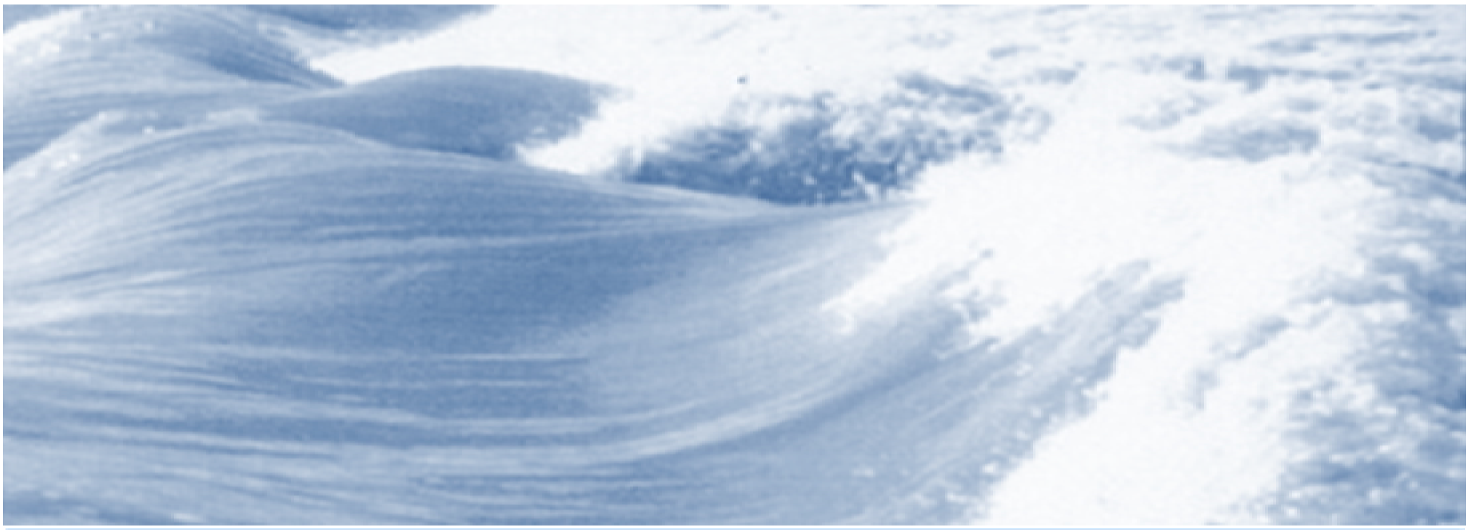
PITTWATER COUNCIL

Great Mackerel Beach Floodplain Risk Management Study & Plan

FINAL REPORT

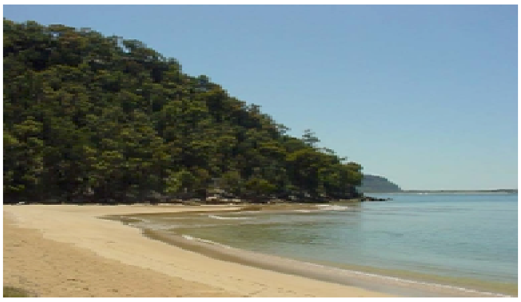
November 2010



PITTWATER COUNCIL

GREAT MACKEREL BEACH

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN



Final Report

NOVEMBER 2010

wma water

Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: 9299 2855
Fax: 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

GREAT MACKEREL BEACH FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT

NOVEMBER, 2010

Project Great Mackerel Beach Floodplain Risk Management Study and Plan	**Project Number** 27010
Client Pittwater Council	**Client's Representative** Sue Ribbons
Authors Richard Dewar	**Prepared by**
Date 5 November 2010	**Verified by**

Revision	Description	Date
3	Final Report	5 November 2010
2	Draft Final Report for Public Exhibition	April 2010
1	1st Draft for Review	Nov 2009

GREAT MACKEREL BEACH FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

TABLE OF CONTENTS

PAGE

LIST OF APPENDICES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

LIST OF TABLES

1. FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the following four sequential stages:

1. *Flood Study*
    - determine the nature and extent of the flood problem.

2. *Floodplain Risk Management Study*
    - evaluates management options for the floodplain in respect of both existing and proposed development.

3. *Floodplain Risk Management Plan*
    - involves formal adoption by Council of a plan of management for the floodplain.

4. *Implementation of the Plan*
    - construction of flood mitigation works to protect existing development,
    - use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Great Mackerel Beach Floodplain Risk Management Study and Plan constitutes the second and third stages of the management process for the Great Mackerel Beach catchment. It has been developed for Pittwater Council and prepared by WMAwater (formerly Webb, McKeown & Associates) for the future management of flood liable lands in the area.

2. GREAT MACKEREL BEACH FLOODPLAIN RISK MANAGEMENT PLAN

2.1. Introduction

The Great Mackerel Beach Floodplain Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual (April 2005) and:

- *Is based on a comprehensive and detailed evaluation of all factors that affect and are affected by the use of flood prone land;*
- *Represents the considered opinion of the local community on how to best manage its flood risk and its flood prone land;*
- *Provides a long-term path for the future development of the community.*

Flooding in the catchment has occurred on numerous occasions in the past (May 1974, November 1987, 1992, August 1998 and June 2003) and has caused property damage as well as risk to life to residents (e.g. drowning and/or being swept away). The most flood affected properties are those on the valley floor, particularly those adjacent to Monash Avenue.

Great Mackerel Beach is an ICOLL (Intermittent Open and Closed Lake or Lagoon) with a sandy beach berm at the entrance that is intermittently open and closed. Flooding occurs as a result of intense rainfall over the catchment which causes overtopping of the narrow incised channel and inundation of the lagoon and surrounding floodplain. The extent of flooding is influenced by the level of the beach berm at the entrance and whether elevated ocean levels in the Pittwater can overtop the berm and inundate the lagoon area.

The community consists of three “grass” streets with no vehicular traffic. Of the 120 properties that are affected by inundation in the PMF (Probable Maximum Flood), 22 houses are inundated above floor level in a 1% AEP event with this number increasing to approximately 60 in the PMF. The remainder of the houses are on higher ground within the property located to the south of the lagoon.

The Great Mackerel Beach Flood Study (September 2005) defined the existing flood behaviour for a range of design flood events through the use of sophisticated hydrologic and hydraulic modelling in combination with detailed aerial ground survey. Subsequently the Great Mackerel Beach Floodplain Risk Management Study determined the nature of the flood problem (extent and magnitude of flood damages) and investigated possible floodplain management measures.

2.2. Floodplain Risk Management Measures Considered

A matrix of all possible management measures was prepared and evaluated in the Floodplain Risk Management Study taking into account a range of parameters. This process eliminated a number of measures (refer Section 8) including:

- Flood mitigation dams and retarding basins,
- Channel modification works (dredging, straightening, concrete lining, removal of vegetation etc.),

- Levees, flood gates and pumps,
- Flood proofing of buildings,
- Voluntary purchase.

The two issues which provoked the most discussion were approaches to management of the entrance (should it be dredged or left to open/close naturally?) and how should climate change be addressed (what are the likely impacts and how will they impact on the community?).

The evaluation process for assessing each measure involved an “entrance management workshop” as well as interaction with the Floodplain Management Committee technical committee (known as the Community Working Group), Community and Stakeholder Meeting to discuss the Draft Floodplain Risk Management Plan and a Community Open Day at Great Mackerel Beach. Thus the proposed measures represent the considered opinion of both technical experts and local residents.

2.3. Proposed Floodplain Risk Management Measures in Plan

The proposed measures are described below (in no particular order within each priority group).

HIGH Priority

1. Preparation of a Draft Entrance Management Policy

- **Cost:** $30,000,
- **Responsibility:** Council, DECCW, NPWS,
- **Timeframe:** proposed commencement in 2011–2012.

The technical studies to date have raised many issues regarding the management of the entrance, the various benefits and dis-benefits of works/actions, the possible climate change impacts, the responsibilities of the various government organisations and lastly the importance of the entrance in impacting on flood levels upstream. A policy is therefore required to clearly establish the future management of the entrance. This policy would initially define the objectives of the policy, outline the data collection/inspection program and clearly define the roles and responsibilities. The Policy would be developed over time as data becomes available. As part of this policy a monitoring/inspection program (using line of site poles and regular monitoring of the entrance) is recommended that will provide additional data to make sound decisions and will provide the residents with some form of “ownership” of the issues and how they are being addressed. The monitoring program could start upon adoption of this Plan.

2. Review of Strategic Planning Issues

- **Cost:** internally within Council,
- **Responsibility:** Council,
- **Timeframe:** proposed commencement in 2011–2012.

Council has adopted flood-related development controls through its Development Control Plan (DCP). This includes a requirement for a refuge above the level of the Probable Maximum Flood (PMF) for all new dwellings where no flood-free access to evacuation is available, with associated requirements for structural integrity during such an extreme flood. It is recommended that through the flood-related development controls in the DCP that consideration is given to promote, or even require, second storey redevelopment in the lowermost areas of Great Mackerel Beach to provide additional refuge areas above the PMF.

It is recommended that more stringent controls be implemented to control discharge from septic tanks during a flood.

It is also recommended that Council investigates the possible problem of non-compliance, such as the construction of illegal structures that may exacerbate the flood problem or are not compliant with current development standards. Finally it is recommended that Council review its policies on approving access bridges that may act as debris collectors and so increase flood levels. Climate change issues have been addressed separately.

3. Modification to the Section 149 Certificate

- **Cost:** internally within Council,
- **Responsibility:** Council,
- **Timeframe:** proposed commencement in 2011–2012.

The Section 149 Certificate provides an important source of information into how a prospective property purchaser can determine the flood risk. Thus it is essential that this information is as accurate and up-to-date as possible. Property owners also wish to use this information to obtain (or not to obtain) flood insurance which has recently been introduced by major insurance companies. In order to provide as much information as possible to prospective property purchasers it is recommended that Council consider the inclusion of information on the Section 149 Part 5 Certificate about the percentage of the property inundated in the 1% AEP event.

4. Adaptation Strategies for Climate Change

- **Cost:** unknown and depends on whether physical work undertaken,
- **Responsibility:** Council, DECCW, local residents,
- **Timeframe:** (a) Update Flood Planning Levels to include 2100 climate change scenario: proposed implementation in 2011.
  (b) Investigation of Long-Term Viability of Community: proposed commencement in more than 2 years.

Climate change and in particular the potential rise in ocean level presents many challenges for the residents of Great Mackerel Beach. The study has evaluated many possible climate change scenarios (ocean level rise and rainfall increase) and the implications for existing and future development. Flooding of house floors can occur due to two broad conditions: a combination of intense rainfall over the catchment in combination with an elevated ocean level (runoff dominated) or as a result of ocean inundation (ocean dominated) in the absence of intense rainfall (the lowest floor is at 1.5m AHD). In general the effect of an ocean level rise is significantly attenuated upstream of the lagoon (where the houses are located) in a runoff dominated event (a 0.9m ocean level rise only increases the 1% AEP flood levels by 0.3m as the main determinant is the runoff and not the downstream water level). A 10% rainfall increase raises flood levels by approximately 0.1m. However, in an ocean dominated event a 0.9m increase in ocean level will increase tidal levels by 0.9m within the affected area (as any increase in ocean level equates to a similar increase within the study area).

Thus the most significant impact of climate change will be in ocean dominated events which will produce a significant increase in frequency of inundation. The highest tide in a year is 1.1m AHD and with a 0.9m increase a large number of properties (approximately 10 floors inundated) will be inundated on a regular basis. There are no viable means of providing protection from rises in ocean level and this frequency of land inundation may threaten the continued existence of the community.

Pittwater Council has adopted that for all future development that involves intensification of development, the 2100 climate change scenario (namely a 0.9m increase in sea level and an increase in rainfall intensity of 30%) shall be considered (development that does not involve intensification of development, such as single dwellings, may be required to consider climate change in the future). However, new design flood levels and hence new Flood Planning Levels have not been adopted for any floodplain at this stage. If new Flood Planning Levels are to be adopted for Great Mackerel Beach, then this will be the first floodplain in Pittwater LGA to apply Flood Planning Levels that include the 2100 Climate Change Scenario. On advice from Council, it is understood that it is proposed to progressively adopt Flood Planning Levels that include the 2100 Climate Change Scenario for other floodplains in Pittwater LGA as the studies are completed.

Therefore it is recommended that new Flood Planning Levels be adopted for Great Mackerel Beach that include the 2100 Climate Change Scenario of 0.9m sea level rise and 30% increase in rainfall intensity. This will include an update of Council's Flood Risk Database and Flood Mapping used to inform the Pittwater 21 Development Control Plan as well as Section 149(2) and Section 149(5) Planning Certificates. This will also involve a review of Council's Flood Risk Management Policy and associated flood-related development controls.

Council should consider the following timeframe of climate change scenarios.

Recommended Climate Change Scenarios

Approximate Timeframe	Approximate Year	Ocean Level Rise	Rainfall Increase
20 years	2030	0.2m	nil
20 years	2030	0.2m	10%
40 years	2050	0.4m*	say 15%
55 years	2065	0.55m	20%
90 years	2100	0.9m	30%

* NSW Sea Level Rise Policy Statement benchmark
Note: assume linear increase between years shown

Council should consider the long term viability of the community and in the absence of a viable mitigation measure one possible measure is to fill low lying areas. The siting and design of all new infrastructure must also take into account the potential for climate change increasing the flood hazard.

5. Update Flood Emergency Management

- **Cost:** $5,000,
- **Responsibility:** SES,
- **Timeframe:** proposed commencement in 2011–2012.

A sound Community Flood Emergency Response Plan (flood awareness and preparedness procedures as well as post flood recovery actions) will ensure that damages and the risk to life during a flood are minimised as far as possible. The Plan supports the updating of this work by the SES and Rural Fire Service (RFS) and can make available all relevant data. Upon completion this should be made available to all residents and local authorities (RFS at Great Mackerel Beach).

During consultation with the community and the RFS during the course of this project, it was highlighted that the only community facility at Great Mackerel Beach, the RFS shed, is severely flood-affected. This shed houses the RFS truck and all the emergency management equipment for this isolated community. It is recommended that an investigation be undertaken into finding an alternative location for the RFS shed that is less flood-affected, yet still meets the need for emergency management and the community.

6. Coastal Vulnerability Assessment

- **Cost:** $120,000,
- **Responsibility:** Council, DECCW,
- **Timeframe:** project commenced with proposed completion in 2011.

This study supports the undertaking of the proposed coastal vulnerability assessment for the Great Mackerel Beach community. It is also recommended that a detailed coastal processes/vulnerability study be undertaken for the Great Mackerel Beach lagoon entrance to assess the dynamics of the entrance and possible impacts on flooding, wave runup as well as the implications for climate change.

The Pittwater Coastline Definition and Climate Change Vulnerablity Study for the Pittwater LGA is currently in preparation. This study will include the assessment of coastal processes and impacts at all coastal beaches in the Pittwater LGA, together with Great Mackerel Beach for existing conditions and well as for the future implications of ocean/sea level rise.

7. Improve Flood Warning

- **Cost:** $25,000 plus $4,000 annual cost (depends upon measures implemented),
- **Responsibility:** Council,
- **Timeframe:** (a) installation of rainfall gauge: proposed for 2011.
  (b) other flood warning initiatives: to be investigated in conjunction with development of Community Flood Emergency Response Plan (see Item 5 of this Plan).

An accurate and reliable flood warning system is not possible for such a small catchment. However the installation of a siren (based on the creek reaching a certain level) and/or installation of a pluviometer (monitors rainfall) may assist in providing some advanced warning and at a minimum will provide additional data for improving the accuracy of design flood levels.

8. Improve Public Awareness of the Flood Hazard

- **Cost:** unknown as depends on measures,
- **Responsibility:** Council, SES,
- **Timeframe:** ongoing and in conjunction with development of Community Flood

Emergency Response Plan (see Item 5 of this Plan).

Improved public awareness of the flood hazard will reduce flood damages and the risk to life by making people aware of the means to mitigate damages (raise goods, having an evacuation plan) and lessen the risk of harm or injury (making people aware than drowning or being swept away can occur). The Plan supports all such measures and actions undertaken in this regard by the SES or Council, including Council's recent implementation of a Community Working Group framework.

The development of the Community Flood Awareness Program is likely to include the SES's FloodSafe program, information on the SES and Council's websites and continuation of the existing Community Working Group to provide regular updates and information to the community. The Community Flood Awareness Program will be developed and implemented in conjunction with the Community Flood Emergency Response Plan.

MEDIUM Priority

9. House Raising

- **Cost:** $80,000 per house,
- **Responsibility:** Council, DECCW, house owner,
- **Timeframe:** (a) house raising scheme: proposed commencement of liaison in 2011.
  (b) house rebuilding subsidy scheme: proposed commencement in more than 2 years

For the majority of flood affected properties house raising may not be technically possible (brick construction or two storey). Six houses may be suitable for raising (probably only economically viable for 2 houses) and this measure should be discussed with the owners. If viable and acceptable to property owners, a house raising scheme could be investigated further. House raising may attract grant funding assistance from the NSW Government for the property owner. Up to two-thirds of the cost of raising a house may be available.

House rebuilding to flood-compatible standards in accordance with Council's flood-related development controls is currently not eligible for grant funding assistance. For the most severely flood-affected properties, Council may wish to investigate a house rebuilding subsidy scheme some time in the future.

10. Management of Local Drainage – Great Mackerel Beach Local Drainage Strategy

- **Cost:** $20,000,
- **Responsibility:** Council,
- **Timeframe:** proposed commencement of strategy development in 2011.

The study has identified some past local drainage issues (ponding of runoff, re direction into properties, waterlogging of grass roads). In the first instance it is recommended that Council establish and maintain a framework by which residents can advise Council of the issues immediately following heavy rain. Secondly it is recommended that Council prepare the Great Mackerel Beach Local Drainage Strategy which would include a "road regrading plan" to identify if the problems can be minimised and if so undertake the necessary work. It would also include advice regarding whether the “low slung” pipes under the Monash Avenue bridge can be realigned. As local drainage improvements have minimal benefit in large flood events these works may not receive financial support under the State and Federal Government’s flood mitigation grants program.

LOW Priority

11. Water Quality/Ecosystem Enhancement

- **Cost:** internally within Council,
- **Responsibility:** Council,
- **Timeframe:** (a) Pittwater Estuary Management Plan: adoption anticipated in early 2011.
  (b) Great Mackerel Beach Creek Rehabilitation Plan: timeframe unknown.

The study supports measures that promote water sensitive urban design. Residents have complained about the lack of vegetation clearing of the creek. From a flooding perspective there is no tangible benefit if clearing is undertaken and thus this measure cannot be included in this Plan, however this plan supports preparation of a Great Mackerel Beach Creek Rehabilitation Plan or similar. The Pittwater Estuary Management Plan is currently nearing finalisation with Public Exhibition completed in October 2010 and adoption by Council expected in December 2010. One of the recommendations in the Plan is the preparation of a Great Mackerel Beach Creek Rehabilitation Plan and so funding may be available through the Estuary Management Program.

2.4. Implementation of Great Mackerel Beach Floodplain Risk Management Plan

Once the Great Mackerel Beach Floodplain Risk Management Plan is adopted by Council (proposed for December 2010), Council can commence implementation of the Plan. With an adopted Plan, Council can apply for grant funding assistance under the annual NSW Government’s Floodplain Management program and the Natural Disaster Resilience Grants Scheme (NDRGS) (or their equivalent). Currently these grant programs can provide Council with two-thirds of project costs, with Council providing the remaining one-third of costs.

It must be emphasised that these grant programs are highly competitive, with limited funds that cannot be guaranteed. Projects are prioritised against all other projects across the state. Also, the NDRGS does not just cover flood-related projects, but other natural hazards as well such as bushfire, tsunami and earthquakes.

Also, implementation of the Floodplain Risk Management Plan must tie in with Council’s Strategic Plan and will be limited by Council’s budgetary constraints.

It is recommended that the Great Mackerel Beach Floodplain Risk Management Plan be reviewed every 5 years to provide a regular update of Council’s actions and priorities.

3. INTRODUCTION

Great Mackerel Beach (Figure 1) is a small coastal community on the western shore of Pittwater in Sydney's northern beaches (within Pittwater Local Government Area). The majority of the 265 hectare catchment lies within Ku-ring-gai Chase National Park and is mostly forested. The community is small, lying in the lower valley area of the catchment, with approximately 130 properties. Flooding has occurred on numerous occasions in the past, most notably in November 1987, causing property damage (inundation above floor level and a house moved from its footings) and risk to life for the community (potential for drowning or injury to residents).

Pittwater Council engaged WMAwater (formerly Webb, McKeown & Associates) to prepare a Floodplain Risk Management Study and Plan for Great Mackerel Beach. The objectives of the Study are to identify and compare various management options, including an assessment of their social, economic and environmental impacts, together with opportunities to enhance the river and floodplain environments. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk.

A glossary of flood related terminology is provided in Appendix A.

3.1. Floodplain Risk Management Process

As described in the Floodplain Development Manual (Reference 1), the Floodplain Risk Management Process entails four sequential stages:

Stage 1: *Flood Study.*
Stage 2: *Floodplain Risk Management Study.*
Stage 3: *Floodplain Risk Management Plan.*
Stage 4: *Implementation of the Plan*.

The Great Mackerel Beach Floodplain Risk Management Study and Plan constitutes the second and third stages in the process. The Flood Study stage was completed in September 2005 with publication of the Great Mackerel Beach Flood Study (Reference 2). In this study a two-dimensional (2D) hydraulic computer model was used to determine design flood levels for the Great Mackerel Beach Creek floodplain across the full range of design events.

3.2. History of Flooding

Flooding in the Great Mackerel Beach catchment has occurred on numerous occasions in the past and has caused property damage as well as risk to life to residents living close to the major drainage channels. The most flood affected properties are those on the valley floor, particularly those adjacent to Monash Avenue. The area has experienced major flood events in May 1974, November 1987, (unknown month) 1992, August 1998 and June 2003, with the November 1987 event causing the most damage to the community. Figure 2 shows flood photographs taken after this event. Three houses (36, 38 and 40 Monash Avenue) were shifted from their foundations, fifteen residents needed to be evacuated and there was considerable damage to private property during this event.

The November 1987 flood was primarily caused by intense rainfall over the catchment and was not accompanied by elevated ocean levels. Based on a comparison of recorded versus design flood levels this event approximated an event that would be equalled or exceeded on average every 50 years (i.e had a probability of occurrence of 2% in any year).

No flood since 1987 has inundated habitable floors or caused a significant risk to life or damage. However they have caused inconvenience and yard damages.

3.3. Previous Studies

A number of studies have been undertaken which are relevant to flooding at Great Mackerel Beach. The following are the key references pertaining to this present study.

3.3.1. Great Mackerel Beach Flood Study (Reference 2)

This study established and calibrated a 2D SOBEK hydraulic model of the Great Mackerel Beach floodplain. The creek (up to the top of bank) was modelled using cross-sections (ground survey undertaken in November 2003 to January 2004) in a one-dimensional (1D) layout with the overbank area in 2D based on a digital terrain model (DTM - derived from a combination of the ground survey and 2m ground contours). The DTM (or grid) is a mesh of square cells representing the topography. A cell size of 5m by 5m was adopted for the Great Mackerel Beach study area. The model extended from the top of Monash Avenue eastwards to the confluence with Pittwater, covering some 15 hectares (6%) of the catchment. The November 1987 flood was the only historical event used for model calibration.

The state of the entrance berm has a major affect on flood levels. When the berm is ‘open’ the full effect of the estuary water level influences peak flood levels. When the entrance is fully closed, the water level rises until the berm is overtopped and it then opens through scour action, or is opened artificially. For the design events, the berm was assumed to be in the condition as surveyed in November 2003 (closed to tidal influences at a level of 1.3m AHD) and was assumed not to scour in design events (Reference 2 does not provide the rationale for this assumption).

The design inflow hydrographs were derived from a XP-RAFTS hydrologic model established for the study. The downstream boundary, representing Pittwater, was set as a constant water level. Table 1 shows the peak flood levels and the adopted downstream boundaries for the design floods.

Table 1: Design Flood Levels

Event	Flood Level at Monash Avenue* (m AHD)	Assumed Water Level in Pittwater (m AHD)
PMF	3.23	1.5
1% AEP	2.39	1.5
2% AEP	2.32	1.47
5% AEP	2.27	1.43
20% AP	2.13	1.36

* Location indicated as *Point 152* on Figure 3.

3.3.2. Pittwater Estuary Processes Study (Reference 3)

The Pittwater Estuary Processes Study completed the third stage (of eight) in the Estuary Management Process for the Pittwater Estuary. The Study involved analysing and interpreting the available data (as identified in the Data Compilation Study) in order to describe the key waterway processes and their interactions. The main findings of the investigation were categorised as hydraulic processes, water quality processes, sedimentary processes, ecological processes and human user processes. The key management issues for the Pittwater Estuary were identified and would then be addressed in the subsequent Estuary Management Study (Reference 4).

3.3.3. Pittwater Estuary Management Study (Reference 4)

This study addressed the issues identified in the Estuary Processes Study (Reference 3) and provided a series of recommendations for the successful management of the Pittwater Estuary. The study considered the complex interactions and processes occurring in the estuary and how best to manage its use so as to ensure a healthy estuary is sustained. A list of 42 management options was prepared which aimed to address the issues of water quality, sedimentation and erosion, ecology, waterway usage, foreshore usage, heritage and future development. By use of an assessment matrix, recommendations were then made for which options should be included in the subsequent Pittwater Estuary Management Plan (in progress in 2007). None of these options would have any significant impact on flooding in the study area.

The Pittwater Estuary Management Plan is currently nearing finalisation with Public Exhibition completed in October 2010 and adoption by Council expected in December 2010. The Pittwater Estuary Management Plan includes options from all floodplain risk management studies in the Pittwater Estuary catchment that relate to the environmental management of the creek systems and smaller estuaries that flow into the Pittwater Estuary. This includes Great Mackerel Beach.

3.3.4. Estuarine Planning Level Mapping, Pittwater Estuary (Reference 5)

This report built on from the information provided in the Estuary Processes Study (Reference 3) so as to calculate the Estuary Planning Levels (EPLs) for the Pittwater Estuary, which includes the Great Mackerel Beach. The base EPLs were determined using the following components:

- 1% AEP storm tide event, plus

- 200 mm sea level rise due to climatic conditions, plus
- associated wind setup, plus
- wave runup, plus
- a freeboard allowance ranging from 0 to 300 mm depending on the adopted edge treatment and height of wave runup.

This base EPL then had a reduction factor applied (depending on the distance to the development from the foreshore edge treatment) to determine the final EPLs. These are provided in Appendix B for the Great Mackerel Beach community.

Estuarine Planning Levels for the entire Pittwater Estuary, including Great Mackerel Beach, are currently being revised to incorporate the sea level rise planning benchmarks from the NSW Sea Level Rise Policy of 0.4m by 2050 and 0.9m by 2100, in a project titled "Pittwater Foreshore Floodplain — Mapping of Sea Level Rise Impacts". This project is due for completion in 2011 and will see the commencement of the phasing out of Council's use of the terms 'Estuarine Risk' and 'Estuarine Planning Level' and the phasing in of the terms 'tidal risk' and 'Foreshore Flood Planning Level' to provide more consistent terminology with the Floodplain Development Manual (Reference 1).

3.4. Other Available Data

A range of other data is available for the Great Mackerel Beach catchment, including:

a) topographic survey obtained in November 2003/January 2004 by Council for the establishment of the Flood Study (Reference 2) hydraulic model. This included cross-section survey of the main channel, significant overland flow paths, floodplain storage areas and control structures;
b) model results from the Flood Study (Reference 2) including depth, velocity and water level grids, discharges at key location, provisional hazard and hydraulic categorisation maps and water level profiles;
c) survey data of the area offshore of the beach and away from the floodplain (down to -2m AHD) derived from available bathymetry of Pittwater;
d) historic rainfall data from the nearest Bureau of Meteorology (West Head daily read gauge) and Sydney Water gauges (pluviometer at Warriewood). No private rainfall gauge information was found;
e) cadastral data, 2 m Land Information Centre contours and land-use zoning data;
f) historic and recent (2005) aerial photographs;
g) property data obtained by Byrne and Associates in June 2006, including floor and ground level data, photographs and details of buildings (discussed further in Section 6.2);
h) historic flood photos (provided from residents);
i) Pittwater Council's Local Environmental Plan (LEP), Reference 6, and the Pittwater 21 Development Control Plan (DCP), Reference 7;
j) Pittwater Council's website for flood information, maps and policies;
k) NSW Floodplain Management Authorities Project Assessment Sheets;
l) Newport Flood Education and Communications Plan (Reference 8).

4. STUDY AREA

4.1. Overview

As previously mentioned, Great Mackerel Beach (Figure 1) is a small coastal community on the western shore of Pittwater. The entrance system at Great Mackerel Beach is termed an ICOLL (Intermittent Open and Closed Lake and Lagoon) as the entrance to the lagoon is periodically closed. Only a small portion of the catchment in the lower valley has been developed. The community consists of only three streets (with approximately 130 properties) and no vehicular traffic. Ross Smith Parade is in the form of a footpath along the Pittwater foreshore, while Monash Avenue and Diggers Crescent are wide grassed areas that provide access to properties.

The upper catchment of Great Mackerel Creek is characterised by steep slopes with an incised creek valley, which changes to a flat floodplain area prior to the outlet into Pittwater. Great Mackerel Beach (approximately 650 m long and crescent shaped) is enclosed between two high headlands. The main flow path through Great Mackerel Beach is Great Mackerel Creek itself, which discharges into Pittwater via a berm at the northern end of the beach (Photos 1 and 2). The creek forms a small lagoon at the northern end of the beach (Photo 3), fed by an intermittent stream which rises to the plateau of the Lambert Peninsula. The lagoon is often open to tidal action and supports a shallow nearshore sandbar (or delta). The state of the entrance (whether open or closed) during a flood plays a significant part in the resulting flood levels. A brief overview of the history of the entrance is provided in Section 4.3.2.

The study area covers only those areas in the community affected by mainstream flooding (Figure 3). This includes 116 houses (on 120 residential lots) which have some flood-affectation in a Probable Maximum Flood (PMF).

4.2. Photographs

Photo 1: Looking downstream to entrance into Pittwater

Photo 2: Looking upstream from entrance

Photo 3: Lagoon area upstream from entrance.

Photo 4: One of the two electricity sub-stations.

Photo 5: Examples of bank stabilisation works.

Photo 6: One of the eight privately owned bridges crossing the creek.

Photo 7: Telstra cable running beneath the 'road bridge' (indicates the original level of the bridge).

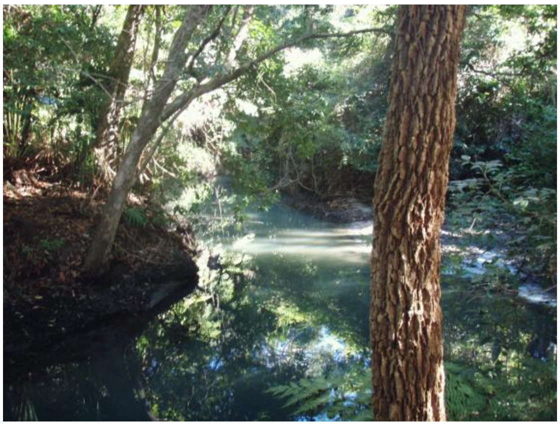


Photo 8: Typical vegetation in downstream reaches of the creek.

Photo 9: House on Monash Avenue adjacent to creek.

Photo 10: New building on piers adjacent to lagoon.

Photo 11: Diggers Crescent

Photo 12: Creek crossing.

Photo 13: Lagoon near the entrance.

Photo 14: Example of bank stabilisation works.

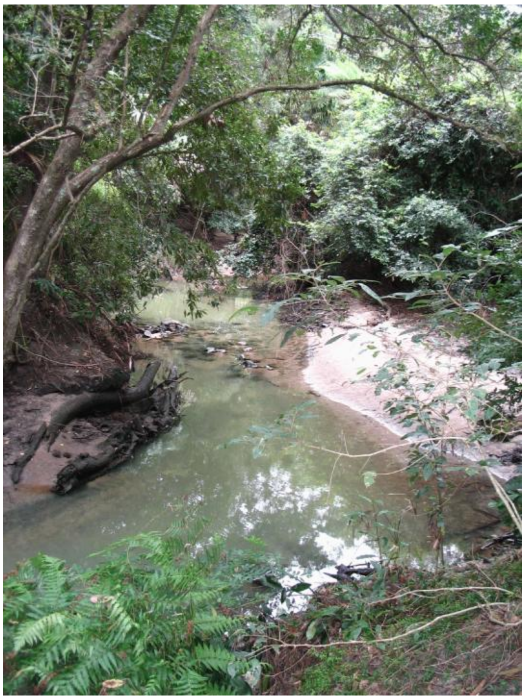


Photo 15: Typical creek vegetation within lagoon.

4.3. Key Features in the Catchment

4.3.1. Overview

The majority of the Great Mackerel Creek catchment remains in its natural (vegetated) state, with only the developed areas in the lower catchment having been cleared. Figure 1 shows the current land-use zonings which highlights that only a small area is currently zoned 2(a) residential. There are no paved roads in the community and thus no vehicles are used (besides one or two golf ‘buggies’). The only access to Great Mackerel Beach is by boat and there is a regular ferry service from Palm Beach. In addition to flooding, Great Mackerel Beach is exposed to other natural hazards such as bushfire, tidal inundation and coastal erosion.

The residential area is supplied with electricity from two ‘substations’ within the catchment. One is near the foreshore on Ross Smith Parade, the other in Monash Avenue (Photo 4) and both have been inundated by floodwaters in the past. Similarly the underground telephone lines have also been damaged from floodwaters. Water is supplied from privately owned rainwater tanks on each of the properties. These are generally unaffected by floodwaters. Septic tanks are used for sewerage and will be affected by floodwaters. However residents advised that this was not a significant issue in the November 1987 event. Regardless it is of concern. There is no underground stormwater system in the residential area. The Rural Fire Service building, located on Diggers Crescent, is the only non-residential building in the area.

Great Mackerel Creek runs through the community on private property and divides the residential area approximately in half. There are eight privately owned bridge crossings (Photos 6 and 12), as well as a Council owned “road bridge” which crosses from Monash Avenue to Diggers Crescent. This bridge was recently raised as it formed an obstruction to floodwaters in the past. Some bank stabilisation works have been undertaken in various reaches of the creek. As the creek runs through private property, these works have been undertaken by the individual landowners and are thus quite varied. In some areas there are rock retaining walls of various ages and conditions (Photos 5 and 14), in others only minor vegetation clearing has occurred when necessary (fallen trees and so forth).

There are approximately 20 to 25 permanently occupied properties in the community (some 40 - 45 residents). The remainder of the properties are used for short term accommodation, particularly over the Christmas period when there can be as many as 600 people in the community. For this reason it is difficult to know exactly how many people are within the flood affected areas at any one time, which is problematic in terms of evacuation planning. Similarly, the temporary nature of the majority of the residents makes it difficult to maintain a high level of community flood awareness.

4.3.2. The Entrance

Great Mackerel Creek discharges into Pittwater via a berm at the northern end of the beach. The location and the configuration of the berm are dependent on the sea level and the conditions shaping the berm prior to the flood (i.e. coastal processes such as wind and wave action).

Historically the location of the entrance of the creek has varied from its current northern position, adjacent to the headland, to further south in the centre of the beach, near the existing properties. As far as can be determined from photograph and anecdotal records, the entrance was in its northern location up until approximately 1974.

Between 1970 and 1974 the dune barrier became degraded and may have first breached in the south sometime in 1972. Severe ocean storms of May 1974 and associated catchment flood events (the magnitude of the associated rainfall event is unknown but elsewhere the rainfall was not very intense) resulted in the creek breaking across the dune barrier approximately 100 m south of the northern headland.

It is understood that sand was cleared from the entrance of the creek only a matter of weeks prior to the November 1987 event. The exact details of this clearing and if this affected flood behaviour are unknown.

Elevated tides in the summer of 1988/1989 highlighted the severe bank erosion that had occurred at Great Mackerel Beach since the entrance had relocated southwards. Ten properties on the foredune came under threat from the erosion. Subsequently Council barged in heavy machinery to the beach and moved sand from the northern section of the beach to immediately in front of the affected properties. Sand bags were also installed for further protection.

Following these works a study was undertaken which found that the delta margin (sandbar) erosion, that is erosion of the submerged sand masses that would have been present near the shoreline, associated with the relocated entrance was in part contributing to the severe erosion. The study recommended that the entrance be relocated to its northern location. In 1989, 4000 m^3 of sand was placed to create a new barrier, with a further 4000 m^3 to renourish the beach area in front of properties. The shoreline was re-established and built seawards by 30 m along the northern part of the beach. The realignment promoted recovery of the shoreline over several hundred metres. Subsequently the dune has suffered only minor scouring following heavy rainfall.

Since relocation, the entrance has remained in the northern location and the southern entrance remains closed.

4.4. Preliminary Environmental Assessment

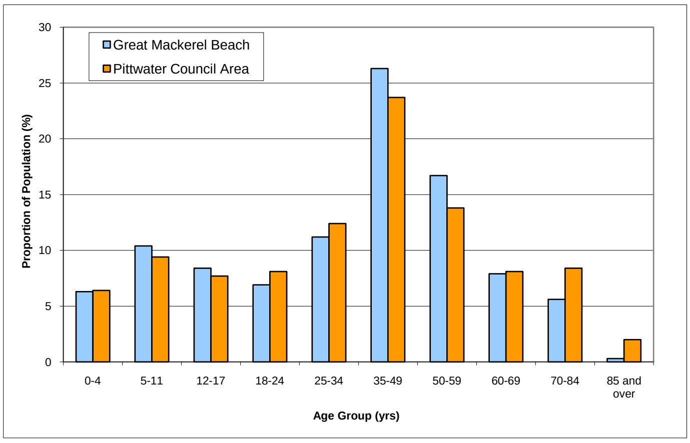
The majority of the Great Mackerel Beach catchment is part of the Ku-ring-gai Chase National Park and remains heavily vegetated. Only in the lower valley has any development occurred and consequently some vegetation clearing has taken place. However this area (approximately 15 hectares) represents only 6% of the total catchment area. Similarly the creek remains predominantly in its natural state although some modifications have occurred in the downstream reaches within the developed area. The lower reaches of the creek forms a lagoon behind the beach dune that is commonly brackish. The lagoon area is vegetated by dense aquatic and riparian vegetation. The entrance of the creek is ephemeral with the entrance dynamics controlled by both catchment and coastal processes. Studies of other ephemeral systems (also known as Intermittently Closed and Open Lakes and Lagoons - ICOLLs) indicate that the opening and closing of the entrance is an important part of the wider ecological processes.

Overall, the environmental condition of Great Mackerel Creek and its catchment is considered good. The minimal development has prevented issues common to urbanised areas such as water pollution, loss of habitat, weed infestation etc. However the use of septic tanks for the residential development could be a source of contamination and is of some concern, particularly in times of flood. Similarly, any modifications to the creek entrance, in particular its regime of opening and closing, could potentially have significant impacts on the ecology of the system. This mechanism may also be affected by any future sea level rise associated with climate change.

4.5. Community Demographics

The 2001 Census information (Reference 9) for the Church Point - Scotland Island - West Pittwater area is available through Pittwater Council and has been used in the following discussion to give an overview of the community demographics. The information covers the residential areas of Coasters Retreat, Church Point, Elvina Bay, Great Mackerel Beach, Morning Bay, Scotland Island and Towlers Bay.

The area of Church Point - Scotland Island - West Pittwater is a predominantly national parks besides the seven small communities listed above. A graph of the age profile of the area, compared to that if the whole Pittwater Council area is provided below.



From this it can be seen that there is a greater portion of school aged children (5 - 17 years) and their parents in their 30s and 40s. The age structure is indicative of an established housing market which is attracting more mature families. This is also reflected in the larger proportion of owned or purchasing houses compared to the Pittwater Council area as a whole.

The area has an extremely educated and skilled workforce with a greater share of households in the high income quartile, a higher percentage of professionals and larger proportion working in well-paid industries with an associated high level of socio-economic status.

5. COMMUNITY CONSULTATION

5.1. Community Consultation – Flood Study

As part of the 2005 Flood Study, community consultation was undertaken in the form of a questionnaire as well as a public meeting (coinciding with the exhibition of the Flood Study Report). The questionnaire was sent to 60 residents of Great Mackerel Beach and twelve responses were received. As a result of this process two historical flood levels (from the November 1987 event) were surveyed. Other responses from the public consultation program are listed below.

- Street flooding results in access issues to properties, such events were quoted to occur three times a year;
- The June 2003 event caused water levels to remain up to 500 mm deep at the entrance to Diggers Crescent for approximately one week;
- Council relocated the creek entrance in 1974 after a severe flood event (this is the opinion of a resident and may not necessarily be correct);
- In 1992 (estimated) there was a flood at night causing difficulties for residents crossing the main bridge (prior to it being replaced);
- The main bridge was reported to have acted as a dam in the November 1987 event (it has since been raised);
- The creek entrance was opened to the Pittwater on 25/10/87 (prior to the November 1987 flood event);
- Historically, the National Parks and Wildlife Service (NPWS) came about once every four years to open out the creek entrance (using an excavator brought to the site on a barge);
- Maintenance of the creek is required and is currently undertaken in an ad hoc fashion by residents;
- Electricity and phone services are affected during major flood events;
- The Rural Fire Service building appears to be in a floodway;
- The NPWS has installed a diversion at the top of the valley which residents have concerns (this is the opinion of a resident and may not necessarily be correct).

5.2. Community Consultation Strategy – Present Study

A rigorous community consultation strategy was developed as part of the present study. This included:

- an initial letter of introduction in November 2006 to local residents, property owners, stakeholders and those who previously had been involved in flood related matters (see Appendix C). Accompanying the letter was a copy of Council's hazard map and flood risk management brochure. The letter invited community members to become involved with the Flood Risk Community Working Group to be established to assist Council with the Floodplain Risk Management Study,
- establishment of a Flood Risk Community Working Group comprising two community members with a number of state agencies including, Department of Environment,

Climate Change and Water (DECCW), State Emergency Services (SES), NSW Fisheries, National Parks and Wildlife Services (now incorporated within DECCW) and the Rural Fire Services (RFS),

- brochure/flyer and questionnaire to residents and stakeholders in May 2007 (see Appendix C),
- follow up telephone calls to key respondents,
- reporting of the project through Council's then Land, Water and Coastal Committee (acting as Council's floodplain management committee) which included a number of community and elected representatives,
- an Entrance Management Workshop in July 2008,
- Community and Stakeholder meeting to present the Draft Report in February 2010,
- workshop/site inspection and interviews,
- public exhibition of material including a Community Information Day at Great Mackerel Beach in June 2010 during the public exhibition period.

5.3. Outcomes

5.3.1. Community Questionnaire

A resident questionnaire was posted to the Great Mackerel Beach community at the commencement of this Floodplain Risk Management Study in May 2007. In total, 116 surveys were sent out and 21 responses received. Figure 4 shows a graphical summary of the information collected.

Overall the community seems to have a moderate to high level of flood awareness. Nine respondents had incurred property damage as a result of flooding, a further five had experienced flooding on their property, though without any significant damage occurring. A third of the respondents (7) indicated a preference for widening/dredging of the creek as well as some form of entrance works, with other options such as creek maintenance, house raising and installation of detention basins also being supported.

Other key issues raised include:

- suggestions to raised the Telstra pipe that runs beneath the 'road bridge;
- concerns over the classification of 'flood prone land' in Council's maps and on Section 149 certificates. Some residents consider that this may affect their insurance cover should water damage occur and/or their property value;
- suggestions that restrictions should be placed on the use/type of fencing permitted as well as the types/amounts of vegetation to be planted;
- use of levees to protect small areas of low lying land and some form of protection for the swing-set (which is considered to be a local heritage item);
- it would appear that the depth of the lagoon has changed since the 1970's when it was "deep enough to swim in". Thus if the lagoon was re-constructed and/or the beach berm modified to its previous level would this have an overall beneficial effect?
- is an Entrance Management policy required to:

  - ensure a low level berm can be maintained to allow overtopping in a flood,
  - ensure maintenance of a pilot channel,
  - should Council, residents or the NPWS be permitted to open the entrance for flood prevention or non flood reasons,
- input is required from the NPWS at management committee meetings involving potential changes to the entrance;
- consideration needs to be given to the potential water quality and health risks of floodwaters entering septic tanks during floods;
- is vegetation management or stream rehabilitation works required to manage the existing flood problem? If so there are a number of additional concerns:
  - whose responsibility is it?
  - who pays?
  - what liability is attached if the works are not undertaken or not maintained?
- re-shaping of Monash Avenue to allow it to drain to the creek and reduce ponding;
- house raising is a potentially cost effective and environmentally sound solution for suitable existing houses;
- whilst the November 1987 flood was a large flood, unfortunately larger floods will occur. This fact must be realised by the community. Also, are the entrance conditions that are adopted for design suitable or could a worse situation develop?

5.3.2. Community Meetings/Workshops

A workshop was held on 30th July 2008 to present the study findings to key stakeholders and in particular to discuss an entrance management program (EMP) as a means of reducing flood levels at Great Mackerel Beach. Appendix D provides the Powerpoint slides presented at the Workshop together with a summary of the conclusions.

A Community and Stakeholder meeting was held on 3rd February 2010 to present the Draft Report. This meeting was attended by staff members from Council, community representatives and representatives from state government agencies including, DECCW, SES and the RFS. A summary of the outcomes of the project was provided as a Powerpoint slide presentation and this was followed by a discussion.

During the Public Exhibition of the Draft Final Report, a Community Information Day was held on Sunday 20th June 2010 in conjunction with the SES and the RFS. The Community Information Day involved presentations and questions time by WMAwater, Council and the SES, followed by a sausage sizzle allowing informal discussions between all attendees. The event was well-attended by representatives of the Great Mackerel Beach Community.

5.4. Other Stakeholder Consultation

In addition to the residential community, other stakeholders were contacted as part of this study. Relevant officers from a number of agencies and organisations were contacted via email and letters to inform them of the study being undertaken and to gather any relevant information. The following organisations (during the course of the study the names of several agencies have changed) were contacted:

- NSW State Emergency Service (SES),
- NSW Department of Planning,
- NSW Department of Environment Climate Change and Water (DECCW),
- NSW National Parks and Wildlife Service (NPWS - now within DECCW),
- NSW Department of Primary Industries (Fishing and Aquaculture) (DPI),
- Bureau of Meteorology (BOM),
- Pittwater Local Emergency Management Committee,
- Mackerel Beach Association.

The significant outcomes to date from the above are:

- NPWS were able to confirm that they had been involved in creek entrance openings in the past, in response to calls from residents during times of flooding. Specific information about the dates, protocol, etc., is not readily available.
- NPWS were not able to confirm if there are any damming type structures in the upper catchment, as suggested by some of the residents (Section 5.1).

6. EXISTING FLOOD ENVIRONMENT

6.1. Flood Behaviour

There are potentially three main causes of flooding in the Great Mackerel Beach study area:

- local catchment flooding that results from intense short duration storms (generally less than 6 hours duration). These impacts were addressed in the Flood Study,
- flooding from tidal and oceanic influences within the Pittwater Estuary,
- a combination of the above.

Flooding which occurs primarily as a result of intense rainfall over the catchment is termed *rainfall dominated or induced* flooding, whilst if flooding occurs primarily from tidal and oceanic influences it is termed *oceanic or wave dominated/induced* flooding. Flooding in the upper part of the catchment will always be as a result of intense rainfall (as the oceanic influence only extends to the height of the ocean/tide) but in the lower part both mechanisms affect flooding with the oceanic influence greater closer to the ocean. The influence of the two mechanisms will vary between events.

Local catchment flooding is a result of flow generated in the forested part of the Great Mackerel Creek catchment which is carried via overland flow paths and informal channels to the creek system within the floodplain. Floodwaters in the creek flow down a steep slope and enter the residential area upstream of Monash Avenue. When rainfall is excessive, floodwaters break out from Monash Avenue along Diggers Crescent and inundate the surrounding properties. As floodwaters reach the mangrove swamp area to the east of the catchment the floodwaters slow and pond behind the sand dune until it is high enough to overtop it and flow into The Pittwater. There will be some erosion of the sand berm as floodwaters overtop.

Flooding as a result of tidal and oceanic influences in the Pittwater Estuary occurs due to:

- *Elevated estuary water levels from tidal, storm surge and wave set up influence.* The 1% AEP water level in the Pittwater Estuary is estimated to be 1.5m AHD (Reference 2 provides the background to how this level was established) which is approximately 0.4 m above the highest normal tide in a year. The effect of the elevated estuary water level depends upon the condition of the entrance berm and the water level in the lagoon. If the entrance is open a similar water level will be reached within the lagoon causing inundation of properties and roads. If the entrance is closed and the berm is above the estuary water level the effect will be minimal unless associated with wave runup (see below). If the elevated estuary water levels occur in conjunction with catchment flooding it will result in higher levels of flooding compared to a lower estuary water level.

- *Wind wave runup along the foreshore.* No detailed studies have been undertaken into wind wave runup at Great Mackerel Beach but it is likely that waves will overtop the frontal dune and impact upon the residential buildings along Ross Smith Parade. The overtopping waves will also raise the water level in the lagoon, possibly inundating property. The main effect of wind wave runup will be to the buildings immediately fronting the beach as the wave energy quickly dissipates. The wave action could also cause erosion of the frontal dune and consequent inflow of estuary floodwaters. There is the possibility of catastrophic damage to buildings and a risk to life due to wind wave runup.

Results from the Flood Study indicate that ponding and storage of local catchment floodwaters behind the sand dune at the creek outlet are the key mechanisms that affect peak flood levels in Great Mackerel Beach. Consequently, there is little difference in flood levels between design events (Figures 5 and 6) through the residential area. The study also reports that peak flood levels are generally independent of water levels in Pittwater in most of the study area, due to the presence of the sand dune berm. Scouring of the berm will occur during a rainfall dominated event as runoff exits to the ocean but this was not accounted for in Reference 2 in the hydraulic modelling. Scouring can only occur once the berm is overtopped by floodwaters and as the duration of flooding/overtopping will be only a few hours, the amount of lowering of the berm that can occur is likely to be small, thus the reduction in peak flood level will be small. Scouring will still continue after the flood peak for as long as the berm is overtopped.

The sand dune berm (along Ross Smith Parade) is shown to just be overtopped in the 5% AEP event (flow of $1m^3/s$), breaking through in the vicinity of 4 Ross Smith Parade. The southern end of the berm (between 7 Ross Smith Parade and the intersection of Monash Avenue) remains flood free for all events up to the PMF (Probable Maximum Flood – refer to Appendix A for further details on the terminology used). The depth of floodwaters across the berm remains less than 0.5 m for all events.

Design peak water levels and flows are provided on Table 2 with the locations shown on Figure 3.

Table 2: Design Peak Water Levels and Flows

		Peak Water Level (m AHD)				
Location ID	Location Description	PMF	1% AEP	2% AEP	5% AEP	20% AEP
143	18 Monash Avenue	3.16	2.37	2.31	2.26	2.12
152	Monash Ave	3.23	2.39	2.32	2.27	2.13
153	Bridge 1 (Monash Ave)	3.45	2.44	2.36	2.31	2.17
154	Diggers Crescent	3.40	2.42	2.35	2.30	2.16
155	38 Monash Avenue	4.15	2.69	2.59	2.47	2.31
156	Northern End of Diggers Crescent	3.05	2.35	2.30	2.25	2.11
157	Outlet of Creek, Northern end of Beach	2.54	2.16	2.12	2.08	1.98
158	Northern End of Swamp	2.85	2.32	2.27	2.22	2.09
159	North of 1 Ross Smith Parade	2.90	2.34	2.29	2.24	2.11
160	Middle of Swamp, rear 3 Ross Smith Parade	2.97	2.35	2.30	2.25	2.11
2	Electricity Sub-station, Monash Avenue	3.05	2.36	2.31	2.26	2.12
20	Stream Channel, near 69 Monash Ave	4.54	2.97	2.86	2.73	2.53
30	Bridge 3, Downstream	4.19	2.76	2.67	2.56	2.41
40	Stream Channel, near 61 Monash Ave	3.97	2.60	2.50	2.41	2.27
50	Stream Channel, near 53 Monash Ave	3.59	2.48	2.39	2.33	2.19
60	Stream Channel, at 26 Monash Ave	3.33	2.41	2.34	2.29	2.15
70	Stream Channel, at 20 Monash Ave	3.18	2.38	2.31	2.27	2.13
80	Stream Channel, at 14 Monash Ave	3.09	2.36	2.30	2.26	2.12
90	Stream Channel, rear of 24 Diggers Cres.	3.06	2.36	2.30	2.26	2.12
100	Stream Channel, rear of 26 Diggers Cres.	3.02	2.35	2.30	2.25	2.11
110	Stream Channel, 20m North of 28 Diggers Cres	2.99	2.35	2.29	2.25	2.11
120	Stream Channel, 80m North of 28 Diggers Cres.	2.96	2.34	2.29	2.24	2.11
130	Stream Channel, 120m North of Diggers Cres.	2.94	2.34	2.29	2.24	2.11
140	End of 1D Channel section	2.93	2.34	2.28	2.24	2.11
		Peak Flow (m^3/s)				
13	Northern end of Swamp	114	32	28	25	18
155	End of 1D Channel Section	13	4	3	3	2
164	Creek outlet through dunes	75	33	30	27	20
165	Top of Berm along Ross Smith Parade	125	4	2	1	0
167	Western property boundary of 38 Monash Ave (house washed off foundations in November 1987 event)	124	18	14	10	6

6.1.1. Hydraulic Classification

The Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to areas of the floodplain; floodway, flood storage and flood fringe. Hydraulic categories were derived for existing conditions in the study area as part of the Flood Study (Reference 2). Categorisations were derived for the 1%, 2%, 5%, 20% AEP and PMF events and were delineated based on the following criteria.

The Floodplain Development Manual (Reference 1) considers *floodways* as being “those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.” At Great Mackerel Beach the floodway area at a minimum followed the creek line from bank to bank. In addition any roadway was considered a floodway as were any areas that met the following condition (refer Reference 2 for details):

velocity (v) * depth > 0.25 m^2/s AND v > 0.25 m/s
OR
v > 1m/s

Flood storage is defined in Reference 1 as those “areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.” Reference 2 applied this to Great Mackerel Beach by classifying an area as flood storage if, by obstructing the area 10% of the conveyance was lost. To calculate this the depth was determined at which 10% of the flow was conveyed. This depth, averaged across several sections, was found to be 0.2 m at Great Mackerel Beach. Therefore those areas with a depth greater than 0.2 m not already classed as floodway were classified as flood storage.

As defined in Reference 1 and applied in Reference 2 *“flood fringe* is the remaining area of flood prone land after floodway and flood storage areas have been defined”.

Figure 7 shows these categorisations for the 1% AEP and PMF events respectively. This information was also used to classify properties in the study area, which was included in Pittwater Council’s property database and summarised in Table 3 below.

Table 3: Summary of Hydraulic Classification

Hydraulic Classification	**Number of Properties Classified**	
	1% AEP event	**PMF event**
Floodway	71	90
Flood Storage	26	14
Flood Fringe	2	0
TOTAL	**99**	**104**

6.1.2. Flood Hazard Classification

The Floodplain Development Manual (Reference 1) determines the *provisional flood hazard* categorisation of an area based on the combination of the depth and velocity of floodwaters on the land. As part of the Great Mackerel Beach Flood Study (Reference 2), the provisional hazard categories were derived using this method for the 1% AEP and PMF events (Figure 8). In the 1% AEP event, the creek channel and areas in the immediate surrounds are classified as High Hazard, with the rest of the study area being Low Hazard. In the PMF event almost all of the study area is classified as High Hazard. This information was used to classify each flood-affected property in the study area and then incorporated into Pittwater Council’s property data base.

Flood hazard is a measure of the overall adverse effects of flooding. As well as considering the provisional (hydraulic) hazard it also incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. As with provisional (hydraulic) hazard, land is classified as either *low* or *high* hazard for a range of flood events. The classification is a qualitative assessment based on a number of factors as listed in Table 4.

Table 4: Hazard Classification

Criteria	Weight (1)	Comment
Rate of Rise of Floodwaters	High	Less than six hours
Duration of Flooding	Low	Recedes quickly (particularly if berm is open)
Effective Flood Access	High	Very limited access for many buildings.
Size of the Flood	Medium	There is not a significant difference in flood level between the 1% AEP and the PMF.
Effective Warning and Evacuation Times	High	Evacuation can be difficult in some areas and there is little warning time
Additional Concerns such as Bank Erosion, Debris, Wind Wave Action	High	All these elements are significant factors.
Evacuation Difficulties	High	Some residents would need to wade through flood waters, others can move across dry land to high ground. All must still remain in Great Mackerel Beach and cannot readily reach Palm Beach or any other urban centre.
Flood Awareness of the Community	Medium	Parts of the community are flood aware, though parts will not be (visitors and temporary residents).
Depth and Velocity of Floodwaters	High	Some properties will experience high velocities and significant depths of inundation (3 buildings shifted in the November 1987 event).

Note: (1) Relative weighting in assessing the hazard.

Based on the above assessment, the hazard at Great Mackerel Beach would be modified slightly. In particular, the 'islands' of low hazard, surrounded by areas of high hazard seen in the 1% AEP event would be reclassified as high hazard, predominantly due to the evacuation difficulties. Similarly, in the PMF event the area of low hazard along the berm (on Ross Smith Parade) would be classified as High hazard. The hazard categorisation for each of the properties in Council's database were reviewed based on this flood hazard and are summarised in Table 5. As a result of this process, six property classifications were changed.

Table 5: Summary of Hazard Classification

Hydraulic Classification	Number of Properties Classified	
	1% AEP event	PMF event
Low Hazard	35	14
High Hazard	64	90
TOTAL	99	104

6.1.3. Sensitivity Analysis

As part of the Flood Study a sensitivity analysis was undertaken for the 1% AEP 2 hour event. The following cases were tested:

- increase/decrease in runoff (+/- 20%). Peak flows increased by up to 5 m^3/s and decreased by up to 7 m^3/s. The maximum change in flood level was a 0.14 m decrease and a 0.12 m increase in peak water level;

- change in roughness of topography. These changes produced a less than +/- 3 m^3/s change in peak flow and a maximum 0.14 decrease and 0.12 m increase in peak water level;
- blockage of bridges/culverts (50% and 100%). The effect of blockage was isolated to the immediate locality and produce up to a 0.1 m increase in peak water level for 100% blockage;
- lower downstream water level in the Pittwater (0.6m AHD). Lowering the water level in the Pittwater produced a less than 0.1m reduction in peak water level. No sensitivity was undertaken for an increase in downstream water in level.

The results of the sensitivity analysis indicated that the characteristics of the majority of the floodplain areas are not particularly sensitive to changes in any of the modelled parameters, mostly due to the sand berm restricting outflows from the creek. The exception is the portion of the study area upstream of Chainage 900 (Figures 3 and 5), where the backwater effect of the berm has less influence on flood levels.

6.2. Flood Risk and the Social Impacts of Flooding

Information for each of the properties in the study area was collected by Byrne & Associates (Registered Surveyors) in June 2006. For each property the lowest habitable floor level, indicative ground level and building description (number of storeys, foundation construction, wall materials, condition and photograph) was obtained and has been provided in Appendix B. A summary of the data is provided in Table 6 and shown on Figure 9.

Table 6: Property Data

PROPERTY DETAIL	NUMBER
WALL CONSTRUCTION TYPE	
Brick Veneer	1
Fibro	29
Weatherboard	25
Cladding	27
Other	10
FOUNDATION TYPE	
Piers	75
Slab on Ground	17
BUILDING STOREYS	
Single Storey	52
Two Storey	30
Habitable ground floor	28
Non-habitable ground floor	2
Three Storey	10
Habitable ground floor	7
Non-habitable ground floor	3

Using this information a better understanding of the social impacts of flooding could be obtained. For each property in the study area, the event at which the building floor is first inundated was calculated (shown on Figure 10 and summarised in Table 7).

Table 7: Properties at Risk

Event Building Floor First Inundated (includes Fire Station) (1)	Number
20% AEP	14
5% AEP	18
2% AEP	21
1% AEP	22
PMF	59

(1) Refers to the lowest building on the property.

In addition to the issue of building floor inundation, evacuation/access during a flood is also of importance when determining the social risk a community faces. Due to the local topography, the majority (60%) of the flood affected properties in the Great Mackerel Beach community have flood-free access to high ground. This is usually via the ‘back’ of the properties which lead up towards the steep ground which define the catchment. However there are 49 lots which are located adjacent to the creek on the valley floor that do not have flood-free access. For this reason these areas (shown on Figure 10) have been highlighted as key flood risk areas.

6.3. Environmental Impacts of Flooding

Flooding is a natural phenomenon that has been a critical element in the formation of the present topography. Thus erosion, sedimentation and other results from flooding should be viewed as part of the natural ecosystem. It is only when these effects impact on man-made elements that they are of concern, and similarly, when development impacts or exacerbates these processes.

6.4. Flood Emergency Response Classification

To assist in the planning and implementation of response strategies, the SES in conjunction with DECC have developed guidelines to classify communities according to the impact that flooding has upon them. Flood affected communities are considered to be those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue.

Based on the guidelines, communities are classified as either Flood Islands, Road Access Areas, Overland Access Areas, No Practical Access Areas or Indirectly Affected Areas. From this classification an indication of the emergency response required can be determined.

The guideline was applied for the community at Great Mackerel Beach however it was found that the community did not fit directly into any of the above classifications. For this reason, the issues of evacuation, resupply and rescue have been addressed directly and are discussed below.

Evacuation

Evacuation was considered to mean displacement within the community, that is, moving residents in flood affected areas to higher ground. If residents live in a 2 storey house or have a “dry” flood refuge and the building will withstand the impacts of floodwaters then it may be safer for them to stay in their house. However many houses do not have a “dry” flood refuge and there is a risk of injury if they remain in floodwaters, also there is a risk that the older timber houses may be damaged by floodwaters or have their roofs damaged (rain or high wind). Evacuation may therefore be necessary, particularly those in residences adjacent to the creek in the lower lying areas (Monash Avenue and Diggers Crescent). In past flood events residents have been moved to unoccupied houses on higher ground along the foreshore (unclear the exact motives for this).

Evacuation to higher ground during flooding is achievable for most residents, however there are 49 lots located adjacent to the creek that would be quickly surrounded by water (refer to Section 6.2). Evacuation would still be possible by foot through floodwaters and an evacuation plan is required to ensure the safest approach is adopted. It is not recommended that residents wade out through floodwaters and for many it may be safer to remain in their house. It may be possible to modify a house to include a “dry” flood refuge but this would need to be investigated on an individual house basis taking into account the type of construction and floor layout.

Resupply

During local flood events the resupply of provisions for the community is unlikely to be required. In general, flooding only occurs for a matter of hours before the majority of floodwaters retreat back to the creek. Although some residents may lose supplies because of a flood, there are a number of residents on high ground that are likely to be able to assist. Similarly during (or at worst, immediately following) local flood events Pittwater estuary is likely to still be navigable by boats and the ferry service to Palm Beach is unlikely to be affected.

During a Pittwater estuary event there may be some resupply issues if the estuary becomes unnavigable by boat. If the community is isolated for more than 24 hours the SES may be required to helicopter in supplies.

Rescue

Rescue was considered to mean the need to evacuate residents from the community to other areas, such as Palm Beach. At Great Mackerel Beach this is likely only to be necessary in the case of a medical emergency, and would be possible via boat or helicopter in most situations. The need to undertake rescue operations may increase if the community becomes isolated due to estuary conditions. Helicopters have been used in the past and there is an identified site suitable for landing.

Summary

A local flood action plan should be prepared and provided to the community. Due to the isolated nature of the community the main focus will be on self-help during the flood. The SES will only be able to provide assistance during the recovery phase and/or if required for resupply if the Pittwater is unnavigable and problematic in the longer term if not adequately addressed in the short term.

6.5. Potential Future Changes

6.5.1. Implications of Climate Change and Ocean/Sea Level Rise

Climate change has the potential to cause an increase in the ocean/sea level as well as a possible increase in design rainfall intensities. The likely impacts of a rise in ocean/sea-level include:

- an increase in the intensity and frequency of storm surges;
- increased foreshore erosion and inundation of low lying coastal lands;
- further loss of important coastal wetland ecosystems; and
- damage to and destruction of human assets and settlements.

In developed areas such as Pittwater, changes in average climate together with a rise in ocean/sea level are likely to affect building design, standards and performance as well as energy and water demand and in particular coastal planning.

Given that Pittwater has a long foreshore, future development and redevelopment of foreshore areas will need to factor how future ocean/sea-level rise will impact on the developments. This is particularly pertinent to the construction and reconstruction of foreshore structures, such as seawalls, fixed jetties and boat ramps, and the issue of maintaining public foreshore access in the future. Mitigation and adaptation options to address the potential impacts of climate change, particularly for coastal communities, will become increasingly more expensive and problematic in the longer term.

The effect of climate change (ocean/sea level rise and rainfall increase) has been investigated further in Section 9.

6.5.2. Implications of Future Development

Due to the limited availability of currently residential zoned land the hydrologic impacts (increased runoff) of increased building construction will have no impact on the flood regime. However, what is of concern is the effect of unsuitable development on the floodplain within the zoned land. For example, buildings, fences, water tanks or other structures which impede the overland flows. This may result in damage to these structures, diversion of flood waters elsewhere or an increase in flood levels upstream. Encroachment within the riverine corridor will further restrict overland flows and increase the likelihood of bank destabilisation, loss of structures or affectation on the local ecosystem. These impacts are cumulative, with each development adding to the problem.

7. THE COST OF FLOODING

The cost of flood damages and the extent of the disruption to the community depends upon many factors including:

- the magnitude (depth, velocity and duration) of the flood,
- land usage and susceptibility to damage,
- awareness of the community to flooding,
- effective warning time,
- the availability of an evacuation plan or damage minimisation program,
- physical factors such as erosion of the river bank, flood borne debris, sedimentation.

Flood damages can be defined as being “tangible” or “intangible”. Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value (stress, injury, loss to life, etc.).

7.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories, direct and indirect damages. Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or a reduction in their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood including the cost of temporary accommodation, loss of wages by employees etc.

While the total likely damages in a given flood are useful to get a “feel” for the magnitude of the flood problem, it is of little value for absolute economic evaluation. When considering the economic effectiveness of a proposed mitigation option, the key question is what are the total damages prevented over the life of the option? This is a function not only of the high damages which occur in large floods but also of the lesser but more frequent damages which occur in small floods.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. By this means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. For the calculation of AAD at Great Mackerel Beach it was assumed that there are no flood damages in the one year event.

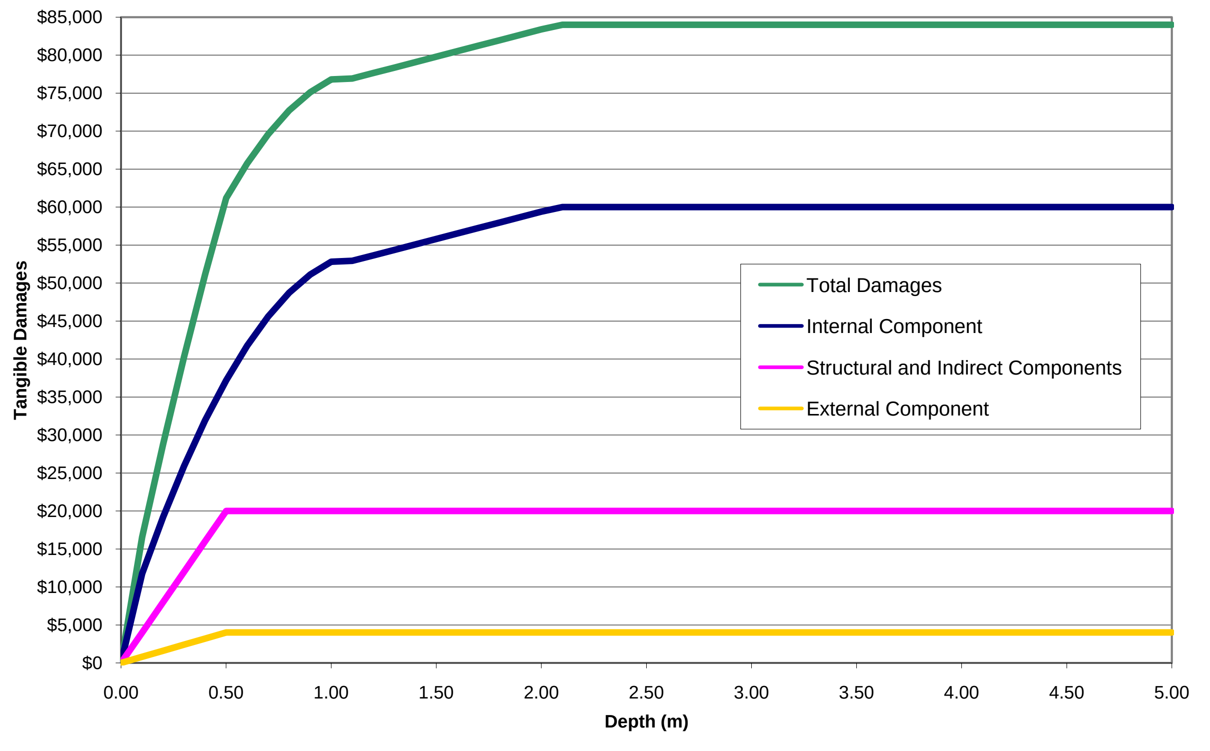
A flood damages assessment was undertaken for existing development in the Great Mackerel Beach community and is summarised in Table 8. It should be noted that a significant contribution to the average annual damages is the houses inundated in the 20% AEP and smaller events.

Table 8: Summary of Flood Damages

Design Flood	House Floors Inundated # (total = 98)	Granny Flats Inundated (total = 12)	Tangible Damages*
20% AEP	11	3	$540,000
5% AEP	13	5	$756,000
2% AEP	15	6	$845,000
1% AEP	16	6	$949,000
PMF	50	9	$3,221,000
		Average Annual Damages	**$367,000**

* Tangible damages includes external damages which may occur with or without house floor inundation
# Includes Rural Fire Service building.

The damages were calculated with use of a number of stage damage curves (that is, curves which relate flood depths with tangible damages) which were developed based on guidelines provided by DECCW (refer below).



NB: *The depth refers to floodwaters above the building floor level for internal, structural and indirect damages. For external, it refers to the depth above nonimal ground level*

Each component of tangible damages is allocated a maximum value and a maximum stage at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damage has already occurred.

For the Great Mackerel Beach assessment internal damages were allocated a maximum value of $60,000 occurring at a depth of 2 m above the building floor level (and linearly proportioned between the depths of 0 - 2 m). Structural and indirect damages were grouped together and given a maximum value of $20,000 assumed to occur at 1.5 m depth above building floor level and linearly proportioned for the depths below this. External damages were allocated a maximum of $4,000 occurring at 0.5 m above the property ground level and linearly proportioned for depths below this.

There are no commercial properties within the Great Mackerel Beach community and very little infrastructure. However, the two electricity substations have been damaged in the past as well as disruption to the telephone service. Thus the true cost of flood damages to the community will be greater than provided in Table 8.

7.2. Intangible Flood Damages

The intangible damages associated with flooding are inherently more difficult to estimate. In addition to the direct and indirect damages discussed in Section 7.1 additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors including the size of flood, the individuals affected, community preparedness, etc. However, it is important that the consideration of intangible damages are included when considering the impacts of flooding on a community. An overview of the types of intangible damages likely to occur at Great Mackerel Beach is discussed below.

Isolation

Isolation is already a significant factor for local residents and the majority (if not all) have in built mechanisms to address this issue (food reserves, emergency lighting etc). There is also a high level of community support and spirit, which can to some extent negate the effects of isolation and can certainly assist in a flood (as happened in November 1987). However, isolation is of significant concern if a medical emergency arises during a flood.

Population Demographics

As discussed in Section 4.5, the community of Great Mackerel Beach has a larger proportion of school aged (5 - 17 years) children and adults in their 30's and 40's than other urban communities. There are also few residents aged 18 - 35 years. Although it is not possible to conclusively determine the effects this might have on intangible damages during or after a flood, some potential impacts are:

- The dominance of residents aged in the 30s and 40s may result in a community that has had more experience at dealing with hazards (floods, bush fire, storm damage etc.,) compared to a younger community. This may result in the residents taking more notice of agency advice and having a more controlled response.
- The high number of family groups may mean that the residents are less likely to take undue risks however may become worried or stressed by a flood situation (concerns for their families and personal safety, possessions).
- The smaller portion of young children (0 - 4 years) and older adults (60 + years) may be an advantage during times of flood as there is a smaller portion of individuals

requiring physical assistance from others.

Stress

In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.,) many residents who have experienced a major flood are fearful of the occurrence of another flood event and its associated damage. The extent of the stress depends on the individual. To some extent this does not appear to be a significant issue at Great Mackerel Beach as a number of residents experienced the November 1987 event and do not indicate this as a problem.

Risk to Life and Injury

During any flood event there is the potential for injury as well as loss of life. At Great Mackerel Beach the high velocities in the upper reaches (three houses were moved from their foundations in the November 1987 event) as well as high flood depths in the lower reaches presents a significant risk to personal safety.

8. FLOODPLAIN RISK MANAGEMENT MEASURES

8.1. General

The NSW Government's Floodplain Development Manual (2005) (Reference 1) separates floodplain management measures into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees. At Great Mackerel Beach this would also include any works that modify the entrance of the creek to the Pittwater Estuary.

Property modification measures modify land use including development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), planning and building regulations (such as land use zoning and flood-related development controls) or voluntary purchase.

Response modification measures modify the community's response to flood hazard by educating flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows). It is a standard method for using the time value of money to appraise long-term projects) of the reduction in flood damages (benefit) compared to the cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. The public consultation program has ensured that identifiable social, intangible and environmental factors were considered in the decision making process at Great Mackerel Beach.

8.1.1. Criteria for Assessment of Measure in Matrix

The following criteria have been assigned a value in the management matrix:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events,
- number of properties benefited by measure,

- technical feasibility (design considerations, construction constraints, long-term performance),
- community acceptance and social impacts,
- economic merits (capital and recurring costs versus reduction in flood damages),
- financial feasibility to fund the measure,
- environmental and ecological benefits,
- impacts on the State Emergency Services,
- political and/or administrative issues,
- long-term performance given the likely impacts of climate change and ocean/sea level rises
- risk to life.

Details of the scoring system for the above criteria are provided in Table 9 and largely relate to the impacts in a 1% AEP event.

Table 9: Matrix Scoring System

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefited	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straightforward	straightforwa rd	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political/administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

It should be noted that in some communities any increase in flood level is unacceptable, however for flood mitigation works that provide a major benefit to one part of the community, whilst having a minor impact to another part a less rigid approach may be considered.

8.1.2. Matrix

The full range of possible management measures (as indicated in Reference 1) was evaluated. The range of measures included was based on experience and judgement obtained Council staff, the local community and representatives from state government agencies. Table 10 provides a matrix which scores each measure and a ranking.

Table 10: Matrix of Management Measures

Description	Section in Report	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental and Ecological Benefits	Impacts on SES	Political & Administrative Issues	Long Term Performance	Risk to Life	Total Score	Rank	Proposed Inclusion in Floodplain Risk Management Plan
1. Flood Modification Measures															
Flood Mitigation Dams	8.2.1	3	3	-3	-2	-3	-3	-3	1	-3	3	2	-5	14	No due to high economic and environmental cost.
Channel Modifications	8.2.2	1	3	-3	-2	-3	-3	-3	0	-2	-1	1	-12	16	No due to high environmental and maintenance costs.
Modifications to the Entrance	8.2.3	1	2	3	3	3	3	3	0	3	3	1	25	1	Yes an Inspection Program is proposed.
Levees, Flood gates, Pumps	8.2.4	0	3	-3	-3	-3	-3	-2	0	-1	0	1	-11	15	No for practical reasons
Local Drainage Issues	8.2.5	0	0	3	3	3	3	0	0	0	3	0	15	7	Yes database of issues, Council prepare road re-grading plan.
Measures to Mitigate the Effects of Wave Runup	8.2.6	1	3	3	3	3	3	0	0	0	0	1	17	4=	Yes a Study is proposed.
2. Response Modification Measures															
Flood Warning	8.3.1	0	3	1	1	1	1	0	0	0	1	0	8	12	No too short a warning to be of value but suggestions to install water level or rainfall device.
Evacuation Planning	8.3.2	0	3	3	3	3	3	0	3	1	2	2	23	2	Yes to be addressed by the SES.
Public Information and Raising Awareness	8.3.3	0	0	3	3	3	3	0	3	1	2	1	19	3	Yes Minimal cost and assumed high benefit cost ratio.
3. Property Modification Measures															
Development Control and Flood Planning Levels	8.4.1	0	3	3	0	3	3	0	0	-2	3	1	14	8	Yes but only to manage non compliance such as more controls on developments impinging on the floodplain.
Further Controls on bridges	8.4.1	1	1	1	1	3	3	1	0	-1	3	0	13	9=	Yes low cost
House Raising	8.4.2	0	3	2	0	2	2	0	0	0	3	1	13	9=	Yes should be investigated further.
Voluntary Purchase	8.4.3	0	3	3	-3	-3	-3	0	1	-3	3	3	1	13	No for economic and social reasons.
4. Other Management Measures															
Modification to the s149 Certificate	8.5.1	0	3	3	3	3	3	0	0	-1	3	0	17	4=	Yes consider including percentage of property inundated in Part 5.
Water Quality/Ecosystem Enhancement	8.5.2	0	3	3	3	3	3	3	0	1	-2	0	17	4=	Yes but undertaken under another Program.
Adaptive Strategies for Climate Change	8.5.3	0	3	3	0	3	3	0	0	-2	3	0	13	9=	Yes consideration of climate change freeboard.

8.2. Flood Modification Measures

Flood modification involves changing the behaviour of the flood itself, by reducing flood levels or velocities, or excluding floodwaters from areas under threat. This includes:

- dams,
- retarding basins,
- channel modifications,
- modifications to the entrance,
- levees,
- flood gates,
- pumps,
- local drainage issues,
- measures to mitigate the effects of ocean inundation.

Discussion on each of these measures is provided in the following sections.

8.2.1. Dams and Retarding Basins

DESCRIPTION

Flood mitigation dams and their smaller urban counterparts termed retarding basins have frequently been used in NSW to reduce peak flows downstream.

DISCUSSION

They are rarely used as a “retro fitted” flood mitigation measure to protect existing development but have been successfully used in developing urban areas in Canberra and western Sydney. The main benefits of these structures are that they reduce the peak outflow and thus the peak flood levels downstream. They can also provide some water quality benefit. At Great Mackerel Beach the following factors need to be considered:

- high cost of construction,
- high environmental damage caused by construction (at Great Mackerel Beach it would need to be located in the National Park),
- possible sterilisation of land within the dam area,
- high cost of land purchase,
- risk of failure of the dam wall,
- likely low benefit cost ratio,
- lack of suitable sites as a considerable volume of water needs to be impounded by the structure in order to provide a significant reduction in flood level downstream,
- a dam would only impact on rainfall induced inundation and would have no effect on estuary induced inundation.

OUTCOMES

Generally retarding basins are only used in an urban environment (there are many in western Sydney) to mitigate the adverse effects of urban development (increase in peak flow, increase in sedimentation) due to the difficulties in retro fitting them in an existing urban area.

At Great Mackerel Beach the relatively steep terrain upstream and because the land is part of the National Park means that there are no suitable sites.

8.2.2. Channel Modifications

DESCRIPTION

Channel modification works include all works that increase the waterway capacity of the channel, which in turn can reduce the flood levels. Examples are dredging, lining of channels, straightening and vegetation clearing.

DISCUSSION

Channel modifications have been widely used in the past to reduce flood levels in urban areas or along main river systems. However today they are probably used less often as a flood modification measure due to:

- the likely high environmental damage caused by the works,
- the subsequent possible change in ecology,
- the ongoing maintenance requirement,
- the works may increase flood levels, flows or velocities adjacent to the works or downstream ,
- there may be some liability issues for Council if maintenance is not undertaken and a flood occurs,
- there is no guarantee the works (say dredging) will be undertaken immediately prior to a flood. Also the early part of the flood or period of heavy rain prior to flooding may bring down sediments and debris which will infill any dredging,
- in some river systems the impacts of the channel modifications on flood levels may be less than might be expected as the channel only contains a small percentage of the total flow with the remainder in the overbank areas,
- concrete lining of the channel or channel widening or deepening has been used in urban areas in the past where there is a significant flood problem. However due to the nature of the residential community at Great Mackerel Beach these particular measures would be rejected on environmental and social grounds.

Removal of hydraulic obstructions (bridges, fences, dense vegetation) can also assist in reducing flood levels. Removal of the foot bridges would only provide a minimal hydraulic benefit as they are relatively minor structures with a large percentage of the flow in the overbank area. The main issue with public and private bridges is that they might become blocked by vegetative or other debris during a flood. The Flood Study indicated that 100% blockage of all bridges explicitly modelled (only 3 out of a possible 9) would increase levels by a maximum of 0.11 m and for 50% blockage only 0.04 m.

OUTCOMES

In summary the reduction in flood level caused by removal of the bridges is not great enough to justify their removal or re design. However some amendments to flood related development control for bridges is proposed in Section 8.4.1 (to ensure that new bridges are constructed in a flood compatible manner). Channel modifications, as a means of reducing flood levels, was not considered further for the above reasons. However channel maintenance issues (including vegetation growth, debris and bank stabilisation works) are discussed further in Section 8.5.2.

8.2.3. Management of the Entrance

DESCRIPTION

If the creek entrance to the Pittwater Estuary becomes blocked by sand build up (formation of a berm) then floodwaters in the creek and lagoon will pond to the height of the berm before any outflow occurs. Thus potentially, a small rainfall event could cause significant flooding. This situation is typical of all Intermittently Open and Closed Lake and Lagoons (ICOLL) along the NSW coast. Councils adopt different management approaches depending on the nature of the ICOLL and the local constraints. For example, Gosford City Council has different approaches for each of its four lagoons (Wamberal, Terrigal, Avoca and Cochrone Lagoons). The management approach needs to be developed taking into account the hydraulic, social, economic and environmental factors. Generally the approaches adopted today involve less human interference and a more “natural” opening regime. Ad hoc or informal opening or clearing of the entrance is not recommended.

DISCUSSION

From a flooding perspective, an entrance that is as wide and as deep as possible ensures flood levels are as low as possible for a rainfall-induced event (i.e flooding from rainfall is the dominant mechanism). The opposite is true for an ocean/estuary_induced event (flooding due to high ocean/estuary levels rather than due to high rainfalls). At some of the smaller ICOLLs (Terrigal, Wamberal, Smiths lake) Councils “control” the height of the entrance (by opening the entrance by mechanical means) to minimise flooding. However, this can only be achieved through regular maintenance and a quick response to the weather conditions. This procedure is an additional expense for Council, but more importantly, alters the natural lagoon ecosystem.

The current best-practice for managing ICOLLs is for the opening/closing regime to be self-maintaining, as far as possible, with human intervention only when there is likely to be a significant adverse social impact. It is recommended that this management approach be written up in an Entrance Management Policy.

The Great Mackerel Beach Flood Study (Reference 2) adopted an entrance berm level in the order of 1.3m AHD for determination of design flood levels. However, for all design events modelled, the assumed design water level in the Pittwater Estuary was above 1.3m AHD.

Appendix I of the Flood Study provides a review *of the entrance dynamics in the context of determining whether a formal management practice is required for the management of flood risk from catchment flooding.* The recommended actions were:

- there is a need to ensure that the entrance is located as far north as possible to ensure that erosion to the most northerly beach front properties is minimised,
- the barrier dune (beach berm) to be subject to ongoing maintenance and stabilised with vegetation, as well as restrictions to pedestrian access. The original design was

to raise the beach berm to 3m AHD (works proposed in 1989/90) but either this was not executed or the berm has eroded to its existing level of 2.15m AHD. A review of scour protection requirements was suggested at the southern side of the creek entrance,

- detailed hydraulic modelling analysis of the recommended options for the management of the entrance be undertaken as part of the floodplain risk management study,
- the entrance condition at the time of the November 1987 flood is unknown, the Flood Study assumed a berm at above 1.1m AHD. It should be noted that the peak ocean level was only 0.56m AHD during this event and the creek was opened in October 1987 (i.e. a month prior).

It should be noted that the entrance scenario that existed at the time of the November 1987 event may not necessarily be present in future flood events.

An entrance management workshop was held on 30th July 2008. This provided insight into the nature of the entrance and also provided some results of hydraulic modelling of different entrance scenarios. A summary of the workshop presentation together with comments from the stakeholders are provided in Appendix D.

Management of the entrance would ensure that the build up of sands is removed prior to the beach berm reaching a level which would have an adverse effect on flood levels. This could be done as scheduled maintenance (as occurs at Narrabeen Lagoon or Terrigal Lagoon) and should be considered further. Having an excavator “at call” to be brought over prior to the flood event is impractical for logistical reasons.

The possibility of a second entrance to the south was considered at the workshop but eliminated for environmental reasons.

A detailed assessment of sand movements near the entrance has not been undertaken to date and research in this area may lead to a greater understanding of the processes and possible solutions.

The technical hydraulic analysis of “opening” the entrance has only been undertaken to date for the 1% AEP event and it is possible that greater “benefit” from the “opening” will occur for the more frequent floods. This will need to be looked at further in any future study of the entrance.

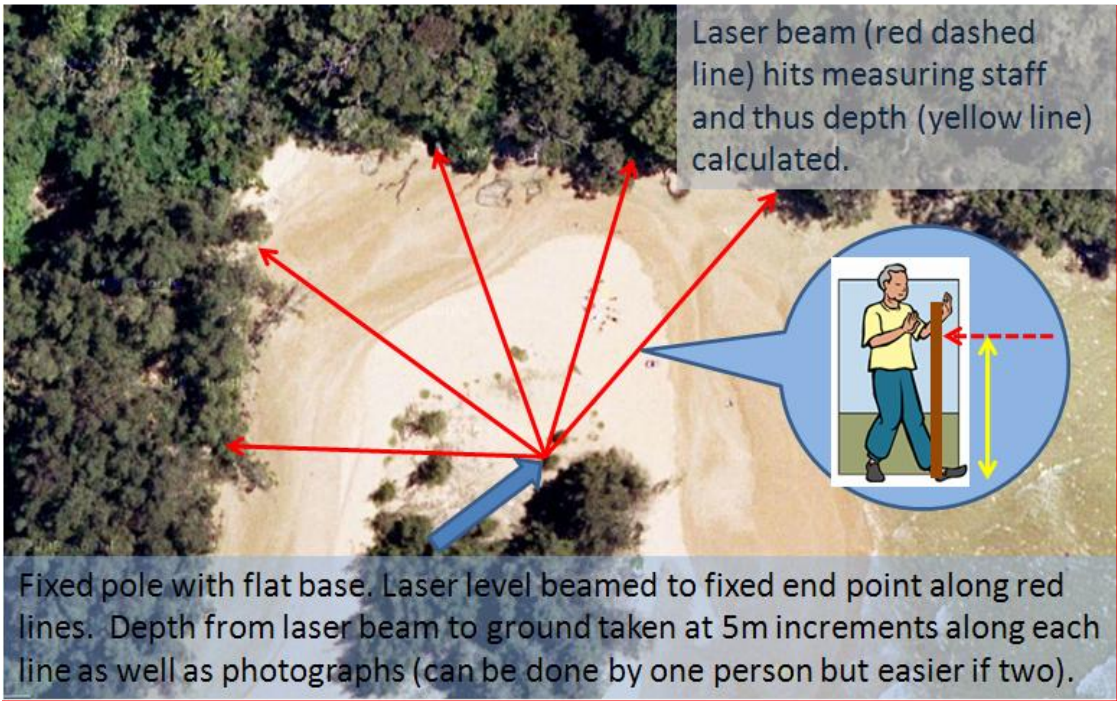
Whilst any enhancement of the creek entrance will provide a reduction in flood level the magnitude of the reduction depends upon the scale of the works and the size of the flood. The works will generally provide a greater reduction in smaller floods where there are smaller peak flows and the increased waterway area represents a high percentage of the total area available. However, the hydraulics at the entrance is complicated as there is a long stretch of relatively shallow creek from the lagoon to the actual mouth. Just clearing the mouth may provide little benefit as the restriction then becomes the channel immediately upstream.

OUTCOMES

At the time of this study (2007 to 2009) the creek was open to the Pittwater Estuary and none of the residents suggested further excavation of the existing outlet. A mechanical opening of the entrance before or during a flood to reduce flood levels is not possible and large scale entrance works (rock gabion entrance walls) will not eliminate the flood problem and are not supported by the community. However some form of mechanical opening is required if the sand builds up at the entrance to say 1.5m AHD as with heavy rain the lagoon area will fill to this level and so inundate low lying land and floor levels.

The major outcome of the entrance management workshop (Appendix D) was that continued monitoring is required in order to provide guidelines for an entrance management program which may or may not involve some form of mechanical opening and to ensure that the flood problem is not worsened. The proposed approach is therefore to undertake a regular inspection program (as proposed in the Flood Study). The suggested inspection program is based on the use of “sight poles” and digital photography to record berm levels and entrance conditions at regular time intervals. The primary benefit of this approach is that it will ensure an accurate record of the berm conditions is obtained. It is also expected that the program will be implemented with assistance from the local residents, therefore promoting a sense of “ownership” of the issues, outcomes and management.

The exact details of the sight poles and the frequency of photography would need to be developed on site and in conjunction with the residents (who would be undertaking the work). An initial concept is to have four pairs of poles (one either side of the channel) and a laser level would be projected from one pole to the other. This beam provides a horizontal datum and using another pole with height markings the horizontal and vertical distances can be obtained to define the channel cross section. The data (levels & photographs) would be collected say every 3 weeks and then emailed to Council for analysis. An example of the setup is provided below.



One outcome of the workshop of February 2010 was that this could be undertaken as a University research project. The poles and signage for the monitoring would be unobtrusive and largely vandal proof. The community representatives supported this measure and even suggested to volunteer to provide photographs. They considered that ground truthing was very important to justify any significant works.

This program will hopefully identify the rate and extent of any changes to the beach berm. Should an adverse condition develop, Council will need to assess the situation at the time and determine if some form of intervention is required. This data collection program may also assist with evaluating any changes to the entrance due to climate change (needs to be undertaken for at least 10 years).

It is recommended that an outcome of this present study is that a Draft Entrance Management Policy be prepared (i.e before any data collection program is complete). This policy would initially define the objectives of the policy, outline the data collection/inspection program and clearly define the roles and responsibilities. The Policy would be developed over time as data becomes available. In addition an interim approach for entrance management needs to be developed and this might be modified as results became known. Possible environmental issues would need to be evaluated if any works at the entrance are proposed. Part of this policy would include an awareness program so that the community are fully informed about the outcomes of the Policy and for example details of “why opening up the entrance does not always reduce flood levels”. This latter issue is very important to ensure residents fully understand and “take ownership” of the problem. To date the NPWS (now part of DECCW) are supportive of this approach and will assist where they can.

8.2.4. Levees, Flood Gates and Pumps

DESCRIPTION

Levees are built to exclude previously inundated areas of the floodplain from the river up to a certain design event and are commonly used on large river systems (e.g. Hunter and Macleay Rivers) but can also be found on small creeks in urban areas.

Flood gates allow local runoff to be drained from an area (say an area protected by a levee) when the external level is low, but when the river is elevated, the gates prevent floodwaters from the river entering the area (they are commonly installed on drainage systems within a leveed area).

Pumps are generally also associated with levee designs. They are installed to remove local runoff behind levees when flood gates are closed or if there are no flood gates.

Unless designed for the PMF, levees will be overtopped. Under overtopping conditions the rapid inundation may produce a situation of greater hazard than exists today. This may be further exacerbated if the community is under the false sense of security that the levee has “solved” the flood problem.

DISCUSSION

There are currently no levees, flood gates or pumps in Great Mackerel Beach.

It is not considered feasible to construct a levee system at Great Mackerel Beach for many reasons, including high economic cost, aesthetic issues, lack of available space, access and land take issues (the creek is located on private property in many areas). Also the levees restrict the flowpath and so increase flood levels elsewhere, unless all the properties are protected by a levee this inequality is usually unacceptable.

Whilst flood gates have been used successfully at a number of locations throughout NSW over many years, they require ongoing maintenance to ensure their continued success. Vandalism, damage or vegetation growth can all result in failure at critical times. Some form of ongoing maintenance program is therefore generally required. At Great Mackerel Beach the installation of flood gates is considered impractical due to the lack of any formal drainage paths and/or piped systems.

It has been suggested that pumps could be used to remove floodwaters ponding behind the beach berm, into the Pittwater Estuary. The cost to purchase and maintain the size of pumps required to provide any substantial benefit would be over $1 million. Furthermore, generally two pumps are installed so as to provide for some form of redundancy as well as the requirement for ongoing maintenance. Combined with other issues such as logistics (power, position) and aesthetics, pumps cannot be justified for use at Great Mackerel Beach.

OUTCOMES

The installation/construction of levees, flood gates and/or pumps at Great Mackerel Beach is not considered practical for the reasons discussed above and have not been considered further.

8.2.5. Local Drainage Issues

DESCRIPTION

Several residents have highlighted the issue of runoff within the community ponding in low lying areas or flowing at shallow depths across private property and the grass roads. For many residents, this problem is of greater concern than flooding as it occurs relatively regularly (at least once a year on average) and causes inconvenience as well as being considered unsightly. It also contributes to degradation of the grass roads, particularly if motorised vehicles (golf carts) are used. Residents consider that this is a significant community issue and can and should be resolved.

Also mentioned is the build up of debris caused by the various pipes under the Monash Avenue bridge (see photograph 7).

DISCUSSION

Local drainage issues are found in all urban communities and generally occur as a result of historical circumstances (basic or no road and drainage system at the time of development, little or no kerb and guttering) and the nature of the topography (land not graded to form flow paths).

Local drainage issues generally do not result in any significant damage to properties and in most circumstances there is minimal risk to life. However, it does cause significant inconvenience to residents.

In flood liable areas building floors must be at the nominated Flood Planning Level and as a general guide, all building floors in non-flood prone areas should be constructed a minimum of 300 mm above the surrounding ground level. This combined approach for flood prone and non flood prone areas will generally ensure that these minor drainage issues do not inundate building floors. To address the issue of ponding or flow through other areas, Council could undertake minor regrading works or construction of formal drainage paths to reduce the problem.

The “low slung” pipes under the Monash Avenue bridge will increase the likelihood of debris build up. However it is unlikely that this will result in a significant increase in flood levels in large floods (say greater than a 20% AEP event). Nevertheless it is something that could be investigated further and possibly resolved.

OUTCOMES

Local drainage issues are a significant issue in settlements such as Great Mackerel Beach which have developed over a period of years and without a formal road/drainage system.

In the first instance local residents should ensure that all such drainage issues are adequately documented (written and photographic) and reported to Council.

It is recommended that Council prepare a Great Mackerel Beach Local Drainage Strategy which would involve a regrading plan showing the works necessary to reduce the ponding problem and possible some minor mitigation works to reduce nuisance flooding. This will involve survey of the roads to indicate where overland flow can be safely diverted and discussions with local residents to seek their opinion on past experiences. These works must take into account any possible long term regrading strategy for the community due to climate change. As part of this strategy and for emergency management purposes it was suggested (workshop in February 2010) that a slightly elevated all weather path be constructed. Consideration should be given to re aligning the “low slung” pipes under the Monash Avenue bridge.

As local drainage improvements have minimal benefit in large flood events these works may not receive financial support under the State and Federal Government’s flood mitigation grants program.

8.2.6. Coastal Vulnerability Assessment

DESCRIPTION

The Great Mackerel Beach community has been identified as one of Pittwater Council’s coastal vulnerability sites and is currently being investigated as part of the Pittwater Coastline Definition and Climate Change Vulnerability Study, due for completion in mid-2011. The present situation will be exacerbated if/when the impacts of climate change (ocean/sea level rise and rainfall increase) are realised.

The effects of wave runup are one element of the proposed coastal vulnerability assessment. Wave runup is confined to the nearshore area and is highly dependent on factors such as the wave height and length, water depth and embayment slope. The action of these waves may cause inundation of properties and/or foreshore erosion. Wave runup effects may vary in time and space as a result of changing foreshore profiles, which may occur naturally (sedimentation, erosion, vegetation growth) or as a result of human activities (construction of jetties, levees or similar). There is no accurate historical record (height of waves, damage, frequency of occurrence etc.) of significant wave runup activity at Great Mackerel Beach, though it has definitely occurred in the past according to many residents and based on past experiences in other similar locations.

DISCUSSION

Wave runup effects can produce flooding on the foreshore as well as foreshore erosion. The effects of wave runup also require that the structural integrity of any proposed structure be more closely examined as, in general, no allowance is made for the structural impacts of these waves. The damages resulting from wave runup are difficult to accurately quantify as little data are available. To accommodate the effects of wave runup, it is becoming standard practice for Councils to determine a wave runup or Estuarine Planning Level in addition to the Flood Planning Level.

Pittwater Council has already implemented this approach with a sophisticated web based tool (http://www.pittwater.nsw.gov.au/building__and__development/property_information/flood_and_estuarine_levels) that provides an Estuarine Planning Level for each property. Details of the approach and references are also provided on the web site.

As discussed in Section 3.3.4, Estuarine Planning Levels for the entire Pittwater Estuary, including Great Mackerel Beach, are currently being revised to incorporate the sea level rise planning benchmarks from the NSW Sea Level Rise Policy of 0.4m by 2050 and 0.9m by 2100, in a project titled “Pittwater Foreshore Floodplain — Mapping of Sea Level Rise Impacts”. This project is due for completion in 2011.

Mitigation measures for wave runup are possible and at some beaches concrete barriers (or similar) are used to deflect the waves (South Cronulla). At other places vegetation re growth can be used to “dampen” the waves. Both these approaches are unlikely to be acceptable to the local community at Great Mackerel Beach (access and aesthetic impacts) and for this reason development controls to include wave runup are the preferred approach rather than mitigation measures.

However the different management approaches will be evaluated in detail in the proposed coastal vulnerability assessment .

OUTCOMES

The effects of wave runup on the houses fronting on to the foreshore needs to be considered further. At present a study has not been undertaken which considers the effects of wave runup for the Great Mackerel Beach township specifically, although such a mechanism was considered in the formation of the Estuary Planning Levels. It is recommended that further studies are undertaken so as to quantify the impacts on houses.

This study supports the undertaking of the proposed coastal vulnerability assessment for the Great Mackerel Beach community. It is also recommended that a detailed coastal processes/vulnerability study be undertaken for the Great Mackerel Beach lagoon entrance to assess the dynamics of the entrance and possible impacts on flooding, wave runup as well as the implications for climate change.

A Coastal Vulnerability Study for the Pittwater LGA is scheduled to commence in April 2010. This study will include the assessment of coastal processes and impacts at Great Mackerel Beach for existing conditions and well as for the future implications of ocean/sea level rise.

8.3. Response Modification Measures

8.3.1. Flood Warning

DESCRIPTION

It may be necessary for a number of residents to evacuate their homes during or following a major flood. In the November 1987 event residents had to evacuate from the two houses “dislodged” from their footings and following the event the loss of power, water and sewerage systems meant that the house was not “habitable” (in accordance with minimum public health and safety requirements). In future events a similar scenario may occur.

The amount of time for evacuation depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services (for Great Mackerel Beach emergency services are not available, although local residents are likely to assist in rescues and general emergency management such as bush fires etc.).

Flood warning and the implementation of evacuation procedures by the State Emergency Services (SES) are widely used throughout NSW to reduce flood damages and protect lives. Adequate warning gives residents time to move goods above the reach of floodwaters and to evacuate from the immediate area to high ground. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding,
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators,
- the flood awareness of the community responding to a warning.

For smaller catchments a Severe Weather Warning (SWW) is provided by the BOM but this is not specific to a particular catchment.

DISCUSSION

The Bureau of Meteorology (BOM) is responsible for flood warnings on major river systems. Flood warning systems are based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided to the SES who undertake evacuation. At present, such warning systems are not in use for smaller catchments, such as Great Mackerel Beach.

For these smaller catchments the BOM issues a Severe Weather Warning. This warning is issued if there is a likelihood of large hail, strong damaging winds, flash floods, tornadoes or any combination. This warning is "Sydney wide" and not specific to individual catchments and can be issued up to a day in advance, with subsequent revisions as more detail becomes available. The SWW provides an excellent means of advance warning suitable for major events (yacht races, sports etc.) and major authorities (Energy Australia, Sydney Water) but it is unlikely that this procedure would be appropriate for the community as:

- it would likely provide many false alarms as the catchment is small and the storms may change direction (etc.) after the warning is giving or never develop as expected,
- presumable it could only function with an audible alarm which creates issues with maintenance, ongoing education/awareness programs etc,
- flooding at Great Mackerel Beach can be via three main mechanisms (from intense rainfall or elevated ocean levels or a combination). This type of warning would generally only provide information for rain-induced events, although the BOM also issues a warning about strong wave activity.

Studies have shown that flood warning systems generally have high benefit/cost ratios if sufficient warning time is provided. In this regard all residents should be made aware of the types of warnings issued by the BOM (refer flood awareness in Section 8.3.3).

The main issue with any type of specific warning system for Great Mackerel Creek is the short time from the start of the rainfall to the flood peak. This is a function of the catchment size and for Great Mackerel Creek, is in the order of two hours. This is insufficient time to enable an effective and accurate system. Even with an effective flood warning system, some tangible and intangible flood damages will still occur.

Possible measures that could be installed include:

- a siren which produces an audible alarm once a given water level is reached (in the upper reaches of the creek). This is a relatively inexpensive measure ($15,000) but requires continued maintenance and there is risk of failure or false alarms. Gosford City Council has had mixed results with such a system on Narara Creek,
- a pluviometer (installation $8,000 plus annual maintenance of say $2,000) installed on the roof of the Rural Fire Service building which sounds an audible alarm if a certain rainfall intensity/duration is obtained. The associated costs and problems are similar to those for a water level siren. It should be noted that some local residents have collected rainfall information for several years. This data should be collected and analysed if appropriate.

Warnings from a siren or a pluviometer can be included into a data management service (such as Manly Hydraulic Laboratory), into Council's network or directly to SES. They could also be programmed to phone residents (mobile or landline), but such a system then relies on the phone system working during a storm (which has failed in previous storms at Great Mackerel Beach). Advances in technology mean that this system is a viable management measure and even if the phone system fails the siren may warn residents.

OUTCOMES

The installation of some form of water level or rainfall recorder within the catchment should be investigated further. The details (siren, how the warning is distributed) would need to be developed in conjunction with the relevant authorities and the local residents. Even if not ultimately used as part of a flood warning system, the information collected would assist in gaining more specific information about the flood/flow regime of Great Mackerel Creek.

8.3.2. Flood Emergency Management

DESCRIPTION

As mentioned above, it may be necessary for some residents to evacuate their homes in a major flood. However, as there is no permanent SES team located within the community, it is very unlikely that the SES will have a presence (probably not even in life threatening situations) during a flood, given the access issues. Some residents may leave on their own accord or upon advice from the radio or other warning and may be assisted by local residents. The main problems with all flood evacuations are:

- they must be carried out quickly and efficiently,
- they are hazardous for both rescuers and the evacuees,
- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers,
- people do not appreciate the dangers of crossing floodwaters.

For this reason, the preparation of a Community Flood Emergency Response Plan (CFERP) helps to minimise the risk associated with evacuations by providing information regarding evacuation routes, refuge areas, what to do/not to do during floods etc. It is the role of the SES to develop a CFERP and they are currently preparing the Manly–Warringah–Pittwater Local Flood Plan, which covers all floodplains in the Manly–Warringah–Pittwater area. It is understood that a separate appendix will be dedicated to emergency management, including evacuation, for each floodplain in the area. This will need to highlight that there is no SES presence at Great Mackerel Beach and that the residents would generally have to be responsible for their own emergency management during times of flood. It would only be possible for the SES to be present some time after the flood. Details of the CFERP would need to be confirmed with the SES Region Controller.

DISCUSSION

During the November 1987 event, floodwaters cut off many residents and several evacuations to high ground were undertaken. There is no permanent SES team located within the community, thus the residents must rely on a “self-help” approach.

At present, there is no SES Flood Evacuation Plan specifically for Great Mackerel Beach, though it is considered in general under a wider plan for the Pittwater and will be included in the new Manly–Warringah–Pittwater Local Flood Plan. An Evacuation Plan is necessary as residents will be isolated again in future floods. Any plan should give consideration to flood preparedness, response and recovery from the perspective of the community undertaking the activities (rather than the SES).

Fortunately there is abundant high ground within the township which will mean that there is no ongoing risk to life from floodwaters (assuming all people move safely). However if they evacuate during the event they will have to cross floodwaters (risk to life). If residents do not have the time to evacuate, and it is unlikely that they will as they will tend to remain in their house to protect furniture and goods, the concept of “vertical evacuation” (i.e move to a second floor during a flood) is the only means of protection. It is also not recommended to walk through floodwaters and thus it is probably safer to remain in the house, particularly as the flood will only be at its peak for approximately 30 minutes or less with the entire flood receding within 2 hours.

Development controls to require “vertical evacuation” are therefore the only means of ensuring the safety of the occupants whose buildings are surrounded by floodwaters.

Whilst not recommended, for the majority of existing residents they could remain dry by standing on furniture, even in a PMF. The maximum depth of above floor inundation (for the present houses) in the PMF is 1.9 m, however this is in a two storey house where evacuation to the second floor is possible. The second highest is only 1.4 m and is for a single storey house where standing on furniture in the PMF is probably just possible. In the 1% AEP event the maximum above floor inundation is presently 0.9 m and thus residents could stand on furniture or raise goods on furniture to minimise flood damages. Standing on furniture is not recommended as a protection means for new developments but for existing homes with no other means of protection and there is insufficient time to evacuate, then the only viable alternative is to stay within the house rather than risk wading through floodwaters, particularly as the peak of the flood will have receded within of the order of 2 hours.

The major risk with “vertical evacuation” is if the house moves or becomes damaged by floodwaters threatening the life of residents inside. This is a real risk at Great Mackerel Beach and occurred at two houses in the November 1987 event. For this reason the structural integrity of all new houses must be sufficient to withstand inundation, velocity and debris loadings. For new houses it is possible to construct them with a flood free refuge, however for existing houses this is not practically achievable for all houses, although for many a refuge could be retro-fitted.

As all new houses will be built at or above the 1% AEP +0.5 m level the maximum depth of inundation in the PMF at any property will be 0.9 m. Thus the requirement for all houses to be two storey to take into account vertical evacuation cannot be justified as long as there is some “flood free” safe refuge (such as a loft). This means that the requirement for structural integrity must include to the PMF level (as required by the DCP).

In past floods, the community have assisted each other in raising furniture (etc.) above the threat of floodwaters. If necessary, supplies could be provided by boat or by air, however it is presumed that there would already be sufficient supplies of flood and water within Great Mackerel Beach for at least one day of isolation if the ferry could not make a crossing. Thus the need for evacuation from the township, during or immediately following a flood, is only likely to be for medical reasons, related or not to the flood hazard. The SES would need to evaluate this risk within the proposed Flood Evacuation Plan and incorporate sufficient management measures.

The impact of a large flood at Great Mackerel Beach on the SES would depend upon the nature of the catastrophe. It is impossible for the SES to be present prior to or during the event due to the access issues. However they may be called upon after the event to provide assistance as well as the Department of Community Services. The November 1987 flood was a major flood (greater than a 5% AEP) and two houses were moved from their footings. It is unclear the nature of the SES's response at the time but as far as residents are aware the damage or risk to life was not of a nature that required immediate response from the SES. It is presumed that in the majority of floods (up to the 1% AEP) if houses are inundated the residents will generally clean up themselves and require little outside assistance, though Council or SES assistance would be beneficial. The only requirement for immediate SES assistance is if the damage presents an immediate danger or likelihood of further significant damage. It is possible that this could occur in events greater than the 1% AEP if there are significant structural damages to homes. This situation would present problems for the SES to address on account of the isolated nature of the community and lack of available equipment.

During consultation with the community and the RFS in the course of this project, it was highlighted that the only community facility at Great Mackerel Beach, the RFS shed, is severely flood-affected. This shed houses the RFS truck and all the emergency management equipment for this isolated community. The shed is located on the road reserve at the northern end of Diggers Crescent.

OUTCOMES

Recommended changes to the DCP to include vertical evacuation are discussed in Section 8.4.1.

The SES is currently updating the Local Flood Plan for all settlements in the Pittwater and for Great Mackerel Beach this should include additional floor level, flood level and flood related data provided in this report and the Flood Study. In addition input from the local community (e.g Council, RFS, SES and community representatives) through a Community Flood Emergency Response Plan (CFERP)) is required to ensure that workable actions for Great Mackerel Beach are incorporated. Priority should be given to the implementation of this Plan once completed, which will involve ongoing community education and awareness.

On completion it should be made available to the residents as well as local authorities (such as the Rural Fire Services). The SES should review the Local Flood Plan and the CFERP every 5 years or immediately following each major flood.

It is recommended that an investigation be undertaken into finding an alternative less flood-affected location for the RFS shed, yet still meets the need for emergency management and the community. The investigation of the relocation of the shed would need to involve close consultation between Council, the RFS and the local community.

8.3.3. Public Information and Raising Flood Awareness

DESCRIPTION

The success of any flood warning system and the evacuation process depends on:

Flood Awareness: How aware is the community to the threat of flooding? Has it been adequately informed and educated?

Flood Preparedness: How prepared is the community to react to the threat? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?

Flood Evacuation: How prepared are the authorities and the residents to evacuate households to minimise damages and the potential risk to life? How will the evacuation be done, where will the evacuees be moved to?

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. Photographs and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner. To some extent many of the above issues are valid for Great Mackerel Beach as a result of the November 1987 flood and subsequent minor events.

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including:

- *Frequency and impact of previous floods.* A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low. As a result of the November 1987 flood, which caused significant damage, and a number of minor events since (where residents have had to wade through water etc.,) the community generally has a medium level of awareness at this time (it will have declined as the time since the last flood increases).

- *History of residence*. Families who have owned properties for a long time will have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. It would appear that the majority of the Great Mackerel Beach residents have lived in the area for several years and are familiar with flooding. However there is also a large number of visitors (particularly during the Christmas/New Year period) and they would not be familiar with the hazard. Furthermore, they are the people most likely to attempt to evacuate without full knowledge of the local circumstances.
- *Whether an effective public awareness program has been implemented.* It is understood that no large scale awareness program has been implemented.

For floodplain risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness, diminishes as the time since the last flood increases.

A major hurdle is often convincing residents that major floods (larger than November 1987) will occur in the future.

Council has initiated a pilot/community (business and residential) flood awareness strategy in Newport in 2006. For Great Mackerel Beach only a residential strategy is required as there are no businesses.

As part of this study a database of flood liable houses has been prepared and this will be made available to the SES. Due to the small number of flood affected properties compared with the entire Pittwater LGA and because the nature of flooding is similar to other locations in the LGA, although within a more isolated community, it is considered that the existing Floodsafe brochure would be suitable for Great Mackerel Beach. The SES has advised that when a Local Flood Plan has been developed a “local” brochure that reflects the Great Mackerel Beach situation could be developed. Council’s and the SES website also provide excellent information on flood awareness and other flood related information.

OUTCOMES

Based on feedback from the interviews and general discussions, the residents of Great Mackerel Beach have a medium level of flood awareness and preparedness. However this would not be the case for the “holiday” visitors.

As the time since the last significant flood increases, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include a Floodsafe brochure as well as advice provided on the Councils and SES’s web sites. These need to be updated on regular basis to ensure that they are current.

This study also supports the recently implemented Community Working Group framework as a means of implementing flood awareness strategies. Table 11 provide examples of various methods that can be used.

The development of the Community Flood Awareness Program is likely to include the SES's FloodSafe program, information on the SES and Council's websites and continuation of the existing Community Working Group to provide regular updates and information to the community. The Community Flood Awareness Program will be developed and implemented in conjunction with the Community Flood Emergency Response Plan.

Table 11: Flood Awareness Methods

Method	Comment
Letter/Pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of ongoing implementation of the Floodplain risk Management Plan, changes to flood levels or any other relevant information.
Council Web Site	Council has developed a web site that provides both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This site provides an excellent source of knowledge on flooding within Great Mackerel Beach (and elsewhere in the LGA) as well as on issues such as climate change. It is recommended that it be updated as and when required.
Community Working Group	Council has recently initiated a Community Working Group framework which will provide a valuable two way conduit between the local residents and Council.
School Project or Local Historical Society (not undertaken at Great Mackerel Beach)	This provides an excellent means of informing the younger generation about flooding. It may involve talks from various authorities and can be combined with topics relating to water quality, estuary management, etc.
Displays on the Wharf	This is an inexpensive way of informing the community and may be combined with related displays.
Historical Flood Markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective.
Articles in Local Newspapers	Ongoing articles in the newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents
Collection of Data from Future Floods	Collection of data assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible.
Types of Information Available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 149 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all visitors who may rent or “house sit” for a period.
Establishment of a Flood Affectation Database and Post Flood Data Collection Program	A database would provide information on (say) which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event. It is already being developed as part of this present study. This database should be updated following each flood with input from the Community Working Group.
Flood Preparedness Program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop Approaches to Foster Community Ownership of the Problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as potential blockage of the entrance or debris build up. This process can be linked to water quality or other water related issues including estuary management. The specific approach can only be developed in consultation with the community.

The specific flood awareness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed by the Community Working Group.

8.4. Property Modification Measures

8.4.1. Strategic Planning Issues

DESCRIPTION

The division of flood prone land into appropriate land use zones can be an effective and long term means of limiting danger to personal safety and flood damage to future developments. Zoning of flood prone land should be based on an objective assessment of land suitability and capability, flood risk, environmental and other factors. In many cases, it is possible to develop flood prone lands without resulting in undue risk to life and property.

The strategic assessment of flood risk (as part of the present study) can prevent new development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new developments likely to be affected by flooding to acceptable levels. Development control planning includes both zoning and development controls.

DISCUSSION

Pittwater 21 Development Control Plan (DCP): The Pittwater 21 DCP is an amalgamated DCP containing all development controls for the Pittwater LGA. This DCP already includes Council's Flood Risk Management Policy and a comprehensive range of flood-related development controls for the entire LGA, including Great Mackerel Beach. Therefore it was beyond the scope of this current Floodplain Risk Management Study and Plan to undertake a comprehensive review of Council's Flood Risk Policy and associated flood-related development controls, so a detailed discussion on these matters has not been provided in this document. Similarly, appropriate flood planning levels (which consider both estuary induced levels and rain induced levels) have already been designated for properties in Great Mackerel Beach. These controls were developed on a LGA wide basis and not just specifically for Great Mackerel Beach and are available on Council's website together with the various planning levels. The controls contained in the DCP have to undergo a rigorous approval process to ensure that they are equitable and in accordance with best practice.

Flood Risk Mapping: Mapping has been undertaken as part of this study and is based on the best available information (airborne laser scanning and accurate to ±0.2m) should be used by Council to properties subject to flood related development controls.

Flood Planning Levels Database: As part of this study the flood planning level database has been updated and is provided as Appendix B with flood extent mapping and hazard mapping on Figures 3 and 8. This information, together with other flood related information will be available on Council's web site following completion of this study.

Due to the small size of the community and the fact that all zoned land has already been developed, land rezoning to provide mitigation benefits is not considered applicable.

Given the type of existing development, local topography and isolated nature of the community, there is no pressure for a change in land use activities or increase in urban density in the future.

In light of this the existing planning instruments provide adequate control on the existing and future development potential of the area from a flooding perspective.

Implementation of these controls will change the nature of development (largely because house floors will have to be elevated) and possibly the character of Great Mackerel Beach. Whilst raised floor levels will eliminate damage to the adopted flood level there is still the possibility of structural collapse due to water and debris loadings (although structural integrity is one of the development controls) or the risk to life to residents/rescuers wading through floodwaters.

The possible implications of increases in flood level due to climate change are discussed in Section 9.

Evacuation from a house surrounded by floodwaters is not recommended, particularly with adverse weather conditions (rain and wind) and the recommended procedure is to remain in the property until floodwaters subside. For this reason all new houses which will be surrounded by floodwaters must provide a flood free area (this could be a loft or a second storey) in the PMF (vertical evacuation).

There is a potential health risk during floods from septic tanks overflowing. This was reported not to be an issue in the November 1987 event. To eliminate this risk Council's development control policies should ensure that the design of new tanks adequately addresses the issue. Septic tanks are not specifically mentioned in DCP 21 however this issue could be mentioned in other Council documentation regarding septic tanks.

Section 8.2.2 identified that bridges are susceptible to blockage by debris and for this reason there should be as few bridges as possible. It is recommended that Council change its flood related development control policies to ensure that at Great Mackerel Beach the:

- the number of bridges constructed is minimised (share between two properties),
- the bridge design is in accordance with current standards for such a foot bridge,
- the bridge design has minimal hydraulic impact during a flood.

From a flood perspective, there are a number of structures that have been built at Great Mackerel Beach that may redirect or block floodwaters or may not be structurally stable during a flood. It is likely that many of these structures would not meet current development standards. It is recommended that Council investigates the possible problem of non-compliance, such as the construction of illegal structures that may exacerbate the flood problem or are not compliant with current development standards.

Another issue that has been raised by the community is the maintenance and construction techniques of Great Mackerel Creek itself, most of which lies within private land. This issue will be incorporated in the Entrance Management Policy (Section 8.2.3) and/or the Creek Rehabilitation Plan (8.5.2).

Of particular concern to the residents is the content of the Section 149 Certificates and this is discussed in Section 8.5.1.

OUTCOMES

Council has adopted flood-related development controls through its Development Control Plan (DCP). This includes a requirement for a refuge above the level of the PMF for all new dwellings where no flood-free access to evacuation is available, with associated requirements for structural integrity during such an extreme flood. It is recommended that through the flood-related development controls in the DCP that consideration is given to promote, or even require, second storey redevelopment in the lowermost areas of Great Mackerel Beach to provide additional refuge areas above the PMF.

To eliminate the potential health risk from overflowing septic tanks during a flood Council's development control policies should ensure that the design of new tanks adequately addresses the issue.

It is recommended that Council investigates the possible problem of non-compliance, such as the construction of illegal structures that may exacerbate the flood problem or are not compliant with current development standards.

It is recommended that Council review its policy to ensure that existing and new bridges do not act as debris collectors during a flood and increase flood levels upstream. This issue will be an important consideration in the Great Mackerel Beach Creek Rehabilitation Plan (refer Section 8.5.2).

The issue of climate change and the inclusion of the impacts on flood levels are discussed in Section 9.

8.4.2. House Raising

DESCRIPTION

House raising has been widely used throughout NSW to eliminate or significantly reduce inundation from habitable floors. However it has limited application as it is not suitable for all building types. Also, it is more common in areas where there is a greater depth of inundation than at Great Mackerel Beach and where raising the houses allows for the creation of an underfloor garage or non-habitable area (though it is essential that this underfloor area and its contents will not incur flood damages, if it is infilled this may negate the benefits of house raising).

DISCUSSION

House raising is suitable for most non-brick single storey houses on piers and is particularly relevant to those situated in low hazard areas on the floodplain. The benefit of house raising is that it eliminates inundation to the height of the floor and consequently reduces the flood damages. It should be noted that larger floods than the design flood (used to establish the minimum floor level) will inundate the house floor. It also provides a "safe refuge" during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or larger floods than the design flood occurs.

The house raising potential of houses at Great Mackerel Beach was based on building construction material, number of storeys and floor type for those houses inundated above floor level in events up to and including the 1% AEP event.

The main limiting factor was that of the 21 houses inundated above floor level in the 1% AEP event only 9 are single storeys and thus potentially raiseable. Of these only 6 are of pier construction.

Table 12 summaries the key details of the 6 houses that potentially could be raised.

Table 12: Houses Considered for Raising

	ADDRESS					
	26 DIGGERS CRESCENT	16 MONASH AVENUE	14 MONASH AVENUE	16 DIGGERS CRESCENT	18 MONASH AVENUE	24 MONASH AVENUE
Floor Level (m AHD)	1.86	2.12	2.23	2.24	2.27	2.27
DEPTH OF INUNDATION ABOVE FLOOR (m)						
20% AEP	0.25	not inundated	not inundated	not inundated	not inundated	not inundated
5% AEP	0.39	0.14	0.03	0.02	not inundated	not inundated
2% AEP	0.44	0.19	0.08	0.07	0.04	0.05
1% AEP	0.49	0.24	0.13	0.13	0.10	0.11
PMF	1.12	0.98	0.87	0.92	0.87	0.92
1% AEP						
Average Velocity (m/s)	<0.5	<0.5	<0.5	<0.5	<0.5	0.5 - 1.0
Provisional Hazard Category	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Hydraulic Flood Category	FLOODWAY	FLOODWAY	FLOODWAY	FLOODWAY	FLOODWAY	FLOODWAY
PMF						
Average Velocity (m/s)	0.5 - 1.0	0.5 - 1.0	0.5 - 1.0	0.5 - 1.0	0.5 - 1.0	1 - 1.5
Provisional Hazard Category	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Hydraulic Flood Category	FLOODWAY	FLOODWAY	FLOODWAY	FLOODWAY	FLOODWAY	FLOODWAY
DAMAGES						
Net Present Worth of Reduction in Damages	$184,000	$45,000	$14,000	$13,000	$6,000	$6,000
Benefit Cost Ratio (B/C)	2.3	0.6	0.2	0.2	0.1	0.1

A benefit-cost analysis was undertaken based on raising the houses to above the PMF level (i.e no above floor damages in the PMF) and assuming that the raised building is designed to remain standing in the PMF. The cost of raising was assumed to be $80,000 per house. The benefits were measured as the reduction in the average annual damages as a result of raising the floors and converted to a net present worth (based on 7% over 20 years). The results of the analysis show that for one house the B/C ratio is 2.3. For the remainder it is less than 1. Thus from an economic viewpoint houses should not be considered for raising in Great Mackerel Beach unless they are inundated is say the 10% AEP or smaller events.

An alternative to house raising for buildings that are not compatible, is flood proofing or sealing of the entry points to the building. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. However this measure is really only suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue. Also there are issues of compliance and maintenance. Based upon our experience we do not consider flood proofing a viable measure for existing houses in Great Mackerel Beach. However flood compatible building or renovating techniques should be employed for extensions or renovations where appropriate. Guidelines are provided in a booklet *"Reducing Vulnerability to Flood Damage"* prepared for the Hawkesbury Nepean Floodplain Management Steering Committee (June 2006).

House raising was a successful method of reducing tangible flood damages in the past but is less prevalent today in NSW as:

- the majority of suitable buildings have already been raised,
- the houses that can be raised are nearing the end of their useful life,
- house styles and requirements (ensuites, cabling, air conditioning) means that the timber, piered homes are less attractive than in the past,
- re-building rather than renovations are becoming more cost effective. In many suburbs in Sydney 30 year old brick homes are being demolished as the cost per m^2 to renovate is up to twice the per m^2 cost of re-building. Thus if 50% of the house is to be renovated it is cheaper to re-build.

A house raising/re-building subsidy scheme has been considered whereby the home owner can put the payment towards the cost of a replacement house constructed in a flood-compatible way rather than raising the existing building. Such a scheme has been promoted in other flood prone communities in NSW where there are large numbers of houses that could be raised but many owners wish to re build and/or consider it more cost effective. This scheme would provide a financial incentive to undertake house raising or re-building works and would be available to all house owners whose house is flood liable. However such a scheme is not expected to receive funding from the Federal or State government's flood mitigation program and thus the costs may have to be borne entirely by Council.

OUTCOMES

For the majority of flood affected properties in Great Mackerel Beach house raising and flood proofing are not viable means of flood protection. However, house raising should be investigated further for the six properties identified, to determine its viability, resident acceptance, likelihood of funding and structural suitability. Though from an economic viewpoint four of the six houses have benefit cost ratios below 0.5. If viable and acceptable to property owners, a house raising scheme could be investigated further. House raising may attract grant funding assistance from the NSW Government for the property owner. Up to two-thirds of the cost of raising a house may be available.

House rebuilding to flood-compatible standards in accordance with Council's flood-related development controls is currently not eligible for grant funding assistance. For the most severely flood-affected, Council may wish to investigate a house rebuilding subsidy scheme some time in the future.

8.4.3. Voluntary Purchase

DESCRIPTION

Voluntary purchase of the entire area cannot be economically or socially justified but can be used as a long term strategy to reduce the number of flood liable buildings. Voluntary purchase is generally not favoured by most communities. Among their concerns are:

- it can be difficult to establish a fair market value,
- in many cases residents may not wish to move for a reasonable purchase price,
- progressive removal of properties may impose stress on the social fabric of the area,
- it may be difficult (if not impossible) to find alternate flood compatible equivalent priced housing in the nearby area with similar aesthetic values.

DISCUSSION

Assuming an order of cost of $1 million per property the cost to purchase all inundated buildings would be in excess of $20 million. Council could then re-sell the land and approve new flood compatible development. This strategy is unlikely to be accepted by the Council or the community.

Generally voluntary purchase is only undertaken when the houses are in a high hazard area and frequently inundated and there are no other viable means of protection. Of the fourteen buildings inundated in a 20% AEP event eleven are classified as High Hazard in the 1% AEP event. Only one of these buildings could be raised and four are “Granny Flats”.

The benefit cost ratio of purchasing all fourteen buildings and assuming no re-building (i.e. no external damages) is 0.3 (assuming a property with a “Granny Flat” is the same as one without i.e. the total cost is $10 million). This is a relatively high benefit /cost ratio for voluntary purchase and reflects the high frequency of inundation of the house floor.

OUTCOMES

In light of the reservations above voluntary purchase is not considered to be an economically or socially viable means of reducing the number of house floors inundated in Great Mackerel Beach. However for many of the houses there is no other management measure if re-development is not undertaken.

8.5. Other Management Measures

8.5.1. Modification to the s149 Certificates

DESCRIPTION

Councils issue planning certificates to potential purchasers under Section 149 of the Environmental Planning and Assessment Act of 1979. The function of these certificates is to inform purchasers of planning controls and policies that apply to the subject land. Planning certificates are an important source of information for prospective purchasers on whether there are flood related development controls on the land. They need to rely upon the information under both Section 149(2) and 149(5) in order to make an informed decision about the property. It should be noted that only Part 2 is compulsory when a house is purchased and thus detail in Part 5 may not be made known to the purchaser unless it is specifically requested. Under Part 2 Council is required to advise if it is aware of the flood risk as it is of any other known risk (bush fire).

The current wording shown on Section 149(2) and 149(5) certificates issued by Pittwater Council is shown in Appendix B. Further detailed information can be obtained from Council's web site.

DISCUSSION

Because of the wide range of different flood conditions across the State, there is no standard way of conveying information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on the type of flooding, whether from major rivers or local overland flooding, and the extent of flooding (whether widespread or relatively confined).

It should be noted that the Section 149 certificate only relates to the subject land and not any building on the property. This can be confusing or misleading to some.

The information provided under Part 2 of the certificate is determined by the legislation and unless specifically included by the Council provides no indication of the extent of inundation. Under Part 5 there is scope for providing this additional type of information. Residents have suggested that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated. To address this concern Council could add information onto Part 5 to show the percentage of the property inundated. This could be undertaken on an LGA wide basis or just for specific areas such as Great Mackerel Beach. It is suggested that the wording would be based on the percentage of the property inundated, for example:

- less than 10% of the property inundated in the 1% AEP event,
- between 10% and 50% the property inundated in the 1% AEP event,
- over 50% the property inundated in the 1% AEP event,
- data not available on the percentage of the property inundated in the 1% AEP event.

OUTCOMES

It is recommended that Council consider adding information to Part 5 of the Section 149 Certificate to indicate the percentage of the property inundated in the 1% AEP event. This Draft information is provided in Appendix B and on Figure 11.

8.5.2. Water Quality/Ecosystem Enhancement

DESCRIPTION

Funding under the NSW or Federal Government Floodplain Management Program is not available for works that do not reduce the flood hazard. Nevertheless this study has suggested works that could be undertaken under other similar programs (such as the NSW Government's

Estuary Management Program).

DISCUSSION

Water quality is not generally of concern at Great Mackerel Beach as there are no large scale man-made pollutant sources within the catchment. The only possible source is from septic tanks and particularly during a flood, this is addressed in Section 8.4.1.

Local residents have also raised the issue of clearing the creek of vegetative debris that may cause blockages, upgrading the creek banks, revegetation and enhancing the quality of the aquatic ecosystem. It should be noted that the creek is mostly on private land and thus Council has no control within these areas. Possibly these issues could be addressed in a creek rehabilitation plan.

OUTCOMES

This floodplain risk management study generally supports these and other similar measures but as none of these measures provide any significant flood mitigation benefit they cannot be supported under the Government's floodplain mitigation funding program. These measures or the preparation of a Great Mackerel Beach Creek Rehabilitation Plan are supported in the Floodplain Risk Management Plan but will need to be funded under a different funding program (Rivercare, bush re generation, Estuary Management Program etc.). A key aim of the Plan would be to assist residents with appropriate treatment of the creek within their property. The Pittwater Estuary Management Plan is currently nearing finalisation with Public Exhibition completed in October 2010 and adoption by Council expected in December 2010. One of the recommendations is preparation of a Great Mackerel Beach Creek Rehabilitation Plan and so funding may be available through the Estuary Management Program.

9. CLIMATE CHANGE: IMPLICATIONS & ADAPTIVE STRATEGIES

9.1. Background

The *2005 Floodplain Development Manual* requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change on flood behaviour.

Since commissioning of the Great Mackerel Beach Floodplain Risk Management Study and Plan in April 2007, current best practice for considering the impacts of climate change (ocean level rise and rainfall increase) have been evolving rapidly. Key developments have included:

- the release of the Fourth Assessment Report by the Inter-governmental Panel on Climate Change (IPCC) in February 2007 (Reference 10), which updated the Third IPCC Assessment Report of 2001 (Reference 11);
- the preparation of *Climate Change Adaptation Actions for Local Government* by SMEC Australia for the Australian Greenhouse Office in mid 2007 (Reference 12);
- the preparation of *Climate Change in Australia* by CSIRO in late 2007 (Reference 13), which provides an Australian focus on Reference 10;
- the release of the Floodplain Risk Management Guideline *Practical Consideration of Climate Change* by the NSW Department of Environment and Climate Change in October 2007 (Reference 14 - referred to as the DECC Guideline 2007);
- Hunter, Central and Lower North Coast Regional Climate Change Project — Report 3: Climate Change Impact for the Hunter, Lower North Coast and Central Coast Region of NSW (Hunter and Central Coast Regional Environmental Strategy, 2009 (Reference 15);
- NSW Sea Level Rise Policy Statement (October 2009) (Reference 16) which states: "*Over the 20th century, global sea levels have risen by 17 cm and are continuing to rise. The current global average rate is approximately three times higher than the historical average. Sea level rise is a gradual process and will have medium- to long-term impacts. The best national and international projections of sea level rise along the NSW coast are for a rise relative to 1990 mean sea levels of up to 40 cm by 2050 and 90 cm by 2100. There is no scientific evidence to suggest that sea levels will stop rising beyond 2100 or that the current trends will be reversed*";
- In August 2010, the NSW Department of Planning adopted the *NSW Coastal Planning Guideline: Adapting to Sea Level Rise* (Reference 17). To accompany this Guideline, the NSW Department of Environment, Climate Change and Water also adopted the *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (Reference 18) and the *Coastal Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Coastal Risk Assessments* (Reference 19).

As a result of the information provided in the above and other documents, and to keep up-to-date with current best practice, the requirements of this study have been updated to provide a more rigorous assessment of climate change. It should be noted that the estimated rise in ocean/sea level along the NSW varies between the above reports and at this time there is no absolute value that has been adopted by all experts.

As the climate change analysis in this report was undertaken prior to release of the draft NSW Sea Level Rise Policy Statement in February 2009, the climate change scenarios were in accordance with the DECC Guideline 2007 as indicated as follows (which were current best practice at that time):

- **ocean level rise:**
  - low level ocean rise = 0.18 m,
  - medium level ocean rise = 0.55 m,
  - high level ocean rise = 0.91 m.

- **increase in peak rainfall and storm volume:**
  - low level rainfall increase = 10%,
  - medium level rainfall increase = 20%,
  - high level rainfall increase = 30%.

A high level rainfall increase of up to 30% is recommended for consideration due to the uncertainties associated with this aspect of climate change and to apply the "precautionary principle". It is generally acknowledged that a 30% rainfall increase is probably overly conservative and that a timeframe for the provision of definitive predictions of the actual increase is unknown.

It should be noted that Estuarine Planning Levels calculated for the Pittwater Estuary in 2004, which includes Great Mackerel Beach, already include an allowance of 0.2 m for ocean level rise, over and above the freeboard of 0.3 m. Estuarine Planning Levels for the entire Pittwater Estuary, including Great Mackerel Beach, are currently being revised to incorporate the sea level rise planning benchmarks from the NSW Sea Level Rise Policy of 0.4m by 2050 and 0.9m by 2100, in a project titled "Pittwater Foreshore Floodplain — Mapping of Sea Level Rise Impacts". This project is due for completion in 2011 and will see the commencement of the phasing out of Council's use of the terms 'Estuarine Risk' and 'Estuarine Planning Level' and the phasing in of the terms 'tidal risk' and 'Foreshore Flood Planning Level' to provide more consistent terminology with the Floodplain Development Manual (Reference 1).

Pittwater Council has now adopted for consideration in all future flood risk studies the ocean/sea level rise benchmarks in the NSW Draft Policy Statement on Sea Level Rise (October 2009) with the range of rainfall intensity increases as set out in the DECC Guideline 2007.

9.2. Approach

9.2.1. General

To determine the possible impacts upon the coastal community of Great Mackerel Beach (Figure 1) by climate change, numerous climate change scenarios were modelled as indicated in Table 13. The impact of each climate change scenario was gauged by comparing the peak flood level and number of building floors inundated against the corresponding existing design flood behaviour.

Table 13: Scenarios Modelled to Assess Impacts of Climate Change

			Run 1	Run 2	Run 3	Run 4	Run 5
			Ocean Rise	Ocean Rise	Existing Ocean	Ocean Rise	Ocean + Rainfall Increase
Climate Change Scenario	**Ocean Level Rise**	**Rainfall Increase**	**No Rainfall**	**Existing Rainfall**	**Increase Rainfall**	**Increase Rainfall**	**Berm Rise & Fall by 0.2 m**
LOW LEVEL RISE	0.18 m	10%	1% AEP	20% AEP 1% AEP PMF	20% AEP 1% AEP PMF	20% AEP 5% AEP 1% AEP PMF	20% AEP 1% AEP
MEDIUM LEVEL RISE	0.55 m	20%	1% AEP	20% AEP 1% AEP PMF	20% AEP 1% AEP PMF	20% AEP 1% AEP PMF	20% AEP 1% AEP
HIGH LEVEL RISE	0.91 m	30%	1% AEP	20% AEP 1% AEP PMF	20% AEP 1% AEP PMF	20% AEP 1% AEP PMF	20% AEP 1% AEP

Run 5 reflects the incremental effects (compared to Run 4) of a possible change in entrance conditions that may occur as a result of climate change.

9.2.2. Ocean Levels

The SOBEK model in the Flood Study adopted static ocean levels in association with the design rainfall events as shown in Table 14.

As a static water level was adopted in the Flood Study the influence of the tidal cycle on design flood levels has not been evaluated. Whilst this could be undertaken, a key issue is determining the relative timing of the peak ocean and peak runoff events. There is no commonly adopted approach for addressing this issue and for this reason a static ocean level is usually applied (as it is a conservative assumption). Table 14 also shows the adopted design ocean level for each climate change scenario.

Table 14: Design Ocean Levels

Design Ocean Event	Existing Design Ocean Level (m AHD)	Design Ocean Level with Climate Change Ocean Rise (m AHD)		
		Low (0.18 m)	**Medium (0.55 m)**	**High (0.91 m)**
PMF	1.50	1.68	2.05	2.41
1% AEP	1.50	1.68	2.05	2.41
2% AEP	1.47	1.65	2.02	2.38
5% AEP	1.43	1.61	1.98	2.34
20% AEP	1.36	1.54	1.91	2.27

Note: The "normal" daily tide reaches around 0.6m AHD with a typical low tide of -0.4m AHD and the highest annual tidal peak is approximately 1.1m AHD in the Pittwater Estuary. The design peak ocean levels shown above are based on approximately 100 years of records in Sydney Harbour (Ft Denison) and occur due to a combination of high tides and oceanic storm surge and wave setup conditions which elevate the "normal" ocean level. It should be noted that the wave setup component will be much greater on the coast than at Ft Denison. Coastal areas will also be subject to a wave runup component (i.e waves running up the beach).

As there is less than a 0.2 m difference in level between the existing 20% (1.36m AHD) and the existing 1% (1.5m AHD) AEP events, even the low ocean rise of 0.18 m would mean that the existing 1% AEP ocean level would be exceeded on average every 5 years.

9.3. Hydrology

The increase in design flows as a result of climate change was simulated by increasing the adopted critical duration design rainfall depths by 10%, 20% and 30%. Thus the possible effect of a change in the critical storm duration was not evaluated. This procedure was considered reasonable as all storm durations produced similar peak flood levels. The design critical storm durations are shown in Table 15.

Table 15: Adopted Design Critical Storm Durations and Peak Inflows

	Peak Inflow at Upstream Boundary (m^3/s)				
	Critical Storm Duration (min)	**Existing**	**10% Increase**	**20% Increase**	**30% Increase**
PMF	45	250	280	310	340
1% AEP	120	45	53	60	68
5% AEP	540	26	29	32	35
20% AEP	540	19	22	24	26

The existing RAFTS hydrological model was re-run for the increase in design rainfalls, using identical model parameters, to generate a set of inflow hydrographs for the three rainfall increase scenarios. The change in peak inflow at the upstream limit of the SOBEK model is also shown in Table 15. It should be noted that the increase in peak inflow in response to rainfall is non-linear. There are also other minor tributary catchment inflows but these are not shown in Table 15.

9.4. Beach Berm at Mouth

The SOBEK model includes a low-lying area at the mouth of the creek/lagoon which represents the "beach berm". The level of this berm varies due to wave and runoff action (a large flow in the creek will scour out the entrance which will later re-build due to wave action). A berm level adopted for establishing design flood levels was determined in the Flood Study based on historical information, survey and model calibration results. The dimensions (adopted in the Flood Study) are that the base of the berm is at approximately 1.25 m to 1.5m AHD and this level extends over a width of approximately 50 m. This level has been adopted for design flood estimation as a "typical" berm condition when a large flood occurs. However it should be noted that in reality a larger or smaller opening may be present. In a "real" flood the entrance will also be impacted by wave activity and runoff which may alter the dimensions during the actual flood event. These conditions cannot be accurately simulated in SOBEK.

The combination of ocean level and the level of the beach berm is the key control determining the flood levels upstream. The effect of each factor will vary depending upon the relative levels. For example, in a Low ocean scenario a High beach berm will largely be the determining factor.

However if the ocean level is greater than the level of the berm the ocean level will become the determining factor. Thus lowering the beach berm may be of value in some design events but not in others. Obviously a very High beach berm level (say at 2m AHD) will have a major impact for all design rainfall events. The situation is complex as once overtopping of the berm occurs there will be erosion and thus “lowering” of the berm. Measurements taken at man made openings of Wamberal Lagoon and Smiths Lake indicates that it takes several hours for floodwaters to greatly erode the berm. A High berm level will also prevent inundation from the Pittwater in an elevated ocean scenario and may cause a reduction in flood levels in Great Mackerel Beach unless the event is accompanied by runoff within the catchment.

The level of the beach berm is constantly changing in response to the duration, magnitude and frequency of runoff as well as from oceanic impacts (tides, wind, waves, storm surge). Human activity has altered the natural processes by the undertaking of “man-made” openings as well as reconstructing the berm and revegetating it, following past major storm events. Climate change is likely to affect this regime but the exact nature of the change is unknown. More than likely the berm will rise in response to an ocean level rise, though if rainfalls increase this may cause a greater frequency of openings and possibly lower the average berm level.

For this reason two climate change beach berm scenarios were evaluated (Run 5 in Table 13). These were raising and lowering the berm by 0.2 m (refer Figure 3 for extent of berm that is raised/lowered).

9.5. Results

9.5.1. Flood Levels

The flood levels and change in flood levels for the scenarios described in Table 13 are provided as Tables 16, 17 and 18 for the Low, Medium and High climate change scenarios respectively. The results from each run were compared to the respective existing design flood conditions at the locations shown on Figure 3 (same locations as for the Flood Study) with the exception of Run 1. For Run 1 the results were compared to the existing design ocean level with no runoff.
The existing flood levels at each of the locations together with a location description are shown on Table 19

Model runs have been abbreviated as follows:

- run number (abbreviated),
- the ocean level rise is indicated as low, med or hig (short for high) (Runs 2 & 4),
- the rainfall increase is indicated as either 10%, 20% or 30% (Runs 3 & 4),
- the event is shown as either 5y (20% AEP), 20y (5% AEP), 100y (1% AEP) or PMF (100y rather than 1% terminology was adopted in order not to confuse with the % rainfall increase).

Thus R4_Hig_30%_100y refers to Run 4, High Ocean Level Rise, 30% rainfall increase, 1% AEP event. Run 5 was only undertaken for the 20% and 1% AEP events for Run 4 climate change conditions (i.e. only difference between Run 5 and 4 is the rise or fall in berm by 0.2 m).

Table 16: Low Level Rise Results

Location ID refer Figure 3	R1_Low100y		R2_Low_005y		R2_Low_100y		R2_Low_PMF		R3_10%_005y		R3_10%_100y		R3_10%_PMF		R4_Low_10%_005y		R4_Low_10%_020y		R4_Low_10%_100y		R4_Low_10%_PMF		R5_005_lw_Fall		R5_005_lw_Rise		R5_100_lw_Fall		R5_100_lw_Rise	
	Ocean Rise No Rainfall		Ocean Rise Existing Rainfall						Existing Ocean Increase Rainfall						Ocean Rise and Increase Rainfall								Ocean Rise and Increase Rainfall and Change in Berm Crest							
	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel
143	1.68	0.2	2.13	0.0	2.39	0.0	3.16	0.0	2.18	0.1	2.43	0.1	3.22	0.1	2.18	0.1	2.31	0.0	2.44	0.1	3.22	0.1	2.07	-0.1	2.30	0.2	2.40	0.0	2.47	0.1
152	1.68	0.2	2.14	0.0	2.41	0.0	3.22	0.0	2.19	0.1	2.44	0.1	3.29	0.1	2.19	0.1	2.32	0.0	2.45	0.1	3.29	0.1	2.08	-0.1	2.30	0.2	2.42	0.0	2.49	0.1
153	1.68	0.2	2.17	0.0	2.45	0.0	3.43	0.0	2.22	0.1	2.49	0.1	3.52	0.1	2.22	0.1	2.35	0.0	2.51	0.1	3.52	0.1	2.13	0.0	2.32	0.2	2.48	0.0	2.54	0.1
154	1.68	0.2	2.16	0.0	2.45	0.0	3.40	0.0	2.21	0.1	2.49	0.1	3.49	0.1	2.22	0.1	2.35	0.0	2.51	0.1	3.49	0.1	2.13	0.0	2.32	0.2	2.48	0.0	2.53	0.1
155	1.68	0.2	2.30	0.0	2.69	0.0	4.12	0.0	2.35	0.1	2.76	0.1	4.25	0.1	2.36	0.1	2.51	0.1	2.77	0.1	4.25	0.1	2.31	0.0	2.43	0.1	2.76	0.1	2.78	0.1
156	1.68	0.2	2.12	0.0	2.37	0.0	3.04	0.0	2.17	0.1	2.40	0.0	3.09	0.1	2.17	0.1	2.30	0.0	2.41	0.1	3.09	0.1	2.05	-0.1	2.29	0.2	2.37	0.0	2.45	0.1
157	1.68	0.2	1.98	0.0	2.17	0.0	2.54	0.0	2.02	0.0	2.19	0.0	2.57	0.0	2.02	0.0	2.11	0.0	2.19	0.0	2.57	0.0	1.84	-0.1	2.18	0.2	2.08	-0.1	2.29	0.1
158	1.68	0.2	2.10	0.0	2.33	0.0	2.84	0.0	2.14	0.1	2.35	0.0	2.89	0.0	2.15	0.1	2.26	0.0	2.36	0.0	2.89	0.0	2.01	-0.1	2.27	0.2	2.31	0.0	2.41	0.1
159	1.68	0.2	2.11	0.0	2.35	0.0	2.90	0.0	2.16	0.1	2.38	0.0	2.94	0.0	2.16	0.1	2.29	0.0	2.39	0.1	2.94	0.0	2.04	-0.1	2.28	0.2	2.35	0.0	2.43	0.1
160	1.68	0.2	2.12	0.0	2.37	0.0	2.98	0.0	2.17	0.1	2.40	0.0	3.03	0.1	2.17	0.1	2.29	0.0	2.41	0.1	3.03	0.1	2.05	-0.1	2.29	0.2	2.37	0.0	2.44	0.1
2	1.68	0.2	2.12	0.0	2.38	0.0	3.05	0.0	2.17	0.1	2.41	0.0	3.10	0.1	2.18	0.1	2.30	0.0	2.43	0.1	3.10	0.1	2.06	-0.1	2.29	0.2	2.39	0.0	2.46	0.1
20	1.68	0.2	2.50	0.0	2.95	0.0	4.50	0.0	2.56	0.1	3.04	0.1	4.64	0.1	2.56	0.1	2.72	0.1	3.05	0.1	4.64	0.1	2.55	0.0	2.59	0.1	3.05	0.1	3.05	0.1
30	1.68	0.2	2.39	0.0	2.75	0.0	4.15	0.0	2.44	0.0	2.82	0.1	4.27	0.1	2.44	0.0	2.58	0.1	2.84	0.1	4.27	0.1	2.41	0.0	2.49	0.1	2.83	0.1	2.84	0.1
40	1.68	0.2	2.25	0.0	2.60	0.0	3.92	0.0	2.30	0.1	2.66	0.1	4.04	0.1	2.31	0.1	2.45	0.1	2.68	0.1	4.04	0.1	2.25	0.0	2.39	0.1	2.66	0.1	2.69	0.1
50	1.68	0.2	2.19	0.0	2.49	0.0	3.57	0.0	2.24	0.1	2.54	0.1	3.67	0.1	2.24	0.1	2.38	0.0	2.56	0.1	3.67	0.1	2.16	0.0	2.34	0.2	2.53	0.1	2.58	0.1
60	1.68	0.2	2.15	0.0	2.43	0.0	3.37	0.0	2.20	0.1	2.47	0.1	3.45	0.1	2.21	0.1	2.34	0.0	2.49	0.1	3.45	0.1	2.11	0.0	2.31	0.2	2.46	0.0	2.52	0.1
70	1.68	0.2	2.13	0.0	2.39	0.0	3.17	0.0	2.18	0.1	2.43	0.1	3.24	0.1	2.18	0.1	2.31	0.0	2.44	0.1	3.24	0.1	2.07	-0.1	2.30	0.2	2.40	0.0	2.47	0.1
80	1.68	0.2	2.12	0.0	2.38	0.0	3.09	0.0	2.17	0.1	2.41	0.0	3.15	0.1	2.18	0.1	2.30	0.0	2.43	0.1	3.15	0.1	2.06	-0.1	2.29	0.2	2.39	0.0	2.46	0.1
90	1.68	0.2	2.12	0.0	2.38	0.0	3.05	0.0	2.17	0.1	2.41	0.0	3.11	0.1	2.17	0.1	2.30	0.0	2.42	0.1	3.11	0.1	2.05	-0.1	2.29	0.2	2.38	0.0	2.45	0.1
100	1.68	0.2	2.12	0.0	2.37	0.0	3.03	0.0	2.17	0.1	2.40	0.0	3.08	0.1	2.17	0.1	2.30	0.0	2.41	0.1	3.08	0.1	2.05	-0.1	2.29	0.2	2.37	0.0	2.45	0.1
110	1.68	0.2	2.12	0.0	2.37	0.0	2.99	0.0	2.17	0.1	2.39	0.0	3.05	0.1	2.17	0.1	2.29	0.0	2.40	0.1	3.05	0.1	2.04	-0.1	2.29	0.2	2.37	0.0	2.44	0.1
120	1.68	0.2	2.12	0.0	2.36	0.0	2.99	0.0	2.16	0.1	2.39	0.0	3.04	0.1	2.17	0.1	2.29	0.0	2.40	0.1	3.04	0.1	2.04	-0.1	2.29	0.2	2.36	0.0	2.44	0.1
130	1.68	0.2	2.12	0.0	2.36	0.0	2.98	0.0	2.16	0.1	2.39	0.0	3.03	0.1	2.17	0.1	2.29	0.0	2.40	0.1	3.03	0.1	2.04	-0.1	2.29	0.2	2.36	0.0	2.44	0.1
140	1.68	0.2	2.11	0.0	2.34	0.0	2.88	0.0	2.15	0.1	2.37	0.0	2.93	0.0	2.16	0.1	2.28	0.0	2.38	0.0	2.93	0.0	2.03	-0.1	2.28	0.2	2.33	0.0	2.42	0.1

Abs refers to the calculated flood level in m AHD.

Rel refers to the change in flood level (in m) between the 'no climate change' scenario and the 'climate change' scenario.

Table 17: Medium Level Rise Results

Location ID refer Figure 3	R1_Med100y		R2_Med_005y		R2_Med_100y		R2_Med_PMF		R3_20%_005y		R3_20%_100y		R3_20%_PMF		R4_Med_20%_005y		R4_Med_20%_100y		R4_Med_20%_PMF		R5_005_md_Fall		R5_005_md_Rise		R5_100_md_Fall		R5_100_md_Rise	
	Ocean Rise No Rainfall		Ocean Rise Existing Rainfall						Existing Ocean Increase Rainfall						Ocean Rise and Increase Rainfall						Ocean Rise and Increase Rainfall and Change in Berm Crest							
	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel
143	2.05	0.6	2.19	0.1	2.43	0.1	3.16	0.0	2.22	0.1	2.47	0.1	3.29	0.1	2.26	0.1	2.51	0.1	3.29	0.1	2.20	0.1	2.33	0.2	2.49	0.1	2.53	0.2
152	2.05	0.6	2.20	0.1	2.45	0.1	3.22	0.0	2.23	0.1	2.49	0.1	3.37	0.1	2.27	0.1	2.53	0.1	3.37	0.1	2.21	0.1	2.34	0.2	2.51	0.1	2.55	0.2
153	2.05	0.6	2.22	0.1	2.50	0.1	3.43	0.0	2.26	0.1	2.55	0.1	3.61	0.2	2.30	0.1	2.59	0.2	3.61	0.2	2.25	0.1	2.36	0.2	2.58	0.1	2.61	0.2
154	2.05	0.6	2.22	0.1	2.49	0.1	3.41	0.0	2.26	0.1	2.54	0.1	3.58	0.2	2.29	0.1	2.58	0.2	3.58	0.2	2.24	0.1	2.36	0.2	2.57	0.1	2.60	0.2
155	2.05	0.6	2.34	0.0	2.73	0.1	4.12	0.0	2.41	0.1	2.84	0.2	4.38	0.3	2.43	0.1	2.89	0.2	4.38	0.3	2.40	0.1	2.47	0.2	2.88	0.2	2.90	0.2
156	2.05	0.6	2.18	0.1	2.41	0.1	3.04	0.0	2.21	0.1	2.44	0.1	3.15	0.1	2.25	0.1	2.48	0.1	3.15	0.1	2.18	0.1	2.32	0.2	2.46	0.1	2.50	0.1
157	2.05	0.6	2.06	0.1	2.23	0.1	2.55	0.0	2.05	0.1	2.21	0.1	2.59	0.1	2.10	0.1	2.27	0.1	2.60	0.1	2.02	0.0	2.20	0.2	2.22	0.1	2.33	0.2
158	2.05	0.6	2.16	0.1	2.37	0.1	2.85	0.0	2.19	0.1	2.39	0.1	2.93	0.1	2.22	0.1	2.42	0.1	2.93	0.1	2.15	0.1	2.30	0.2	2.39	0.1	2.46	0.1
159	2.05	0.6	2.17	0.1	2.39	0.1	2.90	0.0	2.21	0.1	2.41	0.1	2.98	0.1	2.24	0.1	2.45	0.1	2.99	0.1	2.17	0.1	2.31	0.2	2.43	0.1	2.48	0.1
160	2.05	0.6	2.18	0.1	2.41	0.1	2.98	0.0	2.21	0.1	2.43	0.1	3.07	0.1	2.25	0.1	2.47	0.1	3.08	0.1	2.18	0.1	2.32	0.2	2.45	0.1	2.49	0.1
2	2.05	0.6	2.18	0.1	2.42	0.1	3.05	0.0	2.22	0.1	2.46	0.1	3.15	0.1	2.26	0.1	2.49	0.1	3.15	0.1	2.19	0.1	2.33	0.2	2.48	0.1	2.52	0.2
20	2.05	0.6	2.52	0.0	2.97	0.0	4.50	0.0	2.61	0.1	3.14	0.2	4.78	0.3	2.63	0.1	3.16	0.2	4.78	0.3	2.62	0.1	2.65	0.1	3.16	0.2	3.16	0.2
30	2.05	0.6	2.41	0.0	2.78	0.0	4.15	0.0	2.48	0.1	2.90	0.2	4.40	0.3	2.50	0.1	2.94	0.2	4.40	0.3	2.48	0.1	2.53	0.1	2.94	0.2	2.95	0.2
40	2.05	0.6	2.30	0.0	2.64	0.1	3.92	0.0	2.35	0.1	2.73	0.2	4.16	0.2	2.38	0.1	2.78	0.2	4.16	0.2	2.34	0.1	2.43	0.2	2.77	0.2	2.79	0.2
50	2.05	0.6	2.24	0.1	2.54	0.1	3.58	0.0	2.29	0.1	2.60	0.1	3.77	0.2	2.32	0.1	2.65	0.2	3.77	0.2	2.27	0.1	2.38	0.2	2.63	0.2	2.66	0.2
60	2.05	0.6	2.21	0.1	2.48	0.1	3.37	0.0	2.25	0.1	2.53	0.1	3.54	0.2	2.29	0.1	2.57	0.2	3.54	0.2	2.23	0.1	2.35	0.2	2.55	0.1	2.59	0.2
70	2.05	0.6	2.19	0.1	2.44	0.1	3.17	0.0	2.23	0.1	2.47	0.1	3.31	0.1	2.26	0.1	2.51	0.1	3.31	0.1	2.20	0.1	2.33	0.2	2.49	0.1	2.53	0.2
80	2.05	0.6	2.18	0.1	2.42	0.1	3.09	0.0	2.22	0.1	2.45	0.1	3.21	0.1	2.26	0.1	2.49	0.1	3.21	0.1	2.19	0.1	2.33	0.2	2.47	0.1	2.52	0.2
90	2.05	0.6	2.18	0.1	2.42	0.1	3.06	0.0	2.22	0.1	2.45	0.1	3.17	0.1	2.25	0.1	2.49	0.1	3.17	0.1	2.19	0.1	2.32	0.2	2.47	0.1	2.51	0.1
100	2.05	0.6	2.18	0.1	2.41	0.1	3.03	0.0	2.21	0.1	2.44	0.1	3.14	0.1	2.25	0.1	2.48	0.1	3.14	0.1	2.18	0.1	2.32	0.2	2.46	0.1	2.50	0.1
110	2.05	0.6	2.18	0.1	2.40	0.1	3.00	0.0	2.21	0.1	2.43	0.1	3.10	0.1	2.25	0.1	2.47	0.1	3.10	0.1	2.18	0.1	2.32	0.2	2.45	0.1	2.49	0.1
120	2.05	0.6	2.18	0.1	2.40	0.1	2.99	0.0	2.21	0.1	2.43	0.1	3.09	0.1	2.25	0.1	2.47	0.1	3.09	0.1	2.18	0.1	2.32	0.2	2.44	0.1	2.49	0.1
130	2.05	0.6	2.18	0.1	2.40	0.1	2.98	0.0	2.21	0.1	2.43	0.1	3.08	0.1	2.25	0.1	2.46	0.1	3.08	0.1	2.18	0.1	2.32	0.2	2.44	0.1	2.49	0.1
140	2.05	0.6	2.17	0.1	2.38	0.1	2.88	0.0	2.20	0.1	2.40	0.1	2.97	0.1	2.23	0.1	2.44	0.1	2.97	0.1	2.16	0.1	2.31	0.2	2.41	0.1	2.47	0.1

Abs refers to the calculated flood level in m AHD.

Rel refers to the change in flood level (in m) between the 'no climate change' scenario and the 'climate change' scenario.

Table 18: High Level Rise Results

Location	R1_Hig100y		R2_Hig_005y		R2_Hig_100y		R2_Hig_PMF		R3_30%_005y		R3_30%_100y		R3_30%_PMF		R4_Hig_30%_005y		R4_Hig_30%_100y		R4_Hig_30%_PMF		R5_005_hg_Fall		R5_005_hg_Rise		R5_100_hg_Fall		R5_100_hg_Rise	
ID refer Figure 3	Ocean Rise No Rainfall		Ocean Rise Existing Rainfall						Existing Ocean Increase Rainfall						Ocean Rise and Increase Rainfall						Ocean Rise and Increase Rainfall and Change in Berm Crest									
	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel
143	2.41	0.9	2.38	0.2	2.52	0.2	3.16	0.0	2.26	0.1	2.51	0.1	3.35	0.2	2.41	0.3	2.61	0.2	3.36	0.2	2.40	0.3	2.43	0.3	2.60	0.2	2.61	0.2
152	2.41	0.9	2.38	0.2	2.54	0.2	3.23	0.0	2.27	0.1	2.53	0.1	3.44	0.2	2.42	0.3	2.62	0.2	3.44	0.2	2.41	0.3	2.43	0.3	2.62	0.2	2.63	0.2
153	2.41	0.9	2.39	0.2	2.58	0.1	3.44	0.0	2.30	0.1	2.60	0.2	3.69	0.3	2.44	0.3	2.69	0.3	3.69	0.3	2.43	0.3	2.45	0.3	2.69	0.3	2.70	0.3
154	2.41	0.9	2.39	0.2	2.57	0.1	3.41	0.0	2.30	0.1	2.59	0.2	3.66	0.3	2.44	0.3	2.68	0.3	3.66	0.3	2.43	0.3	2.45	0.3	2.68	0.3	2.69	0.3
155	2.41	0.9	2.47	0.2	2.78	0.1	4.12	0.0	2.45	0.2	2.92	0.3	4.50	0.4	2.55	0.3	2.99	0.3	4.50	0.4	2.55	0.3	2.56	0.3	2.99	0.3	2.99	0.3
156	2.41	0.9	2.37	0.3	2.51	0.2	3.05	0.0	2.25	0.1	2.48	0.1	3.21	0.2	2.41	0.3	2.57	0.2	3.22	0.2	2.40	0.3	2.42	0.3	2.57	0.2	2.58	0.2
157	2.41	0.9	2.29	0.3	2.44	0.3	2.63	0.1	2.08	0.1	2.24	0.1	2.62	0.1	2.31	0.3	2.46	0.3	2.69	0.2	2.30	0.3	2.32	0.3	2.45	0.3	2.47	0.3
158	2.41	0.9	2.32	0.2	2.48	0.2	2.86	0.0	2.22	0.1	2.42	0.1	2.97	0.1	2.35	0.3	2.53	0.2	2.98	0.1	2.33	0.2	2.36	0.3	2.52	0.2	2.54	0.2
159	2.41	0.9	2.34	0.2	2.49	0.2	2.91	0.0	2.24	0.1	2.45	0.1	3.03	0.1	2.37	0.3	2.54	0.2	3.04	0.1	2.36	0.3	2.39	0.3	2.54	0.2	2.55	0.2
160	2.41	0.9	2.36	0.2	2.50	0.1	2.99	0.0	2.25	0.1	2.47	0.1	3.12	0.1	2.40	0.3	2.56	0.2	3.13	0.2	2.39	0.3	2.41	0.3	2.56	0.2	2.57	0.2
2	2.41	0.9	2.37	0.3	2.52	0.2	3.06	0.0	2.26	0.1	2.50	0.1	3.19	0.1	2.41	0.3	2.59	0.2	3.20	0.1	2.40	0.3	2.42	0.3	2.58	0.2	2.60	0.2
20	2.41	0.9	2.59	0.1	3.00	0.1	4.51	0.0	2.66	0.2	3.23	0.3	4.90	0.4	2.72	0.2	3.27	0.3	4.90	0.4	2.71	0.2	2.72	0.2	3.27	0.3	3.27	0.3
30	2.41	0.9	2.51	0.1	2.83	0.1	4.15	0.0	2.52	0.1	2.98	0.2	4.52	0.4	2.60	0.2	3.04	0.3	4.52	0.4	2.60	0.2	2.61	0.2	3.04	0.3	3.04	0.3
40	2.41	0.9	2.44	0.2	2.70	0.1	3.92	0.0	2.40	0.1	2.80	0.2	4.27	0.4	2.51	0.3	2.88	0.3	4.27	0.4	2.50	0.3	2.52	0.3	2.88	0.3	2.89	0.3
50	2.41	0.9	2.40	0.2	2.61	0.1	3.58	0.0	2.33	0.1	2.66	0.2	3.87	0.3	2.46	0.3	2.74	0.3	3.87	0.3	2.45	0.3	2.47	0.3	2.74	0.3	2.75	0.3
60	2.41	0.9	2.39	0.2	2.56	0.1	3.38	0.0	2.29	0.1	2.57	0.2	3.62	0.3	2.43	0.3	2.67	0.3	3.63	0.3	2.42	0.3	2.44	0.3	2.66	0.2	2.67	0.3
70	2.41	0.9	2.38	0.2	2.53	0.2	3.18	0.0	2.27	0.1	2.51	0.1	3.38	0.2	2.41	0.3	2.61	0.2	3.38	0.2	2.41	0.3	2.43	0.3	2.60	0.2	2.62	0.2
80	2.41	0.9	2.37	0.3	2.52	0.2	3.10	0.0	2.26	0.1	2.49	0.1	3.27	0.2	2.41	0.3	2.59	0.2	3.28	0.2	2.40	0.3	2.42	0.3	2.58	0.2	2.60	0.2
90	2.41	0.9	2.37	0.3	2.51	0.2	3.06	0.0	2.25	0.1	2.49	0.1	3.23	0.2	2.41	0.3	2.58	0.2	3.23	0.2	2.40	0.3	2.42	0.3	2.57	0.2	2.59	0.2
100	2.41	0.9	2.37	0.3	2.51	0.2	3.04	0.0	2.25	0.1	2.48	0.1	3.19	0.2	2.41	0.3	2.57	0.2	3.20	0.2	2.40	0.3	2.42	0.3	2.57	0.2	2.58	0.2
110	2.41	0.9	2.37	0.3	2.50	0.2	3.01	0.0	2.25	0.1	2.47	0.1	3.15	0.2	2.41	0.3	2.56	0.2	3.16	0.2	2.40	0.3	2.42	0.3	2.56	0.2	2.57	0.2
120	2.41	0.9	2.37	0.3	2.50	0.2	3.00	0.0	2.25	0.1	2.47	0.1	3.14	0.2	2.40	0.3	2.56	0.2	3.15	0.2	2.39	0.3	2.41	0.3	2.56	0.2	2.57	0.2
130	2.41	0.9	2.29	0.2	2.50	0.2	2.99	0.0	2.25	0.1	2.46	0.1	3.13	0.2	2.32	0.2	2.56	0.2	3.14	0.2	2.31	0.2	2.33	0.2	2.55	0.2	2.57	0.2
140	2.41	0.9	2.30	0.2	2.49	0.2	2.90	0.0	2.23	0.1	2.44	0.1	3.02	0.1	2.33	0.2	2.54	0.2	3.03	0.1	2.32	0.2	2.34	0.2	2.53	0.2	2.55	0.2

Abs refers to the calculated flood level in m AHD.

Rel refers to the change in flood level (in m) between the 'no climate change' scenario and the 'climate change' scenario.

Table 19: Existing Flood Levels and Location Description shown in Tables 16 to 18

Location ID	Location Description	PMF	1% AEP	5% AEP	20% AEP
143	18 Monash Avenue	3.16	2.37	2.27	2.13
152	Monash Ave	3.22	2.39	2.27	2.13
153	Bridge 1 (Monash Ave)	3.43	2.43	2.30	2.16
154	Diggers Crescent	3.40	2.43	2.30	2.16
155	38 Monash Avenue	4.12	2.67	2.45	2.30
156	Northern End of Diggers Crescent	3.04	2.35	2.25	2.11
157	Outlet of Creek, Northern end of Beach	2.54	2.16	2.08	1.98
158	Northern End of Swamp	2.84	2.32	2.23	2.09
159	North of 1 Ross Smith Parade	2.90	2.34	2.24	2.11
160	Middle of Swamp, rear 3 Ross Smith Parade	2.98	2.35	2.25	2.11
2	Electricity Sub-station, Monash Avenue	3.05	2.37	2.26	2.12
20	Stream Channel, near 69 Monash Ave	4.50	2.94	2.66	2.50
30	Bridge 3, Downstream	4.15	2.74	2.52	2.39
40	Stream Channel, near 61 Monash Ave	3.92	2.58	2.40	2.25
50	Stream Channel, near 53 Monash Ave	3.57	2.47	2.33	2.19
60	Stream Channel, at 26 Monash Ave	3.37	2.41	2.29	2.15
70	Stream Channel, at 20 Monash Ave	3.17	2.38	2.27	2.13
80	Stream Channel, at 14 Monash Ave	3.09	2.36	2.26	2.12
90	Stream Channel, rear of 24 Diggers Cres.	3.05	2.36	2.26	2.12
100	Stream Channel, rear of 26 Diggers Cres.	3.03	2.35	2.25	2.11
110	Stream Channel, 20m North of 28 Diggers Cres	2.99	2.35	2.25	2.11
120	Stream Channel, 80m North of 28 Diggers Cres.	2.99	2.35	2.25	2.11
130	Stream Channel, 120m North of Diggers Cres.	2.98	2.35	2.25	2.11
140	End of 1D Channel section	2.88	2.33	2.24	2.10

9.5.2. Building Floor Levels

Figure 12 provides a graph of building floor levels versus height and the design flood levels for Runs 2, 3 and 4 at Chainage 700 m (near ID 70 — refer Table 19 and Figure 3 and typical of the lower area near the lagoon). This information is also provided in Table 20.

Table 20: Building Floors Inundated

		20% AEP		5% AEP		1% AEP		PMF	
		Number	Change	Number	Change	Number	Change	Number	Change
Scenario	**Existing**					**1**			
Low	Run 1*					3*	2*		
Medium	Run 1*					12*	11*		
High	Run 1*					24*	23*		
Scenario	**Existing**	**14**		**18**		**22**		**59**	
Low	Run 2	14	0			23	1	59	0
	Run 3	14	0			24	2	60	1
	Run 4	15	1	21	3	27	5	60	1
	Run 5_Fall	12	-2			23	1		
	Run 5_Rise	21	7			31	9		
Medium	Run 2	15	1			25	3	59	0
	Run 3	16	2			32	10	60	1
	Run 4	18	4			34	12	60	1
	Run 5_Fall	15	1			33	11		
	Run 5_Rise	21	7			35	13		
High	Run 2	22	8			33	11	59	0
	Run 3	18	4			35	13	61	2
	Run 4	24	10			37	15	61	2
	Run 5_Fall	24	10			37	15		
	Run 5_Rise	25	11			38	16		

Notes:

* Value used to calculate change was the existing ocean level with no rainfall.
Rise and Fall refers to the raising and lowering of the beach berm by 0.2 m for Run 5.

9.5.3. Design Flood Profiles

Design flood profiles for the 20%, 1% AEP and PMF events for Existing conditions together with the 1% AEP Run 2, Run 3 and Run 4 High rise results are shown on Figure 12 along with the building floor levels. It is noted (Figure 5) that the majority of the building floors are between 500 m and 800 m upstream of the mouth (i.e. where the flood profiles are largely flat).

The results indicate that for a 0.91 m rise in ocean level (Run 2) the 1% AEP flood level increases by less than 0.2 m adjacent to the houses. Run 3 (30% increase in rainfall) produces a similar rise in flood level around Chainage 700 m but differs elsewhere.

Run 4 reflects the combination of Run 2 and Run 3 but only produces less than a 0.3 m rise in the 1% AEP flood level at Chainage 700 m.

9.5.4. Flood Extents – Ocean Inundation

Figure 13 shows the change in extent of inundation for various ocean/sea level rises assuming nil runoff from the catchment. This shows that there is little change in the lateral extent of inundation due to the relatively steep sides to the floodplain.

9.6. Discussion

9.6.1. Run 1

Run 1 assumes a rise in design ocean level with no runoff from the catchment (i.e a 1% AEP ocean rainfall but no rainfall).

Table 20 indicates that for the 1% AEP event a low, medium and high ocean level rise (no rainfall) causes an additional 2, 11 and 23 building floors to be inundated compared to the existing 1.5m AHD 1% AEP ocean level.

Figure 13 provides a comparison between the 1% AEP flood extents for the Run 1 scenarios (no rainfall) and the existing flood extent (no rainfall). The figure indicates that there is little change in the extent of inundation between the Run 1 scenarios. This occurs as a result of the relatively steep slopes at the perimeter of the floodplain.

A key assumption of this scenario is that the peak water level within Great Mackerel Beach is the same as the assumed ocean level. This therefore assumes no restriction at the mouth of the creek to prevent the peak level in the lagoon equalising with the peak ocean level.

9.6.2. Run 2

Run 2 assumes a rise in ocean level for the existing design flood scenario but no increase in design rainfalls.

<u>Run 2 - Low rise</u> (Table 16) indicates no increase in flood level for the 20% AEP, 1% AEP or the PMF. This is to be expected as the design flood level within the residential area of Great Mackerel Beach is much greater than the ocean level.

<u>Run 2 - Medium rise</u> (Table 17) produces approximately a 0.1 m rise for the 20% and 1% AEP events. For the PMF there is no increase as the PMF flood level in the residential area is dominated by the magnitude of runoff in the creek rather than ocean level. This relatively small increase in flood level results in an increase in the number of building floors inundated of 1 and 3 in the 20% and 1% AEP events respectively (Table 20) and 1 in the PMF.

<u>Run 2 - High rise</u> (Table 18) produces a maximum increase of 0.3 m in the 20% and 1% AEP events but only 0.1 m in the PMF. Thus the effect of a 0.91 m ocean level rise is significantly reduced within the residential area. The increase in flood levels results in 8 and 11 additional building floors inundated (Table 20) in the 20% and 1% AEP events respectively.

9.6.3. Run 3

Run 3 assumes no ocean level rise but a 10%, 20% and 30% increase in design rainfalls.

Run 3 - Low rise (Table 16) produces a maximum increase of 0.1 m for the 20%, 1% AEP and PMF.

Run 3 - Medium rise (Table 17) produces a maximum increase in flood level of 0.1 m, 0.2 m and 0.3 m for the 20%, 1% AEP and PMF events respectively. The increase in flood levels (Table 20) results in 2 and 10 additional building floors inundated in the 20% and 1% AEP events respectively.

Run 3 - High rise (Table 18) produces a maximum increase of 0.2 m, 0.3 m and 0.4 m for the 20%, 1% AEP and PMF events respectively. The increase in flood levels (Table 20) results in 4 and 13 additional building floors inundated in the 20% and 1% AEP events respectively.

9.6.4. Run 4

Run 4 assumes an ocean level rise as well an increase in rainfall.

The results for Run 4 - Low rise (Table 16) indicates similar results to Run 3 - Low rise.

Run 4 - Medium rise (Table 17) also indicates a similar increase in flood level as Run 3 _ Medium rise. In the 20% and 1% AEP events 4 and 12 additional building floors are inundated.

Run 4 - High rise (Table 18) indicate an increase in flood level of up to 0.3 m, 0.3 m and 0.4 m for the 20% AEP, 1% AEP and PMF events respectively. In the 20% and 1% AEP events 10 and 15 additional building floors are inundated (6 and 2 more than for the respective Run 3 - High rise scenario).

9.6.5. Run 5

Run 5 simulates the effect of a possible change in the beach berm level (by ±0.2 m), as a result of climate change, assuming Run 4 (increase in ocean level and rainfall) conditions. It should be noted that lowering the beach berm does not necessarily lower the flood levels upstream as lowering the berm means that there is greater opportunity for an elevated ocean level to enter the upstream area.

Run 5 - Low rise (Table 16) indicates that for the 20% AEP, lowering the berm by 0.2 m reduces flood levels by up to -0.1 m compared to existing conditions (even with a 10% increase in rainfall and 0.18 m ocean level rise). Raising the berm by 0.2 m for the 20% AEP increases flood levels by up to 0.2 m compared to existing conditions and by up to 0.1 m compared to Run 4 - Low rise.

Run 5 - Low rise (Table 16) indicates that for the 1% AEP event lowering the berm by 0.2 m produces a maximum 0.1 m increase in flood level whilst raising the berm by 0.2 m produces a similar 0.1 m increase except that the increase is at every location rather than at only 5 locations for the 0.2 m berm lowering.

In summary lowering the berm by 0.2 m largely negates the impacts of Run 4 - Low rise (ocean level and rainfall increase).

Run 5 - Medium rise (Table 17) indicates that lowering the berm by 0.2 m raises the flood levels by up to 0.1 m and 0.2 m in the 20% and 1% AEP events respectively. Raising the berm by 0.2 m raises the flood levels by up to 0.2 m for both events.

Run 5 - High rise (Table 18) indicates a maximum 0.3 m increase in flood levels for both raising and lowering for the 20% and 1% AEP events.

In summary the raising or lowering of the berm for the High Scenario - Run 5 compared to Run 4 (same ocean and rainfall increase) produces little change in flood level within the residential area.

9.7. Adaptation Strategies

9.7.1. New Design Flood Levels

Flood Planning Levels (FPLs) at Great Mackerel Beach are based on the 1% AEP flood level plus a 0.5 m freeboard (to account for local wave action (as opposed to wave activity in The Pittwater Estuary waterbody), errors in calculation and some climate change allowance). An increase in design flood levels due to either an ocean level rise, rainfall increase or other action (beach berm change), as a result of climate change, is recommended to be incorporated into the FPL.

To do this Council must firstly determine the magnitude of the increase and the timeframe over which it may occur (it may be non_ linear). The timeframe is important to account for the life span of the proposed works requiring the FPL (it is noted that Pittwater DCP 21 requires all structures to have a 100 year design life). At this time there are no definitive answers to the above from the worlds' experts.

The NSW Sea Level Rise Policy Statement (October 2009) identifies sea level rise benchmarks that Councils need to consider for planning purposes, namely 0.4m by 2050 and 0.9m by 2100. Pittwater Council adopted the use of these benchmarks in December 2009. The Sea Level Rise Policy Statement does not provide similar guidance for increased rainfall intensities. The best available guidance for increased rainfall intensities are from the 2007 DECC Guideline, namely the low (10% increase), medium (20% increase) and high (30% increase) scenarios modelled as part of this study. In February 2110, Pittwater Council adopted these low, medium and high increases in rainfall intensities to be considered in all flood risk management studies. However, no timeframe is provided in the 2007 DECC Guideline for changes in these rainfall intensities.

Using a combination of the Sea Level Rise Policy Statement, the 2007 DECC guideline (both of which have been adopted by Council), together with the scenarios that have been assessed as part of this study, Table 21 provides a timetable of possible climate change scenarios that could be considered for Great Mackerel Beach from now until 2100. It should be noted that the timetable has not been adopted by Council at this stage and climate change impacts will continue to occur past 2100.:

Table 21: Recommended Climate Change Scenarios

Approximate Timeframe	Approximate Year	Ocean Level Rise	Rainfall Increase	Model Run	Increase in Number of Floors inundated 1%AEP event
20 years	2030	0.2m	nil	Run 2 Low	1
20 years	2030	0.2m	10%	Run 4 Low	can be calculated
40 years	2050	0.4m*	say 15%	not modelled	not calculated
55 years	2065	0.55m	20%	Run 4 Medium	can be calculated
90 years	2100	0.9m	30%	Run 4 High	can be calculated

* NSW Sea Level Rise Policy Statement benchmark
Note: assume linear increase between years shown

Thus for a project with a life span of say 75 years (to year 2085) the expected ocean level rise would be 0.75 m and the rainfall increase of about 25%. At this time no account has been taken of a possible change in the beach berm level.

As there is an assumed climate change allowance within the 0.5 m freeboard, it can be argued that for a structure with a design life of 20 years, no additional increase in FPL should be applied as the 0.2 m ocean level rise is accounted for in the existing freeboard.

Figure 12 and Table 18 indicate that even for the 1% AEP - Run 4 - High scenario the resulting change in flood level (and resulting FPL) is a maximum of 0.3 m within the residential area.

Therefore it is recommended that the values of 1% AEP – Run 4 – High be adopted to be used to determine new Flood Planning Levels for Great Mackerel Beach, and that Flood Mapping and Council's web-based data base be updated accordingly. It should also be noted that, in accordance with the Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments (August 2010 – Reference 18), new values for other flood events, including the probable maximum flood, will also need to be recalculated to incorporate the Run 4 – High climate change scenarios.

Pittwater Council has adopted that for all future development that involves intensification of development, the 2100 climate change scenario (namely a 0.9m increase in ocean level and an increase in rainfall intensity of 30%) shall be considered. (development that does not involve intensification of development, such as single dwellings, may be required to consider climate change in the future). However, new design flood levels and hence new Flood Planning Levels have not been adopted for any floodplain at this stage. If new Flood Planning Levels are to be adopted for Great Mackerel Beach, then this will be the first floodplain in Pittwater to apply such levels that include the 2100 climate change scenario. On advice from Council, it is understood that Flood Planning Levels that include the 2100 climate change scenario will be progressively adopted for other floodplains in Pittwater as the studies are completed.

Therefore it is recommended that new Flood Planning Levels be adopted for Great Mackerel Beach that include the 2100 Climate Change Scenario of 0.9m sea level rise and 30% increase in rainfall intensity. This will include an update of Council's Flood Risk Database and Flood Mapping used to inform the Pittwater 21 Development Control Plan as well as Section 149(2) and Section 149(5) Planning Certificates. This will also involve a review of Council's Flood Risk Management Policy and associated flood-related development controls.

9.7.2. Review of Studies

Usually Flood Studies, Floodplain Risk Management Studies and Plans are reviewed around every five years. This will enable Council to update the studies (if required) as soon as new trends in climate change are identified.

9.7.3. Long Term Viability of Great Mackerel Beach Community

Climate change (particularly ocean level rise) has the potential to affect the long term viability of the community. As noted on Figure 3 a large part of the residential land north of Monash Avenue and east of Diggers Crescent is below 1.75m AHD.

The highest tide in a year reaches approximately 1.1m AHD, thus with a 0.5 m ocean level rise (highest tide of 1.6 m) the majority of the land will be inundated by tidal inundation every year (Figure 13). If the land is not entirely inundated in such an event it will certainly affect drainage of the area. The level of climate change ocean level rise that results in making parts of the residential areas uninhabitable is dependent on the practicality of elevating some or all of the development. This will depend on the individual property owner. However if ocean level rise continues (as is expected) at some point parts of the residential area will be so frequently inundated that habitation may not be practical in its present form. Flood insurance is now available for residential properties but flood level increases due to climate change may mean that insurance companies may stop or limit the cover available.

9.7.4. Filling

One measure to reduce the flood and drainage issues due to climate change is to fill the land. The hydraulic impacts of this were investigated in Run 6, for the 1% AEP event only, for two modelling scenarios; assuming filling of the house pad on each lot only and also for filling the entire lot excluding floodway (the fill was assumed to be to an infinite height) (refer Figure 11 for extents of fill). This Run assumed the same climate change scenario as Run 2 - High rise (i.e. an ocean level increase of 0.91 m but no increase in rainfall). A comparison of results with Run 2 - High rise indicates that Run 6 increases 1% AEP flood levels by a maximum of 0.04 m if the house pads only are filled and by a maximum of 0.14 m if the entire lots are filled. It should be noted that the 0.14 m increase could be reduced by modifying the extent of fill to minimise the increase in flood level.

Filling of the floodplain is generally not a desirable floodplain management strategy for hydraulic and environmental considerations. Pittwater Council for this reason requires building construction on piers. However Great Mackerel Beach is an exception to more typical floodplain situations as there is no locally available fill or earthmoving equipment and importing fill would likely be cost prohibitive, thus piers will most likely be the preferable approach.

One concern with pier construction is that owners store goods in the "below floor" area and thus will likely suffer some extent of flood damages. Another issue that if all buildings are on piers then the long term use of the frequently tidal inundated land surrounding and under the house may mean that the land is no longer habitable. Therefore filling may the only option to 'save Great Mackerel Beach'. However, filling (outside the floodway) will have a long-term cumulative impact of increasing flood levels by 0.1m–0.15m. Whether this is acceptable to the community, given the alternative, is yet to be discussed or determined.

Filling of the house pad eliminates this concern. Filling at Great Mackerel Beach should be considered for this and the following reasons:

- the volume of material to fill the house pads only is relatively small compared to the total floodplain storage available,
- there is no or very limited potential for further development that could contribute to the cumulative impacts of filling (i.e. set a precedent for future developments),
- Run 6 demonstrates that filling of the house pad has very little impact on flood levels.

Filling will have to be considered to raise roads but the affect on local drainage needs to be analysed. It is therefore recommended that:

- short-term - filling be permitted under house pads only (outside the 1%AEP floodway, to a maximum of say 30% of the block or the existing house pad whichever is the larger) and Pittwater DCP 21 be amended accordingly,
- medium-term - further modelling be undertaken to determine the optimum extent of fill that could be accommodated at Great Mackerel Beach to assist in the long-term viability of the community. Any increase in Flood Planning Levels as a result of the filling would need to be limited to say 0.1m and the new levels and development controls would have to be incorporated in Pittwater DCP 21. The impacts of any modifications to filling patterns on local drainage would have to be carefully assessed as part of the project and be considered in relation to any other measure proposed in this study.

9.7.5. Siting of Future Infrastructure

The future development potential on vacant flood liable land within Great Mackerel Beach is very limited due to the unavailability of vacant land and the isolated locality of the community. Should any such land become available or there is a development proposal for a new private or public structure on the floodplain then the impacts of climate change must be incorporated into the design and required flood related development controls. The exact detail would depend on the nature of the proposed development. However, elevation of future development above any climate change included Flood Planning Level would be the preferred option.

10. ACKNOWLEDGMENTS

This study was carried out by WMAwater and funded by Pittwater Council and the Department of Environment, Climate Change and Water. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- Pittwater Council,
- Department of Environment, Climate Change and Water,
- Floodplain Management Committee,
- Residents of Great Mackerel Beach.

11. REFERENCES

1. **Floodplain Development Manual**
NSW Government, April 2005

2. Pittwater Council
Great Mackerel Beach Flood Study
Cardno Lawson Treloar Pty Ltd, September 2005

3. Pittwater Council
Pittwater Estuary Processes Study
Lawson and Treloar, November 2002

4. Pittwater Council
Pittwater Estuary Management Study
Cardno Lawson Treloar and WBM Oceanics Australia, 2006

5. Pittwater Council
Estuarine Planning Level Mapping, Pittwater Estuary
Lawson and Treloar, September 2004

6. **Pittwater Local Environmental Plan**
Pittwater Council, 1993

7. **Pittwater 21 Development Control Plan**
Pittwater Council, 2009

8. Pittwater Council
Newport Flood Education and Communications Plan
Molino Stewart, June 2006

9. Pittwater Council
2001 and 1996 Census Information for: Church Point-Scotland Island-West Pittwater
Pittwater Council, August 2007

10. **Fourth Assessment Report "Climate Change 2007" - Synthesis Report**
Intergovernmental Panel on Climate Change (IPCC), 2007

11. **Third Assessment Report "Climate Change 2001" - Synthesis Report**
Intergovernmental Panel on Climate Change (IPCC), 2001

12. Australian Greenhouse Office – Department of the Environment and Water Resources
Climate Change Adaptation Actions for Local Government
SMEC, 2007

13. **Climate Change in Australia – Technical Report 2007**
CSIRO, 2007

14. **Floodplain Risk Management Guideline - *Practical Consideration of Climate Change***
NSW Department of Environment and Climate Change (DECC), October 2007

15. **Hunter, Central and Lower North Coast Regional Climate Change Project 2009 – *Report 3, Climatic Change Impact for the Hunter, Lower North Coast and Central Coast Region of NSW***
Hunter & Central Coast Regional Environmental Management Strategy, 2009

16. **NSW Sea Level Rise Policy Statement**
New South Wales Government, October 2009

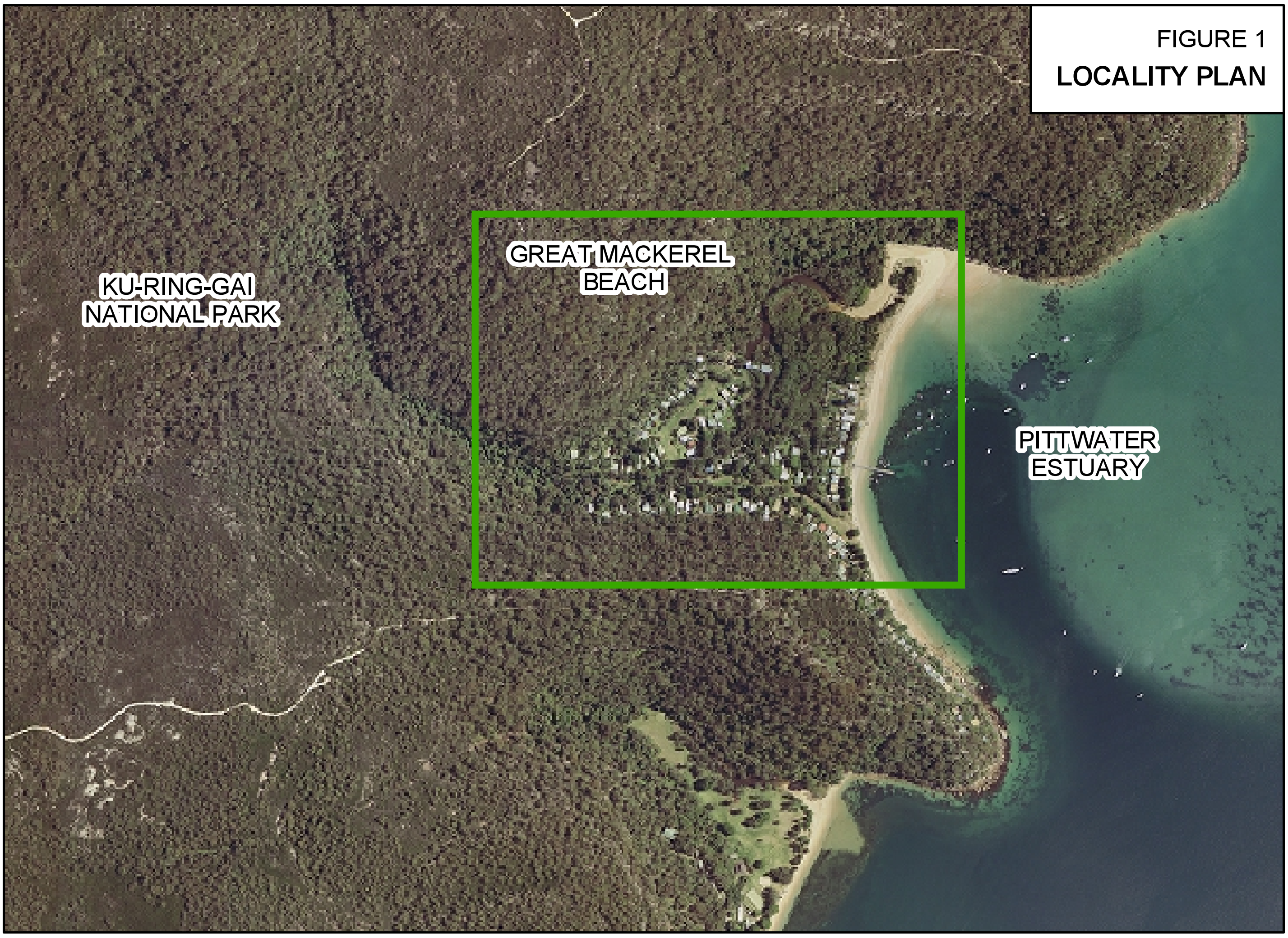
17. **NSW Coastal Planning Guideline: Adapting to Sea Level Rise**
NSW Department of Planning, August 2010

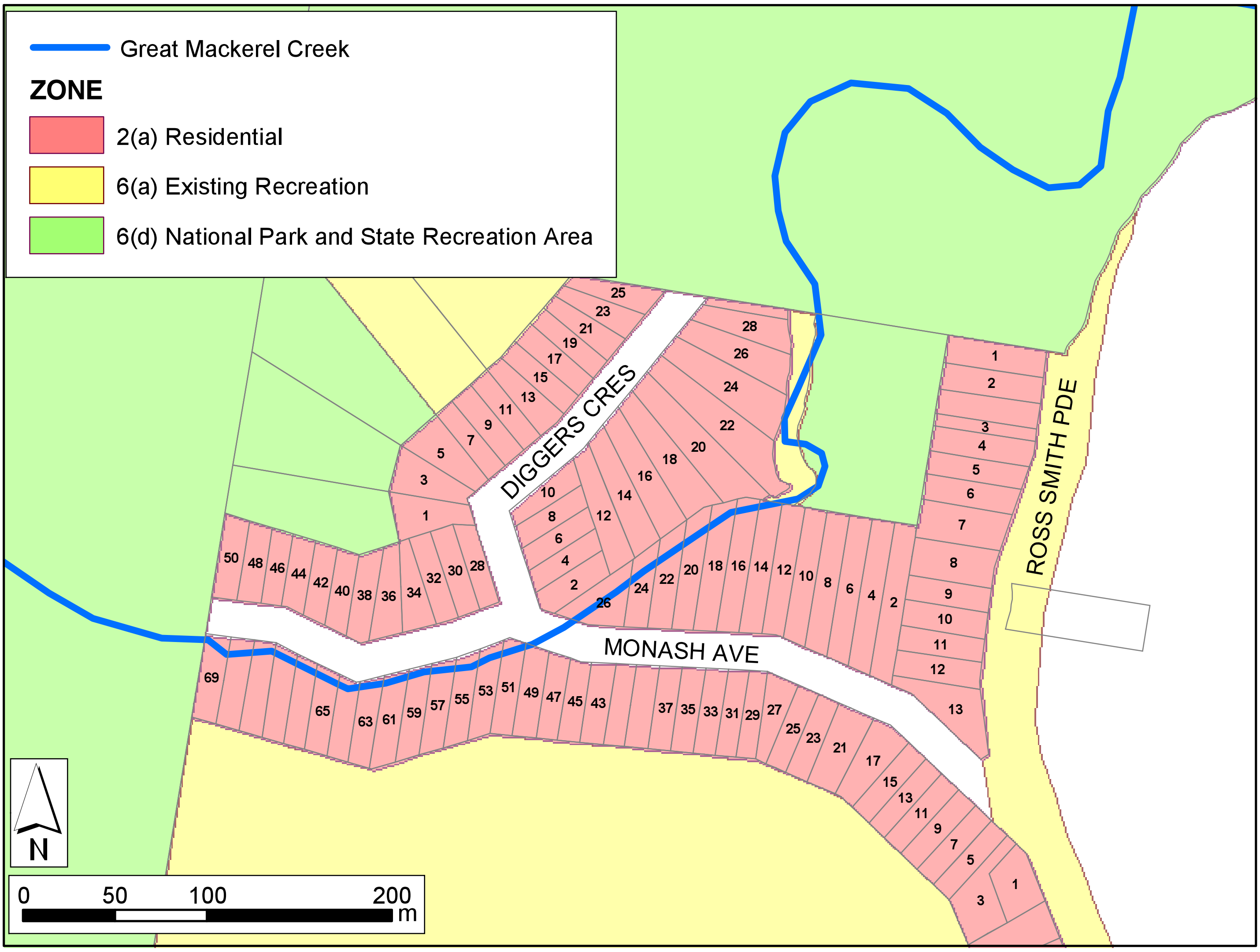
18. **Flood Risk Management Guide:** Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments
Department of Environment, Climate Change and Water NSW, August 2010

19. **Coastal Risk Management Guide:** Incorporating Sea Level Rise Benchmarks in Coastal Risk Assessments
Department of Environment, Climate Change and Water NSW, August 2010

Figures

FIGURE 1
LOCALITY PLAN





J:\Jobs\27010\ClimateChange\ArcView\ArcMaps\Figures\Figure1_LocalityPlan.mxd

FIGURE 2
HISTORICAL FLOOD PHOTOGRAPHS
NOVEMBER 1987 EVENT


36 Monash Avenue


38 Monash Avenue


65 Monash Avenue - view east


Floodwaters in house18 Monash Avenue - just after flood peak


Half way along Monash Avenue - view north


Looking at Berm


Monash Avenue - view west


Monash Avenue looking west - ankle deep


Monash Avenue


The spirit disaster can't beat

Following the devastating storm several weeks ago, which hit the tiny Pittwater village of Mackerel Beach particularly hard, residents are still struggling to get their lives back into order.

Several houses shifted from their foundations have to be rebuilt, but the owners are philosophical.

They will rebuild on higher foundations to withstand future floods.

The wife of volunteer fire brigade captain Bob Mitchell said the floods which ran shoulder-high through houses were frightening enough, but it had been a nightmare since repairing the damage.

"Fifteen of the 42 permanent residents had to be evacuated from their homes due to rising flood-waters," Christine Mitchell said.

People and dogs were saved by residents who left their belongings behind to help others.

In the last two weeks people such as the Mitchells have been trying to get their lives together.

The Mitchells found they were not insured. They let their policy lapse because money was needed for their son's optical problems.

Others were in the same boat and nearly lost everything.

As soon as news of the disaster spread, town folk who use their houses only for holidays were quick to offer accommodation, beds and clothes.

"Everyone was helping everyone. It was a great demonstration of community unity and goodwill," Richard Cornielje said.

"Many of the people weren't worrying about their own uninsured possessions because they were busy helping others.

"Even last weekend, everyone was still scrubbing, cleaning and trying to get their lives back in order. It has been a physical and mental drain on everyone."

Mr Mitchell said the floods had caused about $10 000 damage to his house and contents, but he hoped he had learnt by the experience.

The loss of carpet, a pump, refrigerator, washing machine, mattresses and shoes hurt, but he was heartened by the response shown by people under disaster conditions.

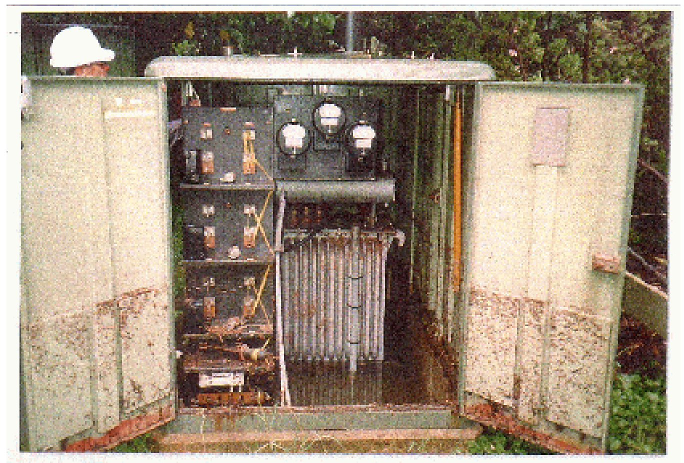
The Sydney County Council restored power under very trying conditions and workmen helped by carrying generators and filling potholes.

Most insurance claims have been settled, but some companies were "trying to wriggle out of it", Mr Mitchell said.

Seven of the residents who lost uninsured possessions are being helped by the disaster relief committee of Youth and Community Services.

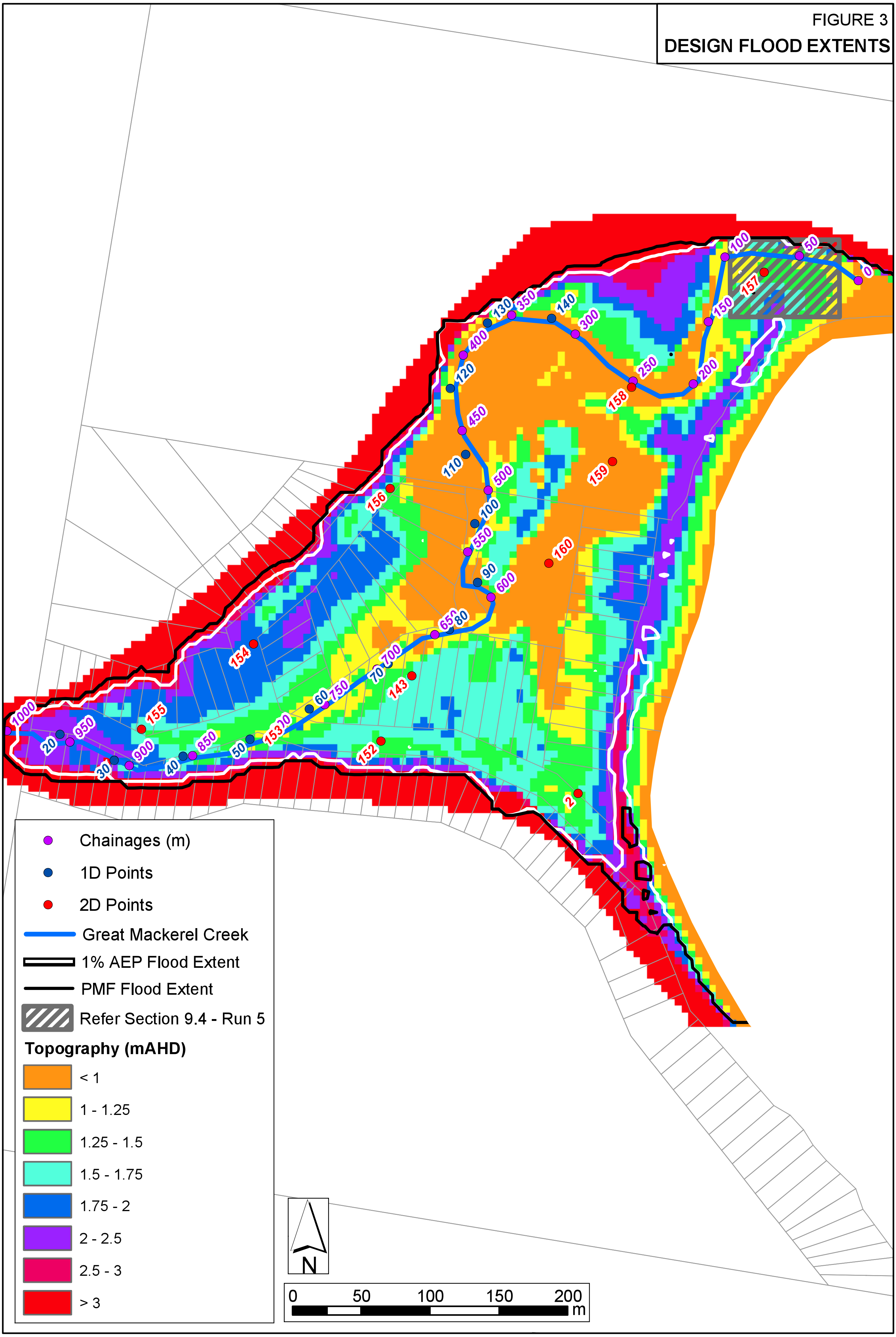
One thing shines through the adversity ... if it happens again the people of Mackerel Beach will cope.

Newspaper Item


Power box near creek

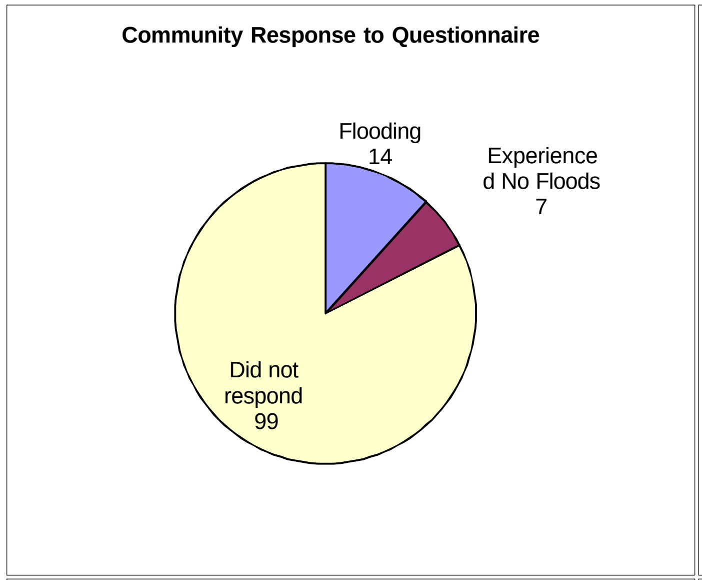

Very top of Monash Avenue - north side of road

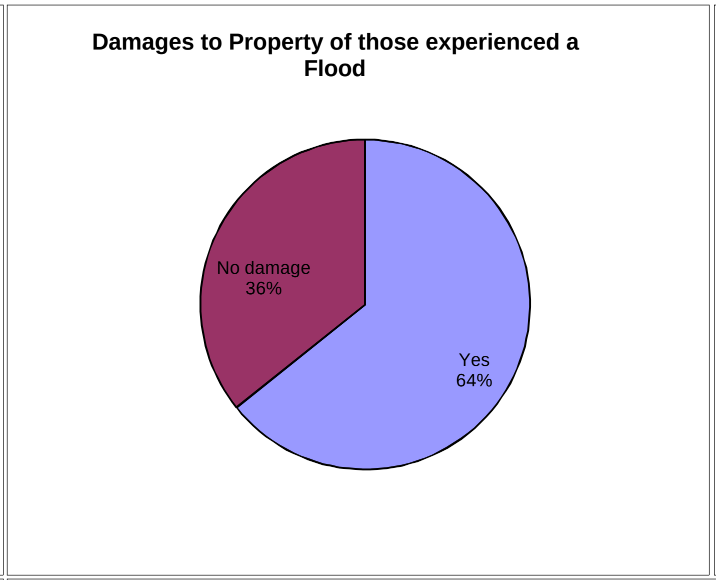
FIGURE 3
DESIGN FLOOD EXTENTS

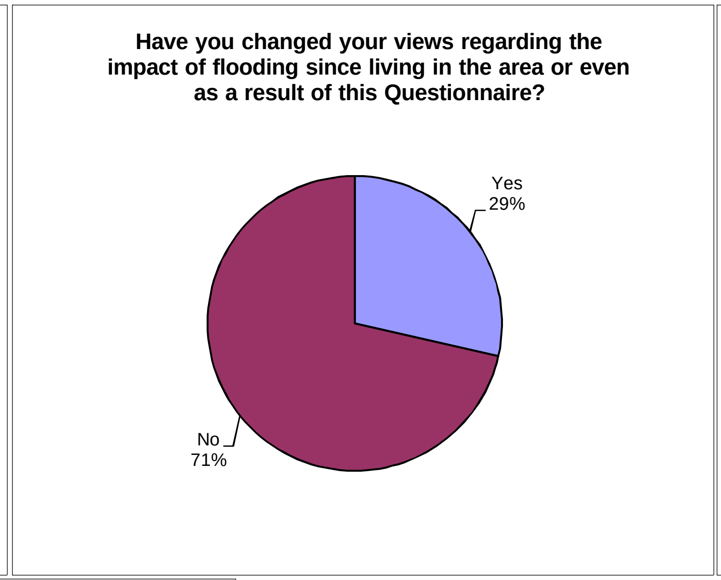


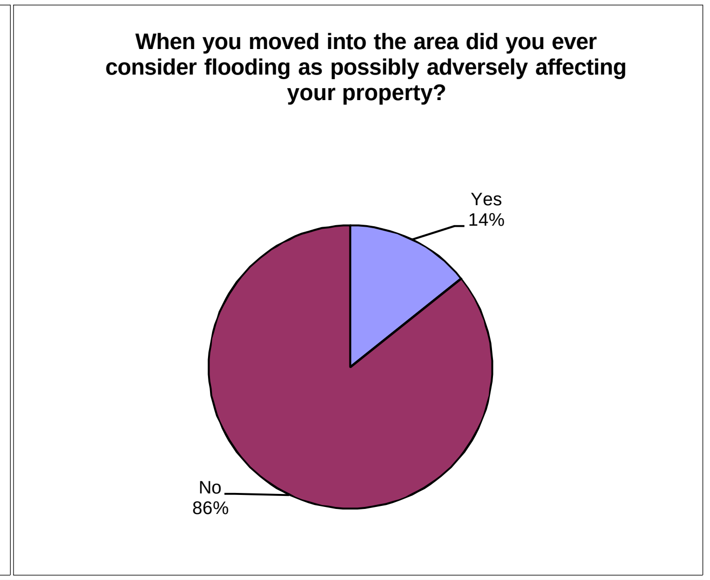
J:\Jobs\27010\ClimateChange\ArcView\ArcMaps\Figures\Figure3_DesignFloodExtents.mxd

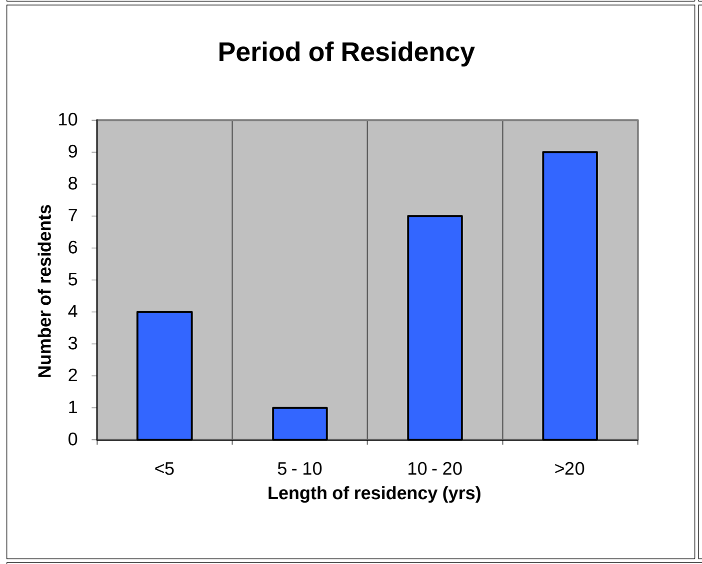
FIGURE 4
COMMUNITY CONSULTATION
RESPONSE SUMMARY

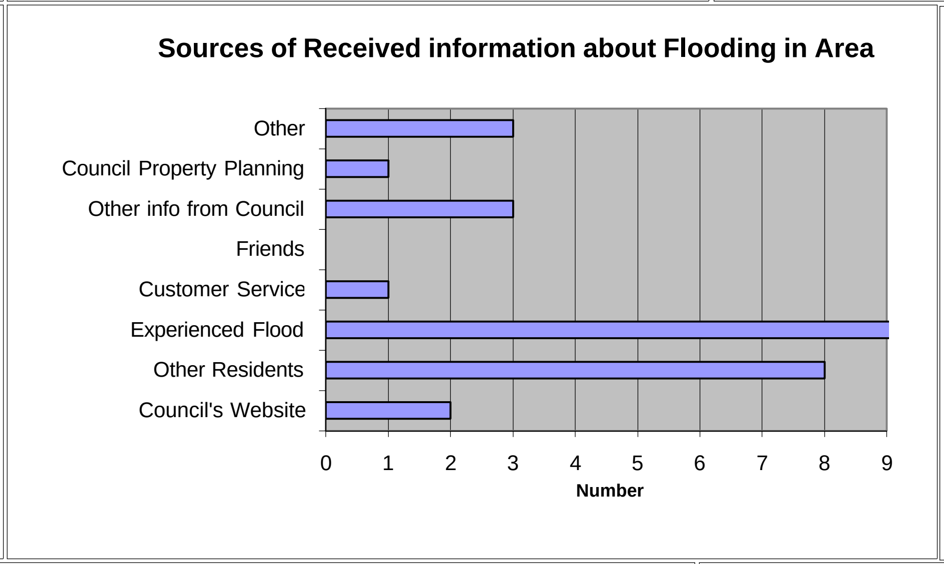


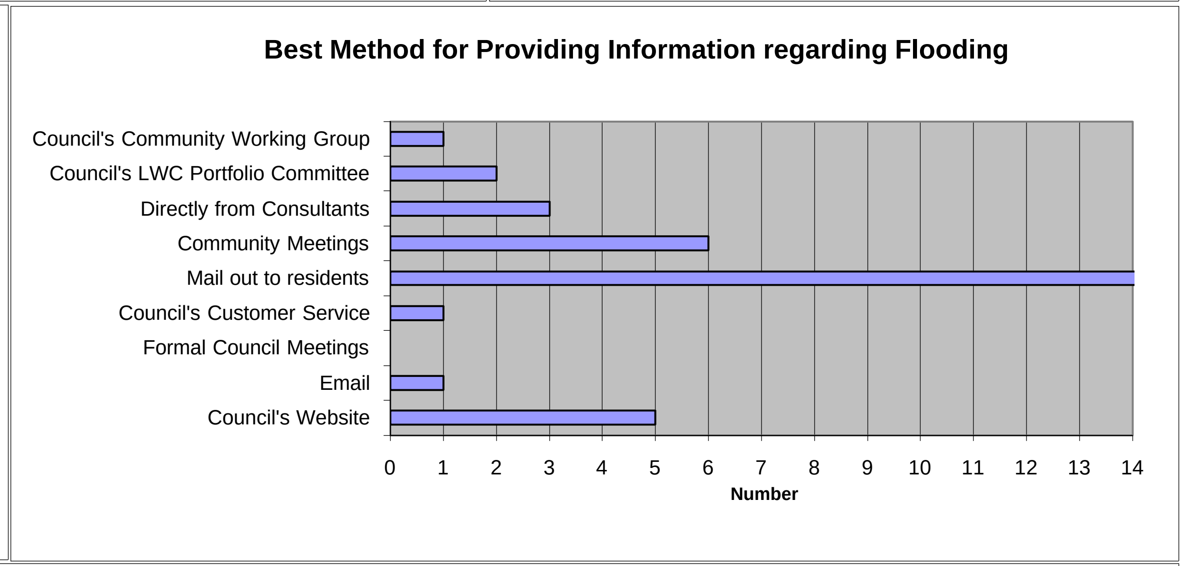


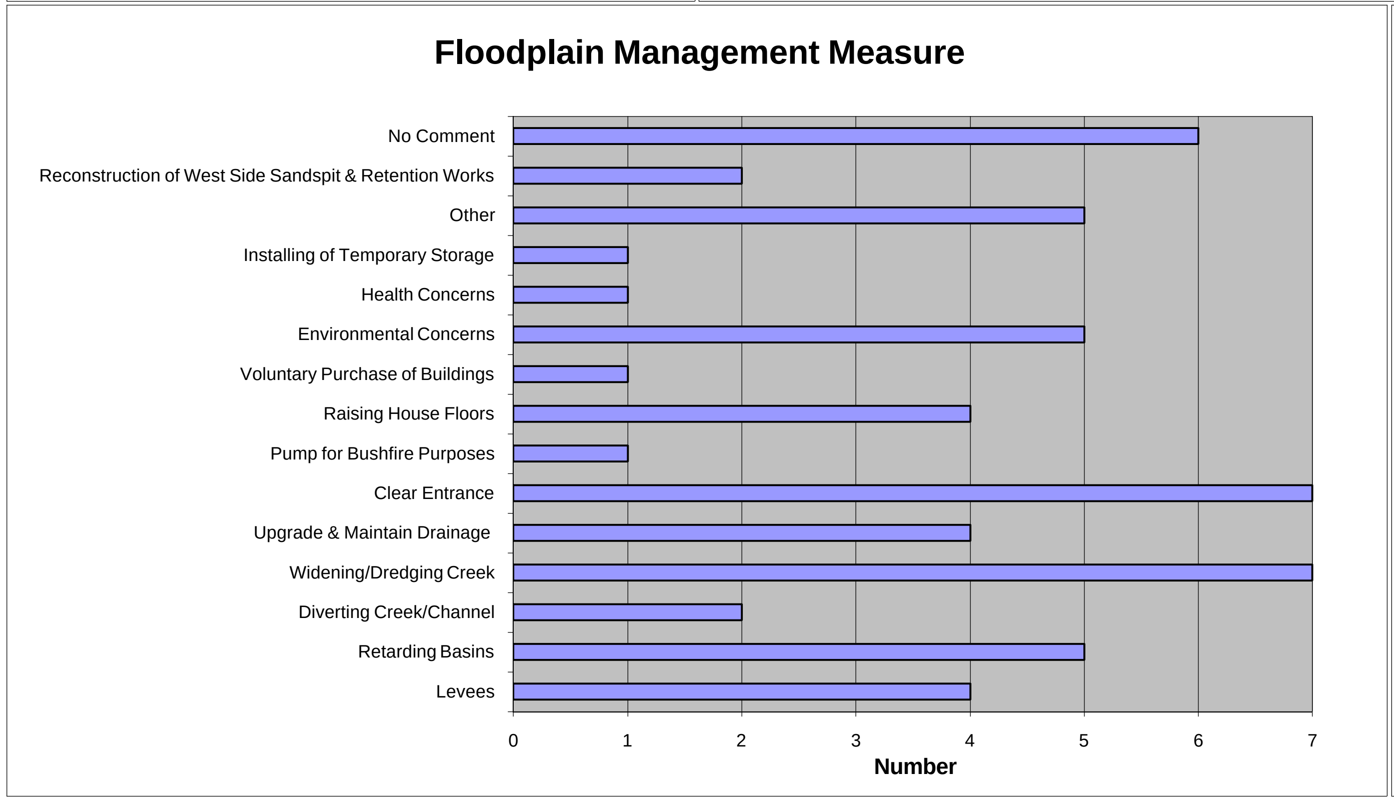












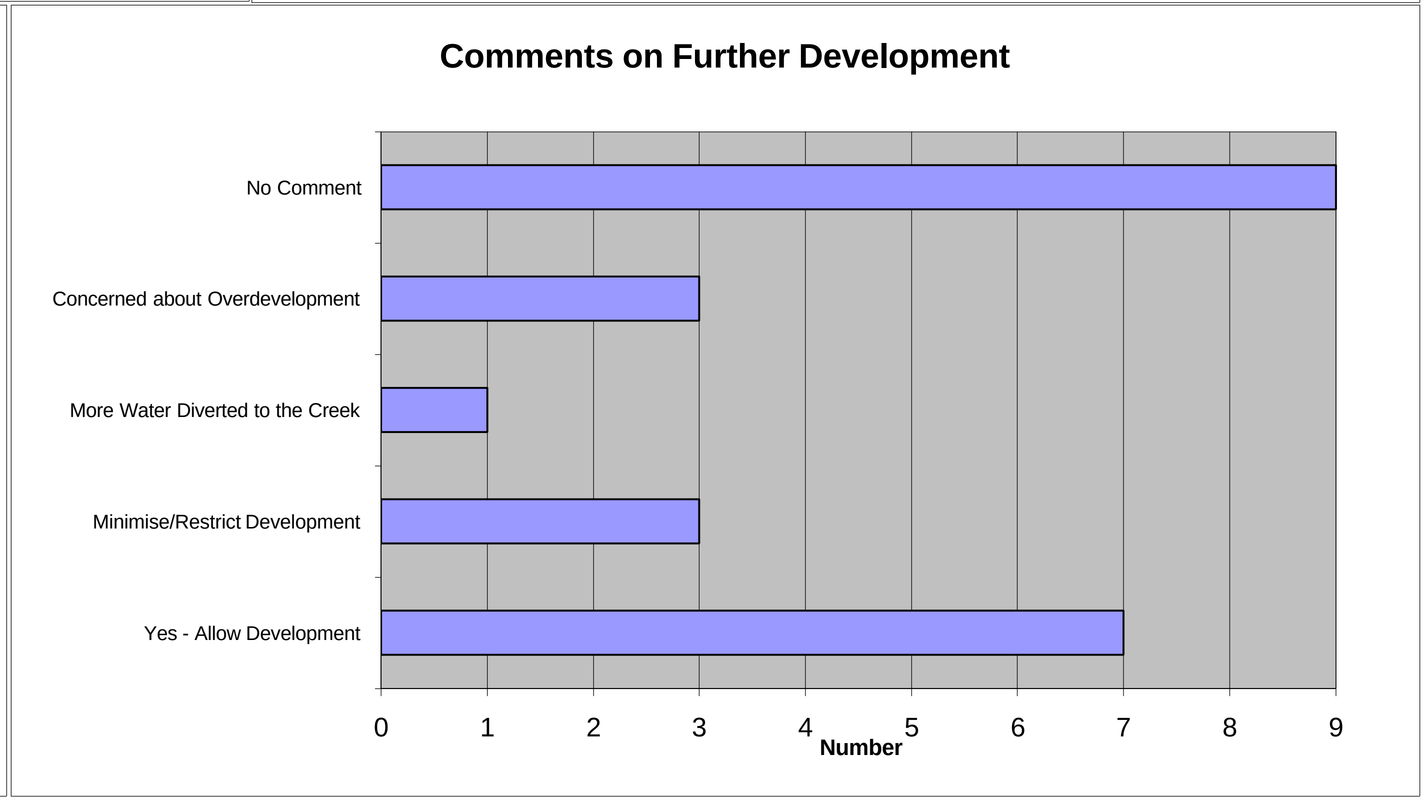
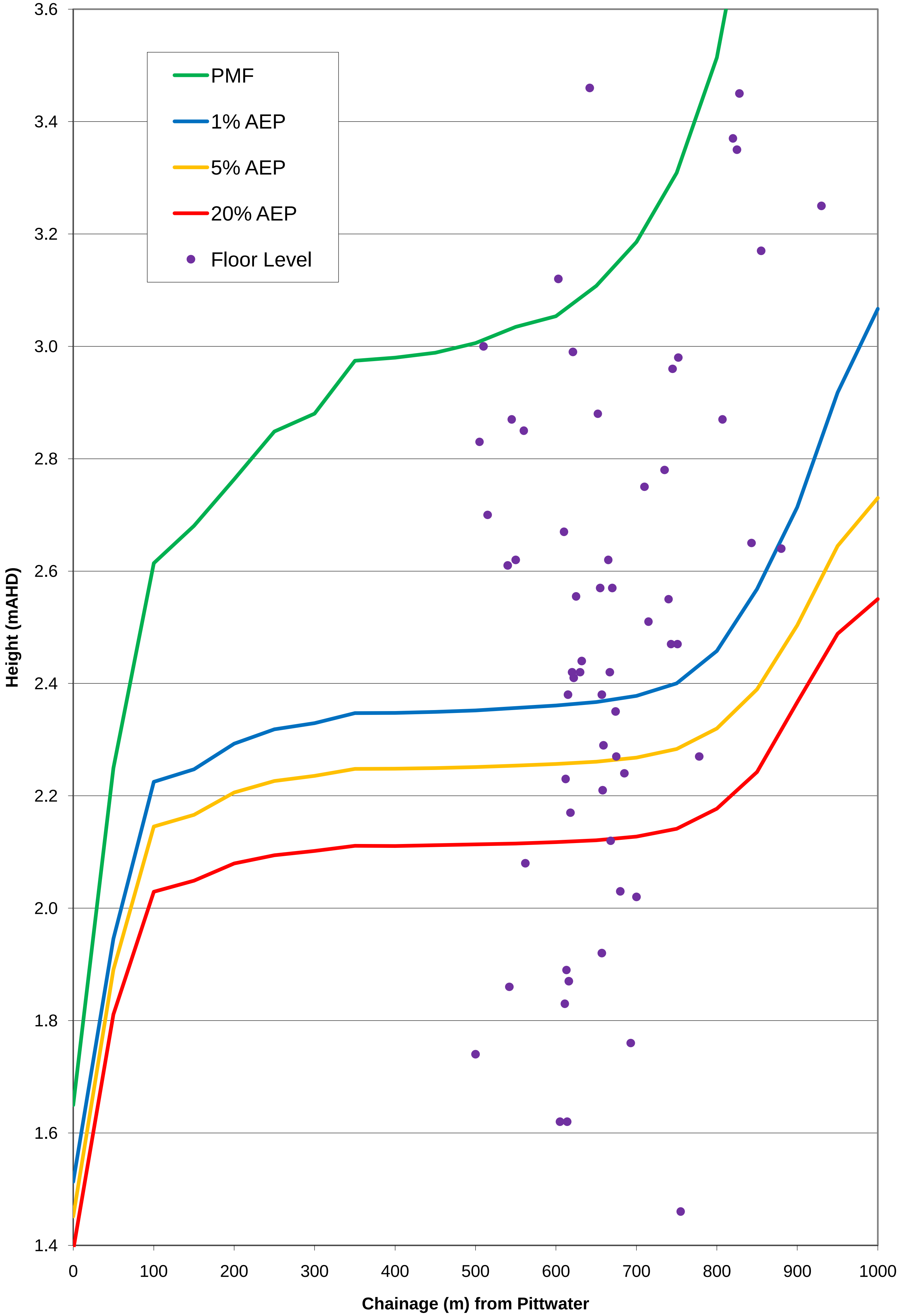


FIGURE 5
DESIGN FLOOD PROFILES



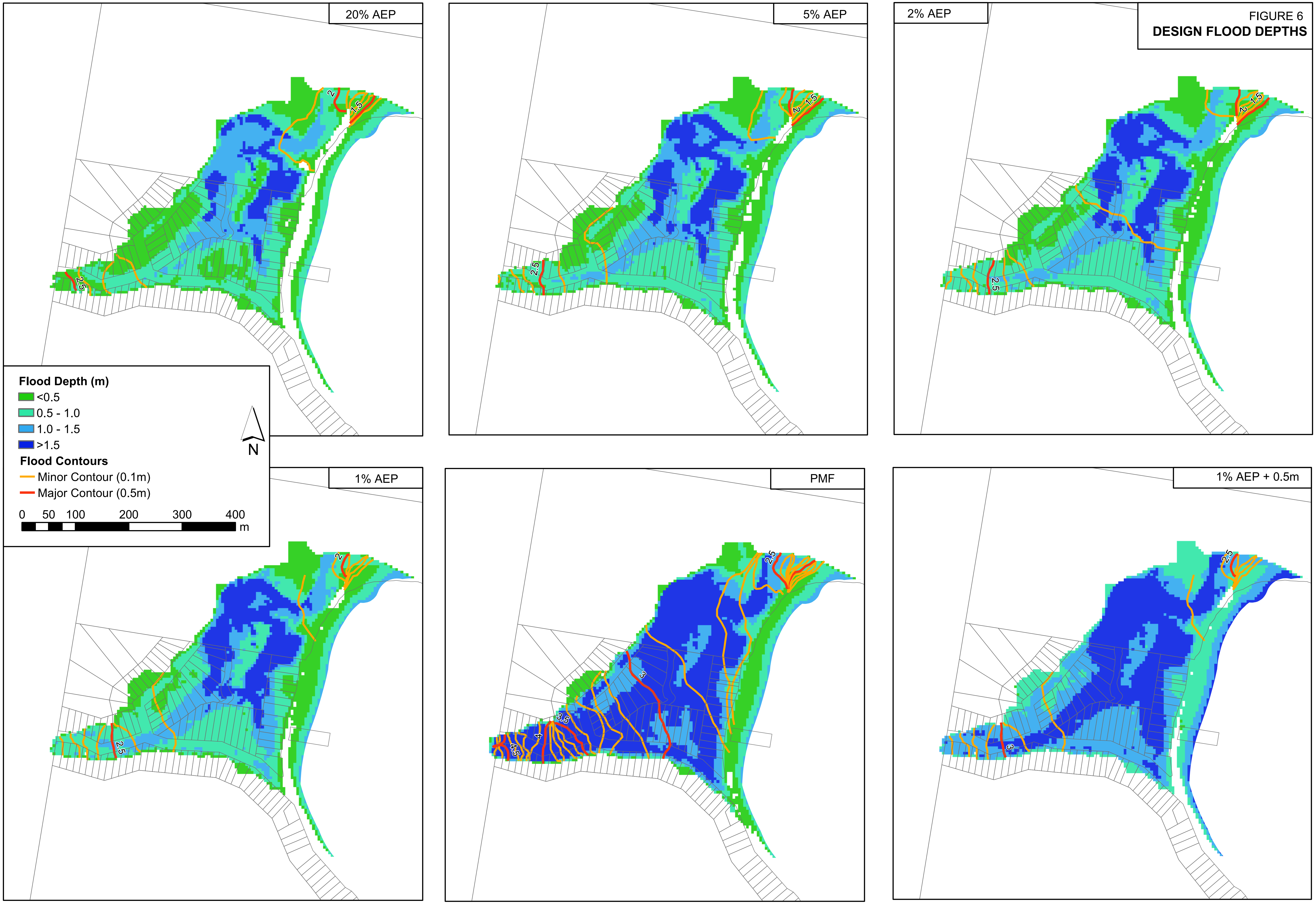
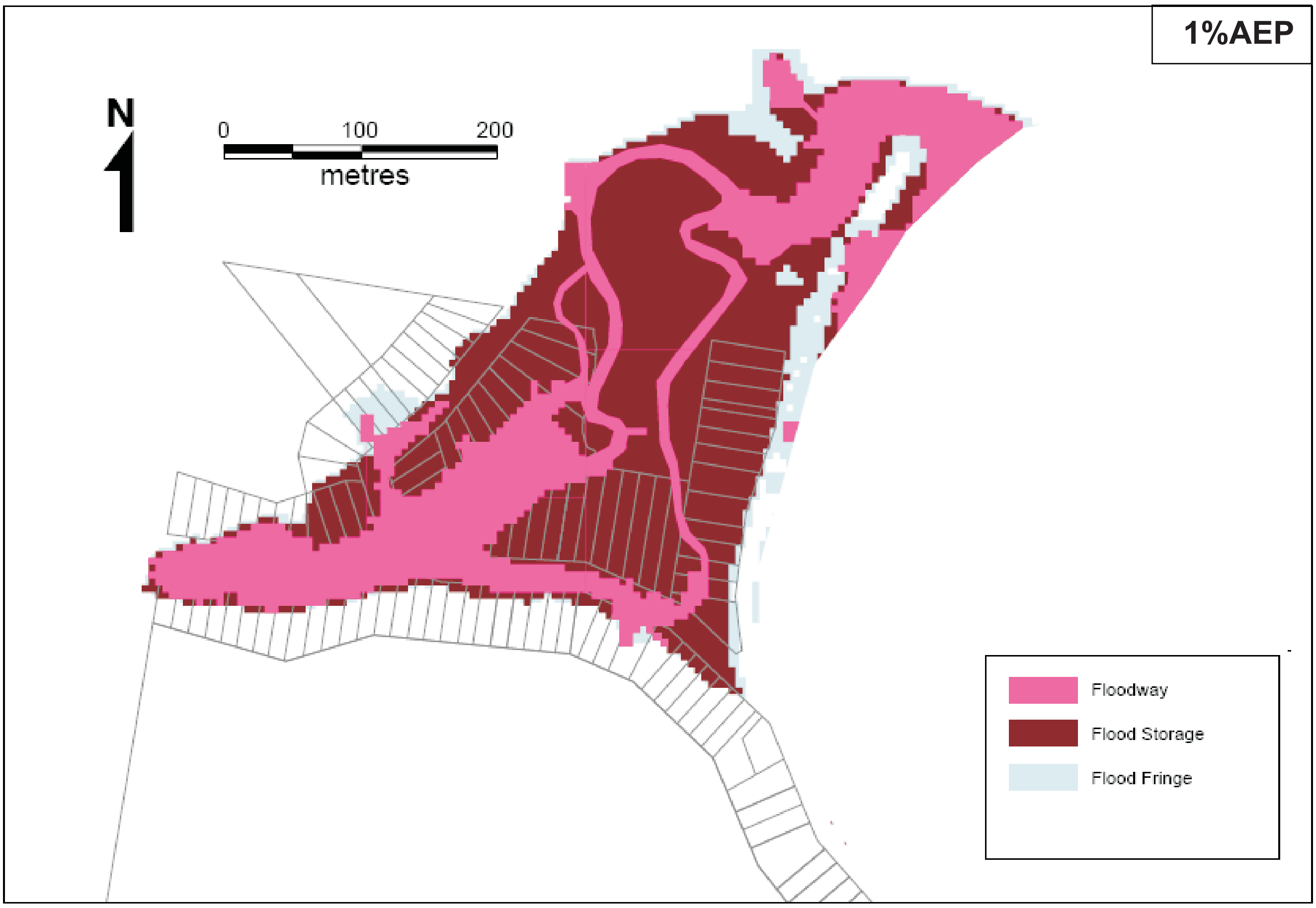
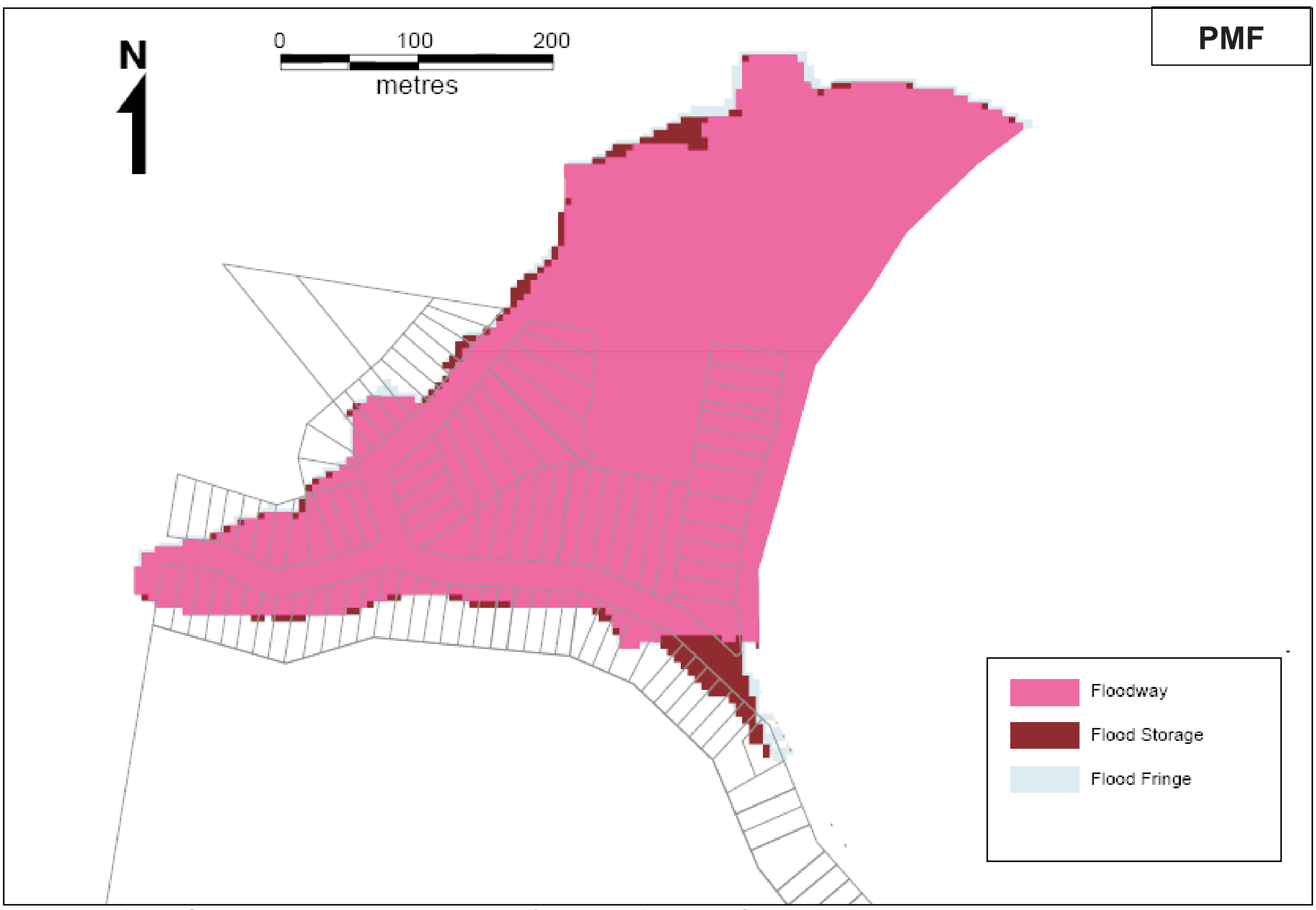


FIGURE 6
DESIGN FLOOD DEPTHS
20% AEP
5% AEP
2% AEP
1% AEP
PMF
1% AEP + 0.5m
Flood Depth (m)
<0.5
0.5 - 1.0
1.0 - 1.5
>1.5
Flood Contours
Minor Contour (0.1m)
Major Contour (0.5m)
0 50 100 200 300 400 m
N

FIGURE 7

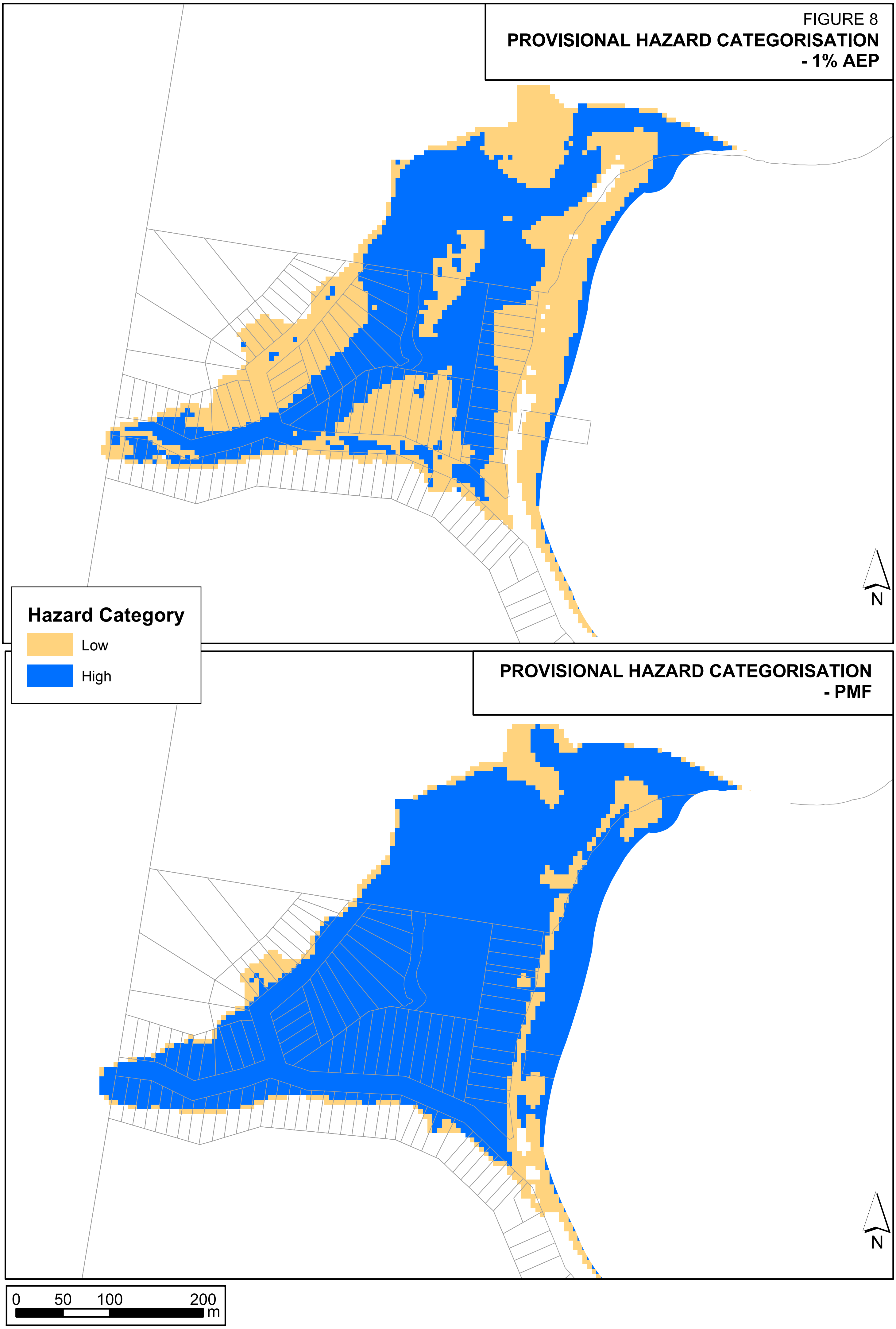
HYDRAULIC CATEGORISATION





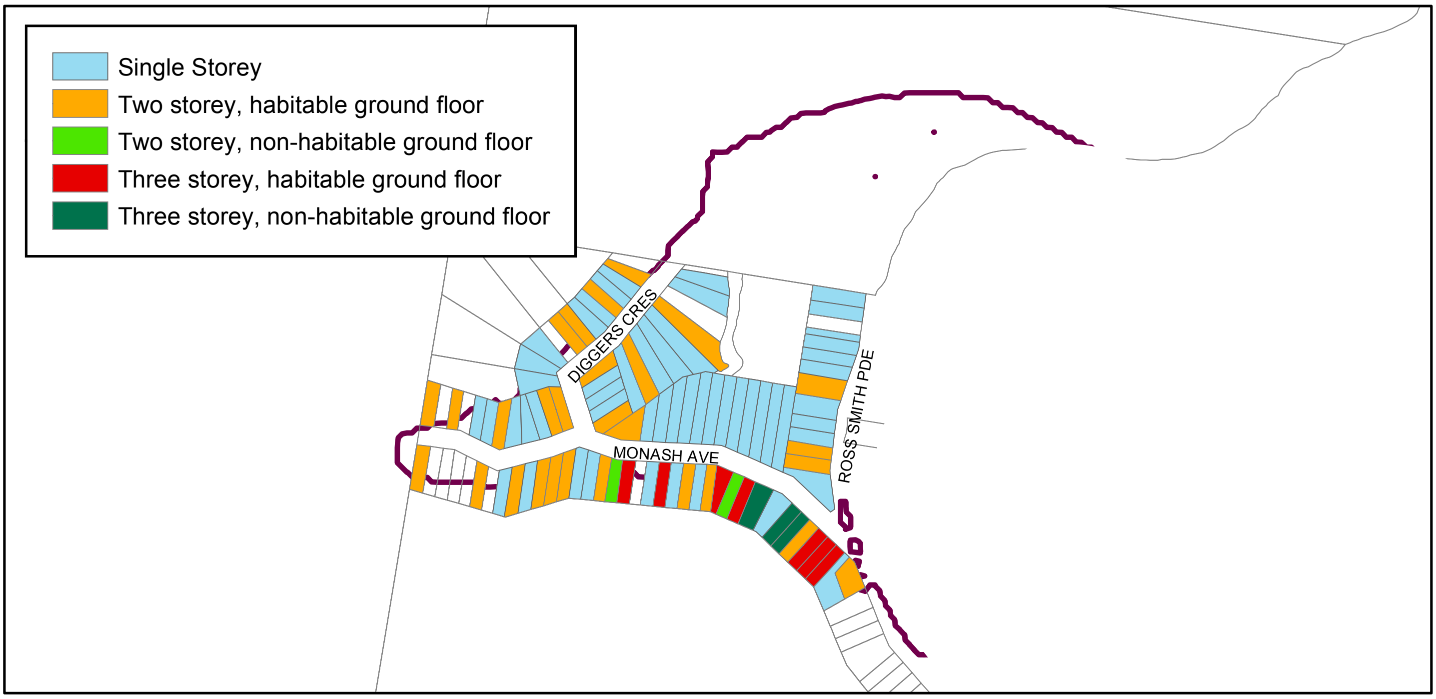
Extracted from Great Mackerel Beach Flood Study (Reference 2)

FIGURE 8



PROVISIONAL HAZARD CATEGORISATION
- 1% AEP
N
Hazard Category
Low
High
PROVISIONAL HAZARD CATEGORISATION
- PMF
N
0
50
100
200
m

FIGURE 9
PROPERTY DETAILS



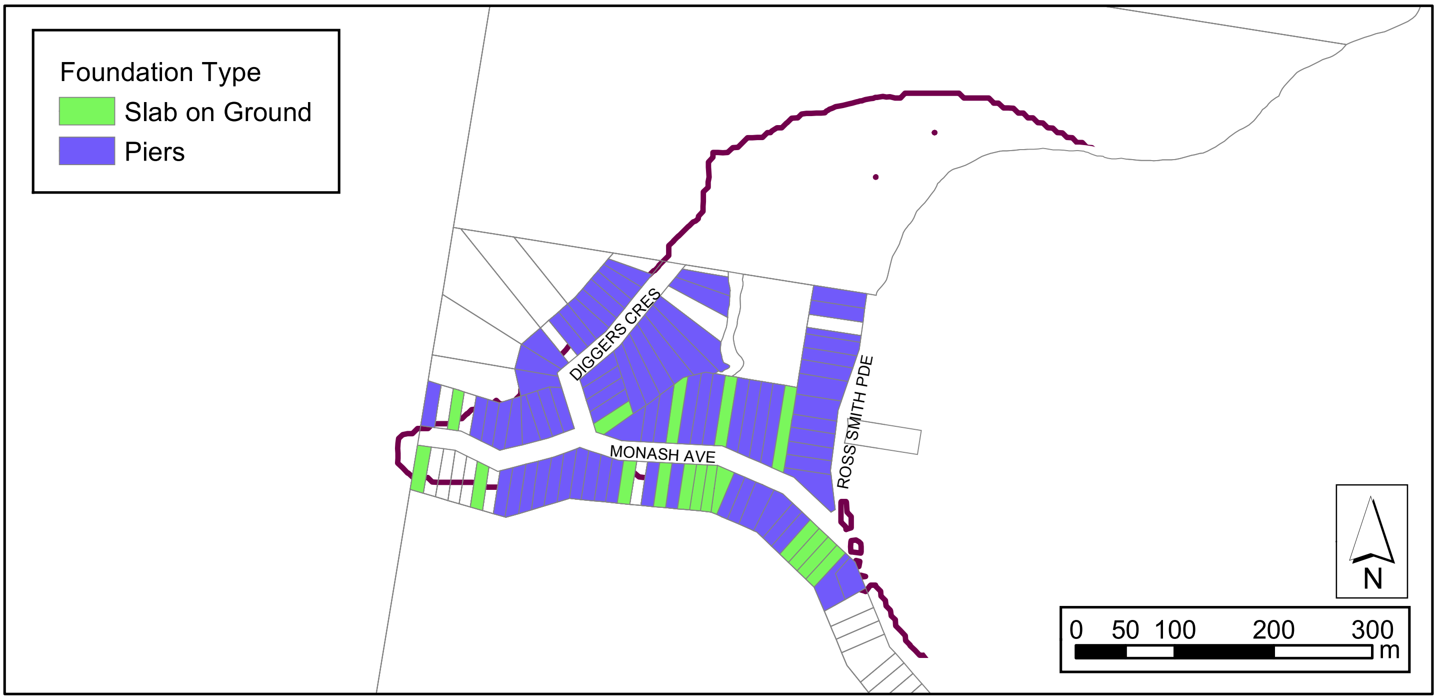
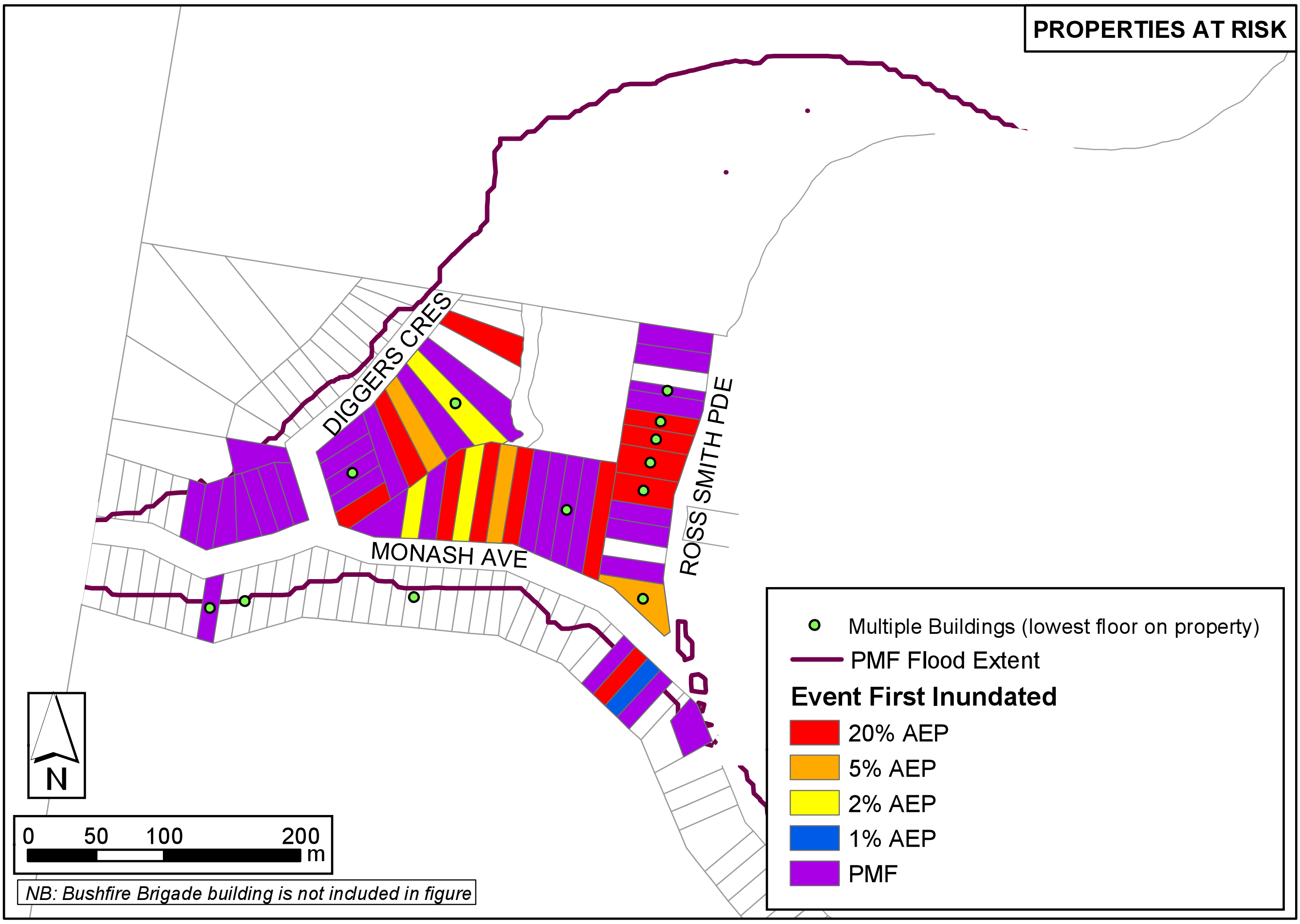
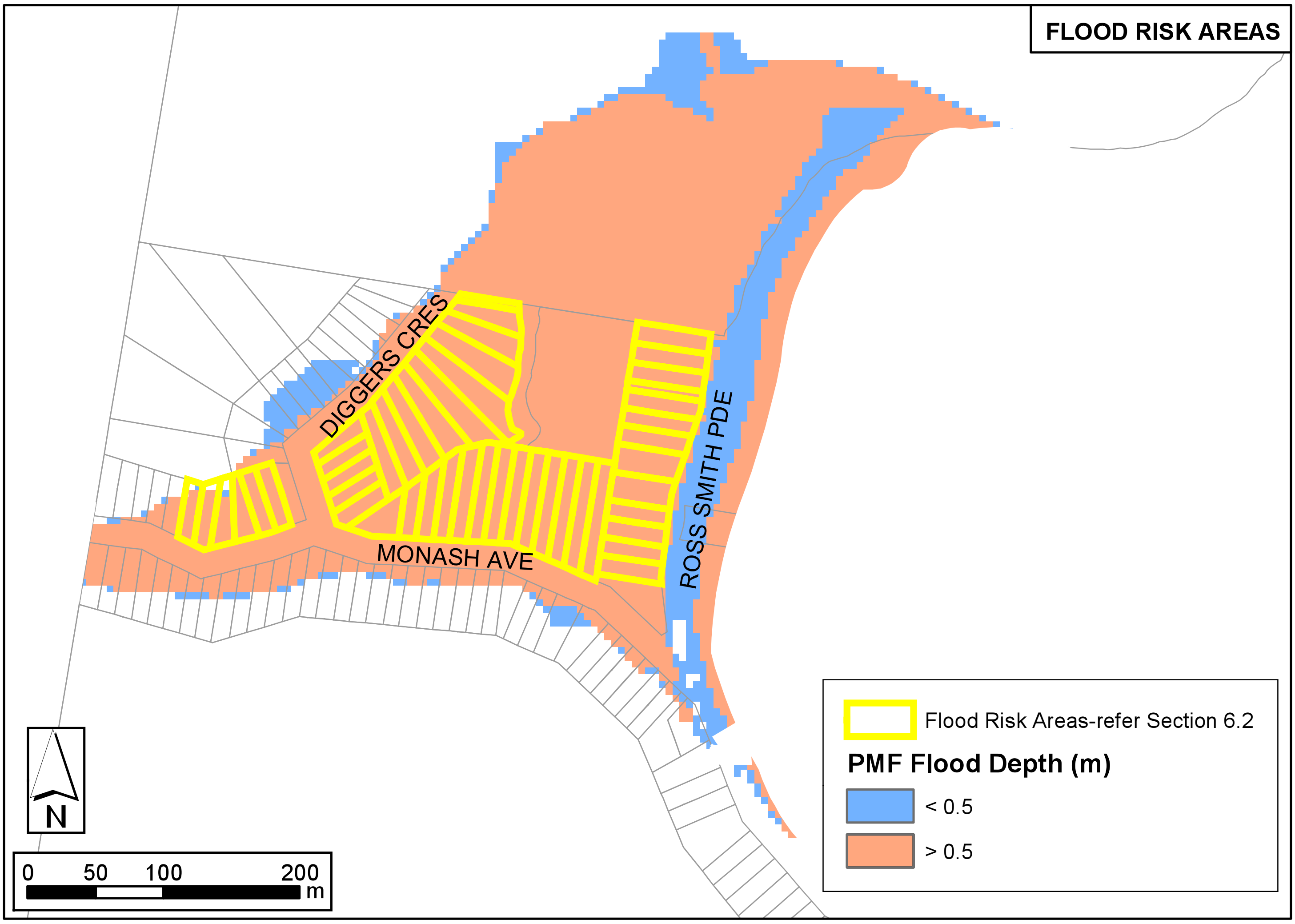


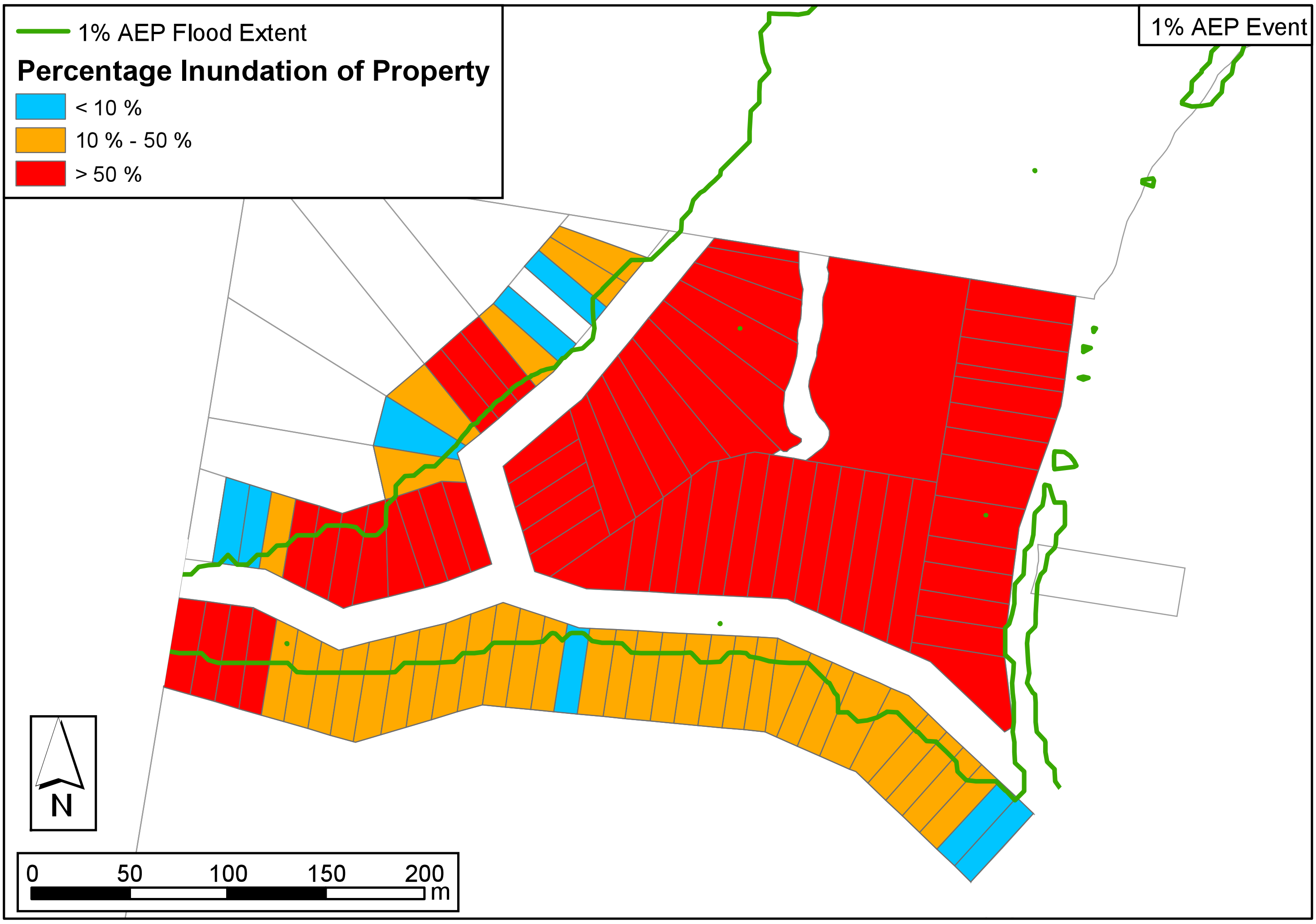
FIGURE 10
PROPERTIES AT RISK AND FLOOD RISK AREAS

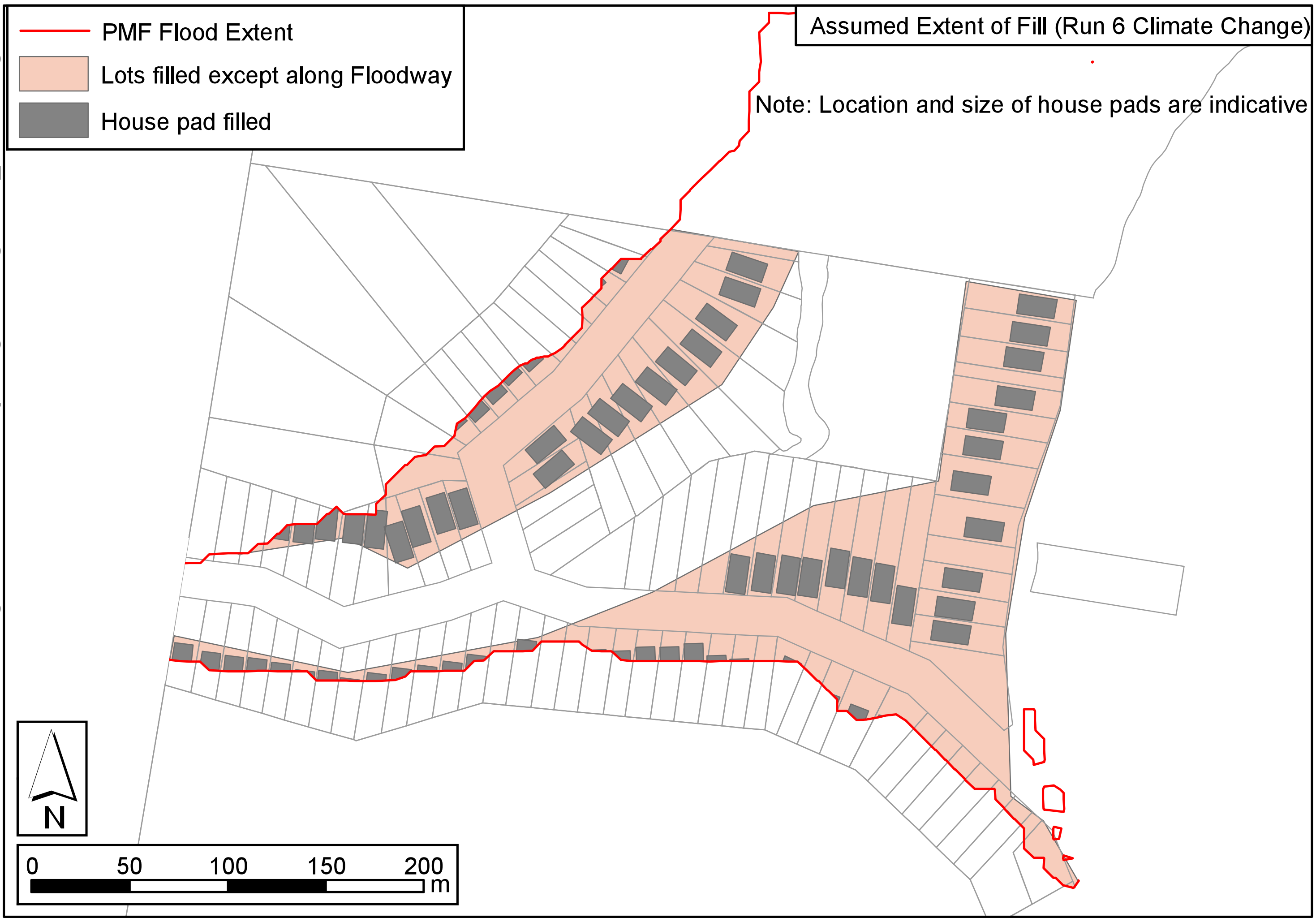




J:\Jobs\27010\Arcview\Maps\Figures\Figure10_PropRiskandAreas.mxd

FIGURE11
PERCENTAGE INUNDATION OF PROPERTIES AND ASSUMED EXTENT OF FILL

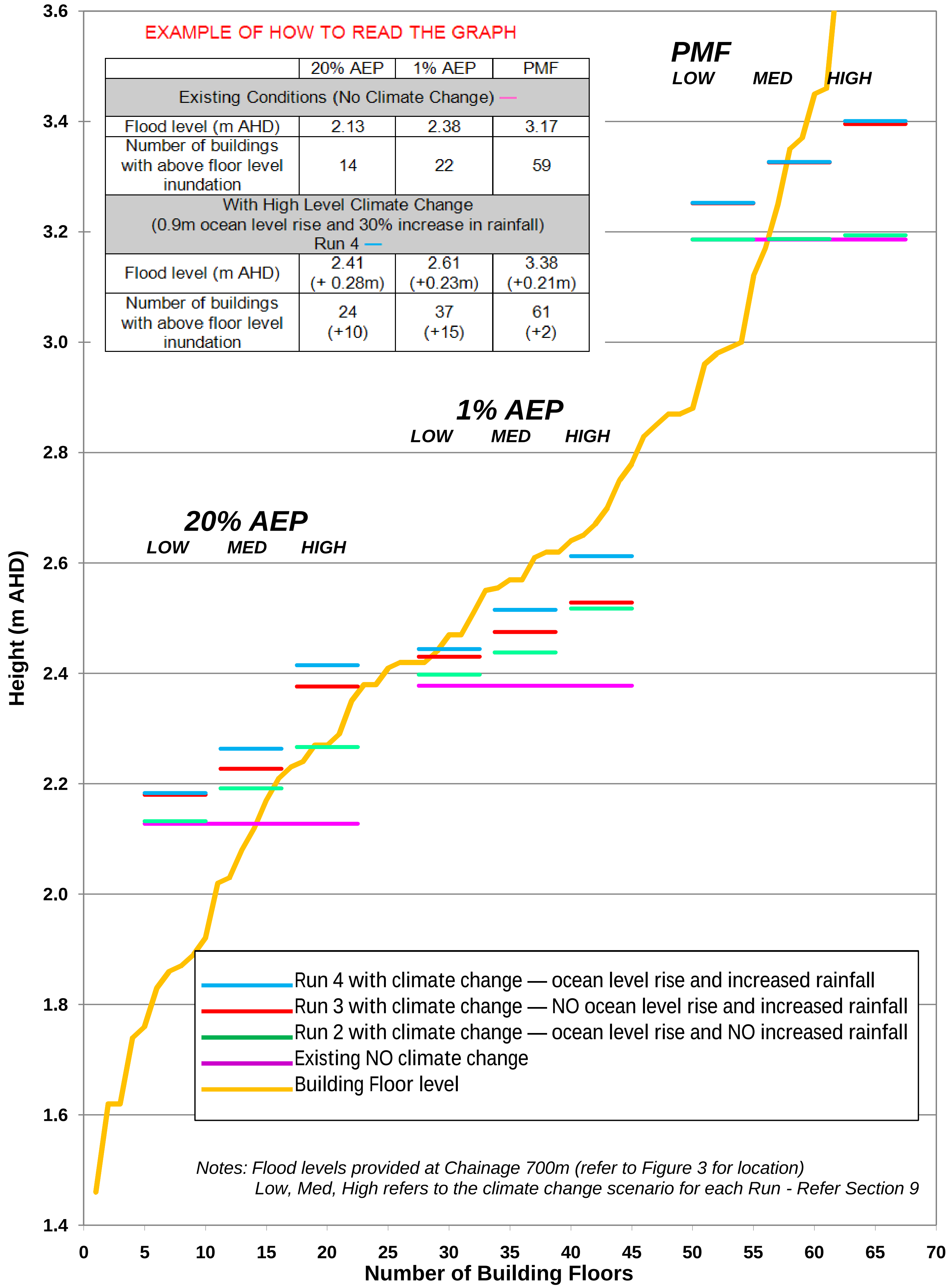




J:\Jobs\27010\ClimateChange\ArcView\ArcMaps\Figures\Figure11_PercentageInundationofProperties.mxd

FIGURE 12

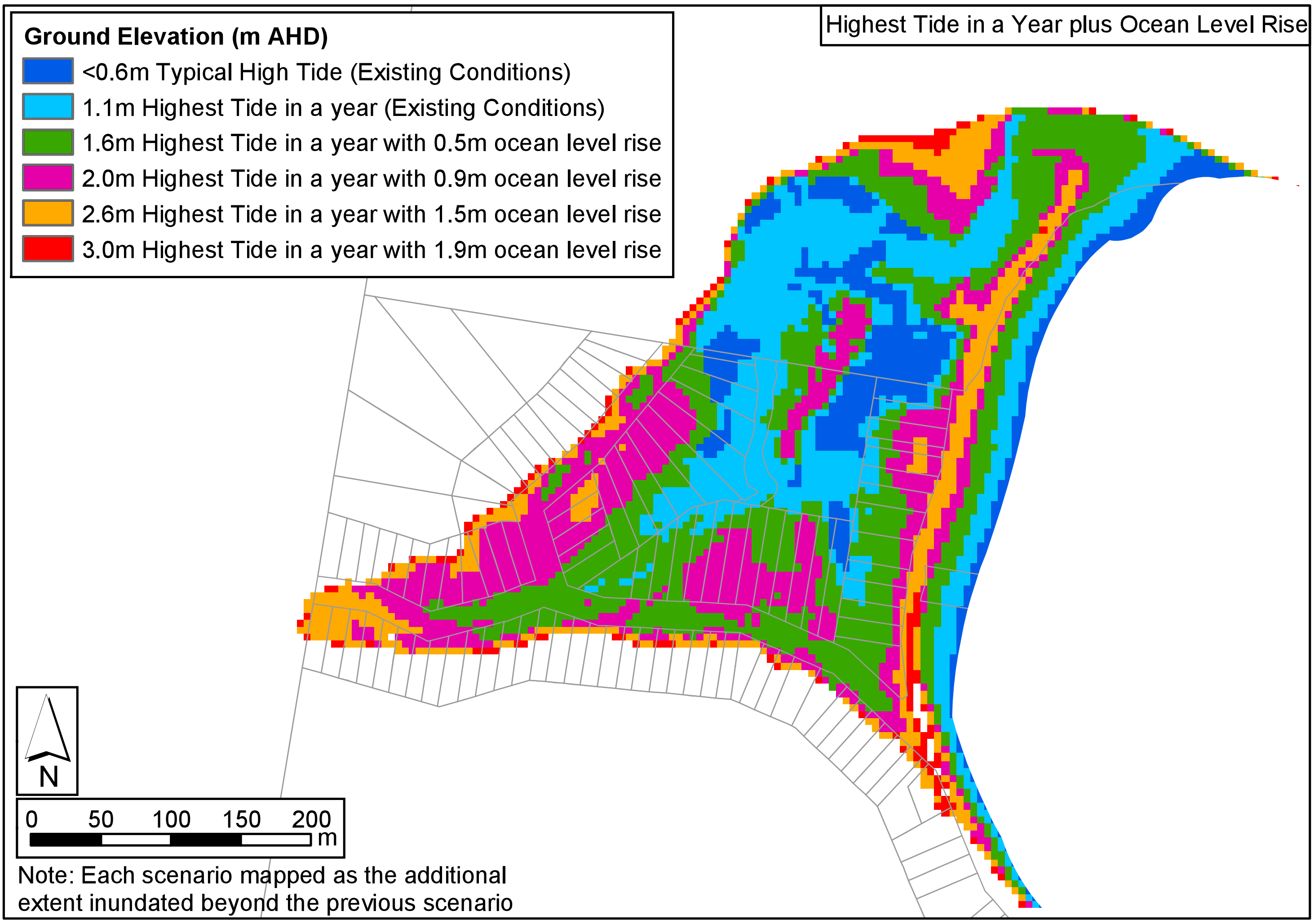
BUILDING FLOOR LEVELS

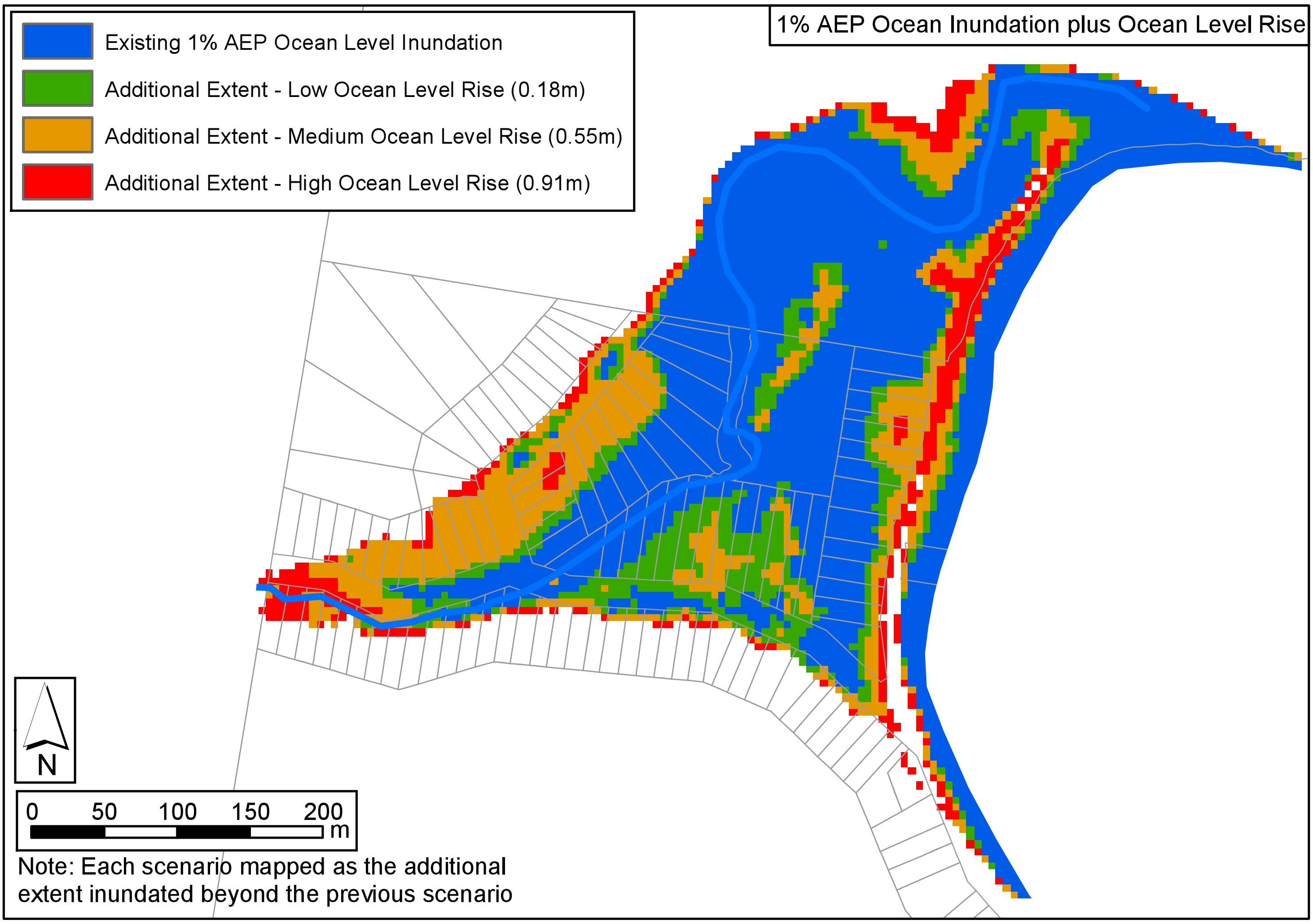


	20% AEP	1% AEP	PMF
Existing Conditions (No Climate Change)			
Flood level (m AHD)	2.13	2.38	3.17
Number of buildings with above floor level inundation	14	22	59
With High Level Climate Change (0.9m ocean level rise and 30% increase in rainfall) Run 4			
Flood level (m AHD)	2.41 (+ 0.28m)	2.61 (+0.23m)	3.38 (+0.21m)
Number of buildings with above floor level inundation	24 (+10)	37 (+15)	61 (+2)

Notes: Flood levels provided at Chainage 700m (refer to Figure 3 for location)
Low, Med, High refers to the climate change scenario for each Run - Refer Section 9

FIGURE13
EXTENT OF INUNDATION
OCEAN INUNDATION





J:\Jobs\27010\ClimateChange\ArcGis\ArcMaps\Figures\Figure13_ExtentofInundation.mxd

Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas

age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

disaster plan (DISPLAN) A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

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 for example, metres per second (m/s).

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. The use of sustainability and sustainable in this manual relate to ESD.

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.

flash flooding Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

flood Relatively high stream flow which 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 Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood education Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

flood fringe areas The remaining area of flood prone land after floodway and flood storage areas have been defined.

flood liable land Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).

flood mitigation standard The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.

floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the “flood liable land” concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL’s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the “standard flood event” in the 1986 manual.
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 flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach The merit approach weighs 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.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP) The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability A statistical measure of the expected chance of flooding (see AEP).

risk Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage Equivalent to “water level”. Both are measured with reference to a specified datum.

stage hydrograph A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

survey plan A plan prepared by a registered surveyor.

water surface profile A graph showing the flood stage at any given location along a watercourse at a particular time.

wind fetch The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

PITTWATER COUNCIL SECTION 149 PART 2 NOTATIONS

Flood Risk July 05 - Category1/High Hazard

Flood related development controls information

EP&A Regulations 2000
Schedule 4, Clause 7A

On the information available to Council, the land in question is affected by the Flood Planning Level and the Probable Maximum Flood and is therefore classified as Category 1 – High Hazard in Council's Flood Risk Management Policy for Pittwater.

The land in question is subject to flood related development controls for the purposes (where permissible) of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings.

The land in question is also subject to flood related development controls for any other purpose.

Development controls are set out in Council's Development Control Plan No 30, Pittwater Flood Risk Management.

Note:
Flood levels have been determined using the available information from the most recent flood analysis, incorporating hydraulic modeling, surveyed cross sections and contour plans. The Flood Levels are available from Council's website and should be compared with the surveyed floor level and ground levels to assess flood risk.

On the information available to Council, the land in question may be subject to high velocities and/or depth during a flood event and is therefore classified as being subject to a High Hazard Risk under Council's Flood Risk Management Policy for Pittwater. Advice should be sought from Council regarding the High Hazard classification of the land.

Flood Risk July 05 - Category1/Low Hazard

Flood related development controls information

EP&A Regulations 2000
Schedule 4, Clause 7A

On the information available to Council, the land in question is affected by the Flood Planning Level and the Probable Maximum Flood and is therefore classified as Category 1 – Low Hazard in Council's Flood Risk Management Policy for Pittwater.

The land in question is subject to flood related development controls for the purposes (where permissible) of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings.

The land in question is also subject to flood related development controls for any other purpose.

Development controls are set out in Council's Development Control Plan No 30, Pittwater Flood Risk Management.

Note:
Flood levels have been determined using the available information from the most recent flood analysis, incorporating hydraulic modeling, surveyed cross sections and contour plans. The Flood Levels are available from Council's website and should be compared with the surveyed floor level and ground levels to assess flood risk.

Flood Risk July 05 – Category 2

Flood related development controls information

EP&A Regulations 2000
Schedule 4, Clause 7A

On the information available to Council, the land may be affected by the Probable Maximum Flood event and is therefore classified as Category 2 in Council's Flood Risk Management Policy for Pittwater.

The land in question is not subject to flood related development controls for the purposes (where permissible) of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing).

The land in question is subject to flood related development controls for any other purpose.

Development controls are set out in Council's Development Control Plan No 30, Pittwater Flood Risk Management.

Note:
Flood levels have been determined using the available information from the most recent flood analysis, incorporating hydraulic modeling, surveyed cross sections and contour plans. The Flood Levels are available from Council's website and should be compared with the surveyed floor level and ground levels to assess flood risk.

Flood Risk July 05 - Warriewood Land Release

Flood related development controls information

EP&A Regulations 2000
Schedule 4, Clause 7A

The land in question is located within the Warriewood Valley Urban Land Release Area. All development on this land is subject to the requirements of the Warriewood Valley Water Management Specification (12 February 2001 or as revised).

The land in question is subject to flood related development controls for the purposes (where permissible) of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings.

The land in question is also subject to flood related development controls for any other purpose.

Note:
At the time of registration of the Plan of Subdivision for building lots released for any portion of a Sector, this notation will be removed and replaced by a Section 149(2) Notation for either Category 1 or Category 2, or the notation removed as set out in Council's Flood Risk Management Policy for Pittwater to accord with the Sector Water Management Report.

All other land not identified in Council Flood Risk Management Policy

Flood related development controls information

EP&A Regulations 2000
Schedule 4, Clause 7A

The land in question is not subject to flood related development controls for the purposes, (where permissible), of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings.

Also, the land in question is not subject to flood related development controls for any other purpose.

PITTWATER COUNCIL SECTION 149 PART 5 NOTATIONS

General Notation on all 149 Part 5 certificates

GENERAL FLOOD NOTATION

If the land is in the vicinity of a watercourse, drainage system, drainage easement, low point in the road or associated floodways and floodplains then flood related development controls may be imposed by Council on development of the land. Information in this regard should be sought from Council.

CRITERIA FOR RANKING OF 'DANGER TO LIFE' AT FLOOD-AFFECTED

Old	New	LEVEL OF OVER FLOOR FLOODING	FLOODING LEVEL OF PROPERTY FLOODING
1	1 a	Over floor flooding in 5 year flood	High flood hazard on property in 100 year flood
2	1 b	Over floor flooding in 5 year flood	Floodway located on property in 100 year flood
3	1 c	Over floor flooding in 5 year flood	No high flood hazard on property in 100 year flood
4	2 a	Over floor flooding in 20 year flood	High flood hazard on property in 100 year flood
5	2 b	Over floor flooding in 20 year flood	Floodway located on property in 100 year flood
6	2 c	Over floor flooding in 20 year flood	No high flood hazard on property in 100 year flood
7	3 a	Over floor flooding in 100 year flood	High flood hazard on property in 100 year flood
8	3 b	Over floor flooding in 100 year flood	Floodway located on property in 100 year flood
9	3 c	Over floor flooding in 100 year flood	No high flood hazard on property in 100 year flood
10	4 a	Over floor flooding at FPL*	High flood hazard on property in 100 year flood
11	4 b	Over floor flooding at FPL*	Floodway located on property in 100 year flood
12	4 c	Over floor flooding at FPL*	No high flood hazard on property in 100 year flood
13	5 a	Over floor flooding between FPL* and Probable Maximum Flood	High flood hazard on property in 100 year flood
14	5 b	Over floor flooding between FPL* and Probable Maximum Flood	Floodway located on property in 100 year flood and not high hazard
15	5 c	Over floor flooding between FPL* and Probable Maximum Flood	No high flood hazard on property in 100 year flood
16	5 d	Over floor flooding between FPL* and Probable Maximum Flood	Property flooded in floods larger than 100 year flood
17	6 a	Floor above Probable Maximum Flood	High flood hazard on property in 100 year flood
18	6 b	Floor above Probable Maximum Flood	Floodway located on property in 100 year flood
19	6 c	Floor above Probable Maximum Food	No high flood hazard on property in 100 year flood
20	6 d	Floor above Probable Maximum Flood	Property flooded in floods larger than 100 year flood and not high hazard

Notes: * FPL = Flood Planning Level = 100 year flood level + 0.5m

													FLOOD LEVEL					DEPTH OF INUNDATION ABOVE FLOOR					DEPTH OF INUNDATION ABOVE GROUND					1% AEP			PMF				
Number	Property Number	LAND NO	Street No	Street Name	No of Storeys	Do people live on ground floor? (Y or N)	Esturaine Planning Level (m AHD)	Ground Level (m AHD)	Floor Level (m AHD)	Floor (3)	Walls (4)	% Inundated in 1% AEP: 1=<10%, 2=>10%<50%, 3= > 50%	20% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	5% AEP	2% AEP	1% AEP	PMF	Average Velocity (m/s)	Provisional Hazard Category	Hydraulic Flood Category	Average Velocity (m/s)	Provisional Hazard Category	Hydraulic Flood Category	Danger to Life Rank (old rank system)	Danger to Life Rank (new rank system)
1	26174	4907	1	DIGGERS CRESCENT	1	Y	need to confirm appropriate EPL with Sue - for each prop. Need to know which EPL and which RF applies	2.18	3.35	2	5	2	2.18	2.32	2.38	2.46	3.53	0.00	0.00	0.00	0.00	0.18	0.00	0.14	0.20	0.28	1.35	<0.5	LOW	FLOOD STORAGE	<0.5	HIGH	FLOODWAY	16	5 d
2	26200	4932	2	DIGGERS CRESCENT	2	Y		1.39	1.46	1	6 (CONC. BLK GND LEVEL, CLAD TOP LEVEL)	3	2.14	2.28	2.33	2.40	3.30	0.68	0.82	0.87	0.94	1.84	0.75	0.89	0.94	1.01	1.91	0.5 - 1.0	HIGH	FLOODWAY	>1.5	HIGH	FLOODWAY	1	1 a
3	26175	4908	3	DIGGERS CRESCENT	1	Y		3.9	5.64	2	3	1	2.18	2.32	2.38	2.46	3.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD STORAGE	<0.5	LOW	FLOODWAY	19	6 c
4	26199	4931	4	DIGGERS CRESCENT	1	Y		1.67	2.47	2	3	3	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.83	0.47	0.61	0.66	0.73	1.63	<0.5	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	10	4 a
5	26176	4909	5	DIGGERS CRESCENT	1	Y		4.54	6.48	2	3	2	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD FRINGE	<0.5	LOW	FLOODWAY	18	6 b
6	26198	4930	6	DIGGERS CRESCENT	1	Y		1.66	2.47	2	3	3	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.83	0.48	0.62	0.67	0.74	1.64	<0.5	LOW	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	10	4 a
7	26198	4930	6	DIGGERS CRESCENT				1.81	2.96			3	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.34	0.33	0.47	0.52	0.59	1.49	<0.5	LOW	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	13	5 a
8	26177	4910	7	DIGGERS CRESCENT								3	2.14	2.28	2.33	2.40	3.30											<0.5	LOW	FLOOD STORAGE	<0.5	HIGH	FLOOD STORAGE	19	6 c
9	26197	4929	8	DIGGERS CRESCENT	1	Y		1.98	2.55	2	3	3	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.75	0.16	0.30	0.35	0.42	1.32	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	11	4 b
10	26178	4911	9	DIGGERS CRESCENT	2	Y		5.61	7.57	2	4	3	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD STORAGE	<0.5	HIGH	FLOOD STORAGE	19	6 c
11	26196	4928	10	DIGGERS CRESCENT	2	Y		1.9	2.78	2	4	3	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.52	0.24	0.38	0.43	0.50	1.40	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	11	4 b
12	26180	4913	11	DIGGERS CRESCENT	2	Y		4.69	6.79	2	5	3	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD STORAGE	<0.5	LOW	FLOOD STORAGE	19	6 c
13	26195	4927	12	DIGGERS CRESCENT	1	Y		2	2.51	2	3	3	2.13	2.27	2.32	2.38	3.21	0.00	0.00	0.00	0.00	0.70	0.13	0.27	0.32	0.38	1.21	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
14	26181	4914	13	DIGGERS CRESCENT	1	Y		5.19	6.79	2	3	2	2.13	2.27	2.32	2.38	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD STORAGE	<0.5	LOW	FLOOD STORAGE	19	6 c
15	26194	4926	14	DIGGERS CRESCENT	2	Y		1.77	2.02	2	4	3	2.13	2.27	2.32	2.38	3.18	0.11	0.25	0.30	0.36	1.16	0.36	0.50	0.55	0.61	1.41	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	1	1 a
16	26182	4915	15	DIGGERS CRESCENT	1	Y		4.3	7.43	2	3	1	2.13	2.27	2.32	2.38	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				<0.5	LOW	FLOOD STORAGE	20	6 d
17	26193	4925	16	DIGGERS CRESCENT	1	Y		1.79	2.24	2	5	3	2.12	2.27	2.31	2.37	3.16	0.00	0.02	0.07	0.13	0.92	0.33	0.48	0.52	0.58	1.37	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	4	2 a
18	26183	4916	17	DIGGERS CRESCENT	2	Y		4.56	7.17	2	5	not inu	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				<0.5	LOW	FLOOD STORAGE	20	6 d
19	26192	4924	18	DIGGERS CRESCENT	1	Y		1.86	2.42	2	3	3	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.00	0.00	0.71	0.26	0.40	0.45	0.51	1.27	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
20	26184	4917	19	DIGGERS CRESCENT	1	Y		5.59	7.13	2	5	1	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD STORAGE	<0.5	LOW	FLOODWAY	19	6 c
21	26191	4923	20	DIGGERS CRESCENT	1	Y		1.8	2.38	2	5	3	2.12	2.26	2.31	2.37	3.10	0.00	0.00	0.00	0.00	0.72	0.32	0.46	0.51	0.57	1.30	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
22	26191	4923	20	DIGGERS CRESCENT				1.98	2.29			3	2.12	2.26	2.31	2.37	3.10	0.00	0.00	0.02	0.08	0.81	0.14	0.28	0.33	0.39	1.12	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	4	2 a
23	26185	4918	21	DIGGERS CRESCENT	1	Y		5.05	5.48	2	3	2	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD STORAGE	<0.5	HIGH	FLOODWAY	19	6 c
24	26190	4922	22	DIGGERS CRESCENT	2	Y		1.83	2.67	2	4	3	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.38	0.29	0.43	0.47	0.53	1.22	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
25	26186	4919	23	DIGGERS CRESCENT	2	Y		12.31	12.81	2	5	2	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD STORAGE	<0.5	HIGH	FLOODWAY	19	6 c
26	26189	4921	24	DIGGERS CRESCENT								3	2.12	2.26	2.30	2.36	3.05											<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY		
27	26187	4920	25	DIGGERS CRESCENT			nfirm appropriate EPL with Sue - for each prop. Need to know which EPL and which RF applies					not inu	2.12	2.26	2.30	2.36	3.05																		
28	78146	20191	26	DIGGERS CRESCENT	1	Y		1.47	1.86	2	5	3	2.11	2.25	2.30	2.35	2.98	0.25	0.39	0.44	0.49	1.12	0.64	0.78	0.83	0.88	1.51	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	1	1 a
29	78145	20190	28	DIGGERS CRESCENT	1	Y		1.28	3	2	4	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.00	0.83	0.97	1.02	1.07	1.70	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	13	5 a
30	fire station		PART ROAD RESERVE	DIGGERS CRESCENT	1	N		1.66	1.74	1	5																								
31	45515	10292	1	MONASH AVENUE	2	Y		2.3	2.99	2	4	not inu	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.06	0.75				<0.5	LOW	FLOOD STORAGE	20	6 d
32	45458	10236	2	MONASH AVENUE	1	Y		1.77	1.83	1	3	3	2.11	2.25	2.30	2.35	2.98	0.28	0.42	0.47	0.52	1.15	0.34	0.48	0.53	0.58	1.21	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	1	1 a
33	45514	10291	3	MONASH AVENUE	1	Y		11.73	15.37	2	3	not inu	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				<0.5	LOW	FLOOD STORAGE	20	6 d
34	45459	10237	4	MONASH AVENUE	1	Y		1.77	2.38	2	4	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.60	0.34	0.48	0.53	0.58	1.21	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
35	45513	10290	5	MONASH AVENUE	3	Y		2.48	5.26	1	4	1	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57				<0.5	LOW	FLOOD STORAGE	20	6 d
36	45460	10238	6	MONASH AVENUE	1 (SMALL FLAT AT BACK)	Y		1.62	2.42	2	4	3	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.63	0.50	0.64	0.68	0.74	1.43	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	17	6 a
37	45512	10289	7	MONASH AVENUE	3	Y		2.46	2.57	1	5	1	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.59	<0.5	LOW	FLOOD STORAGE	<0.5	LOW	FLOOD STORAGE	12	4 c
38	45461	10239	8	MONASH AVENUE	1	Y		1.61	2.555	2	4	3	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.50	0.51	0.65	0.69	0.75	1.44	<0.5	HIGH	FLOOD STORAGE	<0.5	HIGH	FLOODWAY	7	3 a
39	45511	10288	9	MONASH AVENUE	3	Y		2.33	2.35	1	6 (RENDERED SHEETING)	2	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.01	0.70	0.00	0.00	0.00	0.03	0.72	<0.5	LOW	FLOOD STORAGE	<0.5	LOW	FLOOD STORAGE	9	3 c
40	45462	10240	10	MONASH AVENUE	1	Y		1.66	2.42	2	3	3	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.63	0.46	0.60	0.64	0.70	1.39	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	10	4 a
41	45510	10287	11	MONASH AVENUE	2	Y		1.95	2.03	1	5	2	2.12	2.26	2.30	2.36	3.05	0.09	0.23	0.27	0.33	1.02	0.17	0.31	0.35	0.41	1.10	<0.5	LOW	FLOOD STORAGE	<0.5	HIGH	FLOOD STORAGE	3	1 c

													FLOOD LEVEL					DEPTH OF INUNDATION ABOVE FLOOR					DEPTH OF INUNDATION ABOVE GROUND					1% AEP			PMF				
Number	Property Number	LAND NO	Street No	Street Name	No of Storeys	Do people live on ground floor? (Y or N)	Esturaine Planning Level (m AHD)	Ground Level (m AHD)	Floor Level (m AHD)	Floor (3)	Walls (4)	% Inundated in 1% AEP: 1=<10%, 2=>10%<50%, 3= > 50%	20% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	5% AEP	2% AEP	1% AEP	PMF	Average Velocity (m/s)	Provisional Hazard Category	Hydraulic Flood Category	Average Velocity (m/s)	Provisional Hazard Category	Hydraulic Flood Category	Danger to Life Rank (old rank system)	Danger to Life Rank (new rank system)
42	45463	10241	12	MONASH AVENUE	1	Y	need to co	1.83	1.92	1	3	3	2.12	2.26	2.30	2.36	3.05	0.20	0.34	0.38	0.44	1.13	0.29	0.43	0.47	0.53	1.22	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	1	1 a
43	45509	10286	13	MONASH AVENUE	3	N		2.08	2.62	2	4	2	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.43	0.04	0.18	0.22	0.28	0.97	<0.5	LOW	FLOOD STORAGE	<0.5	HIGH	FLOOD STORAGE	12	4 c
44	45464	10242	14	MONASH AVENUE	1	Y	need to confirm appropriate EPL with Sue - for each prop. Need to know which EPL and which RF applies	1.72	2.23	2	6 (LOG-CABIN)	3	2.12	2.26	2.31	2.37	3.10	0.00	0.03	0.08	0.14	0.87	0.40	0.54	0.59	0.65	1.38	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	4	2 a
45	45508	10285	15	MONASH AVENUE	3	N		8.39	9.59	2	5	2	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOOD STORAGE	<0.5	HIGH	FLOOD STORAGE	19	6 c
46	45465	10243	16	MONASH AVENUE	1	Y		1.69	2.12	2	3	3	2.12	2.26	2.31	2.37	3.10	0.00	0.14	0.19	0.25	0.98	0.43	0.57	0.62	0.68	1.41	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	4	2 a
47	83990	26556	17	MONASH AVENUE	1	Y		3.08	7.04	2	5	2	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	<0.5	HIGH	FLOODWAY	19	6 c
48	45466	10244	18	MONASH AVENUE	1	Y		1.73	2.27	2	5	3	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.04	0.10	0.86	0.39	0.53	0.58	0.64	1.40	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	7	3 a
49	45467	10245	20	MONASH AVENUE	1	Y		1.67	1.76	1	4	3	2.12	2.26	2.31	2.37	3.13	0.36	0.50	0.55	0.61	1.37	0.45	0.59	0.64	0.70	1.46	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	1	1 a
50	83991	26571	21	MONASH AVENUE	3	N		5.94	8.02	2	4	2	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	LOW	FLOODWAY	19	6 c
51	45468	10246	22	MONASH AVENUE	1	Y		1.73	2.75	2	6 (LOG-CABIN)	3	2.12	2.27	2.31	2.37	3.16	0.00	0.00	0.00	0.00	0.41	0.39	0.54	0.58	0.64	1.43	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
52	45504	10281	23	MONASH AVENUE	3	Y		4.04	5.11	2	6 (S'STONE LOWER LEVEL, CLADDING UPPER LEVELS)	2	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	LOW	FLOODWAY	19	6 c
53	45469	10247	24	MONASH AVENUE	1	Y		1.58	2.27	2	3	3	2.13	2.27	2.32	2.38	3.18	0.00	0.00	0.05	0.11	0.91	0.55	0.69	0.74	0.80	1.60	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	7	3 a
54	45503	10280	25	MONASH AVENUE	2	N		2.86	3.69	2	6 (LOG-CABIN)	2	2.12	2.26	2.30	2.36	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
55	45470	10248	26	MONASH AVENUE	2	Y		1.5	2.98	2	5	3	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.32	0.64	0.78	0.83	0.90	1.80	0.5 - 1.0	HIGH	FLOODWAY	>1.5	HIGH	FLOODWAY	10	4 a
56	45502	10279	27	MONASH AVENUE	3	Y		5.13	6.86	1	6 (S'STONE LOWER LEVEL, CLADDING UPPER LEVELS)	2	2.12	2.26	2.31	2.37	3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
57	45471	10249	28	MONASH AVENUE	2	Y		1.92	2.87	2	5	3	2.18	2.32	2.38	2.46	3.53	0.00	0.00	0.00	0.00	0.66	0.26	0.40	0.46	0.54	1.61	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
58	45501	10278	29	MONASH AVENUE	2	Y		4.72	4.87	1	3	2	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
59	45472	10250	30	MONASH AVENUE	2	Y		1.87	3.37	2	4	3	2.19	2.33	2.39	2.48	3.59	0.00	0.00	0.00	0.00	0.22	0.32	0.46	0.52	0.61	1.72	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
60	45500	10277	31	MONASH AVENUE	1	Y		7.27	8.08	1	3	2	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
61	45473	10251	32	MONASH AVENUE	1	Y		1.87	2.64	2	3	3	2.21	2.35	2.43	2.51	3.70	0.00	0.00	0.00	0.00	1.06	0.34	0.48	0.56	0.64	1.83	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	7	3 a
62	45499	10276	33	MONASH AVENUE	2	Y		4.85	5.29	1	5	2	2.12	2.26	2.31	2.37	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
63	45474	10252	34	MONASH AVENUE	1	Y		1.89	2.65	2	2	3	2.22	2.36	2.44	2.52	3.73	0.00	0.00	0.00	0.00	1.08	0.33	0.47	0.55	0.63	1.84	<0.5	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	10	4 a
64	45498	10275	35	MONASH AVENUE	1	Y		6.38	8.3	2	4	2	2.13	2.27	2.32	2.38	3.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
65	45475	10253	36	MONASH AVENUE	1	Y		1.76	3.17	2	5	3	2.25	2.40	2.50	2.58	3.90	0.00	0.00	0.00	0.00	0.73	0.49	0.64	0.74	0.82	2.14	<0.5	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	13	5 a
66	45497	10274	37	MONASH AVENUE	3	Y		5.58	5.76	1	3	2	2.13	2.27	2.32	2.38	3.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
66	45476	10254	38	MONASH AVENUE	2	Y		1.87	3.45	2	4	3	2.29	2.44	2.57	2.65	4.07	0.00	0.00	0.00	0.00	0.62	0.42	0.57	0.70	0.78	2.20	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	13	5 a
67	45496	10273	39-41	MONASH AVENUE	1	Y		6.51	8.37	2	4	2	2.13	2.27	2.32	2.38	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
68	45477	10255	40	MONASH AVENUE	1	Y		1.8	3.25	2	5	3	2.30	2.46	2.60	2.68	4.12	0.00	0.00	0.00	0.00	0.87	0.50	0.66	0.80	0.88	2.32	<0.5	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	13	5 a
69	45478	10256	42	MONASH AVENUE	1 (ON HIGH PIERS)	Y		3.49	7.22	2	4	3	2.34	2.50	2.66	2.74	4.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	17	6 a
70	76648	19582	43	MONASH AVENUE	3	Y		6.74	6.98	1	5	2	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	<0.5	HIGH	FLOODWAY	19	6 c
71	45479	10257	44	MONASH AVENUE								2	2.36	2.52	2.69	2.77	4.26											<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY		
72	76647	19581	45	MONASH AVENUE	2	N		6.72	9.9	2	4	1	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
73	45480	10258	46	MONASH AVENUE	2	Y		5.8	6.45	1	5	1	2.40	2.56	2.74	2.82	4.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	<0.5	HIGH	FLOODWAY	19	6 c
74	45494	10272	47	MONASH AVENUE	2	Y		5.85	8.05	2	4	2	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	LOW	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	19	6 c
75	45481	10259	48	MONASH AVENUE								1	2.48	2.63	2.82	2.90	4.44											<0.5	LOW	FLOOD FRINGE	<0.5	HIGH	FLOODWAY		
76	45493	10271	49	MONASH AVENUE	1	Y	need to confirm appropriate EPL with Sue - for each prop. Need to know which EPL and which RF applies	7.05	8.15	2	5	2	2.14	2.28	2.33	2.40	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a
77	45482	10260	50	MONASH AVENUE	2	Y		14.72	15.71	2	3	not inu	2.49	2.66	2.86	2.94	4.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00								
78	45492	10270	51	MONASH AVENUE	1 (ON HIGH PIERS)	Y		3.53	6.33	2	5	2	2.18	2.32	2.38	2.46	3.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a
79	45491	10269	53	MONASH AVENUE	2	Y		6.75	7.08	2	3	2	2.18	2.32	2.38	2.46	3.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a
80	45490	10268	55	MONASH AVENUE	2	Y		5.53	7.16	2	5	2	2.19	2.33	2.39	2.48	3.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a
81	45489	10267	57	MONASH AVENUE	2	Y		4.14	5.96	2	4	2	2.21	2.35	2.43	2.51	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a
82	45488	10266	59	MONASH AVENUE	1 (SMALL FLAT AT BACK)	Y		3.53	4.61	2	3	2	2.22	2.36	2.44	2.52	3.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a
83	45487	10265	61	MONASH AVENUE	2	Y		8.08	9.27	2	3	2	2.25	2.40	2.50	2.58	3.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a

Number	Property Number	LAND NO	Street No	Street Name	No of Storeys	Do people live on ground floor? (Y or N)	Esturaine Planning Level (m AHD)	Ground Level (m AHD)	Floor Level (m AHD)	Floor (3)	Walls (4)	% Inundated in 1% AEP: 1=<10%, 2=>10%<50%, 3= > 50%	FLOOD LEVEL					DEPTH OF INUNDATION ABOVE FLOOR					DEPTH OF INUNDATION ABOVE GROUND					1% AEP			PMF			Danger to Life Rank (old rank system)	Danger to Life Rank (new rank system)
													20% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	5% AEP	2% AEP	1% AEP	PMF	Average Velocity (m/s)	Provisional Hazard Category	Hydraulic Flood Category	Average Velocity (m/s)	Provisional Hazard Category	Hydraulic Flood Category		
84	45486	10264	63	MONASH AVENUE	1	Y	need to confirm appropriate EPL with Sue - for each prop. Need to know which EPL and which RF applies	2.15	3.87	2	5	2	2.26	2.41	2.52	2.60	3.97	0.00	0.00	0.00	0.00	0.10	0.11	0.26	0.37	0.45	1.82	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	13	5 a
85	45486	10264	63	MONASH AVENUE	2	Y		6.86	8.41	2	5	2	2.26	2.41	2.52	2.60	3.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	13	5 a
85	45484	10262	69	MONASH AVENUE	2 (3 LEVELS)	Y		5.7	5.95	1	6 (S'STONE LOWER LEVEL, W/B TOP LEVEL)	3	2.49	2.66	2.86	2.94	4.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5 - 1.0	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a
86	45485	10263	65	MONASH AVENUE	2	Y		7.54	8.08	1	6 (SANDSTONE)	2	2.30	2.46	2.60	2.68	4.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.5	HIGH	FLOODWAY	1 - 1.5	HIGH	FLOODWAY	17	6 a
86	59351	14193	1	ROSS SMITH PARADE	1	Y		1.84	2.83	2	6 (LOG-CABIN)	3	2.11	2.25	2.29	2.35	2.93	0.00	0.00	0.00	0.00	0.10	0.27	0.41	0.45	0.51	1.09	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
87	59352	14194	2	ROSS SMITH PARADE	1	Y		1.88	2.7	2	3	3	2.11	2.25	2.29	2.35	2.93	0.00	0.00	0.00	0.00	0.23	0.23	0.37	0.41	0.47	1.05	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
88	59353	22779	3	ROSS SMITH PARADE	1 (SMALL FLAT AT BACK)	Y		1.75	2.61	2	3	3	2.11	2.25	2.29	2.35	2.93	0.00	0.00	0.00	0.00	0.32	0.36	0.50	0.54	0.60	1.18	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
89	59353	22779	3	ROSS SMITH PARADE				2.19	2.62			3	2.11	2.25	2.29	2.35	2.93	0.00	0.00	0.00	0.00	0.31	0.00	0.06	0.10	0.16	0.74	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
90	59354	14196	4	ROSS SMITH PARADE	1	Y		1.74	2.87	2	3	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.11	0.37	0.51	0.56	0.61	1.24	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	13	5 a
91	59355	14197	5	ROSS SMITH PARADE	1	Y		1.81	2.85	2	5	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.13	0.30	0.44	0.49	0.54	1.17	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	13	5 a
92	59355	14197	5	ROSS SMITH PARADE				1.78	2.08			3	2.11	2.25	2.30	2.35	2.98	0.03	0.17	0.22	0.27	0.90	0.33	0.47	0.52	0.57	1.20	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	1	1 a
93	59356	14198	6	ROSS SMITH PARADE	1	Y		1.7	3.12	2	4	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.00	0.41	0.55	0.60	0.65	1.28	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	17	6 a
94	59356	14198	6	ROSS SMITH PARADE				1.17	1.62			3	2.11	2.25	2.30	2.35	2.98	0.49	0.63	0.68	0.73	1.36	0.94	1.08	1.13	1.18	1.81	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	1	1 a
95	59357	14199	7	ROSS SMITH PARADE	2 (SMALL FLAT AT BACK)	Y		1.71	1.89	2	4	3	2.11	2.25	2.30	2.35	2.98	0.22	0.36	0.41	0.46	1.09	0.40	0.54	0.59	0.64	1.27	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	1	1 a
96	59357	14199	7	ROSS SMITH PARADE				1.22	1.62			3	2.11	2.25	2.30	2.35	2.98	0.49	0.63	0.68	0.73	1.36	0.89	1.03	1.08	1.13	1.76	<0.5	HIGH	FLOOD STORAGE	0.5 - 1.0	HIGH	FLOODWAY	1	1 a
97	59358	14200	8	ROSS SMITH PARADE	1 (SMALL FLAT AT BACK)	Y		1.35	1.87	2	4	3	2.11	2.25	2.30	2.35	2.98	0.24	0.38	0.43	0.48	1.11	0.76	0.90	0.95	1.00	1.63	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	1	1 a
99	59358	14200	8	ROSS SMITH PARADE				1.15	2.17			3	2.11	2.25	2.30	2.35	2.98	0.00	0.08	0.13	0.18	0.81	0.96	1.10	1.15	1.20	1.83	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	4	2 a
100	59359	14201	9	ROSS SMITH PARADE	1	Y		1.58	2.41	2	5	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.57	0.53	0.67	0.72	0.77	1.40	<0.5	HIGH	FLOODWAY	0.5 - 1.0	HIGH	FLOODWAY	10	4 a
101	59360	14202	10	ROSS SMITH PARADE	1	Y		1.81	2.44	2	3	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.54	0.30	0.44	0.49	0.54	1.17	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	10	4 a
102	59361	14203	11	ROSS SMITH PARADE	2	Y		1.88	3.46	2	4	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.00	0.23	0.37	0.42	0.47	1.10	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	17	6 a
103	59362	14204	12	ROSS SMITH PARADE	2	Y		1.51	2.88	2	5	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.10	0.60	0.74	0.79	0.84	1.47	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	13	5 a
104	59363	14205	13	ROSS SMITH PARADE	1	Y		1.9	2.57	2	3	3	2.11	2.25	2.30	2.35	2.98	0.00	0.00	0.00	0.00	0.41	0.21	0.35	0.40	0.45	1.08	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	10	4 a
105	59363	14205	13	ROSS SMITH PARADE				1.33	2.21			3	2.11	2.25	2.30	2.35	2.98	0.00	0.04	0.09	0.14	0.77	0.78	0.92	0.97	1.02	1.65	<0.5	HIGH	FLOODWAY	<0.5	HIGH	FLOODWAY	4	2 a

Notes:

(3) *. Floor Construction code: (1) slab on ground (2) Piers (3) Other*

(4) *Wall Construction code : (1) Brick (2) Brick Veneer (3) Fibro (4) Weather Board (5) Cladded (6) Other*

Average velocity has been approximated for the flood affected portion of the property which may, or may not, be the entire lot

Each property was allocated the most severe provisional hazard and flood category that occurs on any portion of the lot

13 17 20 21 58

does not include fire station

GREAT MACKEREL BEACH — ESTUARINE PLANNING LEVEL DATA BASE (Source: Estuarine Planning Level Mapping — Pittwater Estuary, Lawson and Treloar, 2004)

Property No	Land No	Street No.	Street Name	Property No	Land No	Attribute Class	Attribute Type	EPL 1	EPL 2	EPL 3	EPL 4	EPL 5	RF 5	RF 10	RF 15	RF 20	RF 25	RF 30	RF 35	RF 40
26200	4932	2	DIGGERS CRESCENT	26200	4932	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
26199	4931	4	DIGGERS CRESCENT	26199	4931	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
26195	4927	12	DIGGERS CRESCENT	26195	4927	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
26194	4926	14	DIGGERS CRESCENT	26194	4926	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
26193	4925	16	DIGGERS CRESCENT	26193	4925	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
26192	4924	18	DIGGERS CRESCENT	26192	4924	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
26191	4923	20	DIGGERS CRESCENT	26191	4923	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
26190	4922	22	DIGGERS CRESCENT	26190	4922	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
26189	4921	24	DIGGERS CRESCENT	26189	4921	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
78146	20191	26	DIGGERS CRESCENT	78146	20191	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
78145	20190	28	DIGGERS CRESCENT	78145	20190	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45515	10292	1	MONASH AVENUE	45515	10292	Estuarine	EPL2003	2.6	2.5	2.3	3.53	3.83	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45458	10236	2	MONASH AVENUE	45458	10236	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45514	10291	3	MONASH AVENUE	45514	10291	Estuarine	EPL2003	2.6	2.5	2.3	3.53	3.83	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45459	10237	4	MONASH AVENUE	45459	10237	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45513	10290	5	MONASH AVENUE	45513	10290	Estuarine	EPL2003	2.6	2.5	2.3	3.53	3.83	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45460	10238	6	MONASH AVENUE	45460	10238	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45512	10289	7	MONASH AVENUE	45512	10289	Estuarine	EPL2003	2.6	2.5	2.3	3.53	3.83	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45511	10288	9	MONASH AVENUE	45511	10288	Estuarine	EPL2003	2.6	2.5	2.3	3.53	3.83	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45462	10240	10	MONASH AVENUE	45462	10240	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45510	10287	11	MONASH AVENUE	45510	10287	Estuarine	EPL2003	2.6	2.5	2.3	3.53	3.83	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45463	10241	12	MONASH AVENUE	45463	10241	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45509	10286	13	MONASH AVENUE	45509	10286	Estuarine	EPL2003	2.6	2.5	2.3	3.53	3.83	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45464	10242	14	MONASH AVENUE	45464	10242	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45508	10285	15	MONASH AVENUE	45508	10285	Estuarine	EPL2003	2.6	2.5	2.3	3.53	3.83	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45465	10243	16	MONASH AVENUE	45465	10243	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45466	10244	18	MONASH AVENUE	45466	10244	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45467	10245	20	MONASH AVENUE	45467	10245	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45468	10246	22	MONASH AVENUE	45468	10246	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45469	10247	24	MONASH AVENUE	45469	10247	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
45470	10248	26	MONASH AVENUE	45470	10248	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59351	14193	1	ROSS SMITH PARADE	59351	14193	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59352	14194	2	ROSS SMITH PARADE	59352	14194	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59353	14195	3	ROSS SMITH PARADE	59353	14195	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59353	22779	3	ROSS SMITH PARADE	59353	22779	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59354	14196	4	ROSS SMITH PARADE	59354	14196	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59355	14197	5	ROSS SMITH PARADE	59355	14197	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59356	14198	6	ROSS SMITH PARADE	59356	14198	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59357	14199	7	ROSS SMITH PARADE	59357	14199	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59358	14200	8	ROSS SMITH PARADE	59358	14200	Estuarine	EPL2003	2.6	2.5	2.3	3.5	3.8	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59359	14201	9	ROSS SMITH PARADE	59359	14201	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59360	14202	10	ROSS SMITH PARADE	59360	14202	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59361	14203	11	ROSS SMITH PARADE	59361	14203	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59362	14204	12	ROSS SMITH PARADE	59362	14204	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59363	14205	13	ROSS SMITH PARADE	59363	14205	Estuarine	EPL2003	2.6	2.5	2.3	3.51	3.81	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59364	14206	14	ROSS SMITH PARADE	59364	14206	Estuarine	EPL2003	2.6	2.5	2.3	3.54	3.84	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59365	14207	15	ROSS SMITH PARADE	59365	14207	Estuarine	EPL2003	2.6	2.5	2.3	3.54	3.84	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4
59366	14208	16	ROSS SMITH PARADE	59366	14208	Estuarine	EPL2003	2.6	2.5	2.3	3.54	3.84	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4

Notes

EP1 to EP5 denotes the Base Estuarine Planning Level that is dependent on foreshore treatments as follows:

EP1 =	Sandy Beach
EP2 =	Vertical Wall Crest at 1.5mAHD
EP3 =	Vertical Wall Crest at 2.0mAHD
EP4 =	Sloping Rock Wall
EP5 =	Natural Rocky Shoreline

RF denotes the reduction factor to be subtracted from the Base Estuarine Planning Level depending on the distance from the Foreshore Edge eg. RF15 = 15m from foreshore edge

Appendix C

PHOTOGRAPH 5: November 1987 Flood - 18 Monash Avenue

HOW DO I GET INVOLVED?

Community input to the Floodplain Risk Management Study and Plan is essential. Draft copies of both studies will be placed on Council's web site, on public exhibition in the local community and available free on CD for comments and questions prior to finalisation. You will be informed of the date in due course. There will also be a community workshop where you can ask Council and the consultants any questions.

Once the Floodplain Risk Management Study and Plan has been completed and adopted by Council, Pittwater Council will then commence the process to obtain funds to undertake the recommended floodplain management measures. This is likely to begin in 2008 depending upon continual government grant assistance.

Many of the residents responded to the first Questionnaire in November 2003 and provided valuable information and photographs. This was greatly appreciated. This next phase is very important as it will determine the appropriate floodplain managementmeasures for the study area.

You can also participate in the study process through your Community Working Group who can represent your views at Council's Land, Water and Coastal Portfolio Committee meetings. Contact details of your local member are:

1. **Warren Lewis**

   Home: (02) 99297528
   Mobile: 0407 911 119
   Mackerel Home: (02) 9974 5699

Council and the consultants will be visiting the area on Sunday 27th May from approximately 10 to 12am. If you wish please speak to them and ask any questions you wish.

WHO TO SPEAK TO?

The Project Manager is: Mr Richard Dewar
The Project Engineer is: Ms Ella Thomason

They can be contacted at:
Webb, McKeown & Associates
Level 2, 160 Clarence Street
SYDNEY NSW 2000
Telephone: 9299 2855
Facsimile: 9262 6208
Email: thomason@webbmckeown.com.au

Should you only wish to make a comment or seek clarification on any issue, please do not hesitate to contact us.

Alternatively you may contact Ms Sue Ribbons, Project Leader - Floodplain Management, Pittwater Council on 9970 1208 to discuss any aspects of the project.

PHOTOGRAPH 6: November 1987 Flood - Monash Avenue

11.11.87

The spirit disaster can't beat

Following the devastating storm several weeks ago, which hit the tiny Pittwater village of Mackerel Beach particularly hard, residents are still struggling to get their lives back into order.

Several houses shifted from their foundations have to be rebuilt, but the owners are philosophical.

They will rebuild on higher foundations to withstand future floods.

The wife of volunteer fire brigade captain Bob Mitchell said the floods which ran shoulder-high through houses were frightening enough, but it had been a nightmare since repairing the damage.

"Fifteen of the 42 permanent residents had to be evacuated from their homes due to rising flood-waters," Christine Mitchell said.

People and dogs were saved by residents who left their belongings behind to help others.

In the last two weeks people such as the Mitchells have been trying to get their lives together.

The Mitchells found they were not insured. They let their policy lapse because money was needed for their son's optical problems.

Others were in the same boat and nearly lost everything.

As soon as news of the disaster spread, town folk who use their houses only for holidays were quick to offer accommodation, beds and clothes.

"Everyone was helping everyone. It was a great demonstration of community unity and goodwill," Richard Cornielje said.

"Many of the people weren't worrying about their own uninsured possessions because they were busy helping others.

"Even last weekend, everyone was still scrubbing, cleaning and trying to get their lives back in order. It has been a physical and mental drain on everyone."

Mr Mitchell said the floods had caused about $10 000 damage to his house and contents, but he hoped he had learnt by the experience.

The loss of carpet, a pump, refrigerator, washing machine, mattresses and shoes hurt, but he was heartened by the response shown by people under disaster conditions.

The Sydney County Council restored power under very trying conditions and workmen helped by carrying generators and filling potholes.

Most insurance claims have been settled, but some companies were "trying to wriggle out of it", Mr Mitchell said.

Seven of the residents who lost uninsured possessions are being helped by the disaster relief committee of Youth and Community Services.

One thing shines through the adversity ... if it happens again the people of Mackerel Beach will cope.

PHOTOGRAPH 7: Newspaper Article November 11, 1987

NSW Government
DEPARTMENT OF NATURAL RESOURCES

Great Mackerel Beach
FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

COMMUNITY INFORMATION SHEET May 2007

Council, the Consultants and the SES will be on site on Sunday 27 May from 10 to 12am to answer questions.

INTRODUCTION

This Community Information Sheet is to inform you of the studies about to commence as the second and third stages in the Floodplain Management Process being undertaken for Great Mackerel Beach.

Pittwater Council has received a State Government grant offer for part funding of this project and has appointed Webb, McKeown & Associates Pty Ltd (Water and Environmental Engineers) to prepare a Great Mackerel Beach Floodplain Risk Management Study and Floodplain RiskManagement Plan .

The first stage of the process, the "Flood Study", was completed in 2005. That Study involved data collection and a comprehensive technical investigation to define the nature, magnitude and extent of flooding in the lagoon and residential areas. Those results provide the technical basis for this second stage, "Risk Management Study" which aims to identify flooding problems and areas of concern and then develop strategies to manage existing problems and reduce future damage. This information will provide the basis for sound catchment planning and management thereby optimising development potential while obtaining the social and economic benefits derived from the reduction in flood damages.

The third stage of the process is to use the preceding studies to develop a comprehensive "Risk Management Plan", including resources and timing, for Council to implement the identified floodplain managementmeasures.

FIGURE 1: Aerial Photograph

You may recall that a Questionnaire was distributed in November 2003 seeking information about past floods. That information was a valuable input into the first stage "Flood Study". **Similarly, accompanying this Information Sheet is a new Questionnaire which you are earnestly asked to complete in order to expand the Community's input into the Floodplain Management Process.**

THE STUDY AREA

Great Mackerel Beach has a catchment area of about 2.6 km^2 to Pittwater (Figure 1) and includes approximately 120 residential dwellings. The catchment is characterised by two distinct upper and lower sections. The upper section of the catchment is undeveloped natural bushland. From the upper section the catchment slopes very steeply down undeveloped, densely forested slopes to the lower flat "lagoon" area fronting the western shore of Pittwater.

PHOTOGRAPH 1: Study Area

The main area of interest is the lagoon area which has experienced several floods in recent times , particularly the major event in November 1987. However other floods have occurred in 1974, 1992, 1998 and 2003.

COMMUNITY CONSULTATION PROGRAM

Community involvement is important at all stages of the Floodplain Management Process. Residents' local knowledge of the catchment and personal experiences of flooding have provided an invaluable source of data to define the nature and extent of flooding at the Flood Study phase of the process. During the Floodplain Management phases where management and planning strategies are outlined, it is important to get community input and feedback to ensure proposed measures meet the needs of the local community.

During this Floodplain Risk Management Study stage, the nature of the flood hazard will be investigated with a view to undertaking management measures to reduce the existing and future flood damages.

PHOTOGRAPH 2: November 1987 Flood - 36 Monash Avenue

While the Floodplain Risk Management Study will focus on flooding issues and flood damage risks in the lagoon area, it should nevertheless be noted that the entire catchment area contributing to flows in the creek, is within the study area. In addition the study will include determining the potential increase in flooding risks due to possible increased development (vegetation, fences, bridges). **We are currently seeking your comments and suggestions on possible floodplain management and development measures with regard to minimising flood risk in Great Mackerel Beach.**

QUESTIONNAIRE

We have prepared a brief set of questions to help us identify possible floodplain management measures (see attached). If you (or anyone that you may know) can assist us, please fill out the details on the attached questionnaire and return by 31st May 2007 using the reply-paid envelope enclosed (no stamp required). With your permission (box provided on questionnaire), we may then contact you to discuss your information and to arrange for a resident interview if appropriate.

THE FLOODPLAIN RISK MANAGEMENT PROCESS

The implementation of sound floodplain management practice is an important process (Diagram 1) which can be used to optimise development potential, and to obtain social and economic benefits from the reduction in flood damages.

The first stage in the process is data collection and preparation of a Flood Study (now complete) to define the nature and extent of flooding, including establishing design flood levels. Design flood levels are levels that have a known likelihood of occurrence. For example the “100 year” or “1% event” has a 1% or 1 in 100 chance of being equalled or exceeded in any year.

The second stage is the preparation of a Floodplain Risk Management Study (FRMS) that analyses a range of floodplain management measures to address the problems and areas of concern. The third stage involves preparation of a Plan that documents how the proposed measures identified in the FRMS are to be implemented in terms of resourcing and timing. The final stage of the process is the implementation of the Plan.

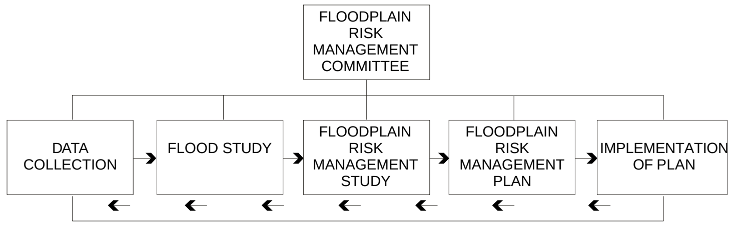


DIAGRAM 1: The Floodplain Risk Management Process

THE FLOOD STUDY (Stage 1)

The Flood Study involved a comprehensive technical investigation of the existence, nature and extent of flooding within the lower lagoon area. Computer modelling of the catchment was undertaken to determine flowrates in the creek for storms of varying severity (hydrologic modelling). These flowrates were then used to determine corresponding water levels, velocities and flood extents (hydraulic modelling). Available historical data was used to ensure that the flood behaviour from these models replicated historical flood behaviour.

The key objectives of the Flood Study were to:

- define the flood behaviour of the water course and its associated floodplain,
- identify the hydraulic category (floodway, flood storage or flood fringe) and hydraulic hazard category (high hazard or low hazard) for flood prone land,
- develop hydrologic and hydraulic models of the catchment that can be used to assess the impact of development and mitigation options during the Floodplain RiskManagement Study phase.

THE FLOODPLAIN RISK MANAGEMENT STUDY (Stage 2)

The Flood Study provides a technical basis from which the Floodplain RiskManagement Study is developed.

PHOTOGRAPH 3: November 1987 Flood - Monash Avenue

The objectives of the Floodplain Risk Management Study are to:

- manage flooding as an integral part of the planning and development process,
- systematically identify and address flooding problems,
- prepare a schedule of strategies to manage the existing flood problem and reduce future flood damages,
- ensure sustainable development principles are achieved,
- maintain and enhance the quality of the lagoon area,
- ensure community participation in the decision making process.

MANAGEMENT MEASURES

The possible floodplain management measures to be considered in the Floodplain Risk Management Study address the various problems that may be categorised under the following headings.

- **Flood Modification** - structural works to modify flood behaviour - (e.g entrance works)
- **Property Modification** - modifies buildings and land uses - (e.g house raising)
- **Response Modification** - planning, education and awareness measures that aim to modify the community's response to the flood hazard - (e.g flood warning)

Flood modificationmeasures may be found that reduce future flood damages and the risk to life. However the value of these measures needs to be weighed against any possible adverse environmental, social or economic effects. The works need to compliment rather than detract from the objectives of any community based environmental program such as Rivercare or Bushcare or similar such works. In addition to potential flood modification measures, it is also possible that property modification measures may be necessary to address existing encroachments and development in the floodplain. Response modification measures may also be appropriate to minimise future flood damages.

SECTION 149 CERTIFICATE

The end objective of the Floodplain Risk Management Plan is to reduce the risk to life and damage to property. One outcome from this process is the creation of Section 149 certificates to advise residents that flood related development controls pertain to their land.

Councils issue Section 149 certificates under the Environmental Planning and Assessment Act. The function of the certificates is to inform current owners and potential purchasers of planning controls and policies that apply to the subject land. This may include controls relating to all natural hazards including bushfire, landslide, flood, earthquake, subsidence and others.

PHOTOGRAPH 4: November 1987 Flood - 65 Monash Avenue

Pittwater Council has already determined the Flood Planning Level (FPL) as the 100 year flood (1% probability of occurrence in any one year) plus a freeboard of 0.5m. All residential zoned properties with any part of the land below the FPL will be subject to flood related development controls. For Great Mackerel Beach the controls are principally that any new house must be built with a floor level above the FPL. This mechanism means that when redevelopment occurs and a new house is built the house will be at a high level and thus rarely inundated.

The November 1987 flood at Great Mackerel Beach was approximately a 100 year event but unfortunately floods larger than this will occur. These are obviously very rare floods but they have occurred in February 1984 at Dapto and in November 1996 at CoffsHarbour.

NSW Government
DEPARTMENT OF NATURAL RESOURCES

Great Mackerel Beach Floodplain Risk Management Study
RESIDENT QUESTIONNAIRE – May 2007

Your response to this questionnaire will help Council and the consultants with the preparation of a Floodplain Risk Management Study and Plan for Great Mackerel Beach. To help us collate relevant data for this investigation, please mail the completed questionnaire by 31 May, 2007 using the prepaid self-addressed envelope provided.

Contact Details *(Please note that the return of the completed questionnaire is voluntary and any personal information included in the questionnaire will be subject to the Privacy and Personal Information Protection Act 1998. This information will only be used as an input into the Great Mackerel Beach Floodplain Risk Management Study & Plan). Do you give permission to be contacted (if required) directly by the consultants?* ❒ Yes ❒ No

Contact name: ___________________________ Address: ________________________

Tel No: ___________________________ Email : ________________________

Flooding Related Information *(Please tick relevant boxes)*

1. When did you first live in or own this property? ________ *(year approximately)*

❒ owner occupied and property is permanently occupied ❒ occupied by a tenant ❒ not occupied on a permanent basis

2. Have you ever experienced a flood? ❒ Yes ❒ No _____________________ *Please provide the dates*

❒ inundated yard ❒ inundated house ❒ the creek broke its banks

3. Have you ever experienced inconvenience or damage to your property as a result of flooding? ❒ Yes ❒ No

❒ damage to house structure ❒ damage to house contents ❒ yard damages ❒ evacuated house ❒ other way

____

____

____ *Please provide other details*

4. When you moved into the area did you ever consider flooding as possibly adversely affecting your property?

❒ Yes ❒ No ____

____

____ *Please provide some details*

5. Have you changed your views regarding the impact of flooding since living in the area or even as a result of this Questionnaire?

❒ Yes ❒ No ____

____

____ *Please provide some details*

6. Have you ever recieved information about flooding at Mackerel Beach? ❒ Yes ❒ No

❒ Council's web site ❒ Council's Customer Service ❒ other information from Council (please specify)_________

❒ other residents ❒ friends elsewhere ❒ Council's Property Planning (Section 149) Certificate

❒ experienced a flood myself ❒ other (please specify) ___________________________

7. What is the best method to get input and feedback regarding this study?

❒ Council's web site ❒ Council's Customer Service ❒ directly from the consultants

❒ Manly Daily ❒ mail out to residents ❒ Council's Land, Water and Coastal Portfolio Committee

❒ formal Council meetings ❒ community meetings ❒ Council's Community Working Group

Contact details: Ella Thomason : Webb, McKeown & Associates Pty Ltd
L2/160 Clarence Street, SYDNEY NSW 2000 Ph: 9299 2855 Fax: 9262 6208 email: thomason@webbmckeown.com.au

Views On Possible Floodplain Management Measures

There are a range of possible floodplain management measures available in the entire catchment area to minimise the effects of flooding within the area. These include construction of raised banks (levees) to divert floodwaters away from property, construction of retarding basins in the upper catchment to reduce the amount of runoff entering the creek system, widening or dredging the existing channel, enlarging the entrance, upgrading culverts and bridges, concrete lining the channel, raising house floors, voluntary purchase of buildings and several others.

We are seeking your views on the above or any other measures that you feel would be appropriate. However you should be aware that each measure will be evaluated in terms of the economic, social, environmental and flooding benefit and disbenefit. Thus a measure, such as widening or enlarging the entrance, may not qualify for inclusion in the Management Plan if it causes significant environmental damage. Other measures may be rejected as cost prohibitive (possibly dams).

However please do not feel constrained and express your views as you feel appropriate. Each view WILL be addressed in the study and you can be assured that there will be NO linkage between the name of the proponent and the measure.

____

____

____

____

____

____

____

Views On Hydraulic Impacts Of Further Development On The Floodplain

Apart from examining measures that minimise the effects of flooding, the study will also examine the development potential of the floodplain and how these works may affect flood behaviour. Will future development increase the risk of flooding, by raising flood levels or diverting floodwaters elsewhere, and/or will development adversely affect water quality, sedimentation or erosion? Should development (fences, local bridges, vegetation, house location) be restricted to take these issues into account?

We seek your views in this regard.

____

____

____

____

____

____

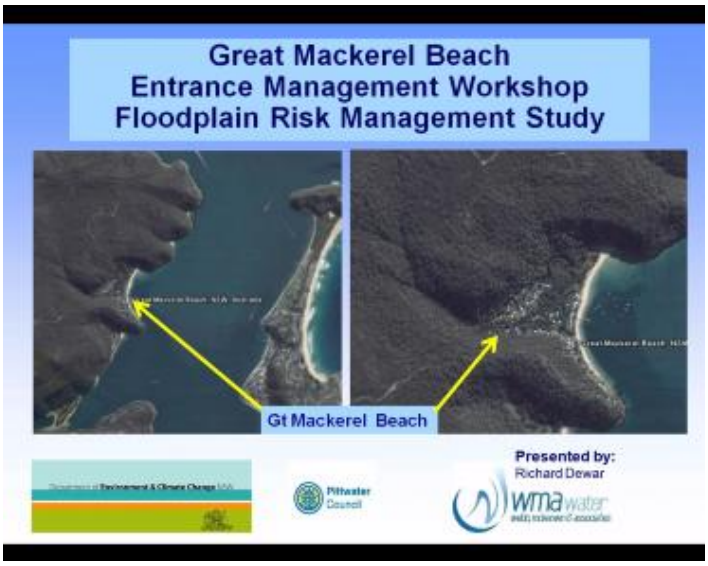
____

Appendix D

APPENDIX D: ENTRANCE MANAGEMENT WORKSHOP

D1. INTRODUCTION

As part of the Floodplain Risk Management Study a workshop was held on 30th July 2008 to present the study findings to key stakeholders and in particular to discuss an entrance management program (EMP) as a means of reducing flood levels at Great Mackerel Beach. This Appendix summarises the Powerpoint slides presented at the Workshop.



Slide 1 indicates the relatively isolated nature of the study area and thus the difficulty in providing assistance prior to or during a flood and possibly even within several hours after the event. There is also no safe helicopter landing pad, although a winch rescue would be possible.

D1.1 STUDY AREA

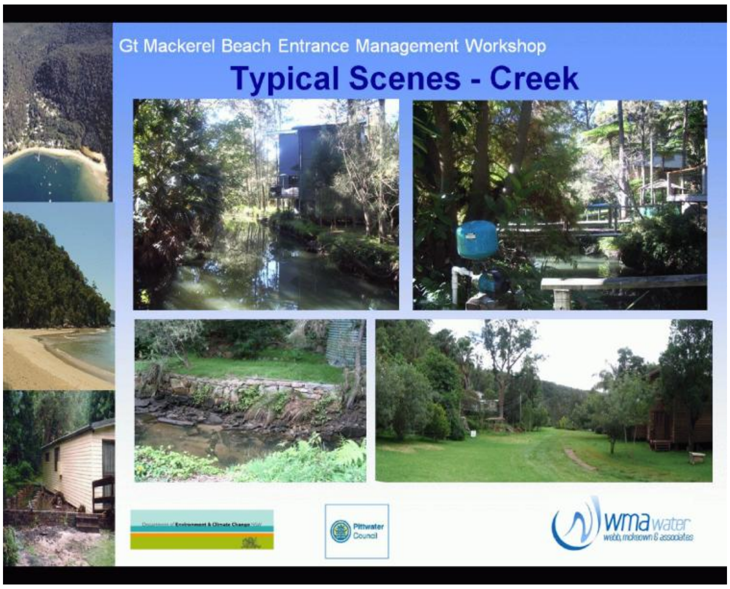
D1.2 General

An overview of the study area is listed on Slide 2. This shows that the mouth of the creek is on land within the National Park. It is important to note that there is currently no machinery on site, or a storage area to house machinery such as an excavator that may be required for an EMP. Access is only available by water.

Slide 3 lists the main reasons for the workshop. Entrance management is perhaps the only practical management option available to reduce flood levels and has been undertaken in the past. Levee protection is not suitable for the area and whilst some houses could be raised many are not suitable.

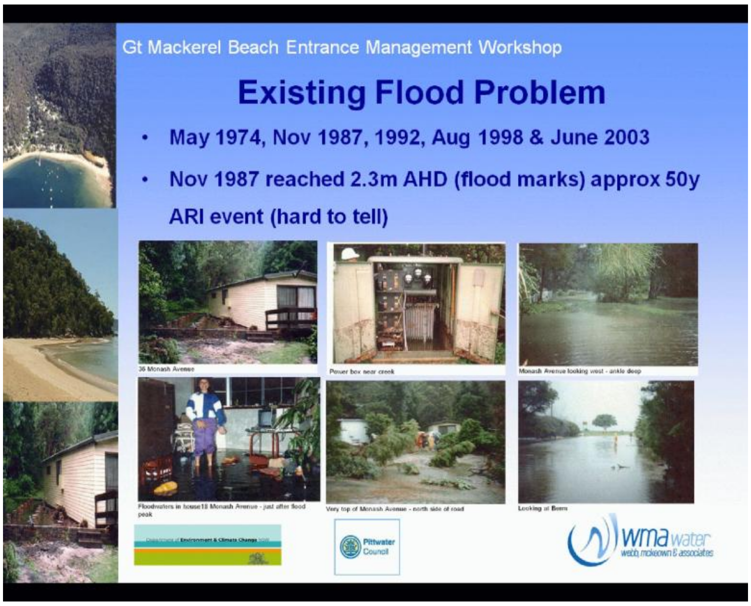
D1.3 The Flood Problem

Slide 4 shows typical images of Mackerel Creek which runs through the centre of the community. It is typically 1 m deep and 3 to 4 m wide. Nuisance flooding is common for certain properties within the riparian zone. Buildings and other structures (bridges) in the riparian zone produce additional problems by reducing the creek conveyance, and increasing the likelihood of blockage.



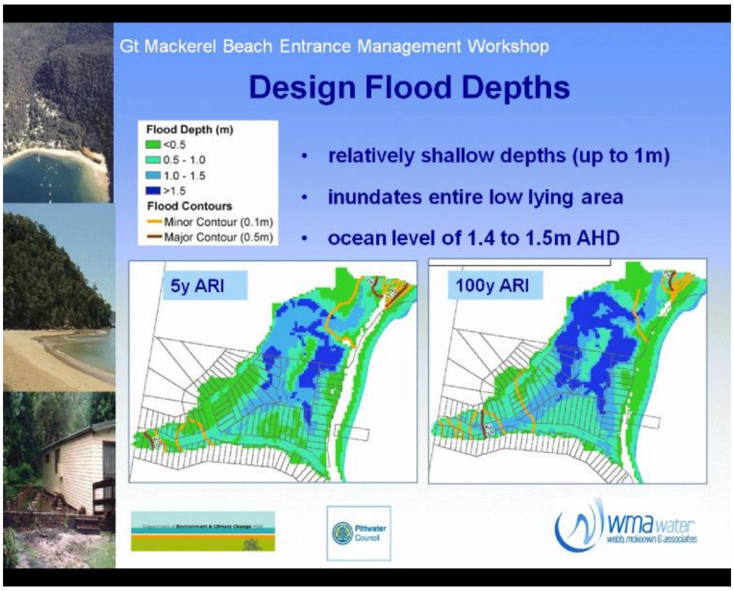
Images of the creek entrance are shown in Slide 5. North of the entrance is a steeply vegetated hillside. The flow area for discharge is wide (up to 50 m) and shallow due to the significant sand build up. At the time of the photo in May 2007 the entrance was open to the Pittwater, though this is not always the case.

There is a recorded history of flooding since 1974. Slide 6 shows images of the November 1987 flood (approximates a 50y ARI event and the largest recorded) and lists other key flood events.

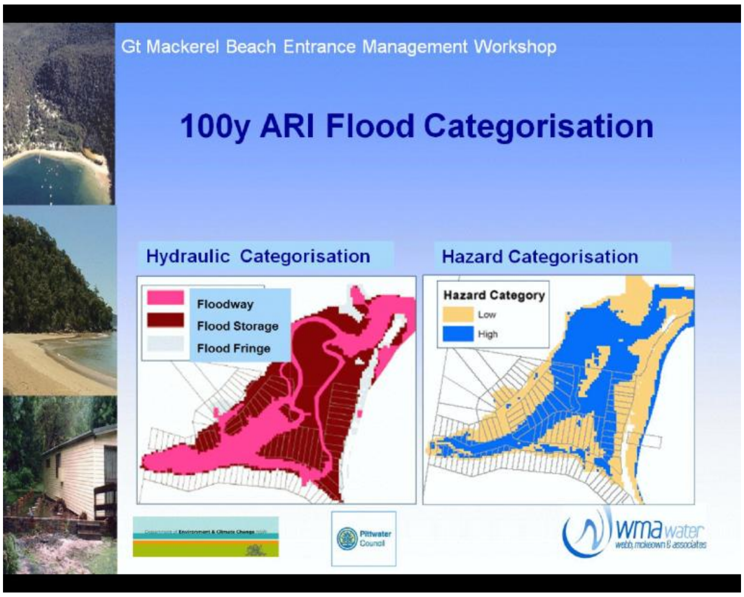


D1.4 Design Floods

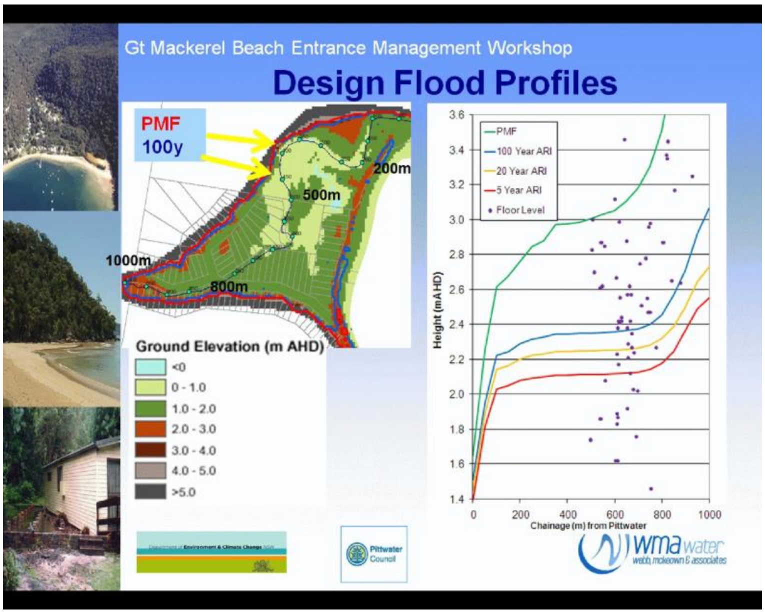
The Great Mackerel Beach Flood Study determined flood levels for the 5y, 20y, 50y, 100y ARI events and the PMF. Slide 7 shows the design flood depths for the 5y and 100y ARI events. The nature of flooding is largely insensitive to the ocean tide and is primarily influenced by the height and dimensions of the beach berm at the entrance.



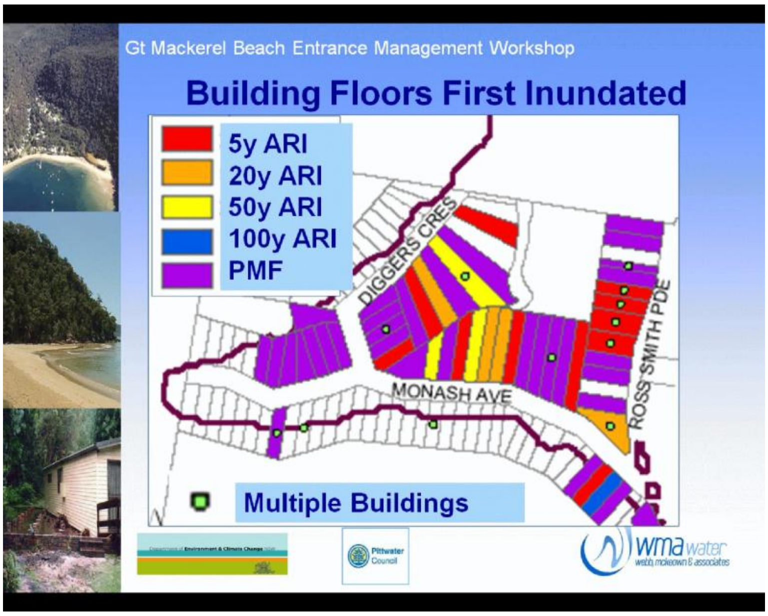
The location of the 100y ARI floodway is shown on Slide 8 as well as the hazard categories. Buildings should generally not be built in high hazard areas.



Ground elevations within the study area are shown on Slide 9. It can be seen that the majority of the ground is less than 2 mAHD and is surrounded by relatively steep sides. This means that the lateral extent of flooding is practically indistinguishable between the range of design flood events.

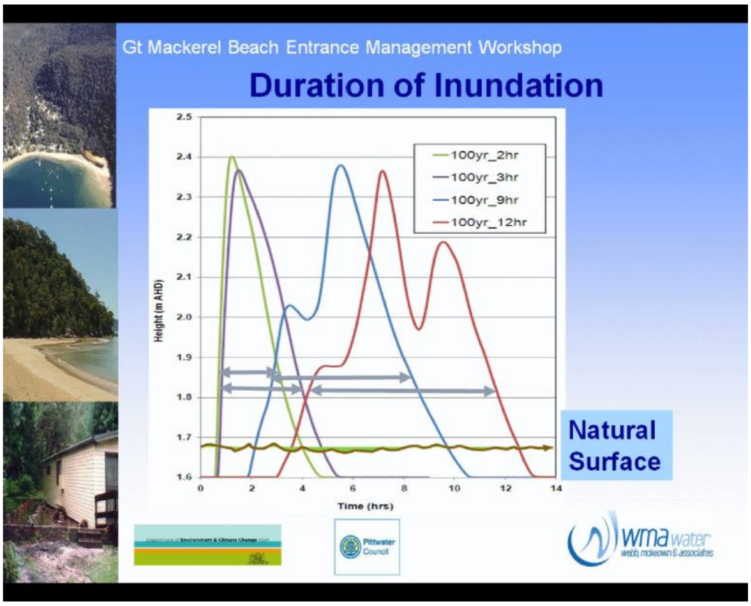


Slides 9 and 10 show the buildings which are flooded above floor level by the various ARI design events. A significant number of buildings are shown to be inundated by even the 5y ARI event.



It should be noted that several properties have multiple buildings (granny flats) and this accounts for the difference between the number of building floors inundated on the two slides.

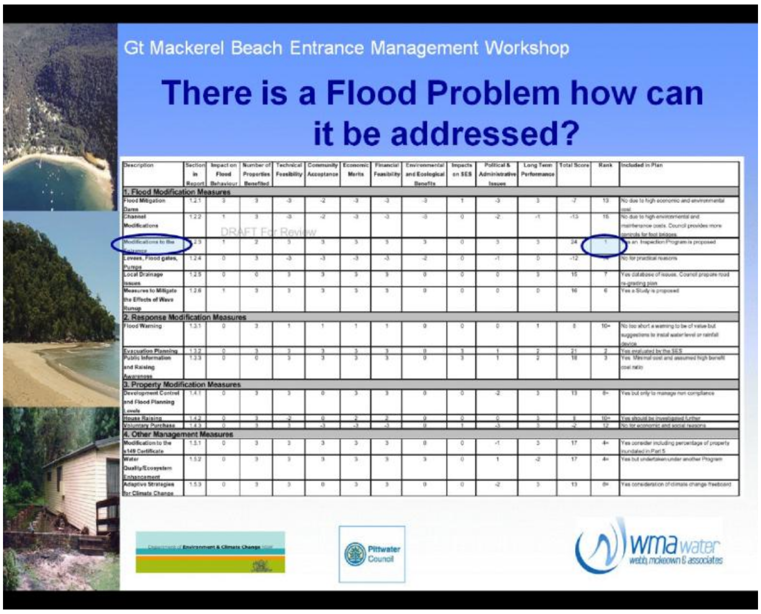
The critical (produces the highest flood level) 100y ARI design storm duration is 2 hours. The design hydrographs at chainage 700 for a range of durations are shown on Slide 11 and indicates that the peak flood level varies by less than 0.05 m for durations ranging from 2h to 12h. This means that the duration of overbank flooding could extend from 2 to over 8 hours depending on the duration. This situation of several design flood durations producing similar peak levels is due to the lagoon and entrance berm topography in the lower floodplain.


Gt Mackerel Beach Entrance Management Workshop
Duration of Inundation
Height (m AHD)
Time (hrs)
100yr_2hr
100yr_3hr
100yr_9hr
100yr_12hr
Natural Surface
Pittwater Council
wma water
webb, mckeown & associates

D2. ENTRANCE MANAGEMENT

D1.1 Introduction

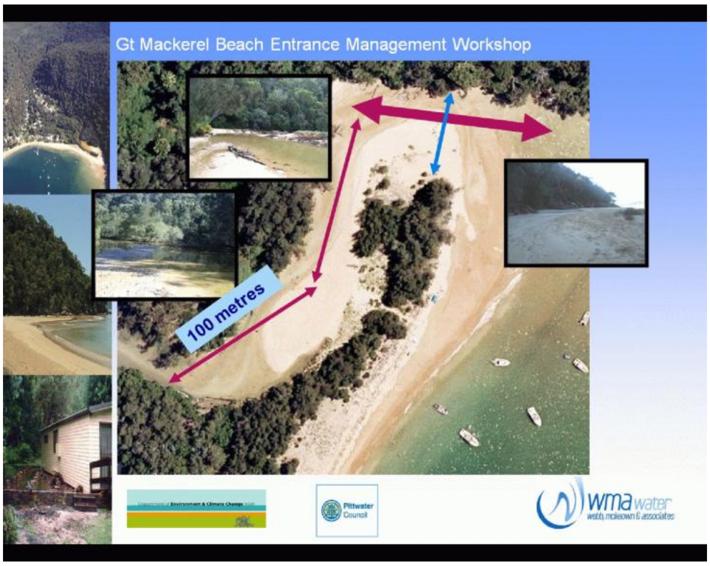
Possible management of the entrance was previously identified by a decision matrix as the optimal means of addressing the flood problem (Slide 12).



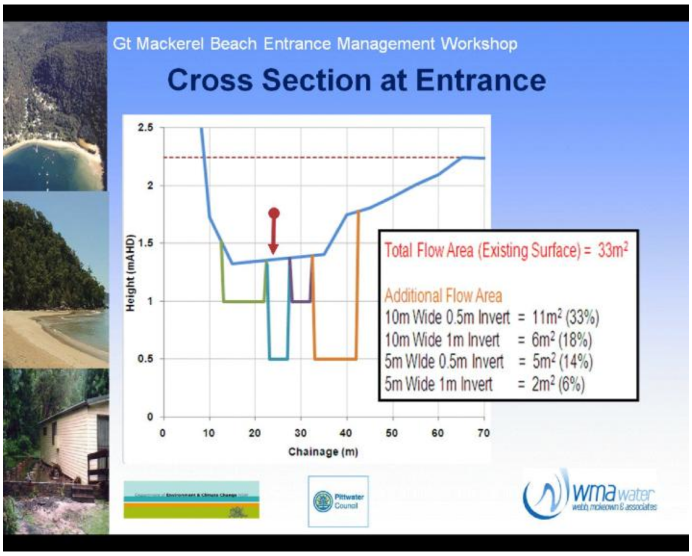
Slide 13 raises questions that need to be addressed when considering an EMP. An ocean level rise due to climate change should also be considered as part of any investigation to ensure the long term viability of any EMP.

D1.2 Modelled Entrance Management Results

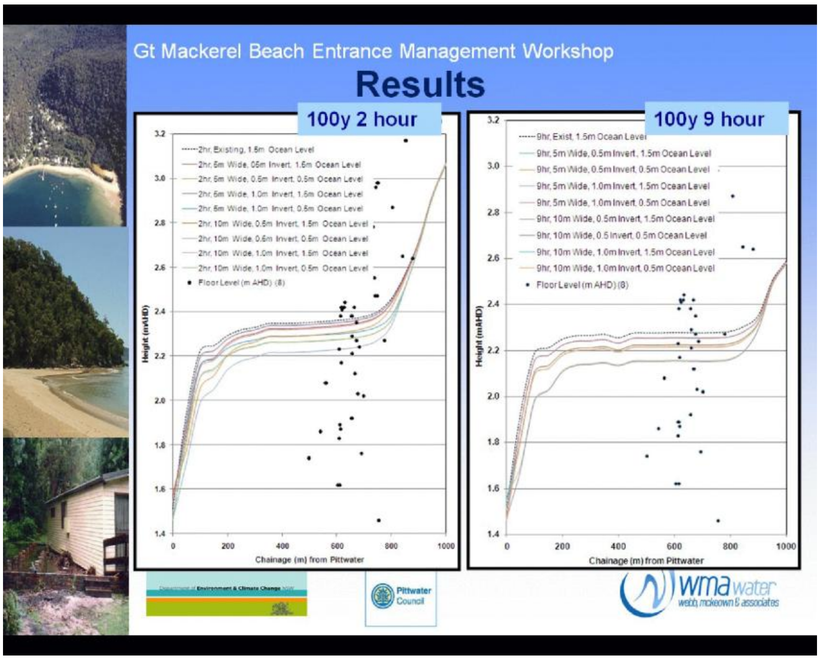
The hydraulic model established for the Flood Study was used to simulate a 100 m long trench as shown by the bold red line in Slide 14. The additional 200 m section of sand upstream of the trench is actively moving. This dynamic section would need to be monitored as part of any EMP and it may be that a 300 m length of sand will be required to be excavated.



To determine the relative impacts on flood levels of a 100 m excavated trench as part of an EMP, four configurations were modelled (shown in Slide 15). The additional flow area for each configuration is also shown on the slide. The cross-section shown in Slide 15 is taken along the blue line in Slide 14. It should be noted that the centre of the four configurations was aligned with the red arrow on Slide 15.



Slide 16 shows the model results and indicates that at best the flood profile is reduced by 0.1 m at Chainage 700 if a 100 m long, 10 m wide trench with an invert of 0.5 mAHD was excavated. Approximately 1 house floor would become flood free in the 100y ARI event with this option (though all other inundated buildings would have reduced above floor depths).

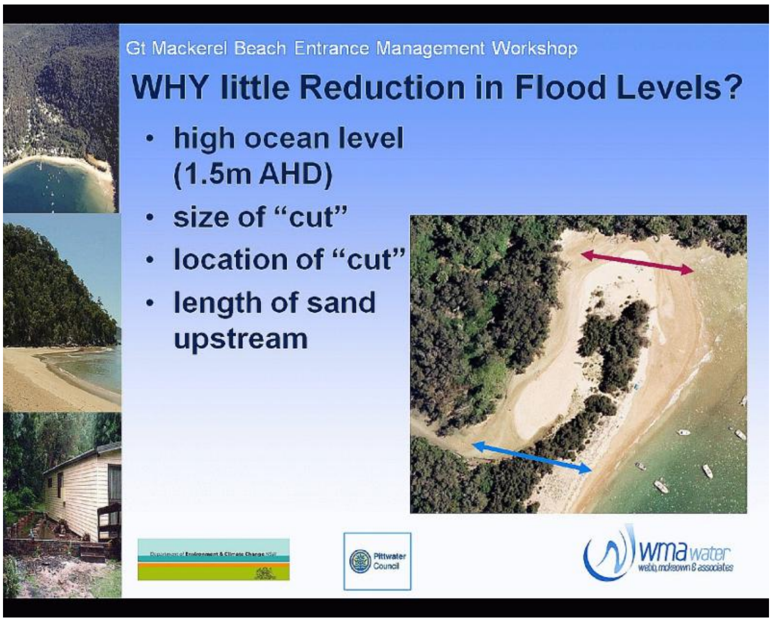


If this option is pursued it would be necessary to analyse the full range of design events. The results for the 100y ARI event indicate that assuming a lower ocean level (0.5 m rather than 1.5 mAHD) slightly increases the benefit of the works.

A cost/benefit ratio for these types of works has not yet been determined.

D1.3 Discussion of Modelled Results

Slide 17 identifies that the key reasons why such a little reduction in flood levels is attainable from the modelled entrance management works is due to the location of the excavated trench (red line). The blue line represents an alternate trench route which would offer greater hydraulic efficiency and hence achieve a greater reduction in flood levels. It is noted that the beach berm north of the blue line was artificially developed following the November 1987 flood.

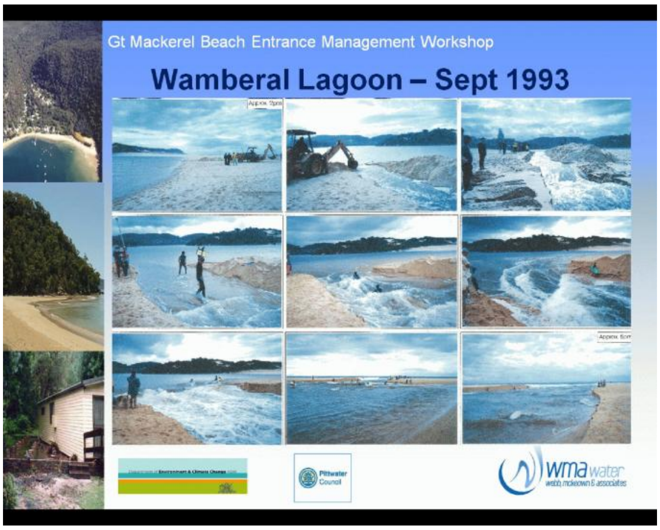


D3. DISCUSSION OF OTHER ENTRANCE MANAGEMENT PROGRAMS

There are many Intermittent Closing and Opening Lakes and Lagoons (ICOLLs) in NSW. Slide 1 lists numerous ICOLLs which employ successful EMP's.

Slides 19, 20 and 21 show time series photographs of ICOLLs that have been opened as part of an Entrance Management Policy. Key differences between Great Mackerel Beach and many ICOLLs are the size of upstream catchment and the time to fill the lagoon. Great Mackerel Beach has a relatively small catchment area which results in a short critical duration (2 hours), the lagoon additionally has a small (relatively) storage volume so the response time to undertake an EMP is critical.

The SES response time to Great Mackerel Beach with a suitable excavator would be 6-8 hours if a barge was available. If on-site storage of an excavator is available a permanent resident would be required to operate the excavator (licence and OH&S are required).

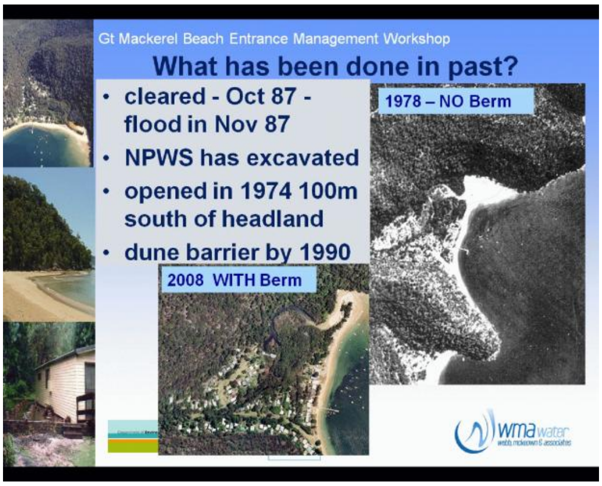

Gt Mackerel Beach Entrance Management Workshop
Wamberal Lagoon – Sept 1993
Pittwater Council
wma water
webb, mckeown & associates


Gt Mackerel Beach Entrance Management Workshop
Smiths Lake – Nov 2006
Pittwater Council
wma water
webb, mckeown & associates

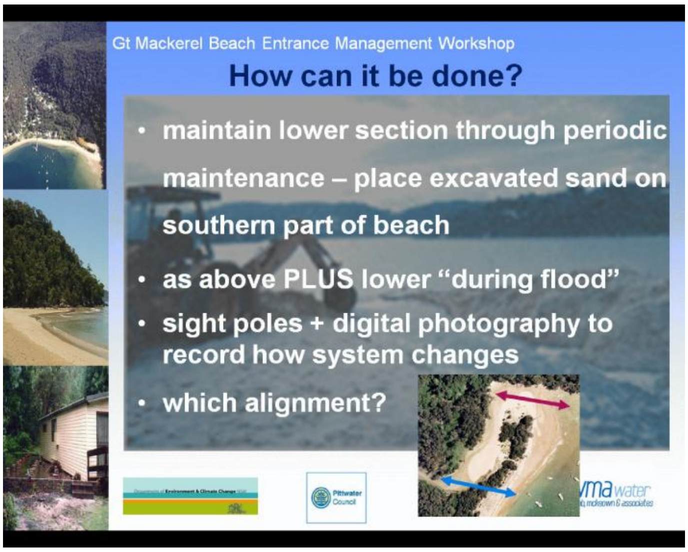

Gt Mackerel Beach Entrance Management Workshop
Terrigal Lagoon – August 1993
Artificial Opening of Terrigal Lagoon 5 August 1993
Lowered entrance berm before a channel was cut.
Bulldozer excavates a channel in the berm.
A narrow channel is eroded as outflow occurs.
The channel widens to its full width.
Pittwater Council
wma water
webb, mckeown & associates

D4. CONCLUSIONS

There are still many unknowns regarding the natural state of the entrance at Great Mackerel Beach. These need to be investigated prior to implementing an entrance management program. Slide 22 shows an aerial photograph taken in 1978 compared to a recent photograph. Clearly there has been significant evolution of the berm and seagrass cover. An investigation of all the available historic aerial photographs is required, particularly in determining the dynamic nature of the berm and to assess the possible ecological impact on seagrasses.



An EMP has been undertaken in the past. In October 1987 the entrance was opened just prior to the November 1987 flood. Following this event the present berm was formed in 1990. An EMP could be achievable if the cost benefit ratio was acceptable. Initially it is necessary to employ a monitoring program to understand the dynamic nature of the entrance more thoroughly. Possible strategies are shown on Slide 23 and include sight poles to observe the beach berm height, a rain gauge to record local rainfall and a water level recorder in the creek. Climate change should additionally be considered to ensure the long term viability of any EMP. Some form of mechanical opening is required if the berm built up to say 1.5m AHD, otherwise in even a modest rainfall event floodwaters would pond to this level and inundate houses floors.



D5. REVIEW OF AERIAL PHOTOGRAPHY

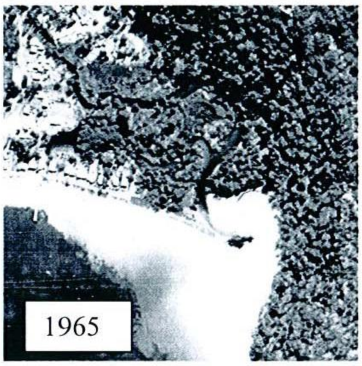
DECC provided the following interpretation of aerial photography at the entrance.

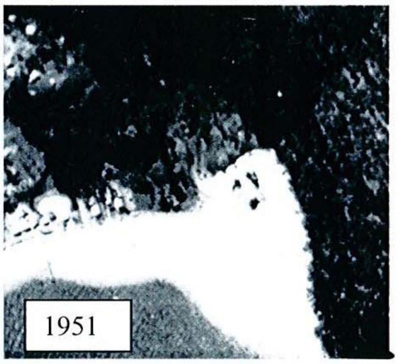
Mackeral Beach Lagoon – DECC Aerial Photograph Analysis and Comments on Changing the Entrance Channel Alignment

Aerial Photo Interpretation

The 2006 photo shows the current alignment of the entrance channel meandering around the man made vegetated spit and alongside the northern ridge. Although this spit was not vegetated prior to the 1990 photo, the historical aerial photos show that it was not unusual for the channel to have the same meandering alignment as currently (e.g. 1990 aerial).

It is also apparent that the spit has been previously vegetated in the past (e.g. 1965 photo), which the entrance channel meandered around. Some spit vegetation is also evident in the 1951 photo. It is not known whether this was also planted or natural regrowth.

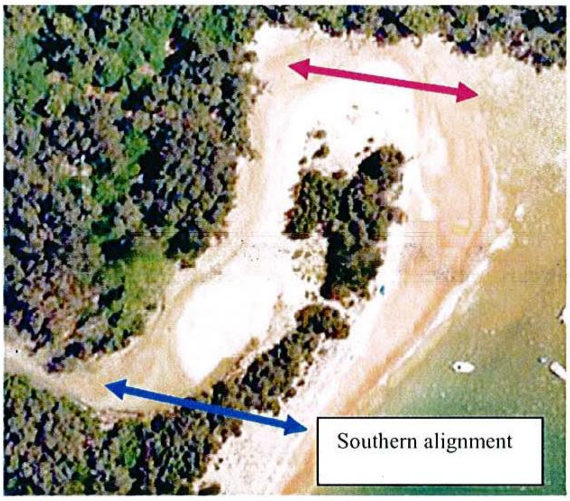




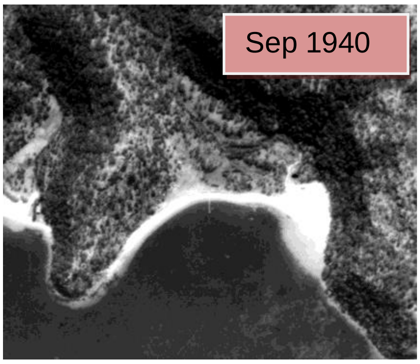
There are no available aerial photos that show the entrance channel alignment coming straight out through Mackeral Beach to Pittwater (as apposed to bending to the north and then following the ridge back to the Beach). However, it is possible that the entrance channel may have migrated over the length of the spit area.

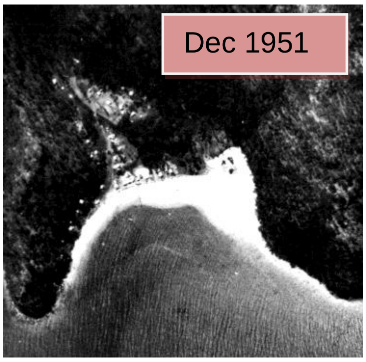
Entrance Channel Alignment – Human Intervention

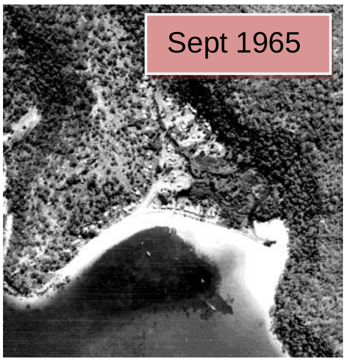
If the entrance channel was made to have an alignment straight through to mackerel beach (southern alignment) through intervention (as proposed as one option in the Great Mackerel Beach Floodplain Risk Management Study and Plan by Webb, Mckeown in 2008) then it is very likely that sand accumulation in the entrance channel would still continue to be a problem. Marine sand would move into the new alignment on the flood tides when the entrance is open and eventually the build up would create a similar problem to that experienced now with a sand accumulation over a long length of the entrance channel. In addition, the dominant position of the entrance channel appears to be the current alignment so intervention would likely need to be ongoing to keep the entrance channel in this position or through structural training works.

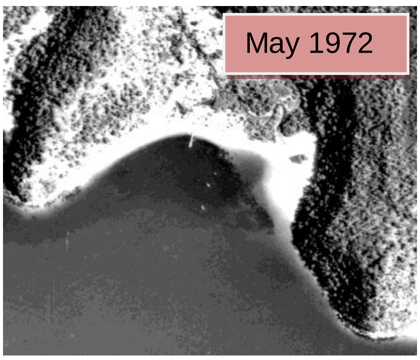


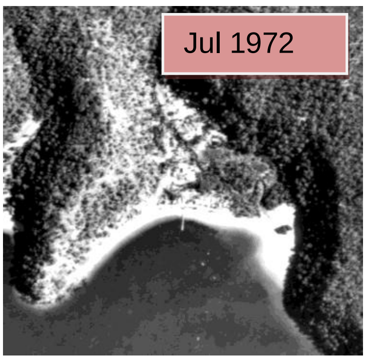
The following provides a historical photographic record of the entrance conditions at Great Mackerel Beach.

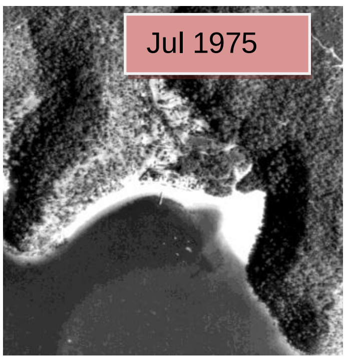


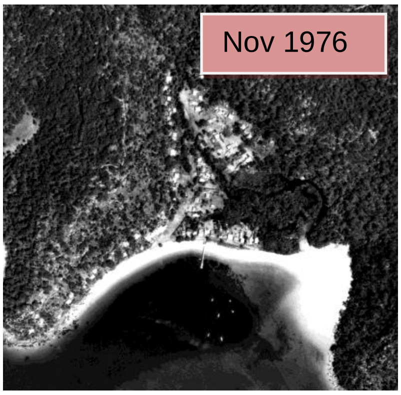




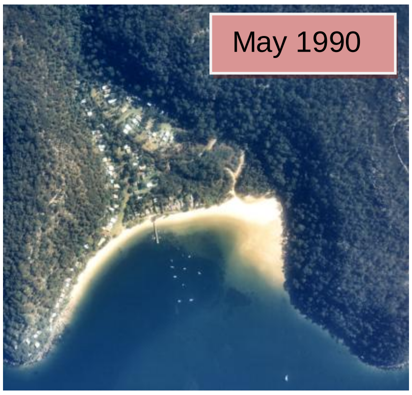







Nov 1976


Aug 1986


May 1990


Apr 1993


May 1996


May 1999


Sept 2001


May 1999

D6. MINUTES OF MEETING of 30th JULY 2008

GREAT MACKEREL BEACH FLOODPLAIN RISK MANAGEMENT STUDY
MINUTES - ENTRANCE MANAGEMENT WORKSHOP - 30th JULY 2008

Attendees:
Chris Hunt (Chair - Pittwater Council) - CH
Richard Dewar (WMAwater) - RD
Bowen Hicks (WMAwater) - BH
Daniel Wiecek (DECC - Estuary Management) - DW
Warren Lewis (Community Representative) - WL
Natasha Funke (National Parks & Wildlife) - NF
Chris Grudnof (National Parks & Wildlife) - CG
Paul Davies (Pittwater Council) - PD
David Avery (DECC) - DA
James Sakker (DPI - Fisheries) - JS
Mark Beharrell (Pittwater Council) - MB
Sue Ribbons (Pittwater Council) - SR
Apologies:
Bob Mitchell (Community Representative and Great Mackerel Beach Fire Brigade)
George Sheppard (Rural Fire Service)
Bernard Kates (State Emergency Service)

INTRODUCTION
The workshop was used to discuss flooding issues identified in the Draft Great Mackerel Beach Floodplain Risk Management Study and review possible entrance management measures. Key issues and actions identified by each of the stakeholders are listed below with a summary of the discussions following.

KEY ISSUES AND ACTIONS
DPI Fisheries
- Concerned about the impact upon seagrass cover from any entrance management program, this should be addressed before implementation of such a program.

Pittwater Council
- No specific issues identified.

Department of Environment and Climate Change
- Noted the merits process for funding and the need to examine the full range of design floods and not just the 100yr ARI flood.
- Expensive entrance works are unlikely to receive funding.
- DECC offered to review historic aerial photographs to help understand the dynamic nature of the beach berm.

National Parks and Wildlife Services

- In principle no objection to an entrance management program if it is done in conjunction with relevant planning controls.
- Generally supportive of an EMP and have assisted in past with removal of material at the entrance.
- Bush regeneration around the spit was highlighted as an important project as it helps to stop the spread of household weeds into the rest of the park.

Community

Request for the following works to conducted:

- verification of flood modelling through community consultation,
- determine source of road flooding,
- examine creek dynamics with a view to local mitigation works,
- collect rainfall data,
- establish sight poles and review aerial photographs,
- establish emergency response procedure,
- review dynamics of creek behind entrance barrier,
- environmental review _ present state, potential effects,
- alternate definition for property flood affectation,
- undertake a community consultation program.

SUMMARY OF DISCUSSION

- The only way to reduce flood levels at affected buildings is an entrance management program (RD).
- Caution should be taken when implementing any management measures to reduce flood levels as if the measure fails Council may be liable (RD).
- The entrance is a very dynamic system and the sand moves frequently (WS).
- DECC could review historic aerial photographs to help understand the dynamic nature of the sand at the entrance (DW).
- (DA) questioned the sediment erosion mechanisms at the berm and whether it should be included in the model.
- Based on model results the velocities at the berm are relatively low (approx 1 m/s), hence scouring is not significant (RD).
- The number of building floors that become flood free under the modelled entrance management scenario in the 100y ARI event is small. (JS) considered that this would have a low Benefit/Cost ratio.
- In the 1987 storm there was a breakaway across the berm to the south (WS).
- The present berm to the north was developed artificially (RD).
- Lengthening of the creek (from artificial berm development) would have changed its properties (DW).
- The berm has migrated west since construction (WS).
- Recommended that at least monitoring of sand levels using sight poles undertaken (RD).

- Localised flooding could possibly be prevented by creek works. Possibly by raising bank levels at low points. Maintenance of this nuisance flooding by increasing the efficiency of the creek may help flush the berm (WS).
- Levee protection or bunding of houses are other measures to mitigate inundation of the few houses that would benefit from the entrance management? This would require a single payment rather than ongoing payments (JS).
- The only way to reduce flood levels is by an entrance management program, a few houses are suitable for raising (RD).
- The dynamics of the creek are unknown. How often is the lagoon open? Is it tidal? How would an entrance management program affect the salt marsh? A preliminary study should be conducted for the management plan. A desktop study is proposed primarily using historic aerial photographs (DW).
- A water level recorder has been installed at Bundeena (Sutherland) and a similar recorder could be placed at Great Mackerel Beach (DW).
- Smaller more frequent flood events should be considered for Cost Benefit analysis of any works, not just the 100y ARI flood (DA).
- Establish new berm overtopping points (to the south of existing), even if only as a spillway for major events (CH).
- Establishment of the southern berm overtopping point would be restoring the creek to its natural state (DW).
- NPWS has twice opened the berm with a bob_cat in the last 10 years when requested by Council (CG).
- Best available SES response time would be 6 to 8hrs (PD).
- Do residents understand that even with the modelled entrance management measures floodwater would still inundate over half the affected building floors (CG)?
- Changes to the entrance could change the seagrass beds. This has already been demonstrated by the aerial photographs from 1978 to present with construction of the berm (JS).
- Roads could be re-graded to prevent nuisance flooding (RD).
- There is a false community perception that council intervention (opening the berm) could have prevented previous flood events (MB).
- Information detailing difficulty in bringing in earth moving machinery on a barge, the requirement for a large earth moving machinery and the low benefit (in terms of lowering the flood level) of entrance management should be outlined to the community (WL).
- NPWS are not opposed to an entrance management program (CG).
- Earthworks as part of an entrance management program must not exacerbate the existing climbing asparagus weed problem (NF).
- Flood awareness is the most cost effective solution (RD).
- (WS) offered to internally review/distribute any flood awareness pamphlet.
- Installation of a rainfall gauge is a cost effective way to gain local rainfall data (SB).
- 100 year protection is not necessarily required to get funding for works (PD).
- If a seminar is presented to the community it should be held Oct/Nov when most of the

residents are present (WS).

- A large excavator is required to create a pilot channel and it would take some 6 hours to arrange a barge and get the excavator to the site (assuming an excavator is available and there are no other logistical issues). It is not practical or economic to have machinery permanently at the site (SR).
- Scheduled maintenance of the entrance berm is possible (as occurs at Narrabeen lagoon or Terrigal Lagoon) but may be costly (SR).
- Mention was also made at the workshop of installation of a rainfall gauge in the upper catchment and resolution of local drainage issues (SR).
- There are existing studies which detail the primary sediment transport paths in the Pittwater.