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Residential Development

23-27 Warriewood Road, Warriewood

Water Management Report
Issue 01

Prepared for Knowles Group/ArCare

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Table of Contents

1 Executive Summary 7

2 Introduction 10

2.1 Brief 10

2.2 Limitations 10

2.3 Reference Documents 10

2.4 Author 11

3 Natural & Built Environment 12

3.1 Local Catchment 12

3.2 Proposed Development 12

4 Glossary 15

5 Water Cycle Assessment 18

5.1 General 18

5.2 Existing Geotechnical Conditions 18

5.3 Existing Catchment and Topography 19

5.4 Assessment of Developed Conditions 19

6 Water Quality Assessment 22

6.1 Water Balance 22

6.2 Assessment of Developed Conditions 23

6.3 WSUD Measures Operations and Maintenance 25

6.3.1 Gross Pollutant Trap 25

6.3.2 Bio-retention Basin 26

6.4 Construction Phase 28

6.5 Preliminary Mosquito Risk Management 29

7 Watercourse & Creekline Corridor 32

7.1 Overview & Objectives 32

7.2 Existing & Design Conditions 32

7.3 Design Flow Conditions 32

7.4 Creek Design 33

7.5 Discharge Point 33

8 Flood Study 34

8.1 Narrabeen Creek 34

8.2 Objectives 34
8.3 Authorities' Requirements 34
8.3.1 Flood Assessment Analysis 34
8.3.2 Assessment of Impacts 35
8.3.3 Evacuation Procedures 36
8.3.4 Mitigation Measures 36
8.4 Design Flood Modelling 37
8.4.1 Introduction 37
8.4.2 Design Flood Modelling Results 37
8.5 Flood Mitigation 37
8.6 Discussion 38
8.6.1 Flooding Assessment Analysis 38
8.6.2 Assessment of Impacts 39
8.6.3 Evacuation Procedures 41
8.6.4 Mitigation Measures 42
8.7 Conclusions 42
9 Water Quantity Management 45
9.1 General 45
9.2 Piped Drainage 45
9.3 On-Site Detention 45
9.4 Council requirements 46
9.5 Modelling 46
Checklist 48
Rainfall Data 50
Pre vs Post Outflow Hydrographs 52
Flood Mapping 58
References 75
Creek Design Drawings 76

List of Figures

Figure 1-1 Site Masterplan 7
Figure 3-1 Locality Plan 12
Figure 3-2 Ground Floor Plan – Aged Care Facility (approved under DA N0611/16) 13
Figure 3-3 General Arrangement Plan – Residential Development 14

Figure 5-1 Sector Plan 18
Figure 5-2 Site Topography 19
Figure 5-3 Proposed Land Use (full size copy in set of stormwater plans) 21
Figure 6-1 MUSIC Model Layout 24
Figure 6-2 Sediment Basin Calculations 29

Figure A 1.1 Completed DA Checklist 49
Figure A 2.1 IFD Chart (Northern Beaches Council – Pittwater) 50
Figure A 2.2 IFD Table (Northern Beaches Council – Pittwater) 51
Figure A 3.1 Catchment 1 – 1% AEP-30mins 53
Figure A 3.2 Catchment 1 – 1% AEP-60mins 53
Figure A 3.3 Catchment 1 – 1% AEP-120mins 54
Figure A 3.4 Catchment 1 – 1% AEP-180mins 54
Figure A 3.5 Catchment 1 – 1% AEP-360mins 55
Figure A 3.6 Catchment 2 – 1% AEP-30mins 55
Figure A 3.7 Catchment 2 – 1% AEP-60mins 56
Figure A 3.8 Catchment 2 – 1% AEP-120mins 56
Figure A 3.9 Catchment 2 – 1% AEP-180mins 57
Figure A 3.10 Catchment 2 – 1% AEP-360mins 57
Figure A 4.1 Study Area 59
Figure A 4.2 2-yr ARI Depth & Level – Existing Site Conditions 60
Figure A 4.3 5-yr ARI Depth & Level – Existing Site Conditions 61
Figure A 4.4 10-yr ARI Depth & Level – Existing Site Conditions 62
Figure A 4.5 20-yr ARI + CC Depth & Level – Existing Site Conditions 64
Figure A 4.6 50-yr ARI Depth & Level – Existing Site Conditions 64
Figure A 4.7 100-yr ARI + CC Depth & Level – Existing Site Conditions 65
Figure A 4.8 PMF Depth & Level – Existing Site Conditions 66
Figure A 4.9 100-yr ARI + CC Hazard – Existing Site Conditions 67
Figure A 4.10 20-yr ARI + CC Depth & Level – Proposed Site Conditions 68
Figure A 4.11 100-yr ARI + CC Depth & Level – Proposed Site Conditions 69
Figure A 4.12 PMF Depth & Level – Proposed Site Conditions 70
Figure A 4.13 100-yr ARI + CC Hazard – Proposed Site Conditions 71
Figure A 4.14 100-yr ARI + CC Flood Impact Map – Levels 72
Figure A 4.15 PMF Flood Impact Map – Levels 73
Figure A 4.16 PMF Flood Impact Map – Velocity 74

List of Tables

Table 6.1 Water Balance Results 23
Table 6.2 MUSIC Model Summary Results 25
Table 6.3 VortCapture Maintenance Frequency 26
Table 6.4 Bio-retention System Maintenance Frequency 28
Table 7.1 Peak Design Flows – WVWMS 32
Table 9.1 Site Catchment Area 46
Table 9.2 Detention Requirements – WVWMS 46
Table 9.3 Detention Requirements – Site Specific 46
Table 9.4 XP-STORM Model Results – Summary 47

1 Executive Summary

This document is a water management report in support of the proposed residential development at 23-27 Warriewood Road, Warriewood. This report should be read in conjunction with the approved water management report (ref. 20160112-R01 revision 05) prepared by SGC for the aged care facility at the same site address under DA r.

Arcare are proposing to subdivide the existing site into two lots, lot 1 for the approved aged care facility and lot 2 for a residential development. The extension to Lorikeet Grove is located entirely within the residential lot but has been approved by Council under DA N0611/16. The proposed masterplan is illustrated in **Figure 1-1** below.

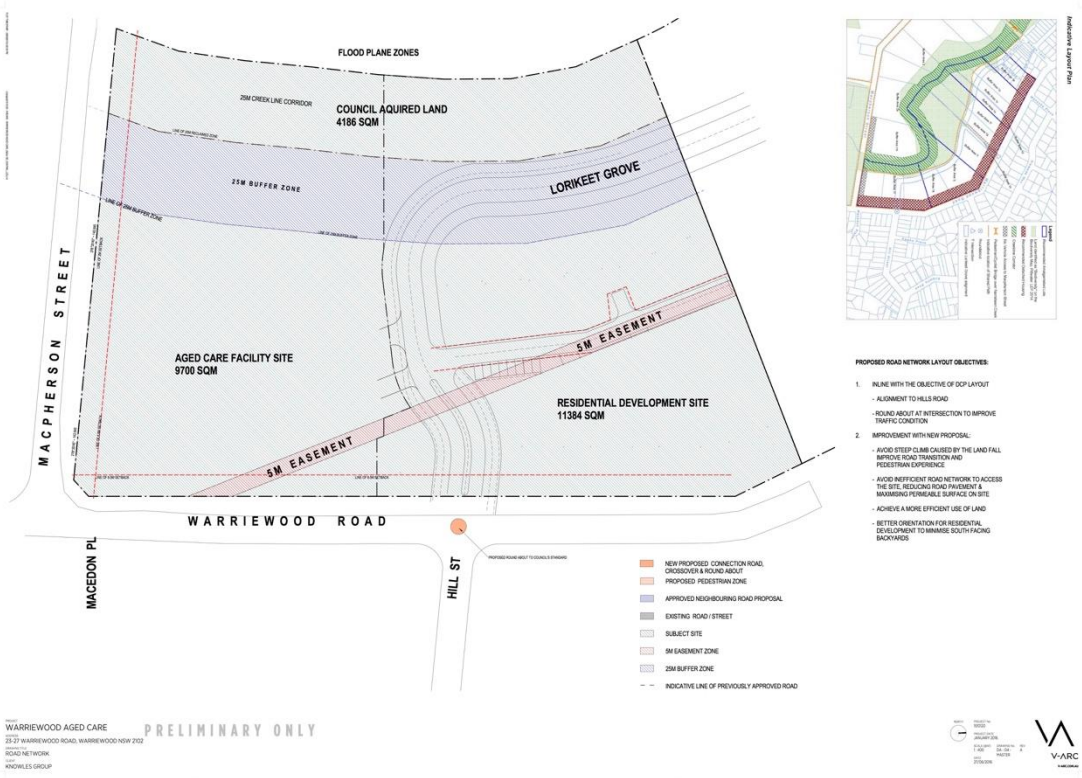


Figure 1-1 Site Masterplan

This water management report addresses the requirements of Council for the residential development only as the aged care is already approved by Council.

This water management report provides: -

- An assessment of flooding from Narrabeen Creek;
- Assessment of any flood impact from the proposed development under Stage 2 and filling of the site;
- Mitigation measures to negate the impact of the development including proposed creek corridor works;

- Addressing the requirements of the Warriewood Valley Water Management Specification (WVWMS) with respect to water quantity, balance and quality; and
- Addressing the requirements of the NSW Floodplain Development Manual (2005) in relation to flood hazard and flood risk from the creek.

The Flood Planning Level (FPL) adopted for the residential development is RL 4.29m AHD which achieves 0.5m above the 100-year ARI flood level inclusive of the Climate Change controls.

The creek has been widened to cater for the 50% AEP flows, while the 50m wide corridor is provided to convey the 1% AEP flows.

The following water management measures are proposed for the residential development site: -

- 129m3, 141m3 and 15m3 OSD tanks/basins for catchments 1, 2 & 3 respectively;
- 2.2KL rainwater tank for each townhouse and 20KL rainwater tank for the units;

A treatment train approach is proposed for the WSUD to achieve the water balance and to meet the pollutants reduction ratios which involves rainwater tanks for internal and external re-use, a gross pollutant trap to collect litter, leaves and other pollutants larger than 5mm and a bio-retention basin to reduce the finer and suspended pollutants.

The proposed development achieves the water quantity and water quality requirements set out by Council in the WVWMS.

Reference is made to the attached stormwater and civil drawings for details.

SECTION A – GENERAL

2 Introduction

2.1 Brief

S&G Consultants Pty Ltd (SGC) have been engaged by The Knowles Group to prepare a water management report in support of the proposed residential development at 23-27 Warriewood Road, Warriewood identified as Stage 2 in reference to Stage 1 which is the approved aged care facility under DA N0611/16.

The Northern Beaches Council (Pittwater) requires the water management report because the site falls in the Warriewood Valley release area.

The following tasks were carried out: -

- Site visit was undertaken on the 10th of May 2016 to ascertain on-site conditions and familiarise with the catchment;
- Supplied documents and previous studies were reviewed;
- Liaison with Council Engineers;
- A flood impact assessment was carried out;
- Water quantity and water quality modelling and design was undertaken; and
- This report has been compiled.

2.2 Limitations

This report is intended solely for The Knowles Group as the Client of SGC and no liability will be accepted for use of the information contained in this report by other parties than this client.

This report is limited to visual observations and to the information including the referenced documents made available at the time when this report was written.

2.3 Reference Documents

The following documents have been referenced in this report: -

1. Site survey prepared by SDG ref. 6952 rev B dated 13/05/2016;
2. Architectural drawings prepared by V-Arc;
3. Water management report prepared for the aged care facility by SGC reference 20160112-R01 revision 05 dated 12/05/2017;
4. NSW Government The Floodplain Development Manual – The management of Flood Liable Land (2005);
5. Engineers Australia, *Australian Rainfall & Runoff* (AR&R 1999);
6. Narrabeen Lagoon Flood Study Tuflow Model received from Council;
7. Northern Beaches (Pittwater) Council DCP 21;

8. Warriewood Valley Land Release Water Management Specification by Northern Beaches Council; and
9. *Draft MUSIC Modelling Guidelines* by Sydney Metropolitan Catchment Authority ref. R.B17048.001.01 dated August 2010.

2.4 Author

This report has been prepared by Samer El Haddad from S&G Consultants Pty Ltd. Samer has more than 20 years' experience preparing flood studies and flood risk management reports.

Samer's qualifications are as follows: -

- B.E. Civil Engineering – 1997;
- Masters in Engineering Management – 2004;
- Chartered Member – Engineers Australia (MIEAust CPEng 2247040); and
- On the National Professional Engineering Register (NPER-3 Civil).

3 Natural & Built Environment

3.1 Local Catchment

The site is made out of three lots being Nos. 23, 25 & 27 Warriewood Road (lots 27, 28 & 29 of Sec 7 in DP 5464) in the suburb of Warriewood on the northern beaches of Sydney. The site falls in the Local Government Area of Northern Beaches Council (Pittwater).

The site is bounded by Narrabeen Creek to the West, Warriewood Road to the East, Macpherson Street to the South and adjoining properties to the North.

Narrabeen Creek flows in a southerly direction. It originates about 1.5km to the west of the site and discharges into Narrabeen Lagoon.

The land adjoining the creek is extensively vegetated and overgrown.

The site has a trapezoidal shape and is characterised by a natural gradient from Warriewood Road towards the creek. Figure 3-1 shows the location of the site.

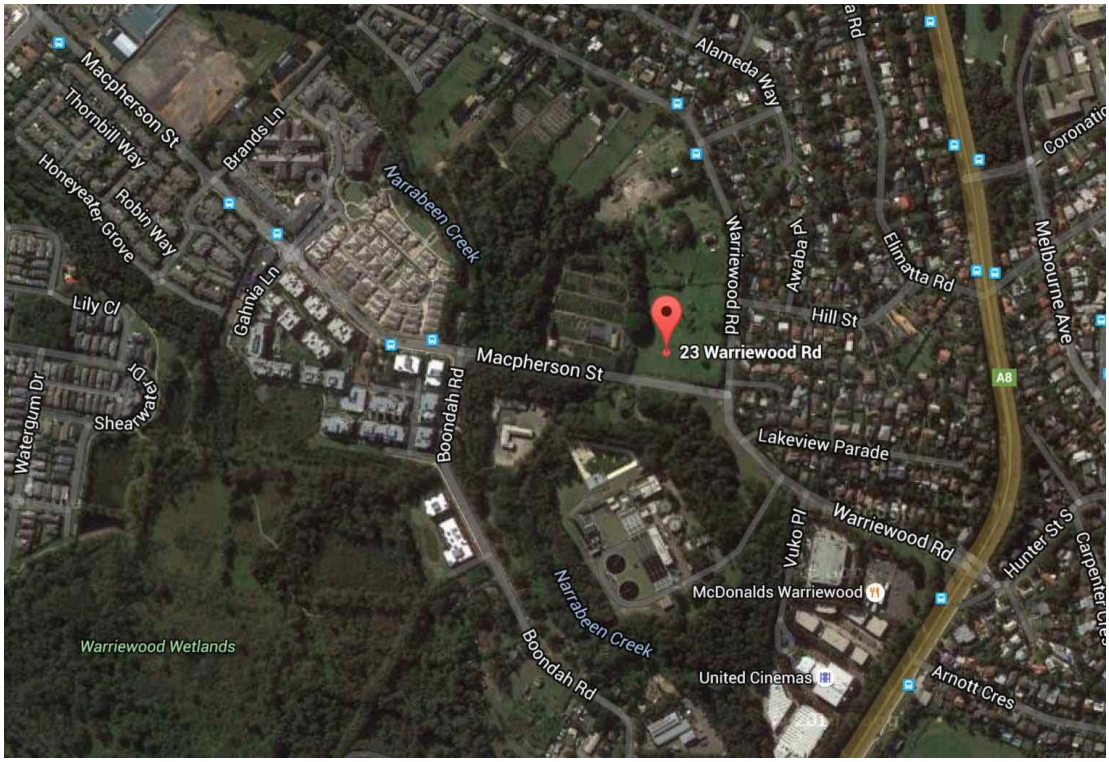


Figure 3-1 Locality Plan

3.2 Proposed Development

The site is proposed to be consolidated and then subdivided into two lots. Lot 1 is on the corner of Warriewood Road and MacPherson Street and will be developed with an aged care facility for ArCare. The proposed aged care facility was subject to a previous and separate DA that is already approved by Council under DA N0611/16. The water management specific to

this development have been addressed by SGC in report reference 2016.0112-R01 revision 05 that accompanied the DA documents. The approved DA included the extension to Lorikeet Grove from the northern boundary towards the proposed roundabout on Warriewood Road.

Lot 2 will be a residential development which is the subject of this water management plan. The water management measures for this lot were previously addressed as part of the previous submission for DA N0611/16, however because the proposed development layout has been modified from the original layout and because Council did not include this lot in the consent, this report is prepared to demonstrate compliance with requirements of the WVWMS.

The residential development includes a residential flat building on the lower side facing Lorikeet Grove with two basement levels and eleven split level townhouses facing Warriewood Road.

Reference should be made to the architectural drawings prepared by V-Arc for more details on the proposed development.

Figure 3-2 Ground Floor Plan – Aged Care Facility (approved under DA N0611/16)

Figure 3-3 General Arrangement Plan – Residential Development

4 Glossary

Annual Exceedance Probability (AEP)

The chance of a flood of a given or a larger size occurring in any one year, usually expressed as a percentage.

Australian Height Datum (AHD)

A common national surface level datum approximately corresponding to mean sea level.

Average Recurrence Interval (ARI)

The long term average number of years between the occurrence of a flood as big as or larger than the selected event.

Catchment

The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

Flood

Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse.

Flood Liable Land or Flood Prone Land

Land susceptible to flooding by the PMF.

Flood Planning Levels (FPLs)

Are the combinations of flood levels and freeboards selected for floodplain risk management purposes.

Freeboard

Is a factor of safety typically used in relation to the setting of floor levels.

Habitable Room

In industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to damage in the event of a flood.

Peak Discharge

The maximum discharge occurring during a flood event.

Probable Maximum Flood

PMF is the largest flood that could conceivably occur at a location, usually estimated from probable maximum precipitation.

Probable Maximum Precipitation

PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year.

Runoff

The amount of rainfall which actually ends up as stream flow.

SECTION B – WATER QUALITY

5 Water Cycle Assessment

5.1 General

This section addresses the requirements of Section 4.1 of the Warriewood Valley Water Management Specification (WVWMS).

The site is located in Sector D of the Warriewood Valley release area.

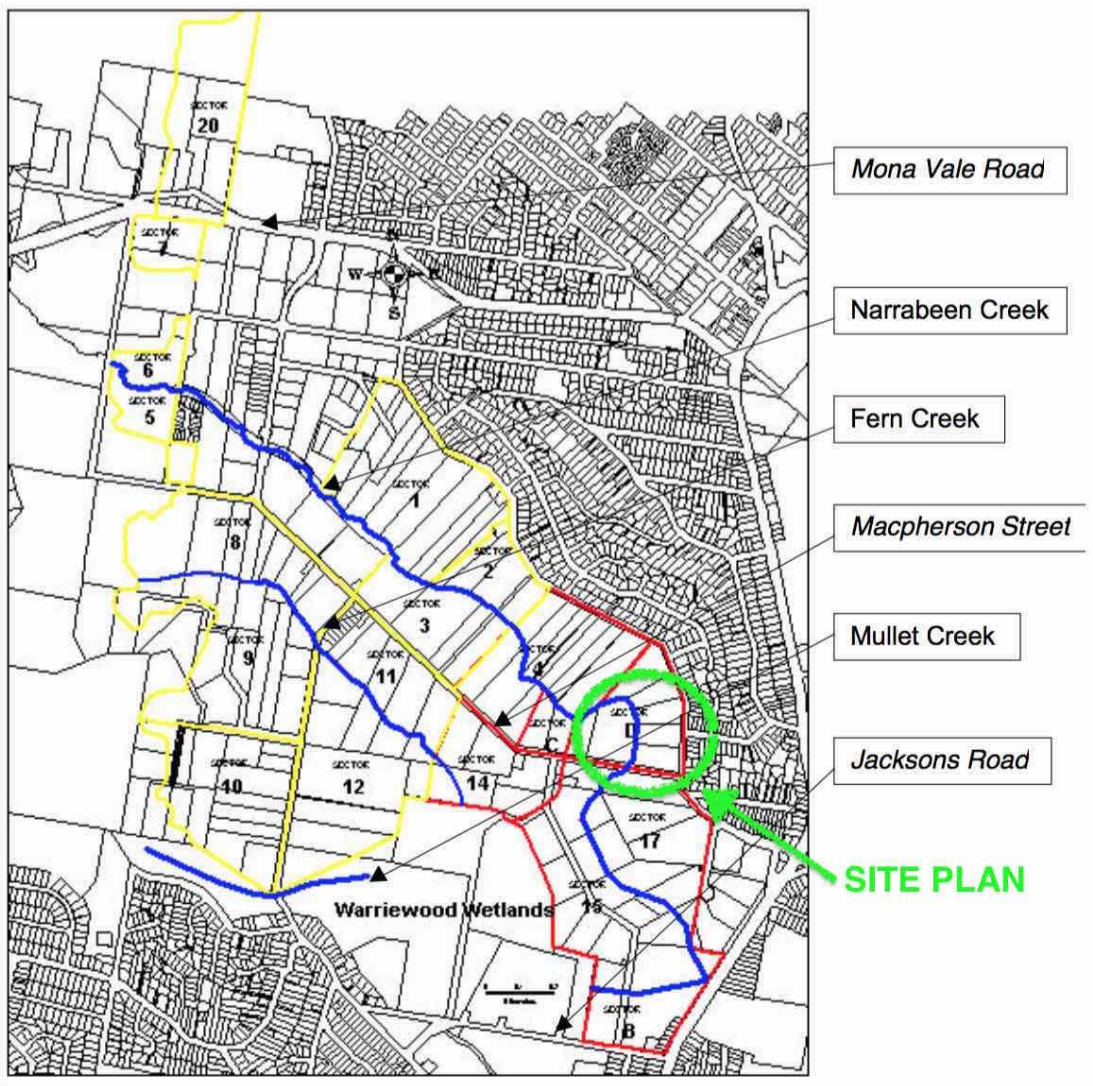


Figure 5-1 Sector Plan

5.2 Existing Geotechnical Conditions

This section of the report relates to existing subsurface conditions as identified by the geotechnical engineer for the site. A summary of the field works and results is included below. Reference is made to Geotechnique Pty Ltd Job No. 13787/1-AA (03/08/2016).

- Fill is encountered up to a depth of 0.4m;

- Bedrock is encountered at a depth ranging from 6.0m to 10.3m;
- Depth of groundwater varies between 4.3m and over 11.7m;
- Soil likely to be disturbed in Non-Salin;
- Soil is mildly to moderately aggressive; and
- The site is generally underlain with fine to medium grained sand, clayey sand, silty sand and low to high plasticity silty clay and sandy clay with ironstone.

5.3 Existing Catchment and Topography

The site is currently a green field and is made of three lots being Nos 23, 25 & 27 Warriewood Road, Warriewood. There is an existing double storey brick dwelling in No.27. The rest of the site is vacant.

The total site area is 2.53ha. The natural gradient of the land falls towards Narrabeen Creek which outlines the western boundary of the site (average slope of 5.5%). Refer Figure 5-2 below which is a copy of the detailed survey plan by SDG.

Figure 5-2 Site Topography

The site is traversed with a Sydney Water sewer easement as shown in the survey plan.

5.4 Assessment of Developed Conditions

The proposed site conditions are as per the general arrangement plans prepared by V-Arc (ref. 1510121). The site will be developed as follows: -

1. The first 25m setback from the creek will be the public setback which will include the riparian corridor which will be re-shaped to convey the 100-yr flows associated with the Narrabeen Creek;
2. The second 25m setback will for the private buffer that will not have any structures but will provide the required areas for the proposed water quantity and quality measures to meet the requirements of the WVWMS; and
3. The northern part of the site will form the proposed lot that will be developed with the residential development subject of this water management report and strategy. This area will provide the extension of Lorikeet Grove, new internal private road and new residential lots. Figure 5-3 below show the proposed land uses for the site.

A water balance model is prepared to assess the impact of the proposed conditions and to propose mitigation measures to ensure that the development will not have any adverse impacts on water quality. Reference is made to Section 6 “Water Quality Assessment” for details.

The proposed land-use of the site is shown in Figure 5-3 below. Reference is made to the stormwater concept plans for more details.

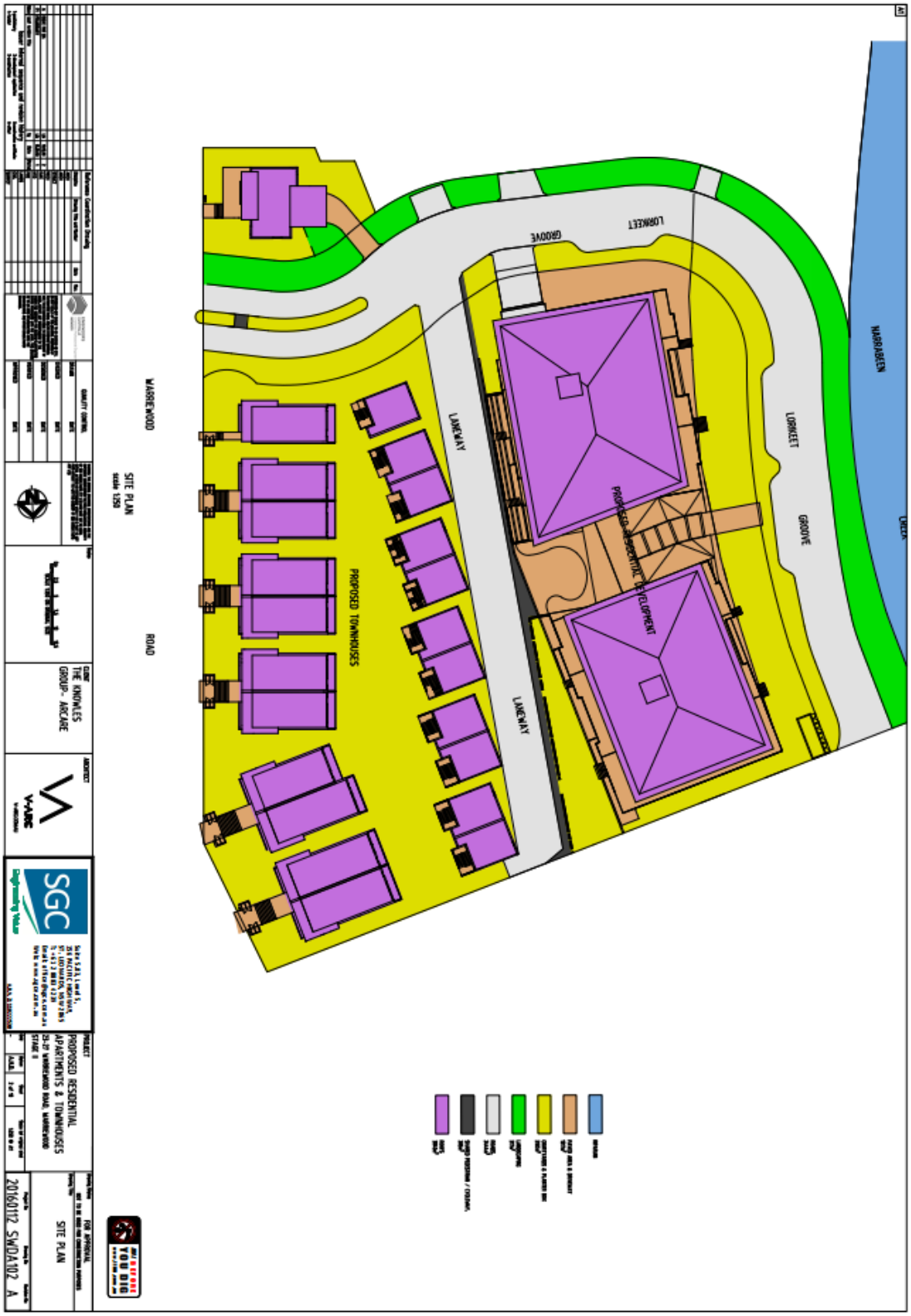


Figure 5-3 Proposed Land Use (full size copy in set of stormwater plans)

6 Water Quality Assessment

The water quality assessment is being carried out by another specialist consultant.

Reference is made to the report and the documents prepared by Marine Pollution Research Pty Ltd (March 2017) for details on water quality monitoring, sites chosen, methodology, monitoring regime, etc...

6.1 Water Balance

The proposed development will have rainwater reuse tanks to collect roof water for internal and external reuse as per the requirements of BASIX. At this stage, we have assumed that a 2,200 litres rainwater tank will be provided for each of the townhouses and a 20,000 litres rainwater tank for the residential flat building.

Based on the above, the provision of 12 townhouses will include a combined 46.4KL rainwater tank volume in conjunction with the residential flat building. The tanks will supply daily demands, which will include laundry, toilet flushing and watering of landscaping.

The daily demands are calculated based on the following: -

- Internal non-potable demand based on 0.25KL/day per unit (refer SCA MUSIC Modelling Guidelines); and
- Watering of grassed areas based on 0.0011KL/day/m2 (refer Blacktown Council WSUD Guidelines).

Based on the above, the daily demand is proposed to be at 4.32KL/day for the townhouses and 8.55KL/day for the units based on 100m2 of irrigation area per townhouse and 500m2 irrigation area for the units. This has been included in the MUSIC model as detailed below.

It is assumed that direct connection will be made to the kerb or to the in-ground drainage infrastructure in the streets from the overflows of the rainwater tanks, which will eventually drain through the proposed on-site detention basin and then through the bio-retention basin.

The internal drainage will be designed to cater for 20-yr ARI storm event. All roof drainage will pass through a first flush device prior to discharging into the rainwater tanks. All roof gutters draining into the rainwater tanks will be fitted with leaf guards.

It is also envisaged that the bio-retention basin will have infiltration capabilities into the ground to increase the groundwater recharge and reduce the volume of runoff into the creek.

The results of the MUSIC modelling indicate that the yearly volume of runoff from the proposed development will be less than the yearly volume of runoff under existing conditions. This result meets the requirement of Section 4.6.4 of the specification as tabulated below. Reference is made to the MUSIC model file for details.

Table 6.1 Water Balance Results

Site Condition	Site Runoff (ML/yr)	Residual Runoff (ML/yr)
Existing	7.08	7.08
Proposed	12.8	6.77

6.2 Assessment of Developed Conditions

A water balance model is prepared to assess the impacts of the proposed development on water quality downstream of the site. The model compares the post-developed site conditions to pre-development conditions based on soil conditions, land use, site coverage, etc….

A "MUSIC" model is assembled to assess the effectiveness of the proposed treatment measures.

The existing site is entered as a combination of "Agriculture" for the cleared area of the site and "Forest" for the riparian corridor in the base model and water quality discharges from the site are obtained to establish a benchmark. Figure 6-1 below shows the layout of the model.

The model is then modified to include all the proposed developed site conditions along with the treatment measures. The results of the water quality discharge are compared with the existing site discharges. A "no adverse impact" approach is adopted with respect to frequent flows.

The parameters adopted in the model are based on the recommendations included in the "Draft MUSIC Modelling Guidelines" by Sydney Metropolitan Catchment Authority.

Although not required in the WVWMS, we have adopted the current best practice of achieving the post-development pollutants' load reduction as follows:-

- 85% reduction in Total Suspended Solids (TSS);
- 65% reduction in Total Phosphorus (TP); and
- 45% reduction in Total Nitrogen (TN).

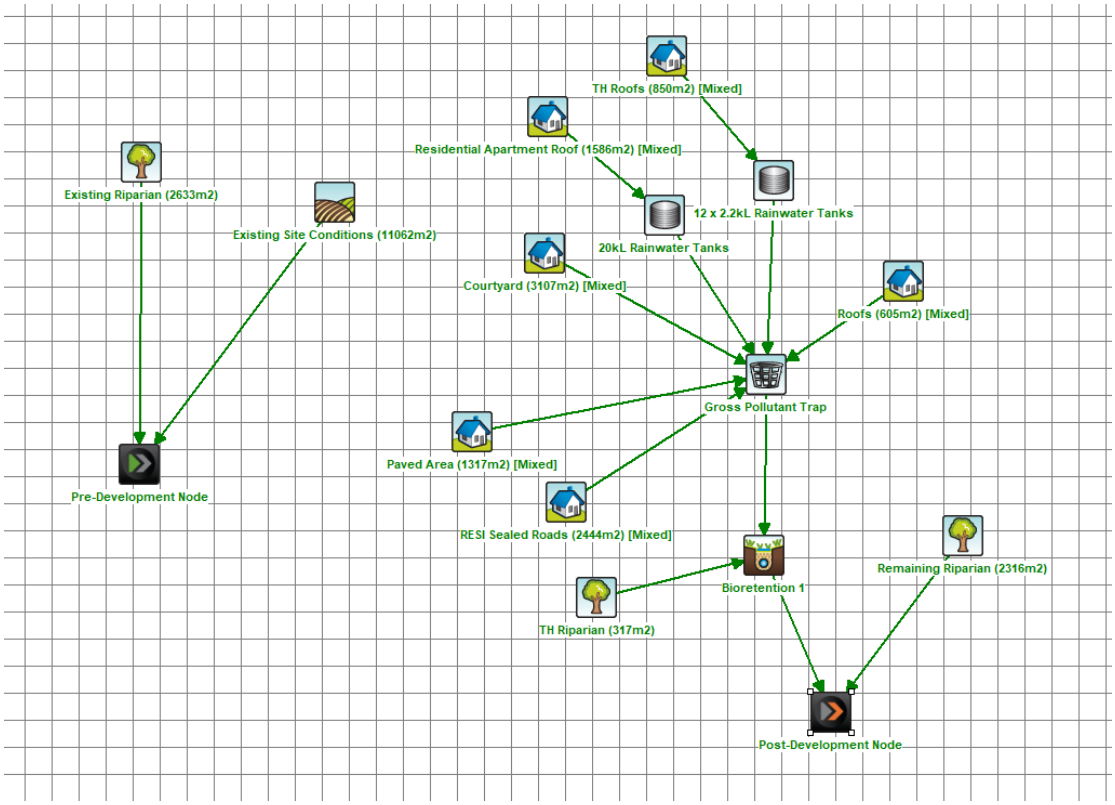


Figure 6-1 MUSIC Model Layout

For the purpose of achieving a "No Adverse Impact" result, it is proposed to adopt a treatment train approach solution as follows:-

- Install a 2.2KL rainwater tank to every townhouse;
- Install a 20KL rainwater tank for the residential flat building;
- Install a Gross Pollutant Trap (GPT) on the upstream side of the bio-retention basin that drains the roads and the townhouses only to capture large pollutants, litter and leaves. The GPT is sized to cater for all frequent minor flows. A Vortcapture VC80 by Stormwater 360 is proposed; and
- Construct a bio-retention basin to treat the stormwater runoff from the development. The basin is proposed outside the 25m public riparian corridor (inside the 25m private corridor). The bio-retention basins will have the following parameters:-

1. Bio Basin
    a. An overall surface area of 75m2;
    b. A filter media area of 35m2;
    c. A filter media depth of 0.5m;
    d. Filter media to have a saturated hydraulic conductivity of 125mm/hr;
    e. Exfiltration rate of 55mm/hr;

f. An extended water depth of 0.3m;

g. TN content of filter media no more than 400mg/kg;

h. Basin to be vegetated with effective nutrient removal plants; and

i. Basin to have underdrain subsoil lines.

The treatment measures above are detailed in the stormwater concept plans to be read in conjunction with this report. The proposed bio-retention will also treat the runoff from Lorikeet Grove.

The results of the MUSIC simulations indicate that the proposed treatment train approach adopted will reduce the pollutants load to less than pre-development conditions and meet the requirements of current industry best practice approach. Table 6.2 below summarises the results of the modelling.

Table 6.2 MUSIC Model Summary Results

Pollutant	Source Load (Existing)	Source Load (Proposed – no treatment)	Residual Load (after Treatment)	Effectiveness	Best Practice Objectives	Council Policy "No Adverse"
Flow (KL/yr)	7.08	12.8	6.77	45.4		Yes
TSS	477	2470	274	88.9	85	Yes
TP	2.7	4.56	1.04	77.2	65	Yes
TN	16.7	62	9.62	62.0	45	Yes
GP	30.8	260	0	100	90	Yes

6.3 WSUD Measures Operations and Maintenance

6.3.1 Gross Pollutant Trap

The proposed gross pollutant trap is type VortCapture VC80 by Stormwater 360.

The maintenance frequency of the gross pollutant trap is dependent on several variables, such as catchment area, surrounding land use, vegetation type, traffic loading and rainfall patterns. It is recommended that during the first year of operation the units should be monitored monthly, with maintenance as required.

Maintenance frequency should be adjusted to accommodate variable rainfall patterns. Regions east of the Great Dividing Range typically are dominated by greater rainfall during summer and Autumn Months, as such more maintenance is typically required during these periods. It is recommended that biannual inspections be carried out in November and April, while quarterly inspections should be conducted in February, April, July and November.

It is also recommended that additional monitoring should be conducted following moderate to extreme rainfall events, in particular when preceding months have had little to no rainfall. This monitoring is considered necessary to accommodate for higher volumes of runoff generated during major rainfall events, an anticipated greater accumulation of surface contamination during low rainfall periods and to ensure that the units have not been

damaged due to high pipe velocities. Table 6.3 below indicates the recommended inspection and maintenance frequency.

Table 6.3 VortCapture Maintenance Frequency

Item	Period	Responsibility	Maintenance Procedure
Inspection – Minor Maintenance	3 monthly and after major storms	Maintenance Contractor	Follow recommended procedure set out in Stormwater 360 "Operation and Maintenance Guidelines"
Inspection – Major Maintenance	12 monthly except in case of spill	Maintenance Contractor	Follow recommended procedure set out in Stormwater 360 "Operation and Maintenance Guidelines"

Reference should be made to manufacturer's specifications for inspection procedure, OHS, grates removal, cleaning methods, disposal of material and other procedures.

6.3.2 Bio-retention Basin

As previously mentioned in this report, there is one (1) basin proposed.

6.3.2.1 Elements of a Bio-retention basin

A bio-retention system includes the following components:-

- Vegetation: vegetation minimises surface clogging and assists in pollutant removal via biological processes;
- Extended detention (or ponding depth): it stores stormwater temporarily on the surface to buffer flows so that a greater volume can be treated;
- The filter media: it is the principal treatment zone. As stormwater passes through the filter media, pollutants are removed by filtration, adsorption and biological processes;
- A transition layer: it is a layer of clean well graded sand/coarse sand prevents the filter media from washing out of the system;
- The drainage layer: it is a layer of clean fine gravel which collects treated water at the base of the system and contains perforated pipes to convey treated water out of the system
- An impervious liner: required to prevent infiltration into surrounding soils, particularly if the treatment system is immediately adjacent to roads or buildings where infiltration may cause structural issues. Inlet and scour protection;
- An inlet for stormwater runoff. The inlet should be designed to protect the surface of the bio-retention system from scour and erosion;
- An overflow pit (or other controlled overflow point) to allow high flows, beyond the capacity of the treatment system, to escape to the stormwater drainage system in a

controlled manner;

- A flushing point connected to the perforated pipes, so they can be cleaned in the event of blockage.
- Edge treatment (e.g. a raised kerb or series of bollards) may be required to protect the bio-retention system from traffic; and
- Pre-treatment is recommended when sediment loads are likely to be high, or if there is a risk of spills. The simplest option is to incorporate a pit with a sump immediately upstream of the bio-retention system.

6.3.2.2 Construction, Operation & Maintenance

During the construction phase, the proposed bio-retention basins should be protected from high sediment loads associated with construction on site (erosion and sediment control measures should be in place to manage stormwater during this phase).

The commission of the bio-retention basins should not proceed or be brought on line until the civil works are completed and the catchment is stable (i.e. at least 80% of the housing construction is finished). Prior to this it should be used as a sedimentation device to manage the unstable upstream catchment.

Regular maintenance is important to ensure the ongoing performance of bio-retention systems. Maintenance requirements of bio-retention systems include:-

- Monitoring for scour and erosion, and sediment or litter build-up;
- Weed removal and plant re-establishment; and
- Monitoring overflow pits for structural integrity and blockage.

6.3.2.3 Inspection and Monitoring

Following construction, bio-retention basins should be inspected every 1 to 3 months (or after each major rainfall event) for the initial vegetation establishment period to determine whether or not the bio-retention zone requires maintenance or the media requires replacement. The following critical items should be monitored: -

- Ponding, clogging and blockage of the filter media;
- Establishment of desired vegetation/plants and density; and
- Blockage of the outlet from the bio-retention system.
- After the initial establishment period (typically 1 to 2 years), inspections may be extended to the frequencies shown in Maintenance and Inspection Checklist for Bio-retention Systems.

6.3.2.4 Maintenance

If the bio-retention system is not maintained frequently, the entire filter media may need to be replaced due to clogging of the media material with fine particles. This can result in frequent maintenance being more cost effective in the long-term.

The following maintenance activities will be required with inspection frequencies shown in the Maintenance and Inspection Checklist: -

- Maintenance of flow to and through the system;
- Maintaining the surface vegetation;
- Preventing undesired overgrowth vegetation/weeds from taking over the area;
- Removal of accumulated sediments; and
- Debris removal.

The recommended maintenance frequency for the Bio-retention basins is included in Table 6.4 below.

Table 6.4 Bio-retention System Maintenance Frequency

Item	Period	Responsibility
Debris Cleanout	6 monthly	Maintenance Contractor
Trench Surface Vegetation	6 monthly	Maintenance Contractor
Dewatering	6 monthly	Maintenance Contractor
Outlet/Overflow pit	yearly	Maintenance Contractor

6.4 Construction Phase

A Soil and Water Management Plan (also known as an Erosion and Sediment Control Plan) is prepared to control the water quality discharge from the site during construction in accordance with Landcom's publication "Managing Urban Stormwater: Soils and Construction" (known as The Blue Book).

The objective of the plan is to provide temporary measures to be adopted by the contractor during construction. The measures will be monitored and controlled during the construction period. The maintenance and the operation of the measures will be the responsibility of the main contractor.

The effectiveness of the measures will be monitored during the construction period and reported on a monthly basis and after every noticeable rainfall event. Any incident of failure will also be reported and corrective action will be implemented where required.

The treatment measures proposed are detailed in drawing SW700. In summary, the following has been provided: -

- A silt fence is provided at the lower end of the site;
- A temporary all weather construction entry/exit point is provided off the end of Lorikeet Grove;
- Catch drains are provided to convey the "dirty" water to the sediment basin; and

- A sediment basin is proposed at the downstream side of the disturbed areas to collect and treat "dirty" water from the construction zone. The calculations of the storage capacity of the basin is done in accordance with the Blue Book and is shown below.

Project Name		ArCare - Warriewood			
Project Number		2016.0112			
(after DepHousing Blue Book)					
Sedimentation Basin		"Informal Area"			
5-day Rainfall Events (Table 6.5, Page 6-21)					
Station	Mona Vale	70th	75th	80th	90th
Rainfall Depth (mm)		0.0	29.0	0.0	0.0
Settling Zone					
Volumetric Runoff Coeff:		0.5	<<chosen, because a portion of site is stockpile		
Area		1.55	ha		
	Assuming Rainfall	70th	75th	80th	90th
Settling Zone (m^3)		**0**	**225**	**0**	**0**
TOTAL VOLUME					
Method 2:					
Assume Sedment Zone is		50% of Settling Zone (note minimum is 30% !!)			
	Assuming Rainfall	70th	75th	80th	90th
Settling + Sediment Zone		0	337	0	0 m^3
	RECOMMENDED	**0**	**337**	**0**	**0** m^3
	(based on max)				

Figure 6-2 Sediment Basin Calculations

6.5 Preliminary Mosquito Risk Management

No permanent waterbodies have been proposed for this development therefore the risk of increasing mosquito activity is low. However, as part of the water quality management system that will be implemented consideration should be given to the potential for measures acting as pest mosquito breeding areas.

The bio-retention basin is not expected to contain storage for extended lengths of time. The pond is underlain with subsoil drains that will drain any water on the surface of the pond.

If the pond is properly constructed and maintained, there is a low risk that the pond will act as a mosquito habitat.

The flood storage pond is designed as a dry pond and will not hold any water permanently. The pond is also underlain with subsoil drainage that will ensure no ponding occurs after the floodwaters have receded below the invert of the pond.

At this stage, it is expected that the low risk of providing habitat for pest mosquitoes shall remain the same before and after the proposed works.

During the construction certificate stage, it is recommended that a specialist in this field undertake a further detailed mosquito risk assessment.

SECTION C – FLOOD PROTECTION

7 Watercourse & Creekline Corridor

7.1 Overview & Objectives

This section of the report addresses the requirements of Section 4.4 of the WVWMS. Because a large portion of the creek corridor is degraded, Council is seeking the upgrade of the creek corridor to, among other things, retain the pervious areas, preserve a water balance, provide a landscaping buffer, provide effective flood conveyance (1% AEP), provide a habitat and wildlife corridor and provide common link between open spaces.

For the purpose of this report, the creek line works are associated with the flood conveyance to ensure that the 50m wide public corridor is able to convey the flows generated from a 1% AEP storm event. Reference should be made to the landscaping reports and drawings for other corridor design aspects.

This report addresses the requirements of the creek widening works along the rear frontage of the site. The works are limited to the 25m public corridor on the side of the site only. No works are proposed within the opposing 25m corridor.

These works will be subject to approval by the Office of Water and Northern Beaches Council.

7.2 Existing & Design Conditions

The existing creek line has been surveyed by SDG (ref. 6952/B dated 13/05/2016). From the above documents, cross sections at 20m intervals have been prepared (refer SGC civil drawings for details).

7.3 Design Flow Conditions

The WVWMS provides the peak design flows for the 100-yr in 2-hr storm duration which were derived using RAFTS model (XP Solutions).

As previously advised the site is located in Sector D. The peak design flow rates provided in Appendix B of the WVWMS are tabulated below.

Table 7.1 Peak Design Flows – WVWMS

Sector	PMF		1% AEP		2% AEP		5% AEP		20% AEP		50% AEP	
	u/s m3/s	d/s m3/s	u/s m3/s	d/s m3/s	u/s m3/s	d/s m3/s	u/s m3/s	d/s m3/s	u/s m3/s	d/s m3/s	u/s m3/s	d/s m3/s
D	180.5	193.5	39.6	42.2	32.3	34.5	24.1	25.6	12.8	13.5	5.7	6.2

The narrow creek line is upgraded to convey the 50% AEP up to the top of the batters, while the 50m wide corridor is sized to cater for the 1% AEP flows.

Because the site falls towards the upstream end of the sector, a peak design flow of 6.2m3/s is adopted to size the bank full section of the creek. A design peak flow of 42.2m3/s is required to be carried in the creek corridor. Refer to Section 8 for flood conveyance and protection details.

7.4 Creek Design

An average overall creek corridor width of 50m is adopted across the length of the site frontage. The widening and the trimming of the creek line corridor are shown in the civil drawings, which provide for a long section and cross sections at 20m intervals.

On average, the width of the narrow creek has been widened by 10m towards the site. Sections at 20m intervals have been provided showing the proposed changes between the existing and the proposed levels.

The following batters have been adopted in the design of the creek corridor: -

- 1V:3H maximum for the batters of the narrow creek carrying the 50% AEP flows (bank full section);
- 1V:6H maximum for the remaining width of the public corridor; and
- 1V:8H batters are proposed beyond to raise the site area above the FPL and provide flood free development site.

Reference should be made to the civil drawings for more details and to the landscaping design for all other requirements such as vegetation, cycleways, footpaths and pedestrian links.

7.5 Discharge Point

The stormwater discharge point from the site is proposed in the creek corridor. Reference is made to the stormwater drawings for details.

An all-weather stabilised discharge point is provided. The location of the discharge arrangement is within the 25m public corridor. A separate discharge point is proposed for the aged care and the townhouses.

The discharge will be stabilised through a natural rock mattress made of rock boulders sunk 200mm into the ground similar to outlet control structure by the Office of Water. A detail of the proposed two discharge points is shown on the stormwater plans.

8 Flood Study

8.1 Narrabeen Creek

Narrabeen Creek is a natural watercourse draining a catchment area of 354ha approximately upstream of the study area.

The creek originates approximately 1.5km to the West and flows in a northerly direction to the confluence of Mullet Creek and then discharges in Narrabeen Lagoon.

Narrabeen Creek forms part of the Warriewood Valley creek system which also includes Fern Creek and Mullet Creek.

8.2 Objectives

The purpose of this flood study is to determine if the proposed subdivision and development platform will impact the flood levels and will propose the mitigation measures to negate the impact.

In summary, the objectives are as follows: -

- Use the existing TUFLOW model obtained from Council to develop a post-development model that can be used to predict the magnitude and extent of future flood events;
- Define design flood levels, velocities and depths for the catchment;
- Define the extent of flooding for the 100-year and the PMF for the catchment to establish a benchmark;
- Determine if the proposed development has any impact on the flooding; and
- Propose mitigation measures (i.e. creek widening works) to negate the impacts and provide post-development modelling to verify the mitigation measures.

8.3 Authorities' Requirements

Northern Beaches Council (Pittwater) requirements for development on flood prone land are detailed in DCP 21 Section B. Any development in the Warriewood Valley is also affected by additional requirements included in the "Warriewood Valley Urban Land Release Water Management Specification".

Council's Floodplain Management Engineer has provided Council's specific requirements for subdividing and developing the site as outlined below.

8.3.1 Flood Assessment Analysis

A typical Flood Assessment Analysis should include (but not limited to) the following details:

- Determine and detail whether the development is located either wholly or partially on land being within an area classified as a flood prone in a 1% AEP flood event;

- Determine and detail whether the development (as a whole or partially) is located on land that can conceivably be affected by a probable maximum flood (PMF) level;
- Detail the flood characteristics of the site; hazard, hydraulic classification, depth, velocity, direction and the impact this may have on the proposed development;
- For non-residential development - detail the main use and number of occupants in the building/development, hours of operation and proposed traffic usage/movement; and
- For Major Overland Flow Paths, the Flood Assessment is to outline/map the 5m horizontal buffer (placed horizontally on the 1% AEP Major Overland Flow extent).

8.3.2 Assessment of Impacts

This section must state compliance with Part B3 (Hazard Controls) of the Pittwater 21 DCP and should include (but not limited) to the following: -

- Detail on how the flood affected land is to be sited and designed to minimise the impacts of flooding on the property with regards to the existing flood regime up to the PMF;
- There is no additional adverse flood impact on the surrounding properties or flooding processes for any flood event up to the Probable Maximum Flood event;
- There is no net decrease in the floodplain volume of a floodway or flood storage area within the property for any flood event up to the 1% AEP flood event;
- The impact that that development has to surrounding properties (with regard to flooding) needs to be detailed up to the PMF;
- Explain how the work will not reduce flood storage area or impact upon the existing flood regime (including calculations);
- Ensure and explain that the habitable storeys (floor level) of the building are set at or above the Flood Planning Level (shown in written form and diagrammatically);
- Determine if fences are included in the plans for the development and identify any impacts this will have on the existing flood regime;
- Detail how buildings or works are to be affected by flooding and how this can be mitigated through the use of flood compatible building materials;
- If there are any adverse impacts on surrounding sites, upstream or downstream, this must be detailed;
- On occasion, high flood volume and flow may cause movement of vehicles or other large objects. Devices such as bollards and gates can be installed to activate in the event of such a flood and if these are required, they need to be detailed;
- If any hazardous materials are to be stored on-site, details must be made as to their location and the affect they may have if a flood occurs; and
- Ensure consistency with Australian Standards and the New South Wales Floodplain Development Manual.

8.3.3 Evacuation Procedures

This section of the Flood Management Report should contain the following information at the very least: -

- Evidence must be provided that the development provides an evacuation route that is flood free up to the PMF or an area to shelter in the event of a flood. If shelter-in-place is the only alternative, details must be provided that show the structural integrity of the building up to the level of the PMF (i.e./ show that the shelter can withstand the hydraulic forces of the PMF flood event); and
- If an evaluation plan is reposed a Draft Evacuation Plan containing the following is required: -

a. Route of evacuation to higher ground/shelter;

b. Depth of water for a PMF surrounding the building;

c. Details of the 'last chance' evacuation water levels/times for evacuation prior to floodwaters surrounding the building;

d. Details of flood warning systems and protocols; and

e. Details of how this information will be disseminated amongst users of the property.

8.3.4 Mitigation Measures

This section is used to outline and detail all the preventative measures used to assist the site and users of the site in the event of a flood. This includes flood compatible materials and is at the discretion of the applicant.

If flood mitigation works that modify a major drainage system, stormwater system, natural water course, floodway or flood behaviour within the development site the flood risk report needs to demonstrate the following: -

- The flood mitigation works do not have an adverse impact on any surrounding property or flooding processes for any flood event up to the Probable Maximum Flood event;
- The flood mitigation works result in no net decrease in the floodplain volume of a floodway or flood storage area within the property for any flood event up to the 1% AEP flood event;
- The flood mitigation works result in the protection of the existing and proposed development from a flood event to the minimum floor level requirement as defined in this control; and
- The works do not have an adverse impact on the environment. (This includes but is not limited to the altering of natural flow regimes, the clearing of riparian vegetation, artificial modification of the natural stream, such as by relocation, piping etc.).

8.4 Design Flood Modelling

8.4.1 Introduction

A copy of the TUFLOW model was purchased from Council which formed the base for our flood modelling. The runs in the model were used as the base models for additional runs carried out to include the proposed development (i.e. fill platforms on site, creek works, etc…).

Two scenarios were prepared as part of this flood impact assessment. The scenarios are as follows: -

- Scenario 0: Existing Site Conditions. This scenario is basically the flood modelling that Council has undertaken and establishes the base case scenario and a benchmark for any development on site; and
- Scenario 1: Proposed Site Conditions. This scenario is based on the fully developed site conditions inclusive of the creek corridor works.

The modelling includes the upgrade of McPherson Street as provided by Council. The modelling takes into account the raising of the road levels, the upgrade of the existing 3x1200mm pipes crossing under the road and the new 9x3.6x1.2m culverts.

8.4.2 Design Flood Modelling Results

Design flood modelling was undertaken for the 5, 10, 20, 50 & 100-year ARI standard design flood event and the PMF. Modelling was also carried out for the 20-year and the 100-year ARI inclusive of Climate Change considerations which involves the increase in rainfall by 30% and rise in sea level by 0.9m by year 2100 due to the proposed intensification of the site.

The modelling was undertaken for the critical durations of 120min and 9hr as per the flood modelling report by BMT WBM, which identified the 2-hr storm as the critical duration for all the storms up to the 10% AEP and the 2% AEP and the 9hr storm as the critical duration for the 5% AEP and the 1% AEP inclusive of Climate Change and the PMF events.

The results for the 100-year ARI event including climate change and the PMF are presented in Appendix 4 of this report.

8.5 Flood Mitigation

The modelling results indicate that the proposed development and the proposed creek widening works do not have any adverse impact on the flooding in the Narrabeen Creek.

It is proposed to modify the creek corridor in accordance with the requirements of Section 4.4 of the WVWMS. The narrow creek section has been widened to convey the 50% AEP flows with side banks with maximum batters at 1V:3H. The 1% AEP flows are contained within the 50m wide corridor which is capable of conveying the flows without having an impact on downstream and upstream flood levels.

The mitigated post-development site conditions is modelled and the results are included in Appendix 4. Flood impact maps are produced for the 100-yr +CC and the PMF events to verify that the flood levels and the flood conveyance in the creek is generally unchanged once the proposed works are completed with the exception of a small and localised rise in flood levels confined to the creek corridor.

8.6 Discussion

8.6.1 Flooding Assessment Analysis

Mainstream flooding occurs within the site when the capacity of Narrabeen Creek is exceeded. The 1% AEP flood level for the site is RL 3.79mAHD and the PMF flood level is RL 4.88m AHD. The flooding is classified as Category – High Hazard.

This flood level is mainly due to the increase in rainfall volume by 30% across the upstream catchment because of the Climate Change considerations.

The Flood Planning Level (FPL) adopted for the proposed aged care facility is **RL 4.88m AHD**. The FPL for the townhouses is **RL 4.29m AHD**, which achieves 0.5m above the 100-year ARI flood level inclusive of Climate Change considerations.

Determine and detail whether the development is located either wholly or partially on land being within an area classified as a flood prone in a 1% AEP flood event;

The proposed development is separated from the creek by Lorikeet Grove extension and is wholly outside the 1% AEP flood extent.

Determine and detail whether the development (as a whole or partially) is located on land that can conceivably be affected by a probable maximum flood (PMF) level;

The proposed development is wholly outside the PMF flood extent because the proposed levels on Lorikeet Grove are at or above the PMF flood level.

Detail the flood characteristics of the site; hazard, hydraulic classification, depth, velocity, direction and the impact this may have on the proposed development;

The flood characteristic details of the site area have been determined and mapped in Appendix 4. As the proposed development is outside the flooding extents, there is no impact on the flooding behaviour.

For Major Overland Flow Paths, the Flood Assessment is to outline/map the 5m horizontal buffer (placed horizontally on the 1% AEP Major Overland Flow extent).

This requirement is not applicable for this site.

8.6.2 Assessment of Impacts

The site finished levels are raised above the PMF and the 100-yr flood level with 500mm freeboard for the residences as required in Part B3 (Hazard Controls) of the Pittwater 21 DCP. The residences levels vary across the site with the lowest being at RL 8.35m AHD.

The comparison of the modelling results between existing and post-development scenarios indicate that there are no flooding impacts within the creek corridor and no adverse impacts on surrounding properties. The flood impact maps demonstrate that the flooding is reduced approximately everywhere in the surrounding areas.

In the 100-yr event + CC, the adverse impacts are nil as can be shown in the flood maps (refer Figure A 4.14). There are no adverse impacts on any developable land in the floodplain.

In the PMF event, there are no adverse impacts as well. Due to the large coverage of the flooding in this event, the impacts of the proposed changes are absorbed in the floodplain and the impact maps do not show any rise in flood levels across the floodplain (refer Figure A 4.15).

Reference is made to the flood impact map in Appendix 4. The results indicate that the proposed subdivision does not cause a decrease in the flood storage in the 1% AEP flood event. As such, the proposed development should not increase the flood hazard or risk to other properties. There is no upstream afflux created by this development indicating that the loss of flood storage due to the development of the site is negligible.

Based on the above, we believe that these results should be acceptable to Council as the proposed development does not adversely impact on the adjoining properties.

Detail on how the flood affected land is to be sited and designed to minimise the impacts of flooding on the property with regards to the existing flood regime up to the PMF;

The flood affected land is re-graded as required in the WVWMS so that the flood extents up to the PMF event are contained within the creek corridor and do not impact on the proposed development.

There is no additional adverse flood impact on the surrounding properties or flooding processes for any flood event up to the Probable Maximum Flood event;

The modelling has been undertaken for the pre- and the post-developed scenarios. The flood impact maps are included in Appendix 4 for reference. There are no adverse impacts.

There is no net decrease in the floodplain volume of a floodway or flood storage area within the property for any flood event up to the 1% AEP flood event;

The flood impact map for the 1% AEP (Figure A 4.14) demonstrates that there is no net decrease in floodplain volume because there is no increase in flood levels.

The impact that that development has to surrounding properties (with regard to flooding) needs to be detailed up to the PMF;

The flood impact map for the PMF (Figure A 4.15) demonstrates that there is no net decrease in floodplain volume because there is no increase in flood levels.

Explain how the work will not reduce flood storage area or impact upon the existing flood regime (including calculations);

The flood extent does not encroach substantially into the site, specifically where the development is proposed. The creek works provide additional flood conveyance and storage volumes such that the flood levels are not impacted elsewhere in the floodplain. This has been modelled in the TUFLOW model supplied by Council and pre- vs post- site conditions maps have been provided to substantiate these changes.

Ensure and explain that the habitable storeys (floor level) of the building are set at or above the Flood Planning Level (shown in written form and diagrammatically);

The proposed development is set at RL 6.10m AHD. This level is above the PMF flood level of the site (4.88m AHD). Reference is made to the architectural plans and the civil plans for level details.

Determine if fences are included in the plans for the development and identify any impacts this will have on the existing flood regime;

The fences around the perimeter of the site are above the PMF flood level and have no impact on the flooding regime.

Detail how buildings or works are to be affected by flooding and how this can be mitigated through the use of flood compatible building materials;

This requirement is not applicable as the proposed development is above the PMF flood level.

If there is any adverse impacts on surrounding sites, upstream or downstream, this must be detailed;

This requirement does not apply because there are no adverse impacts.

On occasion, high flood volume and flow may cause movement of vehicles or other large objects. Devices such as bollards and gates can be installed to activate in the event of such a flood and if these are required, they need to be detailed;

This requirement does not apply because the roads and the development are above the predicted flood levels even in extreme storm events.

If any hazardous materials are to be stored on-site, details must be made as to their location and the affect they may have if a flood occurs; and

This requirement does not apply because there is no storage of hazardous material proposed on this site.

Ensure consistency with Australian Standards and the New South Wales Floodplain Development Manual.

This requirement has been addressed in the flood modelling.

8.6.3 Evacuation Procedures

This section of the report contains information relating to the proposed off-site evacuation.

Evidence must be provided that the development provides an evacuation route that is flood free up to the PMF or an area to shelter in the event of a flood. If shelter-in-place is the only alternative, details must be provided that show the structural integrity of the building up to the level of the PMF (i.e./ show that the shelter can withstand the hydraulic forces of the PMF flood event); and

Because the site is set above the PMF flood level, then the proposed development is not subject to flooding in any event. This indicates that evacuation will not be required for this development.

The proposed residential development is above the PMF flood level so there is no need for evacuation as these townhouses are considered flood free.

The extension to Lorikeet Grove is proposed at levels above the PMF flood level and can be used for evacuation during extreme flood events such as the PMF. Lorikeet Grove connects to Warriewood Road which is raised even further above the flood levels. The site can be classified as “Areas with Rising Road Access (RRA)” as labelled under the “Flood Emergency Response Planning – Classification of Communities”.

If an evaluation plan is reposed a Draft Evacuation Plan containing the following is required: -

Route of evacuation to higher ground/shelter;

Depth of water for a PMF surrounding the building;

Details of the ‘last chance’ evacuation water levels/times for evacuation prior to floodwaters surrounding the building;

Details of flood warning systems and protocols; and

Details of how this information will be disseminated amongst users of the property.

As stated above, the above requirements do not apply.

Pittwater Council’s DCP 21 sets some controls for land uses on flood prone land as follows:-

- A site emergency response flood plan must be prepared in case of a PMF flood;
- Adequate flood warning systems, signage and exists must be available to allow safe

and orderly evacuation without increased reliance upon the State Emergency Services (SES) or other authorized emergency personnel; and

- Reliable access for pedestrians or vehicles must be provided from the building, commencing at a level equal to the lowest habitable floor level to an area of refuge above the PMF.

8.6.4 Mitigation Measures

The flood mitigation works do not have an adverse impact on any surrounding property or flooding processes for any flood event up to the Probable Maximum Flood event;

The proposed mitigation measures involve creek works to increase the conveyance and the storage of flood in the creek corridor along the rear of the site. The works are coordinated with the proposed upgrade of McPherson Street and the new culverts/bridges. The creek design is also sympathetic with the proposed design for 29-31 Warriewood Road upstream of the site. These works have been taken in the modelling of the post-development scenario and the water level change has been mapped. The results indicate that there are no adverse impacts elsewhere in the floodplain.

The flood mitigation works result in no net decrease in the floodplain volume of a floodway or flood storage area within the property for any flood event up to the 1% AEP flood event;

This has been assessed and the flood impact maps demonstrate that this requirement has been met. We have addressed this requirement in previous sections of this report.

The flood mitigation works result in the protection of the existing and proposed development from a flood event to the minimum floor level requirement as defined in this control; and

This requirement has been complied with in full. The habitable levels across the development have been raised above the PMF flood levels.

The works do not have an adverse impact on the environment. (This includes but is not limited to the altering of natural flow regimes, the clearing of riparian vegetation, artificial modification of the natural stream, such as by relocation, piping etc.).

The requirements of the WVWMS have been implemented with regards to creek corridor design. There are no alterations to the natural regime or any modification proposed that is in contradiction to the WVWMS.

8.7 Conclusions

A detailed investigation on the flooding behaviour has been undertaken in the vicinity of 23-27 Warriewood Road, Warriewood.

A detailed 1D/2D hydraulic model was established based on the TUFLOW model prepared by Council.

Using the established model, the study has determined the flood behaviour for the 1% AEP design flood including Climate Change. The primary flood characteristics reported for the

design events considered include depths, levels and velocities. The study has also defined the Provisional Flood Hazard for flood-affected areas.

The study looked into the impact of the proposed site filling on the flooding behaviour in the creek and its impact on the flood levels both upstream and downstream.

Mitigation measures are proposed to eliminate the adverse impact of the proposed subdivision on flood characteristics. These are detailed in the engineering plans and in Section 7.4 of this report.

The flood maps are included under Appendix 4.

SECTION D – WATER QUANTITY

9 Water Quantity Management

9.1 General

The water quantity criteria is expressed as follows in the WVWMS: -

"Post-development peak flows both from the sector and in the channel at the downstream boundary of each sector are not to exceed the pre-development flows for the full range of duration's and frequencies up to the 1% AEP level."

The design of the water quantity measures will cater for all rainfall events including the climate change requirements, which require the increase in average rainfall depth of 30% as required by Council.

9.2 Piped Drainage

The internal drainage design adopts the minor/major design approach. The piped drainage infrastructure is designed to cater for 5% AEP storm event inclusive of the 30% increase in rainfall to comply with the Climate Change requirements. The road network carries the flows from the storms in excess of the piped drainage capacity to the OSD.

Reference is made to the stormwater drawings for details.

9.3 On-Site Detention

The details of the proposed On-Site Detention (OSD) are as follows: -

- The reduction of post development discharge flows to the flows nominated in the WVWMS for the 1% AEP 30, 60, 120, 180 & 360 minutes durations. In order to achieve this outcome, it is proposed to provide On-Site Detention (OSD) systems;
- The site is split into two (2) large separate catchment areas and one small single dwelling as catchment 3. The upper area of the development is identified as catchment 1 and the lower area is catchment 2. Catchment area 3 is only a single residential development. Catchment 1 drains into OSD 1, catchment 2 into OSD 2 and catchment 3 into OSD 3;
- The reserve areas for the extension of Lorikeet Grove and the laneway, which will be a public domain to be handed over to council once completed, are not included in the OSD catchments;
- The catchment areas for OSD 1 & OSD 2 are 0.478ha and 0.402ha respectively; and
- The catchments have been modelled as follows: -
- No seepage allowed from the OSD tanks;
- 100% Pervious for the existing site conditions;
- 77.6% impervious fraction for the developed aged care site and 59% (averaged) impervious for the townhouses site; and
- Manning's roughness adopted 0.08 for pervious and 0.02 for impervious.

Table 9.1 Site Catchment Area

Catchment	Area (ha)	Impervious Fraction (%)	Slope (%)
1	0.478	51.6	4.9
2	0.402	56.5	4.9

9.4 Council requirements

Council has determined the detention requirements on a sector-by-sector basis using a RAFTS model. The model outlines the minimum storage requirements, the permissible site discharge, the maintenance of the base case hydrograph and use of the Australian Rainfall & Runoff.

Based on the site area, the specific council requirements for the development are reported in the table below.

Table 9.2 Detention Requirements – WVWMS

Sector	SSR (m3/ha)	1%-30min PSD (L/s/ha)	1%-1hr PSD (L/s/ha)	1%-2hr PSD (L/s/ha)	1%-3hr PSD (L/s/ha)	1%-6hr PSD (L/s/ha)
D	368	138	226	230	187	205

Based on Table 9.2 above, the site specific detention requirements are calculated for each catchment and reported in Table 9.3.

Table 9.3 Detention Requirements – Site Specific

Catchment	Site Area (ha)	SSR (m3/ha)	1%-30min PSD (L/s)	1%-1hr PSD (L/s)	1%-2hr PSD (L/s)	1%-3hr PSD (L/s)	1%-6hr PSD (L/s)
1	0.478	160.82	60.31	98.762	100.51	81.719	89.585
2	0.402	147.94	55.48	90.852	92.46	76.174	82.41

9.5 Modelling

An XP-STORM Model has been prepared to simulate the site stormwater discharge and to size the OSD system that is suitable for the development and at the same time respond to Council requirements as per the above tables.

XP-STORM is a hydrology and a hydraulic software package by XP Solutions the providers of XP-RAFTS. Both softwares use the same hydrology method (Laurenson) and would ultimately provide similar peak discharge results. We note that XP-STORM is more suited for sizing OSD basins because it incorporates a hydraulic component which RAFTS does not. From our discussions with engineers from XP Solutions is that RAFTS should not be used for modelling OSD basins in their opinion and they have been advising engineers not to use the software for any hydraulic modelling.

The difference between the STORM model by SGC and the RAFTS model prepared by Council is that the STORM model considers the increase in rainfall of 30% due to Climate Change. Hence the results of the STORM simulations may produce slightly different results to those proposed in the WVWMS by Council and more OSD volume is potentially provided.

The modelling results are tabulated below. The results are for the 1% AEP event for a range of storm durations as per the WVWMS.

Table 9.4 XP-STORM Model Results – Summary

Catchment	Volume (m3)	1%-30min Q (L/s)	1%-1hr Q (L/s)	1%-2hr Q (L/s)	1%-3hr Q (L/s)	1%-6hr Q (L/s)
1	157.442	42	75	88	81	78
2	97.74	46	82	86	76	74

Council requires that the pre-development hydrograph and the post development hydrograph be shown. The figures in Appendix 3 show the post-development site discharge hydrographs in comparison with the pre-development discharge flows.

The results indicate that the proposed on-site detentions achieve the requirements of the WVWMS as follows:-

- The OSD volumes are achieved; and
- The permissible site discharges are met.

A1 Appendix 1

Checklist

Figure A 1.1Completed DA Checklist

DOCUMENTATION CHECKLIST - DEVELOPMENT APPLICATION

(Detach and include with submissions)

Section	Item	Requirement	Check (√)
4.1	Water Cycle Assessment - Water Balance Modelling Pre & Post Development	++++++++++	✓
4.1.1	Stream Gauging, infiltration testing and use of local rainfall data for modelling	♦♦♦♦♦♦♦♦	✓
4.2.1	Water Quality Monitoring Plan	♦♦♦♦♦♦♦♦	✓
4.2.1	Water Quality Monitoring Sites Shown on Plan (at least three)	♦♦♦♦♦♦♦♦	✓
4.2.1, 2, C	Water Quality Monitoring Data	♦♦♦♦♦♦♦♦	✓
4.2.1, 2, C	Assessment and interpretation of water quality monitoring data	♦♦♦♦♦♦♦♦	✓
4.2.1, 2, C	Assessment and interpretation of water quality monitoring data from SQID's		
4.3	Water Quality Management Assessment - Load Modelling Pre and Post Development	++++++++++	✓
4.3.1, 3	Justification of assumptions for Event Mean Concentrations	♦♦♦♦♦♦♦♦	✓
4.3.2	Identification of and details for Stormwater quality facilities		✓
4.3.2, 4.4.5	Mosquito Risk Assessment for both Watercourse and Water Quality/Quantity features	♦♦♦♦♦♦♦♦	✓
4.3.6, 4.6.5	Inspection and Cleaning Reports for SQID's and OSD		
4.3.6	Management Plan for Stormwater Quality Improvement Devices	♦♦♦♦♦♦♦♦	✓
4.3.5	Environmental Management Plan (Soil and Water Aspects)		
4.3.4	Erosion and Sediment Control Plan		
4.4.3, 4, 5	Existing and Proposed Creek Corridor in plan with cross/long sections with flood levels	♦♦Note 1♦♦	✓
4.4.4	Proposed Creek Corridor Planting Schedule	Note 1	✓
4.4.5	Creek Corridor Vegetation Monitoring and Management Plan	Note 1	✓
4.4.5	Vegetation and Creek Maintenance and Monitoring Reports		
4.5	Flood Analysis – existing and design conditions		✓
4.5.2	Compliance of structures and creek corridor with flood planning levels		✓
4.5.4	Details of Interim Flood Protection Works		✓
4.6.3	Design Storm Hydrological Modelling of Site - Pre and Post Development	++++++++++	✓
4.6.3	On-Site Detention Facilities		✓
4.6.4	Stormwater Retention Facilities		✓
4.7	Stormwater Concept Drainage Plan	♦♦♦♦♦♦♦♦	✓

KEY:

	Preliminary Calculations/Assessment Required		*Work as Executed Plans*
	Concept Design Required	♦♦♦♦♦♦	*Required/Reviewed/Updated*
+++++++	*Detailed Assessment/Calculations/Design*		*Not required*

Note 1 Even if the works are not to be constructed by the Applicant on the land to be transferred to Council under the Material Public Benefit Option in the Section 94 Plan, preliminary investigation for Rezoning and concept design at DA stage is required

Completed by Principal Certifier:

Name: SAMER EL HADDAD
Title: CIVIL ENGINEER
Organisation: S&G CONSULTANTS PTY LTD

Signature:
Date: 15/09/2017

Warriewood Valley Water Management Specification Page 84
J1887/R1817_v5

Figure A 1.1 Completed DA Checklist

A2 Appendix 2

Rainfall Data

Figure A 2.1IFD Chart (Northern Beaches Council – Pittwater)

Figure A 2.2IFD Table (Northern Beaches Council – Pittwater)

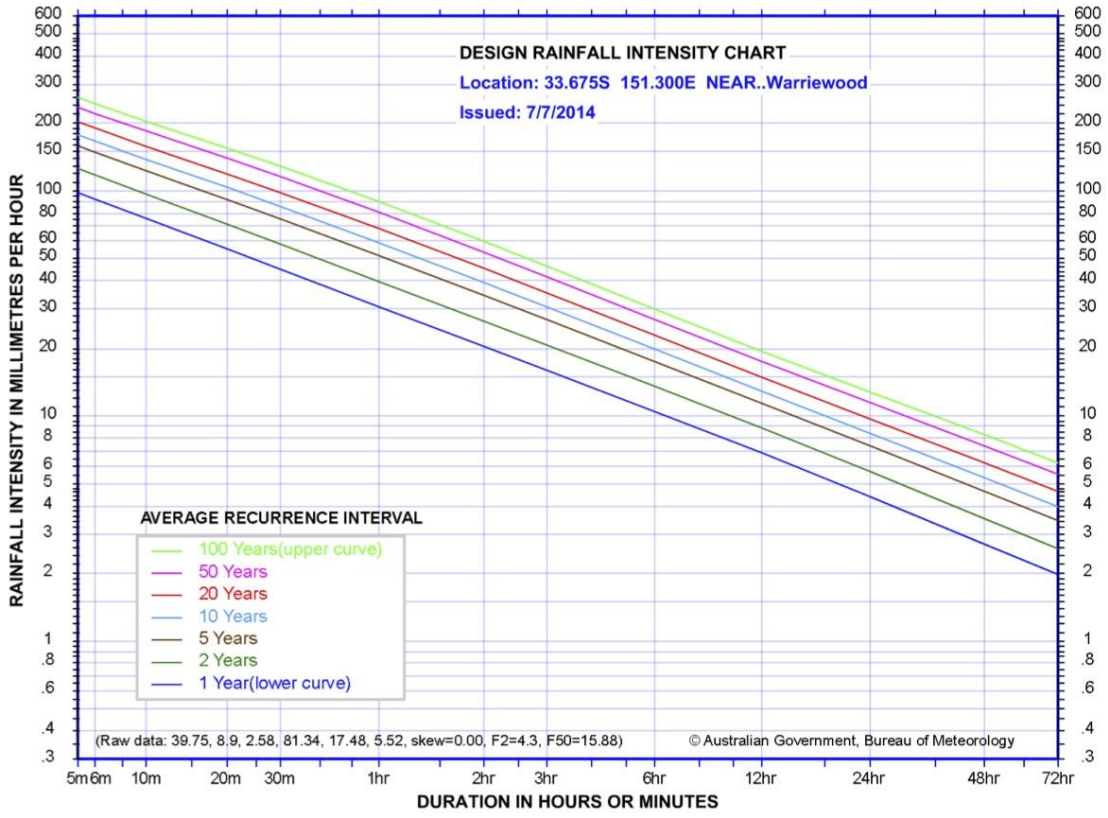


Figure A 2.1 IFD Chart (Northern Beaches Council – Pittwater)

Intensity-Frequency-Duration Table

Location: 33.675S 151.300E NEAR.. Warriewood Issued: 7/7/2014

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	98.5	126	159	178	203	236	261
6Mins	92.2	118	149	167	191	221	245
10Mins	75.6	96.9	123	138	158	185	204
20Mins	55.3	71.2	91.6	104	119	140	155
30Mins	44.9	58.1	75.2	85.3	98.4	116	129
1Hr	30.6	39.6	51.7	58.9	68.2	80.5	89.8
2Hrs	20.4	26.4	34.4	39.2	45.4	53.5	59.8
3Hrs	16.0	20.7	26.9	30.6	35.3	41.6	46.4
6Hrs	10.5	13.6	17.5	19.9	22.9	26.9	29.9
12Hrs	6.87	8.86	11.4	12.9	14.9	17.5	19.4
24Hrs	4.39	5.68	7.39	8.40	9.72	11.5	12.8
48Hrs	2.70	3.51	4.64	5.33	6.21	7.38	8.28
72Hrs	1.98	2.58	3.44	3.96	4.63	5.52	6.20

(Raw data: 39.75, 8.9, 2.58, 81.34, 17.48, 5.52, skew=0.00, F2=4.3, F50=15.88)

Figure A 2.2 IFD Table (Northern Beaches Council – Pittwater)

A3 Appendix 3

Pre vs Post Outflow Hydrographs

Figure A 3.1 Catchment 1 – 1% AEP-30mins
Figure A 3.2 Catchment 1 – 1% AEP-60mins
Figure A 3.3 Catchment 1 – 1% AEP-120mins
Figure A 3.4 Catchment 1 – 1% AEP-180mins
Figure A 3.5 Catchment 1 – 1% AEP-360mins
Figure A 3.6 Catchment 2 – 1% AEP-30mins
Figure A 3.7 Catchment 2 – 1% AEP-60mins
Figure A 3.8 Catchment 2 – 1% AEP-120mins
Figure A 3.9 Catchment 2 – 1% AEP-180mins
Figure A 3.10 Catchment 2 – 1% AEP-360mins

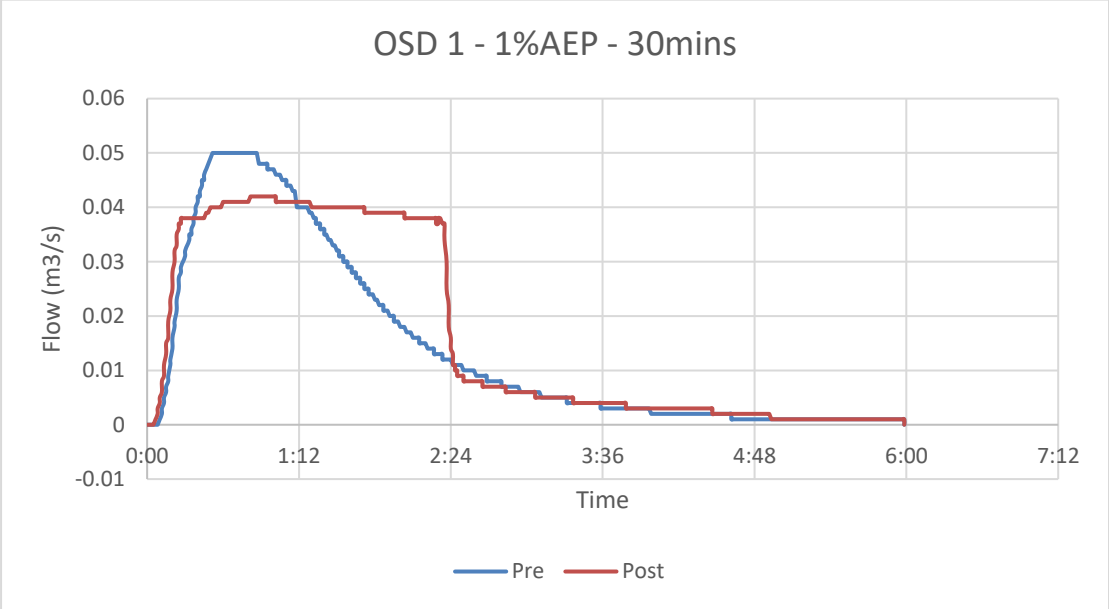


Figure A 3.1 Catchment 1 – 1% AEP-30mins

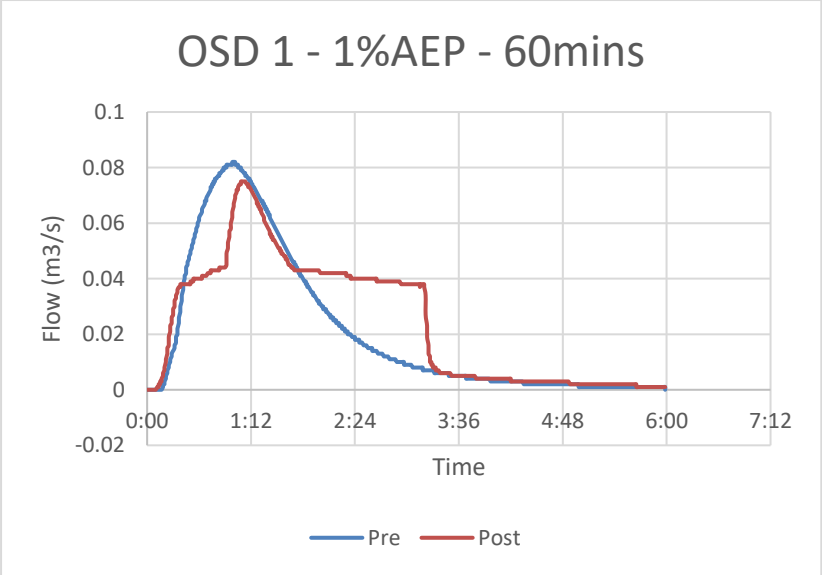


Figure A 3.2 Catchment 1 – 1% AEP-60mins

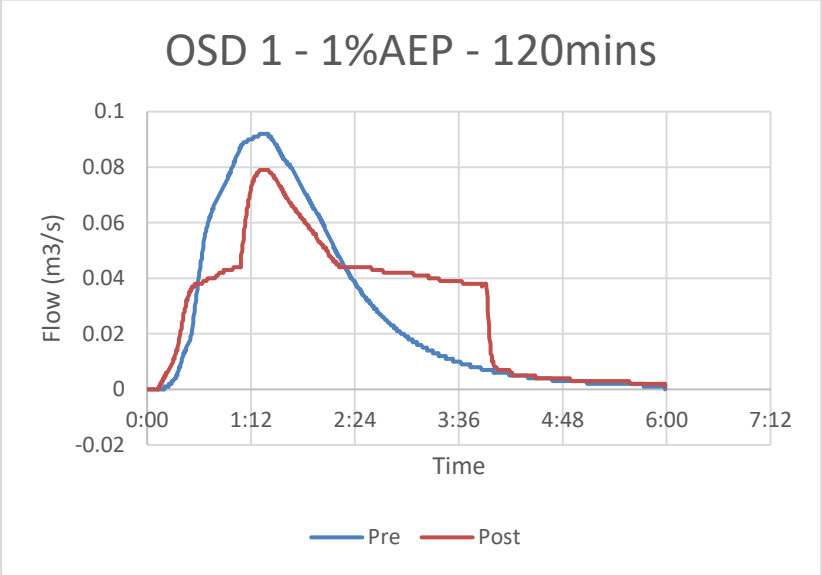


Figure A 3.3 Catchment 1 – 1% AEP-120mins

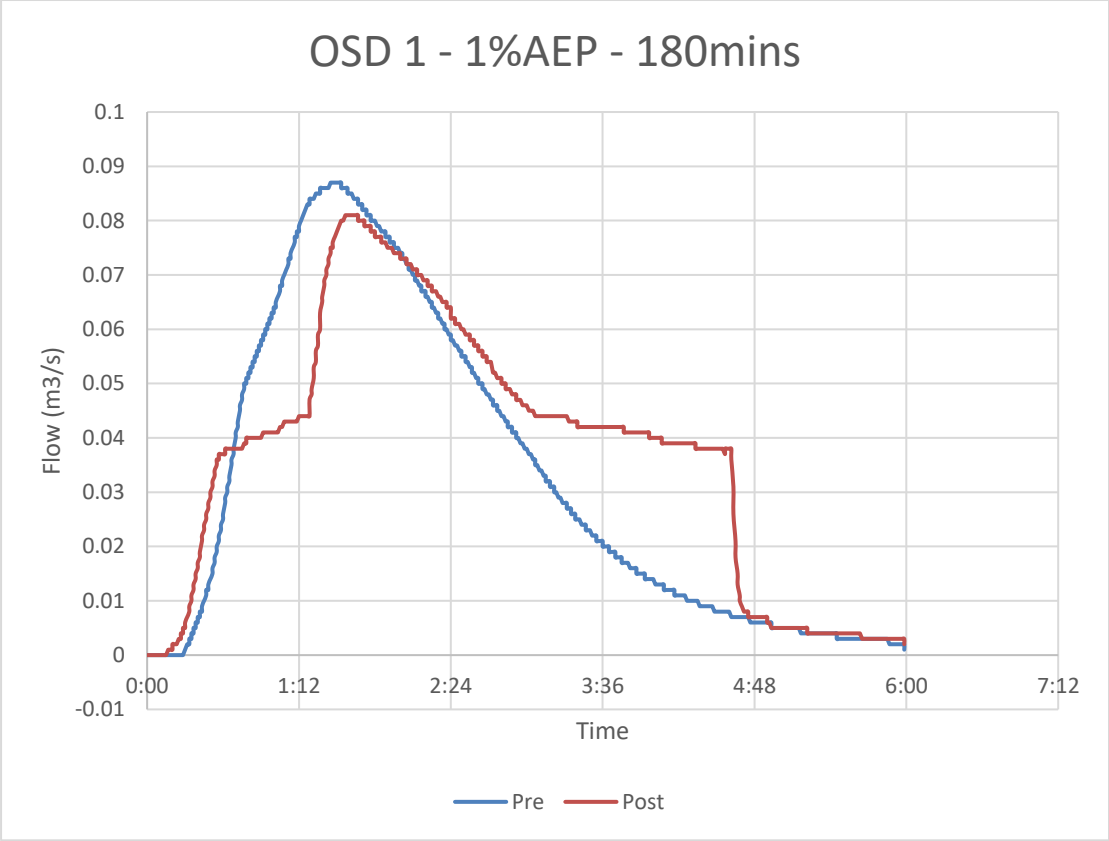


Figure A 3.4 Catchment 1 – 1% AEP-180mins

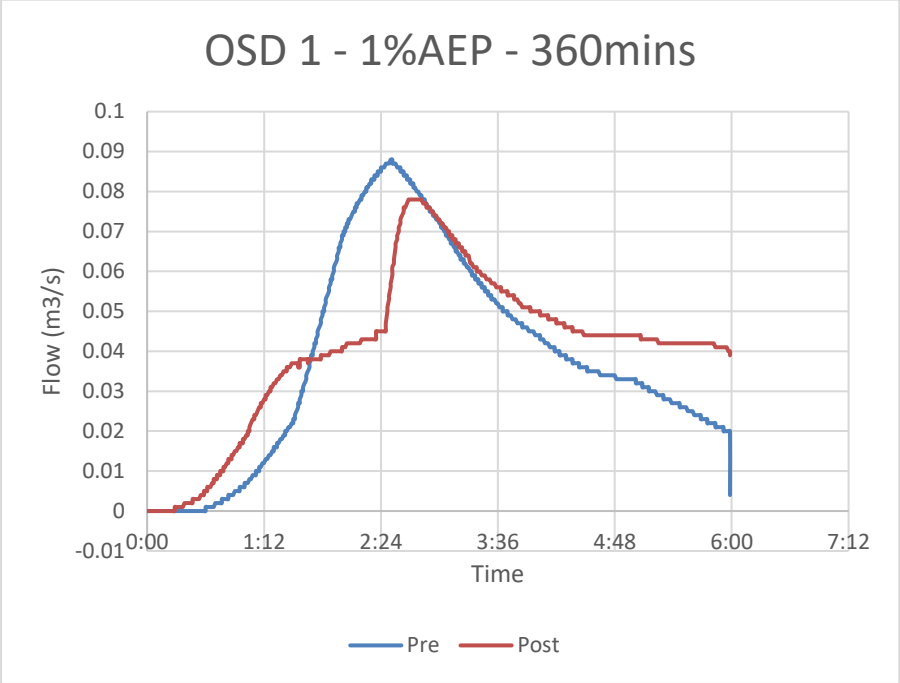


Figure A 3.5 Catchment 1 – 1% AEP-360mins

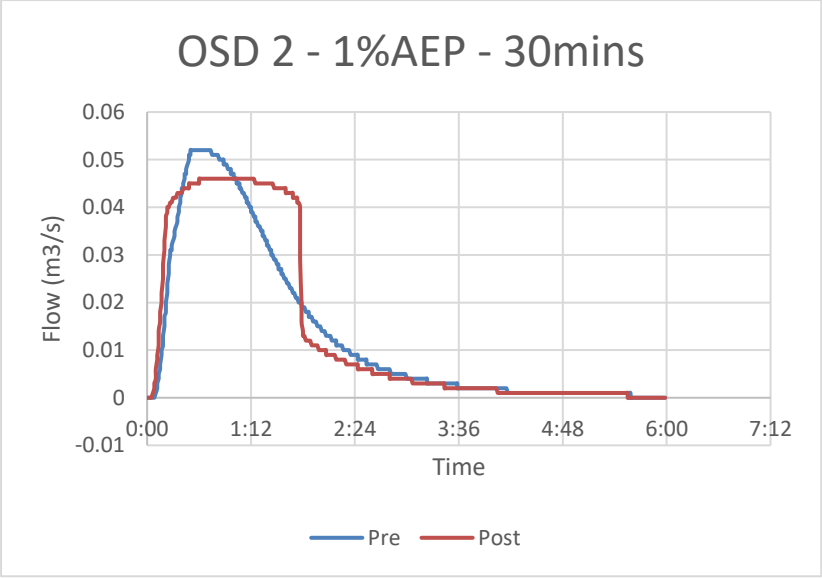


Figure A 3.6 Catchment 2 – 1% AEP-30mins

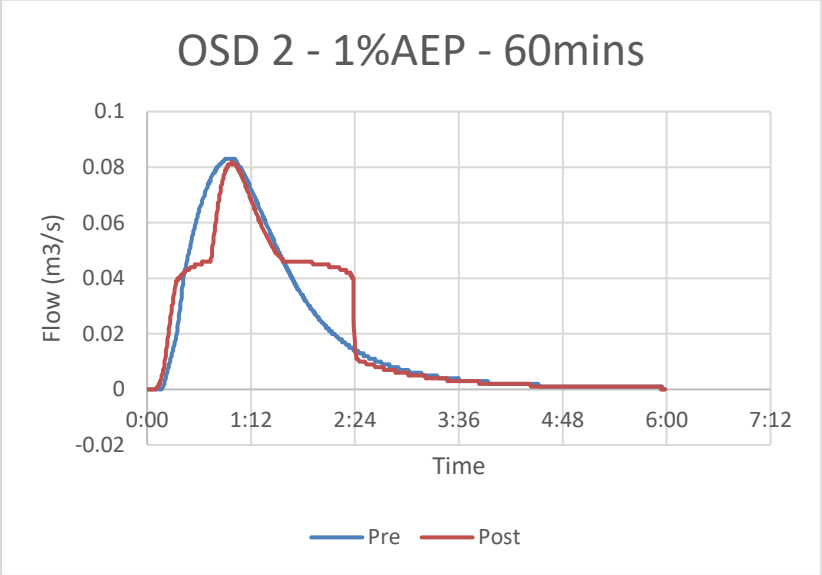


Figure A 3.7 Catchment 2 – 1% AEP-60mins

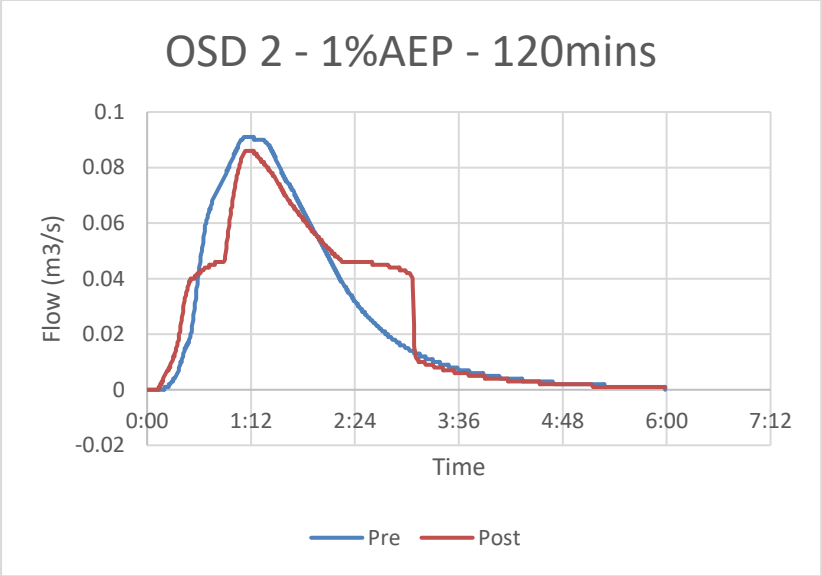


Figure A 3.8 Catchment 2 – 1% AEP-120mins

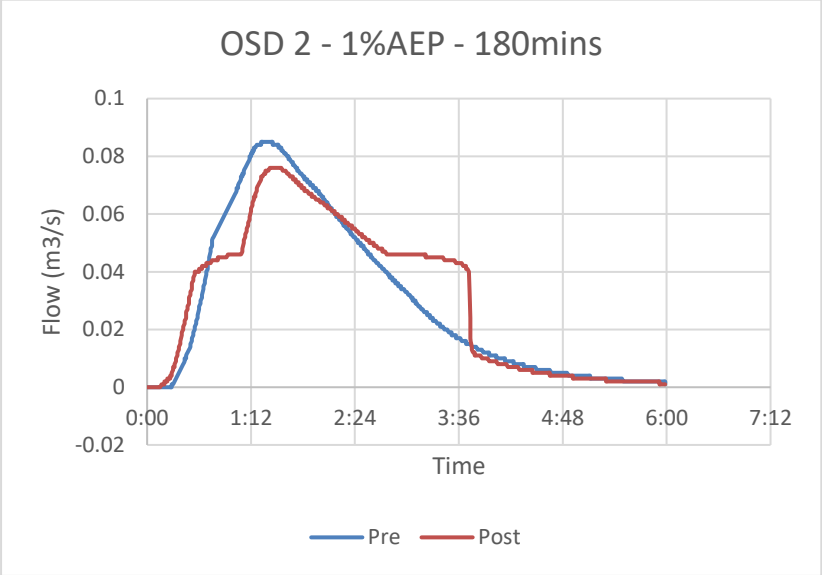


Figure A 3.9 Catchment 2 – 1% AEP-180mins

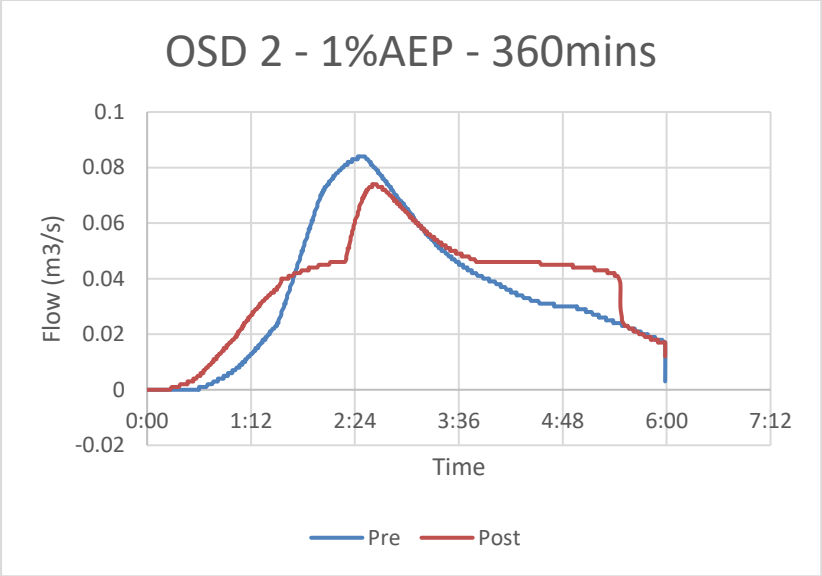


Figure A 3.10 Catchment 2 – 1% AEP-360mins

A4 Appendix 4

Flood Mapping

Figure A 4.1 Study Area

Figure A 4.2 2-yr ARI Depth & Level – Existing Site Conditions

Figure A 4.3 5-yr ARI Depth & Level – Existing Site Conditions

Figure A 4.4 10-yr ARI Depth & Level – Existing Site Conditions

Figure A 4.5 20-yr ARI + CC Depth & Level – Existing Site Conditions

Figure A 4.6 50-yr ARI Depth & Level – Existing Site Conditions

Figure A 4.7 100-yr ARI + CC Depth & Level – Existing Site Conditions

Figure A 4.8 PMF Depth & Level – Existing Site Conditions

Figure A 4.9 100-yr ARI + CC Hazard – Existing Site Conditions

Figure A 4.10 20-yr ARI + CC Depth & Level – Proposed Site Conditions

Figure A 4.11 100-yr ARI + CC Depth & Level – Proposed Site Conditions

Figure A 4.12 PMF Depth & Level – Proposed Site Conditions

Figure A 4.13 100-yr ARI + CC Hazard – Proposed Site Conditions

Figure A 4.14 100-yr ARI + CC Flood Impact Map

Figure A 4.15 PMF Flood Impact Map – Levels

Figure A 4.16 PMF Flood Impact Map – Velocity

Figure A 4.1 Study Area

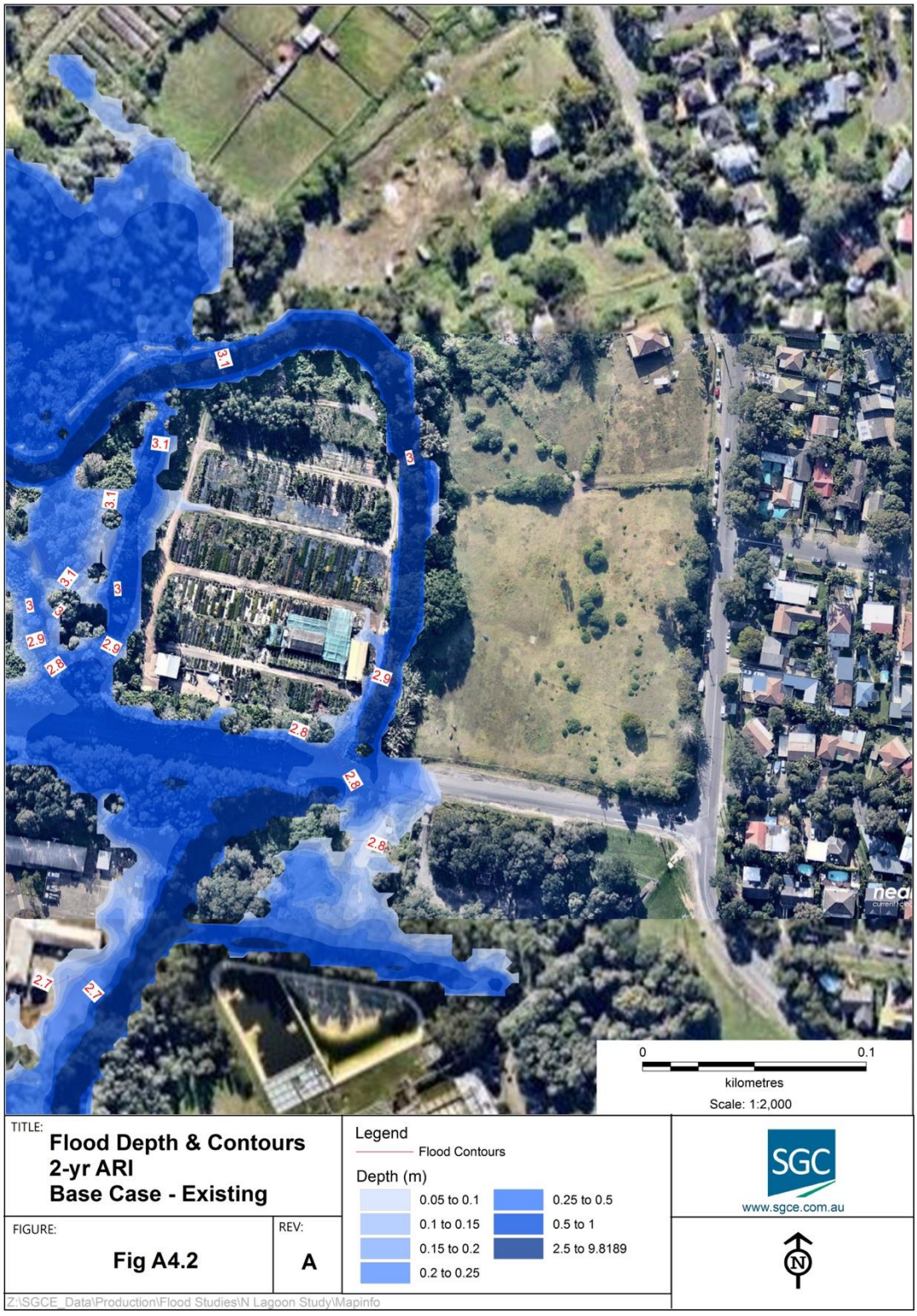


Figure A 4.2 2-yr ARI Depth & Level – Existing Site Conditions

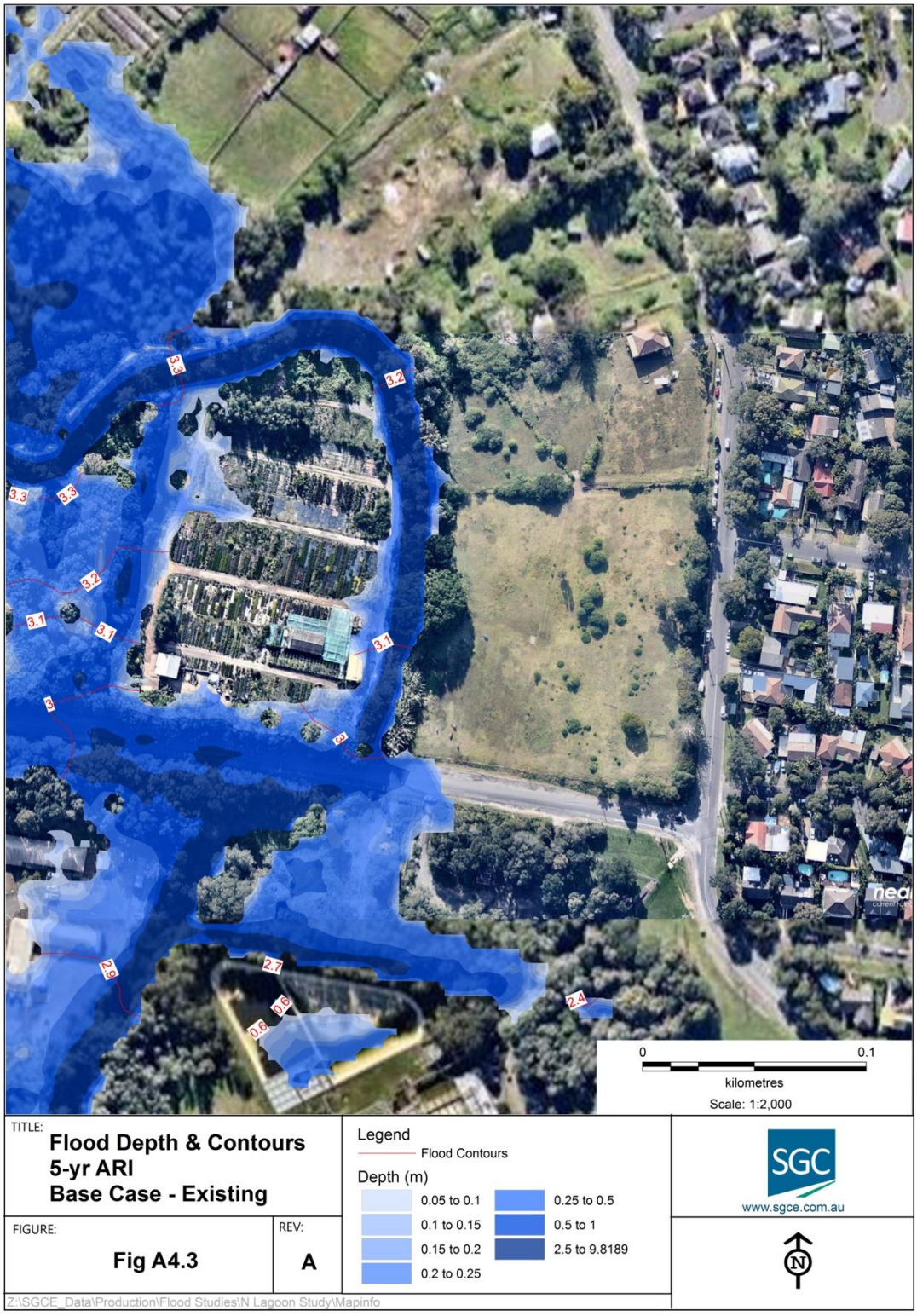


Figure A 4.3 5-yr ARI Depth & Level – Existing Site Conditions

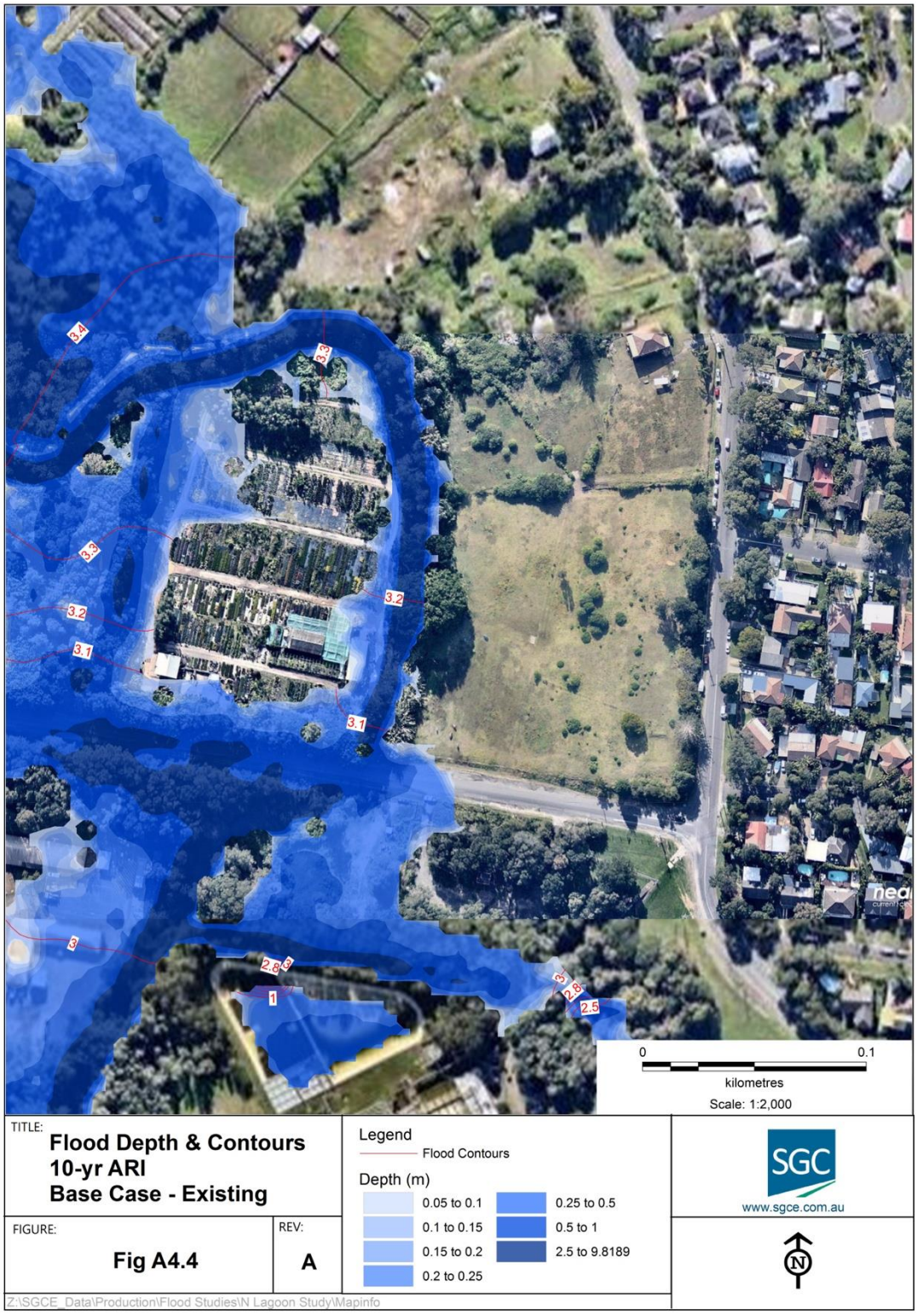


Figure A 4.4 10-yr ARI Depth & Level – Existing Site Conditions

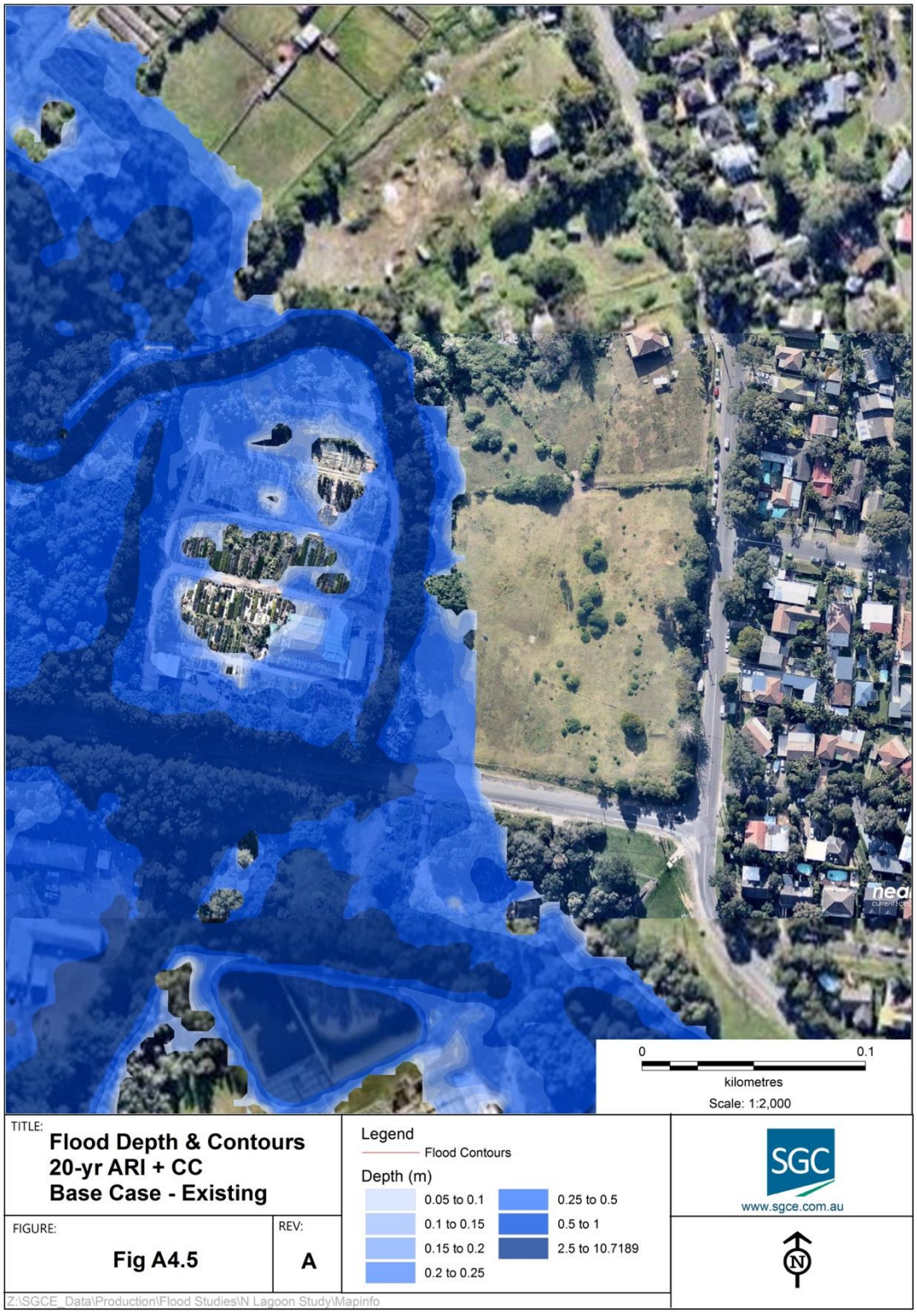

0
0.1
kilometres
Scale: 1:2,000
TITLE:
Flood Depth & Contours
20-yr ARI + CC
Base Case - Existing
FIGURE:
Fig A4.5
REV:
A
Legend
Flood Contours
Depth (m)
0.05 to 0.1
0.1 to 0.15
0.15 to 0.2
0.2 to 0.25
0.25 to 0.5
0.5 to 1
2.5 to 10.7189
SGC
www.sgce.com.au
N
Z:\SGCE_Data\Production\Flood Studies\N Lagoon Study\Mapinfo

Figure A 4.5 20-yr ARI + CC Depth & Level – Existing Site Conditions

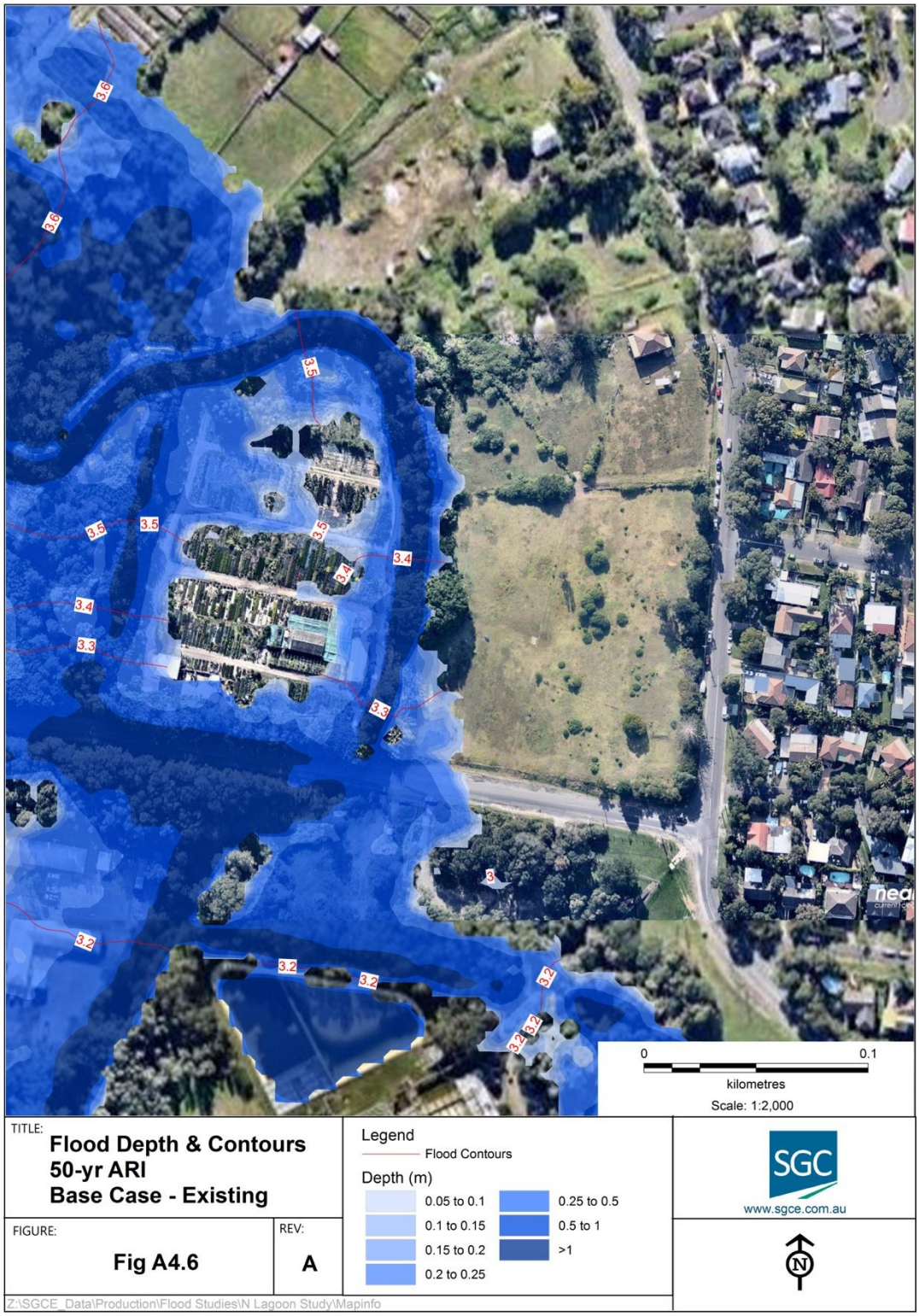


Figure A 4.6 50-yr ARI Depth & Level – Existing Site Conditions

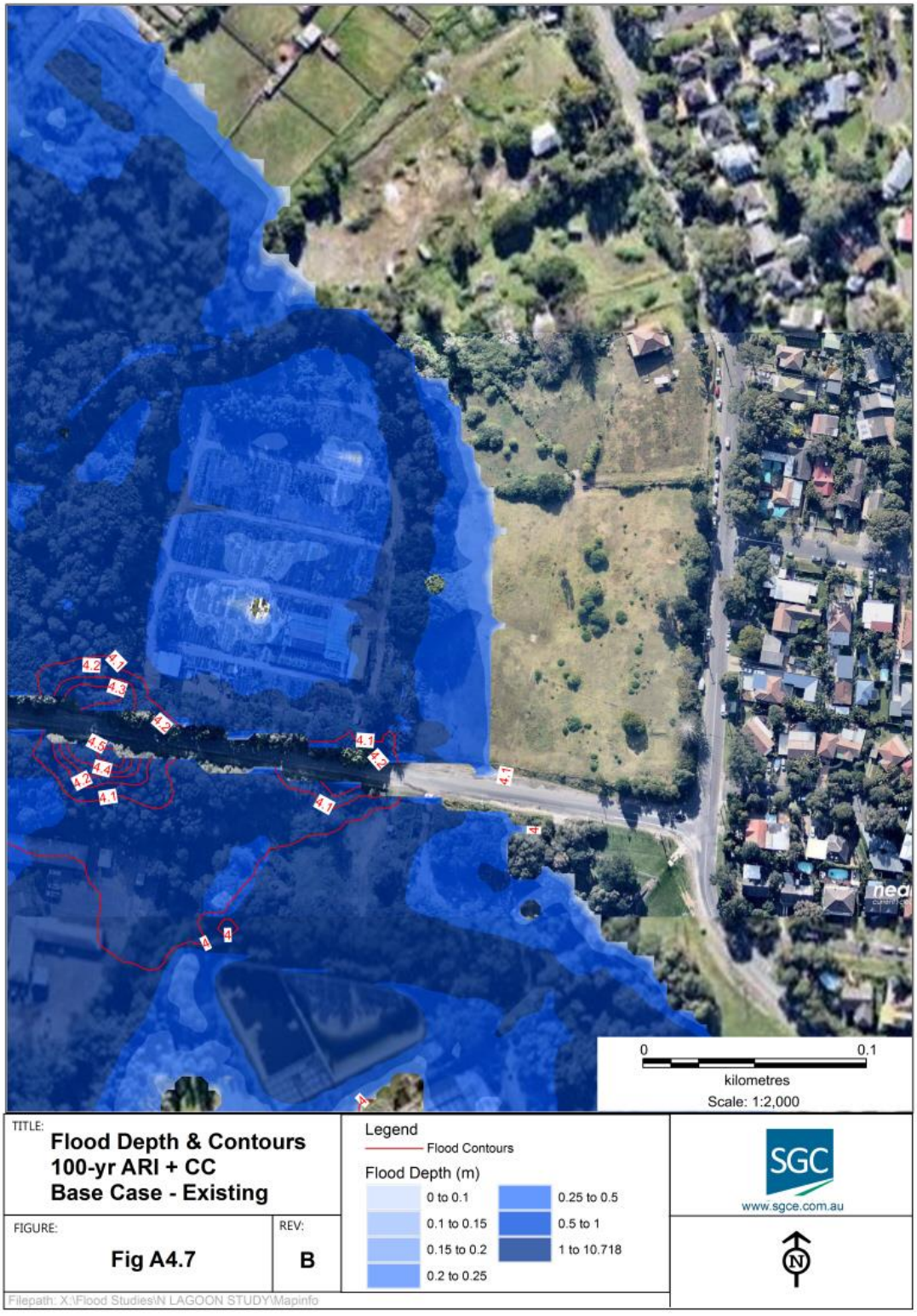


Figure A 4.7 100-yr ARI + CC Depth & Level – Existing Site Conditions

Figure A 4.8 PMF Depth & Level – Existing Site Conditions

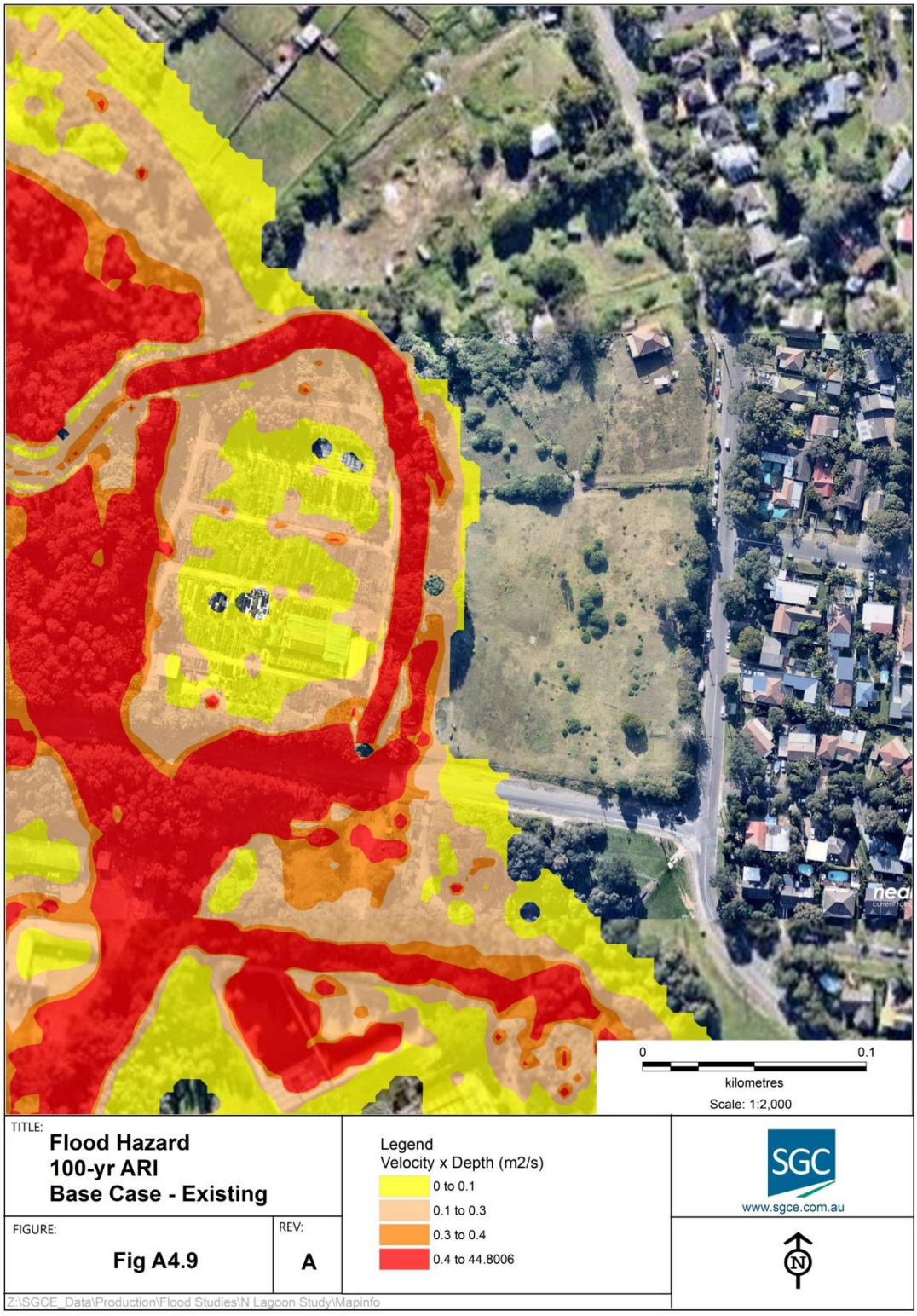


Figure A 4.9 100-yr ARI + CC Hazard – Existing Site Conditions

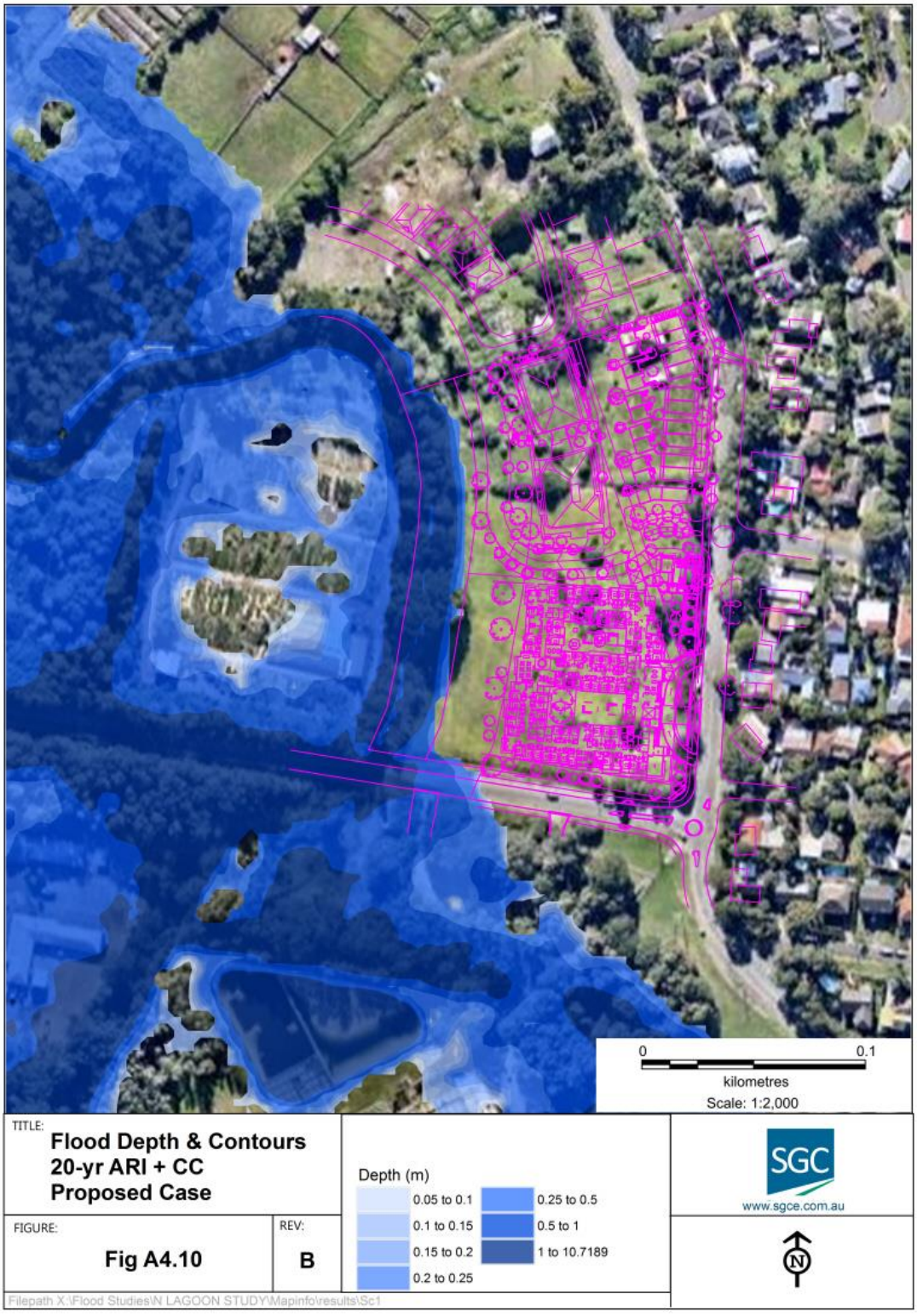


Figure A 4.10 20-yr ARI + CC Depth & Level – Proposed Site Conditions

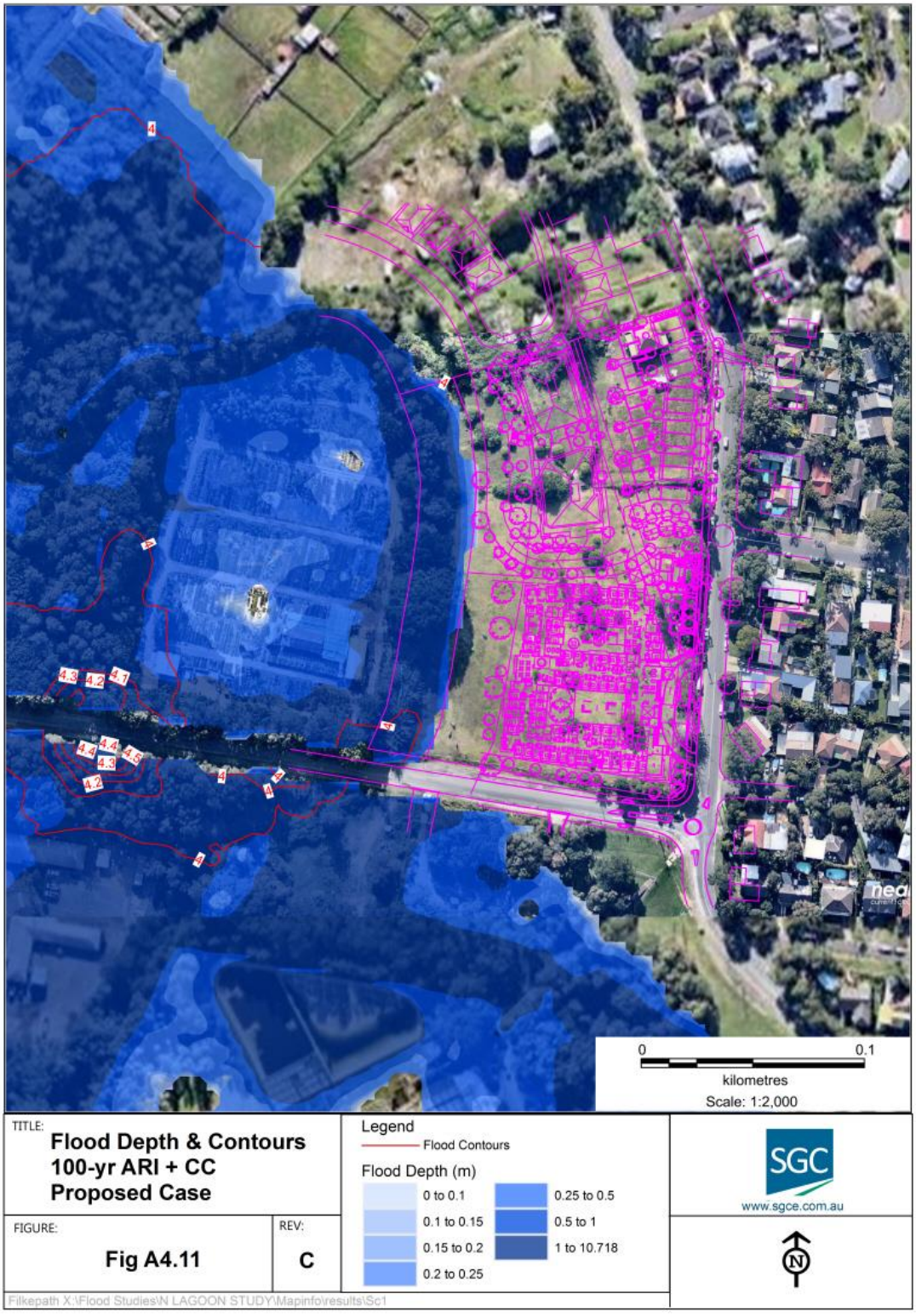


Figure A 4.11 100-yr ARI + CC Depth & Level – Proposed Site Conditions

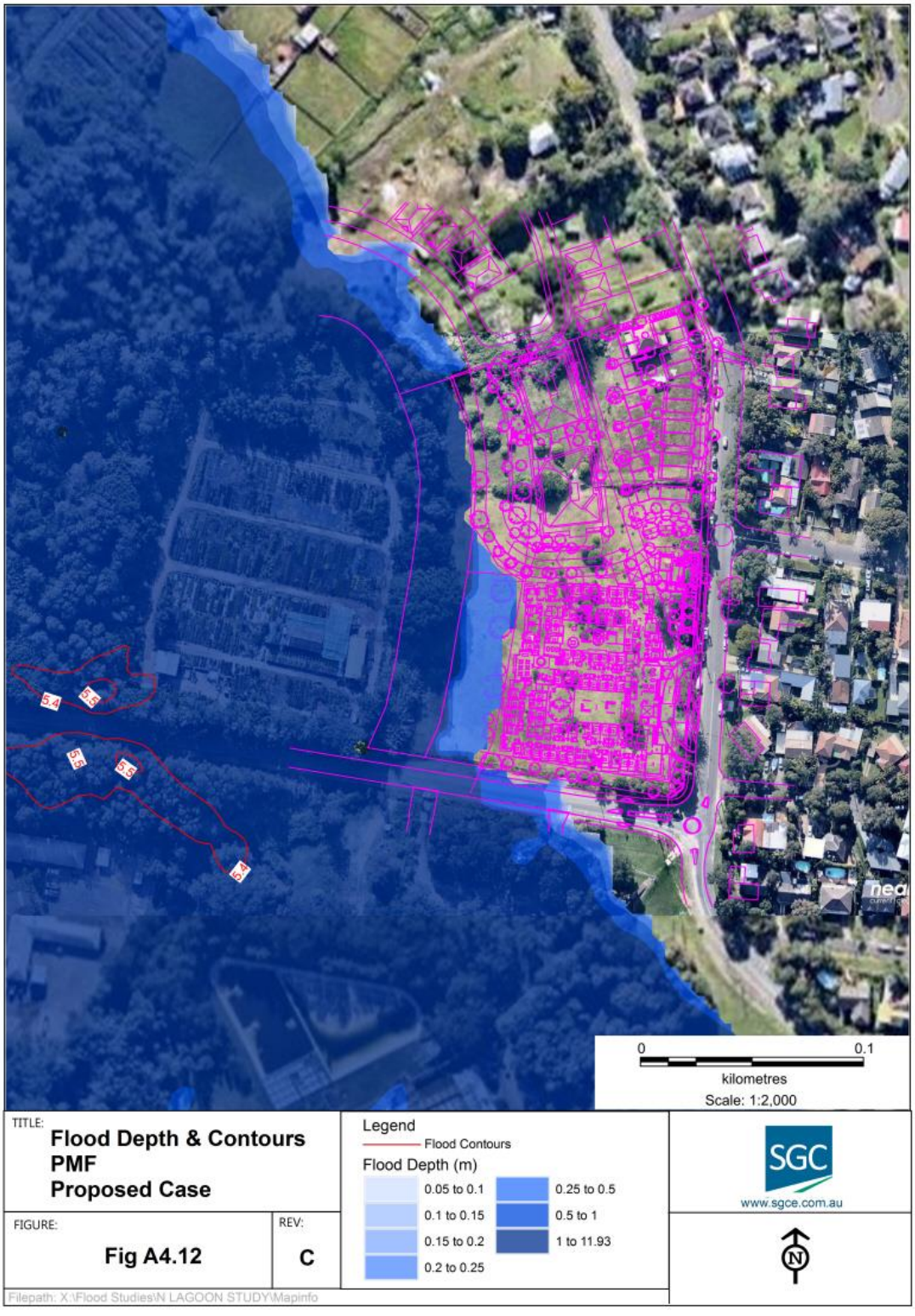


Figure A 4.12 PMF Depth & Level – Proposed Site Conditions

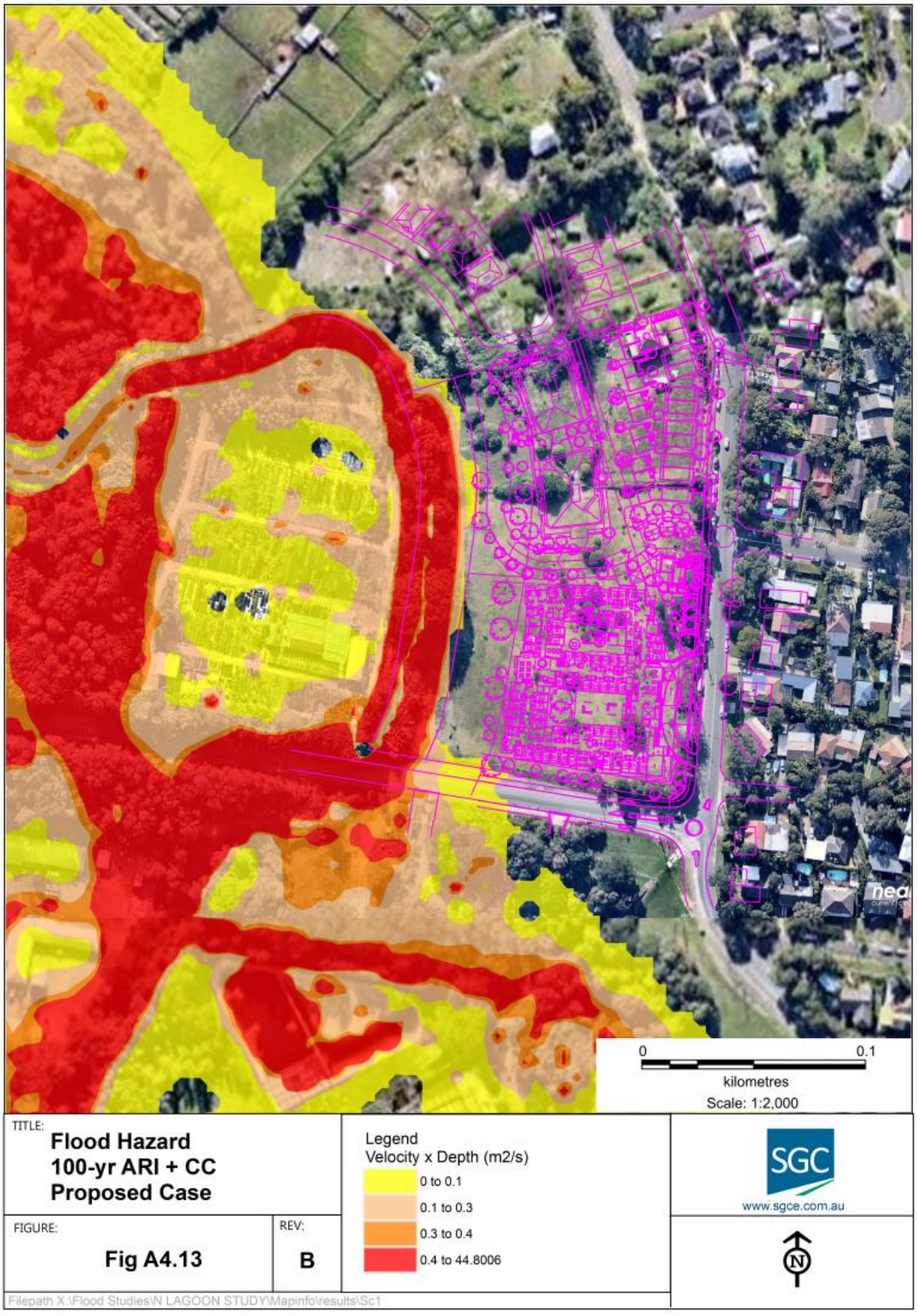


Figure A 4.13 100-yr ARI + CC Hazard – Proposed Site Conditions

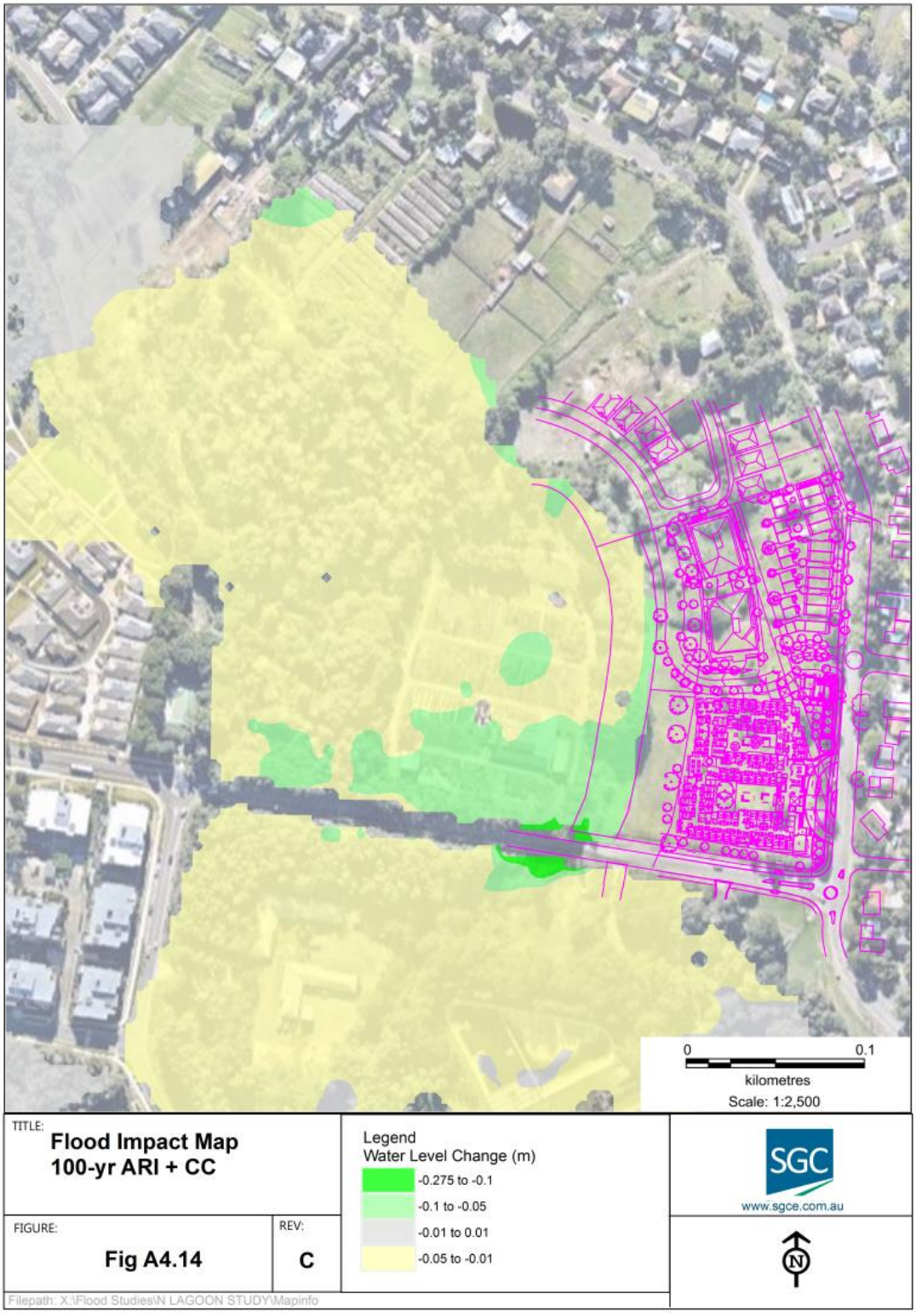


Figure A 4.14 100-yr ARI + CC Flood Impact Map – Levels

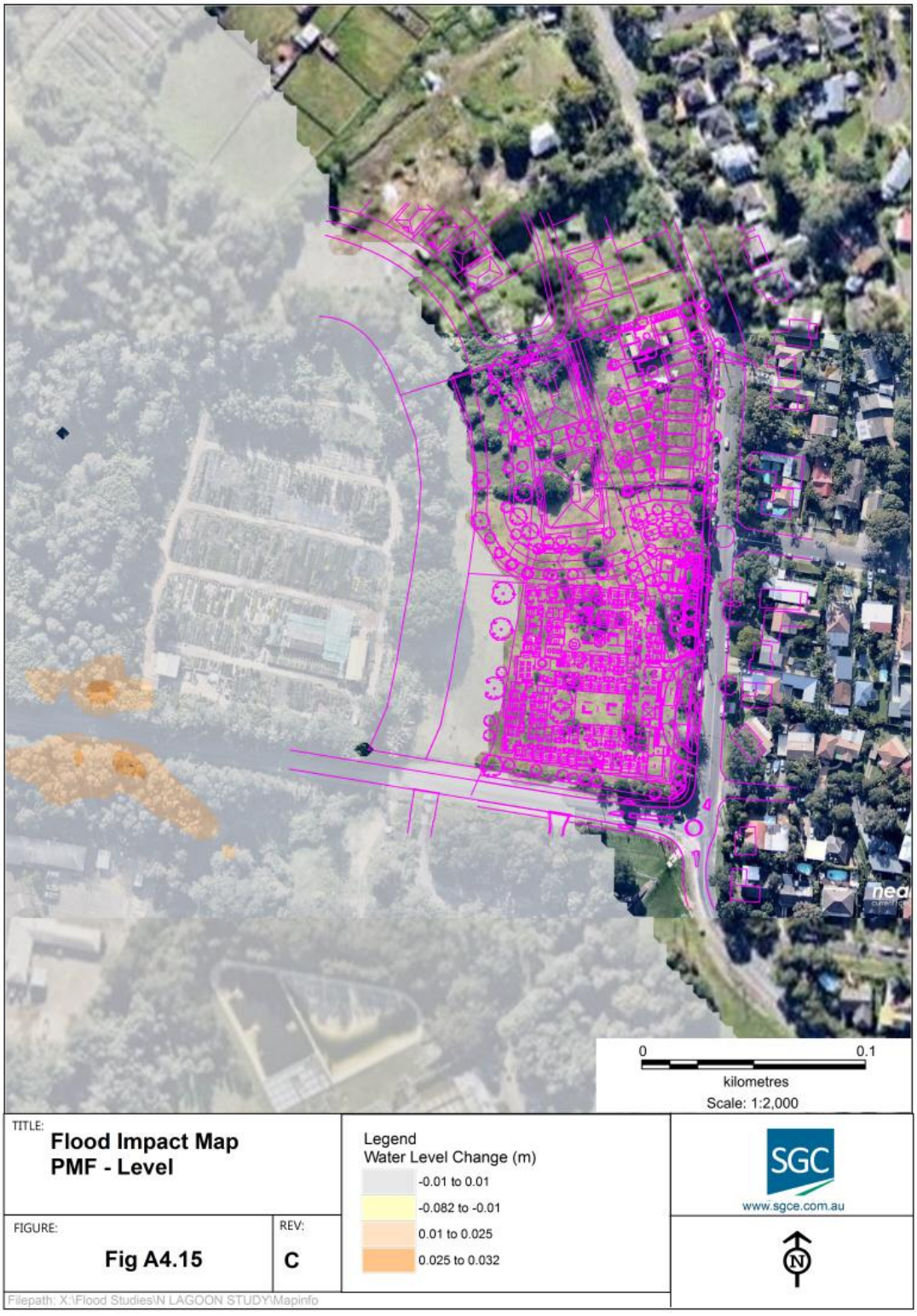


Figure A 4.15 PMF Flood Impact Map – Levels

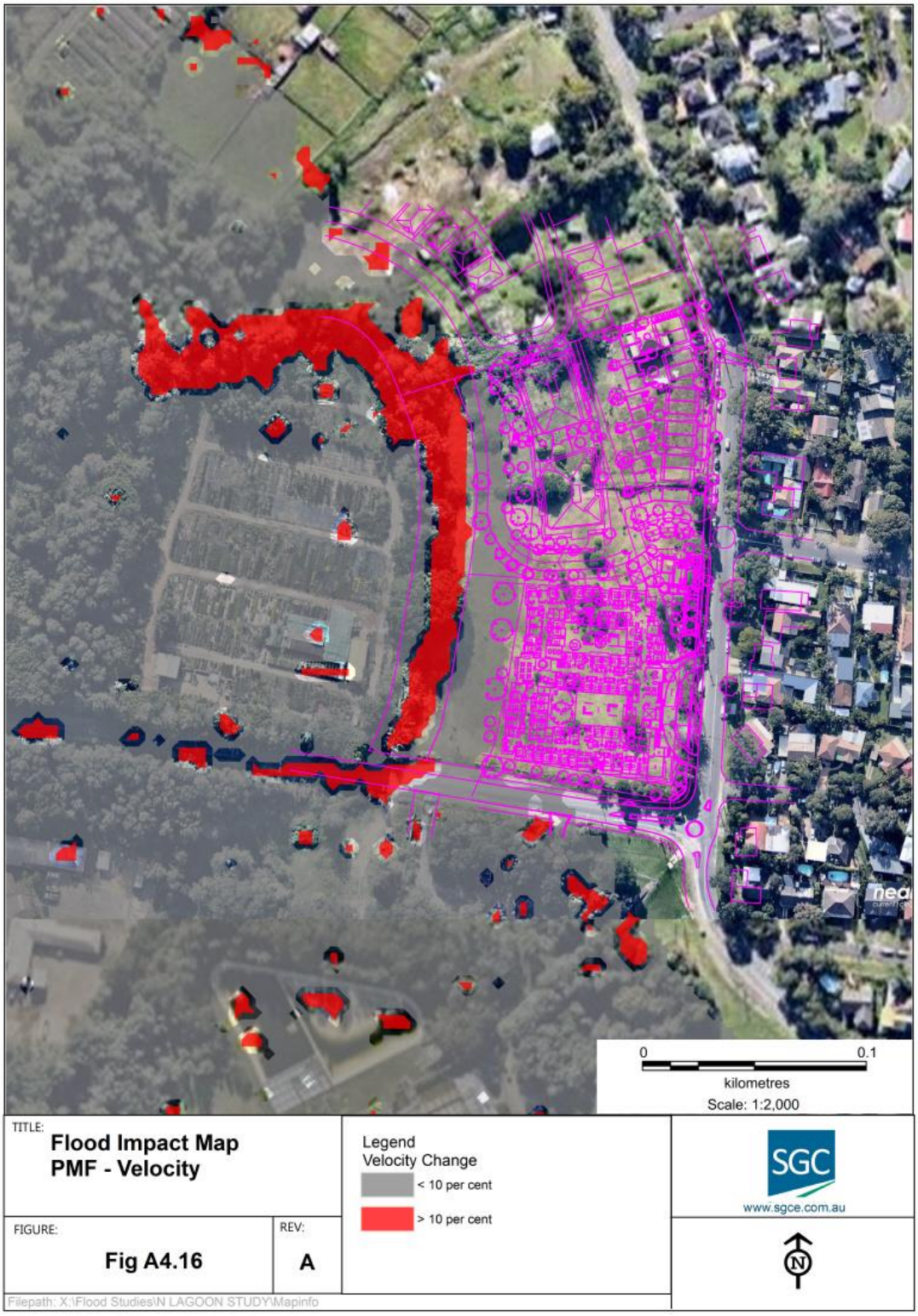


Figure A 4.16 PMF Flood Impact Map – Velocity

A5 Appendix 5

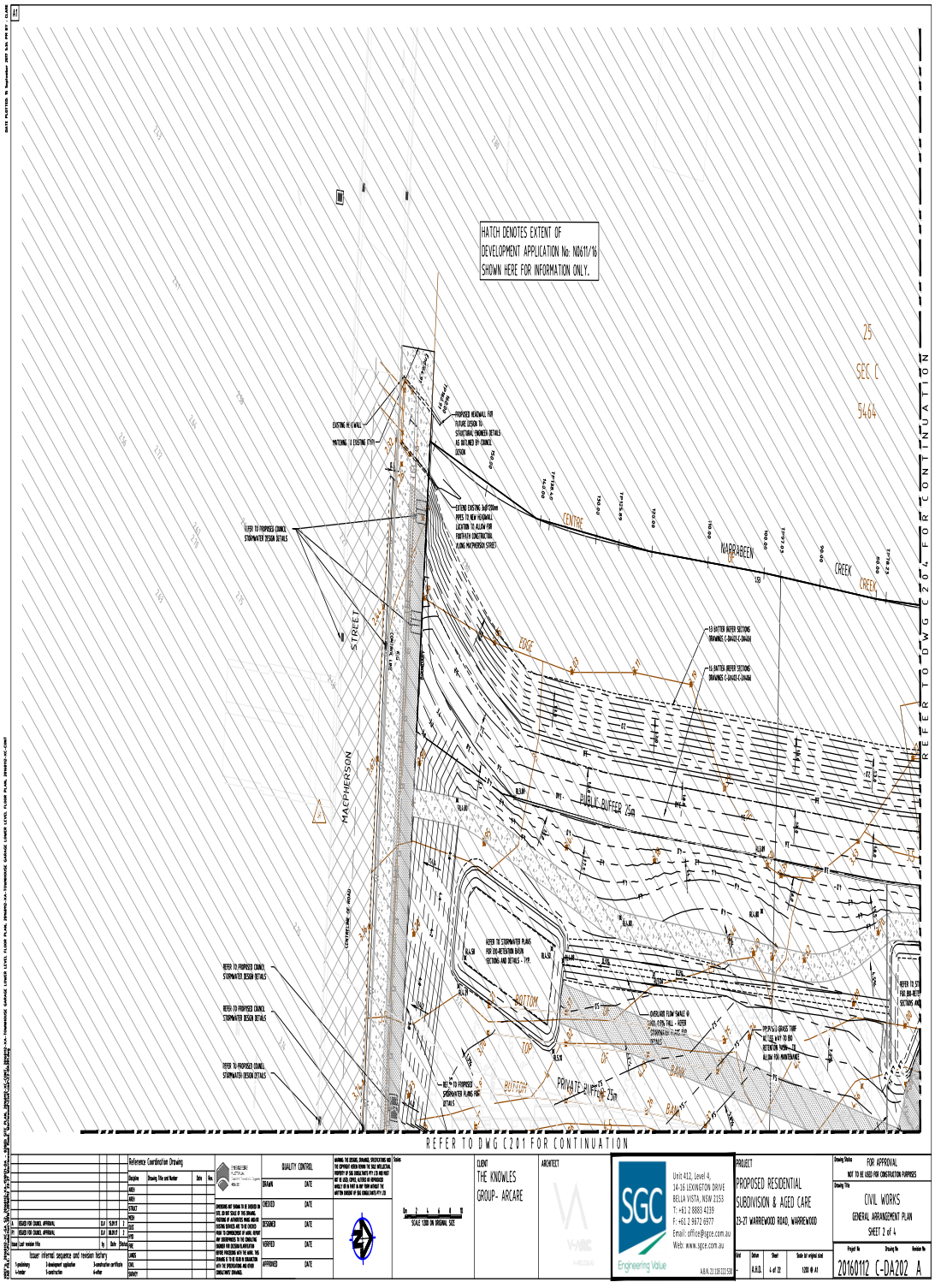
References

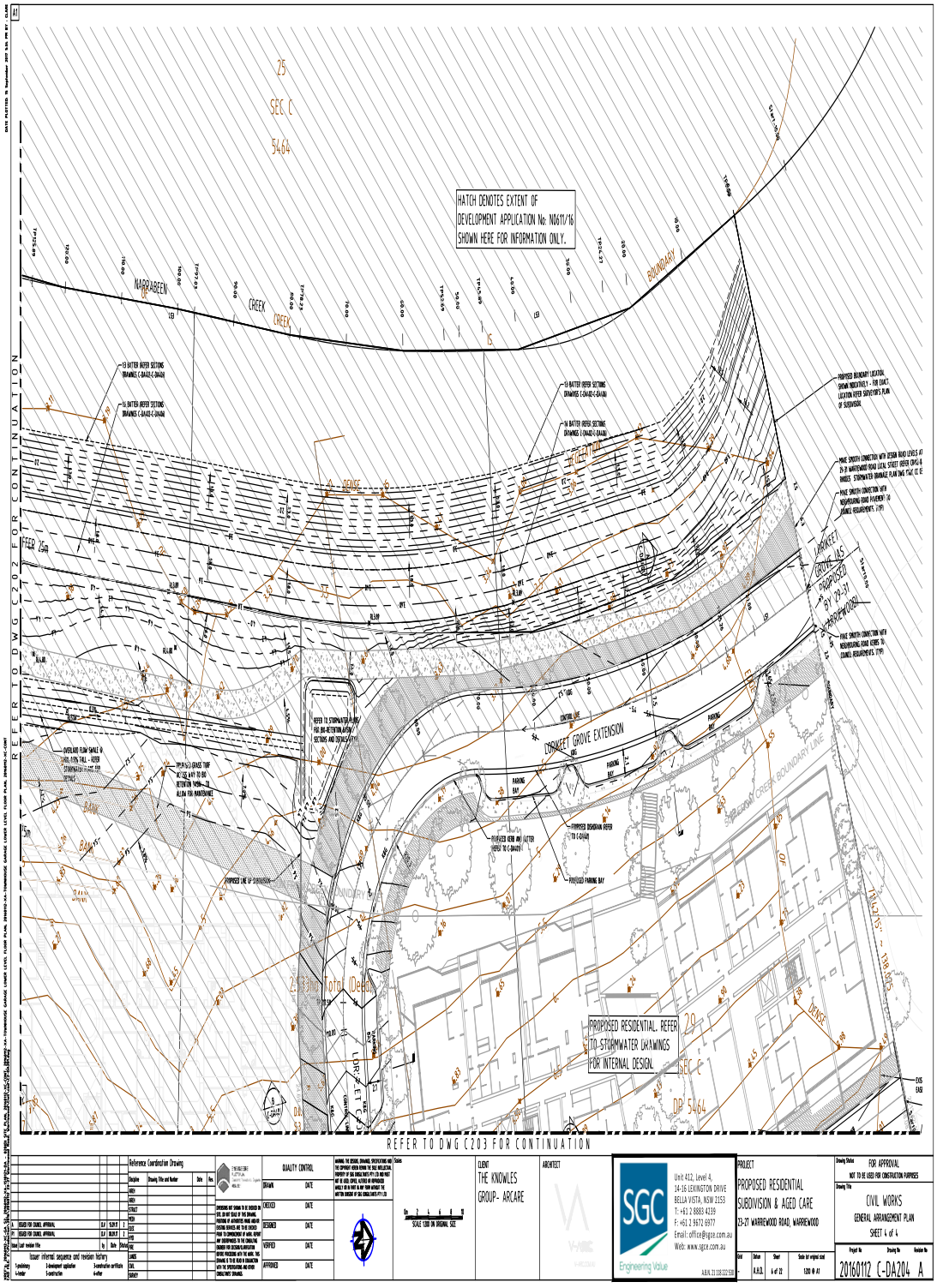
Reference reports by other consultants

1. Vegetation Management Plan by Eco Logical Australia ref. 16SYD:5292; and
2. Water Quality Monitoring Plan/Sites Shown/Data/Assessment & interpretation of water quality monitoring data from SQID's by Marine Pollution Research Pty Ltd.

A6 Appendix 6

Creek Design Drawings

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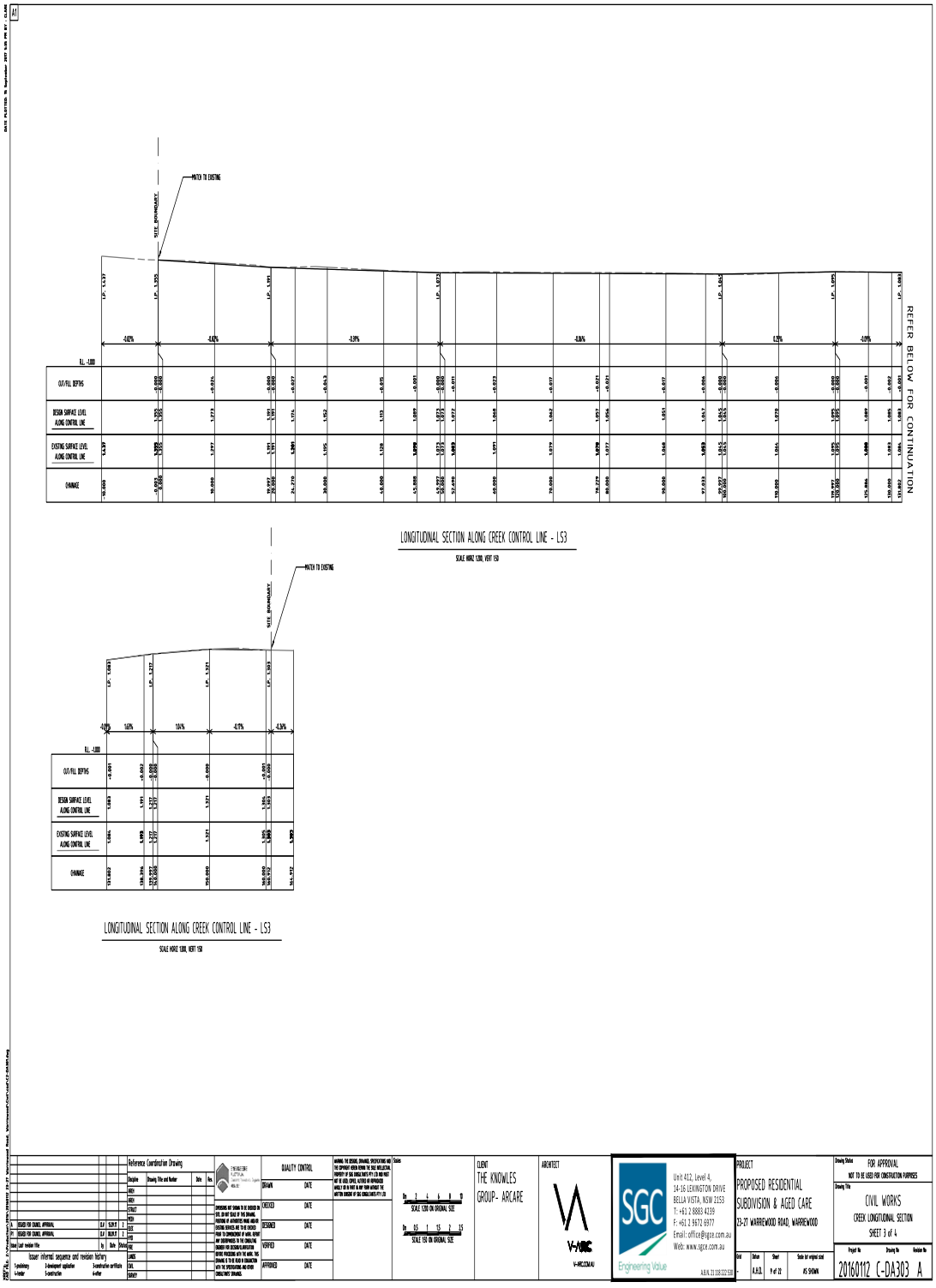
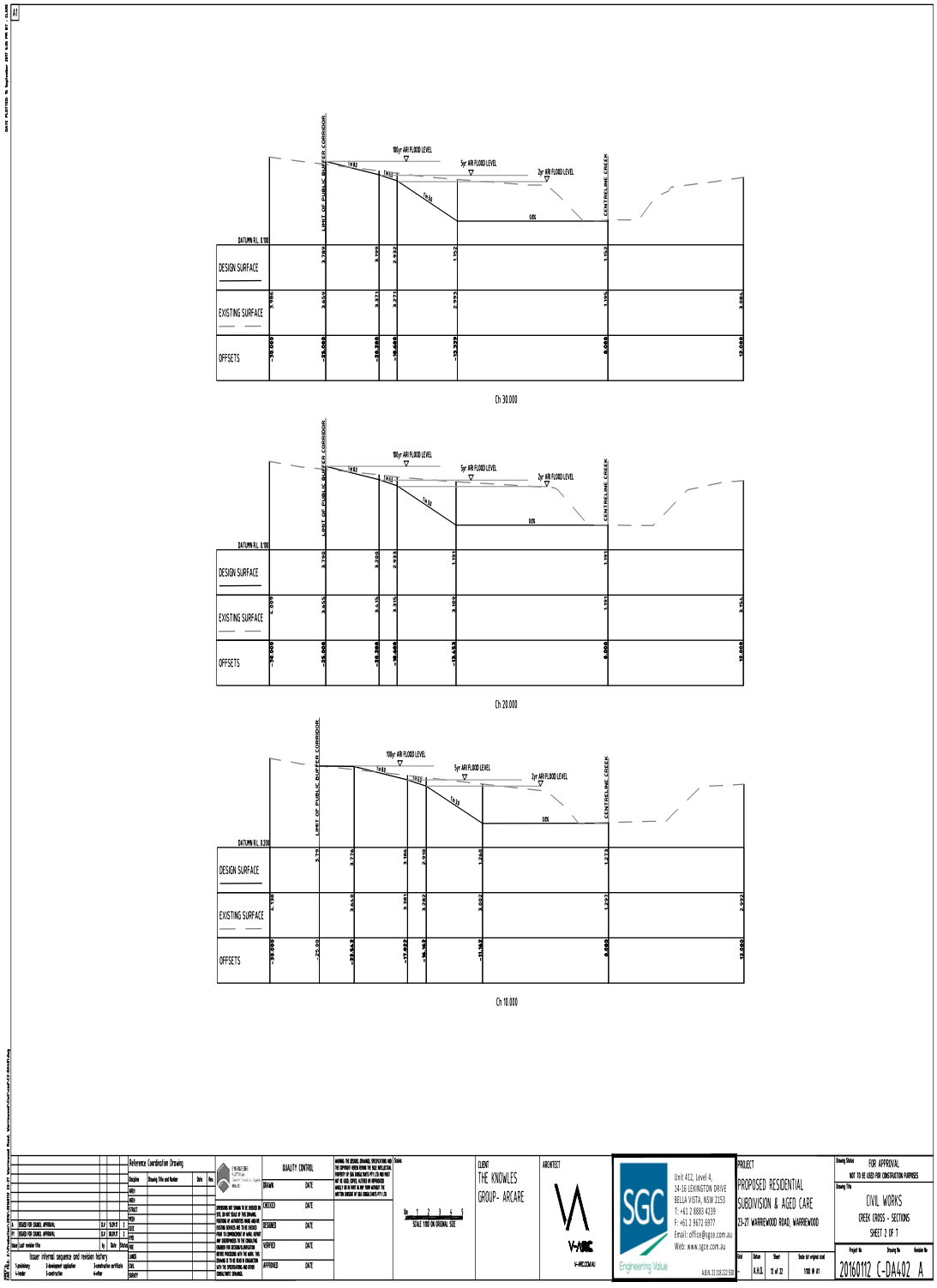
MARRABEEN CREEK
BOUNDARY
CORRIGET GROVE EXTENSION
PROPOSED RESIDENTIAL. REFER TO STORMWATER DRAWINGS FOR INTERNAL DESIGN.
DP 5464
REFER TO DWG C203 FOR CONTINUATION
THE KNOWLES GROUP- ARCARE
PROPOSED RESIDENTIAL SUBDIVISION & AGED CARE
23-27 WARRIEWOOD ROAD, WARRIEWOOD
CIVIL WORKS
GENERAL ARRANGEMENT PLAN
SHEET 4 of 4
20160112 C-DA204 A


MATCH TO EXISTING
SITE BOUNDARY
REFER BELOW FOR CONTINUATION
LONGITUDINAL SECTION ALONG CREEK CONTROL LINE - LS3
SCALE HORIZ 1:200, VERT 1:50
MATCH TO EXISTING
SITE BOUNDARY
LONGITUDINAL SECTION ALONG CREEK CONTROL LINE - LS3
SCALE HORIZ 1:200, VERT 1:50
CLIENT
THE KNOWLES GROUP- ARCARE
ARCHITECT
Unit 412, Level 4,
14-16 LEXINGTON DRIVE
BELLA VISTA, NSW 2153
T: +61 2 8883 4139
F: +61 2 9672 6977
Email: office@sgce.com.au
Web: www.sgce.com.au
PROJECT
PROPOSED RESIDENTIAL SUBDIVISION & AGED CARE
23-27 WARREWOOD ROAD, WARREWOOD
FOR APPROVAL
NOT TO BE USED FOR CONSTRUCTION PURPOSES
CIVIL WORKS
CREEK LONGITUDINAL SECTION
SHEET 3 of 4
20160112 C-DA303 A


100yr ARI FLOOD LEVEL
5yr ARI FLOOD LEVEL
2yr ARI FLOOD LEVEL
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CENTRELINE CREEK
DATUM R.L. 0.000
DESIGN SURFACE
EXISTING SURFACE
OFFSETS
Ch 30.000
Ch 20.000
Ch 10.000
PROPOSED RESIDENTIAL SUBDIVISION & AGED CARE
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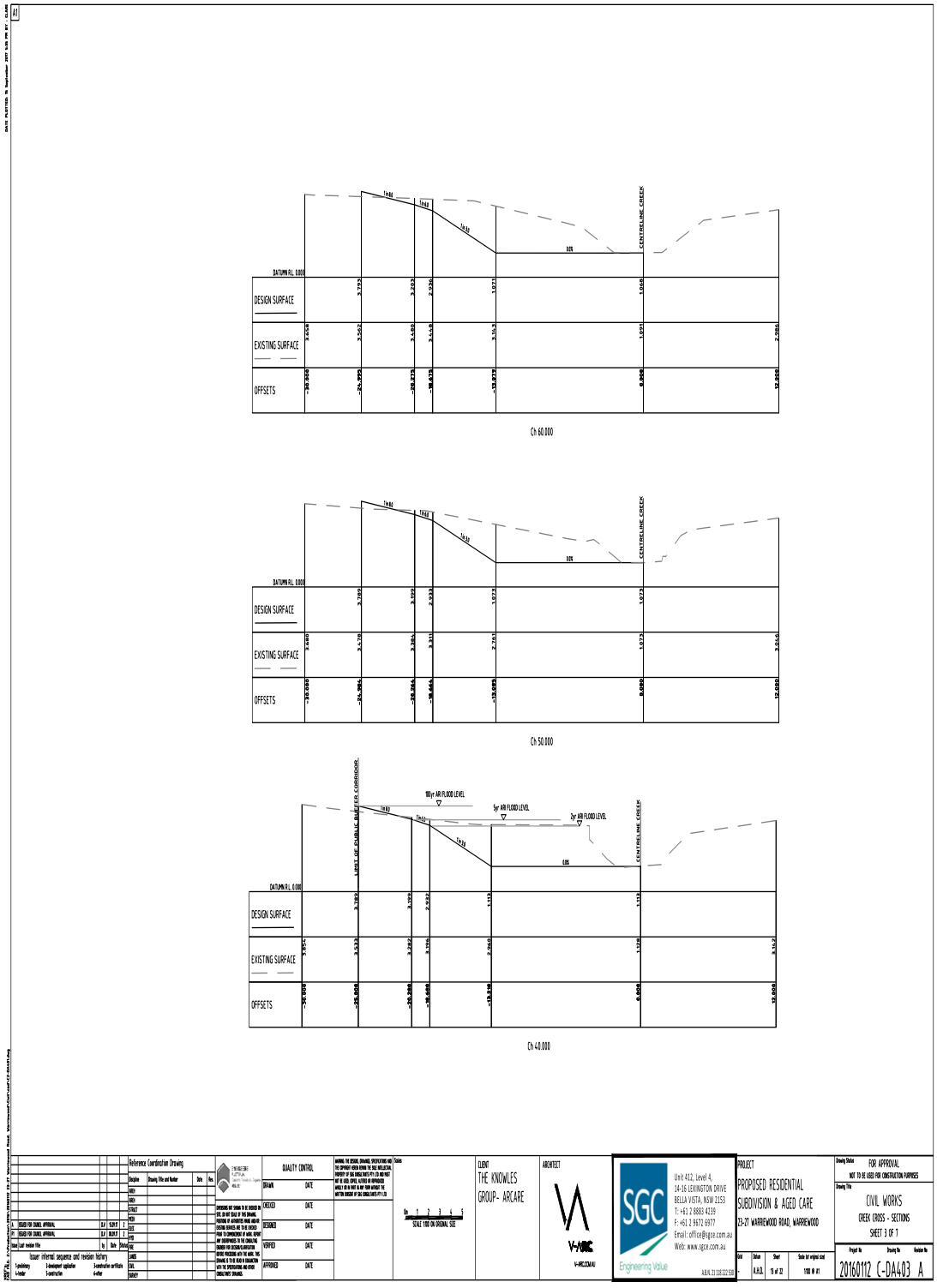
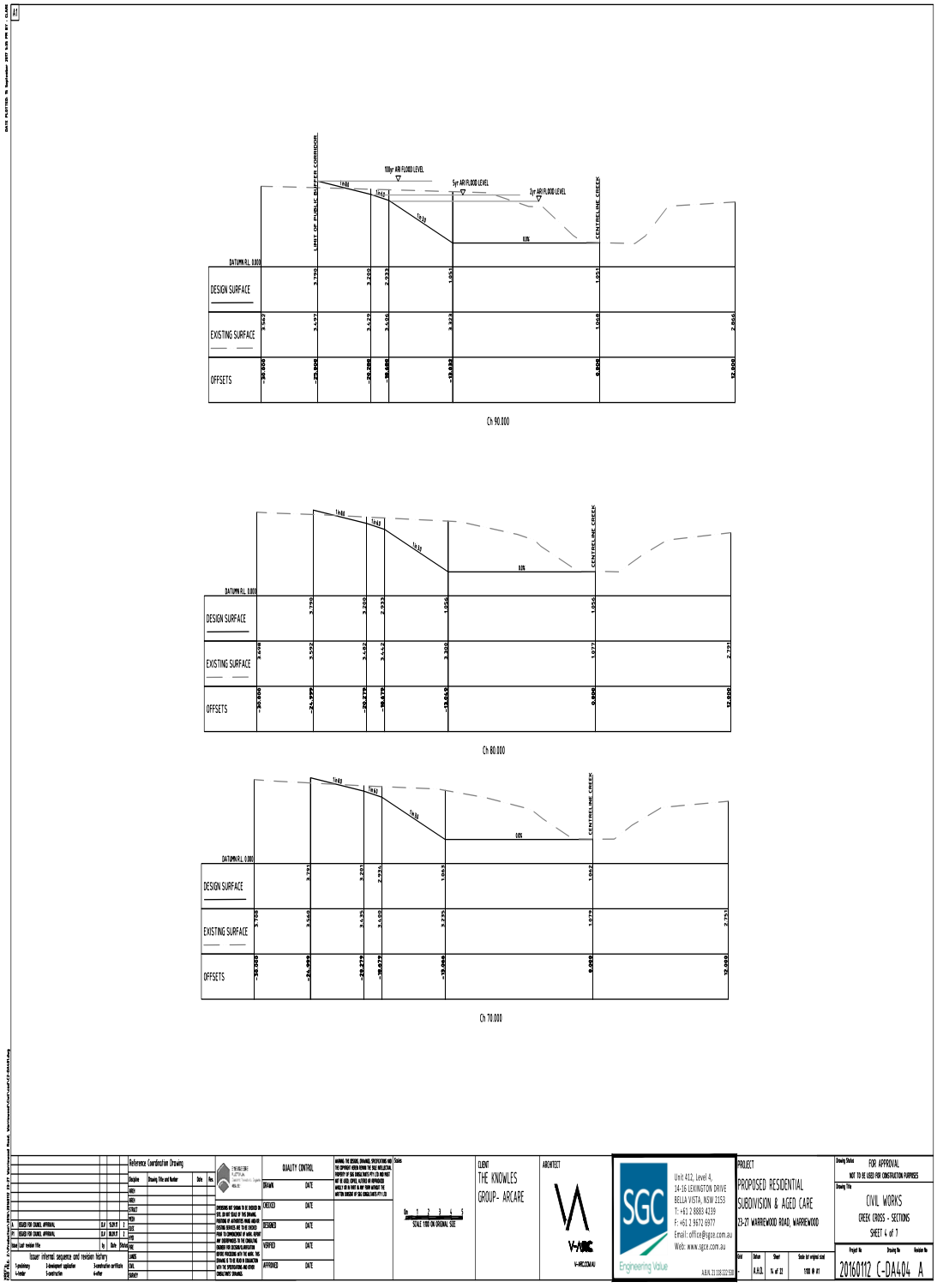
CIVIL WORKS
CREEK CROSS - SECTIONS
SHEET 2 OF 7
20160112 C-DA402 A


DESIGN SURFACE
EXISTING SURFACE
OFFSETS
CENTRELINE CREEK
Ch 60.000
Ch 50.000
100yr ARI FLOOD LEVEL
5yr ARI FLOOD LEVEL
2yr ARI FLOOD LEVEL
Ch 40.000
THE KNOWLES GROUP- ARCARE
PROPOSED RESIDENTIAL SUBDIVISION & AGED CARE
23-27 WARREWOOD ROAD, WARRIEWOOD
CIVIL WORKS
CREEK CROSS - SECTIONS
SHEET 3 OF 7
20160112 C-DA403 A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5yr ARI FLOOD LEVEL
2yr ARI FLOOD LEVEL
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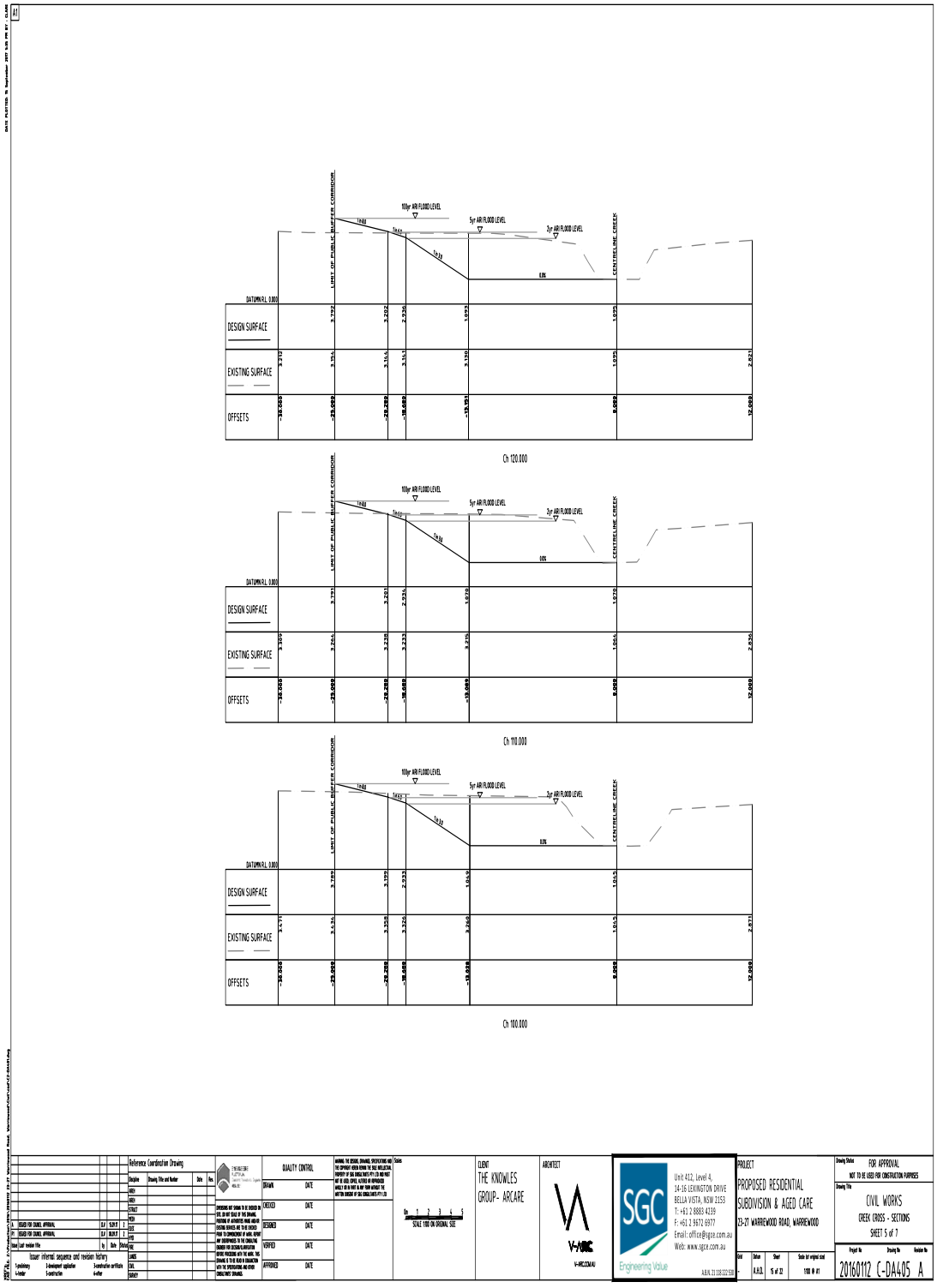
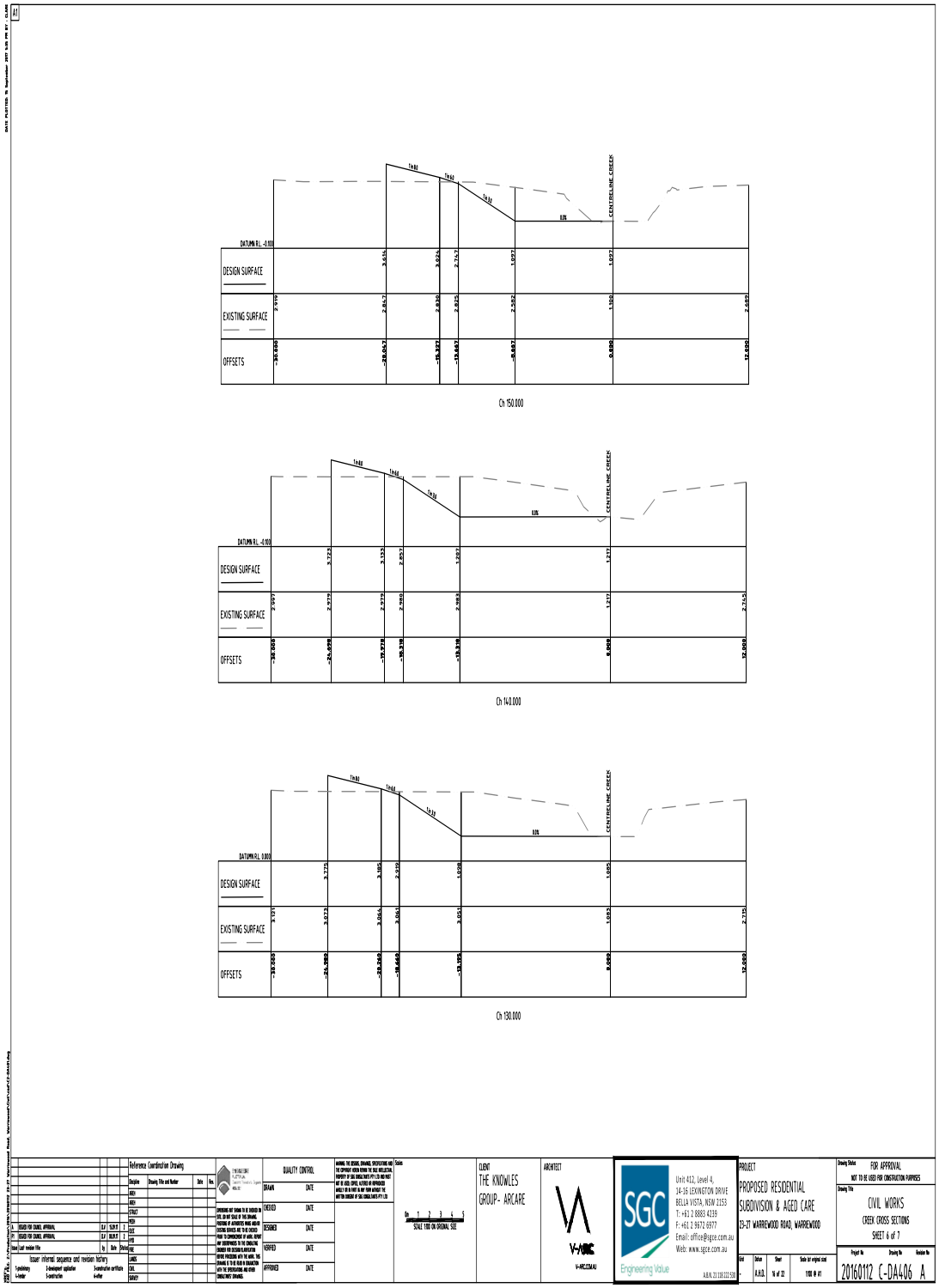
CENTRELINE CREEK
DATUM RL 0.000
DESIGN SURFACE
EXISTING SURFACE
OFFSETS
Ch 90.000
Ch 80.000
Ch 70.000
PROPOSED RESIDENTIAL SUBDIVISION & AGED CARE
23-27 WARREWOOD ROAD, WARRIEWOOD
CIVIL WORKS
CREEK CROSS - SECTIONS
SHEET 4 of 7
20160112 C-DA404 A


10yr ARI FLOOD LEVEL
5yr ARI FLOOD LEVEL
2yr ARI FLOOD LEVEL
LIMIT OF PUBLIC BUFFER CORRIDOR
CENTRELINE CREEK
DATUM RL 0.000
DESIGN SURFACE
EXISTING SURFACE
OFFSETS
Ch 120.000
Ch 110.000
Ch 100.000
PROPOSED RESIDENTIAL SUBDIVISION & AGED CARE
23-27 WARREWOOD ROAD, WARREWOOD
CIVIL WORKS
CREEK CROSS - SECTIONS
SHEET 5 of 7
20160112 C-DA405 A


DESIGN SURFACE
EXISTING SURFACE
OFFSETS
CENTRELINE CREEK
Ch 150.000
Ch 140.000
Ch 130.000
CLIENT
THE KNOWLES GROUP- ARCARE
ARCHITECT
PROJECT
PROPOSED RESIDENTIAL SUBDIVISION & AGED CARE
23-27 WARREWOOD ROAD, WARRIEWOOD
CIVIL WORKS
CREEK CROSS SECTIONS
SHEET 6 of 7
20160112 C-DA406 A

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