VOLUME 2

APPENDICES

APPENDIX A

RESPONSES TO QUESTIONNAIRES

April 2005

Dee Why Lagoon Floodplain Management Study and Plan

Warringah Council

Community Newsletter

To Residents and Businesses of Dee Why Lagoon Catchment

Warringah Council has engaged Lyall & Associates Consulting Water Engineers to prepare a Floodplain Management Study and Plan for Dee Why and Curl Curl Lagoons. The study is funded jointly by Warringah Council and the Department of Infrastructure, Planning and Natural Resources.

The primary objectives of the study will be to assess options for reducing the impacts of flooding on existing development and to prepare a framework within which future development can proceed in accordance with current best floodplain management principles. The Plan has the objective of reducing the flood risk and minimising the long-term impact of flooding on the community, through assessment and recommendation of flood mitigation measures.

Have Your Say on Floodplain Management

The Study and Plan are set to run over a period of ten months. An important step in the preparation of the Study is the compilation of a database of community expectations and preferences on ways of reducing the flood risk within the catchment. A questionnaire will be provided to selected residents and businesses, but any interested person is invited to complete it. All information provided will remain confidential and for use in this study only.

- **Businesses** are invited to complete Part 1 of the attached Community Questionnaire.
- **Residents** may choose to complete EITHER Part 1 or Part 2 (abbreviated version) of the attached Community Questionnaire.

Please return the completed questionnaire in the reply paid envelope provided by FRIDAY 30 JANUARY 2004.

Dee Why Lagoon Floodplain Management Study and Plan

Warringah Council

Community Questionnaire

PART 1: FOR RESIDENTS AND BUSINESSES

This questionnaire is part of the Dee Why and Curl Curl Lagoons Floodplain Management Study, currently being undertaken by Consultants on behalf of Warringah Council. It will help us determine the flood issues that are important to you.

Please return your completed questionnaire in the reply paid envelope provided before **FRIDAY 30 JANUARY 2004.** No postage stamp is required. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

Lyall & Associates Consulting Water Engineers
Reply Paid 78855
NORTH SYDNEY NSW 2060

Your Address (optional) _____

Name of Business/Organisation (if applicable)_____

About your property

1. Please tick as appropriate:

a.	I am a resident	24
b.	I operate a business	3
c.	I own the property	25
d.	I rent the property	0
e.	Other (please specify_____)	◻

2. How long have you owned, lived at or conducted business at this address?

a.	Less than 1 year	3
b.	1 year to 5 years	5
c.	5 years to 20 years	9
d.	More than 20 years (… years)	5

3. What is your property?

a.	Shop/Retail	0
b.	Factory/Industrial	1
c.	House	28
d.	Villa/Townhouse	0
e.	Unit/Flat/Apartment	1
f.	Vacant land	0
g.	Other (_____)	1

Your flood experience

4. Do you have any information about flooding at the property?

a. Yes 22 b. No 6

If yes, what information do you have?

c.	Own experience	18
d.	Information from real estate agency	0
e.	Information from someone else	4
f.	Flood levels from Council	0
g.	Council planning certificate	0
h.	Other (_____)	0

5. Have you ever experienced flooding at the property?

a.	Yes	13
b.	No	17

If yes, which floods?

c.	April 1998	5
d.	Other (_____)	8

6. In the biggest flood you have experienced, was the property flooded above floor level of the main residence?

a. No 23 b. Yes 4

If yes, what was the depth of water over the floor? _____

What year? _____

7. In this biggest flood where did you hear the flood warning?

Tick one or more boxes

a.	No warning whatsoever	16
b.	TV	0
c.	Radio	1
d.	Own observations	9
e.	Police	0
f.	State Emergency Service (SES)	0
g.	Neighbours, relatives or friends	0
h.	Other (_____)	0

Are you prepared for a flood?

8. If a flood were likely, how would you try to find out what to do?

a.	TV	9
b.	Radio	20
c.	Internet	2
d.	Use phone hotline	13
e.	Wait for door knock or call by SES / Police	4
f.	Neighbours, relatives or friends	6
g.	Other (_____)	3

Your attitudes to Council's development controls

9. Which <u>types of development</u> should be protected from floods?

Please rank the following in order of importance (1=most to 7=least important)

a. Commercial	95
b. Residential	49
c. Essential community facilities	64
d. Critical utilities	58
e. Minor development and additions	157
f. Recreation areas	158
g. Agricultural land	159
h. New residential subdivisions	156

10. What <u>level of control</u> should be placed on new development to minimise flood-related risks?

Please tick only one box

a. Prohibit all new development on land with any potential to flood.	20
b. Prohibit all new development only in those locations where it would be extremely hazardous to people and property.	6
c. Place restrictions on development such as minimum floor levels and/or the use of flood compatible building materials.	5
d. Advise of the flood risks, and allow people to choose how they would reduce flood damage.	3
e. Provide no advice regarding the potential to flood nor of the measures that could minimise potential flood risk.	0

11. What <u>notifications</u> should be given about the potential flood affectation of individual properties?

Tick one or more boxes

a. Advise every resident and property owner on a regular basis of the known potential threat.	23
b. Advise only those who enquire to Council about the known potential flood threat.	2
c. Advise prospective purchasers of property of the known potential flood threat.	10

Your opinions on floodplain risk management measures

12. Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the Dee Why Lagoon Catchment.

This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

		Yes	*No*
a.	Increase capacity of bridge crossings.	10	11
b.	Enlarge the creek to increase capacity.	17	5
c.	Maintenance programs to clear lagoon or creek of unnecessary vegetation.	28	0
d.	Review/maintain existing flood mitigation works.	22	1
e.	Construct upstream dams/basins to temporarily store floodwaters.	13	7
f.	Construct permanent levees.	7	12
g.	Revise lagoon entrance management.	21	1
h.	Voluntary property purchase scheme	7	8
i.	Provide funding or subsidies to raise houses above 100 year flood level.	4	12
j.	Flood proof individual properties eg. by waterproofing walls, installing shutters.	3	12
k.	Ensure controls on future development in flood-liable area (eg. controls on extent of filling, on site detention, impervious areas, floor requirements, etc)	25	1
l.	Prohibit subdivision of properties within the floodplain.	22	4
m.	Prohibit all rezoning for new development within the floodplain.	23	3
n.	Improve flood warning both before and during a flood.	24	0
o.	Improve evacuation and emergency assistance plans.	22	0
p.	Community education, participation and flood awareness programs.	24	0
q.	Ensure all information about the potential risks of flooding is available to residents and business owners.	28	0
r.	Provide a certificate to all residents stating whether their property is flood affected and to what extent.	18	6
s.	Making sure residents and business owners have a Flood Action Plan	20	1
t.	Install flood markers (eg. on power poles) to act as reminders of heights of previous floods.	22	4

13. Are you aware of any flood mitigation measures that affect you and would reduce <u>your</u> flood risk should a big flood occur?

Tick one or more boxes

a.	Not aware of any measures	20
b.	House built at minimum floor level	1
c.	House raised	2
d.	Flood compatible building materials	0
e.	Area 'protected' by levees	0
f.	Creek capacity has been enlarged	3
g.	Lagoon entrance has been mechanically opened	7
h.	Known evacuation route	0
i.	Other (please specify_____) ❑	

Have you received any information about these measures?

a. No 26 b. Yes 0

If yes, what information did you receive and who was it from? What do you know about these measures? How do they affect you? Do you think they are adequate?

_____

_____

_____

Please use the space at the end of this questionnaire if more space is required.

14. What floodplain risk management measures are most important to you?

Please list your 5 most favoured options in order. You can choose from the list provided in Question 12 or include your own. (No. 1 is your most favoured option)

1_____

2_____

3_____

4_____

5_____

Please list your 5 least favoured options in order. (No. 1 is your least favoured option)

1_____

2_____

3_____

4_____

5_____

Other Information

15. How would you like to become more involved in this project?

Tick one or more boxes

a.	Please put me on your mailing list.	12
b.	Please contact me for a phone interview.	2
c.	I am interested in attending a meeting of the Dee Why/Curl Curl Lagoons Joint Estuary/Floodplain Management Committee.	4
d.	I am interested in attending the public workshop to be held later in the study to consider options for my area.	9

16. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?

Tick one or more boxes

a.	Council's website	7
b.	Other website(s)	0
c.	Articles in local newspaper	23
d.	Open days or drop-in days	9
e.	Community workshops	4
f.	Public meetings	10
g.	At formal Council meetings	1
h.	Through Council's Floodplain Risk Management Committee	8
i.	Other (please specify _____) ❑	

17. If you ticked any of the boxes where you would like us to contact you, please provide your details below:

Name: 15 supplied names and addresses

Address: _____

_____

Phone (Home) _____

Best time to call is _____

Fax No. _____

Email: _____

18. Are you a member of any local community group? If yes, please specify:

4 are members of a group. _____

_____

_____

19. Please provide more information on the *COMMENTS* sheet provided after the *SUPPLEMENTARY QUESTIONS FOR BUSINESS* or attach a separate sheet if required.

Who can I contact for further information?

Warringah Council
Valerie Tulk
Phone: 9942 2359

Lyall & Associates
Consulting Water Engineers
Scott Button
Phone: 9929 4466

Further information and copies of this questionnaire can be obtained from:

www.warringah.nsw.gov.au/lagoons_flood_mgt_study.htm

SUPPLEMENTARY QUESTIONS FOR BUSINESSES

Please complete this part only if you operate a business from this property

20. Name of Business:

_____

_____

21. Which of the following best describes the type of building you operate your business from?

a.	Industrial unit in larger complex	1
b.	Stand alone factory	0
c.	Stand alone warehouse	0
d.	Shop	0
e.	Office	0
f.	Eduction	0
g.	Club	0
h.	Community building	0
i.	Other (please specify_____)	0

22. What is the approximate floor area of these premises? _____**m²**

23. How many employees are there normally working at your premises?

a.	1-5	1
b.	5-10	1
c.	10-20	0
d.	More than 20 employees	0

If you have not experienced a flood at this property, please go to the next page.

24. In the biggest flood you have experienced, what action did you take to protect your property against flood damage?

a.	Took no action	1
b.	Moved vehicles	0
c.	Lifted carpet, stock, equipment	0
d.	Used sandbags to try to prevent water entering the premises	0
e.	Other action	0

please specify:_____

25. In the biggest flood, was your business or facility closed or disrupted in any way (including any clean up)?

a. No 0 b. Yes 1

If yes, for how long was your business or facility closed or disrupted?

c.	Less than 1 day	1
d.	1 to 2 days	0
e.	2 days to 1 week	0
f.	More than 1 week	0

26. During the biggest flood, were your premises flooded above the floor level of the main work area?

a. No 1 b. Yes 0

If yes, what was the depth of the water over the floor? _____

27. During the biggest flood, what was damaged by floodwaters? (Tick one or more boxes)

a.	No damage occurred	1
b.	Vehicles	0
c.	Electrical equipment, machinery, tools	0
d.	Stock and other goods	0
e.	Carpet, furniture, fittings and/or office equipment	0
f.	Your premises (paint, structurally, etc)	0
g.	Other part of your property	0

Please specify _____

28. During the biggest flood, what was the approximate cost to you (at the time) from the damage caused by the flood?

$_____

29. As a result of the biggest flood, did you experience any problems during or after the flood?

Tick one or more boxes

a.	No problems experienced	0
b.	Inconvenience or disruption to normal routine	1
c.	Isolation (blocked by floodwaters)	0
d.	Employees unable to come to work	0
e.	Loss of business / trade	1
f.	Experienced general ill-health	0
g.	Higher employee absenteeism	0
h.	Higher insurance premiums	0
i.	Considered selling/moving the business	0

COMMENTS

Please write your comments here:

Thank you for your participation in this study

Dee Why Lagoon Floodplain Management Study and Plan

Warringah Council

Community Questionnaire

PART 2: ABBREVIATED VERSION FOR RESIDENTS ONLY

This questionnaire is part of the Dee Why and Curl Curl Lagoons Floodplain Management Study, currently being undertaken by Consultants on behalf of Warringah Council.

Please return your completed questionnaire in the reply paid envelope provided before **FRIDAY 30 JANUARY 2004.** No postage stamp is required. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

Lyall & Associates Consulting Water Engineers
Reply Paid 78855
NORTH SYDNEY NSW 2060

	Please Tick	
	Yes	**No**
Would you like to be included on the mailing list for the study? We can then send you further information as the study progresses.	7	0
	Yes	**No**
Would you be available for a phone interview? Please provide your contact details so we may call you.	4	1
	Yes	**No**
Would you like to participate in a workshop? The workshop will provide more information about the study and allow you to have your say in the floodplain management plan that is prepared.	0	6
	Yes	**No**
Are there any issues that you would like the study to consider?	4	1

Please provide your contact details so we may call you and provide any comments below.

Other comments:

Contact Details

Name:

Address:

Telephone Business:

Home:

Best time to call is

Thank you for your participation in this study

Curl Curl Lagoon Floodplain Management Study and Plan

Warringah Council

Community Newsletter

To Residents and Businesses of Curl Curl Lagoon Catchment

Warringah Council has engaged Lyall & Associates Consulting Water Engineers to prepare a Floodplain Management Study and Plan for Dee Why and Curl Curl Lagoons. The study is funded jointly by Warringah Council and the Department of Infrastructure, Planning and Natural Resources.

The primary objectives of the study will be to assess options for reducing the impacts of flooding on existing development and to prepare a framework within which future development can proceed in accordance with current best floodplain management principles. The Plan has the objective of reducing the flood risk and minimising the long-term impact of flooding on the community, through assessment and recommendation of flood mitigation measures.

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The Study and Plan are set to run over a period of ten months. An important step in the preparation of the Study is the compilation of a database of community expectations and preferences on ways of reducing the flood risk within the catchment. A questionnaire will be provided to selected residents and businesses, but any interested person is invited to complete it. All information provided will remain confidential and for use in this study only.

- **Businesses** are invited to complete Part 1 of the attached Community Questionnaire.
- **Residents** may choose to complete EITHER Part 1 or Part 2 (abbreviated version) of the attached Community Questionnaire.

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Curl Curl Lagoon Floodplain Management Study and Plan

Warringah Council

Community Questionnaire

PART 1: FOR RESIDENTS AND BUSINESSES

This questionnaire is part of the Dee Why and Curl Curl Lagoons Floodplain Management Study, currently being undertaken by Consultants on behalf of Warringah Council. It will help us determine the flood issues that are important to you.

Please return your completed questionnaire in the reply paid envelope provided before **FRIDAY 30 JANUARY 2004.** No postage stamp is required. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

Lyall & Associates Consulting Water Engineers
Reply Paid 78855
NORTH SYDNEY NSW 2060

Your Address (optional) _____

Name of Business/Organisation (if applicable)_____

About your property

1. Please tick as appropriate:

a.	I am a resident	32
b.	I operate a business	3
c.	I own the property	25
d.	I rent the property	0
e.	Other (please specify_____)	☐

2. How long have you owned, lived at or conducted business at this address?

a.	Less than 1 year	2
b.	1 year to 5 years	3
c.	5 years to 20 years	15
d.	More than 20 years (… years)	20

3. What is your property?

a.	Shop/Retail	0
b.	Factory/Industrial	2
c.	House	32
d.	Villa/Townhouse	4
e.	Unit/Flat/Apartment	0
f.	Vacant land	0
g.	Other (_____)	☐

Your flood experience

4. Do you have any information about flooding at the property?

a. Yes 27 b. No 13

If yes, what information do you have?

c.	Own experience	9
d.	Information from real estate agency	0
e.	Information from someone else	1
f.	Flood levels from Council	3
g.	Council planning certificate	1
h.	Other (_____)	☐

5. Have you ever experienced flooding at the property?

a.	Yes	18
b.	No	30

If yes, which floods?

c.	April 1998	2
d.	Other (_____)	☐

6. In the biggest flood you have experienced, was the property flooded above floor level of the main residence?

a. No 27 b. Yes 4

If yes, what was the depth of water over the floor? _____

What year? _____

7. In this biggest flood where did you hear the flood warning?

Tick one or more boxes

a.	No warning whatsoever	17
b.	TV	0
c.	Radio	0
d.	Own observations	4
e.	Police	0
f.	State Emergency Service (SES)	0
g.	Neighbours, relatives or friends	1
h.	Other (_____)	☐

Are you prepared for a flood?

8. If a flood were likely, how would you try to find out what to do?

a.	TV	13
b.	Radio	17
c.	Internet	4
d.	Use phone hotline	16
e.	Wait for door knock or call by SES / Police	6
f.	Neighbours, relatives or friends	13
g.	Other (_____)	❑

Your attitudes to Council's development controls

9. Which <u>types of development</u> should be protected from floods?

Please rank the following in order of importance (1=most to 7=least important)

a. Commercial	117
b. Residential	80
c. Essential community facilities	82
d. Critical utilities	67
e. Minor development and additions	182
f. Recreation areas	194
g. Agricultural land	177
h. New residential subdivisions	168

10. What <u>level of control</u> should be placed on new development to minimise flood-related risks?

Please tick only one box

a. Prohibit all new development on land with any potential to flood.	18
b. Prohibit all new development only in those locations where it would be extremely hazardous to people and property.	8
c. Place restrictions on development such as minimum floor levels and/or the use of flood compatible building materials.	14
d. Advise of the flood risks, and allow people to choose how they would reduce flood damage.	7
e. Provide no advice regarding the potential to flood nor of the measures that could minimise potential flood risk.	1

11. What <u>notifications</u> should be given about the potential flood affectation of individual properties?

Tick one or more boxes

a. Advise every resident and property owner on a regular basis of the known potential threat.	23
b. Advise only those who enquire to Council about the known potential flood threat.	8
c. Advise prospective purchasers of property of the known potential flood threat.	21

Your opinions on floodplain risk management measures

12. Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the Curl Curl Lagoon Catchment.

This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

		Yes	*No*
a.	Increase capacity of bridge crossings.	11	17
b.	Enlarge the creek to increase capacity.	16	12
c.	Maintenance programs to clear lagoon or creek of unnecessary vegetation.	29	1
d.	Review/maintain existing flood mitigation works.	29	0
e.	Construct upstream dams/basins to temporarily store floodwaters.	13	12
f.	Construct permanent levees.	9	13
g.	Revise lagoon entrance management.	21	3
h.	Voluntary property purchase scheme	8	11
i.	Provide funding or subsidies to raise houses above 100 year flood level.	11	13
j.	Flood proof individual properties eg. by waterproofing walls, installing shutters.		10
k.	Ensure controls on future development in flood-liable area (eg. controls on extent of filling, on site detention, impervious areas, floor requirements, etc)	29	2
l.	Prohibit subdivision of properties within the floodplain.	24	5
m.	Prohibit all rezoning for new development within the floodplain.	27	5
n.	Improve flood warning both before and during a flood.	27	0
o.	Improve evacuation and emergency assistance plans.	23	2
p.	Community education, participation and flood awareness programs.	25	11
q.	Ensure all information about the potential risks of flooding is available to residents and business owners.	30	0
r.	Provide a certificate to all residents stating whether their property is flood affected and to what extent.	28	2
s.	Making sure residents and business owners have a Flood Action Plan	23	4
t.	Install flood markers (eg. on power poles) to act as reminders of heights of previous floods.	27	4

13. Are you aware of any flood mitigation measures that affect you and would reduce <u>your</u> flood risk should a big flood occur?

Tick one or more boxes

a.	Not aware of any measures	28
b.	House built at minimum floor level	2
c.	House raised	3
d.	Flood compatible building materials	2
e.	Area 'protected' by levees	3
f.	Creek capacity has been enlarged	4
g.	Lagoon entrance has been mechanically opened	7
h.	Known evacuation route	3
i.	Other (please specify_____)	❑

Have you received any information about these measures?

a. No 30 b. Yes 0

If yes, what information did you receive and who was it from? What do you know about these measures? How do they affect you? Do you think they are adequate?

_____

_____

_____

Please use the space at the end of this questionnaire if more space is required.

14. What floodplain risk management measures are most important to you?

Please list your 5 most favoured options in order. You can choose from the list provided in Question 12 or include your own. (No. 1 is your most favoured option)

1_____

2_____

3_____

4_____

5_____

Please list your 5 least favoured options in order. (No. 1 is your least favoured option)

1_____

2_____

3_____

4_____

5_____

Other Information

15. How would you like to become more involved in this project?

Tick one or more boxes

a.	Please put me on your mailing list.	22
b.	Please contact me for a phone interview.	7
c.	I am interested in attending a meeting of the Dee Why/Curl Curl Lagoons Joint Estuary/Floodplain Management Committee.	7
d.	I am interested in attending the public workshop to be held later in the study to consider options for my area.	16

16. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?

Tick one or more boxes

a.	Council's website	10
b.	Other website(s)	2
c.	Articles in local newspaper	28
d.	Open days or drop-in days	3
e.	Community workshops	4
f.	Public meetings	14
g.	At formal Council meetings	2
h.	Through Council's Floodplain Risk Management Committee	9
i.	Other (please specify _____)	❑

17. If you ticked any of the boxes where you would like us to contact you, please provide your details below:

Name: 25 supplied names and addresses___

Address: _____

_____

Phone (Home) _____

Best time to call is _____

Fax No. _____

Email: _____

18. Are you a member of any local community group? If yes, please specify:

14 were members of a group. _____

_____

_____

19. Please provide more information on the *COMMENTS* sheet provided after the *SUPPLEMENTARY QUESTIONS FOR BUSINESS* or attach a separate sheet if required.

Who can I contact for further information?

Warringah Council
Valerie Tulk
Phone: 9942 2359

Lyall & Associates
Consulting Water Engineers
Scott Button
Phone: 9929 4466

Further information and copies of this questionnaire can be obtained from:

www.warringah.nsw.gov.au/lagoons_flood_mgt_study.htm

SUPPLEMENTARY QUESTIONS FOR BUSINESSES

Please complete this part only if you operate a business from this property

20. Name of Business:

_____

_____

21. Which of the following best describes the type of building you operate your business from?

a.	Industrial unit in larger complex	0
b.	Stand alone factory	0
c.	Stand alone warehouse	0
d.	Shop	0
e.	Office	0
f.	Eduction	0
g.	Club	1
h.	Community building	0
i.	Other (please specify_____)	❑

22. What is the approximate floor area of these premises? _____**m²**

23. How many employees are there normally working at your premises?

a.	1-5	1
b.	5-10	0
c.	10-20	1
d.	More than 20 employees	0

If you have not experienced a flood at this property, please go to the next page.

24. In the biggest flood you have experienced, what action did you take to protect your property against flood damage?

a.	Took no action	0
b.	Moved vehicles	1
c.	Lifted carpet, stock, equipment	0
d.	Used sandbags to try to prevent water entering the premises	0
e.	Other action	❑

please specify:_____

25. In the biggest flood, was your business or facility closed or disrupted in any way (including any clean up)?

a. No 1 b. Yes 0

If yes, for how long was your business or facility closed or disrupted?

c.	Less than 1 day	0
d.	1 to 2 days	0
e.	2 days to 1 week	0
f.	More than 1 week	0

26. During the biggest flood, were your premises flooded above the floor level of the main work area?

a. No 1 b. Yes 0

If yes, what was the depth of the water over the floor? _____

27. During the biggest flood, what was damaged by floodwaters? (Tick one or more boxes)

a.	No damage occurred	1
b.	Vehicles	0
c.	Electrical equipment, machinery, tools	0
d.	Stock and other goods	0
e.	Carpet, furniture, fittings and/or office equipment	0
f.	Your premises (paint, structurally, etc)	0
g.	Other part of your property	0

Please specify _____

28. During the biggest flood, what was the approximate cost to you (at the time) from the damage caused by the flood?

$_____

29. As a result of the biggest flood, did you experience any problems during or after the flood?

Tick one or more boxes

a.	No problems experienced	1
b.	Inconvenience or disruption to normal routine	0
c.	Isolation (blocked by floodwaters)	0
d.	Employees unable to come to work	0
e.	Loss of business / trade	0
f.	Experienced general ill-health	0
g.	Higher employee absenteeism	0
h.	Higher insurance premiums	0
i.	Considered selling/moving the business	0

COMMENTS

Please write your comments here:

Thank you for your participation in this study

Curl Curl Lagoon Floodplain Management Study and Plan

Warringah Council

Community Questionnaire

PART 2: ABBREVIATED VERSION FOR RESIDENTS ONLY

This questionnaire is part of the Dee Why and Curl Curl Lagoons Floodplain Management Study, currently being undertaken by Consultants on behalf of Warringah Council.

Please return your completed questionnaire in the reply paid envelope provided before **FRIDAY 30 JANUARY 2004.** No postage stamp is required. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

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Reply Paid 78855
NORTH SYDNEY NSW 2060

	Please Tick	
	Yes	**No**
Would you like to be included on the mailing list for the study? We can then send you further information as the study progresses.	10	2
	Yes	**No**
Would you be available for a phone interview? Please provide your contact details so we may call you.	6	5
	Yes	**No**
Would you like to participate in a workshop? The workshop will provide more information about the study and allow you to have your say in the floodplain management plan that is prepared.	4	5
	Yes	**No**
Are there any issues that you would like the study to consider?	1	6

Please provide your contact details so we may call you and provide any comments below.

Other comments:

Contact Details

Name:

Address:

Telephone Business:

Home:

Best time to call is

Thank you for your participation in this study

APPENDIX B

ASSESSMENT OF FLOOD DAMAGES ON FLOOD PLAINS OF DEE WHY AND CURL CURL LAGOONS

November 2005

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FIGURES

SYNOPSIS

Estimation of flood damages has been carried out on the floodplains of Dee Why and Curl Curl Lagoons to permit a "broad brush" economic assessment of various flood mitigation options and to provide information to assist Council in the selection of the flood planning level. Damages from floods ranging between the 20% AEP and Probable Maximum Flood (PMF) events were assessed.

Data for the flood damages model comprised a knowledge of the depth of inundation over the floodplain, as well as information on the value of damages to residential, commercial and industrial property.

The depth of inundation was determined from the results of the hydraulic modelling undertaken in the Flood Study, from floor level survey and from site inspection. The type of structure and potential for property damage were assessed from a visual inspection carried out during the preparation of the Property Survey Report (LACE, 2003).

There is little data available on historic flood damages in the study area, principally due to the absence of recent major flooding in the catchments. Damage assessments reported after flooding in other flood liable urban centres in NSW were adjusted and used to estimate “potential” damages likely to be experienced on the Dee Why and Curl Curl floodplains. “Potential” damages represent losses likely to be experienced if no action were taken by residents to mitigate impacts. A reduction in the potential damages is usually made to allow for property evacuation and raising valuables above floor level, which would reduce the damages actually experienced to values below the potential damages. The resulting damages are denoted “actual damages”.

In the present case, flooding on both catchments is of a “flash flooding” nature with a rapid rise in flood levels. Consequently, the ability for residents to mitigate damage is limited. Potential damages were multiplied by 0.90 to arrive at estimates of actual damages. On other flood prone centres where the warning time is likely to be longer, a greater reduction in potential damages could be achieved, particularly if there was a warning system in place to advise of imminent flooding.

The estimated actual damages, which could occur for various floods, are summarised in **Tables S1 and S2** below.

TABLE S1
FLOOD DAMAGES IN DEE WHY LAGOON STUDY AREA

Flood Event % AEP	No. of Properties Flooded			Total Damage ($ x 1000)
	Residential	Commercial	Public	
20	9	0	0	150
10	12	0	0	205
2	14	2	0	330
1	17	2	0	660
PMF	67	6	3	4,905

TABLE S2
FLOOD DAMAGES IN CURL CURL LAGOON STUDY AREA

Flood Event % AEP	No. of Properties Flooded			Total Damage ($ x 1000)
	Residential	Commercial	Public	
20	2	10	0	1,030
10	3	13	0	1,285
2	9	24	0	2,170
1	23	24	0	3,120
PMF	104	40	2	10,410

1. INTRODUCTION AND SCOPE

1.1 Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned, and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of floodwater with damageable property. They include damages to commercial and residential building structures and contents as well as damages to infrastructure services such as electricity and water supply. Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Generally, tangible damages are estimated in dollar values using survey procedures, interpretation of data from actual floods and research of government files.

The various factors included in the **intangible damage** category may be significant. However, these effects are difficult to quantify due to lack of data and the absence of an accepted method. Such factors may include:

- inconvenience
- isolation
- disruption of family and social activities
- anxiety, pain and suffering, trauma
- physical ill-health
- psychological ill-health.

1.2 Scope of Investigation

In the following sections, damages to residential, commercial and industrial properties have been estimated in the Dee Why and Curl Curl Study Areas. Damages to community assets have also been assessed where data were available.

2. DESCRIPTION OF APPROACH

The potential damage caused by a flood to a particular property is largely a function of the depth of flooding above floor level and the value of the property and its contents. A spreadsheet model which had been developed for previous investigations of this nature was used to estimate residential, commercial and public assets damages on a property by property basis according to a probable damage category (high, medium or low value), the location of the property and the depth of inundation.

Using the results of the Dee Why Lagoon and Curl Curl Lagoon Flood Studies, a flood height for each event was interpolated at each property. The interpolated property flood levels were input to the spreadsheet model which also contained property characteristics and stage-damage relationships. The depth of flooding was computed as the difference between the interpolated flood level and the surveyed floor elevation at each property. Damage was estimated by depth-damage curves entered as a series of points with the losses in each property category indexed to a depth of inundation of 2 metres.

Included within the model is the ability to simulate the reduction in “potential” flood damages, which result from flood awareness and flood warning. As mentioned previously, the reduced damages are denoted "actual" damages.

It should be understood that this approach is not intended to assess the values of damages in individual properties, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- the use of "average" stage-damage relationships, rather than a relationship for each property;
- the uncertainty associated with assessing an appropriate factor to convert potential to actual flood damages for each property.

The consequence of the above assumptions is that damages in individual properties may be underestimated or overestimated. Nevertheless, when applied over a broad area these effects would tend to cancel, and the resulting estimates of overall damages, both potential and actual, would be expected to be reasonably accurate, thereby meeting the requirements of this analysis.

Similarly, the information contained in the spreadsheets used to prepare the estimates of flood damages for the catchments should not be used to provide depths of above-floor inundation or extents of inundation within individual residences or commercial properties, The reasons for caution are:

- the assessed extent of inundation is based on available 2 metre contour mapping;
- the assumption that the water surfaces between hydraulic model sections are adequately represented by interpolation and are not subject to localised influences;

3. SOURCES OF DATA

To estimate average annual flood damages for a specific area it is necessary to estimate the damages for several floods of different magnitudes, i.e. of different frequencies, and then to integrate the damages over the whole range of frequencies. To do this it is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this:

- The ideal way would be to conduct specific damage surveys in the aftermath of a range of floods, preferably immediately after each. An example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990). This approach would not be practicable in the present case due to the absence of recent major flooding in the Curl Curl/Dee Why areas.

- The second best way is for experienced loss adjusters to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study (LMJ, 1985). It was not used for the present investigation.

- The third way is to use generalised data such as that published by CRES (Centre for Resource & Economic Studies, Canberra) and used in the Floodplain Management Study for Forbes (SKM, 1994) This kind of data is considered to be suitable for generalised studies, such as broad regional studies. It is not considered to be suitable for use in specific areas, unless none of the other approaches can be satisfactorily applied.

- The fourth way is to adapt or transpose, data from other flood liable areas. This was the approach used for Dee Why and Curl Curl Study Areas. It involved use of the basic data collected for the Nyngan survey and making adjustments to account for changes in values due to inflation, and to account for differences in the nature of developments in the Study Areas, when compared to Nyngan. Conducting the property and floor level survey in the flood liable areas of the Study Areas assisted this. The adjusted damage values were then checked for consistency with those presented in the recently completed Narrabeen Lagoon Floodplain Management Study (SMEC, 2002) which was jointly managed by Warringah and Pittwater Councils.

As indicated above, an important source of data for this study was the inspection and levelling of floors of properties in the study area estimated to be affected by flooding events up to and including the PMF event (LACE, 2003). The properties were divided into three categories: residential, commercial/industrial and public buildings.

For residential properties, the data obtained in the Property Survey included:

- the location/address of each property
- a description of the residence
- an estimate of the residence's value, age and size
- an assessment of the construction type and foundations
- a description of any external buildings/structures
- floor level of the residence

For commercial/industrial properties and public buildings, the Property Survey obtained information regarding:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- an estimation the construction type and foundations of the property
- floor level

The property descriptions were used to classify the properties into categories (i.e. high, medium or low value properties) which relate to the magnitude of likely flood damages.

4. RESIDENTIAL DAMAGES

4.1 Direct Residential Damages

4.1.1 Method

Damages were estimated for an area that extended approximately to the extent of the PMF event.

4.1.2 Damage Functions

A depth-damage curve relates flood damage to depth of flooding above floor level for different property types. In this study, depth-damage curves were used to estimate:

- Direct internal damages
- Structural damages
- External damages

Previous studies have shown that residential depth-damage curves, both actual and potential, can be reduced to a generalised relationship of the following form (Water Studies, 1986):

$$\frac{D}{D_2} = 0.06 + 1.42H - 0.61H^2 \qquad \text{for } H < 1 \text{ metre}$$

and

$$\frac{D}{D_2} = 0.75 + 0.12H \qquad \text{for } H > 1 \text{ metre}$$

Where D = potential damages ($)

H = depth of inundation above floor level (metres)

D_2 = potential damages ($) at 2 metres inundation

These equations provide an estimate of the potential damage to a property if no action is taken by the householder to reduce damage during a flood (such as removing valuable electronic equipment or lifting furniture onto a table). The ability of a resident to effectively reduce damage is closely related to the degree of flood awareness and the warning time available.

On the study catchments the “flash flooding” nature of inundation and the absence of recent flood experience both indicated that only a small reduction in potential damages should be made in their conversion to actual estimates.

Potential damages were reduced by 10 per cent to give estimates of actual internal and external damages on Dee Why and Curl Curl Lagoon catchments.

No reduction was applied to potential structural damages when computing actual damage, as this damage category is not sensitive to flood warning time or flood preparedness of residents.

Values of potential damage D_2 are given below:

	Internal	External	Structural
Low Value Property	$18,500	$2,000	$9,000
Medium Value Property	$21,750	$2,500	$15,000
High Value Property	$25,000	$3,000	$20,000

These values are based on the actual damages suffered in the 1990 flooding in Eugowra and Forbes (Water Studies, 1992) and Nyngan (DWR, 1990), increased to allow for inflation.

The total potential damages for a high value property subject to 2 m of inundation amounts to about $48,000. This value compares with estimated potential damages of $46,200 and $39,000 for brick and weatherboard properties respectively in Camden (in 2002 values). These damages were estimated from an evaluation of flood liable properties undertaken by a loss adjustor (LMJ, 1985).

By comparison, total potential damages for a High Value property (property value in the range of $0.7 – 1.5M) in the Narrabeen Lagoon Floodplain Management Study (SMEC, 2002) were $50,000, reducing to $30,000 for a Low Value property (property value $0.35 – 0.55M).

4.2 Indirect Residential Damages

Indirect residential damages comprise the costs of evacuating people and contents, providing temporary accommodation, cash grants to welfare and relief agencies, clean-up costs after the flood and loss of wages.

Because of the lack of readily useable data on this subject, these costs are sometimes estimated as a percentage of the direct damages. Typically, a value of 15% of actual direct damages is adopted (LMJ, 1985, SKM, 1994). The Narrabeen Lagoon Study also adopted a value of 15%.

In the Forbes Study the average indirect cost was $2,450 per flooded property. The cost of clean up was $600 and the remaining financial cost amounted to 40% of the actual direct cost. This is higher than often used, reflecting the low actual direct damages.

In the Nyngan study, the average indirect cost was $7,700 per flooded property. Of this amount the cost of clean up was $2,400 and the remaining financial cost of $5,300 amounted to 28% of the total actual direct cost to surveyed properties. The Nyngan residents were away from their homes for a long period (21 - 28 days) and were accommodated at public expense. In other situations, eg. Georges River in 1986 where the ratio to direct damage was 5%, the flooded individuals were away for a shorter duration, around 12 days, and found private accommodation.

For the present study clean up costs were estimated at $1,000 per dwelling, based on the Forbes Study and adjusted for inflation. Additional welfare and disaster relief costs were assessed at 25% of actual direct damages, based on the Forbes and Nyngan Studies.

4.3 Total Residential Damages

Tables B4.1 and **B4.2** summarise residential damages for a range of floods. The damage estimates were carried out for floods between the 20% AEP flood level and the extreme flood, which were modelled in the Flood Study.

The properties have been listed as being flood "damaged" and "affected." Flood affected properties include those which only have water within the allotment, as well as those having water above floor level, while damaged properties are defined as those for which flooding above floor level occurs.

TABLE B4.1
RESIDENTIAL DAMAGES IN DEE WHY LAGOON STUDY AREA

Flood Event % AEP	Number of Properties		Damage $ x 10^3		
	Flood Affected	Damaged	Direct	Indirect	TOTAL
20	47	9	116	38	154
10	53	12	155	51	206
2	67	14	223	70	293
1	73	17	254	81	335
PMF	143	67	1,284	388	1,672

TABLE B4.2
RESIDENTIAL DAMAGES IN CURL CURL LAGOON STUDY AREA

Flood Event % AEP	Number of Properties		Damages $ x 10^3		
	Flood Affected	Damaged	Direct	Indirect	TOTAL
20	11	2	14	6	20
10	19	3	25	9	34
2	59	9	119	39	158
1	77	23	482	144	626
PMF	153	104	2,808	806	3,614

5. COMMERCIAL AND INDUSTRIAL DAMAGES

5.1 Direct Commercial and Industrial Damages

5.1.1 Method

Direct damages up to the PMF flood event were estimated using the approach outlined in **Section 2**.

The depth of inundation was calculated as the difference between the surveyed floor level and the flood surface at that location.

5.1.2 Damage Functions

The method used to calculate damages requires each property to be categorised in terms of the following:

- damage category
- floor area
- ground level
- estimated floor height above ground.

The damage category assigned to each enterprise was either "low", "medium" or "high", depending on the nature of the enterprise and the likely effects of flooding. Damages were then determined on the basis of floor area. The following damage functions were adopted for potential internal damages for both commercial and industrial properties:

Low value enterprise	$350/m^2	(eg. joinery or auto workshop with concrete floor and minimal goods at floor level)
Medium value enterprise	$550/m^2	(enterprise with furniture/fixtures at floor level, which would suffer damage if inundated)
High value enterprise	$750/m^2	(eg. showroom or retailer with goods and furniture, or other high value items at ground or lower floor level)

These values were based on results presented in the Forbes/Eugowra Study (Water Studies, 1992) and the Nyngan Study (DWR, 1990) adjusted for inflation.

The above values are indexed to a depth of inundation of 2 metres. At floor level and 1.2 m inundation, zero and 70% of these values respectively were assumed to occur. The resulting depth-damage relationship is rather similar to that used in the ANUFLOOD computer model (SKM, 1994).

The factor for converting potential to actual damages depends on a range of variables such as the available warning time, flood awareness and the depth of inundation. Given sufficient warning time a well prepared business will be able to temporarily lift property above floor level. However, unless property is actually moved to flood free areas, floods which result in a large depth of inundation, will cause considerable damage to stock and contents.

For the present study, the potential to actual damages was assessed by conversion factors related to the depth of inundation. Potential damages were converted to actual damages using a ratio of 0.9. This factor and the shape of the resulting relationship are related to the relatively short warning time available.

External and structural damages were assessed as 4% and 10% of actual internal damages on the basis of data derived from studies of flood losses in Forbes, Eugowra and Nyngan.

5.2 Indirect Commercial and Industrial Damages

Indirect commercial and industrial damages comprise clean-up costs, costs of removal of goods and storage, loss of trading profit and loss of business confidence.

Disruption to trade takes the following forms:

- The loss through isolation at the time of the flood when water is in the business premises or separating clients and customers. The total loss of trade is influenced by the opportunity for trade to divert to an alternative source. There may be significant local loss but due to the trade transfer this may be considerably reduced at the regional or state level.

- In the case of major flooding, a downturn in business can occur within the flood affected region due to the cancellation of contracts and loss of business confidence. This is in addition to the actual loss of trading caused by closure of the business by flooding.

Loss of trading profit is a difficult value to assess and the magnitude of damages can vary depending on whether the assessment is made at the local, regional or national level. Differences between regional and national economic effects arise because of transfers between the sectors, such as taxes, and subsidies such as flood relief returned to the region.

Some investigations have lumped this loss with indirect damages and have adopted total damage as a percentage of the direct damage. In other cases, loss of profit has been related to the gross margin of the business, i.e. turnover less average wages. The former approach has been adopted in this present study. Indirect damages have been taken as 50% of direct actual damages.

For the purpose of the damage assessment it was assumed that clean-up cost was based on the floor area of each enterprise, and estimated at $\$15/m^2$.

5.3 Total Commercial and Industrial Damages

Tables B5.1 and **B5.2** summarise estimated commercial and industrial damages within the township.

TABLE B5.1
COMMERCIAL AND INDUSTRIAL DAMAGES IN THE DEE WHY LAGOON STUDY AREA

Flood Event % AEP	Number of Properties		Damages $ x 10^3		
	Flood Affected	Damaged	Direct	Indirect	TOTAL
20	4	0	0	0	0
10	4	0	0	0	0
2	4	3	17	13	30
1	6	3	187	138	325
PMF	12	6	1,696	900	2,596

TABLE B5.2
COMMERCIAL AND INDUSTRIAL DAMAGES IN THE CURL CURL LAGOON STUDY AREA

Flood Event % AEP	Number of Properties		Damages $ x 10^3		
	Flood Affected	Damaged	Direct	Indirect	TOTAL
20	20	10	611	401	1,012
10	24	13	759	491	1,250
2	29	24	1,236	774	2,010
1	35	27	1,517	980	2,497
PMF	49	40	3,841	2,258	6,099

6. DAMAGES TO PUBLIC BUILDINGS

6.1 Direct Damages – Public Buildings

Included under this heading are government buildings, churches, swimming pools and parks. Damages were estimated individually on an areal basis according to the perceived value of the property. Potential internal damages were assigned as follows:

Very low value	\$ 50/m^2 (eg. park buildings)
Low value	\$350/m^2
Medium value	\$500/m^2 (eg. council buildings)
High value	\$750/m^2 (eg. schools)

These values were obtained from the Nyngan Study (DWR, 1990) as well as commercial data presented in the Forbes/Eugowra Water Studies report.

External and structural damages were taken as 12.5 and 15% of internal damages respectively. An allowance was also made for damages to external buildings. It was estimated that 50% of public properties had external buildings and for each, damages were taken as 25% of internal damages to the main building.

6.2 Indirect Damages – Public Buildings

A value of \$8,000 was adopted for the clean-up of each property. This value is based on results presented in the Nyngan Study and adjusted for inflation. Total "welfare and disaster" relief costs were assessed as 50% of the actual direct costs, as for commercial properties.

6.3 Total Damages – Public Buildings

TABLE B6.1
DAMAGES FOR PUBLIC BUILDINGS IN DEE WHY LAGOON STUDY AREA

Flood Event % AEP	Number of Buildings		Damages \$ x 10^3		
	Flood Affected	Damaged	Direct	Indirect	TOTAL
20	1	0	0	0	0
10	2	0	0	0	0
2	2	0	0	0	0
1	3	0	0	0	0
PMF	4	3	409	229	638

TABLE B6.2
DAMAGES FOR PUBLIC BUILDINGS IN CURL CURL LAGOON STUDY AREA

Flood Event % AEP	Number of Buildings		Damages $ x 10^3		
	Flood Affected	Damaged	Direct	Indirect	TOTAL
20	1	0	0	0	0
10	2	0	0	0	0
2	2	0	0	0	0
1	2	0	0	0	0
PMF	3	2	456	244	700

7. DAMAGES TO INFRASTRUCTURE AND COMMUNITY ASSETS

Infrastructure in the Study Areas, such as electrical and telephone supply, sewerage and water supply systems, and road network, are potentially prone to damaging flooding. Community assets such as parks and other recreational amenities could also suffer damages. No data are available on damages experienced during historic flood events. However, a qualitative matrix of the effects of flooding on these categories is presented in **Table B7.1**.

Table B7.1
QUALITATIVE EFFECTS OF FLOODING ON INFRASTRUCTURE AND COMMUNITY ASSETS IN DEE WHY AND CURL CURL LAGOONS STUDY AREAS

Damage Sector	Flood Event (AEP%)				
	20	10	2	1	PMF
Electricity	0	0	0	0	X
Telephone	0	0	0	X	X
Roads	0	0	X	X	X
Bridges	0	0	0	0	X
Sewerage	0	0	0	0	X
Water Supply	0	0	0	0	X
Parks and Gardens	0	X	X	X	X

Notes: 0 = No significant damages likely to be incurred.
X = Some damages likely to be incurred.

8 SUMMARY OF TANGIBLE DAMAGES

Flood damages under existing conditions have been computed for the two catchments for a range of flood frequencies from 20% AEP to the PMF event. The 20% AEP is the "threshold" flood magnitude at which significant damages are experienced.

The total damages for each flood event are shown on **Tables B8.1** and **B8.2**. Cumulative average annual damages were assessed and are also shown. **Figures B8.1** and **B8.3** show the resulting damage - frequency curves and **Figures B8.2** and **B8.4** show the cumulative average annual damage curve for the two catchments.

TABLE B8.1
TOTAL DAMAGES IN DEE WHY LAGOON STUDY AREA

Flood Event % AEP	No. of Properties Flooded						Total Damages $ x 10^3	Cumulative AAD $
	Residential		Commercial/ Industrial		Public			
	A	D	A	D	A	D		
20	47	9	4	0	1	0	150	23,000
10	53	12	4	0	2	0	205	41,000
2	67	14	4	3	2	0	330	62,000
1	73	17	6	3	3	0	660	67,000
PMF	143	67	12	6	4	3	4,905	95,000

TABLE B8.2
TOTAL DAMAGES IN CURL CURL LAGOON STUDY AREA

Flood Event % AEP	No. of Properties Flooded						Total Damages $ x 10^3	Cumulative AAD $
	Residential		Commercial/ Industrial		Public			
	A	D	A	D	A	D		
20	11	2	20	10	1	0	1,030	155,000
10	19	3	24	13	2	0	1,285	271,000
2	59	9	29	24	2	0	2,170	409,000
1	77	23	35	27	2	0	3,120	435,000
PMF	153	104	49	40	3	2	10,410	502,000

Note: A - flood affected property (includes flooding in allotments and above floor flooding
D - flood damaged property (above floor flooding)

Average annual damages (also termed "expected damages") are determined by integrating the area under the damage-frequency curve. They represent the time stream of annual damages, which would be expected to occur on a year by year basis over a long duration.

Using an appropriate discount rate, average annual damages may be expressed as an equivalent "*present worth value"* of damages and used in the economic analysis of potential flood management measures.

Cumulative annual average damages may be referenced to a particular flood frequency. They represent the average damages which would be expected on an annual basis for all flood events up to and including that nominated frequency.

For example, the cumulative average annual value of damages in the Curl Curl Lagoon catchment for all floods up to the 1% AEP level is around $435,000 (**Table B8.2**). A flood management scheme which has a 1% AEP level of protection will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods, then these damages represent the benefits of the scheme expressed on an average annual basis.

Under current NSW Treasury guidelines, economic analyses are carried out assuming a 20 year economic life for projects and discount rates of 7% pa. (best estimate) and 10% and 4% pa. (sensitivity analysis).

The present worth values of damages likely to be experienced in the study areas for all flood events up to the PMF, a 20 year economic life and discount rates of 4, 7 and 10 per cent are shown on **Table B8.3**.

TABLE B8.3
PRESENT WORTH OF DAMAGES FOR ALL FLOODS UP TO THE PMF AND ECONOMIC LIFE OF 20 YEARS
$ X 10^3

Location	Discount Rate – per cent		
	4	7	10
Dee Why Lagoon	1,290	1,005	805
Curl Curl Lagoon	6,820	5,315	4,270

For a discount rate of 7% pa, the *present worth value* of damages for all flood events up to the PMF level in the Curl Curl Lagoon Study Area is about $5.3 million for a 20 year economic life. Therefore a scheme costing up to $5.3 million could be economically justified if it eliminated damages for all flood events up to this level. More expensive schemes would have a benefit/cost ratio less than 1, but may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.

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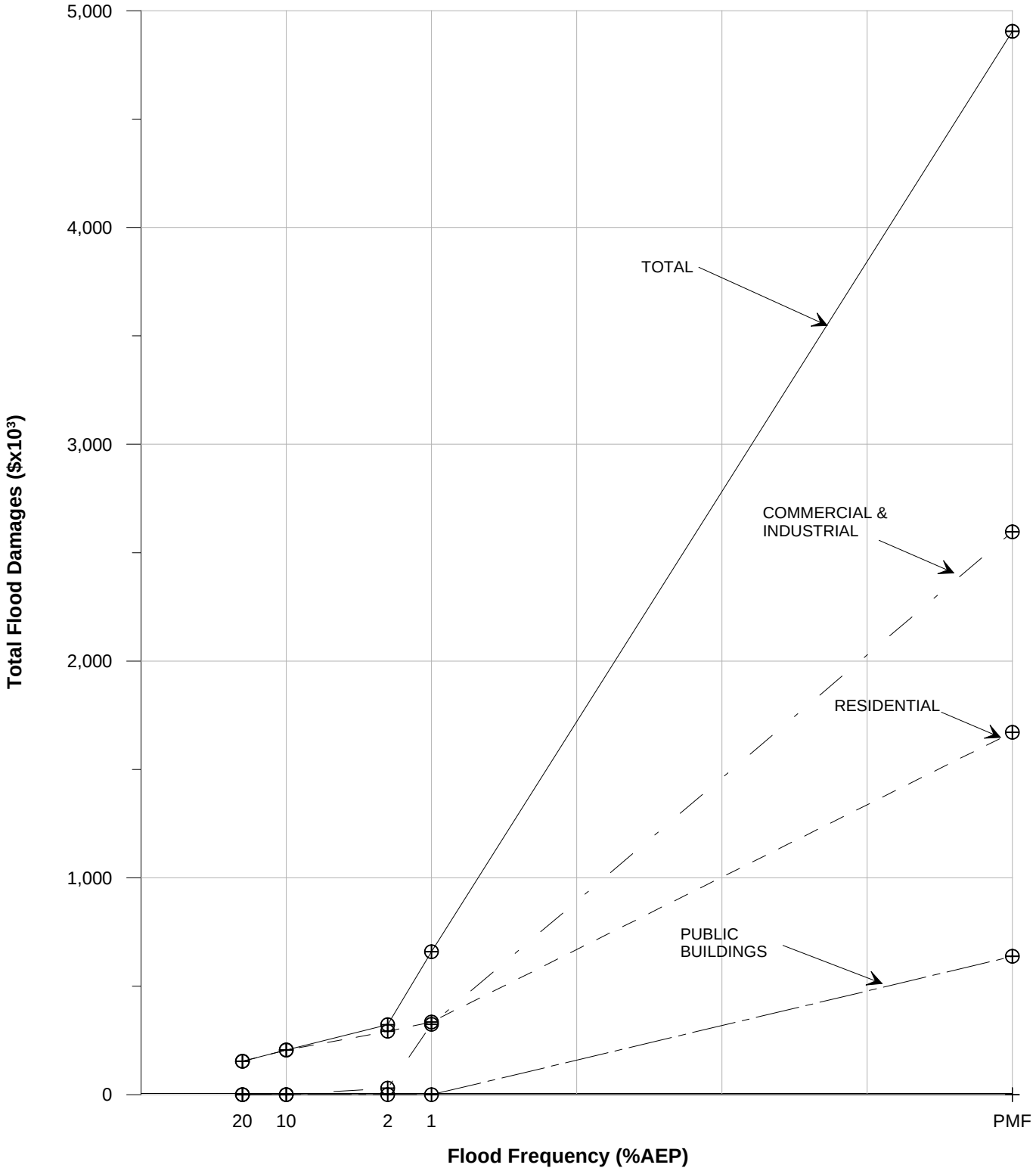
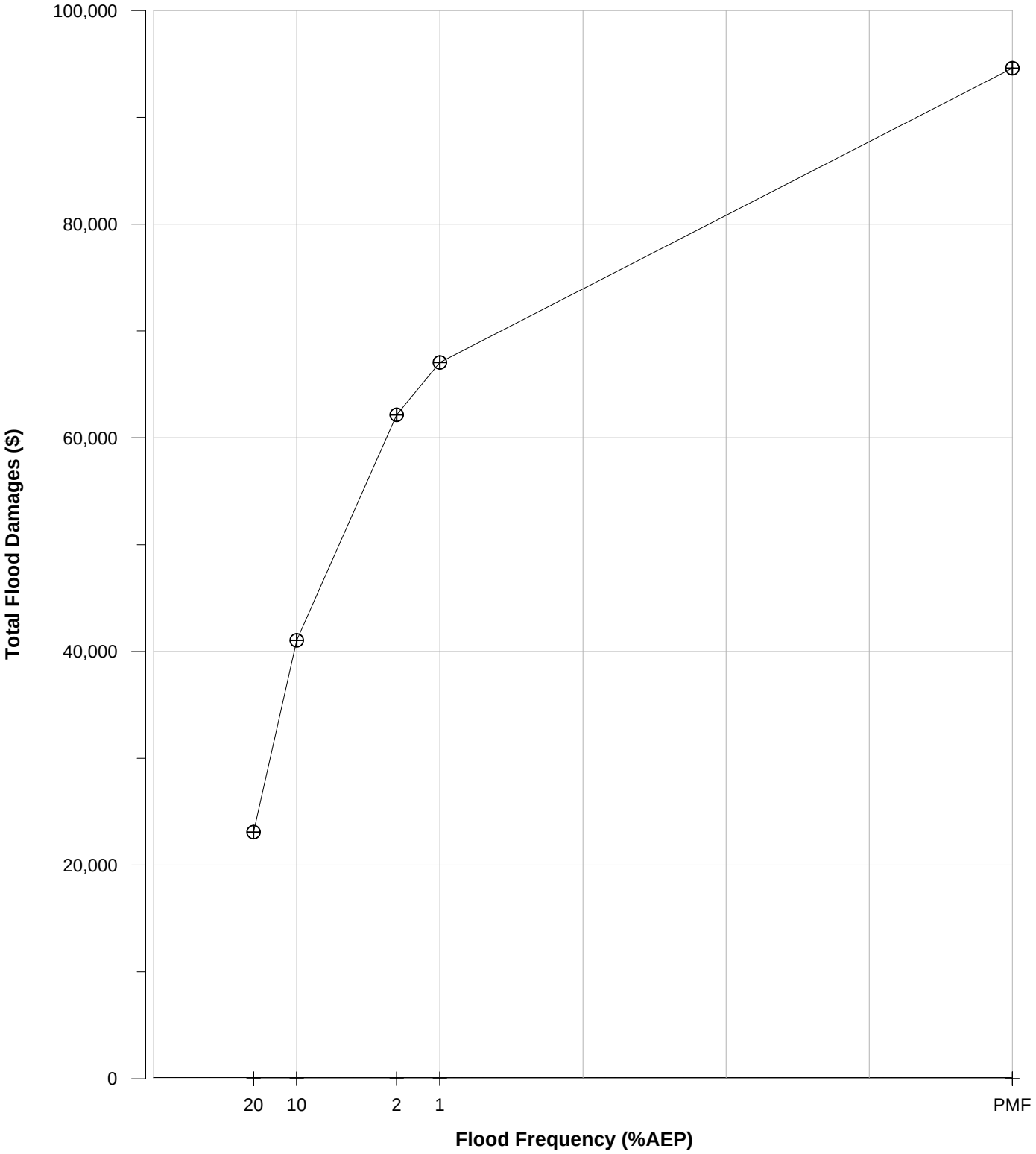


DEE WHY & CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY

Figure B8.1

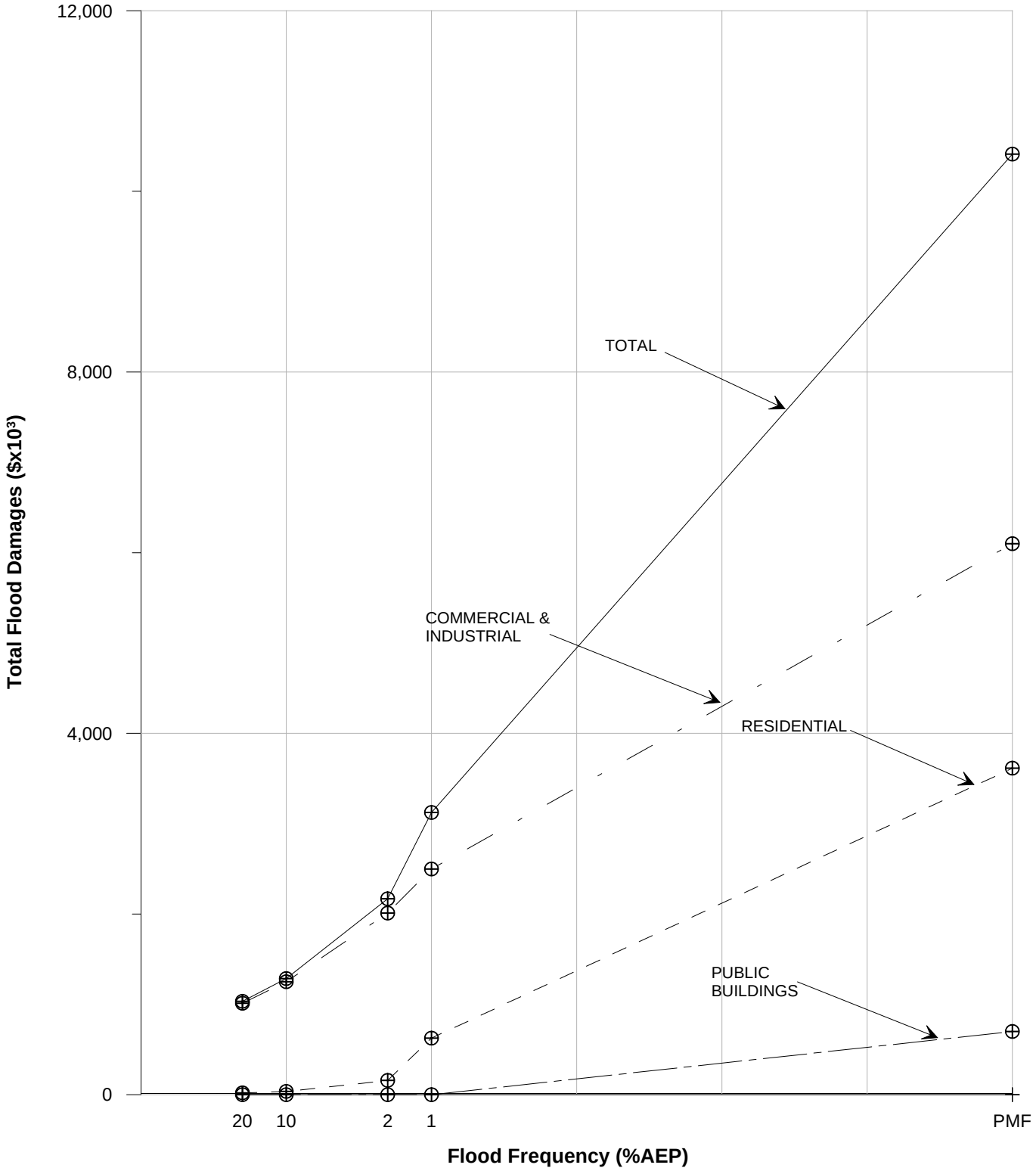
DAMAGE-FREQUENCY CURVES
DEE WHY LAGOON



DEE WHY & CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY

Figure B8.2

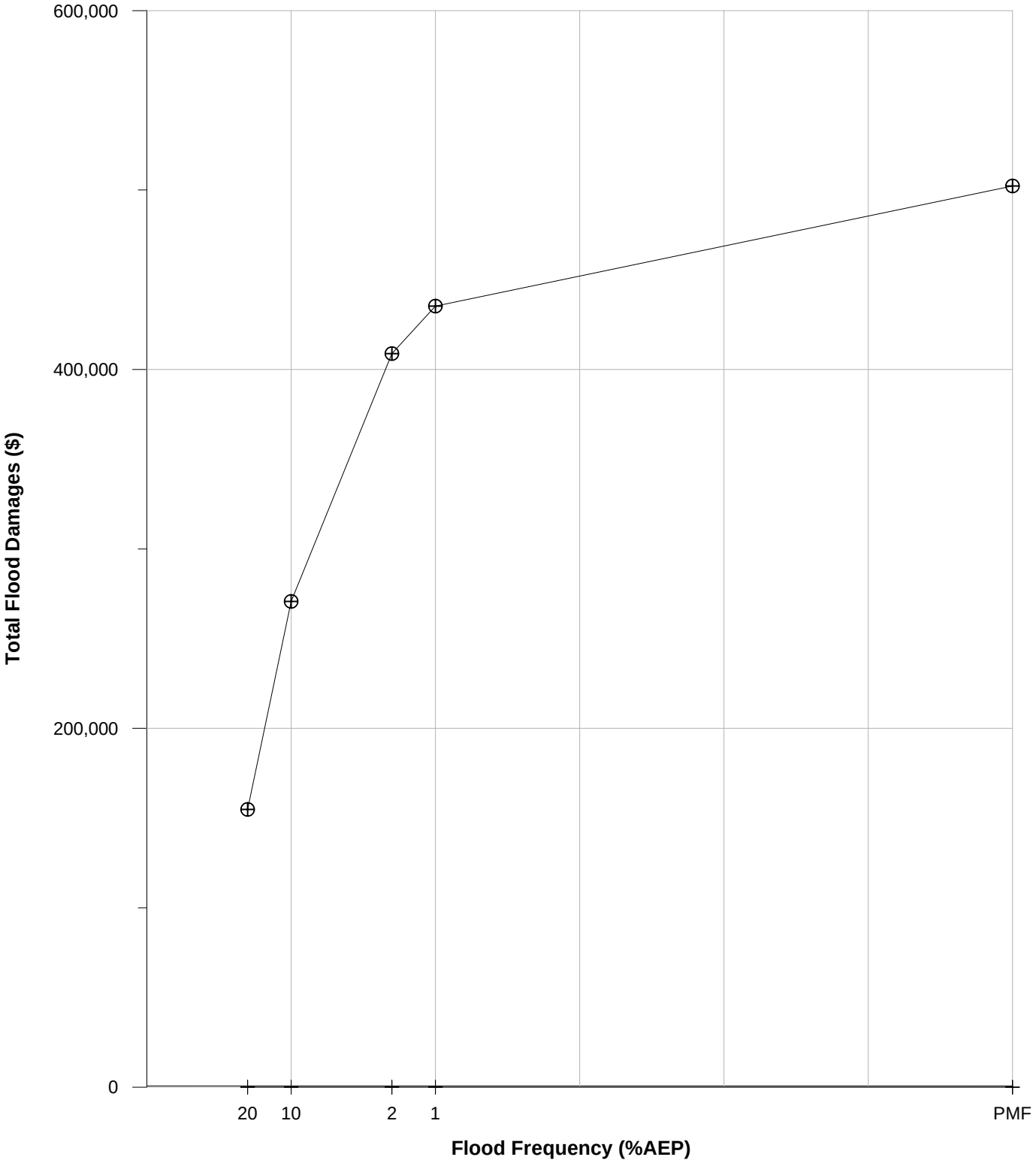
CUMULATIVE AVERAGE ANNUAL DAMAGES
DEE WHY LAGOON



DEE WHY & CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY

Figure B8.3

DAMAGE-FREQUENCY CURVES
CURL CURL LAGOON



DEE WHY & CURL CURL LAGOONS
FLOODPLAIN RISKMANAGEMENT STUDY

Figure B8.4

CUMULATIVE AVERAGE ANNUAL DAMAGES
CURL CURL LAGOON

APPENDIX C

EXISTING PLANNING INSTRUMENTS AND POLICIES RELATING TO FLOODPLAIN MANAGEMENT

November 2005

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1 EXISTING PLANNING INSTRUMENTS AND POLICIES

1.1 Introduction

Planning Instruments used by Warringah Council to manage development in the catchments draining to Dee Why and Curl Curl Lagoons comprise:

- Warringah Local Environmental Plan 2000; and
- Warringah Design Guidelines, August 2001

A previous flood policy which was applied to both the Warringah and Pittwater LGA's, "Interim Policy and Guidelines, 1990" has been superseded by the August 2001 Guidelines.

In the Pittwater LGA, the Guidelines have been superseded by Development Control Plan No. 30 entitled "Pittwater Flood Risk Management", December 2002,

1.2 Warringah Council Local Environmental Plan, 2000

1.2.1 Approach to Planning Controls

The Warringah LEP does not contain generic zones such as Residential, Industrial or Business Zones, but adopts a "place based" approach to planning controls. Individual localities have been grouped to reflect the distinctive features or built character of the area.

The Warringah area has been divided into 73 localities, each of which has a Locality Statement which outlines the specific planning controls to achieve the desired qualities for the locality. The Desired Future Character statement is set out at the beginning of each Locality Statement and provides a description of the important characteristics of a locality. It also identifies any key features of the area which should be retained and provides direction as to how future development will replicate, reflect or add to the important features that contribute to the character of the locality.

The localities bordering the Dee Why Creek and Lagoon are as follows:

Locality	Location	Desired Future Character	Flood Impacts in this Locality
E1 Dee Why North	Northern side of Dee Why Creek west of Pittwater Road.	Detached style housing in landscaped settings interspersed by a range of complementary and compatible uses.	Damaging flooding occurs at 20% AEP in Tarra Crescent and Billarong Avenue, upstream of Pittwater Road bridge.
E3 Cromer Industrial	Northern Side of Dee Why Creek west of Campbell Avenue.	This area will remain an industrial/employment centre with industries and ancillary service uses and a range of compatible community and leisure uses.	Damaging flooding occurs at 2% AEP in commercial/industrial properties in Dumic Place.

Locality	Location	Desired Future Character	Flood Impacts in this Locality
E2 Dee Why Lagoon Suburbs	Southern Side of Dee Why Creek. This area includes Dee Why Bowling Club, Manly Warringah Soccer Club and Evergreen Tennis Centre	This locality will remain characterised by detached housing and a small pocket of apartment development in landscaped settings interspersed by a range of complementary and compatible uses.	Residences inundated along Fisher Road North south of Dee Why Bowling Club and at eastern ends of Heron Place and Tulich Avenue at 20% AEP flood level.
E13 Dee Why Park	Southern Side of Dee Why Creek West of Pittwater Road	This area will remain characterised by apartment style housing in landscaped settings and uses which are compatible with housing.	Park area inundated during medium floods. Inundation of several residential properties in the event of major floods.

Localities bordering Greendale Creek and Curl Curl Lagoon are:

Locality	Location	Desired Future Character	Flood Impacts in this Locality
F5 Curl Curl	Northern and Southern Sides of Greendale Creek, east of Harbord Road.	Detached style housing in landscaped settings interspersed by existing apartment buildings and a range of complementary and compatible uses.	Low lying residences at southern end of Surf Road inundated at 20% AEP flood level. Low lying residences on southern side of Greendale Creek behind John Fisher Park flooded at 2% AEP flood level.
F3 Brookvale Industrial	Northern and Southern Sides of Trunk Drainage System, west of Harbord Road.	The Brookvale Industrial locality will remain an industrial and employment centre incorporating industrial warehouses and ancillary service uses.	Industrial/ commercial properties on western side of Harbord Road flooded at 20% AEP level.

1.2.2 Development on Flood Prone Land

The LEP divides development into two categories:

(1) Exempt Development which may be carried out without development consent, and

(2) Complying Development which is assessed on the bases of its compliance with Council Planning Instruments.

Development which does not fall into either of these categories is assessed on the basis of its level of compliance with Planning Instruments.

Exempt development is outlined in Schedule 1 of the LEP. According to Clause 1(c) of the LEP, land that is "flood prone as shown on a map deposited in the office of the Council" is not Exempt Development.

Clause 7 of the LEP requires that all development apart from exempt development and that in Schedule 2 require Council consent. Clause 7(b) and Schedule 2 allow flood mitigation to be carried out by Council or the Department of Land and Water Conservation, now Department of Planning and Natural Resources. Maintenance dredging may occur without development consent where carried out by a public authority, provided that certain bodies are consulted.

The LEP also identifies development that is complying, which is assessed on the bases of compliance with the provisions of Council's LEP and where the merit of the proposed development is not considered. Clause 8(2)(b) of the LEP specifically excludes development on flood prone land from this category. These clauses ensure that full development assessment is carried out for any development on flood prone land, except for flood mitigation works.

Clause 47 is the main clause relating to flooding in the Warringah LEP and states:

> *"Development on flood plain land is to be sited and designed to minimise impacts of flooding on property and have regard to the existing flood regime.*
> *In particular:*
>
> - *Development is not to reduce flood storage area or impact upon the existing flood regime,*
> - *Habitable floor areas of buildings are to be at a level of at least 500mm above the 1% annual exceedence probability flood level, and*
> - *Buildings or works affected by flooding are to be constructed of flood compatible building materials."*

In addition to Clause 46, Schedule 7 of the LEP, *Matters for Consideration in a Subdivision of Land*, has some relevance to development on flood prone land. Clause 4 of the Schedules states that "*subdivision on flood prone land should be avoided*", effectively discouraging the intensification of development on flood prone land.

A set of maps accompanies the Warringah LEP 2000 and provides the land use zones for areas within the floodplain.

1.2.3 Environmental Protection of Waterways

Clause 60 of the LEP requires that development must be '*sited and designed to maintain and enhance natural watercourses and aquatic habitat*'. This clause encourages the continuing preservation of waterbodies such as Dee Why and Curl Curl Lagoons, and the natural flow of water in the watercourses draining to them. Water quality is also preserved through Clause 78, which specifies controls over erosion and sedimentation on a site during development. A soil and water management plan must be prepared to minimise soil erosion and maintain downstream water quality, wherever a degree of soil erosion and sedimentation is likely to occur.

1.2.4 Housing for Older People with Disabilities

The LEP takes a permissive approach to housing for older people or people with disabilities, the provision of which is regulated under State Environmental Planning Policy No. 5 (SEPP 5). Clause 40 of the LEP describes the various requirements for such housing developments, including adequate access to various goods and services. Schedule 16, *Principles and standards for housing for older people or people with disabilities*, adds further detail to the standard of such housing.

1.3 Interim Warringah Design Guidelines, 2001

The Interim Warringah Design Guidelines were prepared in August 2001 as an accompaniment to Warringah LEP 2000. The Design Guidelines provide a greater level of detail and explanation of the design standards for development in Warringah than is found in the LEP.

Cl.47 of Part C of the Design Guidelines expands on Clause 47 of the LEP, *Flood Affected Land*, to outline the appropriate guidelines for development on flood affected land. Three design guidelines are provided.

Guideline 1 states:

> *"Do not reduce the flood storage area or impact upon existing flood regime."*

Three categories of flood liable land are identified, namely: floodways, flood storage areas and flood fringe area. The definitions used for these three categories are similar to definitions used in the *Floodplain Development Manual, 2005* which sets out the NSW Government's policy for the management of flood liable land.

The text explains that if the flood storage area is reduced by landfill or the construction of levees, adjacent flood levels will rise and the peak discharge downstream may increase. It is then stated that plans accompanying development proposals should show the 1% AEP flood level.

Guideline 2 states:

> *"Design habitable floor areas at least 500mm above the 1% Annual Exceedence Probability"*

A brief explanation of the meaning of the term '1% Annual Exceedence Probability' is provided below this guideline, as well as a diagram to demonstrate the location of a habitable floor level, 500 mm above the flood level.

Guideline 3 states:

> *"Use flood compatible building materials"*

The text provides a list of the materials and construction methods that are suitable for development on the floodplain. This list expands the statement in the LEP that buildings affected by flooding should be constructed of flood compatible building materials, giving appropriate guidance to developers. The list of materials and construction methods is derived from the *Floodplain Development Manual, 2005*.

Other clauses related to flooding in the LEP are also expanded in the Design Guidelines. These provide guidelines for erosion and sedimentation, landfill, stormwater management, and watercourses and aquatic habitat. The flood related guidelines focus on preventing unnecessary alteration or inhibition to the natural flowpath of watercourses. Within the guidelines on stormwater management, the use of on-site stormwater detention is encouraged to reduce the impacts of increased runoff on the existing natural and constructed drainage systems.

2 COMMENTS ON EXISTING POLICIES

The guidelines as they relate to the development of flood affected land are quite short, being limited to two pages of discussion. The first page sets out three general principles for development:

- No reduction in flood storage or impact upon the existing flood regime.
- Habitable floor levels to be at least 500 mm above 1% AEP flood level.
- Building works affected by flooding are to be constructed of flood compatible materials.

The document then goes on to define the three hydraulic categories of flood liable land (floodways, flood storage and flood fringe) and briefly outlines the impacts of building in each zone. A list of flood compatible building materials is also presented.

The guidelines are embedded in a long list of other considerations for the control of development. They are also LGA wide guidelines and do not necessarily relate to the catchment specific issues in the Dee Why and Curl Curl Lagoon catchments.

They relate to residential categories of development, with no specific guidelines for development in industrial/commercial areas, or for essential services or SEPP 5 development.

In the Pittwater LGA, Council has proposed a local flood policy, Development Control Plan No. 30, entitled “Pittwater Flood Risk Management”, December 2002.

That policy has adopted the 1% AEP flood with 500 mm of freeboard as the Flood Planning Level for residential and commercial development, with more stringent controls adopted for development in high hazard areas of the floodplain. A modified version of Pittwater Council’s DCP 30 has been proposed as a Local Flood Policy for the Dee Why Curl Curl Lagoon study area.

A draft of the Local Flood Policy for the study area is attached as **Appendix D**. Features of the draft policy are as follows:

1) The Flood Policy relies upon the catchment specific flood data developed in the Flood Study (LACE, 2002).
2) The Flood Policy proposes the 1% AEP flood level plus 500 mm of freeboard as the Flood Planning Level for residential and commercial/industrial development. It proposes the Probable Maximum Flood level plus 300 mm of freeboard for essential services and SEPP 5 development. The policy applies to new development in the floodplain (i.e. land inundated by the Probable Maximum Flood).
3) The Flood Policy discourages development in high hazard/floodway areas and sets out more stringent requirements for those areas, aimed at ensuring that the hydraulic conveyance capacity of the floodplain is not adversely affected by development.
4) The Flood Policy nominates the documentation required to be submitted with the Development Application. Procedures are aimed at maximising the use of existing flood data on the two catchments (LACE, 2002) and ensuring that developments in flood affected areas are evaluated in a cost effective manner, without imposing undue costs by way of privately commissioned flood study investigations.

APPENDIX D

DRAFT LOCAL FLOOD POLICY
DEE WHY AND CURL CURL
LAGOON CATCHMENTS

November 2005

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1 PLANNING CONTEXT AND OBJECTIVES

1.1 Planning Context

This plan is known as *Development Control Plan No XXXX, Local Flood Policy Dee Why and Curl Curl Lagoon Catchments.*

The provisions of this plan apply in addition to and complement those of the *Warringah Local Environmental Plan, 2000* and the associated *Warringah Design Guidelines, August 2001*.

This Development Control Plan is to be read in conjunction with the *Floodplain Risk Management Study and Plan for Dee Why and Curl Curl Lagoon Catchments, 2004,* which has been prepared as part of the NSW Government's program to mitigate the impact of major floods and reduce the associated hazards in the floodplain.

1.2 Policy Objectives

The purpose of this Local Flood Policy is to responsibly exercise Council's duty of care, in order that the development of properties located in flood prone areas within the Dee Why and Curl Curl Lagoon Catchments is undertaken in a responsible manner to minimise the potential risk associated with major flood events.

The policy applies to all flood prone land adjacent to the main streams in the two catchments, as identified in the *Floodplain Risk Management Study and Plan, 2004.*

The objectives of this policy are to implement development controls that over time raise the floor levels of all development on flood affected properties to the **Flood Planning Level** as a minimum floor elevation and ensure that all new development is located in areas compatible with the flood risk, with minimum impact on adjacent development and flooding patterns.

Definitions of flood related terms used herein are provided in the **Glossary** in **Section 5** of this document.

1.3 Variations to the Flood Policy

In keeping with the merits based objectives of the NSW Government's *Floodplain Development Manual, 2005*, Council may consider development proposals which incorporate variations to the policy, where it is demonstrated that Council's objectives can be achieved, without detriment to the safety of occupants of the floodplain, or increasing the potential flood risk.

2 APPLICATION OF THE POLICY

2.1 Overview

Development controls on flood prone land are set out in **Chapter 3** of this Flood Policy. The **Flood Planning Level** for residential, commercial and industrial and subdivision development is based on the 1% annual exceedence probability (AEP) flood, with an allowance of 500 mm for freeboard.

Adoption of a **1% AEP flood** for planning purposes strikes a reasonable balance between the dual objectives of minimising risk to existing and future development, whilst not imposing excessive development costs or unnecessarily sterilising land.

Location of essential services, schools and housing for aged persons and people with disabilities on flood prone land is not encouraged. For those categories of land use the Policy requires floor levels to be 300 mm above the level of the **Probable Maximum Flood.**

The **Flood Policy** is based on the recognition that individual developments should not be evaluated in isolation, but rather, should be considered in a strategic sense as if it were one of several developments in the area. Whilst individual developments in isolation may not have a measurable impact on flooding, the cumulative impacts of ongoing development could be significant.

Accordingly, emphasis is placed on the requirements that developments should not result in a net displacement of flood storage regardless of their location in the floodplain, and that in addition, there should be no loss of floodway area for the conveyance of flows in **High Hazard** areas. Hydraulic analysis has shown that on the Dee Why and Curl Curl Lagoon catchments, the **High Hazard** areas closely correspond with the floodways, ie the extent of flood affected land in which most of the flood flow is conveyed.

Development in **High Hazard** areas is not encouraged. Development proposals in **High Hazard** areas require the preparation of a **Flood Risk** report by a suitably qualified Floodplain Management Consultant, to be submitted in support of the Development Application.

3 DEVELOPMENT CONTROLS

3.1 Controls Applying to All Development

3.1.1 General

The following applies to all development under this plan, including situations where any part of a new structure is located below the **Flood Planning Level.**

a) All structures below the **Flood Planning Level** shall be constructed from flood compatible materials. A list of flood compatible materials is presented in **Section 5.4** of this document.

b) All development must be designed and constructed so that it will have a low risk of instability due to hydrodynamic forces resulting from flow velocities for all floods up to the **1% AEP** flood and due to hydrostatic and buoyancy forces for flood levels up to the **Flood Planning Level.**

c) All development must be designed and constructed so that it will not adversely impact on surrounding properties by increasing flood levels or re-directing flood flows. The filling on flood prone land or enclosure of structures will only be permitted where there is no net decrease in floodplain storage.

d) Implementation of a suspended floor on open pier/pile footings to allow for the flow of water beneath the structure and maintenance of flood storage is encouraged as an alternative to providing compensatory excavation in order to meet the requirements of item c) above.

e) All electrical equipment, wiring, fuel lines or any other service pipes and connections shall be waterproofed to the **Flood Planning Level.**

3.2 Residential (1-2 Dwellings)

3.2.1 New Dwellings, Replacement Dwellings and Additions

For residential (1 – 2 dwelling) developments, all floor levels shall be at or above the **Flood Planning Level** or raised to the **Flood Planning Level**.

3.2.2 Possible Exemptions for Minor Additions to Existing Single Dwellings

An addition to a single residential dwelling may be permissible where existing floor levels are retained below the **Flood Planning Level**, provided that the following controls are complied with:

a) The cumulative maximum gross floor area of the ground floor and upper storey addition, is restricted to 30 m^2 if any part of the existing dwelling is below the **Flood Planning Level**.

b) The property must not be subject to a **High Hazard Classification**.

c) The floor levels of the addition must be at or above the **Flood Planning Level**.

d) If the floor level of the existing dwelling is to be retained at the existing level, the existing dwelling must be satisfactorily flood proofed (either wet or dry) to the **Flood Planning Level**.

e) The addition must be designed and constructed such that it does not preclude the raising of the floor level of the existing structure to the **Flood Planning Level** at a future date or when further additions are proposed. The ability for a future raising could be achieved through the provision of a construction joint.

f) A second storey addition to the dwelling requires the floor level of the second storey to be of a height that allows for the internal ground floor of the existing dwelling to be either at or raised to the **Flood Planning Level,** whilst maintaining Council's minimum floor to ceiling height requirements of 2.4 m.

3.2.3 Carparking Facilities

The floor level of new enclosed garages shall be a minimum of 300 mm above the **1% AEP** flood level. Consideration may be given to a floor level at a lower level where it can be demonstrated that providing the floor level at the **Flood Planning Level** is not practical.

Basement (i.e. below natural ground level) carparking must have all access and potential water entry points above the **Flood Planning Level**.

Open carpark areas and carports are permissible at the existing ground level provided the area would not be inundated by more than 200 mm in the event of a **1% AEP** flood.

3.2.4 Development on Land with a High Hazard Classification

For residential (1 – 2 dwelling) development on land that has a **High Hazard Classification**, there is to be no net loss in flood storage and floodway area, as a result of the development for the **1% AEP** flood, i.e. the development is not to result in an increased impact on the floodway.

Carpark areas and carports are not permissible on land that has a **High Hazard Classification**.

3.3 Residential (Medium Density Dwellings, Apartments)

3.3.1 New Development

All floor levels of the development are to be at or above the **Flood Planning Level**.

3.3.2 Carparking Facilities

Basement (i.e. below natural ground level) or enclosed carparking facilities must have all access, ventilation and any other potential water entry point above the **Flood Planning Level** and a clearly signposted flood free pedestrian evacuation route from the basement area separate to the vehicular access ramps.

Open carpark areas and carports are permissible at the existing ground level provided the area would not be inundated by more than 200 mm in the event of a **1% AEP** flood.

3.3.3 Development on Land with a High Hazard Classification

Medium Density/ Apartment housing developments are not permissible where the property is subject to a **High Hazard Classification**, except where it can be demonstrated that:

a) the building platforms and developable areas including carpark facilities and access are outside the area of the property affected by the **High Hazard Classification**, and

b) there is no net loss in flood storage or floodway area as a result of the development for the **1% AEP** flood, i.e. the development is not to result in an increased impact on the floodway.

3.4 Industrial and Commercial (Including Shop Top Housing)

3.4.1 New Developments and Additions to Existing Development

All floor levels of the development, including any existing components to be retained, are to be at or above the **Flood Planning Level** or raised to the **Flood Planning Level**.

3.4.2 The Following Exceptions May Apply for Commercial/Industrial Development

Where constructing the floor level at the **Flood Planning Level** or raising the floor level of existing development to the **Flood Planning Level** may be difficult to achieve due to site and access constraints, consideration may be given to a floor level with a freeboard of less than 500 mm above the 1% AEP level provided that satisfactory flood proofing of the development (either wet or dry) is achievable to the **Flood Planning Level**.

3.4.3 Change of Use of Existing Premises

All floor levels of the development, including any existing components to be retained, are to be at or above the **Flood Planning Level** or raised to the **Flood Planning Level**.

3.4.4 The Following Exceptions May Apply for Change of Use of Existing Premises

Where constructing the floor level at the **Flood Planning Level** or raising the floor level of existing development to the **Flood Planning Level** may be difficult to achieve due to site and access constraints, consideration may be given to satisfactory flood proofing (either wet or dry) to the **Flood Planning Level**.

3.4.5 Carparking Facilities

Basement (i.e. below natural ground level) or enclosed carparking facilities must have all access, ventilation and any other potential water entry point above the **Flood Planning Level** and a

clearly signposted flood free pedestrian evacuation route from the basement area separate to the vehicular access ramps.

Open carpark areas are permissible at the existing ground level provided the area would not be inundated by more than 200 mm in the event of a **1% AEP** flood.

3.4.6 Development on Land with High Hazard Classification

For commercial and industrial development on land that has a **High Hazard Classification**, there is to be no net loss in flood storage and floodway area as a result of the development, for the **1% AEP** flood, i.e. the development is not to increase its impact in the floodway.

Carpark areas are not permissible on land that has a **High Hazard Classification**.

3.5 Land Uses Requiring Special Flood Protection

3.5.1 Development Type

The Flood Policy has regard to the following special types of development.

- A school;
- A child care centre;
- Emergency services (eg hospital; fire or ambulance station, police station)
- A hotel, motel and other tourist accommodation;
- A building wholly or partially used as a home or other establishment for mentally incapacitated persons;
- Housing for older people or people with disabilities;
- Group homes as defined in State Environmental Planning Policy No. 9 Group Homes; and
- A retirement village

3.5.2 New Developments and Additions to Existing Development

New developments on land inundated by the **1% AEP** flood are not permissible. All floor levels of new developments and additions to existing development must be 300 mm above the **Probable Maximum Flood** level.

3.5.3 Carparking Facilities

Basement (i.e. below natural ground level) or enclosed carparking facilities must have all access, ventilation and any other potential water entry point set 300 mm above the **Probable Maximum Flood** level and a clearly signposted flood free pedestrian evacuation route from the basement area separate to the vehicular access ramps.

Open carpark areas and carports are permissible at the existing ground level provided finished levels are 300 mm above the **Probable Maximum Flood** level and a clearly signposted flood-free pedestrian evacuation route is available.

3.6 Subdivision on Flood Affected Land

3.6.1 Subdivision

Subdivision on flood affected land will not be permitted on land with a **High Hazard** classification, or where additional flood affected residential allotments will be created below the **Flood Planning Level**.

3.6.2 The Following Exceptions May Apply.

Subdivision on flood affected land may be permissible where it can be demonstrated that:

a) the building platforms and developable areas including carpark facilities and access are outside any areas of the property affected by the **High Hazard Classification.**

b) there is to be no net loss in floodplain storage or in the floodway area as a result of the development for the **1% AEP** flood, i.e. the development is not to result in an increased impact on the floodway.

4 INFORMATION TO BE SUBMITTED WITH THE DEVELOPMENT APPLICATION

4.1 Flood Planning Levels – Hazard Classification

A statement of the **Flood Planning Level** and **Hazard Classification** details that apply to the subject property are to be submitted with the application. These details are established by one of the following methods:

Using Council's Flood Data

On the main streams in the Dee Why and Curl Curl Lagoon Catchments, the **Flood Planning Level** and **Hazard Classification** information is generally available upon written application to Council.

Independent Assessment

Alternatively, an applicant may choose to seek independent advice to determine the **Flood Planning Level** and **Hazard Classification.** Under those circumstances, a Flood Study prepared by a suitably qualified Consulting Engineer must be submitted for Council's consideration. The Flood Study will provide basic information for the **Flood Risk Report** for the project, which will also be required. Requirements of the **Flood Risk Report** are set out in Section 4.3.

4.2 Survey Details

A Survey Plan prepared by a Registered Surveyor is required to be lodged with the Development Application. For flood affected property additional details relating to flood affectation are required. The Survey Plan must indicate the following:

- The location of existing building or structures;
- The floor levels and ceiling heights of all existing buildings or structures to be retained;
- Existing and/or proposed drainage easements and watercourses or other means of conveying flood flows that are relevant to the flood characteristics of the site;
- **Flood Planning Level, Probable Maximum Flood** level and flood extents;
- 0.2 metre natural surface contour intervals across the entire property. Note: All levels must be relative to Australian Height Datum (AHD)

4.3 Flood Risk Report

For Residential, Commercial and Industrial development, a Flood Risk Report is NOT required to be submitted with the development application where the applicant can demonstrate, using Council supplied flood information, that:

1. All floor levels, including those of existing components of the development, are at or above the Flood Planning Level or raised to the Flood Planning Level;

2 The development does not result in a net reduction in floodplain storage; AND

3. The property is not subject to a High Hazard Classification for the 1% AEP flood.

However, a **Flood Risk Report** is to be submitted for all development on land subject to a **High Hazard Classification** or where the proposed development has floor levels below the **Flood Planning Level**, or where the applicant chooses to seek independent advice to determine the above flood parameters. This report is to be prepared by a suitably qualified Consulting Engineer and must address the following:

a) Establish **Flood Hazard** Classification, **Flood Planning Level** and **Probable Maximum Flood** information (see **Sections 4.1 and 4.2**).

b) Specify proposed floor levels (and existing floor levels where they are to be retained) of habitable and non-habitable structures, and where basement or enclosed carparking is proposed, include levels of access, ventilation and any other potential water entry points.

c) Identification of the constraints due to flood impacts on the land, including an assessment of the degree of inundation, hazard level, impacts of waterborne debris, buoyancy, evacuation and emergency issues during the **1% AEP** and **Probable Maximum Flood** storm events.

d) For development in **High Hazard** areas, a site specific flood assessment that may include flood modelling, must be provided to demonstrate that there will be no adverse impact on surrounding properties and no net reduction in flood storage or floodway area as a result of the development, up to the **1% AEP** flood.

e) For subdivisions, demonstrate that adequate building platforms or developable area, including carparking facilities, can be provided on each of the proposed new lots with levels at or above the **Flood Planning Level** and outside that portion of the property affected by the **High Hazard Classification**.

f) Incorporate recommendations for the structural design and construction of the total development, including the existing structures to be retained.

g) Propose measures to minimise risk to personal safety of occupants and the risk of property damage, addressing the flood impacts on the site of the **1% AEP** and **Probable Maximum Flood** storm events. These measures shall include but are not limited to the following:

- Types of materials to be used, up to the **Flood Planning Level** to ensure the structural integrity for immersion and impact of velocity and debris for the 1% AEP flood.
- Waterproofing methods, including but not limited to electrical equipment, wiring, fuel lines or any other service pipes and connections.
- Flood warning signs/depth indicators for areas that may be inundated, such as open carparking areas.
- A flood evacuation strategy to minimise damage, a point of assembly within a place of low risk, and proposals for evacuation of people to a place of low risk away from the effects of flooding.
- Provision of a detailed on-site response plan to minimise flood damage, demonstrating that adequate storage areas are available for hazardous materials and valuable goods at or above the **Flood Planning Level**.

h) Specify Architectural/Engineering plans on which the assessment is based.

i) Specify professional qualifications and experience of the authors.

4.3.1 Flood Level Variations (Single Dwelling only)

Where it is proposed to retain the floor level(s) of the existing part of the dwelling below the **Flood Planning Level**, the following issues must be addressed in the architectural drawings and the **Flood Risk Report**, in addition to the issues listed above:

a) Demonstrate the cumulative gross floor area of the ground floor and/or upper storey addition, does not exceed 30 m^2.

b) Demonstrate that the property is not subject to a **High Hazard Classification**.

c) Demonstrate that the floor level of the addition is at or above the **Flood Planning Level**.

d) Demonstrate how the portion of the existing dwelling to remain at the existing level will be satisfactorily wet or dry flood proofed to the **Flood Planning Level**

e) Justification of the proposed method of flood proofing (wet or dry) is to be provided accounting for the flood risk and potential damage to the property.

f) Demonstrate that the addition has been designed such that it does not preclude the raising of the floor level of the existing structure to the **Flood Planning Level** at a future date or when further additions are proposed, eg through the provision of a construction joint.

g) For a second storey addition, demonstrate that the floor level of the second storey is at a height that allows for the internal ground floor of the existing dwelling to be either at or raised to the **Flood Planning Level** whilst maintaining the minimum floor to ceiling height requirements of 2.4 metres.

4.3.2 Floor Level Variations (Commercial and Industrial Development only)

Where it is proposed to retain the floor levels of any existing part of the development below the **Flood Planning Level**, the following issues must be addressed in the architectural drawings and the **Flood Risk Report**, in addition to the issues listed above in Section 4.3 for consideration in the report.

a) Provide sound reasoning as to why the exemption is being sought including identification of the constraints that make it impracticable to raise the floor levels to the **Flood Planning Level**.

b) Demonstration that there are no potential adverse impacts created by this development on the future development of surrounding properties.

c) Demonstrate that the floor level of any existing portion of the dwelling to be retained, is at or above the 1% AEP flood level and will be satisfactorily wet or dry flood proofed up to the **Flood Planning Level**.

4.4 Professional Requirements – Floodplain Management and Structural Consultants

Floodplain Management and Structural Consultants engaged to undertake Flood Risk Reports and Flood Studies as required under this Flood Policy, must satisfy the following requirements, in order for the assessment of the Development Application to proceed:

a) Registration on the National Professional Engineers Register (NPER) as administered by Institution of Engineers Australia

b) Floodplain Management Consultant

- Have a minimum 10 years practice as a Floodplain Management Engineer during the past 15 years, and
- At least 5 years specific practical experience relevant to flooding and floodplain management in small urban coastal catchments in New South Wales.

c) Structural Consultant

- Have a minimum 10 years practice as a Structural Engineer during the past 15 years.
- Experience in design of structures and foundations that could be subjected to water inundation and velocity flow (in particular impact loading, flood compatible materials, buoyancy and flood proofing).

5 GLOSSARY

5.1 Definitions

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. The 1% AEP flood has a 1% chance (ie a one-in-100 chance) of occurrence in any one year. In relation to the economic life of structures, there is a 26% chance of the 1% AEP event occurring in a 30 year period, a 48% change of occurrence in a 50 year period and a 99.9% chance within a 100 year period.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
First Floor Additions	This is the next building level above the Ground Floor.
Flood Affected Properties	Properties that are either encompassed or intersected by the Flood Planning Level (FPL).
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined in the *Dee Why and Curl Curl Lagoon Floodplain Risk Management Study, 2004* and incorporated in the associated *Floodplain Risk Management Plan*. For residential, commercial and industrial development in the Dee Why and Curl Curl Lagoon catchments, it is the flood levels derived from the 1% AEP flood event, plus the addition of a 500 mm Freeboard. (refer diagrams 1 and 2).
Flood Prone/Liable Land	Land susceptible to flooding up to Probable Maximum Flood (PMF) event.
Flood Proofing – DRY	Protecting a building by sealing its exterior walls to prevent the entry of flood waters. *(Source Homeowner's Guide to Retrofitting – Six Ways to Protect Your House from Flooding – USA – Federal Emergency Management Agency, June 1998)*.
Flood Proofing – WET	A combination of measures incorporated in the design, construction and alteration of individual buildings, structures and surrounds, to be able to withstand the forces due to ingress and passage of flood waters to mitigate flood damages and remain structurally sound.
Floodway	Those areas of the floodplain where a significant discharge of water occurs during floods, they are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels.

TERM	DEFINITION
Freeboard	The factor of safety usually expressed as a height above the Planning Level flood. Freeboard allows for factors such as wave action, localised hydraulic effects, greenhouse and climatic change, as well as accuracy of flood modelling data. The default value for freeboard is 500 mm unless a site specific freeboard to take account of localised effects is agreed to by Council.
High Hazard	Where land in the event of a 1% AEP flood is subject to a combination of flood water velocities and depths greater than the following combinations: 2 metres per second with shallow depth or flood water depths greater than 0.8 metres in depth with low velocity. Damage to structures is possible and wading would be unsafe for able bodied adults (refer Figures 1 and 2).
Low Hazard	Where land may be affected by floodway or flood storage subject to a combination of flood water velocities less than 2 metres per second with shallow depth or flood water depths less than 0.8 metres with low velocity. Nuisance damage to structures is possible and able bodied adults would have little difficulty wading (refer to Figures 1 and 2).
Probable Maximum Flood (PMF)	The largest flood that could reasonably be expected to occur at a particular location, usually estimated from probable maximum precipitation.

5.2 Hazard Classification

[Council to inset]

5.3 Diagrammatic Representation of Flood Levels

[Council to inset]

5.4 Flood Compatible Materials

Building Component	Flood Compatible Material	Building Component	Flood Compatible Material
Flooring and Sub Floor Structure	• Pier and beam construction or • Suspended reinforced concrete slab	**Doors**	• Solid panel with waterproof adhesives • Flush door with marine ply filled with closed cell foam • Painted material construction • Aluminium or galvanised steel frame
Floor Covering	• Clay tiles • Concrete, precast or in situ • Concrete tiles • Epoxy formed-in-place • Mastic flooring, formed-in-place • Rubber sheets or tiles with chemical set adhesive • Silicone floors formed-in-place • Vinyl sheets or tiles with chemical-set adhesive • Ceramic tiles, fixed with mortar or chemical set adhesive • Asphalt tiles, fixed with water resistant adhesive • Removable rubber-backed carpet	**Wall and Ceiling Linings**	• Brick, face or glazed • Clay tile glazed in waterproof mortar • Concrete • Concrete block • Steel with waterproof applications • Stone natural solid or veneer, waterproof grout • Glass blocks • Glass • Plastic sheeting or wall with waterproof adhesive
Wall Structure	Solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation**	• Foam or closed cell types
Windows	Aluminium frame with stainless steel or brass rollers	**Nails, Bolts, Hinges and Fittings**	• Galvanised • Removable pin hinges

APPENDIX E

DEE WHY AND CURL CURL LAGOONS ENTRANCE BEHAVIOUR AND MANAGEMENT

November 2005

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1 INTRODUCTION

1.1 Synopsis

This appendix deals with the impacts of entrance conditions in the Dee Why and Curl Curl Lagoons on upstream flooding conditions and draws upon the results of the flood investigation (LACE, 2002), as well as recent *Estuary Management Studies and Plans*.

Current procedures for opening the entrances in the event of a flood emergency are reviewed in **Section 3**. These procedures are documented in formal Entrance Management Policies prepared in 1996 by Warringah Council in consultation with the respective Estuary Management Committees.

Hydraulic analyses was also carried out to test the sensitivity of flood levels to various berm heights. These results are reviewed in **Section 4** of this Appendix.

The results of this investigation showed that opening the entrance prior to a flood did not have a significant impact on flooding on Dee Why Creek upstream of Pittwater Road, notwithstanding the resident perceptions to the contrary, as noted in the next section. Opening Curl Curl Lagoon had a small impact on flood levels in the low lying Surf Road area.

It is acknowledged, however, that regardless of the results of the hydraulic analysis, it would be difficult to change residents' views regarding the beneficial effect on flooding of opening the Dee Why Lagoon entrance. Opening the lagoons will continue to be supported by the residents on both lagoons, as a precautionary measure.

At present, the opening procedure is triggered by the lagoons reaching predetermined critical water levels following several days of antecedent rainfall. There appears to be no formal linkage with predicted weather patterns. Consequently, there may be instances where the lagoons are opened unnecessarily. It is suggested that a greater degree of reliability could be incorporated into the decision making process by using the weather monitoring service provided by the Bureau of Meteorology's Special Services Unit, as discussed in **Section 5**.

1.2 Respondent Views

The responses to the Questionnaire discussed in **Appendix A** showed that residents in the lower reaches of both catchments were strongly of the view that the elevation of the entrance berm had a considerable impact on flood levels. They considered that opening of the entrances prior to the occurrence of heavy rainfall was essential to mitigating upstream flooding.

Residents in Tarra Crescent on Dee Why Creek described the situation in the last significant flood event in 1998 when a reduction in flood levels upstream of Pittwater Road closely followed the opening of the entrance of the Dee Why Lagoon by Council.

They considered that opening the lagoon as a precautionary measure should be undertaken in the event of an observed rise in the water surface level following a period of prolonged rainfall. They were concerned at the time taken to initiate a controlled opening following the onset of heavy rainfall and would welcome formalisation of a procedure catering for such an eventuality.

2 BACKGROUND

2.1 Dee Why Lagoon

Dee Why Lagoon is about 30 ha in area, with a contributing catchment of 510 ha and is drained by Dee Why Creek and the Dee Why main drain to the south of the catchment. The lagoon entrance is located centrally along the Dee Why/Long Reef Beach and is intermittently open to the ocean. At most times the entrance is closed as a result of the build up of a sand berm by wave action and wind.

Parameters of the entrance berm which were adopted in the Flood Study (LACE, 2002) were:

Crest length	80 m
Top width	12 m
Design berm level	RL 2.0 m
Design starting storage level	RL 1.8 m
Maximum potential berm elevation	RL 2.5 m
Final bottom elevation after scour seam across the entrance).	RL 0.35 m (approximates the elevation of a clay

2.2 Curl Curl Lagoon

Curl Curl Lagoon is the smallest of the four coastal lagoons found in the Warringah Council area and has a surface area of 5.7 ha and a catchment area of 440 ha. The lagoon entrance is located at the northern end of Curl Curl beach.

Parameters of the entrance berm adopted in the Flood Study were:

Crest length	70 m
Top width	12 m
Design berm level	RL 2.2 m
Design starting storage level	RL 2.0 m
Maximum potential berm elevation	RL 2.9 m
Final bottom elevation after scour seam across the entrance).	RL 0.35 m (approximates the elevation of a clay

2.3 Lagoon Entrance Conditions

The lagoons are typical of many coastal lagoons which are normally closed to the ocean as a result of the build up of a sand berm and then break out either naturally or due to human intervention. When the lagoons are closed, water levels are perched above ocean levels and when opened, drain to the ocean. Curl Curl Lagoon totally drains, exposing the bed.

Many of the entrance openings are not due to natural processes but are caused by people cutting a channel through the sand berm to start the water flowing out of the lagoon. The increased frequency of openings due to human intervention has a major impact on lagoon ecology by reducing the ability for fish and other organisms to establish in the lagoon. In addition, opening of the entrance may impact on the swimming water quality of the beach as the quality of the water discharging can be poor.

The lagoons are also occasionally opened mechanically as a flooding procedure for mitigating potential flooding. During times of steady rainfall or when heavy rain occurs in the catchment in the preceding week, Council Officers monitor the water levels in the lagoon. The opening of the lagoon is achieved by using a bulldozer which excavates a pilot channel across the beach berm. The opening is timed to coincide with the receding ocean high tide to establish optimum hydraulic conditions for the opening flow.

Dee Why Lagoon

The current practice is to open Dee Why Lagoon when the water level exceeds the obvert of the stormwater pipe draining into the channel at the end of Billarong Avenue. The elevation of the top of pipe is about RL 1.8 m. This elevation corresponds with the starting water surface elevation prior to the arrival of the flood wave on Dee Why Creek adopted in the flood study (LACE, 2002) and is about 1.4 m below the peak 20% AEP flood level in the Tarra Crescent/Billarong Avenue area (see **Table E2.1**).

TABLE E2.1
DESIGN PEAK FLOOD LEVELS
DEE WHY LAGOON
(RL m AHD)

Flood Event % AEP	Lagoon	u/s Pittwater Road Bridge
20	2.3	3.23
1	2.55	3.42

Source LACE, 2002

The water surface profile within the area of the lagoon is quite flat, consistent with the very low flow velocities within the waterway. However, there is a considerable increase in peak water levels across the bridge, indicative of the fact that the bridge at Pittwater Road imposes a constriction on the flow. As discussed later, the bridge constriction reduces the sensitivity of flood levels in this area to entrance conditions.

Nearby residents become concerned at the risk of flooding prior to the water level exceeding the overt of the stormwater pipe. This has led to unauthorised openings being conducted by residents. Unauthorised openings are also conducted by board riders and children, to create a ‘standing wave’ to surf ride.

A boulder wall has been recently constructed on the southern shoreline of the lagoon’s entrance. This, combined with the gabion wall which currently exists on the northern shoreline, has subsequently trained the lagoon’s entrance. The training of the lagoon’s entrance will have an unknown effect and provision has been made to remove the southern boulder wall if it is found to be detrimental to the lagoon’s entrance environment.

Curl Curl Lagoon

Curl Curl Lagoon is opened when the water level exceeds the obvert of the reinforced concrete pipe in the drainage pit at the end of Surf Road. The level of the pipe obvert is 2.08 m. As the pipe is not readily visible, the visual indicator adopted is when the lagoon water level surface reaches the underside of the cast iron grate over the pit, which corresponds to a level of 2.21 m.

The latter elevation is about 200 mm above the starting water surface elevation adopted in the flood study (LACE, 2002) and is about 700 mm below the 20% AEP flood level in the vicinity of the low lying property at the southern end of Surf Road (see **Table E2.2**).

There is a considerable flood slope within Curl Curl Lagoon due to the comparatively narrow extent of the waterway resulting in significant flow velocities. As discussed later, this feature reduces the sensitivity of flood levels to entrance conditions in this area.

TABLE E2.2
DESIGN PEAK FLOOD LEVELS
CURL CURL LAGOON
(RL m AHD)

Flood Event % AEP	Lagoon	u/s Pittwater Road Bridge
20	2.59	2.92
1	2.81	3.33

3 ENTRANCE MANAGEMENT POLICY

3.1 Issues Addressed

The issues addressed in the Entrance Management Policies, 1996 for each lagoon are:

- The frequency of unauthorised lagoon openings and preventative measures.
- Swimming water quality in the beach after a lagoon opening has occurred and subsequent safety actions required.
- Responsibility for opening the lagoon as a flood mitigation measure and when this should occur, the conditions required before the lagoon is opened and the opening procedure.
- Current and future monitoring of the lagoon's water level and water quality.

3.2 Deterrence of Unauthorised Openings

The Entrance Management Policies incorporated a number of proposed measures for deterring unauthorised openings:

a) Signage was to be displayed at the entrance of each lagoon to state the reasons not to artificially open and the penalties involved in unauthorised openings of the lagoon. Signage is located on the northern shore near the entrance to the Dee Why Lagoon. However, no signage is evident at Curl Curl Lagoon.

b) A community information program involving the distribution of an educational "Lagoon Watch" brochure to residents in the immediate area of the lagoon entrance was to be undertaken at the beginning of the swimming season. This would encourage residents to watch for unauthorised openings and report this to Council.

c) Develop a comprehensive local education program focussing on the teenage and younger board riding section of the community who appear to be the main offenders of lagoon openings. This program should also inform residents of flood mitigation policies, environmental impacts of frequent openings and penalties which could be incurred.

   The aim of the program was to inform young people of the conservation value of the lagoon and the impact frequent openings has on the lagoon's environment. The main objective would be to deter unauthorised openings.

d) Under Local Government Act 1993, Council has the authority to penalise persons opening the lagoon without authorisation.

e) The Warringah Lifeguards and the Long Reef SLSCs and North Curl Curl are required to play a stewardship role in the monitoring and management of their local area. This extends further than the lagoon entrance and includes the beach and dune natural environments.

f) To encourage the stewardship of the Warringah Lifeguards and the SLSCs in their local areas, a formal letter and follow up consultation from Council was to be made to the respective parties. This action would ensure that the Warringah Lifeguards and the Long

Reef SLSC would play an active role in assisting Council in the monitoring and managing of the lagoon entrance and the local beach/dune environment.

g) The Warringah Lifeguards and the Long Reef SLSC would be required to monitor the lagoon entrance, deter any illegal openings and inform the Council of any related activity occurring at the entrance and in their beach/dune environment.

3.3 Procedure After Opening has Occurred

a) There is the potential for poor quality water to be released from the lagoon into the beach zone after a storm period. If this occurs it was recommended that the beach remain closed for a period of 24 hours after an opening has occurred to reduce the possibility of health hazard to beach users.

b) The Warringah Lifeguards and the SLSCs would have the responsibility of closing the beach after an opening has occurred and to inform beach users of the potential health hazard.

c) Pollution warning signage should be displayed for the duration of the beach closure.

3.4 Monitoring of Lagoon Openings

a) Lagoon water levels are monitored by an automatic water level recorder installed by the Australian water and Coastal Studies (AWACS) adjacent to the lagoon entrance channels. This instrument provides a continuous record of water level variation.

3.5 Procedure for Mechanical Breakout

Separate procedures for mechanical breakout have been prepared for each lagoon. They are essentially the same, relating the initiation of the breakouts to defined water levels at Billarong Avenue in the case of Dee Why Lagoon, and Surf Road for Curl Curl Lagoon (see **Section 2.3**).

For example, the procedures as they specifically relate to Curl Curl Lagoon are as follows:

"The following procedure for mechanical breakout of the Curl Curl Lagoon Entrance is to be followed primarily in response to the threat of flooding to adjacent properties, and secondly in response to declining water quality in the lagoon.

A. Conditions that are <u>essential</u> before mechanical breakout is actioned

1. *Lagoon water level at or exceeding RL 2.08 m, which is the obvert level of the RC pipe in the drainage pit at the end of Surf Road (this pipe is difficult to observe, in practice the visual indicator used is the underside of the cast iron grate over the pit, at a level of RL 2.21 m).*

2. *Steady rain is falling or heavy rain has occurred in the catchment in the week preceding the rise in lagoon level.*

B. The following conditions are <u>desirable</u> to enable a successful breakout, but <u>not</u> essential

1. *Moderate to heavy rainfall (recent and/or continuing).*

2. *Relatively large ocean tidal range (greater than 1.0 m).*

3. *Relatively low wave action.*

C. Procedure for Opening

1. *The procedure is to be planned so that actual breakout and opening to the sea occurs <u>shortly</u> after the tide turns from high to low, for the lower tide of the day.*

2. *Excavated sand is to be deposited on the southern side of the entrance at least 2 m from the trench and above the high tide mark (if possible).*

3. *It has been recommended that experimentation regarding the width and depth of the breakout channel continue to be undertaken to determine the best arrangement for the Curl Curl system. It should be noted that different weather and tidal conditions may require different widths and depths of the channel. A photographic date record of each breakout is to be maintained by the Plant Controller.*

D. Responsibility for Opening

1. *The decision to open the Lagoon will be made by the Environmental Projects Manager after conferring with the Director Technical Services and the Plant Controller. In the absence of the Environmental Projects Manager, the decision will be made by the Engineering Development Manager.*

2. *Responsibility for plant management and on-site control will be with the Plant Controller, or in his absence with the District Engineer or the Assistant Plant Controller."*

4 HYDRAULIC ANALYSIS

4.1 Sensitivity of Upstream Flood Levels to Entrance Conditions at Dee Why Lagoon

Hydraulic analysis was undertaken in the flood study (LACE, 2002) to assess the sensitivity of peak flood levels on Dee Why Creek to entrance conditions. Results showed that within the area of the lagoon, 1% AEP flood levels would rise proportionally with the increase in berm height. In the case of the 1% AEP flood, the peak level would rise by 450 mm from RL 2.55 m for the "best estimate" level of RL 2.0 m, to RL 3.0 m for the potential upper limit berm height of RL 2.5 m.

For this present investigation, hydraulic analysis was undertaken to assess potential reductions in flood levels resulting from amendments to the current Entrance Management Policy to maintain the berm height at specific elevations which more closely correspond with semi-open conditions.

Table E4.1 shows peak water surface levels for a range of controlled berm heights ranging in elevation from RL 1.4 m to the "best estimate" of RL 2.0 m adopted in the flood study (LACE, 2002).

The results obtained in the flood study used the berm erosion module attached to MIKE 11 are shown in column (2). The results using MIKE 11, but with an assumed berm level which remains constant over the duration of the flood event, are shown in columns (3) to (7) inclusive. The berm erosion module of MIKE 11 was not available for this present investigation and accordingly, a fixed berm was adopted. However, the results shown in columns (2) and (6) both of which apply for a berm elevation of RL 2.0 m are in close agreement.

By inspection of the results in columns (3) to (7), there is no variation in flood levels on the upstream side of Pittwater Road for the various berm heights. It is evident that peak flood levels at this location are dependent on the waterway area of the Pittwater Road Bridge rather than on lagoon entrance conditions. Enlargement of the bridge opening would reduce flood levels, but this option is unlikely to proceed, as discussed in **Chapter 3** of the *Floodplain Risk Management Study* (**Volume 1**).

Hydraulic analysis confirmed that varying the berm height had no impact on minor (20% AEP) flood levels upstream of Pittwater Road – **Table E4.2**. The 20 % AEP defines the threshold flood at which damages are initiated in the Tarra Crescent / Billarong Avenue area bordering Dee Why Creek.

TABLE E4.1
SENSITIVITY OF 1% AEP FLOOD LEVELS
TO ENTRANCE CONDITIONS
ON DEE WHY LAGOON

Location	Adopted Berm Height (m AHD)					
	Flood Study 2.0 m	1.4 m	1.6 m	1.8 m	2.0 m	2.2 m
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ocean	1.0	1.0	1.0	1.0	1.0	1.0
Lagoon Entrance	2.55	2.10	2.14	2.05	2.50	2.42
d/s side of Pittwater Road	2.55	2.09	2.12	2.10	2.49	2.44
u/s side of Pittwater Road	3.42	3.42	3.42	3.42	3.42	3.42
Heron Place	3.98	3.98	3.98	3.98	3.98	3.98

Column (2) shows results from Flood Study (LACE, 2002)

TABLE E4.2
SENSITIVITY OF 20% AEP FLOOD LEVELS
TO ENTRANCE CONDITIONS
ON DEE WHY LAGOON

Location	Adopted Berm Height (m AHD)					
	Flood Study 2.0 m	1.4 m	1.6 m	1.8 m	2.0 m	2.2 m
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ocean	1.0	1.0	1.0	1.0	1.0	1.0
Lagoon Entrance	2.30	1.73	1.84	2.12	2.15	2.23
d/s side of Pittwater Road	2.30	1.76	1.86	2.12	2.16	2.23
u/s side of Pittwater Road	**3.22**	**3.22**	**3.22**	**3.22**	**3.22**	**3.22**
Heron Place	3.74	3.74	3.74	3.74	3.74	3.74

Column (2) shows results from Flood Study (LACE, 2002)

4.2 Sensitivity of Upstream Flood Levels to Entrance Conditions on Curl Curl Lagoon

Hydraulic analysis was undertaken in the flood study (LACE, 2002) to test the sensitivity of peak flood levels on Cur Curl Lagoon to entrance conditions. Results showed that in the vicinity of Surf Road, 1% AEP flood levels would rise by only 100 mm with the increase in berm elevation from the "best estimate" value of RL 2.2 m adopted for design purposes to the potential upper limiting berm height of RL 2.9 m.

For this present investigation, analyses similar to that described above for Dee Why Lagoon were undertaken to test the response of flood levels to maintenance of the berm at various elevations corresponding with semi-open conditions. The range of berm elevations was from RL 2.2 m to a minimum of RL 1.4 m. The results obtained from the flood study and from a MIKE 11 analysis assuming a constant berm level over the duration of the flood event are shown in **Table E4.3**.

TABLE E4.3
SENSITIVITY OF 1% AEP FLOOD LEVELS
TO ENTRANCE CONDITIONS
ON CURL CURL LAGOON

Location	**Adopted Berm Height m AHD**		
	Flood Study		
	2.2 m	**1.4 m**	**1.6 m**
(1)	(2)	(3)	(4)
Ocean	1.0	1.0	1.0
Lagoon Entrance	2.81	2.56	2.58
Surf Road	**3.33**	**3.26**	**3.31**
d/s side of Harbord Road	3.60	3.56	3.62

Column (2) shows results from Flood Study (LACE, 2002)

By inspection of the results in columns (2) and (3), there is a variation of only 50 mm in peak flood levels at Surf Road which would result from a policy which ensures the berm level at RL 1.4 m AHD prior to the arrival of the flood, compared with best estimate levels resulting from the existing policy.

Table E4.4 shows the sensitivity of flood levels to berm heights for a medium (10% AEP) flood.

TABLE E4.4
SENSITIVITY OF 10% AEP FLOOD LEVELS
TO ENTRANCE CONDITIONS
ON CURL CURL LAGOON

Location	Adopted Berm Height m AHD		
	Flood Study		
	2.2 m	1.4 m	1.6 m
(1)	(2)	(3)	(4)
Ocean	1.0	1.0	1.0
Lagoon Entrance	2.64	1.75	1.95
Surf Road	**3.01**	**2.81**	**2.84**
d/s side of Harbord Road	5.53	5.52	5.52

Column (2) shows results from Flood Study (LACE, 2002)

4.3 Summary of Hydraulic Analysis

The hydraulic analysis outlined in the previous section shows that manipulation of the elevation of the level of the entrance berms of both lagoons would not have a significant impact on flood levels on Dee Why Creek for the range of floods from a minor (20% AEP) to a major (1% AEP) event. The constriction imposed by the Pittwater Road culvert controls upstream flood levels.

On Curl Curl Lagoon reducing the berm height to RL 1.4 m prior to the arrival of the flood (about 800 mm below the design level of RL 2.2 m adopted for the Flood Study) would not have a significant effect on flood levels for a major (1% AEP) flood. For a medium (10% AEP) flood a small reduction in flood levels of 200 mm would be achieved at Surf Road.

5 SUMMARY

The hydraulic analysis presented in **Section 4** has demonstrated that flooding in the low lying residential sectors on Dee Why Creek is not sensitive to variations in the berm level of Dee Why Lagoon. In the case of Curl Curl Lagoon, a minor reduction in peak water levels of around 200 mm events could be achieved for a medium flood in the low lying Surf Road area by ensuring that the berm is no higher than RL 1.4 m prior to the occurrence of the flood.

In Surf Road, there are several low lying properties which would be flooded in the event of minor (20% AEP) flooding with the berm at the RL 2.2 m level adopted for the Flood Study. Reducing the flood level by lowering the berm would be beneficial in this area.

Regardless of the hydraulic model results, however, residents on both lagoons are convinced that lowering the berm prior to the occurrence of a flood would have a beneficial impact and would support enforcement of such a policy, as outlined in the respective Entrance Management Policies.

Due to the “flash flooding” nature of the two catchments and the limited storage volumes contained in each lagoon, water levels in the potential damage centres respond quickly to heavy rainfall. A predictive flood warning model may have limited success in mitigating flooding. There would be insufficient time to interrogate mathematical models of the catchments and mobilise the forces necessary to effect an opening of the lagoons if the requirement for such action were “triggered” on the initiation of heavy rainfall over the catchment.

The approach outlined in the Entrance Management Policy, 1996 for initiating an opening, namely several days of prior rainfall resulting in a significant rise in lagoon levels, is appropriate, although there may be occasions when the lagoon is opened and the heavy rainfalls required to initiate flooding do not eventuate.

The reliability of the decision making process could be strengthened by linking the opening procedure to the prediction and monitoring of rainfall by the Bureau of Meteorology, which could be supplied on a customised website which could be set up by the BOM’s Special Services Unit. The BOM’s Prediction and Monitoring service would comprise:

a) Daily monitoring of the weather situation by BOM and supply of information on the Customised Web page set up for Council.

b) Daily Forecast: The weather forecast is included on the Customised Web page and provides rainfall probabilities in the Sydney area for the next 4 days, including expected amounts, plus expert comment by a duty Meteorologist. The Web page also provides access to the latest rainfall, radar images and weather information.

c) In the event of expected rainfalls of significance in the vicinity of the Dee Why – Curl Curl catchments, the BOM would phone Council to advise. This advice would be forwarded when information becomes available to BOM of predicted heavy rainfall on the catchment. It will in most cases provide a minimum of 3 hours warning time. However, a thunderstorm cell could develop within 30 minutes or directly over the catchment, in which case, warning times would be shorter.

d) During a flood emergency there will be telephone access to a BOM Meteorologist. This will allow Council to obtain a second opinion before initiating an opening.

e) In addition, Public Weather warnings will be directly faxed to Council after issue by BOM.

6 REFERENCES

Lyall and Associates Consulting Water Engineers (2002). *"Dee Why Lagoon and Curl Curl Lagoon Flood Studies"*.

Warringah Council (1996). *"Dee Why Lagoon Entrance Management Policy, July 1996"*.

Warringah Council (1996). *"Curl Curl Lagoon Entrance Management Policy, March 1996"*.

APPENDIX F

EXTENSION OF CURL CURL LAGOON FLOOD STUDY

November 2005

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LIST OF FIGURES

1. INTRODUCTION

1.1 Background

The flood study investigation carried out on the Curl Curl Lagoon catchment (LACE, 2002) extended upstream as far as Harbord Road. From that location to the outfall at the eastern end of Curl Curl Lagoon, the pattern of flooding was assessed using a quasi two-dimensional hydraulic model of the open channel and adjacent floodplains based on the MIKE 11 software.

Discharge hydrographs which were applied to the hydraulic model were determined from a catchment model based on the RORB software. Inflow hydrographs and lateral inflows into the MIKE 11 model were estimated by abstracting flows conveyed in the piped stormwater system from the total discharge hydrographs for the various sub-catchments determined by the RORB rainfall runoff model.

1.2 Study Objectives

The objective of this present investigation is to extend the hydraulic analysis upstream of Harbord Road to Pittwater Road. Within the extent of this portion of the catchment, flows which surcharge the capacity of the stormwater system are mainly conveyed within the street system, which act as a network of floodways. The closely spaced mainly industrial developments lining the streets generally have few gaps to allow for “leakage” of flows.

The only significant path for the conveyance of flows other than the street system is the remnant channel of the creek, which runs in a south-easterly direction commencing on the southern side of Winbourne Road. This channel continues for a short distance downstream of Winbourne Road and directs flows which surcharge the capacity of the drainage system to a piped trunk drainage line which initially comprises twin 1800 RCP’s. These pipes extend to a surcharge pit located at the eastern end of Sydenham Road. Three 1200 RCP’s convey flows from that pit downstream to the culverts which run under Harbord Road and discharge to the channel of Greendale Creek.

1.2.1 Hydraulic Modelling of Street System

The overland flows are conveyed along the street system and hence the required analysis differs from the usual situation where flows are conveyed along open channels either unlined or lined. The hydraulically “smooth” texture of the paved streets together with their hydraulically “steep” longitudinal gradients which are typically in the range 0.5 to 2 per cent, would result in supercritical conditions being experienced in the steeper sections, whereas in the flatter sections conditions would be in the transition zone between sub- and super- critical flow and consequently would tend to be hydraulically unstable.

Because of stability concerns associated with running a MIKE 11 unsteady flow simulation in such conditions, it was decided to adopt a steady state approach within the street system using the HEC-RAS software to assess depths and velocities of flow.

It is also to be noted that when MIKE 11 is called upon to analyse supercritical flow problems, it solves a simplified version of the momentum equation of flow known as the kinematic wave solution. This simplification is required in order to maintain stability in the solution procedure. The estimate of peak flood level derived from this approach is similar to that derived by a steady state analysis of the peak discharge using HEC-RAS.

Each street was modelled as a separate reach, with an "off-line" calculation carried out to determine the distribution of flow at the road intersections.

1.3 Study Tasks

The approach to the investigation involved the following tasks:

1) A detailed site inspection of the study area was carried out to ascertain the direction of overland flows within the street system and identify locations where floodwaters could leak through buildings and the resulting flow paths through the allotments.
2) Spreadsheets were prepared which abstracted flows conveyed by the piped system from the total runoff generated by the RORB model and provided an estimate of overland flows traversing the catchment. Spreadsheets were prepared for the range of flood events from 20 to 1 % AEP.
3) Hydraulic analysis was carried out to convert overland flows to depths and velocities of flow. The HEC–RAS software was adopted for this purpose. Separate models were prepared of the network of streets between Pittwater Road and the Winbourne Industrial Estate and of the service roads within the Industrial Estate.
4) Based on the results of the hydraulic modelling an appraisal of the likely impacts of flooding on adjacent development was undertaken.

2. APPRAISAL OF FLOW PATTERN

2.1 Winbourne Road Area

The layout of the RORB model sub–catchments contributing flows to the drainage system was presented in the LACE, 2002 Flood Study and is reproduced as **Figure F2.1** herein.

Flows from catchments E1 to E4, which are located west of Pittwater Road, surcharge the piped drainage system at Pittwater Road, cross that street at the gap in the median near the intersection with Winbourne Road. The eastern side of Pittwater Road between Winbourne Road and Mitchell Road is quite flat and there is little opportunity for overland flows to leak through the commercial properties on the eastern side of the road. Ponding on the eastern side of Pittwater Road would build up until relief was provided by flow commencing down Winbourne Road and Mitchell Road.

Flows down Mitchell Road would be joined by contributions from catchment E5, with the combined discharge flowing southwards to the intersection with Winbourne Road. Downstream of the intersection, some of the flow would continue eastwards along Winbourne Road to the remnant channel of Greendale Creek. The balance would continue southwards along Mitchell Road to the intersection with Chard Road, where it would be joined by flows derived from catchment E9 which is centred on Chard Road and extends westwards to Pittwater Road. Chard Road on the eastern side of Mitchell Road acts as a floodway and directs overland flows traversing the street into the Winbourne Industrial Estate.

Some of the combined flow at the intersection of Chard Road and Mitchell Road may continue southwards to Sydenham Road and continue along that street into the Industrial Estate.

Flows gathering at the remnant channel of Greendale Creek in Winbourne Road would be joined by contributions from sub-catchments E6 and E8 and E7, E10 and E11. These catchments are located on the northern side of Winbourne Road and extend as far as Warringah Road. It is likely that most of the combined discharge in Winbourne Road would flow over the southern footpath into the channel, although some of the flow may continue eastwards towards the Industrial Estate.

The remnant channel of Greendale Creek commences on the southern side of Winbourne Road at the outlet of the 1500 mm diameter pipe which comprises the trunk drain for the urban catchments to the north. The unlined channel continues for a short distance to the inlet of twin 1800 RCP's which pipe flows a distance of 230 m to a large grated surcharge pit located on the northern side of Sydenham Road near the entrance to the Industrial Estate.

On the downstream side of the pit the piped drainage system continues as three 1200 mm diameter RCP's (of lesser hydraulic capacity than the incoming 1800 RCP's) which convey flows to the south-east corner of the Industrial Estate. As the hydraulic capacity of the piped drainage is reduced at the pit, it is likely that surcharge would occur in the event of a major flood. In this situation, the surcharge flow would be directed by the prevailing grade into the Industrial Estate.

Further to the east of the channel, flows from catchment E12 would flow southwards down Carter Street and enter the Winbourne Industrial Estate.

Thus, there are four locations of inflow into the Industrial Estate in the event of surcharges of the piped stormwater system: at the northern entrance on the prolongation of Carter Road, at Chard Road and via the two sources (i.e. surcharge of the piped system and overland flow) at Sydenham Road.

2.2 Powells Road Area

The catchment of Curl Curl Lagoon extends southwards as far as Wattle Street and Wyadra Avenue. Flows generated by sub-catchment E13 gather in the low spot in Mitchell Road near the intersection with Powells Road. Twin 1050 RCP's convey flows in a north easterly direction across industrial allotments to join the main trunk drainage system at the south-west corner of the Winbourne Industrial Estate. Surcharges of the piped system would follow a meandering course through the allotments as shallow overland flow.

Sub-catchment E14 drains the area immediately to the east of E13 and flows generated by this catchment flow northwards to join overland flows for E13 which eventually reach the main flow path running eastwards along the southern side of the Industrial Estate.

3. DESIGN FLOOD ESTIMATION

3.1 Study Approach

3.1.1 Hydraulic Analysis in Street System

The following methodology was adopted for each flood event modelled:

1) The RORB catchment model used in the Flood Study was adjusted to provide information on the contributions of flow from each sub-area.
2) An estimate was made of the flow conveyed by the piped trunk drainage system. By subtraction from the total flows generated on the catchment, an estimate of the overland flow hydrographs conveyed by the street system was obtained. The 1500 mm diameter pipeline terminating on the southern side of Winbourne Road had an estimated capacity of 7.7 m^3/s. The twin 1800 RCP's in the gully of Greendale Creek had a capacity of 35.9 m^3/s based on inlet control conditions and the three 1200 RCP's continuing on the downstream side of the pit near Sydenham Street had a capacity of 24.0 m^3/s.
3) Cross sections of the streets were surveyed upstream and downstream of the intersections. This information, together with consideration of features such as roundabouts, direction of gutter flows and other local topographic conditions which could influence flows, was used to assess the capture by the downstream streets of the overland flow arriving at the various intersections.
4) The peak discharge along each potential flow path was noted and applied to the network hydraulic model defining the street system.

3.1.2 Hydraulic Analysis in Winbourne Estate

The road system within the Industrial Estate comprises a network of diverging and converging branches. Within the extent of several of the service roads, there is the potential for significant ponding to occur. As mentioned above, the sources and magnitude of flows entering the Estate were reasonably well defined from the analysis of the public road system.

Hydraulic analysis was based on two HEC-RAS models which represented flow entering the Estate from:

a) Winbourne Road opposite the extension of Carter Road (denoted the ***Eastern Branch***); and
b) Chard and Sydenham roads, including the surcharge pit which is located within the Estate at the eastern end of the latter road (denoted the ***Western branch***).

The peak discharges entering the Industrial Estate, as derived from the analysis of the public street system were adopted as the upstream boundaries to the two models.

Within the prolongation of Chard and Sydenham road, stormwater is forced to pond on the road surface due to the presence of several raised section of pavement. A series of broad crested weir relationships were developed at these locations to compute the magnitude of flow which will be redistributed between the Eastern and Western Branch models.

At the downstream boundary of the Western Branch, where floodwaters flowing through the Estate enter No. 190 Harbord Road, a wooden fence was observed extending across the overland flow route. For the purpose of this study, it was assumed that the fence would not withstand the force of the approaching flow for the full range of modelled flood events and would therefore not act as an obstruction to the passage of floodwaters leaving the Estate.

3.2 Results of Hydraulic Analysis in Street System

Flows, velocities and depths of flow for the various flood events are shown on **Figures F3.1 to F3.4**. The depths of flow are referenced to the gutter.

3.3 Impacts of Flooding on Surrounding Developments

The floor levels of several industrial premises located adjacent to the Winbourne Industrial Estate were surveyed as part of the Property Survey Report (LACE, 2003). **Figure 3.5** shows the peak water surface levels for the various flood events modelled and the surveyed floor levels at the doorways to each of these properties.

Of the 9 properties surveyed in Chard Road, whilst flood affected, none will experience above floor inundation for events up to and including the 100 year ARI flood.

In Sydenham Road, No. 52-54 will experience flooding during events as frequent as 5 year ARI, when floodwaters will enter the property from the road reserve.

Along the south boundary of the Winbourne Industrial Estate, natural surface levels have been raised to divert floodwaters towards Harbord Road, away from a number of relatively low lying industrial properties which are located along Ada and Ethel avenues.

In Ada Avenue, Nos. 21-23 and 27 will be inundated by floodwaters which originate from the Estate for events larger than 10 year ARI. Along Ethel Avenue, the surveyed industrial properties of Nos. 17A, 17B, 19, 19A and 21 would also experience above floor inundation during an event of this magnitude.

It can be expected that Nos. 25 and 27 Ethel Avenue will experience above floor inundation on a more frequent basis due to their close proximity to the open section of channel which runs through No. 190 Harbord Road.

3.4 Results of Hydraulic Analysis in Winbourne Industrial Estate

Flows, velocities and depths of flow for the various flood events are shown on **Figures F3.1 to F3.4**. The depths of flow are referenced to the lowest point in the surveyed cross section.

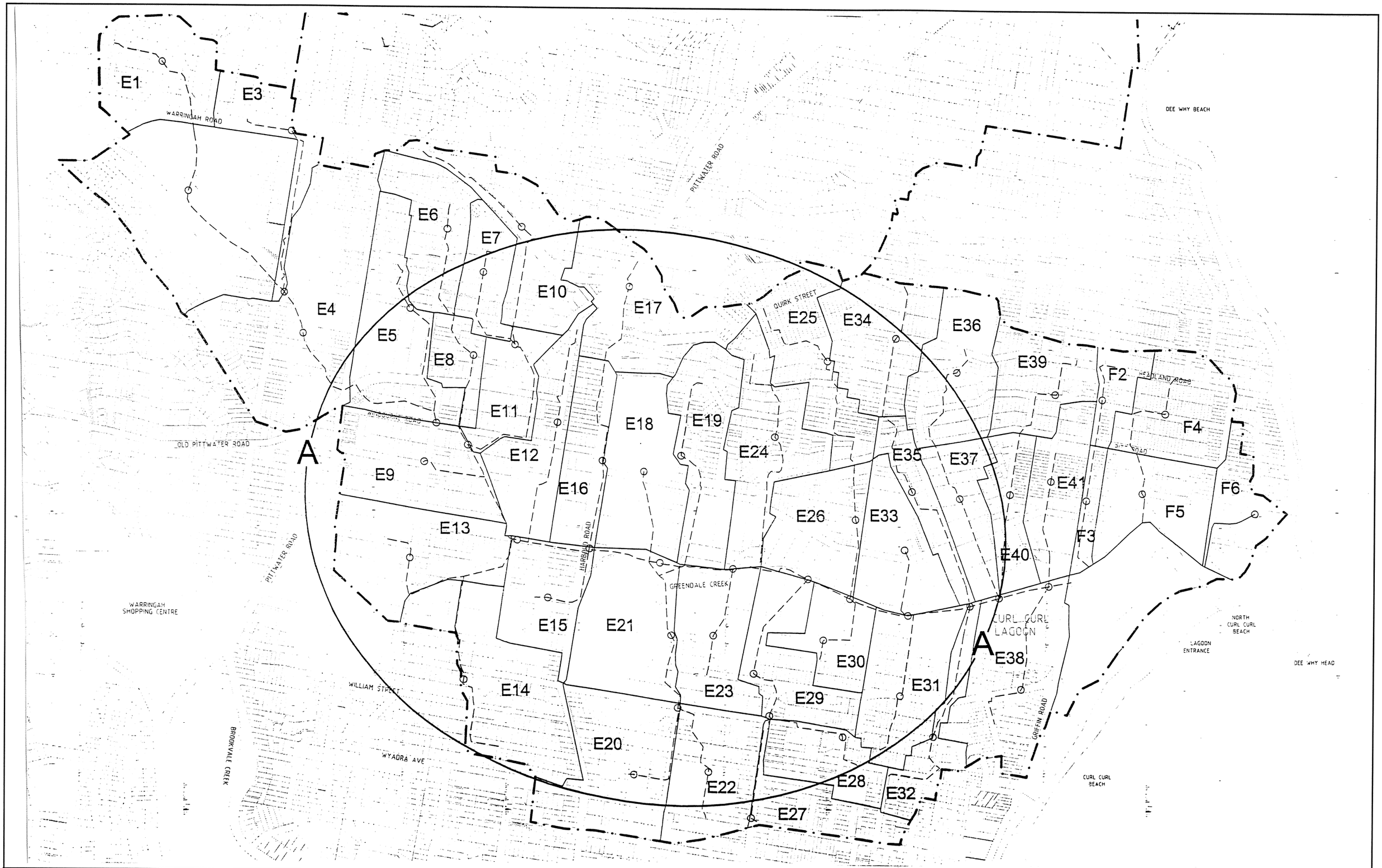
3.5 Impacts of Flooding on Units Within the Estate

Figure 3.5 shows the peak water surface elevations for the various modelled flood events and the surveyed floor levels of the various Units within the Estate.

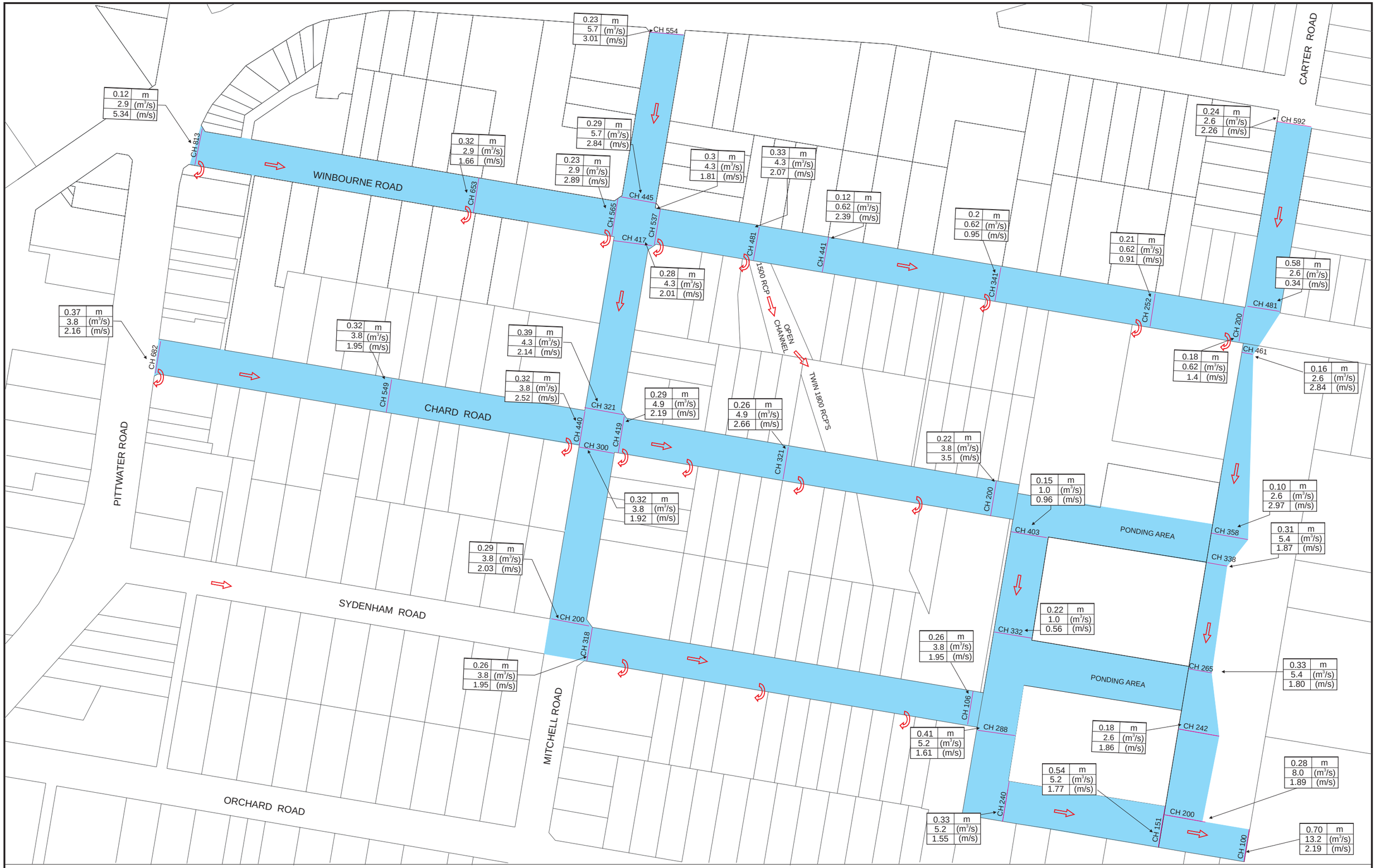
Units 3A, 4A, 4B, 4C and 4D, which are located along the prolongation of Chard Road, are inundated by floodwaters which pond in the service road for events of 5 year ARI and larger.

The floor levels of Units 4F, 4G, 4H are at or just above the 10 year ARI peak water surface level, whilst Unit 11A/B is inundated by floods of 50 year ARI or larger.

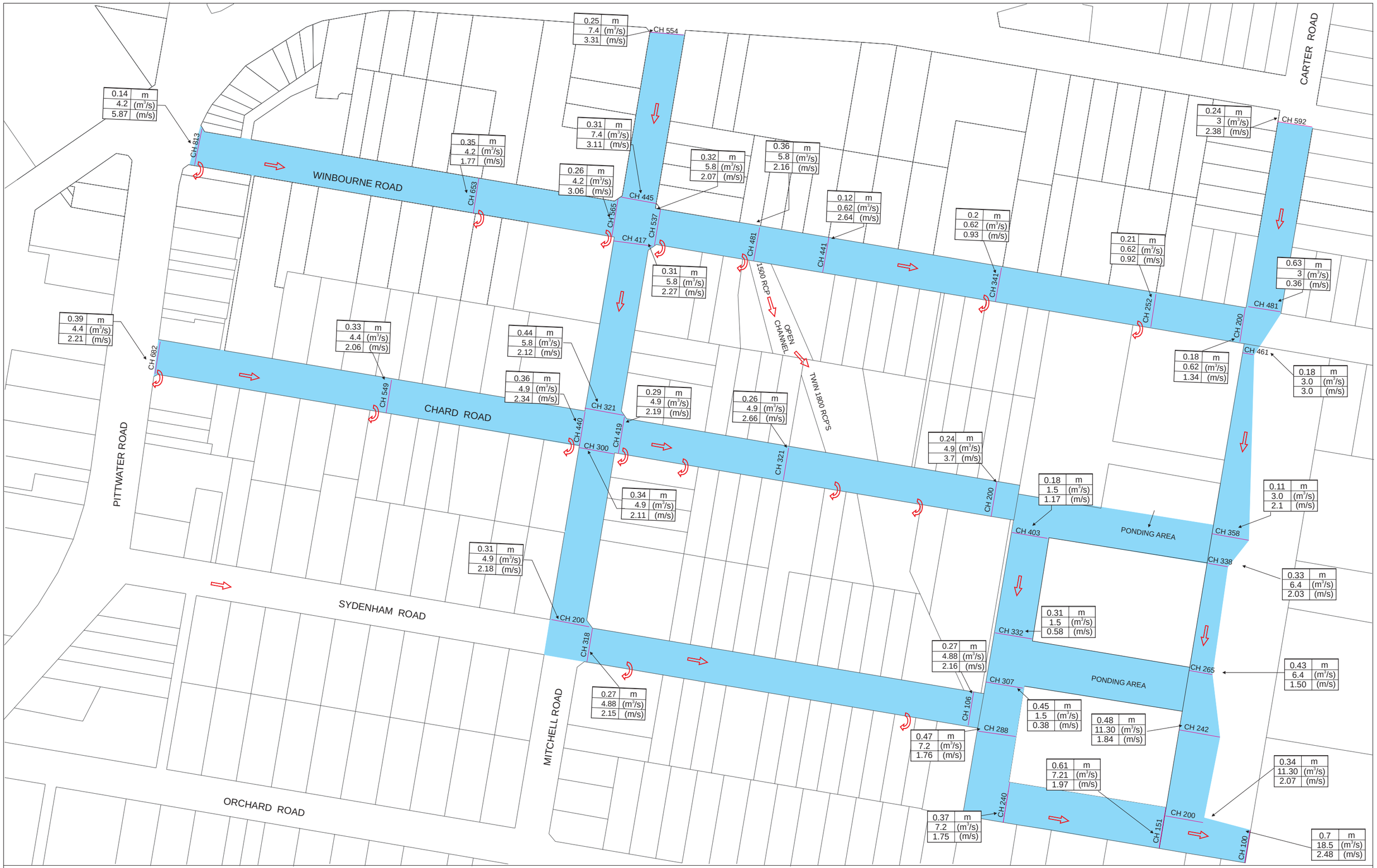
Along the Eastern Branch, floodwaters will inundate Units 7 and 9 for events as frequent as 5 year ARI, whilst Units 8 and 10 are inundated during a flood of 50 year ARI or larger.



DEE WHY LAGOON AND CURL CURL LAGOON
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure F2.1
RORB MODEL LAYOUT
CURL CURL LAGOON CATCHMENT



DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure F3.1
CHARACTERISTICS OF FLOODING UPSTREAM
HARBORD ROAD 5 YR ARI FLOOD



N

0 100m

Scale

Ch300 HEC-RAS CROSS SECTION

INDICATION OF LIKELY INUNDATION OF PROPERTY FRONTAGES ALONG EDGE OF ROAD RESERVE

INDICATIVE EXTENT OF FLOODING

DIRECTION OF OVERLAND FLOW

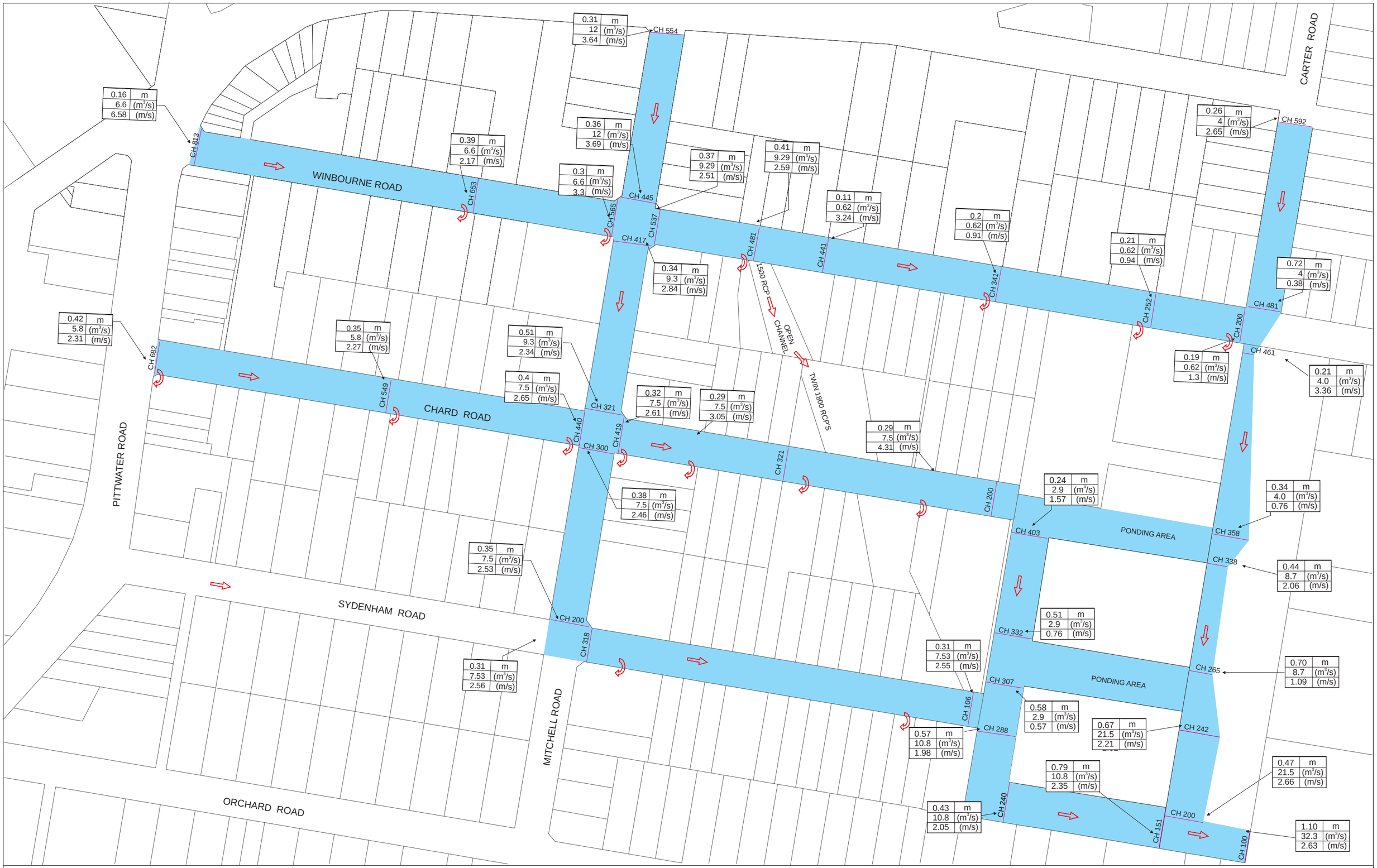
SHALLOW SHEET FLOW

Maximum depth of flow in road gutter	m
Peak discharge	(m³/s)
Peak flow velocity	(m/s)

DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure F3.2

CHARACTERISTICS OF FLOODING UPSTREAM HARBORD ROAD 10 YR ARI FLOOD



N

0 100m

Scale

Ch300 HEC-RAS CROSS SECTION

INDICATION OF LIKELY INUNDATION OF PROPERTY FRONTAGES ALONG EDGE OF ROAD RESERVE

INDICATIVE EXTENT OF FLOODING

DIRECTION OF OVERLAND FLOW

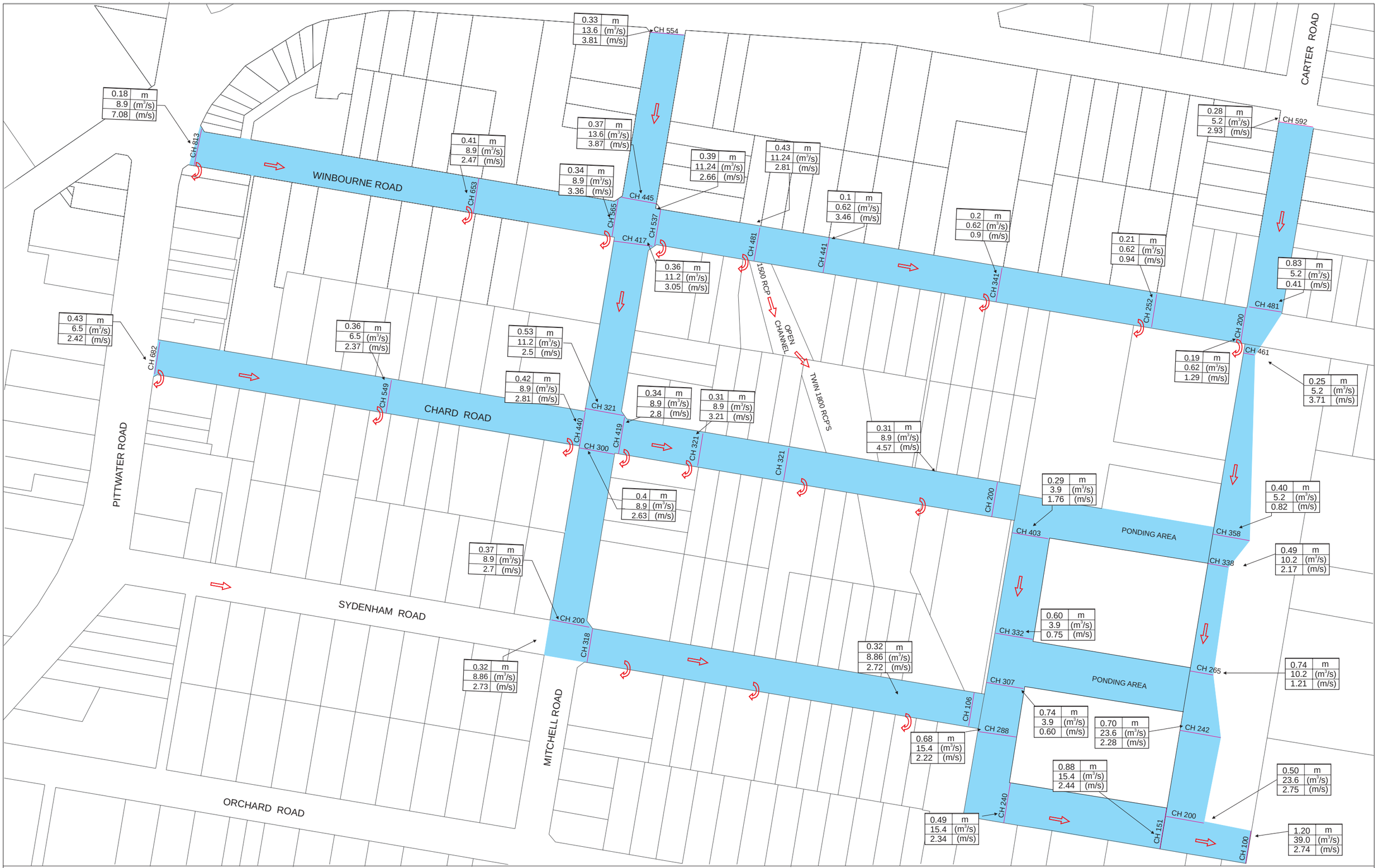
SHALLOW SHEET FLOW

Maximum depth of flow in road gutter	m
Peak discharge	(m³/s)
Peak flow velocity	(m/s)

DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure F3.3

CHARACTERISTICS OF FLOODING UPSTREAM HARBORD ROAD 50 YR ARI FLOOD



N

0 100m

Scale

Ch300 HEC-RAS CROSS SECTION

INDICATION OF LIKELY INUNDATION OF PROPERTY FRONTAGES ALONG EDGE OF ROAD RESERVE

INDICATIVE EXTENT OF FLOODING

DIRECTION OF OVERLAND FLOW

SHALLOW SHEET FLOW

Maximum depth of flow in road gutter	m
Peak discharge	(m³/s)
Peak flow velocity	(m/s)

DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure F3.4

CHARACTERISTICS OF FLOODING UPSTREAM HARBORD ROAD 100 YR ARI FLOOD

N

0 100 200 m
Scale

LENGEND

7.36 SURVEYED FLOOR LEVEL (m AHD)

EXTENT OF WINBOURNE INDUSTRIAL ESTATE

SURVEYED PROPERTIES SUBJECT TO ABOVE FLOOR INUNDATION AT 1 % AEP

DIRECTION OF OVERLAND FLOW

REFER FIGURES F3.1 TO F3.4 FOR HEC-RAS CROSS SECTION LOCATIONS

DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure F3.5
PEAK FLOOD LEVELS
WINBOURNE INDUSTRIAL ESTATE

APPENDIX G

FLOOD PLANNING LEVEL CONSIDERATIONS ON DEE WHY AND CURL CURL LAGOON

November 2005

Job No: AL128 J:/AL128/reports/DY Appendix G.doc	Date: 10 November, 2005 Rev No: 3.0	Principal: BWL Reviewer: SAB

TABLE G.1
FLOOD PLANNING LEVEL CONSIDERATIONS FOR
DEE WHY AND CURL CURL LAGOONS

Issues	Considerations	Range of Planning Flood Level (%AEP)		
		Residential	Commercial/ Industrial	Essential Services
Is there a characteristic of the local topography which points to a particular FPL for any land use?	• Flows mainly contained within vicinity of channels up to 20 %AEP. • Comparatively large increases in discharge result in comparatively small increases in level (220 – 500 mm increase between 20 % and 1%AEP, depending on location). • From a topographic perspective, there is no reason to differentiate between the appropriate planning levels for residential and commercial/industrial premises.	1	1	> 1
Is there a characteristic of land use in the area, the pattern of development or Council's current policies that points to a particular planning flood level?	• Flood affected land within the floodplain is mainly open space apart from isolated pockets of residential land bordering the lagoons and immediately upstream of Pittwater Road and commercial and industrial development upstream of Harbord Road on the Curl Curl Lagoon. • Council's flood policy adopts the 1%AEP flood as the flood standard and sets the FPL as the 1%AEP flood level plus 500 mm for freeboard.	1	1	1
Does the flood history on the catchment suggest a particular FPL? This involves a consideration of the magnitude and frequency of historic floods, as well as the "flood awareness" of the population.	• The last significant flood occurred in 1998 and was a 10 %AEP. • Extent of flooding and flood levels for the 1998 flood are probably not recognised by residents. • The community has only a limited appreciation that larger floods can occur.	> 5	> 5	1

TABLE G.1
(Continued)

Issues	Considerations	Range of Planning Flood Level (%AEP)		
		Residential	Commercial/ Industrial	Essential Services
Does the nature or rate of increase of flood damages vary greatly within the feasible range of planning levels?	• Damages begin at about the 20%AEP flood level. • There is only 220 – 500 mm difference between the 20%AEP and 1%AEP floods, but this leads to a fourfold increase in damages on Dee Why Lagoon catchment. On Curl Curl Lagoon, there is a large increase in residential damages, but commercial damages dominate and are four times residential damages for the 1%AEP. • Commercial damages are 4 times residential damages for the 100 year flood on Curl Curl lagoon and equal to residential damages at the 100 year level on Dee Why lagoon.	1	1	1
Will the choice of FPL affect future trends in flood damages, either adversely or beneficially?	• Damages and flood risk will increase if planning levels are set too low. • Increase in flood risk if residential development permitted in high hazard areas unless adequate building controls adopted.	1	1	> 1

TABLE G.1
(Continued)

Issues	Considerations	Range of Planning Flood Level (%AEP)		
		Residential	Commercial/ Industrial	Essential Services
Will the selection of a particular FPL encourage a complacent attitude towards flooding which will result in markedly adverse effects when a larger flood eventually occurs?	• A flood greater than the FPL will eventually occur unless the extreme flood is adopted. • If a medium flood (eg. 5%AEP) was adopted this could result in a large amount of additional unwise development. Significant damages commence at around the 20%AEP (there is already existing development in the floodplain between this level and the 1%AEP flood extent). The occurrence of a similar or larger flood could therefore have a substantial impact. • If a major flood was adopted there may develop a sense of complacency amongst those occupying new developments above that level. The occurrence of a flood greater than this can and will occur and would result in increased damages. • Unless the PMF was adopted (with an appropriate freeboard), the adopted planning flood level would need to be implemented in conjunction with measures to provide information and procedures to cope with larger floods.	>5	>5	>1
Is there a range of FPLs which would have a marked economic or social impact? Does the built environment suffer or benefit from the selection of a particular planning level?	• A very restrictive planning flood level would increase development costs. Too low a standard encourages unwise development and increases flood damages. • Controls for minor re-development could be less stringent than for new development. • Social impacts likely with any removal or restriction of residential development in the floodplain. • Choice of FPL would have negligible impact on the riparian environment.	5	5	1

TABLE G.1
(Continued)

Issues	Considerations	Range of Planning Flood Level (%AEP)		
		Residential	Commercial/ Industrial	Essential Services
Will the choice of the FPL affect flood warning, evacuation, response issues?	• Unless the PMF, plus and appropriate freeboard, is chosen as the planning level, flooding in excess of the FPL will occur and will need to be managed by other means, principally by emergency management. • The FPL should be chosen with the risk to emergency management personnel and feasibility of evacuation in mind. • It would be unwise to allow development in areas which are likely to become isolated and would be hazardous for evacuations routes. • Commercial property owners are likely to be more aware of flood impacts than residential owners and will tend to respond to early flood warnings.	2	5	1

APPENDIX H

REHABILITATION OF DEE WHY CREEK BETWEEN PITTWATER ROAD AND CAMPBELL AVENUE

November 2005

Job No: AL128 J:/AL128/reports/DY Appendix H.doc	Date: 10 November, 2005 Rev No: 4.0	Principal: BWL Reviewer: SAB

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LIST OF FIGURES

1. SYNOPSIS

This appendix deals with the proposed rehabilitation of Dee Why Creek in the reach between Campbell Avenue and Pittwater Road (**Figure H1.1**).

A proposal was developed by Panetta, 2000 to replace the existing half-round concrete pipe which forms the invert of the creek with a system of pools and riffles, together with an adjacent riparian area of local native vegetation more consistent with natural creeks. The proposal was supported in the recent Estuary Management Study (Lawson and Treloar, 2003), which additionally, proposed the implementation of a wetland at the downstream end of the reach.

These proposals are reviewed in this present investigation, which has the benefit of additional site surveys used in the Flood Study of the Dee Why Creek catchment prepared by LACE, 2002. The presence of existing sewer infrastructure and a wet weather overflow point into the creek system within the proposed wetland area were also found to have a significant adverse effect on the viability of the wetland project.

Hydraulic modelling of the wetland and riparian zone proposal was undertaken using the dynamic MIKE 11 model developed for the Flood Study. The results show that a project involving planting of the 20 m wide zone available along the line of the existing creek would have a significant adverse impact on flood levels and flow patterns along the reach which potentially extends upstream of Campbell Avenue. Flood levels would be increased over the range of flood magnitudes from a 20% AEP to a major 1% AEP flood.

As flooding of residential property in the Tarra Crescent/Billarong Avenue area would be experienced under present day conditions at the 20% AEP level, any increase in flood levels resulting from this project would increase the flood risk.

Consequently, it is recommended that the implementation, of the wetland and riparian zone not proceed in its currently proposed layout. Rehabilitation of this reach of the creek should be restricted to the replacement of the existing concrete pipe invert by a rock zone of roughly equivalent width and invert level, together with a narrow zone of low riparian plantings on each side, such that the overall conveyance capacity of the waterway is not reduced. A schematic layout is attached to this Appendix and an indicative budget cost is included in Chapter 5. Additional survey of the reach, including mapping the locations of significant trees to be retained, would be required to confirm the numbers and locations of the rock ramps and the degree of sinuousity that could be incorporated in the channel design.

In regard to the wetland proposal, it is to be noted that there are two existing remnant areas upstream of Campbell Avenue which have a sufficient surface area relative to the size of their upstream catchments to provide a beneficial effect on downstream water quality, if formalised into wetlands. These wetlands receive runoff the Cromer Industrial Area. Further investigation would be required to confirm their suitability for incorporation in a wetland strategy, including an assessment of the flow paths through these areas and the potential impacts on adjacent developed areas.

However, as both of these measures are not seen as fulfilling a flood mitigation role they would be unlikely to attract funding from State and Commonwealth Government under the formers' Flood Mitigation Program. Hence, these two measures have not been included in the Floodplain Risk Management Plan for Dee Why Curl Curl Lagoons. Council is advised to seek funding through the State Government's Estuary Management Program.

2. THE STUDY AREA

The channel of Dee Why Creek between the Gross Pollutant Trap immediately downstream of Campbell Avenue and the Pittwater Road crossing is about 500 m long and has an average gradient of 0.44%.

The influence on flooding of the lagoon and the culvert beneath Pittwater Road extends upstream about 200 m and includes the flood liable residential area of Billarong Avenue and Tarra Crescent. Within this zone, the water surface profile during flooding is quite flat and is within the backwater influence of the bridge. Further upstream, the water surface profile is parallel with the longitudinal profile of the streambed. Flood levels in this reach are influenced by the conveyance capacity of the waterway area.

The creek originally took a sinuous course over its extent, but was straightened at the time of development of the area and a 1200 mm diameter half pipe was constructed as a low flow invert. The earth behind the invert has eroded over time, particularly at its downstream end. Trees were planted within the channel area in a zone about 20 m in width. The trees have subsequently matured and the area is grassed and well maintained so that it maximises hydraulic conveyance capacity. On the northern side of the channel, residential development has encroached to about 10 m from the channel centreline in the upper reaches below Campbell Avenue. On the southern overbank, there are playing fields which convey a portion of the flow during medium to major flood events.

Further downstream, the northern floodplain was filled, levelled and grassed with more sparsely planted trees. This area is bounded by the residential properties in Tarra Crescent, many of which have gated access to the grassed area.

There is an open channel leading from a piped tributary of Dee Why Creek which drains the Billarong Avenue area. This channel joins the main stream at the eastern end of the grassed area. The banks of this channel are overgrown and there is evidence of a build up of sediment upstream of the Pittwater Road crossing.

There are two Gross Pollutant Traps in the area. The first trap is located on the eastern (downstream) side of Campbell Avenue at the head of the reach. The second GPT is located at the outfall of a piped tributary which drains the residential catchment on the southern side of Dee Why Creek and Tulich Avenue.

The invert level of the channel of Dee Why Creek increases from about RL 0.8 m at Pittwater Road to RL 1.2 m at the end of the concrete invert about 170 m upstream. This reach is subject to tidal influences when the lagoon entrance is open. In the event of a build up of the elevation of the berm at the lagoon outlet to the design elevation of RL 2.0 m adopted in the Flood Study (LACE, 2002), the area would be subject to backwater inundation of brackish water from the lagoon.

As discussed in Appendix E, which deals with Entrance Behaviour and Management, the current policy is to open Dee Why lagoon following several days of heavy rainfall, when the water level reaches the obvert of the stormwater pipe draining into the channel at the end of Billarong Avenue. The elevation of the top of this pipe is RL 1.8 m. In the event of flooding on the catchment, flood levels in the bridge backwater could reach a maximum level of RL 3.23 m for the 20% AEP flood, increasing to RL 3.42 for the 1% AEP event.

3. PREVIOUS INVESTIGATIONS

3.1 Outline of Investigations

In the recent Dee Why Estuary Management Study (EMS) prepared by Lawson and Treloar, 2003, it was proposed to rehabilitate Dee Why Creek in the reach between Campbell Avenue and Pittwater Road. The proposal, which was a development of a previous investigation (Panetta, 2000) involved the construction of a pool and riffle section of channel which would replace the existing half pipe concrete invert, in conjunction with an off-line wetland on the northern floodplain in the grassed area adjacent to the residences in Tarra Crescent/Billarong Avenue.

According to the EMS, the design of the rehabilitated creek system would have the following main objectives:

- Maximise the reinstatement of aquatic and terrestrial native flora endemic to the local area, to the extent compatible with flow conveyance objectives.

- Maximise the water quality and habitat improvement opportunities (eg. by including pool and riffle systems) – the design of a slow moving stream with vegetation and the construction of pools will help to improve the water quality of the stream and subsequently of the receiving water body.

- Creek system to be located within available land bounded by the location of residential dwellings on the northern overbank and the current extent of sports fields on the southern side.

- Creek design to be compatible with underground utility services such as electricity, gas, water, sewerage, existing vegetation to be retained and geotechnical conditions.

- Creek to include passive recreational opportunities and become part of a linked pedestrian/cycleway trail system that connects the tributaries with the lagoon.

- If practicable, the design is to achieve a reduction in flood extent and flood hazard in areas that are currently affected by flooding.

The Panetta, 2000 investigation proposed to locate the creek along the line of the existing 1200 mm diameter half pipe, which extends for a distance of 370 m downstream of Campbell Avenue. Variations in the creek invert would be achieved by a pool and riffle system. Within this reach, the creek invert falls by about 1.8 m, allowing four riffles to be included, each with a fall of 0.48 m from riffle crest to creek invert. At an average longitudinal grade of 1 vertical to 20 horizontal, each riffle would extend for a distance of about 10 m downstream of the crest. On the upstream side of the riffle, a pond would be created with a maximum depth of water from riffle crest to pond invert of 0.75 m. This depth was selected on the basis of maintenance and public safety considerations.

In the EMS investigation, the straight section of creek was to be replaced by a more sinuous alignment more in keeping with natural systems. An offline wetland was proposed on the northern bank in the lower reaches. Low flows from the creek would be diverted into the wetland. Typical cross sections of the proposed creek are presented in the EMS which indicate that

excavation would be confined to a narrow strip of about 6 m width, centred on the location of the existing half pipe invert.

No details of the alignment of the new creek line are shown. However, it appears that on the basis of the cross sections presented in the EMS, there would be only marginal sinuosity incorporated in the proposal as the proposed area of excavation, as shown on the cross sections, is confined to the vicinity of the existing creek centreline. Substantial deviations in the creek alignment towards the existing sloping overbanks would have required significant excavation within the creek. After allowing for the excavation batter, this would have resulted in a lowering of existing natural surface levels across the 20 m strip available for the rehabilitation. However, it appears that a scheme of this scope would also have required removal of the existing mature trees within the riparian zone.

No comments are given in the EMS on the likely disturbance to the existing trees resulting from implementation of the project.

Panetta, 2000 identified a plant schedule for the rehabilitation works, reproduced here as **Table H3.1**. A zoned approach would be required to separate plants into those permanently inundated, regularly inundated, periodically inundated and rarely inundated areas of the channel.

TABLE H3.1
PROPOSED PLANT SPECIES LIST (after Panetta, 2000)

Scientific Name	Common Name
Schoenoplectus validus	River Clubrush
Baumea rubignosa	Twigrush
Miriophylium trachycarpum	Water Milfoyle
Cyperus exaltatus	Umbrella Sedge
Philydrum lanuginosum	Frogsmouth
Schoenoplectus mucronatus	Clubrush
Triglochin procerum	Water Ribbons
Crassula helmsii	Swamp Crassula
Carex appressa	Tussock Sedge
Juncus usitatus	Common Rush
Eleocharis pusilla	Spikerush
Eleocharis sphacelate	Tall Spikerush
Phragmites australis	Common Reed

Panetta, 2000 identified each species was selected for the following purposes:

- Ability to provide habitat, food or nesting conditions for native fauna.
- Ability to provide a deep root network to bind the soil of the stream bed and banks, protecting them from erosion during periods of peak stormwater flows.

Other environmental objectives and details for the vegetation selection included:

- Macrophyte species choice that have the ability to uptake nutrients as well as providing effective bank stability and erosion control.

- Potential to withstand occasional estuarine inundation at high tide when the entrance is open.

- Taller more erect species to be placed on the margins and fringes of the pools and runs where total contact with water is not frequent, while the areas subject to more regular flows are to be planted with smaller species that prefer to be more frequently watered.

- Species on the creek margins will lie down flat in higher flow events to reduce flooding potential.

- Flatter species to be selected for the active riffle zones.

- Microphyte selection reflects the need for maximum diversity in order to provide habitat whilst also encouraging water quality, creek conveyance capacity and protection against erosion.

- Capacity to resist removal by high stream velocities – the selection of deep rooted plant types to withstand peak flows was considered an important design feature.

3.2 Comments on Investigations

The riparian zone is shown on the plan incorporated in the EMS as extending over the full 20 m available width. The intention was apparently to incorporate new plantings in the spaces between the existing trees. The result would have been a vegetated strip which although fulfilling environmental objectives, would have imposed considerable restrictions on the passage of floodwaters.

Many of the typical species proposed in **Table H3.1**, whilst providing excellent cover and stabilisation of earth banks, would thicken and grow over time and significantly reduce waterflow (Sainty and Jacobs, 1994).

The future condition of any riparian zone implemented along the reach in terms of its hydraulic roughness, (i.e. the principal parameter influencing the conveyance capacity and hence flood levels) cannot be predicted with any certainty. The future roughness depends on climate, patterns of growth in the planted species, possible colonisation of the area by other species and maintenance of the area by Council.

As residential development bordering the channel is currently floodprone, it is likely that any alterations by way of a riparian zone or wetlands could be viewed by affected residents as contributing to future flooding, especially if flooding were to occur shortly after implementation of the project. To minimise Council's future liability, a conservative approach should be adopted to ensure that the conveyance capacity of the channel is not reduced. This would require a less ambitious rehabilitation project where the riparian plantings are restricted to a narrow zone centred on the creek invert and careful attention is given to their height and density. The following sections provide a commentary on the proposals for a wetland and riparian zone.

4. THE WETLAND PROPOSAL

4.1 Commentary on Constraints Imposed by Infrastructure and Available Land

Recent survey of the area and collection of services and utilities data undertaken for this present investigation have shown that the area available for the construction of an off-line wetland in the lower reaches is restricted to a triangular shaped portion of land on the northern side of Dee Why Creek, which extends for a distance of 120 m parallel with the creek and increases to a width of 60 m at its downstream end which would be parallel with the channel draining the Billarong Avenue area.

The extension of the wetland in the eastern (downstream) direction would be constrained by the presence of a sewer overflow structure which is situated on the western bank of the tributary channel. The sewer overflow would discharge to the tributary during periods of heavy rainfall. The overflow structure is located at the junction of two trunk sewers. The first sewer is of 400 mm diameter and drains the area on the southern side of Dee Why Creek and crosses the creek from south to north en route to the overflow point. The sewer is concrete encased as it crosses the creek and the top of the encasement may be observed at the invert level of the creek. The second trunk sewer, also of 400 mm diameter, drains the area to the north of Dee Why Creek and runs in a south-easterly direction beneath the proposed wetland area. The sewer is at a shallow depth and would impose a constraint on the allowable depth of excavation for the wetland construction.

The area available for a wetland comprises about 0.36 ha, equivalent to only 0.13 per cent of the 2.6 km^2 Dee Why Creek catchment. In the EMS, an available area of 0.68 ha was suggested, but this is clearly an overestimate in view of the limitations on the available areal extent imposed by the sewer overflow. It would clearly not be advisable to bund the wetland so that it encloses the overflow, with the consequent impoundment of sewage after periods of heavy rainfall.

For this reason, it would also not be feasible to extend the wetland so that it captures runoff from the stormwater system of the Billarong Avenue area, as proposed in the EMS. As mentioned previously, the sewer overflow discharges to the channel conveying stormwater flows from Billarong Avenue. A major diversion of the Billarong Avenue piped stormwater system would be required to bypass the channel and direct flows into the wetland. Consequently, runoff from the Billarong Avenue catchment could neither be treated in the wetland nor used as a source of water for its replenishment during periods of low flow.

4.2 Hydraulic Constraints

A wetland representing only 0.13% of the catchment would have such a small retention time of stormwater flows that it would not provide significant water quality benefits. In addition, as the wetland plants grow with the passage of time, it is likely that they would impose an increasing restriction on the conveyance of flood flows, with consequent increase in peak water levels. A hydraulic simulation of the combined impacts of the wetland and the upstream riparian zone on flood levels on Dee Why Creek is discussed later in **Section 5** of this Appendix.

4.3 Alternative Wetland Locations

The existing wetland area upstream of Campbell Avenue (**Figure H4.1**) captures runoff from an area of 0.95 km^2 of the upper catchment of Dee Why Creek, including the Cromer Industrial Estate. The surface area of this wetland is about 2 ha, equivalent to the 2% of the catchment which is the threshold area at which significant water quality benefits may be achieved.

There is no published information available on the flow paths through this wetland or structures, either natural or man-made, which would influence retention times of runoff. However, on the basis of area alone, it appears that this wetland offers the potential for improving water quality on the Dee Why Creek catchment and appears to be a much more viable option than the proposed wetland in the lower reaches.

There is also a remnant wetland area on Council owned land between the Dee Why Bowling Club and South Creek Road. It may be worth incorporating this area, together with the wetland area upstream of Campbell Avenue in an overall wetland strategy for the treatment of stormwater runoff from the contributing industrial and residential catchments. It would of course be necessary to demonstrate that there would be no adverse flood impacts on adjacent lands as a result of implementing wetlands in these areas.

5. COMMENTARY ON THE RIPARIAN ZONE PROPOSAL

5.1 Potential Impacts on Flood Levels

The zone available for planting as a riparian zone is limited to about 20 m in width. It is bounded on the northern side by existing residential development. This development is at a progressively lower level relative to major flood levels, with increasing distance downstream. At the downstream end at Tarra Crescent/Billarong Avenue, residences are flooded in the event of a 5% AEP flood.

The construction of a riparian zone according to the EMS would involve the replacement of the existing half-pipe invert by a pool and riffle zone, with adjacent plantings of endemic species. Over time, it is likely that these plantings would become progressively more dense and taller, imposing a progressively greater restriction on the conveyance of flows.

Hydraulic analysis was undertaken to simulate the effects of the riparian zone on flooding patterns. The MIKE 11 dynamic hydraulic model developed for the Flood Study (LACE, 2002) was used for this purpose. It was assumed that the half-pipe would be replaced by a rock lined section with invert levels no higher than present day levels and the remainder of the 20 m zone comprising the existing overbanks would be planted. The proposed wetland on the northern bank of the creek was also included in the model.

Whilst the estimation of hydraulic roughness (Mannings n) values is well established for normal channels, the estimation in areas of dense vegetation is subject to large variations depending upon the experience of the engineer and the perceived density of vegetation. WRP, 1994 undertook testing to ascertain typical roughness values in wetland areas, which gave values in the range of 0.2 to 0.6 depending on the surface density of the plants. Over a range of flow velocities, the average value of n was 0.3. For this present simulation, a value of 0.28 was adopted in the wetland area.

Investigations undertaken by U.S. Army Corps of Engineers, 2000 have shown that the hydraulic roughness of a vegetated channel is a function of the stiffness of the plants growing in the channel, the depth, velocity and hydraulic radius of the channel, plant density and frontal area of the plants obstructing the flow.

Resistance increases with the depth of flow for partially submerged plants as the blockage area increases with depth until the plants are submerged. When the plants are submerged, the plant leaf mass tends to trail downstream forming a streamlined, almost teardrop shaped profile. The transition between submerged and partially submerged flow occurs at a depth of about 80 per cent of the undeflected plant height.

At the 1% AEP level of flooding, the maximum depth of flow in the channel would be about 1.6 m measured from the top of the half round pipe to the water surface. For the more frequent flood events, the corresponding depth would be around 1.2 m.

Accordingly, if all of the 20 m width of drainage corridor were planted, then the outer part would contain partially submerged plants with a comparatively higher resistance to flow than the submerged plants adjacent to the channel invert. For the purposes of the analysis, an average Mannings n of 0.18 was adopted for the vegetated section and a value of 0.09 was adopted for the rock riffle innermost zone.

The 1% and 5% AEP design hydrographs were applied to the model. **Table H5.1** compares present day and post-project peak water surface levels.

TABLE H5.1
COMPARISON OF PRESENT DAY WITH
POST-CREEK REHABILITATION PEAK FLOOD LEVELS
1% AND 5% AEP FLOODS

Location	1% AEP		Increase in Flood Levels m	5% AEP		Increase in Flood Levels m
	Present Day RL – m	Post-Rehab RL – m		Present Day RL – m	Post-Rehab RL – m	
Billarong Avenue/ Tarra Cres	3.42	3.42	0	3.22	3.20	–0.2
End of Concrete Half Pipe	3.60	3.68	+0.08	3.32	3.39	+0.07
Existing Footbridge	3.98	4.23	+0.25	3.74	3.97	+0.23
d/s GPT at Campbell Avenue	5.24	5.91	+0.67	4.82	5.56	+0.74
Campbell Avenue	5.31	5.93	+0.62	4.89	5.57	+0.68

As shown in **Table H5.1**, the combined riparian zone and wetland project would result in significant increases in flood levels along the planted reach and would increase flood levels at and upstream of Campbell Avenue. The loss in conveyance capacity of the creek would also result in a re-direction of flows onto the playing fields and properties in the southern overbank.

5.2 Comments on Results of Hydraulic Modelling

The potential increase in flood levels of a 20 m wide riparian zone would clearly not be acceptable. From the above analysis it was concluded that rehabilitation should be restricted to the following activities:

1) Removal of the half-pipe concrete invert over its 170 m length downstream of Campbell Avenue.

2) Replacement of the invert by a rock lined invert of approximately the same width and at the same level. The pool and rock riffle concept could be introduced. The degree of sinuosity of the new channel would be limited by the requirement to maintain existing natural surface levels in the grassed areas on each side of the rock invert, so that the existing trees may be retained. **Figure H5.1** is a schematic diagram showing three rock ramps with some modest excavation of the invert, which would provide a standing water depth of around 0.6 m in the pool upstream of the rock ramp.

3) It may also be possible to have a narrow strip of riparian plantings along the creek. However, the plants and the width of the riparian zone would need to be carefully chosen so that when fully grown, they do not impose a significant restriction on the flow.

More detailed hydraulic modelling would be required to fix the parameters of the riparian zone. For preliminary planning, a width of 2 m on each side of the rock zone has been adopted for planting and the width of the rock invert has been restricted to an average of 2 to 3 m with some local widening at the rock riffles. **Figure H5.2** is a schematic diagram illustrating this arrangement.

An indicative budget estimate for the proposal works is presented in **Table H5.2**.

TABLE H5.2
INDICATIVE COST OF CREEK REHABILITATION

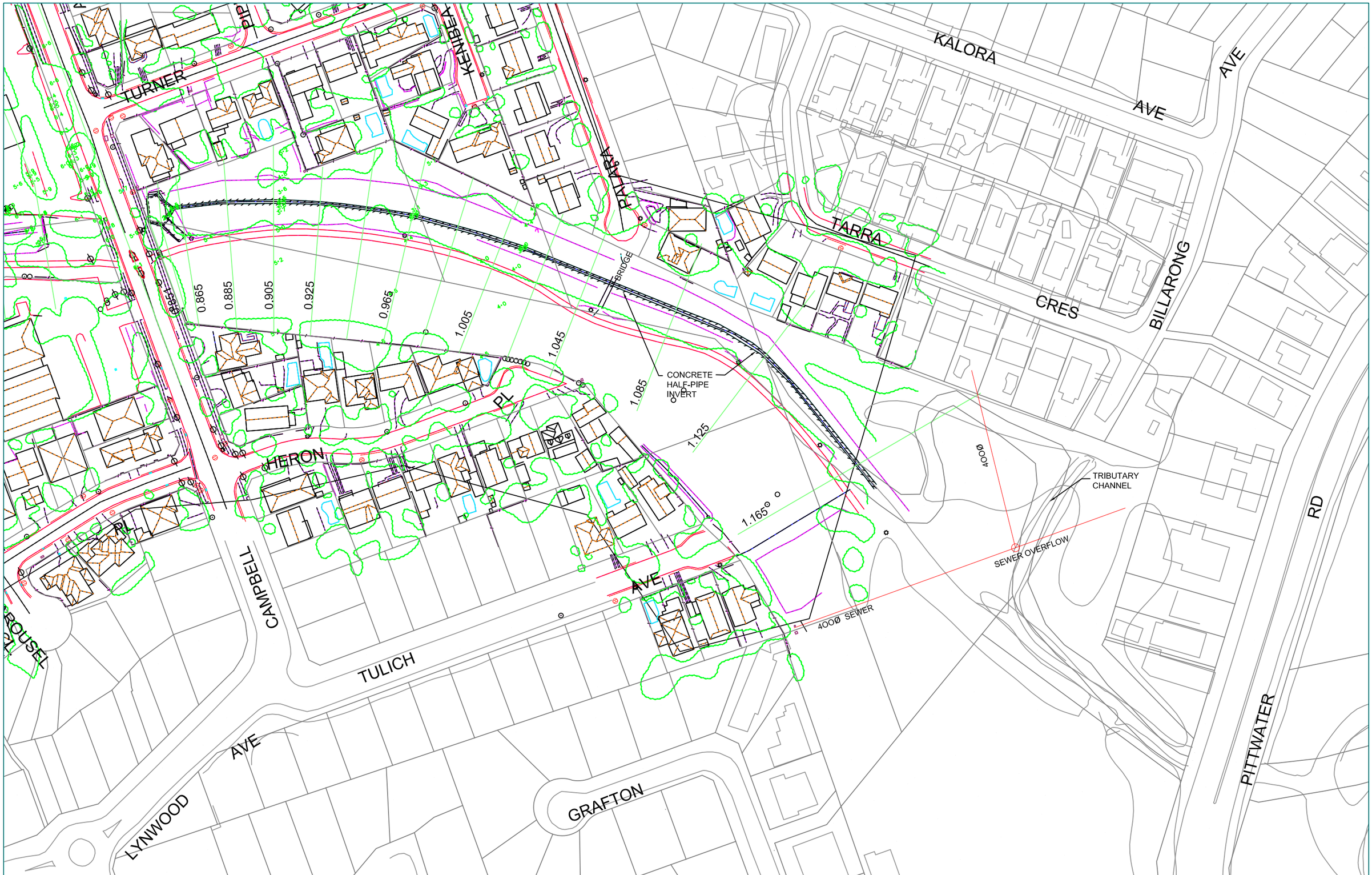
Item	Description	Cost
1.	Establishment; setting out works; temporary fencing; diversion and care of creek; safety signs.	$80,000
2.	Remove concrete invert; strip and dispose of existing vegetation; excavate to finished levels.	$20,000
3.	Compact foundation of rock invert and prepare base layer of crushed sandstone, with overlying geotextile.	$20,000
4.	Supply and place rock invert over 340 m length of channel.	$120,000
5.	Prepare surface, supply and plant shrubs and ground covers over 340 m length of channel.	$30,000
6.	Clean channel and banks d/s end of concrete invert and re-plant (approx. 150 m length of channel).	$50,000
7.	Investigation and design of scheme.	$50,000
8.	Unestimated items and contingencies	$80,000
	TOTAL BUDGET	**$450,000**

6. REFERENCES

"Effects of Vegetation on Hydraulic Roughness and Sedimentation in Wetlands". WRP Technical Notes SD-CP-2.2, May 1995

U.S. Army Corps of Engineers, 2000. *"Determination of Flow Resistance Coefficients Due to Shrubs and Woody Vegetation"*. ERDC/CHL HETN-II-3.

Sainty G.R. and Jacobs S.W.L. (1994). *"Waterplants in Australia A Field Guide"*.



SCALE

0 50m 100m

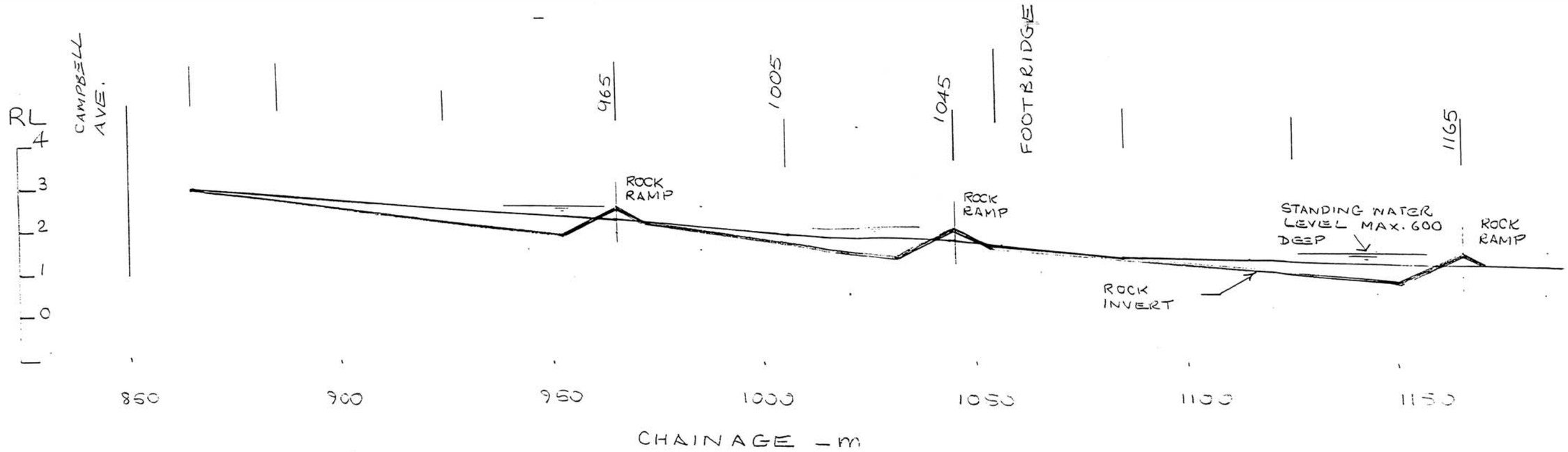
DEE WHY AND CURL CURL LAGOONS FLOODPLAIN
RISK MANAGEMENT STUDY AND PLAN

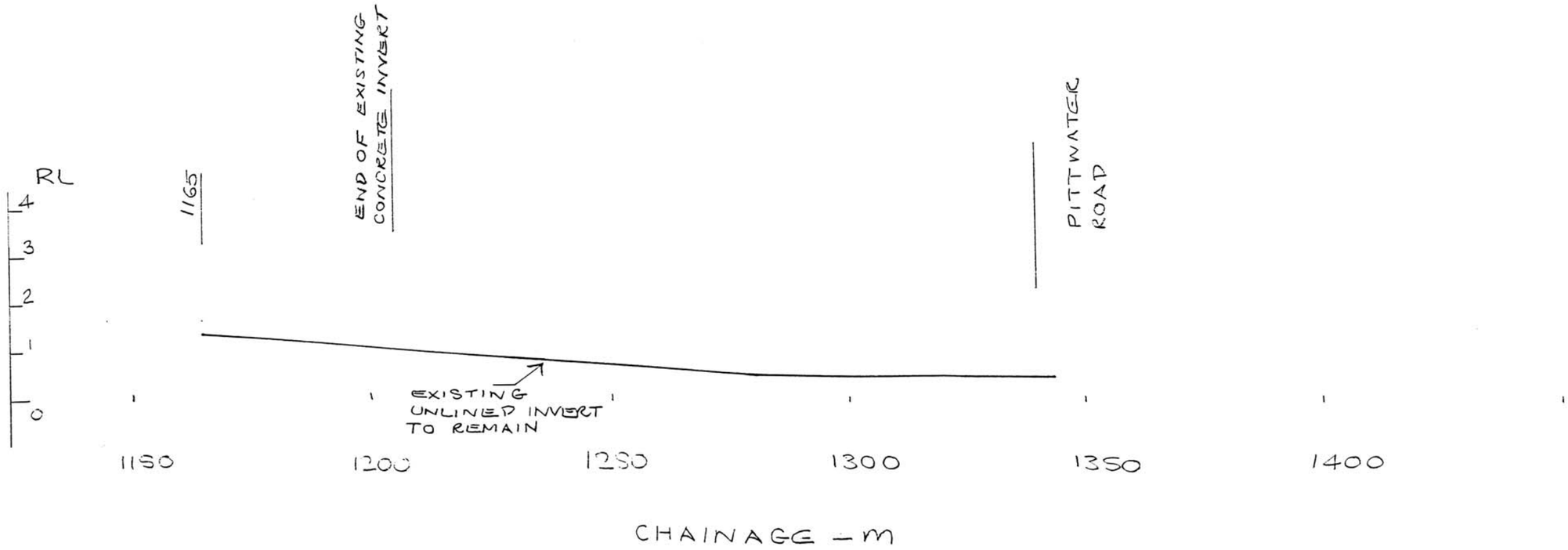
Figure H1.1
LOCATION PLAN

N

0 100 200
meters

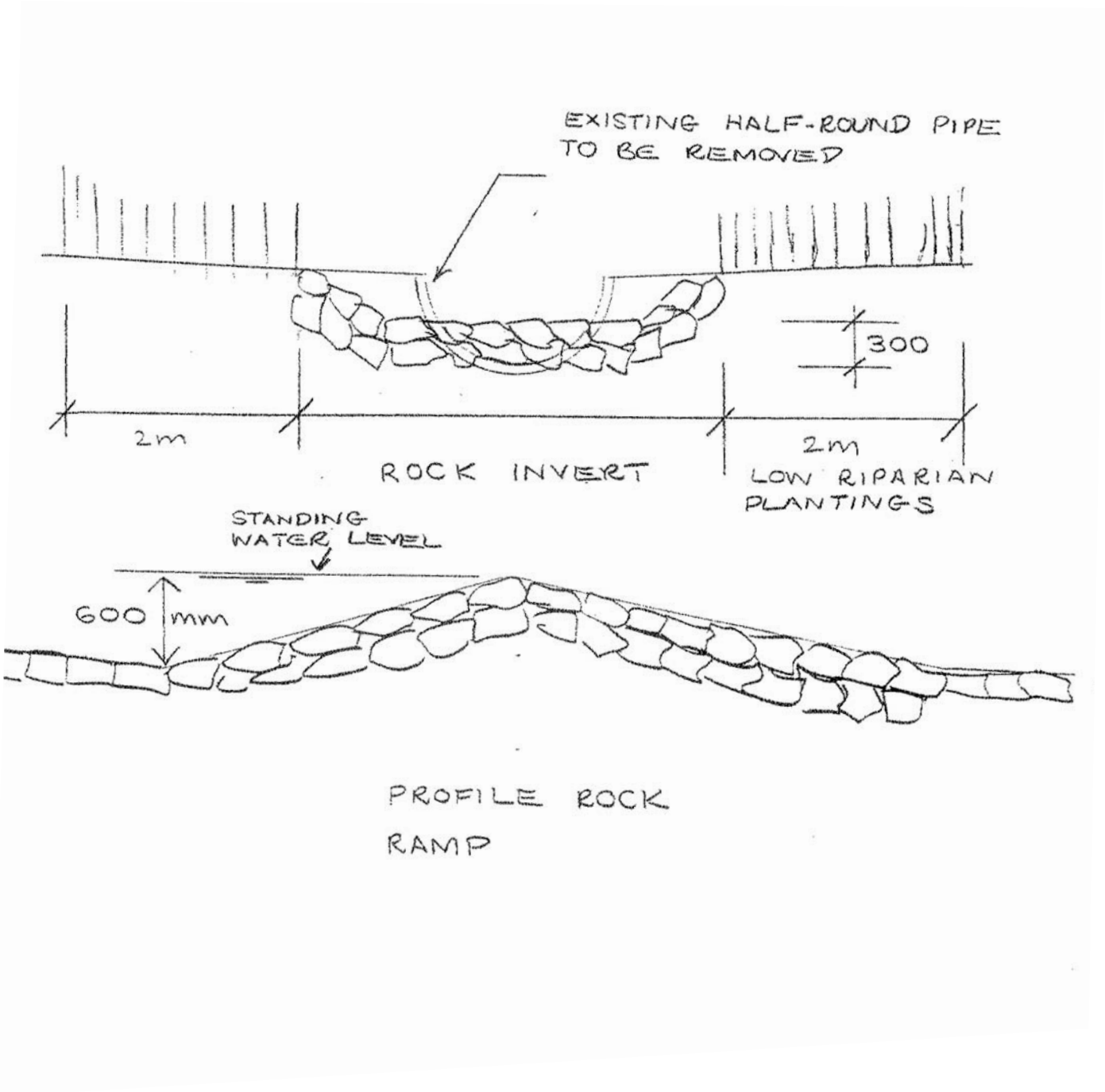
DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure H4.1
Remnant Wetland Upstream of Campbell Avenue





LONGITUDINAL PROFILE DEE WHY CREEK

DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure H5.1
Schematic Diagram Rock Invert and Rock Ramps



NOT TO SCALE

DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure H5.2
Section Rock Invert and Rock Ramp