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MIKE FLOOD Modelling

Model Build Report

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Prepared by Awa Environmental Limited

for Weston Lea Ltd

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15 June 2018

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Project No.	J000098
Document title	Model Build Report
Document number	02
Version number	02
Date	16 May 2018
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Document History

Version	Date	Description	Author	Reviewed
1	06/03/2018	DRAFT Report Review	Tony Trueman	Steven Cornelius
2	16/05/2018	Review	Tony Trueman	Tony Trueman

About your report

The sole purpose of this report and the associated services performed by Awa Environmental Limited is to provide MIKE FLOOD modelling of the Amberfield Sub-catchment in accordance with the scope of services set out in the contract between Awa Environmental Limited and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Awa Environmental Limited has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Awa Environmental Limited has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Awa Environmental Limited for use of any part of this report in any other context.

The MIKE FLOOD modelling undertaken uses a 2m grid. This is considered suitable for broad scale flood management planning. Localised flood levels may vary in the vicinity of buildings, fences and other structures that are not represented in the model.

This report has been prepared on behalf of, and for the exclusive use of, Awa Environmental Limited's Client, and is subject to, and issued in accordance with, the provisions of the contract between Awa Environmental Limited and the Client. Awa Environmental Limited accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

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1 Executive Summary

Weston Lea Ltd propose to develop the Amberfield sub-catchment South of Hamilton, located between Peacockes Road and the Waikato River.

This modelling study has been undertaken to assist Weston Lea Ltd in understanding the existing flood hazard within the site and from the Waikato River to inform future post development stormwater mitigation options.

Existing drainage within the sub-catchment is via numerous farm drains, roadside drains, ephemeral, intermittent and permanent water courses. These are typically highly modified with numerous culverts. All watercourses flow to the Waikato River, either directly or indirectly via the central gully.

Results from the existing model show the main area of flooding occurs adjacent to Peacockes Road and is a function of localised low topography, localised catchment discharges, upstream catchment overflows and restrictions within the open channel network. Otherwise, flooding within the site is largely contained within the watercourses.

The Northern extent of the site, adjacent to the Waikato River, is potentially affected by flooding from the Waikato River. Any development within this area will need to ensure developed ground levels are above flood levels.

Soakage testing has returned moderate to good soakage results across the site. This will enable soakage to be used as the primary stormwater disposal method.

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2 Report Presentation

For ease of reading and results presentation this report has been broken into the two sections. The first section gives an overview of the existing modelled flood hazard.

The second section details the approach and modelling schematisation used to build the model and discusses all aspects of the model build process including;

- Spatial data source, quality, completeness and manipulation,
- Boundary conditions,
- Site specific data,
- Mike21 model build,
- Mike11 model build,
- MikeUrban model build,
- MikeFlood coupling parameters.

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3 Introduction

3.1 Site Overview

The Amberfield sub-catchment ICMP boundary is identified in the shaded area in Figure 1 – Amberfield Sub-catchment boundary. The approximately 105 ha sub-catchment area is situated within the Hamilton City Council territorial authority boundary to the south of Hamilton City and has been ear marked for mixed use development as part of the Peacocke Structure Plan.

The sub-catchment is largely confined by Peacockes Road to the West, except for a small area in the South-West, and the Waikato River to the East. Existing land use is predominately dairy farming with isolated areas of native bush predominately in the gully's and flanking the Western bank of the Waikato River.

Topographically the site generally grades from West to East over a number of broad river terraces intersected with steep transition slopes terminating with large, steep free face slopes adjacent to the Waikato River. An incised gully bisects the Southern extent of the sub-catchment, as shown in Figure 2.

The Institute of Geological and Nuclear Sciences (GNS) 1:250,000 geological map has been used as a basis for the geological map and shows the sub-catchment underlain by Holocene aged river deposits, alluvial and colluvial deposits of the Walton subgroup and the Piako subgroup as shown in Figure 3.

Drainage within the sub-catchment is via numerous farm drains, roadside drains, ephemeral, intermittent and permanent water courses. These are typically highly modified with numerous culverts. All watercourses flow to the Waikato River, either directly or indirectly via the central gully. Some additional drainage features including road-side ditches, depression features and drainage exiting the site to the South have been added in the model for additional accuracy. Figure 4.

Soakage testing has been undertaken across the site to inform the potential disposal of stormwater to ground. Soakage results across the site were cross-referenced against adjacent soil profile logs to provide a detailed picture of soil soakage potential. All the geotechnical investigation sites were then reviewed, and their profiles assessed to build a detailed wider picture of soil soakage potential. Good to moderate soakage rates have been identified across the site, as shown in Figure 5.

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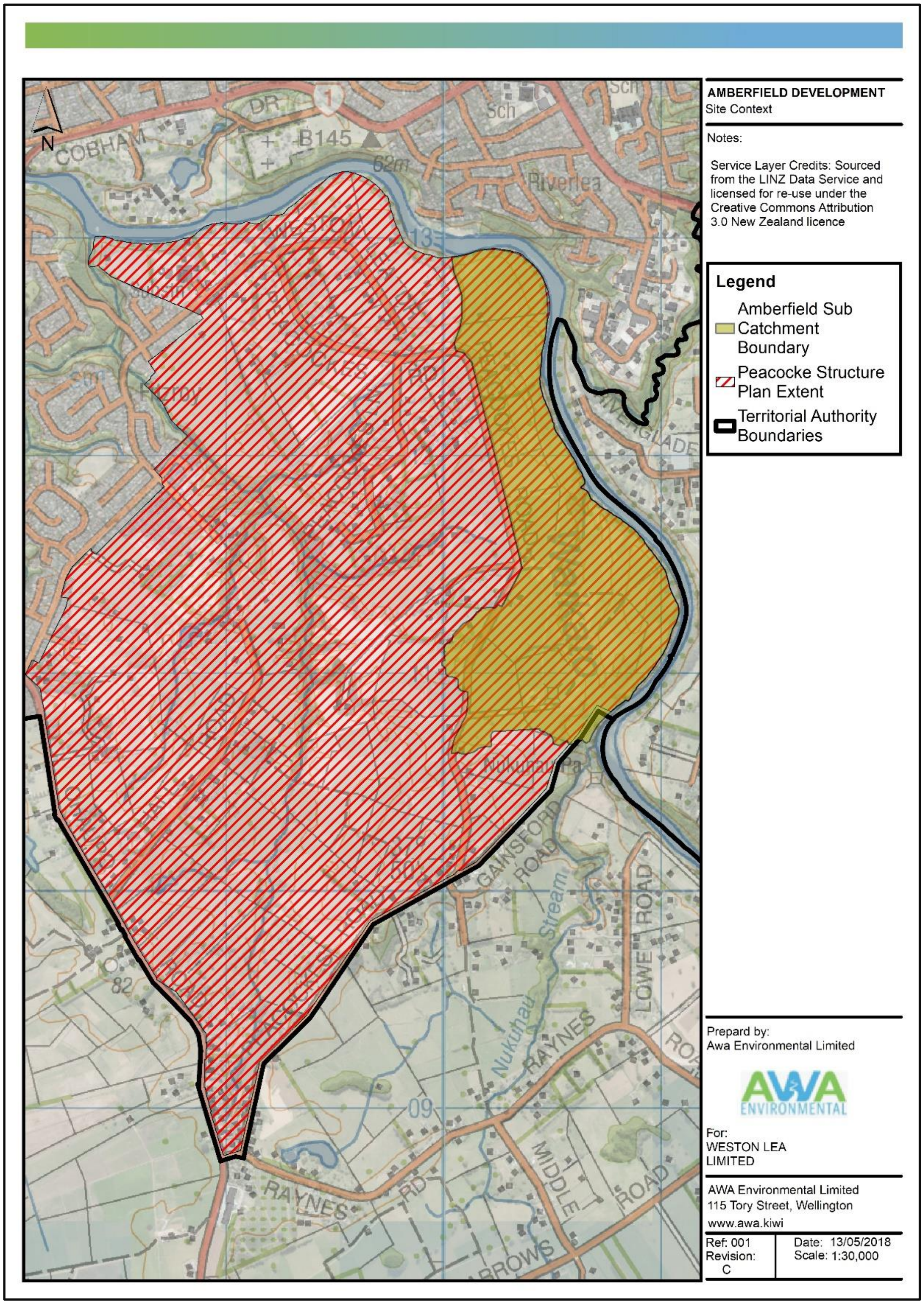

Figure 1 Amberfield Sub-Catchment Overview

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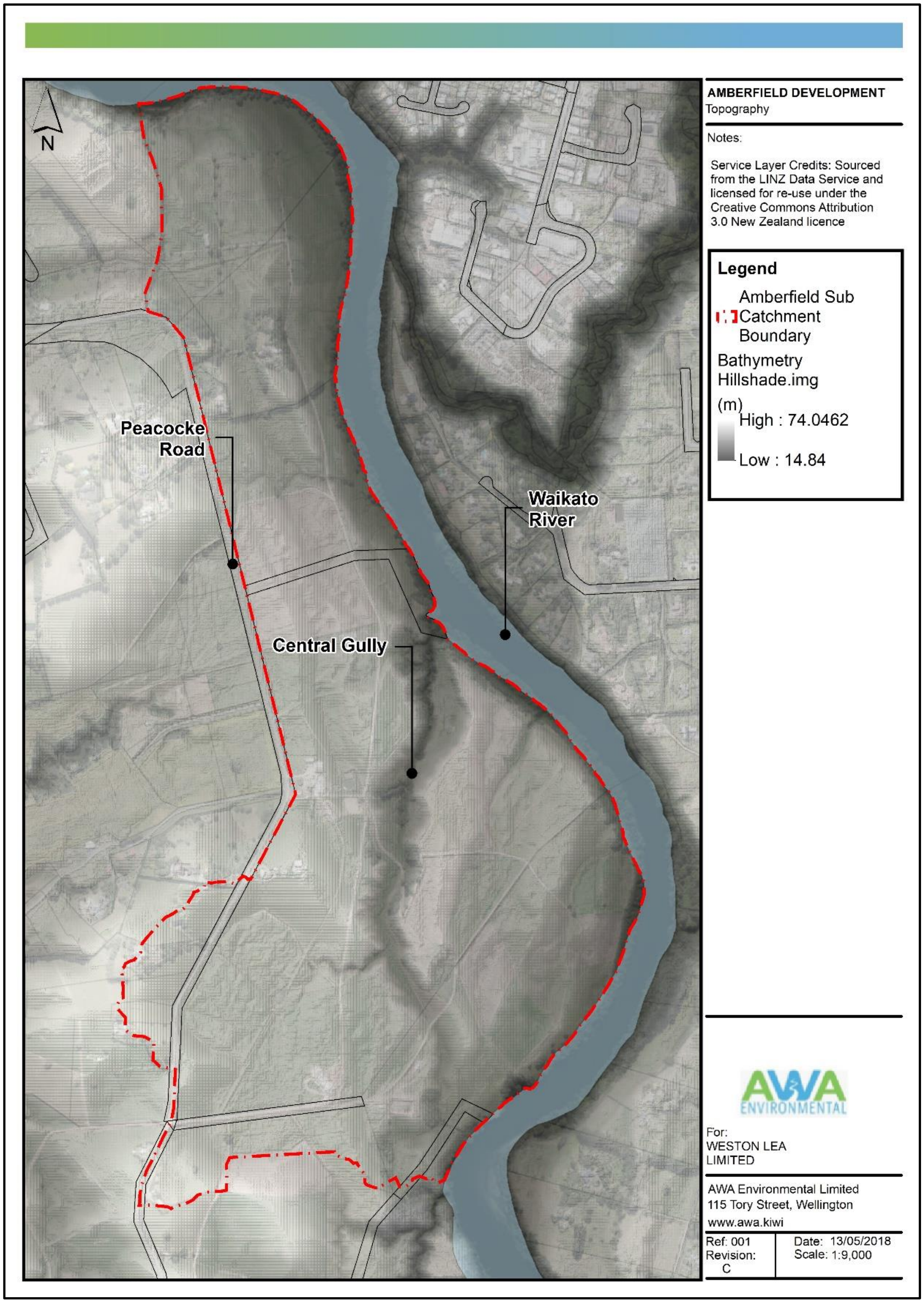

Figure 2 Existing Topography Overview

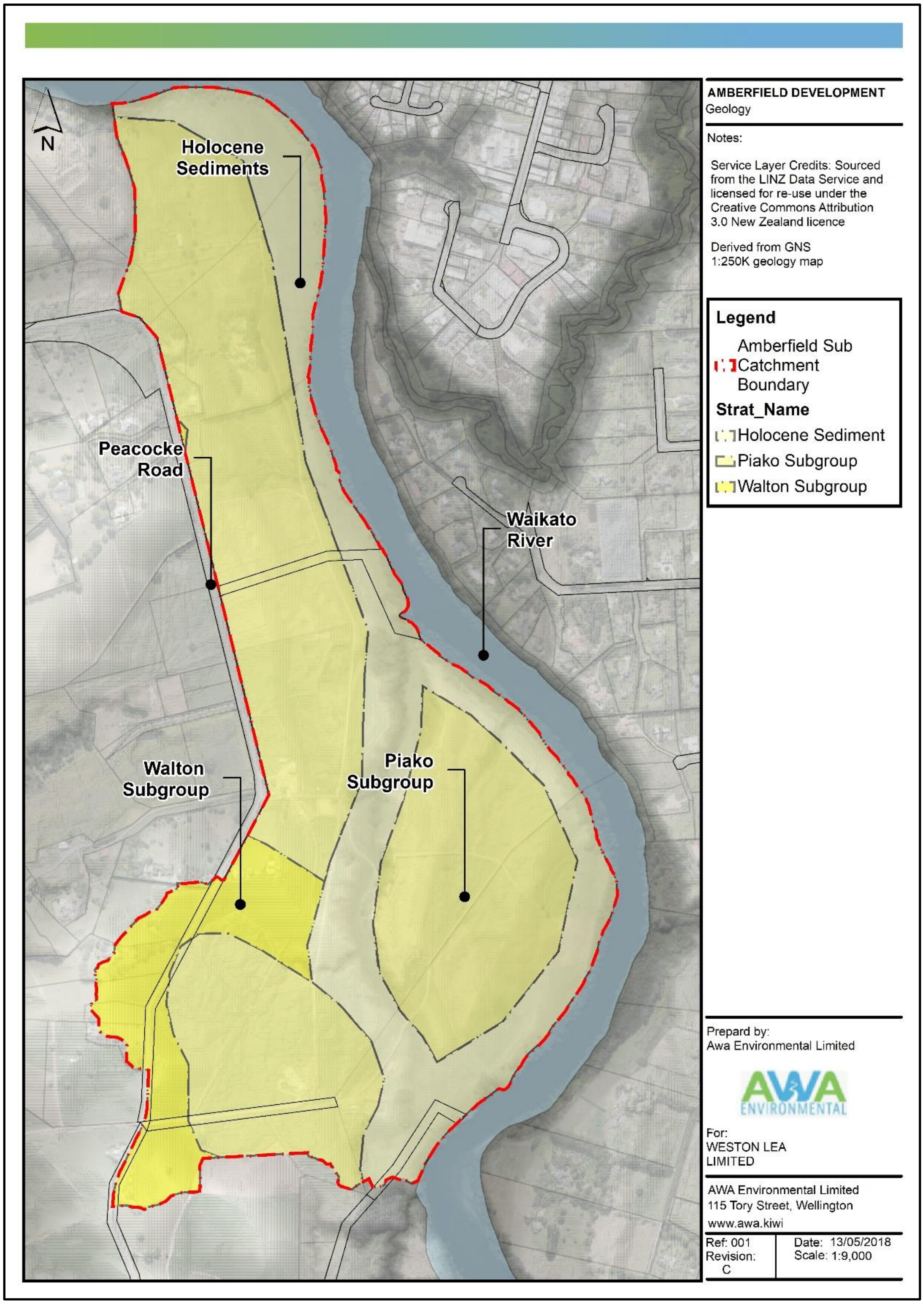

Figure 3 Geology Overview

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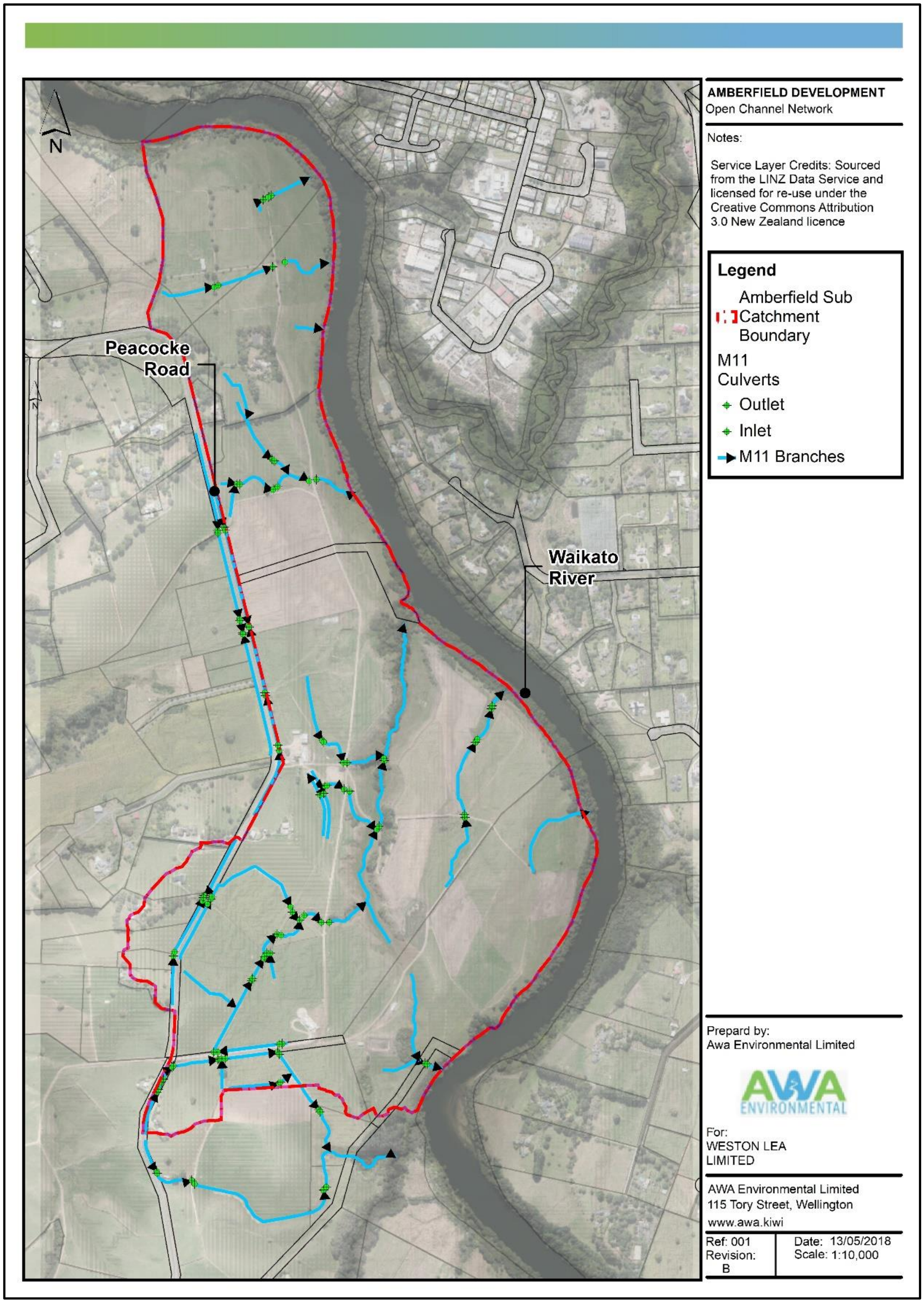

Figure 4 Model Drainage

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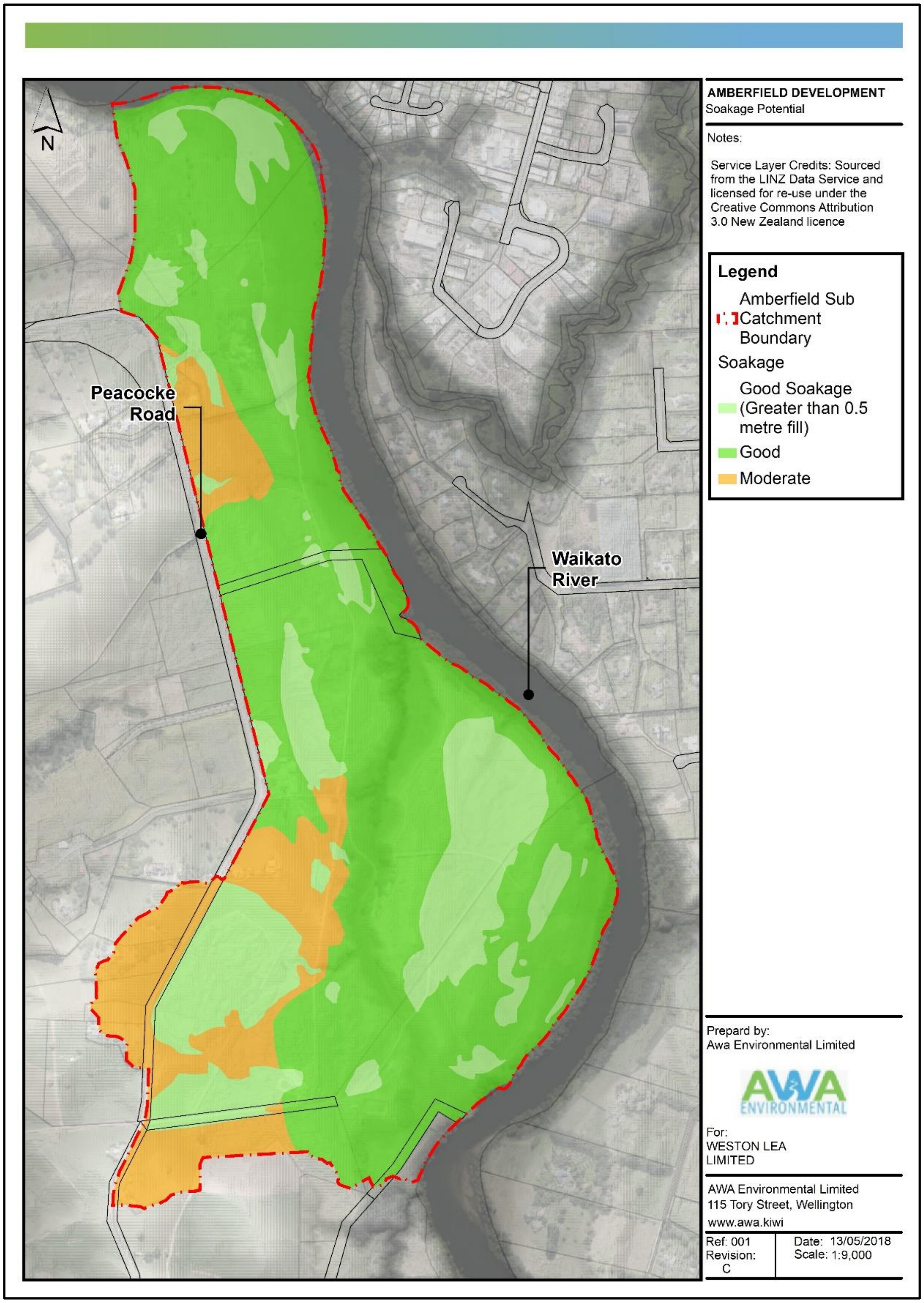

Figure 5 Soakage Potential

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3.2 Literature Review

Several documents have been reviewed and are briefly discussed in this section.

<u>RAPID FLOOD HAZARD ASSESSMENT</u>

A Rapid Flood Hazard Assessment (RFHA) was undertaken by AECOM in 2012 to provide a high-level understanding of the potential flooding hazards across the City. The RFHA results for the Amberfield sub-catchment are shown in Figure 6.

A full discussion of the modelling and outcomes is provided in the document, AECOM, Three Waters Modelling Programme, Hamilton City Council, 29 October 2012 – Flood Hazard Report.

<u>WAIKATO RIVER FLOOD HAZARD ASSESSMENT</u>

Waikato Regional Council provided information on various flood hazard events in the Waikato River including;

- 1% AEP flood extent excluding climate change
- Dam break scenario

<u>1% AEP flood event excluding climate</u>

The information from the Waikato Region Council has been summarised by AWA in the document, *AWA, Adare Flood Hazard Report, 10 November 2017* (Appendix1).

Figure 7 shows the northern extent of the site affected by flooding in the 1% AEP flood event excluding climate change using levels supplied by Waikato Regional Council with flood levels predicted between RL 19.1m to 18.5m.

<u>1% AEP flood event excluding climate – design level</u>

In the *Adare Flood Hazard Report, 10 November 2017,* AWA recommended, in the absence of a model with climate change, that an allowance of 1 metre be added to the flood hazard extents and levels to represent a design level between RL 20.1m to 19.5m as shown in Figure 8.

Further discussions around quantifying the effects of climate change on flood levels is currently ongoing with Hamilton City Council and Waikato Regional Council.

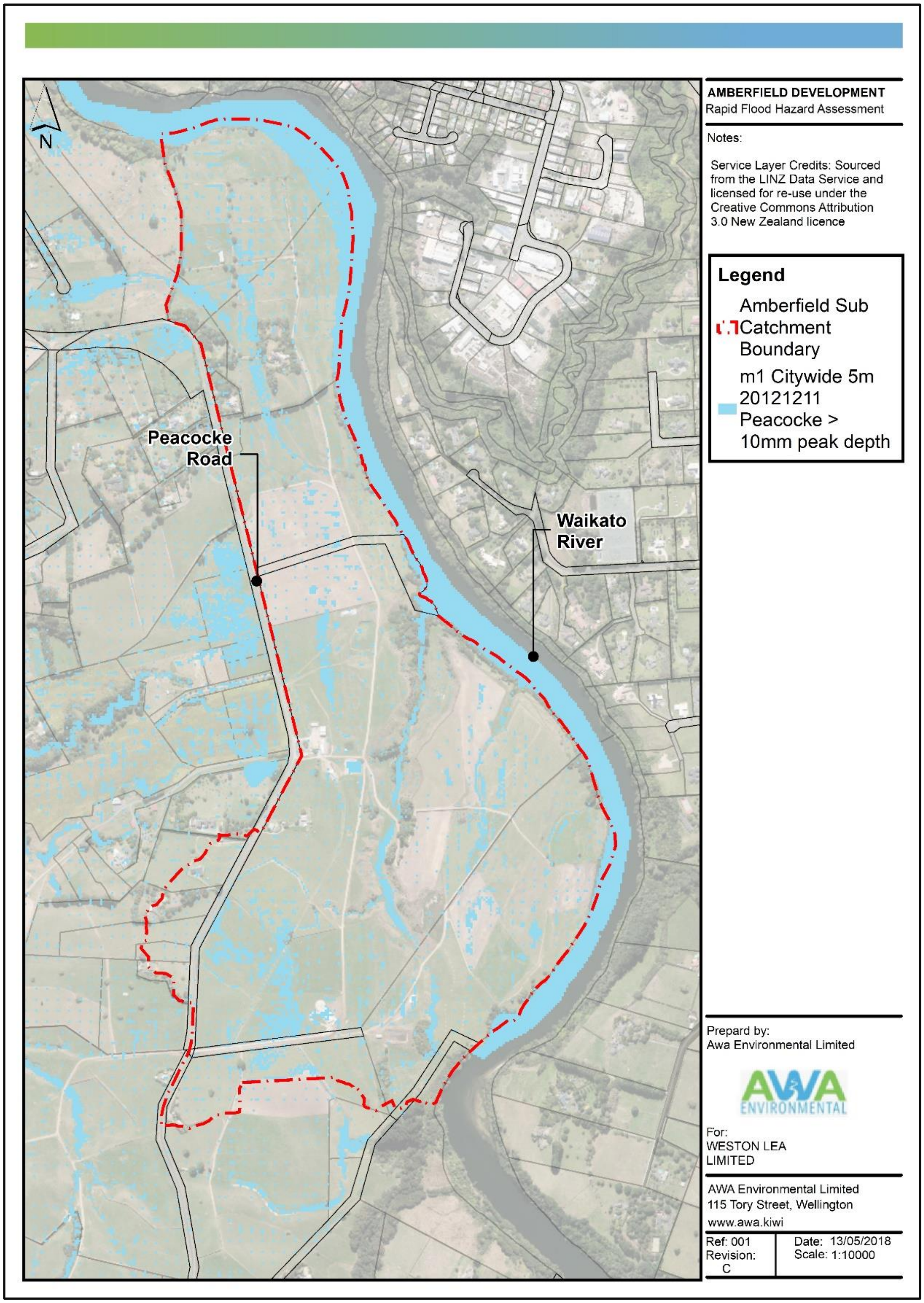

Figure 6 Rapid Flood Hazard Assessment

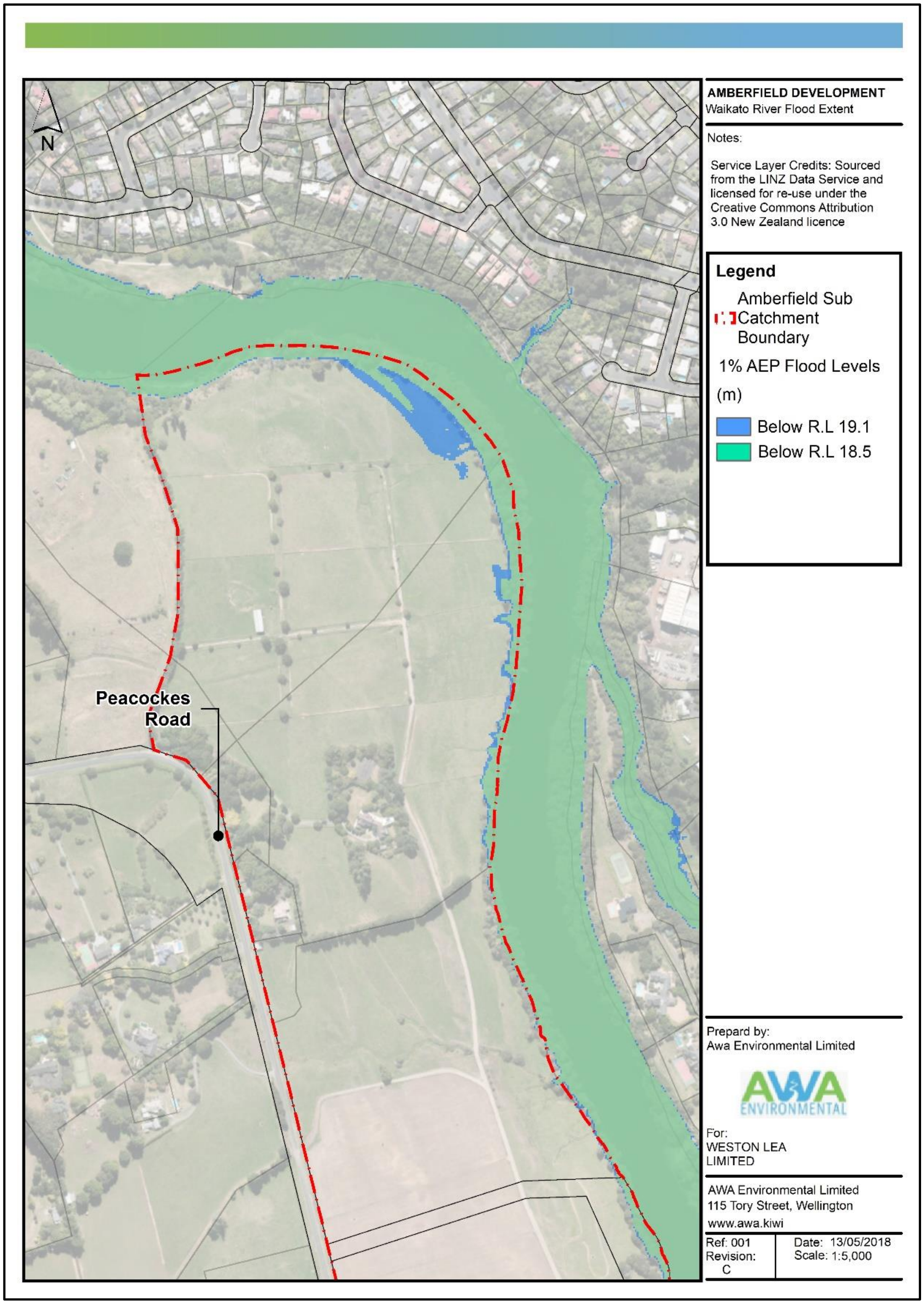

Figure 7 - 1% AEP Flood Extent Excluding Climate Change

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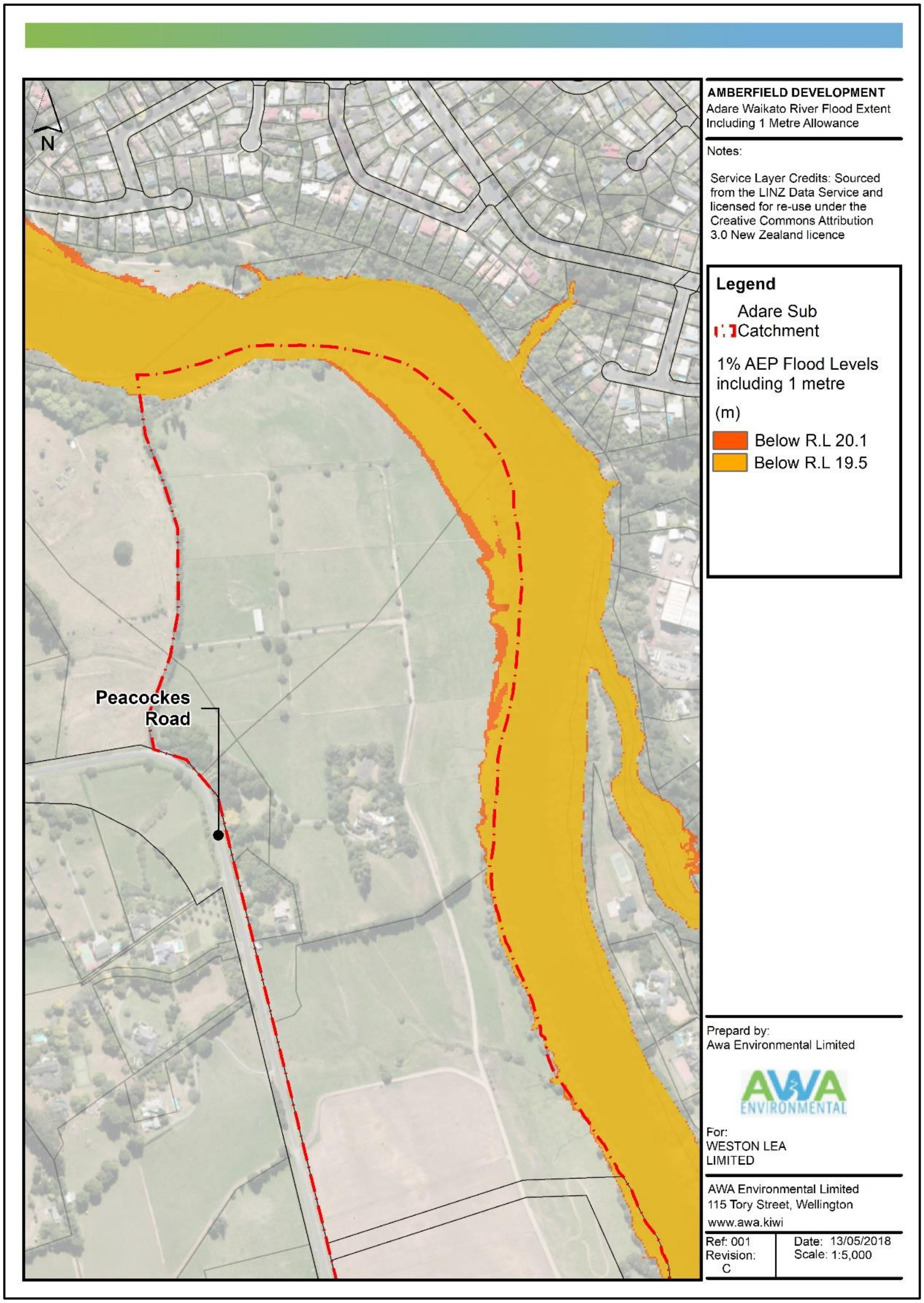

Figure 8 - 1% AEP Flood Extent Excluding Climate Change + 1m Allowance

Karapiro dam break scenario

Waikato Regional Council also supplied flood levels associated with a Karapiro dam break scenario.

The Karapiro dam break cross sections and levels have been taken from the 1989 Works and Development Services Corporation report 'Karapiro Dam: Report on dam break analysis" by G. Webby, which was undertaken for the Electricity Corporation of New Zealand Ltd.

The dam break scenario used was sliding of either of the gravity abutments at the dam leading to catastrophic collapse of the dam structure (assuming a linear failure over 0.1 hours) due to earthquake shaking. An initial lake level of RL 53.25 m was assumed. Mean annual flows were used for the initial conditions between Karapiro and Ngaruawahia (228 cumecs) and Ngaruawahia and Huntly (328 cumecs). The dam burst was modelled to cause peak outflows of approximately 15,400 cumecs.

Levels were modelled using DAMBRK (a numerical finite difference model) over 62 cross sections (from Karapiro to the Huntly Power Station were stage-flow relationships were available for up to 1700 cumecs to inform boundary conditions). Hydraulic roughness values (Manning n) for channels were taken from previous studies or inferred from aerial photographs.

The dam burst flood levels have been extracted from cross-sections located close to the development. The levels grade down between the two locations from predicted RL 27.0 in the South to RL 26.3 in the North as shown in Figure 9.

Waikato Regional Council have indicated that development within the dam break flood extent does not need to be avoided and the likelihood of a dam burst event is considered outside of the planning timeframes, the information is held primarily for emergency response purposes. This is in line with AWA's experience as we would consider it would be very unusual for a dam break scenario on a major dam to be the driver for setting the extent of residential development.

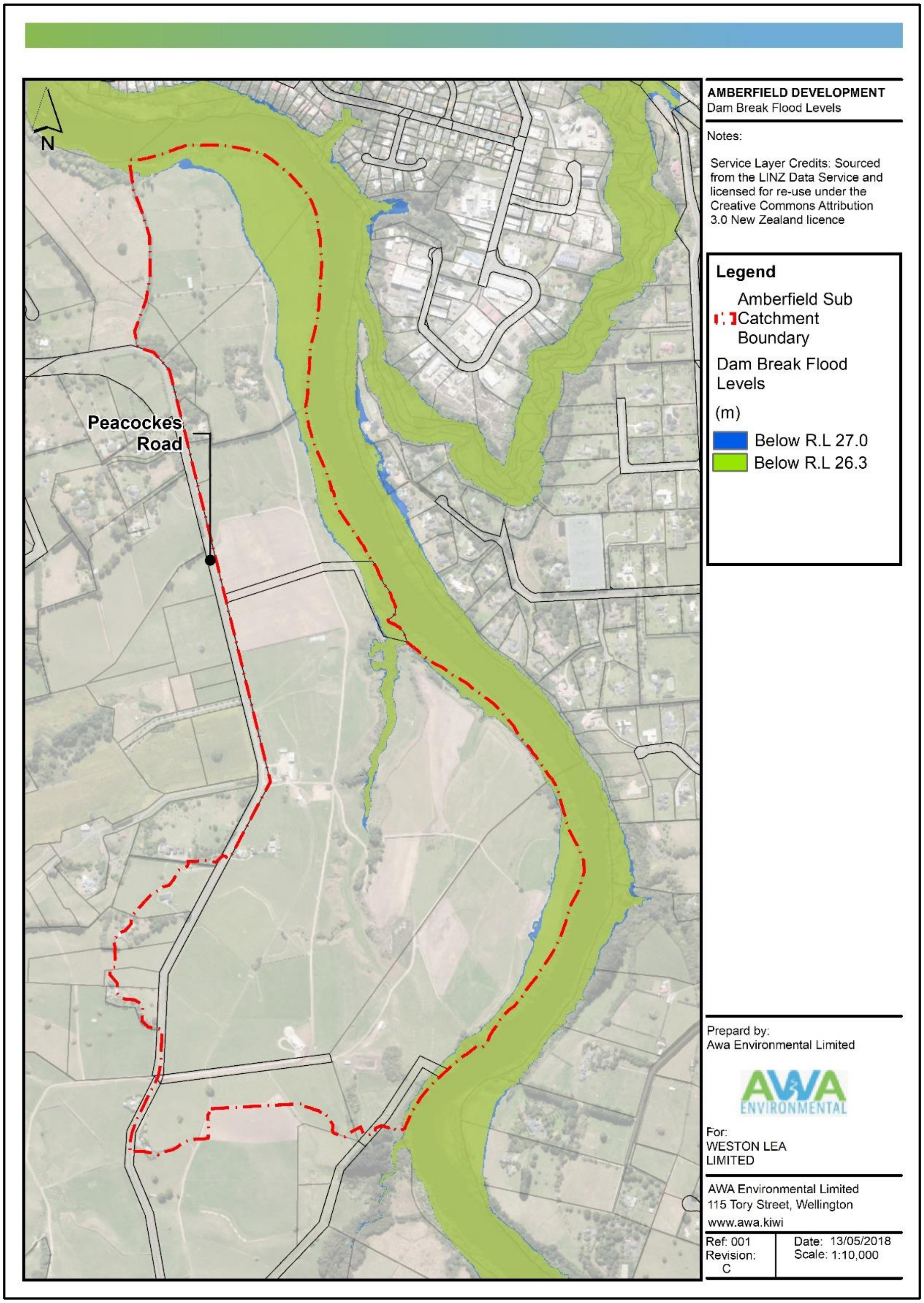

Figure 9 Karapiro Dam Break Extent

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3.3 Modelled Flood Hazard – Existing

Modelling results of the present climate for assessing pre-development flows indicates the site will be affected by flooding in the 100 Year ARI event.

Overall, flooding is largely contained within the watercourse channels with the numerous culverts throttling the flow as shown in Figure 10.

The main area of flooding within the sub-catchment occurs adjacent to Peacockes Road and is a function of localised low topography, localised catchment discharges, upstream catchment overflows and restrictions within the open channel network.

Survey of Peacockes Road identified a number of culverts running parallel to the Road under driveway access points. During survey no culverts were identified running under Peacockes Road connecting both sides of the road side drainage. Stormwater information supplied by Hamilton City Council indicates a 225mm diameter culvert may exist under Peacockes Road. While this culvert has not been included in the model the impacts of such a small culvert on flood depths and extents are likely minor as the low-lying area on the East of Peacockes Road has sufficient volume to fill and spill over the Road to the West in four locations as shown in Figure 11.

The Waikato River flood hazard has been supplied by the Waikato Regional Council in the form of maximum water levels in the vicinity of the sub-catchment for the 1% AEP event excluding climate change. The maximum water levels range from RL 17.32m in the Southern extent of the site to RL 16.86 m in the Northern extent of the site. At these levels tail water effects on the streams within the site entering the Waikato River are minimal as the streams are elevated well above these levels before dropping steeply to the Waikato River.

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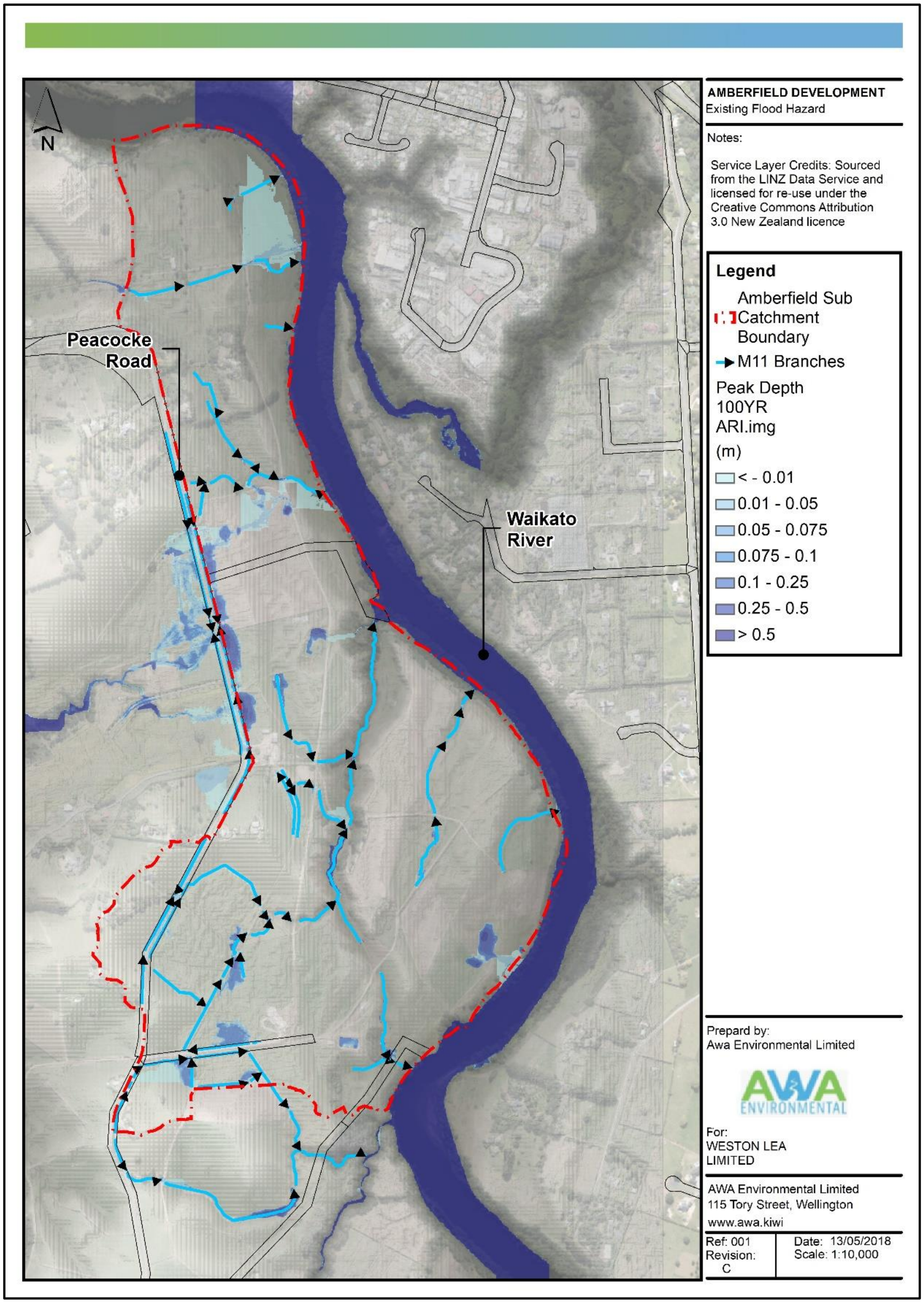

Figure 10 Existing Modelled Flooding – Peak Depth

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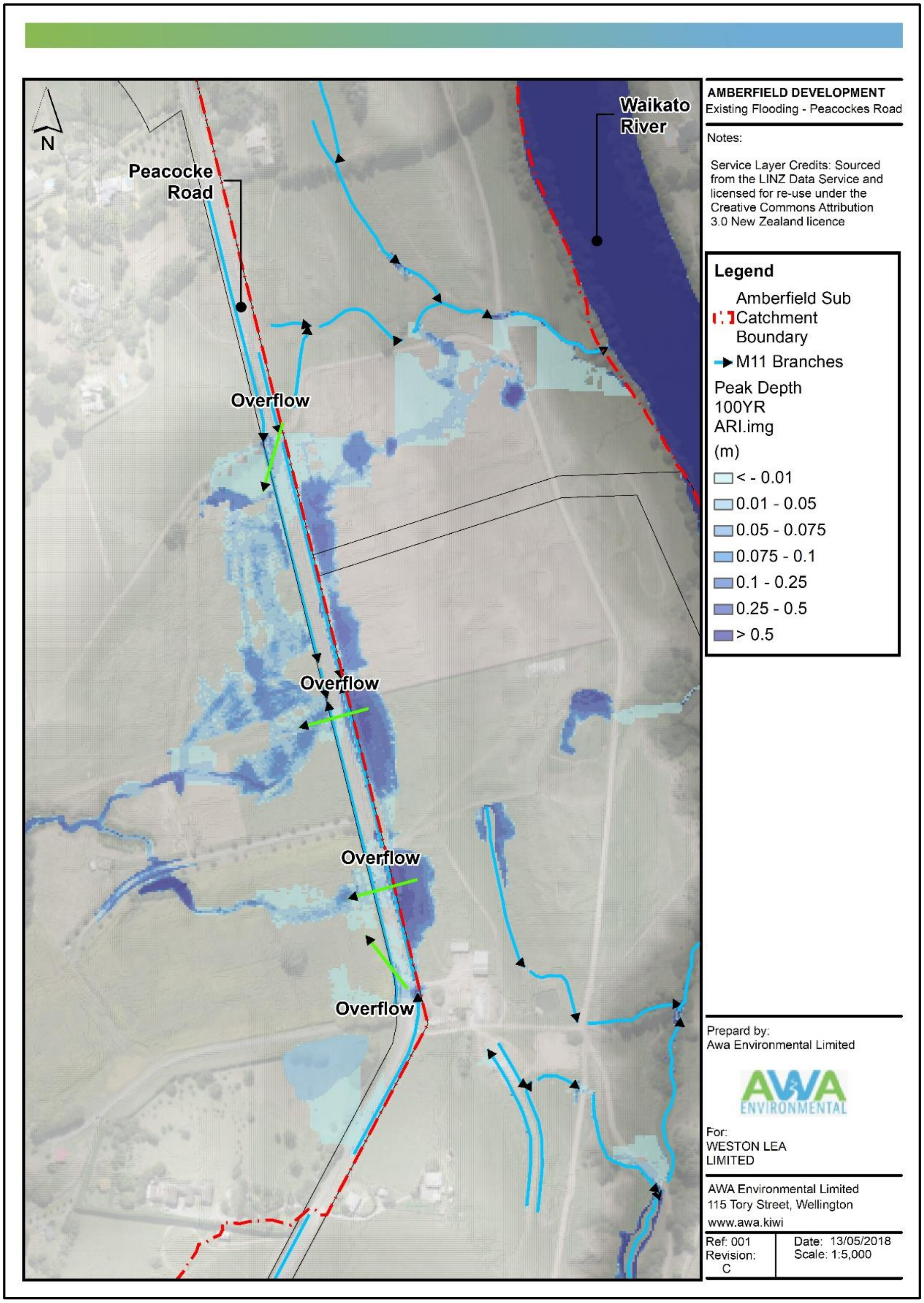

Figure 11 Existing Modelled Flooding – Peak Depth – Peacockes Road

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4 Summary

Modelling results show the site is affected by flooding in the existing scenario. However, flooding is largely contained within the watercourses, with the exception of the area adjacent to Peacockes Road where flooding is a function of localised low topography, localised catchment discharges, upstream catchment overflows and restrictions within the open channel network.

Various flood levels for the Waikato River have been provided by Waikato Regional Council. These levels do not include Climate Change which would likely increase flood levels and extents. AWA recommended, in the absence of a model with climate change, that a conservative allowance of 1 metre be added to the flood hazard extents and levels to represent a design level between RL 20.1m to 19.5m.

Taking into consideration this 1 metre conservative allowance will result in the Northern extent of the site, adjacent to the Waikato River, potentially affected by flooding from the Waikato River. Any development within this area will need to ensure developed ground levels are above flood levels.

Soakage testing has returned moderate to good soakage results across the site. This will enable soakage to be used as the primary stormwater disposal method in accordance with Hamilton City Council's Infrastructure Technical Specifications (ITS) for stormwater, HCC, 2016.

5 MIKE FLOOD model build

5.1 Modelling Software

The hydraulic model has been developed using MIKEFLOOD software by DHI. Overland flow has been modelled using MIKE21 Classic Grid with a 2 metre grid sizing. The culvert and open channel networks have been modelled using MIKE11.

5.2 Data

5.2.1 Asset Data

The 1D culvert network in the model is primarily based on survey data supplied by Harrison Grierson. Some stormwater network asset information contained within the supplied Hamilton City GIS data has also been included in the model.

5.2.2 Survey Data

Open channel cross sections and culvert data were surveyed by Harrison Grierson. This data has been incorporated into the MIKE11 and MIKE21 models.

5.2.3 Topographical Data

A 2m x 2m LiDAR derived digital elevation model (DEM) was generated for use in the model. The DEM has been derived from two sources;

- LiDAR flown in 2010 for Hamilton City Council.
- LiDAR flown in 2017 by Harrison Grierson

Lidar from both Hamilton City Council and Harrison Grierson has been merged to create a hybrid bathymetry. This hybrid bathymetry combines the most accurate aspects of both data sources. The HCC LiDAR provides accuracy in the gully areas where thick vegetation is encountered, in these areas the HGC UAV data is less accurate. The HGC UAV LiDAR provides accuracy in open areas where any changes to topography since 2017 will be captured.

Interrogation of the two DEM's shows the HCC DEM is consistently higher than the HGC UAV DEM except in areas where there is thick vegetation, which is mostly in the gullies. A hybrid DEM has been created by taking the minimum value of both DEM's. This has the advantage of capturing the most recent changes to ground levels on non-vegetated areas of the site while still maintaining accurate data within the gullies.

The HCC LiDAR derived DEM is shown in Figure 12 and the HGC UAV LiDAR derived DEM is shown in Figure 13. The difference between the DEM's, HGC UAV DEM minus HCC DEM, shows the HGC UAV DEM is higher in the gully and vegetated areas, see Figure 14. The final hybrid DEM is shown in Figure 15.

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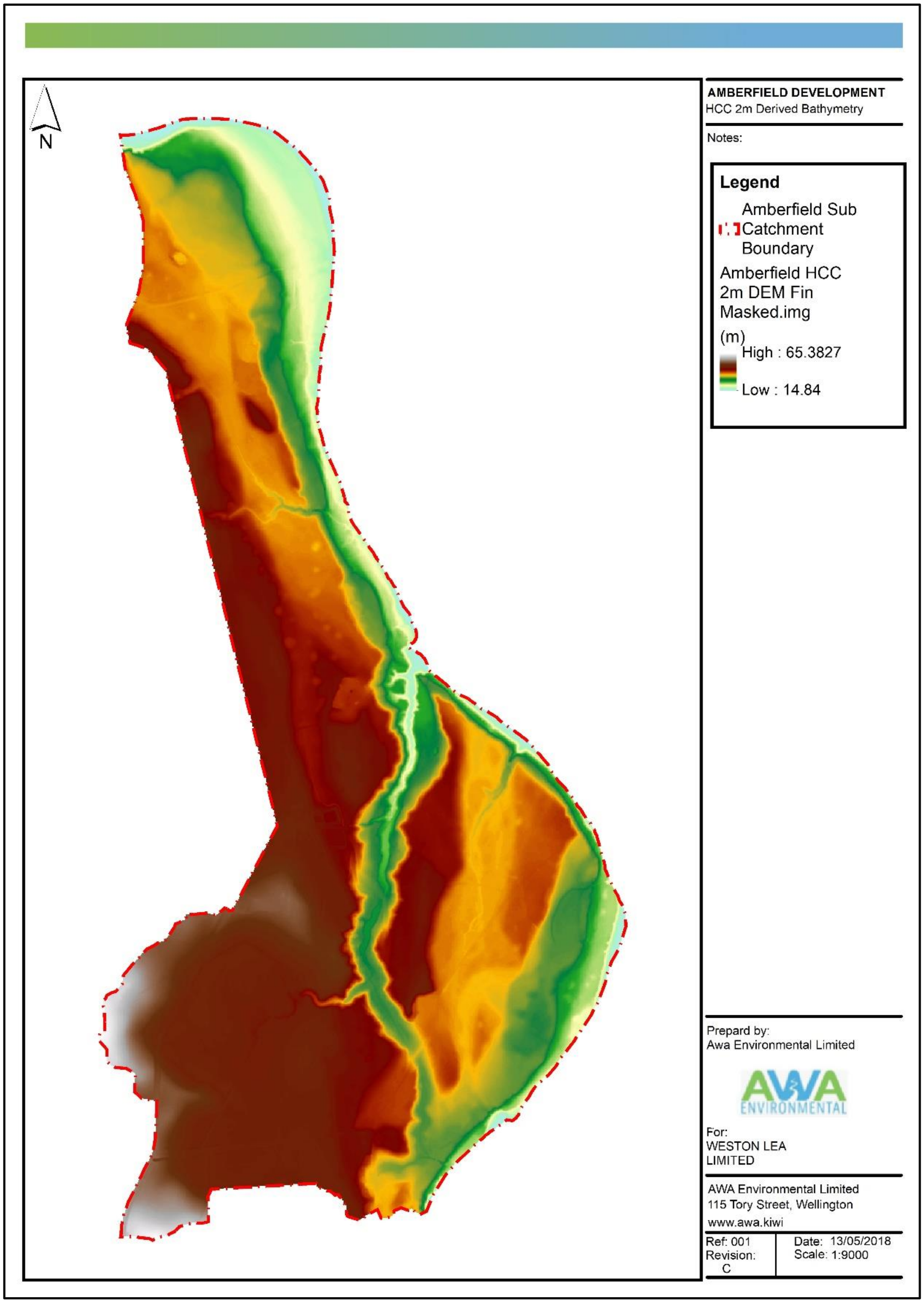

Figure 12 HCC LiDAR Derived DEM

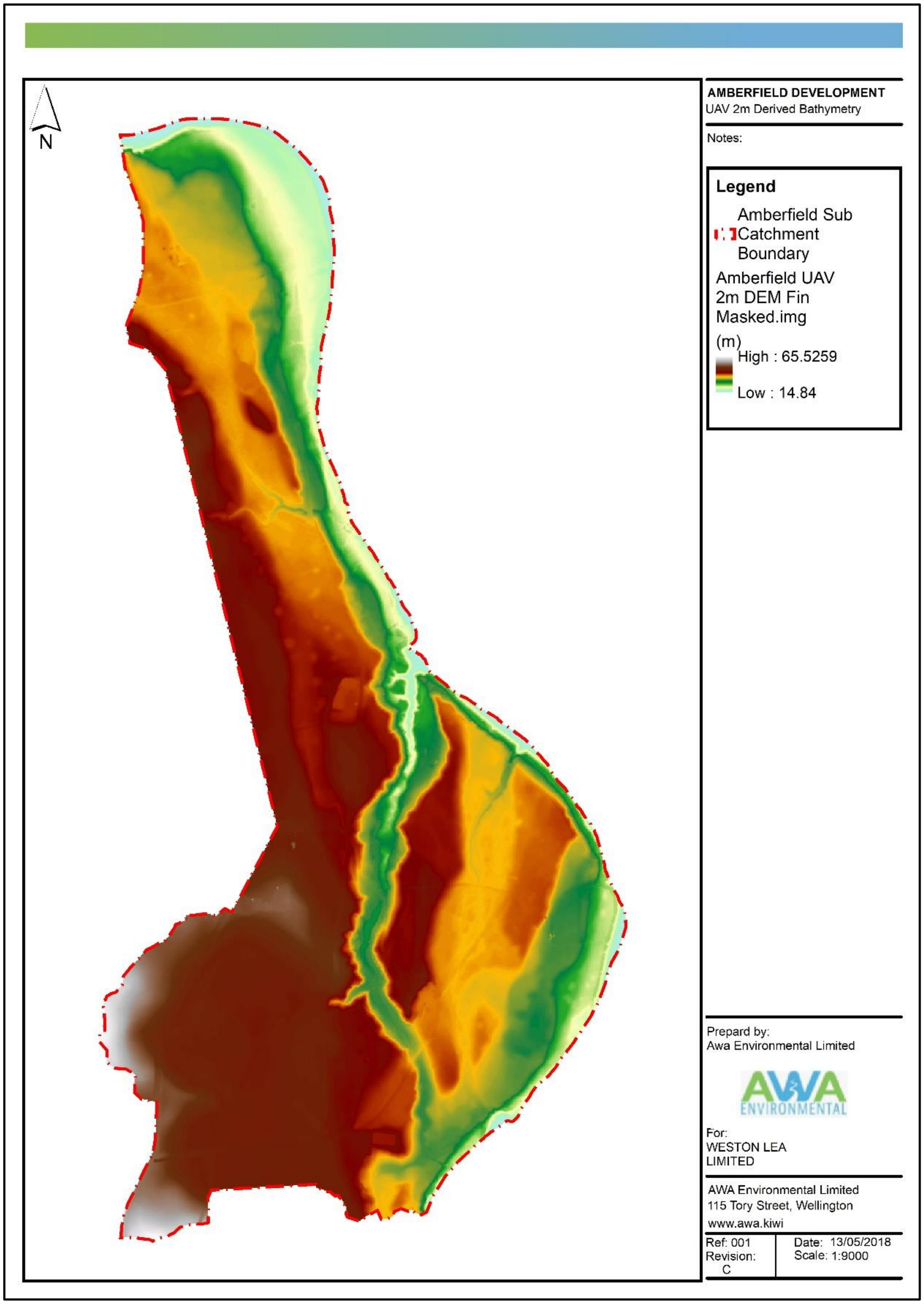

Figure 13 HGC UAV LiDAR Derived DEM

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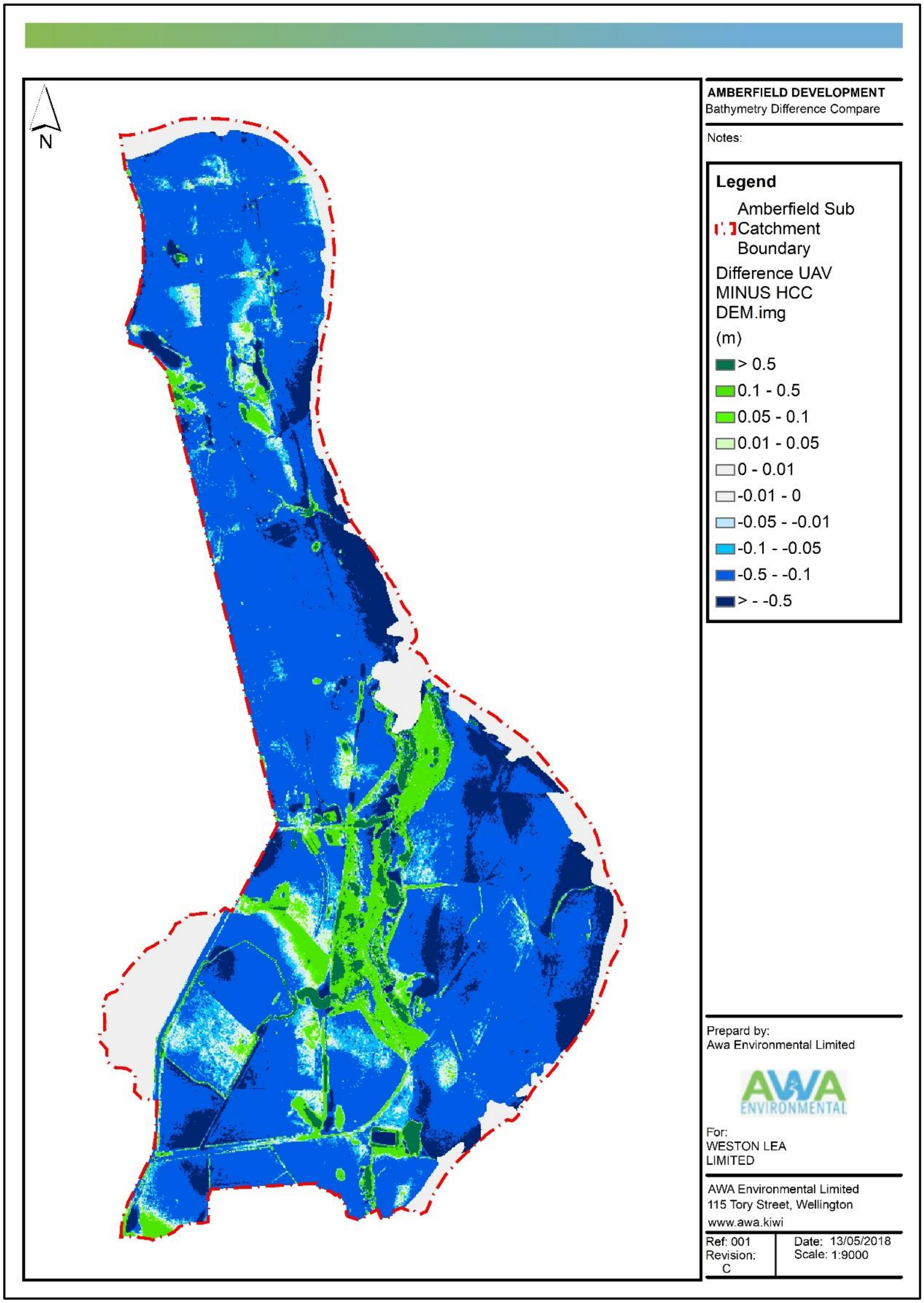

Figure 14 Elevation Difference

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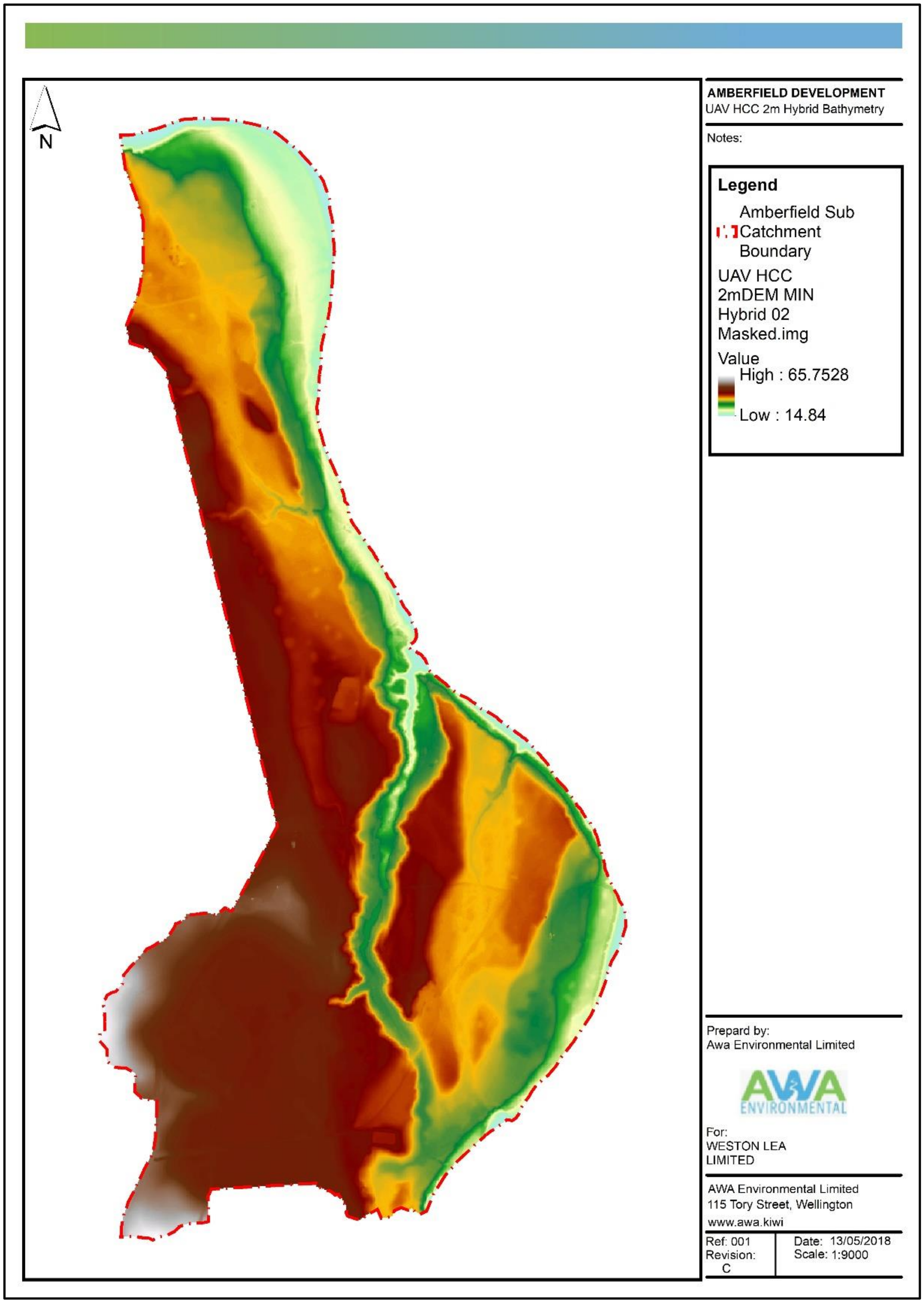

Figure 15 Hybrid DEM

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5.2.4 Site-specific Data

A site walkover was undertaken by Awa Environmental Ltd staff to resolve errors, anomalies and omissions in the stormwater network data.

5.2.5 Hydrologic/Hydrometric Data

RAINFALL DEPTH

Rainfall depth data for the modelled design storm for the present climate has been obtained from Hamilton City Council's **Infrastructure Technical Specifications (ITS) for Stormwater** design requirements which derives rainfall design data from the Ruakura rainfall gauge as shown in Table 1.

The modelling of the "existing" scenario which represents the present climate for assessing pre-development flows uses the 100-year ARI rainfall depth.

Table 1 Present Climate Design Storms

Present Climate – For Assessing Pre - Development Flows			
Ruakura Design Storms, 1947-2006 Climate			
Start time hh:mm	Time Interval min	100-year ARI	
		Depth (mm)	Intensity (mm/h)
0:00	360	13.7	2.3
6:00	180	11.5	3.8
9:00	120	9.8	4.9
11:00	30	6.0	11.9
11:30	15	7.8	31.2
11:45	5	4.4	52.4
11:50	5	5.9	70.8
11:55	10	21.8	130.6
12:05	5	5.9	70.8
12:10	5	4.4	52.4
12:15	15	7.8	31.2
12:30	30	6.0	11.9
13:00	120	9.8	4.9
15:00	180	11.5	3.8
18:00	360	13.7	2.3
24:00			
		139.7	

WAIKATO WATER LEVELS

Waikato River water surface levels were obtained from Waikato Regional Council. The levels provided are derived from the 2009 hydraulic model and represent maximum levels, excluding climate change as shown in Table 2. The location of the water surface levels is shown in Figure 16.

Table 2 Flood Levels

Flood Levels (m in terms of Moturiki 1953 Vertical Datum)	
	2009 hydraulic model (maximum level, excluding climate change)
	1 % AEP
Cross-section	
157A	17.32
157	17.17
156A	17.06
156	16.97
155A	16.86
155	16.78
154B	16.69
154A	16.64
154	16.55
153B	16.46

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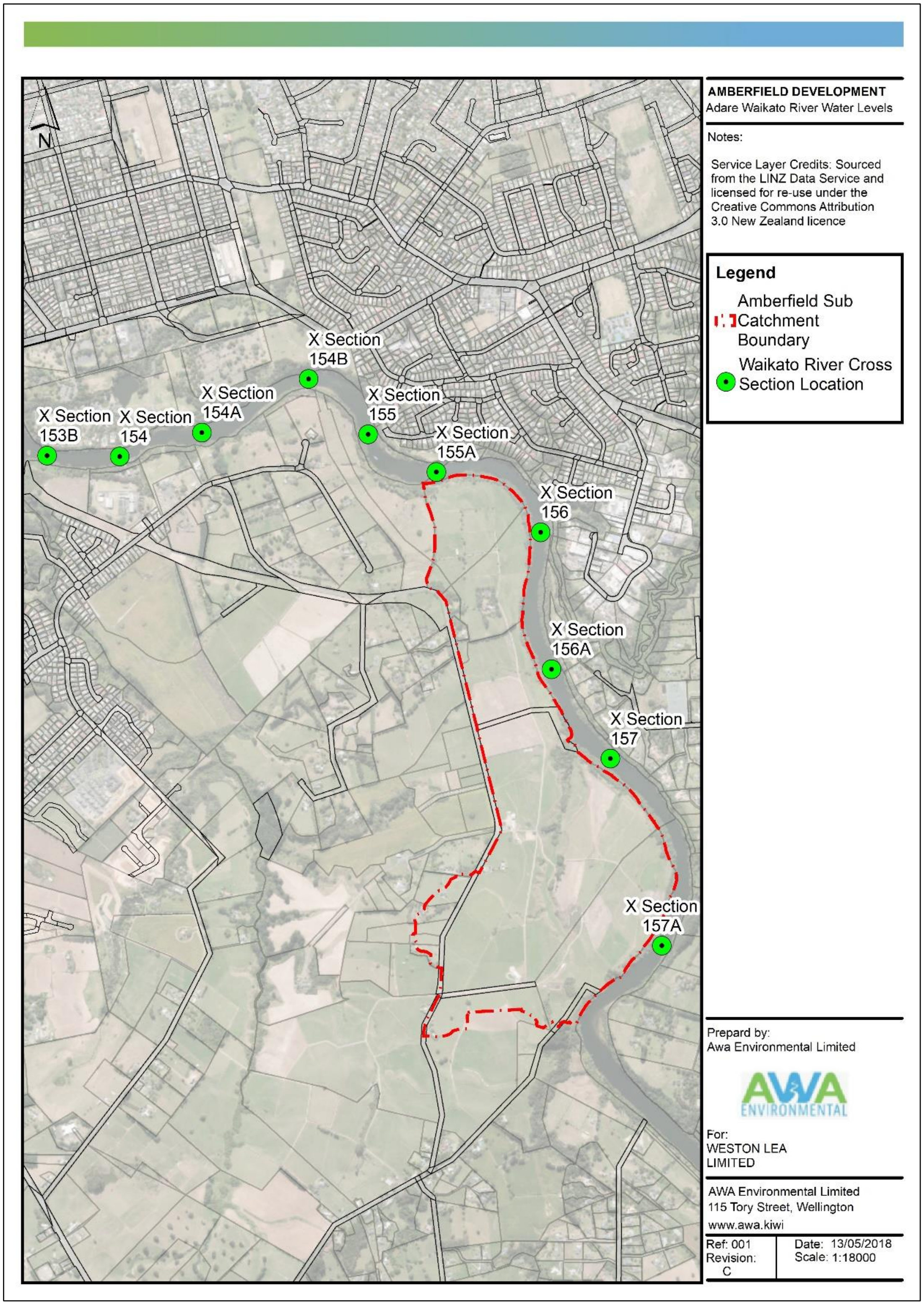

Figure 16 Waikato River Water Surface Level Locations

6 Hydrological Model

6.1.1 Methodology

Hydrological modelling has been undertaken using the Rational Method in accordance with *Hamilton City Council's Infrastructure Technical Specifications (ITS) for Stormwater* and *Acceptable Solutions and Verification Methods for New Zealand Building Code Clause E1 Surface Water*.

6.1.2 Rainfall – Runoff model

Key parameters of the Rational Method approach include;

- run-off coefficient for a land-use,
- rainfall intensity
- catchment area
- time of concentration

A run-off coefficient grid was created with parameters spatially varying depending on connected impervious area, ground cover and soil classification.

Sub-catchment parameters use an area weighted mean of the losses and assume medium soakage soil types.

6.1.3 Sub-catchment delineation

Sub-catchments have been delineated for each culvert and open channel using the ArcGIS Hydrology Toolkit. This approach allows the discharges from the hydrological model to be widely distributed across the hydraulic model.

The study area has been delineated into 99 sub-catchments, as shown in Figure 17.

6.1.4 Runoff Coefficients

Runoff Coefficients have been derived from;

- UAV aerial photography flown in 2017.
- Land Cover Database V4.1 (LCDBV4.1)
- Soils map (NZFSL class Drainage)

Each identified land-use type has been attributed with a runoff coefficient, as shown in Figure 18, derived from the document *Acceptable Solutions and Verification Methods for New Zealand Building Code Clause E1 Surface Water*, as shown in Table 3.

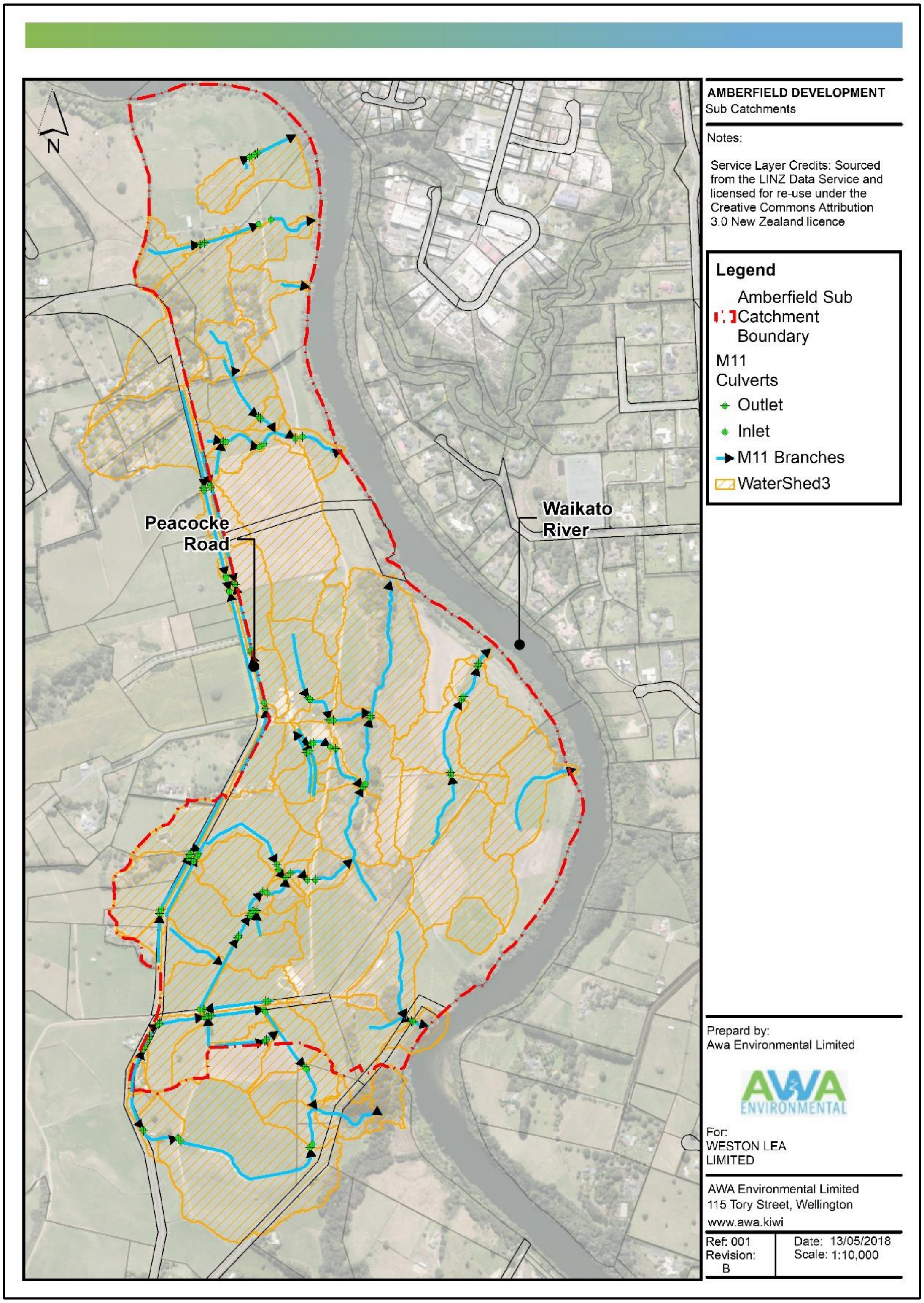

Figure 17 Delineated sub-catchments

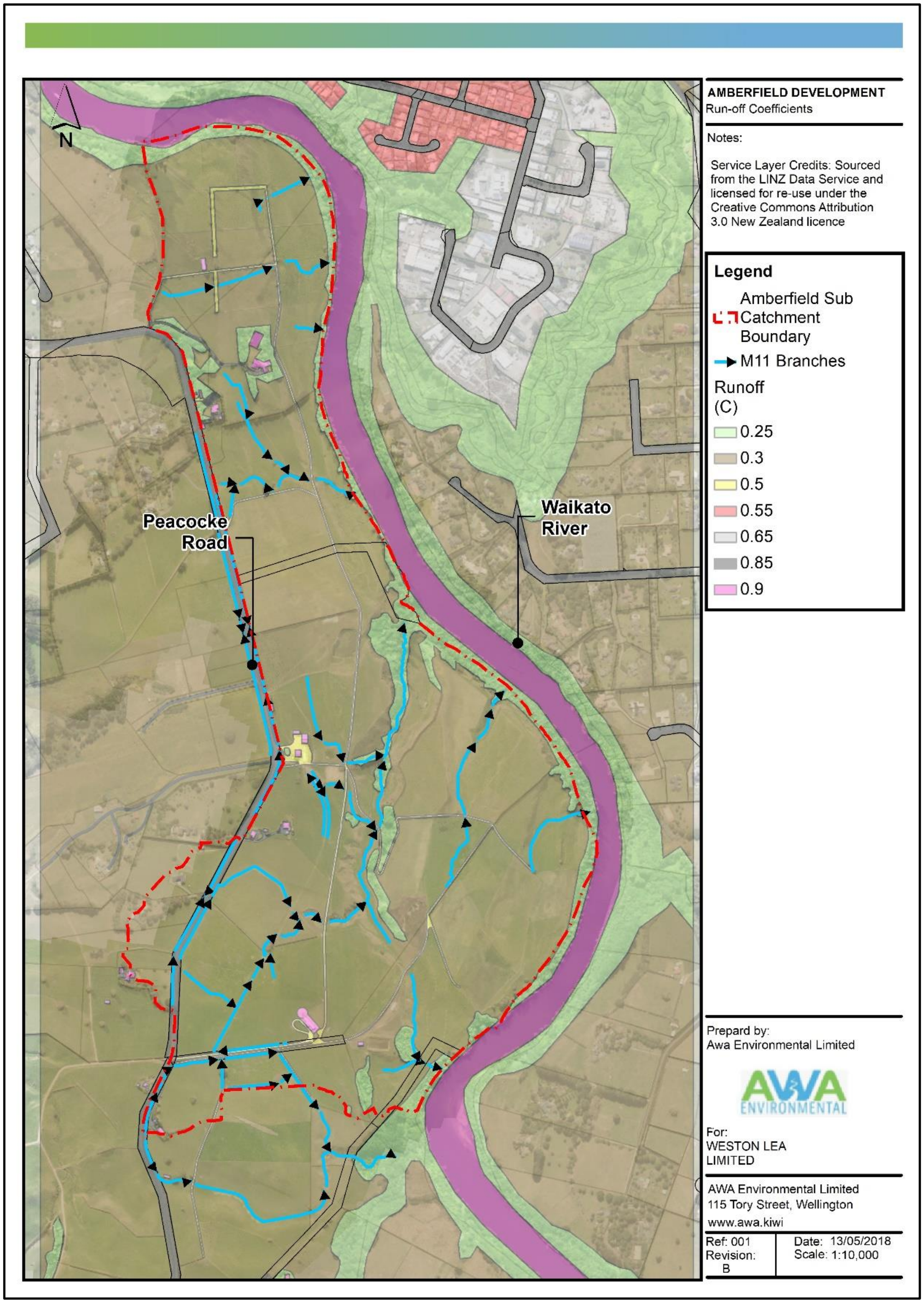

Figure 18 Run-off Coefficients – Existing

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Table 3 Run-off Coefficients

Surface Type	Run-off Coefficients
MEDIUM SOAKAGE SOIL TYPES	
Pasture and scrub cover	0.30
Bush and scrub cover	0.25
Fully roofed and/or sealed developments	0.90
Unsealed roads	0.50
Residential areas (36% to 50%)of gross area	0.55
Industrial, commercial areas	0.65
Asphalt and concrete paved surfaces	0.85

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6.1.5 Time of Concentration

The time of concentration in each sub-catchment has been calculated using the following equations:

$$Time\ of\ Overland\ Flow = \frac{107nL^{0.333}}{S^{0.2}}$$

Where:

- flow is in minutes,
- n is Horton's roughness value for the surface,
- L is length in metres (m),
- S is slope in percentage (integer i.e 3.0 for 3%).

$$Time\ of\ Shallow\ Concerntated\ Flow = \frac{L}{295\ S^{0.5}}$$

Where:

- flow is in minutes,
- L is length in metres (m),
- S is slope in metres per metre (m/m).

$$Time\ of\ Gutter\ Flow = 0.025\frac{L}{S^{0.5}}$$

Where:

- flow is in minutes,
- L is length in metres (m),
- S is slope in percentage.

The time of overland flow has been applied over a maximum distance of 50m. The shallow concentrated flow equation has been applied over a maximum distance of 100m starting from the end of the overland flow component. The kerb flow equation has been applied from the point where the flow path enters the road as identified from the roughness layer or from the end of the shallow concentrated flow component.

An example of the outputs from the time of concentration equations is shown in Figure 19.

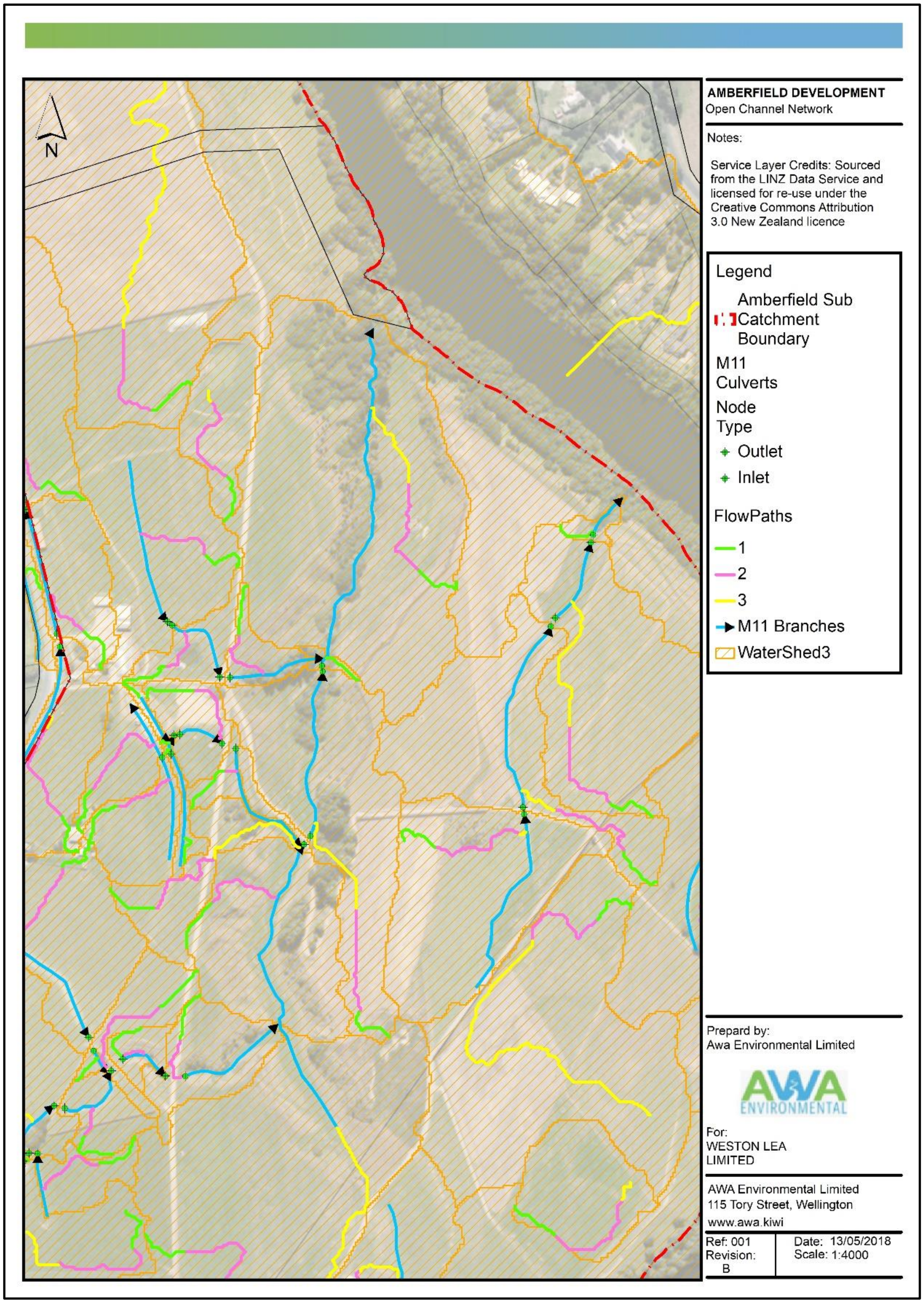

Figure 19 Time of Concentration Calculations

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6.2 Hydraulic Model

A coupled 1D and 2D hydraulic model has been developed in MIKEFLOOD to represent flow interchanges between the 1D pipe network, 1D open channels and the 2D surface.

6.2.1 2D Model

The MIKE 21 Classic Grid 2D model is used to describe overland flow within the catchment.

The 2m x 2m DEM was processed using the ArcGIS Hydrology toolbox to develop watershed boundaries. The resulting watershed boundaries were used to determine the extent of the model.

6.2.1.1 Surface Roughness

A surface roughness grid for use in the MIKE21 model was created by applying the values shown in Table 4 to the various ground cover types as identified in the aerial photography.

Table 4 Surface Roughness

Surface Type	Manning's N
Bare earth Areas	0.0275
Grass/Pasture Areas	0.045
Scrub/Brush Areas	0.060
Road Areas	0.015

The resulting grid for the existing scenario is shown in Figure 20.

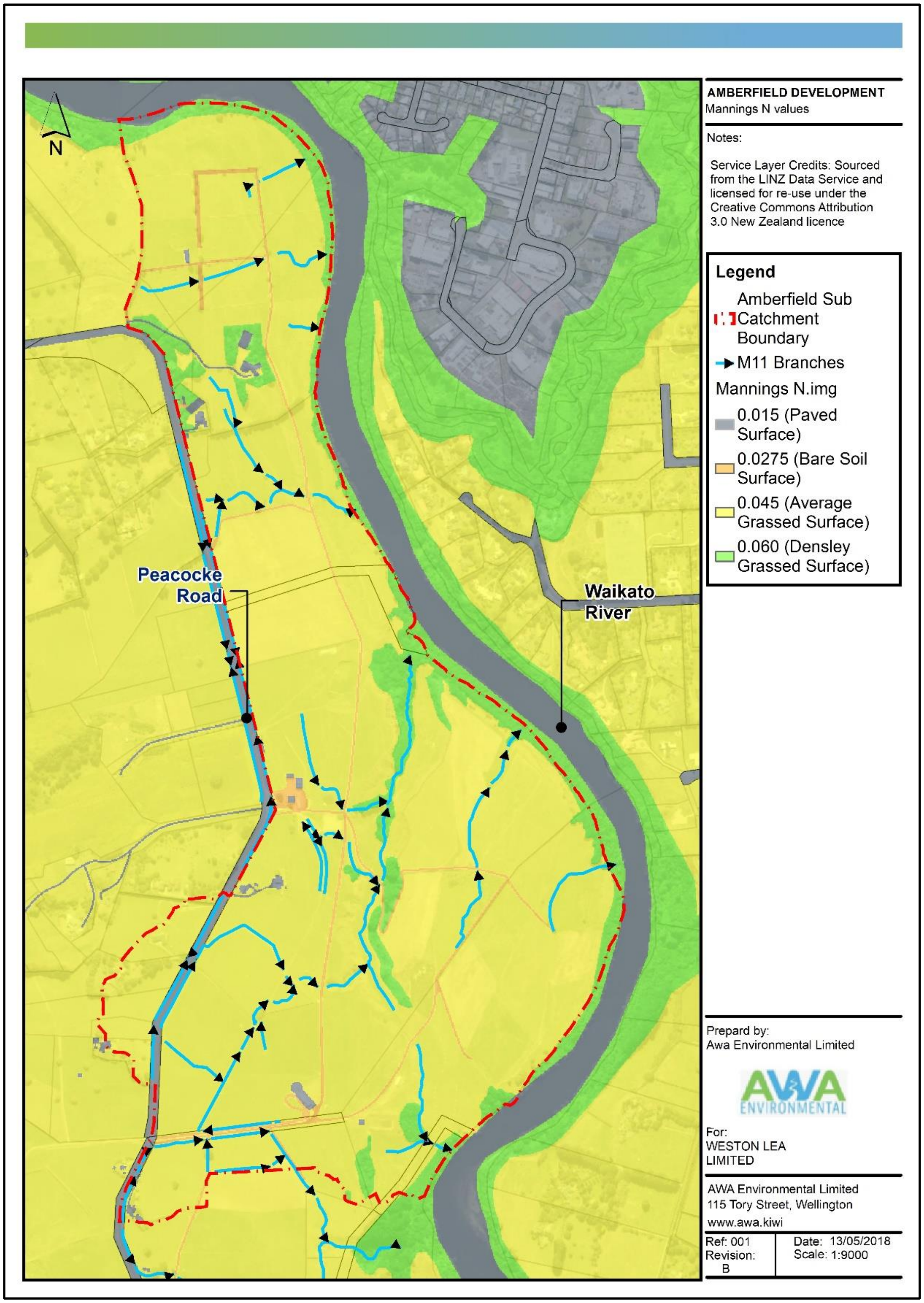

Figure 20 Surface Roughness Layer – Existing

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6.2.1.2 Boundaries

Constant water level boundaries have been applied to the MIKE21 model at either end of the Waikato River and along the western edge of the model extent where overland flow leaves the study area, as shown in Figure 21 and Table 5. Boundaries 1 and 2 were included in the model to allow water to flow overland out of the study area.

An initial surface level layer that covers the Waikato River was created by interpolating the peak water levels between Boundaries 3 and 4. The levels of boundaries of 3 and 4 were taken from the 100-year ARI event as supplied by Waikato Regional Council. As the boundaries use a constant (peak) water level the model represents the situation where the peak discharge from the study area coincides with the peak level in the Waikato River.

Table 5 Water level boundaries

Surface Type	Manning's N
Boundary 1	35.79
Boundary 2	37.5
Boundary 3	16.86
Boundary 4	17.32

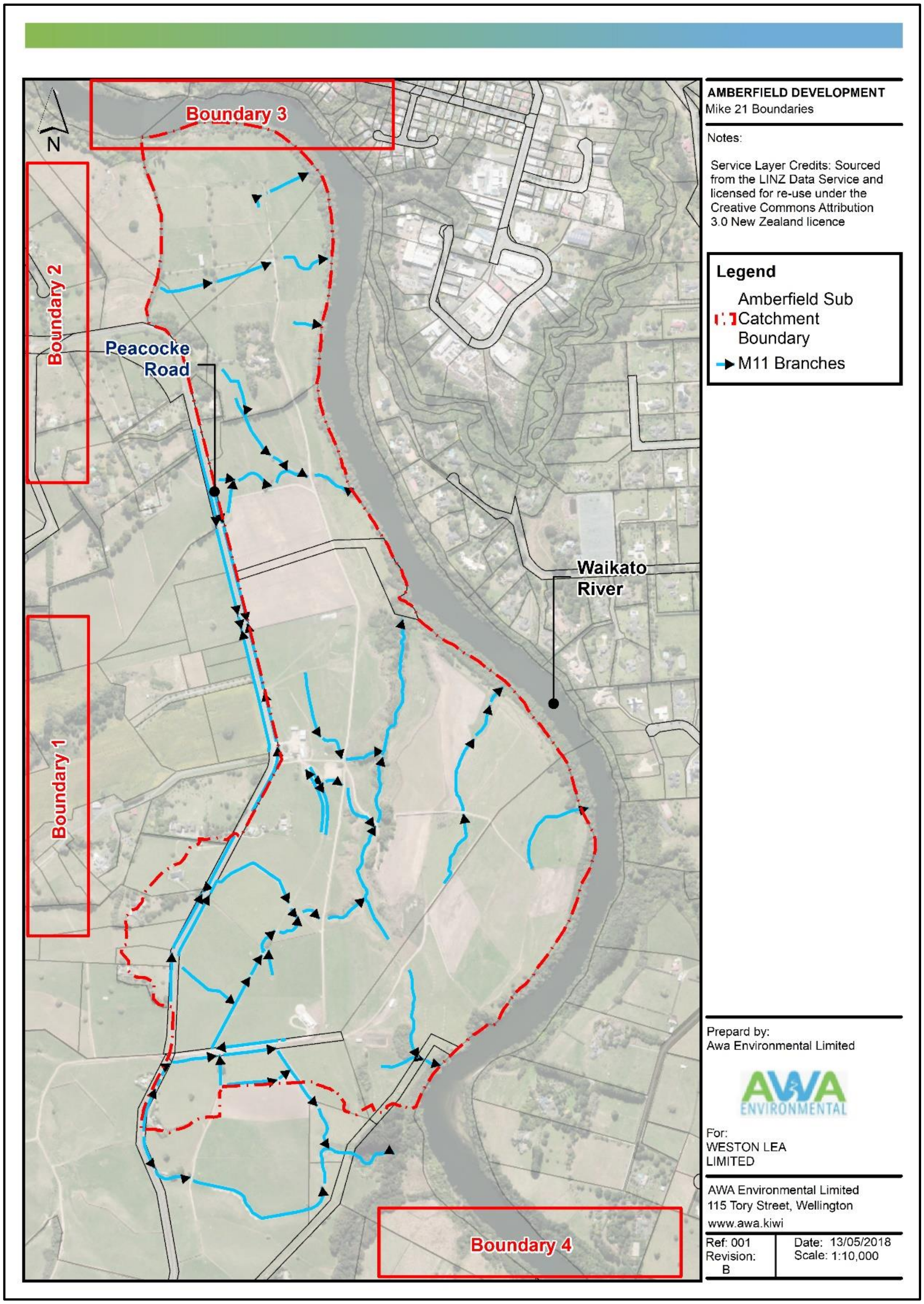

Figure 21 Location of Constant Water Level Boundaries

6.2.2 MIKE 11 model build

The MIKE11 component of the model has been used to represent the open channels within the model extent. The MIKE11 branches have been laterally linked to the MIKE21 model and the tops of the cross sections have been set to align with the ground levels in the MIKE21 bathymetry.

6.2.2.1 Network

The sections of open channel included in the MIKE11 network are shown in Figure 22.

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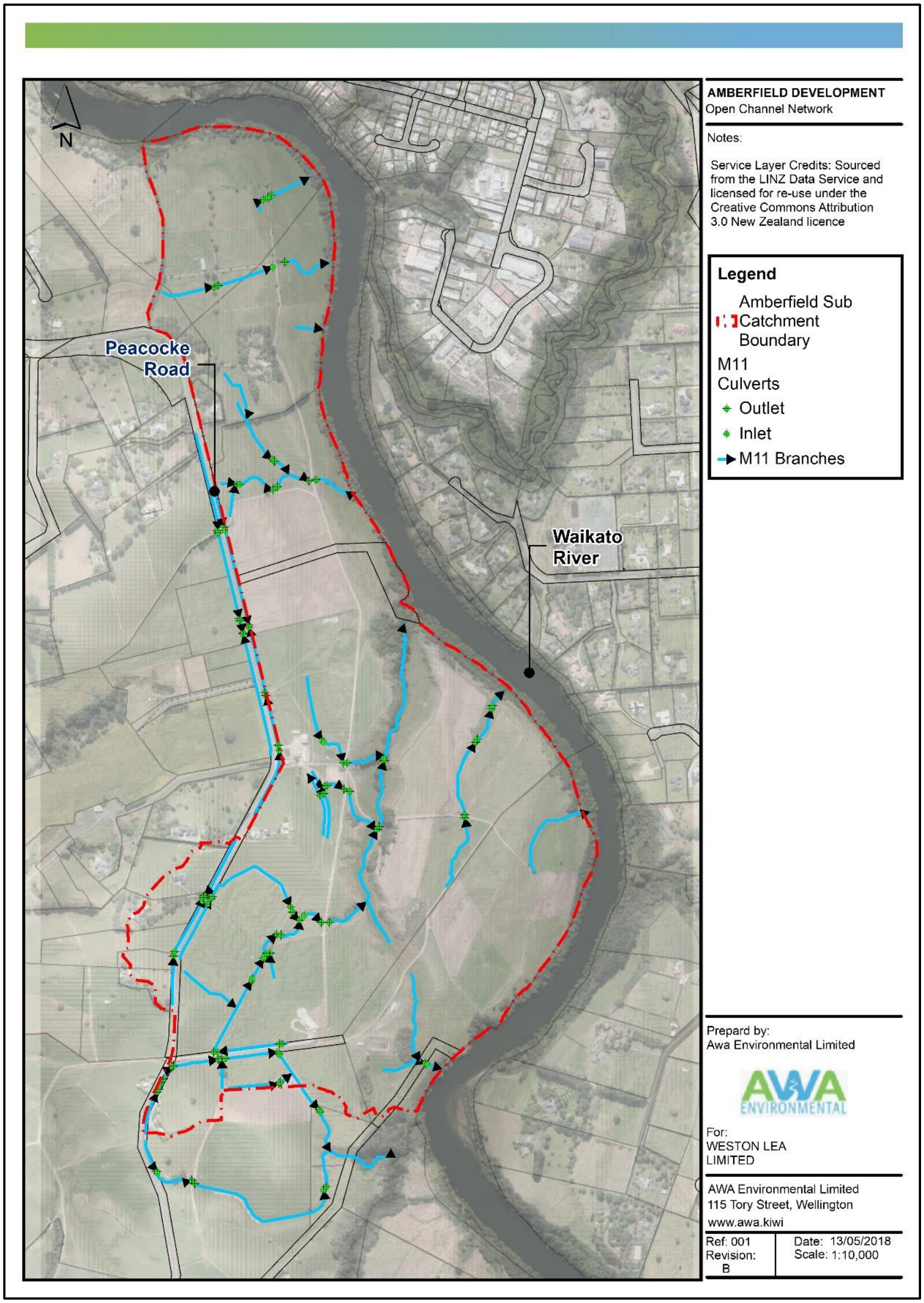

Figure 22 Modelled Open Channels

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6.2.2.2 Cross-sections

Cross section data associated with open channels and farm drains was surveyed by Harrison Grierson. For sections of open channel where no survey existed cross sections have been extracted from the bathymetry. As these sections of open channel are small, uniform and consistent in grade and dimension this approach was considered sufficient to represent the open channel dimensions.

6.2.2.3 Resistance

Uniform bed resistance of Manning's M = 30 has been used for all branches.

6.2.3 Boundaries and model loading.

Inflow and water level boundaries have been applied to the upstream and downstream ends of the section of the Waikato River included in the model.

6.2.3.1 Hydrodynamic parameters

Default values have been used for all other hydrodynamic parameters.

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6.2.4 MIKE URBAN model build

The MIKEURBAN model has been used to simulate the hydraulic processes in isolated catchments which do not connect to the open channel network. In these isolated catchments discharge hydrographs have been loaded into MIKEURBAN loading nodes. These loading nodes allow the hydrograph to discharge onto the MIKE21 surface.

6.2.5 MIKE FLOOD Model coupling

The MIKEFLOOD model is used to dynamically connect the various components (MIKEURBAN, MIKE21 and MIKE11) together. This coupling allows water to transfer between the various components during the simulation.

MIKE21 to MIKE 11 lateral links have been configured as weirs with the weir crest set to the MIKE 21 cell level.

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7 Discussion

7.1 Model Build

The computational accuracy of models is directly affected by the accuracy of the input information they are based upon, and the data available to verify their accuracy. The primary sources of information for this investigation were

- Asset and LiDAR data provided by Hamilton City Council.
- 2017 survey and UAV LiDAR data provided by Harrison Grierson.
- Site visit information collected by Awa Environmental staff.

The constraints and limitations of the stormwater flood model are as follows:

- Large parts of the model are based on LiDAR. Where the quality of the LiDAR is suspect or there have been changes made since the collection of LiDAR the model will not represent actual ground levels.
- Cross sections for a number of the modelled open channels have been generated from the LiDAR data.

7.2 Hydraulic Model Assumptions

The following assumptions have been applied in the development of the hydraulic model:

- The LiDAR generated ground model is an accurate representation of catchment topography;
- Culverts are sediment free;
- Inlets, outlets are sediment free.

8 References

Infrastructure Technical Specifications (ITS) for stormwater, HCC, 2016.

Acceptable Solutions and Verification Methods – For New Zealand Building Code Clause – E1 Surface Water, Amendment 9.

Guidelines for Stormwater Modelling using MikeFlood, DHI, November 2013