Sutherland Shire COUNCIL

Gwawley Bay Catchment Flood Study

Flooding along Parraweena Road, Taren Point in May 2003

Final Report

November 2012

Bewsher

FloodMit

SUTHERLAND SHIRE COUNCIL

GWAWLEY BAY CATCHMENT FLOOD STUDY

Final Report

November 2012

Prepared with the assistance of Sutherland Shire Council's
Floodplain Management Committee

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FOREWORD

In New South Wales the prime responsibility for local planning and the management of flood liable land rests with local government. To assist local government with floodplain management, the NSW Government has adopted a Flood Prone Land Policy in conjunction with the *Floodplain Development Manual*.

The Policy is directed at providing solutions to existing flood problems and to ensure that new development is compatible with the flood hazard and does not create additional flood problems.

The policy sets out four sequential stages in the development of a floodplain management plan:

1. Flood Study	Assessment to define the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluation of management options for the floodplain with respect to both existing and proposed development.
3. Floodplain Risk Management Plan	Formal adoption by Council of a management plan for floodplain risks.
4. Implementation of the Plan	Measures undertaken to reduce the impact of flooding on existing development, and implementing controls to ensure that new development is compatible with the flood hazard.

This Flood Study report constitutes the first stage of the management process for the Gwawley Bay catchment, and has been prepared for Sutherland Shire Council by Bewsher Consulting Pty Ltd. The study provides information on flood conditions throughout the catchment for a range of design floods, from relatively frequent events to more extreme floods. Information on the extent of flood inundation, depth of flooding, and velocity of floodwater is provided.

These results will form the technical basis for a subsequent floodplain management study that will further identify problem areas and investigate options to reduce the risk of flooding.

Funding and technical assistance was provided for the study through both Sutherland Shire Council and the Department of Environment and Climate Change (now Office of Environment and Heritage) under the State Government's Floodplain Management Program.

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SUMMARY

Reasons for the Study

Significant flooding problems were reported within the Gwawley Bay catchment from a storm that occurred on 13th May 2003. A number of houses, factories and motor vehicles were reported to have flooded during this event. The worst affected areas were in Parraweena Road and Box Road (in Caringbah) and Bay Road (Taren Point).

The purpose of the current study is to define flood behaviour throughout the Gwawley Bay catchment, including the analysis of surface runoff across the catchment, flows within the major pipe drainage network, and flooding within open drains, Gwawley Creek and Gwawley Bay.

Results from the study will form the technical basis for subsequent floodplain management investigations, including the identification of problem areas and assessment of flood mitigation options to reduce the risk of flooding.

Responsibilities

The prime responsibility for planning and management of flood prone land in New South Wales rests with local government. The NSW Government provides assistance on state-wide policy issues and technical support. Financial assistance is also provided to undertake flood studies and floodplain management studies, and for implementing measures identified in these studies.

The study has been undertaken under the direction of Sutherland Shire Council and with the assistance of their floodplain management committee. The committee includes councillors and Council staff, officers from the Department of Environment and Climate Change, the State Emergency Service and community representatives.

Study Area

The study area is the catchment that drains to Gwawley Bay, at Sylvania Waters. Gwawley Bay is located on the south side of the Georges River, immediately upstream of the Captain Cook Bridge at Taren Point. A smaller catchment area draining to the Production Road Channel, on the east side of Taren Point Road, is also included in the study area.

The catchment is wholly within Sutherland Shire.

Outcomes from the Study

Outcomes from this study include:

(i) a database of all drainage assets within the study area;

(ii) establishment of computer models capable of assessing flood behaviour;

(iii) information on flood behaviour under existing catchment conditions; and

(iv) a model that can be used to assess flood mitigation options and future development proposals.

Database of Drainage Assets

All data collected for the study has been included within a GIS database. This allows the data to be spatially represented across the study area and allows for easy retrieval of the data as required. Information in the database includes available data on some 3,100 stormwater pits and 3,000 stormwater drainage pipelines. Photos of culverts and other plans are also linked to the database.

Other catchment data, including aerial photography, property cadastre, building footprints and the terrain surface (based on ALS survey) is also represented in the database.

Computer Modelling

The modelling approach adopted for this study involves the use of a RAFTS hydrologic model for estimating catchment flows and a TUFLOW hydraulic model to estimate flood levels and velocities. Surface flows are represented in the TUFLOW model through a 2-dimensional grid covering the study area. Major stormwater pipes, drains and creeks are included as 1-dimensional elements within this grid.

Existing Flood Behaviour

Design flood behaviour has been computed for a range of floods, ranging from relatively frequent events to more extreme floods.

The model produces a grid of results over the study area providing data on flood levels, flood depths and flood velocities. Flood level contours have also been prepared showing contours of equal flood heights throughout the study area. This data is provided digitally and can be overlaid on base mapping such as aerial photos and cadastral plans showing property boundaries.

Results from the flood model will be provided to Council for incorporation into their GIS computer system. Hard copy maps have also been prepared at A1 size for Council's use. Much of this information is also represented on reduced scale A3 sized plans included in this report.

It is intended to develop a database of properties that are potentially affected by flooding as part of the floodplain management study, which is the next phase of the investigations. This will help to identify the problem areas within the catchment and allow an assessment of potential flood mitigation options. Further delineation of the floodplain into different flood risk management precincts, including consideration of appropriate development controls for each precinct, will be undertaken during the floodplain management study.

Consideration of climate change impacts on flood behaviour will also be considered during the floodplain management study.

1 BACKGROUND TO THE STUDY

1.1 INTRODUCTION

Bewsher Consulting was commissioned by Sutherland Shire Council to undertake a floodplain Risk Management Study and Plan for Gwawley Bay. The first step in this process is to conduct a flood study to assess the nature of flooding across the study area.

The study has been undertaken under the direction of Sutherland Shire Council and their floodplain management committee. The committee includes councillors and Council staff, officers from the Department of Environment and Climate Change, the State Emergency Service and community representatives.

The study investigates flood behaviour throughout the Gwawley Bay catchment. This includes the analysis of:

(i) surface runoff across the catchment;

(ii) flows within the underground pipe drainage network;

(iii) flooding within Gwawley Creek and other watercourses towards the lower part of the catchment; and

(iv) backwater flooding in Gwawley Bay from the Georges River.

A two-dimensional computer model was established for the catchment to analyse flood behaviour under existing catchment conditions. The model provides information on the extent of flood inundation, flood depths and flood velocities throughout the catchment for design floods ranging from relatively frequent events to more extreme floods.

Results from this study will form the technical basis for the subsequent floodplain management study and plan. The floodplain management study will further identify problem areas and investigate options to reduce the risk of flooding.

The flood model developed during this study will also provide Council with a valuable tool in which to assess the flooding impacts of development applications that may be proposed in the future.

1.2 THE STUDY AREA

The study area is the catchment that drains to Gwawley Bay, at Sylvania Waters. Gwawley Bay is located on the south side of the Georges River, immediately upstream of the Captain Cook Bridge at Taren Point. A smaller catchment area draining to the Production Road Channel, on the east side of Taren Point Road, is also included in the study area.

The study area is shown on **Figure 1.1**. It is located within Sutherland Shire Council, and includes Sylvania Waters and parts of the surrounding suburbs of Sylvania, Taren Point, Caringbah, Miranda and Gymea.

The catchment area is approximately 9.2km^2. It is densely developed and contains a mix of residential, commercial and industrial development. Some development within the catchment is prone to flooding with potentially high hazard and damage.

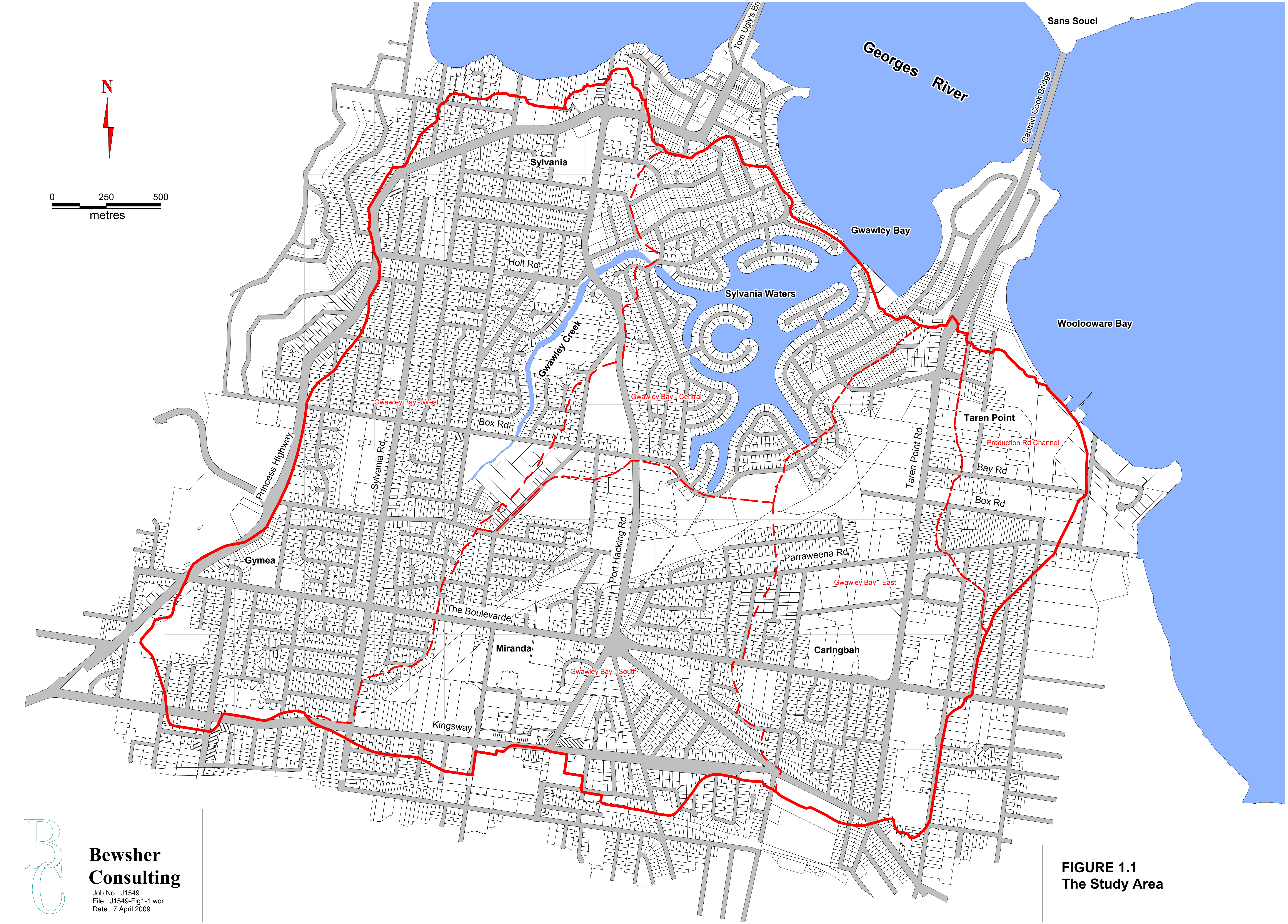

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FIGURE 1.1
The Study Area

1.3 THE GOVERNMENT'S FLOODPLAIN MANAGEMENT PROCESS

The prime responsibility for planning and management of flood prone land in New South Wales rests with local government. The NSW Government provides assistance on state-wide policy issues and technical support. Financial assistance is also provided to undertake flood studies and floodplain management studies, and for the implementation of works identified in these studies.

A Flood Prone Land Policy and a *Floodplain Development Manual* (NSW Government, 2005) forms the basis of floodplain management in New South Wales.

The objectives of the Policy include:

- reducing the impact of flooding and flood liability on existing developed areas by flood mitigation works and other measures; and
- reducing the potential for flood losses in new development areas by the application of ecologically sensitive planning and development controls.

The Policy provides some legal protection for Councils and other public authorities and their staff against claims for damages resulting from their issuing advice or granting approvals on floodplains, providing they have acted substantially in accordance with the principles contained in the *Floodplain Development Manual*.

The implementation of the Flood Prone Lands Policy generally culminates in the preparation and implementation of a Floodplain Management Plan. The Plan details Council's suite of works and measures to best manage its flood risk and its flood prone land. The Gwawley Bay Flood Study is one of the first steps in preparing the Plan, and involves an assessment of existing flood conditions throughout the catchment.

The steps in the floodplain management process are summarised on **Figure 1.2**.

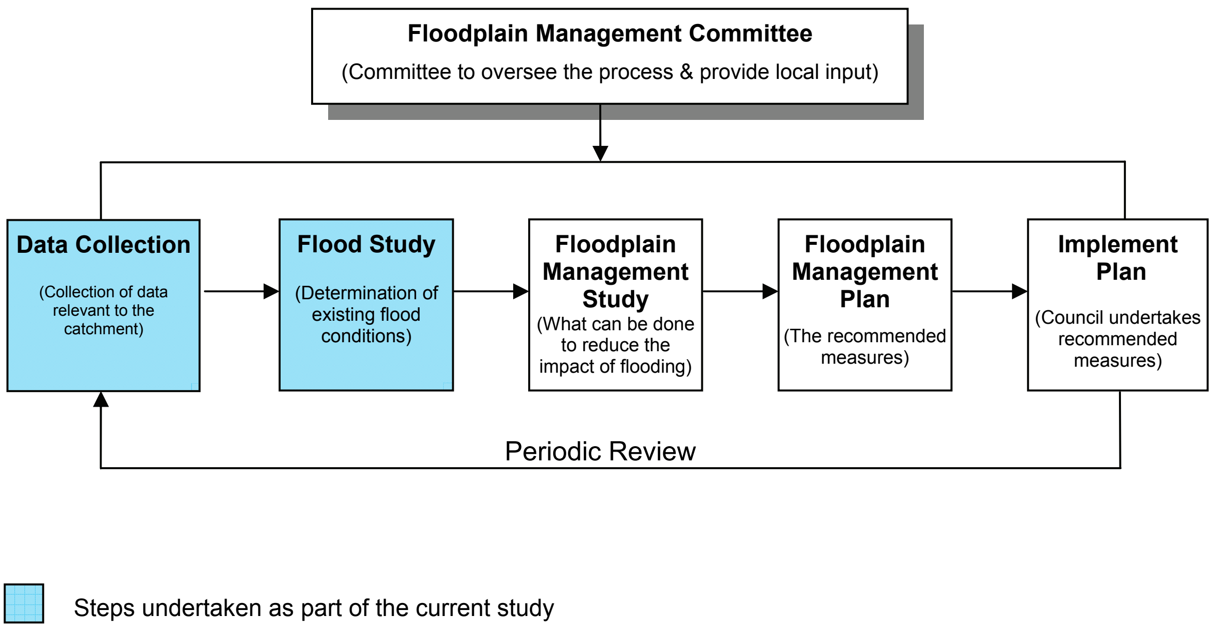

Figure 1.2
The Floodplain Management Process

1.4 OUTCOMES FROM THE STUDY

The main outcomes from the Gwawley Bay Flood Study include:

(i) a database of drainage assets within the study area;

(ii) establishment of a computer model capable of assessing flood behaviour;

(iii) information on flood behaviour under existing catchment conditions; and

(iv) a model that can be used to assess flood mitigation options and future development proposals.

1.5 STRUCTURE OF REPORT

This report is divided into the following chapters:

Chapter 1 – Background to the study

Chapter 2 – Catchment data collected for the study

Chapter 3 – Consultation activities

Chapter 4 – A summary of the adopted modelling approach

Chapter 5 – Description of flood behaviour

Chapter 6 – List of References

Chapter 7 – Glossary of terms used in this report

2 CATCHMENT DESCRIPTION AND AVAILABLE DATA

2.1 CATCHMENT DESCRIPTION

The study area includes the catchment that drains to Gwawley Bay and a smaller catchment that drains to Woolooware Bay via a channel known as the Production Road channel. The Gwawley Bay catchment has been further subdivided into four main subcatchments. Catchment areas are provided in **Table 2.1** and are shown on **Figure 1.1**.

Table 2.1
Catchment Areas within the Study Area

Catchment	Subcatchment	Area (km^2)
Gwawley Bay	West	3.25
Gwawley Bay	South	2.05
Gwawley Bay	East	1.75
Gwawley Bay	Central	1.58
Production Road Channel		0.54
Total Study Area		9.17

The Gwawley Bay Western subcatchment commences near the Kingsway at Gymea. It drains in a northerly direction through the stormwater pipe system to Corea Oval, where Gwawley Creek first becomes evident. Gwawley Creek continues to the north as a natural watercourse until finally joining Gwawley Bay at Sylvania Waters. There is a major gross pollutant trap on Gwawley Creek immediately downstream of Box Road, and another litter trap on the downstream side of Port Hacking Road.

Photo 1 – The start of Gwawley Creek in Corea Oval

Photo 2 – Gross pollutant trap downstream of Box Road

The Gwawley Bay Southern subcatchment commences near the Kingsway at Miranda. It drains in a northerly direction through a mix of stormwater pipes and narrow constructed channels. It joins the southern extremity of Gwawley Bay near the Southern Districts Rugby Club.

The Gwawley Bay Eastern subcatchment commences near the intersection of the Kingsway and Taren Point Road, at Caringbah. It drains to the north through the stormwater pipe system to Parraweena Road, and then on to Gwawley Bay through a series of short channels and culverts. A mix of commercial and industrial development occurs between Kumulla Road, Parraweena Road and Box Road. Some of this development restricts overland flow paths, and significant flood problems have been noted in the past.

The Gwawley Bay Central subcatchment is the remaining catchment area that drains directly to Gwawley Bay through the stormwater pipe system. There are approximately 70 stormwater outlets that drain to Gwawley Bay.

The Production Road Channel catchment commences south of Parraweena Road at Caringbah and drains a largely industrial area. It drains to the north through the stormwater pipe system to Bay Road, and then on to Woolooware Bay via a constructed channel, known as the Production Road channel. Significant flood problems have been noted in the past in the vicinity of Box Road and Bay Road.

Photo 3 – Open drain upstream of Port Hacking Road

Photo 4 – Production Road Channel

2.2 AERIAL PHOTOGRAPHY

Aerial photography is an important data source for the study, which helps to define the drainage network and other catchment characteristics required for modelling flood behaviour. Two sets of ortho-rectified aerial photography were provided by Sutherland Shire Council for the study area.

The first photography was undertaken in conjunction with Airborne Laser Scanning (ALS) terrain survey undertaken during October 2005. The second photography was flown in March 2006, and contains slightly improved resolution.

All photography has been incorporated into a geographical database (MapInfo). It provides a good mapping base to overlay other sources of information.

2.3 TERRAIN SURFACE

A requirement of the study is the analysis of surface flows and overland flow paths across the catchment. This requires detailed terrain survey over the entire study area. Available orthophotomaps, with 2m contour intervals, do not provide sufficient accuracy for this purpose.

Airborne laser scanning (ALS) survey was commissioned by Sutherland Shire Council at the commencement of the study. This technique captures the elevation of millions of ground points by a laser fitted to the underside of an aircraft. The points are then filtered and used to define a regular grid of ground points describing the terrain surface.

The ALS survey was captured by AAMHATCH in October 2005. A digital elevation model (DEM) was subsequently generated by Bewsher Consulting to provide a regular grid of elevation points across the study area at 1m spacing. The grid is used to define surface conditions in the computer model. It has also been used to generate 0.5m contours to assist with the delineation of catchment boundaries.

The accuracy of the ALS survey method is typically ±0.15m on clear ground. In heavily vegetated areas, or within narrow watercourses or drains, the ALS survey is less reliable and more traditional ground survey is required.

2.4 BUILDINGS AND OBSTRUCTIONS

The presence of existing buildings and other structures within the catchment can have a potential impact on flood behaviour, particularly if they are in or near an overland flow path.

Some buildings will be elevated on fill and may totally obstruct floodwater around the footprint of the building. Other buildings may be inundated, in which case floodwater can temporality pond within the building. Others may be elevated on piers, allowing some limited flow under the building. To complicate matters further, the impact of individual buildings will vary depending on the height of floodwater.

The footprint of all buildings within the study area has been digitised from aerial photography. These building footprints have then been included in the flood model to restrict the flow that is able to pass through each building (by assigning a high roughness coefficient to the building footprint).

Fences are another potential obstruction to flood flows. Many of these will have an impact in low flood conditions, but are likely to collapse as flood levels increase. The approach has been to allow an average impact (through increased roughness coefficients applied to urban blocks) for all fences within the study area. Other types of obstructions, including earth embankments and retaining walls, will be identified in the terrain surface.

2.5 DRAINAGE NETWORK AND FIELD SURVEY

The drainage network within the study area, shown on **Figure 2.1**, consists of:

- a network of underground drainage pits and pipes;
- overland flow areas or depressions;
- creeks or open channels (notably Gwawley Creek itself); and
- other hydraulic structures, such as culverts and bridges.

The network of drainage pits and pipe drainage was provided by Council in digital format. There are approximately 3,100 drainage pits and 3,000 stormwater pipes within the study area. Some of the data assigned to these drainage elements were found to be incomplete or missing. Consequently, Council was asked to confirm details for the major pipe drainage network (generally those pipelines with a diameter of 750mm or greater).

Overland flow areas and depressions will be evident from the digital elevation model. Further field survey was not considered necessary.

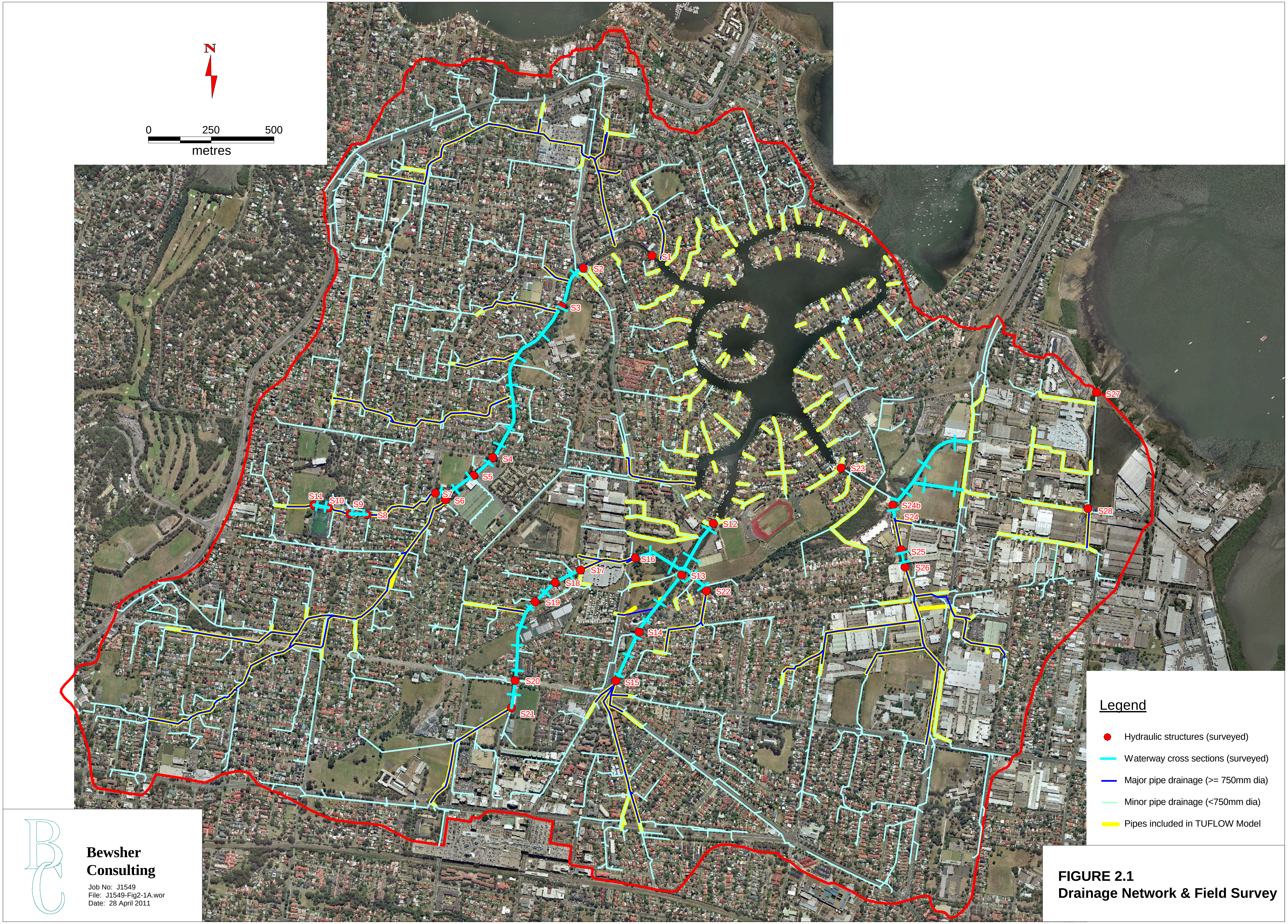

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FIGURE 2.1
Drainage Network & Field Survey

Many of the creeks and open channels will be visible in the aerial photographs and surface levels can be extracted from the digital elevation model. However, many of these areas also contain heavy vegetation and therefore ground levels sourced from the ALS survey may be less accurate. The ALS survey is also unable to provide levels below water level. Field survey was undertaken by Sutherland Shire Council to more accurately define the shape and capacity of the creeks and open channels.

There are some 28 culverts, bridges or other hydraulic structures within the study area. Field survey was undertaken by Council during 2004/5 to confirm the dimensions for each structure.

2.6 PREVIOUS REPORTS AND PLANS

A number of previous reports, survey drawings and other plans were provided by Sutherland Shire Council for the study area. These are located geographically on **Figure 2.2** and are summarised in **Table 2.2**.

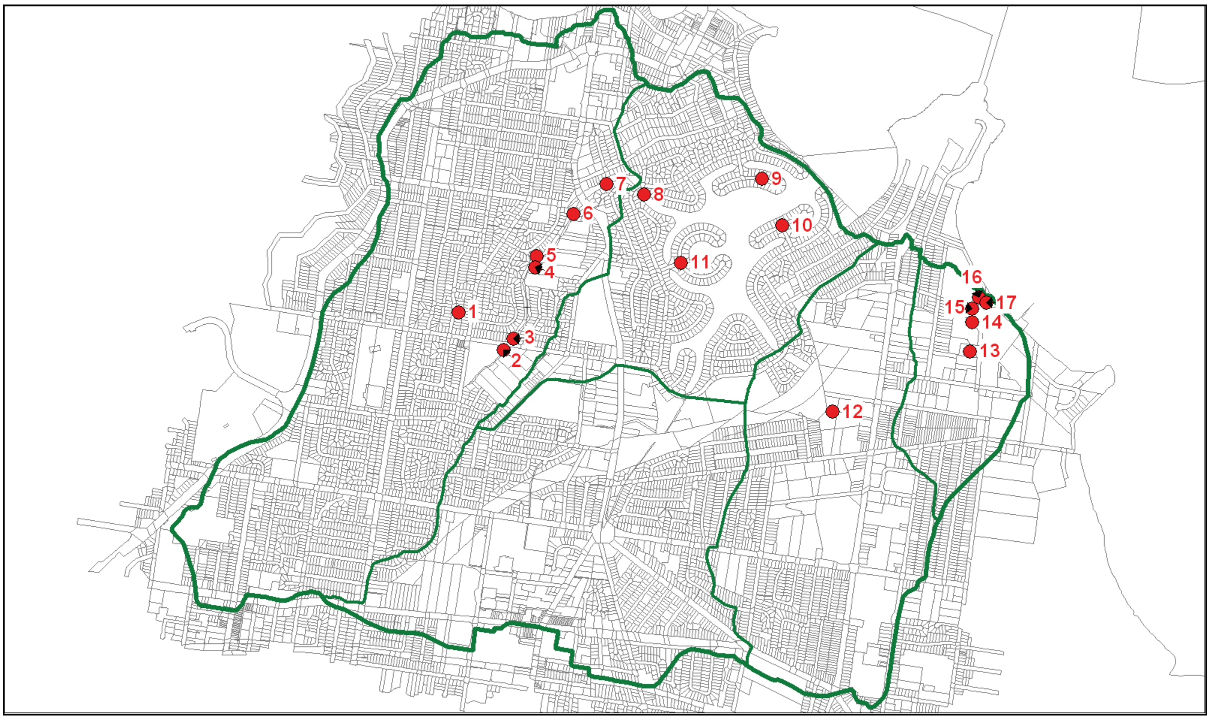


Figure 2.2
Location of Available Reports, Survey and other Plans

Stormwater drainage plans are available for a local drainage area in the vicinity of Craigholm Street, Sylvania (Ref 1). There are significant differences in the size of the drainage pipes shown on these plans when compared with Council's drainage database.

Survey of Gwawley Creek and some of the structures on the creek are available (Refs 2, 3, 4, 5, 6, 7, 8). The most extensive creek survey (Ref 5) extends between Box Road and Port Hacking Road. However this survey is now over 26 years old and may no longer be representative of the creek today. Survey of the lower reaches of Gwawley Creek, downstream of Port Hacking Road (Ref 8), is more recent and provides good detail of the creek in this area.

Table 2.2
Available Reports, Survey & Plans

Ref	Name	Description	Comment
1	Craigholm Street, Sylvania - Drainage Investigations, SSC, Dwg 12006, 4 sheets	Plan shows existing and proposed pipes, kerbs & gutters	All pipes >750mm differ from those shown in Council's GIS (between Durham Pl & Corea Rd)
2	Box Road, Sylvania - Detail Survey of Gwawley Creek, SSC Dwg 13202, Dec 95	Creek survey	Provides details of culvert u/s of Box Rd (3 x 1350 pipes) and Box Rd Culverts (structure not detailed)
3	Gwawley Ck - Gross Pollutant Trap, SSC Dwg 13250, March 1996	Design drawings of GPT	Provides levels and layout of existing GPT. No culvert dimensions under Box Rd.
4	Gwawley Creek Stabilisation Works, Box Rd to Port Hacking Rd, SSC Dwg 12875, 1994	Shows proposed bank stabilisation measures at three sections	Bank stabilisation using large boulders at three separate locations. No survey data provided.
5	Gwawley Creek - Box Rd to Port Hacking Rd - SSC Dwg 6401, Dec 1980	Creek survey	Reasonable survey of Gwawley Ck, but survey is 26 years old. New survey warranted. ALS is blocked by heavy vegetation.
6	Port Hacking Rd, Sylvania - Detail survey of Gwawley Ck between Leichhardt Cr and Willowbrook Pl. SSC Dwg 13147, Aug 95	Creek survey	Good invert and bank levels provided. Good supplement to ALS from PH Rd to u/s timber bridge.
7	Port Hacking Rd, Sylvania `Waters - Gwawley Ck embankment stabilisation Port Hacking Rd to Belgrave Esp. SSC Dwg 1399	Plan showing proposed gabion bank protection works	Includes good survey cross sections at 20m intervals. Also very recent.
8	Port Hacking Rd, Sylvania Waters - Detail survey Gwawley Ck Port Hacking Rd to Belgrave Esp. SSC, Dwg 13690, Dec 98	Creek survey	Provides invert and bank levels for lower Gwawley Ck. Good supplement to other survey d/s of Belgrave Esplanade
9	Murray Island (Eastern End) - Sylvania Waters Gutter Invert Levels, SSC Dwg 7828, June 1987	Monitoring settlement on island.	Gutter has sunk from 0.97m (1971) to 0.61 (1993). Similar level shown in ALS (2005) - mainly eastern end.
10	Barcoo Island, Sylvania Waters, Kerb Levels. SSC Dwg 6599	Monitoring settlement of island (between 1982 and 1985).	Negligible difference in historical levels.
11	James Cook Island, Sylvania Waters - Kerb Levels SSC Dwg 6594	Monitoring settlement of island (between 1982 and 1992)	Appears to be fairly negligible difference (typically less than 30mm).
12	Flood Study for Proposed Subdivision at No. 70-78 Box Rd Taren Point	Tuflow modelling	Detailed modelling of site downstream of Parraweena Rd, including overland flow paths.
13	Proposed Alterations & Additions No 3 Production Rd, Taren Point	Investigates effects of filling site above 100 year flood and effects of increase in impervious areas	Provides typical cross sections of channels. Refers to Taren Point Flood Study, Thomson Kane, 2002.
14	Taren Point Flood Study, Young Consulting Engineers, Sept 2003	Report to accompany DA for proposed retirement village and light industrial Complex.	Basement car parking proposed. Refers to previous FS by Taylor Thomson Whitting on east of channel
15	Anglican Retirement Village - Drawings by Young Consulting Engineers, Dec 2003. Some rehabilitation reports also.	Drawings showing proposed filling and channel works to alleviate flooding on site	Drainage easement to contain 100 year flood. New channel seems to be well represented in ALS.
16	HEC-RAS Cross Sections - for proposed culvert extensions	Assessment for proposed culvert extensions (near Woolooware Bay)	3 cell culvert, 55m long. Left bank of channel (adjacent to Production Rd) appears to be higher than ALS data
17	Internal report by Council concerning relocation of the Anglers Club to accommodate the flood mitigation scheme	Report on possible compensation	The Club's building is still evident in the 2006 aerial photo.

Historical surveys (Refs 9,10,11) have been undertaken on Murray Island, Barcoo Island and James Cook Island to monitor potential settlement. This provides useful information on the amount and rate of settlement on these islands. Murray Island in particular appears to have settled by over 0.4m since 1971.

A number of reports have been prepared for specific flood investigations. These include investigations for a proposed subdivision at Box Road (Ref 12) and for development adjacent to the Production Road Channel (Refs 13,14,15,16,17).

2.7 HISTORICAL FLOOD DATA

The most recent significant flooding within the Gwawley Bay study area occurred on 13th May 2003. Newspaper reports and correspondence received by Council record heavy damages to factories, houses and motor vehicles. About 60 factories are reported to have been flooded in Bay Road, Taren Point. Two photos of flooding along Parraweena Road were provided by the Sutherland Leader (from publications on 15th May, 2003 and 3rd June 2003).

Photo 5 – Parraweena Road in flood, May 2003

Photo 6 – Garden Centre, Parraweena Road, May 2003

A database of resident complaints was established by Council following this flood. The database comprises a total of 130 complaints in the vicinity of the study area. These complaints have further been subdivided into the following 5 categories:

i) Reference to flooding above floor level – 14 complaints
ii) Reference to flooding on property – 44 complaints
iii) Flooding on adjacent roadways – 17 complaints
iv) Stormwater Maintenance issues – 37 complaints
v) Complaints unrelated to flooding – 18 complaints.

Theses complaints were fairly evenly distributed across the catchment, as shown on **Figure 2.3**. Although 14 complaints refer to flooding above floor level of the premises (either commercial or residential), there is no definitive information on actual flood heights. There have also been reports that blockage of drains largely contributed to the flooding problems.

There is no data on other historical flood events.

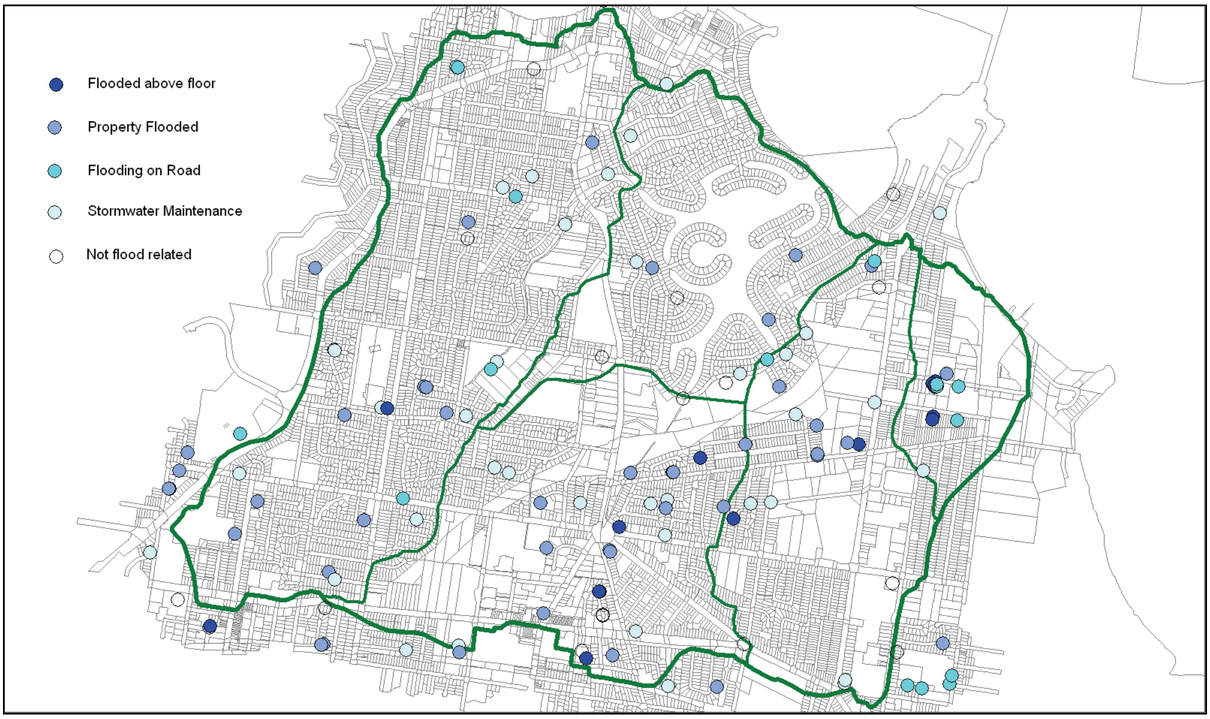


Figure 2.3
Complaints Database – Location & Type of Complaint

There are no daily rainfall stations or pluviographs stations within the catchment. The rainfall associated with the flood was quite variable over Sutherland Shire. Rainfall recorded at three pluviographs stations indicated the following 2 hour rainfall totals:

- Cronulla South Bowling Club 46mm (1-2 years)
- Lucas Heights 29mm (<1 year)
- Audley, Royal National Park 97mm (20 – 50 years)

It is noted that all of these stations are quite remote from the study catchment.

2.8 ASSEMBLY OF DATA WITHIN A GIS DATABASE

All data that has been collected for the study has been assembled within a GIS database using MapInfo software, suitably tagged with a source identifier. This allows the data to be spatially represented across the study area, and allows for easy retrieval of the data as required. The data is stored in different "layers" which can be displayed individually, or superimposed onto other layers. Links to photographs and sketches were also included within the system.

The database can also be exported to other GIS systems.

3 COMMUNITY CONSULTATION

3.1 CONSULTATION PROCESS

Community consultation is an important component in the development of a floodplain management plan. Consultation provides an opportunity to collect feedback and ideas from the community on problem areas and potential floodplain management measures. It also provides a mechanism to alert the community about the flood risk, and to improve their awareness and readiness for flooding.

The main consultation elements for this study include:

i) presentations to Council's floodplain management committee;

ii) a community questionnaire;

iii) a web site on the internet; and

iv) further consultation as the floodplain management plan is developed.

These elements are discussed further below.

3.2 FLOODPLAIN MANAGEMENT COMMITTEE

The Lower Georges River and Gwawley Bay Catchment Floodplain Management Committee provided assistance in the preparation of the Gwawley Bay Catchment Flood Study, and will continue to have an important role as the floodplain management plan is developed. The committee comprises representatives from:

i) Sutherland Shire Council (elected councillors and staff);

ii) Department of Environment and Climate Change (DECC);

iii) State Emergency Service (SES);

iv) NSW Maritime;

v) residents from Sylvania Waters; and

vi) other community representatives.

The committee allows for the views of a diverse range of stakeholders to be considered during the floodplain management process.

3.3 COMMUNITY QUESTIONNAIRE

A letter and questionnaire was distributed to residents and business owners adjacent to waterways and other main drainage paths during 2007, as shown in **Figure 3.1**. A copy of the letter and questionnaire is included in **Appendix A**.

The letter provided information about the study, and encouraged participation in the project through the questionnaire. It also provided details concerning the floodplain management committee, and invited nominations for the committee.

The questionnaire sought information on floods that have been experienced in the catchment, issues that the study should look at, and ideas on reducing flood problems.

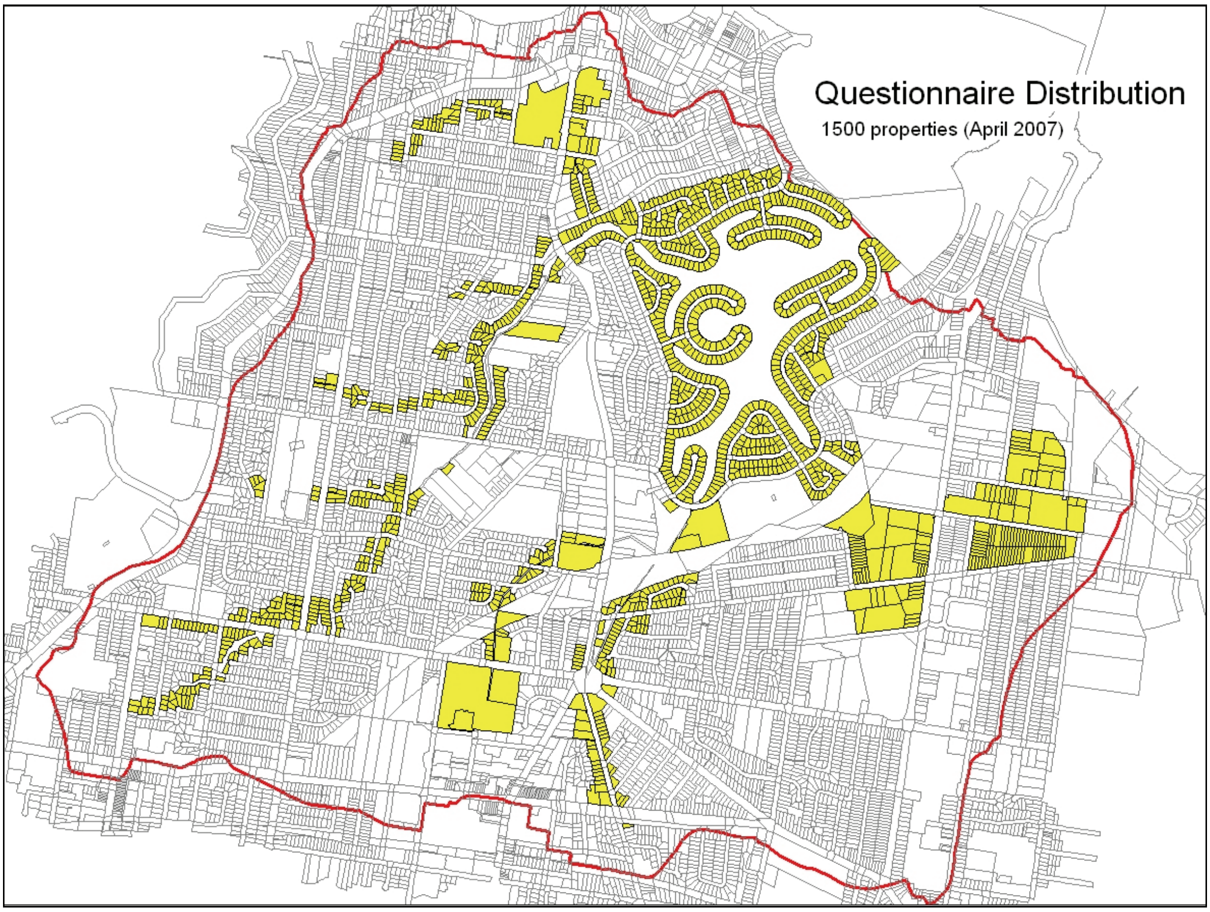


Figure 3.1
Properties that Received a Questionnaire

Approximately 1500 questionnaires were distributed, of which 228 responses (15%) were received.

Some 25 respondents indicated that they had experienced flooding above floor level. Details concerning the date and depth of flooding are recorded in **Table 3.1**. Whilst there appears to be some degree of uncertainty and range in dates nominated, the May 2003 flood is clearly the most nominated flood event. The depth of flooding above floor level ranges from a minimum of 0.005m up to a maximum of 0.5m. The average depth of flooding per dwelling/business is 0.24m.

The main issues raised by the community for the study are shown in **Table 3.2**. The most common responses include the need to clear debris, rubbish and vegetation from drains (18 responses), general stormwater issues (15 responses), and that more information on flooding be provided (13 responses).

The main ideas provided by the community on reducing flood problems are shown in **Table 3.3**. The most common responses include improved stormwater drainage (27 responses), better maintenance (22 responses) and the clearing of rubbish, debris and vegetation from drains (21 responses).

Table 3.1
Residents and Business Owners Experiencing Above Floor Flooding

ID	Type of property			Previous Flooding			
	House	Unit	Bus	Above Floor	Below Floor	When	Depth above floor (m)
2	1		1	1		Twice over 30 years	0.05
20	1			1		Early 2003	
31	1			1		2002-2003	
32	1			1		May 2003	0.3
38	1		1	1		about 1999, 2004	0.25
39			1	1		about 1999, 2004	0.3
53			1	1		May 2003	0.07
54			1	1		2002-2003	0.4
60	1			1		1975/1997	0.01
65			1	1		May 2003	0.5
66			1	1		May 2003	0.5
67			1	1		May 2003	0.5
71	1			1		1973	0.01
72			1	1		2002-2003	0.4
79			1	1		4 or 5 years ago	0.1
101	1			1		May 2003	0.03
121	1			1		Numerous times	0.3
133			1	1		May 2003	
148	1			1		Twice	0.1
152	1			1		2003	0.005
178			1	1		May 2003	0.5
187			1	1		2005 approx	0.5
201		1		1		1987, 1995??	0.03
202	1			1		A few years ago	0.1
209			1	1		A few years ago	0.3

Table 3.2
Main Issues Raised by the Community

Issues Raised	Times Raised	Ranking
Clear debris, rubbish or vegetation from drains	18	1
General stormwater issues	15	2
Would like more information	13	3
Flooding from creeks or open drains	7	4
Flooding of roads	7	5
Global warming and sea level rise	6	6
Increase pipe drainage	6	7
Impact of recent catchment development on flooding	6	8
Siltation, need for dredging waterways	4	9
Flooding of garages	3	10
Sewage overflows	3	11
Flood problems at high tide	3	12
Flooding caused by neighbouring development	2	13
Re-cycling or harvesting runoff	2	14
Problems due top piping open flow paths	2	15
Inadequate hydraulic structures	2	16
Tidal barriers to flooding	1	17
Better planning	1	18

Table 3.3
Community Ideas on Reducing Flood Problems

Ideas on reducing flooding	Times Raised	Ranking
Improved stormwater drainage	27	1
Better maintenance of stormwater system	22	2
Clear rubbish, debris & vegetation	21	3
Rainwater tanks/OSD	6	4
Stormwater harvesting	4	5
Pumping facility to bay or river	4	6
Improved planning and flood management	4	7
Widen creeks, drains	3	8
Erosion control measures, stabilise creek banks	3	9
Dredge creeks, waterways	2	10
Levee banks	2	11
Infiltration measures, permeable driveways, etc	2	12
Stormwater diversions	2	13
Keep sewer/stormwater flows separate	2	14
Kerb & guttering	2	15
Enclose waterway areas	1	16
Install floodgate valves on outlet pipes	1	17
Measures to prevent blockage	1	18
Allow overflow over bridges	1	19

3.4 WEB SITE ON THE INTERNET

A web site was prepared on the internet for posting information about the study, which was made available at: www.bewsher.com.au/studies-gwawley.html.

The web page provides:

i) general information about the study;

ii) a map of the study area;

iii) a copy of the community questionnaire; and

iv) who to contact for more information.

It is anticipated that further details will be posted on the web page as development of the floodplain management plan progresses, including copies of any reports that may be placed on public exhibition.

3.5 FURTHER CONSULTATION ACTIVITIES

It is anticipated that the flood study report will be placed on public exhibition prior to formal adoption by Council. The flood study report would typically be exhibited for a period of 6-8 weeks.

The floodplain management committee will continue to have a major role in the development of the floodplain management study and plan, which are the next steps of the floodplain management process for the Gwawley Bay catchment. The floodplain management study and plan would also be normally placed on public exhibition when they have been prepared, so that the community has an opportunity to further comment on the proposed floodplain management measures.

4 MODELLING APPROACH

4.1 COMPUTER MODELS

Flooding within the Gwawley Bay catchment is a mixture of urban stormwater drainage, overland flow paths, riverine flooding and tidal inundation.

It is usual to use two different types of computer models to analyse flood behaviour. The first type of model is a hydrologic model that simulates the rainfall-runoff process within the catchment. This model produces flows throughout the catchment which are then input to a second hydraulic model that requires catchment runoff data in order to calculate flood levels and flood velocities throughout the creek and drainage system.

The modelling approach adopted for this study involves the use of a RAFTS hydrologic model for estimating catchment flows and a TUFLOW hydraulic model to estimate flood levels and velocities.

RAFTS is a commercially available rainfall-runoff computer model that was developed in Australia by WP Software. The model has been widely applied to flood studies undertaken in Australia, particularly in NSW. Application of the RAFTS model requires the catchment to be divided into a number of smaller subcatchment areas. Rainfall is applied to each subcatchment and a runoff hydrograph generated at the outlet of these areas. These runoff hydrographs are then used as input to the hydraulic model. Further details about the RAFTS model is provided in **Section 5.1**.

Some consideration was given to using a pipe network model, such as DRAINS or MIKE-STORM to analyse flood behaviour within the stormwater pipe system. This would necessitate the analysis of some 3,100 stormwater pits and 3,000 separate stormwater pipes. Given that much of the stormwater data is incomplete and contains some questionable data, this would have required substantial data collection, which was not considered warranted. It was also considered that the majority of flow throughout the study area is conveyed as surface flows within overland flow paths and other watercourses, which is suitably analysed using a combination of the RAFTS and TUFLOW models.

TUFLOW is a hydraulic model that was developed by BMT WBM in Queensland. This flood model that has been used in over 200 applications in NSW, Queensland, Victoria, South Australia, Tasmania, and also in the UK. TUFLOW is a two-dimensional model that is capable of modelling urban overland flow paths and surface flows where there are numerous obstacles and other variations in flow paths. The surface terrain is represented as a regular grid of ground points across the study area, which has been derived using Council's ALS survey. A 3m grid size was adopted for this study. Digitised building outlines and aerial photography have also been used to identify obstructions and surface conditions within the 2D model.

TUFLOW has the ability to include creeks and other watercourses as nested 1D elements within the 2D network. Gwawley Creek and the other drains and watercourses have been included in the model as 1D elements. These elements are described be a series of cross sections, derived from available plans or surveyed by Sutherland Shire Council. Bridges, culverts and other hydraulic structures are also included as 1D elements within the model.

Further details about the TUFLOW model are provided in **Section 5.2**.

4.2 STORMWATER PIPE DRAINAGE

TUFLOW has the ability to include stormwater pipes as 1D elements within the model. However, as there are over 3,000 separate stormwater pipes within the study area, and many of these have incomplete data, it was not considered practical to include all stormwater pipes in the model.

The stormwater pipe drainage network is typically designed for frequent flood events only, and in larger floods the amount of water carried in the pipe network is usually small in comparison with the total surface flow. Smaller pipelines also have a greater propensity to become blocked by debris and are likely to be ineffective in most flood situations.

It was originally intended to only include the larger pipelines, with a diameter of 750mm or greater, in the TUFLOW model. These pipelines were identified from the original dataset provided by Council, and dimensions verified by Council officers in the field.

The modelling approach was further discussed with Sutherland Shire Council and the Department of Environment and Climate Change officers once preliminary model results were available. Substantial flooding was estimated around the foreshore of Gwawley Bay (Sylvania Waters), which was most likely exacerbated by excluding pipelines with a diameter less than 750mm. This area relies on drainage through a multitude of small drainage pipelines. Given the number of pipelines, and the absence of any other drainage mechanism, these smaller pipelines could have a more significant influence on flood behaviour in these areas. A similar situation applies to a number of low depressions along other roads where smaller pipelines provide the only drainage mechanism. Subsequently, an additional 227 pipelines were recommended for inclusion in the hydraulic model to improve the representation of flood behaviour.

4.3 BLOCKAGE ASSUMPTIONS

The potential for culverts or other hydraulic structures to become blocked by debris during floods has gained increased recognition in recent years. Fallen trees, vegetation, shopping trolleys, garbage bins and floating cars can all potentially become trapped on the upstream side of culverts, significantly reducing the capacity of these structures.

Blockage problems were identified as a major contributor to the devastation caused throughout the Wollongong area during the August 1998 floods. In many cases, the hydraulic capacity of culverts, bridges and underground pipe systems was completely eliminated or severely restricted as a result of the blockages. In response to these problems, Wollongong City Council adopted a culvert blockage policy that assumes 100% blockage of all structures where the clear opening is less than 6m. A number of other Councils have since adopted a 50% blockage policy when undertaking flood studies.

Blockage problems were also a significant factor to widespread flooding problems experienced throughout the Newcastle district in June 2007. There were many examples of cars and other large objects blocking the entrance to culverts. There is also some evidence of potential blockage problems within the Gwawley Bay catchment following a minor storm experienced within the catchment during 2007 (Photos 5 and 6).

The potential for culvert blockage was discussed with the floodplain Management Committee during 2008. Following further discussion with Council officers, it was decided to apply a 50% blockage factor to the waterway area of all bridges, box culverts, or pipe culverts within the study area where the clear opening is less than 6m.

Blockage factors of 20% and 50% have also been applied to on-grade and sag pits respectively, in accordance with Sutherland Shire Council policies and industry standards.

Photo 7 – Example of recent debris blockage at culvert

Photo 8 –stormwater grate blocked following a minor storm

4.4 MODEL VERIFICATION

It is usual practise to calibrate or verify flood models against historic data where such information exists. The process includes simulating a known flood event and comparing computed flood levels with recorded flood levels. Model parameters can also be adjusted (calibrated) to match the recorded flood heights.

There are several river gauges on the Georges River for which historical flood data is available. These include river gauges at Liverpool, Lansvale, Milperra, East Hills and Picnic Point. These gauges provide information on flooding within the Georges River, which is associated with long duration storm events typically in excess of 36 hours. They provide little information on flooding that may be experienced in local catchments, such as the Gwawley Bay catchment, where flooding is typically caused by local thunderstorms with durations less than a few hours. The river gauges are also located too far upstream to be on any benefit in verifying model results for Gwawley Bay.

There are no river gauges or flood height recorders within the Gwawley Bay catchment to record historical flood height data. The only available flood records are from personal observations from residents or business operators who may have experienced flooding within the catchment.

Significant flooding was reported to have occurred within the catchment on 13th May 2003. Sutherland Shire Council established a database to record complaints received in relation to this flood. Most complaints were related to blockage problems in the stormwater network, and other stormwater maintenance issues. There were a total of 44 references to flooding within yards, and 12 instances of above floor flooding reported in the study area. Only one of these complaints included a depth of flooding above floor level.

Additional historical data was sought through the community questionnaire. Some 25 respondents indicated that they had previously experienced above floor flooding. Most incidents of flooding appear to relate to the 2003 flood, although many respondents were uncertain of the actual date or provided a descriptive reference only (for example *'twice over 30 years'* or *'numerous times'*).

Model verification requires simulation of a particular flood event and the comparison of computed flood levels with recorded flood levels. In order to simulate the May 2003 flood, adequate rainfall records are required to describe the rainfall total over the catchment and the distribution of this rainfall over time. Unfortunately there are no rainfall stations or pluviograph (shorter duration) stations within the catchment.

Rainfall recorded at the three nearest pluviograph stations are shown in **Table 4.1**. An average recurrence interval has been assigned to different duration intervals within the storm, based on a comparison with rainfall intensity-frequency-duration tables prepared by Sutherland Shire Council. In addition to these records, 3 hour rainfall totals are available for Peakhurst (52mm), San Souci (70mm) and Little Bay (36mm) (Source: *Australian Weather News – 13 May 2003*).

Table 4.1
Pluviograph Records for the May 2003 Flood
(Source: Sutherland Shire Council)

Station	Period	Max Rainfall	Average Recurrence Interval
Cronulla South Bowling Club (east of Gwawley Bay)	10 mins	12	< 1 year
	20 mins	17	< 1 year
	30 mins	20	< 1 year
	1 hour	27	< 1 year
	2 hours	46	1-2 year
	3 hours	66	2-5 year
	6 hours	104	5-10 year
	12 hours	121	2-5 year
Lucas Heights (west of Gwawley Bay)	10 mins	5	< 1 year
	20 mins	8	< 1 year
	30 mins	11	< 1 year
	1 hour	18	< 1 year
	2 hours	29	< 1 year
	3 hours	38	< 1 year
	6 hours	52	< 1 year
	12 hours	62	< 1 year
Audley, Royal National Park (south of Gwawley Bay)	10 mins	13	1-2 year
	20 mins	22	1-2 year
	30 mins	29	2-5 year
	1 hour	53	5-10 year
	2 hours	97	20-50 year
	3 hours	108	20-50 year
	6 hours	137	10-20 year
	12 hours	154	5-10 year

The above records highlight the highly variable nature of the May 2003 storm over the southern suburbs of Sydney. It is not possible to say with any certainty how much rainfall would have been experienced over the Gwawley Bay catchment, or how this rainfall would have been distributed over the duration of the storm. Given this uncertainty, it is not possible to accurately simulate this flood event, and a formal verification of the model is therefore not possible.

Nevertheless, a qualitative verification of the model has been attempted by comparing the distribution of reported above floor flooding from the database and questionnaire with the extent of flooding predicted by the flood models for a 20 year flood. The 20 year flood was selected on the basis that the 2003 flood appears to have been the largest flood reported by residents in the area, the majority of whom are expected to have resided at this address for up to 20 years. It is also unlikely that the event would have exceeded a 20 year flood based on the available pluviograph records.

A comparison of those areas where above floor flooding has been reported with the 20 year flood extent computed by the TUFLOW model is shown on **Figure 4.1**. There is reasonable agreement between those areas where flooding has been reported and the 20 year flood.

The distribution of the recorded flooding is distributed across the study area, but does confirm a few problem areas in particular, including:

i) Parraweena Road (Miranda/Caringbah);

ii) Box Road, Caringbah; and

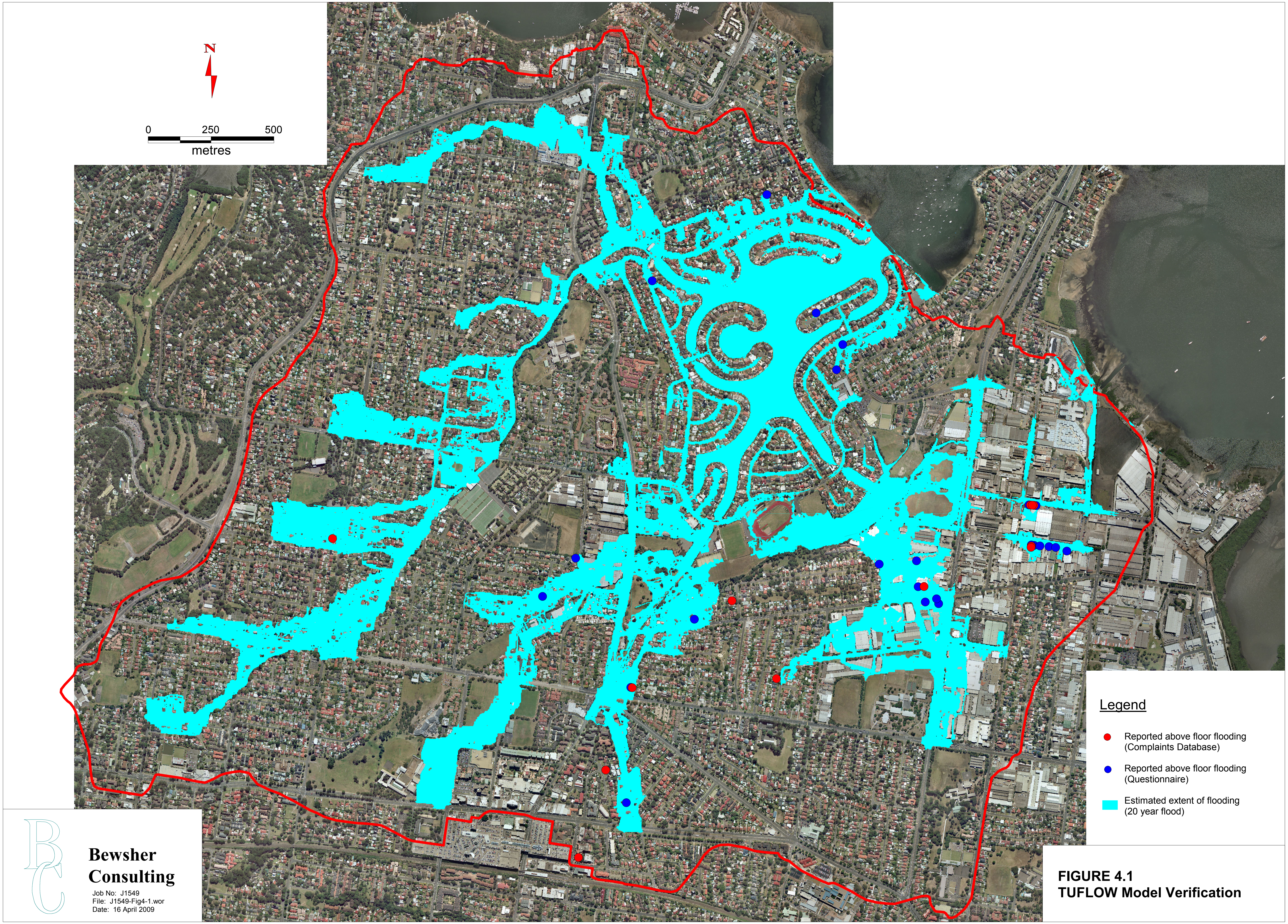
iii) Bay Road, Taren Point.

4.5 MODEL LIMITATIONS

A 2m grid size is normally preferable for modelling urban catchments. Given the size of the Gwawley Bay study area this was not possible, and a larger 3m grid spacing was required in order to keep model run times within practical limits (less than 24 hours). The adopted grid size provides some limitations when modelling narrow flow constrictions. For example, where houses or other structures are less than 3m apart, the model may not faithfully represent the constriction between these features, and some averaging effects may result. Future use of the model to analyse development proposals, or to provide improved resolution in critical areas, could incorporate a finer nested grid to represent the area of interest.

The representation of the terrain surface through the ALS survey has an order of accuracy of 0.15m, and some artificial fluctuation of the terrain surface is evident. Prediction of flood depths that are less than 0.1m is therefore uncertain. Other areas subject to flood inundation may also have a 'fuzzy' boundary within this tolerance. Further filtering of the flood inundation extents derived by the flood model may be warranted during the floodplain management study to improve these boundaries.

Given the uncertainties discussed above, and the variable nature of the historical flood and rainfall data to permit a formal calibration of the flood model, it is considered that flood level results from the model have an absolute accuracy of about ±0.3m. This should not be confused with the relative accuracy of the model to assess flooding impacts from proposed development and flood mitigation options, which would typically have an accuracy of ±0.01m with this type of model.



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Date: 16 April 2009

FIGURE 4.1
TUFLOW Model Verification

5 DESCRIPTION OF FLOOD BEHAVIOUR

5.1 RAFTS HYDROLOGIC MODELLING

Design flows throughout the catchment were determined using the RAFTS hydrologic model (Version 5.0). These flows were subsequently used as inflows to the TUFLOW hydraulic model to simulate flood behaviour throughout the study area.

The catchment was divided into 248 smaller subcatchments for the RAFTS analysis. Subcatchment boundaries were based on topography, the pipe drainage network, and other areas where inflows to the TUFLOW hydraulic model were desirable. A map of the catchment subdivision is shown on **Figure 5.1**.

Each subcatchment was further divided into pervious and impervious fractions. This was determined by measuring the area of different landuse categories within each subcatchment (from aerial photography) and applying an average impervious percentage for each landuse category. The following landuse categories were adopted:

i) normal residential;

ii) strata development;

iii) industrial development;

iv) schools;

v) road areas;

vi) grassed areas;

vii) densely vegetated areas; and

viii) waterway areas.

Rainfall hyetographs are applied to each subcatchment to determine catchment runoff. Rainfall hyetographs are derived by calculating an average rainfall intensity and applying a rainfall pattern to distribute this rainfall over the duration of the storm. Rainfall intensities were based on standard Intensity-Frequency-Duration data derived by Council for use in Sutherland Shire. This data was found to closely agree against values calculated in accordance with *Australian Rainfall and Runoff*. Rainfall totals were distributed in accordance with patterns recommended in *Australian Rainfall and Runoff*.

Areal reduction factors are sometimes applied to rainfall intensities to account for likely variation across the catchment. This is more often applied to larger catchment areas where greater variability in rainfall is likely. *Australian Rainfall & Runoff* notes that no areal reduction factor would normally be required for smaller catchment areas (eg $4km^2$) or where short duration floods are critical. The largest individual catchment within the Gwawley Bay study area is $3.25km^2$. Hence no areal reduction factors have been applied to the design rainfall intensities.

Rainfall loss rates are also applied to each individual subcatchment in the RAFTS model to account for infiltration into the ground. Different loss rates were applied to pervious areas and to impervious areas. Adopted loss rates were as follows:

Pervious areas	IL=15mm	CL=1.5mm/hr
Impervious areas	IL=1.5mm	CL= 0mm/hr

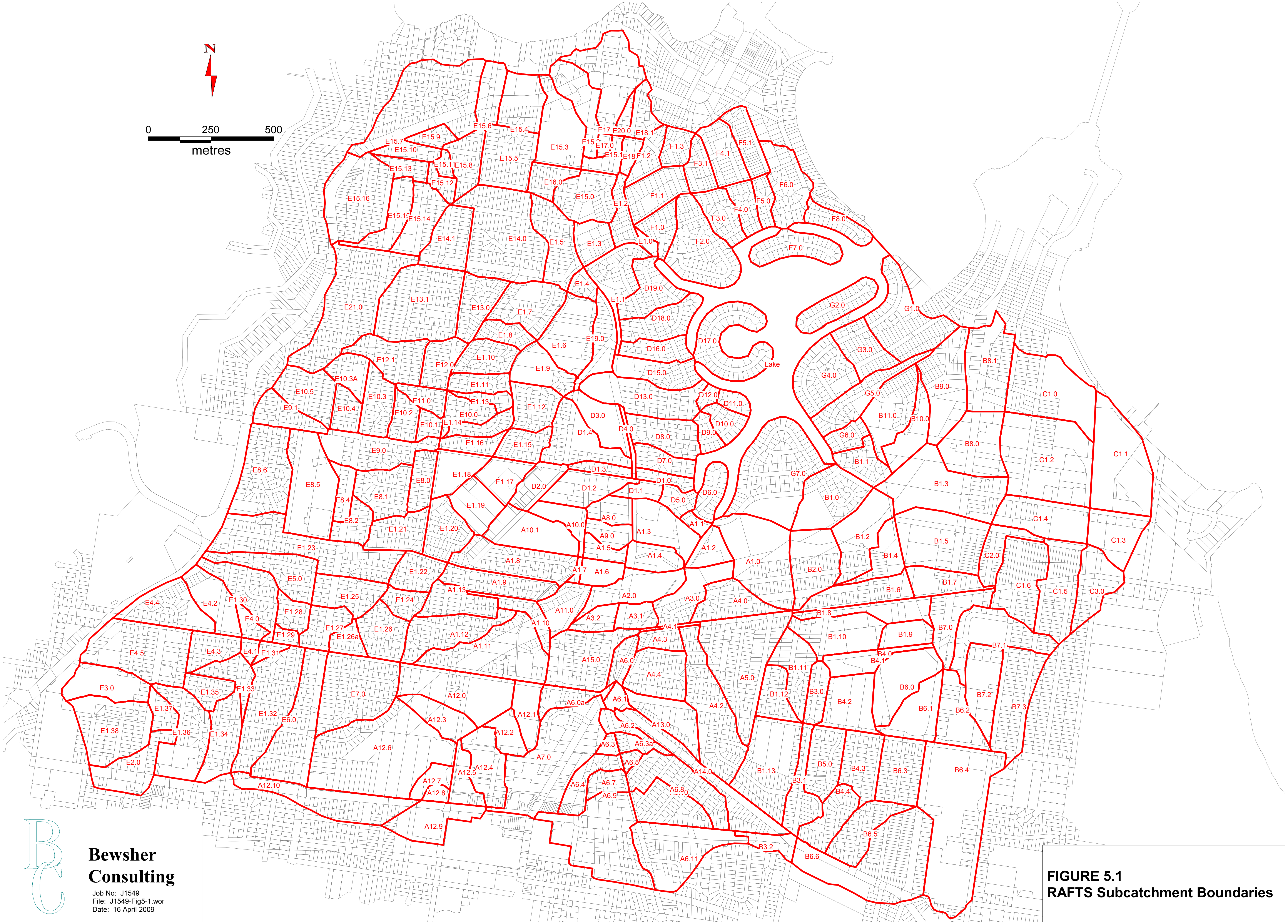

FIGURE 5.1
RAFTS Subcatchment Boundaries

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A range of storm durations was tested to determine which durations provided the highest flows throughout the catchment. These tests were undertaken on the 100 year flood, for storm durations varying between 25 minutes to 12 hours. Storm durations between 1 and 2 hours generally produced the highest flows throughout the catchment. A range in storm durations were also tested using the TUFLOW model to check the critical duration producing the highest flood levels.

Design flow estimates have been provided for the 5 year, 20 year, and 100 year average recurrence interval floods. Estimates have also been provided for the more extreme probable maximum flood. Design flow estimates from the RAFTS model for the 100 year flood are included in **Appendix B**.

RAFTS provides two types of flow hydrographs for each subcatchment. Local flow hydrographs are calculated for the individual subcatchment area alone, whilst total hydrographs provide a cumulative total moving downstream. The total hydrograph relies on simple lagging and addition of upstream hydrographs, based on distance travelled and an average velocity. More rigorous routing through flood storage areas occurs in the TUFLOW model, and flows derived from this model are more reliable in the lower reaches of the catchment.

5.2 TUFLOW HYDRAULIC MODELLING

Different modelling methods can be applied according to the floodplain's hydraulic characteristics and the objectives of the study. The simpler methods lump the left and right overbank floodplain areas with the main channel in a one-dimensional (1D) representation. This approach is relatively simple and the computational process fast. The main limitation, however, is that flow is assumed to occur in a linear direction, and the levels across the floodplain are assumed to be at the same level as the main channel.

A more detailed two-dimensional (2D) approach is recommended in areas where significant differences can occur between the channel flood levels and the floodplain flood levels. This approach is also preferable where separate flow paths and flow around catchment obstructions occur, as is the case in the Gwawley Bay catchment. This is a more complex analysis, which requires greater data requirements and computer resources.

The TUFLOW model adopted for the Gwawley Bay catchment consists of a two dimensional (2D) grid across the surface terrain, and a number of one-dimensional (1D) elements within the grid that represents the flow in pipelines, open channels and creeks. Culverts and other hydraulic structures are also included as 1D elements.

The 2D grid is based on a 3m square grid, with ground topography sampled from the digital elevation model at 1.5m spacing. There are some 650,000 grid elements within the TUFLOW model.

Only major pipelines with a diameter of 750mm or greater were originally included in the model. A number of smaller pipelines have subsequently been included where these are critical to the flood behaviour of an area.

TUFLOW is a dynamic model that simulates the complete progress of a flood, from the commencement of rainfall to the peak of the flood, and whilst the flood subsides. A time step of 0.5 seconds has been adopted for the modelling.

The roughness of the creek and floodplain is represented in the model using the Manning's roughness coefficient, *n*. Roughness coefficients are assigned on the basis of catchment inspections and assessment of aerial photography. The choice of roughness coefficient is made with reference to standard hydraulic texts and previous experience with the model. Adopted roughness coefficients for the Gwawley Bay catchment are included in **Table 5.1**.

Table 5.1
TUFLOW Roughness Coefficients

Surface Type (Material)	Manning's Roughness Coefficient
2D Elements	
Urban – fences and typical gardens, backyards	0.1
Urban – units and strata titled land	0.03
Roads and paved/concrete areas	0.02
Short grass / bare earth	0.03
Vegetated area	0.05
Vegetated floodplain	0.08
Building footprints	20
1D Elements	
Natural channels (including Gwawley Creek)	0.035 to 0.070 (variable)
Concrete lined channels	0.015
Pipes	0.015

Boundary conditions are normally specified at the downstream end of a model to provide information on the starting flood level. This is specified as either a steady water level, a stage hydrograph, or a rating curve. Appropriate boundary conditions are dependent on the type of flooding under consideration.

Flooding within the study area can occur from two sources:

i) a local catchment flood, due to short duration storm events directly over the Gwawley Bay catchment; and
ii) backwater effects when the Georges River is in flood.

It is unlikely that a 100 year flood on the Gwawley Bay catchment will coincide with a 100 year flood on the Georges River, given the different sized catchments. The critical storm duration for maximum flooding in the Gwawley Bay catchment is of the order of 2 hours, whereas the critical storm duration for floods on the Georges River is around 36 hours.

The approach adopted has been to model a local catchment flood coinciding with a mean high tide level in the Georges River (estimated at 0.6m AHD). This assumes that there is no flood flow in the Georges River at the time that flooding is experienced in the Gwawley Bay catchment.

At the same time, it must be recognised that flooding in Gwawley Bay can occur when the Georges River is in flood, or when the river levels are high due to elevated storm tide events that back-up from Botany Bay. This second flooding mechanism assumes a Georges River or tidal flood with no contributing catchment flows over the Gwawley Bay catchment.

The final design flood profiles have been taken as the maximum envelope from the local catchment flood (with no Georges River flooding) and a Georges River flood (with no local catchment flows). The assumed downstream boundary conditions for both types of flooding are summarised in **Table 5.2**.

Table 5.2
Downstream Boundary Conditions

Average Recurrence Interval of Flood	**Assumed downstream boundary conditions**	
	Local Catchment Flood (m AHD)	**Georges River Flood* (m AHD)**
PMF	0.6	2.4
100 Year	0.6	1.7
20 Year	0.6	1.5
5 Year	0.6	1.1

* Source: Georges River Floodplain Management Study, Bewsher Consulting, 2004.

Different storm durations were tested in the model to determine which event provides the dominant flood levels for the local catchment flood. Storm durations of 90mins, 2hrs, 3hrs and 6hrs were simulated for the 100 year flood, based on results from the RAFTS model. The 90min and 2 hour flood were found to produce the maximum flood levels over almost the entire study area. The difference in flood levels between these two events was generally within ±20mm, although in a few isolated areas the 2 hour flood was up to 0.2m higher. For this reason, the 2 hour flood was adopted as the critical storm duration.

The model produces a grid of results at 3m intervals over the study area. These results include flood levels, flood depths, and flood velocities at regular time intervals throughout the flood simulation. The peak values are also recorded as separate grids. These grids can be interrogated at any point within the study area using a GIS database, such as MAPINFO.

The grid results can be depicted as colour-coded thematic maps of flood levels, depths and flood velocities for each design flood. The results can also be superimposed onto other base mapping, such as aerial photography and cadastral plans showing property boundaries.

Flood level contours have also been derived using the results from the peak flood level grid. These contours show the height of flooding likely to be experienced throughout the study area. This is an important outcome from the flood study, as it provides Council with the necessary information to specify minimum building floor levels and other controls for future development.

5.3 MAPPING OF FLOOD BEHAVIOUR

Maps showing peak water levels, maximum flood depths and peak velocities have been prepared for the 5 year, 20 year and 100 year average recurrence interval floods, as well as an extreme probable maximum flood. The maps have been prepared at A1 size covering the whole of the study area. The maps will also be provided to Council in digital form for inclusion in Council's own GIS system.

The maps have also been produced at reduced scale for inclusion in this report. Maps showing peak water levels and flood depths are provided for the 5 year, 20 year, 100 year and PMF floods on **Figures 5.2 to 5.5**. These maps are sufficient to gain an appreciation of potential problem areas on a catchment-wide basis. Council can provide a more detailed description of flooding than is included in this report.

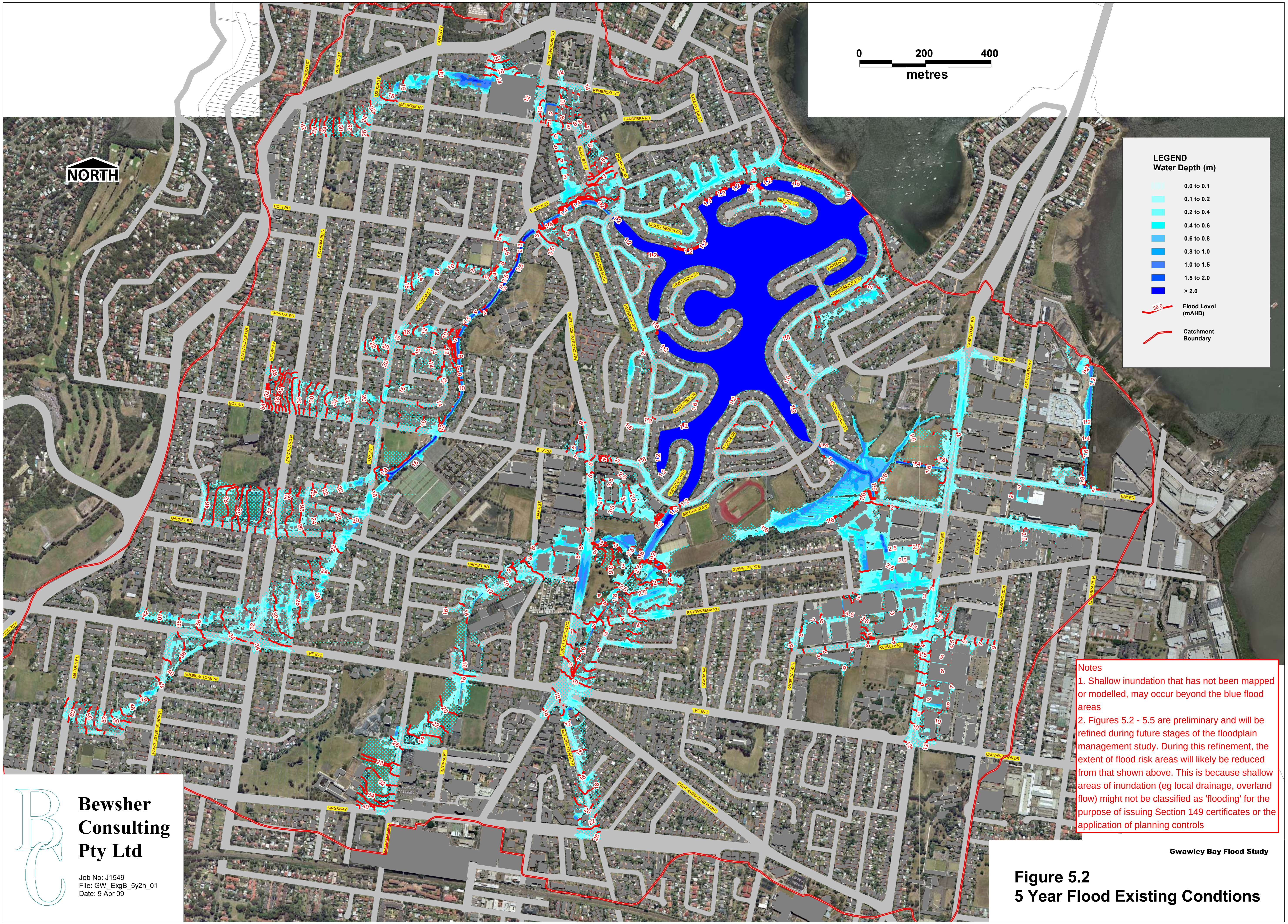
5.4 SUBSEQUENT INVESTIGATIONS

The next phase of the floodplain management process is the preparation of a floodplain management study to investigate options to reduce flooding problems. The flood model will provide the necessary tool to assess the impact of proposed works on flood behaviour, including the impact of future development proposals within the catchment.

It is intended to develop a database of potential flood problem areas as part of the next phase of the investigations. This will help to identify problems within the catchment and allow an assessment of potential flood mitigation options.

Further delineation of the floodplain into different flood risk management precincts will be undertaken during the floodplain management study. It is anticipated that the floodplain will be classified into three different flood risk precincts (High, Medium and Low), consistent with the mapping approach adopted by Council for the Georges River. Appropriate development controls for each flood risk management precinct will also be recommended.

The impact of Climate Change on flood behaviour is also to be considered in the floodplain management study.



Notes
1. Shallow inundation that has not been mapped or modelled, may occur beyond the blue flood areas
2. Figures 5.2 - 5.5 are preliminary and will be refined during future stages of the floodplain management study. During this refinement, the extent of flood risk areas will likely be reduced from that shown above. This is because shallow areas of inundation (eg local drainage, overland flow) might not be classified as 'flooding' for the purpose of issuing Section 149 certificates or the application of planning controls

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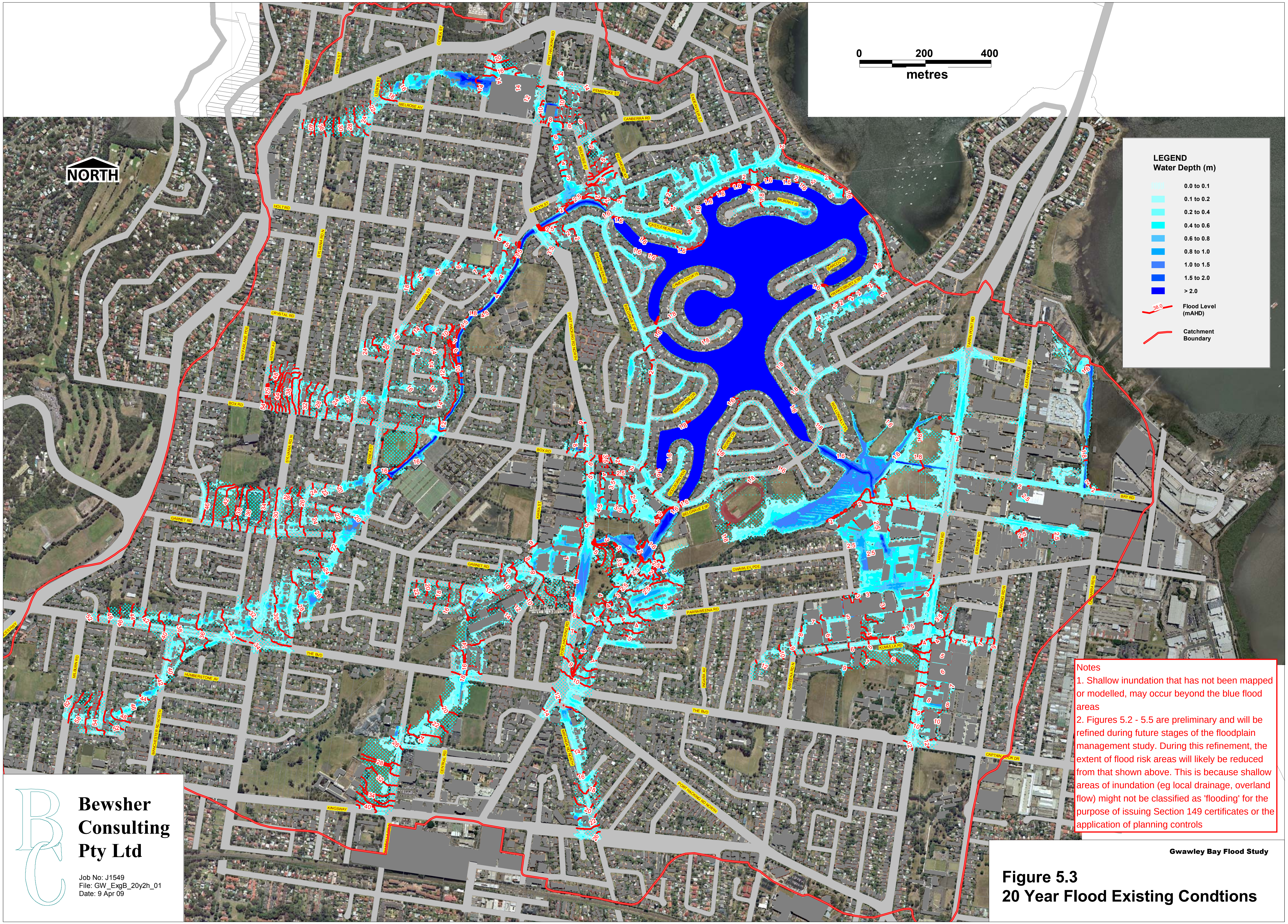
Gwawley Bay Flood Study

Figure 5.2
5 Year Flood Existing Condtions



Notes
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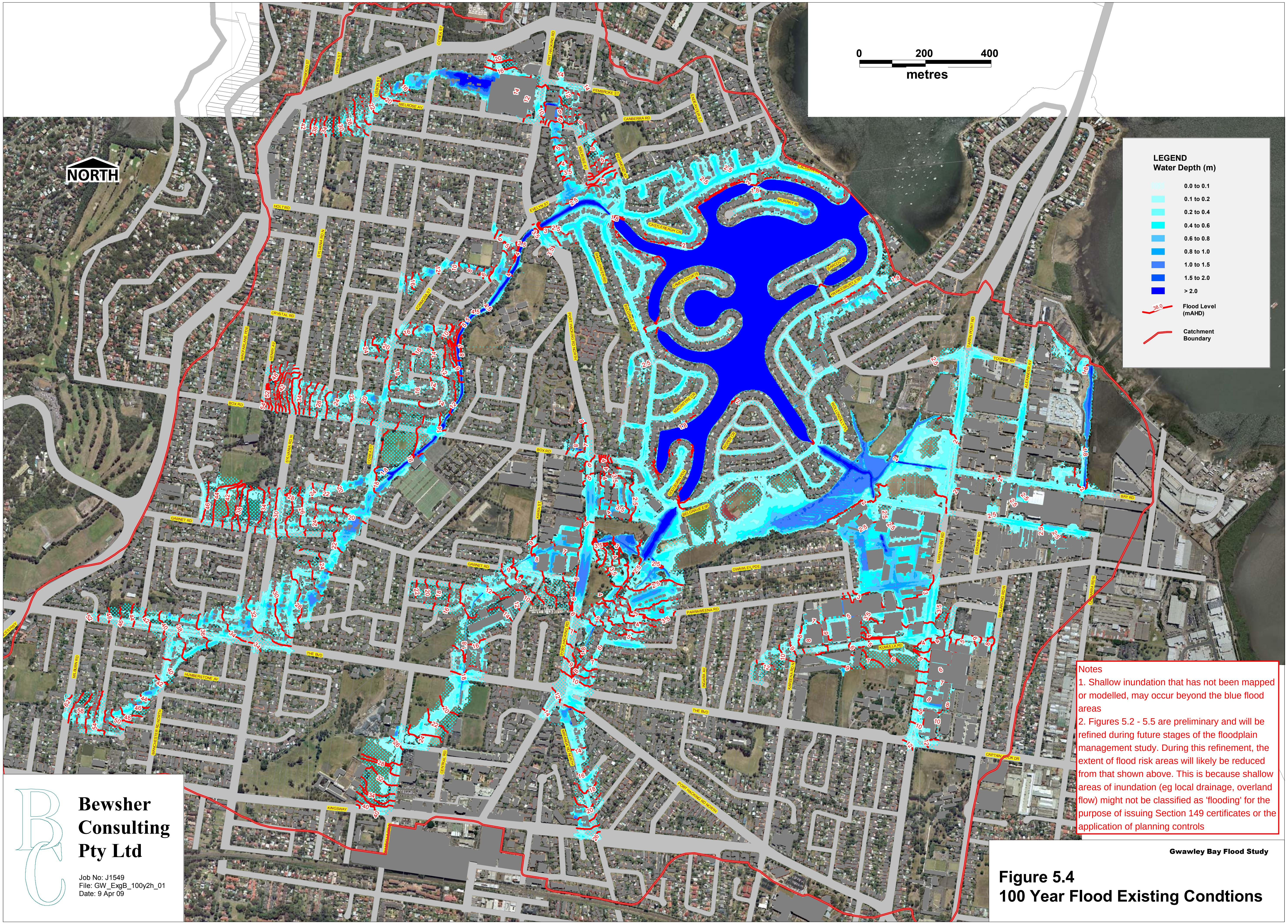
Gwawley Bay Flood Study

Figure 5.3
20 Year Flood Existing Condtions



Notes
1. Shallow inundation that has not been mapped or modelled, may occur beyond the blue flood areas
2. Figures 5.2 - 5.5 are preliminary and will be refined during future stages of the floodplain management study. During this refinement, the extent of flood risk areas will likely be reduced from that shown above. This is because shallow areas of inundation (eg local drainage, overland flow) might not be classified as 'flooding' for the purpose of issuing Section 149 certificates or the application of planning controls

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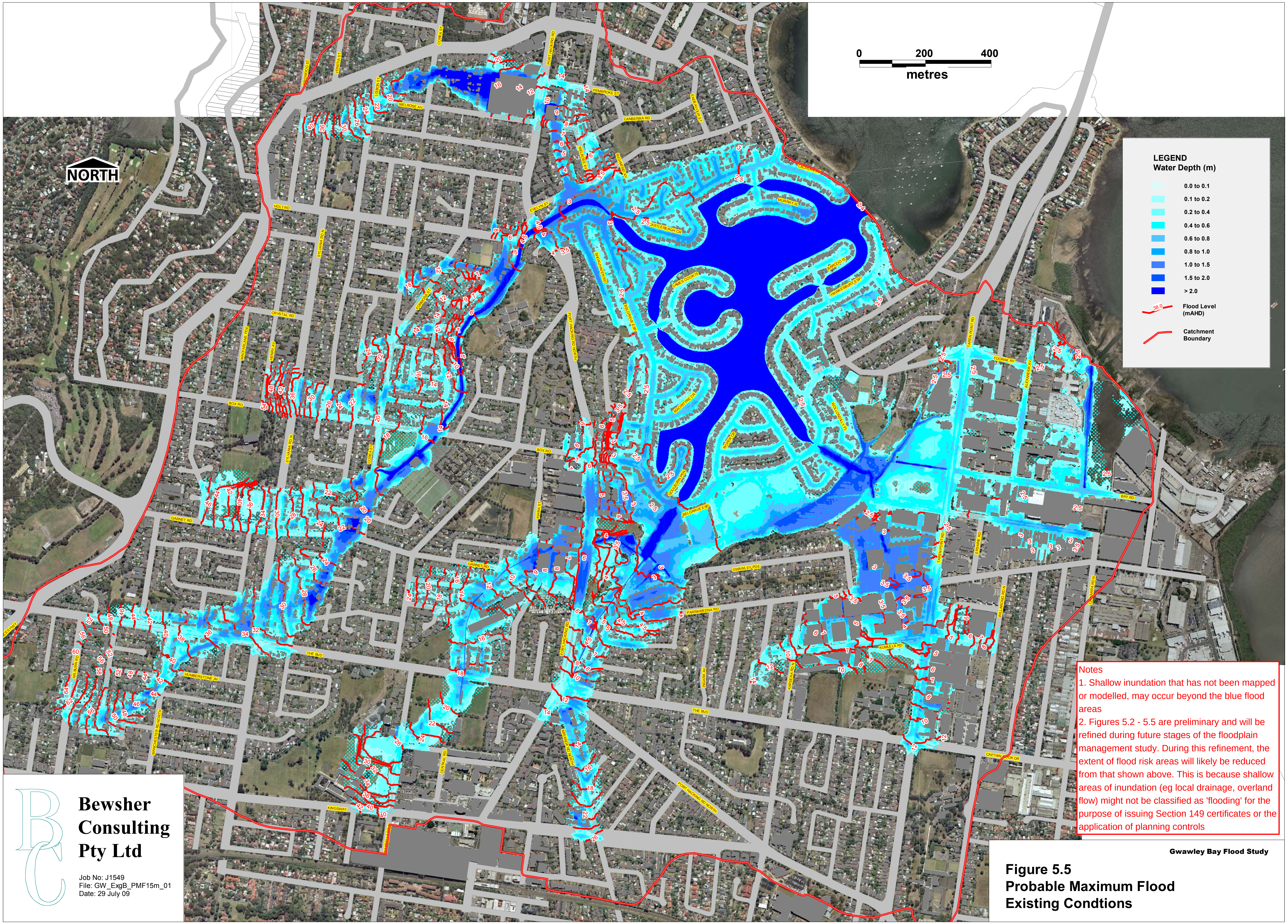
Gwawley Bay Flood Study

Figure 5.4
100 Year Flood Existing Condtions



Notes

1. Shallow inundation that has not been mapped or modelled, may occur beyond the blue flood areas

2. Figures 5.2 - 5.5 are preliminary and will be refined during future stages of the floodplain management study. During this refinement, the extent of flood risk areas will likely be reduced from that shown above. This is because shallow areas of inundation (eg local drainage, overland flow) might not be classified as 'flooding' for the purpose of issuing Section 149 certificates or the application of planning controls

Bewsher Consulting Pty Ltd

Job No: J1549
File: GW_ExgB_PMF15m_01
Date: 29 July 09

Gwawley Bay Flood Study

Figure 5.5
Probable Maximum Flood
Existing Condtions

6 REFERENCES

Bewsher Consulting, May 2004, *"Georges River Floodplain Risk Management Study and Plan – Volume 1, Main Report"*, prepared for Bankstown, Liverpool, Fairfield, and Sutherland Councils.

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Institution of Engineers Australia, 2001, *"Australian Rainfall and Runoff*".

NSW Government, April 2005, *'Floodplain Development Manual: The Management of Flood Liable Land'*.

Public Works Department of NSW, December 1991, *"Georges River Flood Study"*, prepared by the NSW Water Research Laboratory.

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Sutherland Shire Council, July 1997, *"Stormwater Management Policy and Guidelines"*

7 FREQUENTLY ASKED QUESTIONS

Why do flood levels change over time?

There is a chance that floods of various magnitudes will occur in the future. As the size of a flood increases, the chance that it will occur becomes rarer. Because some of these rare floods have never been experienced or accurately recorded since European settlement, the height of future floodwaters is normally predicted using computer models. These computer models simulate flood levels and velocities for a range of flood sizes and flood probabilities. Given the importance of estimating flood levels accurately, councils and the NSW Department of Environment, Climate Change and Water (DECCW) engage experts to establish and operate the computer models.

From time to time the computer models are revised and predicted flood levels can change. The resultant change in flood levels however is normally very small. The reasons why the computer models are revised can include:

- new rainfall or ground topography information becomes available;
- new floods occur which provide additional data from which to fine-tune the models;
- better computer models become available as the science of flood modelling improves and computer capabilities increase; or
- flood mitigation works may have been carried out, or development within the catchment may have occurred, that was not previously simulated in the models.

How are these studies funded?

Flood studies and floodplain risk management studies are often carried out under State Government guidelines and are funded on a 1:1:1 basis among the Federal and State Governments, and councils. This funding arrangement is also available for the construction of flood mitigation works.

My property is in a Low Flood Risk Precinct. What does this mean?

The classification of a 'Low Flood Risk Precinct' can differ slightly between councils. Generally it means that your property would not be inundated in a 100 year ARI flood but still has a very slight chance of inundation from larger (i.e. rarer) floods.

If you are a residential property owner, there will be virtually no change to how you may develop your property. However, there may be controls on the location of essential services such as hospitals, evacuation centres, nursing homes and emergency services.

My property is in a Medium Flood Risk Precinct. What does this mean?

The classification of a 'Medium Flood Risk Precinct' can differ slightly between councils. Often it means that your property is inundated in a 100 year ARI flood, however conditions are not likely to be hazardous during such a flood. If you are a residential property owner development controls will probably be similar to those that currently exist.

My property is in a High Flood Risk Precinct. What does this mean?

The classification of a 'High Flood Risk Precinct' can differ slightly between councils. Often it means that your property will be inundated in a 100 year ARI flood and that hazardous conditions may occur. This could mean that there would be a possible danger to personal safety, able bodied adults may have difficulty wading to safety, evacuation by trucks may be difficult, or there may be a potential for significant structural damage to buildings. This is an area of higher hazard where stricter controls may be applied.

Will my property value be altered if I am in a Flood Risk Precinct?

Any change in a council's classification of properties can have some impact on property values. Nevertheless, councils normally give due consideration to such impacts before introducing a system of flood risk classifications or any other classification system (e.g. bushfire risks, acid sulphate soil risk, etc). If your property is now classified as being in a Flood Risk Precinct, the real flood risks on your property have not changed, only its classification has altered. A prospective purchaser of your property could have previously discovered this risk if they had made enquiries themselves.

If you are in a Low Flood Risk Precinct, generally there will be no controls on normal residential type development. Previous valuation studies have shown that under these circumstances, your property values will not alter significantly over the long term. Certainly, when a new system of classifying flood risks is introduced, there may be some short-term effect, particularly if the development implications of the precinct classification are not understood properly. This should only be a short-term effect however until the property market understands that over the long-term, the Low Flood Risk Precinct classification will not change the way you use or develop your property.

Ultimately, however, the market determines the value of any residential property. Individual owners should seek their own valuation advice if they are concerned that the flood risk precinct categorisation may influence their property value.

My property was never classified as 'flood prone' or 'flood liable' before. Now it is in a Low Flood Risk Precinct. Why?

The State Government changed the meaning of the terms 'flood prone', 'flood liable' and 'floodplain' in 2001. Prior to this time, these terms generally related to land below the 100 year ARI flood level. Now it is different. These terms now relate to all land that could possibly be inundated, up to an extreme flood known as the probable maximum flood (PMF). This is a very rare flood.

The reason the Government changed the definition of these terms was because there was always some land above the 100 year ARI flood level that was at risk of being inundated in rarer and more extreme flood events. History has shown that these rarer flood events can and do happen (e.g. the 1990 flood in Nyngan, the November 1996 flood in Coffs Harbour, the January 1998 flood in Katherine, the August 1998 flood in the northern suburbs of Wollongong, the 2002 floods in Europe, Hurricane Katrina in 2005, etc).

Will I be able to get house and contents insurance if my house is in a Flood Risk Precinct?

In contrast to the USA and many European countries, flood insurance has generally not been available in Australia for residential property. Following the disastrous floods in Coffs Harbour in November 1996 and in Wollongong in August 1998, very limited flood cover began to be offered by some insurance companies. From 2008, many insurance companies started offering wider cover although the extent of the cover particularly for very flood prone properties is still not well known and may differ between insurers. The most likely situation is that your insurer will now offer you some flood cover although this will be dependent on the flood level information that the insurer has for your property. (This may not necessarily be the same as that available from Council). If flood cover is offered, the classification of your property within a Flood Risk Precinct per se, is unlikely to alter the availability of cover. Obviously insurance policies and conditions may change over time or between insurance companies, and you should confirm the specific details of your situation with your insurer.

Will I be able to get a home loan if my land is in a Flood Risk Precinct?

Most banks and lending institutions do not account for flood risks when assessing home loan applications unless there is a very significant risk of flooding at your property. The system of Flood Risk Precinct classification will make it clear to all concerned, the nature of the flood risks. Under the previous system, if a prospective lending authority made appropriate enquiries, they could have identified the nature of the flood risk during assessment of home loan applications. As a result, it is not likely that the classification of your property within a Flood Risk Precinct will alter your ability to obtain a home loan. Nevertheless, property owners who are concerned about their ability to obtain a loan should clarify the situation with their own lending authority.

How have the flood risk maps been prepared?

Because some large and rare floods have often not been experienced or accurately recorded since European settlement commenced, computer models are used to simulate the depths and velocities of major floods. These computer models are normally established and operated by flooding experts employed by local and state government authorities. Because of the critical importance of the flood level estimates produced by the models, such modelling is subjected to very close scrutiny before flood information is formally adopted by a council. Maps of flood risks (e.g. 'low', 'medium' and 'high') are prepared after consideration of such issues as:

- flood levels and velocities for a range of possible floods;
- ground levels;
- flood warning time and duration of flooding;
- suitability of evacuation and access routes; and
- emergency management during major floods.

What is the probable maximum flood (PMF)?

The PMF is the largest flood that could possibly occur. It is a very rare and improbable flood. Despite this, a number of historical floods in Australia have approached the magnitude of a PMF. Every property potentially inundated by a PMF will have some flood risk, even if it is very small. Under the State Government's Floodplain Development Manual (2005), councils must consider all flood risks, even these potentially small ones, when managing floodplains. As part of the State Government's Manual, the definitions of the terms 'flood liable', flood prone' and 'floodplain' refer to land inundated by the PMF.

What is the 100 year flood?

A 100 year flood is the flood that will occur or be exceeded on average once every 100 years. It has a probability of 1% of occurring in any given year. If your area has had a 100 year flood, it is a fallacy to think you will need to wait another 99 years before the next flood arrives. Floods do not happen like that. Some parts of Australia have received a couple of 100 year floods in one decade. On average, if you live to be 70 years old, you have a better than even chance of experiencing a 100 year flood.

Why do councils prepare floodplain management studies and plans?

Under NSW legislation, councils have the primary responsibility for management of development within floodplains. To appropriately manage development, councils need a strategic plan which considers the potential flood risks and balances these against the beneficial use of the floodplain by development. To do this, councils have to consider a range of environmental, social, economic, financial and engineering issues. This is what happens in a floodplain risk management study. The outcome of the study is the floodplain risk management plan, which details how best to manage flood risks in the floodplain for the foreseeable future.

Floodplain risk management plans normally comprise a range of works and measures such as:

- improvements to flood warning and emergency management;
- works (e.g. levees or detention basins) to protect existing development;
- voluntary purchase or house raising of severely flood-affected houses;
- planning and building controls to ensure future development is compatible with the flood risks; and
- measures to raise the community's awareness of flooding so that they are better able to deal with the flood risks they face.

Will the Flood Risk Precinct maps be changed?

Yes. All mapping undertaken by council is subjected to ongoing review. As these reviews take place, it is conceivable that changes to the mapping will occur, particularly if new flood level information or ground topography information becomes available. However, this is not expected to occur very often and the intervals between revisions to the maps would normally be many years. Many councils have a policy of reviewing and updating floodplain management studies and plans about every five to ten years. This is the likely frequency at which the maps may be amended.

8 GLOSSARY

Note that terms shown in bold are described elsewhere in this Glossary.

100 year flood	A **flood** that occurs on average once every 100 years. Also known as a 1% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
50 year flood	A **flood** that occurs on average once every 50 years. Also known as a 2% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
20 year flood	A **flood** that occurs on average once every 20 years. Also known as a 5% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
afflux	The increase in flood level upstream of a constriction of flood flows. A road culvert, a pipe or a narrowing of the stream channel could cause the constriction.
annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe **flood** size. It is a means of describing how likely a flood is to occur in a given year. For example, a 1% AEP flood is a **flood** that has a 1% chance of occurring, or being exceeded, in any one year. It is also referred to as the '100 year flood' or 1 in 100 year flood'. The terms **100 year flood**, **50 year flood**, **20 year flood** etc, have been used in this study. See also **average recurrence interval (ARI)**.
Australian Height Datum (AHD)	A common national plane of level approximately equivalent to the height above sea level. All **flood levels**, floor levels and ground levels in this study have been provided in metres AHD.
average annual damage (AAD)	Average annual damage is the average flood damage per year that would occur in a nominated development situation over a long period of time.
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe **flood** size. It is the long-term average number of years between floods of a certain magnitude. For example, a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years. The terms **100 year flood**, **50 year flood**, **20 year flood** etc, have been used in this study. See also **annual exceedance probability (AEP)**.
catchment	The land draining through the main stream, as well as tributary streams.
Development Control Plan (DCP)	A DCP is a plan prepared in accordance with Section 72 of the *Environmental Planning and Assessment Act, 1979* that provides detailed guidelines for the assessment of development applications.
DECC	Department of Environment and Climate Change, formerly the Department of Natural Resources (DNR).
discharge	The rate of flow of water measured in terms of volume per unit time, for example, **cubic metres per second (m^3/s)**. Discharge is different from the speed or **velocity** of flow, which is a measure of how fast the water is moving.
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the *Local Government Act 1993*.

effective warning time	The time available after receiving advice of an impending **flood** and before the floodwaters prevent appropriate flood response actions being undertaken. The **effective warning time** is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
EP&A Act	*Environmental Planning and Assessment Act, 1979*.
extreme flood	An estimate of the **probable maximum flood (PMF)**, which is the largest flood likely to occur.
flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	An appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood hazard	The potential for damage to property or risk to persons during a **flood**. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.
flood level	The height of the **flood** described either as a depth of water above a particular location (eg. 1m above a floor, yard or road) or as a depth of water related to a standard level such as **Australian Height Datum** (eg the flood level was 7.8m AHD). Terms also used include **flood stage** and **water level**.
flood liable land	Land susceptible to flooding up to the **probable maximum flood (PMF)**. Also called **flood prone land**. Note that the term flood liable land now covers the whole of the **floodplain**, not just that part below the **flood planning level**.
flood planning levels (FPLs)	The combination of flood levels and **freeboards** selected for planning purposes, as determined in **floodplain management studies** and incorporated in **floodplain management plans**. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.
flood prone land	Land susceptible to flooding up to the **probable maximum flood (PMF**). Also called **flood liable land**.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate damages during a **flood**.
flood stage	see **flood level**.
flood study	A study that investigates flood behaviour, including identification of flood extents, **flood levels** and flood velocities for a range of flood sizes.
floodplain	The area of land that is subject to inundation by floods up to and including the probable maximum flood event, that is, **flood prone land** or **flood liable land**.
Floodplain Risk Management Plan	The outcome of a **Floodplain Risk Management Study**.

Floodplain Risk Management Study	Studies carried out in accordance with the *Floodplain Development Manual* (NSW Government, 2005) that assesses options for minimising the danger to life and property during **floods**. These measures, referred to as 'floodplain management measures/options', aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a **Floodplain Risk Management Plan**.
floodway	Those areas of the **floodplain** where a significant discharge of water occurs during **floods**. Floodways are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in **flood levels**.
flow	see **discharge**
foreshore building line	A line fixed by resolution of Council in respect of land fronting any bay, river, creek, lagoon, harbour or ocean, which provides a setback distance where buildings or other structures would normally be prohibited.
freeboard	A factor of safety expressed as the height above the **design flood level**. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the **floodplain**, such and wave action, localised **hydraulic** behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change.
high flood hazard	For a particular size **flood**, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and **velocity**.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of **peak discharges**, flow volumes and the derivation of hydrographs (graphs that show how the discharge or stage/flood level at any particular location varies with time during a flood).
Local Environmental Plan (LEP)	A Local Environmental Plan is a plan prepared in accordance with the *Environmental Planning and Assessment Act*, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.
low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
m AHD	metres **Australian Height Datum (AHD)**.
m/s	metres per second. Unit used to describe the **velocity** of floodwaters.
m^3/s	Cubic metres per second or 'cumecs'. A unit of measurement for creek or river flows or **discharges**. It the rate of flow of water measured in terms of volume per unit time.

merit approach	The principles of the merit approach are embodied in the *Floodplain Development Manual* (NSW Government, 2005) and weigh up social, economic, ecological and cultural impacts of land use options for different **flood prone** areas together with flood damage, **hazard** and behaviour implications, and environmental protection and well being of the State's rivers and **floodplains**.
overland flow path	The path that floodwaters can follow if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Floodwaters travelling along overland flow paths, often referred to as 'overland flows', may or may not re-enter the main channel from which they left — they may be diverted to another water course.
peak discharge	The maximum **flow** or **discharge** during a flood.
present value	In relation to flood damage, is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value.
probable maximum flood (PMF)	The largest flood likely to ever occur. The PMF defines the extent of **flood prone land** or **flood liable land**, that is, the **floodplain**. The extent, nature and potential consequences of flooding associated with the PMF event are addressed in the current study.
rainfall hyetograph	A graphical representation or tabulation of the variation of rainfall depth or intensity over time.
reliable access	During a **flood**, reliable access means the ability for people to safely evacuate an area subject to imminent flooding within **effective warning time**, having regard to the depth and **velocity** of floodwaters, the suitability of the evacuation route, and other relevant factors.
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall that ends up as flow in a stream, also known as rainfall excess.
SES	State Emergency Service of New South Wales.
stage–damage curve	A relationship between different water depths and the predicted flood damage at that depth.
velocity	the term used to describe the speed of floodwaters, usually in **m/s**.
water level	see **flood level**.
water surface profile	A graph showing the height of the **flood** (**flood stage**, **water level** or **flood level**) at any given location along a watercourse at a particular time.

APPENDIX A

Community Letter & Questionnaire

Administration Centre
4–20 Eton Street
Sutherland NSW
Australia
Please reply to:
General Manager
Locked Bag 17
Sutherland NSW 1499
Australia
Tel: (02) 9710 0333
Fax: (02) 9710 0265
DX4511 SUTHERLAND
Email: ssc@ssc.nsw.gov.au
www.sutherland.nsw.gov.au
ABN 52 018 204 808
Office Hours:
8.30am to 4.30pm
Monday to Friday

Peter Le
Stormwater Engineer
Tel: 9710 0119

Reference: GS/06/140545

11 April 2007

Dear Sir/Madam,

Gwawley Bay Catchment Floodplain Risk Management Study & Plan
(Subject property:)

Sutherland Shire Council recently commissioned a floodplain management study for the Gwawley Bay catchment. This letter is being sent to all residents and business owners within the study area to let you know about the study and to invite your input. Bewsher Consulting is undertaking the study for Council. The study will examine flooding within this catchment and investigate possible solutions to reduce these flooding problems. A map of the study area is enclosed for your information.

The project will take about twelve months to complete. The first stage is to gather any available information on flooding and to establish a computer model to simulate flood behaviour. Various floodplain management options will then be investigated to see how these problems could be reduced. A project web site has been established to provide more information about the study as it progresses. The web site address is www.bewsher.com.au/gwawley.htm

If there are any particular problem areas that you are aware of, or other flooding issues that you would like investigated, we would be most pleased to hear from you. A brief questionnaire has been included to help compile this information.

A floodplain management committee will be established to oversee the project. The committee will comprise representatives from Council, the State Emergency Service, Department of Natural Resources and several community representatives. If you would like to be considered for one of the community representative positions, please refer to conditions and requirements briefly described on the reverse.

We are pleased to invite you to participate in this project.

Yours faithfully

G C Amos
For J W Rayner
General Manager

Nomination are called for Community Membership to the Gwawley Bay Catchment Floodplain Risk Management Study Committee

This is unique opportunity for members of the community to contribute to development of a long-term strategy to manage flood risk in the Gwawley Bay Catchment.

We are looking for (3) to five (5) motivated individuals to provide a community prospective on the Committee.

The nominee should either live or work within the catchment and have a general interest in floodplain management.

You will join Sutherland Shire Councillors, representatives from various NSW (State) Government authorities and Council staffs. The Committee will guide and oversee development of the Floodplain Risk Management Study & Plan for the Gwawley Bay Catchment.

Meetings shall be convened on weekday evenings as required, generally once per month. The nominee should be prepared to play an active role on the committee for the length of the investigation, which is anticipated to be about 12 months.

In your nomination, please demonstrate the following:
a) Your interest in flood related issues;
b) Your involvement in continuing participation and advocacy;
c) Your skills and experience; and
d) The contribution you will make to the committee.

Nominations close on Friday 11 May 2007 at 4.30pm and should be forwarded to Council's Stormwater Engineer, Mr Peter Le, Sutherland Shire Council, Locked Bag 17, Sutherland NSW 1499.

Please ring Mr Le on Tel: 9710 0119 if you have any queries.

Gwawley Bay Floodplain Management Study
Questionnaire for Residents and Business Owners

The information provided from this questionnaire will help us to identify any flooding problems within the catchment, and to consider measures that may reduce these problems. It would help us if you could indicate the location of your property, or other problem areas, on the map on the back.

The questionnaire is voluntary. No names or addresses will be included in any published material.

---

1. Your Address? ____

2. Within the study area, do you own:
   - ☐ A residential house
   - ☐ A residential unit or apartment
   - ☐ A business premises

3. Has your property previously flooded? When did this happen? ____________________
   - ☐ Yes, above floor level — Depth above floor? __________m.
   - ☐ Yes, but floor level of building was not flooded
   - ☐ Minor flooding within property only
   - ☐ No flooding within this property

4. Are there any flood problems that you are aware of beyond your property?

   ____
   ____
   ____

5. Are there any flooding issues you would like the study to consider?

   ____
   ____
   ____

6. Do you have any ideas on reducing flood problems?

   ____
   ____
   ____

7. Other comments

   ____
   ____
   ____

8. Your Contact Details (in case we need to ask you anything further)

   Name: ______________________________________
   Email: ______________________ Phone: ______________

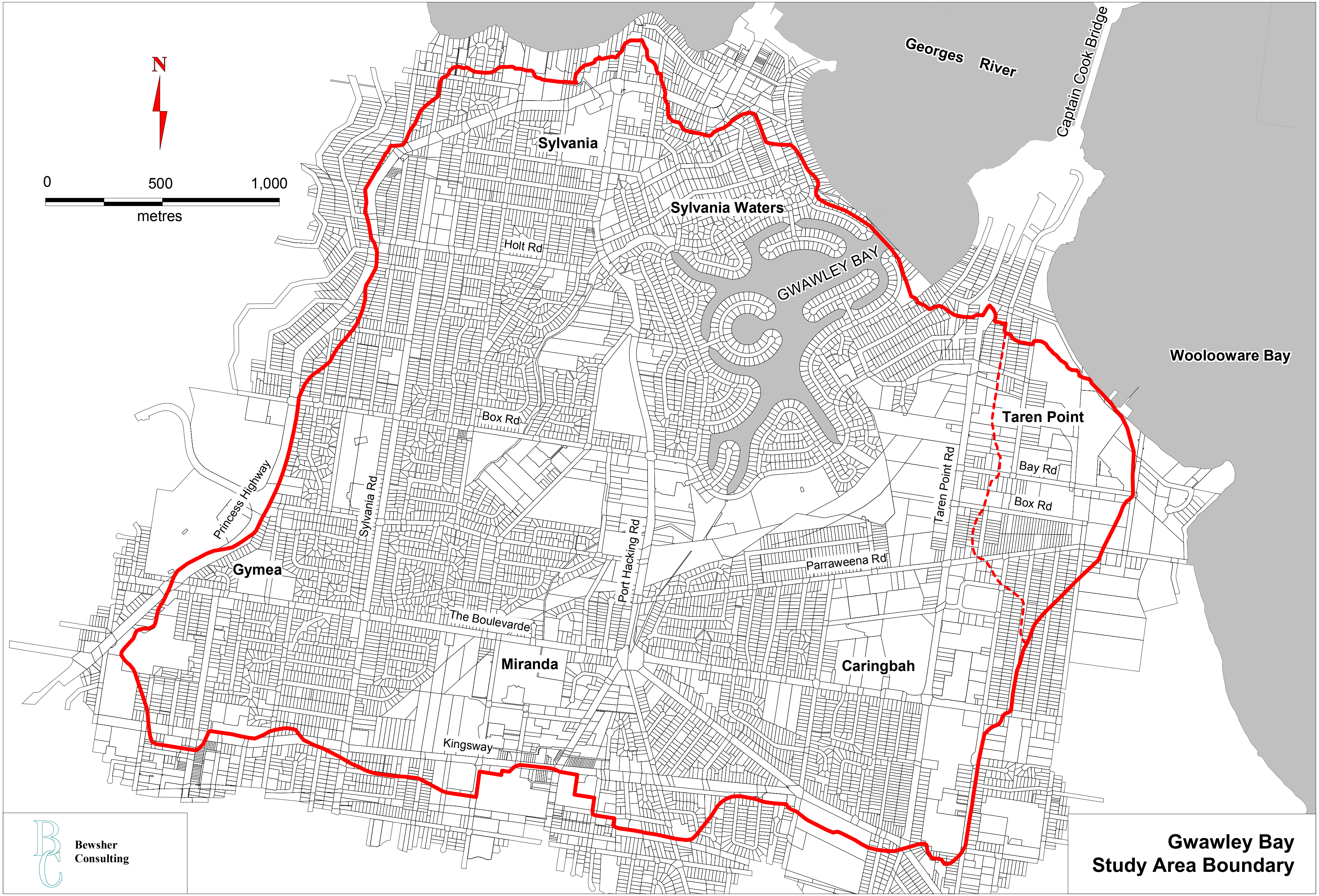
Please return your completed questionnaire by <u>FRIDAY 27th APRIL 2007.</u>
Questionnaires should be returned to the following address **(no postage stamp is required).**

Reply Paid Permit Number 32
Gwawley Bay Floodplain Management Study
Bewsher Consulting Pty Ltd
P.O. Box 352,
Epping NSW 1710

Thank you for your participation

Sutherland Shire Council

Bewsher Consulting



Bewsher Consulting

Gwawley Bay
Study Area Boundary

APPENDIX B

RAFTS Model Flow Estimates

RAFTS PEAK FLOW ESTIMATES (m3/s)

Assessment of Critical Storm Duration - 100 Year Flood

RAFTS_ID	Storm Duration (mins)									
	25	60	90	120	180	270	360	540	720	Max
C2.0	1.6	1.6	1.7	**1.7**	0.8	0.8	0.5	0.5	0.4	*1.7*
C1.6	5.4	5.2	5.4	**5.5**	2.8	2.5	1.8	1.5	1.5	*5.5*
C3.0	2.6	2.6	2.7	**2.7**	1.4	1.2	0.8	0.7	0.7	*2.7*
C1.5	11.1	10.6	**11.2**	10.5	6.0	5.2	3.7	3.2	3.1	*11.2*
C1.4	13.2	12.8	**13.2**	13.1	7.7	6.5	4.8	4.1	4.0	*13.2*
C1.3	15.0	14.0	14.4	**15.4**	9.0	7.7	5.6	4.8	4.7	*15.4*
C1.2	19.5	18.0	18.2	**20.7**	12.6	10.9	7.9	6.8	6.8	*20.7*
C1.1	20.6	19.5	19.4	**22.1**	14.1	12.3	9.3	8.0	8.0	*22.1*
C1.0	22.4	21.7	21.1	**23.8**	16.6	14.3	11.0	9.4	9.4	*23.8*
D19.0	2.1	2.1	**2.2**	2.1	1.2	1.0	0.8	0.7	0.6	*2.2*
D18.0	4.1	4.1	**4.4**	4.1	2.4	2.1	1.5	1.3	1.3	*4.4*
D17.0	1.0	**1.3**	1.2	1.2	1.0	0.9	0.8	0.7	0.7	*1.3*
D16.0	6.1	6.4	**6.9**	6.2	4.1	3.5	2.7	2.4	2.4	*6.9*
D15.0	8.0	8.3	**8.9**	8.0	5.2	4.4	3.4	3.0	3.0	*8.9*
D13.0	11.5	11.8	**12.6**	11.5	7.3	6.1	4.6	4.0	4.0	*12.6*
D12.0	11.8	12.1	**12.9**	11.7	7.4	6.3	4.7	4.1	4.1	*12.9*
D8.0	2.2	2.2	**2.3**	2.2	1.3	1.1	0.8	0.7	0.7	*2.3*
D9.0	2.7	2.7	**2.9**	2.7	1.6	1.4	1.0	0.9	0.9	*2.9*
D5.0	0.6	0.6	**0.7**	0.6	0.4	0.4	0.3	0.2	0.2	*0.7*
D2.0	**1.6**	1.5	1.5	1.4	0.8	0.7	0.5	0.4	0.4	*1.6*
D3.0	**2.1**	1.9	2.0	1.9	1.1	0.9	0.7	0.6	0.6	*2.1*
D1.4	5.0	4.8	**5.0**	4.3	2.7	2.4	1.7	1.5	1.4	*5.0*
D1.3	6.9	6.7	**6.9**	6.0	3.9	3.3	2.4	2.1	2.0	*6.9*
D4.0	0.3	0.3	**0.3**	0.3	0.2	0.1	0.1	0.1	0.1	*0.3*
D1.2	8.7	8.5	**8.8**	8.1	5.2	4.5	3.2	2.8	2.7	*8.8*
D1.1	9.1	8.9	**9.1**	8.7	5.6	4.8	3.4	3.0	2.9	*9.1*
D1.0	9.4	9.3	**9.4**	9.2	5.9	5.1	3.7	3.2	3.1	*9.4*
D7.0	1.2	1.2	**1.3**	1.1	0.7	0.6	0.4	0.4	0.4	*1.3*
D6.0	10.9	11.0	10.9	**11.4**	7.4	6.3	4.6	4.0	4.0	*11.4*
D10.0	13.1	13.1	13.5	**14.3**	9.5	8.0	6.0	5.2	5.1	*14.3*
D11.0	25.3	25.3	**26.7**	24.8	17.1	14.4	10.9	9.4	9.3	*26.7*
F3.1	**1.4**	1.3	1.3	1.2	0.7	0.6	0.4	0.4	0.4	*1.4*
F4.1	**2.2**	2.0	2.1	2.0	1.1	1.0	0.7	0.6	0.6	*2.2*
F5.1	**1.7**	1.6	1.7	1.5	0.9	0.8	0.5	0.5	0.5	*1.7*
F8.0	1.0	1.0	**1.1**	1.0	0.6	0.5	0.4	0.4	0.4	*1.1*
F6.0	3.4	3.5	**3.7**	3.5	2.1	1.8	1.4	1.2	1.2	*3.7*
F7.0	0.7	**0.8**	0.8	0.8	0.6	0.5	0.5	0.4	0.4	*0.8*
F5.0	6.2	6.4	**6.9**	5.8	4.0	3.5	2.6	2.3	2.3	*6.9*
F4.0	8.9	9.1	**9.7**	8.7	5.8	5.0	3.7	3.2	3.2	*9.7*
F3.0	11.5	11.7	**12.3**	11.2	7.4	6.4	4.7	4.0	4.0	*12.3*
F2.0	15.0	15.2	**16.2**	14.1	9.6	8.2	6.1	5.2	5.2	*16.2*
G1.0	4.2	4.1	**4.3**	4.0	2.4	2.0	1.4	1.3	1.2	*4.3*
G2.0	0.6	**0.7**	0.7	0.7	0.6	0.5	0.4	0.4	0.4	*0.7*
G3.0	6.8	6.8	**7.2**	6.5	4.1	3.4	2.6	2.2	2.2	*7.2*
G4.0	8.3	8.4	**8.8**	7.6	5.2	4.4	3.3	2.9	2.9	*8.8*
G6.0	0.7	0.7	**0.7**	0.7	0.4	0.3	0.3	0.2	0.3	*0.7*
G5.0	3.0	3.0	**3.1**	3.0	1.7	1.5	1.1	0.9	0.9	*3.1*
G7.0	7.3	7.2	**7.7**	6.8	4.2	3.7	3.0	2.6	2.7	*7.7*
A12.10	3.8	3.8	**3.9**	3.8	2.1	1.8	1.3	1.1	1.1	*3.9*
A12.9	6.3	6.2	**6.5**	5.9	3.5	3.0	2.1	1.9	1.8	*6.5*
A12.8	6.6	6.6	**6.9**	6.3	3.7	3.2	2.3	2.0	1.9	*6.9*
A12.7	7.3	7.3	**7.6**	6.9	4.1	3.5	2.5	2.2	2.2	*7.6*
A12.6	12.5	13.4	13.2	**13.4**	9.0	7.5	5.7	4.9	4.8	*13.4*
A12.5	12.9	14.0	14.0	**14.0**	9.5	8.1	6.1	5.3	5.2	*14.0*
A12.3	**1.7**	1.6	**1.7**	1.4	0.9	0.8	0.6	0.5	0.5	*1.7*
A12.4	15.3	**16.3**	16.3	15.9	11.5	9.9	7.5	6.5	6.4	*16.3*
A12.2	15.8	**16.8**	16.8	16.4	11.9	10.3	7.8	6.7	6.7	*16.8*
A12.0	3.4	3.6	**3.8**	3.4	2.3	2.0	1.4	1.2	1.2	*3.8*
A12.1	18.6	19.8	**19.9**	18.7	14.3	12.6	9.7	8.4	8.3	*19.9*
A1.13	**2.0**	1.9	2.0	1.9	1.1	0.9	0.7	0.6	0.6	*2.0*
A1.12	19.8	**21.7**	21.5	20.4	15.6	14.3	11.1	9.8	9.7	*21.7*
A1.11	21.2	**23.8**	23.1	22.7	17.7	16.0	12.8	11.3	11.1	*23.8*
A1.10	21.3	**24.2**	23.4	23.1	18.2	16.4	13.1	11.6	11.4	*24.2*

RAFTS PEAK FLOW ESTIMATES (m3/s)

Assessment of Critical Storm Duration - 100 Year Flood

RAFTS_ID	Storm Duration (mins)									
	25	60	90	120	180	270	360	540	720	Max
A1.9	21.5	**24.9**	24.1	24.0	19.0	17.2	13.8	12.3	12.1	24.9
A1.8	21.8	**26.0**	25.0	25.2	20.1	18.4	14.9	13.3	13.1	26.0
A10.1	2.3	2.5	**2.6**	2.3	1.6	1.3	1.0	0.8	0.8	2.6
A10.0	3.4	3.6	**3.7**	3.3	2.3	1.9	1.4	1.2	1.2	3.7
A1.7	22.5	27.6	26.7	**27.6**	22.3	19.9	16.4	14.6	14.3	27.6
A11.0	1.7	1.7	**1.7**	1.7	0.9	0.8	0.6	0.5	0.5	1.7
A1.6	22.6	28.3	27.7	**28.5**	23.0	20.7	17.2	15.3	15.1	28.5
A1.5	22.6	28.5	27.9	**28.6**	23.2	20.9	17.4	15.6	15.3	28.6
A2.0	1.6	1.9	**2.1**	1.8	1.3	1.1	0.8	0.7	0.7	2.1
A3.2	0.9	0.9	**0.9**	0.8	0.5	0.4	0.3	0.3	0.3	0.9
A6.11	**4.6**	4.4	4.6	4.4	2.4	2.1	1.5	1.3	1.3	4.6
A6.9	**6.2**	6.0	**6.2**	5.9	3.3	2.9	2.0	1.8	1.7	6.2
A6.10	13.2	12.6	**13.2**	11.6	7.1	6.1	4.3	3.8	3.7	13.2
A6.7	**1.0**	0.9	1.0	0.9	0.5	0.4	0.3	0.3	0.3	1.0
A6.8	16.9	16.5	**17.2**	15.0	9.3	8.0	5.7	5.0	4.9	17.2
A6.4	**1.7**	1.6	1.7	1.6	0.9	0.8	0.5	0.5	0.5	1.7
A6.5	18.2	17.9	**18.5**	16.5	10.3	8.9	6.3	5.6	5.5	18.5
A6.3	**0.4**	0.4	0.4	0.4	0.2	0.2	0.1	0.1	0.1	0.4
A6.3a	18.7	18.5	**18.9**	17.2	10.8	9.4	6.7	5.9	5.7	18.9
A6.2	19.1	18.9	**19.2**	17.6	11.1	9.7	6.9	6.1	5.9	19.2
A7.0	7.5	7.1	**7.5**	7.4	3.9	3.4	2.4	2.1	2.1	7.5
A6.0a	8.2	8.2	**8.6**	8.3	4.5	3.9	2.8	2.4	2.4	8.6
A13.0	2.3	2.2	**2.3**	2.2	1.2	1.1	0.8	0.7	0.7	2.3
A14.0	3.5	3.3	**3.5**	3.4	1.8	1.6	1.1	1.0	1.0	3.5
A6.1	**28.6**	28.2	28.5	25.0	18.7	16.3	11.7	10.3	10.1	28.6
A6.0	**29.0**	28.7	28.9	25.3	19.0	16.6	12.0	10.6	10.3	29.0
A15.0	30.5	**30.6**	30.4	27.1	20.1	18.0	13.3	11.7	11.4	30.6
A3.1	31.4	**31.6**	31.2	28.4	20.7	18.7	14.0	12.2	12.0	31.6
A4.4	2.7	2.6	**2.7**	2.5	1.5	1.3	0.9	0.8	0.8	2.7
A4.3	3.2	3.3	**3.4**	3.2	2.0	1.7	1.2	1.1	1.0	3.4
A4.2	7.4	7.5	**7.8**	7.2	4.7	3.9	2.9	2.5	2.5	7.8
A5.0	5.8	5.9	**6.2**	5.7	3.4	2.9	2.1	1.8	1.8	6.2
A4.1	13.3	13.4	**14.1**	12.1	8.1	6.8	5.0	4.4	4.3	14.1
A4.0	14.5	14.8	**15.2**	13.8	9.3	7.8	5.8	5.0	4.9	15.2
A3.0	39.3	**41.2**	39.6	39.9	28.9	26.8	20.4	17.8	17.5	41.2
A1.4	61.2	68.5	67.7	**69.4**	51.6	46.6	38.6	33.8	33.4	69.4
A8.0	1.2	1.2	**1.3**	1.2	0.6	0.5	0.4	0.3	0.3	1.3
A9.0	1.1	1.1	**1.1**	1.1	0.6	0.5	0.3	0.3	0.3	1.1
A1.3	62.2	70.2	69.3	**71.0**	52.8	48.2	39.7	35.1	34.7	71.0
A1.1	62.3	70.4	69.4	**71.1**	52.9	48.3	39.8	35.2	34.8	71.1
A1.2	0.7	0.7	**0.8**	0.7	0.5	0.5	0.4	0.3	0.3	0.8
A1.0	63.7	72.8	71.7	**73.6**	55.0	50.8	41.6	37.0	36.6	73.6
F1.2	**1.3**	1.2	1.3	1.2	0.7	0.6	0.4	0.4	0.3	1.3
F1.3	**1.2**	1.1	1.2	1.1	0.6	0.5	0.4	0.3	0.3	1.2
F1.1	**4.3**	4.0	4.2	3.9	2.4	2.1	1.5	1.3	1.3	4.3
E13.1	**6.0**	5.7	5.9	5.4	3.1	2.7	1.9	1.7	1.6	6.0
E13.0	**7.8**	7.5	7.7	7.2	4.3	3.7	2.6	2.3	2.2	7.8
E10.5	2.5	2.4	**2.5**	2.3	1.4	1.2	0.8	0.7	0.7	2.5
E10.3A	**1.5**	1.4	1.4	1.3	0.7	0.6	0.5	0.4	0.4	1.5
E10.4	4.9	4.8	**5.0**	4.5	2.7	2.3	1.7	1.4	1.4	5.0
E10.3	**6.4**	6.1	6.4	6.1	3.7	3.2	2.3	2.0	2.0	6.4
E10.2	6.9	6.8	6.9	**7.0**	4.4	3.7	2.7	2.3	2.3	7.0
E11.0	**1.0**	1.0	1.0	0.9	0.5	0.5	0.3	0.3	0.3	1.0
E10.1	7.7	7.7	7.6	**8.0**	5.2	4.3	3.2	2.8	2.8	8.0
E10.0	8.1	8.3	8.0	**8.6**	5.8	4.7	3.6	3.2	3.1	8.6
E9.1	1.5	1.6	**1.6**	1.5	0.9	0.8	0.5	0.5	0.5	1.6
E9.0	**4.3**	4.0	4.2	3.8	2.6	2.3	1.6	1.4	1.4	4.3
E8.6	4.2	4.1	**4.3**	4.0	2.3	2.0	1.4	1.3	1.2	4.3
E8.5	7.8	7.9	**8.2**	7.8	4.8	4.1	2.9	2.5	2.5	8.2
E8.4	8.4	8.6	**8.8**	8.5	5.3	4.6	3.3	2.8	2.8	8.8
E8.2	9.0	9.4	**9.4**	9.1	5.9	5.1	3.7	3.2	3.1	9.4
E8.1	9.9	**10.5**	10.3	10.0	7.1	5.9	4.5	3.9	3.8	10.5
E8.0	10.5	**11.2**	10.8	10.5	7.8	6.5	5.0	4.3	4.2	11.2

RAFTS PEAK FLOW ESTIMATES (m3/s)

Assessment of Critical Storm Duration - 100 Year Flood

RAFTS_ID	Storm Duration (mins)									
	25	60	90	120	180	270	360	540	720	Max
E5.0	**2.8**	2.6	2.8	2.6	1.5	1.3	0.9	0.8	0.8	*2.8*
E1.38	4.2	4.1	**4.3**	4.0	2.3	2.0	1.4	1.2	1.2	*4.3*
E3.0	2.3	2.3	**2.3**	2.0	1.3	1.1	0.8	0.7	0.7	*2.3*
E2.0	**2.7**	2.5	2.7	2.6	1.4	1.2	0.9	0.7	0.7	*2.7*
E1.37	9.2	9.2	**9.6**	9.3	5.5	4.7	3.4	2.9	2.9	*9.6*
E1.36	11.1	11.4	11.6	**12.2**	7.4	6.1	4.5	3.9	3.9	*12.2*
E1.35	**1.3**	1.2	1.3	1.2	0.7	0.6	0.4	0.4	0.3	*1.3*
E1.34	12.9	13.5	13.3	**15.0**	9.4	7.7	5.8	5.0	4.9	*15.0*
E1.33	13.5	14.2	13.8	**15.7**	10.0	8.3	6.2	5.4	5.3	*15.7*
E1.32	15.2	16.3	15.4	**17.5**	12.1	10.0	7.8	6.7	6.6	*17.5*
E1.31	15.3	16.5	15.6	**17.7**	12.2	10.1	7.9	6.8	6.7	*17.7*
E4.5	**5.4**	5.1	5.4	4.9	2.9	2.5	1.8	1.5	1.5	*5.4*
E4.4	7.8	7.6	**7.9**	7.3	4.5	3.9	2.7	2.4	2.4	*7.9*
E4.2	**2.3**	2.2	2.3	2.0	1.2	1.1	0.7	0.7	0.6	*2.3*
E4.3	11.0	10.9	**11.3**	10.4	6.5	5.4	4.0	3.5	3.4	*11.3*
E4.0	**0.6**	0.6	0.6	0.6	0.3	0.3	0.2	0.2	0.2	*0.6*
E4.1	11.4	11.5	**11.6**	11.1	7.0	5.9	4.3	3.8	3.7	*11.6*
E1.30	12.8	**13.1**	13.0	12.7	8.4	7.2	5.3	4.6	4.5	*13.1*
E1.29	26.2	**28.0**	27.0	27.8	20.7	17.1	13.3	11.5	11.3	*28.0*
E1.28	26.5	**28.5**	27.3	28.1	20.9	17.6	13.6	11.8	11.6	*28.5*
E6.0	4.7	4.6	**4.8**	4.6	2.6	2.2	1.6	1.4	1.3	*4.8*
E7.0	4.9	4.8	**5.0**	4.7	2.7	2.3	1.7	1.5	1.4	*5.0*
E1.26a	5.4	5.4	**5.6**	5.4	3.2	2.7	2.0	1.7	1.7	*5.6*
E1.27	31.3	34.5	**34.5**	32.4	24.7	22.3	17.7	15.0	14.9	*34.5*
E1.26	32.1	35.3	**35.3**	32.9	25.3	23.0	18.3	15.6	15.5	*35.3*
E1.25	34.0	**37.5**	37.3	34.4	27.1	24.8	19.8	17.0	16.9	*37.5*
E1.24	34.2	**37.9**	37.6	34.6	27.3	25.2	20.1	17.3	17.1	*37.9*
E1.23	34.7	**39.9**	39.5	36.0	28.7	27.2	21.8	19.1	18.8	*39.9*
E1.22	34.7	**40.4**	39.9	36.3	29.0	27.8	22.2	19.5	19.3	*40.4*
E1.21	34.8	**40.9**	40.5	36.8	29.5	28.4	22.7	20.1	19.9	*40.9*
E1.20	39.0	**47.8**	46.5	45.7	36.1	34.0	27.8	24.7	23.9	*47.8*
E1.19	39.1	**48.3**	46.9	46.1	36.5	34.2	28.3	25.1	24.4	*48.3*
E1.18	39.4	**48.8**	47.4	46.5	37.1	34.6	28.7	25.6	24.8	*48.8*
E1.17	39.4	**49.2**	47.7	46.9	37.4	34.8	29.0	25.9	25.3	*49.2*
E1.16	40.2	**50.8**	49.2	48.6	39.3	35.8	30.3	27.6	26.9	*50.8*
E1.15	40.2	**51.0**	49.6	48.9	39.6	36.0	30.6	27.9	27.4	*51.0*
E1.14	41.6	**54.2**	52.6	53.9	44.0	38.8	33.4	31.3	30.7	*54.2*
E1.13	41.6	**54.3**	52.7	54.0	44.1	38.9	33.5	31.4	30.9	*54.3*
E1.12	41.7	**54.6**	53.2	54.5	44.6	39.1	34.0	31.9	31.4	*54.6*
E1.11	41.7	**54.8**	53.4	54.7	44.8	39.2	34.2	32.2	31.8	*54.8*
E12.1	**2.8**	2.6	2.7	2.5	1.4	1.2	0.9	0.7	0.7	*2.8*
E12.0	**4.4**	4.1	4.3	3.9	2.3	2.0	1.4	1.2	1.2	*4.4*
E1.10	41.7	55.8	54.8	**56.0**	46.1	40.2	35.5	33.8	33.4	*56.0*
E1.8	**1.2**	1.1	1.2	1.0	0.6	0.5	0.4	0.3	0.3	*1.2*
E1.9	41.8	56.3	55.4	**56.8**	46.7	40.6	36.2	34.5	34.3	*56.8*
E1.7	41.8	57.9	57.5	**59.5**	49.0	42.1	38.5	37.3	37.0	*59.5*
E1.6	41.9	58.4	58.1	**60.2**	49.8	42.8	39.2	38.1	37.6	*60.2*
E19.0	**1.9**	1.8	1.9	1.8	1.0	0.9	0.6	0.5	0.5	*1.9*
E1.4	2.4	2.4	**2.5**	2.3	1.3	1.2	0.8	0.7	0.7	*2.5*
E14.1	**2.6**	2.5	2.6	2.4	1.3	1.2	0.8	0.7	0.7	*2.6*
E14.0	**8.0**	7.7	7.9	7.3	4.9	4.2	3.0	2.6	2.6	*8.0*
E1.5	41.9	60.1	60.3	**63.5**	53.4	46.8	42.3	41.6	41.1	*63.5*
E21.0	6.4	6.5	**6.8**	6.4	3.8	3.2	2.3	2.0	2.0	*6.8*
E15.16	**5.4**	5.1	5.3	5.1	2.8	2.4	1.7	1.5	1.4	*5.4*
E15.15	12.1	12.3	**12.9**	12.2	7.4	6.2	4.6	3.9	3.9	*12.9*
E15.14	13.3	13.6	**13.9**	13.9	8.5	7.2	5.3	4.6	4.5	*13.9*
E15.13	13.6	14.0	14.2	**14.3**	8.9	7.5	5.6	4.8	4.8	*14.3*
E15.12	13.8	14.3	14.4	**14.7**	9.2	7.8	5.8	5.0	4.9	*14.7*
E15.11	13.9	14.5	14.5	**14.8**	9.4	8.0	6.0	5.1	5.0	*14.8*
E15.10	14.2	14.9	14.8	**15.1**	9.8	8.4	6.3	5.4	5.3	*15.1*
E15.9	14.4	15.2	15.0	**15.3**	10.1	8.8	6.5	5.6	5.5	*15.3*
E15.8	14.8	**15.9**	15.5	15.8	10.6	9.5	7.1	6.1	6.0	*15.9*
E15.7	17.2	18.2	**19.3**	18.2	13.6	12.2	9.4	8.1	8.0	*19.3*

RAFTS PEAK FLOW ESTIMATES (m3/s)

Assessment of Critical Storm Duration - 100 Year Flood

RAFTS_ID	Storm Duration (mins)									
	25	60	90	120	180	270	360	540	720	Max
E15.6	17.6	18.7	**20.3**	18.5	14.1	12.9	9.9	8.6	8.4	*20.3*
E15.5	17.9	20.2	**22.1**	19.2	14.9	14.1	10.9	9.4	9.3	*22.1*
E15.4	18.5	21.5	**23.1**	20.5	15.5	15.0	11.7	10.1	9.9	*23.1*
E15.3	19.5	22.8	**24.1**	21.4	16.1	16.0	12.7	11.0	10.8	*24.1*
E15.2	20.3	23.8	**24.8**	22.1	17.0	16.8	13.5	11.7	11.5	*24.8*
E17.1	4.1	3.9	**4.1**	4.0	2.2	1.9	1.3	1.2	1.1	*4.1*
E17.0	4.2	4.1	**4.3**	4.2	2.3	2.0	1.4	1.3	1.2	*4.3*
E20.0	**0.5**	0.4	0.5	0.4	0.2	0.2	0.2	0.1	0.1	*0.5*
E15.1	22.4	26.6	**27.1**	24.8	20.0	18.9	15.3	13.3	13.1	*27.1*
E16.0	**1.3**	1.2	1.2	1.2	0.6	0.6	0.4	0.3	0.3	*1.3*
E15.0	23.6	28.2	**28.3**	26.1	21.8	20.3	16.6	14.4	14.2	*28.3*
E1.3	57.4	79.3	81.5	**84.7**	70.6	64.9	54.7	55.5	55.5	*84.7*
E18.1	**1.3**	1.2	1.3	1.2	0.6	0.5	0.4	0.3	0.3	*1.3*
E18.0	**1.8**	1.7	1.8	1.7	0.9	0.8	0.6	0.5	0.5	*1.8*
E1.2	57.9	79.8	82.1	**85.4**	71.3	65.8	55.5	56.3	56.1	*85.4*
E1.1	58.1	80.2	82.7	**85.9**	72.0	66.3	56.1	56.9	56.5	*85.9*
E1.0	58.1	80.3	82.7	**86.0**	72.1	66.4	56.2	57.0	56.6	*86.0*
F1.0	59.6	81.2	84.0	**87.2**	73.6	68.4	57.9	58.6	58.0	*87.2*
B1.5	4.5	4.4	**4.8**	4.6	2.6	2.2	1.6	1.4	1.4	*4.8*
B1.13	4.4	4.5	**4.6**	4.1	2.6	2.2	1.6	1.4	1.4	*4.6*
B1.12	5.2	5.3	5.3	**5.4**	3.4	2.9	2.1	1.8	1.8	*5.4*
B3.2	0.9	0.9	**1.0**	0.9	0.5	0.4	0.3	0.3	0.3	*1.0*
B3.1	**2.7**	2.5	2.5	2.3	1.6	1.4	1.0	0.8	0.8	*2.7*
B3.0	3.2	**3.3**	3.2	3.3	2.1	1.9	1.4	1.2	1.1	*3.3*
B1.11	8.9	9.5	9.2	**9.9**	6.7	5.7	4.2	3.6	3.6	*9.9*
B1.10	10.0	10.8	10.2	**10.9**	7.7	6.7	5.2	4.5	4.4	*10.9*
B6.6	7.3	7.1	**7.5**	7.3	4.0	3.4	2.4	2.1	2.1	*7.5*
B6.5	9.4	9.2	**9.7**	9.6	5.3	4.5	3.2	2.8	2.8	*9.7*
B6.4	14.4	15.2	14.9	**16.9**	10.5	8.9	6.5	5.6	5.5	*16.9*
B6.3	16.2	16.7	16.7	**19.0**	11.8	10.2	7.4	6.4	6.3	*19.0*
B6.2	2.8	2.7	2.8	**2.8**	1.4	1.3	0.9	0.8	0.7	*2.8*
B6.1	18.0	18.9	18.4	**20.6**	14.1	11.9	9.1	7.8	7.7	*20.6*
B6.0	19.4	20.4	19.8	**22.1**	15.6	13.0	10.1	8.7	8.6	*22.1*
B4.4	**2.1**	2.0	2.1	1.9	1.1	1.0	0.7	0.6	0.6	*2.1*
B4.3	3.9	3.9	**4.0**	3.8	2.4	2.1	1.5	1.3	1.3	*4.0*
B5.0	2.4	2.3	**2.4**	2.2	1.3	1.1	0.8	0.7	0.7	*2.4*
B4.2	7.8	7.8	**7.9**	7.4	4.9	4.3	3.1	2.6	2.6	*7.9*
B4.1	8.2	**8.4**	8.3	8.0	5.6	4.7	3.5	3.0	2.9	*8.4*
B4.0	27.8	28.6	28.1	**30.1**	21.1	17.8	13.7	11.8	11.6	*30.1*
B1.9	37.7	39.7	38.4	**41.3**	29.1	24.9	19.2	16.6	16.4	*41.3*
B7.3	3.5	3.6	**3.8**	3.6	2.1	1.8	1.3	1.1	1.1	*3.8*
B7.2	5.9	5.9	**6.3**	5.8	3.4	2.9	2.1	1.8	1.8	*6.3*
B7.1	**8.5**	7.8	8.3	8.4	5.3	4.4	3.3	2.8	2.8	*8.5*
B7.0	**10.3**	9.4	10.0	10.1	6.5	5.5	4.0	3.5	3.4	*10.3*
B1.8	42.0	45.9	43.9	**46.3**	35.1	30.3	23.7	20.7	20.3	*46.3*
B1.6	42.3	46.7	44.6	**46.9**	35.7	31.2	24.3	21.4	21.0	*46.9*
B1.7	42.4	47.1	45.0	**47.3**	36.1	31.8	24.8	21.9	21.5	*47.3*
B1.4	42.8	**48.9**	46.8	48.8	37.5	34.0	26.3	23.4	23.0	*48.9*
B8.1	3.6	3.6	**3.8**	3.5	2.1	1.8	1.3	1.1	1.1	*3.8*
B8.0	5.5	5.9	**6.2**	5.9	3.8	3.3	2.4	2.1	2.1	*6.2*
B9.0	8.4	8.5	**9.0**	8.8	5.9	5.1	3.7	3.2	3.1	*9.0*
B1.3	9.5	10.0	10.4	**10.7**	7.3	6.4	5.1	4.4	4.5	*10.7*
B1.2	48.7	**55.7**	54.3	54.0	42.6	40.3	32.1	28.3	28.1	*55.7*
B10.0	1.1	1.2	**1.3**	1.2	0.9	0.7	0.6	0.5	0.5	*1.3*
B1.1	49.3	**56.8**	55.3	54.8	43.4	41.1	32.9	29.0	28.9	*56.8*
B11.0	2.4	2.6	**2.7**	2.5	1.6	1.3	1.0	0.9	0.8	*2.7*
B2.0	2.7	2.7	**2.9**	2.5	1.7	1.4	1.0	0.9	0.9	*2.9*
B1.0	50.7	**59.8**	57.9	57.5	45.5	43.3	35.2	31.2	31.1	*59.8*
Lake	194.9	240.5	236.7	**241.5**	194.3	189.8	160.2	149.2	149.7	*241.5*
Sea	209.4	260.3	255.0	**260.6**	210.9	204.1	170.8	157.9	157.8	*260.6*

RAFTS PEAK FLOW ESTIMATES (m3/s)
Summary of Peak Flows (for Critical Storm Duration)

RAFTS_ID	5 Year Flood		20 Year Flood		100 Year Flood	
	Peak Flow	Critical Duration	Peak Flow	Critical Duration	Peak Flow	Critical Duration
C2.0	1.0	25	1.3	120	1.7	120
C1.6	3.2	25	4.4	25	5.5	120
C3.0	1.6	25	2.2	25	2.7	120
C1.5	6.6	25	9.1	25	11.2	90
C1.4	7.9	25	10.7	25	13.2	90
C1.3	9.1	25	12.3	25	15.4	120
C1.2	12.1	120	16.4	120	20.7	120
C1.1	12.8	120	17.4	120	22.1	120
C1.0	13.8	120	18.8	120	23.8	120
D19.0	1.2	90	1.8	90	2.2	90
D18.0	2.4	90	3.5	90	4.4	90
D17.0	0.6	120	0.9	120	1.3	60
D16.0	3.7	90	5.4	90	6.9	90
D15.0	4.8	90	6.9	90	8.9	90
D13.0	6.9	90	9.8	90	12.6	90
D12.0	7.1	90	10.1	90	12.9	90
D8.0	1.3	90	1.8	90	2.3	90
D9.0	1.6	90	2.3	90	2.9	90
D5.0	0.4	25	0.5	90	0.7	90
D2.0	0.9	90	1.2	25	1.6	25
D3.0	1.2	90	1.7	25	2.1	25
D1.4	2.9	90	4.0	90	5.0	90
D1.3	4.0	90	5.5	90	6.9	90
D4.0	0.2	25	0.3	25	0.3	90
D1.2	5.1	90	7.0	90	8.8	90
D1.1	5.3	90	7.3	90	9.1	90
D1.0	5.4	90	7.5	90	9.4	90
D7.0	0.7	90	1.0	90	1.3	90
D6.0	6.4	120	8.9	120	11.4	120
D10.0	7.9	120	11.2	120	14.3	120
D11.0	14.5	90	20.7	90	26.7	90
F3.1	0.8	25	1.1	25	1.4	25
F4.1	1.3	90	1.8	25	2.2	25
F5.1	1.0	90	1.3	90	1.7	25
F8.0	0.6	25	0.8	90	1.1	90
F6.0	2.0	90	2.9	90	3.7	90
F7.0	0.4	120	0.6	120	0.8	60
F5.0	3.7	90	5.4	90	6.9	90
F4.0	5.3	90	7.6	90	9.7	90
F3.0	6.8	90	9.7	90	12.3	90
F2.0	8.8	90	12.6	90	16.2	90
G1.0	2.5	90	3.4	90	4.3	90
G2.0	0.4	120	0.5	120	0.7	60
G3.0	4.0	90	5.6	90	7.2	90
G4.0	4.9	90	6.9	90	8.8	90
G6.0	0.4	25	0.6	25	0.7	90
G5.0	1.8	90	2.5	90	3.1	90
G7.0	4.4	25	6.0	90	7.7	90
A12.10	2.3	90	3.1	90	3.9	90
A12.9	3.8	90	5.2	90	6.5	90
A12.8	4.0	90	5.6	90	6.9	90
A12.7	4.4	90	6.1	90	7.6	90
A12.6	7.3	120	10.4	90	13.4	120
A12.5	7.5	120	10.7	120	14.0	120
A12.3	0.9	90	1.3	90	1.7	115
A12.4	8.7	120	12.4	90	16.3	60
A12.2	8.9	120	12.7	90	16.8	60
A12.0	2.0	90	3.0	90	3.8	90
A12.1	10.5	90	15.0	90	19.9	90
A1.13	1.2	90	1.6	25	2.0	25
A1.12	11.3	90	16.2	90	21.7	60
A1.11	12.2	90	17.5	90	23.8	60
A1.10	12.4	90	17.8	60	24.2	60

RAFTS PEAK FLOW ESTIMATES (m3/s)

Summary of Peak Flows (for Critical Storm Duration)

RAFTS_ID	5 Year Flood		20 Year Flood		100 Year Flood	
	Peak Flow	Critical Duration	Peak Flow	Critical Duration	Peak Flow	Critical Duration
A1.9	12.8	90	18.3	60	24.9	60
A1.8	13.3	90	19.1	60	26.0	60
A10.1	1.4	90	2.0	90	2.6	90
A10.0	2.0	90	2.9	90	3.7	90
A1.7	14.4	120	20.7	120	27.6	120
A11.0	1.0	90	1.4	25	1.7	90
A1.6	14.8	120	21.4	120	28.5	120
A1.5	14.9	120	21.5	120	28.6	120
A2.0	1.0	90	1.5	90	2.1	90
A3.2	0.5	90	0.7	90	0.9	90
A6.11	2.7	90	3.7	25	4.6	25
A6.9	3.7	90	5.0	90	6.2	115
A6.10	7.7	90	10.6	90	13.2	90
A6.7	0.6	90	0.8	25	1.0	25
A6.8	10.0	90	13.7	90	17.2	90
A6.4	1.0	25	1.4	25	1.7	25
A6.5	10.8	90	14.7	90	18.5	90
A6.3	0.2	90	0.3	25	0.4	25
A6.3a	11.1	90	15.0	90	18.9	90
A6.2	11.2	90	15.3	90	19.2	90
A7.0	4.4	90	6.0	25	7.5	90
A6.0a	4.9	90	6.8	90	8.6	90
A13.0	1.3	90	1.8	90	2.3	90
A14.0	2.1	90	2.8	25	3.5	90
A6.1	16.3	90	22.6	90	28.6	25
A6.0	16.6	90	22.9	90	29.0	25
A15.0	17.4	90	24.0	90	30.6	60
A3.1	17.8	90	24.6	90	31.6	60
A4.4	1.6	90	2.2	90	2.7	90
A4.3	1.9	90	2.7	90	3.4	90
A4.2	4.3	90	6.2	90	7.8	90
A5.0	3.5	90	4.9	90	6.2	90
A4.1	7.9	90	11.1	90	14.1	90
A4.0	8.5	90	12.0	90	15.2	90
A3.0	22.2	60	31.4	60	41.2	60
A1.4	36.4	120	52.5	120	69.4	120
A8.0	0.8	25	1.0	25	1.3	90
A9.0	0.7	25	0.9	25	1.1	90
A1.3	37.3	120	53.7	120	71.0	120
A1.1	37.4	120	53.8	120	71.1	120
A1.2	0.4	90	0.6	90	0.8	90
A1.0	38.8	120	55.7	120	73.6	120
F1.2	0.8	25	1.1	25	1.3	25
F1.3	0.7	25	1.0	25	1.2	25
F1.1	2.4	90	3.3	90	4.3	25
E13.1	3.5	90	4.9	25	6.0	25
E13.0	4.5	90	6.2	90	7.8	25
E10.5	1.5	90	2.0	90	2.5	90
E10.3A	0.9	25	1.2	25	1.5	25
E10.4	2.9	90	4.0	90	5.0	90
E10.3	3.7	90	5.1	90	6.4	25
E10.2	4.0	120	5.5	120	7.0	120
E11.0	0.6	25	0.9	25	1.0	25
E10.1	4.6	120	6.3	120	8.0	120
E10.0	4.9	120	6.7	120	8.6	120
E9.1	0.9	90	1.3	90	1.6	90
E9.0	2.5	25	3.5	25	4.3	25
E8.6	2.5	90	3.4	90	4.3	90
E8.5	4.7	90	6.5	90	8.2	90
E8.4	5.0	90	7.0	90	8.8	90
E8.2	5.4	90	7.4	90	9.4	90
E8.1	5.9	90	8.1	90	10.5	60
E8.0	6.2	90	8.5	60	11.2	60

RAFTS PEAK FLOW ESTIMATES (m3/s)

Summary of Peak Flows (for Critical Storm Duration)

RAFTS_ID	5 Year Flood		20 Year Flood		100 Year Flood	
	Peak Flow	Critical Duration	Peak Flow	Critical Duration	Peak Flow	Critical Duration
E5.0	1.6	90	2.2	90	2.8	25
E1.38	2.5	90	3.4	90	4.3	90
E3.0	1.3	90	1.9	90	2.3	90
E2.0	1.6	90	2.2	25	2.7	25
E1.37	5.4	90	7.6	90	9.6	90
E1.36	6.8	120	9.6	120	12.2	120
E1.35	0.7	90	1.1	25	1.3	25
E1.34	8.5	120	11.8	120	15.0	120
E1.33	8.9	120	12.4	120	15.7	120
E1.32	10.0	120	13.8	120	17.5	120
E1.31	10.1	120	13.9	120	17.7	120
E4.5	3.1	90	4.3	90	5.4	25
E4.4	4.6	90	6.3	90	7.9	90
E4.2	1.3	90	1.8	25	2.3	25
E4.3	6.5	90	8.9	90	11.3	90
E4.0	0.4	90	0.5	25	0.6	25
E4.1	6.8	90	9.3	90	11.6	90
E1.30	7.5	90	10.3	90	13.1	60
E1.29	16.0	120	21.8	120	28.0	60
E1.28	16.2	120	22.0	120	28.5	60
E6.0	2.8	90	3.9	90	4.8	90
E7.0	2.9	90	4.0	90	5.0	90
E1.26a	3.2	90	4.5	90	5.6	90
E1.27	18.2	60	26.2	90	34.5	90
E1.26	18.7	60	26.9	90	35.3	90
E1.25	19.8	90	28.4	90	37.5	60
E1.24	20.0	90	28.6	90	37.9	60
E1.23	21.1	90	30.0	90	39.9	60
E1.22	21.3	90	30.4	90	40.4	60
E1.21	21.6	90	30.8	90	40.9	60
E1.20	25.0	90	35.3	60	47.8	60
E1.19	25.2	60	35.7	60	48.3	60
E1.18	25.5	60	36.1	60	48.8	60
E1.17	25.7	60	36.3	60	49.2	60
E1.16	26.6	60	37.5	60	50.8	60
E1.15	26.7	60	37.7	60	51.0	60
E1.14	29.2	120	40.8	120	54.2	60
E1.13	29.3	120	40.9	120	54.3	60
E1.12	29.5	120	41.2	120	54.6	60
E1.11	29.6	120	41.4	120	54.8	60
E12.1	1.6	25	2.3	25	2.8	25
E12.0	2.5	90	3.5	25	4.4	25
E1.10	30.4	120	42.4	120	56.0	120
E1.8	0.7	90	1.0	25	1.2	25
E1.9	30.8	120	42.9	120	56.8	120
E1.7	32.1	120	44.9	120	59.5	120
E1.6	32.5	120	45.5	120	60.2	120
E19.0	1.1	90	1.5	25	1.9	25
E1.4	1.4	90	2.0	90	2.5	90
E14.1	1.6	90	2.2	25	2.6	25
E14.0	4.6	90	6.3	90	8.0	25
E1.5	34.5	120	47.9	120	63.5	120
E21.0	3.8	90	5.4	90	6.8	90
E15.16	3.2	90	4.4	25	5.4	25
E15.15	7.2	90	10.1	90	12.9	90
E15.14	7.8	120	10.9	90	13.9	90
E15.13	8.1	120	11.2	120	14.3	120
E15.12	8.3	120	11.5	120	14.7	120
E15.11	8.3	120	11.6	120	14.8	120
E15.10	8.5	120	11.8	120	15.1	120
E15.9	8.7	120	12.0	120	15.3	120
E15.8	8.9	120	12.3	120	15.9	60
E15.7	10.3	90	14.6	90	19.3	90

RAFTS PEAK FLOW ESTIMATES (m3/s)
Summary of Peak Flows (for Critical Storm Duration)

RAFTS_ID	5 Year Flood		20 Year Flood		100 Year Flood	
	Peak Flow	Critical Duration	Peak Flow	Critical Duration	Peak Flow	Critical Duration
E15.6	10.9	90	15.4	90	20.3	90
E15.5	12.0	90	16.9	90	22.1	90
E15.4	12.6	90	17.8	90	23.1	90
E15.3	13.1	90	18.5	90	24.1	90
E15.2	13.6	90	19.0	90	24.8	90
E17.1	2.4	90	3.3	90	4.1	90
E17.0	2.5	90	3.4	90	4.3	90
E20.0	0.3	90	0.4	25	0.5	25
E15.1	14.8	90	20.7	90	27.1	90
E16.0	0.7	25	1.1	25	1.3	25
E15.0	15.5	90	21.8	90	28.3	90
E1.3	46.3	120	64.0	120	84.7	120
E18.1	0.8	25	1.1	25	1.3	25
E18.0	1.1	90	1.5	25	1.8	25
E1.2	46.7	120	64.5	120	85.4	120
E1.1	47.0	120	64.9	120	85.9	120
E1.0	47.0	120	64.9	120	86.0	120
F1.0	47.7	120	66.0	120	87.2	120
B1.5	2.8	25	3.7	90	4.8	90
B1.13	2.6	90	3.6	90	4.6	90
B1.12	3.0	90	4.2	90	5.4	120
B3.2	0.5	90	0.8	90	1.0	90
B3.1	1.5	25	2.1	25	2.7	25
B3.0	1.9	120	2.6	120	3.3	60
B1.11	5.4	120	7.7	120	9.9	120
B1.10	6.0	120	8.5	120	10.9	120
B6.6	4.3	90	5.9	90	7.5	90
B6.5	5.6	90	7.7	90	9.7	90
B6.4	9.0	120	13.1	120	16.9	120
B6.3	10.2	120	14.7	120	19.0	120
B6.2	1.7	25	2.3	25	2.8	120
B6.1	11.2	120	16.0	120	20.6	120
B6.0	12.1	120	17.2	120	22.1	120
B4.4	1.2	90	1.7	25	2.1	25
B4.3	2.3	90	3.2	90	4.0	90
B5.0	1.4	90	1.9	90	2.4	90
B4.2	4.5	90	6.3	90	7.9	90
B4.1	4.7	90	6.5	90	8.4	60
B4.0	16.5	120	23.4	120	30.1	120
B1.9	22.7	120	32.1	120	41.3	120
B7.3	2.1	90	3.0	90	3.8	90
B7.2	3.5	90	5.0	90	6.3	90
B7.1	5.0	25	6.8	25	8.5	25
B7.0	6.1	25	8.4	25	10.3	25
B1.8	25.6	120	36.0	120	46.3	120
B1.6	26.0	120	36.5	120	46.9	120
B1.7	26.2	120	36.7	120	47.3	120
B1.4	27.1	120	37.9	120	48.9	60
B8.1	2.1	90	3.0	90	3.8	90
B8.0	3.3	90	4.8	90	6.2	90
B9.0	4.8	90	7.0	90	9.0	90
B1.3	5.5	120	8.1	120	10.7	120
B1.2	29.9	120	41.7	120	55.7	60
B10.0	0.6	90	1.0	90	1.3	90
B1.1	30.3	120	42.4	120	56.8	60
B11.0	1.5	90	2.1	90	2.7	90
B2.0	1.6	90	2.2	90	2.9	90
B1.0	31.5	120	43.9	60	59.8	60
Lake	129.3	120	182.0	120	241.5	120
Sea	140.0	120	196.7	120	260.6	120

APPENDIX C

Further Discussion on Model Boundary Conditions

Further Discussion on Model Boundary Conditions

Introduction

Following exhibition of the draft Flood Study report during 2009/2010, it was apparent that there was considerable confusion regarding the combination of flooding events that the study had been based on. A group opposed to the Study stated that the Study's model "incredibly combines the effects of a 1 in 100 year flood, combined with extreme tides and winds and excessively blocked drains and unrealistically high sea levels" (www.shirefloodwatch.com.au, 2011)

Many of these matters were discussed at a technical meeting held on 6 April 2011 at Sutherland Shire Council's administration building between the study team and an independent consultant (J Wyndham Prince). It was agreed that further clarification should be provided in the Flood Study report on several of these matters.

1. Combination of Flood Events Considered

The Study has considered that flooding can occur from the Gwawley Bay catchment and also from the Georges River. These events have been considered separately, but it is not assumed that they will occur at the same time.

For instance, the design 100 year flood considers two types of flooding scenarios:

i) Backwater flooding into the study area from a 100 year Georges River flood (estimated at RL 1.7m AHD). No flow from the Gwawley Bay catchment has been considered in this scenario. The extent of flood inundation from this scenario is shown on Figure 1.

ii) Flooding caused by 100 year flows from the Gwawley Bay catchment coinciding with a normal high tide in the Georges River of RL 0.6m AHD. This assumes that there is no elevation of river levels due to flooding of the Georges River or elevation of ocean levels at Botany Bay other than a normal high tide. The extent of flood inundation from this scenario is shown on Figure 2.

The first flooding scenario (Figure 1) provides the highest flood levels immediately adjacent to waterway areas of Sylvania Waters. In most instances floodwater is confined to the waterway areas and do not breach the canal banks by more than a few metres. The main exceptions include some low lying properties on Murray Island and in Castlereagh Crescent. Many of the roads within Sylvania Waters are lower than the adjacent property levels, and experience inundation through floodwater in the canal backing up through the stormwater pipe network.

The second flooding scenario (Figure 2) considers flow from the catchment area coinciding with a normal high tide level. This generally provides the highest flood levels within the catchment, with the exception of the immediate waterway areas in Sylvania Waters.

The 100 year design flood in the flood study is the envelope of the first and second flooding scenarios. This does not assume that flooding in the Gwawley Bay catchment is coincident with flooding in the Georges River or Botany Bay. A 100 year flood in the Gwawley Bay catchment coincident with a 100 year flood in the Georges River would produce a significantly higher flood level.

2. Adopted Flood levels in the Georges River and Botany Bay

The adopted 100 year flood level in the Georges River is based on a previous analysis of flood behaviour in the lower Georges River that was undertaken as part of the Georges River Floodplain Risk Management Study and Plan (Bewsher Consulting, 2004). That study estimated that there was no difference in the 100 year storm tide level experienced in Botany Bay and the 100 year flood level experienced in the Georges River adjacent to Gwawley Bay.

Whilst the definition of flood behaviour in the Lower Georges River is not included in the project brief for the Gwawley Bay Study, some questions have been raised regarding differences in the adopted 100 year flood level in Botany Bay (RL 1.7m AHD) and other estimates that have been provided for the 100 year ocean level in Sydney Harbour at Fort Denison (RL 1.45m AHD). Consequently, some discussion on the potential difference in flood level estimates at both sites has been provided.

There is a continuous period of tide records available from the Fort Denison tide gauge for the period from 1914 to present. During this time, the highest recorded water level recorded at the gauge was RL 1.475m AHD recorded on 25th May 1974. The second highest recorded water level was RL 1.425m AHD recorded on 27th April 1990. The estimated 100 year still water level at Fort Denison, based on a frequency analysis of the available data, has been estimated at RL 1.435m AHD (Watson P.J and D.B Lord, 2008, *Fort Denison Sea Level Rise Vulnerability Study*).

Storm tide ocean levels are comprised of normal astronomic tidal variations and other sea level rise anomalies due to reduced barometric pressure, long shore wave set-up, and wind stress over the waterway area. Estimates for the 100 year storm tide level along the NSW coast generally range from RL 2.4m AHD to RL 2.6m AHD. The level experienced in a deep harbour, such as at Fort Denison, will be somewhat less as the effects of wave set-up and wind stress are reduced.

The 100 year storm tide level that has been adopted for Botany Bay (RL 1.7m AHD) is some 0.265m higher than the estimated 100 year level at Fort Denison. It is not unreasonable to expect a higher level in Botany Bay during ocean storm events, as it is more exposed to long shore ocean waves than Fort Denison. It is also a much shallower water body and the influence of wind stress on water levels is expected to be higher.

Whilst there is no long term tide recorder located within Botany Bay, it is expected that the 100 year storm tide level will be somewhere between that estimated for Fort Denison and that estimated for the NSW coast (i.e. between RL 1.435m AHD and RL 2.6m AHD). The adopted level of RL 1.7m AHD would appear to be a reasonable estimate.

Despite no formal study on storm tide levels in Botany Bay, a number of flood studies that have been undertaken on waterways that drain to Botany Bay have adopted a 100 year storm tide level of RL 1.7m AHD. These studies include:

- Woronora River Flood Study (Public Works Department, 1991);
- Cooks River Floodplain Management Study (Webb McKeown & Associates, 1994);
- Georges River Floodplain Risk Management Study (Bewsher Consulting, 2004);
- Oyster Creek Flood Study (Webb McKeown & Associates, 2005);
- Kurnell Flood Study (Webb McKeown & Associates, 2008);
- Cooks River Flood Study (MWH+PB Engineering & Planning Services, 2009).

A separate Sea Level Rise Risk Assessment undertaken for Sutherland Shire Council (GHD, September 2011) investigated storm tide levels within the Lower Georges River estuary for existing and future conditions. The assessment was based on the statistical analysis of astronomic and storm surge levels recorded at Fort Denison and numerical modelling of these tides, including allowance for regional and local waves, through Botany Bay and the Lower Georges River estuary. Plots showing storm tide levels are provided for various locations along the Lower Georges River. The storm tide estimate provided at Tom Uglys Bridge under existing (2010) conditions is shown to be approximately mid way between RL 1.6m AHD and 1.7m AHD. GHD advised that this estimate would be representative of conditions that would be experienced in the vicinity of Gwawley Bay.

The GHD estimate provides relatively close agreement to the 100 year storm tide level of RL 1.7m AHD previously adopted for the Lower Georges River under existing conditions.

3. Joint Coincidence of Flooding

The Gwawley Bay Flood Study has assumed that flood flows from the catchment are coincident with a high tide level of RL 0.6m AHD. Some comments on the draft study included the suggestion that a lower tailwater level should have been considered.

Design flood levels within the lower catchment area are comprised of an envelope of flooding from either:

i) Backwater flooding into the study area from a 100 year Georges River flood (estimated at RL 1.7m AHD). No flow from the Gwawley Bay catchment has been considered in this scenario. The extent of flood inundation from this scenario is shown on Figure 1; or

ii) Flooding caused by 100 year flows from the Gwawley Bay catchment coinciding with a normal high tide in the Georges River of RL 0.6m AHD. The extent of flood inundation from this scenario is shown on Figure 2.

The assumed coincidence of catchment runoff with a high tide level in the river is considered to be on the low side of what would reasonably be expected to occur. The meteorological conditions that are required to generate a 100 year flood in the Gwawley Bay catchment could also be expected to produce significant runoff in the Georges River and/or elevated storm tide conditions in Botany Bay.

Studies that include an assessment of the joint coincidence of flooding would normally consider a 100 year catchment flood with a 20 year Georges River flood, or a 20 year catchment flood with a 100 year Georges River flood. The joint coincidence of flooding under these conditions would lead to a higher estimate of flooding within the lower catchment.

Regardless of the tailwater level assumed to coincide with catchment flooding (in Scenario ii), flood levels in the lower study area and in the waterway areas of Sylvania Waters, can be no lower than that which would occur from backwater flooding in the Georges River (in Scenario i) or RL 1.7m AHD.

Reducing the tailwater level during a catchment flood will also have negligible impact in the catchment area surrounding Sylvania Waters. These areas are typically above RL 1.5m AHD, and the adopted high tide boundary condition of RL 0.6m AHD will have little influence on the stormwater drainage system in these areas. The vast majority of pipe systems draining to Sylvania Waters are ‘inlet controlled’ meaning that the discharge capacity of the pipe system is not influenced to any extent by the water level in Sylvania Waters.

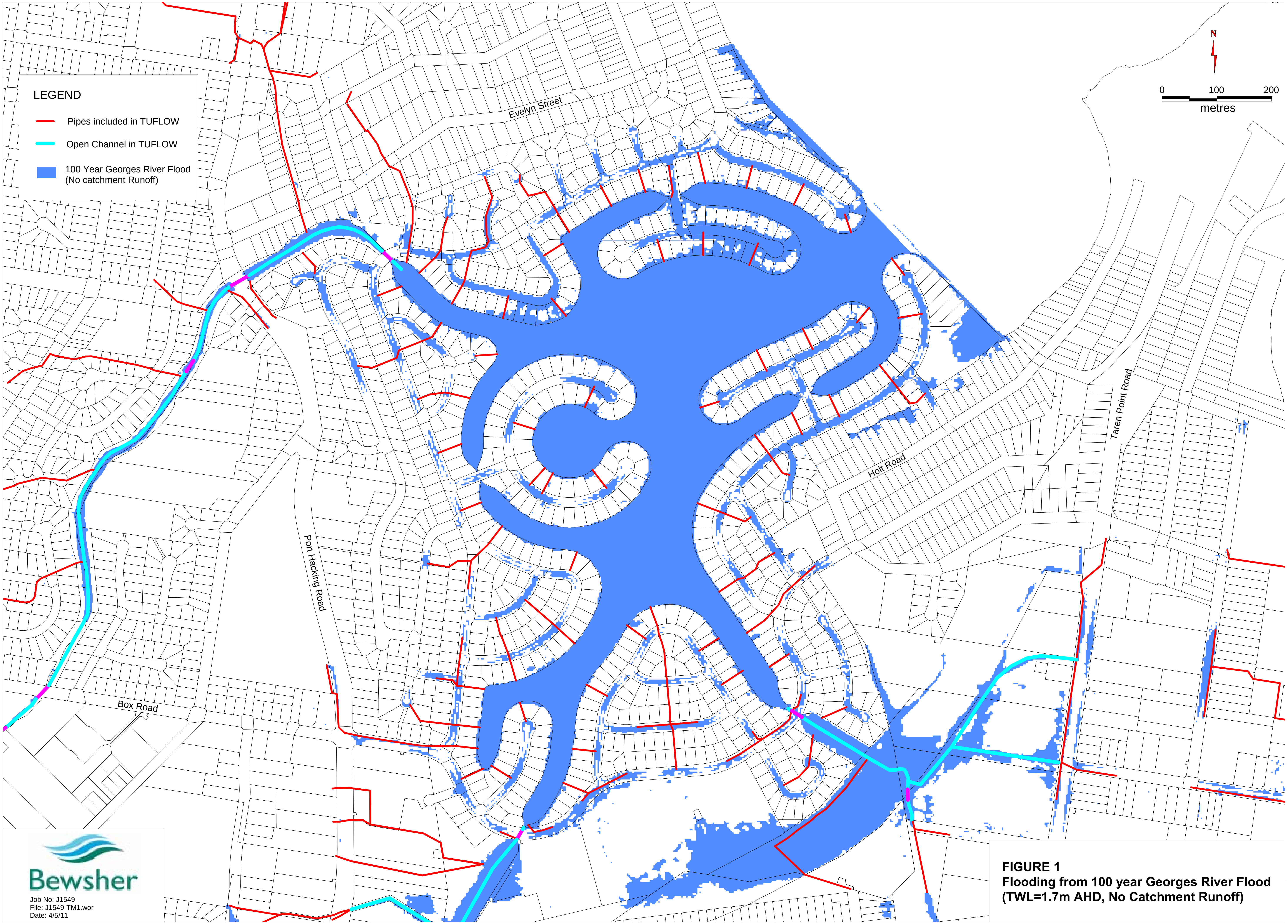


FIGURE 1
Flooding from 100 year Georges River Flood
(TWL=1.7m AHD, No Catchment Runoff)

FIGURE 2
Flooding from 100 year Catchment Runoff
(TWL=0.6m AHD, 100yr Catchment Runoff)