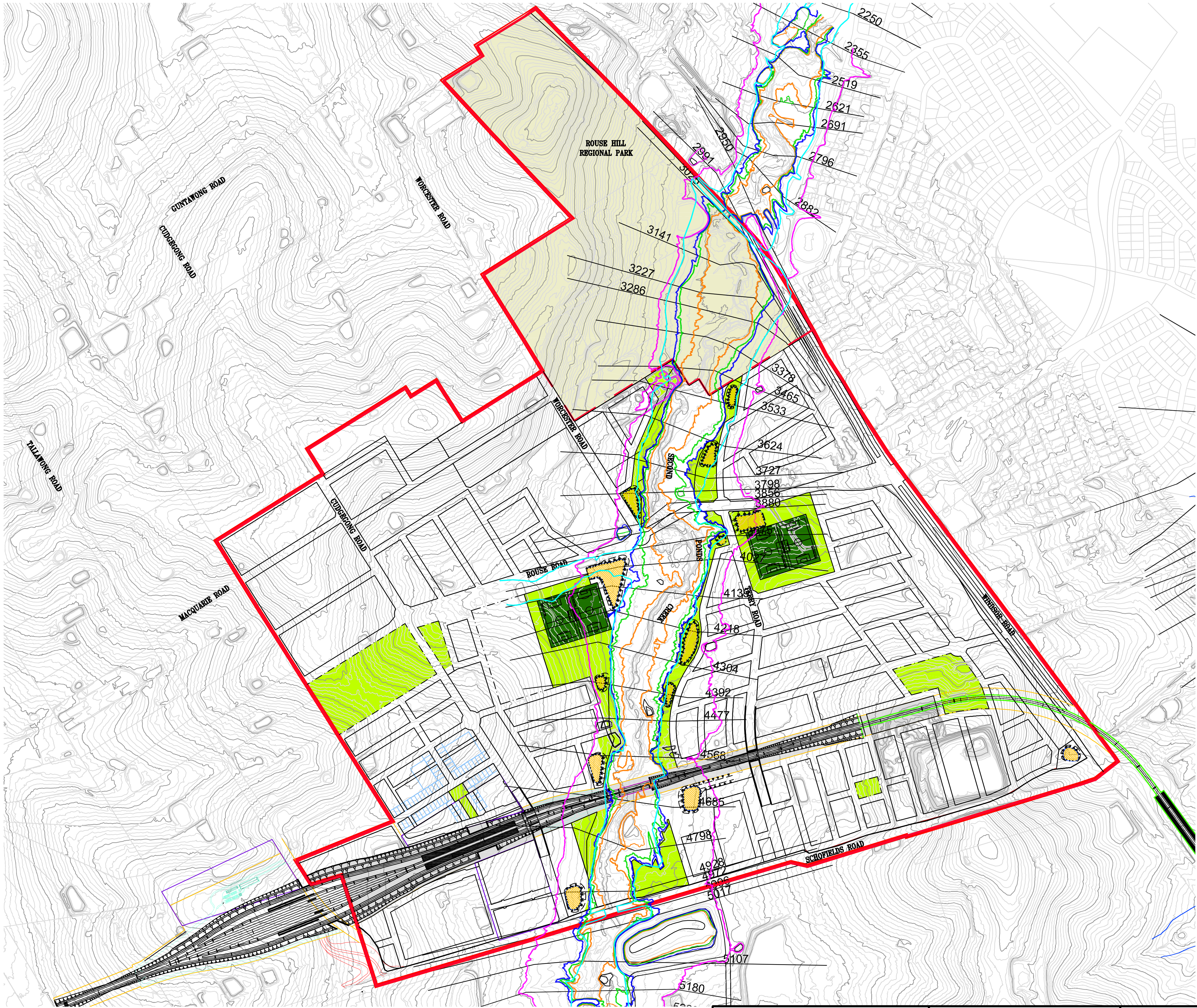

LEGEND

- AREA 20 PRECINCT BOUNDARY
- 2 YEAR ARI ULTIMATE FLOOD EXTENTS
- 20 YEAR ARI ULTIMATE FLOOD EXTENTS
- 100 YEAR ARI ULTIMATE FLOOD EXTENTS
- PMF ULTIMATE FLOOD EXTENTS
- 100 YEAR ARI FLOOD EXTENTS (SYDNEY WATER ADOPTED MODEL)
- 3227 HEC-RAS SECTION & STATION NUMBER
- PARK
- SPORTING FIELD

FIGURE 6

100 50 0 50 100 150 200 250 300 350 400 450 500
METRES

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ISSUE	AMENDMENT	DATE	BY
F			
E			
D			
C	AMENDMENTS FOR RAIL CORRIDOR	OCT 10	DG
B	SECOND ISSUE	JUN 10	VG
A	FIRST ISSUE	SEPT 09	NM

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AREA 20 PRECINCT, ROUSE HILL

2, 20 & 100 YEAR ARI & PMF ULTIMATE FLOOD EXTENTS AND HEC - RAS RIVER STATION LAYOUT AND NUMBERS

PLAN No. 8622/SW06 C
FILE No. 8622SW06
SHEET 6 OF 10 SHEETS

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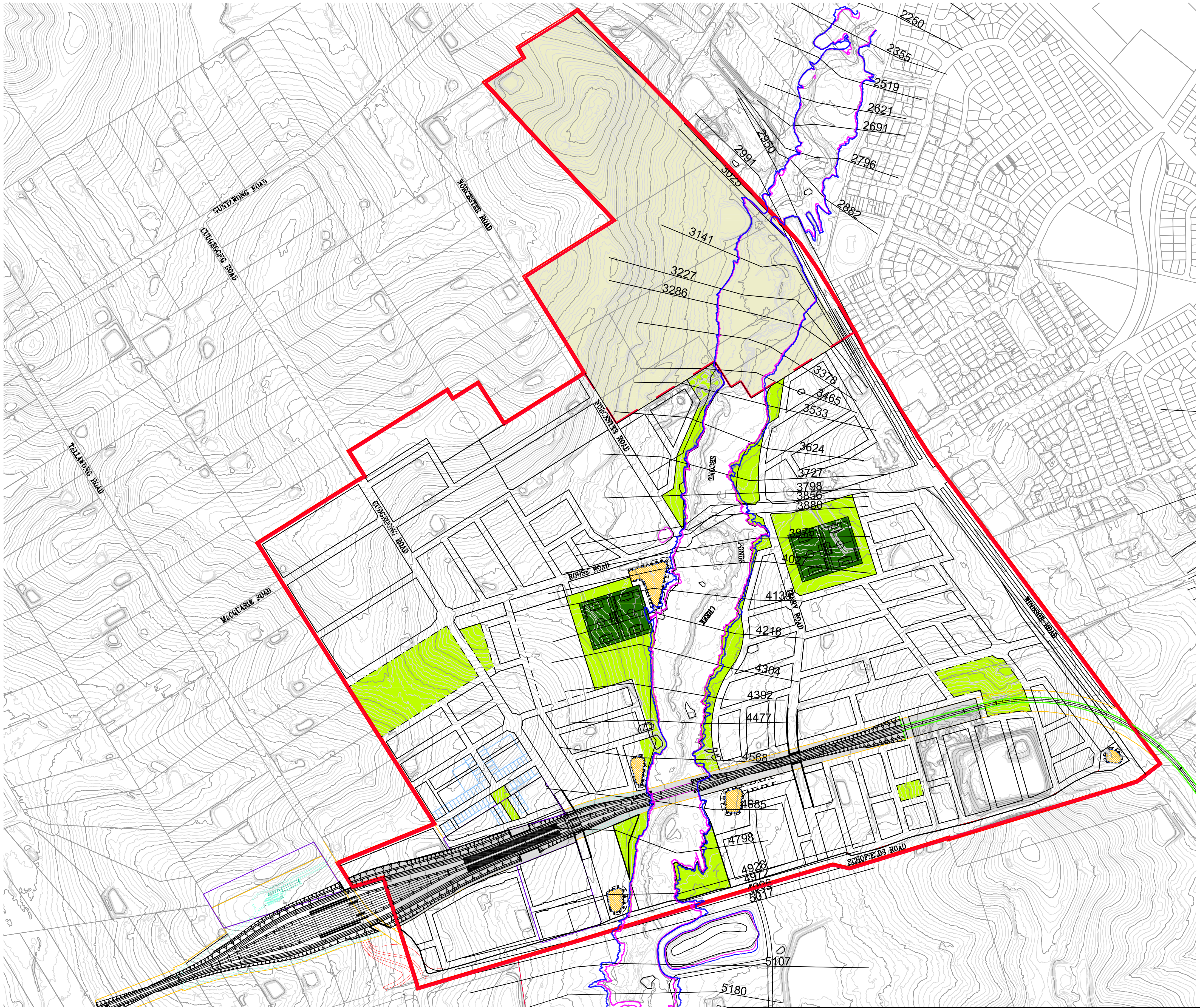

LEGEND

- AREA 20 PRECINCT BOUNDARY
- 100 YEAR ARI FLOOD EXTENTS - PRE CLIMATE CHANGE
- 100 YEAR ARI FLOOD EXTENTS - POST CLIMATE CHANGE
- 3227 HEC-RAS SECTION & STATION NUMBER
- PARK
- SPORTING FIELD

FIGURE 7

100 50 0 50 100 150 200 250 300 350 400 450 500
METRES

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AREA 20 PRECINCT, ROUSE HILL

100 YEAR ARI FLOOD EXTENTS
PRE & POST CLIMATE CHANGE

PLAN No. 8622/SW07 C
FILE No. 8622SW07
SHEET 7 OF 10 SHEETS

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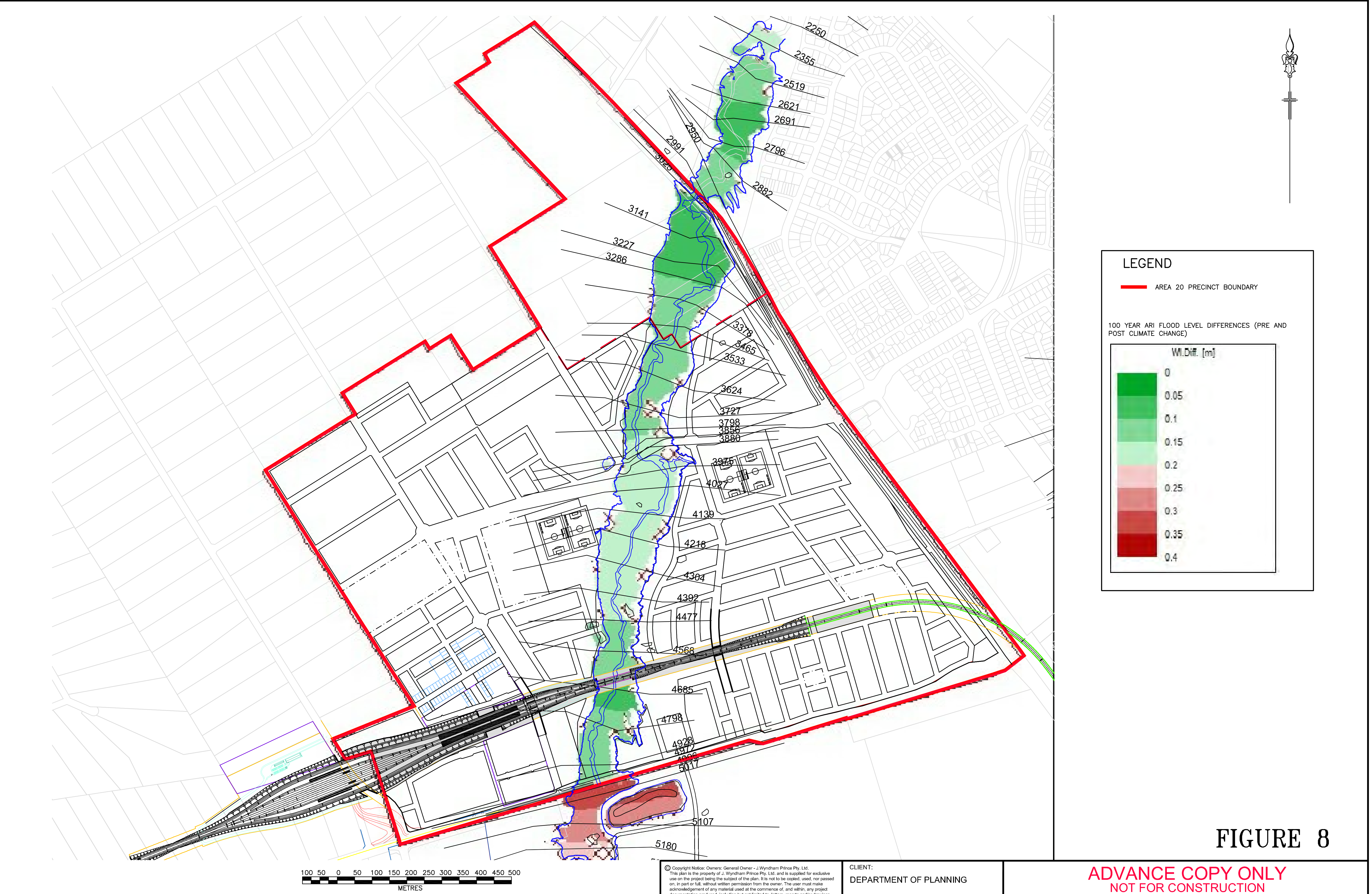

FIGURE 8

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AREA 20 PRECINCT, ROUSE HILL

100 YEAR ARI FLOOD DIFFERENCE MAP
(PRE AND POST CLIMATE CHANGE)

PLAN No. 8622/SW08 C
FILE No. 8622SW08
SHEET 8 OF 10 SHEETS

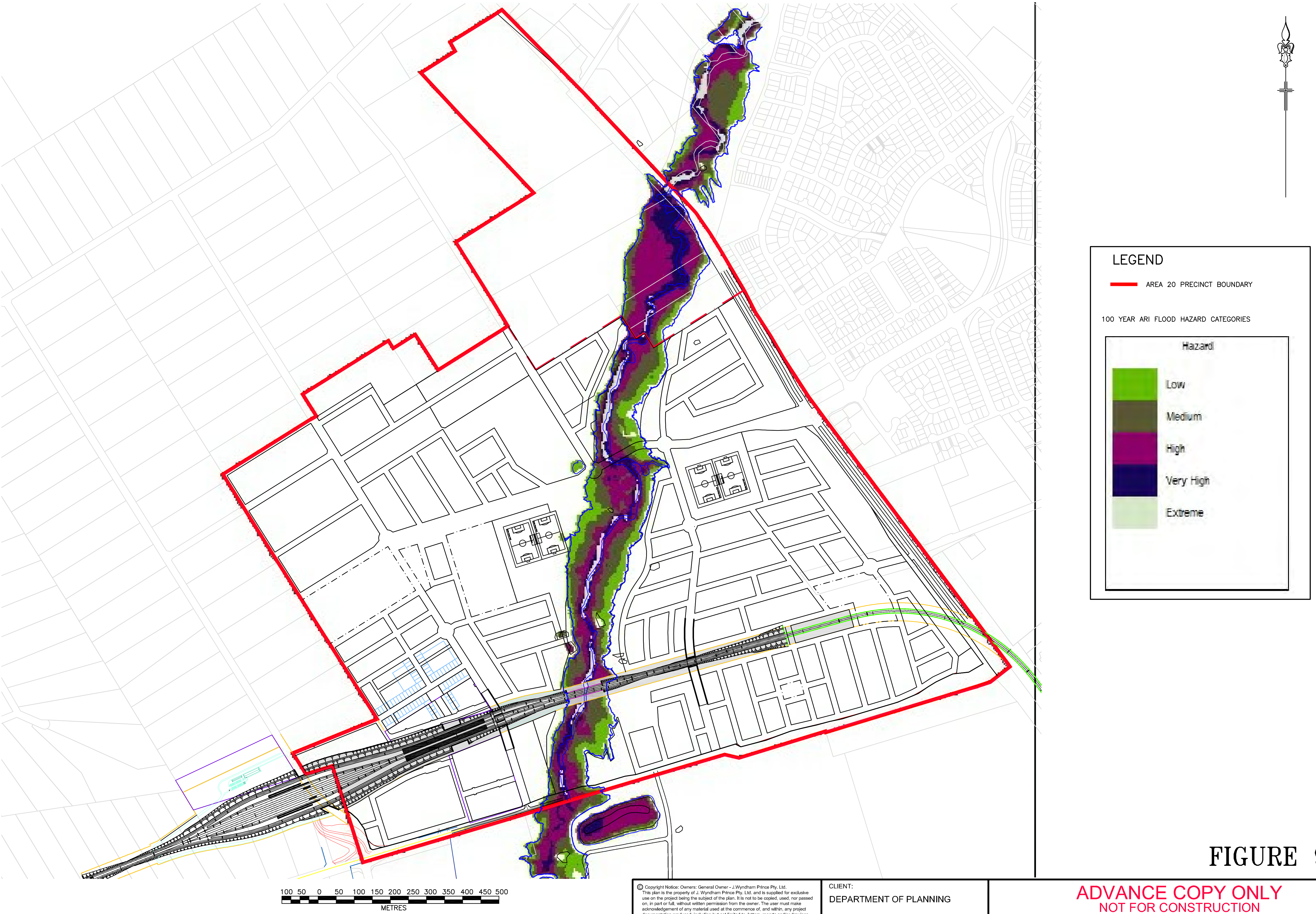

FIGURE 9

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AREA 20 PRECINCT, ROUSE HILL

100 YEAR ARI FLOOD HAZARD CATEGORY MAP

PLAN No. 8622/SW09 B
FILE No. 8622SW09
SHEET 9 OF 10 SHEETS

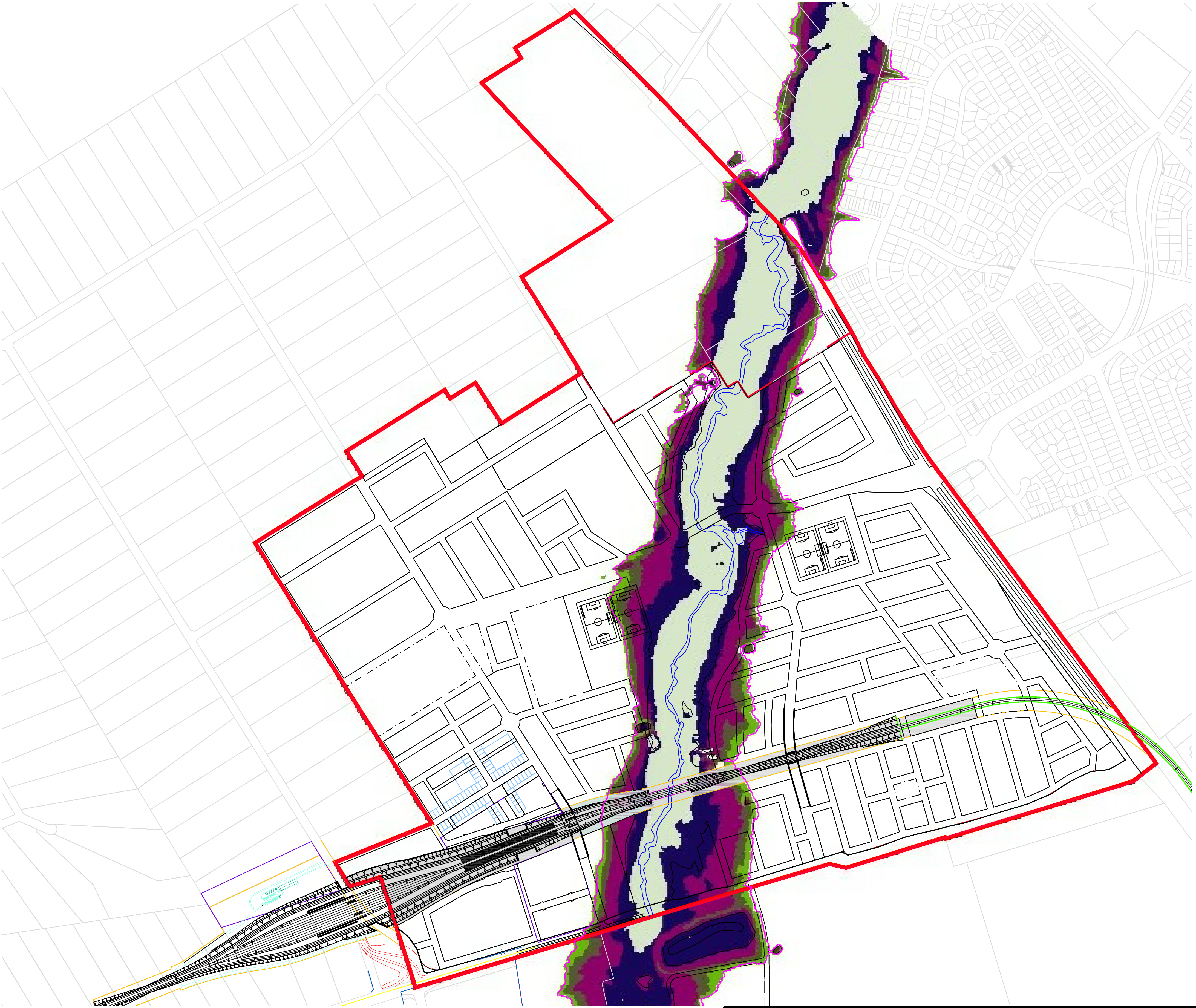

FIGURE 10

100 50 0 50 100 150 200 250 300 350 400 450 500
METRES

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AREA 20 PRECINCT, ROUSE HILL

PMF FLOOD HAZARD CATEGORY MAP

PLAN No. 8622/SW10 B
FILE No. 8622SW10
SHEET 10 OF 10 SHEETS

Attachment A

Indicative Layout Plan


Area 20 Precinct
Draft Indicative Layout Plan
Precinct Boundary
Land to which Precinct Plan Applies
Local Centre
Mixed Use
Light Industrial
Preferred Location for Neighbourhood Services
Medium to High Density Residential
Medium Density Residential
Low Density Residential
Very Low Density Residential
School
Parks
Sporting Fields
Drainage & Infrastructure
Bio-Retention Area
Riparian Corridor
North West Rail Link Corridor Extension
Commuter Car Park
Major Road
Local Road
Proposed Traffic Signal
Bus Interchange
Existing Transmission Easement
Creek Line
Scale
0 100 200 500m
1:5,000 @ A1
1:10,000 @ A3
NSW
Planning
BOX HILL INDUSTRIAL
WINDSOR ROAD
ANNANGROVE ROAD
WORCESTER ROAD
ROUSE HILL HOUSE & ESTATE
CURRENT PLANNING CONTROLS UNCHANGED
ROUSE HILL REGIONAL PARK
RIVERSTONE EAST
CUDGEGONG ROAD
SYDNEY WATER RESERVOIR SITE
WORCESTER RD
EXISTING ANGLICAN SCHOOL
EXISTING OVAL
MILE END RD
ROUSE HILL
ROUSE RD
BRIDGE
MACQUARIE ROAD
ROUSE RD
COMMERCIAL RD
SCHOOL
CUDGEGONG RD
TERRY RD
CUDGEGONG RESERVE
COMMERCIAL RD WEST
WINDSOR ROAD
TALLAWONG ROAD
ROUSE HILL TOWN CENTRE
ELEC. SUB
PROPOSED STABLING YARD
SCHOFIELDS ROAD
THE PONDS
SCHOFIELDS ROAD
ALEX AVENUE

Attachment B

Riparian Corridor Extents Within Area 20

Figure 3 Riparian categories within Area 20

Attachment C

Condition Assessment And Performance Evaluation Of Bioretention Systems - Practice Note 1: In Situ Measurement of Hydraulic Conductivity

CONDITION ASSESSMENT AND PERFORMANCE EVALUATION OF BIORETENTION SYSTEMS

PRACTICE NOTE 1: *In Situ* Measurement of Hydraulic Conductivity

Belinda Hatt, Sebastien Le Coustumer

April 2008

The Facility for Advancing Water Biofiltration (FAWB) aims to deliver its research findings in a variety of forms in order to facilitate widespread and successful implementation of biofiltration technologies. This Practice Note for *In Situ* Measurement of Hydraulic Conductivity is the first in a series of Practice Notes being developed to assist practitioners with the assessment of construction and operation of biofiltration systems.

1. SCOPE OF THE DOCUMENT

This Practice Note for *In Situ* Measurement of Hydraulic Conductivity is designed to complement FAWB's Guidelines for Soil Filter Media in Bioretention Systems, Version 2.01 (visit http://www.monash.edu.au/fawb/publications/index.html for a copy of these guidelines). However, the recommendations contained within this document are more widely applicable to assessing the hydraulic conductivity of filter media in existing biofiltration systems.

For new systems, this Practice Note ***does not*** remove the need to conduct laboratory testing of filter media prior to installation.

2. DETERMINATION OF HYDRAULIC CONDUCTIVITY

The recommended method for determining *in situ* hydraulic conductivity uses a single ring infiltrometer under constant head. The single ring infiltrometer consists of a small plastic or metal ring that is driven 50 mm into the soil filter media. It is a constant head test that is conducted for two different pressure heads (50 mm and 150 mm). The head is kept constant during all the experiments by pouring water into the ring. The frequency of readings of the volume poured depends on the filter media, but typically varies from 30 seconds to 5 minutes. The experiment is stopped when the infiltration rate is considered steady (i.e., when the volume poured per time interval remains constant for at least 30 minutes). This method has been used extensively (e.g. Reynolds and Elrick, 1990; Youngs *et al.*, 1993).

Note: This method measures the hydraulic conductivity at the surface of the soil filter media. In most cases, it is this top layer which controls the hydraulic conductivity of the system as a whole (i.e., the underlying drainage layer has a flow capacity several orders of magnitude higher than the filter media), as it is this layer where fine sediment will generally be deposited to form a "clogging layer". However this shallow test would not be appropriate for systems where the controlling layer is not the surface layer (e.g. where migration of fine material down through the filter media has caused clogging within the media). In this case, a 'deep ring' method is required; for further information on this method, please consult FAWB's report "Hydraulic performance of biofilter systems for stormwater management: lessons from a field study", available at www.monash.edu.au/fawb/publications/index.html.

2.1 Selection of monitoring points

For bioretention systems with a surface area less than 50 m^2, *in situ* hydraulic conductivity testing should be conducted at three points that are spatially distributed (Figure 1). For systems with a surface area greater than 50 m^2,an extra monitoring point should be added for every additional 100 m^2. It is ***essential*** that the monitoring point is flat and level. Vegetation should not be included in monitoring points.

Figure 1. Spatially distributed monitoring points

2.2 Apparatus

The following is required:

- 100 mm diameter PVC rings with a height of at least 220 mm. The bottom edge of the ring should be bevelled and the inside of the ring should be marked to indicate 50 mm and 150 mm above the filter media surface (Figure 2).
- 40 L water
- 100 mL, 250 mL and 1000 mL measuring cylinders
- Stopwatch
- Thermometer

- Measuring tape
- Spirit level
- Hammer
- Block of wood, approximately 200 x 200 mm

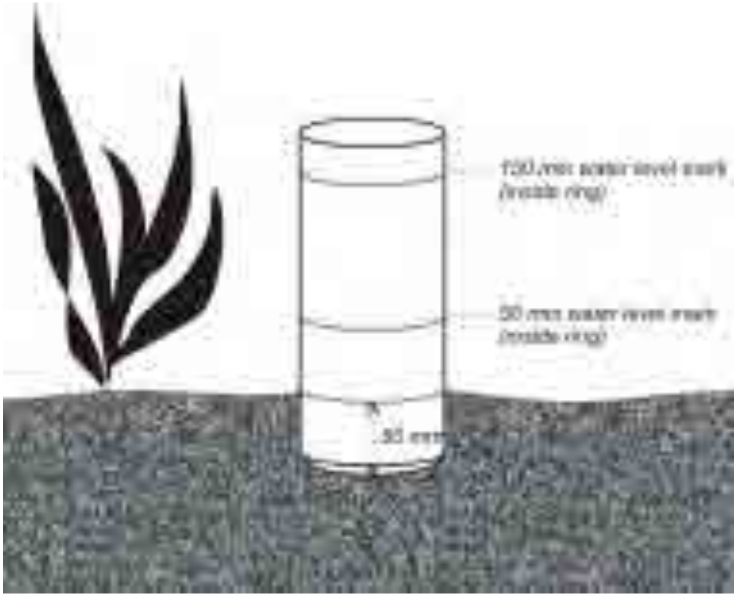

Figure 2. Diagram of single ring infiltrometer

2.3 Procedure

a. Carefully scrape away any surface covering (e.g. mulch, gravel, leaves) ***without disturbing*** the soil filter media surface (Figure 3b).

b. Locate the ring on the surface of the soil (Figure 3c), and then place the block of wood on top of the ring. Gently tap with the hammer to drive the ring 50 mm into the filter media (Figure 3d). Use the spirit level to check that the ring is level.

   Note: It is ***essential*** that this the ring is driven in slowly and carefully to minimise disturbance of the filter media profile.

c. Record the initial water temperature.

d. Fill the 1000 mL measuring cylinder.

e. Using a different pouring apparatus, slowly fill the ring to a ponding depth of 50 mm, taking care to minimise disturbance of the soil surface (Figure 3f). Start the stopwatch when the water level reaches 50 mm.

f. Using the 1000 mL measuring cylinder, maintain the water level at 50 mm (Figure 3g). After 30 seconds, record the volume poured.

g. Maintain the water level at 50 mm, recording the time interval and volume required to do so.

Note: The time interval between recordings will be determined by the infiltration capacity of the filter media. For fast draining media, the time interval should not be greater than one minute however, for slow draining media, the time between recordings may be up to five minutes.

Note: The smallest measuring cylinder that can pour the volume required to maintain a constant water level for the measured time interval should be used for greater accuracy. For example, if the volume poured over one minute is 750 mL, then the 1000 mL measuring cylinder should be used. Similarly, if the volume poured is 50 mL, then the 100 mL measuring cylinder should be used.

h. Continue to repeat Step f until the infiltration rate is steady i.e., the volume poured per time interval remains constant for at least 30 minutes.

i. Fill the ring to a ponding depth of 150 mm (Figure 3h). Restart the stopwatch. Repeat steps e – g for this ponding depth.

Note: Since the filter media is already saturated, the time required to reach steady infiltration should be less than for the first ponding depth.

j. Record the final water temperature.

k. Enter the temperature, time, and volume data into a calculation spreadsheet (see "Practice Note 1_Single Ring Infiltration Test_Example Calculations.xls", available at www.monash.edu.au/fawb/publications/index.html, as an example).

2.4 Calculations

In order to calculate K_{fs} a 'Gardner's' behaviour for the soil should be assumed (Gardner, 1958 in Youngs *et al.*, 1993):

$$K(h) = K_{fs} e^{\alpha h} \qquad \text{Eqn. 1}$$

where K is the hydraulic conductivity, α is a soil pore structure parameter (large for sands and small for clay), and h is the negative pressure head. K_{fs} is then found using the following analytical expression (for a steady flow) (Reynolds and Elrick, 1990):

$$K_{fs} = \frac{G}{a}\left(\frac{Q_2 - Q_1}{H_2 - H_1}\right) \qquad \text{Eqn. 2}$$

where a is the ring radius, H_1 and H_2 are the first (50 mm) and second (150 mm) pressure heads, respectively, Q_1 and Q_2 are the steady flows for the first and second pressure heads, respectively, and G is a shape factor estimated as:

$$G = 0.316\frac{d}{a} + 0.184 \qquad \text{Eqn. 3}$$

where d is the depth of insertion of the ring and a is the ring radius.

G is nearly independent of soil hydraulic conductivity (i.e. K_{fs} and α) and ponding, if the ponding is greater than 50 mm.

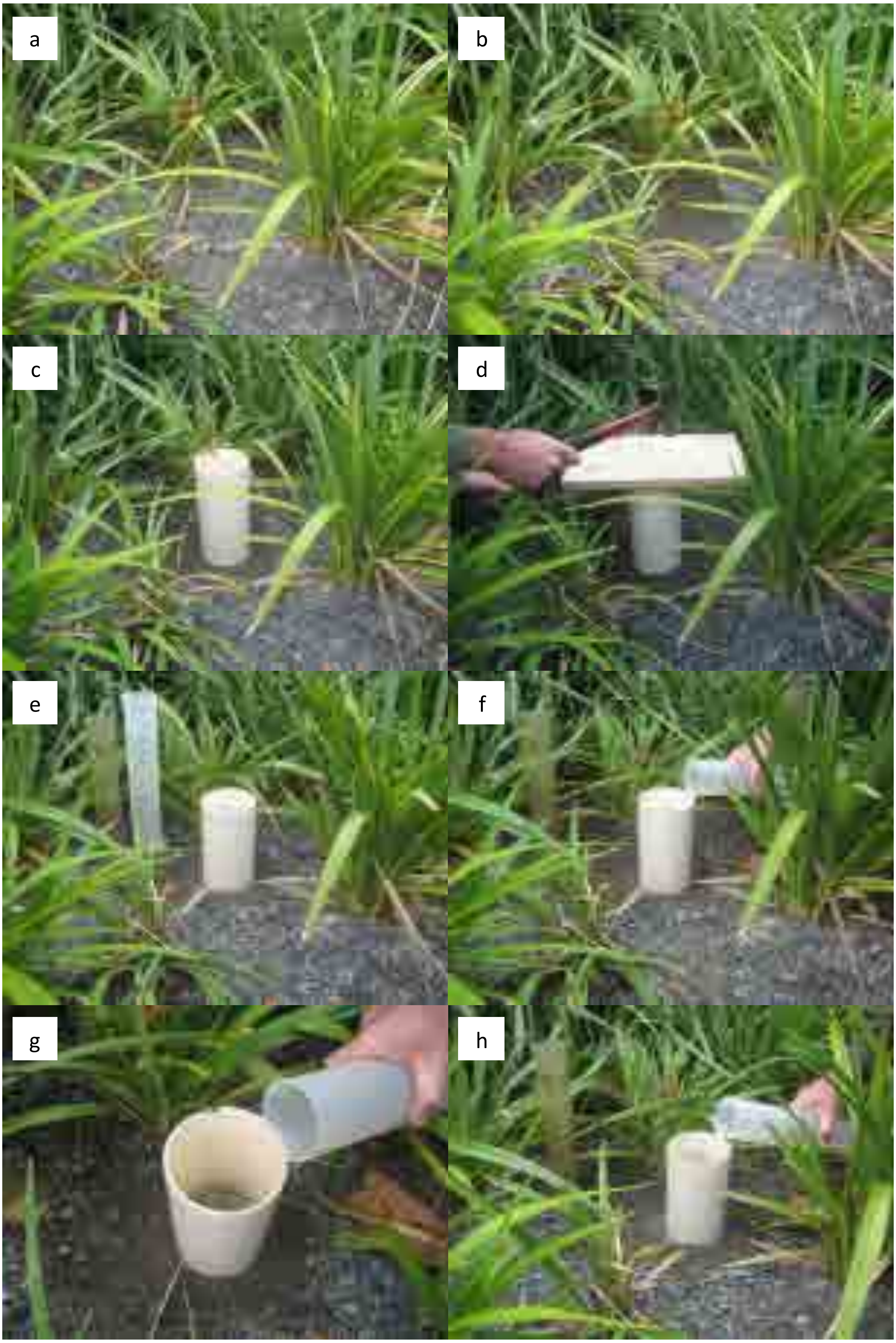

Figure 3. Measuring hydraulic conductivity

The possible limitations of the test are (Reynolds *et al.*, 2000): (1) the relatively small sample size due to the size of the ring, (2) soil disturbance during installation of the ring (compaction of the soil), and (3) possible edge flow during the experiments.

3 INTERPRETATION OF RESULTS

This test method has been shown to be relatively comparable to laboratory test methods (Le Coustumer *et al.*, 2008), taking into account the inherent variability in hydraulic conductivity testing and the heterogeneity of natural soil-based filter media. While correlation between the two test methods is low, results are not statistically different. In light of this, laboratory and field results are deemed comparable if they are within 50% of each other. In the same way, replicate field results are considered comparable if they differ by less than 50%. Where this is not the case, this is likely to be due to a localised inconsistency in the filter media, therefore additional measurement should be conducted at different monitoring points until comparable results are achieved. If this is not achieved, then an area-weighted average value may need to be calculated.

4 MONITORING FREQUENCY

Field testing of hydraulic conductivity should be carried out at least twice: (1) One month following commencement of operation, and (2) In the second year of operation to assess the impact of vegetation on hydraulic conductivity. Following this, hydraulic conductivity testing should be conducted every two years or when there has been a significant change in catchment characteristics (e.g., construction without appropriate sediment control).

REFERENCES

Gardner, W. R. (1958). Some steady-state solutions of the unsaturated moisture flow equation with application to evaporation from a water table. *Soil Science* **85**: 228-232.

Le Coustumer, S., T. D. Fletcher, A. Deletic and M. Potter (2008). Hydraulic performance of biofilter systems for stormwater management: lessons from a field study, Melbourne Water Corporation.

Reynolds, W. D., B. T. Bowman, R. R. Brunke, C. F. Drury and C. S. Tan (2000). Comparison of tension infiltrometer, pressure infiltrometer, and soil core estimates of saturated hydraulic conductivity. *Soil Science Society of America journal* **64**(2): 478-484.

Reynolds, W. D. and D. E. Elrick (1990). Ponded infiltration from a single ring: Analysis of steady flow. *Soil Science Society of America journal* **54**: 1233-1241.

Youngs, E. G., D. E. Elrick and W. D. Reynolds (1993). Comparison of steady flows from infiltration rings in "Green and Ampt" and "Gardner" soils. *Water Resources Research* **29**(6): 1647-1650.

Single Ring Infiltration Test

Site: ____

Date: ____

Constant water level = 50 mm		
Time (min)	Volume (mL)	Q (mL/s)

Constant water level = 150 mm		
Time (min)	Volume (mL)	Q (mL/s)

Attachment D

XP-RAFTS Ultimate Development Results – 100 Year ARI, 120 Minute Storm

##
SECOND PONDS CREEK ULTIMATE MODEL EXCL. CLIMATE CHANGE

Results for period from 5: 0.0 4/ 8/1986
to 10: 0.0 4/ 8/1986
##

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 120.
RETURN PERIOD (YRS) = 100.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 407.84
TOTAL OF SECOND SUB-AREAS (ha) = 691.27
TOTAL OF ALL SUB-AREAS (ha) = 1099.10

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	Catch. Area #2	Slope #1 (%)	Slope #2	% Impervious #1 (%)	% Impervious #2	Pern #1	Pern #2	B #1	B #2	Link No.
58.0	8.465	12.439	2.500	2.500	5.000	100.0	.025	.015	.0402	.0035	1.000
58.01	2.333	8.749	2.500	2.500	5.000	100.0	.025	.015	.0206	.0029	1.001
58.02	6.236	8.477	1.500	1.500	5.000	100.0	.025	.015	.0442	.0037	1.002
58.03	22.735	14.411	1.800	1.800	5.000	100.0	.025	.015	.0791	.0044	1.003
58.04	26.818	24.936	1.400	1.400	5.000	100.0	.025	.015	.0978	.0067	1.004
58.05	13.723	32.010	3.300	3.300	5.000	100.0	.025	.015	.0450	.0050	1.005
60.0	8.168	24.407	1.900	1.900	5.000	100.0	.025	.015	.0452	.0057	2.000
58.05B	.00001	0.000	1.000	0.000	5.000	0.000	.025	0.00	0.000	0.000	1.006
59.0	7.691	28.608	2.400	2.400	5.000	100.0	.025	.015	.0390	.0055	3.000
59.01	7.300	23.847	1.800	1.800	5.000	100.0	.025	.015	.0438	.0058	3.001
62.0	7.633	21.444	2.200	2.200	5.000	100.0	.025	.015	.0406	.0049	4.000
58.06	11.665	25.183	1.400	1.400	5.000	100.0	.025	.015	.0634	.0067	1.007
61.01	7.588	19.770	2.800	2.800	5.000	100.0	.025	.015	.0359	.0042	5.000
58.06B	.00001	0.000	1.000	0.000	5.000	0.000	.025	0.00	0.000	0.000	1.008
58.06A	2.240	0.000	3.000	0.000	5.000	0.000	.025	0.00	.0184	0.000	1.009
58.07	9.219	7.071	2.200	2.200	5.000	100.0	.025	.015	.0448	.0028	1.010
64.0	8.051	15.061	2.700	2.700	5.000	100.0	.025	.015	.0377	.0037	6.000
63.0	3.945	13.042	2.000	2.000	5.000	100.0	.025	.015	.0302	.0040	7.000
65.0	6.368	13.154	3.400	3.400	5.000	100.0	.025	.015	.0297	.0031	8.000
58.08	1.401	0.6559	3.000	3.000	5.000	100.0	.025	.015	.0144	.0007	1.011
58.09	18.782	19.794	1.900	1.900	5.000	100.0	.025	.015	.0698	.0051	1.012
66.0	5.103	17.424	3.900	3.900	5.000	100.0	.025	.015	.0247	.0033	9.000
66.01	17.519	14.524	3.700	3.700	5.000	100.0	.025	.015	.0482	.0031	9.001
66.02	4.775	2.943	3.700	3.700	5.000	100.0	.025	.015	.0245	.0014	9.002
58.10	6.109	6.462	1.900	1.900	5.000	100.0	.025	.015	.0389	.0029	1.013
1.00	.00001	9.370	3.600	3.600	0.000	100.0	.025	.015	0.000	.0025	10.00
3.00	1.760	9.950	3.900	3.900	5.000	100.0	.025	.015	.0142	.0025	11.00
3.01	0.5160	2.920	2.400	2.400	5.000	100.0	.025	.015	.0096	.0017	11.00
BP15.00	0.2460	1.240	1.800	1.800	5.000	100.0	.025	.015	.0075	.0012	12.00
BP16.00	0.2600	1.500	3.100	3.100	5.000	100.0	.025	.015	.0059	.0010	13.00
MR1.00	0.7200	4.110	1.000	1.000	5.000	100.0	.025	.015	.0176	.0031	14.00
MR1.01	0.1600	0.9200	1.000	1.000	5.000	100.0	.025	.015	.0081	.0014	14.00
MR2.00	0.1900	1.090	1.000	1.000	5.000	100.0	.025	.015	.0088	.0016	15.00
MR2.01	0.1300	0.7400	1.000	1.000	5.000	100.0	.025	.015	.0072	.0013	15.00
58.11	5.930	0.1210	3.200	3.200	0.000	100.0	.035	.015	.0465	.0003	1.014
4.00	.00001	5.810	4.700	4.700	0.000	100.0	.025	.015	0.000	.0017	16.00
4.01	0.8100	4.570	4.700	4.700	5.000	100.0	.025	.015	.0087	.0015	16.00
5.00	0.6900	3.940	2.000	2.000	5.000	100.0	.025	.015	.0122	.0021	17.00
6.00	0.5450	3.090	4.500	4.500	5.000	100.0	.025	.015	.0072	.0013	18.00
58.12	3.150	0.0640	3.500	3.500	0.000	100.0	.035	.015	.0320	.0002	1.015
7.00	2.270	12.840	3.300	3.300	5.000	100.0	.025	.015	.0176	.0031	19.00
58.12B	2.750	0.0560	4.000	4.000	0.000	100.0	.035	.015	.0279	.0002	1.016
10.00	0.2570	1.454	3.500	3.500	5.000	100.0	.025	.015	.0055	.0010	20.00
8.00	1.740	9.860	5.200	5.200	5.000	100.0	.025	.015	.0123	.0022	21.00
8.01	2.910	16.490	5.500	5.500	5.000	100.0	.025	.015	.0156	.0027	21.00
8.02A	0.4310	2.440	4.800	4.800	5.000	100.0	.025	.015	.0062	.0011	22.00
8.02	5.000	0.5560	3.000	3.000	5.000	100.0	.025	.015	.0279	.0006	21.00
9.00	2.270	12.840	3.300	3.300	5.000	100.0	.025	.015	.0176	.0031	23.00
9.01	3.640	0.4040	3.000	3.000	5.000	100.0	.025	.015	.0237	.0005	23.00
Ang.Sch	0.8100	4.590	6.000	6.000	5.000	100.0	.025	.015	.0077	.0013	24.00

11.00	1.320	7.480	6.300	6.300	5.000	100.0	.025	.015	.0096	.0017	25.00
58.13	3.400	0.0690	5.600	5.600	0.000	100.0	.035	.015	.0263	.0002	1.017
BP17.00	0.1890	1.070	3.000	3.000	5.000	100.0	.025	.015	.0051	.0009	26.00
12.00	1.120	6.330	3.400	3.400	5.000	100.0	.025	.015	.0120	.0021	27.00
13.00	0.6260	3.550	2.500	2.500	5.000	100.0	.025	.015	.0104	.0018	28.00
58.13B	4.570	0.0930	4.400	4.400	0.000	100.0	.035	.015	.0346	.0002	1.018
RHRP	22.590	2.510	8.500	8.500	0.000	100.0	.025	.015	.0452	.0008	29.00
58.14	5.420	0.1110	4.600	4.600	0.000	100.0	.035	.015	.0370	.0002	1.019
58.15	.00001	0.000	1.000	0.000	5.000	0.000	.025	0.00	0.000	0.000	1.020
69.0	6.204	8.646	2.700	2.700	5.000	100.0	.025	.015	.0329	.0028	30.00
70.0	6.936	12.615	2.800	2.800	5.000	100.0	.025	.015	.0342	.0033	31.00
58.16	13.834	16.284	3.000	3.000	5.000	100.0	.025	.015	.0474	.0037	1.021
71.0	5.798	13.531	2.800	2.800	5.000	100.0	.025	.015	.0312	.0035	32.00
58.17	16.070	23.196	2.700	2.700	5.000	100.0	.025	.015	.0540	.0047	1.022
72.0	7.633	22.107	3.800	3.800	5.000	100.0	.025	.015	.0309	.0038	33.00
58.18	7.521	5.910	3.400	3.400	5.000	100.0	.025	.015	.0324	.0020	1.023
73.0	3.854	7.630	3.200	3.200	5.000	100.0	.025	.015	.0236	.0024	34.00
58.19	2.057	1.877	3.000	3.000	5.000	100.0	.025	.015	.0176	.0012	1.024
74.0	7.362	12.889	4.000	4.000	5.000	100.0	.025	.015	.0296	.0028	35.00
75.0	4.961	8.978	4.100	4.100	5.000	100.0	.025	.015	.0238	.0023	36.00
76.0	1.137	6.703	5.400	5.400	5.000	100.0	.025	.015	.0096	.0017	37.00
75.01	0.4842	0.8056	6.900	6.900	5.000	100.0	.025	.015	.0055	.0005	36.00
58.20	10.187	10.717	2.700	2.700	5.000	100.0	.025	.015	.0426	.0031	1.025
58.21	6.321	6.730	3.200	3.200	5.000	100.0	.025	.015	.0305	.0022	1.026
77.0	5.365	18.643	5.300	5.300	5.000	100.0	.025	.015	.0218	.0030	38.00
58.22	7.490	16.088	3.500	3.500	5.000	100.0	.025	.015	.0319	.0034	1.027
1.28	4.338	11.330	4.200	4.200	5.000	100.0	.025	.015	.0219	.0026	1.028

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2	Cont. Loss #1 (mm/h)	Cont. Loss #2	Excess Rain #1 (mm)	Excess Rain #2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
58.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	7.701	35.00	0.000
58.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	10.734	40.00	0.000
58.02	44.640	15.00	1.500	2.500	0.000	70.113	87.780	13.734	40.00	0.000
58.03	44.640	15.00	1.500	2.500	0.000	70.113	87.780	14.313	59.00	0.000
58.04	44.640	15.00	1.500	2.500	0.000	70.113	87.780	14.755	35.00	0.000
58.05	44.640	15.00	1.500	2.500	0.000	70.113	87.780	23.563	35.00	0.000
60.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	13.349	34.00	0.000
58.05B	44.640	15.00	0.000	2.500	0.000	70.113	0.000	35.952	35.00	0.000
59.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	15.690	33.00	0.000
59.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	23.595	40.00	0.000
62.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	11.999	33.00	0.000
58.06	44.640	15.00	1.500	2.500	0.000	70.113	87.780	72.871	40.00	0.000
61.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	11.370	33.00	0.000
58.06B	44.640	15.00	0.000	2.500	0.000	70.113	0.000	48.235	46.00	0.000
58.06A	44.640	15.00	0.000	2.500	0.000	70.113	0.000	48.662	47.00	0.000
58.07	44.640	15.00	1.500	2.500	0.000	70.113	87.780	50.803	53.00	0.000
64.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	9.054	35.00	0.000
63.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	7.249	33.00	0.000
65.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	8.074	35.00	0.000
58.08	44.640	15.00	1.500	2.500	0.000	70.113	87.780	60.063	40.00	0.000
58.09	44.640	15.00	1.500	2.500	0.000	70.113	87.780	63.997	46.00	0.000
66.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	10.086	35.00	0.000
66.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	19.290	36.00	0.000
66.02	44.640	15.00	1.500	2.500	0.000	70.113	87.780	21.667	39.00	0.000
58.10	44.640	15.00	1.500	2.500	0.000	70.113	87.780	68.298	47.00	0.000
1.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	4.800	33.00	0.000
3.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	5.543	35.00	4.000
3.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	6.881	36.00	0.000
BP15.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	0.7093	32.00	0.000
BP16.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	0.8738	32.00	0.000
MR1.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	2.235	33.00	2.500
MR1.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	2.677	36.00	0.000
MR2.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	0.5897	35.00	2.000
MR2.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	0.9908	35.00	0.000
58.11	44.640	15.00	1.500	2.500	0.000	70.113	87.780	73.579	65.00	0.000
4.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	3.086	32.00	2.500
4.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	5.693	35.00	0.000
5.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	2.177	33.00	0.000
6.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	1.809	32.00	0.000
58.12	44.640	15.00	1.500	2.500	0.000	70.113	87.780	76.312	65.00	0.000
7.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	7.104	33.00	0.000

58.12B	44.640	15.00	1.500	2.500	0.000	70.113	87.780	78.381	65.00	0.000
10.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	0.8560	32.00	0.000
8.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	5.602	32.00	2.000
8.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	14.721	35.00	1.500
8.02A	44.640	15.00	1.500	2.500	0.000	70.113	87.780	1.454	32.00	0.000
8.02	44.640	15.00	1.500	2.500	0.000	70.113	87.780	17.356	37.00	0.000
9.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	7.104	33.00	0.000
9.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	8.209	35.00	0.000
Ang.Sch	44.640	15.00	1.500	2.500	0.000	70.113	87.780	2.702	32.00	0.000
11.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	4.310	32.00	0.000
58.13	44.640	15.00	1.500	2.500	0.000	70.113	87.780	87.598	65.00	0.000
BP17.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	0.6376	32.00	0.000
12.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	3.545	35.00	0.000
13.00	44.640	15.00	1.500	2.500	0.000	70.113	87.780	1.982	35.00	0.000
58.13B	44.640	15.00	1.500	2.500	0.000	70.113	87.780	88.120	70.00	0.000
RHRP	44.640	15.00	1.500	2.500	0.000	70.113	87.780	8.204	40.00	0.000
58.14	44.640	15.00	1.500	2.500	0.000	70.113	87.780	90.112	80.00	0.000
58.15	44.640	15.00	0.000	2.500	0.000	70.113	0.000	90.025	81.00	0.000
69.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	5.612	35.00	0.000
70.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	7.698	35.00	0.000
58.16	44.640	15.00	1.500	2.500	0.000	70.113	87.780	94.377	85.00	0.000
71.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	7.989	35.00	0.000
58.17	44.640	15.00	1.500	2.500	0.000	70.113	87.780	96.462	91.00	0.000
72.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	12.850	35.00	0.000
58.18	44.640	15.00	1.500	2.500	0.000	70.113	87.780	98.803	98.00	0.000
73.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	4.840	35.00	0.000
58.19	44.640	15.00	1.500	2.500	0.000	70.113	87.780	99.655	100.0	0.000
74.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	8.308	35.00	0.000
75.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	5.879	35.00	0.000
76.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	3.814	32.00	0.000
75.01	44.640	15.00	1.500	2.500	0.000	70.113	87.780	10.063	35.00	0.000
58.20	44.640	15.00	1.500	2.500	0.000	70.113	87.780	102.95	100.0	0.000
58.21	44.640	15.00	1.500	2.500	0.000	70.113	87.780	102.92	105.0	0.000
77.0	44.640	15.00	1.500	2.500	0.000	70.113	87.780	10.999	35.00	0.000
58.22	44.640	15.00	1.500	2.500	0.000	70.113	87.780	104.50	112.0	0.000
1.28	44.640	15.00	1.500	2.500	0.000	70.113	87.780	105.11	112.0	0.000

SUMMARY OF BASIN RESULTS

Link Label	Time to Peak	Peak Inflow (m^3/s)	Time to Peak	Peak Outflow (m^3/s)	Total Inflow (m^3)	--------- Basin --------- Vol. Avail	Vol. Used	Stage Used
58.02	40.00	13.73	51.00	8.925	37980.2	0.0000	11192.8	70.420
58.03	59.00	14.31	120.0	4.739	66762.5	0.0000	42322.2	68.183
58.06	40.00	72.87	51.00	44.65	251315.	0.0000	47295.1	53.607
66.02	39.00	21.67	106.0	2.850	49829.0	0.0000	32514.1	48.028
Ang.Sch	32.00	2.702	36.00	2.061	4596.0	0.0000	1471.9	44.105

SUMMARY OF BASIN OUTLET RESULTS

Link Label	No. of	S/D Factor (m)	Dia (m)	Width (m)	Pipe Length (m)	Pipe Slope (%)
58.02	1.0	1.000		0.000	5.000	3.000
58.03	1.0	1.000		0.000	31.600	0.2000
58.06	1.0	1.000		0.000	20.000	0.2000
66.02	1.0	1.000		0.000	20.000	0.2000
Ang.Sch	1.0	1.000		0.000	20.000	0.2000

SUMMARY OF CHANNEL/FLOODWAY DATA AND RESULT

Link Label	Ave. Vel. (m/s)	Ave. Rough. (n)	Flow Depth (m)	Max. Flow (m^3/s)	No. of Pipes	Pipe Dia. (m)	Pipe Slope (%)	Pipe Flow (m3^/s)
58.0	0.631	.0475	1.505	6.843	1.0	0.000	0.000	0.000
58.01	0.698	.0463	1.609	9.970	1.0	0.000	0.000	0.000
58.02	0.683	.0468	1.559	8.583	1.0	0.000	0.000	0.000
58.03	0.594	.0492	1.400	4.719	1.0	0.000	0.000	0.000
58.04	0.749	.0458	1.663	12.181	1.0	0.000	0.000	0.000
58.05	0.914	.0444	1.869	23.072	1.0	0.000	0.000	0.000
58.05B	0.966	.0437	2.016	31.867	1.0	0.000	0.000	0.000

59.0	1.46	.0600	4.750	13.345	1.0	0.000	0.000	0.000
58.06	1.11	.0433	2.138	44.655	1.0	0.000	0.000	0.000
58.06B	1.13	.0432	2.175	48.173	1.0	0.000	0.000	0.000
58.06A	1.13	.0432	2.178	48.409	1.0	0.000	0.000	0.000
58.07	1.14	.0431	2.200	50.774	1.0	0.000	0.000	0.000
58.08	1.17	.0429	2.281	58.299	1.0	0.000	0.000	0.000
58.09	1.22	.0428	2.319	63.911	1.0	0.000	0.000	0.000
66.0	2.42	.0600	2.213	9.634	1.0	0.000	0.000	0.000
66.01	2.74	.0600	3.675	19.006	1.0	0.000	0.000	0.000
58.10	0.886	.0662	3.594	68.208	1.0	0.000	0.000	0.000
58.11	0.935	.0661	3.612	73.490	1.0	0.000	0.000	0.000
58.12	0.847	.0656	3.737	76.178	1.0	0.000	0.000	0.000
58.12B	0.852	.0655	3.756	78.131	1.0	0.000	0.000	0.000
58.13	0.754	.0647	3.987	86.684	1.0	0.000	0.000	0.000
58.13B	0.687	.0644	4.100	87.420	1.0	0.000	0.000	0.000
58.14	0.957	.0654	3.781	90.025	1.0	0.000	0.000	0.000
58.15	0.954	.0654	3.781	89.696	1.0	0.000	0.000	0.000
58.16	0.965	.0653	3.812	93.688	1.0	0.000	0.000	0.000
58.17	0.980	.0652	3.825	96.285	1.0	0.000	0.000	0.000
58.18	0.985	.0652	3.844	98.650	1.0	0.000	0.000	0.000
58.19	0.986	.0652	3.850	99.308	1.0	0.000	0.000	0.000
75.0	1.27	.0600	2.450	5.672	1.0	0.000	0.000	0.000
58.20	0.992	.0651	3.875	102.38	1.0	0.000	0.000	0.000
58.21	0.994	.0651	3.875	102.65	1.0	0.000	0.000	0.000
58.22	1.00	.0650	3.887	104.50	1.0	0.000	0.000	0.000

Run completed at: 28th October 2010 7:56:32

Attachment E

Area 20 Precinct Climate Change Assessment

Our Ref: 8622 Climate Change Assessment.doc
DG.dg

15 June 2010

Department of Planning
PO Box 1457
Parramatta NSW 2124

Attn: **Mr Lee Mulvey**

Subject: **Area 20 Precinct – Rouse Hill**
Climate Change Assessment

Dear Lee,

The following information is offered as an explanation of our investigations into the anticipated impacts of Climate Change on the performance of the Drainage System proposed for the Area 20 Precinct. The objective of this assessment is to provide information on the possible impacts of Climate Change.

BACKGROUND TO CLIMATE CHANGE ASSESSMENTS

When undertaking a risk assessment into the impact of flooding on urban infrastructure, as a consequence of Climate Change predictions, it is necessary to quantify the possible changes in rainfall intensity and assess the impact that these changes may have on the catchment hydrology. In the absence of specific quantifiable guidelines from Blacktown City Council (BCC) the primary reference sources agreed to, for this assessment, are:

1. *NSW Climate Change Action Plan: Summary of Climate Change Impacts Sydney Region, October 2008*, prepared by the NSW Department of Environment and Climate Change;

2. *Practical Consideration of Climate Change – Floodplain Risk Management Guideline, October 2007*, prepared by the NSW Department of Environment and Climate Change;

3. *Climate Change in the Hawkesbury-Nepean Catchment, 2007*, prepared by the Commonwealth Scientific and Industrial Research Organisation, were adopted as the primary reference documents for this assessment; and

4. *Climate Change in Australia – Observed Changes and Projections, October 2007*, prepared by Australian Government Bureau of Meteorology.

Prior to assessing the estimated impacts of Climate Change on the Area 20 Precinct, it is necessary to compare the various recommended increases to Rainfall Intensities identified in these documents, determine the most appropriate Rainfall Intensity increase and apply it to the hydrologic assessment for the site.

This process is consistent with the "Management Strategies For Future Development" outlined in Reference 2. Table 1 summarises the State and Federal Government approaches to accounting for changes to predicted rainfall intensities and storm volumes associated with Climate Change. All documents predict increases in peak rainfall intensity with an associated increase in storm runoff volume. However the overall Average Annual Rainfall for the region is anticipated to reduce, whilst summer rainfall is predicted to increase. Drawing a direct comparison between each of the predictions, and relating a conclusion to a predicted increase in rainfall intensity is not as straightforward as it may seem and it has been necessary to relate the stated volumetric predictions to a more tangible Average Recurrence Interval (see Reference 2).

TABLE 1 - Comparison of the Various Climate Change Strategies

Reference	Rainfall Intensity	Comment
1. Climate Change Impacts – Sydney Region, 2008 (DECC)	Summer runoff depths estimated to increase by 0% to 26% Summer rainfall volume projected to increase by 20% to 50%	Hydrologic change assessment based on seasonal variation estimates. The summer runoff depth increase is the largest.
2. Practical Consideration of Climate Change – Flood Risk Management, 2007 (DECC)	Sensitivity Analysis based on increases of: 10% peak rainfall & vol.; 20% peak rainfall & vol.; 30% peak rainfall & vol. Table of increases in Extreme Rainfall Intensities (40-yr, 24-hr) based on %age change in Intensity and Storm Volume.	This approach relies on a risk analysis based on the potential impacts of the various increases. The lowest value with an acceptable An Av Damage is then adopted. Consideration of the AAD where this value is exceeded must be included and a strategy to accommodate the additional risk identified.
3. Climate Change in the H-N Catchment, 2007 (CSIRO)	Projected max. Change in the 40-yr, 24-hr rainfall by: 2030 – 12%; 2070 – 10%.	Total annual rainfall is predicted to decline by about 80 mm with the possibility of seasonal increases in extreme rainfall events.
4. Climate Change in Australia, 2007 (BofM)	General increase in daily rainfall intensities in summer only.	Expected volumetric change is to be minimal but extreme daily rainfall is expected to increase.

A summary of the information contained in the above reference documents is outlined below.

- All references agree on a general increase in summer rainfall volume;
- Reference 1 determines the summer daily volumetric runoff depth to increase by 26%;
- Reference 2 refers to a sensitivity analysis of Climate Change based on the risks associated with an Annual Average Damage analysis to determine the appropriate Flood Planning Levels, which can then be related to an Average Recurrence Interval (ARI). This approach accommodates a 10%, 20% and 30% increase in the rainfall intensities to determine revised flow rates and runoff depths;

- Reference 3 is the only reference to provide a quantifiable relationship between Climate Change and rainfall intensity for a particular Average Recurrence Interval (ARI). It estimates that the maximum projected change in rainfall intensity for the larger scale storms (40-yr, 24-hr) is about 12%.

These four (4) references were prepared as background documents to assist with Floodplain Risk Management planning. They provide limited guidance with respect to assessing the possible impacts of Climate Change on new urban developments and the costs associated with the subsequent increase in the land required for local flood control.

NOTE: Based on the 12% increase predicted in Reference 3, the rainfall intensities in the existing XP-RAFTS hydrologic computer models, prepared to represent Caddies Creek catchment, were 'conservatively' increased by 15%. The resulting increase in runoff depth, for the 100-yr ARI critical storm, was determined as approximately 25%, which approximates the summer seasonal runoff depth increases of 26% predicted in Reference 1.

DISCUSSION

The Sensitivity Analyses outlined above provides information to assist in determining appropriate parameters to be used when considering the impact of an anticipated increase in rainfall intensities as a result of Climate Change predictions. A discussion of the results follows:

- The peak discharge generated by a 15% increase in rainfall intensity approximates a peak discharge rate midway between the existing peak discharge and that generated by a 30% increase in rainfall intensity. Reference 2 predicts a 12% rainfall intensity increase by 2030 with a reduction to a 10% increase by 2100, over present day rainfall intensities. Further, a 15% increase in rainfall intensity results in a 25% increase in the peak runoff depth. This increase in peak runoff depth approximates the 26% increase anticipated in the seasonal summer runoff depth referred to in Reference 1.

- In our opinion, adoption of a 15% increase in rainfall intensities provides a reasonable estimate of CCI.

- Drainage Reserve / Easements Numbers 1 and 2 (Refer Plan 8622SW04) can accommodate the impact of climate change without increasing the depth of flow above 200 mm or the velocity depth product above 0.4.

- Drainage Reserve Numbers 3 and 4 can accommodate the impact of climate change within the first 200 mm of the available 500 mm of freeboard.

RECOMMENDATION

Rainfall Intensity – increased by 15% for the 100-year critical storm in consideration of the possible impact of Climate Change. Table 5 compares land requirements for a Drainage Strategy that matches the existing peak flow rates and one which includes a 15% increase in rainfall intensity utilising both Options 1 and 2 to control peak discharges.

Trunk Channel Waterway Area – profile to be based on a 15% increase in rainfall intensity. The capacity of the channel must contain the runoff generated by a 15% increase in the 100-year peak flow rate for the developed catchment.

Freeboard – adoption of 0.5 m clearance over and above the flow depth generated by the existing 100-year peak flow from the developed catchment. This freeboard allowance includes a maximum of 0.2 m to accommodate the impact of Climate Change.

If you have any questions please do not hesitate to contact the undersigned.

Yours faithfully
J. WYNDHAM PRINCE

DANIEL GARDINER
Water Resources Engineer

Attachment F

Drainage Reserves / Easements Hydraulic Calculations