Flood Risk Assessment

Elizabeth Enterprise Precinct (EEP)

59918138

Prepared for
Mirvac

6 September 2021

Cardno
Shaping the Future

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Executive Summary

The purpose of this report is to provide a high-level understanding of the opportunities and constraints of the Elizabeth Enterprise Precinct (EEP) due to flooding and to inform the development of a precinct wide stormwater strategy/management plan for the EEP based on an assessment of flooding under 2015 and 2018 conditions using two-dimensional hydrodynamic flood models of the South Creek floodplain prepared using the following topographic data.

- LiDAR (2015) – Light Detection and Ranging (LiDAR) survey that was gathered for the entire South Creek floodplain between 2002 and 2006 and input into a hydraulic model by Worley Parsons in 2015;
- Detailed Survey (2018) – Detailed survey for the EEP site completed by Lockley Title Solutions in October 2016 and incorporated into a hydraulic model by Cardno in 2018. This detailed survey included for the earthworks completed over Lot 5 DP860456 and Lot 741 DP810111 as approved by Penrith City Council (Ref: DA08/0681) and completed in accordance with the consent as certified by Blackett Maguire + Goldsmith in Certificate No. CC09-104 on 13 May 2009.

In 2015 an Updated South Creek Flood Study was prepared by Worley Parsons Services on behalf of Penrith City Council, acting in association with Liverpool, Blacktown and Fairfield City Councils. This flood study was based on the LiDAR topographic survey data gathered for the entire South Creek floodplain between 2002 and 2006.

In November 2020, a final report titled the "Wianamatta (South) Creek Catchment Flood Study – Existing Conditions" was released by Infrastructure NSW (Advisian, 2020). This study updated the 2015 hydrological and hydraulic assessments.

Hydrology

Hydrological modelling of the South Creek catchment was undertaken at the catchment and development scale using XP-RAFTS. The hydrological model assembled by Worley Parsons in 2015 was used for consistency with the 2015 study. This model is based on ARR1987 IFD.

While the precinct overlaps adjoining subcatchments the great majority of the precinct lies within Subcatchments 1.14 and 1.15 (refer **Figure 5**). Consequently the precinct was partitioned into local subcatchments which would be drained into Subcatchment 1.14 (Subcatchment BE13) and into Subcatchment 1.15 (Subcatchment BE12) to separate any future development from the remainder of the subcatchment.

The estimated peak flows (m^3/s) in South Creek in the precinct in a 2 yr ARI and 100 yr ARI 2 hr, 9hr and 36 hr storm bursts and a PMP 6 hr storm are summarised as follows.

ARI (yrs)	2	2	2	100	100	100	PMF
Storm Burst (mins)	120	540	2160	120	540	2160	360
Node ID							
BE13	0.02	1.0	1.46	2.7	4.8	4.0	14.6
1.14	13.0	90.6	167.4	215.0	439.3	498.9	1,812
BE12	0.01	0.6	1.61	1.5	4.1	5.4	19.2
1.15	13.3	112.1	211.0	256.7	555.3	648.3	2,300

Advisian, 2020 advised:

> *The XP-RAFTS hydrologic model that was applied as part of the 2015 Flood Study has also been updated. The results of simulations undertaken using the updated XP-RAFTS model indicate that peak flows for the 1% AEP 36 hour critical duration event are similar to those determined as part of the modelling completed for the 2015 Flood Study. Peak flows along South Creek are generally within 2% of the corresponding flows determined in 2015, with a maximum change of up to 8% near the downstream boundary at Richmond Road. Changes along tributaries have greater variability with a maximum change of up to 15% (refer Figure 4.9).*

Hydraulics

Cardno assembled a local TUFLOW model of the reaches of South Creek and Kemps Creek which extended 1 km upstream and downstream of the subject site. The upstream inflow boundary conditions and the downstream stage boundary conditions were obtained from the WorleyParsons (LiDAR survey based) 2015 flood study results. The roughness zones for the floodplain were based on the roughness values and their spatial distribution adopted in the WorleyParsons 2015 flood study.

The local floodplain model of LiDAR survey (2015) Conditions was based on the Digital Elevation Model (DEM) adopted for the WorleyParsons 2015 flood study. It was noted from Figure 3.1 in WorleyParsons, 2015 that the Elizabeth Enterprise Precinct is located within the zone identified as *ALS data collected within the Penrith LGA in 2003.*

The TUFLOW floodplain model was run for the 100 yr ARI 36 hour storm burst duration and the 6 hour PMP event to estimate flooding under LiDAR survey (2015) Conditions.

The local floodplain model of detailed survey (2018) conditions was assembled by updating the DEM adopted for LiDAR survey (2015) Conditions based on site survey provided by Mirvac. It was noted that the site survey disclosed that earthworks were undertaken on the site subsequent to the collection of ALS in 2003. In 2008 Penrith City Council approved DA08/0691 for "Earthworks – Pasture improvement to improve Drainage". The consent become operational on 31 October 2008. The earthworks were completed in accordance with the consent as certified by Blackett Maguire + Goldsmith in Certificate No. CC09-104 on 13 May 2009.

The updated TUFLOW floodplain model was run for the 20 yr ARI, 100 yr ARI, 200 yr ARI and 500 yr ARI 36 hour storm burst duration events and the 6 hour PMP event to estimate flooding under Detailed Survey (2018) Conditions.

Figure 3-2 from the 2020 Advisian study attached in **Appendix B** indicates that the terrain in the 2020 Advisian model was updated and this is expected to align closely the detailed survey (2018) conditions in the local study area.

The differences between the 100 yr ARI flood levels estimated by the local TUFLOW model under Detailed Survey (2018) conditions and the 2015 RMA-2 model disclosed that the earthworks locally decreased or locally increased 100 yr ARI flood levels through the site. This is also observed in Figure 4-11 from the 2020 Advisian study attached in **Appendix B** which indicates that the updated terrain in the Advisian model has slightly lowered 1% AEP flood levels in comparison to 2015 flood levels. It is concluded that impact of the 2018 terrain on 2015 flood levels reported in this study aligns with the Advisian, 2020 results.

It was therefore concluded that under Detailed Survey (2018) Conditions are comparable to the updated 2020 Advisian floodplain modelling.

The estimated 20 year ARI, 200 yr ARI and 500 yr ARI flood levels and extent, depths, velocities, velocity x depth and hazards under Detailed survey (2018) Conditions have been plotted.

The estimated 100 year ARI hydraulic categories under Detailed Survey (2018) Conditions are also plotted as are also the estimated extents of the flood planning level under Detailed Survey (2018) Conditions.

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1 Introduction

1.1 Purpose of this Report

The purpose of this report is to provide a high-level understanding of the opportunities and constraints of the site due to flooding and to inform the development of a precinct wide stormwater strategy/management plan for the Elizabeth Enterprise Precinct based on an assessment of flooding under 2015 and 2018 conditions.

A review of previous flooding studies undertaken on the subject site, namely Penrith City Council's Updated South Creek Flood Study, Worley Parsons (2015) was to be undertaken. Modelling of design flood levels under detailed survey (2018) conditions was also commissioned.

In November 2020, a final report titled the "Wianamatta (South) Creek Catchment Flood Study – Existing Conditions" was released by Infrastructure NSW (Advisian, 2020).

As discussed by Advisian, 2020:

> *An Agency Working Group (AWG) was established by Infrastructure NSW to oversee a review of flood constraints that could impact on land use planning across the South Creek catchment. The AWG comprises representatives from Infrastructure NSW and the NSW Department of Planning, Industry and Environment (DPIE). The objective of the study is to inform the AWG of the flood constraints that could impact on development within the South Creek catchment so that options for optimally managing future development of the South Creek catchment can be determined and so that recommendations for land use planning can be made to the NSW Government. …..*
>
> *The modelling builds on the existing XP-RAFTS and RMA-2 models that were developed for the 'Updated South Creek Flood Study' (Advisian 2015) and the 'South Creek Floodplain Risk Management Study and Plan' (Advisian, 2020).*
>
> *This Wianamatta (South) Creek Catchment Flood Study documents the findings of the first phase of investigations, including the review and update of the existing flood models developed for South Creek to account for the latest available topographic data and the current extent of development across the catchment.*

The modelling undertaken under detailed survey (2018) conditions was compared with the flood mapping reported by Advisian, 2020.

1.2 Location

The location of the Elizabeth Enterprise Precinct is indicated in **Figure 1**.

1.3 2015 Updated South Creek Flood Study

The Updated South Creek Flood Study was prepared by WorleyParsons Services on behalf of Penrith City Council, acting in association with Liverpool, Blacktown and Fairfield City Councils. As described by WorleyParsons, 2015:

> *This flood study covers the South Creek catchment extending from Bringelly Road in the south to the Blacktown/Richmond Road Bridge crossing in the north. The total study area is about 240 km^2 and lies within the Hawkesbury, Penrith, Blacktown, Liverpool and Fairfield LGAs.*

The hydrologic modelling for this study is based on the previous RAFTS (Runoff Analysis and Flow Training Simulation) hydrologic modelling (Version 2.56, 1991) that was developed by the Department of Water Resources for the 'South Creek Flood Study' (1990). As part of this study, the RAFTS model of the South Creek catchment has been updated to Version 6.52 (2005) XPRAFTS.

As part of the current study, the sub-catchment delineation and break-up was compared against the latest topographic data available for the study area to determine whether the sub-catchment boundaries required adjustments. Some further refinement of subcatchments was undertaken in order to improve the inter-relationship between the XPRAFTS model and the RMA-2 hydraulic flood model. This improved the interconnectivity between the hydrologic and hydraulic models and made possible the creation of additional localised inflows within the RMA-2 model. ….

The adopted roughness parameters for each sub-catchment were also reviewed against aerial photography in order to determine any changes in vegetation and/or floodplain development that may have occurred since 1990. ….

Intensity-Frequency-Duration (IFD) data was developed for the study catchment according to the standard procedures outlined in Chapter 2 of 'Australian Rainfall & Runoff – A Guide to Flood Estimation' (1987). Due to the significant spatial extent of the study area, across which numerous local catchments and tributaries apply, a total of nine (9) different IFDs were adopted. ….

As no definitive loss rate data is available for the catchment of South Creek and its tributaries, the adopted rainfall loss rates were based on data contained in the 1990 Flood Study. …

The validation of the updated XP-RAFTS model was based on a comparison between the peak discharge and hydrograph shape produced by the RAFTS model developed for the 1990 Flood Study and the results of the latest XP-RAFTS model. ….

In order to undertake validation of the model, the updated XP-RAFTS model was used to simulate the 100 year ARI storm with a critical storm duration of 36 hours. ….

Since completion of the 1990 Flood Study, there have been many changes occur across the South Creek catchment. These changes include the implementation of a number of measures recommended in the South Creek Floodplain Management Study, including works upstream of Elizabeth Drive, at Overett Avenue, and at South St Marys. Major development of the ADI site at St Marys and small areas on the fringe of Erskine Park has also occurred. Changes have also occurred to areas of the floodplain including the construction of levees and earthworks that have the potential to alter flooding patterns. …..

Accordingly, a two-dimensional hydrodynamic model of the South Creek system has been developed using the RMA-2 software package. The model is based on the latest topographic data for the catchment, which was derived from Light Detection and Ranging (LiDAR) data that was gathered for the entire South Creek floodplain between 2002 and 2006. ….

The RMA-2 flood model that has been developed for this study has not been calibrated against historic floods. The Project Brief specified that the model only needed to be validated against predicted peak flood levels generated for the 100 year ARI flood using the MIKE-11 and HEC-2 modelling that was developed for the 1990 Flood Study.

…. The computer models identified in Sections 4 and 5 were used to derive design flood estimates for the 20, 50, 100, 200 and 500 year recurrence floods as well as an Extreme Flood.

The calculated 100 yr ARI and PMF flood depths and velocities in the vicinity of Elizabeth Enterprise Precinct are plotted in **Figures 3** and **4** respectively.

1.4 2020 Wianamatta (South) Creek Catchment Flood Study – Existing Conditions

As concluded by Advisian, 2020:

> *The RMA-2 hydraulic flood model that was developed for the 'Upper South Creek Flood Study' (2015) has been updated to incorporate the latest available topographic data which has been derived from LiDAR, as well as information from recent flood investigations and recent industrial and urban developments that have occurred in parts of the catchment. This has included extensions to the RMA-2 flood model in the upper reaches of the study area, particularly in the vicinity of Bringelly Road.*
>
> *The XP-RAFTS hydrologic model that was applied as part of the 2015 Flood Study has also been updated. The results of simulations undertaken using the updated XP-RAFTS model indicate that peak flows for the 1% AEP 36 hour critical duration event are similar to those determined as part of the modelling completed for the 2015 Flood Study. Peak flows along South Creek are generally within 2% of the corresponding flows determined in 2015, with a maximum change of up to 8% near the downstream boundary at Richmond Road. Changes along tributaries have greater variability with a maximum change of up to 15% (refer Figure 4.9).*
>
> *The 36 hour storm duration has been confirmed to be critical for the study area generating the largest peak flows along South Creek and at many of the major bridge crossings. Although shorter storm durations such as the 2 and 9 hour storms generate the largest flows along many of the smaller tributaries such as Thompsons, Bonds, Claremont and Werrington creeks (refer Table 4.3), the 36 hour duration is considered most relevant to the study and the assessment of impacts along the length of South Creek.*
>
> *The updated XP-RAFTS hydrologic model was also used to simulate the 1% AEP flood based on ARR 2019 inputs and procedures. Peak flows at the Elizabeth Drive crossing were derived based on both ARR 1987 and ARR 2019 inputs and procedures, and the results were compared to peak flows derived at Elizabeth Drive from Flood Frequency Analysis (FFA). The comparison established that the modelling based on ARR 1987 generated a peak flow for the 1% AEP event that matched more closely (9% lower) to the FFA than was the case based on ARR 2019 (29% lower) (refer Table 4.5). Hence, it was determined that the assessment of flood hydrology for the South Creek catchment should continue to be based on ARR 1987 temporal patterns and Intensity-Frequency-Duration (IFD) data. This is consistent with the 'Updated South Creek Flood Study' (Advisian, 2015).*
>
> *Revised mapping has been prepared for flood levels, depths and hazard for a range of design events. The hydraulic category mapping prepared previously for Penrith City Council as part of the 'South Creek Floodplain Risk Management Study & Plan' (2020) has also been updated according to the revised modelling results. Some differences have been observed between the 2015 and 2020 flood model results for the 1% AEP flood. This is not unexpected given the catchment and floodplain changes associated with recent development and also the incorporation of more detailed topographic data that has led to a significant increase in the number of RMA-2 model nodes; i.e., greater network detail.*

Detailed inspection of the modelling results has established that the areas where the changes occur and their magnitude are consistent with the expected impact due to the local changes to the floodplain and catchment that have been observed over the last 5 years.

Accordingly, the updated flood models are considered to suitably represent the contemporary conditions across the South Creek catchment and floodplain. The models are therefore considered to be fit for purpose and appropriate tools for assessing the potential impact of future development scenarios on flood characteristics, including the potential impact of the blue-green grid infrastructure that is proposed as part of the Western Sydney Aerotropolis.

Selected Figures from Advisian, 2020 are included in **Appendix B.**

1.5 Approach

The approach adopted to the hydrological and hydraulic assessments is outlined as follows.

1.4.1 Hydrology

The hydrological model assembled by WorleyParsons in 2015 was based on ARR1987 IFD. 100 yr ARI runoff in the upper South Creek catchment south of Bringelly Road has been assessed previously for 2 hour, 9 hour and 36 hour storm bursts. An assessment of the sensitivity of 100 yr ARI peak runoff to storm burst rainfall losses has also been undertaken.

It should be noted that the 2015 study identified the critical storm burst duration for South Creek downstream of Bringelly Road to be 36 hours. While any future development would be expected to have an adverse impact of peak flows in a 2 hour storm burst it is likely that any future development will have minimal or nil adverse or beneficial impact on peak flows in a 36 hour storm due to the duration of the storm and timing effects due to runoff from impervious areas occurring more rapidly than runoff from pervious areas.

1.4.2 Hydraulics

The floodplain model assembled for the 2015 study is an RMA-2 model. It is our understanding that the adoption of this model was a legacy from when the study was commenced more than 5 years before the study was finally released in 2015.

The clear preference of NSW Councils and others is for floodplain modelling to be undertaken using other packages including TUFLOW. It was therefore proposed to assemble a local TUFLOW model of the reaches of South Creek and Kemps Creek which extend at least 1 km upstream and downstream of the subject site. The upstream inflow boundary conditions and the downstream stage boundary conditions would be obtained from the WorleyParsons 2015 flood study results. The roughness zones for the floodplain would be informed by the roughness values and their spatial distribution adopted in the 2015 flood study.

1.6 Terminology

Book 1, Chapter 2, Section 2.2.5. Adopted Terminology in Australian Rainfall & Runoff, 2016 describes the adopted terminology as follows:

To achieve the desired clarity of meaning, technical correctness, practicality and acceptability, the National Committee on Water Engineering has decided to adopt the terms shown in Figure 1.2.1 and the suggested frequency indicators.

Navy outline indicates preferred terminology. Shading indicates acceptable terminology which is depends on the typical use. For example in floodplain management 0.5% AEP might be used while in dam design this event would be described as a 1 in 200 AEP.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓	
			PMP/ PMPDF	

Figure 1.2.1. Australian Rainfall and Runoff Preferred Terminology

As shown in the third column of Figure 1.2.1, the term Annual Exceedance Probability (AEP) expresses the probability of an event being equalled or exceeded in any year in percentage terms, for example, the 1% AEP design flood discharge. There will be situations where the use of percentage probability is not practicable; extreme flood probabilities associated with dam spillways are one example of a situation where percentage probability is not appropriate. In these cases, it is recommended that the probability be expressed as 1 in X AEP where 100/X would be the equivalent percentage probability.

For events more frequent than 50% AEP, expressing frequency in terms of annual exceedance probability is not meaningful and misleading, as probability is constrained to a maximum value of 1.0 or 100%. Furthermore, where strong seasonality is experienced, a recurrence interval approach would also be misleading. An example of strong seasonality is where the rainfall occurs predominately during the Summer or Winter period and as a consequence flood flows are more likely to occur during that period. Accordingly, when strong seasonality exists, calculating a design flood flow with a 3 month recurrence interval is of limited value as the expectation of the time period between occurrences will not be consistent throughout the year. For example, a flow with the magnitude of a 3 month recurrence interval would be expected to occur or be exceeded 4 times a year; however, in situations where there is strong seasonality in the rainfall, all of the occurrences are likely to occur in the dominant season.

Consequently, events more frequent than 50% AEP should be expressed as X Exceedances per Year (EY). For example, 2 EY is equivalent to a design event with a 6 month recurrence interval when there is no seasonality in flood occurrence

The terminology adopted herein is the same as adopted for the 2015 Updated South Creek Flood Study was prepared by WorleyParsons Services, namely, ARI for design floods.

2 Hydrology

Hydrological modelling of the South Creek catchment was undertaken at the catchment and precinct scale using XP-RAFTS. The hydrological model assembled by WorleyParsons in 2015 was used for consistency with the 2015 flood study. This model is based on ARR1987 IFD. The subcatchment layout is given in **Figure 5**.

While the precinct overlaps adjoining subcatchments the great majority of the precinct lies within Subcatchments 1.14 and 1.15 (refer **Figure 5**). Consequently, the precinct was partitioned into local subcatchments which would be drained into Subcatchment 1.14 (Subcatchment BE13) and into Subcatchment 1.15 (Subcatchment BE12) to separate any future development from the remainder of the subcatchment.

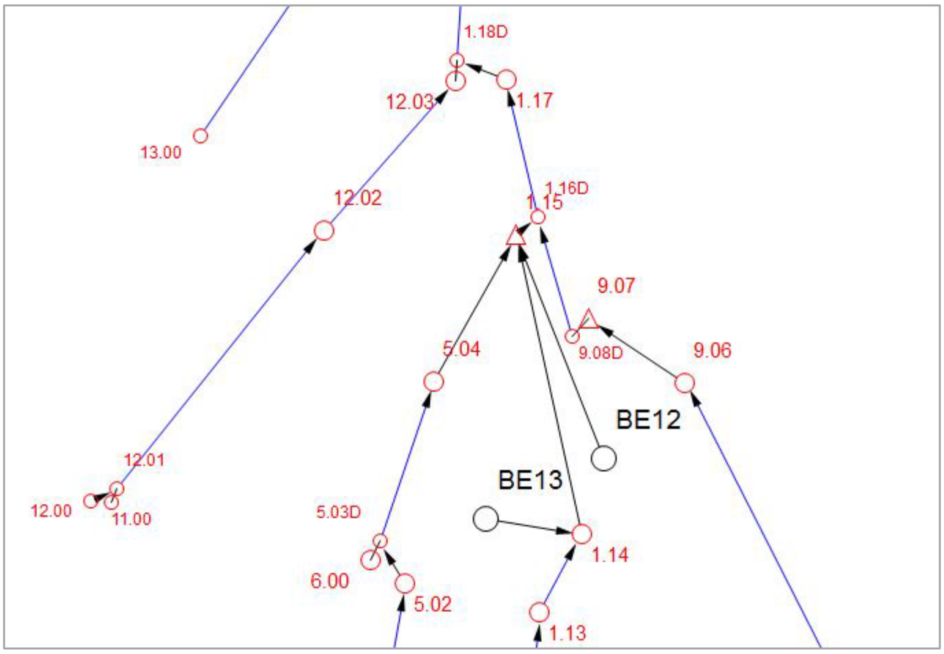
The XP-RAFTS model was run to estimate peak flows under LiDAR survey (2015) conditions as follows

ARI (years)	Storm Burst Durations
2, 100	2, 9, 36 hours
PMF	6 hours

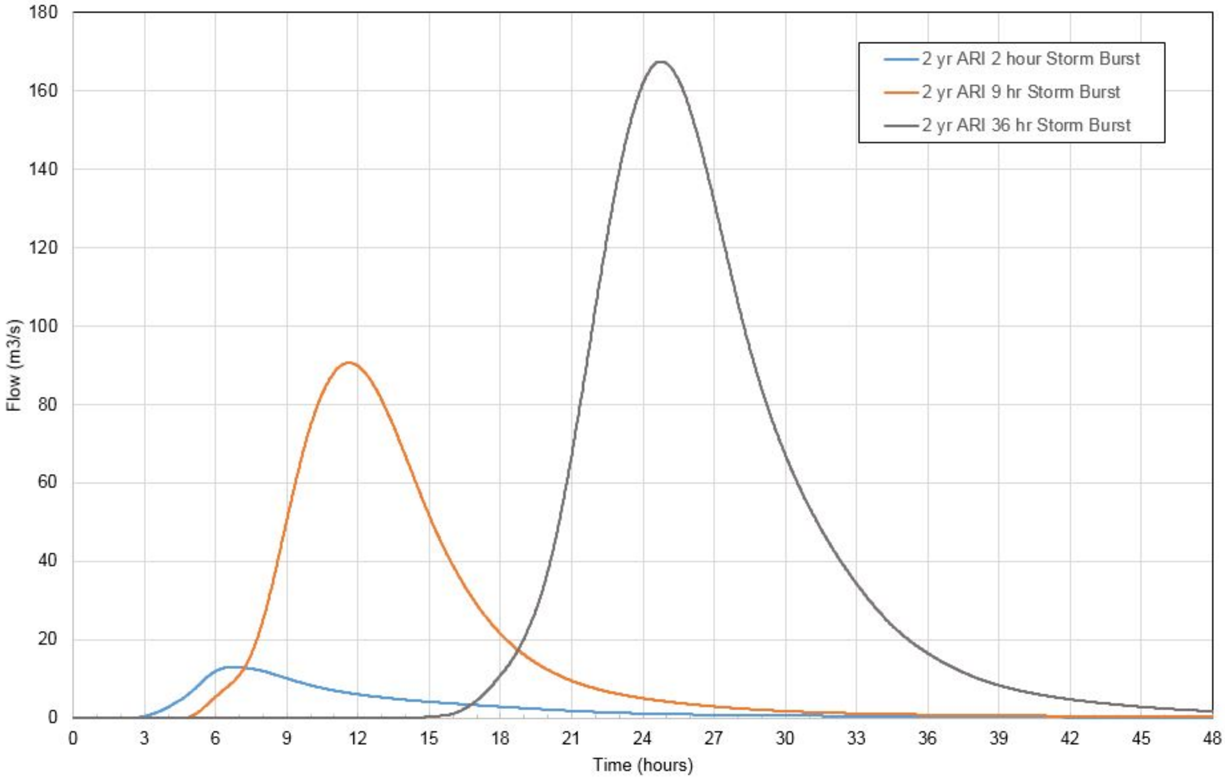
Table 1 summarises the estimated peak runoff from the development and in South Creek as well as including the link-node layout in the vicinity of the precinct.

Table 1 Summary of 2 yr ARI, 100 yr ARI and PMF Peak Flows (m3/s) under LiDAR Survey (2015) Conditions

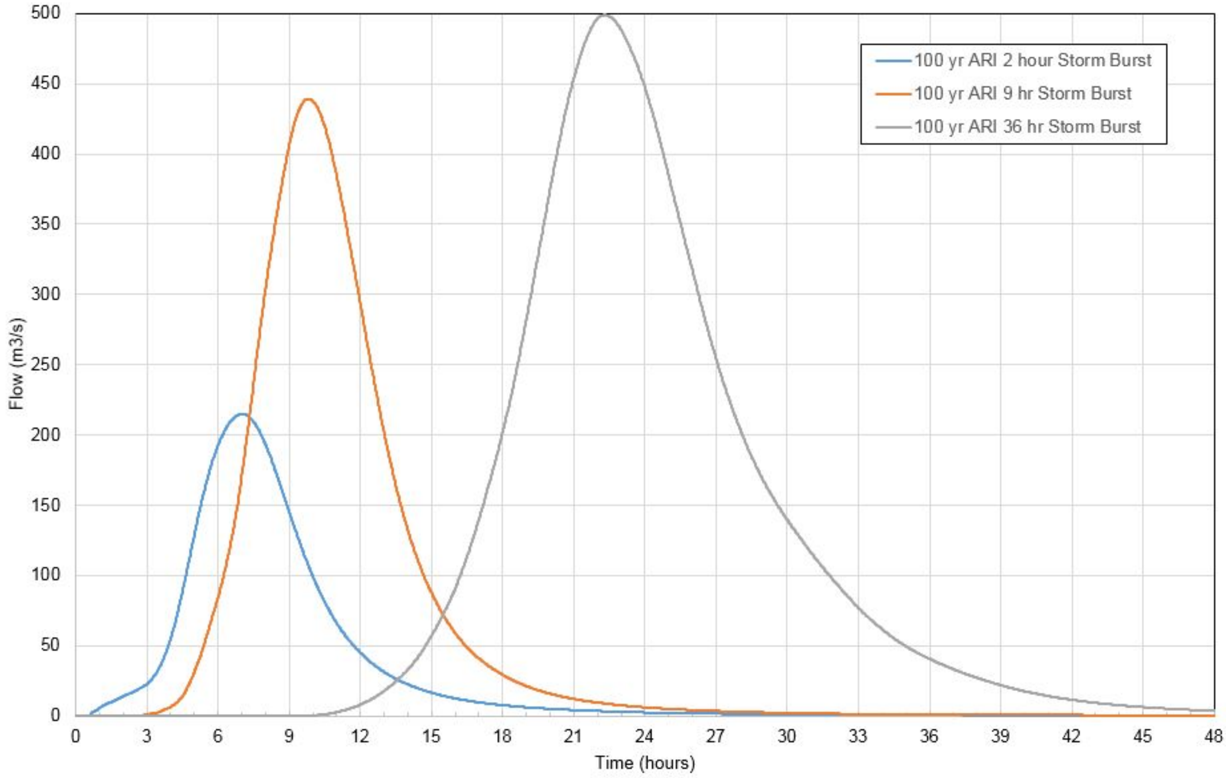
ARI (yrs)	2	2	2	100	100	100	PMF
Storm Burst (mins)	120	540	2160	120	540	2160	360
Node ID							
BE13	0.02	1.0	1.46	2.7	4.8	4.0	14.6
1.14	13.0	90.6	167.4	215.0	439.3	498.9	1,812
BE12	0.01	0.6	1.61	1.5	4.1	5.4	19.2
1.15	13.3	112.1	211.0	256.7	555.3	648.3	2,300



The following plots display the magnitudes and the relative timing of runoff in South Creek at Node 1.14 in a 2 yr ARI and 100 yr ARI 2 hr, 9hr and 36 hr storm bursts. It is also very clear that the 36 hr storm burst is the critical storm burst for catchment flooding downstream of Bringelly Road.

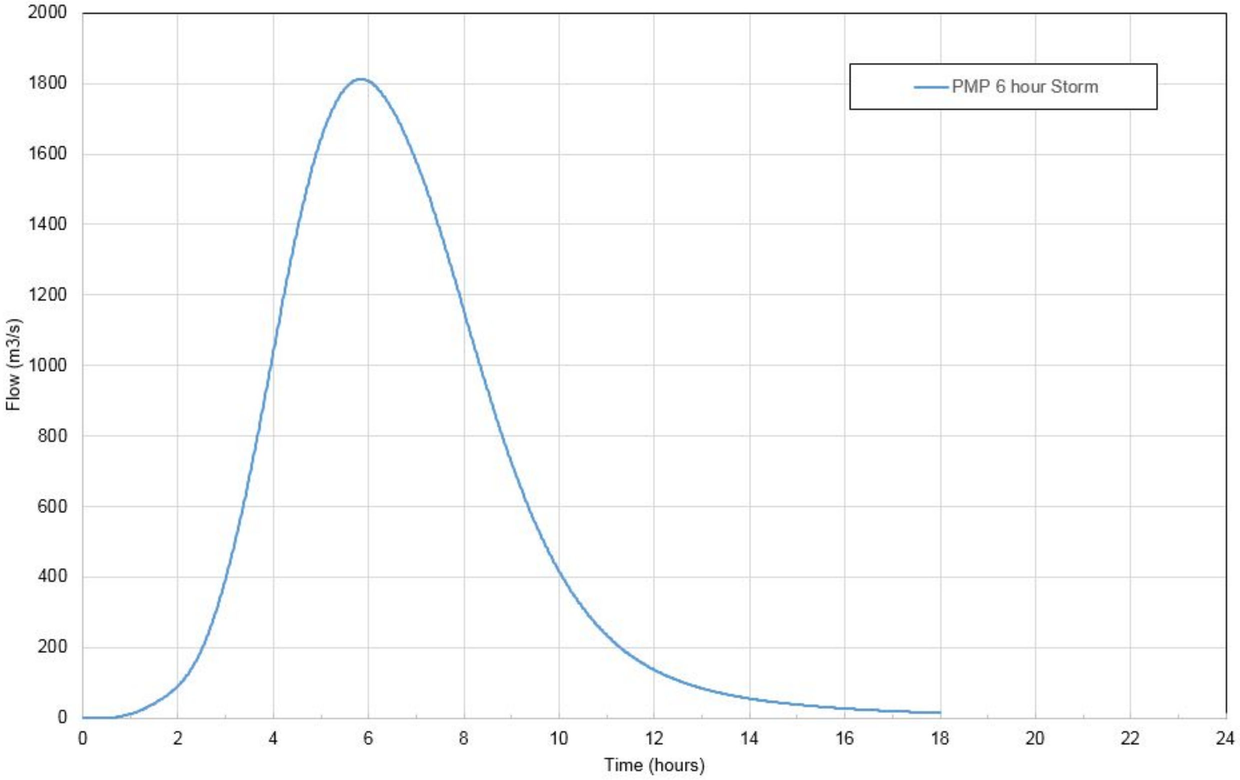


2 yr ARI Hydrographs at Node 1.14 under LiDAR Survey (2015) Conditions



100 yr ARI Hydrographs at Node 1.14 under LiDAR Survey (2015) Conditions

The following plot displays the magnitudes and the relative timing of runoff in South Creek in a PMP 6 hour storm at Node 1.14.



PMF Hydrograph at Node 1.14 under LiDAR Survey (2015) Conditions

Advisian, 2020 also advised:

> *The XP-RAFTS hydrologic model that was applied as part of the 2015 Flood Study has also been updated. The results of simulations undertaken using the updated XP-RAFTS model indicate that peak flows for the 1% AEP 36 hour critical duration event are similar to those determined as part of the modelling completed for the 2015 Flood Study. Peak flows along South Creek are generally within 2% of the corresponding flows determined in 2015, with a maximum change of up to 8% near the downstream boundary at Richmond Road. Changes along tributaries have greater variability with a maximum change of up to 15% (refer Figure 4.9).*

3 Flooding Assessment

A local TUFLOW model of the reaches of South Creek and Kemps Creek which extended 1 km upstream and downstream of the subject site was assembled. The upstream inflow boundary conditions and the downstream stage boundary conditions were obtained from the WorleyParsons 2015 flood study results. The roughness zones for the floodplain were based on the roughness values and their spatial distribution adopted in the 2015 flood study.

An initial run of the local TUFLOW model gave 100 yr ARI flood levels upstream of Elizabeth Drive which were lower than the 2015 study and matching higher 100 yr ARI flood levels downstream of Elizabeth Drive than the 2015 study. Following a search of our project archives we were able to locate details on the various crossings under Elizabeth Drive on the South Creek floodplain. A review of this data confirmed the adopted configuration of the two primary western Elizabeth Drive crossings. It also provided details not available in the 2015 study on the culverts installed at the two eastern Elizabeth Drive crossings. The local model was updated with these details.

The additional crossing information was found to locally redistribute floodplain flows in the vicinity of Elizabeth Drive and increased 100 yr ARI flood levels upstream of Elizabeth Drive (refer **Figure 10**). It was found that there remained a zone of local increases upstream of Elizabeth Drive which is present in the results for both the initial and modified floodplain models. It was concluded that these differences are due to the differences between the TUFLOW representation of the RMA-2 model and the RMA-2 model itself.

3.1 LiDAR Survey (2015) Conditions

The local floodplain model of LiDAR Survey (2015) Conditions was based on the Digital Elevation Model (DEM) adopted for the 2015 flood study. The source of the typographic data adopted in the 2015 floodplain model was described by WorleyParsons, 2015 as follows:

Details of the topography of the study area can be interpreted from the following sources:

- *Digital Elevation Model (DEM) data for the floodplain developed from Airborne Laser Scanning (ALS) data for the study area;*
- *DEM data developed from site specific survey;*
- *Previously surveyed cross-sections collected for the 1985 and 1990 Flood Studies; and,*
- *1:25,000 series topographic maps published by the Central Mapping Authority; These data sources are described in the following sections.*

Airborne Laser Scanning Data

Airborne Laser Scanning (ALS) data is available for the entire study area. This ALS data comprises very large data sets that contain thousands of points defining the existing ground surface elevations within the study area. The latest ALS data available includes:

- *ALS data collected within the Penrith LGA in 2003;*
- *ALS data collected within the Blacktown LGA in May 2006;*
- *ALS data collected within the Fairfield LGA in 2005; and,*
- *ALS data collected within the Liverpool LGA in 2005.*

The extent of the available ALS data sets are shown in Figure 3.1.

ALS procedures are unable to penetrate through water, and do not typically include hydrographic features important for flood modelling, such as the bathymetry of streams that carry water under normal flow conditions.

However, South Creek and its tributaries did not carry significant flow during the periods when the ALS data was collected. Moreover, the definition of the creek beds and banks was compared to the surveyed cross-sections collected for the 1990 Flood Study and it was determined that the ALS data adequately defined the bed and banks within the study area. Accordingly, the ALS data has been used to define the channel and floodplain for the South Creek system within the study area.

It was noted from Figure 3.1 in WorleyParsons, 2015 that the Elizabeth Enterprise Precinct is located within the zone identified as *ALS data collected within the Penrith LGA in 2003.*

3.1.1 100 yr ARI

The TUFLOW floodplain model was run for the 36 hour storm burst duration.

The estimated 100 year ARI flood levels and extent, depths and velocities under LiDAR Survey (2015) Conditions are plotted in **Figures 5, 6** and **7** respectively.

When initially considering pedestrian and vehicular stability, three velocity x depth criteria were identified as follows:

Velocity x Depth	Comment
≤ 0.4 m^2/s	This is typically adopted by Councils as a limit of stability for pedestrians
0.4 – 0.6 m^2/s	Unsafe for pedestrians but safe for vehicles if overland flood depths do not exceed around 0.3 m
> 0.6 m^2/s	This is typically adopted by Councils as a limit of stability for vehicles

The latest edition of Australian Rainfall and Runoff released in 2016 provides guidance on both pedestrian and vehicle stability in floods. As stated in ARR2016:

Cox et al., 2010 concluded that self-evacuation of the most vulnerable people in the community (typically small children, and the elderly) is limited to relatively placid flow conditions. Furthermore, a D.V as low as 0.4 m2s-1 would prove problematic for people in this category, i.e. the more vulnerable in the community.

These hazard regimes for tolerable flow conditions (D.V) as related to the individual's physical characteristics (H.M) are presented in Figure 9.2.4 …...

Determining safety criteria for vehicles requires an understanding of the physical characteristics of the vehicle along with the nature of the flow.

The measure of physical attributes for vehicle stability analysis is the vehicle classification as based on length (L, m), kerb weight (W, kg) and ground clearance (GC, m). Three vehicle classifications are suggested:

- *Small passenger: L < 4.3 m, W < 1250 kg, GC < 0.12 m*
- *Large passenger: L > 4.3 m, W > 1250 kg, GC > 0.12 m*
- *Large 4WD: L > 4.5 m, W > 2000 kg, GC > 0.22 m*

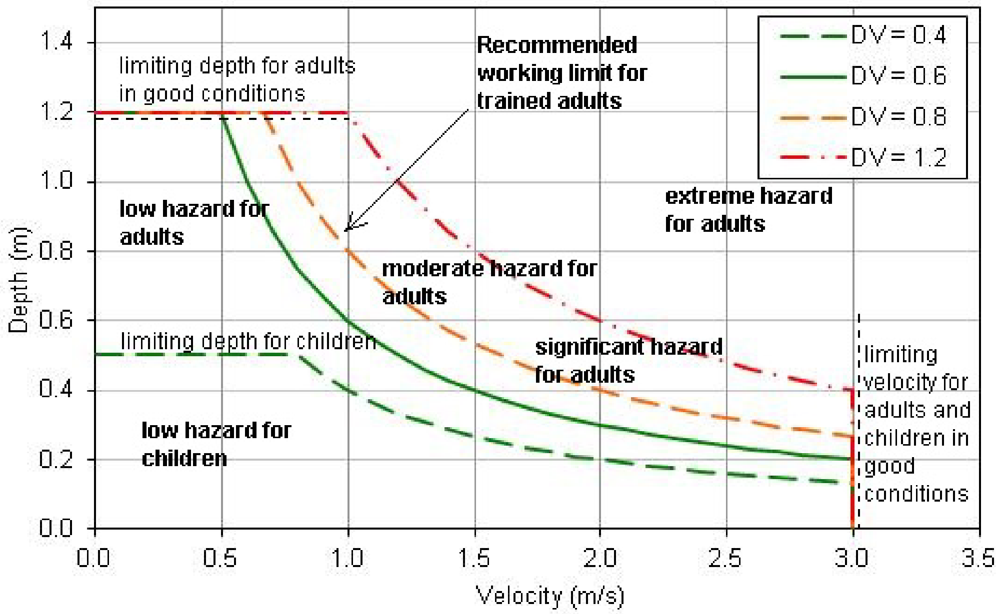


Figure 9.2.4. Safety Criteria for People in Variable Flow Conditions (After Cox et al, 2010)

The measure of flow attributes for vehicle stability analysis is D.V m2s-1, determined as the product of flow depth (D, m) and flow velocity (V, ms-1).

Limiting conditions exist for each classification based on limited laboratory testing of characteristic vehicles. The upper tolerable velocity for moving water is defined based on the frictional limits, and is a constant 3.0 ms-1 for all vehicle classifications.

The upper tolerable depths within still water are defined by the floating limits:

- *Small passenger vehicles: 0.3 m*
- *Large passenger vehicles: 0.4 m*
- *Large 4WD vehicles: 0.5 m*

The upper tolerable depths within high velocity water (at 3.0 ms^{-1}) are defined by the frictional limits:

- *Small passenger vehicles: 0.1 m*
- *Large passenger vehicles: 0.15 m*
- *Large 4WD vehicles: 0.2 m*

… Stability criteria based on the best available information for stationary small passenger cars, large passenger cars and large 4WD vehicles in various flow situations are presented in Figure 9.2.6 …..

Shand et al (2011) concludes that the available datasets do not adequately account for the following factors and that more research is needed in these areas:

- *Friction coefficients for contemporary vehicle tyres in flood flows;*
- *Buoyancy changes in modern cars;*
- *The effect of vehicle orientation to flow direction (including vehicle movement);*
- *Information for additional categories including small and large commercial vehicles and emergency service vehicles*

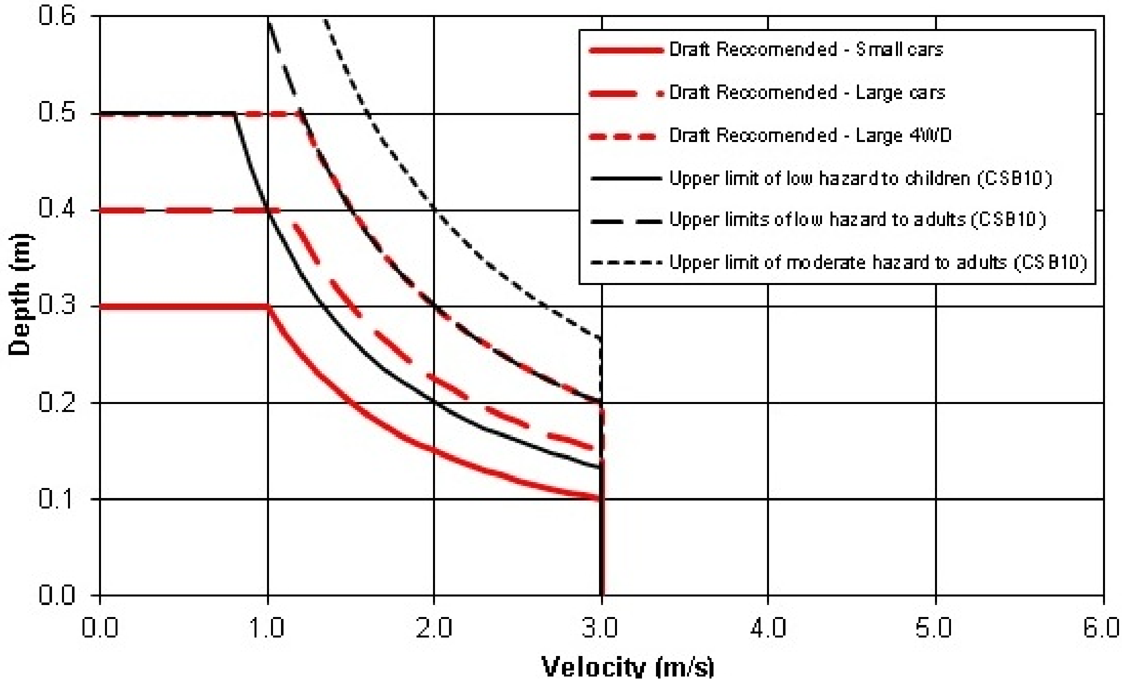
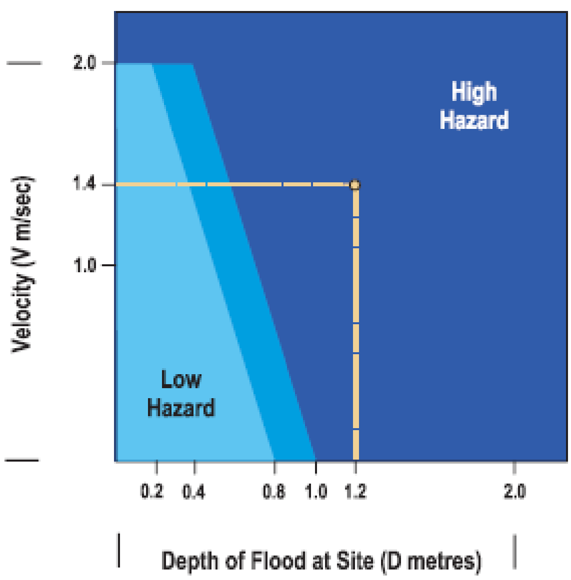


Figure 9.2.6. Interim Safety Criteria for Vehicles in Variable Flow Conditions (After Shand et al, 2011)

The estimated 100 year ARI velocity x depth under LiDAR Survey (2015) Conditions is plotted in **Figure 8.**

Experience from studies of floods throughout NSW and elsewhere has allowed authorities to develop methods of assessing the hazard to life and property on floodplains. This experience has been used in developing the NSW Floodplain Development Manual to provide guidelines for managing this hazard. These guidelines are shown schematically below.



Provisional Hazard Categories (after Figure L2, NSW Government, 2005)

To use the diagram, it is necessary to know the average depth and velocity of floodwaters at a given location. If the product of depth and velocity exceeds a critical value (as shown below), the flood flow will create a high hazard to life and property.

There will probably be danger to persons caught in the floodwaters, and possible structural damage. Evacuation of persons would be difficult. By contrast, in low hazard areas people and their possessions can be evacuated safely by trucks. Between the two categories a transition zone is defined in which the degree of hazard is dependent on site conditions and the nature of the proposed development.

This calculation leads to a provisional hazard rating. The provisional hazard rating may be modified by consideration of effective flood warning times, the rate of rise of floodwaters, duration of flooding and ease or otherwise of evacuation in times of flood. The estimated 100 year ARI provisional flood hazard under LiDAR Survey (2015) Conditions is plotted in **Figure 9**.

The differences between the 100 yr ARI flood levels estimated by the local TUFLOW model and the 2015 RMA-2 model are plotted in **Figure 10**. It was found that there remained a zone of local increases upstream of Elizabeth Drive which is present in the results for both the initial and modified floodplain models. It was concluded that these differences are due to the differences between the TUFLOW representation of the RMA-2 model and the RMA-2 model itself and that overall these results provide an appropriate benchmark against which to assess impacts of any future Masterplan.

3.1.2 PMF

The TUFLOW floodplain model was run for the 6 hour duration PMP event.

The estimated PMF flood levels and extent, depths and velocities under LiDAR Survey (2015) Conditions are plotted in **Figures 11, 12** and **13** respectively.

The estimated PMF velocity x depth under LiDAR Survey (2015) Conditions is plotted in **Figure 14.**

The estimated PMF provisional flood hazard under LiDAR Survey (2015) Conditions is plotted in **Figure 15**.

The differences between the PMF levels estimated by the local TUFLOW model and the 2015 RMA-2 model are plotted in **Figure 16**. It was found that in the vicinity of the Precinct that the PMF level differences are typically within ± 0.05 m with modest areas of greater differences.

3.2 Detailed Survey (2018) Conditions

The local floodplain model of Detailed Survey (2018) conditions was assembled by updating the DEM adopted for LiDAR Survey (2015) Conditions based on site survey provided by Mirvac.

It was noted that the site survey disclosed that earthworks were undertaken on the site subsequent to the collection of ALS in 2003. In 2008 Penrith City Council approved DA08/0691 for “Earthworks – Pasture improvement to improve Drainage”. The consent become operational on 31 October 2008. The earthworks were completed in accordance with the consent as certified by Blackett Maguire + Goldsmith in Certificate No. CC09-104 on 13 May 2009.

On the basis the local earthworks completed prior to 13 May 2009 have a negligible impact on peak flows in South Creek in the design floods, the model was run to estimate flooding under Detailed Survey (2018) Conditions based on the design flood hydrographs extracted from the 2015 flood study.

Figure3-2 from the 2020 Advisian study attached in **Appendix B** indicates that the terrain in the 2020 Advisian model has been updated and this is expected to align closely the detailed survey (2018) conditions in the local study area.

3.2.1 20 yr ARI

The estimated 20 year ARI flood levels and extent, depths, velocities, velocity x depth and hazards under Detailed Survey (2018) Conditions are plotted in **Figures 17, 18, 19, 20** and **21** respectively.

3.2.2 100 yr ARI

The estimated 100 year ARI flood levels and extent, depths, velocities, velocity x depth and hazards under Detailed Survey (2018) Conditions are plotted in **Figures 22, 24, 25, 26** and **27** respectively.

The differences between the 100 yr ARI flood levels estimated by the local TUFLOW model under Detailed Survey (2018) conditions and the 2015 RMA-2 model are plotted in **Figure 23**. The difference scale is similar to the difference scale adopted by Advisian, 2020. It was found that the earthworks locally decreased or locally increased 100 yr ARI flood levels through the site and that the local increases extend upstream of Elizabeth Drive.

This is also observed in Figure 4-11 from the 2020 Advisian study attached in **Appendix B.** This Figure indicates that the updated terrain in the Advisian model has slightly lowered 1% AEP flood levels in comparison to 2015 flood levels. It is concluded that impact of the 2018 terrain on 2015 flood levels reported in this study aligns with the Advisian, 2020 results.

It was therefore concluded that under Detailed Survey (2018) Conditions are comparable to the updated 2020 Advisian floodplain modelling.

Hydraulic Categories

The Floodplain Development Manual (NSW Government, 2005) defines flood prone land into three hydraulic categories:

> *Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.*
>
> *Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the storage area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked, would cause peak flood levels to increase by 0.1 m and/or would cause the peak discharge to increase by more than 10%.*
>
> *Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas were defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.*

For the purpose of mapping the extents of the hydraulic categories, the following approach was adopted.

> **Floodways** were determined for four events, namely PMF, 100 year, 20 year and 5 year ARI by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways was derived from Howells et al. (2003).
>
> As a minimum, the floodway was assumed to follow the creekline from bank to bank. In addition, the following depth and velocity criteria was used to define a floodway:
>
> - Velocity x Depth must be greater than 0.25 m^2/s **and** velocity must be greater than 0.25 m/s, **OR**
> - Velocity is greater than 1 m/s.
>
> **Flood storage** was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharge anywhere to increase by more than 10%. Previous analysis of flood storage in 1D cross sections assumed that if the cross-sectional area is reduced such that 10% of the conveyance is lost, the criteria for flood storage would be satisfied.
>
> To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.2 m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:
>
> - Depth greater than 0.2m; and
> - Not classified as floodway.
>
> All areas that were not categorised as Floodway or Flood Storage, but still fell within the flood extent are represented as **Flood Fringe**.

The estimated 100 year ARI hydraulic categories under Detailed Survey (2018) Conditions are plotted in **Figure 28**.

Flood Planning Level

Clause 7.2 ‘Flood Planning’ in the Penrith LEP2010 applies to all land at or below the flood planning level (100 year average recurrence interval (ARI) event plus 0.5m freeboard). The LEP also includes Flood Planning Land Maps defining the Flood Planning Area (FPA).

The estimated extents of the flood planning level under Detailed Survey (2018) Conditions are plotted in **Figure 29**.

3.2.3 200 yr ARI

The estimated 20 year ARI flood levels and extent, depths, velocities, velocity x depth and hazards under Detailed Survey (2018) Conditions are plotted in **Figures 30 31, 32, 33** and **34** respectively.

3.2.4 500 yr ARI

The estimated 500 year ARI flood levels and extent, depths, velocities, velocity x depth and hazards under Detailed Survey (2018) Conditions are plotted in **Figures 35, 36, 37, 38** and **39** respectively.

3.2.5 PMF

The estimated PMF flood levels and extent, depths, velocities, velocity x depth and hazards under Detailed Survey (2018) Conditions are plotted in **Figures 40, 42, 43, 44** and **45** respectively.

The differences between the PMF levels estimated by the local TUFLOW model under Detailed Survey (2018) conditions and the 2015 RMA-2 model are plotted in **Figure 41**. It was found that within the Precinct that the PMF level differences are typically greater than 0.15 m in comparison to the 2015 PMF levels. These differences in PMF levels are much reduced south of Elizabeth Drive.

4 References

Advisian (2020) “Wianamatta (South) Creek Catchment Flood Study – Existing Conditions”, *Final Report*, Rev H, prepared for Infrastructure NSW, November, 27 pp + Maps + Apps

Howells, L., McLuckie, D., Collings, G., Lawson, N. (2003). *Defining the Floodway – Can One Size Fit All?* Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes.

NSW Government (2005) *Floodplain Development Manual.* Sydney: NSW Government.

WorleyParsons (2015) “Updated South Creek Flood Study”, *Final Report*, 2 Vols, prepared for Penrith City Council, acting in association with Liverpool, Blacktown and Fairfield City Councils, 74 pp + Apps.

APPENDIX A
FIGURES

FIGURE 1

0 500

km

Scale 1:18,800,000

Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

Location of Elizabeth Enterprise Precinct (EEP)

N

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_1.wor

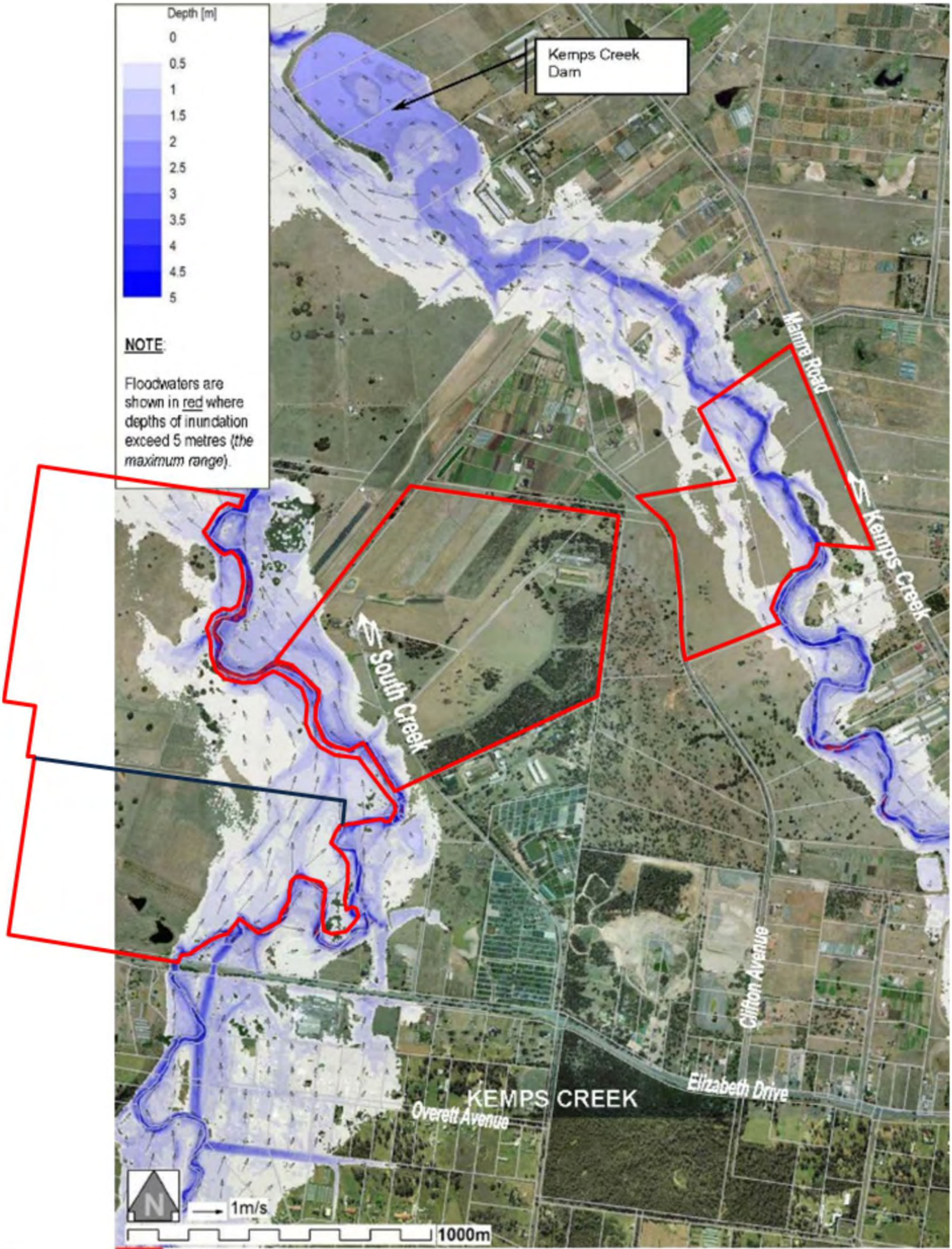


FIGURE 2

0 500
km
Scale 1:18,800,000

Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Flood Map

(after WorleyParsons, 2015)

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_2.wor

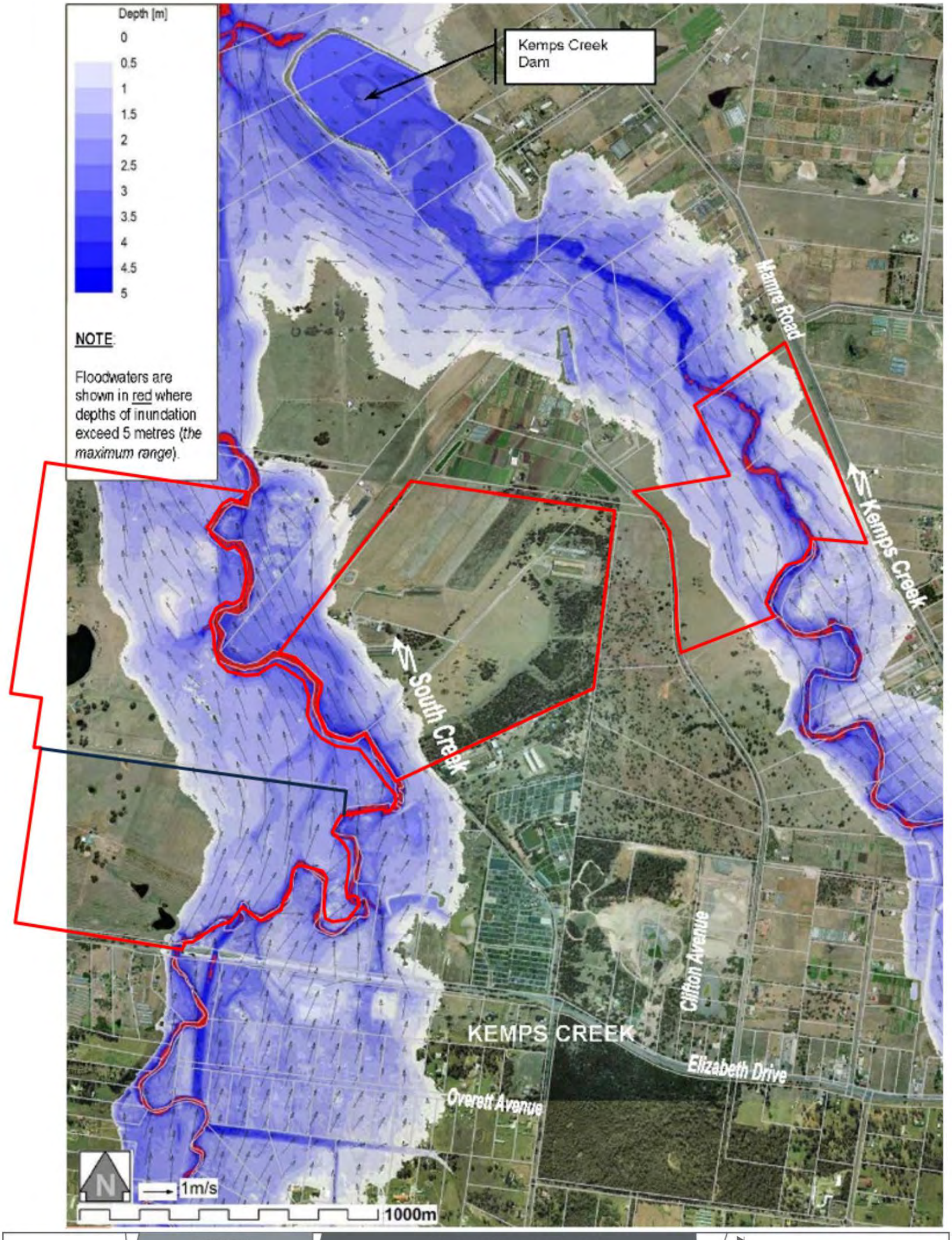


FIGURE 3

0 500
km
Scale 1:18,800,000

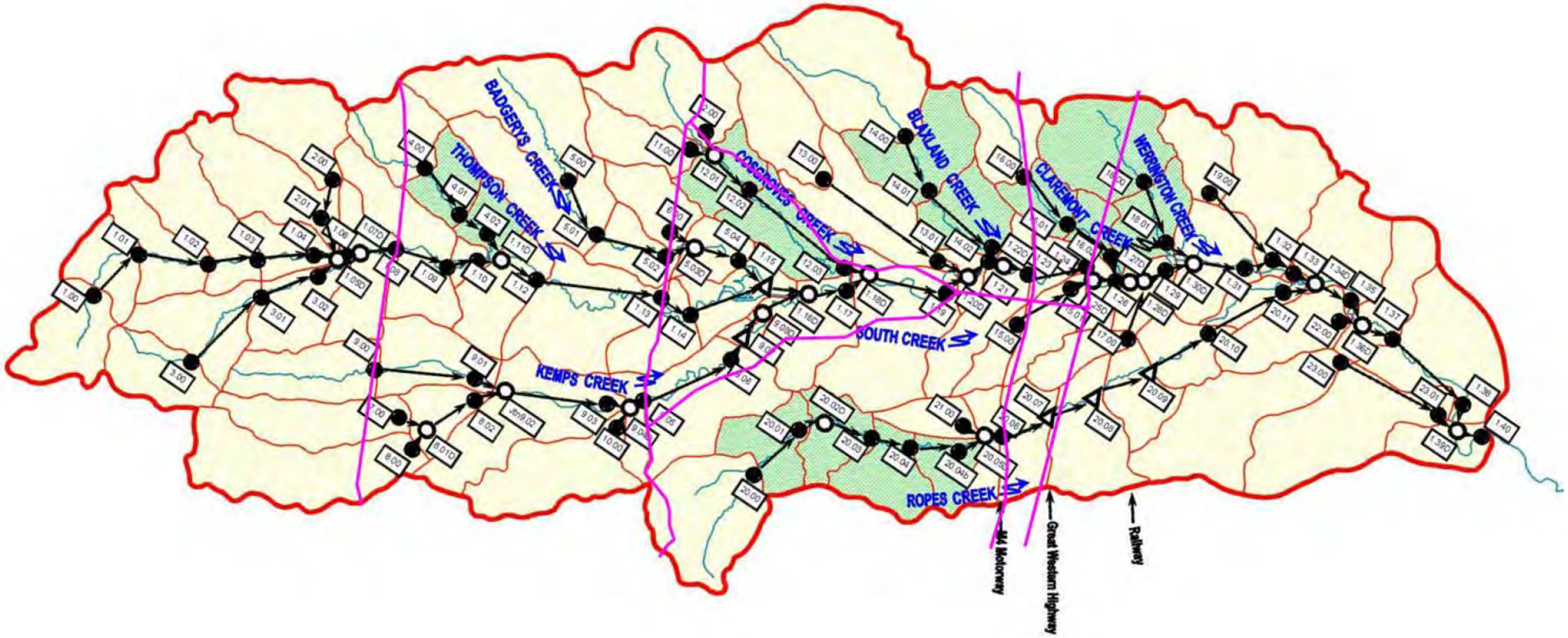
Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Map

(after WorleyParsons, 2015)

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_3.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

Subcatchment Boundaries in the vicinity of Elizabeth

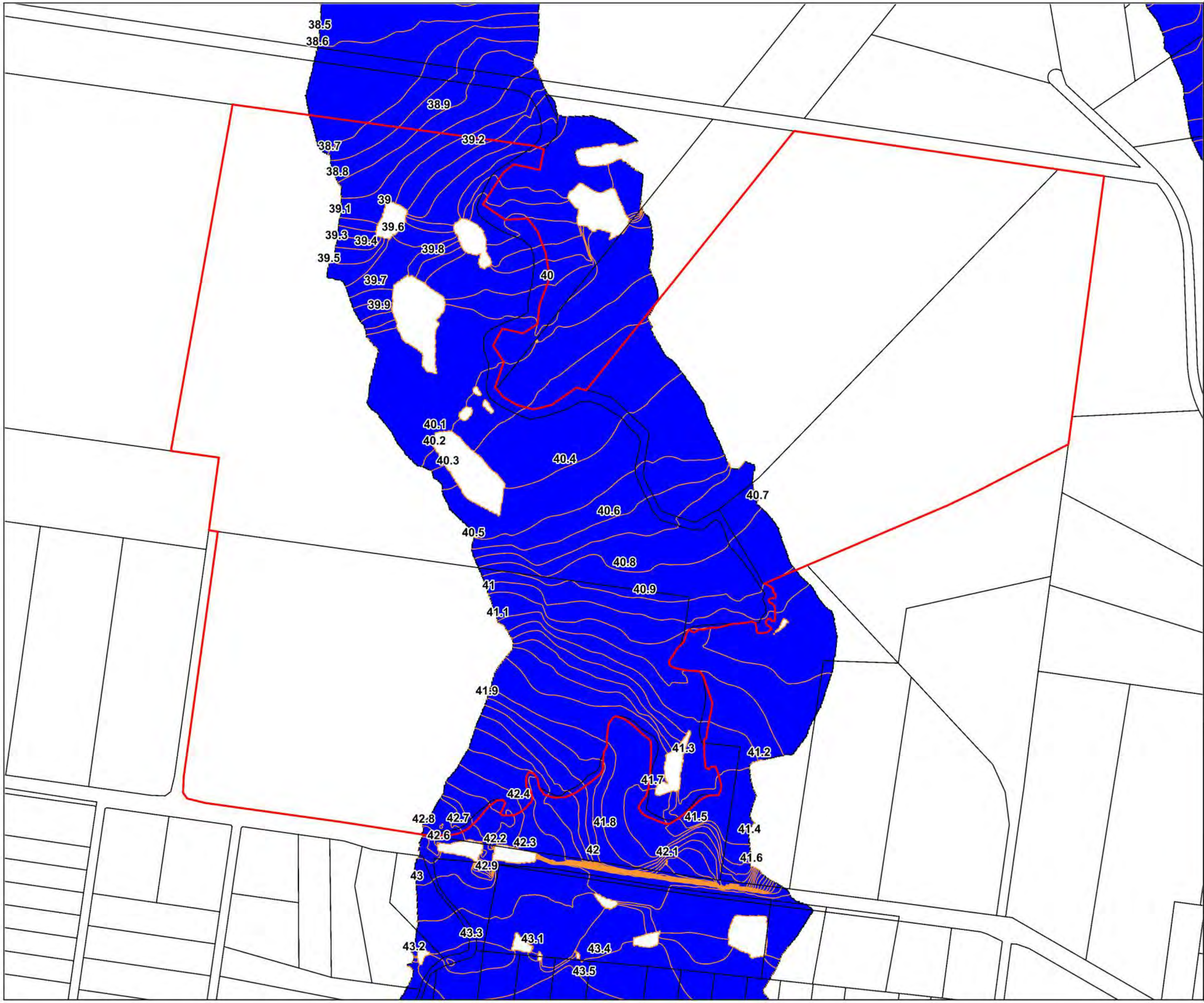
FIGURE 4

Map Not on scale

N

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_24_100yr_FloodDepths.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Flood Extents and Flood Levels

LiDAR survey (2015) Conditions

LEGEND

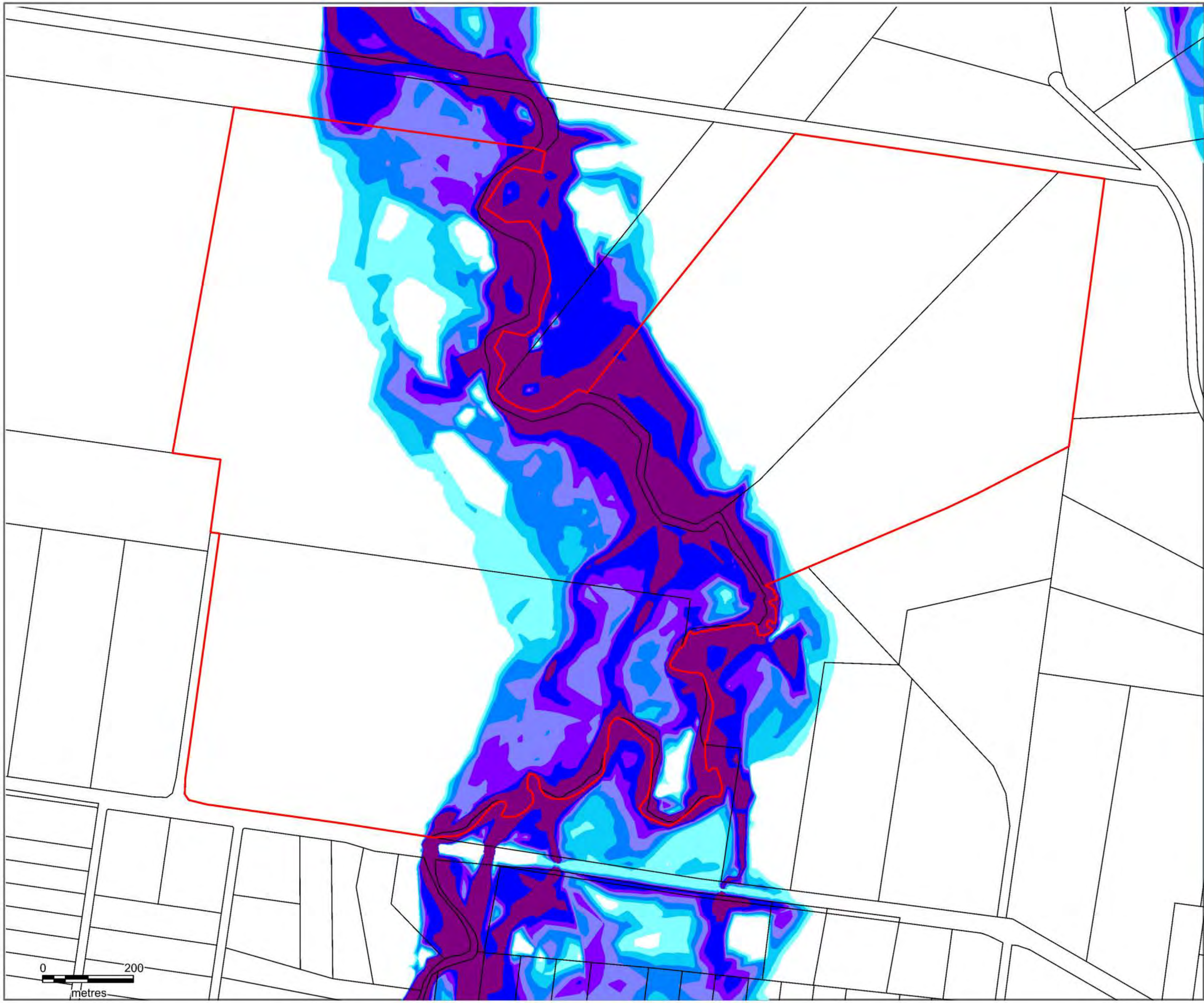
Study Area
0.2m Flood Level Contours
Flood Extent

FIGURE 5

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map Fig_5_100yr_FloodLevels.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Flood Depths

LiDAR survey (2015) Conditions

LEGEND

Depth (metres)

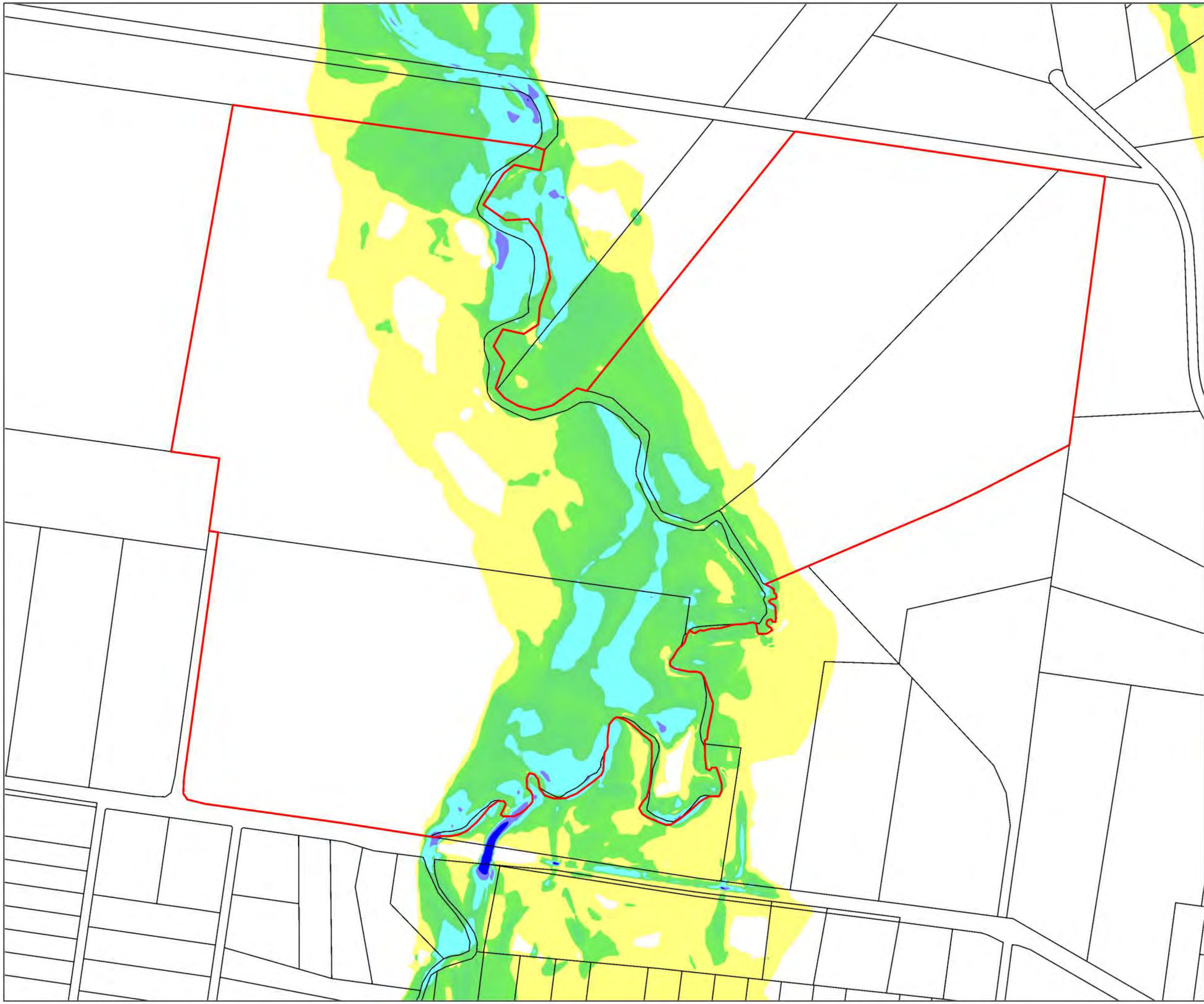
- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- > 1.5

FIGURE 6

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map: Fig_6_100yr_FloodDepth.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Flood Velocities

LiDAR survey (2015) Conditions

LEGEND

Water Velocity
(m/s)

2.00-3.00
1.50-2.00
1.00-1.50
0.50-1.00
0.00-0.50

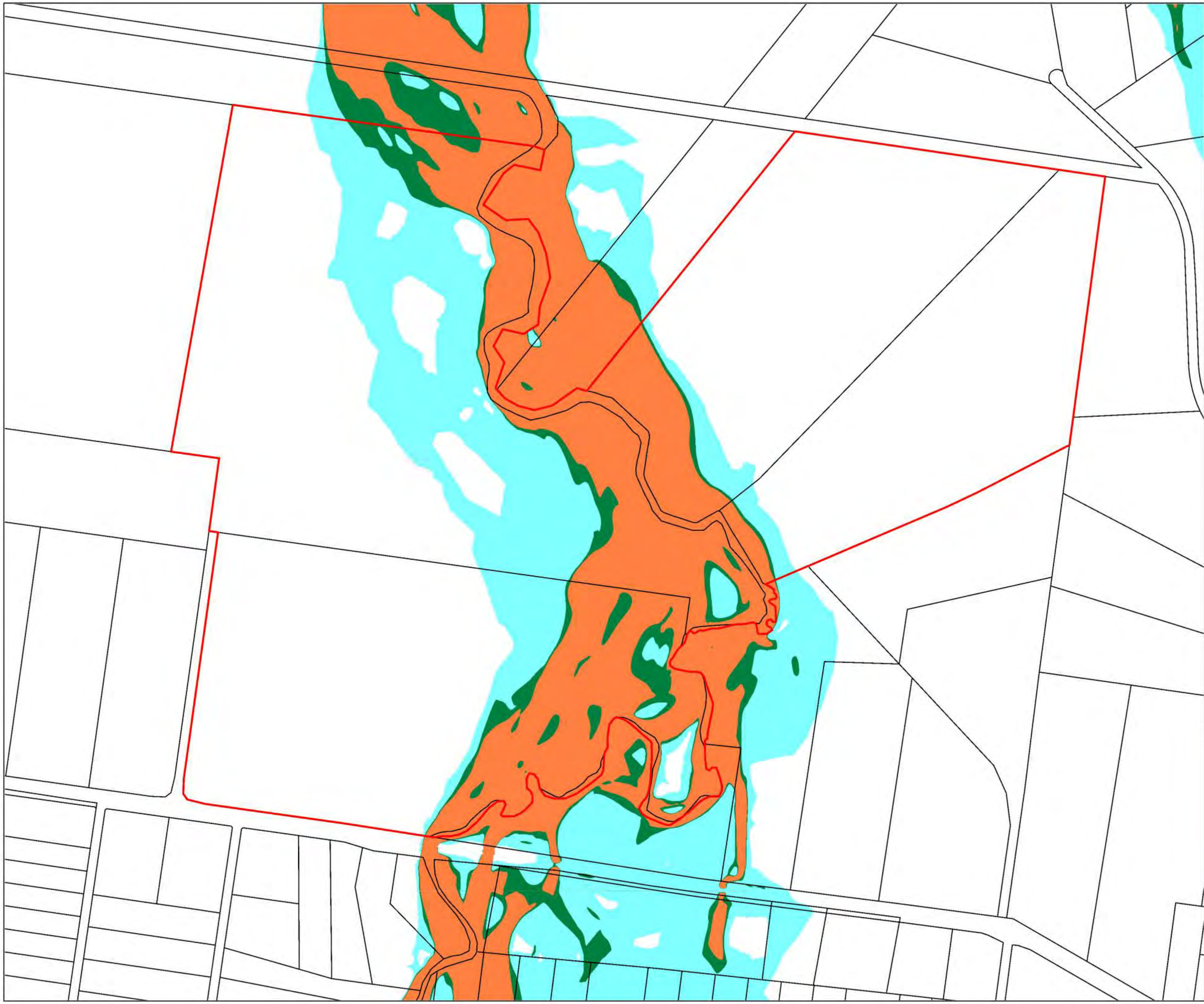
FIGURE 7

0 0.25
km
Scale 1:8,000

N

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map Fig_9_100yr_FloodVelocities.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Flood Velocity x Depth

LiDAR survey (2015) Conditions

LEGEND
Velocity x Depth

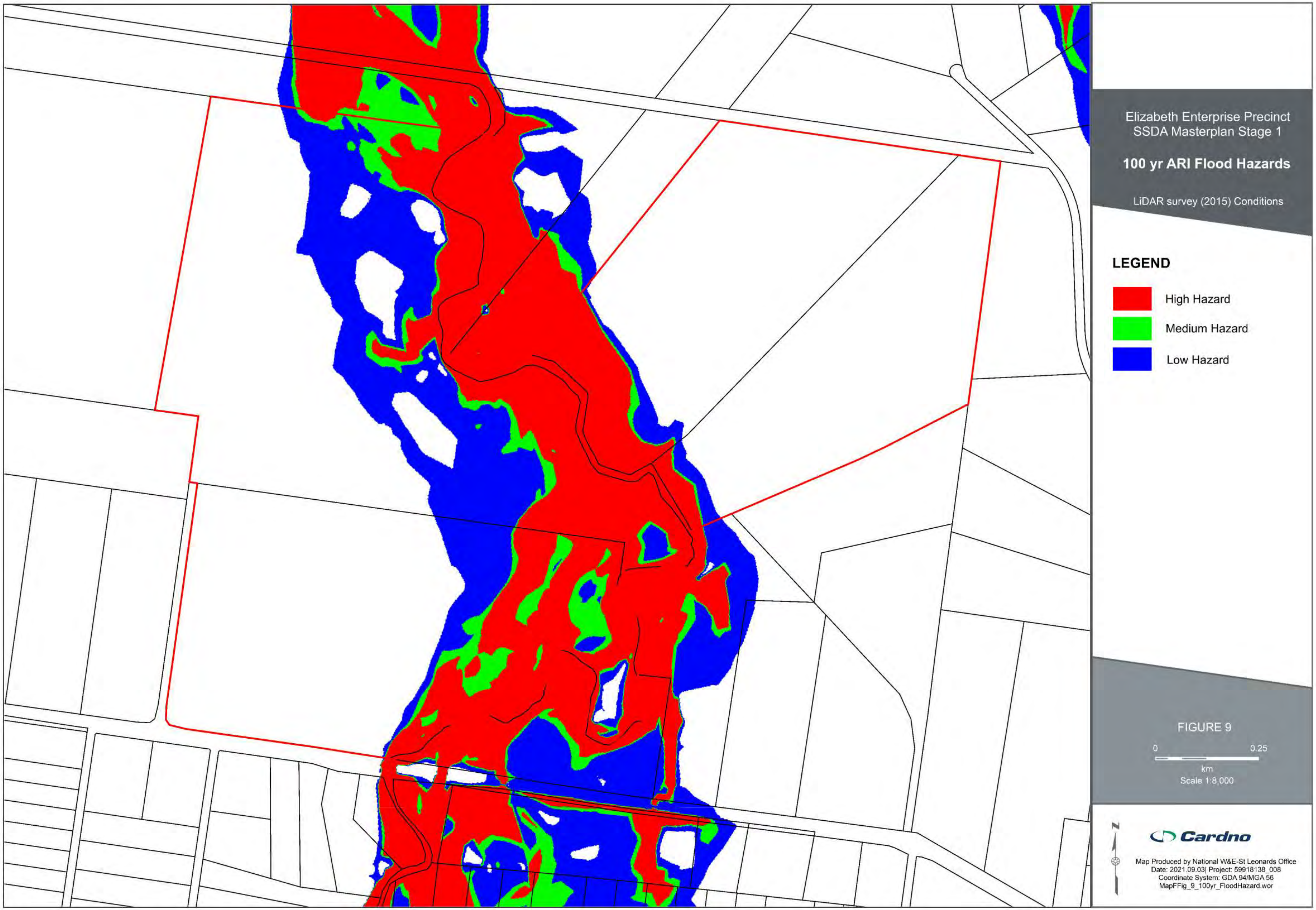
- 0 to 0.4
- 0.4 to 0.6
- > 0.6

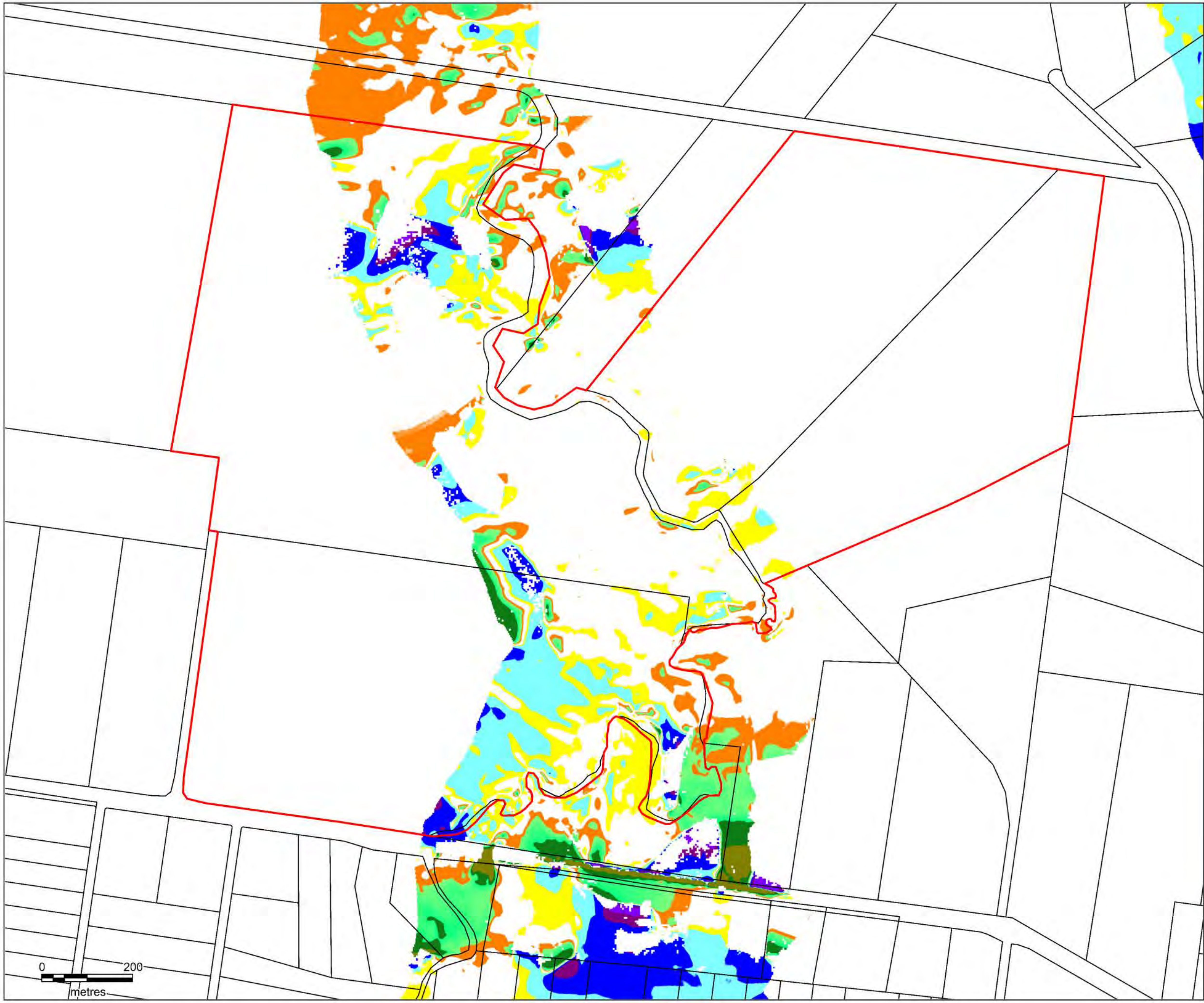
FIGURE 8

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
MapFig_8_100yr_FloodVelocities_x_Depth.wor


Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
100 yr ARI Flood Hazards
LiDAR survey (2015) Conditions
LEGEND
High Hazard
Medium Hazard
Low Hazard
FIGURE 9
0
0.25
km
Scale 1:8,000
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
MapFFig_9_100yr_FloodHazard.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Level Differences

(LiDAR survey (2015) – WorleyParsons, 2015)

LEGEND

Water Level Difference
metres

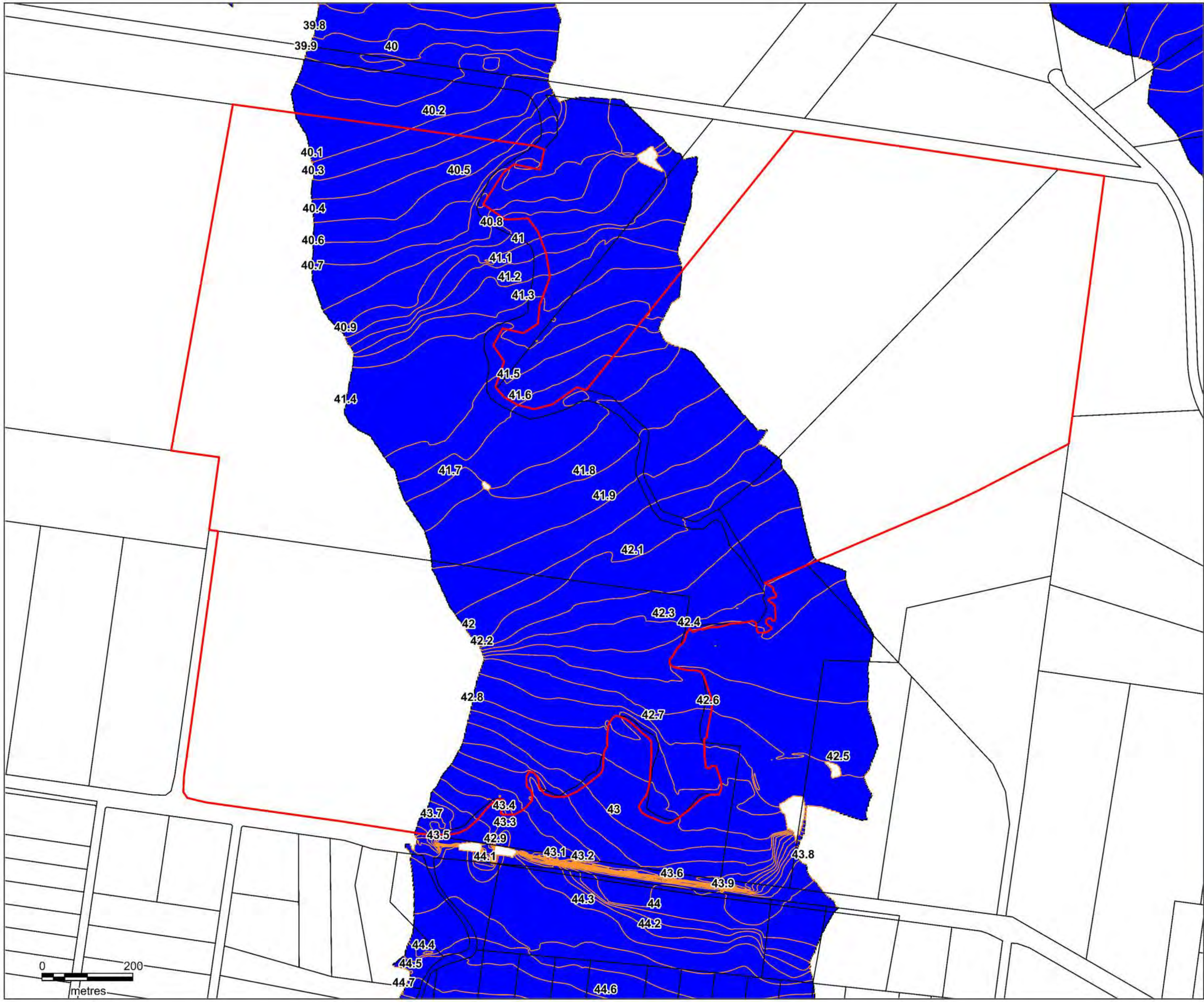
- >0.15
- 0.1 to 0.15
- 0.05 to 0.1
- 0.02 to 0.05
- 0.01 to 0.02
- -0.01 to -0.02
- -0.02 to -0.05
- -0.05 to -0.1
- -0.1 to -0.15
- <-0.15

FIGURE 10

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map: Fig_10_100yr_FloodLevelDIfferences



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Extents and Flood Levels

LiDAR survey (2015) Conditions

LEGEND

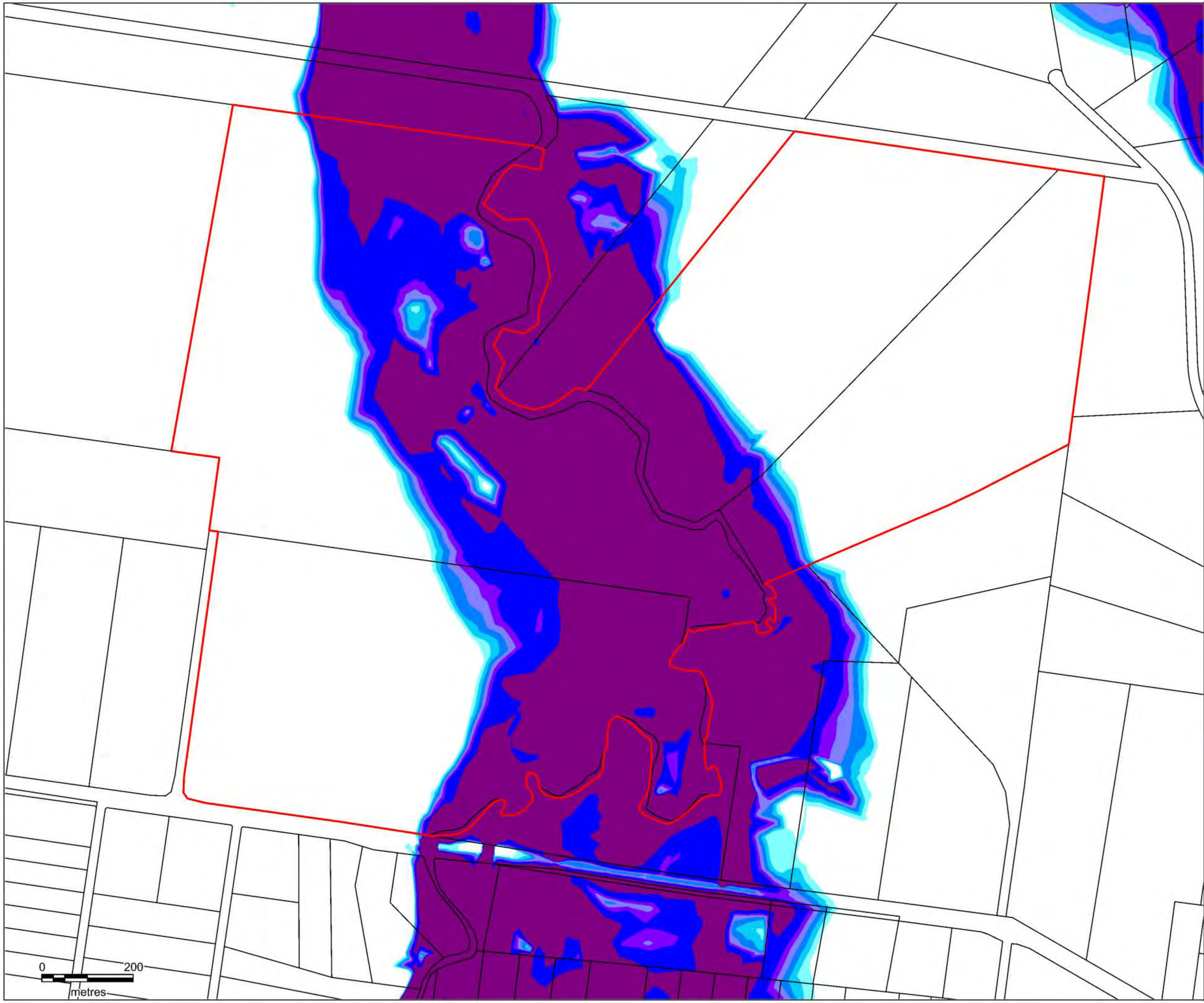
- Study Area
- 0.1m Flood Level Contours
- Flood Extent

FIGURE 11

0 0.25
kilometres
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_11_PMF_FloodLevels.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Depths

LiDAR survey (2015) Conditions

LEGEND

Depth (metres)

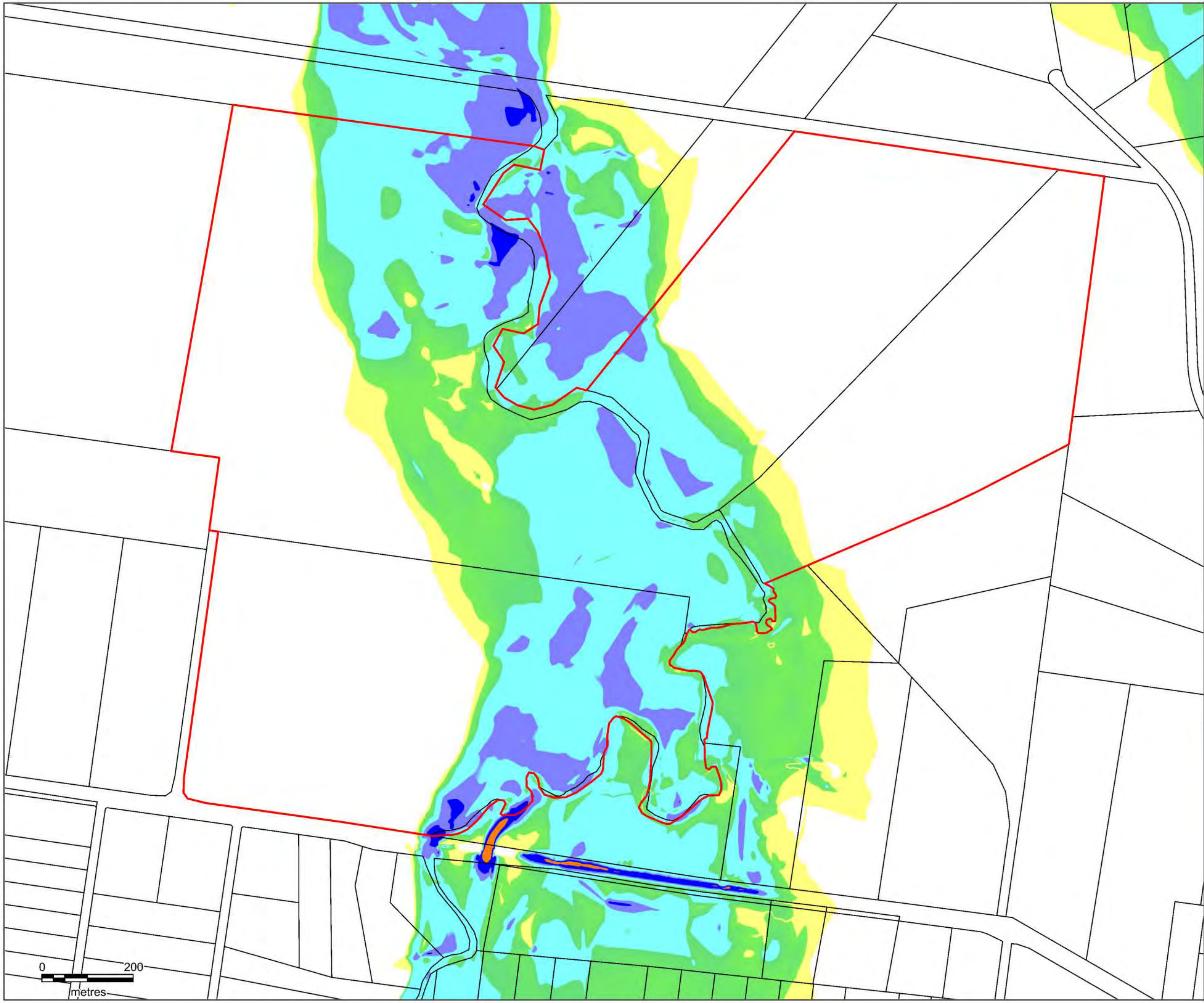
- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- > 1.5

FIGURE 12

0 0.25
kilometres
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_12_PMF_FlooddDepth.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Velocities

LiDAR survey (2015) Conditions

LEGEND

Water Velocity
(m/s)

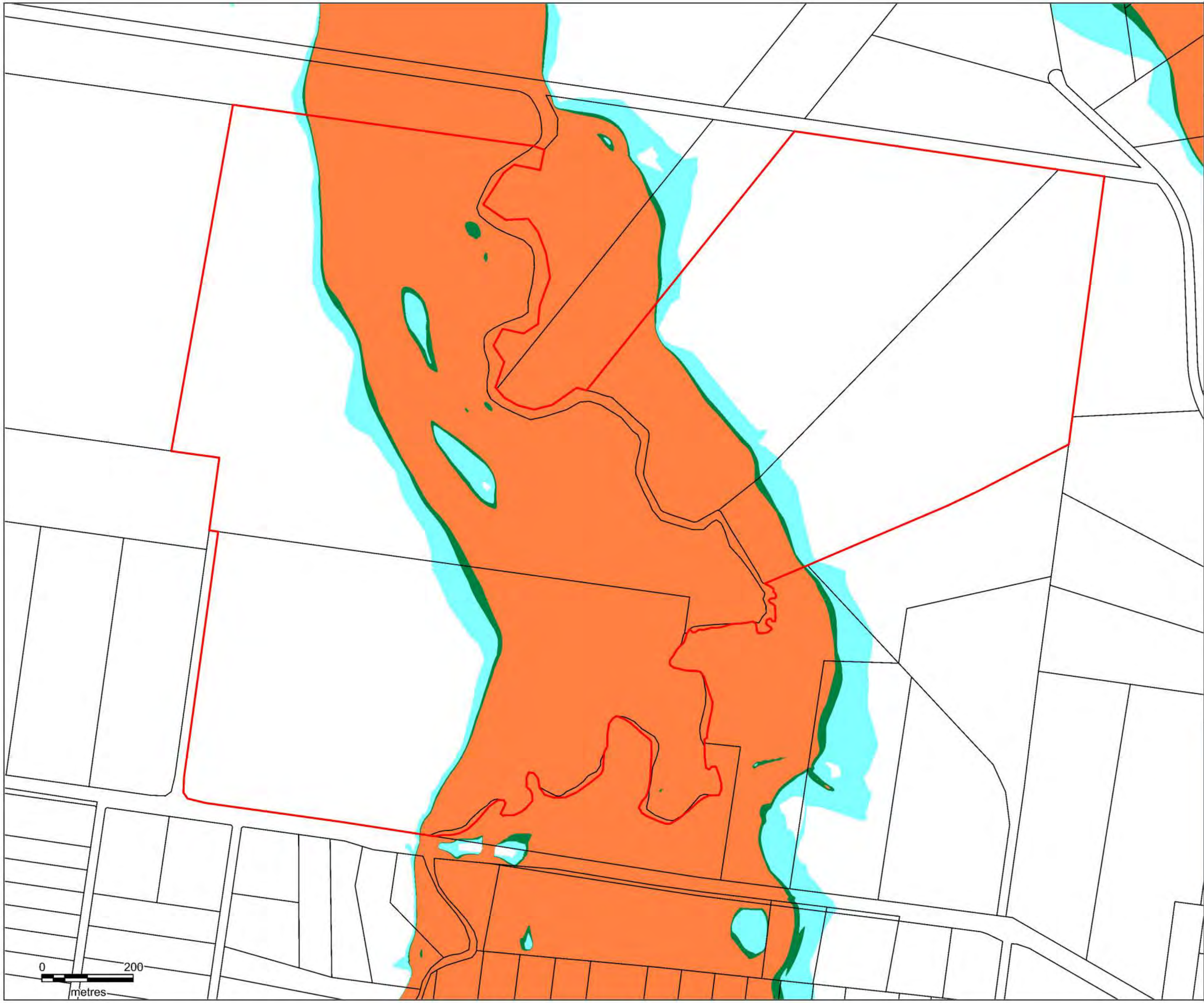
- 2.00-3.00
- 1.50-2.00
- 1.00-1.50
- 0.50-1.00
- 0.00-0.50

FIGURE 13

0 0.25
kilometres
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_13_PMF_FloodVelocities .wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Velocity x Depth

LiDAR survey (2015) Conditions

LEGEND
Velocity x Depth

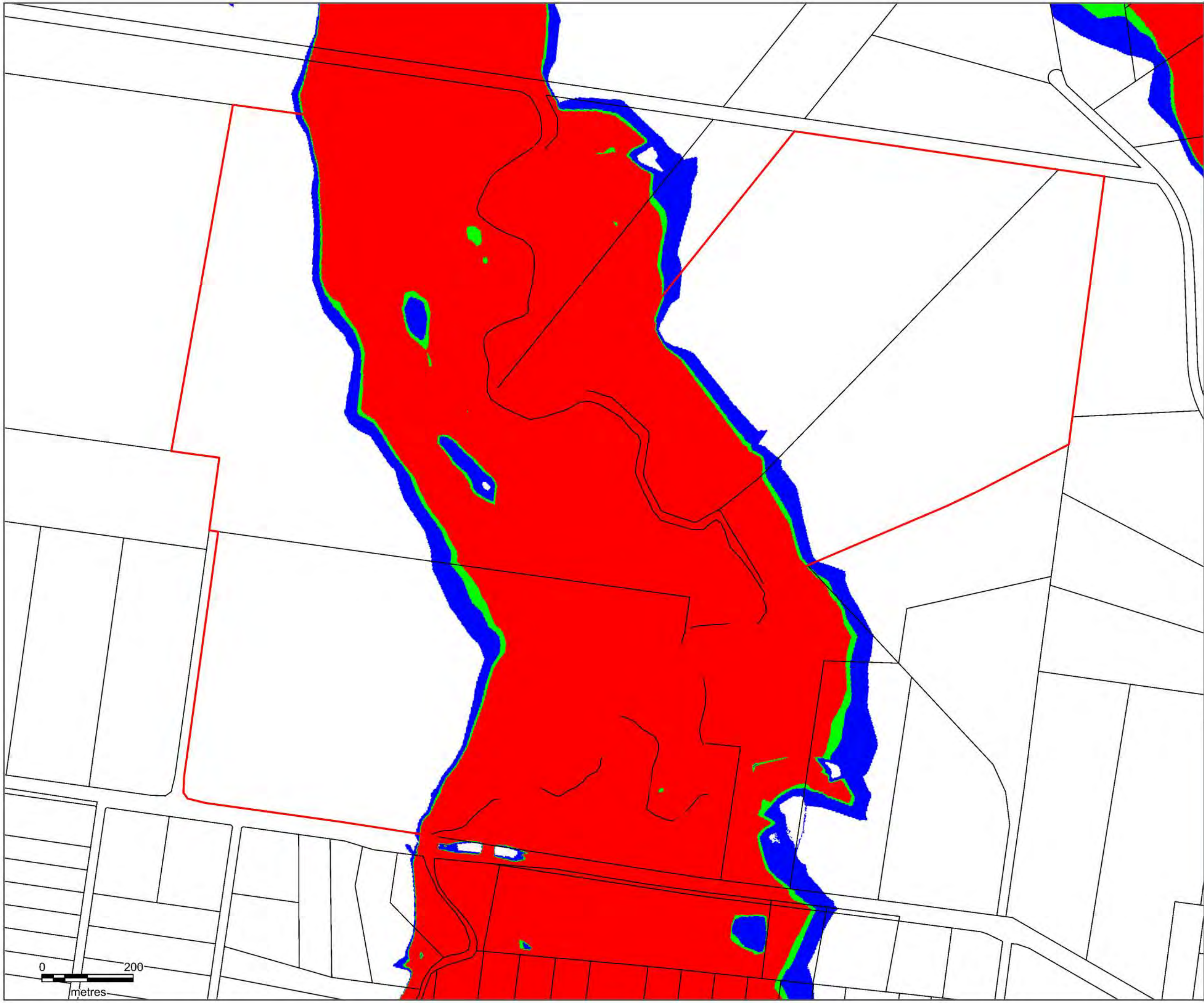
- **0 to 0.4**
- **0.4 to 0.6**
- **> 0.6**

FIGURE 14

0 0.25
kilometres
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_14_PMF_FloodVelocity x Depth .wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Hazards

LiDAR survey (2015) Conditions

LEGEND

High Hazard

Medium Hazard

Low Hazard

FIGURE 15

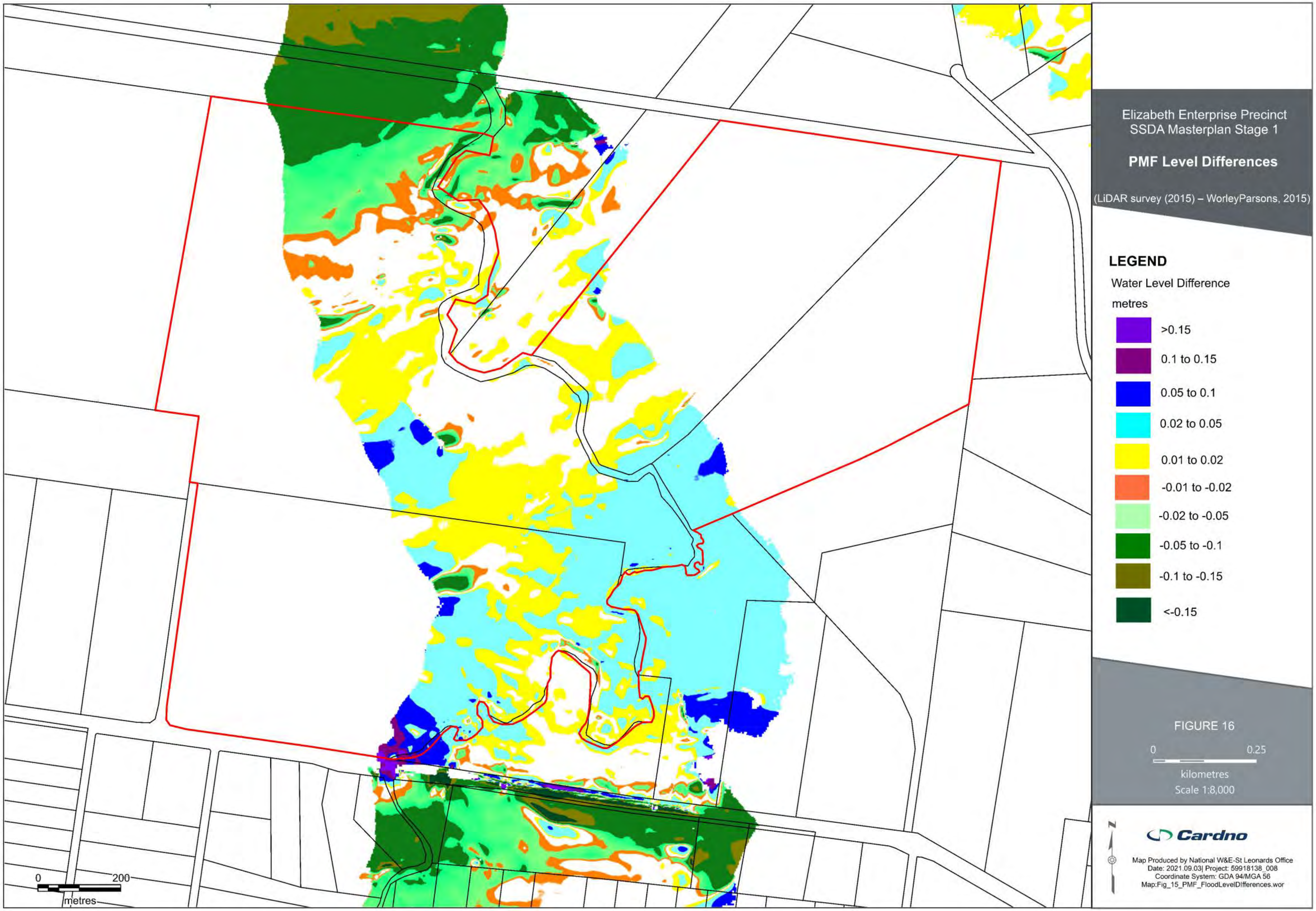
0 0.25

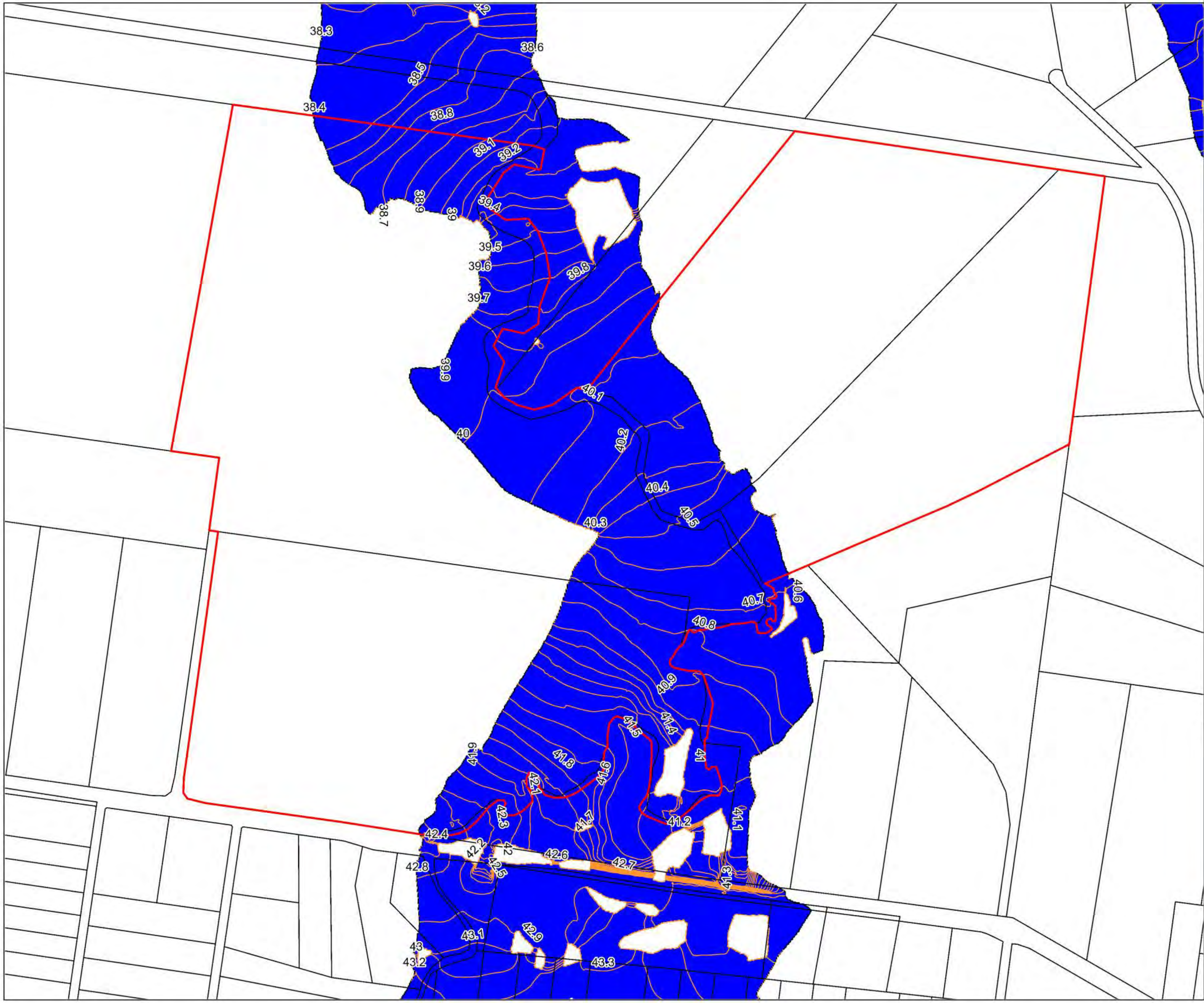
kilometres

Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_15_PMF_FloodHazards .wor


0
200
metres
Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
PMF Level Differences
(LiDAR survey (2015) – WorleyParsons, 2015)
LEGEND
Water Level Difference
metres
>0.15
0.1 to 0.15
0.05 to 0.1
0.02 to 0.05
0.01 to 0.02
-0.01 to -0.02
-0.02 to -0.05
-0.05 to -0.1
-0.1 to -0.15
<-0.15
FIGURE 16
0
0.25
kilometres
Scale 1:8,000
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_15_PMF_FloodLevelDifferences.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

20 yr ARI Flood Extents and Flood Levels

Detailed Survey (2018) Conditions

LEGEND

Study Area

0.1m Flood Level Contours

Flood Extent

FIGURE 17

0 0.25

km

Scale 1:8,000

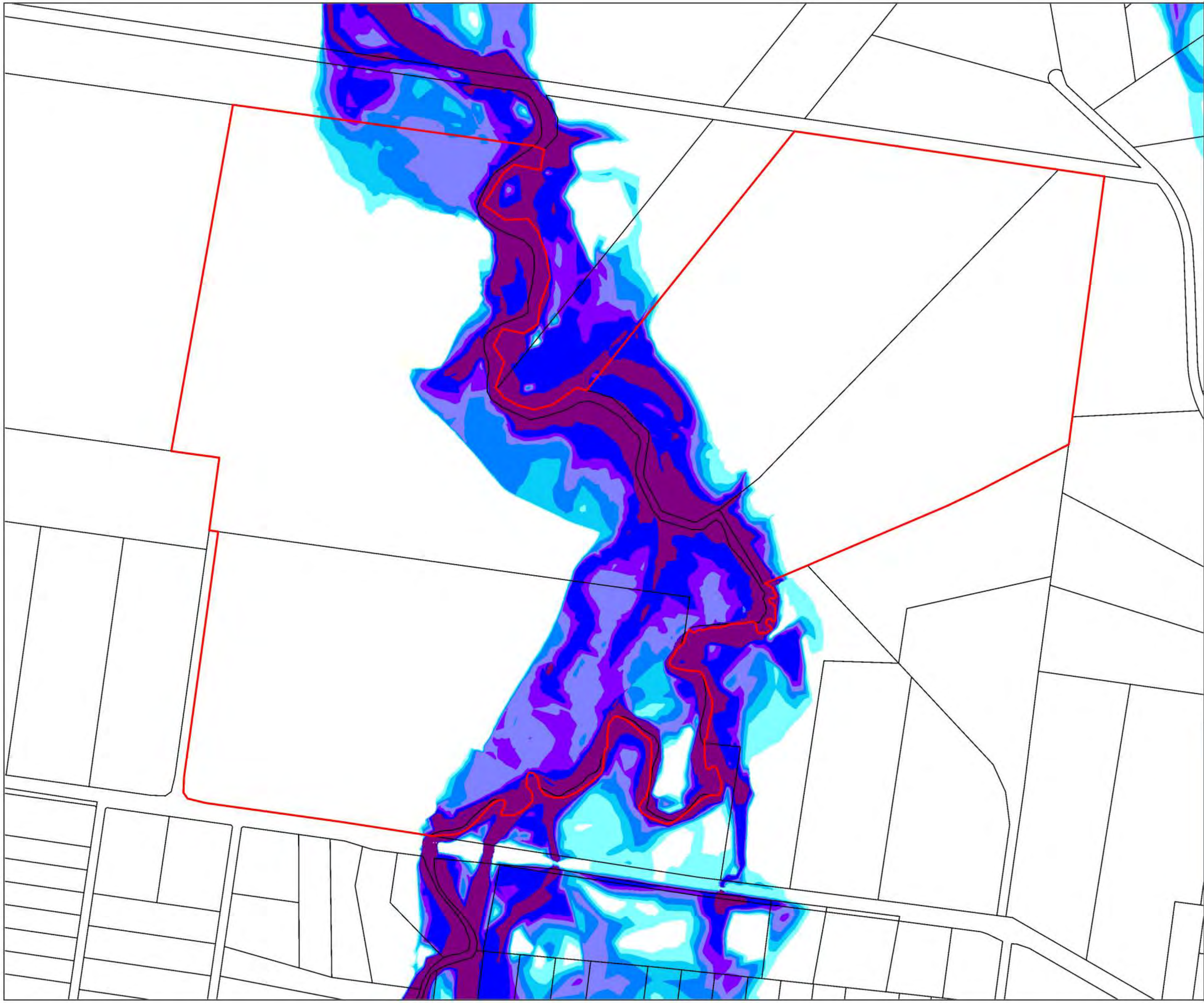
Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_17_20yr_FloodLevels.wor

Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

20 yr ARI Flood Depths

Detailed Survey (2018) Conditions



LEGEND

Depth (metres)

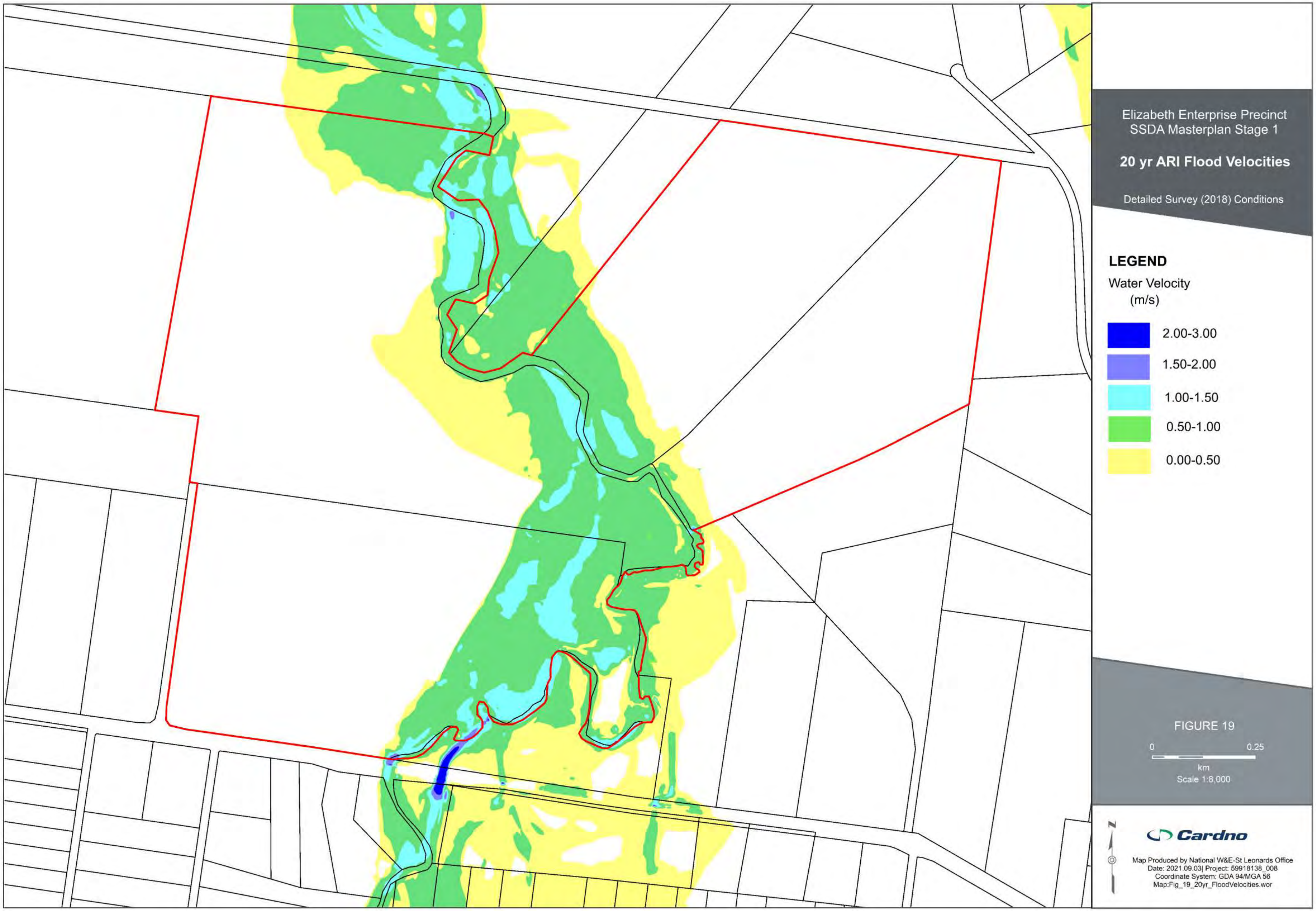
- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- > 1.5

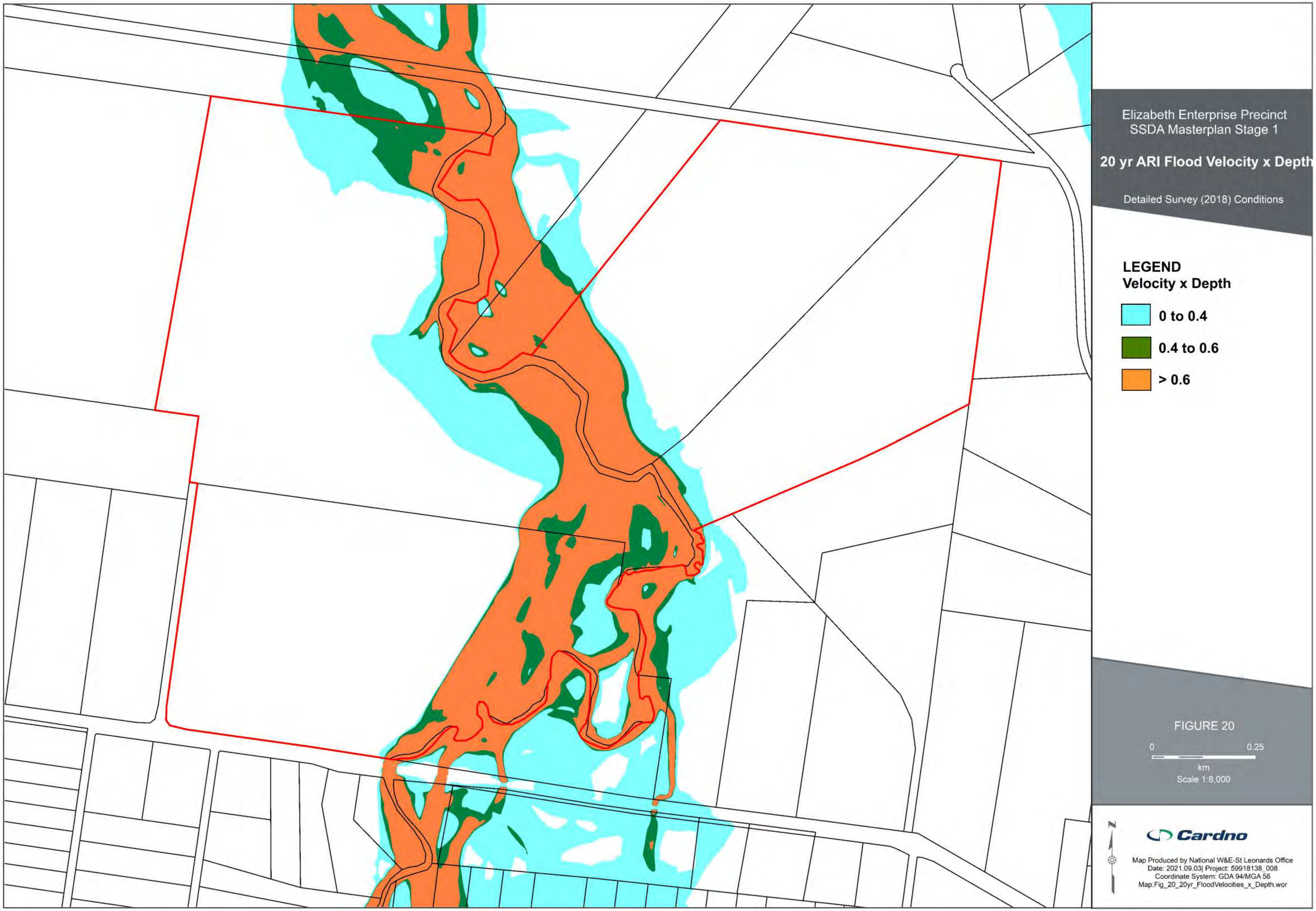
FIGURE 18

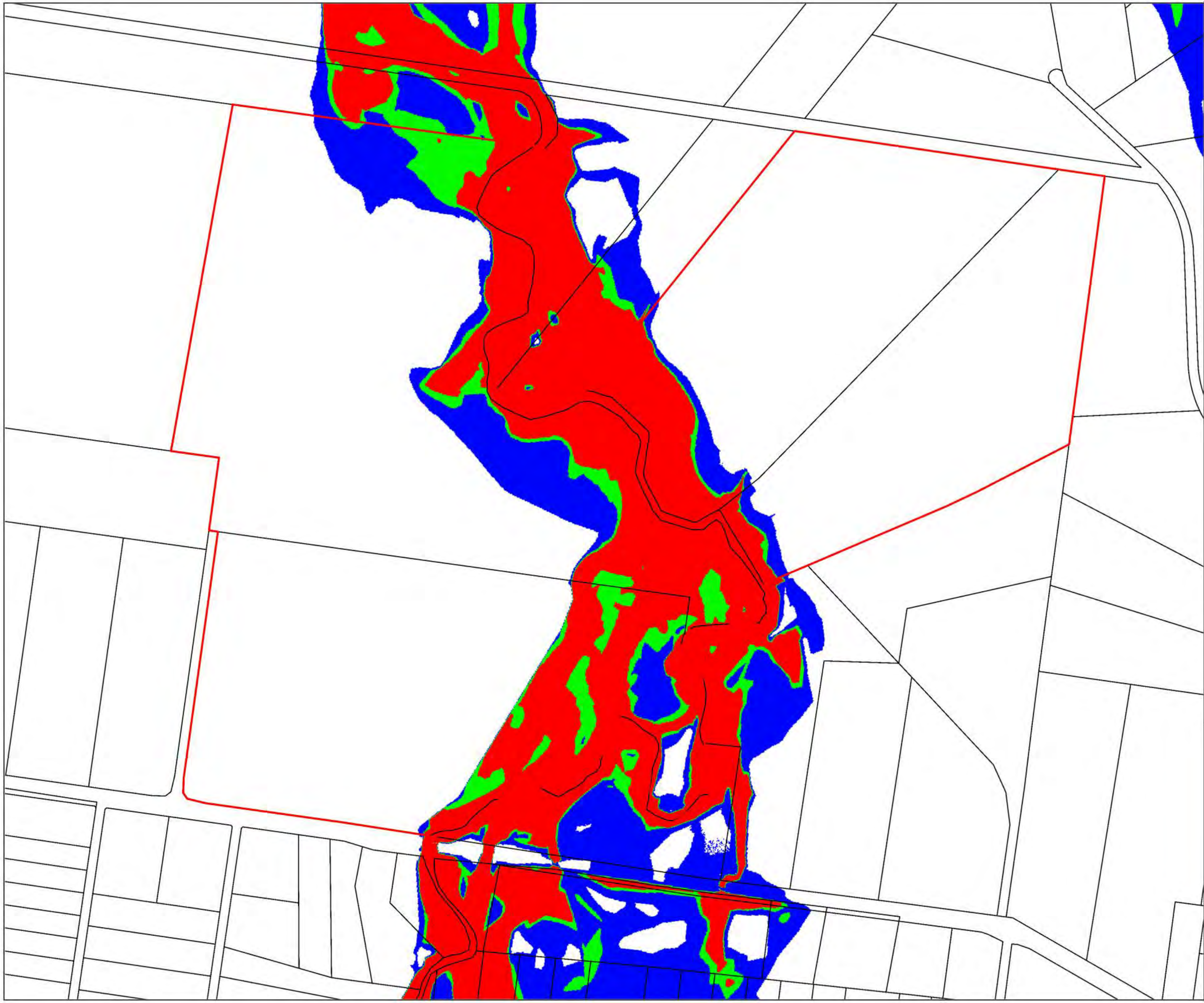
0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_18_20yr_FloodDepth.wor


Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
20 yr ARI Flood Velocities
Detailed Survey (2018) Conditions
LEGEND
Water Velocity
(m/s)
2.00-3.00
1.50-2.00
1.00-1.50
0.50-1.00
0.00-0.50
FIGURE 19
0
0.25
km
Scale 1:8,000
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_19_20yr_FloodVelocities.wor


Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
20 yr ARI Flood Velocity x Depth
Detailed Survey (2018) Conditions
LEGEND
Velocity x Depth
0 to 0.4
0.4 to 0.6
> 0.6
FIGURE 20
0
0.25
km
Scale 1:8,000
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_20_20yr_FloodVelocities_x_Depth.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

20 yr ARI Flood Hazards

Detailed Survey (2018) Conditions

LEGEND

- High Hazard
- Medium Hazard
- Low Hazard

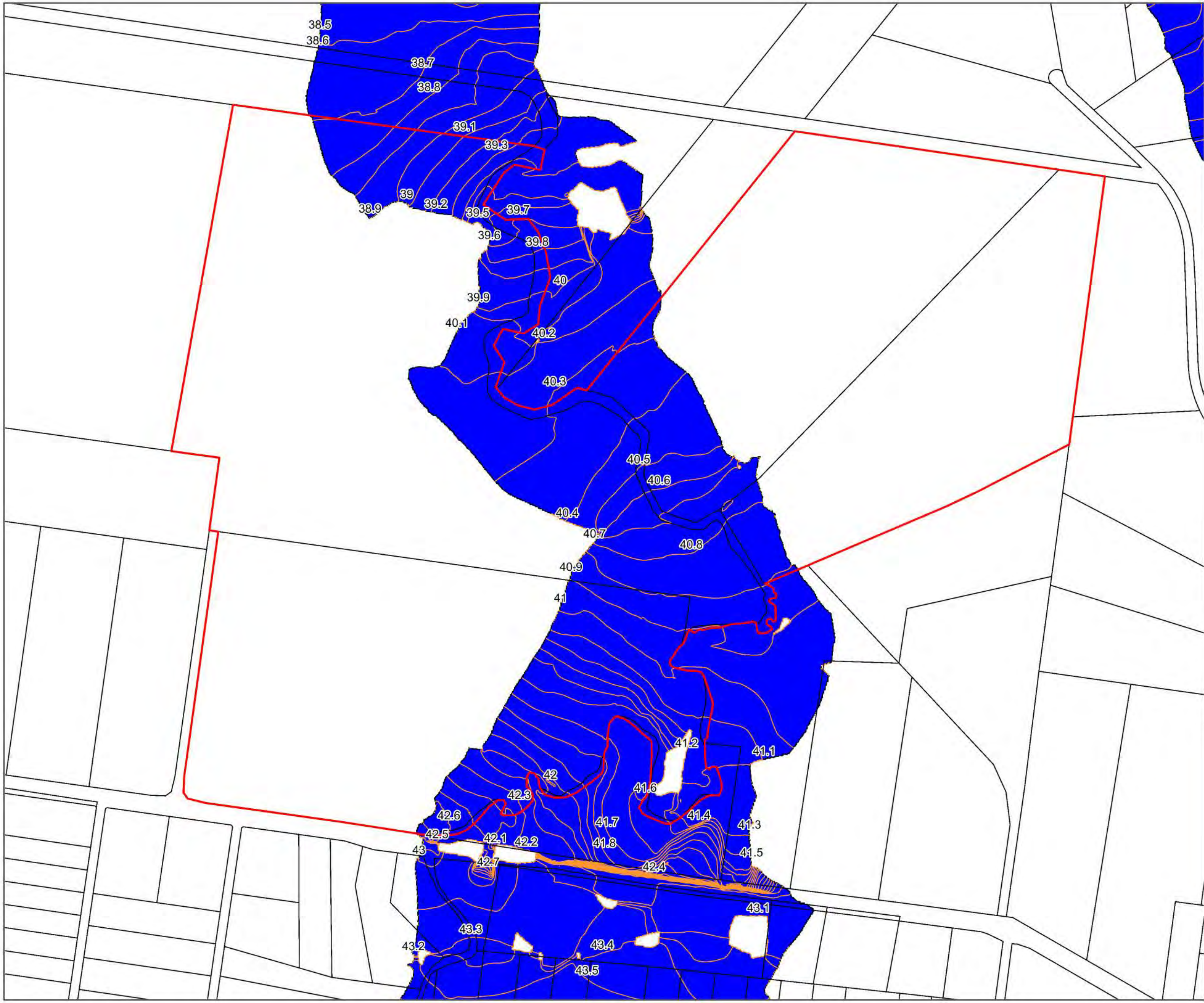
FIGURE 21

0 — 0.25 km

Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_21_20yr_FloodHazards.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100yr ARI Flood Extents and Flood Levels

Detailed Survey (2018) Conditions

LEGEND

Study Area

0.1m Flood Level Contours

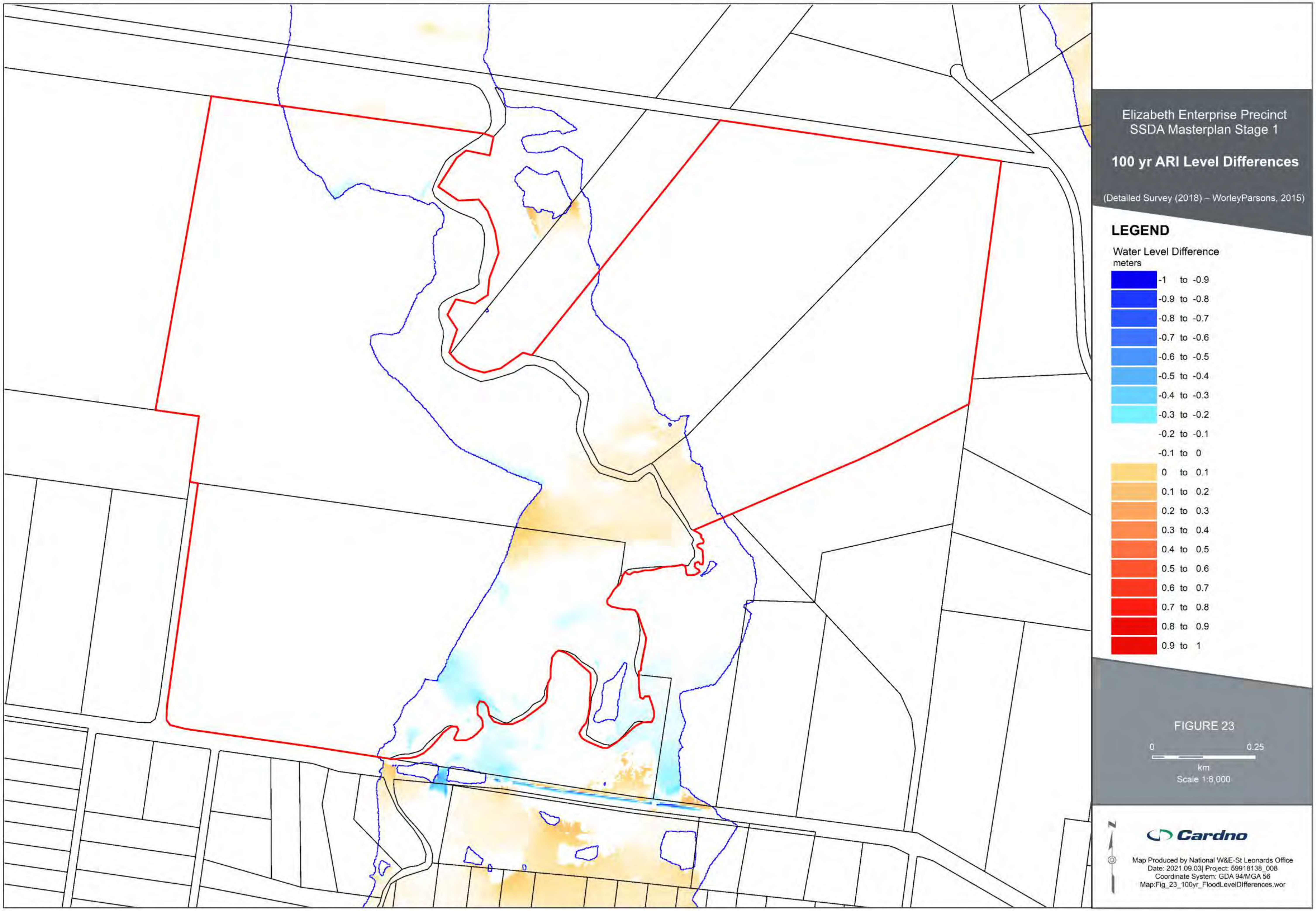
Flood Extent

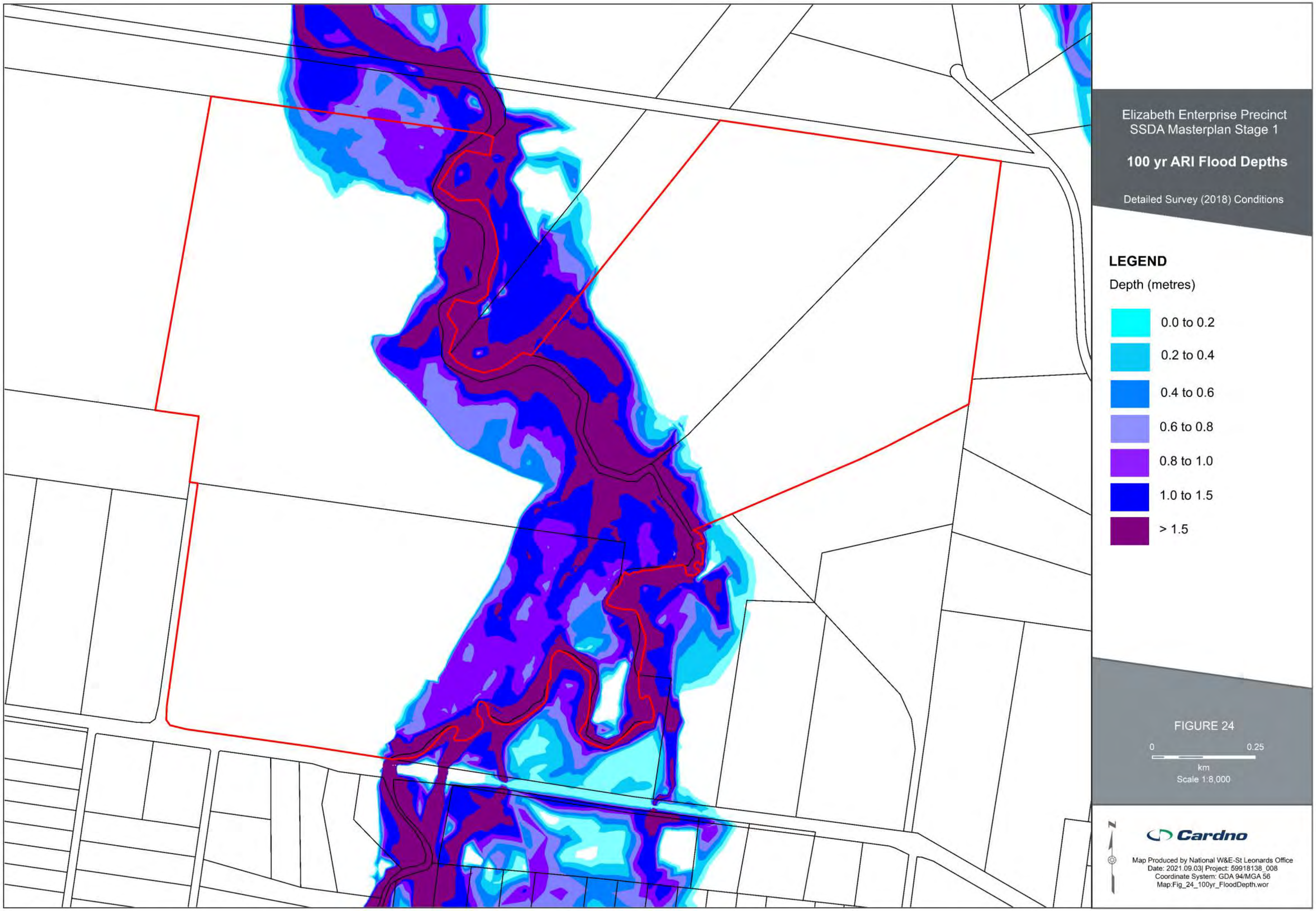
FIGURE 22

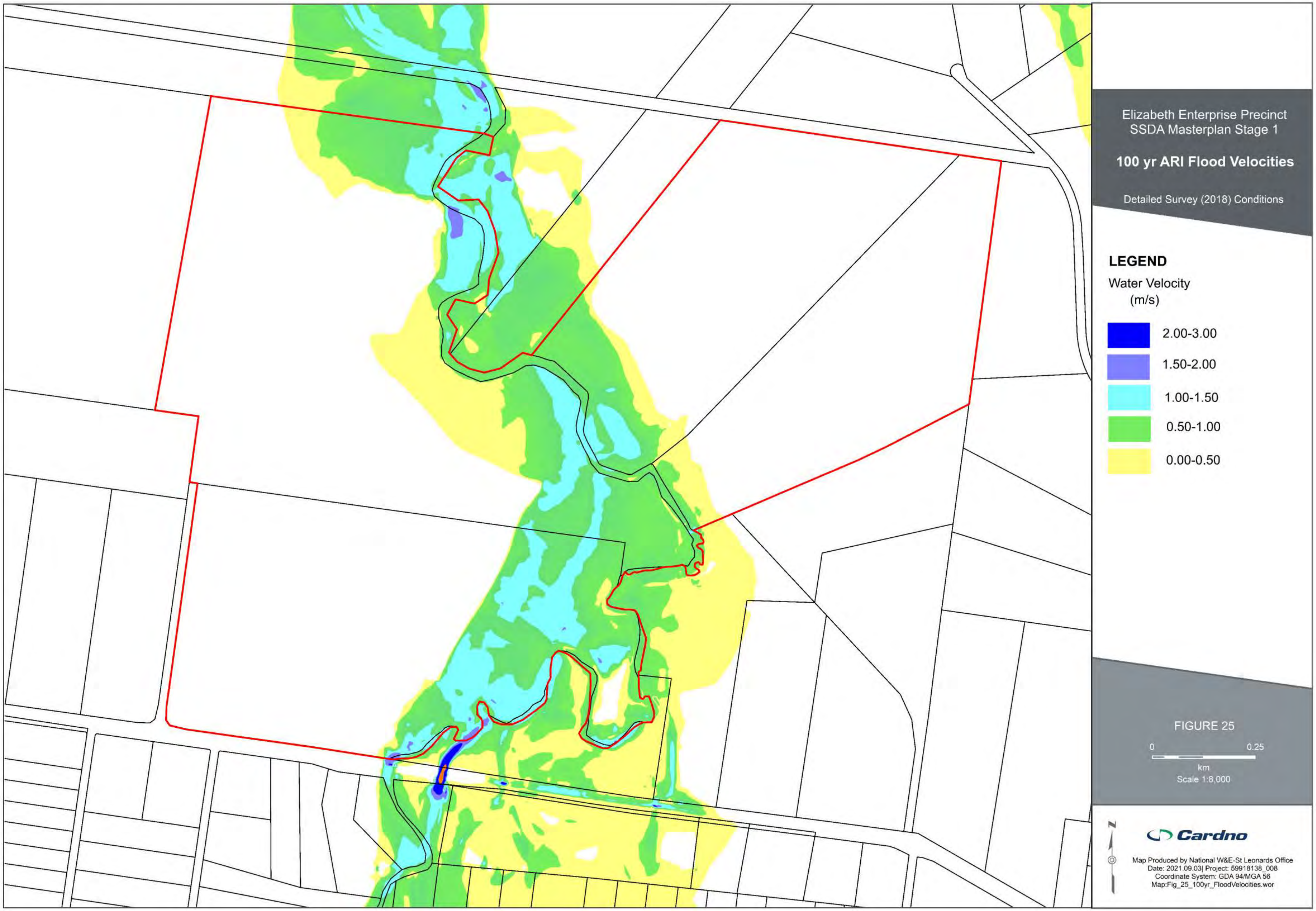
0 0.25
km
Scale 1:8,000

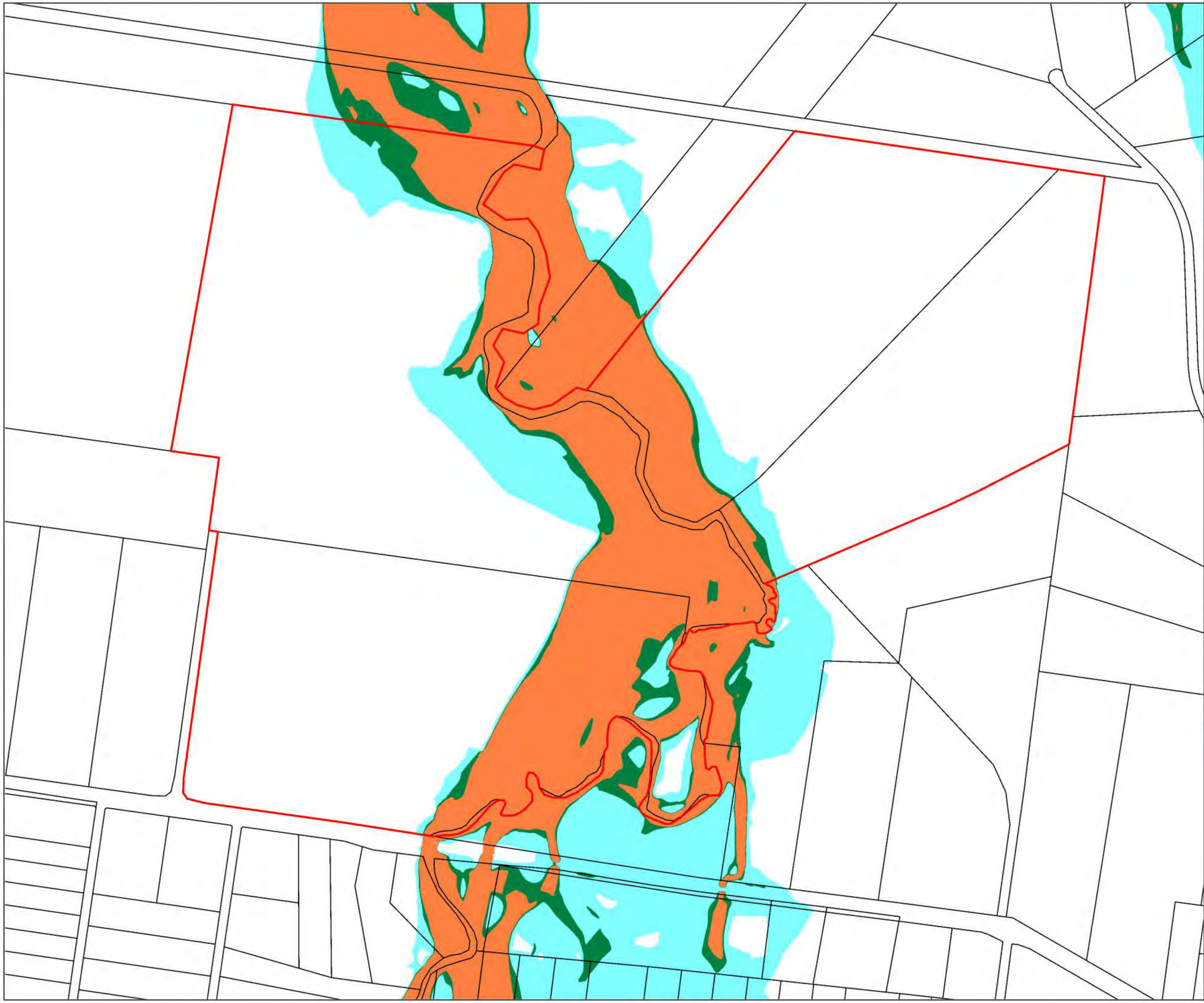
Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_22_20yr_FloodLevels.wor


Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
100 yr ARI Level Differences
(Detailed Survey (2018) – WorleyParsons, 2015)
LEGEND
Water Level Difference
meters
-1 to -0.9
-0.9 to -0.8
-0.8 to -0.7
-0.7 to -0.6
-0.6 to -0.5
-0.5 to -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to 0
0 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
0.6 to 0.7
0.7 to 0.8
0.8 to 0.9
0.9 to 1
FIGURE 23
0
0.25
km
Scale 1:8,000
N
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_23_100yr_FloodLevelDIfferences.wor


Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
100 yr ARI Flood Depths
Detailed Survey (2018) Conditions
LEGEND
Depth (metres)
0.0 to 0.2
0.2 to 0.4
0.4 to 0.6
0.6 to 0.8
0.8 to 1.0
1.0 to 1.5
> 1.5
FIGURE 24
0
0.25
km
Scale 1:8,000
N
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_24_100yr_FloodDepth.wor


Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
100 yr ARI Flood Velocities
Detailed Survey (2018) Conditions
LEGEND
Water Velocity
(m/s)
2.00-3.00
1.50-2.00
1.00-1.50
0.50-1.00
0.00-0.50
FIGURE 25
0
0.25
km
Scale 1:8,000
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_25_100yr_FloodVelocities.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Flood Velocity x Depth

Detailed Survey (2018) Conditions

LEGEND
Velocity x Depth

- 0 to 0.4
- 0.4 to 0.6
- > 0.6

FIGURE 26

0 0.25
km
Scale 1:8,000

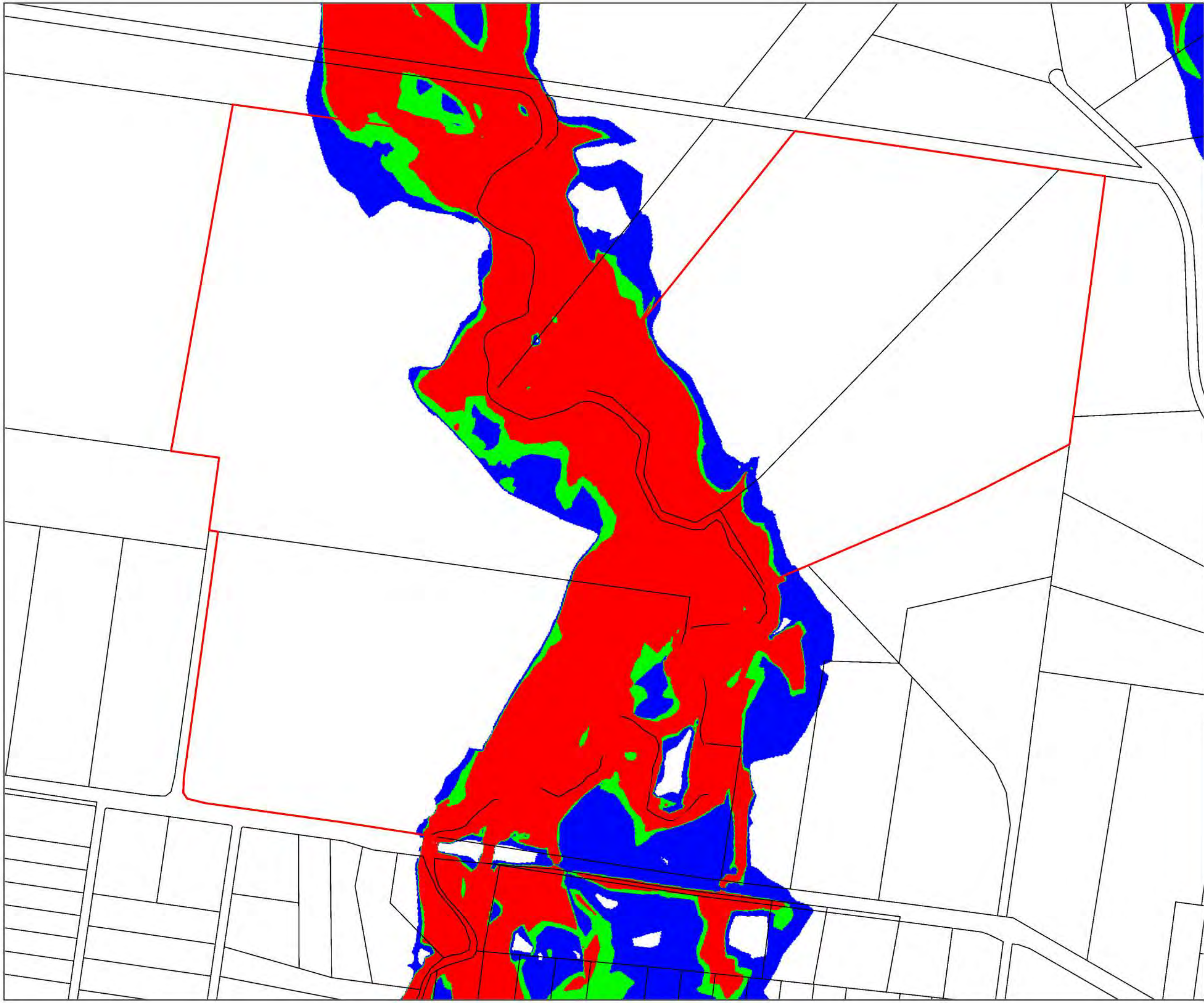
Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_26_100yr_FloodVelocities_x_Depth.wor

Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Flood Hazards

Detailed Survey (2018) Conditions



LEGEND

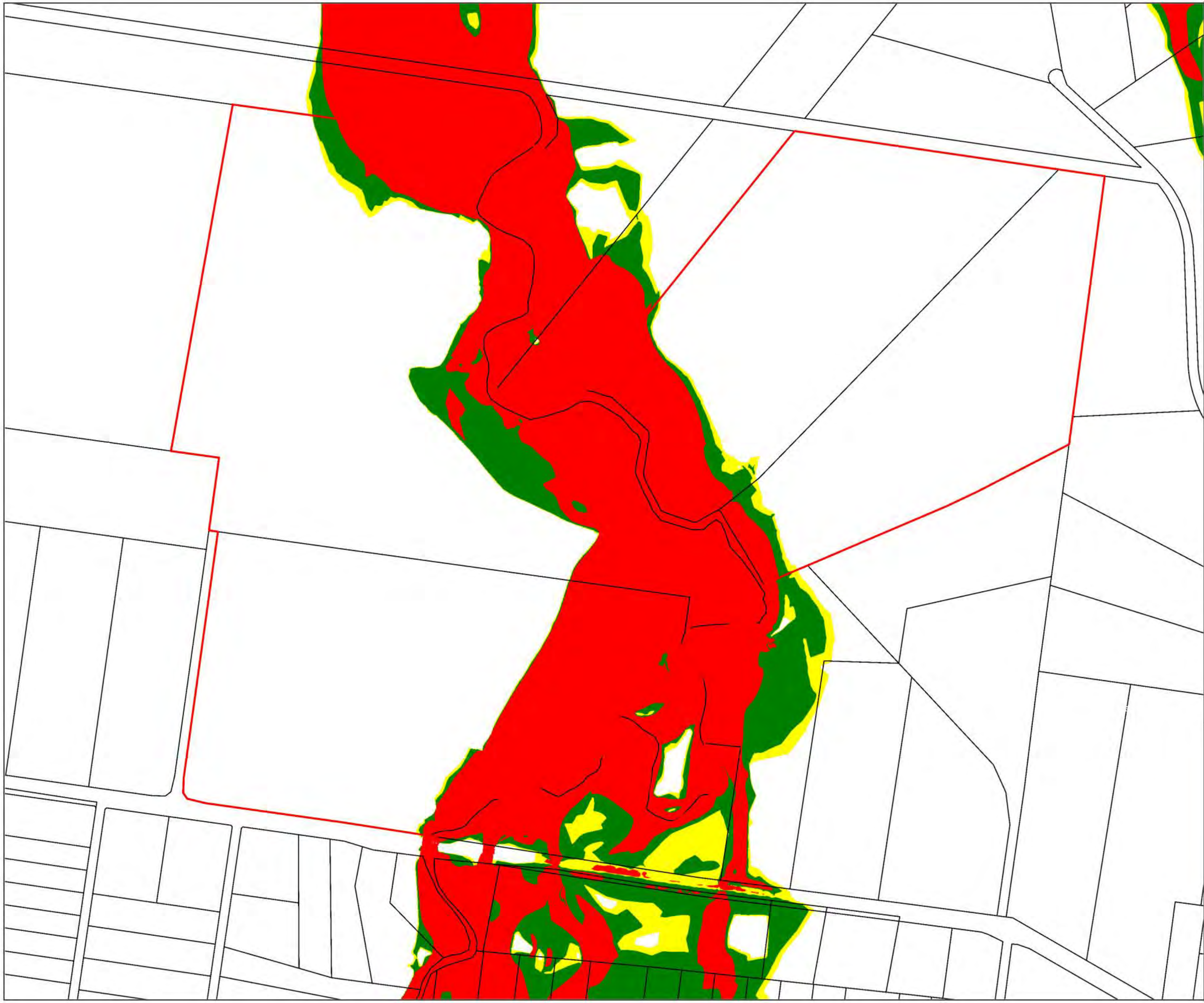
- High Hazard
- Medium Hazard
- Low Hazard

FIGURE 27

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_27_100yr_FloodHazard.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

100 yr ARI Hydraulic Categories

Detailed Survey (2018) Conditions

LEGEND

Flood Fringe
Flood Storage
Floodway

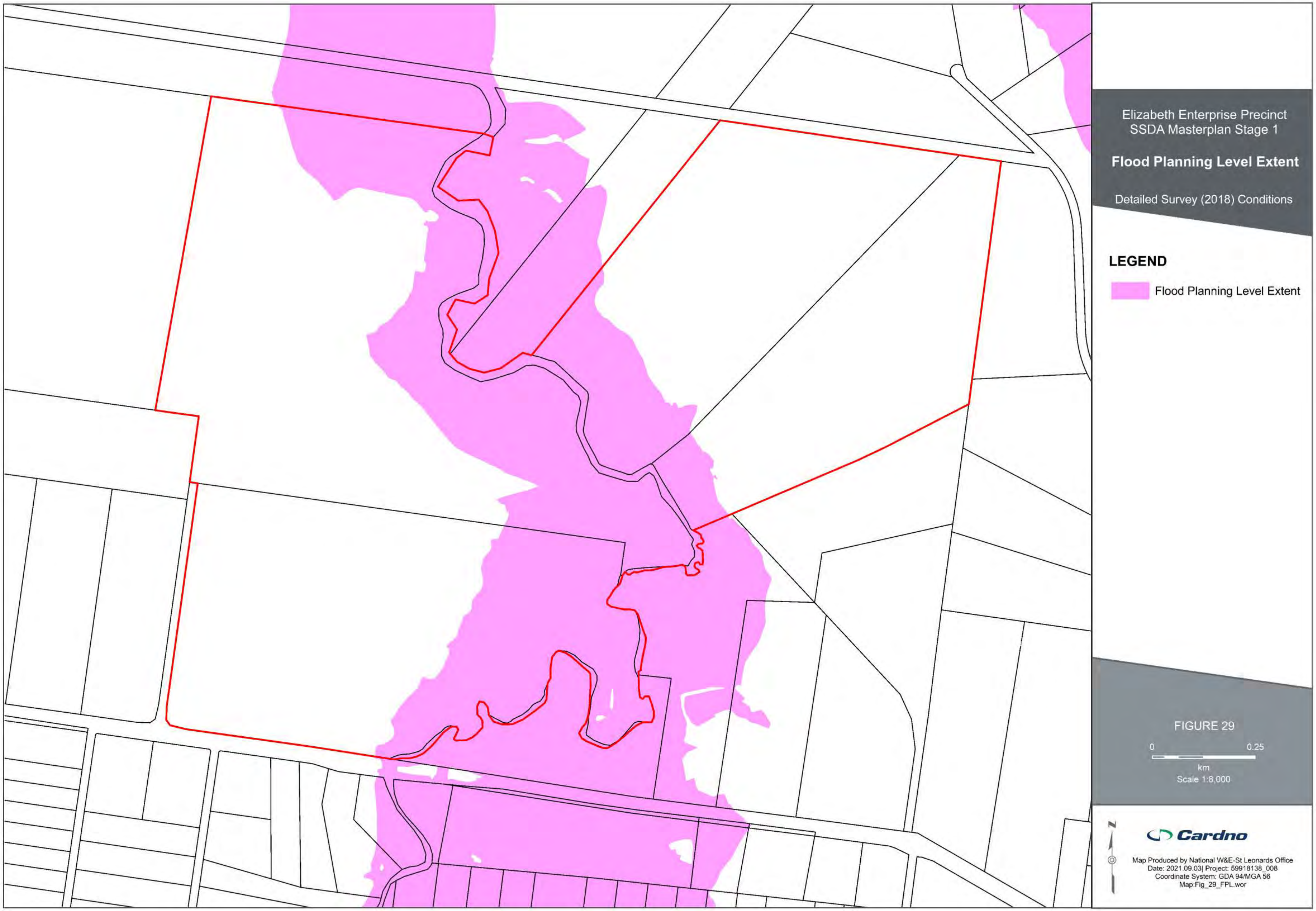
FIGURE 28

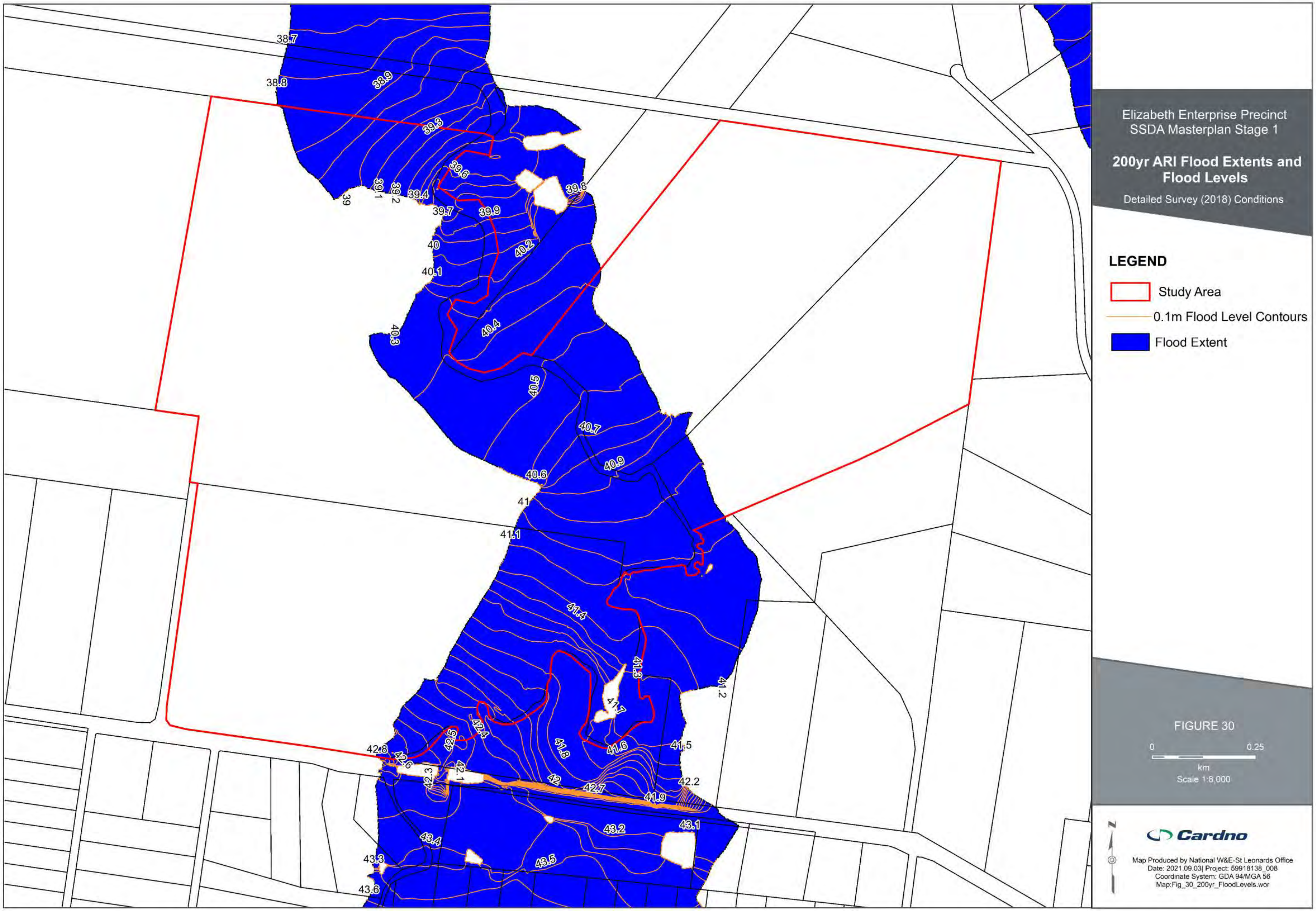
0 0.25
km
Scale 1:8,000

N

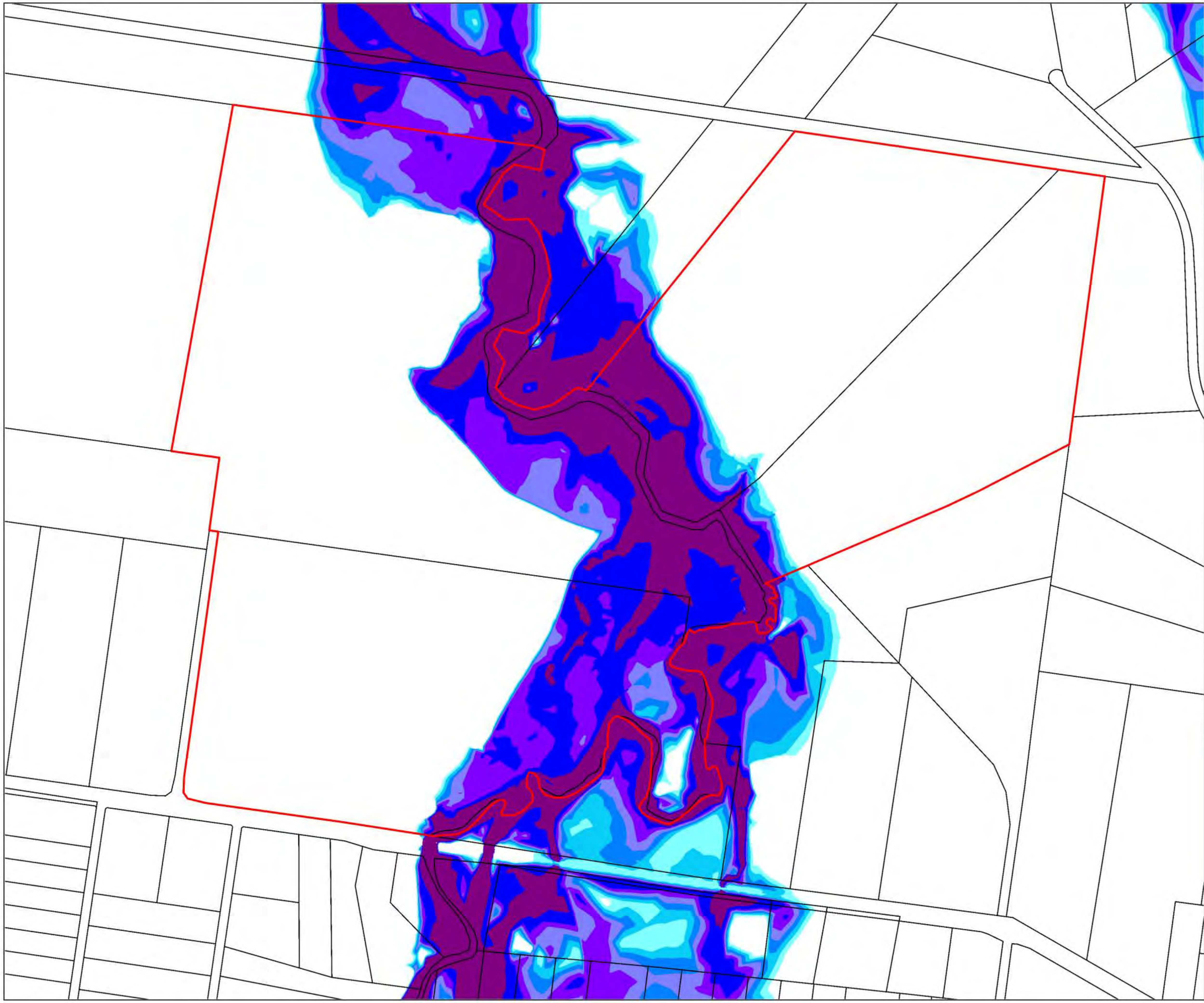
Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_41_PMF_FloodLevelDIfferences.wor


Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
Flood Planning Level Extent
Detailed Survey (2018) Conditions
LEGEND
Flood Planning Level Extent
FIGURE 29
0
0.25
km
Scale 1:8,000
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_29_FPL.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
200yr ARI Flood Extents and Flood Levels
Detailed Survey (2018) Conditions
LEGEND
Study Area
0.1m Flood Level Contours
Flood Extent
FIGURE 30
0
0.25
km
Scale 1:8,000
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_30_200yr_FloodLevels.wor
38.7
38.8
38.9
39
39.1
39.2
39.3
39.4
39.6
39.7
39.8
39.9
40
40.1
40.2
40.3
40.4
40.5
40.6
40.7
40.9
41
41.1
41.2
41.3
41.4
41.5
41.6
41.7
41.8
41.9
42
42.1
42.2
42.3
42.4
42.5
42.6
42.7
42.8
43.1
43.2
43.3
43.4
43.5
43.6



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

200 yr ARI Flood Depths

Detailed Survey (2018) Conditions

LEGEND

Depth (metres)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- > 1.5

FIGURE 31

0 0.25
km
Scale 1:8,000

N

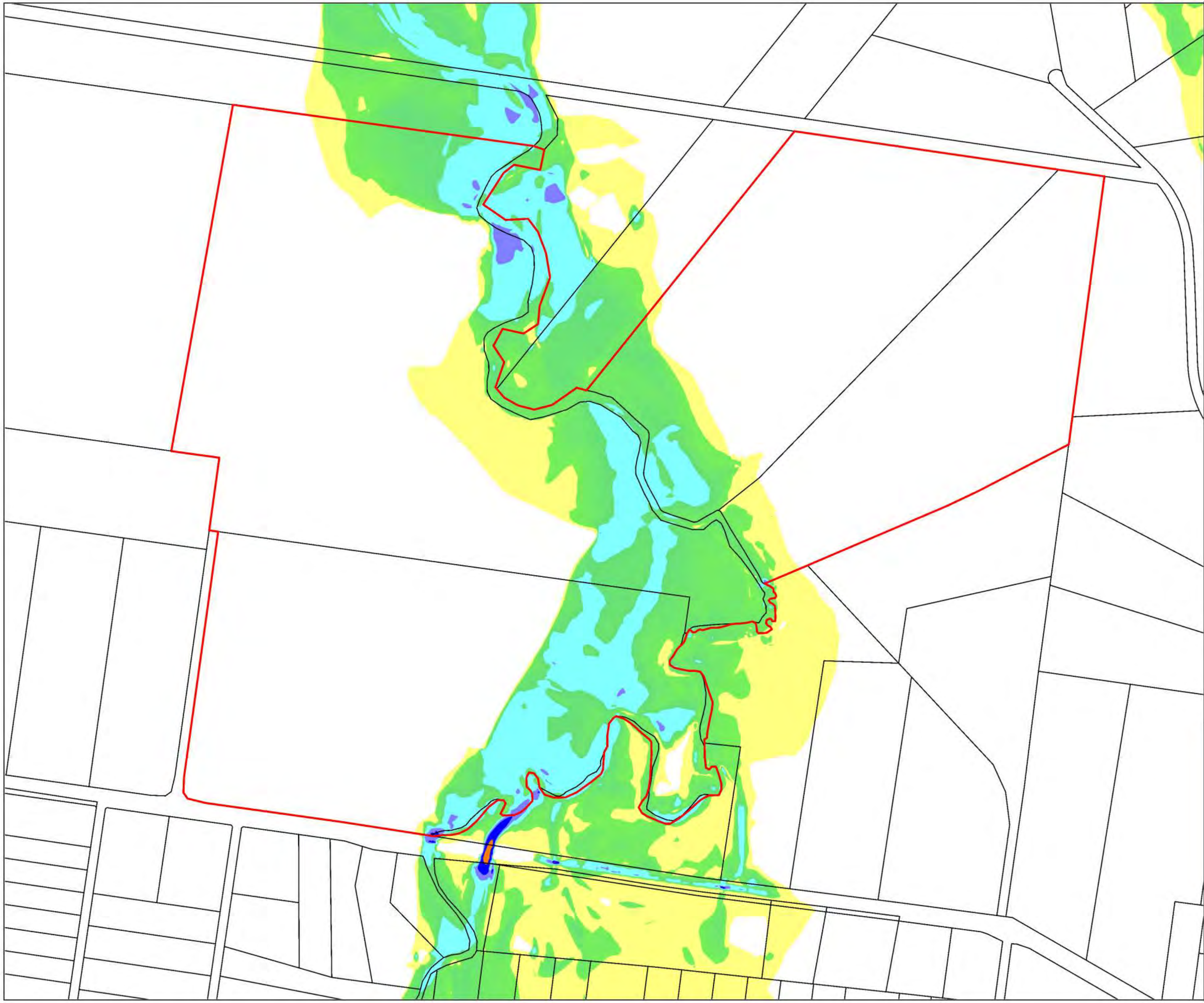
Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_31_200yr_FloodDepth.wor

Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

200 yr ARI Flood Velocities

Detailed Survey (2018) Conditions



LEGEND

Water Velocity (m/s)

- 2.00-3.00
- 1.50-2.00
- 1.00-1.50
- 0.50-1.00
- 0.00-0.50

FIGURE 32

0 — 0.25 km

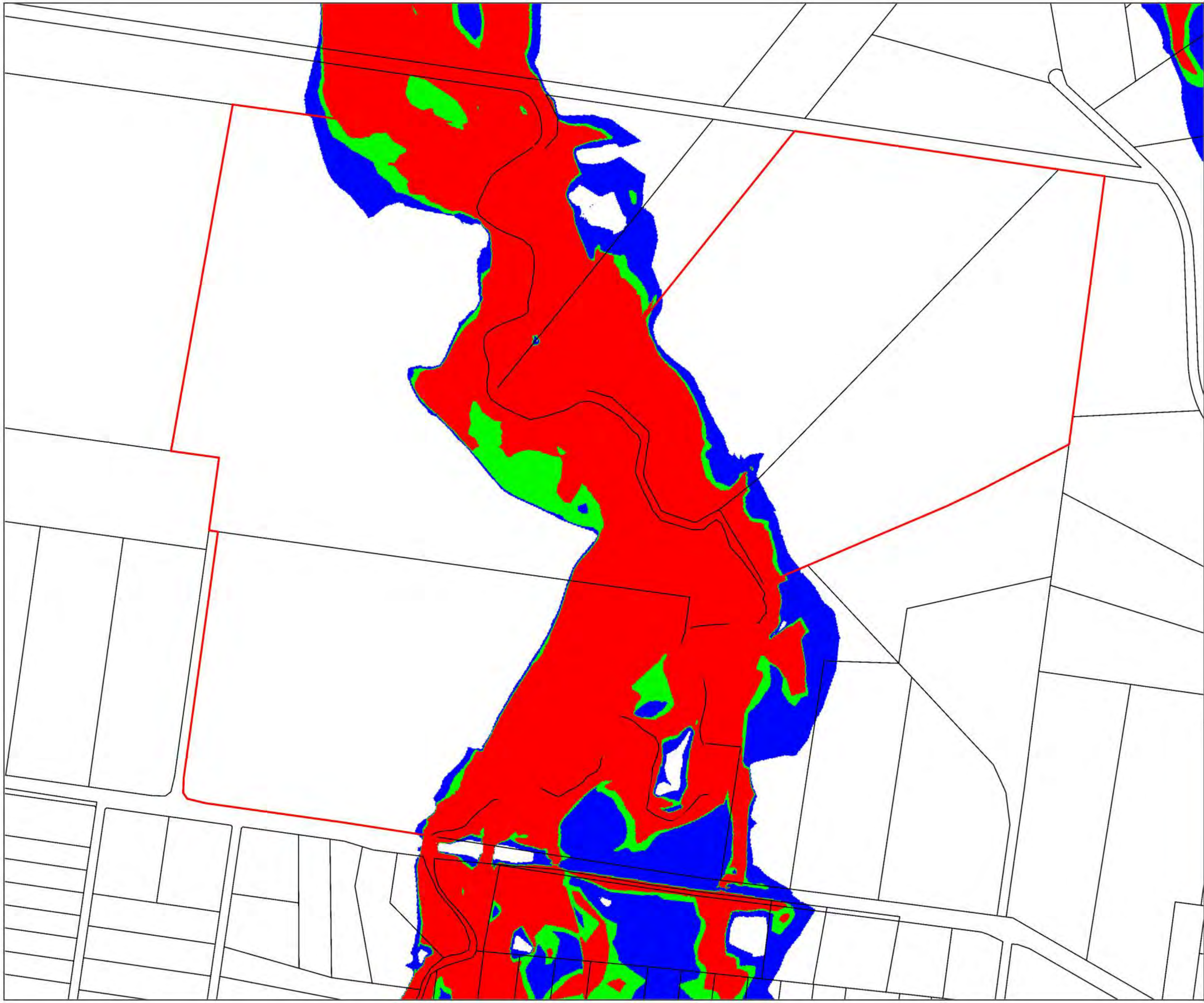
Scale 1:8,000

N

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_32_200yr_FloodVelocities.wor


Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1
200 yr ARI Flood Velocity x Depth
Detailed Survey (2018) Conditions
LEGEND
Velocity x Depth
0 to 0.4
0.4 to 0.6
> 0.6
FIGURE 33
0
0.25
km
Scale 1:8,000
Cardno
Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_33_200yr_FloodVelocities_x_Depth.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

200 yr ARI Flood Hazards

Detailed Survey (2018) Conditions

LEGEND

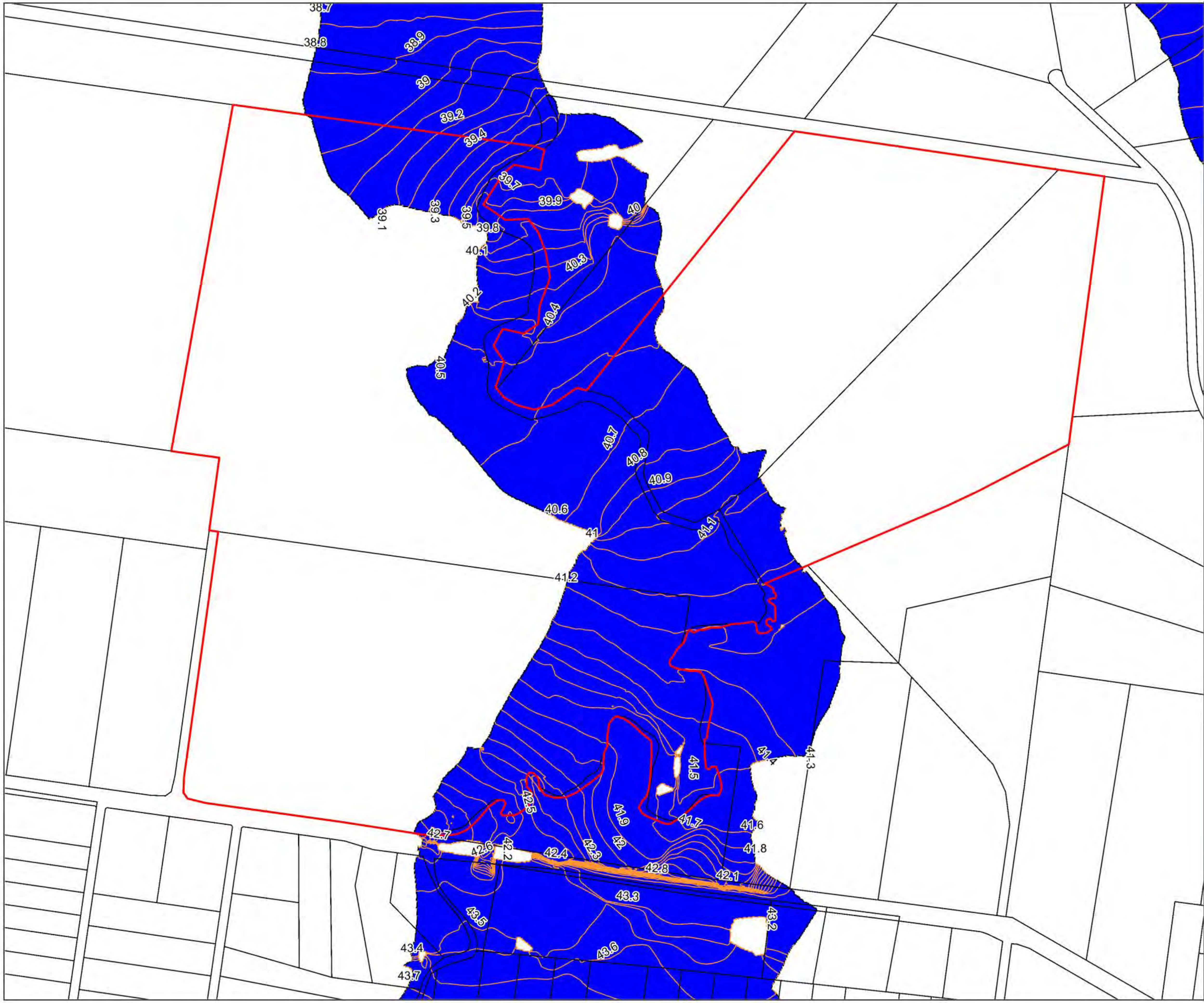
- High Hazard
- Medium Hazard
- Low Hazard

FIGURE 34

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_34_200yr_FloodHazard.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

500yr ARI Flood Extents and Flood Levels

Detailed Survey (2018) Conditions

LEGEND

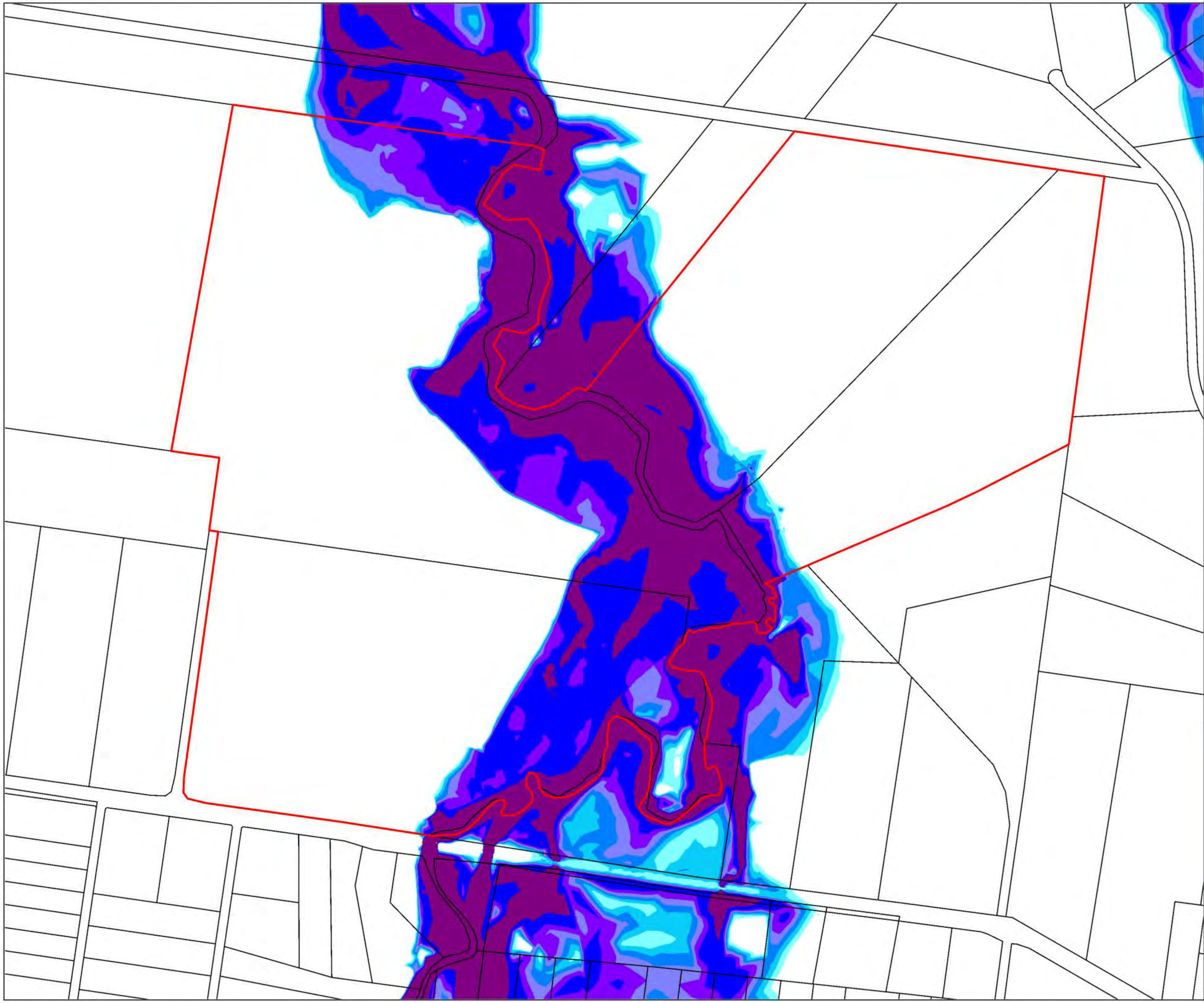
- Study Area
- 0.1m Flood Level Contours
- Flood Extent

FIGURE 35

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_35_500yr_FloodLevels.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

500 yr ARI Flood Depths

Detailed Survey (2018) Conditions

LEGEND

Depth (metres)

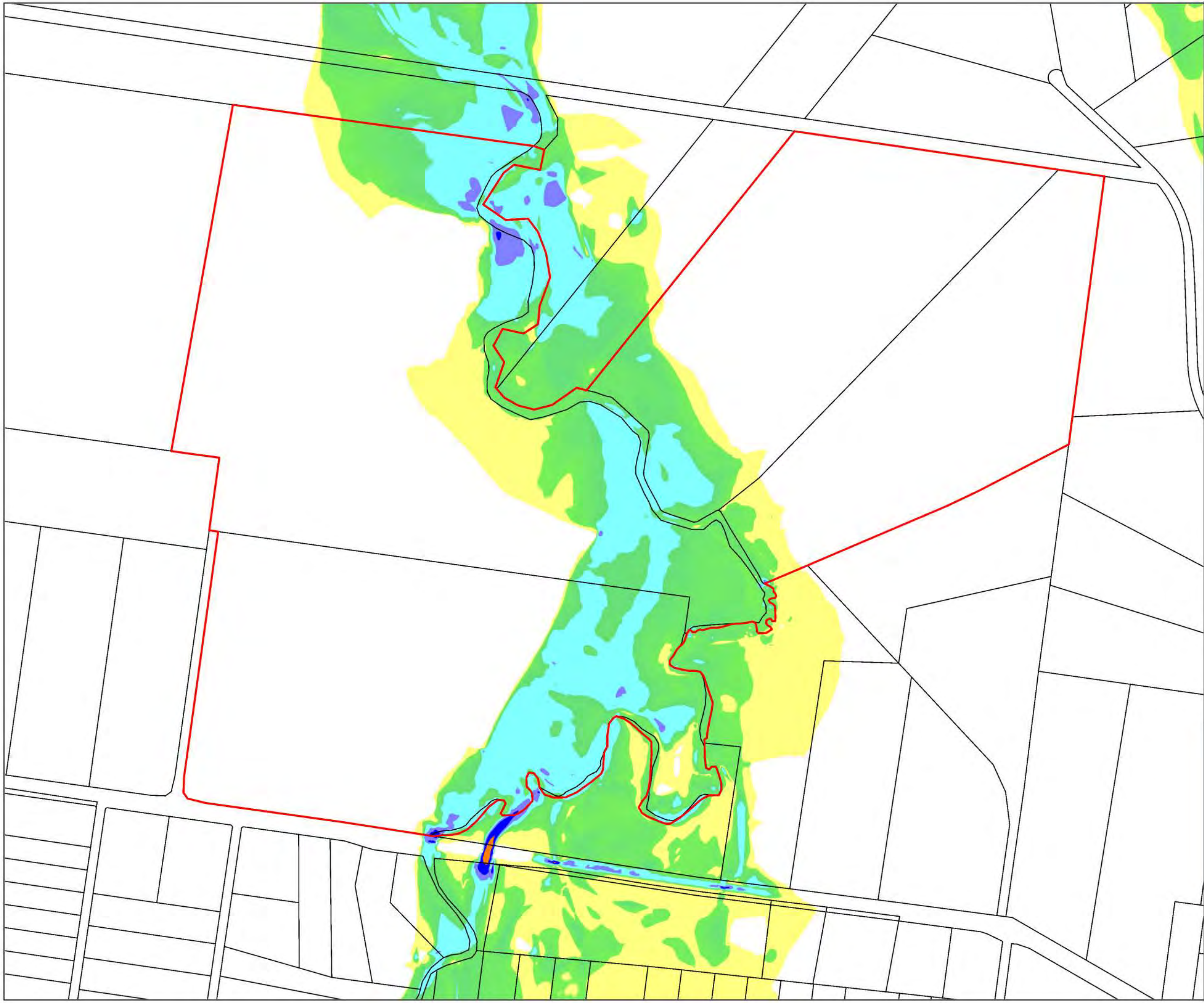
- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- > 1.5

FIGURE 36

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_36_500yr_FloodDepth.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

500 yr ARI Flood Velocities

Detailed Survey (2018) Conditions

LEGEND

Water Velocity (m/s)

- 2.00-3.00
- 1.50-2.00
- 1.00-1.50
- 0.50-1.00
- 0.00-0.50

FIGURE 37

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_37_500yr_FloodVelocities.wor

Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

500 yr ARI Flood Velocity x Depth

Detailed Survey (2018) Conditions

LEGEND
Velocity x Depth

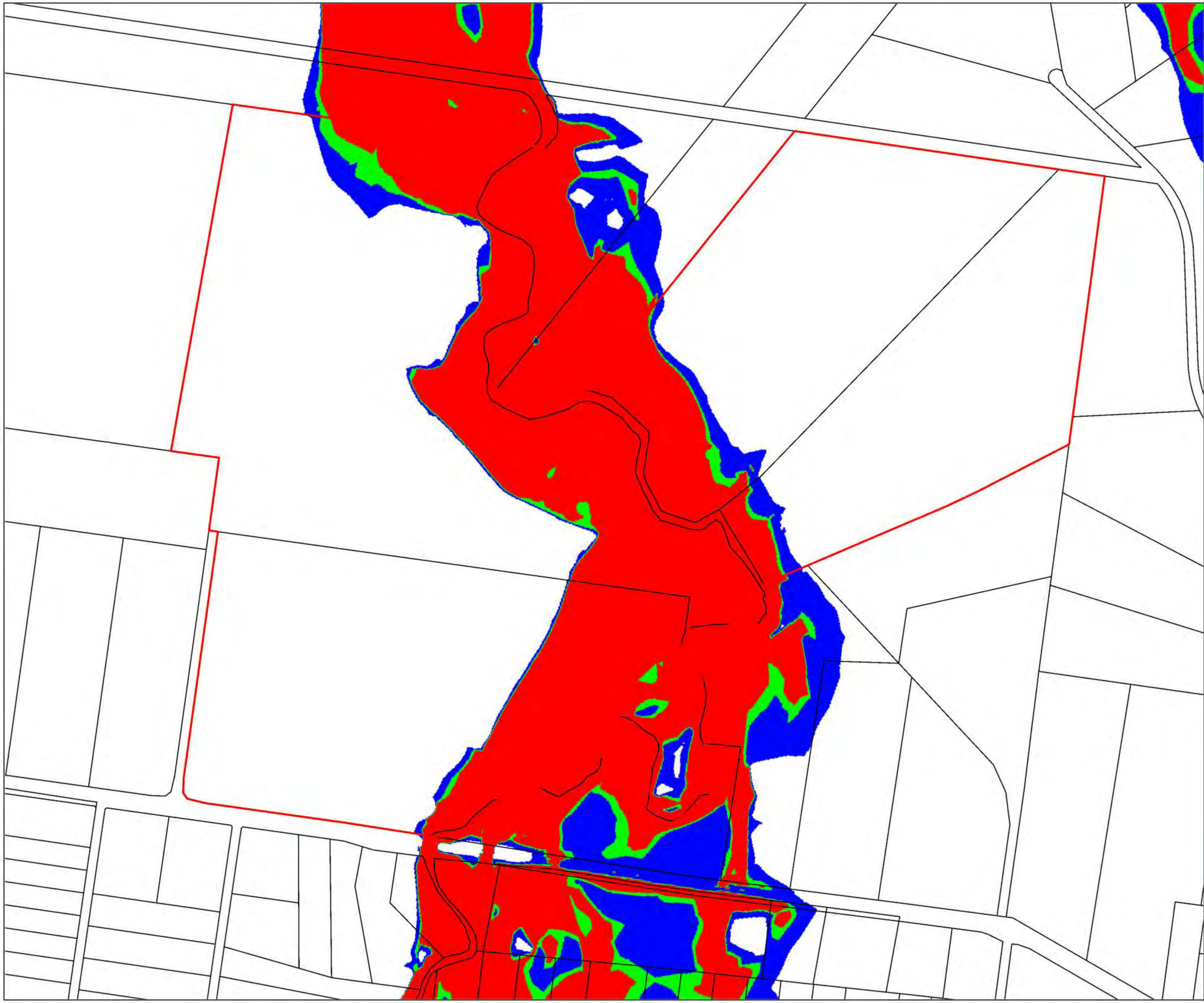
- 0 to 0.4
- 0.4 to 0.6
- > 0.6

FIGURE 38

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_38_500yr_FloodVelocities_x_Depth.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

500 yr ARI Flood Hazards

Detailed Survey (2018) Conditions

LEGEND

High Hazard

Medium Hazard

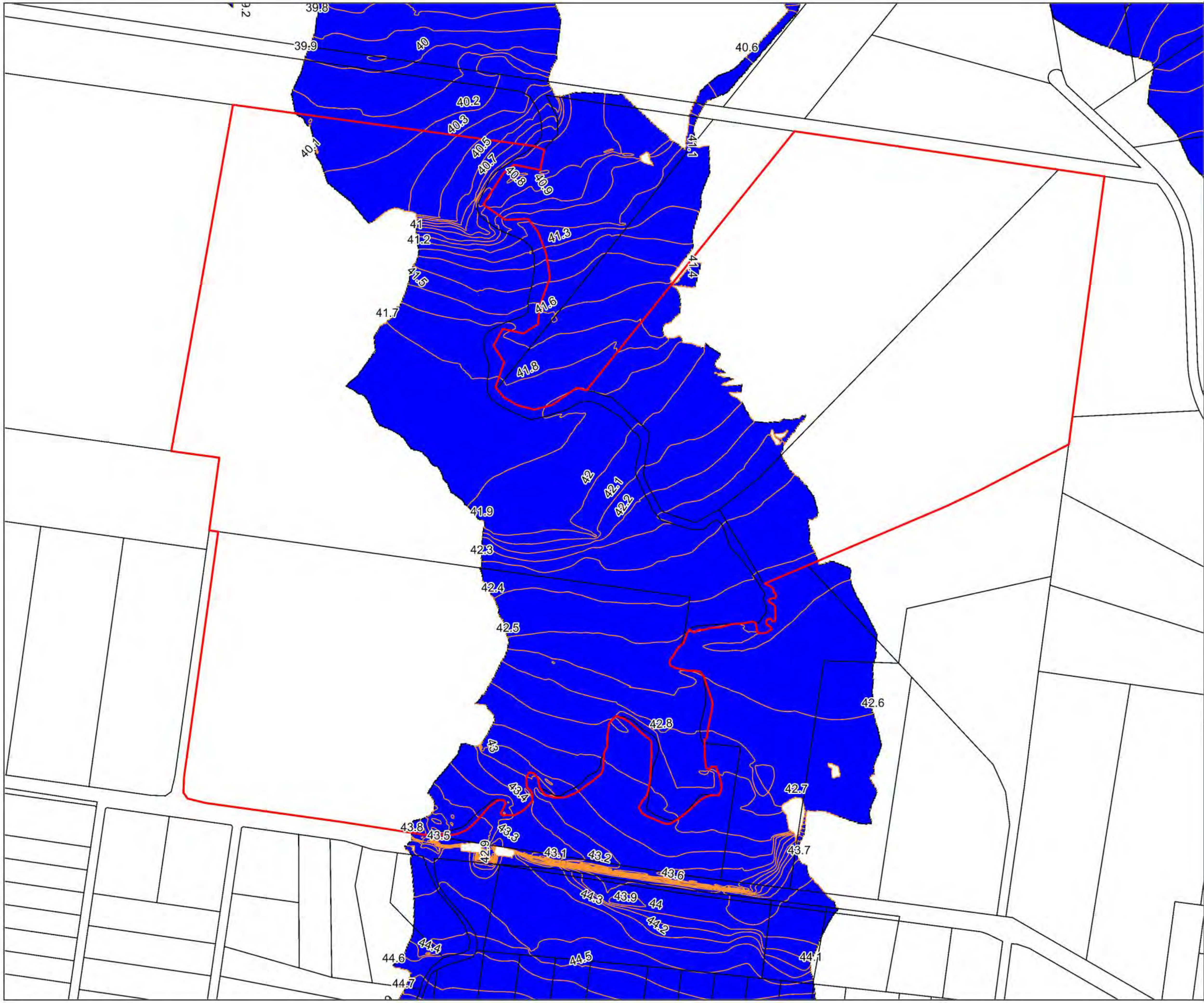
Low Hazard

FIGURE 39

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_39_500yr_FloodHazard.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Extents and Flood Levels

Detailed Survey (2018) Conditions

LEGEND

Study Area

0.1m Flood Level Contours

Flood Extent

FIGURE 40

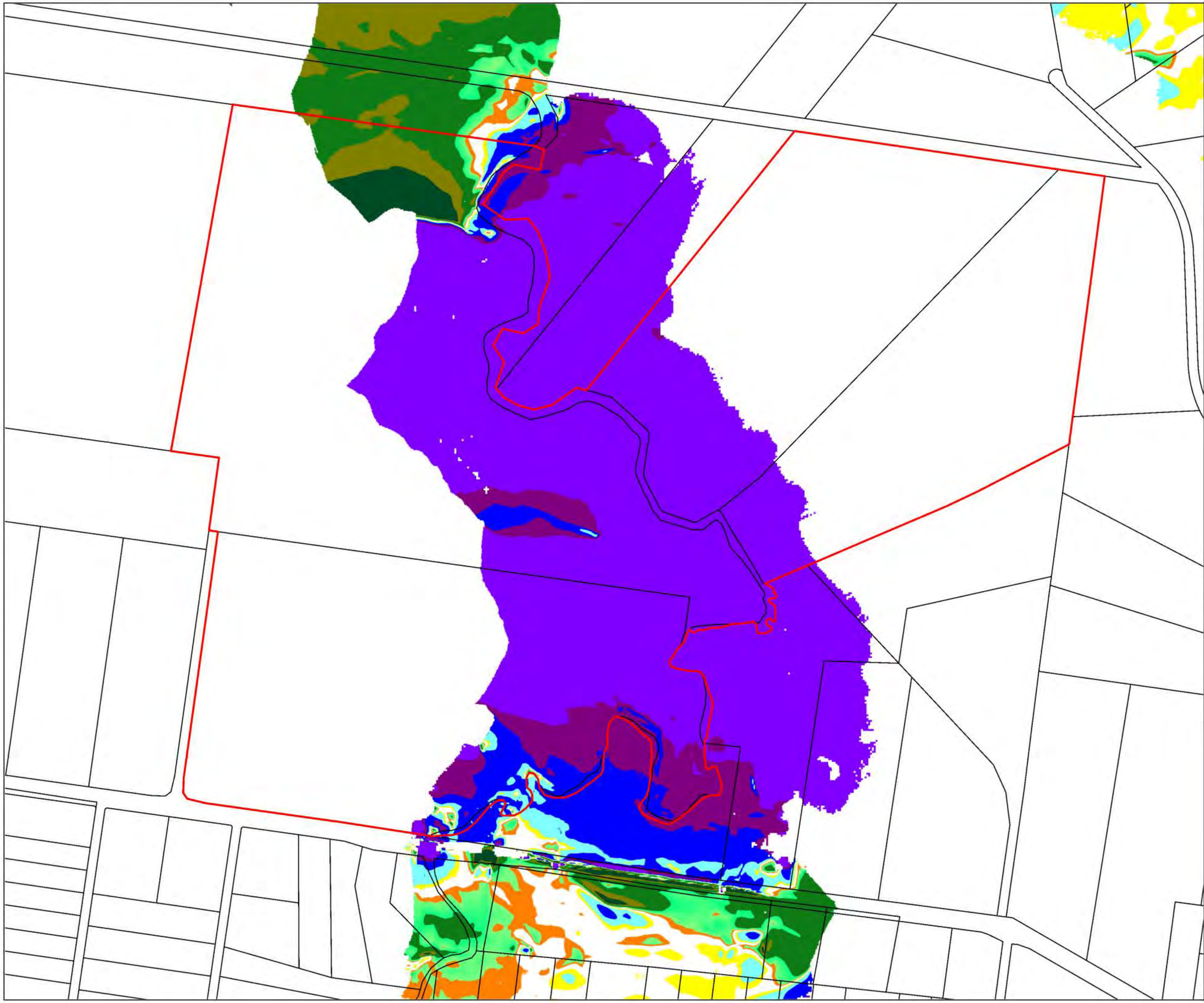
0 0.25

km

Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_40_PMF_FloodLevels.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Level Differences

(Detailed Survey (2018) – WorleyParsons, 2015)

LEGEND

Water Level Difference

metres

- >0.15
- 0.1 to 0.15
- 0.05 to 0.1
- 0.02 to 0.05
- 0.01 to 0.02
- -0.01 to -0.02
- -0.02 to -0.05
- -0.05 to -0.1
- -0.1 to -0.15
- <-0.15

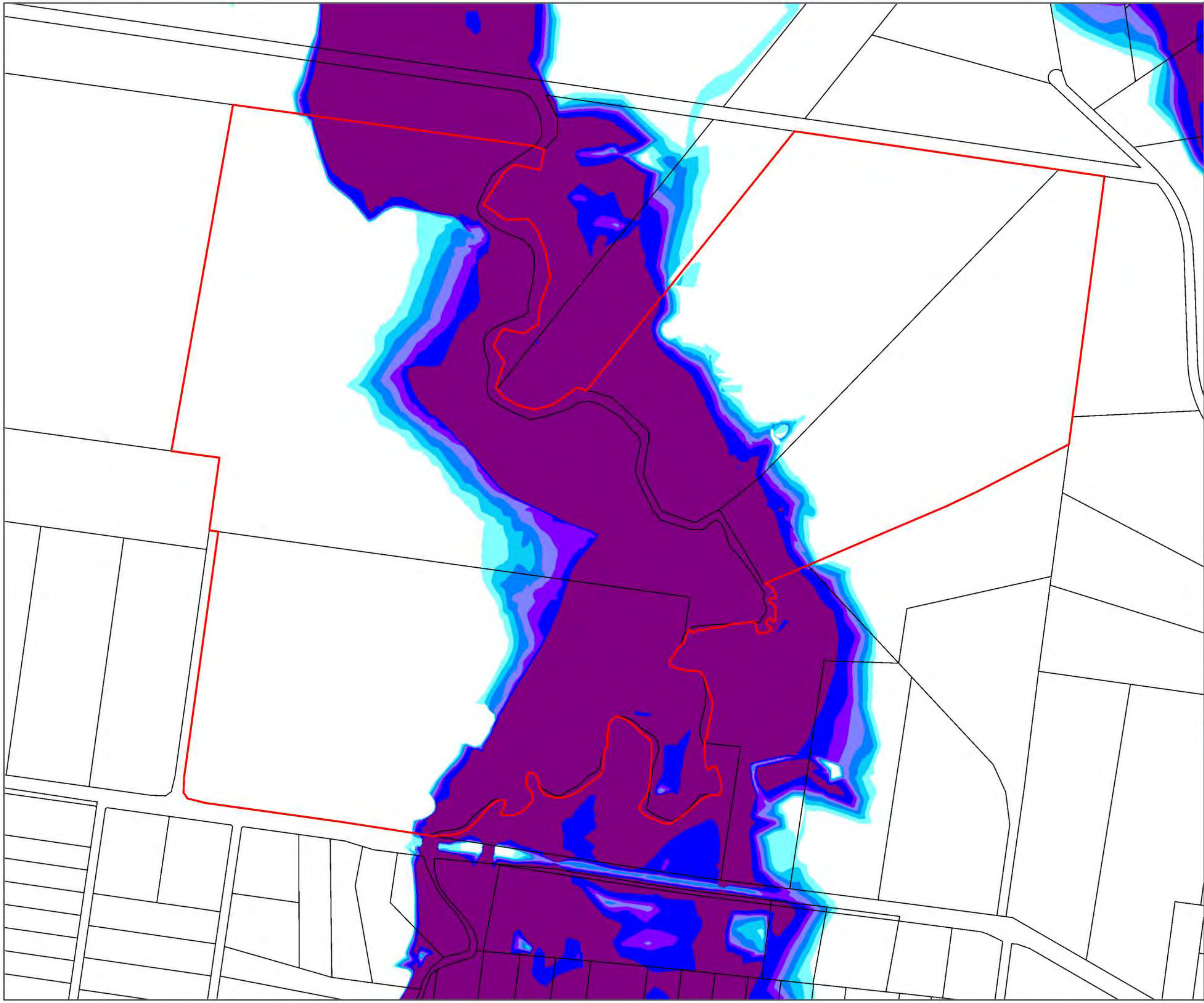
FIGURE 41

0 0.25
km
Scale 1:8,000

N

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_41_PMF_FloodLevelDIfferences.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Depths

Detailed Survey (2018) Conditions

LEGEND

Depth (metres)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- > 1.5

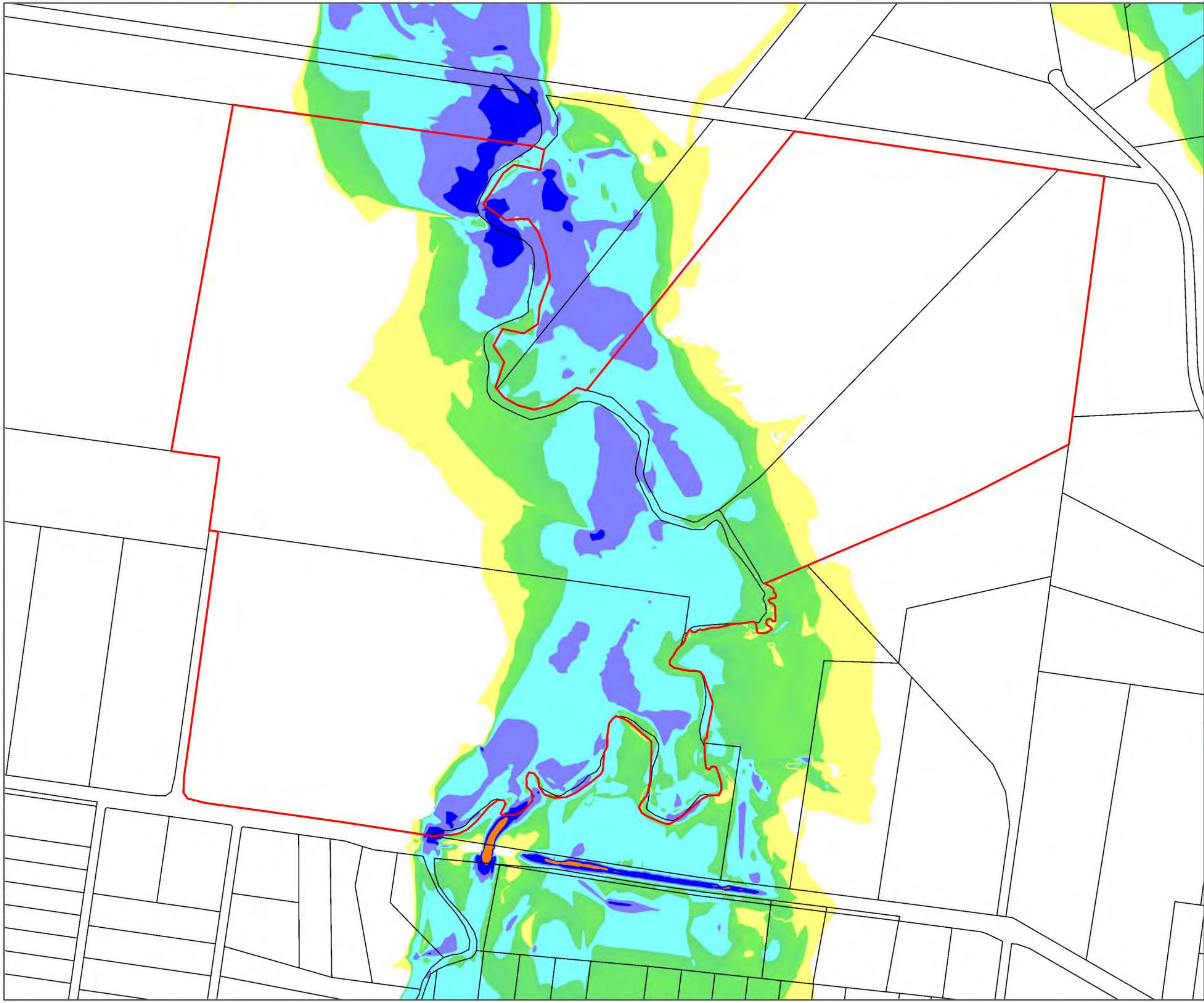
FIGURE 42

0 — 0.25 km
Scale 1:8,000

N

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_42_PMF_FloodDepth.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Velocities

Detailed Survey (2018) Conditions

LEGEND

Water Velocity
(m/s)

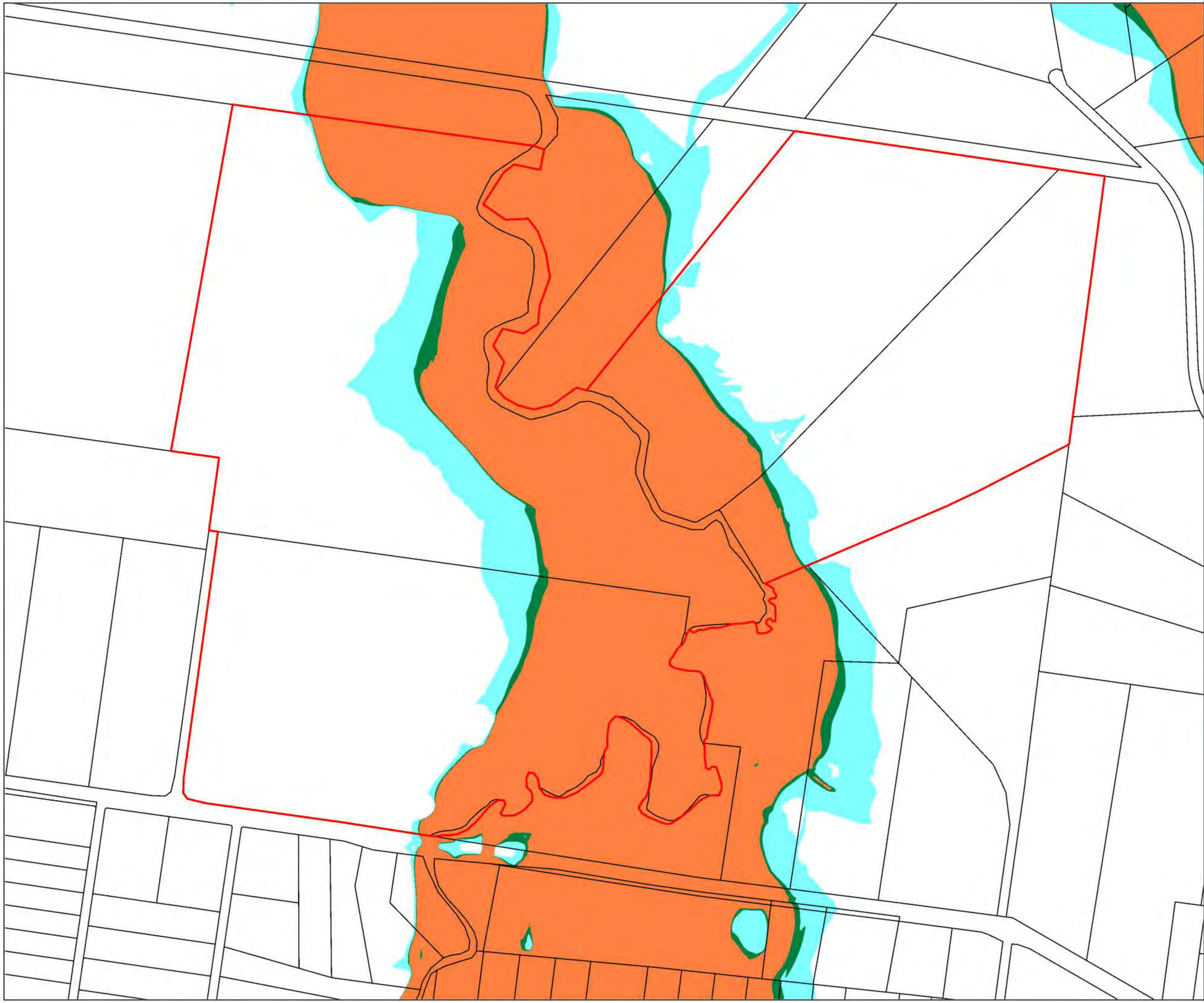
- 2.00-3.00
- 1.50-2.00
- 1.00-1.50
- 0.50-1.00
- 0.00-0.50

FIGURE 43

0 0.25
km
Scale 1:8,000

Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_43_PMF_FloodVelocities.wor



Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Velocity x Depth

Detailed Survey (2018) Conditions

LEGEND
Velocity x Depth

- 0 to 0.4
- 0.4 to 0.6
- > 0.6

FIGURE 44

0 0.25
km
Scale 1:8,000

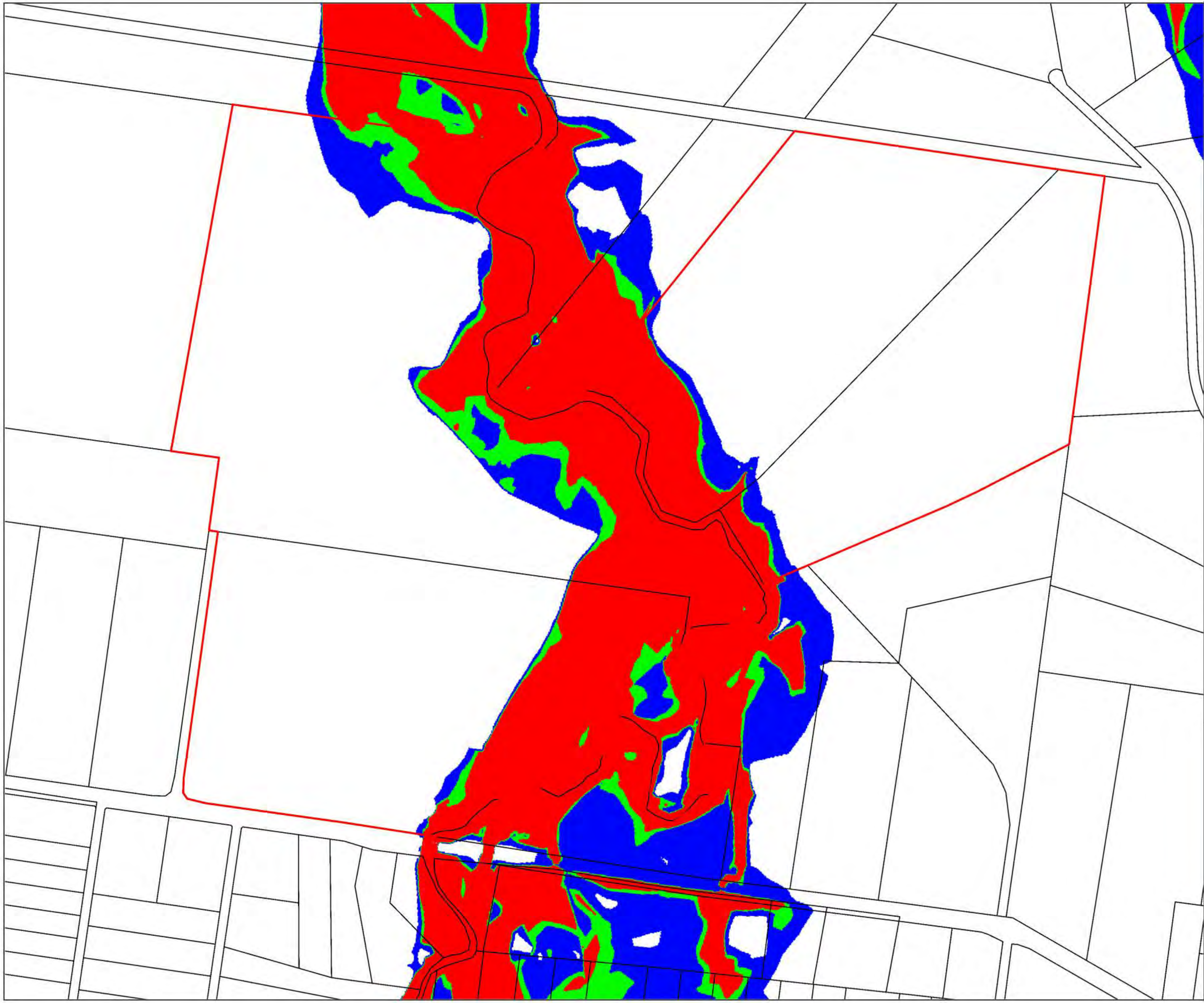
Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_44_PMF_FloodVelocities_x_Depth.wor

Elizabeth Enterprise Precinct
SSDA Masterplan Stage 1

PMF Flood Hazards

Detailed Survey (2018) Conditions



LEGEND

High Hazard

Medium Hazard

Low Hazard

FIGURE 45

0 0.25
km
Scale 1:8,000

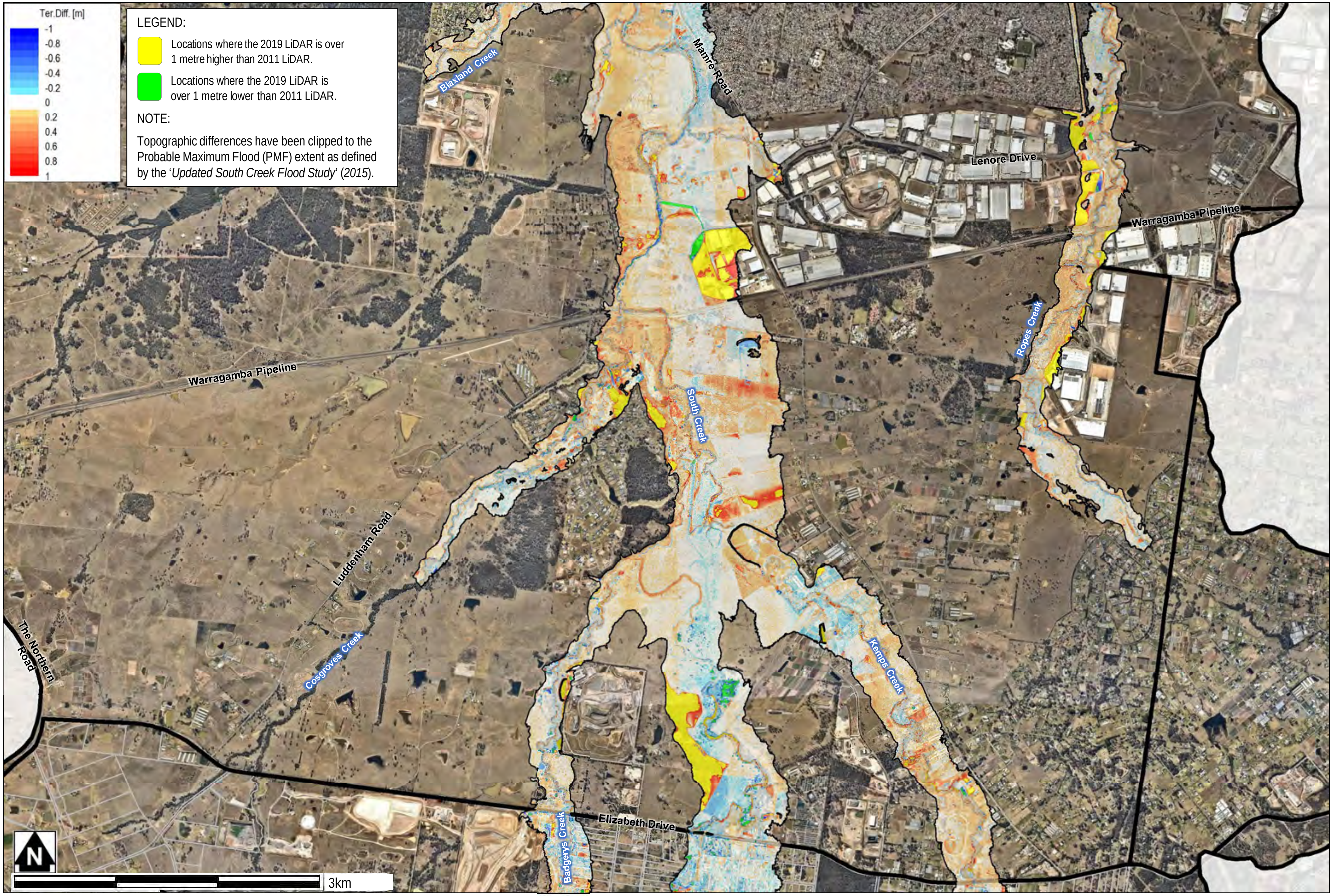
Cardno

Map Produced by National W&E-St Leonards Office
Date: 2021.09.03| Project: 59918138_008
Coordinate System: GDA 94/MGA 56
Map:Fig_45_PMF_FloodHazard.wor

APPENDIX B

2020 ADVISIAN SELECTED FIGURES

Cardno
Shaping the Future



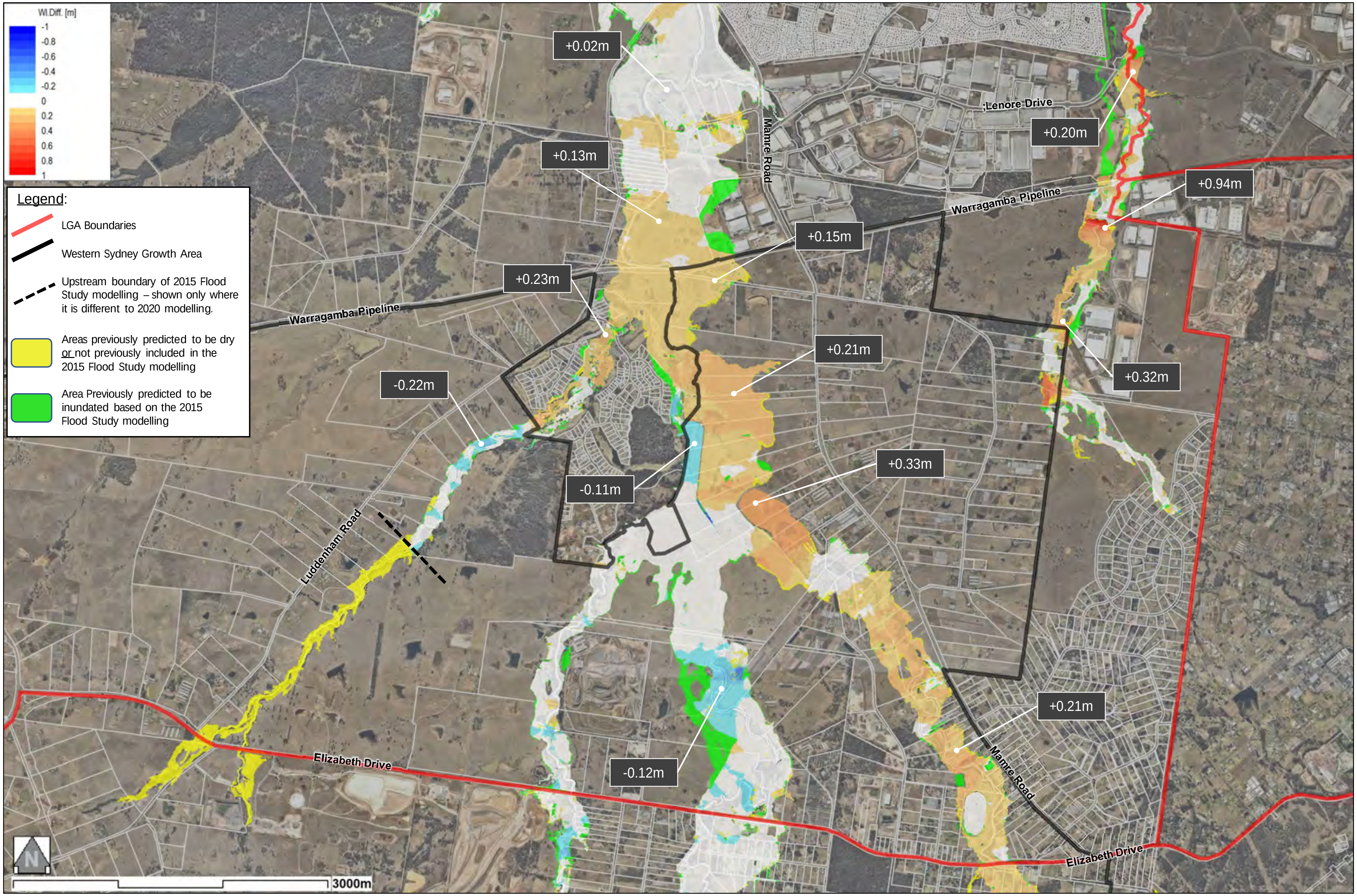
Advisian

311015-00033 – Wianamatta (South) Creek Catchment FS

fg311015-00033_2019 VS 2011/2017 LiDAR.pptx

TOPOGRAPHIC DIFFERENCE MAPPING
COMPARING 2019 LiDAR and 2003-2005 ALS
[View 2 of 4]

FIGURE 4.11



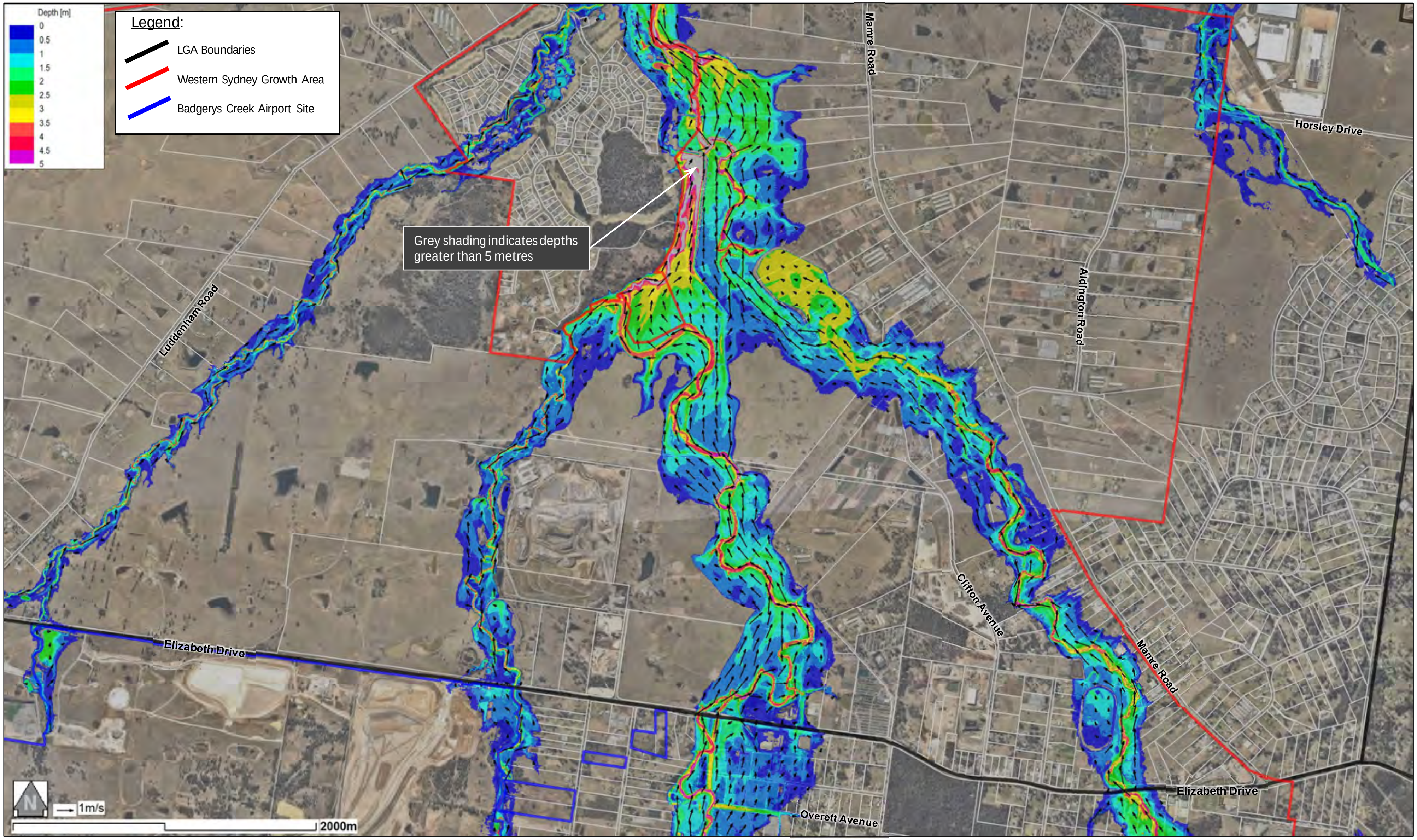
Advisian

311015-00033 – Wianamatta (South) Creek Catchment FS

fg311015-00033_2019 VS 2011/2017 LiDAR.pptx

VALIDATION OF PEAK 1% AEP FLOOD LEVELS PREDICTED AS PART OF THIS FLOOD STUDY (2020) [COMPARISON TO 2015 SOUTH CREEK FLOOD STUDY – EXTENT 2]

FIGURE 5.36



Note:

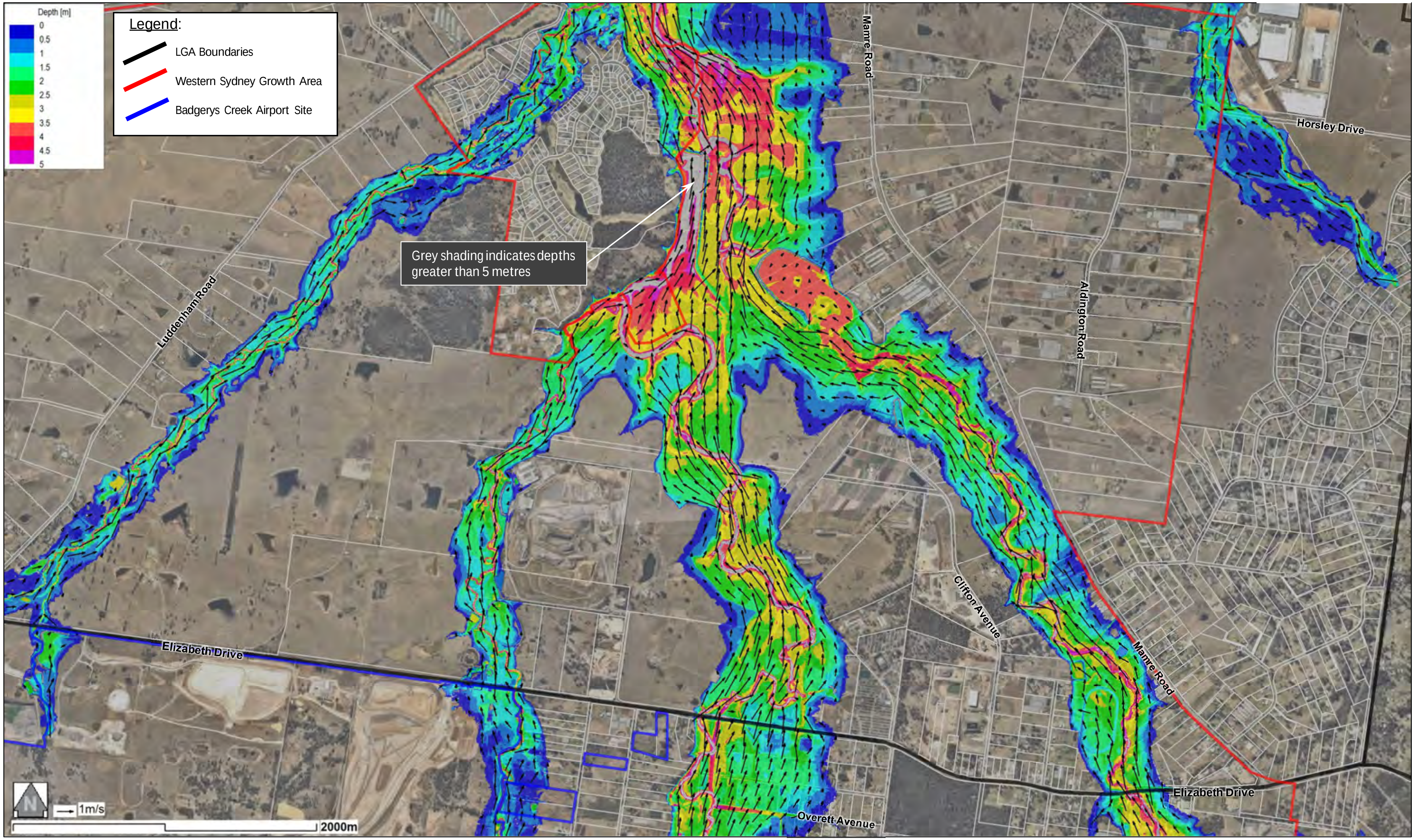
Peak 1% AEP flood depths and velocity vectors are based on a 'Peak-of-Peaks' surface generated from simulations of 2, 9 and 36 hour duration 1% AEP events.

Advisian
Worley Group

311015-00033 – Wianamatta (South) Creek Catchment FS

fg311015-00033_2019 VS 2011/2017 LiDAR.pptx

PREDICTED DEPTHS & VELOCITIES AT THE PEAK OF THE 1% AEP FLOOD [BASE CASE - EXTENT 4 of 8]



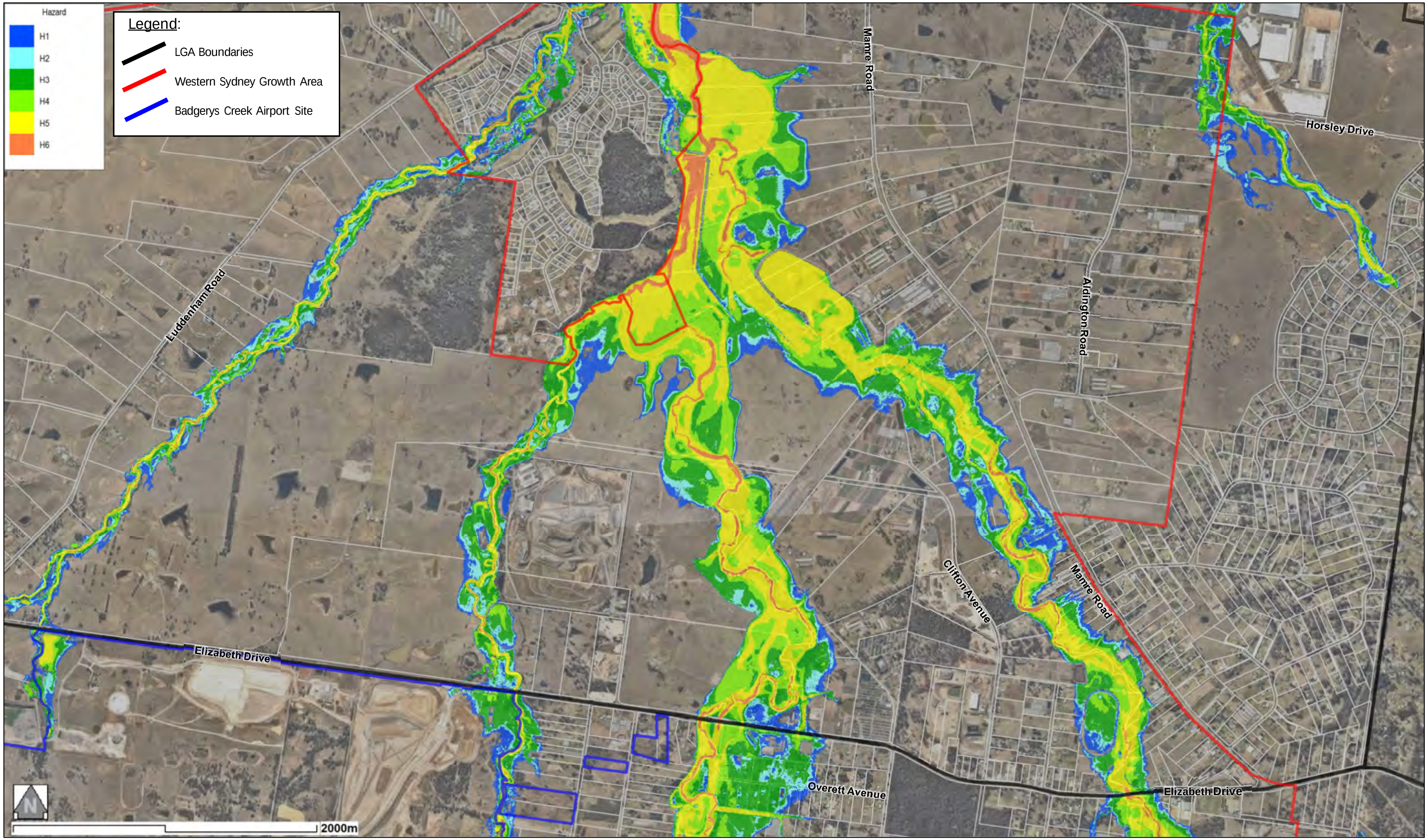
Advisian

311015-00033 – Wianamatta (South) Creek Catchment FS

fg311015-00033_2019 VS 2011/2017 LiDAR.pptx

PREDICTED DEPTHS & VELOCITIES AT THE PEAK OF THE PROBABLE MAXIMUM FLOOD [BASE CASE - EXTENT 4 of 8]

FIGURE 6.4



Note:

The 1% AEP provisional flood hazard mapping is based on a 'Peak-of-Peaks' surface generated from simulations of 2, 9 and 36 hour duration 1% AEP events.

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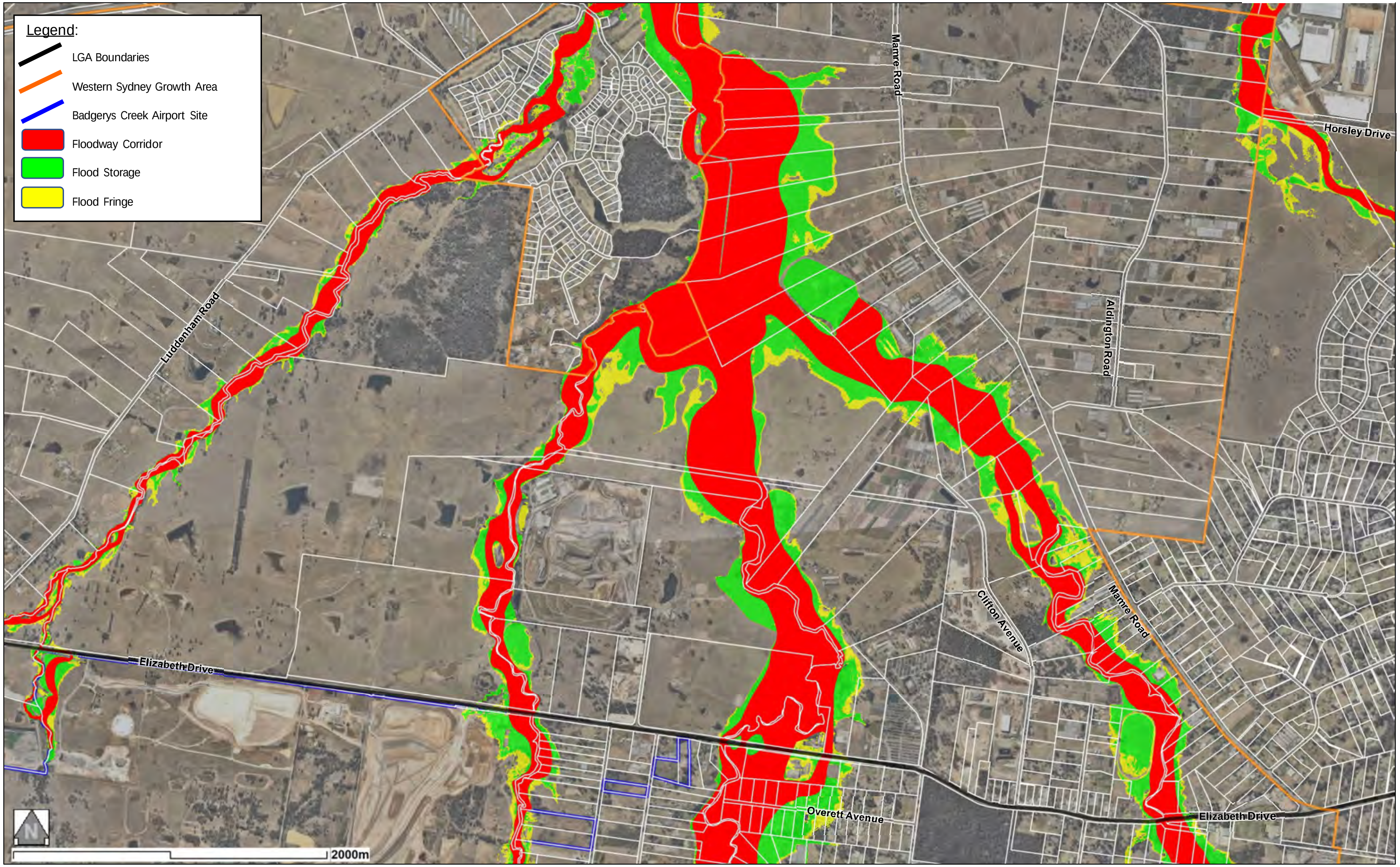
fg311015-00033_2019 VS 2011/2017 LiDAR.pptx

PROVISIONAL FLOOD HAZARDS AT THE PEAK OF THE 1% AEP FLOOD [BASE CASE - EXTENT 4 of 8]



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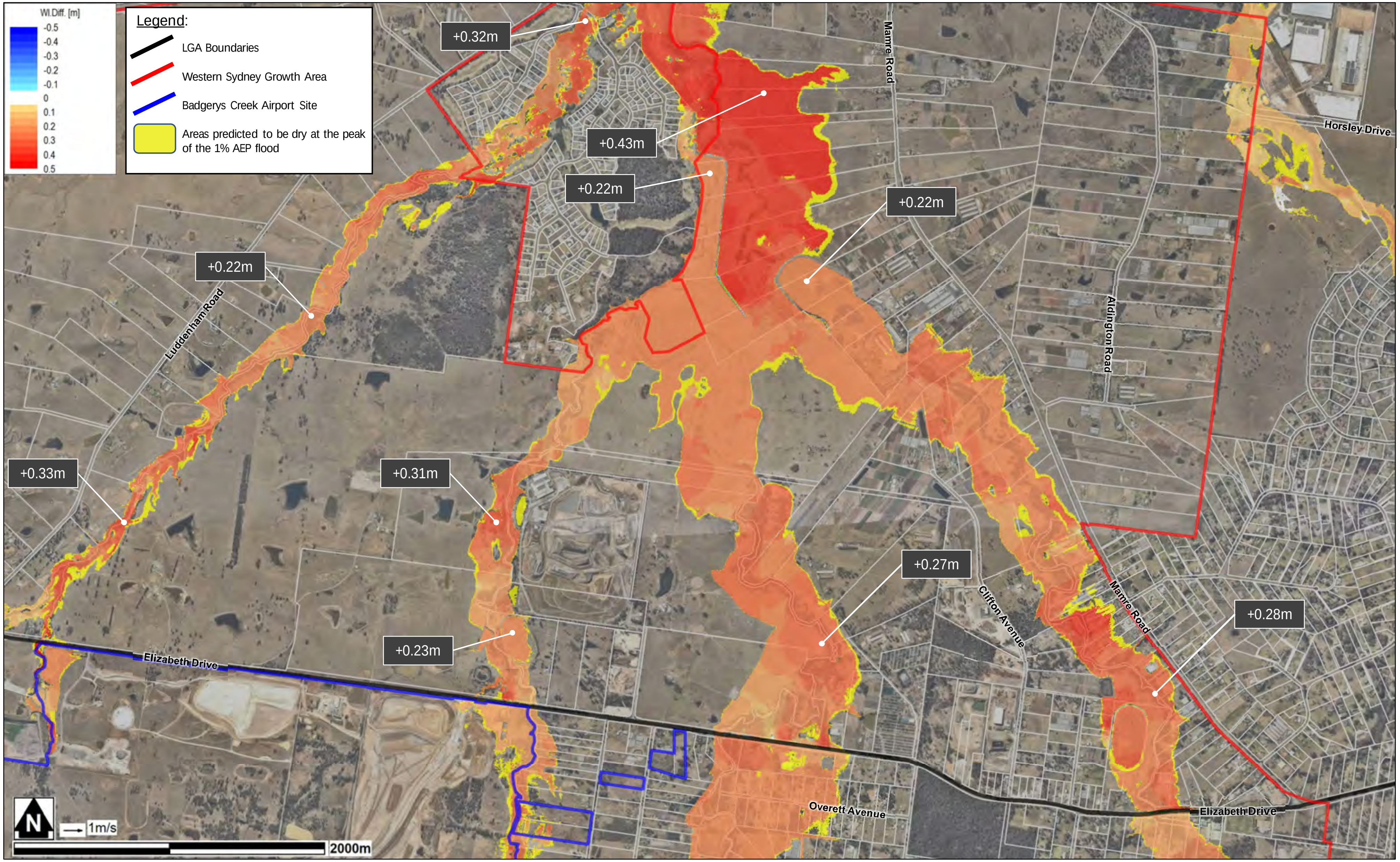
HYDRAULIC CATEGORY MAPPING
[BASE CASE - EXTENT 4 of 8]



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PREDICTED CHANGES TO FLOOD LEVELS AS A RESULT OF THE ADOPTED CLIMATE CHANGE SCENARIO – 0.2% AEP FLOOD [BASE CASE - EXTENT 4 of 8]