



**Foothills County**

# **Phase 2 Scoping Study of the Little Bow River**

**Bathymetry Survey and Modelling Support**

**Funding for this study was provided by Alberta  
Environment and Parks**

307011-00079.100 -WW-LET-0001

**Advisian**

Suite 500, 151 Canada Olympic Rd SW  
Calgary, AB T3B 6B7 CANADA  
Phone: +1 403 247 0200  
Facsimile: +1 403 247 4811  
[www.advisian.com](http://www.advisian.com)

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**Advisian**  
WorleyParsons Group

8 May 2019

Proj. No.: 307011-00079

Foothills County  
309 Macleod Trail Box 5605  
High River AB T1V 1M7

Attention: Robert Miller

Dear Rob:

## **Re: Phase 2 Scoping Study of the Little Bow River - Bathymetry Survey and Modelling Support**

### **1. Introduction**

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WorleyParsons Canada Services Ltd., operating as Advisian, is pleased to provide Foothills County (FC), formerly the Municipal District (MD) of Foothills No. 31, with documentation of the completed Phase 2 of the Little Bow River (LBR) Scoping Study to improve low-flood accuracy of the two-dimensional (2D) hydraulic model developed for the flood-related areas of concern on the LBR upstream from the Twin Valley Reservoir (TVR) and inside FC, Vulcan County (Vulcan), and the Municipal District of Willow Creek No. 26 (Willow Creek). The data acquired with a bathymetric survey of the LBR were the main upgrade to the model to improve its forecasting performances for low-flow events. The bathymetric survey was completed for the length of the LBR from 12<sup>th</sup> Avenue LBR crossing in the Town of High River (the Town) to the TVR northern limits (Figure 1-1).

The LBR two-dimensional (2D) model used for the evaluation of the flood mitigation effects (Advisian 2017), also adopted in the 2017 scoping study (Advisian & Amec Foster Wheeler 2017), was improved adding the bathymetry data of the channel conveying low flows. The model then was tested for the low flow registered during the bathymetric survey against the surveyed water levels and two intermediate flow scenarios to route the flow hydrographs or the peak flows in a steady state condition. Flow values to the LBR are determined by the Highwood River (HWR)-LBR flow split and routed starting at the Highway 2 and continuing downstream to the TVR northern end (Legal section NW-34-15-26-W4). The model was re-tested for a 2013 flood event's flow to refine its calibration following the bathymetric data set-up.

### **2. Purpose and Scope of Work**

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Prior to the bathymetric survey, the model used for flood mitigation effects assessment (Advisian 2017) was populated using historic channel cross-section information and tested with a set of sensitivity analysis as the LBR channel was hypothesized to have little influence on significant flood event's flows (approximately above 300 m<sup>3</sup>/s along the LBR). However, it was estimated that the LBR channel would have a greater influence for

flows from the HWR upstream from the Woman's Coulee Inlet around 750-1,000 m<sup>3</sup>/s or lower, corresponding to an overflow routed along the LBR in the range of 15-85 m<sup>3</sup>/s for both the 2013 Landscape Scenario or the most updated Mitigation Scenario inclusive of the South West Dike (SWD) in section 35-18-29 W4 (WorleyParsons 2018).

The bathymetric survey has the purpose to improve low-flow model accuracy in support to Phase 2 program of the LBR Scoping Study (Advisian & Amec Foster Wheeler 2017). The Addendum aims characterizes results and effects of improving the entire length of the 2D LBR model, from the Highway 2 crossing in Town to the upper part of the TVR (the Study Area), with updated channel's bed elevation information. The update of the model provided a simulation tool suitable to represent low flow scenarios deriving from the HWR-LBR flow spilt as determined by both the original 2013 Landscape and the updated scenario 55A, inclusive of all flood mitigation features as-built in and around the Town after June 2013 flood event. Table 1 describes the historical HWR model scenarios prepared to support design and assessment of the post-2013 flood mitigation features and has been updated from the same table presented in Advisian (2018) with the latest scenario 55A used for results documented here.

The high-level scope of work to achieve this purpose is as follows:

- refine the model in and around the LBR channel over the Study Area as defined above;
- update model calibration with the survey collected flows and water levels to fit the model to low flow runs;
- test the sensitivity of the new calibration for the June 2013 peak flow hydrograph;
- simulate a peak flow event along the LBR for both the 55A flood mitigated scenario and 2013 Landscape scenario as determined by the HWR-LBR spilt for a '750 m<sup>3</sup>/s at the HWR';
- simulate a peak flow event along the LBR for both scenarios as determined by the HWR-LBR spilt for a '1,000 m<sup>3</sup>/s at the HWR'; and
- report on the methodology and results of the tasks above.

### **3. Bathymetry Data Collection and Use**

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The LBR bathymetric survey was conducted over 14 days of campaign during the month of June 2018, from Monday the 4<sup>th</sup> to Friday the 29<sup>th</sup>.

A total of 333 full cross sections were surveyed starting from the north at the LBR crossing under 12<sup>th</sup> Avenue in the Town and arriving about 5 km downstream from the Highway 533 bridge (Figure 1-1) with an interval of 150-200 m. For each cross section, about 10 points in the channel and about five points on each side of the upper bank outside of the wetted width were shot. Each cross-section's survey extended about 20 m beyond the top of banks on both side. The LBR was not wadable beyond 5-5.5 km downstream from Highway 533 bridge because of the backwater effect from the TVR, with depths exceeding 1.5-1.6 m, at about. From that point and for the following 5 km leading to the north end of the TVR, the in-bank portion was surveyed using a sonar boat whereas the banks still were surveyed using on-foot GPS. The sonar boat allowed for more bed

elevation shots to be captured, and therefore produced a points-cloud dense enough to build, in post-processing, the complete bathymetry surface of the last 5 km of the LBR upstream of the inflow into the TVR.

In addition to bed elevation, other categories of points surveyed included edge of bank, out of bank ground, ground slope obvious breaklines, fence lines, in-line river structure (bridges, culverts) basic information, edge of water, top of water, and top and toe of slope.

A total of 718 edge of water and 77 top of water points were collected over the survey period at the cross section and a few other meaningful locations.

Photos 1, 2 and 3 illustrate different situations of the survey in June 2018.

Flow values along the LBR during the period of the bathymetric survey were downloaded from the Alberta Environment and Parks (AEP) website (Alberta Government 2019) at the Water Survey of Canada (WSC) stations below (Figure 1-1):

- 05BL015 Little Bow Canal at High River, and
- 05AC930 Little Bow River at Highway No. 533.

Table A below summarizes the main parameters of the WSC flow data during the period where the bulk of the water levels were surveyed, from 2018-06-04 at 8:50 am to 2018-06-25 at 2:20 pm.

**Table A WSC Measured Flow Data**

Flow Data	05BL015	05AC930	Average
Measurement Interval	5 min	15 min	
Mean Flow (m <sup>3</sup> /s)	2.92	2.90	2.91
Max. Flow (m <sup>3</sup> /s)	6.76	3.66	5.21
Third Quartile Flow (m <sup>3</sup> /s)	3.05	3.05	3.05
First Quartile Flow (m <sup>3</sup> /s)	2.60	2.72	2.66
Min. Flow (m <sup>3</sup> /s)	1.82	2.34	2.08

The Little Bow Canal at High River, whose flow is measured at station 05BL015, joins the LBR some 7.5 km upstream from the model northern beginning at Highway 2., LBR flow then is measured at the Highway 533 bridge, station 05AC930, about 49.5 km downstream from Highway 2 (Figure 1-1).

Except for maximum and minimum flows, the values of Table A show a noticeably constant value going from the model upstream end through km 49.5 (the total model length is about 60 km). Particularly for the mean flow and the first and third quartile flows (lowest and highest 25% of the measured flows, respectively). This

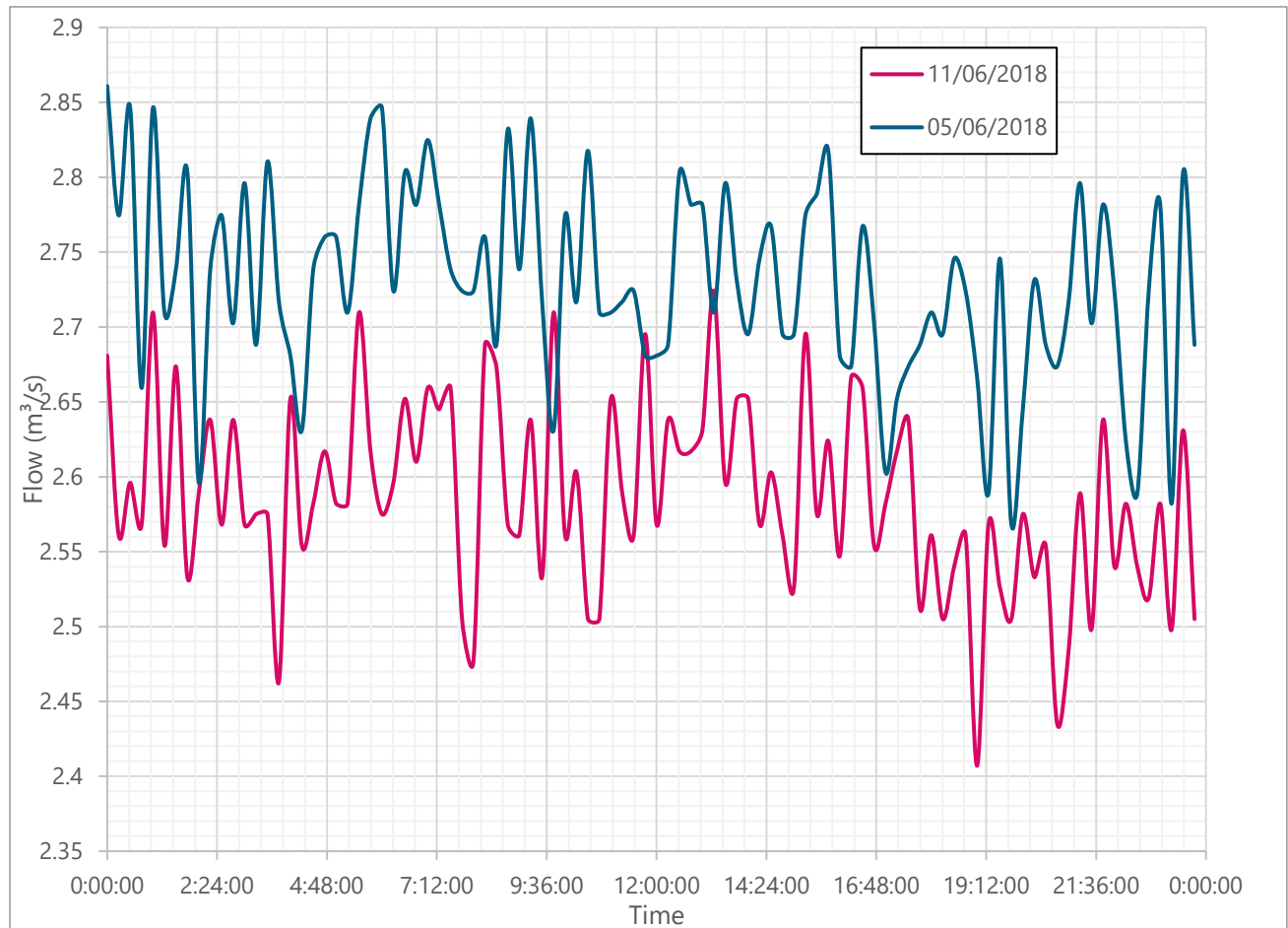


suggests that the overall catchment contribution from outfalls and minor affluent streams along the LBR was offset substantially by irrigation takes and other uses during the period under consideration, or inflows were negligible for most of the period. Maximum and minimum flows recorded by WSC, given their more relevant difference, were used to obtain highest and lowest water profiles in the simulations in consideration of the long period during which water levels and flows were measured.

Figure A below shows, as an example for two of the days of the survey, the hydrographs for a 24 hours period. In both instances the flow variation is contained within 0.30 m<sup>3</sup>/s.

As the water levels also were shot over the survey duration moving from upstream to the TVR, a steady-state approach with average flows and measured water elevations to check the model predicted levels was used for the simulations.

**Figure A** Registered Flow Hydrograph for the LBR at Highway No. 533 (Station 05AC930) during two different days of the bathymetric survey

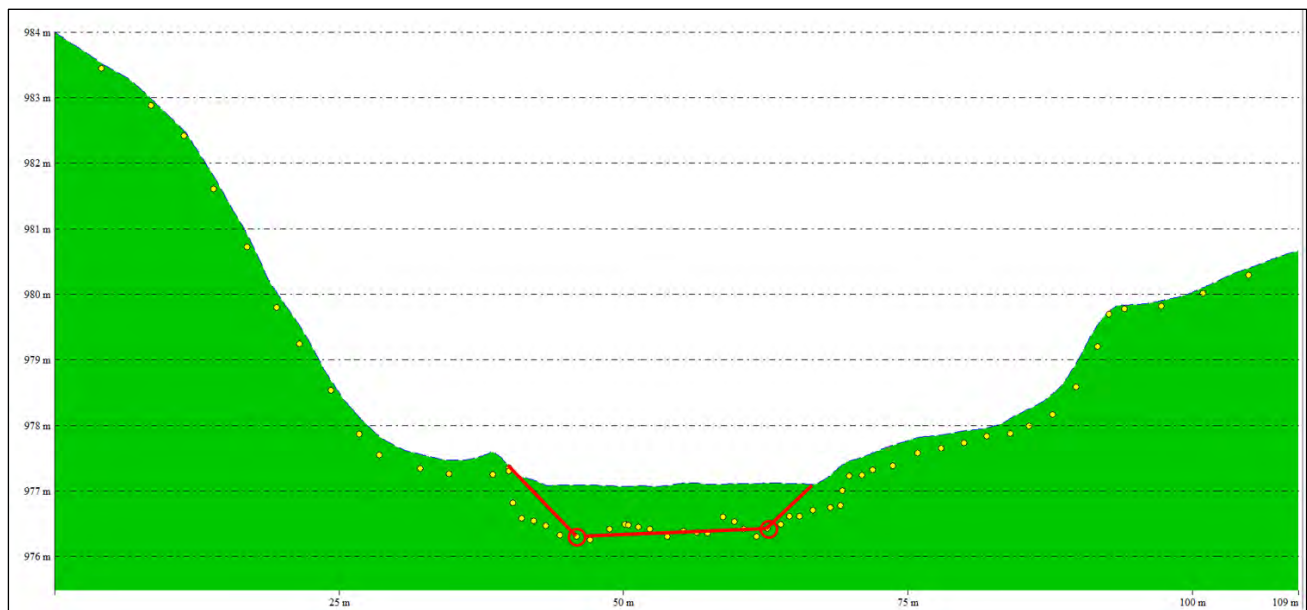


## 4. Model Update and Low-Flow Results

Survey data were used to update the finite element grid of the LBR 2D model, created with the RMA-2 platform, for the flood mitigation effects and scoping studies (Advisian 2017, Advisian & Amec Foster Wheeler 2017). It spans from the Highway 2 bridge at the northern upstream start and arrives at the June 2013 High Water Mark (HWM) 74, only 0.5 km upstream from the inflow into the TVR, for a total length of about 60 km.

The point density of the surveyed cross sections in relation to the dimension of the grid's elements required some simplification on the low-flow channel representation. The channel was modelled with an irregular trapezoidal cross section whose two bottom points were updated, in position and elevation, with the river's bed surveyed points. The two points were selected for each cross section to obtain a flow area equivalent to the physical cross section of the channel. The process is illustrated below in Figure B which shows the improvement to the original LiDAR surface (green) obtained with the modelled channel (red) derived from the surveyed points (yellow).

**Figure B** LiDAR surface, survey points and model equivalent area for a typical channel cross section



The stretches between cross sections were interpolated linearly in elevation.

In the last 5 km of the model, the entire grid was updated reading the nodes elevation from the bathymetry surface's digital elevation model (DEM) obtained from the points-cloud read by the sonar boat.

Following the considerations reported in section 3, for the purposes of the modelling exercise a steady state flow has been simulated along the LBR for mean, maximum, and minimum flows registered and reported in Table A and corresponding to the averaged values of the two WSC stations.

Channel roughness distribution as determined and illustrated in the original model (Advisian 2017) has been review and adjusted.

At the downstream end of the model, a fixed water elevation of 964.43 m was set as a boundary condition (Figure 4-1) corresponding to the of top of water measured on June 25, 2018 at the same location where June 2013 HWM 74 was taken (Advisian 2017).

The updated model was calibrated improving the grid location over the channel against the measured water elevation profile using the mean low flow of 2.91 m<sup>3</sup>/s, with maximum and minimum simulated levels as visual reference of the model sensitivity to a flow variation.

The edge of water and top of water elevations collected over the survey allowed the determination of an average measured water level line along the LBR as shown in Figures 4-2 to 4-10, which also illustrate the relative results of modelled water levels.

Predicted flood levels for the June 2018 bathymetric survey flows described in section 3 are shown in the maps of Figures 4-11 to 4-15.

## 4.1 Intermediate and High Flows

As agreed with FC, the additional following scenarios were simulated once the LBR model was updated with the bathymetry data (Table B).

**Table B Additional Simulations Data**

HWR Flow (m <sup>3</sup> /s)	LBR Flow (m <sup>3</sup> /s)	Scenario	State
1,820	520	2013 Landscape	Dynamic
1,820	330	55A	Dynamic
750	20	2013 Landscape	Steady
750	20	55A	Steady
1,000	82	2013 Landscape	Steady
1,000	70	55A	Steady

The above flows are rounded to the closest 10 m<sup>3</sup>/s in consideration of expected accuracy of the regional scale model and its limitations, detailed in section 5.2.

The first column shows the flow at the HWR upstream from the Town, above Woman's Coulee Inlet (Figure 1-1) and the second one the corresponding flow along the LBR as determined by the HWR-LBR flow split for the relative second-generation scenario reported in column three and described in Table 1.

Dynamic state indicates that the hydrograph, of which the reported flow represents the peak value, has been set as upstream condition. In a steady state, consistent with AEP flood modeling procedures, a constant (peak)

flow is run during the entire period of the simulation. Steady state generally is a more conservative approach that can be applied when storage or backwater effects are limited by water course morphology or slope and adopted more aptly for lower flows to preserve continuity when the dynamic state hydrographs may present a narrow curve to its peak. As the peak flow is the value run for the steady state, the higher levels always are to be expected as result of the simulation.

The 2013 flood flow peak at the HWR upstream of the Woman's Coulee Inlet was estimated initially by WSC as 1,820 m<sup>3</sup>/s, and successively refined to 1,760 m<sup>3</sup>/s. In consistency with the choice made over the period of studies relative to the 2013 flood throughout the modelling of various scenarios, the 1,820 m<sup>3</sup>/s has been maintained in this study to provide a consistent base of comparison (see also Advisian 2017).

In the above scenarios floodplain roughness has been reviewed from the one determined in the calibration process of the original LBR model (Advisian 2017).

On the downstream end of the model a constant water level of 965.97 m was set up for all the simulations of Table B.

As discussed in the 2017 Flood Mitigation Effects Assessment Report for the LBR (Advisian 2017), the value corresponds to the reliable HWM 74 recorded following June 2013 flood event. As the water level at the model's downstream end is determined by the regulated storage level of the TVR, the measured HWM represented a conservative choice also for the 750 and 1,000 m<sup>3</sup>/s simulations, pending a better determination of the elevation that the Reservoir would impose for said flows. Moreover, via the sensitivity tests of the Advisian (2017) report it had been determined already that the backwater from the TVR would not influence water levels along the LBR beyond the 10 km upstream for a variation of 0.50 m at the model's downstream boundary.

## 5. Other Results and Discussion

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The overall statistical parameters for the high-flow calibration after the bathymetric survey improved channel are shown below (Table C) with reference to Figures 5-1 to 5-5 which updated the 2017 Flood Mitigation Effects Assessment Report comparison of modelled levels for the June 2013 1,820 m<sup>3</sup>/s flow to the HWMs.

HWMs deemed erroneous were removed from the statistics in uniformity with the criteria followed in the 2017 Report. Erroneous HWMs are identified based on comparison with the surrounding HWMs.



**Table C**      **Statistic Parameters of the Calibration to the June 2013 HWMs of the Updated Model**

Location	Parameter	2017 Model (m) <sup>1</sup>	Updated Model (m)	Difference (m)
Figure 5-1	Median	0.27	0.13	-0.14
	Mean	0.37	0.23	-0.12
Figure 5-2	Median	0.11	-0.03	-0.08
	Mean	0.28	0.24	-0.04
Figure 5-3	Median	-0.01	-0.09	+0.08
	Mean	0.28	0.24	-0.04
Figure 5-4	Median	0.41	0.18	-0.19
	Mean	0.60	0.44	-0.28
Figure 5-5	Median	0.18	0.07	-0.11
	Mean	0.18	0.07	-0.11

**Note:** <sup>1</sup> The 2017 Model for the LBR used the flow hydrographs produced by the 2013 Landscape HWR model second-generation

For example, in Figure 5-1 the mean difference between surveyed HWMs and modelled level was reduced by 0.12 m as it went from 0.37 m 0.23 m signaling improved model accuracy. Only the greyed-out value of Figure 5-3 showed a worse-off situation, likely because of the lower quality of the HWMs collected in this section also revealed by the higher concentration of erroneous ones. The overall up-dated model is, therefore, better performing also for simulation of high flows.

The water surface profiles of Figures 5-6 to 5-14 illustrate variation in the water level along the LBR as determined by the fully mitigated scenario 55A in comparison with the June 2013 landscape scenario for the steady state (SS) or dynamic flows described in section 4.1. The set of profiles also include the 2013 HWMs along the channel to be checked against the June 2013 prediction by the updated model after its channel bathymetry update and re-calibration.

The maps of Figures 5-15 to 5-19 show how the updated model predicts the 2013 flood extent and elevation under mitigated scenario 55A.

The maps of Figures 5-20 to 5-24 focus on the same scenario but showing instead estimated depths and velocities.

Figures 5-25 to 5-29 show the estimated flood level differences for an 1,820 m<sup>3</sup>/s flow at the HWR as a result of post-mitigation scenario 55A.

Figures 5-30 to 5-34 show the estimated modelled flood levels for a 750 m<sup>3</sup>/s at the HWR under the same post mitigation scenario.

Figures 5-35 to 5-39 is based on the same 750 m<sup>3</sup>/s at the HWR 55A scenario but showing instead estimated depths and velocities.

Figures 5-40 to 5-44 show the estimated flood level differences for a 750 m<sup>3</sup>/s at the HWR as a result of post-mitigation scenario 55A. This flow also was modelled in the latest document relative to the Southwest Dike (WorleyParsons 2018), therefore for this set of figures a consistent representation has been adopted. A white area for a peak level difference from -5 to 5 cm (negligible impact) then a different coloration for areas outside this range. The two scenarios compared, 55A and June 2013 Landscape, were characterized by a flow difference along the LBR less than 5 m<sup>3</sup>/s which explains any local subtle differences in level but the same flow reported in Table B given the approximation deemed appropriate to reflect model accuracy. These minor changes in water level shown are assumed to be less than the accuracy level of the model.

Figures 5-45 to 5-49 show the estimated modelled flood levels for a 1,000 m<sup>3</sup>/s at the HWR under the 55A post-mitigation scenario.

Figures 5-50 to 5-54 is based on the same 1,000 m<sup>3</sup>/s at the HWR 55A scenario but showing instead estimated depths and velocities.

Figures 5-55 to 5-59 show the estimated flood level differences for a 1,000 m<sup>3</sup>/s at the HWR as a result of post-mitigation scenario 55A. This set shows a different coloration of the level differences compared to the Figures 5-40 to 5-44, highlighting the reduction of peak water level along the LBR floodplain but still in increments rounded to the closest 0.05 m.

Most of the model runs (all except the 2013 Landscape Scenario, 1,820 m<sup>3</sup>/s simulation) were performed using steady-state simulation. In addition, a comparison was made with steady state results versus dynamic results for the 1,820 m<sup>3</sup>/s simulation. What this assessment indicated was that the steady-state runs provided an accurate representation of flooding; however, results are on the conservative side with water levels increasing from 5 cm to 20 cm for steady state results when compared with the dynamic results. This assessment confirms that there would be only minor changes given the limited storage of the LBR segment in question. The steady-state results provide a more conservative scenario for planning and take away some of the concern with uncertainty in terms of hydrograph shape associated with dynamic modelling, for which data are limited.

The downstream TVR boundary is not expected to affect the model results in the FC area.

## 5.1 Model Accuracy

Model accuracy is generally determined using real world data and sensitivity analysis to test the ranges of the various parameters to better understand how much error is associated with each. Validation data and sensitivity analysis were not part of the scope for this modelling project for the 750 m<sup>3</sup>/s and 1,000 m<sup>3</sup>/s runs; hence, it is not possible to provide an accuracy using these methods. However, the accuracy of approximately +/-0.4 m provided in the LBR 2017 modelling report (Advisian 2017) for the 1,820 m<sup>3</sup>/s likely provides a reasonable range for the 1,000 m<sup>3</sup>/s model. In addition, considering that the low-flow channel representation was improved in the model, accuracy also may have improved slightly.

It is important to note, however, that these are regional models developed for planning purposes and do not account for local effects that could result in real-world water levels that extend significantly beyond the approximated range of  $\pm 0.4$  m range. Just as the model does not account for natural and manmade hydraulic influences, it also does not account for potential encroachment (e.g. local berming and filling) which often occurs locally when a property is developed. Under Government of Alberta design flood modeling, encroachment limit boundaries within the floodplain are stipulated based on a maximum increase to flood levels of less than 0.3 m. This type of analysis has not been included as part of the project and ungoverned encroachment could result in local effects being greater than 0.3 m. It is important to note that a recommended freeboard also should be added to modelled water levels after encroachment is considered to address uncertainty, and other potential changes to the system (avulsions, wave action, etc.). Considering all factors, a total of 1.0 m or more, depending on the degree of risk, should likely be added to design water levels unless local site assessment and analysis is undertaken which supports otherwise. Ideally this site assessment also defines set-back limits until a formal flood fringe is defined.

The regional flooding model produced for the LBR was developed for assessment and planning purposes. The model can be a tool used for design purposes; however, it should be made more robust by enhancing the details in the model DEM in the area of interest (with a focus on addressing the limitations discussed) and assessed using local site-specific information. The regional modeling results provide a base for the detailed DEM, characterization of regional hydraulic behavior, and boundary conditions as a minimum. However, it does not negate the need for a qualified professional to assess the site locally and determine how the modelling results should be interpreted, improved, or expanded upon for site-specific design purposes while considering encroachment, as well as necessary freeboard requirements.

## 5.2 Model Limitations

As the modelling sensitivity analysis was not undertaken for this exercise and hence the uncertainty of the results is not known, the 2017 Flood Mitigation Effects Assessment Report (Advisian 2017) should be referred to for model background, procedures, uncertainty, accuracy, and limitations.

This iteration of the LBR model included detailed bathymetry, so this limitation has been addressed. However, several limitations still exist with the modeling exercises which include:

- limited existing information on the minor agricultural crossing (e.g. fording) and culverted crossing along the LBR channel. Their limited capacity has little effect on water levels associated with a 2013 flood magnitude. However, at lower flows they will increasingly play a more important role as intermediate control sections. Hence, water levels near these crossings are uncertain;
- lack of flood high water mark information to perform a model validation step. Additional peak flow information from another significant flood event is not available for model validation. This would help improve understanding of model uncertainty and robustness;
- lack of a measured 2013 inflow flow hydrograph (including peak magnitude, duration, and overall volume). The hydrographs used for modelling purposes for the 2013 Landscape Scenarios is based on an hydrograph from an upstream modelling exercise which adds another level of uncertainty with the model. In addition, the upstream model, the Town of High River Flood Model (Advisian & Amec Foster Wheeler 2017) also has significant uncertainty in terms of its upstream boundary condition (input flow hydrograph) as the magnitude was determined post-flood by the slope-area and backwater calculation

methods; and the hydrograph shape was estimated based on past flood hydrograph information as all monitoring stations were destroyed during the 2013 flood;

- limited detail of the model domain and the large extent of the models. The models have been developed as regional models for planning purposes and hence lack detail required to accurately simulate local hydraulic effects caused by small changes in topography, land use, or infrastructure;
- limited accuracy of the LiDAR surface and its control on floodplain levels and flow patterns. Although LiDAR accuracy is considered very good, even an error in the 10 cm range can cause significant error in flood plain flow and routing because of its sensitivity to elevation over a broad cross-sectional area. This is a major limitation when simulating relatively shallow flooding throughout a complex flood plain;
- the accuracy in which the DEM can be represented by the model surface network. Significant detail can be lost through this process which must consider the model run times, project resources, and overall project goal;
- limitations with the accuracy of HWMs that were collected, about 19 or 40 months following the flood event. The HWMs had to be estimated in many cases and very few were considered good to excellent in quality (Advisian 2017);
- inability of the model to reflect the failure of bridges and the pre- and post-water levels associated with this mechanism at crossings. During flooding, water levels likely experienced back water effects upstream due to pressurized or confined flow associated with the bridges and potentially surges downstream which would have influenced HWMs and limited the ability of the model to replicate the marks; and
- RMA-2 provides results in the subcritical domain only. At some crossings, flows within the channel at the crossing may have been super critical. At these locations, the model would not be able to predict water levels accurately.

Considering these limitations, it is recommended that results are used only in a planning context. Performing design analysis or determining design requirements (local flood building level) should be undertaken only by a registered professional.





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## 6. Closure

We trust that this report satisfies your current requirements and provides suitable documentation for your records. If you have any questions or require further details, please contact the undersigned at any time.

Sincerely,



**Andrea Pipinato, P.Eng., M.Sc., .M.Eng.**  
Senior Water Resources Engineer

**Roy Golaszewski**  
Senior Water Resources Engineer

Senior Review by:

**Joal Borggard, M.Eng., M.E.Des., CPESC, LEED AP, P.Eng.**  
Technical Director, Water Resources Engineering

**Advisian, Americas**

## 7. References

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## Disclaimer

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*Any questions concerning the information or its interpretation should be directed A. Pipinato, Author or J. Borggard, Reviewer.*



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## Appendix 1      Tables

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**Table 1 Model Scenarios Description**

Scenario's Name	Description	Generation
2013 Landscape	The model of the conditions at the time of the 2013 flood, with a surface consistent with that apparent just after the 2013 inundation. The floodplain and active channel topography above the low water level are defined with LiDAR collected after the flood. Cross-section survey data collected after the flood were also used to define the low water channel through Town from just upstream of George Lane Park to just downstream of the Little Bow Canal Dike. The remaining low flow channel areas were estimated using pre-2013 flood information.	1 and 2
28A	Complete Mitigation Scenario: all mitigation features built after June 2013 flood event are included. On 12 Avenue SW and Centre Street the conceptual footage and cross-section of the dike denominated "Hockey Stick Alignment" was added as the more advanced option at the time of preparation.	1
28A	Generation 1 plus: the information obtained from the survey on three among railway and road corrugated steel pipes (CSP) located about 1.5 km and 2 km southeast of the Highway 2 crossing on the Highwood River, in section 32-19-28 W4, north of High River and south of Aldersyde (Advisian 2018). Moreover, in section 35-18-29 W4, southern limit of High River Town limits, two important ridge lines (along 12 Avenue SW, 72 Street E and 88 Street E), previously modelled using the LiDAR information, were surveyed to improve their accuracy (Advisian 2018).	2
37A	Existing Condition: represents the study area condition obtained from 28A Gen 2 by taking off the 12 Avenue SW and Centre Street Dike which is proposed but not yet built.	2
49A	Complete Mitigation Scenario plus Hockey Stick Dike-Detail Design: 12 Avenue SW-Centre Street Dike is added to 37A Gen 2 with its detail design alignment available at the time. Minor improvements also became available while completing this scenario and were therefore included: a raised portion of 12 Avenue SW (to the west of the West Town Dike (WTD) and Hockey Stick Dike connection) and two new 2.7 m diameter culverts at the Baker Creek crossing of 12 Avenue SW (previously a single 1.6 m culvert) (Advisian 2018).	2
50A	Complete Mitigation Scenario plus Hockey Stick Dike-Detail Design plus 72 Street SE lowering: this scenario addresses the project team's potential solution of lowering a limited stretch of 72 Street SE	2

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Scenario's Name	Description	Generation
	embankment as further development of 49A and observing changes in the Highwood River/Little Bow River flow split.	
53A	Complete Mitigation Scenario that closely represents Scenario 49A except for inclusion of an updated South West Dike (SWD) with swale and raised portion of the former CP Railway embankment. Used in WorleyParsons, 2018.	2
55A	Complete Mitigation Scenario that includes all mitigation measures included within Scenario 53A but with their representation within the model updated to reflect as built survey. This includes at minimum the inclusion of all topographic changes that have occurred on the unprotected side of the Town Levee System. In addition to model changes to better represent dikes further model upgrades were made to incorporate the as-constructed Centre Street upgrades, finished surface elevations across Wallaceville, and changes to channel bank elevations associated with completed scour protection measures.	2



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## Appendix 2      Photos

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**Photo 1**      **June 4, 2018 – On-foot GPS survey of a wadable cross section between 12<sup>th</sup> Avenue and Highway 2 crossings**







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**Photo 2**      **June 18, 2018 – On-foot GPS survey of the out-of-bank portion of a cross section upstream 170 Township Road crossings**







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**Photo 3**      **June 25, 2018 –Sonar Boat Survey of the LBR segment immediately upstream of the inflow into the TVR**





**Advisian**

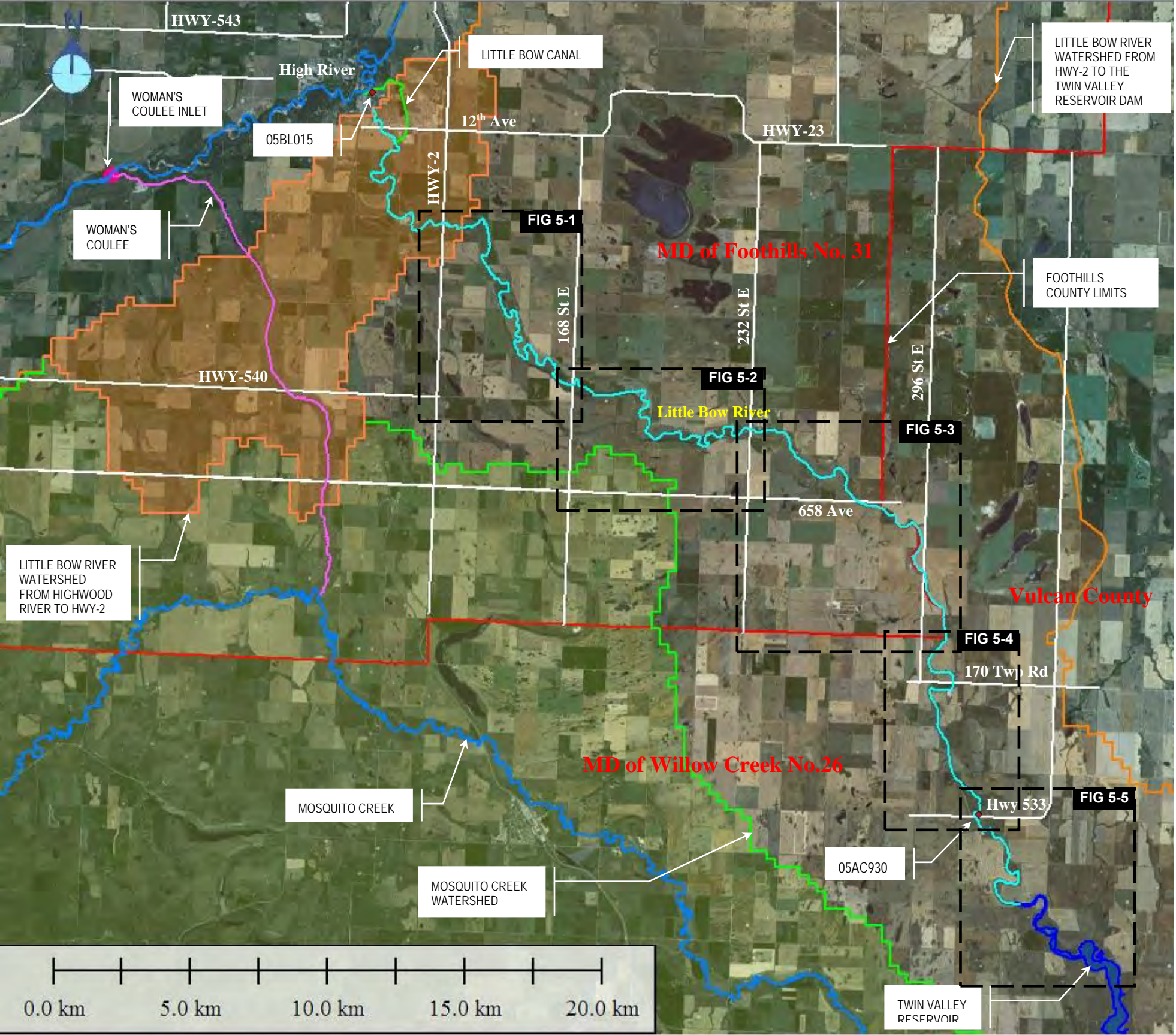
WorleyParsons Group

## Appendix 3      Figures

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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling




Study Area Overview

 <div>Advisian WorleyParsons Group</div>	Created By: AP	Date: Mar 29, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 1-1	Rev: 0
	Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons). WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.			



Model Inflow Upstream Boundary:  
- Flow Hydrograph  
OR  
-Steady State Flow Peak

**LEGEND**

-  - Model predicted flood extent for the June 2013 Flood on mitigated scenario 55A
-  - Model Inflow Location
-  - Model Outflow Location



10000m

Little Bow River at the Highway 2 crossing: Bridge 09469

Bridge 02009 on 168 St E near Cayley

Bridge 00957 on 232 St E near Cayley

Bridge 06548 on 658 Ave 19 km east of Cayley

Bridge 00918 on 296 St E 25 km west of Vulcan

Foothills County limits

Bridge 00999 on 170 Twp Rd 19 km west of Vulcan

Bridge 00962 on Highway 533 15 km east of Nanton

Model Outflow Downstream Boundary at the Twin Valley Reservoir northern end:  
-Water level at 965.97 m (June 2013 flood HWM 74)  
OR  
-Water level at 964.43 (June 2018 Survey)

**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

**Location of Little Bow River RMA-2 Model Boundaries**



**Advisian**  
WorleyParsons Group

Created By: AP

Reviewed By: JB

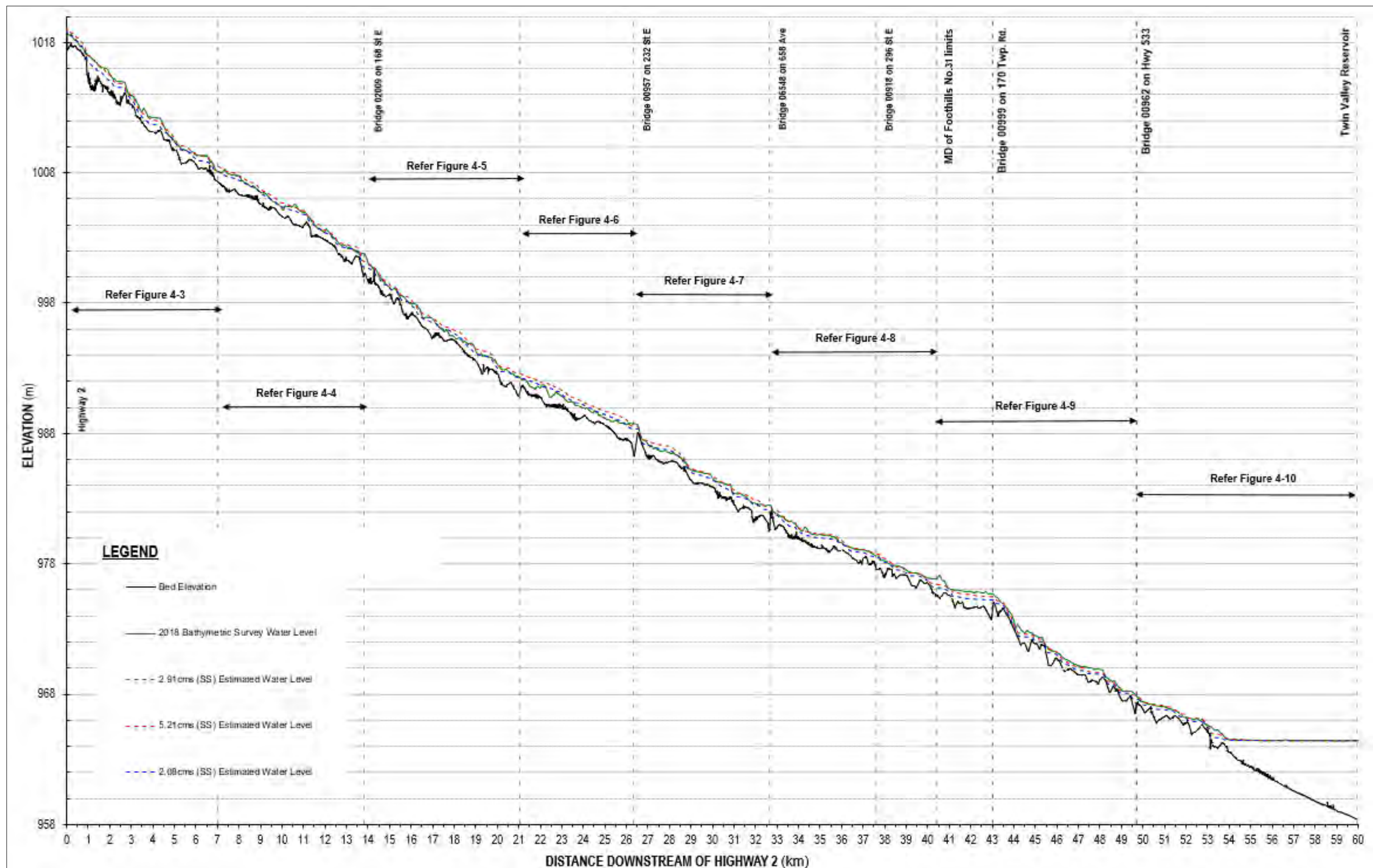
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Figure No: 4-1


Rev: 0

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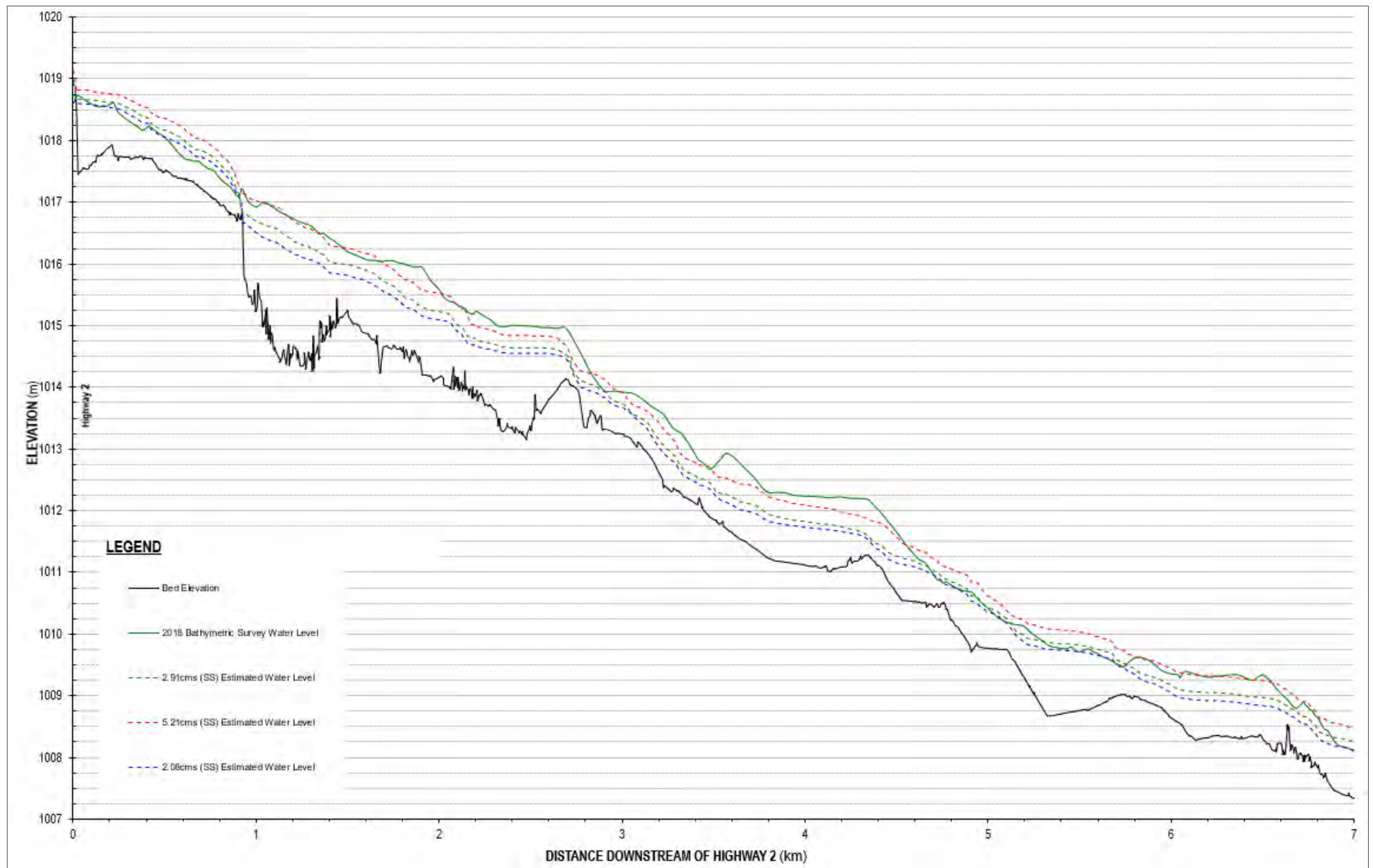


**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

**Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River - Overview**

 <p><b>Advisian</b> WorleyParsons Group</p>	Created By: AP	Date: Mar 29, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 4-2	Rev: 0
	Reviewed By: JB	<p><i>This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons). WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.</i></p>			





# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River – (1 of 8)



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Created By: AP

Reviewed By: JB

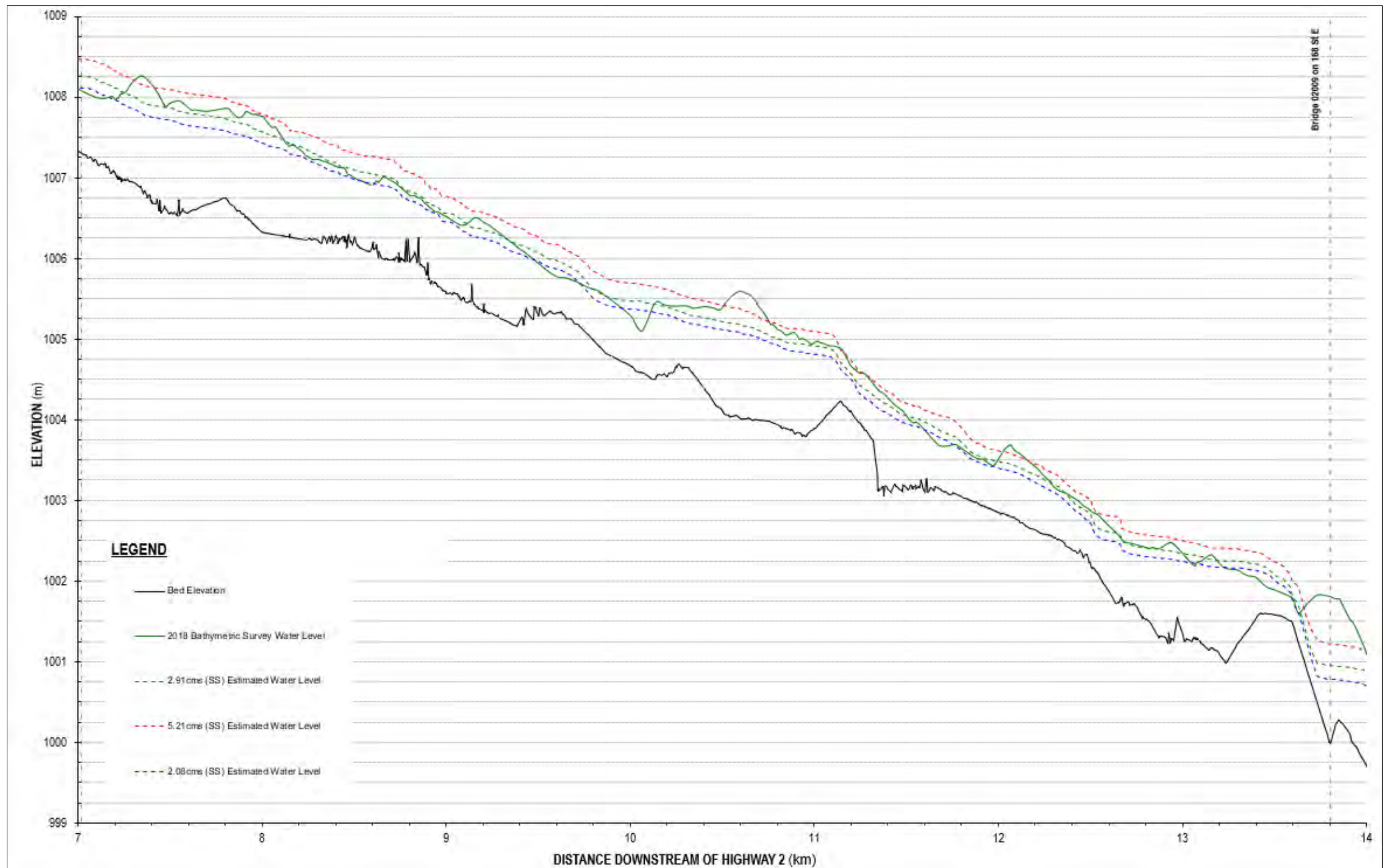
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Figure No: 4-3

Rev: 0

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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River – (2 of 8)



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Created By: AP

Reviewed By: JB

Date: Mar 29, 2019

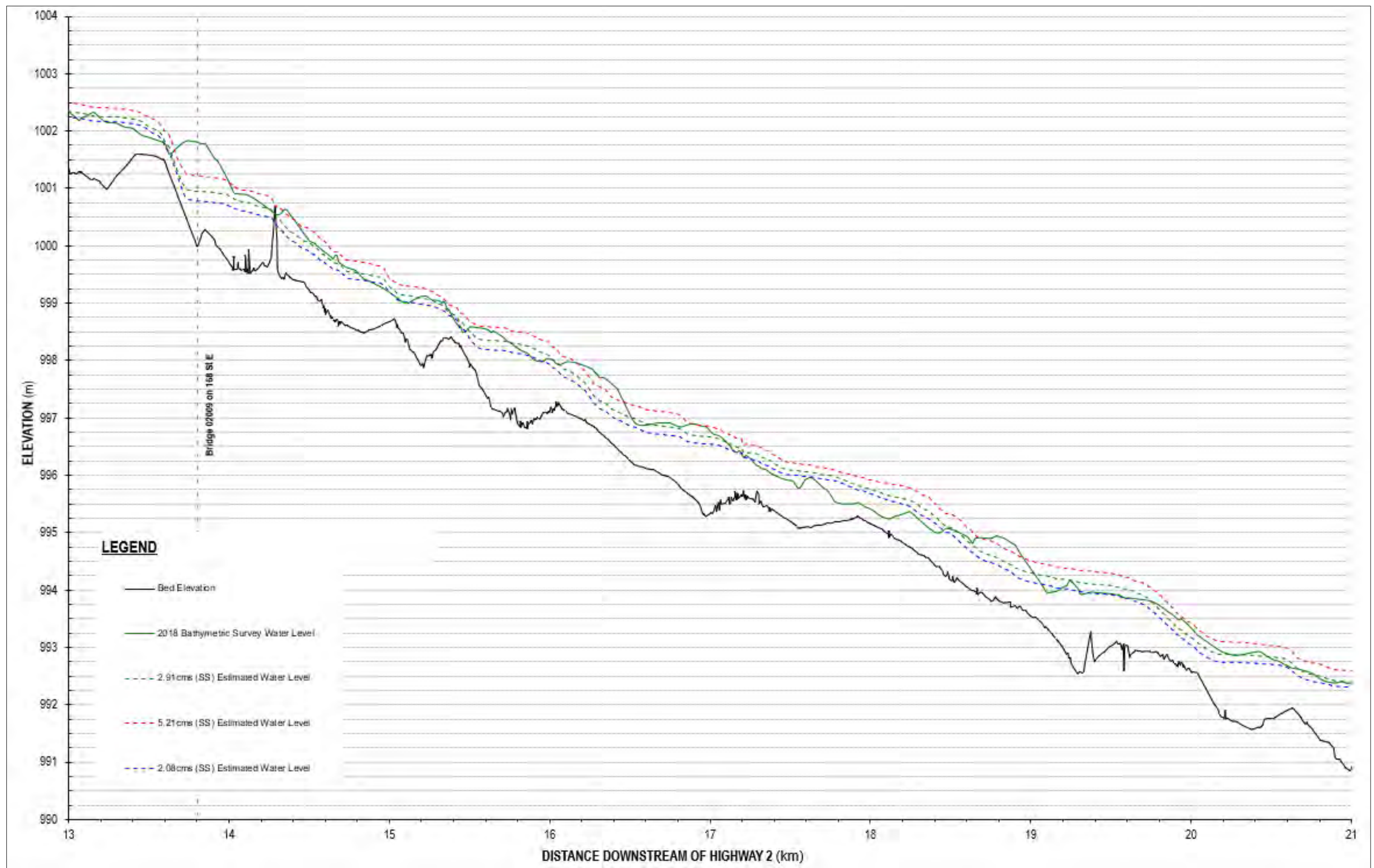
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Figure No: 4-4

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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River – (3 of 8)



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Reviewed By: JB

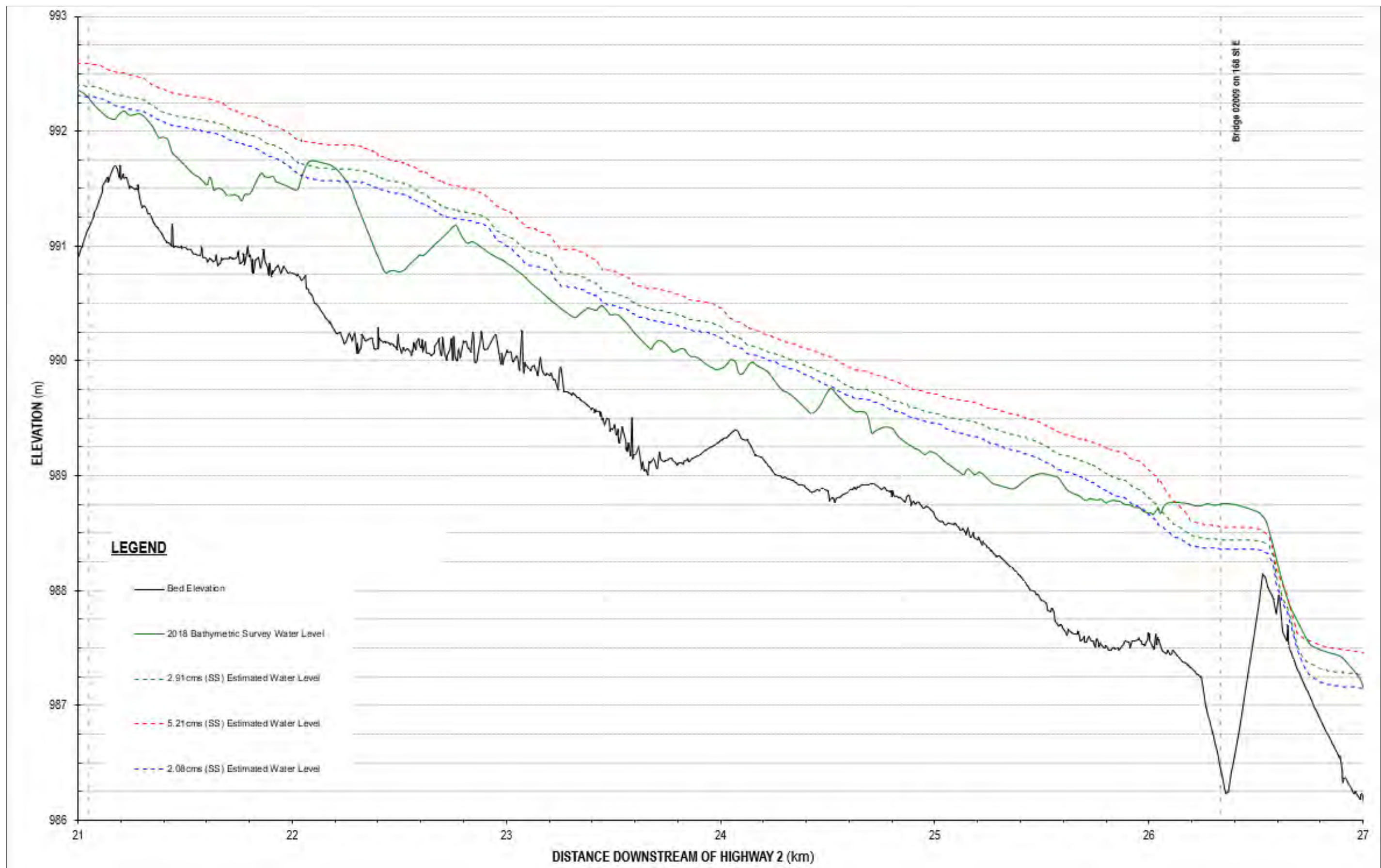
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Figure No: 4-5

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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River – (4 of 8)



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Created By: AP

Reviewed By: JB

Date: Mar 29, 2019

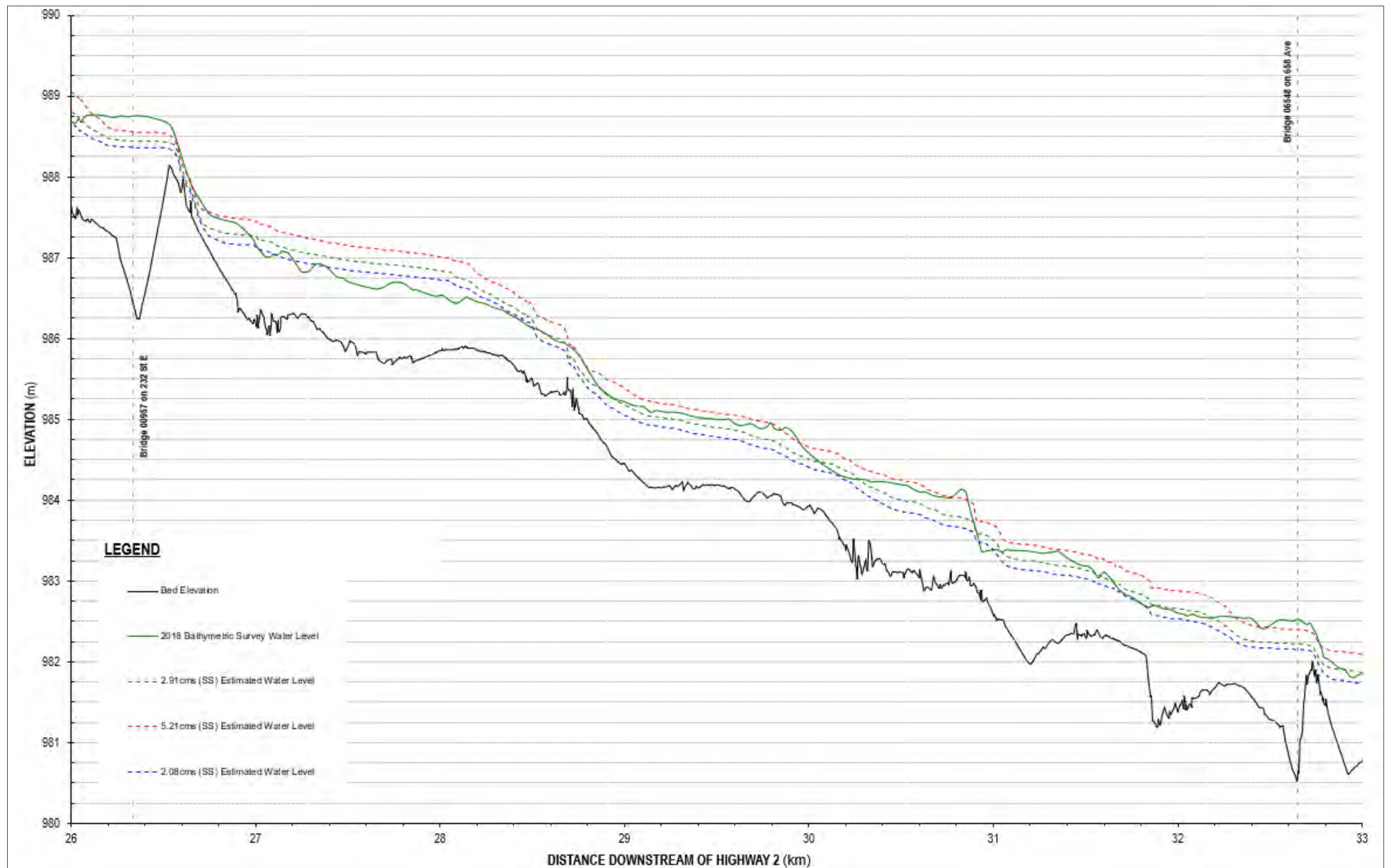
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Figure No: 4-6

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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River – (5 of 8)



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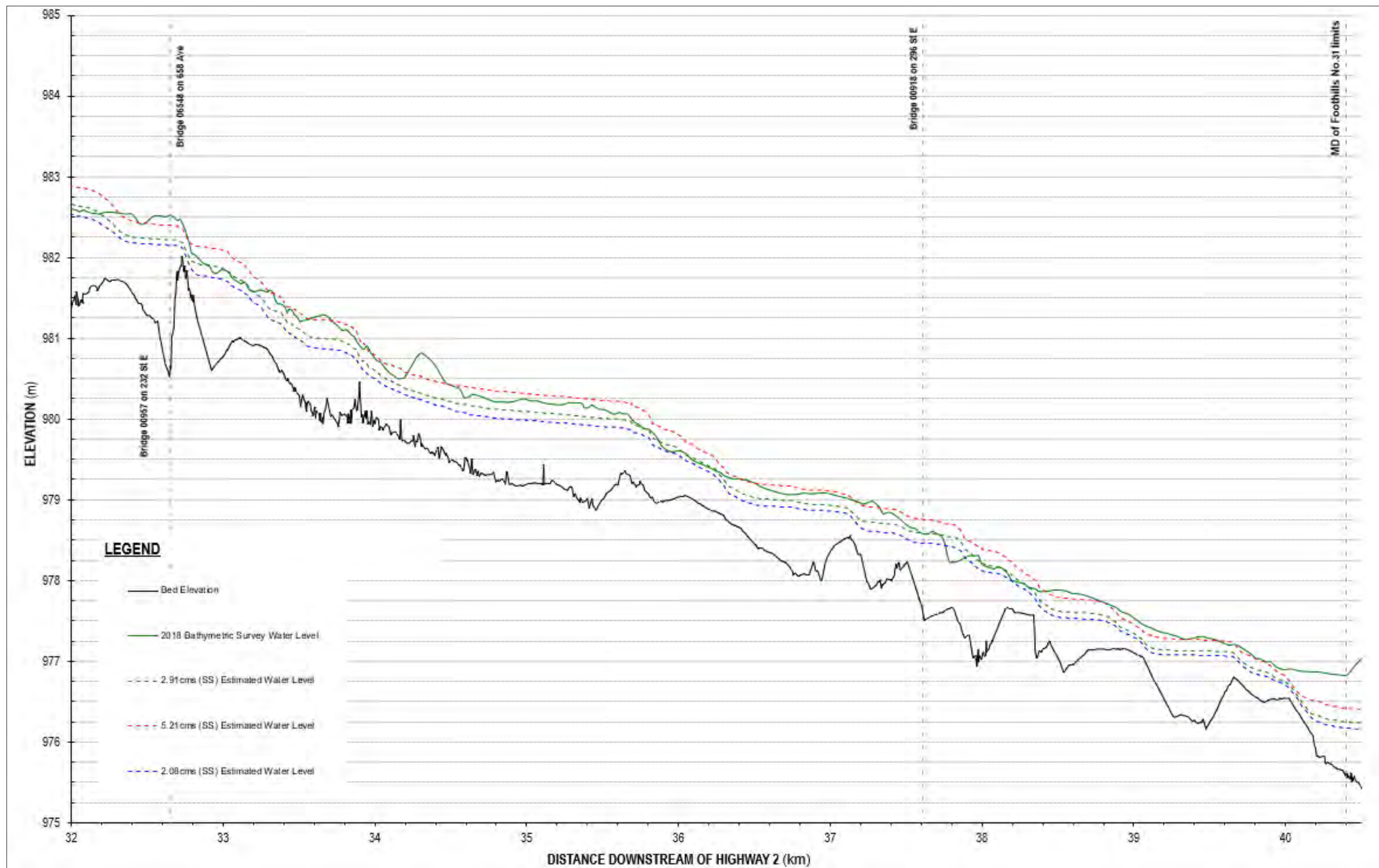
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Figure No: 4-7

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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

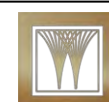
## Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River – (6 of 8)

Date: Mar 29, 2019

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Figure No: 4-8

Rev: 0



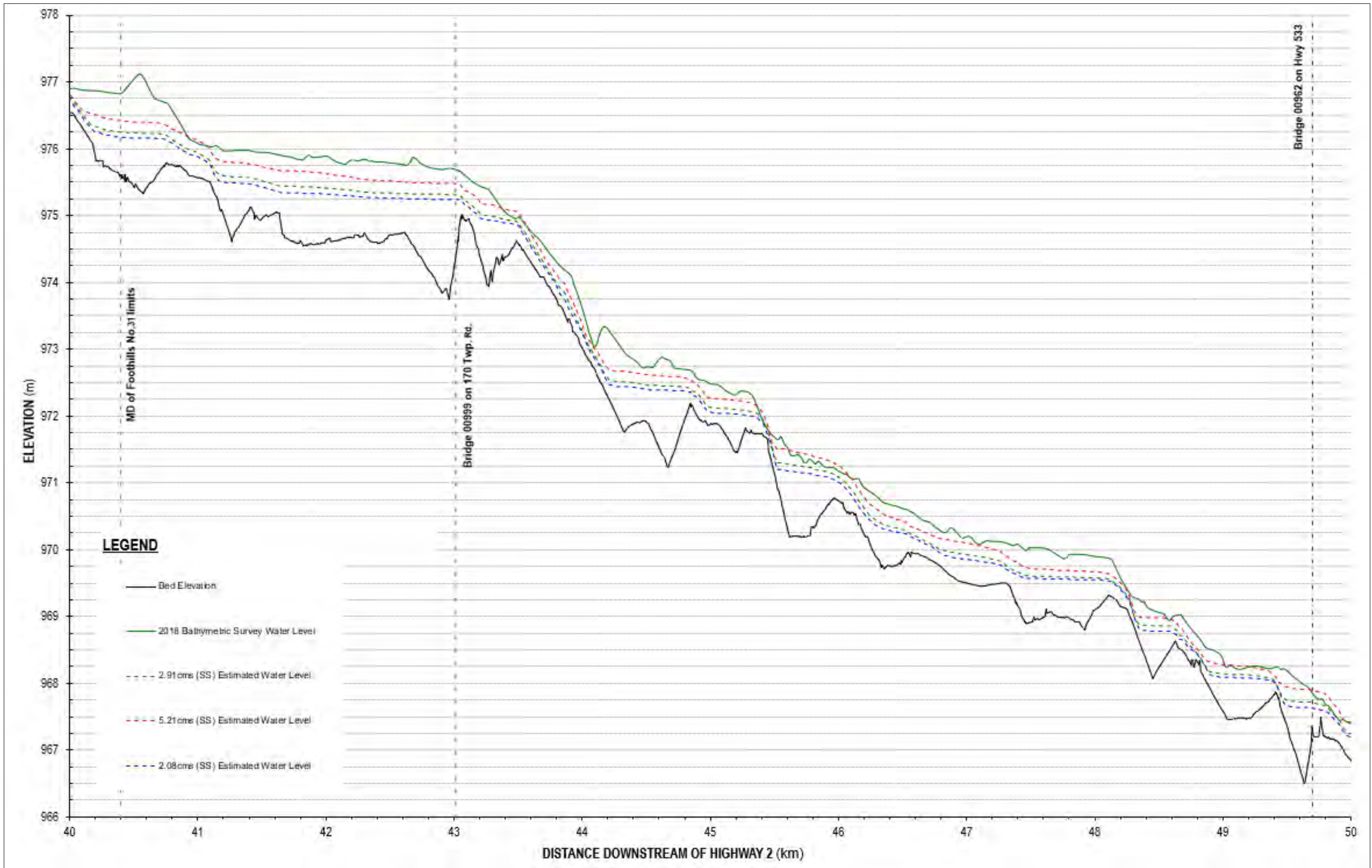
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WorleyParsons Group

Created By: AP

Reviewed By: JB

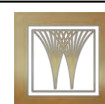
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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River – (7 of 8)



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Reviewed By: JB

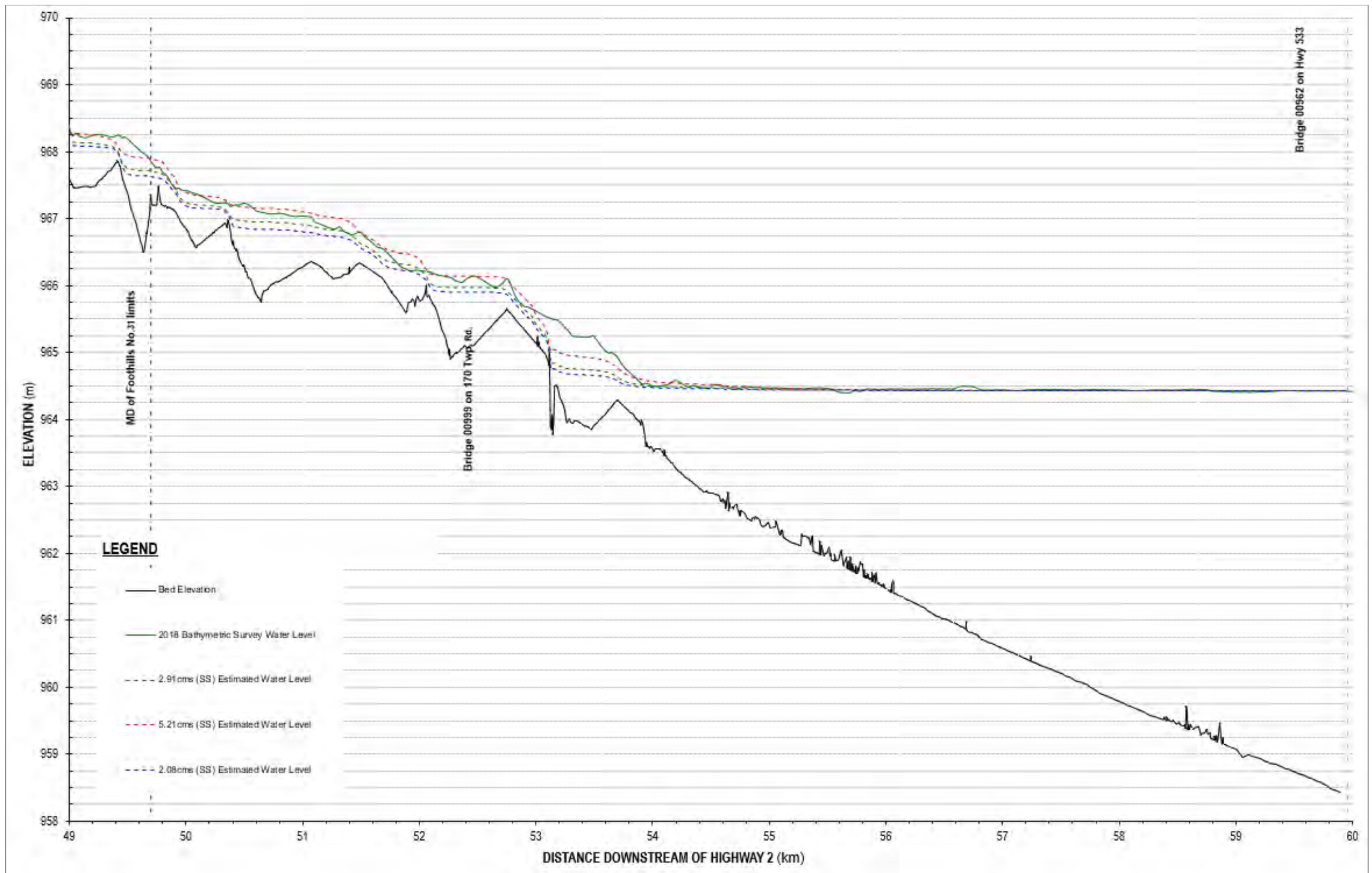
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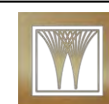
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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Modelled versus Measured Water Surface Profiles for Low Flows on the Little Bow River – (8 of 8)



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Reviewed By: JB

Date: Mar 29, 2019

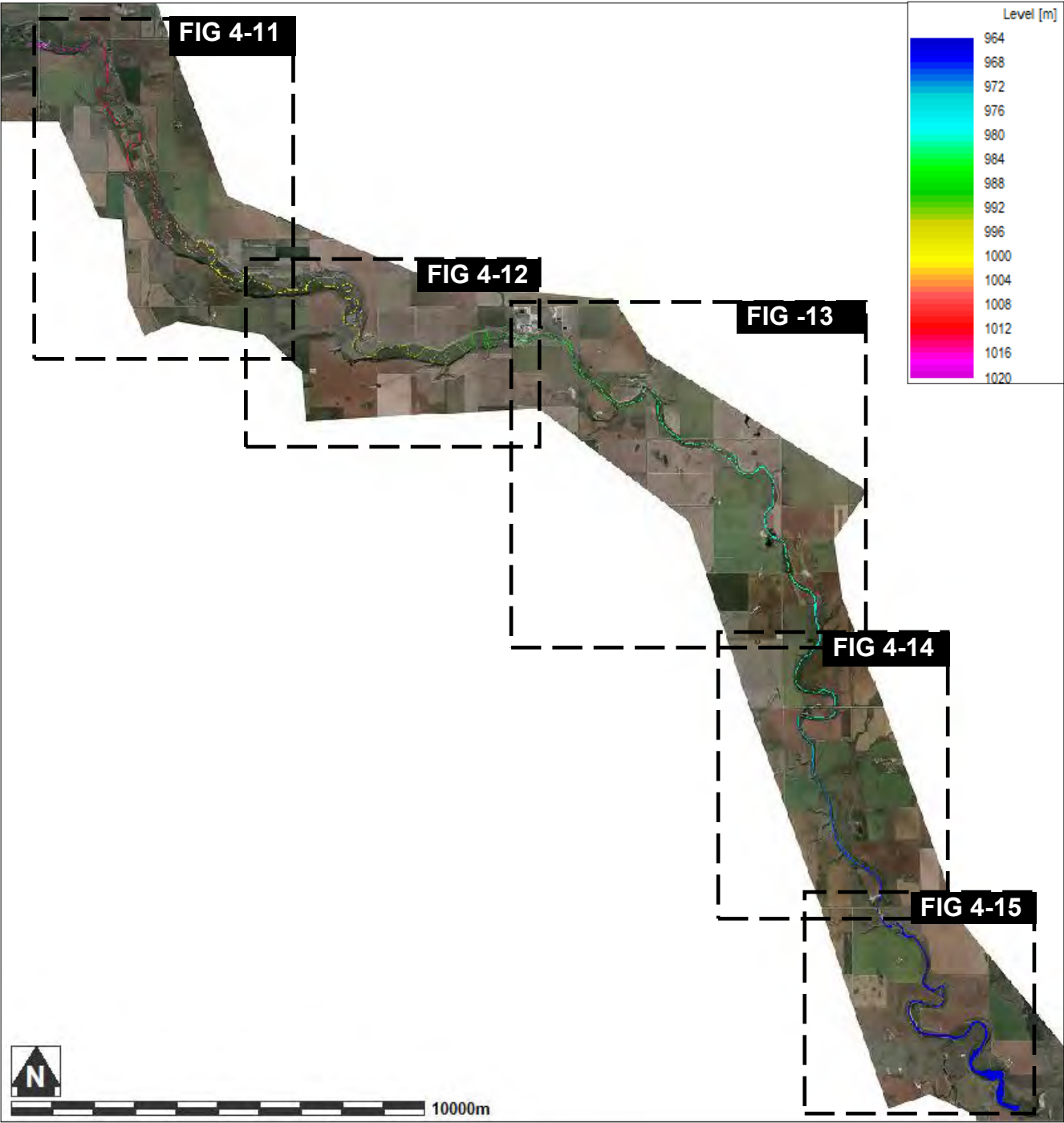
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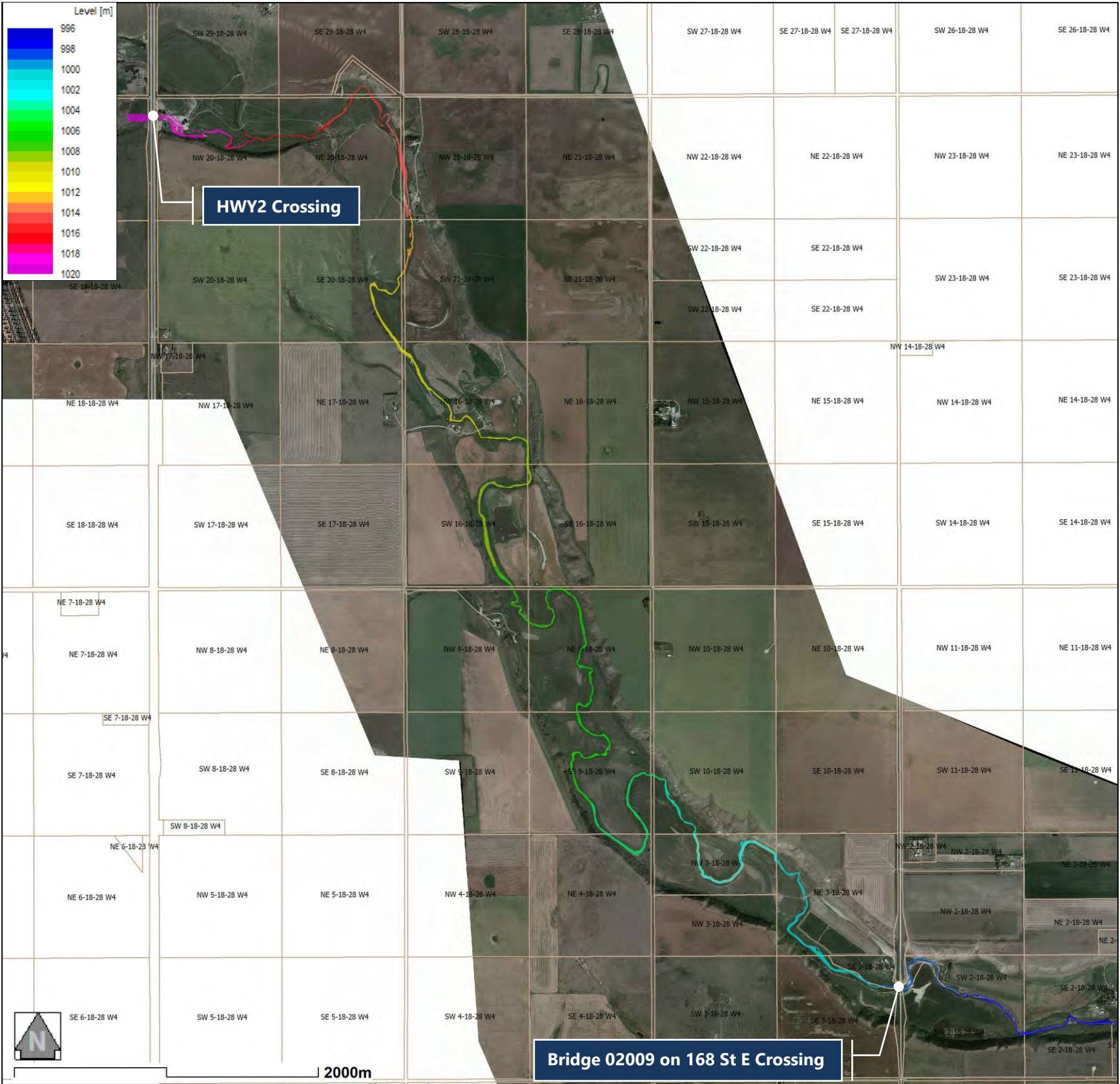
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NOTE:  
Flood level contours shown at 1 m intervals

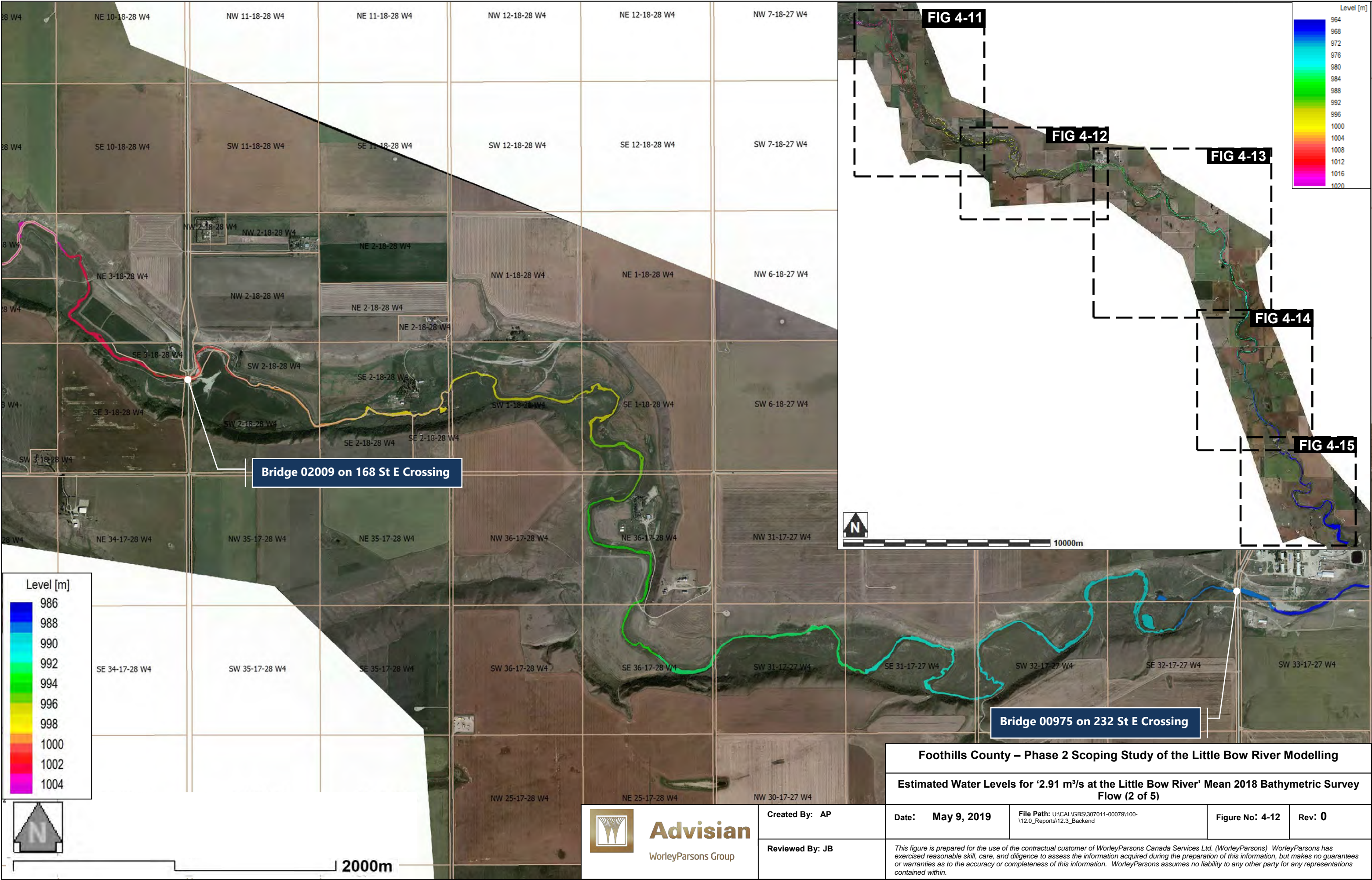


Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

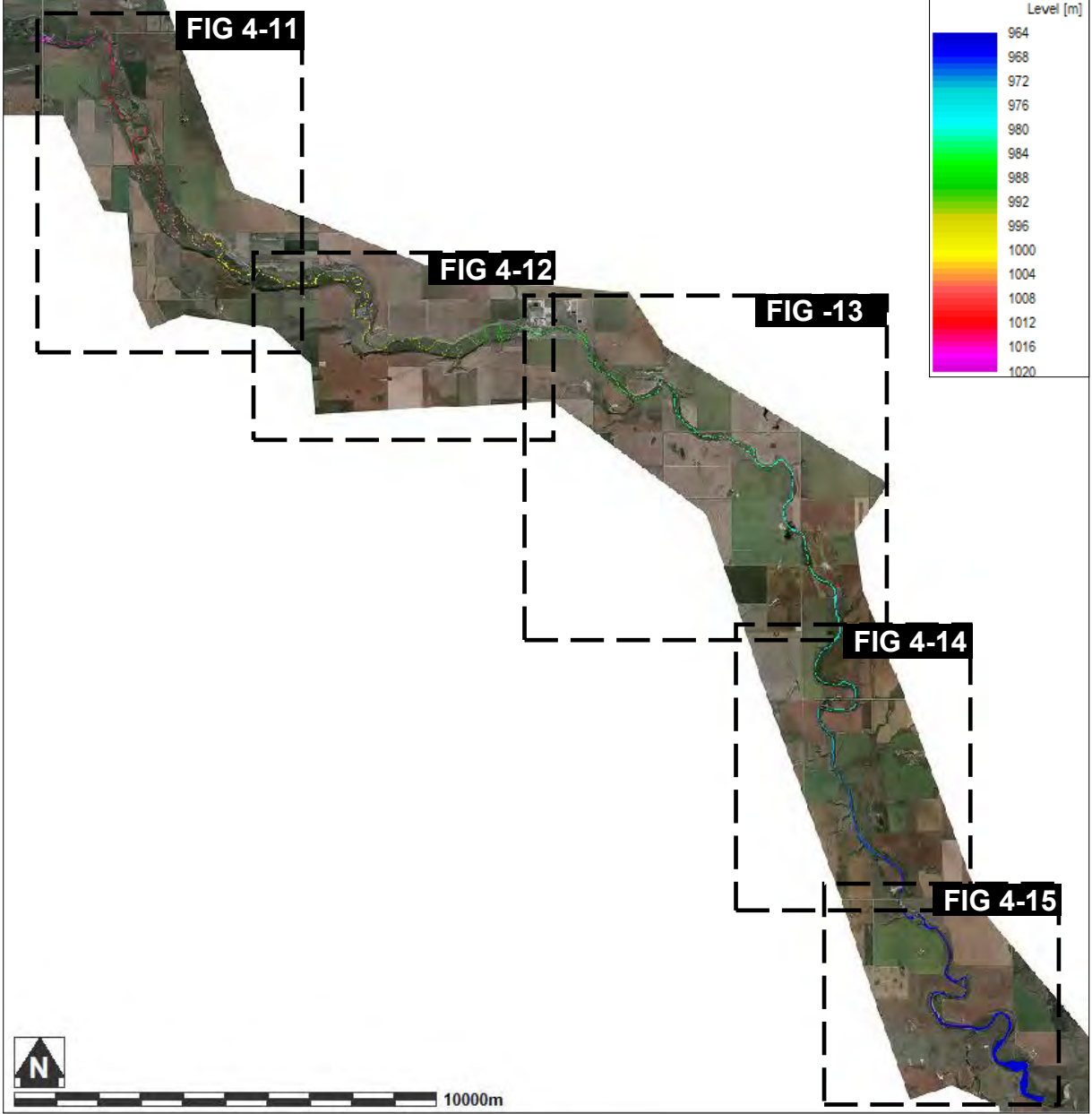
Estimated Water Levels for '2.91 m³/s at the Little Bow River' Mean 2018 Bathymetric Survey Flow (1 of 5)

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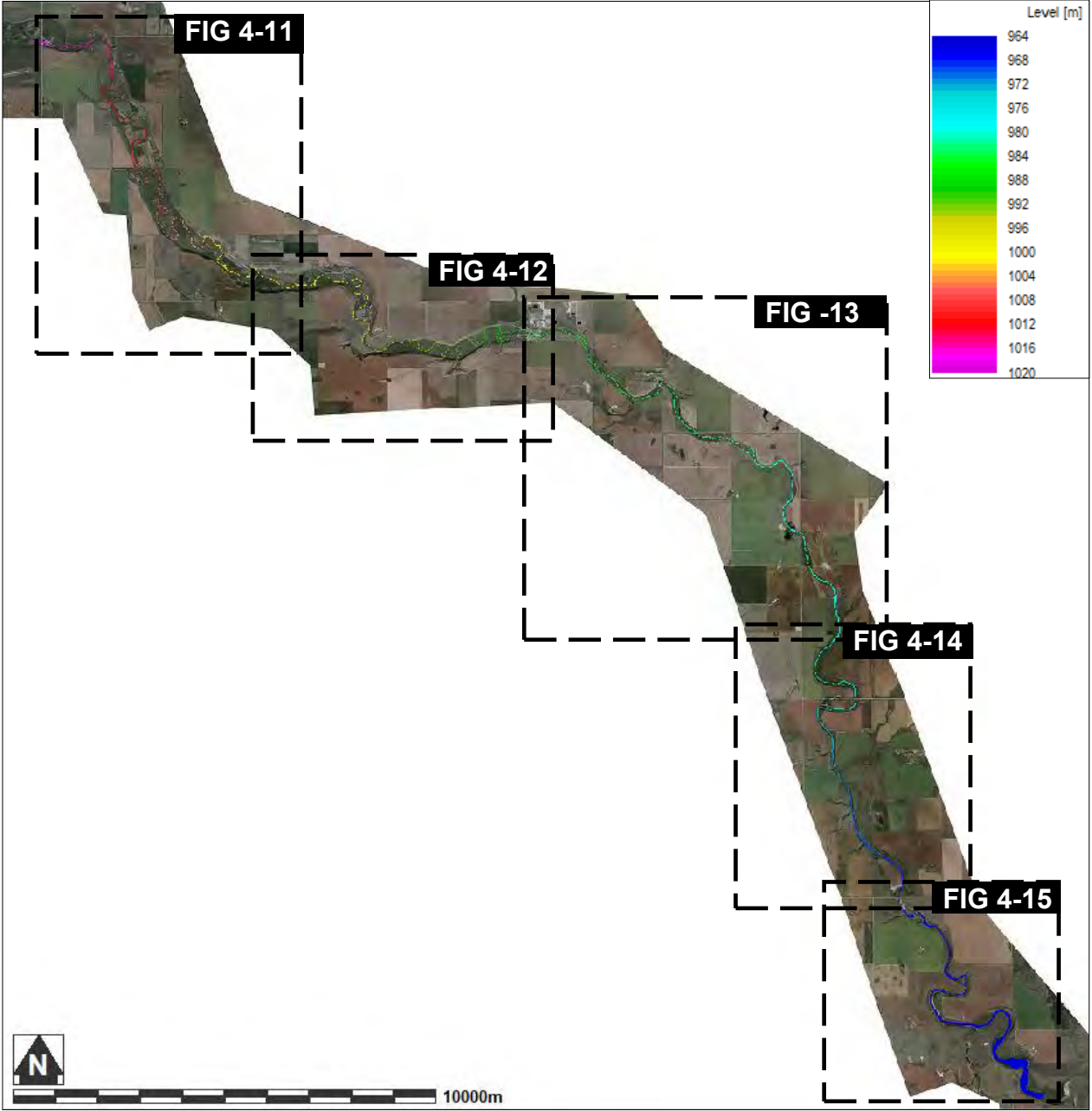
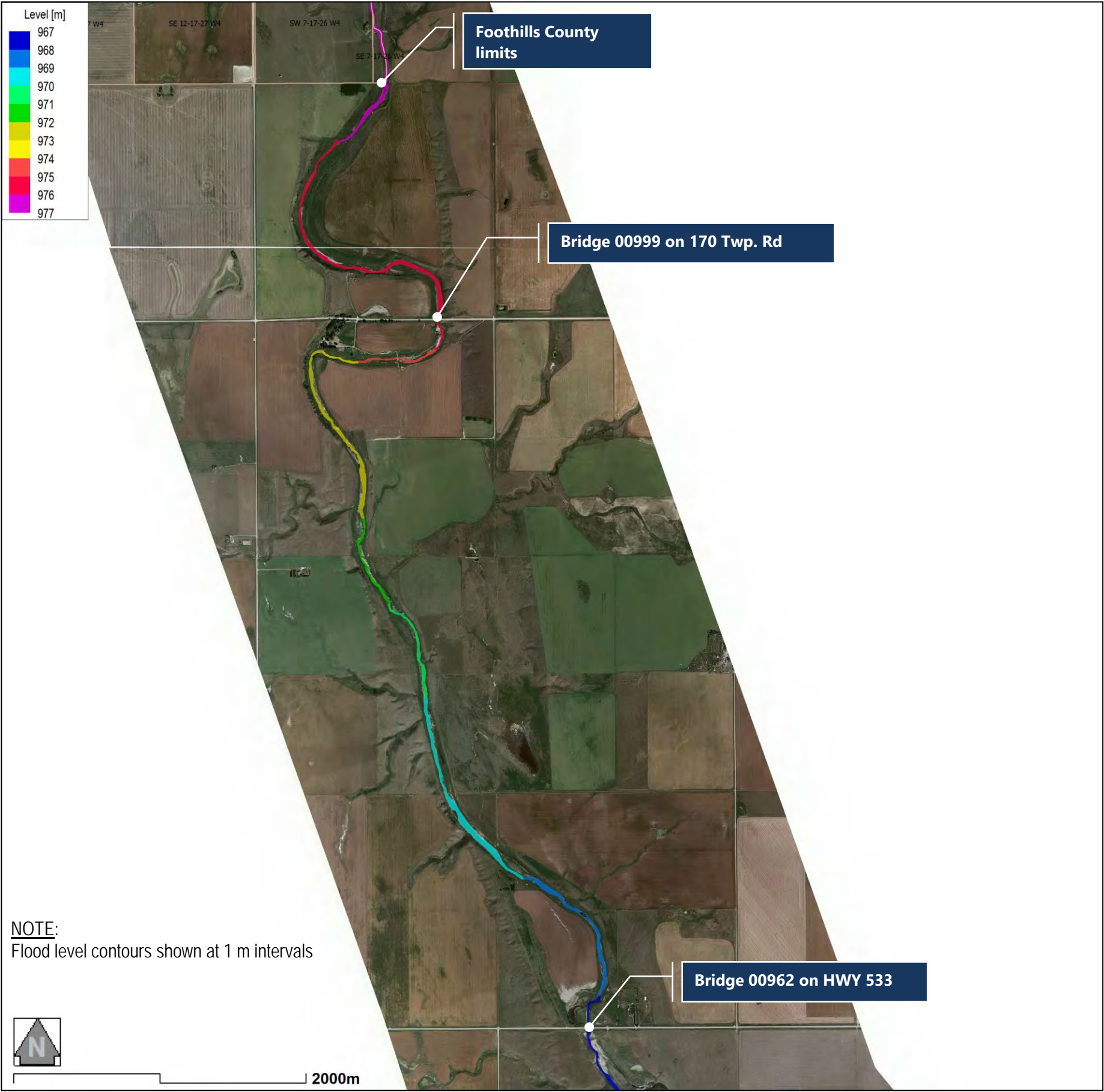






Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Water Levels for '2.91 m³/s at the Little Bow River' Mean 2018 Bathymetric Survey Flow (3 of 5)				
Date:	May 9, 2019	File Path:	U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 4-13
Created By:	AP	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.		
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**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

**Estimated Water Levels for '2.91 m³/s at the Little Bow River' Mean 2018 Bathymetric Survey Flow (4 of 5)**

Date: May 9, 2019

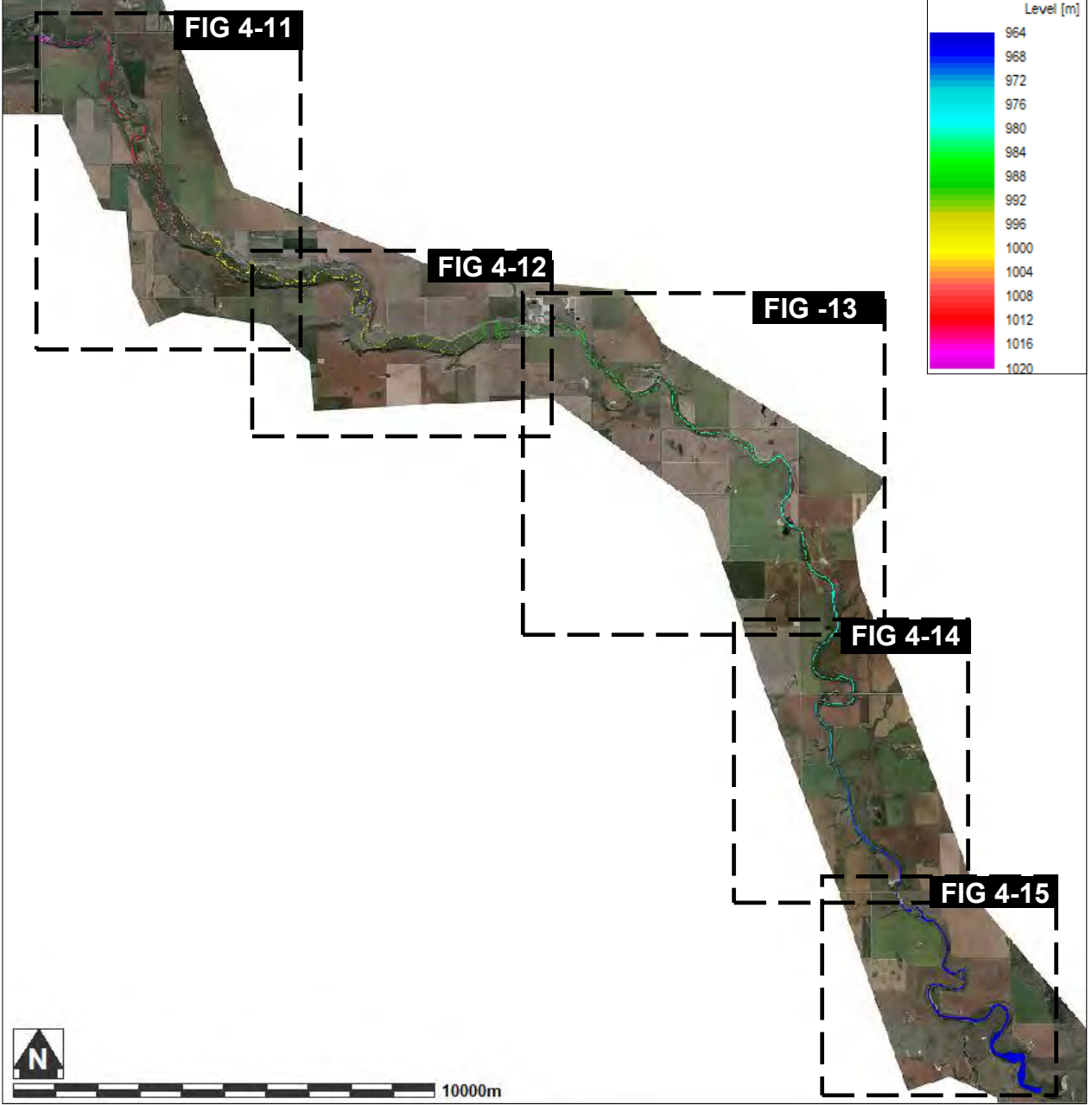
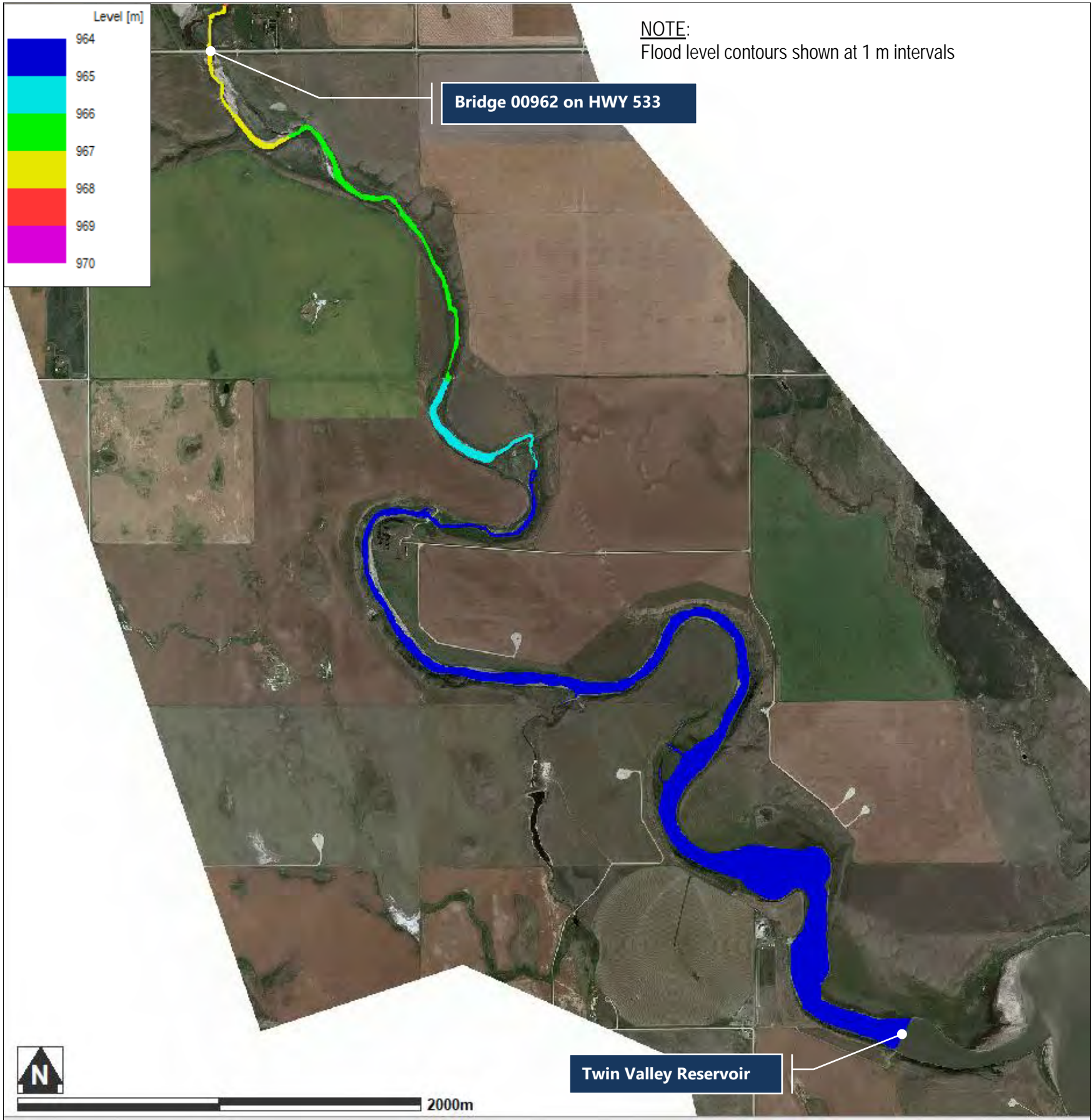
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Figure No: 4-14

Rev: D

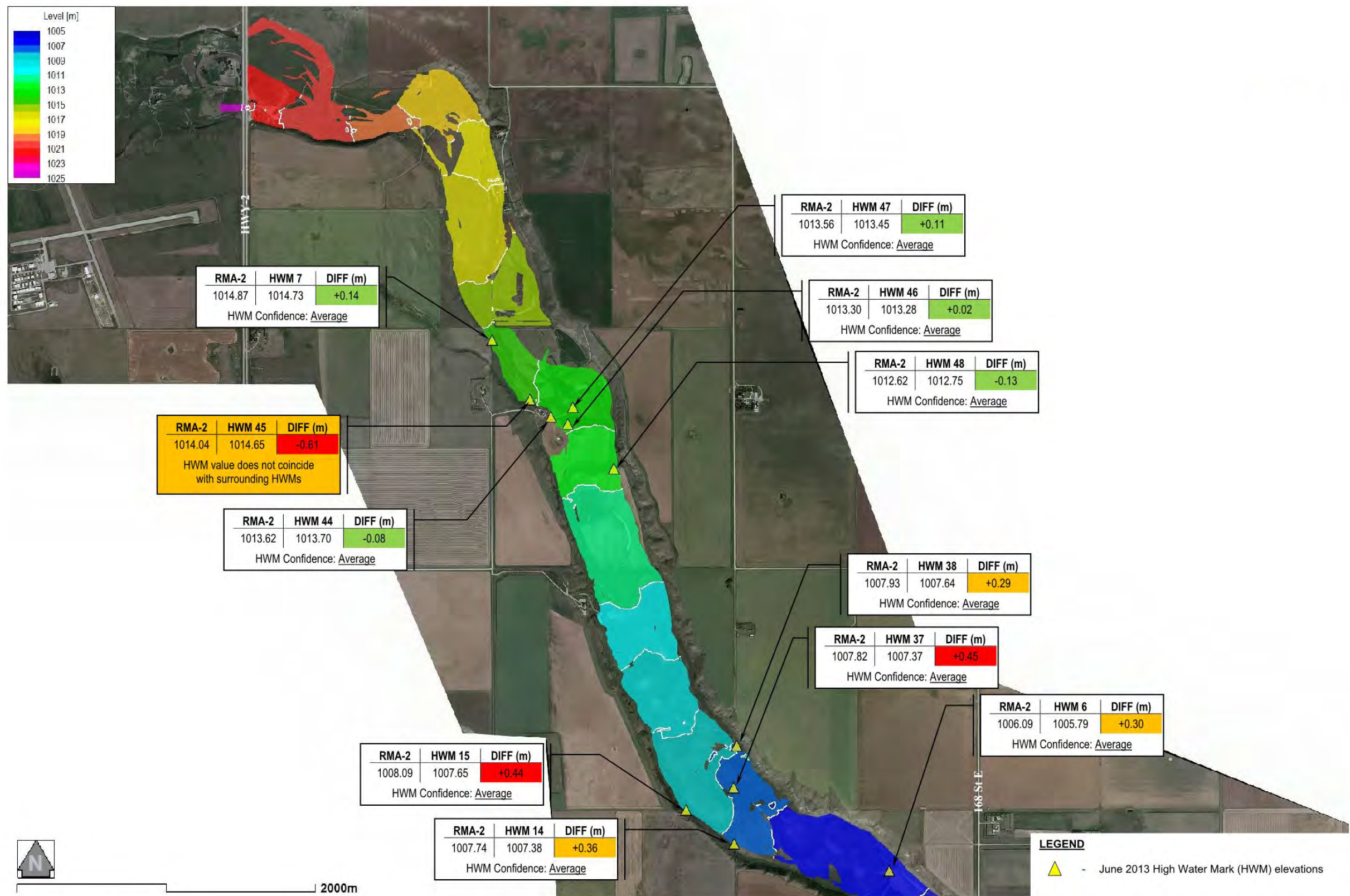
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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Water Levels for ‘2.91 m³/s at the Little Bow River’ Mean 2018 Bathymetric Survey Flow (5 of 5)				
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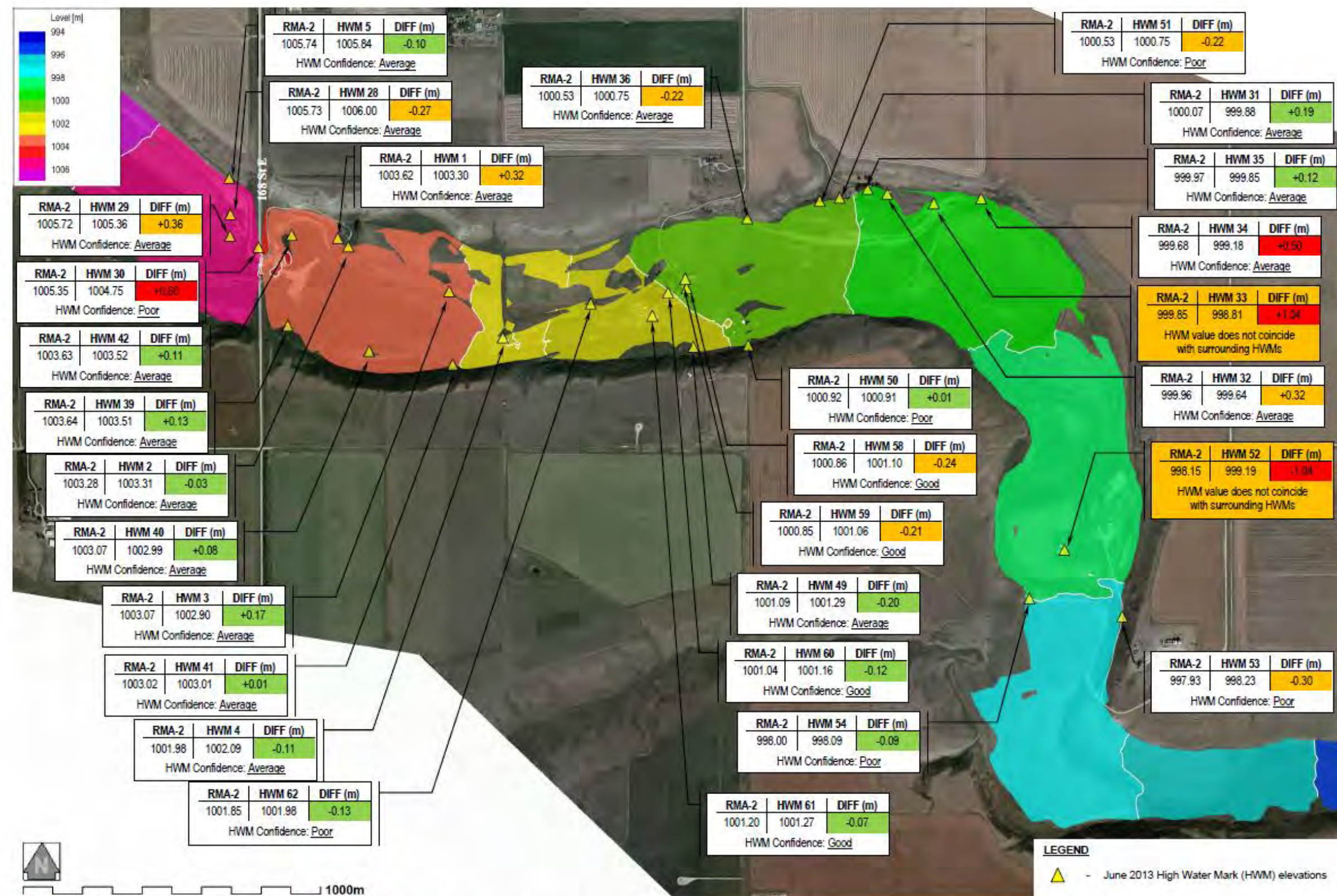


Note: Shading representative of magnitude of WL difference between observed and modelled flood levels.  
Green = 0 – 200 mm difference, Orange = 200 – 400 mm difference, Red = 400+ mm

Text boxes shaded entirely in orange represent those that we believe to be erroneous. Erroneous HWMs have been identified based on a comparison with surrounding HWMs.

Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Comparison of RMA-2 Modelled Levels for the June 2013 Flood to Surveyed HWMs (1 of 5)				
Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-1	Rev: D
Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.			





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## Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

### Comparison of RMA-2 Modelled Levels for the June 2013 Flood to Surveyed HWMs (2 of 5)



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Date: May 9, 2019

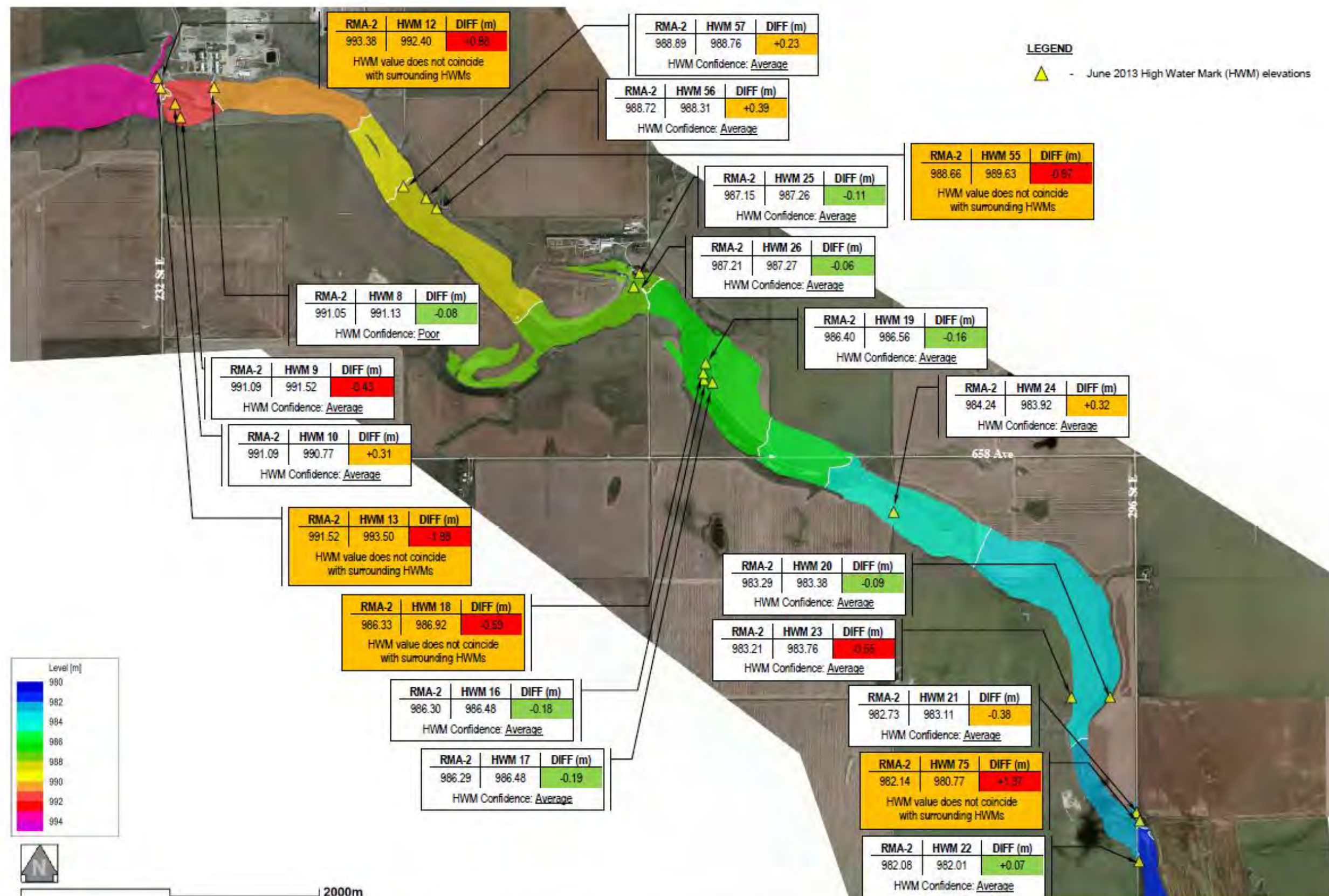
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## Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

### Comparison of RMA-2 Modelled Levels for the June 2013 Flood to Surveyed HWMs (3 of 5)



**Advisian**  
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Created By: AP

Reviewed By: JB

Date: May 9, 2019

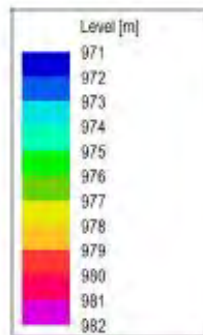
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Rev: D

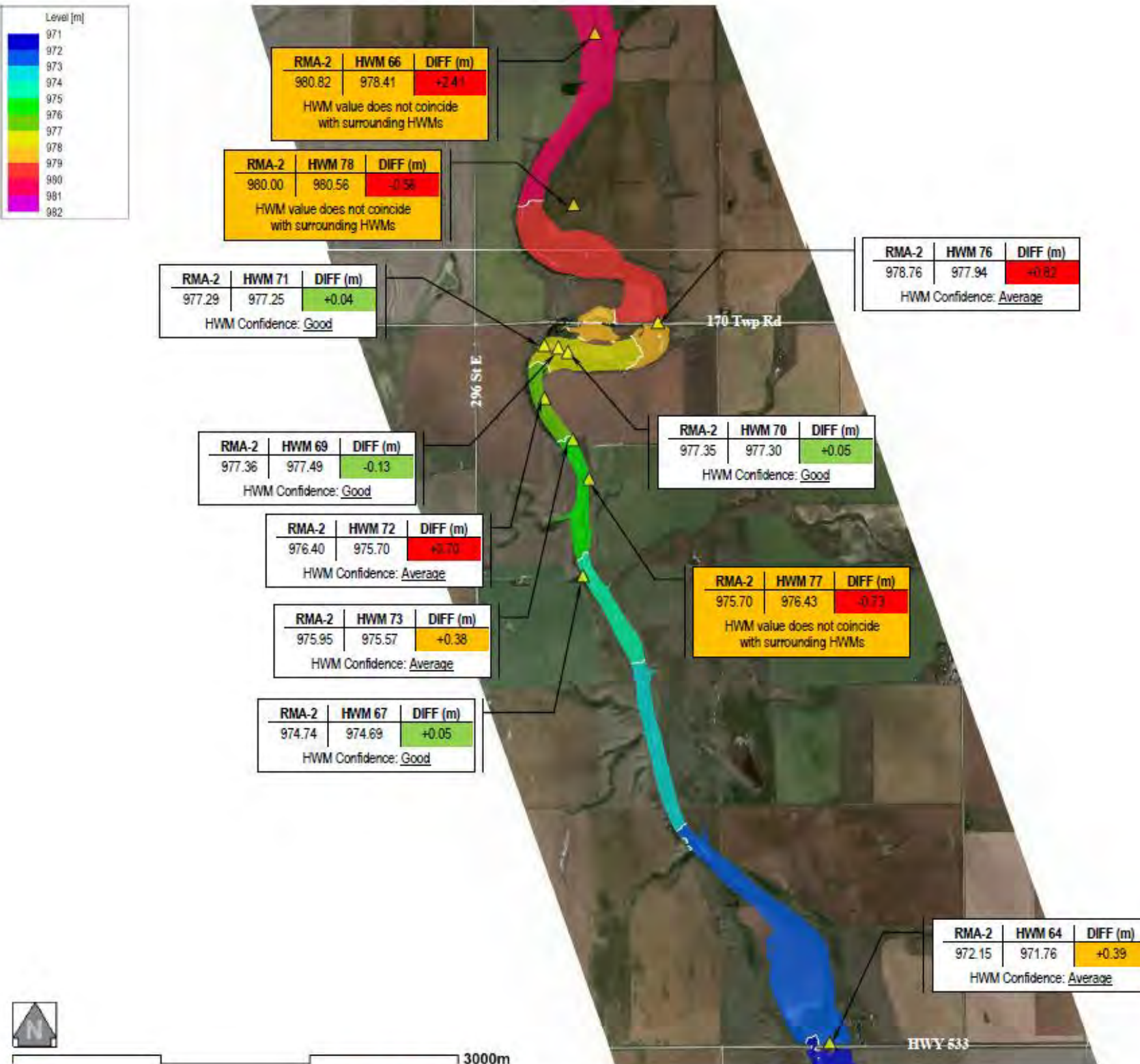
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LEGEND

- June 2013 High Water Mark (HWM) elevations

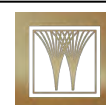


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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

Comparison of RMA-2 Modelled Levels for the June 2013 Flood to Surveyed HWMs (4 of 5)



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## Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

### Comparison of RMA-2 Modelled Levels for the June 2013 Flood to Surveyed HWMs (5 of 5)



**Advisian**  
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Created By: AP

Reviewed By: JB

Date: May 9, 2019

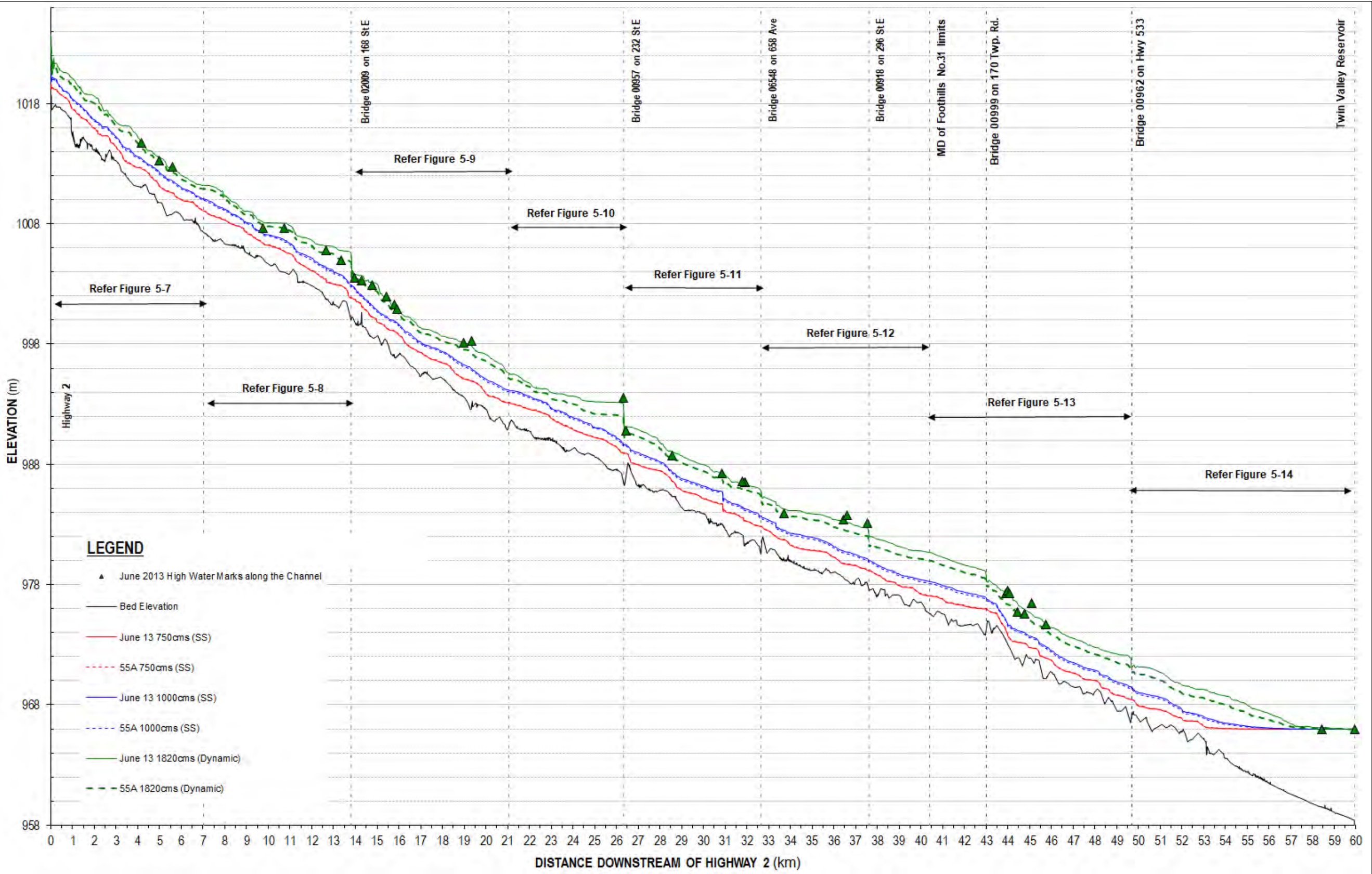
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Figure No: 5-5

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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013 Versus 55A Overview				
 <div>Advisian WorleyParsons Group</div>	Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-6
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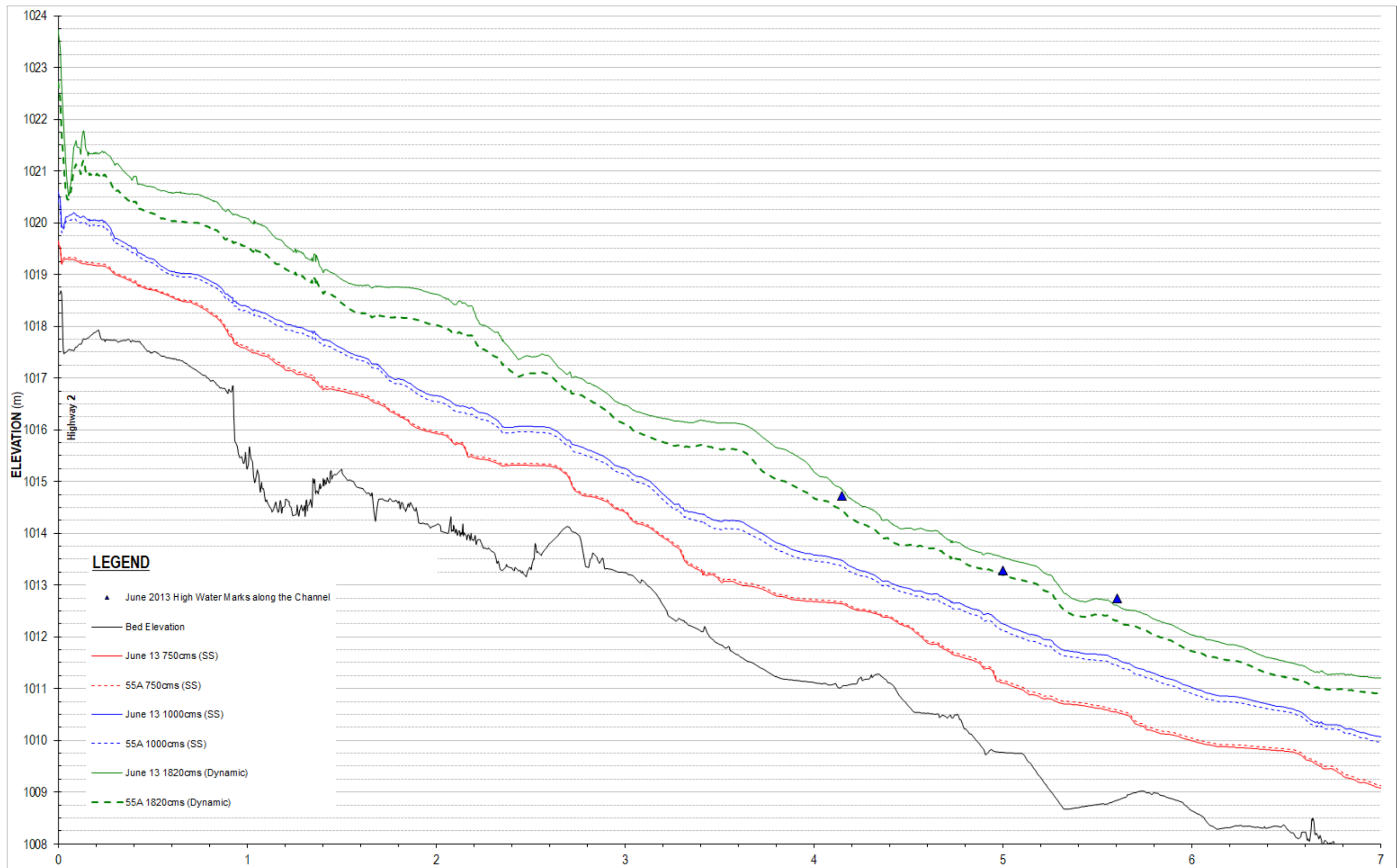
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Figure No: 5-6

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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013  
Versus 55A (1 of 8)



**Advisian**  
WorleyParsons Group

Created By: AP

Reviewed By: JB

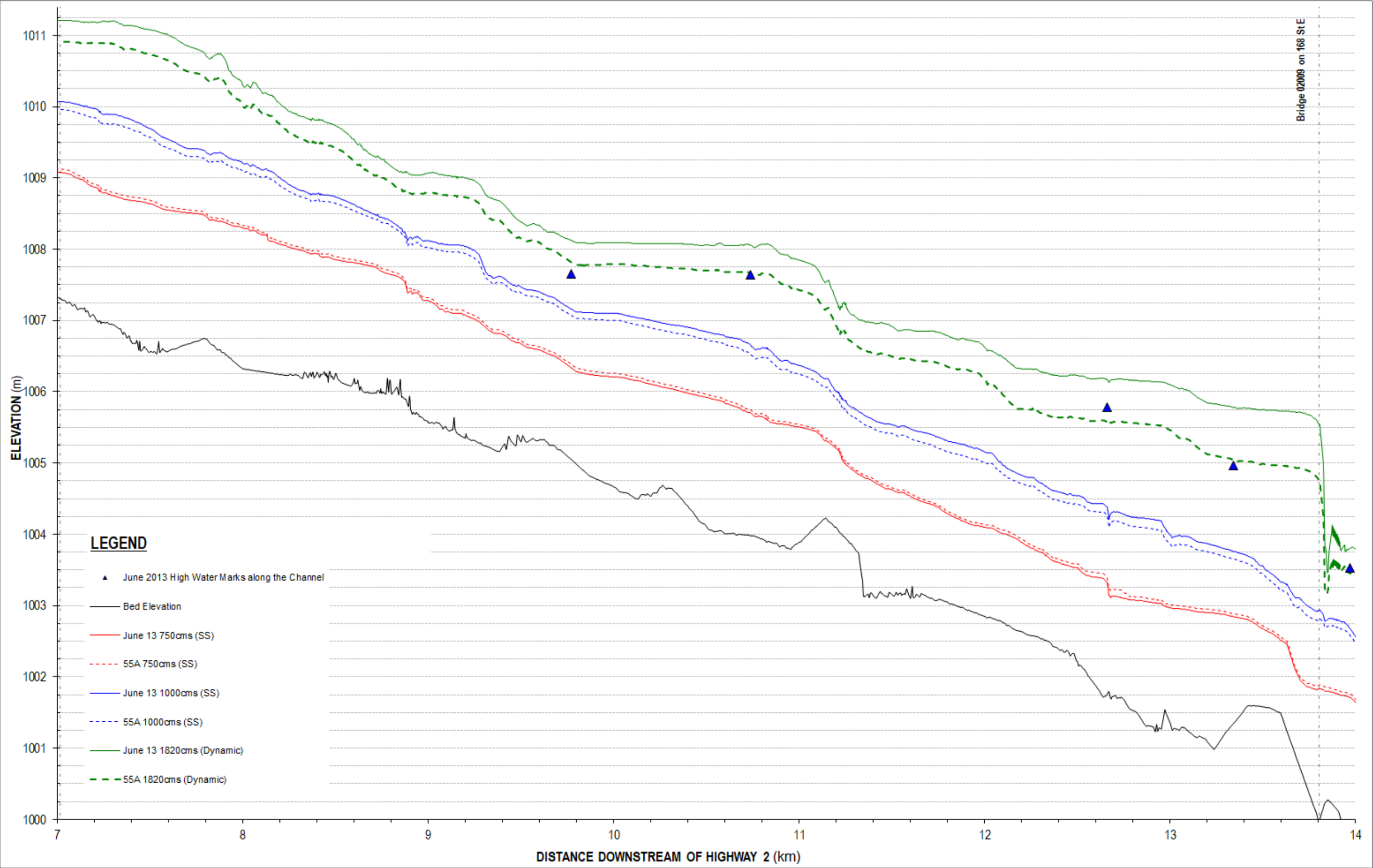
Date: May 9, 2019


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Figure No: 5-7

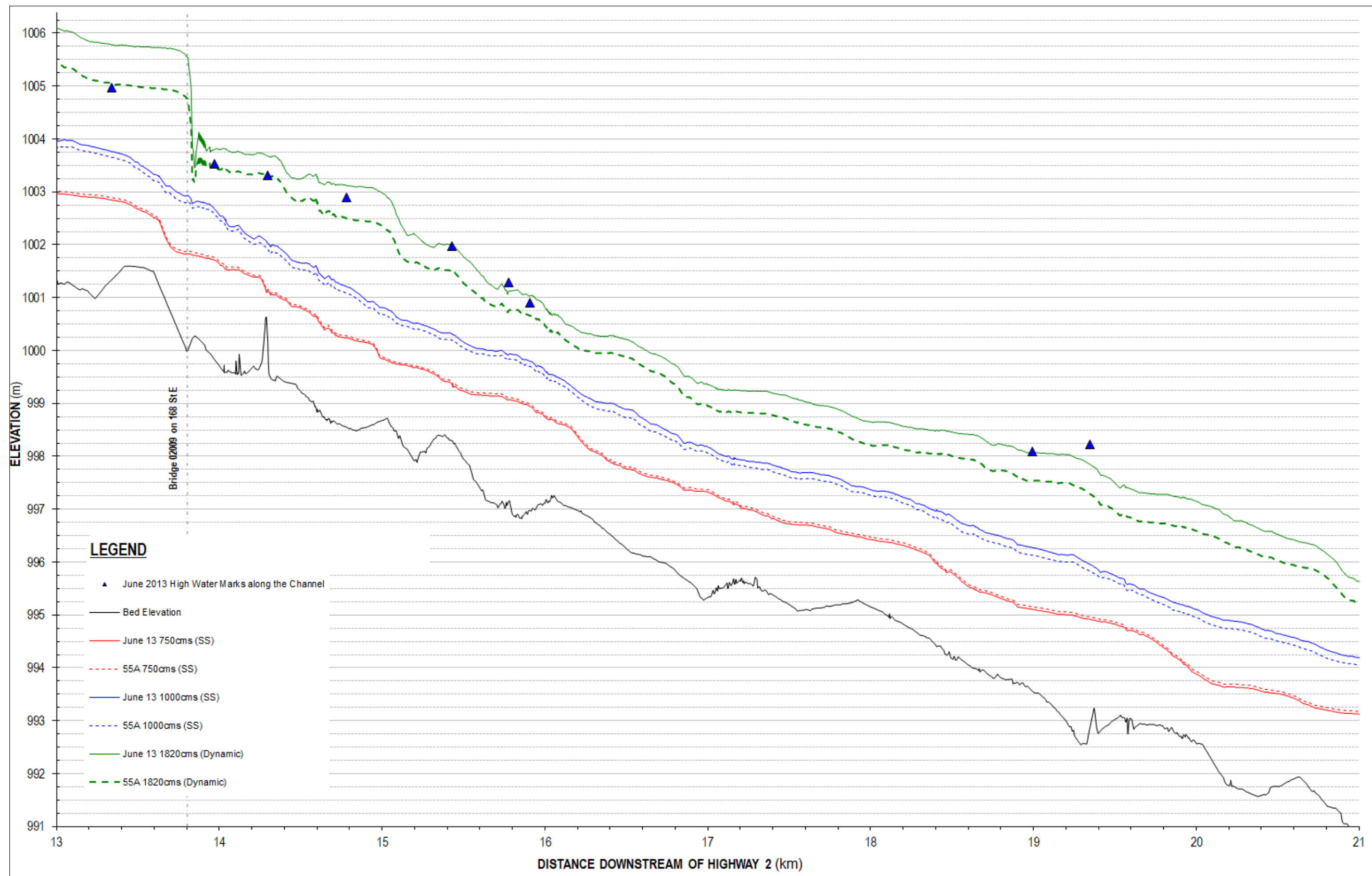
Rev: 0

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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013 Versus 55A (2 of 8)				
 <div>Advisian WorleyParsons Group</div>	Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-8
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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013 Versus 55A (3 of 8)



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**Created By:** AP

**Reviewed By:** JB

**Date:** Mar 29, 2019


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**Figure No:** 5-9

**Rev:** 0

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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013 Versus 55A (4 of 8)				
 <div>Advisian WorleyParsons Group</div>	Created By: AP	Date: Mar 29, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-10
	Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.		



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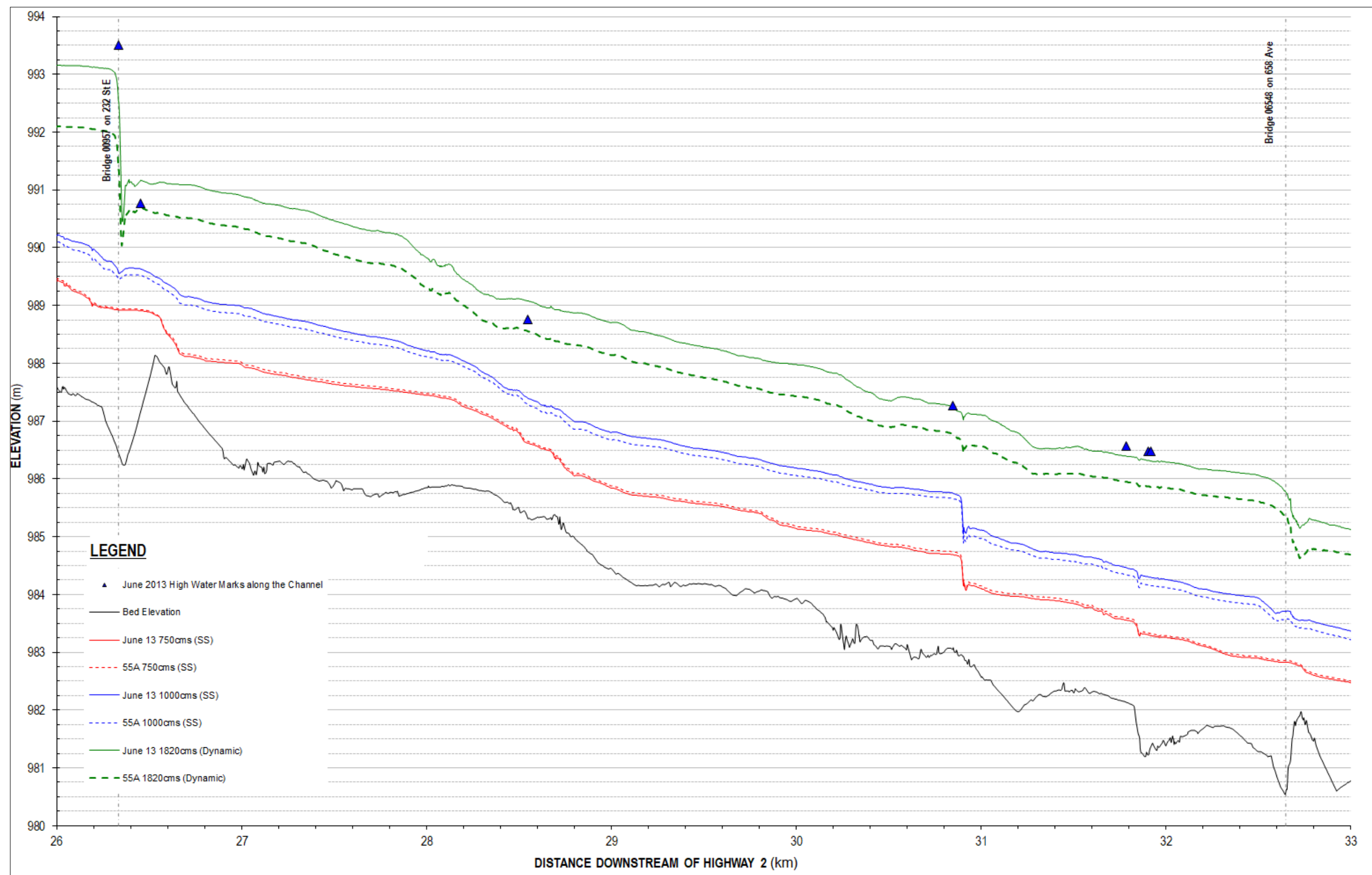
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Figure No: 5-10

Rev: 0

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# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013 Versus 55A (5 of 8)



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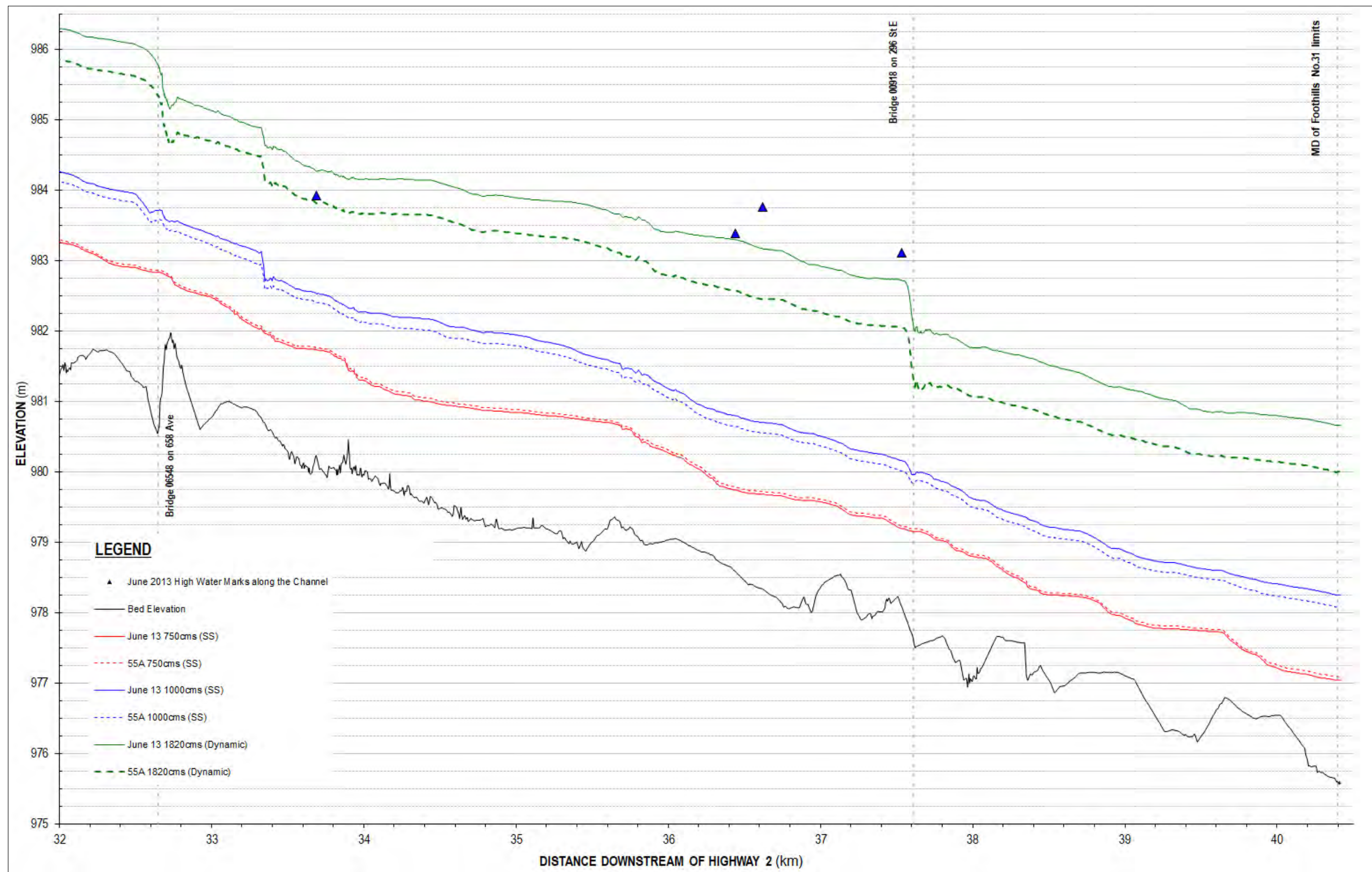
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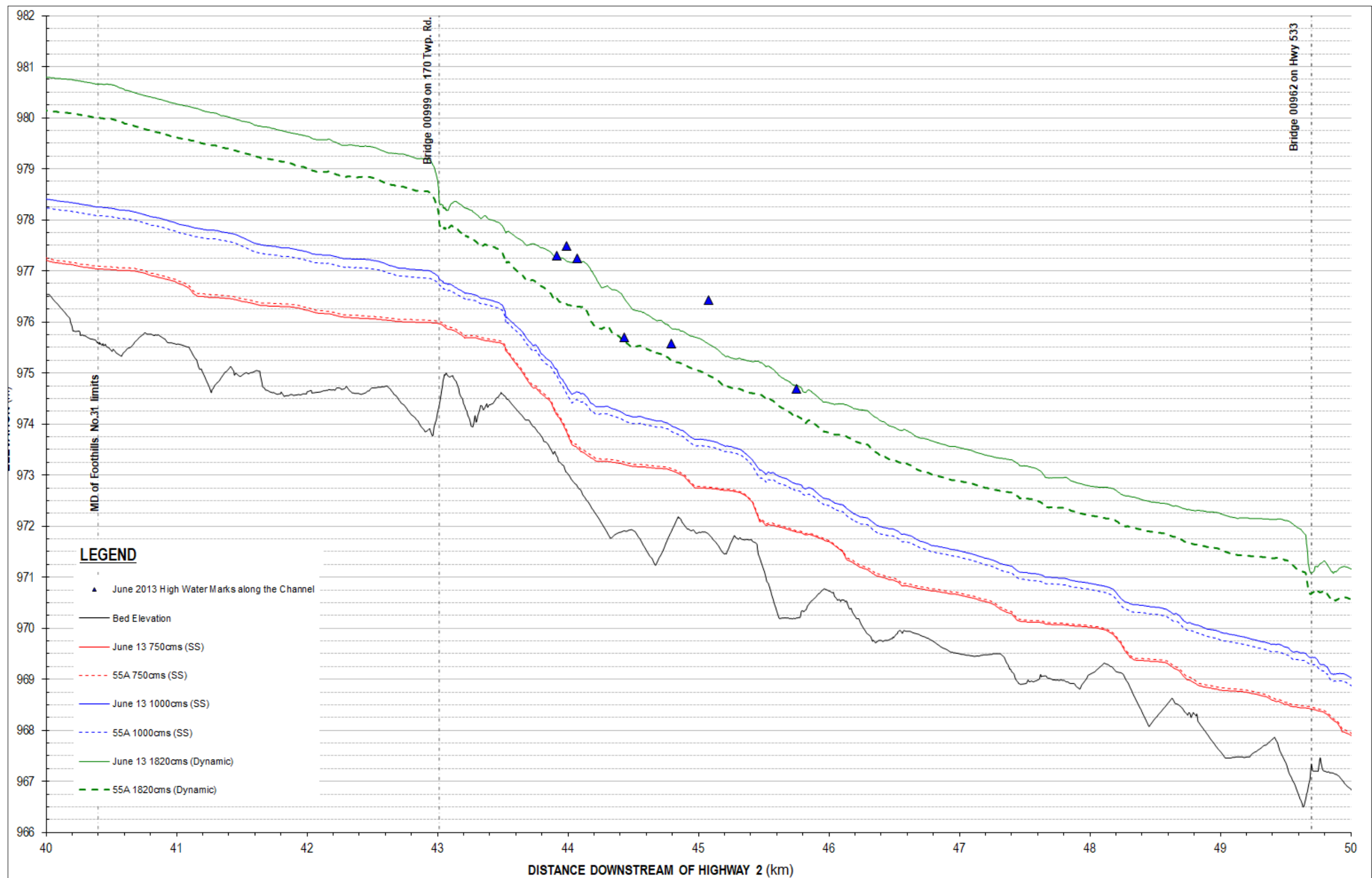
Figure No: 5-11

Rev: 0

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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013 Versus 55A (6 of 8)				
 <div>Advisian WorleyParsons Group</div>	Created By: AP	Date: Mar 29, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-12
	Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.		



# Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

## Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013 Versus 55A (7 of 8)



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Date: Mar 29, 2019

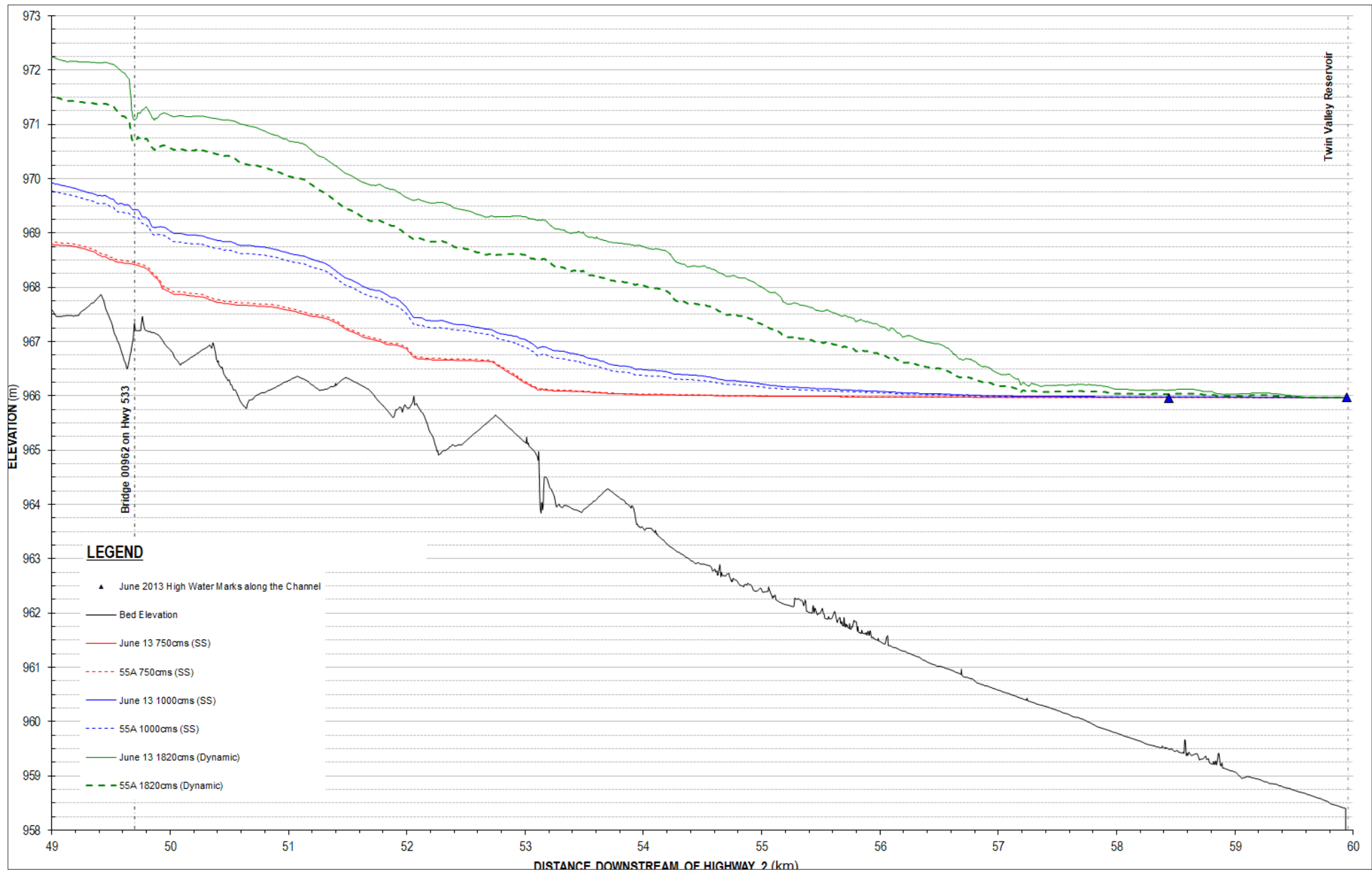
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Figure No: 5-13

Rev: 0

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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

Comparison of Water Surface Profiles for Steady or Dynamic State Conditions for June 2013  
Versus 55A (8 of 8)



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Created By: AP

Reviewed By: JB

Date: Mar 29, 2019

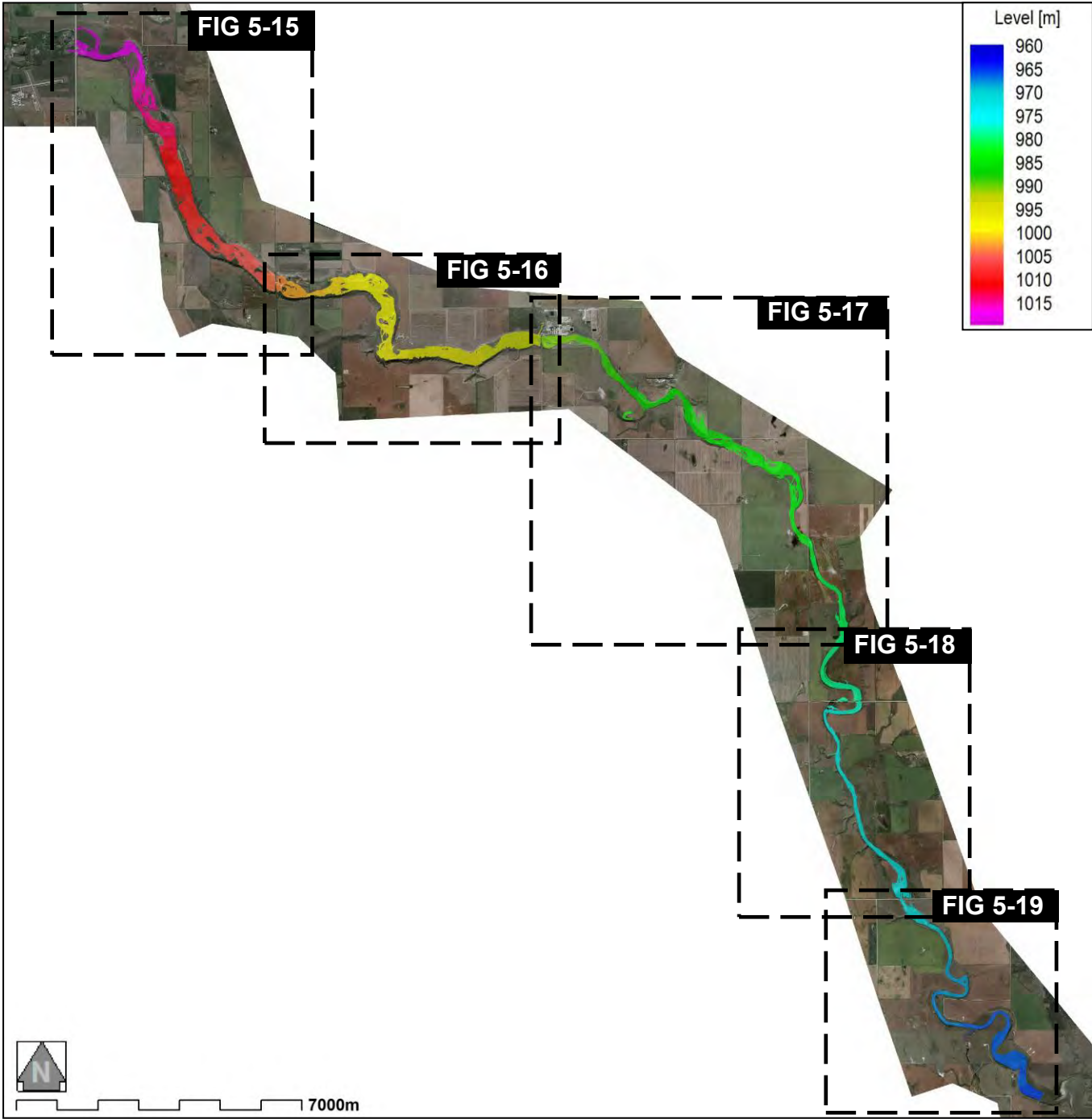
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Figure No: 5-14

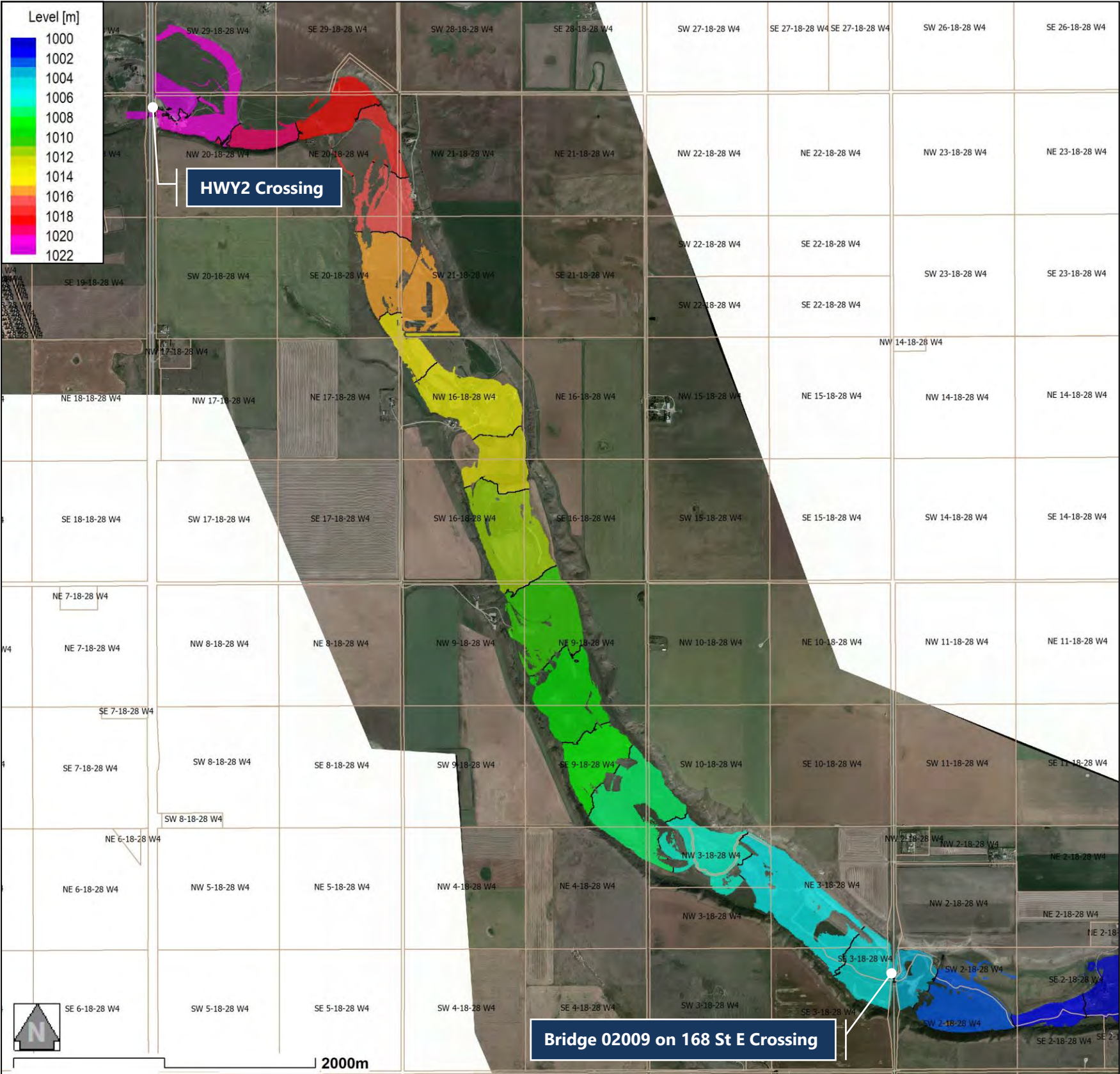
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NOTE:  
Flood level contours shown at 1 m intervals

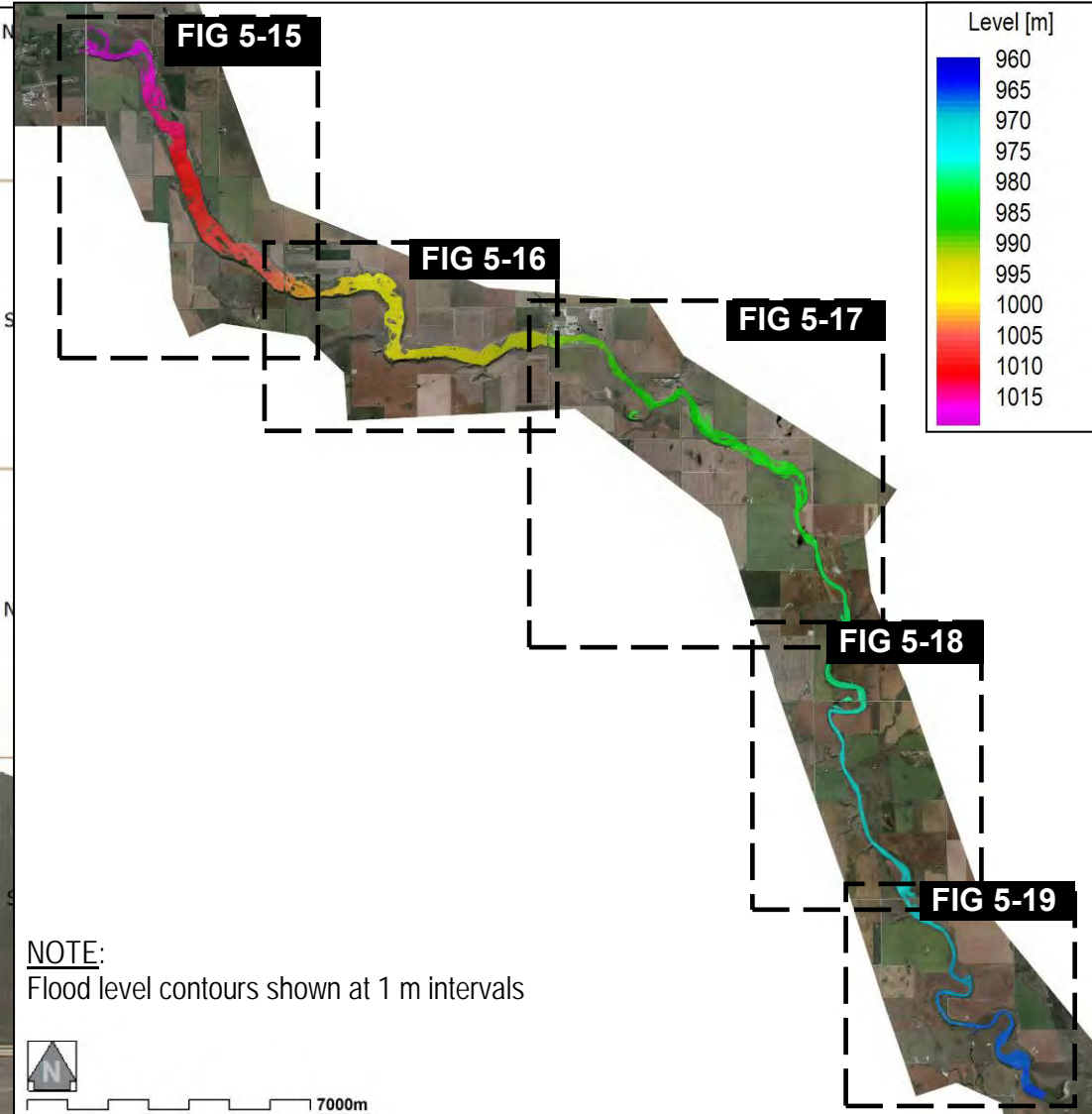
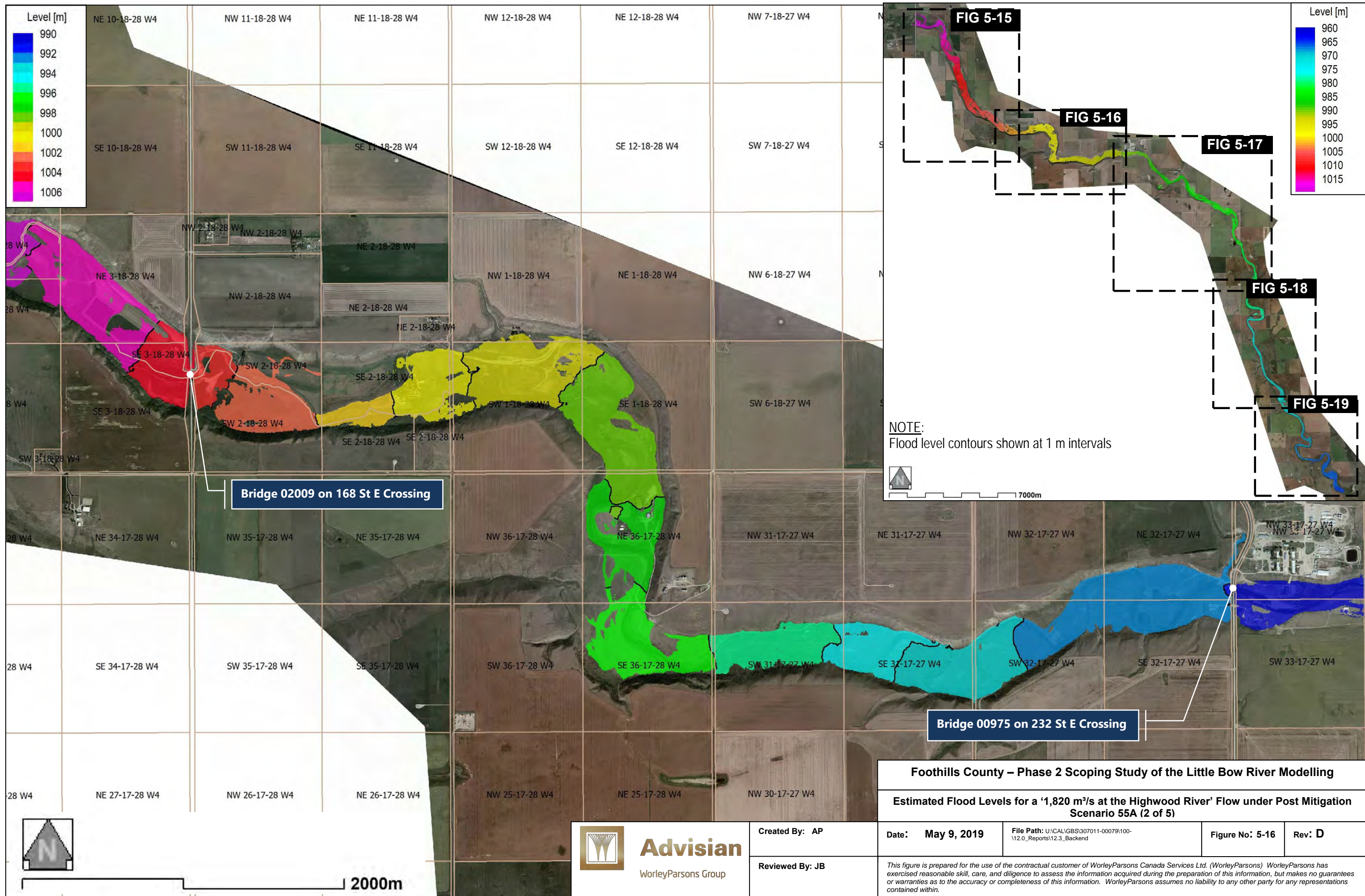


**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

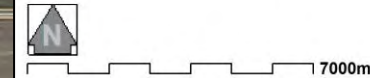
**Estimated Flood Levels for a ‘1,820 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (1 of 5)**

 <b>Advisian</b> WorleyParsons Group	Created By: AP	Date: May 9, 2019	File Path: U:\CALIGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-15	Rev: D
	Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.			



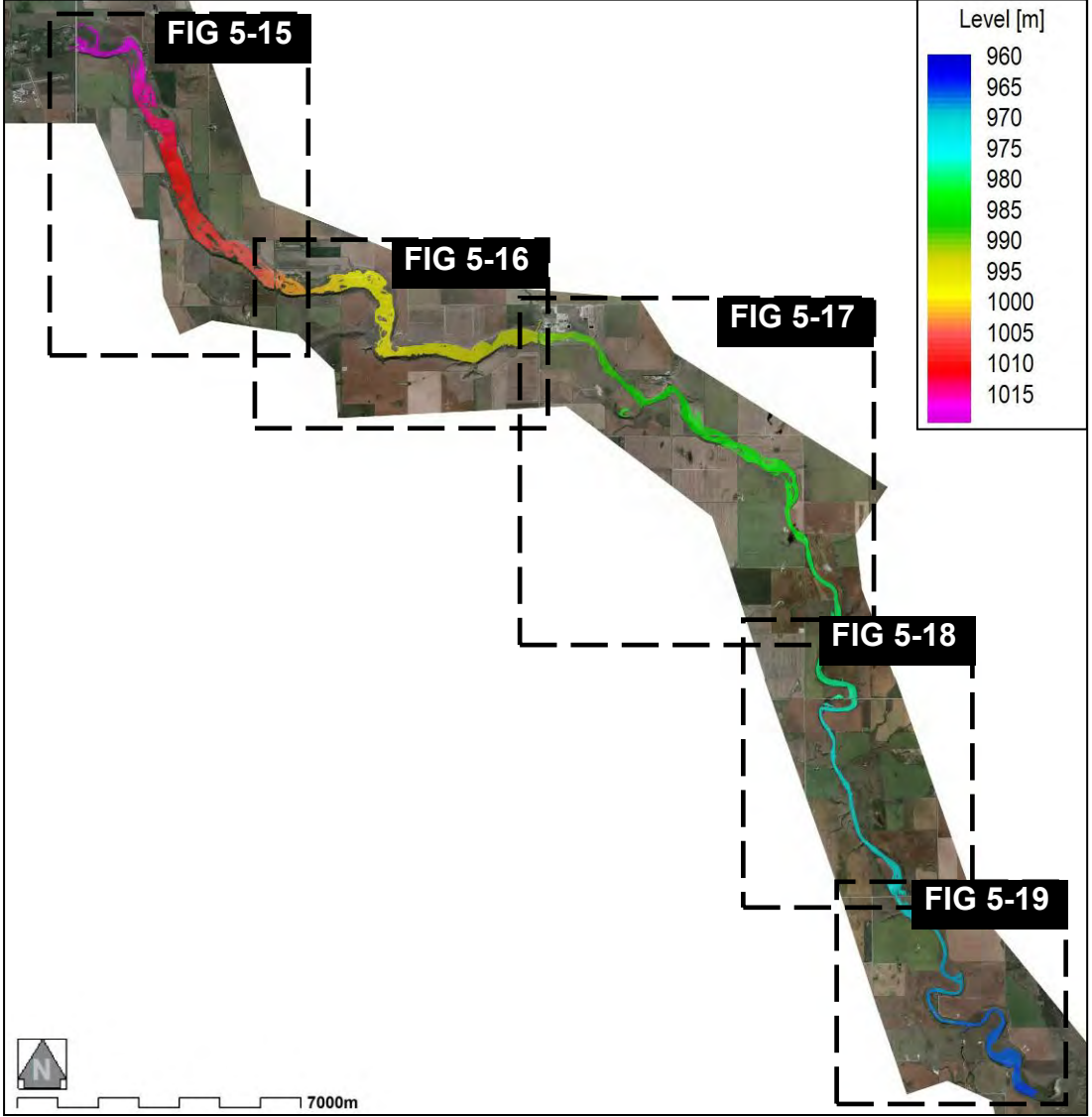
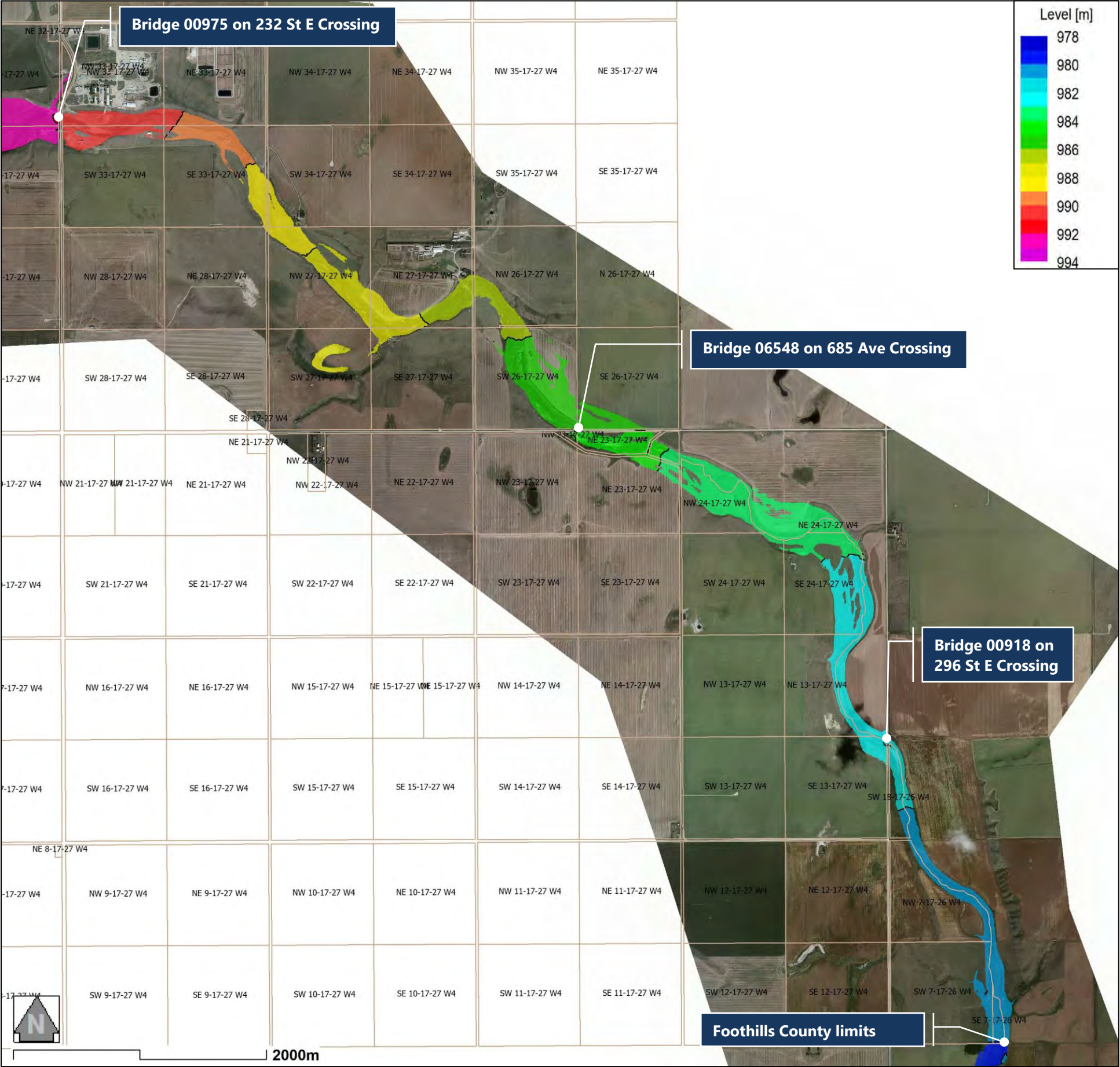


NOTE:  
Flood level contours shown at 1 m intervals



Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Levels for a ‘1,820 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (2 of 5)				
Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-16	Rev: D
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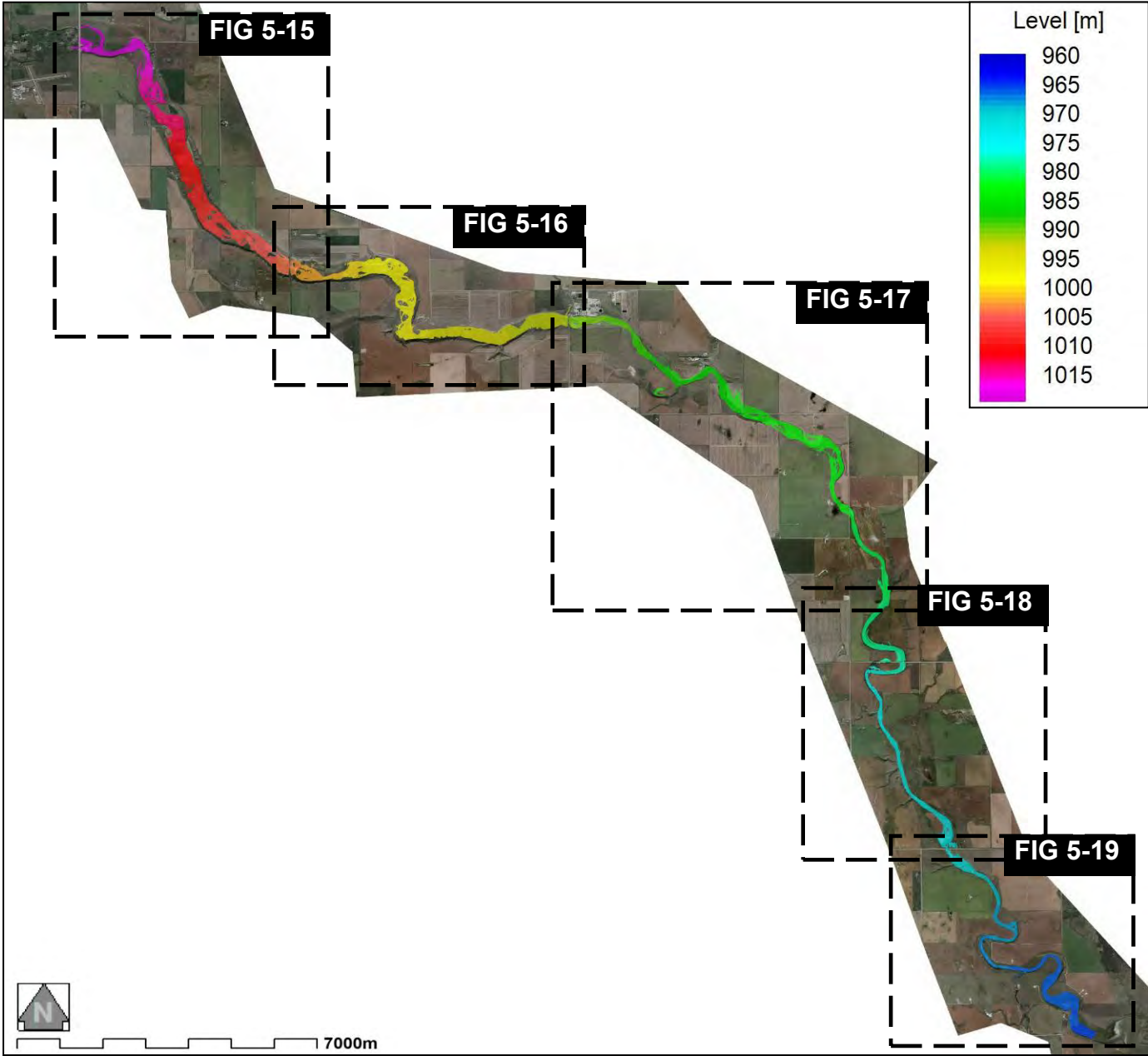
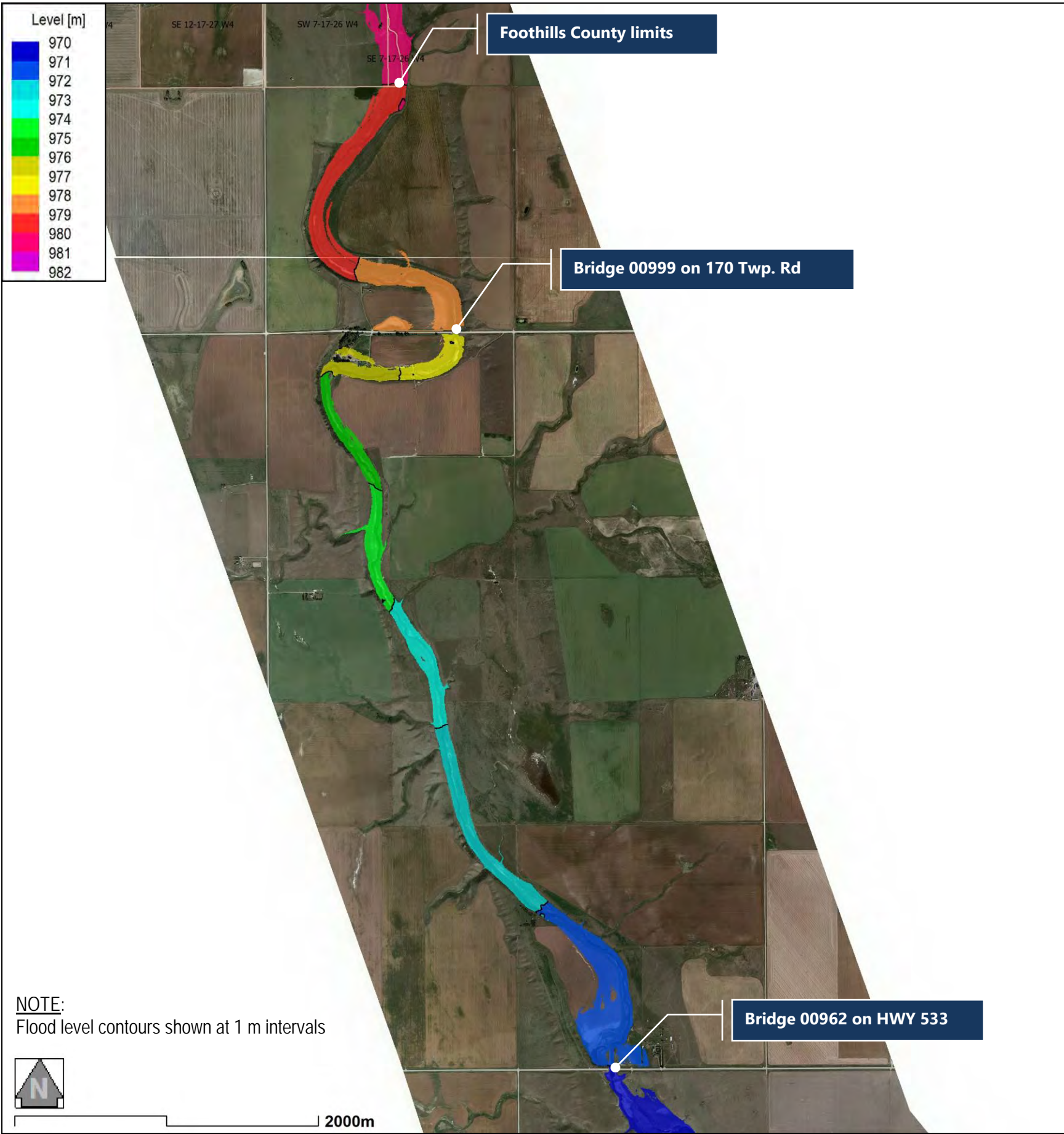




NOTE:  
Flood level contours shown at 1 m intervals

Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling			
Estimated Flood Levels for a ‘1,820 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (3 of 5)			
Date:	May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-\12.0_Reports\12.3_Backend	Figure No: 5-17
			Rev: D
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**Estimated Flood Levels for a '1820 m<sup>3</sup>/s at the Highwood River' Flow under Post Mitigation Scenario 55A (4 of 5)**

Date: May 9, 2019

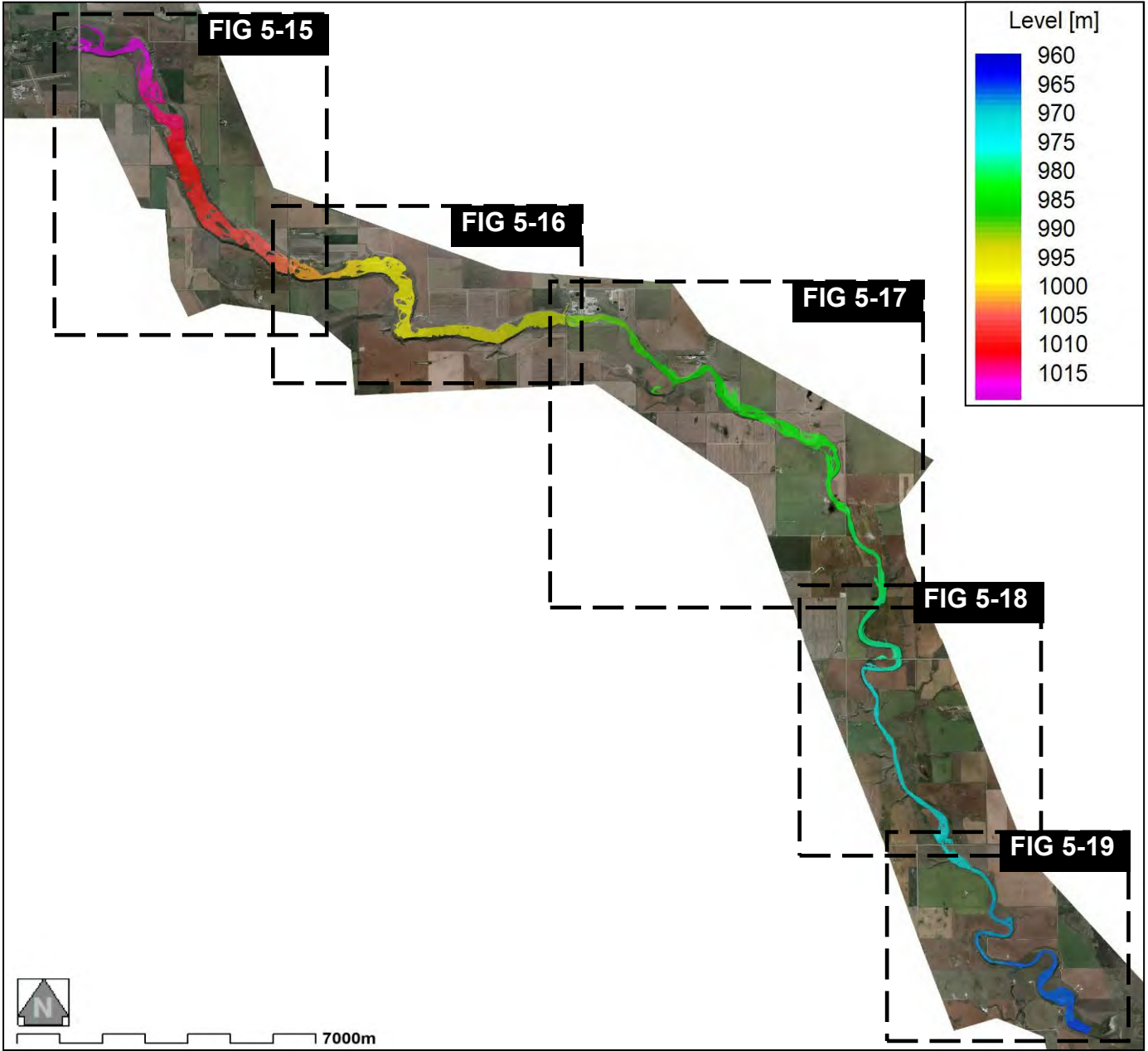
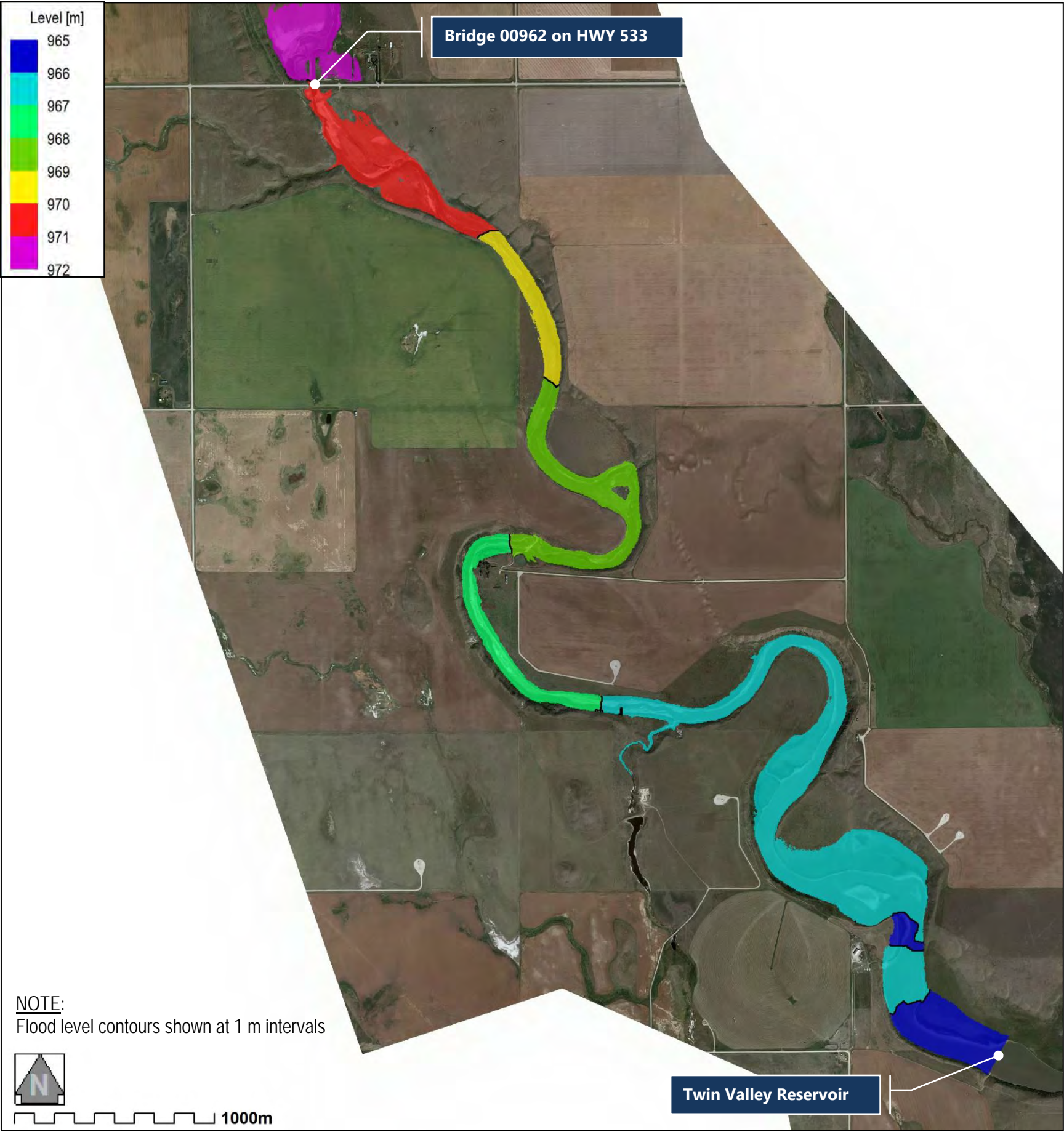
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Figure No: 5-18

Rev: D

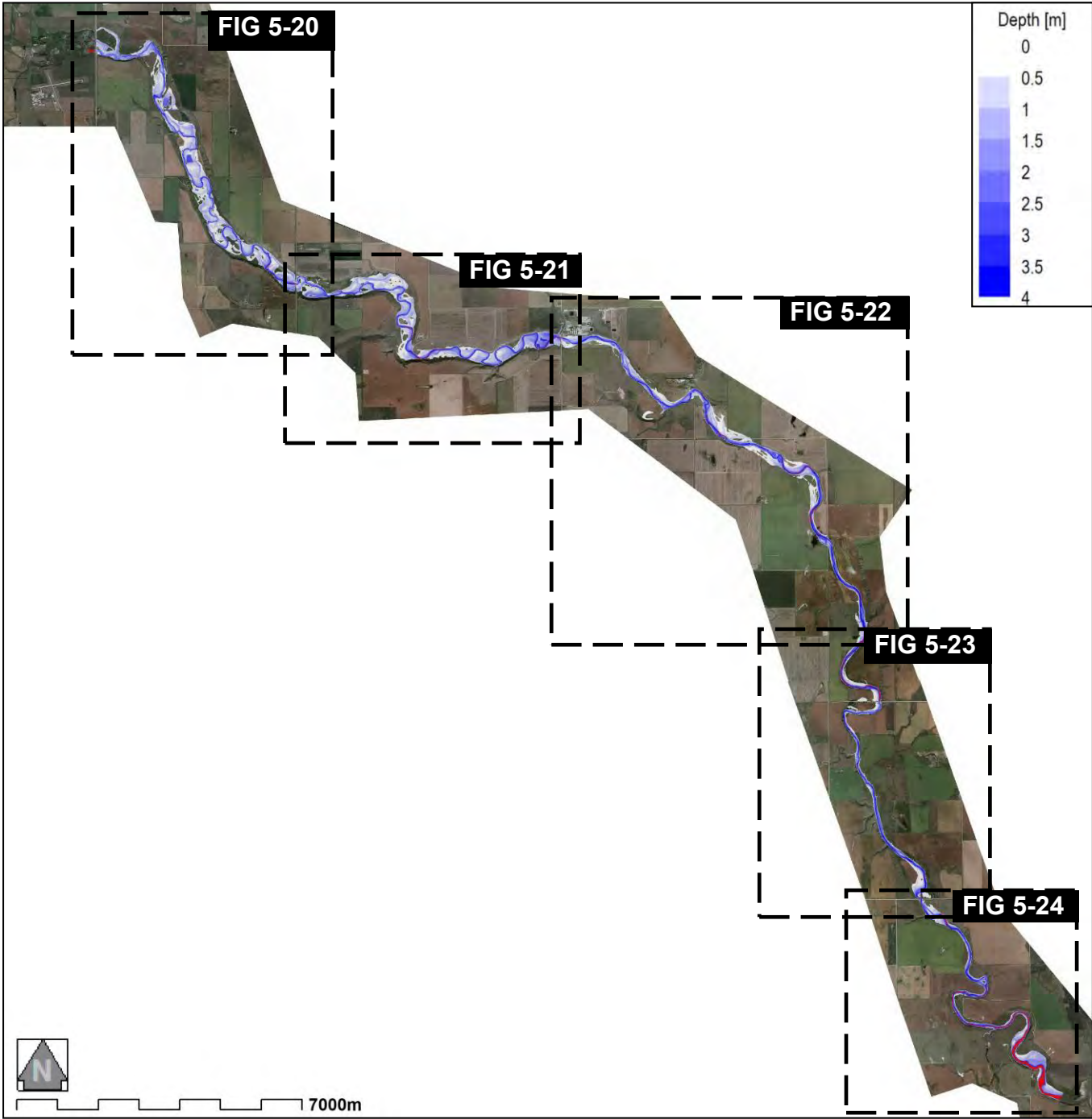
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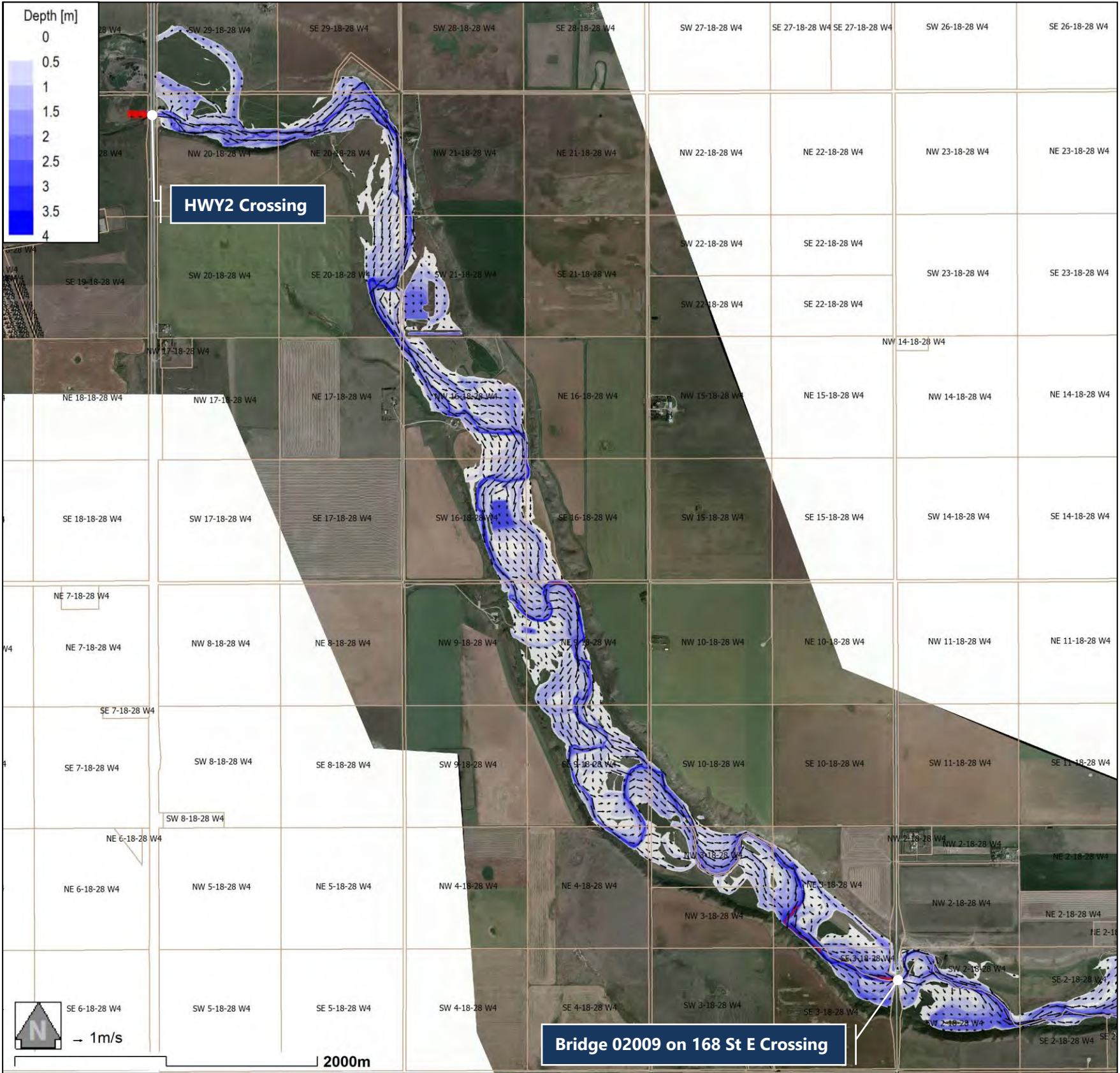


Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Levels for a ‘1,820 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (5 of 5)				
Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\112.3_Backend	Figure No: 5-19	Rev: D
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**NOTE:**  
Red mapping indicates locations where depths are predicted to exceed the maximum range; i.e., 4 metres

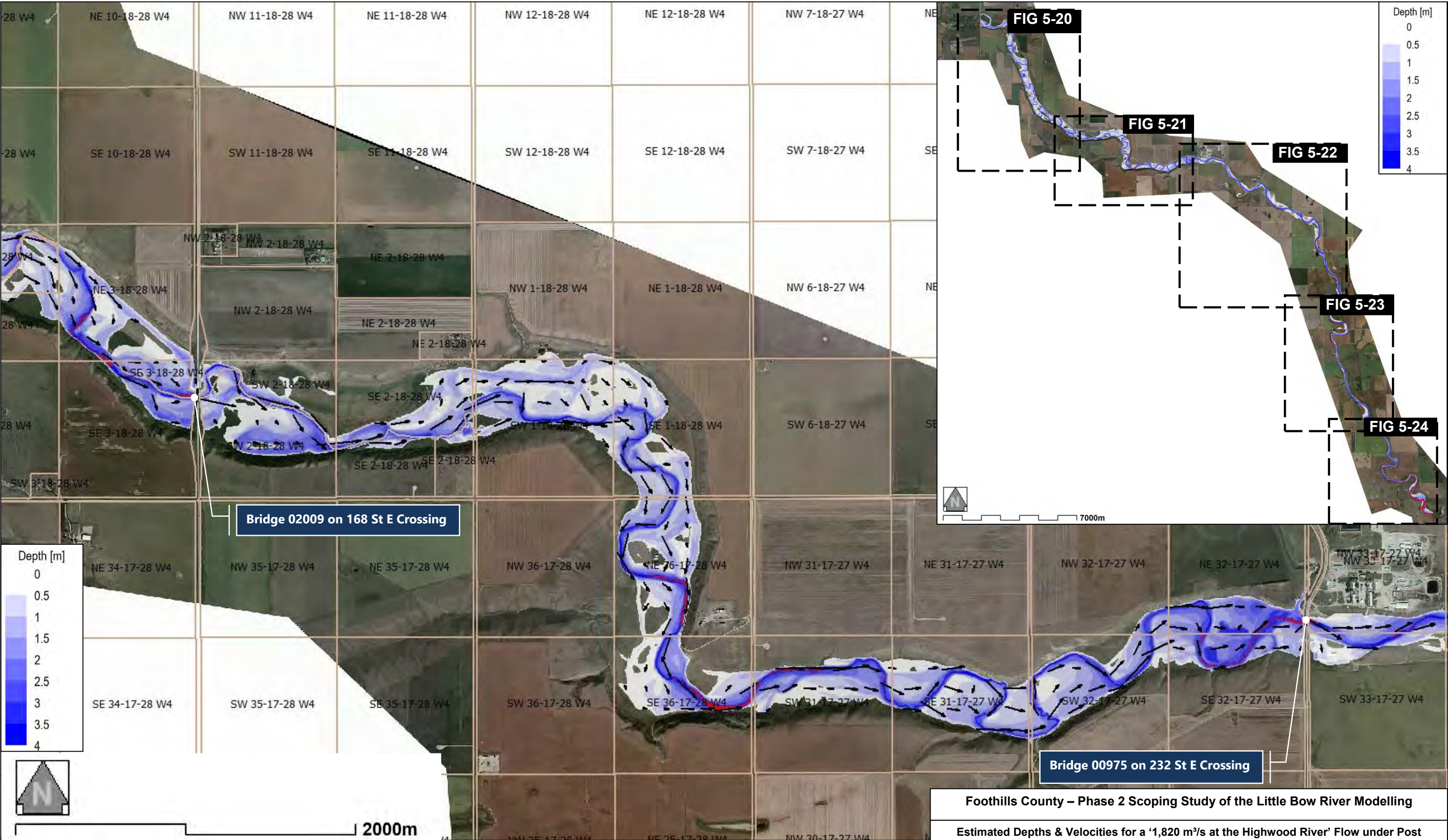


**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**


**Estimated Flood Depths and Velocities for a ‘1,820 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (1 of 5)**

 <div><b>Advisian</b> WorleyParsons Group</div>	Created By: AP	Date: May 9, 2019	File Path: U:\CALIGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-20	Rev: D
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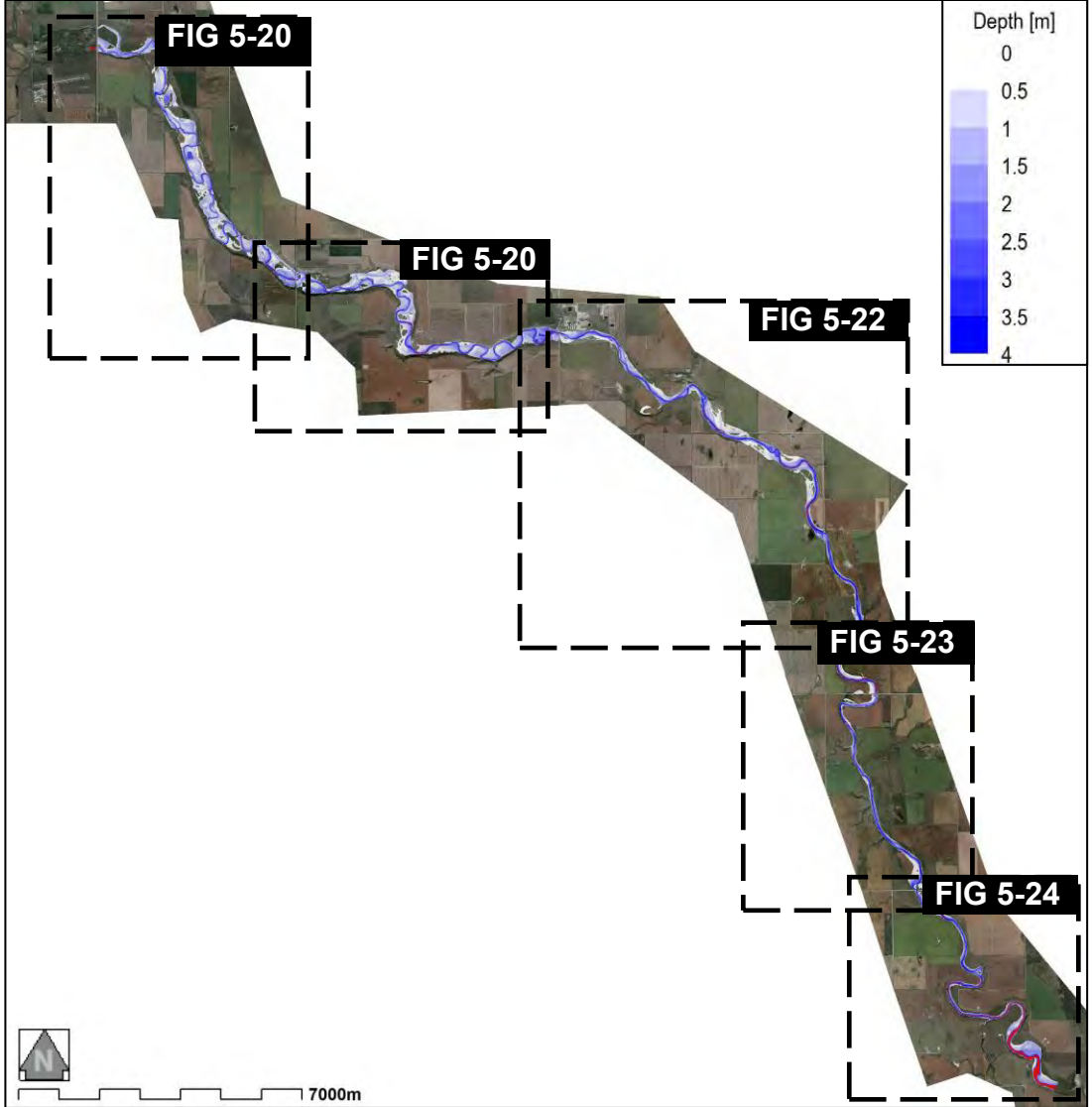
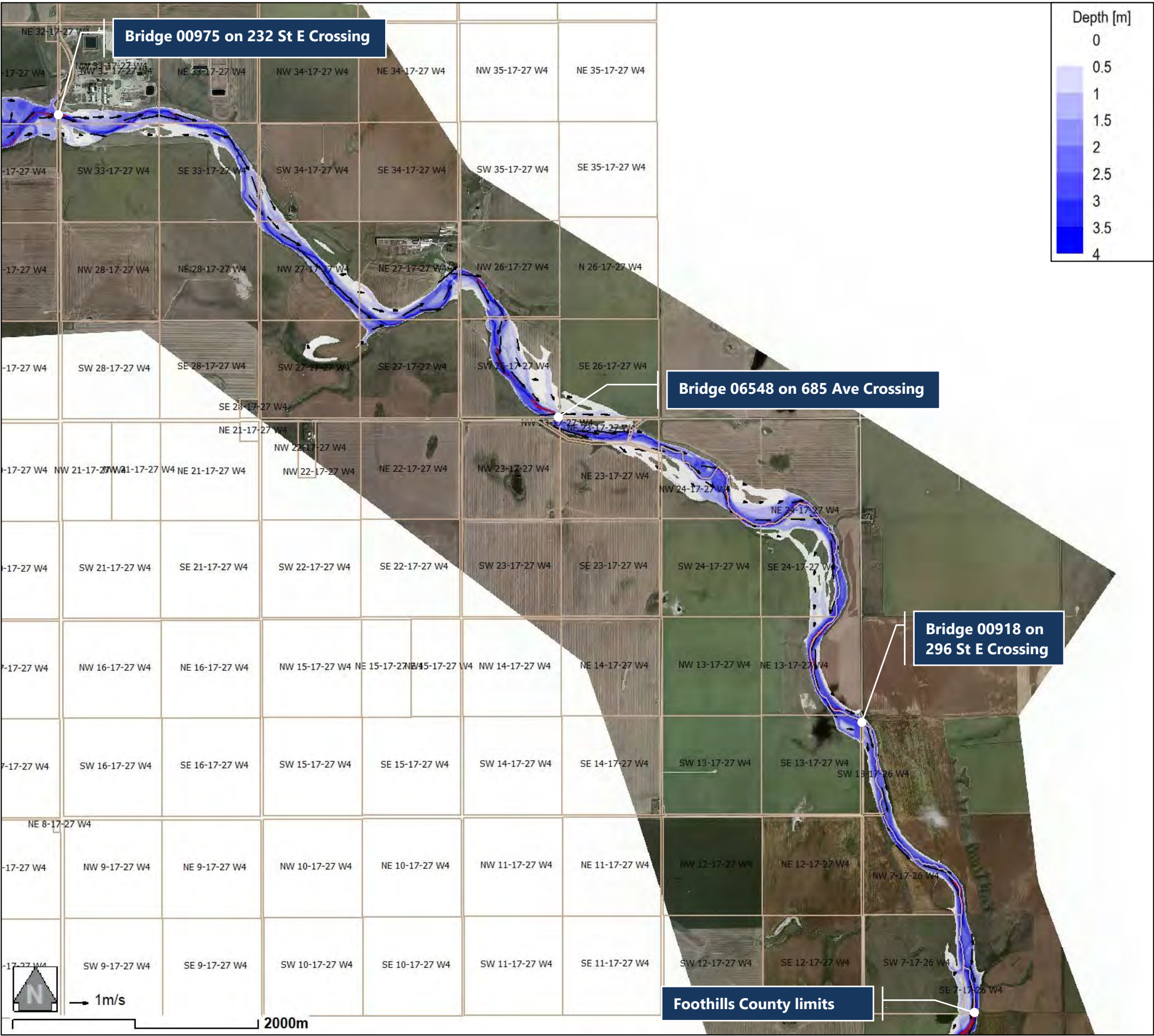




NOTE:  
Red mapping indicates locations where depths are predicted to exceed the maximum range; i.e., 4 metres

 <b>Advisian</b> WorleyParsons Group	Created By: AP	Date: May 9, 2019		File Path: U:\CALIGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-21	Rev: D
	Reviewed By: JB	<i>This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons). WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.</i>				

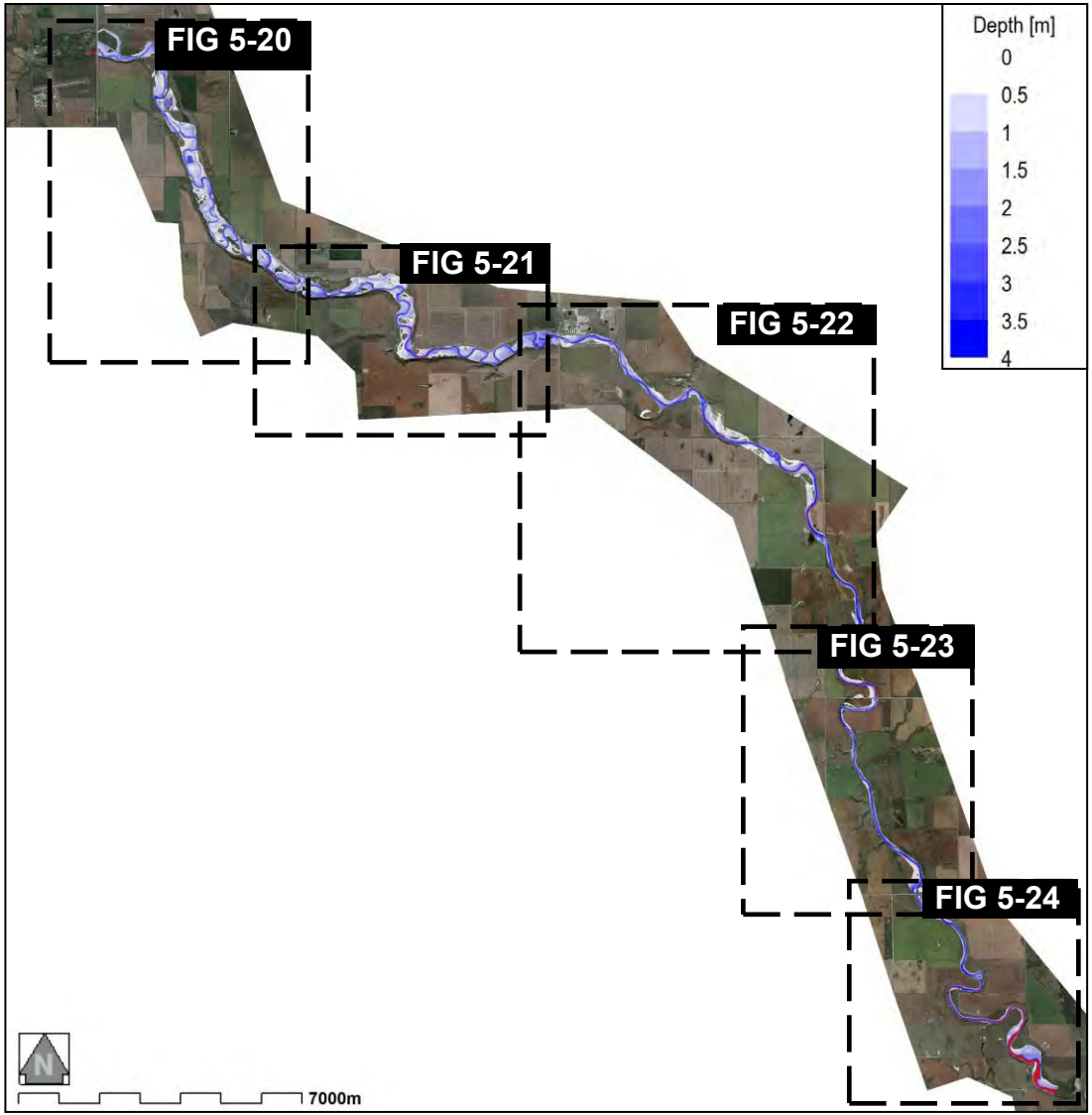
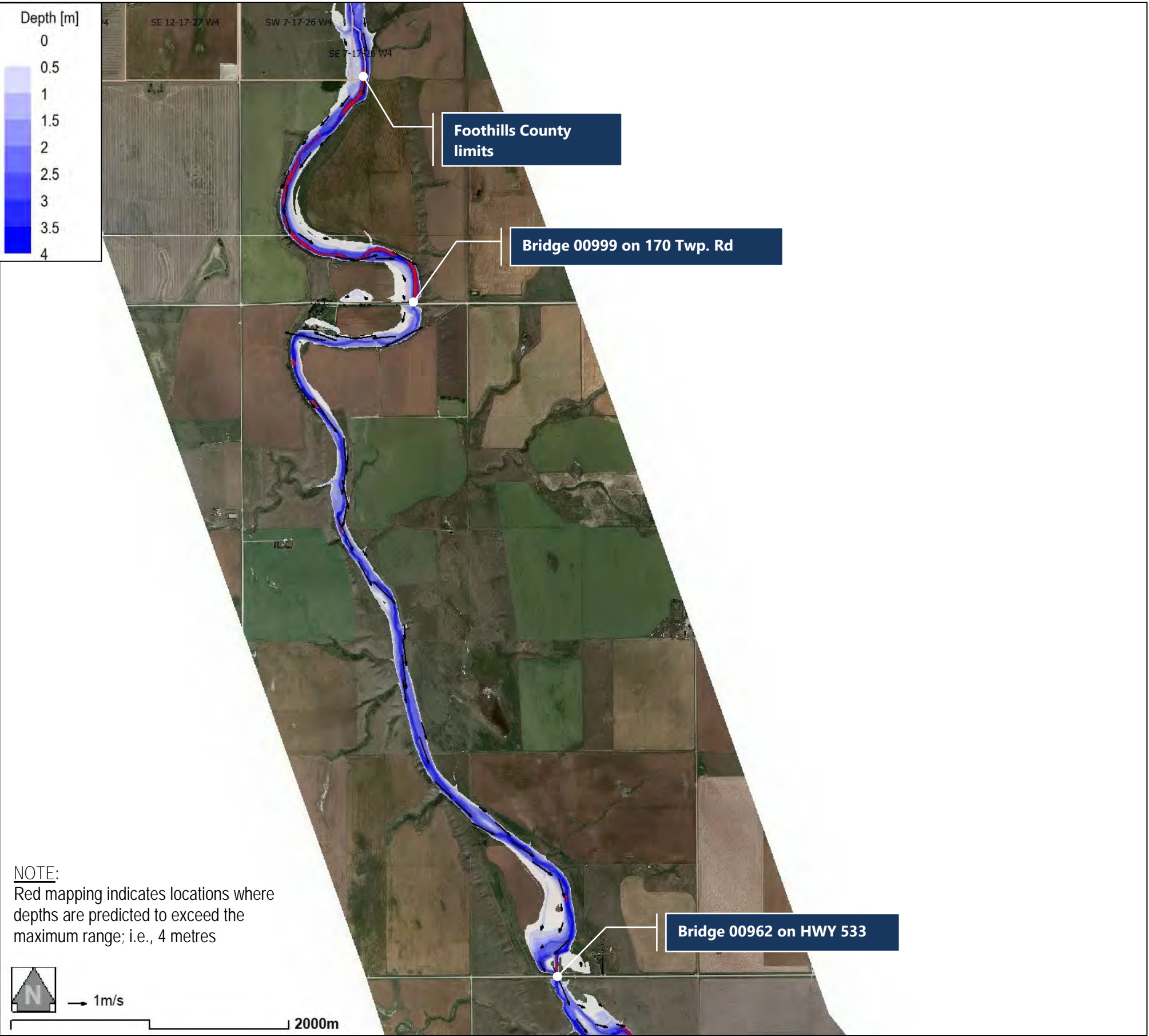




**NOTE:**  
Red mapping indicates locations where depths are predicted to exceed the maximum range: i.e., 4 metres

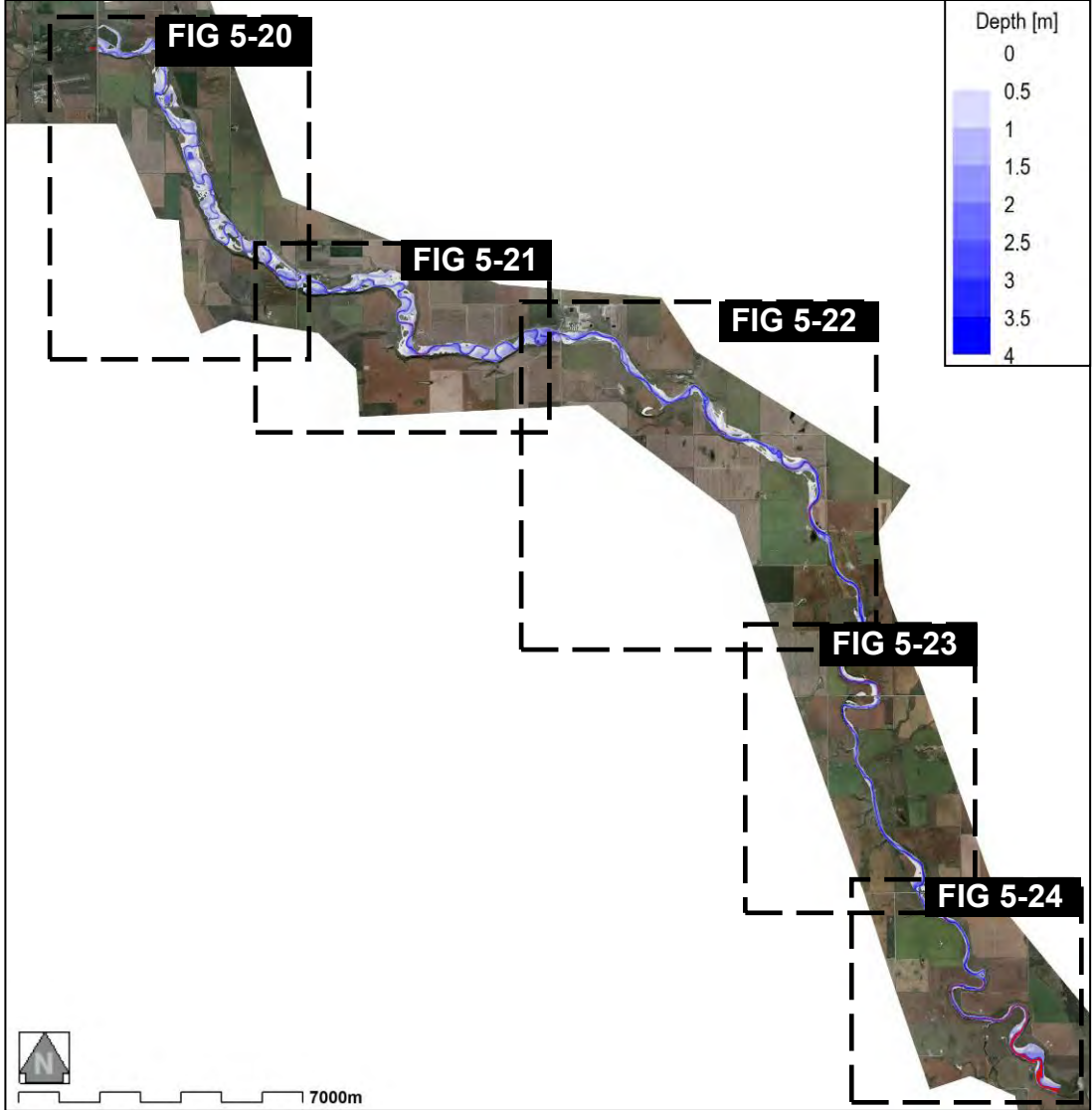
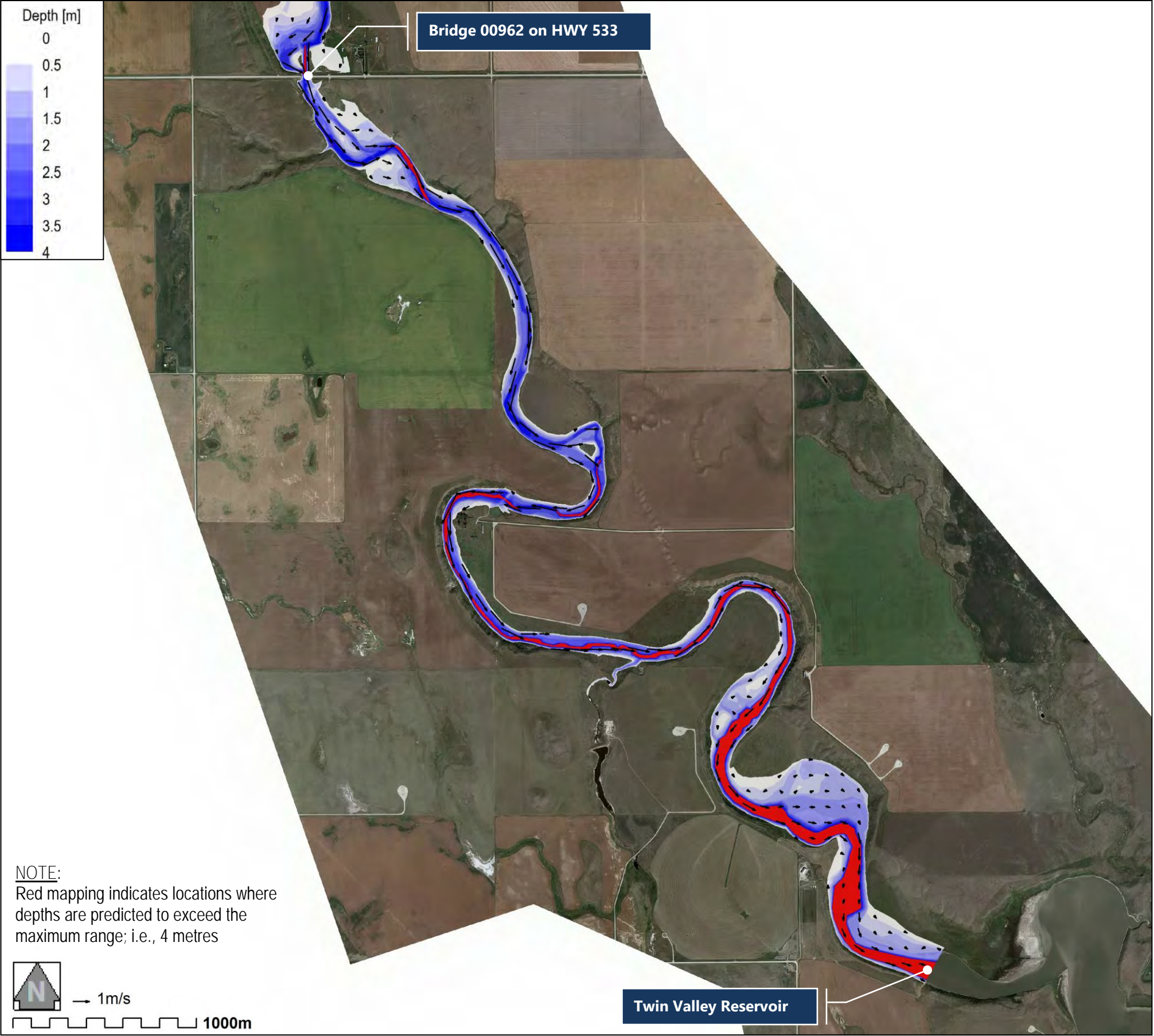
Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Depths & Velocities for a ‘1,820 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (3 of 5)				
Date:	May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-12.0_Reports\12.3_Backend	Figure No: 5-22	Rev: D
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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling			
Estimated Depths & Velocities for a ‘1,820 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (4 of 5)			
Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-12.0_Reports\12.3_Backend	Figure No: 5-23	Rev: D
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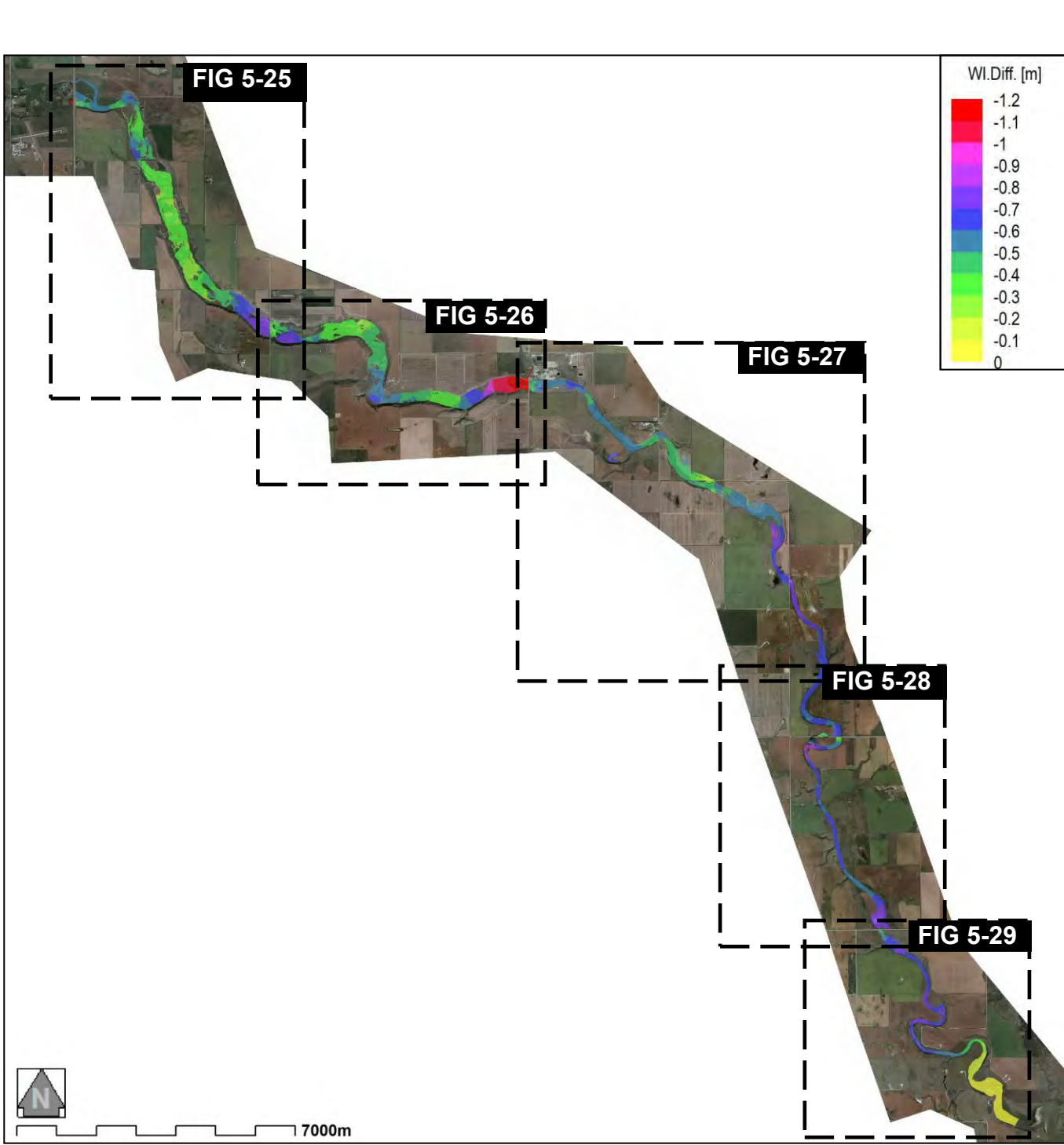
Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Depths & Velocities for a ‘1,820 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (5 of 5)				
Date:	May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-12.0_Reports\12.3_Backend	Figure No: 5-24	Rev: D
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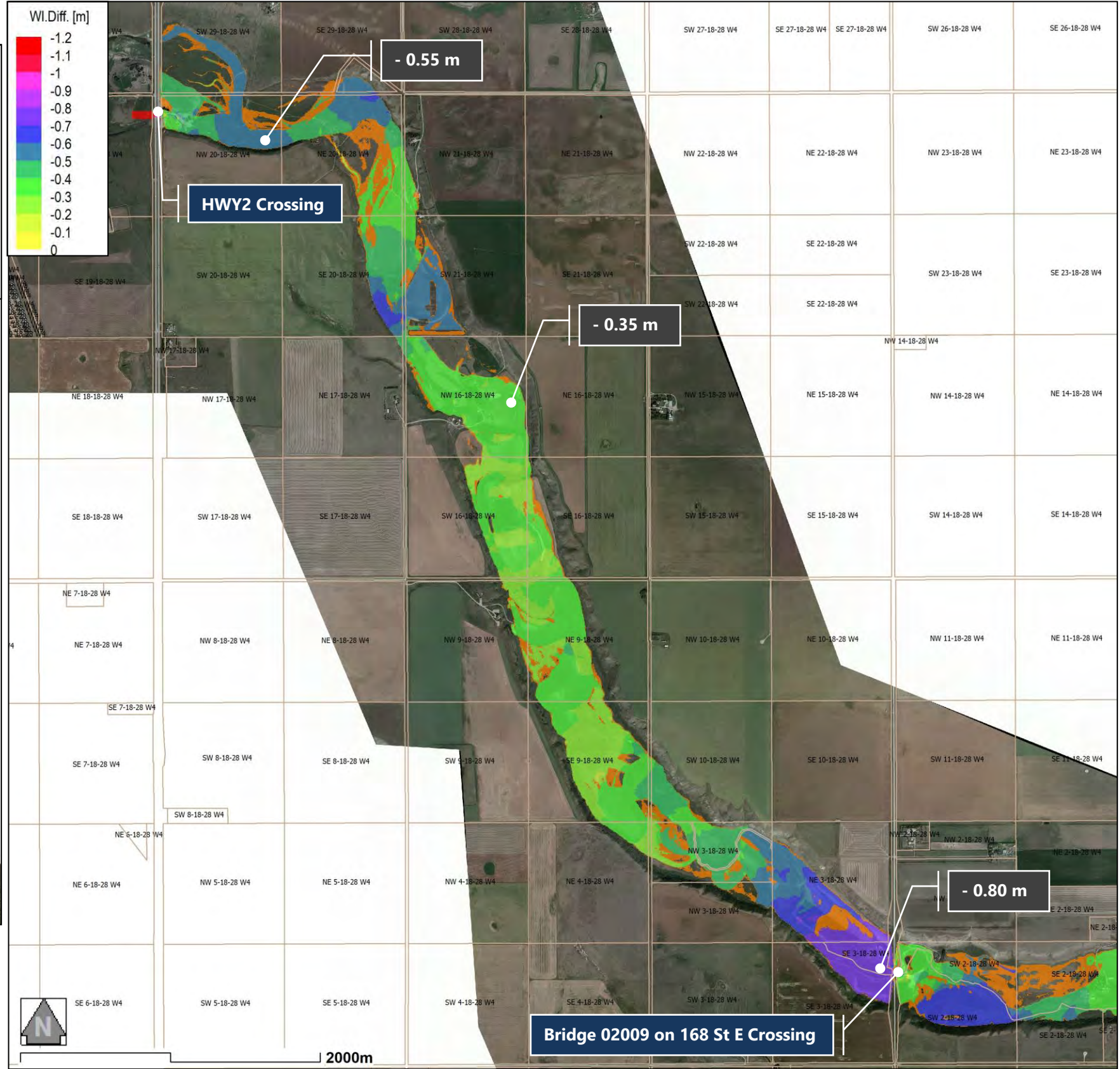
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Created By:	AP
Reviewed By:	JB






**NOTE:**  
Orange flood extents indicate locations where a reduction in flood extents has occurred due to Mitigation Scenario 55A

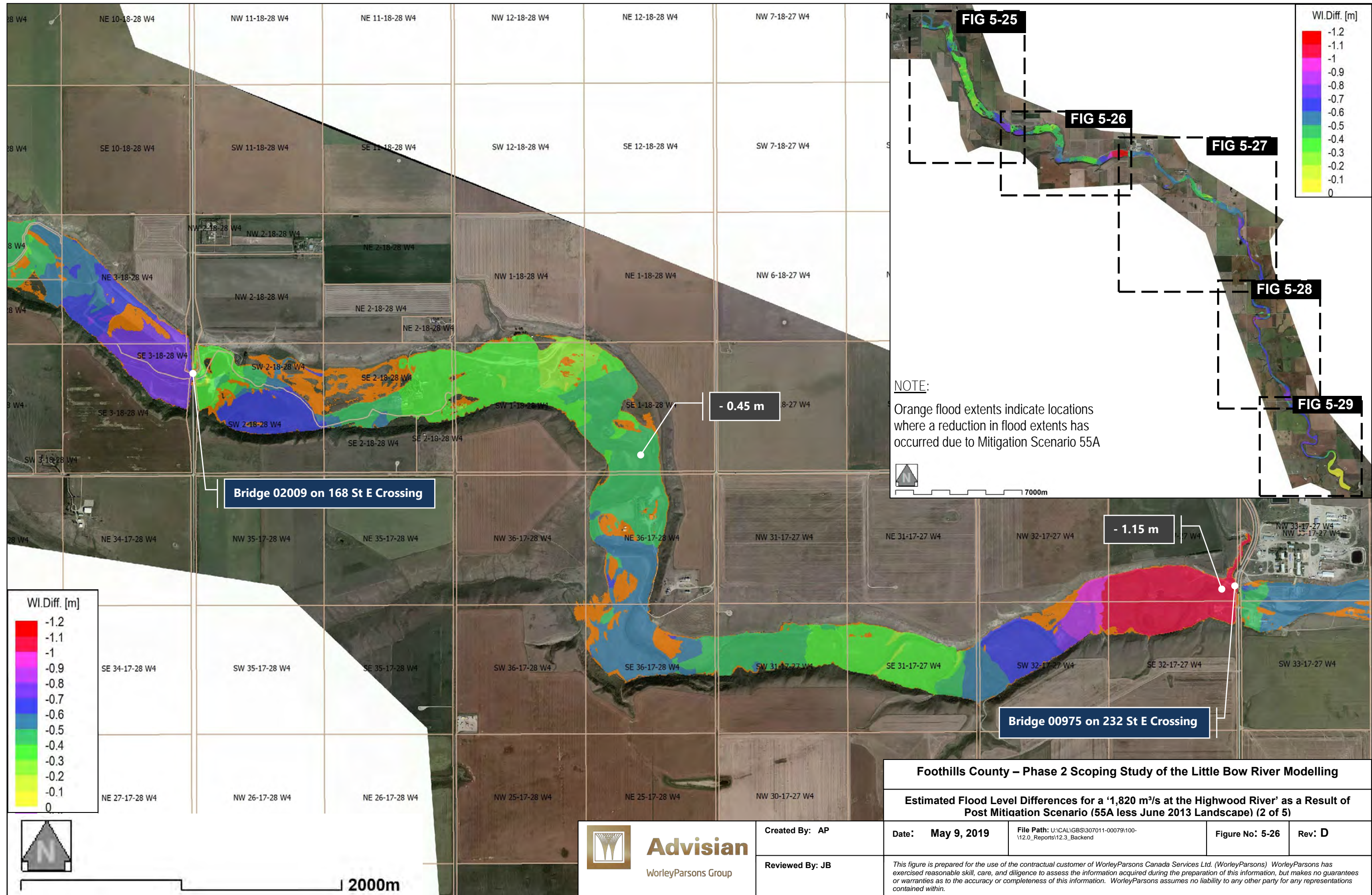


**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

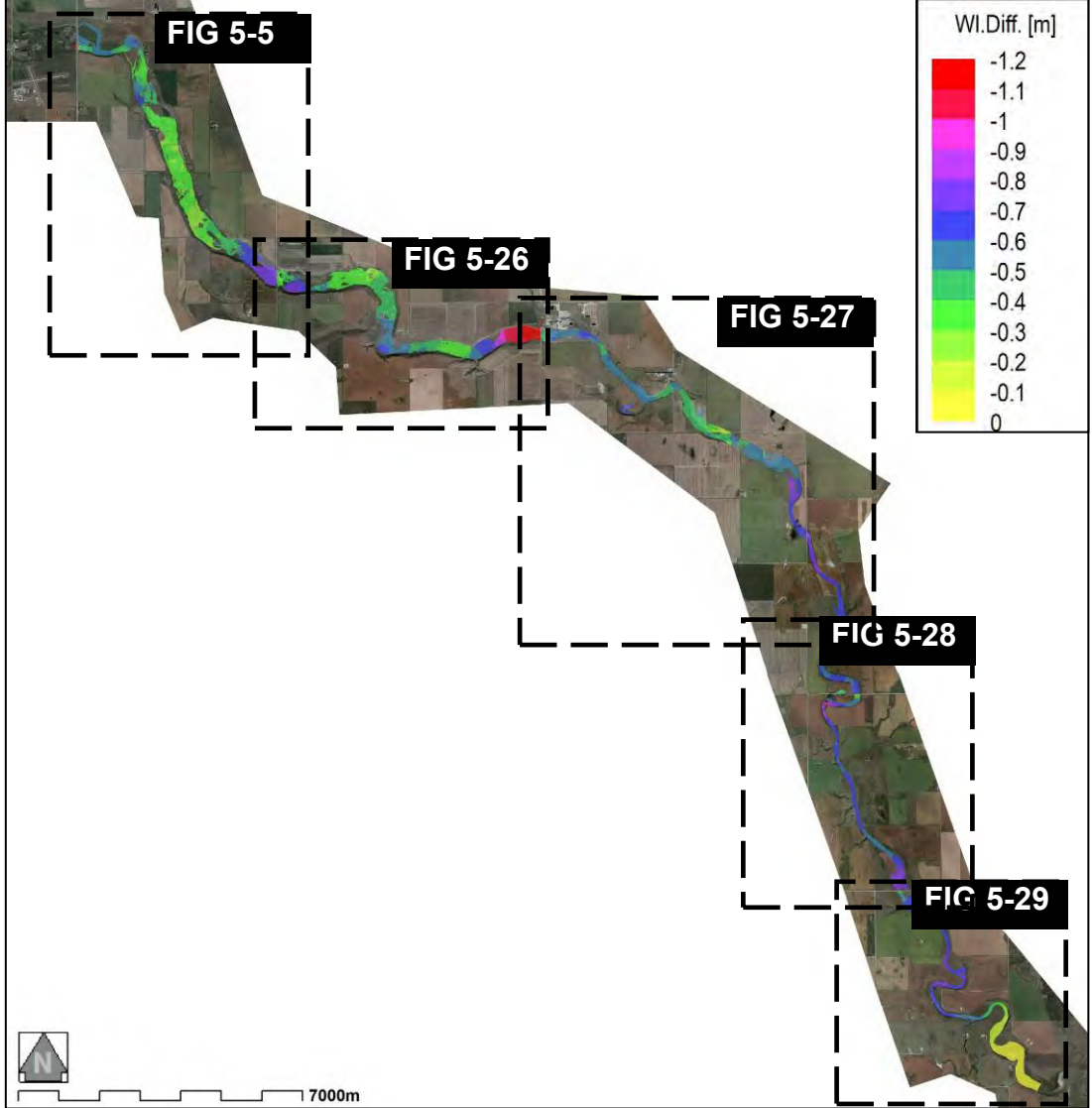
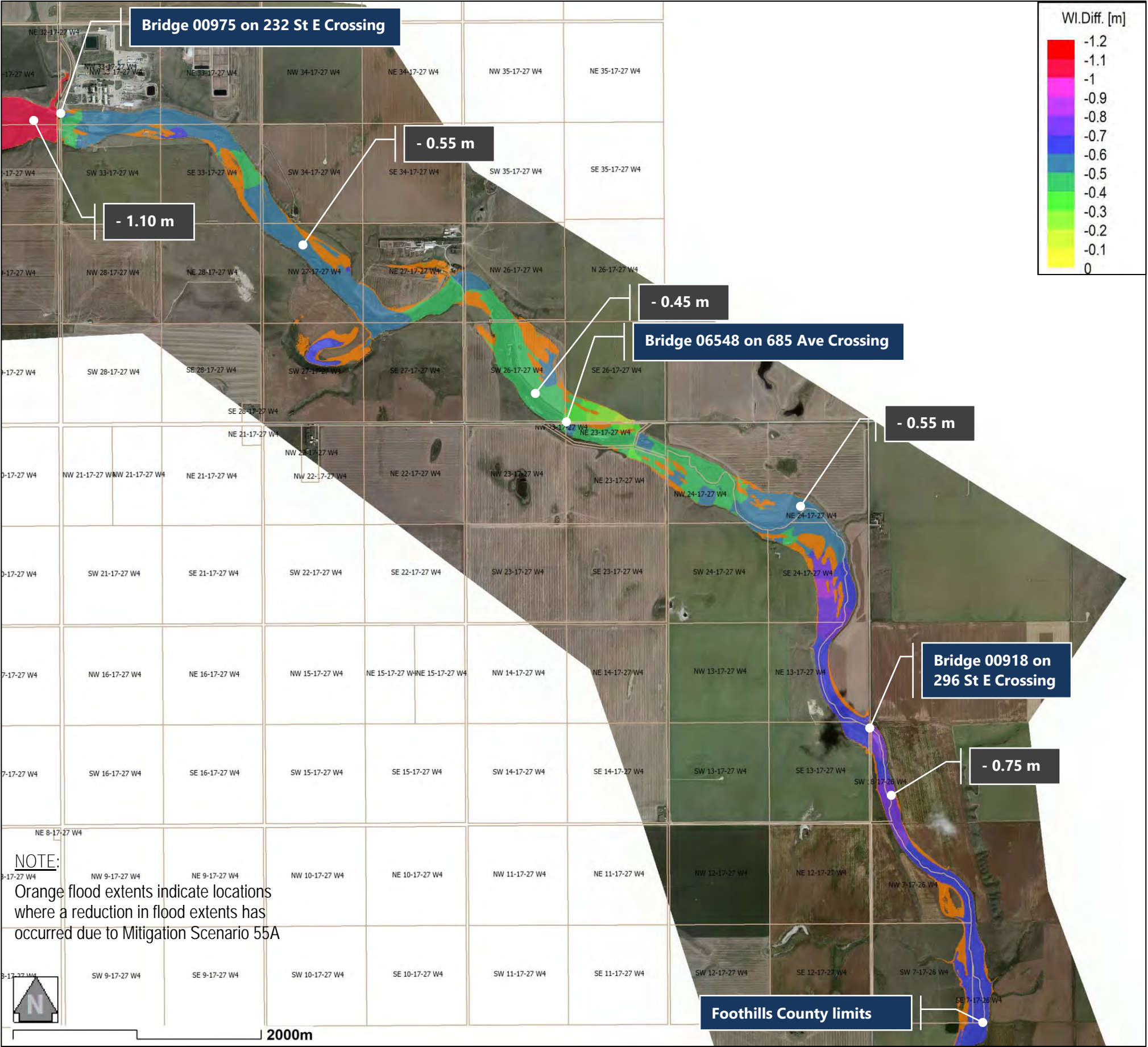
**Estimated Flood Level Differences for a '1,820 m³/s at the Highwood River' as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (1 of 5)**

 <b>Advisian</b> WorleyParsons Group	Created By: AP	Date: May 9, 2019	File Path: U:\CALIGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-25	Rev: D
	Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.			



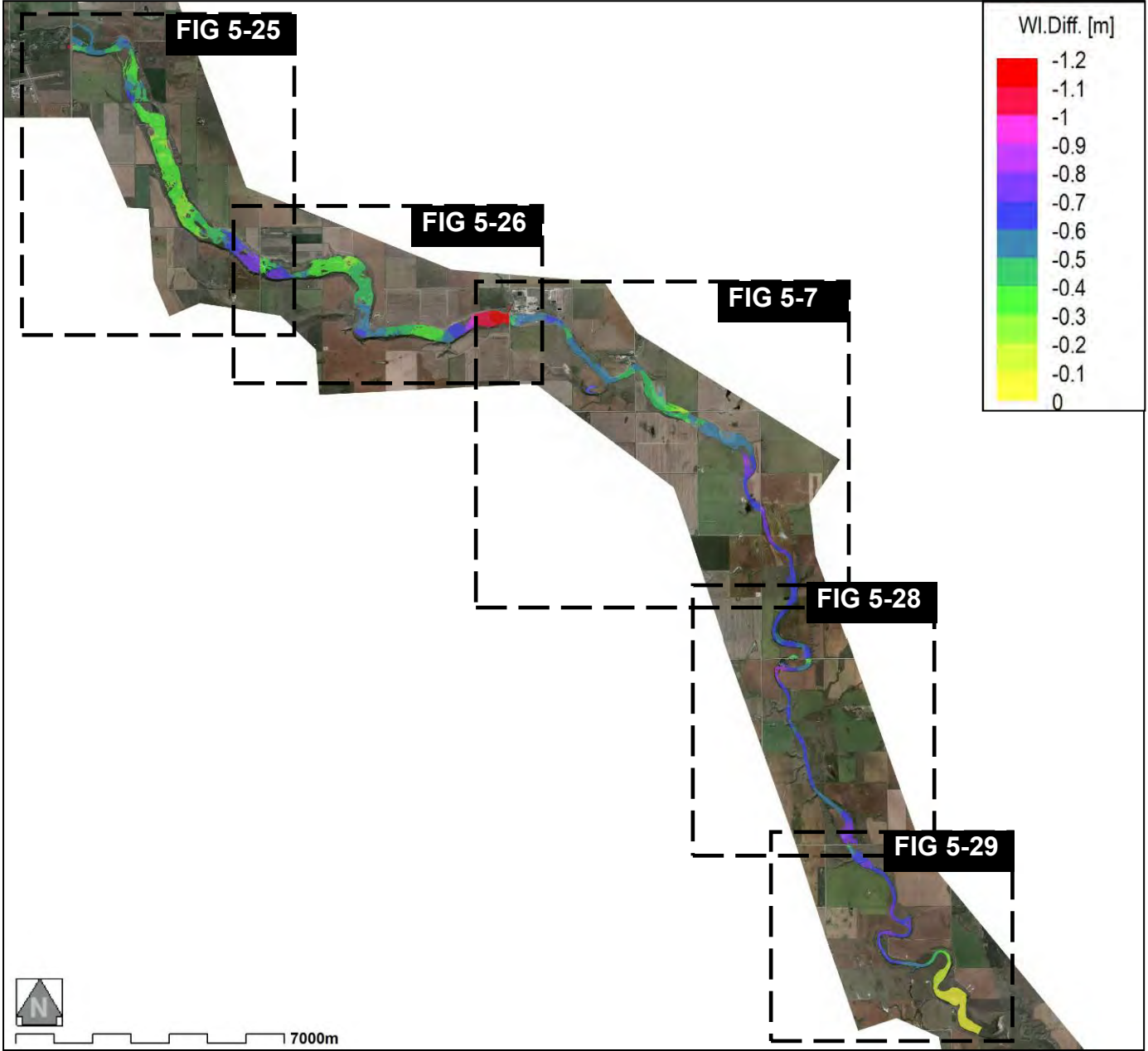
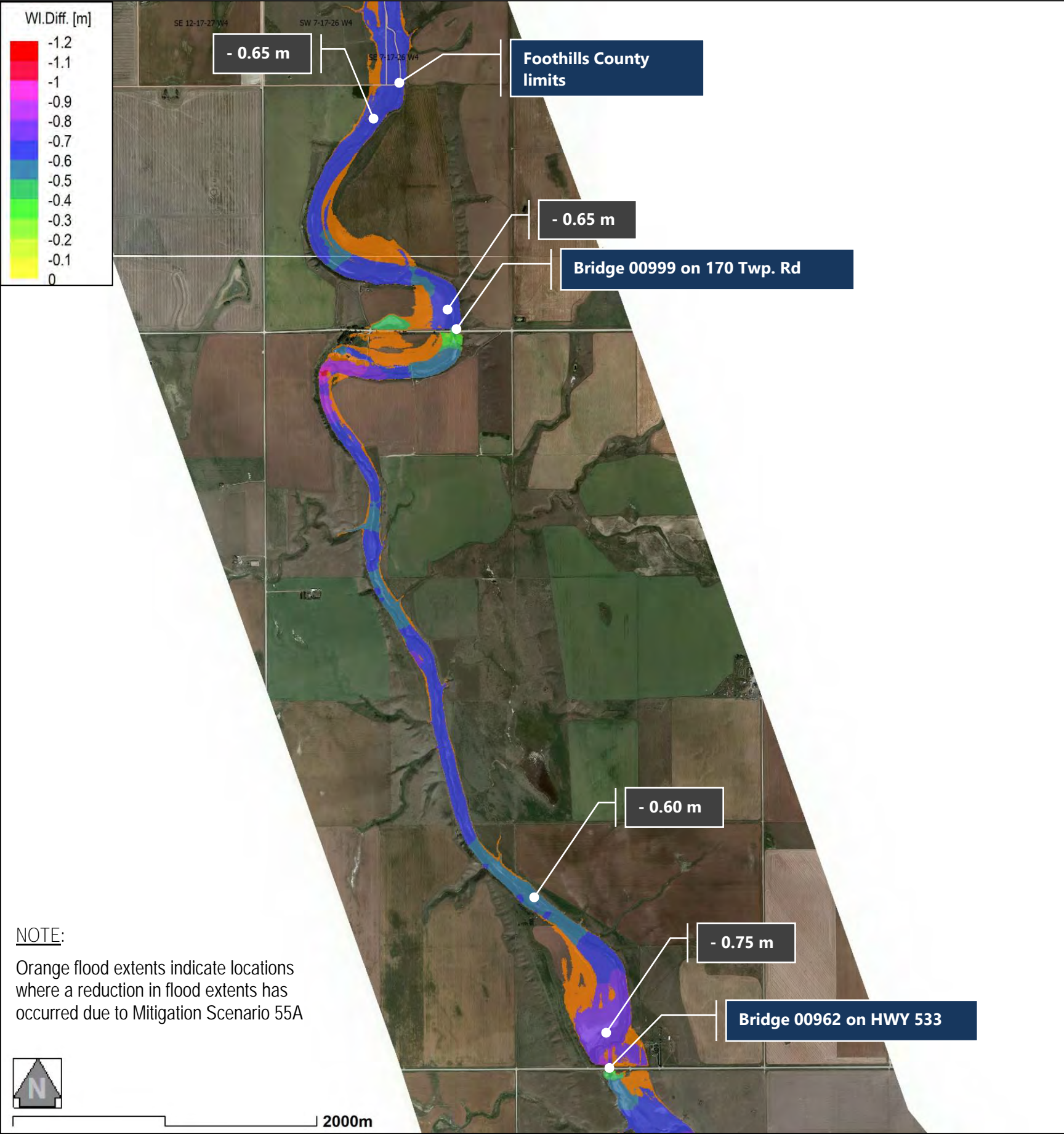






Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Level Differences for a ‘1,820 m³/s at the Highwood River’ as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (3 of 5)				
Date:	May 9, 2019	File Path:	U:\CAL\GBS\307011-00079\100-1\12.0_Reports\12.3_Backend	Figure No: 5-27
Created By:	AP	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons). WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.		
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**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

**Estimated Flood Level Differences for a '1,820 m³/s at the Highwood River' as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (4 of 5)**

Created By: AP

Date: May 9, 2019

File Path: U:\CAL\GBS\307011-00079\100-  
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Figure No: 5-28

Rev: D

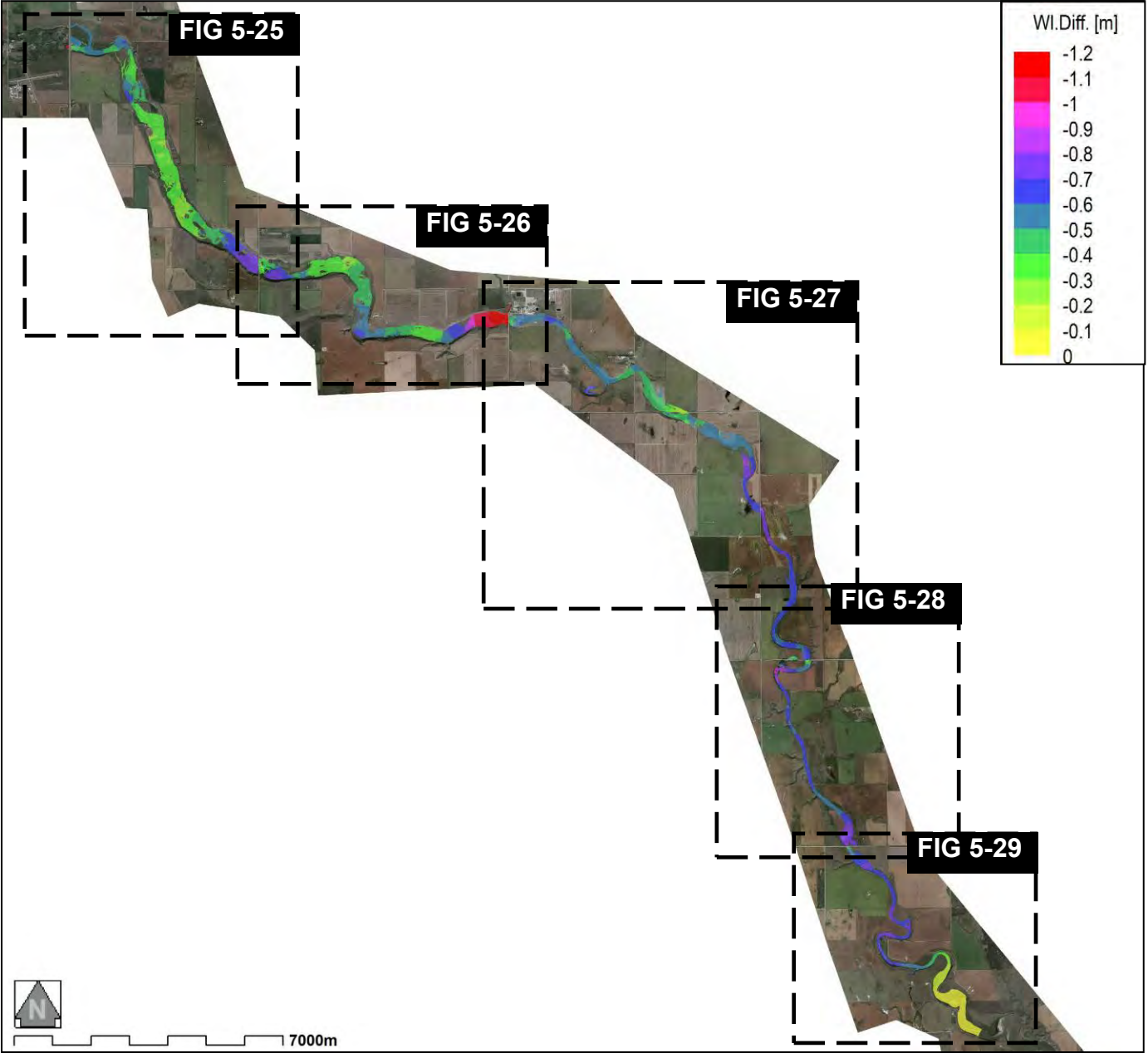
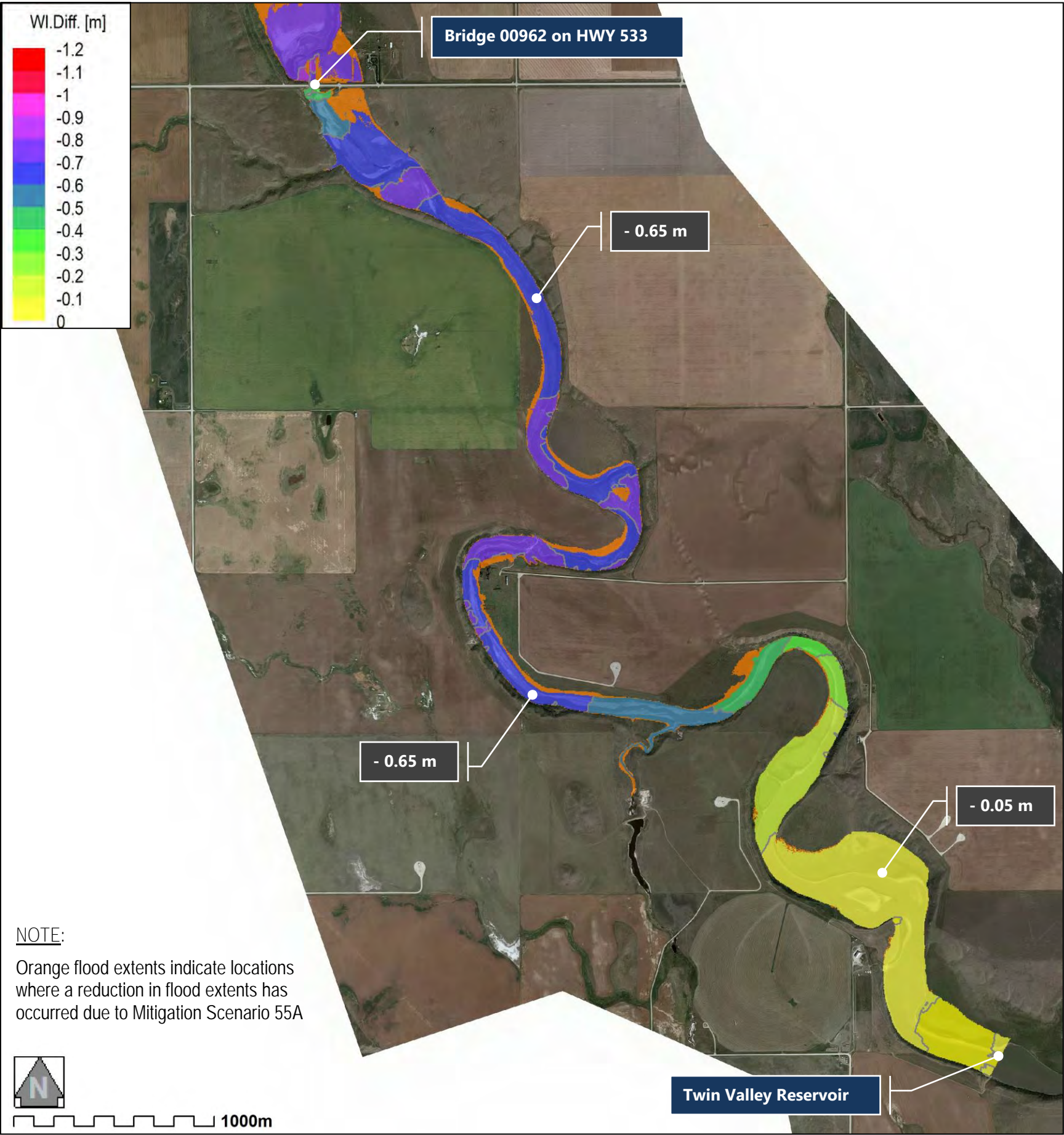
Reviewed By: JB

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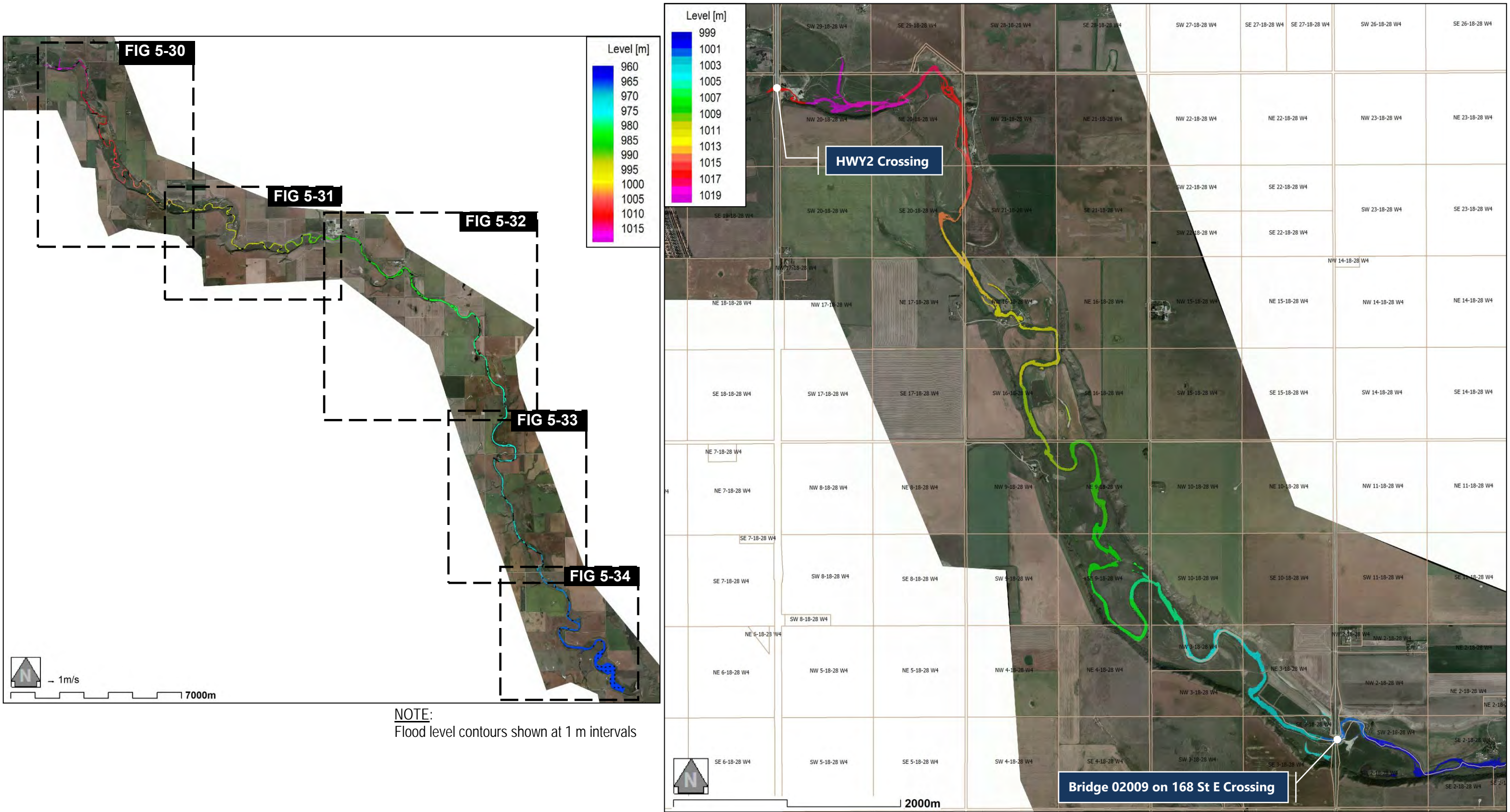
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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Level Differences for a ‘1,820 m³/s at the Highwood River’ as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (5 of 5)				
Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\112.3_Backend	Figure No: 5-29	Rev: D
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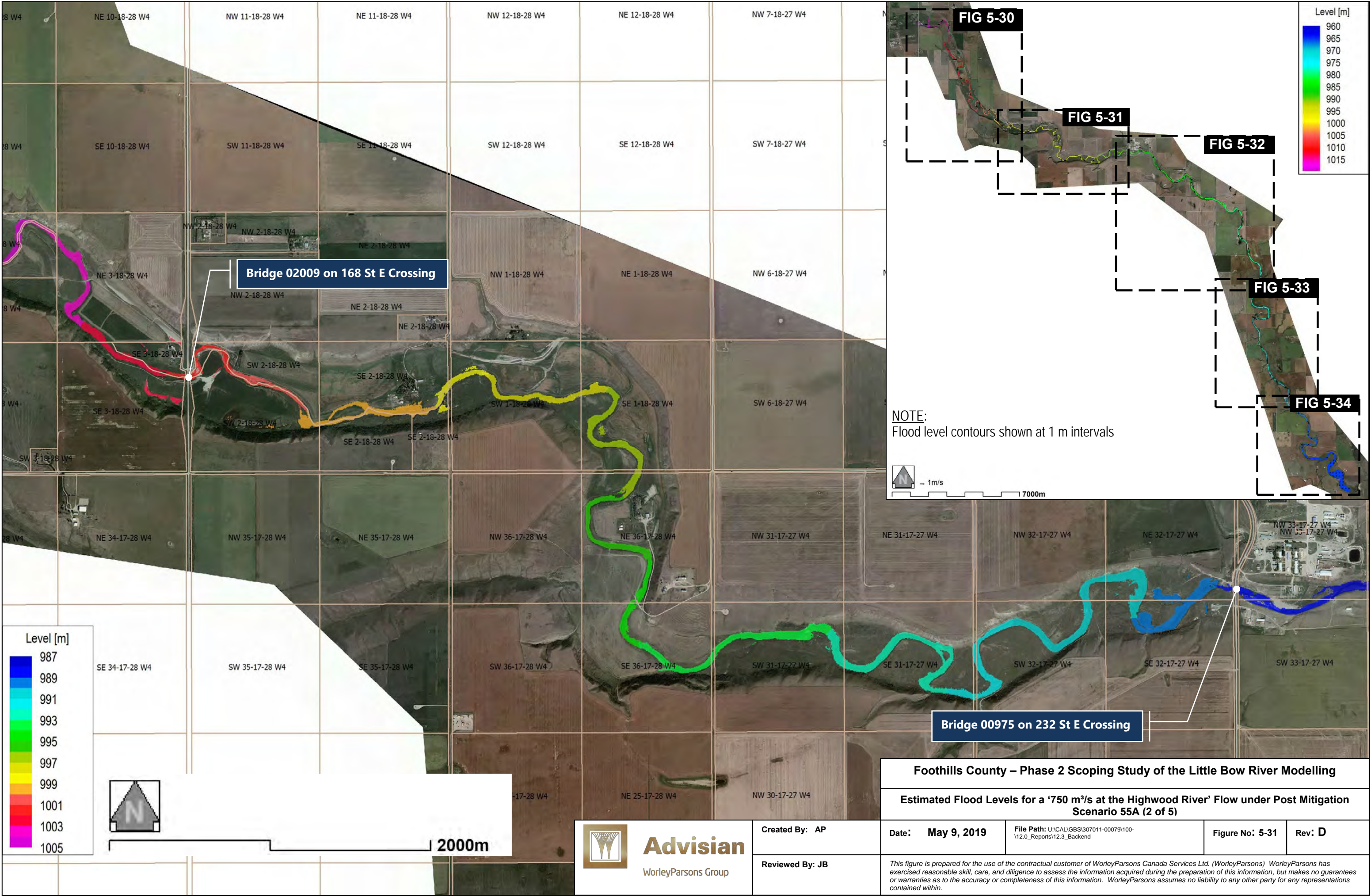
NOTE:  
Flood level contours shown at 1 m intervals

**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

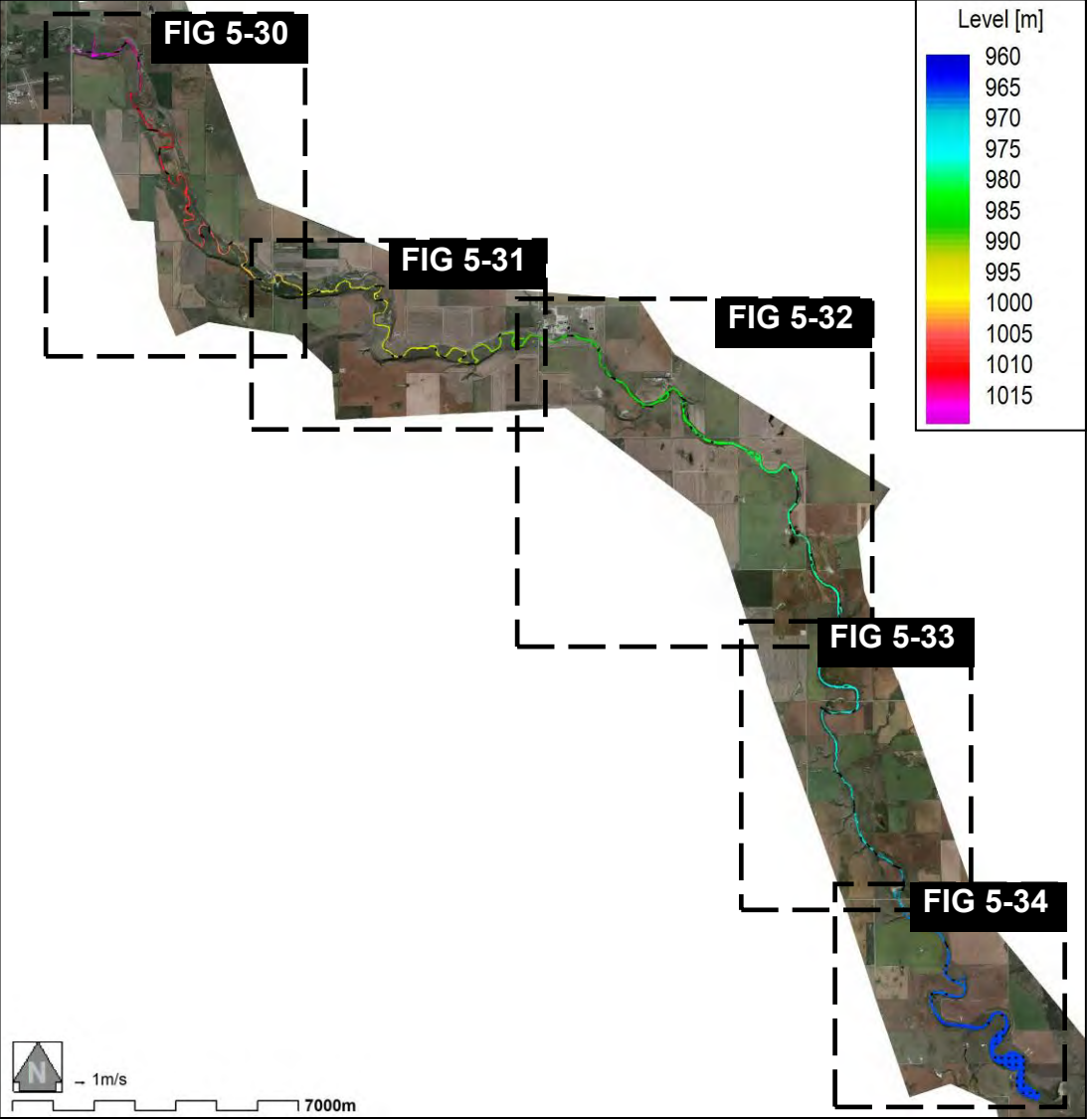
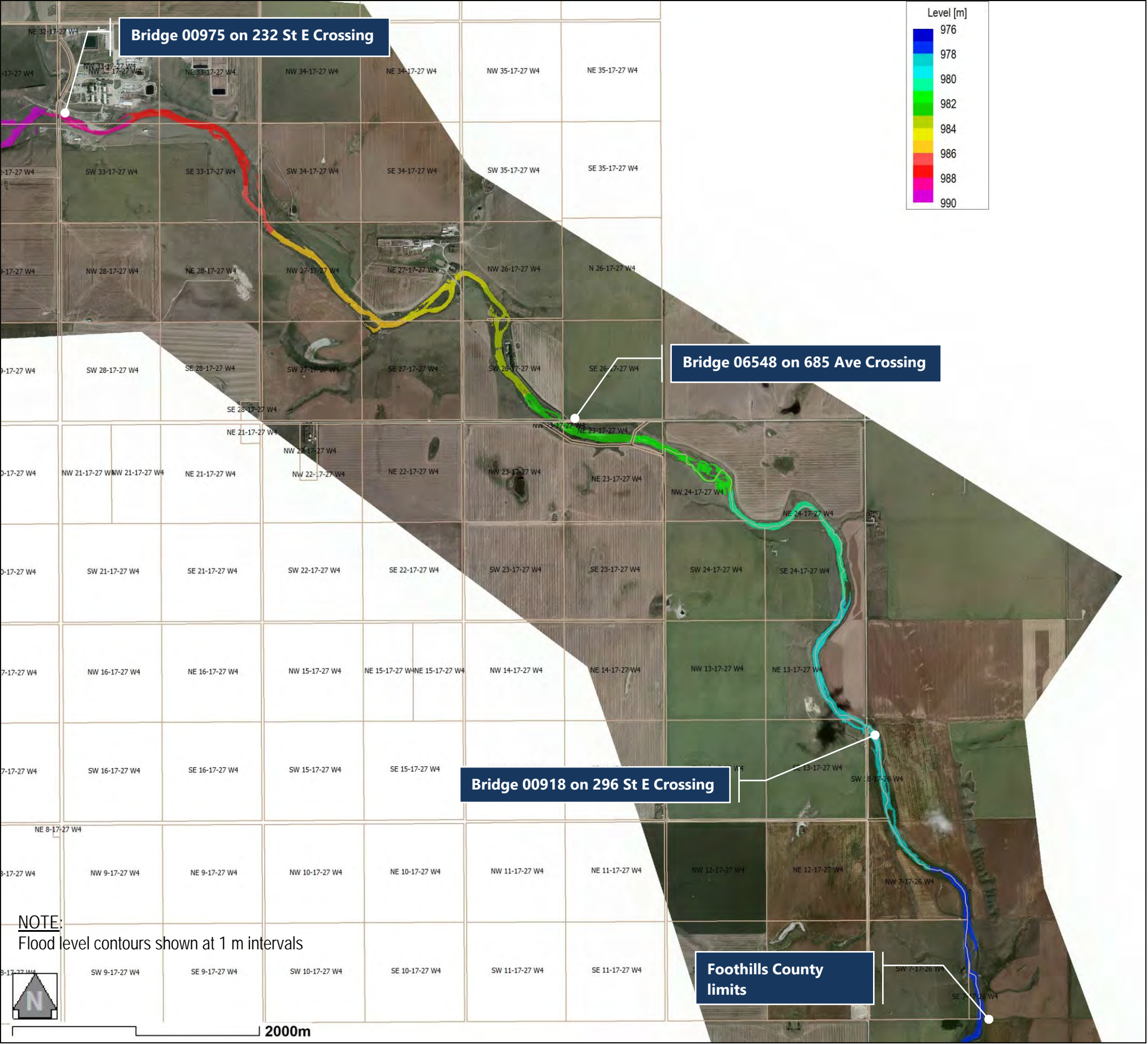
**Estimated Flood Levels for a '750 m<sup>3</sup>/s at the Highwood River' Flow under Post Mitigation Scenario 55A (1 of 5)**

 <b>Advisian</b> WorleyParsons Group	Created By: AP	Date: May 9, 2019	File Path: U:\CALIGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-30	Rev: D
	Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.			



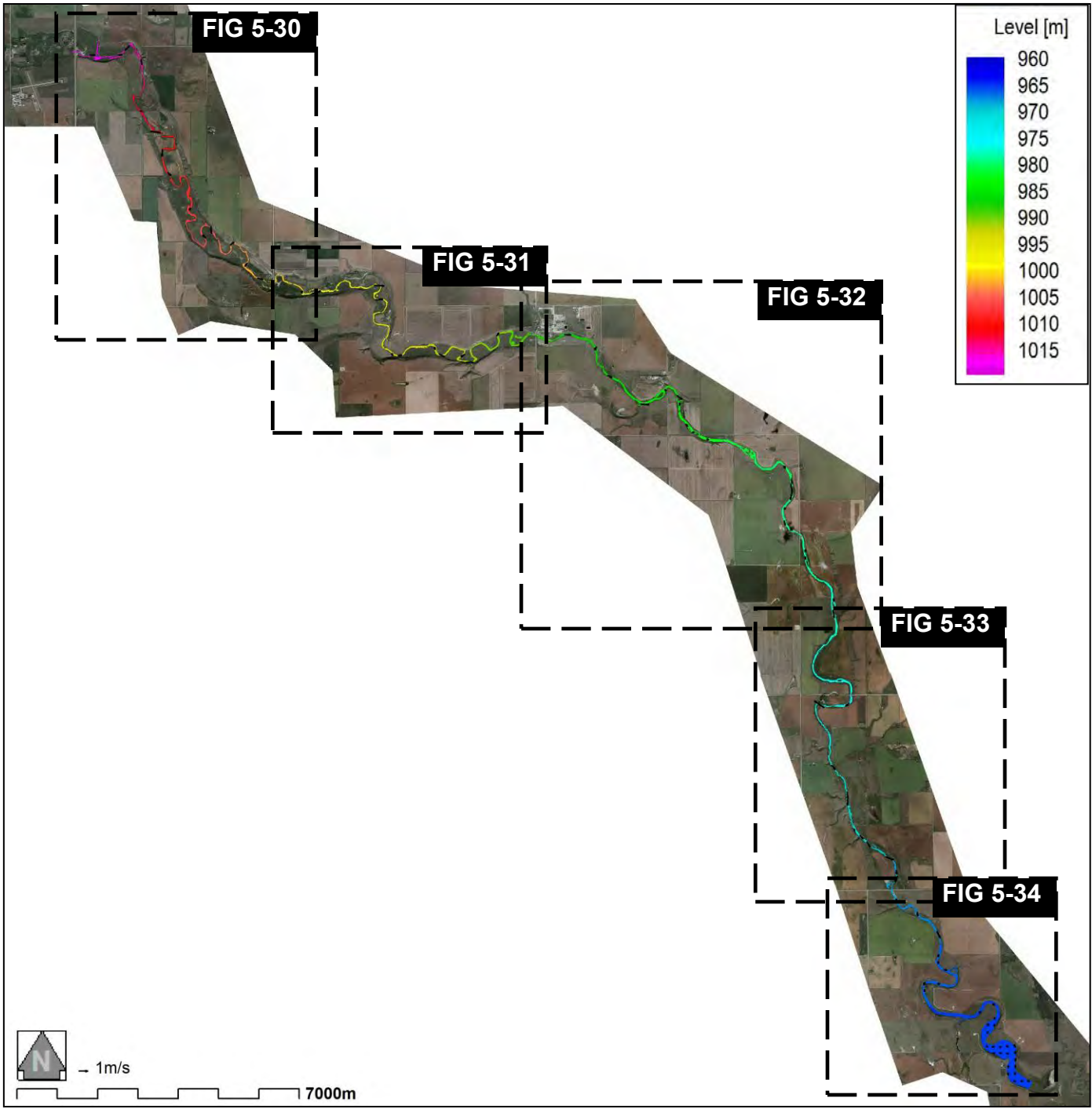
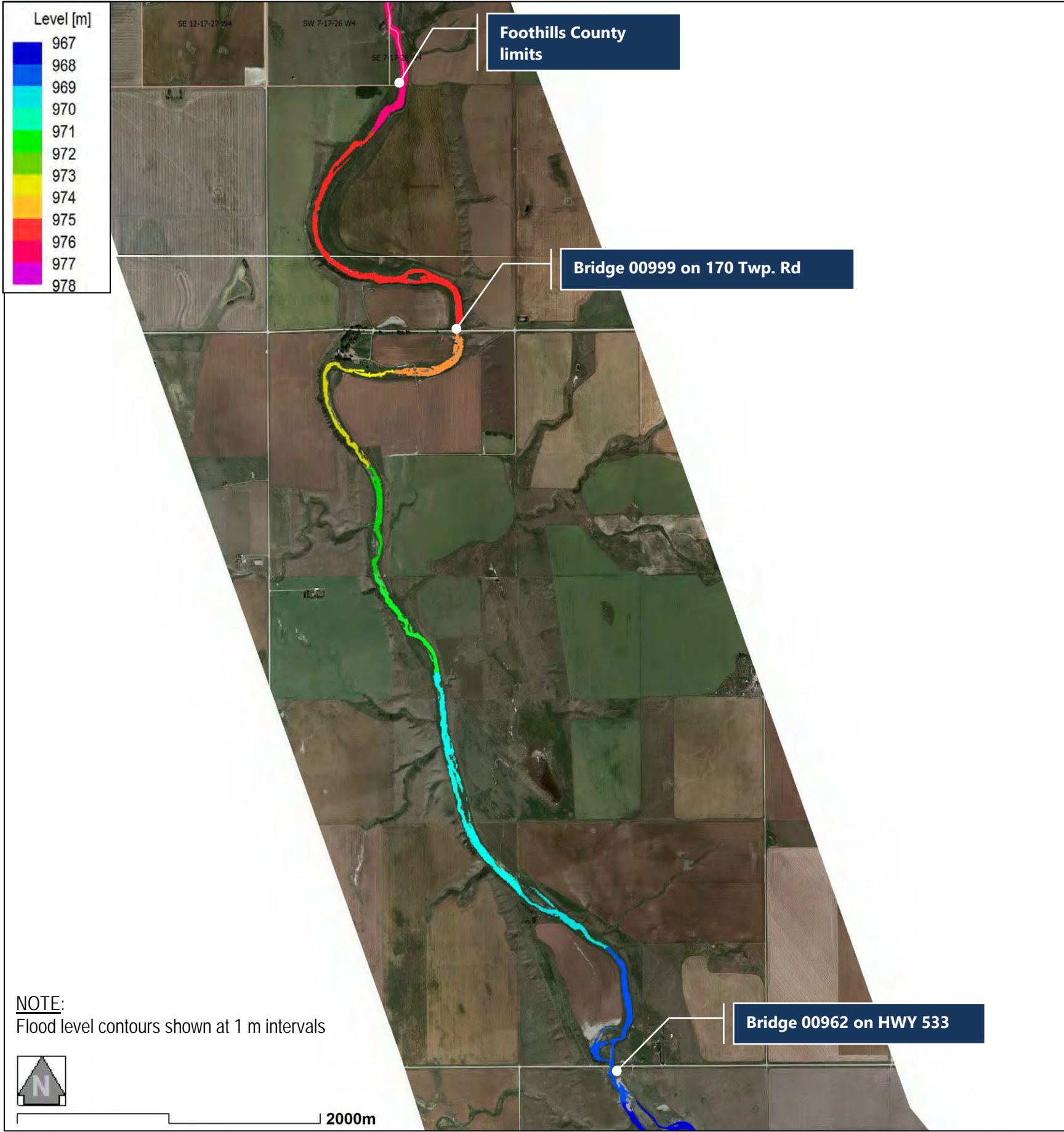






Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Levels for a ‘750 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (3 of 5)				
Date:	May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-32	Rev: D
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**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

**Estimated Flood Levels for a '750 m<sup>3</sup>/s at the Highwood River' Flow under Post Mitigation Scenario 55A (4 of 5)**

Date: May 9, 2019

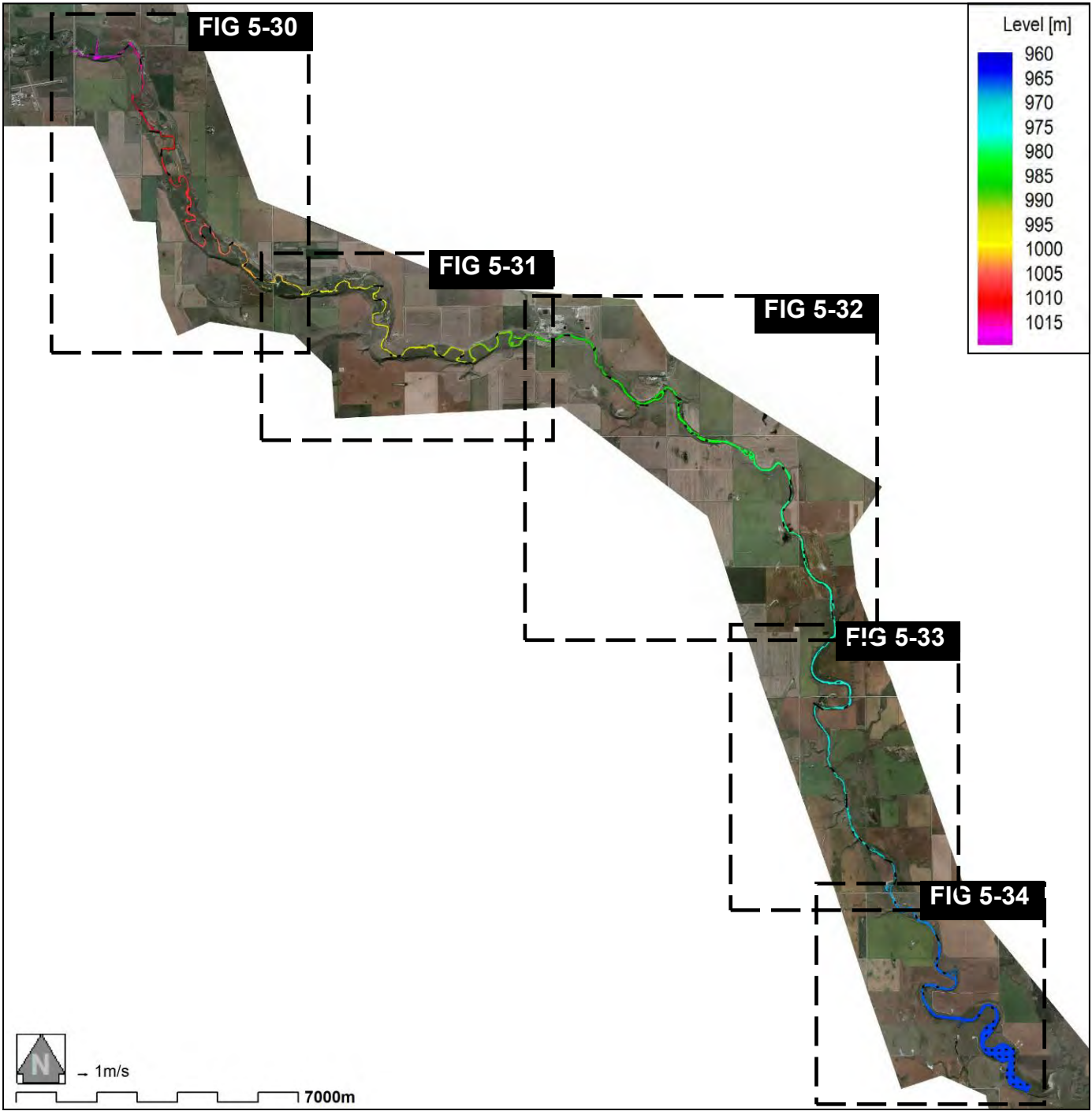
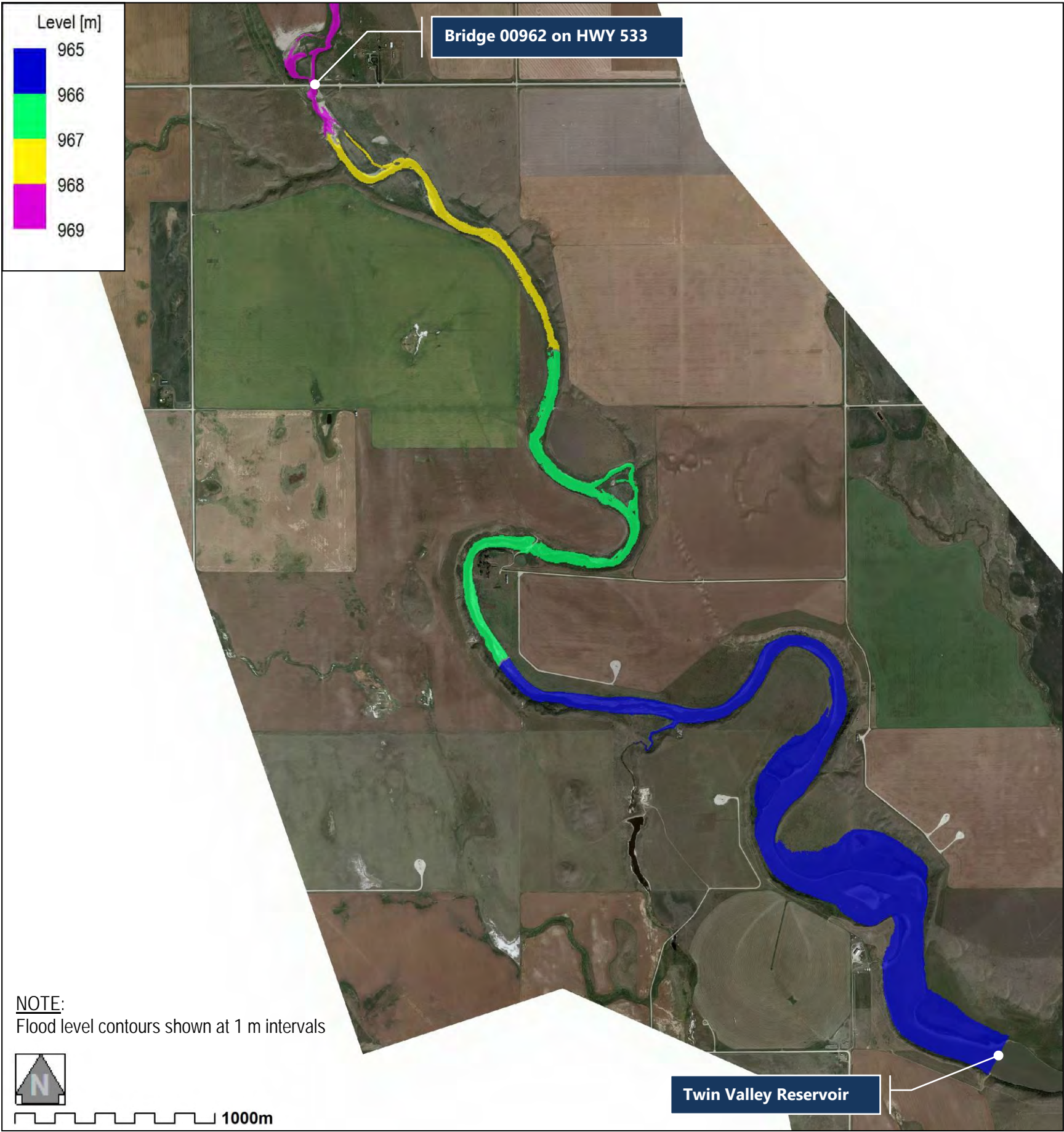
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Figure No: 5-33

Rev: D

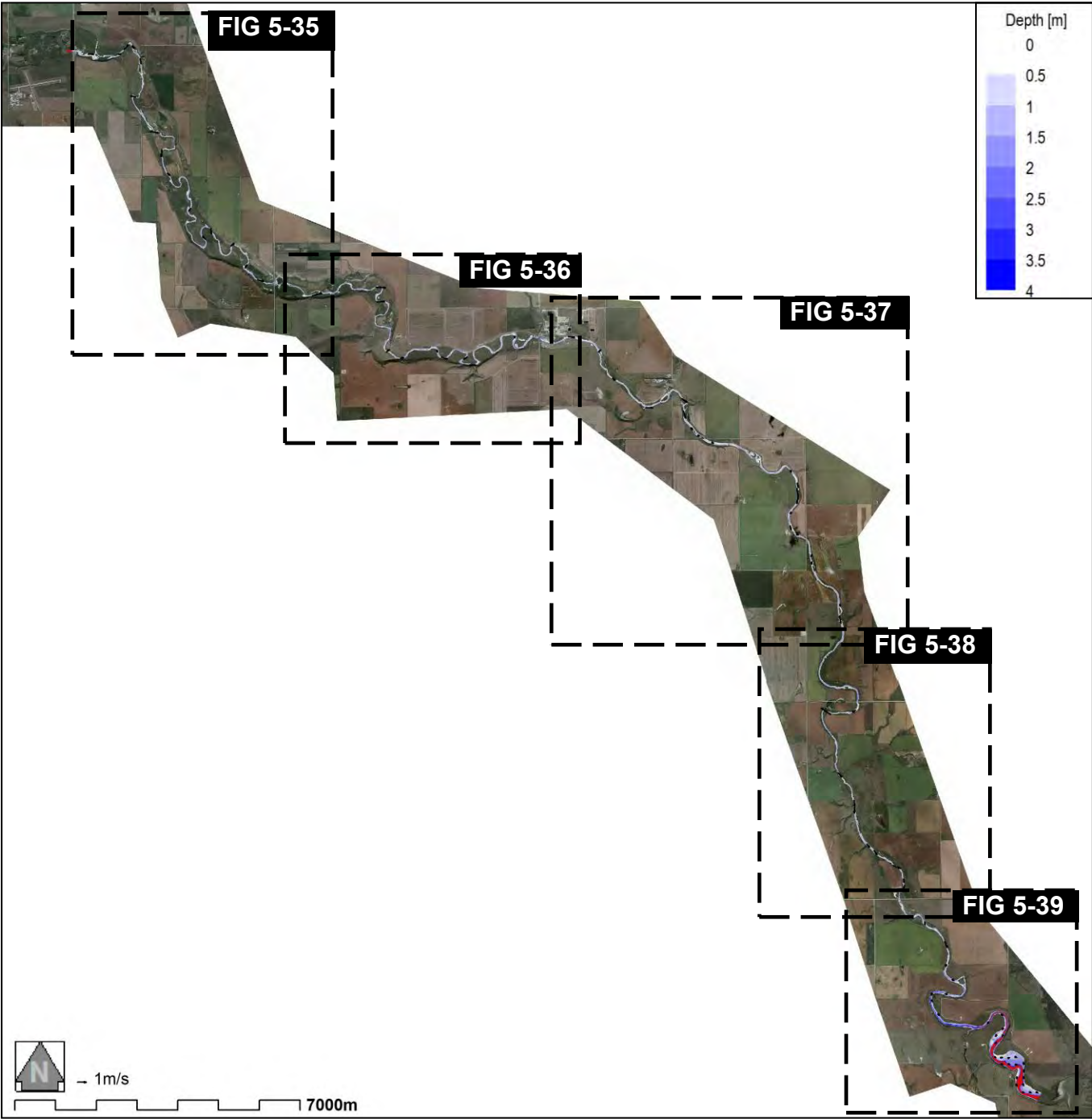
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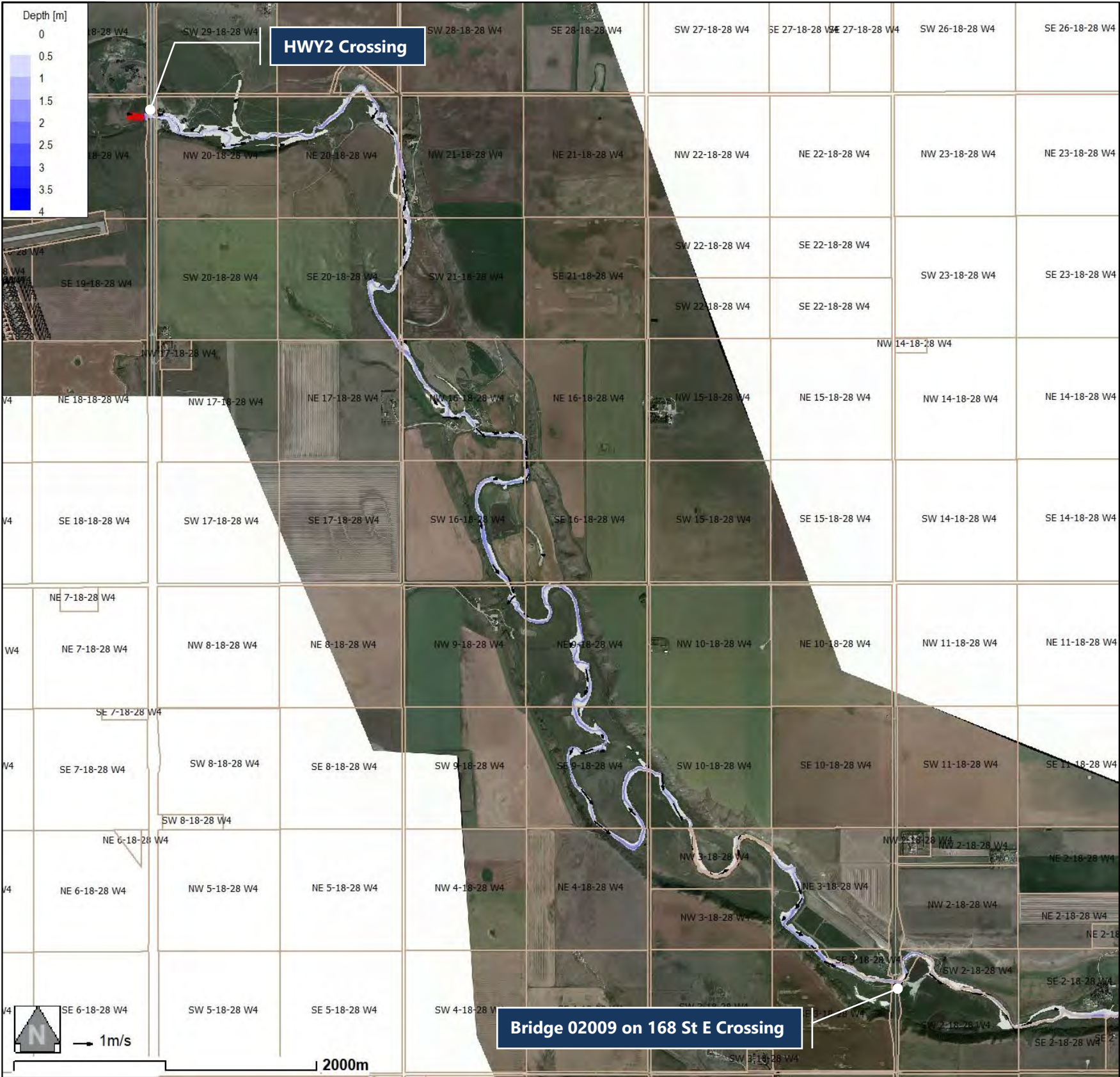



Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Levels for a ‘750 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (5 of 5)				
Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\112.3_Backend	Figure No: 5-34	Rev: D
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NOTE:  
Red mapping indicates locations where depths are predicted to exceed the maximum range; i.e., 4 metres

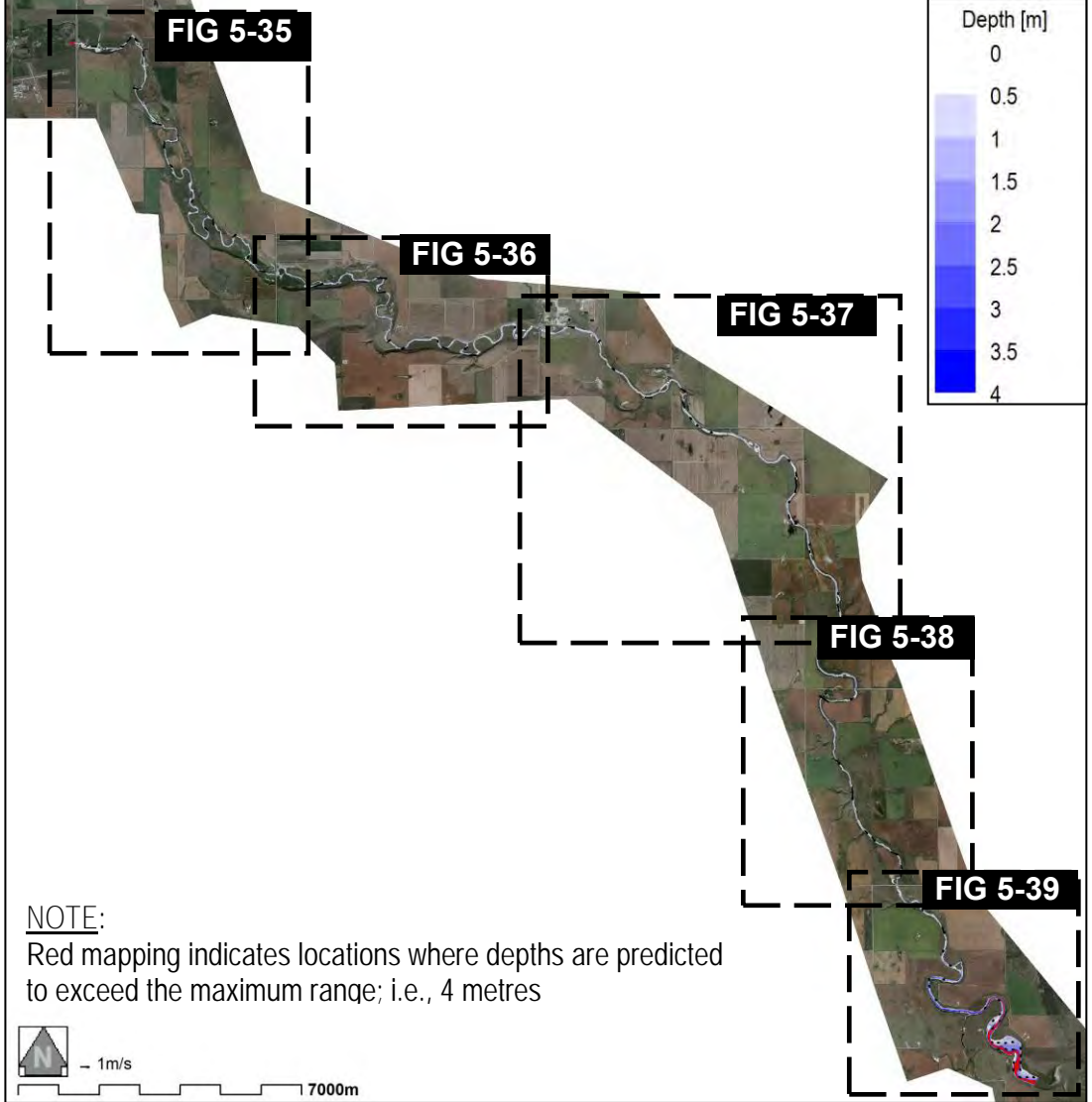


Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Depths and Velocities for a '750 m³/s at the Highwood River' Flow under Post Mitigation Scenario 55A (1 of 5)				
 <b>Advisian</b> WorleyParsons Group	Created By: AP	Date: May 9, 2019	File Path: U:\CALIGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-35
	Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.		










Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling			
Estimated Depths & Velocities for a ‘750 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (3 of 5)			
Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-12.0_Reports\12.3_Backend	Figure No: 5-37	Rev: D
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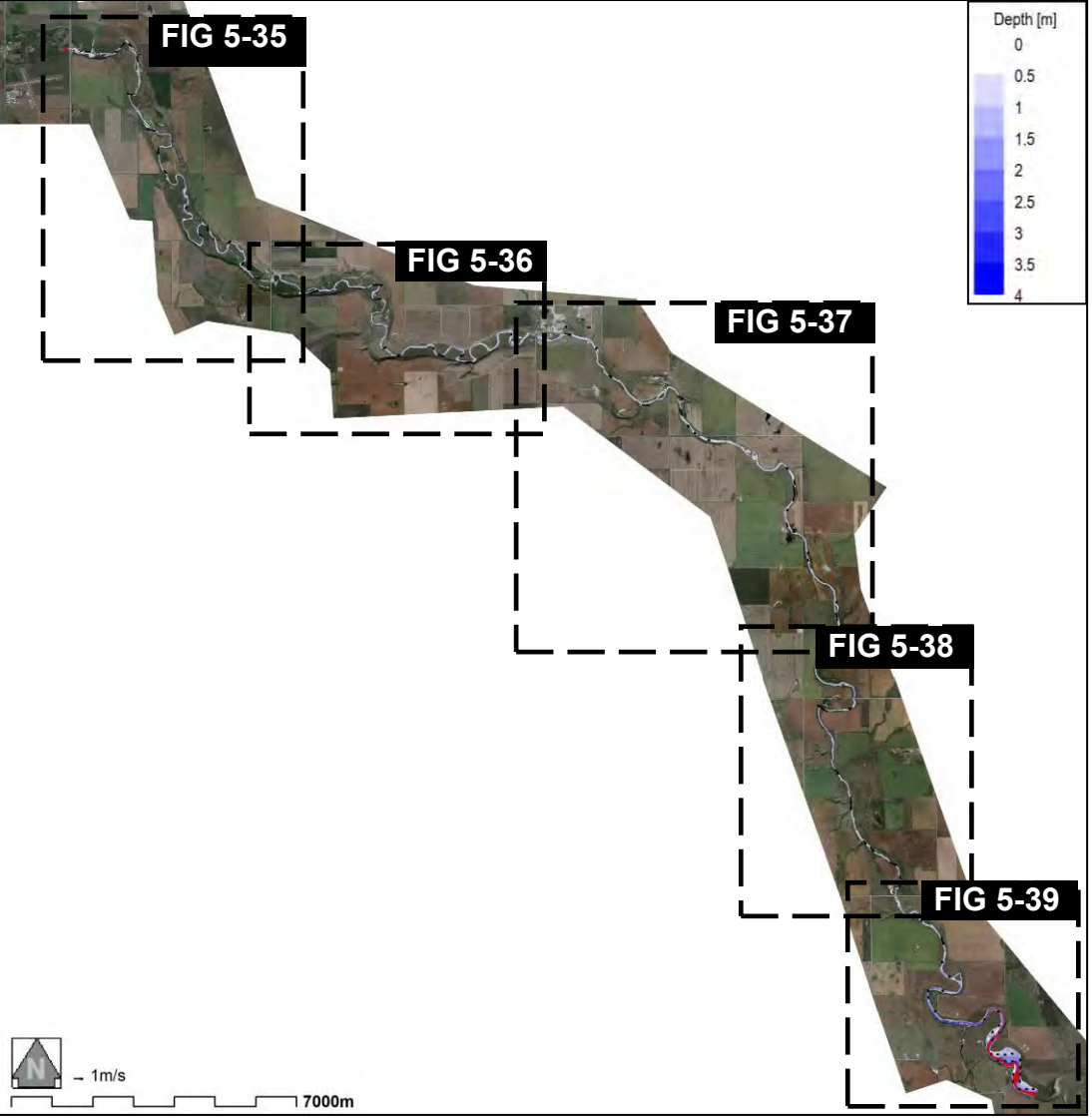
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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Depths & Velocities for a ‘750 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (4 of 5)				
Date:	May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-12.0_Reports\12.3_Backend	Figure No: 5-38	Rev: D
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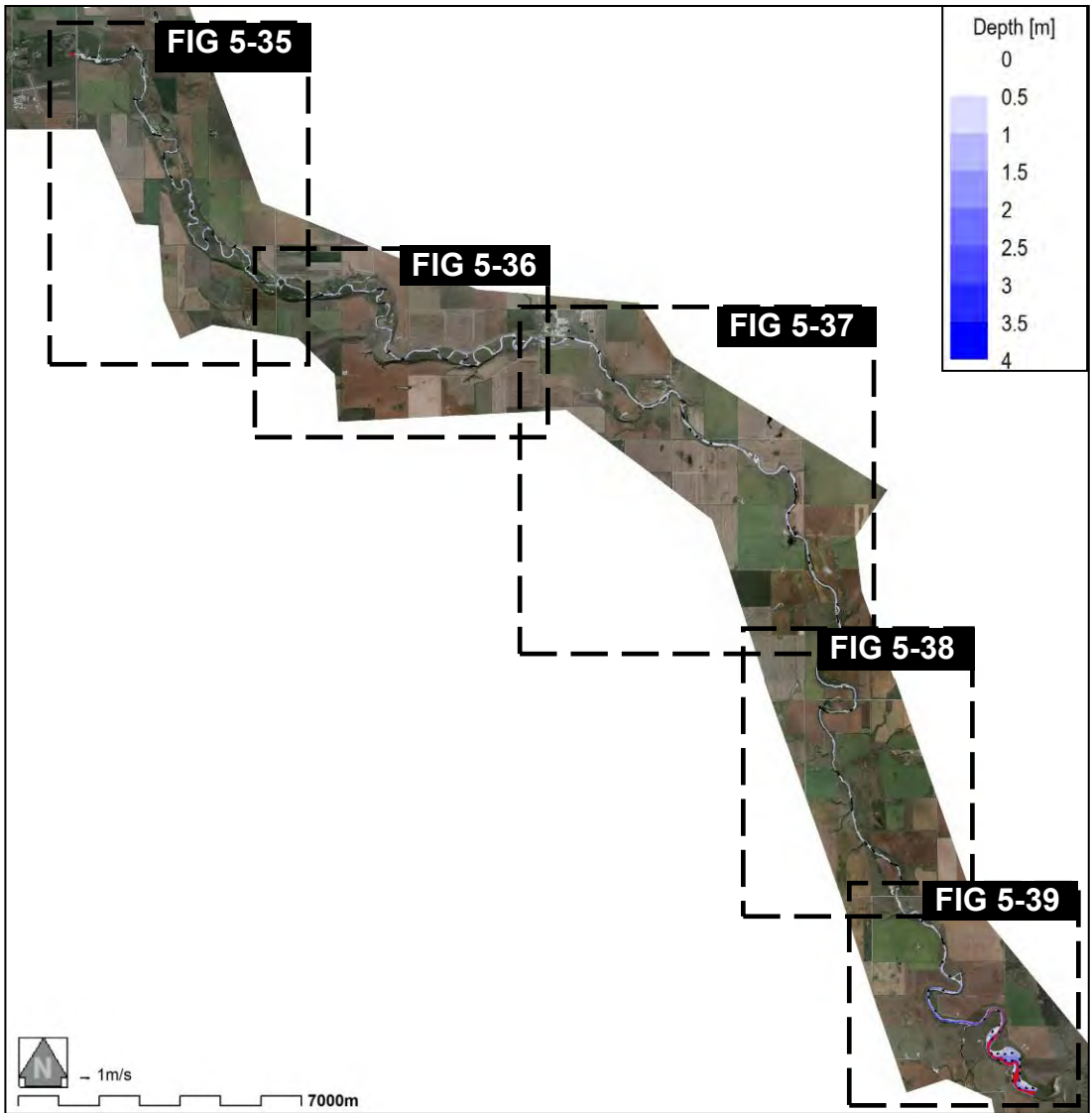
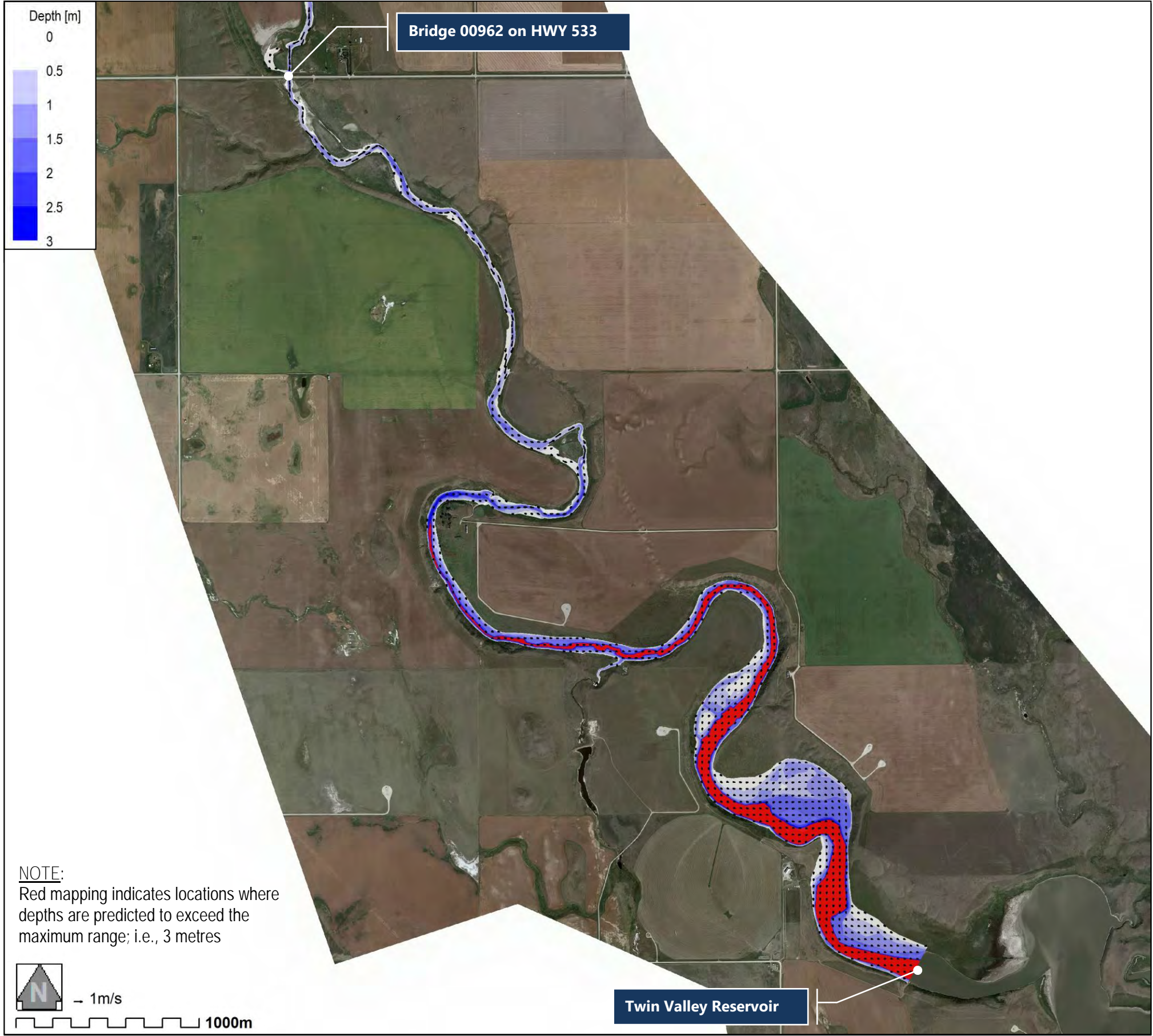


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Reviewed By:	JB





**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

**Estimated Depths & Velocities for a '750 m<sup>3</sup>/s at the Highwood River' Flow under Post Mitigation Scenario 55A (5 of 5)**

**Date:** May 9, 2019

**File Path:** U:\CAL\GBS\307011-00079\100-  
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**Figure No:** 5-39

**Rev:** D



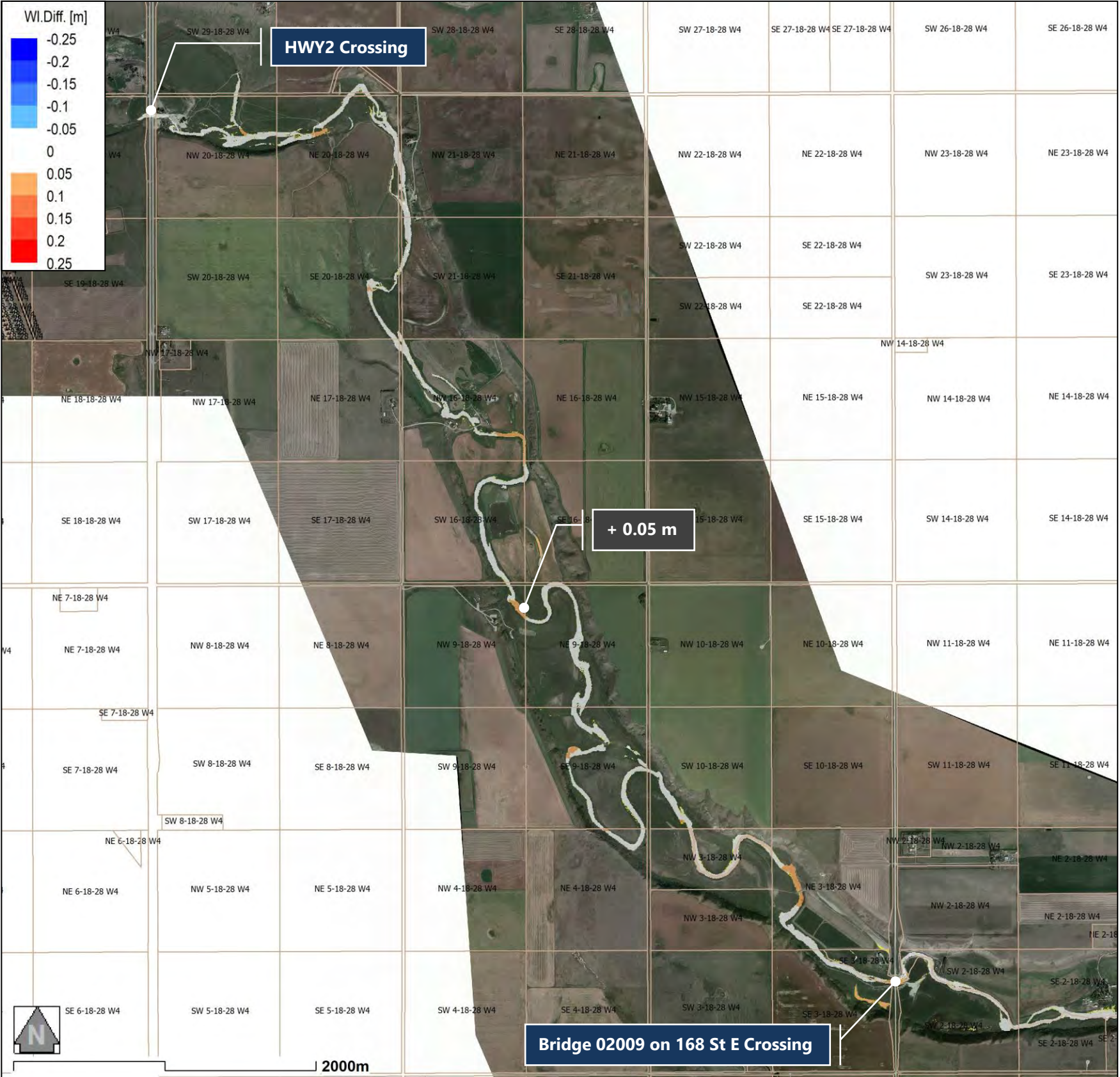
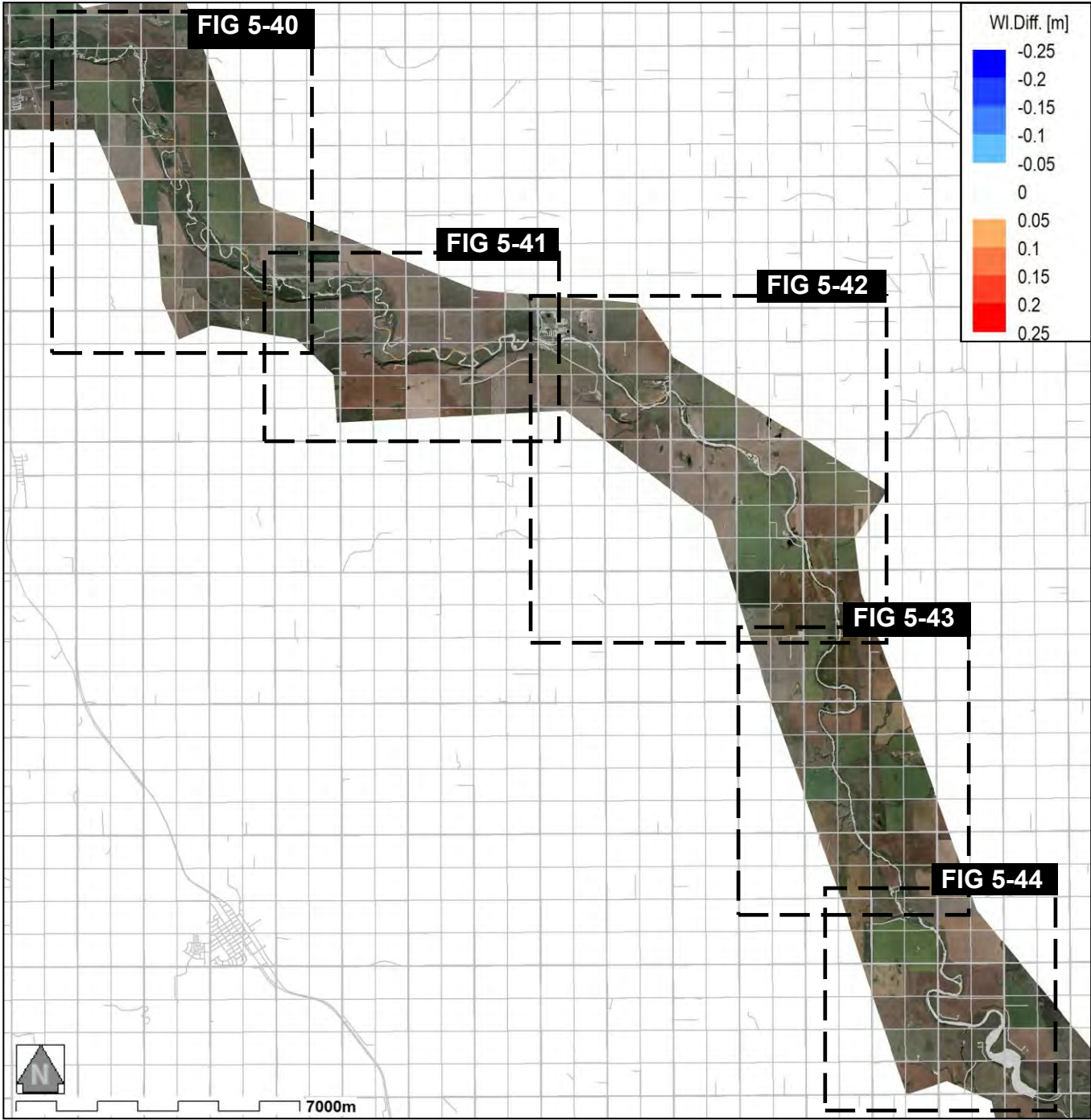
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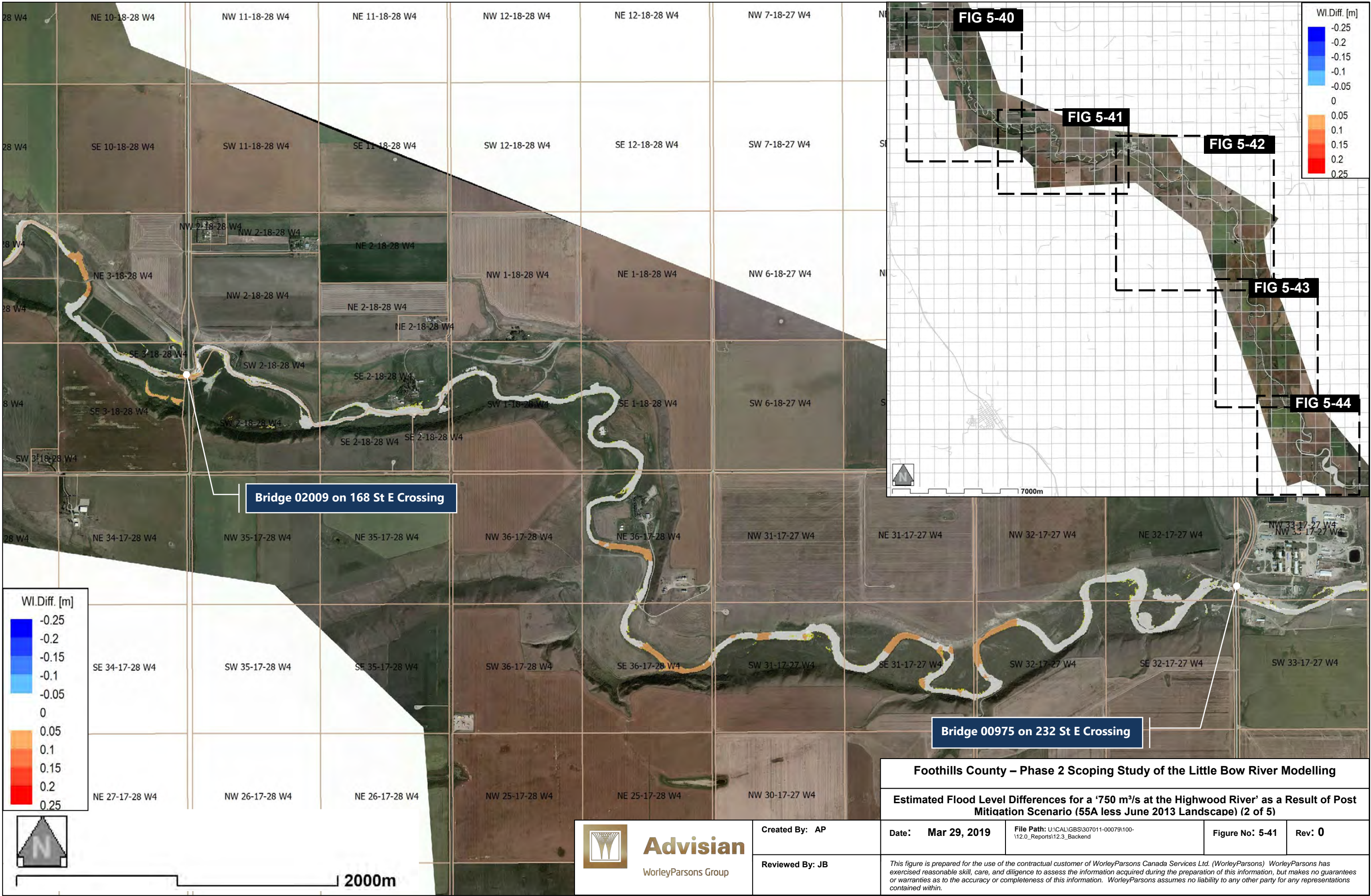


Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

Estimated Flood Level Differences for a ‘750 m³/s at the Highwood River’ as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (1 of 5)

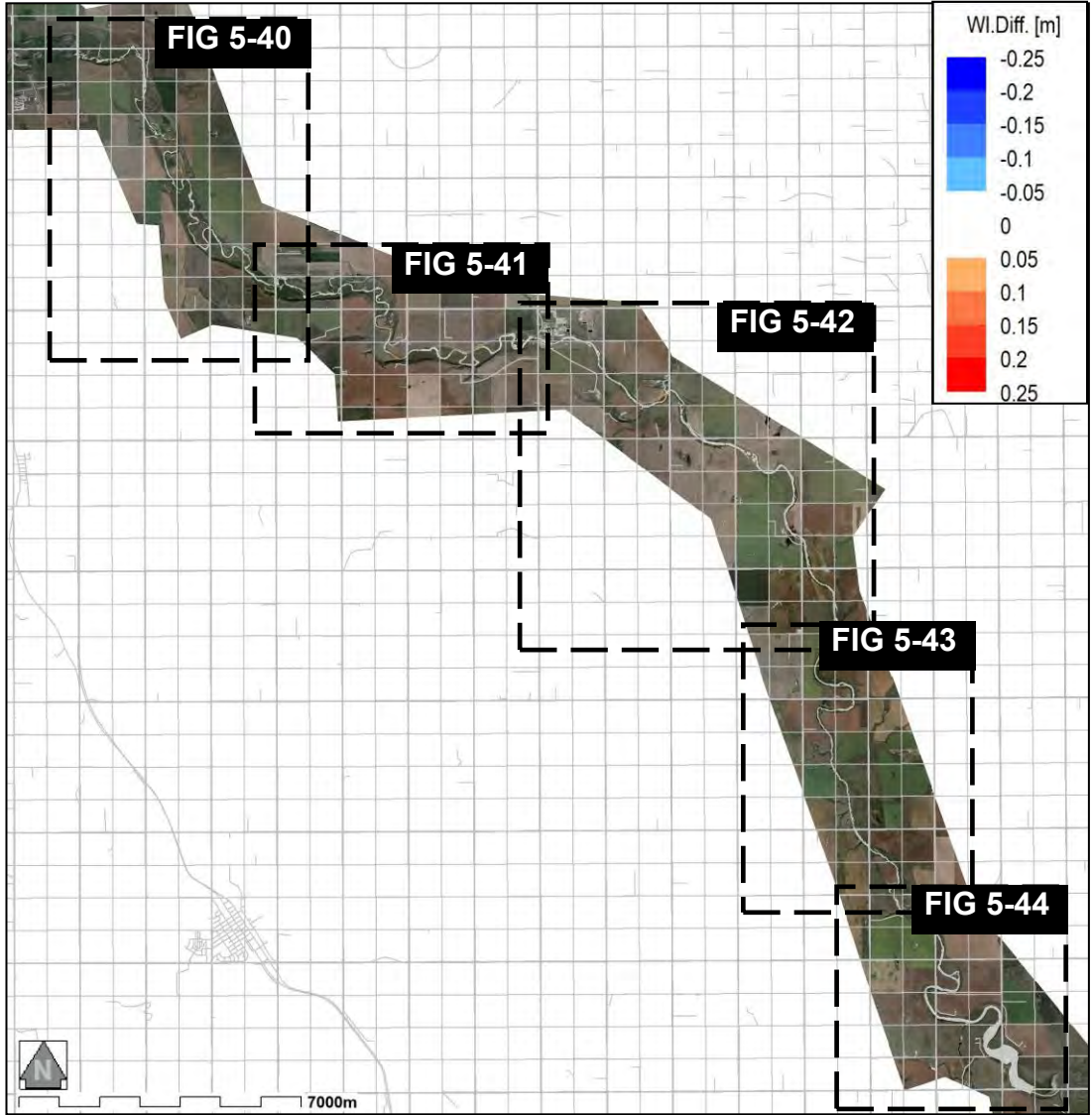
 <div>Advisian WorleyParsons Group</div>	Created By: AP	Date: May 9, 2019	File Path: U:\CALIGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-40	Rev: D
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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Level Differences for a '750 m³/s at the Highwood River' as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (2 of 5)				
Created By: AP	Date: Mar 29, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-41	Rev: 0
Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons). WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.			





Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

Estimated Flood Level Differences for a '750 m³/s at the Highwood River' as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (3 of 5)

Date: May 9, 2019 File Path: U:\CAL\GBS\307011-00079\100-112.0\_Reports\12.3\_Backend Figure No: 5-42 Rev: D

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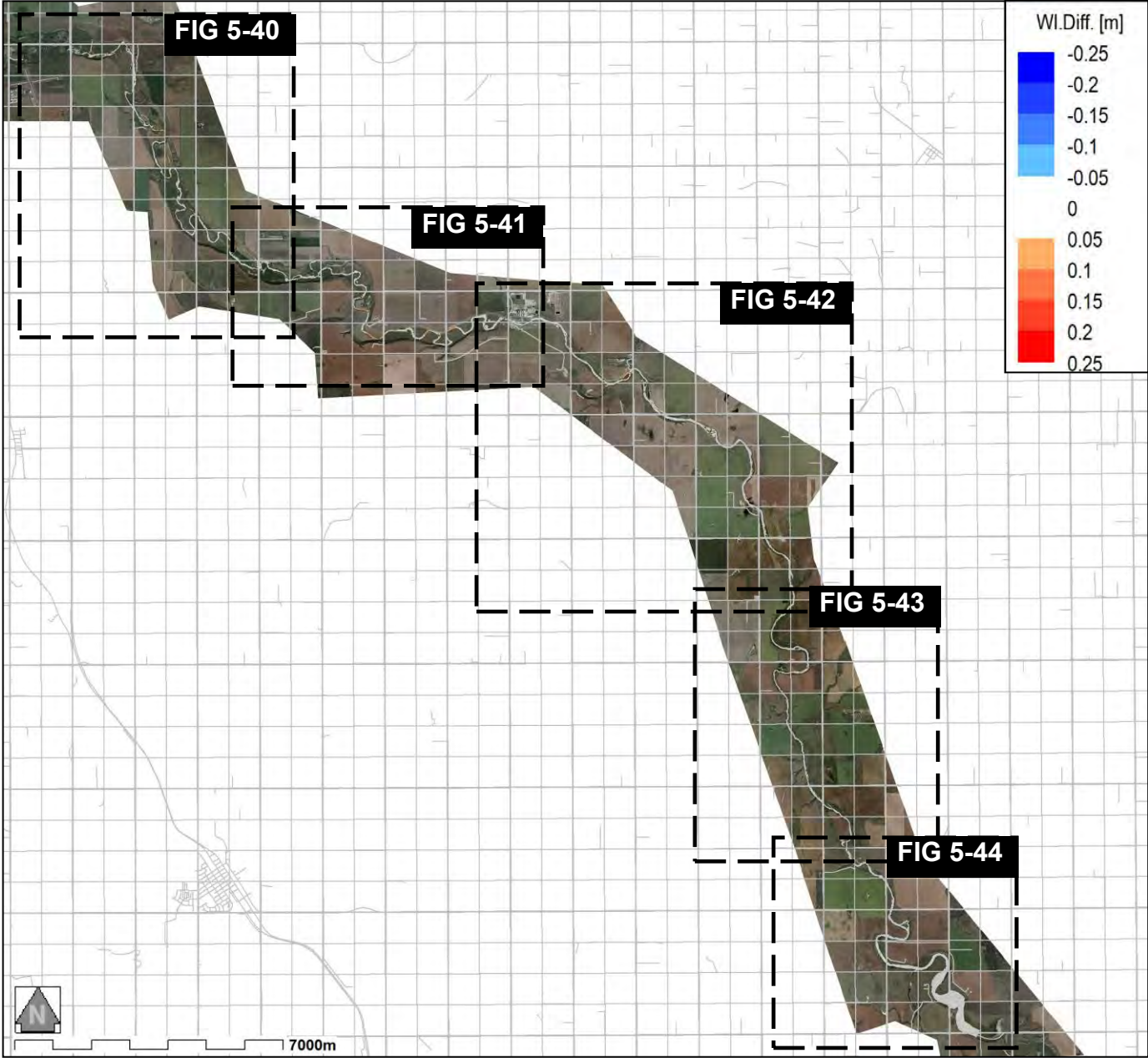
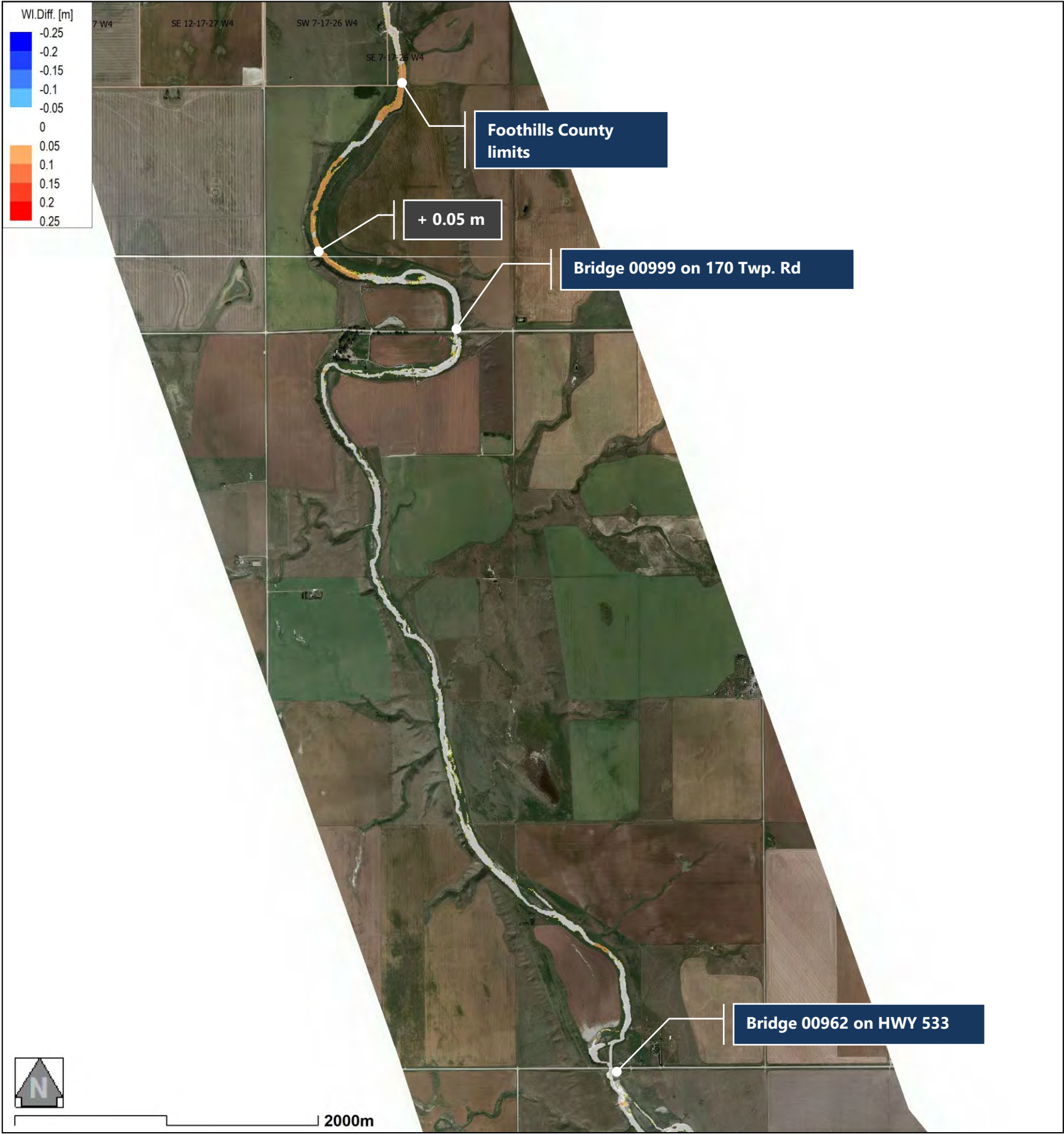


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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

Estimated Flood Level Differences for a '750 m<sup>3</sup>/s at the Highwood River' as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (4 of 5)

Created By: AP

Date: May 9, 2019

File Path: U:\CAL\GBS\307011-00079\100-  
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Figure No: 5-43

Rev: D

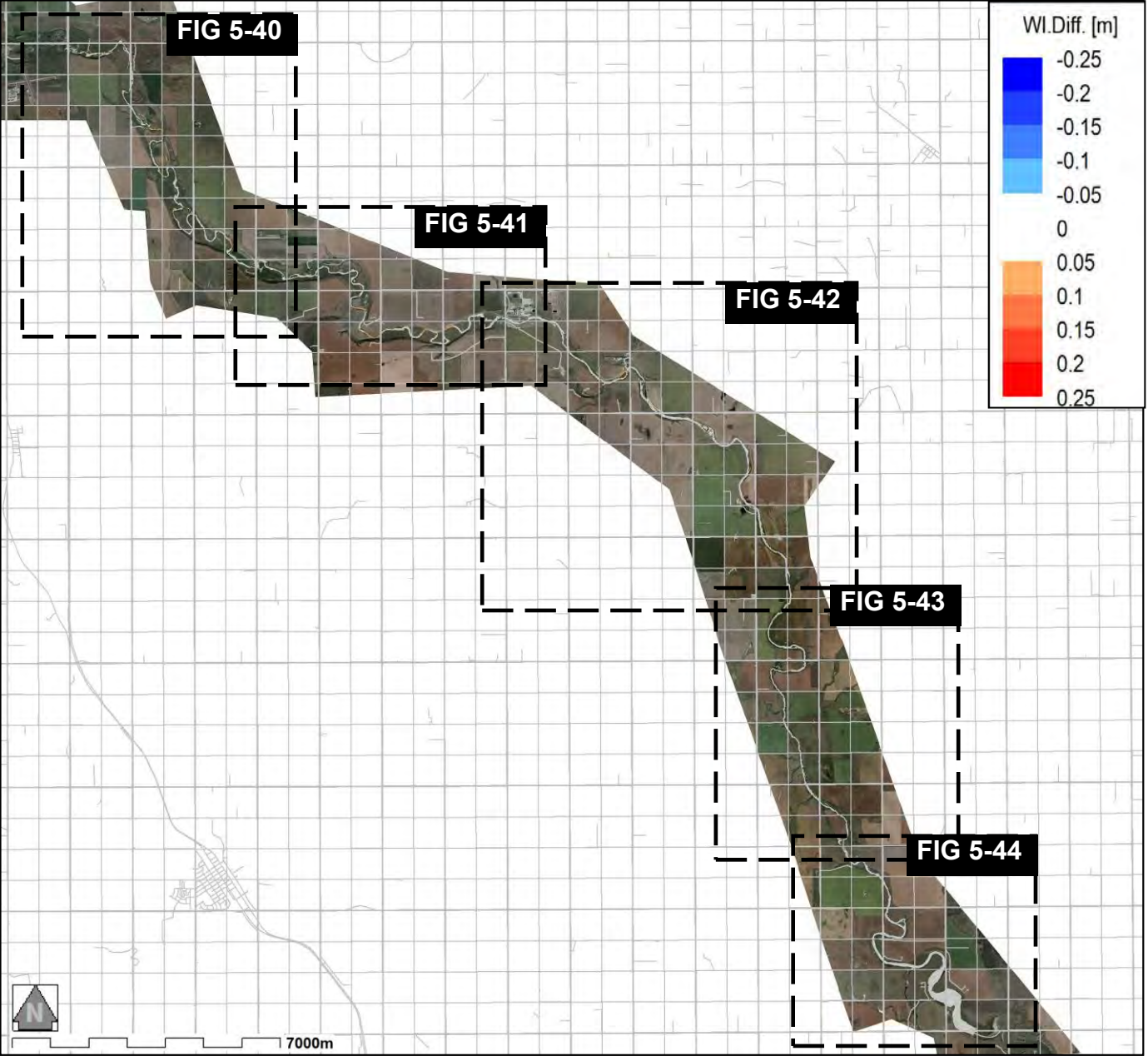
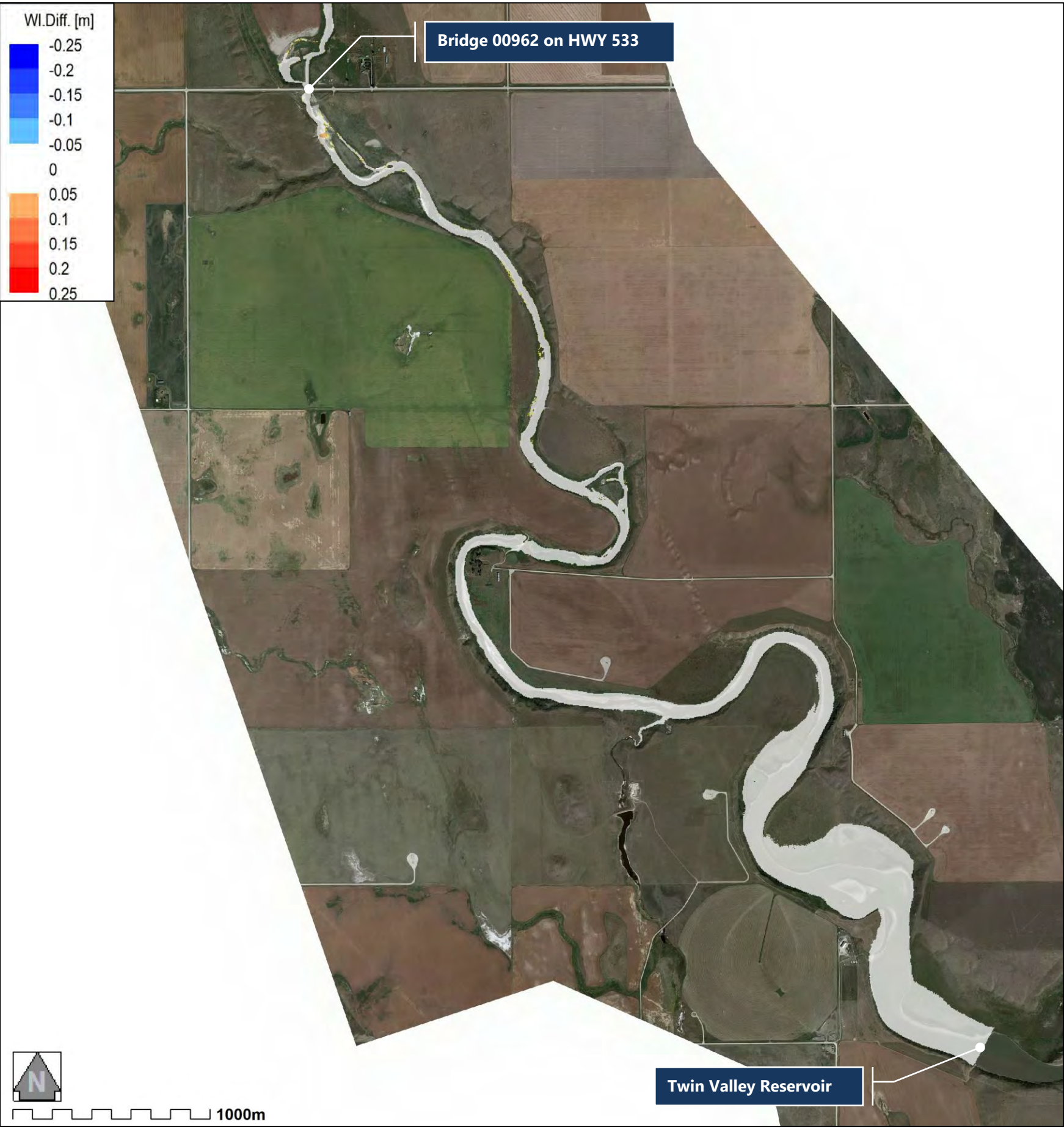
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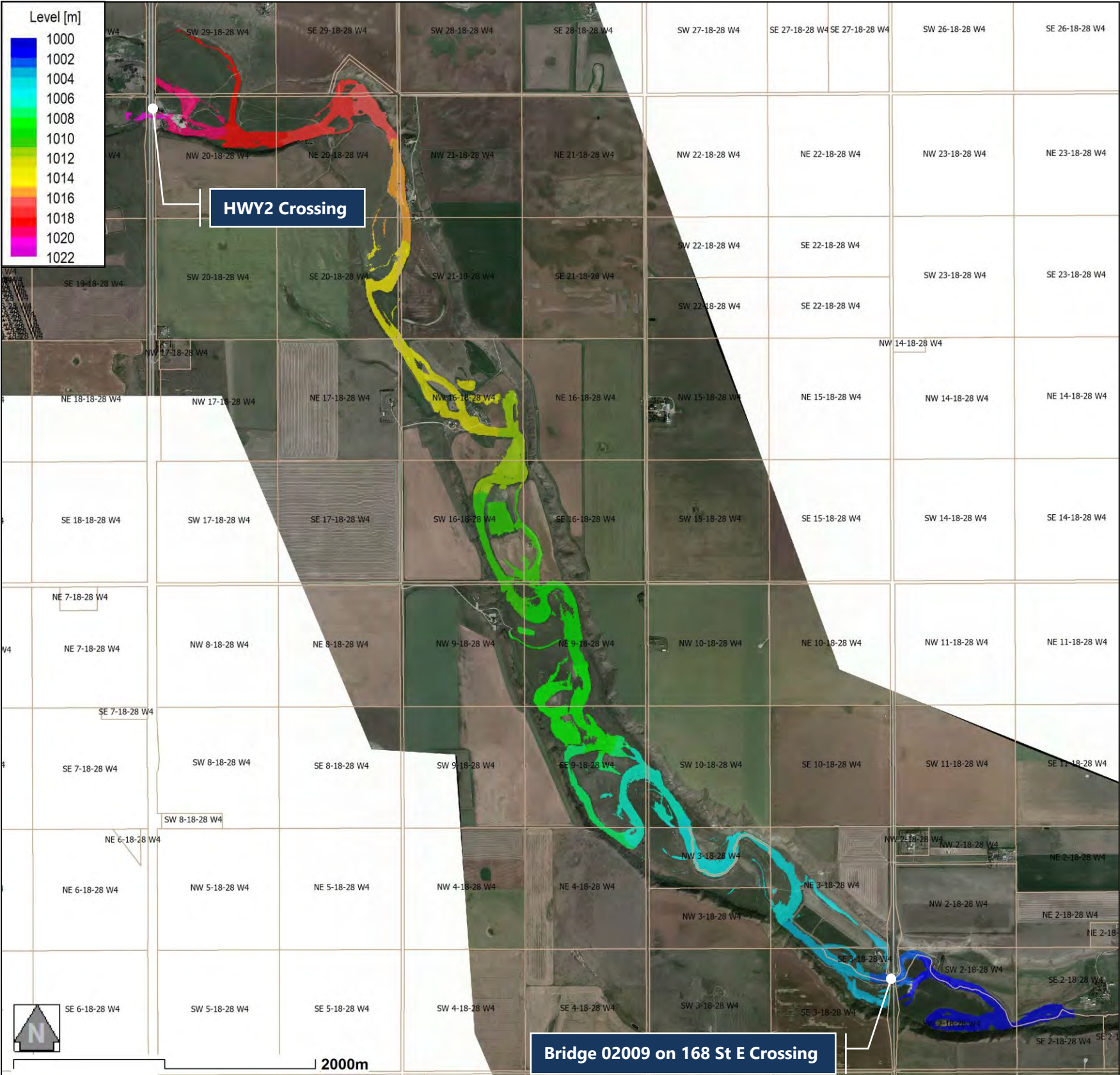
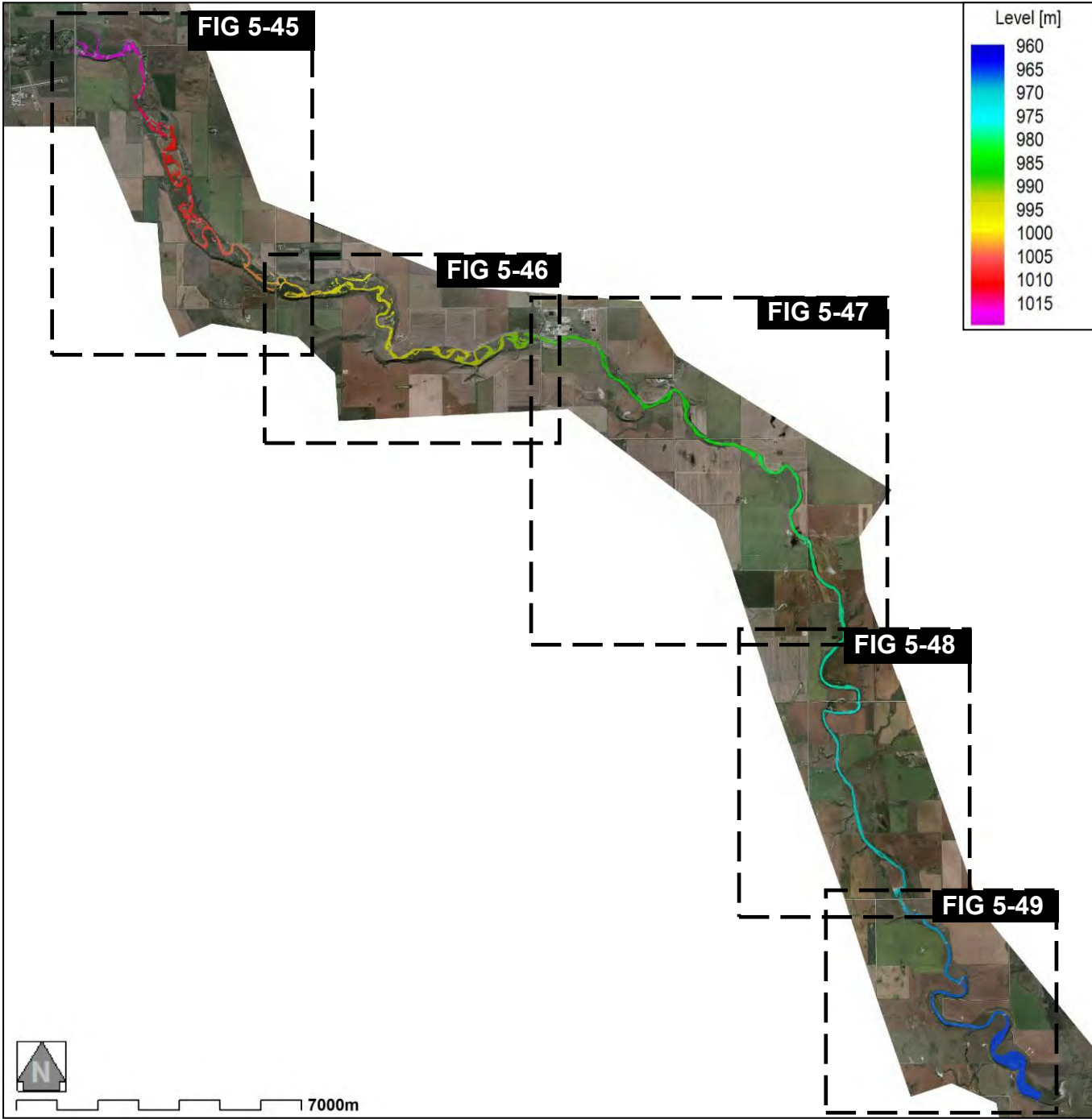
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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Level Differences for a '750 m³/s at the Highwood River' as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (5 of 5)				
Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\112.3_Backend	Figure No: 5-44	Rev: D
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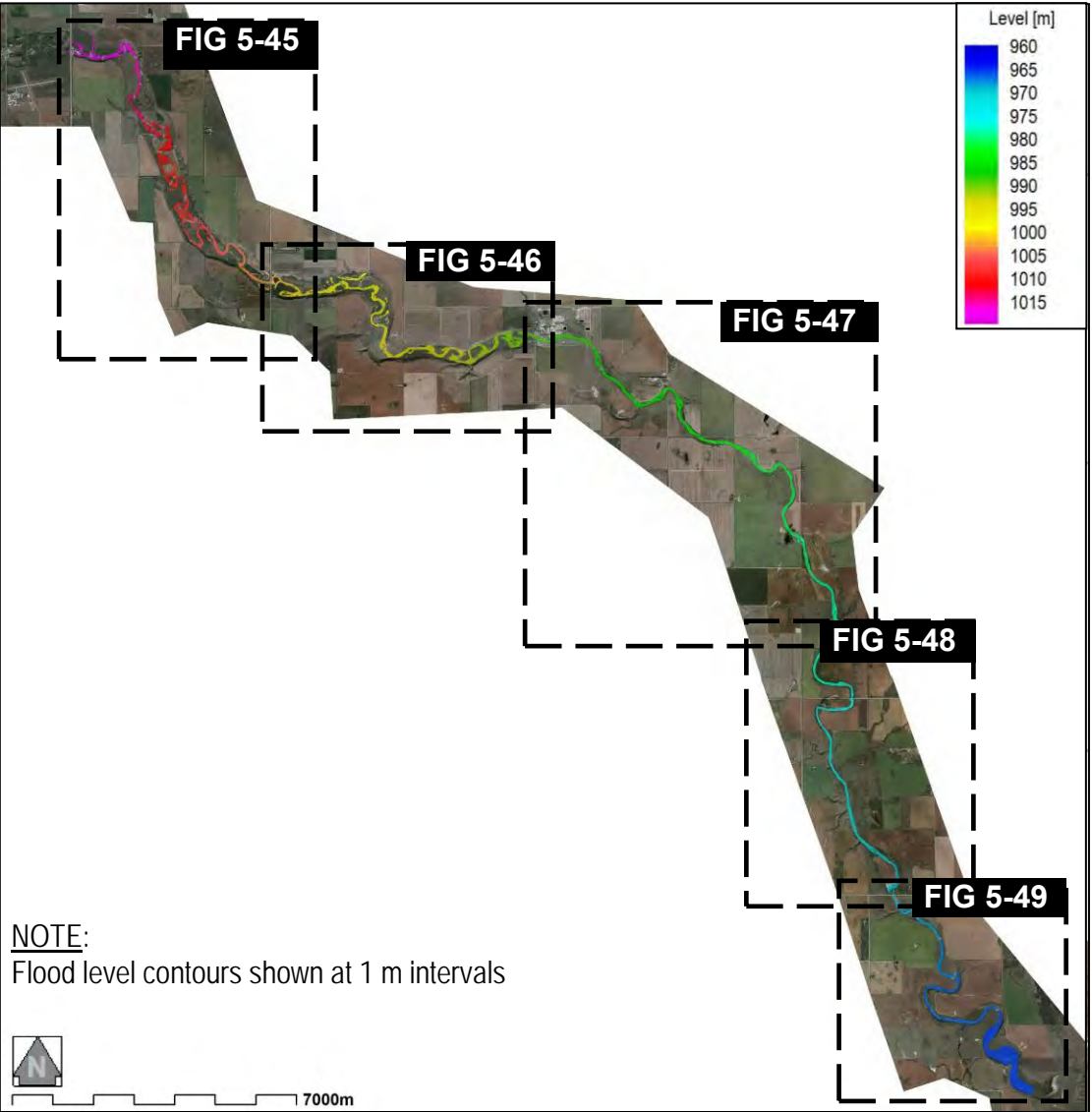
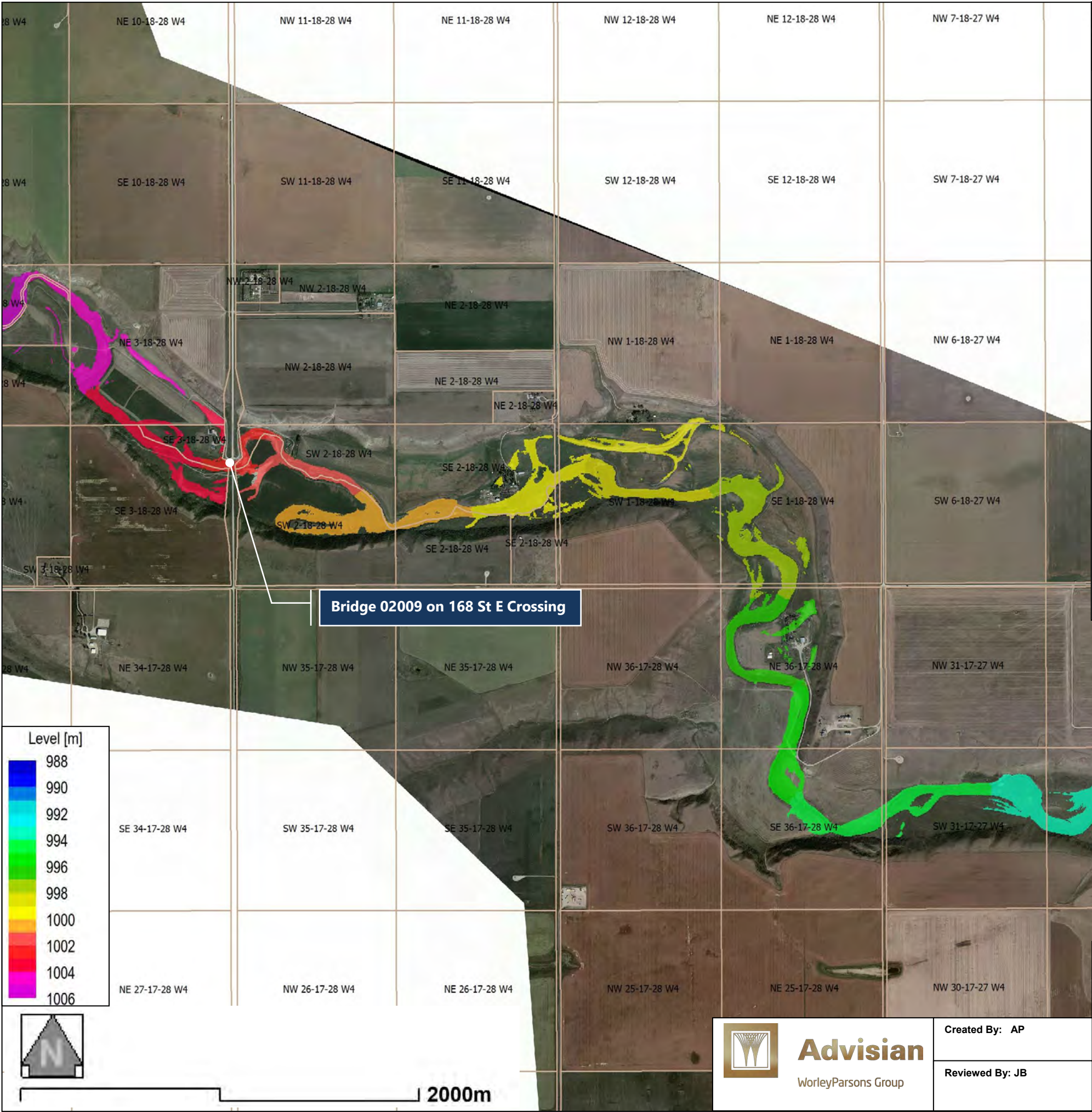


Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

Estimated Flood Levels for a ‘1,000 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A  
(1 of 5)

 <div>Advisian WorleyParsons Group</div>	Created By: AP	Date: May 9, 2019	File Path: U:\CAL\IGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-45	Rev: D
	Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.			





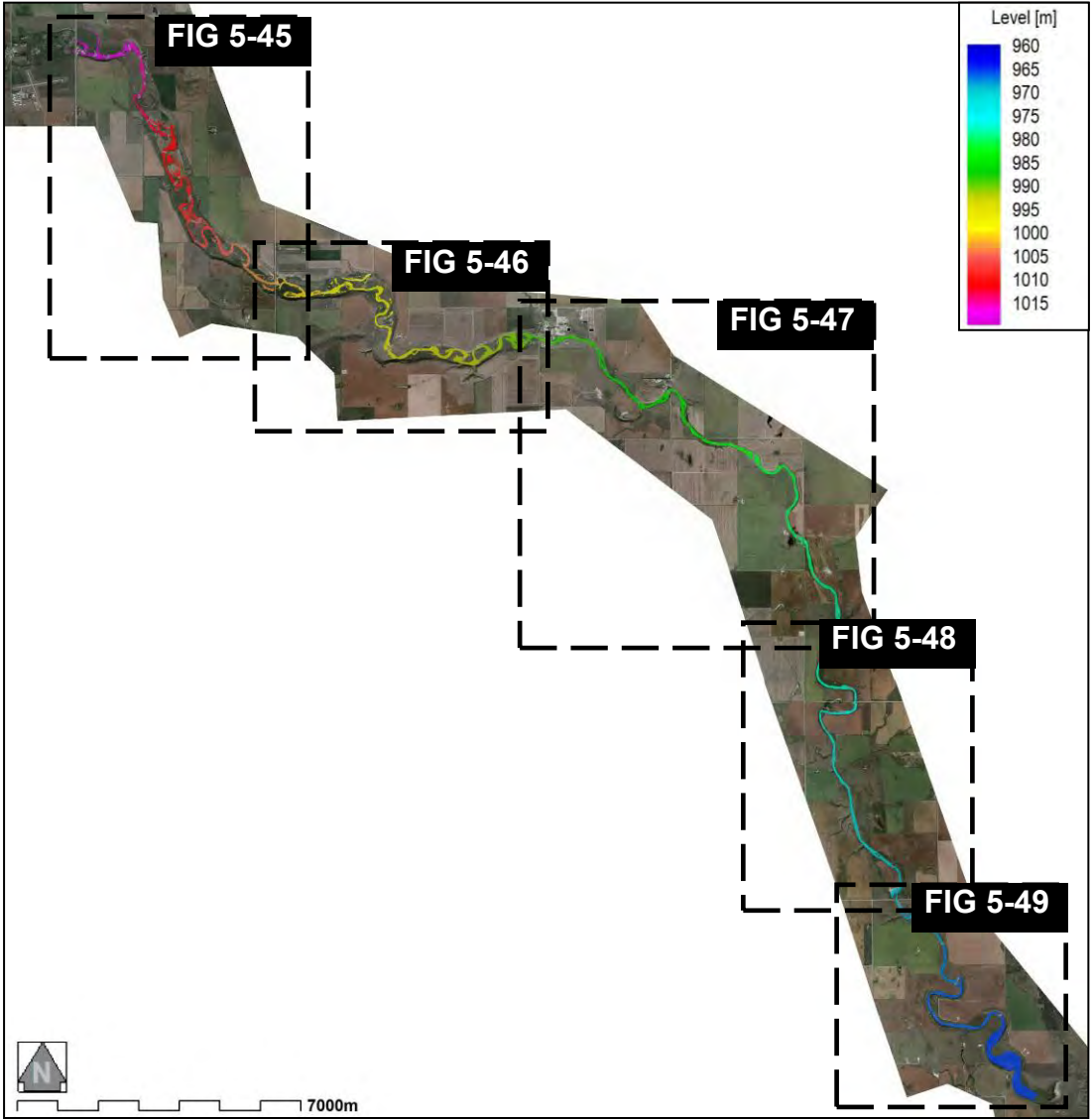
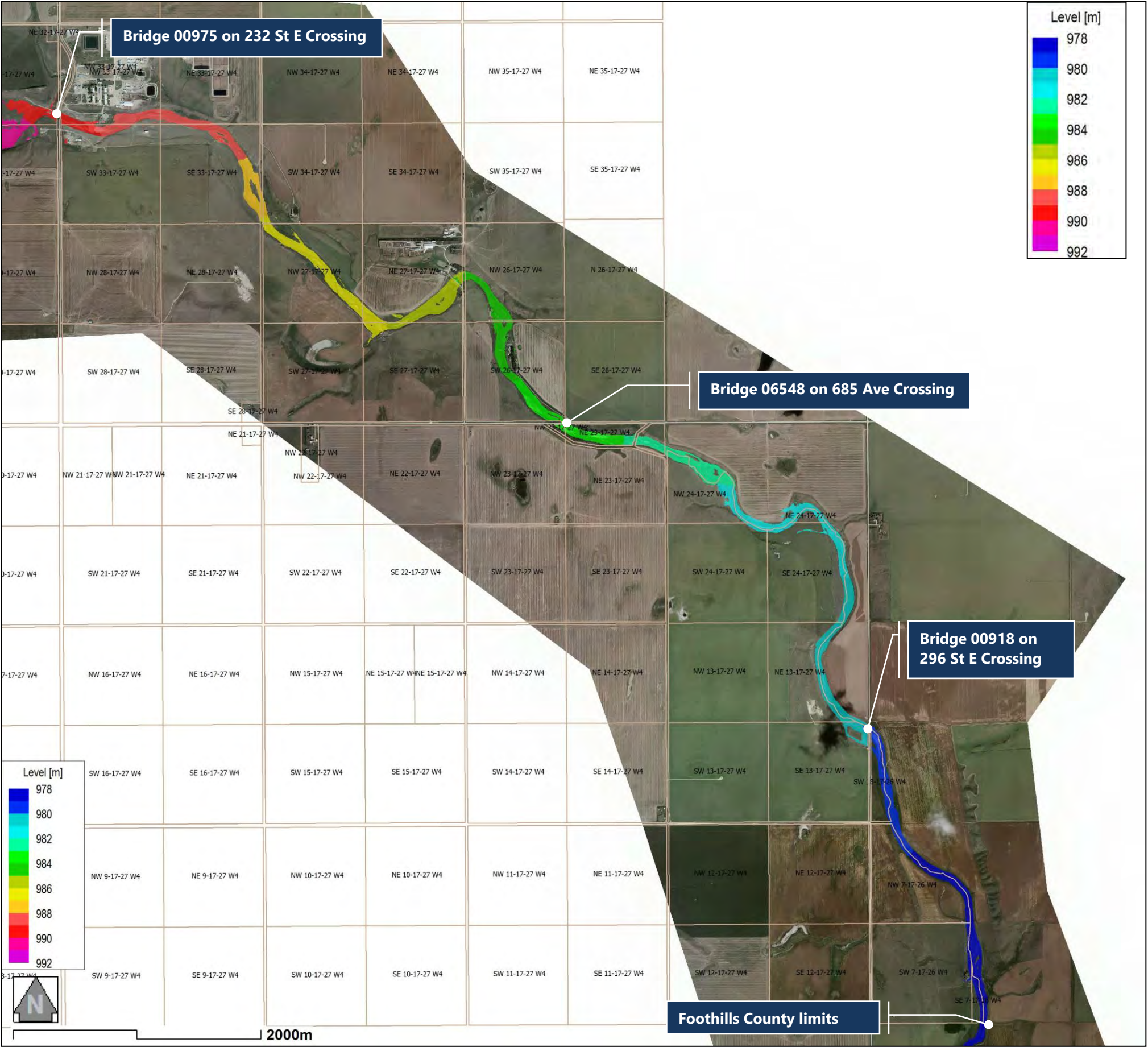
NOTE:  
Flood level contours shown at 1 m intervals



Bridge 00975 on 232 St E Crossing

Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Levels for a '1,000 m³/s at the Highwood River' Flow under Post Mitigation Scenario 55A (2 of 5)				
Created By:	AP	Date:	May 9, 2019	Figure No: 5-46
Reviewed By:	JB	File Path:	U:\CAL\GBS\307011-00079\100-112.0_Reports\112.3_Backend	Rev: D
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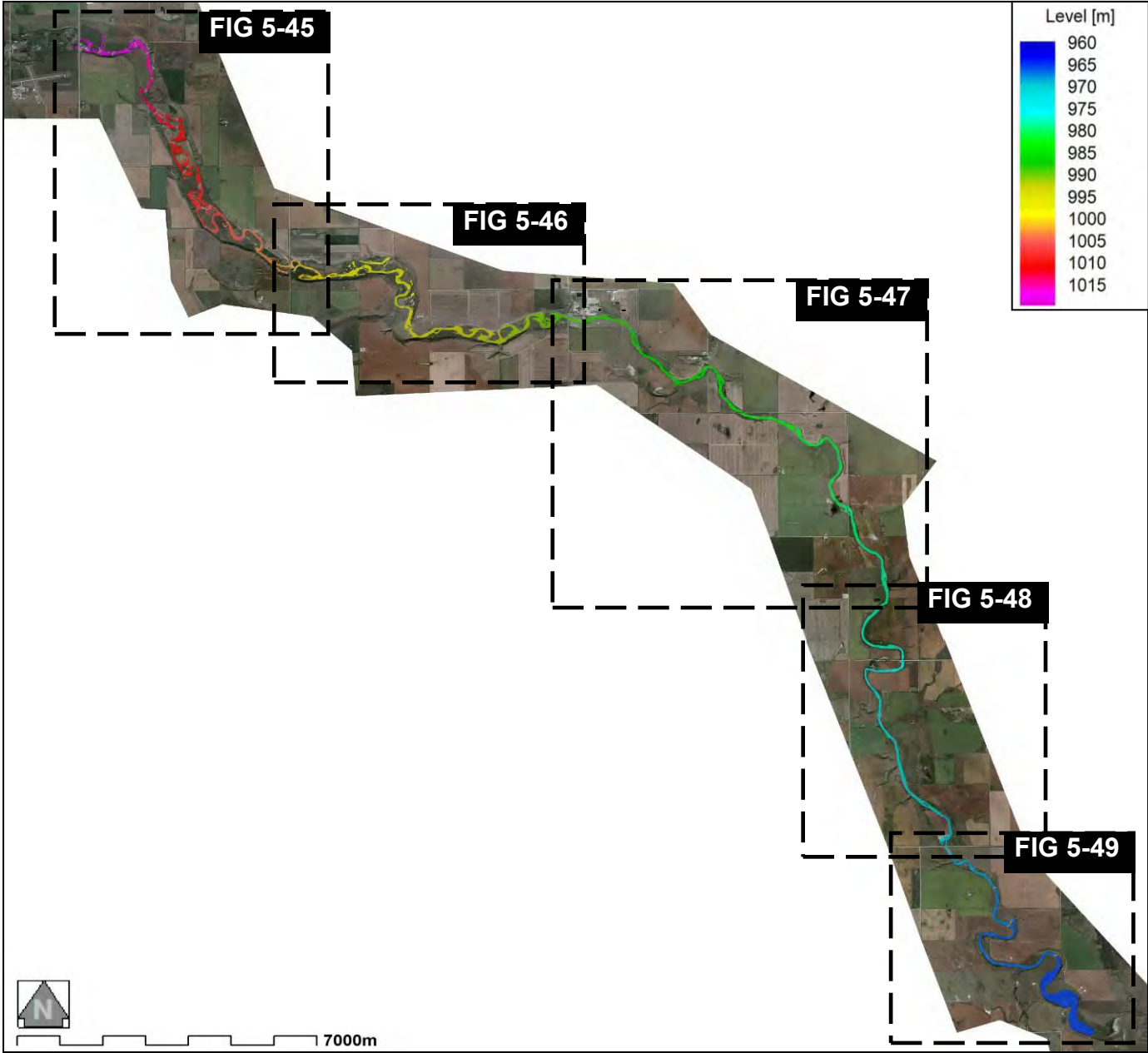
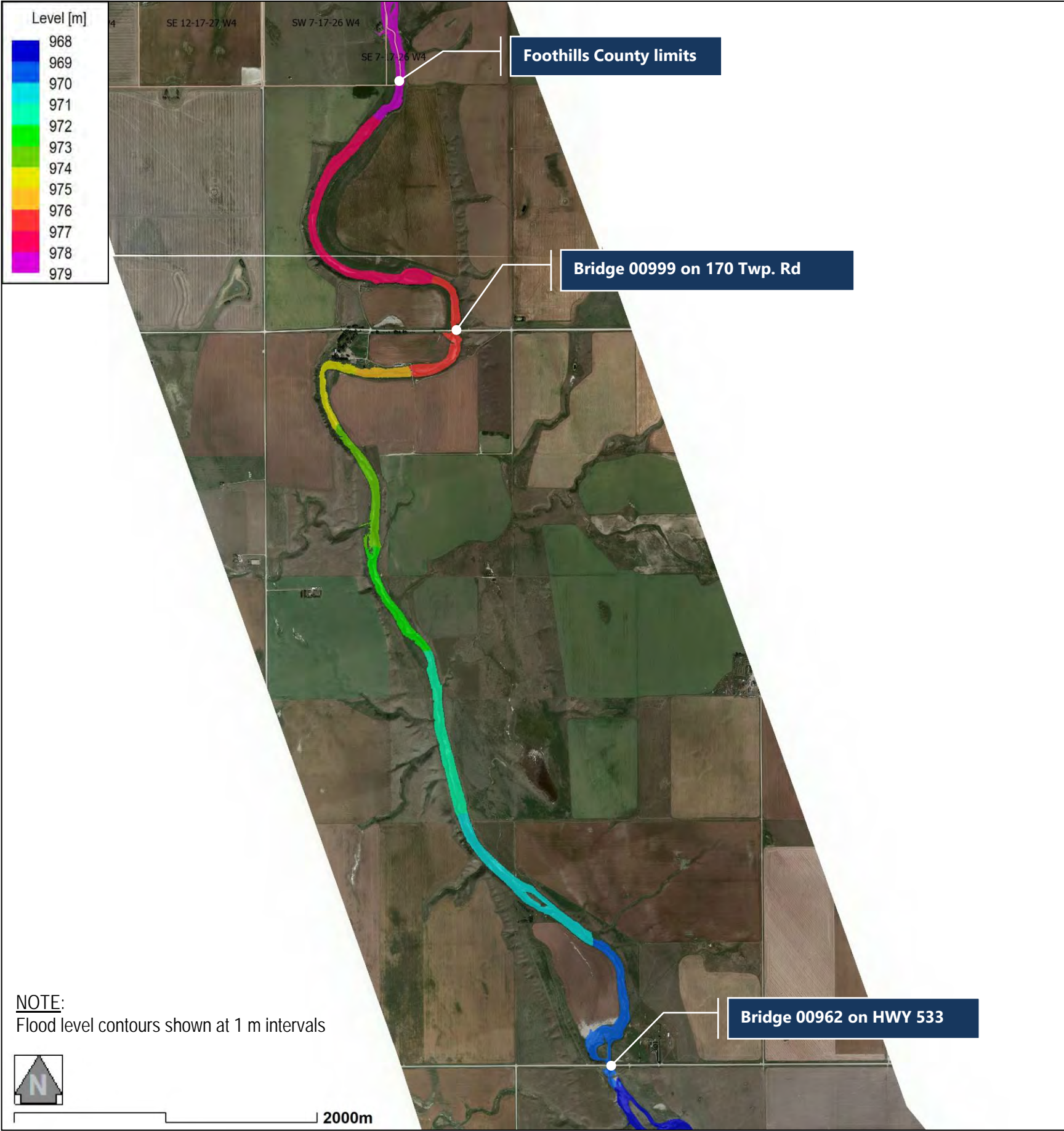




**NOTE:**  
Flood level contours shown at 1 m intervals

Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Levels for a ‘1,000 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (3 of 5)				
Date:	May 9, 2019	File Path:	U:\CAL\GBS\307011-00079\100-1\12.0_Reports\12.3_Backend	Figure No: 5-47
Created By:	AP	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons). WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.		
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**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

**Estimated Flood Levels for a '1,000 m<sup>3</sup>/s at the Highwood River' Flow under Post Mitigation Scenario  
55A (4 of 5)**

Date: May 9, 2019

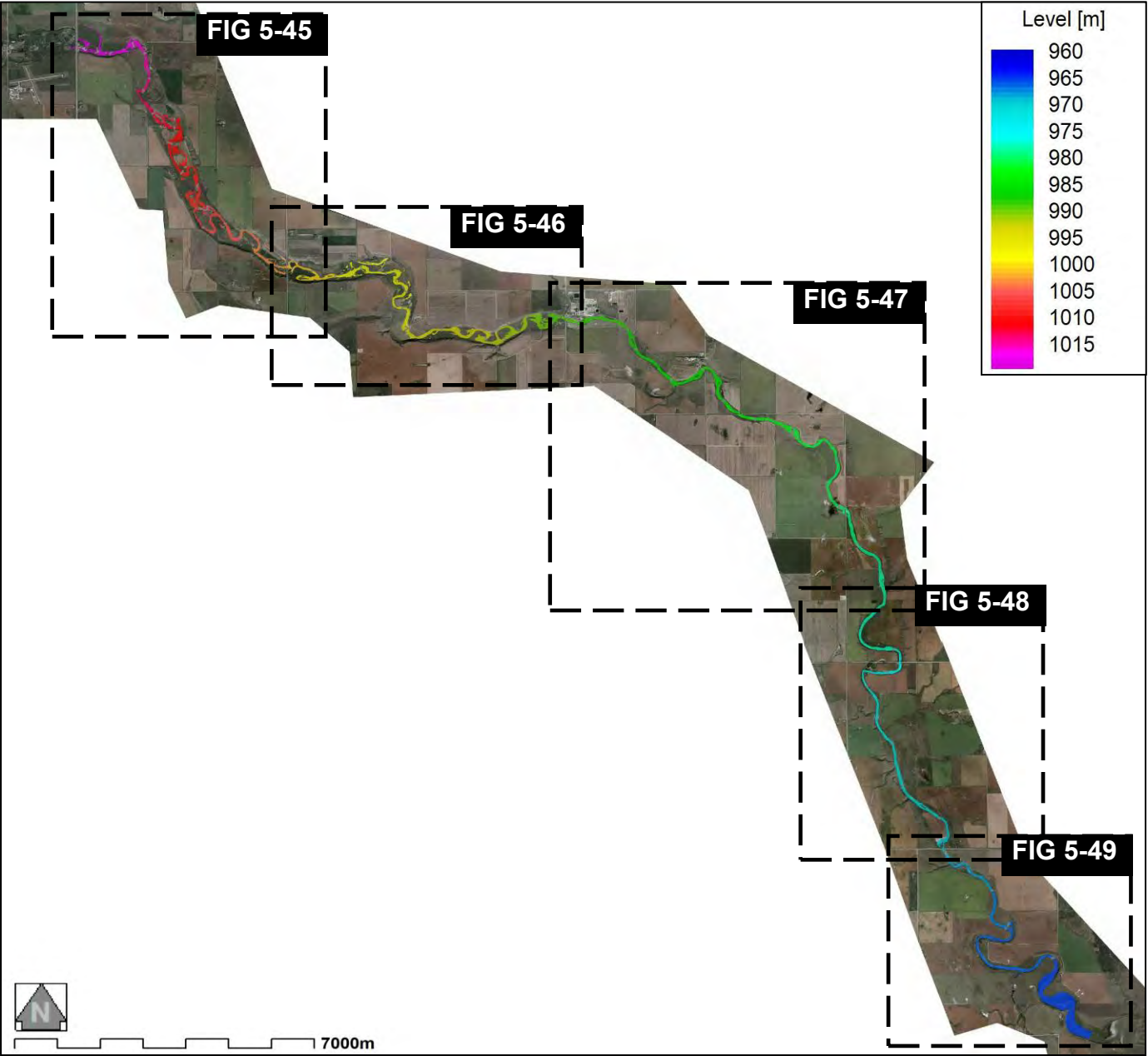
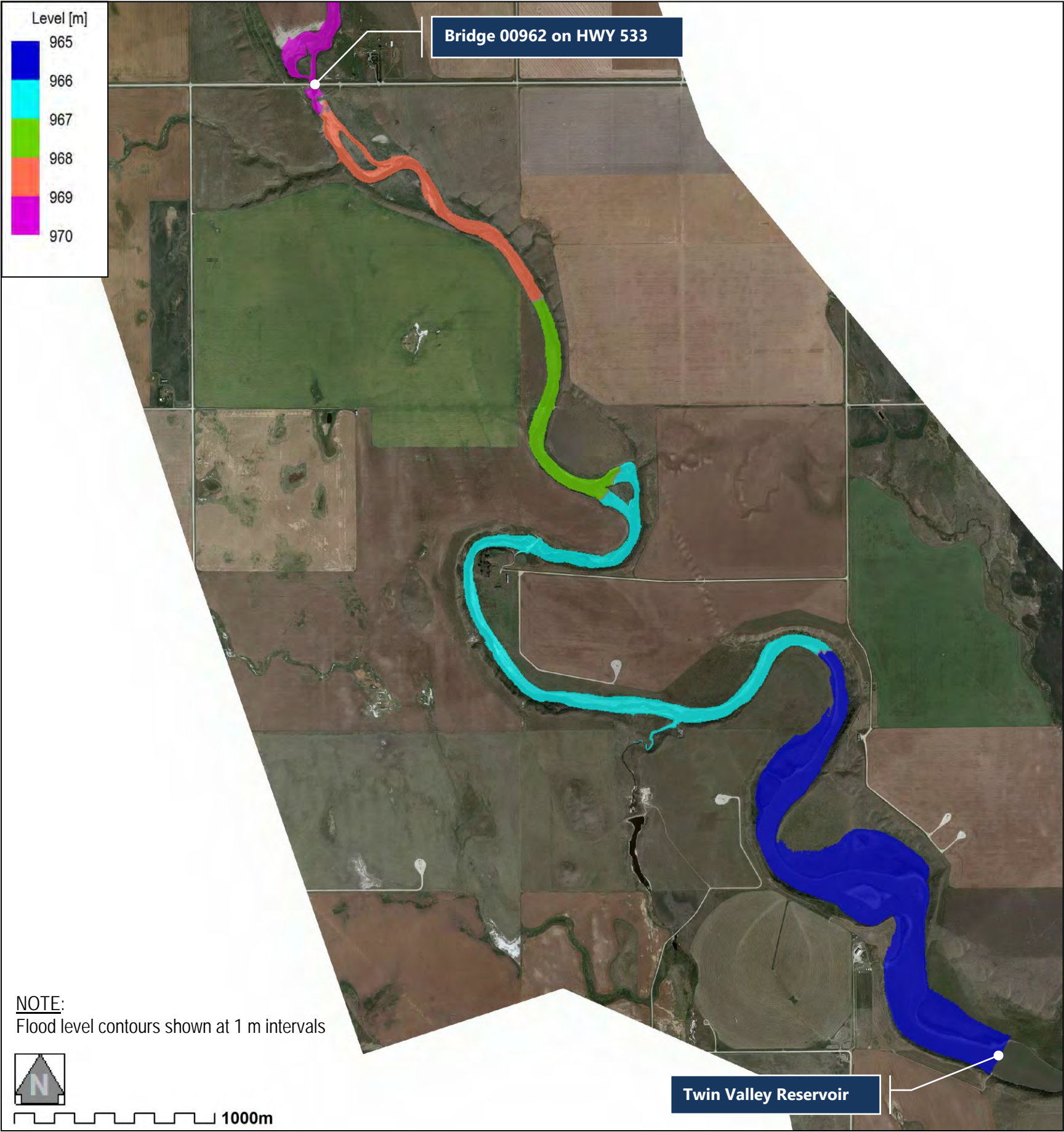
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Figure No: 5-48

Rev: D

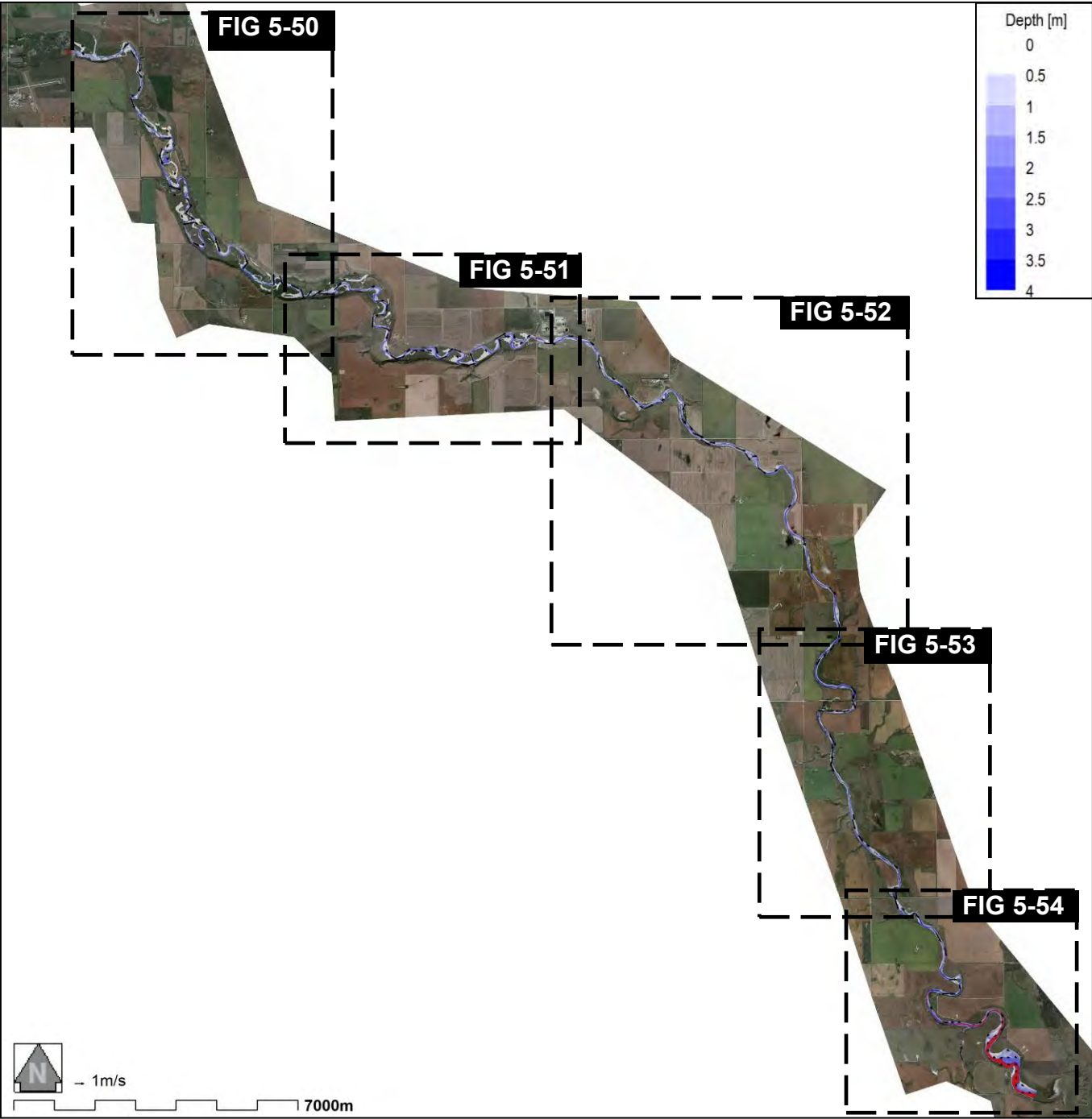
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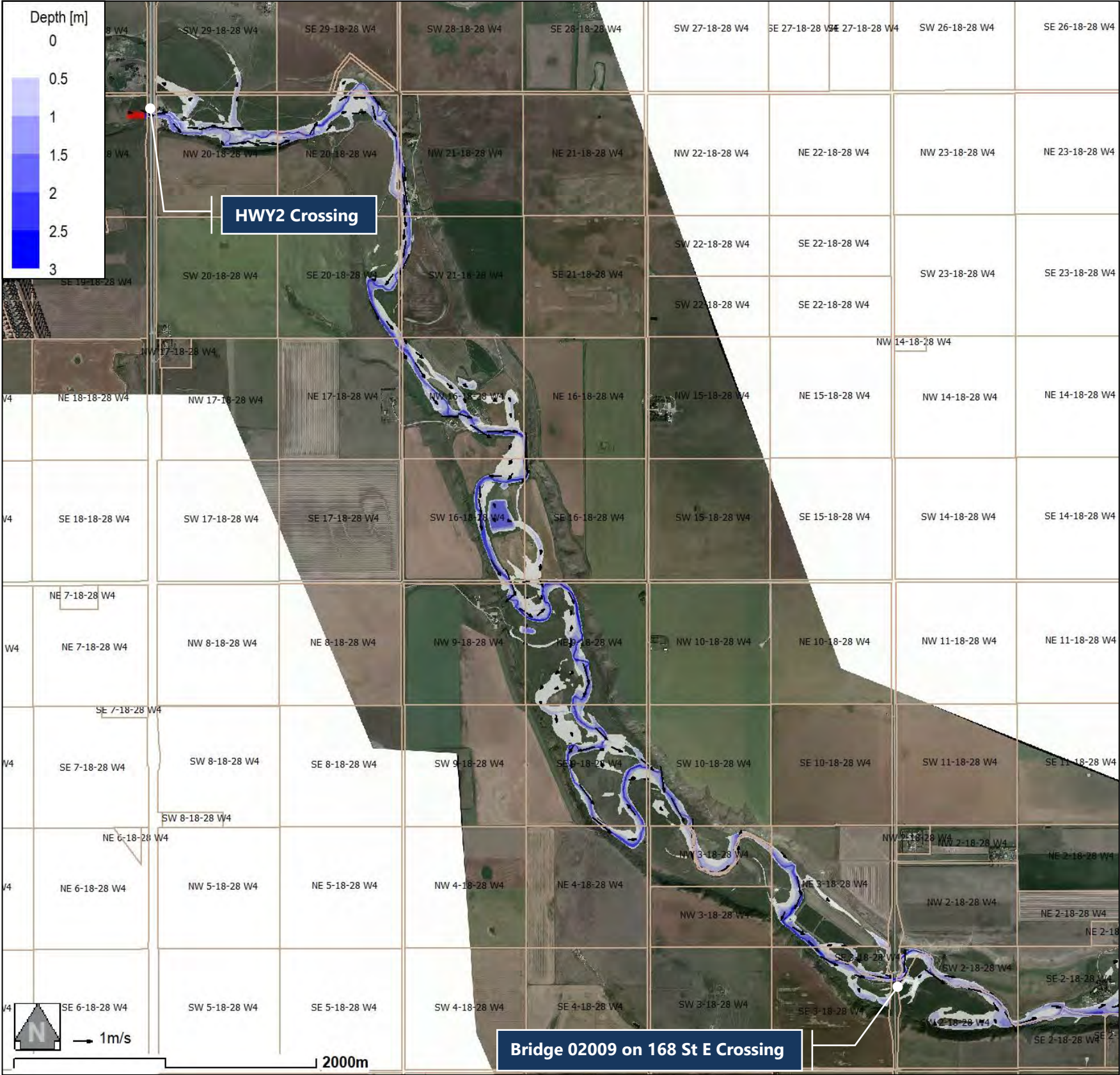


Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Levels for a '1,000 m³/s at the Highwood River' Flow under Post Mitigation Scenario 55A (5 of 5)				
Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\112.3_Backend	Figure No: 5-49	Rev: D
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NOTE:  
Red mapping indicates locations where depths are predicted to exceed the maximum range; i.e., 3 metres

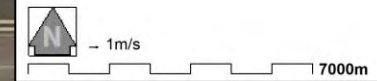


Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Depths and Velocities for a ‘1000 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (1 of 5)				
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NOTE:  
Red mapping indicates locations where depths are predicted to exceed the maximum range; i.e., 3 metres



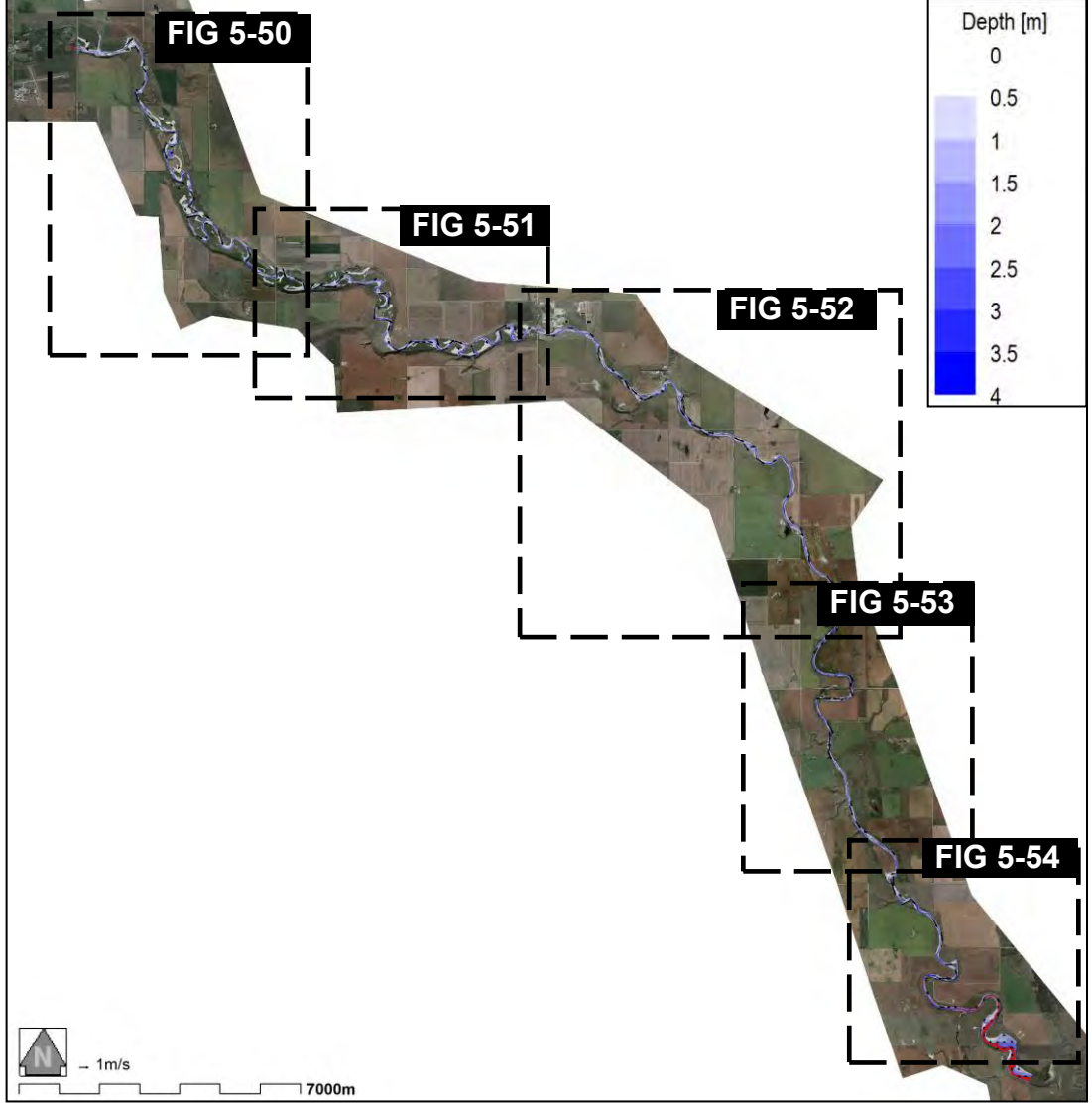
**Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling**

**Estimated Depths & Velocities for a '1000 m³/s at the Highwood River' Flow under Post Mitigation Scenario 55A (2 of 5)**

Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-51	Rev: D
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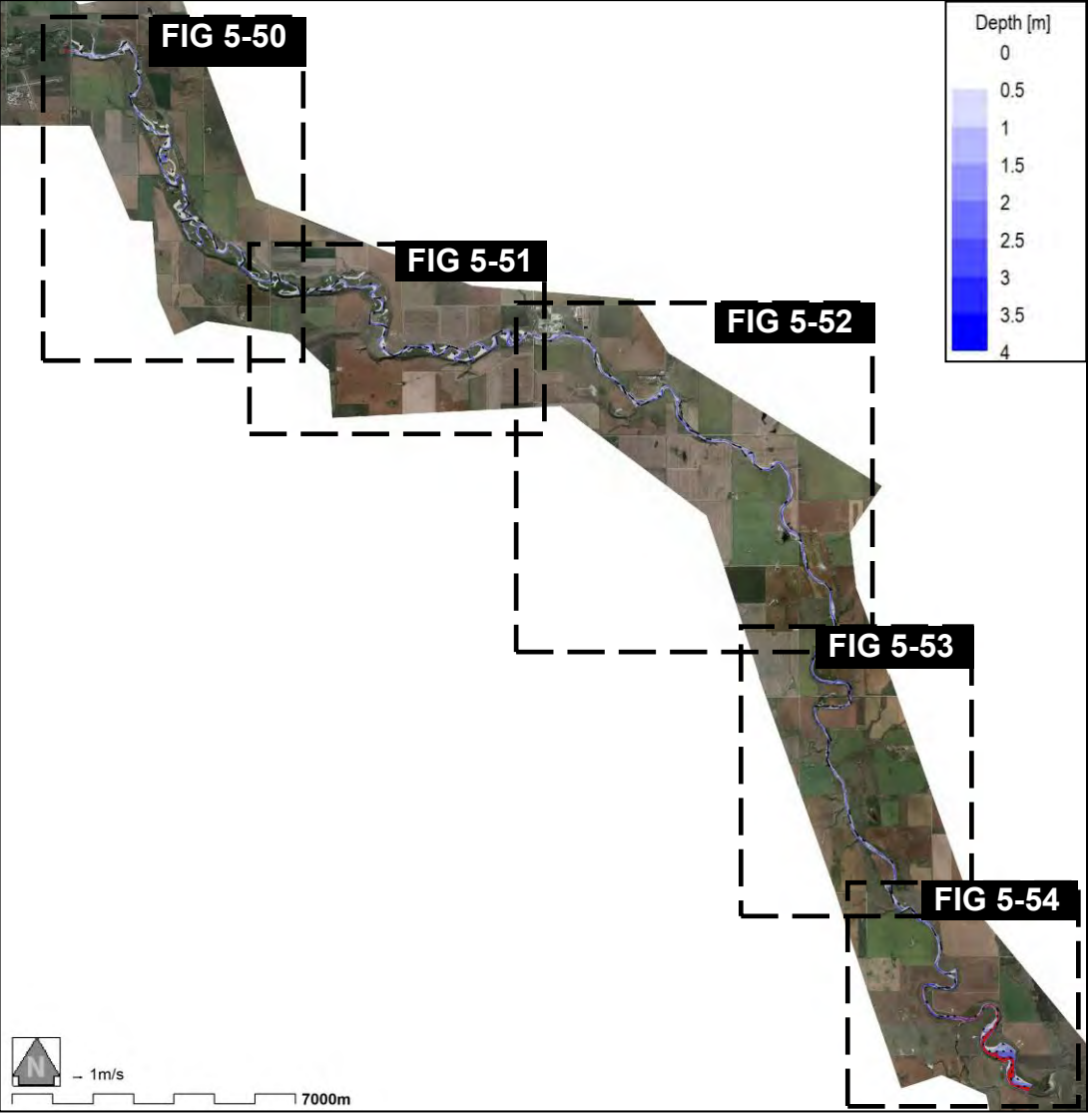
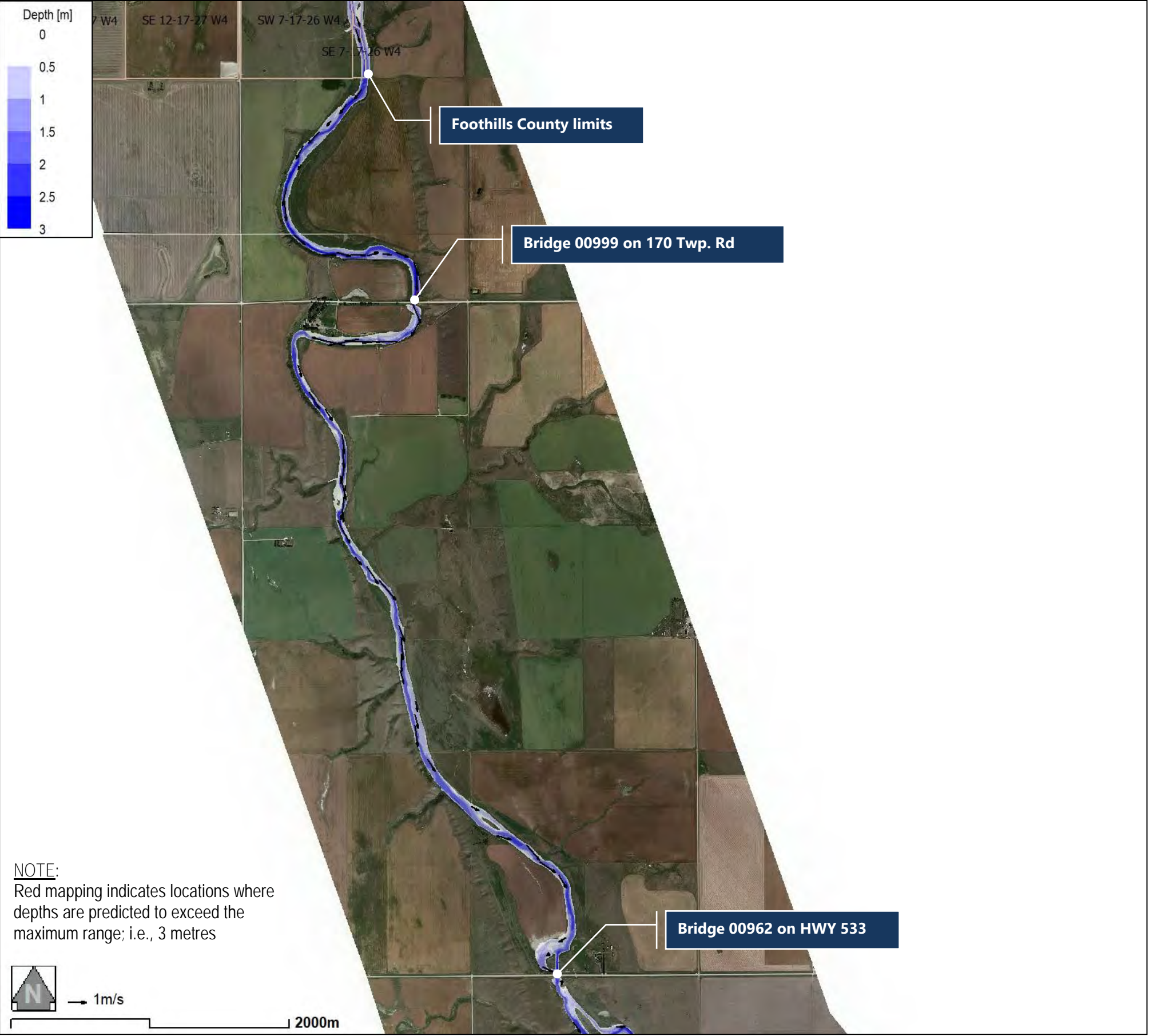




**NOTE:**  
Red mapping indicates locations where depths are predicted to exceed the maximum range; i.e., 3 metres

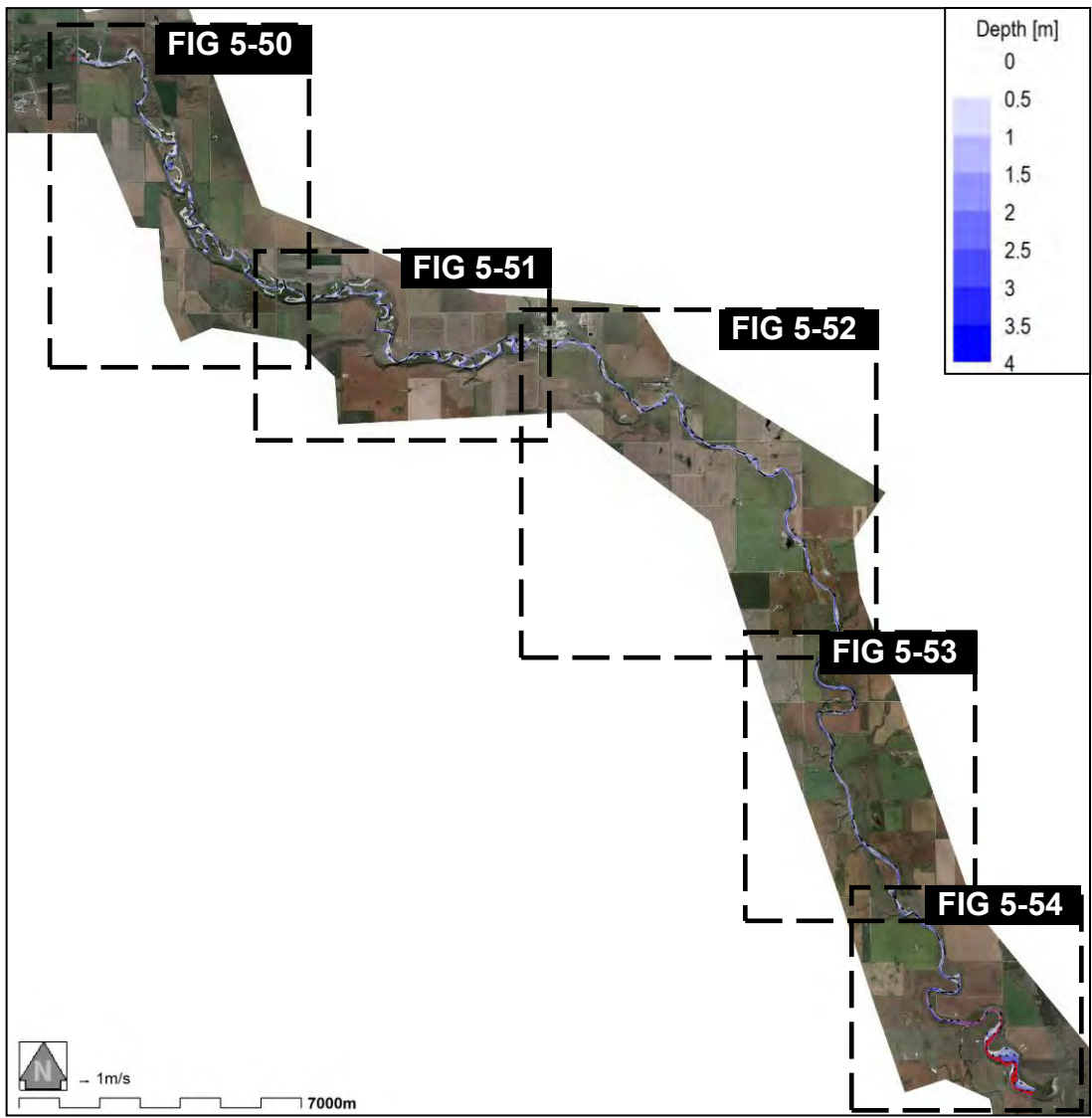
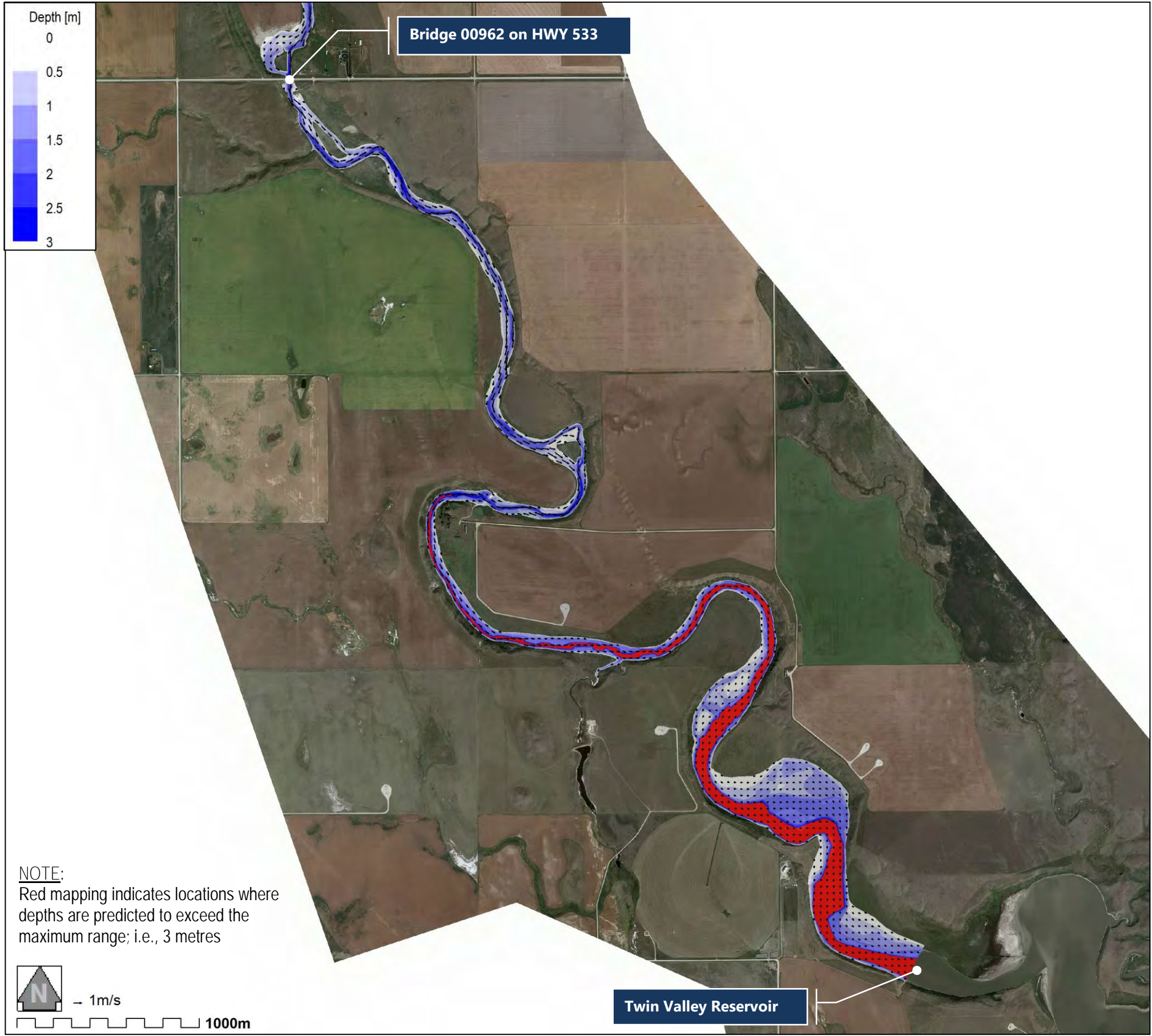
Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Depths & Velocities for a ‘1000 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (3 of 5)				
Created By: AP	Date: May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-12.0_Reports\12.3_Backend	Figure No: 5-52	Rev: D
Reviewed By: JB	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons) WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.			





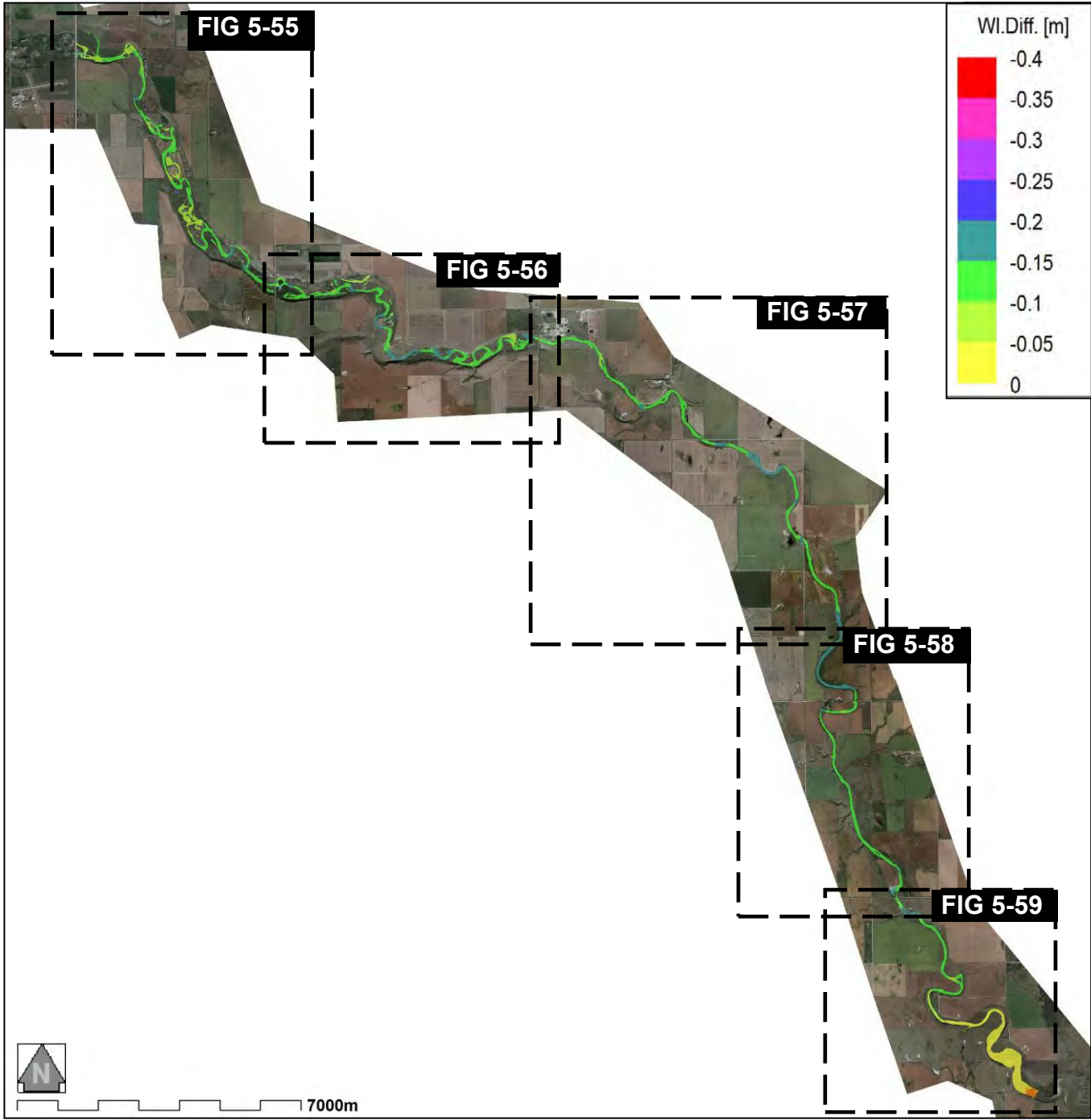
Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Depths & Velocities for a ‘1000 m³/s at the Highwood River’ Flow under Post Mitigation Scenario 55A (4 of 5)				
Date:	May 9, 2019	File Path: U:\CAL\GBS\307011-00079\100-12.0_Reports\12.3_Backend	Figure No: 5-53	Rev: D
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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Depths & Velocities for a '1000 m <sup>3</sup> /s at the Highwood River' Flow under Post Mitigation Scenario 55A (5 of 5)				
<b>Date:</b> May 9, 2019	<b>File Path:</b> U:\CAL\GBS\307011-00079\100-12.0_Reports\12.3_Backend	<b>Figure No:</b> 5-54	<b>Rev:</b> D	
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**NOTE:**  
Orange flood extents indicate locations where a reduction in flood extents has occurred due to Mitigation Scenario 55A

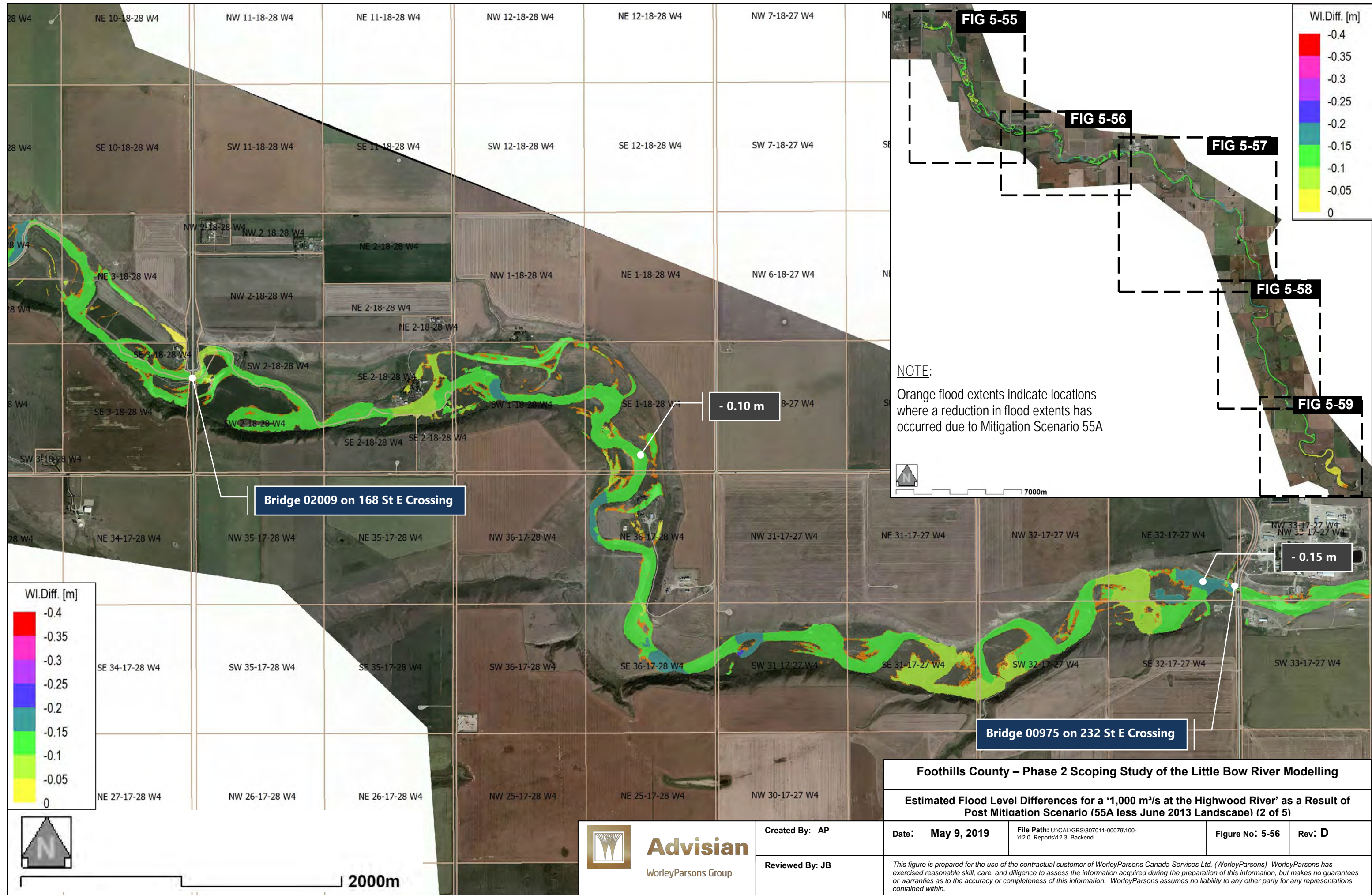


Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling			
Estimated Flood Level Differences for a ‘1,000 m³/s at the Highwood River’ as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (1 of 5)			
Date:	May 9, 2019	File Path: U:\CALIGBS\307011-00079\100-112.0_Reports\12.3_Backend	Figure No: 5-55
			Rev: D
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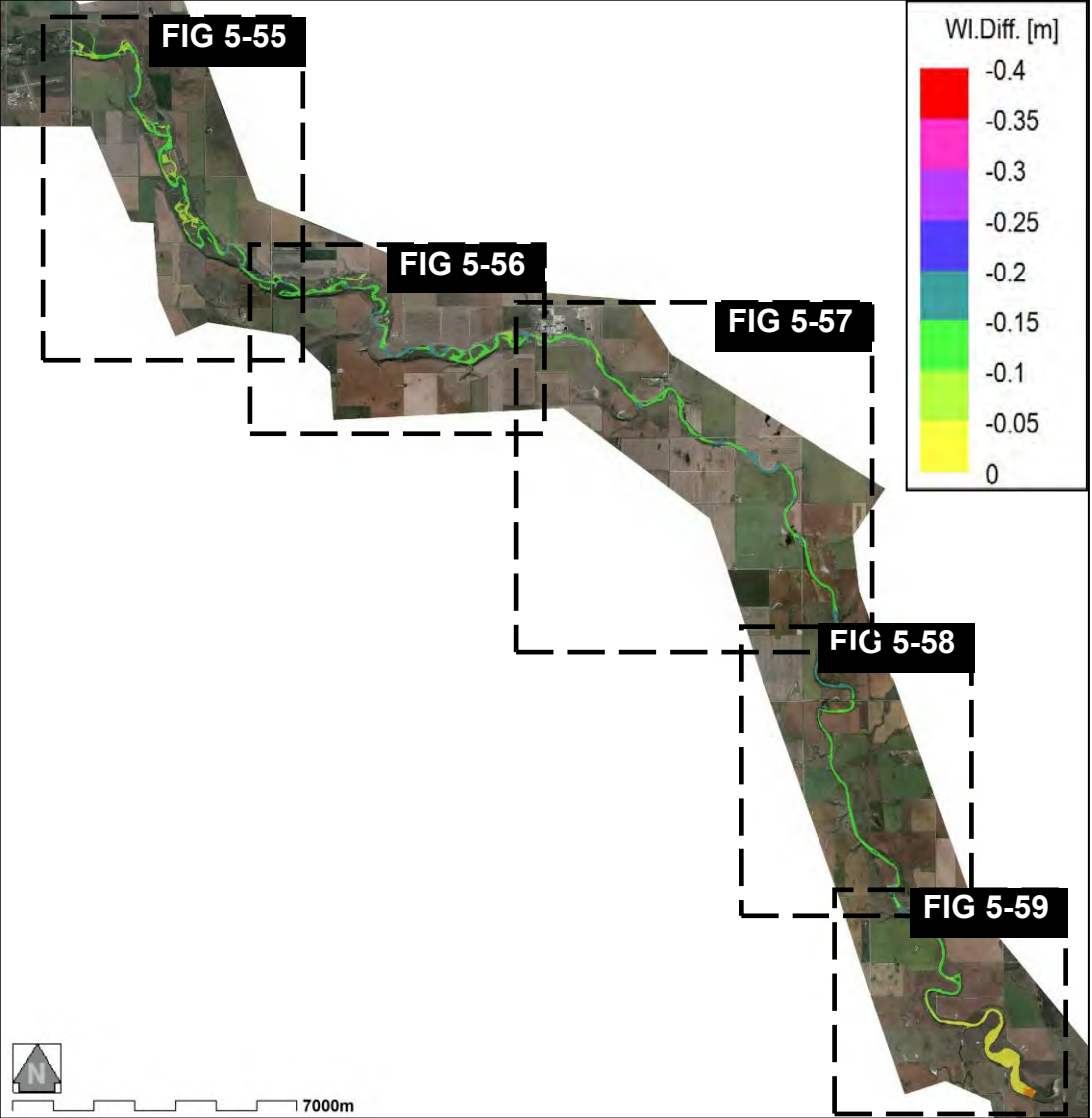


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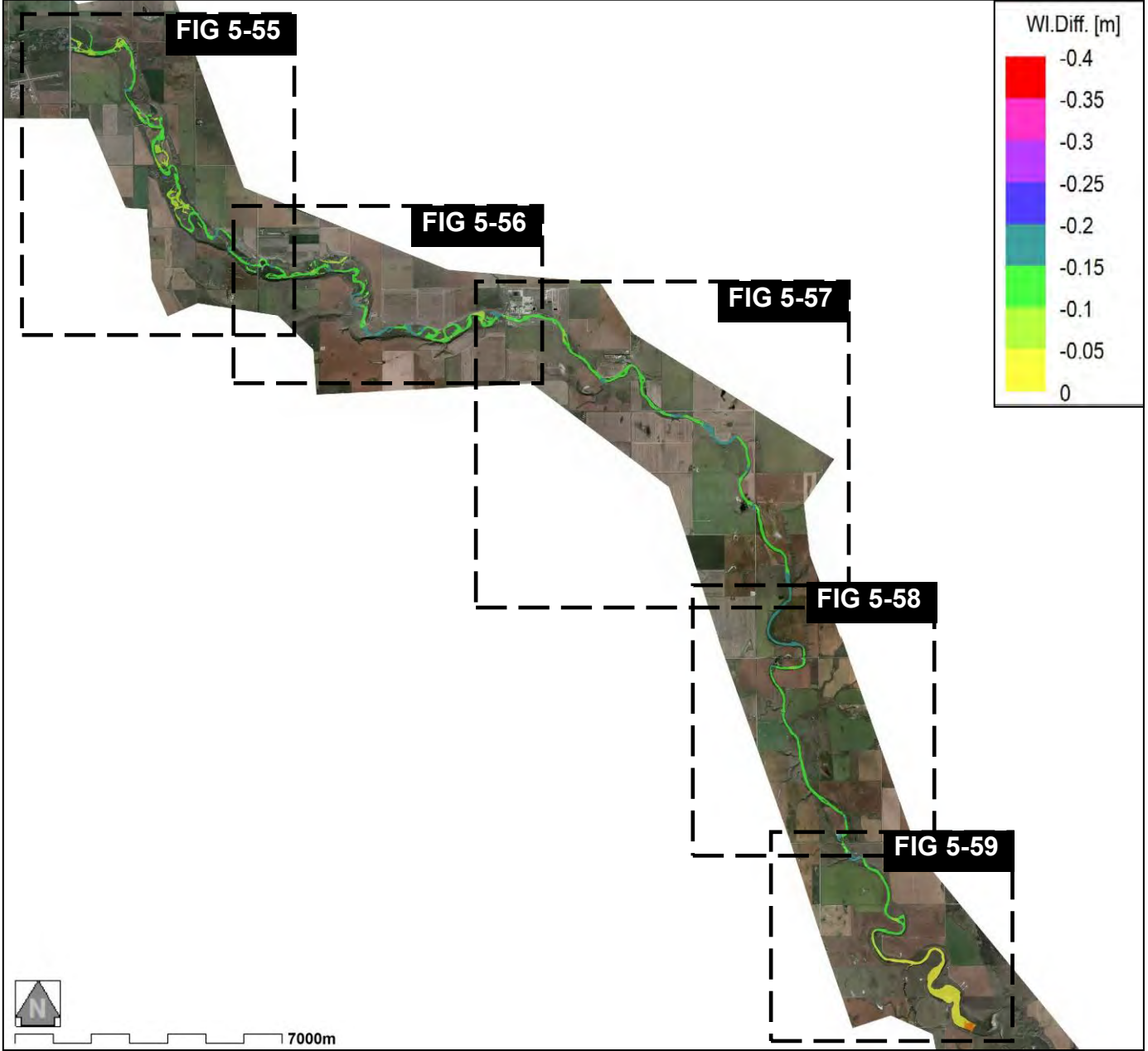
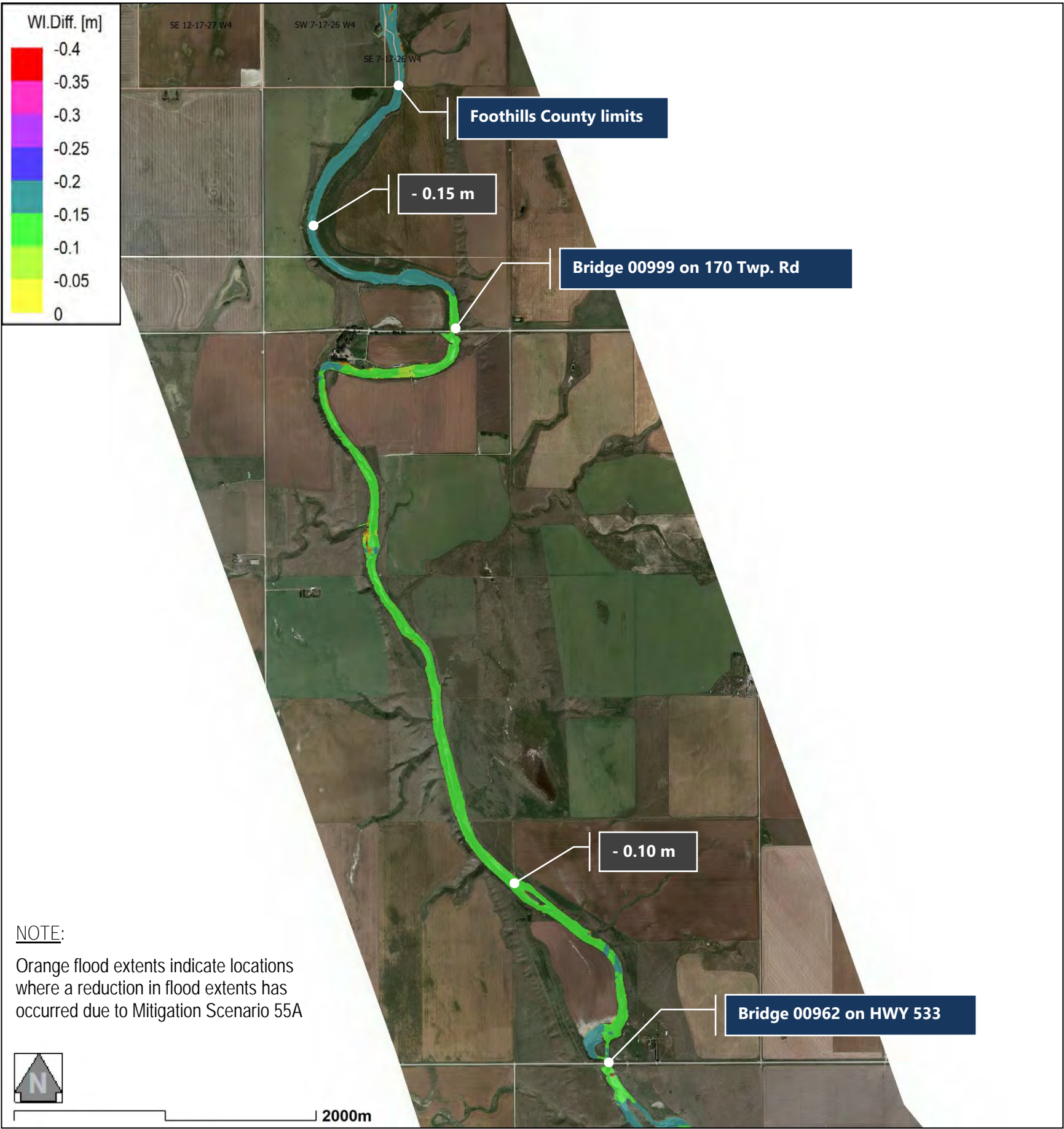




NOTE:  
Orange flood extents indicate locations where a reduction in flood extents has occurred due to Mitigation Scenario 55A

Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Level Differences for a ‘1,000 m³/s at the Highwood River’ as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (3 of 5)				
Date:	May 9, 2019	File Path:	U:\CAL\GBS\307011-00079\100-1\2.0_Reports\12.3_Backend	Figure No: 5-57
Created By:	AP	This figure is prepared for the use of the contractual customer of WorleyParsons Canada Services Ltd. (WorleyParsons). WorleyParsons has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this information, but makes no guarantees or warranties as to the accuracy or completeness of this information. WorleyParsons assumes no liability to any other party for any representations contained within.		
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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling

Estimated Flood Level Differences for a '1,000 m³/s at the Highwood River' as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (4 of 5)

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Date: May 9, 2019

File Path: U:\CAL\GBS\307011-00079\100-  
112.0\_Reports\112.3\_Backend

Figure No: 5-58

Rev: D

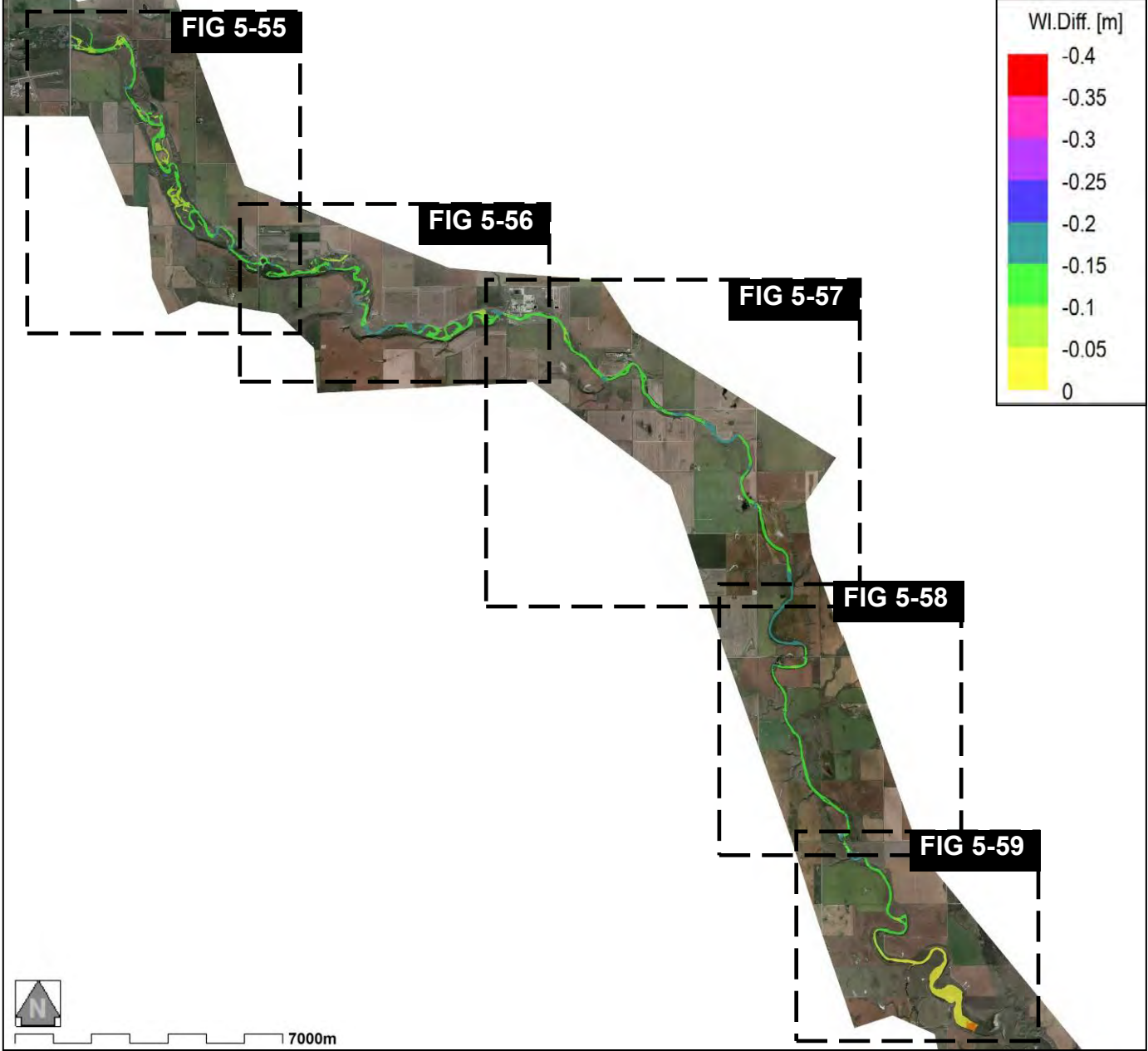
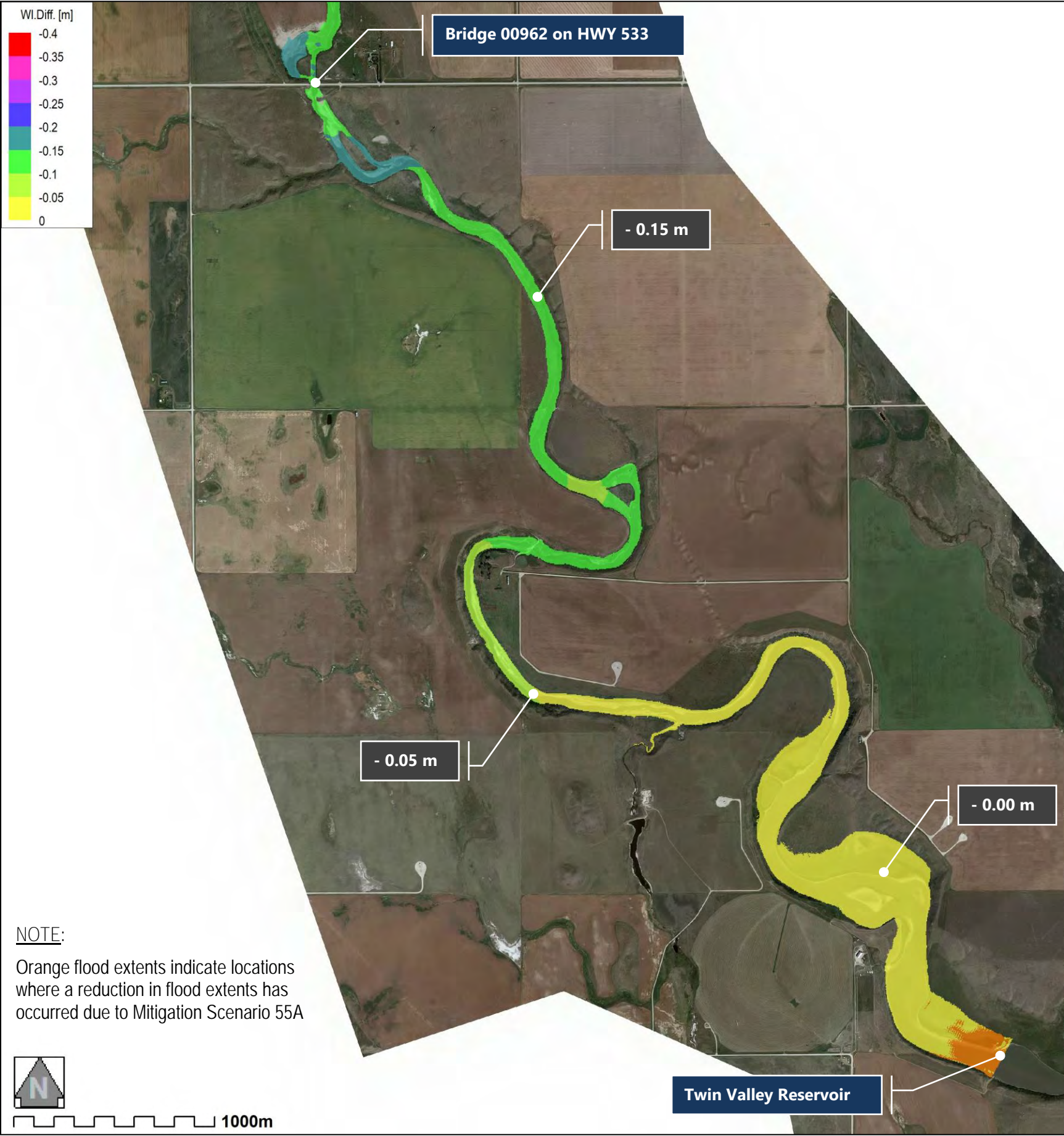
Reviewed By: JB

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Foothills County – Phase 2 Scoping Study of the Little Bow River Modelling				
Estimated Flood Level Differences for a '1,000 m³/s at the Highwood River' as a Result of Post Mitigation Scenario (55A less June 2013 Landscape) (5 of 5)				
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