Water Cycle Management Report

Backsaddle and Wallace Planning Proposal

82018069-01

Prepared for

Backsaddle Pty Ltd and Mr. Chad Wallace

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Table of Contents

1	Introduction		5
	1.1	Background	5
	1.2	Site Description	5
	1.3	Scope of Work	7
2	Available Data		8
	2.1	Topographic Data	8
	2.2	Previous Studies	8
3	Hydrology		9
	3.1	Catchment Description	9
	3.2	Hydrological Model Selection	11
	3.3	Model Inputs	11
	3.4	Design Storm Results	13
4	Flooding		14
	4.1	Hydraulic Model Set Up	14
	4.2	Results	18
5	Water Quality and On-Site Detention		22
	5.1	Water Quality Treatment Train	22
	5.2	OSD Basins	22
6	Conclusions		24
	6.1	Conclusions	24

Appendices

Appendix A Hydrological Model

Tables

Table 3-1	Sub-catchment Properties	10
Table 3-2	Rainfall IFD Parameters	11
Table 3-3	GSDM Input Data	11
Table 3-4	PMF Rainfall Parameter Output	12
Table 3-5	XP-RAFTS Model Parameters	12
Table 3-6	Peak Flow Rate Comparison	13
Table 4-1	Adopted Roughness Values	15

Figures

Figure 1-1	Site Location	6
Figure 3-1	Catchment Plan	9
Figure 4-1	Hydraulic Model Extents (ground elevation contours in 1m intervals)	14
Figure 4-2	Delineation of material types in TUFLOW model	15
Figure 4-3	Inflow Locations and Boundary Conditions	16
Figure 4-4	Upstream 100 year ARI Flood Level Comparison	17
Figure 4-5	Downstream 100 year ARI Flood Level Comparison	17
Figure 4-6	100 Year ARI Flood Extents	18
Figure 4-7	PMF Flood Extents	19
Figure 4-8	Provisional Hazard Classification	20
Figure 4-9	Hydraulic categories	21
Figure 5-1	OSD and Water Quality Preliminary Layout and Sizes	23

1 Introduction

1.1 Background

Cardno NSW/ACT Pty Ltd (Cardno) has been engaged by Backsaddle Pty Ltd and Mr. Chad Wallace ("the client") to complete a Planning Proposal (PP) to support an amendment to the development controls and associated mapping within the Kiama Local Environmental Plan 2011 (KLEP 2011) for land off Greyleigh Drive and Old Saddleback Road, Kiama.

As part of this Planning Proposal application, Cardno is to undertake a comprehensive Water Cycle Management Study (WCMS) to demonstrate that the proposal is in accordance with the environmental controls of floodplain management, stormwater management and water sensitive urban design with reference to the Kiama Development Control Plan 2012 (KDCP 2012).

This study investigates detailed flooding behaviour across the site and ascertains whether any flood mitigation measures need to be incorporated into the proposed development. On-site stormwater quality is also assessed with recommendations given on improvement devices to be incorporated into the subdivision design.

1.2 Site Description

The proposed development site consists of a number of lots which have been under the ownership of the client for approximately 10 years. The site originally investigated is shown in **Figure 1-1** and the revised site area is shown in **Figure 1-2.** The area of the site has been revised as explained in Section 3.1 to the Planning Proposal application report.

The site is currently zoned primarily RU2, with a small proportion of E2 and E3 land located across existing vegetated areas. It is bounded by residential and pastural areas. Medium/dense vegetation areas are also prominent in the surrounding region at areas of higher ground level or near to flow paths.

Figure 1-1 Site Location for original field investigations and capability analysis

Figure 1-2 Revised site boundaries

1.3 Scope of Work

The main objective of this study is to identify any flood prone land within the site, and to derive recommendations for the development of the site. Specifically, the scope includes:

- Revise background data and work undertaken to date
- Refine sub-catchment and impervious cover delineation at the site
- Develop hydrological model of the existing scenario to estimate peak flows for the critical duration 100 year ARI and PMF design storm events and compare with Councils Flood Study
- Develop TUFLOW hydraulic model and incorporate existing scenario flows and review flooding extents in relation to zoning
- Develop preliminary layout, sizes and locations of water quality treatment devices and detention basins to demonstrate no net impact of the proposed development on Spring Creek
- Develop Water Cycle Management report to reflect analyses undertaken and the returned results

2 Available Data

2.1 Topographic Data

2.1.1 Aerial Laser Scanning Survey

Aerial Laser Scanning (ALS) survey data provides complete coverage of the study area and catchments. The ALS survey data, captured in 2011, was purchased by Cardno from NSW Land and Property Information (LPI).

The ALS digital elevation model (DEM) represents the existing natural surface for the study area. Features such as vegetation and buildings have been removed from the data. The DEM has been used for catchment delineation in the preparation of the hydrological model and in the development of the existing ground surface for the TUFLOW model.

It is noted that this data creates some minor inaccuracies in the surface, however the level of detail is considered sufficient in defining the general extent of flooding across the site at this preliminary phase.

2.2 Previous Studies

2.2.1 Spring Creek Catchment Flood Study (GHD, 2014)

A catchment wide study of Spring Creek was developed by GHD (2014) for Kiama Municipal Council (KMC). The proposed development site is located within this catchment and this study adopted XP-RAFTS for hydrology, and TUFLOW for 2D hydraulic analysis. The study provides information on appropriate hydrological losses for the area which have been adopted for this study. It also contains useful calibration information for multiple storm events such as:

- Creek discharges
- Flood water extents

This study will be referred to as the ‘Spring Creek Flood Study’ for the remainder of this report.

3 Hydrology

3.1 Catchment Description

The proposed residential development site is located centrally in the Spring Creek Catchment. The Spring Creek Catchment is approximately 5.8km^2 in area and is typified by steep slopes leading into well-defined natural water courses. The catchment consists primarily of dense vegetation (near to the natural flow paths) and pastural areas. Watershed in the Spring Creek catchment generally flows north easterly and dissipates into the ocean at the southern-most end of Bombo Beach.

The hydrological catchment plan for the site is presented in **Figure 3-1**.

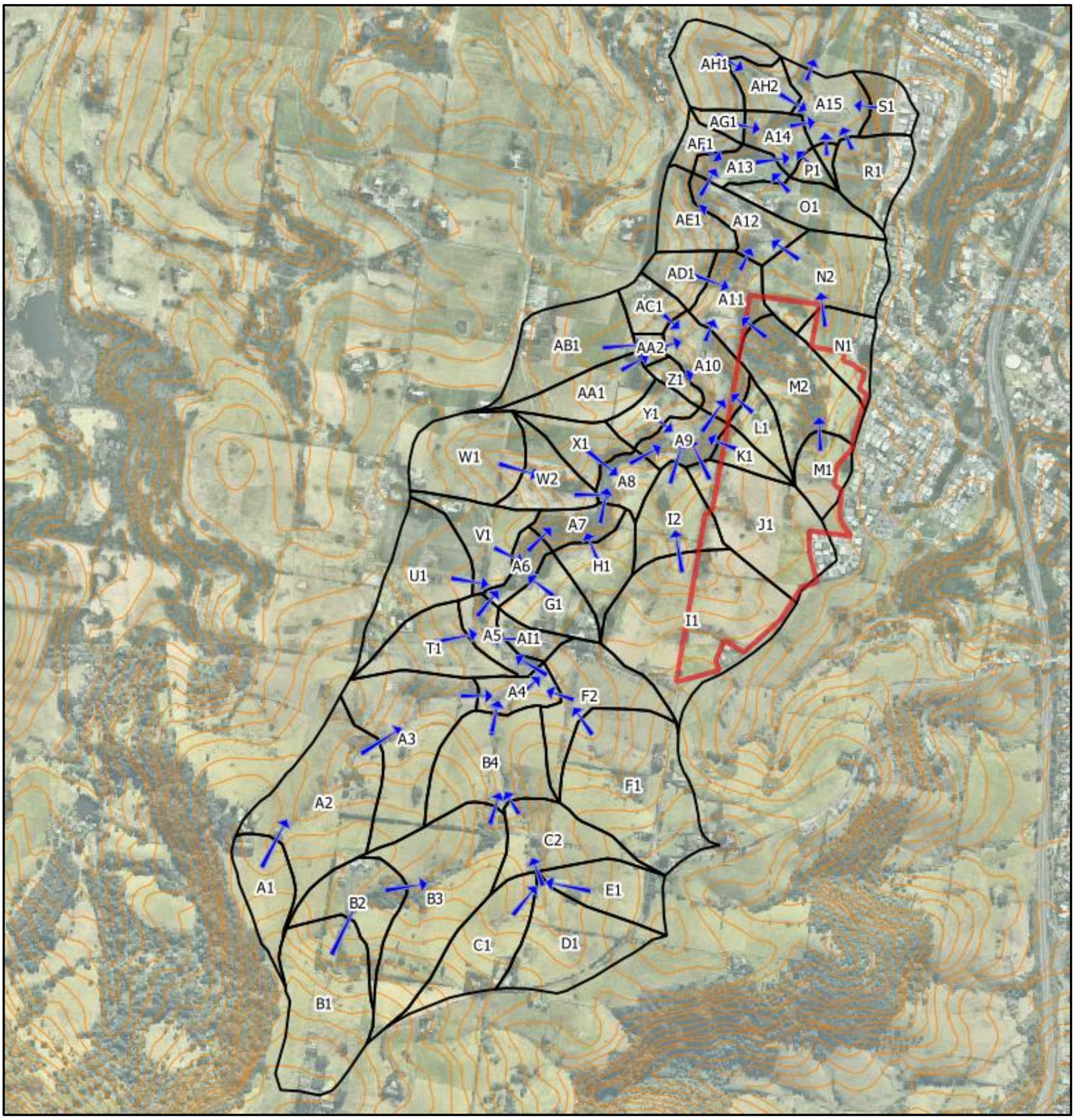

Figure 3-1 Catchment Plan

Table 3-1 Sub-catchment Properties

Sub-catchment	Area (ha)	Vectored Slope (%)	Impervious Area (%)	Sub-catchment	Area (ha)	Vectored Slope (%)	Impervious Area (%)
A1	4.871	12.504	0.944	C1	7.369	12.048	1.276
A10	4.845	3.064	0.000	C2	6.356	12.367	0.566
A11	4.686	5.397	0.000	D1	8.872	9.297	3.122
A12	4.056	3.034	0.740	E1	5.261	13.009	2.224
A13	2.534	3.810	0.000	F1	15.654	11.656	3.916
A14	2.700	3.658	1.407	F2	7.516	12.411	2.807
A15	4.454	1.688	2.492	G1	4.434	12.505	4.623
A2	13.740	10.184	0.990	H1	4.302	16.890	0.000
A3	12.137	7.750	0.000	I1	18.280	11.716	3.200
A4	2.697	4.842	0.000	I2	5.596	9.876	0.000
A5	2.625	2.278	5.295	J1	10.550	11.378	5.820
A6	1.939	7.817	0.000	K1	1.768	16.375	0.000
A7	2.715	7.085	0.000	L1	2.501	14.752	0.000
A8	2.571	10.304	0.000	M1	3.364	17.493	0.000
A9	3.129	5.486	0.000	M2	8.960	10.330	0.000
AA1	5.230	11.547	0.822	N1	4.124	15.000	8.190
AA2	0.754	12.183	0.000	N2	8.795	12.736	5.992
AB1	8.321	11.360	2.524	O1	4.640	13.792	6.983
AC1	2.380	22.817	9.916	P1	0.865	17.536	3.006
AD1	2.558	24.141	0.078	Q1	0.465	18.754	0.000
AE1	3.959	29.969	0.000	R1	4.929	18.491	11.118
AF1	1.723	23.402	6.965	S1	2.574	38.879	16.900
AG1	1.069	17.996	6.268	T1	5.798	15.422	5.847
AH1	5.559	17.048	1.673	U1	8.367	11.258	5.127
AH2	2.552	7.868	8.738	V1	5.039	12.529	8.017
AI1	1.645	14.008	8.875	W1	8.426	12.187	2.623
B1	12.959	18.544	4.684	W2	4.222	12.997	0.000
B2	6.102	16.917	9.177	X1	3.518	20.824	0.000
B3	15.352	12.640	0.599	Y1	2.651	26.947	0.830
B4	9.678	11.008	0.000	Z1	1.131	33.404	7.869

3.2 Hydrological Model Selection

The computer program XP-RAFTS was used to develop a hydrological model of the Spring Creek Catchment. XP-RAFTS estimates the runoff hydrograph based on catchment and rainfall data and is considered to be an appropriate model choice as it provides dynamic estimation of peak flow hydrographs.

3.3 Model Inputs

3.3.1 Sub-Catchment Topology

Sub-catchment topology for the constructed model reflected input from Aerial Laser Survey (ALS) data purchased from NSW Land and Property Information (LPI) to represent the existing surface.

Sub-catchments were delineated from the total catchment in order to accurately model the peak flows and flood extents over the site.

3.3.2 Rainfall

Rainfall data for the site was applied in consistency with the Spring Creek Flood Study. The Intensity Frequency Duration (IFD) parameters adopted for the Spring Creek Flood Study were used to generate the design storm bursts in the Cardno XP-RAFTS model. These parameters are presented in **Table 3-2**.

Table 3-2 Rainfall IFD Parameters

Parameter	Value
2 Year 1 Hour Intensity	47.95 mm/hr
2 Year 12 Hour Intensity	10.33 mm/hr
2 Year 72 Hour Intensity	3.08 mm/hr
50 Year 1 Hour Intensity	102.08 mm/hr
50 Year 12 Hour Intensity	22 mm/hr
50 Year 72 Hour Intensity	7.43 mm/hr
F2 Geographic Factor	4.27
F50 Geographic Factor	15.81
Location Skew Coefficient	0.0

The assessment of PMF flood events in XPRAFTS requires the development of a PMF temporal pattern using the Bureau of Meteorology Australia Generalised Short Duration Method (GSDM, BOM 2003). GSDM is a suitable estimation method for catchments up to 1000 km^2 and storm durations up to 6 hours and is therefore appropriate for the subject site. Data used to generate the PMF is presented in **Table 3-3**, and the output developed from this method and applied in the model is presented in **Table 3-4**. **Table 3-4** also presents the equivalent PMF parameter output as determined and used in the Spring Creek Flood Study, which shows a close comparison and therefore acceptability for use of the parameters in the Cardno study.

Table 3-3 GSDM Input Data

Parameter	Value	Comment
Fraction Rough	100%	Terrain is classified rough when elevation changes of 50m or more within horizontal distances of 400m are common
Elevation Adjustment Factor	1.00	Adjusted by -0.05 per 300m above 1500m
Moisture Adjustment Factor	0.68	From BOM (2003)

Table 3-4 PMF Rainfall Parameter Output

Storm Duration (hr)	PMP Rainfall Depth (GHD, 2014) (mm)	PMP Rainfall Intensity (GHD, 2014) (mm/hr)	PMP Rainfall Depth (mm)	PMP Rainfall Intensity (mm/hr)
0.25	150	600	160	627
0.5	220	440	230	455
0.75	280	373	290	383
1	320	320	330	334
1.5	410	273	430	287
2	480	240	500	252
3	580	193	610	203
4	670	168	700	174
6	780	130	810	135

3.3.3 Hydrological Parameters

The hydrological parameters used for input to the XP-RAFTS model are listed in **Table 3-5**. The values presented for the initial loss and continuing loss parameters have been taken and applied for consistency with the Spring Creek Flood Study.

Table 3-5 XP-RAFTS Model Parameters

Parameter	Pervious Area	Impervious Area
Initial loss (100y ARI)	10 mm	1.5 mm
Initial loss (PMF)	0 mm	0 mm
Continuing loss (100y ARI)	2.5 mm/hr	0 mm/hr
Continuing loss (PMF)	1 mm/hr	0 mm/hr
Catchment Manning's 'n'	0.035	0.025
% Impervious	0	100
Vectored Slope	Calculated based on catchments topography data	

The model was constructed with catchment nodes using the above parameters and the sub-catchment properties as presented in **Table 3-1**. These were then linked with channel routing connections. Each channel routing connection was given a cross-sectional profile, length and slope for the model to accurately transfer the flow hydrographs through the connected nodes. This is not in alignment with the method used in the Spring Creek Flood Study, which instead used only simple lag connections.

3.3.4 Impervious Fraction

The impervious area for each sub-catchment was estimated using the most recent available aerial photography. The surface area of impervious features was determined as a percentage of the individual sub-catchment areas and an impervious factor was assigned to each which represented the density of impervious features present. The impervious fraction of each sub-catchment was modelled in XP-RAFTS by splitting each catchment node into a wholly pervious (0% impervious) and a wholly impervious (100% impervious) segment, which sum to give the total area of each sub-catchment.

The impervious fraction of each sub-catchment is presented in **Table 3-1**, sub-catchment properties.

3.4 Design Storm Results

3.4.1 Critical Storm Duration

The storm events analysed in this study included the 100 year ARI and PMF events.

The XP-RAFTS hydrological model was run with a spectrum of storm durations to allow determination of the critical design storm duration for the existing catchment.

It was established that for the 100 year ARI event, the critical duration is 2 hours. For the PMF event the critical duration is 30min.

Flow hydrographs from the XP-RAFTS program have been applied to the hydraulic model at key locations.

3.4.2 Flow Rate Comparison

The peak flow rates as determined from the XP-RAFTS model have been compared with the results from the Spring Creek Flood Study to rationalise the model performance. The catchment plan of the Cardno study is only concerned with the upstream components of the Spring Creek catchment and therefore points for comparisons with the Spring Creek Flood Study are limited. However, two locations in the Spring Creek Flood Study are available for direct flowrate comparison.

Catchments C12 and C42 of the Spring Creek Flood Study generally represent catchments A5 and A15 respectively in the Cardno study. Comparisons between the peak flowrate experienced at these locations in each study are presented in **Table 3-6**.

Table 3-6 Peak Flow Rate Comparison

Location (Spring Creek Flood Study XP-RAFTS sub catchment outlet)	Recurrence Interval	Modelled Peak Flow Rates (m^3/s)	
		Spring Creek Flood Study	*Cardno (This Study)*
Upstream (C12)	100yr ARI	68.0	78.7
	PMF	197.7	227.0
Downstream (C42)	100yr ARI	125.0	165.8
	PMF	364.0	512.0

The flow rates estimated in this study are consistently higher than the Spring Creek Flood Study results by approx. 15-20%. This discrepancy is likely due to the use of more detailed routing methods, as opposed to simple lag links, in the linking of nodes in the XP-RAFTS model, and an increased detail in the catchment delineation.

As the results obtained from the model are relatively equivalent, but slightly larger magnitude, they are considered suitable to be used in the hydraulic model to produce results in a conservative manner.

4 Flooding

4.1 Hydraulic Model Set Up

4.1.1 Selection of Model

The computer program TUFLOW was used to develop a 2D hydraulic model of the study area. A 2D model was selected in preference over a 1D model to better represent the complex hydraulics associated with overland flow.

4.1.2 Model Geometry

The TUFLOW model was established over a 2m grid with elevations extracted from the ALS topographic data. The model extents are shown in **Figure 4-1**.

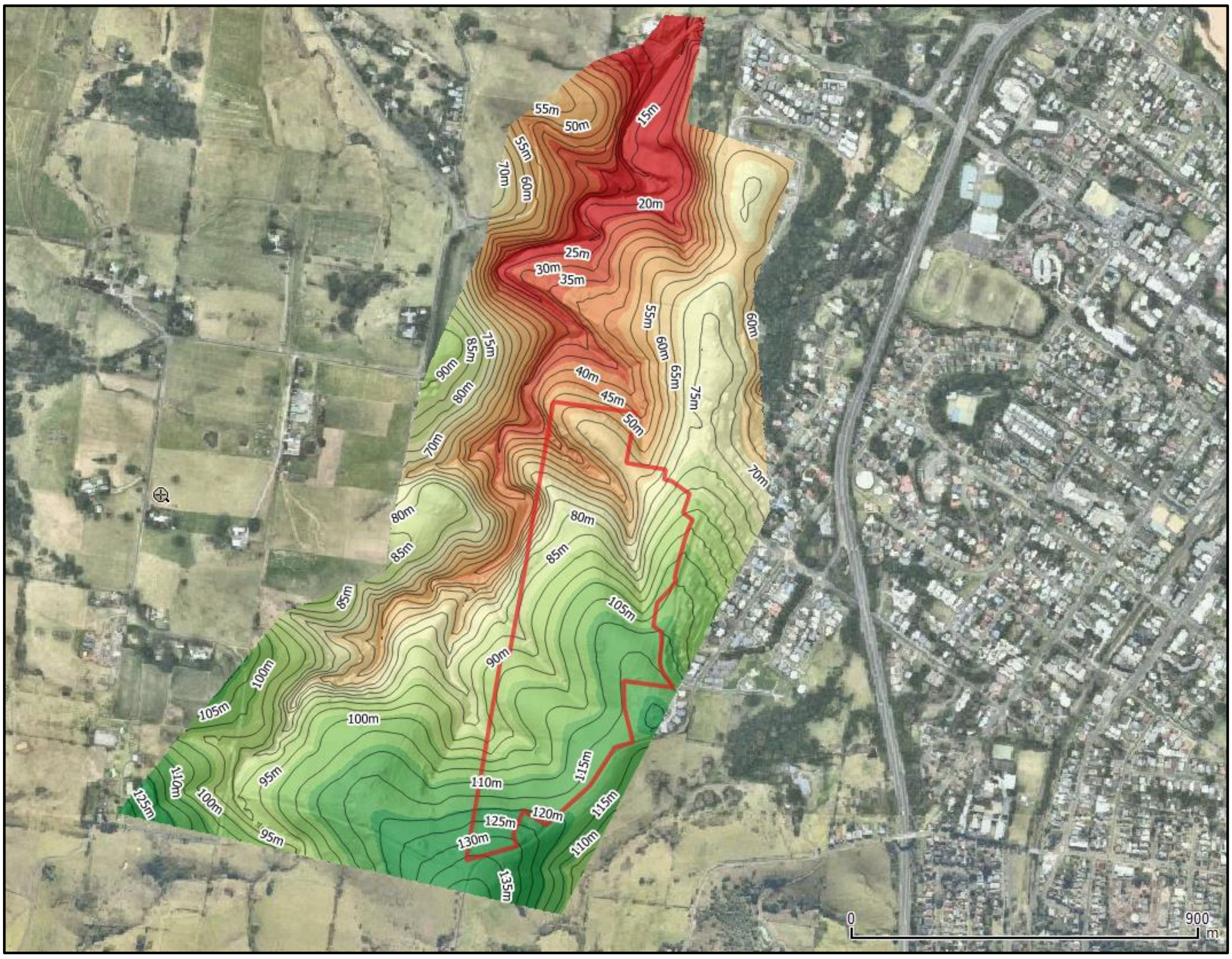

Figure 4-1 Hydraulic Model Extents (ground elevation contours in 5m intervals)

4.1.3 Roughness

Manning's roughness values were applied to the model based on aerial imagery. The roughness values adopted in the model are presented in **Table 4-1**. The delineation of the materials in the TUFLOW model is shown in **Figure 4-2**. The default material type applies to all other area of the model not delineated in the figure below as passive material.

Table 4-1 Adopted Roughness Values

Surface Type	Manning's n Value
Pasture (default)	0.035
Creek Channel Bed	0.03
Dense Vegetation	0.15
Road Reserve	0.025
Buildings	3

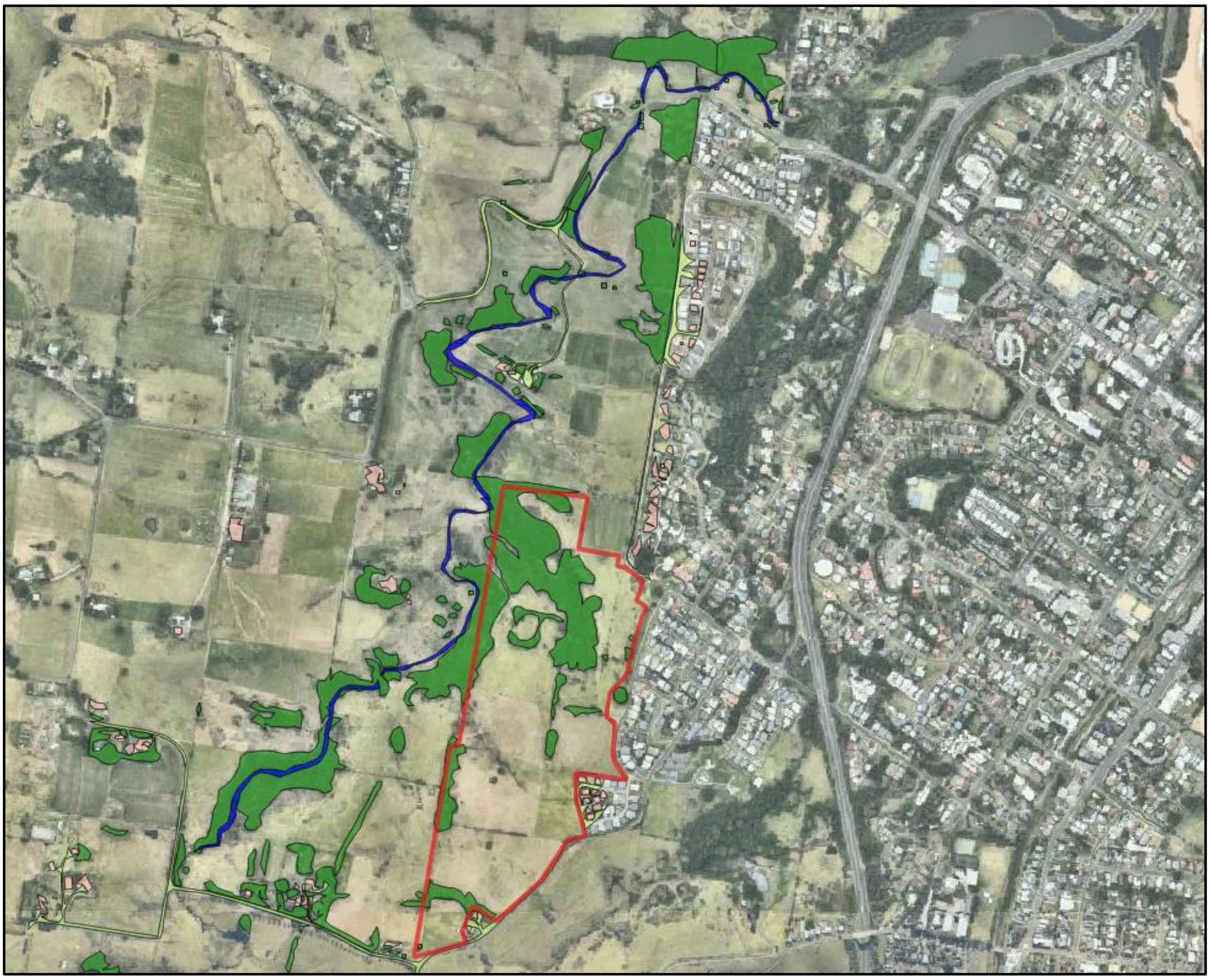

Figure 4-2 Delineation of material types in TUFLOW model

4.1.4 Inflow Locations and Boundary Conditions

Hydrographs determined using the XP-RAFTS model were applied as boundary conditions within the hydraulic model. Inflow location and downstream tail water condition line are demonstrated in **Figure 4-3.**

Both total (red polygon) and local (blue polygon) inflows are demonstrated in **Figure 4-3**. The downstream boundary condition was modelled using a rating curve which is calculated within the TUFLOW model and is based on the cross section and water surface slope. It is noted that the downstream boundary condition line has been located approximately 1.2 km away from the site along the main creek channel.

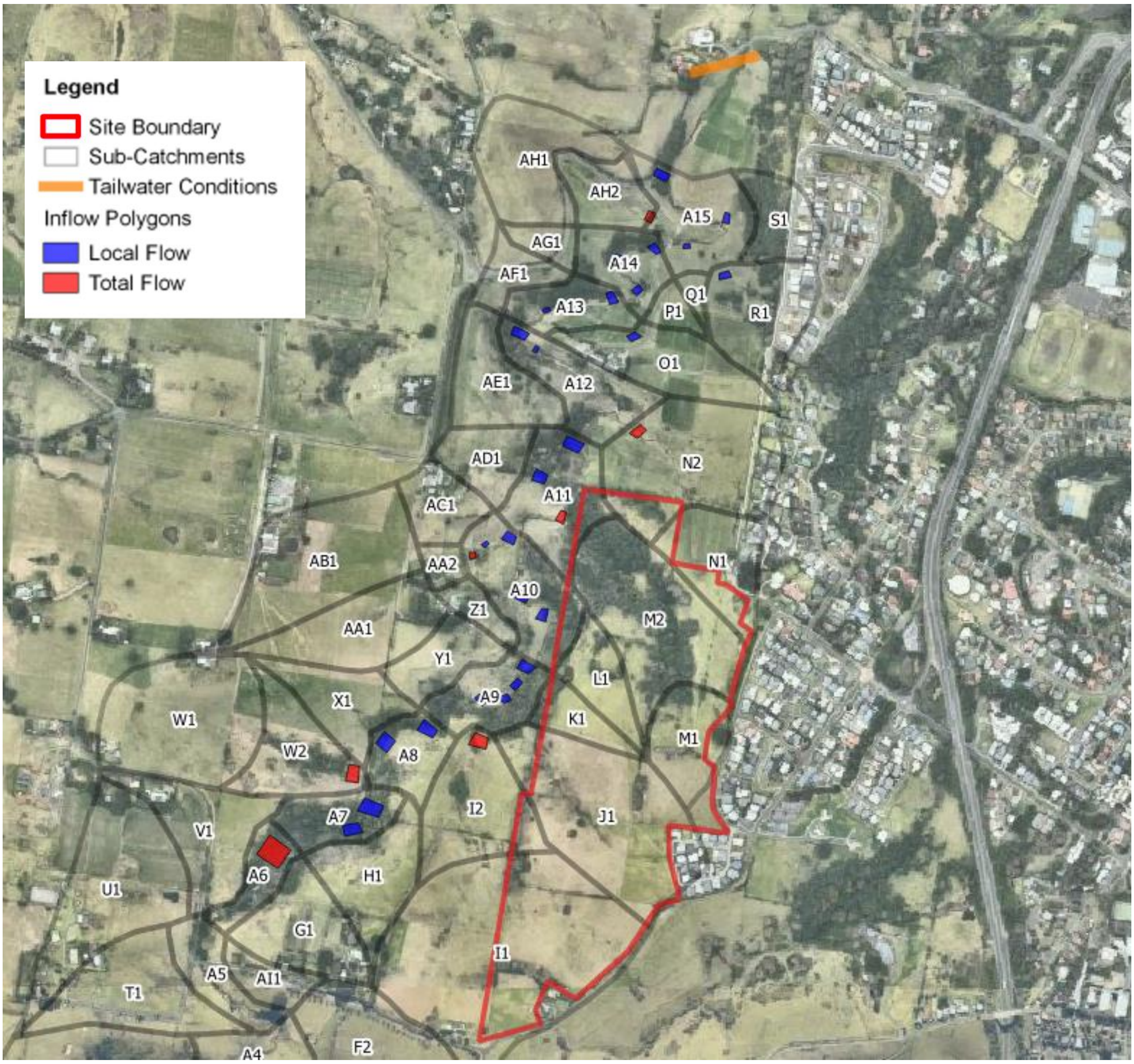

Figure 4-3 Inflow Locations and Boundary Conditions

4.1.5 Model Calibration

A comparison has been made showing reasonable consistency of the flood level between the Cardno Study and the Spring Creek Flood Study. The calibration results for the 100 year ARI are presented in **Figure 4-4** and **Figure 4-5** for upstream and downstream locations respectively. Red contour lines and text are derived from Cardno's model while blue lines and **black** font are sourced from the Spring Creek Flood Study.

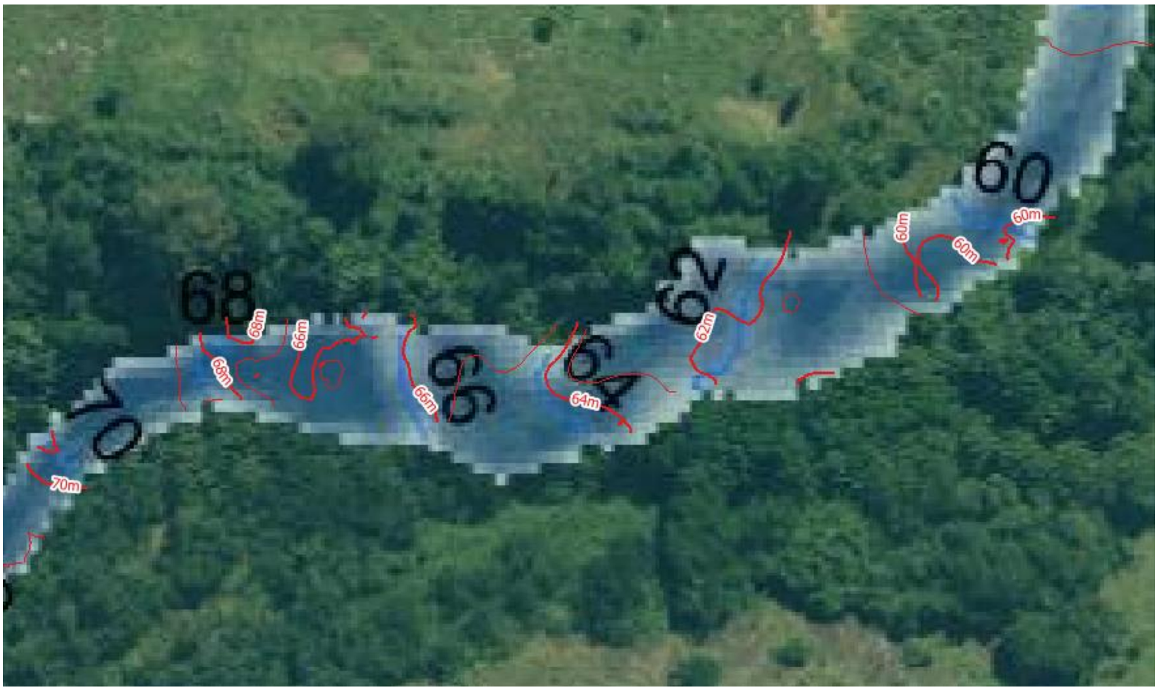

Figure 4-4 Upstream 100 year ARI Flood Level Comparison

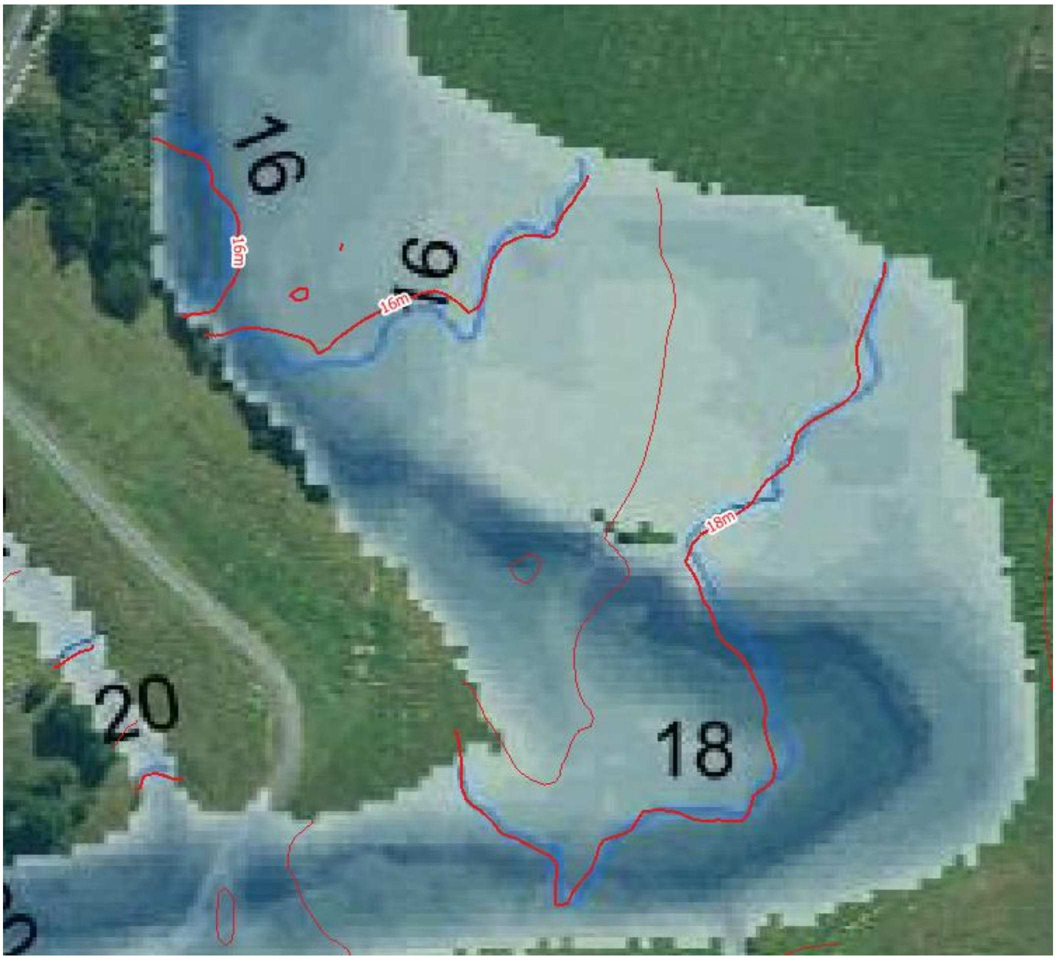

Figure 4-5 Downstream 100 year ARI Flood Level Comparison

4.2 Results

4.2.1 Existing Flood Extents

The TUFLOW model was run to determine the extent and depth of flooding that could occur at the existing site during the 100 year ARI and PMF storms. These simulation results provide the basis for the impact study on the effect of the building development on water level behaviour during flood events.

The water depth and water levels contours for the 100 year ARI and PMF events near the site are presented in **Figure 4-6** and **Figure 4-7** respectively.

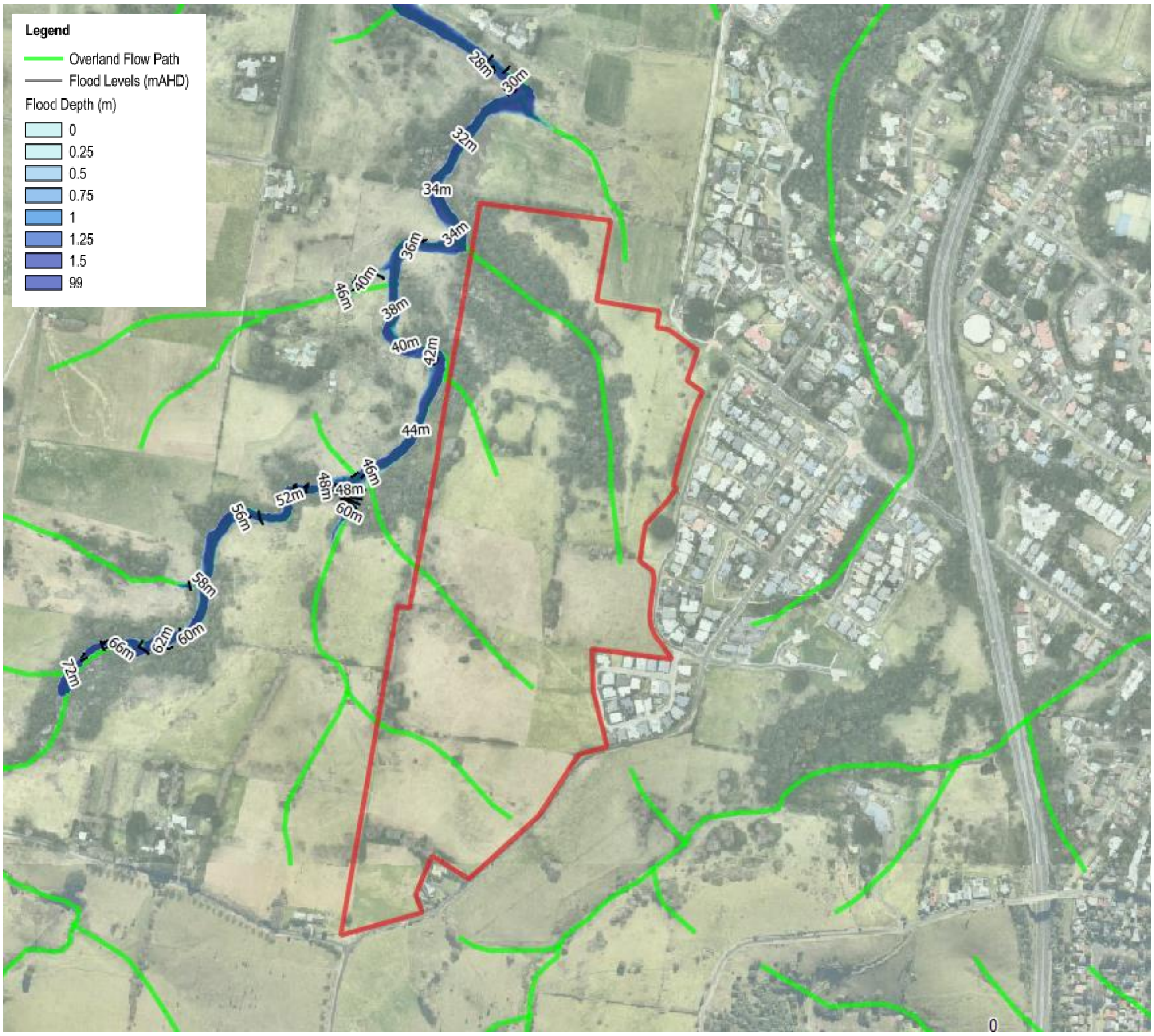

Figure 4-6 100 Year ARI Flood Extents

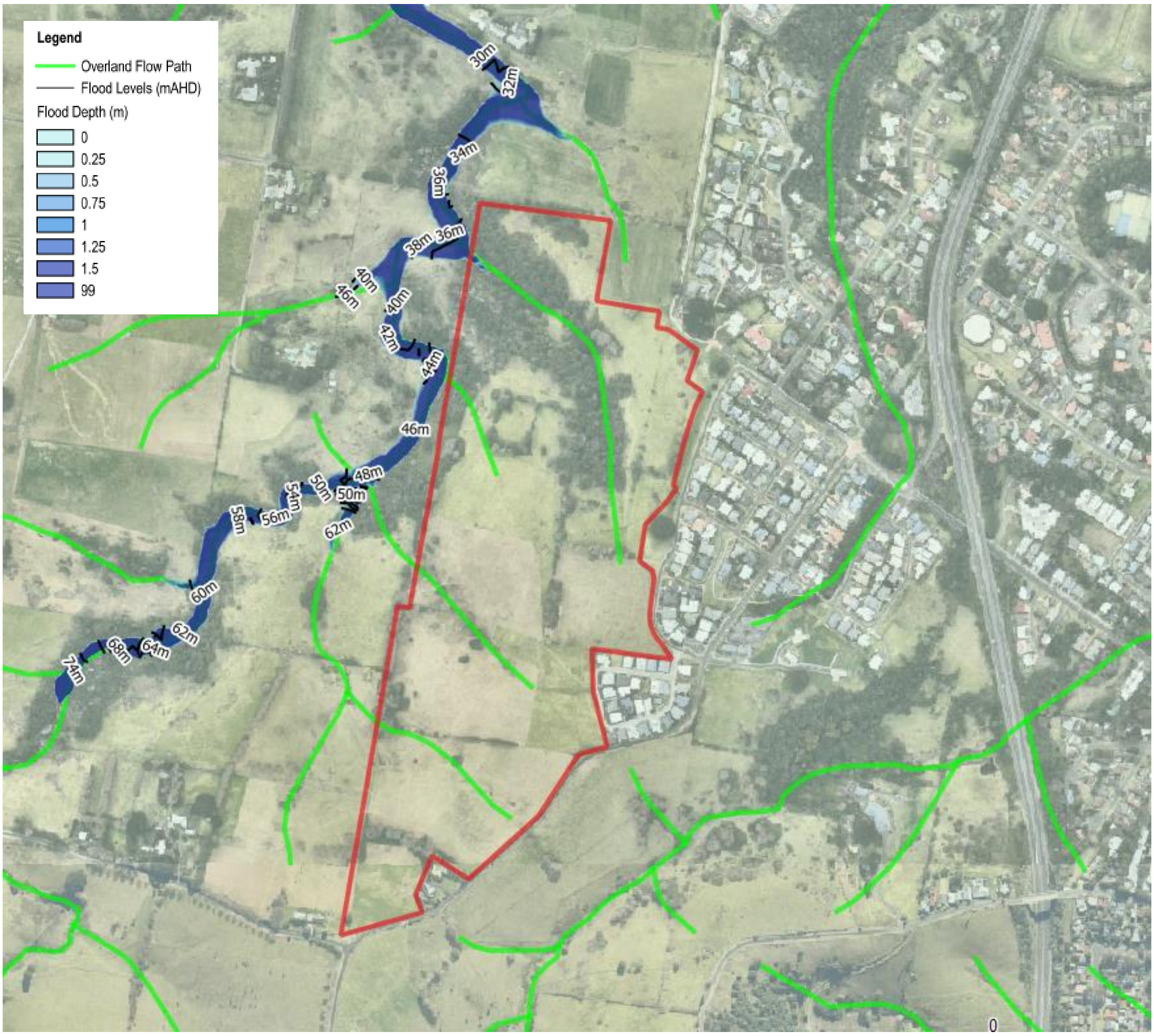

Figure 4-7 PMF Flood Extents

As can be seen in the figures, the flood water is well contained in the main channel of Spring Creek and the majority of the site is outside of the extent of floodwaters during the 100 year ARI and PMF events

It is noted that there are five flow paths, as shown in green lines within the original site boundary, which are not included in the flood model. These are 1st order watercourses and will potentially be realigned or filled during earthwork and piped in the future storm water network. Therefore they are not considered as flood constraints to the site rezoning.

4.2.2 Provisional Hydraulic Hazard Determination

Hydraulic hazard is categorised in the NSW Floodplain Development Manual (2005) into the following levels:

- High Hazard
  - Possible danger to personal safety
  - Evacuation by trucks difficult
  - Able-bodied adults would have difficulty in wading to safety
  - Potential for significant structural damage to buildings
- Low Hazard
  - Evacuation by truck possible
  - Able-bodied would have little difficulty in wading to safety

Provisional Hazard Classification of the study are presented in **Figure 4-8.**

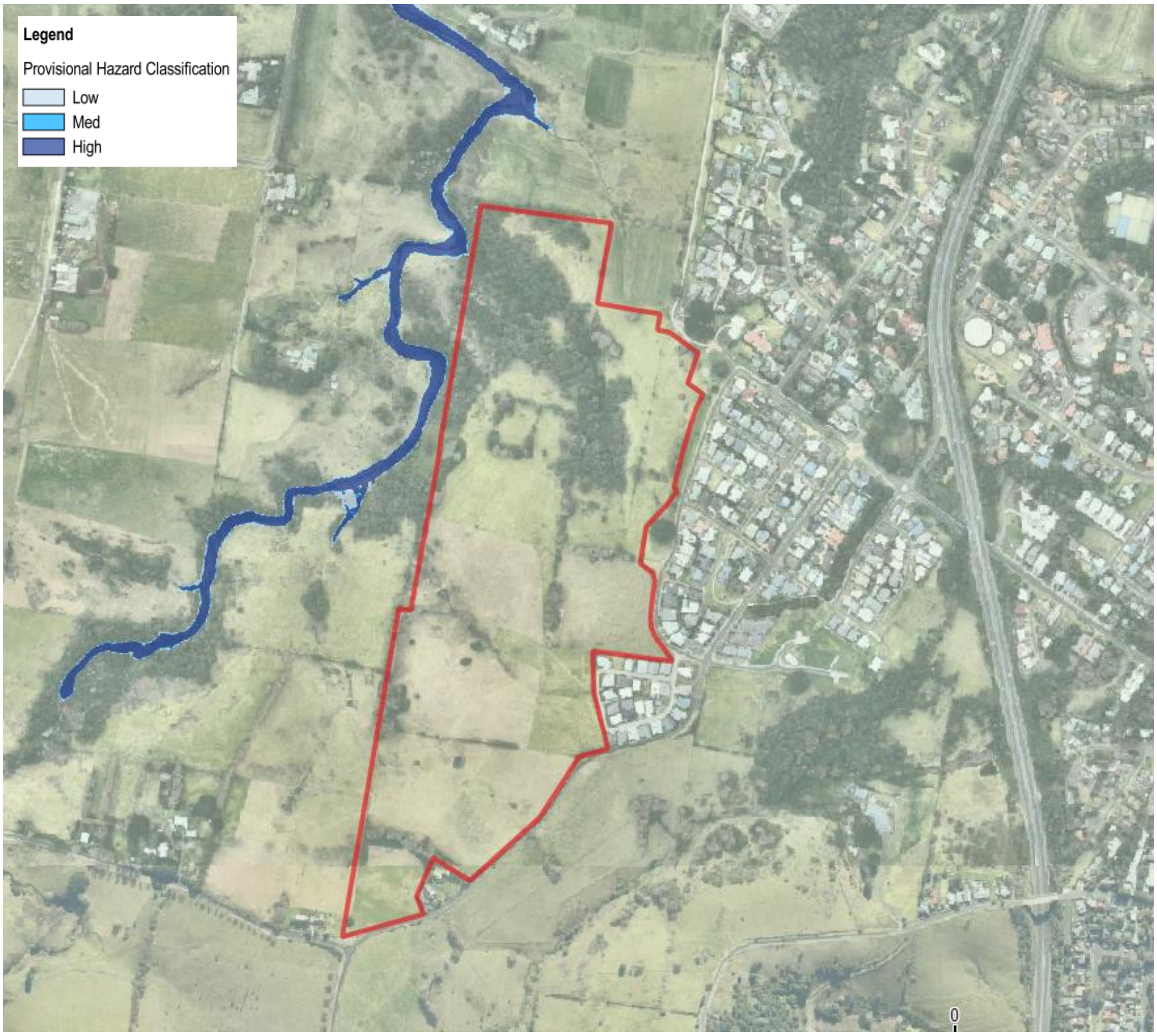

Figure 4-8 Provisional Hazard Classification

4.2.3 Hydraulic Categories

The Floodplain Development Manual defines three categories of flood prone land. In this study, Cardno adopted an initial classification of the Spring Creek Flood Study as follows:

- Floodway - areas of channel where peak velocity-depth was 1m/s or greater
- Flood Storage – areas based on flood depth being greater than or equal to 0.25 m
- Flood fringe - areas were initially identified as the remaining flood extent for each event

Hydraulic categories of this study are presented in **Figure 4-9**.

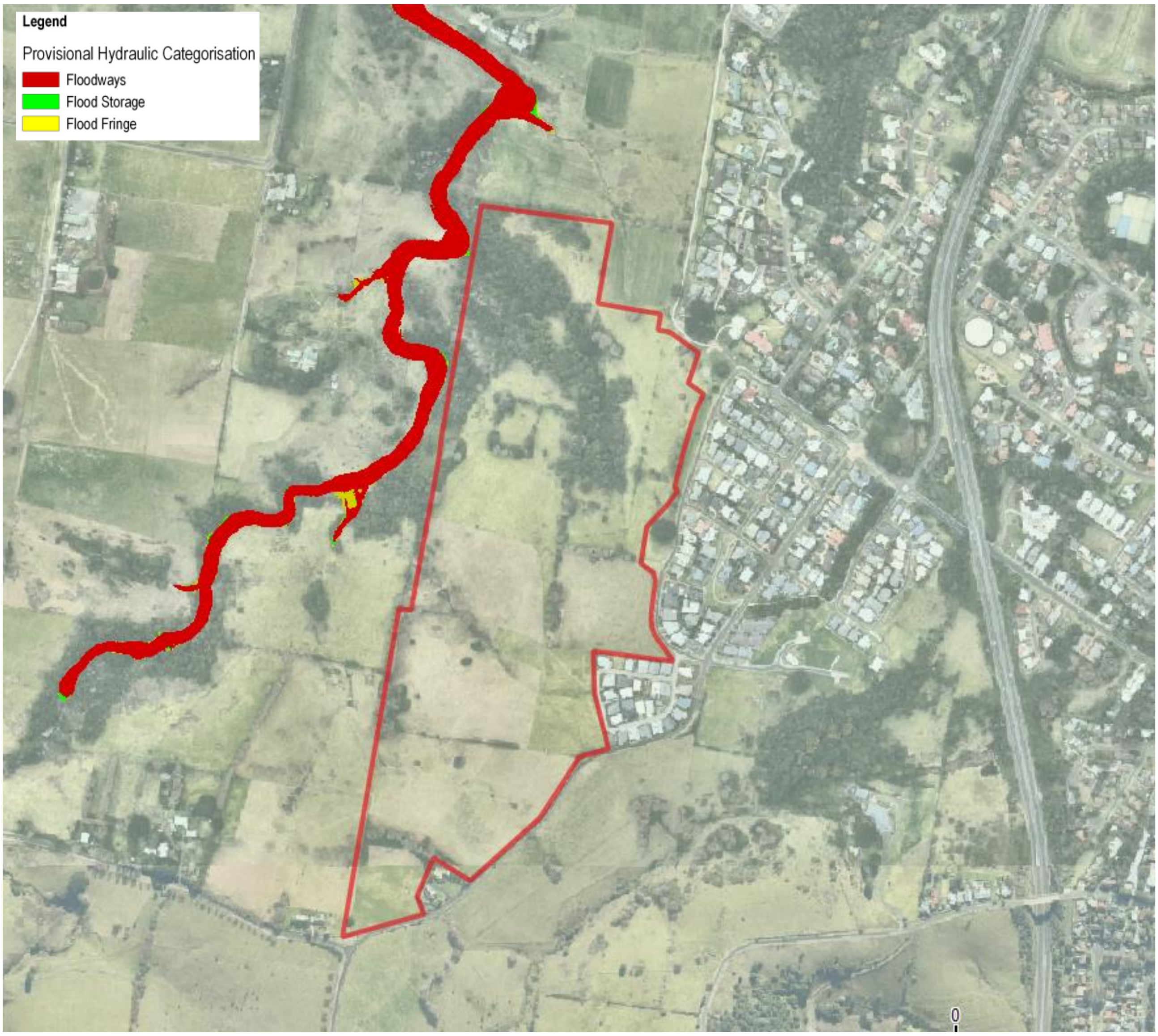

Figure 4-9 Hydraulic categories

5 Water Quality and On-Site Detention

Water Quality treatment devices and On-Site Stormwater Detention (OSD) basins will be used in this project to reduce the environmental impact of the development. Preliminary layout, sizes and locations of the treatment devices and detention basins are presented in the pursuing sections.

5.1 Water Quality Treatment Train

It is assumed that a treatment train consisting of rain water tanks, gross pollutant traps and bioretention basins or wetlands will be used to manage the pollutant runoff from the developed site.

All water from the site will be diverted into a GPT and bioretention basin before discharging into the major watercourses within the site boundary. As a preliminary sizing, it is expected that the size of each bioretention basin will be approximately 2% of the area of the proposed development site that will drain into it. This will result in the design of 4 bioretention basins, their indicative locations and areas as presented in **Figure 5-1**.

5.2 OSD Basins

OSD basins will be included in the design at the same 4 locations as the bioretention basins, from which the site runoff will be discharged into the major watercourses within the site boundary. As a preliminary sizing, each OSD will be approximately 4% of the area of the site that flows into it. The preliminary size and location of the OSD basins is illustrated in **Figure 5-1**.

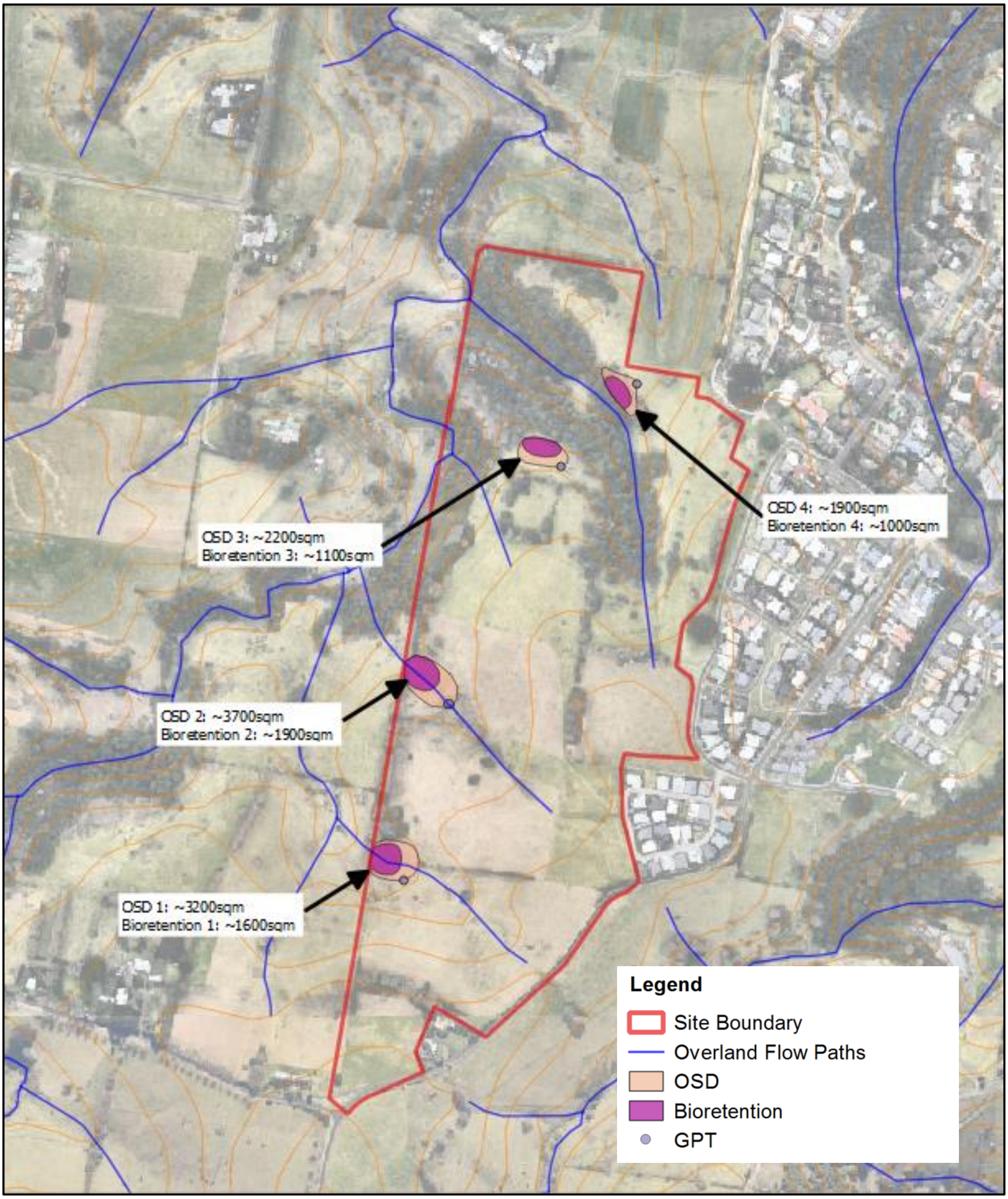

Figure 5-1 OSD and Water Quality Preliminary Layout and Sizes

6 Conclusions

6.1 Conclusions

It is concluded that:

- The flow rates determined through the hydrological modelling in the Cardno study are generally comparable to but slightly higher than those presented in the Spring Creek Flood Study
- The existing site contains marginal flood prone land
- Five flow paths within the site are over land flow paths for the local catchments, and will be filled during earthworks and piped in the future storm water network, and are hence not considered as flood constraints in the site rezoning
- The site development will require the use of a network of treatment devices including bioretention basins (total preliminary footprint, ~5600sqm), rainwater tanks and GPTs to meet water quality targets, and OSD basins (total preliminary footprint, ~11000sqm) to meet post development flowrate standards.