Flood and Drainage Assessment- Freemans Drive, Cooranbong

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A Partnership between PPK E&I Pty Ltd and
Parsons Brinckerhoff International (Australia) Pty Ltd
Parsons Brinckerhoff Companies

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1. Introduction

1.1 Study Objectives

PPK Environment and Infrastructure has been engaged by Harper Somers O'Sullivan Pty Ltd on behalf of Avondale Greens Pty Ltd to undertake a preliminary flood and drainage assessment of various land holdings to the north of Freemans Drive, Cooranbong. The holdings include Lot 21 DP565586, Lot 1 DP348173, Pt 15 DP3533, Lot 2 DP625266 and Lot 1 DP170378. A locality plan of the site is shown in Figure 1.

It is understood that this study will form part of an application to rezone the site for residential development.

The objectives of this study are to:

- determine the peak 100 year average recurrence interval (ARI) flow from the local catchment; and
- determine the estimated 100 year flood levels within the local catchment.

1.2 Catchment

On a regional scale the site lies within the Dora Creek Catchment, which consists of steep terrain and low lying flood plains, and discharges to Lake Macquarie through the town of Dora Creek. However, for the purposes of this study the site catchment was broken down into four smaller local subcatchments; the Dora Creek, Felled Timber Creek, Unnamed Tributary NE and Unnamed Tributary SW subcatchments.

The Felled Timber Creek subcatchment includes an area of approximately 1539 ha draining to a point upstream of the Dora Creek and Felled Timber Creek confluence. Surface elevations within the Felled Timber Creek subcatchment vary from RL 430m at the top of the catchment to RL 2.5m at the confluence of Dora Creek and Felled Timber Creek.

The Dora Creek subcatchment includes an area of approximately 6911 ha, and drains to a point upstream of the existing bridge at Cooranbong. Surface elevations within the Dora Creek subcatchment vary from RL 450m at the top of the catchment to RL 2m at the existing bridge at Cooranbong. It should be noted that only a small area of the site is within the Dora Creek subcatchment.

The unnamed tributary subcatchments drain to two sets of culverts along Freeman's drive, with the subcatchment outlets corresponding to the culvert locations. The Unnamed Tributary NE and SW subcatchments include areas of 114 and 36 ha respectively. There is no defined stream in the Unnamed Tributary SW subcatchment, only a turf table drain running along Freemans Drive. Surface elevations within the Unnamed Tributary subcatchments vary from RL 40m at the top of the catchment to RL 3.5m along Freemans Drive.

The site varies from RL 34.2m to the east of Alton Rd to RL 4m to the north of Freemans Drive.

1.3 Previous Investigations

PPK on behalf of Johnson and Johnson prepared a *Martinsville Flood Study* (September, 2000) (reference: 67M094A:PR_1339.doc). The *Martinsville Flood Study* was concerned with Lots 35 and 36 DP755225, located along Martinsville Road, west of Cooranbong. The *Martinsville Flood Study* made the following findings, which are of significance to this study:

- the peak 100 year ARI flow upstream of the existing bridge at Cooranbong was estimated to be 428m^3/s using the Probabilistic Rational Method; and
- the 100 year flood level along Dora Creek approximately 1km upstream of the bridge was estimated to be 7.55m using the HEC-RAS water surface profile model. It was assumed that water levels were controlled by the bridge.

1.4 Available Data

The following information was utilised in this investigation:

- 1:25,000 Topographic map to determine the extent of the site catchment;
- DLWC 1:4,000 orthophotos (U3635-5, U3635-6) with a 2 metre contour interval; and
- *Martinsville Flood Study* (PPK, 2000).

A site visit was undertaken on the 7 June 2002 for familiarisation purposes and to identify critical features and potential problem areas. Control structures beneath Freemans Drive, typical creek cross-sections at strategic locations, and main stream and overbank Manning's n values were noted.

Surveyed detail cross sections of the creeks were not available for this study. Thus creek cross-sections were estimated using orthophotos and interpolation from the site inspection.

Rainfall intensity-frequency-duration (IFD) data for the Cooranbong area was derived using Australian Rainfall & Runoff (AR&R) [1] [2] (1987).

2. Methodology

2.1 Peak Discharge Determination

Peak discharges from the site catchments for the 100 year ARI storm event were determined using the Probabilistic Rational Method detailed in AR&R [1] [2] (1987). Peak discharges for the Dora Creek catchment, upstream of the existing bridge in Cooranbong, were obtained from the *Martinsville Flood Study* (PPK, 2000).

It should be noted that no hydrologic modelling has been included in this study.

2.2 Flood Level Determination

Flood levels within the unnamed tributary and Felled Timber Creek were determined from Manning's Equation hydraulic calculations. Backwater levels in the unnamed tributary catchments were determined from control structures along Freemans Drive and were calculated assuming inlet control.

Flood levels in Dora Creek were obtained from the *Martinsville Flood Study* (PPK, 2000).

Creek cross-sections were determined from orthophotos and on-site inspection at specific locations.

3. Hydrological Modelling

3.1 Catchment Plan

A detailed catchment plan showing the Dora Creek, Felled Timber Creek, Unnamed Tributary NE and Unnamed Tributary SW catchment boundaries used for determining the peak 100 year flows is shown in Figure 2.

Rainfall IFD data for the Cooranbong area was generated by the method described in AR&R [1] (1987).

3.2 Peak Discharge Determination

Long-term stream flow data is not available to enable calibration of catchment runoff. For this reason, peak discharges from the catchments were estimated using the Probabilistic Rational Method detailed in AR&R [1] [2] (1987). The 100 year peak flow was estimated:

- on Felled Timber Creek immediately upstream of its confluence with Dora Creek;
- immediately upstream of the Freemans Drive culverts for the Unnamed Tributary NE; and
- immediately upstream of the Freemans Drive culverts for the Unnamed Tributary SW.

Peak discharges were estimated for both the existing situation, including existing development in the catchment, and the developed situation, including the proposed residential development for the site. It was assumed that residential development would increase the percentage impervious area by 40 percent, as stated in the Lake Macquarie City Council subdivision code. The catchment data and Probabilistic Rational Method Calculations are detailed in Appendix A.

The estimated peak flow immediately upstream of the bridge at Cooranbong was obtained from the *Martinsville Flood Study* (PPK, 2000). This value was estimated for the undeveloped catchment. Due to the large size of the Dora Creek catchment, it was assumed that the impact of development at the site on the peak flow at the bridge was negligible.

Predicted flows are summarised in Table 3.1 below.

Table 3.1 Peak Runoff for the 100 tear ARI Storm Event

ARI	Location	Probabilistic Rational Method	
		Peak Existing Flow (m^3/s)	Peak Developed Flow (m^3/s)
100	Unnamed Tributary (NE) Catchment immediately upstream of Freemans Drive culverts	15.0	15.3
100	Unnamed Tributary (SW) Catchment immediately upstream of Freemans Drive culverts	7.2	7.5
100	Felled Timber Creek Catchment (immediately upstream of Dora Creek confluence)	111.9	112.2
100	Immediately upstream of existing bridge in Cooranbong	428.1*	-

*Obtained from *Martinsville Flood Study* (PPK, 2000)

From Table 3.1 it can be seen that there is a minimal increase in total catchment peak flow between the existing and developed situation.

4. Hydraulic Modelling

4.1 Flow Regime

Subcritical flow was assumed to dominate flow in Dora Creek, Felled Timber Creek and the Unnamed Tributary.

It was assumed that the culverts beneath Freemans Drive controlled water levels in the Unnamed Tributary NE and SW subcatchments. Also, as there was no defined channel in the Unnamed Tributary SW subcatchment, it was assumed that the culverts were the sole control on water levels in this subcatchment.

A summary of the control structures for the subcatchments is given in Table 4.1 below.

Table 4.1 Summary of Control Structures

Location	Control Structure	No.	Size	Depth to Invert (m)	Estimated Spillway Length (m)	Estimated Spillway RL (m)
Freemans Drive- Unnamed Tributary (NE) subcatchment outlet	Circular Culvert	3	1200mm ϕ	2.1	35	5.7
Freemans Drive- Unnamed Tributary (SW) subcatchment outlet	Circular Culvert	2	900mm ϕ	1.3	35	4
Freemans Drive- Dora Creek	Bridge*	-	-	-	-	-

* Bridge representation not considered in this study.

The control of the existing bridge at Cooranbong on upstream water levels was accounted for in the flood levels obtained from the *Martinsville Flood Study* (PPK, 2000).

4.2 Backwater Flood Level Calculations

Backwater flood levels were calculated for the culverts along Freemans Drive assuming inlet control. Backwater flood levels were estimated for both the existing and developed predicted peak 100 year ARI flows. The backwater flood levels are given below in Table 4.2.

Table 4.2 Backwater levels for culverts along Freemans Drive for the existing and developed situation.

Culvert Location	Depth to invert (m)	Backwater Flood RL (m)- Existing situation	Backwater Flood RL (m)- Existing Situation
Unnamed tributary NE subcatchment	2.1	2.25	2.26
Unnamed tributary SW subcatchment	1.3	1.46	1.47

From Table 4.2 it can be seen that there is a minimal increase in backwater levels between the existing and developed situations.

4.3 Manning's n values

Manning's 'n' values for friction losses were estimated for the defined creek line and overbank regions. The Manning's 'n' was assumed to be 0.04 for the defined creek line and 0.08 for the overbank region for both Felled Timber Creek and the Unnamed Tributary.

4.4 Cross-section geometry

Creek cross sections for the Unnamed Tributary and Felled Timber Creek were utilised in Manning's Equation hydraulic calculations.

Creek cross sections were estimated from orthophotos and on site inspection at specific locations.

4.5 Flood Levels

Manning's Equation hydraulic calculations were used to estimate the 100 year ARI water levels in the creeks. The Manning's Equation hydraulic calculations are detailed in Appendix B.

As there was no defined channel in the Unnamed Tributary SW subcatchment, the 100 year flood level within this subcatchment was assumed to be the 100 year developed backwater level calculated for the culvert beneath Freemans Drive.

The flood levels estimated within the site are shown in Table 4.3 below. Flood levels are provided for the site in its developed state.

Table 4.3 100 year flood levels

Location	Approximate Developed Flood Level (m)
Upstream (Felled Timber Creek) end of site to west of Bushland Drive	9.5
Downstream (Felled Timber Creek) end of site to west of Bushland Drive	8.5
Downstream end of site in Unnamed Tributary (NE) catchment	5.9
Downstream end of site in Unnamed Tributary (SW) catchment	5.9

Flood levels within the site range from RL 9.5m at the upstream end of Felled Timber Creek to 5.9m in the Unnamed Tributary SW Catchment.

Figure 3 shows the extent of the 100 year water level with respect to the site.

The Manning's Equation Hydraulic Calculations indicate that approximately 29% of the site is at risk of inundation during a 100 year ARI storm event.

It should be noted that the flood level in Dora Creek, approximately 1km upstream of the existing bridge in Cooranbong, estimated in the Martinsville Flood Study was approximately 7.5m. This level is lower than that calculated in this study using Manning's Equation for Felled Timber Creek at the downstream end of the site (i.e. RL 8.5m). This indicates that flows from the Felled Timber Creek Catchment control water levels in this section of the site, rather than backwater affects in Dora Creek from the bridge.

5. Limitations of Analysis

It should be noted that creek cross sections within Dora Creek, Felled Timber Creek and the unnamed tributary were derived from orthophotos and on site inspections. Due to the lack of detailed survey within the creek and overbank sections within the proposed development, the flood envelope estimation is approximate only.

6. Conclusions and Recommendations

Based on the Manning's Equation hydraulic calculations, and backwater calculations assuming inlet control, the 100 year flood level encroaches upon approximately 29% of the site. Estimated 100 year flood levels within the site range from RL 9.5 at the upstream end of Felled Timber Creek to RL 5.9m in the Unnamed Tributary SW catchment. The interpolated extent of the 100 year flood envelope is shown on Figure 3.

Mitigative measures that may be undertaken to increase the extent of developable land include:

- Cut to fill, thereby increasing the area of land that could be developed. This might involve the construction of 'fingers' into the flood envelope to provide filled floodfree building sites with floodfree access; and
- The location of houses near the edge of the flood envelope with allotment boundaries extending towards the creek represents a low cost option. Whilst most of the lot would be flood-prone, individual dwelling sites would be above the flood level, with the remainder of the lot subject to restrictions on use prohibiting buildings.

In any of the above options, a minimum freeboard of 500mm is recommended between dwelling floor levels and the estimated 100 year flood levels.

Finally, it should be noted that this is a preliminary study only and the estimates may be conservative. A further detailed study, which would include modelling in XP-RAFTS and backwater analysis using HEC II with detailed survey of the site to be developed, is highly recommended to confirm the boundary of the 100 year flood envelope.

7. References

- PPK Environment & Infrastructure, September 2000. Martinsville Flood Study.
- Australian Rainfall & Runoff (AR&R) [1] [2] (1987).
- Department of Land and Water Conservation, 1998. 1:4,000 Orthophotos (U3635-5, U3635-6). Second Edition.

Figures

Client: Avondale Greens Pty Ltd
Project: Flood and Drainage Assessment
Location: Freemans Drive, Cooranbong

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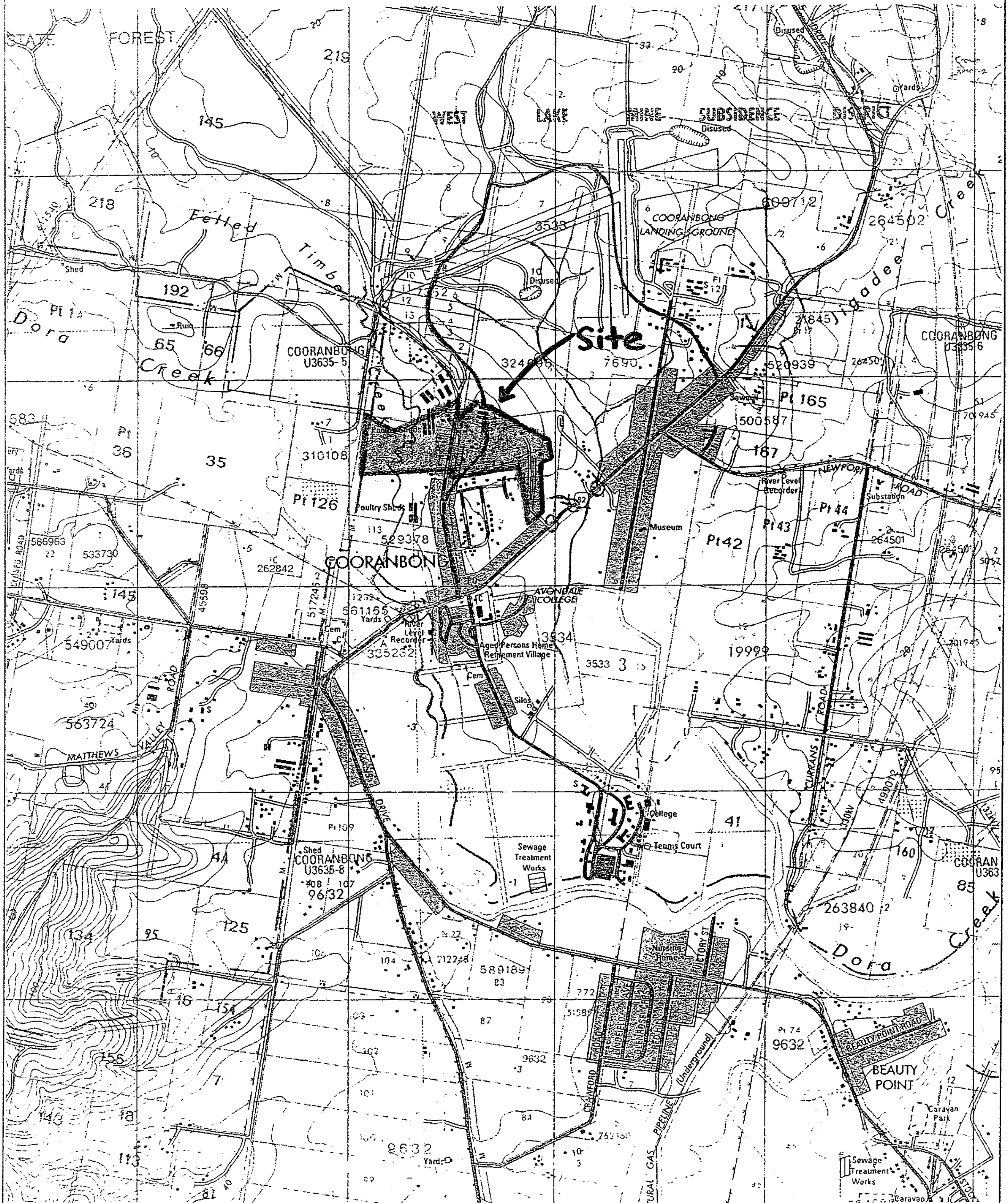
250 0 250 500 750 1000 1250 m

Scale 1: 25,000



Locality Plan

Figure 1

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Client: Avondale Greens Pty Ltd
Project: Flood and Drainage Assessment
Location: Freemans Drive, Cooranbong

50 0 250 500 750 1000 1250 m

Scale 1: 25,000

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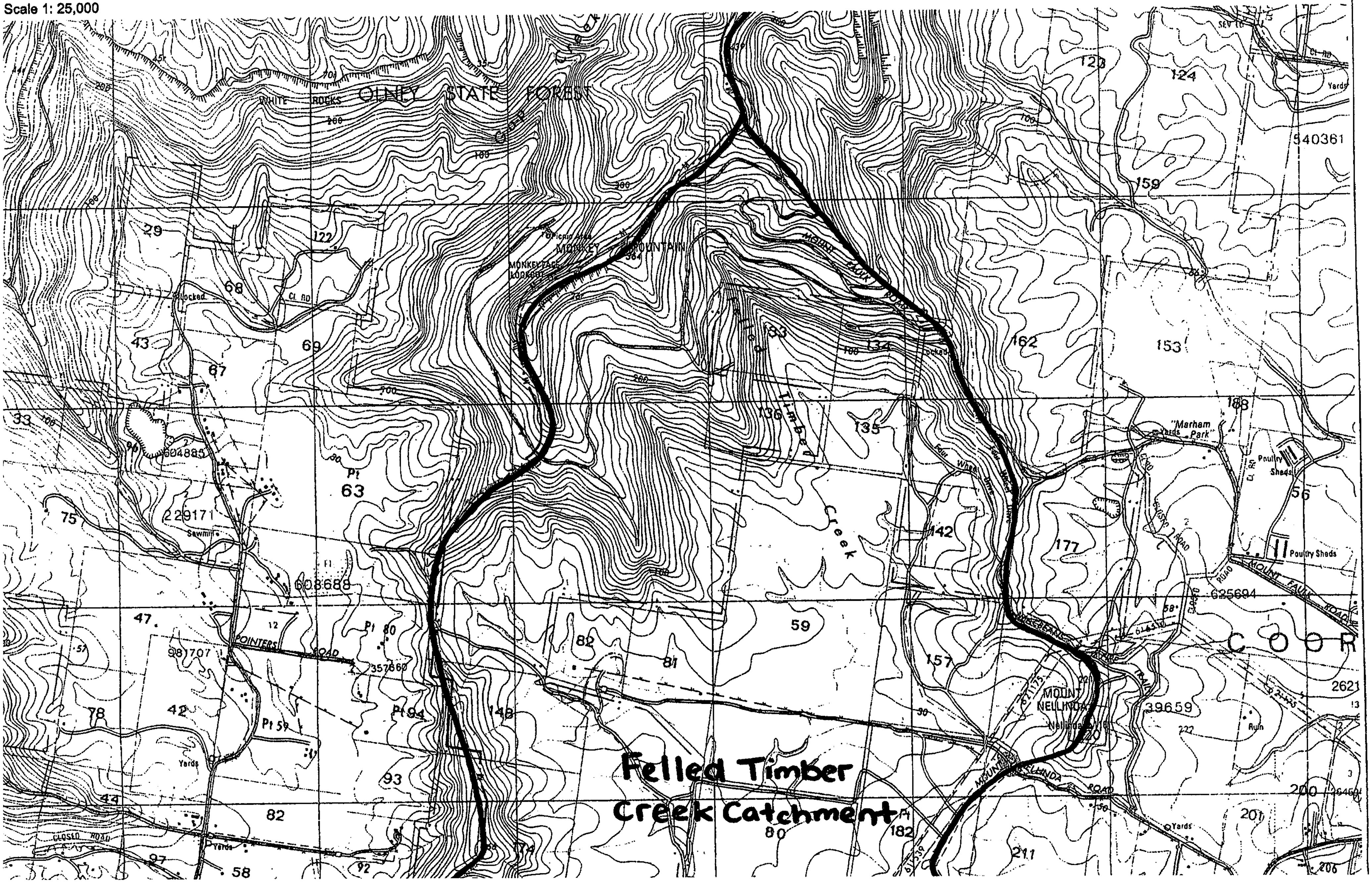

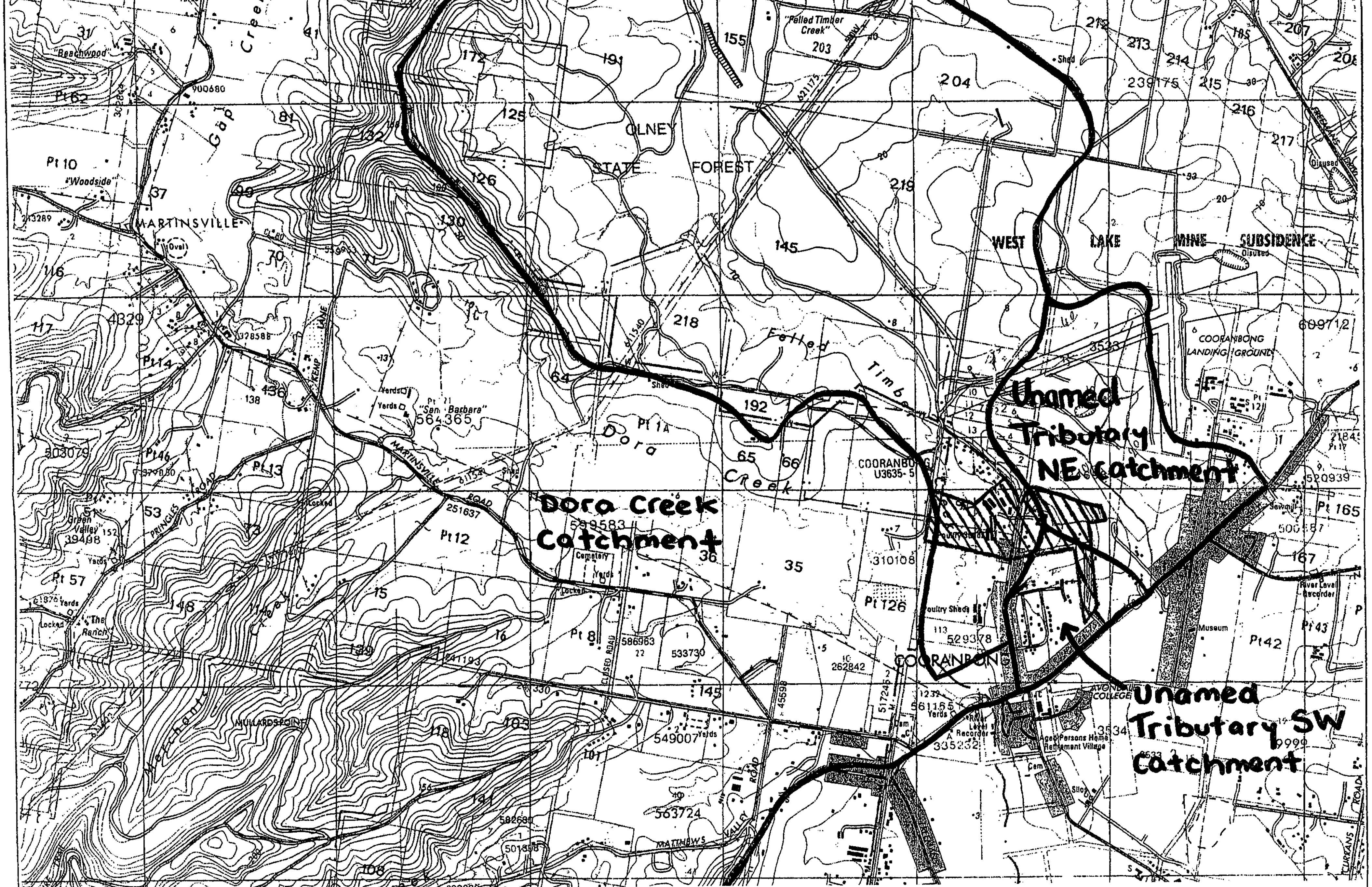

Catchment Plan
Figure 2

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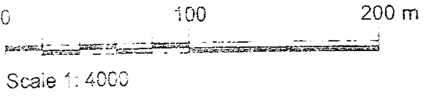
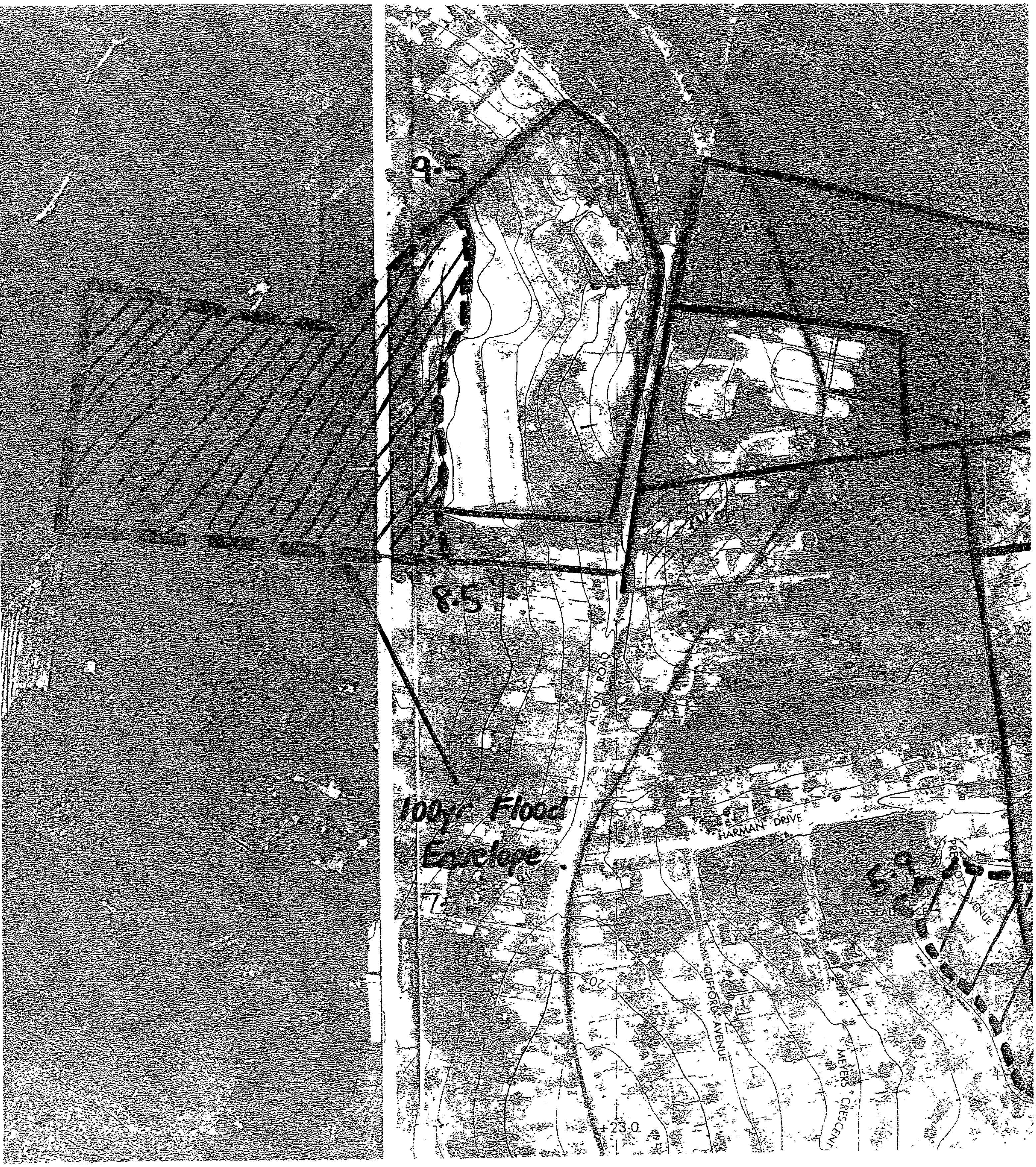
CAD REFERENCE: E:\2122196A\CAD\Pr 0762\FIGURE2.DWG

Client: Avondale Greens Pty Ltd
Project: Flood and Drainage Assessment
Location: Freemans Drive, Cooranbong





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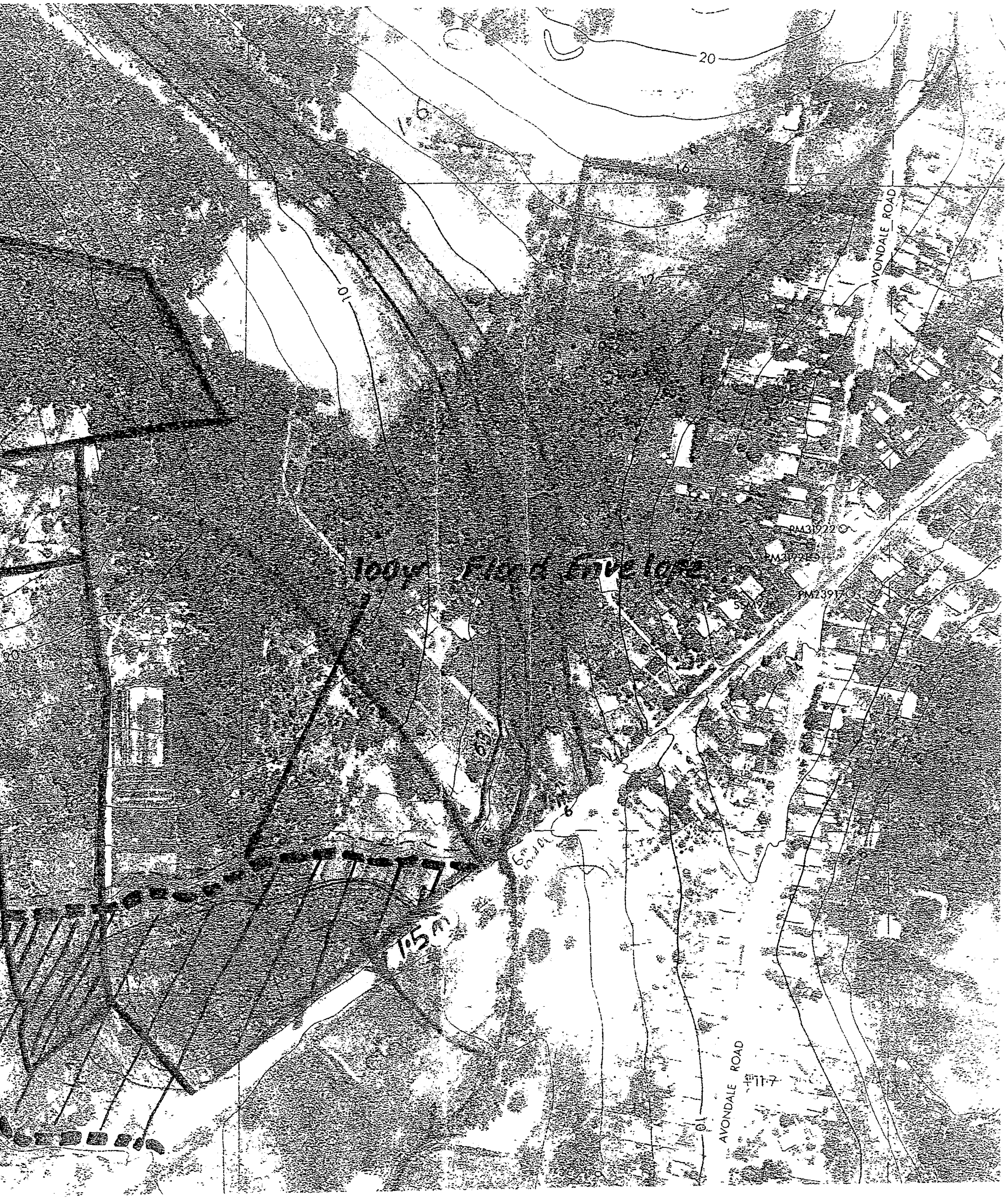

100 yr Flood Envelope
Figure 3

Appendix A

Probabilistic Rational Method

FLOOD STUDY- FREEMANS DRIVE, COORANBONG
Existing and Developed Percentage Impervious

Subcatchment	Total Area (ha)	Existing Impervious Area (ha)	Existing % Impervious	Developed Impervious Area (ha)	Developed % Impervious
Unamed Tributary (NE catchment)	114	4.48	**3.9**	6.496	**5.7**
Unamed Tributary (SW catchment)	36	7.50	**20.8**	9.316	**25.9**
Felled Timber Creek	1539	2.24	**0.1**	6.44	**0.4**
Dora Creek (above Felled Timber Creek confluence)	6911	0.00	**0.0**	0.12	**0.0**
Dora Creek (above bridge)	8450	2.24	**0.0**	8.80	**0.1**

*Assuming 40% impervious for residential development

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FLOOD STUDY- FREEMANS DRIVE, COORANBONG

RATIONAL METHOD HYDROLOGICAL CALCULATIONS- Existing Situation

ARI	100		
C10	0.4	Min Tc	5
Rainfall Data for:		Cooranbong	

Minimum tc	5
Method for tc	2

1 = Bransby Williams

2 = Regional $tc=0.76A^{0.38}$

3 = Kinematic Wave

Frequency Factors:

ARI	1	2	5	10	20	50
FFy	0.62	0.74	0.88	1	1.12	1.2351

Node	CATCHMENT DATA								SUBCAT. t_c				MAIN CHANNEL			TIME OF CONC.		RAINFALL	CA	F.
	Area	%Imperv.	FFy	C	CA	L	S	n	Bransby	Regional	Kinematic	tc	L	v	t	u/s	this	INTENSITY		
	ha	%	-	-	ha	m	m/m	-	Min.	Min.	Min.		m	m/s	Min.	Min.	Min.	mm/hr	ha	r
Catchment outlet																				
Unnamed tributary (NE)- Upstream of Freemans Drive culverts	114	3.9%	1.3573	0.569	64.91					47.9		47.9					*47.9*	82.9	64.9	1
Unnamed tributary (SW)- Upstream of Freemans Drive culverts	36	20.8%	1.3573	0.684	24.63					30.9		30.9					*30.9*	104.5	24.6	7
Felled Timber Creek (at Dora Creek confluence)	1539	0.1%	1.3573	0.544	836.99					128.9		128.9					*128.9*	48.1	837.0	1
Dora Creek (at Felled Timber Creek confluence)	6911	0.0%	1.3573	0.543	3751.98					228.0		228.0					*228.0*	35.0	3752.0	36
Bridge	8450	0.0%	1.3573	0.543	4587.51					246.1		246.1					*246.1*	33.6	4587.5	42

9266.0

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FLOOD STUDY- FREEMANS DRIVE, COORANBONG

RATIONAL METHOD HYDROLOGICAL CALCULATIONS- Developed Situation

ARI	100		
C10	0.4	Min Tc	5
Rainfall Data for:		Cooranbong	

Minimum tc	5
Method for tc	2

1 = Bransby Williams

2 = Regional $tc=0.76A^{0.38}$

3 = Kinematic Wave

Frequency Factors:

ARI	1	2	5	10	20	50	100
FFy	0.62	0.74	0.88	1	1.12	1.2351	1.357

	CATCHMENT DATA								SUBCAT. t_c				MAIN CHANNEL			TIME OF CONC.		RAINFALL INTENSITY	CA	FLOW
Node	Area	%Imperv.	FFy	C	CA	L	S	n	Bransby	Regiona	Kinema	tc	L	v	t	u/s	this			
	ha	%	-	-	ha	m	m/m	-	Min.	Min.	Min.		m	m/s	Min.	Min.	Min.	mm/hr	ha	m^3/s
Catchment outlet- Developed																				
Unnamed tributary (NE)- Upstream of Freemans Drive culverts	114	5.7%	1.35725	0.582	66.30					47.9		47.9					*47.9*	82.9	66.3	15.27
Unnamed tributary (SW)- Upstream of Freemans Drive culverts	36	25.9%	1.35725	0.719	25.87					30.9		30.9					*30.9*	104.5	25.9	7.52
Felled Timber Creek (at Dora Creek confluence)	1539	0.4%	1.35725	0.546	839.70					128.9		128.9					*128.9*	48.1	839.7	112.24
Dora Creek (at Felled Timber Creek confluence)	6911	0.0%	1.35725	0.543	3751.98					228.0		228.0					*228.0*	35.0	3752.0	365.27
Bridge	8450	0.1%	1.35725	0.544	4593.24					246.1		246.1					*246.1*	33.6	4593.2	428.65

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Appendix B

Manning's Equation Hydraulic Calculations

FLOOD STUDY- FREEMANS DRIVE, COORANBONG

MANNINGS EQUATION HYDRAULIC CALCULATIONS

$$Q = 1/n\ A\ R^{2/3}\ S_0^{1/2}$$

where n = Mannings 'n'
A = Cross-sectional Area of Flow (m^2)
R = Hydraulic Radius = A/P (m), P = Wetted Perimeter (m)
S = Channel Slope (m/m)
Q = Channel Discharge (m^3/s)

Node	Q_{design}	Chan Slope, S	Chan base RL	Flow depth y	LEFT OVERBANK REGION n	1:k	y-D	A	P	R	Q_1
	m^3/s	m/m	m	m			m	m^2	m	m	m^3/s
Trapezoidal Section											
100 year flows (existing)											
Unnamed tributary (NE) (Freemans Drive)	14.95	0.013		1.907	0.08	15	0	0	0	0	0
Unnamed tributary (NE) (Site)	14.95	0.013		1.574	0.08	15	0.07	0.04	1.11	0.04	0.01
Felled Timber Creek (Site)	111.88	0.005		3.50	0.08	10	1.5	11.3	15.1	0.75	8.2
100 year flows (developed)											
Unnamed tributary (NE) (Freemans Drive)	15.27	0.013		1.930	0.08	15	0	0	0	0	0
Unnamed tributary (NE) (Site)	15.27	0.013		1.588	0.08	15	0.09	0.06	1.32	0.04	0.01
Felled Timber Creek (Site)	112.24	0.005		3.50	0.08	10	1.5	11.3	15.1	0.75	8.23

Node	MAIN CHANNEL n	1:k	B	D	y-D	A	P	R	Q_2
			m	m	m	m^2	m	m	m^3/s
Trapezoidal Section									
100 year flows (existing)									
Unnamed tributary (NE) (Freemans Drive)	0.04	0.5	2	2	0	5.632	6.26	0.899073	14.953
Unnamed tributary (NE) (Site)	0.04	1	2	1.5	0.07	5.62	6.24	0.900335	14.938
Felled Timber Creek (Site)	0.04	0.5	2	2	1.5	12	6.47	1.854759	32.035
100 year flows (developed)									
Unnamed tributary (NE) (Freemans Drive)	0.04	0.5	2	2	0	5.722	6.32	0.90603	15.271
Unnamed tributary (NE) (Site)	0.04	1	2	1.5	0.09	5.691	6.24	0.911555	15.249
Felled Timber Creek (Site)	0.04	0.5	2	2	1.5	12.01	6.47	1.856143	32.074

Node	RIGHT OVERBANK REGION n	1:k	y-D	A	P	R	Q_3	Q_{total}	Q_{design}/Q_{total}	Top water level	Width of Flow	Velocity	F N
			m	m^2	m	m	m^3/s	m^3/s		m	m	m/s	
Trapezoidal Section													
100 year flows (existing)													
Unnamed tributary (NE) (Freemans Drive)	0.08	20	0	0.00	0	0	0	15.0	0.999777376	1.9	70.65	2.65	
Unnamed tributary (NE) (Site)	0.08	20	0.07	0.05	1.48	0.04	0.01	15.0	0.999798137	1.6	60.24	2.62	
Felled Timber Creek (Site)	0.08	87	1.5	98.01	131	0.75	71.5	111.8	1.000935137	3.5	345.10	0.92	
100 year flows (developed)													
Unnamed tributary (NE) (Freemans Drive)	0.08	20	0	0.00	0	0	0	15.3	0.999924522	1.9	71.47	2.67	
Unnamed tributary (NE) (Site)	0.08	20	0.09	0.08	1.76	0.04	0.01	15.3	0.999771796	1.6	60.76	2.62	
Felled Timber Creek (Site)	0.08	87	1.5	98.31	131	0.75	71.8	112.1	1.000954818	3.5	345.32	0.92	

REPORT

to

J W Planning Pty Ltd

for

Flood Investigation Assessment

for

North Cooranbong Investigation Area

Job No. NEW03073

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Date: February 2004
Revision C

	BY	DATE
Prepared	AB	7.3.05
Checked	BC	7.3.05

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FIGURES

1.0 Introduction

1.1 Investigation Objectives

Northrop Engineers have been engaged by J W Planning to undertake a preliminary flood inundation assessment for an investigation zone as defined by the Draft LEP 2002 (refer to LMCC correspondence dated 11 April 2003), to form part of a proposed master planning process for a 240ha parcel of land that lies to the north of Freeman's Drive and west of Avondale Road, Cooranbong.

The objectives of this investigation are to;

- Determine the peak 100 year average recurrence internal (ARI) flowrates from catchments within the study area, and
- Determine the predicted 100 year flood inundation levels with the study area.

1.2 Site Description

The 'subject site' covers an area of approximately 240ha, lying to the north of Freeman's Drive and west of Avondale Road. Refer to Figure 1 for the location and extent of the study area.

The study area has been divided into 4 major catchment areas and 3 minor catchment areas. The major catchments consist of; NW catchment, SW catchment, SE catchment and Felled Timber Creek catchment. The minor catchments consist of tributaries A-D. All areas on a regional scale form part of the Dora Creek catchment and ultimately drain to Lake Macquarie (refer Figure 2 for catchment location and extents).

The NW and SW catchments both drain from the north towards Freeman's Drive where two sets of circular culverts discharge to the south of the road and join with flow from the SE catchment before the flow is controlled by a weir located at the downstream end of the pond in the retirement village. Ultimately, this flow arrives at Dora Creek a few kilometres downstream of the pond.

The vast majority of the subject site falls within the NW catchment, whilst none of the subject site lies within the SW or SE catchments. There is however, a splitting of the NW catchment flow during major events which results in a portion of this flow arriving at the outlet point of the SW catchment. Elevations within the NW catchment range between RL48m and 3.6m, the SW catchment ranges between RL33m and RL 2.8m, whilst the SE catchment falls from RL12m to RL1.0m

Felled Timber Creek encompasses an area of approximately 1539ha (Avondale Greens Flood Investigation, PPK 2002). The subject site lies to the east of Felled Timber Creek and only contributes approximately 0.2ha of catchment to this Creek system (refer Figure 2 for catchment location and extents). Catchment elevations range from RL430m at the top of the catchment down to approximately RL7.5m in the study area and falling further to the confluence with Dora Creek, with over 10km of creek line length.

Tributary A covers an area of approximately 15.2 ha running in a westerly direction, with elevations ranging from RL 48m to RL 9m, whilst Tributary B runs south-east, comprising of approximately 9.7 ha with elevations between RL48m and RL19m. Tributary C is the largest of the minor catchments with approximately 58.1 ha flowing in an easterly direction, from RL 49m to RL9m. Tributary D is 13.9ha, meandering in a south-easterly direction, from RL36m to RL8m.

1.3 Available Data

The following information was used in the investigation;

- 1:25,000 Topographical map (with 10m contour intervals) – regional scale,
- Digital Terrain Map (DTM - with 1m contour intervals) – local site and catchment scale, derived from an aerial photograph,
- Avondale Green Pty Ltd Cooranbong Flood & Drainage Assessment Report (PPK 2002),
- Australian Rainfall & Runoff (AR&R, 1987) was used to derive rainfall intensity frequency duration (IFD) data for the Cooranbong area.

2.0 Hydraulic Modelling

2.1 Peak Flowrate Determination

Long-term stream flow data is not available within the study area (Avondale Greens Flood Study, PPK 2002) and hence the Statistical Rational Method was used to determine flowrates emanating from each catchment. Flowrates were also calculated at regular and progressive intervals along the streamline of the NW and SE catchments for use in the backwater curve modelling program suite 'Hydrologic Engineering Center's River Analysis System' (HEC RAS). Table 2.1 below depicts predicted 100year ARI flows at select locations within the study area (refer to Figure 3 for these flow locations and Appendix A for a summary of flow calculations).

Table 2.1. - 100year ARI Flowrate for select location within the study area.

Flow location	Flowrate (m^3/s)
Q1	2.06
Q2	5.73
Q3	13.01
Q4	16.02
Q5	1.36
Q6	17.41
Q7	17.81
Q8	13.34
Q9	13.70
Q10	14.49
Q11	26.49
Q12	11.06
Q13	18.26
Q14	112
Q15	0.95

Q16	2.92
Q17	0.72
Q18	2.01
Q19	4.44
Q20	6.82
Q21	8.78
Q22	0.93
Q23	2.71

It should be noted that the calculated flowrates for the NW catchment assume a 10% impervious fraction, the SE catchment assumes a 40% impervious fraction and the SW catchment a 15% impervious fraction. In the Tributaries A-D, the impervious fraction was deemed to be effectively 0%. These fractions have been determined from observation of the aerial photograph and 1:25,000 orthomap.

The flowrate for the Felled Timber Creek Catchment were reviewed, but ultimately taken from the Avondale Greens Flood Study, which estimated the peak 100yr flow at 112m^3/s.

2.2 Model Parameters

A site visit was conducted to familiarise ourselves with the study area and review the accuracy of the DTM at critical locations. Manning's 'n' values for main stream and overbank zones were ascertained during this visit and major hydraulic control influences (multiple driveway crossings) were observed along the lower section of the creek line adjacent to Freeman's Drive road crossing.

Manning 'n' values for channel flow and overbank flow were estimated during the site visit and based on published material by Chow (Chow, Van Te., Open Channel Hydraulics, 1959). Adopted stream channel 'n' values ranged from 0.05 for the upper and middle reaches to 0.13 for the lower section of the NW catchment, where multiple driveway crossings would interfere with channel flow, to 0.15 for a section of the SE catchment gully where a sub-capacity road weir crossing and dense vegetation would hinder flow. Adopted overbank 'n' values generally ranged from 0.04 through to 0.06 depending upon observed site conditions.

For the tributaries A-D, a channel 'n' value of 0.05 was chosen for each of the minor tributaries. Furthermore, given the relatively low flowrates and simple channel cross-sections, a separate overbank value was not used in the calculations.

Cross section information at regular chainages (typically 40m to 80m intervals) along the stream channel length was derived from the DTM for the NW and SE catchments. It was observed that the DTM did not match the actual geometry of the main gully line adjacent to Freeman's Drive and directly to the north. The cross-sections at these locations were manually altered to more closely represent the actual gully geometry, based on field observations.

It was further observed that the survey levels for the pond in the SE catchment seemed to relate to the pond surface rather than the pond invert levels, hence the cross-sections at these locations were also amended. Cross-section locations are shown on Figure 3.

Subcritical flow was assumed to govern the flow regime in all sub-catchments, whilst downstream control was assumed to regulate water levels at the outflow of the NW, SE and SW catchments. Table 2.2 below outlines the various downstream control structures for these catchments.

Table 2.2. - Downstream control structures for NW, SW and SE catchments for 100year ARI.

Location	Low-flow Control Type	Low-flow Control Characteristics	Predicted Spillway length (m)	Estimated Spillway RL (m –AHD)
Q7 – eastern road crossing under Freeman's Drive at outlet from NE catchment	Circular culvert	3/1200ϕ pipes	-	4.4
Q11 – pond weir at southern end of SE catchment	Broad-crested weir	-	Approx. 60m	1.55
Q12 – intercatchment overflow link	-	-	approx. 25m – channel flow	4.0
Q13 – western road crossing under Freeman's Drive at outlet from SW catchment	Circular culvert	2/900ϕ pipes	45m	3.5

From the onsite inspection it was observed that the low point along Freeman's Drive occurs adjacent to the 2/900ϕ pipes at the outlet from the SW catchment and that the road steadily grades from the outlet point of the NW catchment (approximately RL 4.4AHD) toward the outlet point from the SW catchment (approximately RL 3.5AHD). Additionally, an overflow link exists between the downstream end of the NW and SW catchments on the north side of Freemans Drive. This link has a critical overflow point of approximately RL 4.0 AHD and can serve to split higher flows and allow a significant portion of the flow to be directed towards the SW catchment.

For the 100year ARI event, all pipes were modelled with a 50% blockage factor. Due to the lack of detailed survey information on the circular culverts it was assumed that they had a hydraulic grade of 1% and were affected by high tail water conditions during the 100 year event.

Flow from the NW catchment in excess of the maximum allowable pipe flow (3/1200ϕ pipes with 50% blockage factor) and minimum water surface level of RL 4.0AHD was assumed to flow along the north side of Freeman's Drive, in a westerly direction, before combining with the flow from the SW catchment. This is due to a low level relief point on the northern edge of Freeman's Drive as previously described.

2.3 Backwater Curve Modelling Methodology

Select cross-section information for the main gully line in the NW catchment was used in HEC RAS to model the backwater curve in the NW catchment, with a starting water surface level at the culvert outlet of RL 4.2m AHD. This starting water level was derived from determining the depth of bypass flow (flowing on the north side of Freeman's Drive towards the SW catchment) and head over culvert (manual iterative procedure), assuming a 50% blockage in the culverts, using a simple Manning's equation calculation for flow depth and a standard design chart for conduit culvert capacity.

A HEC RAS simulation was then carried out for the main gully line in the SE catchment, using a starting water level of RL1.95m AHD at the Retirement Village pond weir, which is located some 200m downstream of the three 1200mm diameter culverts under Freeman's Drive (refer to Figure 3 for pond location). This starting level was determined by a simple calculation for a broad-crested weir given the full 100yr peak flow derived from the NW, SW and SE catchments (some 26.49m^3/s). An effective weir width of 65m and a coefficient of 1.71 were assumed for this calculation.

Flood levels in the SW catchment were governed by the road/weir overflow on Freeman's Drive, given a 50% blockage factor on the two 900 diameter culverts. This was estimated using the broad-crested weir equation assuming an effective weir width of 45m and coefficient of 1.71, combined with culvert flow taken from design charts.

Furthermore, there are several man-made drainage channels adjacent to the air strip towards the top end of the NW catchment, which have a tendency to concentrate flows. The extent of predicted flow for the 1 in 100yr ARI event was estimated using the Statistical Rational Method and Manning's equation.

In the case of the tributaries (A-D) the predicted flood levels in each of the streams was also determined using the Statistical Rational Method and Manning's equation. Channel cross sections were defined at select locations along the gully lines by approximations drawn from the DTM. As mentioned earlier the channel geometry for each of these tributaries was found to be relatively simple, and hence a simple prismatic geometry, with a single Manning's 'n' to cover channel and overbank, was used. Using these calculated water surface levels at the select location, we then interpolated (assuming linear interpolation) along the gully to determine the extent of the predicted flood inundation, during a 1 in 100 year ARI event, for the four tributaries.

3.0 Results

3.1 Backwater Flood Levels

Backwater flood levels were calculated for the NW and SE catchments using HEC RAS.

No defined channel was observed in the lower reaches of the SW catchment system and as such the predicted flood levels were manually calculated after estimating water levels discharging over Freeman's Drive above the 2/900ϕ pipes. In short, the predicted flow reaching this point comprises of a portion of the NW catchment flow (for major events only - NW catchment flow minus 50% of the 3/1200ϕ pipe capacity) plus the flow emanating from the SW catchment. The predicted depth of water flowing across Freeman's Drive has estimated to be approximately 400mm during the 100 year ARI event.

Given the relatively minor hydrological effect that the proposed development site has on Felled Timber Creek (i.e., subject site contribute less than 0.02% of catchment area) it was not remodelled as part of this study, but rather the predicted flood level and extent of inundation were directly taken from the Avondale Greens Flood Study (PPK, 2002).

Relatively minor inundation was predicted along each of the four tributaries. It should however be noted that Tributary C has a dam towards the lower end of the study area, and as such a widening of the predicted flow would be expected.

Tabulated results for all catchments are shown below in table 3.1, whilst the land area that is predicted to be affected by the 100 year flood is shown in Figure 4.

Table 3.1. - Predicted 100year ARI Water Level

Location	Predicted 100year ARI Water Level (m AHD)
Q1 – NW catchment upstream extent of HEC RAS model	14.16
Q2 – NW catchment	12.09
Q3 – NW catchment	9.15
Q4 – NW catchment	7.00
Q6 – NW catchment	5.28
Q7 – pipe crossing under Freeman's Drive for NW catchment	4.20
Q8 – upstream end of SE catchment	3.90
Q9 – midstream of SE catchment	2.99
Q10 – middle of pond in SE catchment	1.95
Q13 – outlet across Freeman's Drive from SW Catchment	3.90
Felled Timber Creek – upstream extent of study area under Avondale Greens Flood Study (PPK, 2002)	9.5
Felled Timber Creek – downstream extent of study area under Avondale Greens Flood Study (PPK, 2002)	8.5
Q15 – Tributary A, Node 1	20.26
Q16 – Tributary A, Node 2	9.31
Q17 – Tributary B, Node 1	28.20
Q18 – Tributary B, Node 2	19.11
Q19 – Tributary C, Node 1	23.32
Q20 – Tributary C, Node 2	16.50
Q21 – Tributary C, Node 3	9.55
Q22 – Tributary D, Node 1	21.19
Q23 – Tributary D, Node 2	12.25

4.0 Conclusion

Based on the Statistical Rational Method, Manning's Equation and the hydraulic program suite HEC RAS, the 100 year ARI flood affected areas of the study area have been predicted and, with graphical interpolation, are presented in Figure 4, whilst Appendix B presents the tabulated water surface levels for each cross section modelled within HEC RAS.

Predicted flood inundation levels along the creek line between Freeman's Drive and the Retirement Village pond, and to the north of Freeman's Drive adjacent to the creek line can be seen to threaten low lying residences. A major contributing factor to flooding within these areas is the choked creek conditions (dense vegetation and litter) and sub-capacity driveway crossing structures.

It should be noted that there may be other isolated locations within the study area where overland flow could potentially pond and that have not been identified within this report. These areas may seem flood prone but are generally due to minor changes to the landscape, typically man made, which could result in wet or boggy ground. This report was aimed at identifying flood prone land for the purpose of developing a subdivision and therefore we may not have included these areas in the report given that the relatively minor flows could easily be dealt within the subdivision design.

5.0 Model Constraints and Limitation of Analysis

It should be noted that with any type of flood investigation study there are a variety of limitations inherent within models, model parameters and modelling methodologies. This particular study is based on information derived form aerial photogrammetry, and consequently predicted flood levels can be taken to be indicative only.

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APPENDIX A - ESTIMATED FLOWRATE (PAGE 1/2)

C10 imp. 0.9
C10 per. 0.37

subcatchment analysis

NORTH CATCHMENT

Flow location	subcatchment	Area	FF_{100}	Imp. Frac.	Total C_{10}	Tc (progressive)	Intensity	Flowrate	Cumulative Flowrate
		ha	-	(%)	-	min	mm/hr	m3/s	m3/s
Q1	NW1	9.1613	1.3573	10	0.423	18.39	140.0	2.06	2.06
Q2	NW2	20.3056	1.3573	10	0.423	28.70	112.0	3.66	5.72
Q3	NW3	48.8588	1.3573	10	0.423	41.50	92.9	7.30	13.01
Q4	NW4	21.5452	1.3573	10	0.423	45.60	87.8	3.04	16.06
Q5	NW5	9.8100	1.3573	10	0.423	47.20	86.0	1.36	
Q6	NW6	confulence							17.41
Q7	NW7	2.8500	1.3573	10	0.423	47.70	85.8	0.39	17.81
Q8	SE1	1.8000	1.3573	40	0.582	48.00	85.3	0.34	13.34
Q9	SE2	1.9300	1.3573	40	0.582	48.30	85.1	0.36	13.70
Q10	SE3	4.2000	1.3573	40	0.582	48.90	84.6	0.79	14.49
Q11	below se catchment								26.49
Q12	SW1	divergence						11.06	
Q13	SW2	sw outlet						7.2	18.26
Q14									
Q15	TribA1	4.2344	1.3573	0	0.37	13.71	159.6	0.95	0.95
Q16	TribA2	11.0313	1.3573	0	0.37	22.32	127.0	1.97	2.92
Q17	TribB1	3.0396	1.3573	0	0.37	12.09	168.1	0.72	0.72
Q18	TribB2	6.6518	1.3573	0	0.37	18.78	137.8	1.29	2.01
Q19	TribC1	27.8281	1.3573	0	0.37	28.05	113.4	4.44	4.44
Q20	TribC2	16.2500	1.3573	0	0.37	33.40	104.3	2.38	6.82
Q21	TribC3	14.0312	1.3573	0	0.37	37.10	99.1	1.96	8.78
Q22	TribD1	4.1133	1.3573	0	0.37	13.56	160.4	0.93	0.93
Q23	TribD2	9.8164	1.3573	0	0.37	21.56	129.1	1.78	2.71

APPENDIX A - ESTIMATED FLOW DEPTHS (PAGE 2/2)

MANNINGS FLOW CALCULATIONS

From Mannings Eqn= $(^1/_n)*(A)*(R^{2/3})*(S_o^{1/2})$

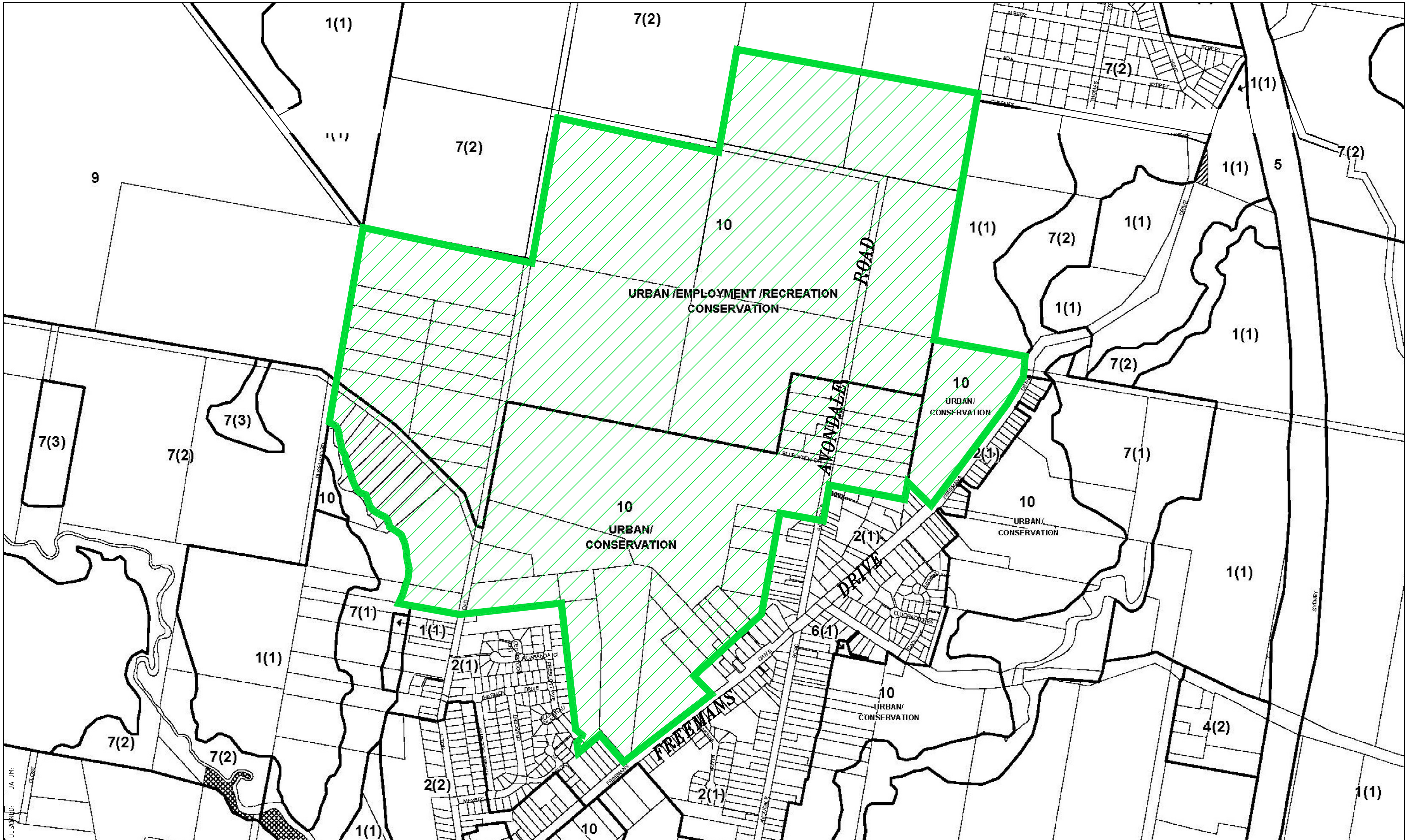
Mannings equation was used to solve for flow depth, given a flow rate.

Flow Location	Flowrate	Mannings 'n'	Side Slope	Flow Width	Flowdepth	X-sect Area	Wetted Peri.	Hyd. Radius	Channel Slope	Calc Q	Error:
Q15	0.95	0.05	0.075	6.86	**0.26**	0.88	6.88	0.128	0.045	0.951	3E-07
Q16	2.92	0.05	0.041	15.22	**0.31**	2.38	15.24	0.156	0.045	2.919	2E-07
Q17	0.72	0.05	0.059	6.89	**0.20**	0.70	6.90	0.101	0.056	0.719	7E-07
Q18	2.01	0.05	0.040	23.44	**0.11**	2.25	23.44	0.096	0.045	2.007	1E-07
Q19	4.44	0.05	0.025	25.86	**0.32**	4.18	25.87	0.162	0.032	4.435	6E-07
Q20	6.82	0.05	0.039	25.64	**0.50**	6.41	25.66	0.250	0.018	6.819	4E-07
Q21	8.78	0.05	0.046	23.72	**0.55**	6.47	23.75	0.273	0.026	8.775	3E-08
Q22	0.93	0.05	0.031	12.36	**0.19**	1.18	12.37	0.096	0.035	0.927	4E-07
Q23	2.71	0.05	0.020	25.17	**0.25**	3.17	25.18	0.126	0.029	2.710	2E-10
	(m3/s)	**-**	**(m/m)**	**(m)**	**(m)**	**(m2)**	**(m)**	**(m2/m)**	**(m/m)**		

Appendix B - Water Surface Level Information

The following table depicts predicted water surface levels at each cross-section modelled with HEC RAS. Figure 3 graphically depicts the location of each cross-section within the subject site.

Catchment	Section No.	Predicted 100yr ARI Water Level (AHD)
NW	105	14.16
NW	104	13.78
NW	103	13.26
NW	102	12.88
NW	101	12.33
NW	100	12.22
NW	99	12.07
NW	98	11.68
NW	96	10.64
NW	95	10.37
NW	94	9.86
NW	93	9.42
NW	92	9.17
NW	91	8.64
NW	90	8.39
NW	88	7.68
NW	87	7.30
NW	86	7.00
NW	85	6.23
NW	83	5.88
NW	81	5.28
NW	79	4.61
NW	78	4.20
SE	10	3.90
SE	9	3.48
SE	8	2.99
SE	7	1.86
SE	6	1.95



SOURCE: LAKE MACQUARIE CITY COUNCIL EXTRACT FROM LAKE MACQUARIE LEP 2004 MAP22 & 28

SCALE 1:10000 @ A3

DENOTES SUBJECT SITE

ISSUE	AMENDMENT	DATE
1	INFORMATION	09.07.03
2	INFORMATION	29.04.04

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PROJECT
STORMWATER MANAGEMENT INVESTIGATION
AVONDALE RD, COORANBONG

DRAWING TITLE
INVESTIGATION AREA PLAN

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FAX (02) 49297515
ABN 82 064 775 088

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NEW03073

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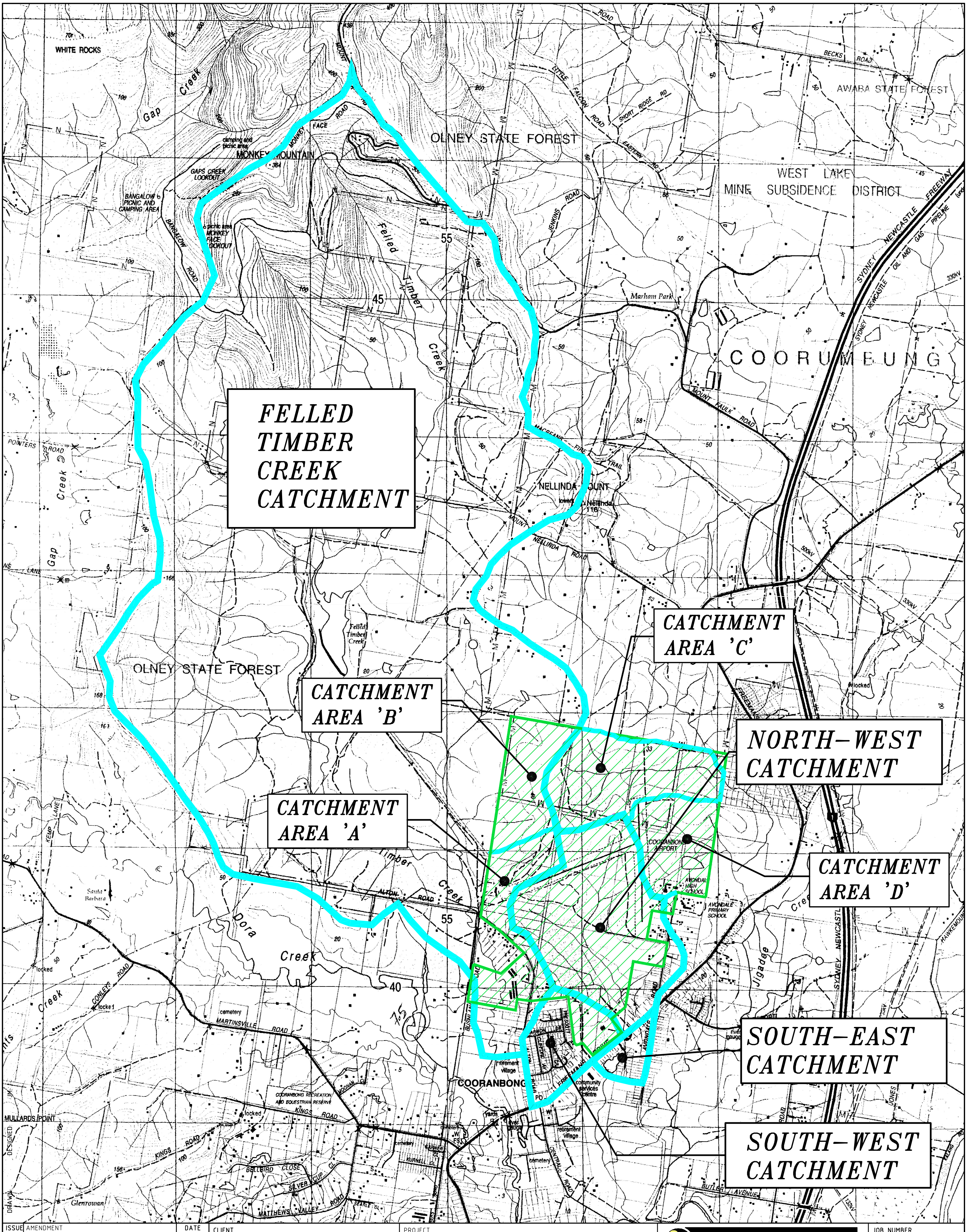
FIG.1 (2)

NUMBER IN SET:



ISSUE	AMENDMENT	DATE
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AVONDALE RD, COORANBONG

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CATCHMENT PLAN
SCALE 1:25000

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PH (02) 49295744
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JOB NUMBER
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FIG.2 (2)
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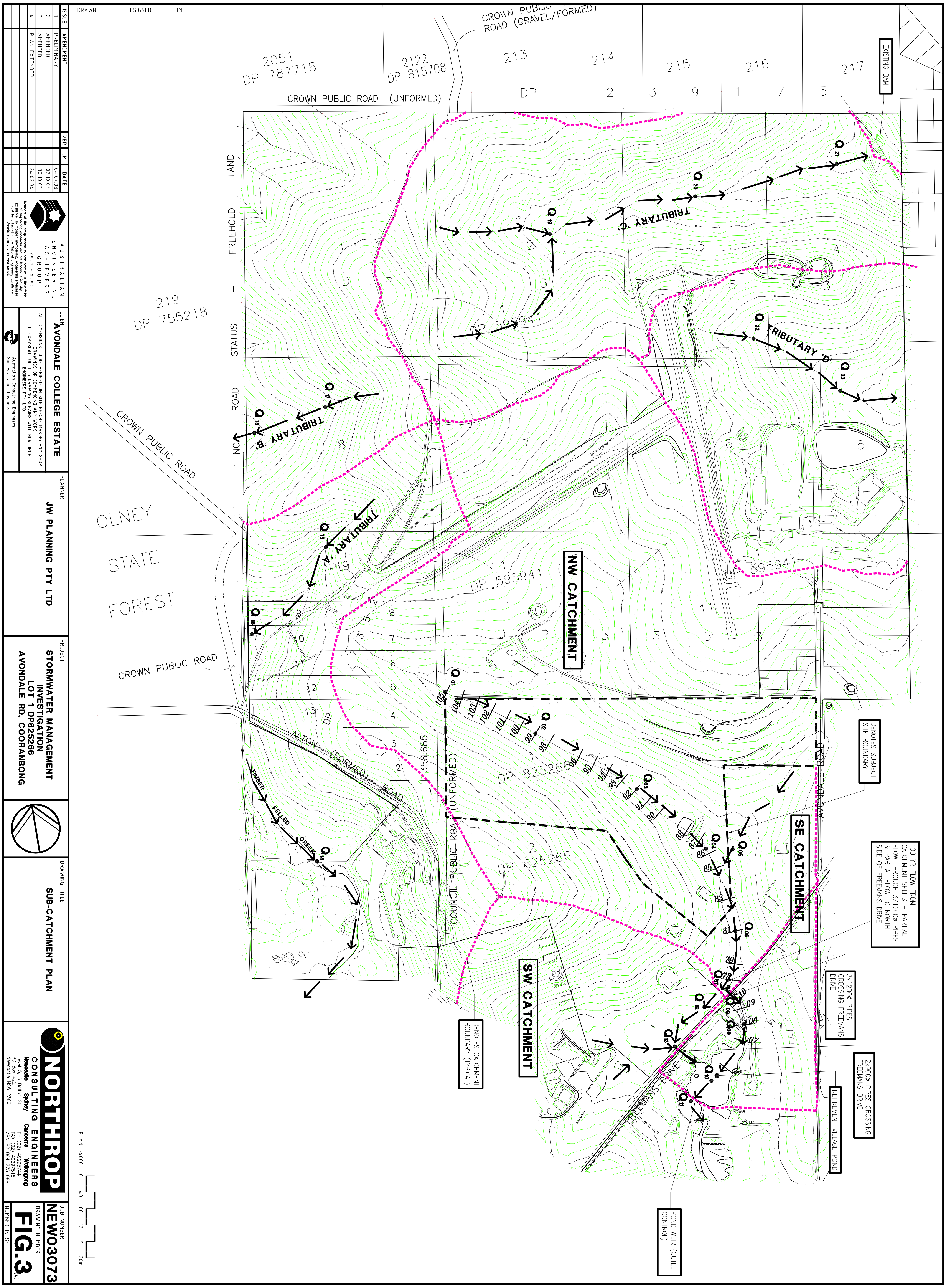
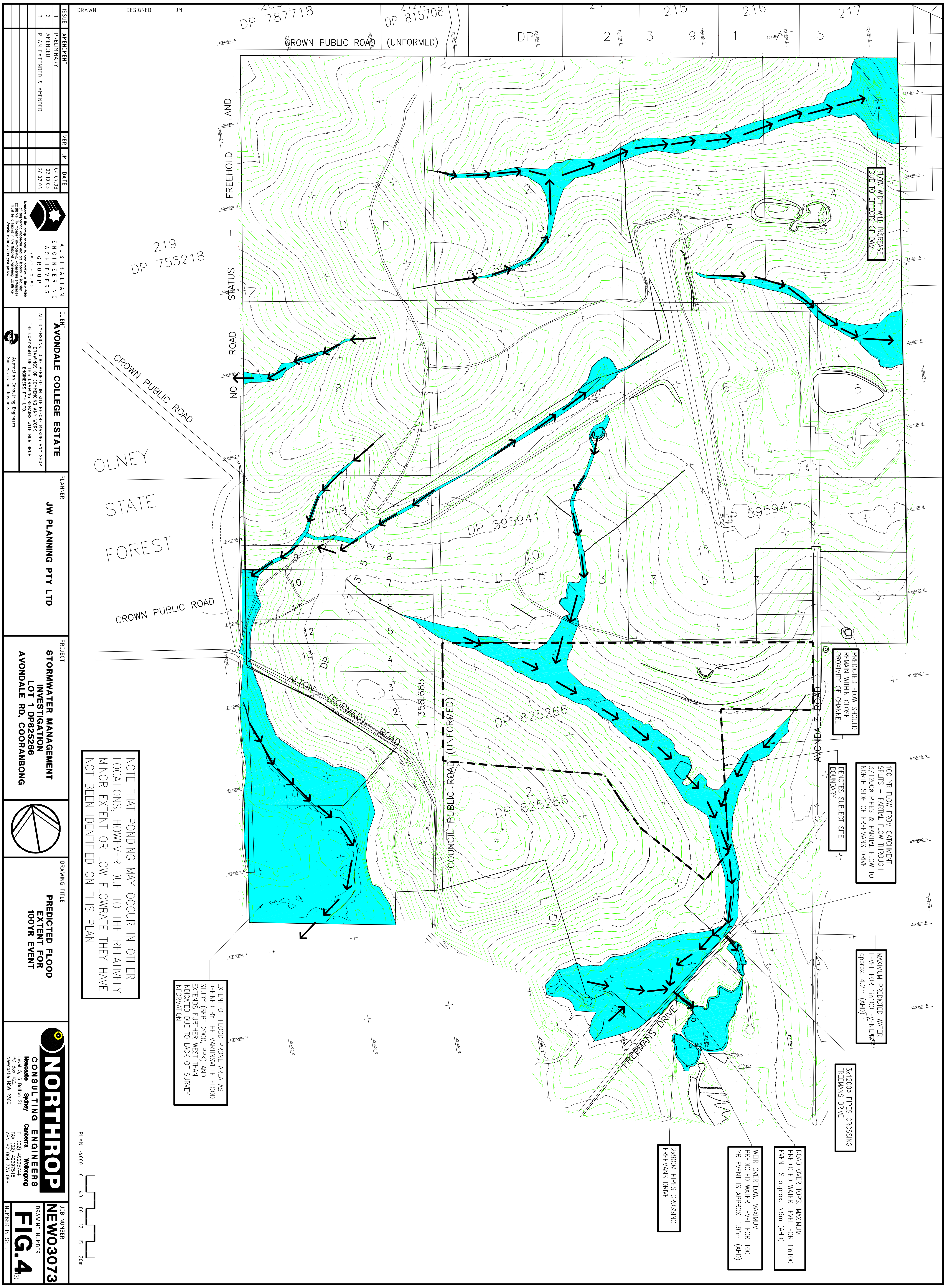


CROWN PUBLIC ROAD (GRAVEL/FORMED)
CROWN PUBLIC ROAD
(UNFORMED)
2051 DP 787718
2122 DP 815708
213
214
215
216
217
EXISTING DAM
219 DP 755218
LAND - FREEHOLD - STATUS - ROAD - NON
CROWN PUBLIC ROAD
OLNEY STATE FOREST
CROWN PUBLIC ROAD
ALTON (FORMED) ROAD
TIMBER FELLED CREEK
TRIBUTARY 'A'
TRIBUTARY 'B'
TRIBUTARY 'C'
TRIBUTARY 'D'
DP 595941
DP 825266
NW CATCHMENT
SE CATCHMENT
SW CATCHMENT
COUNCIL PUBLIC ROAD (UNFORMED)
AVONDALE ROAD
FREEMANS DRIVE
DENOTES SUBJECT SITE BOUNDARY
DENOTES CATCHMENT BOUNDARY (TYPICAL)
100 YR FLOW FROM CATCHMENT SPLITS - PARTIAL FLOW THROUGH 3/1200Ø PIPES & PARTIAL FLOW TO NORTH SIDE OF FREEMANS DRIVE
3x1200Ø PIPES CROSSING FREEMANS DRIVE
2x900Ø PIPES CROSSING FREEMANS DRIVE
RETIREMENT VILLAGE POND
POND WEIR (OUTLET CONTROL)
PLAN 1:4000
CLIENT AVONDALE COLLEGE ESTATE
PLANNER JW PLANNING PTY LTD
PROJECT STORMWATER MANAGEMENT INVESTIGATION LOT 1 DP825266 AVONDALE RD, COORANBONG
DRAWING TITLE SUB-CATCHMENT PLAN
NORTHROP CONSULTING ENGINEERS
JOB NUMBER NEW03073
DRAWING NUMBER FIG.3



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DRAWING TITLE
PREDICTED FLOOD EXTENT FOR 100YR EVENT
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Level 5, 6 Bolton St
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PH (02) 49295744
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ABN 82 064 775 088
PLAN 1:4000
0 40 80 120 160 200m
JOB NUMBER
NEW03073
DRAWING NUMBER
FIG.4
NUMBER IN SET
(3)
DP 787718
DP 815708
CROWN PUBLIC ROAD (UNFORMED)
215
216
217
FREEHOLD LAND - STATUS OF ROAD NOT KNOWN
219
DP 755218
CROWN PUBLIC ROAD
OLNEY STATE FOREST
CROWN PUBLIC ROAD
ALTON (FORMED) ROAD
COUNCIL PUBLIC ROAD (UNFORMED)
DP 595941
DP 825266
AVONDALE ROAD
FREEMANS DRIVE
FLOW WIDTH WILL INCREASE DUE TO EFFECTS OF DAM
PREDICTED FLOW SHOULD REMAIN WITHIN CLOSE PROXIMITY OF CHANNEL
DENOTES SUBJECT SITE BOUNDARY
100 YR FLOW FROM CATCHMENT SPLITS - PARTIAL FLOW THROUGH 3/1200ø PIPES & PARTIAL FLOW TO NORTH SIDE OF FREEMANS DRIVE
MAXIMUM PREDICTED WATER LEVEL FOR 1in100 EVENT IS approx. 4.2m (AHD)
3x1200ø PIPES CROSSING FREEMANS DRIVE
ROAD OVER TOPS. MAXIMUM PREDICTED WATER LEVEL FOR 1in100 EVENT IS approx. 3.9m (AHD)
WEIR OVERFLOW. MAXIMUM PREDICTED WATER LEVEL FOR 100 YR EVENT IS APPROX. 1.95m (AHD)
2x900ø PIPES CROSSING FREEMANS DRIVE
EXTENT OF FLOOD PRONE AREA AS DEFINED BY THE MARTINSVILLE FLOOD STUDY (SEPT 2000, PPK) AND EXTENDS FURTHER WEST THAN INDICATED DUE TO LACK OF SURVEY INFORMATION
NOTE THAT PONDING MAY OCCUR IN OTHER LOCATIONS, HOWEVER DUE TO THE RELATIVELY MINOR EXTENT OR LOW FLOWRATE THEY HAVE NOT BEEN IDENTIFIED ON THIS PLAN