Hornsby Flood Models Upgrade to ARR2019

Hornsby Floodplain Risk Management Study and Plan

NW30006

Prepared for
Hornsby Shire Council

25 November 2020

Cardno

Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Level 9 - The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia

www.cardno.com
Phone +61 2 9496 7700
Fax +61 2 9439 5170

Document Information

Prepared for	Hornsby Shire Council
Project Name	Hornsby Floodplain Risk Management Study and Plan
File Reference	NW30006_R001_REvA_Hornsby_Models_Upgrade_to_ARR2019.docx
Job Reference	NW30006
Date	25 November 2020
Version Number	Rev A

Author(s):

Venus Jofreh
Water Engineer

Effective Date 25/11/2020

Approved By:

Dr Brett C Philips
Discipline Leader, Water

Date Approved 25/11/2020

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
Rev A	25/11/20	Draft for Council Review	Venus Jofreh	Dr Brett C Philips

Table of Contents

Appendices

Tables

1 Introduction

On behalf of the Hornsby Shire Council, Cardno (NSW/ACT) Pty Ltd (Cardno) prepared the Hornsby Floodplain Risk Management Study (FRMS) and a draft Floodplain Risk Management Plan (FRMP) for the urban areas within Hornsby LGA in 2014. The study was undertaken to define existing flood behaviour and associated hazards across the study area and to identify and assess potential flood mitigation options to reduce flood damages and risk.

In 2020 Hornsby Shire Council commissioned Cardno to update and finalise the Hornsby Floodplain Risk Management Study and Plan based on the latest Australian Rainfall and Runoff 2019 (ARR2019) guidance and data, and the latest Light Detection and Ranging (LiDAR) topographical data.

This report describes the floodplain model updates and also the outcomes of the latest modelling assessments.

2 Background

As a part of update to the Floodplain Risk Management Study (FRMS) a pilot study was undertaken in August 2020 to evaluate the changes in flood behaviour arising from updated data and guidance provided by the ARR2019 guidelines and to make a recommendation on the adoption of either the 1987 or 2019 editions of Australian Rainfall and Runoff for final model runs and options assessment. The Pennant Hills catchment was selected by Council for the pilot study as it covers a significant portion of the urban area and has sufficient variability to enable reasonable extrapolation of the study outcomes to the other urban catchments across the LGA.

The primary objective of the pilot study was to evaluate the impact on flood characteristics in the Pennant Hills catchment of adopting the updated data and guidance provided in ARR2019 Guidelines. A secondary objective was to assess the differences in flood levels based on the adoption of the CPU (classic) version or the GPU (HPC) version of the TUFLOW numerical engine with a view to re-running the models with the latest version of the software (TUFLOW GPU) as long as this does not substantially change the assessed flood behaviour.

Based on the outcomes of the various assessment, it was recommended that the Hornsby FRMS Update be based on:

- The 2019 LiDAR;
- A 2 m x 2 m or 3 m x 3 m grid size (based on the size of the model);
- TUFLOW 2020 HPC (GPU) engine (version AB)

The final decision on adopting ARR1987 or ARR2019 data needed to consider:

- The ARR1987 runs that have already been undertaken;
- The adoption of ARR2019 would require a complete update of all previous hydrological assessments;
- The adoption of ARR2019 would slightly lower the estimated design flood levels in urban areas with an expected median reduction in peak 1% AEP flood levels of around 0.05 m; and
- The adoption of ARR2019 may reduce the number of flood control lots by around 7% to 10%.

Based on the outcomes of the pilot study, Council decided to adopt ARR2019 data and guidance when upgrading the eight remaining flood models for Asquith, Beecroft, Berowra, Brooklyn, Cowan, Galston, Glenorie and Pennant Hills.

3 Updates to the Hydraulic Models and Model Scenarios

All seven remaining rainfall-on-grid (TUFLOW) flood models were updated using the latest LiDAR data as well as a finer grid size. This required a number of other updates to the model for the purpose of consistency. The updates applied to the Hornsby overland flow flood models included:

- The adoption of rainfall IFD and storm burst temporal patterns from ARR2019;
- The Digital Elevation Model (DEM) levels were updated using the latest 2019 LiDAR data. **Figures A1** to **A8** (in **Appendix A)** plot the differences between the latest 2019 LiDAR and the LiDAR data adopted for the 2015 study;
- Model grid cell sizes were refined from 6 m x 6 m to 3 m x 3 m or 2 m x 2m (depending on the size of each model and the resulting number of grid cells) to provide a more detailed representation of the catchment topography;
- The TUFLOW numerical engine was updated to the latest version (2020-01-AB);
- All models were run with the Heavily Parallelised Compute (HPC) GPU engine. The HPC version can achieve significantly shorter model run times which allows hydraulic models to be run in a timely manner with higher grid resolution across larger domains;
- Drainage invert levels were updated to be consistent with the latest 2019 LiDAR data (where required); and
- The model boundary was modified (where required) to ensure the contributing catchment is presented accurately and also an robust representation of hydraulic behaviour is achieved.

Table 3-1 provides details of the updates made into each of the Hornsby overland flow flood models.

Table 3-1 Updates to the Hornsby TUFLOW Models

Model Name	ARR2019	2019 Lidar	Cell Size	Drainage Invert Levels Updated	Model Boundary Updated	TUFLOW Engine
Asquith	Yes	Yes	2m x 2m	-	No	2020-01-AB
Beecroft	Yes	Yes	3m x 3m	Yes	No	2020-01-AB
Berowra	Yes	Yes	2m x 2m	-	Yes	2020-01-AB
Brooklyn	Yes	Yes	2m x 2m	Yes	Yes	2020-01-AB
Cowan	Yes	Yes	2m x 2m	-	Yes	2020-01-AB
Galston	Yes	Yes	2m x 2m	-	Yes	2020-01-AB
Glenorie	Yes	Yes	2m x 2m	-	Yes	2020-01-AB
Pennant Hills	Yes	Yes	3m x 3m	Yes	Yes	2020-01-AB

4 ARR2019 Update

4.1 Overview

In 2019 a new edition of ARR was released. There were specific changes to the methodology for development of accurate estimates of flood behaviour. These include:

> **Rainfall** – the Bureau of Meteorology re-analysed all the Intensity-Frequency-Duration (IFD) data across Australia, incorporating 30 further years of data and many more rainfall stations. The method of derivation also changed, meaning the previously used IFD coefficients are no longer valid;

> **Design Storms** – ARR 2019 recommends the utilisation of an ensemble of design storm burst temporal patterns, with ten patterns for each Annual Exceedance Probability (AEP) and burst duration;

> **Storm Losses**– ARR 2019 recommends the use of initial and continuing storm loss rates, and no longer recommends the use of runoff coefficients for hydrological modelling. In NSW the ARR Data Hub provides guidance on both the rural storm loss rates as well as rural burst initial losses as a function of AEP and burst duration, which differ from the burst losses recommended in ARR1987; and

> **Storm Losses in Urban Areas** – ARR 2019 provides for the use of three types of area when assessing loss rates in urban areas - directly connected impervious areas, indirectly connected areas and pervious areas. The document also provides guidance as to the calculation of these areas.

4.2 Model Inputs

4.2.1 Rainfall

Rainfall data for the Hornsby LGA were downloaded from ARR DataHub. The rainfall data included 10 temporal patterns and durations from 25 minutes to 120 minutes. An example of the temporal patterns for the 1%AEP 60 minute storm burst is given in **Table 4-1**.

Table 4-1 ARR2019 Temporal Patterns for 1% AEP 60 minute storm burst (Source: ARR DataHub, Accessed: 3/06/2020)

	Temporal Pattern									
Time (hr)	TP01	TP02	TP03	TP04	TP05	TP06	TP07	TP08	TP09	TP10
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.08	5.26	6.29	4.16	5.92	4.63	2.49	1.70	2.68	6.67	3.38
0.17	9.47	3.55	7.09	8.29	4.26	3.93	8.49	3.56	5.39	3.95
0.25	12.60	3.38	1.09	7.47	10.42	4.28	4.68	5.45	5.11	1.41
0.33	12.89	8.94	3.90	6.17	10.96	4.64	6.80	5.90	5.54	1.41
0.42	5.16	3.54	3.31	4.62	6.36	5.36	3.82	4.01	6.11	2.54
0.50	0.68	4.67	3.85	6.52	2.53	7.14	7.22	4.68	6.96	2.54
0.58	0.69	9.10	3.00	4.74	3.93	8.21	2.97	5.79	4.68	5.92
0.67	4.15	3.06	2.56	6.40	4.00	7.85	7.65	8.23	4.26	10.99
0.75	4.36	3.38	8.69	3.32	3.43	7.85	4.68	7.35	5.11	9.59
0.83	2.50	8.13	8.83	2.14	3.22	3.57	4.68	4.90	4.26	7.89
0.92	1.33	3.22	8.05	2.25	4.27	3.22	5.10	4.78	3.69	4.23
1.00	1.24	3.06	5.79	2.49	2.32	1.79	2.55	3.00	2.56	6.49
1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.2.2 Rainfall Losses

The methodology for determining the rainfall losses based on ARR2019 guidance was as followed:

Step 1: The rural pervious losses were downloaded from the ARR DataHub. The Probability Neutral Burst Initial Loss (PNBIL) were adopted for rural and urban pervious catchments which circumvented the need to identify preburst rainfall. An example of the PNBIL for Pennant Hills model is shown in **Table 4-2.**

Table 4-2 The Probability Neutral Burst Initial Losses extracted for Pennant Hills (Source: ARR Data Hub Accessed 30/06/2020)

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	16.7	10.3	10.7	11.5	12.3	9.7
90 (1.5)	19.4	12.3	12.4	13.1	12.3	10.2
120 (2.0)	19.6	12.9	12.8	12.9	12.9	10.0
180 (3.0)	19.2	13.9	14.1	14.1	12.9	7.3
360 (6.0)	18.6	12.9	12.8	11.0	11.1	5.7
720 (12.0)	24.0	17.5	16.4	14.4	14.5	4.3
1080 (18.0)	26.5	19.6	17.8	15.3	16.6	4.4
1440 (24.0)	30.6	23.4	21.9	19.4	18.9	7.6
2160 (36.0)	33.2	26.7	25.2	23.5	22.5	7.7
2880 (48.0)	36.9	30.4	29.3	31.2	24.8	10.6
4320 (72.0)	40.2	35.4	34.8	37.5	25.1	11.7

Step 2: As per ARR2019 Guideline advice (Section 3.5.3 of Book 5) the urban pervious and impervious areas were further segregated into the following three (3) categories:

> Urban Effective Impervious Areas (EIA)

> Urban Indirectly Connected Areas (ICA)

> Urban Pervious (Parks, Ovals, Open Space corridors, etc.)

Step 3: All the adopted areas of the various surface types were calculated through GIS analysis of the Hornsby LEP Zones and Nearmap aerial images. Based on the PNBIL losses, new weighted initial losses and continuing rainfall losses were calculated for each urban catchment.

The calculated weighted storm losses for each Hornsby model are given in **Table B1 (**see **Appendix B).**

4.3 Mean Burst Temporal Patterns

As a part of the pilot study, the updated Pennant Hills Tuflow model all 10 temporal patterns for 1% AEP and 20% AEP for burst durations from 30 mins to 120 mins were run using the "Rain on Grid" method. These Results were then analysed to identify the mean burst temporal patterns for each burst duration.

The mean temporal patterns identified for each flood event and burst duration are shown in Table **4-3**. These burst temporal patterns were also applied as the mean burst temporal patterns for the other seven overland flow flood models.

4.4 Critical Burst Durations

All the models were run for the identified mean burst temporal patterns for the 30 minutes, 45 minutes, 60 minutes, 90 minutes and 120 minutes 1% AEP and 20% AEP storm bursts depending on the size of catchments. The resultant flood levels were compared to identify the critical duration for each catchment with specific considerations for the urban areas. Plots showing the critical durations for each of the models are presented in **Figures C1** to **C16** (refer **Appendix C**).

A summary of the critical burst durations identified for each of the models is given in **0**.

Table 4-3 20% AEP and 1% AEP Mean Burst Temporal Patterns identified in the Pennant Hills Pilot Study

Event	Burst Duration	Mean Temporal Pattern
1% AEP	30 mins	T09
1% AEP	45 mins	T09
1% AEP	60 mins	T08
1% AEP	90 mins	T01
1% AEP	120 mins	T10
20% AEP	30 mins	T06
20% AEP	45 mins	T08
20% AEP	60 mins	T08
20% AEP	90 mins	T05
20% AEP	120 mins	T04

Table 4-4 Comparison of the 20% AEP and 1% AEP Critical Storm Burst Durations for the 2015 and 2020 Studies

Model	Event	ARR2019 Critical Burst Durations	2015 FRMSP Critical Burst Duration
Asquith	1% AEP	30 mins	1 Hour
	20% AEP	30 mins	1 Hour
Beecroft	1% AEP	30 mins	2 Hours
	20% AEP	30 mins	2 Hours
Berowra	1% AEP	30 mins	1 Hour
	20% AEP	30 mins	1 Hour
Brooklyn	1% AEP	30 mins	1 Hour
	20% AEP	60 mins	1 Hour
Cowan	1% AEP	30 mins	1 Hour
	20% AEP	30 mins	1 Hour
Galston	1% AEP	30 mins	1 Hour
	20% AEP	60 mins	1 Hour
Glenorie	1% AEP	90 mins	1 Hour
	20% AEP	90 mins	1 Hour
Pennant Hills	1% AEP	30 mins	1 Hour
	20% AEP	45 mins	1 Hour

5 Climate Change

In 2015 the Hornsby overland flow flood models were run for 10%, 20% and 30% increase in rainfall to quantify the potential impacts of climate change.

A feature of the ARR DataHub is the guidance provided on the Interim Climate Change Factors. The guideline values for the Hornsby LGA obtained from ARR2019 are shown in **Table 5-1**. ARR2019 further recommends that consideration be given to the RCP 4.5 and RCP 8.5 scenarios.

As disclosed in Table 5-1 the highest increase in rainfall (19.7%) is associated with RCP 8.5 in 2090. After discussions with Council, it was decided to adopt the following climate change scenarios for the 2020 update assessments:

> 2090 RCP 4.5 and 2050 RCP 8.5 (rounded up to 10%)

> 2090 RCP 8.5 (rounded up to 20%)

Table 5-1 Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	0.869 (4.3%)	0.783 (3.9%)	0.983 (4.9%)
2040	1.057 (5.3%)	1.014 (5.1%)	1.349 (6.8%)
2050	1.272 (6.4%)	1.236 (6.2%)	1.773 (9.0%)
2060	1.488 (7.5%)	1.458 (7.4%)	2.237 (11.5%)
2070	1.676 (8.5%)	1.691 (8.6%)	2.722 (14.2%)
2080	1.810 (9.2%)	1.944 (9.9%)	3.209 (16.9%)
2090	1.862 (9.5%)	2.227 (11.5%)	3.679 (19.7%)

The climate change scenarios were only run for the 1% AEP event and the identified critical burst durations for each model.

6 Results

All eight upgraded TUFLOW models were run for the 1% AEP, 20% AEP and 1% AEP Climate Change scenarios.

Plots showing the differences between 1% AEP and 20% AEP flood levels estimated in this study and the 1% AEP and 20% AEP flood levels reported in 2015 are given in **Figures D1** to **D16** (refer **Appendix D**).

Discussions on the results for each of the models are presented in the following sections:

6.1 Asquith

Figures D1 and **D9** plot the 20% AEP and 1% AEP flood level differences, respectively. The plots show that the upgraded models generally have lower flood levels along the main streams with up to 1 m reductions in flood levels. Increases in flood levels are observed in some urban areas which are a result of higher ground levels (from the 2019 Lidar) at these locations.

It should be noted that an increase in flood level does not necessarily mean that the flood depth or flood extent has changed or increased. A review the 20% AEP and 1% AEP flood extents (with a 0.15 m depth filter applied) reveals that in most locations the flood extents resulting from the upgraded models are either similar or less than the 2015 flood extents.

6.2 Beecroft

Figures D2 and **D10** plot the 20% AEP and 1% AEP flood level differences, respectively .

The plots show that the upgraded model has generally lower the 20% AEP and 1% AEP flood levels. Any local increase in flood levels are a result of higher ground levels (from the 2019 Lidar) at these locations.

6.3 Berowra

Figures D3 and **D11** plot the 20% AEP and 1% AEP flood level differences, respectively.

The plots show that the upgraded models have lower flood levels within the Berowra model extent with up to a 2 m reduction in design flood levels in downstream areas. These reductions in flood levels are generally reflect differences between the ground levels in the 2015 and 2019 LiDAR data.

6.4 Brooklyn

Figures D4 and **D12** plot the 20% AEP and 1% AEP flood level differences, respectively.

The plots show both increases and decreases in flood levels within the urban areas. A comparison of the flood level difference plots and the terrain difference plots (see **Figure A4, Appendix A**) reveal that the changes in flood levels are consistent with the changes in the ground levels.

It should be noted that an increase in flood level does not necessarily mean that the flood depth or flood extent has changed or increased. A review the 20% AEP and 1% AEP flood extents (with a 0.15 m depth filter applied) reveals that in most locations the flood extents resulting from the upgraded models are less than the 2015 flood extents.

6.5 Cowan

Figures D5 and **D13** plot the 20% AEP and 1% AEP flood level differences, respectively.

The plots show that the upgraded models have lower flood levels within the Cowan model extent with up to a 1 m reduction in flood levels. The reductions in flood levels are generally in line with differences in LiDAR data between the 2015 and 2020 models. The updated design storm data from ARR2019 is also a contributing factor.

6.6 Galston

Figures D6 and **D14** plot the 20% AEP and 1% AEP flood level differences, respectively.

The plots show that the upgraded model has generally lower 20% AEP flood levels. The general trends in the 1% AEP flood levels is a decrease in the flood levels. Increases in flood levels at the upper reaches of Colah Creek are a result of an adjustment of the catchment boundary in the upgraded model.

6.7 Glenorie

Figures D7 and **D15** plot the 20% AEP and 1% AEP flood level differences, respectively.

The plots show that the upgraded model has generally lower 20% AEP flood levels. 1% AEP flood levels also show a general trend of decease in flood levels with some local increases which are consistent with the differences in the ground levels between the 2015 and 2020 models.

6.8 Pennant Hills

Figures D8 and **D16** plot the 20% AEP and 1% AEP flood level differences, respectively.

The plots show that the upgraded model has generally lower 20% AEP flood levels. 1% AEP flood levels also show a general trend of decease in flood levels with some local increases which are consistent with the differences in the ground levels between the 2015 and 2020 models.

7 Conclusions

In 2020 Hornsby Shire Council commissioned Cardno to update and finalise the Hornsby Floodplain Risk Management Study and Plan based on the latest Australian Rainfall and Runoff 2019 (ARR2019) guidance and data, and the latest Light Detection and Ranging (LiDAR) topographical data.

As a part of update to the Floodplain Risk Management Study (FRMS) a pilot study was undertaken in August 2020 to evaluate the changes in flood behaviour arising from updated data and guidance provided by the ARR2019 guidelines and to make a recommendation on the adoption of either the 1987 or 2019 editions of Australian Rainfall and Runoff for final model runs and options assessment.

The Pennant Hills catchment was selected by Council for the pilot study as it covers a significant portion of the urban area and has sufficient variability to enable reasonable extrapolation of the study outcomes to the other urban catchments across the LGA.

Based on the outcomes of the pilot study, Council decided to adopt ARR2019 data and guidance when upgrading the eight overland flow flood models for Asquith, Beecroft, Berowra, Brooklyn, Cowan, Galston, Glenorie and Pennant Hills.

All eight upgraded TUFLOW models were run for the 1% AEP, 20% AEP and 1% AEP Climate Change scenarios.

A comparison of the 2015 and 2020 flood levels for all the overland flow flood models disclosed that the 2020 models generally give lower 20% AEP and 1% AEP flood levels with the exception of some local increases which are attributed to differences between the 2015 and 2020 ground levels. The decreased design flood levels are a results of the following factors:

> Differences between the 2015 and 2020 model terrains;

> Finer cell sizes in the 2020 models which provides a greater definition of overland flowpaths particularly for smaller flowpaths;

> Differences between ARR1987 and ARR2019 design storms and in particular the differences between the 1987 storm burst temporal pattern and the 2019 ensemble of design storm burst temporal patterns (refer **Appendix B**); noting that

> Reductions in design flows between ARR1987 and ARR2019 peak flow estimates have been also reported elsewhere across the Sydney metropolitan area ie. the findings of these assessments align with recent studies elsewhere in Sydney.

It is proposed that the upgraded 2020 overland flow flood models be adopted for the purpose of updating the Hornsby Floodplain Risk Management Study and Plan.

8 References

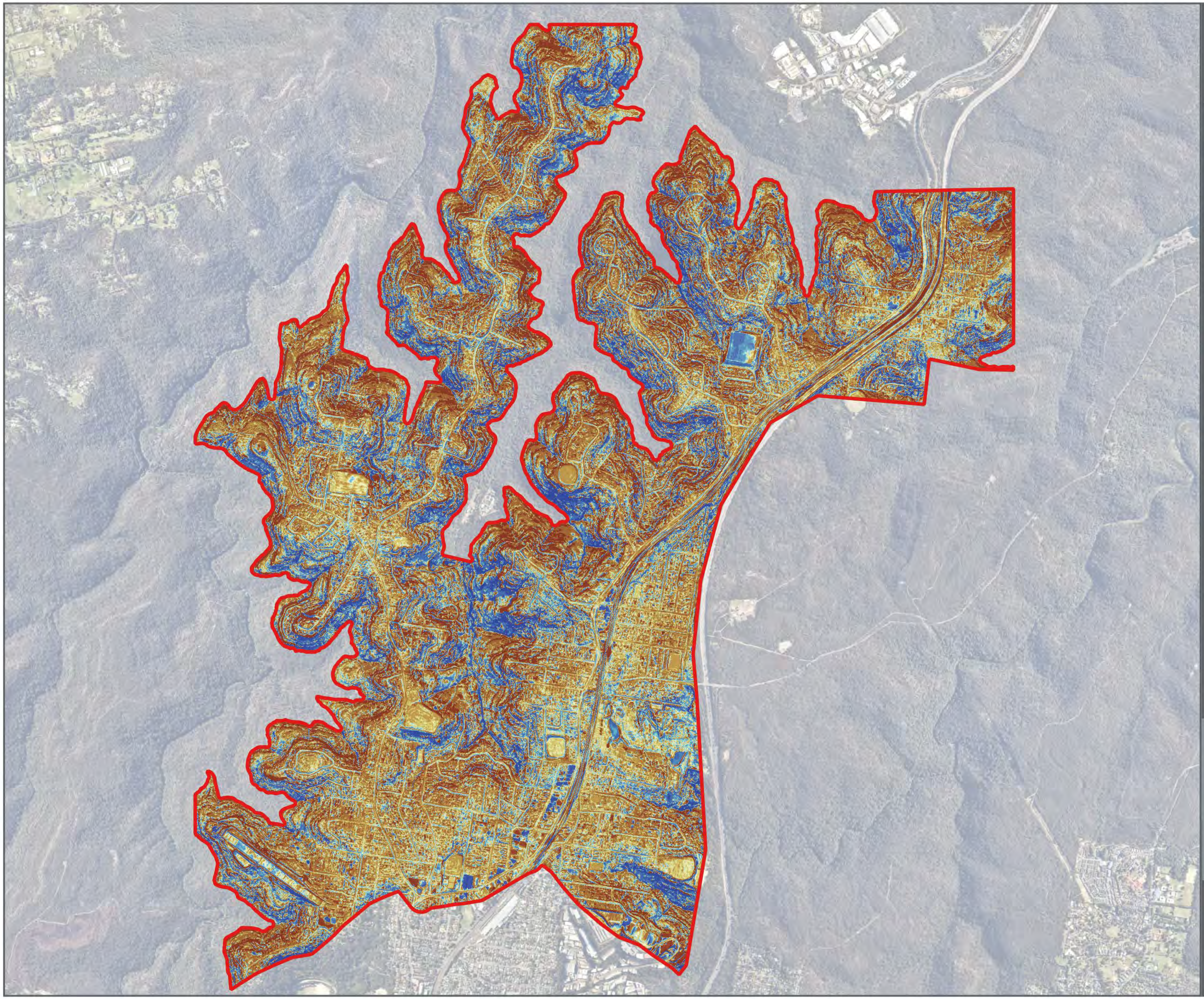
Cardno (2015) “Hornsby Floodplain Risk Management Study and Plan, *Draft for Exhibition*, Version 4, prepared for Hornsby Shire Council, December, 59 pp + Apps. (Cardno 2015)

Cardno (2020) “Pennant Hills Catchment ARR 2019 Pilot Study’, *Discussion Paper*, prepared for Hornsby Shire Council, August, 10 pp + Figs. (Cardno 2020)

APPENDIX

A

LIDAR COMPARISONS



HORNSBY SHIRE COUNCIL

Asquith Difference Plot Lidar (2019) Less Old Lidar (FRMSP 2015)

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Terrain Difference (m):

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

FIGURE A1

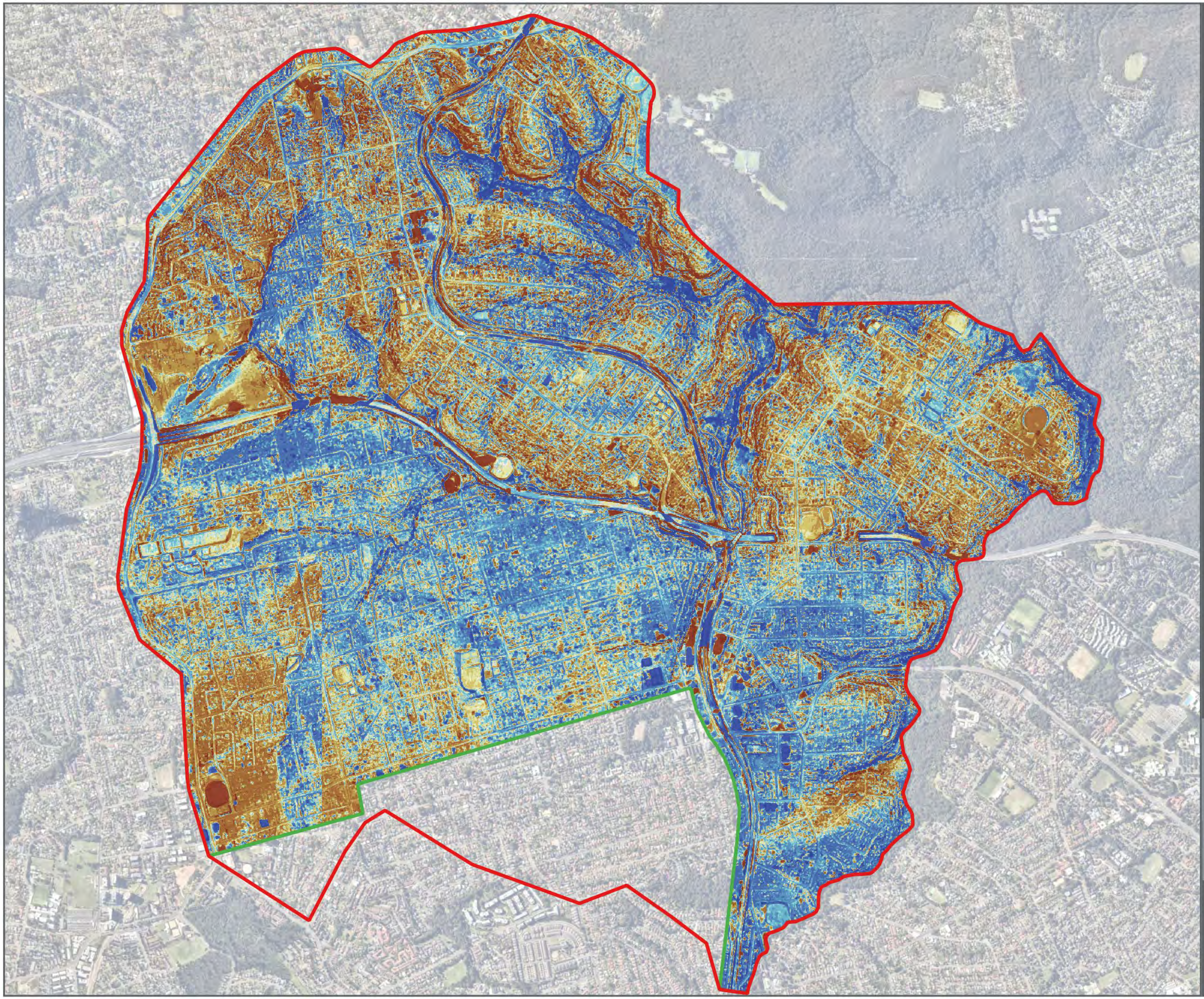
1:24338 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Beecroft Difference Plot Lidar (2019) Less Old Lidar (FRMSP 2015)

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Terrain Difference (m):

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

FIGURE A2

1:19991 Scale at A3

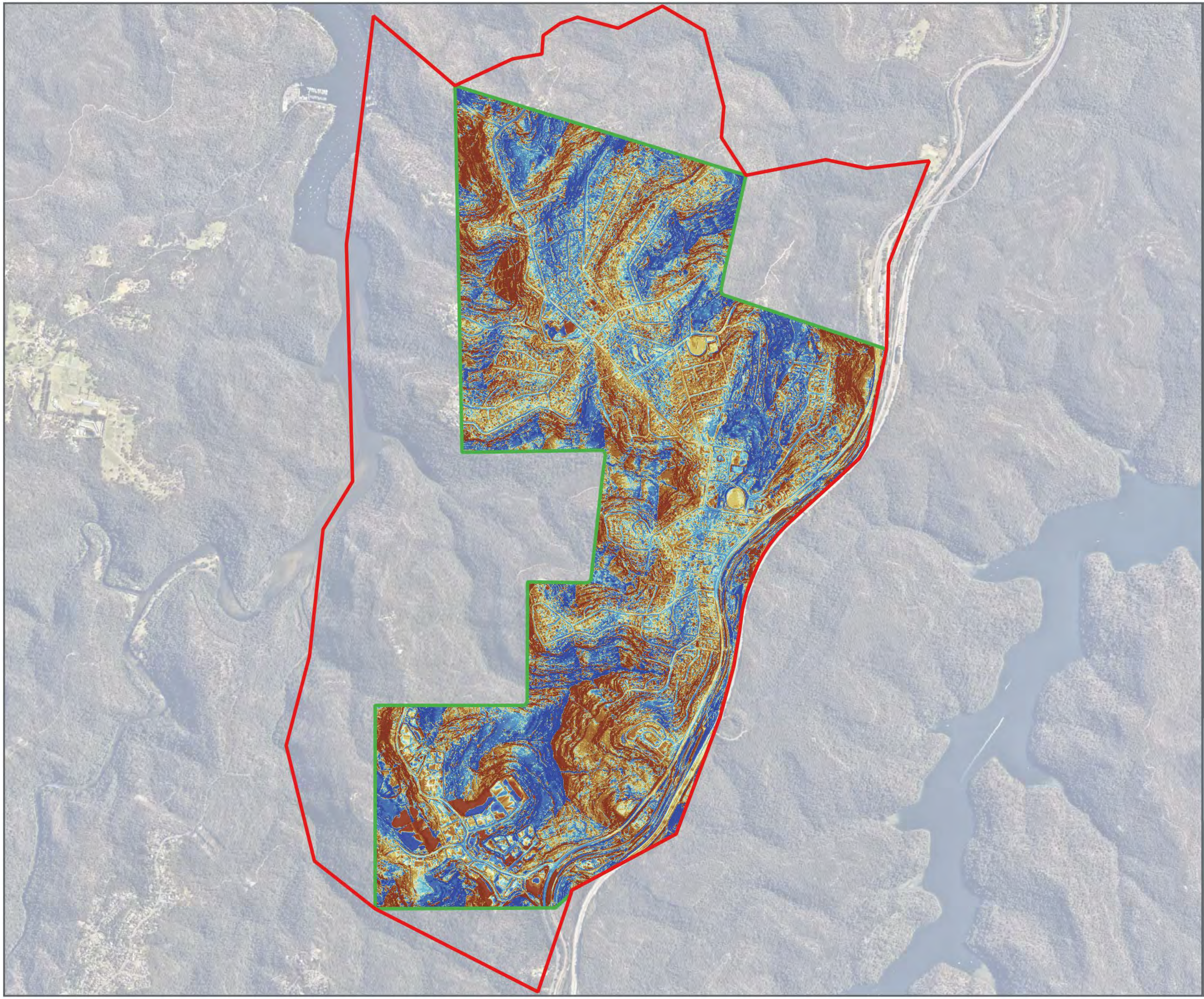
Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Berowra Difference Plot Lidar (2019) Less Old Lidar (FRMSP 2015)

Hornsby Floodplain Risk Management Study and Plan



LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Terrain Difference (m):

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

FIGURE A3

1:23090 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Brooklyn Difference Plot Lidar (2019) Less Old Lidar (FRMSP 2015)

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Terrain Difference (m):

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

FIGURE A4

1:12872 Scale at A3

0 250 500 m

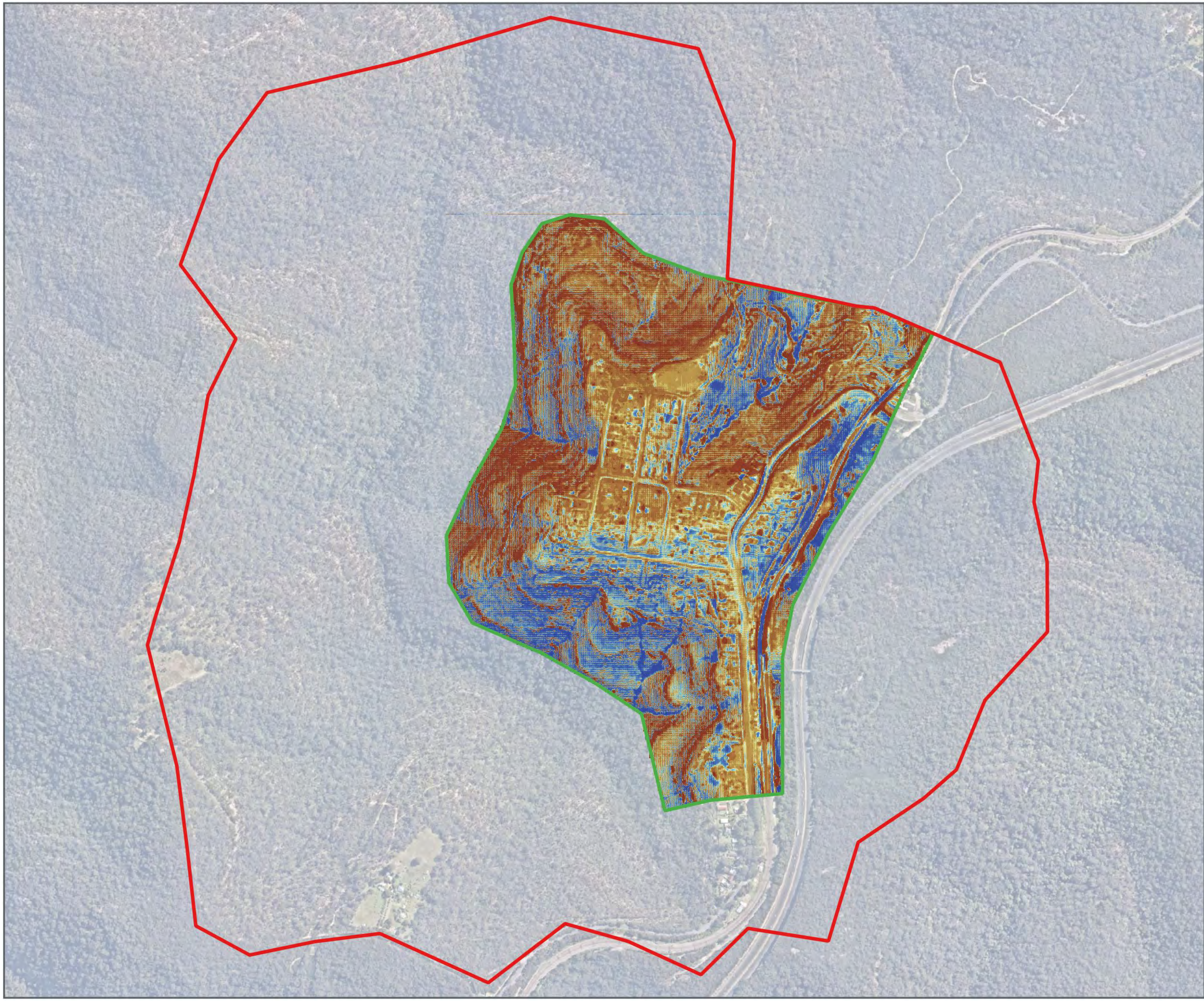
Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Cowan
Difference Plot Lidar (2019) Less Old Lidar (FRMSP 2015)

Hornsby Floodplain Risk Management Study and Plan



LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Terrain Difference (m):

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

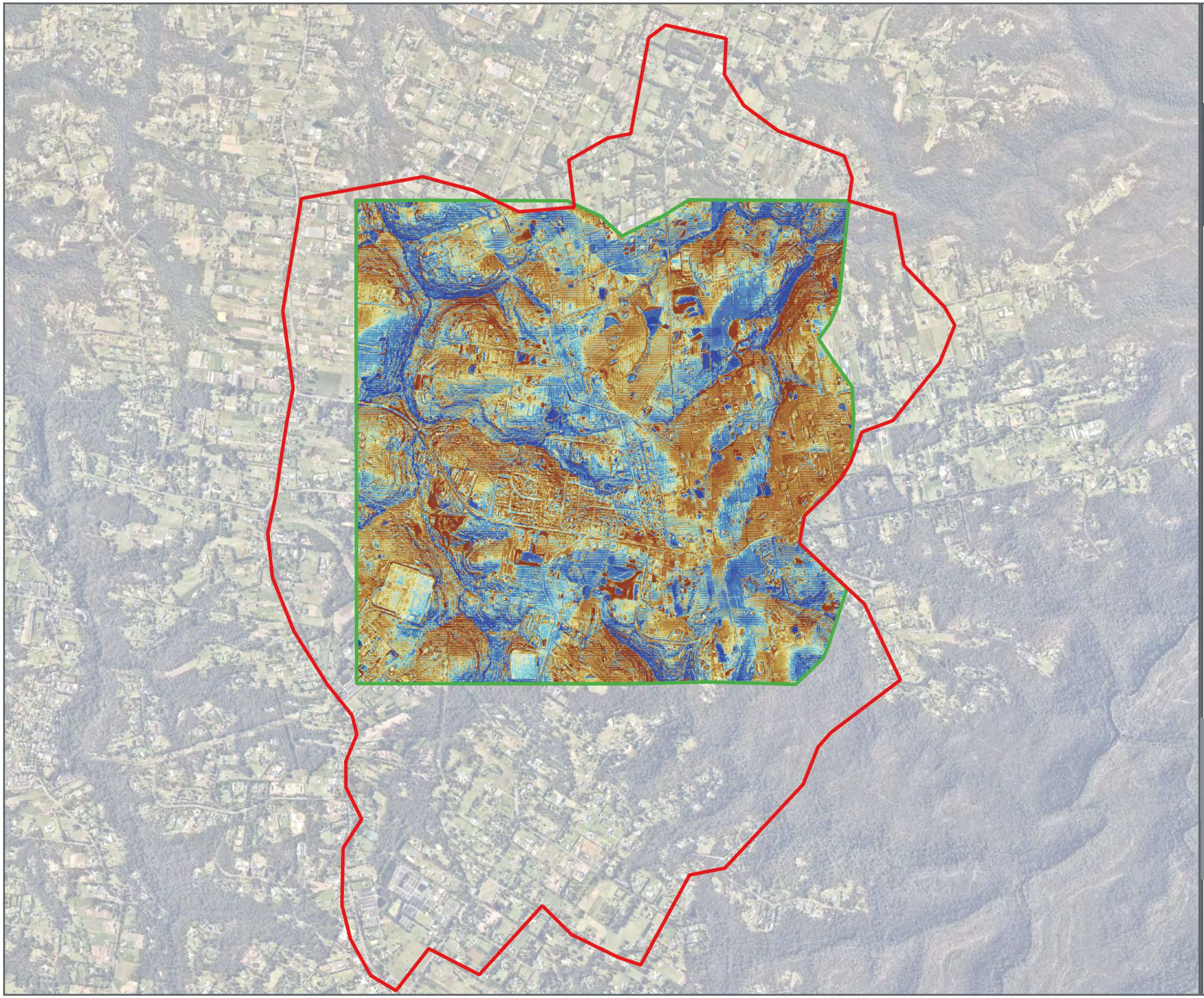
FIGURE A5

1:8850 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Galston Difference Plot Lidar (2019) Less Old Lidar (FRMSP 2015)

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Terrain Difference (m):

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

FIGURE A6

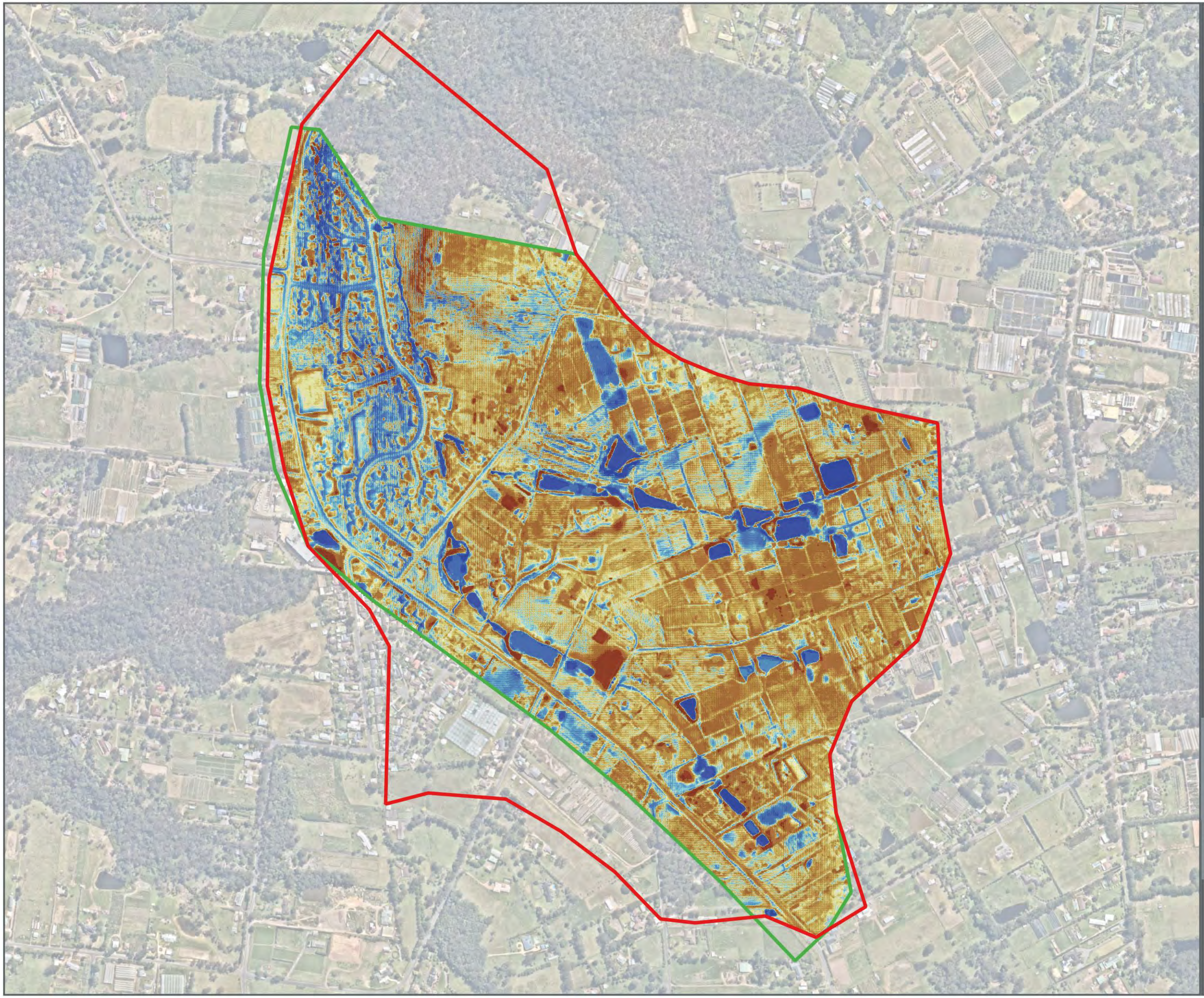
1:23815 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Glenorie Difference Plot Lidar (2019) Less Old Lidar (FRMSP 2015)

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Terrain Difference (m):

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

FIGURE A7

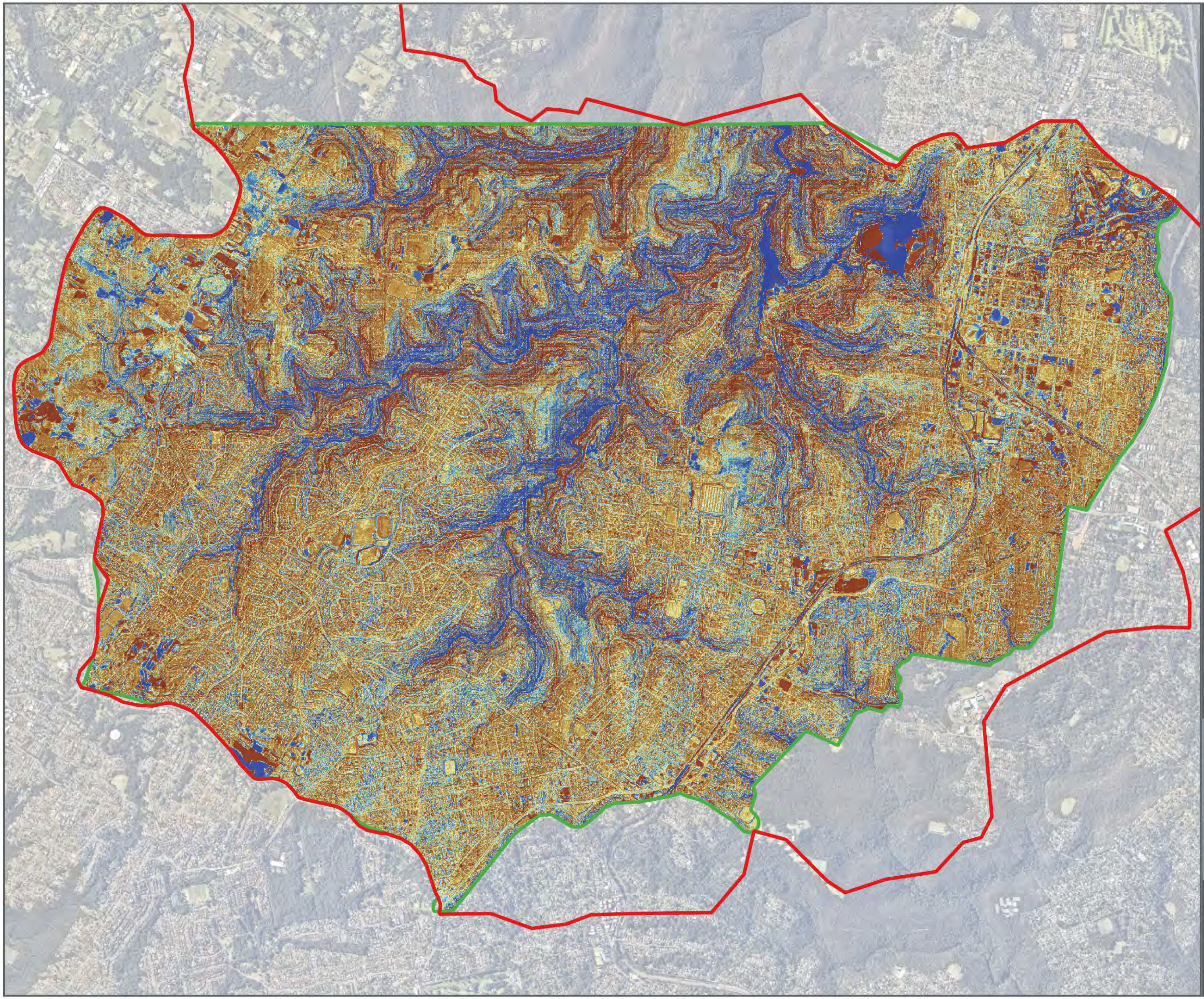
1:8358 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Pennant Hills Difference Plot Lidar (2019) Less Old Lidar (FRMSP 2015)

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Terrain Difference (m):

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

FIGURE A8

1:31102 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

APPENDIX

B

ARR2019 RAINFALL LOSSES

Table B1 Comparisons of Weighted ARR2019 Initial and Continuing Storm Burst Losses and adopted ARR1987 Rainfall Losses in Hornsby FRMSP (2015)

Model	Roughness zone	ARR2019 1% AEP		ARR2019 20% AEP		2015 Rainfall Losses	
		Initial Loss (mm)	Continuing Loss (mm/h)	Initial Loss (mm)	Continuing Loss (mm/h)	Initial Loss (mm)	Continuing Loss (mm/h)
Asquith	Dense Bush	8.9	2.0	12.4	2.0	10	5
	Residential	0.0	1.7	0.0	1.7	5	5
	Commercial	0.0	1.1	0.0	1.1	5	5
	Roads	0.0	0.8	0.0	0.8	0	0
	Industrial	0.0	1.0	0.0	1.0	5	2
	Special uses	0.0	1.5	0.0	1.5	5	5
	Parks and Oval	8.9	2.2	12.4	1.8	10	5
	Default Material	8.9	1.8	12.4	1.8	10	5
Beecroft	Dense Bush	7.5	2.0	9.9	2.0	10	5
	Residential	0.0	1.7	0.0	1.7	5	5
	Commercial	0.0	1.1	0.0	1.1	5	5
	Roads	0.0	0.8	0.0	0.8	0	0
	Industrial	-	-	-	-	-	-
	Special uses	0.0	1.5	0.0	1.5	5	5
	Parks and Oval	7.5	1.8	9.9	1.8	10	5
	Default Material	7.5	1.9	9.9	1.9	10	5
Berowra	Dense Bush	10.6	2.0	15.0	2.0	10	5
	Residential	0.0	1.7	0.0	1.7	10	5
	Commercial	0.0	1.1	0.0	1.1	5	5
	Roads	0.0	0.8	0.0	0.8	0	0
	Industrial	0.0	1.0	0.0	1.0	5	2
	Special uses	0.0	1.8	0.0	1.8	10	5

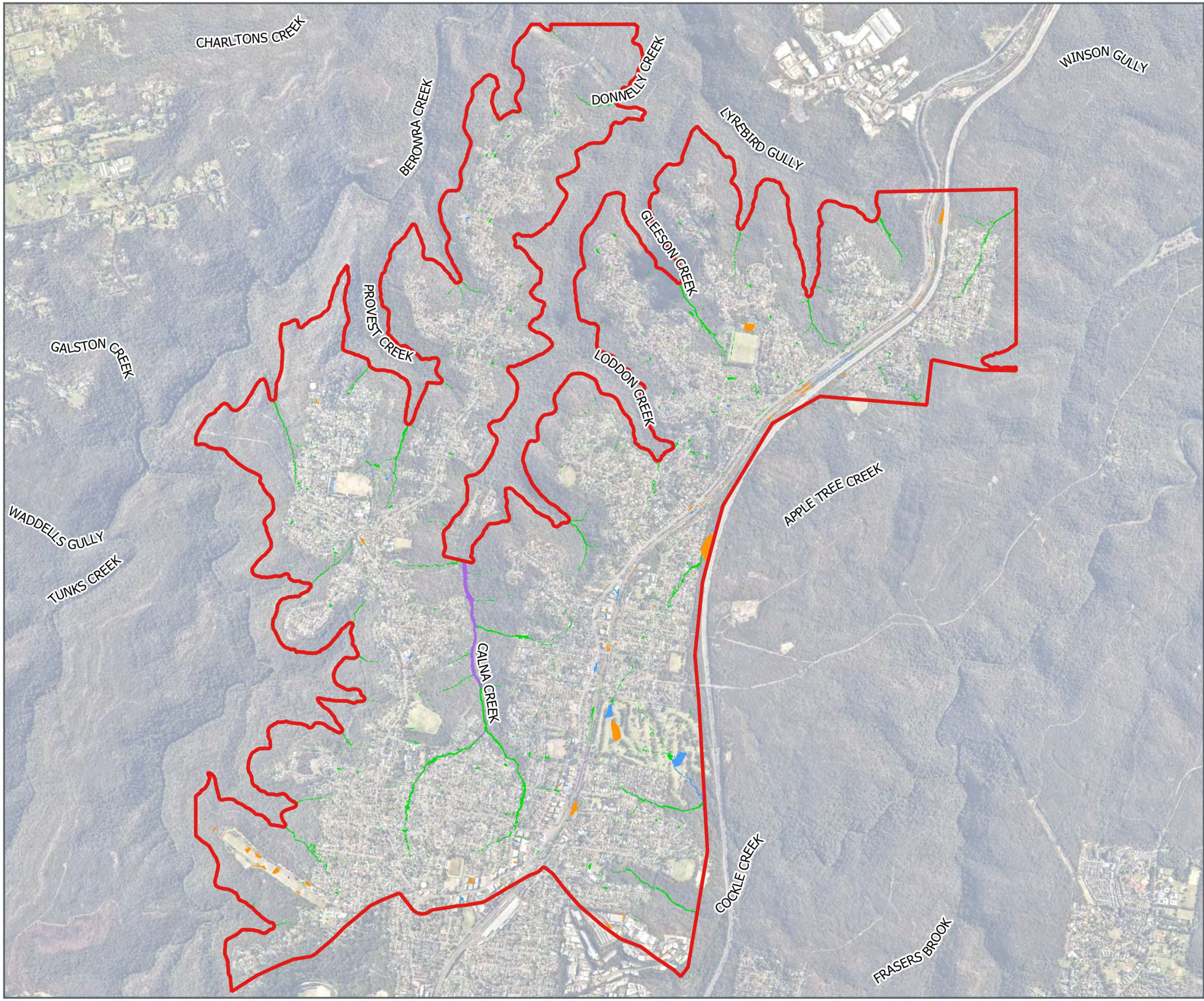
	Parks and Oval	10.6	1.7	15.0	1.7	10	5
	Default Material	10.6	1.9	15.0	1.9	10	5
Brooklyn	Dense Bush	11.2	2.4	16.1	2.4	10	5
	Residential	0.0	1.7	0.0	1.7	5	5
	Commercial	0.0	1.1	0.0	0.0	5	5
	Roads	0.0	0.8	0.0	1.1	0	0
	Industrial	-	-	-	-	-	-
	Special uses / Environmental protection	0.0	1.9	12.9	1.9	5	5
	Parks and Oval	8.9	2.4	16.1	2.4	5	5
	Default Material	11.2	2.4	16.1	2.4	0	0
Cowan	Dense Bush	11.2	2.6	16.1	2.6	10	5
	Residential	0.0	1.7	0.0	1.7	5	5
	Commercial	0.0	1.1	0.0	1.1	5	5
	Roads	0.0	0.8	0.0	0.8	0	0
	Industrial	-	-	-	-	-	-
	Special uses	0.0	1.0	0.0	1.0	5	5
	Parks and Oval	11.2	2.6	16.1	2.6	10	5
	Default Material	0.0	0.0	0.0	0.0	0	0
Galston	Dense Bush	8.9	2.0	12.4	2.0	10	5
	Residential	0.0	1.7	0.0	1.7	5	5
	Commercial	0.0	1.1	0.0	1.1	5	5
	Roads	0.0	0.8	0.0	0.8	0	0
	Industrial	0.0	0.0	0.0	0.0	5	2
	Special uses	4.5	1.4	6.2	1.4	5	5
	Parks and Oval	8.9	2.0	12.4	2.0	10	5
	Default Material	8.0	1.9	11.1	1.9	10	5

Glenorie	Dense Bush	9.1	3.1	14.5	3.1	10	5
	Residential	0.0	1.7	0	1.65	5	5
	Commercial	0.0	1.1	0	1.14	5	5
	Roads	0.0	0.8	0	0.8	0	0
	Industrial	-	-	-	-	-	-
	Special uses	0.0	1.5	0	1.48	5	5
	Parks and Oval	9.1	3.1	14.5	3.1	10	5
	Default Material	8.2	2.9	13.05	2.87	10	5
Pennant Hills	Dense Bush	8.9	2.0	12.4	2.2	10	5
	Residential	0.0	1.7	0.0	1.7	5	5
	Commercial	0.0	1.1	0.0	1.1	5	5
	Roads	0.0	0.8	0.0	0.8	0	0
	Industrial	0.0	1.0	0.0	1.0	5	2
	Special uses	0.0	1.5	0.0	1.5	5	5
	Parks and Oval	8.9	2.2	12.4	2.2	10	5
	Default Material	8.9	1.9	12.4	2.2	0	0

APPENDIX

C

STORM BURST DURATIONS



HORNSBY SHIRE COUNCIL

Asquith 20% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

20% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

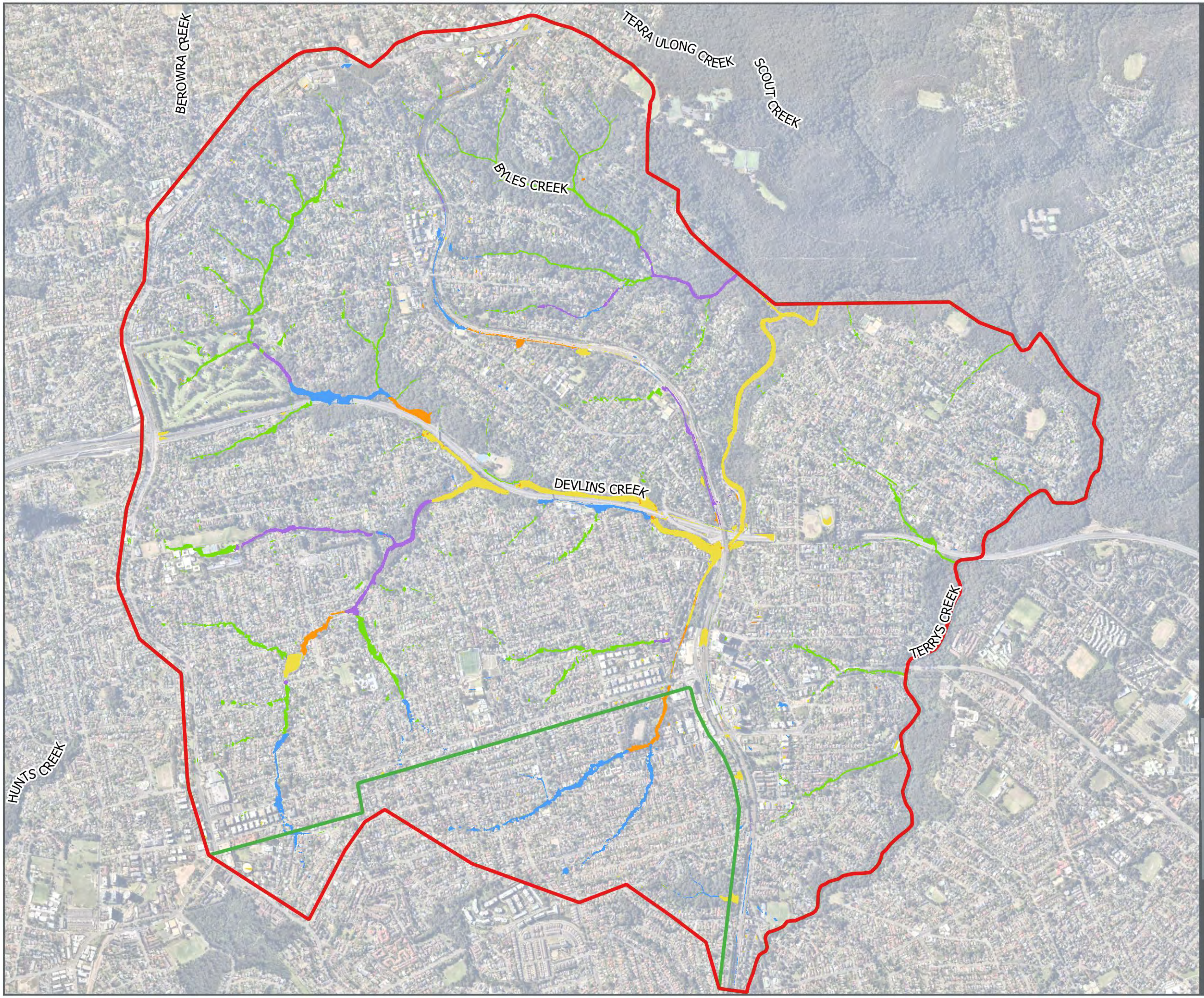
FIGURE C1

1:24338 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Beecroft 20% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

20% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins
- 120 mins

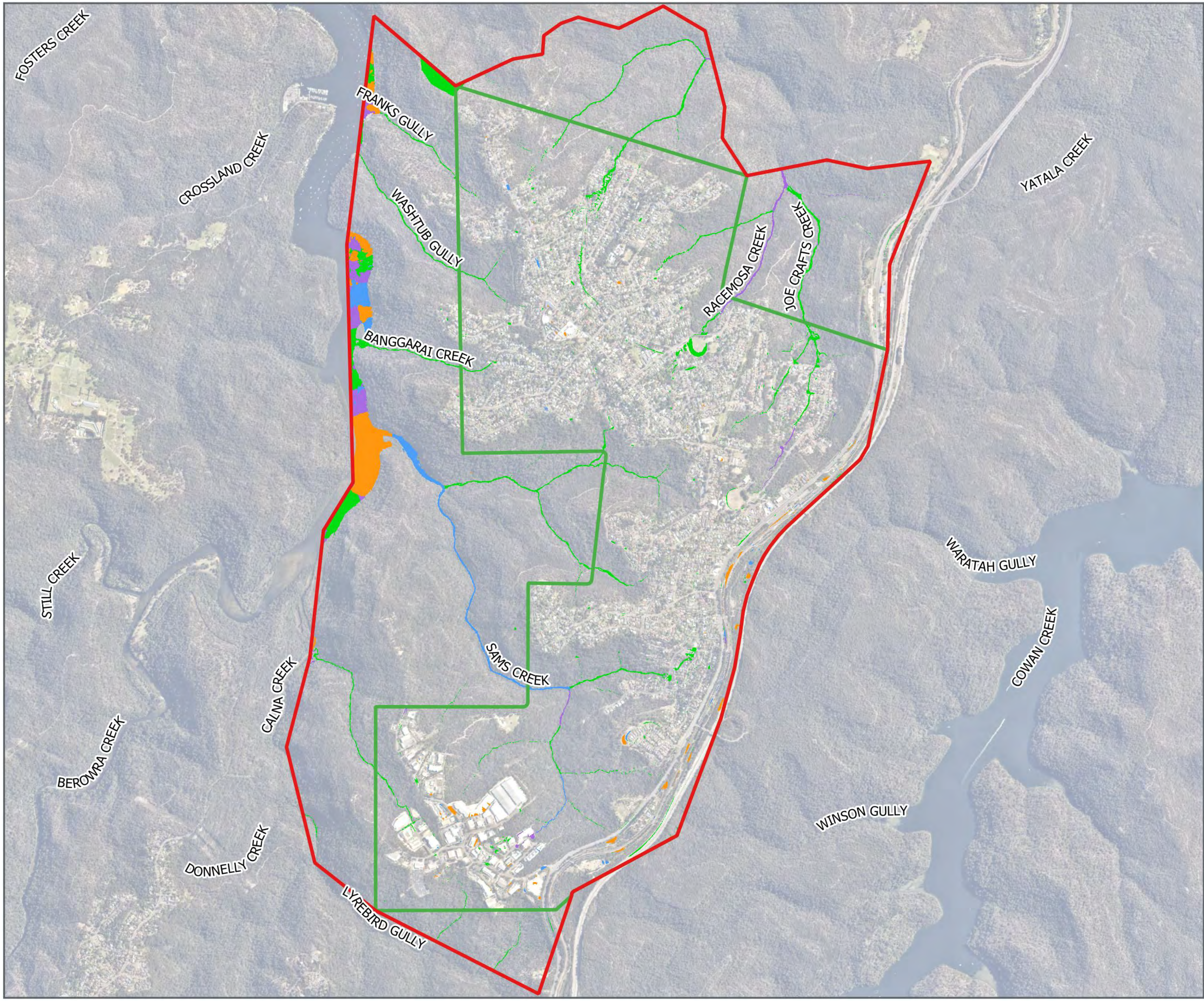
FIGURE C2

1:19991 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Berowra 20% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

20% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

FIGURE C3

1:23090 Scale at A3

0 250 500 m

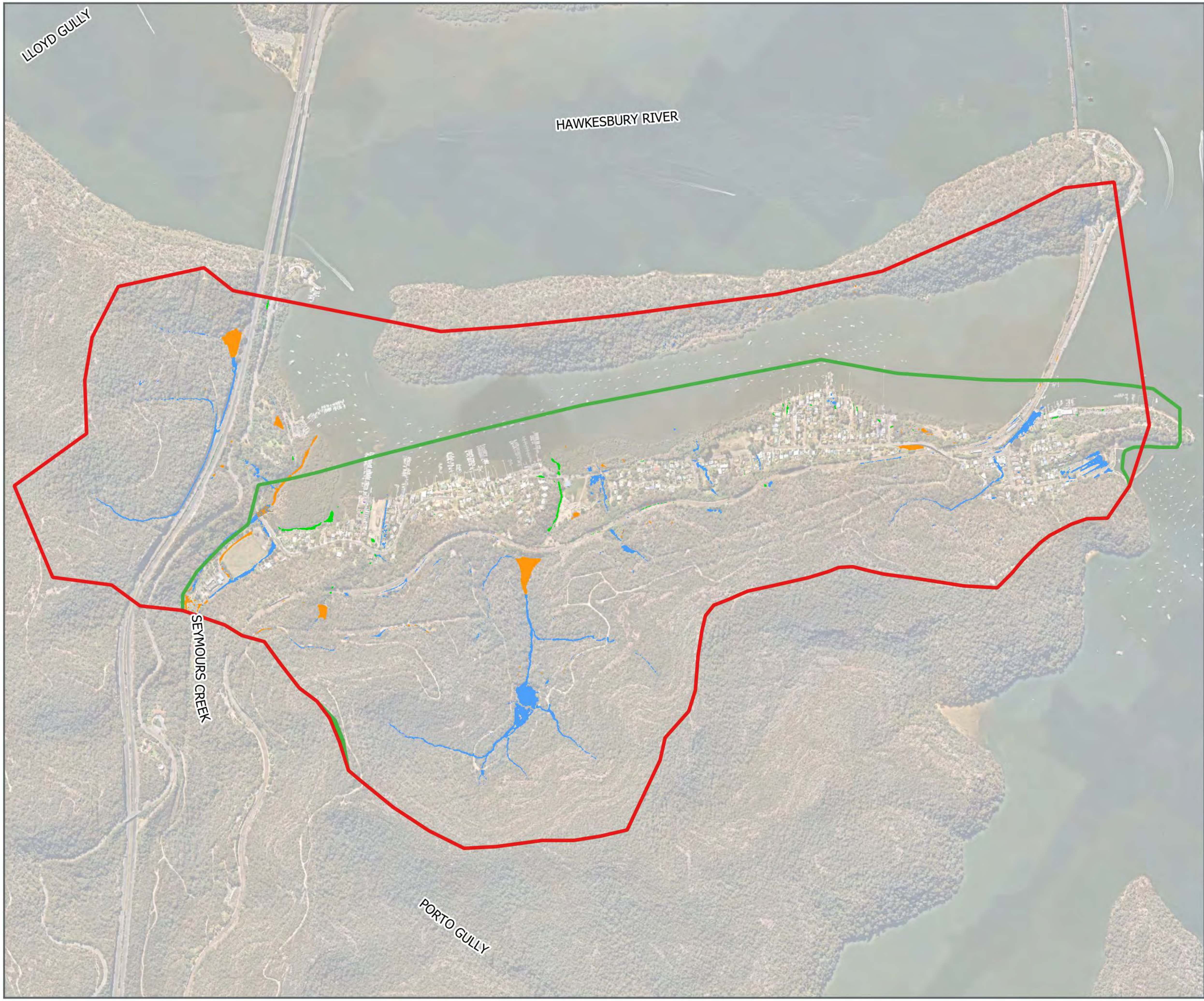
Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Brooklyn
20% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan



LEGEND:

- Previous Model Boundary
- Updated Model Boundary

20% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

FIGURE C4

1:12872 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Cowan
20% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

20% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

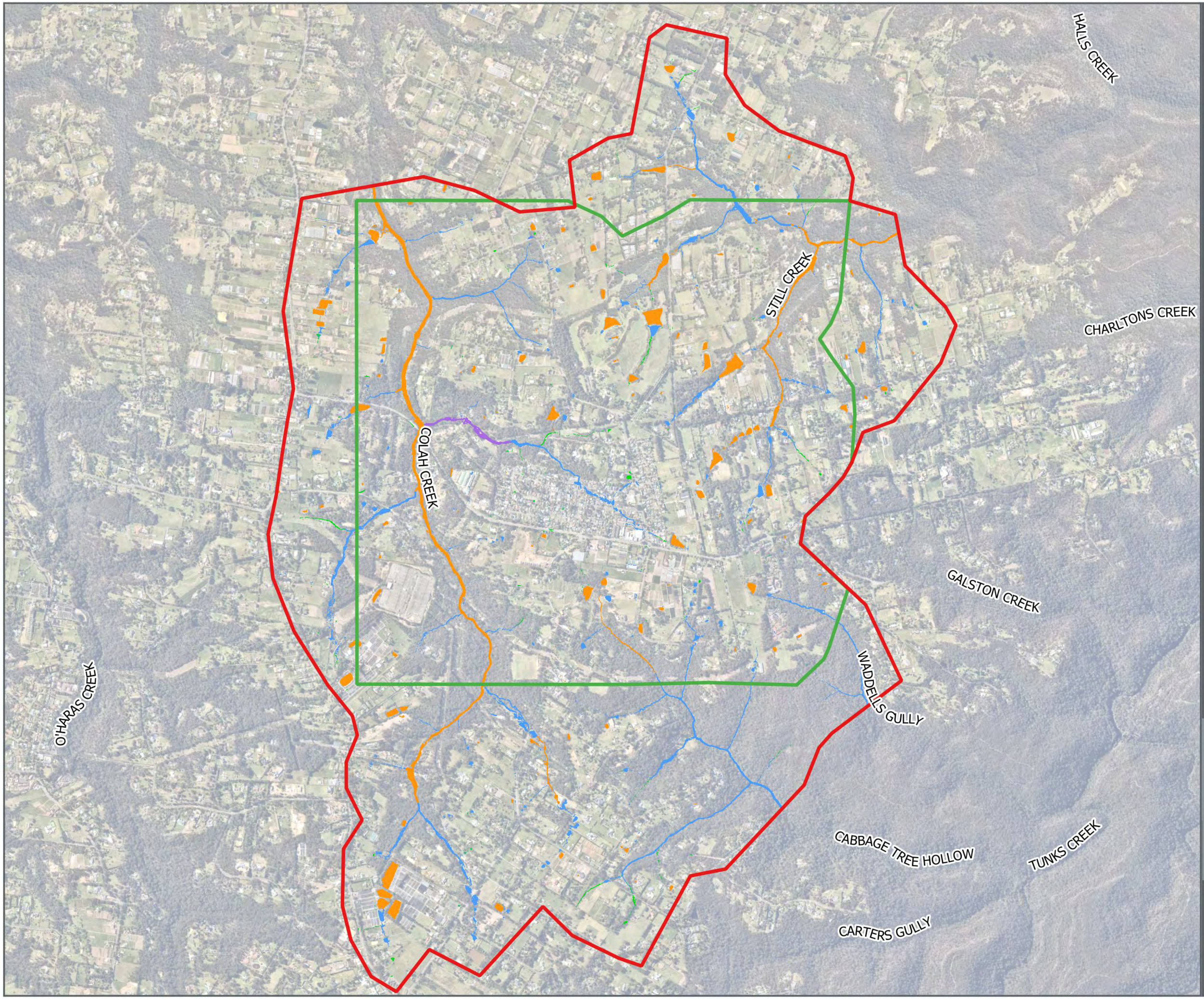
FIGURE C5

1:8850 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Galston
20% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

20% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

FIGURE C6

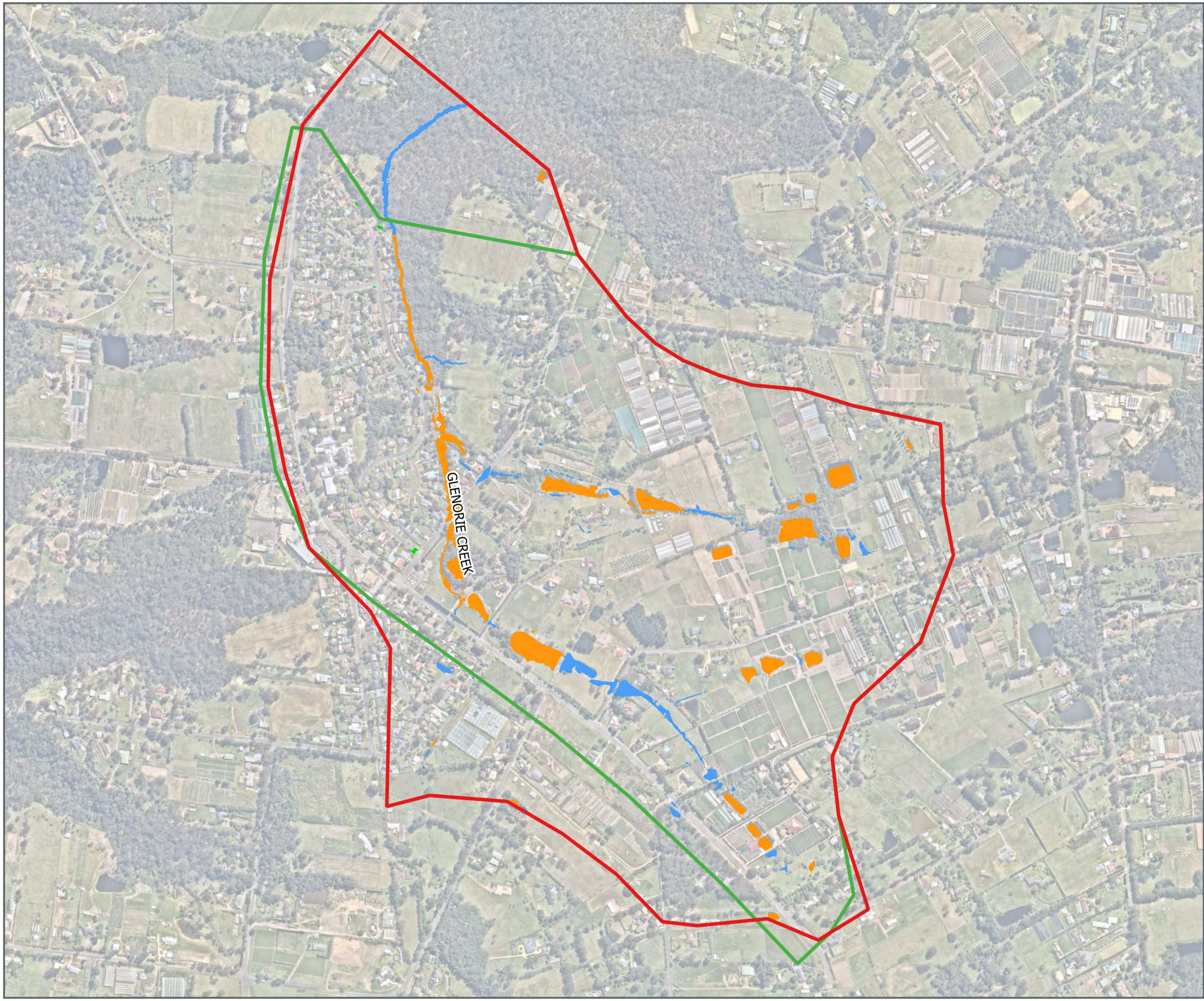
1:23815 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-17| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Glenorie 20% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

20% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

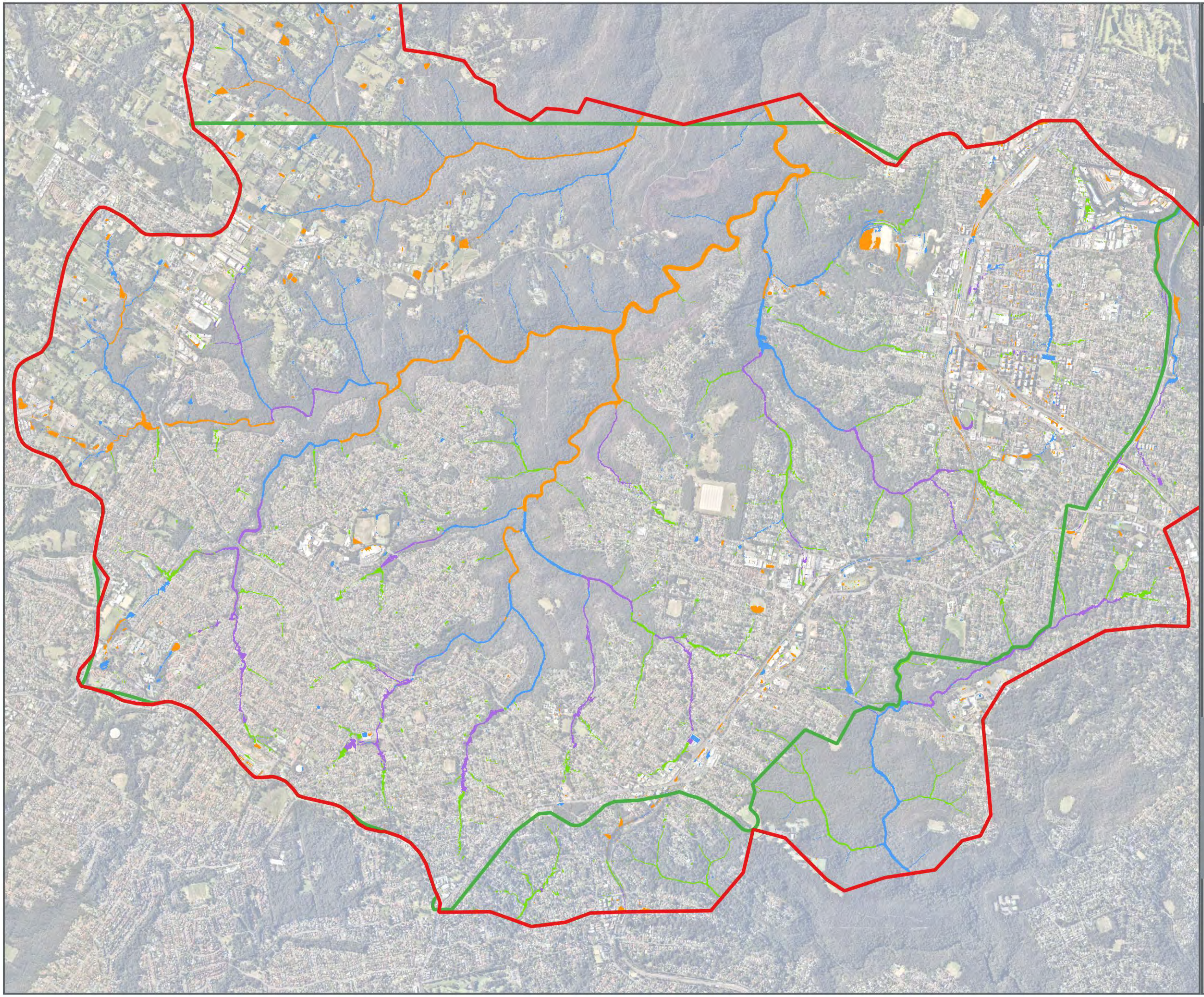
FIGURE C7

1:8358 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Pennant Hills 20% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

20% AEP Critical Duration:

- 25 mins
- 30 mins
- 45 mins
- 60 mins
- 90 mins

FIGURE C8

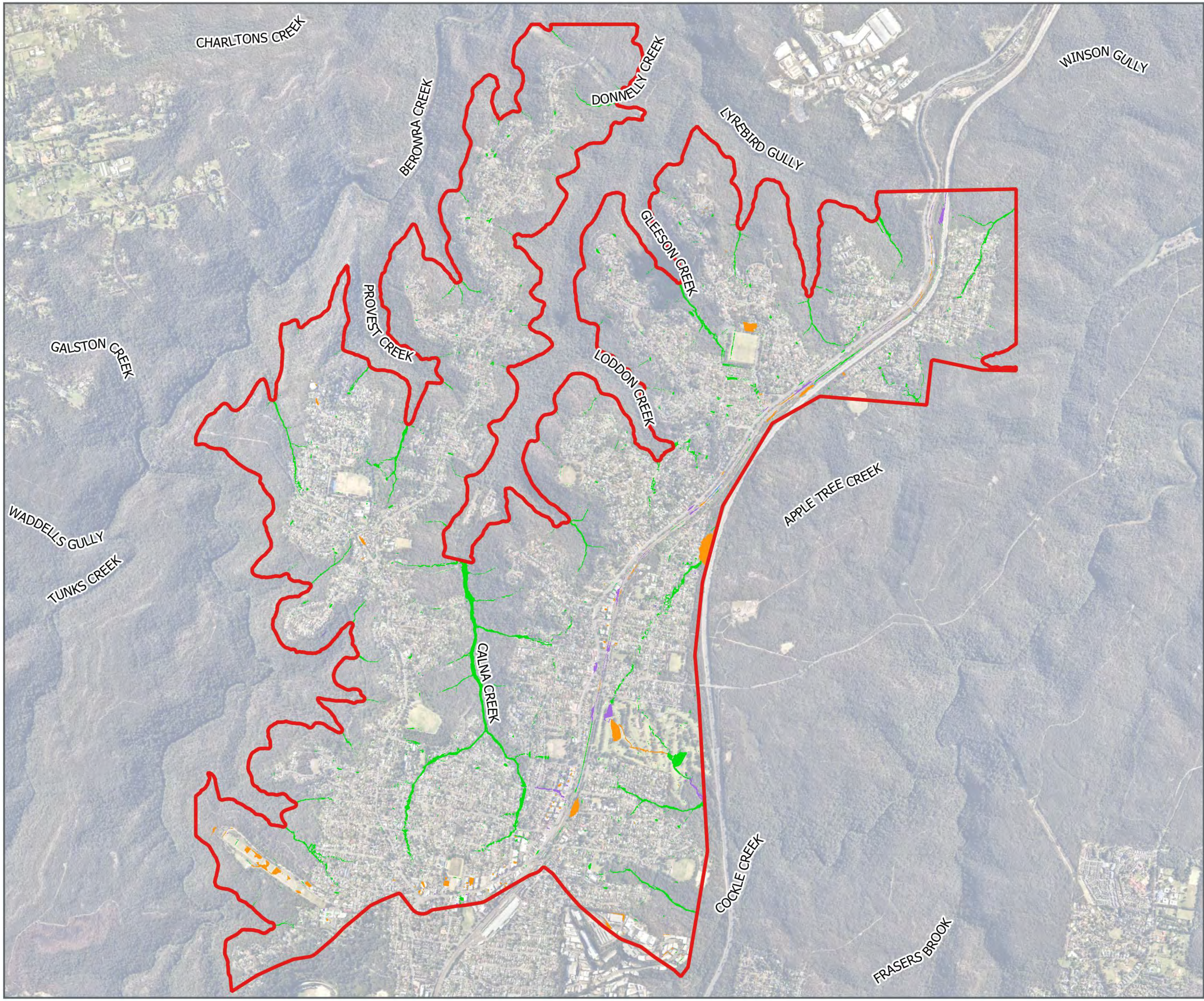
1:31102 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Asquith 1% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

1% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

FIGURE C9

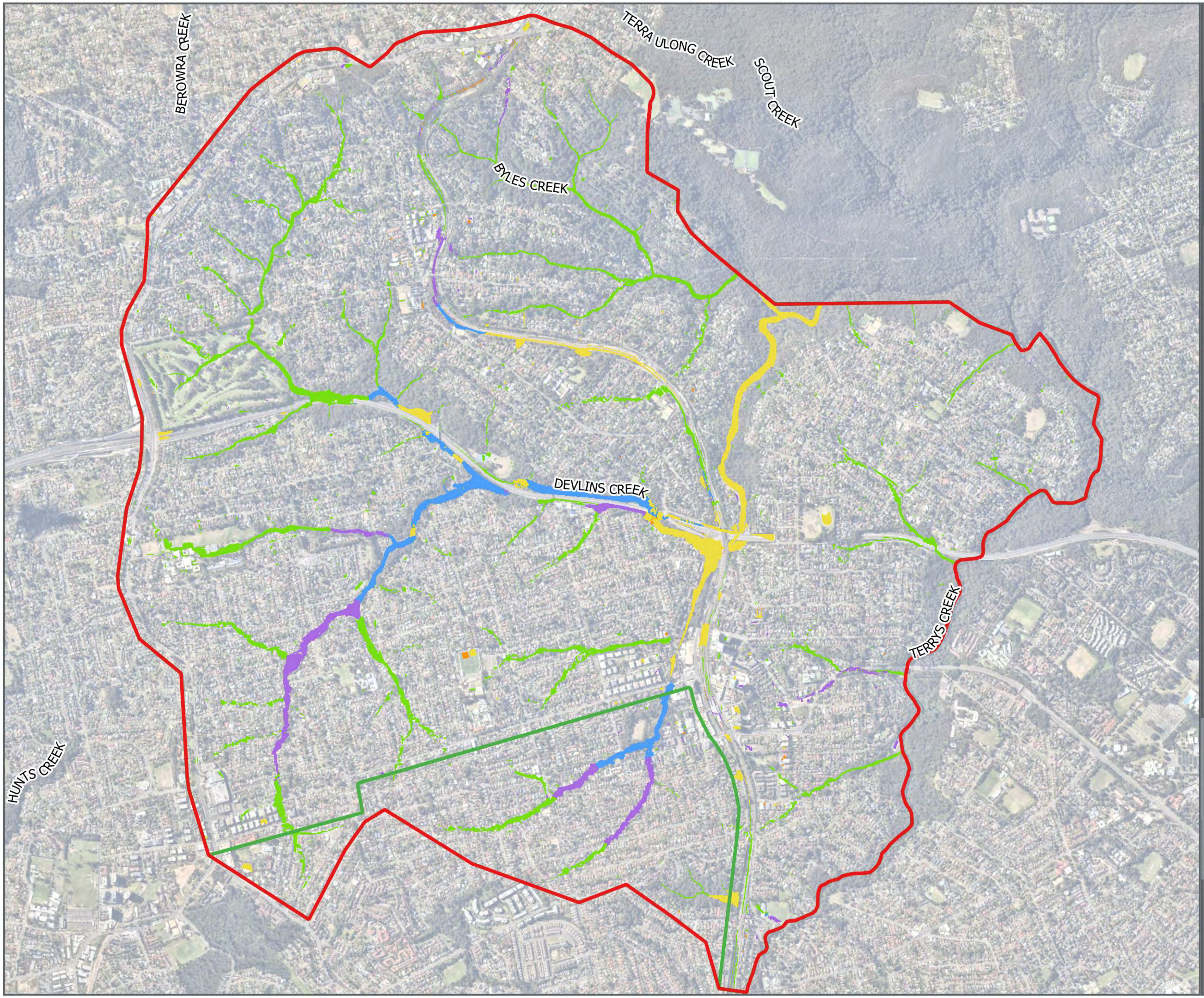
1:24338 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Beecroft 1% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

1% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins
- 120 mins

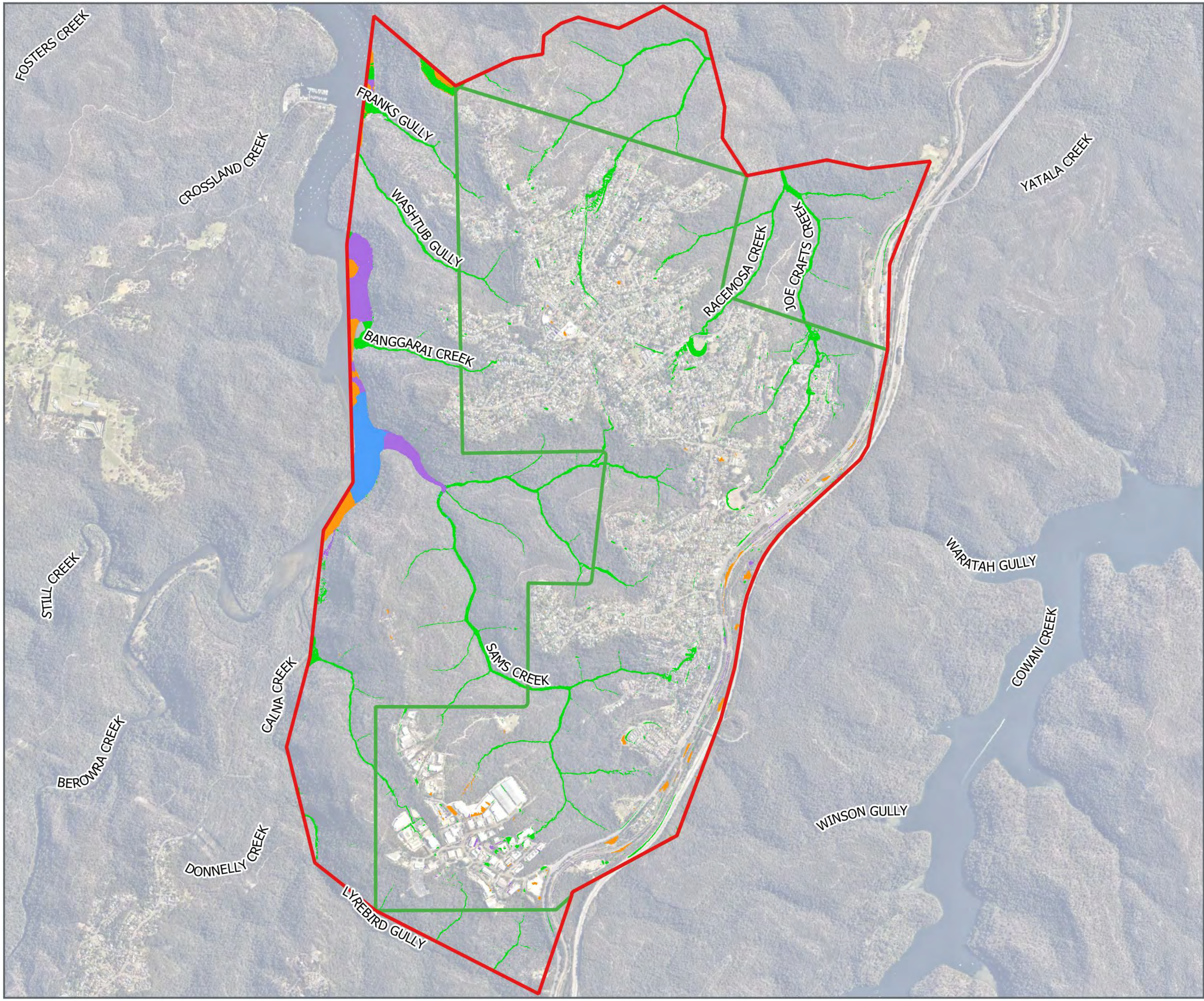
FIGURE C10

1:19991 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Berowra 1% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

1% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

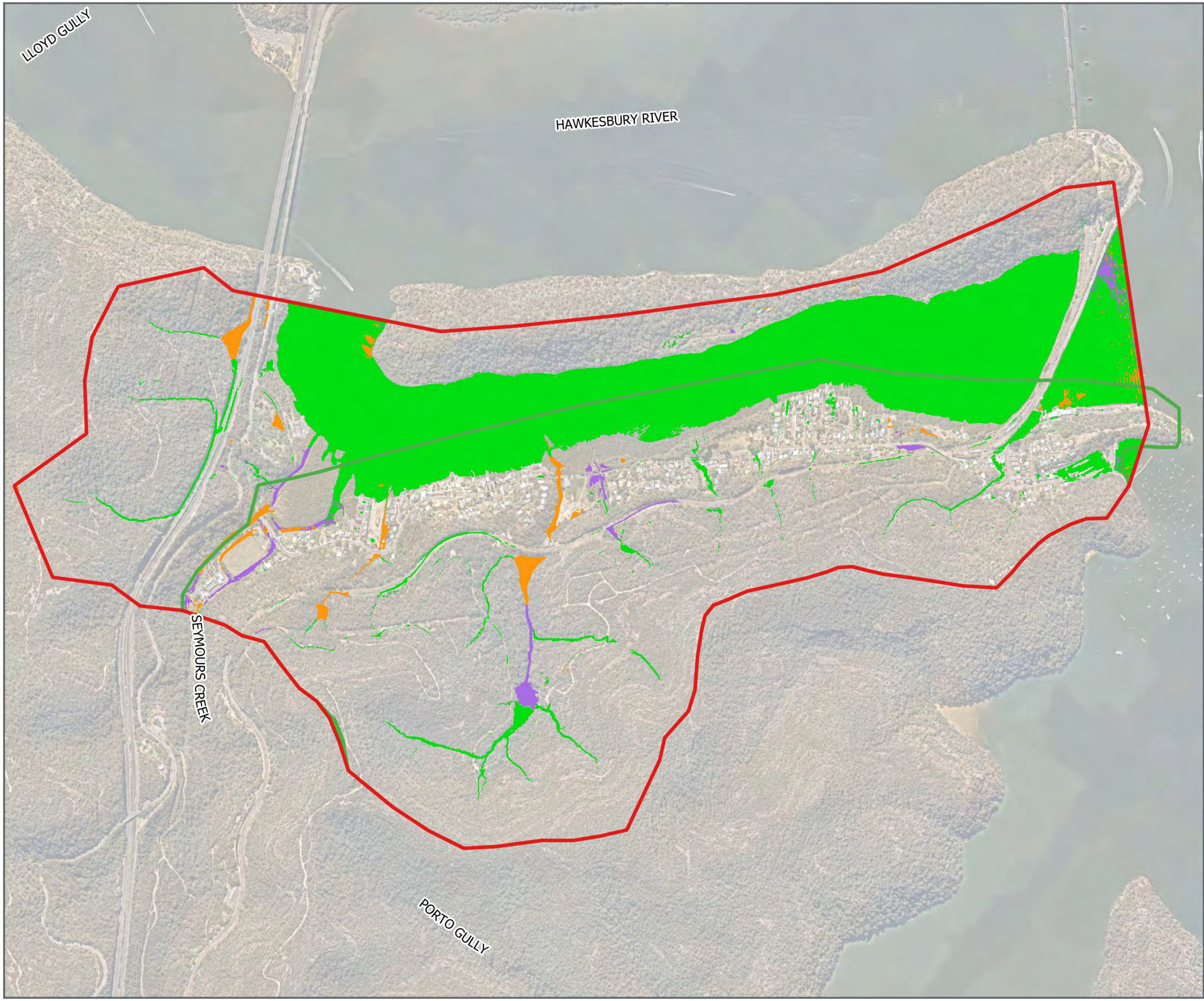
FIGURE C11

1:23090 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Brooklyn
1% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

1% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

FIGURE C112

1:12872 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Cowan 1% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

1% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

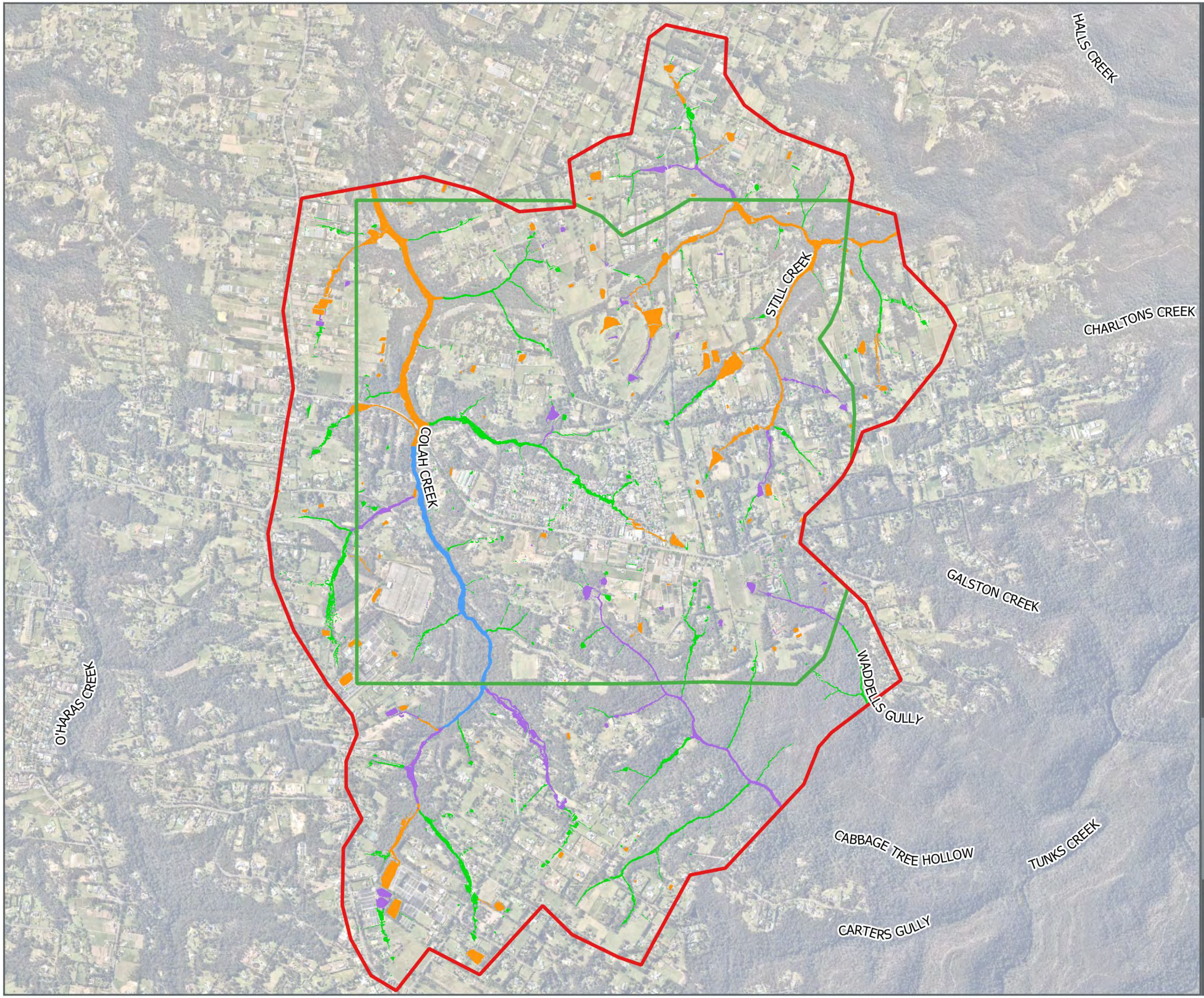
FIGURE C13

1:8850 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Galston
1% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

1% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

FIGURE C14

1:23815 Scale at A3

0 250 500 m

N

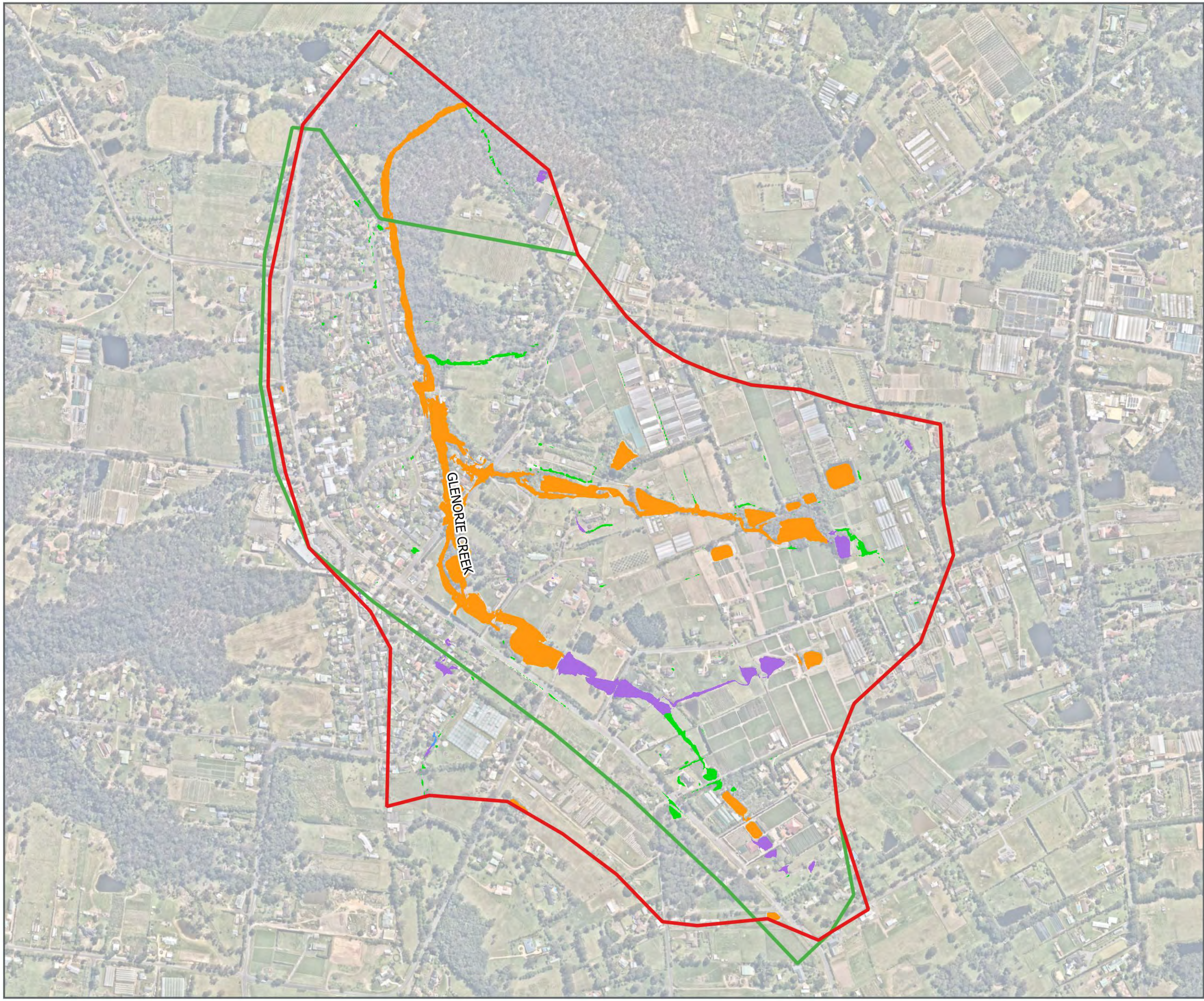
Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-17| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Glenorie 1% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan



LEGEND:

- Previous Model Boundary
- Updated Model Boundary

1% AEP Critical Duration:

- 30 mins
- 45 mins
- 60 mins
- 90 mins

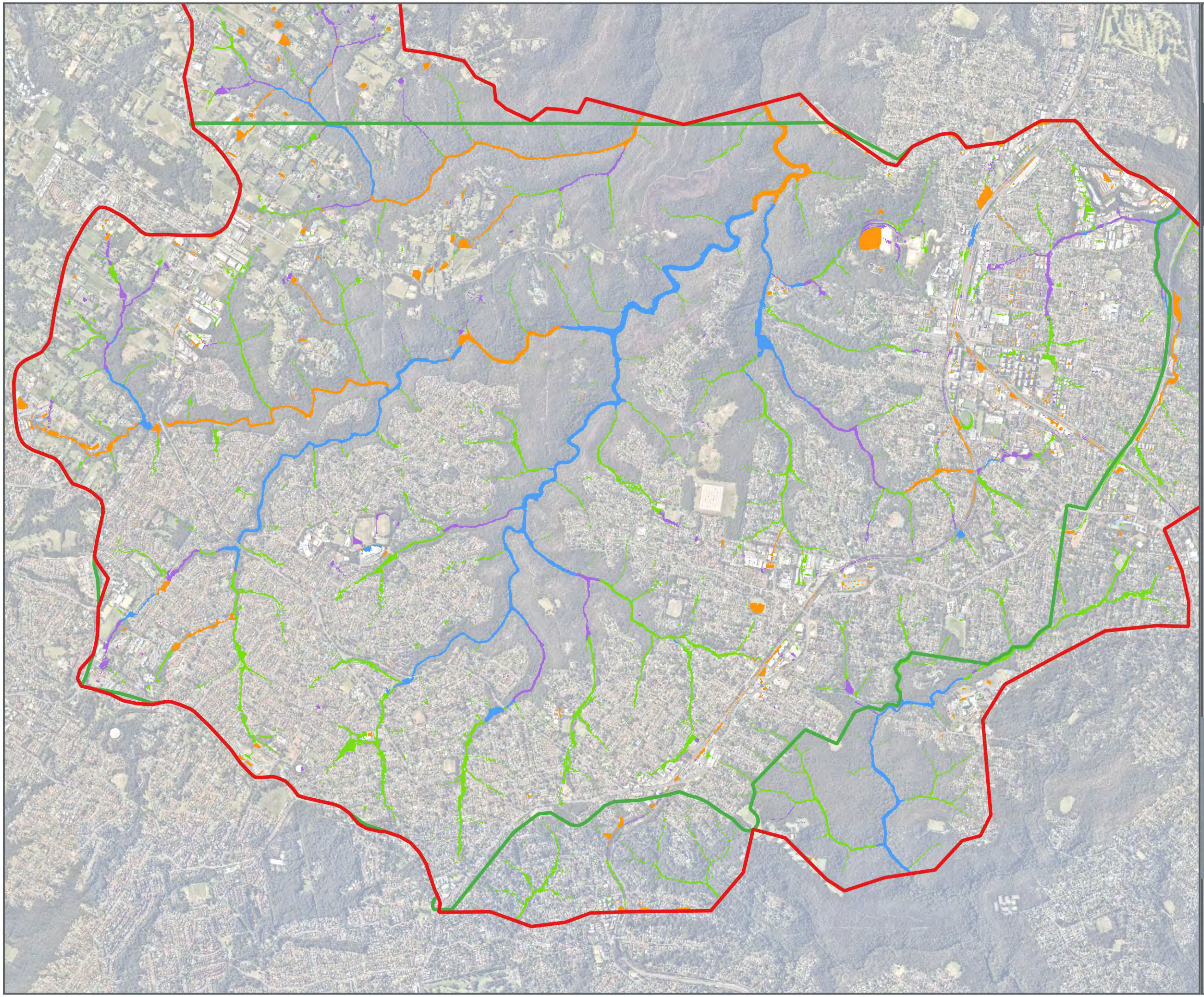
FIGURE C15

1:8358 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Pennant Hills 1% AEP ARR2019 Critical Duration

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

1% AEP Critical Duration:

- 25 mins
- 30 mins
- 45 mins
- 60 mins
- 90 mins

FIGURE C16

1:31102 Scale at A3

0 250 500 m

N

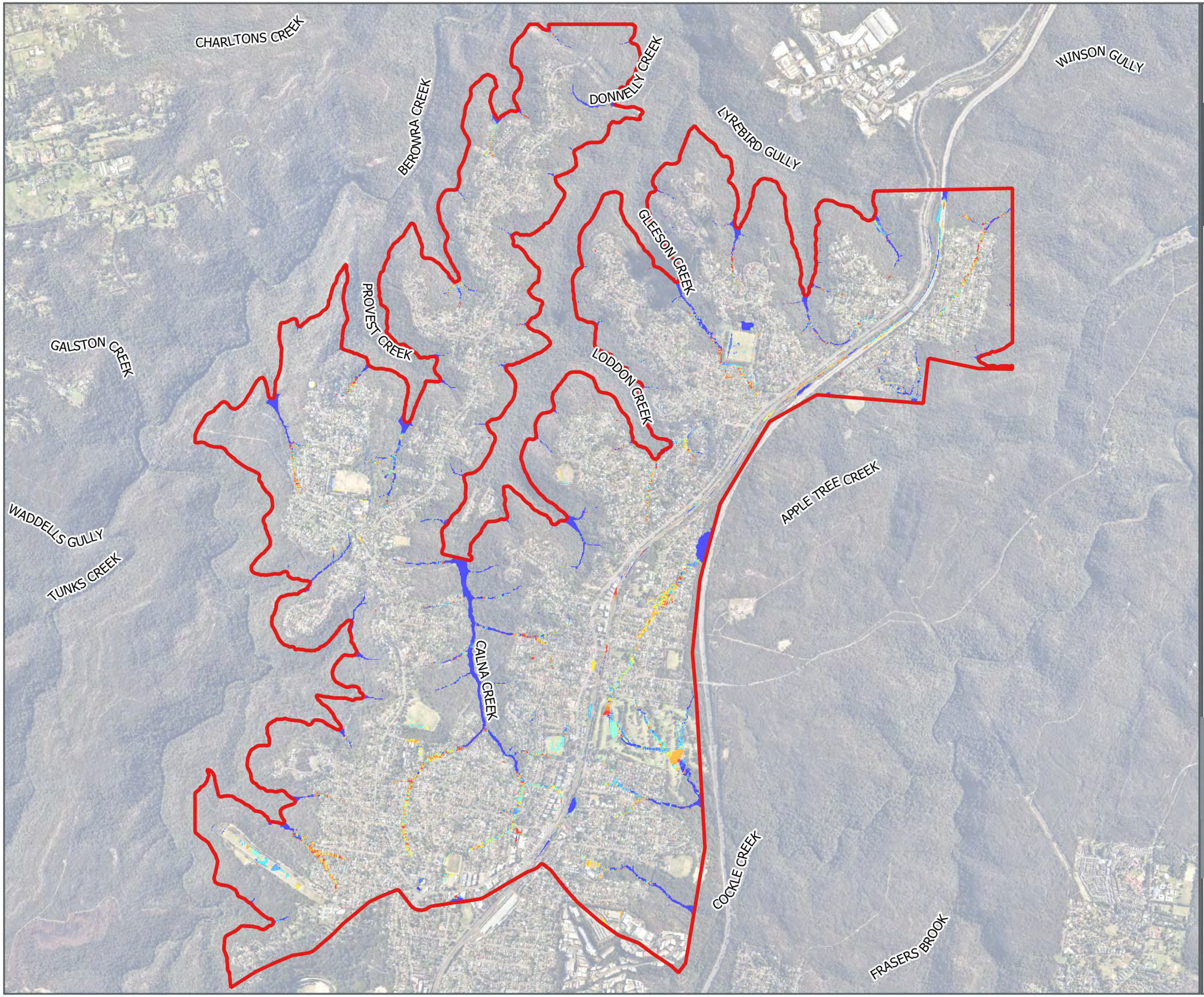
Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

APPENDIX

D

FLOOD LEVEL DIFFERENCES



HORNSBY SHIRE COUNCIL

Asquith 20% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D1

1:24338 Scale at A3

0 250 500 m

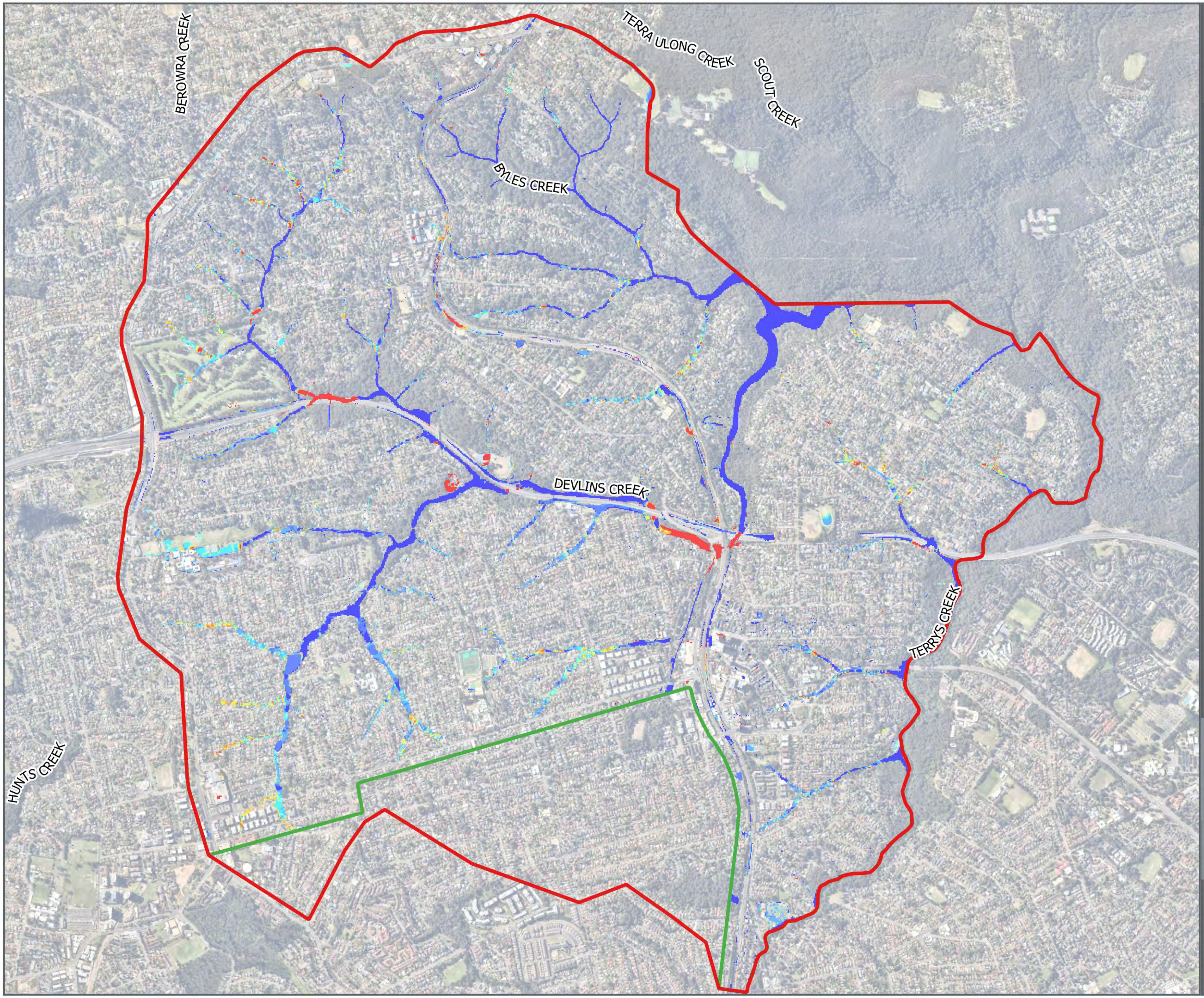
Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Beecroft 20% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan



LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

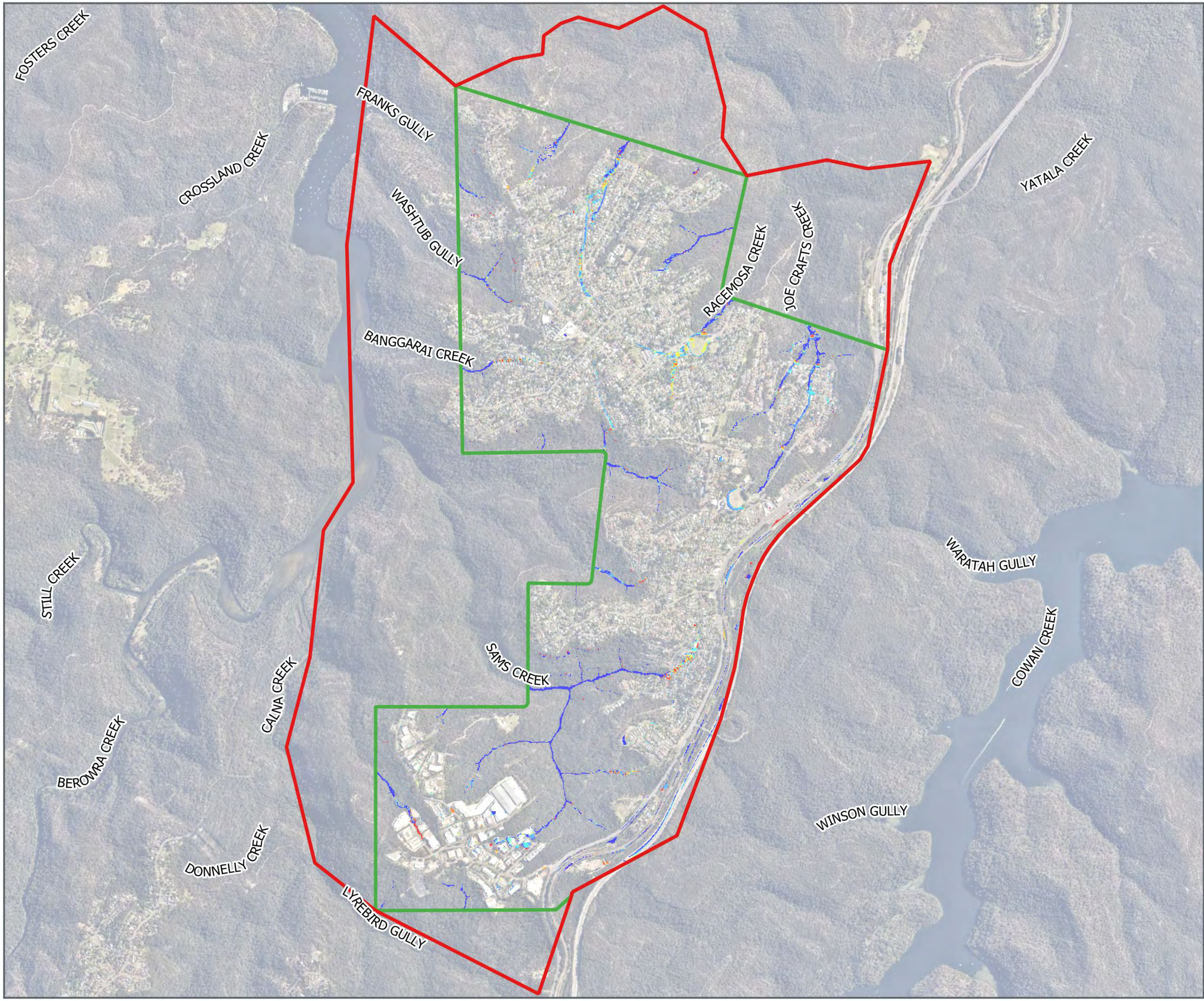
FIGURE D2

1:19991 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Berowra 20% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

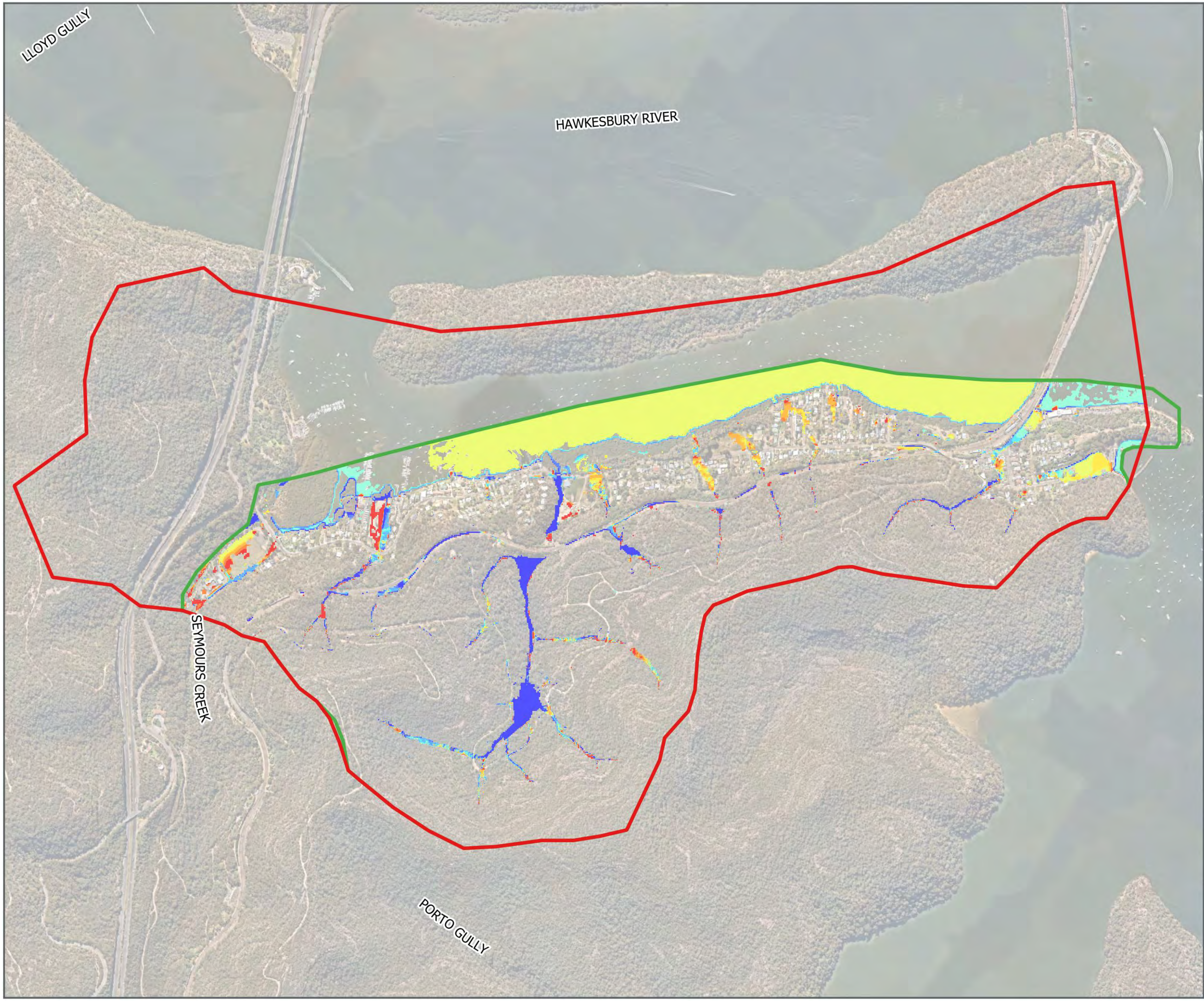
FIGURE D3

1:23090 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Brooklyn
20% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D4

1:12872 Scale at A3

0 250 500 m

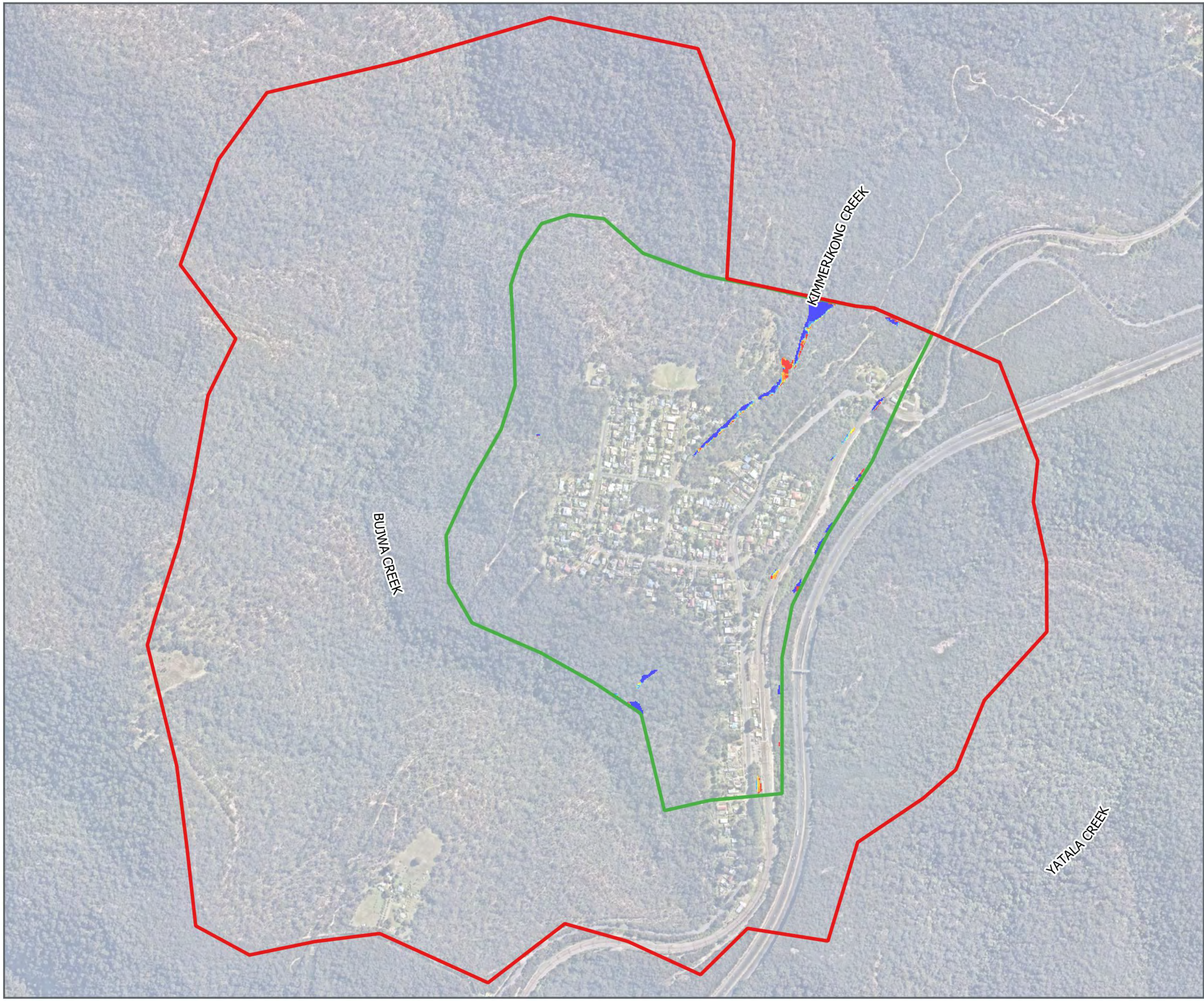
Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Cowan 20% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan



LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D5

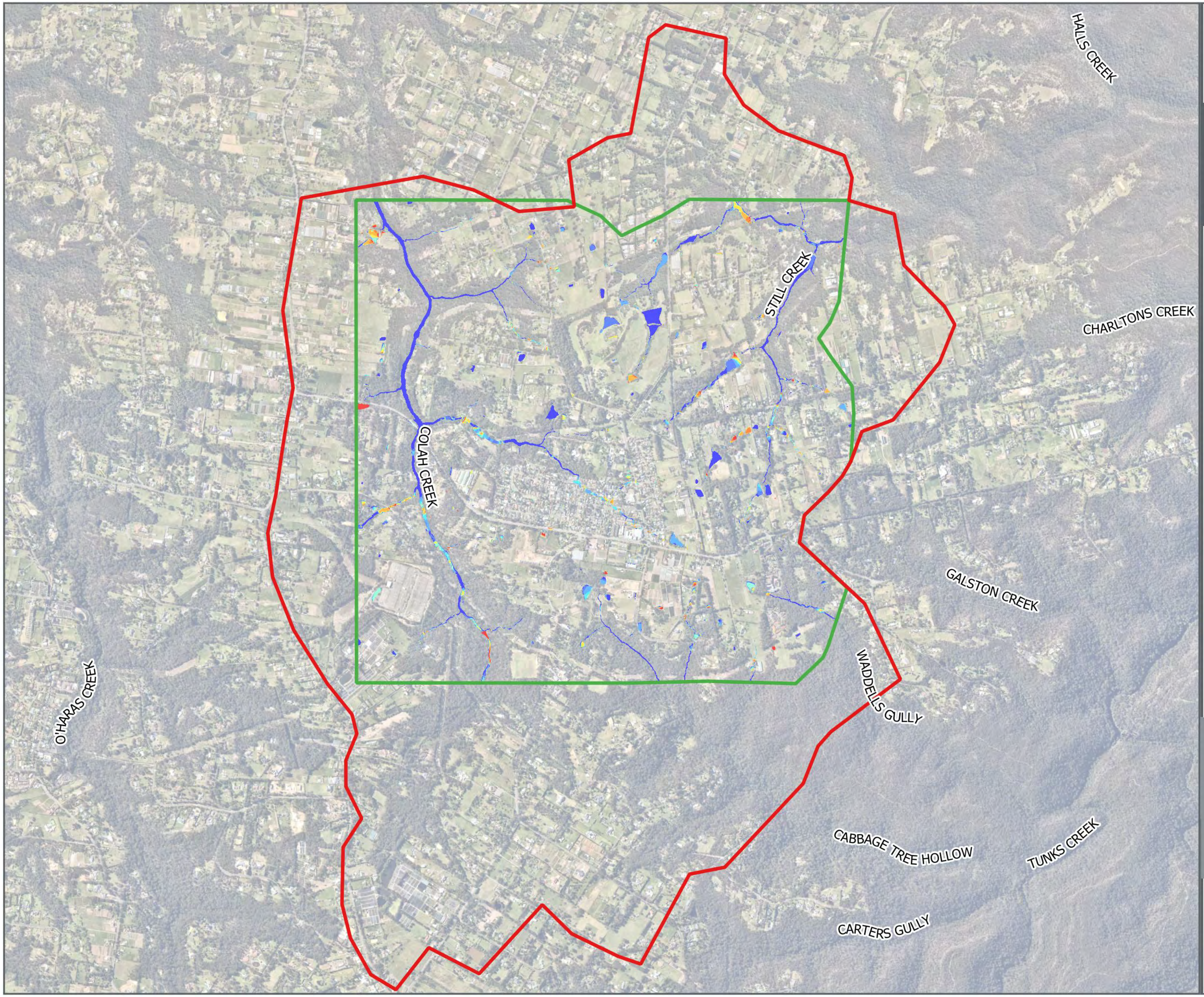
1:8850 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Galston 20% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

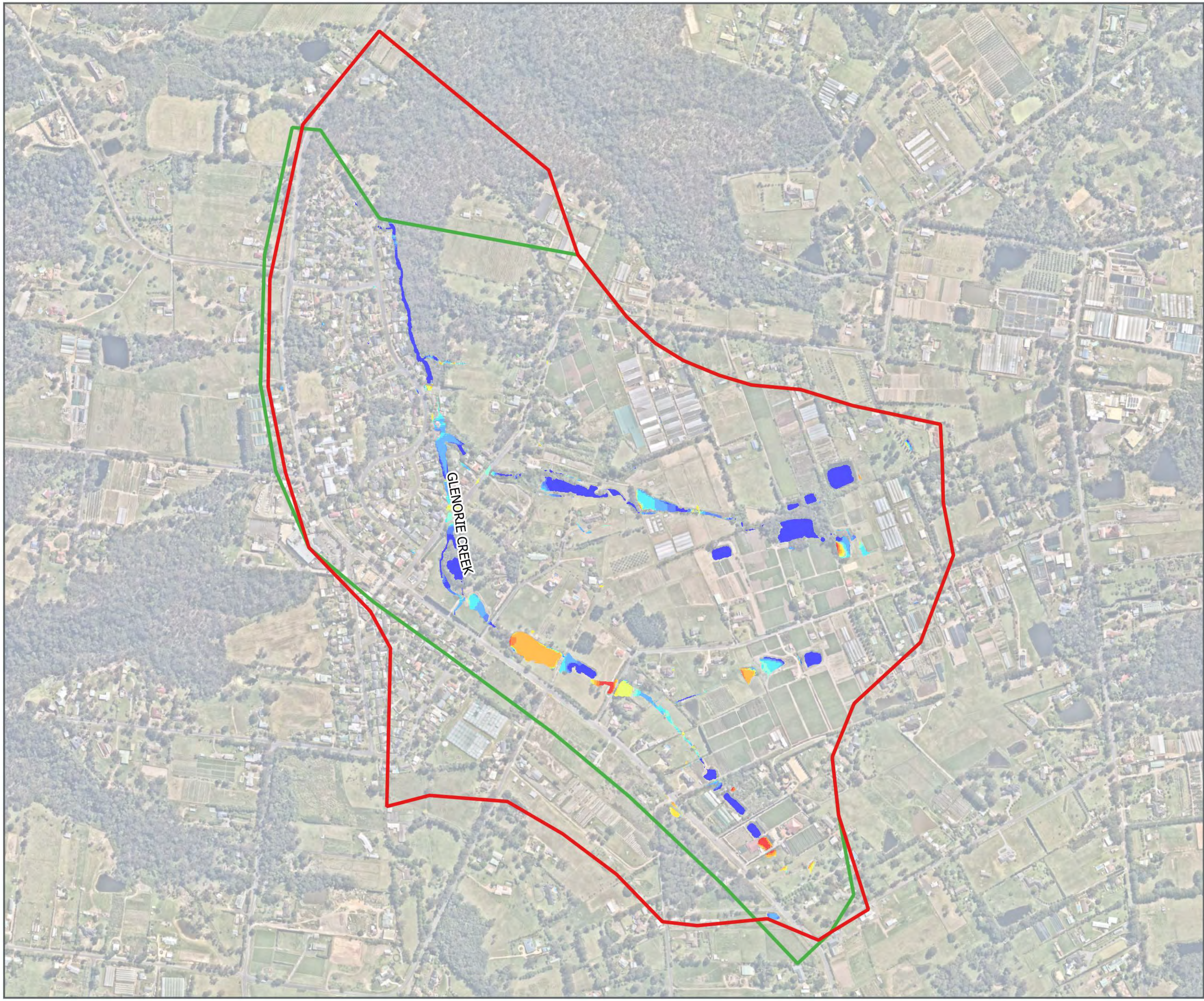
FIGURE D6

1:23815 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY
SHIRE COUNCIL

Glenorie 20% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D7

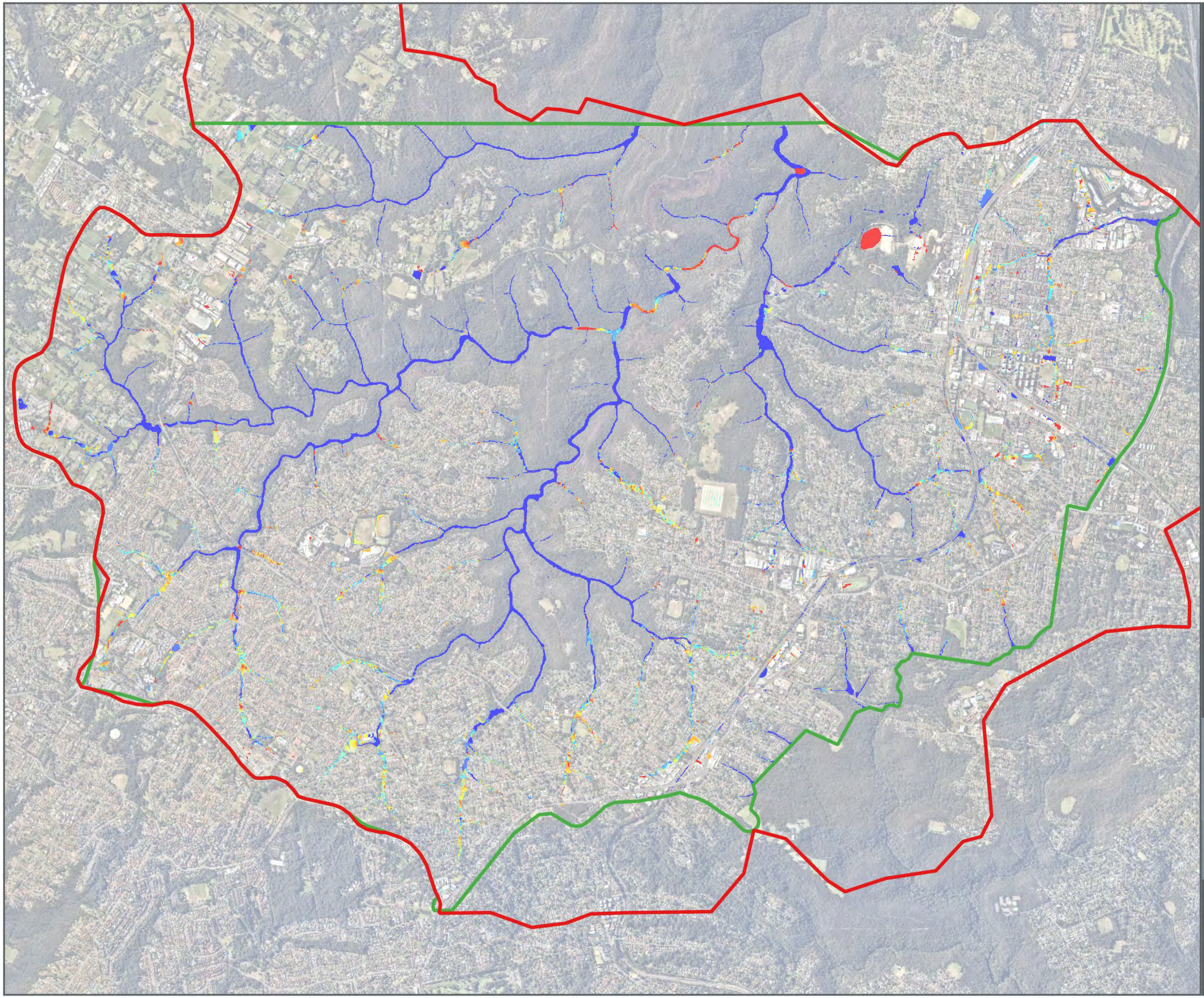
1:8358 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-17| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Pennant Hills 20% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D8

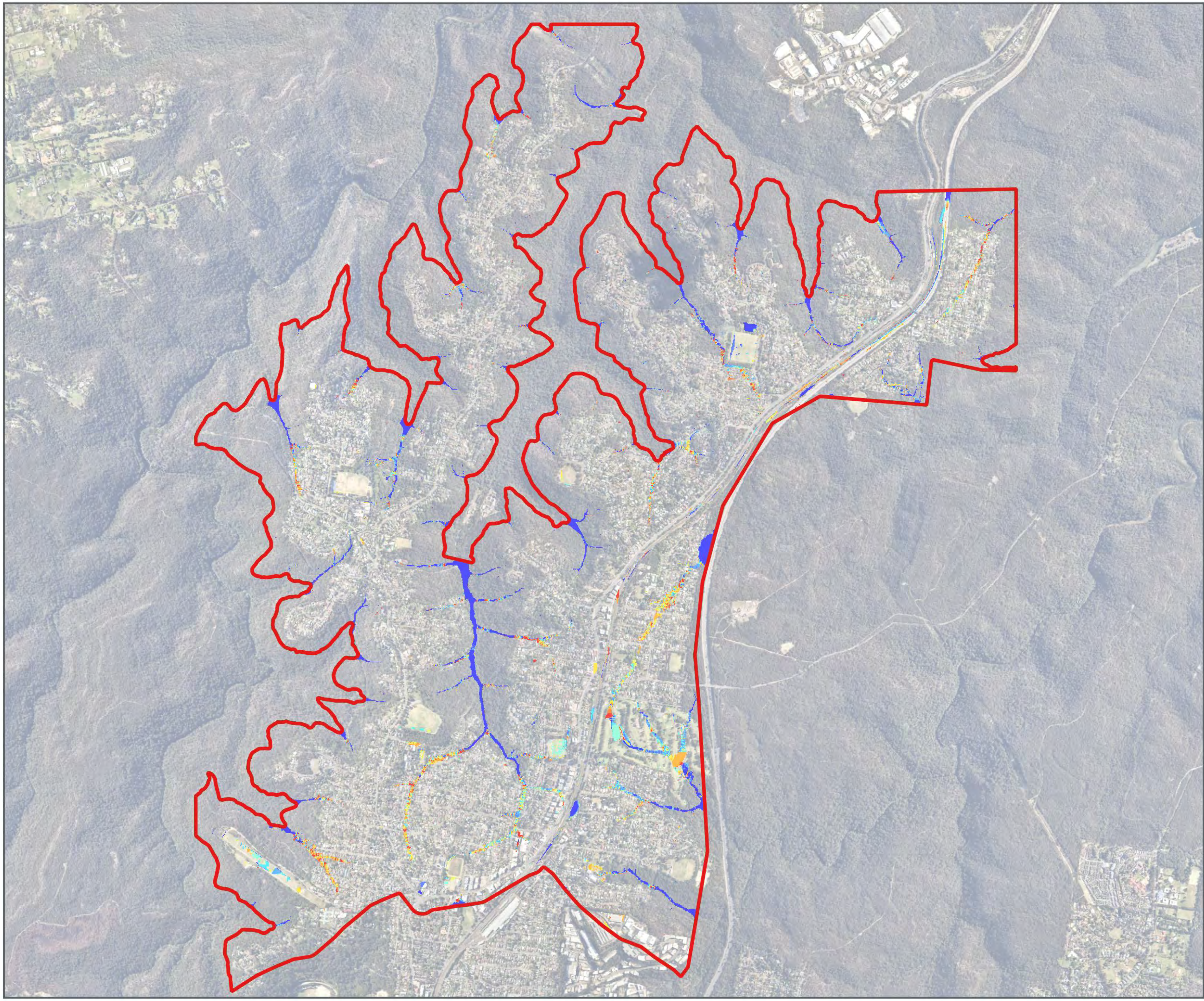
1:31102 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Asquith 1% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

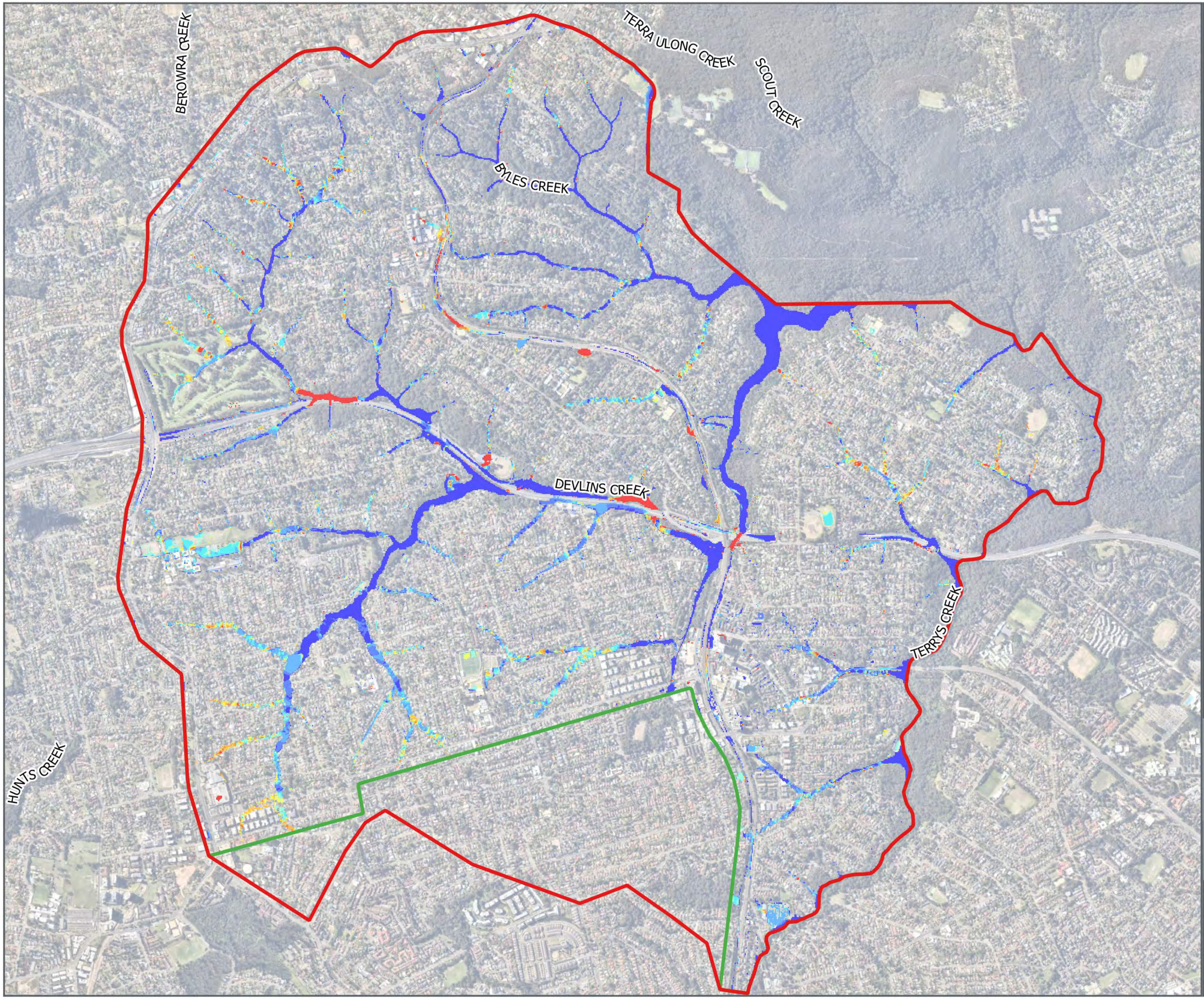
FIGURE D9

1:24338 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Beecroft
1% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D10

1:19991 Scale at A3

0 250 500 m

N

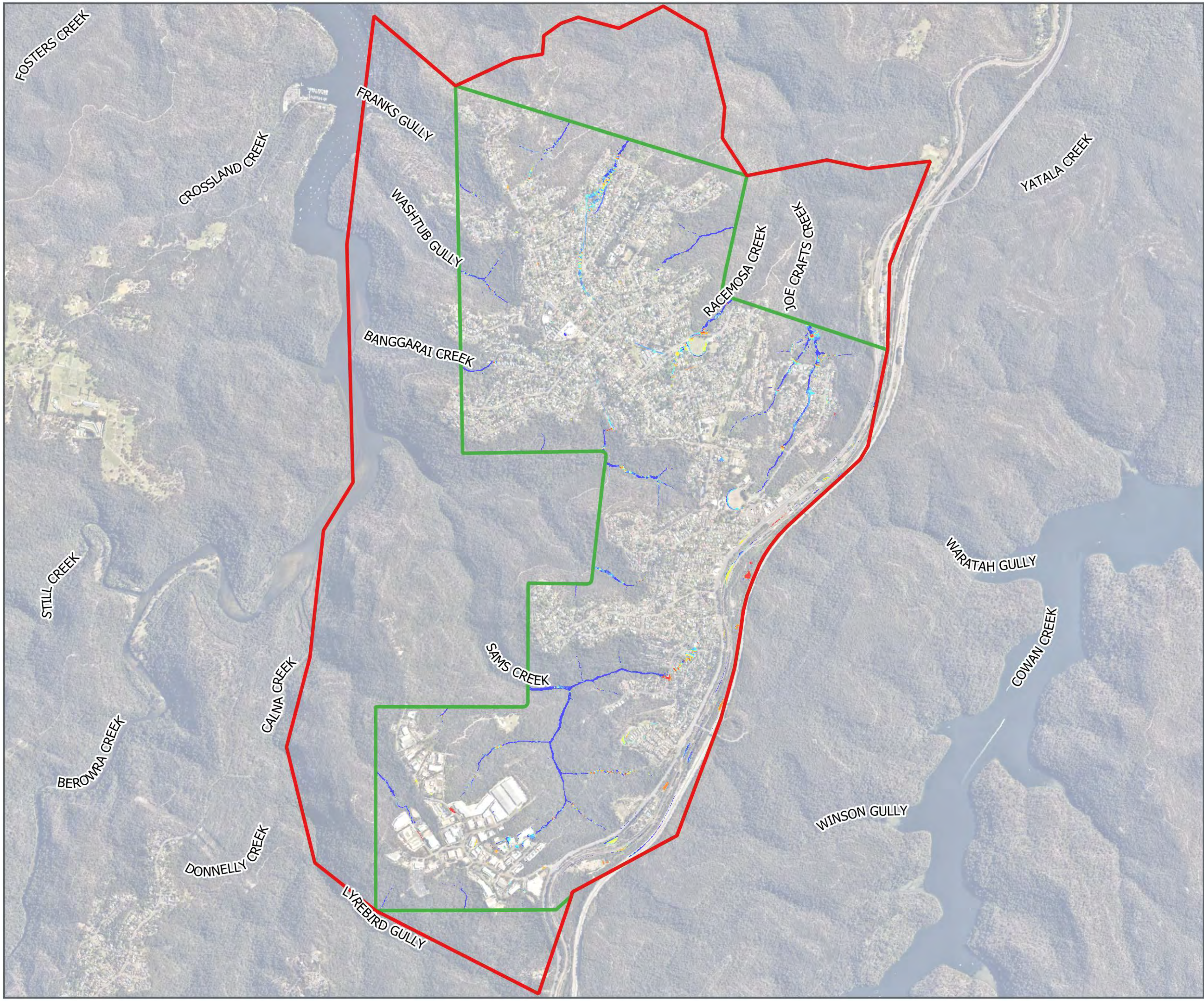
Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz

HORNSBY SHIRE COUNCIL

Berowra 1% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan



LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

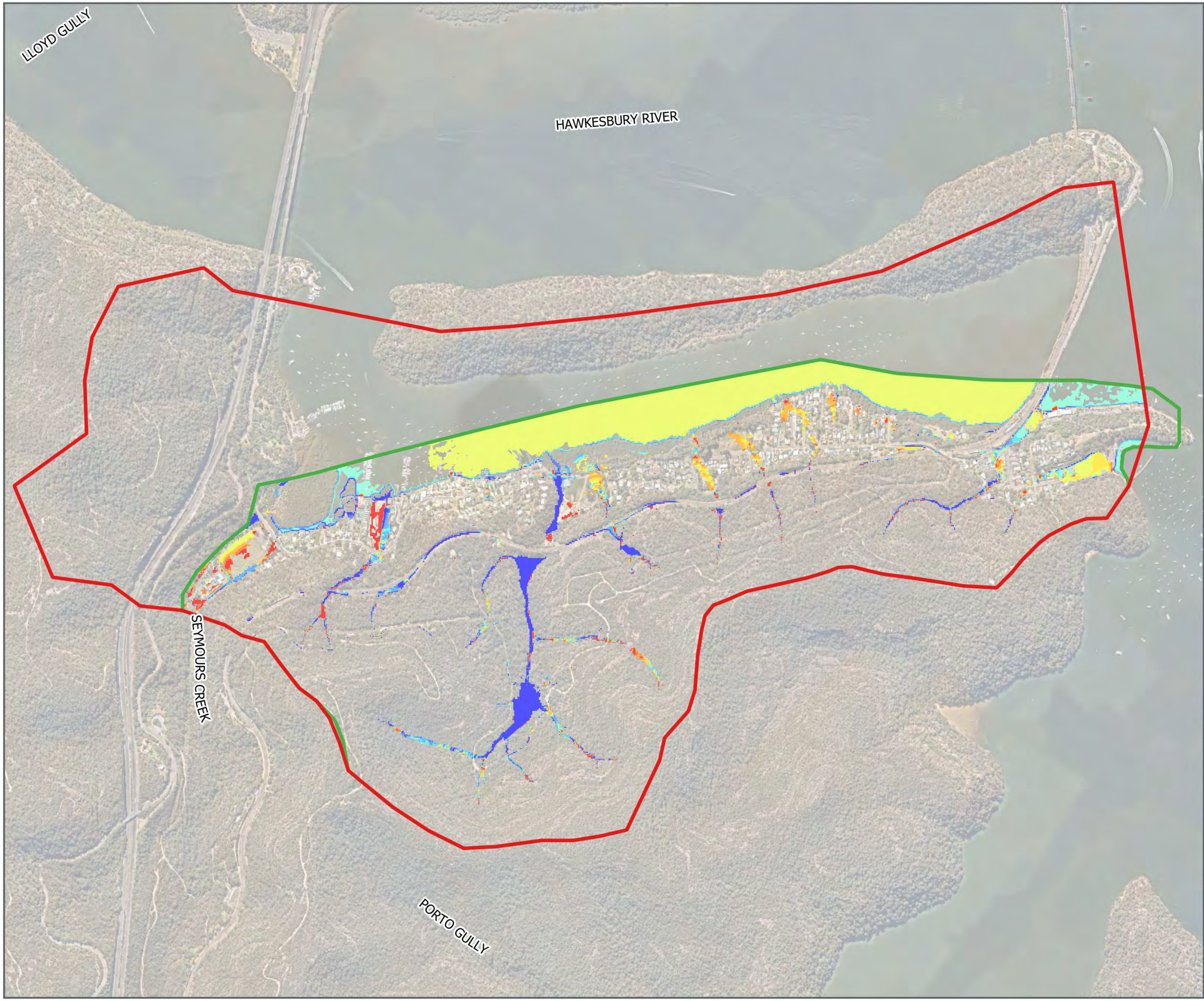
FIGURE D11

1:23090 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Brooklyn 1% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

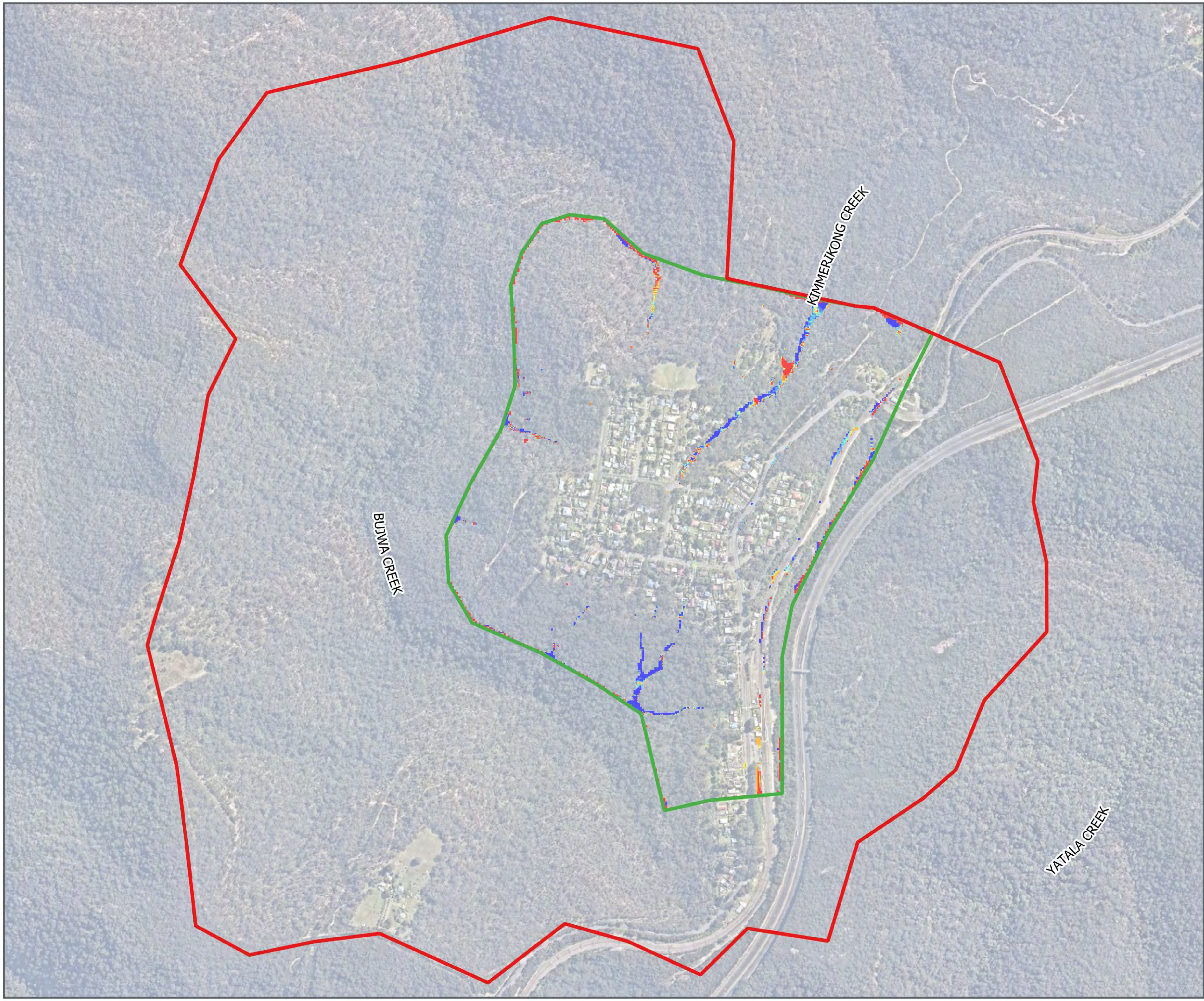
FIGURE D12

1:12872 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Cowan 1% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

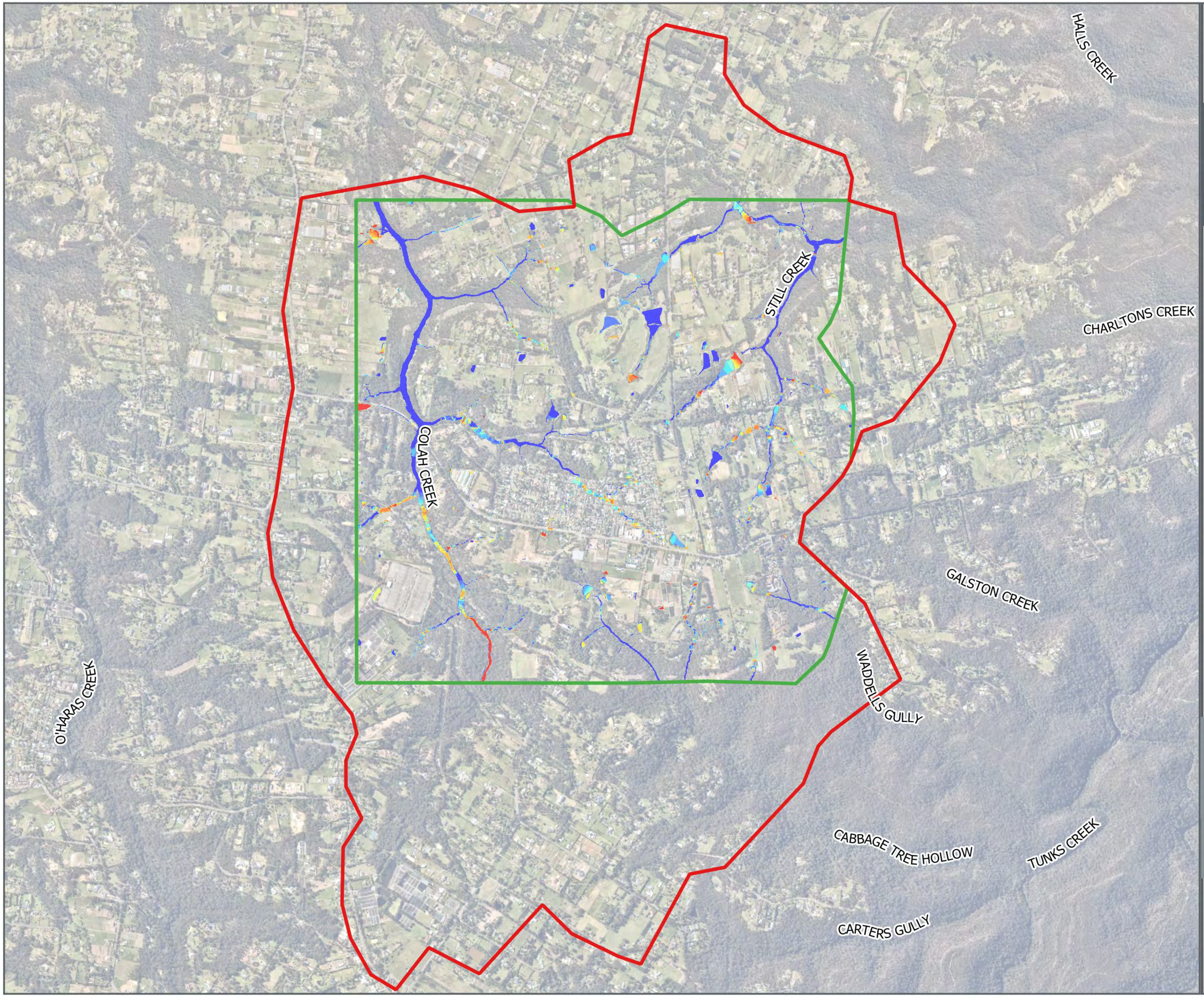
FIGURE D13

1:8850 Scale at A3

0 250 500 m

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Galston 1% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D14

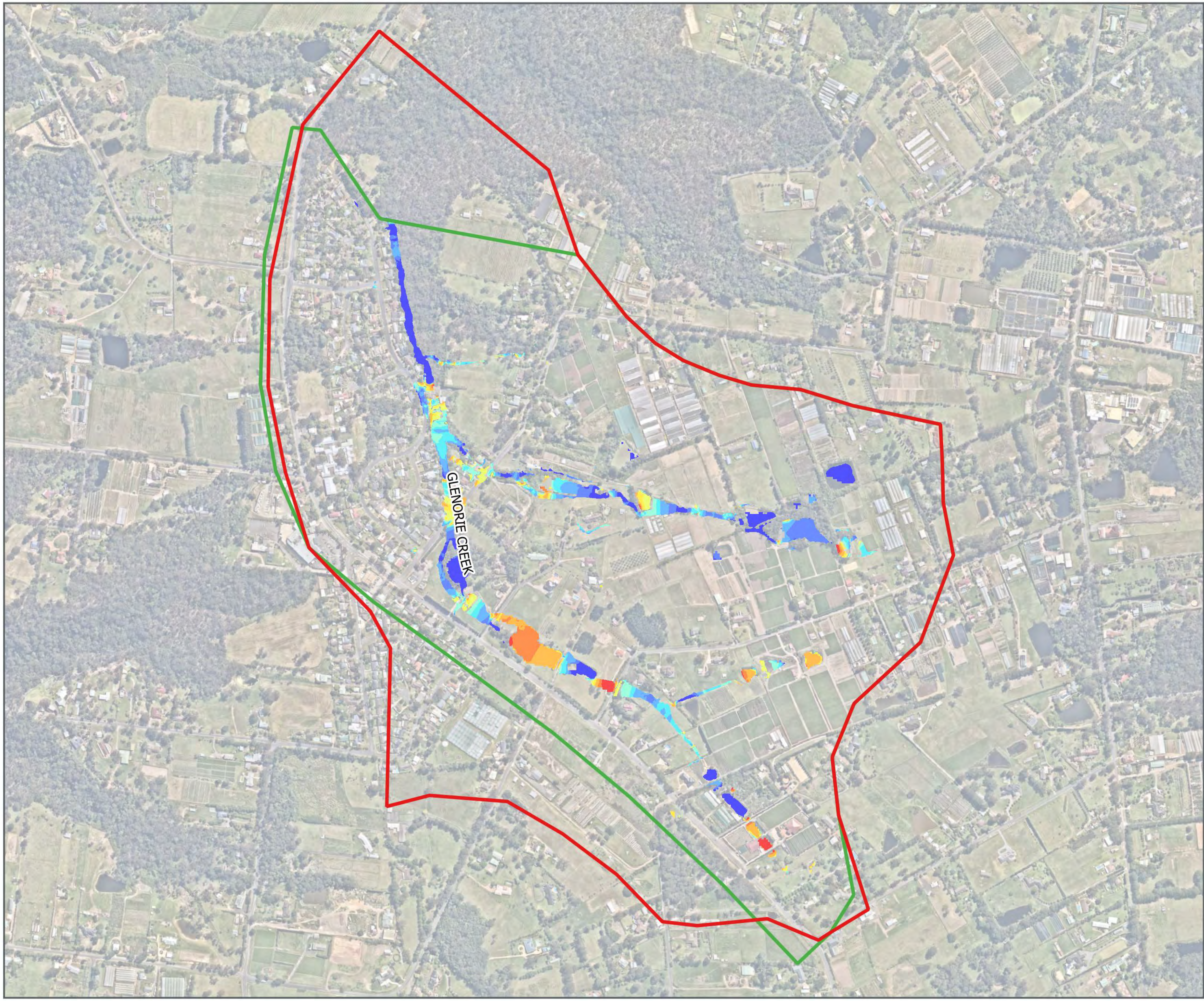
1:23815 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Glenorie 1% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D15

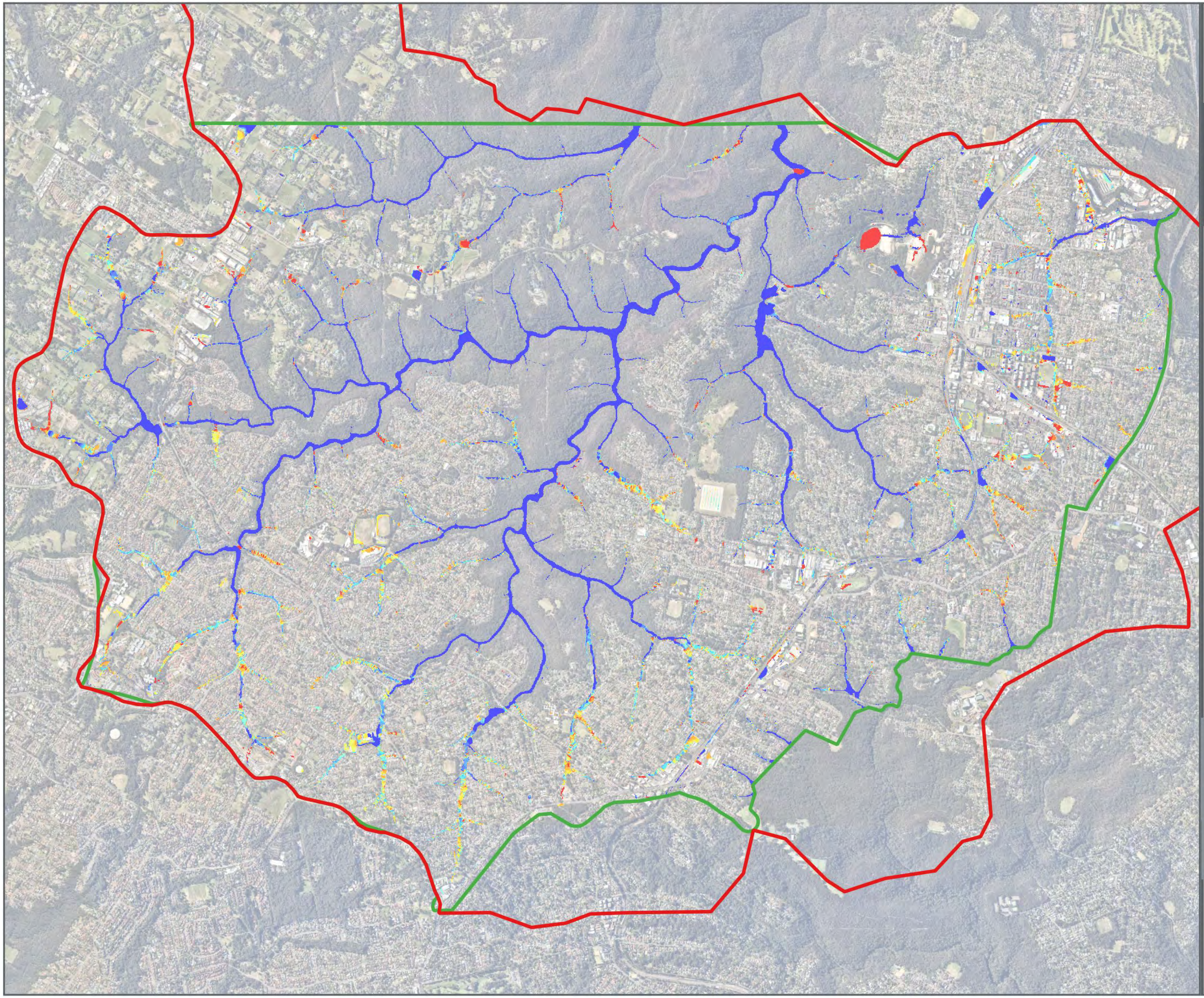
1:8358 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz



HORNSBY SHIRE COUNCIL

Pennant Hills 1% AEP Water Level Difference ARR2019 vs ARR1987

Hornsby Floodplain Risk Management Study and Plan

LEGEND:

- Previous Model Boundary
- Updated Model Boundary

Water Level Difference (m):

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- > 0.30

FIGURE D16

1:31102 Scale at A3

0 250 500 m

N

Cardno

Map Produced by St Leonards Water (AWE)
Date: 2020-11-16| Project: NW30006
Coordinate System: MGA Zone 56
Map: All_Model_Review Results.qgz