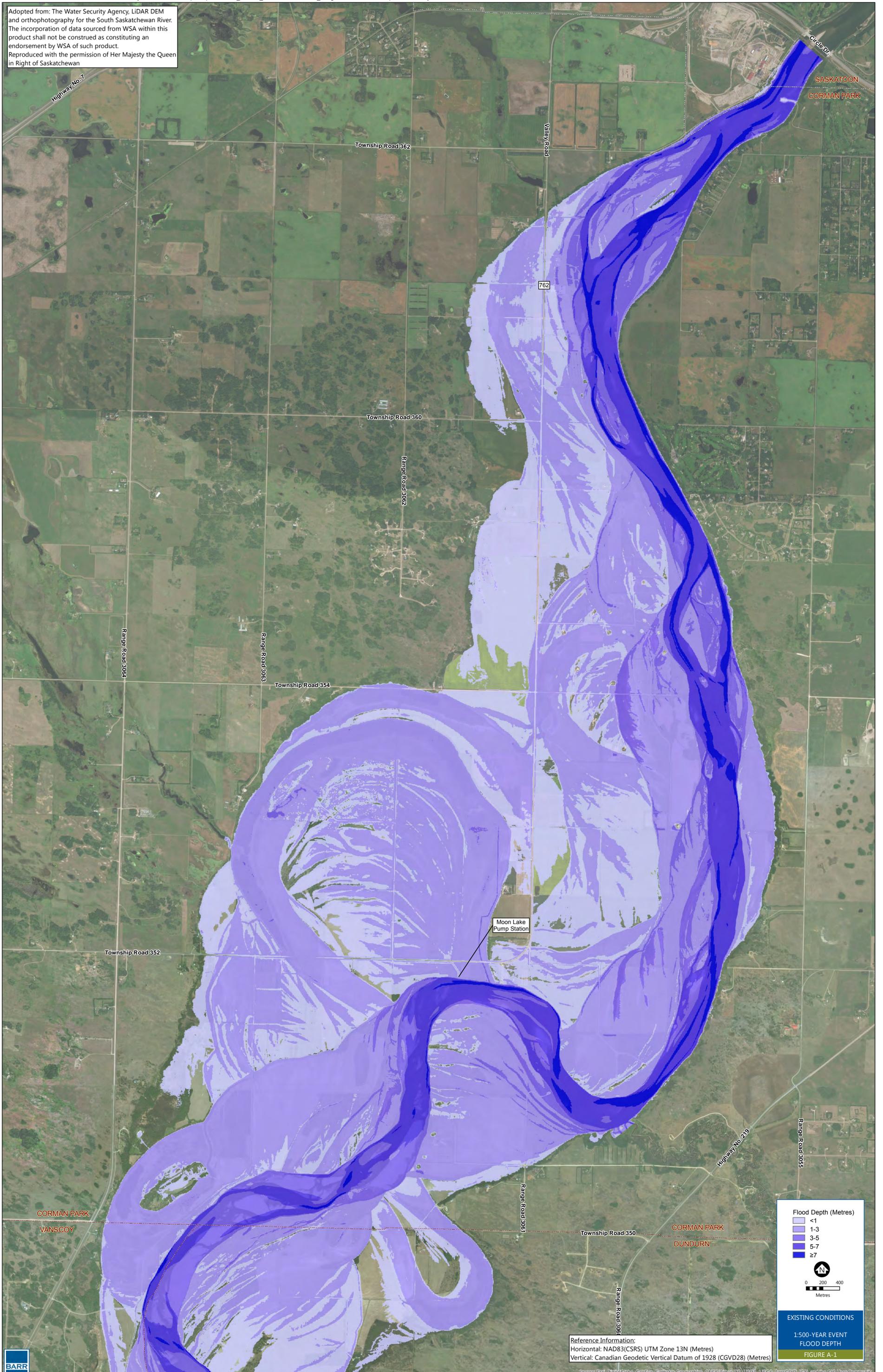
6.0 References

- [1] Government of Saskatchewan, "The Statements of Provincial Interest Regulations, 2014," March 2012.
- [2] Rural Municipality of Corman Park No. 344, "Request for Proposals: South Saskatchewan River Flood Plain - Hydraulic Modelling and Mapping Study," Saskatoon, SK, January 16, 2018.
- [3] Rural Municipality of Corman Park No. 344, "Official Community Plan," Consolidated 2018.
- [4] Corman Park - Saskatoon Planning District, "Official Community Plan," Consolidated 2017.
- [5] The Water Security Agency, "Updated WSA Model (HEC-RAS)," Saskatchewan, 2016/2017.
- [6] A. Skibinsky, "Design Water Levels - South Saskatchewan River Upstream of Saskatoon," May 2009.
- [7] Rural Municipality of Corman Park No. 344, "Draft Zoning Bylaw," August 2012.
- [8] The Water Security Agency, "LiDAR DEM for the South Saskatchewan River," 2007.
- [9] The Water Security Agency, "Report on Hydrometric Review of South Saskatchewan River Watershed," Hydrometric Program, Basin Operations Unit, Engineering and Geoscience Division, August 2013.
- [10] The Water Security Agency, "Rating Curve, South Saskatchewan River at Moon Lake Pumphouse," Curve Start Date 2015.
- [11] Rural Municipality of Corman Park No. 344, "Zoning Bylaw," Consolidated 2018.
- [12] Corman Park - Saskatoon Planning District, "Zoning Bylaw," Consolidated 2017.
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- [14] The Water Security Agency, "Orthophotography for the South Saskatchewan River," June 27-28, 2013.
- [15] D. Dill, "Subject: 2005 Moon Lake Water Levels," March 21, 2006.
- [16] Rural Municipality of Corman Park No. 344, "Examples of Proposed Residential Building Site Options, 80-Acre Parcels," 2018.
- [17] Rural Municipality of Corman Park No. 344, "Examples of Proposed Residential Building Site Options, 1/4-Section Parcels," 2018.

Attachment A

Existing-Condition Maps

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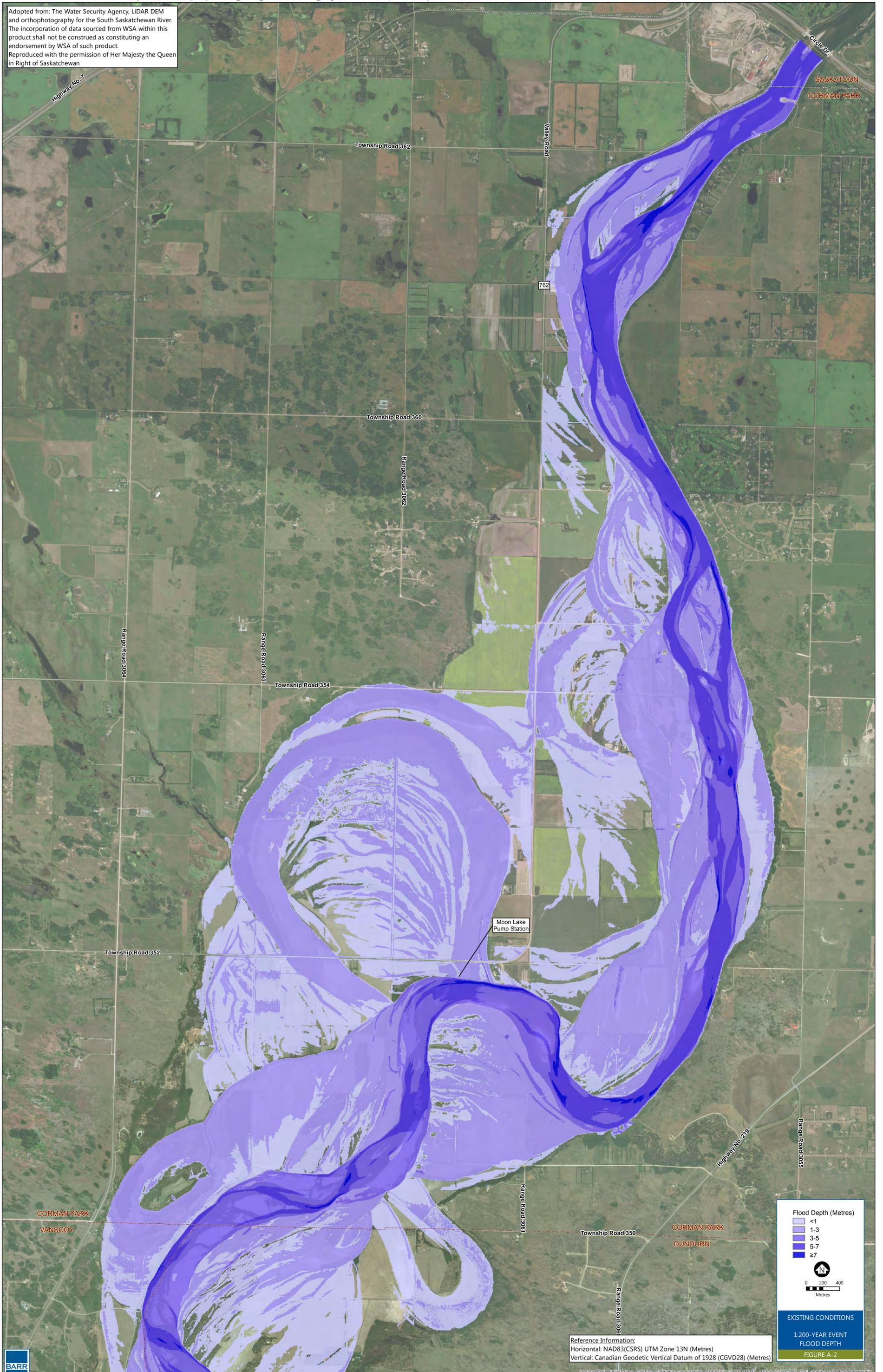


EXISTING CONDITIONS
1:500-YEAR EVENT
FLOOD DEPTH
FIGURE A-1

Reference Information:
Horizontal: NAD83(CSR5) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)



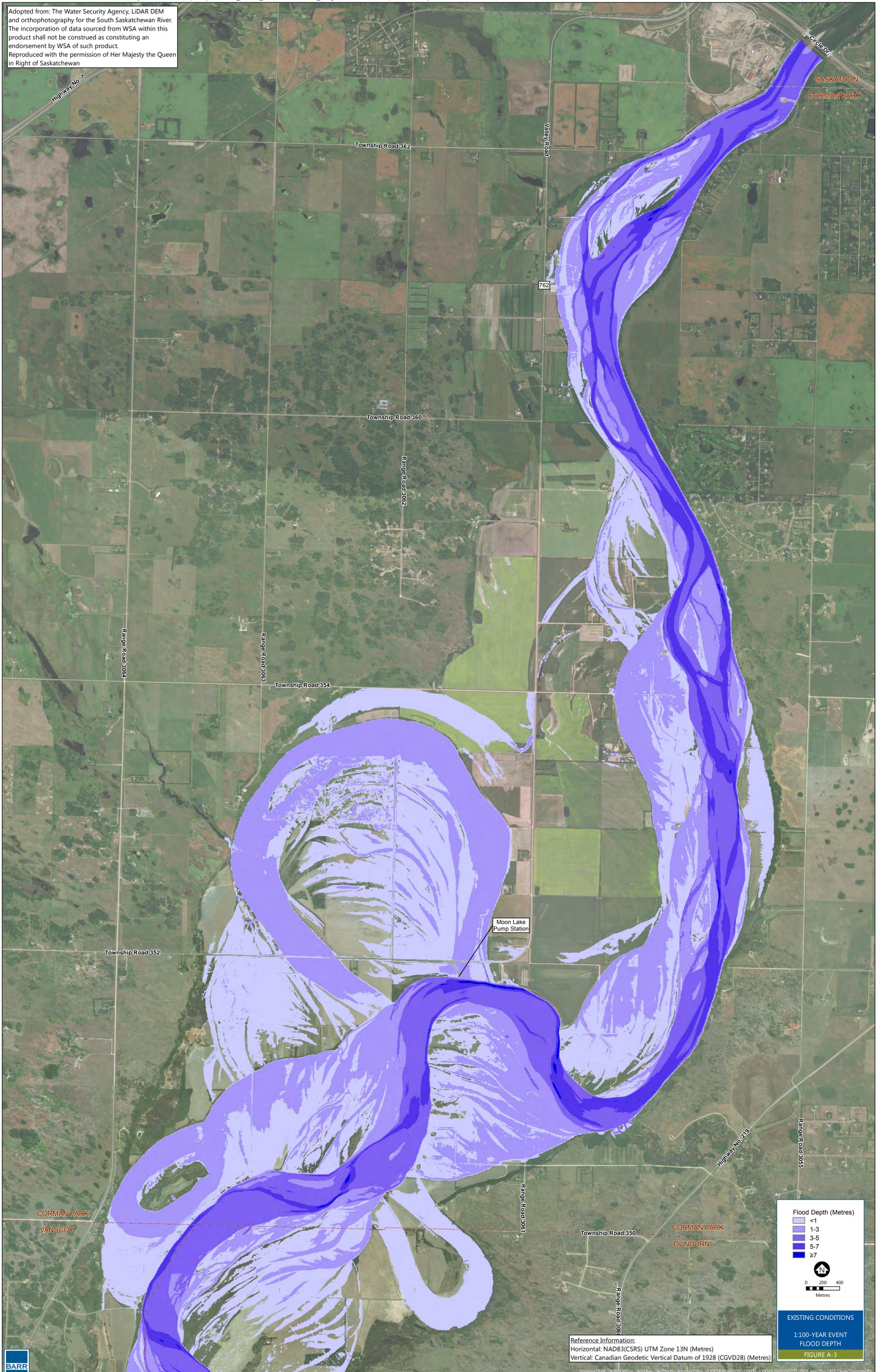
Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

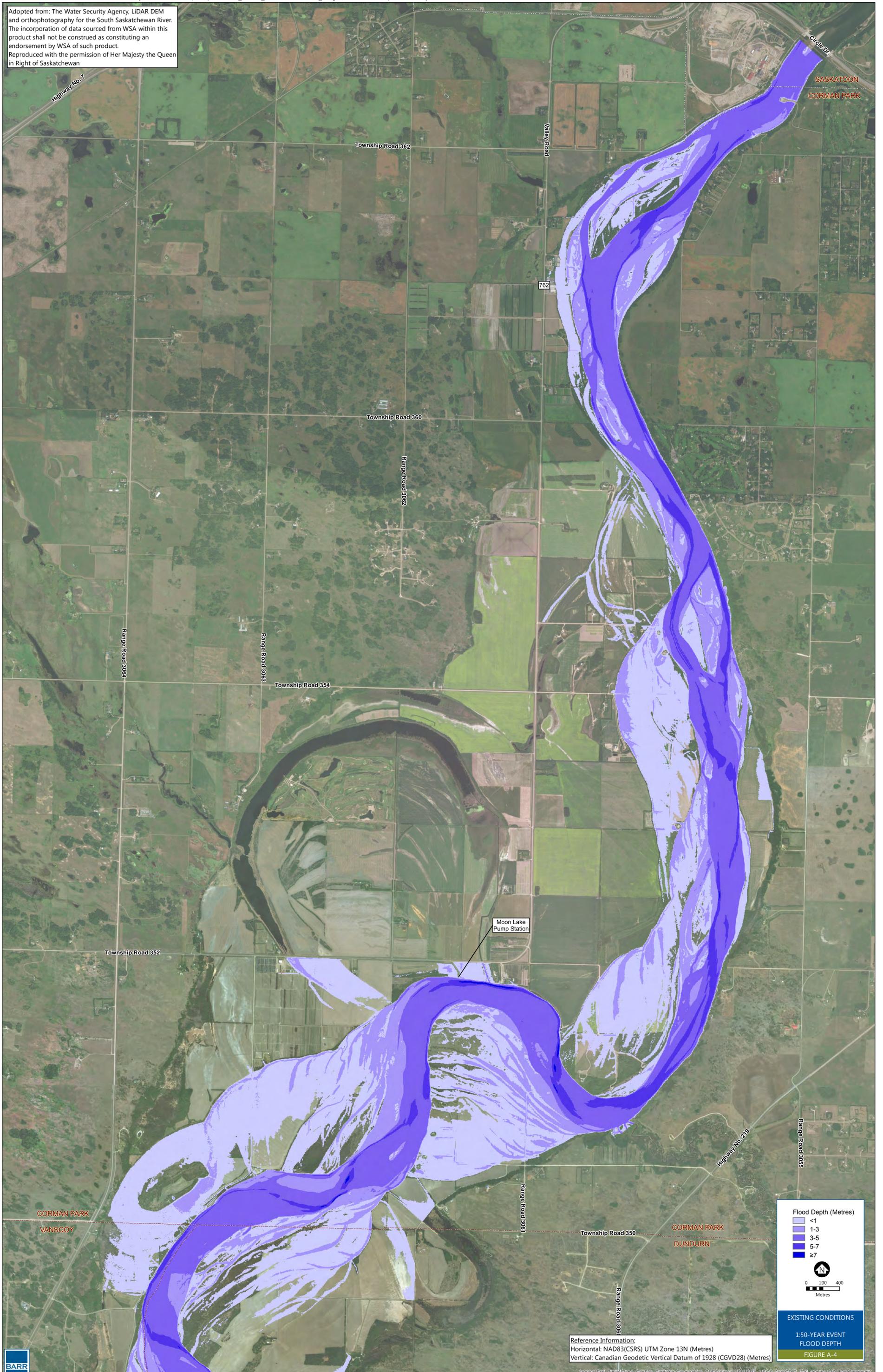


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Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

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Reference Information:
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Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

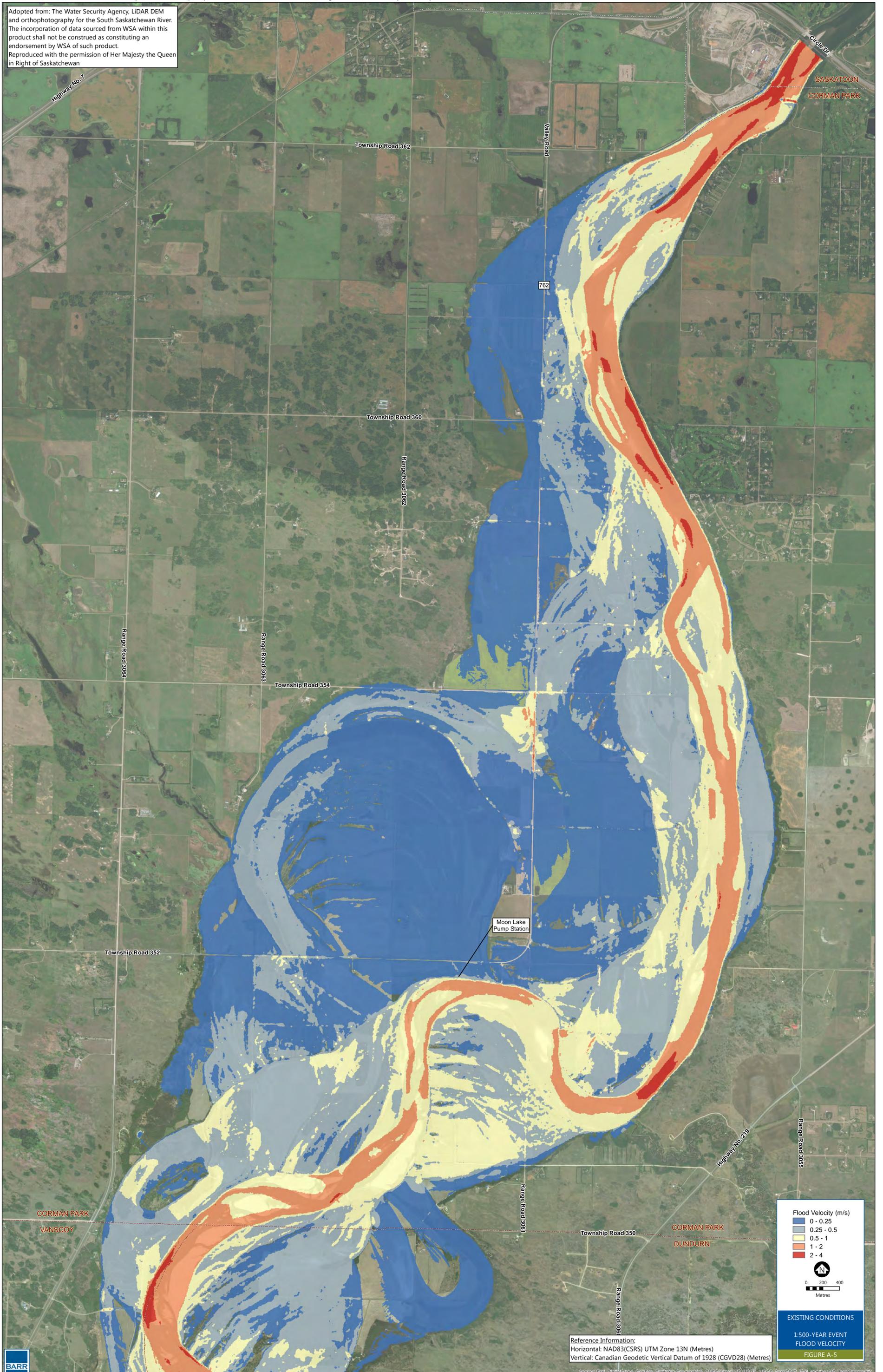
Flood Depth (Metres)

- <1
- 1-3
- 3-5
- 5-7
- ≥7

0 200 400
Metres

EXISTING CONDITIONS
1:50-YEAR EVENT
FLOOD DEPTH
FIGURE A-4

Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Flood Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4

0 200 400 Metres

EXISTING CONDITIONS

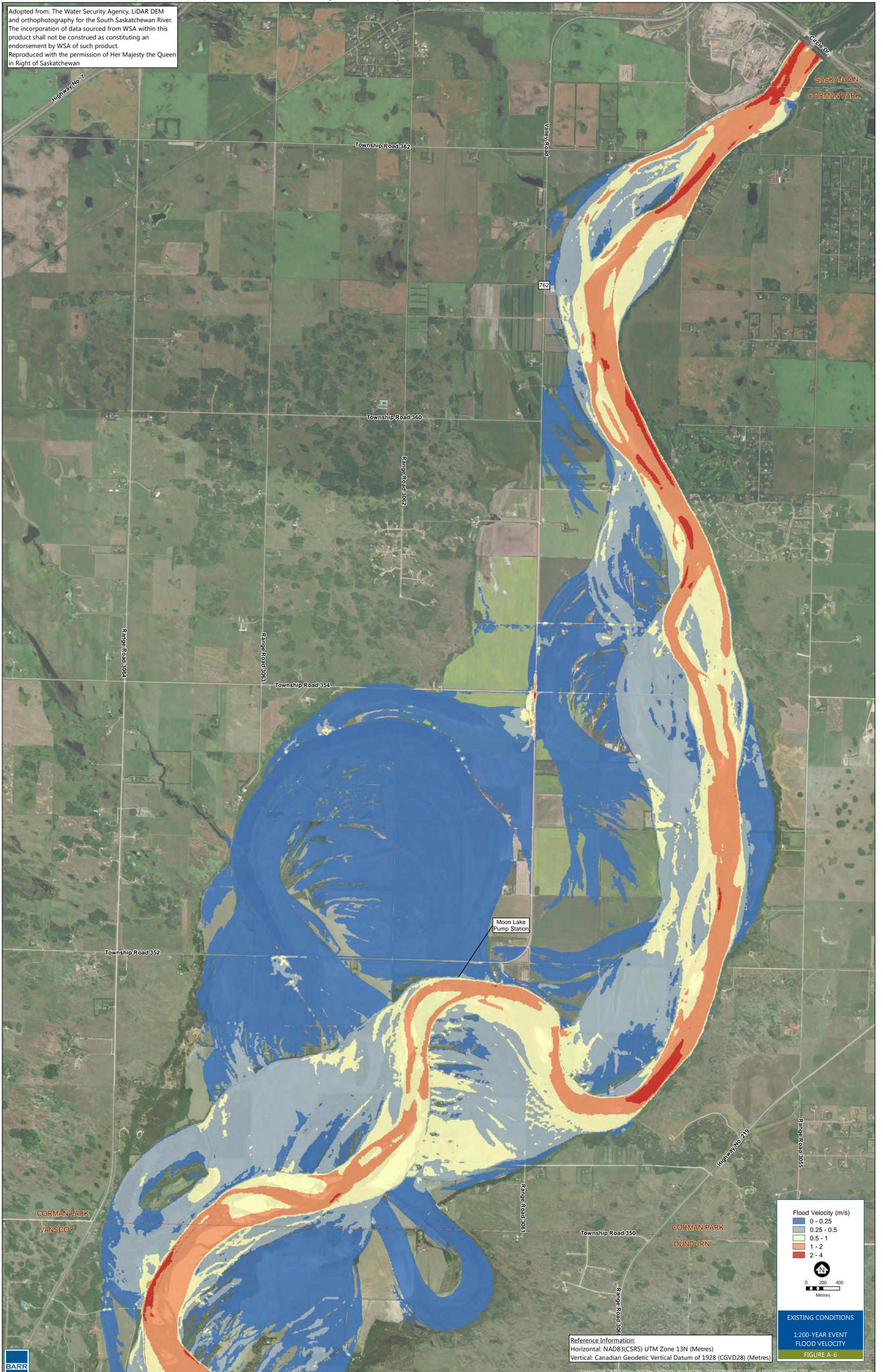
1,500-YEAR EVENT FLOOD VELOCITY

FIGURE A-5

Reference Information:
Horizontal: NAD83(CSR) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)



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Reference Information:
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Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

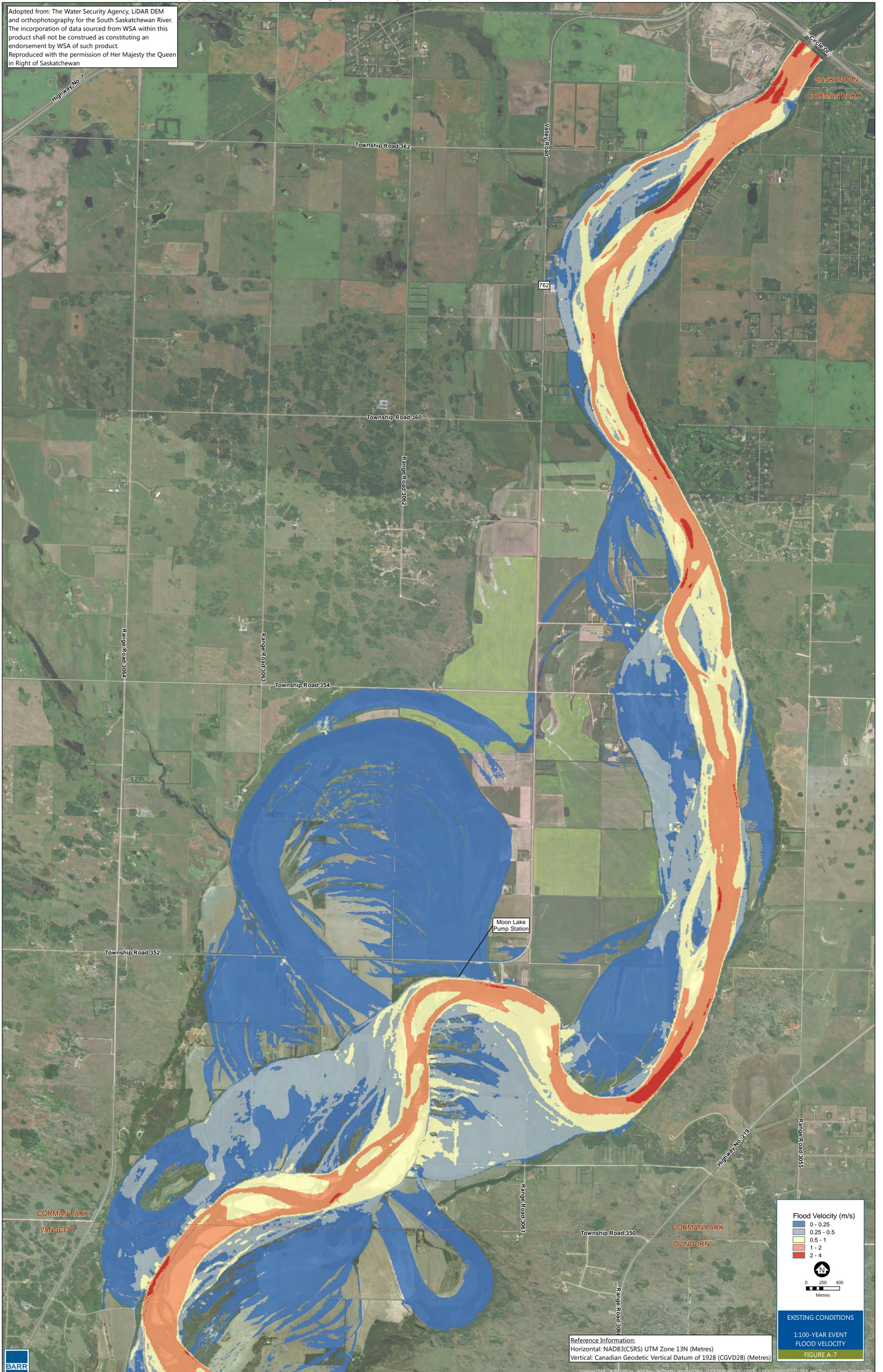
Flood Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4

0 200 400
Metres

EXISTING CONDITIONS
1:200-YEAR EVENT
FLOOD VELOCITY
FIGURE A-6

Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Flood Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4

EXISTING CONDITIONS

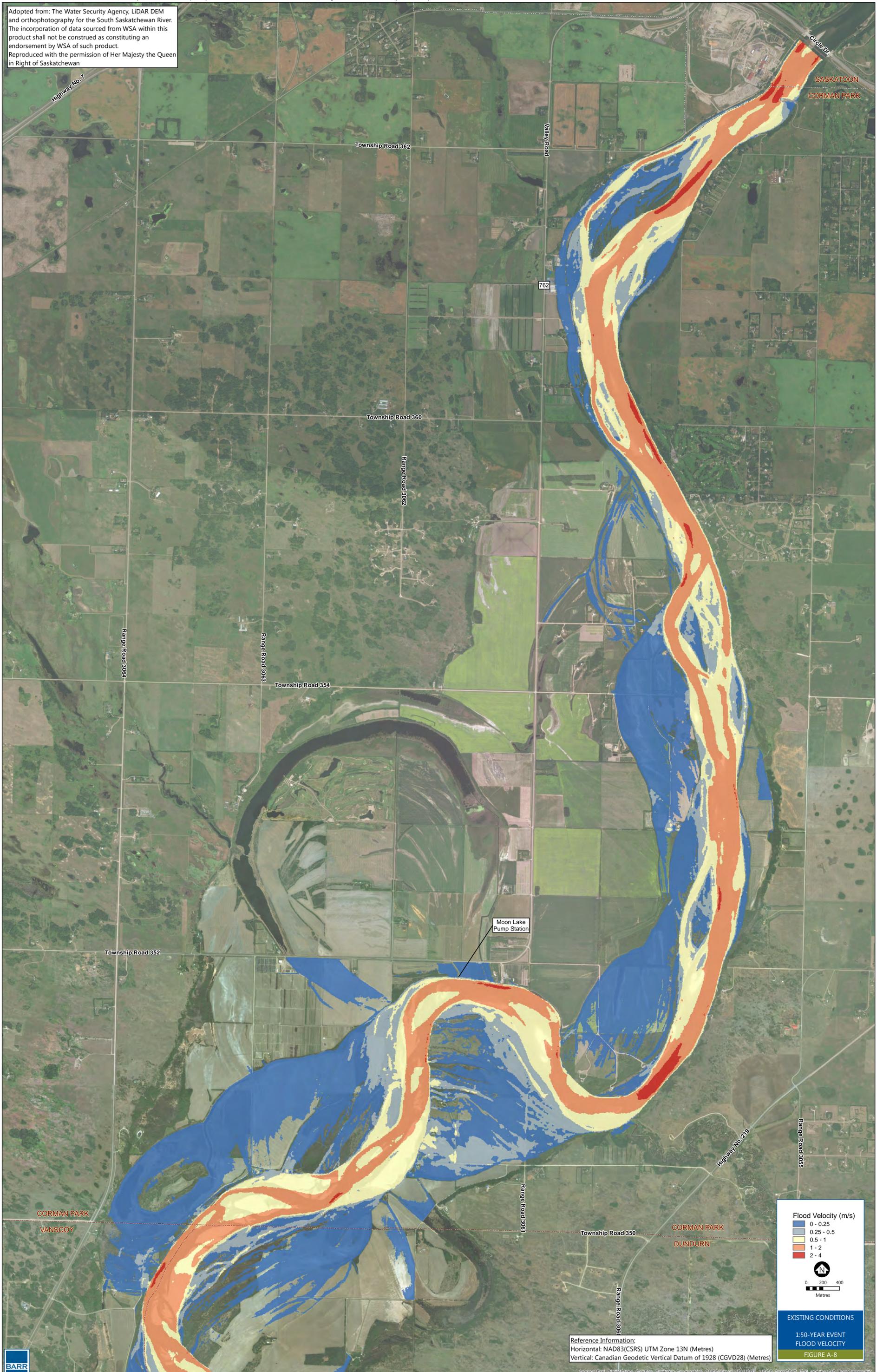
1:100-YEAR EVENT
FLOOD VELOCITY

FIGURE A-7

Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)



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Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Flood Velocity (m/s)

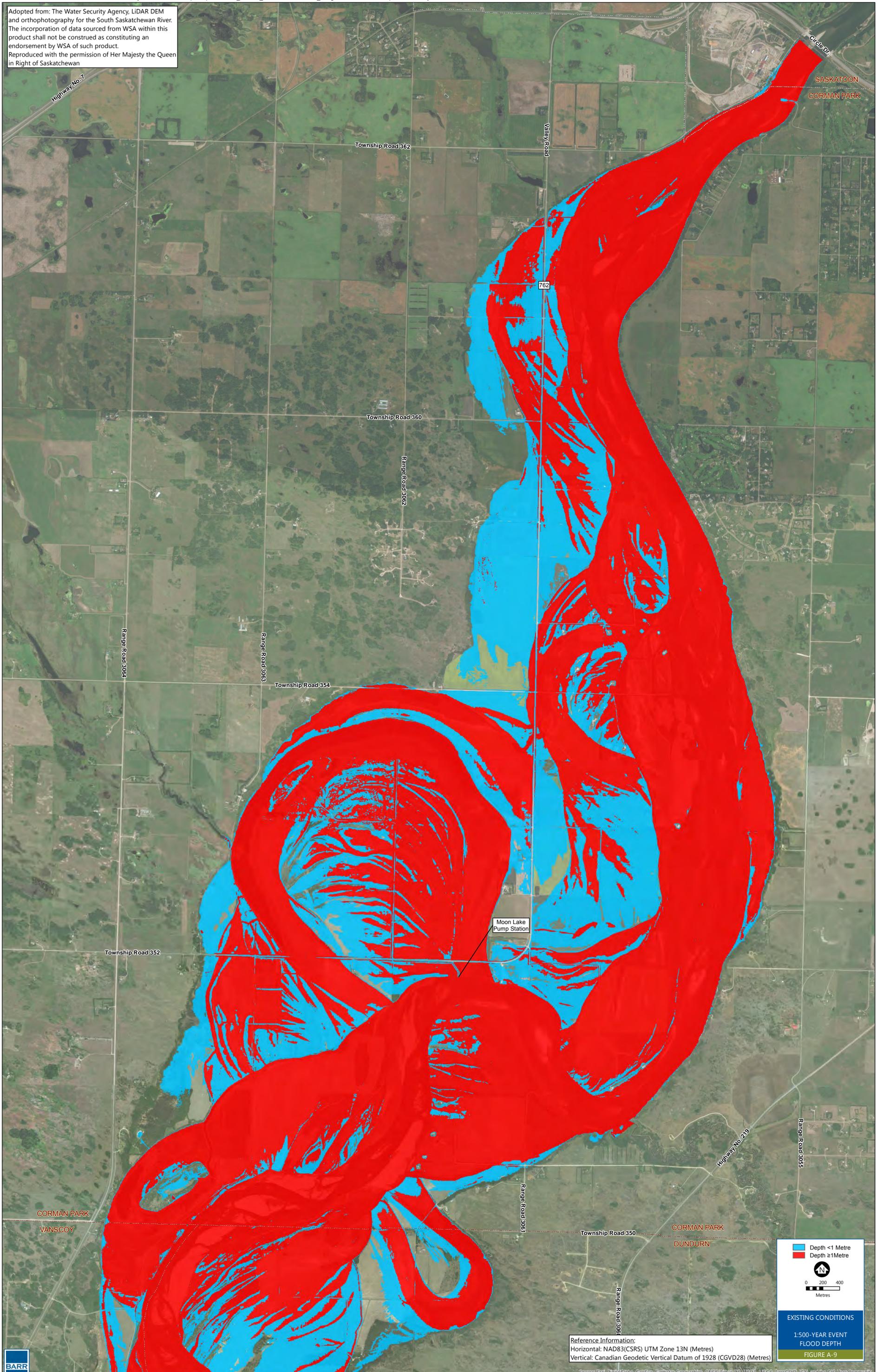
- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4

EXISTING CONDITIONS

1:50-YEAR EVENT FLOOD VELOCITY

FIGURE A-8

Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Reference Information:
Horizontal: NAD83(CSR) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Legend:
Depth <1 Metre (Red)
Depth ≥1 Metre (Blue)

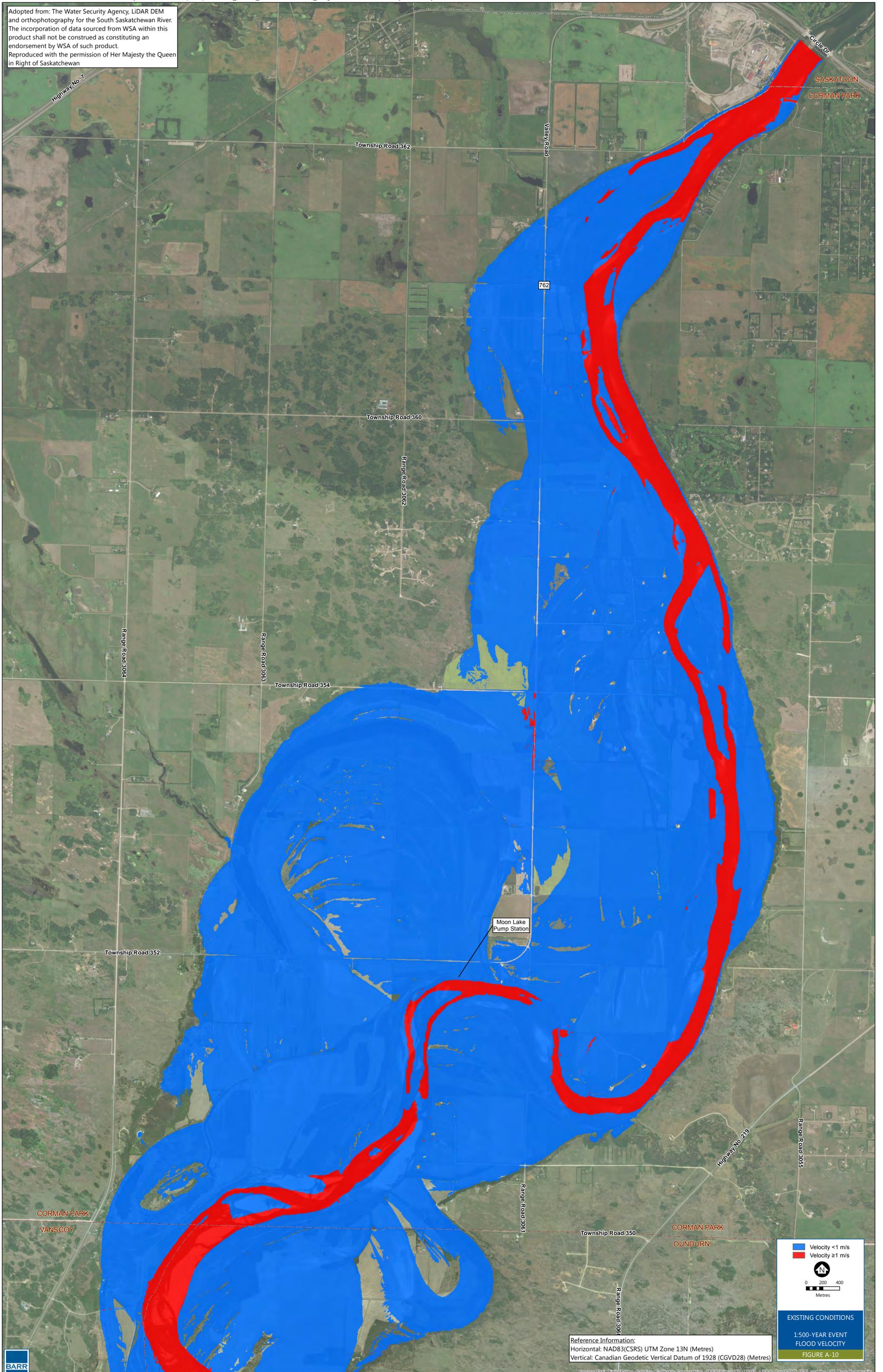
Scale:
0 200 400 Metres

North Arrow

EXISTING CONDITIONS
1:500-YEAR EVENT
FLOOD DEPTH
FIGURE A-9



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Reference Information:
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Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

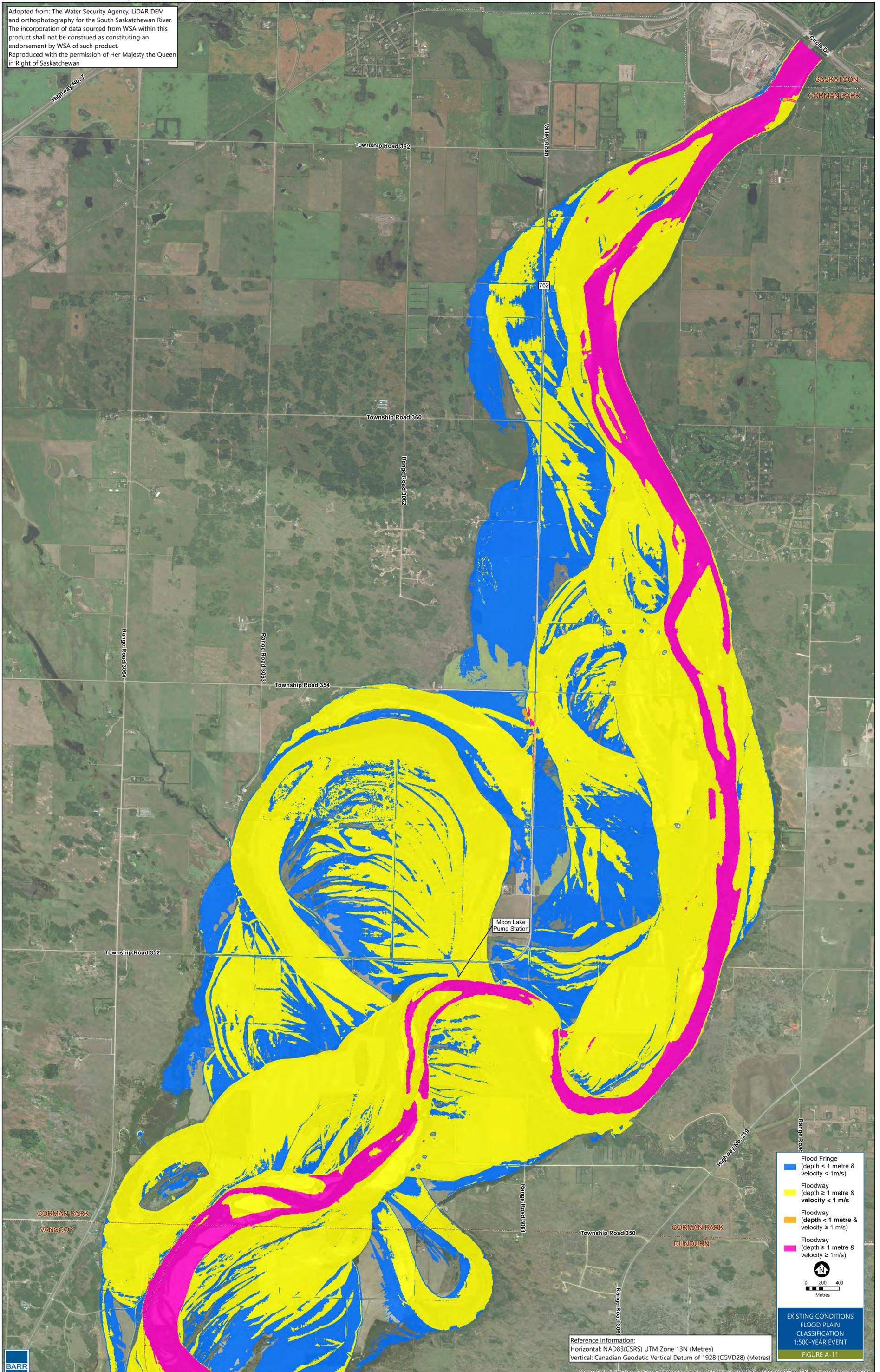
Legend:
Blue: Velocity < 1 m/s
Red: Velocity ≥ 1 m/s

Scale:
0 200 400
Metres

North Arrow

EXISTING CONDITIONS
1:500-YEAR EVENT
FLOOD VELOCITY
FIGURE A-10

Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



■ Flood Fringe (depth < 1 metre & velocity < 1 m/s)
■ Floodway (depth ≥ 1 metre & velocity < 1 m/s)
■ Floodway (depth < 1 metre & velocity ≥ 1 m/s)
■ Floodway (depth ≥ 1 metre & velocity ≥ 1 m/s)

0 200 400
 Metres

Reference Information:
 Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
 Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

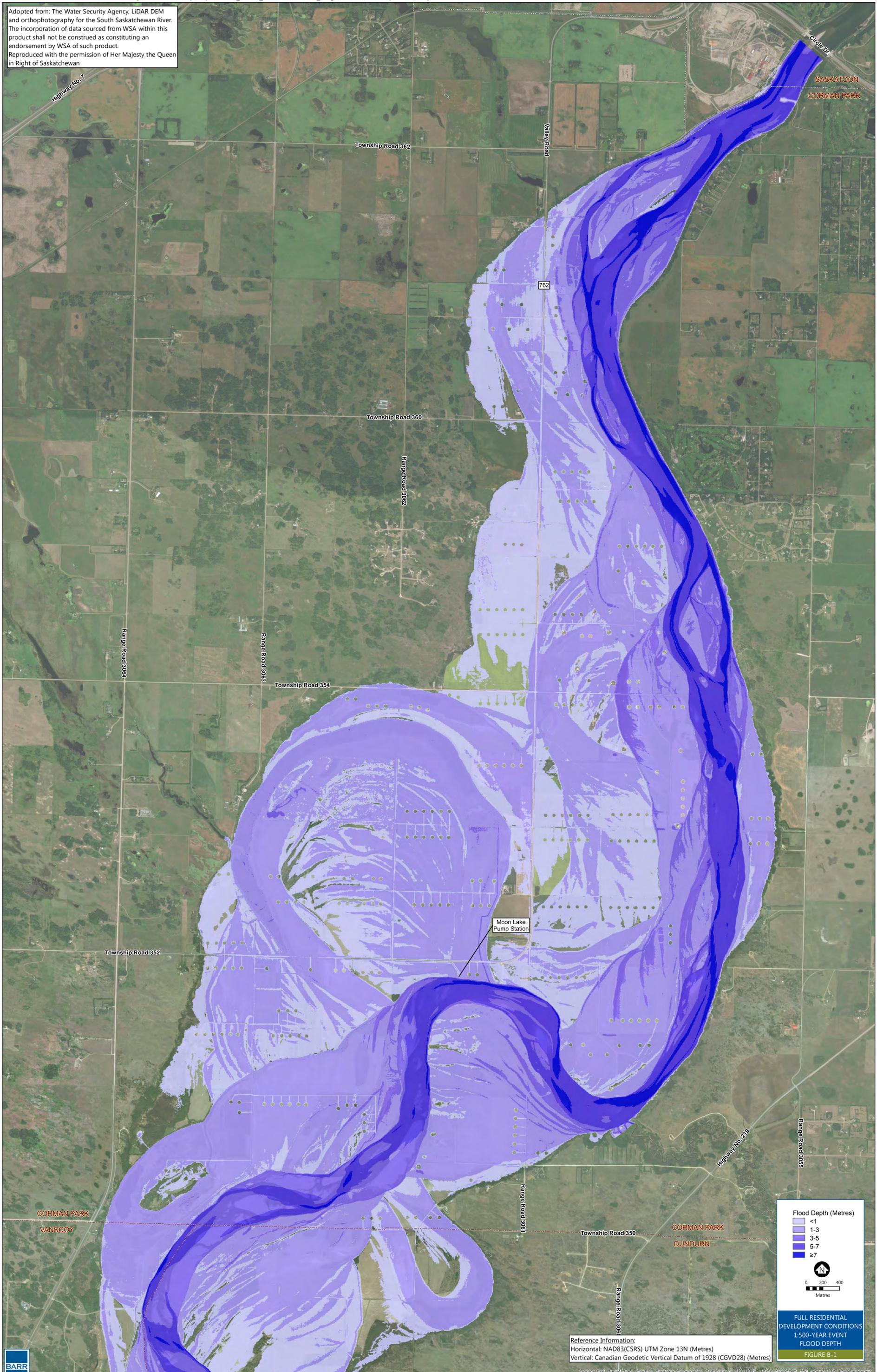
EXISTING CONDITIONS
 FLOOD PLAIN
 CLASSIFICATION
 1,500-YEAR EVENT
 FIGURE A-11



Attachment B

Full Residential Development Condition Maps

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Reference Information:
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Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

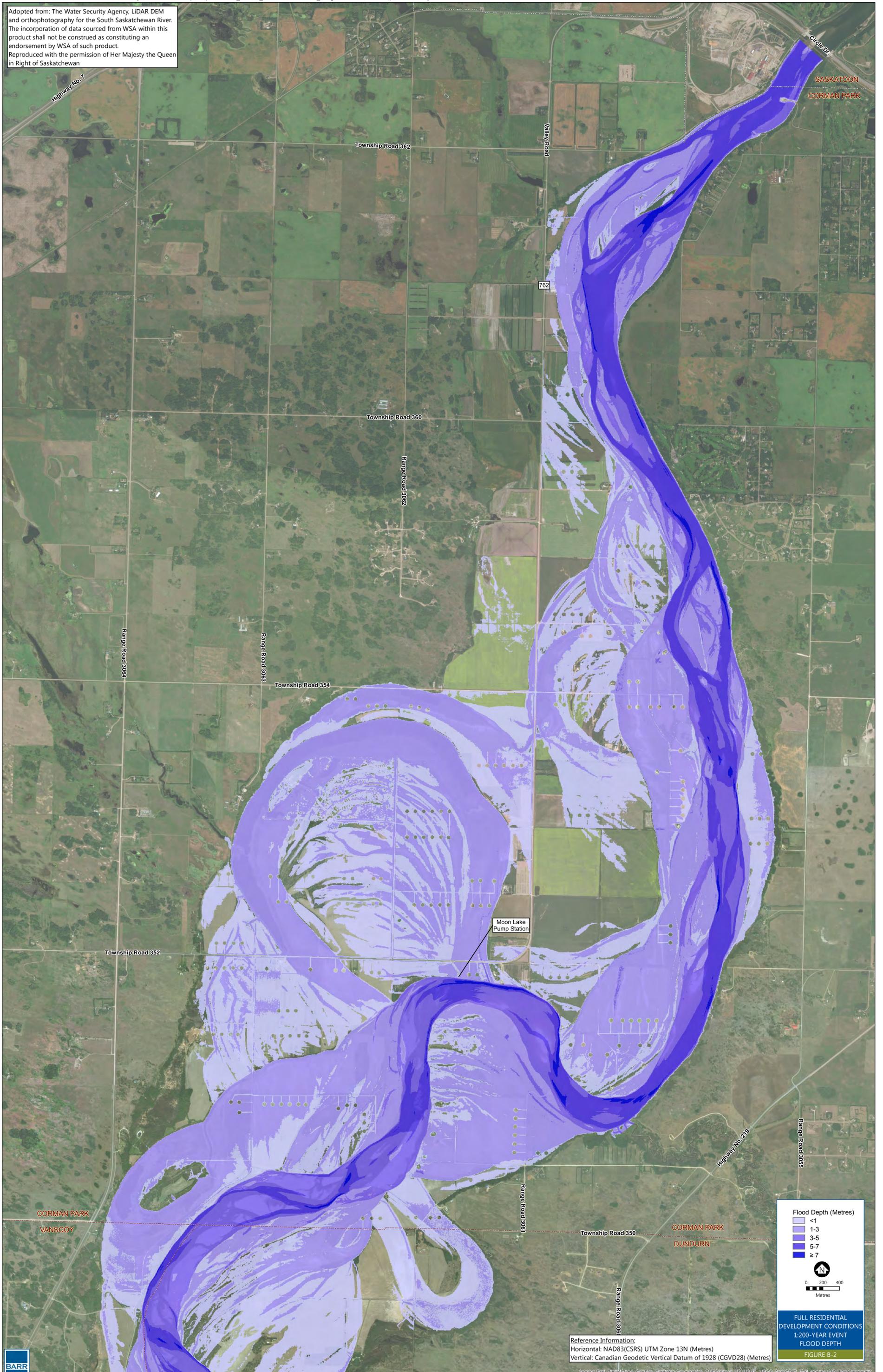
Flood Depth (Metres)

- <1
- 1-3
- 3-5
- 5-7
- ≥7

0 200 400
Metres

FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1:500-YEAR EVENT
FLOOD DEPTH
FIGURE B-1

Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Reference Information:
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Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Flood Depth (Metres)

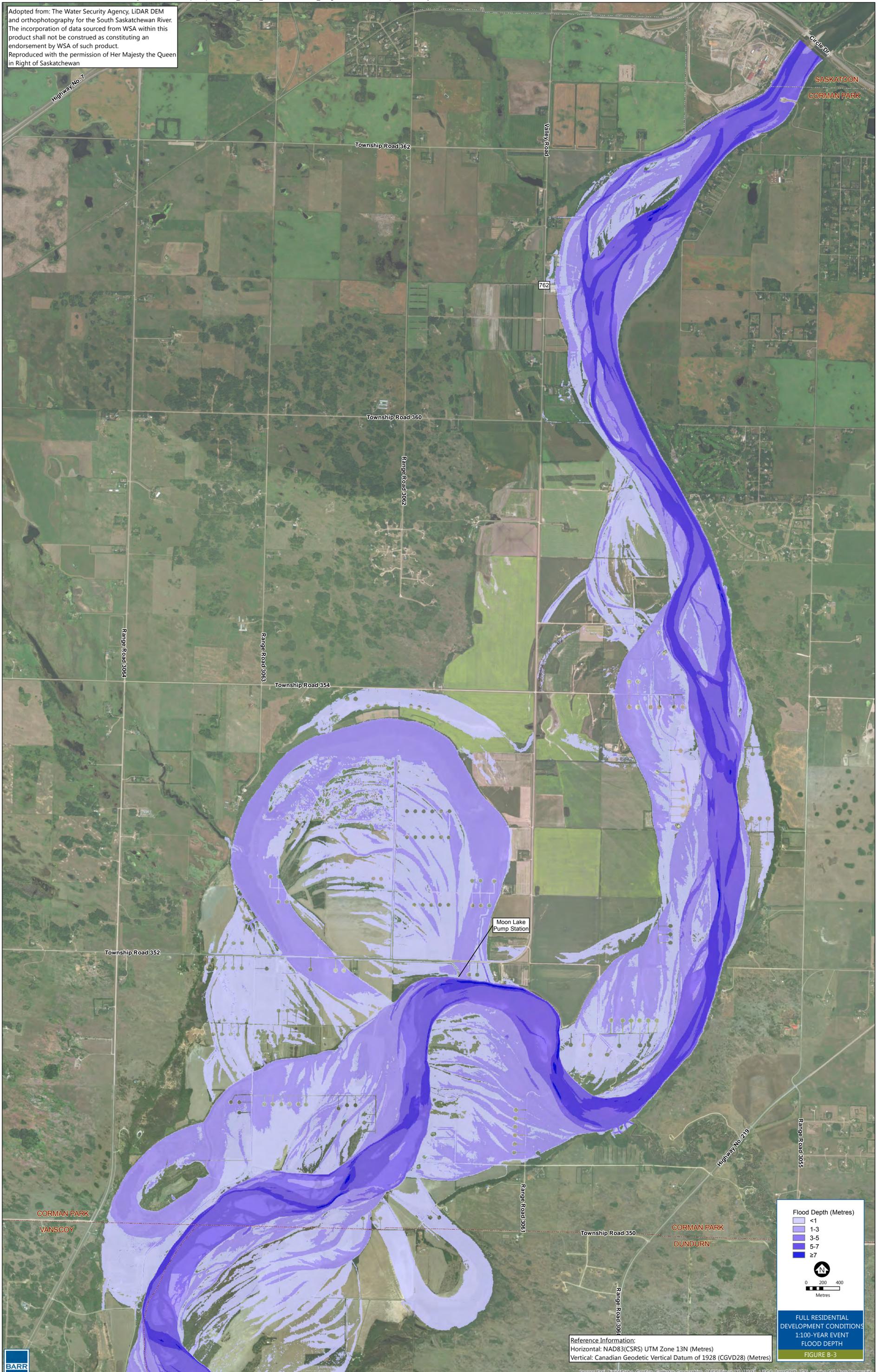
- <1
- 1-3
- 3-5
- 5-7
- ≥ 7

0 200 400
Metres

FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1:200-YEAR EVENT
FLOOD DEPTH
FIGURE B-2



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Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Flood Depth (Metres)

- <1
- 1-3
- 3-5
- 5-7
- ≥7

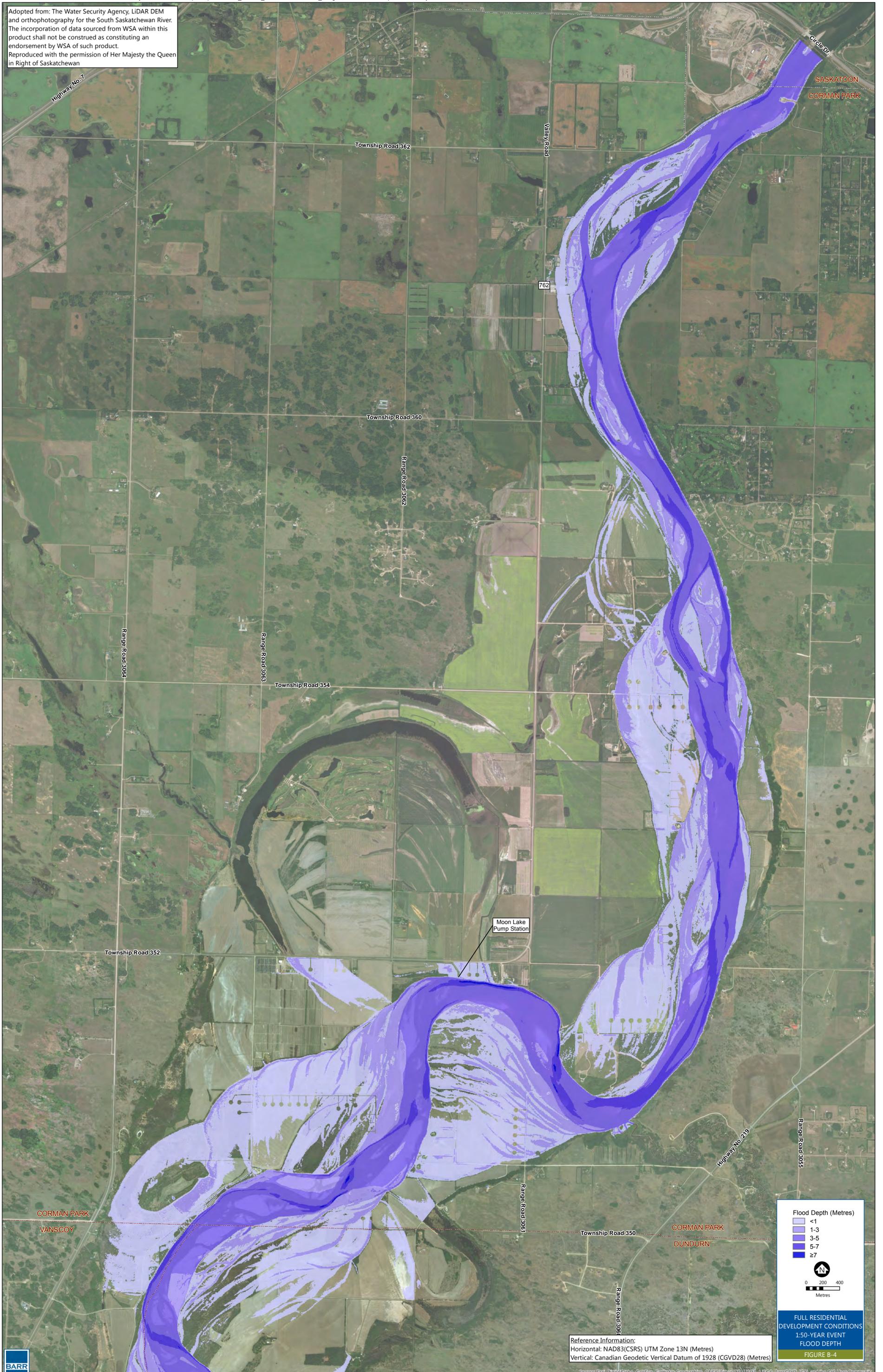
0 200 400
Metres

FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1:100-YEAR EVENT
FLOOD DEPTH

FIGURE B-3



Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Flood Depth (Metres)

- <1
- 1-3
- 3-5
- 5-7
- ≥7



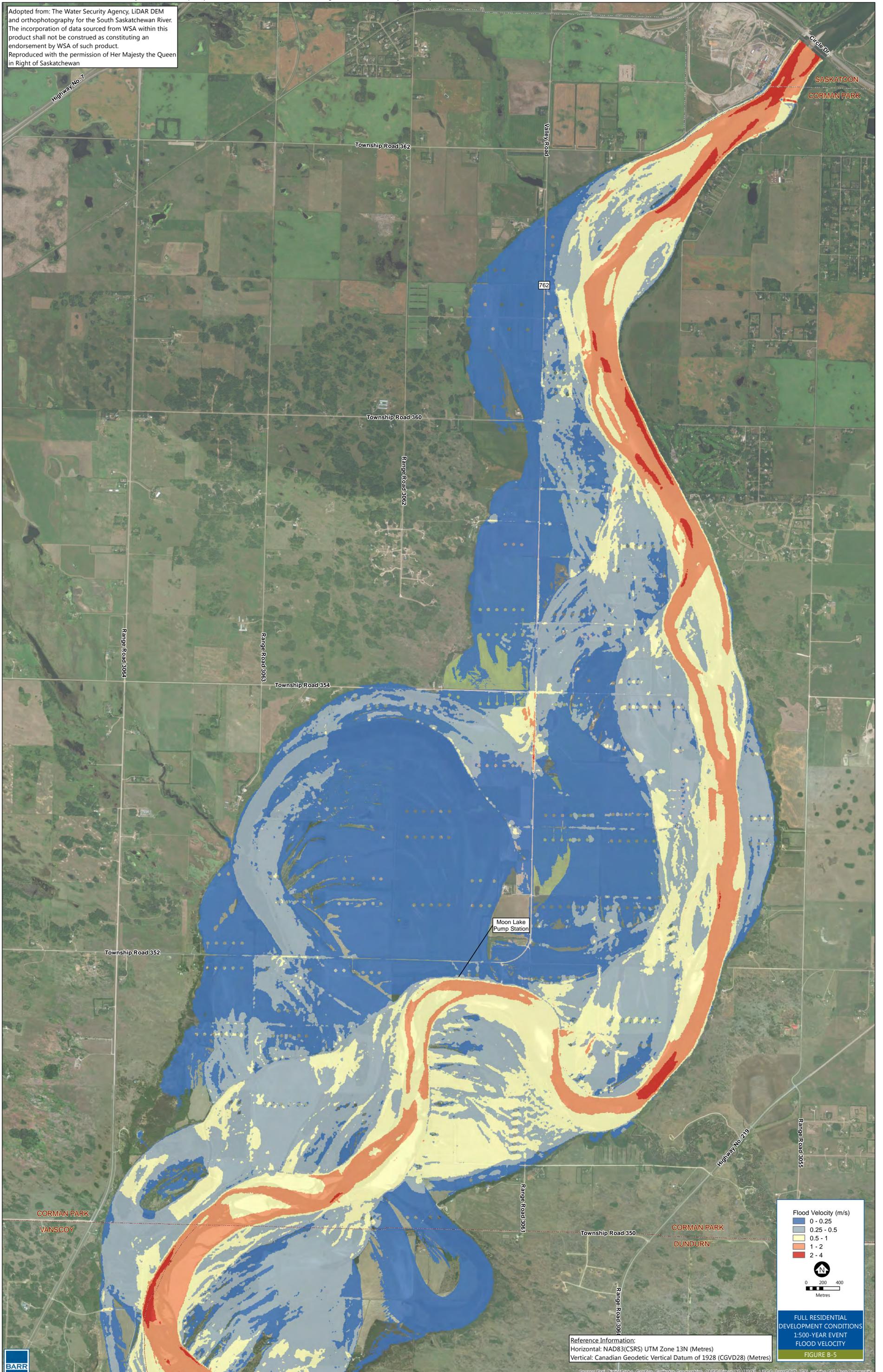
0 200 400
Metres

FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1:50-YEAR EVENT
FLOOD DEPTH
FIGURE B-4

Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)



Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



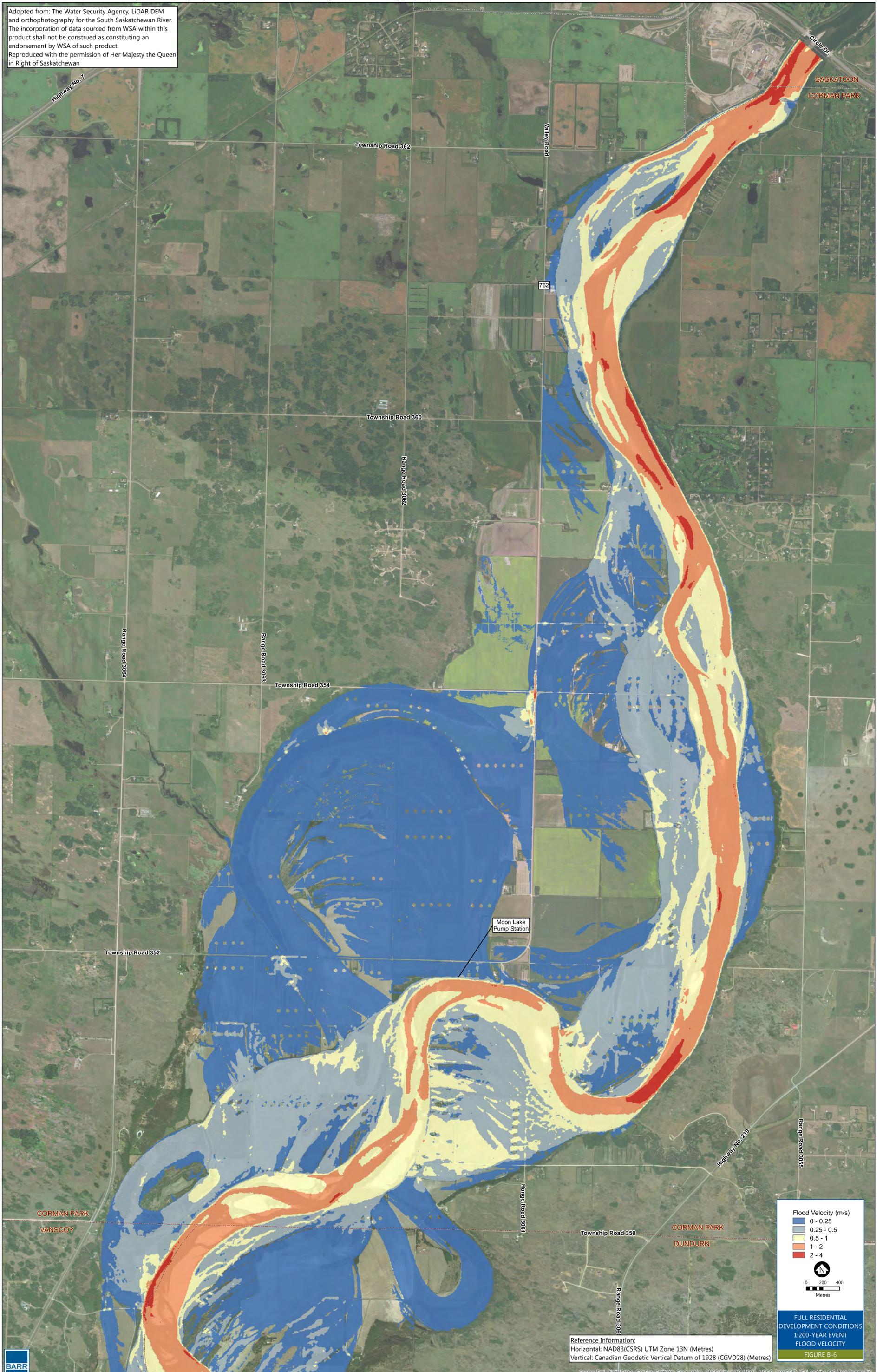
Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Flood Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4

FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1,500-YEAR EVENT
FLOOD VELOCITY
FIGURE B-5

Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

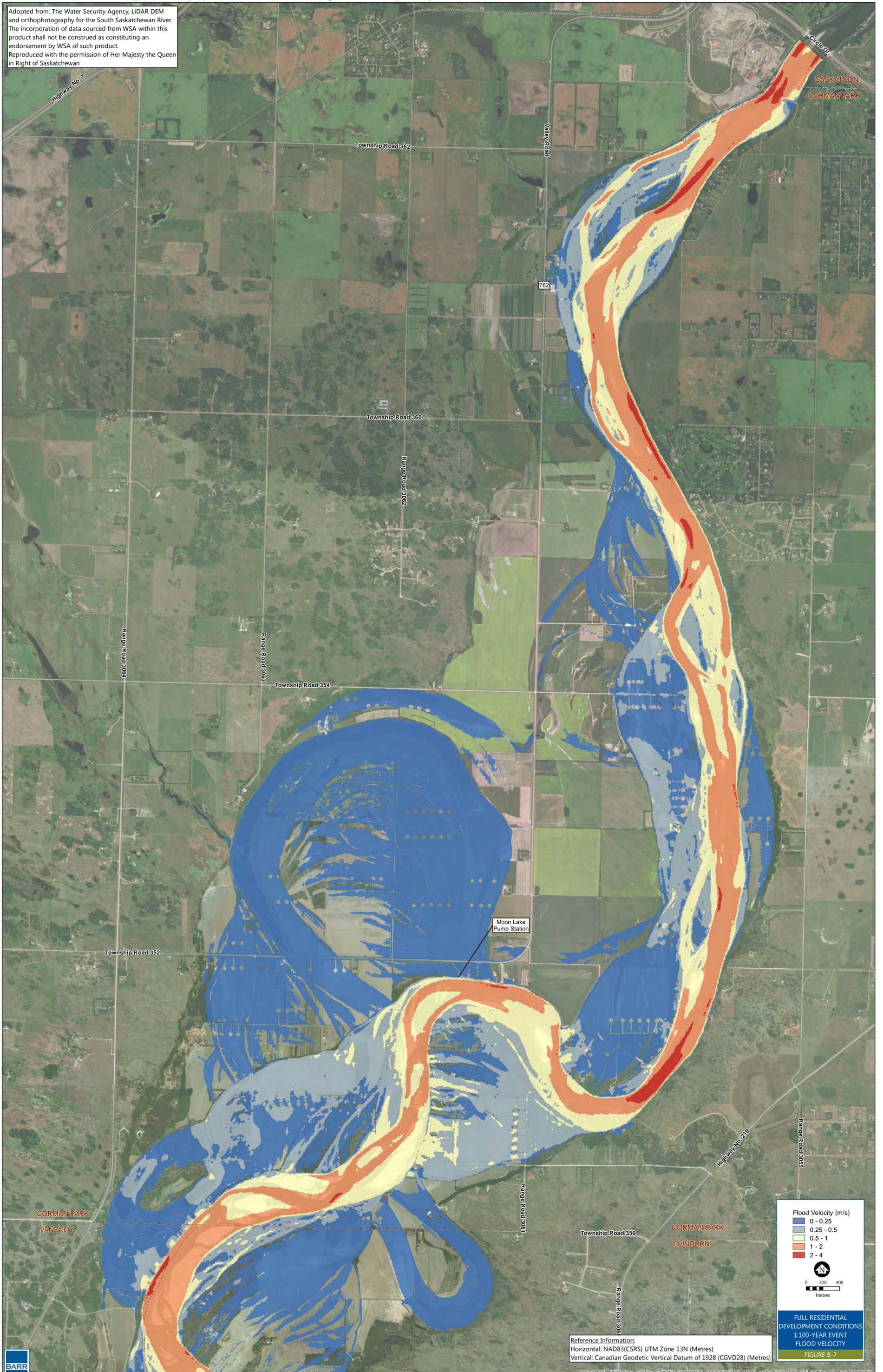
Flood Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
2 - 4

0 200 400
Metres

FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1:200-YEAR EVENT
FLOOD VELOCITY
FIGURE B-6



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Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Flood Velocity (m/s)

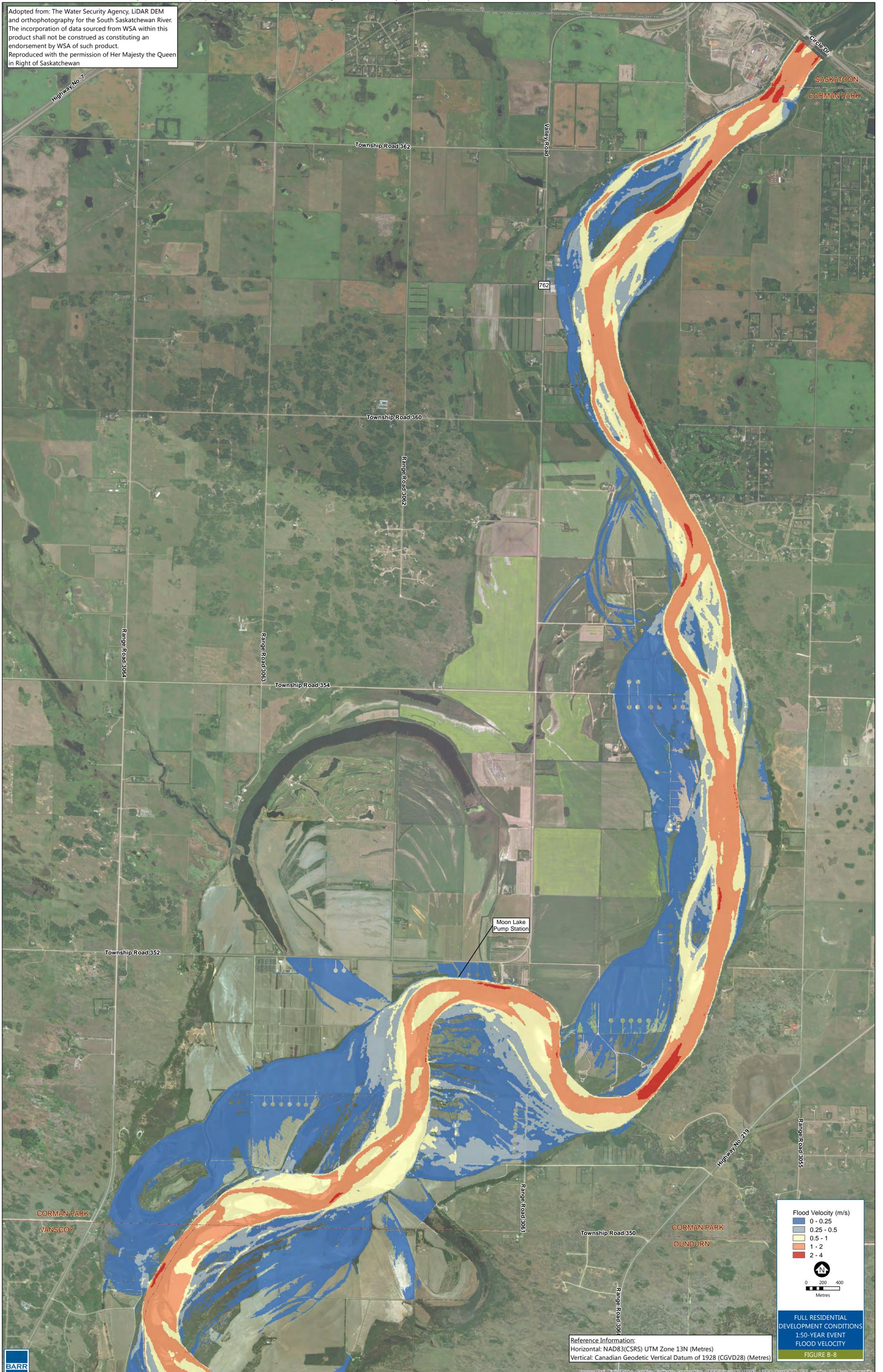
- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4

0 200 400
Metres

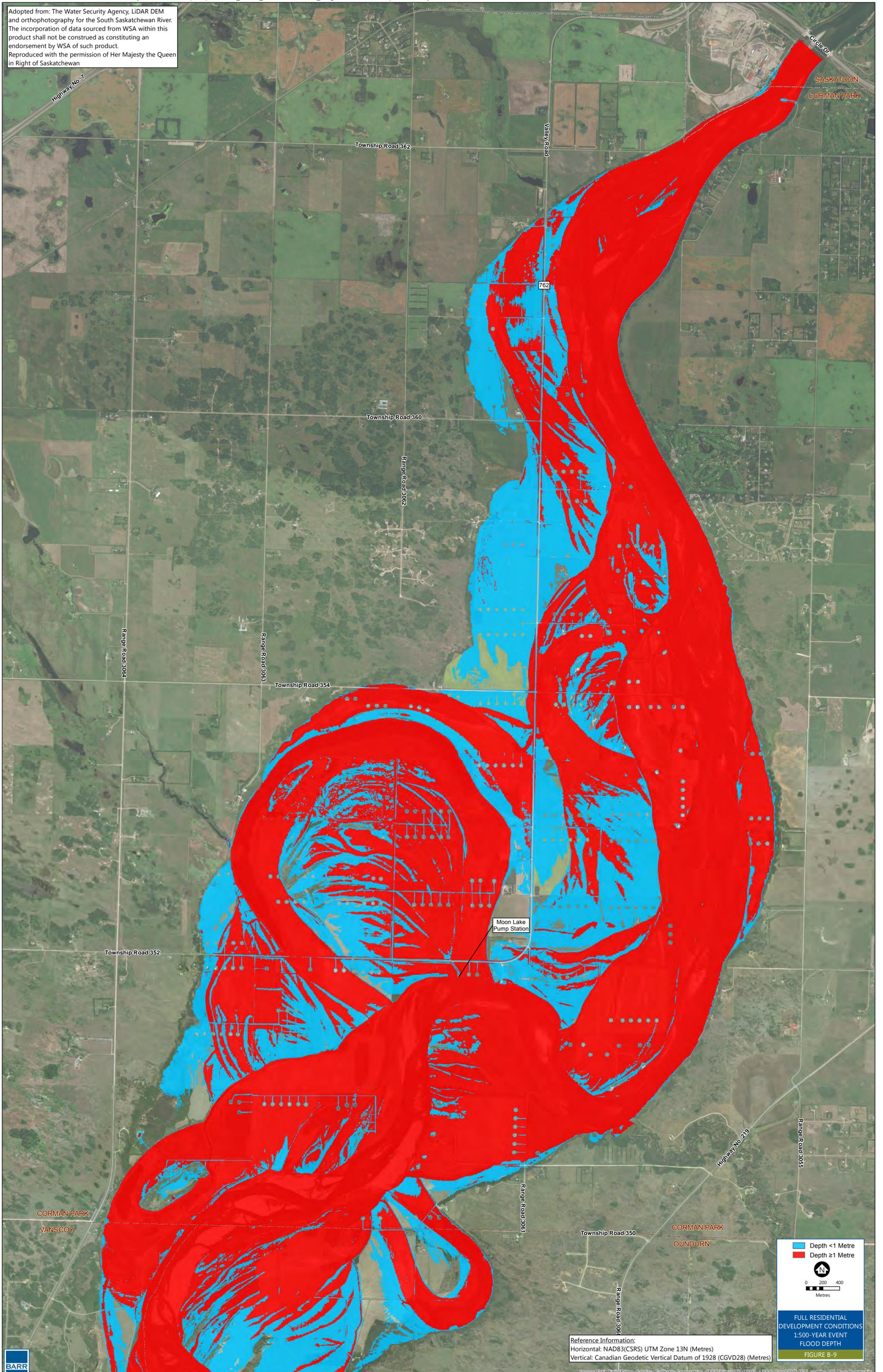
FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1:100-YEAR EVENT
FLOOD VELOCITY
FIGURE B-7



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Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Legend:
Depth <1 Metre
Depth ≥1 Metre

Scale:
0 200 400
Metres

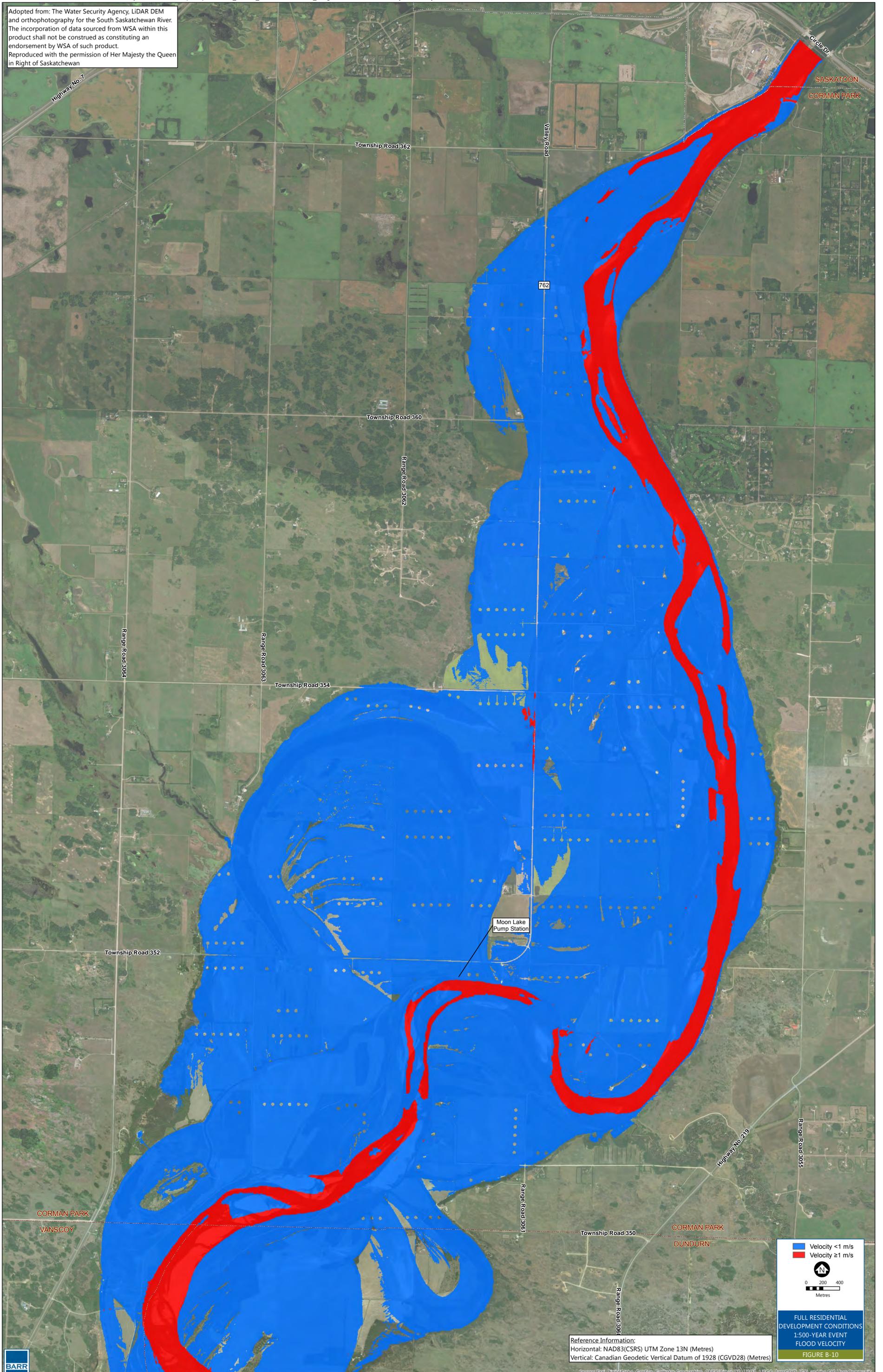
Orientation:
North Arrow

Event Information:
FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1:500-YEAR EVENT
FLOOD DEPTH

Figure Label:
FIGURE B-9



Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



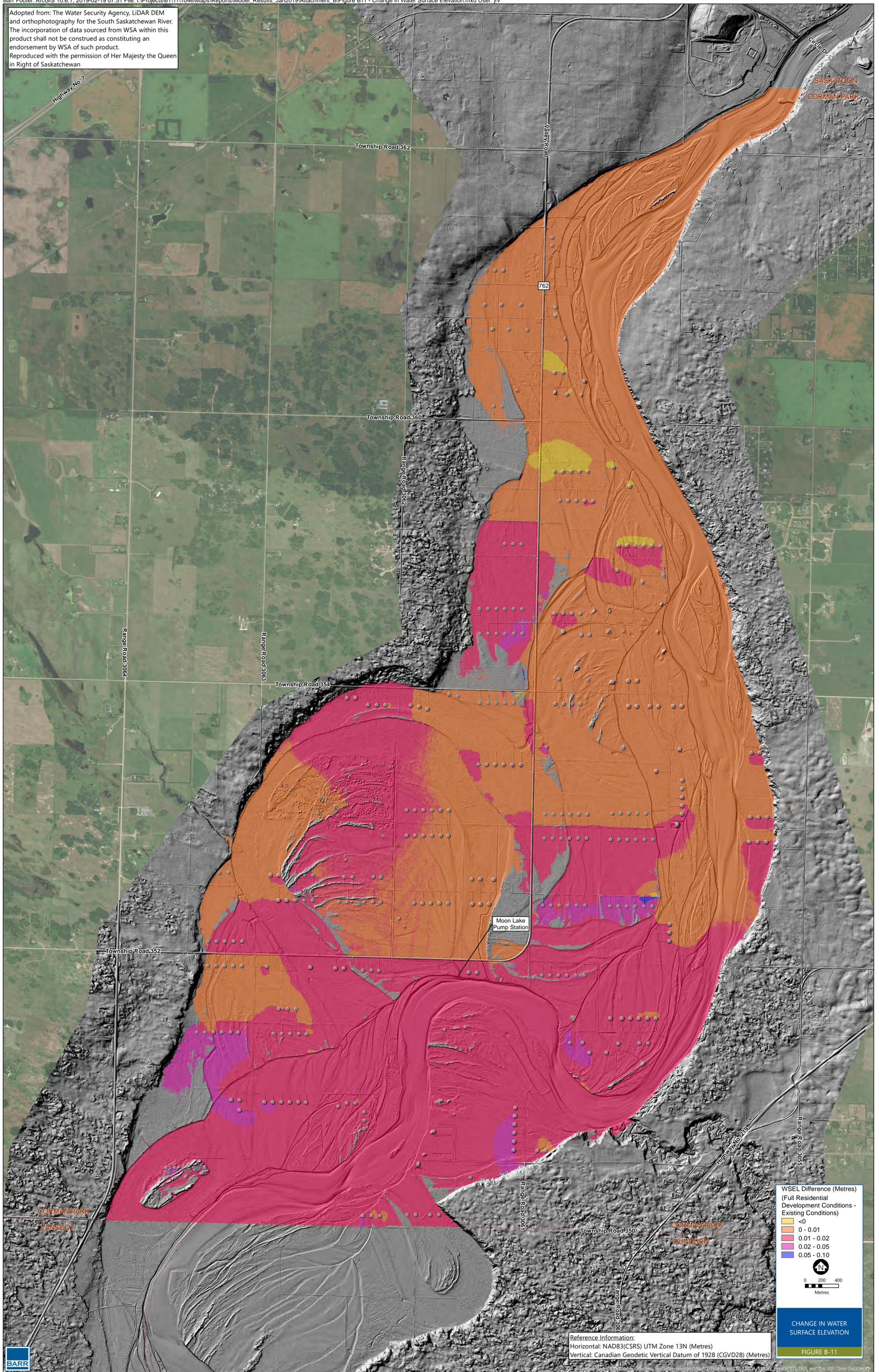
Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Velocity < 1 m/s
Velocity ≥ 1 m/s

0 200 400
Metres

FULL RESIDENTIAL DEVELOPMENT CONDITIONS
1:500-YEAR EVENT
FLOOD VELOCITY
FIGURE B-10

Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



WSEL Difference (Metres)
(Full Residential
Development Conditions -
Existing Conditions)

- <math>< 0</math>
- 0 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.10

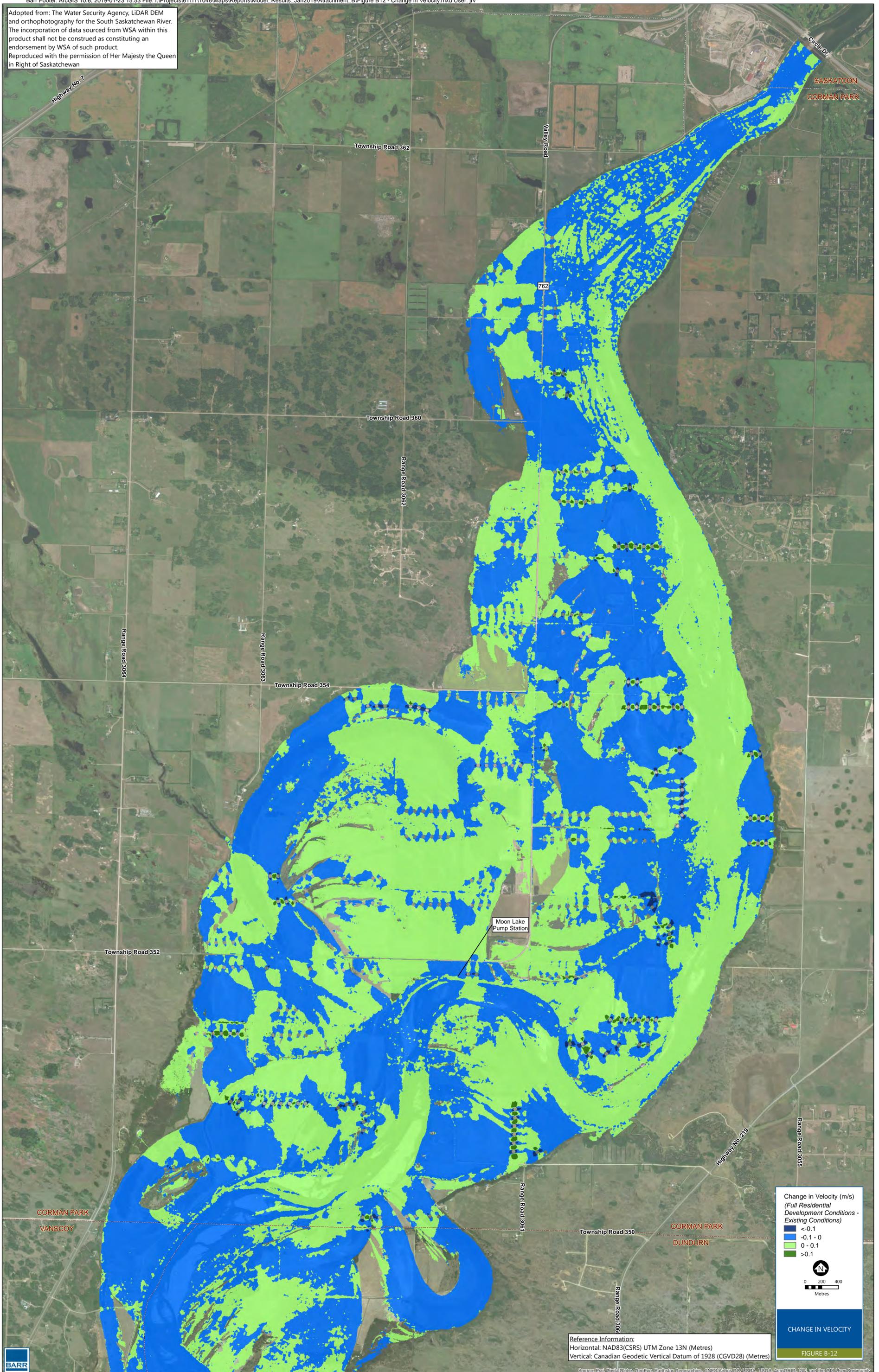
0 200 400
Metres

Reference Information:
Horizontal: NAD83(CRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

CHANGE IN WATER
SURFACE ELEVATION
FIGURE B-11



Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Attachment C

Bathymetry Data Survey Summary Figure and Data (Electronic)

Data Collected May 15, 2018 through May 18, 2018

Corman Park South Saskatchewan River

Bathymetry Data and LiDAR Comparison

Incorporation of the two data sets

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Each cross section (XS) that was surveyed is a red line on this map. Each surveyed bathymetry point is a black dot on this map. Note: the black dots are so close together they appear as a thick black line.

The LiDAR and the bathymetry data were compared at each XS (see Figure C-2 for an example).

The black line and markers on Figure C-2 represent the bathymetry data that was collected in May 2018.

The pink line and markers on Figure C-2 represent the LiDAR data that was flown in 2007.



- Bathymetry Data Point
- Surveyed XS
- Urban Municipality Boundary
- Rural Municipality Boundary

Elevation (m)
High : 520.4
Low : 470.249

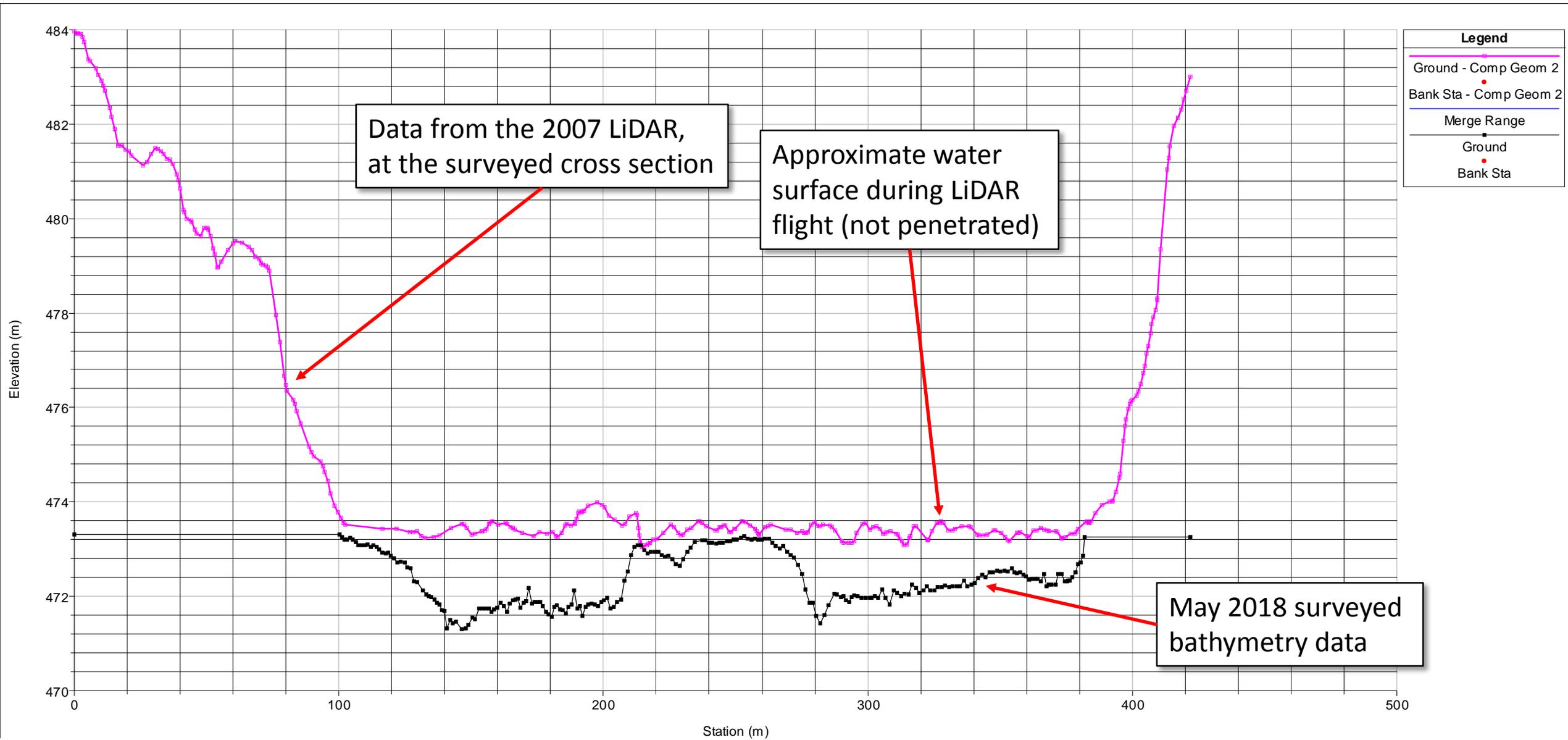
0 200 400 600
Metres

Reference Information:
Horizontal: NAD83(CSRS) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

BATHYMETRY DATA CROSS SECTIONS
FIGURE C-1



Figure C-2 Data comparison at XS 100

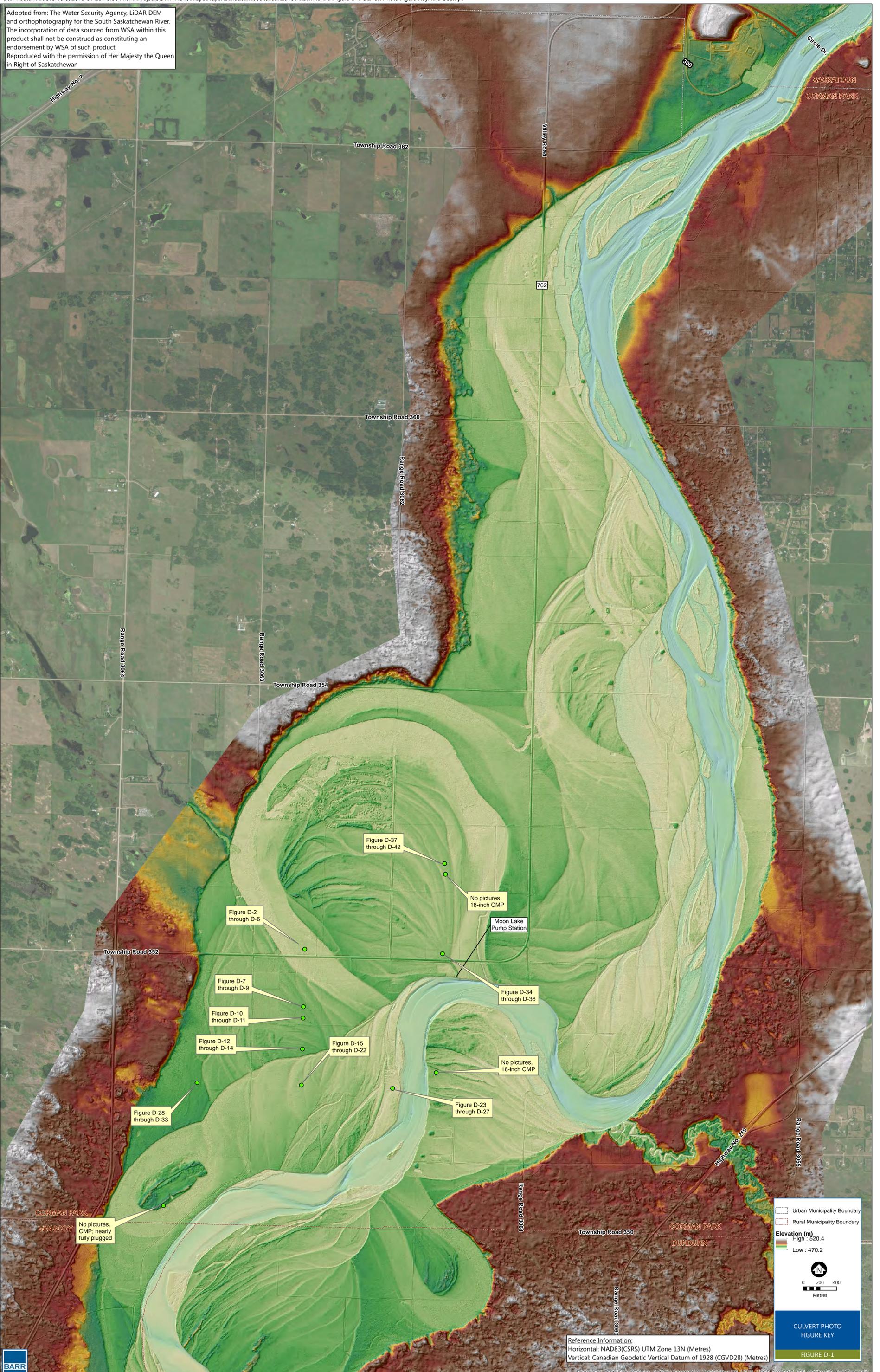


Attachment D

Field Reconnaissance Pictures

Data Collected May 15, 2018

Adopted from: The Water Security Agency, LiDAR DEM and orthophotography for the South Saskatchewan River. The incorporation of data sourced from WSA within this product shall not be construed as constituting an endorsement by WSA of such product. Reproduced with the permission of Her Majesty the Queen in Right of Saskatchewan



Reference Information:
Horizontal: NAD83(CSR) UTM Zone 13N (Metres)
Vertical: Canadian Geodetic Vertical Datum of 1928 (CGVD28) (Metres)

Urban Municipality Boundary
Rural Municipality Boundary

Elevation (m)
High : 520.4
Low : 470.2

0 200 400
Metres

CULVERT PHOTO
FIGURE KEY

FIGURE D-1



Figure D- 2 DSC01641.JPG



Figure D- 3 DSC01642.JPG



Figure D- 4 DSC01643.JPG



Figure D- 5 DSC01644.JPG



Figure D- 6 DSC01645.JPG



Figure D- 7 DSC01646.JPG



Figure D- 8 DSC01647.JPG



Figure D- 9 DSC01648.JPG



Figure D- 10 DSC01649.JPG



Figure D- 11 DSC01650.JPG



Figure D- 12 DSC01652.JPG



Figure D- 13 DSC01653.JPG



Figure D- 14 DSC01655.JPG



Figure D- 15 DSC01657.JPG



Figure D- 16 DSC01658.JPG



Figure D- 17 DSC01659.JPG



Figure D- 18 DSC01660.JPG



Figure D- 19 DSC01661.JPG



Figure D- 20 DSC01662.JPG



Figure D- 21 DSC01663.JPG



Figure D- 22 DSC01664.JPG



Figure D- 23 DSC01665.JPG



Figure D- 24 DSC01666.JPG



Figure D- 25 DSC01667.JPG



Figure D- 26 DSC01668.JPG



Figure D- 27 DSC01669.JPG



Figure D- 28 DSC01670.JPG



Figure D- 29 DSC01671.JPG



Figure D- 30 DSC01672.JPG



Figure D- 31 DSC01673.JPG



Figure D- 32 DSC01674.JPG



Figure D- 33 DSC01675.JPG



Figure D- 34 DSC01678.JPG



Figure D- 35 DSC01679.JPG



Figure D- 36 DSC01680.JPG



Figure D- 37 DSC01681.JPG



Figure D- 38 DSC01682.JPG



Figure D- 39 DSC01683.JPG



Figure D- 40 DSC01685.JPG



Figure D- 41 DSC01687.JPG



Figure D- 42 DSC01688.JPG

Attachment E

Modeled (1D vs 2D) Water Surface Profiles

Comparing the water surface elevation profiles of the 1D and 2D models

Table E-1

Comparison of HEC-RAS model results; 1D vs. 2D.

Existing Condition of the South Saskatchewan River in Corman Park

1D HEC-RAS XS	River Station (metres)	Modelled Water Surface Elevation (metres), Canadian Geodetic Vertical Datum of 1928 (CGVD28)											
		1:500 year Event 4,200 cms		1:200 year Event 3,200 cms		1:100 year Event 2,500 cms		1:50 year Event 2,000 cms		1,100 cms		400 cms	
		1D Model	2D Model	1D Model	2D Model	1D Model	2D Model	1D Model	2D Model	1D Model	2D Model	1D Model	2D Model
330638.*	330605.7	481.75	481.89	481.26	481.46	480.87	481.09	480.48	480.76	479.42	479.67	477.98	478.38
330233.*	330200.5	481.69	481.82	481.18	481.38	480.78	481.01	480.40	480.68	479.35	479.58	477.87	478.26
329828.*	329795.3	481.63	481.77	481.12	481.33	480.72	480.96	480.33	480.63	479.28	479.51	477.78	478.18
329423.*	329390.2	481.59	481.74	481.06	481.29	480.66	480.92	480.27	480.59	479.23	479.48	477.71	478.15
329018	328985.0	481.56	481.67	481.02	481.21	480.63	480.83	480.23	480.49	479.19	479.37	477.66	478.03
328575.*	328542.7	481.51	481.62	480.98	481.16	480.57	480.77	480.18	480.42	479.15	479.31	477.61	477.96
328133.*	328100.4	481.47	481.56	480.94	481.09	480.53	480.70	480.14	480.35	479.12	479.22	477.58	477.83
327691.*	327658.0	481.43	481.53	480.89	481.06	480.49	480.66	480.10	480.30	479.08	479.17	477.55	477.78
327248.*	327215.7	481.40	481.50	480.85	481.03	480.45	480.63	480.06	480.25	479.05	479.12	477.52	477.75
326806.*	326773.3	481.36	481.46	480.82	480.97	480.42	480.55	480.02	480.15	479.02	478.98	477.49	477.59
326364	326331.0	481.34	481.42	480.80	480.93	480.39	480.49	480.00	480.08	478.99	478.88	477.46	477.45
326002	325969.1	481.32	481.40	480.77	480.90	480.34	480.45	479.93	480.03	478.89	478.84	477.39	477.41
325567.*	325534.9	481.25	481.36	480.66	480.84	480.21	480.39	479.80	479.95	478.81	478.75	477.31	477.35
325133.*	325100.7	481.21	481.33	480.61	480.80	480.15	480.32	479.73	479.86	478.75	478.64	477.26	477.19
324699.*	324666.5	481.18	481.31	480.57	480.76	480.11	480.27	479.68	479.79	478.71	478.55	477.22	477.04
324265.*	324232.3	481.15	481.28	480.54	480.72	480.08	480.22	479.64	479.72	478.67	478.46	477.19	476.94
323831	323798.2	481.14	481.25	480.52	480.68	480.05	480.17	479.62	479.67	478.64	478.41	477.16	476.89
323337.*	323304.8	481.11	481.21	480.49	480.62	480.01	480.10	479.57	479.60	478.61	478.35	477.14	476.83
322844.*	322811.5	481.08	481.14	480.46	480.53	479.98	480.01	479.53	479.52	478.57	478.29	477.11	476.80
322351.*	322318.2	481.05	481.04	480.41	480.39	479.94	479.84	479.49	479.36	478.53	478.16	477.08	476.71
321858.*	321824.9	481.02	480.98	480.37	480.29	479.89	479.73	479.44	479.25	478.48	478.07	477.05	476.62
321365	321331.6	480.99	480.93	480.32	480.22	479.85	479.64	479.39	479.15	478.42	477.98	477.01	476.55
320925.*	320891.8	480.93	480.88	480.26	480.16	479.76	479.56	479.32	479.08	478.36	477.91	476.98	476.50
320485.*	320452.1	480.88	480.83	480.20	480.10	479.70	479.50	479.25	479.01	478.29	477.84	476.95	476.45
320045.*	320012.3	480.84	480.77	480.14	480.02	479.63	479.41	479.19	478.91	478.22	477.73	476.91	476.35
319606.*	319572.6	480.79	480.74	480.09	479.97	479.57	479.34	479.12	478.84	478.14	477.66	476.87	476.27
319166.*	319132.8	480.75	480.69	480.04	479.90	479.52	479.26	479.06	478.74	478.07	477.55	476.82	476.13
318726.*	318693.1	480.72	480.65	480.00	479.84	479.47	479.18	479.01	478.66	478.01	477.47	476.77	476.02
318286.*	318253.3	480.68	480.62	479.96	479.80	479.43	479.14	478.96	478.61	477.96	477.42	476.71	475.98
317847	317813.6	480.66	480.60	479.94	479.77	479.40	479.10	478.93	478.57	477.92	477.38	476.67	475.93
316586	316553.0	480.52	480.50	479.75	479.63	479.20	478.93	478.71	478.37	477.67	477.15	476.49	475.72
316143.*	316110.6	480.39	480.44	479.55	479.55	478.96	478.84	478.44	478.28	477.43	477.07	476.33	475.65
315701.*	315668.2	480.26	480.38	479.38	479.47	478.78	478.75	478.23	478.19	477.20	476.98	476.13	475.57
315258.*	315225.7	480.17	480.32	479.25	479.40	478.62	478.68	478.05	478.12	476.98	476.92	475.91	475.53
314816.*	314783.3	480.08	480.26	479.13	479.32	478.49	478.59	477.90	478.03	476.77	476.84	475.66	475.48
314373.*	314340.8	479.99	480.17	479.03	479.22	478.38	478.48	477.77	477.92	476.59	476.72	475.40	475.35
313931.*	313898.4	479.92	480.08	478.94	479.10	478.29	478.36	477.67	477.79	476.46	476.59	475.21	475.20
313489	313456.0	479.85	480.02	478.87	479.03	478.22	478.27	477.58	477.71	476.37	476.51	475.11	475.13
311744	311710.4	479.68	479.82	478.62	478.79	477.90	478.01	477.22	477.42	475.98	476.17	474.74	474.76
311100	311066.1	479.56	479.75	478.45	478.71	477.64	477.91	476.98	477.31	475.76	476.06	474.56	474.69
310410	310376.8	479.43	479.62	478.33	478.56	477.50	477.75	476.86	477.13	475.63	475.89	474.37	474.56
309741	309708.0	479.35	479.51	478.24	478.45	477.41	477.62	476.76	477.00	475.51	475.75	474.20	474.43
309487	309453.7	479.32	479.47	478.22	478.40	477.39	477.58	476.75	476.95	475.50	475.70	474.19	474.38
309221	309187.8	479.29	479.38	478.19	478.30	477.37	477.47	476.72	476.84	475.49	475.60	474.18	474.30
308727	308693.2	479.25	479.28	478.15	478.18	477.32	477.34	476.68	476.71	475.44	475.47	474.16	474.18
308708	308674.2	479.26	479.27	478.15	478.17	477.33	477.34	476.69	476.71	475.45	475.47	474.16	474.17

Notes:

The downstream end of the 2D model is at the 1D XS "308708"

The Corman Park southern boundary is at the 1D XS "330638."

The Moon Lake Pump Station is approximately at the 1D XS "326002"

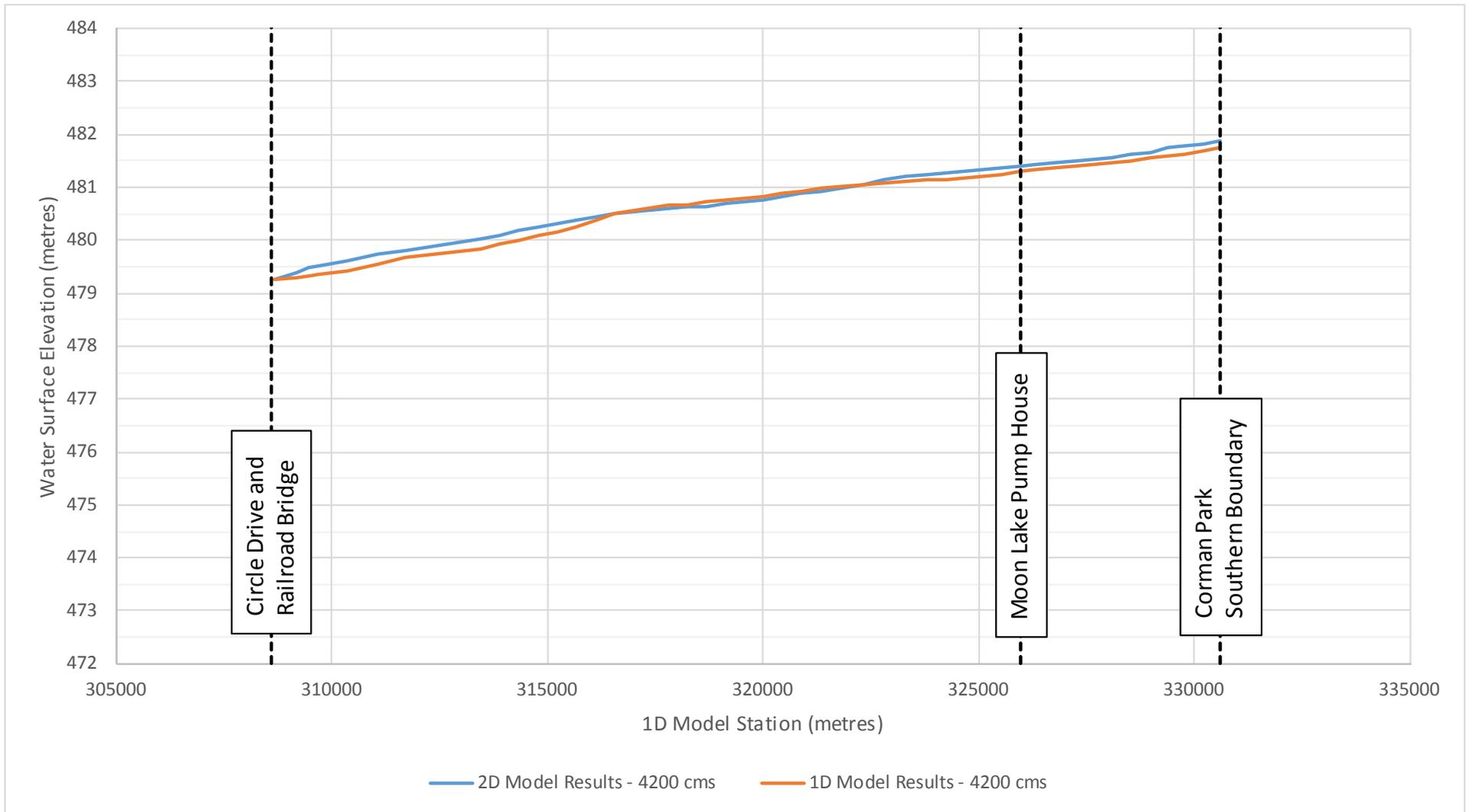


Figure E- 1 Comparison of the 1D HEC-RAS water surface profile with the 2D HEC-RAS water surface profile for the 1:500 year flood event (4,200 cms)

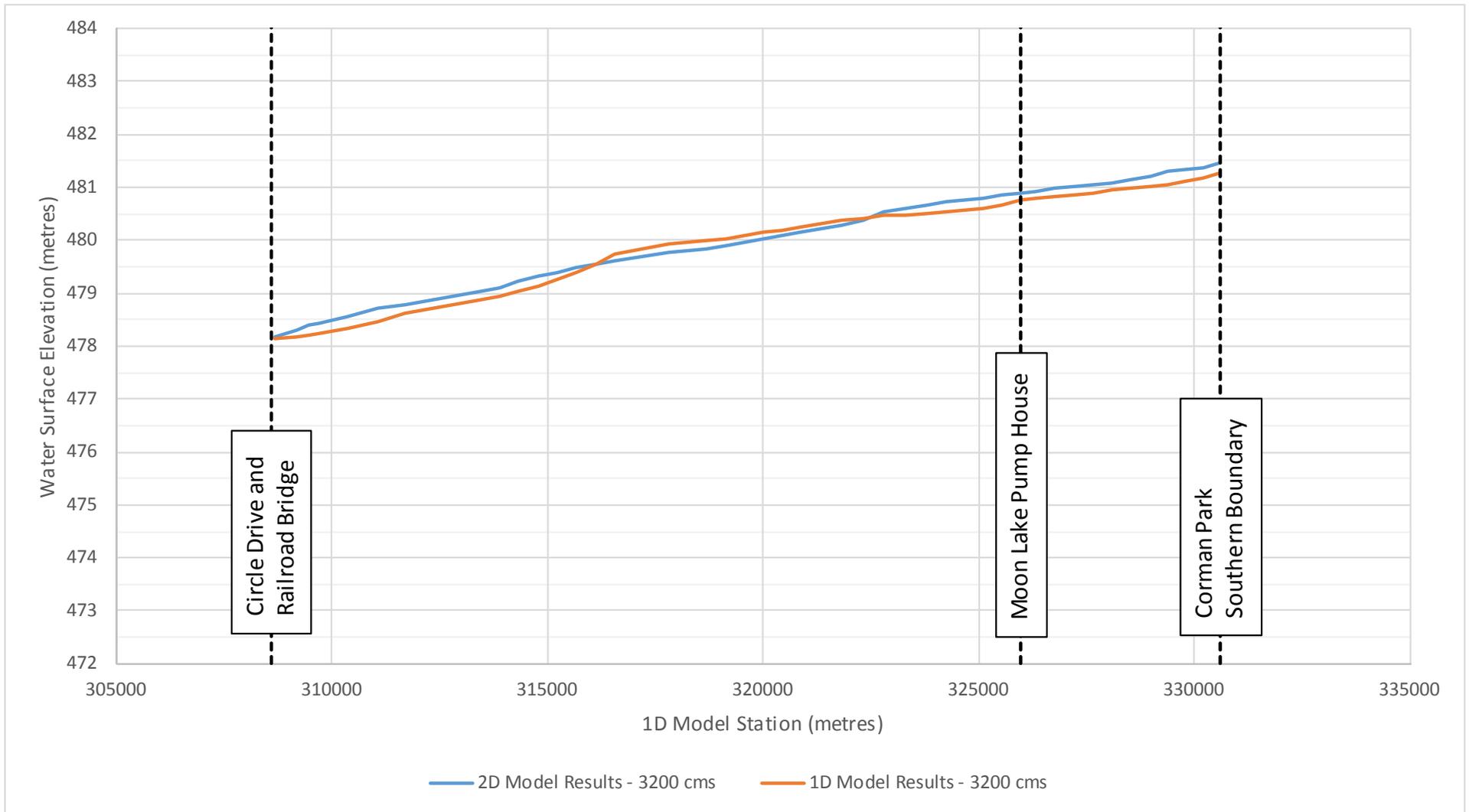


Figure E- 2 Comparison of the 1D HEC-RAS water surface profile with the 2D HEC-RAS water surface profile for the 1:200 year flood event (3,200 cms)

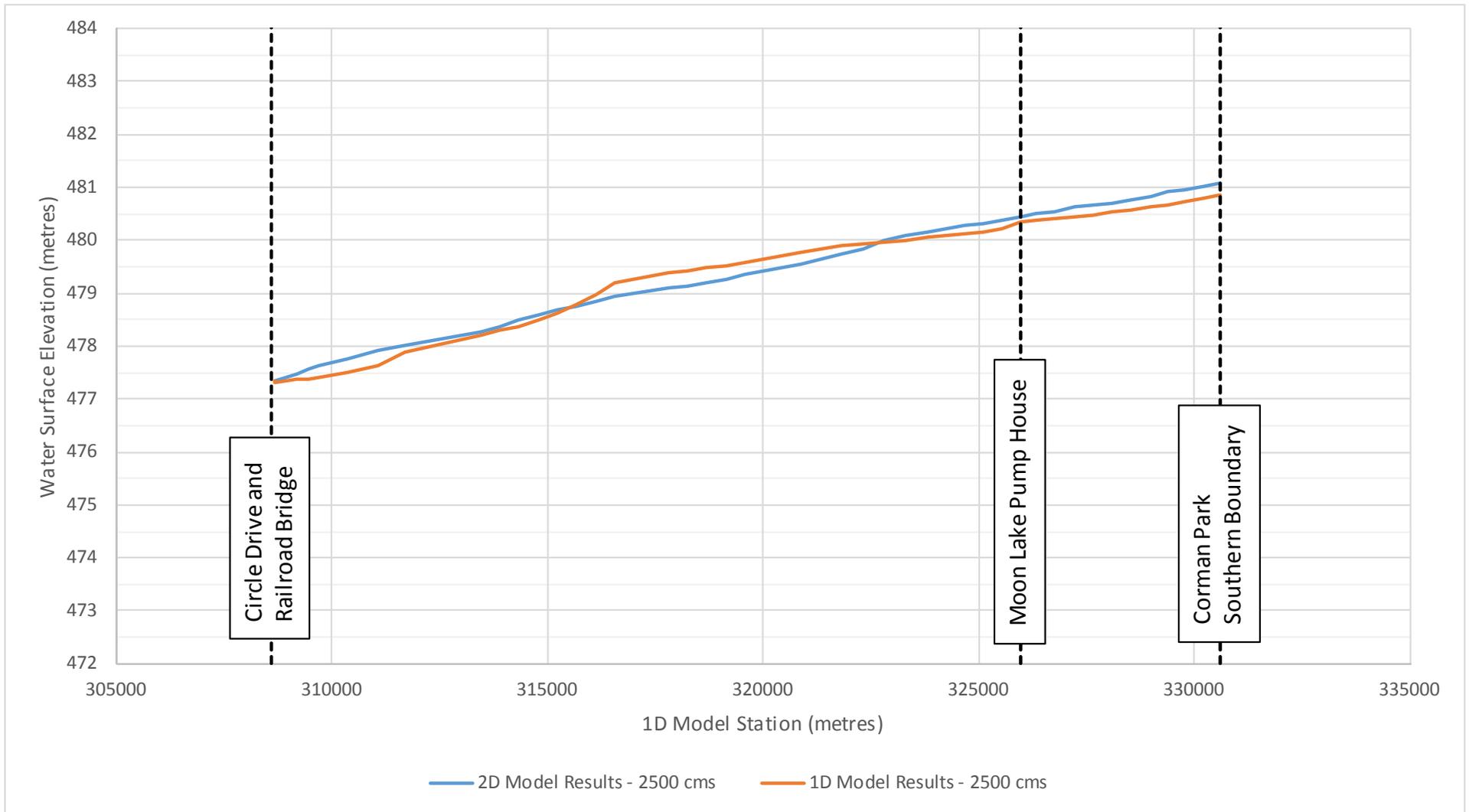


Figure E- 3 Comparison of the 1D HEC-RAS water surface profile with the 2D HEC-RAS water surface profile for the 1:100 year flood event (2,500 cms)

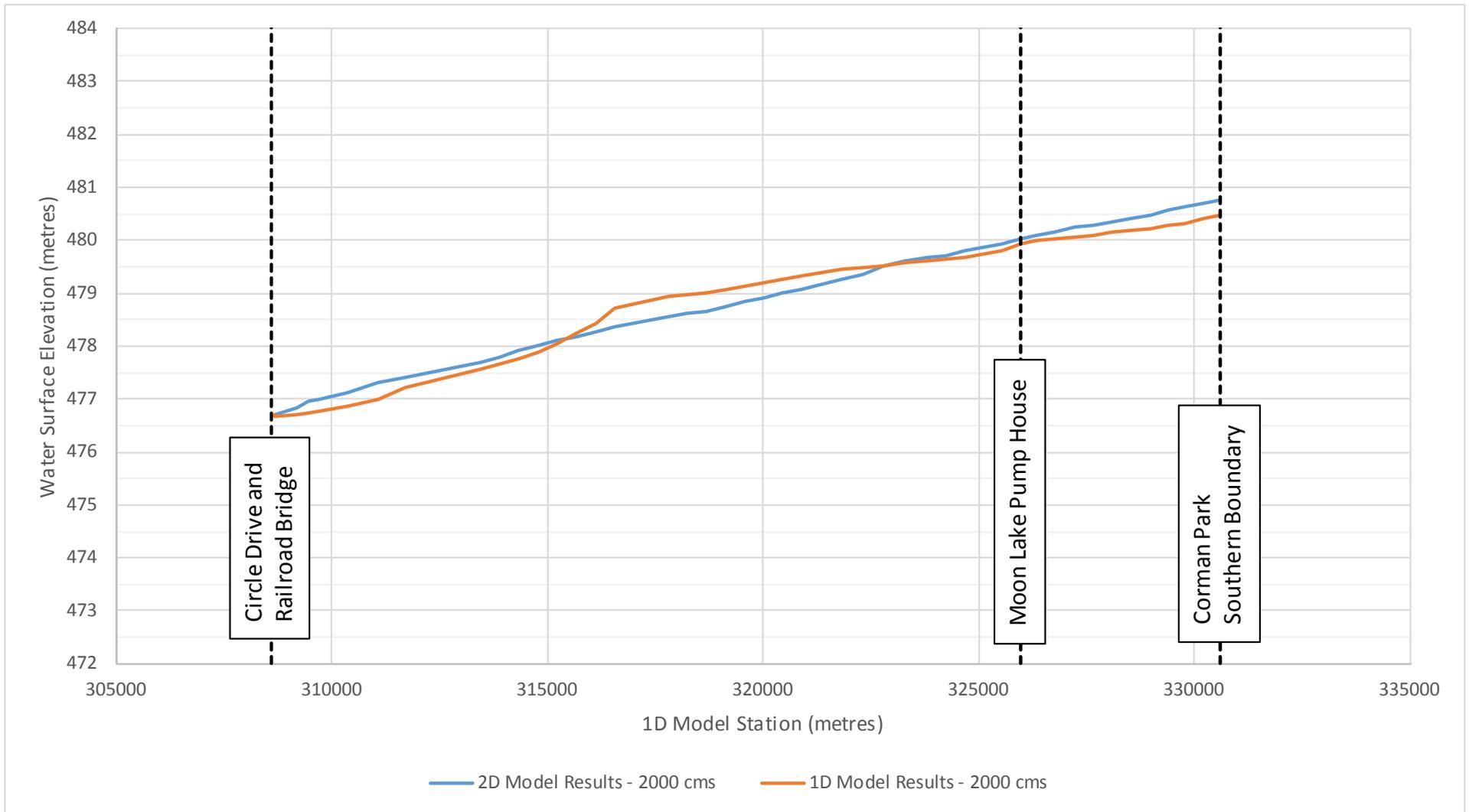


Figure E- 4 Comparison of the 1D HEC-RAS water surface profile with the 2D HEC-RAS water surface profile for the 1:50 year flood event (2,000 cms)

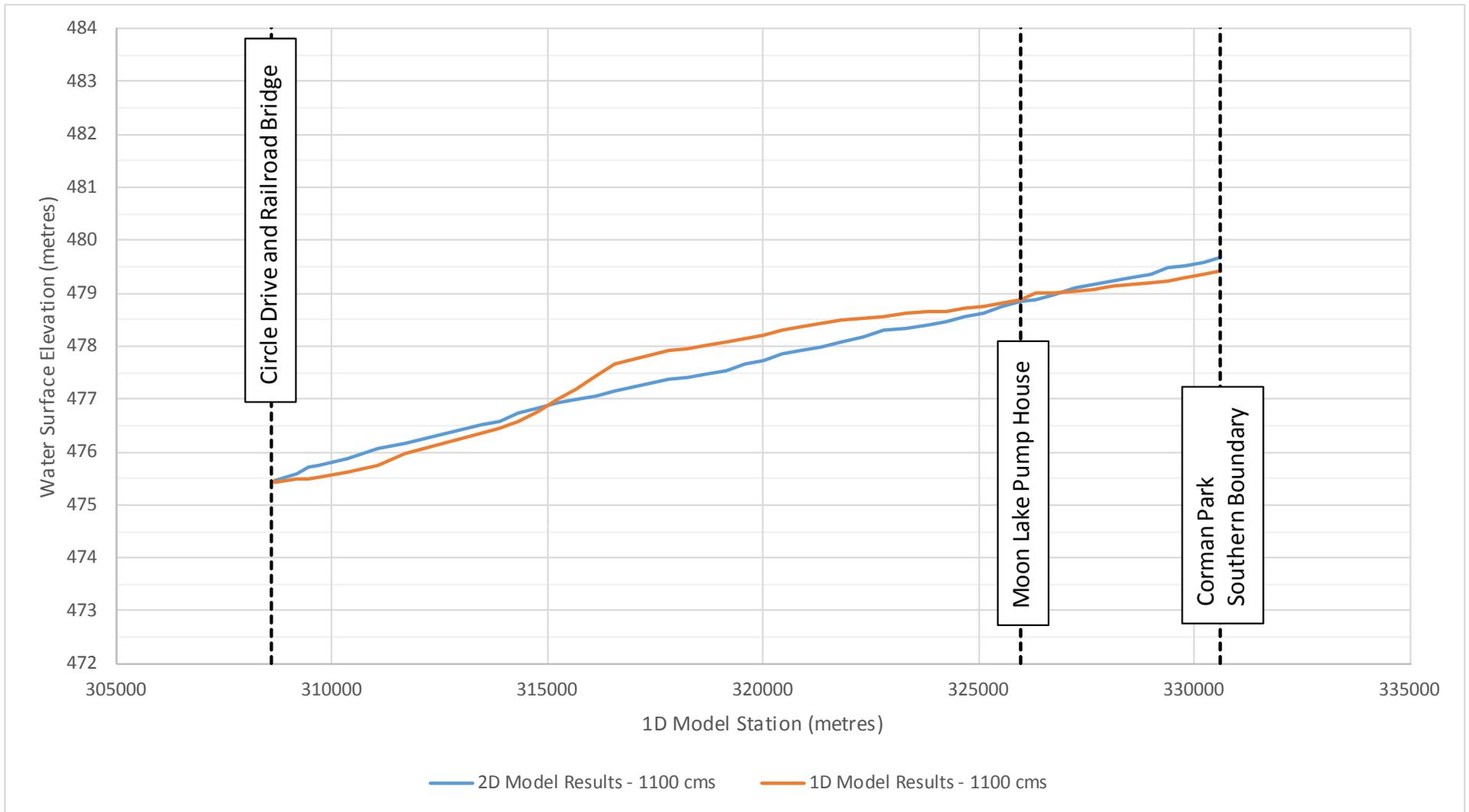


Figure E- 5 Comparison of the 1D HEC-RAS water surface profile with the 2D HEC-RAS water surface profile a flow of 1,100 cms

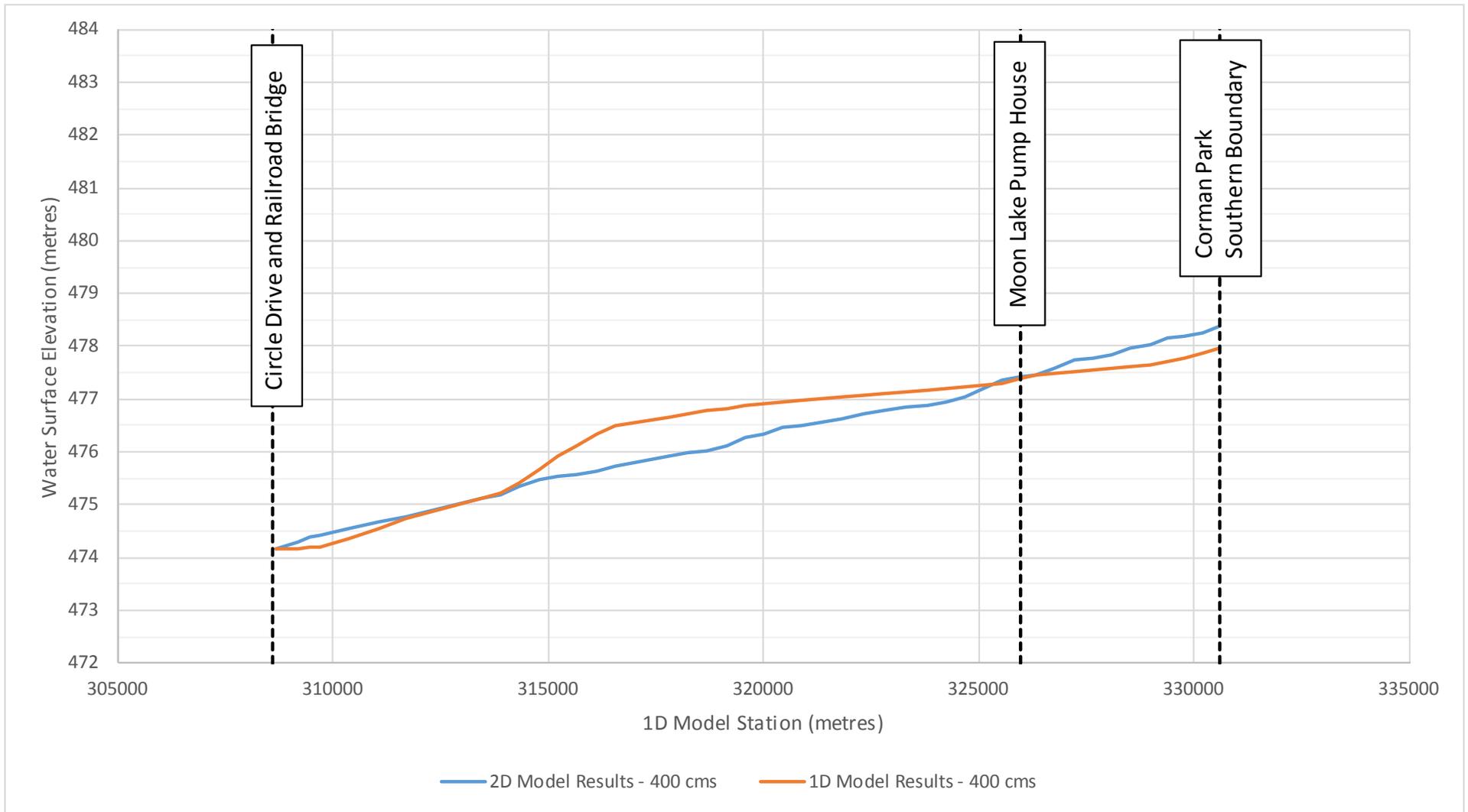


Figure E- 6 Comparison of the 1D HEC-RAS water surface profile with the 2D HEC-RAS water surface profile a flow of 400 cms