Franz Josef Stopbanks

Preliminary Design Report

OCTOBER 26, 2021

Client: WCRC
Report by: Matthew Gardner
Land River Sea Consulting Ltd
www.landriversea.com

LANDRIVERSEA CONSULTING

THE WEST COAST REGIONAL COUNCIL

FRANZ JOSEF STOPBANKS

REVISION HISTORY

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1. INTRODUCTION

1.1 BACKGROUND

Land River Sea Consulting Ltd was contracted by the West Coast Regional Council [WCRC] to provide technical advice in regard to raising the stopbanks on the true right bank of the Waiau River (Waiho) adjacent to the town of Franz Josef. Land River Sea Consulting has significant experience working in the Waiau River having been actively involved in a range of technical investigations in the river since 2013 (Gardner, 2014) (Gardner, 2016) (Gardner & Brasington, 2019). Land River Sea Consulting has also engaged Dr. Dai Thomas from Tetra-Tech Coffey (Geomorphologist) as well as Gary Williams from Waterscape (FEngNZ, Water Resources Engineer / Geomorphologist) to provide advice and input into the design process.

Following this stage of the design, Dr. Thomas with input from Gary Williams, will perform rock sizing and scour calculations to check the WCRC design specifications. Following on, Dr. Thomas will develop the stopbank design that will include the alignment and stopbank elevations.

It is our understanding that ongoing high-level discussions are underway with central government in regard to the future of the town with an option of allowing the river to actively reclaim its natural fan on the true left bank of the river. Due to the significant length of time required to make any such option and the significant ongoing channel aggradation, the WCRC considers it necessary to raise the banks now. A proposal had to been put to central government to raise banks on both sides of the river. At this time, funding has only been provided to raise the bank on the true right bank. Any design needs to assume that the true left stopbanks will also be raised. In addition to raising the existing banks, it has been proposed to construct a new section of stopbank joining the existing helipad stopbank to the Havill Wall stopbank that protects the state highway and the treatment ponds. The proposed stopbank is referred to as the NZTA stopbank. This study has investigated three potential alignments for the NZTA stopbank referred to as Alignment A, B & C (Figure 1-1).

The WCRC have indicated they intend to raise the entire length of existing bank by an average of 2m to allow for ongoing aggradation in the river. In addition, the WCRC are proposing to install a rock lined bund to prevent overflows into the Tatare River.

A 3-D visualisation of the area if interest highlighting the different sections of stopbank is presented in Figure 1-1 below.

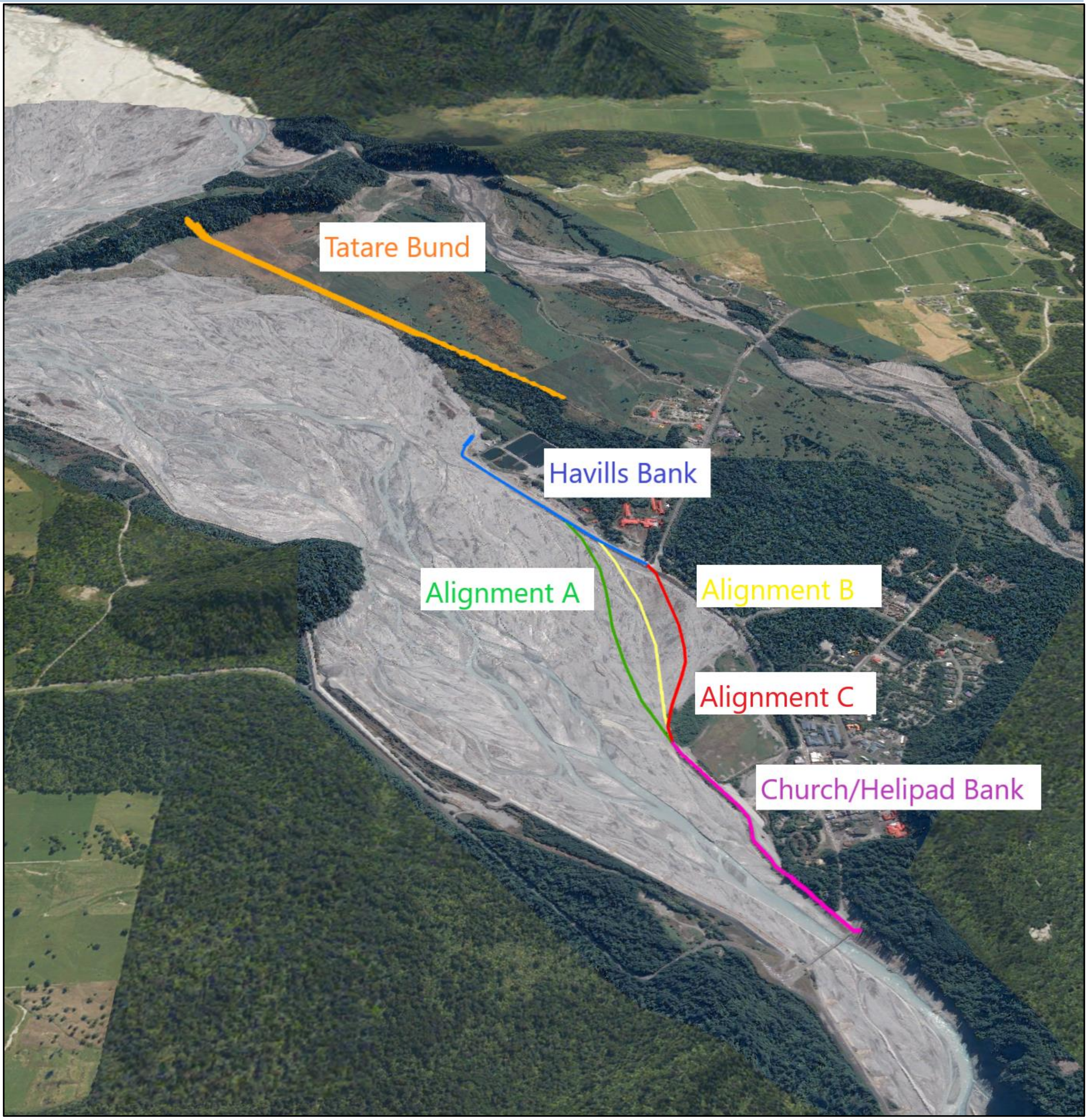


Figure 1-1 – Stopbanks to be raised / constructed

1.2 SCOPE OF PROJECT

Our scope for this project is;

- Review available reports, aerial photography, and time-sequential cross-section surveys of the channel.
- Assess the potential aggradation rates in the Waiho River from the glacier to the Waiho Loop over a 20-year time period.
- Select a design discharge.
- Build a 2D hydraulic model of the river based on the 2019 LiDAR (Brasington, 2019) and the 2021 satellite DEM (Sirguey, 2021). Run the model at the design discharge and use the model output to:
    - Evaluate the 3 proposed alignments and select a design alignment
    - Evaluate the impacts of the aggradation on design levels
- The model output will be used in the following phase of the study to:
    - Perform scour and rock sizing calculations.
    - Develop the design profile for the crest level of the stop banks.

1.3 SITE VISIT

Matthew Gardner has visited the site on numerous occasions over the years, however a project specific site visit was carried out by Matthew Gardner (Land River Sea Consulting) and Dai Thomas (Tetra-Tech Coffey) on the 21st of June 2021. The purpose of the visit was to observe the existing assets on the ground as well as to better visualise the current bed profiles and river set up, to assist in our understanding of river processes.

Crest level survey of the stopbanks was carried out by Matthew Gardner using an RTK GPS system to confirm the existing crest profiles.

Depth and width of historic braids were measured and the bed material was measured using the pebble-count method (Wolman, 1954) to characterise the size of the material. A selection of photos taken during the site visit are presented on the following page.

	
Figure 1-2 – View downstream of the existing rock on the Havill Wall Bank.	Figure 1-3 – Rock lining on the Church bank
	
Figure 1-4 –Scour from a recent braid adjacent to the bank	Figure 1-5 – Old bank adjacent to new Havill Wall Bank

2. DATA USED IN THIS STUDY

The main basis of information for this study has been LiDAR data collected in 2016 (NZ Aerial Surveys), 2019 (Brasington, 2019) as well as satellite Digital Elevation Model (DEM) developed by Pascal Sirguey in 2021 using advanced photogrammetry techniques from Pleides Satellite Imagery (Sirguey, 2021). In addition to this, existing stopbank crest levels were surveyed by Matthew Gardner from Land River Sea Consulting on the 21st of June 2021.

In addition to the DEM data, cross sections 13 to 22 were re-surveyed by Coastwide Surveys Ltd in May 2021 (Figure 2-1) The survey data covered the full width of the active channel of the river, but did not include the below water portion due to health and safety reasons, although a few below water points were collected near the edge of the water. As a result, the Mean Bed Levels (MBL) collected in 2021 will slightly overestimate the MBL, in particular in the confined reach between from State Highway bridge and the end of the Helipad Bank.

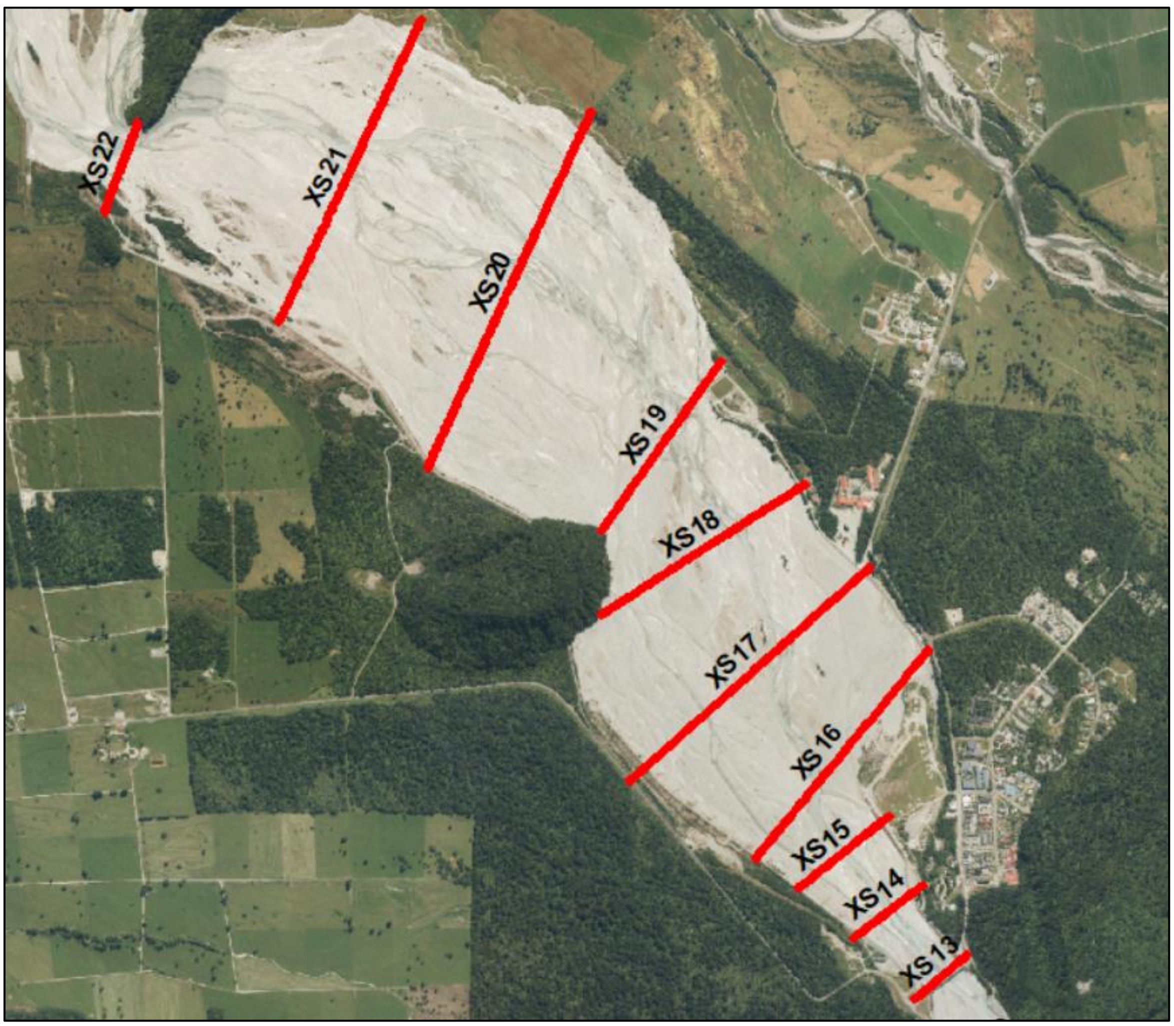


Figure 2-1 – Location of surveyed cross sections surveyed by Coastwide Surveys Ltd in May 2021

Plots of the cross sections compared with cross sections extracted from the 2019 LiDAR is presented in Appendix A.

2.1 ASSESSMENT OF 2021 SATELLITE DEM

On 19 March 2021, Professor Pascal Sirguey from the University of Otago arranged for the Pléiades-1B satellite to acquire a triplet of cloud-free imagery of Franz Josef Glacier and surroundings (ie three overlapping satellite images captured at different angles). The triplet was tied to an existing triangulated photogrammetric image block spanning across the Main Divide to benefit from an existing and extensive network of sub-metre accurate Ground Control Points (GCP). (Sirguey, 2021)

The final output was a 0.5m pixel resolution orthorectified cloud free image of the river valley, as well as a 2m resolution digital surface model (DSM) with a reported residual of 0.47m CE90 (circular error of 90 %) and 0.58m LE90 (linear error of 90 %). These errors are reported based on a comparison with the GCP network, which likely contain points within steep mountain valleys, and therefore increasing the uncertainty. A comparison of the bed levels from the DSM with the cross-section survey data collected between the 13 to 22 of May 2021 show an excellent agreement (Appendix B), with the main differences occurring at the wetted area of the river. Because the survey data was collected approximately 2 months apart, some of the differences in bed levels is due to the aggradation/degradation that occurred between the surveys. A comparison between the datasets at cross section 17 is presented in Figure 2-2.

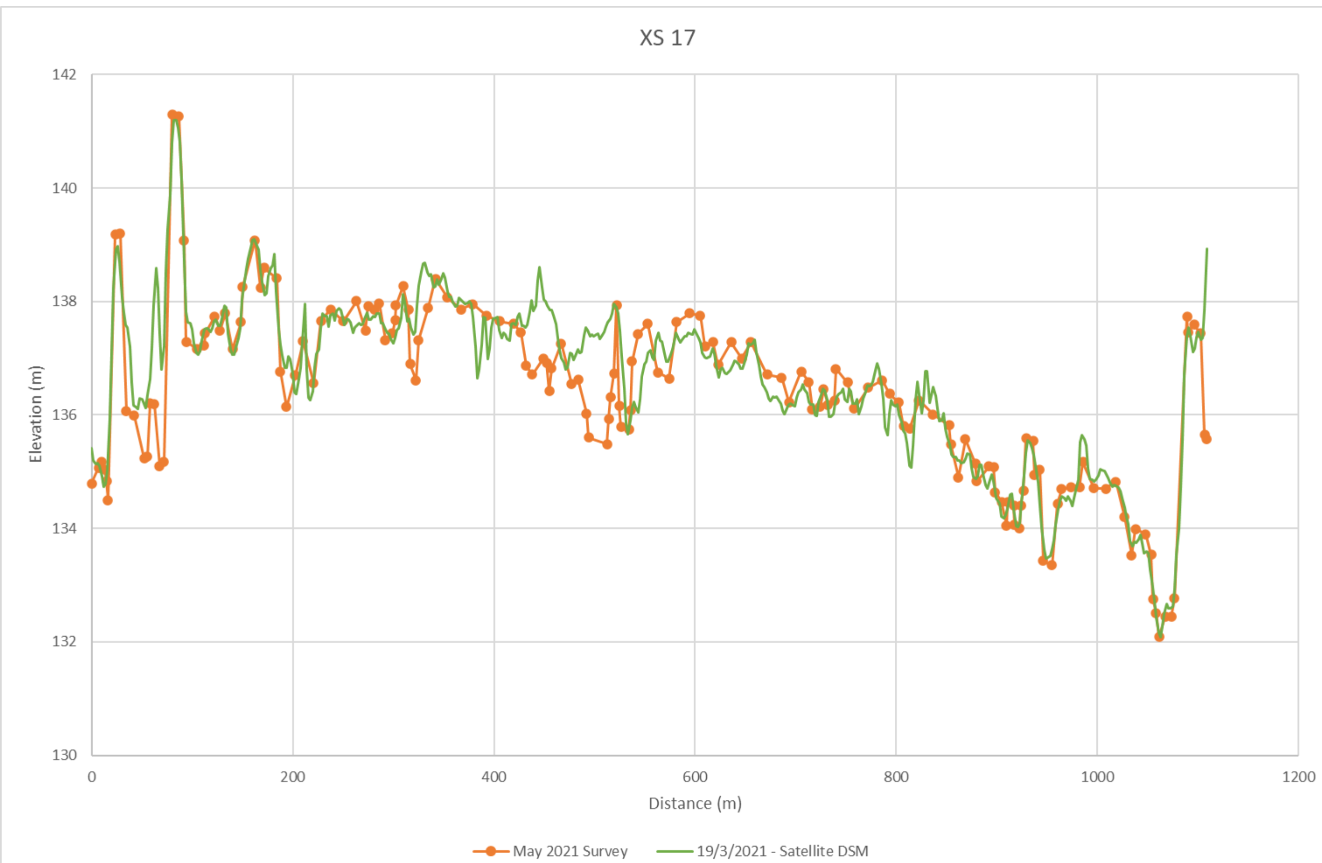


Figure 2-2 – Comparison of May 2021 survey data with the 19 March 2021 Satellite DSM

Overall we conclude that there is an excellent match between the satellite data and actual ground survey.

We conclude that the satellite data is fit for the purposes of representing the active channel in a hydraulic model and can be relied upon for the purposes of sizing stopbanks. Whilst there is greater uncertainty in the ground levels with this data, it must be kept in mind that the Waiau river is very active with constantly changing bed levels. We consider this surface to be more suitable than using the 2019 LIDAR DEM data as it gives a very realistic spatial representation of the overall bed levels / slopes etc and will be more reliable than simply adjusting the 2019 LiDAR using average trends from the latest cross section survey data.

This satellite data can be acquired on a regular basis fairly easily and at a significantly lower cost than a more detailed LiDAR survey. We believe that serious consideration should be given to carrying acquiring regular repeat surveys using these techniques as this would allow ongoing monitoring of the aggradation rates over the entire river area. This would be useful to detect any rapid or unexpected aggradation along the length of the stopbanks which would compromise the safety of the scheme.

3. ASSESSMENT OF POTENTIAL AGGRADATION

The Waiau River valley is set in a highly active geologic area and receives large volumes of sediment from the surrounding catchment which is resulting in ongoing aggradation in the river valley. Cross-section surveys from 1983 to present at the State Highway Bridge show an average rate of aggradation of about 0.18 m/ year. Aggradation trends down the length of the river have been assessed previously and are updated in this report based on the most recently available cross section survey data (May 2021) as well as a comparison of the LiDAR and Satellite DEM data from 2016, 2019 and 2021.

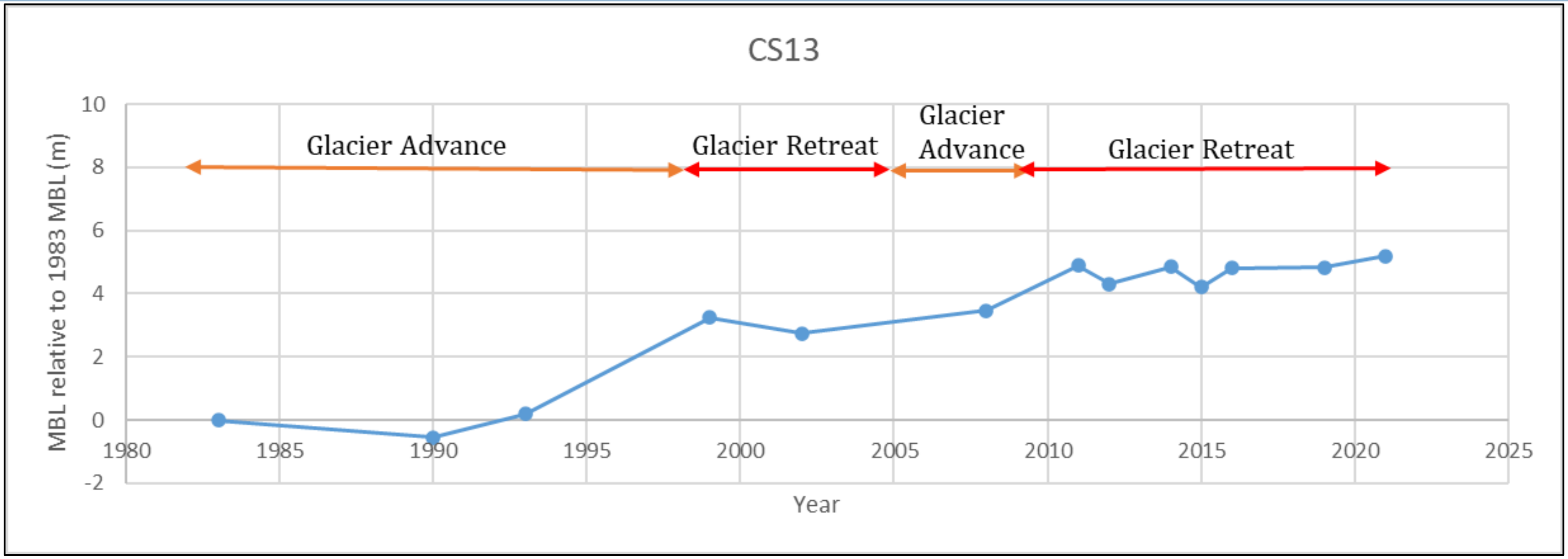
3.1 CROSS SECTION DATA

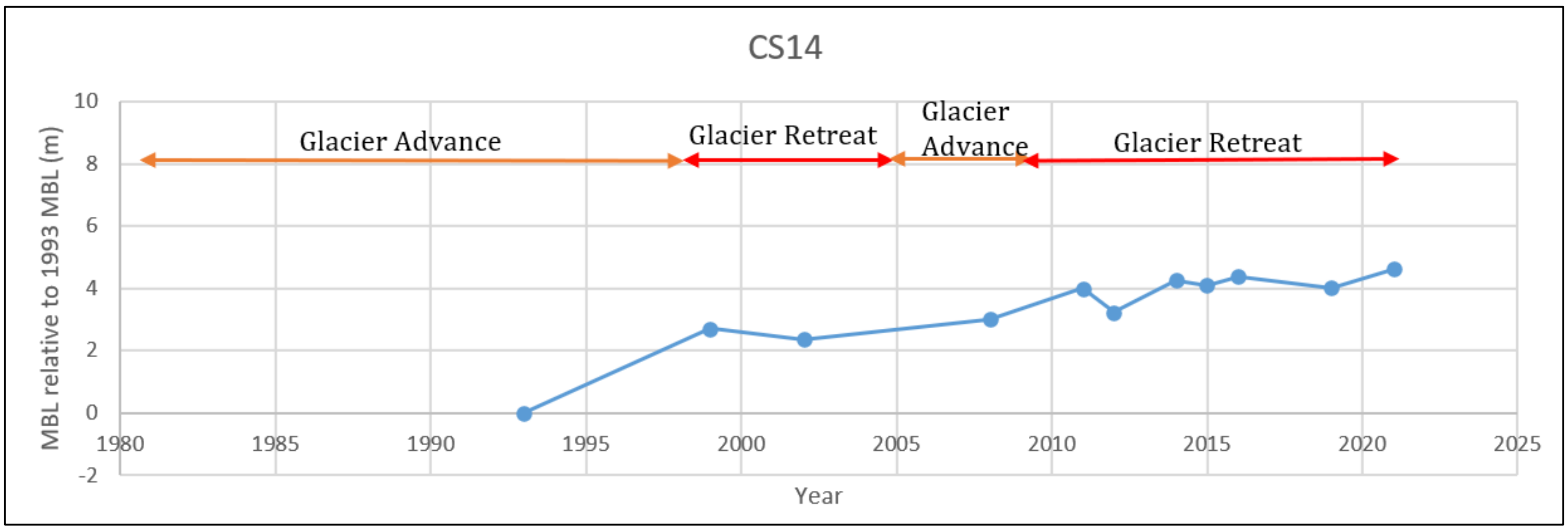
A mean bed level (MBL) assessment from XS13 to XS22 was performed to update the MBL trends presented in the recent 2019 report. It should be highlighted that the 2021 cross section survey did not include a full survey of the wetted channel and the MBL numbers in particular at XS13 to XS15 are likely indicating slightly higher levels of aggradation than has actually occurred when comparing with the historic data.

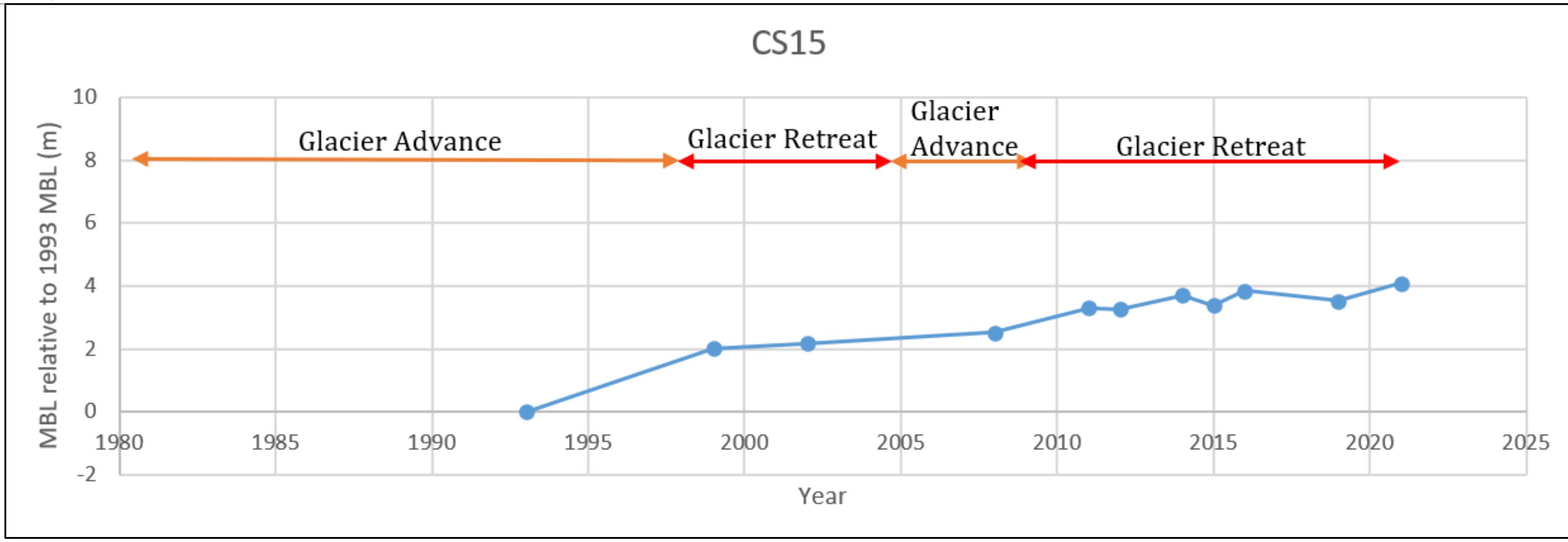
The calculated MBL values for each cross section from XS13 to XS21 is presented in Table 3-1 and plots of the mean bed level trends are presented on the following pages.

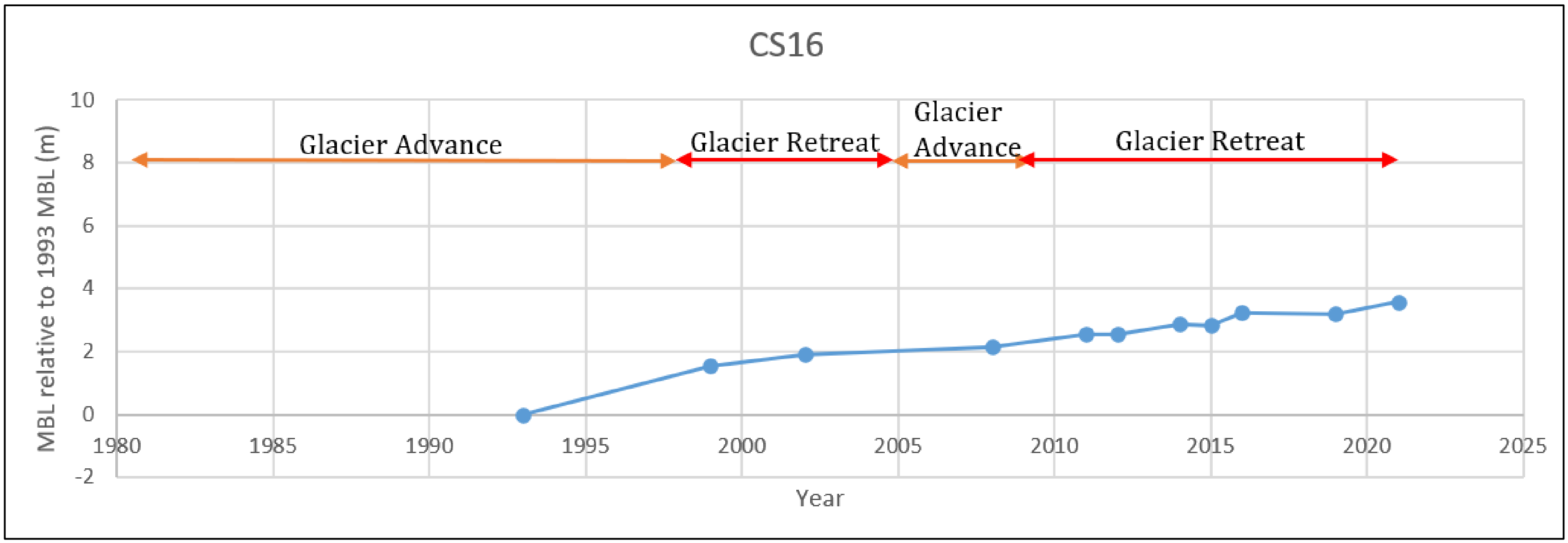
Table 3-1 – MBL Calculation (1983 to 2021)

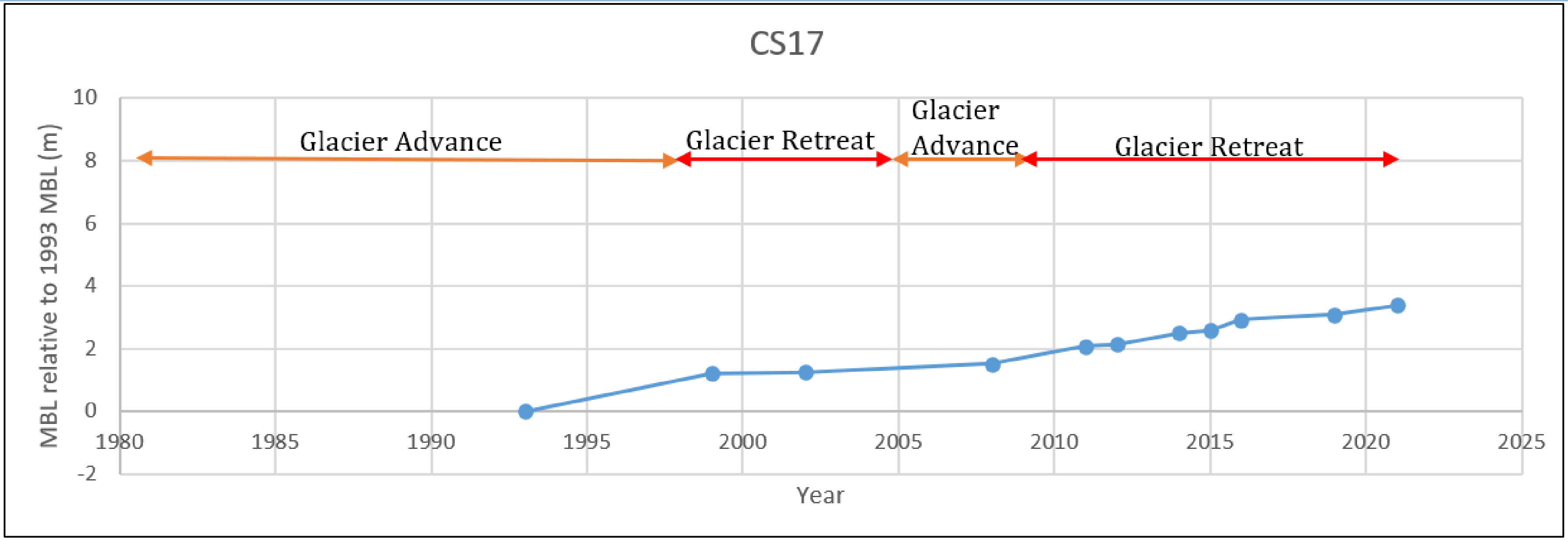
	1983	1990	1993	1999	2002	2008	2011	2012	2014	2015	2016	2019	2021
CS13	145.7	145.1	145.9	148.9	148.4	149.1	150.6	150	150.5	149.9	150.5	150.5	150.87
CS14			143.6	146.3	145.9	146.6	147.6	146.8	147.8	147.7	148	147.6	148.20
CS15			141.2	143.2	143.4	143.7	144.5	144.5	144.9	144.6	145.1	144.7	145.31
CS16			137.7	139.2	139.6	139.8	140.2	140.2	140.5	140.5	140.9	140.9	141.26
CS17			133.1	134.3	134.4	134.6	135.2	135.2	135.6	135.7	136	136.2	136.48
CS18			127.8	128.7	128.9	129.2	129.7	129.7	129.8	129.8	130.1	130.7	130.90
CS19	123.6		124	124.3	124.6	124.8	125.2	125.3	125.2	125.3	125.6	126.5	126.49
CS20	116.9		117.1	117.4	117.4	117.9	118.3	118.4	118.5	118.8	118.7	119.1	117.67
CS21	109.1		109.1	109.2	109.2	109.4	109.5	109.6	109.6	109.7	109.7	109.9	109.88
CS22	101.4		100.9	101	101	101	101	100.8	100.9	101	100.9	101.7	101.86

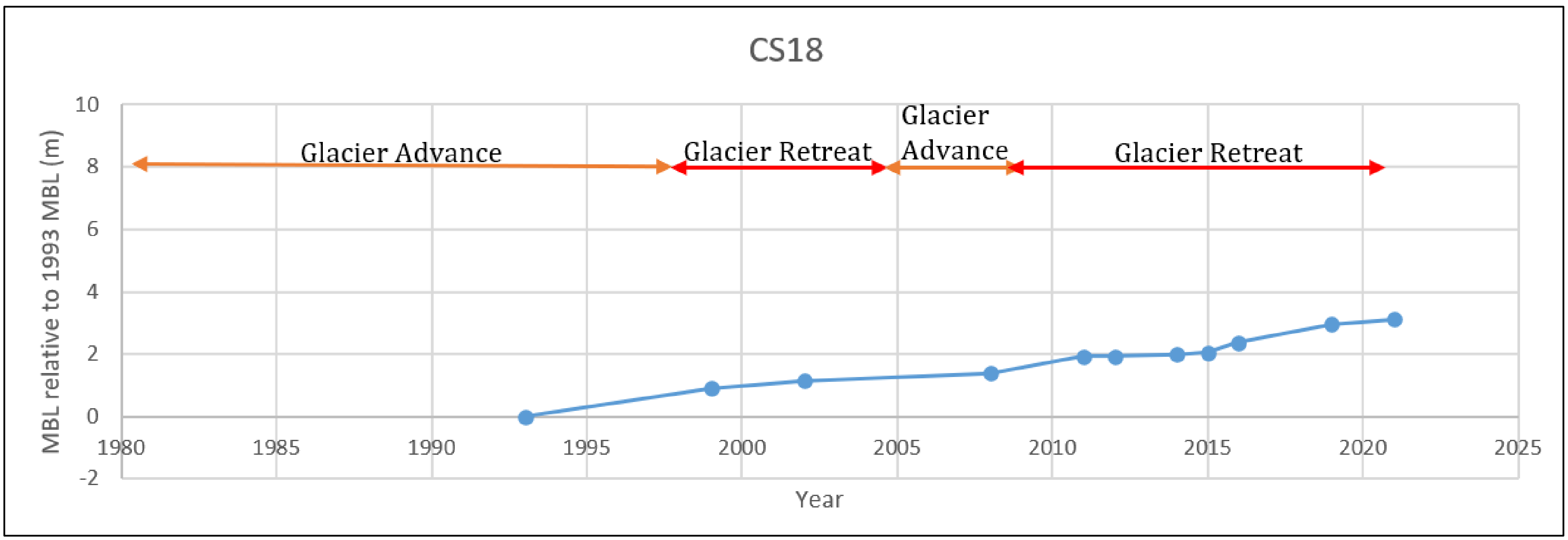

CS13
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat
MBL relative to 1983 MBL (m)
10
8
6
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year

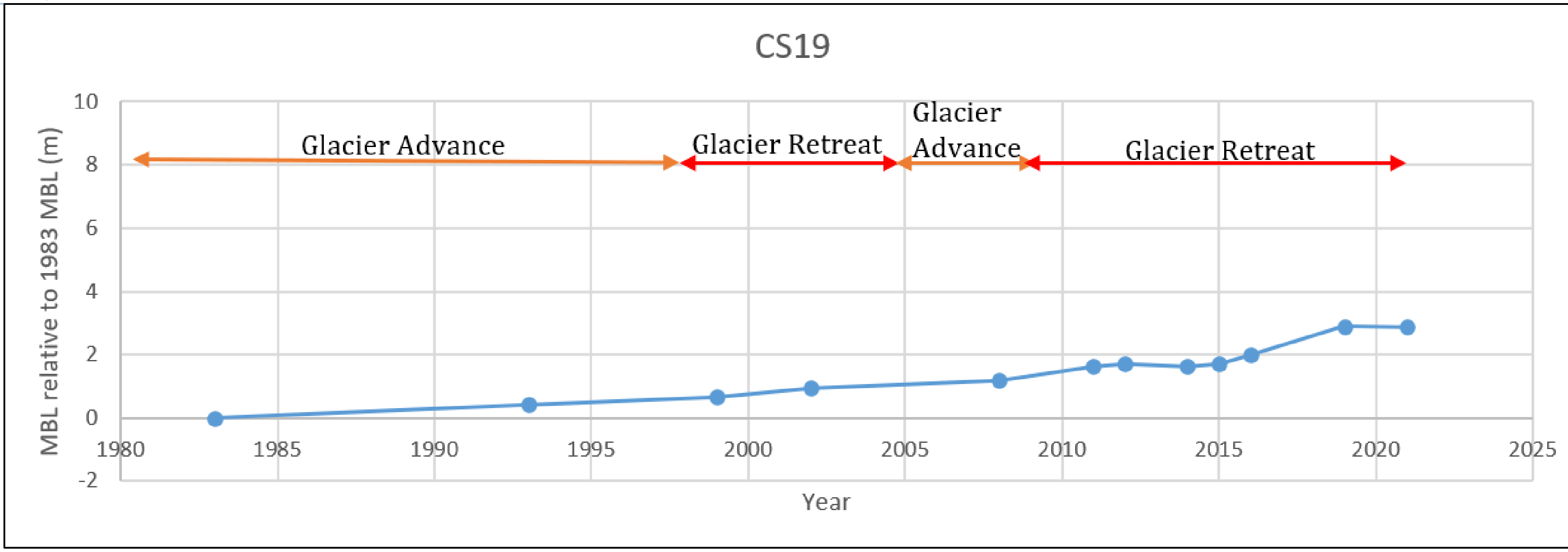

CS14
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat
MBL relative to 1993 MBL (m)
10
8
6
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year

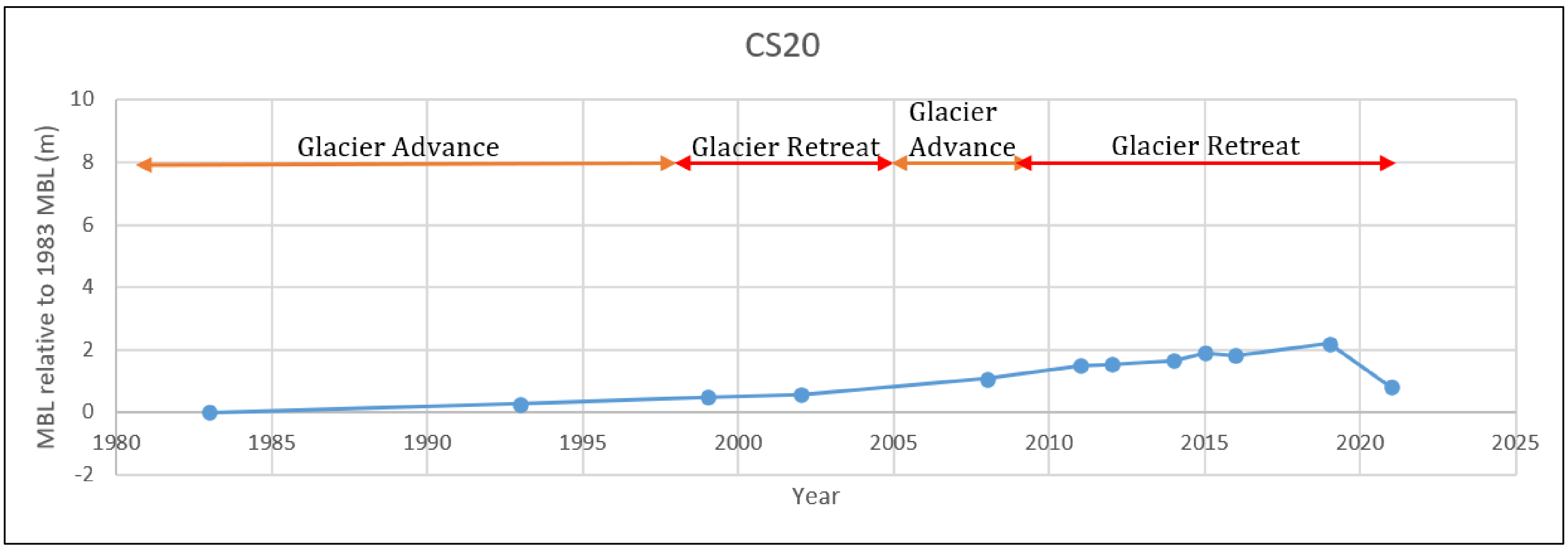

CS15
10
8
6
4
2
0
-2
MBL relative to 1993 MBL (m)
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat

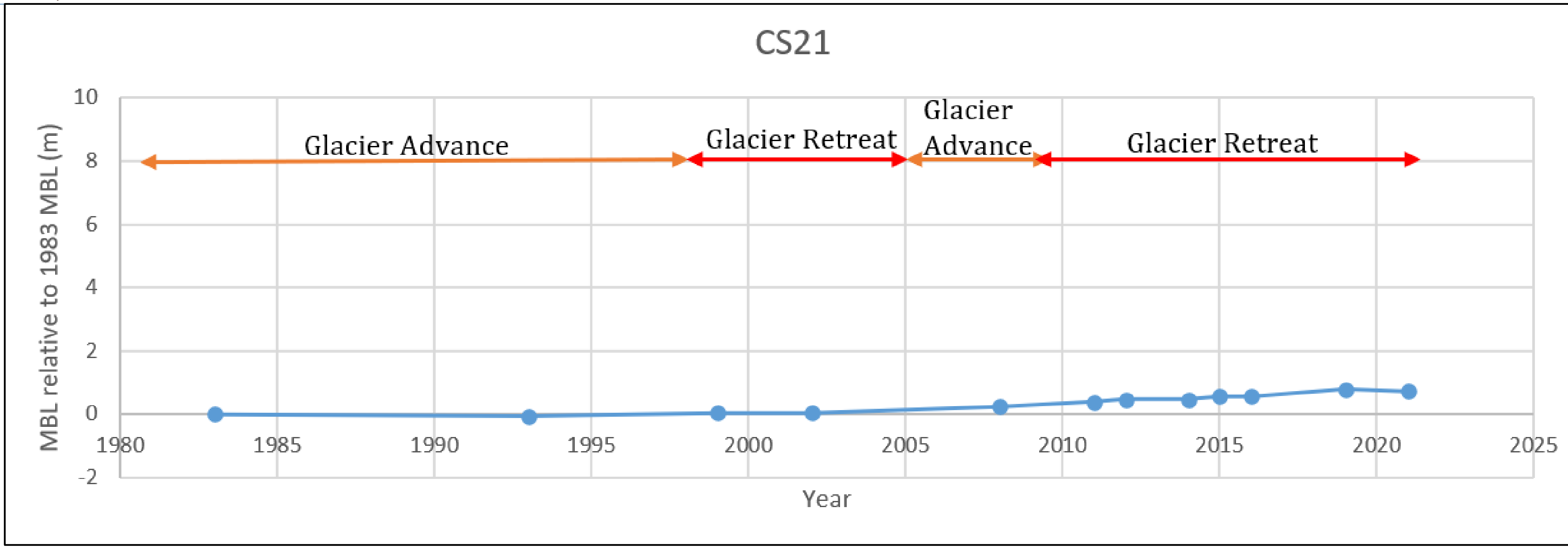

CS16
10
8
6
4
2
0
-2
MBL relative to 1993 MBL (m)
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat

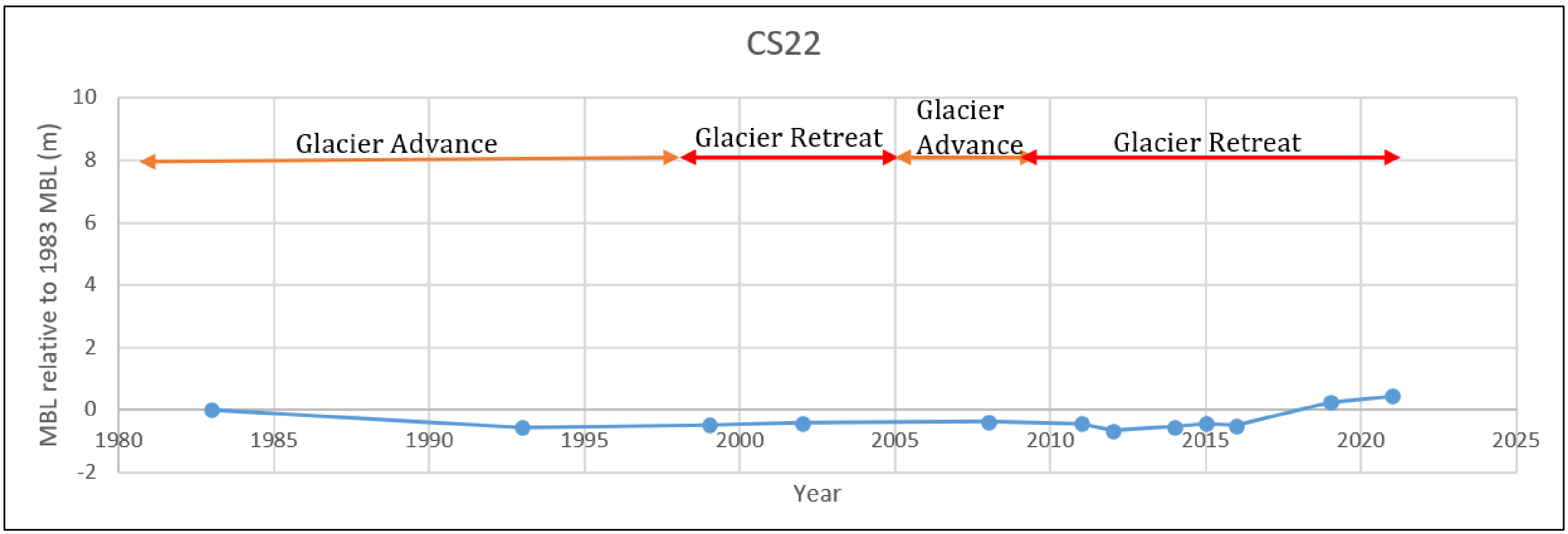

CS17
MBL relative to 1993 MBL (m)
Year
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat
10
8
6
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025


CS18
MBL relative to 1993 MBL (m)
Year
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat
10
8
6
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025


CS19
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat
MBL relative to 1983 MBL (m)
10
8
6
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year


CS20
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat
MBL relative to 1983 MBL (m)
10
8
6
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year


CS21
MBL relative to 1983 MBL (m)
10
8
6
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat


CS22
MBL relative to 1983 MBL (m)
10
8
6
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year
Glacier Advance
Glacier Retreat
Glacier Advance
Glacier Retreat

3.2 GCD ANALYSIS

In order to gain a detailed spatial understanding of the dynamics of the system, a change detection analysis (GCD) analysis was performed the using 2021 Satellite DEM and the 2019 LiDAR DEM the area of interest (AOI) is shown on Figure 3-1. The method is the same as applied to the previous study in 2019 which analysed the difference between the 2019 and 2016 LiDAR DEMs (Gardner & Brasington, 2019).

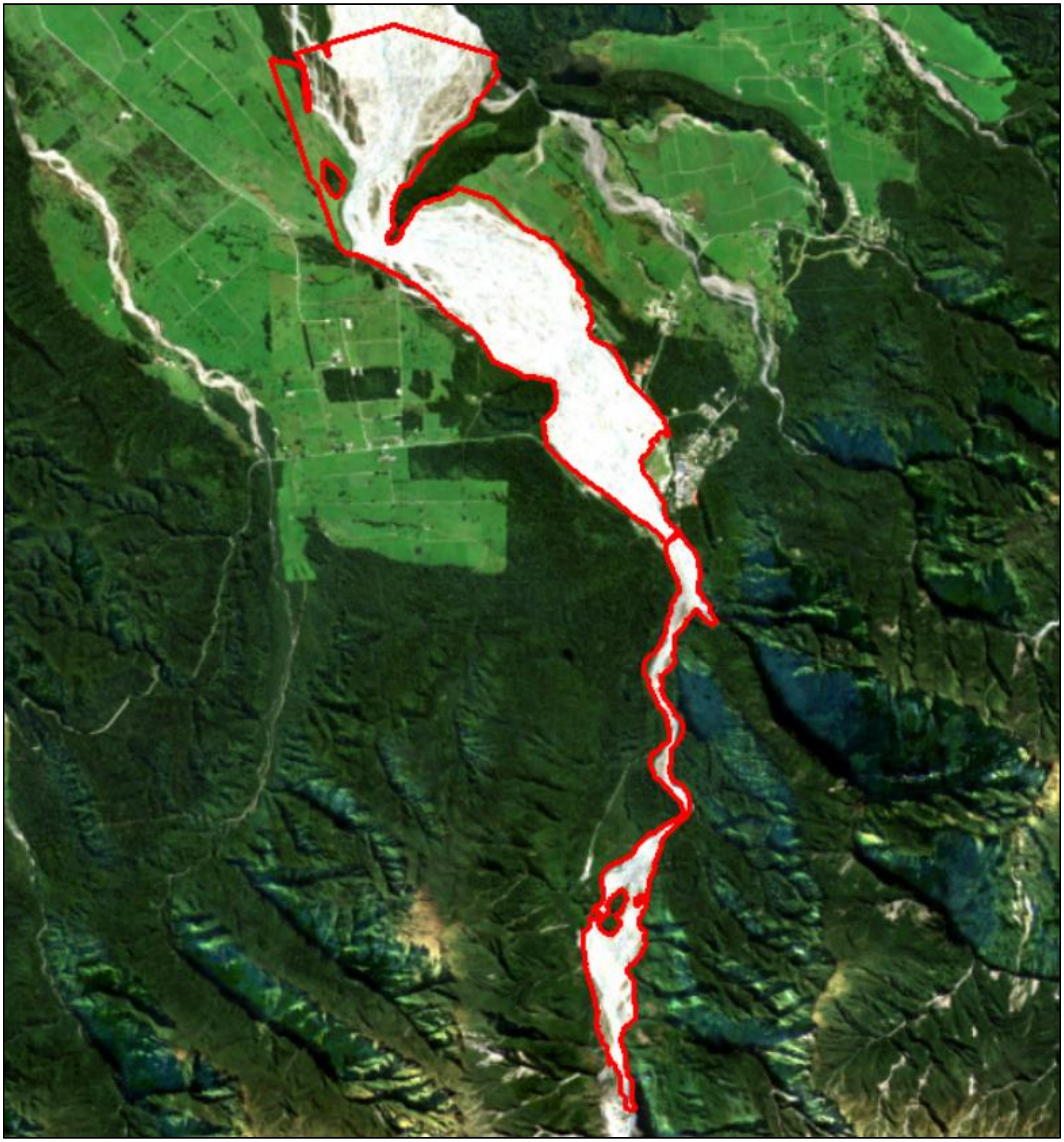


Figure 3-1 – Area of interest for GCD study

Overall the analysis has shown that over the AOI, there has been a build-up of gravel in the system in excess of 1 million cubic metres between April 2019 and March 2021. A summary of volumetric changes for each cross-section reach is presented in Figure 3-2. Of particular note is the significant aggradation in the reach from XS2 to XS4 as well as the degradation from XS0 to XS2. This likely indicates that the material which filled up the valley during the 2019 flood events, is slowly working its way down the system and will be likely to be causing ongoing aggradation for many years to come.

Of further note is the absence of significant change immediately upstream of the State Highway Bridge indicating that in this section, the sediment passes through with little change in channel geometry. Downstream of the bridge the volumetric changes are notable, particularly from XS15 to XS19 where the river widens significantly and there is a reduction in sediment-transport capacity, and an associated increase in sediment deposition that results in fairly rapid aggradation rates.

A visual presentation of the change detection is presented in Figure 3-2a and 3-2b on the following pages.

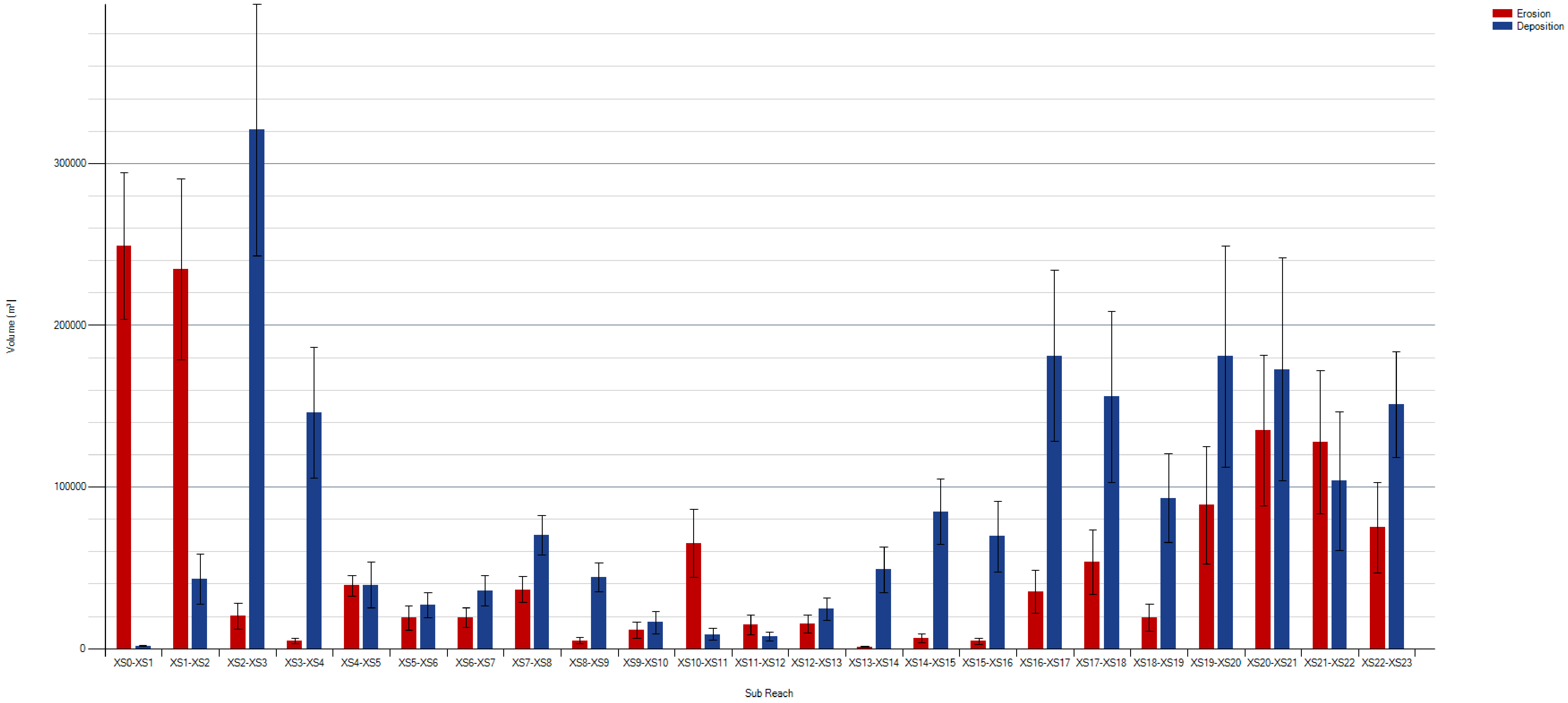
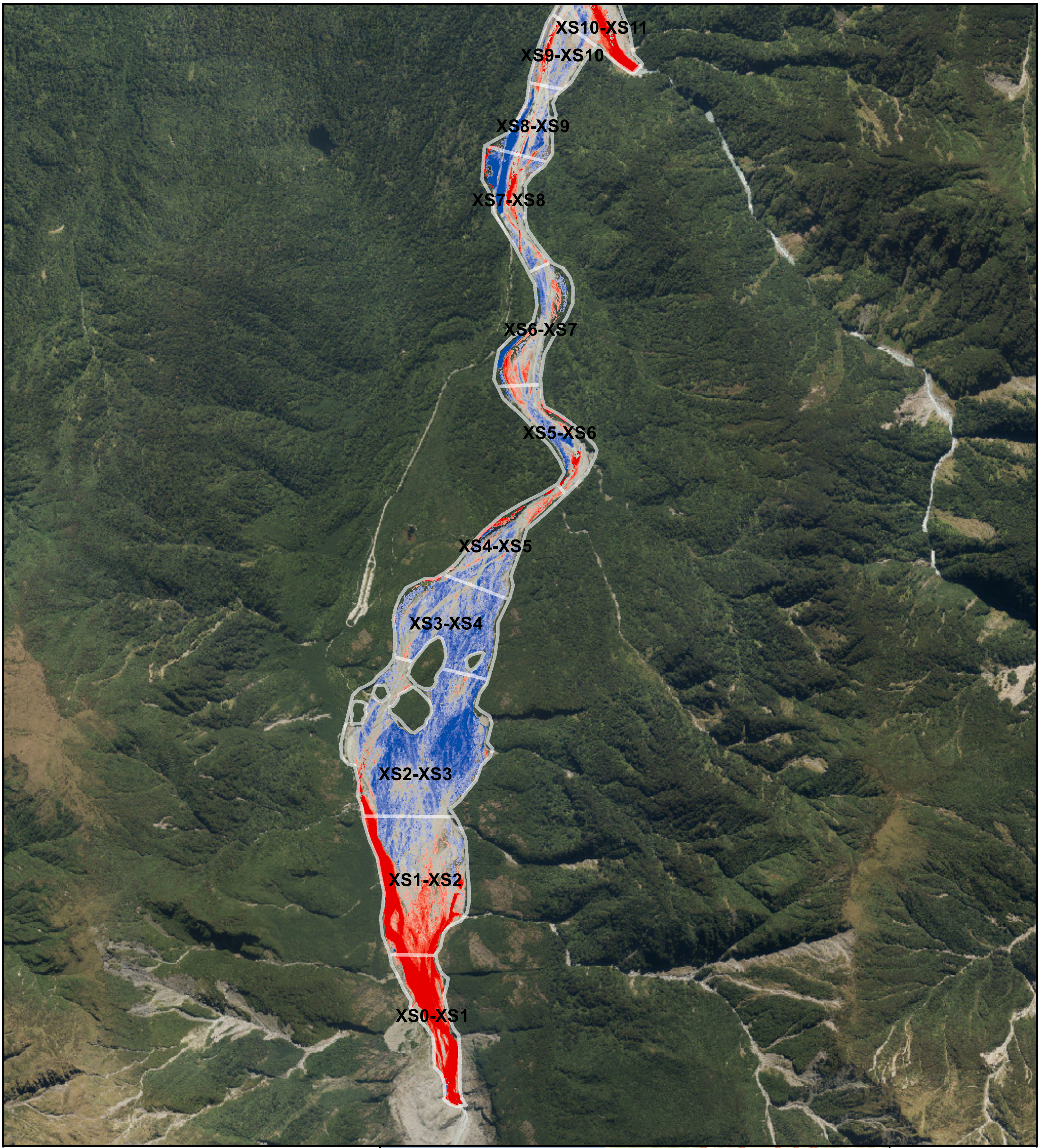


Figure 3-2 – Change in volume for each cross section reach for time period 2019 to 2021 based on 2019 LiDAR DEM and 2021 Satellite DEM



SCALE BAR

0 0.25 0.5 1 km

Legend

XS Budget Cells

Elevation Difference (m)

- < -2.20
- -2.20 to -2.00
- -1.90 to -1.70
- -1.70 to -1.50
- -1.40 to -1.20
- -1.20 to -1.00
- -1.00 to -0.80
- -0.70 to -0.50
- -0.50 to -0.30
- -0.20 to 0.00
- 0.00 to 0.20
- 0.20 to 0.40
- 0.50 to 0.70
- 0.70 to 0.90
- 1.00 to 1.20
- 1.20 to 1.40
- 1.40 to 1.60
- 1.70 to 1.90
- 1.90 to 2.10
- > 2.20

PROJECT

Waiho River Change Detection Analysis

TITLE Glacier to Callery Confluence
April 2019 LiDAR to March 2021 Satelitte DEM
Map 1 of 2

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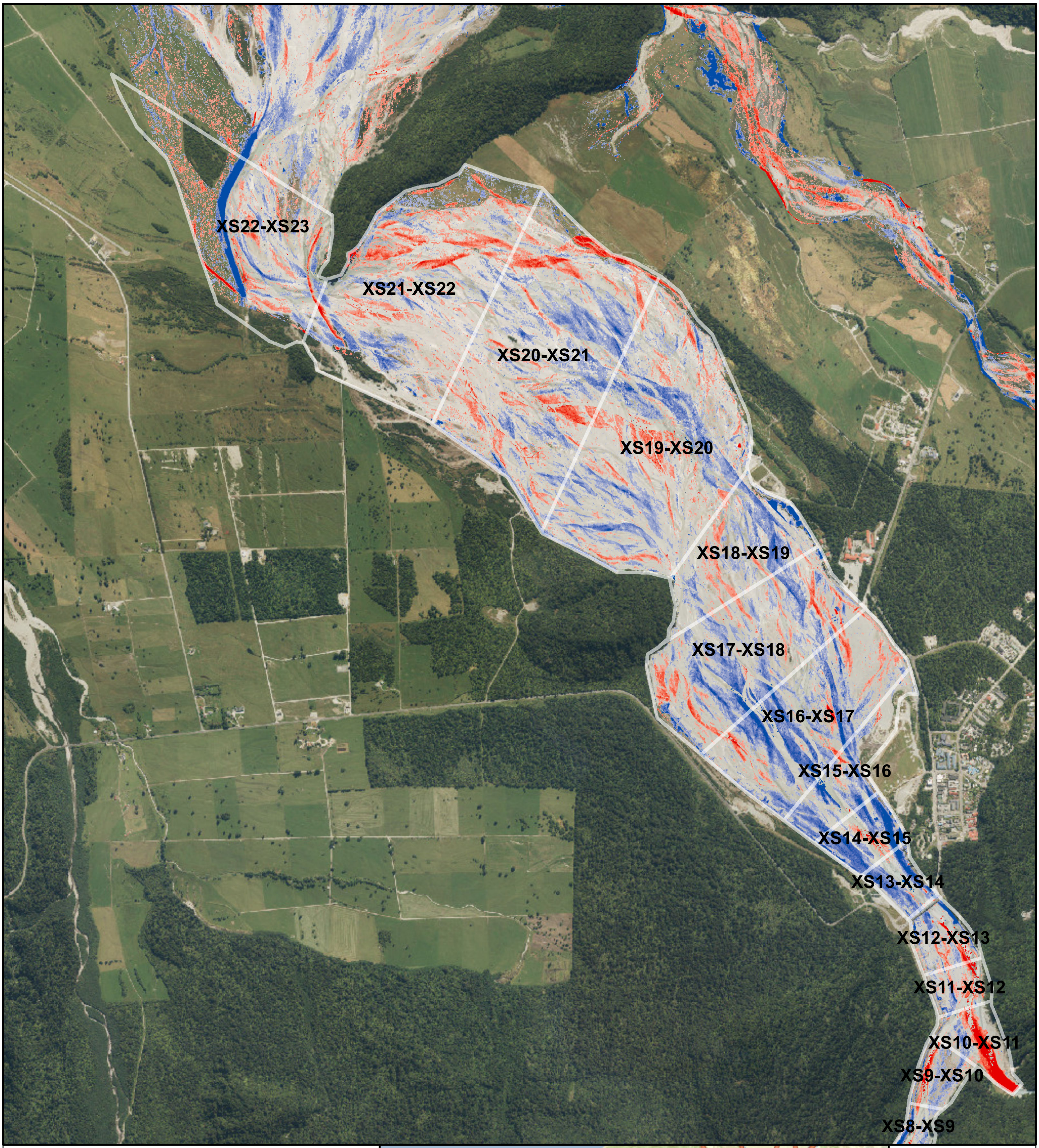
AUTHOR	DATE	JOB CODE	REVISION	
Matthew Gardner	1 Oct 2021	WCRC029	01	N



SCALE BAR

0 0.25 0.5 1 km

Legend

XS Budget Cells

Elevation Difference (m)

- < -2.20
- -2.20 to -2.00
- -1.90 to -1.70
- -1.70 to -1.50
- -1.40 to -1.20
- -1.20 to -1.00
- -1.00 to -0.80
- -0.70 to -0.50
- -0.50 to -0.30
- -0.20 to 0.00
- 0.00 to 0.20
- 0.20 to 0.40
- 0.50 to 0.70
- 0.70 to 0.90
- 1.00 to 1.20
- 1.20 to 1.40
- 1.40 to 1.60
- 1.70 to 1.90
- 1.90 to 2.10
- > 2.20

PROJECT

Waiho River Change Detection Analysis

TITLE

Glacier to Callery Confluence April 2019 LiDAR to March 2021 Satelitte DEM Map 2 of 2

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AUTHOR	DATE	JOB CODE	REVISION	
Matthew Gardner	1 Oct 2021	WCRC029	01	N

In order to further illustrate the significant ongoing aggradation in the river, a cross-section profile was developed across the river in the location of the historic Glacier Gateway motel which was relocated in 2015, after modelling showed that it was at risk of inundation in a 1 in 10 year return period event (Gardner, 2014).

LiDAR is available in this location from 2011, 2016 and 2019 as well the satellite DEM from March 2021. A cross section profile has been extracted from each dataset in the location highlighted in red in Figure 3-3.

Figure 3-3 – Location of extracted cross section

The cross section profiles presented in Figure 3-4 show very clearly that although the stopbanks have been raised on several occasions, the river bed has continued to aggrade along the true left side by over 4m over a 10 year period.

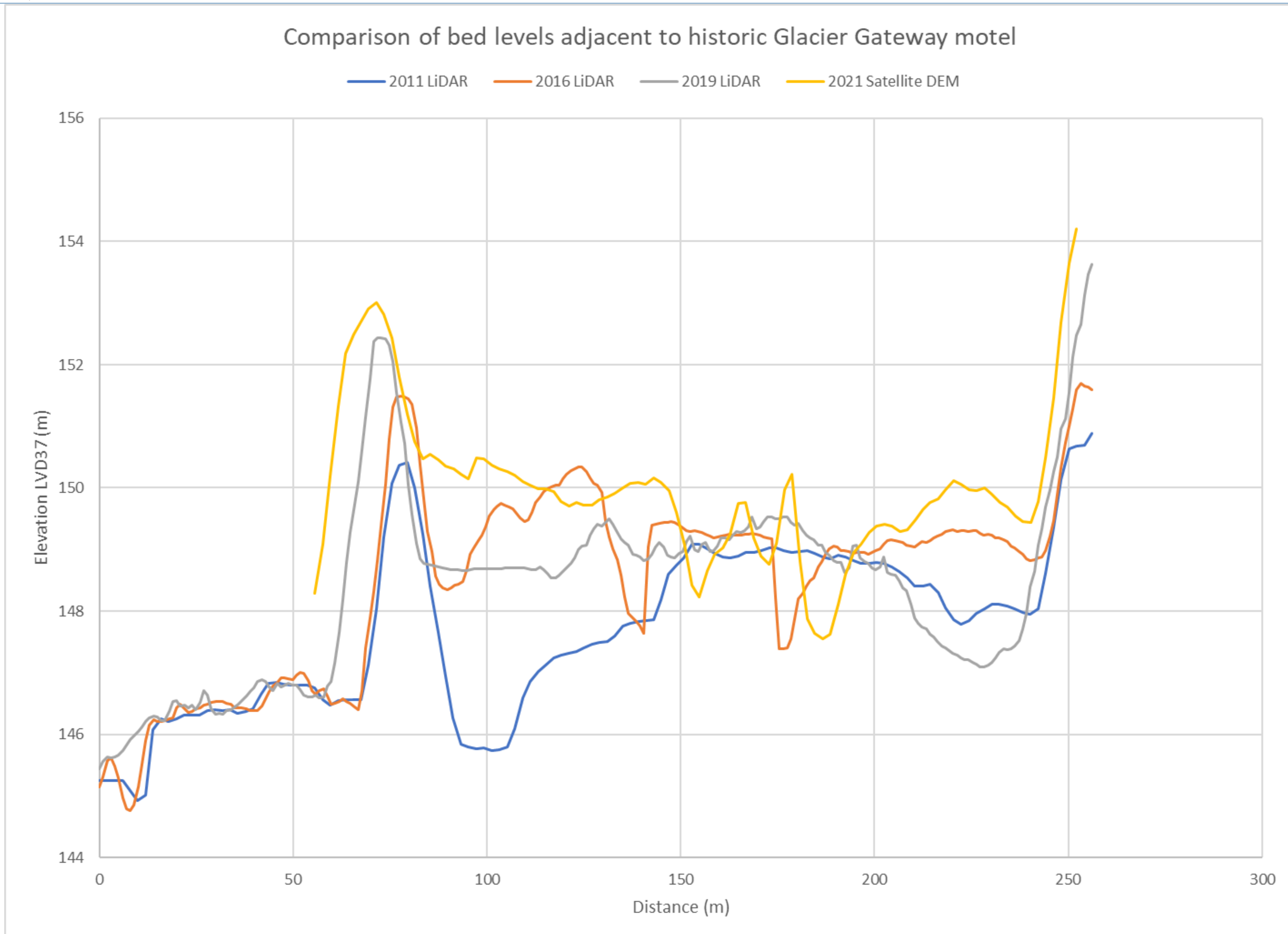

Figure 3-4 – Cross section profile plot adjacent to Glacier gateway hotels

4. POTENTIAL STOPBANK ALIGNMENTS

In late 2014 / early 2015, Gary Williams and I were contracted to provide emergency advice on potential works to prevent a breakout of the river in the vicinity of what is referred to as the 55km corner. We considered a range of options which took into account the likely sedimentation patterns and river dynamics. We recommended the construction of a stopbank that extends from the helipad bank to downstream of the treatment ponds.

Since then, a flood in March 2016 broke out in this location destroying the Scenic Circle Hotel (Mueller) and the treatment ponds. Subsequently a new section of stopbank was built which is referred to as the Havill Wall bank which connects the existing Waka Kotahi (NZTA) section of stopbank and extends the full length to beyond the treatment ponds. The Havill Wall bank is significantly higher and wider than the old bank and sits in front of the previous section of stopbank. As a result, the stopbank design proposed in 2015 will need adjusting in order to be able to tie into the new section of bank.

The preliminary design submitted to the government as part of the application for provincial growth funding has assumed an alternative alignment. A summary of the existing banks is shown as well as the proposed design alignments in Figure 0-1 below.

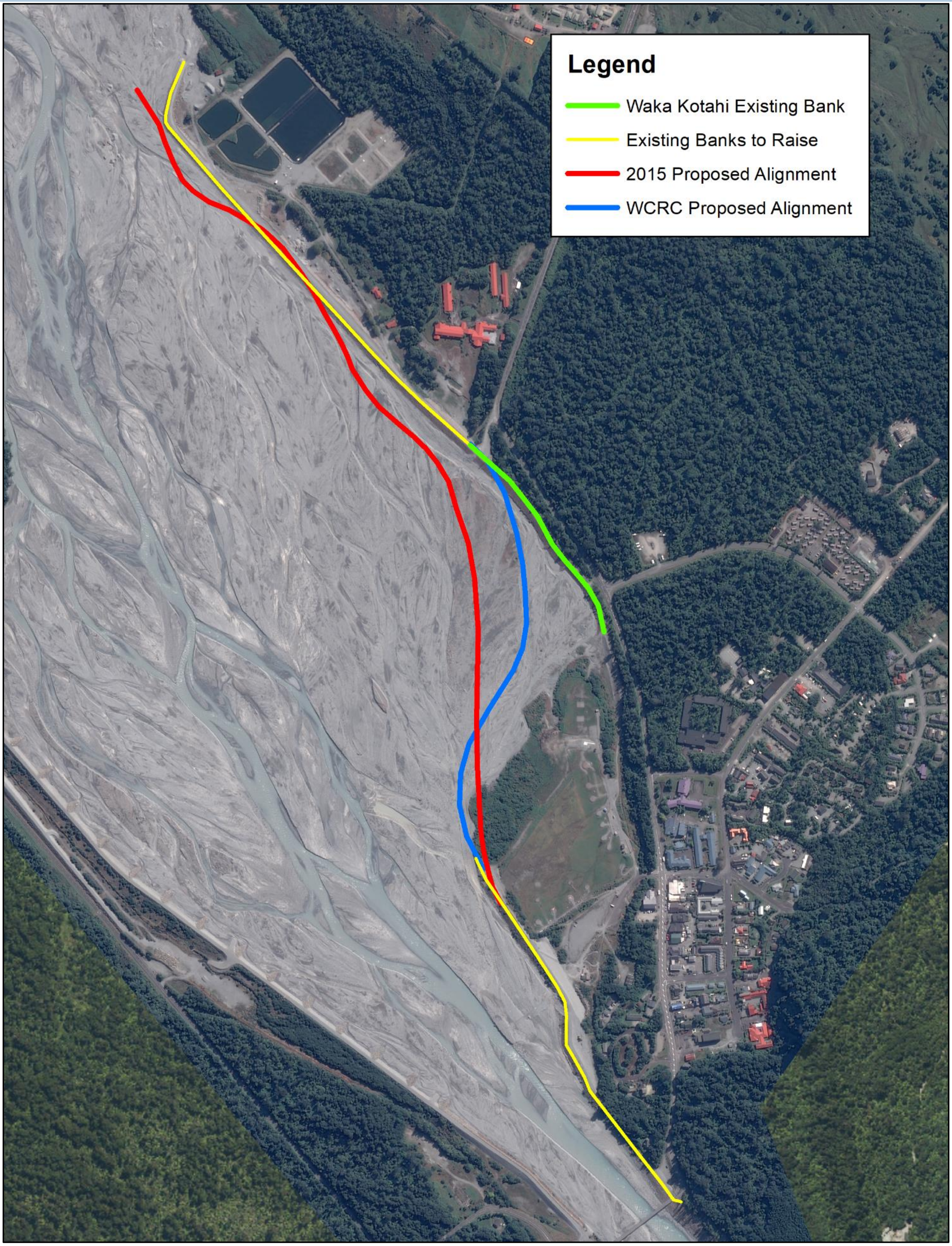

Figure 0-1 – Proposed design alignment for new section of stopbank

FRANZ JOSEF STOPBANKs

On review of the alignment submitted as part of the funding proposal, we have concern that the alignment is less than ideal due to the following reasons:

- The stop bank alignment has a significant expansion with the potential to cause sediment deposition midway along the bend
- The bend alignment will likely cause flow to impact the stopbank at a sharp angle upstream of the hotel and have an associated increase in velocity and shear stress against the bank, with the potential for increased toe scour and bank erosion.
- There is potential to significantly increase the velocity near the stopbank upstream of the hotel
- There is excessive fall towards the 55km corner

Gary, Dai and myself have workshopped a range of potential alignments internally and selected three alignments for further analysis, the results of which were used to select a preferred alignment (Figure 1-1).

4.1 TATARE OVERFLOW BUND

In addition to raising the existing banks, the proposal includes the construction of a rock lined bund to prevent flow into the Tatare River. Due to the aggradation in the Waiho River, there is potential for the Waiho River to avulse into the Tatare River, which could create significant threat to the township as discussed in previous reports (Hall, 2012).Floodwaters have already been spilling over this area in recent flood events, with significant scour and headcutting occurring each time. The construction of a bund to prevent an avulsion at this location is considered to be highly prudent. The location of the proposed bund is presented in Figure 0-2 below.

Figure 0-2 – Location of Tatare overflow bund

5 HYDRAULIC MODEL SETUP

A MIKE21FM hydraulic model of the river was built to evaluate the three stopbank alignments. Elevations were assigned to the model primarily using the March 2021 satellite DEM and supplemented with the raw survey data. The model extends from the confluence with the Callery River downstream of the Waiho Loop.

The model has been constructed using a flexible mesh with variable mesh size ranging from 25m^2 for the main channel to 1000 m^2 near the downstream boundary to provide mesh stability (Figure 5-1).

To ensure stopbank crest elevations are accurately represented, the crest locations have been carefully included in the mesh to allow the elevations to be defined using a 1D dike feature within the software. A schematic of the final mesh is presented in Figure 5-1.

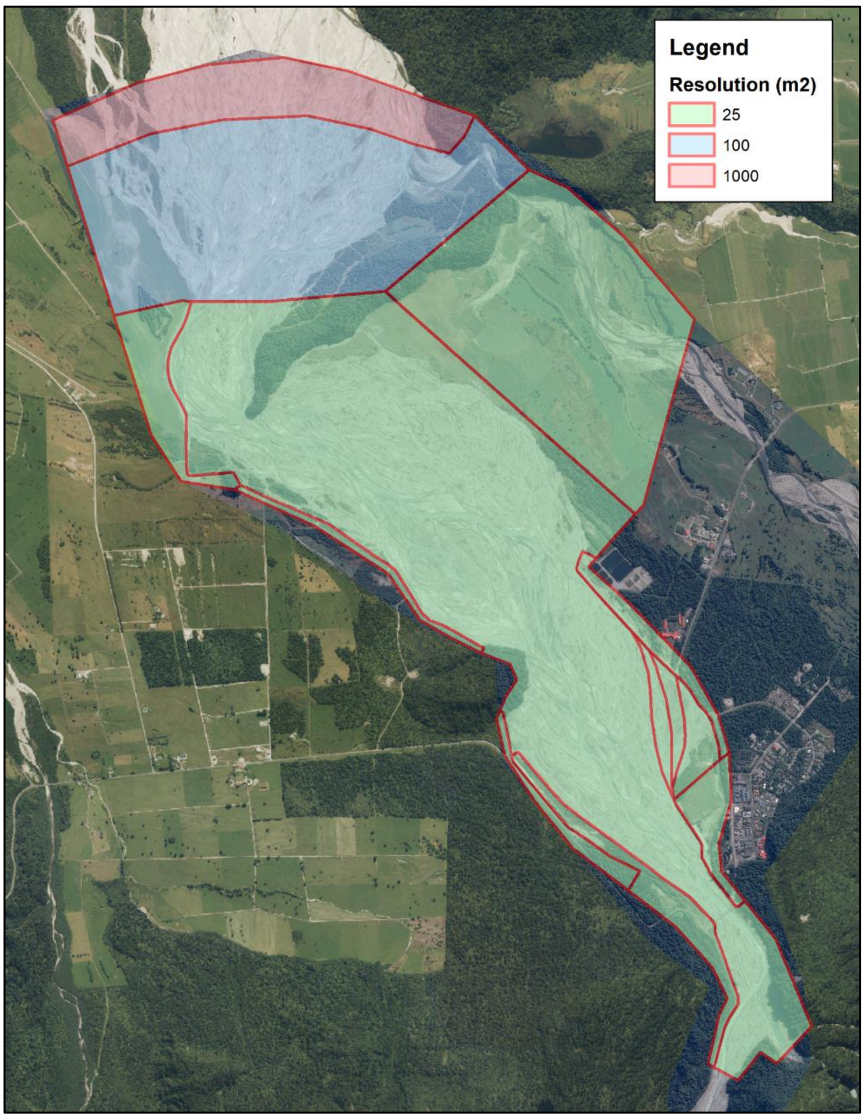

Figure 5-1 – Mesh Extent

It must be highlighted that this is a fixed bed hydraulic model, which does not account for the mobile nature of the bed during flood events nor for ongoing aggradation, and hence needs to be interpreted by a suitably qualified and experienced engineer. The purpose of the model should be seen as a tool to assist in decision making, rather than a definitive model of the river.

4.1 Model Terrain

The model bathymetry has been interpolated using points generated at a 2m grid resolution from the satellite DEM. Because the DEM did not contain the subaqueous portion of the river, the DEM was modified by burning in a 1.5m deep by 18m wide trapezoid channel (Figure 5-2, Figure 5-3, Figure 5-4). The channel edges were designed to tie in with the DEM elevations.

The model was run with the inserted channel braid for the existing conditions, the three braid alignments and the Manning's n-value sensitivity runs.

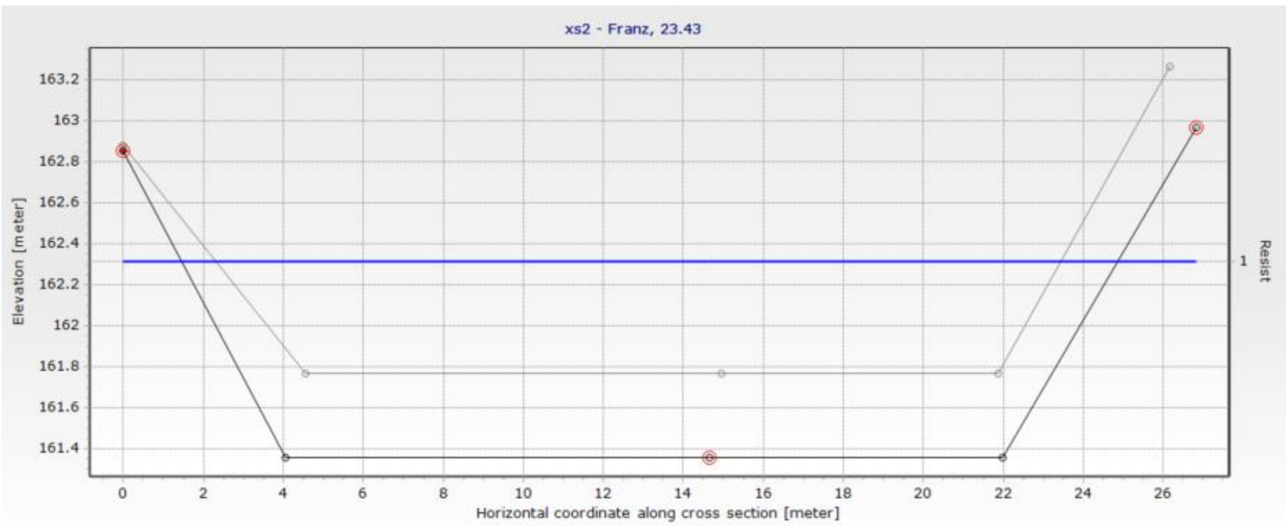

Figure 5-2 – Example of typical trapezoidal channel shape in MIKE Hydro River

Figure 5-3 - Example of cross section locations in relation to main channel

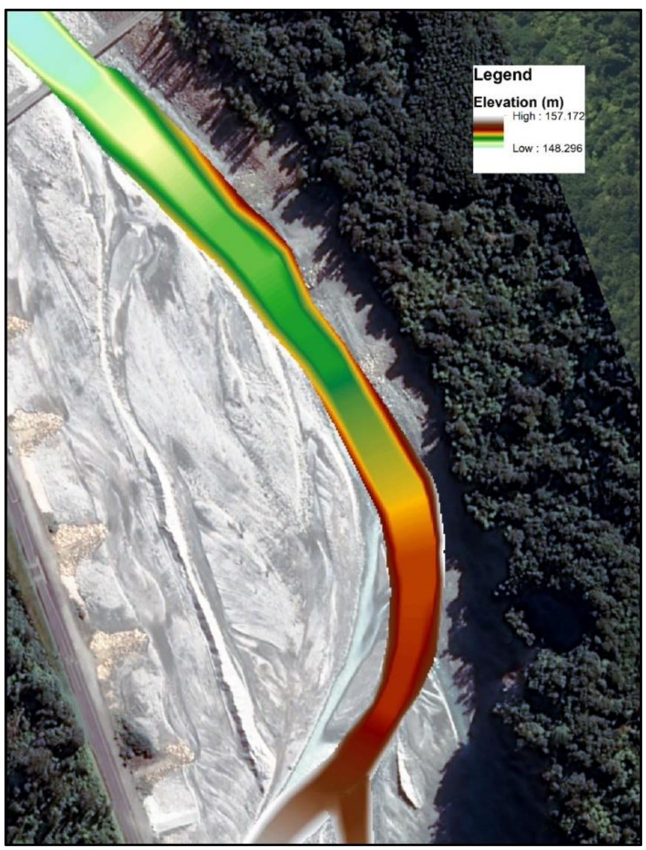

Figure 5-4 - Visualisation of interpolated 2D bathymetry

4.2 Manning's n roughness values.

Based on previous experience with modelling the river (Gardner, 2014 & 2016), a Manning's 'n' value of 0.05 was selected as being representative of the likely roughness characteristics of the channel bed. This is slightly higher than suggested by standard formula for gravel-based rivers based on the grain size distribution (D_{50} = 165 mm, D_{84}=285 mm) however due to the significant turbulence observed during flood events, we consider this value to be suitable. This value is also consistent with assessments carried out by NIWA (2011) and Bob Hall (Hall, 2012)

In addition to the base value of 0.05, the model was run with a Manning's of 0.04 for scour calculations and at 0.06 to evaluate the freeboard.

4.3 Hydrology

Due to the significant mobilisation of the entire bed during high flow events, it is not considered practical to install a flow gauge in the river. There is also only limited rain gauge information in the catchment, hence there is no known relationship between rainfall and runoff available making it difficult to assess flood frequency.

Previous assessments have assessed the 1% Annual Exceedance Probability (AEP) flow in the catchment to be between 2000 to 3000 m^3/s at the State Highway Bridge. A recent assessment was carried out in 2014 and was based on a scaling of flows in the adjacent Whataroa catchment (Gardner, 2014). This assessment placed the 1%AEP flow as 2451 m^3/s and was rounded up to 2500 m^3/s to account for uncertainty.

Whilst it would be possible to undertake a more detailed hydrological assessment, considering the significant uncertainties in the catchment due to a lack of flow and rainfall gauges as well as a continually changing climate, we do not believe that there is significant merit in changing the design flow from 2500 m^3/s, especially considering that any stopbank heights will be controlled more by the ongoing aggradation, rather than flow.

4.4 Stopbank Alignments

In addition to the existing river setup, three potential stopbank alignments (A, B and C) were simulated, The banks were represented in the model using 1D dike features in MIKE21fm. To simulate a likely braid set up at the base of each bank alignment; a 30m wide, 2m deep trapezoidal braid has been burnt into the DEM for each stopbank alignment. These dimensions have been based on site measurements of braids that have clearly formed adjacent to the existing stopbank in the vicinity of the 55km corner. An example of the braid for alignment A is presented in Figure 5-5 below.

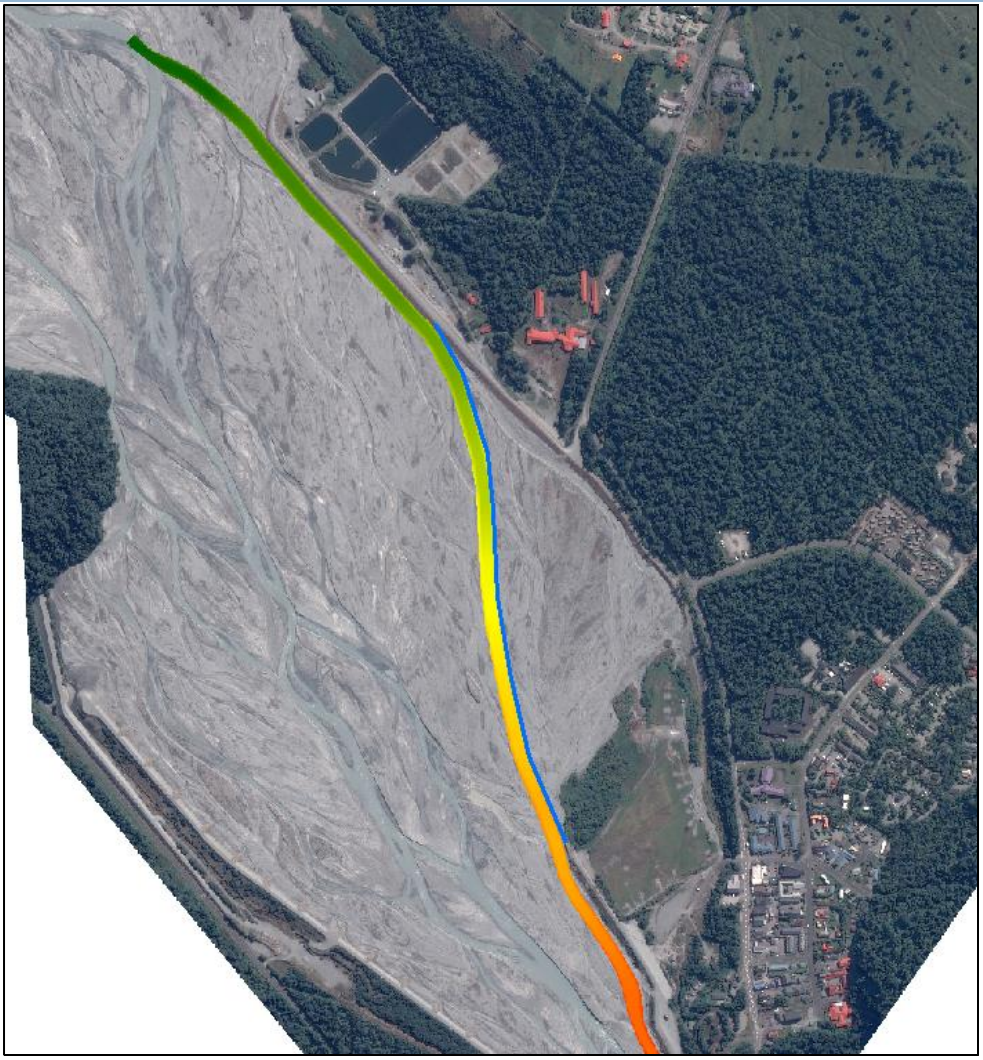

Figure 5-5 – Example of braid channel burnt into terrain for alignment A

4.5 Aggradation Scenarios

To assess the likely aggradation in the vicinity of the stopbanks over a 20-year period, an analysis was performed of the historic aggradation trends at each cross section from 1993 to 2021. When examining the trends presented in section 3, it is apparent that there are three potential pivot points which could be used to assess varying aggradation trends. The average rate of aggradation was calculated for the three following time periods:

- 1993 to 2021
- 1998 to 2021
- 2008 to 2021

Table 5-1 – Cross sectional average aggradation rates – 1993 to 2021

	Rate (m/year)			Aggradation - 20 year period (m)		
	1993 - 2021	1998 - 2021	2008 - 2021	Rate1	Rate2	Rate3
CS13	0.18	0.09	0.14	3.6	1.8	2.7
CS14	0.16	0.09	0.12	3.3	1.7	2.5
CS15	0.15	0.10	0.12	2.9	1.9	2.5
CS16	0.13	0.09	0.11	2.5	1.9	2.2
CS17	0.12	0.10	0.14	2.4	2.0	2.9
CS18	0.11	0.10	0.13	2.2	2.0	2.6
CS19	0.09	0.10	0.13	1.8	2.0	2.6
CS20	0.02	0.01	-0.02	0.4	0.2	-0.4
CS21	0.03	0.03	0.04	0.6	0.6	0.7
CS22	0.03	0.04	0.07	0.7	0.8	1.3

In order to assess the potential impact on flood levels, an aggradation surface was developed by interpolating an aggradation rate at each cross section, and increasing the bed level at that location by that amount.

6 MODEL SIMULATIONS

A range of simulations have been run through the model in order to assist with the detailed design process. The runs have been decided upon jointly, based upon the needs of the detailed design stage of the project.

Table 6-1 summarises the modelled scenarios.

Table 6-1 – Modelled Scenarios

Scenario	Discharge m^3/s	Alignment	Mannings 'n'	Aggradation Rate
1	500	B	0.05	
2	1000	B	0.05	
3	1500	B	0.05	
4	2000	B	0.05	
5	2500	A	0.05	
6	2500	B	0.05	
7	2500	C	0.05	
8	2500	Existing	0.05	
9	3000	B	0.05	
10	3500	B	0.05	
11	2500	B	0.04	
12	2500	B	0.06	
13	2500	B	0.05	Aggradation Rate 1
14	2500	B	0.05	Aggradation Rate 2
15	2500	B	0.05	Aggradation Rate 3

Model output each run has been provided electronically with long section profiles showing peak elevation as well speed as presented in Appendix C. Maps showing peak speed and flood extent for each modelled scenario are also presented in Appendix D.

Peak water levels for the Tatare Overflow Bund are provided in Appendix E.

7 RESIDUAL RISK

Whilst raising stopbanks may be seen as essential in order to prevent flooding to property and infrastructure, it must also be kept in mind that raising of stopbanks also increases the residual risk and consequences should a stopbank failure occur.

The Waiho River is receiving a large volume of sediment from the upstream catchment which is resulting in rapid rates of aggradation over the entire fan area. It is unlikely that the rate of aggradation will decrease in the near future, and with increased storm intensities predicted with the changing climate, it only seems likely that these rates of aggradation will accelerate.

It is my professional opinion that the further raising of the stopbanks comes with increased risk and should be considered as a short-term solution, purely for the purposes of buying time to allow the implementation of more permanent solutions, such as vacating the true left bank of the river, allowing the river to reclaim its natural floodplain, and hence distribute the sediment inputs over a significantly larger area.

Whilst the exact impact of allowing the river to reclaim its natural floodplain on the true left bank of the river is uncertain, it is in my opinion likely that the overall rate of aggradation will decrease, considering the fact that the river will have the ability to distribute its sediment over a much larger area.

8 CONCLUSIONS

- Based on our analysis we conclude that Alignment B is the most suitable alignment for the construction of the new bank.
- It is very apparent that ongoing aggradation is a very significant issue for the river, and future trends are uncertain. We recommend using Aggradation Scenario 2 for sizing the stopbanks as this gives a fairly uniform trend and provides a realistic profile for design purposes. Based on historic rates of aggradation, we could expect this to provide approximately 20 years of design life for a design flow of 2500 m^3/s. Regular monitoring of aggradation is recommended via LiDAR or satellite technology.
- The consequence of a stopbank breach or failure increases every time that a stopbank is raised. It is not recommended that these stopbanks are raised again after this raise and that serious consideration is given to managed retreat due to the significant nature of the hazard.
- The results of the modelling scenarios used in this preliminary design are appropriate to be used for detailed design.
- The satellite DEM data utilised in this study acquired through the Otago University School of surveying has proven to be extremely useful, reliable and cost effective. Serious consideration should be given to carrying acquiring regular repeat surveys using these techniques.

9 REFERENCES

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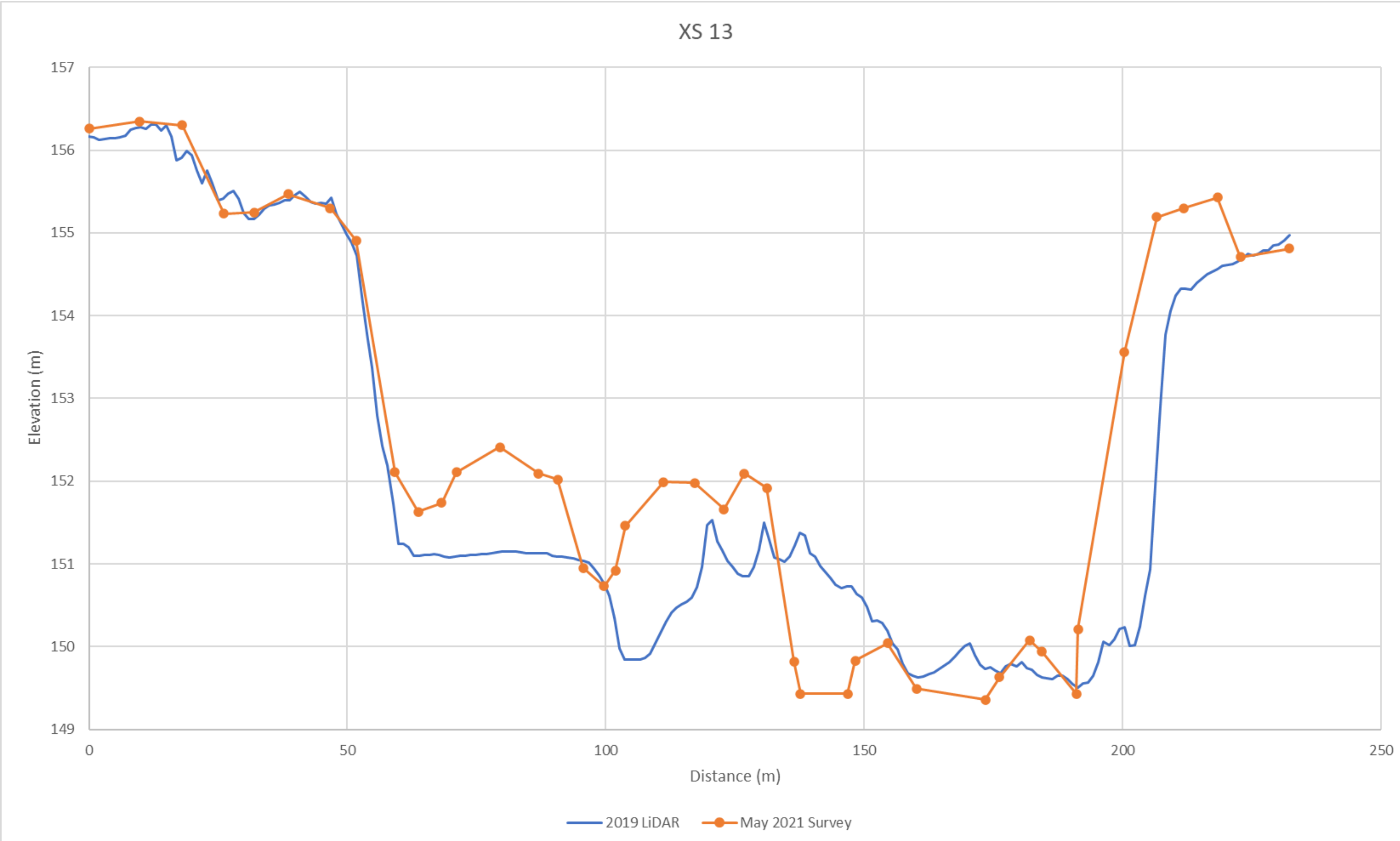
Sirguey, Pascal. 2021. *Topographic mapping of Waiho River with Pleiades satellite imagery.* Dunedin : Otago University, 2021.

Wolman, M G. 1954. *A method for sampling coarse river bed material. Transactions of American Geophysical Union, v.35 (6), pp. 951-956.* 1954.

APPENDIX A – CROSS SECTION PLOTS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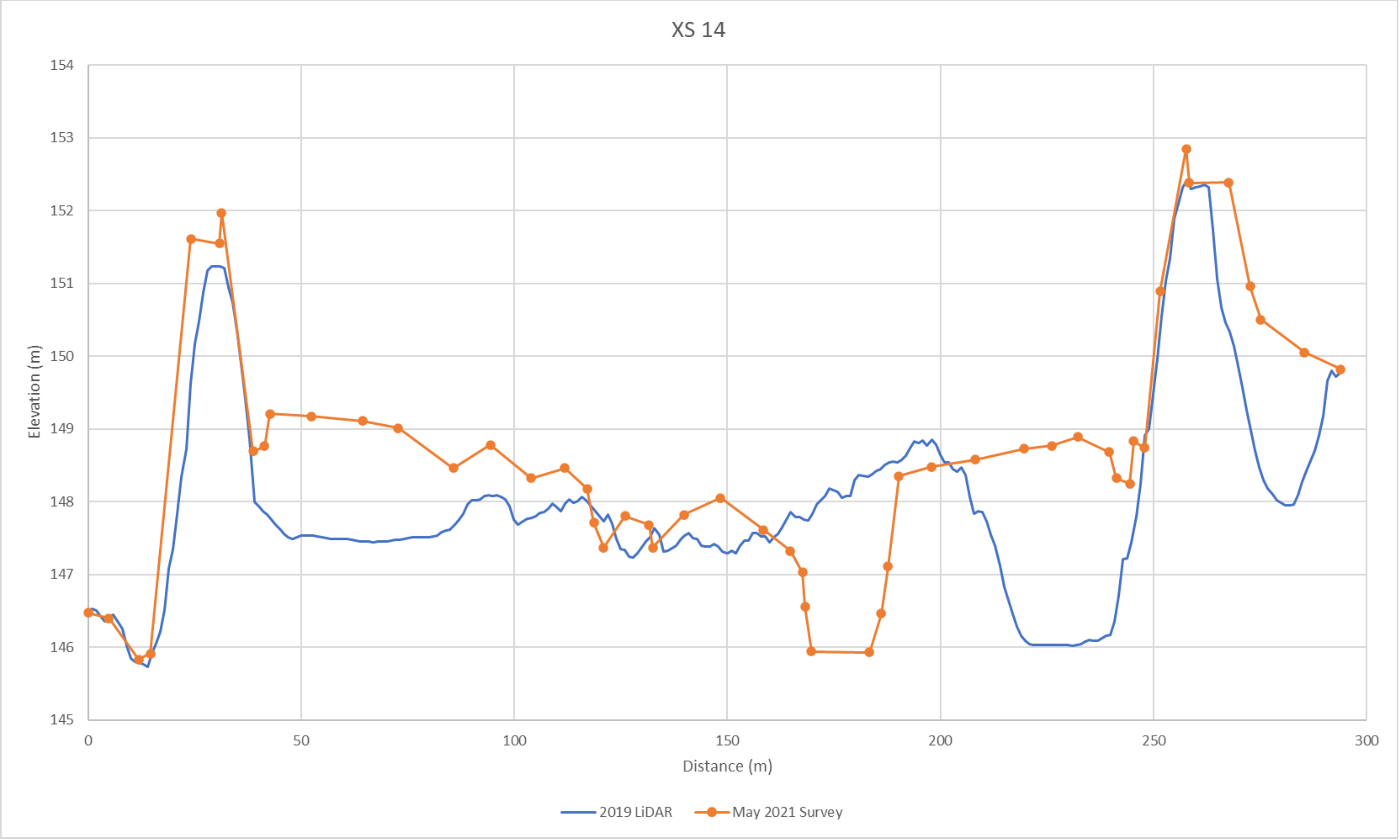
156
155
154
153
152
151
150
149
Elevation (m)
0
50
100
150
200
250
Distance (m)
2019 LiDAR
May 2021 Survey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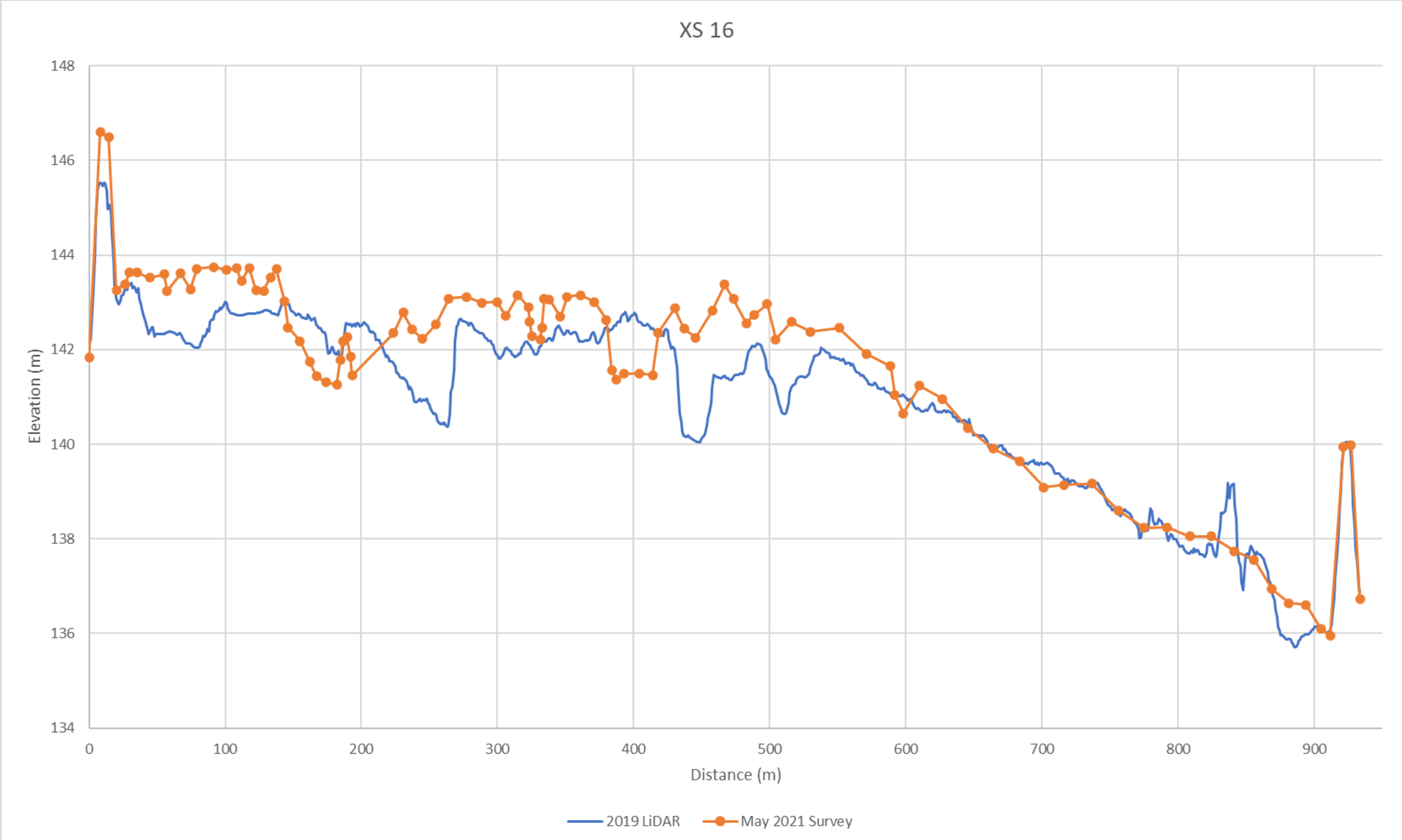
153
152
151
150
149
148
147
146
145
0
50
100
150
200
250
300
Distance (m)
2019 LiDAR
May 2021 Survey


XS 15
Elevation (m)
150
149
148
147
146
145
144
143
142
141
0
50
100
150
200
250
300
350
400
Distance (m)
2019 LiDAR
May 2021 Survey


XS 16
148
146
144
142
140
138
136
134
Elevation (m)
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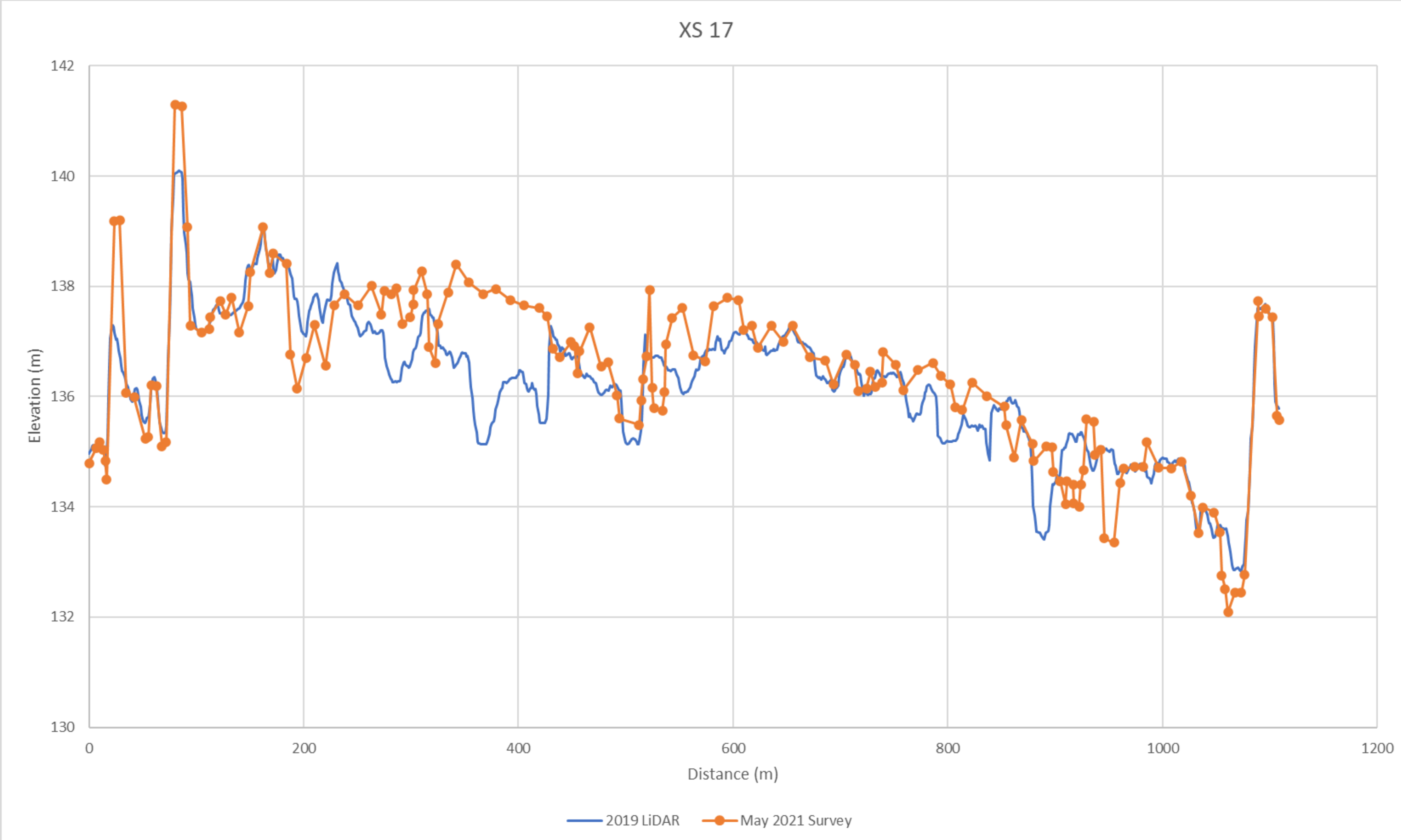
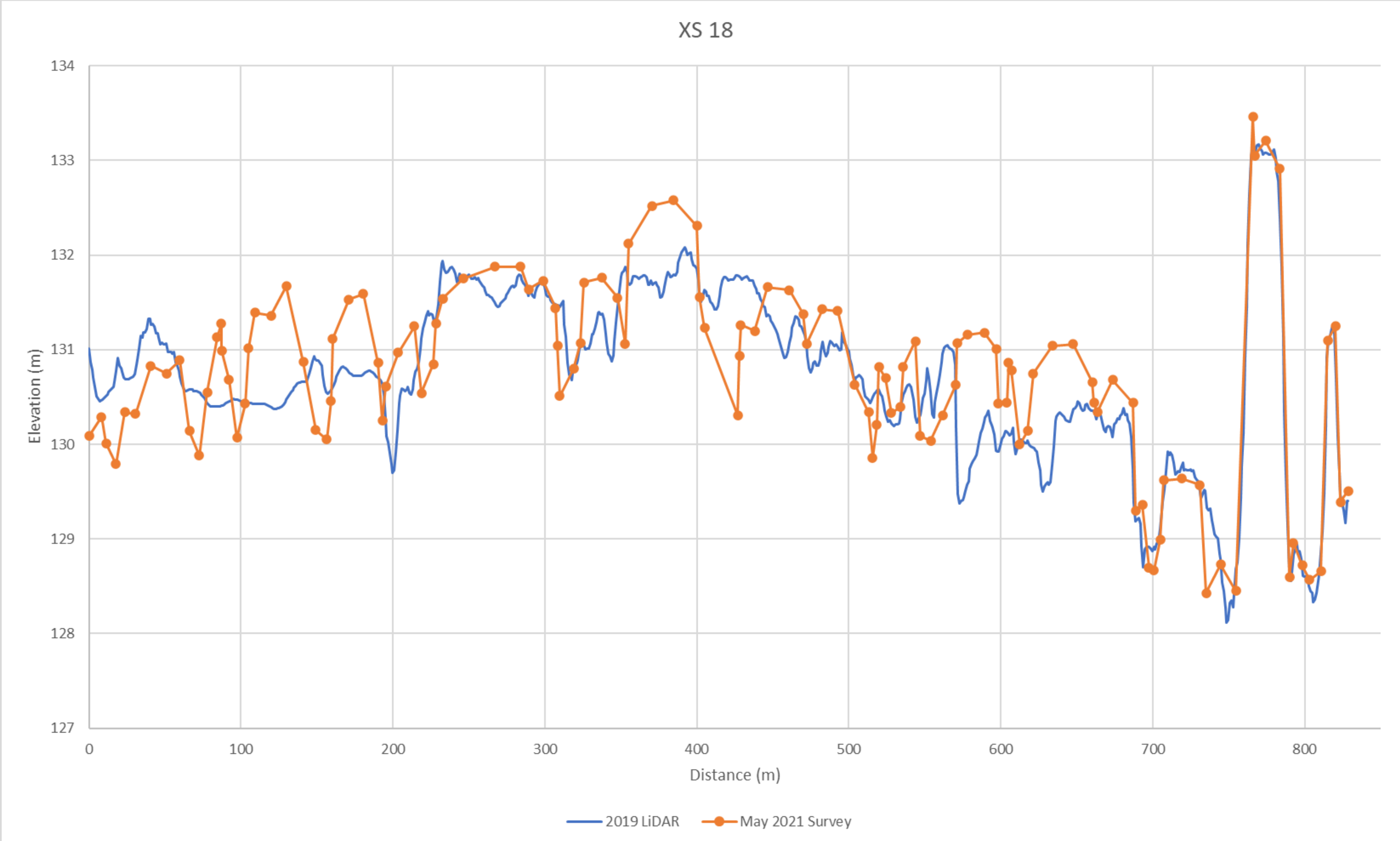
100
200
300
400
500
600
700
800
900
Distance (m)
2019 LiDAR
May 2021 Survey


XS 17
Elevation (m)
142
140
138
136
134
132
130
0
200
400
600
800
1000
1200
Distance (m)
2019 LiDAR
May 2021 Survey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Elevation (m)
134
133
132
131
130
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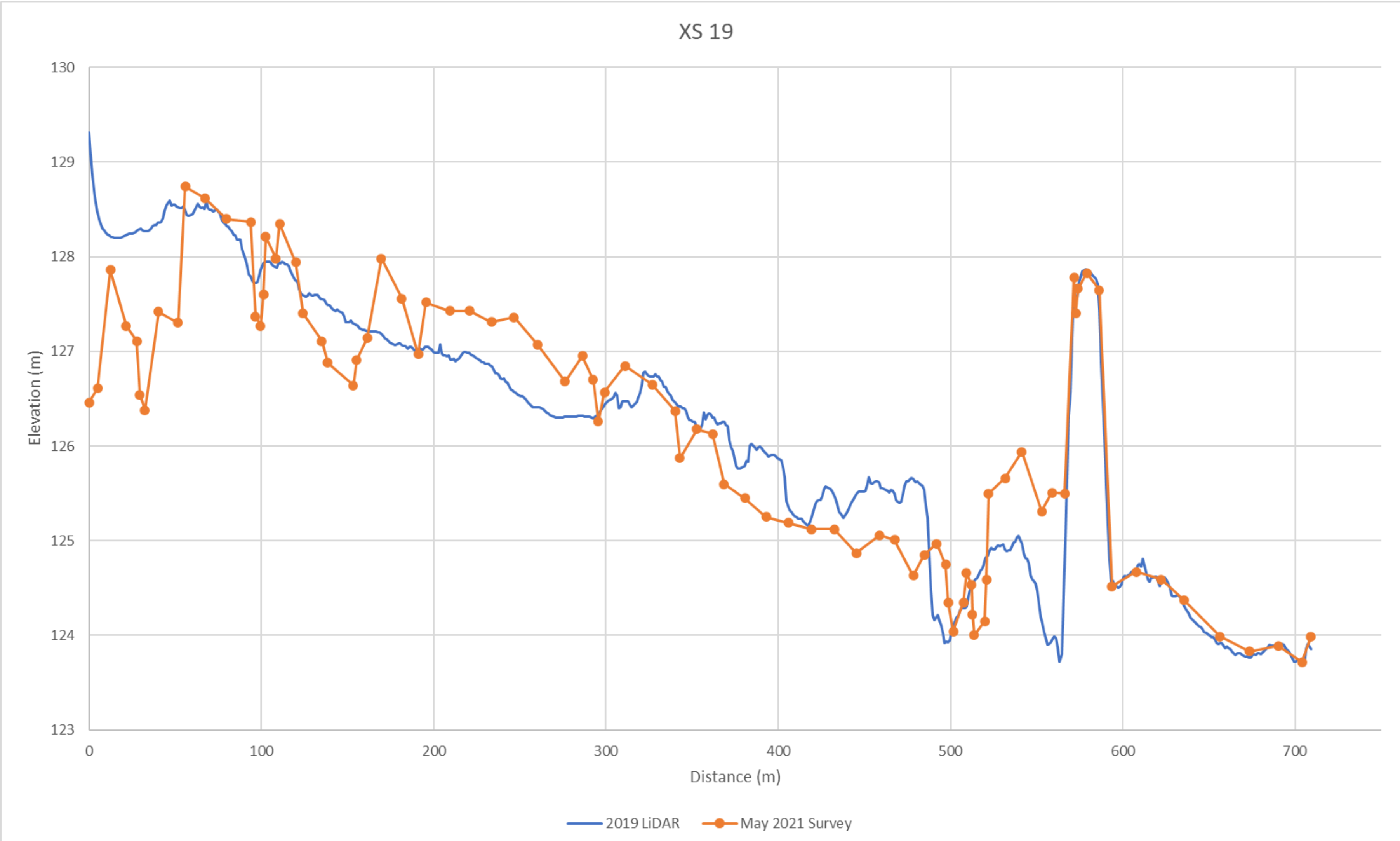
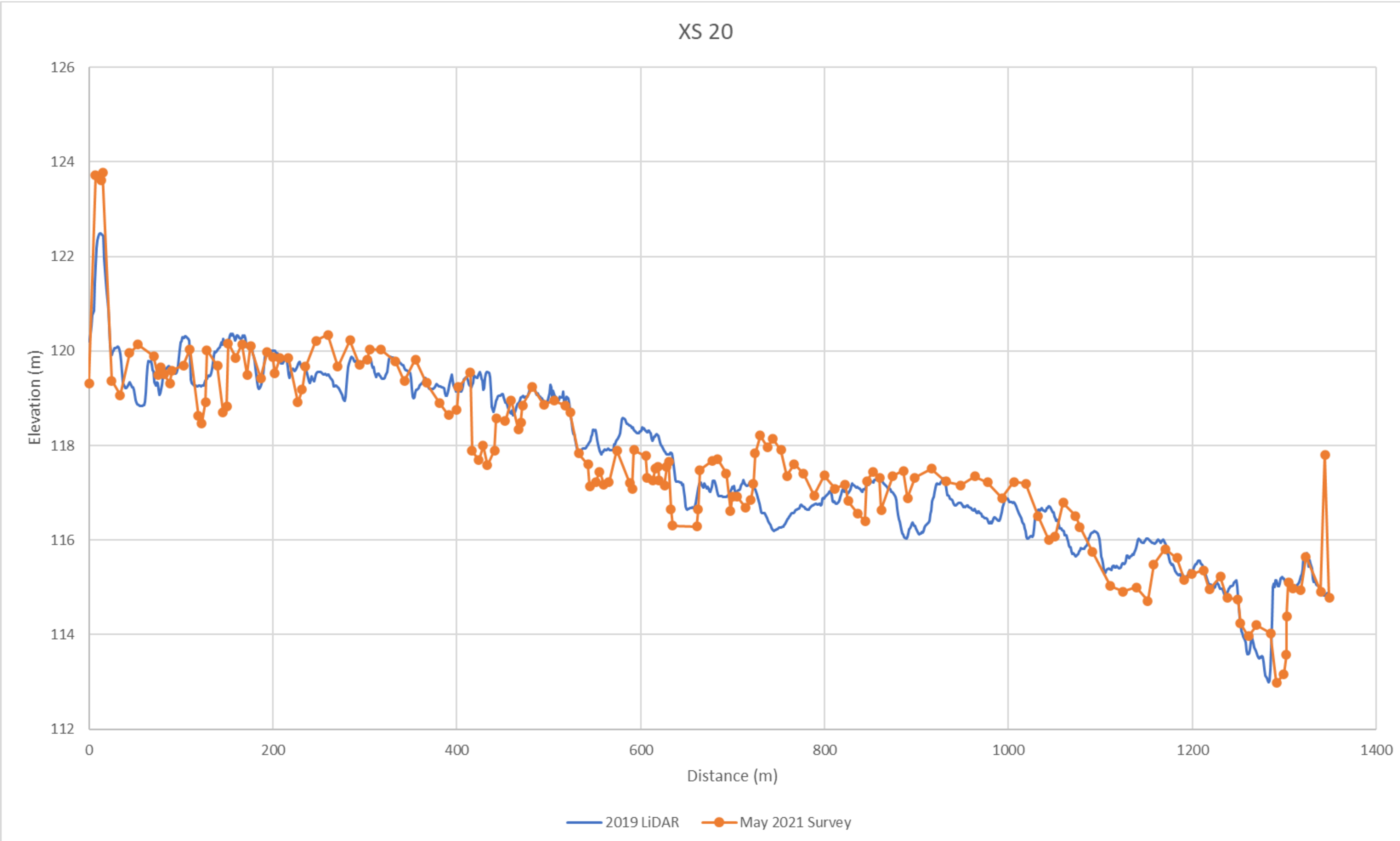
128
127
0
100
200
300
400
500
600
700
800
Distance (m)
2019 LiDAR
May 2021 Survey


XS 19
130
129
128
127
126
125
124
123
Elevation (m)
0
100
200
300
400
500
600
700
Distance (m)
2019 LiDAR
May 2021 Survey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126
124
122
120
118
116
114
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Elevation (m)
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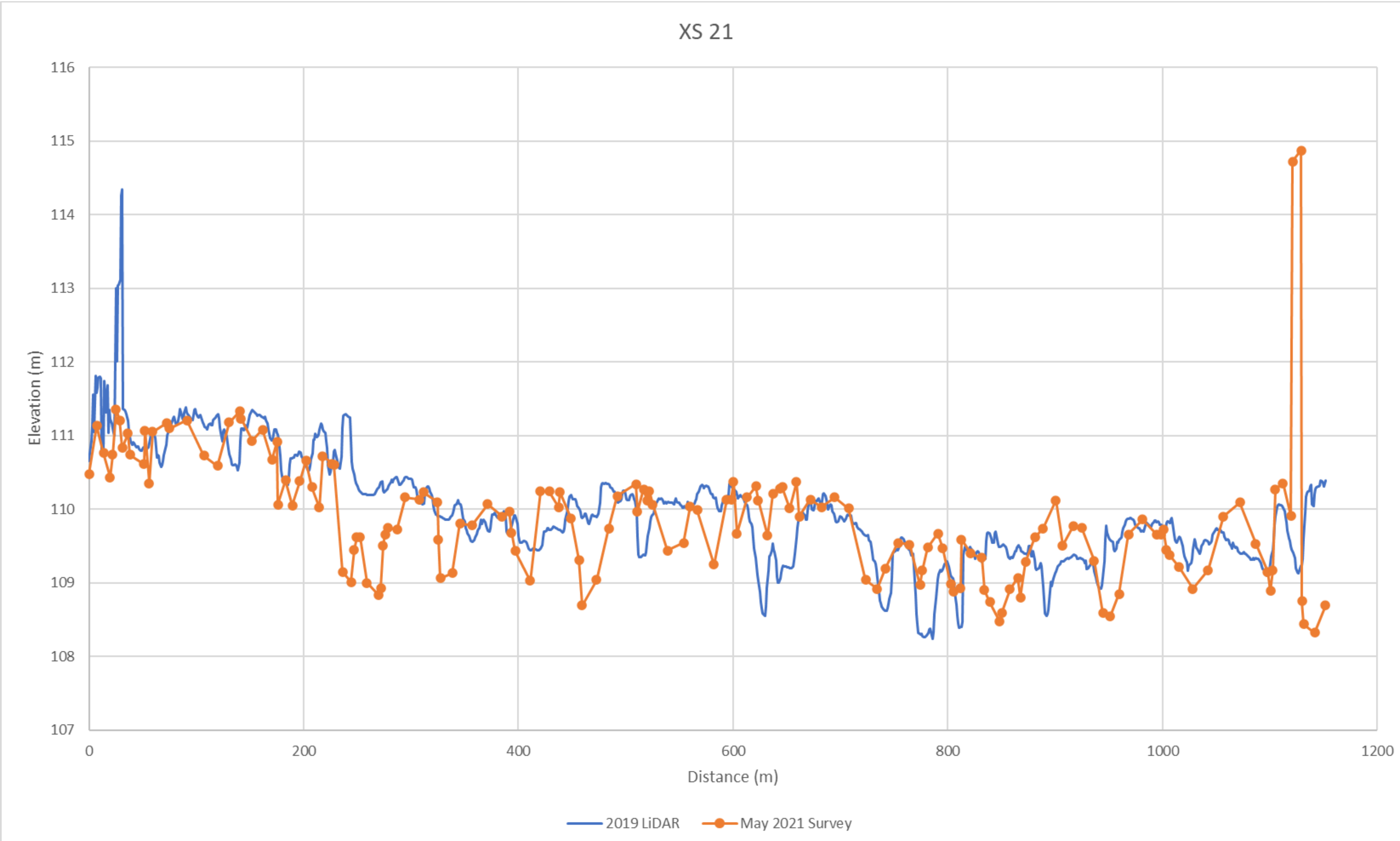
200
400
600
800
1000
1200
1400
Distance (m)
2019 LiDAR
May 2021 Survey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114
113
112
111
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108
107
Elevation (m)
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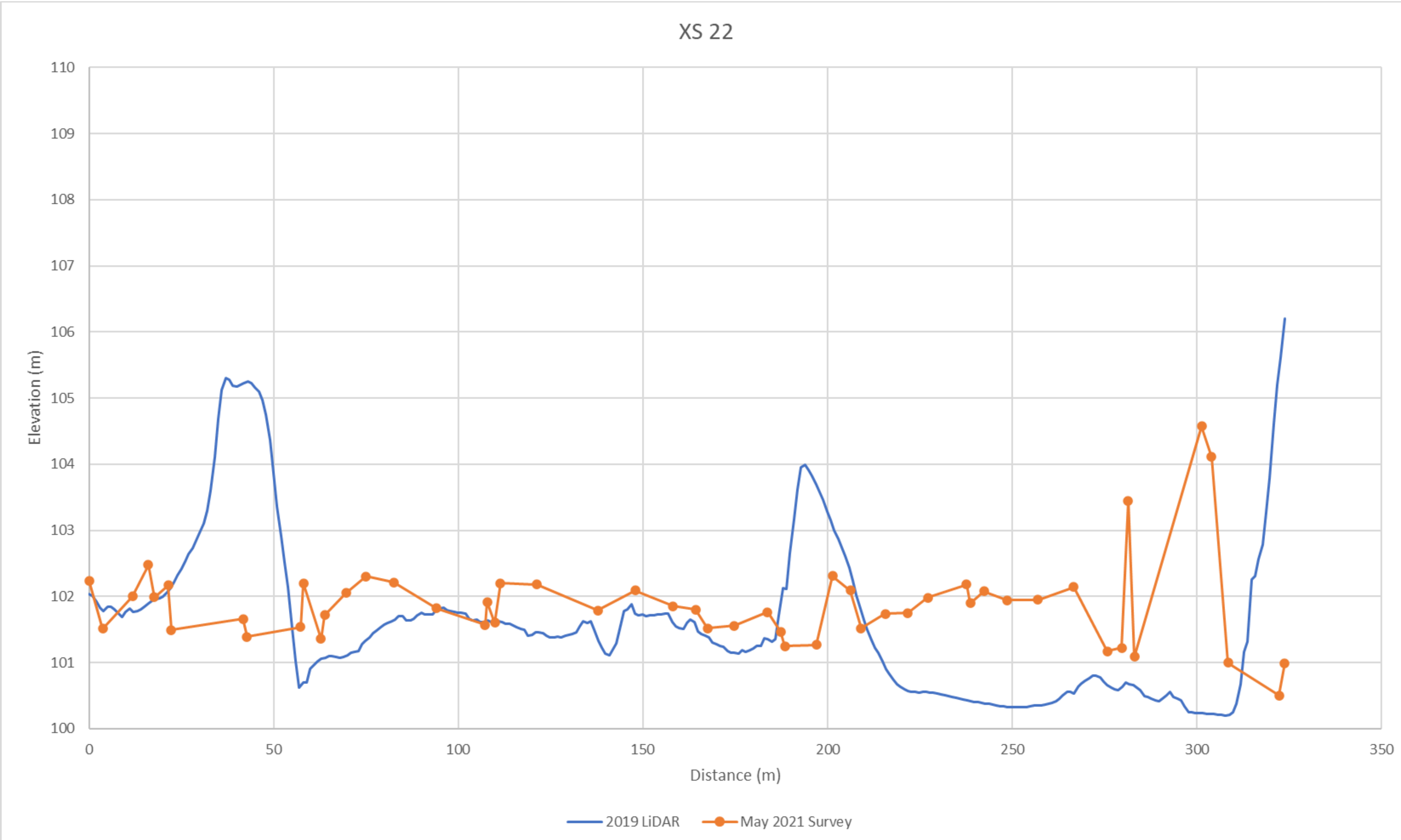
200
400
600
800
1000
1200
Distance (m)
2019 LiDAR
May 2021 Survey



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APPENDIX B – COMPARISON OF MAY 2021 CROSS SECTION SURVEY WITH MARCH 2021 SATELLITE DEM

.

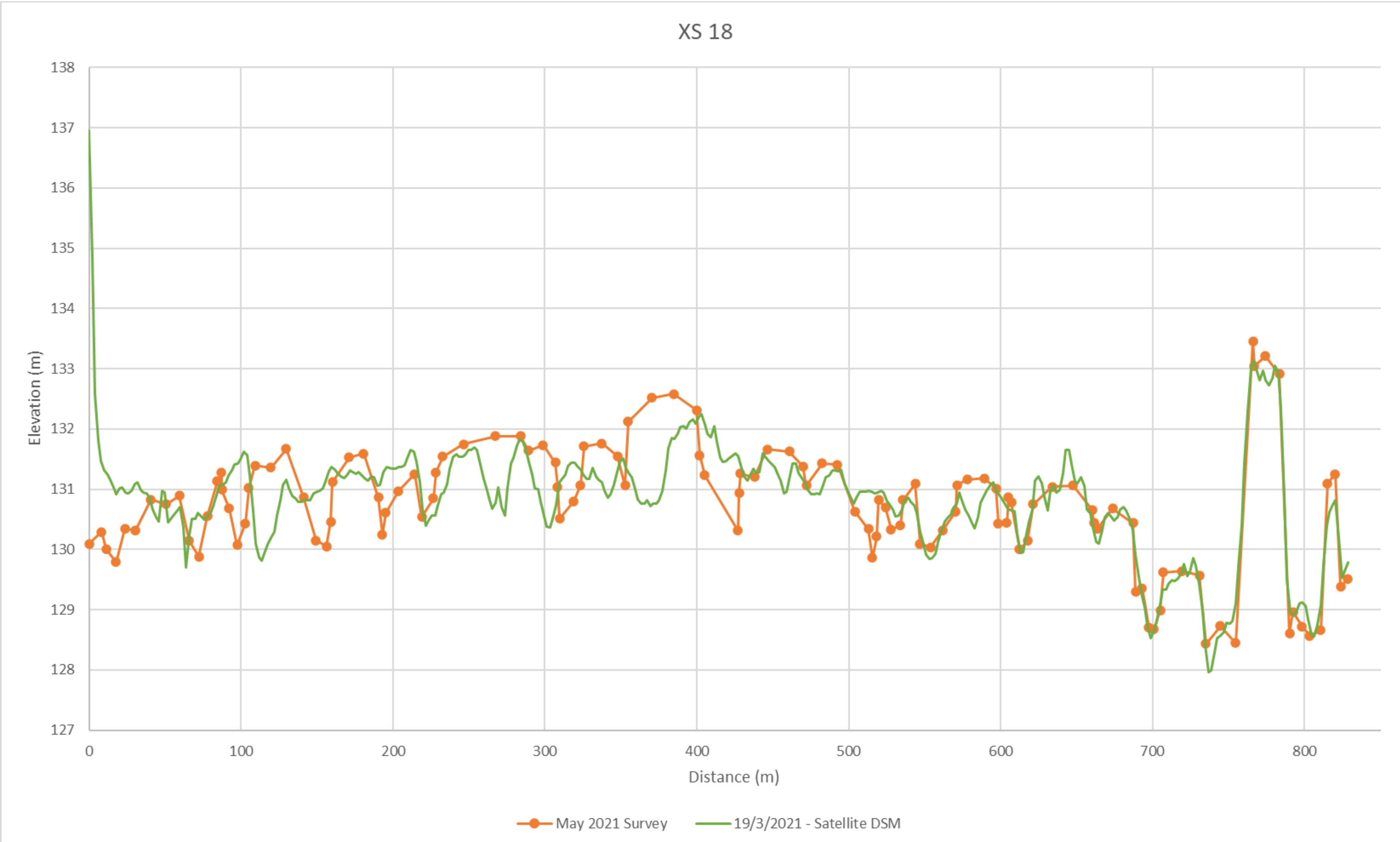

XS 13
Elevation (m)
157
156
155
154
153
152
151
150
149
148
0
50
100
150
200
250
Distance (m)
May 2021 Survey
19/3/2021 - Satellite DSM


XS 14
154
153
152
151
150
149
148
147
146
145
Elevation (m)
0
50
100
150
200
250
300
Distance (m)
May 2021 Survey
19/3/2021 - Satellite DSM


XS 15
Elevation (m)
150
149
148
147
146
145
144
143
142
141
0
50
100
150
200
250
300
350
400
Distance (m)
May 2021 Survey
19/3/2021 - Satellite DSM

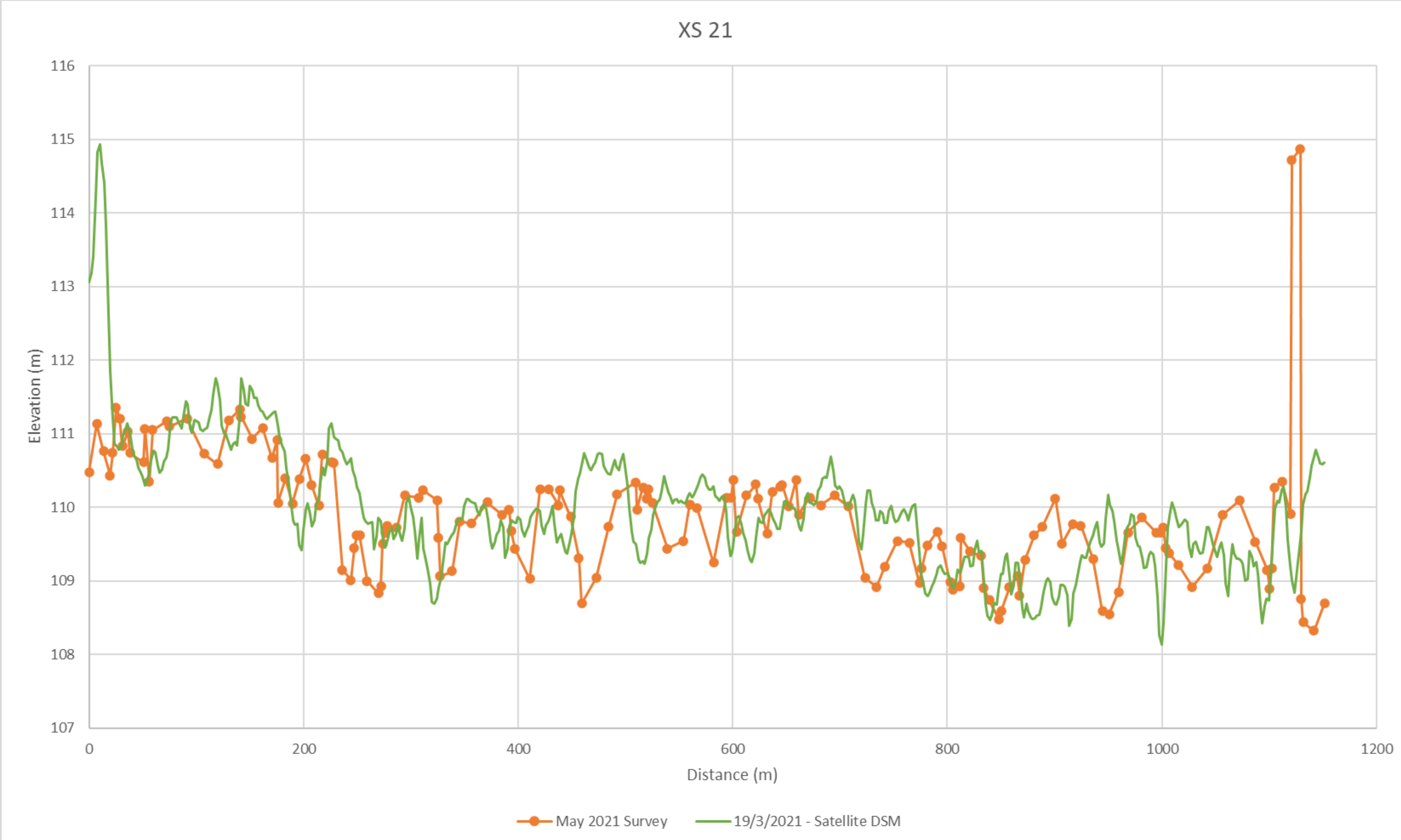

XS 16
148
146
144
142
140
138
136
134
Elevation (m)
0
100
200
300
400
500
600
700
800
900
Distance (m)
May 2021 Survey
19/3/2021 - Satellite DSM

LANDRIVERSEA CONSULTING

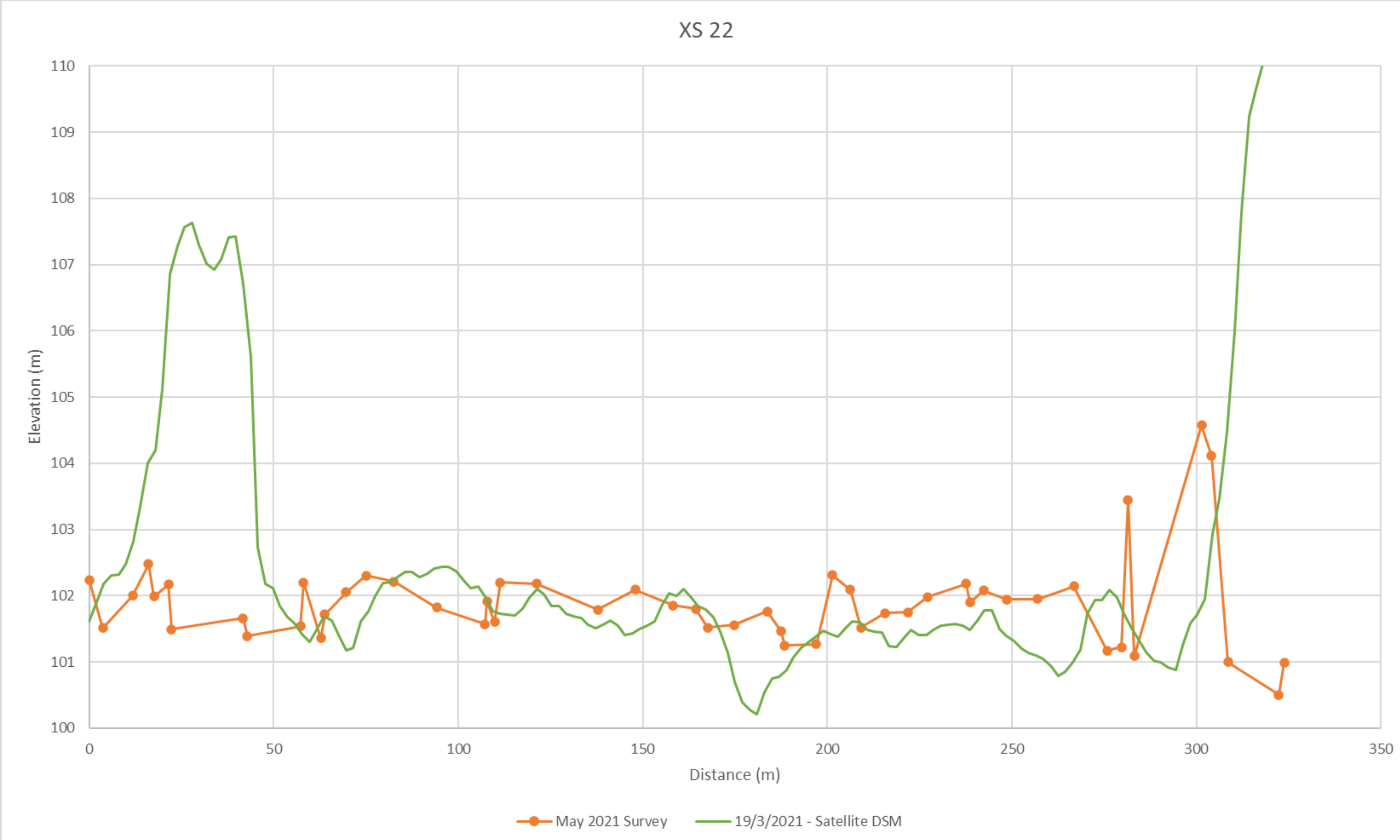

XS 18
Elevation (m)
138
137
136
135
134
133
132
131
130
129
128
127
0
100
200
300
400
500
600
700
800
Distance (m)
May 2021 Survey
19/3/2021 - Satellite DSM


XS 19
130
129
128
127
126
125
124
123
Elevation (m)
0
100
200
300
400
500
600
700
Distance (m)
May 2021 Survey
19/3/2021 - Satellite DSM


XS 20
Elevation (m)
126
124
122
120
118
116
114
112
0
200
400
600
800
1000
1200
1400
Distance (m)
May 2021 Survey
19/3/2021 - Sattelite DSM



LANDRIVERSEA CONSULTING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Elevation (m)
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108
107
106
105
104
103
102
101
100
0
50
100
150
200
250
300
350
Distance (m)
May 2021 Survey
19/3/2021 - Satellite DSM

Figure 0-1 to Figure 0-5 show the location used for the distance marker for each of the longsection profiles presented in the following pages.

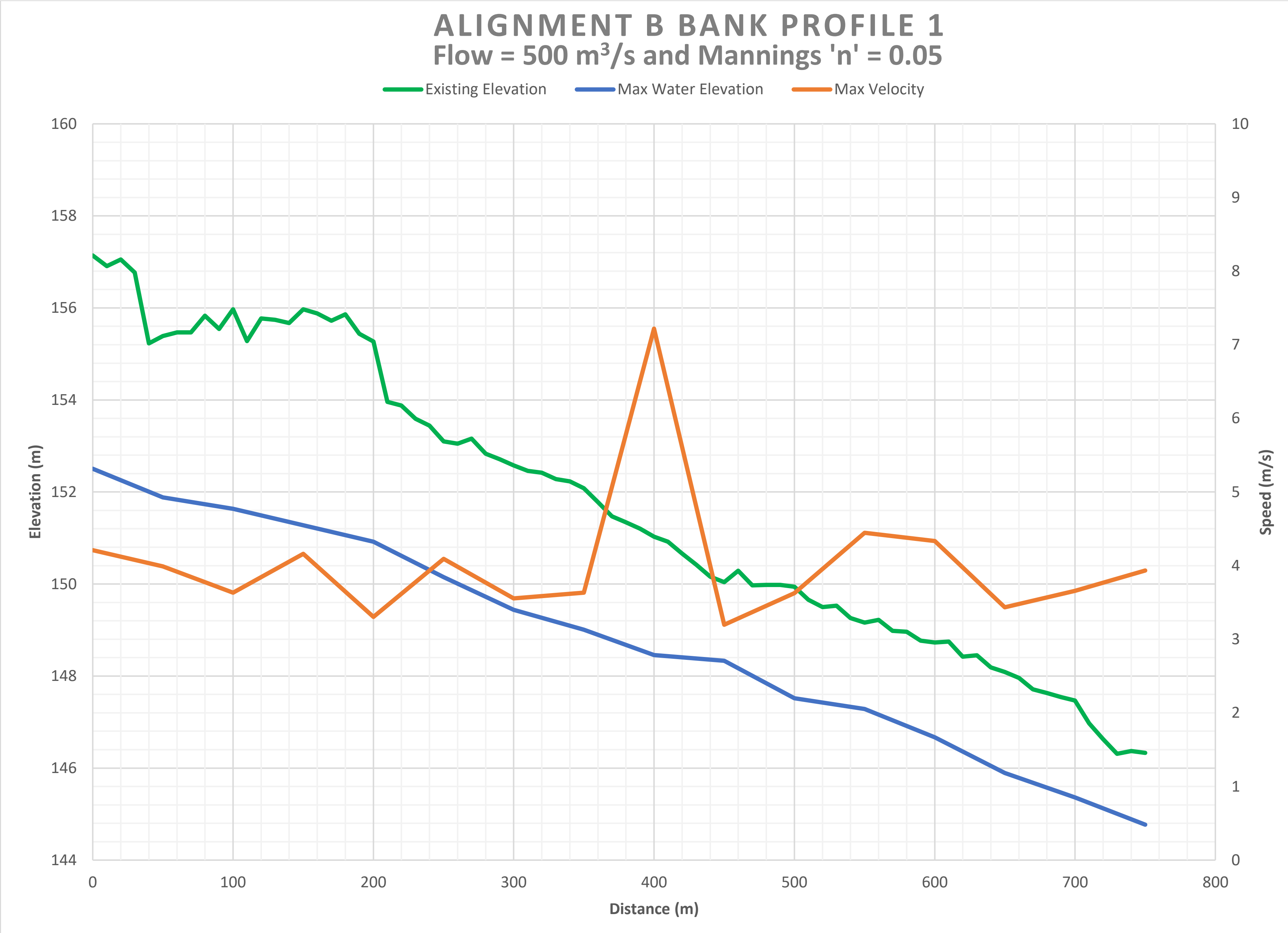
Figure 0-1 – Bank 1 profile distance markers

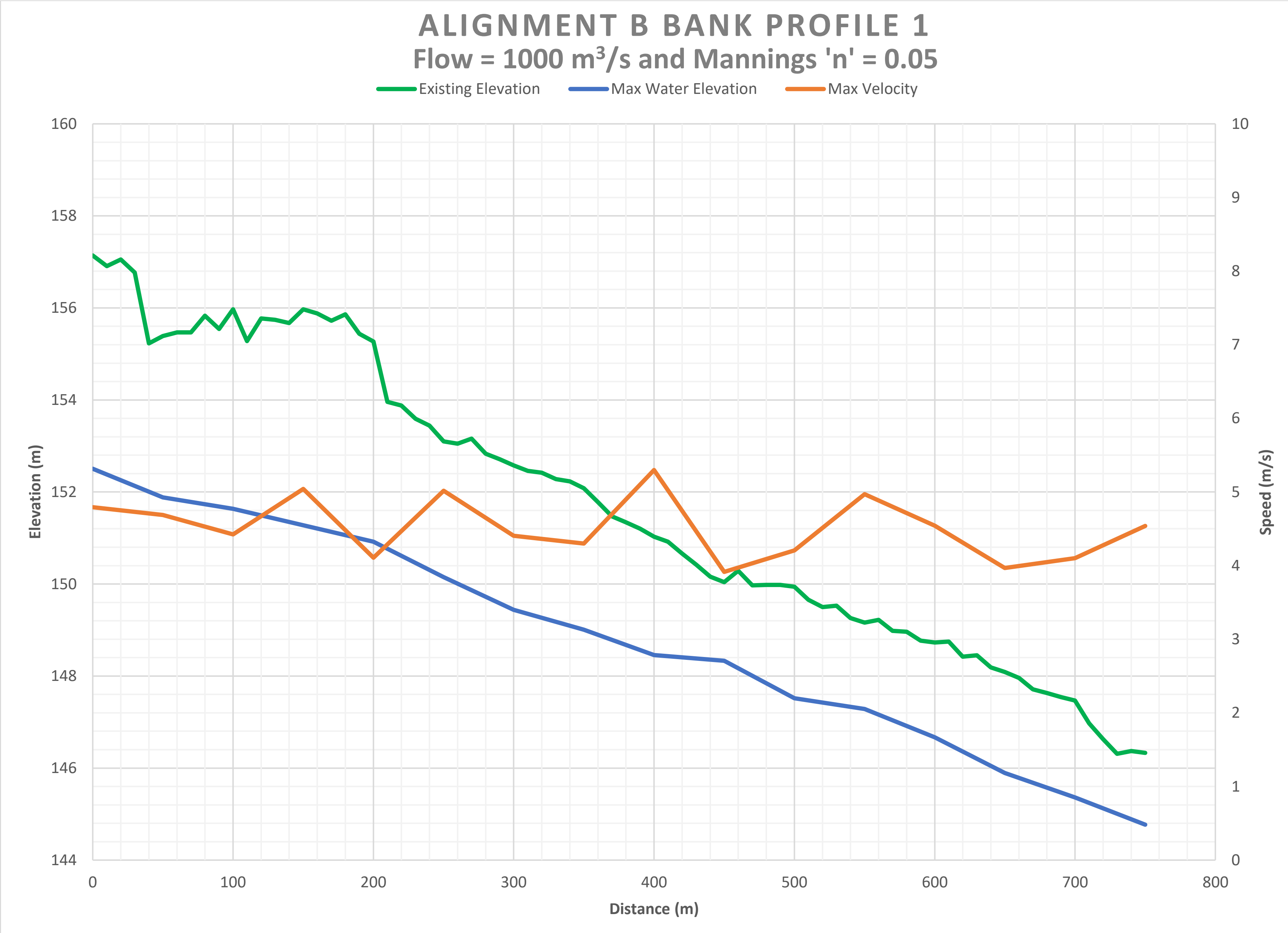
Figure 0-2 – Bank 2, Existing Alignment, distance markers

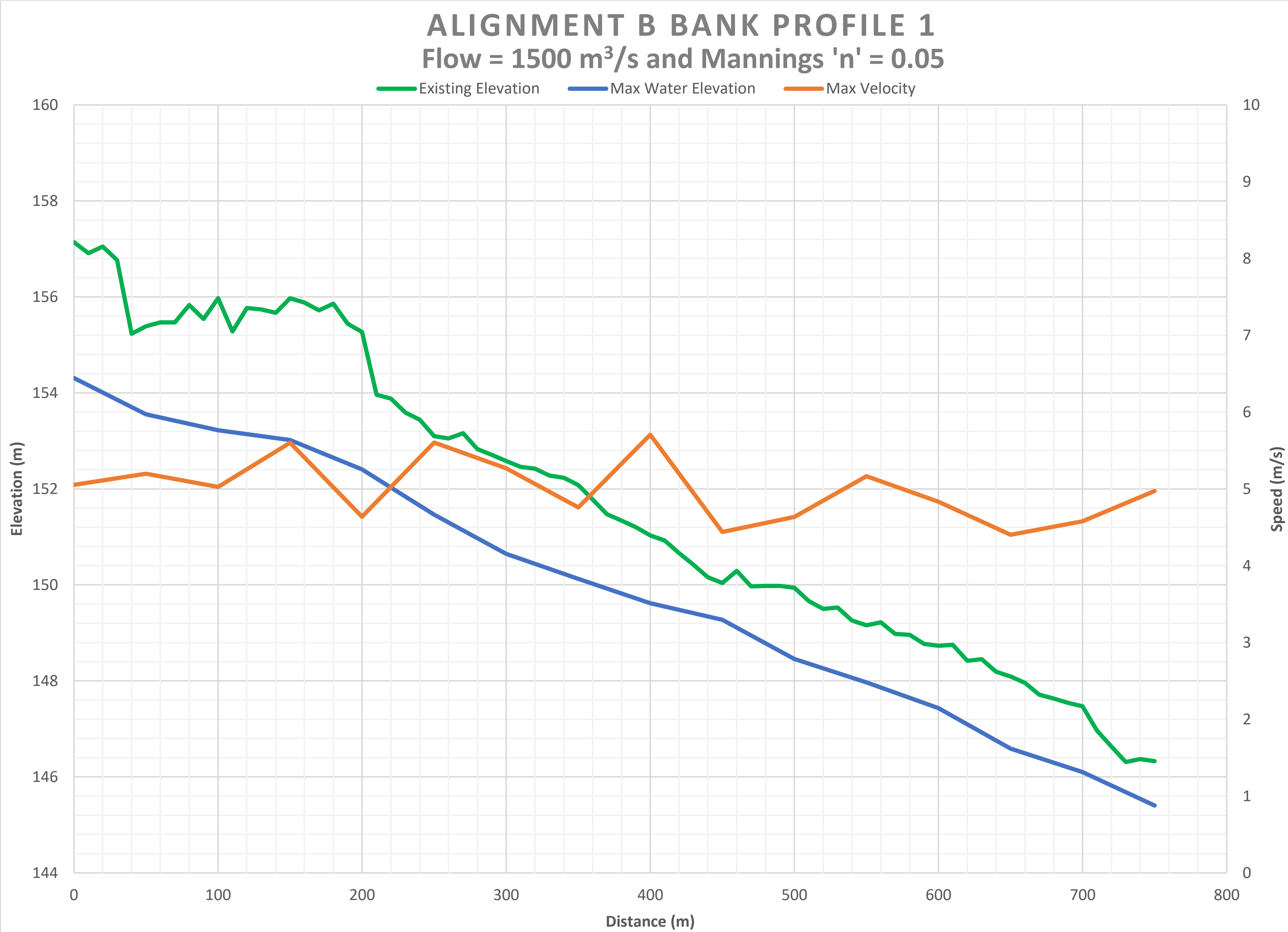
Figure 0-3 – Bank 2 – Alignment A distance markers

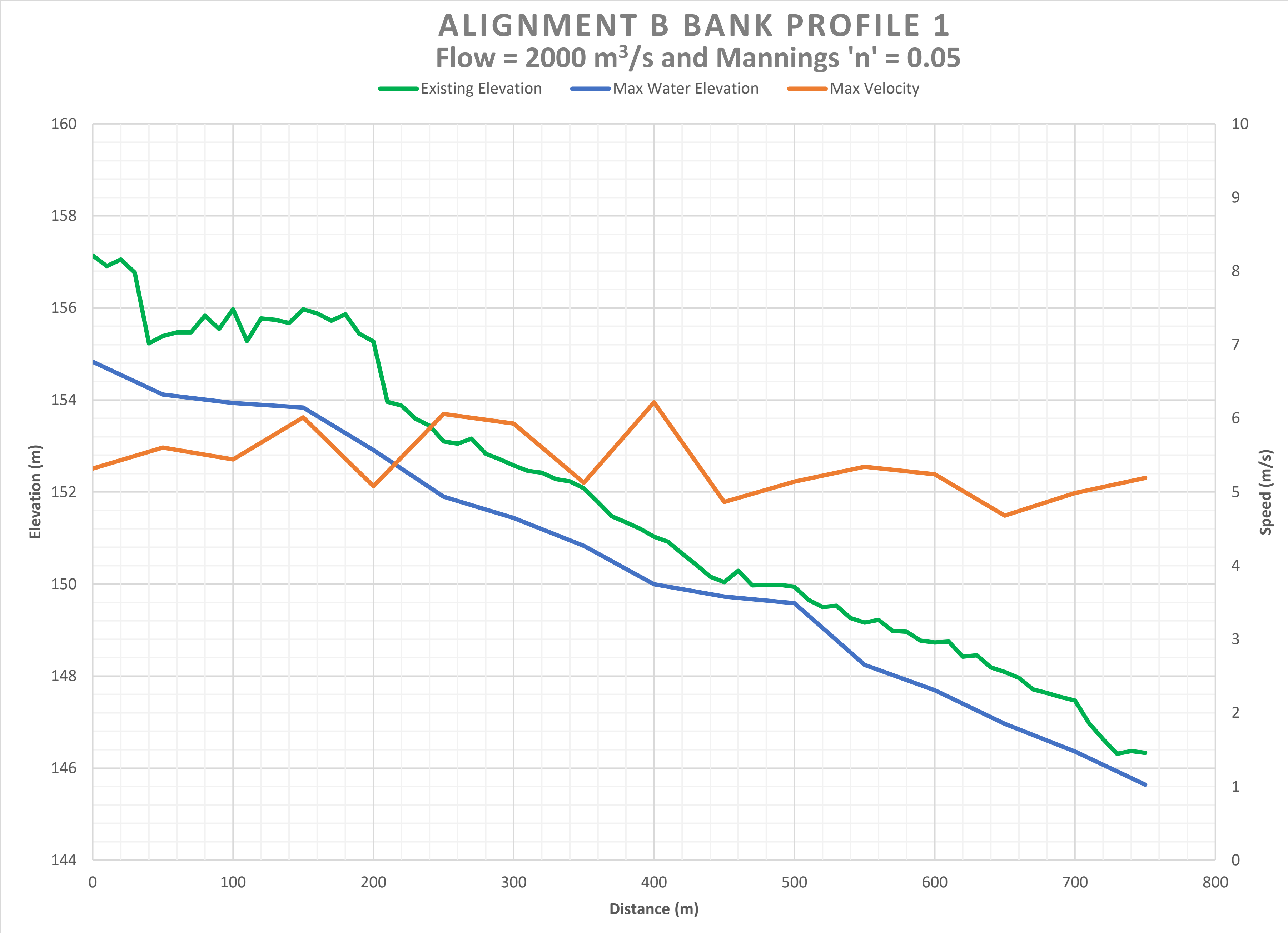
Figure 0-4 – Bank 2 – Alignment B distance marker

Figure 0-5 – Bank 2 – Alignment C distance markers


ALIGNMENT B BANK PROFILE 1
Flow = 500 m³/s and Mannings 'n' = 0.05
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800


ALIGNMENT B BANK PROFILE 1
Flow = 1000 m3/s and Mannings 'n' = 0.05
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800


ALIGNMENT B BANK PROFILE 1
Flow = 1500 m3/s and Mannings 'n' = 0.05
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800


ALIGNMENT B BANK PROFILE 1
Flow = 2000 m³/s and Mannings 'n' = 0.05
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
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6
5
4
3
2
1
0
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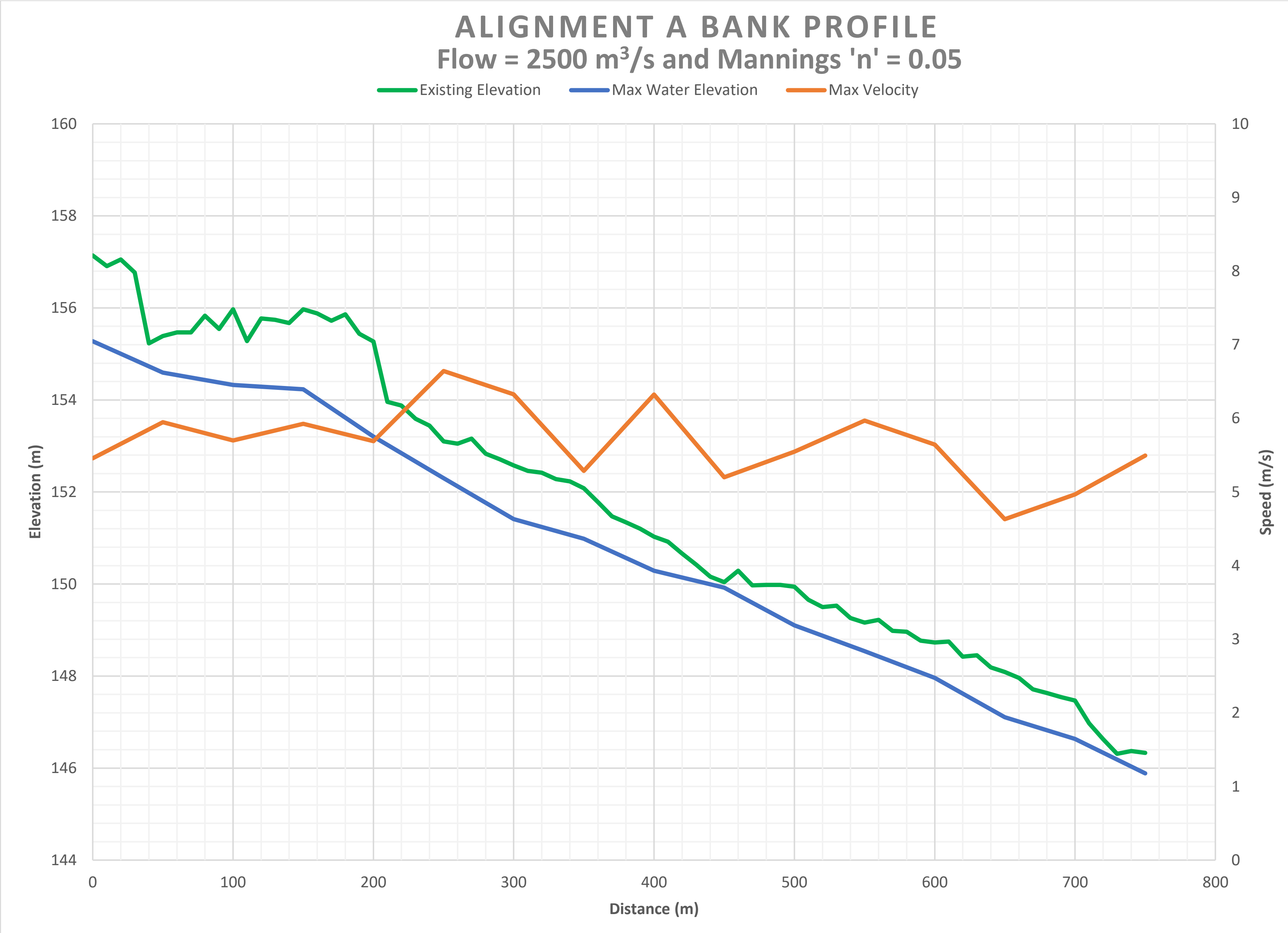

ALIGNMENT A BANK PROFILE
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Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
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8
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4
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2
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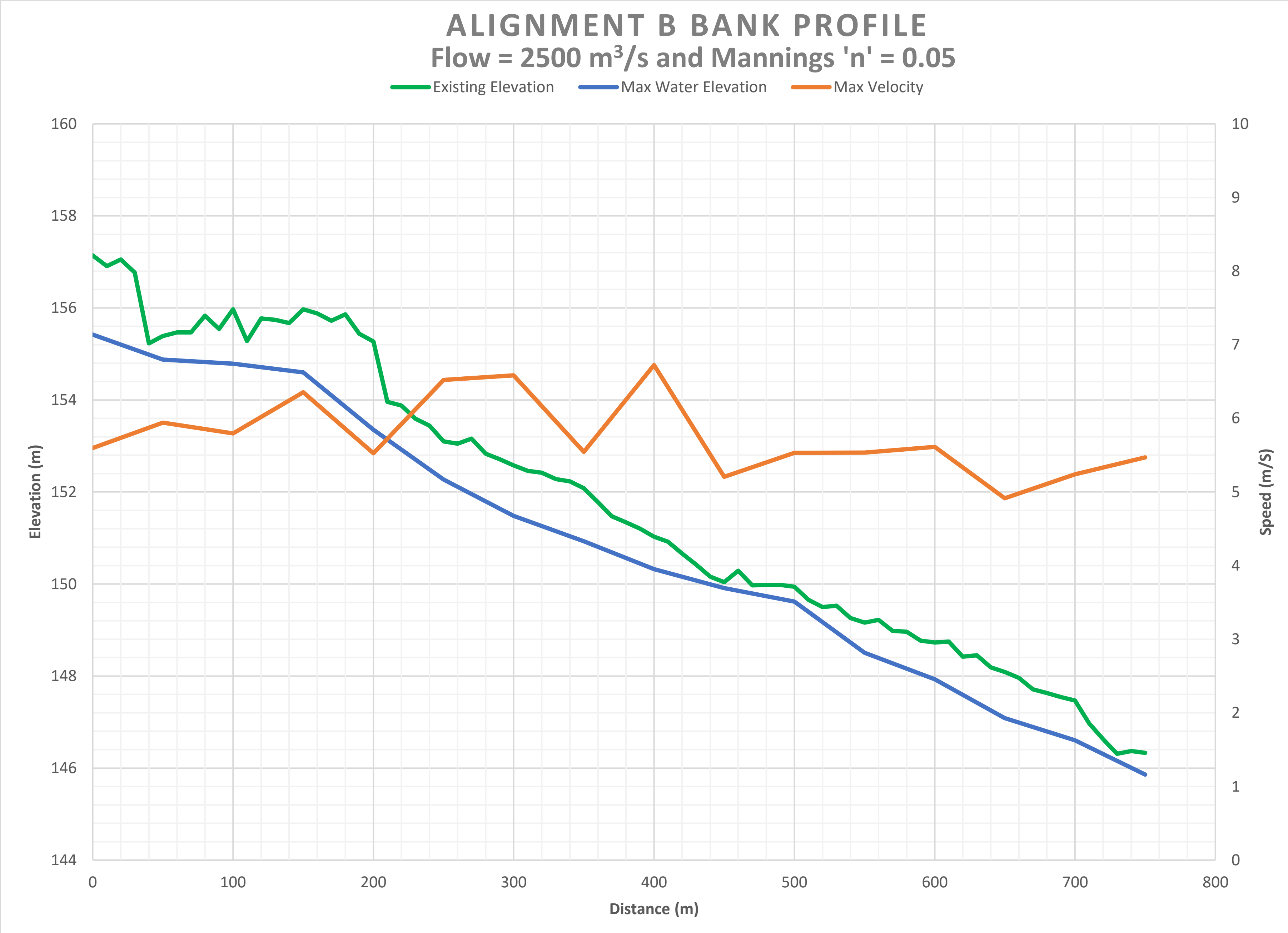
800


ALIGNMENT B BANK PROFILE
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Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/S)
Distance (m)
160
158
156
154
152
150
148
146
144
10
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6
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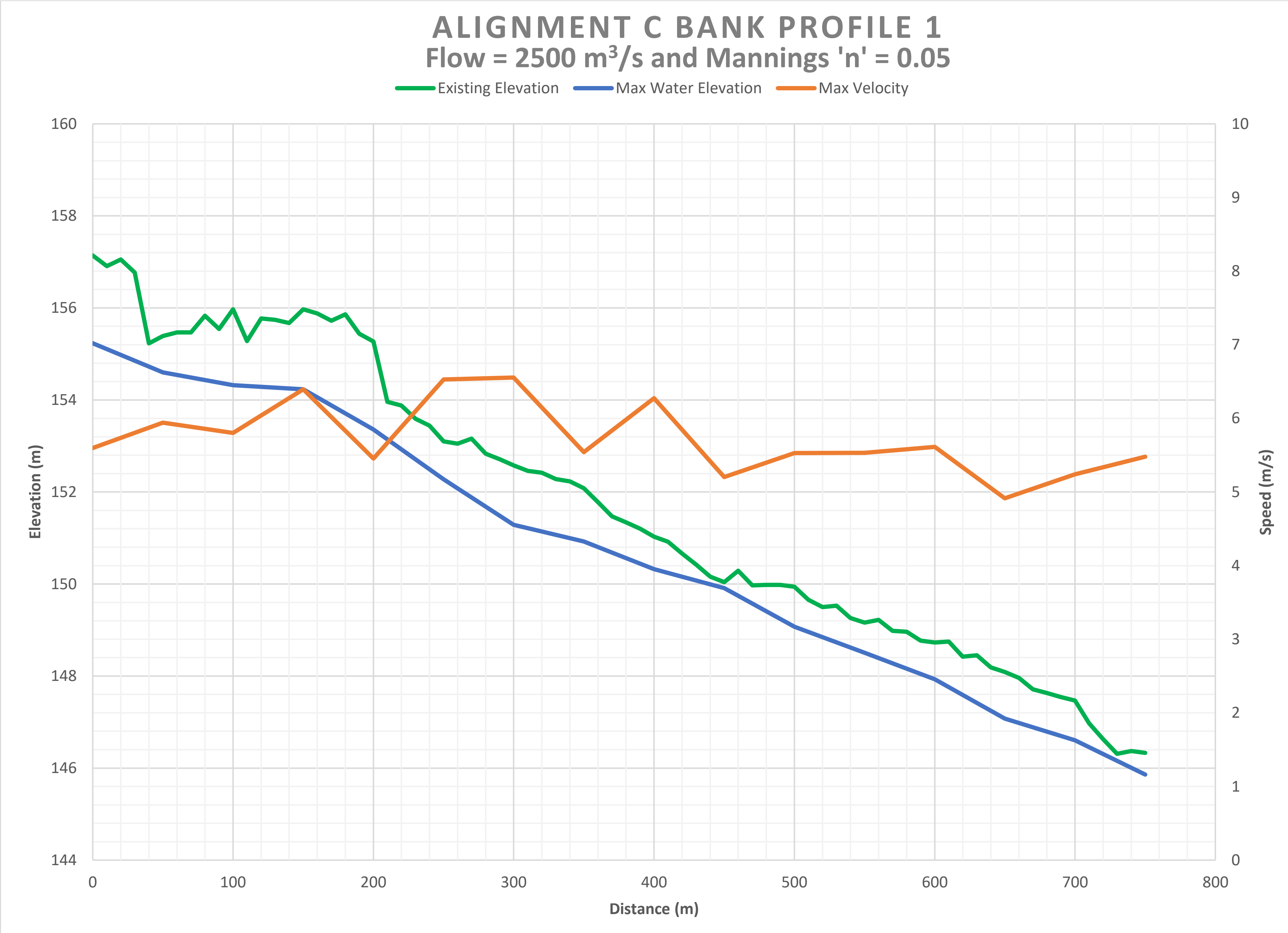

ALIGNMENT C BANK PROFILE 1
Flow = 2500 m3/s and Mannings 'n' = 0.05
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800


EXISTING ALIGNMENT BANK PROFILE 1
Flow = 2500 m3/s and Mannings 'n' = 0.05
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
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8
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2
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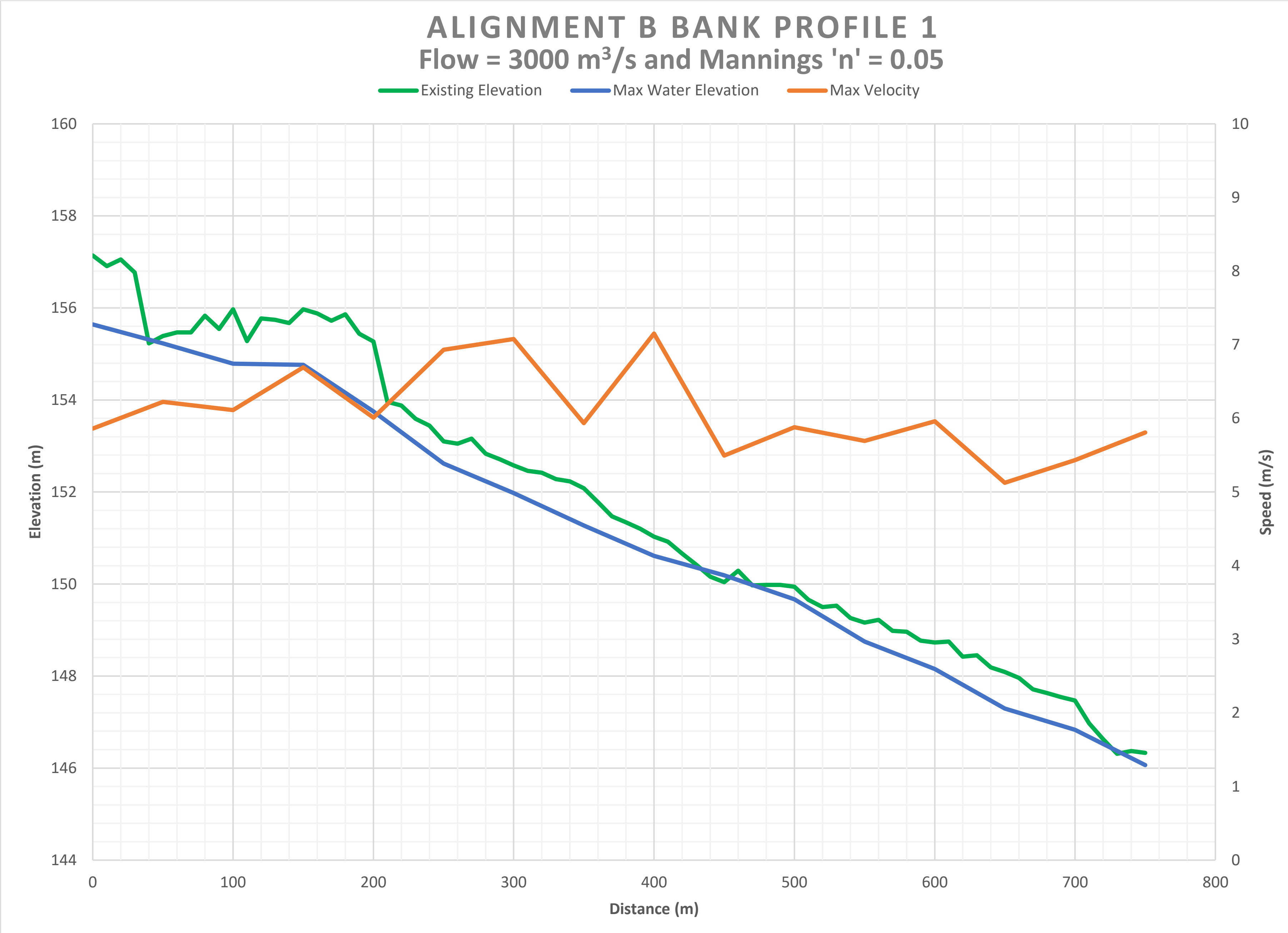
ALIGNMENT B BANK PROFILE 1
Flow = 3000 m³/s and Mannings 'n' = 0.05
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Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
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10
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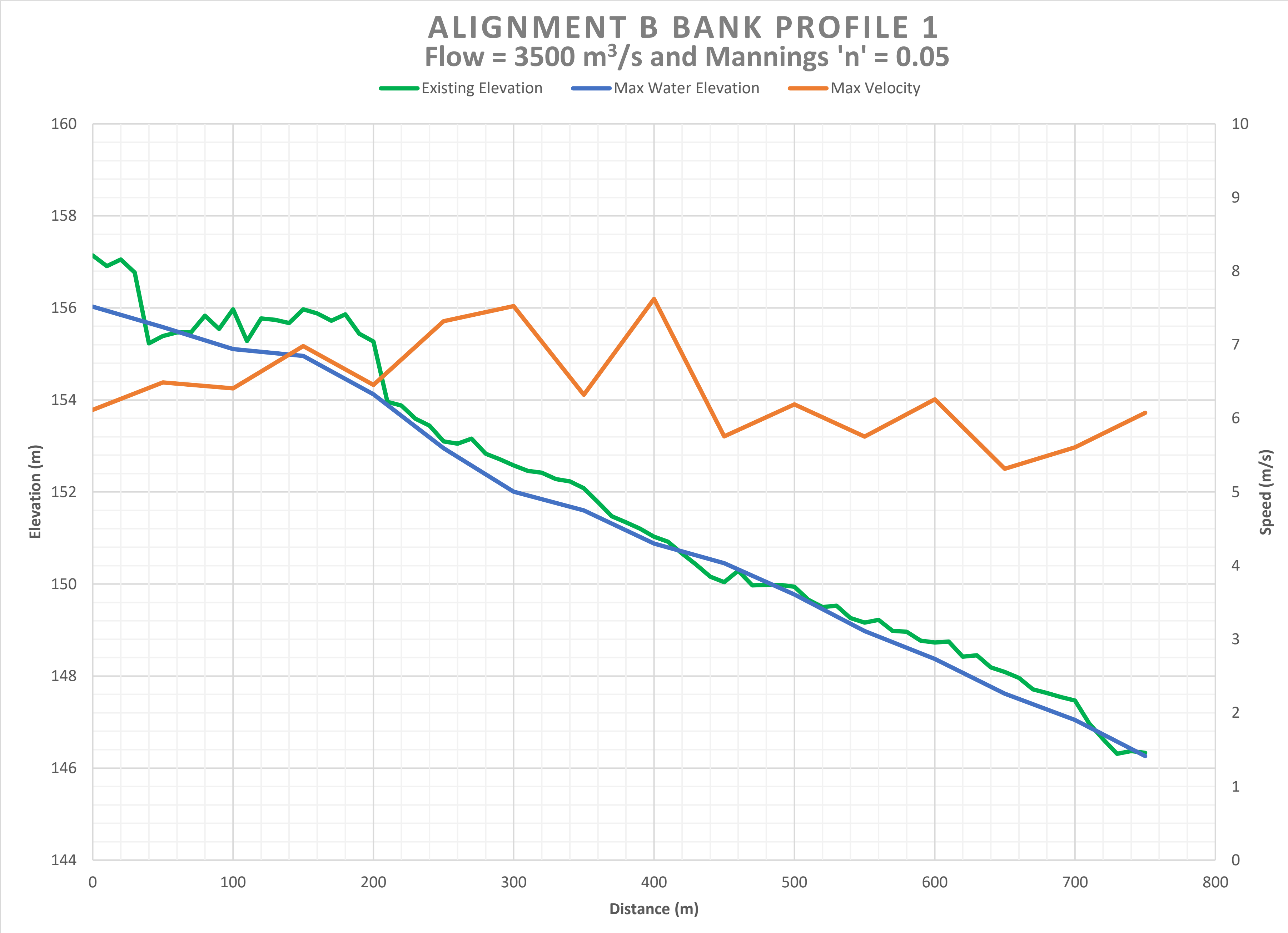

ALIGNMENT B BANK PROFILE 1
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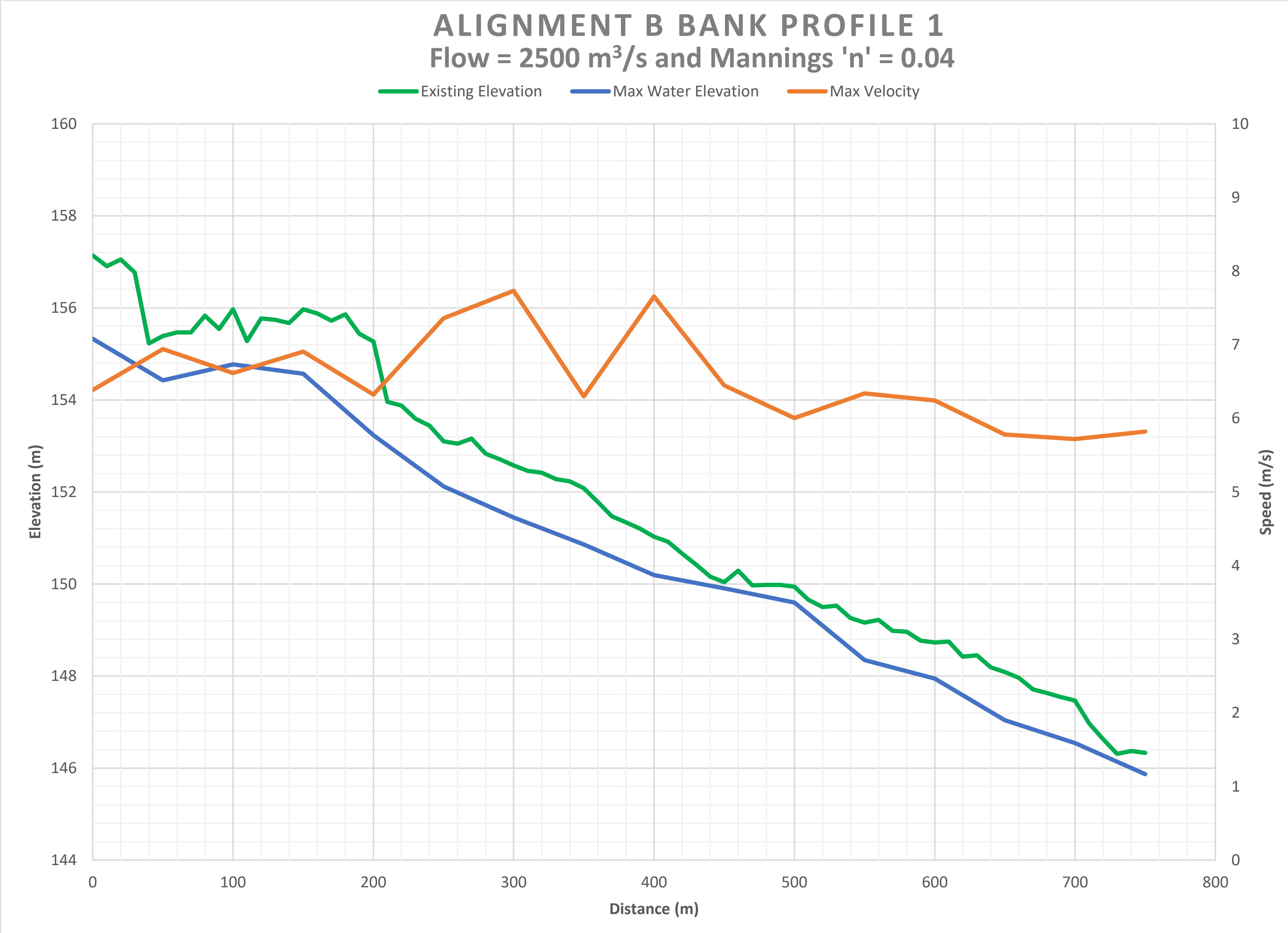
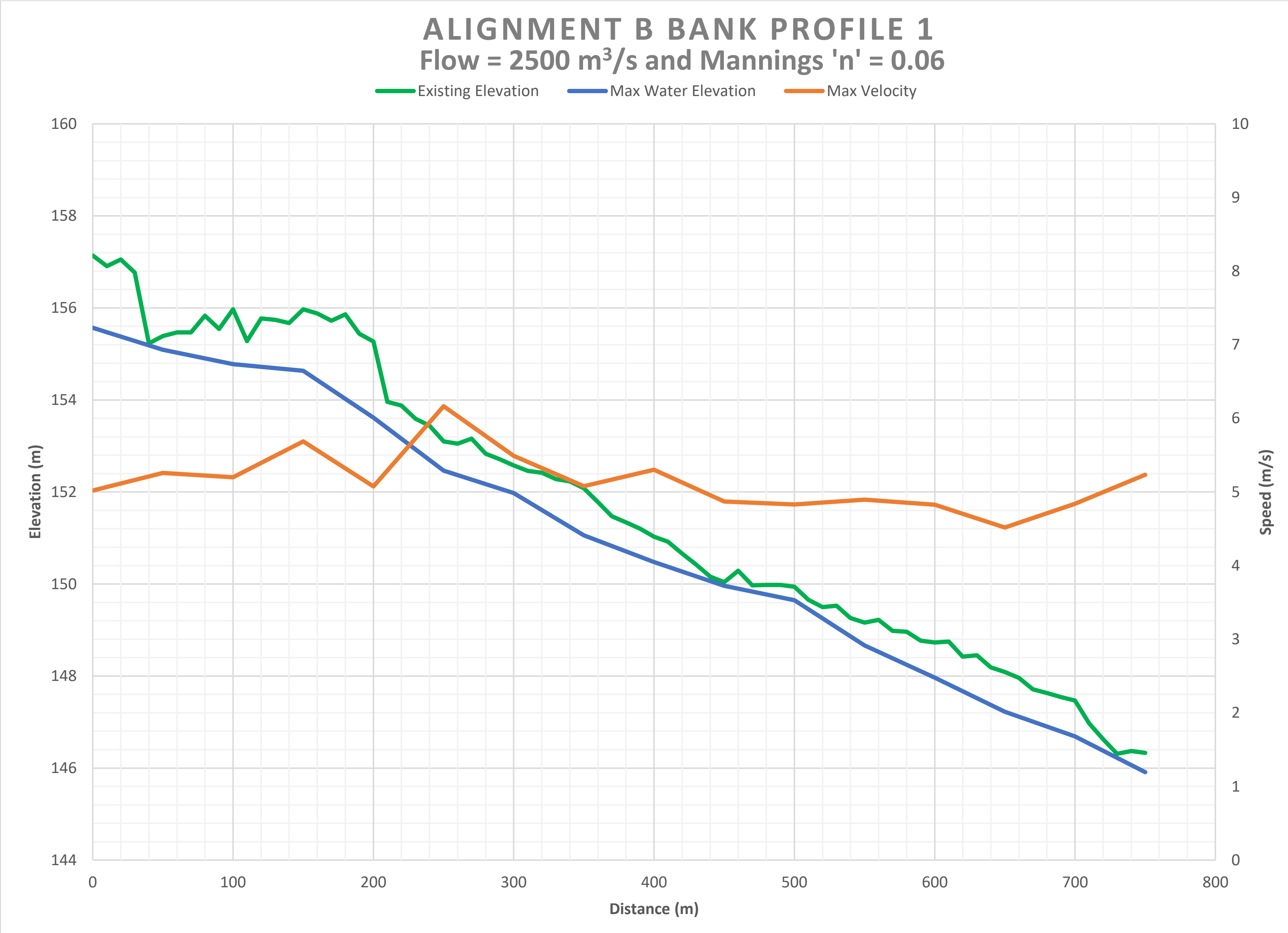
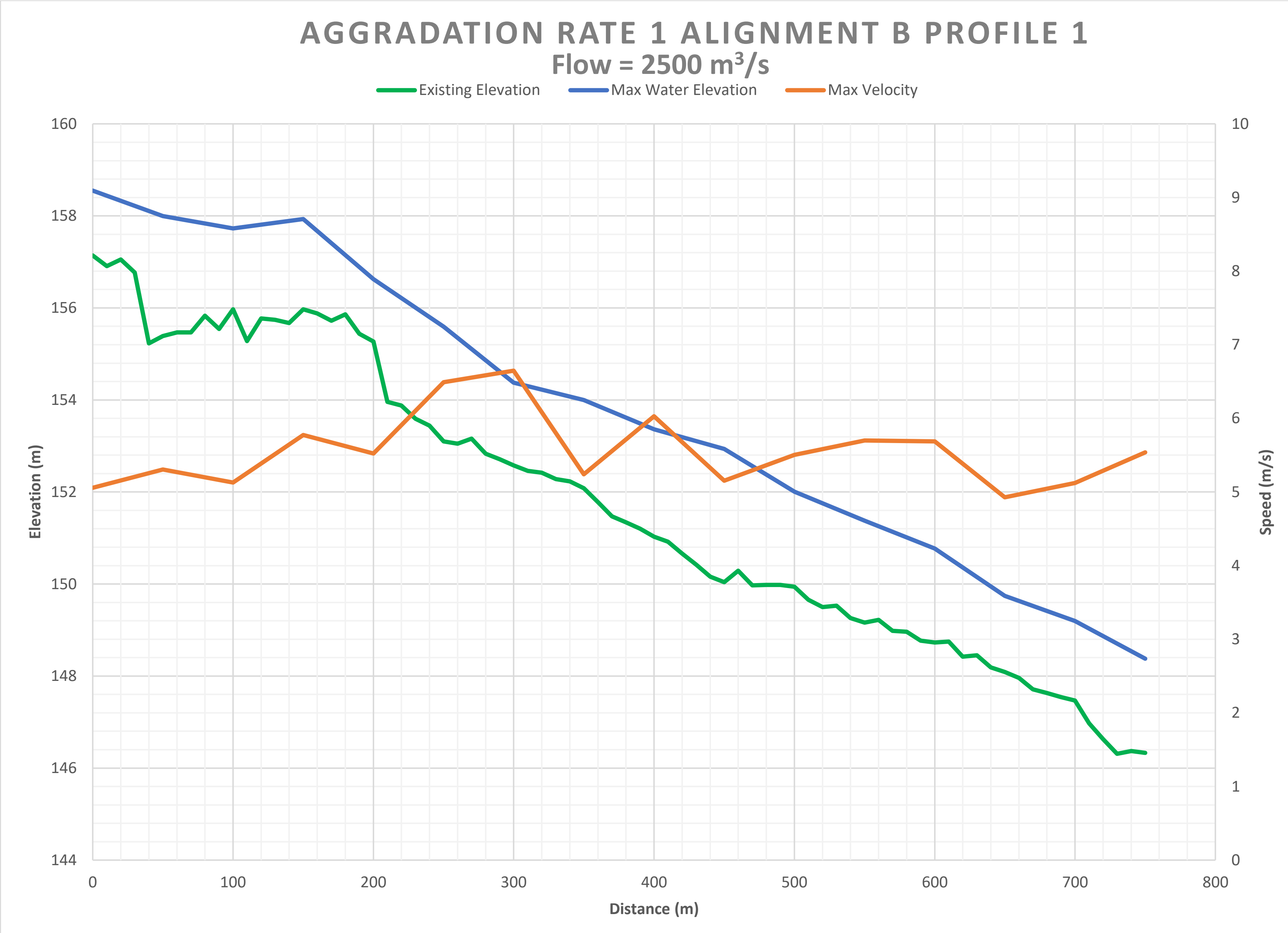
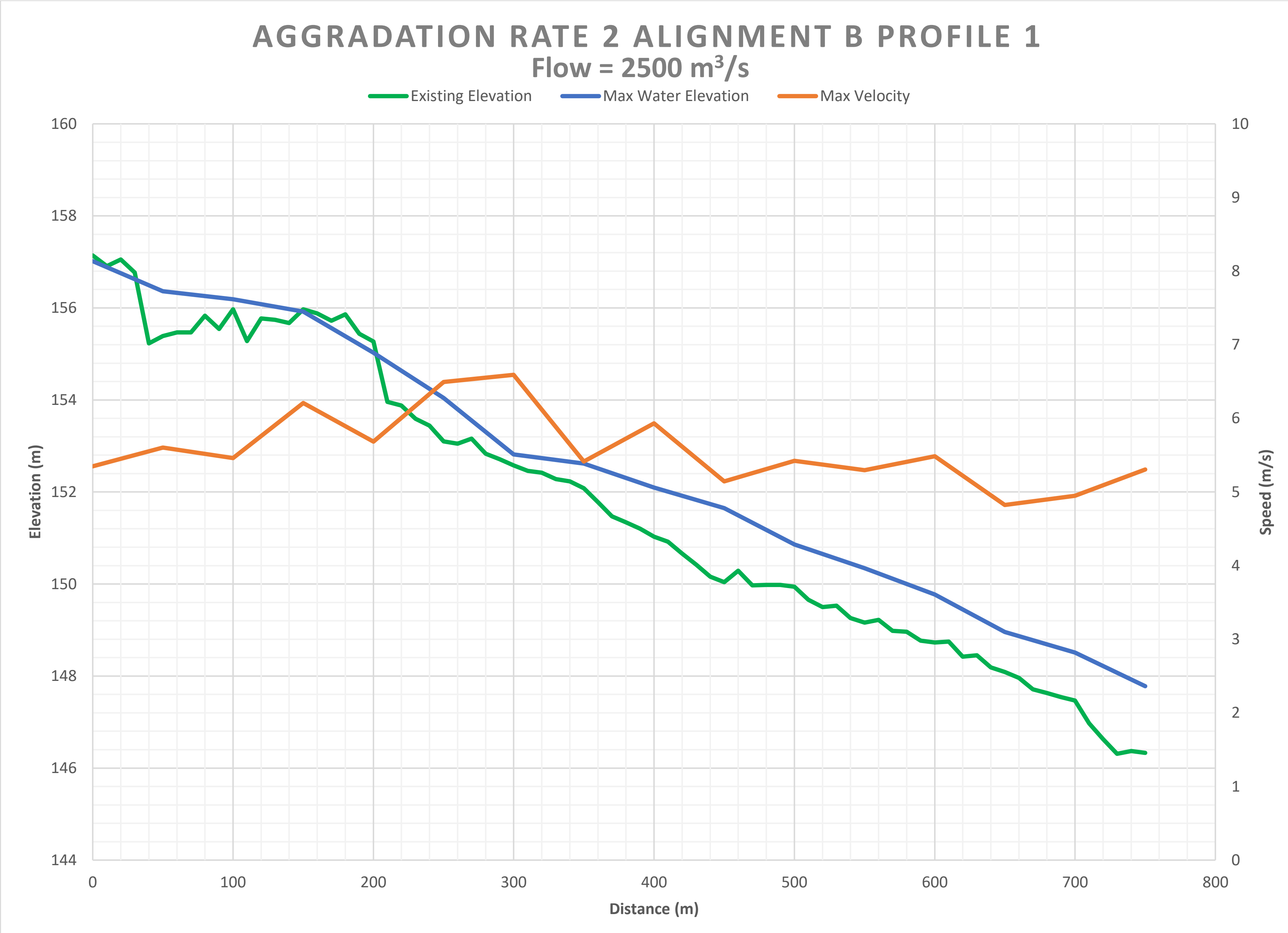
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800

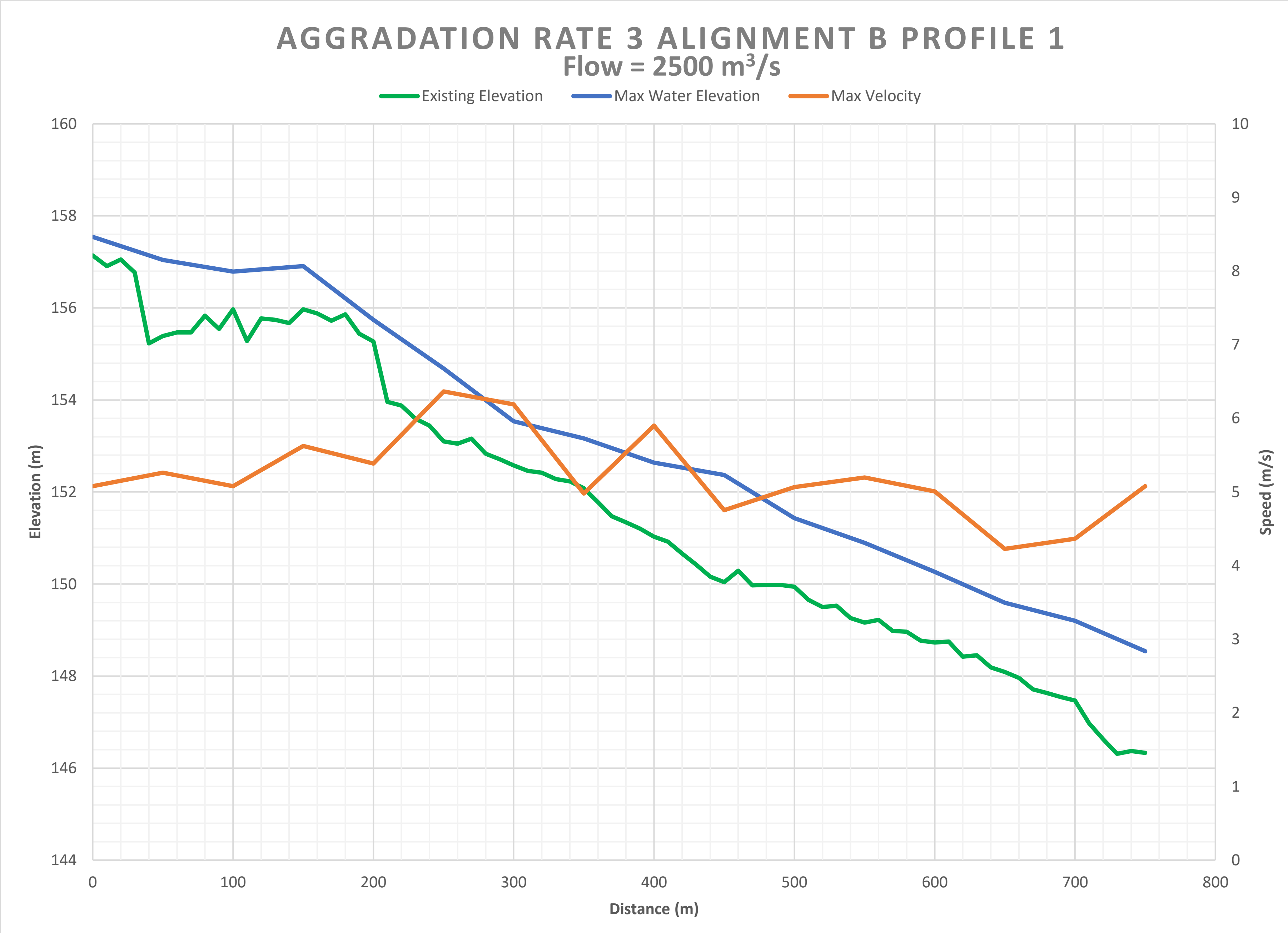

ALIGNMENT B BANK PROFILE 1
Flow = 2500 m3/s and Mannings 'n' = 0.04
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800



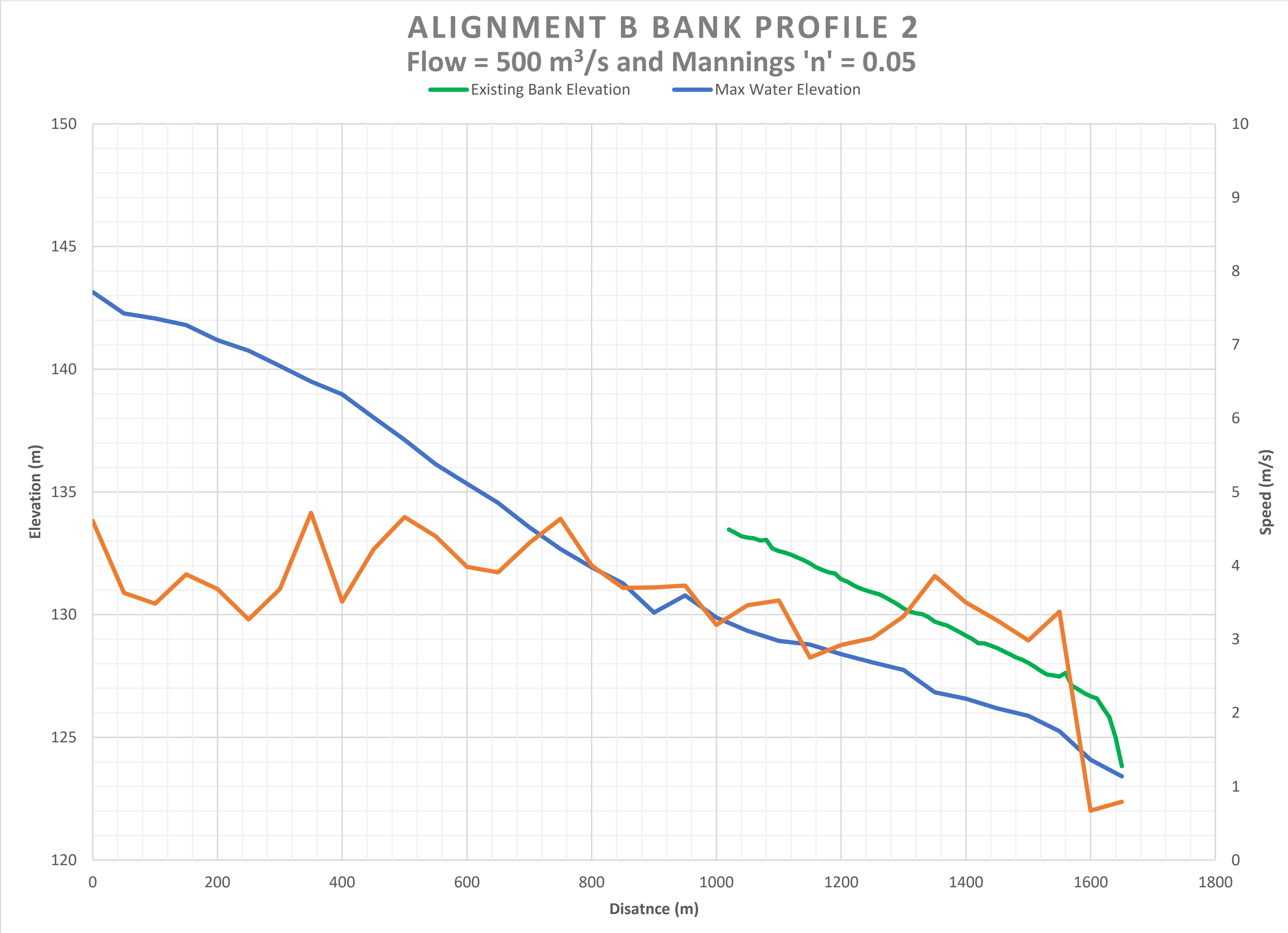
ALIGNMENT B BANK PROFILE 1
Flow = 2500 m³/s and Mannings 'n' = 0.06
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800

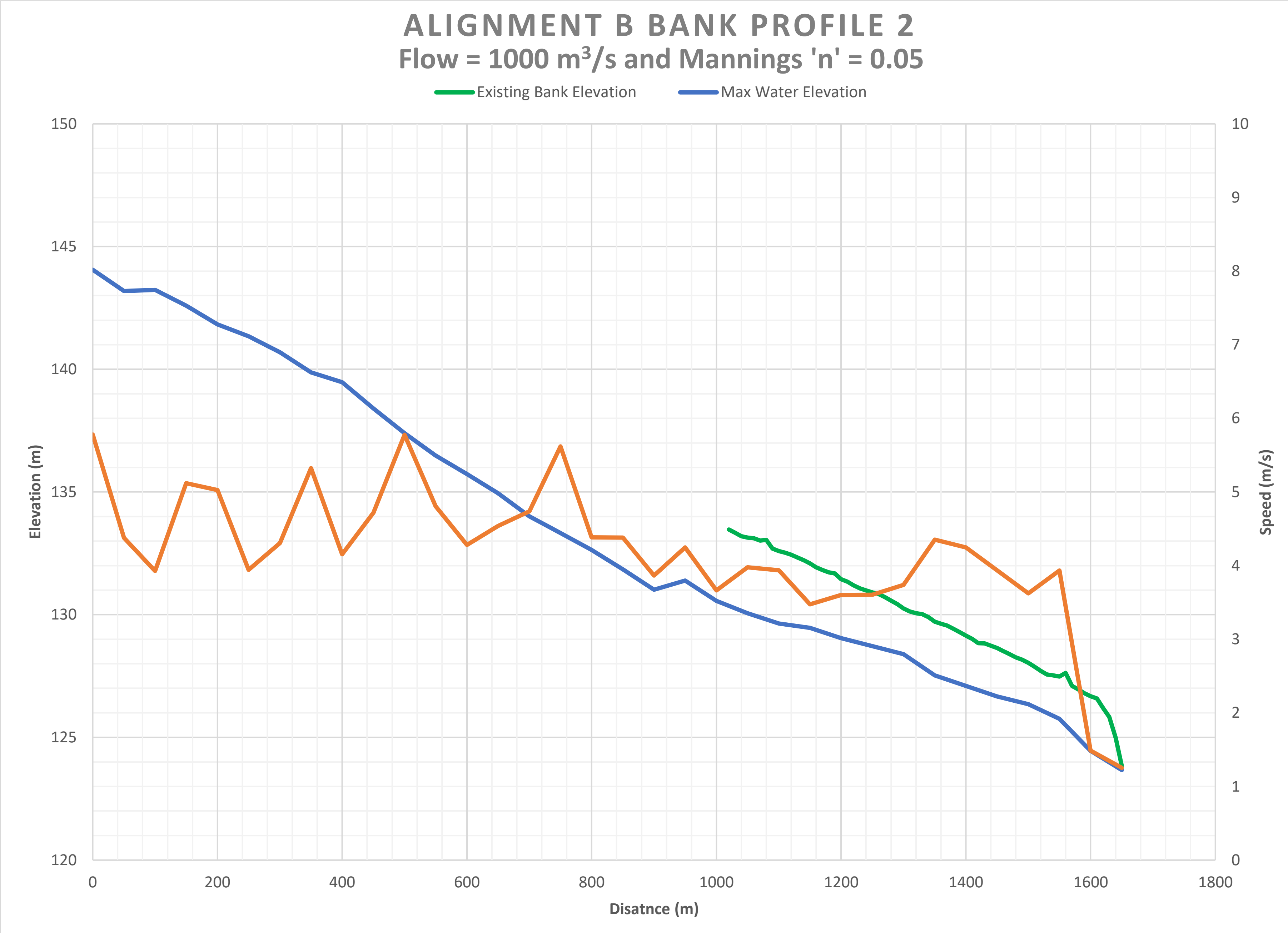

AGGRADATION RATE 1 ALIGNMENT B PROFILE 1
Flow = 2500 m³/s
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800

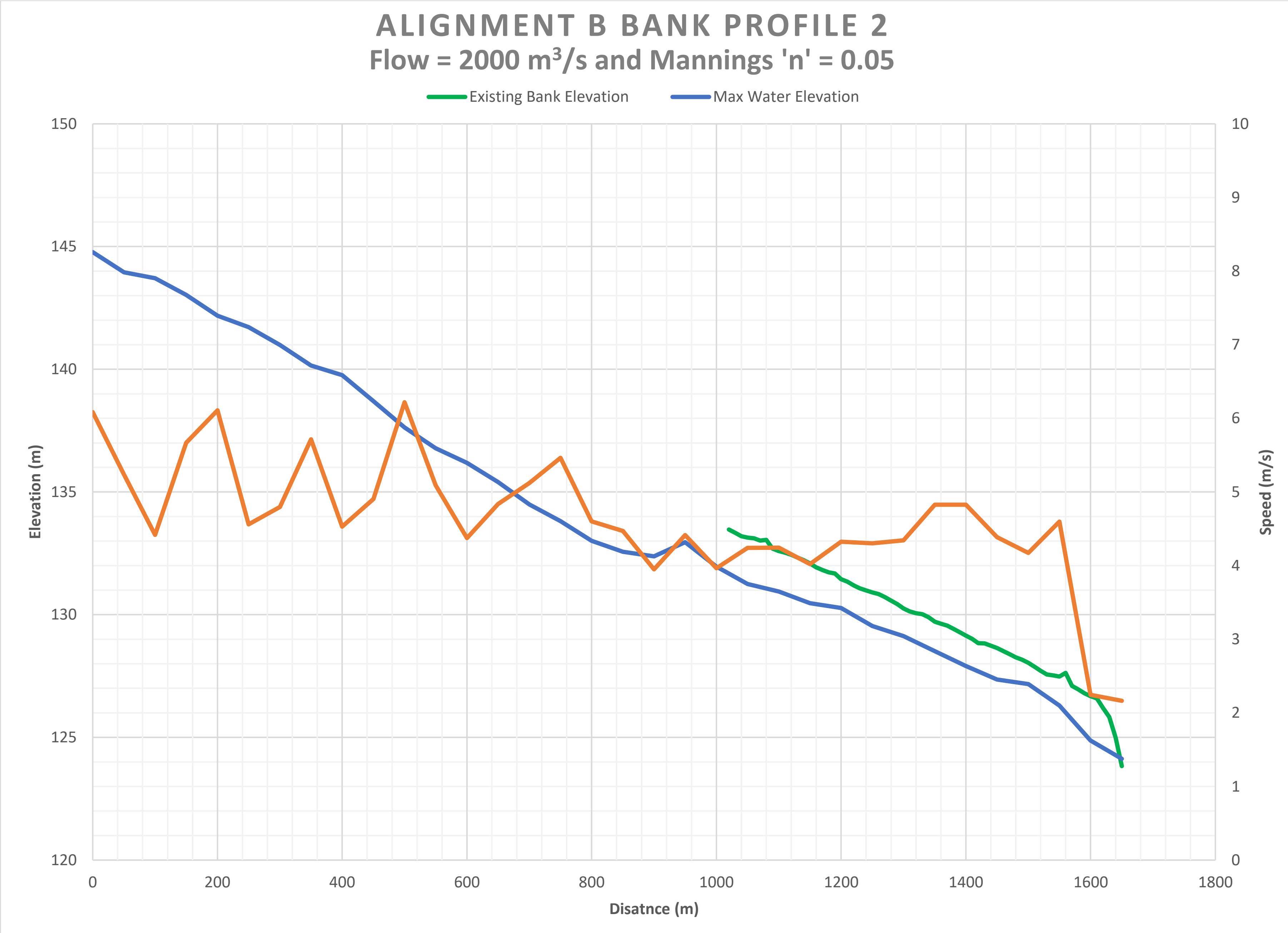

AGGRADATION RATE 2 ALIGNMENT B PROFILE 1
Flow = 2500 m3/s
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800



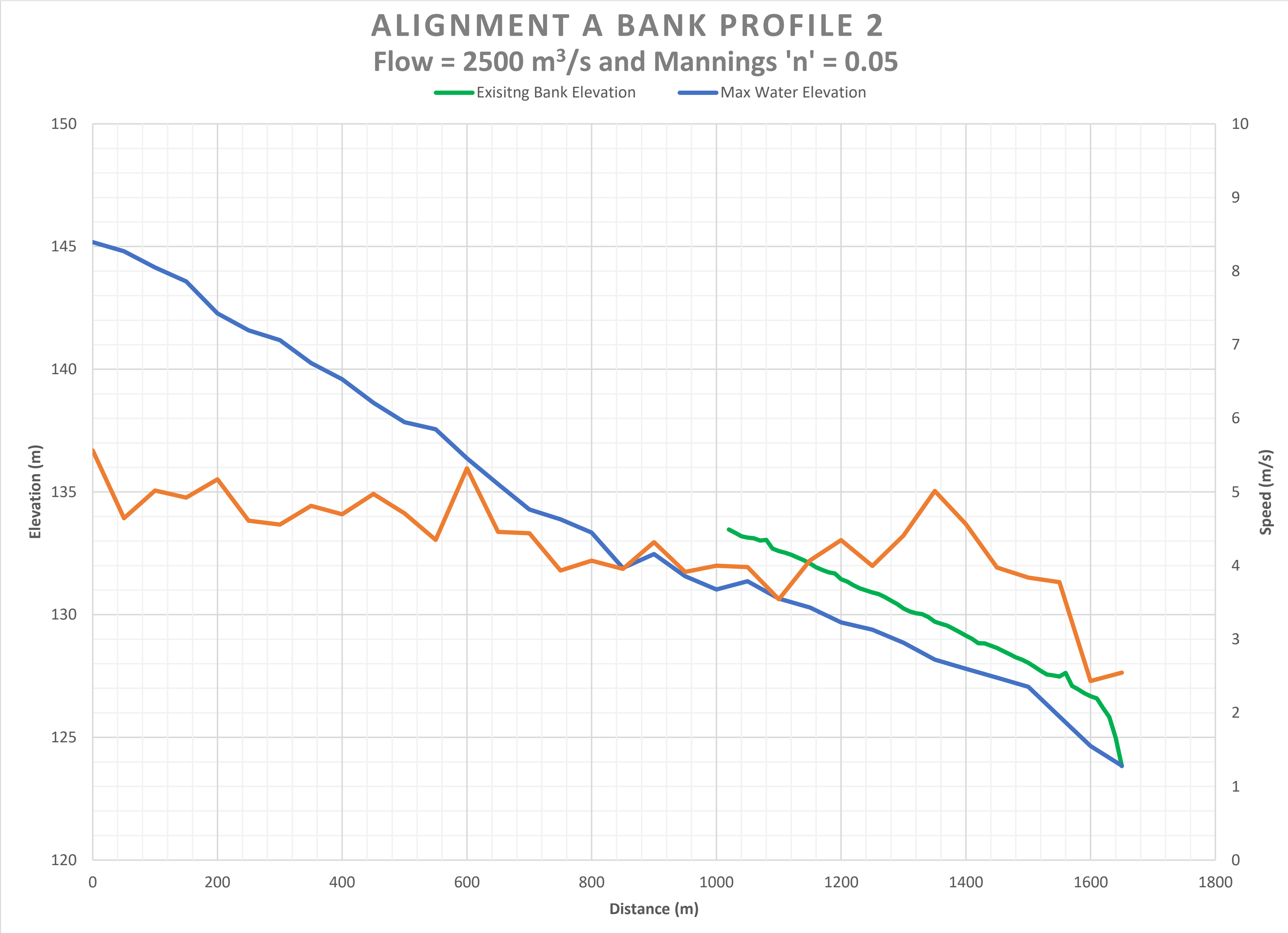
AGGRADATION RATE 3 ALIGNMENT B PROFILE 1
Flow = 2500 m³/s
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
Speed (m/s)
Distance (m)
160
158
156
154
152
150
148
146
144
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800


ALIGNMENT B BANK PROFILE 2
Flow = 500 m³/s and Mannings 'n' = 0.05
Existing Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Disatnce (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800

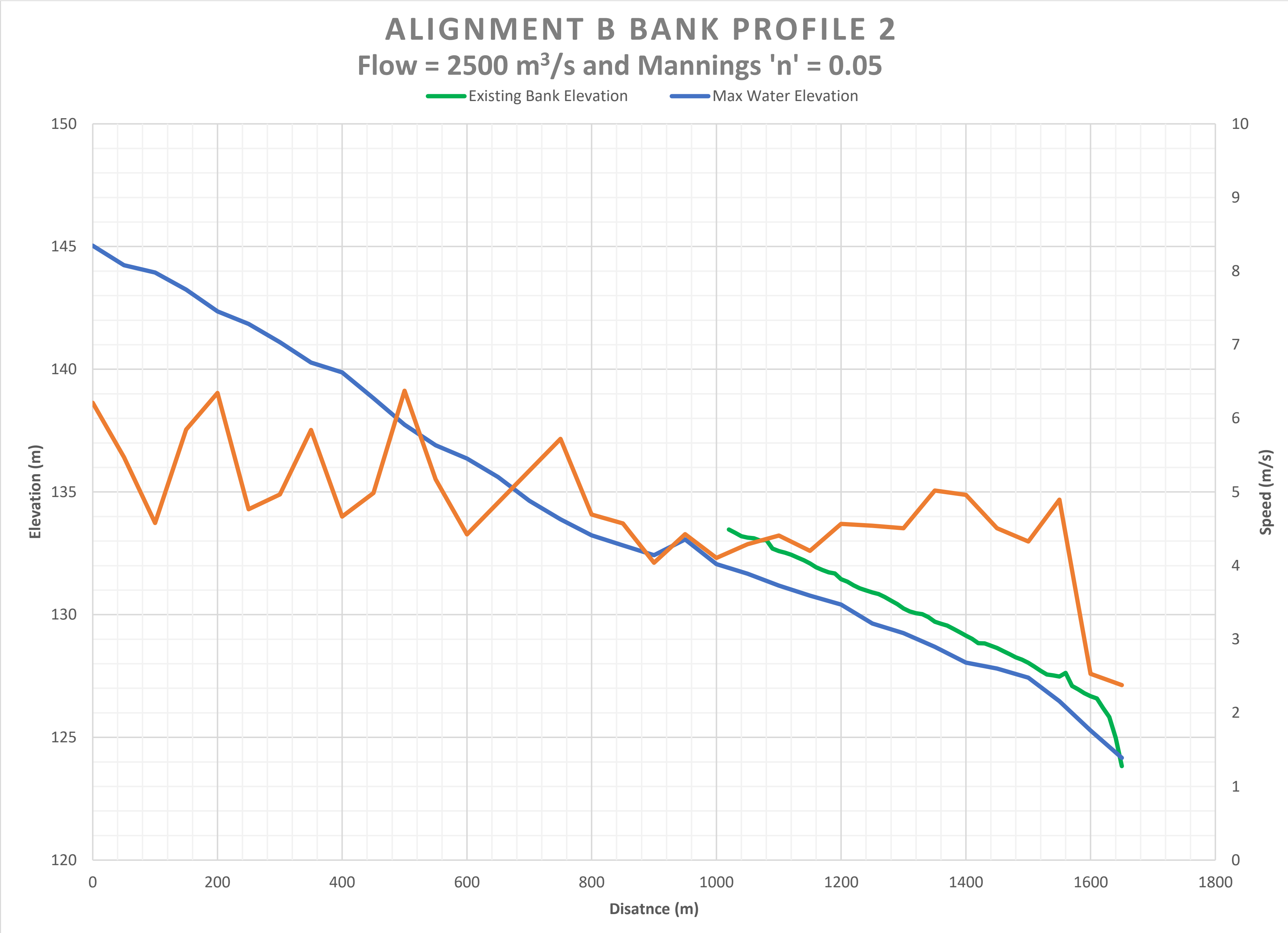

ALIGNMENT B BANK PROFILE 2
Flow = 1000 m³/s and Mannings 'n' = 0.05
Existing Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Disatnce (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800

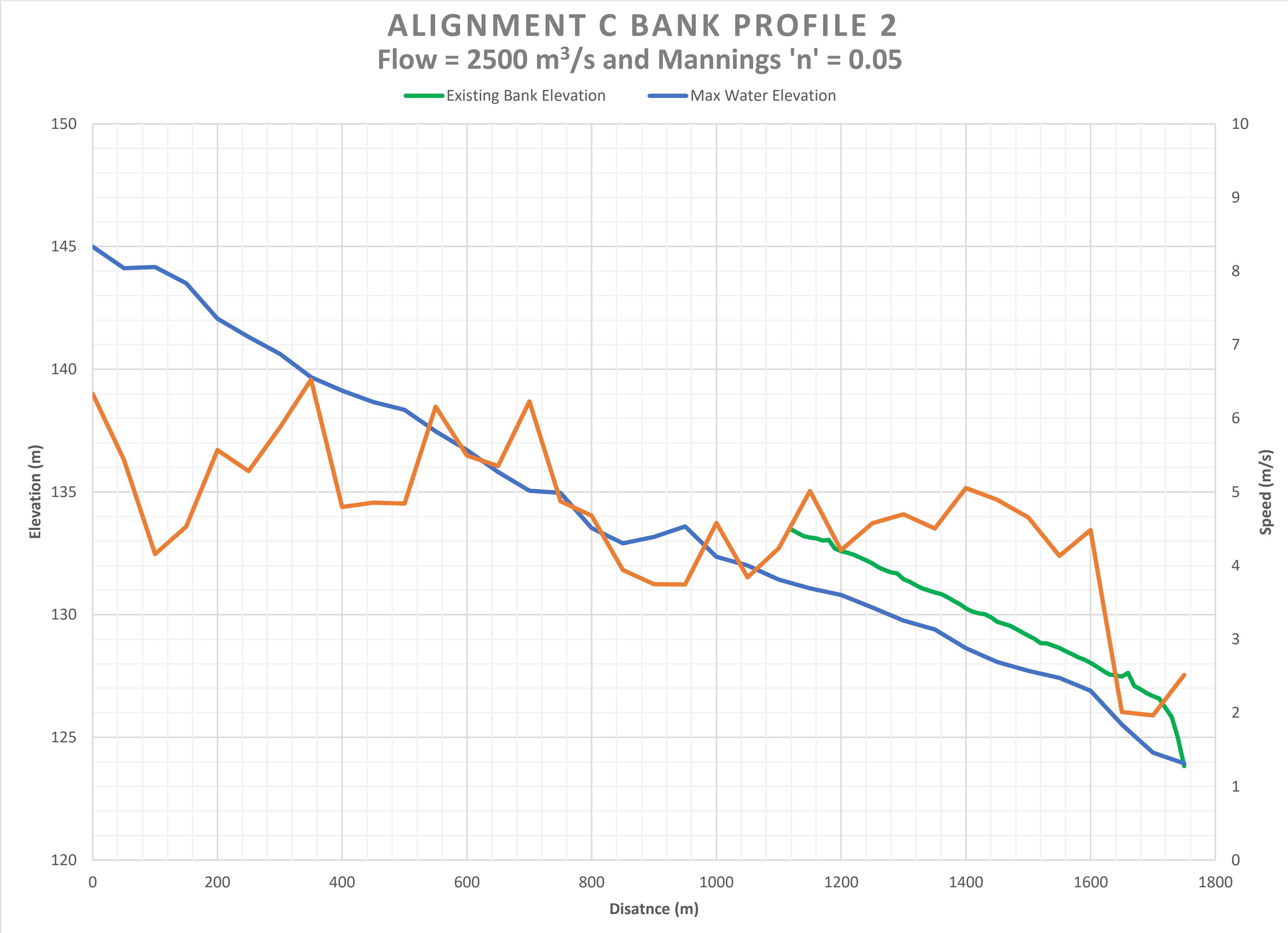


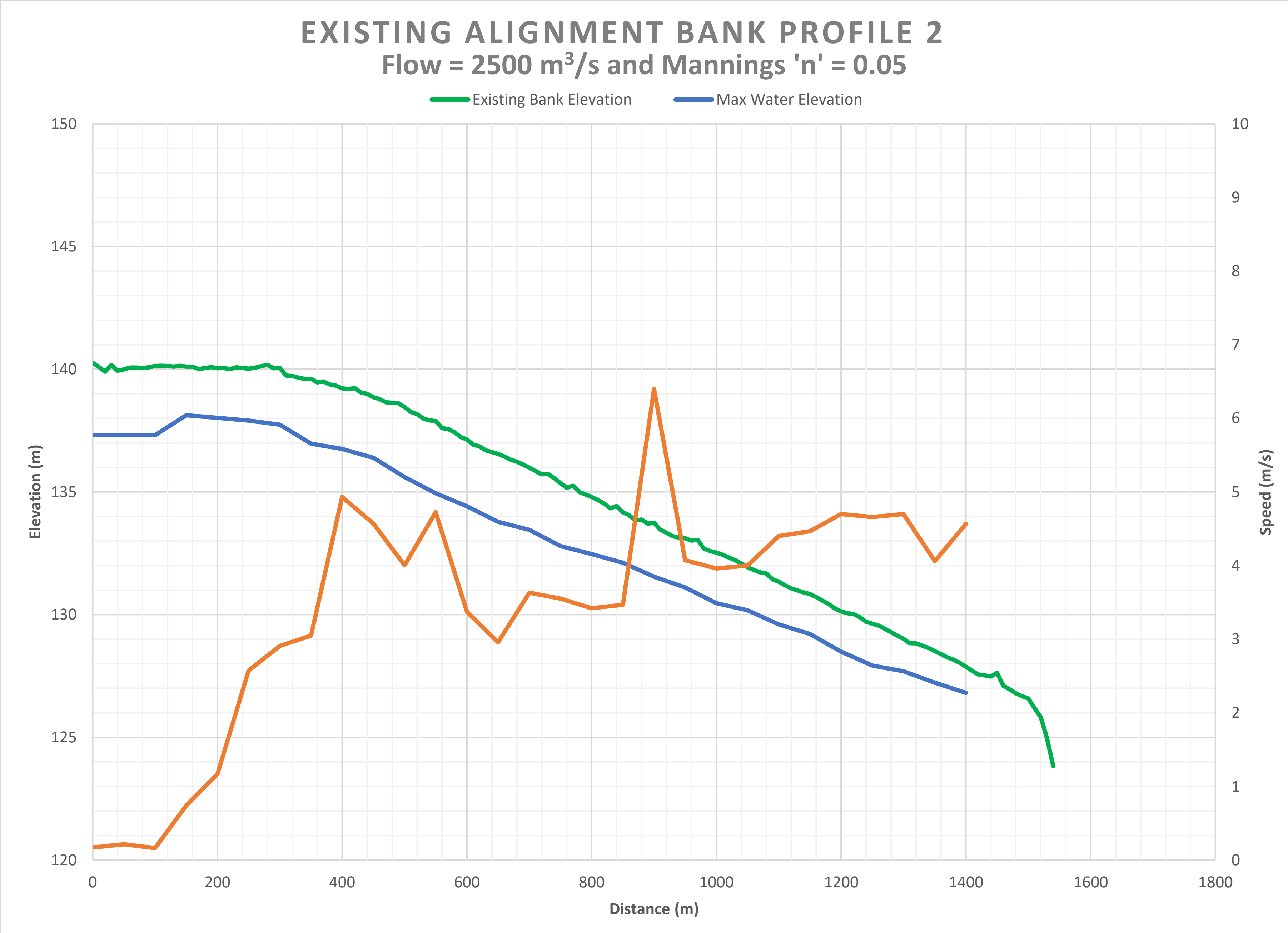
ALIGNMENT B BANK PROFILE 2
Flow = 2000 m³/s and Mannings 'n' = 0.05
Existing Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Disatnce (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800

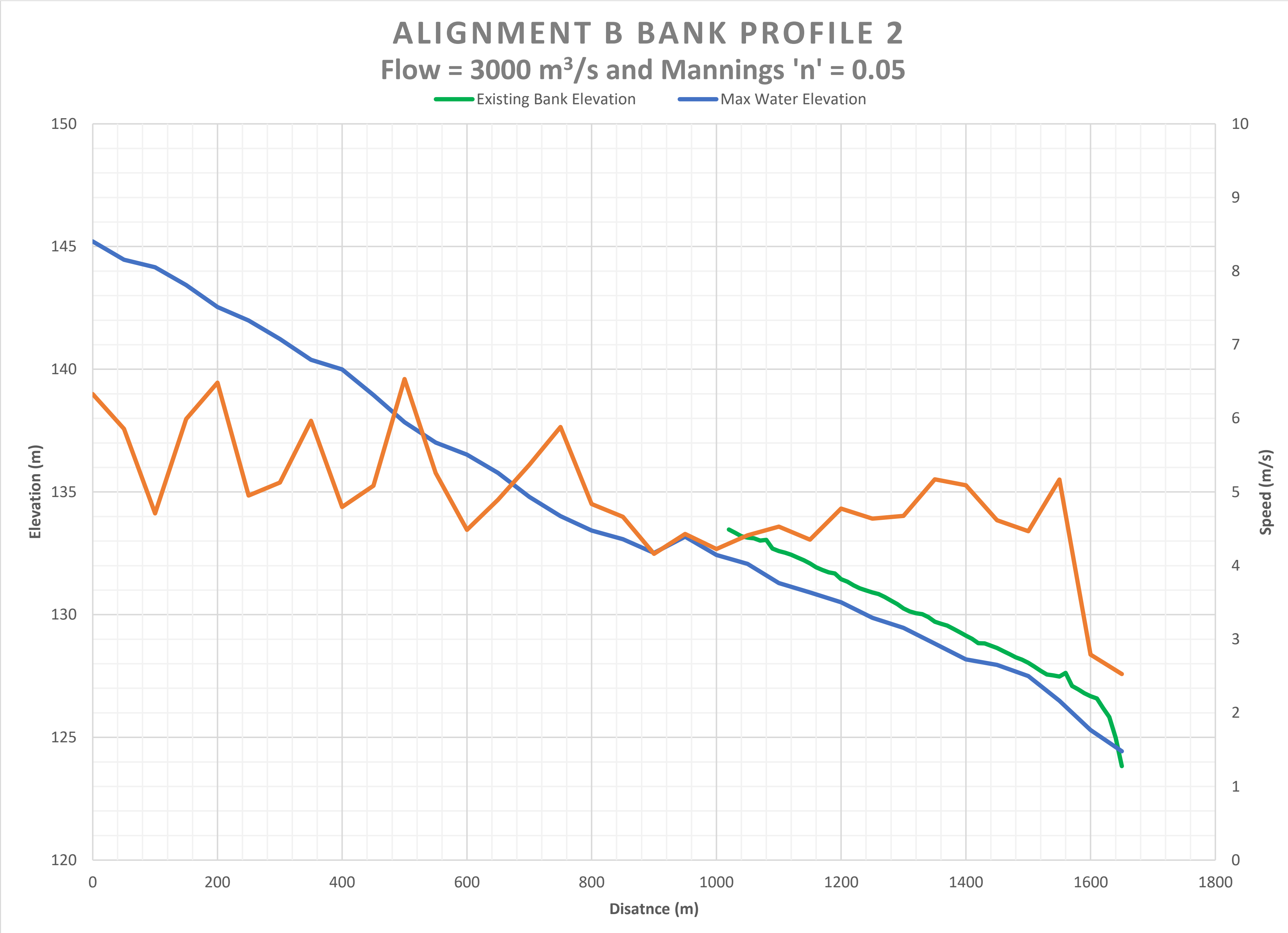


ALIGNMENT A BANK PROFILE 2
Flow = 2500 m³/s and Mannings 'n' = 0.05
Exisitng Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Distance (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800

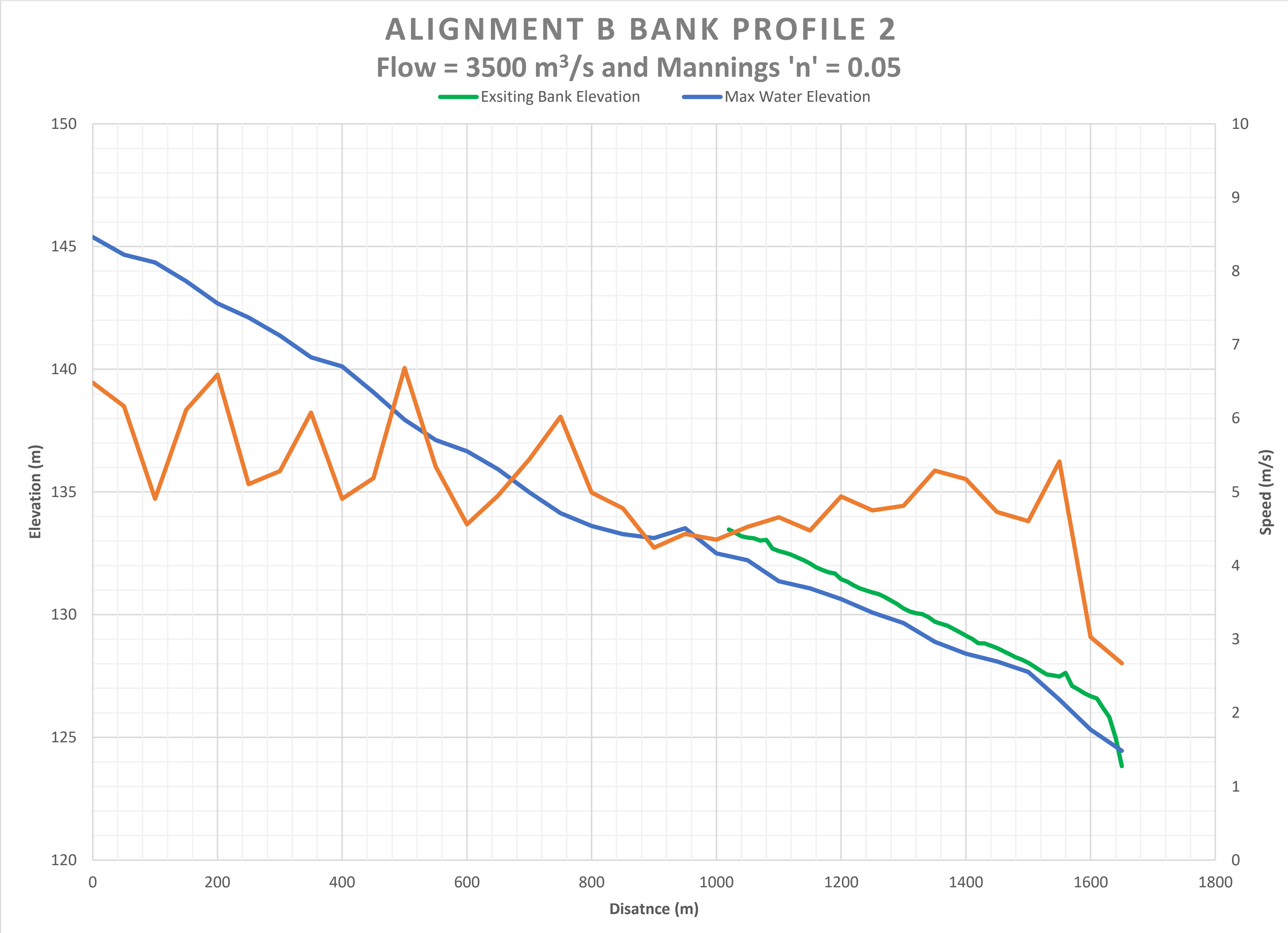

ALIGNMENT B BANK PROFILE 2
Flow = 2500 m³/s and Mannings 'n' = 0.05
Existing Bank Elevation
Max Water Elevation
150
145
140
135
130
125
120
Elevation (m)
10
9
8
7
6
5
4
3
2
1
0
Speed (m/s)
0
200
400
600
800
1000
1200
1400
1600
1800
Disatnce (m)

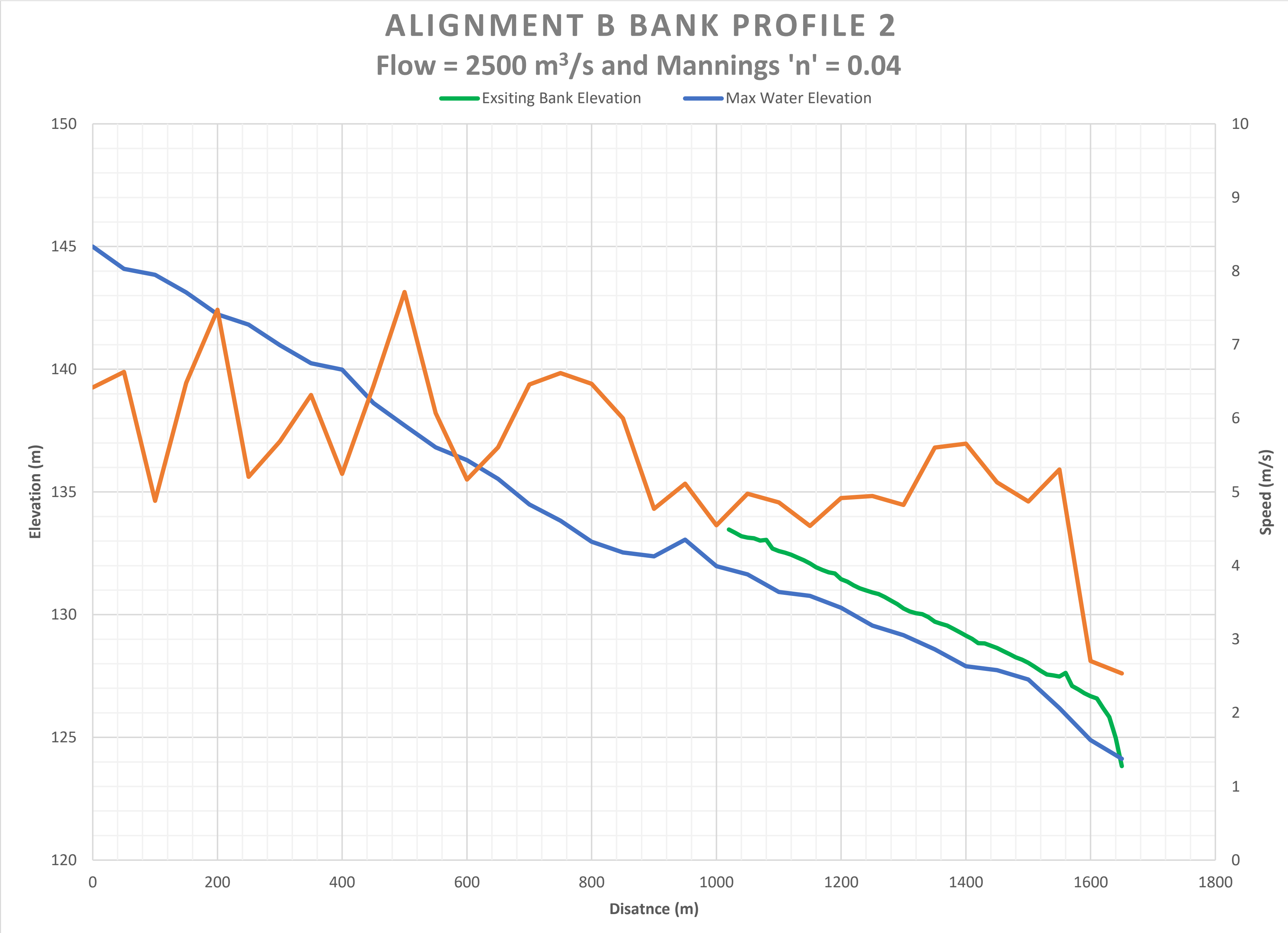

ALIGNMENT C BANK PROFILE 2
Flow = 2500 m³/s and Mannings 'n' = 0.05
Existing Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Disatnce (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800

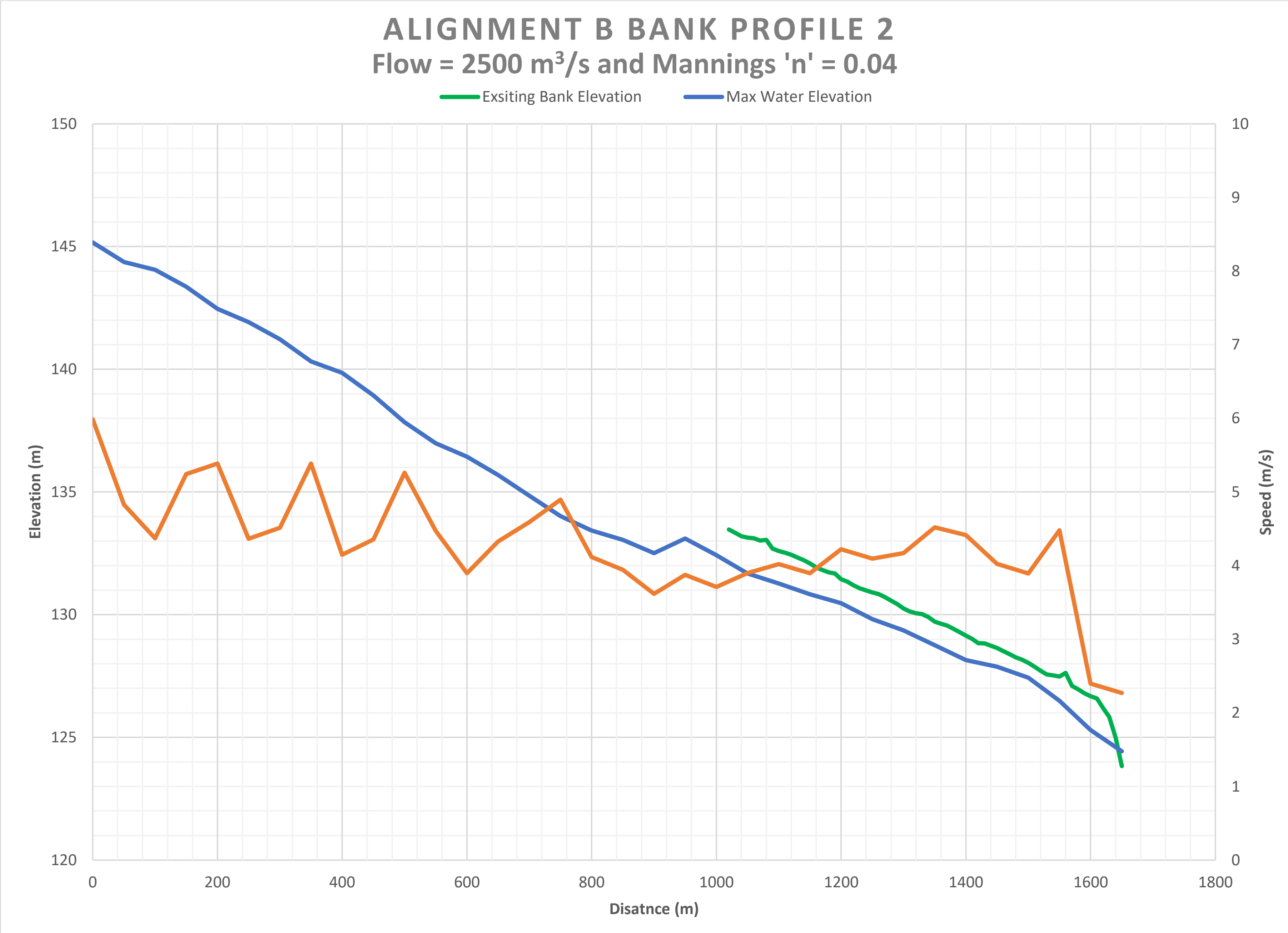

EXISTING ALIGNMENT BANK PROFILE 2
Flow = 2500 m³/s and Mannings 'n' = 0.05
Existing Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Distance (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800



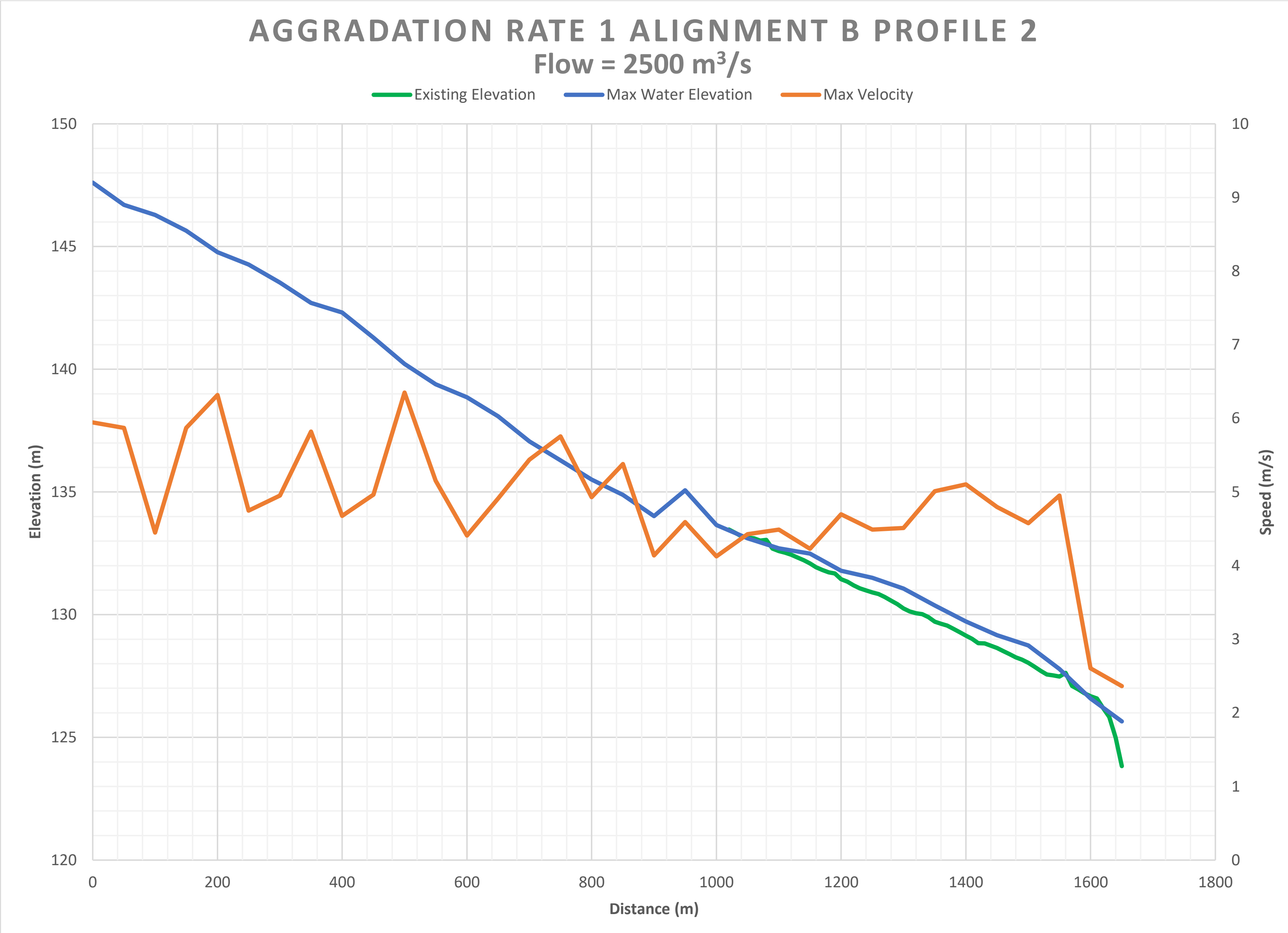
ALIGNMENT B BANK PROFILE 2
Flow = 3000 m³/s and Mannings 'n' = 0.05
Existing Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Disatnce (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800


ALIGNMENT B BANK PROFILE 2
Flow = 3500 m³/s and Mannings 'n' = 0.05
Exsiting Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Disatnce (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800

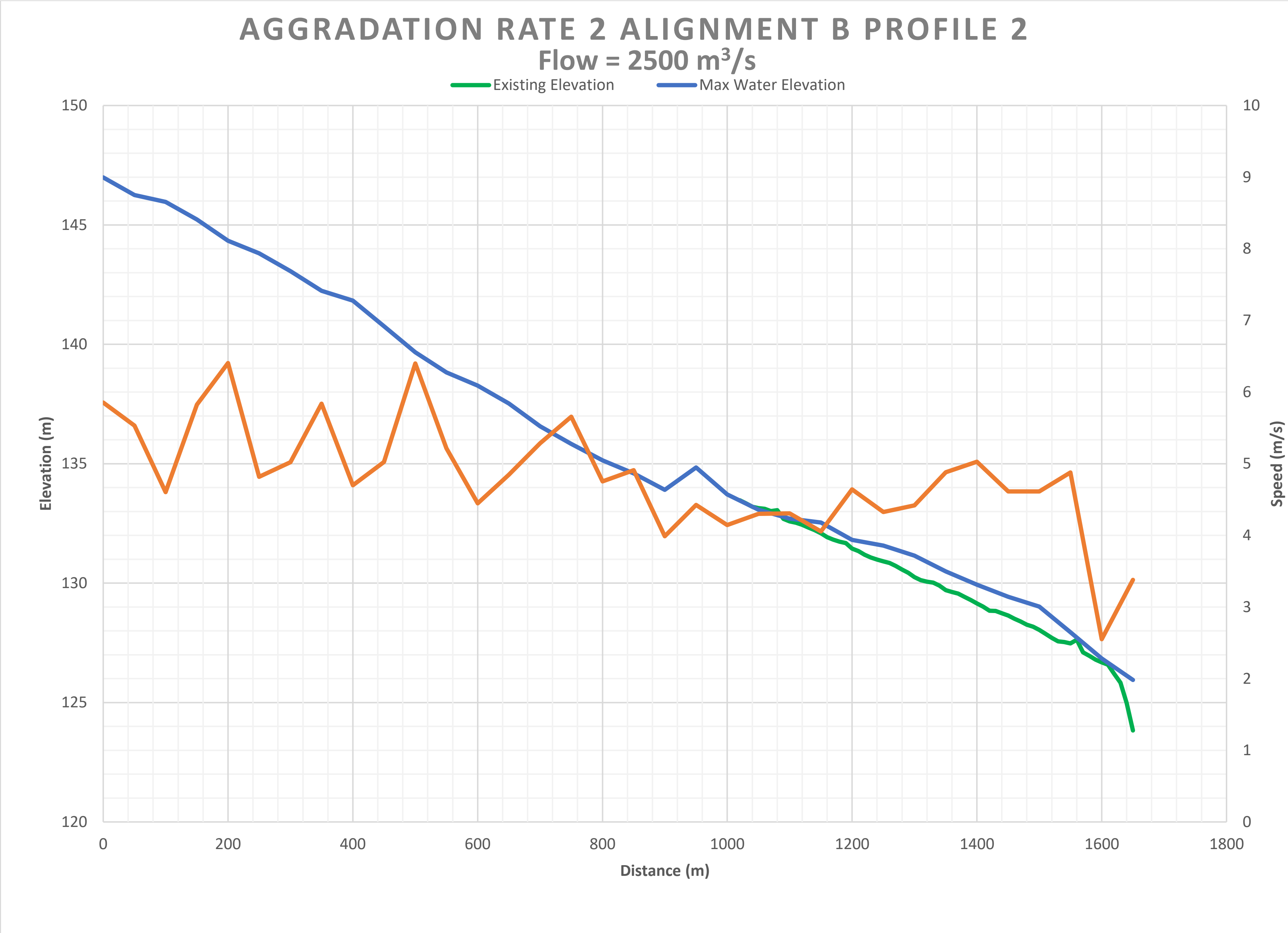

ALIGNMENT B BANK PROFILE 2
Flow = 2500 m³/s and Mannings 'n' = 0.04
Exsiting Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Disatnce (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800



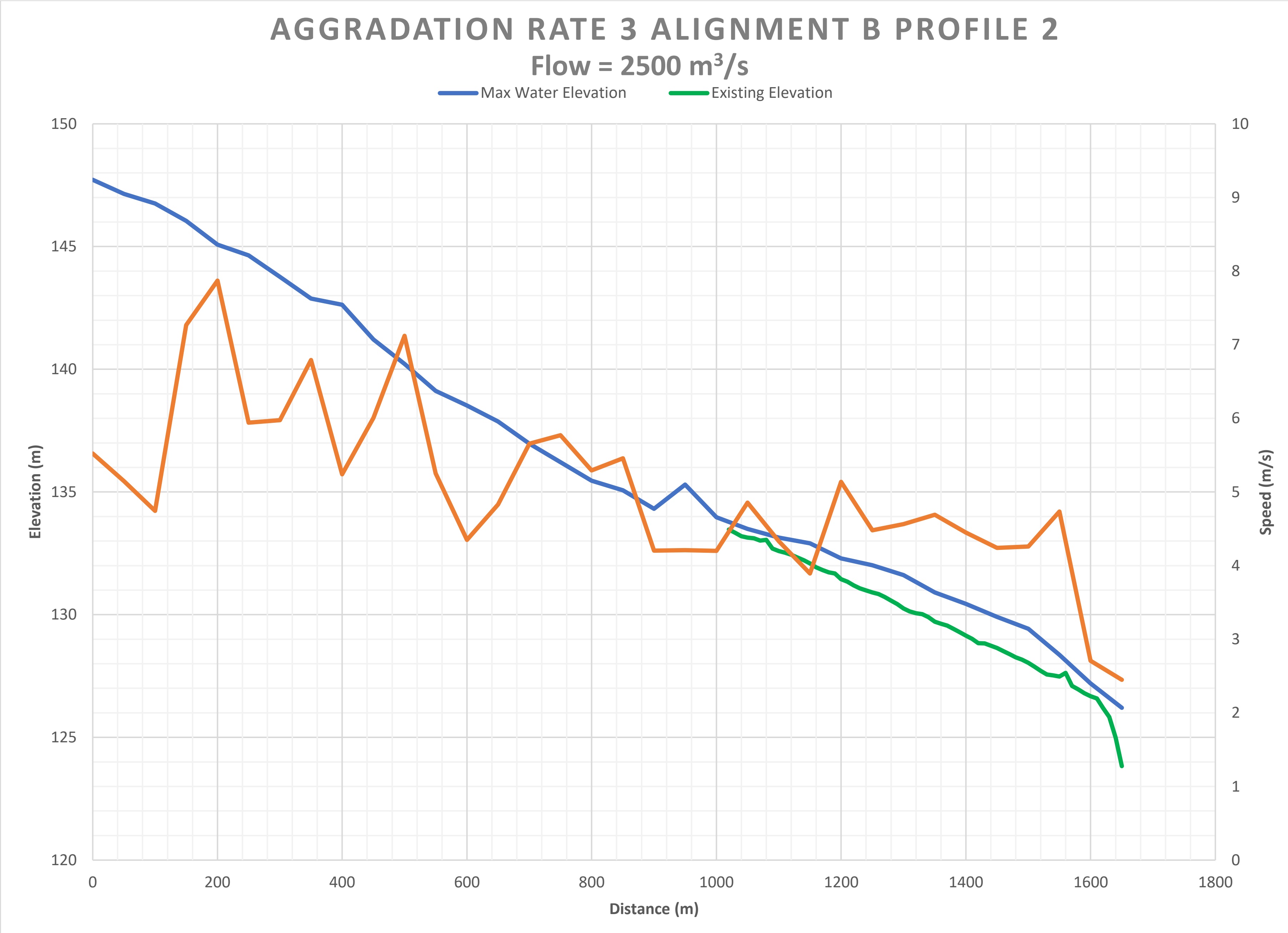
ALIGNMENT B BANK PROFILE 2
Flow = 2500 m3/s and Mannings 'n' = 0.04
Exsiting Bank Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Disatnce (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800



AGGRADATION RATE 1 ALIGNMENT B PROFILE 2
Flow = 2500 m³/s
Existing Elevation
Max Water Elevation
Max Velocity
Elevation (m)
150
145
140
135
130
125
120
Speed (m/s)
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800
Distance (m)

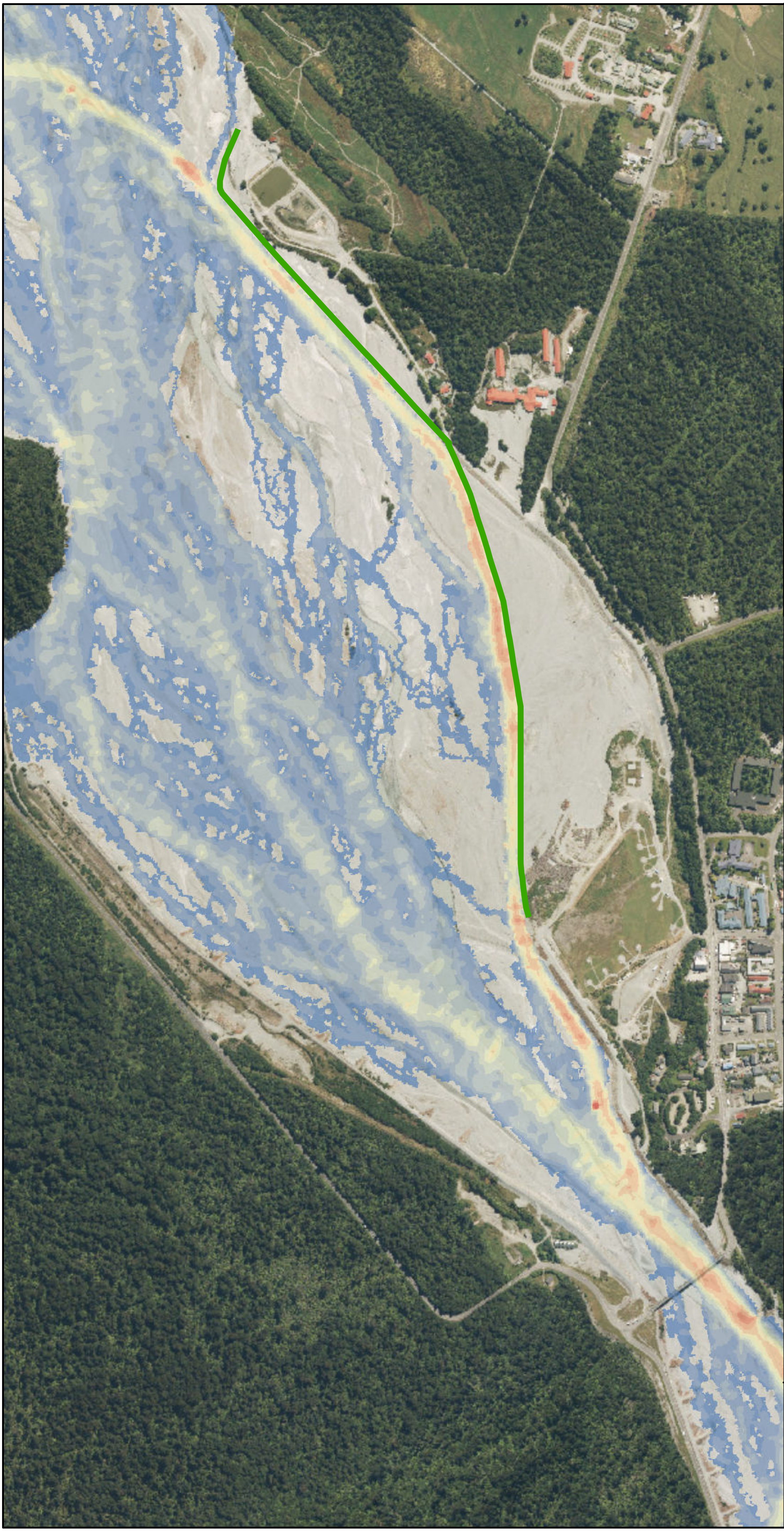


AGGRADATION RATE 2 ALIGNMENT B PROFILE 2
Flow = 2500 m³/s
Existing Elevation
Max Water Elevation
Elevation (m)
Speed (m/s)
Distance (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800



AGGRADATION RATE 3 ALIGNMENT B PROFILE 2
Flow = 2500 m³/s
Max Water Elevation
Existing Elevation
Elevation (m)
Speed (m/s)
Distance (m)
150
145
140
135
130
125
120
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800

APPENDIX D – MODEL RESULTS - PEAK SPEED / EXTENT MAPS



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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PROJECT

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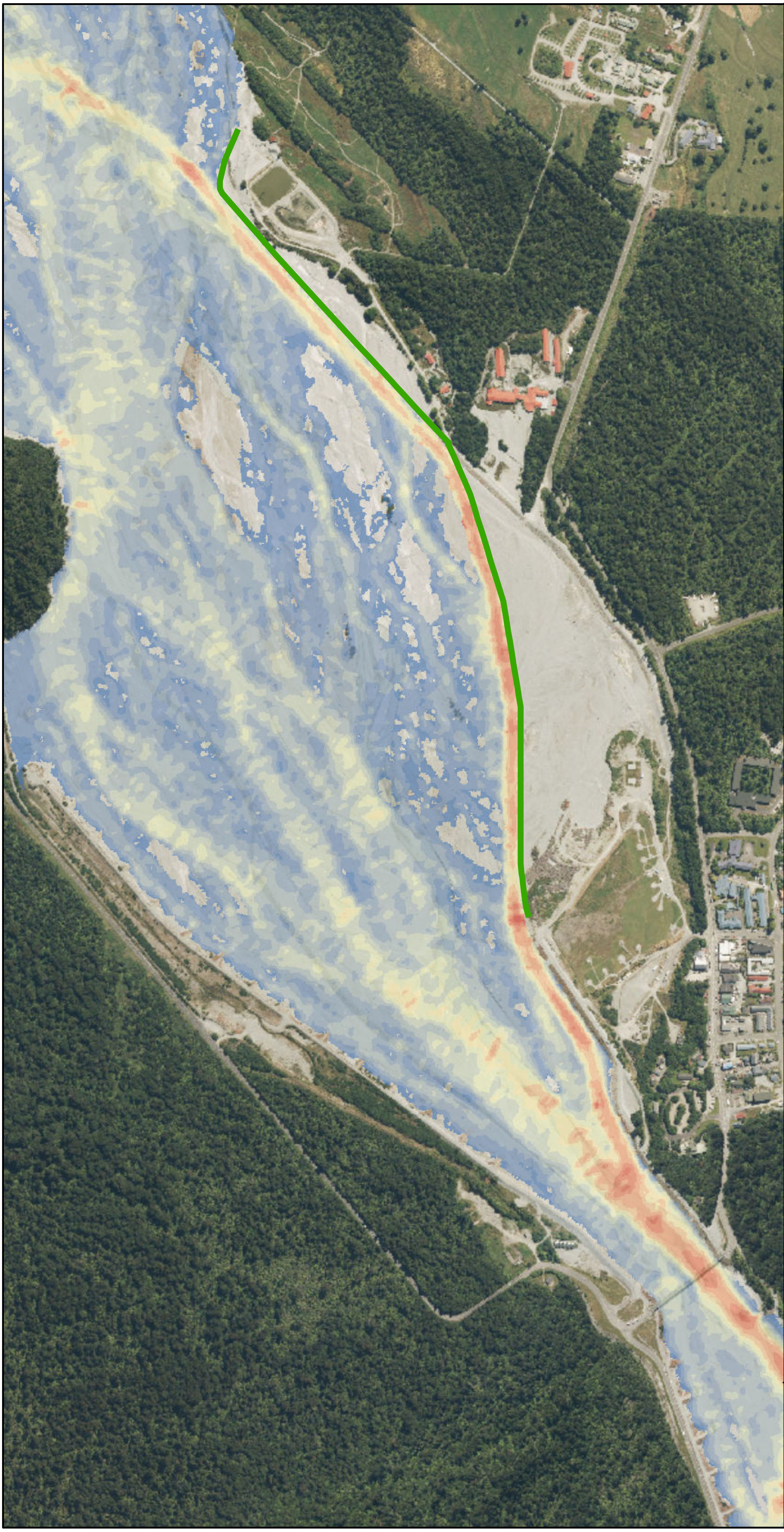
MAP TITLE

Peak Speed Map
Bank Alignment B
Q500 m3/s
Mannings 'n' 0.05

REVISION	DATE	
01	19 July 2021	N
A3 SCALE	AUTHOR	
1:10,000	Matthew Gardner	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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PROJECT

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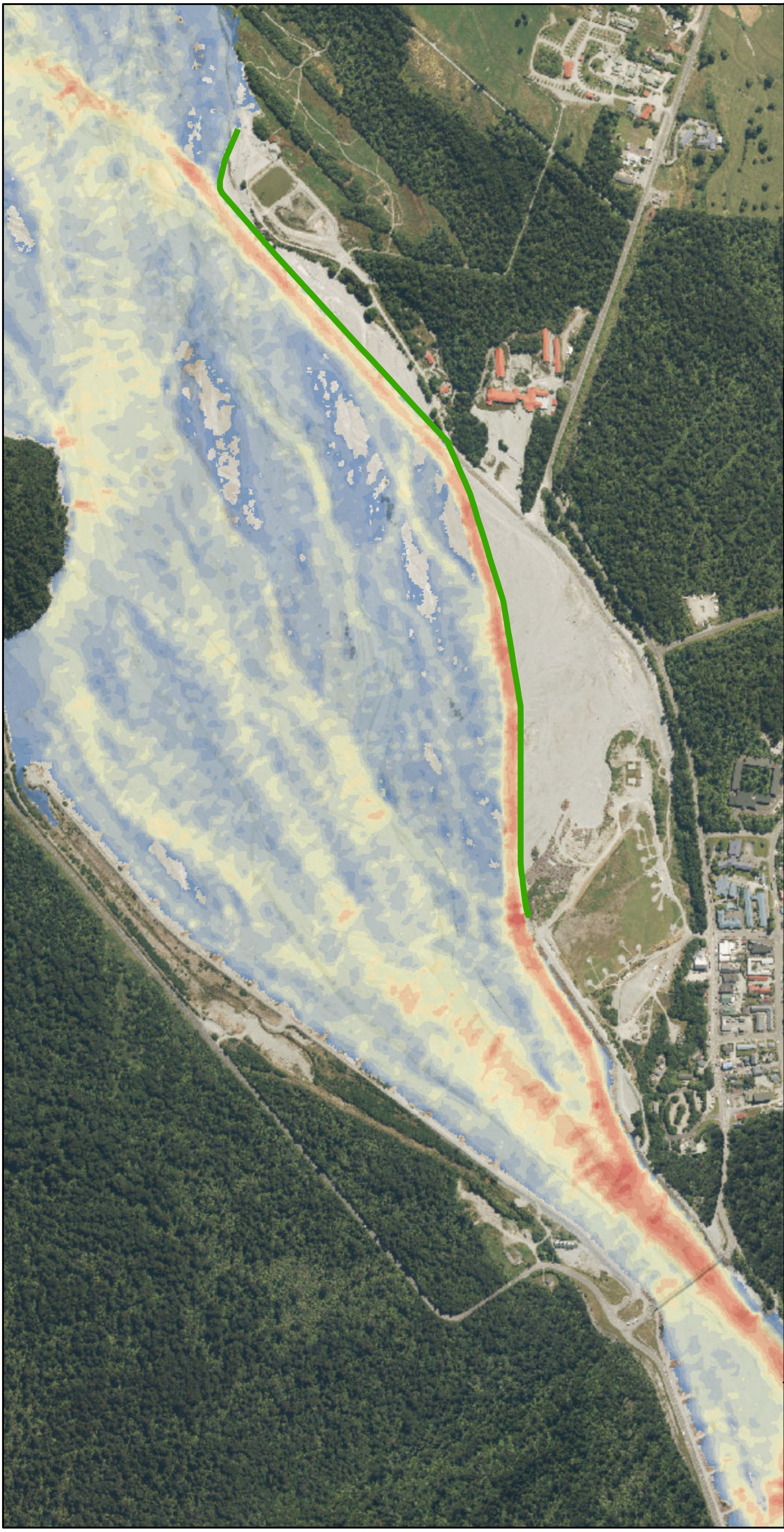
MAP TITLE

Peak Speed Map
Bank Alignment B
Q1000 m3/s
Mannings 'n' 0.05

REVISION	DATE
01	19 July 2021
A3 SCALE	AUTHOR
1:10,000	Matthew Gardner

N

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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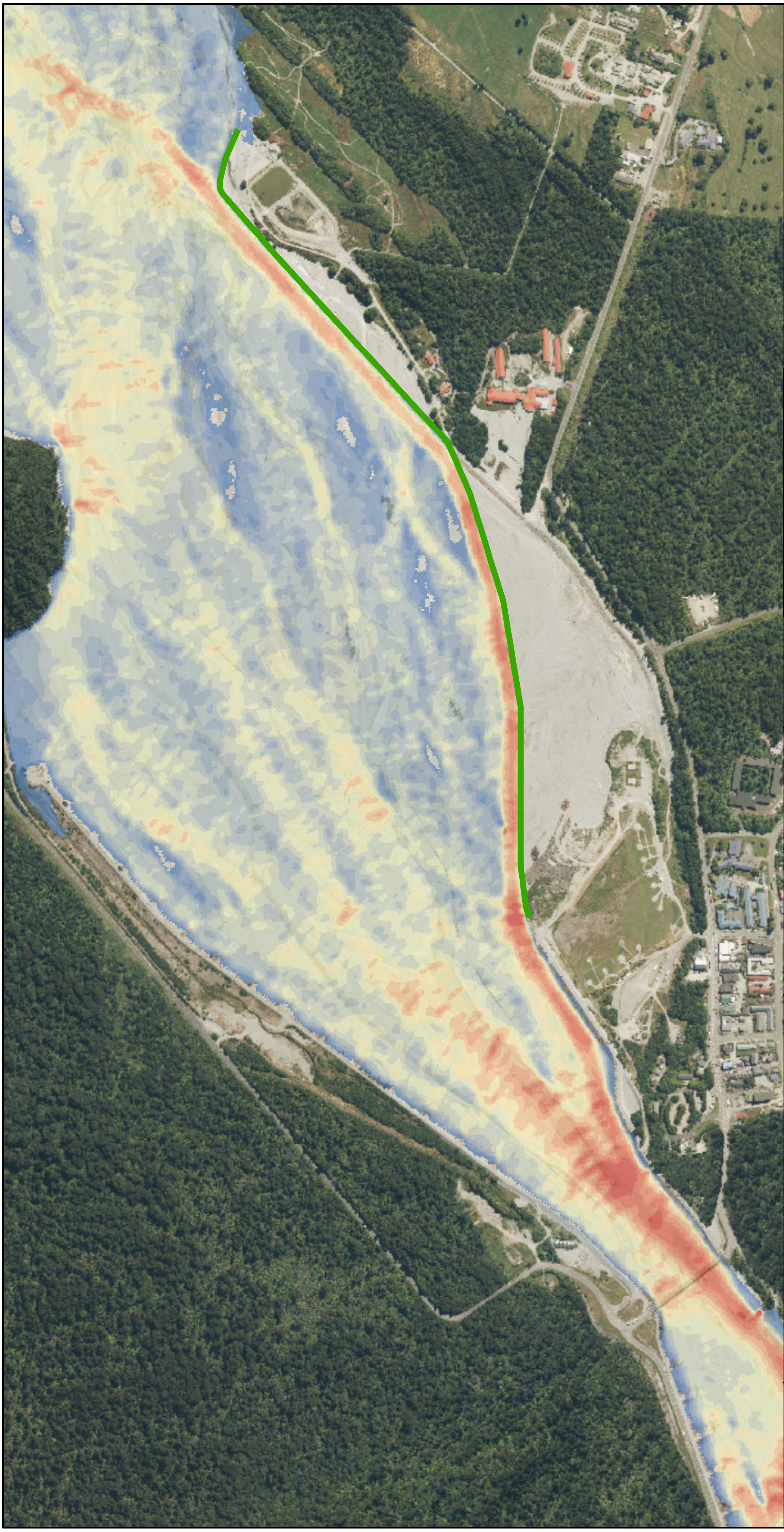
MAP TITLE

Peak Speed Map
Bank Alignment B
Q1500 m3/s
Mannings 'n' 0.05

REVISION	DATE	
01	**19 July 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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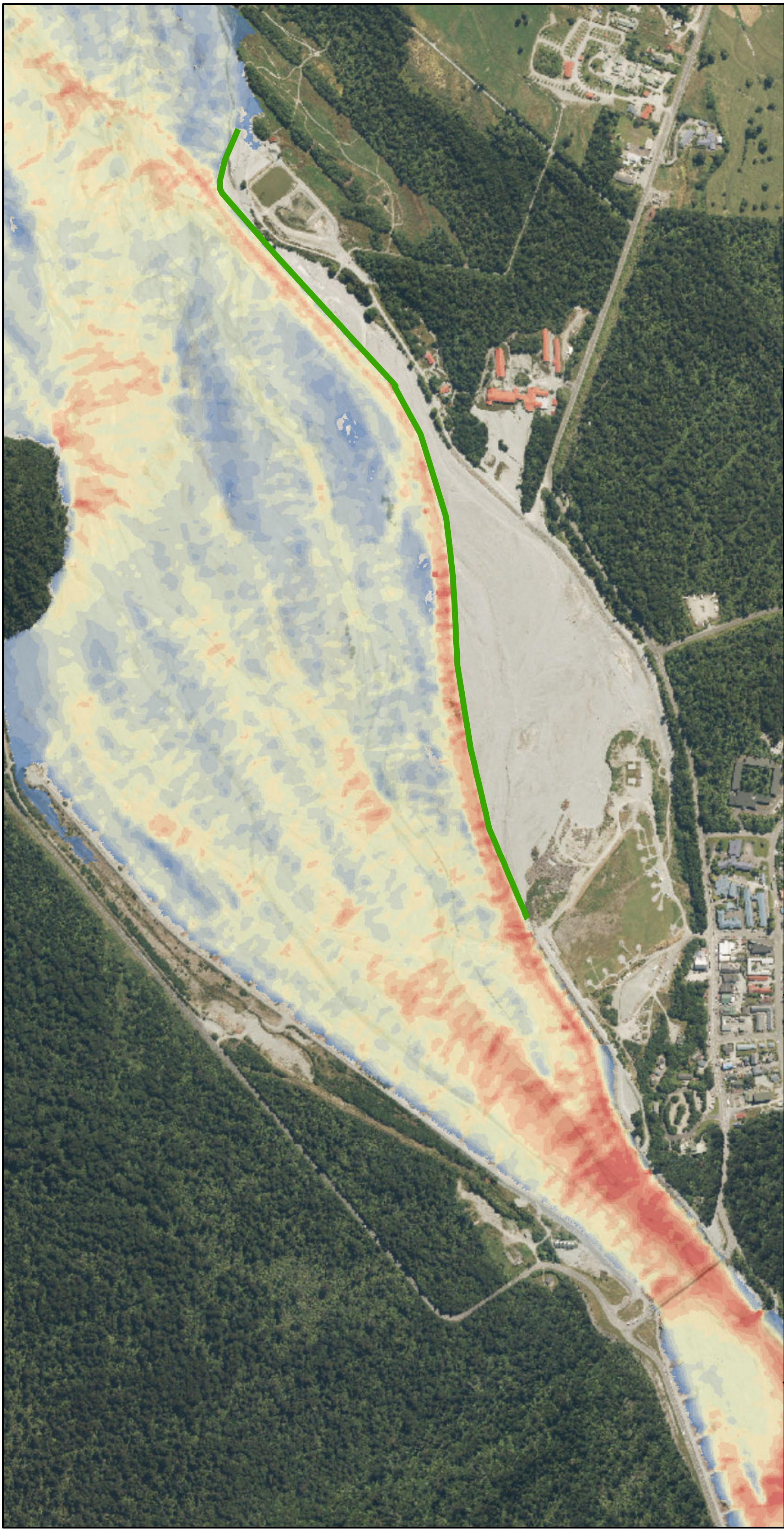
MAP TITLE

Peak Speed Map
Bank Alignment B
Q2000 m3/s
Mannings 'n' 0.05

REVISION	DATE	
01	**19 July 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment A

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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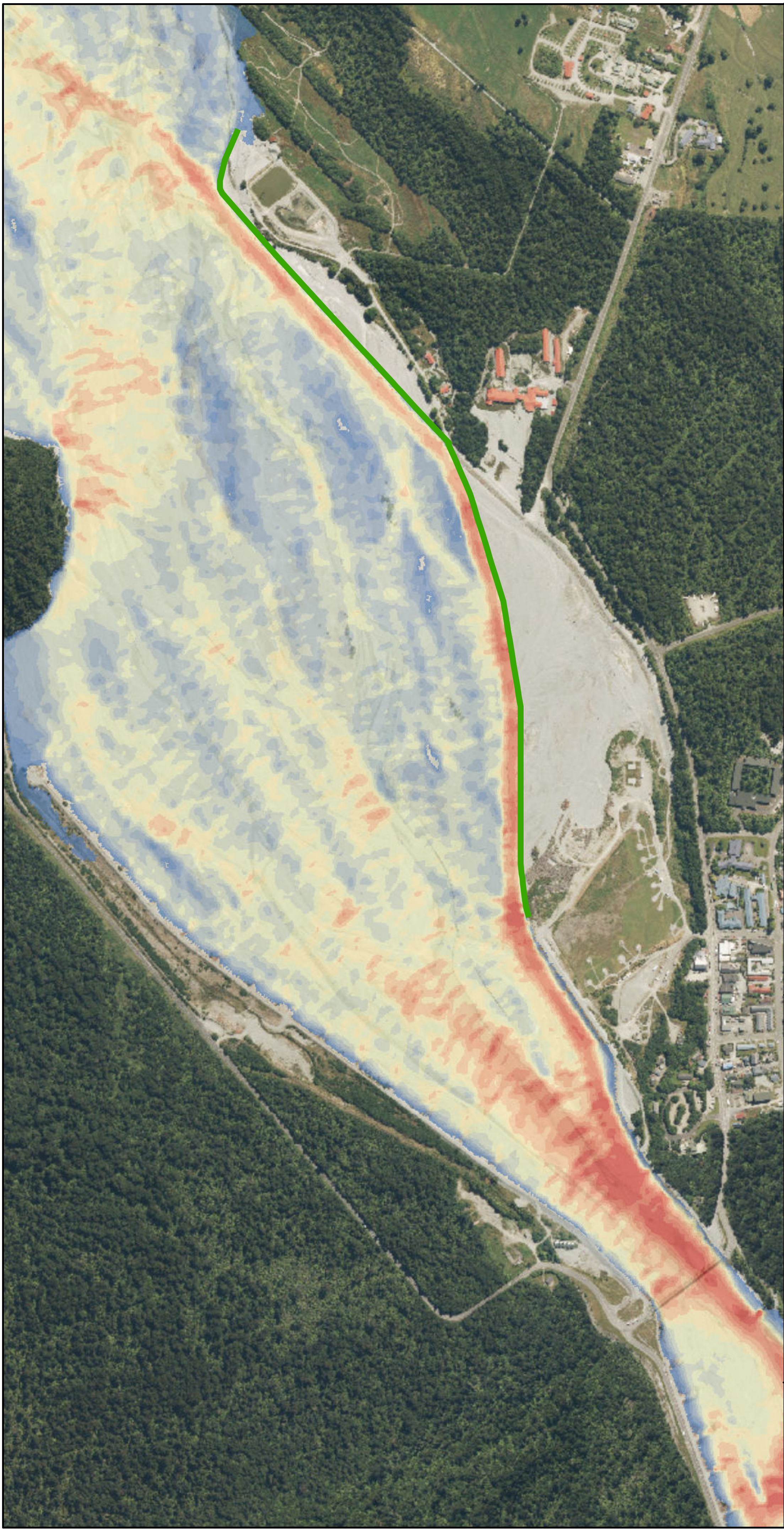
MAP TITLE

Peak Speed Map
Bank Alignment A
Q2500 m3/s
Mannings 'n' 0.05

REVISION	DATE	
01	**19 July 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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PROJECT

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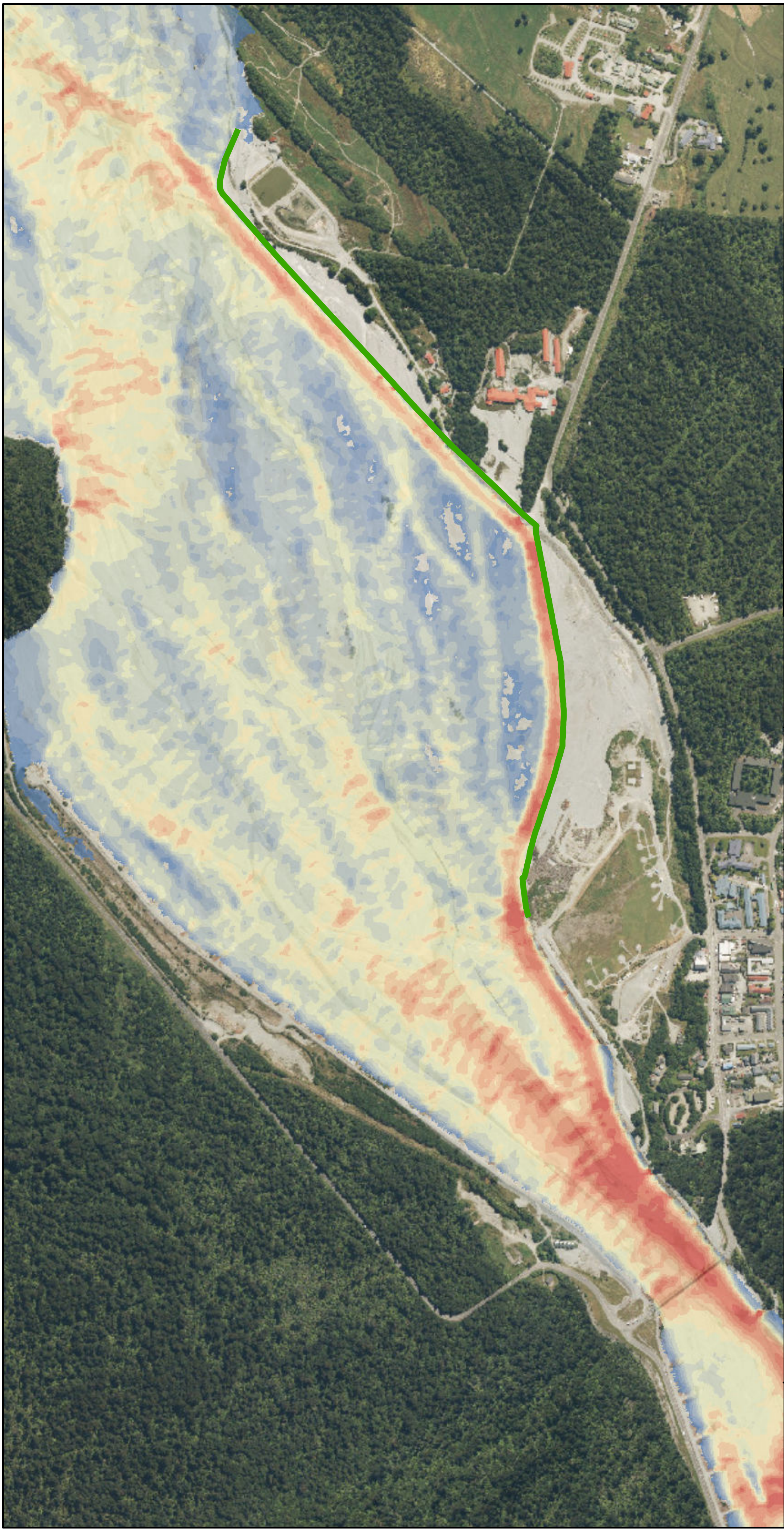
MAP TITLE

Peak Speed Map
Bank Alignment B
Q2500 m3/s
Mannings 'n' 0.05

REVISION	DATE	
01	19 July 2021	N
A3 SCALE	AUTHOR	
1:10,000	Matthew Gardner	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment C

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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PROJECT

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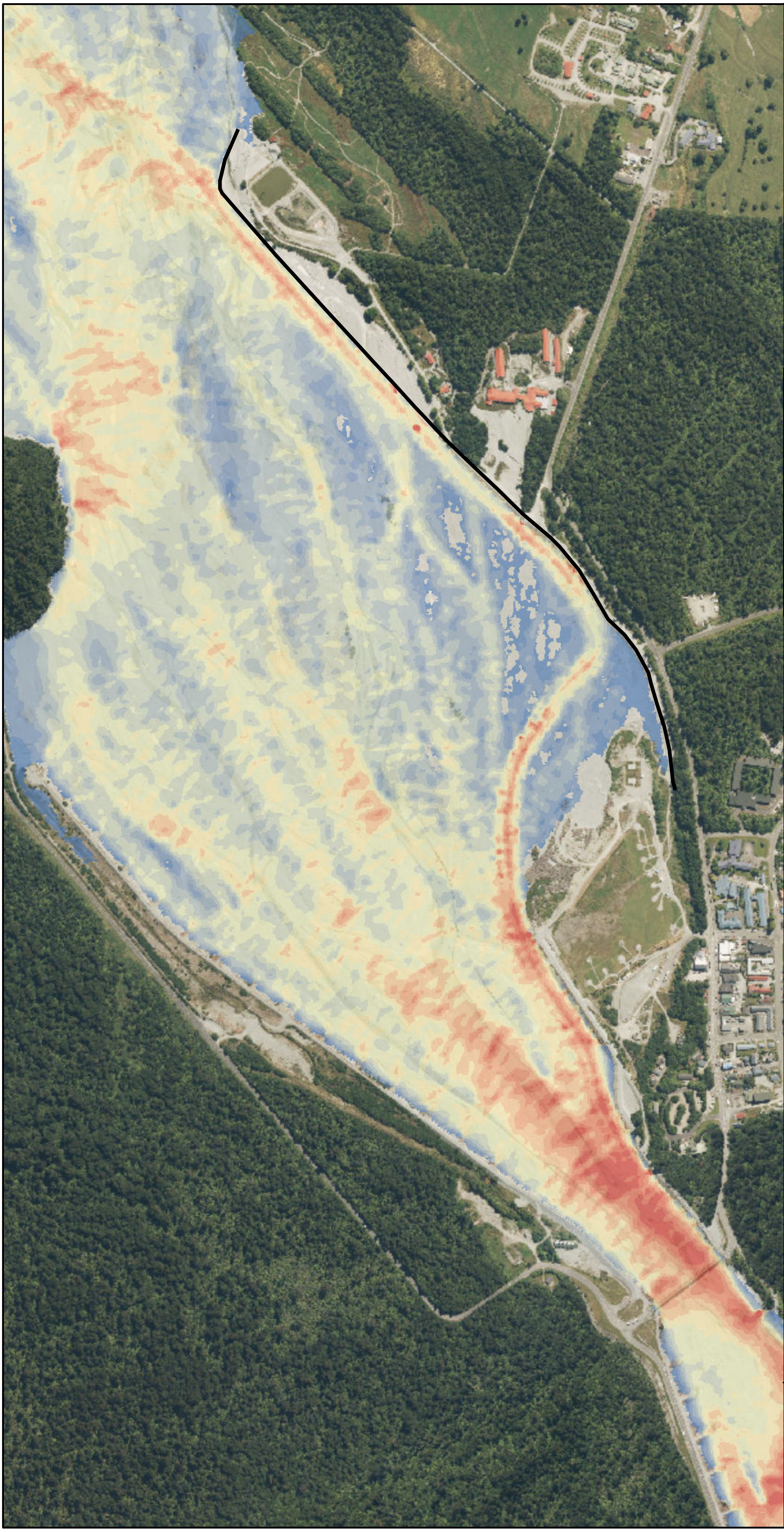
MAP TITLE

Peak Speed Map
Bank Alignment C
Q2500 m3/s
Mannings 'n' 0.05

REVISION	DATE
01	**19 July 2021**
A3 SCALE	AUTHOR
1:10,000	**Matthew Gardner**

N

0 0.125 0.25 0.5
Kilometers



Legend

Existing Dike

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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PROJECT

Franz Josef Stopbank Upgrade

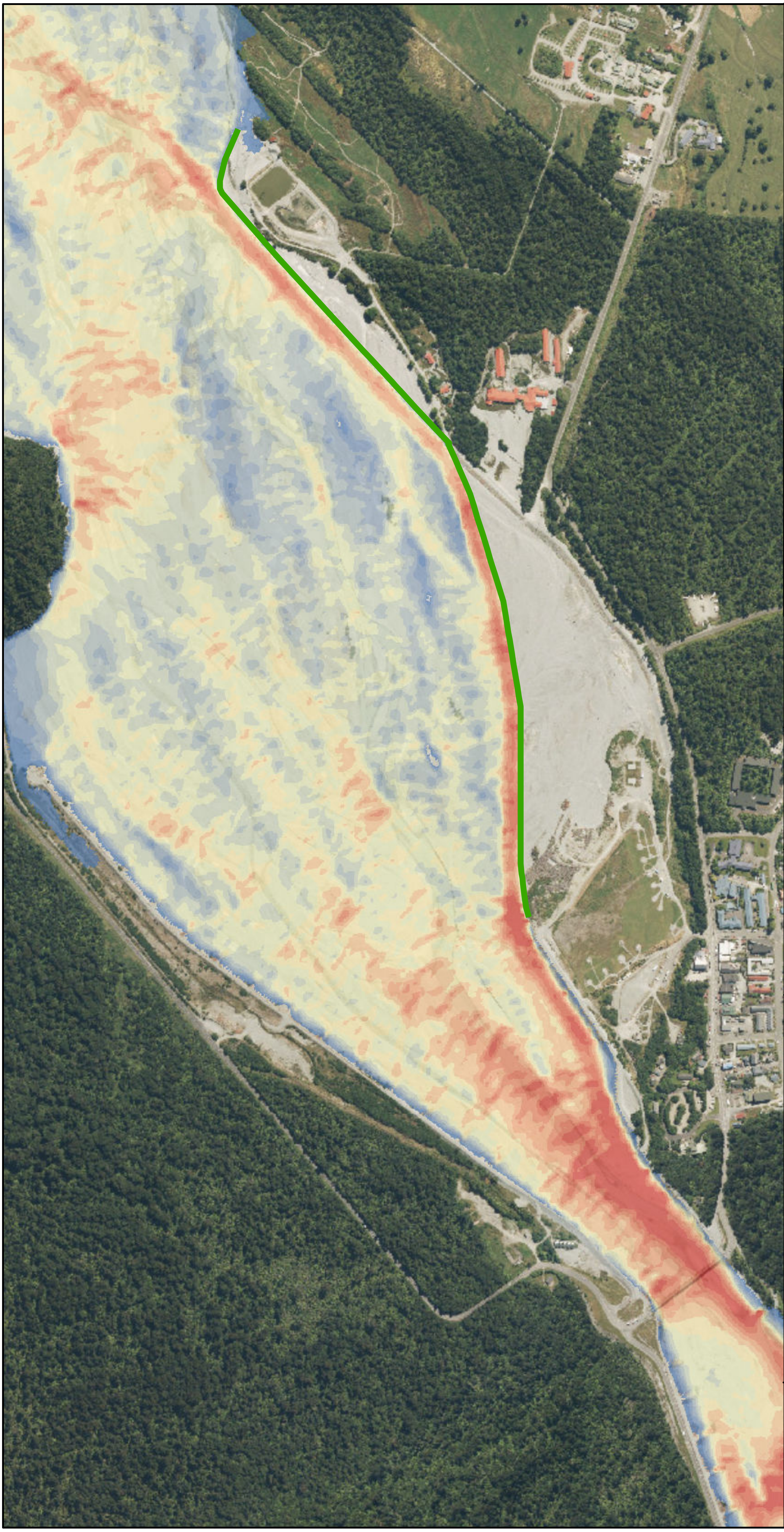
MAP TITLE

Peak Speed Map
Existing Dike
Q2500 m3/s
Mannings 'n' 0.05

REVISION	DATE
01	**19 July 2021**
A3 SCALE	AUTHOR
1:10,000	**Matthew Gardner**

N

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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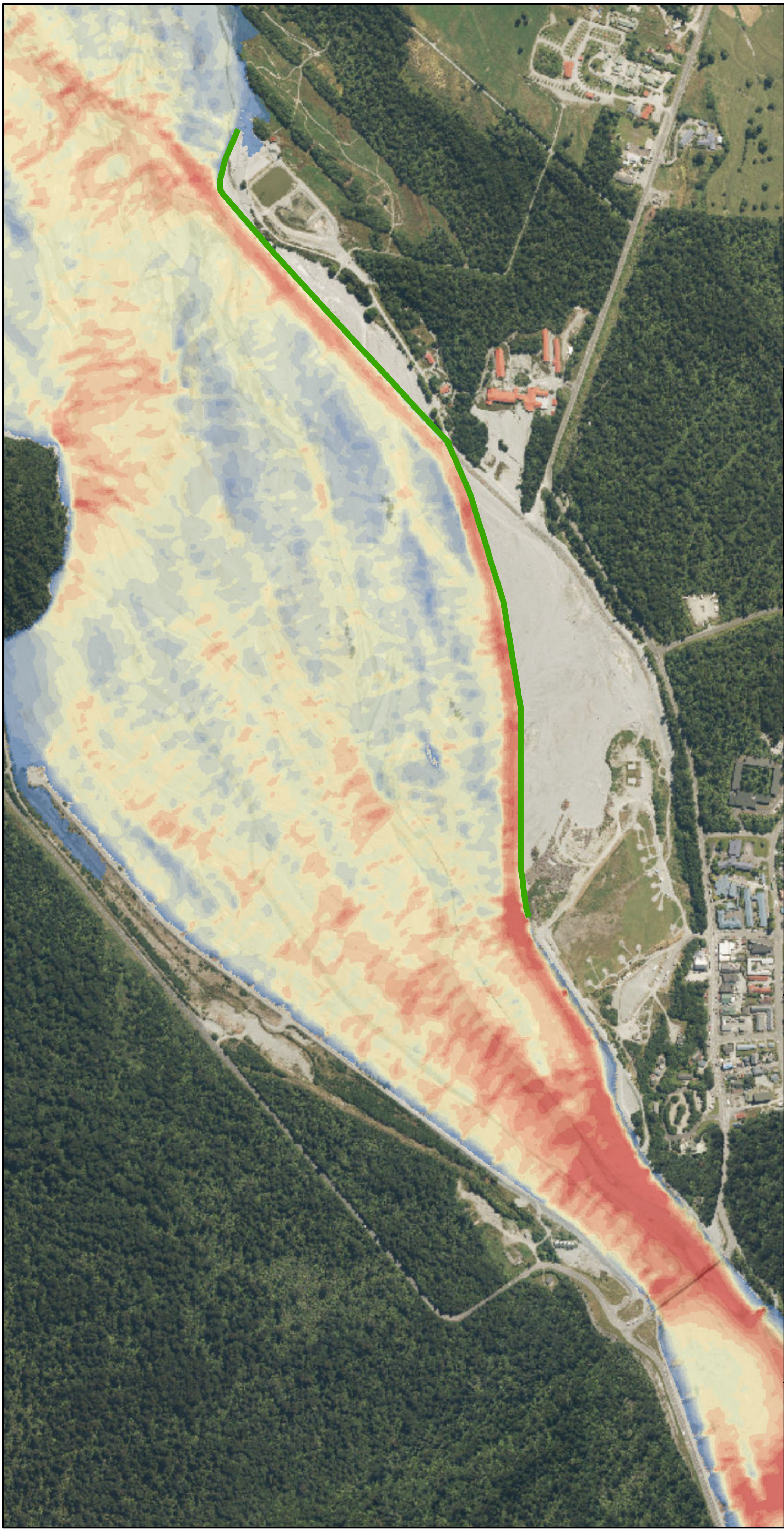
MAP TITLE

Peak Speed Map
Bank Alignment B
Q3000 m3/s
Mannings 'n' 0.05

REVISION	DATE	
01	**19 July 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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THE WEST COAST REGIONAL COUNCIL

PROJECT

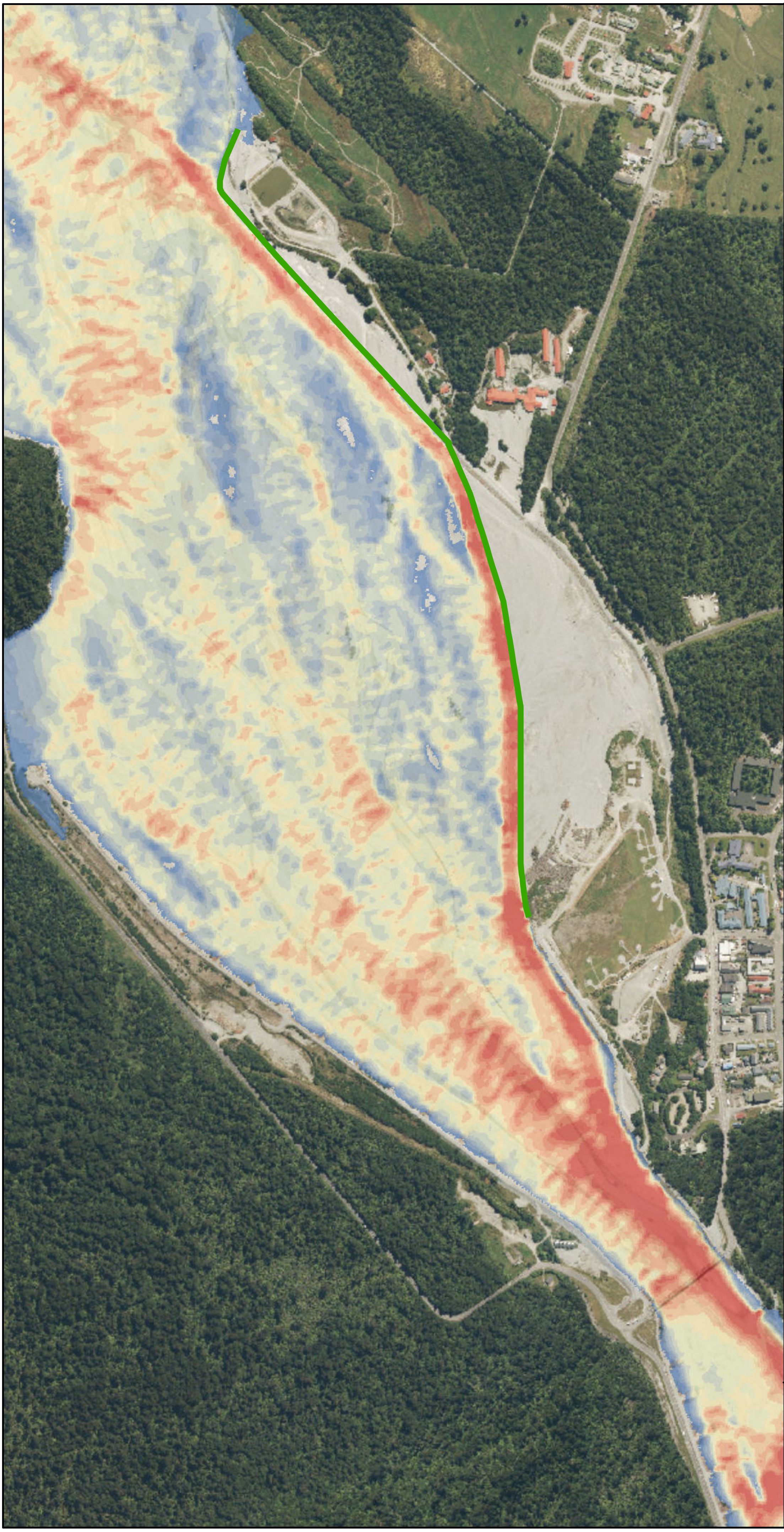
Franz Josef Stopbank Upgrade

MAP TITLE

Peak Speed Map
Bank Alignment B
Q3500 m3/s
Mannings 'n' 0.05

REVISION	DATE	
01	**19 July 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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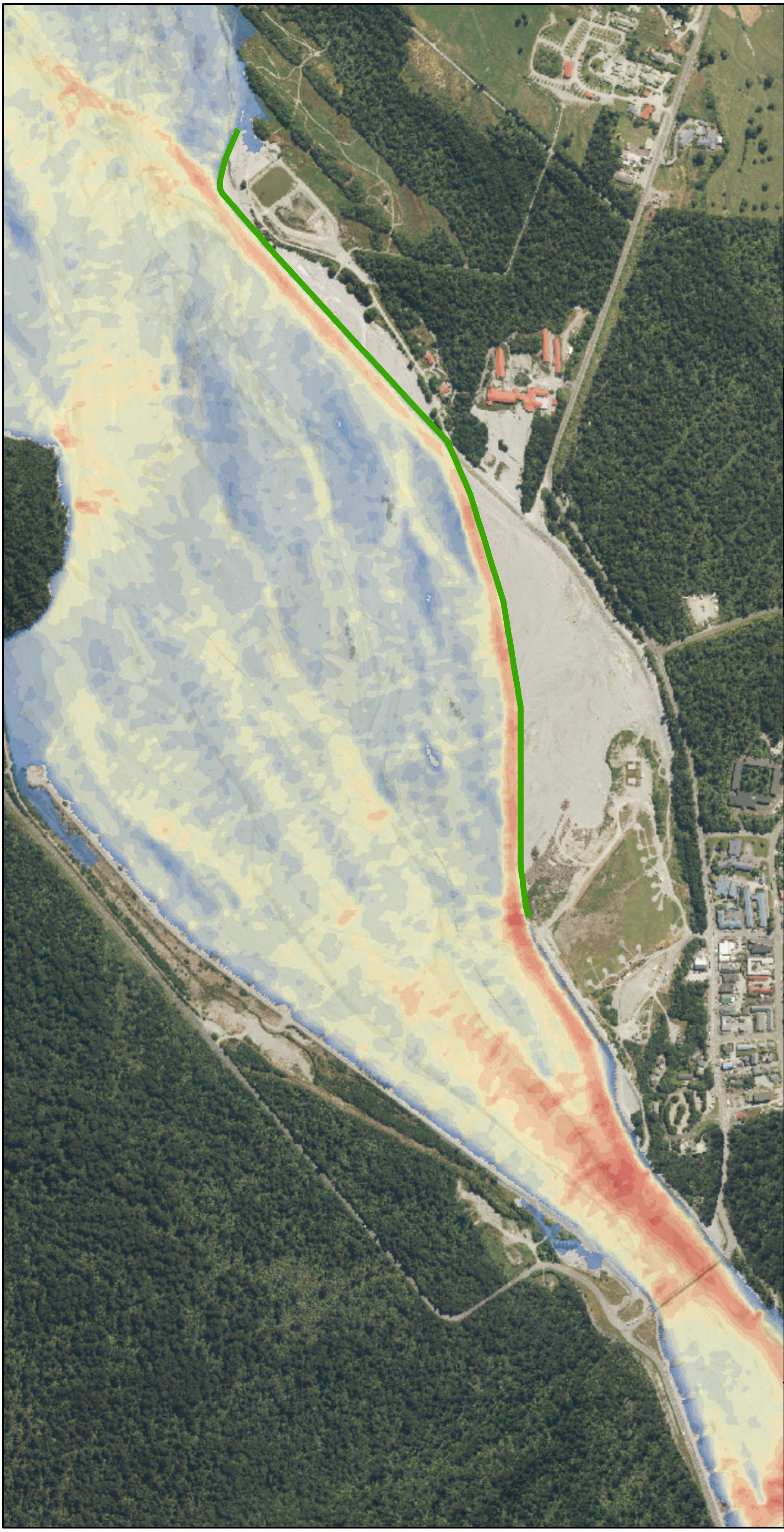
Franz Josef Stopbank Upgrade

MAP TITLE

Peak Speed Map
Bank Alignment B
Q2500 m3/s
Mannings 'n' 0.04

REVISION	DATE	
01	**19 July 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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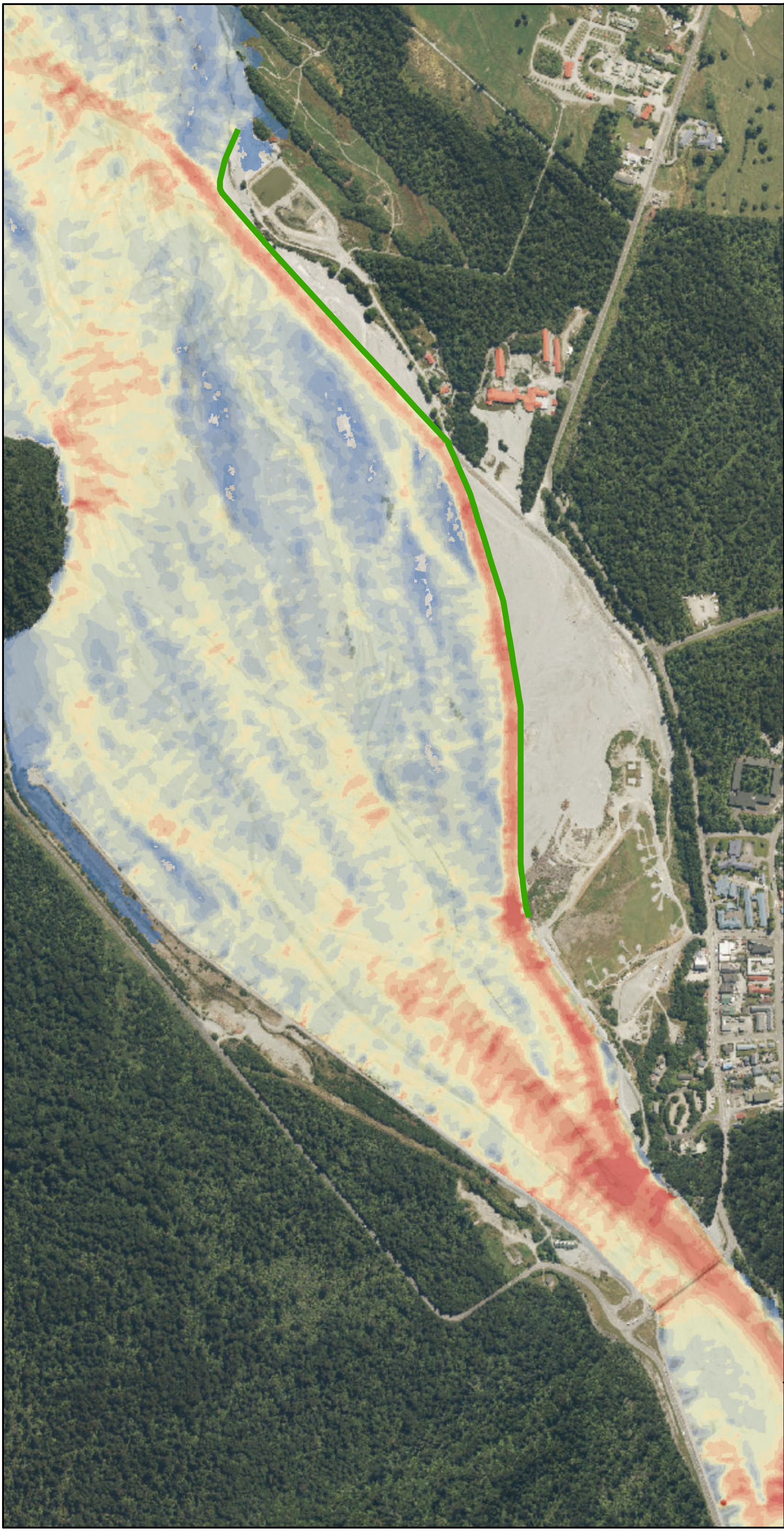
MAP TITLE

Peak Speed Map Bank Alignment B Q2500 m3/s Mannings 'n' 0.06

REVISION	DATE	
01	**19 July 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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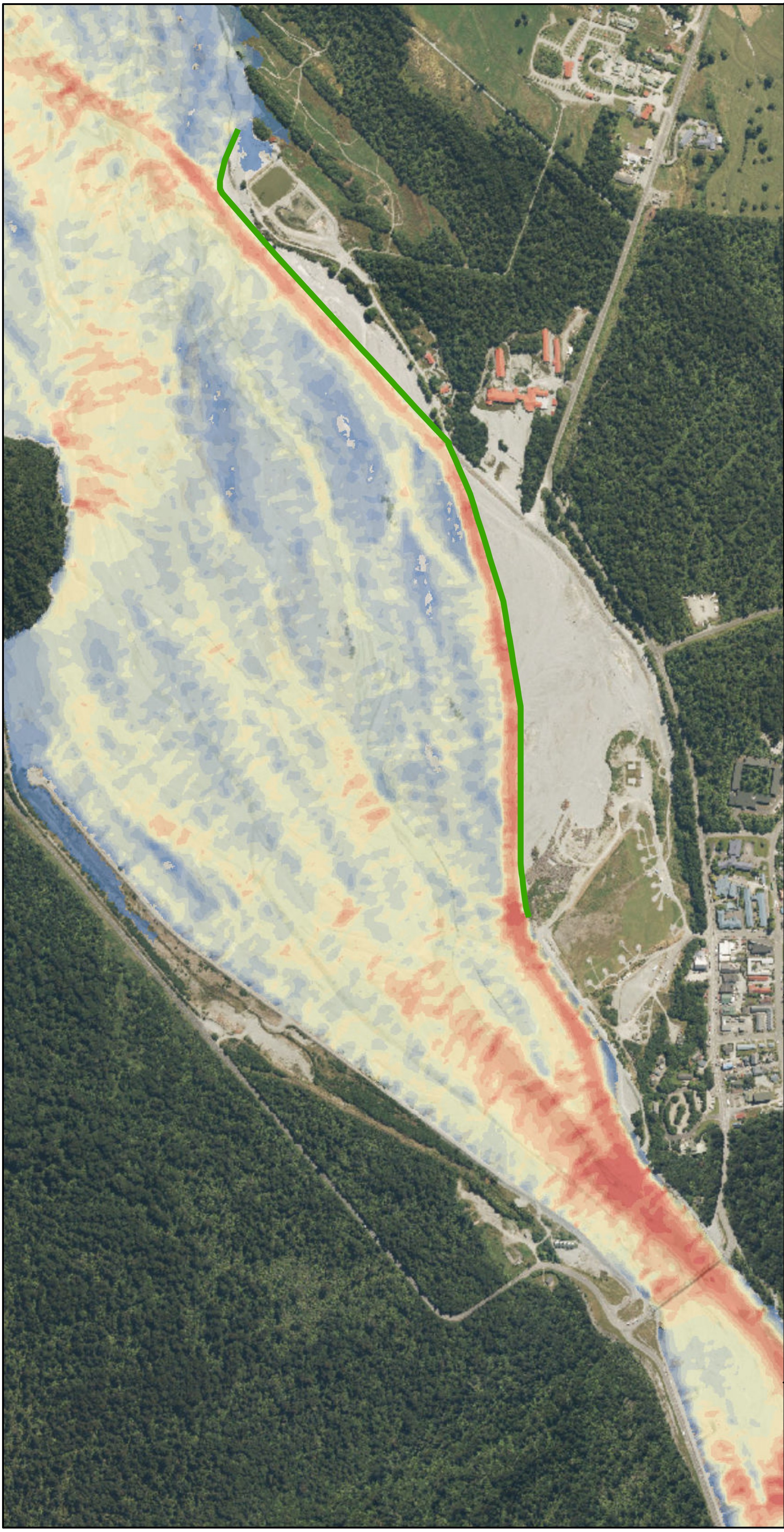
MAP TITLE

Peak Speed Map
Bank Alignment B
Q2500 m3/s
Mannings 'n' 0.05
Aggradation Rate 1

REVISION	DATE	
01	**24 Aug 2021**	N
A3 SCALE	**AUTHOR**	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers



Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5

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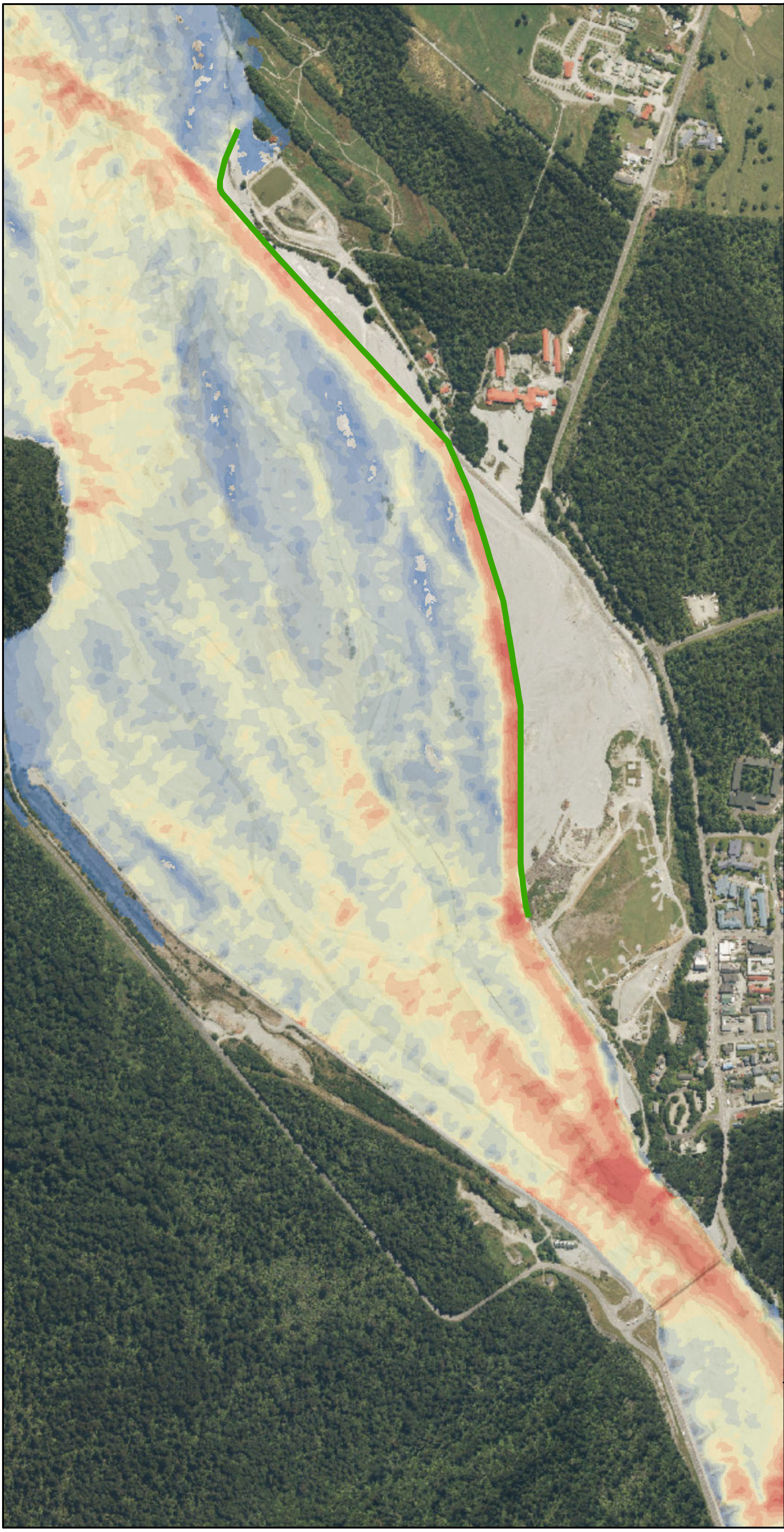
MAP TITLE

Peak Speed Map
Bank Alignment B
Q2500 m3/s
Mannings 'n' 0.05
Aggradation Rate 2

REVISION	DATE	
01	**24 Aug 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers

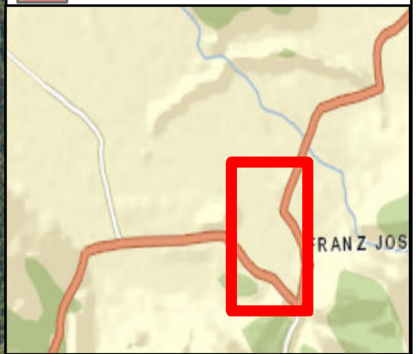


Legend

Bank Alignment B

Peak Speed (m/s)

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5



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Franz Josef Stopbank Upgrade

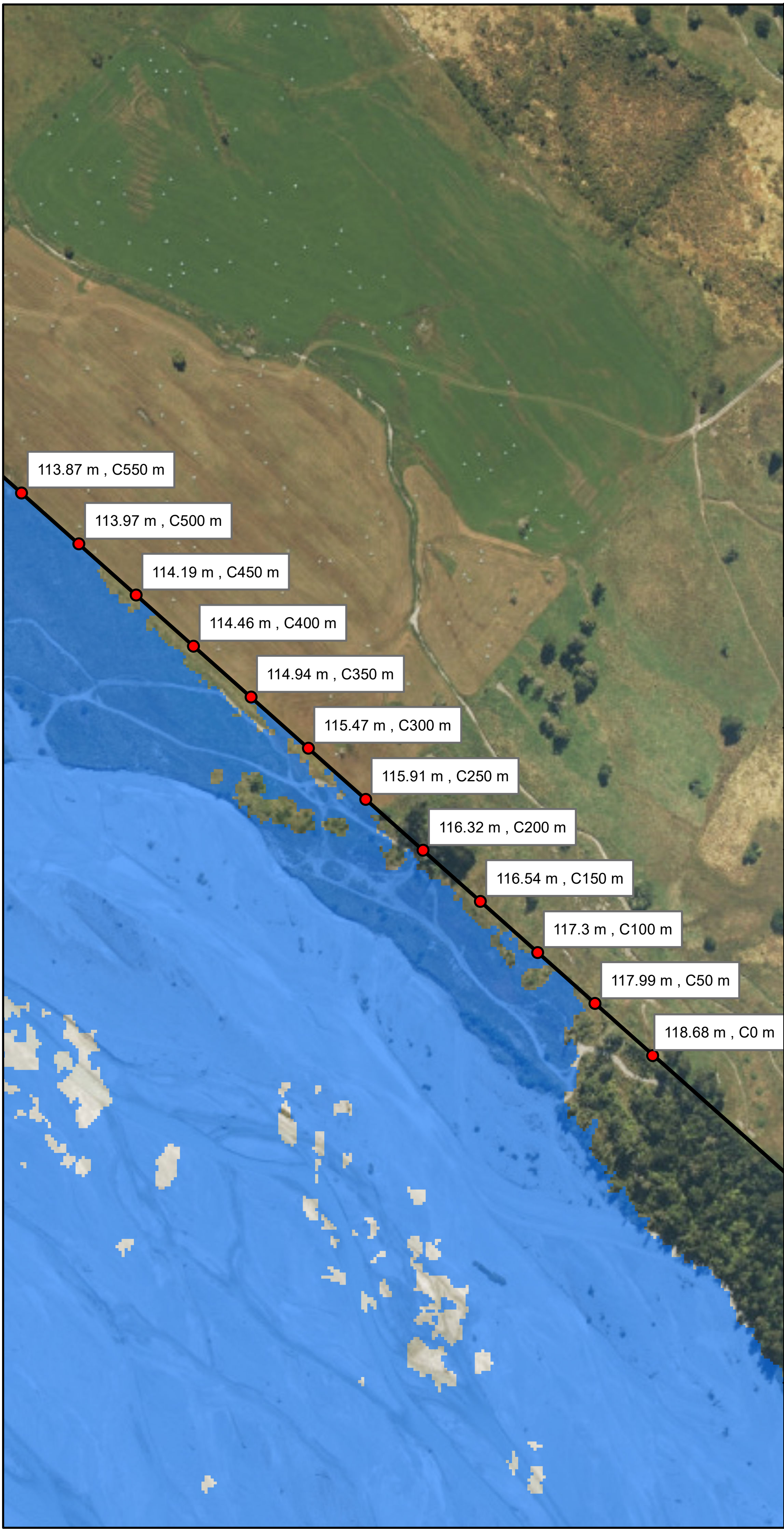
MAP TITLE

Peak Speed Map
Bank Alignment B
Q2500 m3/s
Mannings 'n' 0.05
Aggradation Rate 3

REVISION	DATE	
01	**24 Aug 2021**	N
A3 SCALE	AUTHOR	
1:10,000	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers

APPENDIX E – TATARE OVERFLOW BUND – PEAK WATER LEVELS



Legend

- Water Level Locations
- Tatare Bund Alignment
- Modelled Water Extent

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MAP TITLE

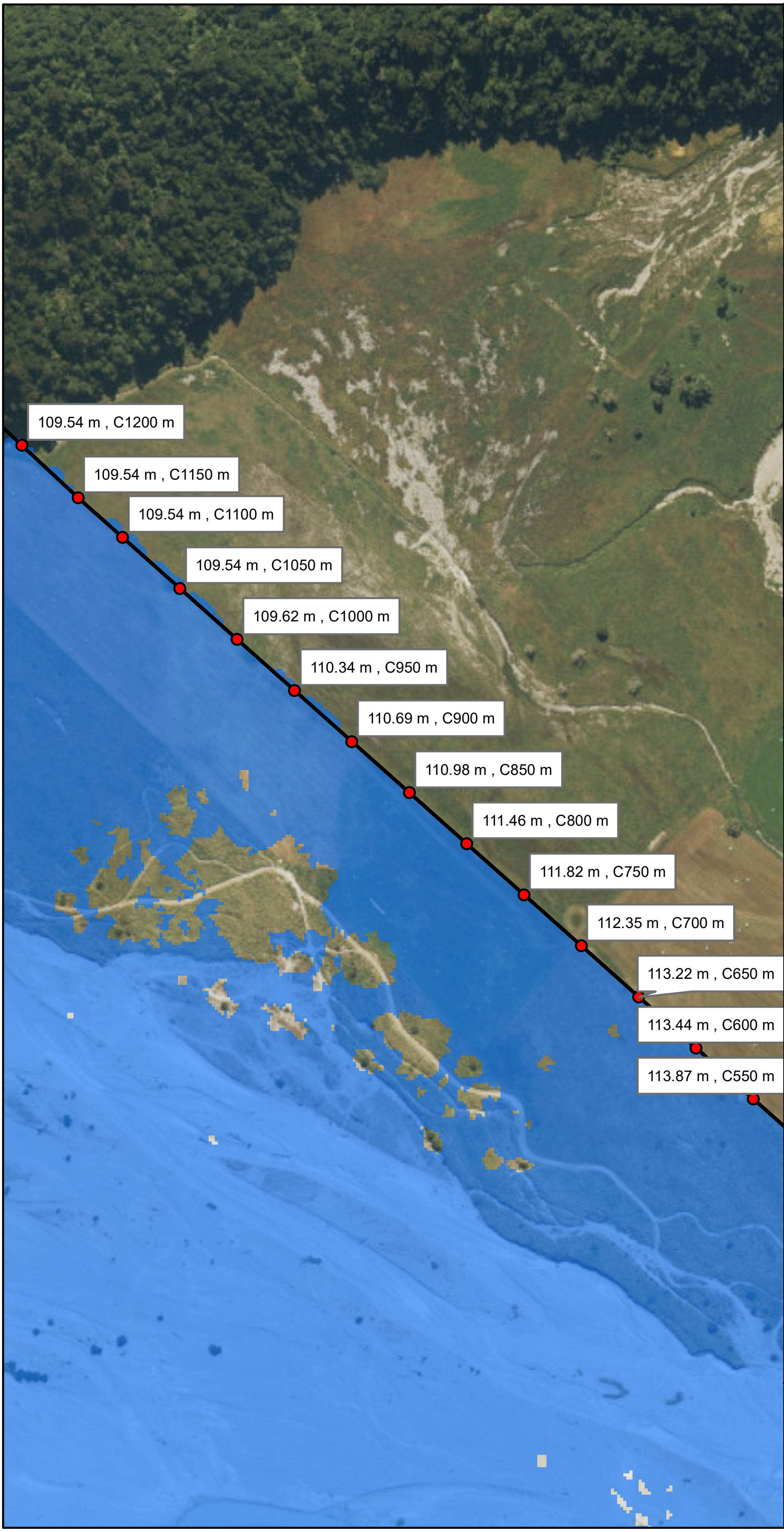
Tatare Bund Location and Peak Water Level

Map 1 of 2

REVISION	DATE
01	**09 Sep 2021**
A3 SCALE	AUTHOR
1:3,500	**Matthew Gardner**

N

0 0.0425 0.085 0.17
Kilometers



Legend

- Water Level Locations
- Tatare Bund Alignment
- Modelled Water Extent

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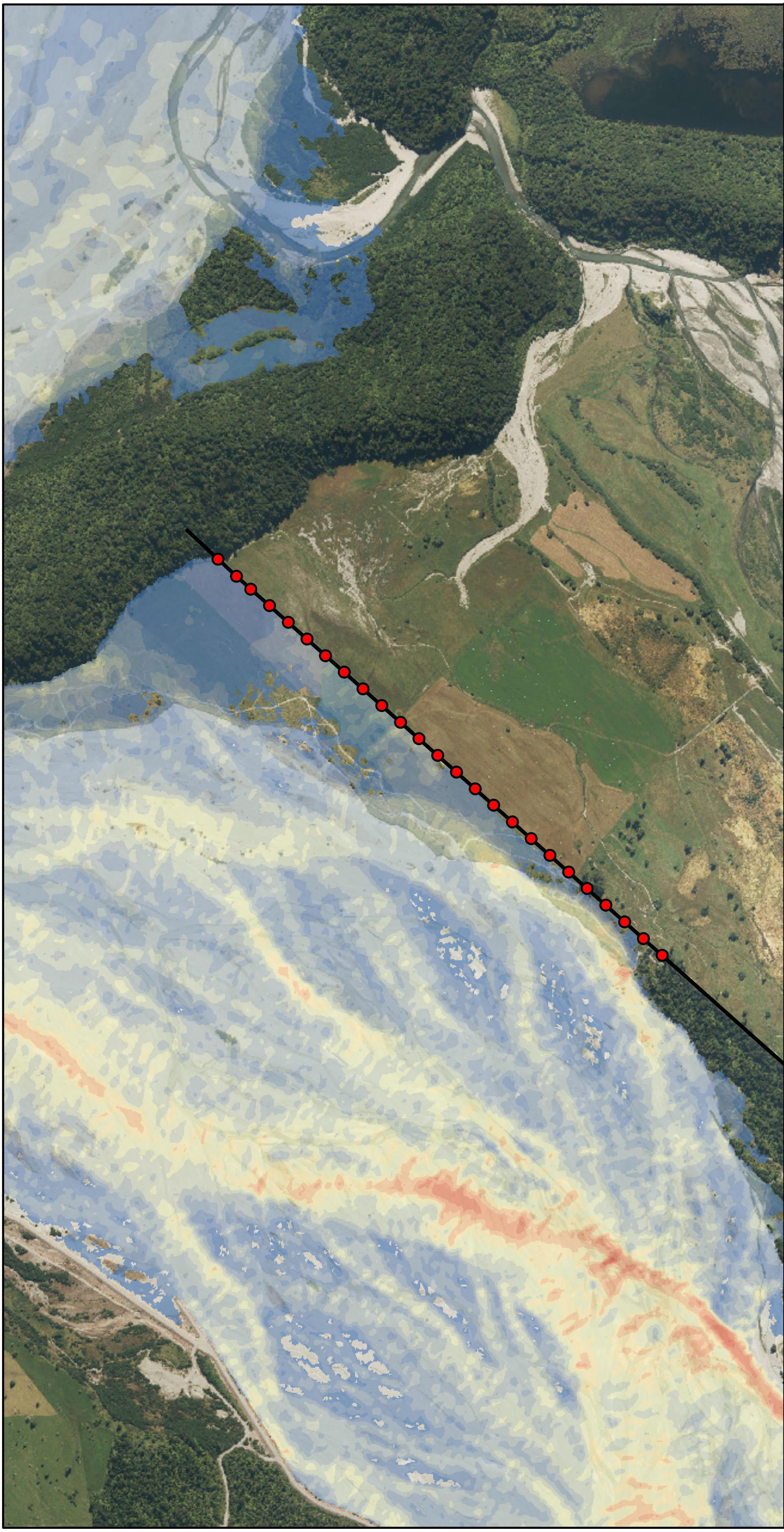
MAP TITLE

Tatare Bund Location and Peak Water Level

Map 2 of 2

REVISION	DATE	
01	**09 Sep 2021**	N
A3 SCALE	AUTHOR	
1:3,500	**Matthew Gardner**	

0 0.0425 0.085 0.17
Kilometers

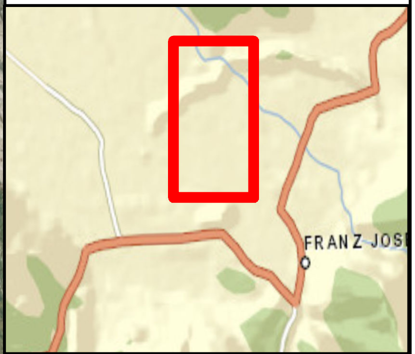


Legend

- Water Level Locations
- Tatare Bund Alignment

Peak Speed

- <0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 -2
- 2 -2.5
- 2.5 -3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 -5
- 5 - 5.5
- >5.5



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MAP TITLE

Tatare Bund Location and Peak Speed Map

REVISION	DATE	N
01	**09 Sep 2021**	
A3 SCALE	AUTHOR	
1:10,741	**Matthew Gardner**	

0 0.125 0.25 0.5
Kilometers