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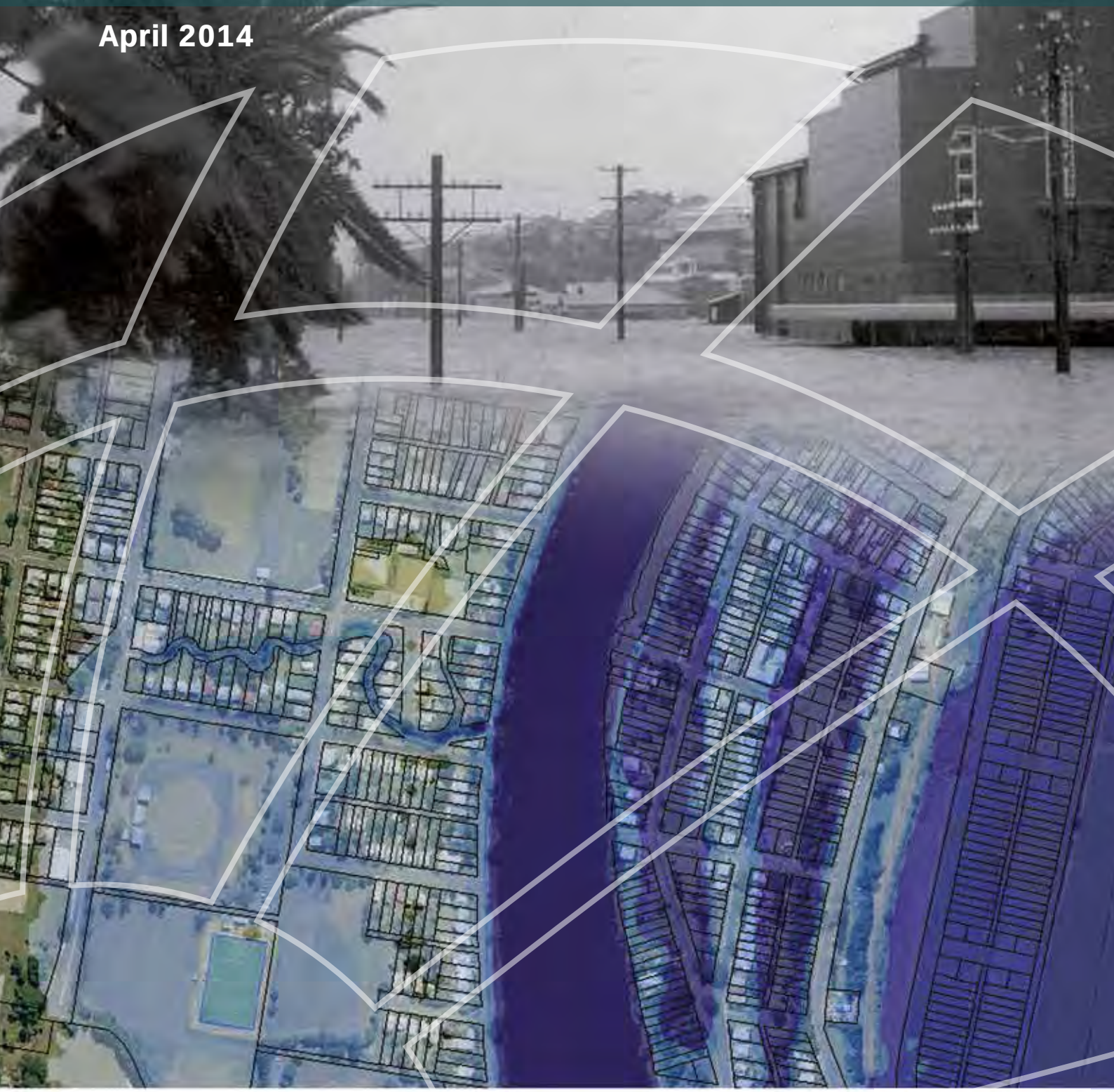
TWEED VALLEY FLOODPLAIN RISK MANAGEMENT STUDY

FINAL POST EXHIBITION DRAFT

April 2014



TWEED SHIRE COUNCIL

Tweed Valley Floodplain Risk Management Study (FINAL POST EXHIBITION DRAFT)

Prepared For:	Tweed Shire Council
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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DOCUMENT CONTROL SHEET

BMT WBM Pty Ltd

BMT WBM Pty Ltd
Level 8, 200 Creek Street
Brisbane 4000
Queensland Australia
PO Box 203 Spring Hill 4004

Tel: +61 7 3831 6744
Fax: + 61 7 3832 3627

ABN 54 010 830 421

www.bmtwbm.com.au

Document :	R.B16879.017.04.FRMS.docx
Project Manager :	Sharon Wallace
Client :	Tweed Shire Council
Client Contact:	Danny Rose
Client Reference	

Title :	Tweed Valley Floodplain Risk Management Study (COMMITTEE ENDORSED DRAFT)
Author :	Carrie Dearnley, Sharon Wallace, Melissa Hovey, Drew Bewsher, Paul Grech
Synopsis :	Floodplain Risk Management Study summarising assessment of measures considered for the Tweed Valley (COMMITTEE ENDORSED DRAFT).

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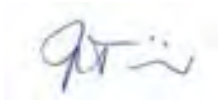
2	2 October 2013	DRAFT		SAW	
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EXECUTIVE SUMMARY

This Study draws together a wide range of floodplain management options which have been investigated as part of the Tweed Valley Floodplain Risk Management Study. These options have been identified through extensive consultation with agencies including Tweed Shire Council, the State Emergency Service (SES) and the Office of Environment and Heritage, as well as consultation with the community, industry and the Bureau of Meteorology.

Each option was investigated to determine the likely impacts to safety, the environment, property, social issues, and hydraulic behaviour. Where possible, the economic cost and benefits of implementing each measure was also estimated. This document summarises the existing flood risk, describes relevant benefits and constraints to various floodplain management measures, and considers the planning and development issues associated with a region facing significant development pressures.

Existing Flood Risk

The Tweed Valley study area has a long history of flooding and will continue to flood in the future. The extent, behaviour and likelihood of future flooding were assessed through the Tweed Valley Flood Study Update (2009) and that information was used in this study to determine the current flood risk. There was found to be a high level of flood risk in the study area.

There is a considerable number of people and properties located in flood prone land (within the Probable Maximum Flood (PMF) extent), including a large number at risk in the 100 year Average Recurrence Interval (ARI) flood. Flood depths and flows are of a dangerous magnitude in many locations and flood waters can rise quickly, often with short warning periods. This can pose a high risk to personal safety and has the potential to cause extensive damage to properties and infrastructure. A large number of major roads are affected by flooding and would constrain the evacuation process.

Estimated population currently in flood prone land: ***41,500 people***

Estimated Average Annual Damage (AAD) due to current flood risk:
$22.5 million

The community is also recognised to be highly vulnerable to the impacts of flooding. In general, the population is older than other areas of the state, there are often a large number of tourists who are unfamiliar with local flood risk, and there are many riverside caravan parks.

Past efforts to reduce the flood risk have resulted in levees in Murwillumbah and Tweed Heads South, as well as a voluntary house purchase and house raising program. The SES has also developed an extensive Flood Emergency Sub Plan (FESP), which details flood risk and evacuation procedures. However, since these flood management options were undertaken, development has intensified and there is improved understanding of flood behaviour in the area. It is therefore timely to reassess the options to manage flood risk, whether through **flood, response** or **property modification** measures.

Flood Modification Measures

A preliminary hydraulic analysis and cost benefit analysis was completed to determine how much additional protection the Tweed Heads South levee would provide to people and property, if it were raised to provide protection up to a 100 year ARI flood. Extension (westwards) of the Tweed Heads South levee, to provide protection to the Philp Parade area, was also considered at a preliminary level.

Tweed Heads South Levee
Estimated cost to protect up to 100 year ARI
$11 million
Additional time to evacuate during PMF
3 hours
Estimated reduction in property flood damages
$36 million

Catchment scale flood modification options, including dams and floodways, were considered but none were identified as being both effective and feasible. Other engineering options including dredging, other levee works, and development of a new river mouth or flood relief outlet, were revisited but not found to be viable. It is however recommended that additional studies be undertaken to investigate and manage flood risk behind levees, and from local stormwater drainage in key locations throughout the catchment.

Response Modification Measures

Response modification measures are essential to the minimisation of personal flood risk in the Tweed Valley study area. Flood response is the responsibility of many organisations and individuals, including the SES, the Bureau of Meteorology, Tweed Shire Council, community groups and individuals. The range of response modification options considered in this study aim to address this wide cross-section of responsibilities.

The SES has been provided with a range of flood intelligence from this study, including road closure timing, flood extents and broadscale evacuation capability assessments, which can be used to update their FESP and inform more detailed evacuation plans for areas of greatest flood risk. This information can be used to supplement the information already held by the SES, derived from prior flood modelling, historical floods and professional experience. Evacuation management options, such as pre-emptive evacuation and pedestrian evacuation have also been considered.

Other response modification measures considered as part of the study include additional flood awareness education, provision of personalised flood information, adoption of new storm surge prediction technology and review of evacuation centre capacity and procedures.

Property Modification Measures

Property modification was addressed via a hydraulic assessment to identify properties which are at particularly high risk in terms of either personal safety or property damage. Depending on the degree of risk, these properties have been recommended for either voluntary house purchase or voluntary house raising. These schemes would generally be conducted over a long timeframe, such as 20 years or more.

Voluntary house purchase
Suitable properties: ***10***
Total cost: approx. ***$3 million***
Benefit to cost ratio: ***1.1***

Voluntary house raising
Suitable properties: ***30***
Total cost: approx. ***$2 million***
Benefit to cost ratio: ***2.6***

Future Flood Risk

The study considers measures to quantify and manage flood risk into the future. Two likely drivers for increased flood risk are climate change, and continued development and increased populations on the floodplain.

Additional climate change flood risk
(over current 100 year ARI flood risk)

***55%** more people*
***66%** more houses*
***33%** more businesses*

Climate Change

Council has adopted a climate change flood scenario in line with current scientific guidance and previous state policy which accounts for a 10% increase in rainfall intensity and a sea level rise of 91cm for the 100 year ARI event by 2100. This climate scenario will result in a greater flood extent and increase the flood risk for those already on flood prone land.

Outcomes from this study can be used to inform updates of Council's climate change adaptation plan that has been undertaken to manage this future risk to existing people and property. Council already has a number of planning mechanisms in place for limiting climate change risk to future development, and some additional recommendations have been made as part of a review of planning considerations for the study area.

Planning and Future Development

Despite the considerable existing flood risk and the risk posed by future climate change, the study area should not be sterilised. Future development can occur with well designed flood controls and appropriate assessment to determine and limit the impact of development.

A range of options were hydraulically assessed to determine the effect of increasing development in particular locations in Chinderah, West Kingscliff, South Murwillumbah and Kielvale, as well as broader development of rural zoned land. In general, it was found that the Chinderah Village and South Murwillumbah areas are hydraulically sensitive and the future development potential of these areas is extremely constrained. Kielvale and the areas of Chinderah and West Kingscliff east of the Pacific Highway are hydraulically more suitable for development, and a development scenario has been adopted for the management of cumulative hydraulic impacts.

Evacuation safety risks for potential large scale development areas have also been reviewed to inform the strategic planning process. The proposed development form under the Tweed City Centre Masterplan for Tweed Heads North is generally supported, subject to detailed assessment and management of evacuation risks. However, due to a lack of rising road access, similar intensification of the Tweed Heads South city centre is generally not supported based on the currently proposed building form. In Chinderah / West Kingscliff, evacuation risks are considered to be manageable for areas with rising road access towards Kingscliff, however most other locations could pose unacceptable risks. South Murwillumbah and some parts of the Murwillumbah CBD area identified through the planning process for potential increases in residential density are also not recommended due to unacceptable flood risk.

Well designed flood controls are essential for the safe and sustainable development of the floodplain. Tweed Shire Council's planning instruments were reviewed and recommendations were made to update these instruments with best-practice flood planning controls together with specific flood risk management recommendations from this study. These include suitable floor and fill levels, inclusion of climate change policy and suitable flood certificate wording. These recommendations are based on updated information about flood behaviour in the study area.

Summary of Measures

A summary of the floodplain management measures recommended in this study is presented in Table ES- 1. These measures are summarised in an options assessment matrix which highlights quantifiable impacts, costs and benefits, but also intangible considerations such as social and environmental factors. The matrix can be used to compare options and inform the selection of measures to be adopted for implementation.

Measures are also marked on Figure ES-1 where possible / appropriate.

A number of other measures were considered during the study. Measures which were not carried over to this document were found to be not feasible or practicable based on hydraulic assessments and advice from members of the Floodplain Management Technical Sub-committee.

Table ES- 1 Summary of Recommended Floodplain Risk Management Options

No.	Modification Type	Description	Region	Considerations	Section	Recommendation
1	Flood	Local drainage studies	Murwillumbah	Improve drainage behind levee, including operation of flood pumping stations; Quantify risk and identify potential mitigation; Inform development planning re local flood risk; Moderate study cost; Medium to high implementation costs, depending on works	4.3	Commission study
2	Flood	Local drainage studies	Lower Tweed, Chinderah	Improve evacuation capability through better route immunity; Quantify risk and identify potential mitigation; Inform development planning re local flood risk; Moderate study cost; Medium to high implementation costs, depending on works	4.3	Commission study
3	Flood	Raise Tweed Heads South levee to provide 100 year ARI protection	Lower Tweed	Provides sufficient additional time for residents along Dry Dock Road to evacuate to Tweed Heads; 190 additional dwellings protected in 100 year ARI event; Potential impact on visual amenity, particularly in concrete sections; Cost benefit ratio > 3; Total cost approximately $11m	4.2.2.1	Further investigation, including quantity surveyor costing
4	Flood	Tweed Heads South Levee Overtopping Study	Lower Tweed	Improves understanding of hydraulic behaviour around levee and informs future decisions about levee works; Low to moderate cost	4.2.2.2	Commission study
5	Flood	Extend Tweed Heads South levee to provide 100 year ARI protection to Philp Parade area	Lower Tweed	Provides sufficient additional time for residents along Philp Parade to evacuate to Tweed Heads; > 60 additional dwellings protected in 100 year ARI event; Potential impact on visual amenity; Easement considerations; Total benefit approximately $10m; High capital costs	4.2.2.3	Further investigation
6	Flood / Planning	Preserve / enhance South Murwillumbah - Condong flowpath	Murwillumbah	No worsening of flooding in South Murwillumbah basin (Potential 50 to 100mm reduction in 100 year ARI flood levels)	4.2.4.1 and 8.4.3.2	Decide on planning mechanism and pursue funding sources for securing (and potentially enhancing) flowpath at Lot 4 Quarry Road; Further investigation of hydraulic structure at Quarry Road
7	Flood	Murwillumbah Levee Overtopping Study	Murwillumbah	Improves understanding of hydraulic behaviour around levee and informs future decisions about levee works; Low to moderate cost	4.2.4.2	Commission study
8	Response	SES Community FloodSafe Engagement Program	Whole study area	Increase community awareness and community flood planning; Improve community confidence due to flood planning; Low cost	5.2.1.1	Continue funding to implement SES Community Engagement Program; Prioritise high risk issues from this study and vulnerable groups (risks behind levees, large floods, interpreting flood warnings, increased risk at caravan parks)
9	Response	Evacuation planning information	Whole study area	Improve community awareness of evacuation procedures; Improve community satisfaction through inclusion / awareness; Low cost	5.2.1.2	Provide information on evacuation routes, centres and process to community

No.	Modification Type	Description	Region	Considerations	Section	Recommendation
10	Response	Relate flood prediction information to flood risk	Whole study area	More informed personal evacuation planning; Improve community confidence when floods are predicted; Improve information available for emergency response; Moderate cost	5.2.1.3	Derive links between stream gauge heights and individual properties / infrastructure (for a range of flood behaviours) and disseminate; Investigate flood mapping software to provide visualisation and analysis of existing flood datasets
11	Response	Update SES Flood Intelligence Cards and Flood Emergency Sub Plan (FESP)	Whole study area	Better understanding and quantification of flood risk; Improve response planning and evacuation procedures; Low cost to incorporate existing flood intelligence; Moderate cost to commission additional studies	5.2.2.1	Update Flood Intelligence Cards with information from Flood Study, FRMS and Flood Intelligence Review; Undertake detailed evacuation planning where insufficient resources or evacuation capability have been identified by the FRMS; Remove Tweed Civic Centre from FESP as designated flood evacuation centre
12	Response	Flood information website	Whole study area	Improve understanding of flood risk and access to flood information; Low to moderate cost	5.2.2.2	Provide a comprehensive, centralised flood information website (e.g. including flood predictions, flood warnings, evacuation information, road closures, interactive flood mapping)
13	Response	Flood watch network	Whole study area	Improve understanding of flooding and flood impacts; Utilise residents' knowledge of historical and real time flood behaviour	5.2.2.3	Continue formal FWN system to receive community flood intelligence
14	Response	Method of flood warning	Whole study area	Plan for flood warning in an extreme flood event; Low to medium cost, depending on selected method(s)	5.2.3.1	Review and update flood warning plans based on outcome of this study; Include risk-based prioritisation of resources to manage warning process
15	Response	Inclusion of Tumbulgum stream gauge in flood warning system	Whole study area	More informed prediction and response planning; Low cost	5.2.3.2	Discuss inclusion of Tumbulgum stream gauge in flood warning system with Flood Warning Consultative Committee
16	Response	Update storm surge prediction system	Whole study area	Improve evacuation capability through earlier prediction (Already funded via BoM)	5.2.3.3	Incorporate storm surge prediction system in Flood Emergency Sub Plan when available
17	Response	Detailed evacuation planning study	Whole study area	Improve understanding of evacuation constraints and identify risk reduction strategies; Establish evacuation plans for communities that currently face evacuation constraints; Moderate cost	5.2.4.1	Commission detailed evacuation planning study
18	Response	Targeted flood education	Whole study area / high risk areas	Improve flood awareness in residents in high evacuation risk areas; Low cost	5.2.4.2	Identify high evacuation risk areas and educate residents about local risk
19	Response	Early / pre-emptive warning	Whole study area / high risk areas	Improve safety by providing more time for residents in high risk areas to evacuate	5.2.4.3	Review areas with insufficient warning time, educate residents and pre-emptively warn during evacuations
20	Response	Pedestrian evacuation	Whole study area / suitable locations	Improve safety of residents who are close to evacuation centres and reduce evacuation traffic	5.2.4.4	Identify areas where pedestrian evacuation may be viable / beneficial; Educate local residents that evacuation on foot is an option
21	Response	Rural evacuation	Whole study area / high risk areas	Improve safety of rural residents in flood risk areas who are distant from evacuation centres	5.2.4.5	Establish evacuation plans for rural properties that currently face evacuation constraints
22	Response	Evacuation centre planning	Whole study area	Ensure effective evacuation communications and operations Low cost	5.2.5.1	Review communication between SES, TSC and DoCS after future evacuations
23	Response	Assess evacuation centre capacity	Whole study area	Improves safety of residents by ensuring sufficient evacuation centre capacity; Moderate cost if additional centre facilities required	5.2.5.2	Prepare a review of evacuation centres
24	Response	Investigate alternative evacuation centres to Tweed Civic Centre	Tweed Heads	Improves safety of residents by diverting evacuation to flood proof centres	5.2.5.3	Remove Tweed Civic Centre from Flood Emergency Sub Plan; Replace with alternative centre

No.	Modification Type	Description	Region	Considerations	Section	Recommendation
25	Property	Voluntary house purchase	Murwillumbah	Improve safety through removal of people from high hazard areas; Total cost approximately $3m; Benefit cost ratio 1.1	6.2.1	Review and implement VHP scheme (8 properties); Review feasibility of extending VHP scheme (21 properties)
26	Property	Voluntary house raising	Murwillumbah, Tweed Heads	Improve safety (if isolated); May be some worsening of visual amenity if not consistent with existing streetscape; Totally cost approximately $2m; Benefit cost ratio 2.6	6.2.2	Review and implement VHR scheme (30 properties)
27	Flood / Response / Property	Climate change adaptation	Whole study area	Design infrastructure for future climate; Improve flood awareness in residents of future increase in flood risk; Design development for future climate; Implementation within other measures / normal operating budget	7.4.2	Include climate change in design of infrastructure and flood defences; Educate residents of future increase in flood risk due to climate change; Incorporate climate change in development planning
28	Property	Climate change planning	Whole study area	Design development for future climate; Implementation within normal operating budget	7.4.4	Retain climate change controls for greenfield residential subdivision; Introduce climate change controls for strategic planning / rezoning; Introduce climate change controls for commercial and industrial development where practical; Introduce climate change controls for new rural development; Introduce time-limited consents for suitable short term or adaptable development
29	Property	Development controls	Whole study area	Refinement of LEP flood related local provisions; Updates to Tweed DCP to adequately control immediate and future floodplain development pressures; Clarify high risk areas for purposes of Codes SEPP; Funding of flood mitigation works necessary for future development; Updates to Council's flood policies	8.1.4	Consider future refinement of LEP flood related local provisions; Update controls to reflect hydraulic constraints to development fill; Introduce floor level controls on commercial and industrial development where practical; Retain provisions relating to enclosures below habitable floors; Introduce consistent car parking and driveway controls; Retain and refine provisions relating to caravan parks and moveable dwellings; Detail definition of acceptable on-site or communal refuge; Provision of guidance for assessing climate change effects; Controls for management of flood risks from stormwater and overland flow paths; Specify high risk areas identified and mapped for complying development; Establishment of S94 contributions plans in future development areas where required; FRMP to supercede Council's flood policies
30	Property	Communication of flood risk	Whole study area	Refinement of Section 149 notifications; Availability of flood information to the public	8.2	Refinements to Section 149 notification and notations; Periodic reviews of protocols to release flood risk information to public as available
31	Property	Strategic planning	Whole study area	Manage hydraulic and safety risks associated with future development	8.3.4	Adopt cumulative development scenario for management of hydraulic impacts; Apply evacuation risk classes (ERCs) in the strategic planning process
32	Property	Strategic planning	Lower Tweed	Ensure future development plans for the Lower Tweed appropriately consider flood risk	8.4.1.5	Support current plans for Tweed Heads North subject to more detailed assessment, access improvements and provision of refuge / support facilities; Tweed Heads South plans not supported in current form

No.	Modification Type	Description	Region	Considerations	Section	Recommendation
33	Property	Development controls	Lower Tweed	Ensure design of future development in the Lower Tweed appropriately manages flood risk	8.4.1.5	Tweed City Centre habitable floor level to be 2100 climate change 100 year ARI flood level and preferential emphasis on evacuation rather than shelter-in-place, or if cannot be practically achieved specify nature of on-site refuge
34	Property	Strategic planning	Chinderah, Fingal Head, West Kingscliff	Ensure future development plans for Chinderah, Fingal Head and West Kingscliff appropriately consider flood risk	8.4.2.5	Support current plans for Tweed Coast Strategy subject to other planning criteria; Chinderah Village expansion not supported due to hydraulic and evacuation constraints; Other Chinderah / West Kingscliff development supported subject to rising road access and hydraulic constraints to cumulative development
35	Property	Development controls	Chinderah, Fingal Head, West Kingscliff	Ensure design of future development in Chinderah, Fingal Head and West Kingscliff appropriately manages flood risk	8.4.2.5	Clarify requirements for a detailed evacuation assessment prior to proceeding with future urban development areas; Relaxation of Chinderah / West Kingscliff industrial fill restrictions from 50% to 65% site coverage Incremental intensification of development not supported due to evacuation constraints; Retain provisions relating to emergency response
36	Property	Strategic planning	Murwillumbah, South Murwillumbah	Ensure future development plans for Murwillumbah and South Murwillumbah appropriately consider flood risk	8.4.3.5	Subject to more detailed evacuation assessment (option 17), review plans to increase residential development in areas of the CBD with rising road access; Subject to local drainage (option 1) and levee overtopping (option 7) studies, review plans for filling of allotments behind the levee; Increases in residential densities in the Prospero Street, South Murwillumbah Riverfront and the South-Side Residential Precincts not supported due to low flood immunity, very high hydraulic hazard, and evacuation constraints; Support commercial redevelopment which reduces flood risk; Development in Wardrop Valley / Fernvale is limited by hydraulic constraints and requires consideration of evacuation constraints; Industrial development in South Murwillumbah limited by hydraulic constraints; Secure South Murwillumbah Condong flowpath through Lot 4, Quarry Road; Development in West Murwillumbah supported due to low flood risk
37	Property	Development controls	Murwillumbah, South Murwillumbah	Ensure design of future development in Murwillumbah and South Murwillumbah appropriately manages flood risk	8.4.3.5	Major redevelopment subject to detailed evacuation planning; Support redevelopment of River Front precinct into river front park; Subject to local drainage (option 1) and levee overtopping (option 7) studies, consider concessions to lower storey habitable floor levels with damage mitigation measures
38	Property	Strategic planning	Riverside villages	Ensure future development plans for the riverside villages appropriately consider flood risk	8.4.4.5	Subdivision or intensification of development in Condong / Tumbulgum not supported due to evacuation constraints; New Condong / Tumbulgum development subject to evacuation constraints; Support redevelopment in Condong / Tumbulgum which reduces flood risk; Support current plans for Kielvale and Potential Employment Land Area 6 in the Condong-Chinderah basin subject to other planning criteria
39	Property	Strategic planning	Rural areas	Ensure future development of rural areas appropriately considers flood risk	8.4.5.4	Limit filling to 1% of rural flood prone land (excluding floodways) without additional cumulative development assessment
40	Property	Development controls	Rural areas	Ensure design of future development in rural areas appropriately manages flood risk	8.4.5.4	Introduce 2100 climate change design flood levels for habitable floor levels; Introduce high level access to flood-free refuge for subdivision or other use; Retain provision for on-site refuge as secondary evacuation measure

Other (non location specific) options not shown on this map include:

- *Flood Awareness measures*
- *Flood Intelligence measures*
- *Flood Warning System measures*
- *Evacuation Planning measures*
- *Evacuation Centre measures*
- *Planning measures*

Identify alternative evacuation centre to Tweed Civic Centre

Raise Tweed Heads South levee

Levee overtopping study

Extend Tweed Heads South levee

Include Tumbulgum stream gauge in flood warning system

Levee overtopping study

Ingleside
Point Danger
Coral Sea
Tweed Heads
Fingal Head
Banora Point
Wommin Bay
Glengarrie
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point

LEGEND

- Local Drainage Studies
- Potential Voluntary House Purchase and / or Raising Properties
- Tweed River
- Principal Road
- Sealed Road

Title:
Summary of Floodplain Risk Management Options

Figure: ES-1

Rev: A

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0km 3 6

Approx. Scale

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LIST OF ABBREVIATIONS

AAD	Average Annual Damages
mAHD	metres to Australian Height Datum
ARI	Average Recurrence Interval (of flood)
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECC	(former) Department of Environment & Climate Change
DECCW	(former) Department of Environment, Climate Change & Water
DIPNR	(former) Department of Infrastructure, Planning and Natural Resources
DISPLAN	(Tweed Shire Local) Disaster Plan
DoCS	Department of Community Services
DoP	(former) Department of Planning
DPC	Department of Premier and Cabinet
DPI	Department of Planning and Infrastructure
EP&A Act	Environmental Planning and Assessment Act
ERC	Evacuation Risk Class
FIC	Flood Intelligence Card
FESP	Flood Emergency Sub Plan
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
LEP	Local Environment Plan
LGA	Local Government Area
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood, also referred to as flood prone land
REP	Regional Environmental Plans
RMS	Roads and Maritime Services
SEPP	State Environmental Planning Policies
SES	State Emergency Service
TSC	Tweed Shire Council
VHP	Voluntary House Purchase
VHR	Voluntary House Raising
VxD	velocity-depth product

1 INTRODUCTION

This document examines existing and future flood risk for the study area, and assesses and makes recommendations for a range of flood, response and property modification measures to minimise the community's exposure to flood risk. The information from this document was used to inform the Tweed Valley Floodplain Risk Management Plan: a written document outlining a plan of management for flood risk in the Tweed Valley, which was exhibited for consultation and formally adopted by Council.

The Tweed Valley Floodplain Risk Management Study has been prepared on behalf of Council by consultants BMT WBM Pty Ltd.

1.1 Flood Risk

1.1.1 General Principles

The primary objective of the NSW Government's Flood Prone Land Policy is to *"reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property"* and to *"reduce private and public losses resulting from floods"*.

At the same time, the policy recognises the benefits flowing from the use, occupation and development of flood prone land.

The only way to completely remove flood risks from a development is for it to be located outside the extent of the probable maximum flood (PMF). This is a very risk-averse approach to floodplain management which is generally not supported by the Floodplain Development Manual (DIPNR, 2005). In particular, one of the principal tenants of the Flood Prone Land Policy is that "flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development".

When considering future development, both the policy and the Floodplain Development Manual promote the use of a *"merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable. In this way the policy avoids the unnecessary sterilisation of flood prone land. Equally it ensures that flood prone land is not the subject of uncontrolled development inconsistent with its exposure to flooding"*.

In view of the above, a key issue to be determined is the level of risk that the community considers to be acceptable, noting that the elimination of all risk is generally not practical or appropriate.

As a general rule, almost any development involves some risks to property or people. For example, construction of a new subdivision introduces traffic risks which may be managed (e.g. through construction of traffic lights, signage, etc.) but are not completely eliminated. Rather the risks are reduced to a level which is considered acceptable to the community. Flood risks are managed in a similar fashion. Nevertheless in some situations if the residual risks remain unacceptably high, alternative safer forms of development should be pursued.

1.1.2 Defining Flood Risk

Within the context of this report, 'flood risk' is defined as the combination of probabilities and consequences that may occur over the full spectrum of floods that are possible at a particular location.

1.1.3 Managing Flood Risk

There are three principal options for managing flood risks:

- *Avoiding the risk* – land use planning is the key management option by which inappropriate flood risks can be avoided. Effective land use planning ensures that only development compatible with the flood hazard can be located in the floodplain.
- *Reducing the likelihood* – construction of detention basins, levees and other structural measures can reduce the probability of flooding.
- *Reducing the consequences* – a range of measures are available including:
  - Development controls;
  - Raising flood awareness amongst communities;
  - Improved emergency management;
  - Improved flood warning;
  - Provision of insurance; and
  - Provision of disaster relief.

In every situation, avoiding the risk through effective land use planning is the preferred option, if possible. Nevertheless pressures for land development, the lack of suitable land outside the floodplain, and a range of other non-flood related issues mean that use of some floodplain land may still be the best option for the community. The NSW Floodplain Development Manual guides Councils and consent authorities to use the 'merit approach' in making these land use decisions, balancing flood risk with other social, environmental and economic considerations.

The management of flood risk considers options for managing both the risk to property and the risk to people (personal safety).

1.1.3.1 Risk to Property

The most common method of reducing the consequences to property is by applying development controls that specify the minimum height of floor levels relative to a given probability flood. A range of flood planning levels (FPLs) are usually established by Councils for this purpose, and may vary depending on the use of the building (e.g. residential, commercial, industrial, community services, emergency facilities).

Other complementary development controls are used to manage property risks including the use of flood compatible building materials and methods as well as ensuring buildings are strong enough to withstand the forces of flood waters without collapse. These types of controls are included in Council's existing Development Control Plan (DCP).

1.1.3.2 Risk to People

When considering future development in the Tweed LGA, risk to property can generally be managed, provided appropriate controls are applied. However, risk to life is seen as the key flood constraint within several flood prone localities, where evacuation constraints have hindered potential new developments. Accordingly, the consideration of flood risk to people and the most appropriate means to manage these risks is the focus of a large part of this Study.

A range of structural and non-structural measures are being considered, including identifying evacuation and emergency management constraints, and increasing the community's awareness and preparedness for flooding.

Emergency management is a principal mechanism that requires consideration within the land use planning process as it can influence the:

- *Location of new development* – in areas free of flood risk or where evacuation away from the flood risk is possible;
- *Form of development* – so that it is designed to allow for pedestrian and/or vehicular evacuation, and buildings that are structurally resilient to the forces of floodwaters if unavoidably required to provide a refuge; and
- *Connections between developments and safe refuges or support facilities* – to ensure that pedestrian paths and road systems are designed to facilitate evacuation and access to safe refuges, support facilities and/or evacuation centres.

The report of the 2009 Victorian Bushfires Royal Commission articulated and emphasised the following principles of emergency risk management. As core principles they can be readily applied to the management of hazards other than bushfire (Opper, 2011):

- Protection of life is the highest priority.
- Property protection is always secondary.
- Urban design and development must take into account expected human behaviour.
- Urban design and development must take into account the expected range of severity of hazards.
- Emergency management strategies must take into account expected human behaviour.
- Emergency management strategies must take into account the expected range of severity of the hazards.
- The safest place for people to be during the impact of hazard is away from the area being impacted.

There are no prescriptive standards for an acceptable risk to life for floodplain developments. Consent authorities require guidance on characteristics of the floodplain, matters of best practice and levels of risk considered acceptable to the community.

Experience from floods across the nation suggests that flooding is dangerous but not particularly so. The most serious loss of life in floods during the 20th and 21st centuries occurred recently during the January 2011 floods in the Toowoomba, Lockyer Valley, Brisbane and Ipswich areas when around 30

people lost their lives. This follows the Brisbane floods of 1974 when 12 lives were lost. The other most significant loss of life during floods occurred during the 1955 floods in Maitland when 14 people lost their lives. About 90 people lost their lives when a large part of the township of Gundagai was washed away in one night in 1852.

When deaths occur during floods, most die due to misadventure, exposure to unidentified risks, or by foolhardiness.

When compared against other voluntary and involuntary lifestyle risks that the community accepts (e.g. traffic fatalities, accidents at home, fatal cancers), the risk of death during floods is not seen as large. However, individual risk is different to what a society might consider acceptable because a number of people might be involved and their identity is unknown. These societal risks reflect communities' aversions to disasters and it has been suggested that in respect of flooding, society might accept one fatality in a 100 year ARI flood increasing to about 20 fatalities in a PMF. While statistical values (which are by nature imprecise and vary between communities) are less important, it is recognised that society does accept some risk of fatalities from flooding.

1.2 Floodplain Risk Management Process

The NSW Government's Flood Prone Land Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the NSW Floodplain Development Manual (DIPNR, 2005).

Under the policy, the management of flood prone 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 their floodplain management responsibilities.

The policy provides for technical and financial support by the State Government through the following four sequential stages, as outlined in Table 1-1, below:

Table 1-1 Stages of Floodplain Risk Management Process

Stage	Description
1. Flood Study	Determines the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluates management options for the floodplain in consideration of social, ecological and economic factors.
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management with preferred options for the floodplain.
4. Plan Implementation	Implementation of flood mitigation works, response and property modification measures by Council.

Overseeing the entire process is the Floodplain Management Committee, composed of representatives from the community and relevant industries, Council, the State Emergency Service (SES), and the Office of Environment and Heritage (OEH). Within this committee sits the Technical Sub-committee who discusses technical aspects of the project to ensure there is a best-practice approach to the study.

Community consultation occurs throughout the process.

This study represents the second of the four stages for the Tweed Valley area. It has been prepared for Tweed Shire Council to identify and assess potential flood mitigation options and to outline how flood prone land within the study area may be managed. The floodplain management plan ensures that:

- The use of flood prone land is planned and managed in a manner compatible with the assessed frequency and severity of flooding;
- Flood prone lands are managed considering social, economic and ecological costs and benefits, to individuals as well as the community;
- Floodplain management matters are dealt with considering community safety, health and welfare requirements;
- Information on the nature of possible future flooding is available to the public;
- All reasonable measures are taken to alleviate the hazard and damage potential resulting from development on floodplains;
- There is no significant growth in hazard and damage potential resulting from new development on floodplains; and
- Appropriate and effective flood warning systems exist, and emergency services are available for future flooding.

1.3 Study Area

The Tweed River is located in Tweed Shire, the northern-most coastal region of New South Wales (see Figure 1-2). The main arm of the river has a length of about 50 km and a catchment area of about 1,100 km^2, including its various tributary systems. The main arm of the river flows in a general north-easterly direction through the towns of Murwillumbah (about 28 km upstream) and Tweed Heads (at the mouth) and past the villages of Condong, Tumbulgum, Chinderah and Fingal Head. The main tributaries include Oxley River, Rous River, Dunbible Creek and the Terranora and Cobaki Broadwaters. The river flows to the sea immediately south of Point Danger, close to the border with Queensland.

Regular flooding occurs, particularly in the low-lying regions of the valley, which are largely used for sugar cane production. Most recently the catchment experienced moderate flood events in January 2008 and January 2012. The catchment has experienced larger flood events on a number of occasions, including in March 1974 and most severely in February 1954. This flood caused extensive inundation in all flood prone areas.

Regional flooding occurs via catchment rainfall, ocean storm surge or some combination of these events. The small tributaries in the Bilambil and Terranora regions and local areas can also experience flash flooding; however the focus of the Tweed Valley FRMS is catchment scale inundation. The critical storm duration for catchment flooding at Murwillumbah was determined to be approximately 36 hours as part of previous flood studies.

Development in the catchment is centred on two major centres, Tweed Heads and Murwillumbah, with a number of smaller villages throughout the catchment. The Far North Coast Regional Strategy

(Department of Planning, 2006) was prepared to provide guidance in planning for the growth of the six North Coast Local Government Areas, including Tweed Shire, for a projected population growth of 26% over a 25 year period. Of this, the Strategy aims to focus 35% of new housing in the regional centres which includes Tweed Heads (to yield an additional 19,100 new dwellings).

The study area covers the Tweed Valley floodplain downstream of Byangum defined by the extent of the Probable Maximum Flood (PMF), also referred to as the extent of 'flood prone land'. The study area was defined in the Tweed Valley Flood Study Update (2009).

Within the Tweed Valley, the study area has been divided into four regions for reporting purposes:

- Lower Tweed;
- Chinderah, Fingal Head and West Kingscliff;
- Murwillumbah and South Murwillumbah; and
- Riverside Villages (Condong and Tumbulgum).

This report refers to these regions when describing risk or proposed measures which apply to specific areas, rather than the whole study area. See Figure 1-3 for the boundaries of these reporting areas.

Hinterland villages including Uki, Tyalgum and Chillingham are upstream of the study area, and will be the subject of separate studies. Tweed Shire also consists of several other smaller coastal catchments, separate to the Tweed Valley. These areas are the subject of the separate Tweed Coastal Creeks Floodplain Risk Management Study and Plan, under development at the time of writing.

1.4 Consultation

Consultation provides a forum for the relevant stakeholders, including the community, to work together to shape a collective vision for the catchment and future floodplain risk management. Effective consultation can increase community acceptance of the floodplain risk management plan and provide the opportunity for better decision making. The Tweed Valley FRMS included five distinct phases of consultation:

1 Consultation with major stakeholders (community, industry and environmental groups). This was conducted early in the study and outcomes were used to inform the options assessment process.

2 Following consideration by the Floodplain Management Committee, exhibition of the draft study and plan, online and in hard copy at Council's offices in Murwillumbah and Tweed Heads, and Kingscliff Library. Submissions received during this exhibition were considered by the consultants and Floodplain Management Committee to inform the study and plan.

3 Region specific community sessions at Tweed Heads and Murwillumbah. These sessions presented the draft study and plan to the community. Feedback received at these sessions was considered by the consultants and Floodplain Management Committee to inform the study and plan.

4 Re-exhibition of the draft study and plan including amendments made in response to the submissions and feedback received during the initial exhibition period.

5 Release of the final study and plan. The plan will be made public, online and in hard copy at Council's offices in Murwillumbah and Tweed Heads.

Figure 1-1 Consultation Process

1.4.1 Stakeholder Consultation

Consultation from project stakeholders was sought at the commencement of the study and feedback was addressed in committee meetings. During the study, an online survey was conducted as part of the Tweed Coastal Creeks FRMS. Many of the respondents live within the Tweed Valley catchment, and these responses have also been included in this study. Feedback predominantly addressed the following issues:

Flood Awareness. A number of responses highlighted the need to increase flood awareness within the community. It was recommended that flood awareness campaigns target particularly vulnerable sections of the community, such as schools and the elderly, as well as residents new to the area. Suggested options for increasing flood awareness included the use of flood markers with historical and design flood levels.

Evacuation. Evacuation concerns were mentioned in a number of the stakeholder responses, including issues such as:

- Evacuation centres have been closed in past flood events, despite residents being directed to these centres.
- Old Ferry Road and Piggabeen Road require improvement to ensure they were suitable to use as evacuation routes.
- Flood plans be developed for health facilities and businesses to ensure these places knew how to protect their property and safety of employees/customers/patients in the event of a flood.
- Fingal Head and Chinderah residents indicated that they did not feel evacuation was necessary from their region and they did not wish to be mandatorily evacuated.
- Isolation in the Philp Parade area (as experienced in 2012 floods).

Information. Many responses requested a greater level of information be made available, including flood maps, locations of evacuation routes and centres, details about Council's climate change policy and how this policy was derived, and details of the SES's disaster plan (DISPLAN). Alternative options for information dissemination during floods were requested by many respondents. These included suggestions for more information on Council's website, SMS warnings and increased localised radio announcements.

Flood Warning. A few responses mentioned flood warning as an issue of concern. In particular, there was some negative sentiment about the lack of localised flood warning with the feeling that warnings were issued 'out of Wollongong' and therefore not relevant to the Tweed Valley. There was also a request for more information about the flood warning system generally.

Development. Development of the study area was of major concern to most stakeholders. Some responses were concerned that flood controls would result in the 'sterilisation' of flood prone land, particularly in the South Murwillumbah and Chinderah areas. There was also some concern for potentially negative cumulative impact effects resulting from multiple large scale developments, with specific reference to the proposed 'bug' farm (approved aquaculture development at Chinderah) and the RivaVue residential subdivision development in Murwillumbah.

Engineering Options. Specific recommendations included flood levees around the Old Ferry Road area, dam construction on Byrrill Creek, dredging of the river, and entrance / flood relief works in the area south of Fingal Heads.

Other issues were raised in the stakeholder responses which were beyond the scope of the study. These included drainage of flood water at Lavender Creek and behind Murwillumbah levee, backing up of one-way drains on Fingal Road, salt water intrusion past Bray Park weir, boat wash effects in Oxley Cove and Fingal Head, debris in Oxley Cove, and stormwater drainage and blocked drains. This study does recommend local stormwater drainage studies of problem areas be undertaken. The remaining issues are noted by Council and will be considered separately.

1.4.2 SES Consultation

The SES was consulted throughout the study as members of the technical committee. Written feedback was provided during the study and during the formal consultation period towards the end of the study. A summary of the main issues is provided below:

- The SES found the evacuation assessment to be a very useful resource and plan to reference the results in future SES flood emergency response planning.
- The SES is concerned about the cumulative impact of multiple developments throughout the floodplain and the implications this might have for the total number of evacuees who may need to be managed by the SES.
- The SES reiterated their opinion that flood refuges are not equivalent to evacuation and that they do not support PMF refuges as a primary risk treatment strategy for flood risk when it is proposed as an alternative to evacuation.
- The SES believe that human behavioural responses are extremely difficult to change and that community education should not be used in isolation, but as part of a suite of flood management options.

- The SES would like to establish a system of locals who can monitor road points.

1.4.3 Community Consultation

The draft Tweed Valley Floodplain Risk Management Study and Plan (including supporting Discussion Papers) were put on exhibition by Tweed Shire Council from 19th July to 30th August 2012 and 12th February to 12th March 2014. During the exhibition periods, electronic copies of all documents were available on Council's website, with hard copies provided at Council's Murwillumbah office. During the exhibition period, a number of key stakeholders also sought private meetings with Council to discuss specific aspects.

Two community consultations were hosted by Council, the SES and BMT WBM towards the end of the initial exhibition period. The first consultation was held at the Murwillumbah Civic Centre 13th August, with a second consultation held at Tweed Civic Centre the following day. Both consultations had sessions during lunch (11:30 – 2:30) and the early evening (4:30 – 7:30).

The consultation sessions were held as drop-in sessions with a dual purpose:

1. To inform the community about the draft Study and Plan (including methodology, outcomes and recommendations), and general flood behaviour and risk in the catchment; and
2. To consult with the community about the draft Study and Plan, especially to obtain public feedback on recommendations and discuss alternative options.

Many queries received during the consultation sessions related to design and historical flood behaviour. Hard-copy and computer-based flood maps were available to support discussion with residents. A number of other issues were raised at the consultations and through written submissions. These issues are summarised below.

Engineering Options. Many of the responses requested further consideration of 'hard' engineering options (i.e. flood modification options) in the Study, including:

- Dredging of the Tweed River and lakes system;
- Establishment of Byrill Creek Dam, at least partially, for the purposes of flood mitigation;
- Relocating the Tweed River entrance to the south and increasing the conveyance (width and depth) of the entrance;
- Creation of a second Tweed River entrance / flood relief channel south of Fingal Head;
- Creation of an earthen levee and second floodgate outlet in Oxley Cove;
- Upgrading of revetment walls, such as the existing wall on the River Road peninsula; and
- Mitigation of Rous River flooding in Murwillumbah (around Mooball Street).

Tweed Heads South Levee. Awareness of the current levee and flood protection in Tweed Heads South is lower than expected. Some residents in the highly flood prone Philp Parade area are not aware of the degree of local flood risk. Responses also indicate that some residents may not be aware of the full extent of the current levee. There was both support and opposition to raising the Tweed Heads South levee, with concerns including the following:

- Will raising the levee worsen flooding in other areas of the lower Tweed?

- Will raising the levee worsen flooding behind the levee?
- Will sufficient drainage infrastructure be installed with the levee?
- Will extension of the levee affect visual amenity?

Flood Education Measures. One response indicated that the Plan was overly reliant on flood education measures. This response stated that education was an insufficient response and believed that flood modification measures should be the primary measure used to manage the flood risk.

Flood Warning and Evacuation. There was some confusion and concern regarding the current flood warning system, primarily whether flood warnings are issued locally by the SES, or by DoCS, BoM or SES headquarters (Wollongong). There was also a recommendation for establishment of a local radio station to improve warning dissemination. There is a general sentiment that the evacuation risk is overstated. In particular, businesses and land owners in Prospero Street noted that they consider their evacuation risk to be low due to adjacent high level access (the Murwillumbah bridge). Requests have been made for more details of the evacuation plan and the various responsibilities associated with evacuation. A request was made for additional, automated stream level gauges to be installed and linked to a flood prediction system.

Recovery Planning. One response requested more forthcoming waste disposal services for locally affected areas after a flood event, and inclusion of cane waste as well as household items.

Property Modification. One response requested inclusion in the voluntary house raising scheme.

Planning and Development. Planning and development issues were raised by several consultation responses, with a range of issues discussed. These included:

- There is support for rezoning of residential development around Prospero Street. The response recognised that there is a high flood risk in this area but believed that the risks are acceptable for residential properties on upper floors of multi-storey buildings (i.e. residential properties built above commercial properties).
- There was some concern that Centrelink and a community centre were allowed to be constructed in the floodplain area.
- There was support to form a continuous river front park in South Murwillumbah; however, it is a costly and lengthy process.
- Shelter in place was raised with specific reference to a development in Banora Point. A request was made to alter the Development Control Plan to allow for rezoning of the development site and shelter in place as a development control for sensitive land uses.
- A request that the allowable site coverage for industrial development in Chinderah be increased from 50% to 65% supported by further hydraulic assessment.
- Greater community input into landuse planning was requested by one response.
- Some proposed development sites include environmental protection zones which cannot be developed.
- An informal submission queried whether pontoons have been considered and fully addressed in the DCP. In particular, there was concern that failure of pontoons would put downstream infrastructure, such as the South Murwillumbah levee, at risk.

Consultation. The consultation process and format received mixed responses from the community. Informal discussion at the consultation sessions indicated that some residents were happy with the consultation process and enjoyed the opportunity to discuss local flooding issues. However, other formal and informal responses critiqued the process, citing such issues as:

- Lack of formal (oral) presentation at the sessions;
- Lack of a Chinderah session focussing on local flood implications;
- The consultation focused on the study process rather than the outcomes and recommendations;
- Information provided at the consultation was too general; and
- Insufficient period and amount of consultation.

Report Structure. Mixed feedback was received about the structure of the reports produced during the study. Particular issues raised include:

- The discussion papers were too long to be easily read, understood and printed;
- The documents in general are hard to follow;
- There is some inconsistency and duplication of material;
- It is necessary to read multiple documents to fully understand some issues; and
- The Plan did not include sufficient information.

Other issues were raised in the responses which were beyond the scope of the study. These included:

- **Historical Flooding.** A number of residents discussed historical flood events, particularly the 1954 flood. Of particular interest was the flood behaviour around Fingal and the mouth of the Tweed River and the location of the river breakout to the sea. Suggestions were also made to apply the 1954 flood extent for planning purposes in preference to the 100 year ARI design flood.
- **Climate Change.** There was some discussion about the climate change flood levels published in the preceding Flood Study Update and the application of these levels to the Study and Plan. The discussion focused on the following issues:
  - Derivation of the climate change scenario and the scientific validity of assumptions; and
  - Application of long-term climate change projections to short-term development planning.
- **Probable Maximum Flood.** A number of the consultation responses and queries related to the PMF, in particular:
  - Derivation of the PMF – How is it derived, why did it increase from the PMF levels in the 2005 Flood Study, what recurrence interval is the PMF, how reliable is the PMF and how is it represented in the flood model (e.g. overtopping of the coastal dunes)?
  - Application of the PMF – Why is the planning based on a flood event which is uncertain and improbable, and is the application of PMF overly cautious?
- **Flash Flooding and Local Flooding.** A number of queries were raised during the consultation sessions about flash flooding and local flooding, especially the Banora Point flooding in 2005. Some residents were unclear about whether the existing flood modelling (and proposed management strategies) addressed these types of flooding. A formal request was made for more

information on flash flooding in the catchment and there was support for the commissioning of local drainage studies in Murwillumbah.

- **Insurance Premiums.** Although the issue was not directly addressed in the Study, many residents and groups had questions about the impact that the Study (and the preceding Flood Study) may have had on local insurance premiums. Feedback indicates that flood insurance premiums have increased substantially in recent years, with two specific concerns identified:
  - Houses in high risk areas are unable to afford insurance; and
  - Insurance premium increases do not appear to directly correlate to flood risk. Design flood levels may have been applied at an overly broad scale by the insurance companies.
- **Land Values.** Several responses raised the issue of land values for flood prone land. One response indicated that the classification of certain land as flood prone was in contradiction with increases in NSW Valuer General Valuations (with the implication that either the land is not flood prone or land valuations should not increase).
- **Banora Point Highway Upgrade.** There is some concern that the Banora Point Highway upgrade project may worsen existing flooding in Banora Point.

1.4.4 Incorporation into Study

All of the issues raised during the various consultation processes have been considered by the Floodplain Management Committee, including those beyond the scope of the study. These issues have been addressed in the study in various ways, including one or a combination of the following:

- Creation of a *Frequently Asked Questions* (FAQs) brochure discussing some of the most topical issues related to flooding and floodplain management in the Tweed Valley. This brochure is attached to the study (see Appendix A) as well as available separately. It provides a useful medium in which to address issues that are beyond the scope of the study.
- Post-flood clean-up is also an operational issue that is assessed by Council after each event and is outside the scope of the study.
- Inclusion and / or clarification of relevant issues in study.
- Re-drafting of the reports to provide a stand-alone study and plan for the re-exhibition.
- Additional assessment, which included a full hydraulic assessment or provision of additional qualitative information.
- Provision of individual responses to submissions received.
- Direct discussion with an individual or organisation where the issue is localised and not relevant to other residents.
- Recognition that some issues will continue to evoke conflicting responses and that not all parties can be satisfied all of the time.

Coral Sea

Tweed Heads

Tumbulgum

Murwillumbah

Tyalgum

Fernvale

Mount Warning

Uki

Elevation (m)

1100
1000
900
800
700
600
500
400
300
200
100
0

LEGEND

Tweed Catchment Boundary

Tweed River
Watercourse Line
Principal Road
Sealed Road

Title:
Tweed River and Surrounds

Figure: 1-2

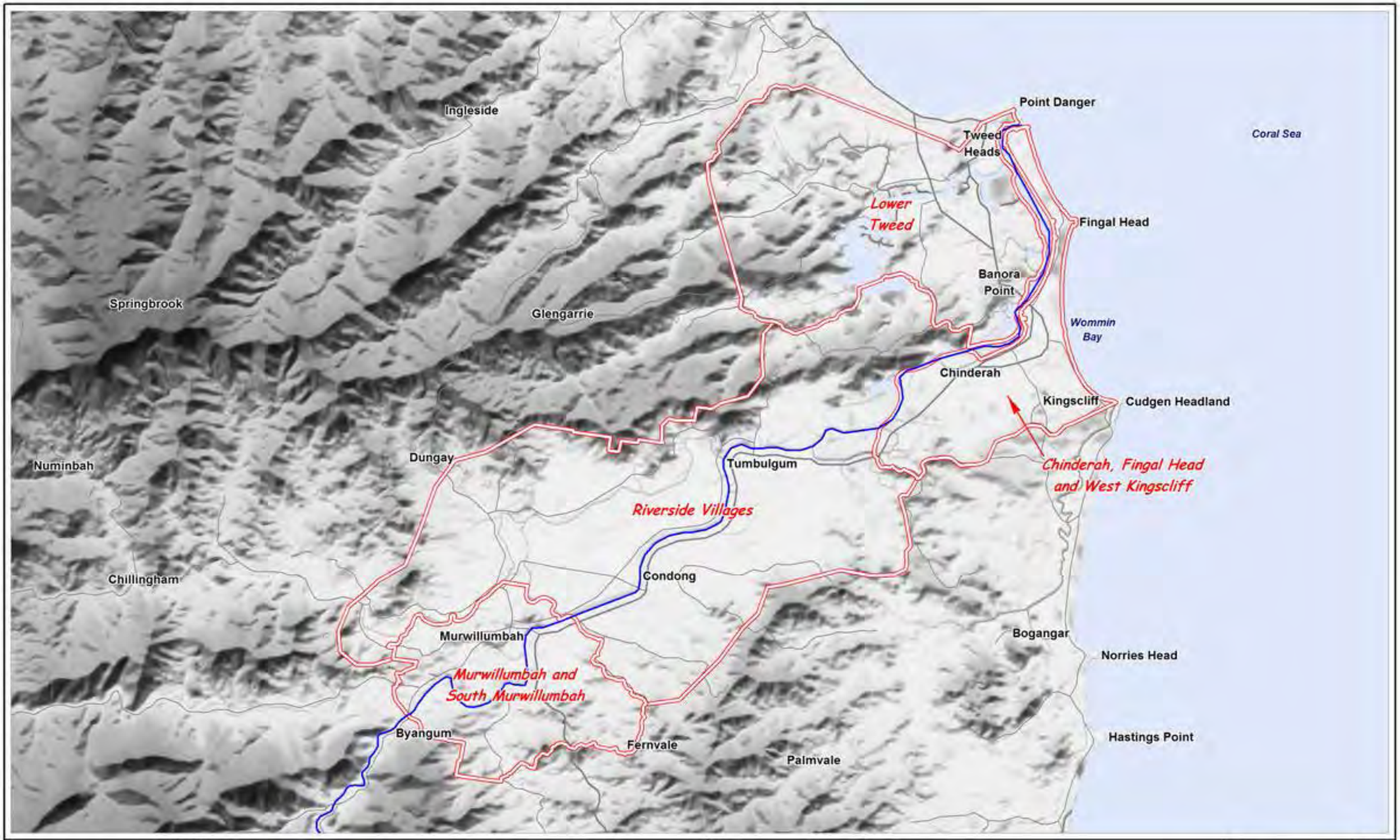
Rev: A

N

0km 4 8
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_001_120426_Tweed River and Surrounds.WOR



LEGEND

- Tweed River
- Principal Road
- Sealed Road

Title:
Study Regions

Figure: 1-3

Rev: A

N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_002_120503_Study Regions.WOR

2 METHODOLOGY

The process used to define flood risk and subsequently assess measures to manage the risk, is provided in the NSW Floodplain Development Manual (2005). This process has been followed during the Tweed Valley FRMS, in conjunction with industry standard approaches. In preparation of this study, the consultants prepared a series of Discussion Papers for consideration by the Floodplain Management Committee and the Technical Sub-Committee, and formed part of the public exhibition material. These papers provide extensive background information for the study, however do not form part of the Study or Plan and shall not be relied upon hereafter. A description of the methodology and sources of information and data is provided below. Further detail is provided in Appendix B.

2.1 Information and Data

The Tweed Valley FRMS covers a wide geographic area with multiple townships, a diverse range of land uses and a large population. In addition, the area is subject to multiple types of flood risk and faces significant development pressure. Therefore, a wide range of information and data sources was required for the characterisation of flood risk in this area, including flood behaviour, demographic data, property survey and planning information.

Information about flood behaviour in the Tweed Valley area was primarily derived from the Tweed Valley Flood Study Update (2009). Some additional flood modelling was required during this study, particularly to quantify the hydraulic impacts of potential management measures and future development, as well as evacuation constraints.

Demographic data was vital to highlight the flood risk to people in the study area. This information, including population, vehicles and vulnerability indices (such as age), was derived primarily from the 2006 Census and geographically distributed to help identify which sections of the population are exposed to the greatest flood risk.

An extensive property survey was commissioned as part of the FRMS to accurately identify the location of every property in flood prone land (both residential and commercial) and record information about floor levels, building and contents. This data informed the damages assessment and was also used to identify potential properties for voluntary house raising or purchase.

A review was completed of the Tweed Shire Council planning framework in relation to flood risk, including the Development Control Plan (DCP) and Local Environment Plan (LEP). This review looked at ways the existing planning documents could incorporate best-practice flood planning controls together with specific flood risk management recommendations from this study.

2.2 Hydraulic Impact Assessment

Hydraulic impact assessments look at the way that flood behaviour (e.g. depth, velocity, duration of inundation) might change as a result of changes in the floodplain, such as raising a flood levee, building a residential development or dredging a river. An assessment starts by using a flood model to define the design flood behaviour (e.g. a flood with a 100 year ARI) for existing conditions. The model is then altered to include the changes in the floodplain, and the results are compared to estimate the impact (positive or negative) on flood behaviour.

2.3 Evacuation Capability Assessment

Evacuation capability assessments consider the ability of people within the floodplain to evacuate safely during a flood event. The assessments use the timeline method developed by the SES to quantify and compare estimates of the time required to evacuate each area versus estimates of the time available.

Results of this assessment will assist the SES to plan for flood evacuations and identify options to reduce risk, particularly in areas where there may be insufficient time to safely evacuate everyone. These may include, for example, upgrading the capacity or flood immunity of evacuation routes, or changes to evacuation plans. In addition, evacuation capability assessments can also help quantify the potential impact of proposed development (and associated additional population) within the floodplain on the ability of the existing community to evacuate safely.

2.4 Flood Damages Assessment

The main objective of the flood damages assessment is to establish the 'baseline' economic costs of flooding (i.e. based on current conditions) which can then be used to help quantify the benefits of potential mitigation measures.

Flood damages are classified as intangible or tangible, depending on whether costs can be assigned monetary values. Intangible damages arise from adverse social and environmental effects caused by flooding, including factors such as loss of life and limb, stress and anxiety. Tangible damages are monetary losses directly attributable to flooding. The flood damages assessment estimates these tangible damages to provide information on the economic impact of flooding and potential management measures.

2.5 Cost Benefit Assessment

Cost benefit assessments are carried out on proposed management options to determine the economic merits of pursuing and / or implementing these options. The assessments compare the cost of implementing the option (e.g. construction and maintenance) with the likely reduction in flood damages (i.e. economic benefit). This comparison produces a ratio which can help inform the decision making process. It must be noted that the cost benefit assessment does not include intangible benefits, such as improved safety or environmental benefits.

2.6 Planning Assessment

In addition to the above quantitative assessments, an extensive review of Council's planning instruments was undertaken and recommendations made to update these with best-practice flood planning controls based on flood behaviour including the hydraulic impact and evacuation capability assessments above. The planning assessment includes an evacuation risk classification dependent not only on flood (hazard and hydraulic) characteristics, but also the nature of proposed development. This assessment includes consideration of topography, proceeding to the safest place, where is the safest place, flash flood environments, scale of development, concurrent fire and medical risks, and refuge in place. The evacuation risk classification is applied to potential development areas in each locality to assist planners and consent authorities in strategic planning and rezoning proposals.

3 EXISTING RISK

The Tweed Valley study area has a long history of flooding and will continue to flood in the future. The extent, behaviour and likelihood of future flooding were assessed through the Tweed Valley Flood Study Update (2009) and that information was used in this study to determine the current flood risk. There was found to be a high level of flood risk in the study area.

There is a considerable number of people and properties located in flood prone land (within the PMF extent), including a large number at risk in the 100 year ARI flood. Flood depths and flows are of a dangerous magnitude in many locations and flood waters can rise quickly, often with short warning periods.

Past efforts to reduce the flood risk have resulted in levees in Murwillumbah and South Tweed Heads, as well as a voluntary house purchase and house raising program. However, since these flood management options were undertaken, development has intensified and there is an improved understanding of flood behaviour in the area. It is therefore timely to quantify the existing risk and use this information to guide selection of flood management measures.

3.1 Flood Behaviour

There have been a number of major floods in the Tweed catchment in living memory, including the largest flood on record in 1954. During this flood, much of the floodplain was inundated with high velocity floodwater that caused significant damage to houses at South Murwillumbah. Calculations in the *Murwillumbah Floodplain Management Plan* (Tweed Shire Council, 1989) estimated the 1954 flood had a return period of between a 60 and 70 year ARI.

The design flood behaviour, modelled in the *Tweed Valley Flood Study Update* (BMT WBM, 2009), considered a range of events, from the relatively frequent 5 year ARI to the largest theoretical flood (the probable maximum flood, or PMF). The events include a 5, 20, 100 and 500 year ARI flood, together with an 'extreme' flood (10,000 year ARI) and PMF.

In the Tweed Valley, information about the 100 year ARI event has been based on a combination of two sources of flooding:

- A catchment / rainfall dominated flood with a smaller storm surge; and
- A storm surge dominated flood with a moderate catchment flood.

The catchment flood dominates (i.e. produces higher peak flood levels) along the Tweed River floodplain downstream to Shallow Bay, as well as the Cobaki / Piggabeen Creek floodplains down to Terranora Creek. The storm surge inundation dominates along the lower Tweed River floodplain from Shallow Bay to the mouth, and the Terranora Creek floodplain from the lower Bilambil / Duroby Creek floodplains down to Tweed Heads.

In the 100 year ARI event, the main high flow areas in the Murwillumbah area include the Bray Park flowpath upstream of town and the flowpath from Blacks Drain to Condong Creek via the Murwillumbah airfield. In the mid Tweed, there are large areas of floodplain conveying high flow between the Tweed and Rous Rivers, as well as from Condong to Stotts Island. In the lower Tweed,

the valleys of the Broadwater tributaries (Cobaki, Piggabeen, Bilambil and Duroby Creeks) all convey high flows.

During smaller flood events, water is predicted to flow from the Rous River to the Tweed River via Mayal Creek, just downstream of Murwillumbah. As the floodwaters rise, the Tweed River becomes the dominant flow and floodwater flows from the Tweed River to the Rous River.

The Tweed Valley is generally quite wide, flat and steep sided with few structures that significantly control the hydraulics of the floodplain. Low natural and man-made banks and levees are present along much of the Rous and Tweed Rivers, but are generally exceeded in small flood events. One exception is the constriction at Murwillumbah created by the town levees, the Murwillumbah Bridge and the sharp bend of the river immediately downstream of the bridge. This constriction causes high velocities in the river, reaching over 2 m/s.

In the lower Tweed, the embankment and drainage structures of the Pacific Highway and the constriction at Barneys Point influence flood behaviour in large events. In extreme events, flood levels in the lower Tweed area are controlled by the constriction at the river mouth / entrance and the dunes between Kingscliff and Fingal Head. There is anecdotal information to suggest that floodwaters break through the coastal dune at Fingal in large events, such as the 1954 flood.

The extent of the PMF is significant, with extremely high depths in some locations. In general, it is not economically or physically possible to provide protection against an event of this magnitude (DIPNR, 2005). However, it is important that the PMF be considered to define the scope and magnitude of potential flood risk, particularly with respect to evacuation and safety considerations.

Figure 3–1 shows the extent of catchment flooding in the Tweed Valley study area.

Ingleside
Springbrook
Glengarrie
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Byangum
Fernvale
Palmvale
Point Danger
Tweed Heads
Coral Sea
Fingal Head
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Bogangar
Norries Head
Hastings Point

LEGEND

- 100 Year ARI Flood Extent
- Probable Maximum Flood Extent
- Tweed River
- Principal Road
- Sealed Road

Title:
Existing Flood Extent

Figure: 3-1

Rev: A

N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\ORG\FRM Study\FLD_007_120427_Existing Flood Extent.WOR

3.2 Hydraulic Categories

Hydraulic categorisation is one of the tools used to identify flood behaviour and risk in a FRMS. Outcomes of the categorisation are primarily used to inform future land use planning. The categorisation is not used to assess individual developments, but rather to give a catchment-scale overview of which areas may be appropriate for various types of land use.

Three hydraulic categories are defined in the Floodplain Development Manual, as follows:

- **Floodways** – Areas conveying a significant proportion of flood flow where partial blocking will adversely affect flood behaviour. Future development should not be allowed to take place in these areas.
- **Flood Storage Areas** – Areas outside floodways which store significant volumes of floodwaters. Reduction in flood storage would cause downstream flood flows to increase.
- **Flood Fringe** – The remaining area of land affected by flooding, after floodway and flood storage has been defined. Development in flood fringe areas would not generally cause significant hydraulic impact.

These definitions are not precise and vary in application between catchments. A number of categories were tested in the Tweed Valley based on flood flows. Of those tested, the following definitions were found to best meet the criteria outlined in the Floodplain Development Manual:

Table 3-1 Hydraulic Categories

Floodway	100 year ARI velocity-depth > 0.3 m^2/s
Flood Storage	100 year ARI velocity-depth > 0.025 m^2/s
Flood Fringe	Remainder of floodplain (up to PMF)

The hydraulic categories have been mapped in Figure 3–2.

The impacts of filling the *flood fringe* indicate that this area is very limited in the catchment. Most areas in the catchment will therefore require hydraulic investigation prior to major filling or development works. Impacts also indicate that a number of locations in the catchment are sensitive to filling, especially the South Murwillumbah Basin. This has also been considered in the assessment of filling future urban areas undertaken as part of this study (Section 8.3.2).

Ingleside
Point Danger
Tweed Heads
Coral Sea
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point

LEGEND

- Floodway (Q100 VxD>0.3m²/s)
- Flood Storage (Q100 VxD>0.025m²/s)
- Flood Fringe
- Tweed River
- Principal Road
- Sealed Road

Title:
Hydraulic Categories

Figure: 3-2

Rev: A

N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_008_120427_Hydraulic Categories.WOR

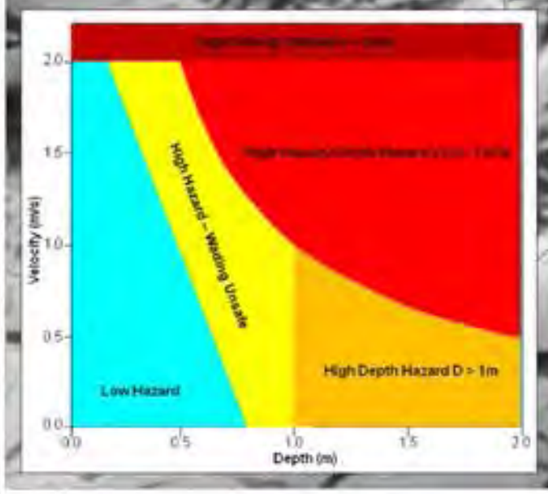
3.3 Hazard Categories

Hazard categorisation supplements the hydraulic categorisation process by considering a wider range of flood risks, particularly those relating to personal safety and evacuation. These hazard factors are derived from both hydraulic risk factors (such as depths and velocities) and human / behavioural issues (such as flood readiness). These considerations are summarised in Table 3-2 in the context of the Tweed Valley.

Table 3-2 Hazard Categories

Size of Flood	Hydraulic categorisation was undertaken using the 100 year ARI design flood. Evacuation capability assessments were undertaken for the 20 and 100 year ARI events, as well as the PMF.
Flood Readiness	Flood readiness will be similar across the catchment, although residents in areas which have experienced historical flooding, such as South Murwillumbah, may have a greater level of flood readiness. The Lower Tweed area may have a lower flood readiness due to the high level of tourists and new residents who are unfamiliar with the local flood risk.
Rate of Rise	Flood waters will rise fastest high up in the catchment, in areas prone to flash flooding, such as Bilambil. Flash flooding is not the focus of this study, however should be considered where known to be an additional hazard in high risk areas. Flood levels behind levees also rise rapidly once overtopping begins, which poses a significant hazard (Tweed Heads South, South Murwillumbah and Murwillumbah CBD).
Hydraulic Hazard	Hydraulic hazard has been mapped for the 100 year ARI in Figure 3–3. Hazard due to high velocity (more than 2 m/s) and velocity-depth (more than 1 m^2/s) is generally confined to in-bank areas and the Bray Park flowpath. Most of the floodplain is subject to high depth hazard (more than 1 m). The areas of Tweed Heads South behind the levee have low hydraulic hazard.
Prediction, Warning and Evacuation	Flood warnings are likely to be issued at a similar time throughout the catchment; however the timing of inundation and peak varies down the floodplain and for different events. In addition, evacuation constraints, such as early road closures, warning dissemination, route and evacuation centre capacities, will vary between locations.
Effective Flood Access	Effective flood evacuation access varies by location and has been considered as part of the evacuation capability assessment.
Type of Development	This flood hazard refers primarily to *future* development.
Isolation	Major low and high island areas were mapped and are presented for the study area in Figure 3–4.

Ingleside
Springbrook
Glengarrie
Numinbah
Dungay
Tumbulgum
Point Danger
Coral Sea
Tweed Heads
Fingal Head
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point



LEGEND

- Tweed River
- Principal Road
- Sealed Road
- Flood Prone Land

Title:
Hydraulic Hazard Categories

Figure: 3-3

Rev: A

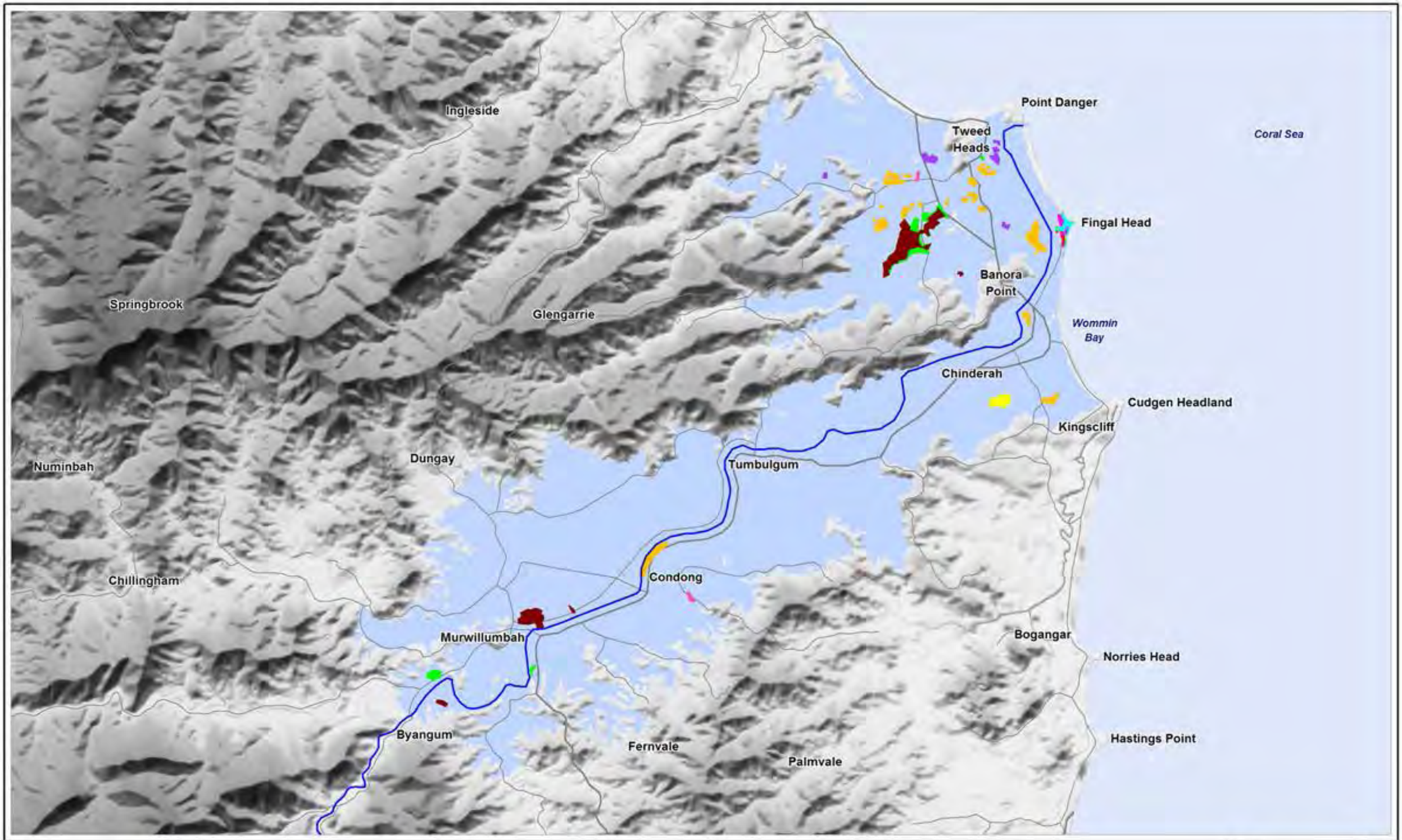
N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_009_120427_Hydraulic Hazards.WOR



LEGEND

- Low island; isolated in 5 year ARI flood; inundated in larger flood events
- Low island; isolated in 20 year ARI flood; inundated in larger flood events
- Low island; isolated in 100 year ARI flood; inundated in larger flood events
- Low island; isolated in 500 year ARI flood; inundated in larger flood events
- Low island; isolated in extreme flood; inundated in larger flood events
- High island; isolated in PMF; unlikely to be inundated
- Probable Maximum Flood Extent
- Tweed River
- Principal Road
- Sealed Road

Title:
Low and High Islands

Figure: 3-4

Rev: A

N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_010_120427_Low and High Islands.WOR

3.4 Demographics

The Tweed LGA has an older demographic, with 26% of the population over 65 years of age (Australian Bureau of Statistics, 2008). People in this demographic are likely to require assistance during evacuation and may be socially isolated, resulting in delayed awareness of evacuation warnings (SES, 2008). Furthermore, an estimated 1,200 people reside in aged care facilities, with up to 50% of these patients classified as 'high risk', requiring one-on-one assistance for evacuation purposes (SES, 2008).

A large proportion of the population reside in caravan parks, with more than 20 caravan parks in the catchment (SES, 2008) housing an estimated 4 to 5% of the population in permanent accommodation (Housing New South Wales, 2008). Caravan parks are often located in areas of higher flood risk and tend to need additional assistance during flood evacuations.

3.4.1 Population at Risk

Numbers of people and houses estimated to be at risk of inundation in the study area during a 5 and 100 year ARI flood, as well as the PMF, is provided in Table 3-3 below. (This has been estimated based on dwellings located within the flood extent.)

Table 3-3 Population at Risk

Numbers at Risk	5 year ARI	100 year ARI	PMF
People	1,600	11,700	41,500
Residential properties	600	4,300	16,800

Risk severity will vary between locations due to flood behaviour, isolation etc as described in Table 3-2.

3.5 Evacuation

The Tweed Valley includes a number of distinct townships and the flood risk varies significantly throughout the catchment. Evacuation is primarily managed by the SES and guided by the Flood Emergency Sub Plan document they have developed. This document summarises existing flood risk and known evacuation issues, and provides a plan for best managing flood evacuations. A summary of existing evacuation issues in each study region is provided below. Detailed findings of evacuation assessments have been provided to the SES to inform their flood planning.

3.5.1 Lower Tweed

Evacuation in the Lower Tweed is extremely constrained. The area is densely populated and although flood free land is generally nearby, it has limited capacity to safely house evacuees and evacuation routes are limited to a few key roads. Flooding occurs relatively frequently, especially in the older parts of town, leading to a high risk of isolation and/or inundation for many residential areas.

Many locations in Lower Tweed are flooded in the relatively frequent 20 year ARI flood, which is a serious evacuation concern. Most of the older parts of Tweed Heads South are flooded in the 100 year ARI, although newer areas, such as Banora Point, were generally filled above this level.

Significant areas of the Lower Tweed area are inundated in the PMF event. Therefore when combined with evacuation constraints, much of the development in this area is considered to be low island development.

In addition to catchment and ocean flooding, there are a number of locations in the Lower Tweed area which are affected by stormwater flooding, including Dry Dock Road, Kennedy Drive, Leisure Drive, Darlington Drive, Minjungbal Drive and Piggabeen Road. Although this type of flooding is not explicitly addressed in this study, stormwater flooding can occur quickly and seriously impede evacuation.

Areas identified to have a particularly high evacuation risk are:

Philp Parade. A key location on the evacuation route for Philp Parade closes early, prior to the issuing of evacuation warnings by the SES. This seriously affects the ability of residents to evacuate to an evacuation centre during large flood events, although the area is connected to high land at Hillcrest Avenue.

Dry Dock Road. There are a number of houses in this area which all evacuate along the same single lane route (Dry Dock Road). This route closes early in the PMF event, potentially constraining evacuation.

Kennedy Drive. This road closes early in the PMF flood event, before the SES is able to issue flood warnings. This provides a serious constraint to properties which are required to evacuate along this route.

Seagulls Estate. Access to and from the Estate (Lakes Drive / Gollan Drive) is restricted to a single lane which has poor flood immunity.

Piggabeen Road. Early route closure may restrict the evacuation potential of vehicles using this route, including residents of Cobaki Broadwater Village.

Banora Point. Evacuation is constrained by a lack of through access roads. Although many at-risk properties are within a few blocks of PMF immune land, residents are unable to drive directly to the nearest high ground and must instead take a longer route through the floodplain.

Evacuation in the Lower Tweed area is exacerbated due to an older demographic and a number of vulnerable institutions, such as the Tweed Hospital and multiple nursing homes and retirement villages.

3.5.2 Chinderah, Fingal Head & West Kingscliff

Evacuation is constrained in a number of areas in the Chinderah, Fingal Head and West Kingscliff region. Low lying roads near the Tweed River are frequently inundated and may prevent evacuation access for a number of residents. There are many caravan parks in this region, particularly around Chinderah.

Areas identified to have a particularly high evacuation risk are:

Fingal Head. Fingal Road closes early in the PMF events, restricting evacuation. This road is the only access route to the Fingal Head peninsula and would isolate all residents if closed by flooding.

There is a high island on Fingal Head, but there are currently no designated evacuation centres or similar support infrastructure at this location.

Chinderah Village. Main evacuation routes (the Pacific Highway and Wommin Bay Road) remain open in small flood events (up to the 20 year ARI), however local access roads (e.g. Chinderah Road and Chinderah Bay Drive) are likely to be inundated, preventing residents from reaching the evacuation routes. Flood risk is increased for Chinderah Village due to the high density of caravan parks and the additional time and resources required to evacuate these locations.

3.5.3 Murwillumbah & South Murwillumbah

Evacuation capability varies across the Murwillumbah and South Murwillumbah region. As this area is mid catchment, there is less time to predict and prepare for flooding before the peak hits. This factor adds a major constraint to the evacuation process and makes evacuation planning difficult in large flood events.

Areas identified to have a particularly high evacuation risk are:

Murwillumbah. Most evacuation routes close before warnings can be issued in a PMF event. Additional resources may be required to provide assistance to the hospital, which would be isolated in such an extreme event. Evacuation may be possible from areas in a 100 year ARI event; however some routes are known to be susceptible to stormwater flooding, which may also impede the process. The Murwillumbah CBD levee is approximately 0.5m lower than the 100 year ARI flood level and so evacuation is reliant on the community's preparation and adherence to evacuation orders prior to the onset of inundation, as flood levels behind the levee rise rapidly once overtopping begins.

South Murwillumbah. Most evacuation routes close before warnings can be issued in a PMF event. Evacuation to Murwillumbah may be possible along most of the main route (Tweed Valley Way and Alma Street) in a 100 year ARI event, subject to local stormwater flooding. In addition, the South Murwillumbah levee (which includes Alma Street) only has a low level of immunity (less than a 5 year ARI) and so the onset of inundation occurs much earlier than in Murwillumbah. Evacuation is reliant on the community's preparation and adherence to evacuation orders prior to the onset of inundation, as flood levels behind the levee rise rapidly once overtopping begins.

Rural Areas. Evacuation of rural areas can be difficult, due to the isolation of these properties and the distance through the floodplain the residents may have to travel in order to reach an evacuation centre.

3.5.4 Riverside Villages

The Riverside Villages area has a moderate evacuation risk. Riverside towns, such as Condong and Tumbulgum, can be frequently inundated, however evacuation is generally possible for smaller flood events. Low-lying roads near the river flood frequently and can seriously impede evacuation. Areas with easy access to higher ground, such as Terranora, have a good evacuation capability.

Areas identified to have a particularly high evacuation risk are:

Tumbulgum. Evacuation is likely to be possible during most large flood events, but is constrained during a PMF event.

Condong. Evacuation to Murwillumbah is likely to be possible during most large flood events, but seriously constrained during a PMF event.

Dulguigan and Tygalgah. The evacuation route identified in the Flood Emergency Sub Plan for the area, Dulguigan Road, is frequently affected by flooding, rendering it unsuitable for use as an evacuation route.

3.6 Risk to Property

In addition to personal risk, properties can also be at risk of serious structural damage due to high velocities, depths and flood flows, as well as internal, external and indirect losses. Using the flood model and property survey, the number of residential and commercial properties experiencing above floor flooding was estimated, shown in Table 3-4.

Table 3-4 Estimated Number of Inundated Properties

Flood Event	Inundated Properties (Above Floor)	
	Residential	Commercial
5 year ARI	16	35
20 year ARI	395	80
100 year ARI	1,120	340
500 year ARI	6,140	720
Extreme flood	14,360	970
PMF	14,760	1,000

3.6.1 Flood Damages

A flood damages assessment has been completed for the entire floodplain study area, using the existing flood model, as developed for the Tweed Valley Flood Study. This assessment estimated an annual average damages (AAD) cost of **$22.5 million**. By way of comparison, this is more than double the estimated AAD in Ballina ($9m), comparable with Newcastle ($21m) and less than the Hawkesbury Valley ($70m).

This value includes damages incurred by residential and commercial properties and approximated infrastructure damages, but excludes agricultural losses. Whilst flooding does significantly impact on agriculture in the Tweed Valley and remains an important consideration, the economic assessment of floodplain mitigation and management options in this study is based on urban damages.

Results of this assessment for the entire study area are presented in Table 3-5.

Table 3-5 Flood Damage Estimates (millions of $)

Flood Event	Flood Damage Estimates (millions of $)			
	Residential	Commercial	Infrastructure	Total
5 year ARI	$7	$3	$1	$12
20 year ARI	$65	$7	$10	$82
100 year ARI	$152	$46	$27	$225
500 year ARI	$679	$187	$120	$986
Extreme flood	$2,380	$637	$419	$3,436
PMF	$2,638	$682	$463	$3,782
AAD	**$16.2**	**$3.6**	**$2.8**	**$22.5**

4 FLOOD MODIFICATION MEASURES

Flood modification measures are designed to modify the behaviour of floodwaters by either reducing flood depths and velocities, or by excluding floodwater from certain areas.

4.1 Existing Measures

There has been a long and extensive history of investigations into structural works to mitigate flooding in the Tweed Valley, particularly in the 1970s and 1980s. These have primarily resulted in the construction of levees and minor drainage works, including flap gates. Other options, including flood mitigation dams, floodways and channel modifications, have also been considered in the past; however the benefits were not found to justify the often considerable expense.

4.1.1 Levees

Flood mitigation levees have been constructed in multiple locations within the study area, most notably around Murwillumbah and Tweed Heads South, as outlined in Table 4-1. These levees provide varying degrees of flood protection, though are generally less than 100 year ARI flood levels. Numerous rural levees have also been constructed to reduce agricultural losses.

Table 4-1 Levee Summary

Levee	Approximate Year of Construction	Design Protection	Estimated Protection
East Murwillumbah	2006	Raised to 100 year ARI	Approx. 0.2m below the 100 year ARI level
Dorothy/William Street Murwillumbah	2006	100 year ARI	Approx. 0.4m above the 100 year ARI level
Murwillumbah CBD Commercial Road	1990	Raised to 100 year ARI	Approx. 0.5m below the 100 year ARI level
South Murwillumbah	1990	Raised to level of Alma Street	Approx. 0.6m below the 5 year ARI level
Tweed Heads South	Pre 1979	Above historic level	Approx. 0.2m below the 20 year ARI level

4.1.2 Clarrie Hall Dam

Clarrie Hall Dam, located in the upper catchment between Doon Doon and Uki, was completed in 1982. The primary function of the dam is water supply and the dam is operated to meet this function. It was not designed as a flood mitigation dam, being off-line to the Tweed River, though it may provide some limited storage in the Doon Doon Creek catchment.

4.1.3 Other Minor Drainage Works

A number of other drainage works that assist in mitigating Tweed River flooding have been constructed throughout the study area, including:

- Flap gates on Blacks Drain and Condong Drain (outlet behind Quarry Road);

- Flood gating of:
  - The Lavender Creek outlet;
  - Drains around Murwillumbah showgrounds and Kynnumboon Bridge;
  - Drainage outlets into the Tweed River around North Tumbulgum Flats ; and
  - Tweed River Left Bank Flats (golf course to Tweed Heads to Terranora Broadwater);
- General drainage works along Tweed River, from McLeod's Creek to Fingal Head, including flood gating and raising of the old Pacific Highway (now Tweed Valley Way); and
- The Lavender Creek pump station.

4.2 Flood Modification Options

4.2.1 Whole of Study Area

A number of flood modification options are available to reduce the impacts of flooding on a catchment scale, however these are generally very expensive and can have significant environmental implications. None were identified as being suitable for further assessment to benefit the broader study area. The options considered during the study and reported in the discussion papers include:

- Retarding basins;
- Bypass floodways;
- Channel modifications; and
- (Additional) levees.

A number of other flood modification options have previously been considered for the study area and found to be not viable. These options include:

Flood mitigation dams. This is considered unlikely to be economically feasible or effective given the catchment size, significant cost and potential for environmental degradation. Cost-benefit assessments of dual flood mitigation / water supply storage at the Clarrie Hall Dam site, Rocky Cutting and Terragon have been previously undertaken and reviewed but rejected, primarily based on economic feasibility (Soros-Longworth and McKenzie, 1980).

Relocation or development of a new river mouth or flood relief outlet. This option is unlikely to be economically feasible and has potential adverse hydraulic, safety and environmental impacts. The coastal dynamics (long shore transport) in the region cause the Tweed River mouth to migrate northwards and the development of a new river mouth (e.g. near Fingal Head) would require extensive and expensive training works to maintain the channel. Whilst a new mouth (or flood relief outlet) may incrementally reduce catchment flood risk, it would also increase storm surge flood risk along the lower reaches and increase isolation risk for Fingal Heads. This option has also been considered previously and rejected on economic, environmental and hydraulic grounds (Soros-Longworth and McKenzie, 1980).

Dredging. Previous investigations have indicated that dredging may reduce peak flood levels by up to 0.15m at Chinderah (WBM Oceanics Australia, 1995). However, this relatively minor benefit is unlikely to be economically viable solely to reduce flooding and has associated adverse

environmental impacts. Dredging from Murwillumbah to Tweed Heads was also rejected on this basis in previous studies (Soros-Longworth and McKenzie, 1980). However, dredging may provide some benefit to Chinderah and the Lower Tweed if it were pursued for other objectives (e.g. sand nourishment of Kingscliff Beach).

4.2.1.1 Commission Local Drainage Studies

It was noted throughout the study that there are known local drainage issues affecting multiple locations throughout the study area. Whilst these were not the focus of this study, it is recommended that studies focussed on local drainage and the associated flood risks are undertaken.

Specifically, local drainage issues have been known to be key impediments to evacuation in the past, in areas that are already facing significant evacuation risks. More generally, information on local flood risk is useful for the purposes of quantifying stormwater risks, identifying potential for mitigation and development planning.

It is recommended that hydraulic models are developed which include drainage infrastructure, such as pipes and pits. Based on anecdotal evidence from past flooding events (particularly 2005), local drainage studies are recommended for the lower Tweed area (including Tweed Heads South and Banora Point), and Chinderah. A local drainage study for Murwillumbah CBD is also needed for quantifying and mitigating stormwater risks behind the town levee, to optimise the operation of the Lavender Creek pump station, and for development planning purposes. This study could also incorporate a levee overtopping analysis for completeness.

Recommendations 1 and 2: Undertake local drainage studies focussed on specific areas. For the lower Tweed and Chinderah areas this should include consideration of local stormwater constraints to key evacuation routes. For Murwillumbah CBD, further information is needed on extent and level of local stormwater inundation for planning purposes and potential mitigation works.

4.2.2 Lower Tweed

4.2.2.1 Raise Tweed Heads South Levee

The Tweed Heads South levee was constructed in the late 1960s / early 1970s and was designed to provide immunity above the historic flood level (1954), with a design crest of approximately 2.0m AHD. The *Tweed Valley Flood Study Update* (BMT WBM, 2009) and the Tweed Shire Flood Emergency Sub Plan identified that the levee has been poorly maintained and does not provide the level of protection it was designed for. The location of the levee is shown in Figure 4-1 which was based on ground survey undertaken and included in the flood model developed for the Flood Study.

Issue: There is a high flood risk to people and properties behind the levee.

In 2010, Jeffery and Katauskas were commissioned by Council to undertake geotechnical investigations into the feasibility of raising the levee. Due to topographical constraints, some areas along the existing levee need to be concrete levees in order to raise the crest to the required height.

The Tweed Valley flood model, developed as part of the Flood Study, was used to check the hydraulic impact of raising the levee for the full range of modelled events (5 year ARI to PMF). The modelling confirmed the reduction in inundation behind (i.e. to the south of) the levee for events up to

and including the 100 year ARI event. There is also a reduction in flood levels in the 500 year ARI event. In an extreme flood event or PMF, the extent of inundation is generally unchanged as the levee is significantly overtopped; however, there is a delay in the time of first inundation as the levee initially provides extra protection from the rising floodwaters.

The hydraulic impact of raising the levee was assessed by comparing peak flood levels for the existing and raised levee scenarios, shown in Figure 4-2 and Figure 4-3, for a 100 year ARI catchment flood and storm surge dominated event respectively. This shows the area protected by the raised levee, properties bounded by Kirkwood Road and the Pacific Highway, which are no longer inundated during a 100 year ARI event. The area behind the levee is primarily at risk of inundation from ocean storm surge, even in a catchment flood dominated event. It does not currently experience significant flooding from the Tweed River catchment due to the terrain and the presence of the existing levee. The assessment found there would be minimal change in the peak100 year ARI flood levels in other areas in the catchment, which are generally within ± 0.03 m of existing peak levels. Significant stormwater infrastructure would also be required, to ensure properties behind the levee are not at increased risk of stormwater damage from local catchment inundation.

The potential benefits of raising the Tweed Heads South levee to approximately 2.8m AHD to provide a 100 year ARI standard of flood protection (including 0.5 metre freeboard) have been assessed, including consideration of both evacuation capability and flood damages.

The assessment determined that raising the levee would provide significant protection to properties behind the levee in larger flood events. Raising the levee would also provide an additional three hours to evacuate in a PMF event, due to a delay in levee overtopping. The additional time is sufficient for the entire Dry Dock Road area (excluding Philp Parade, see Section 4.2.2.3 below) to cross Boyds Bay Bridge into Tweed Heads.

A significant reduction in flood damages of $2.6 million per year (AAD) was identified. A preliminary cost benefit assessment was undertaken, with the final values provided in Table 4-2 below.

Table 4-2 Cost Benefit Ratio

Total Benefit ($2011)	$35.4m
Total Cost ($2011)	$11.4m
Monetary Benefit-Cost Ratio	**3.1**

This benefit cost ratio is high and provides good support for raising the levee. However, it should be noted that levees can foster a false sense of security in the community, with the belief that their property is “flood proof”. Raising the levee will require a significant outlay, although it is expected to bring significant economic benefit. It will also offset costs to raise 7 properties in Tweed Heads South as part of a voluntary house raising scheme (estimated cost of approximately $490,000, see Section 6.2). The cost estimate includes $1 million for stormwater pumps.

Recommendation 3: Raising the Tweed Heads South levee to provide 100 year ARI protection is a viable and beneficial option. A more detailed costing by a quantity surveyor is required, along with community consultation and detailed consideration of social and environmental impacts and mitigation.

LEGEND

- Tweed Heads South Levee
- Area Benefitting from Raising Levee
- Philp Parade Levee
- Area Benefitting from Philp Parade Levee
- Cadastral boundaries
- 100 Year ARI Flood Extent
- Probable Maximum Flood Extent

Title:
Tweed Heads South Levee

Figure: 4-1

Rev: A

N

0m 300 600

Approx. Scale

BMT WBM
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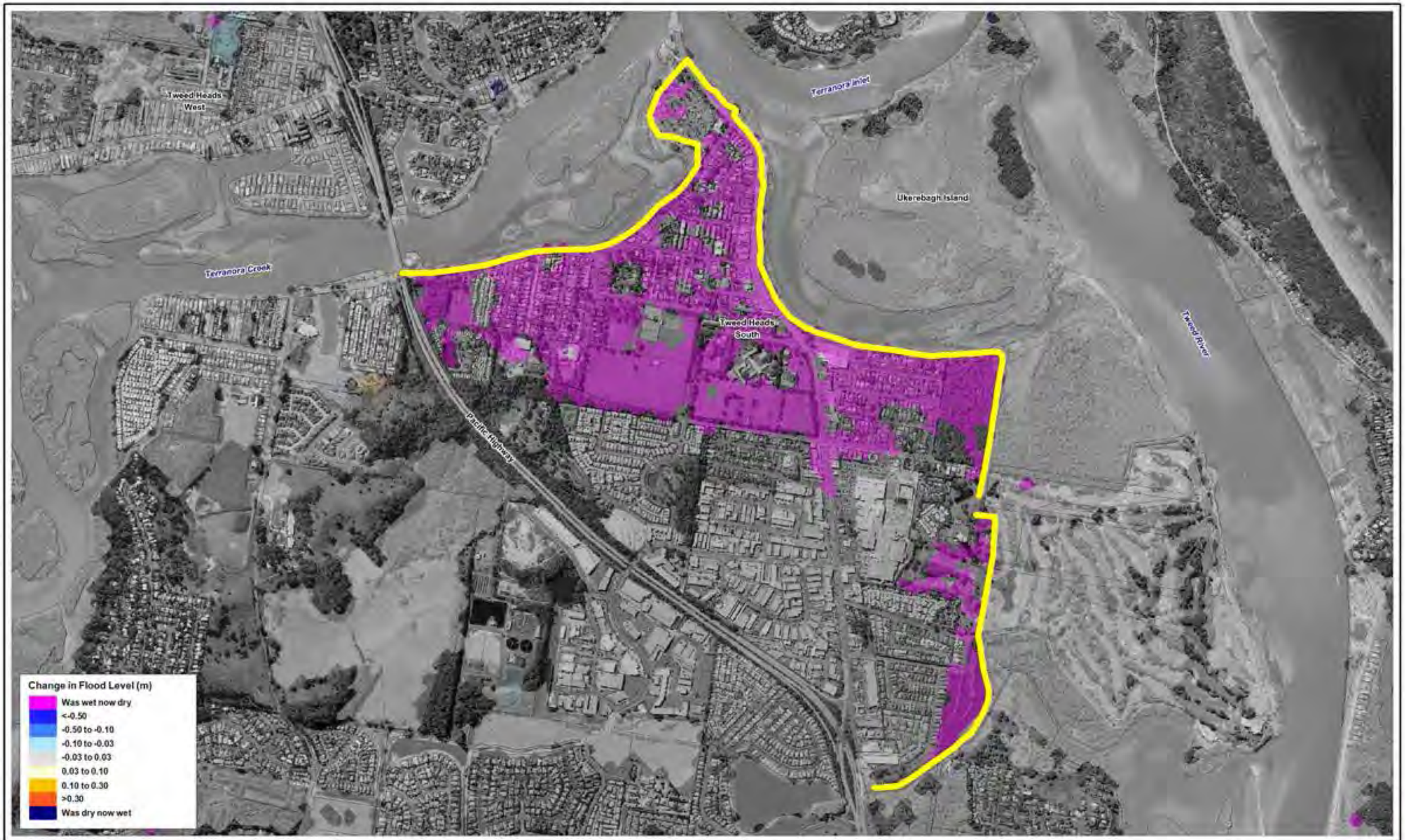

LEGEND

- Tweed Heads South Levee
- Cadastral boundaries

Title:

Impact of Raising Tweed Heads South Levee 100 Year ARI Catchment Flood

Figure: 4-2

Rev: A

N

0m 300 600

Approx. Scale

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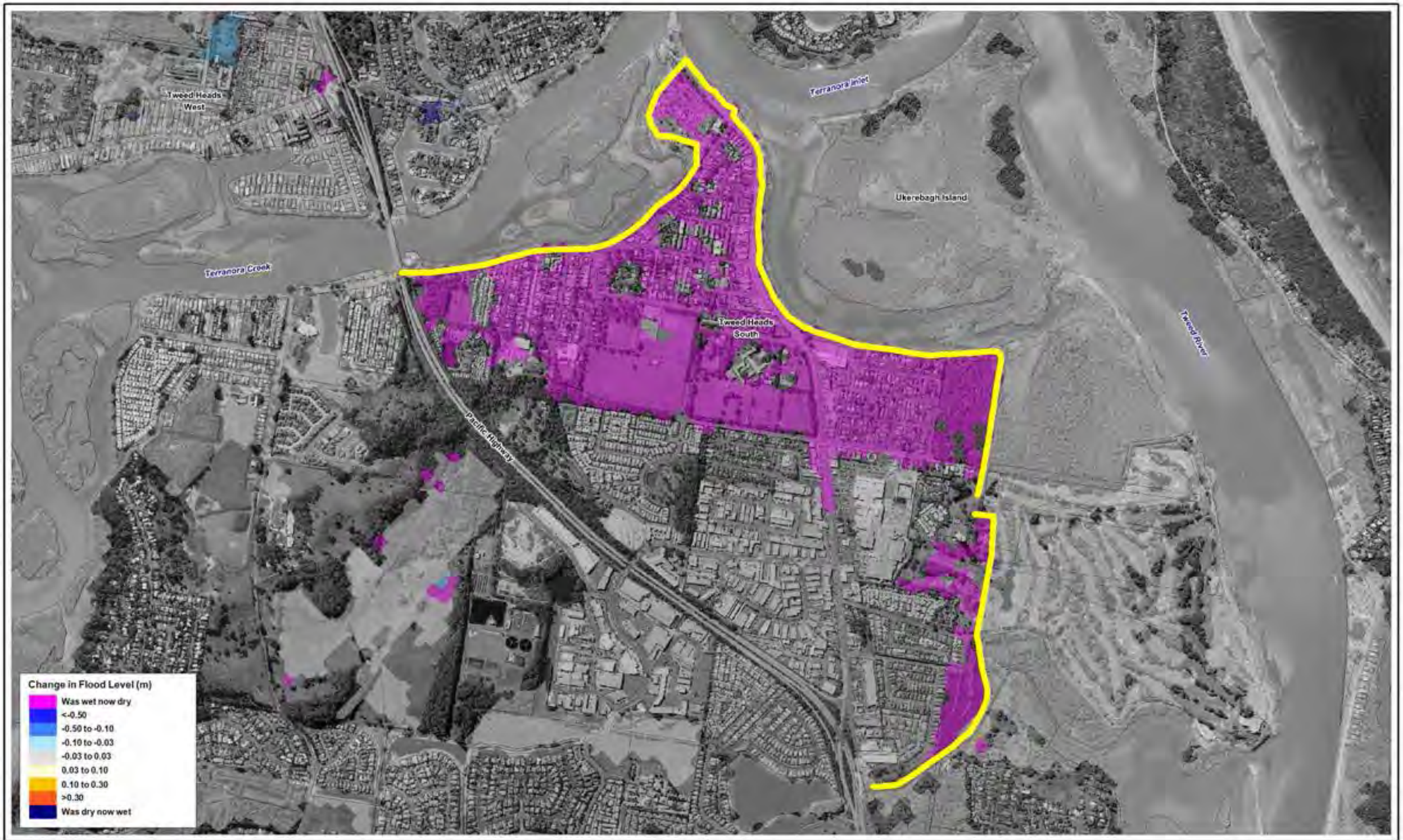

LEGEND

Tweed Heads South Levee

Cadastral boundaries

Title:

Impact of Raising Tweed Heads South Levee 100 Year ARI Storm Surge

Figure: 4-3

Rev: A

N

0m 300 600

Approx. Scale

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4.2.2.2 Commission Levee Overtopping Study

Levee overtopping studies consider the particular flood risk associated with levee overtopping and the effects it has on people, properties and infrastructure. A levee overtopping study for the Tweed Heads South levee would need to compare the relative overtopping risks for the levee at the current height and at the proposed raised height.

A levee overtopping study of the South Tweed Levee would likely include the following:

- Improved detail in the flood model in the levee area, including addition of the proposed (raised) levee height in the proposed scenario;
- Consideration and assessment of controlled overtopping locations;
- Assessment of time and location of overtopping, relationship to stream gauge levels;
- Assessment of hazard behind the levee, including time of inundation following overtopping, high flow hazards, road closures;
- Assessment of impact to personal safety, properties and infrastructure following levee overtopping;
- Sensitivity analysis comparing levee overtopping for floods of different durations and / or combinations with storm surges;
- Recommendations for SES to improve flood response and emergency planning in the event of levee overtopping; and
- Recommendations for Council regarding land use and building design in the area behind the levee.

Recommendation 4: Additional investigations into raising the Tweed Heads South levee should include a levee overtopping assessment to better understand the impact that the measure will have on flood risk and risk management in the Tweed Heads South area.

4.2.2.3 Extend Tweed Heads South Levee to Philp Parade

Another option identified during the study was the extension of the Tweed Heads South levee (westwards) to protect the Philp Parade area.

Issue: Philp Parade has a high flood risk and an extremely constrained evacuation capability due to frequent inundation.

Preliminary hydraulic assessment of the levee extension modelled the levee crest at 2.8m AHD, consistent with the raised levee option, and showed minimal change in the peak 100 year ARI flood levels in other areas in the catchment, which are generally within ± 0.03 m of existing peak levels. Results from the preliminary assessment indicate that extension of the levee will protect approximately 60 properties from inundation in flood events up to and including the 100 year ARI event. This should also provide sufficient time to evacuate to Tweed Heads in a PMF event due to a delay in levee overtopping.

This measure will significantly improve the safety of residents in the Philp Parade area. Residents and properties will be protected from smaller flood events and have more time to evacuate during larger events.

Constructing a levee in the proposed location would significantly impact the visual amenity and character of the area by blocking direct river access in this location. These factors should be considered in conjunction with further, more detailed hydraulic and economic assessment.

The total economic benefit is estimated at **$10 million**, based on an associated reduction in average annual damages for flood events up to and including the 100 year ARI. It would also offset costs to raise 5 properties in the Philp Parade area as part of a voluntary house raising scheme (estimated cost of approximately $350,000, see Section 6.2). Capital cost estimation has not been completed at this stage.

Recommendation 5: The levee extension option should be considered by the Floodplain Management Committee and Council, in conjunction with appropriate community consultation, to determine whether it might be viable. If so, a full and separate study would need to be undertaken to analyse the hydraulic, safety, environmental, social and economic impacts of the extension.

4.2.3 Chinderah, Fingal Head & West Kingscliff

No suitable flood modification options were identified for the Chinderah, Fingal Head and West Kingscliff area as part of this study.

A number of other flood modification options have previously been considered for the study area and found to be not viable. These options include:

Development of a new river mouth or flood relief outlet. This option is unlikely to be economically feasible and has potential adverse hydraulic, safety and environmental impacts (see Section 4.2.1).

Dredging. This option is unlikely to be economically viable solely to reduce flooding and has associated adverse environmental impacts (see Section 4.2.1).

Levees. This option is unlikely to be viable for Chinderah due to technical difficulties, costs associated with the levee and works to existing structures, and hydraulic and visual impacts.

Floodway. There are limited opportunities to provide benefit in a very large flood event without adverse impacts and / or significant property resumption.

Although no flood modification options were suitable, other response modification measures have been recommended (Section 5.3).

4.2.4 Murwillumbah & South Murwillumbah

A number of flood modification options have previously been considered for the Murwillumbah and South Murwillumbah region but were not found to be viable. These options include:

Raising and / or New Levees. Previous studies have investigated options for raising levees in Murwillumbah, South Murwillumbah, East Murwillumbah and Bray Park (Soros-Longworth and McKenzie, 1980 and Tweed Shire Council, 1989). These levees have all now been raised based on

hydraulic and cost-benefit assessments and it is unlikely that these levees will be further raised or new levees constructed due to hydraulic constraints. Mitigation options for Rous River flooding in Murwillumbah (around Mooball Street) have also been considered but were not found to be viable due to the scale of works required and the limited number of affected properties.

Channel Modifications. This option is unlikely to be effective for large, out-of bank flow events that cause the most impact and damage. It may also exacerbate downstream risk and the scale of works required may be prohibitive.

Floodways. There are limited opportunities to provide benefit in a very large flood event without adverse impacts. The costs associated with implementation of the floodways, particularly the purchase of land, are likely to be prohibitive. However, the potential to alleviate flooding via a South Murwillumbah bypass floodway from Blacks Drain to the airfield was revisited. This would require the purchase and lowering of land at Blacks Drain (to increase flow into the basin when the river is in flood) and at the outlet to the Condong Basin at Quarry Road.

Whilst hydraulic modelling confirmed a bypass floodway would reduce flood levels in the river (and in the areas behind the town and East Murwillumbah levees, i.e. north of the river), it would lead to higher flood levels in the South Murwillumbah basin, affecting existing areas of development, and so was not considered to be a viable option. This was consistent with the findings of previous investigations undertaken as part of the 1989 Murwillumbah Floodplain Management Plan (Tweed Shire Council, 1989).

4.2.4.1 South Murwillumbah Condong Flowpath

Whilst a bypass floodway was not considered viable without some adverse impacts, it was found that flooding in the South Murwillumbah basin can be alleviated (by depths of 50 to 100 mm in a 100 year ARI flood) by increasing flow through the South Murwillumbah / Condong Basin connection at Lot 4 Quarry Road (i.e. without increasing flow into the basin via Blacks Drain). This parcel, which is zoned for industrial development but remains vacant, has separately been identified for preservation as a critical floodway via purchase by Council or planning controls (see Section 8.4.3.2).

If it is to be purchased, lowering of the land to the level of the airfield upstream will increase flows from the South Murwillumbah to the Condong basin and reduce levels in the basin by approximately 50mm without significant downstream impacts. Incorporating a hydraulic structure under Quarry Road may reduce levels further.

Recommendation 6: Depending on the approach to secure the South Murwillumbah Condong flowpath (purchase by Council or planning controls), consider lowering of this lot (together with further design of a hydraulic structure under Quarry Road) to reduce flooding in the South Murwillumbah basin.

4.2.4.2 Commission Levee Overtopping Study

Levee overtopping studies consider the particular flood risk associated with levee overtopping and the effects it has on people, properties and infrastructure. A levee overtopping study for the Murwillumbah levees would primarily focus on quantifying the current level of protection, highlighting

areas which may need augmenting and identifying areas of particularly high hazard which may influence local development controls.

A levee overtopping study of the Murwillumbah levees would likely include the following:

- Improved detail in the flood model in the levee area;
- Consideration and assessment of controlled overtopping locations;
- Assessment of time and location of overtopping, relationship to stream gauge levels and degree of protection provided (e.g. protection from 100 year ARI flood);
- Assessment of hazard behind the levee, including time of inundation following overtopping, high flow hazards, road closures;
- Assessment of impact to personal safety, properties and infrastructure following levee overtopping;
- Sensitivity analysis comparing levee overtopping for floods of different;
- Recommendations for SES to improve flood response and emergency planning in the event of levee overtopping; and
- Recommendations for Council regarding land use and building design in the area behind the levee.

Recommendation 7: A levee overtopping assessment of the Murwillumbah levee system would improve understanding of local flood behaviour and better inform future floodplain management measures for the area.

4.2.5 Riverside Villages

No suitable flood modification options were identified for the Riverside Villages area as part of this study.

Levees have previously been considered for this area but found to not be viable due to high capital costs and undesirable impact on visual amenity.

Although no flood modification options were suitable, other response modification measures have been recommended (Section 5.3).

4.3 Flood Modification Recommendations

Extensive previous investigations, together with a review of flood modification options as part of this study, indicate there are unlikely to be any options found to be effective or economical at the catchment scale.

Raising the existing Tweed Heads South Levee to the 100 year ARI flood level was found to have a high benefit cost ratio as well as increased protection to residents and evacuation time during extreme flood events. This option has a strong case for pursuing further.

Extension of the South Tweed Levee to Philp Parade is an option which may be considered in the future to decrease the considerable safety risks in the area. A detailed analysis has not been

undertaken on this option to date, however recognised constraints to the extension of the levee include loss of visual amenity and likely loss of direct river access in this location.

A number of smaller scale flood modification options might be considered to improve stormwater flooding and drainage issues across the catchment, which have not been the focus of this study. These options include detailed stormwater assessments (possibly through the development of a finer scale flood model), and the inclusion of pumps and flood gates in leveed areas. It is, however, recommended that separate studies be undertaken to investigate and manage flood risk from local drainage and stormwater in key locations, specifically the Lower Tweed, Chinderah, and Murwillumbah.

5 RESPONSE MODIFICATION MEASURES

Response modification measures are essential for managing residual flood risk. In general, response modification measures are the simplest and most cost effective measures to install, alongside planning measures for reducing risk to future development.

5.1 Existing Measures

A number of response modification measures are currently in use in the study area including a detailed flood warning system, various sources of flood intelligence and the Flood Emergency Sub Plan (FESP) developed and maintained by the SES. These measures are described below.

5.1.1 Flood Warning System

The flood warning system commences with the issue of Flood Watches and Flood Warnings from the Bureau of Meteorology (BoM) and concludes with the public receiving a detailed message about flood risk and required action.

The BoM maintains an operational (hydrologic) model of the Tweed catchment which utilises recorded and forecast rainfall to predict flooding in the catchment. It is estimated that forecast rain in excess of 120 mm per day would trigger a Flood Watch and ongoing monitoring and modelling. Stream gauges actively monitored by BoM include Murwillumbah (previously known as the "Powerhouse" Gauge) and Barneys Point (Chinderah), as marked on Figure 5–1. The BoM also have a flood peak correlation relationship for estimating peak height at the Tumbulgum gauge based on the Murwillumbah gauge, however this is not part of the flood prediction network and therefore does not explicitly take account of the tide or Rous River inflow. The BoM also have a similar flood peak correlation relationship for estimating peak height at the Chinderah gauge based on the Tumbulgum gauge.

The SES monitors a number of additional stream gauges, provided in Appendix C.

The flood levels correlating to these BoM definitions for minor / moderate / major floods, as well as design flood levels, have been provided for the Murwillumbah and Chinderah gauges in Table 5-1.

Flood classifications of minor, moderate or major relate to the effects of flooding, as per the following BoM definitions:

- **Minor flooding**: Causes inconvenience. Low-lying areas next to watercourses are inundated, which may require the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged.
- **Moderate flooding**: In addition to the above, the evacuation of some houses may be required. Main traffic routes may be inundated. The area of inundation is substantial in rural areas requiring the removal of stock.
- **Major flooding**: In addition to the above, extensive rural areas and/or urban areas are inundated. Properties and towns are likely to be isolated and major traffic routes likely to be closed. Evacuation of people from flood affected areas may be required.

Table 5-1 Flood Event Levels at Stream Gauges

Flood Event	Murwillumbah Gauge	Chinderah Gauge
Minor Flood	3.0m AHD	1.5m AHD
Moderate Flood	4.0m AHD	1.7m AHD
Major Flood	4.8m AHD	2.0m AHD
5 year ARI	5.3m AHD	1.3m AHD
20 year ARI	5.7m AHD	2.2m AHD
100 year ARI	6.6m AHD	3.0m AHD
500 year ARI	7.4m AHD	4.4m AHD
PMF	11.4m AHD	7.7m AHD

5.1.2 Flood Intelligence

In the Tweed Valley, flood intelligence is primarily recorded in Flood Intelligence Cards. These cards detail the relationship between flood gauge heights and flood consequences. They are used by the SES to interpret the meaning of quantitative flood predictions and to help decide appropriate flood response actions. Within the study area, flood intelligence cards exist for the Murwillumbah, Tumbulgum and Barneys Point (Chinderah) gauges. These cards are maintained and updated by SES Headquarters and, as they contain sensitive information such as house addresses, are not publically available.

5.1.3 Flood Emergency Sub Plan

The Tweed Shire Flood Emergency Sub Plan (FESP, formerly Local Flood Plan) was prepared by the SES in consultation with the Local Emergency Management Committee and is a sub-plan of the Tweed Shire Local Disaster Plan (often referred to as DISPLAN).

The FESP outlines preparedness, response and initial recovery strategies for flooding of all magnitudes and from all sources within the local government area. Information contained in the FESP is derived from a range of sources including Flood Studies, Floodplain Risk Management Studies and Plans, modelling, maps, historical records, archived print media, other agency records (including Council records), expert testimony and local knowledge.

The FESP is an agreed set of arrangements used to inform operational decision making during floods. The SES also uses real time data from sources, including BoM Flood Watches and Flood Warnings, current river and rainfall readings, SES reconnaissance and community feedback, to determine the most appropriate response strategies for a given flood.

5.1.4 Cross Border Planning

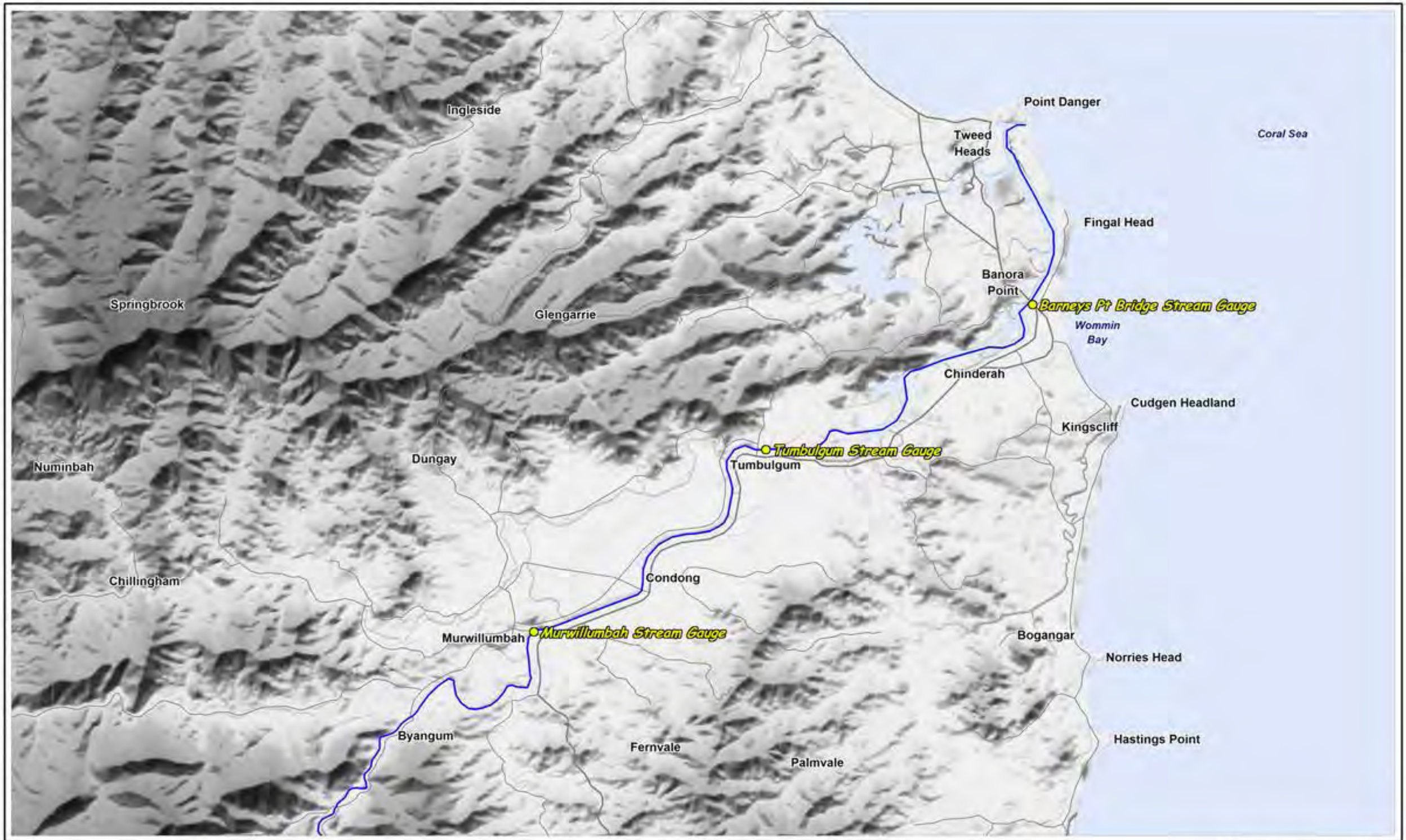
A Cross Border Plan has been developed by Gold Coast City Local Disaster Management Group and Tweed Shire Local Emergency Management Committee to assist coordination of emergency response between Tweed Heads and Gold Coast. Cross border disaster planning faces a number of

challenges including differences in command and control structures, terminology and communication channels, legislative frameworks, and (during summer) time zones. The Cross Border Plan, in conjunction with continued liaison between the two Council groups, aims to minimise the effect of these challenges in preparation for, during and following a disaster event that impacts the cross border community.

5.1.5 Flood Awareness

There is no record of past formal assessments (e.g. surveys) to gauge community flood awareness in the study area; however anecdotal evidence suggests that flood awareness is low, due to the following reasons:

- There have been few major floods in recent times;
- Residents may have a false sense of security about the effectiveness of flood protection structures, such as levees;
- There are a large number of new residents in the area who are unfamiliar with local flood behaviour;
- There is low awareness amongst residents that large scale filled residential development on the floodplain (e.g. in Banora Point and the Tweed canal estates) is at risk of inundation from floods greater than the 100 year ARI; and
- The lower Tweed is a major tourist area, with tourists unaware of local flood behaviour or evacuation procedures.



LEGEND

- Tweed River
- Principal Road
- Sealed Road

Title:
Flood Warning Network

Figure: 5-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map

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Approx. Scale

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5.2 Response Modification Options

The following response modification options have been put forward as suggestions to augment the extensive evacuation planning already undertaken by the SES.

5.2.1 Flood Awareness

5.2.1.1 Community FloodSafe Engagement Program

The SES has recently created a Community Engagement Officer position for the Richmond Tweed Region. One of the Officer's primary responsibilities is the creation of the Community FloodSafe Engagement Program. The stated aims of this program are to:

- Increase community awareness of flood risk;
- Increase community understanding of what to do before / during / after floods;
- Increase awareness of SES role and SES phone number; and
- Build partnerships with local community / business / local and state government.

Planned strategies include media releases, SES community education training, additional brochures targeting other sectors of the community, flood risk workshops with retirement village managers and business breakfasts.

Issue: Flood awareness is low.

This program is in its infancy and has yet to secure funding for all of the planned programs and strategies.

In addition to the target groups identified by the SES, based on key risks identified in this study, it is recommended that the following issues also be prioritised in the awareness program:

- Understanding the limits of levee protection, as well as residual risks such as the fast rate of inundation when a levee is overtopped;
- The range and full extent of flood risk (e.g. the depth differential between a 'major' flood as predicted by the BoM, a 100 year ARI flood and PMF);
- Assistance in interpreting flood warnings; and
- The increased flood risk at caravan parks.

Recommendation 8: Financial assistance be provided to support the SES achieve their stated aims of increasing flood awareness.

5.2.1.2 Evacuation Planning Information

Feedback from stakeholder submissions indicates that the community would like to know more about the evacuation planning process. This could be done via the SES Community FloodSafe Engagement Program (Section 5.2.1.1).

Issue: The community wants more information about local evacuation planning.

The Tweed Shire Flood Emergency Sub Plan is a public document and is provided on request and / or distributed to interested parties as required, however it is currently under review.

Recommendation 9: The SES publish and publicise the locations of major evacuation routes and evacuation centres. This will also serve to enhance community flood awareness and readiness.

5.2.1.3 Understanding Personal Flood Risk

It has been identified in previous flood events that residents have difficulty relating broad scale flood warnings (e.g. 'major' flood predicted) or predicted gauge heights to their personal level of flood risk.

Issue: Residents have difficulty interpreting the scale of flood classifications and return periods, and relating this information to personal flood risk.

This issue is particularly evident in Murwillumbah, where the issue of minor/moderate/major flood classification has been contentious in the past. A major flood in Murwillumbah (i.e. capable of closing major traffic routes, isolating properties etc.) is smaller than the 5 year ARI event (shown in Table 5-1). Relative heights at the flood gauge are shown in Figure 5–2, below.

Note that the 100 year ARI flood level at the Murwillumbah gauge is 2m higher than the 'major' flood level (and the PMF level is 5m higher again).

This means that 'major' floods are likely to occur relatively frequently. As a result, when a major flood is predicted, residents in Murwillumbah don't know whether to expect flooding on a scale which is seen frequently, or something much more serious. In the case of a larger flood (such as the 100 year ARI or up to PMF), many people and properties would be at risk.

In addition, although the predicted gauge height is generally given with the flood warning, most residents are unable to translate this into a personal flood risk. Very few residents would know the absolute height (i.e. in metres AHD) of their property or local roads. Even if residents are aware of their property level, flood slope and local flood behaviour means that it is not a simple translational exercise to estimate flood levels at specific locations.

Recommendation 10: Utilise information on flood behaviour to show the relationship between individual locations (e.g. dwellings, major evacuation routes etc) and the nearest stream gauge.

If implemented, this recommendation would also serve to enhance community flood awareness of the scale of flood classifications and large to extreme flood events in excess of those previously experienced.

This option would require some modelling of additional flood events (i.e. durations, magnitudes, spatial and temporal patterns etc.) to maximise the robustness of estimates, as every flood is different. It would also be necessary to ensure the community understood and was correctly interpreting individual prediction information. A potential output from this process might be a figure showing the local stream gauge in relation to the resident's property. An example is provided in Figure 5–3.

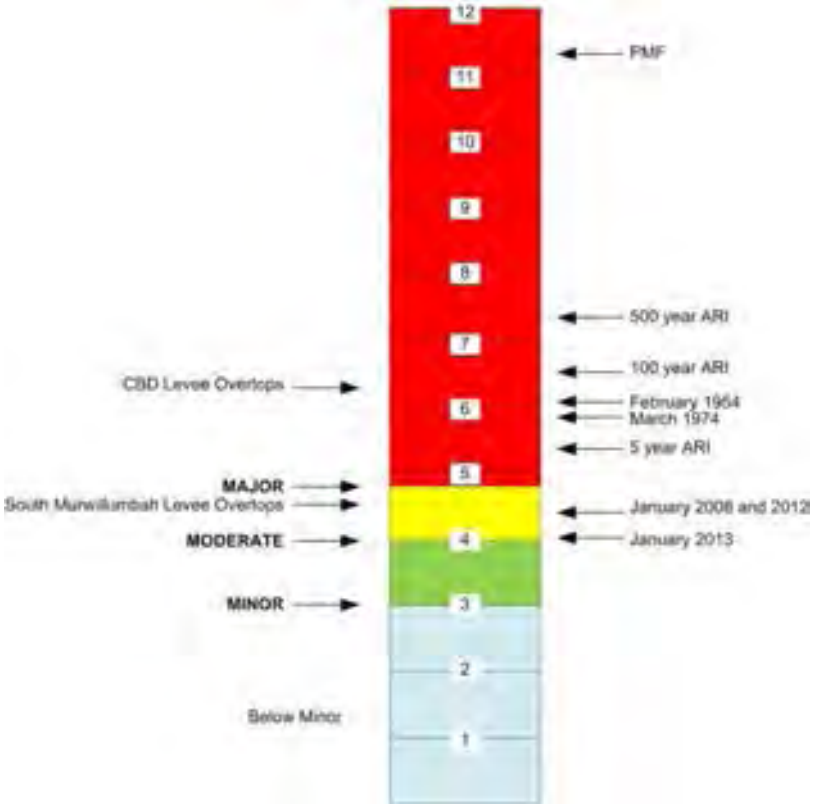


Figure 5–2 Murwillumbah Gauge Heights [1]

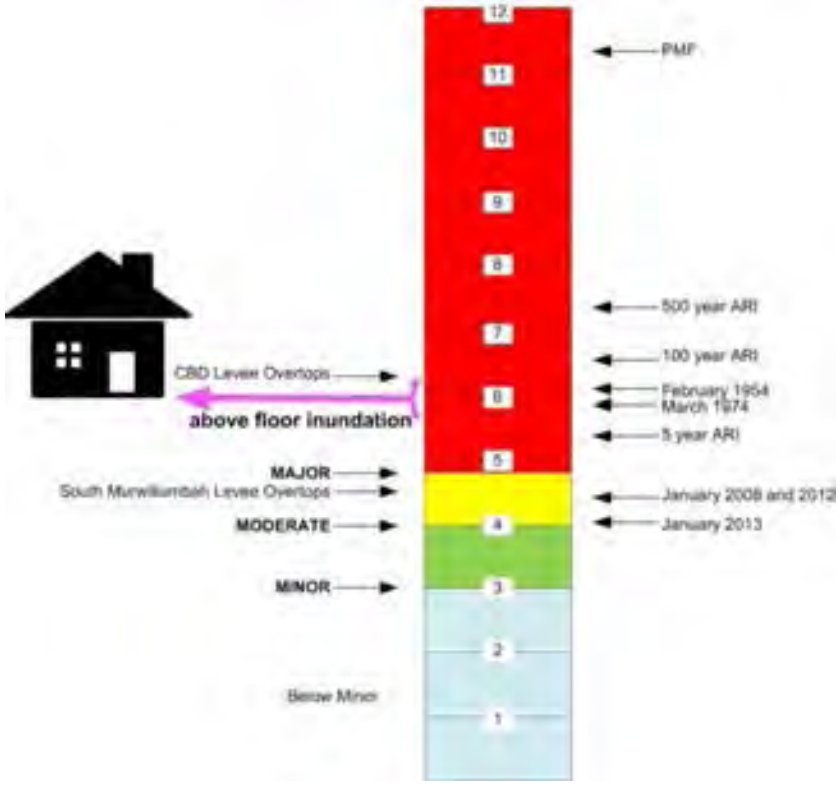


Figure 5–3 Floor Level to Gauge Relationship [1]

[1] Note that the gauge height at which levee overtopping commences may vary between individual flood events, due to differences in flood severity and profile.

5.2.2 Flood Intelligence

5.2.2.1 Flood Intelligence Cards

The Flood Intelligence Cards (FICs) used for flood planning in the Tweed Valley (i.e. Murwillumbah, Tumbulgum and Chinderah) were reviewed by Bewsher Consulting following the most recent major flood event in 2008. Recommendations included updates to the FICs and advice regarding ambiguous flood datums.

The SES has advised that recommendations provided in the review have not yet been implemented.

Issue: Flood intelligence requires updating

Recommendation 11: Flood intelligence cards should be updated with recommendations from the Bewsher review of the January 2008 flood event, design flood levels determined in the Tweed Valley Flood Study Update (2009) and any further flood intelligence developed as part of this study. Information on flood behaviour from these studies should be provided to the SES in WaterRIDE format for compatibility with their current system.

It is recommended that the SES consider the inclusion of 'triggers' in the flood intelligence cards. At present, a number of critical levels are noted along with correlated effects, such as road closures. Value could be added to this information by linking each critical level with a (lower) trigger level. If the trigger level was reached and flood levels were rising, the SES would act to minimise the impact which is predicted to occur at the critical flood level.

It is understood that the SES intend to update the cards in the near future, however the process has been delayed due to the need to verify recommendations made about flood datums in the review. This verification process will most likely be the joint responsibility of SES and Council.

5.2.2.2 Flood Information Website

Recent floods in Queensland and elsewhere in Australia have highlighted that the general public looks for flood information online during flood events.

Council have provided some flood information (such as online mapping and copies of reports), however the public still have to search multiple other websites to gain a full understanding of flood conditions and warnings etc.

In addition, standard websites can become overwhelmed when a large number of people try to access them simultaneously. Flood information websites need to be robust enough to handle high volumes of web traffic, which may include simplifying the sites visuals to include only critical visuals and information, i.e. a 'bare bones' site.

Issue: Tweed Valley flood information is spread over multiple, unrelated websites. Council's website may crash during major flood events.

Recommendation 12: Council provide a comprehensive, centralised flood information website (e.g. including flood warnings, predictions, evacuation information, road closures, interactive flood mapping etc.) and develop measures to divert to a more robust 'bare bones' site during high web traffic times.

5.2.2.3 Flood Watch Network

Many residents in the Tweed Valley access their properties by rural roads which are not easily monitored by the SES during a flood event. In addition, a number of residents in these rural areas have extensive knowledge of historical flood behaviour in the region. These residents' knowledge could be utilised through a Flood Watch Network (FWN).

The Flood Emergency Sub Plan states that a network of community members forms a FWN on the Tweed, Rous and Oxley Rivers. However, consultation and a submission from the local SES suggest that this network does not currently exist.

Flood Watch Networks provide a formal mechanism for local residents to contribute real-time flood information and improve the SES's understanding of flooding and flood impacts across the entire study area. These types of networks have been successfully used in other areas and often exist informally.

Recommendation 13: SES continues the FWN in the Tweed Valley, including development of a system to receive community flood intelligence, identification and recruitment of network members and education of network members.

5.2.3 Flood Warning System

5.2.3.1 Method of Flood Warning

Flood warnings are issued via a number of methods; however the most reliable method is doorknocking (Opper et al, 2009). Doorknocking requires teams of two SES personnel and is estimated to take each team five minutes per house. To maximise the likelihood of safe evacuation (and minimise rescues), the SES aims to manage the warning process to best utilise route capacities. To simultaneously carry this out across the entire floodplain (i.e. the PMF extent) requires extensive personnel and time resources.

A number of warning methods are used in addition to doorknocking. A comparison of various warning methods is provided in Figure 5–4. In practice, the SES uses a range of media to disseminate flood warnings, including radio and TV, public address systems from emergency service vehicles, telephone, two-way radio, SES website, variable message signs and SES social media channels. Doorknocking is likely to be undertaken in areas which are most at risk or where the hazard is most imminent.

Issue: Significant numbers of SES personnel would be required to doorknock in an extreme flood event.

In addition, outcomes from this study will provide new and / or supplementary information about flood behaviour and risk to the SES.

Issue: The Flood Emergency Sub Plan needs updating to reflect the most recent flood information including information from this study.

Recommendation 14: SES review and update response plans based on the outcomes of this study, e.g. to include risk-based prioritisation of resources and plans to manage the warning process.

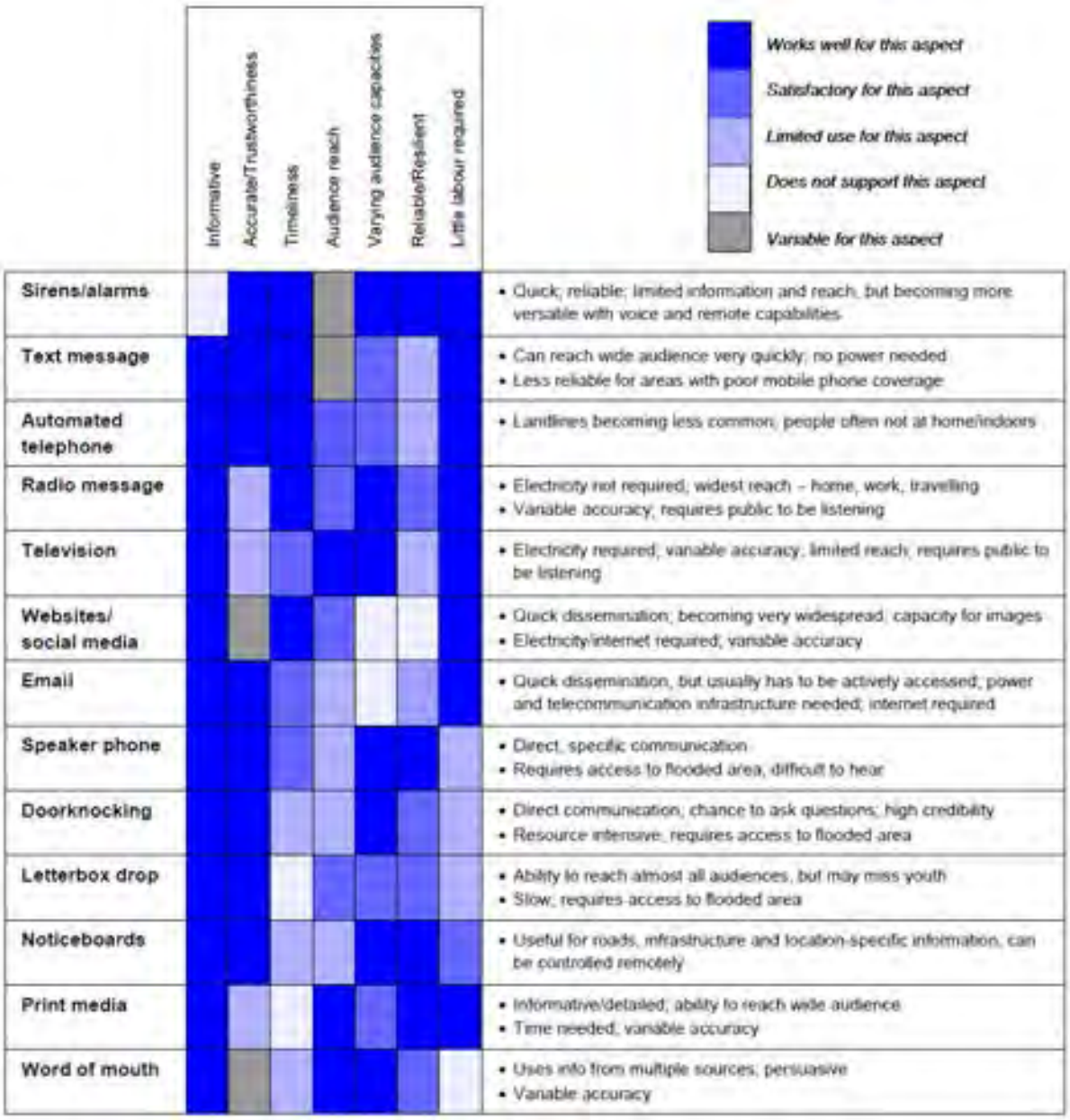


Figure 5–4 Comparison of Flood Warning Communication Methods [2]

5.2.3.2 Tumbulgum Stream Gauge

An automatic stream gauge is in place at Tumbulgum, at the confluence of the Tweed and Rous Rivers. The SES has developed a flood intelligence card relating flood heights at the Tumbulgum stream gauge to effects in the surrounding floodplain. The BoM have a flood peak correlation relationship for the Tumbulgum gauges based on the Murwillumbah gauge, however this does not explicitly take account of the tide or Rous River inflow (see Section 5.1.1).

As the Tumbulgum gauge does not form part of BoM's formal flood warning network, predictions may be less accurate than predictions based on the BoM hydrologic model, which will also include influences from the tide and Rous River.

[2] (Office of the Queensland Chief Scientist, 2011)

Issue: Additional information exists for Tumbulgum, but is not being best utilised.

Recommendation 15: Discuss this issue with the NSW Flood Warning Consultative Committee to determine whether it is feasible to expand the formal flood warning system to include predictions for the Tumbulgum gauge.

5.2.3.3 Storm Surge Prediction

Storm surge predictions are currently issued on the peak prior to the storm, i.e. 12 hours prior to peak. This may not be sufficient time to prepare, warn and evacuate the public.

Issue: Storm surges are difficult to predict more than 12 hours in advance.

The Bureau's research centre is developing storm surge predictions products that should extend this warning lead time, even to the extent of flagging this in Flood Watches. It is likely that experimental coverage for the Tweed River will be available within the next 12 months.

Recommendation 16: Update flood planning and warning as improved warning products become available from BoM.

5.2.4 Evacuation Planning

Detailed recommendations about improving the evacuation capability of individual locations has been provided to the SES in the discussion papers provided to the Floodplain Management Committee. A number of more general evacuation planning recommendations have been provided below.

5.2.4.1 Detailed Evacuation Planning Study

The evacuation capability assessments undertaken in preparation of this study were able to highlight constraints in the evacuation system, such as early road closures, lack of evacuation centre capacity and insufficient warning times. However, a more detailed evacuation planning study will be required to investigate trouble spots more closely and plan strategies for reducing evacuation risk at a local level. These strategies might include targeted flood education, early or pre-emptive warning, or pedestrian evacuation, as described below.

Recommendation 17: Undertake detailed evacuation planning study to identify risk reduction strategies for evacuation constraints identified in this study as well as any additional local constraints identified.

5.2.4.2 Targeted Flood Education

It is recommended that residents in high evacuation risk areas should be warned about the increased flood risk in their location and be made aware that they may be evacuated more frequently than other areas. Residents behind levees should also be the subject of targeted education campaigns to highlight the limits of protection provided by the levee. This could be done via the SES Community FloodSafe Engagement Program (Section 5.2.1.1).

Recommendation 18: Educate community about local evacuation risks in high risk areas.

5.2.4.3 Early / Pre-emptive Warning

Residents in areas which may be affected by flooding before the SES are able to issue warnings (according to standard timeframes and prediction certainty) should be considered for pre-emptive warning. This would accelerate the evacuation process for at-risk areas, potentially improving evacuation capability. However, this should be weighed against the fact that the chance of residents being evacuated unnecessarily will increase. This could be incorporated into the detailed evacuation planning study and targeted flood education recommended above (Section 5.2.4.1 and 5.2.4.2).

Recommendation 19: Review and educate community about evacuation plans for areas with insufficient warning time.

5.2.4.4 Pedestrian Evacuation

There are some locations where there may be less risk associated with pedestrian evacuation (than by car). In particular, locations with rising road access, high density development and close to evacuation centres would be suitable. Where pedestrian evacuation is appropriate, traffic congestion and associated delays may be reduced. This could be incorporated into the detailed evacuation planning study and targeted flood education recommended above (see Section 5.2.4.1 and 5.2.4.2).

Recommendation 20: Review and educate community about evacuation plans for areas where pedestrian evacuation may be necessary.

5.2.4.5 Rural Evacuation

The rural floodplain is generally sparsely populated, and the ability to evacuate is limited given the low flood immunity of various rural roads that connect rural properties to the main centres, such as Murwillumbah.

Pre-emptive warnings of extreme events should be considered in areas where access can be cut before the SES are able to issue warnings. This would accelerate the evacuation process for at-risk areas, potentially improving evacuation capability. However, this should be weighed against the fact that the chance of residents being evacuated unnecessarily will increase.

As evacuation to main centres is not practical in many areas where dwellings are scattered without easy access to main roads, these properties may be better advised to evacuate to local high ground, rather than drive through the floodplain.

This option would reduce the likelihood of inundation, but would likely increase the risks associated with isolation. To reduce these risks, it is recommended that the SES consider working with rural residents to prepare individual evacuation plans. This could be incorporated into the detailed evacuation planning study and targeted flood education recommended above (see Section 5.2.4.1 and 5.2.4.2).

Recommendation 21: Establish and educate community about evacuation plans for rural areas where evacuation may be required.

5.2.5 Evacuation Centres

5.2.5.1 Evacuation Centre Planning

It is understood that responsibility for establishing evacuation centres lies with the Department of Community Services (DoCS). Feedback from stakeholders and the community indicates that evacuation centres have been closed in the past during an evacuation, however the Tweed Local Emergency Management Officer has advised that this issue occurred as a result of self-evacuation, not official evacuation orders directing to closed centres.

It is noted that during the course of this study, this issue was reviewed and communication protocols confirmed between DoCS, Council and the SES through the DISPLAN. However a recommendation has been retained as a prompt to review after future evacuations to ensure communication and procedures remain effective.

Recommendation 22: Review Council, SES and DoCS communication protocols after future evacuations regarding the operation of evacuation centres.

5.2.5.2 Evacuation Centre Capacity

Although a number of evacuation centres have been identified in the study area, it is likely that there would not be sufficient capacity in the event of a complete evacuation of the floodplain. Attempts have been made by the SES and Council to liaise with the Department of Community Services (DoCS) regarding the facilities available at the evacuation centres however this issue has not yet been addressed.

The capacity at each evacuation centre has been estimated from aerial photography building footprints and minimum Department of Health NSW (2011) recommendations of 3.5m^2 per evacuee.

Note that the number of people evacuating includes all residents whose house falls within the PMF extent. In practice, many residents are likely to evacuate to friends and family on high ground. Therefore, estimates of requirements might be considered an 'upper limit' for evacuation requirements.

Issue: Most evacuation centres have insufficient space, in particular Banora Point and Tweed Heads.

Recommendation 23: DoCS should continue to review existing evacuation centre capacity, including an inventory of the available facilities. Additional facilities, such as water and sanitation requirements, must be considered when determining the capacity and suitability of each evacuation centre. Additional safe evacuation centres should be identified where required and included in the FESP.

5.2.5.3 Tweed Civic Centre

As part of the evacuation capability assessment, it was recognised that the Tweed Civic Centre is within the 100 year ARI flood extent. Therefore, the Civic Centre is not suitable for use as a flood evacuation centre.

Issue: The Flood Emergency Sub Plan directs residents to an unsuitable flood evacuation centre.

Recommendation 24: Tweed Civic Centre be removed from the Flood Emergency Sub Plan as an evacuation centre and an alternative evacuation centre(s) be identified.

5.3 Response Modification Recommendations

A number of response modification options have been put forward based on the outcomes of this study. Response modification options are the simplest and most cost effective ways of reducing risk to life.

The recommendations addressed five general areas:

1 **Flood awareness**: improved flood awareness helps the community to better understand the flood risk and how it relates to them. An informed community is more likely to respond appropriately and safely during flood evacuation.

2 **Flood intelligence**: better use and understanding of flood information will enable the SES to better predict and plan for floods.

3 **Flood warning system**: improvements to the ability to convey flood warnings, either between agencies (such as BoM and SES) or to the community will increase the chance that evacuation will happen in a timely fashion.

4 **Evacuation planning**: detailed evacuation capability analyses highlighted which areas of the catchment have the greatest evacuation risk. This information should be used by the SES to create detailed evacuation plans, which may require different approaches for different areas.

5 **Evacuation centres**: better communication between the agencies responsible for evacuation planning will increase community safety by ensuring that there is sufficient evacuation centre capacity and that the centres are located in flood free areas.

6 PROPERTY MODIFICATION MEASURES

Property modification measures seek to reduce flood risk through careful planning of future developments. Property modification measures can also be applied to existing developments to either reduce the flood risk by raising the house, or by removing the property from the flood prone location altogether.

6.1 Existing Measures

As part of the 1989 Murwillumbah Floodplain Management Plan, a number of properties were identified as being at high flood risk. These properties were included in voluntary purchase and voluntary raising schemes, as detailed below.

Voluntary Purchase Scheme

- 11 properties identified (along River Street between Greville and Colin Streets).
- Of these, 4 dwellings currently remain.

Voluntary House Raising Scheme

- 54 properties identified (including 15 in Bray Park and 39 upstream of Colin Street).
- All eligible properties have been raised.

6.2 Property Modification Options

A number of criteria (or combinations of criteria) were compared for identifying and prioritising at-risk properties. These were derived from the Floodplain Development Manual, floodway classification and other hydraulic criteria.

6.2.1 Voluntary House Purchase

Properties which may be eligible for Voluntary House Purchase (VHP) have the highest hydraulic hazard in the study area.

Issue: There are existing properties located in high hazard areas.

Several options for appropriate hydraulic criteria were tested for the 100 year ARI event for properties with above floor flooding, as shown in Table 6-1. A VHP scheme based on high hydraulic hazard, floodways and option 1 hydraulic criteria would be cost-prohibitive. In options 2 and 3, houses with the greatest hazard are prioritised. As shown in Figure 6–1, these houses are located in Murwillumbah, and include the 4 remaining dwellings from the 1989 scheme.

A summary cost benefit analysis of the VHP scheme options is provided in Table 6-2, below. Option 3 has a significantly higher cost benefit ratio but only removes 8 properties from high hazard areas. Cost benefit is only a secondary consideration in the VHP scheme, as the primary objective is to reduce risk to personal safety by removing dwellings from high hazard areas.

Table 6-1 Properties Eligible for VHP

Potential Criteria	Eligible Properties
High hydraulic hazard (DIPNR, 2005)	773
Floodways (VxD > 0.3m2/s)	394
Option 1 (velocity > 2m/s or VxD > 1m2/s or depth above ground > 2.0m)	69
Option 2 (velocity > 2m/s or VxD > 1m^2/s or depth above ground > 2.5m)	29
Option 3 (velocity > 2m/s or VxD > 1m^2/s or depth above ground > 3.0m)	8

Table 6-2 VHP Cost Benefit Summary

	Option 2	Option 3
Properties Purchased	29	8
Mean Property Price	$350,000 - $400,000	
Total Cost	$10,300,000	$2,800,000
Annual Average Benefit	$407,000	$220,000
Total Benefit	$5,619,000	$3,039,500
Benefit Cost Ratio	0.6	1.1

Recommendation 25: Review and implement VHP scheme for the 8 properties identified in Option 3, followed by a review to consider the feasibility of a VHP scheme for the additional 21 properties identified in Option 2.

6.2.2 Voluntary House Raising

Voluntary house raising (VHR) is aimed at reducing the flood damage to houses by raising the habitable floor level of individual buildings. Such measures can only be undertaken on a voluntary basis. VHR is a suitable management measure for houses in low hazard areas of the floodplain (DIPNR, 2005).

Potential eligible properties were identified based on above floor flooding in the 5, 20 or 100 year ARI events as shown in Table 6-2, excluding those identified for VHP in high hazard areas above. Houses also had to be structurally suitable for raising (i.e. wooden, not slab on ground) confirmed from the property survey.

Issue: There are existing properties located in areas that are regularly inundated above floor level.

Several options for appropriate criteria were tested for properties with above floor flooding, as shown in Table 6-2. A VHR scheme based on above floor flooding in the 100 year ARI would be cost-prohibitive and so houses with above floor flooding in the 20 year ARI were prioritised. As shown in Figure 6–2 and Figure 6–3, these houses are located in Murwillumbah and the Lower Tweed.

Table 6-3 Properties Eligible for VHR

Potential Criteria	Eligible Properties		
	100 year ARI	20 year ARI	5 year ARI
Option 1 (above floor flooding, not eligible for VHP option 1)	166	24	0
Option 2 (above floor flooding, not eligible for VHP option 2)	192	25	0
Option 3 (above floor flooding, not eligible for VHP option 3)	211	30	2

A summary cost benefit of the VHR scheme options is provided in Table 6-4, below for raising of eligible properties to the 100 year ARI design flood level plus 0.5m freeboard. Both schemes have a good cost benefit ratio (greater than 1), with Option 3 providing a higher ratio and reducing the flood risk for a greater number of properties (but at slightly greater cost).

Table 6-4 Voluntary House Raising Summary

	Option 2	Option 3
Properties Raised	25	30
Mean Property Raising Price	$70,000	
Total Cost	$1,750,000	$2,100,000
Annual Average Benefit	$223,000	$389,000
Total Benefit	$3,079,000	$5,368,000
Benefit Cost Ratio	1.8	2.6

Recommendation 26: Review and implement VHR scheme for 30 properties identified in Option 3.

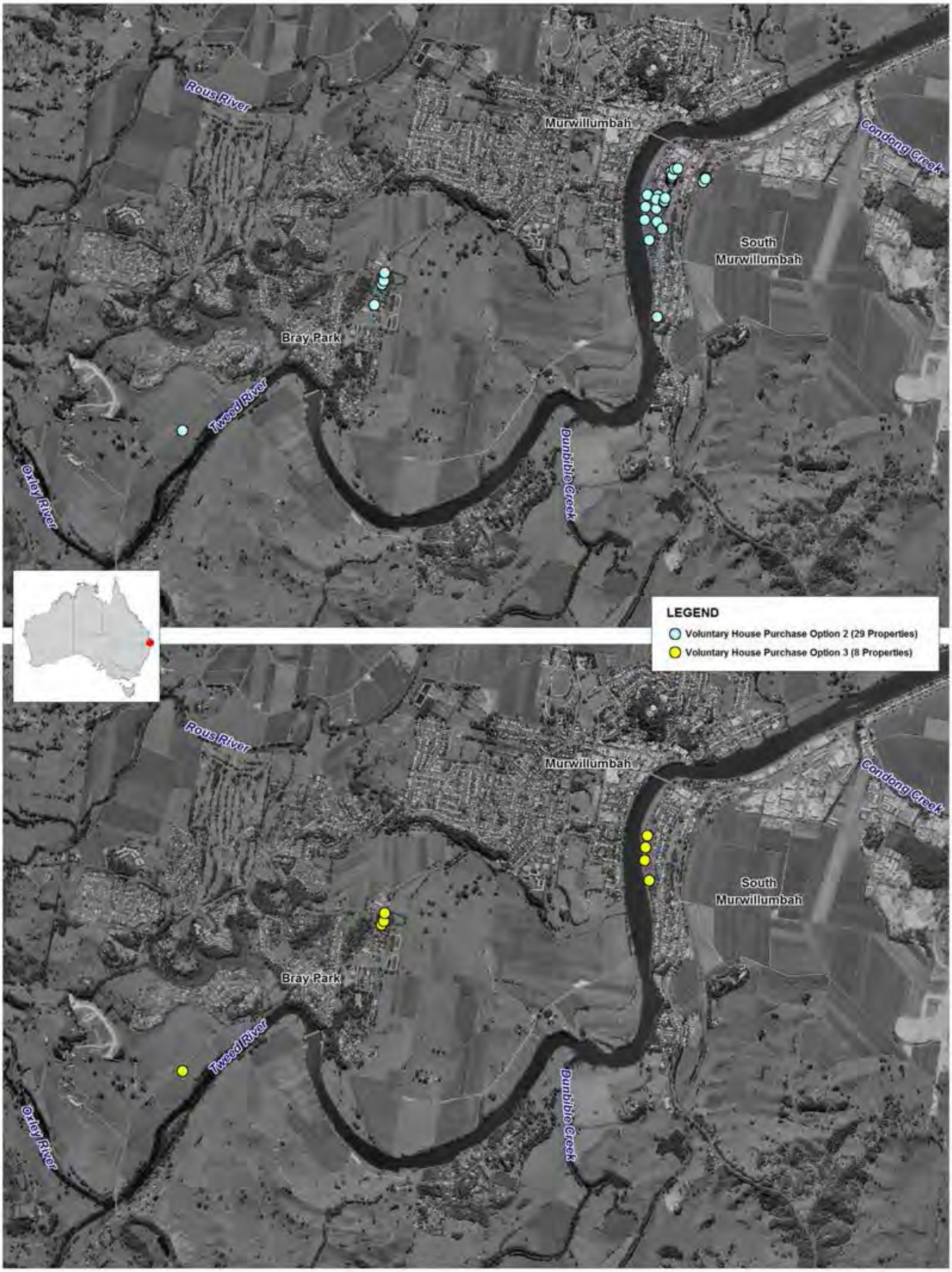
Note that if the Tweed Heads South levee is raised and / or extended (see Section 4.2.2) this would reduce the number of properties to be raised by 7 and 5 respectively in the Tweed Heads South and Philp Parade areas.

During community consultation, one request for inclusion in the VHR was received. However this property was assessed as having a lower exposure to flood damage and so has not been included in the recommended scheme.

6.3 Property Modification Recommendations

The Murwillumbah Floodplain Management Plan established voluntary house purchase and raising schemes for Murwillumbah in 1989. With the benefit of more detailed flood hazard information and floor level survey of the whole floodplain, this study has undertaken a comprehensive review of all residential properties in the Tweed Valley study area for potential VHP or VHR and identified:

- **VHP scheme:** 8 properties in Murwillumbah (including the 4 remaining dwellings from the 1989 scheme) followed by a review to consider the feasibility of an additional 21 properties in Murwillumbah.
- **VHR scheme:** 30 properties in Murwillumbah and the Lower Tweed.



Title:

Voluntary House Purchase Options

Figure: 6-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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Mayal Creek

Condong Creek

Murwillumbah

Tweed River

South Murwillumbah

LEGEND

- Voluntary House Raising Option 2 (1 Property)
- Voluntary House Raising Option 3 (6 Properties)

Mayal Creek

Condong Creek

Murwillumbah

Tweed River

South Murwillumbah

Title:

VHR Option 2 and 3, Murwillumbah

Figure: 6-2

Rev: A

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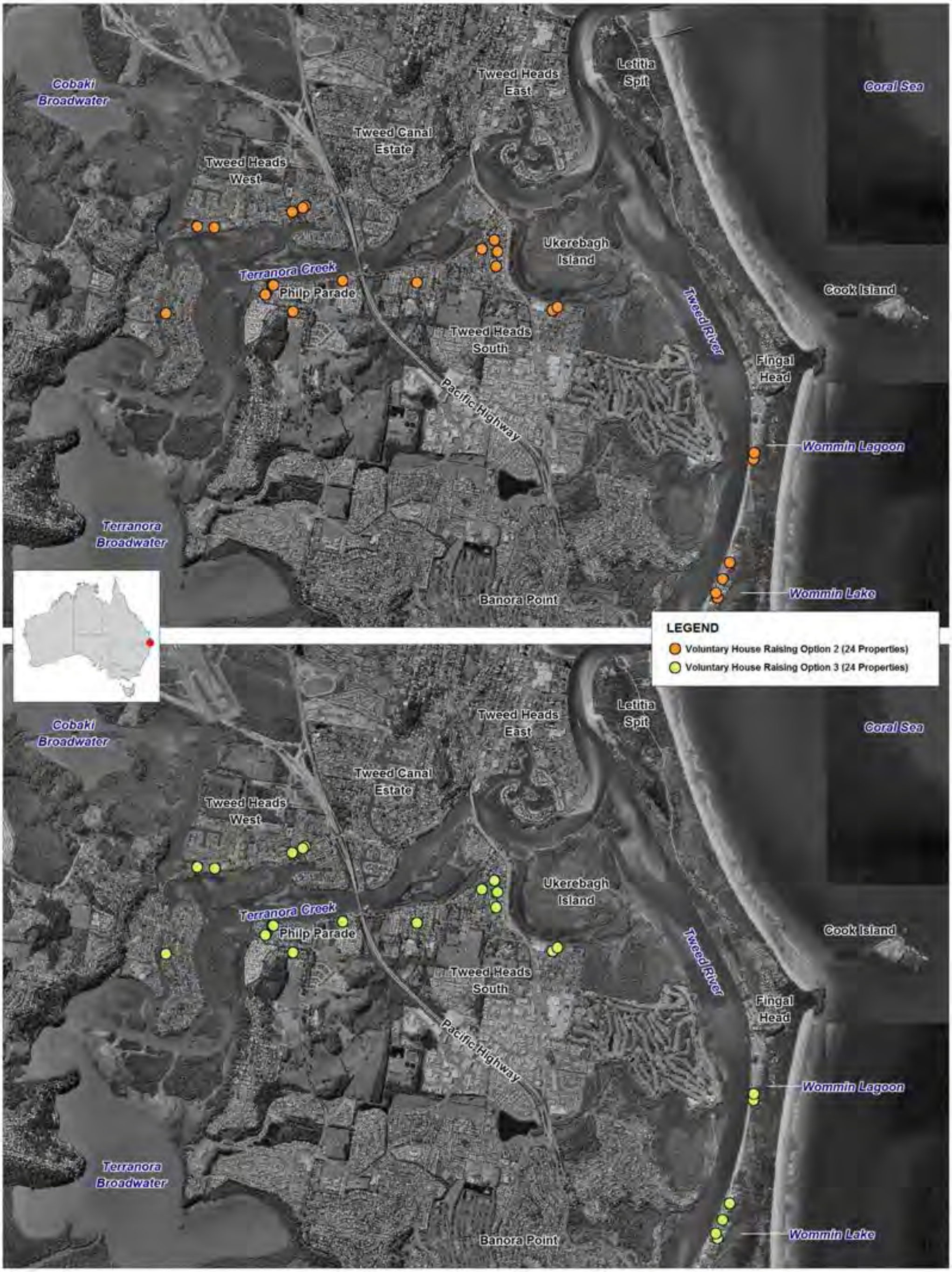

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VHR Option 2 and 3, Lower Tweed

Figure: 6-3

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7 FUTURE CLIMATE CHANGE RISK

As the Earth's climate changes, it is anticipated that the intensity and frequency of flooding will also change. Tweed Shire Council has adopted various measures to plan for the impacts caused by changed flooding behaviour.

7.1 Climate Change Scenario

The climate change scenario adopted by Council in its flooding Development Control Plan (DCP Section A5) in 2010 is derived from the latest climate science and CSIRO region-specific projections, presented in New South Wales government guidelines and policy:

- Floodplain Risk Management Guideline: Practical Consideration of Climate Change (DECC, 2007); and
- NSW Sea Level Rise Policy Statement (DECCW, 2009).

The scenario includes for rainfall projections for the year 2070 to be increased by 10%, although it is predicted that there will be fewer storms overall (i.e. more intense storm events but lower annual average rainfall). In addition, sea levels for the year 2100 are projected to increase by 0.91m.

While the NSW Government has since abandoned the Sea Level Rise Policy and no longer prescribes state-wide sea level rise projections, Council has not undertaken any scientific investigations of its own and have maintained the 0.9m benchmark used in the 2009 policy.

The above climate change scenario was then applied to the catchment dominated and storm surge dominated 100 year ARI design flood events and modelled as part of the 2009 Tweed Flood Study Update.

7.2 Climate Change Flood Behaviour

The change in rainfall intensity and sea level caused by climate change is likely to cause the following flood impacts in the above scenario:

- Flood levels increase by ~0.5m in the lower Tweed area;
- Flood levels increase by 0.2 to 0.4m throughout the broader valley area;
- Flood levels increase by up to 3.9m behind the town levee in Murwillumbah[3] (in the area of Knox Park and Commercial Road / Wharf Street intersection);
- Flood extents increase to include the area north of Cobaki Creek and Cobaki Broadwater;
- Flood extents increase to include the southern part of Seagulls Estate;
- Flood extents increase to include water-front properties in the Tweed Heads canal estates;
- Flood extents increase to include additional small areas in the Dry Dock Road region; and

[3] In the existing (current climate) 100 year ARI flood, the Murwillumbah levee is overtopped but does not fill the basin around Knox Park. Under climate change conditions, this basin does fill due to the increase in duration and height of overtopping. This causes the significant increase in flood levels between existing and future climate conditions at this location.

- Flood extents increase to include low-lying areas of the Tweed Heads foreshore and Greenbank Island.

A comparison of the 100 year ARI flood extent under existing and future climate conditions is shown in Figure 7–1. The impacts on peak levels due to climate change in the 100 year ARI flood event are shown in Figure 7–2.

7.3 Climate Change Flood Risk

The effects of climate change will increase the risk for most properties which are already affected by flooding and increase the number of properties at risk. The number of people and properties within the 100 year ARI flood extent under both existing and future climates is presented in Table 7-1 below.

Table 7-1 Population at Risk, Climate Change

Numbers at Risk	100 Year ARI Existing Climate	100 Year ARI Future Climate	% Increase
People	11,700	18,200	55%
Residential properties	4,300	7,200	66%

Issue: The large increase in people and properties which will be affected by flooding under the climate change scenario has undesirable impacts on the evacuation capability of the study area. Much of the study area already faces evacuation constraints in a large flood event, and most in an extreme flood. Some roads will close earlier under climate change conditions, reducing the amount of time available to evacuate. Higher flood levels and velocities will mean that residents face more dangerous conditions if they become inundated or isolated.

The additional risk to properties and estimated damages resulting from climate change conditions in a 100 year ARI flood is presented in Table 7-2 and Table 7-3 below.

Table 7-2 Estimated Number of Inundated Properties, Climate Change

Inundated Properties (Above Floor)	100 Year ARI Existing Climate	100 Year ARI Future Climate	% Increase
Residential properties	1,130	3,040	170%
Commercial properties	340	510	50%

Table 7-3 Flood Damage Estimates, Climate Change

Flood Damage Estimates	100 Year ARI Existing Climate	100 Year ARI Future Climate	% Increase
Residential properties	$150m	$365m	140%
Commercial properties	$45m	$100m	120%

Ingleside
Point Danger
Coral Sea
Tweed Heads
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point

LEGEND

- 100 Year ARI Flood Extent; Current Climate
- 100 Year ARI Flood Extent; 2100 Climate
- Flood Prone Land
- Tweed River
- Principal Road
- Sealed Road

Title:
Climate Change 100 Year ARI Flood Extent

Figure: 7-1

Rev: A

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Approx. Scale

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Ingleside
Springbrook
Glengarrie
Point Danger
Tweed Heads
Coral Sea
Fingal Head
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point

Change in Flood Level (m)

- Was wet now dry
- < -1.5
- -1.5 to -1.0
- -1.0 to -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- > 2.5
- Was dry now wet

LEGEND

- Tweed River
- Principal Road
- Sealed Road

* In the existing (current climate) 100 year ARI flood, the Murwillumbah levee is almost overtopped. With the increased peak flood level under climate change conditions, the levee overtops and fills the basin around Knox Park. This causes the significant increase in flood levels between existing and future climate conditions at this location.

Title:
Flood Impact of Climate Change

Figure: 7-2

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7.4 Climate Change Management Measures

The measures available to manage the increased flood risk to existing people and property are generally the same as those available to manage current flood risk, i.e. the same flood, property and response options. Similarly, future development will manage climate change risk primarily through development controls. The management of climate change risk to future development is summarised in Section 7.4.3.

Climate change management measures which are responding to the effects of climate change (rather than trying to change the severity of climate change) are referred to as adaptation measures.

7.4.1 Existing Climate Change Adaptation Measures

A climate change adaptation plan was developed for Tweed Shire Council (in conjunction with Byron Shire Council) in 2009. This plan utilised information provided by Council representatives to highlight climate change related risks and develop actions to address these risks.

Following consultation with both Councils, 8 issues were identified as priority concerns, including flooding. Flooding was recognised to pose a 'high risk' in the present climate and for the planning time frames of 2030 and 2070. Potential consequences arising from increased flooding in a changed climate were identified, including increased insurance premiums, increased risk of injury and death during flood events, and loss of agricultural yield.

Following identification of these consequences, 5 broad recommendations were made. These recommendations were categorised as engineering, policy/planning, or engagement, as marked in brackets below:

a) Upgrade design standards for infrastructure (policy);

b) Replace infrastructure (engineering);

c) Implement other defences, such as levees (engineering);

d) Community awareness and education (engagement); and

e) Improved development planning (policy/planning).

In addition to these flood specific risks, the adaptation plan also recommended that climate change policy be applied consistently across all of Council's planning documents and that further quantitative assessments be commissioned to support the qualitative recommendations in the report.

Further detail about these recommendations can be found in the *Byron and Tweed Shire Councils Climate Change Adaptation Action Plan* (GHD, 2009).

7.4.2 Climate Change Adaptation Recommendations

It is recommended that the flood model developed for the Tweed Valley Flood Study Update (2009) be used to hydraulically assess the level of risk present and quantify the actions required to meet the recommendations provided in the adaptation plan. The evacuation capability assessment can also be used to quantify the additional evacuation risk likely as a result of climate change. The following recommendations are made with respect to the 5 recommendations made in the adaptation plan:

- **Infrastructure (Recommendations a and b):** Due to the changing climate, infrastructure which was designed to provide a particular standard of protection may not provide sufficient protection throughout the design life of the structure. It is therefore important to consider future climate projections when designing new infrastructure. For example, to ensure that a road continues to be 100 year ARI flood immune in the year 2050, it is recommended that the adopted climate change flood scenario be incorporated into design standards. This will apply to the design of new infrastructure and the replacement / retrofitting of existing infrastructure.
- **Flood Defences (Recommendation c):** As for infrastructure, consideration should be given to the level of flood protection provided by flood defences (levees) now and in future climates. Under climate change, existing levees are likely to provide less protection than at present, increasing the risk of personal and property damage due to flooding. It is recommended that investigations into flood defences (e.g. raising of the Tweed Heads South levee) consider the future climate projections and the implications that this may have on flood risk.
- **Community Awareness and Education (Recommendation d):** A comprehensive community awareness and education campaign is recommended as part of this study (Section 5.2.1.1), to address existing flood risk. It is recommended that this campaign also includes information from climate change flood modelling to discuss the increased flood risk which will likely occur due to climate change.
- **Development Planning (Recommendation e):** Climate change related controls are recommended as part of the review into development controls (Section 7.4.4).
- **General:** It is recommended that Council considers both existing and future flood risk when determining appropriate floodplain management measures (including development controls) for the Tweed Valley study area. A careful balance must be maintained between addressing the present risk and planning for the future. The existing risk in the study area is widespread and significant and must be addressed as a priority. However, it must not be forgotten that the risk will increase substantially in a changed climate. It is also recommended that the 'adopted' climate change scenario be reviewed periodically and updated where new science is available.

Recommendation 27: Implement Council's climate change adaptation action plan for design of infrastructure and flood defences, community awareness and education programs, and development planning.

7.4.3 Existing Climate Change Planning Measures

In June 2010, the Tweed DCP Section A3 - Development of Flood Liable Land was amended to incorporate the climate change predictions as described in Section 7.1. Based on this climate change scenario, climate change design flood levels and climate change flood maps were inserted into Appendix D of the DCP. The DCP requires residential land as part of a greenfield subdivision to be above or filled to the climate change design flood levels. The climate change design flood levels do not currently apply to all other development.

7.4.4 Climate Change Planning Recommendations

The 2009 NSW Sea Level Rise Policy (since abandoned) recommended that strategic and statutory planning documents could respond to the projected 2050 and 2100 coastal flood risk area by restricting the intensification of development in areas subject to predicted climate change flood risk or

applying planning controls to manage the additional risk. The mechanisms that might be applied include:

- Adopting climate change design flood levels where assessing the suitability of rural land for future urban purposes at the strategic planning stage;
- Increasing the design flood levels that would otherwise apply to buildings and land required of development to take into account predicted climate change effects. This would typically be practical in greenfield developments but often impractical for developments within established areas; and
- Imposing time-limited consents to provide the potential to remove, replace or adapt development in the future.

The application of these mechanisms varies depending on the stage of planning and nature of the development proposed. The aim is to take a precautionary approach to contain flood risks at those levels otherwise considered acceptable today, where this can be practically achieved. While no longer government policy, these mechanisms remain relevant considerations for Council.

The first two mechanisms above are currently being applied by Council in respect of residential development and these are endorsed as appropriate having regard to current Government policy and guidelines and best planning practice. However, it is recommended that at the strategic planning level, climate change flood risks also be considered when assessing the suitability of rural land for non-residential urban development such as commercial or industrial uses.

The third mechanism could be beneficial for development types that have a shorter typical life span and a higher design flood level would be cost prohibitive to a development that is otherwise considered acceptable and supportable in the public interest.

In addition to the above, there is a need to consider how climate change flood risks should be communicated to the public, irrespective of whether related planning controls are imposed. Recommendations in respect of this are included in Section 8.2.

Recommendation 28: Retain climate change controls for greenfield residential subdivision, introduce climate change controls for strategic planning (including rezoning of rural land for urban purposes), commercial and industrial development where practical, new rural development, and time-limited consents for suitable short term or adaptable development.

8 PLANNING AND FUTURE DEVELOPMENT

Parts of the Tweed Valley are subject to significant development pressure and whilst it is always preferable to avoid flood risk through effective land use planning, it is also recognised that pressures for land development, the lack of suitable land outside the floodplain, and a range of other non-flood related issues mean that use of some floodplain land may still be the best option for the community. The Floodplain Development Manual guides Councils and consent authorities to use the merit approach in making these land use decisions, balancing flood risk with other social, environmental and economic considerations.

Land use planning and development controls are the most effective measures for managing flood risk to future development. Planning mechanisms can maximise the compatibility of new development with flood risk, taking into consideration both current and potential future climate conditions. They can also gradually reduce the risk to existing development over time through sensible redevelopment. It is necessary to consider hydraulic and evacuation constraints to development at a strategic (as well as individual) planning level for the Tweed Valley.

Ultimately the planning recommendations of this FRMS will need to be reflected in planning instruments and policies brought into force in accordance with the Environmental Planning and Assessment Act 1979. There are three mechanisms for achieving this:

- **Strategic planning:** Providing direction at a local and state strategic planning level to manage flood risks (e.g. where new urban areas should be located and the distribution of land uses therein).
- **Development controls and related policies:** Recommending development controls and related policies to be incorporated in appropriate planning instruments (i.e. Local Environment Plans (LEPs), Development Control Plans (DCPs) and Section 94 Contributions Plans) to mitigate the risk to development where permitted in the floodplain.
- **Communication of flood risk:** Ensuring that the planning controls and associated documents (e.g. Section 149 planning certificates) appropriately inform the community about the flood risk.

8.1 Review of Development Controls and Related Policies

8.1.1 Local Environment Plan (LEP)

8.1.1.1 Tweed LEP 2014

The Tweed LEP 2014 was published and made law on 4 April 2014, replacing the Tweed LEP 2000. Tweed LEP 2014 is based on the State Government's model LEP template. This includes flood related local provisions (clauses 7.3 and 7.4). These clauses as adopted are reproduced below:

7.6 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land;

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change;

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land identified as "Flood planning area" on the Flood Planning Map; and

(b) other land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land; and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties; and

(c) incorporates appropriate measures to manage risk to life from flood; and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(5) In this clause:

***land at or below the flood planning level** means land at or below the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard.*

7.7 Floodplain risk management

(1) The objectives of this clause are as follows:

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level;

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) This clause applies to:

(a) land between the flood planning area and the line indicating the level of the probable maximum flood shown on the Flood Planning Map; and

(b) land surrounded by the flood planning area.

but does not apply to land subject to the discharge of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

(3) Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land:

(a) caravan parks;

(b) correctional centres;

(c) emergency services facilities;

(d) group homes;

(e) hospitals;

(f) residential accommodation (except for dwelling houses, secondary dwellings or dual occupancies) on land in Zone RU5 Village, Zone R1 General Residential, Zone R2 Low Density Residential, Zone R3 Medium Density Residential or Zone R5 Large Lot Residential;

(g) residential care facilities;

(h) tourist and visitor accommodation.

(4) In this clause:

***flood planning area** means the land shown as "Flood planning area" on the* Flood Planning Map*.*

***probable maximum flood** has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0), published in 2005 by the NSW Government.*

Note.

*The **probable maximum flood** is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation.*

Clause 7.3 is the model flood clause provided by the Department of Planning and Infrastructure (DPI). As this clause is limited to applying to land within the Flood Planning Area / up to the Flood Planning Level (that is, the 100 year ARI flood level plus 0.5m freeboard), Council applied to DPI to insert Clause 7.4 in order to apply floodplain risk management controls to land up to the PMF, which defines the floodplain in Council's DCP. This required a request for exceptional circumstances approval from DPI and OEH, which was granted on 4 October 2012. The letter of approval also confirmed the wording of the local flood clauses for the exhibition draft.

These clauses require a consent authority to consider emergency management issues for all development up to and including the PMF, except for standard residential forms of development,

such as dwelling houses and dual occupancies in urban zones. A consent authority is only required to consider emergency management issues for these standard residential forms if located within the Flood Planning Area.

The implications of this are that while there would be an imperative for Council to consider risk to life issues for residential development associated with flood hazard up to the PMF, in accordance with s79C of the EP&A Act 1979 the Draft LEP indicates this is not required. This inconsistency was unable to be resolved through the exceptional circumstances variation imposed by the State Government, with no further amendment to the draft clauses resulting.

8.1.2 Development Control Plan (DCP)

Tweed Development Control Plan (DCP) 2008 is a comprehensive DCP applying to the whole Tweed LGA. *"Section A3 – Development of Flood Liable Land"* (version 1.4) includes the primary controls with regard to development on flood liable land.

8.1.2.1 DCP Section A3 - Development of Flood Liable Land

Important elements of the DCP include the following:

- The DCP applies to all flood liable land within the Tweed LGA defined, consistent with the *Floodplain Development Manual*, to include all land up to and including the PMF.
- The flood planning level for habitable floors of most forms of development (in particular residential development) is described as the design flood level (DFL) plus freeboard of 0.5 metres (see Section A3.2.4). The DFL is provided as either a level shown on maps contained at Appendix C of the DCP, or a minimum of RL 2.6 metres AHD.
- The DCP does not apply minimum floor levels for commercial and industrial development. The DFL applies for the provision of flood free storage and flood compatible materials.
- A climate change DFL is also identified, for application to "*greenfield subdivision*" (Section A3.2.4 of DCP). This is determined based on a "high level impact scenario" consisting of 0.91 metres sea level rise and 10% increased rainfall intensity applied to the 100 year ARI design flood. Flood maps providing the climate change flood extents are provided at Appendix D of the DCP for the Tweed Valley and Coastal Creeks Catchments.
- The concept of "*high flow areas*" (Section A3.2.5 of DCP) is outlined, providing restrictions on the extent of development permitted within these areas. *High flow areas* are defined as that part of the floodplain subject to a flood velocity and depth product at the peak ARI 100 year flood which exceeds $0.3m^2/s$, and are identified on maps contained within the DCP. High flow areas identify and attempt to preserve significant out of river conveyance flow paths to minimise cumulative impacts of development.
- The DCP defines and includes provisions requiring the incorporation of a "*PMF refuge*" in various types of development, where evacuation is otherwise not achievable. A *PMF refuge* is defined to include habitable area located above the PMF level, and various notes in the DCP specify design criteria.
- The DCP describes the flood behaviour and provides controls separately for different flood prone localities within the LGA.

8.1.3 Council Policies

8.1.3.1 Tweed Flood Risk Management Policy

Tweed Shire Council has adopted a Flood Risk Management Policy (18 December 2007, Version 1.0) which applies generally across the LGA.

While this policy reiterates some aspects of DCP Section A3, it does outline Council's position with regard to a number of "non-development application" matters, including:

- Rezoning proposals;
- Community awareness and education;
- Flood mitigation works;
- Interaction with the Flood Emergency Sub Plan; and
- Section 149 planning certificates.

The above matters are important considerations. However ultimately this policy should be refined and incorporated into FRMPs produced and adopted for individual floodplains including the Tweed Valley.

8.1.4 Development Control Recommendations

Land use planning and development controls are key mechanisms by which Council can manage the risks to property and people in flood-affected areas. Such mechanisms will influence future development (and redevelopment) and therefore the benefits will accrue gradually over time. Without comprehensive floodplain planning, existing problems may be exacerbated and opportunities to reduce flood risks may be lost. This study reviewed the planning and development controls discussed in Section 8.1 to determine their adequacy to control immediate and future floodplain development pressures. This review provides the following key recommendations for development controls and related policies.

Recommendation 29a (Tweed LEP 2014):

- The flood provisions in LEP 2014 (clauses 7.3 and 7.4) should be reviewed at an appropriate future opportunity in consultation with the DPI. Preferably a singular flood clause should be adopted that is consistent with the DPI Model Clause with the exception that its application should be to the whole of the floodplain (i.e. up to the PMF) as defined by the Floodplain Development Manual, whether or not mapped as the flood planning area.
- Should the LEP 2014 clauses be reviewed as recommended, the accompanying Flood Planning Map should delineate the PMF extent as the "flood planning area" (for the purposes of the LEP). This would effectively mean deleting the 100 year flood extent from these maps, to simplify the application of the relevant clause and the requirements of any future amendments to the Map as further information becomes available.
- The LEP 2014 flood maps should also include a note that not all flood liable lands may have been mapped. This is consistent with Departmental directions.
- The LEP 2014 flood maps should also have climate change flood extents included for the year 2050 and 2100.

Recommendation 29b (DCP provisions):

- Flood mapping of the 100 year flood extent (with climate change scenarios) and "high flow areas" has already been adopted as part of Council's DCP. It is at the DCP level that this more detailed information is of relevance, and more easily amended as further information becomes known.
- Additional useful information such as flood depth maps are not necessary in the DCP, but should be separately maintained by Council as part of its general GIS information.
- The application of a risk management approach to the structure and content of the DCP controls and mapping would be desirable. Such a detailed reworking of the DCP document was beyond the scope of this study. Future reviews should also consider adoption of flood maps that categorise the whole floodplain based on risk.
- The following recommendations are made for review of the Tweed DCP, in particular Section A3, including:

  - Update controls to reflect hydraulic constraints to development fill (Section 8.3.2) including adoption of a cumulative development scenario, permissible rural development scenario and associated hydraulic assessment requirements;
  - The introduction of floor level controls that encourage the attainment of a minimum floor level (typically the 100 year ARI flood level) on commercial and industrial development for at least those that meet the 'habitable room' definition but with sufficient flexibility to allow for dispensation when such controls can clearly not be practically met;
  - Support for the intent of the DCP provisions relating to enclosures below habitable floors, with refinement to specify the objectives of the controls, define what constitutes enclosure and non-habitable uses, and specifying the uses of flood compatible material for all parts of a building below the design flood level;
  - Review car parking and driveway controls and ensure consistency in particular for basement car parking across the study area;
  - Support for the intent of the DCP provisions relating to caravan parks and moveable dwellings, with refinement to impose equivalent controls on long term residents as standard residential development; clarification of 'high land'; and greater specificity in regard to assessing hydraulic impact;
  - Additional detail as to what would constitute an acceptable on-site or communal refuge where proposed as a secondary emergency management measure and for special types of development such as aged care;
  - Controls for management of flood risks from stormwater and overland flow paths; and
  - Additional recommendations have also been made referenced to provisions for specific localities in Section 8.4.

Recommendation 29c (complying development):

- The FRMP should specify that only areas identified and mapped by Council to be other than land below the 100 year flood level and not evacuation constrained (e.g. a low flood island) are deemed to be high risk for the purposes of the Codes SEPP. This information should desirably be mapped so it can be readily provided to private certifiers and the general public upon enquiry.

Recommendation 29d (Section 94 contributions plans):

- Contribution Plans could be established within the study area, where it is necessary or appropriate to fund flood mitigation works through such plans. This would be relevant in new greenfield release areas or substantial urban renewal areas (such as the Tweed City Centre) where such works are required to ensure the acceptability of the development (e.g. for the upgrading of evacuation routes or evacuation centres to cater for increased population densities).
- The Plans cannot be used to rectify existing problems in established areas. Where such works are required for both existing and future development the cost could be apportioned between the future development (within a Section 94 Plan) and existing development (to be funded by Council through general revenue or other sources such as special grants).

Recommendation 29e (flood policy):

- The Tweed Shire Flood Risk Management Policy 2007 should ultimately be replaced with FRMPs that apply to the various floodplains in the LGA. The Tweed Valley FRMP would be the first of these.
- The individual FRMPs should contain Council's policies for all matters relating to flood risk management, including town planning recommendations relating to strategic planning, development controls and the communication of information where shown in planning documents.
- A number of SEPPs including deemed SEPPs (being the North Coast REP) refer to, and sometimes define, flood liable land. These policies are not entirely consistent in this regard. Council does not have control of these policies but the FRMP should be forwarded to the DPI when adopted with a request that any future policy reviews have regard to this FRMP.

8.2 Communication of Flood Risk

The following summarise the key recommendations for communication of flood risk.

Recommendation 30a (Section 149 notifications):

- As Section A3 of the Tweed DCP applies to all land up to the PMF, Council must notify this on Section 149(2) certificates.
- Include a notation that not all flood liable land may be mapped.
- Include a notation that flood extents projected into the future may change due to climate change effects.
- It is recommended that a notation be included on all certificates to indicate that further information in regard to flood risks may be available upon enquiry with Council or in a Section 149(5) Certificate.
- Council's Section 149 certificates should recognise that inundation from stormwater and overland flow (except for 'local drainage') is 'flooding' under the Floodplain Development Manual and the presence or absence of such inundation risks and policies should be notified accordingly.

Recommendation 30b (release of flood information to the public):

- Ensure that flood risk information (such as flood studies or an FRMS or FRMP) once obtained by Council, and checked for its integrity, is made available to persons upon enquiry. Such information may require qualification as to its status in Council (e.g. whether adopted by Council) and its purpose (e.g. for general FRM actions, to provide a basis for the assessment of development applications, etc.) when made available.
- Undertake periodic audits of protocols and information provided by all Council staff relating to the release of flooding information and provide training as required.

8.3 Strategic Planning

8.3.1 Future Development

As part of this study, a review of flood risks associated with possible large scale developments has been undertaken. These developments include:

- Identification of existing zoned land with potential for additional development (including land with current development consents that may not have been acted upon);
- Planning strategies that have been formally considered by Council as part of a broader planning exercise, including:
  - Tweed City Centre Plan Vision 2011 and supporting draft Tweed City Centre LEP and DCP addressing Tweed Heads, and including the deferred area of Tweed Heads South;
  - Tweed Coast Strategy (Tweed DCP Section B9) addressing areas of Chinderah, West Kingscliff and Cudgen;
  - Murwillumbah Town Centre (Tweed DCP Section B22) addressing Murwillumbah CBD, and including the deferred area of South Murwillumbah; and

  - Tweed Urban and Employment Land Release Strategy 2009 including Kielvale and Potential Employment Land Area 6;

- Representations made formally or informally to Council but not yet adopted as part of a broader planning exercise (including land in Banora Point, Chinderah, West Kingscliff and South Murwillumbah).

These last development scenarios have not been evaluated having regard to the broader range of planning issues and their assessment as part of this study should not be considered as an endorsement by Council. The inclusion of these areas as part of this study provides an opportunity to determine as part of a comprehensive FRMS whether there are any flood risk issues and management responses to consider, should they be the subject of broader planning studies in the future. Notwithstanding, flood risk issues could provide a basis upon which Council rules out considering a particular area for intensive development.

8.3.2 Hydraulic Considerations

Substantial parts of future urban areas are low lying and will require filling to a minimum 100 year ARI flood level (including an allowance for climate change). Where required, this fill has the potential to impact on flood storage and flood conveyance. The cumulative effects of this fill have been assessed as part of this study to determine the hydraulic constraints to future development and inform appropriate planning control recommendations.

Hydraulic assessments were undertaken for large scale urban development in three separate localities in the study area: Chinderah / West Kingscliff, South Murwillumbah, and Kielvale (within the Riverside Villages region). Development in Tweed City Centre is not expected to have significant hydraulic constraints in a 100 year ARI flood event, as flood behaviour in the Lower Tweed is mainly governed by ocean levels and is not storage dependent.

Assessments were completed for each of the localities and developments that were viable (in terms of hydraulic considerations) were then assessed cumulatively to identify a suitable development scenario for the broader study area. In addition to development scenarios for each of the localities, potential filling on rural land was also assessed to identify a maximum threshold to include in the cumulative development scenario.

Note that for the purposes of this study, the following criteria have been used to define the limits of acceptable hydraulic impacts using the 100 year ARI design flood:

- Impacts less than +0.035m in urban zoned areas; or
- Impacts less than +0.1m in rural zoned areas.

Based on this assessment, the following cumulative development scenario was adopted for management of cumulative hydraulic impacts associated with future development:

- **Chinderah / West Kingscliff:** Development of current approvals and zoned land in accordance with existing controls in the Tweed DCP together with a relaxation of industrial fill restrictions from 50% to 65% site coverage and additional land development along Tweed Coast Road and Old Ferry Road (Banora Point) subject to rezoning (see Section 8.4.2.3).

- **South Murwillumbah:** Despite many options being investigated, results of the hydraulic assessment found that development in the South Murwillumbah is extremely constrained and cannot be included in the cumulative development scenario in any form. The primary constraints are caused by loss of floodplain storage associated with filling of any areas within the basin and constriction of the floodplain in the industrial area (see Section 8.4.3.3).
- **Kielvale and Potential Employment Land Area 6:** Development of remaining urban zoned land around Kielvale and rezoning and development of Potential Employment Land Area 6 within the Condong-Chinderah basin (see Section 8.4.4.3).
- **Rural Land:** A maximum filling threshold of 1% of rural flood prone land area, outside of floodways (see Section 8.4.5.2).

The adopted cumulative development scenario is shown in Figure 8-1 and can be updated as development plans change into the future on the basis of revised hydraulic assessment and acceptable impacts. This scenario includes consideration of all development within the current planning horizon and has reached the currently nominated limit of acceptable impacts at Chinderah and Tumbulgum. In the longer term it is likely that there will continue to be development pressure in the Tweed Valley floodplain that will require balanced consideration of existing development, future development and flood risk, and how to avoid, minimise and / or manage impacts in sensitive locations.

The adopted cumulative development scenario should be linked to a development control requiring appropriate hydraulic assessment and management of both local and cumulative development impacts. For example, it may be possible to utilise local drainage systems and perimeter drainage to offset localised impacts with more detailed studies of individual developments. In a practical sense, application of this control would require developers to:

- **For all developments:** Quantify and mitigate *local* hydraulic impacts of their proposed development (i.e. using the base case flood model).
- **For developments not included in the adopted cumulative development scenario, or requiring works in excess of DCP controls:** Quantify and mitigate *regional* hydraulic impacts of their development (i.e. using the cumulative development case flood model).

It should be noted that the cumulative development assessment undertaken as part of this study relies on the regional hydraulic model and changes to the underlying digital elevation model to examine broadscale impacts. Hydraulic assessment of local and additional cumulative development impacts, as required above, may be able to demonstrate by way of higher resolution modelling that flood impacts can be further mitigated by the addition of local drainage systems or provision for flood flows through development parcels.

Ingleside
Point Danger
Tweed Heads
Coral Sea
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Palmvale
Hastings Point

LEGEND

- 1% Rural Fill
- Chinderah / West Kingscliff Development
- Kielvale
- Potential Employment Land Area 6
- Flood Prone Land
- Tweed River
- Principal Road
- Sealed Road

Title:
Adopted Cumulative Development Scenario

Figure: 8-1

Rev: A

N

0km 3 6

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_018_140415_Cumulative Development Locality Map.WOR

8.3.3 Evacuation Considerations

Emergency management is concerned with both risk to life and risk to property, although risk to life is of paramount concern. Emergency management comprises four components:

- Prevention;
- Preparation;
- Response; and
- Recovery.

The prevention and preparation (or planning) phases are carried out prior to the onset of flood. The response phase is carried out during a flood and the recovery phase is carried out afterwards.

When the prevention and preparatory phases have been implemented to the fullest extent possible, evacuation is the preferred emergency management strategy of the NSW State Emergency Service (SES) during flood events. Evacuation has been defined as:

"The temporary movement (relocation) of people from a dangerous or potentially dangerous place to a safe location, and their eventual return. It is a safety strategy that uses distance to separate people from the danger created by a hazard."

Within NSW the SES is the combat agency of flooding. It is the principal government agency responsible for emergency management during floods, including evacuation.

Some of the future urban areas have significant evacuation constraints and associated public safety risks. Four graded evacuation risk classes (ERCs) have been derived to provide advice to planners and consent authorities concerning these evacuation risks. This advice relates to the development proposal, including any mitigation measures that have been incorporated to minimise evacuation risks within the floodplain. The advice is provided principally in relation to strategic planning and rezoning proposals.

Table 8-1 Evacuation Risk Classes (ERCs)

Class A	**Risks are Minor – No Detailed Consideration is Required** Whilst potential for inundation and/or isolation exists, there are no significant evacuation constraints.
Class B	**Risks are Moderate – Detailed Consideration is Required** Evacuation constraints exist although in most situations these are not so severe as to significantly influence the planning decision.
Class C	**Risks are Serious – Very Detailed Consideration is Required** Serious evacuation risks exist. These may be close to the limit of community acceptance. Careful consideration of these risks must be undertaken when evaluating the appropriateness of the development having regard to all social, economic and environmental issues.
Class D	**Risks are Intolerable/Unacceptable – Development Should Not Proceed** Evacuation risks are so serious that irrespective of other considerations, the development should not proceed.

These ERCs have been determined for potential development areas in each locality based on a range of factors influencing evacuation constraints associated with development. These factors are dependent not only on the flood (hazard and hydraulic) characteristics of the site but also the nature of the proposed development. These factors include:

- Proposed land use and demographic characteristics of occupants;
- Access to evacuation facility including time available / required to evacuate;
- Topographical constraints;
- Availability of a refuge above the reach of flood waters; and
- Availability of support facilities within the refuge.

Relevant considerations for each of these factors are outlined in further detail in Appendix B.

Proposals identified as ERC Class A have evacuation risks so minor that they would not preclude progress of the otherwise desired planning outcome. Proposals with ERC Class D are so severe that the evacuation risks alone would be a reason to discontinue consideration. If determined to be ERC Class B or C, then further investigations would be required to determine whether mitigation measures would be acceptable, or whether the planning proposal should be abandoned, based on social, economic and environmental factors, e.g. Is the risk at a level that the community would tolerate (Class A) or can housing be provided elsewhere? Are mitigation costs affordable to the community and/or the developer? Will mitigation measures impact on ecological or amenity values or planned character of the area?

The principles in Table 8-2 should be considered by Council when undertaking strategic planning of flood prone areas, including preparation of LEPs, DCPs and Floodplain Risk Management Plans.

Table 8-2 Determining the Evacuation Risk Classification

Access to evacuation facility As determined by evacuation capability assessment (ECA)	**Flood Duration**	**Refuge with Support Facilities**	**Refuge without Support Facilities**	**Topo Class**							**Residential** Note (d)		**Commercial & Industrial**	**Recreation & Non Urban**	**Concessional Development**
				LFI	**HFI**	**LTP**	**HTP**	**OER**	**RRA**	**IAA**	**Major Subdivision**	**New Development on Zoned Land**			
Access likely to be continuously available Access between site and evacuation facility not cut by flood waters	n.a.	n.a.	n.a.								Note (a)	Note (a)	Note (c)		
		n.a.	n.a.								Note (a)	Note (a)	Note (c)		
Access is constrained Access will be cut during floods but the *ECA* indicates a *Safety Factor* exists	n.a.	Yes	No										Note (c)		
		No	Yes									Note (a)			
		No	No								Note (b)	Note (b)	Note (b)	Note (b)	Note (b)
Access is seriously constrained Access will be cut during floods. A *Rescue* is indicated by the ECA	Short	Yes	No												
		No	Yes												
		No	No										Note (b)	Note (b)	Note (b)
	Long	Yes	No												
		No	Yes												
		No	No										Note (b)	Note (b)	Note (b)

Refer to explanatory notes on following pages.

Notes

Refer Table 8-1 for a description of the Evacuation Risk Advice depicted by the colour coding.

Note (a): This will be Class C if the probability and consequence of loss of services is high and likely to significantly influence the wellbeing of the residents.

Note (b): Assumes that loss of life is not expected in major flood events up to the PMF. If new development on a vacant site is proposed and loss of life is expected, then upgrade to Class D. If loss of life is expected in a redevelopment scenario, then the first priority should be voluntary purchase of the existing development.

Note (c): This will be Class B if the probability and consequence of loss of services is high and likely to significantly influence the viability of the enterprise.

Note (d): Critical and sensitive uses and facilities have not been shown in Table 8-2. Proposals for these types of land uses need to be treated more conservatively than residential proposals. However given the diverse nature of these types of land uses and their often complex considerations, determination of an Evacuation Risk Class will be dependent on many site-specific and use-specific issues.

Access to Evacuation Facility

Availability of this access would normally be determined by an evacuation capability assessment (ECA). The assessment is carried out using 'timeline procedures' (Opper et al., 2009) and it is assumed that the evacuation would likely be initiated and managed by the SES in accordance with the SES' local or regional emergency management plan.

The ECA usually assumes evacuation to a government evacuation centre and recognises that it is preferable for evacuees to seek shelter amongst relatives and friends outside the floodplain, in preference to attending an evacuation centre, wherever possible.

The ECA utilises various assumptions concerning warning time, mobilisation time, vehicle travel speeds etc., and compares the time required for evacuation with the time available. Where a deficit exists, a Rescue is assumed. Where the available time available exceeds the time required, the difference in time is referred to as the Safety Factor.

Flood Duration

Short duration floods would typically be flash floods (i.e. up to six hours to flood peak from start of rainfall). This might be adjusted subject to the demographics of the population being evacuated or sheltering on site. For example, a shorter period may be appropriate for occupants of a nursing home (requiring frequent assistance) whilst a longer period may be appropriate for agricultural communities with experience and resilience in coping with flood isolation.

Topo Class

Refer to Appendix B for a description of the topo classes.

Shading indicates that this topo class will likely apply to this combination of access and refuge conditions.

Refuge Available with/without Support Facilities

Fail-safe access to a place of refuge above the reach of the probable maximum flood (PMF) either on or off site, is assumed.

If this is provided in a building or other structure it must be structurally sound and able to resist the buoyancy and debris loads imposed by floodwaters.

The access needs to be available at the critical inundation level (usually the level at which the main floor becomes inundated). The critical inundation level represents the likely highest flood level at which occupants who fail to heed evacuation warnings, or otherwise choose to remain on site, must flee to the place of refuge.

Support facilities are those necessary for health and safety during emergencies, having regard to the probability of the emergency occurring, the duration of use, the number of the people using the facility, and their needs. When the number of people likely to use the facility will exceed those residing in a single dwelling, the facility would normally need to provide for back-up power, water, sanitation, bedding, food and communications.

Concessional Development

This comprises alterations and additions, or redevelopment that significantly reduces the existing flood risk at the site.

8.3.4 Strategic Planning Recommendations

It is recommended that hydraulic and evacuation constraints to development be considered at a strategic (as well as individual) planning level for the Tweed Valley.

Recommendation 31a (hydraulic constraints): Substantial parts of future urban areas are low lying and will require filling to a minimum 100 year ARI flood level (including an allowance for climate change). Where required, this fill has the potential to impact on flood storage and flood conveyance. The cumulative effects of this fill have been assessed as part of this study to determine the hydraulic constraints to future development and inform appropriate planning control recommendations (Section 8.3.2).

Recommendation 31b (evacuation constraints): Some of the future urban areas have significant evacuation constraints and associated public safety risks. Four graded evacuation risk classes (ERCs) have therefore been derived to provide advice to planners and consent authorities concerning these evacuation risks (Section 8.3.3). These ERCs have been determined for formal planning proposals based on evacuation capability assessments, the nature of the floodplain topography, access to support facilities and other risk considerations.

8.4 Planning and Future Development by Locality

The planning strategy review, hydraulic assessment and evacuation risk classification described above have been carried out on each of the study area localities; the Lower Tweed; Chinderah, Fingal Head and West Kingscliff; Murwillumbah and South Murwillumbah; the riverside villages and rural development.

8.4.1 Lower Tweed

8.4.1.1 Tweed City Centre Plan

According to the Tweed City Centre Plan Vision 2011, the majority of future development in the Lower Tweed area is envisaged to occur within Tweed Heads, east of Razorback Hill (referred to as Tweed City Centre North in the document). The Vision was prepared by the NSW Department of Planning & Infrastructure's City Centre Taskforce in collaboration with Council, exhibited in early 2010 and adopted by Council in December 2011. It is accompanied by the draft Tweed City Centre LEP.

The Vision document describes a vision and strategic framework for Tweed Heads as a regional city and includes an action plan to facilitate the city's growth, in particular the LEP and DCP.

Initially, the scope of the City Centre Plan included Tweed Heads and Tweed Heads South (referred to as Tweed City Centre North and South respectively). Based on an ideal planning outcome, the dwelling growth targets Table 8-3 were originally considered.

Flooding, climate change and evacuation considerations during the development of the City Centre Plan led to the deferral of Tweed City Centre South and part of North (east of Wharf Street), for due consideration as part of this study.

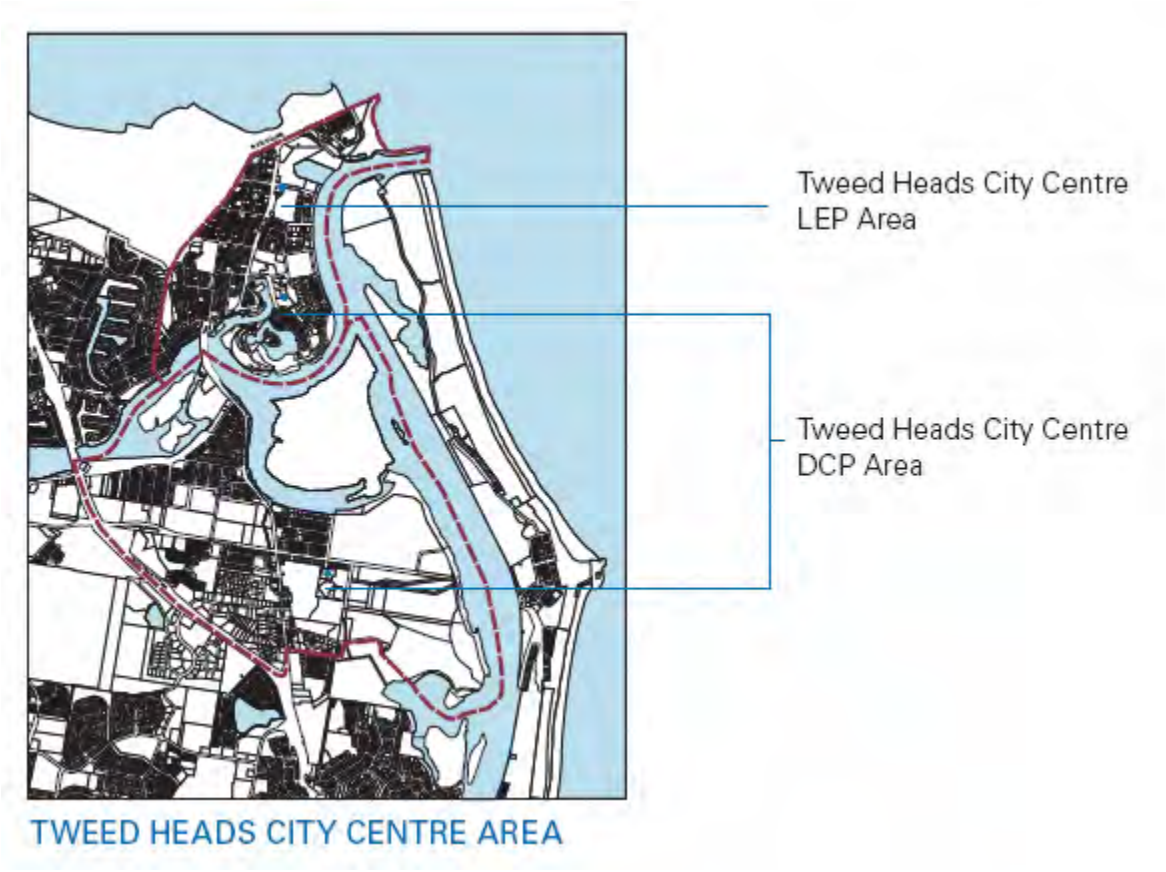


Figure 8-2 Tweed City Centre LEP and DCP Areas (Tweed City Centre Plan Vision 2011)

Table 8-3 Ideal Growth Dwelling Targets Tweed City Centre

Area	Existing Dwellings	Additional Dwellings	Total Dwellings
Tweed City Centre North	2,541	10,459	13,000
Tweed City Centre South	2,198	5,502	7,700

The exhibited plans provide for revised growth within Tweed City Centre North of approximately 9,600 dwellings and 215,000 m^2 of commercial / industrial floor space. Some limited infill development could be expected in Tweed City Centre South in line with current planning controls (equating to an additional 1,000 dwellings). An additional 180,000 m^2 of commercial / industrial floor space was proposed for Tweed City Centre South.

Building forms will vary as generally reflected by the proposed zonings and heights outlined in the planning instruments. Outside of the commercial core, developments are likely to be standalone with side and rear setbacks. Within the commercial core and mixed use zones, the lower 3 to 6 storeys are proposed to be “built to boundaries” (i.e. no boundary setbacks) while the storeys above are to be a series of towers (setback from boundaries).

Note that in this section of the study, future flood risk considerations are limited to the Tweed City Centre Plan area within the wider Lower Tweed locality. Future development in Tweed Heads West is currently limited to minor infill residential redevelopment and limited industrial / business park

development on the zoned land in Tringa Street and the Boyds Bay Garden World site. The Bilambil Heights urban release area is generally unconstrained by flooding.

8.4.1.2 Flood Risk

Tweed Heads North

The majority of the Tweed Heads North area is not inundated in a 100 year ARI flood event. Where inundation does occur, it is largely confined to roadways near the river. Nevertheless under the adopted climate change scenario, 100 year ARI flood levels will rise about 0.5m and inundation will occur beyond the road areas, although virtually all of this will occur east of Wharf Street.

Flood modelling shows that the PMF is 2.5m above the 100 year ARI flood level. A large part of Tweed Heads North is inundated in the PMF event, although the western fringe of the area, where the evacuation centre is located, contains high ground that is above the PMF (Razorback Hill). It is noted that there is a considerable area of high ground further to the west within Queensland. Whilst this area is technically excluded from the study area (and not considered in SES operations or the ECA), in a significant flood emergency there may be scope for evacuees to seek refuge in this area and for its resources to be used to service the flood emergency.

Tweed Heads South

The Tweed Heads South area can be divided broadly into the land west and east of the Pacific Highway. West of the Pacific Highway, whilst almost all of the land is inundated in a PMF, a large portion remains flood-free in a 100 year ARI event, except for the land in the north western extremity adjacent to Terranora Creek (around Philip Street and James Road) where inundation occurs in a 20 year ARI flood. East of the Pacific Highway, most of the land north of Kirkwood Road is inundated in a 20 year ARI event, whilst the land south of Kirkwood Road remains flood free in a 100 year ARI event. Under climate change conditions, 100 year ARI flood levels will rise about 0.5m and the extent of the 100 year flood will increase south of Kirkwood Road.

8.4.1.3 Cumulative Development Assessment

Due to the ocean dominated nature of flooding in the Lower Tweed, and the infill nature of much of the cumulative development in this area, no specific large scale fill areas in this locality were modelled.

The Urban Release Areas of Cobaki Estate and Area E, within the subject locality, have been assessed separately as part of the planning process, so have not been revisited in this study.

8.4.1.4 Evacuation Risk

Tweed Heads North

The existing evacuation capability assessment (ECA) has been carried out at a sector level; refinement of the assessment will provide greater detail across sub-areas of the proposed development area and allow the classifications to be provided for each sub-area.

Overall there appears to be relatively good access to high ground and the existing evacuation centre (Police Citizens Youth Club, Florence Street). However given the large increases in population that

are proposed, considerable expansion of the existing evacuation centre or the provision of a new centre will be required. A new centre would be best located on land above the PMF in the western portion of the development area, possibly close to the existing evacuation centre. Subject to appropriate cross-border arrangements being put in place, it may also be possible for the new centre to be located inside Queensland.

In a flood emergency, evacuation of the existing and future populations of Tweed Heads North to an evacuation centre or suitable alternative accommodation on flood free land is the preferred means of managing the risk to life that can arise from flood inundation or flood isolation. When road access away from Tweed Heads North is cut by floodwaters, evacuation can still generally occur to the existing evacuation centre.

The ERCs for Tweed Heads North have been classified as:

- Class C is generally applicable to the large scale development proposals in Tweed Heads North, given rising road access to the evacuation centre and multi-storey building forms, which provide areas above PMF level.
- The unique development form proposed for the Tweed City Centre could potentially allow for a substantial number of people to find safe refuge from floods, possibly in communal situations, within upper levels of multistorey buildings. The forms of these multistorey buildings could have pedestrian connections at higher levels, which can allow for the gathering and interaction of persons affected by flooding. Furthermore, a number of support facilities would be expected to be available within these interconnected buildings. The conditioning of new development to comply with Council's existing controls for *Critical Infrastructure* and the recommendations for addressing concurrent fire and medical risks (Appendix B) would ensure suitable support facilities were available for the health and wellbeing of any residents isolated in these elevated buildings. Any large scale development proposed in the area should be provided with on-site refuges (as a fall-back provision in the event that residents fail to heed evacuation warnings). A flood free refuge would generally need to be located on the first (or higher) storey of a multi-storey development. All development with access to these support facilities would have their evacuation risk revised to Class B. When planning new large scale developments, reliance on road access to evacuation centres or pedestrian access to local refuges should be determined using 2100 climate change 100 year flood planning levels.
- Class D applies to low island areas east of Wharf Street, where rising road access is not available, unless measures are provided to improve road access or otherwise provide the necessary support facilities on site.

Tweed Heads South

The ECA has been based on areas in the north evacuating by Dry Dock Road to the Tweed Heads North evacuation centre (i.e. the PCYC). Dry Dock Road is flood affected and at risk of inundation from local catchment runoff. There may be potential for some of the evacuation traffic from these areas to be directed to the south to the Banora Point evacuation centre. Nevertheless there remain significant evacuation risks in the area, generally north of Kirkwood Road and there are likely to be number of small flood islands in this area where people could become trapped during a flood. A range of measures including the raising of existing levies are considered within the FRMS to mitigate the evacuation risks to which the existing population is exposed.

South of Kirkwood Road and east of the Pacific Highway, the ECA shows there is ample capacity available for evacuation traffic from existing areas to reach the Banora Point evacuation centre. This area appears to have rising road access, subject to local stormwater conditions.

West of the Pacific Highway, a little more than a third of the proposed development area is already above the PMF. Through refinement of the ECA, or with upgrades to Fraser Drive, it is possible that two thirds of this area could safely reach the evacuation centre.

As with the ECA carried out at Tweed Heads North, the assessment has been carried out at a sector level and is unable to provide sufficient detail within sub-areas to adequately inform the planning of these sub-areas. Further refinements to the ECA will be needed if planning proposals are to proceed.

The ERCs for Tweed Heads South have been classified as:

- Class D for *low island* development areas - due to the significant evacuation constraints and the form of development that is currently proposed for this area. Although on-site refuges may be available (or could be incorporated) with individual buildings, they will likely lack support facilities and will isolate occupants within individual buildings without potential to access communal facilities in adjacent buildings.
- The presence of *low flood islands* and the lack of *rising road access* in sub-areas of Tweed Heads South present significant person safety risks that are a serious impediment to any future expansion. It would appear that significant alterations to the proposed building form (e.g. to provide support facilities within elevated interconnected buildings as is being considered for Tweed Heads North) are required in order to reduce the risk to life and allow a corresponding down grading of the evacuation risk from Class D to Class C. These building form changes are not consistent with Council's current strategic planning intent for the area.
- Class B for areas where rising road access is available, or could be provided as part of the development.
- Class C for areas where although rising road access is not available, refinement of the ECA confirms that sufficient time is available to evacuate via Fraser Drive to the Banora Point evacuation centre.

Any large scale development proposed in the area should be provided with onsite refuges (as a fall-back provision in the event that residents fail to heed evacuation warnings). Given the flood level range, refuges located on the first storey or higher will likely be outside the reach of the PMF.

8.4.1.5 Lower Tweed Recommendations

Recommendation 32 (strategic planning):

- **Tweed Heads North:** The current strategic planning directions for this area could be supportable on flood risk grounds, subject to more detailed assessment; road access improvements where required; and / or provision of necessary on site refuges and support facilities. This includes the area both west and east of Wharf Street.
- **Tweed Heads South:** The presence of low flood islands and the lack of rising road access present significant person safety risks that are a serious impediment to any future expansion. It would appear that significant alterations to the proposed building form (e.g. to provide support facilities within elevated interconnected buildings as is being considered for Tweed Heads) are required in order to reduce the risk to life. Areas where there may be sufficient time to evacuate via Fraser Drive may also be lesser risk, though still serious, requiring very detailed consideration when evaluating the appropriateness of any development in this area.

Recommendation 33 (development controls): The following recommendations are made for review of the Tweed DCP referenced to the provisions for Tweed City Centre.

- The 2100 climate change 100 year flood level (plus freeboard) as the habitable residential floor level in Tweed City subject to variations in some circumstances;
- A preferential emphasis on providing for evacuation away from the floodplain in preference to sheltering on-site; and
- If the above cannot be practically achieved then the DCP should specify the nature of an on-site refuge that would be acceptable, including the facilities to be provided within the refuge, procedures to access the refuge, and procedures for rescue from the refuge in case of fire or the need for medical attention; those that meet the requirements of Section 3.2.5(a) (Essential Community Facilities and Critical Services) of the existing DCP would likely be suitable, together with those recommended for addressing coincident fire and medical risks.

8.4.2 Chinderah, Fingal Head and West Kingscliff

8.4.2.1 Tweed Coast Strategy

Development in the region is guided by the Tweed Coast Strategy outlined in Section B9 of the Tweed DCP, which covers parts of Chinderah, Kingscliff and Cudgen, as well as land to the south of the Tweed Valley study area in the Cudgen Creek catchment.

The population of the Tweed Coast was estimated as 6,900 people at 1999. Under this planning strategy, it is envisaged that when fully developed, this area will have a population of approximately 26,150 people. Of the population growth, an estimated 3,600 are anticipated within the study area in Chinderah / West Kingscliff, Kingscliff and Cudgen Village. Figure 8-3 shows the Structure Plan which depicts existing and future urban areas.

Notwithstanding the above current planning strategy, this study has also assessed other large scale development options including some informal options (shown in Figure 8-4):

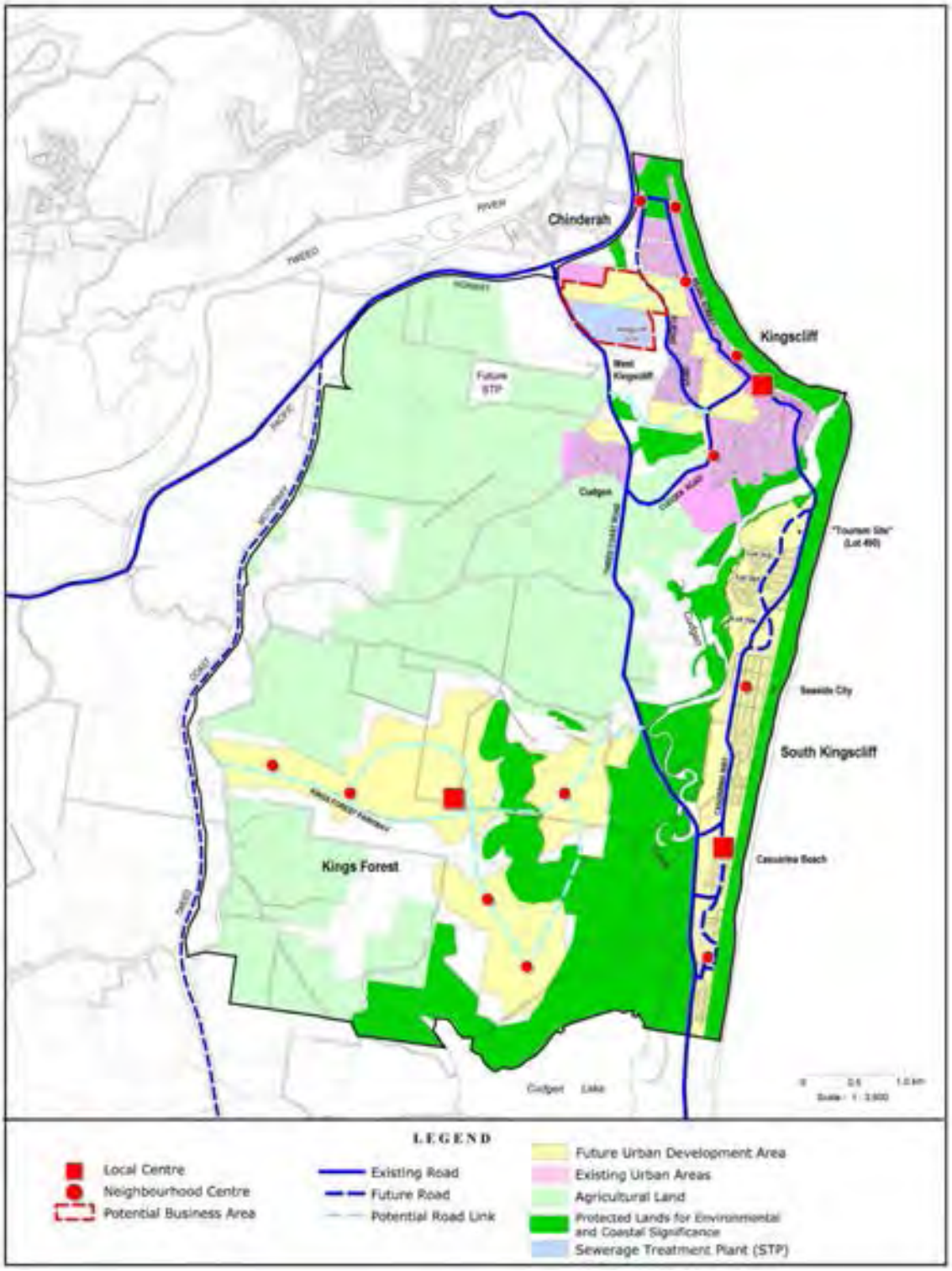
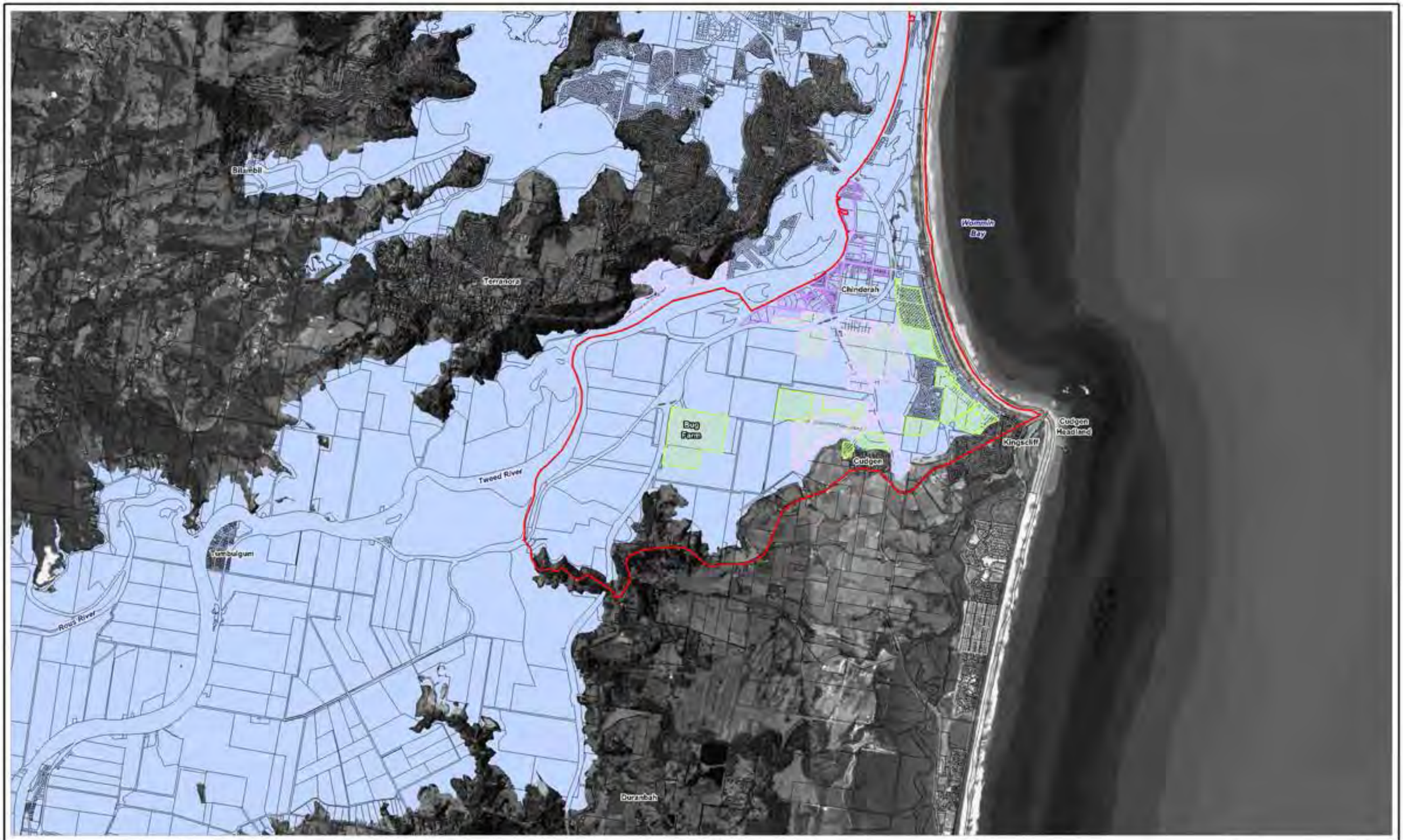


Figure 8-3 Tweed Coast Strategy Structure Plan (Tweed DCP 2008)



LEGEND

- Chinderah Boundary
- Development Scenario 1
- Development Scenario 2
- Development Scenario 3
- Cadastral boundaries
- Flood Prone Land

Title:

Chinderah and West Kingscliff Development Scenarios

Figure: 8-4

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Approx. Scale

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- Increased residential redevelopment in Chinderah Village based on potential relaxation of DCP controls that currently limit subdivision and filling;
- Increased industrial development in Chinderah based on potential relaxation of DCP controls that limit filling and site coverage;
- Updated development concepts for Gales Holdings land in West Kingscliff in consultation with Gales' consultants;
- Development of the old Kingscliff Sewage Treatment Plant site for industrial land uses; and
- Potential rezoning and development of Rural 1(a) zoned land in Chinderah Village, West Kingscliff, and on the northern side of the Tweed River via Old Ferry Road Banora Point.

Substantial parts of the future urban area are presently low lying and will require filling to a minimum level equal to the 100 year ARI flood (including an allowance for climate change). This will have potential flood risk management implications which are discussed further below.

8.4.2.2 Flood Risk

Chinderah, Fingal Head and West Kingscliff can experience major flooding from both rainfall events over the Tweed River catchment, and ocean storm surge, often during the same event. The Chinderah and Kingscliff areas are generally dominated by catchment flooding, while Fingal Head may experience higher flood levels due to storm surge events.

Chinderah

Significant flooding of Chinderah Village occurs in events greater than the 5 year ARI event. Large areas of Chinderah experience flooding in the 20 year ARI event with depths up to 1.5 metres in low lying areas adjacent to the Kingscliff drain. In the 100 year ARI event, most of Chinderah is inundated with depths up to 2.5 metres. Velocities are generally low; floodwaters are generally deep but slow-moving.

Kingscliff

The coastal fringe, including the majority of Kingscliff, is above the 100 year ARI flood level. Some residential areas in the north west of Kingscliff (Sand Street to Kingscliff Street) are inundated in the 100 year ARI flood event with depths up to 1.5m. Velocities in this area are generally low. All of the area, except for the hills around Cudgen to the south and the high sand dunes at the beachfront, are inundated in the PMF, with flood breakouts to the ocean expected at some locations.

Fingal Head

The main population centre of Fingal Head is a high island, isolated but flood free in a PMF event. Fingal Road, which represents the only road connection to Chinderah to the south, is affected by flooding in the 5 year ARI flood event. This road and adjoining properties are predicted to be completely inundated in the 20 year ARI event. The depth of inundation over Fingal Road is up to 1.5 metres near Wommin Lake in the 100 year ARI event. Flood water is expected to breakout across the peninsula to the ocean in a PMF event. There is anecdotal evidence that such breakouts have occurred in major historic floods.

Under climate change, flood levels in the above localities are expected to rise a further 0.3m (approximately), which will have a small impact on flood extents, but further increase depth hazard in these flat, low lying areas.

8.4.2.3 Cumulative Development Assessment

Floodplain development in the area will generally require substantial filling. This fill has the potential to impact on flood storage and flood conveyance and has been assessed in a number of cumulative development scenarios using Council's Tweed Valley flood model.

Three main scenarios for large scale urban development in the Chinderah and Kingscliff area were assessed as part of this study. Hydraulic impact assessments were completed for each of these scenarios based on a 100 year ARI design flood event. Where impacts were found to be unacceptable, options were tested to mitigate impacts.

Council has indicated that these scenarios are to be prioritised, such that if Scenario 1 is found to be acceptable, the next priority is Scenario 1 combined with Scenario 2, and similarly for Scenario 3.

Figure 8-4 below, shows the three different development scenarios.

Scenario 1: Comprises developments that are generally compatible with current zoning and DCP controls. Some of these developments have been recently approved and are built or currently under construction.

- Residential development and infill in Kingscliff (minimum 100 year ARI flood immunity);
- Industrial development in Chinderah (filled to 2.2 mAHD, 50% site coverage for flow obstructions above 2.2 mAHD); and
- Other approved development, including;
  - Aquaculture development (bunded to 100 year ARI flood level);
  - Sewage treatment plant (100 year ARI flood immunity); and
  - Quarry (bunded to 1.8 mAHD).

Scenario 1 Impacts: Impacts from development Scenario 1 are shown in Figure 8-5.

The hydraulic impacts of the above scenario were found to be broadly acceptable. In general, low level impacts of up to 0.1m were evident in the floodplain primarily in rural zoned land from around Stotts Island to the aquaculture development and adjacent developments. There are some more significant localised impacts of up to 0.3m immediately upstream of the aquaculture development.

Scenario 1 Summary: Hydraulic impacts due to development compatible with current zoning and DCP controls are generally acceptable, with low level impacts and confined to non urban areas.

Scenario 2: Includes potential additional development based on a relaxation of DCP controls to allow filling in Chinderah Village (excluding floodways). Scenario 2 retains current land zoning.

- Residential development at the Chinderah waterfront (minimum 100 year ARI flood immunity); and
- Infill development in urban zoned areas of Chinderah (minimum 100 year ARI flood immunity).

Scenario 2 Impacts: Fill and bunding associated with the cumulative development of Scenarios 1 and 2 combined were found to generate significant impacts of up to 0.3m in and around Chinderah Village. There are also broader low level impacts of up to 0.1m in the surrounding floodplain.

Despite investigating a number of options (including limiting to 50% site coverage and limiting to the riverfront to retain flow between the riverfront and the Pacific Highway), results of the hydraulic assessment found that development in Chinderah Village is extremely constrained and cannot be included in the cumulative development scenario. The primary constraint is the constriction of the floodplain (or reduction of flow conveyance) associated with any filling between the river and Pacific Highway. This is consistent with previous investigations undertaken as part of the Chinderah Floodplain Management Study (Cameron McNamara, 1984).

Scenario 2 Summary: There are hydraulic constraints in Chinderah Village caused by the constriction of the floodplain between the river and Pacific Highway. Filling in Chinderah Village results in unacceptable hydraulic impacts and is not suitable for inclusion in the cumulative development scenario.

Scenario 3: Includes potential additional development based on a relaxation of DCP controls to allow additional filling of Chinderah industrial development, rezoning rural zoned 1A land between Chinderah Village, West Kingscliff and the Pacific Highway (excluding floodways) and a pocket of land accessed via Old Ferry Road in Banora Point.

- Increased flood immunity for industrial development in Chinderah (minimum 100 year ARI flood immunity,100% site coverage);
- Additional residential development along Tweed Coast Road (minimum 100 year ARI flood immunity);
- Recreational land (filled to 1m below 100 year ARI flood level) and lake; and
- Development of land accessed off Old Ferry Road (minimum 100 year ARI flood immunity).

Scenario 3 Impacts: Fill associated with the cumulative development of Scenario 1 and 3 combined were found to generate unacceptable impacts of up to 0.05m adjacent to West Kingscliff and Cudgen. This is due to both a loss of floodplain storage and constriction of the floodplain (or reduction of flow conveyance) through the Chinderah basin. The additional filling of Chinderah industrial land was reduced to 75% site coverage, however there were still downstream impacts at Fingal Road due to a loss of floodplain storage. The additional filling of Chinderah industrial land was further reduced to 65% site coverage, which reduced impacts to acceptable levels. Figure 8-7 shows the impacts of development Scenarios 1 and 3 including filling of Chinderah industrial land to 65% site coverage.

Scenario 3 Summary: There are hydraulic constraints in the Chinderah basin, caused by the cumulative loss of floodplain storage and constriction of the floodplain. Hydraulic impacts from the cumulative development scenario 1 and 3 were found to be acceptable if filling of Chinderah industrial development is limited (i.e. filled to 2.2m AHD, 65% site coverage for flow obstructions above 2.2 mAHD). Under the revised scenario, there are low level impacts typically confined to non-urban areas.

Conclusion: Development of the Chinderah Village area (between the Pacific Highway and Tweed River) produced unacceptable impacts and cannot be included in a cumulative development

scenario. Development of the Chinderah basin must be managed to limit impacts due to loss of floodplain storage and / or constriction of the floodplain. An optimal Chinderah/West Kingscliff development scenario has been identified which allows the greatest amount of potential development in the area without Chinderah Village. This development scenario slightly increased flood levels in the catchment, but within acceptable levels and is suitable for inclusion in the cumulative development scenario for the broader study area (Section 8.3.2). Additional development of land outside of the development scenario, or requiring works in excess of the recommended controls, can be considered on its merits based on site specific design and further detailed flood modelling using the cumulative development case flood model as outlined in Section 8.3.2.

LEGEND

Chinderah boundary

Development Scenario 1

Cadastral boundaries

Title:

Impact of Chinderah and West Kingscliff Development Scenario 1

Figure: 8-5

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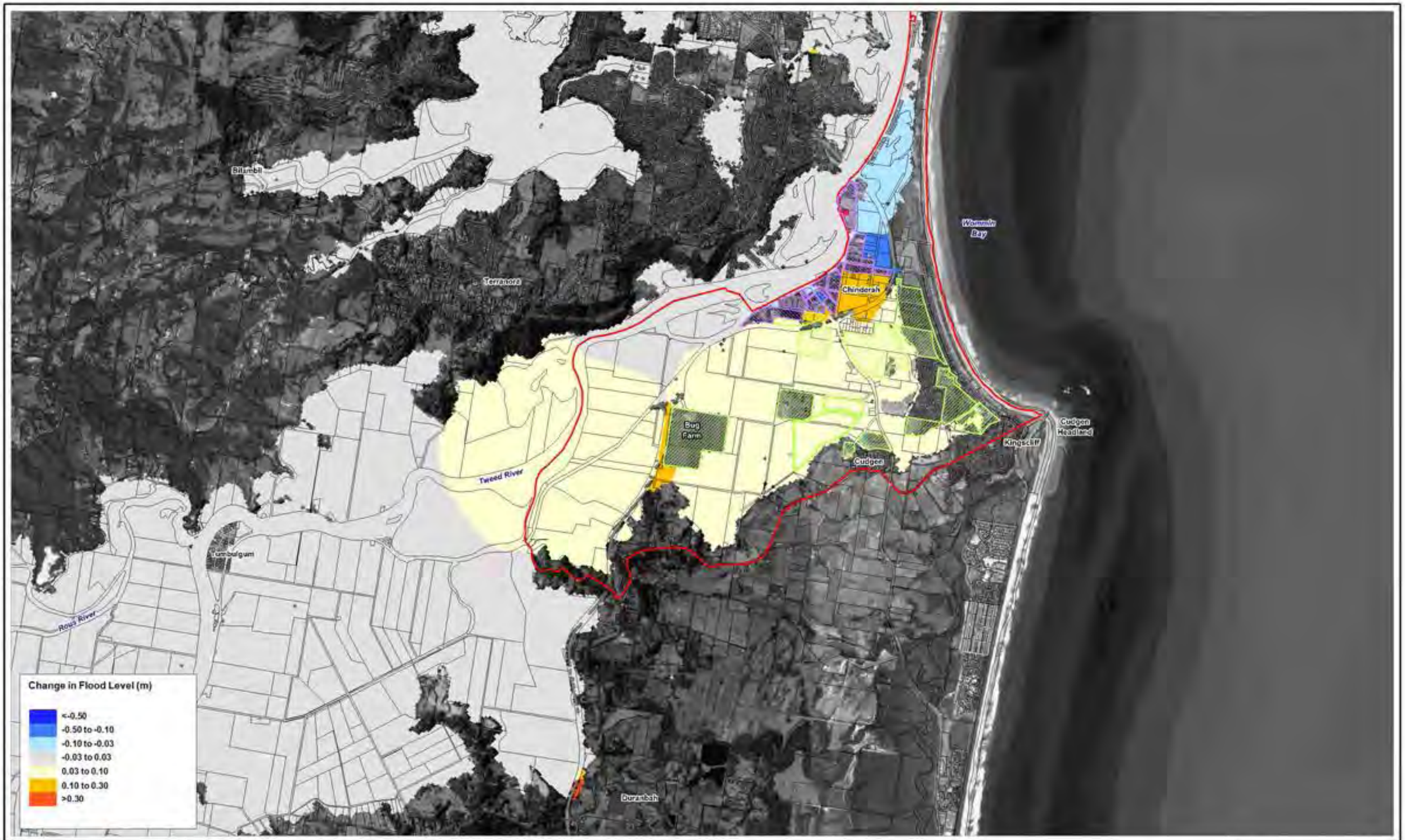

LEGEND

- Chinderah boundary
- Development Scenario 1
- Development Scenario 2
- Cadastral boundaries

Title:

Impact of Chinderah and West Kingscliff Development Scenario 2

Figure: 8-6

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Approx. Scale

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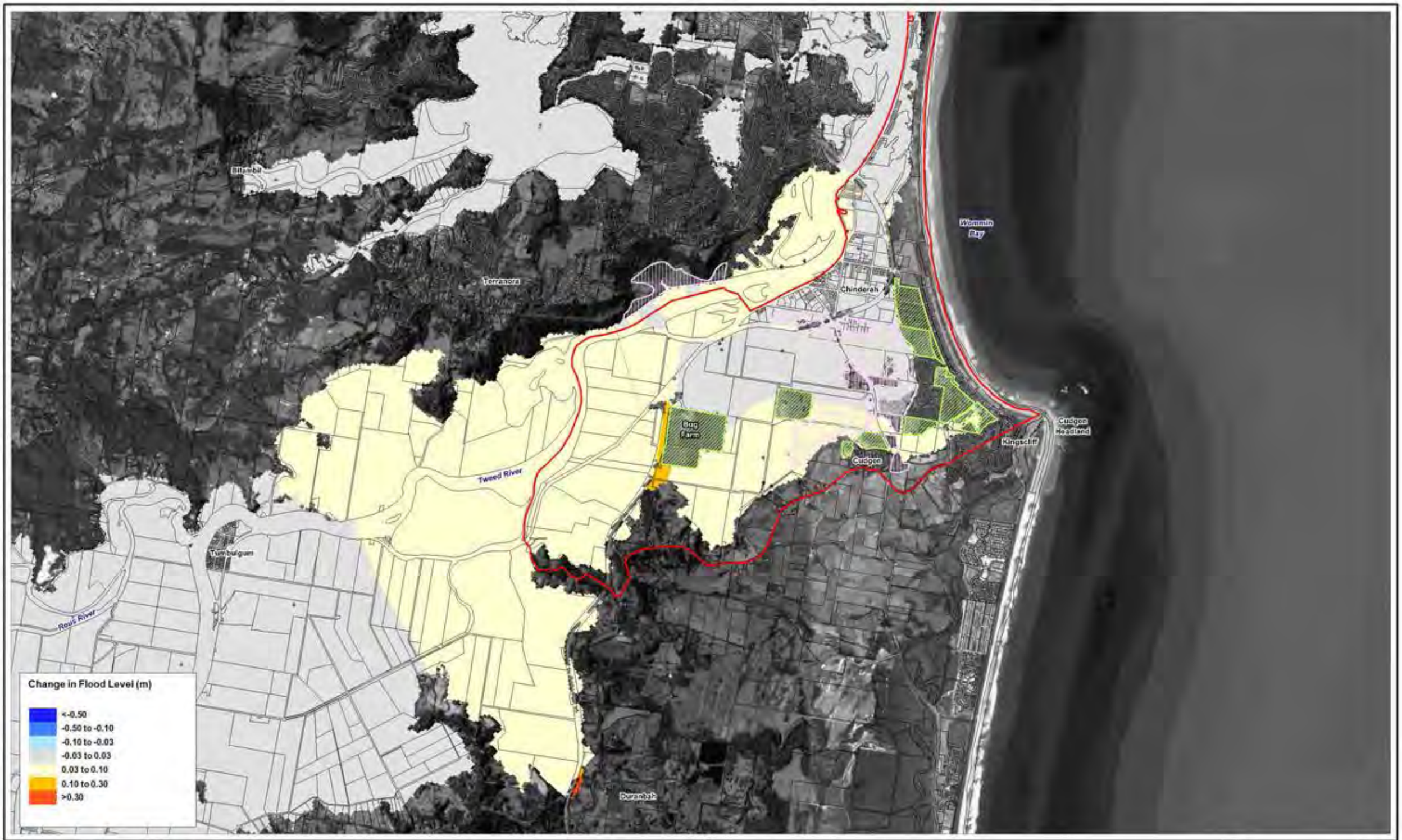

LEGEND

- Chinderah boundary
- Cadastral boundaries
- Development Scenario 1
- Development Scenario 2
- Development Scenario 3

Title:

Impact of Chinderah and West Kingscliff Development Scenario 3

Figure: 8-7

Rev: A

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Approx. Scale

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8.4.2.4 Evacuation Risk

Evacuation arrangements for existing communities in this area are rather complicated, with various routes (Pacific Highway, Tweed Valley Way, Tweed Coast Road, Wommin Bay Road, Marine Parade) and various evacuation centres (Cudgen Public School ,Kingscliff TAFE, Banora Point) being identified for this sector. There would appear to be opportunities to improve evacuation from the existing developed areas subject to more detailed sub-sector evacuation planning being undertaken, and redirection of evacuees through relatively unaffected roads in Kingscliff. The option for establishing an evacuation centre on the Fingal Head high island should also be considered. While this option is not ideal due to isolation issues, it is likely to be better than the existing approach of trying to evacuate residents via Fingal Road.

In respect of the proposed large scale development areas that have been identified in formal planning proposals and LEP zonings, these will all be filled and the internal road layout and road levels will likely be determined at the time of subdivision. Through careful road planning within these areas, there is potential to make rising road egress available (at least until the internal roads meet the existing regional road network).

From each of these development areas, the most attractive evacuation route would appear to be to travel eastwards to Marine Parade or Kingscliff Street and then in a generally southerly direction to Cudgen. This evacuation route provides rising road access (subject to detailed assessment, survey etc.) and has been shown to have a safety factor, and therefore based on the assumptions in the ECA, each of the proposed developments will likely have sufficient time to evacuate to the evacuation centre, during a PMF event.

No detailed ECA was carried out in respect to informal development proposals (e.g. those proposals that would require rezoning or are significant departures from Section B9 of the Tweed DCP). However preliminary assessments suggest that there may be difficulties in achieving safe evacuation in some areas more remote to the coastal high land, without some upgrading of evacuation routes, such as Tweed Coast Road.

The ERCs for the formal planning proposals in Chinderah and Kingscliff have been classified as:

- Class B for areas where rising road access is available, irrespective of whether support facilities and / or on-site refuges were provided within the development areas;
- Class B for areas where rising road access is not available, but with provision of on-site refuges;
- Class C for areas where rising road access is not available and without the provision of on-site refuges; and
- Class D in Chinderah Village and Fingal Head, where any further large scale development would inevitably result in unacceptable evacuation risks. No further consideration should be given to increasing the development potential beyond their existing zoned capacity.

8.4.2.5 Chinderah, Fingal Head and West Kingscliff Recommendations

Recommendation 34 (strategic planning):

- **Tweed Coast Strategy (Section B9 of the Tweed DCP):** Evacuation of development areas could be considered to be within manageable limits subject to satisfying other planning criteria. Hydraulic impacts due to the cumulative filling of land and associated loss of floodplain storage were found to be acceptable.
- **Chinderah Village:** Hydraulic impacts associated with filling of land limits development potential in Chinderah Village. Further, incremental development that leads to substantial cumulative expansion in the population could result in unacceptable risks due to existing evacuation constraints (specifically evacuation route capacities and local drainage issues).
- **Other informal planning proposals (Chinderah / West Kingscliff):** Hydraulic impacts due to the cumulative filling of land and associated loss of floodplain storage were found to be acceptable for other informal planning proposals. Evacuation of areas with rising road access to Marine Parade or Kingscliff Street should be manageable. However, substantial cumulative expansion in the population in any other areas could result in unacceptable risks due to existing evacuation constraints.

Recommendation 35 (development controls): The following recommendations are made for review of the Tweed DCP specific to the Chinderah, Fingal Head and West Kingscliff region.

- The provisions of Section B9 should be expanded to clarify the requirements for a detailed evacuation risk assessment prior to proceeding with areas identified for future urban development;
- Relaxation of Chinderah / West Kingscliff industrial fill restrictions from 50% to 65% site coverage;
- No changes to the DCP controls should be made to land within the floodplain, which would have the effect of increasing development potential on an incremental basis; and
- Existing emergency response provisions should be retained.

8.4.3 Murwillumbah and South Murwillumbah

8.4.3.1 Murwillumbah Town Centre and Murwillumbah West DCP

Future development in the Murwillumbah region is guided by Sections B22 and B6 of the Tweed DCP, Murwillumbah Town Centre and Murwillumbah West respectively. This includes parts of the existing urban area of the town that have been identified to provide for intensification of residential development, as well as possible future expansion to industrial areas. Development considerations include:

- Infill development of residential zoned land;
- Potential redevelopment / revitalisation within the town centre, including mixed use and multi dwelling / shop top housing proposals;
- Growth in the existing South Murwillumbah industrial area, including expansion into Wardrop Valley / Fernvale; and

- Mixed use commercial development in South Murwillumbah (Prospero Street precinct).

Figure 8-8 and Figure 8-9 show the Urban Structure Plan and precincts respectively for the Murwillumbah Town Centre. Figure 8-10 shows the release area zonings for Murwillumbah West.

Within South Murwillumbah, some residential development proposals (including mixed land use proposals) have previously been deferred in Section B22 of the DCP due, in part, to concerns about the appropriateness of any intensification of residential development given the significant flood risks in the area. These deferred areas comprise Prospero Street, South Murwillumbah Riverfront and the South-Side Residential Precincts.

Figure 8-8 Murwillumbah Town Centre Urban Structure Plan (Tweed DCP 2008)

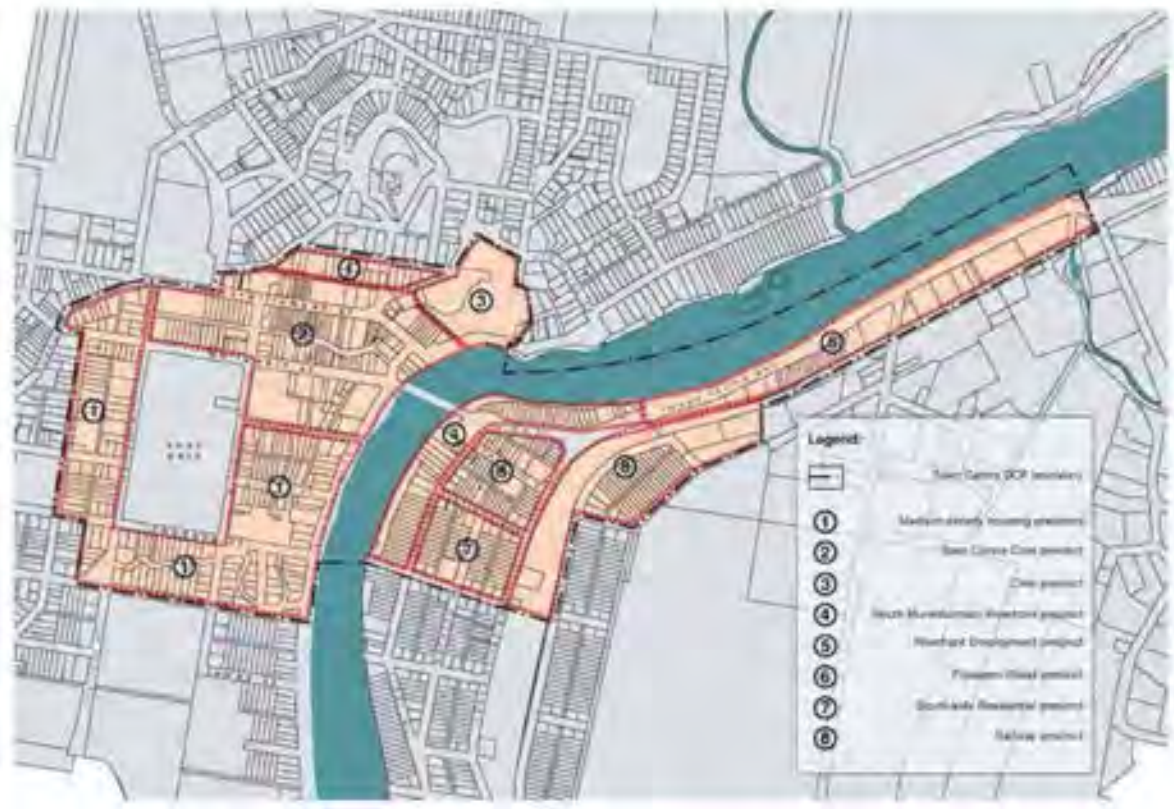


Figure 8-9 Murwillumbah Town Centre Precincts (Town DCP 2008)

Figure 8-10 Murwillumbah West Release Area Zonings (Murwillumbah Town Centre DCP)

8.4.3.2 Flood Risk

There are a number of significant flood risk issues in Murwillumbah and South Murwillumbah. The following general observations can be made for the area:

- The CBD and East Murwillumbah areas on the northern side of the river are protected by levees. South Murwillumbah is also protected by levees but to a lesser extent. Much of South Murwillumbah, located adjacent to the river, has very low immunity and is inundated in a 5 year ARI event. It is subject to very high hydraulic hazard with significant depths and velocities.
- In the existing (current climate) 100 year ARI flood, the Murwillumbah levee is overtopped but does not fill the basin around Knox Park. This results in 100 year ARI flood levels on the northern side of the river being lower than the river level (and those on the southern side). In larger events, this basin does fill due to the increase in duration and height of overtopping and water levels more closely match the river levels.
- The flood range between the PMF and 100 year ARI flood levels in the Tweed River is just over 5m. 100 year flood levels will rise about 0.3m due to the projected effects of climate change. Flood mapping of the Murwillumbah CBD show much larger changes in flood levels due to the protection afforded by the levee, and the dramatic increase in inundation depths once this levee is overtopped and levels equalise with the river.
- There are some large areas of floodway in the Murwillumbah and South Murwillumbah region, adjacent to the main rivers and in the Dunbible Creek, South Murwillumbah and Bray Park basins.
- Flood storage areas include parts of the Rous River floodplain, South Murwillumbah basin and Murwillumbah business centre.
- There are some areas of flood fringe, including around Willard Park on the northern side of Murwillumbah, and in the South Murwillumbah basin / Fernvale area.
- West Murwillumbah has a low flood risk. Evacuation is possible from most suburban areas in all flood events.
- Most of the Murwillumbah and South Murwillumbah area (like the broader study area) is subject to high depth hazard (i.e. depths exceeding 1 metre) in a 100 year ARI flood. However, depths in the main township are somewhat lower due to the presence of the town levee which provides some mitigation in this event.

South Murwillumbah Condong Flowpath

Development of South Murwillumbah adjacent to the airfield is understood to occur in conjunction with filling and it appears significant filling has occurred as part of the existing development. A major flowpath for flood waters currently exists generally along the alignment of the airfield runaway and appears to have been partially impeded by existing development at the northern end of the runway. It will be important that this flowpath is maintained and enlarged where possible as part of any future development in the area.

The hydraulic impact of future development on Lot 4, Quarry Road was investigated. This lot had been flagged by Council as a property of interest to preserve the flow path through industrial zoned land between the South Murwillumbah and Condong basins. This lot is the sole remaining

undeveloped lot between the two basins and previous investigations have shown that the South Murwillumbah basin is very sensitive to changes in floodplain hydraulics. The Valuer General's estimated land value for the parcel is $428,000 (2011).

The effects of filling this lot are:

- Low level impacts (up to 0.1m) in the South Murwillumbah basin affecting existing residential and commercial / industrial development;
- Significant localised impacts (up to 0.3m);
- No properties would be newly inundated as a result of this development but 54 houses would be inundated by up to a further 0.1m; and
- Reduction in levels in the downstream floodplain (Condong basin).

Filling Lot 4, Quarry Road generates unacceptable impacts in the South Murwillumbah basin and preservation of this flow path is required to avoid impacts on existing property. Various planning mechanisms could be used to secure a *"high flow area"* or *"floodway"* corridor through the industrially zoned land including:

1. The reservation and purchase/acquisition of a corridor; and

2. Imposition of planning controls to limit development of the land to create a corridor.

The first mechanism is preferred, subject to the necessary funding being made available to Council, as it is principally required to satisfy a public purpose (reduction of flood risks elsewhere in the floodplain). The costs of the corridor acquisition and works could potentially be apportioned through a S94 Contributions Plan for new industrial development in the precinct benefitting from the works. This option may also lead to the fastest resolution of the problem.

8.4.3.3 Cumulative Development Assessment

In 2005, the impacts of filling in the South Murwillumbah basin were assessed as part of a proposed rezoning of land for industrial purposes at Fernvale. The assessment indicated that this would result in an unacceptable increase in flood levels and risk in both Murwillumbah and South Murwillumbah. As an outcome of this assessment, the Floodplain Management Committee recommended Council oppose any rezoning of the South Murwillumbah / Fernvale floodplain involving a net decrease in the volume of flood storage. This has been revisited as part of the current study.

An updated scenario for large scale urban development in the South Murwillumbah area was assessed as part of this study. Hydraulic impact assessments were completed for this scenario based on a 100 year ARI design flood event. Where impacts were found to be unacceptable, options were tested to mitigate impacts.

The proposed development scenario, shown in Figure 8-11, includes:

- Filled industrial development around the existing Buchanan Street and Quarry Road / Lundberg Drive Estates in South Murwillumbah, either side of the Murwillumbah Airfield (minimum 100 year ARI flood immunity);
- Expansion of the Industry Central Industrial Estate in Wardrop Valley (known as "Dickinsons"); and

- A new urban release area in Fernvale.

The hydraulic impacts of the above scenario were found to be unacceptable. In particular, there were significant impacts of greater than 0.3m in the South Murwillumbah basin and in East Murwillumbah. In addition, there are impacts of up to 0.1m in the floodplain downstream to Chinderah.

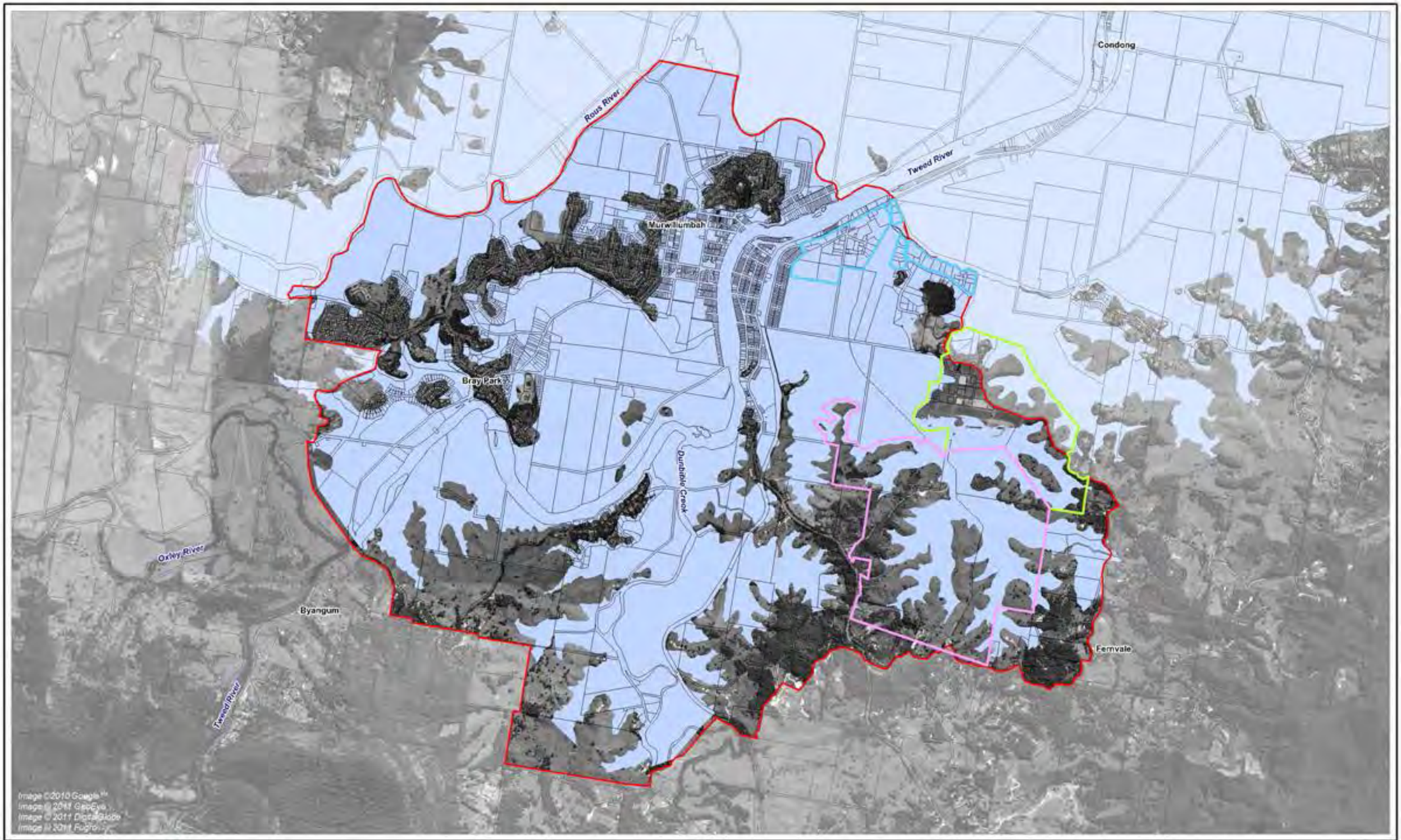
Various measures (and combinations of measures) were investigated to try to reduce the hydraulic impact of additional development in the region. Results of the investigations indicated that significant constraints existing with respect to filing in the South Murwillumbah basin. This is consistent with previous investigations and the hydraulic impact assessment of flood fringe (Section 3.2).

The following are the main hydraulic observations regarding development in the South Murwillumbah basin:

- **Loss of floodplain storage significantly impacts flood levels**, particularly within the South Murwillumbah basin, but also in sensitive adjacent areas including East Murwillumbah (across the river, controlled by levee overtopping). Loss of storage also impacts downstream levels, as far as Tumbulgum and Chinderah under some scenarios.

- **Constriction of the floodplain (or reduction in flow conveyance) is less significant** with respect to these particular developments. Limiting or removing the industrial development did not significantly affect flood levels in the basin. However, due to the sensitivity of surrounding areas such as East Murwillumbah, minor changes in flood behaviour and levels may still have significant impacts.

Summary: There are hydraulic constraints in the South Murwillumbah basin, caused primarily by loss of floodplain storage associated with filling of any areas within the basin, but also affected by constriction of the floodplain in the industrial area.



LEGEND

- Murwillumbah boundary
- South Murwillumbah Industrial
- Dickinsons
- Fernvale
- Cadastral boundaries
- Flood Prone Land

Title:

Murwillumbah Development Scenario

Figure: 8-11

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 0.75 1.5

Approx. Scale

BMT WBM
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Filepath : I:\B16879_I_BRH Tweed GJR\DRG\FRM Study\FLD_025_120531_Large Scale Urban Development Scenario.wor

8.4.3.4 Evacuation Risk

The existing evacuation capability assessment has been carried out at a sector level; refinement of the assessment will provide greater detail across sub-areas of the Murwillumbah CBD and allow the classifications to be provided for each sub-area. More refined evacuation assessments based on sub-sectors which take account of the local topography and road low points, are needed to confirm the capability of individual areas to evacuate.

The very high flood range produces additional safety risks. This is particularly the case for individuals who decide not to evacuate during a major flood and remain to 'sit out the flood' in their houses. Even large two storey houses will apparently be overwhelmed by water above the level of their roofs in a PMF event.

The results of the ECA indicate significant evacuation problems in this area. Areas both on the northern and southern sides of the river have access to adjacent high ground, but may not be able to reach the evacuation centre. Importantly access across the river is cut relatively early isolating the communities on both sides of the river.

The ERCs for infill residential development have been classified as:

- Class B in areas with rising road access;
- Class C in areas without rising road access, such as areas of the Murwillumbah CBD, but with a refuge and support facilities;
- Class D for elevated housing without rising road access or a refuge and support facilities (which include the lower lying areas away from higher ground to the west including the Prospero Street, South Murwillumbah Riverfront and the South-Side Residential Precincts).

The evacuation risks for other types of development have been classified as:

- Class B for Wardrop Valley / Fernvale urban release areas, should they include residential development, subject to provision of safe evacuation through subdivision layout and road design to adjacent high ground.

8.4.3.5 Murwillumbah and South Murwillumbah Recommendations

Recommendation 36 (strategic planning):

- Review appropriateness of increasing residential development within the Town Centre Core Precinct and the Medium Density Housing Precinct of the DCP based on a more detailed evacuation assessment, particularly in the parts of the precincts that are more distant from the higher ground to the west and may have rising road access.
- Undertake a study of stormwater and local drainage issues behind the levee to define flood immunity and examine the potential for filling of allotments to reduce flood storage and exacerbate flooding caused by local catchment runoff behind the levee.
- Any proposed increases in residential densities in the Prospero Street, South Murwillumbah Riverfront and the South-Side Residential Precincts, which have been "Deferred" in the DCP, are not supported, due to low flood immunity, very high hydraulic hazard, and unacceptable evacuation risks.
- Commercial redevelopment which reduces flood risk and hydraulic impact is supported and desirable. Where possible, strategic planning of the area should consider the incorporation of a flood flowpath.
- Wardrop Valley / Fernvale: Whilst evacuation issues would need further detailed consideration, these issues would not be a basis for ceasing further assessment. However, hydraulic constraints limit the potential to fill within the floodplain.
- Industrial development proposals in South Murwillumbah should limit filling due to hydraulic constraints.
- Critical flowpath (Lot 4, Quarry Road): Various planning mechanisms have been identified to secure the critical flowpath through the industrial zoned land.
- West Murwillumbah has a low flood risk for the full range of flood events up to the PMF.

Recommendation 37 (development controls): The following recommendations are made for review of the Tweed DCP specific to the Murwillumbah and South Murwillumbah region.

- Any further consideration of the large development options would necessitate detailed planning of evacuation routes. Any new or augmented roads identified as necessary should be shown within the DCP.
- It would be desirable, from a flood risk perspective, for the whole of the River Front precinct to form a continuous river front park (between the River and River Street as proposed in the DCP).
- Within Murwillumbah, subject to further levee overtopping and drainage studies, consider concessions to allow lower storey habitable floor levels below the current habitable floor level standard, provided other property damage mitigation measures were also included.

8.4.4 Riverside Villages

8.4.4.1 Tweed Urban and Employment Land Release Strategy

The riverside villages of Condong and Tumbulgum generally have minimal further development potential, and future development is likely to be predominantly in the form of redevelopment of existing housing. No formal planning proposals exist for the region.

This study has assessed the potential impact of developing the relatively small portion of remaining urban zoned land in Kielvale and Potential Employment Land Area 6 (within the Condong-Chinderah basin) as identified in the Tweed Urban and Employment Land Release Strategy.

8.4.4.2 Flood Risk

The riverside villages area can experience major flooding from rainfall events over the Tweed River catchment. It includes floodplain along the Tweed River as well as the Rous River, which joins the Tweed River at Tumbulgum. This area is not affected by storm surge inundation.

Condong

Some areas of Condong are predicted to be inundated in small events, including the 5 year ARI flood. In the 100 year ARI flood, most of Condong is inundated, apart from a filled "low island" residential subdivision at the northern end of town (Maria and Carmen Place, "Lizzio" Subdivision). Peak depths are up to 2 metres in low lying areas, and up to approximately 1 metre over Tweed Valley Way in the 100 year ARI flood. Most buildings are located on the higher ground along Tweed Valley Way where depths are lower. The flood range between the PMF and 100 year ARI flood levels at Condong is approximately 5 metres.

Tumbulgum

Parts of Tumbulgum are also predicted to be inundated by small flood events, including the 5 year ARI flood. At the peak of the 5 year ARI flood event, most of the town is inundated, apart from small areas of higher ground, with depths up to 1.5 metres in low lying areas. During the 100 year ARI flood event, the whole town is inundated, with depths up to 3 metres in low lying areas. Velocities through town are generally low. In events larger than the 100 year ARI flood event, Tweed Valley Way and the floodplain to the south, become floodways (with velocity-depth products above $0.3m^2/s$). The flood range between the PMF and 100 year ARI flood levels at Tumbulgum is approximately 5 metres.

8.4.4.3 Cumulative Development Assessment

The hydraulic impacts associated with the development of Kielvale and Potential Employment Land Area 6 in the Condong-Chinderah basin (in isolation) are minimal with no identified constraints. The hydraulic impacts associated with the cumulative development scenario (see Section 8.3.2) are also acceptable.

8.4.4.4 Evacuation Risk

There is currently insufficient time for evacuation of existing residents of Condong and Tumbulgum to occur in an extreme event. The provision of on-site refuges will reduce the risk to development and should be viewed as a secondary, but necessary, emergency management strategy.

The evacuation risks for Condong and Tumbulgum have been classified as:

- Class B for concessional development involving the redevelopment of existing dwellings in a manner which reduces flood risk, and with the provision of on-site refuges;
- Class C for new development on existing zoned with the provision of on-site refuges; and
- Class D for any subdivision or intensification of development due to the inability to evacuate existing residents.

8.4.4.5 Riverside Villages Recommendations

Recommendation 38 (strategic planning):

- **Condong and Tumbulgum:** No new development involving subdivision or intensification of existing development; very detailed consideration of the evacuation risks to new development on existing zoned land; and actively promote redevelopment in a more flood-safe manner.
- **Kielvale and Potential Employment Land Area 6:** Hydraulic impacts due to the cumulative filling of land and associated loss of floodplain storage were found to be acceptable.

8.4.5 Rural Development

8.4.5.1 Flood Risk

Due to the prevailing topography, the rural floodplain consists of large areas of high hazard floodway, significant flood storage areas, and limited flood fringe around the steep sided river valleys. The rural floodplain is prone to rapid inundation, even in minor flood events.

8.4.5.2 Cumulative Development Assessment

To streamline applications for future rural development, Council aimed to identify permissible development thresholds for filling / bunding of rural zoned land, below which detailed flood impact studies and modelling need not be required.

This option was identified by Council as having a lower priority than the large scale urban developments in Chinderah / West Kingscliff, South Murwillumbah and Kielvale. Development of rural zoned land was only to be considered in addition to an appropriate cumulative development scenario and not in place of higher priority urban developments.

Following identification of viable large scale urban development scenarios (described in locality-based sections above), multiple catchment wide hydraulic assessments were completed to identify an approximate proportion of rural areas that could be filled in addition to the urban development without detrimental hydraulic impacts. The rural zoned land used in the hydraulic assessment included all rural zoned flood fringe or flood storage areas, i.e. excluding floodways (VxD > 0.3 m^2/s).

As the large scale urban development scenarios were already approaching acceptable limits of hydraulic impacts, it was found that only 1% of suitable rural zoned land could be filled in addition to the urban cumulative development scenarios. Tumbulgum is the critical area affected where impacts are +0.038m. Whilst this exceeds the nominated limit of +0.035m, it has been deemed acceptable as it is expected that some permissible development will not occur. The increase of +0.003m will also not significantly change the flood impact and risk in Tumbulgum.

Ingleside
Point Danger
Tweed Heads
Coral Sea
Fingal Head
Springbrook
Glengarrie
Banora Point
Wommin Bay
Chinderah
Cudgen Headland
Kingscliff
Numinbah
Dungay
Tumbulgum
Chillingham
Condong
Murwillumbah
Bogangar
Norries Head
Byangum
Fernvale
Hastings Point
Palmvale

LEGEND

- 1% Rural Fill
- Chinderah / West Kingscliff Development
- Kielvale
- Potential Employment Land Area 6

Change in Flood Level (m)

- <-0.50
- -0.50 to -0.10
- -0.10 to -0.03
- -0.03 to 0.03
- 0.03 to 0.10
- 0.10 to 0.30
- >0.30

Title:
Impact of Cumulative Development Scenario

Figure: 8-12

Rev: A

N

0km 3 6

Approx. Scale

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8.4.5.3 Evacuation Risk

General issues associated with the development of rural dwellings and other uses on rural zoned land in the floodplain include:

- Whether to apply a design level based on the higher climate change level applied to greenfield sites; and
- The appropriateness of relying on an on-site refuge to address emergency management requirements.

The primary mechanism for addressing risk to life should be providing for safe evacuation out of the floodplain. Notwithstanding, where current planning controls provide for development of a rural dwelling and there is doubt that safe evacuation may be achievable, it would be desirable as a secondary measure to require the provisions of an on-site refuge. This is consistent with the current DCP provisions that generally apply to rural dwellings. An on-site refuge would also need to meet the criteria contained within clause 3.2.6 and the definition of a "PMF refuge" specified in the DCP.

The existing DCP provisions relating to evacuation from rural dwellings are consistent with the principles discussed previously in this report and are generally supported. However, the acceptance of an on-site refuge to satisfy evacuation requirements should be limited to where there is an existing dwelling house entitlement. Where the development proposal relates to a subdivision that would create an additional dwelling entitlement or a use not related to the residential or agricultural use of land (such as an educational establishment, child care centre, aged care facilities or the like), then the more onerous criteria of having high level vehicular or pedestrian access to a refuge outside of the PMF should apply.

While the scale of rural development is not expected to be substantial, it would normally be practical to construct a higher fill pad when constructing a new dwelling. This could also desirably provide an added level of immunity to, in part, offset the added risks associated with the isolation of rural dwellings. Accordingly, it is recommended that the DCP be amended to apply the 2100 climate change design flood level for habitable floors of new rural dwellings and an associated fill pad.

8.4.5.4 Rural Development Recommendations

Recommendation 39 (strategic planning):

- Adopt as a development control a maximum filling threshold of 1% of flood prone land area outside of floodways (VxD > 0.3 m2/s), below which cumulative development assessment is generally not required.

Recommendation 40 (development controls): The following recommendations are made for review of the Tweed DCP specific to rural development.

- The application of the 2100 climate change design flood level for habitable floors of new rural dwellings and an associated fill pad;
- Support for the existing DCP provisions relating to evacuation from rural dwellings where there is an existing dwelling house entitlement (i.e. provision of an on-site refuge as a secondary measure); and
- A requirement for high level vehicular or pedestrian access to a refuge outside of the PMF for development proposals on rural zoned land that relates to a subdivision that would create an additional dwelling entitlement or a use not related to the residential or agricultural use of land (such as an educational establishment, child care centre, aged care facilities or the like).

9 CONCLUSIONS

Many of the communities in the Tweed Valley face relatively significant flood risks. There is a considerable number of people and properties located in flood prone land, including a large number at risk in the 100 year Average Recurrence Interval (ARI) flood. Flood depths and flows are of a dangerous magnitude in many locations and flood waters can rise quickly, often with short warning periods. This can pose a high risk to personal safety and has the potential to cause extensive damage to properties and infrastructure.

Past efforts to reduce the flood risk have resulted in levees in Murwillumbah and Tweed Heads South, as well as a voluntary house purchase and house raising program. The SES has also developed an extensive Local Flood Plan, which details flood risk and evacuation procedures. However, since these flood management options were undertaken, development has intensified and there is improved understanding of flood behaviour in the area and so it is timely to review options to manage flood risk.

Most major flood mitigation works considered feasible in the Tweed Valley have been constructed over the past few decades. The option to raise and / or extend the Tweed Heads South levee was investigated and recommended to reduce flood damages and improve evacuation capability in the area. Other engineering works including flood mitigation dams, floodways, dredging, other levee works, and development of a new river mouth or flood relief outlet were revisited, but none were identified as being both effective and viable.

To address the significant emergency response and evacuation issues, a range of recommendations have been made for flood awareness, flood intelligence, the flood warning system and evacuation planning. Recommendations for voluntary house purchase and raising schemes have also been made with the benefit of more detailed flood hazard information and floor level survey of the whole floodplain.

Outcomes from this study can be used to inform updates of Council's climate change adaptation plan that has been undertaken to manage this future risk to existing people and property. A wide-ranging review of strategic planning directions and development controls has also been undertaken to ensure future development is both appropriately planned and designed for existing and future flood risk.

Consultation was undertaken throughout the study with the Floodplain Management Committee, technical sub-committee, stakeholders and the community. Many of the most regularly raised concerns related to insurance, land values, stormwater flooding, historical flood risk, climate change and PMF scenarios, which were not directly related to the work undertaken as part of the Floodplain Risk Management Study. However, a Frequently Asked Questions brochure has been prepared, which should assist in addressing the most common queries, including those relevant to or beyond the scope of the study.

This document is accompanied by a draft Floodplain Risk Management Plan (FRMP) presenting the recommended floodplain risk management measures for the Tweed Valley floodplain from this report. The recommended measures have been selected from the range of measures considered, taking into account each measure's impact on flood risk, as well as consideration of environmental, social and economic factors.

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APPENDIX A: FREQUENTLY ASKED QUESTIONS

Frequently Asked Questions

Draft Tweed Valley Floodplain Risk Management Study & Plan

The Draft Tweed Valley Floodplain Risk Management Study and Plan was placed on exhibition in July / August 2012 and February / March 2014 for public comment. The Study reviewed flood risk in the Tweed Valley, including risks to people and other potential impacts of flooding, and assessed a wide range of options to reduce and manage these risks. The Plan outlined the recommendations of the Study and a prioritised plan to implement these.

The Floodplain Management Committee reviewed the submissions and feedback, some additional investigations have been undertaken, and the Final Tweed Valley Floodplain Risk Management Study and Plan is now being prepared.

The following information has been collated in response to some of the frequently asked questions that arose during the study and consultation process.

Contact
Danny Rose
Planning and Infrastructure Engineer
02 6670 2476
drose@tweed.nsw.gov.au

Did the study consider the 1954 flood?

What is the Probable Maximum Flood (PMF) and why is it used?

How has flood mapping affected property values?

How has flood mapping affected insurance?

Why doesn't the study include stormwater or flash flooding?

How were the floodplain management options selected?

Will raising the Tweed Heads South levee worsen flooding in some areas?

How does the SES plan for flood events?

Who issues flood warnings and evacuation orders?

How has climate change been considered?

Will new development worsen flooding?

How was the community consulted?

What happens next?

Frequently Asked Questions

Draft Tweed Valley Floodplain Risk Management Study & Plan

Did the study consider the 1954 flood?

The preceding Tweed Valley Flood Study did consider the 1954 flood, however there was insufficient data (e.g. on the state of floodplain development or hourly rainfalls) to use it reliably in the development of a numerical flood model. Instead other more recent historical floods such as the 1974 event were used to check how well the model was able to replicate flood behaviour.

Whilst historical floods provide useful information about local flood behaviour, these events don't necessarily represent future floods which can behave differently due to different catchment and floodplain conditions, and different weather patterns (e.g. the peak and extent may be more or less, the onset of inundation may be faster or slower, the duration of inundation maybe longer or shorter etc). The flood model allows prediction of future floods based on parameters determined from historical floods.

What is the Probable Maximum Flood (PMF) and why is it used?

The PMF is the worst case scenario for flooding and is used for emergency response planning and specialised land use planning such as the siting of critical infrastructure (e.g. hospitals). Most other planning decisions are based on the 100 year Average Recurrence Interval (ARI) flood and an allowance for uncertainty and the potential effects of climate change.

The PMF is a theoretical flood resulting from the largest rainfall that could possibly occur within the catchment, and therefore is extremely rare and unlikely. It is also used to determine which areas are potentially flood prone (in the floodplain) and which areas are flood free (only land outside the PMF extent is truly 'flood free').

How has flood mapping affected property values?

Reviews of the effect of flood risk disclosure show that most international and domestic studies found no change in residential property values, and that property values are more likely to be affected by actual flooding than flood mapping. Flood mapping has been available for the Tweed Valley since 2005 and is not new to this study.

Council is not in a position to estimate whether this flood mapping has had any effect on property values in Tweed Valley as they are subject to a range of market factors. Irrespective of this, Council has a duty of care to advise property owners, occupiers and developers on the extent and level of flooding as outlined in the floodplain management process set out by the State Government.

How has flood mapping affected insurance?

Council is aware that insurance premiums have risen in recent years and is actively engaging with the Insurance Council of Australia (ICA) through the NSW Floodplain Management Association to raise issues highlighted by members of the Tweed community. Through this engagement, Council understands that flood insurance is a

relatively new product for the insurance industry and premium increases have not been limited to the Tweed Valley. The inclusion of flood insurance in home and contents policies accounts for some, but not all, of the recent increases in premiums. Other factors include reinsurance costs (which is impacted by global events), profit margins, and government taxes.

Flood mapping has been available for the Tweed Valley since 2005 and is not new to this study. However, some residents have highlighted recent instances where insurance companies may be incorrectly interpreting flood mapping. Council has been proactive in this area by dealing directly with the ICA, individual insurance companies, and individual community members who have queries relating to their flood liability and require information to pass on to insurers. Projects such as the compilation of a national flood study database and standardisation of flooding definitions and mapping will help inform insurers as they continue to develop their understanding of, and pricing of flood insurance. In the absence of flood mapping, insurers will tend to quote higher premiums to cover unknown risk.

Council's discussions with the insurance industry have emphasised the need for flood insurance premiums to reflect the true risk of floods occurring at a property. Properties that are located above the 100 year ARI flood level but below the PMF event are at the low end of the risk profile and premiums should be priced accordingly. Pricing is however a matter for each insurance company to determine based on a variety of factors.

Why doesn't the study include stormwater or flash flooding?

Flooding can happen by a number of processes: high tides and elevated ocean levels can inundate coastal areas, prolonged rain over the catchment can cause the Tweed River to overtop its banks, intense localised rain can cause small creeks to rise very quickly (referred to as flash flooding) and inundation can also occur when the capacity of stormwater infrastructure is exceeded. Some or all of these types of flooding can occur during the same weather event, however they require different (though compatible) approaches to manage flood risk.

The focus of the Tweed Valley Floodplain Risk Management Study was ocean and Tweed River (or catchment) flooding only. However, it is recognised that flash flooding and stormwater flooding are also significant risks in the Tweed Valley and will be addressed in subsequent studies. Flood studies to date have been conducted at a regional scale, and have only included major trunk drainage infrastructure, not individual stormwater drains in each street.

One of the recommendations of this study is the commissioning of local drainage flood studies which will improve Council's understanding of stormwater flooding, especially in known hotspots such as Murwillumbah, Banora Point, Tweed Heads South and

Chinderah. This will enable Council to develop a similar plan for the future management and upgrade of stormwater infrastructure and drainage, including behind levees.

How were the floodplain management options selected?

A Floodplain Management Committee was formed at the beginning of the study, made up of representatives from Council, the State Emergency Service, the Office of Environment and Heritage (State Government), elected community representatives and the floodplain management consultants (BMT WBM). The Committee undertook a preliminary review of all flood management options and identified management measures which would be investigated in more detail during the study.

A key objective of the study was to identify opportunities to minimise flood risk to the community, property and infrastructure now and into the future. In a catchment as large and diverse as the Tweed River, there are many floodplain management options to consider, including structural measures, land use and development planning for areas at risk, and options for emergency response planning. However, not all measures are feasible, on economic, environmental and / or social grounds.

The Committee decided some preliminary options were not feasible and / or did not justify further investigation. These options included the construction of flood mitigation dams (such as on Byrill Creek), retarding basins, and channel modifications (such as dredging, or a Fingal Head causeway or outlet). During the community consultation period in August 2012, a number of queries were made about these types of structural measures. As a result, the Committee reconsidered whether any of these options justified more detailed investigation.

Will raising the Tweed Heads South levee worsen flooding in some areas?

Raising the levee will not worsen flood levels elsewhere in the catchment. The area behind the levee is primarily at risk of inundation from ocean storm surge and does not currently experience significant flooding from the Tweed River catchment due to the terrain and presence of the existing levee. The flood model was used to investigate whether raising the levee would affect flood levels and found that levels remain generally unchanged. The levee raising measure also includes new drainage infrastructure and pumps to drain local stormwater from behind the levee.

This is the main structural measures recommended in the Floodplain Risk Management Plan. At present, the levee protects the Tweed Heads South area from small floods (less than a 20 year ARI flood) but would be overtopped in larger floods. The study assessed the feasibility of raising the levee high enough to protect residents and properties from a 100 year ARI flood.

How does the SES plan for flood events?

The State Emergency Service (SES) records their evacuation strategies and flood risk

information in the Local Flood Plan, which is a sub-plan of the Tweed Shire Disaster Plan (DISPLAN). The Local Flood Plan describes the process that the SES will follow in the event of a flood, including the logistics of warning and evacuating communities throughout the Tweed Valley. Local knowledge, information about past flood events and recommendations from studies, such as the Tweed Valley Floodplain Risk Management Study, are all used to develop the Local Flood Plan.

In conjunction with the Local Flood Plan, the SES conducts a range of education and awareness campaigns throughout the year, with a stronger push leading up to the storm season. The SES has helped many businesses and individuals develop personal flood plans and better prepare themselves for future evacuations. Recognising that flood risk doesn't stop at state borders, the Richmond Tweed SES has developed a Cross-Border Plan with Gold Coast City Local Disaster Management Group to improve coordination of emergency response between Tweed Heads and the Gold Coast.

Who issues flood warnings and evacuation orders?

If heavy rainfall and flooding is predicted, the Bureau of Meteorology (BoM) issues a Flood Watch, which is upgraded to a Flood Warning if river levels are expected to go above predefined threshold levels. Flood warnings are published online as well as being provided directly to other government authorities (including the SES and Council) and broadcasters (including ABC North Coast). Flood warnings issued by the BoM don't translate predicted flood levels to risk on the ground, and as such are not used in isolation to trigger an evacuation.

The Richmond Tweed (regional) SES closely monitor local weather and will start to prepare a response if they believe flooding may occur. When a flood warning is issued by the BoM, the Tweed Shire (local) SES translates predictions of flood height into consequences, such as flooding of certain areas or roads which might become cut. The SES then provides bulletins to the media and public about the predicted flooding. If the predicted flooding may result in the need to evacuate, the Richmond Tweed SES issues an evacuation warning, which is upgraded to an evacuation order if evacuation is considered necessary.

How has climate change been considered?

Council aims to balance the economic cost of planning for climate change now, with protection of people and property in the future, via two mechanisms of planning controls for future development and a Climate Change Adaptation Action Plan already developed by Tweed Shire Council in conjunction with Byron Shire Council. Outcomes from the Tweed Valley Floodplain Risk Management Study will be used to review and update these measures.

Council has adopted a climate change projection which allows for a 10% increase in 100 year ARI rainfall intensity and 91cm increase in 100 year ARI sea level by 2100. These

adopted benchmarks are based on State Government advice released in 2007, and consistent with the subsequent NSW Sea Level Rise Policy (2009), applicable at the time of the preceding 2009 Tweed Valley Flood Study. While the State Government has since abandoned the Sea Level Rise Policy and no longer recommends statewide sea level rise benchmarks, it still requires Councils to determine local future hazards, and include consideration of potential sea level rise and climate change impacts in its flood studies and risk management studies, based on the best available data. Accordingly, Council has maintained its adopted climate change benchmarks until further authoritative advice is released, such as the 5th Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC). Council does not possess the required expertise to use and analyse the outputs of complex climactic models to set its own benchmarks in the meantime. Climate change projections do not relate to the PMF, and insurance is based on existing risk, not projected future risks such as climate change affected flood levels.

Will new development worsen flooding?

To ensure new development does not worsen flooding, Council requires a hydraulic assessment of any development that may impact flooding by a suitably qualified engineer. This typically involves the use of the flood model to demonstrate that the proposed development itself is not subject to unacceptable flood risk, and that it does not worsen the flood risk in surrounding areas, prior to being granted development approval.

Much of the Tweed River catchment is in the floodplain but is only likely to be flooded on rare occasions. For these areas, Council aims to encourage suitable development while ensuring that the new development isn't at serious risk of flooding and won't worsen flooding elsewhere in the catchment as a result of its construction.

Council have a detailed land use plan and associated development controls which outline where development can occur, as well as regulating certain features of the development (such as the type or size of development). During the study, a review of Council's planning mechanisms was undertaken using latest information about flooding. Development will not be permitted in areas of the catchment which have an extremely high flood risk, whereas areas which are known to be flood free do not have flood related planning controls.

How was the community consulted?

Council sought input from the community, community representatives and stakeholders throughout the study to help identify flooding problems in the catchment, potential floodplain management options and to determine whether recommended options will be acceptable to the community.

To support the decision making process, Council also sought input from a wide range of community and business groups at the start of the study. Feedback from these groups helped select and shape the management options tested during the study. The

Frequently Asked Questions

Draft Tweed Valley Floodplain Risk Management Study & Plan

Floodplain Management Committee, which includes a number of community representatives, was involved throughout the life of the study, reviewing various stages and providing valuable input to the decision making process. Towards the end of the study, the broader community was invited to view the draft Study and Plan and comment on these documents during the exhibition period (19th July to 30th August 2012). Drop-in consultation sessions were also held at the Murwillumbah Civic Centre and Tweed Civic Centre on 13th and 14th August 2012. The exhibition period and consultation sessions were publicised via Council's website and Tweed Link newsletter.

Council made note of all discussion points and questions made during the session. Feedback from the community was reported back to the Floodplain Management Committee, who updated the Study and Plan to reflect the comments. Significant issues raised during community consultation were considered and, if decided to be necessary, studied in greater detail before finalising the Study and Plan. The updated Study and Plan including amendments made in response to the submissions and feedback received during the initial exhibition period were then re-exhibited from 12th February to 12th March 2014.

What happens next?

The main outcome of the study is the Floodplain Risk Management Plan – a roadmap for Council and other agencies (such as the SES) to implement the recommendations of the study. The Plan prioritises recommendations from the Study, provides a preliminary cost estimate and details the steps required to implement the recommendations.

Some of the recommendations, such as updating the Local Flood Plan, can be undertaken straight away, while other recommendations, such as raising the Tweed Heads South levee, will require more detailed investigation. For recommendations which require a major investment, Council will apply for funding through the NSW State Government's Floodplain Management Program.

APPENDIX B: INFORMATION, DATA, METHODOLOGY

This section provides an overview of the key assessments used in the study, in particular hydraulic impact, evacuation capability, flood damages, cost benefit and planning assessments.

B.1 Hydraulic Impact Assessment

Hydraulic impact assessments are a standard approach to quantifying changes in flood behaviour as a result of potential changes in the floodplain (including impacts on depth, velocity, duration of inundation). This includes assessment of floodplain management options to reduce existing risk (such as structural measures like levees designed to mitigate the extent, depth or timing of inundation) as well as potential changes in future risks (as a result of future development, climate change or both).

Existing flood behaviour is as defined by the flood model derived during the Flood Study which represents existing floodplain conditions. As part of this study, the model has been used to simulate potential changes in the floodplain to determine the hydraulic impact (positive or negative) for various scenarios.

For management options requiring cost benefit assessment, the full range of flood event magnitudes are modelled (from the 5 year ARI flood to the PMF) to quantify the reduction in damages for a range of event probabilities. Future development and climate scenarios have generally been modelled for the 100 year ARI flood, which is typically accepted as the minimum design flood level for most types of development.

For each scenario assessed, maps have been provided in the discussion papers, showing the key hydraulic impacts. In general, the key consideration is change in peak 100 year ARI flood level, however in some cases the change in the onset or duration of inundation is also a key consideration. The results of the hydraulic impact assessment have also been utilised to more specifically detail impacts on existing property (such as changes in internal or external inundation).

B.2 Evacuation Capability Assessment

An evacuation capability assessment has been undertaken to identify areas where there is a risk of insufficient time and / or resources available to complete a full evacuation. These assessments help identify suitable options for reducing that risk and maximising the safety of the community.

B.2.1 Context

The purpose of an evacuation capability assessment is to describe the current evacuation capability of the region as well as determine the benefit of potential floodplain management measures and / or impacts of future floodplain development. It is not a detailed evacuation plan, although much of the information and output can be used to inform response planning.

Evacuation capability based on current emergency response plans has been assessed using information on flood behaviour from the flood model, together with estimates of flood prediction time, human behavioural factors (such as whether to follow evacuation orders and when) and route vehicle capacities.

It is recognised that all of these aspects (flood behaviour, community response and traffic) are difficult to predict and introduce a high level of uncertainty in the estimations of a community's evacuation capability. Nonetheless, the assessment forms a vital part of the flood risk management process and should not be avoided due to uncertainties and the risk of error. The flood intelligence contained in this study is considered sufficient to identify constraints in the current evacuation capability, highlight the need for action and provide guidance on future evacuation decisions.

B.2.2 'Timeline' Approach

The assessment is based on a 'timeline' approach developed by the NSW SES (Opper, 2004 and 2009) which utilises timeline project management to determine the estimated timeframes of various elements during an evacuation procedure. The total available time for evacuation is marked along a timeline; the timeline commences when the storm commences and ends when evacuation is no longer possible due to road closures, or when everyone is safely evacuated. Between these times, a number of key evacuation processes must occur in sequence. Mapping these on a timeline can highlight a number of important features of the process, including:

- What processes must be completed during evacuation;
- How much time is available to safely complete evacuation; and
- What is the latest time evacuation can safely commence.

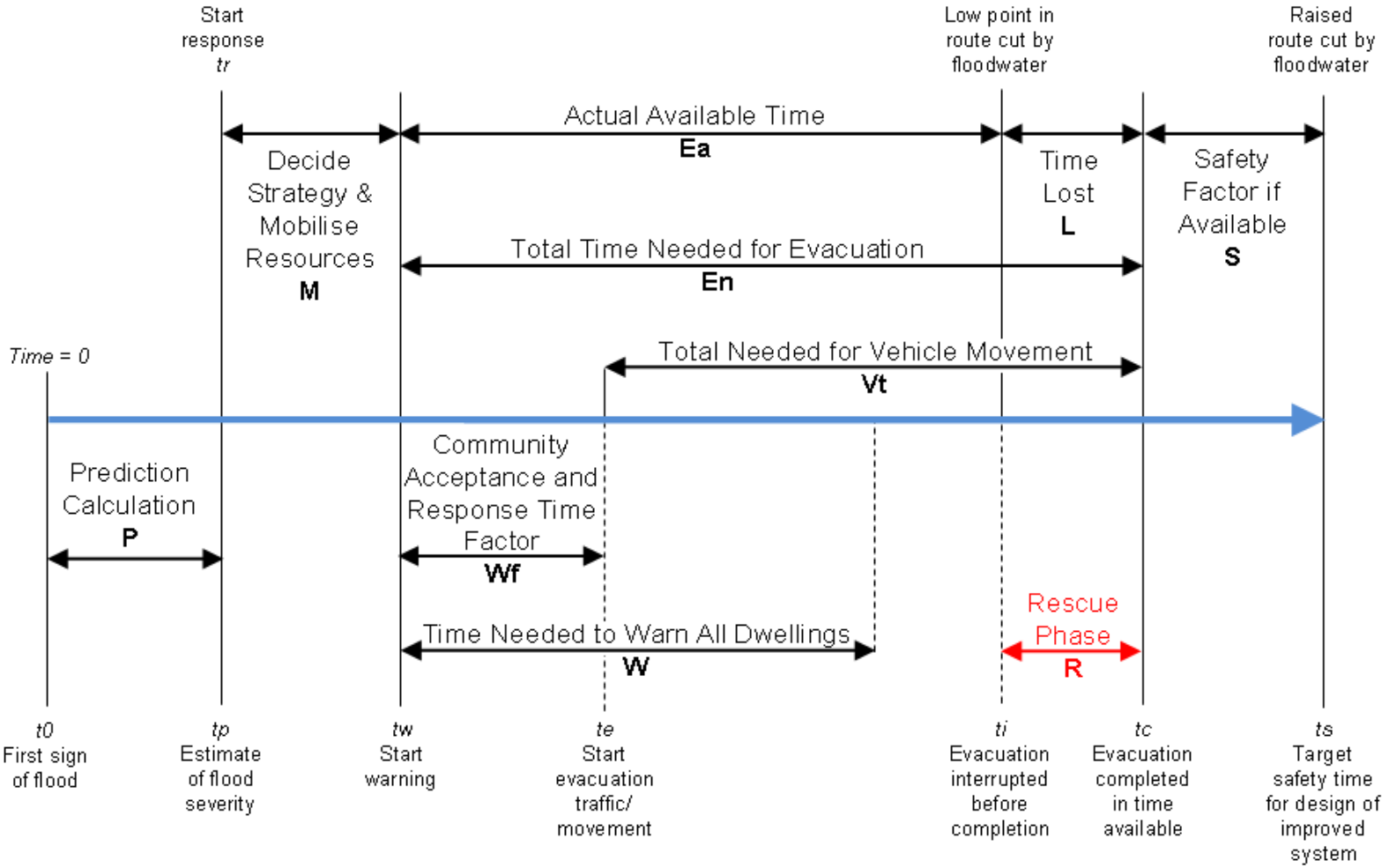
An example timeline is shown in Figure B-1 with Table B-1 describing the key components in the evacuation process.

B.2.3 Application

Existing evacuation capability has been assessed based on current plans for emergency response and evacuation as outlined in the SES's Flood Emergency Sub Plan, including the sectors, routes and evacuation centres outlined in the plan that have been assessed in this study. The assessment has been undertaken in consultation with local, regional and state SES representatives.

The key objective of the SES during a flood evacuation is to maximise the numbers of at-risk residents safely evacuated prior to road closure, and minimise the likelihood of people requiring rescue. To achieve this, the SES aim to manage the warning process so that evacuation routes are at maximum capacity throughout the process. Critical roads were identified in the sectors which act as 'bottlenecks'. For most single lane routes, these are the roads immediately leading to an evacuation centre. The rate of warning (in this case door knocking) is planned to match the road capacity. Slower warning and the roads will be below capacity, increasing the risk of incomplete evacuation. Faster warnings and resources (such as door knocking teams) are wasted.

Table B-1 summarises the application of the timeline approach to evacuation capability assessments of the Tweed Valley evacuation sectors.



Note: S will be negative value (safety factor <0) when *ti* occurs earlier than *tc*. S will be zero when all available time needed (En) is used. Only when *ti* occurs after *tc* does a Safety Factor begin to accrue. The magnitude of S has to be determined by reference to the capacity to cope with uncertainty and interruptions. The time elements are not drawn to scale in this diagram,

Source: (Opper *et al*, 2009)

Figure B-1 Flood Evacuation Timeline Schematic

Table B-1 Summary of Timeline Approach

Component	Description	Application
Prediction	BoM assessment of recorded rainfall and gauge levels and estimation of flood severity.	Flood prediction timeframe based on actual rainfall (not taking into account predicted rainfall) which is conservative for the purposes of evacuation planning (and minimises likelihood of unnecessary evacuation). BoM have indicated that based on the design 100 year ARI and PMF rainfalls, major flood levels would be predicted at Murwillumbah and Chinderah approximately **9 hours** from the start of event.
Resource mobilisation	SES assessment of the severity and likelihood of a flood event (also based on the information provided by BoM during prediction), formulation of a response strategy and mobilisation of resources.	Allow minimum duration of **6 hours**.
Warning	SES warning of all 'at risk' dwellings to evacuate, currently undertaken via door knocking. Also includes time for 'community acceptance and response' to allow for people to process and accept the warning instructions and organise themselves prior to evacuating.	Rate of warning (door knocking) planned to match road capacity. Duration therefore dependent on Evacuation component below. Numbers of door knocking teams (generally 2 people per team) based on field testing estimates that a team can warn approximately 12 houses per hour.
Evacuation	Full evacuation of all people using cars as the primary means of transport. Also includes a traffic safety factor to allow for traffic incidents.	Duration dependent on the number of vehicles within each sector evacuating at maximum road capacity (nominally 600 vehicles per lane per hour, which makes some allowance for adverse weather conditions).
Safety factor / Rescue phase	Safety factor indicates how much time is left (if any) after completion of evacuation until the route is inundated. Rescue phase indicates the shortfall in time available (if any) based on early inundation of the route prior to completion of evacuation.	Safety factor indicates that safe evacuation of the sector is possible. The safety factor allows for uncertainty / unforeseen events in the process, and does not necessarily mean that evacuation can be delayed. If any of the routes close before evacuation of the sector is complete, the sector may require a 'rescue' phase. It is an indication of how much additional time is required to complete evacuation, not how long rescue may take (which will depend on various factors such as method of rescue and resources). Note that rescue may not be necessary if evacuation can be managed on a local (i.e. sub-sector) level (e.g. through the re-direction and / or prioritisation of areas) despite earlier inundation of a route.

B.2.4 Other Issues

The evacuation capability assessment has been used to estimate the ability to evacuate the general floodplain community in a regional flood event based on existing emergency response plans. There are some additional issues that cannot easily be quantified as part of a catchment scale assessment, but that have been identified and included where possible for consideration in the assessment of evacuation issues and management.

- **Local flooding of evacuation routes.** Local flooding, caused by stormwater or flash flooding, may coincide and exacerbate a regional flood event. Where there is anecdotal or other information to indicate key evacuation routes are at risk of local flooding, these have been noted in the assessment and included in the mapping. If the routes are critical for regional evacuation, separate studies have been recommended to investigate and address local flooding issues.
- **Community vulnerability.** Known vulnerable communities have been identified for specific consideration in emergency response plans. These communities may need evacuation resources and assistance surplus to broader community requirements. Vulnerable populations include high proportions of over 65s, people requiring assistance with everyday tasks, caravan parks, nursing homes, hospitals and schools.

B.2.5 Data

The assessment of evacuation capability required the following data:

- **Flood data** was obtained from the Tweed Valley flood model including information on flood extent (the evacuation area), time of inundation of evacuation routes and immunity of evacuation centres. The PMF was the focus of the assessment, however less extreme events were also considered (the 20 and 100 year ARI).
- **Demographic data** was sourced from census and property survey to inform estimates of affected population, dwellings and vehicles requiring evacuation.

B.2.6 Outputs

The primary output of the assessments is an estimate of whether each sector can be safely evacuated in a PMF (and other, less extreme events) based on current response plans and evacuation routes. In addition to this key output, the assessment also provides information on:

- The geographical extent of evacuation required;
- The number of houses affected and, correspondingly, the number of residents and vehicles requiring evacuation;
- Trouble spots and key areas, including low-islands and high-island isolated areas;
- At-risk communities, such as caravan park residents and older demographics;
- Constraints to the evacuation process, such as early cutting of key routes, or insufficient warning/ prediction time; and
- Emergency response resource requirements, including evacuation centre capacities and door knocking teams.

In addition to an assessment of the current capability, the outputs can be used to identify options to reduce risk, particularly in sectors where there may be insufficient time to safely evacuate everyone. Alternatively, where future development within the floodplain is proposed, recommendations can be made for the management of the additional evacuation requirements. It is noted that in areas where there is an existing safety factor, the Floodplain Management Committee, in representing the community, would need to decide what to accept in terms of balancing future development with an increase in evacuation risk (i.e. reduction in safety factor) to the existing residents.

B.3 Flood Damages Assessment

A flood damages assessment has been undertaken to identify and, where possible, estimate the cost of damages associated with the risks of flooding. The main objective of the flood damages assessment is to establish the 'baseline' economic costs of flooding (i.e. based on current conditions) which can then be used to help quantify the benefits of potential mitigation measures.

It is important to note that the assessment of flood damages is never referred to as the *calculation* of flood damages, but rather the *estimation* of flood damages. The distinction is important. Estimating flood damages is not an exact science as methodologies and data used in the valuation process vary. Certain assumptions within the process can have a noticeable impact on damage estimations.

B.3.1 Types of Flood Damages

Flood damages can be classified as tangible or intangible, depending on whether costs can be assigned monetary values. **Intangible damages** arise from adverse social and environmental effects caused by flooding, including factors such as loss of life and limb, stress and anxiety. **Tangible damages** are monetary losses directly attributable to flooding. The flood damages assessment estimates tangible damages to provide information on the economic impact of flooding and potential management measures. Intangible impacts by their nature can not generally be quantified in the flood damages assessment; however they are considered throughout the study, alongside the economic impacts, in terms of identifying key risks and weighing up the costs and benefits of various management options.

Tangible damages comprise both direct and indirect flood damages. **Direct damages** result from the actions of floodwaters, inundation and flow, on property and structures. **Indirect damages** arise from the disruptions to physical and economic activities caused by flooding. Examples include losses due to the disruption of business, expenses of alternative accommodation, disruption of public services, emergency relief aid and clean-up costs.

Direct damages are typically estimated separately for urban, rural and infrastructure damages. **Rural damages** have not been estimated or included in the damage totals here, as the scope of this study does not include assessing measures for mitigating rural losses. The assessment therefore is focussed on quantifying estimates of **urban damages** together with preliminary estimates of **infrastructure damages**. Urban damages are typically further separated into damage to residential and commercial / industrial properties, and internal, external and structural components.

Figure B-2 depicts the different classifications of flood damages.

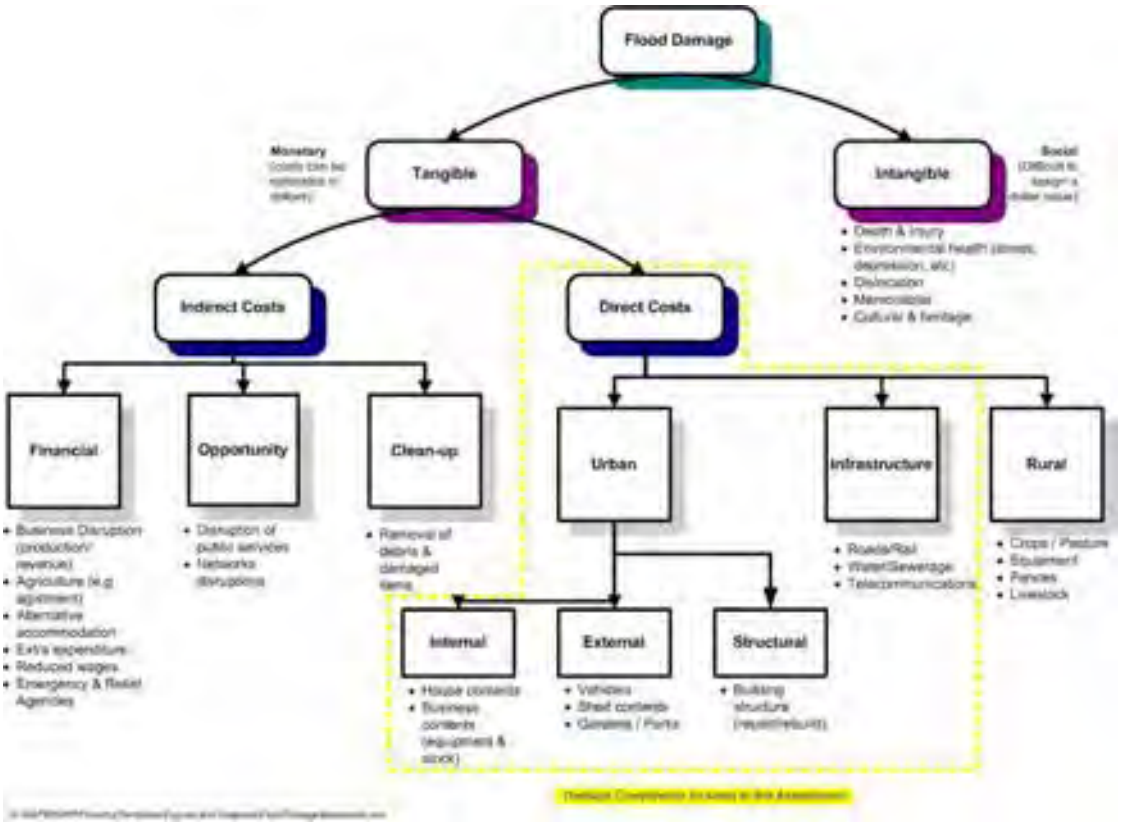


Figure B-2 Types of Flood Damages

B.3.2 Methodology

There are a range of industry-standard approaches for estimating the cost of the different types of flood damages described previously. **Stage-damage curves** are typically used to estimate internal damage sustained based on the depth of flooding through the property. These curves are estimated relationships between damage and depth generally derived from loss adjustor surveys which vary for different types of property and contents. An example of a stage-damage curve and how it is used in the estimation of damages is shown in Figure B-3. External, structural, infrastructure and indirect damages are generally estimated using other approaches.

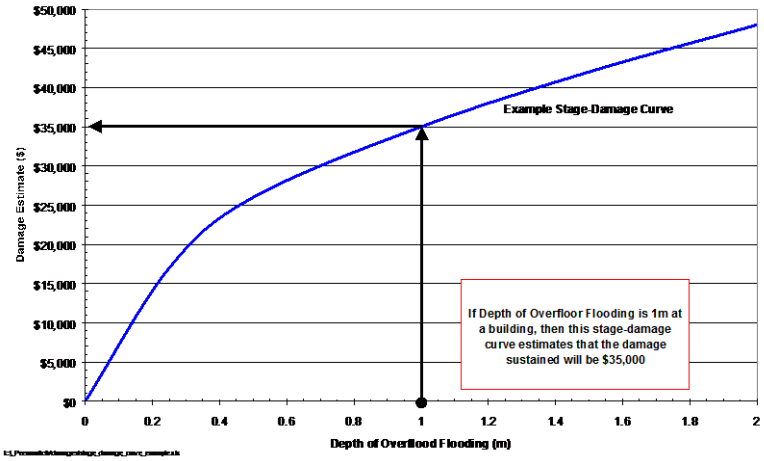


Figure B-3 Example of Stage-Damage Curve

The following is an overview of the methodology adopted for the Tweed Valley flood damages assessments. This is also summarised in Table B-2.

- **Residential damages** are based on *Floodplain Risk Management Guideline: Residential Flood Damages* (DECC, 2007b). This utilises stage-damage curves for three typical dwelling types; low set, high set and double storey. The curves include external and indirect damages. It does not however include multi-unit dwellings or vehicles. Units have been directly multiplied by number of units per storey. Vehicles have been excluded as they are often moved to higher ground, and also to ensure vehicle damage does not drive justification for mitigation works.
- **Commercial damages** are based on *Guidance on the Assessment of Tangible Flood Damages* (NRM, 2002). This utilises a set of stage-damage curves for different types of businesses based on size and contents value. For simplicity, commercial and industrial properties and damages are referred to in this study as *commercial*, but in all cases refer to both. Indirect damage to commercial property can be substantial due to loss of production / revenue etc, for which the guidance suggests an estimate of 55% of direct damages. External damage has been excluded with the majority of damage typically expected to be allowed for when assigning appropriate contents value.
- **Structural damage** to buildings was assumed for properties where the velocity-depth product exceeded 1 m^2/s, the depth above floor exceeded 2 metres, or the velocity exceeded 2 m/s. Following a sensitivity analysis, the technical committee decided to assign a nominal value of $20,000 per property.
- **Infrastructure damages** are difficult to quantify without an extensive valuation and assessment of each of the individual infrastructure at risk. Instead, infrastructure damages have been approximated as 15% of direct urban damages.

Table B-2 Summary of Flood Damages Assessment Approach

TANGIBLE	**DIRECT ►**	**Urban►**	**Internal►**	Commercial►	NRM Stage-Damage Curves
				Residential►	DECC Stage-Damage Curves
			External►	Commercial►	Not explicitly included
				Residential►	DECC Stage-Damage Curves
			Structural►	$20,000 per property based on high depth / velocity criteria	
		Infrastructure►	15% of direct urban damages (DECC)		
		Rural ►	Not included in this assessment		
	INDIRECT►	**Commercial►**	55% of Direct Damages (NRM)		
		Residential►	DECC Stage-Damage Curves		

B.3.3 Data

The assessment of flood damages required the following data:

- **Flood data** was obtained from the Tweed Valley flood model for a range of event magnitudes from the 5 year ARI to the PMF. This included estimates of peak flood levels at each property to inform estimates of internal damages, as well as peak depth, velocity and velocity-depth product (required to estimate structural damages).
- **Property data** from the property survey including location, floor level and other building information (e.g. type, size etc) was used to select appropriate stage-damage curves and above-floor depths for estimation of internal damages.
- **Ground level data** was derived from the DEM developed for the Tweed Valley Flood Study Update and used to estimate external inundation and damages.

B.3.4 Outputs

Using the above data and methodology, flood damages were estimated for a range of event magnitudes. Estimates have been reported in the study for the area as a whole, as well as a breakdown by census zone to provide more detail.

This range of event estimates were then used to calculate the **Average Annual Damage**, or **AAD**, which represents the estimated economic cost of flooding on average each year. AAD takes into account both the likelihood and consequence of flooding, from events such as a 5 year ARI that may cause millions of dollars damage, to extremely rare and unlikely events where damage may be in the billions of dollars.

AAD is calculated by combining estimated damages for each magnitude event with probability, and represents the area under the curve, as per the example shown in Figure B-4. The reduction in damages in individual events (and thus AAD) due to a particular mitigation option then represents the tangible, economic benefit of that option. This benefit can then be used to inform a cost-benefit assessment for the option.

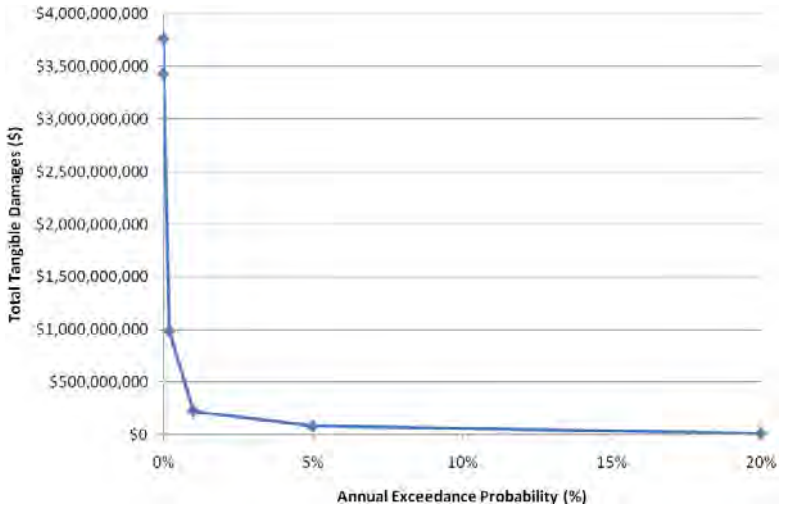


Figure B-4 Average Annual Damage Curve

B.4 Cost Benefit Assessment

The flood damages assessment and AAD described above provides an estimate of the current financial cost of flooding in the study area. This can be used in a cost benefit assessment to determine the relative merits of different options identified to reduce flood damage, and inform selection and prioritisation of preferred measures.

The general procedure for undertaking a cost benefit assessment is as follows:

- **Estimate average annual benefit** associated with the measure, based on the reduction in annual average damages from a flood damages assessment;
- **Estimate total benefit** by multiplying by the present worth factor (see below);
- **Estimate total cost** of the measure; and
- **Calculate monetary benefit-cost ratio** (BCR) as a factor of the total benefit to total cost:

The **present worth factor** is a standard economic approach to quantify future benefits in today's dollars. The adopted present worth factor is 13.8 over a 50 year period (i.e. the annual average benefit is converted to total benefit by multiplying by 13.8).

Monetary BCRs are used to evaluate the economic potential for the measure to be undertaken. A BCR greater than 1 indicates that the monetary benefits outweigh the costs, while a ratio less than 1 indicates that the costs outweigh the benefits. It is important to reiterate however that economics and financial viability is only one criteria for consideration in respect to the value of a measure. As mentioned previously, other issues such as social and psychological impacts, although difficult to quantify, must be taken into account in the complete assessment.

B.5 Planning Assessment

B.5.1 Consideration of Topography

The shape of the land form (i.e. its topography), has a significant influence on the manner in which flood waters inundate the landscape and the ability of its occupants to evacuate. In the emergency management context, this influences the formation of 'islands' during a flood or in other ways restricts access to/from different areas of the floodplain. People, animals and equipment can become isolated on such islands and if flood waters continue to rise and they are not rescued, drowning and loss may occur if the island is overtopped. There are a variety of different land forms that can influence emergency management considerations. The classifications presented in the Floodplain Risk Management Guideline (DECC, 2007) are reproduced below.

- **Flood islands:** These are areas of high ground within the floodplain linked to the flood free valley sides by road access across the floodplain and with no alternative overland access. The road can be cut by flood water, closing the evacuation route and creating an island. After closure of the road the only access to the area is by boat or by aircraft. Flood islands are classified according to what can happen after the evacuation route is cut as follows:
  - **Low flood islands (LFI):** These islands are lower than the limit of flooding (i.e. above the PMF) or do not have enough land above the limit of flooding to cope with the number of people in the area. During a flood event the area is isolated by floodwaters and property will

be inundated. If flood water continues to rise, the island will eventually be covered. People left stranded on the island may drown and property will be inundated. Evacuation will have to take place before isolation occurs.

- **High flood islands (HFI):** These flood islands include enough land higher than the limit of flooding to cope with the number of people in the area. During a flood event the area is surrounded by flood water and property may be inundated. However there is opportunity for people to retreat to high ground on the island and therefore the direct risk to life is limited. The area will require resupply by boat or air if not evacuated before the road is cut. If it would not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

- **Trapped perimeter areas:** These would generally be areas on the fringe of the floodplain where the only practical road or overland access is through flooded land and there is an inability to retreat to high ground due to topography or impassable structures. (There are a few of these areas in the Tweed). Trapped perimeter areas are classified according to what can happen after the evacuation route is cut as follows:

  - **Low trapped perimeter (LTP):** The area is lower than the limit of flooding or does not have enough land above the limit of flooding to cope with the number of people in the area. During a flood event the area is isolated by floodwaters and property may be inundated. If flood waters continue to rise after it is isolated, the area will eventually be covered. People trapped may drown.

  - **High trapped perimeter (HTP):** The area includes enough land to cope with the number of people and is higher than the limit of flooding. During a flood event the area is isolated by floodwaters and property maybe inundated. However as there is an opportunity for people to retreat to high ground, the direct risk to life is limited. The area will require resupply by boat or air if not evacuated before the road is cut. If it would not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

- **Areas able to be evacuated:** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated. The communities are in low lying areas where people can be progressively evacuated to higher ground as the level of inundation increases. This inundation could be caused either by direct flooding from the river or by localised flooding from tributary creeks. The categorisation depends on the type of evacuation access available, as follows:

  - **Overland escape route (OER):** These are areas where access roads to flood free land cross lower lying flood prone land. Evacuation can take place until access roads are closed by flood water. Escape from rising flood water is possible by walking overland to high ground. Anyone not able to walk must be rescued by using boats, heavy vehicles or aircraft. If people cannot get out before inundation occurs, rescue will most likely be from rooftops.

  - **Rising road access (RRA):** These are areas where access roads rise steadily uphill and away from floodwaters. The community cannot be completely isolated. Evacuation can take place by vehicle or on foot along the road as floodwaters advance. People should not be trapped unless they delay the evacuation from their homes. For example, people living in two-storey homes may initially decide to stay but reconsider after water surrounds them.

- **Indirectly affected areas (IAA):** These areas are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or the loss of transport links, electricity supply, water supply, sewerage and telecommunication services. They may therefore require resupply, or in the worst case, evacuation.

B.5.2 Proceeding to the Safest Place

The principle of proceeding to the safest place is a key strategy that minimises risk to life during a flood event. This principle needs to be considered:

- **During development approval:** When developments are being evaluated by the consent authority, consideration needs to be given to:
  - **The provision of access to places of safety.** These places could comprise the nearest evacuation centre, high ground beyond the reach of flood waters, community facilities with access to food, shelter, medical services, etc. These safe places would normally be reached by road, but where distances are short, access by foot is appropriate. Roads (and pedestrian pathways) across floodplains can often be inundated by floodwaters, cutting access. Therefore if the access is being relied upon to reach a place of safety, it is important that the likelihood of the loss of the access be considered during the evaluation of the development proposal;
  - **The provision of safe places themselves.** Some NSW LGAs, including Tweed, allow for safe places to be constructed within dwellings through the provision of a second storey or access to loft space above the PMF. Whilst this form of safe place may not necessarily provide all the facilities that could be available within an evacuation centre or a community centre, in some cases this may provide an appropriate level of safety for the building's occupants. Depending on the scale of the development, it may be possible for much larger spaces with more extensive facilities to be provided;
- **During the prevention and preparatory phases prior to a flood:** These activities are normally undertaken by the SES and landholders. Information concerning flood risks needs to be available so that informed plans and preparations can be made well in advance of the flood threat;
- **During a flood emergency:** In exercising their role as the combat agency for floods in NSW, the SES give directions to residents and other people in the floodplain, concerning the safest place to evacuate to. These directions will usually be in accordance with the plans they have previously prepared. Nevertheless if unforeseen circumstances arise, the SES will make decisions at that time concerning the safest place for people to move to. Similarly if for any reason people are unable to receive directions from the SES, or otherwise are unable to follow any pre-determined plans, people will logically proceed to what they perceive to be the safest place, based on the information available to them at the time and from past experiences. For people who have become isolated in flooded houses with more dangerous floodwaters outside, this on occasion has meant taking refuge in the ceiling space or on the roof.

In each of these situations the SES or the people at risk make decisions about where the safest place is and how best to access it based on the information available to them at the time. There is a role for the SES, Council and other government agencies in educating the community so that they are best

able to make these decisions, particularly if they find themselves in situations where they become isolated or are not in direct contact with emergency services personnel.

B.5.3 Where is the Safest Place?

In actual flood events there may be considerable uncertainty in deciding the safest thing to do and the safest place to go. Nevertheless the following courses of action are likely to produce the safest overall outcomes:

- **Firstly:** Leave the inundated area, or the area about to be inundated, and travel to an area outside the floodplain where sufficient support facilities are available to sustain health and wellbeing. This may be an evacuation centre but it might also be homes of family or friends, or rented accommodation, outside the floodplain. Nevertheless such travel can itself be dangerous if the evacuation route can be cut by flood waters, or there are other related threats such as wind, fallen trees / power lines, or land slips. It is possible that in some situations, the travel may be more dangerous than the risks associated with seeking shelter in the local area.
- **Secondly:** When it is no longer possible to evacuate, or when the risks of evacuation are too great, refuge in place is the next preferable option, (or possibly may be the only option available). This sheltering may be for the duration of the flood or until being rescued (e.g. by boat, helicopter or heavy vehicle).

There are potential difficulties in undertaking either of these courses of action, as listed in Table B-3.

There are a range of factors which influence safety considerations when evacuating beyond the floodplain or sheltering within it. These factors include:

- Velocity and depth of floodwaters at the site and along the evacuation route;
- Duration of inundation and the duration of the post-flood recovery phase, including time to restoration of water, sewerage and other facilities;
- Available warning time;
- History of flooding including community awareness of recent major floods;
- History of past evacuations, including community awareness of successful evacuations and false alarms;
- Demographic characteristics of the community, including age, mobility, language, level of disability, car ownership, etc;
- Risk of erosion and collapse of land or building used for shelter;
- Availability of shelter from wind, rain, sun, cold, etc;
- Building standards (if building is used as a refuge), including ability to withstand the forces of flood debris and buoyancy;
- Driving hazards along the evacuation route, including weather induced visibility hazards, flood induced hazards, fallen trees, etc.;
- Number of people to be evacuated;
- The availability of facilities for the continued health and wellbeing of people who are evacuated or who remain and shelter within the floodplain. This includes access to amenities (toilets,

bedding, food, warmth, washing), medical assistance, financial assistance, counselling support, communication services, law and order services, etc;

- Distance that has to be travelled; and
- Frequency of inundation of the flood.

Having regard to the above factors, selection of the safest course of action is a potentially complex issue. It would appear that there is no one course of action that is the answer for all situations. Whilst evacuating to outside the floodplain should normally be the safest course of action if sufficient warning time is available, it may not be the superior option in every situation.

Table B-3 Potential Difficulties associated with Alternative Evacuation Scenarios

First Priority: Evacuation to Area Outside the Floodplain	Second Priority: Sheltering within the Floodplain
1. Misadventure or other accident on route Vehicles being washed off roads or causeways is the most common form of death during floods. **2. Local flooding** The evacuation route may be cut by local flooding, which is difficult to predict. This may expose evacuees to further dangers or result in evacuees being isolated in a location which is more dangerous than the one they left. **3. Insufficient Time or Route Capacity** Conditions along the access route may be such that there is insufficient time or road capacity available to reach safety before evacuees are overtaken by more dangerous conditions than the one they left. **4. Failure to Heed Evacuation Directions** Experience in Australia has shown that people often do not heed evacuation warnings, preferring 'lay' advice to that of the emergency services personnel. Also, false alarms reduce the credibility of future warnings. Consequently a much larger percentage of people may not heed evacuation directions than otherwise may have been expected. There may be inadequate facilities on site to adequately cater for those who don't evacuate. **5. Immobility** Disadvantaged, infirm and immobile sectors of the population may be unable to evacuate, or unable to evacuate in the time available.	**1. Sanitation, food or medical supplies** Isolation resulting from not evacuating may create significant hardship or in the case of inabilities to access important medical supplies, could lead to death. **2. Building fire** People trapped in buildings isolated by floodwaters may be subject to increased risks due to an inability to evacuate, or due to the inability of fire crews to reach the building (or to transport necessary fire fighting equipment to the building). **3. Medical emergencies** People isolated by floodwaters may be subject to increased risks due to the inability of paramedics to reach them. In this situation, people subject to life threatening emergencies could die. **4. Isolation induced trauma** People trapped in buildings or otherwise isolated by floodwaters may be subject to increased trauma. This trauma could be exacerbated if communication facilities are disrupted. **5. Building collapse / inundation** People trapped in buildings may be drowned if the building is subsequently washed away, or if the building (or 'island') where they are sheltering becomes overwhelmed by floodwaters. **6. Inability to climb** Those disabled or the infirm, may be unable to climb stairs or otherwise be unable to reach the higher areas of the site in order to avoid drowning. **7. Exposure to the weather** This includes associated effects such as hypothermia. **8. Drowning** If the sheltering area becomes overwhelmed with floodwater, people may drown.

B.5.4 Flash Flood Environments

Since 2007 the NSW SES, in consultation with SES's from other states and the National Flood Risk Advisory Group (NFRAG), has undertaken a research and development project targeting flash flood risk. Flash floods are characterised by little or no warning time (typically less than 6 hours), rapid rates of rise in flood level, and by dangerously high velocity flow of water, which presents significant difficulties from a public safety perspective. A draft guideline has resulted from this project (Opper et al, 2011).

The draft guideline maintains that flash flood emergency planning should commence with an assumption that evacuation is the most effective strategy. However, it recognises the likelihood of some proportion of the population failing to evacuate, either by choice or by impediment, and the legacy of impediments to evacuation that have resulted from previous land use planning and design of communities.

In the case where it is likely people will become trapped by floodwaters due to limited evacuation options, the draft guideline advises that people at risk may be advised to not attempt to flee by entering floodwater, and to seek the highest point within the building. Rescue may still be necessary, in the case of secondary emergencies, such as the need for medical assistance, or due to structural instability of the building under flood loadings.

While not an equivalent to evacuation, in certain circumstances this guideline accepts that refuge in place (or "entrapment") is an alternative emergency response in flash flood environments, where evacuation may expose evacuees to increased risk if initiated at the wrong time or under the wrong conditions. Community education, structural building standards and land use planning understanding of flash flood risk is advocated by the draft guideline.

The SES intends for the guideline to be considered nationally, and for each jurisdiction to make their own determination to adopt or modify the guideline into their own legislative frameworks / controls.

B.5.5 Scale of Development

The range of support facilities that can be practically provided to service evacuees and isolated communities is influenced by the number of people involved. As a general rule, the greater the 'critical mass' of people, the greater the ability to provide safety. For example, Tweed Heads City North already has a significant range of facilities including a hospital, supermarkets, communications, hotels, medical centres, financial services, government offices, boat access, etc. Whilst this area can be isolated during a flood and some of these facilities may be shut down, a significant number of support facilities will likely still be available during a flood. This contrasts with smaller isolated rural communities and single houses where fewer facilities are likely to be available.

Furthermore, when planning new support facilities to service future population increases, larger development proposals will likely have access to the greater resources (including Section 94 development contributions funds), and therefore are better able to provide a larger range of support facilities than smaller scale developments.

B.5.6 Concurrent Fire and Medical Risks

Various discussions were held with the NSW Ambulance Service and Fire and Rescue NSW (FRNSW) concerning the potential for flood emergencies to be compounded by concurrent fire and / or medical emergencies. Neither agency has evidence for increased fire/medical emergencies occurring concurrently with flood emergencies, and in terms of calls to '000' for medical assistance, the Ambulance Service's records indicate there are fewer '000' calls during flood emergencies. Neither agency considered that the fire/medical risks associated with new development in potentially flood isolated communities were intolerable, or that the risks were so severe that they were unable to be managed as part of the development process.

Recommendations in relation to measures to address fire and medical risks that might be coincident with floods include:

- Provision of more information to both agencies on completion of the Tweed FRMS so that the potential impact on their existing operations and facilities could be further evaluated;
- When major new buildings are constructed in areas that could be potentially isolated by floodwaters, they should be provided with their own fire fighting equipment to make them self-sufficient;
- When multi-storey buildings are designed which could potentially have their lower storey inundated in a major flood, fire stairs need to provide egress at various lower levels below the PMF, not just at street level;
- Council to ensure that the potential flood height range is made known to building designers when considering concurrent fire / flood risks to ensure buildings are built in accordance with the Building Code of Australia and properly maintained to ensure ongoing compliance;
- Investigate potential to provide FRNSW with additional boats with capacity to serve as flood boats when required. The majority of these boats might normally be operated by other government agencies (e.g. NSW Maritime, Police) but could be utilised for fire fighting and rescue during flood periods, in support of the SES; and
- In areas where potential isolation could occur due to inundation by floodwaters, the preparation of an evacuation management plan should be undertaken by individual developments, as a flood readiness measure, to manage their residual flood risks, including all stakeholders requiring regularly (say two yearly) exercises challenging the practicality and functionality of the plan.

B.5.7 Refuge in Place

This study supports the SES policy that evacuation is the primary emergency flood risk management option, however the unique characteristics of the Tweed Valley floodplain should be considered in formulating *alternative* (although not *equivalent*) strategies.

In the Lower Tweed in particular, where Council is faced with significant areas of urban zoned flood prone land, flood behaviour which is relatively low velocity, and a large existing population with limited evacuation capability, the application of refuge in place to the redevelopment of aged non-flood compatible housing stock is supported as a risk reduction measure if appropriate controls are in place. While this approach may not be supported by the SES in "non-flash flood" conditions, it is

considered that the refuge in place approach, if applied to redevelopment in the Lower Tweed in particular, reduces evacuation risks.

This approach reinforces Council's existing position of applying refuge in place requirements for certain types of flood prone developments, where safe evacuation may not be possible. For example, this may be due to the limited warning times available to the SES, and the need for pre-emptive evacuations, which are unlikely to be acted upon by the at-risk population, particularly if previous evacuation attempts prove to be unnecessary given eventual flood peaks.

It is understood that the NSW Department of Planning and Infrastructure have commissioned a research project to further understand risks to life associated with refuge in place (in flash flood environments) and it is recommended that, once available, the outcomes of this project are reviewed and considered in the context of the Tweed Valley floodplain.

APPENDIX C: GAUGES MONITORED BY TWEED SHIRE SES

Gauge Name	River	AWRC No	Easting	Northing	Projection	Datum	Zero Gauge	Conversion to AHD	Type	Owner
Boat Harbour No.3	Rous River	201005	532938.255	6868452.004	MGA 94	ASS	3.738	N/A		DWE
Kynnumboon	Rous River		538179	6867895	MGA 94	TRHD		-0.926	Telemeter	MHL
Eungella‡	Oxley River	201001	528723.666	6863585.036	MGA 94	ASS		+13.285	Telemeter	DWE
Uki‡	Tweed River	201900	532742.434	6856977.060	MGA 94	ASS		+9.04	Telemeter	DWE
Tyalgum (Oxley River)‡	Oxley River	201006							Manual	
Bray Park Weir	Tweed River		536209	6864484	MGA 94	TRHD		-0.934	Telemeter	MHL
Chillingham‡	Rous River	201008							Manual	
Tyalgum‡	Pumpenbil Ck	201901							Manual	
Murwillumbah Bridge	Tweed River	201420	539219	6866353	MGA 94	TRHD		-0.909	Telemeter	MHL
Murwillumbah*‡	Tweed River	201902	539295	6866485	MGA 94	AHD		0	Telemeter	TSC/BoM
Tumbulgum‡	Tweed River	201432	545172	6871996	MGA 94	TRHD		-0.893	Telemeter	MHL
Tumbulgum			545212	6872325	MGA 94					TSC
Barneys Point (Chinderah) *^	Tweed River	201426	554110	6877724	MGA 94	TRHD		-0.883	Telemeter	MHL
Barneys Point	Tweed River		554505	6877666	MGA 94	AHD		0	Telemeter	MHL
Dry Dock	Tweed River	201428							Telemeter	TSC
Letitia 2A	Tweed River	201429	554314	6882414	MGA 94	TRHD		-0.886	Telemeter	MHL
Terranora	Broadwater	201447	548941	6880375	MGA 94	TRHD		-0.853	Telemeter	MHL
Cobaki	Broadwater	201448	549348	6883136	MGA 94	TRHD		-0.863	Telemeter	MHL
Point Danger‡	Tweed River	201904							Manual	

BMT WBM Brisbane
Level 8, 200 Creek Street Brisbane 4000
PO Box 203 Spring Hill QLD 4004
Tel +61 7 3831 6744 Fax +61 7 3832 3627
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Denver
8200 S. Akron Street, Unit 120
Centennial Denver Colorado 80112 USA
Tel +1 303 792 9814 Fax +1 303 792 9742
Email denver@bmtwbm.com
Web www.bmtwbm.com.au

BMT WBM Mackay
Suite 1, 138 Wood Street Mackay 4740
PO Box 4447 Mackay QLD 4740
Tel +61 7 4953 5144 Fax +61 7 4953 5132
Email mackay@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Melbourne
Level 5, 99 King Street Melbourne 3000
PO Box 604 Collins Street West VIC 8007
Tel +61 3 8620 6100 Fax +61 3 8620 6105
Email melbourne@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Newcastle
126 Belford Street Broadmeadow 2292
PO Box 266 Broadmeadow NSW 2292
Tel +61 2 4940 8882 Fax +61 2 4940 8887
Email newcastle@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Perth
Suite 6, 29 Hood Street Subiaco 6008
Tel +61 8 9328 2029 Fax +61 8 9484 7588
Email perth@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Sydney
Level 1, 256-258 Norton Street Leichhardt 2040
PO Box 194 Leichhardt NSW 2040
Tel +61 2 9713 4836 Fax +61 2 9713 4890
Email sydney@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Vancouver
401 611 Alexander Street Vancouver
British Columbia V6A 1E1 Canada
Tel +1 604 683 5777 Fax +1 604 608 3232
Email vancouver@bmtwbm.com
Web www.bmtwbm.com.au