Lot 37 Stephenson Street, Crookwell

Flood Impact Assessment

Revision 1
December 2022

Catchment Simulation Solutions

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LIST OF FIGURES (APPENDIX A)

1 INTRODUCTION

Johanna Investment Group is proposing to undertake earthworks and regrading within Lot 37 Stephenson Street, Crookwell. The location of the site is shown in **Figure 1**, which is enclosed in **Appendix A**.

The site was formerly used as a brick pit and contains large areas of excavation. The site is also traversed by a non-perennial watercourse. The outcomes of computer flood modelling completed as part of the *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014) shows that during heavy rainfall in the local catchment there is the potential for inundation of large parts of the site, including some significant ponding of water within the excavated areas of the site. The proposed earthworks and regrading have the potential to redistribute flows within and around the site which may adversely impact on local flood behaviour.

In recognition of the potential for inundation of the site and for the proposed works to impact on existing flood behaviour, Johanna Investment Group, engaged Catchment Simulation Solutions to prepare a Flood Impact Assessment for the works. This report summarises the outcomes of the investigation, including:

- Development of hydrologic and hydraulic computer models of the local catchment
- Existing flood behaviour in the vicinity of the proposed development
- Predicted flood behaviour with the proposed works in place
- Impact of the proposed works on flood behaviour in the vicinity of the site (under existing and potential future climate conditions).

Further detailed information on the outcomes of the flooding investigation are provided in the following sections.

2 EXISTING FLOOD BEHAVIOUR

2.1 General

In order to understand the potential impact of the proposed works on flood behaviour, it is first necessary to define flood behaviour for "existing" conditions. As discussed, existing flood behaviour has been defined as part of *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014). Unfortunately, the flood models developed as part of this study were unavailable for use within the current assessment. Therefore, it was necessary to develop new hydrologic and hydraulic models of the local catchment.

The hydrologic model, which is used to simulate rainfall-runoff processes, was developed using the XP-RAFTS software. The hydraulic model, which is used to simulate movement of runoff along the various watercourses, was developed using the TUFLOW software.

The following chapter describes the model development process as well as the outcomes of the existing flood assessment.

2.2 XP-RAFTS Modelling

2.2.1 Catchment Delineation

The CatchmentSIM software was used to delineate the catchment draining through the development site as far downstream as the Crookwell River. The model was extended to Crookwell River to enable the potential flood impacts to be quantified well downstream of the site (and to also ensure the adopted downstream boundary condition did not impact on results).

The subcatchment delineation was based on a 1 metre and 5 metre Digital Elevation Model (DEM) that was developed from 2009 and 2014 LiDAR data respectively, obtained from the ELVIS website. The overall catchment draining to the Crookwell River that was mapped using the CatchmentSIM software is shown in **Figure 1**. In instances where the 1m and 5m DEM overlapped, the 1 m DEM took priority.

The overall catchment was broken up into a number of smaller subcatchments to better define the spatial variation of hydrologic properties across the catchment. The adopted subcatchments are shown on **Figure 2**.

A variety of hydrologic parameters were calculated for each subcatchment to enable the hydrologic model to be parameterised. This included:

- Subcatchment area
- Subcatchment slope
- Percentage impervious
- Roughness (PERN)
- Flow path length.

The subcatchment area, subcatchment slope and flow path length were calculated automatically by the CatchmentSIM software based on the underlying DEM.

The percentage impervious and subcatchment roughness were calculated by developing a representation of land use based on LiDAR point classifications. The extent of each land use is shown on **Figure 3**. A representative impervious percentage and roughness was assigned to each of the land use types and is listed in **Table 1**. This information was then used to calculate a weighted average impervious percentage and roughness value for each subcatchment. The adopted subcatchment properties are provided in **Appendix B**.

Table 1 Adopted land use Impervious percentage and Manning's "n" Roughness Values

Material Description	Impervious (%)	Roughness
Grass	0	0.030
Trees	0	0.100
Waterbodies	100	0.030
Roadway	100	0.015
Building	100	XP-RAFTS: 0.025 TUFLOW: 1.000

2.2.2 Model Development

The subcatchment properties formed the basis for developing a XP-RAFTS hydrologic model of the catchment. The subcatchment and node-link layout is shown on **Figure 2**. Each subcatchment "node" was parameterised based on the information contained in **Appendix B**.

Time delay routing links were adopted to represent the routing of flows between subcatchment "nodes". The Bransby-Williams equation was adopted for the lag calculations.

2.2.3 Results

Once the XP-RAFTS model was developed, a range of 1% AEP storms were simulated based upon procedures set out within *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Geoscience Australia, 2019).

To complete the 1% AEP storm simulations, 1% AEP rainfall depths were downloaded from the Bureau of Meteorology 2016 IFD website. The adopted 1% AEP rainfall depths for the catchment are summarised in **Table 2**.

The initial-continuing loss model was applied as part of the design storm simulations to simulate rainfall losses across the catchment. The burst initial losses for pervious sections of the catchment were assigned using the ARR2019 data hub "probability neutral" burst losses. The pervious continuing loss rates were applied as per the revised New South Wales specific guidance provided on the ARR data hub. This involves applying a 0.4 factor to the published data hub value of 4.10mm/hr (i.e., 0.4 x 4.3mm/hr = 1.72 mm/hr). For impervious surfaces, a burst loss of 0 mm and a continuing loss rate of 0 mm/hr were adopted.

Table 2 Design 1% AEP Rainfall Depths

Duration	Rainfall Depth (mm)
5 mins	10.8
10 mins	17.3
15 min	21.4
20 mins	24.3
25 mins	26.4
30 mins	28.2
45 mins	32.3
1 hour	35.4
1.5 hour	40.4
2 hours	44.8
3 hours	52.6
6 hours	72.2
9 hours	88.5
12 hours	102
18 hours	125
24 hours	142

Temporal patterns for the study area were downloaded from the ARR2019 data hub to simulate the temporal distribution of rainfall for each design storm. Storm durations between 5 minutes and 24 hours were included in this assessment to ensure the critical 1% AEP flows were captured at the site.

Peak discharges were generated for the full range of 1% AEP storm durations and temporal patterns for each of the subcatchments. The critical storm duration for each XP-RAFTS subcatchment was then determined. This involved calculating the average design discharge for each subcatchment (based on consideration of a suite of ten temporal patterns for each storm frequency and duration). The storm duration that produced the highest average discharge was adopted as the critical duration for each subcatchment. The critical duration for each XP-RAFTS model subcatchment is summarised in **Appendix C**. The most suitable ARR2019 temporal pattern for each subcatchment (i.e., the temporal pattern that generated the next highest peak discharge above the average) was also extracted and is included in **Appendix C** along with the corresponding peak discharge.

This analysis determined that the 90-minute storm produced the critical duration at the site. Temporal pattern 3907 was adopted as the representative temporal pattern for the 90-minute storm at the site and was adopted as part of all subsequent analysis to define 1% AEP design flood behaviour for this study.

2.3 TUFLOW Modelling

2.3.1 Model Development

A hydraulic model of the catchment was developed using the TUFLOW software. Key features of the TUFLOW model are summarised below:

- Model Domain: the TUFLOW hydraulic model area extends across the full catchment draining through the development site. The model also extends down to Crookwell River (i.e., well downstream of the site) to ensure the adopted downstream boundary condition did not impact on flood behaviour in the vicinity of the development site. The extent of the model is shown on **Figure 3**.
- Grid Size: a 1 metre grid size was used to represent the variation in terrain and hydraulic properties (e.g., hydraulic roughness) across the catchment.
- Topography:2009 LiDAR data was used to assign elevations to each TUFLOW model grid cell and was supplemented with detailed survey across as well as upstream of the site. Minor terrain modifications were also included in areas where the LiDAR data provided a less reliable representation of the ground surface, such as along the watercourses.
- Land Use and hydraulic Roughness: the land use types that were previously defined as part of the XP-RAFTS model development were also used within the TUFLOW model to assign hydraulic roughness coefficients to each grid cell. The adopted roughness coefficients are included in **Table 1**.
- Buildings: Buildings can provide a significant impediment to flow. Therefore, as shown in **Table 1**, buildings were represented in the TUFLOW model using a high roughness value of = 1.0 to reflect this flow impediment.
- Farm Dams: A number of farm dams are located near the development site as well as the upstream catchment. Although these water bodies do have the potential to temporarily store water during rainfall events, none of the storages are explicitly designed to serve as flood detention basins. As a result, these dams were assumed to be “full” at the start of each simulation and provided no attenuation of flows.
- Inflow hydrographs: The critical 1% AEP flow hydrographs generated by the XP-RAFTS model were used to define inflows to the hydraulic model. The hydrographs were applied to the outlet of each XP-RAFTS model subcatchment.
- Downstream Boundary: The downstream boundary condition was defined using a ‘normal depth’ (i.e.: Manning’s) calculation. A slope of 6% was adopted based on the available LiDAR at the downstream model boundary.
- Hydraulic Structures: Culverts were included under Stephenson Street at two locations adjacent to the development site based on site inspections and field measurements by Civil Development Solutions. The culverts off the north-east and south-east corners of the lot were both included as single barrel 0.45m diameter pipes.

2.3.2 Results

The TUFLOW model was used to simulate the critical 1% AEP flood for existing topographic and development conditions.

Peak 1% AEP floodwater depths and levels, and peak flow velocities were extracted from the TUFLOW model results and are presented on **Figure 4** and **Figure 5** respectively. It should be noted that only areas exposed to an inundation depth of greater than 0.05 metres are shown in **Figure 4** and **Figure 5** to distinguish between areas of negligible inundation and those areas subject to more significant overland flooding. This is consistent with *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014).

Figure 4 shows that most of the floodwater enters the site mid-way along the western site boundary. Water is also predicted to enter the site via a small channel near the south-western corner of the site. Both flow paths move in an easterly direction and contribute to a large area of ponding across the eastern part of the site. Depths within the channels can reach 0.15 metres, however, more significant depths of over 1 metre are predicted within the ponded area. Peak 1%AEP flood levels within the site vary from 895m AHD at the western site boundary and 894.3m AHD at the southern site boundary, down to 893.5m AHD at the eastern boundary where flow leaves the site to Stephenson Street.

Figure 5 shows that peak 1% AEP flow velocities approach 2m/s within the channels through the site. However, the velocities reduce to less than 0.5m/s in the ponded area within the eastern section of the site.

2.3.3 Result Validation

The existing flood behaviour published as part of *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014) was compared against the existing results produced as part of the current assessment to ensure realistic results were being produced. **Plate 1** shows the 1% AEP flood depths in the vicinity of the development site from *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014) and **Plate 2** shows the corresponding 1% AEP flood depths produced from the current assessment.

It should be noted when reviewing the results comparison that *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014) employed a 4-metre grid size as part of the hydraulic modelling and utilised hydrologic procedures from the now superseded *'Australian Rainfall and Runoff'* (Engineers Australia, 1987). The current assessment has adopted a more detailed 1 metre grid size as well as updated hydrologic procedures from *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Ball et al, 2019). However, despite these differences, the flood depths and extents presented on **Plate 1** and **Plate 2** are similar in magnitude and extent. This provides confidence that the model developed as part of the current assessment is providing reliable results and is fit for assessing potential flood impacts.

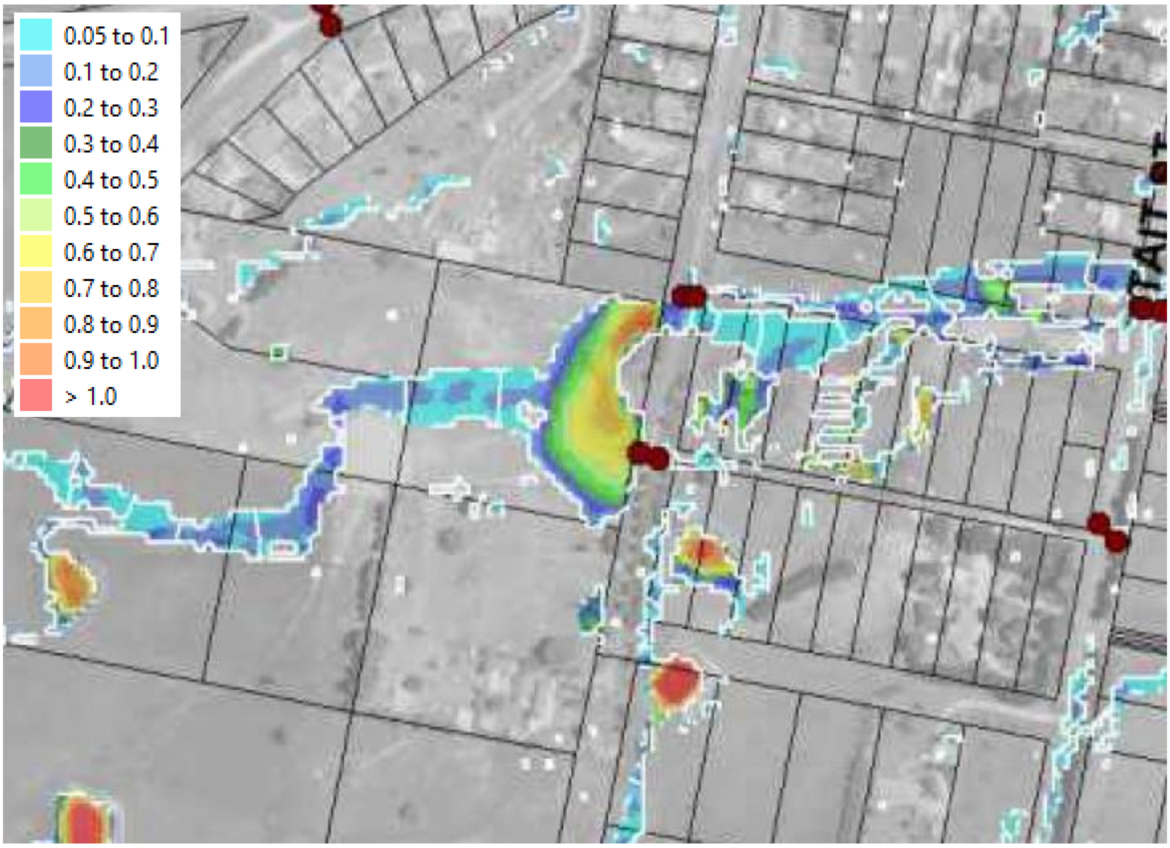

Plate 1 – 1%AEP flood depths in the vicinity of the development site, extracted from *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014)

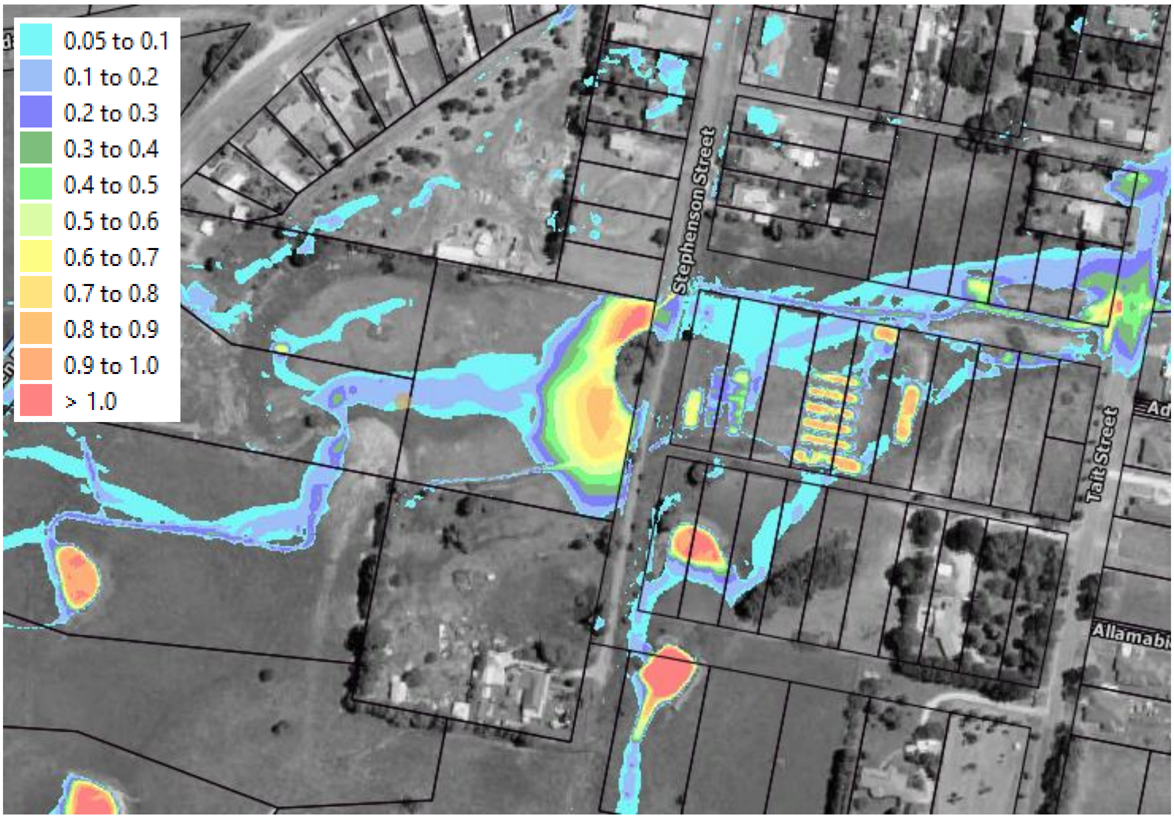

Plate 2 – 1%AEP flood depths in the vicinity of the development site produced from the current assessment

3 Post-Development Flood Behaviour Assessment

3.1 Proposed Works

The proposed works will involve earthworks and regarding of the existing site to form an elevated pad that is free from inundation during the 1%AEP flood and allows an expanded use of the site in the future. Plans of the proposed earthworks are included in **Appendix D**. As shown in **Appendix D**, the proposed works include:

- Fill across the majority of the site, ranging from 0.5 metres near the site boundaries, to 3 metres within the centre portion of the site to form a gently sloping surface towards Stephenson Street
- The construction of swales along the western, southern, northern, and part of the eastern boundary to convey flow entering the site from the west and south to discharge to the culverts under Stephenson Street
- Upgrading of the culvert under Stephenson Street near the south-east corner of the site to a single barrel 0.6m diameter reinforced concrete pipe.

The proposed earthworks will reduce the amount of flood storage that is currently provided within the site (particularly the eastern sections of the site). This has the potential to increase peak discharges leaving the site which may impact on downstream properties.

The following sections describe the assessment that was completed to define “post-development” flood conditions. This includes a discussion on the potential impacts that the proposed earthworks are likely to have on existing flood behaviour.

3.2 XP-RAFTS Model

3.2.1 Model Updates

The XP-RAFTS model parameters were not altered from the “existing” conditions assessment given the land use will remain similar to current conditions. That is, open space with little to no impervious surfaces.

3.3 TUFLOW Model

3.3.1 Model Updates

To quantify the impact that the proposed earthworks are likely to have on existing flood behaviour, the TUFLOW model that was used to define “existing” flood behaviour was updated to reflect the proposed works. This incorporated the following changes:

- Design topography was included across the site based on data provided by Civil Development Solutions on 11th November 2022. A copy of this information is enclosed in **Appendix D**.

- The culvert off the south-east corner of the site under Stephenson Street was upgraded from a 0.45m diameter pipe to a 0.6m diameter pipe.

The extent of the updates that were completed to the TUFLOW model to reflect the proposed development are shown in **Figure 6**.

3.3.2 Results

The updated hydraulic model was used to re-simulate the 1% AEP flood for "post-development" conditions. Peak floodwater depths and levels, as well as velocities were extracted from the results of the flood simulation and are presented on **Figure 7** and **Figure 8** respectively.

Figure 7 shows that the post-development floodwater depths across the site are contained to the dedicated swales near the site boundaries, with the centre portion of the site free from inundation. Depths of over 0.5 metres are common within the swales, with larger depths occurring near Stephenson Street.

Figure 8 shows that the velocity within the swales are generally less than 2m/s. However, some isolated areas of the swale (e.g., near the north-eastern corner of the site) can exceed 2m/s.

Flood level and velocity difference mapping was also prepared to confirm the magnitude and extent of any changes in flood level/extent and velocity associated with the works. The difference mapping was prepared by subtracting peak "existing" water level and velocity results from "post-development" water level and velocity results. The flood level and velocity difference mapping is provided in **Figures 9** and **Figure 10** respectively**.**

Figure 9 shows that the proposed earthworks are predicted to generate large changes in flood level and extents within the development site. The largest of these changes are represented by the 'black' area through the centre of the site and represents areas that were previously inundated and are now free from inundation as a result of the proposed filling. Areas of 'magenta' are also prominent within the proposed swales and represent areas that are now wet because of the construction of the swales and diversion of floodwater into them.

Increases and decreases in existing flood levels are also predicted at various locations. This includes flood level increases of up to 0.3 metres near the western site boundary where flow enters the site, and up to 0.5 metres near the north-eastern corner of the site. Reductions in existing levels are also predicted near the north-eastern corner, indicating that the changes in flood level are driven by the change in topography rather than concentration of flow.

The results on **Figure 9** also show that the proposed earthworks are not predicted to have any significant impact on flood behaviour outside of the development site, and that the swales effectively convey floodwater through the site, with no adverse impact predicted to adjacent properties. It is noted an area of increase of 0.02 metres is predicted outside of the site, near the north-eastern corner. However, this occurs within the area of proposed works and does not impact any private property, nor the roadway surface of Stephenson Street. Furthermore, this flood level increase is coupled with a flood level reduction of 0.02 metres immediately south that extends over a much larger area (refer green area adjacent to Stephenson Street).

Figure 10 indicates that decreases in peak velocity of up to 0.3m/s are predicted where flow enters the site on the western boundary, as well as off the north-eastern corner of the site, adjacent to Stephenson Street. Velocity increases are predicted within part-sections of the swales, together with a small area of velocity increase off the north-eastern corner of the site. However, no increases are predicted within any adjacent private property or on the Stephenson Street roadway surface.

3.4 Sensitivity Analysis

3.4.1 Climate Change

Climate change has the potential to impact flood behaviour, which in turn could impact the proposed works and the surrounding properties. To assess the impact that climate change may have on the proposed works, additional simulations were completed to represent a 20.2% increase in 1% AEP rainfall intensity (reflecting RCP 8.5 for the year 2090).

The XP-RAFTS model was updated to include a 20.2% increase in rainfall intensity. Peak discharges for the same duration/temporal pattern was then extracted and applied to the TUFLOW model. The updated TUFLOW model was used to re-simulate 1% AEP flood behaviour for the existing and post-development scenarios under climate change conditions.

Peak 1% AEP with climate change floodwater depths and levels, as well as velocities were extracted from the TUFLOW model results and are presented on **Figure 11** and **Figure 12**. These figures indicate very little change to the results described in Section 3.3.2 for existing climate conditions. However, slightly higher depths and larger extents of inundation, are predicted (flood depths within the swale are predicted to increase by around 0.05-0.1 metres. The centre portion of the site is still predicted to remain flood free.

Flood level and velocity difference mapping was also prepared. The difference mapping was prepared by subtracting velocity and water level results for existing conditions (with rainfall increases) from post-development velocity and water level results (also with rainfall increases). The difference mapping is presented on **Figure 13** and **Figure 14** respectively.

The difference mapping, again, shows similar flood impacts when compared to existing climatic conditions. That being, the central portion of the site remains flood free, with both increases and decreases in flood level and velocity evident along the swales. The increases in flood level off the north-eastern corner of the site persist with a magnitude of 0.03 metres. However, this does not extend into any private property, or across the roadway surface of Stephenson Street. The small areas of flood velocity increases off the eastern site boundary are more prominent under climate change conditions, but again, do not impact any private property or the Stephenson Street roadway surface, and are localised in nature.

4 Council Requirements

4.1 Upper Lachlan Development Control Plan 2010

Section 4.5.1 of the Upper Lachlan Development Control Plan 2010 (DCP2010) outlines the flood related controls that are applicable to works in areas that are subject to discharge of a 1 in 100-year ARI flood event. The controls, together with commentary on application to the proposed works are included in **Table 3**.

Table 3 Flood related development controls from the Upper Lachlan Development Control Plan 2010

DCP 2010 Control	Comment
Works cannot involve any physical alteration to waterway or floodway including vegetation clearing	No formal waterway currently exists through the development site, and there is little to no vegetation that will be cleared. Figure 6.8 from *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014) indicates that the site would mostly be considered as flood fringe (major overland flow) with a small area of flood storage (major overland flow). As such, no works would be undertaken in a floodway.
Works cannot involve net filling exceeding 50m^3, any reductions of on-site flood storage capacity is avoided and any changes to depth, duration, and velocity of floodwaters of all floods up to and including the 100-year ARI are contained within the site	The net fill across the site is 8595m^3. However, sufficient storage and conveyance is provided by the constructed swales, demonstrated by **Figure 9** and **Figure 10** which indicate that there are no significant alterations to level or velocity of floodwaters outside of the site in the 100-year ARI event, and as such, indicates that no notable change to flood behaviour outside of the development site is predicted (i.e.: no loss of flood storage, no changes to flow paths outside of the site, no acceleration or retardation of flows, and no changes to warning times due to consistent flood behaviour outside of the site).
Works cannot involve any change in the flood characteristics of the 100-year ARI outside of the subject site that result in: - Loss of flood storage, or - Loss of/changes to flow paths, or - Acceleration or retardation of flows, or - Any reduction of warning times elsewhere on the floodplain	
All built form, infrastructure (unless designed to be inundated) and open space must be located on land that would not be subject to flooding during the 100-year ARI flood event	No built form or infrastructure is part of the currently proposed works; however, the works provide a large area of land that is located above the 100-year ARI flood level
Where there is existing development located on land that is subject to inundation during the 100-year ARI flood event, this development /activity must not be intensified through further development	There is no existing development subject to inundation during the 100-year ARI flood event within the site

5 SUMMARY

This report has summarised the outcomes of a flood impact assessment that was completed for proposed earthworks and regrading within Lot 37 Stephenson Street, Crookwell. The assessment was completed to confirm the potential flood impacts that the proposed filling and regrading may have on surrounding properties.

The flood impact assessment was completed using an XP-RAFTS hydrologic model and a TUFLOW hydraulic model that was developed specifically for the assessment.

The XP-RAFTS model was used to simulate a range of 1% AEP design storms based upon hydrologic procedures outlined in the 2019 version of Australian Rainfall and Runoff (Ball et al). This included assessing a full ensemble of storm durations and temporal patterns to determine the critical 1% AEP flow through the site.

The TUFLOW hydraulic model was used to simulate the critical 1% AEP design flood based on the flow hydrographs produced by the XP-RAFTS model. The results of the 1% AEP flood simulations were used to map the extent of flood liable land and generate key flooding characteristics such as water depths, flood level and velocity for existing and post-development catchment conditions. The existing flood depths and extent were qualitatively validated against the published flood mapping generated as part of the *'The Village of Crookwell Flood Study'* (Lyall & Associates, 2014).

Post-development flood modelling was completed for the 1%AEP flood under existing climate conditions as well as potential future climate change conditions. The results of the modelling indicates that the proposed earthworks and regrading are predicted to produce localised changes to flood levels, extents and velocities within the site. This includes a large area of flood free land within the centre of the site with 1%AEP flows contained within dedicated drainage swales around the perimeter of the site.

Flood level and velocity difference mapping was also prepared and indicates that the proposed works are not predicted to adversely impact on existing flood levels, extents or velocities within any private property located around the site or over the Stephenson Street roadway surface.

6 REFERENCES

- 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 (Geoscience Australia).
- Engineers Australia (1987). *Australian Rainfall and Runoff - A Guide to Flood Estimation*. Edited by D. Pilgrim.
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APPENDIX A
FIGURES

LEGEND

Development Site

Catchment Boundary

Flowpaths

Aerial photograph: NSW SixMaps 2022

N
W E
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Scale: 1:10000 (at A3)

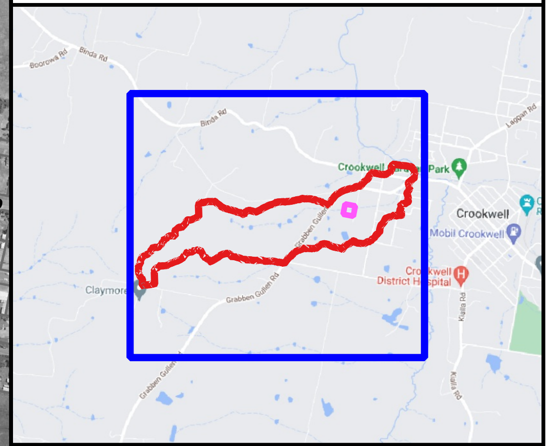
0 100 200 300 400 m

Figure 1: Location of the Development Site

Prepared by:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz



LEGEND

- Development Site
- Subcatchments
- Nodal Link Arrangement

Aerial photograph: NSW SixMaps 2022

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Scale: 1:10000 (at A3)

0 100 200 300 400 m

Figure 2: XP-RAFTS Subcatchment Layout

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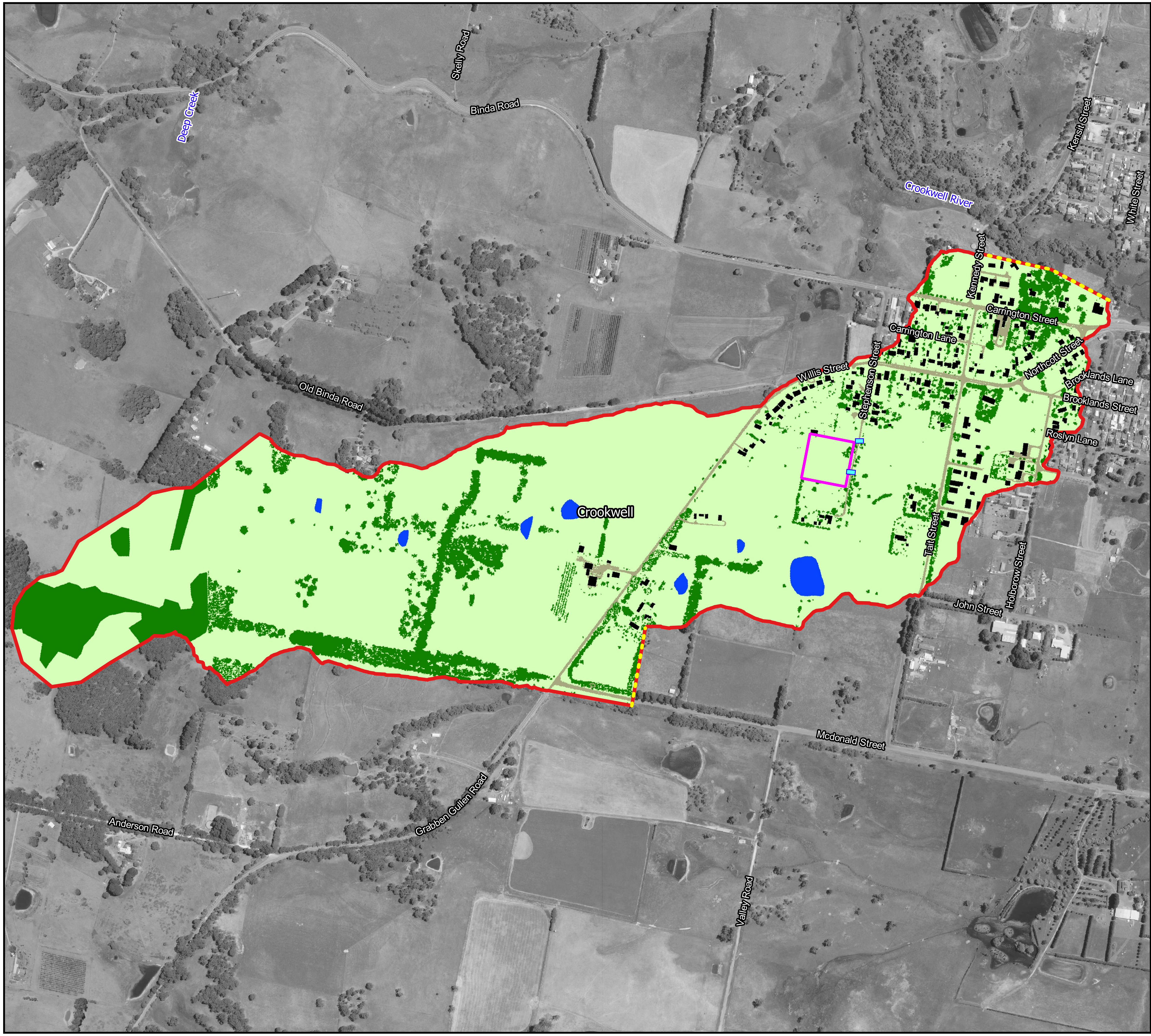

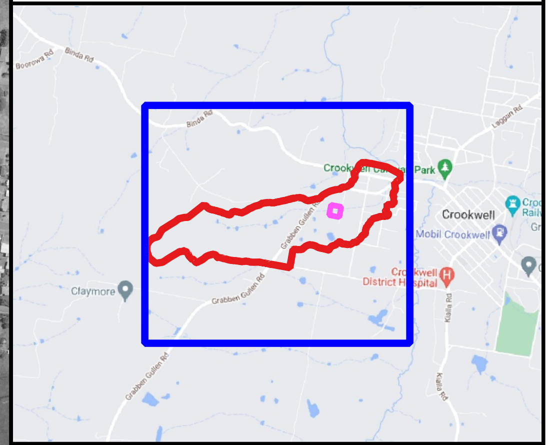

LEGEND

- Development Site
- TUFLOW Extent
- Downstream Boundary
- Stormwater Culverts

Materials

- Grass
- Trees
- Waterbodies
- Buildings
- Roadways

Aerial photograph: NSW SixMaps 2022

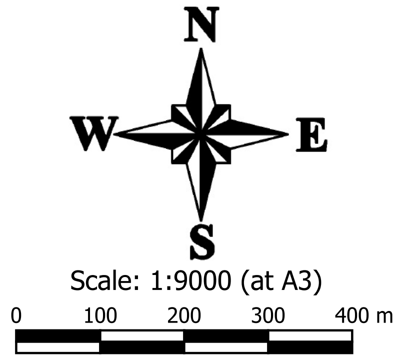

Figure 3: Existing TUFLOW Model Layout

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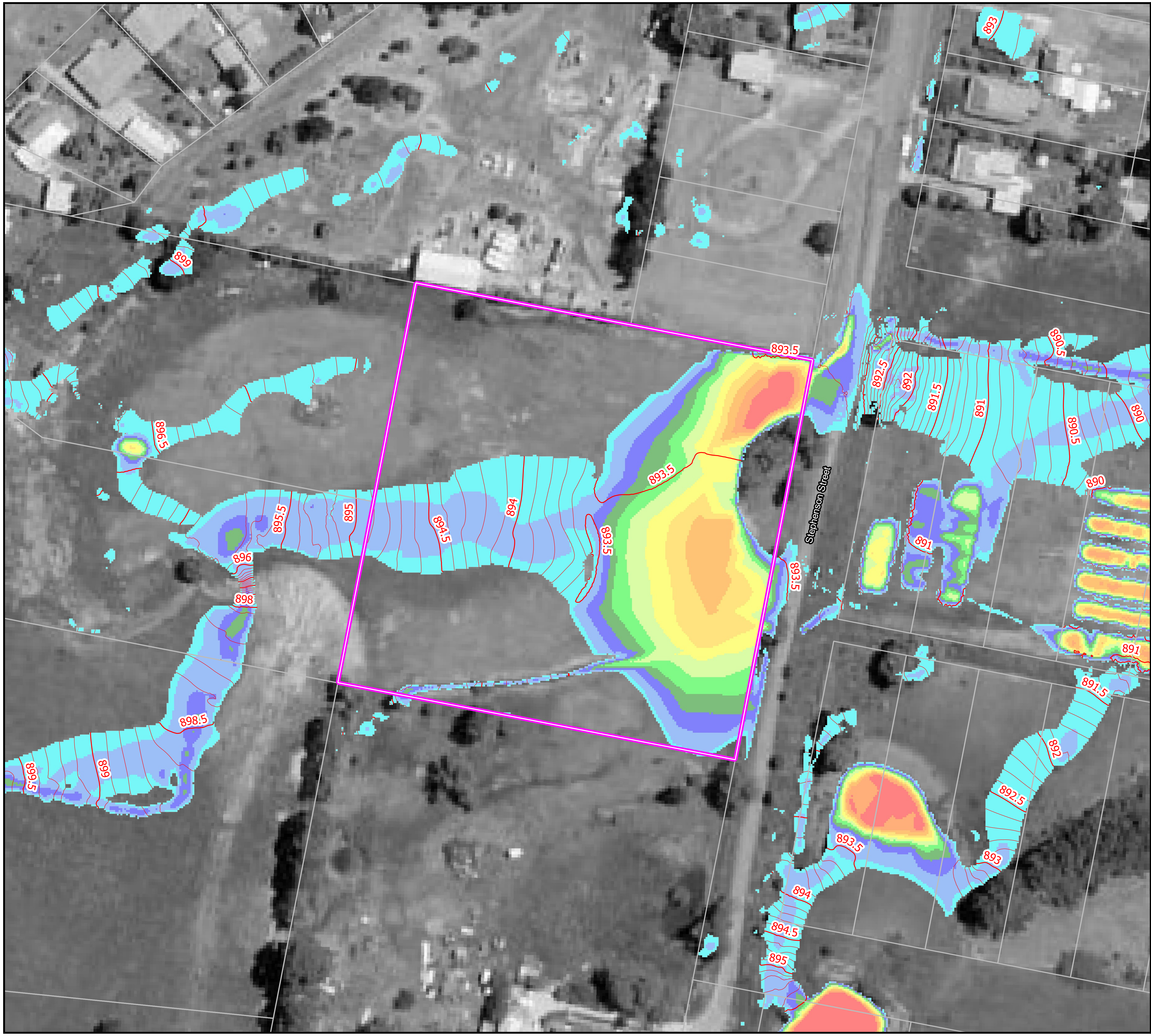
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz



LEGEND

- Development Site
- Water Level Contour (0.5m interval)
- Water Level Contour (0.1m interval)

Depth (m)

- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

N W E S

Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 4: Peak 1% AEP Floodwater Depths and Levels for Existing Conditions

Prepared by:
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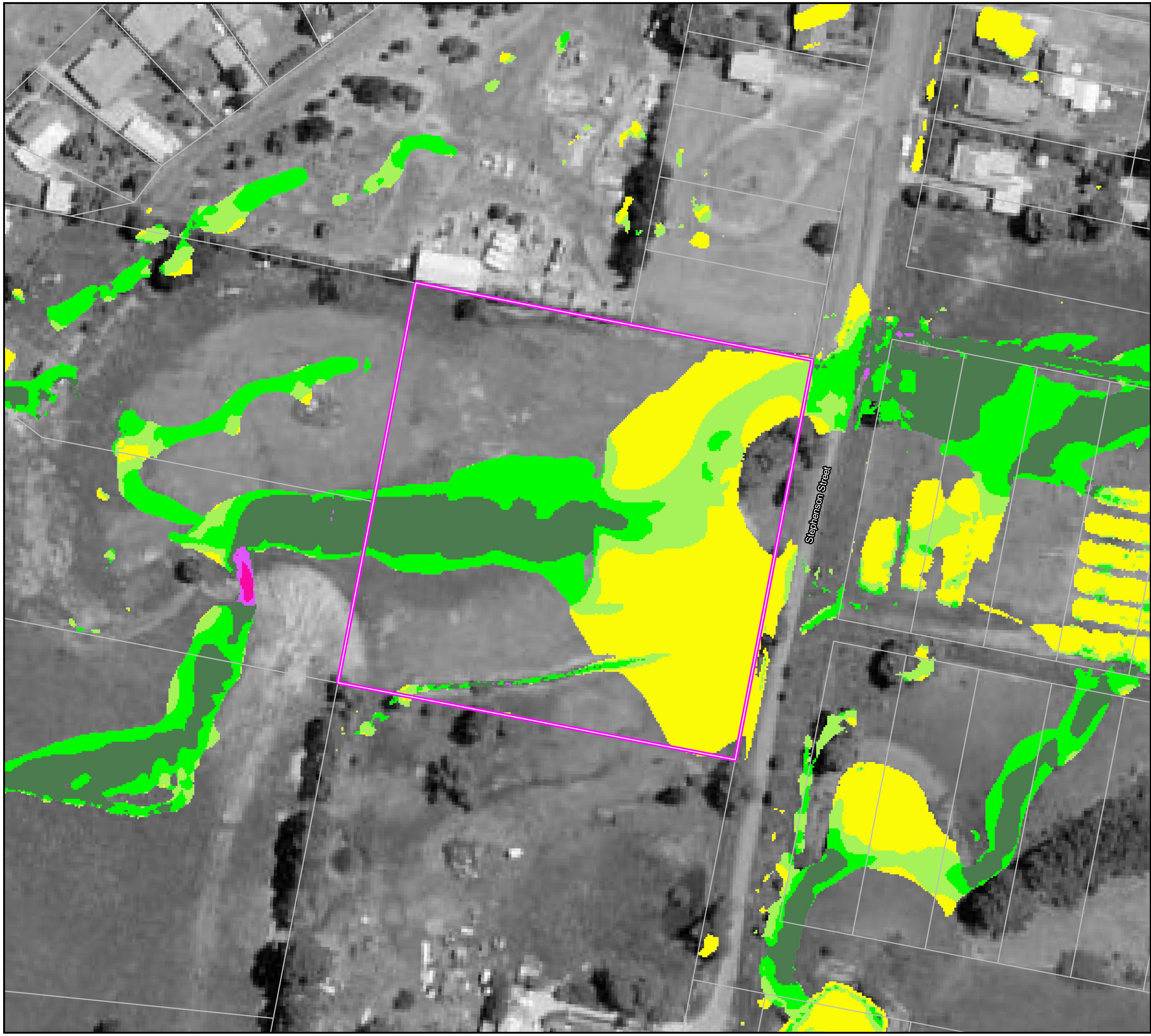
File Name: 37 Stephenson St Report Figures.qgz



LEGEND

Development Site

Velocity (m/s)

- <= 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

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Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 5: Peak 1% AEP Floodwater Velocity for Existing Conditions

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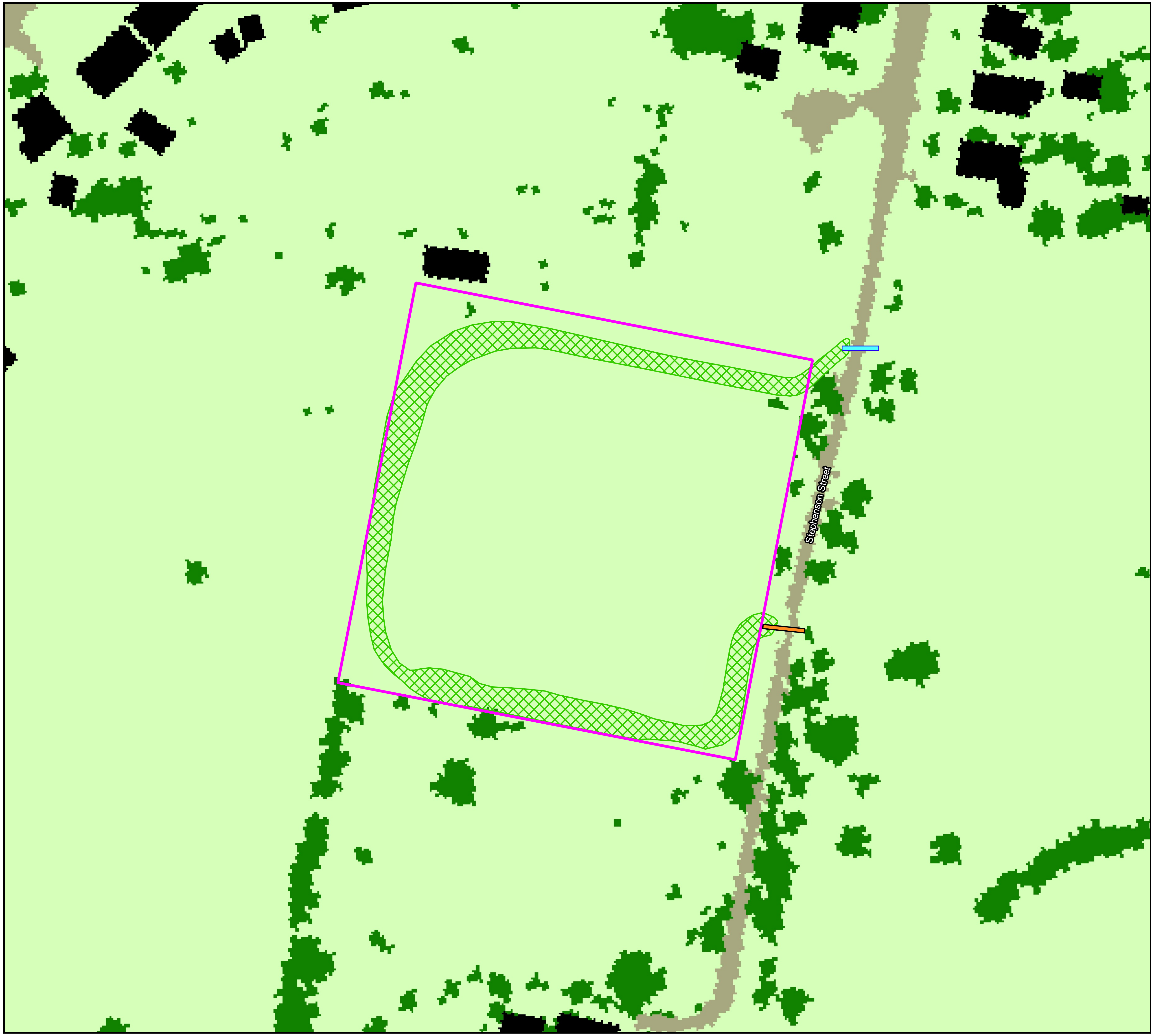
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz



LEGEND

- Development Site
- Proposed Swale
- Existing Culvert
- Upgraded Culvert

Materials

- Grass
- Trees
- Waterbodies
- Buildings
- Roadways

Aerial photograph: NSW SixMaps 2022

N

W E

S

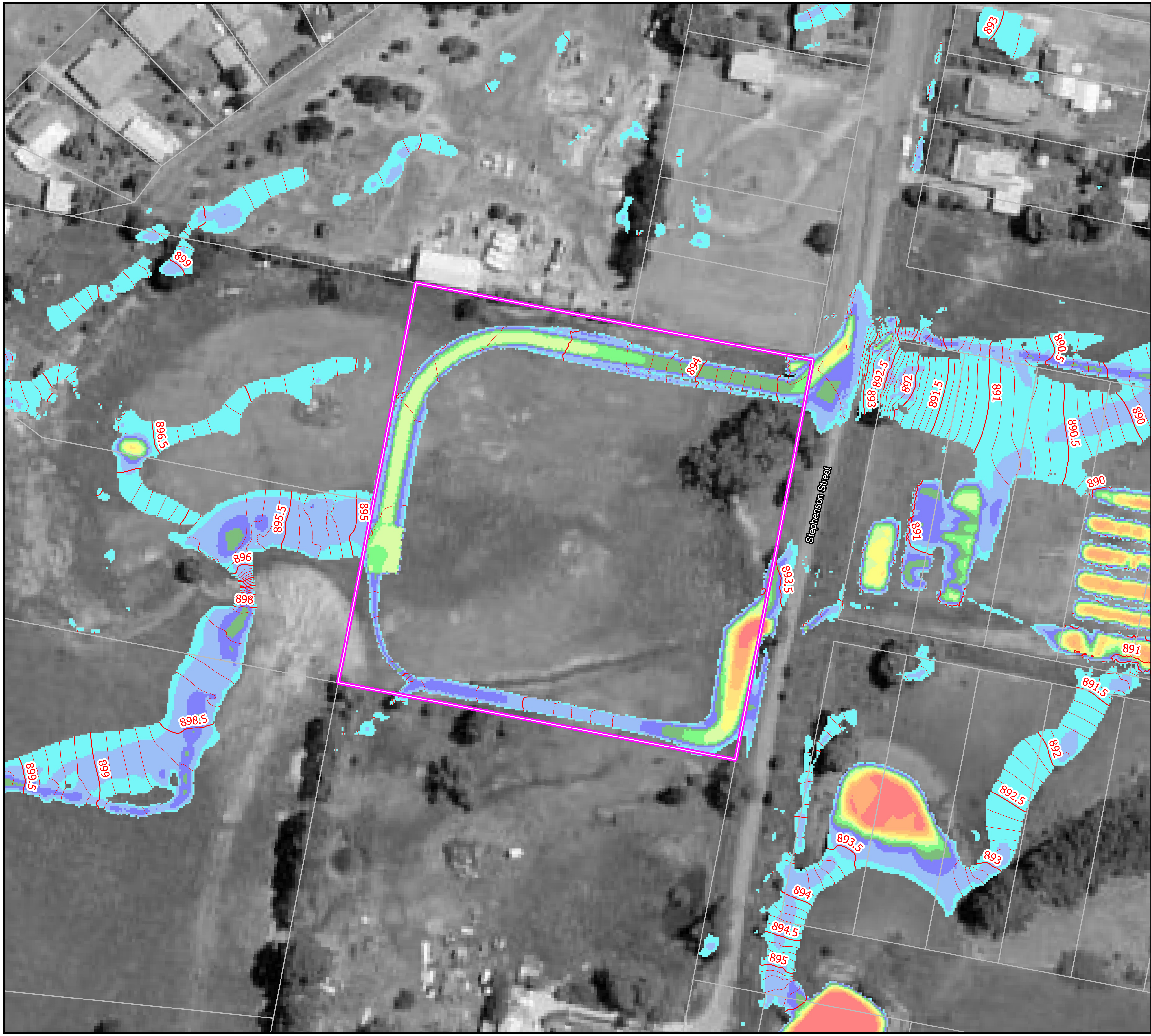
Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 6: Post-Development TUFLOW Model Layout

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz



LEGEND

Development Site
Water Level Contour (0.5m interval)
Water Level Contour (0.1m interval)

Depth (m)

- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 7: Peak 1% AEP Floodwater Depths and Levels for Proposed Conditions

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Sydney, NSW, 2000

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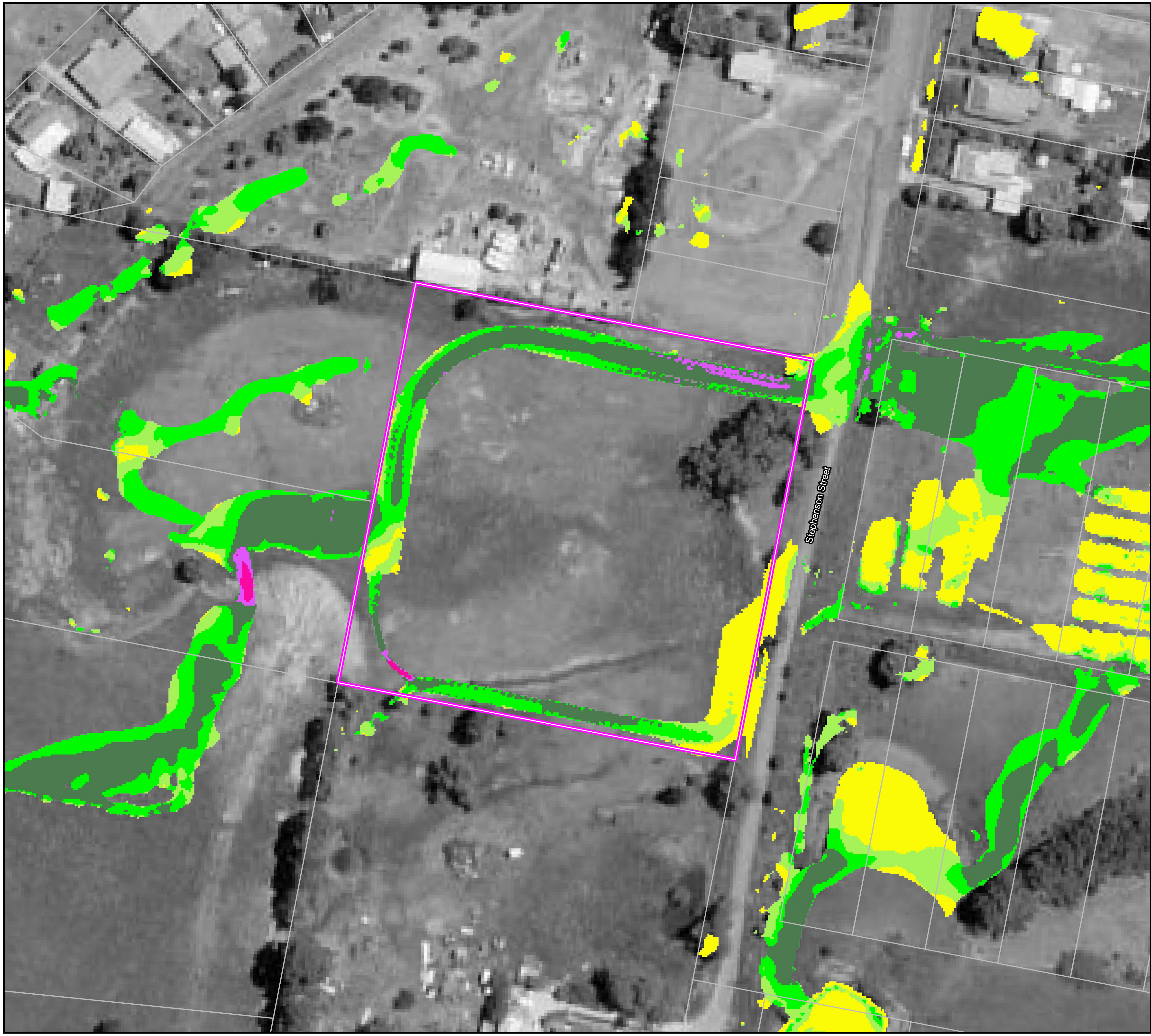


LEGEND

Development Site

Velocity (m/s)

- <= 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 8: Peak 1% AEP Floodwater Velocity for Proposed Conditions

Prepared by:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz

LEGEND

Development Site

Flood Level Difference (m)

- -0.50
- -0.20
- -0.10
- -0.05
- -0.02
- Differences less than ±0.02m
- 0.02
- 0.05
- 0.10
- 0.20
- 0.50
- Was wet, now dry
- Was dry, now wet

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 9: Predicted Change in Peak 1% AEP Flood Levels

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz

LEGEND

Development Site

Velocity Difference (m/s)

- -0.5
- -0.3
- -0.2
- -0.15
- -0.1
- Differences less than ±0.1m/s
- 0.1
- 0.15
- 0.2
- 0.3
- 0.5
- Was wet, now dry
- Was dry, now wet

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

N W E S

Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 10: Predicted Change in Peak 1% AEP Flood Velocity

Prepared by:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz

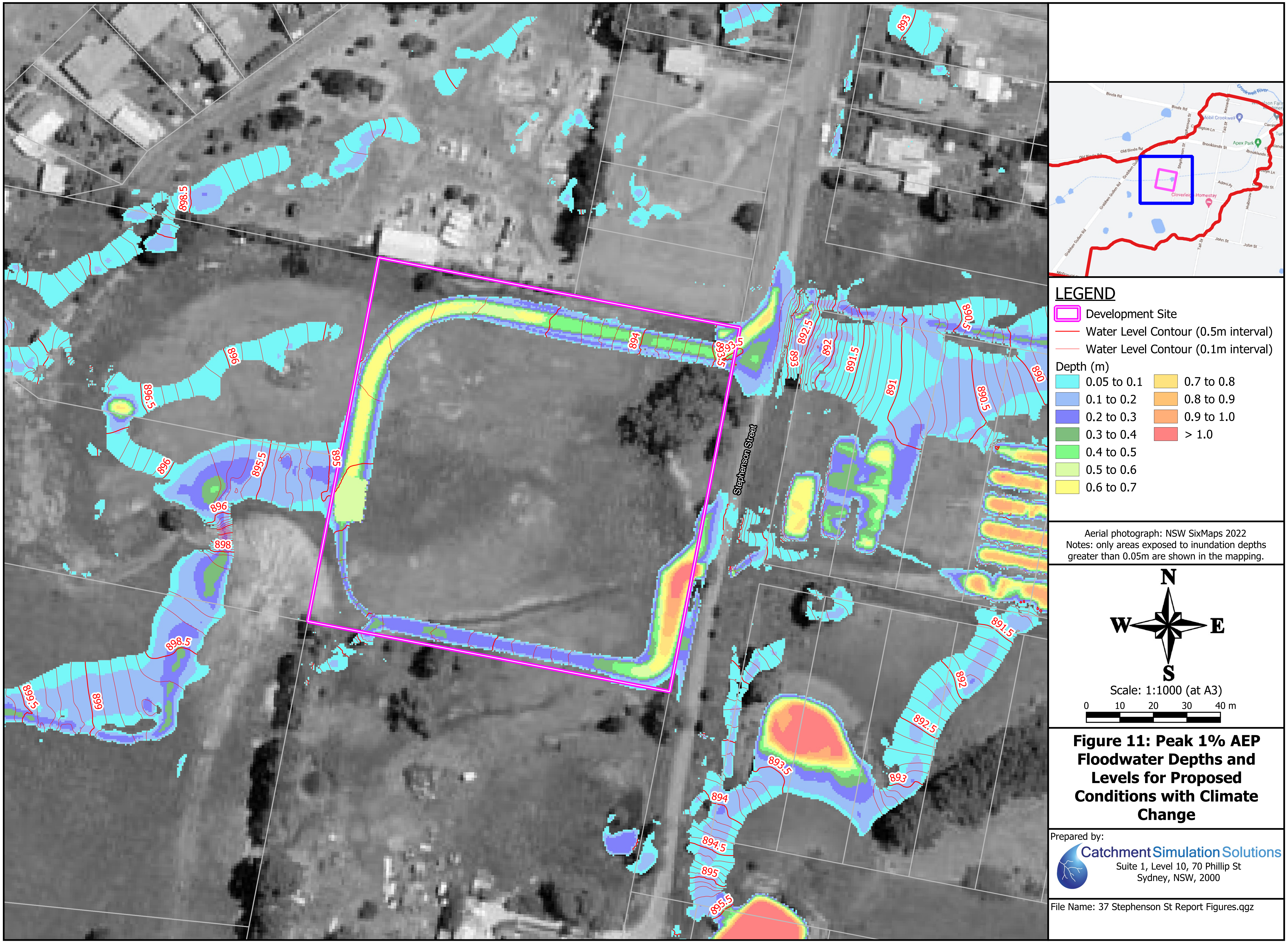
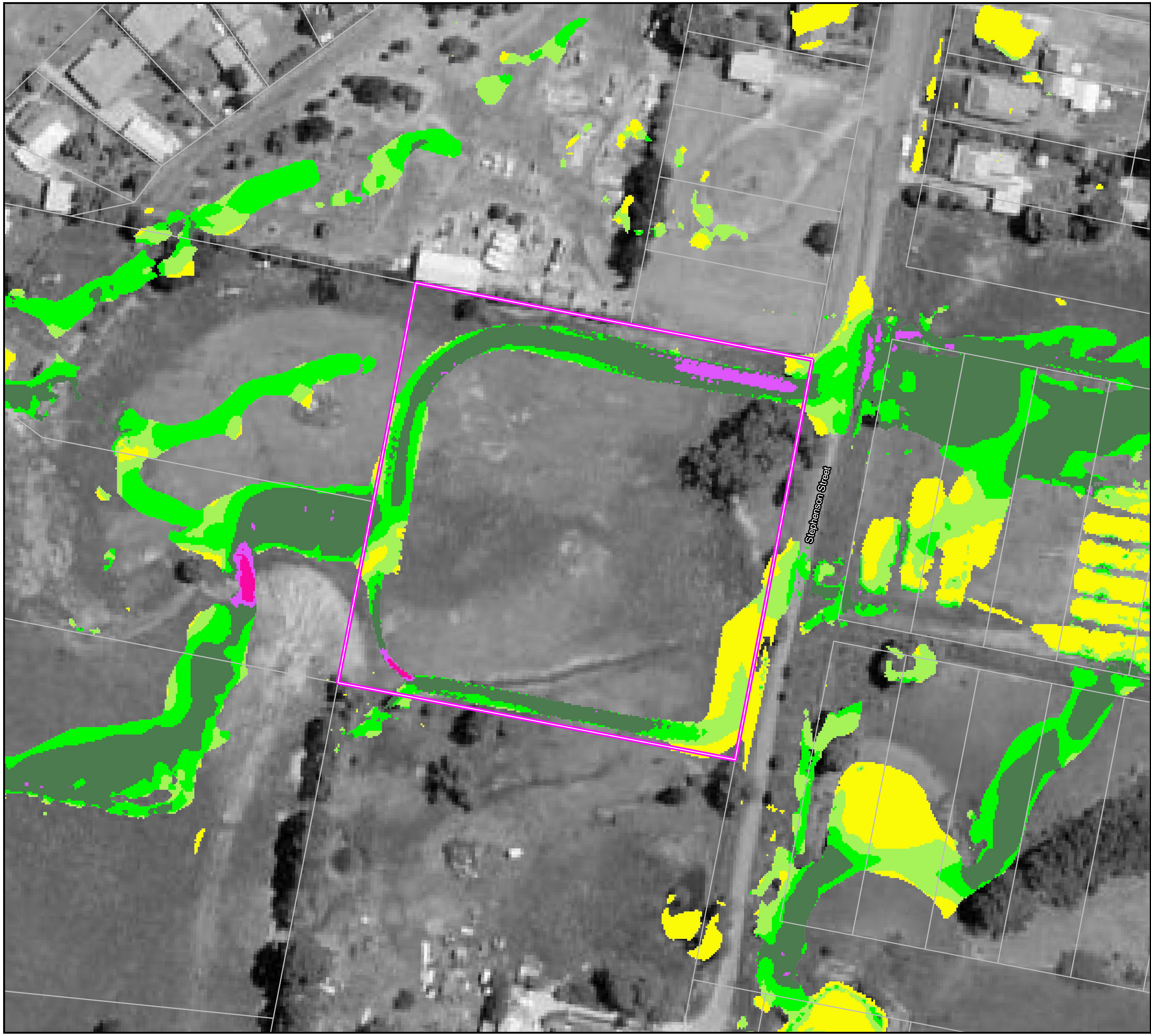


Figure 11: Peak 1% AEP Floodwater Depths and Levels for Proposed Conditions with Climate Change



LEGEND

Development Site

Velocity (m/s)

- <= 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 12: Peak 1% AEP Floodwater Velocity for Proposed Conditions with Climate Change

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz

LEGEND

Development Site

Flood Level Difference (m)

- -0.50
- -0.20
- -0.10
- -0.05
- -0.02
- Differences less than ±0.02m
- 0.02
- 0.05
- 0.10
- 0.20
- 0.50
- Was wet, now dry
- Was dry, now wet

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 13: Predicted Change in Peak 1% AEP Flood Levels with Climate Change

Prepared by:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz

LEGEND

Development Site

Velocity Difference (m/s)

- -0.5
- -0.3
- -0.2
- -0.15
- -0.1
- Differences less than ±0.1m/s
- 0.1
- 0.15
- 0.2
- 0.3
- 0.5
- Was wet, now dry
- Was dry, now wet

Aerial photograph: NSW SixMaps 2022
Notes: only areas exposed to inundation depths greater than 0.05m are shown in the mapping.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 m

Figure 14: Predicted Change in Peak 1% AEP Flood Velocity with Climate Change

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: 37 Stephenson St Report Figures.qgz

APPENDIX B
SUBCATCHMENT PARAMETERS

Crookwell River Subcatchment Parameters						
Subcatchment ID	Subcatchment Area (ha)	Total Upstream Area (ha)	Subcatchment Slope (%)	Impervious Area (ha)	Impervious Prop (%)	Main Stream Length (km)
C1	8.2	141.5	3.0	1.6	19.3	0.28
C2	1.1	66.2	3.9	0.1	7.1	0.03
C3	2.2	70.0	1.7	0.0	1.7	0.17
C4	8.3	8.3	5.1	0.0	0.0	0.67
C5	8.3	8.3	9.9	0.0	0.0	0.57
C6	9.4	17.8	5.6	0.0	0.4	0.59
C7	8.3	26.0	5.6	0.6	7.1	0.23
C8	8.1	16.4	4.3	0.0	0.0	0.35
C9	8.0	34.0	2.0	0.9	10.7	0.62
C10	8.0	41.0	11.2	0.1	1.4	0.35
C11	8.0	33.0	4.7	0.1	0.9	0.22
C12	8.6	24.9	4.7	0.0	0.0	0.32
C13	8.0	49.0	5.0	0.3	4.2	0.68
C14	8.1	57.1	3.6	0.4	4.6	0.39
C15	9.7	116.4	2.9	0.6	6.4	0.25
C16	8.0	8.0	4.6	0.0	0.5	0.92
C17	8.2	124.6	2.1	1.4	17.5	0.44
C18	8.7	8.7	3.5	2.0	22.6	0.78
C19	1.6	1.6	3.8	0.0	0.2	0.39
C20	2.6	36.6	3.1	0.1	4.2	0.12

APPENDIX C
XP-RAFTS OUTPUT

Existing XP-RAFTS Outputs					
Subcatchment ID	Average Discharge (m3/s)	Critical Discharge (m3/s)	Critical Duration (mins)	Critical Temporal Pattern	Comments
C1	7.66	7.87	90	3907	Downstream of Site
C2	3.95	4.03	90	3907	
C3	4.15	4.20	90	3907	
C4	0.96	0.98	30	3815	
C5	1.08	1.12	30	3815	
C6	1.80	1.83	45	3717	
C7	2.49	2.51	45	3717	
C8	1.43	1.47	45	3717	
C9	2.88	2.89	45	3717	
C10	3.06	3.07	60	3819	
C11	2.68	2.73	45	3717	
C12	2.08	2.14	45	3717	
C13	3.38	3.39	60	3819	
C14	3.48	3.57	90	3907	
C15	6.95	7.21	90	3907	Downstream of Site
C16	0.83	0.84	45	3717	
C17	7.20	7.47	90	3907	Downstream of Site
C18	0.92	0.96	45	3844	
C19	0.21	0.22	30	3815	
C20	2.95	2.96	45	3717	

Post Development XP-RAFTS Outputs					
Subcatchment ID	Average Discharge (m3/s)	Critical Discharge (m3/s)	Critical Duration (mins)	Critical Temporal Pattern	Comments
C1	7.66	7.87	90	3907	Downstream of Site
C2	3.95	4.03	90	3907	
C3	4.15	4.20	90	3907	
C4	0.96	0.98	30	3815	
C5	1.08	1.12	30	3815	
C6	1.80	1.83	45	3717	
C7	2.49	2.51	45	3717	
C8	1.43	1.47	45	3717	
C9	2.88	2.89	45	3717	
C10	3.06	3.07	60	3819	
C11	2.68	2.73	45	3717	
C12	2.08	2.14	45	3717	
C13	3.38	3.39	60	3819	
C14	3.48	3.57	90	3907	
C15	6.95	7.21	90	3907	Downstream of Site
C16	0.83	0.84	45	3717	
C17	7.20	7.47	90	3907	Downstream of Site
C18	0.92	0.96	45	3844	
C19	0.21	0.22	30	3815	
C20	2.95	2.96	45	3717	

APPENDIX D
DEVELOPMENT PLANS

MGAN

FILL DEPTH

NUMBER	DEPTH RANGE LOWER	DEPTH RANGE UPPER	COLOR
1	0.00	0.50	
2	0.50	1.00	
3	1.00	2.00	
4	2.00	3.00	

LEGEND

- PAVEMENT
- CONCRETE PAVING
- TREE TO BE REMOVED
- EXISTING TREE

NOTES

1. THESE PLANS ARE TO BE READ AT A1 SIZE.
2. SURVEY PROVIDED BY SOUTHERN CROSS SURVEYORS.
3. NOT FOR CONSTRUCTION, THESE PLANS ARE TO ACCOMPANY A DEVELOPMENT APPLICATION ONLY.
4. ALL BATTERS ARE 1V:5H.
5. FILLING TO BE CARRIED OUT TO THE REQUIREMENTS OF AS2780 LEVEL 1 SUPERVISION.

DIAL BEFORE YOU DIG
www.1100.com.au

UTILITY SERVICES NOTE

No utility service investigations have been undertaken for this project. The presence, exact location, nature and size of utility services must be confirmed by field inspection, prior to the commencement of any excavations, earthworks or roadworks. The contractor is to obtain the relevant utility plans from Dial Before You Dig Ph:1100, all recommendations made by the service authority are to be followed. Caution to be exercised whilst working in the vicinity of all services.

revision	revision details	date	drawn
A	Initial Issue	05/05/22	JC

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WINGECARRIBEE SHIRE COUNCIL DA: -
LOT 37, DP 2474
STEPHENSON STREET,
CROOKWELL

client: DARJEELING PASTORAL

CONCEPT FILL PLAN

0 5 10 15 20 25 METRES
SCALE: 1:250

designed:	J.C.
drawn:	J.C.
checked:	R.A.
datum:	A.H.D.
date:	05/05/22

A1 sheet | revision A
Job Drawing Number 2124 CF01
sheet 1 | sheets 1

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