Appendix D

Flood assessment, September 2013

EMGA Mitchell McLennan

martens consulting engineers

Flood Assessment

Lot 106 DP755923 and Lot 2 DP1161638 Inyadda Drive and Lot 2 DP1121854 Sunset Strip, Manyana, NSW

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

P1303896JR01V02
September 2013

Limitations Statement

The sole purpose of this report and the associated services performed by Martens & Associates Pty Ltd is to provide a flood assessment at the subject site in accordance with the scope of services set out in the contract / quotation between Martens & Associates Pty Ltd and EMGA Mitchell McLennan (hereafter known as the Client). That scope of works and services were defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

Martens & Associates Pty Ltd derived the data in this report primarily from a number of sources which included site inspections, correspondence regarding the proposal, examination of records in the public domain, interviews with individuals with information about the site or the project, and field explorations conducted on the dates indicated. The passage of time, manifestation of latent conditions or impacts of future events may require further examination / exploration of the site and subsequent data analyses, together with a re-evaluation of the findings, observations and conclusions expressed in this report.

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All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Introduction

1.1 Project Scope

Martens & Associates Pty Ltd has prepared this flood assessment to support a rezoning proposal for Lot 106 DP755923 and Lot 2 DP1161638 Inyadda Drive, and Lot 2 DP1121854 Sunset Strip, Manyana, NSW.

Flood levels and extents have been mapped across the site based on available LIDAR and site survey data.

Project scope and objectives are given as follows:

- Prepare a hydrologic model (RAFTS) for the site to determine peak flows of 1 in 20 and 1 in 100 Average Recurrence Interval (ARI) and the Probable Maximum Flood (PMF).
- Prepare a hydraulic model (2D/3D SMS Tuflow) for the site under existing conditions and for a range of different flooding scenarios.
- Prepare relevant flood maps including flood extents, depths, levels, velocities and hazard.

1.2 Relevant Guidelines

This report has been prepared in accordance with the following guidelines and policies:

- Institution of Engineers, Australia (2006) – *Australian Rainfall and Runoff*
- NSW Department of Environment, Climate Change & Water (2010) – *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments*
- NSW Department of Environment, Climate Change & Water (2007) – *Flood Risk Management Guide: Practical Consideration of Climate Change*
- NSW Department of Infrastructure, Planning and Natural Resources (2005) – *Floodplain Development Manual*
- Shoalhaven City Council (2013) – *Development Control Plan 100: Subdivision Code (Amendment No 4)*
- Shoalhaven City Council (2006) – *Development Control Plan 106: Floodplain Management*

- Shoalhaven City Council (2006) – *Development Control Plan 106: Development on Flood Prone Land (Amendment No 1)*

- Shoalhaven City Council (1999) – *Development Control Plan 100: Engineering Design Specifications*

2 Site Description

Site description is provided in Table 1.

Table 1: Site description summary.

Element	Description/Detail
Site Address	Lot 106 DP1161638 Inyadda Drive, Lot 2 DP755923 Inyadda Drive, Lot 2 DP1121854 Sunset Strip, Manyana, NSW
Existing site development	The site has a total combined area of 76.3 ha, and is presently largely undeveloped, with some cleared areas and walking trails. The site is characterised by bushland and grass cover with medium density trees. A site plan showing pertinent site features is provided in Attachment A.
Aspect	The aspect varies from north east to south east.
Typical slope	<12%
Neighbouring environment	Bounded by Inyadda Drive to the west, residential allotments to the south, a fire trail to the east and bushland to the north.
Local Government Area (LGA)	Shoalhaven City Council.
Drainage	Two culverts flow into the site from lots on the western side of Inyadda drive. The uppermost culvert is located at the base of a natural drainage depression and consists of twin 1.06 m diameter concrete pipes draining to the site. The lower culvert directs overflow from a dam on Lot 6 DP755923 through a 0.69 m diameter concrete pipe and drains to the site. Four culverts are also directed from the southern residential allotments into the site carrying urban stormwater runoff. See Attachment B for the culvert drainage survey. An intermittently closed and open lagoon (ICOL) is located at the site's eastern boundary from where the two creeks meet which discharges to the ocean. Council's flooding engineer indicated that the ICOL is not managed by Council (conversations held 22 – 30 August 2013). As bathymetry data is not available the depth of the lagoon is presently unknown.
Geology	The Ulladulla 1:1250,000 Geological Sheet S1 56-13 (NSW Dept. Mineral Resources, 1966) indicates that the site is primarily underlain by undifferentiated sediments including gravel, sand, clay, quartzite, sandstone and conglomerate. Closer to the shore the site is underlain by quaternary alluvial gravels, swamp deposits and sand dunes.
Soil Profile	Site test pit investigations were carried out by Martens staff at the site in August 1999 for a separate investigation. This geotechnical assessment indicated the majority of the natural soil profile at the site where residual soils occur typically consist of weathered conglomerate rock. The soil landscapes at the site's eastern boundary and around the ICOL are typically loamy sands underlain by deep sand deposits.

3 Flooding

3.1 Overview

This assessment has used a hydrological site model (RAFTS) and a 2D/3D hydraulic model (Tuflow) to assess the distribution of flood flows across the site for peak design 1 in 20 and 1 in 100 year ARI storm events and the peak PMF.

3.2 Hydrological Modelling

3.2.1 Overview

The XP-RAFTS model was used to assess the 1 in 20 and 1 in 100 ARI storms and the PMF for the site, and was set up using the following assumptions and data.

3.2.2 Catchment Details

Local catchment areas were determined based on LIDAR data provided by EMGA Mitchell McLennan (EMM), and site survey data provided by Allen Price and Associates. Sub-catchment boundaries used for modelling are provided in Attachment A. Catchment parameters are summarised in Table 2.

Table 2: Details of catchments in RAFTS hydrological modelling.

Sub- Catchment	Sub-catchment Area (ha)	Impervious (%)	Average Slope [1] (%)
SC01	20.0	3.1%	3.7%
SC02	20.0	0.1%	3.2%
SC03	20.0	8.2%	4.6%
SC04	20.0	2.0%	5.3%
SC05	20.0	1.0%	2.7%
SC06	23.5	8.4%	4.6%
SC07	23.5	13.3%	3.6%
SC08	23.4	13.0%	4.4%
SC09	23.3	12.9%	4.1%
SC10	23.2	1.4%	3.1%

Notes

1. Average slope is the difference between the highest and lowest points in the catchment divided by the maximum drainage path between them.

3.2.3 RAFTS Modelling

The RAFTS model was used to determine the peak flow rates for a range of storm durations between 10 mins to 72 hours for each of the 1 in 20 and 1 in 100 ARI storms and the PMF. Parameters used in the model are provided in Table 3.

Table 3: Rainfall data and soil properties used in RAFTS modelling.

Parameter	Element	Value
IFD data [1]	2year 1hour Rainfall Intensity	45.7
	2year 12hour Rainfall Intensity	9.6
	2year 72hour Rainfall Intensity	3.0
	50year 1hour Rainfall Intensity	95
	50year 12hour Rainfall Intensity	21.2
	50year 72hour Rainfall Intensity	6.5
	G	0.025
	F2	4.2625
	F50	15.78
Loss data [2]	Initial impervious area loss (mm)	1.5
	Continuing impervious area loss (mm/hr)	0
	Initial pervious area loss (mm)	10
	Continuing pervious area loss (mm/hr)	3
Roughness coefficients [2]	Impervious area PERN	0.015
	Pervious area PERN	0.08

Notes

1. Obtained from Australian Rainfall and Runoff (2006).
2. Obtained from XP-RAFTS User's Manual (1996).

3.2.4 Results

Modelling indicated that a storm duration of 2 hours yielded a peak critical flow for the 1 in 20 and the 1 in 100 year events, and a storm duration of 45 minutes yielded a peak critical flow for the PMF event. This critical flow was used for hydraulic flood modelling purposes. Results of RAFTS hydrological modelling for the critical storm duration of each storm event are summarised in Table 4.

Table 4: Results of RAFTS hydrological modelling.

Catchment ID	Peak Flow Rate (m^3/s)		
	1 in 20 yr ARI storm	1 in 100 yr ARI storm	PMF storm
SC01	7.53	10.23	26.24
SC02	7.92	10.54	26.65
SC03	7.06	9.80	25.46
SC04	6.55	9.17	24.92
SC05	8.25	10.92	26.95
SC06	8.08	11.23	29.38
SC07	9.03	12.15	30.84
SC08	8.39	11.52	29.77
SC09	8.60	11.70	30.07
SC10	9.01	12.13	30.74

3.3 Hydraulic Modelling

3.3.1 Overview

The SMS Tuflow 2D/3D hydraulic model was used to determine the proposed peak flood characteristics under existing conditions including water height, depth, hydraulic hazard and velocity for the 1 in 20 and 1 in 100 ARI storms and the PMF.

We note that the catchment is ungauged and no anecdotal data are available for the study at time of preparation.

3.3.2 Scenarios

The scenarios adopted for Tuflow hydraulic modelling are summarised in Table 5.

We note the following:

- The LIDAR data depicts water in the lagoon trapped behind a closed sand bar. The water surface level detected by the LIDAR is adopted as the ground surface for the purposes of Tuflow modelling, assuming a full lagoon. The LIDAR data is used for all 'closed' scenarios.

- Under the storm conditions modelled, given the lagoon and catchment size, it is conceivable that the lagoon can be open to the ocean. In the absence of bathymetry data, to simulate this we have lowered the ground level to a nominal depth of 0.6 mAHD from the lagoon inlet to the ocean. This assumption is used in conjunction with the LIDAR data for all 'open' scenarios.

- Combinations of catchment flooding and ocean level boundary conditions were obtained from Department of Environment, Climate Change & Water (2010).
- Only the worst case combination of 1 in 100 ARI 'closed' boundary conditions (A1 – A3) is used in modelling open (B1) and climate change (C1 – C4) scenarios.
- Catchment flood boundary conditions were obtained from RAFTS hydrographs.
- Ocean level boundary conditions were obtained from Department of Environment, Climate Change & Water (2007).
- Climate change boundary conditions were obtained from Council's flooding engineer (conversations held 22 – 30 August 2013) as shown in Table 5.

Table 5: Summary of boundary conditions adopted in hydraulic modelling.

Scenario	Boundary Conditions			
	ICOL[1] Entrance	Catchment Flood [4]	Ocean Level [5]	Climate Change [6]
A1	Closed [2]	1 in 100 yr	1 in 20 yr (2.1 m)	–
A2		1 in 20 yr	1 in 100 yr (2.4 m)	–
A3		1 in 100 yr	Neap tides (0.6 m)	–
A4		PMF	Neap tides (0.6 m)	–
B1	Open [3]	1 in 100 yr	1 in 20 yr (2.1 m)	–
B2		PMF	Neap tides (0.6 m)	–
C1	Closed [2]	1 in 100 yr	1 in 20 yr (2.1 m)	2050 (+ 0.4 m)
C2				2100 (+ 0.9 m)
C3	Open [3]			2050 (+ 0.4 m)
C4				2100 (+ 0.9 m)

Notes

1. ICOL = intermittently closed and open lagoon.
2. Closed ICOL conditions assume a full lagoon at the elevation measured by LIDAR.
3. Open ICOL conditions assume an empty lagoon and no sandbar blockage. The elevation is lowered to a nominal depth of 0.6 mAHD.
4. Obtained from RAFTS modelling.
5. Obtained from Department of Environment, Climate Change & Water (2007).
6. Obtained from Council advice (Council's flooding engineer, conversations held 22 – 30 August 2013).

3.3.3 Modelling Set-up

Tuflow model construction consisted of:

1. Development of a 5 m x 5 m topographic grid based on LIDAR data provided by EMM, and site survey provided by Allen Price and Associates.

2. Establishment of flow boundary conditions based on RAFTS hydrographs.

3. Establishment of model general boundary conditions based on available survey data.

4. Incorporation of headwalls and culverts under Inyadda Drive using 1D/2D model connections. 50 % blockage was assumed for all culverts.

5. Assigning manning's roughness coefficients for hydraulic modelling as shown in Table 6.

Table 6: Manning's roughness values used in Tuflow modelling.

Catchment Material	Manning's Roughness Applied
Building	10.000
Bushland	0.120
Cleared	0.020
Grassland	0.035
Riparian	0.120
Road	0.013
Sand/dunes	0.020
Water body	0.04 when depth < 0.1 m
	0.01 when depth > 0.1 m

3.3.4 Results

Results of flood extents, depths, levels, and hazard for the scenarios in Section 3.3.2 for existing conditions are depicted graphically in Attachment C.

For design purposes as per conversations with Council's flooding engineer Scenario C2 is recommended, which is the worst case 1 in 100 year catchment flood with the ICOL closed, a 1 in 20 year ocean flood level and a sea level rise of 0.9m. This flooding scenario is illustrated in Figures 29 – 32. Scenario A4 (Figures 13 – 16) should be adopted as the worst case PMF event.

3.4 Preliminary Earthworks Requirements

In our opinion some minor earthworks could reduce the flood extents depicted in Attachment C. These works could be undertaken in conjunction with the proposed development. The extent of the reduction would be dependent on the development footprint and a more detailed analysis of creek riparian corridors (stream classification in consultation with NSW Office of Water). Further detailed hydraulic analysis would be required to determine the extent of earthworks required.

Indicative flood extent reduction that could be possible through minor earthworks is provided in Attachment D. This would need to be confirmed through detailed post-development flood modelling.

3.5 Possible Works as part of Development Application

To achieve the largest portion of land free of flooding constraints, the following works would need to be undertaken:

1. Supplementary survey of water course, lagoon bathymetry, inlet and dune at inlet, and incorporating this data into the Tuflow model. This will improve model resolution and accuracy of flood mapping.

2. Stream classification in consultation with NSW Office of Water to determine riparian corridor requirements. This will define boundaries adjacent to waterways where development is permissible.

3. Comparison of the post-development conditions with existing conditions, incorporating earthworks to reduce flood extents.

4. Analysis of sandbar scouring during flood event.

4 References

Institution of Engineers, Australia (2006) – *Australian Rainfall and Runoff*

NSW Department of Environment, Climate Change & Water (2010) – *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments*

NSW Department of Environment, Climate Change & Water (2007) – *Flood Risk Management Guide: Practical Consideration of Climate Change*

NSW Department of Infrastructure, Planning and Natural Resources (2005) – *Floodplain Development Manual*

Shoalhaven City Council (2013) – *Development Control Plan 100: Subdivision Code (Amendment No 4)*

Shoalhaven City Council (2006) – *Development Control Plan 106: Floodplain Management*

Shoalhaven City Council (2006) – *Development Control Plan 106: Development on Flood Prone Land (Amendment No 1)*

Shoalhaven City Council (1999) – *Development Control Plan 100: Engineering Design Specifications*

Ulladulla 1:250,000 Geological Sheet S1 56-13 (1966), New South Wales Geological Survey, Sydney.

XP-RAFTS (1996) – *User's Manual Version 5*

5 Attachment A: Catchment Plan

REV.	DESCRIPTION	DATE	ISSUED
A	FINAL	04.09.13	DD

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REVIEWED: GT	HORIZONTAL RATIO: 1:7000	
PAPER SIZE: A3	VERTICAL RATIO: 1:7000	

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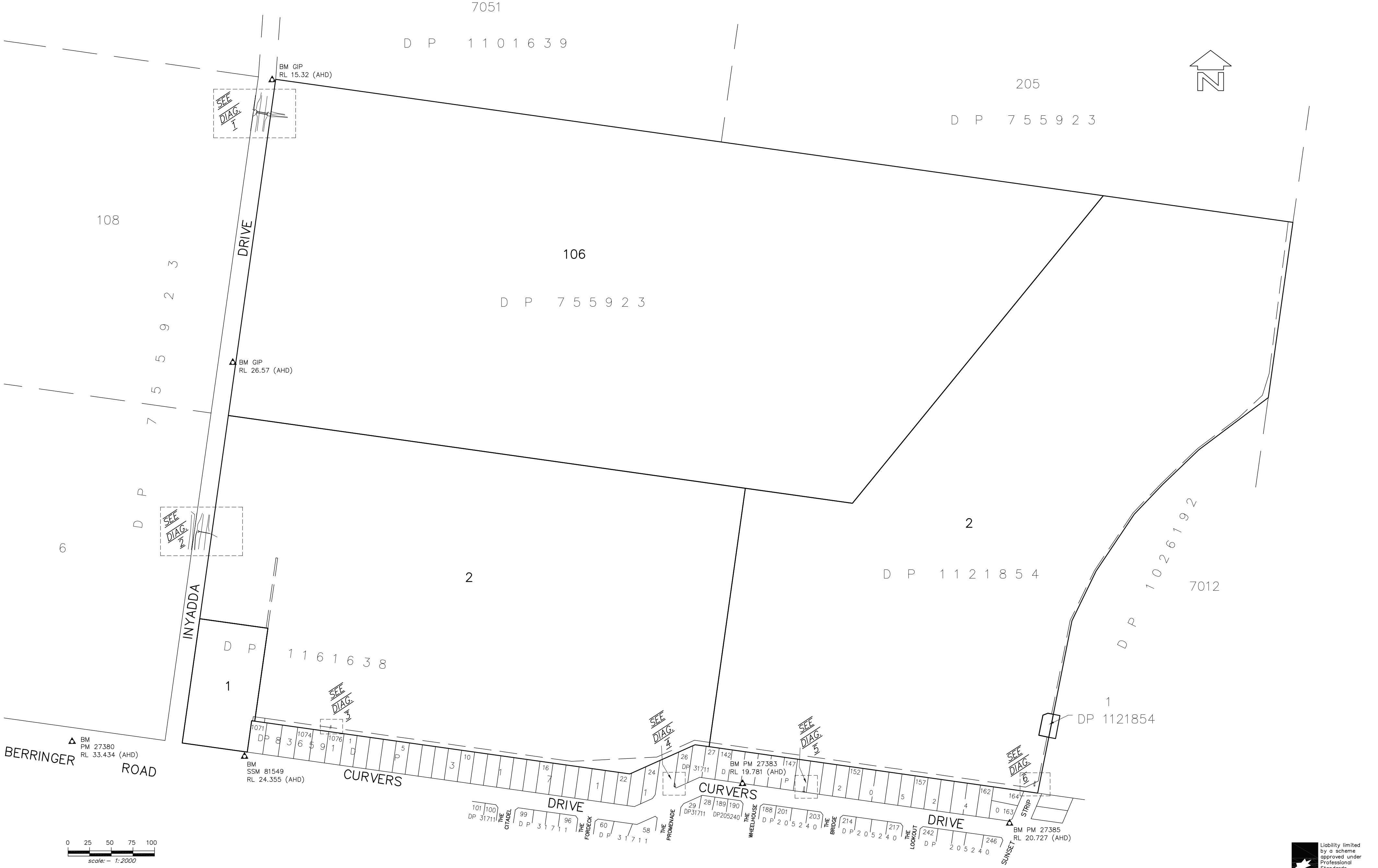
TITLE: CATCHMENT PLANS FOR FLOOD MODELLING

DRAWING ID: SK001

PROJECT MANAGER:	PROJECT NO.:	FILE:	REVISION:
GT	P1303896	JD02V01	A

6 Attachment B: Allen Price & Associates Site Drainage Survey



Liability limited by a scheme approved under Professional Standards Legislation.

COVER OF EXCELLENCE

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		DRAWN DS		
	DATE OF PLAN: 5.8.2013	CHECK'D ARA		

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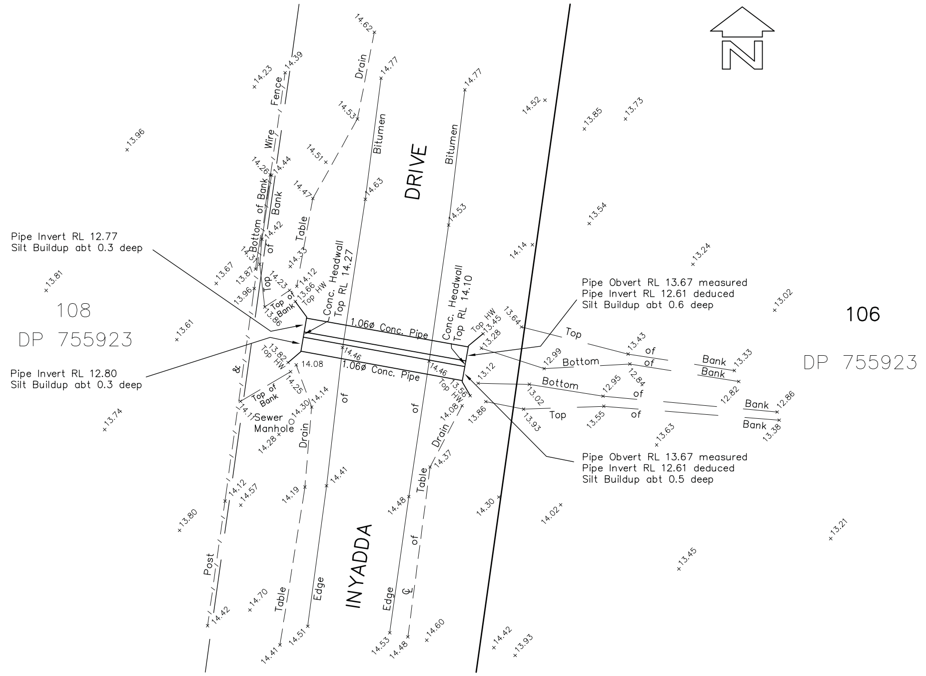
land and development consultants
75 plunkett street, nowra, nsw, 2541

PLAN SHOWING SPOT LEVELS AND DRAINAGE DETAIL
AT INYADDA DRIVE, CURVERS DRIVE
AND SUNSET STRIP MANYANA
FOR EMGA MITCHELL McLENNAN PTY LIMITED

REF. No. 25229–02

SHEET 1 OF 2 SHEETS

REVISION 0



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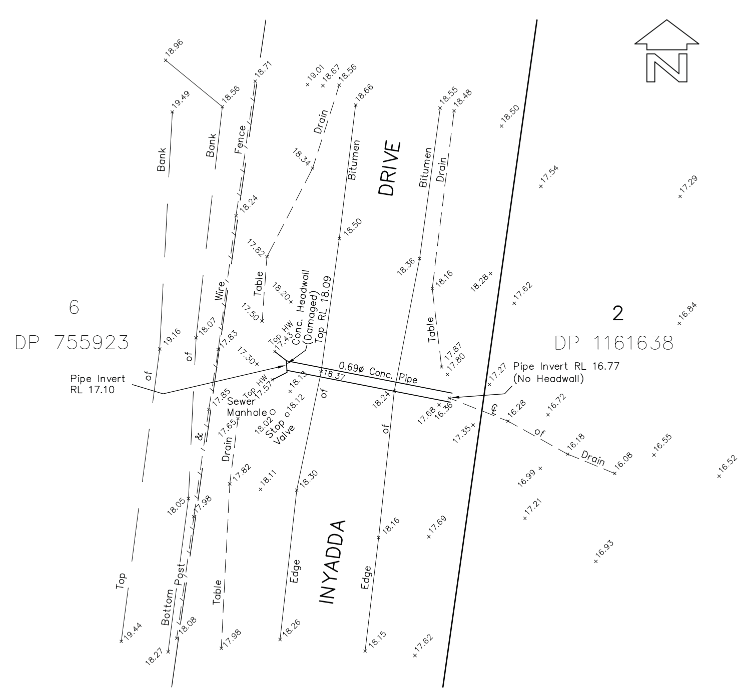

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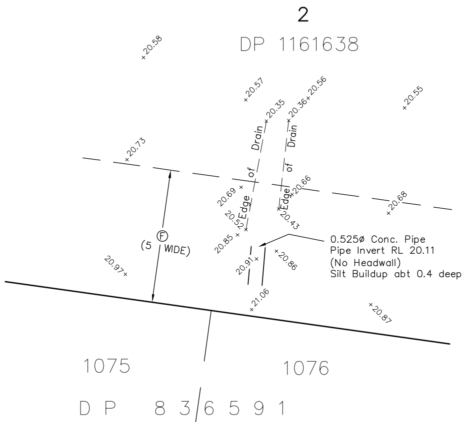

Ⓕ EASEMENT FOR SEWER PIPELINE 5 WIDE & VARIABLE
(VIDE DP 1121854 & DEALING AE 870612)

DIAGRAM 3

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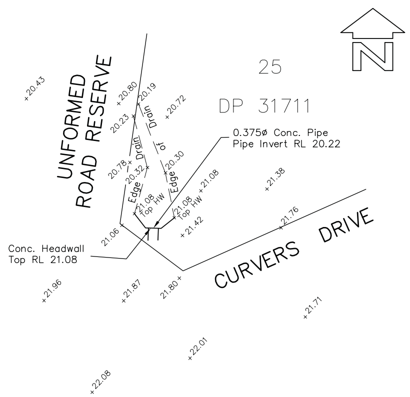

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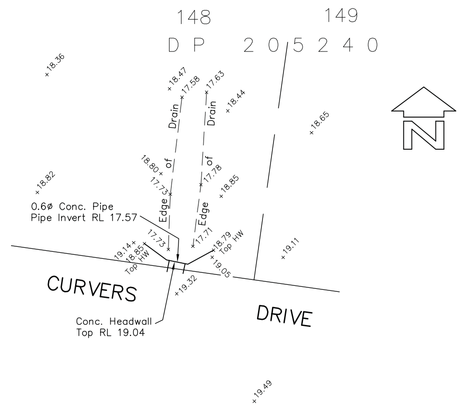

DIAGRAM 5

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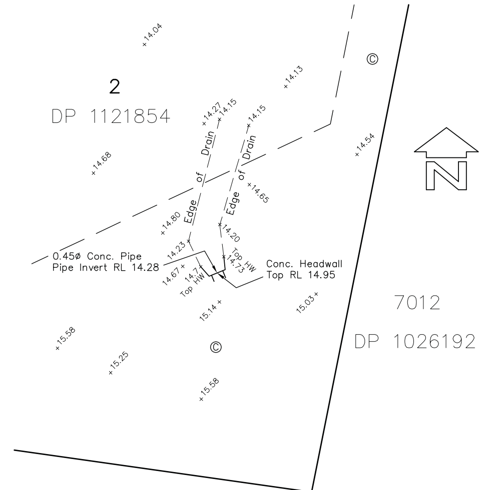

Ⓒ EASEMENT FOR SEWER PIPELINE
2 & 5 WIDE & VARIABLE
(VIDE DP 1121854 & DEALING AE870612)

DIAGRAM 6

REDUCTION RATIO 1:100

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COVER OF EXCELLENCE

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	DATE OF PLAN: 5.8.2013	CHECK'D	ARA			

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PLAN SHOWING SPOT LEVELS AND DRAINAGE DETAIL
AT INYADDA DRIVE, CURVERS DRIVE
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REF. No. 25229–02

SHEET 2 OF 2 SHEETS

REVISION 0

7 Attachment C: Flood Maps