Hawkesbury Floodplain Risk Management Study & Plan

Drawing of night-time rescues during the 1867 Hawkesbury River flood (Source: Illustrated Sydney News, June 1867)

Volume 3 − Flood Maps and Annotated Bibliography

December 2012

Report of Hawkesbury City Council's Floodplain Risk Management Advisory Committee
Adopted by Hawkesbury City Council at its meeting on 11 December 2012

Bewsher

HAWKESBURY CITY COUNCIL

Hawkesbury Floodplain Risk Management Study & Plan

Volume 3 − Flood Maps and Annotated Bibliography

December 2012

Report of Hawkesbury City Council's Floodplain Risk Management Advisory Committee
Adopted by Hawkesbury City Council at its meeting on 11 December 2012

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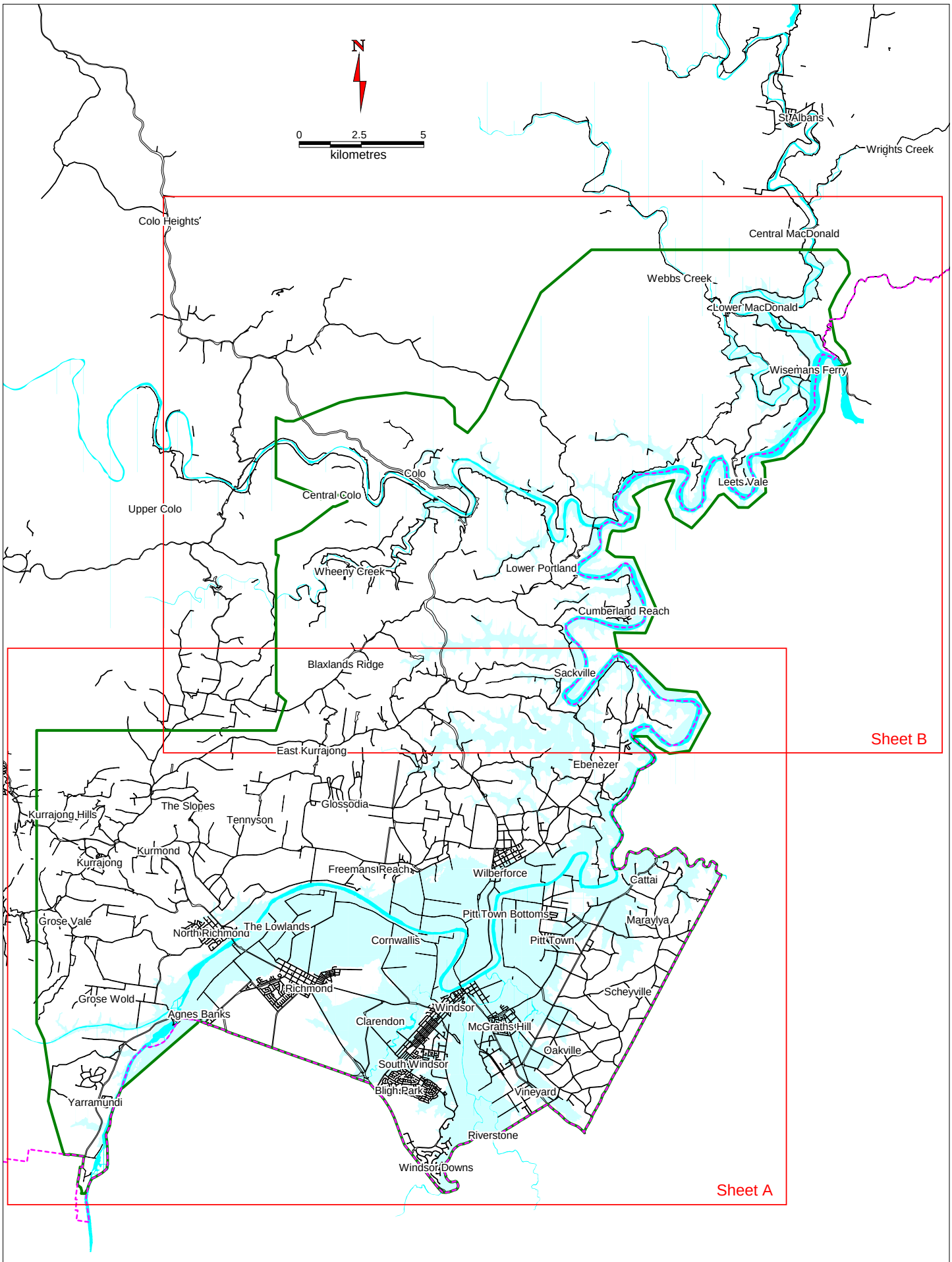
ACN 003137068. ABN 24 312 540 210

APPENDIX A

FLOOD MAPS

LIST OF FLOOD MAPS



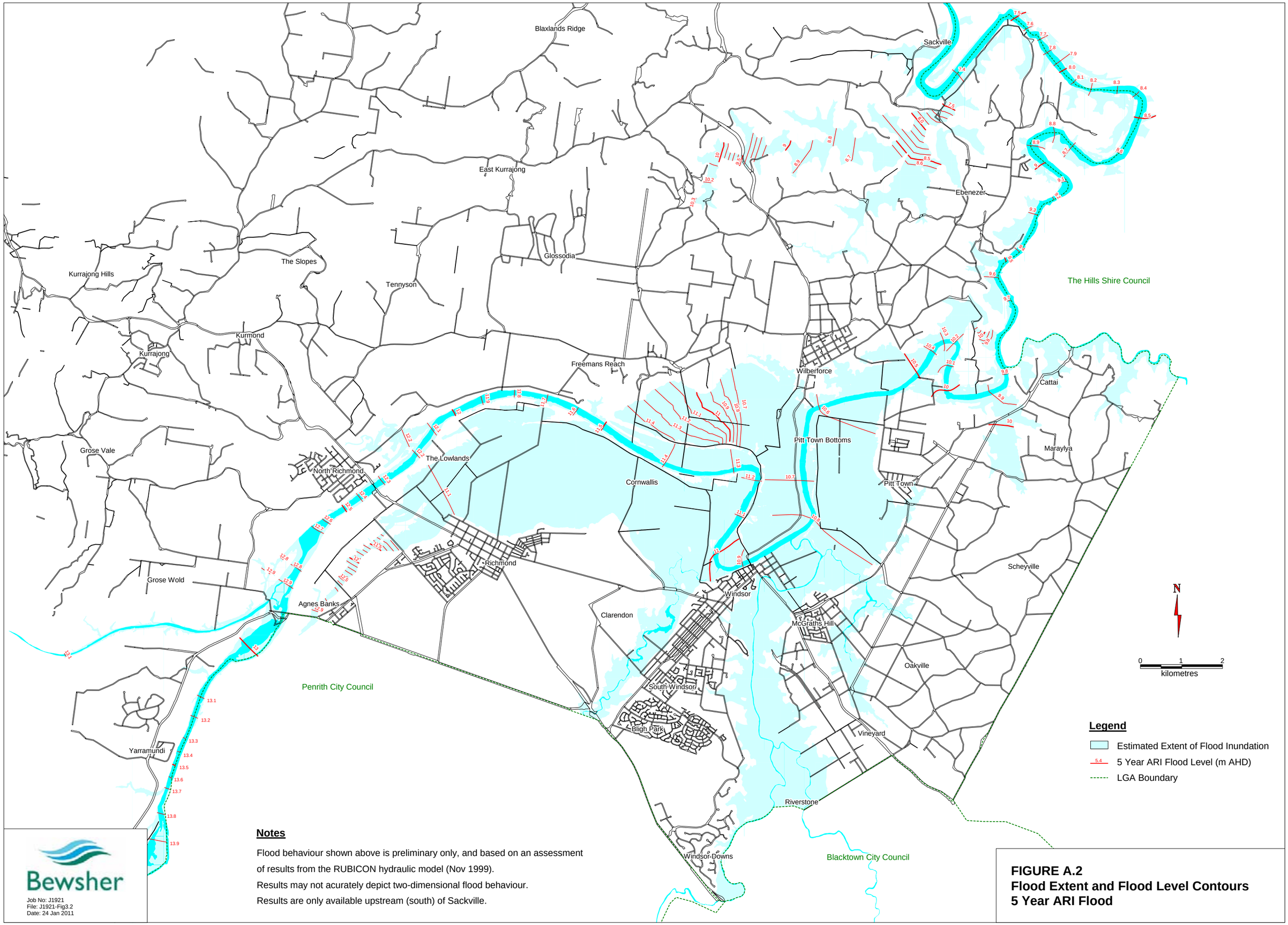
Bewsher

Job No: J1921
File: J1921-Fig3.1.wor
Date:14 Jan 2011

Legend

- LGA boundary
- Limit of DEM and boundary of flood mapping
- Mapping sheet layout
- Estimated extent of 100 year flood

FIGURE A.1
Study Area and Sheet Layout



Notes

Flood behaviour shown above is preliminary only, and based on an assessment of results from the RUBICON hydraulic model (Nov 1999).
Results may not acurately depict two-dimensional flood behaviour.
Results are only available upstream (south) of Sackville.

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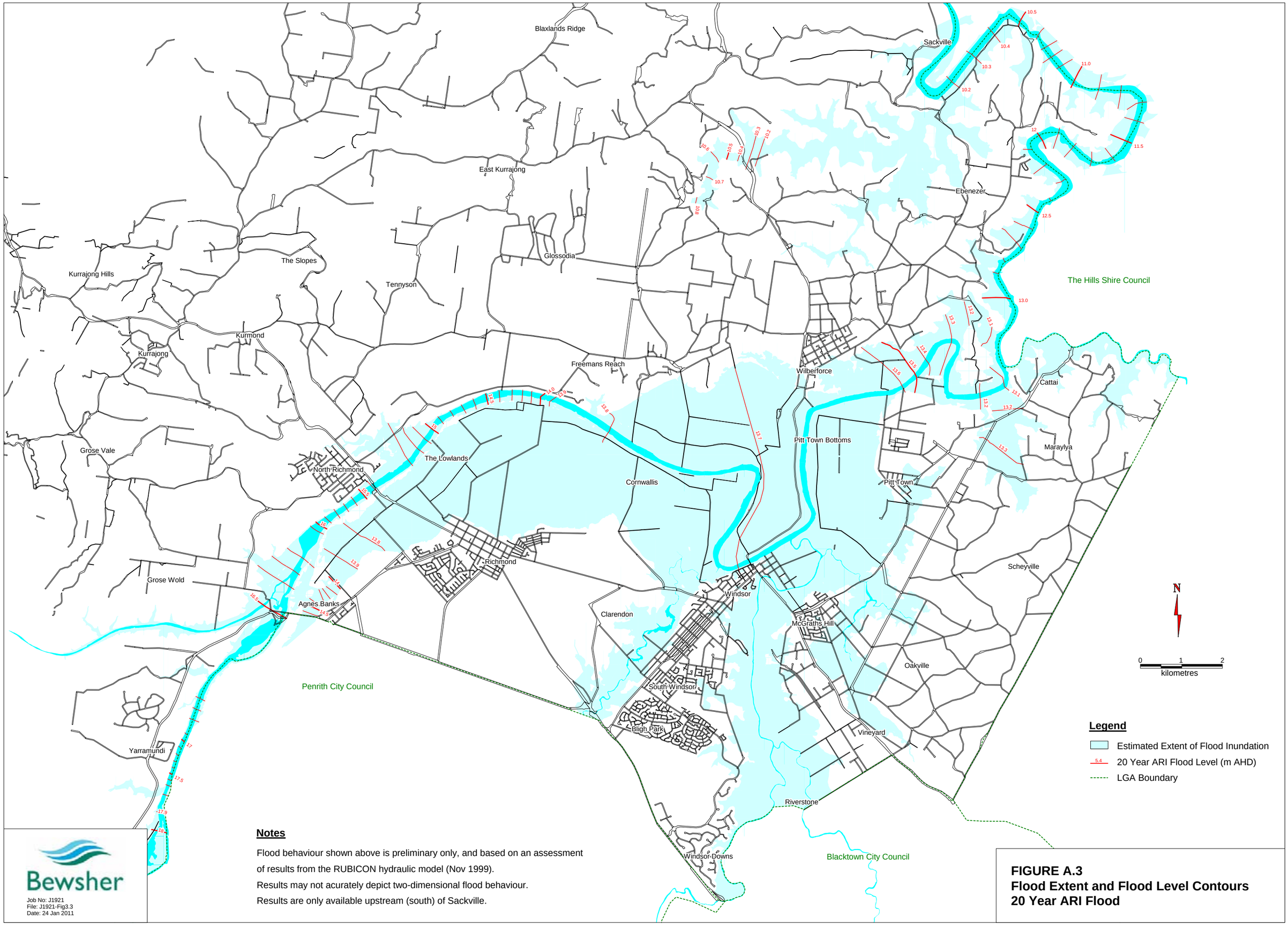
Job No: J1921
File: J1921-Fig3.2
Date: 24 Jan 2011

FIGURE A.2
Flood Extent and Flood Level Contours
5 Year ARI Flood


Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Grose Vale
The Lowlands
North Richmond
Pitt Town Bottoms
Maraylya
Cornwallis
Pitt Town
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council
N
0
1
2
kilometres
Legend
Estimated Extent of Flood Inundation
20 Year ARI Flood Level (m AHD)
LGA Boundary
Notes
Flood behaviour shown above is preliminary only, and based on an assessment of results from the RUBICON hydraulic model (Nov 1999).
Results may not acurately depict two-dimensional flood behaviour.
Results are only available upstream (south) of Sackville.
Bewsher
Job No: J1921
File: J1921-Fig3.3
Date: 24 Jan 2011
FIGURE A.3
Flood Extent and Flood Level Contours
20 Year ARI Flood

Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Pitt Town Bottoms
Grose Vale
The Lowlands
North Richmond
Cornwallis
Pitt Town
Maraylya
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council

N

0 1 2
kilometres

Legend

- Estimated Extent of Flood Inundation
- 5.4 50 Year ARI Flood Level (m AHD)
- LGA Boundary

Notes

Flood behaviour shown above is preliminary only, and based on an assessment of results from the RUBICON hydraulic model (Nov 1999).
Results may not acurately depict two-dimensional flood behaviour.
Results are only available upstream (south) of Sackville.

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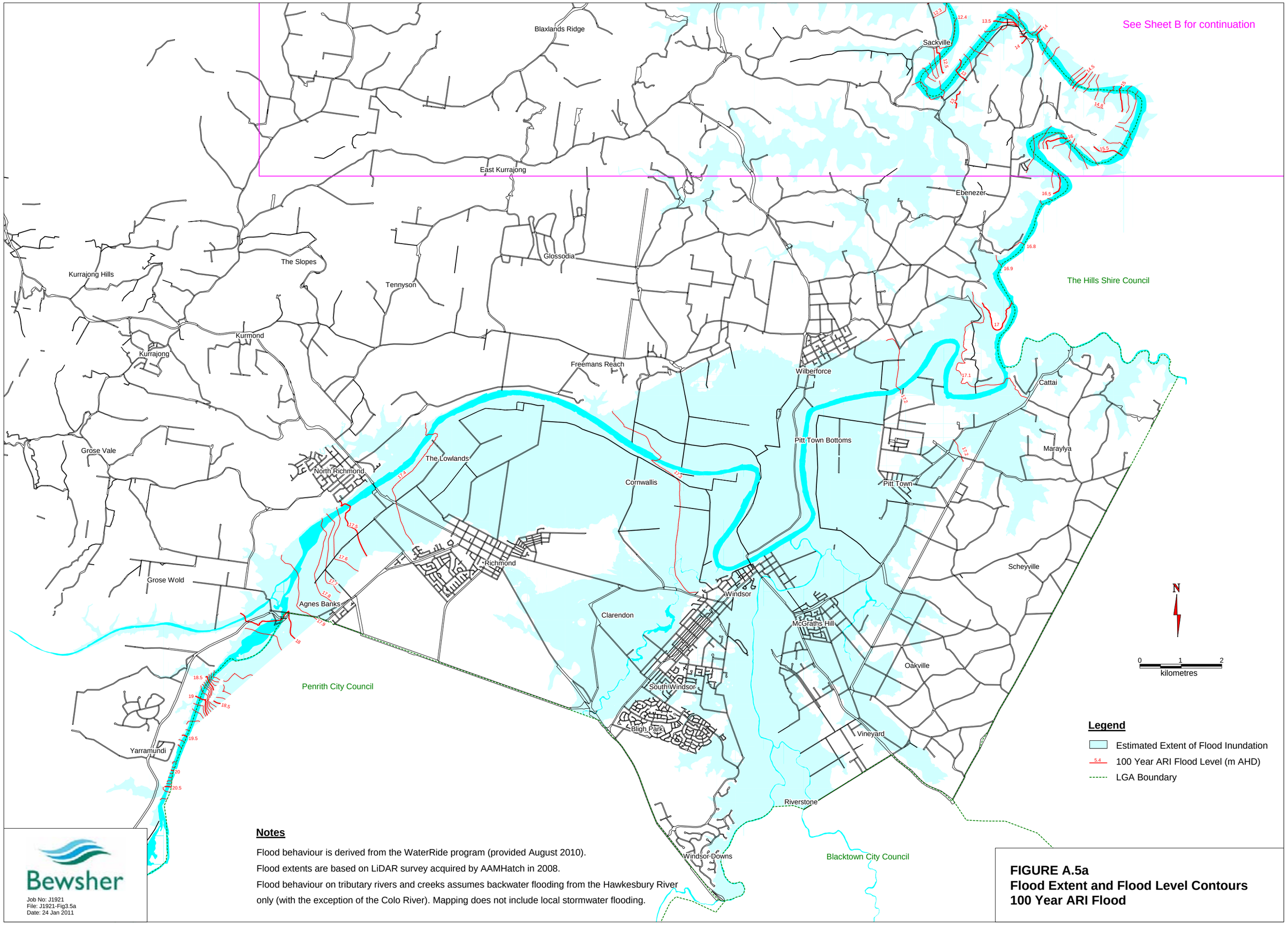
Job No: J1921
File: J1921-Fig3.4
Date: 24 Jan 2011

FIGURE A.4
Flood Extent and Flood Level Contours
50 Year ARI Flood


See Sheet B for continuation
Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Grose Vale
Pitt Town Bottoms
Maraylya
The Lowlands
North Richmond
Cornwallis
Pitt Town
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council
N
0
1
2
kilometres
Legend
Estimated Extent of Flood Inundation
100 Year ARI Flood Level (m AHD)
LGA Boundary
Notes
Flood behaviour is derived from the WaterRide program (provided August 2010).
Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.
Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.
Bewsher
Job No: J1921
File: J1921-Fig3.5a
Date: 24 Jan 2011
FIGURE A.5a
Flood Extent and Flood Level Contours
100 Year ARI Flood

Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).

Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.

Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

Legend

- Estimated Extent of Flood Inundation
- 5.4 100 Year ARI Flood Level (m AHD)
- LGA Boundary

Heights

Central MacDonald

Webbs Creek

Lower-MacDonald

Gosford City Council

Wisemans Ferry

6.4

Hornsby Shire Council

Leets Vale

8.0

7.5

9.5

9

8.5

10

10.3

Colo

Central Colo

10.4

10.5

10.6

10.7

10.8

11.1

11

10.9

Wheeny Creek

Lower Portland

10.5

11

The Hills Shire Council

Cumberland Reach

11.5

12

12.3

12.4

13.5

14

14.5

15

14.8

16

15.5

Blaxlands Ridge

Sackville

See Sheet A for continuation

N

0 1 2

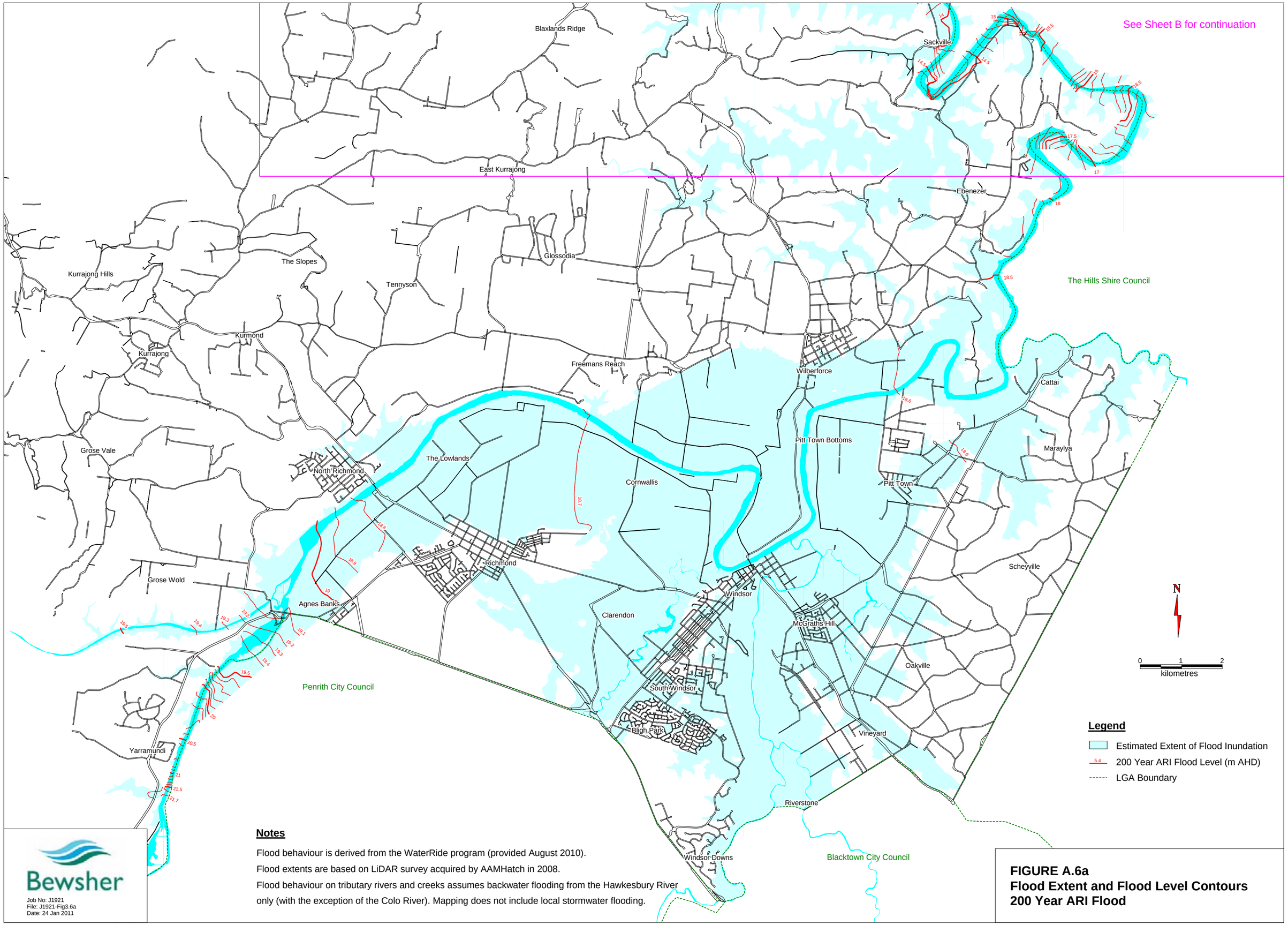
kilometres

Bewsher

Job No: J1921
File: J1921-Fig3.5b
Date: 24 Jan 2011

East Kurrajong

FIGURE A.5b
Flood Extent and Flood Level Contours
100 Year ARI Flood



Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).

Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.

Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

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Job No: J1921
File: J1921-Fig3.6a
Date: 24 Jan 2011

FIGURE A.6a
Flood Extent and Flood Level Contours
200 Year ARI Flood

Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).

Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.

Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

Legend

- Estimated Extent of Flood Inundation
- 5.4 — 200 Year ARI Flood Level (m AHD)
- LGA Boundary

Heights

Central MacDonald

Webbs Creek

Lower-MacDonald

7.9

Gosford City Council

Wisemans Ferry

7.2

8

Hornsby Shire Council

Leets Vale

8.5

9.5

10.5

11

10

9

Colo

Central Colo

12.5

12

11.9

11.5

12

12.5

13

The Hills Shire Council

Lower Portland

Cumberland Reach

13.5

14

15

15.5

14.5

16

16.5

17.5

17

Wheeny Creek

Blaxlands Ridge

Sackville

East Kurrajong

See Sheet A for continuation

N

0 1 2

kilometres

Bewsher

Job No: J1921
File: J1921-Fig3.6b
Date: 24 Jan 2011

FIGURE A.6b
Flood Extent and Flood Level Contours
200 Year ARI Flood

See Sheet B for continuation

Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Grose Vale
Pitt Town Bottoms
Maraylya
The Lowlands
North Richmond
Cornwallis
Pitt Town
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council

N

0 1 2
kilometres

Legend

- Estimated Extent of Flood Inundation
- 5.4 500 Year ARI Flood Level (m AHD)
- LGA Boundary

Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).
Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.
Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

Bewsher

Job No: J1921
File: J1921-Fig3.7a
Date: 24 Jan 2011

FIGURE A.7a
Flood Extent and Flood Level Contours
500 Year ARI Flood

Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).

Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.

Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

Legend

- Estimated Extent of Flood Inundation
- 5.4 500 Year ARI Flood Level (m AHD)
- LGA Boundary

Heights

Central MacDonald

Webbs Creek

Lower MacDonald

Gosford City Council

Wisemans Ferry

9

Hornsby Shire Council

9.5

Leets Vale

10

10.5

11

11.5

12

12.5

13

13.4

13.5

14

14.5

15

15.5

16

16.5

17

17.5

18

18.5

19

Colo

Central Colo

Wheeny Creek

Lower Portland

The Hills Shire Council

Cumberland Reach

Blaxlands Ridge

Sackville

East Kurrajong

N

0 1 2

kilometres

See Sheet A for continuation

Bewsher

Job No: J1921
File: J1921-Fig3.7b
Date: 24 Jan 2011

FIGURE A.7b
Flood Extent and Flood Level Contours
500 Year ARI Flood

See Sheet B for continuation

Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Pitt Town Bottoms
Grose Vale
The Lowlands
North Richmond
Cornwallis
Pitt Town
Maraylya
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council

18.5 18 17.5 17 19 19.5 20.5 20 21 18 21.5 21.6 21.7 21.7 21.7 21.8 21.9 23 22.5 23 23.5 24

N

0 1 2
kilometres

Legend

- Estimated Extent of Flood Inundation
- 5.4 1,000 Year ARI Flood Level (m AHD)
- LGA Boundary

Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).
Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.
Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

Bewsher

Job No: J1921
File: J1921-Fig3.8a
Date: 24 Jan 2011

FIGURE A.8a
Flood Extent and Flood Level Contours
1,000 Year ARI Flood

Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).

Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.

Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

Legend

- Estimated Extent of Flood Inundation
- 5.4 1,000 Year ARI Flood Level (m AHD)
- LGA Boundary

Heights

Central MacDonald

Webbs Creek

Lower MacDonald

Gosford City Council

Wisemans Ferry

Hornsby Shire Council

Colo

Central Colo

Leets Vale

The Hills Shire Council

Wheeny Creek

Lower Portland

Cumberland Reach

Blaxlands Ridge

Sackville

East Kurrajong

See Sheet A for continuation

N

0 1 2
kilometres

Bewsher

Job No: J1921
File: J1921-Fig3.8b
Date: 24 Jan 2011

FIGURE A.8b
Flood Extent and Flood Level Contours
1,000 Year ARI Flood

See Sheet B for continuation

Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Grose Vale
Pitt Town Bottoms
Maraylya
The Lowlands
North Richmond
Cornwallis
Pitt Town
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council

N

0 1 2
kilometres

Legend

- Estimated Extent of Flood Inundation
- 5.4 Probable Maximum Flood Level (m AHD)
- LGA Boundary

Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).
Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.
Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

Bewsher

Job No: J1921
File: J1921-Fig3.9a
Date: 25 Jan 2011

FIGURE A.9a
Flood Extent and Flood Level Contours
Probable Maximum Flood (PMF)

Notes

Flood behaviour is derived from the WaterRide program (provided August 2010).

Flood extents are based on LiDAR survey acquired by AAMHatch in 2008.

Flood behaviour on tributary rivers and creeks assumes backwater flooding from the Hawkesbury River only (with the exception of the Colo River). Mapping does not include local stormwater flooding.

Legend

- Estimated Extent of Flood Inundation
- 5.4 Probable Maximum Flood Level (m AHD)
- LGA Boundary

Heights

Central MacDonald

Webbs Creek

Lower MacDonald

Gosford City Council

Wisemans Ferry

15.7

16

16.5

17

Hornsby Shire Council

Leets Vale

17.5

18

18.5

19

19.5

20

20.5

21

21.5

22

22.1

Colo

Central Colo

22.2

22.3

22.4

Wheeny Creek

Lower Portland

The Hills Shire Council

22.3

22.4

Cumberland Reach

22.5

23

23.5

Sackville

24

24.5

24.8

25

Blaxlands Ridge

East Kurrajong

See Sheet A for continuation

N

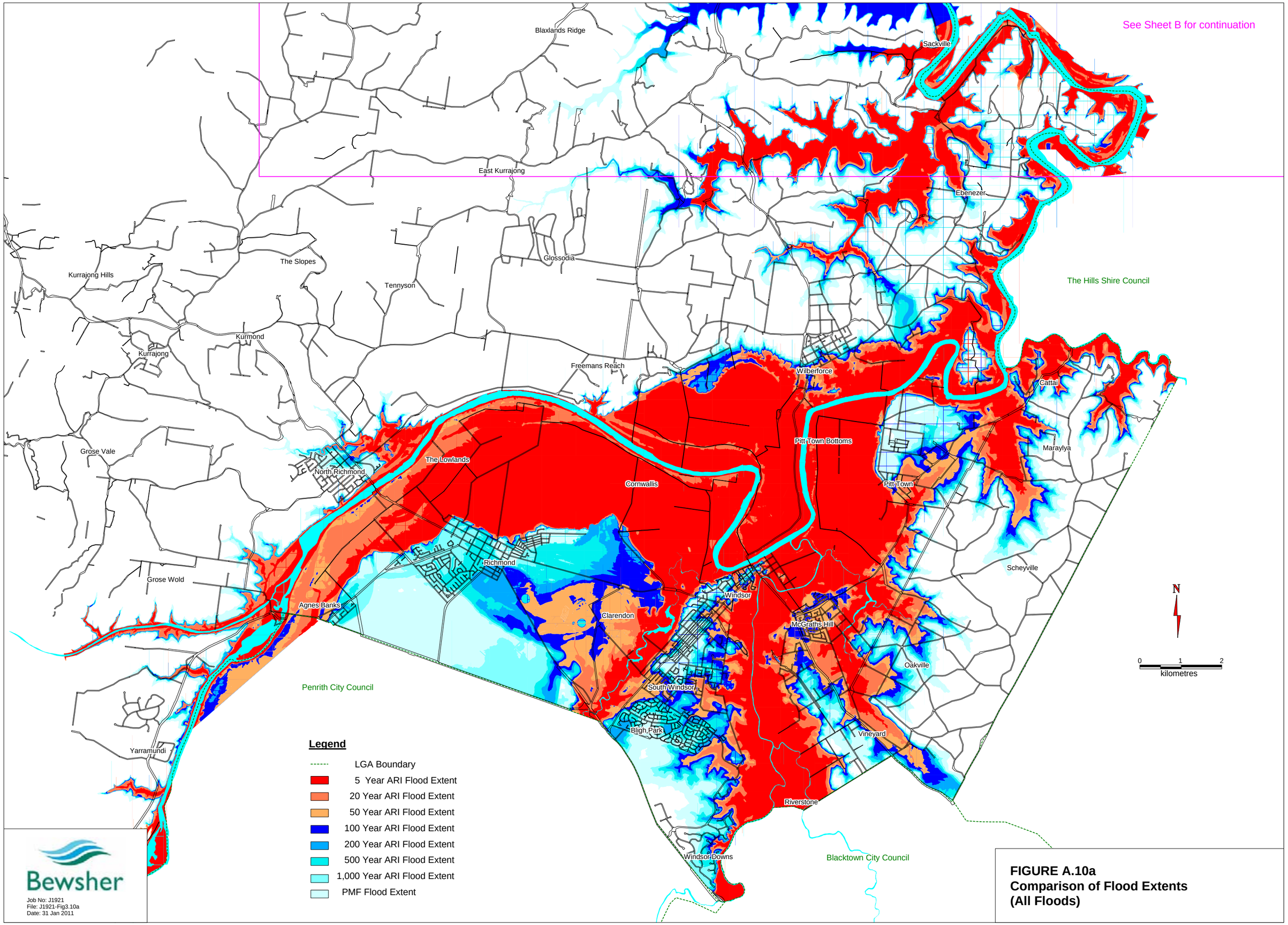
0 1 2

kilometres

Bewsher

Job No: J1921
File: J1921-Fig3.9b
Date: 24 Jan 2011

FIGURE A.9b
Flood Extent and Flood Level Contours
Probable Maximum Flood (PMF)



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Job No: J1921
File: J1921-Fig3.10a
Date: 31 Jan 2011

FIGURE A.10a
Comparison of Flood Extents (All Floods)

Heights

Legend

- LGA Boundary
- 5 Year ARI Flood Extent
- 20 Year ARI Flood Extent
- 50 Year ARI Flood Extent
- 100 Year ARI Flood Extent
- 200 Year ARI Flood Extent
- 500 Year ARI Flood Extent
- 1,000 Year ARI Flood Extent
- PMF Flood Extent

Central MacDonald

Webbs Creek

Lower MacDonald

Gosford City Council

Wisemans Ferry

Hornsby Shire Council

Colo

Central Colo

Leets Vale

Wheeny Creek

Lower Portland

The Hills Shire Council

Cumberland Reach

Limit of available data (5, 20 & 50yr)

Blaxlands Ridge

Sackville

See Sheet A for continuation

N

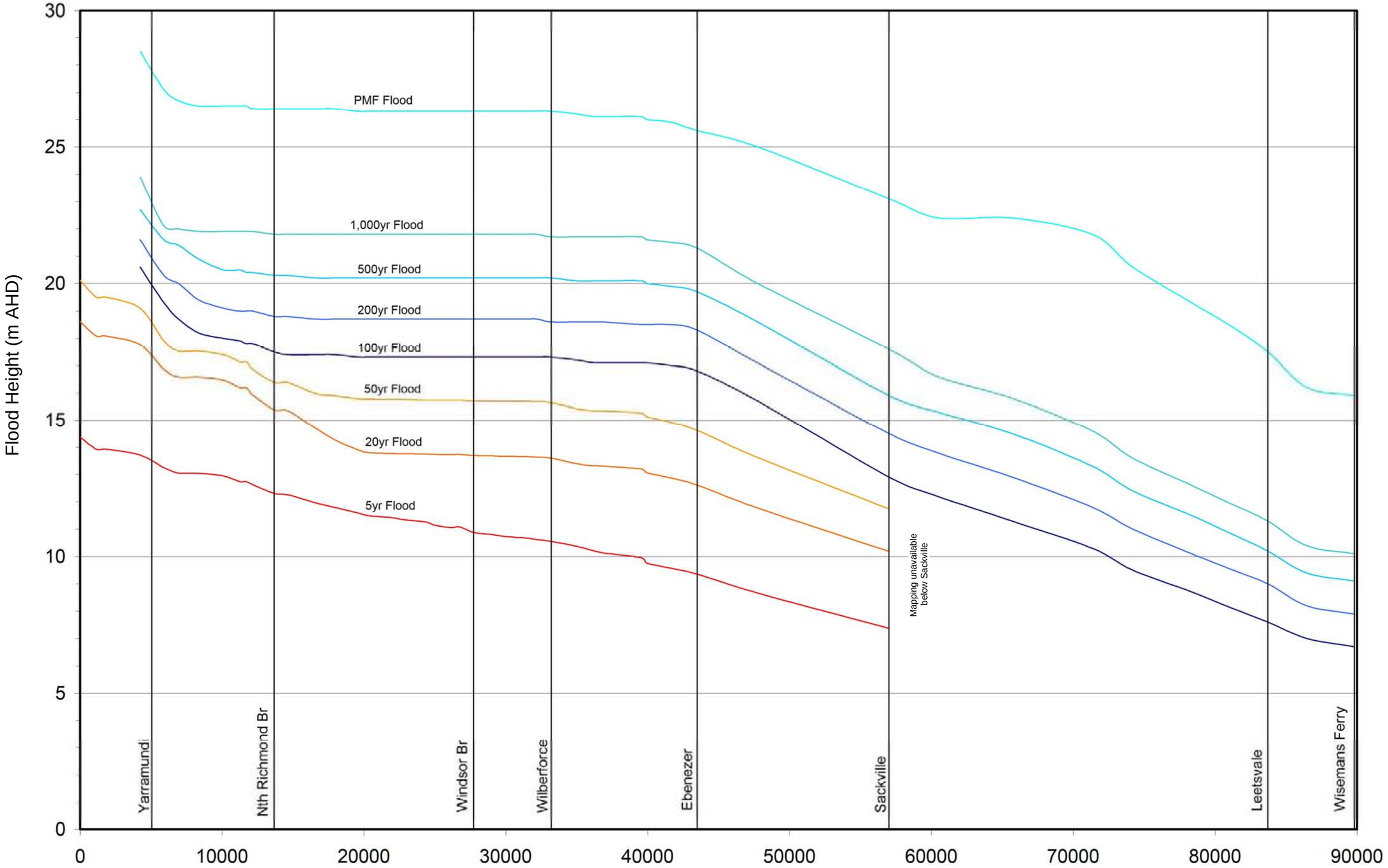
0 1 2
kilometres

Bewsher

Job No: J1921
File: J1921-Fig3.10b
Date: 31 Jan 2011

East Kurrajong

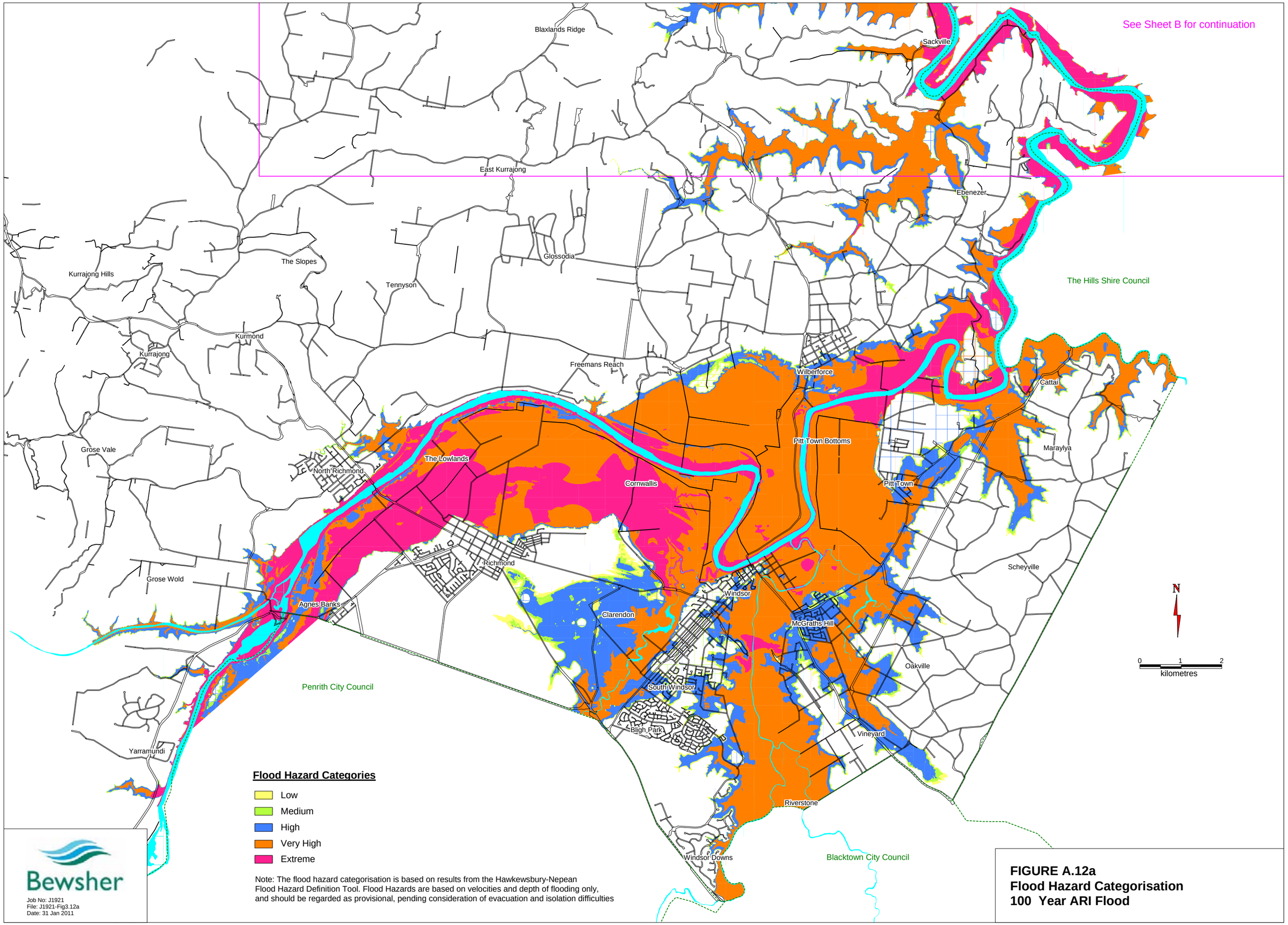
FIGURE A.10b
Comparison of Flood Extents
(All Floods)



Bewsher

Job No: J1921
File: J1921-Fig3.11
Date: 31 Jan 2011

FIGURE A.11
Comparison of Longitudinal Flood Profiles


See Sheet B for continuation
Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Pitt Town Bottoms
Maraylya
Grose Vale
The Lowlands
North Richmond
Cornwallis
Pitt Town
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council
N
0
1
2
kilometres
Flood Hazard Categories
Low
Medium
High
Very High
Extreme
Note: The flood hazard categorisation is based on results from the Hawkesbury-Nepean Flood Hazard Definition Tool. Flood Hazards are based on velocities and depth of flooding only, and should be regarded as provisional, pending consideration of evacuation and isolation difficulties
Bewsher
Job No: J1921
File: J1921-Fig3.12a
Date: 31 Jan 2011
FIGURE A.12a
Flood Hazard Categorisation
100 Year ARI Flood

Heights

Flood Hazard Categories

- Low
- Medium
- High
- Very High
- Extreme

Note: The flood hazard categorisation is based on results from the Hawkewsbury-Nepean Flood Hazard Definition Tool. Flood Hazards are based on velocities and depth of flooding only, and should be regarded as provisional, pending consideration of evacuation and isolation difficulties

Central MacDonald

Webbs Creek

Lower MacDonald

Gosford City Council

Wisemans Ferry

Hornsby Shire Council

Leets Vale

Colo

Central Colo

Lower Portland

Wheeny Creek

The Hills Shire Council

Cumberland Reach

Blaxlands Ridge

Sackville

East Kurrajong

See Sheet A for continuation

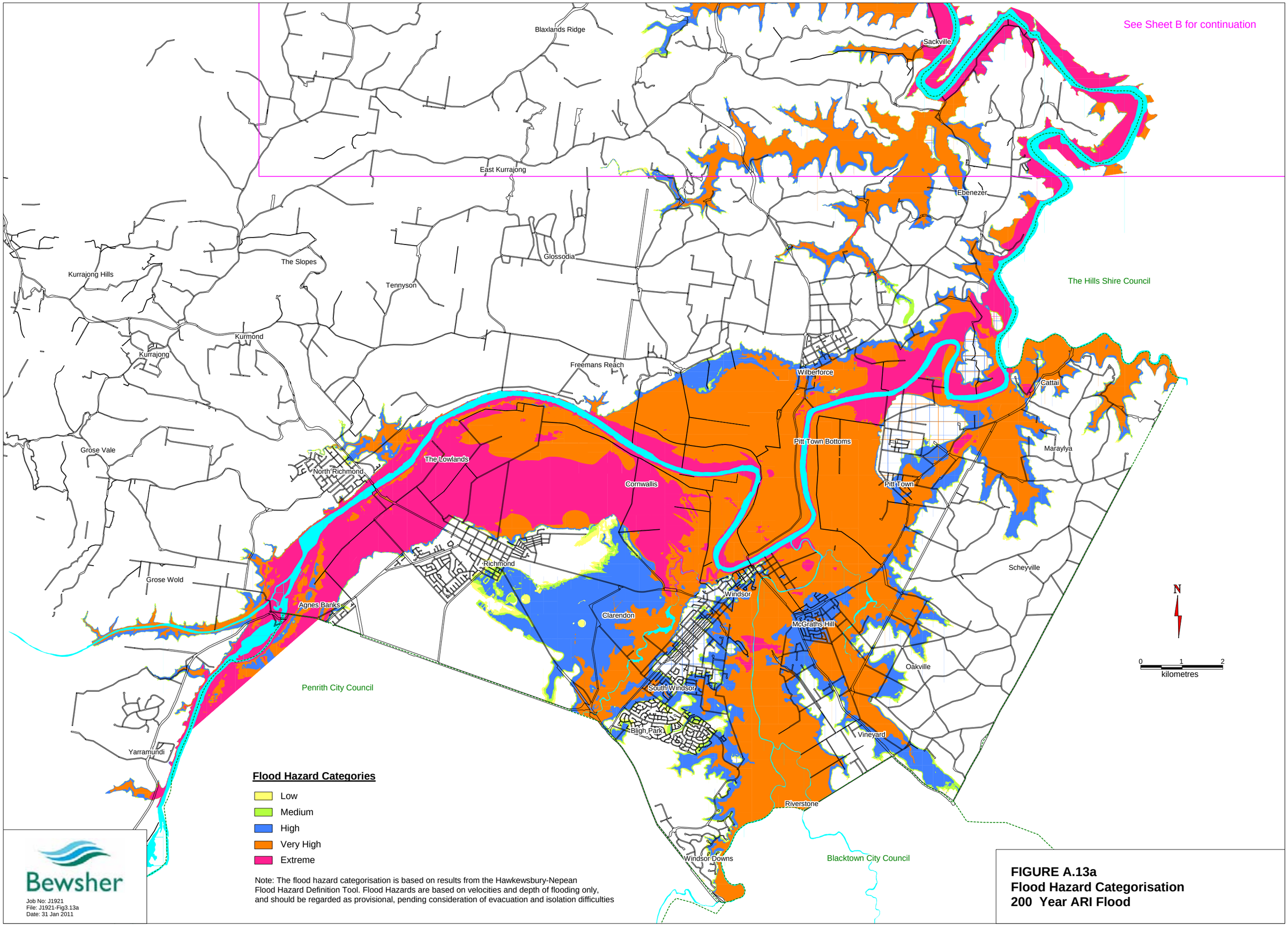
N

0 1 2
kilometres

Bewsher

Job No: J1921
File: J1921-Fig3.12b
Date: 31 Jan 2011

FIGURE A.12b
Flood Hazard Categorisation
100 Year ARI Flood


See Sheet B for continuation
Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Grose Vale
Pitt Town Bottoms
Maraylya
North Richmond
The Lowlands
Cornwallis
Pitt Town
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council
N
0
1
2
kilometres
Flood Hazard Categories
Low
Medium
High
Very High
Extreme
Note: The flood hazard categorisation is based on results from the Hawkesbury-Nepean Flood Hazard Definition Tool. Flood Hazards are based on velocities and depth of flooding only, and should be regarded as provisional, pending consideration of evacuation and isolation difficulties
Bewsher
Job No: J1921
File: J1921-Fig3.13a
Date: 31 Jan 2011
FIGURE A.13a
Flood Hazard Categorisation
200 Year ARI Flood

Flood Hazard Categories

- Low
- Medium
- High
- Very High
- Extreme

Note: The flood hazard categorisation is based on results from the Hawkewsbury-Nepean Flood Hazard Definition Tool. Flood Hazards are based on velocities and depth of flooding only, and should be regarded as provisional, pending consideration of evacuation and isolation difficulties

Heights

Central MacDonald

Webbs Creek

Lower MacDonald

Gosford City Council

Wisemans Ferry

Hornsby Shire Council

Leets Vale

Colo

Central Colo

Wheeny Creek

Lower Portland

The Hills Shire Council

Cumberland Reach

Blaxlands Ridge

Sackville

East Kurrajong

See Sheet A for continuation

N

0 1 2
kilometres

Bewsher

Job No: J1921
File: J1921-Fig3.13b
Date: 31 Jan 2011

FIGURE A.13b
Flood Hazard Categorisation
200 Year ARI Flood

See Sheet B for continuation

Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Cattai
Grose Vale
North Richmond
The Lowlands
Pitt Town Bottoms
Maraylya
Cornwallis
Pitt Town
Grose Wold
Richmond
Scheyville
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council

N

0 1 2
kilometres

Flood Hazard Categories

- Low
- Medium
- High
- Very High
- Extreme

Note: The flood hazard categorisation is based on results from the Hawkesbury-Nepean Flood Hazard Definition Tool. Flood Hazards are based on velocities and depth of flooding only, and should be regarded as provisional, pending consideration of evacuation and isolation difficulties

Bewsher

Job No: J1921
File: J1921-Fig3.14a
Date: 31 Jan 2011

FIGURE A.14a
Flood Hazard Categorisation
500 Year ARI Flood

Heights

Flood Hazard Categories

- Low
- Medium
- High
- Very High
- Extreme

Note: The flood hazard categorisation is based on results from the Hawkewsbury-Nepean Flood Hazard Definition Tool. Flood Hazards are based on velocities and depth of flooding only, and should be regarded as provisional, pending consideration of evacuation and isolation difficulties

Central MacDonald

Webbs Creek

Lower MacDonald

Gosford City Council

Wisemans Ferry

Hornsby Shire Council

Leets Vale

Colo

Central Colo

Wheeny Creek

Lower Portland

The Hills Shire Council

Cumberland Reach

Blaxlands Ridge

Sackville

East Kurrajong

See Sheet A for continuation

N

0 1 2
kilometres

Bewsher

Job No: J1921
File: J1921-Fig3.14b
Date: 31 Jan 2011

FIGURE A.14b
Flood Hazard Categorisation
500 Year ARI Flood

Limit of Mapping
Blaxlands Ridge
Sackville
East Kurrajong
Ebenezer
Glossodia
The Slopes
Kurrajong Hills
Tennyson
The Hills Shire Council
Kurmond
Kurrajong
Freemans Reach
Wilberforce
Gattai
Pitt Town Bottoms
Grose Vale
The Lowlands
North Richmond
Cornwallis
Pitt Town
Maraylya
Richmond
Scheyville
Grose Wold
Windsor
Agnes Banks
Clarendon
McGraths Hill
Oakville
Penrith City Council
South Windsor
Bligh Park
Vineyard
Yarramundi
Riverstone
Windsor Downs
Blacktown City Council

N

0 1 2
kilometres

Flood Risk Precincts

- Very Low Flood Risk
- Low Flood Risk
- Medium Flood Risk
- High Flood Risk
- Extreme Flood Risk

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Job No: J1921
File: J1921-Fig3.16
Date: 14 July 2012

FIGURE A.15
Flood Risk Precincts

APPENDIX B

ANNOTATED BIBLIOGRAPHY OF REVIEWED REPORTS ETC

The material presented here is summarised from the reviewed reports, some of which are more than a decade old. It is included to provide an appreciation of the large amount of previous studies and investigations of flood risks in the Hawkesbury area, many of which are still relevant today. Nevertheless in some cases this material may no longer be current or accurate.

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Consequences/Damage/Impacts

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- Defines flood behaviour for the Lower Hawkesbury from Sackville to the ocean. Design floods are the 5 year, 20 year, 50 year, 100 year, 200 year and the PMF. Modelling shows that 100 year levels could vary by 0.4m depending on the combination of design floods originating for either the Colo or Hawkesbury Rivers. The best estimate design flood levels at selected locations are shown below:

Location	5 year	20 year	50 year	100 year	PMF
Sackville Ferry	7.6	9.9	11.7	12.9	25.4
Lower Portland	5.5	7.5	9.1	10.3	22.3
Leets Vale	3.8	5.2	6.5	7.6	17.9
Webbs Creek Ferry (Wisemans Ferry)	3.2	4.4	5.6	6.7	16.3

Becker, J., Johnston, D., Coomer, M. & Ronan, K. 2008a. *Flood risk perceptions, education and warning in four communities in the Hawkesbury-Nepean Valley, New South Wales, Australia – results of a questionnaire survey, February 2006*, GNS Science Report 2008/02, Institute of Geological and Nuclear Sciences, Lower Hutt, NZ (prepared for NSW SES).

- In February 2006, 250 questionnaires were issued via hand-delivery to household letterboxes in each of McGraths Hill, Windsor/South Windsor and Richmond/Agnes Banks/Richmond Lowlands/Cornwallis, including areas outside the 100 year flood extent. The response rate was 20-22% (i.e. about 50 surveys from each area). Higher proportions of long-term residents answered the questionnaire compared with baseline demographic data for the areas.
- The questionnaire included questions on awareness, risk perception, previous exposure to flooding, information received concerning preparedness activities, information sought for preparedness purposes and the extent to which people engaged or plan to engage in preparedness activities.
- Flooding is perceived as the most likely future hazard by the majority of residents (but not for McGraths Hill).
- About 50% of respondents from Windsor and Richmond had been affected by a flood in the past, compared to 40% for McGraths Hill. On the whole the degree of impact was slight.
- Few respondents had prepared a home flood plan (<13%) or an emergency kit (<7%), which does not accord with results of Colmar Brunton (1999) which found much higher preparedness.
- About 60% of respondents believe it is necessary to make preparations for floods. Those that did not believe it was necessary did not believe they were in a flood risk area or hadn't been affected.
- However, respondents had only a low to moderate personal concern about floods, highlighting a need for individuals to personalise the risk. Very few respondents planned to seek more information about risk.
- There is a moderate to high lack of knowledge of any flood warning systems in the Hawkesbury-Nepean communities, especially at McGraths Hill where residents are newer. The action respondents would most likely take upon hearing a flood warning would be to seek confirmation by contacting the local council or the SES. Some 20% would check the internet. Significant numbers would evacuate at once.
- The SES phone number (132 500) was little recognised as a number people would call for help in a flood.
- About 25% of respondents indicated that if they encountered a flooded area of road not marked with a 'road closed' sign, they would 'continue with care'.
- About 50% of respondents had seen some form of flood information for the river, mostly from the SES or local council. Brochures received in the mail were an especially welcome means of receiving information about preparing for floods, while radio, TV and door-knocking were preferred means for receiving information about current flooding.
- Most respondents' houses were one-storey, with high proportions in Windsor and Richmond raised above ground level.
- Conclusion: '*Simple hazard education is not going to increase levels of preparedness, as levels of knowledge about the hazard are already high. Alternative strategies are required that seek to engage and involve individuals in the process (and help personalise the risk), rather than simply disseminate information'.* There is a need to 1) motivate people to prepare, 2) facilitate the formation of intentions and 3) promote the conversion of intentions to preparedness.

Becker, J., Johnston, D., Ronan, K. & Coomer, M., 2008b. *Flood risk perceptions, education and warning in four communities in the Hawkesbury-Nepean Valley, New South Wales, Australia – data report for a follow-up questionnaire, April 2008*, GNS Science Report 2008/23, Institute of Geological and Nuclear Sciences, Lower Hutt, NZ (prepared for NSW SES).

- In April 2008, 250 follow-up questionnaires were issued via hand-delivery to the *same* households in each of McGraths Hill, Windsor/South Windsor and Richmond/Agnes Banks/Richmond Lowlands/Cornwallis. The response rate was about 10%, and about half the respondents had completed the previous questionnaire. The purpose of this second questionnaire appears to have been to assess the benefits of SES educational activities including Business FloodSafe breakfasts in 2006 and displays at the Hawkesbury Show in 2006, 2007 and 2008.
- There was a noticeable rise in survey respondents from McGraths Hill reporting that they thought flooding was likely to affect their community (54% in 2006 to 90% in 2008).
- There was an increase in survey respondents from Windsor and Richmond reporting that they did not know what elements made up the flood warning system (33% in 2006 to 50% in 2008 for Windsor).
- Self-reported evacuation compliance dropped substantially from 2006 to 2008, with most people now indicating they would stay inside and wait to be told what to do.
- There was a slight increase in people preferring community displays as an information source (16% in 2006 to 28% in 2008) and in people preferring to receive SMS during a flood (19% in 2006 to 33% in 2008).

Bewsher Consulting, February 2000, *Hawkesbury-Nepean Land Use Planning Guidelines: Flood Damage Estimates for Constraints Mapping in the GIS Discussion Paper*, prepared for DLWC.

- Outlines a method for estimating flood damages for a given building type (six categories defined), ground level and flood level region, focussing on the Windsor-Richmond pond region.

Bewsher Consulting, April 2001, *Flood Evacuation and the Implications for Future Land Use*, prepared for DLWC.

- Describes the evacuation problems for the Hawkesbury-Nepean Valley, which are related to: 1) the urban areas being higher than the evacuation routes leading to shrinking islands in a flood; 2) the limited capacity of the evacuation route; and 3) the challenges for flood forecasting (for early and accurate predictions) and emergency response.
- Figure 1 presents key levels relative to the Windsor gauge [note, flood levels superseded].
- Figure 2 shows the regional evacuation routes including low-points, before and after the road upgrade. Features discussion about McGraths Hill, Windsor/South Windsor, Bligh Park/Windsor Downs, Richmond and Pitt Town evacuation issues.
- Table 1 presents an evaluation of the evacuation capability of different communities:

ITEM	POPULATION CENTRE				
	McGRATHS HILL	**WINDSOR AND SOUTH WINDSOR**	**BLIGH PARK AND WINDSOR DOWNS**	**RICHMOND**	**PITT TOWN**
Population 1999 (1)	2,500	6,900	9,200	8,900	700
No. Vehicles 1999 (1)	1,500	3,300	4,700	4,100	500
1. Evacuation Route	Windsor Rd	George St & Northern Rd	Thorley St & Richmond Rd	Londonderry Rd	upgrade current road (see Fig 2)
Road cut at (mAHD):					
– now	12.6m	15.2m	14.1m	18.0m	15.2m
– after completion of road upgrade	13.5m	15.2m	14.1m	18.0m	16.0m
2. Evacuation Route	—	new crossing South Ck	Thorley St & Llandilo Rd	Castlereagh Rd & Agnes Banks	—
Road cut at (mAHD):					
– now		—	17.3m	14.4m	
– after completion of road upgrade		17.3m	17.3m	20.2m	
Ground level of most residential development	16m	16m–20m	18m–20m	up to 20m–25m	15m–20m
Flood level at Windsor Flood Gauge at which evacuation should commence (mAHD)	11m	12m	12m	12m	12m
② Time available to evacuate (2)	1½ hours	8¾ hours	8¾ hours	13 hours	4¾ hours
③ Minimum time required to evacuate (3)	2½ hours	5½ hours	8 hours	7 hours	1 hour
④ Factor of Safety (4)	0.6	1.6	1.1	1.9	4.75
⑤ Extra time needed to evacuate to provide a Factor of Safety of 2 (5)	3½ hours	2¼ hours	7¼ hours	1 hour	no extra time needed
CONCLUSION:	**not able to be completely evacuated**	**not an adequate factor of safety**	**no factor of safety**	**may be just able to evacuate safely**	**likely to be able to evacuate safely**

Notes:

(1) to nearest 100 from Table 3.1 of DLWC (April, 2000)

(2) assumes completion of road upgrade plan and a rate of rise of floodwaters of 0.5m per hour

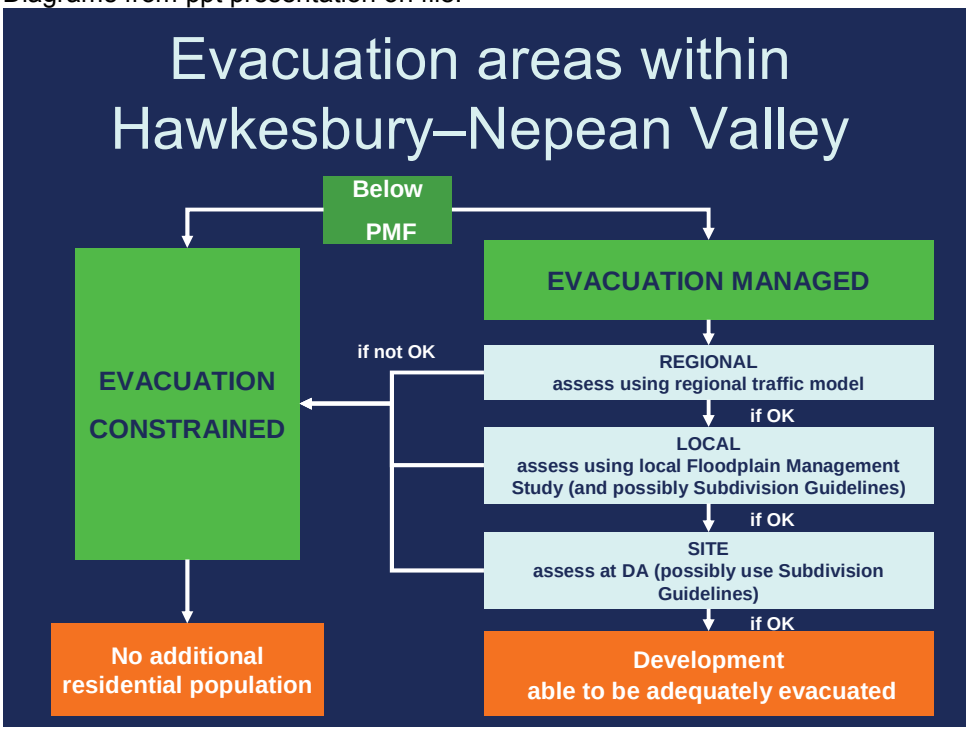
(3) assumes capacity of evacuation road of 600 vehicles per hour

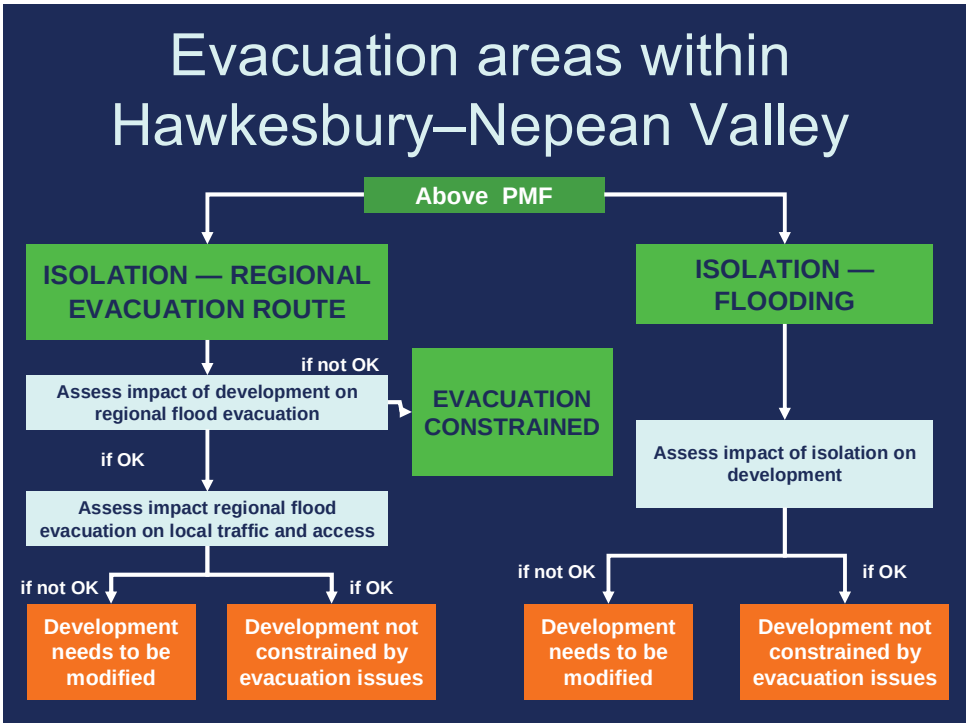
(4) ④ = ② ÷ ③

(5) ⑤ = (③ x 2) – ②

- Figure 4 shows preliminary maps of 'evacuation constrained areas' and 'evacuation investigation areas'. No additional population could be accommodated in the former without compromising the evacuation capability of the existing population. North Bligh Park is identified as being within an evacuation constrained area.

Diagrams from ppt presentation on file:





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Bewsher Consulting, May 2003, *Hawkesbury-Nepean Local Hydraulics Specification Study*, prepared for DSNR.

- Summarises local hydraulics specification studies (for Pitt Town, Wilberforce, Agnes Banks, Llandilo, Cranebrook and Wallacia) conducted for the Hawkesbury-Nepean Floodplain Management Strategy by Bewsher Consulting. The purpose of these studies was to determine the necessary changes to road and associated drainage infrastructure to address local catchment flooding along the nominated regional evacuation routes to ensure that the evacuation plans can be implemented.
- Local flood behaviour was assessed at each low point location for the 5, 10, 20, 50, 100, 200 and 500 year ARI and PMF events. The design flood intended to be conveyed along these evacuation routes was the 500 year event. Where upgrade works involved road raising, their potential adverse impact on upstream levels was assessed by the following criteria: no increase in the 100 year ARI event; minor increases (typically less than 200mm) acceptable in the 500 year event.
- The Wilberforce study concluded that an alternative evacuation route which follows a pronounced ridge line should be used, obviating the need for low point upgrade works.

Bewsher Consulting, September 2004, *Thorley Street (Bligh Park) Flood Evacuation Route: Local Hydraulics Specification Study*, prepared for DIPNR.

- Examines 100 year, 500 year and PMF flood regimes in the vicinity of the Thorley Street flood evacuation route.
- The study was necessary in order to assess the potential impacts of raising the road to the required flood evacuation route level (of RL 18.50).
- Options to upgrade an existing culvert under Thorley Street were modelled and recommendations were made regarding the preferred option.

Bewsher Consulting, December 2007, *Bligh Park Evacuation Route Study*, prepared for HCC.

- Examines at a series of roadway low points within Bligh Park the flooding of which would most likely impact on local area flood evacuations.
- Hydrologic and hydraulic models were developed to assess the 20, 50, 100, 200 and 500 year ARI and PMF event regimes at the low points.
- The analysis found that many of the low points would experience hazardous conditions in the larger design events.
- The study found that some of the worst pockets of flooding occurred in areas where the implications for Bligh Park flood evacuation were very important. It recommended more sophisticated hydraulic modelling be undertaken in those areas.

Bewsher Consulting, August 2008, *Hobartville Evacuation Route Study*, prepared for HCC.

- Examines at a series of roadway low points within Hobartville the flooding of which would most likely impact on local area and regional route flood evacuations (i.e. Castlereagh Road and Londonderry Road).
- Hydrologic and hydraulic models were developed to assess the 20, 50, 100, 200 and 500 year ARI and PMF event regimes at the low points.
- The analysis found that many of the low points would experience hazardous conditions in the larger design events. The conditions were typically less severe on those low points along Castlereagh Road and Londonderry Road.
- The study concluded that if the modelled depth regimes needed to be refined, more sophisticated hydraulic modelling would be required.

Bewsher Consulting, 2010, *Bligh Park Overland Flow Study*, prepared for HCC.

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Bewsher Consulting, 2010, *Hobartville Overland Flow Study*, prepared for HCC.

- *In progress.*

Blong, R., December 2000, *Insurance Industry Perspectives on Flood Losses*, prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee.

- In 2000, the four largest property insurers in the Hawkesbury-Nepean valley were NRMA, GIO/AMP, Allianz and Royal Sun Alliance accounting for 75-80% of the market.
- A 1996 study estimated that 34% of household buildings were underinsured [national averages], 12% of them severely so, and that 52% of household contents were underinsured, 42% of them severely.
- Interviewed insurers displayed limited interest in reducing premiums levels when risk reduction strategies such as house raising and levee construction are undertaken. Also, few insurers would know which policies are for two-storey buildings. The main reason is that it is too difficult because it would require collecting additional information, potentially scaring off a prospective policyholder.
- Most of the interviewed insurers believed that government efforts at mitigation would decrease once flood insurance became widely available, leaving insurers to carry the can for inadequate planning.
- Blong foresaw that more insurers would offer flood cover in the following years though without sufficient information to set realistic flood premiums, redline levels or detailed policy conditions. He suggests that redlining is likely to be a feature of any voluntary scheme – insurers have in mind the 20 year ARI while Blong suggests it might have to be nearer to the 100 year ARI level.

Blong, R., May 2001, *Residential Building Damage*, prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee.

- Uses insurance loss data, especially for the 1998 Katherine flood, and the literature to assess the susceptibility to flooding of various building elements. Built-in furniture and interior lining contribute about 40% to total building damage. Flood losses less for high-set and 2-storey houses than for single-storey dwellings.

Clarke, S. & Tickle, L. (Dept of Actuarial Studies, Macquarie University), May 2001, *Household Financial Flood Risk Investigation*, prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee.

- See summary in Gillespie et al., 2002.
- A flood causing significant damage to local business resulting in disrupted employment would have a more devastating effect on household financial well-being than a flood where damage is restricted to residential properties. This highlights the need for the application of planning principles for commercial/ industrial development as well as residential.
- The ability of a household to withstand the financial consequences of flood damage depends on income levels relative to the size of the mortgage. A single parent household experiences a high level of vulnerability stemming from the low level of disposable income after mortgage repayments and other essential household expenses.
- The value of accumulated savings at the time of a flood impacts on the financial effects of flood damage, especially with an accumulation of time prior to a flood.
- Any household taking out a significant mortgage close to retirement is particularly vulnerable to flood losses.
- Loss of, or severe damage to, the dwelling and its contents may result in families dropping below the poverty line.
- Advocates more appropriate land use and building controls to limit the financial exposure of vulnerable households.

Colmar Brunton Social Research, July 1999, *Implications of Research for Communication Strategy*, prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee.

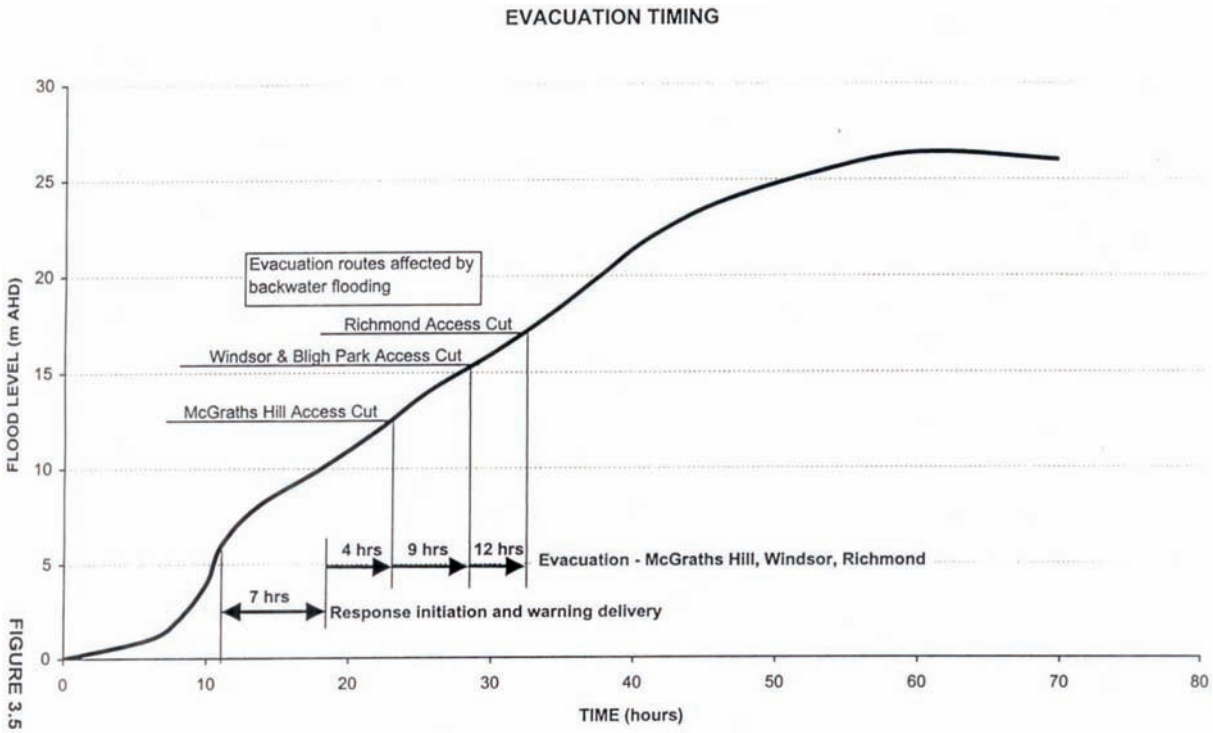
- Includes a baseline survey of community attitudes towards flooding in Windsor and Richmond (Section 4.2).
- Describes research aimed at identifying communication strategies required to encourage residents of flood-prone areas to become prepared for a serious flood.
- Employs a social marketing framework which seeks to influence voluntary behaviour of the target audience.
- Four stages were pursued: 1) review of communications planning, 2) qualitative research involving focus groups and in-depth interviews, 3) quantitative research involving 324 interviews in Richmond and Windsor, 4) development of a communications plan.
- Section 3.1 summarises communications requirements during a flood, including messages, audiences and methods.
- Section 3.2 summarises communications requirements during a flood preparedness program. The “awareness and concern” phase is aimed at conveying the seriousness of the flood threat. The “ways to become prepared” phase consists of constructive, positive messages that give people knowledge of what they can do and a sense of control. The report also provides messages, audiences and methods for this aspect of community education.
- Section 3.3.1 highlights the need for a sustained campaign approach, requiring full-time staff to coordinate the campaign and to staff an information centre and telephone line.
- Section 3.3.2 lists recommended actions including establishment of a flood information centre and flood information hotline telephone number.
- Section 3.3.3 discusses strategic use of the mass media including radio, television, cinema advertising and local print media.
- Section 3.6 lists a budget totalling $700K.

Danielson & Associates, September 1997, *Assessment and Recommendations Concerning Flood Management Options for the Hawkesbury-Nepean Floodplain, New South Wales*.

- Contains Patterson Britton, 1997 and Masson & Wilson, 1997 reports at end.
- See following report (Danielson & Associates, 1997) for main points.

Danielson & Associates, Patterson Britton & Partners and Masson & Wilson Pty Ltd, September 1997, *Emergency Response Planning and Traffic Infrastructure*, prepared for Hawkesbury-Nepean Flood Management Advisory Committee.

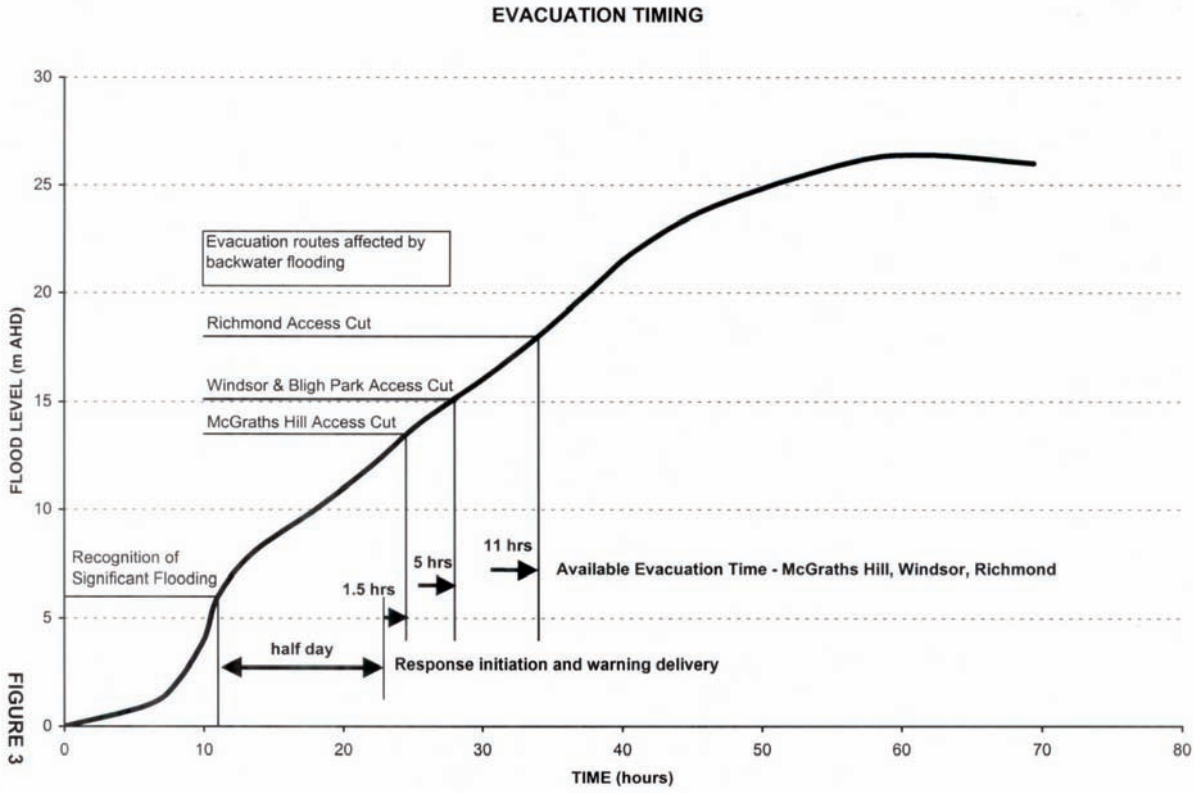
- See summary in *Achieving a Hawkesbury-Nepean Floodplain Management Strategy*.
- Recommends immediate upgrading of evacuation routes ($38.1M).
- Recommends improvements to flood forecasting and access to flood intelligence.
- Recommends consideration of early warning broadcasting system for radio and TV and installation of a warning siren, to complement existing warning system especially door-knocking.
- Recommends evaluation of existing utilities infrastructure emergency plans.
- Recommends comprehensive public awareness program.
- Recommends planning measures to deal with future growth to ensure population increase does not preclude evacuation of existing population.
- Chapter 3 discusses the existing evacuation problem (c.1997) due to mainstream flooding, local flooding, and other influences on the evacuation process such as traffic accidents, fallen trees, collapse of structures including roads and power lines, and panicked behaviour. Uncertainty of forecasts based on predicted rainfall is problematic.



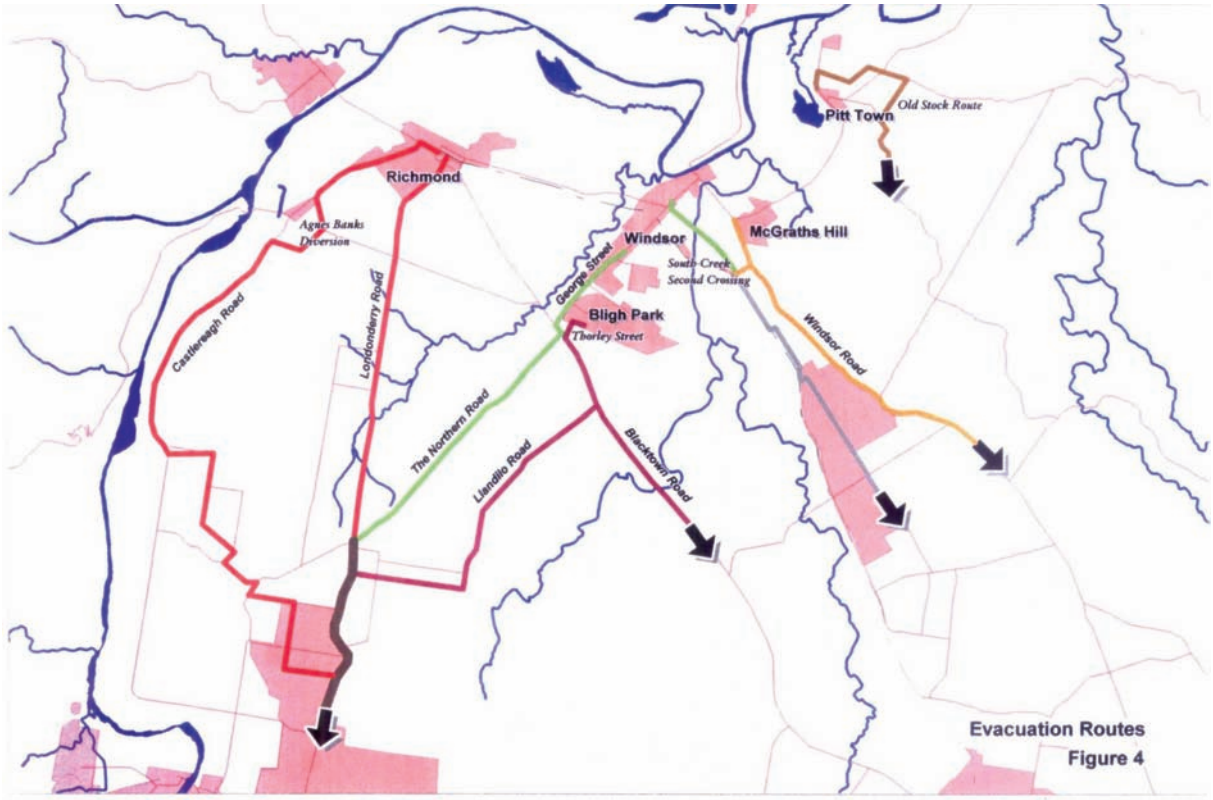
- Appendix B1 details impacts of flooding on evacuation routes. Culverts were inspected and simple hydrologic models (RAFTS) prepared to estimate the duration of road overtopping due to local flooding. Cost estimates prepared for improvements to road and drainage infrastructure to provide protection against 100y local flooding events.
- Appendix B2 provides a detailed commentary on evacuation routes with respect to the sub-sectors listed in the SES Plan, including maps of low-points.
- Appendix C details the current evacuation plan including quantification of the evacuation task, the condition of the existing road system, the determination of evacuation route capacity (note, the report concludes that the assumed 600 vehicles per hour rate is a good planning base), and the availability of time (note, the SES considers that the decision to call an evacuation cannot occur earlier than 7.5m at Windsor). Appendix C3 details required infrastructure improvements. Appendix C4 details population growth potential. Appendix C5 contains a road condition inventory including major intersections.

DLWC, April 2000, *HNFMS Interim Regional Road Upgrade Plan*.

- Documents progress made to 31 March 2000 in the development and implementation of the detailed Regional Road Upgrade Plan to provide an improved road network capable of supporting an emergency flood evacuation.
- Summarises previous and ongoing work including under the HNFMAC (1997), the Route Optimisation Study (PB, 1998), and the Local Hydraulic Specification Studies.
- Reviews evacuation infrastructure parameters including numbers of evacuees and vehicles, existing low points, population growth projections and emergency planning logistics. Updates evacuation timeline from HNFMAC (see Danielson, 1997):



- Describes seven dynamic traffic simulations conducted to determine evacuation route capability. Concludes that with an upgrade of Windsor Road (RL 13.5), a second crossing of South Creek (RL 17.3), two outbound lanes on The Northern Road and traffic management to favour Bligh Park evacuation traffic, there would be sufficient capacity to handle projected urban growth associated with Bligh Park North (1,000 extra vehicles) provided that McGraths Hill was safely evacuated early and that traffic incidents were efficiently managed.
- Summarises the Regional Road Upgrade Plan principles, components, priorities and constraints on future growth.


Pitt Town
Old Stock Route
Richmond
Agnes Banks Diversion
Windsor
McGraths Hill
South Creek Second Crossing
George Street
Bligh Park
Thorley Street
Castlereagh Road
Londonderry Road
Windsor Road
The Northern Road
Llandilo Road
Blacktown Road
Evacuation Routes
Figure 4

Don Fox Planning and Bewsher Consulting, October 1997, *Land use Planning and Development Control Measures*, prepared for HNFMAC.

- See summary in *Achieving a Hawkesbury-Nepean Floodplain Management Strategy*.
- Addresses land use planning and development control measures for future development. It also provides a review of existing floodplain planning within the region and makes recommendations for future changes.
- Reliance on the 100 year ARI flood as a singular FPL has led to a number of problems in the Hawkesbury-Nepean valley: lack of recognition of the significant flood hazard that may exist above the FPL; development within the floodplain which does not recognise the risks to life or the economic costs of flood damage; unnecessary restriction of some land uses from occurring below the FPL, while allowing other inappropriate land uses to occur immediately above the FPL; polarisation of the floodplain into perceived 'flood prone' and 'flood free' areas; creation of a political climate where redefinition of the FPL is fiercely opposed by some parts of the community; creation of a 'hard edge' to development at the FPL. The report recommended discontinuation of reliance on the 100 year FPL.
- Recommends a multi-faceted education program to raise the awareness of the community to flooding issues, including flood warning poles, video, signage of evacuation routes, flood displays, training of key people and special education measures for new business owners, residents and tenants.
- Recommends revision of the regulations for Section 149 certificates to include a flood certificate stating all flood risks up to the PMF, and distribution of the flood certificate to all property owners say every three years with rates notices.

Dovetail Planning Pty Ltd, July 2000, *Regional Public Awareness Program*, prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee.

Chapter 3 Communication Issues

- P.9 The real risk of flood hazard is poorly appreciated by the community.
- P.10 The community expects a safe environment and that decision-makers will adequately inform and prepare them for a foreseeable risk.
- P.10 A long-term sustained communication program is needed to overcome people's natural indifference.
- P.10 Conveying accurate and credible information to the community prior to, during and after a flood is essential.
- P.14 Describes different approaches for different psychographic segments:

Segment	Need	Approach
Knowledge seekers	Control	How to help yourself
Security seekers	Security	How we can help
Helpless trusters	Fun	Immediately enjoyable experience
Confident self-preservers	Power	How you can help others

- P.15 The Regional Public Awareness Program needs to recognise different audiences and target the communications strategically, with the aim of moving people towards independence.
- P.16 The Program needs to promote *changed flood protection behaviour*, not just to inform.
- P.16 The five stages of behavioural change can be used to promote changed behaviours:

Stage	Communication strategy
Pre-contemplation	Raise awareness of flooding through education and provision of information.
Contemplation	Emphasise the benefits of being flood prepared.
Preparation	Increase the use of influential others to persuade the target group that it is personally desirable to change.
Action	Improve an individual's ability to act independently. Make the behaviour easier to undertake.
Confirmation	Reward maintaining change.

- P.19 The Program needs to prepare people both materially and psychologically (to combat fear, anxiety, helplessness).

Chapter 4 Hawkesbury-Nepean Regional Public Awareness Program

- P.21 Describes the objective, approach and nine program elements:
  1) Coordinating public communication in the Hawkesbury-Nepean
  2) Increasing Regional Awareness and Knowledge
  3) Developing Flood Smart Communities
  4) Councils Communicating Flood Risks
  5) Know your local SES
  6) Flood Warning Messages and Delivery
  7) Information Management
  8) Recovery Communication
  9) Production of communication resources
- P.24 The budget was $3.5 million for the five years of the Hawkesbury-Nepean Floodplain Management Strategy to 2003.

Egan National Valuers, July 2000, *Valuation Study: Assessment of the impact of planning controls and public notifications regarding flood risk upon property values*, prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee.

- See summary in Gillespie et al., 2002.
- General lack of understanding and awareness about the nature of flooding in the Hawkesbury-Nepean Valley has lead to a state of confusion and misinformation within the real estate industry and hence within the buying public.
- Robustness of the residential housing market is such that individual property characteristics were stronger determinants of price than flood notification. An actual flood event would have a short term effect on lowering prices, but would be unlikely to have a long term effect as collective memories of disasters fade, are downplayed by vendors and ignored by purchasers who, in a buoyant market, seek to buy regardless of apparent contradictions (summarised from Gillespie et al., 2002).

Executive Summary

- Report seeks to address concerns raised by the community as to possible effects upon property values of existing and proposed planning controls and notifications in areas affected by the Hawkesbury-Nepean Floodplain Management Strategy.
- Examined the impact of notifications through S149 Certificates and found that there is little or no discernable fall in property values as a result of PMF classification. Variations in sales level were noted when a higher level of flood risk was evident such as within some areas of South Windsor which are affected by more frequent flooding such as a 20 year ARI flood.
- The level of accurate knowledge in the community as to the background of a PMF notification was subject to a high level of misinformation. This would indicate that significant education of the community and participants in the property market is required to counter misrepresented views which may lead to increased levels of anxiety in the community.
- Chapter 3 describes the participants within the property market including the vendor, purchaser, selling agent, lending institutions, LGA and the media. Generating fear is far easier to achieve than engendering reassurance.
- Chapter 4 describes the importance of supply and demand in the property cycle. A first home buyer who fears that their ability to ever enter the property market is slipping away will be more likely to be prepared to accept the risk of possible flood damage if the market is moving than if the market is experiencing little growth. Conversely a purchaser in the market during a period of low activity will use flood risk as a stronger negotiating tool than would have been expected in a more buoyant market.
- Chapter 5 describes existing attitudes to flood risk. The authors note that people believe that all land up to the 1:100 chance per year flood level has the same chance of being flooded and that all land between the 1:100 chance per year level and the 1:100,000 chance per year level has an equal chance of being flooded. Many residents also believe that measures such as the construction of Warragamba Dam have alleviated flood risk. Most residents assess flood risk purely in terms of their own property, giving little thought to how a flood occurrence would impact upon other aspects of their lifestyle including their place of employment or damage to public infrastructure.
- Chapter 7 seeks to ascertain whether notification of PMF affectation on the S149(5) Certificate in Blacktown LGA had any adverse effect on preparedness to purchase properties and property values over the years 1999-2000. Found that there was very little variation between comparable properties with or without PMF notification on their S149s.
- Chapter 8 seeks to ascertain whether notification of 100 year flood affectation in Penrith LGA had any adverse effect on property values over the years 1999-2000. Found that there was little variation between comparable properties with or without 100 year notification. Anecdotal understanding of flood risk seems to have played a determining role in the market's reaction (i.e. that little flooding has actually occurred), and an actual flood occurrence through the residential areas of Emu Plains would have a powerful overriding effect on how notification was viewed in the future.
- Chapter 9 assesses the impact of the upwards revision of the 100 year flood level from 16.0m to 17.3m in the Hawkesbury LGA at South Windsor. Found that a maximum differential of 5% can be attributed to flood affectation. "The fact that a large number of properties in the South Windsor region are below the amended flood planning level of 17.3 metres but are still able to attract buyer interest and finance indicates that there are a range of lenders in the market who are willing to accept this style of property as security… This situation could well change if properties were to be

affected by a future flood incident, which was then reported to prospective lenders by professionals such as real estate agents or valuers".

- Chapter 12 states the study conclusions. The study indicates little or no discernable fall in property values as a result of disclosure in regards to PMF affectation. Isolated incidences of variations in property values up to 5% were noted in the Hawkesbury LGA of properties within the 100 year ARI flood area. The level of variation in value increased for properties which are affected by more frequent flooding such as a 20 year ARI flood. The authors expressed the opinion that increased use of a variety of flood awareness material such as advice on rates notices, media releases, flood marker poles, information brochures etc should not have a negative impact upon property values in the long terms for those properties affected by the PMF classification. The authors identified a need to overcome misinformation with an ongoing, multi-pronged education strategy. The authors found that the three strongest influences of flood affectation upon property values were: 1) local anecdotal understanding of flood impact, 2) time period since last flood, 3) level of lending and existing attitude of lenders.

ERM Mitchell McCotter, July 1995, *Proposed Warragamba Flood Mitigation Dam Environmental Impact Statement* (3 vols.), prepared for Sydney Water.

Volume 1

- P.1.5 Considered several strategies for addressing the Hawkesbury-Nepean flood problem and for improving safety at Warragamba Dam. Options considered include property purchase and flood insurance, levees and house raising, channel dredging or straightening, and flood water detention.
- P.1.7 Depleting Lake Burragorang's storage by 15% would require augmentation of Sydney's water supply; the reservoir would have to be almost completely emptied before it would significantly mitigate a repeat of the 1867 flood.
- P.1.7 Decided that the most appropriate flood mitigation strategy would be to gain flood detention air space above Lake Burragorang by raising Warragamba Dam or by building a new, higher dam in its vicinity.
- P.1.11 Favoured a 23m raising of the existing Warragamba Dam wall, which would reduce the 1867 flood level at Windsor to more than one metre below the (then) current FPL (of 16.0m AHD). Estimated to cost $279 million.
- Section 4.2.1 details the procedures used to operate the spillway gates during floods, known as the "H14" procedures.
- Figure 4.4 shows the flood mitigation benefits of Warragamba Dam with respect to the March 1978 flood: peak outflow less than peak inflow, peak outflow later than peak inflow, outflow longer than inflow.
- Table 5.1 lists historical floods above 10m AHD at Windsor. It notes that the November 1961 and March 1978 levels were lower because Warragamba Dam was depleted at the onset of the floods.
- Section 5.2.2 describes the 1867 flood, and Section 5.2.3 describes prehistoric floods which left slackwater deposits.
- Section 5.4.2 estimates that if the 1867 flood was to recur today, more than 7,700 homes would be flooded and $1,850 million of damages would be incurred.
- Section 6.2.1 considers the potential for property purchase. Cons: large socio-economic impacts; very expensive.
- Section 6.2.2 considers flood insurance. Cons: premiums could be too high; does not alleviate social or environmental impacts.
- Section 6.3.1 considers a levee scheme to the level of the 1867 flood. Cons: high visual impact due to height of levees; expense including land acquisition, roadworks and pumping stations/outlet works; requirement to demolish homes; redistribution of floodwaters so as to increase levels in unprotected areas; increased catastrophe potential.
- Section 6.3.2 considers house raising. Cons: impractical for many; increased catastrophe potential; offers no benefits for commercial/industrial.
- Section 6.4.1 considers dredging the Hawkesbury River between Sackville and Wisemans Ferry so as to increase its depth by 10 metres (= 20-30 million cubic metres of material). Would reduce the 1867 flood at Windsor by 2.3m. Cons: cost ($350 million +); disposing material; significant environmental damage including bank erosion upstream and permanent loss of ecosystem.
- Section 6.4.2 considers straightening the lower Hawkesbury between Sackville and Wisemans Ferry. Cons: extremely impractical given excavation through sandstone plateau required.
- Section 6.5.1/2 considers flood detention strategies including dams upstream of Warragamba Dam and dams on the Nepean, Grose or Colo Rivers. Cons: significant cost and environmental impacts.
- Table 6.3 summarises the evaluated strategies according to effectiveness in reducing flood damages, practicality, environmental impacts and cost.
- Section 8.19 provides a history of the influence of flooding on land use planning in the Hawkesbury-Nepean valley. The (then) Hawkesbury LEP proscribed new buildings on land below the 10 year flood level and required the floor level of any habitable room in a new building to be at or above the 100 year level. A level of 16.0m AHD was adopted as the 100 year planning level at Windsor, and 15.9m AHD at Richmond.

Volume 2

- Chapter 10 describes flood modelling undertaken for the study. Section 10.2 describes flood characteristics including a flood scenario.

Table 10.3: Probability and levels of floods at Windsor

Flood	Observed level (m AHD)	ARI of observed flood
1867		~280 year
1961 Nov	15.0	35 year
1964 Jun	14.6	29 year
1969 Nov	10.2	<5 year
1974 May	10.4	<5 year
1975 Jun	11.2	5 year
1978 Mar	14.5	28 year
1986 Aug	11.4	6 year
1988 May	12.8	13 year
1988 Jul	10.9	<5 year
1990 Aug	13.5	18 year

- Table 10.7 shows changes in 100 year planning levels as a result of revised modelling in 1994.
- Section 10.4.6 considers the accuracy of the flood modelling results. Based on sensitivity testing, the flood levels are expected to be accurate to +/- 0.5m.
- Section 10.4.7 considers real floods in relation to design floods. The 1867 flood is estimated to be a 170 year flood at Penrith, a 280 year flood at Windsor and a 15 year event at Camden. This suggests that more rain fell in the Warragamba catchment than in the Upper Nepean catchment, and that heavy rain fell in the Grose catchment.
- Table 10.8 shows the impact of Warragamba Dam on design flood levels at North Richmond and Windsor, *assuming Lake Burragorang is full at the beginning of the flood*.

Design Flood	Flood level (m AHD)			
	North Richmond		Windsor	
	Existing	Pre-dam	Existing	Pre-dam
20	15.1	15.4	13.7	13.6
50	16.4	16.3	15.7	16.1
100	17.5	17.7	17.3	17.4
200	18.9	19.3	18.7	19.1
500	20.4	21.0	20.2	20.9
1000	21.5	22.3	21.3	22.1

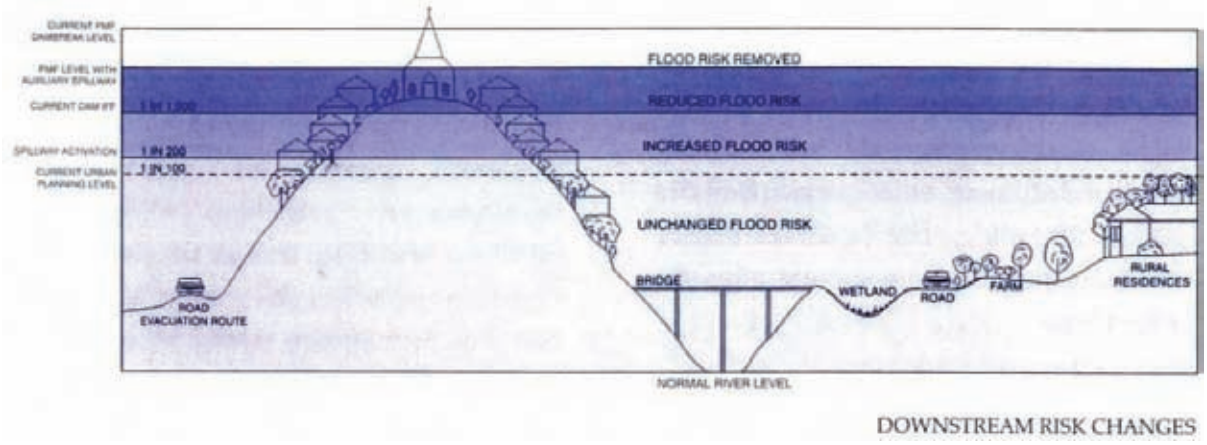
- Table 10.10 shows average overbank velocities for design floods for the Richmond Lowlands, The Breakaway, Pitt Town and Backwaters.
- Table 10.11 shows the durations that Yarramundi, Richmond and Windsor Bridges would be overtopped during design floods.
- Chapter 11 describes the flood damages assessment undertaken for the study. Table 11.1 reports the number of surveyed properties for each locality including "location, height and building type", dating from February 1988 and updated in 1992. In addition to consideration of residential and commercial/industrial damages, the study accounted for damage to caravan parks, extractive industry (Agnes Banks), motor vehicles, agriculture, utilities and public infrastructure (roads and bridges, rail, electricity, communications, oil and gas, water supply and sewerage), defence (RAAF Base), erosion and sedimentation, plus intangible impacts. The 1867 flood would flood 7,780 houses in the Hawkesbury-Nepean Valley if it occurred in 1991, with 2,160 suffering severe structural damage; 1,654 commercial and industrial buildings would be flooded; direct damages in the valley would be about $670 million and indirect damages would be about $586 million. Damages increase sharply between the 50 year and 100 year event because pre-1994 planning levels were lower. The RAAF base experiences significant damage at the 200 and 500 year levels.

ERM Mitchell McCotter, November 1996, *Proposed Warragamba Dam Auxiliary Spillway EIS* (4 vols.), prepared for Sydney Water.

Volume 1 Summary

- In eliminating the effects of dambreak flooding, the auxiliary spillway was assessed to provide benefits of avoiding $4.5 billion worth of possible damage, affecting up to 20,700 fewer people and obviating the need to evacuate up to 5,000 people.

- No changes would occur to flows more frequent than the 200 year ARI flood, which would pass through the existing gated spillway; there would be an increased risk of flooding for events between the 200 and 1,500 year ARI flood, whilst areas currently affected by flows less frequent than the 1,500 year ARI flood would have a reduced risk.



DOWNSTREAM RISK CHANGES

Volume 2 Chapters 1 - 7

- Section 2.5.3 describes a scenario of consequences downstream in the event of a dambreak flood.
- Section 4.20 summarises the hydraulic modelling used to estimate upstream and downstream impacts of the auxiliary spillway. Note that the auxiliary spillway increases flood levels at Windsor for the 500, 1000 and 1500 year events but decreases the dambreak levels.

Change of occurrence	Windsor		
	Existing Dam	1 in 200 Spillway	1 in 500 Spillway
5	11.1	11.1	11.1
10	12.3	12.3	12.3
20	13.7	13.7	13.7
50	15.6	15.6	15.6
100	17.2	17.2	17.2
200	18.6	18.7	18.6
500	20.1	20.6	20.3
1000	21.2	21.9	21.7
1500 (without dam break)	21.8	22.2	22.1
1500 (with dam break)	26.1		
100,000 (PMF) (with dam break)	28.9	26.3	26.4

- Section 4.23.1 details the consequences of a dambreak flood for residential properties, agricultural land, commercial/industrial properties, infrastructure, defence facilities, heritage items, health and life.
- Section 4.24 details the direct and indirect damages of a dambreak flood.

Volume 3 Chapters 8 - 12

- Section 9.2.1 details the procedures used to operate the spillway gates during floods, known as the “H14” procedures.
- Figure 9.4 shows the flood mitigation benefits of Warragamba Dam with respect to the March 1978 flood: peak outflow less than peak inflow, peak outflow later than peak inflow, outflow longer than inflow.

Volume 4 Appendices

- Appendix K discusses extreme flood probabilities.

Erskine, W., 1999, 'Channel morphology'. In Martens & Associates Pty Ltd, *Geomorphology of the Hawkesbury-Nepean River System: A Review of Landforms, Processes and Management*, prepared for HN Catchment Management Trust, pp.26-48.

- P.41 Defines the 'Windsor estuarine reach' as a 25 km long reach from the Grose River junction to Wilberforce, characterised as a slightly sinuous channel flanked by a broad floodplain often possessing a high natural levee.
- P.43 Given the very high flood variability, non-equilibrium rivers that are only stable for short periods of time must be expected. Further, extensive erosion should be expected during FDRs and deposition during DDRs. The creation of a stable channel will rarely be achievable.

GHD and Cox Consulting, August 2001, *Analysis of Community Attitudes to Flood Related Risks* (2 vols.), prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee.

- See summary in Gillespie et al., 2002.
- The study was designed to provide information about: 1) attitudes of current and future communities of the Hawkesbury-Nepean Valley regarding natural hazards; 2) what kind of level of personal losses are acceptable or unacceptable to them; and 3) how much and under what conditions they are willing to pay for measures aimed at reducing the risk and impact of such losses.
- Community supports more effective controls on development in high hazard areas.
- Community expects that a high level of protection by authorities already exists.
- Majority of households believe they have a limited ability to finance flood losses.
- The majority of households stated they would be willing to pay up to 10% more for a house if it was built to a standard that offered protection from flood damages (note: first homebuyers willing to pay only an additional 5%; very few first homebuyers would reject buying in a hazard-prone area).
- Most respondents believed they could afford less than $10,000 to rectify damages from a natural hazard from their own resources.
- Around three-quarters of all households stated that they would take out full house and contents insurance against flood if this was available. However, a very high proportion of respondents did not know how much additional building or home contents premiums they would be willing to pay. Of those hazarding an estimate, over 50% of respondents were willing to pay less than $200 for building flood insurance premiums, and over 50% of respondents were willing to pay less than $200 for contents flood insurance premiums. The authors conclude that “most households in all cohorts are willing to pay relatively significant proportional increases in their existing house and contents premiums for increased peace of mind”.
- P.7 “Under the building codes and development plans now applying in the valley, people who can least afford the consequences are carrying financial risks about which they are not adequately informed. There are grounds to expect that if Councils and other authorities introduce the controls that appear to be required in order to discharge their duty of care, the community will be prepared to accept them and [the] reasonable financial consequences that may flow”.

Gillespie, C., Grech, P. & Bewsher, D., 2002, 'Reconciling development with flood risks: the Hawkesbury-Nepean dilemma', *Australian Journal of Emergency Management*, 17(2), 27-32.

- Briefly describes Hawkesbury-Nepean flood risks including large flood height range from 100 year to PMF, urban growth, isolation caused by early loss of evacuation routes and lack of flood awareness.
- Describes the Hawkesbury-Nepean Floodplain Management Strategy, to the implementation of which the NSW Government committed $58.4 million over five years from 1998.
- Reviews the GHD and Cox Consulting report on community attitudes to flood risk, the Clarke and Tickle report on household financial flood risk and the Egan's National Valuers study on the effect of flood notification on property values.
- Argues for incorporation into land use planning of flood risk management for events higher than the 100 year level, since in the Hawkesbury-Nepean Valley there are areas where there is a one storey difference in height between the FPL and the 250 year event and four storeys to the PMF.

HCC (Hawkesbury City Council), 2009, *Hawkesbury… A Social Atlas 2009: Information from the ABS 2006 Census of Population and Housing*.

- Describes population in 2006: 60,561 in the LGA, including 6,494 in Bligh Park, 2,534 in Hobartville, 2,470 in McGraths Hill, 4,398 in North Richmond, 1,308 in Pitt Town, 4,428 in Richmond, 5,629 in South Windsor and 1,899 in Windsor.
- Describes population change in the LGA from 1996 to 2006 (5.5% growth).
- Describes population projections from 2006 to 2031 (now about 73,000 by 2031), influenced by a slowing growth rate due to an aging population, slowing birth rate and out-migration.

Hawkesbury-Nepean Flood Management Advisory Committee, November 1997, *Achieving a Hawkesbury-Nepean Floodplain Management Strategy*.

- Chapter 2 summarises the planning policy context.
- Chapter 3 summarises the flood management implications of Warragamba Dam. In 1993 the State Government proposed raising the Dam by 23 metres to address both dam safety and the potential for flood mitigation storage. In 1995 the State Government decided not to proceed with this scheme. Sydney Water was in 1997 planning to construct an auxiliary spillway to allow the Dam to safely pass the full PMF, without failure of the Dam itself. A study on the operation of Warragamba Dam's spillway gates found that whilst alternative gate operating procedures could be beneficial in reducing downstream flood levels, it would also result in higher water levels upstream of the Dam, increase the duration of flooding downstream and reduce warning times due to the early release of stored water.
- Chapter 4 summarises the distinctive flood behaviour in the Hawkesbury-Nepean Valley, including description of the 1867 flood and the effects of such a flood in 1997. Flood levels on the floodplain typically rise at a rate of 0.5m/hour for several hours. Based on the 1997 road network, much of the flood-prone population would be unable to be evacuated to safety. The unfamiliarity of the population with severe flooding is also problematic.
- Chapter 5.1 summarises Molino Stewart's investigation of the impacts of flooding on communities and infrastructure. Found that the impacts and damages above the FPL become extremely high because of flood depth and the fact that few measures have been taken to minimise impacts for the rarer events. Decisions have been based mainly on probabilities with minimal consideration of consequences. In extreme floods, the Richmond RAAF Base's damages would be substantial. Describes impacts of flooding of various levels on electricity, telecommunications, gas and sewerage. Outlines opportunities for reducing consequences for infrastructure.
- Chapter 5.2 summarises Webb McKeown's investigation of engineering studies to modify flood behaviour. Major flood mitigation dams were considered inappropriate due to high economic and environmental costs. A bypass channel linking the Hawkesbury River near Wilberforce to Currency Creek would lower levels upstream but increase levels downstream and would require significant excavation and bank protection works with associated environmental and social impacts. Flood warning and voluntary purchase of high risk properties was viewed favourably. Local options for Windsor/Richmond which were considered to have some merit included: 1) a series of levees at McGraths Hill, Riverstone, Windsor, Bligh Park, Mulgrave, Pitt Town and Wilberforce to provide protection up to the 1 in 50 year flood level; 2) raising of various roads to provide high level evacuation routes; and 3) a refuge mound at McGraths Hill.
- Chapter 5.3 summarises Don Fox Planning and Bewsher Consulting's investigation of land use and development control measures. Concluded that a matrix of development controls, based on the flood hazard and the land use, can balance the risk exposure across the floodplain, as well as substantially reduce economic losses. Recommended the promotion of comprehensive floodplain management plans and the use of flood policies by Councils, rather than continuing to rely upon a singular FPL such as that commonly related to the 1:100 chance per year flood. Considered demographic changes and highlighted the financial stress young families moving into the area would experience if flooded. Recommended a flood awareness program coordinated at a regional level, an informed and regionally consistent S149 Certificate, and the regular issuance (every three years) of flood certificates to all property owners and residents in the floodplain.
- Chapter 5.4 summarises Danielson & Associates' investigation of emergency response planning and traffic infrastructure. Recommended improvements to flood forecasting including better data and links with Sydney Water and state-of-the-art radar. Recommended improvements to flood warning including development of an emergency warning broadcast system for radio and television and installation of a warning siren network that supplements the current reliance on door-knocking teams. Concluded that local flooding of the current road network was likely to completely frustrate the existing evacuation plan. Concluded that if no action is taken to upgrade the existing evacuation routes, the majority of the flood-prone population (some 60,000) will be isolated with potential for loss of life if severe flooding (rarer than 250 year ARI) occurs. Even if the threat of local flooding is mitigated by appropriate works, 15,000 people can be expected to remain unevacuated if severe flooding occurs. Proposed a program of road improvements to offer immunity on regional evacuation routes up to the 200 year ARI flood, with a preliminary cost estimate of $46 million.
- Chapter 6 summarises the Hawkesbury-Nepean Floodplain Management Strategy including improvements to flood evacuation and public awareness, protection of existing infrastructure,

development of appropriate planning policies and guidelines, reviewing SES flood plans, enhancing flood forecasting and warning, and planning for recovery.

- Chapter 7 lists recommendations for implementing the Strategy (see below):
  IMMEDIATE PRIORITY
  - Evacuation Routes: Implement the essential program of road improvements to the existing road system
  - Complete Strategy components and Regional Floodplain Management Study
  HIGH PRIORITY
  - Flood Emergency Planning: Provide necessary resources for SES to urgently review/rewrite Hawkesbury-Nepean Flood Emergency Plans and conduct annual exercises and updates…
  - Flood Forecasting: Establish direct computer link between BoM and SW; install redundancy or backup for field gauge communications; expand the gauge network of rainfall and river gauges; encourage BoM to establish continuous interface between meteorologists and river modellers; establish fully operational weather radar acquisition system
  - Flood Warning: Promote preparation or amendment of Federal legislation to establish public broadcast emergency warning system utilising both radio and television; install flood warning sirens for the main towns that have the potential to become isolated; verify feasibility/effectiveness of doorknock method of flood warning including mobilisation of necessary resources
  - Public Awareness: Prepare and implement specifically tailored regional public awareness program; develop public education at local level…; implement evacuation route signage and traffic control markers including marking of flood levels on poles; develop procedures to ensure evacuees register with evacuation centres; increase flood awareness through the provision of flood policy notations on S149 Certificates
  - Regional Floodplain Management: Establish best practice floodplain management methodology for the Hawkesbury-Nepean Valley, including guidelines for graduated planning controls across the full range of flood risk…; preparation of best practice building guidelines; preparation of best practice subdivision guidelines; establishment of additional SES centres
  LOWER PRIORITY
  - Flood Evacuation Infrastructure (Roads): Implement detailed road plans to ensure that presently zoned, undeveloped areas will have sufficient evacuation road capability as they are developed…
  - Post-flood Recovery: Review post-flood recovery for evacuees in the light of current understanding of the magnitude of human trauma occasioned by major flooding; initiate State Government directive to relevant State utility service providers and agencies including Integral Energy, State Water, State Rail, RTA, Hospitals, to prepare flood recovery plans for their assets and infrastructure; encourage relevant private utilities including nursing homes, Telstra, Optus, Vodafone, AGL to prepare flood recovery plans for their assets and infrastructure
  - Local Planning: Promote the preparation of local floodplain management plans by Councils incorporating application of graduated development controls, preparation of LEPs, DCPs and LAPs consistent with regional methodology, inclusion of flood policies on S149 Certificates and investigation of local flood behaviour works such as levees and/or diversion channels and flood detention
- Four consultants' reports are included as Appendices.

Hawkesbury-Nepean Flood Management Advisory Committee, July 1998, *Supplementary Report: Responses to the Public Exhibition of the Committee's November 1997 Report "Achieving a Hawkesbury-Nepean Floodplain Management Strategy"*.

- Reports on submissions arising from the 10 week public exhibition of the report from April-June 1998.
- 41 submissions were received, the majority expressing support for implementation of the Hawkesbury-Nepean Floodplain Management Strategy.
- Flood modification works… Submissions called for raising of Warragamba Dam and more serious consideration of the beneficial effects of a large number of structural works. The summary noted that the flood mitigation benefits of raising the dam wall were outside the Committee's brief, and that the Webb McKeown study *Engineering Studies to Modify Flood Behaviour* examined many flood modification works but rejected most due to their very high economic and environmental costs. The summary identifies that a diversion channel may be worth more detailed evaluation by councils as part of preparation of local FRMPs.

- Evacuation strategy… Submissions suggested improvements to the evacuation strategy. A supplementary recommendation was formulated: *All evacuation route suggestions should be referred to the SES for consideration during reviews of existing and proposed Flood Plans*. The summary confirms that full implementation of the proposed Evacuation Route Upgrading Program would provide adequate evacuation capacity (within the time available) for all residents in existing areas to be safely evacuated.
- Flood emergency planning… Submissions called for a more cost-effective network in addition to flood warning sirens. A supplementary recommendation was formulated: *that the funding provision for flood warning sirens in Section 7.2.3 - Flood Warning of the Committee's Report, be applied to the installation of a cost effective flood warning network comprising a combination of sirens and other appropriate technology*.
- Public awareness… Submissions described an ambivalence about the use of S149 Certificates to promote public awareness and the lack of measures to reduce the impact of flooding on businesses.
- Land use planning… Many submissions on this theme including 1) idea of owners choosing to develop on floodplain indemnifying council against any damage, 2) rezoning urban areas below the FPL back to rural land, with appropriate compensation, 3) prepare a specific SREP for the Hawkesbury-Nepean valley, 4) review the Employment Lands Development Program strategy. A supplementary recommendation was formulated: *that all of the issues and responses relating to this section be drawn to the attention of the action agency responsible for completing the RFMS*.
- Post-flood recovery… A supplementary recommendation was formulated: *that post-flood recovery planning become a "High Priority" Strategy component, funded by the approved Strategy Budget, rather than by the present resources of post-flood recovery agencies, as previously recommended in Section 7.3.3 (p69) of the Report*.
- Infrastructure… Submission critical of the idea in the Molino Stewart report that consideration be given to relocating the RAAF base because this would have significant socio-economic impacts on the region. The summary notes that this advice did not carry over to a recommendation of the Committee.
- Evacuation centres… Submission concerned about lack of information regarding information centres. The summary notes that a review of the location and adequacy of evacuation centres will be undertaken by DOCS as part of the investigation now recommended to be funded by the Strategy.
- Other submissions addressed the use of flood terminology, insurance and Government subsidies, future coordination, and agricultural land and agricultural industries (including the need for the availability of higher ground for flood relief for farmers and livestock including capacity to feed stranded or evacuated stock).

Hawkesbury-Nepean Valley Flood Awareness Committee, January 1994, *Hawkesbury-Nepean Valley Flood Level Information*.

- Design flood levels following the completion of the interim 5m raising of Warragamba Dam in 1989:

Flood event	North Richmond Flood Level (at North Richmond Bridge) (m AHD)	Windsor Flood Level (at Windsor Bridge) (m AHD)
5 year	12.5	11.1
10 year	14.0	12.3
20 year	15.1	13.7
50 year	16.4	15.7
100 year	17.5	17.3
200 year	18.9	18.7
500 year	20.4	20.2
1000 year	21.5	21.3
PMF	29.0	28.9
Current Planning Level	17.2	16.0

a. Based on current gate operating rules (H14) and assuming storage level at full supply at the beginning of the flood.
b. For the PMF, the dam is assumed to have failed prior to the peak of the flood. Options under consideration will enable Warragamba Dam to safely handle a full PMF and lessen the impact of flooding downstream.

- Major historic floods at Windsor (> 10m AHD):

Flood	Observed level (m AHD)	Adjusted level (post-dam) (m AHD)	Adjusted level (pre-dam) (m AHD)	ARI for observed level
1799 Mar	10.5			
1806 Mar	12.9			
1809 Aug	14.7			
1816 Jun	14.1			
1817 Feb	14.4			
1819 Mar	12.9			
1857 Aug	11.9			
1860 Apr	11.8			
1860 Jul	11.1			
1860 Nov	11.4			
1864 Jun	15.1			
1864 Jul	11.4			
1867 Jun	19.7	19.3		
1869 May	11.6			
1870 Apr	14.1			
1871 May	11.7			
1873 Feb	13.1			
1875 Jun	12.3			
1879 Sep	13.6			
1889 May	12.2			
1890 Mar	12.3			
1891 Jun	11.2			
1900 Jul	14.5			
1904 Jul	12.7			
1916 Oct	11.0			
1925 Jun	11.5			
1943 May	10.3			
1949 Jun	12.1			
1952 Jul	11.8			
1956 Feb	13.8			
Warragamba Dam completed 1960				
1961 Nov	15.0		15.8	35 year
1964 Jun	14.6		14.8	30 year
1975 Jun	11.2		12.3	5 year
1978 Mar	14.5		15.2	30 year
1986 Aug	11.4		12.9	5 year
1988 May	12.8		13.1	10 year

Flood	Observed level (m AHD)	Adjusted level (post-dam) (m AHD)	Adjusted level (pre-dam) (m AHD)	ARI for observed level
1988 Jul	10.9		10.9	<5 year
1990 Aug	13.5		13.7	20 year

- Stage 1 works to reduce the high level of flood risk to Warragamba Dam were completed in 1989 at a cost of $29 million, and involved raising and strengthening the Dam wall by 5 metres.

Hawkesbury-Nepean Floodplain Management Strategy, June 2003, *Flood Hazard Definition Tool: Hawkesbury-Nepean River Specific Information Manual (Draft)*.

- Summarises the Hawkesbury-Nepean flood problem and the Hawkesbury-Nepean Floodplain Management Strategy.
- Describes the purpose of the Hawkesbury-Nepean Flood Hazard Definition Tool (FHDT), being the provision of a common set of flood data which all local councils can use.
- Describes the limitations of the Hawkesbury-Nepean FHDT, including: 1) the underlying accuracy of the DTM which especially influences flood extents, depths, velocities and hazards; 2) underestimated flood levels in the upper reaches of some tributaries; and 3) interpolation between nodes utilised in the WaterRIDE™ software.
- The FHDT includes datasets for a DTM and the 100, 200, 500 and 1000 year ARI events and the PMF (flood hydrograph results and peak flood results).
- For the Hawkesbury study area, the main studies used for the FHDT are the *Warragamba Dam Auxiliary Spillway EIS Flood Study* (WMA, October 1996) and the *Lower Hawkesbury River Flood Study* (AWACS, April 1997). Note that the results of the WMA RUBICON model were transferred to RMA-2 format since WaterRIDE™ is more compatible with the output from RMA-2. Details of these flood studies are outlined in an Appendix.

HNFMSC (Hawkesbury-Nepean Floodplain Management Steering Committee), October 2004, *Hawkesbury-Nepean Floodplain Management Strategy Implementation: Reporting the achievements of the Hawkesbury-Nepean Floodplain Management Steering Committee (1998-2004).*

- Summarises the Hawkesbury-Nepean flood problem.
- Details the upgraded Hawkesbury-Nepean evacuation routes, offering protection against 1 in 500 year local flooding [not clear whether this standard applies to all routes]. Makes clear that road upgrades were designed to provide evacuation for existing communities and that "any future development would need to incorporate additional upgrading of the evacuation route infrastructure" (p.6). Acknowledges that in lower risk areas on the edge of the floodplain such as Wilberforce, Pitt Town and Riverstone the evacuation strategy will not be compromised by further growth. Local FRMSs should ensure local councils include local evacuation infrastructure strategies as part of FRMPs for Windsor, Bligh Park, Windsor Downs, McGraths Hill, Pitt Town, Wilberforce, Richmond and North Richmond.
- Summarises improvements to flood forecasting and warning.
- Summarises improvements to flood emergency response including revised flood plans, communications upgrades, flood intelligence enhancements and evacuation time line analysis.
- Community lacks awareness and preparedness for responding to flooding: up to 70% of the 60,000 residents on the Hawkesbury-Nepean floodplain were unaware that they lived in an area affected by floods and could one day need to evacuate. Summarises the Regional Public Awareness Program including launch of the Hawkesbury-Nepean FloodSafe web-site in June 2002, distribution of material to 35,000 homes, development of the Business FloodSafe program, community meetings and installation of flood evacuation route signs. Councils were assisted by providing workshops on the Flood Hazard Definition Tool and advice re s.149 certificates.
- Summarises outcomes to enhance recovery from floods, including assisting utility providers to adopt a risk management approach and assisting community services to plan for flood recovery.
- Describes the Regional Floodplain Management Study.
- Describes the Flood Hazard Definition Tool (FHDT) which utilises the WaterRide software developed by Patterson Britton and Partners.
- Describes the problems of the previous approach relying on a single flood planning level and which view flooding as a constraint rather than a risk which was able to be adjusted and managed. Describes the development of the Land Use Planning Guidelines, and summarises some opportunities to increase property protection through land use controls.
- Describes the development of the Subdivision Guidelines, and summarises some opportunities to promote risk management e.g. allowing for progressive vehicular evacuation to high ground, careful design of detention basins.
- Describes the development of the Building Guidelines, and summarises some opportunities for limiting structural damage due to flooding e.g. flood resistant materials.
- Includes project expenditure summary.

HNFMSC (Hawkesbury-Nepean Floodplain Management Steering Committee), June 2006, *Designing Safer Subdivisions: Guidance in Subdivision Design in Flood Prone Areas*, HNFMSC, Parramatta.

- "Designing Safer Subdivision – Guidance on Subdivision Design in Flood prone Areas" provides practical guidance to assist in the planning and designing of safer residential subdivisions on flood prone land. Referred to here as the Subdivision Guidelines, the document aims to provide practical means to reduce the risk to life and property for new subdivisions. Although specifically written for development in the Hawkesbury-Nepean valley, it is generally applicable to all flood prone land. The Subdivision Guidelines offer increased safety for residents through the promotion of efficient design solutions, which are responsive to the varying range of flood risk. The guidelines include cost-effective and environmentally sustainable solutions to minimise future flood impacts on buildings and associated infrastructure.
- The Subdivision Guidelines contain detailed information regarding site preparation, road layout and drainage information relevant to professionals engaged in the planning, surveying, development and assessment of residential subdivisions on flood prone land.

HNFMSC (Hawkesbury-Nepean Floodplain Management Steering Committee), June 2006, *Managing Flood Risk through Planning Opportunities: Guidance on Land Use Planning in Flood Prone Areas*, HNFMSC, Parramatta.

- The guidance contained in "Managing Flood Risk Through Planning Opportunities – Guidance on Land Use Planning in Flood Prone Areas" (referred to here as the Land Use Guidelines) aims to provide local councils, government agencies and professional planners with a regionally consistent approach to developing local policies, plans and development controls which address the hazards associated with the full range of flood events up to the probable maximum flood (PMF). In accordance with good risk management practice these guidelines give weight to finding solutions for the more frequent flooding problems.
- Guidance is provided on the development of flood prone land for a range of common land uses. A methodology to rate risk and define risk bands is included to assist councils in their flood risk analysis. For residential development, it proposes a series of risk bands as a tool to better manage the flood risk for the full range of floods. It is specifically aimed at all professionals involved in strategic, regional and local planning including development control.

HNFMSC (Hawkesbury-Nepean Floodplain Management Steering Committee), June 2006, *Reducing Vulnerability of Buildings to Flood Damage: Guidelines on Building in Flood Prone Areas*, HNFMSC, Parramatta.

- Modern housing construction results in houses that are ill equipped to withstand inundation or fast flowing water. Given the lack of availability of comprehensive domestic flood insurance, most homeowners of flood prone property are potentially very vulnerable to major losses. "Reducing Vulnerability of Buildings to Flood Damage – Guidance on Building in Flood Prone Areas", referred to here as the Building Guidelines, provides specific and detailed information on house construction methods, materials, building style and design. This approach can reduce structural damage due to inundation or higher velocities and facilitate the clean up after a flood, thus reducing the costs and shortening the recovery period.
- The Building Guidelines include information on how flooding affects the structural components of a house. The document:
  - highlights potential problems for houses subjected to flood water;
  - discusses the benefits and disbenefits of choosing various materials and construction methods and discusses methods to solve those problems;
  - provides indicative costs of adopting those solutions; and
  - advises of the appropriate post-flood actions to repair or reinstate the damaged components.

Martens & Associates Pty Ltd, 1999, *Geomorphology of the Hawkesbury-Nepean River System: A Review of Landforms, Processes and Management*, prepared for HN Catchment Management Trust.

- See entries under “Erskine” and “Warner”

Masson & Wilson Pty Ltd, August 1997, *Roads and Traffic Infrastructure Investigation*, prepared for the Hawkesbury-Nepean Flood Management Advisory Committee.

- See also Danielson, 1997 and Patterson Britton, 1997.
- Examines the dynamics of the evacuation process in particular the ability of the road and transport system to efficiently move people from the floodplain should forecast flood levels require evacuation of the area.
- Finds that local flooding could leave the main population centres without an evacuation route at any time from when SES calls evacuation to when the roads become inundated by mainstream flooding.
- Finds that even if the local flooding issues are resolved, the evacuation routes lack the capacity the allow full evacuation of the major population centres in the time available from when the call to evacuate is made. Estimated that 15,000 people could be isolated in Richmond, Windsor and McGraths Hill in a major flood.
- Finds that a number of the SES designated evacuation routes are unsuitable for evacuation in their current physical state ie poor linemarking, no guideposts, narrow road shoulders, standard geometry etc.
- Recommends three phases of infrastructure improvements, first to allow evacuation to high ground only, second to provide minimum evacuation routes for the current population, and third to provide alternative evacuation routes beyond the minimum level in the event that such routes become blocked due to traffic accident, fallen tree, fallen power lines etc. Phase 3 works would be required to accommodate population growth.

Molino, S., Begg, S., Stewart, L. & Opper, S., March 2002, 'Bells and whistles, belts and braces: designing an integrated flood warning system for the Hawkesbury-Nepean Valley. Part 1: bells and whistles–available technologies', *Australian Journal of Emergency Management*, 17(1), 55-59.

- Describes various alerting and notification technologies.
- Traditional lower technology options such as door knocking and public media broadcasts are extremely valuable.
- No single technology can be relied upon to alert and notify 60,000 people in the floodplain. Hawkesbury-Nepean flood warning system has to use several technologies to reach the population and accommodate contingencies such as loss of power or telephone systems.

Molino, S., Begg, S., Stewart, L. & Opper, S., August 2002, 'Bells and whistles, belts and braces: designing an integrated flood warning system for the Hawkesbury-Nepean Valley. Part 2', *Australian Journal of Emergency Management*, 17(2), 40-49.

- Evaluates various alerting and notification technologies using multi-criteria analysis.
- Adopted options are 1) free-to-air radio and television broadcasts (pros: zero cost, scope for detail, updating easy; cons: may not alert; relies on third parties to accurately communicate warning message), 2) SES Call Centre and 3) Rural Warden System in some locations that are frequently flooded.
- Considers communication barriers associated with each potential warning technology.
- Considers preferred warning systems according to evacuation sector. Fixed Public Address systems are considered essential in the urban parts of the Richmond, Windsor, McGraths Hill and Pitt Town sectors since these are low flood islands. Personal Notification (i.e. door-knocking) is the preferred supplementary alert and notification strategy in these sectors. It was concluded that Tone Alert Radio and Telephone Dial Out Systems could be useful technologies in particular circumstances.
- Analysis of the population distribution, the nature of flooding, warning times and evacuation routes are important considerations in optimising an integrated warning system.

Molino Stewart, September 1997, *Hawkesbury-Nepean River Impacts of Flooding on Communities and Infrastructure*, prepared for HNFMAC.

- See summary in *Achieving a Hawkesbury-Nepean Floodplain Management Strategy*.
- Evaluates for the Hawkesbury-Nepean valley the consequences for a range of floods up to the PMF.
- Chapter 4 describes the consequences of floods of different levels for infrastructure assets including roads and bridges, railways, electricity, telecommunications, gas and oil, water, sewerage, defence, health facilities and emergency services. Notes the potential damages from inundation, erosion and sedimentation.
- Section 5.1.1 ii discusses community attitudes which might influence response during flooding.
- Section 5.2.1 focuses on the impact of loss of electricity for communities.
- Section 5.2.2 focuses on the impact of loss of telecommunications for communities.
- Section 5.2.3 focuses on the impact of loss of gas and oil for communities.
- Section 5.2.4 focuses on the impact of loss of water for communities.
- Section 5.2.5 focuses on the impact of loss of sewerage for communities.
- Section 5.3 focuses on the impact of flooding on road and rail transport.
- Section 5.4 focuses on the impact of flooding on dwellings, including direct, indirect and intangible losses (incl. loss of life).
- Table 5.4 Settlements which are isolated before inundation

Settlement	**Population**	**Highest ground level (mAHD)**
McGraths Hill	2,100	17.0
Pitt Town	1,100	23.5
Richmond	9,100	24.0
Bligh Park	5,400	24.5
Windsor	7,200	26.0
Total	24,900	

- Section 5.5 focuses on the impact of flooding on commerce and industry.
- Section 5.6 focuses on the impact of flooding on agriculture.
- Section 5.7 focuses on the impact of flooding on defence.
- Section 5.8 focuses on the impact of flooding on health services.
- Section 5.9 focuses on the impact of flooding on emergency services.
- Chapter 6 summarises the damages. The average annual damages from flooding is estimated to range from $21 to $68 million with an expected cost of about $38 million, with residential damages contributing about 28%, commercial/industrial 20%, agriculture 11%, electricity supply 10% and the RAAF base 10%. On average about 240 houses per year would flood.
- Chapter 7 considers options to reduce the consequences of flooding including flood modification, asset modification and response modification. Recommends further investigation of raising the transformers in the Hawkesbury electricity transmission substation, and relocating the RAAF base. Recommends opportunistic flood compatible decisions for replacement of utility assets and relocation of key health and emergency service facilities.
- Section 8.3 lists the recommendations of the study including some relating to Integral Energy (raising transformers at Hawkesbury transmission substation) and AGL (consider whether scour protection is required at the gas pipeline's Hawkesbury River crossing).

Molino Stewart, August 2000, *Improving Preparedness of Utility Providers Discussion Paper*, prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee (Draft).

- Chapter 1 provides background including a summary of the unique features of flooding in the Hawkesbury-Nepean valley and a summary of likely consequences in a repeat of the 1867 flood and in the PMF. This study aims to facilitate improved flood planning within agencies.
- Chapter 2 describes the method employed, using a questionnaire and interviews.
- Chapter 3 summarises the questionnaire responses. Out of 18 responses received, only Hawkesbury City Council and Integral Energy had plans that related specifically to flooding in the Hawkesbury-Nepean Valley. 16 organisations indicated that flooding is considered when selecting locations for new assets. 15 organisations take flooding into consideration when designing new assets, and 12 organisations indicated that they already do or would be prepared to give more consideration to the full range of potential floods up to the PMF. HCC indicated that there would be little to gain from considering the full range of potential floods since most of the area is flood-prone.
- Chapter 4 provides an analysis of the current situation. The understanding of flooding and its impacts and preparedness for flooding were found to vary widely between infrastructure providers. Dependency on electricity is a key issue, requiring inter-agency coordination. Merits based planning for new infrastructure is rarely applied, though there is a general acceptance that more can be done. Some issues requiring better understanding are listed, including the role of Warragamba Dam in major flooding and probability concepts.
- Chapter 5 outlines opportunities for improvement: provision of comprehensive and current flood data and information about assets exposed; communication between and within agencies; guidelines to assist the preparation of agency flood plans; and education about the consequences of flooding in the valley and probability.
- Chapter 6 describes mechanisms for improvement under the headings of legislative (mechanisms), agency participation, government initiative and other.
- Appendix A lists the consequences of flooding at specified levels:

  Note that these consequences have not been verified for the current investigation, and that Molino Stewart's (2000) report was not finalised.

PEAK RIVER LEVEL AT WINDSOR (m AHD)	CHANCE PER YEAR 1 IN	INCREMENTAL CONSEQUENCES
0.5-1.0	normal tidal range	Nil
7	3	River breaks its banks North Richmond and Windsor bridges close. Yarramundi Bridge already closed
12.5	10	250 rural dwellings flooded at least 750 people evacuated and needing temporary accommodation for one week electricity supply to 4,000 properties north of River shut down for 2 days Telephone system north of the river will have to rely on battery or generator power for up to 2 days St John of God Hospital at North Richmond will have to rely upon emergency generator power for 2 days North Richmond Sewage Treatment Plant shuts down and raw sewage discharged to river for 2 days
13	14	Up to 500 homes flooded Up to 300 people needing temporary accommodation for two days and 1,700 for about one week Most electricity transmission lines out of Hawkesbury Transmission Substation shut down and up to 15,000 non-flooded properties without electricity for 1 or 2 days Richmond, McGraths Hill, Riverstone and South Windsor sewage systems shut down due to loss of power supply and flooding of some pumping stations. Raw sewage discharged to river for 2 days 045 Telephone system reliant upon battery power for first six hours then generator power for 2 days Possibly some reduction in service for mobile phone customers Almost 200 hospital and nursing home beds reliant upon emergency generators for power supply

PEAK RIVER LEVEL AT WINDSOR (m AHD)	CHANCE PER YEAR 1 IN	INCREMENTAL CONSEQUENCES
14	22	Over 1,000 homes flooded At least 8,000 people evacuated including the whole of McGraths Hill and Pitt Town Up to 6,900 people requiring temporary accommodation for 2 days and 1,100 people for one week McGraths Hill Sewage Treatment Plant Damaged. Untreated sewage discharged to River for 3 months and further 3 months to achieve required effluent quality One Pumping station for Quakers Hill Sewerage System fails and raw sewage overflows into Eastern Creek
16	60	Up to 2,300 homes flooded of which 550 homes fail about 37,000 people evacuated including the whole of Richmond, Windsor and Bligh Park 30,000 people needing temporary accommodation for two weeks, 5,300 for about five weeks and 1,700 for three to six months Hawkesbury District Hospital and Richmond Community Nursing Home evacuated 6,500 properties would lose telephone services due to flooding of exchanges but this would be in evacuated areas Telephone system for whole 045 area code would be reliant upon emergency battery and generator power for two days. Continued operation of generator at Richmond terminal exchange critical to operation of entire system Significant reduction in mobile telephone service
18	120	Up to 4,000 homes flooded and 900 homes fail 25,600 people needing temporary accommodation for about two weeks, 9,500 for five weeks and 900 for three to six months Major sewage pumping station in St Marys Sewerage System flooded and half of system's sewage discharging untreated to South Creek for about one week Electricity supply into Hawkesbury Transmission Substation cut. 22,000 non-flooded properties without power for up to two weeks St John of God Hospital reliant upon generators to supply power for two weeks Telephone system in whole in 045 area reliant upon generators to supply power for two weeks All sewerage systems reliant upon emergency generators for two weeks Possible rupture of gas and oil pipelines at Hawkesbury River crossing. 36,000 residential and commercial gas users at Newcastle and Central Coast without gas supply for 5 months. Petroleum products transported by road for 12 months.
20	400	Up to 5,000 more homes flooded of which 2,000 fail 17,000 people needing temporary accommodation for about 3 months, 15,700 for 6 months and 6,300 for three to 12 months Hawkesbury Transmission substation flooded and substantial damage to transmission lines. 19,000 non-flooded properties without power for up to 3 months St John of God Hospital will have to rely upon emergency generator power for up to 3 months Telephone system for 045 area code reliant upon emergency generator power for up to 3 months Richmond, South Windsor and St Marys sewage treatment plants damaged. 3 months to get South Windsor operational and 6 weeks to get St Marys Operational with untreated sewage being discharged to river. Twice that time to achieve licensed effluent standards. Richmond would take 2 weeks to achieve effluent standards McGraths Hill Sewage Treatment Plant severely damaged. 12 months to rebuild and get fully operational.
22	1,500	Up to 9,500 homes flooded and up to 4,000 of the flooded homes fail 11,000 people needing temporary accommodation for about 3 months, 16,600 for 6 months and 12,400 for three to 12 months Richmond Switching Centre damaged and no terrestrial telephone service to whole of 045 area for 2 weeks. About 10,400 non-flooded properties affected Hawkesbury Transmission Substation significantly damaged. No electricity to 16,370 non-flooded properties for about 3 months North Richmond Sewage Treatment plant damaged. 2 weeks to become fully operational and 3 months to achieve effluent standards.
25	15,000	St Marys, North Richmond, and Richmond Sewage Treatment Plants need total reconstruction and 12 months to be fully operational. St Marys and North Richmond have significant parts of their catchments which would not be affected by flooding and raw sewage would be discharged until the plants were operational.
26.4	100,000	Up to 12,700 homes flooded of which 9,400 fail 2,700 people needing temporary accommodation for about 3 months, 10,200 for 6 months and 29,100 for three to 12 months South Windsor Sewage Treatment Plant needs 12 months to be completely rebuilt. Quakers Hill Sewage Treatment Plant damaged. 6 weeks to become operational and another 3 weeks to achieve effluent standards.

Molino Stewart, November 2007, *Pitt Town Flood Risk Management Review*, prepared for Johnson Property Group.

- Assesses proposal for additional 915 lots in Pitt Town with regard to the Director General Planning's requirements in respect of flooding.
- Concluded that the development was acceptable from flooding perspective, since it is well above the 100 year ARI level and mostly above the 1867 flood level and can be safely evacuated along with the existing Pitt Town community, though the surplus evacuation time would be reduced from three hours to 0.4 hour. Should residents fail to evacuate, there is a high point above the PMF level in Pitt Town.

Molino Stewart, November 2007, *Potential Bligh Park North Flood Evacuation via Windsor*, prepared for Modog Developments.

- Calculated existing evacuation traffic from Windsor/South Windsor as 3,736 registered residential vehicles (based on 2006 Census) plus 1,200 commercial vehicles = 4,936.
- Using SES evacuation timeline methodology to assess existing evacuation capability, found that 738 of the reported residential vehicles could not evacuate in time (i.e. 1.2 hour evacuation time deficit), growing to a 1.6 hour deficit if unreported vehicles are included and a 3.2 hour deficit if commercial vehicles are included.
- Considered ways for upgrading the capacity of the evacuation route including 1) allowing for two lanes out for evacuation traffic, and 2) upgrading the low point on Bandon Road.
- Upgrading to two lanes out would provide sufficient capacity for the existing Windsor and South Windsor traffic as well as the proposed Bligh Park North traffic with a 20 minute time surplus.
- To minimise the risk to life should residents not evacuate in time, the proposed Bligh Park North development includes a pedestrian route to Windsor Downs Nature Reserve, which includes land above PMF level. Multi-storey commercial developments are also proposed on high points, which could act as central refuges with the top floor above the PMF. In addition, residential designs would ensure structural integrity up to the PMF and tiled rooves should people be forced to escape from their roof cavity.
- Conclusions: *Provided that the road infrastructure is appropriately upgraded, it would be possible to evacuate more than 700 new lots in Bligh Park in a way that integrates with the current SES flood evacuation plan for the region and there may be a time safety margin available rather than the current time deficit.*
- *Should residents fail to evacuate in time, the proposed development design features will minimise risk to lives.*

NSW SES, April 2002, *Pitt Town Local Environmental Study Flood Emergency Risk Management: An Analysis of Urban Growth Impact*.

- Provides comment on the flood emergency risk management implications of urban growth in the Pitt Town community. Considers three different scenarios for future urban growth: 450, 685 or 1350 new dwellings. Adopts the principle that population growth must only be permitted if 1) there is no increase in flood risk for the existing population as a result of the growth, and 2) the flood risk for the population of the new development must be no higher than the flood risk for the existing population.
- An additional 450 dwellings creates a time deficit of –1.5 hours, 685 dwellings = –3 hours, and 1350 dwellings = –7 hours, relative to the existing number of dwellings.
- The SES puts forward three options to address the time deficit: road raising, more outbound lanes, or a combination of both road raising and additional outbound lanes.
- Recommends that any permitted urban growth is supported by development of a community hall or similar facility with the capability of operating for several days after Pitt Town has been isolated by floodwater.
- P4. Describes the flood risk situation for Pitt Town. An island will be formed when floodwater exceeds about 16m AHD (60 year ARI). There are only three small areas of ground likely to be above the reach of the PMF. In order to allow sufficient time for evacuation, the decision to begin a full evacuation operation for Pitt Town must be made no later than when the river near Pitt Town reaches 9m AHD. It will only be possible to make a decision not to evacuate when there is a very high degree of confidence that a developing flood cannot reach a height that would close the only escape route, OR that the majority of land would remain dry at the flood peak.
- Documents time-line analysis for various growth scenarios.

NSW SES, June 2002, Emergency Risk Management for Hawkesbury-Nepean Flooding. In Connell Wagner Pty Ltd, *Windsor Flood Evacuation Route, South Creek Environmental Impact Statement, Volume 2 Working Papers, Working Paper 11*.

- Supports the work of the RTA in preparing an EIS for the proposed South Creek Flood Evacuation Route at Windsor.
- Summarises findings of previous relevant reports.
- The proposed crossing at a minimum level of 17.3m AHD and with a minimum of two lanes (one inbound, one outbound) will provide an essential separate evacuation route to deal with the existing population of North and South Windsor. By providing separation of traffic streams, the high-level crossing will allow Bligh Park and Windsor Downs to utilise the available capacity of the Northern Road and Blacktown Road.
- Presents evacuation timeline methodology and lists assumptions. Note 6m AHD corresponds to time = 0 point. Describes the need for safety factors due to the difficulties of prediction, human behaviour in response to flood warnings, or the complete loss or extended blockage of a critical evacuation route.
- Figures 2 and 3 present evacuation timelines for Windsor using existing roads and with the high level crossing over South Creek. The greatest benefit is for Windsor/South Windsor with the Flood Risk Status Quo Line (FRSDL) improving by 8.1 hours from –4.5 hrs pre-crossing to +3.6 hrs post-crossing.
- Table 2 presents parameters and trigger heights for evacuation decisions assuming the new crossing is in place.
- Contains other detail similar to what is in the *Hawkesbury Nepean Flood Emergency Sub Plan* (SEMC, 2005).

O'Neill, P., 'Developing an integrated public education model for the Hawkesbury-Nepean Floodplain Management Strategy, presented at Emergencies 2000 Conference.

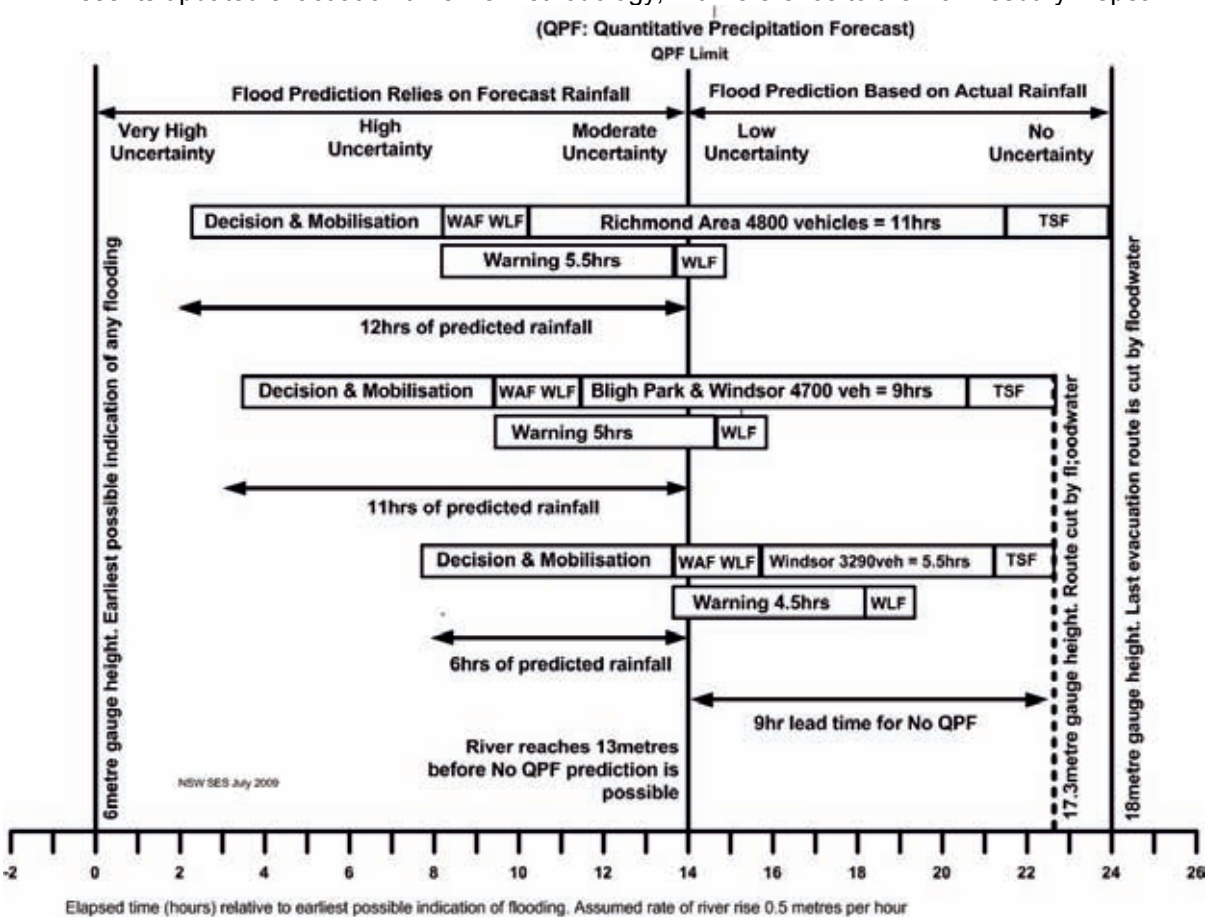
- The paper presents a model for an integrated communication/education program in the context of a severe flood threat. It investigates the elements that contribute to an integrated communication campaign and factors such as risk perception. The paper examines traditional approaches that emphasise the need to raise public awareness and puts forward an alternative model. This model aims to develop an increase in appropriate knowledge, attitudes and behaviours of flood-affected communities and other target audiences.

Opper, S., May 2000, 'Emergency planning for the Hawkesbury-Nepean Valley. In *40th Annual Conference of the NSW Floodplain Management Authorities*, Parramatta, 9-12 May 2000, pp.109-115.

- Presents evacuation timeline methodology for the Hawkesbury-Nepean.
- Major control on effectiveness of a large-scale evacuation strategy is the capacity of the evacuation route (see Danielson et al., 1997).
- Essential to be conservative when estimating the time needed to carry out evacuation tasks when the consequences of underestimation could result in fatalities.
- Complicated by high level of uncertainty especially if using quantitative precipitation forecasting (QPF). Raising evacuation routes allows for later, more informed decisions.

Opper, S. Cinque, P. & Davies, B., September 2009, 'Timeline modelling of flood evacuation operations'. In *First International Conference on Evacuation Modelling and Management, Den Haag, The Netherlands, 23-25 September 2009*.

- Presents updated evacuation timeline methodology, with reference to the Hawkesbury-Nepean.



- Decision to evacuate has to be made 22-24 hours before the expected closure of evacuation routes. To provide this lead time, the Bureau of Meteorology has to use 12 hours of forecast rainfall, which introduces a high level of uncertainty. If the forecast rainfall does not eventuate then the evacuation may be seen, *only with the benefit of hindsight*, to have been triggered un-necessarily. It is not possible to delay the evacuation in the hope that more certainty will emerge as the flood develops, since a late call to evacuate will result in evacuation failure and the need to undertake flood rescue on a massive scale.
- Situation is much better post September 2007 when evacuation bridge was opened.

Patterson Britton & Partners Pty Ltd, June 1993, *Towards a New Floodplain Planning Policy*, prepared for HCC.

- Provides an overview of flood behaviour in the Richmond/Windsor basin. Largest recorded flood of 19.7m at Windsor in 1867. Inflows controlled by Castlereagh restriction; outflows controlled by Sackville gorge. Average rise of 0.5m/hour translates into short warning times. Describes emergency management problems using 1978 flood as example.
- Estimates that a recurrence of the 1867 flood would inundate 10,000+ properties valley wide, requiring up to 50,000 people to be evacuated, and causing damages approaching $2 billion.
- Converted the RUBICON model to a MIKE-11 model, resulting in 100 year flood level of 17.6m AHD at North Richmond and 17.3m AHD at Windsor, higher than the previous estimate of 16.0m AHD derived from stage-frequency studies of the Windsor Bridge records (PWD, 1979). Recognises that raising the flood planning level from 16.0m AHD would be sensitive.
- Contains a map showing evacuation routes (from the Hawkesbury City Local Flood Plan, February 1993).
- Recognises the need to manage flood risk above the planning level.
- Summarises development controls in *Hawkesbury LEP 1989* clause 25, which prohibits development on land lying below the 10 year ARI flood level, permits development above the 100 year ARI flood level, and requires development between the 10 and 100 year levels to have habitable floors above the 100 year level but no more than 3m above existing ground level. Variations of consent are allowed where buildings are other than dwellings or residential flats, or where a building in existence as of April 1984 is to be extended, altered, added to or replaced.
- Criticisms of the policy include 1) changing design flood levels (spatially and with updated studies) and 2) erroneous perception that land above 100 year is flood-free.
- Advocates fixed FPLs in metres AHD for different areas of the floodplain, and with consideration of several factors including hydraulic hazard, peak water level equivalent to 16m at Windsor Bridge, PMF level, flood evacuation setting (e.g. high islands, low islands), evacuation capability and future management options. Suggests that attention be focussed on risk to life since risk of property damage cannot be avoided in the Hawkesbury Valley without sterilising much land.
- Suggests initial consideration of potential urban areas on the basis of elevation range and location in the floodplain:

Situation at planning level (16.0m AHD)	**Situation at extreme flood**	**Example locality**
Fringe @ Current Planning Level	Fringe @ PMF	North Richmond, Wilberforce
Fringe @ Current Planning Level	Flooded @ PMF	Richmond, Bligh Park
Isolated @ Current Planning Level	Flooded @ PMF	Windsor, Pitt Town
Isolated @ Current Planning Level	Flooded @ Current Planning Level	McGraths Hill

- Canvasses a range of issues for consideration in the preparation of a planning policy including 1) local refuges, 2) utility of evacuation routes, 3) flood tolerant housing, 4) provision of property specific flood information, 5) protection of agricultural land. McGraths Hill and Bligh Park subdivisions are cited as examples where evacuation considerations were not properly addressed.

Patterson Britton & Partners Pty Ltd, August 1997, *Emergency Response and Traffic Infrastructure Flood Impacts Assessment*, prepared for the Hawkesbury-Nepean Flood Management Advisory Committee.

- See also Danielson, 1997 and Masson & Wilson, 1997.
- Assesses the potential impacts of both mainstream and local flooding (especially overtopping durations) on the transportation dynamics of preferred evacuation routes as identified in the SES Plan.
- Finds that local flooding of the current road network would heavily constrain the SES Flood Emergency Plan.
- Finds an urgent need to provide reliable early warnings based on forecasted rainfall.
- Finds potential for vehicles and evacuees to be stranded in the floodplain while waters rise at a rate of up to 0.75 metres per hour.
- Recommends development of viable alternate evacuation routes to provide an additional factor of safety through planned evacuation route redundancy.
- Recommends minor infrastructure upgrading on the preferred evacuation routes.
- Recommends investigation of potential for evacuation centres closer to the areas being evacuated.
- Identifies the safety of isolated communities in the lower river reaches as an acute logistics and education problem.

Patterson Britton & Partners Pty Ltd in association with Masson Wilson Twiney, December 1998, *Hawkesbury-Nepean Flood Evacuation Route Optimisation Study*.

- Follows Danielson's 1997 *Emergency Response Planning and Traffic Infrastructure* study, with the objective of facilitating the preparation of preliminary designs for upgrading evacuation routes. Identifies minimum route elevations required to allow population at risk to evacuate prior to route being inundated by backwater flooding. Identifies optimum elevation of low points with respect to economic criteria. Specifies route requirements designed to facilitate the evacuation function of each route e.g. lane requirements, pavement and shoulders, evacuation signage and intersections.

Centre	**Evacuation route**	**Level at which route is cut (mAHD)**	**Min. required elevation (mAHD)**	**Economic optimum level (mAHD)**
Richmond	Londonderry Rd	16.3 (17.6 if via Torkington and Nutt Roads)	19.5 (19.0 if Northern Road upgraded to two lanes outbound)	18
Windsor	George St-Richmond Rd-The Northern Rd	15.2	22 (19.5 if Northern Road upgraded to two lanes outbound)	Not practical to raise George St so seek alternatives…
Bligh Park	George St-Richmond Rd-Llandilo Rd	15.3	18	
McGraths Hill	Windsor Road	12.6	13.5	13.2–15
	Groves Ave-Railway Rd North	13.5	13.2	Not required
Pitt Town	Eldon St-Old Pitt Town Rd	10.2		12.5
	Bootles Ln-Redfern Pl-Mitchell Rd-Cattai Rd-Pitt Town Dural Rd-Unformed track-Old Stock Route Rd	15.2		16 or 17
Wilberforce	King Rd	11.7		(12.5 to provide redundancy)

Patterson Britton & Partners Pty Ltd, July 2004, *Hawkesbury-Nepean Flood Evacuation Routes Upgrade Review*, prepared for DIPNR.

- Chapter 2 describes the then current evacuation route strategy, which was slightly refined from the Interim Regional Road Upgrade Plan (HNFMS, 2000).
- Chapter 3 describes the then status of the evacuation routes upgrade (Table 3.1)
- Chapter 4 describes the operational planning outcomes given the evacuation route upgrades, with reference to the time line methodology. Note that the Quantitative Precipitation Forecast (QPF) limit is the earliest point the Bureau can predict that a particular flood evacuation route will be cut, using actual rainfall data. Ideally the entire evacuation operation including decision making and emergency resources mobilization (requiring 6 hrs) should be able to take place above the QPF limit. The outcomes are presented below:

Location	**Evacuation trigger timing (latest possible)**	**Required no. of door-knock teams**	**No. of evacuation vehicles**	**Comment**
Windsor/South Windsor (with new South Creek crossing)	= Windsor QPF limit	50 minimum	3286	Uncertainty about need to evacuate Windsor is reduced
Bligh Park and Windsor Downs	2½ hours before QPF limit	50 minimum	4681	Bligh Park must evacuate early and in climate of uncertainty to make use of Richmond Road before it gets cut
McGraths Hill	5 hours before QPF limit	20	1487	Evacuation just proceed very early and in period of high forecast uncertainty
Pitt Town	= Pitt Town QPF limit	10 minimum	741	Evacuation uncertainty is reduced
Richmond and Environs	3 hours *after* Windsor QPF	50 minimum	4478	Runs risk of not having Londonderry Road as secondary route

- Chapter 5 describes the increased number of evacuation vehicles assessed from the 2001 census.
- Chapter 6 describes an assessment of flood evacuation traffic queuing, including with respect to traffic streams from the proposed Penrith Lakes development.
- Chapter 7 considers opportunities for new evacuation route infrastructure to address deficiencies.
- Chapter 8 considers solutions to the queuing problem.

PWD, August 1994, *Floodplain Management Issues in the Hawkesbury-Nepean Valley – Summary of Workshop Proceedings*.

- Describes philosophy of floodplain management process in seeking to achieve a balance between benefits of using flood-liable land and the risk of future flooding.
- Describes potential damages from Hawkesbury-Nepean flooding – 18,000 could be affected in the Penrith-Richmond-Windsor areas in the 100 year flood, and over 50,000 in the PMF. Draws lessons from the 1974 Brisbane flood, the 1990 Nyngan flood, and the October 1993 north-east Victoria flood. Documents diverse workshop discussion including idea of self-evident refuges within the flood susceptible areas.
- Describes potential management measures for Hawkesbury-Nepean flooding. Recognises structural works can provide degree of protection up to the design flood event but that emergency response plans are an essential adjunct. Notes the major hazard of possible entrapment of large numbers of people on islands that are eventually inundated. Considers various planning controls:
    - Orientation of access roads;
    - Requiring housing to be 2 storeys;
    - Requiring 2-3 storey cluster housing on higher ground to reduce damage and facilitate rescue;
    - Not burying power and telecommunications services where these are vulnerable to flood damage;
    - Design sewer and septic connections to minimise backflow;
    - Exclude hazardous industry from flood-prone areas;
    - Locate emergency services in flood-free locations;
    - Protect essential infrastructure necessary to hasten recovery process e.g. raise water supply pumping station;
    - Reconstruct public roads cognisant of role in evacuation

  Recommends preparation of floodproofing guidelines and guidelines for cleaning/restoring flooded houses. Documents diverse workshop discussion including need to differentiate controls for existing/infill development from new subdivisions in DCPs, and the need to define 'optimal' levels of new development.
- Appendix C contains some useful factors for categorising flood risk and evacuation capability.

PWD, December 1994, *Emergency Flood Evacuation Route Options for Richmond and Londonderry*.

- Examines the utility of two potential flood evacuation routes from Richmond and Londonderry, from which 10,000 residents would need to evacuate. Recommended upgrading "Option A" (Londonderry Road only) which had a lower cost of upgrading, more flow-on benefits to normal everyday traffic demands and more overall benefits to emergency flood evacuation. The most cost effective standard of upgrade was to provide security against the 500 year ARI local flooding.

SEMC (State Emergency Management Committee), December 2005, *Hawkesbury Nepean Flood Emergency Sub Plan - A Sub Plan of NSW DISPLAN*.

- P.1 This plan deals with "Level 2" flooding, which are defined as floods expected to exceed 15.0 m on the Windsor Bridge gauge.
- P.7 Describes weather systems associated with severe flooding.
- P.8 Describes the PMF.
- P.10 Describes the flood history.
- P.11 Describes flood frequency (*including auxiliary spillway*):

Flood event	**Windsor Flood Level (at Windsor Bridge)**
5 year	11.1
10 year	12.3
20 year	13.7
50 year	15.7
100 year	17.3
250 year (1867 flood)	19.3
500 year	20.2
1000 year	21.9
PMF without dam failure	26.4

- P.13f Describes the consequences of flooding in PMF, 1867-type and less severe events.
- P.15f Describes a classification of flood affected communities.
- P.17f Describes the operational implications of flood consequences.
- P.29f Describes operational sectors (14 for Hawkesbury LGA).
- P.33f Describes response strategies for Flood Islands including McGraths Hill, Windsor, Pitt Town and Richmond.
- P.35f Describes response strategies for Areas Accessible Overland including Yarramundi.
- P.36f Describes response strategies for Areas Accessible by Road including North Richmond and Wilberforce.
- P.41 Describes the road evacuation route network along with closure levels. *[Note an error for Llandilo Road as identified by DECCW]*.
- P.42 Flood Evacuation Route Map (see over).
- P.56f Summarises evacuation timeline results.
- P.C-4 Critical mainstream flooding points:

Evacuation Route	Road Point ID	Height Cut (m AHD)	Gauge Height (m)	Relevant Flood Gauge
Windsor Road Route		13.5	13.35	Windsor Bridge
Richmond Road Route		14.14	13.99	Windsor Bridge
Pitt Town Road Route		16.0	15.85	Windsor Bridge
Northern Road		N/A	N/A	Windsor Bridge
Londonderry Road Route		18.0	17.85	Windsor Bridge
Castlereagh Road Route		20.2	20.05	Windsor Bridge
Llandilo Road Route		19.15	19.00	Windsor Bridge
M4 Motorway Route		35.00	20.86	Penrith (Victoria Bridge)

- Miscellaneous flood intelligence:
  - Windsor Road, the only evacuation route for McGraths Hill, is cut at 13.5 m (p.15);
  - access between Windsor and Richmond cut at 14.2 m (p.15);
  - Richmond railway line effectively cut at 12.5-13.5 m near Vineyard (p.32).

SMEC, December 2000, *Windsor Road and McGraths Hill Local Hydraulics Specification Study*, prepared for DLWC.

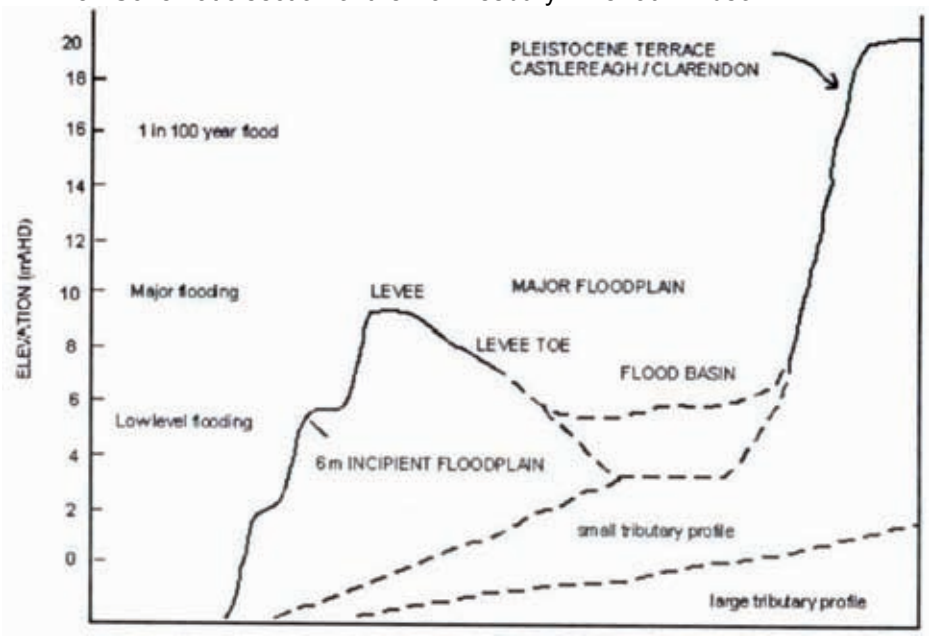
- Reports modelling undertaken to guide road and drainage design of the Windsor Road evacuation route from McGraths Hill (from Curtis Road to Nelson Road), and an alternative route via Groves Avenue, Railway Road North and Railway Road South, so as to provide a uniform level of protection to the 500-year ARI local flood. A minimum level of 13.5 was adopted for the Windsor Road Evacuation Route, and 17.3 for the Windsor evacuation route across South Creek.
- Study involved issuing 540 letters and questionnaires to residents and landholders whose properties were situated along either Windsor Road or the alternative route, with 116 responses received. Whilst 38% of respondents had resided in the area for more than 20 years, 86% of respondents had not experienced a flood, only 3 had been flooded above floor level and 75% had not observed flooding. Respondents noted low points where flooding had been observed.

Warner, R.F., 1999, 'Basin evolution'. In Martens & Associates Pty Ltd, 1999, *Geomorphology of the Hawkesbury-Nepean River System: A Review of Landforms, Processes and Management*, prepared for HN Catchment Management Trust, pp.13-25.

- P.22 Farms settled on the banks of the Hawkesbury downstream of Windsor were in the early years of settlement frequently inundated by floods over 10m. Warnings of the local natives, who pointed out flood debris high in trees were ignored. Six or more of these events between 1799 and 1820 (Jeans, 1972).
- P.22 Discusses concept of flood-dominated regimes (FDRs) and drought-dominated regimes (DDRs) which were first defined with reference to flood heights and frequencies at Windsor: FDRs 1799-1820, 1863-1900 and 1949-'present'.

Warner, R.F., 1999, 'Floods and floodplain management'. In Martens & Associates Pty Ltd, *Geomorphology of the Hawkesbury-Nepean River System: A Review of Landforms, Processes and Management*, prepared for HN Catchment Management Trust, pp.82-95.

- P.84 Schematic section of the Hawkesbury River at Windsor:



- P.90 Further discussion on secular climate changes and their impact on fluvial geomorphology.
- P.92 Queries value of averaged long term data when it can be demonstrated that two populations of data exist (FDRs and DDRs) when there have been quite different flooding patterns and frequencies of surcharging.

Warner, R.F.,1999, 'Climatic geomorphology'. In Martens & Associates Pty Ltd, *Geomorphology of the Hawkesbury-Nepean River System: A Review of Landforms, Processes and Management*, prepared for HN Catchment Management Trust, pp.156-168.

- P.160 Defined FDRs/DDRs
- P.163 Considers the geomorphological impacts of greenhouse plus return to FDR by 2030 AD, where a near doubling of the present FDR mean annual flood or channel-forming discharge would prevail. The remainder of the sandy incipient floodplain would be quickly removed with erosion then attacking the higher, more cohesive banks. The channel would widen at Windsor to nearly 300m.

Warner, R.F., 2009, 'Secular regime shifts, global warming and Sydney's water supply', *Geographical Research*, 47(3), 227-241.

- P.228 Defines DDRs as periods where droughts are more frequent and longer lasting, and floods are lower in magnitude and frequency. Defines FDRs as periods where droughts are shorter and where generally floods increase in magnitude and frequency.

- P.230 Timing of regime shifts:

Table 1 Floods exceeding 8 m, 10 m and 12 m for FDRs and DDRs at Windsor Bridge on the Hawkesbury River. (Based on Josephson (1885), Riley (1981) and Bureau of Meteorology data).

Period	8–10 m	10–12 m	>12 m	Regime
1799–1820	0	0	5	FDR 22 y plus
1821–1856	0	0	0	DDR 26 y
1857–1900	13	10	7	FDR 44 y
1901–1948	3	3	0	DDR 48 y
1949–1990	23	6	7	FDR 42 y
1991–2006	0	1	0	DDR 16 y

WMA (Webb, McKeown & Associates Pty Ltd), October 1996, *Proposed Warragamba Dam Auxiliary Spillway EIS Flood Study* (5 vols), prepared for Sydney Water.

Part A Background

- Summarises the geomorphology of the Hawkesbury-Nepean Valley.
- Summarises the post-European history of the Hawkesbury-Nepean Valley including Governor Macquarie's 1817 Edict and the construction of Warragamba Dam (late 1940s to 1960).
- Warragamba Dam spillway was originally designed for a maximum flow of 10,000 cumecs, but was modified during construction of provide for 12,700 cumecs. The spillway capacity was subsequently increased to 20,000 cumecs.

Part D Design Flood Estimation

- P.D48 Sensitivity testing showed that the Colo River had a 'small but measurable impact on Windsor flood levels across the range of floods'. For a 100 year main river flood, reducing the Colo component from 100 year to 20 year would reduce the level at Windsor by 0.14m. It was decided that the 50 year and 100 year floods would be run with a 20 year flow in the Colo, the 200 year flood would be run with a 50 year flow in the Colo, and the 500 year and 100 year floods would be run with a 100 year flow in the Colo.
- P.D51 Zero drawdown at the time of commencement of inflow to Warragamba Dam was assumed for all design floods. A drawdown of 1m would reduce the 100 year flood level at Windsor by 0.13m.
- P.D57 The 5 year and 10 year ARI design flows at Windsor were adopted directly from the Windsor frequency analysis. The 20 year to 100 year ARI design flows at Windsor used the locally derived flood frequency results as well as the Penrith flood frequency results which were transferred to Windsor using the model.
- P.D58 The 1867 flood would reach 19.2m at Windsor if it occurred today. This flood had a 200 year ARI at Windsor based on the adopted frequency plots.
- P.D59 Assumptions at Warragamba Dam were: wall at the present level; gates operating to H14 procedure; reservoir full at the commencement of the design flood. Note that the post dam levels are higher than pre-dam levels for events up to 20 year ARI at Windsor.
- P.D63 Post-dam design flood levels for use in floodplain management studies (adjusted for expected probability). *[unclear if these incorporate auxiliary spillway]*

Flood event	North Richmond Flood Level (at North Richmond Bridge)	Windsor Flood Level (at Windsor Bridge)
5 year	12.5	11.1
10 year	14.0	12.3
20 year	15.3	13.7
50 year	16.4	15.7
100 year	17.5	17.3
200 year	18.9	18.7
500 year	20.4	20.2
1000 year	21.5	21.3
PMF without dam failure	25.6	25.5
PMF with dam failure	29.0	28.9

- Table D3 Adopted Windsor flood levels 1855-1990

Flood	Observed level (m AHD)
1857 Jul	10.39
1857 Aug	11.91
1860 Apr	11.82
1860 Jul	11.06
1860 Nov	11.39
1864 Jun	15.05
1864 Jul	11.42
1867 Jun	19.68
1869 May	11.64
1870 Apr	14.14
1870 May	11.24
1871 May	11.67
1873 Feb	13.10
1875 Jun	12.28

Flood	Observed level (m AHD)
1879 Sep	13.62
1889 May	12.15
1890 Mar	12.28
1891 Jun	11.24
1894 Mar	10.14
1898 Feb	10.08
1900 Jul	14.50
1904 Jul	12.64
1916 Oct	10.97
1925 Jun	11.50
1943 May	10.26
1949 Jun	12.11
Warragamba Dam commenced	
1952 Jul	11.76
1956 Feb	13.84
Warragamba Dam completed	
1961 Nov	14.95
1964 Jun	14.57
1969 Nov	10.21
1975 May	10.43
1975 Jun	11.20
1978 Mar	14.46
1986 Aug	11.35
1988 May	12.80
1988 Jul	10.89
1990 Aug	13.50

- Appendix D.A evaluates historical information about flood levels at Windsor, with Table D.A4 adding estimates for floods from 1791 to 1854.

Flood	Observed level (m AHD)
1799 Mar	10.5
1806 Mar	12.9
1809 Aug	14.7
1816 Jun	14.1
1817 Feb	14.4
1819 Mar	12.9

WMA (Webb, McKeown & Associates Pty Ltd), September 1997, *Engineering Studies to Modify Flood Behaviour*, prepared for Hawkesbury-Nepean Floodplain Management Strategy Steering Committee.

- See summary in *Achieving a Hawkesbury-Nepean Floodplain Management Strategy*.
- Chapter 2 summarises flood behaviour. Design flood levels *(including auxiliary spillway)*:

Flood event	North Richmond	Windsor
5 year	12.5	11.1
10 year	14.0	12.3
20 year	15.3	13.7
50 year	16.4	15.7
100 year	17.5	17.3
200 year	18.9	18.7
500 year	20.4	20.2
1000 year	22.1	21.9
PMF	26.5	26.4

- Chapter 3 generally describes flood modification, property modification and emergency management modification measures.
- Chapter 4 describes merits of flood modification measures, both valley-wide measures and local measures.
- Chapter 5 discusses potentially viable options.

- Some mitigation dams could significantly reduce flood levels in the valley but the high economic and environmental costs render them inappropriate.
- Bypass channels, including a channel linking the river near Wilberforce to Currency Creek, would have high economic and environmental costs.
- Dredging of the river channel would be very expensive and have a major environmental impact.
- Flood warning is considered one of the most important and effective initiatives available.
- Changing Warragamba Dam gate operations may provide slightly more warning time but would need to be carefully considered and well implemented.

- Local measures in the Windsor/Richmond area assessed as worthy of further consideration are:
- A series of levees providing protection (mostly to the 50 year event) at the locations listed below. One danger is inducing a false sense of security, since the levees will be overtopped in some events.

	Design crest (mAHD)	**Length**	**Height**	**Fill volume**	**Cons**	**Pros**	**Recommend-ation**
Windsor	19.0	7km	9m max 7m (2km)	1,100,000 m^3	Massive height – serious visual impact and difficult access	Protect 1,100 properties up to 200y event	Unviable
Windsor	16.0	5.2km	6m max 4m (2 km) 2-3m (much)	400,000 m^3	Serious visual impact; expense	Protect 700-800 properties up to 50y event	Put to community consultation
Bligh Park	18.0	950m	2-3m (max)	23,000 m^3	Visual impact	Protect 50 properties up to 0.7m higher than 100y event	Put to community consultation
South East Windsor	16.0	1.2km	4-6m	85,000 m^3	Serious visual impact	Protect 60 properties up to 50y event	Unviable
Mulgrave	16.0	1.9km	1-2m (1.1km) up to 4m (800m)	65,000 m^3 plus raising railway line		Protect village up to 50y event	Put to community consultation
McGraths Hill	17.5	4km	2-3.5m	110,000 m^3	Serious visual impact; crest above escape route	Protect 700 properties up to 100y event	Unviable
McGraths Hill	16.0	3.3km	1-2m	30,000 m^3	False sense of security	Protect 700 properties up to 50y event	Put to community consultation (recommended)
Pitt Town	19.0			210,000 m^3	Serious visual impact; expense		Unviable
Pitt Town	16.0	2.2km	3m (half) 1m (half)	50,000 m^3	Visual impact	Protect 110 properties up to 50y event	Put to community consultation
Wilberforce (along King Road and south of Wilberforce Road)	17.5	700m	5m (max)	45,000 m^3	Serious visual impact	Protect 60 properties up to 100y event	Unviable
Wilberforce	16.0	600m	4m (max)	27,000 m^3	Serious visual impact	Protect 40 properties up to 1 in 50y event	Put to community consultation

	Design crest (mAHD)	Length	Height	Fill volume	Cons	Pros	Recommend-ation
Richmond-Windsor macro-levee	20.0	15km+	10m	3,700,000 m^3 plus massive flap gate for Rickabys Creek crossing	Access; cost; environ-mental and visual impact; impacts on heritage buildings; false sense security	Protect up to 1867 flood plus freeboard	Unviable
Richmond-McGraths Hill macro-levee				As above plus massive gate for South Creek	As above	As above	Unviable

- Raising various roads to provide high level evacuation routes:

Windsor	Raise 800m of George Street to 16.0m to provide access to 50y level
Bligh Park	Raise 150m of George Street from Colonial Drive towards Richmond Road to 18.0m to provide evacuation route to 100y level
McGraths Hill	Raise 500m of Wolseley Road by up to 10m and 150m of the road by up to 5m to provide access in 50y event
Pitt Town	Raise 500m of Eldon Street to Old Pitt Town Road route by maximum of 6m at a gully crossing, to
North Richmond	Raise 200m of Bells Line of Road west of Terrace Road by 1m, and by 2m at a creek crossing at the northern boundary of town

- A refuge mound at McGraths Hill above PMF level – would have considerable visual impact but would be a very desirable safety feature; and
- A refuge mound at Gronos Point (p.27).

► Local measures in the area downstream of Sackville assessed as worthy of further consideration are:
- Possible levee at Wisemans Ferry;
- Possible velocity protection at Spencer;
- House raising, though there could be an unacceptable visual impact and a false sense of security;
- Series of escape roads and helicopter pads to service the small communities strung along the Valley (these are detailed in Section 5.6.3); and
- Improved flood warning and dissemination of such information in a timely and effective way to the affected communities.

WMA (Webb, McKeown & Associates Pty Ltd), November 1999, *Hawkesbury Flood & Hazard Mapping: Conversion of Flood Study Data & Hawkesbury DTM* (CD).

- Contains DWG and legend of the RUBICON model used for the Hawkesbury-Nepean Flood Study.
- Contains MIKE 11 design levels for the 5 year, 20 year and 100 year events for Eastern Creek and South Creek by chainage.
- Contains RUBICON flood information (level, flow, velocity by time interval) for the 5, 10, 20, 50 , 100, 200, 500 and 1000 year and PMF design events, as well as for Nov-1961, Jun-1964, Mar-1978, Aug-1986, Apr-1988 and Aug-1990 floods.

WMAwater, July 2009, *Assessment of Potential Impact of Climate Change on Flooding in the Hawkesbury-Nepean River*, prepared for DECC.

- Used RORB hydrologic model and RUBICON hydraulic model to assess potential impact of climate change on flooding in the Hawkesbury-Nepean River. No changes were made to the baseline assumptions including rainfall losses, dam levels and rainfall patterns. Modelled increased rainfall intensities and volumes of 5%, 10% and 20%, sea level rise (SLR) of 0.18m, 0.55m and 0.91m, and combined 20% rainfall and 0.91m SLR for the 20 year, 100 year and 200 year ARI events, plus a 0.91m SLR for the 5 year ARI event.
- Sea level rise produced no significant increases in peak flood levels for the majority of the floodplain. Small rises were recorded downstream of Lower Portland.
- Peak flood levels are quite sensitive to increases in rainfall. For the 100y ARI event, peak flood levels rise by 0.5m (for 5% increase), 0.9m (10%) and 1.7m (20%) at Windsor Bridge.
- A 20% increase in rainfall would mean the existing 100 year ARI flood level would have the frequency of a 40-50 ARI event at Windsor Bridge.