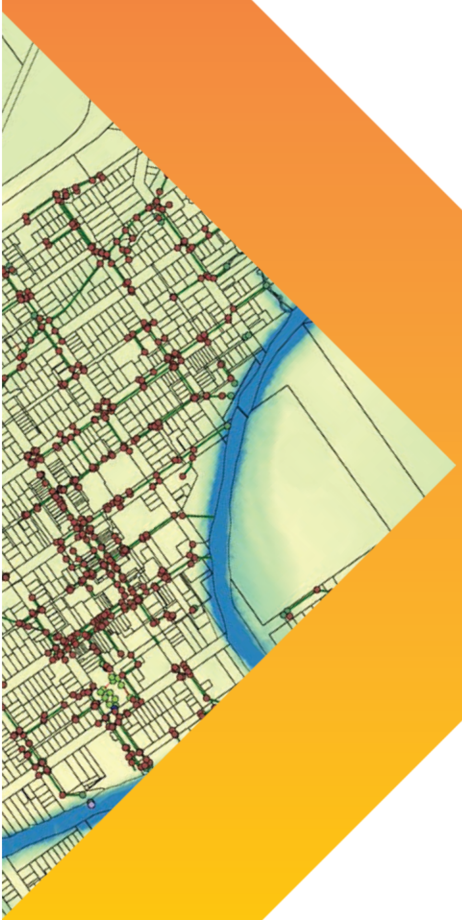
REPORT



68 GRANUAILLE CRESCENT, BANGALOW, NSW

HYDRAULIC ASSESSMENT

Instant Steel Pty Ltd

Contact us to design the sustainable towns and cities of tomorrow.

FLOODWORKS

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Our Ref: FW00007

Date: 10 August 2024

Version 3.0

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Version Register

Version	Status	Author	Reviewer	Change from Previous Version	Authorised for Release	
					Signature	Date
-	Draft	TP	DM		D. Mackenzie	18/10/19
3.0	Final	NT	DM	Existing Case	D. Mackenzie	10/08/24

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1. Introduction

Instant Steel Pty Ltd has requested a hydraulic assessment as part of a proposed Subdivision Development Application for 68 Granuaille Crescent, Bangalow, NSW, Lot 261 DP 1262316, Lot 11DP 807867 (the subject site). The proposed development includes the subdivision of lands into rural lots and associated roads/ancillary development, a bio-basin and a proposed causeway (4/1.2x1.8 RCBC).

The hydraulic assessment will determine the existing landform including the flooded extent, velocity, peak depth and hazard assessment of the subject site.

The key objectives of the project are:

- Reduce flood risk where possible
- Develop a Hydrology model of the catchment to Australian Rainfall and Runoff (ARR2019) methodology
- Calibrate model to Regional Flood Frequency Estimation Tool (RFFE) and anecdotal data
- Construct a base case 1D/2D TUFLOW Hydraulic model of the subject site to ARR2019
- A hydraulics assessment will be undertaken to determine the flooded extent of the subject creek. Additional information will include velocity, peak depth and hazard assessment
- The 1%AEP_CC (100Y ARI+ Climate Change) and PMF (Probable Maximum Flood) design events have been assessed

The principal objective of this hydraulic assessment is to identify existing maximum water levels, maximum depths, maximum hazards and maximum velocities for the subject site. Detailed 1D/2D modelling has been undertaken to confirm the above objectives.

The land area of the subject site (Figure 1) is approximately 4.1ha, with an ephemeral creek running north to south through the eastern portion of the subject site.

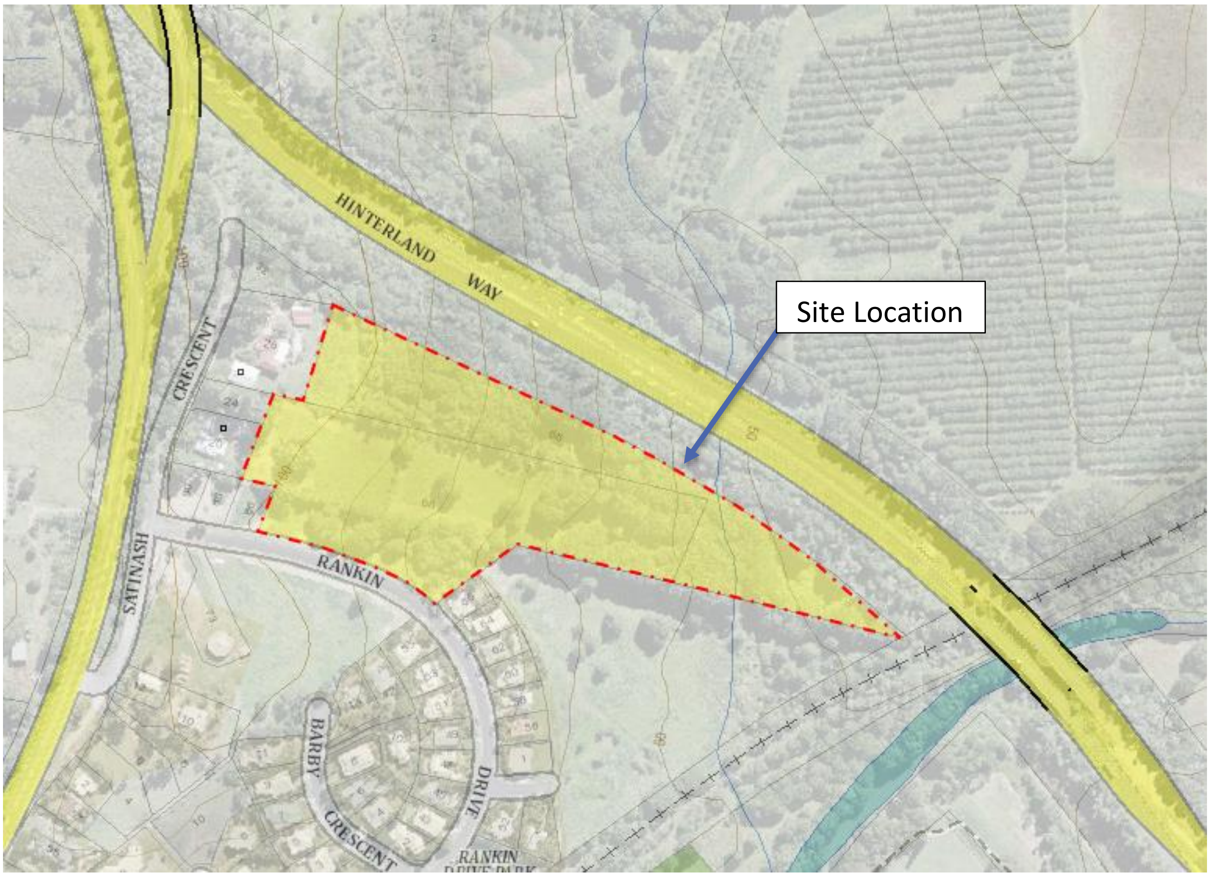

Figure 1 Subject Site

2. Hydrology

2.1. Methodology

The XP-SWMM runoff-routing model has been used to estimate design flood discharges within the study area. The model represents the sub-catchments as a network of nodes linked to either the 1D pipe drainage network or the 2D Digital Terrain Model (DTM) geometric base. The node is defined by its pervious and impervious areas, fraction impervious and average catchment slope. The net rainfall is routed through the network after appropriate losses (initial and continuing) and roughness factors are applied, resulting in a surface runoff hydrograph for each sub-catchment.

The XP-SWMM model was used to estimate the 1% AEP design runoff as per Instant Steel Pty Ltd requirements. The hydrologic assessment has been completed to the Australian Rainfall and Runoff 2019 (ARR2019) methodologies.

A numerical check was performed using the Regional Flood Frequency Estimation model (https://rffe.arr-software.org/) and compared to the XP-SWMM results.

2.2. Hydrologic Model

2.2.1. Configuration

Figure 2 illustrates the extent of the XP-SWMM model. The contributing catchment was modelled as 7 sub-catchments with a total area of 58.6ha. These sub-catchments were delineated to represent the inflow location within the subject site accurately.

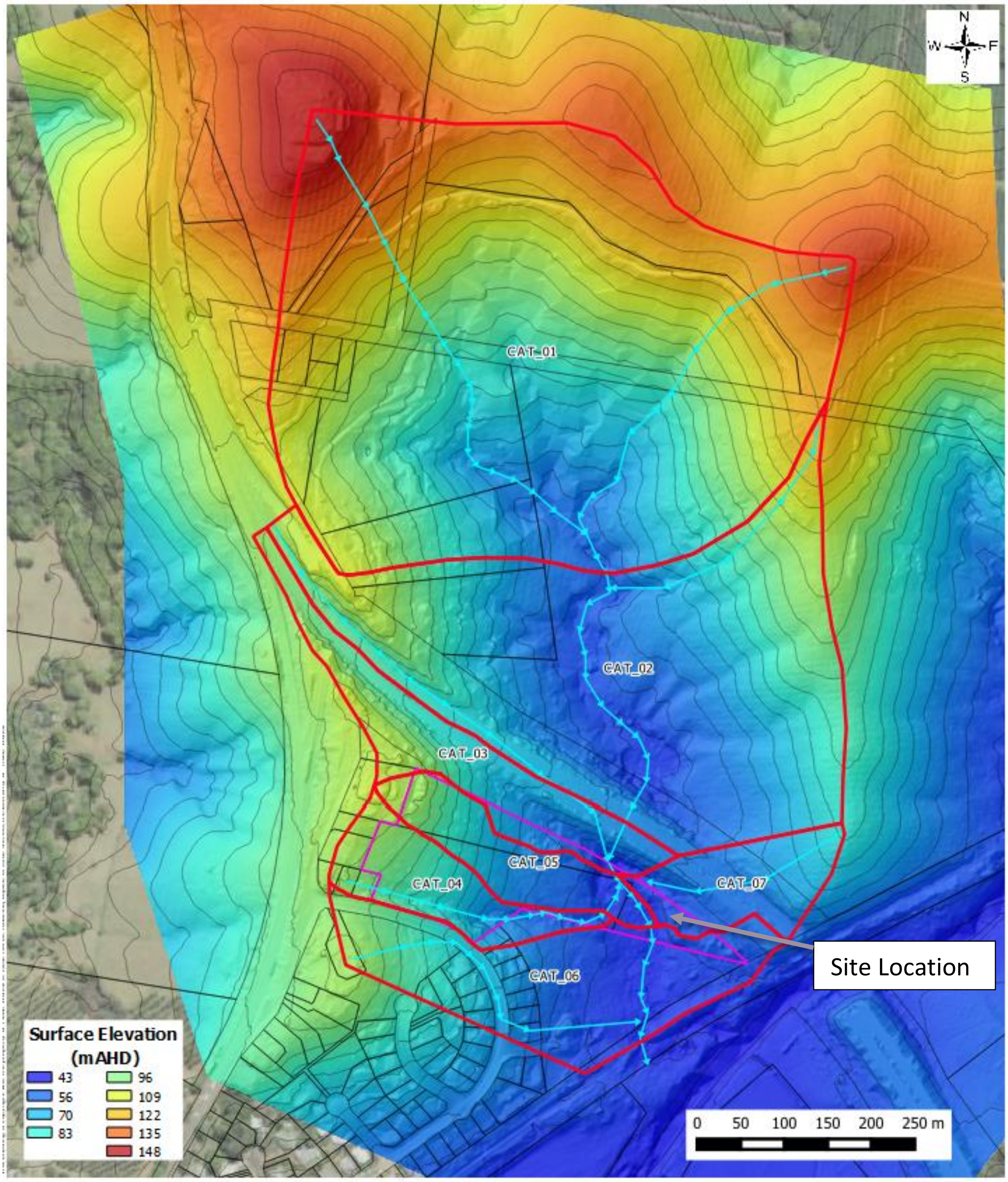

Figure 2 XP-SWMM Model Extents

2.2.2. Hydrologic Routing

Hydrologic modelling has been undertaken using the Laurenson runoff routing method. The Laurenson method requires the catchment to be divided into pervious and impervious portions. A fraction impervious of 0% has been applied to the pervious fraction and 100% to the impervious fraction.

2.2.3. Manning's Roughness

Manning's roughness (n) values represent the undeveloped and developed portions of the catchment. XP-SWMM allows a range to be applied to describe the varied degrees of roughness that could be expected within the catchment.

The Manning value was used as a calibration tool to compare peak flow from XP_SWMM and the ARR Regional Flood Frequency Estimation (RFFE) model.

2.2.4. Rainfall Losses

Initial Loss (IL) and Continuing Losses (CL) were sourced from the Australian Rainfall and Runoff (ARR) Data Hub (*http://data.arr-software.org/*) and were applied to the modelling. The catchment has been modelled as approximately 100% pervious with only a small percentage of roofed area relative to the catchment size. The following loss rates have been adopted:

- Undeveloped Catchment IL = 12.1mm CL = 0.0mm/hr.

2.2.5. Existing Conditions Parameters

Table 1 summarises the XP-SWMM parameters adopted for the existing catchment conditions. The catchment's equal area slope was calculated directly from the Digital Terrain Model.

The percentage impervious was determined using the Queensland Urban Drainage Manual (QUDM) guidelines for the fraction impervious for a rural undeveloped as 0% Impervious (QUDM, 2013).

The total contributing catchment is 58.6ha. The hydrologic factors adopted have been summarised in Table 1.

Table 1 XP-SWMM Hydrologic Model Parameters

Sub-Catchment	Area (ha)	Impervious (ha)	Pervious Area (ha)	Equal Area Slope (%)
CAT_01	27.964	0.933	27.030	27.964
CAT_02	15.886	1.150	14.736	15.886
CAT_03	3.267	0.718	2.549	3.267
CAT_04	2.104	0.274	1.830	2.104
CAT_05	1.956	0.018	1.937	1.956

CAT_06	5.357	0.550	4.807	5.357
CAT_07	2.026	0.382	1.644	2.026

2.3. ARR 2019 Hydrologic Results

The XP-SWMM ARR Storm Generator allows importation of the ARR Data Hub information, including rainfall global database, infiltration global database, and global storm definitions, into XP-SWMM. Information such as the ARR Data Hub Text File, ARR Temporal Patterns Increments File, and Bureau of Meteorology (BOM) IFD table files are used to produce the Annual Exceedance Probability (AEP) and all of the durations for the given location, which are then analysed in the application.

Ten (10) temporal patterns were assessed per duration for each design event, with the results displayed in a box-and-whisker plot to determine the critical storm duration and temporal pattern for the catchment. The box-and-whisker plot displays information about the results' range, median, and quartiles. This plot can easily demonstrate whether a distribution is skewed and whether there are potential outliers in the data set, especially for a large number of observations.

Figure 3 below demonstrates that the highest median storm duration for the 1%AEP, or the 1% Annual Exceedance Probability (AEP) design event, is the 2-hour storm using the standard temporal pattern 1 and producing a peak discharge of **18.3 m^3/s**.

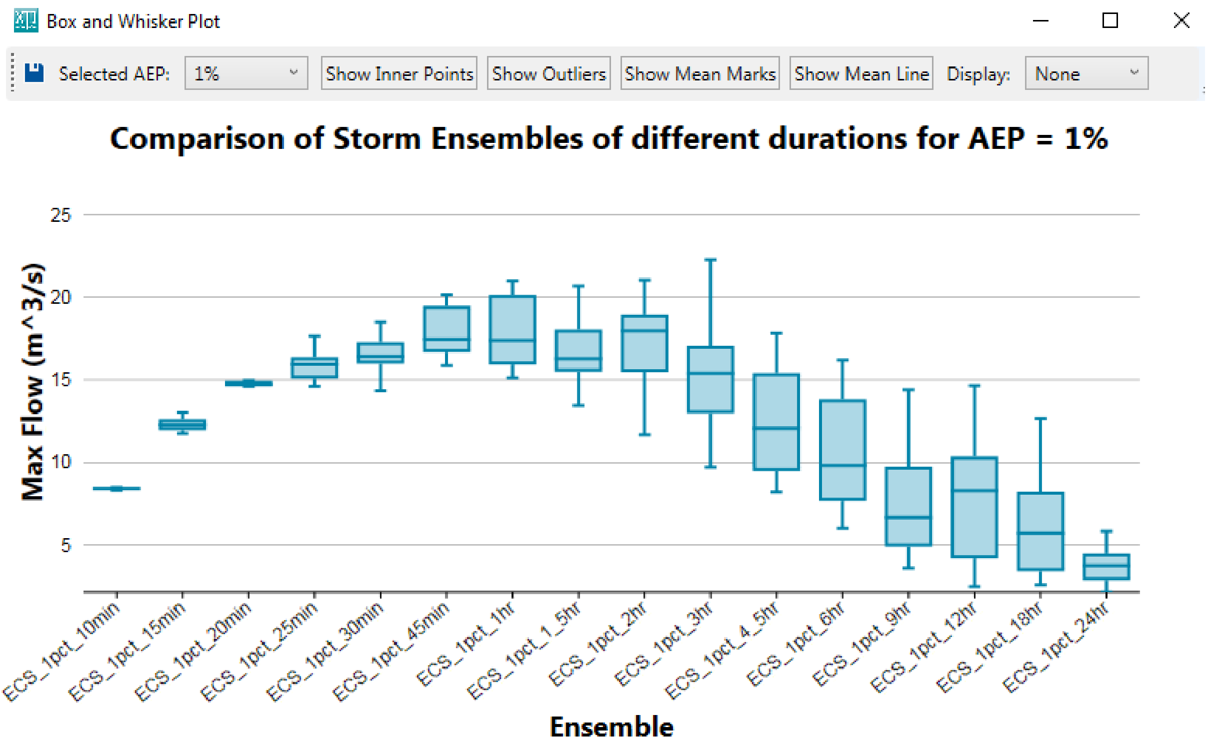

Figure 3 1%AEP Box and Whisker Plot of Ensemble Results

2.4. Flood Frequency Analysis Comparison

The ARR Regional Flood Frequency Estimation (RFFE) model has replaced the rational method for comparing XP-SWMM's calculation to the 1%AEP design event.

The tool requires the geographical coordinates of the catchment centroid and outlet. The tool produces a statistical estimate of peak discharge based on regional rainfall data at gauged locations near the site.

The tool has the following limitations:

- The RFFE tool cannot be used for urban catchments, areas where large-scale land clearing has occurred or where dams or other significant hydraulic controls have significantly affected the natural hydrology (ARR)
- RFFE is not accurate for catchments smaller than $0.5km^2$ or larger than $1000km^2$
- Catchments that are located more than 300km from a gauging station used by the tool

Table 2 and Figure 4 summarise the comparison of the RFFA tool and XP-SWMM peak discharges for the sub-catchment at the outlet.

Table 2 XP-SWMM and RFFE Peak Discharge

Event	Regional Estimation Tool			XP_SWMM (ARR2019)
	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)	
1%AEP	14.2	4.28	47.1	18.262

** Based on Medium Ensemble Storm*

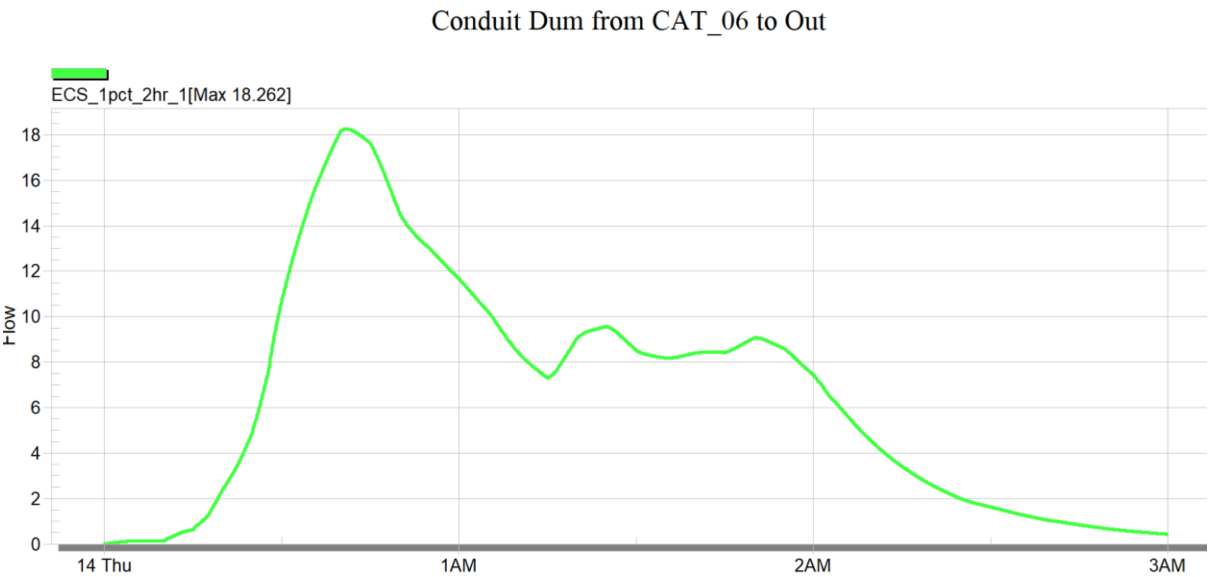

Figure 4 Critical Storm Duration And Temporal Pattern For The Outlet Catchment

3. Overland Flow Hydraulic Assessment

3.1. Objectives

This overland flow assessment aims to demonstrate that the proposed pad does not significantly increase risk within the floodway.

1D/2D TUFLOW has been used for this analysis. The TUFLOW software models the design terrain (i.e. Digital Terrain Model) of the study area as a series of grid points (2D cells). This allows flows in excess of the channel capacity or pipe network to break out and continue along the floodway in the 2D domain, as the topography dictates. The hydraulic structures (i.e. the minor culvert network) have been represented as 1D elements (ESTRY), which are dynamically linked to the 2D elements. The TUFLOW model computes the capacity of the 1D element and once exceeded, the surcharged flow is transferred to the 2D model. Flood levels, discharge and velocity can be extracted from the model as functions of time at required locations.

TUFLOW is an industry-standard two-dimensional river analysis model used to estimate flood characteristics such as flood level, velocity, and depth.

3.2. 2D Model Set Up

3.2.1. Model Extent

The model extents for the TUFLOW model are presented in Figure 4. The extents were set at an appropriate distance from the subject site. The downstream boundary will be normal depth downstream of the railway bridge opening.

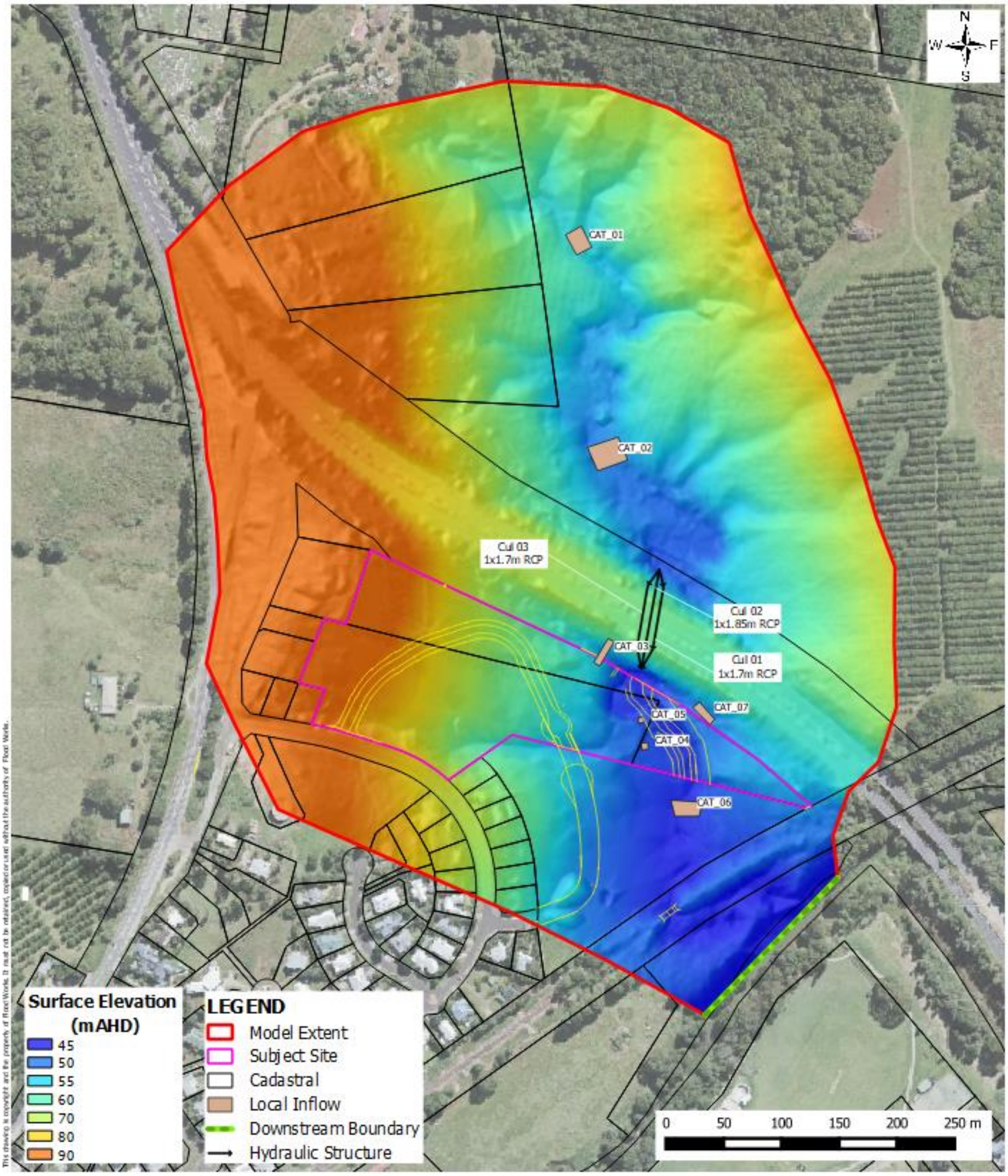

Figure 4 TUFLOW Model Extents

3.2.2. Resolution and Time Step

The TUFLOW model used a grid size of 2m and a time step of 1 second for all scenarios. The grid size is based on model efficiency and size constraints for the extent of the model.

3.2.3. Topography

Lidar 1m (2010) data was used as the base topography for the TUFLOW model. The topography used in the pre-development is shown in Figure 5

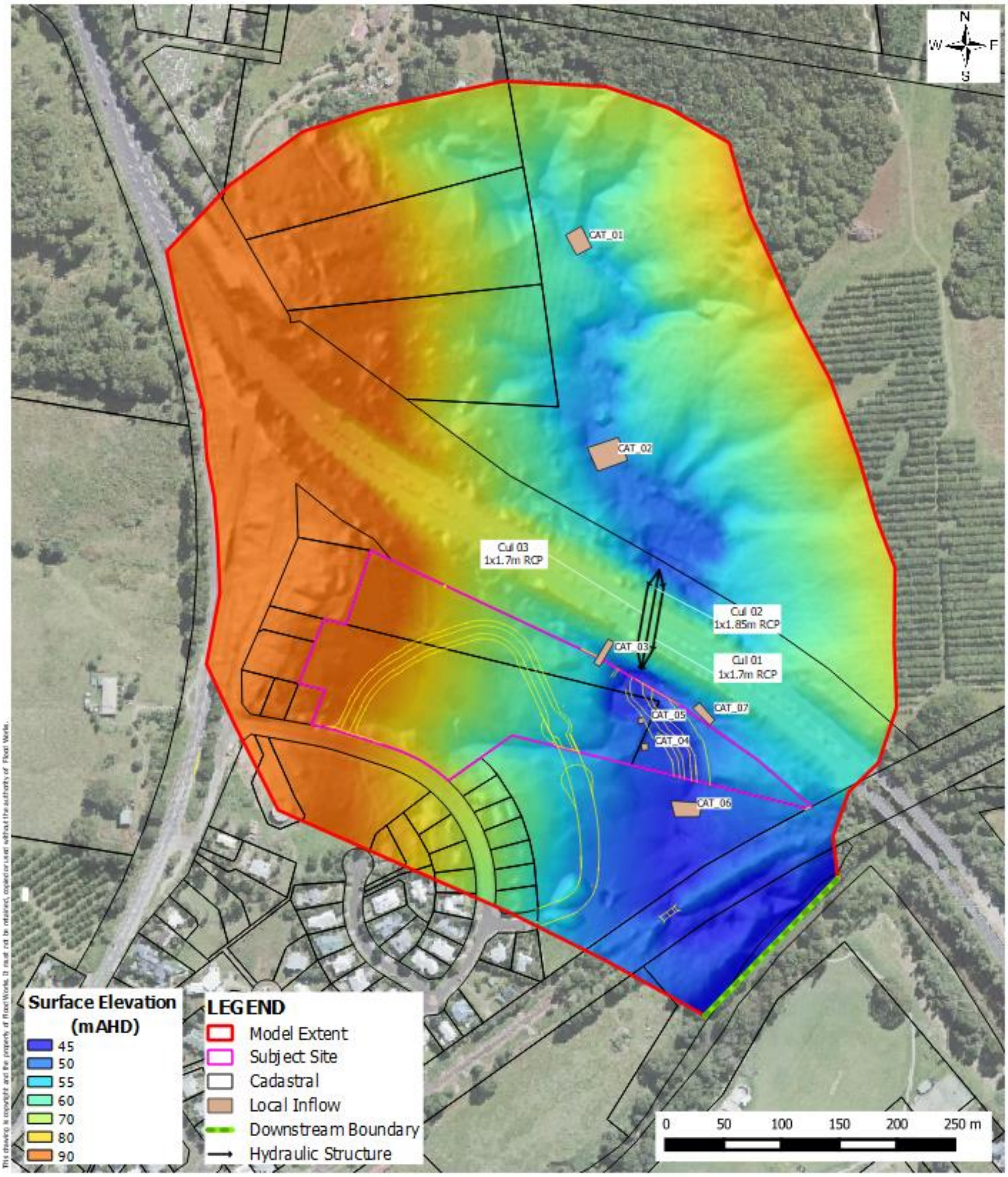

Figure 5 Existing Case Surface Elevation Data

3.2.4. Roughness

Figure 6 show the Manning n roughness values adopted in this assessment.

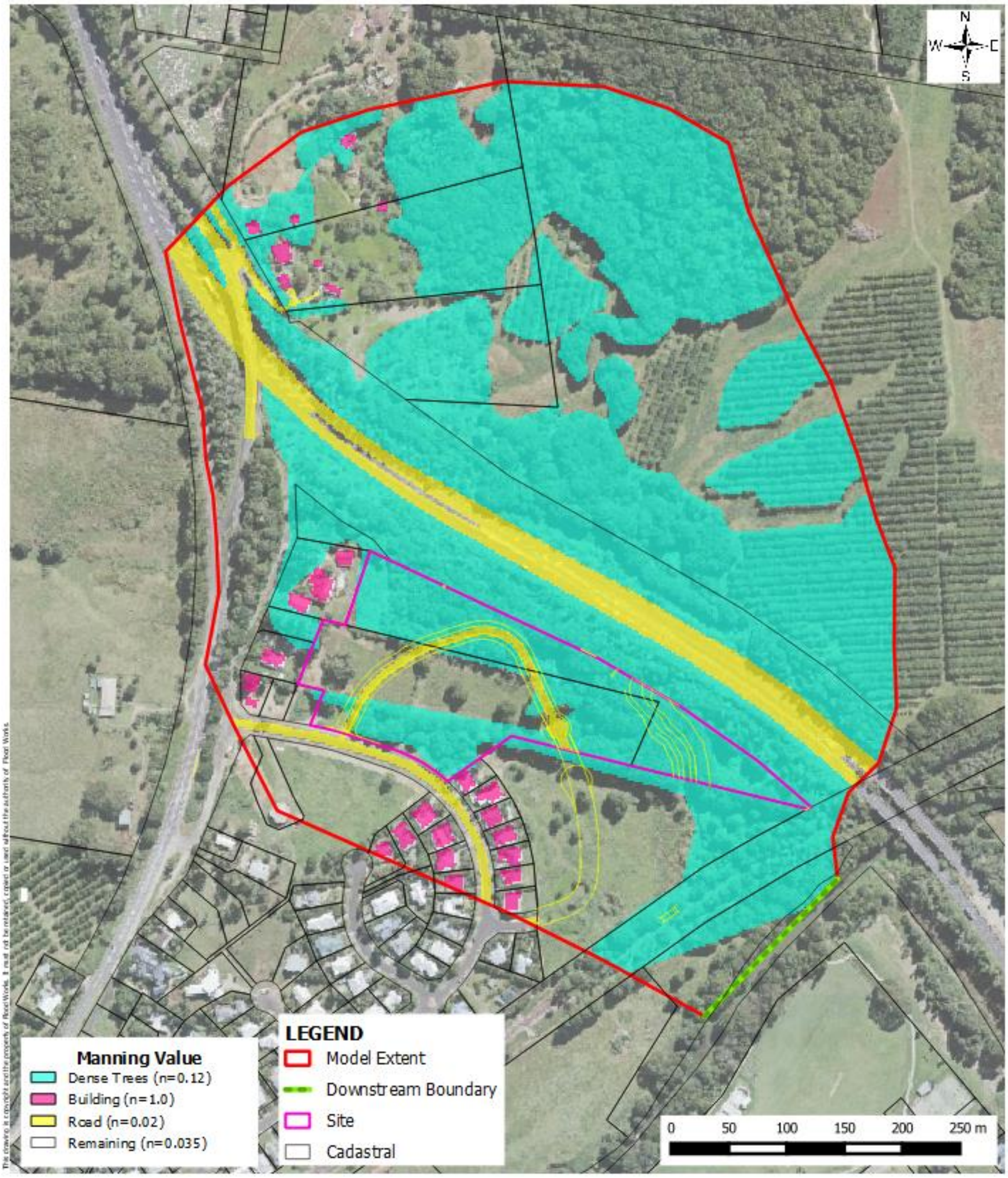

Figure 6 Existing Case Roughness Map

3.2.5. Inflows

The inflows within the TUFLOW model were extracted directly from the XP-SWMM Hydrology model (ARR 2019). See Figure 5 for inflow locations.

3.3. Existing Case

The existing case 1 %AEP_CC (Climate Change) and PMF (Probable Maximum Flood) design event peak water level, depth, velocity and hazard are shown in Figure 7 to Figure 14 below.

The peak water level for the 1%AEP_CC is 46.28 – 47.58mAHD, and the PMF is 47.75 – 48.04mAHD.

The peak water velocity for the 1%AEP_CC is 0.01 – 0.6m/s, and the PMF is 0.18 – 1.09m/s.

The peak flood hazard for the 1%AEP_CC and the PMF is H1 (low hazard) to H5 (high hazard) within the primary conveyance channel.

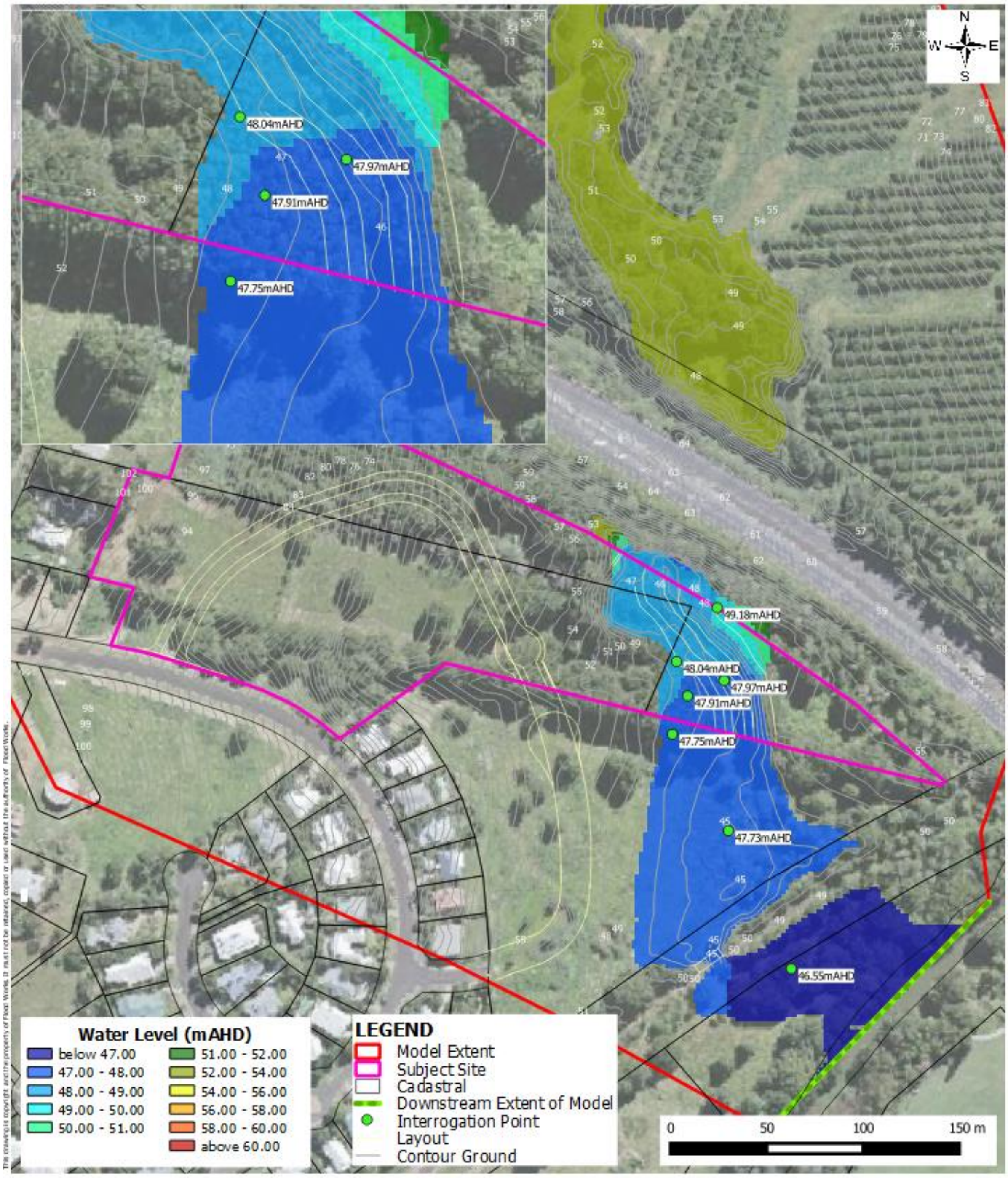

Figure 7 Existing Case Maximum Water Level – PMF EVENT

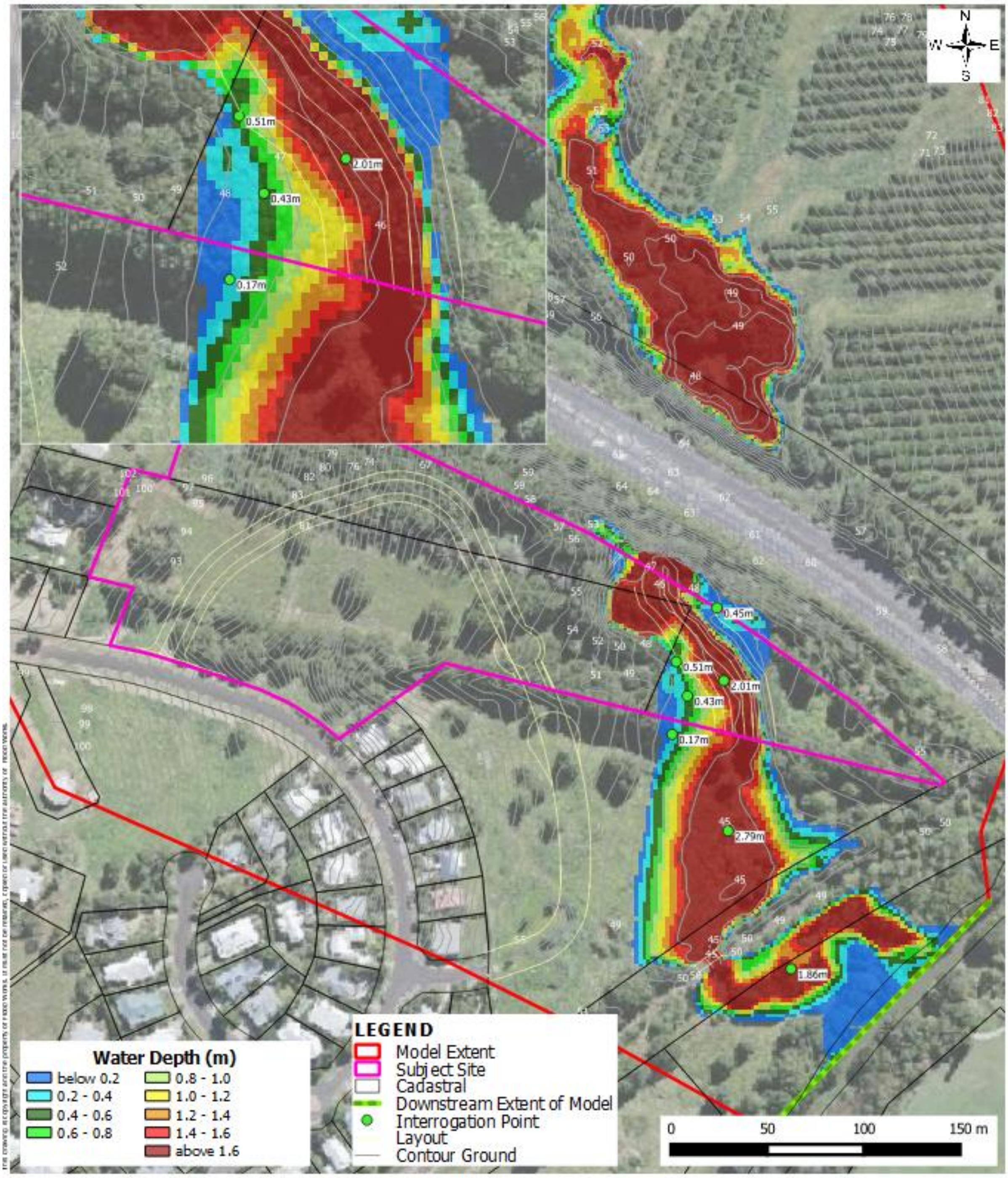

Figure 8 Existing Case Maximum Water Depth – PMF EVENT

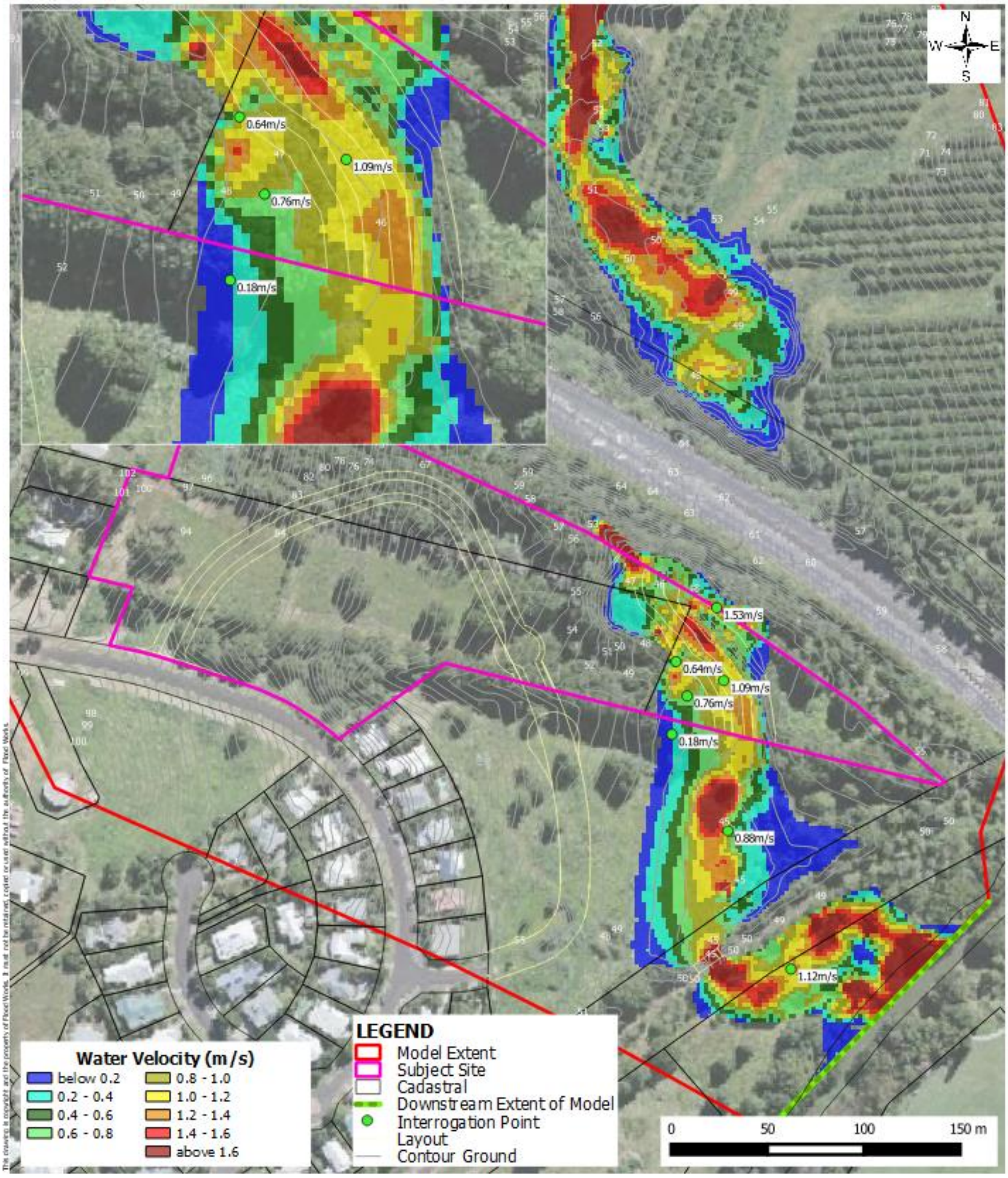

Figure 9 Existing Case Maximum Water Velocity – PMF EVENT

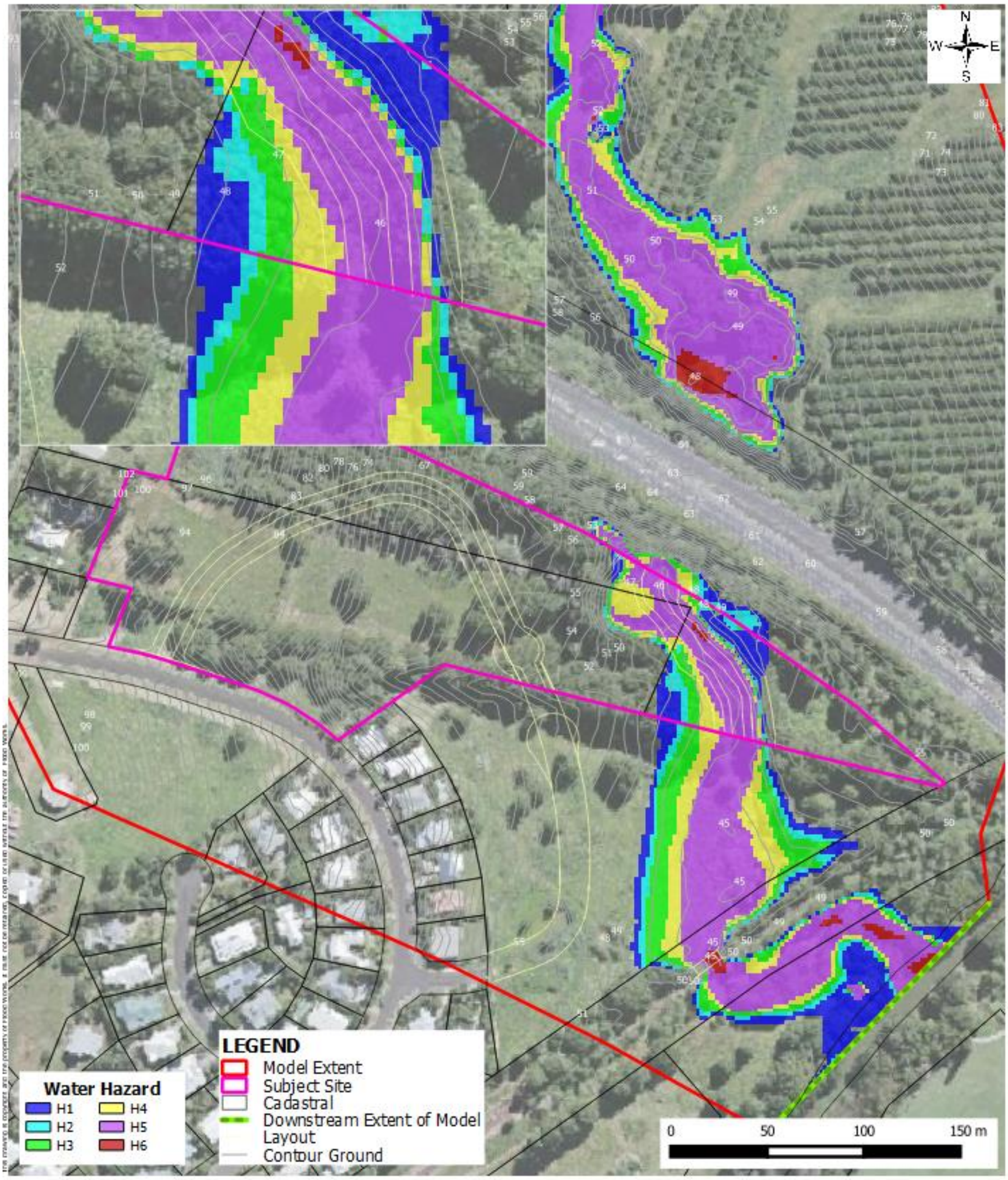

Figure 10 Existing Case Maximum Water Hazard – PMF EVENT

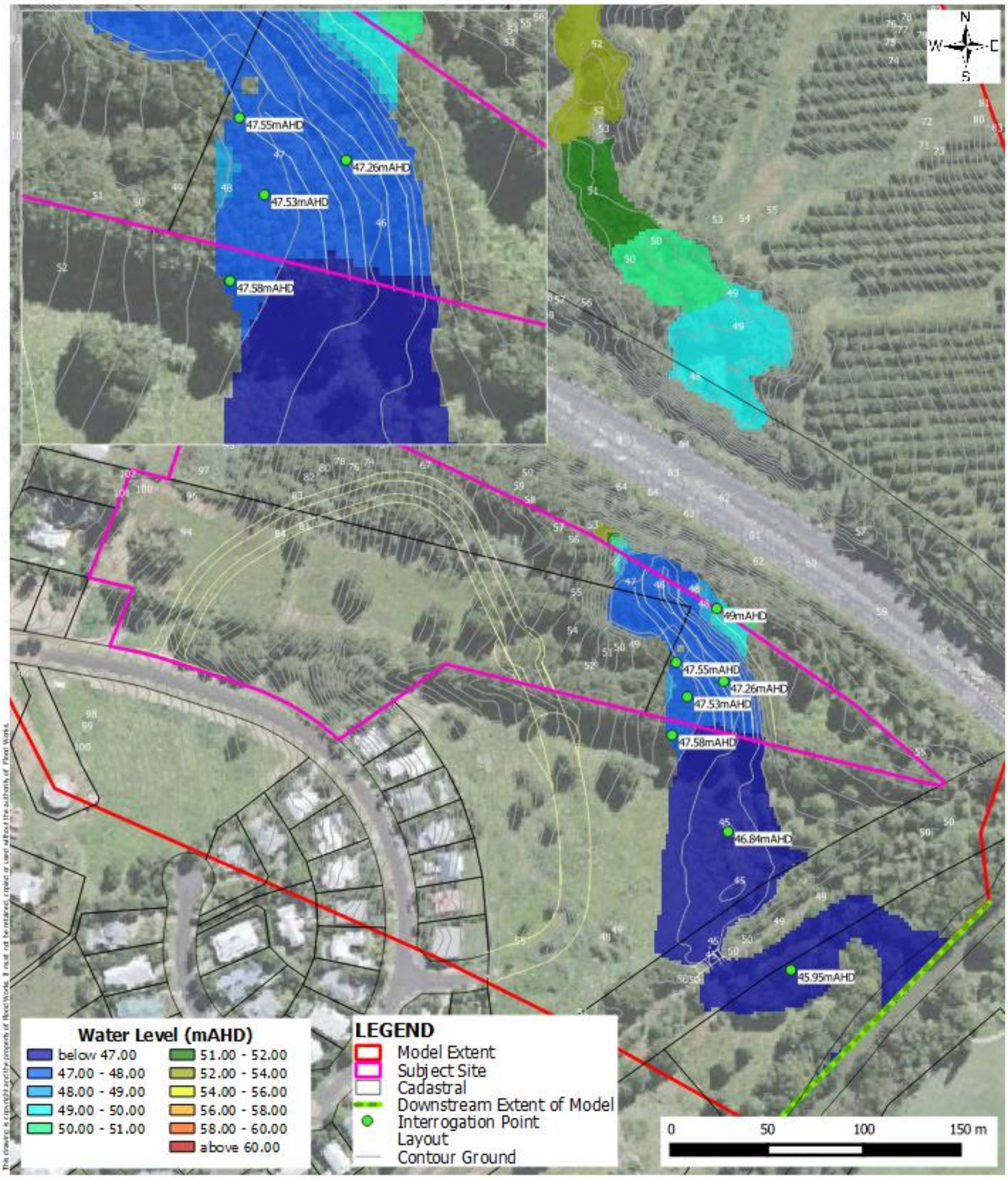

Figure 11 Existing Case Maximum Water Level– 1% AEP CC

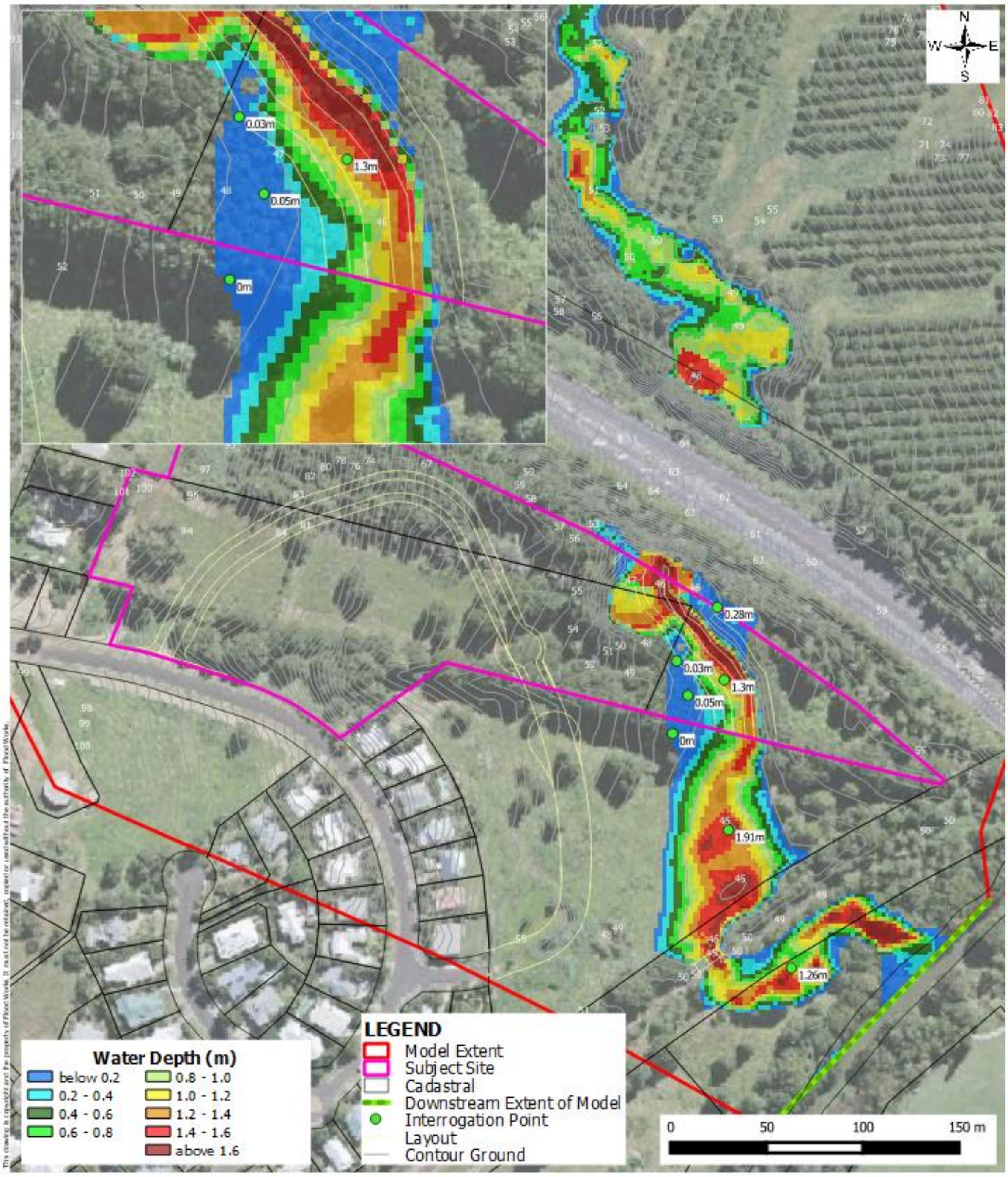

Figure 12 Existing Case Maximum Water Depth– 1% AEP CC

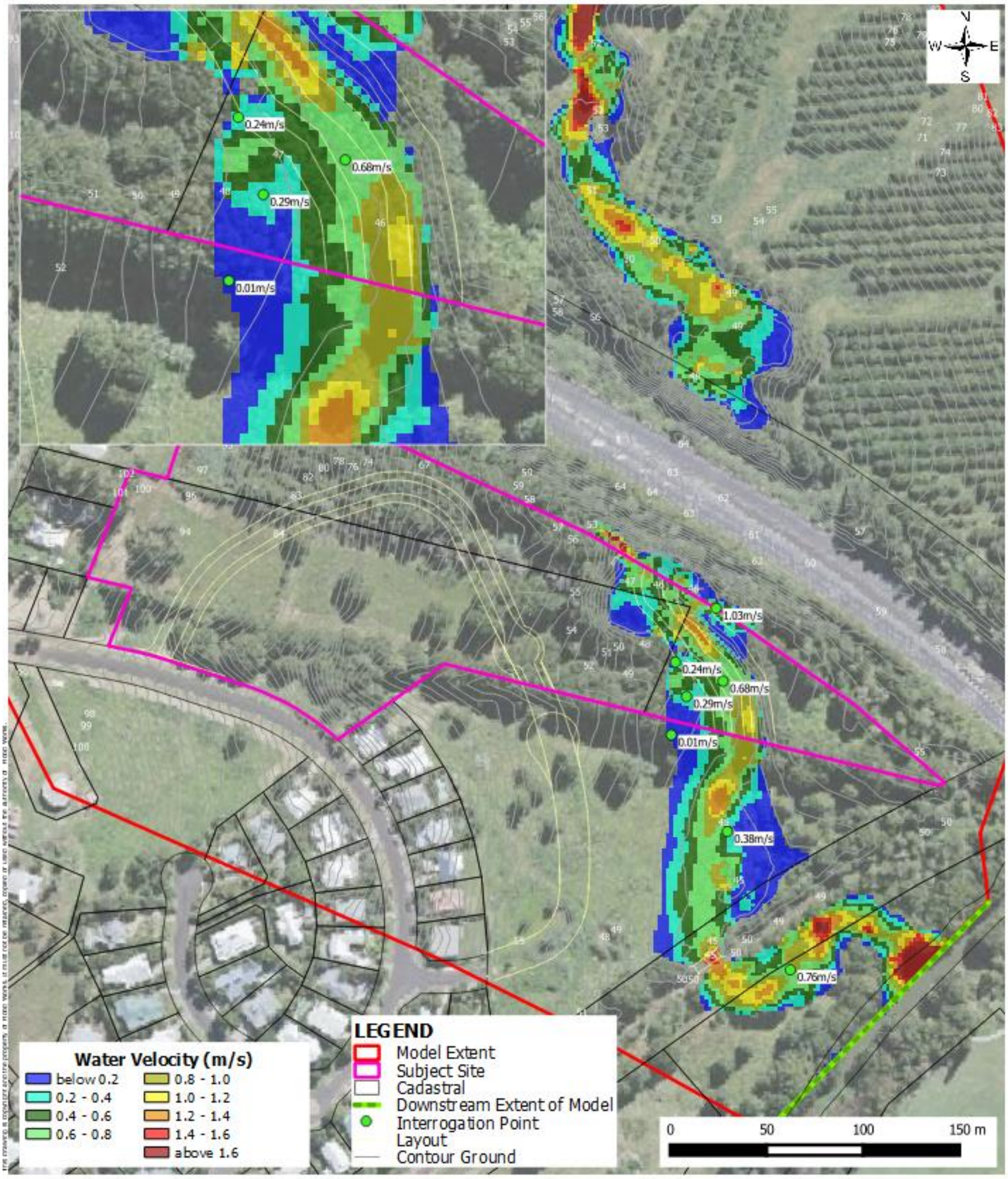

Figure 13 Existing Case Maximum Water Velocity– 1% AEP CC

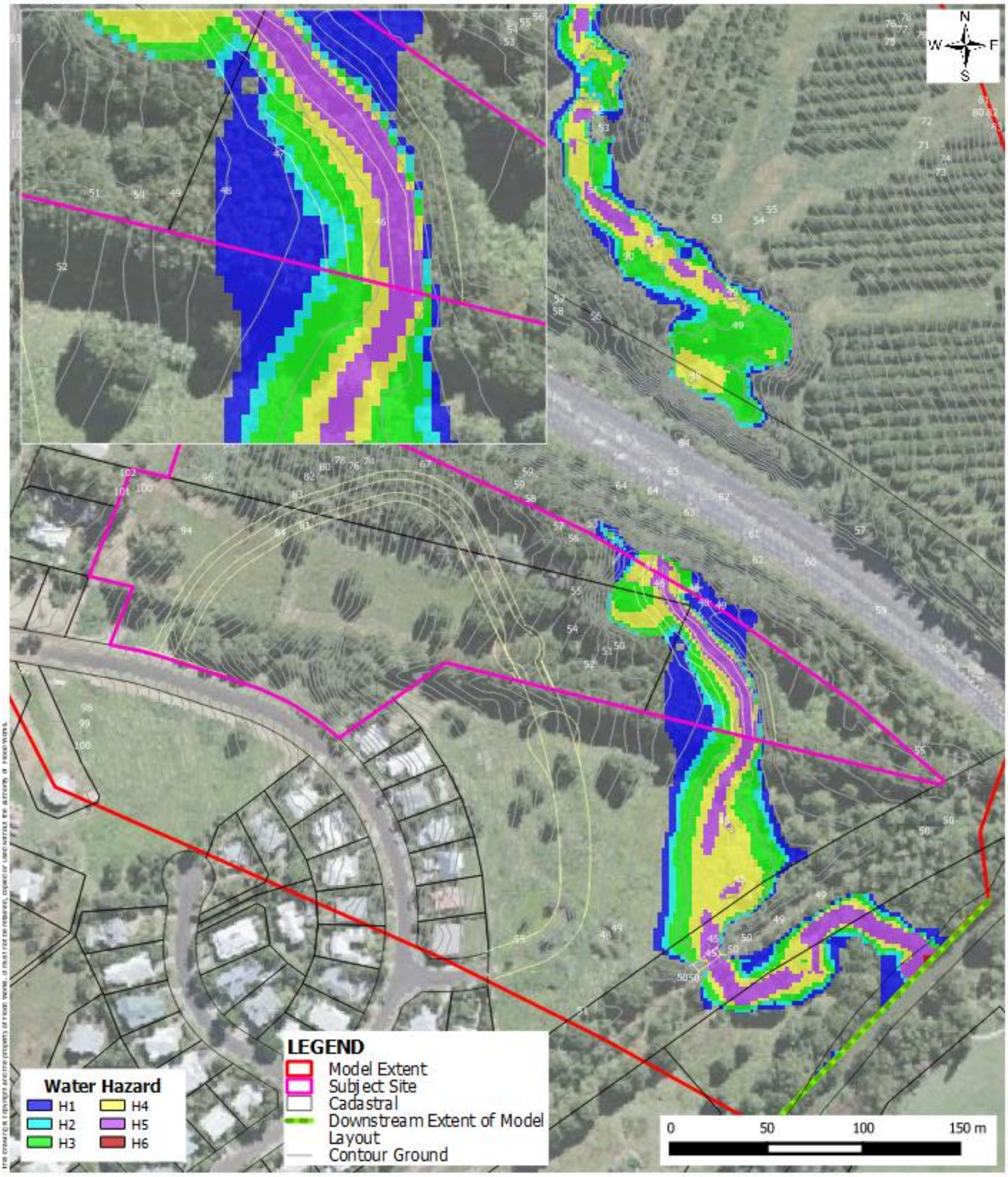

Figure 14 Existing Case Maximum Water Hazard– 1% AEP CC

4. Summary

Floodworks has completed a Hydraulic Assessment for 68 Granuaille Crescent, Bangalow, NSW (the subject site).

An XP-SWMM hydrology model was developed to estimate the 1%AEP (Annual Exceedance Probability), 1%AEP_CC (Climate Change), and PMF events used within the TUFLOW hydrodynamic model. The hydrologic assessment has been completed according to the Australian Rainfall and Runoff 2019 (ARR2019) methodologies, with results comparing well to the Regional Flood Frequency Estimation tool.

A dynamic 1D/2D linked TUFLOW flood model was developed for the existing case, including the existing Hinterland Way culverts and the downstream rail bridge opening. The TUFLOW model provided maximum height, velocity, peak depth and hazard assessment for the 1%AEP_CC and the PMF design events.

The peak water level for the 1%AEP_CC is 46.28 – 47.58mAHD, and the PMF is 47.75 – 48.04mAHD.

The peak water velocity for the 1%AEP_CC is 0.01 – 0.6m/s, and the PMF is 0.18 – 1.09m/s.

The peak flood hazard for both the 1%AEP_CC and the PMF is H1 (low hazard) to H5 (high hazard) within the primary conveyance channel.

5. References

- BOM (2018) Rainfall IFD Data System
- IPWEA 2013, Queensland Urban Development Manual (QUDM)
- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia
- Elevation - Foundation Spatial Data from http://elevation.fsdf.org.au/

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Appendix A Australian Rainfall & Runoff Data Hub – Results

River Region

Division	South East Coast (NSW)
River Number	3
River Name	Richmond River

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
East Coast North	0.327	0.241	0.448	0.36	0.00096	0.48	-0.21	0.012	-0.0013

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	2345.0
Storm Initial Losses (mm)	44.0
Storm Continuing Losses (mm/h)	2.1

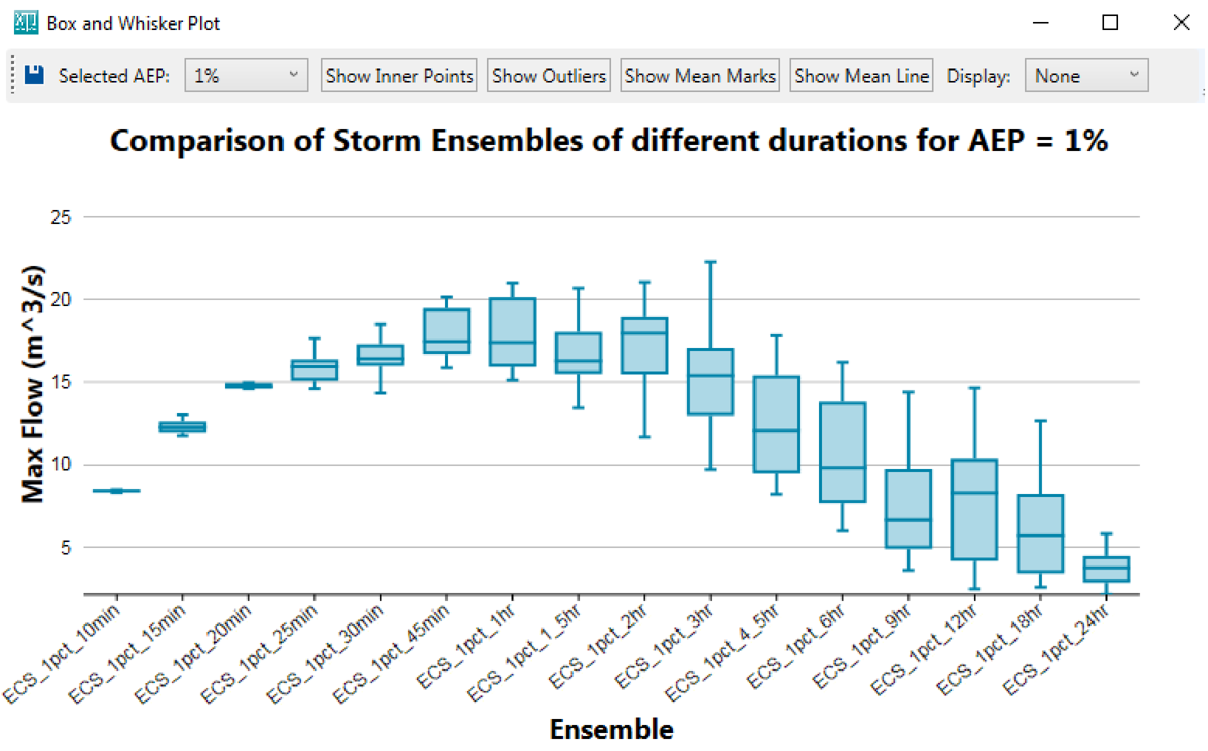
Interim Climate Change Factors

	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%)**

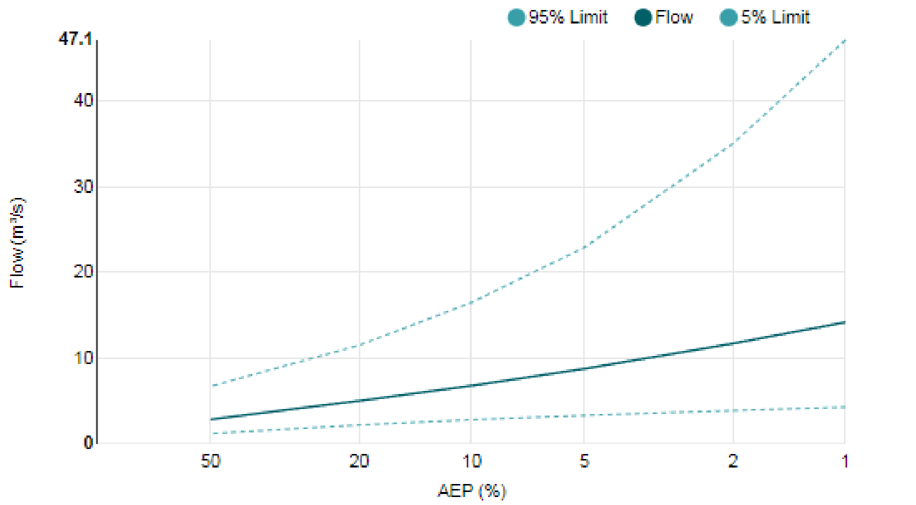
Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	24.2	13.2	12.3	12.0	10.8	7.7
90 (1.5)	25.1	14.7	13.3	12.0	10.2	8.3
120 (2.0)	22.4	13.4	13.0	11.1	10.3	6.1
180 (3.0)	21.9	13.7	12.6	10.2	9.6	5.2
360 (6.0)	19.9	12.8	12.2	10.9	11.1	3.5
720 (12.0)	21.9	15.3	15.0	12.2	13.8	4.5
1080 (18.0)	25.8	19.1	19.6	14.9	16.7	5.4
1440 (24.0)	29.9	21.7	21.4	16.5	14.3	5.9
2160 (36.0)	35.3	26.4	24.8	19.6	17.9	6.2
2880 (48.0)	37.4	27.7	26.6	23.7	23.2	7.0
4320 (72.0)	42.3	32.6	32.1	29.6	27.3	11.7

Appendix B Box and Whisker Plots



Appendix C Regional Flood Frequency Estimation (ARR2019)



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	2.85	1.21	6.71
20	5.03	2.21	11.5
10	6.80	2.82	16.5
5	8.76	3.32	22.9
2	11.7	3.89	35.0
1	14.2	4.28	47.1

Statistics

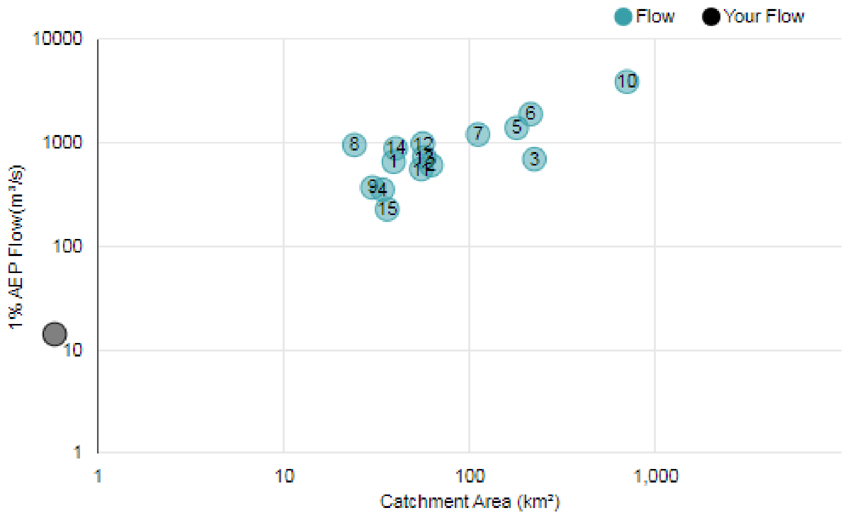
Variable	Value	Standard Dev
Mean	1.034	0.529
Standard Dev	0.642	0.303
Skew	0.074	0.029

Note: These statistics come from the nearest gauged catchment. Details.

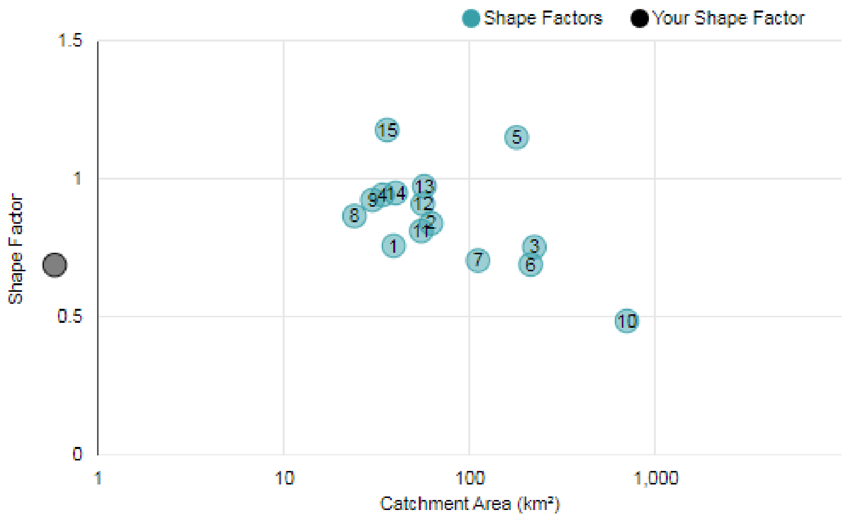
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

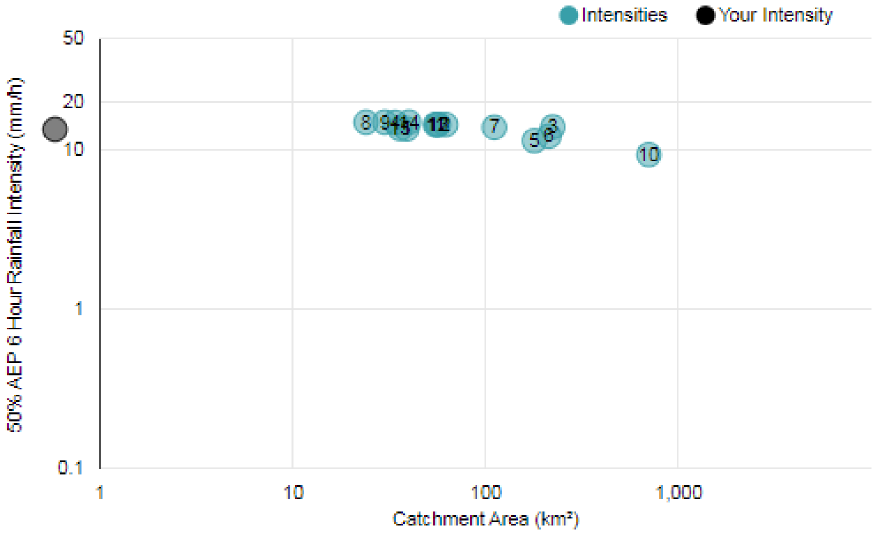
1% AEP Flow vs Catchment Area



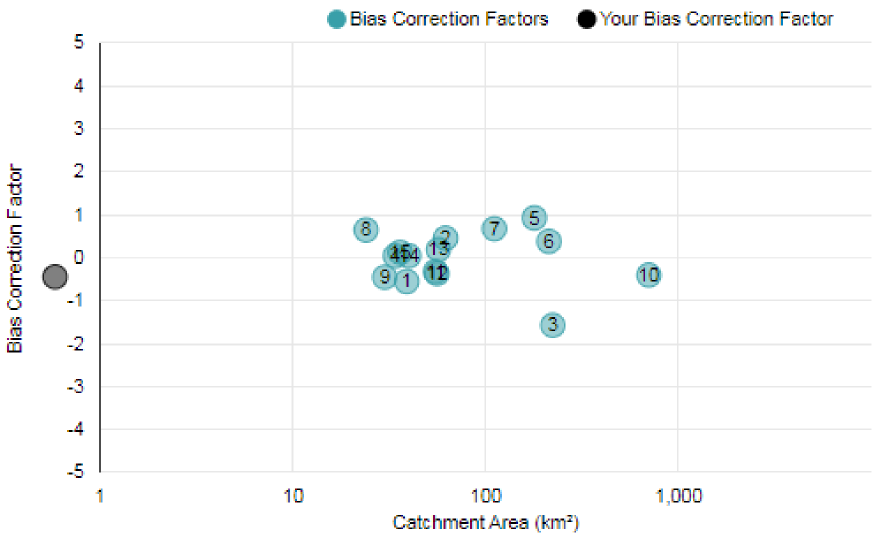
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Appendix D TUFLOW Results

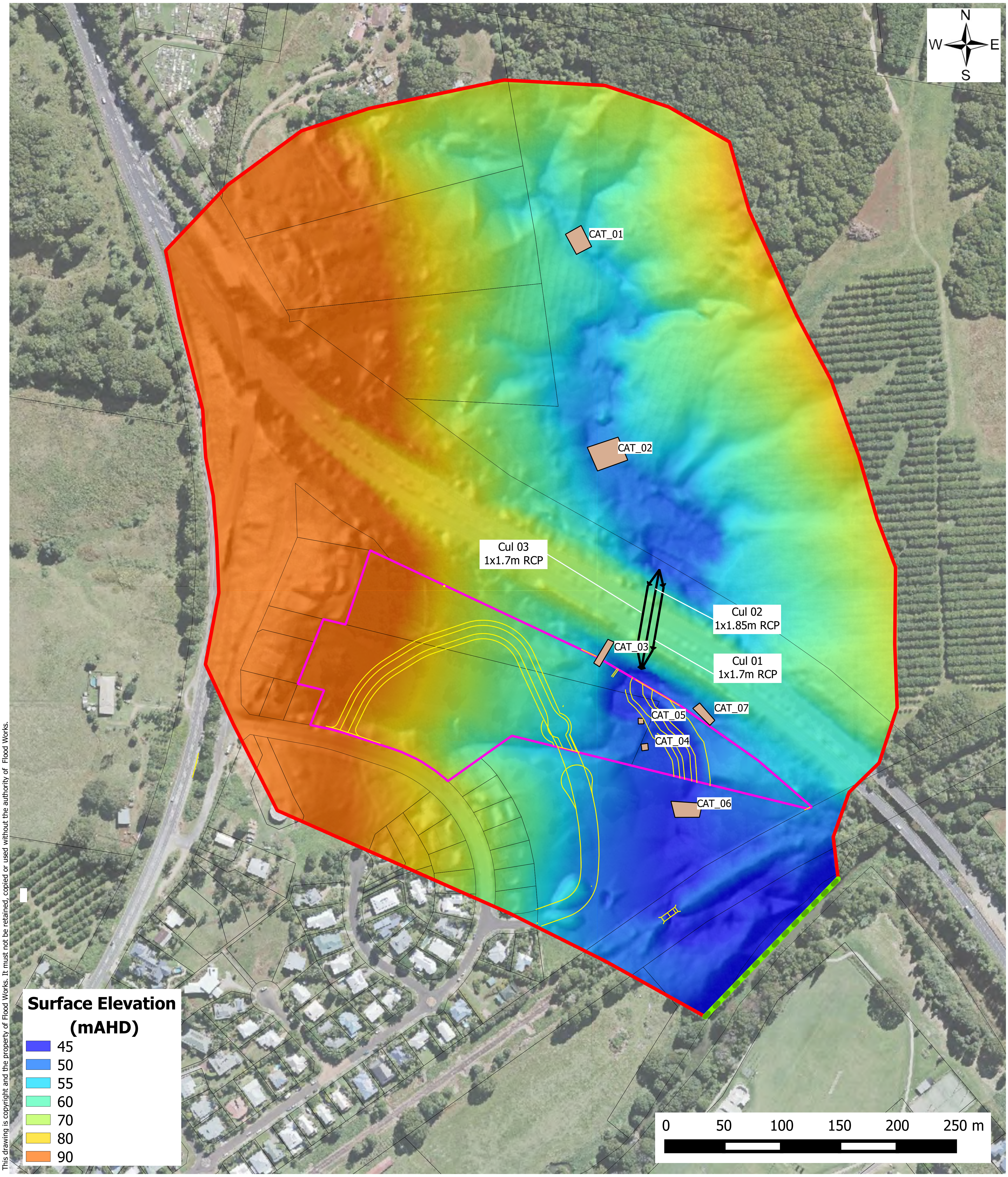


FIG 01 PRE- DEVELOPMENT TUFLOW MODEL FEATURE

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND

- Model Extent
- Subject Site
- Cadastral
- Local Inflow
- Downstream Boundary
- Hydraulic Structure

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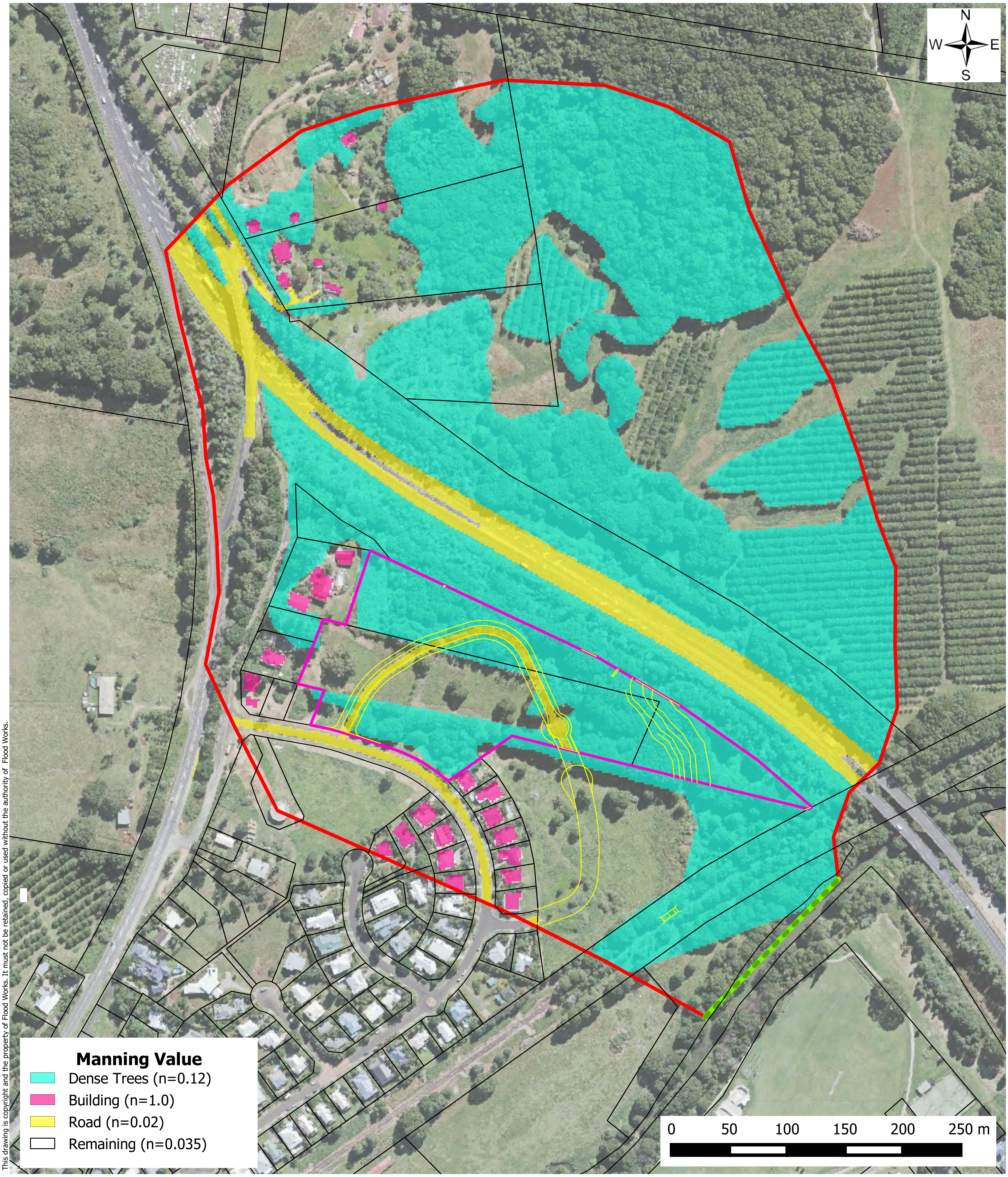

FIG 02 PRE- DEVELOPMENT TUFLOW MODEL MANNING MAP

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND

- Model Extent
- Downstream Boundary
- Site
- Cadastral

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Client

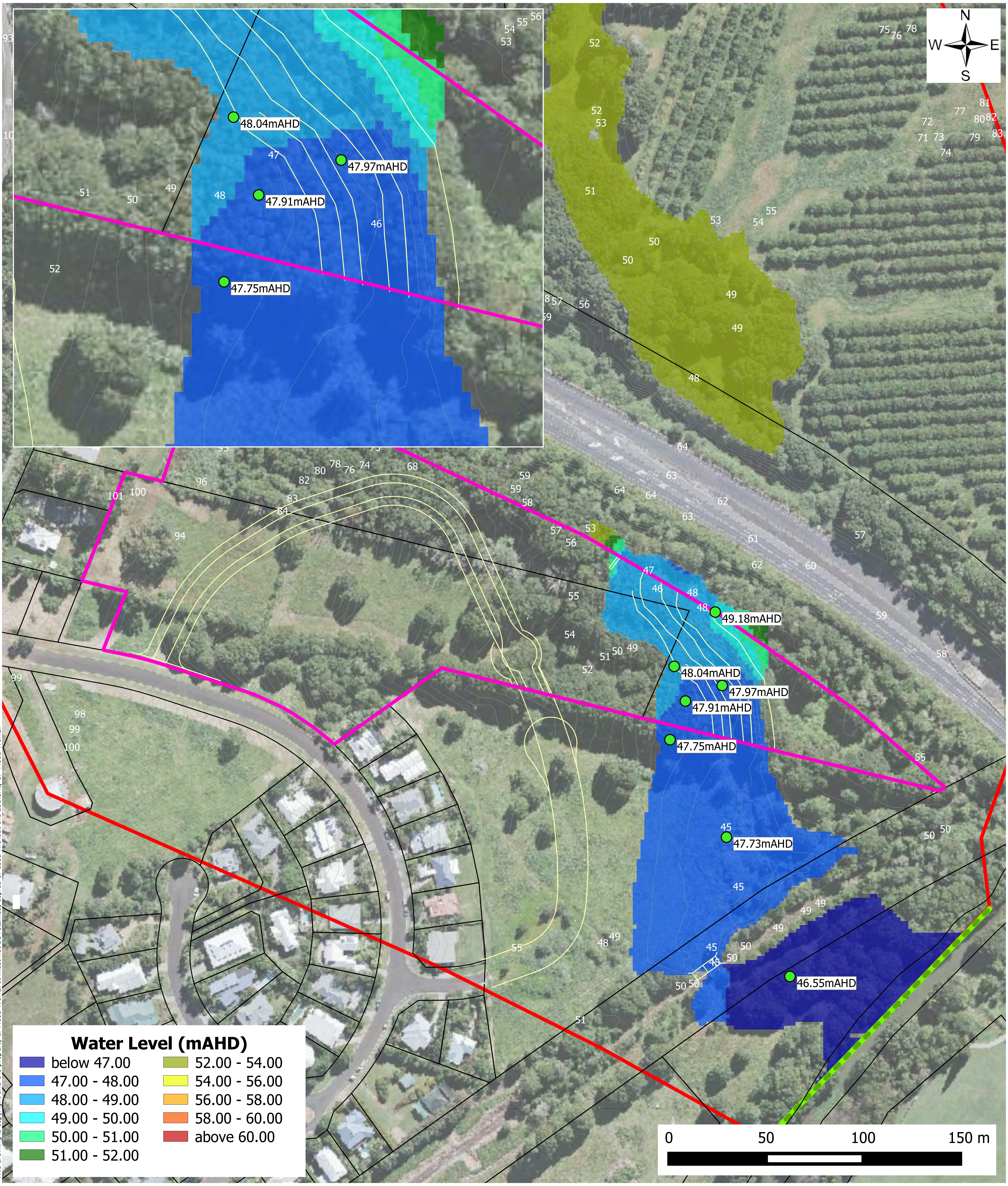

FIG D01 EXISTING CASE PMF EVENT FLOOD WATER LEVEL

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND

- Model Extent
- Subject Site
- Cadastral
- Downstream Extent of Model
- Interrogation Point
- Layout
- Contour Ground

FLOODWORKS
www.floodworks.com.au

Instant Steel Pty Ltd

Client

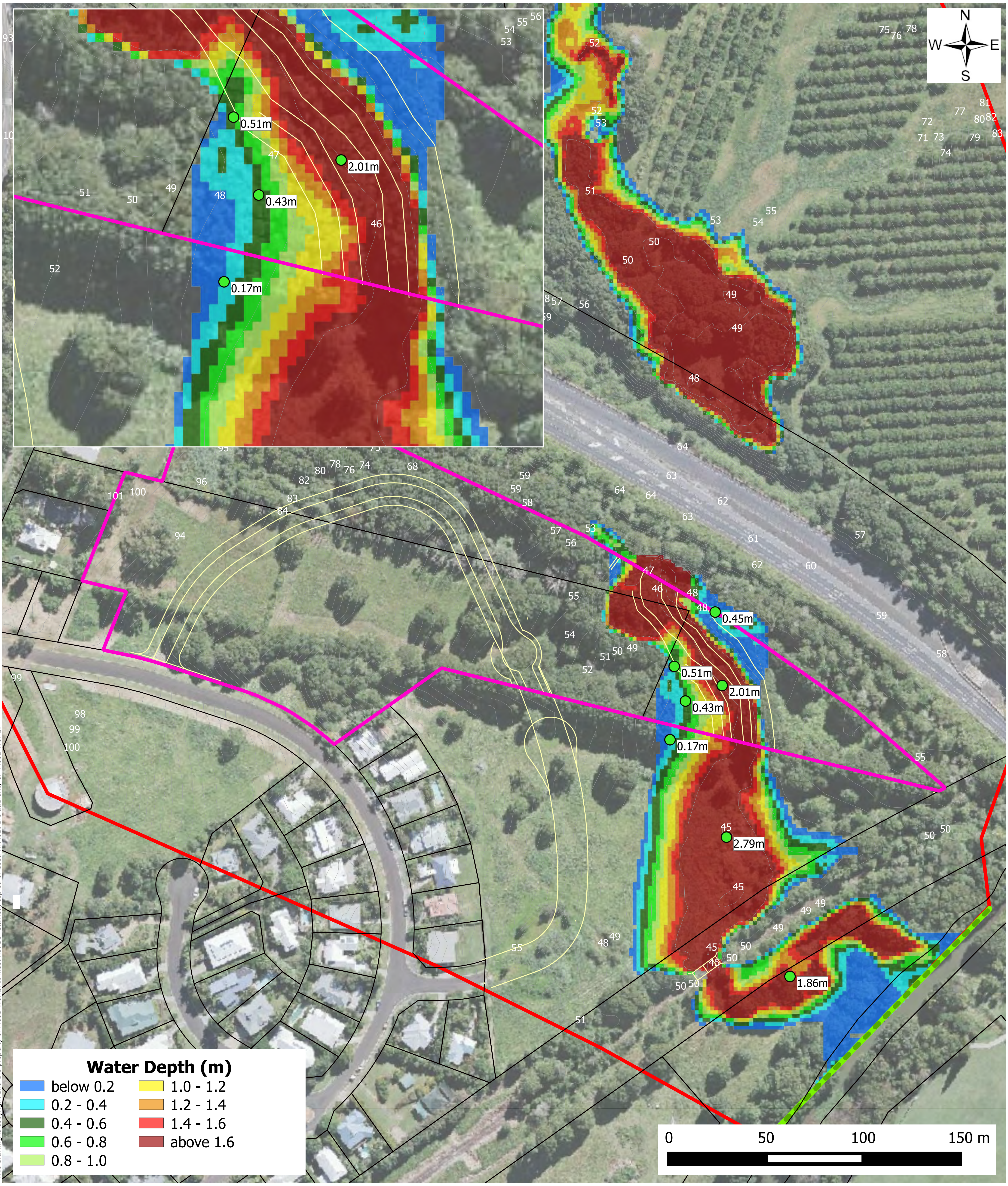

FIG D02 EXISTING CASE
PMF EVENT
FLOOD WATER DEPTH

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND
- Model Extent
- Subject Site
- Cadastral
- Downstream Extent of Model
- Interrogation Point
- Layout
- Contour Ground

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Client

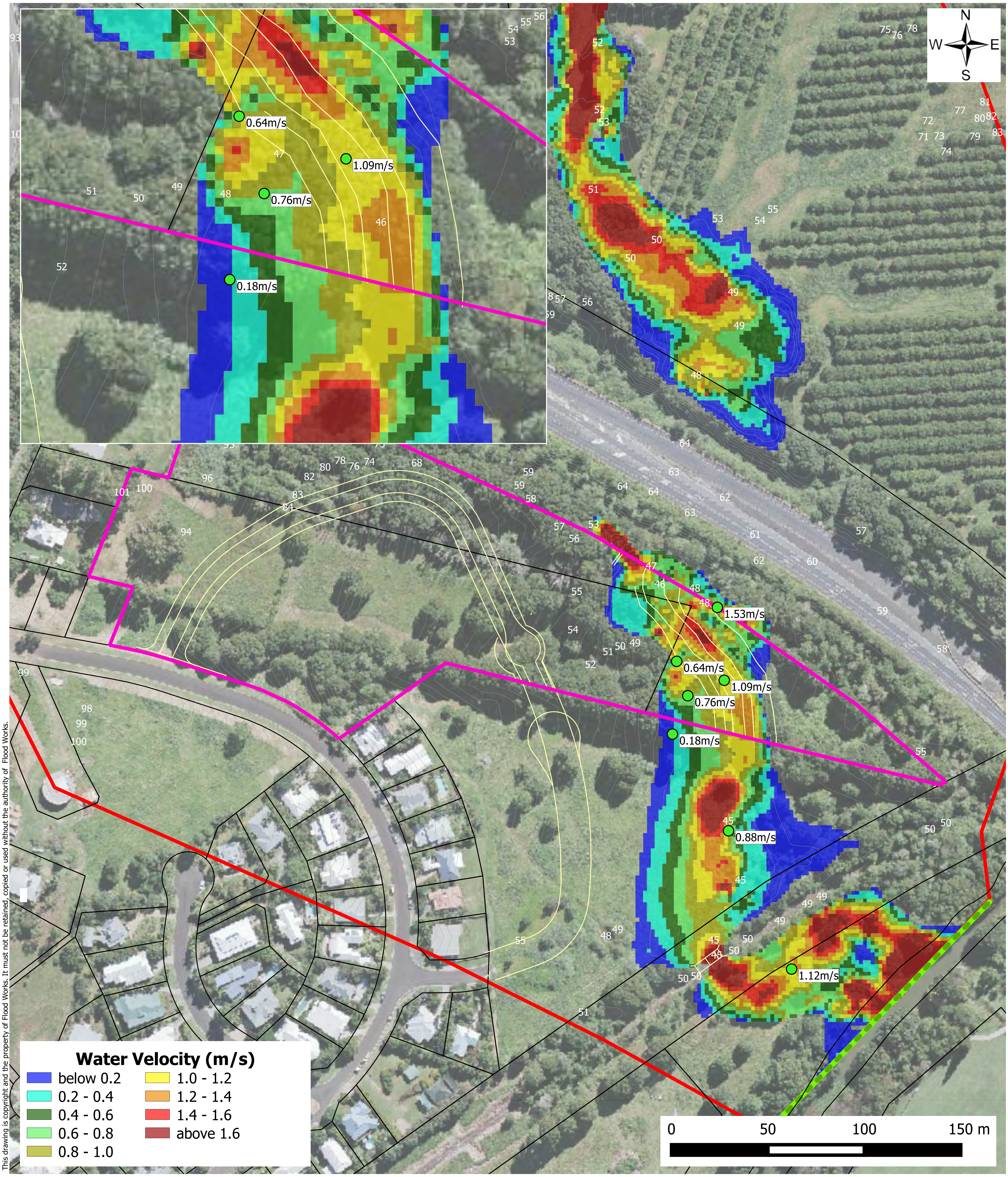

FIG D03 EXISTING CASE PMF EVENT FLOOD WATER VELOCITY

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND

- Model Extent
- Subject Site
- Cadastral
- Downstream Extent of Model
- Interrogation Point
- Layout
- Contour Ground

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Client

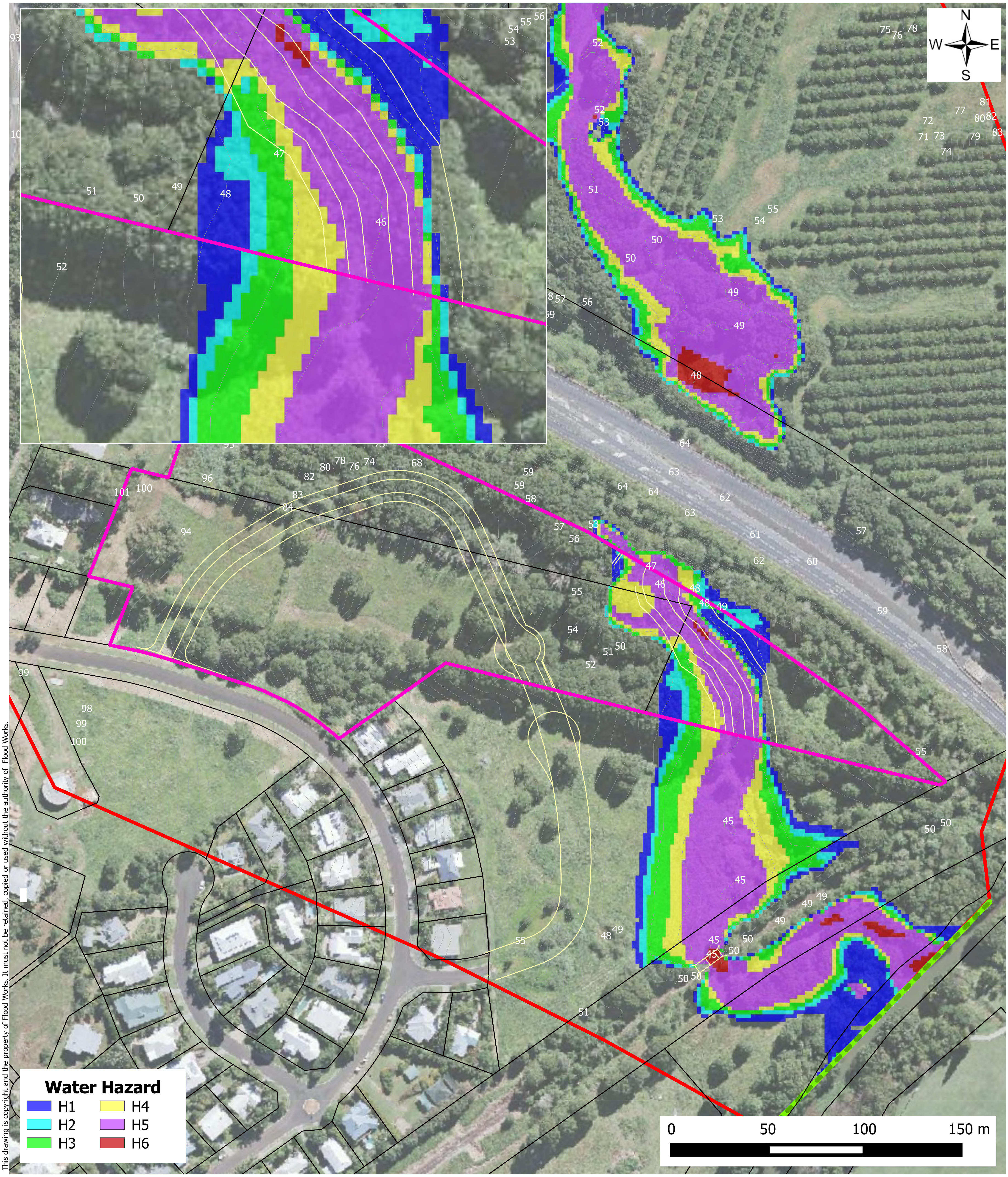

FIG D04 EXISTING CASE PMF EVENT FLOOD WATER HAZARD

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND

- Model Extent
- Subject Site
- Cadastral
- Downstream Extent of Model
- Layout
- Contour Ground

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Client

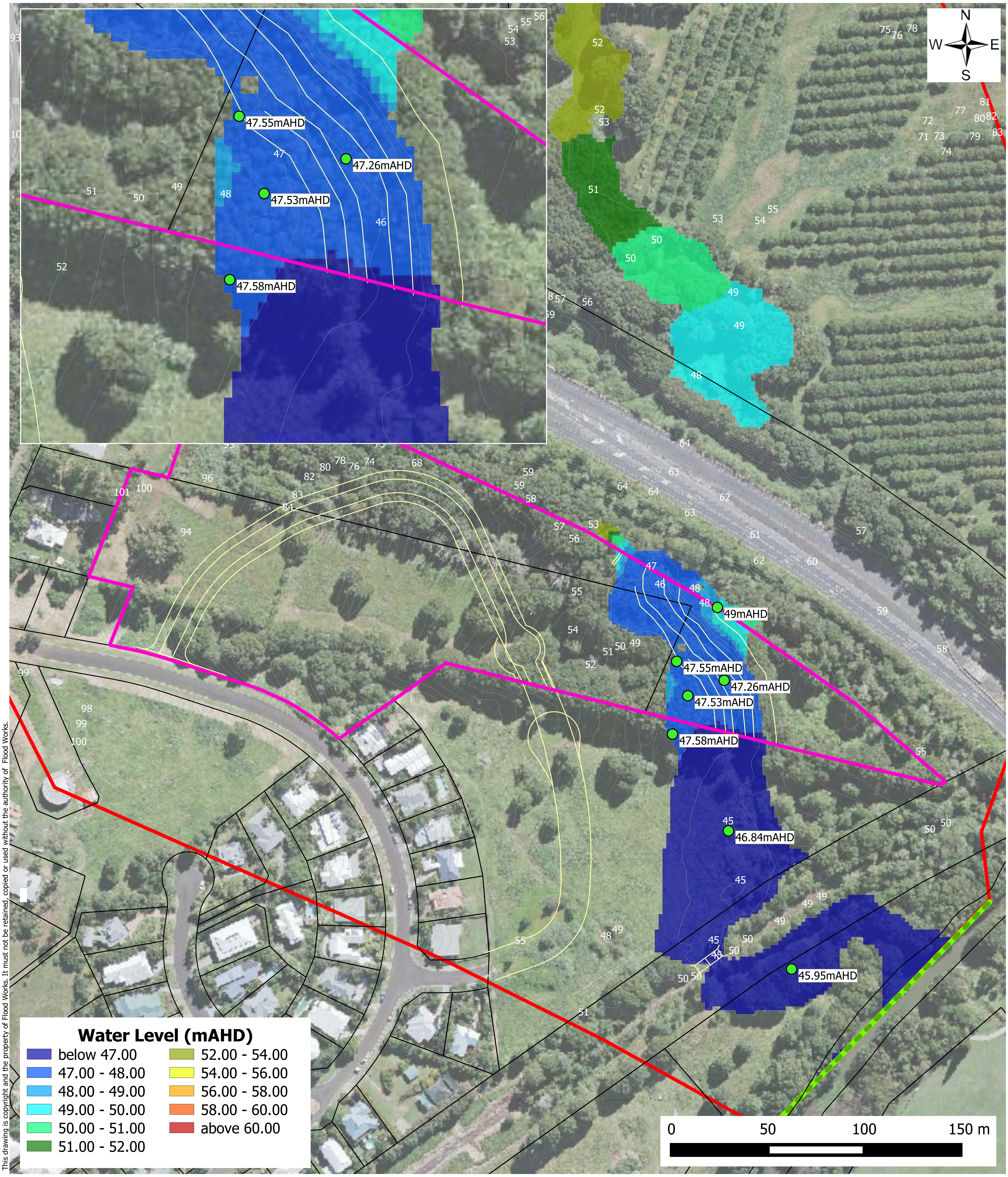

FIG D05 EXISTING CASE 1% AEP CLIMATE CHANGE FLOOD WATER LEVEL

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND

- Model Extent
- Subject Site
- Cadastral
- Downstream Extent of Model
- Interrogation Point
- Layout
- Contour Ground

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Client

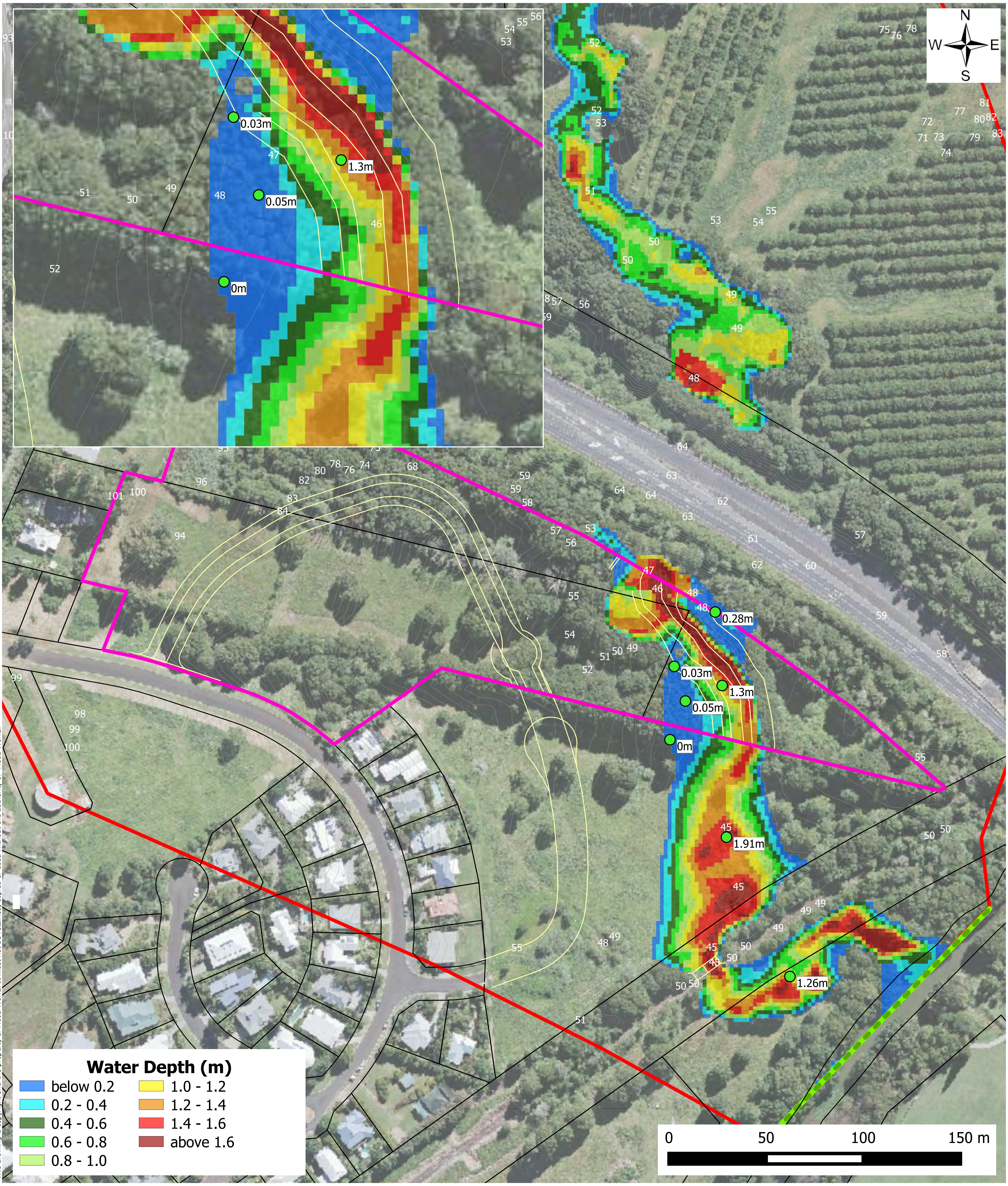

FIG D06 EXISTING CASE
1% AEP CLIMATE CHANGE
FLOOD WATER DEPTH

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND
- Model Extent
- Subject Site
- Cadastral
- Downstream Extent of Model
- Interrogation Point
- Layout
- Contour Ground

FLOODWORKS
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Instant Steel Pty Ltd

Client

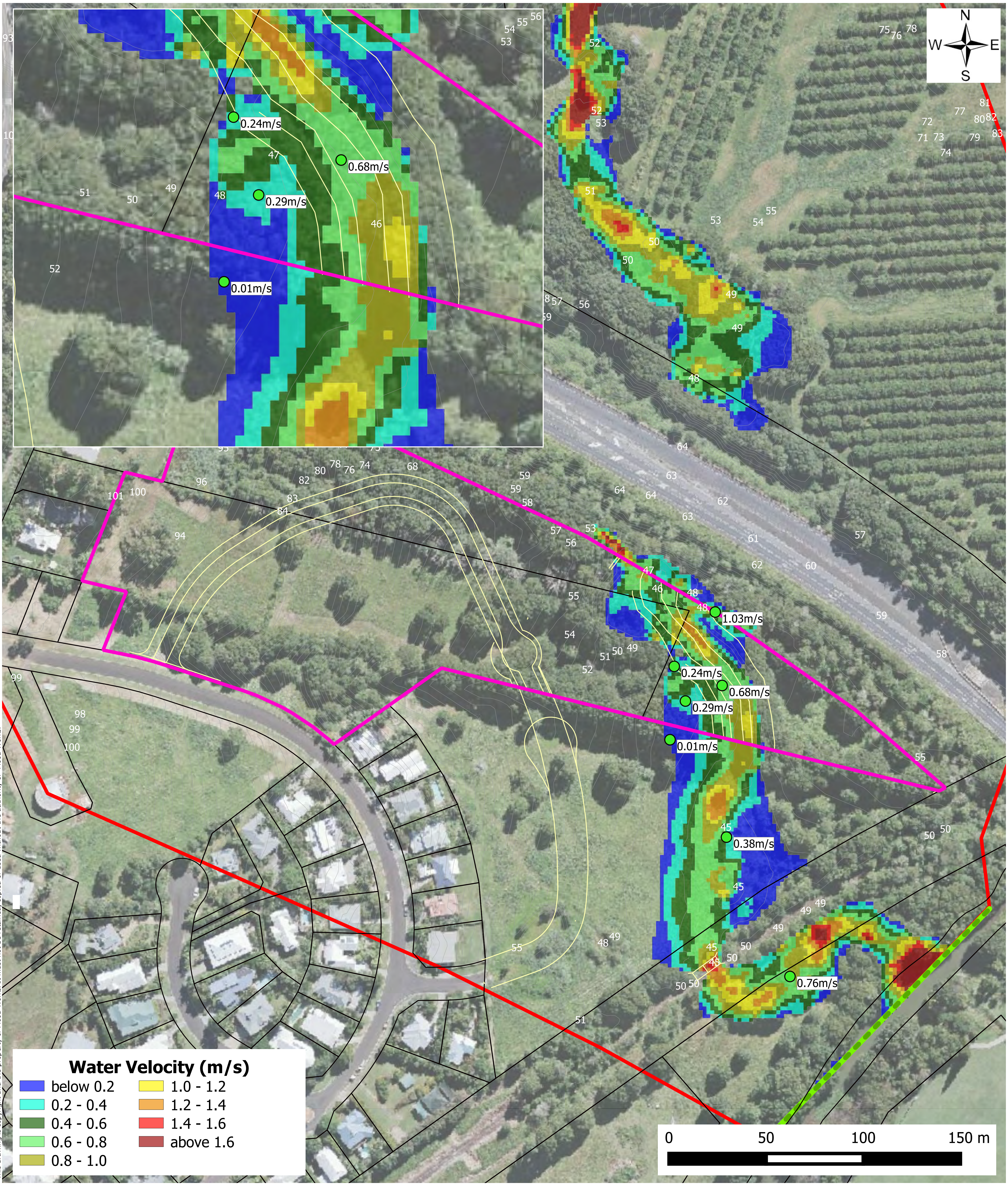

FIG D07 EXISTING CASE
1% AEP CLIMATE CHANGE
FLOOD WATER VELOCITY

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND
- Model Extent
- Subject Site
- Cadastral
- Downstream Extent of Model
- Interrogation Point
- Layout
- Contour Ground

FLOODWORKS
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Instant Steel Pty Ltd

Client

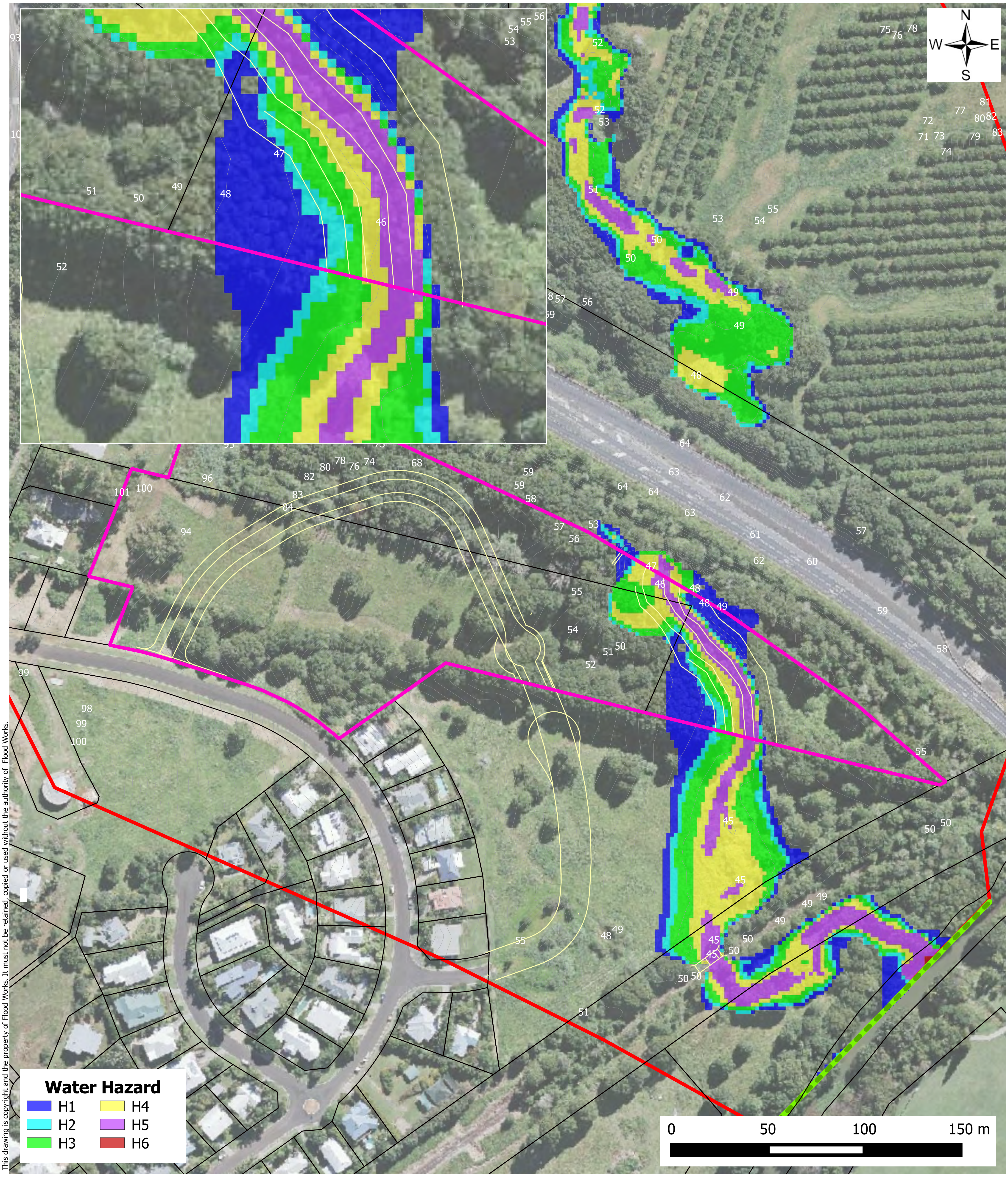

FIG D08 EXISTING CASE
1% AEP CLIMATE CHANGE
FLOOD WATER HAZARD

PROJECTION: GDA94 / MGA ZONE 56
PROJECT: FW00007 68 Granuaille Crescent, Bangalow
DATE: August 2024

LEGEND

- Model Extent
- Subject Site
- Cadastral
- Downstream Extent of Model
- Layout
- Contour Ground

FLOODWORKS
www.floodworks.com.au

Instant Steel Pty Ltd

Client