TURO CREEK, PRETTY BEACH FLOODPLAIN RISK MANAGEMENT STUDY

Gosford City Council

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FOREWORD

The State Government's Flood Policy is directed towards providing solutions to existing flood 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.

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

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

1. Formation of a Committee	Established by Council and includes community group representatives and State agency specialists.
2. Data Collection	Past data such as flood levels, rainfall records, land use, soil types etc.
3. Flood Study	Determines the nature and extent of the floodplain.
4. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
5. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
6. Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The Gosford City Council has established a Floodplain Risk Management Committee that community. Data Collection and the Flood Study for Turo Creek, Pretty Beach was completed in 2003 (PBP, 2003). This report updates the Flood Study and forms the fourth and fifth stages of the management process for the Turo Creek Floodplain.

This report has been prepared for Gosford City Council by Cardno Lawson Treloar to examine floodplain risk management options and formulates a Floodplain Risk Management Plan.

EXECUTIVE SUMMARY

Gosford City Council commissioned Cardno Lawson Treloar to undertake a Floodplain Risk Management Study and prepare a Floodplain Risk Management Plan for the Turo Creek floodplain at Pretty Beach. The Floodplain Risk Management Study includes revision of the previous Flood Study (PBP, 2003). The Floodplain Risk Management Plan draws upon the results of the assessment carried our for the various floodplain management options presented in the Floodplain Risk Management Study. A separate document has been prepared for the Study and Plan.

Escarpment with Waterfalls (courtesy of Gwen Perrie)

The Catchment

The Turo Creek catchment has an area of 44 hectares and is made up of forested and urban areas with the urban areas closer to the beach at the lower end of the catchment. Turo Creek flows between Como Parade and Venice/High View Road to the outlet into Brisbane Water at Pretty Beach. The creek traverses through private properties adjoining Venice Road and has a number of pedestrian bridges which cross the creek and act as controls during major storm events. These bridges also have a tendency to block during storm events.

Pretty Beach Road Culverts

The catchment is very steep with the escarpment to the south having slopes of around 30 to 50%. Flash flooding occurs as a result of the steep upper parts of the catchment. During storm events, waterfalls develop over the steep cliffs in the middle section of the catchment.

Turo Creek near Como Parade

Escarpment (courtesy of Gwen Perrie)

The Issue of Flooding

In the past, flooding within the catchment has caused property damage and posed a high hazard to the residents living in close proximity to the creek.

The major area of concern is the flood prone area that lies within the Probable Maximum Flood (PMF) extent. This area is subject to flooding from catchment flows and includes properties along Venice Road, Pretty Beach Road and Como Parade.

A number of hydraulic features within the floodplain control flood behaviour. These features include:

- Pretty Beach Road culverts
- Limited capacity of Turo Creek to carry floodwaters
- Blockage of private pedestrian bridges across Turo Creek.

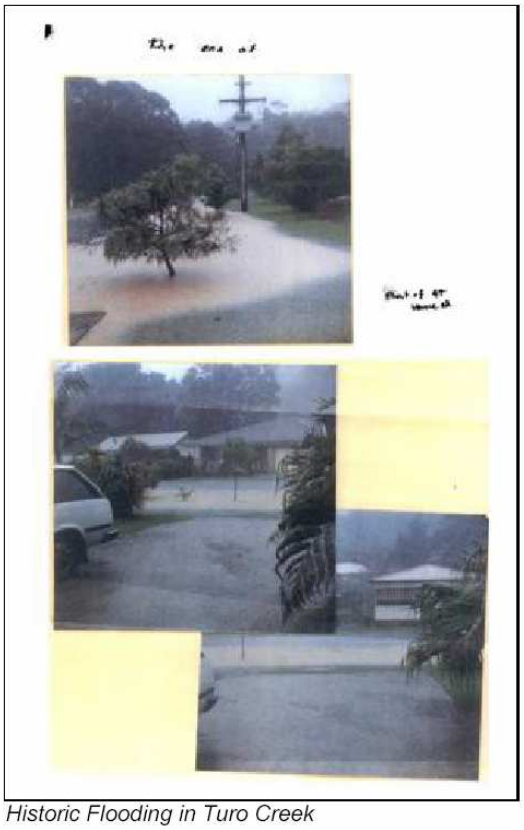
Additionally, the pipe drainage system in the catchment has a limited capacity and overland flow occurs once the capacity of the pipe drainage system is exceeded. A separate study was undertaken to assess the existing capacity of the system and suggest measures for improvement (Pretty Beach Drainage Study (PBP, 2003)).

Flood Behaviour - Existing Conditions

Intense rainfall periods, which are often short in duration, or occurs as a burst within a longer wet weather period are the primary factors that contribute to flood characteristics in the catchment. For example, the 100 year average recurrence interval (ARI) storm event for a 1 hour storm duration has an intensity of approximately 86 mm/hr. For an extreme event, such as the Probable Maximum Flood, the intensity of a similar duration event is substantially greater at 367 mm/hr.

Design flows for the catchment were calculated using the RAFTS hydrological model whereas design flood levels and velocities were estimated from the MIKE11 hydraulic model. This model was calibrated to available historical flood information.

Design flood events considered included the 5, 20, 50, 100, 200 year ARI and the Probable Maximum Flood (PMF) in accordance with current practice.



Historic Flooding in Turo Creek

The findings of the study indicate that significant flooding commences with the 20 year ARI event with a progressive increase in the number of flood affected properties up to the PMF.

Aims of the Study

The Floodplain Risk Management Study has investigated the measures that can be undertaken to minimise the impact of flooding in the catchment. The Floodplain Risk Management Plan recommends a strategy for implementation of these measures.

The objectives of the Floodplain Risk Management Study are to:

- review and modify the flood model (Patterson Britton & Partners, 2003) to include changes in the catchment since the completion of the modelling, prepare various flood interpretation graphs and tables as required by a flood study
- review Councils existing environmental planning policies and instruments including Councils long-term planning strategies for the study area
- identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events
- assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future
- consider whether the proposed works and measures might produce adverse effects (environmental, social, economic or worsened flooding) in the floodplain and whether they can be minimised
- examine the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's development and disaster planning requirements
- examine ways in which the creek and floodplain environment may be enhanced by exploring the possibility of a strategy for vegetation planning that may create a valuable corridor of vegetation without having a detrimental effect on flooding, and
- identify modifications that are required to current policies in light of the investigations.

Impacts and Costs of Flooding

The table below summarises the number of properties that would be flooded in different design flood events together with the flood damage that is likely to occur.

Impacts and Costs of Flooding - Total Number of Properties with Above Floor Flooding

Flood (ARI)	Properties with above floor flooding	Flood Damage ($)
5 yr	3	$192,429
20 yr	5	$276,857
50 yr	6	$293,135
100 yr	7	$314,041
200 yr	8	$320,726
PMF	15	$720,008

Options to Manage Flooding

Using the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (2005) and in consultation with the community, Council and state agency stakeholders, a number of potential options for the management of flooding were identified.

These options included:

- flood modification measures,
- property modification measures, and
- emergency response modification measures.

Options Assessment

Options were assessed against a range of criteria (technical, economic, environmental and social).

Hydraulic modelling was undertaken for a number of the flood modification options. The results of this assessment were used to determine the improvement in flooding impacts due to the implementation of the options.

A detailed economic analysis was undertaken for all flood modification options for which hydraulic modelling was undertaken. A number of property modification options (such as house raising and voluntary purchase programs) were also assessed for their economic feasibility. The economic assessment involved a damages assessment and a benefit-cost ratio analysis

A multi-criteria matrix assessment approach was adopted for the comparative assessment of all options identified using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach of assessing the merits of various options uses a subjective scoring system. The principle merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition it makes the assessment of alternatives .transparent. (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute .right. answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion.

The following criteria were adopted for the matrix assessment:

- **Technical**
  - Likely Overall Hydraulic Improvement

- **Economic**
  - Capital and Operating Costs
  - Reduction in Risk to Property
- **Social**
  - Reduction in Social Disruption
  - Reduction in Risk to Life
- **Environmental**
  - Flow and Water Quality Objectives
  - Fauna/Flora
- **Community**
  - Community Support
- **Authority**
  - Council/Agency/SES support
- **Policy/Legislation**
  - Compatible Policies and Plans.

Floodplain Risk Management Plan

The Floodplain Risk Management Plan is the formalisation of an effective flood risk management process. The Floodplain Risk Management Study and Plan are intrinsically linked. The Study provides the assessment of options that form the basis for the considerations and decisions in the Plan. The Draft Turo Creek Floodplain Risk Management Plan has been prepared as a separate document to this Floodplain Risk Management Study.

GLOSSARY

Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. e.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.

Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.

Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Integrated survey grid (ISG)	ISG is a global co-ordinate system based on a Transverse Mercator Projection. The globe is divided into a number of zones, with the true origin at the intersection of the Central Meridian and the Equator.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.

Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
NPER	National Professional Engineers Register. Maintained by the Institution of Engineers, Australia.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedence Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

CONTENTS

Page

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

This Floodplain Risk Management Study (FRMS) for Turo Creek, Pretty Beach, has been undertaken by Cardno Lawson Treloar for Gosford City Council to identify, assess and compare various options for the management of flood risk within the Turo Creek floodplain. The study has been undertaken in accordance with the NSW Government Floodplain Development Manual (2005).

A locality plan can be found in Figure 1.1. The outline of the study area can be found in Figure 1.2.

1.1 STUDY CONTEXT

The Floodplain Risk Management Study forms one of the multiple stages of the Floodplain Management process, which consists of the following steps: -

- Formation of a Committee
- Data Collection
- **Flood Study (updated from a previous study)**
- **Floodplain Risk Management Study**
- Floodplain Risk Management Plan
- Implementation of Floodplain Risk Management Plan

In addition to undertaking the Floodplain Risk Management Study, revisions have also been made to the Flood Study findings.

The study was jointly funded by Council and the Department of Natural Resources. The Department also assisted in the provision of specialist advice on flooding and related matters.

1.2 STUDY OBJECTIVES

The objectives of the Floodplain Risk Management Study were to:

- Review and modify the flood model developed as part of the Flood Study (Patterson Britton & Partners, 2003) to include changes in the catchment since the completion of the modelling, prepare various flood interpretation graphs and tables as required for a flood study.

- Review Councils existing environmental planning policies and instruments including Councils long-term planning strategies for the study area.

- Identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events.

- Assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future.

- Consider whether the proposed works and measures might produce adverse effects (environmental, social, economic or worsened flooding) in the floodplain and whether they can be minimised.

- Examine the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's development and disaster planning requirements.

- Examine ways in which the creek and floodplain environment may be enhanced by exploring the possibility of a strategy for vegetation planning that may create a valuable corridor of vegetation without having a detrimental effect on flooding.

- Identify modifications that are required to current policies in light of the investigations.

1.3 PREVIOUS INVESTIGATIONS/AVAILABLE DATA

A number of studies have been conducted for the study area. These studies have been reviewed as part of this study and relevant information utilised in the study. Similarly, a range of data available for this investigation was reviewed and processed for use in this study.

Previous studies and available data for the project are summarised in Table 1.1.

Table 1.1: Chronological Summary of Previous Studies and Available Data

Study/Data Source	Description
Turo Creek, Pretty Beach, Flood Study (Patterson Britton & Partners, 2003)	Flood study undertaken in 2003. The flood study was reviewed and updated as part of this Floodplain Management Study.
Pretty Beach Drainage Study (Patterson Britton & Partners, 2003)	Drainage study to analyse the existing system and prepare a drainage management plan to remove deficiency in the system
Turo Creek Flood Study and Pretty Beach Drainage Investigation Questionnaire (Patterson Britton & Partners, 2000)	A resident questionnaire was developed and distributed among the residents of Pretty Beach as part of the Turo Creek, Pretty Beach Flood Study (Patterson Britton & Partners, 2003)
Gosford City Council, Drainage Records, Pretty Beach (1997)	Drainage Records for street drainage within Turo Creek Catchment.
Gosford City Council, Floor Level Survey undertaken for the Flood Study	Floor Level Survey for the flood affected properties.
Gosford City Council, Gosford City Local Flood Plan . A Sub-Plan of the Gosford City Local Disaster Plan (DISPLAN) December 2003.	Details of flood emergency response arrangements.
Gosford City Council, Flood Management (E2.02)	The objective of this policy is to control development within flood prone areas.
Gosford City Council, Flood Management . NSW Government Policy (E2.03)	The objective of this policy is to reduce the flood liability on flood prone land, and to reduce private and public losses resulting from floods.
Gosford City Council, Stormwater Detention Policy (Draft)	The policy aims to prevent increase of flooding to downstream properties or damage to sensitive environmental areas, resulting from the increased peak stormwater flows generated from upstream development.
Gosford City Council, Watercourses-Obstruction (E5.15)	This policy provides guidelines on rectifying obstructions within natural watercourses brought about by material being deposited in the watercourse.

Study/Data Source	Description
Gosford City Council, Water Cycle Management (DCP No 165)	This development control plan provides guidelines for the installation of water efficient systems in order to minimise the impact on the water cycle.
Gosford City Council, Building in Flood Liable Areas (DCP No 115)	Provides controls and guidelines for building in flood liable areas.
Gosford City Council, Setback Policy . Creeks, Rivers & Lagoons (E1.01)	Provides appropriate setbacks from creeks, rivers and lagoons.
Gosford City Council, Natural Area Bushland (R0.13)	Advises on the planting of locally occurring indigenous vegetation in residential areas and private property. Provides guidelines in relation to bushfire hazard reduction.
Gosford City Council, Installation of Unregisterable Movable Dwellings and Rigid Annexes in Caravan Parks on Flood Liable Land (D6.17)	The objective of this policy is to reduce the flood risks on caravan parks.
Department of Public Works, NSW (1997) Brisbane Water Flood Levels May 1974.	This document provides records of the 1974 May storm event in which unusually high water levels were reached in Brisbane Water and flooding occurred.
Gosford City Council, Draft Vision Statement	This document provides strategic direction for the Gosford City Council

1.4 STUDY METHODOLOGY

The report format follows the study methodology, which involved:

- Community consultation (Section 2)
- A review of the Flood Study, including remodelling of the floodplain (Section 3)
- An assessment of the current:
  - economic impact of flooding (Section 4)
  - emergency response arrangements (Section 5)
  - planning and policy framework (Section 6)
  - Flood Planning Level (Section 7.12)
  - environmental and social features of the floodplain (Section 8)
- Identification of Options (Section 9)
- Assessment of Options (Section 13)

An appreciation of the catchment and floodplain was gained by carrying out a review of available information and undertaking two field inspections. The first field inspection was undertaken by the study team on the 27 May 2004 and the second inspection was carried out on the 3 March 2005 in the company of Council representatives and a local resident. A photographic montage of key features in the floodplain can be found in Appendix A.

2 CONSULTATION

2.1 REVIEW OF HISTORICAL FLOOD INFORMATION

A review of information held by Council (listed in Table 1.1) indicates the following:

- Flood inundation of properties, including both overland and over-floor flooding has been observed.
- February 1990 was the most recent significant event in the catchment.
- Turo Creek rises very quickly after the commencement of rainfall events and flows .bank-full. frequently during storm events.
- Pedestrian access crossing on Turo Creek within private properties can block to varying degrees during flood events.

2.2 COMMUNITY INFORMATION BROCHURE/QUESTIONNAIRE

Community consultation was undertaken in July 2004 by distributing an information brochure and a questionnaire. The brochure provided the outline of the floodplain risk management process and the objectives of this study. The questionnaire sought information about historical flooding events and feedback on possible options for the floodplain. Folded A3 brochures were delivered to residents within the floodplain (approximately 60). Of these, 30 questionnaires were returned.

Appendix B contains a copy of the brochure and the questionnaire. A summary of the replies received from the residents is also included in this Appendix.

The replies received indicated that the community suggested or supported the following options:

- Culvert/pipe enlargement
- Channel widening or deepening
- Improved overland flowpaths
- Planning controls.

Residents were able to identify a number of historical flooding events. Floods were identified by residents to have occurred in 1974, 1988, 1990 and 1998. A number of residents were able to provide details of flood levels, inundated areas and general descriptions of flooding behaviour.

2.3 COUNCIL.S FLOODPLAIN RISK MANAGEMENT COMMITTEE

A presentation to the Floodplain Management Committee was given at the outset of the project on 17 June 2004 outlining the objectives of the study. Further to this, updates on the study progress were presented to the Committee on the following dates:

7 April 2005;
1 September 2005;
3 November 2005, and
22 June 2006.

2.4 PUBLIC EXHIBITION

This draft report adopted by the Council was publicly exhibited from 30 October 2006 to 1 December 2006 to invite comments from the community. Copies of the report were also distributed among major stakeholders for review.

Only minor comments were received from the community. Department of Primary Industries and Darkinjung Local Aboriginal Land Council forwarded written submissions, which are included in Appendix B.

The report has been modified to incorporate various comments generated from public exhibition.

3 EXISTING FLOOD BEHAVIOUR

3.1 CATCHMENT DESCIPTION

The 44 hectares Turo Creek catchment is made up of both urban and forested areas. The urban area lies to the north closer to the Pretty Beach whereas forested area is in the south and extends to Bouddi National Park. In the urban area, Turo Creek flows between Como Parade and Venice Road/High View Road, discharging into Brisbane Water at Pretty Beach. It traverses through private properties adjoining Venice Road and has a number of pedestrian bridge crossings that act as hydraulic controls during major storm events. These bridges have a tendency to block with debris during storm events.

The catchment is very steep with the escarpment to the south having slopes of around 30 to 50%. Flash flooding occurs as a result of intense rainfall on steep upper parts of the catchment. During storm events, waterfalls develop at the steep cliffs in the middle part of the catchment.

Brisbane Water at Pretty Beach is the downstream boundary of the study area. The likelihood of flooding of Turo Creek coinciding with flooding in Brisbane Water is low and an appropriate downstream boundary level to reflect this has been adopted in the flood modelling (see section 3.6).

3.2 FLOOD STUDY REVIEW

The Flood Study undertaken in 2003 (Patterson Britton & Partners, 2003) was reviewed as part of this Floodplain Risk Management Study and Plan. The review involved undertaking detailed field inspections and reviewing both the hydrologic (RAFTS) and hydraulic models (MOUSE) established for the study.

A number of historical events were documented in the Flood Study (Patterson Britton & Partners, 2003). These events are listed below:

- 16th . 17th January 1988
- 29th April . 1st May 1988
- 2nd . 4th February 1990
- 8th . 10th February 1992
- 6th August 1998
- February 1990

The only available data for the rainfall and the related observed flood levels was for the February 1990 event. As such, only this event was used for model calibration.

Historical flood photos for the Turo Creek floodplain are presented in Appendix C.

3.3 HYDROLOGY

Generally, the hydrologic model developed for the previous study was found to be suitable except at a few locations in the catchment where further refinement of the subcatchment areas was undertaken.

Design rainfall depths and temporal patterns for the 200 year, 100 year, 50 year, 20 year and 5 year ARI events were developed using standard techniques provided in AR&R (2001). The Probable Maximum Precipitation (PMP) was estimated using the Generalised Short Duration Method recommended by the Bureau of Meteorology (2003).

The final RAFTS model layout is shown in Figure 3.1.

3.4 HYDRAULICS

The approach adopted in the previous flood study for hydraulic modelling was found unsuitable for the purpose of design flood estimation. The creek is a typical urban open channel with road/pedestrian crossings and it was considered that the creek can be adequately modelled using a one-dimensional channel flow model. Therefore a new hydraulic model was developed using the MIKE11 (Version 2003) modelling system. This model was also used for the hydraulic assessment of the options in the Floodplain Risk Management Study (Section 10). Existing ground survey and geometric data from the previous model was used in developing the new hydraulic model.

3.5 MODEL CALIBRATION AND DESIGN FLOOD MODELLING

The layout of the hydraulic model cross sections is shown in Figure 3.2. The raw ground survey and cross sections utilised in the model are provided in Appendix D. The location coordinates for these cross sections are also provided in this appendix.

The new model was calibrated using the data identified in the Flood Study (Patterson Britton & Partners, 2003) for the February 1990 storm event. Calibration results are presented in Figure 3.3.

The hydraulic model was then run for the Probable Maximum Flood (PMF), 200 year, 100 year, 50 year, 20 year and 5 year ARI events for the 15min, 30 min, 45 min, 1 hr, 90min, 2 hr, 3 hr, 6 hr and 12 hr duration events.

3.6 DOWNSTREAM MODEL BOUNDARY

The approach adopted to establish downstream boundary for the design event modelling in this study varied from the approach used in the previous Flood Study (Patterson Britton & Partners, 2003). The previous study utilised a combination of tidal tailwater controls and Brisbane Water flood levels as provided by Council.

As outlined above, the likelihood of flooding of Turo Creek coinciding with flooding of Brisbane Water is low. Hence the levels adopted in the previous study were found to be too conservative. After discussions with Council and DNR, a constant downstream boundary of 0.9m AHD for all design events was adopted. This boundary condition was adopted from the preliminary results of Brisbane Water Estuary Processes Study (Cardno Lawson Treloar, in progress).

3.7 CULVERT BLOCKAGE AND DESIGN FLOOD MODELLING

Blockage of culverts and bridges in a catchment is now a well established phenomenon. For an appropriate flood risk assessment of an urban area like the Turo Creek floodplain, it is therefore necessary to adopt a certain blockage factor for various culverts and bridges. The likely blockage factor is dependent on many factors and is difficult to ascertain. Limited data available in other similar catchments indicate that the culverts in the Turo Creek catchment are likely to block 100%. The experience of local residents (Section 2.3) also indicates that the pedestrian bridges have often blocked to various degrees in the past. Council has therefore adopted a blockage policy for use in the preparation of this Floodplain Risk Management Study and Plan. As per the policy all design and option flood modelling incorporates 100% blockage on all access bridges (including Como Parade) and 50% blockage applied at the Pretty Beach Road Bridge and the pedestrian bridge just upstream of this bridge. The results of design flood modelling are presented in Figure 3.4 and tabulated in Appendix E.

It is recommended that the results presented in Appendix E be adopted for the Floodplain Risk Management Study and Plan and for the assessment of an appropriate flood planning level.

Therefore the results reported in the previous Flood Study (Patterson Britton and Partners, 2003) are superseded.

3.8 SENSITIVITY ANALYSIS

The results of design flood modelling described above were tested for sensitivity to the following model and catchment parameters:

- Catchment discharge +/- 20%
- Channel Roughness +/- 20%
- Downstream Boundary +/- 20%

Model runs were carried out for the 100 year 2 hour event (critical) with the above changes incorporated in the hydraulic model. The results were compared with the existing conditions and are presented in Appendix F.

The results of sensitivity analysis indicate that the model results are most sensitive to the catchment discharge with flood levels varying between +0.41m to -0.15. The results also show that the model is sensitive to the downstream boundary with flood level variations of ±0.18m. However, the impact is only limited to the area on the beach side of Pretty Beach Road, upstream of Pretty Beach Road there is no impact at all. Model sensitivity to channel roughness varies from +0.12m to -0.14m.

3.9 FLOOD EXTENTS

Results from the design flood modelling undertaken for this study were utilised to produce a series of flood extent maps. Figures 3.5, 3.6, 3.7, 3.8, 3.9 and 3.10 show the flood extents for the PMF, 200 year, 100 year, 50 year, 20 year and 5 year ARI events respectively. Figures 3.5, 3.7 and 3.9 also show flood contours for the PMF, 100 Year and 20 Year ARI events.

3.10 FLOOD HAZARD

Provisional .flood hazard. was determined in accordance with Appendix L of the Floodplain Development Manual (NSW Government, 2005). The Manual provides a relationship between the depth and velocity of floodwaters to determine provisional hazard (Provisional hazard = depth x velocity). Based on this relationship, the Floodplain Development Manual (NSW Government, 2005) defines two categories for provisional hazard . High and Low.

Hazard was calculated at each of the model cross sections. Using survey data, the cross section was divided into segments and the velocity for each segment was determined based on the conveyance of individual segments. Hazard was then calculated for each segment based on depth and velocity in that particular section. This process was undertaken for all the model cross sections. Between cross sections, the hazard was interpolated.

Figures 3.11, 3.12, 3.13, 3.14, 3.15 and 3.16 show the provisional flood hazard for the PMF, 200 year, 100 year, 50 year, 20 year and 5 year ARI events respectively.

The assessment of .true. hazard is undertaken by considering those factors that are likely to modify the provisional flood hazard categorisation. These factors and their impact on provisional flood hazard in the Turo Creek catchment is discussed below:

- Size of flood . various size floods were considered ranging from 5 year ARI event to PMF. Effective warning time .
- The effective warning time for flooding is negligible for the floodplain. The only warning could be of an impending intense rainfall event from the Bureau of Meteorology.
- Flood readiness - most residents are likely not to be flood-ready.

- Rate of rise of floodwaters . the rate of rise is very fast (generally less than 1 hour to peak) and as such the residents would not have enough time to take precautionary measures.
- Depth and velocity of floodwaters . mapped as provisional hazard for a range of events.
- Duration of flooding . the duration of flooding is relatively short (generally less than 2 hours) and hence the flood hazard would last for a relatively short time.
- Evacuation problems . generally residents of properties on the eastern side of Venice Road will have little time to evacuate. Similarly flood-affected properties along Pretty Beach Road would not be able to evacuate. However, some flood-affected properties on the western side of Como Parade would be able to evacuate temporarily to higher ground. Figure 3.17 shows the flood affected areas in the PMF event.
- Effective flood access . it is likely that Pretty Beach Road would be inundated in a number of places (including the Turo Creek crossing) in the event of a region-wide flood in the Gosford area. However, the time of inundation would only be a few hours and it would be expected that access for emergency vehicles would not be cut off from the floodplain for an extended period of time, allowing assistance to reach flood affected areas reasonably quickly following the peak of the flood.
- Type of development . The Turo Creek floodplain is residential in nature. The creek runs through a number of properties, which are directly affected by flooding. Hence all those properties would be subjected to high hazard.

Factors such as effective warning time, flood readiness, rate of rise of flood waters and evacuation problems would tend to increase the flood hazard whereas duration of flooding, effective flood access and type of development would play a neutral role in modifying the hazard.

The factors that exacerbate flood hazard are not likely to result in drastic change in high hazard area in the floodplain. As such the provisional hazard is retained as .true hazard. in this study. The factors contributing to increase in hazard have been given due consideration in establishing development control in the floodplain.

3.11 HYDRAULIC CATEGORIES

Hydraulic categories in the Turo Creek floodplain were established as per Appendix L of the Floodplain Management Manual. Figures 3.17 to 3.22 present hydraulic categories for the PMF, 200 year, 100 year, 50 year, 20 year and 5 year ARI events.

The Floodway in the lower reaches of Turo Creek for various design flood events extends over the left bank into Turo Reserve and across Pretty Beach Road. Since Floodway is defined using a depth and velocity relationship, it extends over the left bank of Turo Creek due to the combined depths and velocities achieved through the open space in the Reserve, in comparison to the densely developed area on the right bank of the creek. The structures such as buildings and fences on the right bank result in a reduction in flow velocity which produces a .Flood Storage. area for most design events rather than a .Floodway. area.

3.12 ABOVE-FLOOR FLOODING

A number of properties are affected by above-floor flooding. Table 3.1 and Figure 3.23 detail the properties affected by above-floor flooding in various design flood events. For each flood-affected property, the design flood level was estimated near the upstream end of the property. Model results were interpolated between the relevant hydraulic model cross sections (Figure 3.2) to derive representative flood levels for each property.

Table 3.1: Properties with Over-floor Flooding

Address	Chainage[1] (m)	5yr Over-floor Flooding (m)	20yr Over-floor Flooding (m)	50yr Over-floor Flooding (m)	100yr Over-floor Flooding (m)	200yr Over-floor Flooding (m)	PMF Over-floor Flooding (m)
18 Pretty Beach Rd	278	-	-	-	-	-	0.27
19 Pretty Beach Rd	278	-	-	-	-	-	0.31
20 Pretty Beach Rd	278	-	-	0.01	0.04	0.06	0.38
21 Pretty Beach Rd	278	-	0.04	0.08	0.11	0.13	0.45
22 Pretty Beach Rd	278	-	-	-	-	-	0.25
23 Pretty Beach Rd	304	-	-	-	-	-	0.16
24 Pretty Beach Rd[2]	304	no FL	no FL	no FL	no FL	no FL	no FL
38 Venice Rd[3]	266	0.02	0.13	0.17	0.20	0.22	0.57
38a Venice Rd	266	-	-	-	-	-	0.23
40 Venice Rd	226	-	-	-	-	-	0.41
42 Venice Rd	210	-	0.05	0.09	0.12	0.15	0.59
44 Venice Rd	194	-	-	-	-	-	0.34
46 Venice Rd	178	-	-	-	-	-	0.20
48 Venice Rd	164	-	-	-	-	-	0.18
50 Venice Rd	150	-	-	-	-	-	0.41

1 The chainage is derived from the hydraulic model (MIKE11) chainage and does not exactly correspond to the model chainages.
2 Floor level (FL) not available.
3 There are two houses located on the property at 38 Venice Rd, the second house only experiences over floor flooding in the PMF.

3.13 MAJOR ACCESS ROAD FLOODING

The major access road into the Pretty Beach area is Pretty Beach Road, which is partially inundated in all design events. Other roads affected by flooding are Como Parade and Venice Road. The details of flooding of these roads are provided in Table 3.2.

Table 3.2: Major Access Road Flooding

	Maximum Depth of Flooding Over Road					
Road Name	PMF	200 Year ARI	100 Year ARI	50 Year ARI	20 Year ARI	5 Year ARI
Pretty Beach Road	0.50m	0.20m	0.20m	0.20m	0.10m	-
Como Parade ("uphill end")	2.20m	1.40m	1.40m	1.30m	1.30m	1.00m
Venice Road	0.79m	0.24m	0.21m	0.17m	0.13m	-

The duration of Pretty Beach Road flooding ranges from 8 minutes for a 5year ARI event to 1 hour for the 200year ARI event for the critical duration event (2hr). In PMF, the duration of flooding is 40 minutes for the critical duration event (15 min). Longer duration storms, which may not produce the peak water level, may result in a longer duration of Pretty Beach Road flooding than the critical duration.

4 CURRENT ECONOMIC IMPACT OF FLOODING

4.1 BACKGROUND

The economic impact of flooding can be defined by what is commonly referred to as .flood damages.. Table 4.1 categorises various types of flood damages.

Table 4.1: Types of Flood Damages

Direct	Building contents (internal) Structural (building repair and clean) External items (vehicles, contents of sheds etc)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social . increased levels of insecurity, depression, stress General inconvenience in post-flood stage

The direct damage costs as indicated in the above table are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as .tangible. costs. In addition to this there is also .intangible. costs. The values discussed in this report are the .total. damages and include an assumed intangible cost of 25% of the tangible cost.

Flood damages can be assessed using a number of approaches including the use of programs such as FLDAMAGE or ANUFLOOD or through more generic methods using spreadsheets.
For the purposes of this project, generic spreadsheets have been used with assistance from DNR on the adoption of appropriate flood damage curves.

4.2 FLOOR LEVEL AND PROPERTY SURVEY

A detailed floor level survey was carried out as part of the Flood Study (Patterson Britton & Partners, 2003). Floor levels of all dwellings in the vicinity of the creek were obtained except for No. 24 Pretty Beach Road.

Further details of the properties required for flood damage assessment were provided by Council. Appendix G provides floor level and relevant property details in the floodplain.

4.3 DAMAGE ANALYSIS

The flood damage assessment has been undertaken for the existing catchment conditions and a number of flood management options as a part of the Turo Creek, Pretty Beach Floodplain Risk Management Study. The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchment is not available and recourse is generally made to damage curves from other catchments. DNR has carried out research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The DNR methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW.

The following sections set out our methodology for the determination of damages within the Turo Creek floodplain.

4.3.1 Residential Damage Curves

The draft DNR Floodplain Management Guideline No. 4 Residential Flood Damage Calculation (2004) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings:

- Single Storey, slab on ground
- Two Storey, slab on ground
- Single Storey, high-set.

There were a few properties in the Turo Creek floodplain which were .Two Storey, high-set.. As the spreadsheet program did not include details for these properties a conservative approach was adopted and the properties were classified as .Single Storey, high-set.. A single storey building incurs greater flood damages as it is assumed that in a two storey building, house contents can be transferred to the upper storey for safety from flood waters.

Damages are generally incurred on a property prior to any over floor flooding. The DNR curves allow for a damage of $8,174 (February 2006 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.5m below the floor level for slab on ground and 1.5m below the floor level for high-set). The damage remains constant from the base of the house to the floor level of the house.

Due to the varying nature of the properties and houses located in Pretty Beach i.e. steeply sloping properties, level properties, high set houses, low lying houses the DNR approach did not produce a consistent result in damage calculations. As such, the approach was modified for use in this study.

In the modified approach, a linear increase in flood damages was assumed starting from the lowest point of the property to $8,174 at the highest level on the property (i.e. entire property flooded). Beyond this depth, the damage was assumed constant.

Other Parameters

There are a number of input parameters required for the development of DNR curves, such as floor area and level of flood awareness. We have generally followed the DNR recommended default parameters.

A value of 150m2 was adopted as a conservative estimate of the floor area for residential dwellings within the Turo Creek floodplain. With a floor area of 150m2, the default contents value for a house in Sydney is $37,500. A comparison of property prices would suggest that this value is slightly lower for Pretty Beach and as such $33,600 was adopted as the default value (approximately 10% reduction).

The Effective Warning Time has been assumed to be zero. A long Effective Warning Time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches). Our estimation of zero warning time is based on the fast response of the majority of the catchment.

It has been assumed that there are no post flood inflation costs. These inflation costs are generally experienced in regional areas, where re-construction resources are limited and large floods can cause a strain on these resources.

Average Weekly Earnings

The DNR curves are derived for late 2001, and were updated to represent February 2006 dollars. General recommendations by DNR are to adjust values in residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). DNR proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data for AWE from the Australian Bureau of Statistics at the start of the study was for February 2006. Therefore all ordinates in the residential flood damage curves were updated to the February 2006 dollars. In addition, all damage curves include GST as per DNR recommendation.

While not specified, we have assumed that the curves provided in DNR guidelines were derived in November 2001, which allows us to use November 2001 AWE statistics (issued quarterly) for comparison purposes. The AWE shown in Table 4.2 was taken from the Australian Bureau of Statistics website (www.abs.gov.au).

Table 4.2: AWE Statistics from 2001 and 2006

Month	Year	**AWE**
November	2001	$ 849.90
February	2006	$1,035.90
Change		21.88%

Consequently, all ordinates on the damage curves were increased by 21.88%.

The adopted residential damage curves are shown in Figure 4.1.

4.4 RESULTS

Table 4.3 shows the results of the flood damage assessment for various design events.

Table 4.3: Flood Damage Assessment Summary

Event	No of Houses with Over-Floor Flooding	Structural Damage	No of Houses with Over-Ground Flooding	Garden Damage	Intangible Costs (25% of Tangible Costs)	TOTAL
PMF	15	$499,623	28	$76,383	$144,002	$720,008
200 Year ARI	5	$122,630	27	$133,951	$64,145	$320,726
100 Year AR	5	$121,630	27	$129,603	$62,808	$314,041
50 Year ARI	5	$109,551	27	$124,957	$58,627	$293,135
20 Year ARI	4	$94,260	27	$127,225	$55,371	$276,857
5 Year ARI	2	$33,778	26	$120,165	$38,486	$192,429

The total damage for each design event was plotted against the probability of the design event (Figure 4.2). In plotting this damage-probability curve, it was assumed that the flood damages occur up to the 1 year ARI event and no damages occur for more frequent events.

The Average Annual Damage (AAD) was estimated by calculating the area under the damage-probability curve. The AAD for Turo Creek floodplain under existing conditions came out to be $208,088.

Incremental damages assessment for various design events is provided in Table 4.4.

Table 4.4: Damages for Various Design Events

Design Increment	Damage
up to 5 Year ARI	$153,943
5 Year to 20 Year	$ 35,196
20 Year to 50 Year	$ 8,550
50 Year to 100 Year	$ 3,036
100 Year to 200 Year	$ 4,761
200 Year to PMF	$ 2,602
Total Average Annual Damage	$208,088

5 CURRENT EMERGENCY RESPONSE ARRANGEMENTS

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risk to the area. Current flood emergency response arrangements for managing flooding in Gosford LGA are discussed below.

5.1 DISPLAN

Flood emergency management for the Gosford LGA is organised under the Gosford City Local Flood Plan (Gosford Local Emergency Management Committee, 2003). This plan is a sub-plan of the Gosford City Local Disaster Plan (DISPLAN) and has been issued under the authority of the State Emergency and Rescue Management Act 1989 and the State Emergency Services Act 1989. The plan is consistent with similar plans prepared for areas across NSW and covers the following aspects:

- preparedness measures
- conduct of response operations
- co-ordination of immediate recovery measures.

The plan also consists of a series of appendices, which include details of evacuation centres and marshalling areas. Coastal erosion management measures are also included in the plan.

Council has prepared a plan to coordinate response to communities affected by flooding. The Plan titled .Council's Response to Communities Affected by Flooding, Storms and Tempests (H3.05). have been prepared to meet its requirements under the DISPLAN, although this has not been explicitly stated in the plan. The Mayor, on recommendation from the General Manager, activates this Plan.

The DISPLAN generally addresses flood emergency management measures for the major creek systems in the Gosford LGA. However, there are a number of small coastal catchments that are subjected to flash flooding that may require different emphasis on some aspects of flood emergency management. For example, the nature of flash flooding precludes any flood warning and hence emphasis for these catchments should be on post-flood emergency management including the relief measures.

Similarly, there should be more emphasis on educating the community of the flood hazard and measures during and after the flood event, since the community is not likely to be evacuated due to short durations associated with flash flooding in the catchment. The community therefore need to learn/understand the skills required to manage a flood event. Local schools and community forums can be regularly prompted by SES to hold information sessions for the local residents. in the light of the above it is recommended that the Gosford Local Emergency Management Committee consider incorporating special provisions for the small catchments in the LGA such as the Turo Creek catchment in the Gosford City Local Flood Plan.

5.2 SES/EMERGENCY SERVICE FLOOD INTELLIGENCE AND OPERATIONS

The floodplain lies within the Sydney Northern Division of the State Emergency Service (SES). Discussions were held with an SES officer from the Gosford SES as part of the preparation of this report.

The SES reported that no flooding records for the Turo Creek catchment are available and therefore intelligence associated with flood events prior to this date is generally unavailable.

The Gosford SES maintains an Operations Centre at Erina Works Depot, Pateman Road, Erina. SES vehicles and equipment are located at this site. The Gosford Emergency Operations Centre is located at Woy Woy Road, Kariong.

All emergency services for Pretty Beach are located in Woy Woy. The hospital is at Kathleen Street, the Police Station is at Blackwall Road (near intersection with Railway Street) and the NSW Fire Brigade is at Trafalgar Avenue, Woy Woy.

The SES is primarily a volunteer organisation consisting of crew teams. In times of emergency, the SES operates a paging service for each duty crew. However, more experienced crews know when to mobilise based on their understanding of the local area.

The role of the SES in flash flood areas such as the Turo Creek floodplain is generally at the clean up stage. However, possible services in advance that can be made available to residents at risk include holding of information sessions to educate the community.

5.3 FLOOD WARNING SYSTEMS

Due to the short timeframe of flash flooding in the catchment it is not possible to deploy a flood warning system in the catchment. The Bureau of Meteorology, however, issues a severe weather warning. or a .severe thunderstorm warning. for the likely flood events. Current forecasting and warning mechanisms for the Gosford area are based on predictions of severe rainfall, primarily from rainfall radar systems.

Systems to detect rainfall amounts for intense rainfall events (referred to as an ALERT system) are currently in place for the Central Coast area. This system draws upon the Bureau of Meteorology's rainfall gauge network and includes those gauges located as part of the network of Automatic Weather Stations (AWS) that report on a regular basis. Data from this network is available in real-time at the Bureau of Meteorology Flood Forecasting Page for the .Central Coast. at http://www.bom.gov.au/hydro/flood/nsw/greatersyd_clickable.shtml. Details available include 24 hour rainfall totals and rainfall from the last hour in graphical format. Details of depths of rainfall recorded at specific gauges are also available.

The value of the system in providing flood warnings and the consequent timely actions by residents themselves or combat agencies remains an issue due to the very short times to flood peak from the onset of rainfall in catchments such as the Turo Creek.

Advice from the Bureau of Meteorology indicates that the weather-based warnings (Severe Thunderstorm Warnings, Severe Weather Advices, Gale Warnings etc) are faxed to all of the local media outlets as well as the SES. Flood Watches (from the Hydrology Section of the Bureau) are only sent to the SES who then disseminates the information to the local media.

The Gosford City Local Emergency Management Officer can possibly play a role in warning the community by contacting local groups in case of severe weather warnings issued by the BOM. As a guide a measurement of 20-30 mm in an hour for an approaching rainfall should trigger the warning for the catchment. This value is based on the fact that a 5 year ARI event of 2 hour duration (critical for the catchment) results in overbank flooding and the rainfall intensity of this event is 33 mm/hr.

It is to be noted that the above figures for rainfall totals are adopted from the AR&R design rainfall events. Actual events may vary appreciably from the design events and smaller rainfall totals than provided above may result in major flooding in the catchment.

5.4 EVACUATION

The duration of flooding ranges from 1 to 2 hours for all design flood events. The evacuation would normally be undertaken by moving to higher ground away from the floodwaters. For the majority of the flood-affected properties along Como Parade, the residents can temporarily evacuate to Como Parade. However, residents of the flood affected properties fronting Venice Road would not be able to evacuate since Venice Road is flooded and is likely to present a high hazard during a flood event. Similarly flood-affected properties along Pretty Beach Road cannot evacuate and need to remain in their residences. Residents not able to evacuate should move to the upper level of their residences, where available.

5.5 RECOVERY

In a major flood event, structural damage to flood-affected properties may occur and residents may need to be accommodated temporarily during the recovery operation. The Department of Community Services is responsible for the long term welfare of the affected community. However, the immediate action is undertaken through the Gosford SES Local Controller that assists the Gosford Local Emergency Management Committee in establishing a Recovery Coordinating Committee, which in turn prepares a plan for recovery operations.

The above arrangement, as outlined in the Gosford City Local Flood Plan, can cause delays in helping the people in recovery phase of a major flood event. It needs to be recognised that the recovery operation in the Turo Creek floodplain would need to be in place in a matter of few hours after the onset of a major flood event. Hence it is recommended that a nearby community building is nominated as temporary shelter, where the residents can move immediately after the event, before the Gosford Local Emergency Management Committee can mobilise further assistance.

6 LAND USE, ZONING AND TENURE

6.1 PLANNING INSTRUMENTS/POLICY

The principal planning instruments for the Gosford LGA are the Gosford Planning Scheme Ordinance and Interim Development Control Ordinance No 122. The New South Wales Planning Reforms, which are currently under consideration of New South Wales Government, require all local governments to prepare their planning instruments under new guidelines. These reforms emanate from the recent changes to Parts 3 and 4 of the EP&A Act, legislated by the Parliament. The salient features of these reforms are:

- Reduce the number and layers of planning instruments
- All mandatory controls to be included in the Local Environment Plan (LEP)
- Standard LEP template for Councils to update their plans
- Mandatory timeframe for preparing new LEP (3-5 years)
- Rationalise and clarify Development Control Plan (DCP) relationship to LEP
- Replace Master Plans with DCPs and staged development applications.

Under these reforms it is likely that the two planning instruments for Gosford LGA would be merged into a single document as per the standard LEP template. It should therefore be noted that the recommendations made in this report are based on the current documents and would need to be modified once the new LEP is prepared.

Council has indicated that of the two planning instruments, the Gosford Planning Scheme Ordinance (GPSO) is applicable to the urban/developed areas of the LGA, whereas the Interim Development Control Ordinance No 122 is directed towards the rural areas. Since Turo Creek catchment lies in the urban areas of the LGA, only provisions of the Gosford Planning Scheme Ordinance are discussed in this report.

The current zoning for all of the flood affected properties is 2(a) Residential. This zoning does not recognise the flood prone nature of the area and as such is not suitable for the area in the absence of a strict Development Control Plan. GPSO offers an opportunity for alternative zoning of the area to 9(a) Restricted Development (Flood prone Land), which is a more appropriate zoning for the flood affected properties in the Turo Creek catchment. Consideration may be given to rezoning the flood-affected properties to 9(a). An important benefit to be achieved from rezoning is the establishment of the DA requirement for numerous exempt developments as outlined in Schedule 10 . Exempt Developments, No 2 .Ancillary development relating to a dwelling. (garden sheds, property fences etc.). These developments are currently exempt under Zone 2(a) but not under Zone 9(a).

Historically, the Gosford Planning Scheme Ordnance (deemed LEP), together with DCP and Policy, over the years have been successful in guiding development in consideration of flood liability affectations on land zoned residential, industrial, etc. However, flood affectation of these lands has not been recognised in the LEP. The above recommendation for rezoning land in Turo Creek catchment from 2(a) to 9(a) lacks strategic thrust since the recommendation is only for a small area. The recommendation can however provide guideline for any future city wide initiative to change the zoning of flood prone land.

It may be noted that during the preparation of a new city wide Comprehensive LEP under the state government guidelines, the above rezoning may not be required or would need to be considered in the framework of the new Standard LEP Template.

Zone 9(a) .Restricted Development (Flood Prone Land). is discussed in Part III (Restrictions on Building and Use of Land) of the GPSO. Further controls are provided in Part VI (Special Provisions) of the GPSO under section 26 and 49B. Of special interest is the provision under

49B sub clause (3), which requires the use of principles outlined in the Floodplain Development Manual in granting consent for development on the land subject to mixed zoning, including Zone 9(a).

It is recommended that the following amendments be made in the Zone 9(a) description to make the development controls more effective for the flood prone land.

- Provide definition of flood prone land as per the Floodplain Development Manual
- Provide direction to consult the Development Control Plan 115 (Building in Flood Liable Areas).

Additionally, the following amendment is suggested for section 49B sub clause (3) in Part VI of the GPSO to ensure that the principles of the Floodplain Development Manual are applied to all developments to be consented under this section:

.When considering to grant consent as referred to in sub clause (1) and (2) on land within Zone No 9(a) the Council is to take into account the principles of Floodplain Development Manual
(latest version) published by New South Wales Government ..

Historically, the Gosford Planning Scheme Ordnance (deemed LEP), together with DCP and Policy, over the years have been successful in guiding development in consideration of flood liability affectations on land zoned residential, industrial, etc. However, flood affectation of these lands has not been recognised in the LEP. The above recommendation for rezoning land in Turo Creek catchment from 2(a) to 9(a) lacks strategic thrust since the recommendation is only for a small area. The recommendation can however provide guideline for any future city wide initiative to change the zoning of flood prone land.

It may be noted that the above rezoning may not be required or would need to be considered in a different framework during the preparation of a new city wide Comprehensive LEP using Standard LEP Template under the state government guidelines.

6.2 DEVELOPMENT CONTROL PLANS

The relevant Development Control Plans (DCPs) reviewed for this study is:

- DCP No. 115 . Building in Flood Liable Areas
- DCP No. 165 . Water Cycle Management
- DCP No. 159 . Character Statements and Maps.

DCP No. 115 provides the necessary framework for controlling development in the flood liable areas, specifically for the Zone 9(a) .Restricted Development . Flood Prone Land.. However, a number of improvements are suggested to achieve better development control. The suggestions are:

- Reference to the local Floodplain Risk Management Plan for delineation of floodway, flood storage, flood fringe, high hazard and low hazard areas.
- Specific development controls for high hazard areas
- Use of the term Flood Planning Level (FPL) rather than Minimum Floor Level (MFL) and provision of FPL definition. The definition should mention the freeboard incorporated in the FPL. It should also state that the FPL might vary across catchments.
- Change the terminology .Flood Liable Land. to .Flood Prone Land., and amend its definition to include areas inundated by the PMF event, in line with the Floodplain Development Manual.
- Requirement to submit a flood study as part of the DA to ensure that the proposed development will not have an adverse impact on other properties in the catchment.

As part of this Floodplain Risk Management Study, flood extents and flood hazard areas have been determined for various design events including the Probable Maximum Flood. This information will confirm flood categories for the study area and hence development controls applicable to particular allotments. In addition, controls vary depending on the type of development (e.g. dwelling house, recreation area etc.) and associated considerations relating to management of the flood risk.

DCP No 165 requires provision of rainwater tanks for all new and substantially renovated residential developments. Rainwater tanks can provide significant water saving benefits, however, they are shown to provide limited flood benefits (Thomson et al, 2005). The environmental value associated with rainwater tanks stems from the fact that increased runoff from developed areas is controlled for very frequent events. This prevents degradation of creek systems associated with erosion. However, in some catchments rainwater tanks may retain the environmental flows required for a healthy ecosystem. In the Turo Creek catchment, the environmental impact of rainwater tanks is difficult to assess due to limited available data.

Other relevant Council policies and documents are:

- Flood Management Policy E2.02
- Flood Management . NSW Government Policy E2.03
- Setback Policy . Creeks, Rivers and Lagoons E1.01
- Watercourses Obstructions Policy E5.15
- Natural Area Bushland Policy R0.13
- Installation of Unregisterable Movable Dwellings and Rigid Annexes in Caravan Parks on Flood Liable Land Policy D6.17
- Risk Management . Beach Reserves Policy R3.04.

6.3 CURRENT LAND USE AND ZONING

The subject site is located in the Gosford Local Government Area (LGA) where development is controlled through the Gosford Planning Scheme Ordinance (1968). Figure 6.1 depicts zoning for the study site and Table 6.1 describes land use zones within the catchment, current at the time of the study.

Table 6.1: Land Use Zones within the Catchment

Zones	Description
2(a) Residential	• To provide for the orderly and economic development of suitable land for a variety of low density housing forms which are essentially domestic in scale and which have private gardens; and • To provide for other uses, but only where they are: (i) are compatible with a low density residential environment and afford services to residents at a local level; and (ii) are unlikely to adversely affect residential amenity or place demands on services beyond the level reasonably required for low scale housing
3(a) Business (General)	• To provide for the development of retail and commercial centres which make provision for the shopping and service needs of the community at the regional, district or neighbourhood level (or at 2 or more of these levels); and • To allow residential or other ancillary development but only where it is unlikely to significantly prejudice the supply of retail and commercial floor space within the City of Gosford.
5(a) Special Uses	• To provide for the development of some miscellaneous public

Zones	Description
	facilities; and to provide for other land uses if they do not affect the usefulness of the land for the purpose for which it is zoned.
6(a) Open Space (Recreation)	• To identify and make provision for land for the purposes of leisure and recreation to promote community benefits and contribute to the amount and distribution of public open space areas at acceptable levels and at standards which meet the needs of the community.
7(a) Conservation & Scenic Protection (Conservation)	• To provide for the conservation and rehabilitation of areas of high environmental value; • The preservation and rehabilitation of areas of high visual and scenic quality in the natural landscape; • The provision and retention of suitable habitats for flora and fauna; • The prohibition of development on or within proximity to significant ecosystems, including rainforests and estuarine wetlands; • The provision and retention of areas of visual contrast within the City, particularly the "backdrop" created by the retention of the ridgelines in their natural state; • The provision of opportunities for informal recreational pursuits, such as bushwalking and picnics, in appropriate locations; • The minimisation or prohibition of development so that the environmental and visual qualities of the natural areas are not eroded by the cumulative impact of incremental, individually minor developments; • The minimisation or prohibition of development in areas that are unsuitable for development by virtue of soil erosion, land slip, slope instability, coastal erosion or bushfire hazard.
8 National Parks, Nature Reserves and State Recreation Areas Reservation.	• To identify land which is reserved or dedicated under the *National Parks and Wildlife Act* 1974; and to allow for the management and appropriate use of the that land as provided for in the *National Parks and Wildlife Act* 1974.
9(c) Restricted Development (Steep Land)	• Is to ensure that buildings for residential use on land in the zone identified as being steep or unstable are suitably located and constructed.

Desired Character

DCP 159 .Character Statements and Maps. provides details for the desired character for various areas in the Gosford LGA. A character statement for Pretty Beach is available in DCP 159. This statement provides details of the existing as well as the desired character for the area. In particular the statement recommends preservation of the distinctive ridge-top reserve by allowing very low impact developments. The statement, however, does not refer to the scenic quality of waterfalls that develop during rainfall events.

Given the significant feature of .waterfalls./escarpment in the Turo Creek catchment, the character statement may be modified to incorporate the significance of waterfalls and recommendation for its preservation.

Potential Changes to Land Use

As discussed above, the escarpment and the associated .waterfalls. is a significant feature of the Turo Creek catchment. The community has an appreciation for the escarpment, which even in moderate rain events can turn into a cascading waterfall as is evident from photos in Appendix C (sheet 6). The majority of the escarpment is in Zone 7(a) .Conservation and Scenic Protection. and as such has sufficient development controls for the preservation of this feature. The current land zoning for the adjacent areas to the north-east (see Figure 6.1) is 6(a) .Recreational . Open Space. and 9(c) .Restricted Development . Steep Land..

It may be noted that during the preparation of a new city wide Comprehensive LEP under the state government guidelines, the above rezoning may not be required or would need to be considered in the framework of the new Standard LEP Template.

6.4 GOSFORD VISION 2025

In August 2004, Gosford Council set about preparing a strategic direction for the LGA. As a result, Gosford Vision 2025 was prepared, which is a strategic planning initiative to achieve the community objectives for the future. Key focus areas have been identified in the Draft Vision Statements. The Key Focus Areas identified are:

- Creating Economic Opportunity & Employment
- Improving Transportation & Infrastructure
- Protecting the Environment
- Promoting Health & Safety
- Supporting Families, Youth & the Elderly
- Enhancing Arts & Culture
- Strengthening Community Identity
- Expanding Education & Skills Development
- Creating Economic Opportunity & Employment.

Although it is recognised that these key focus areas cover a broad range of aspects and represent the community values, none of these areas specifically deals with managing .hazard. in the LGA. With regards to this study, flood hazard is a particular concern; however other forms of hazard also exist, such as bushfire hazard.

The current draft vision statements indicate that the majority of the city population would live in suburbs located around Brisbane Water or along the coast. However, the vision statements do not include goals for safe living along the coast. It is recommended that hazard (both flood and others) be included in Gosford Vision 2025 or in a supplementary document, either as a separate .Key Focus Area. or in the .Focus Area Vision Statement. for Promoting Health and Safety.

7 FLOOD PLANNING LEVEL REVIEW

7.1 BACKGROUND

The Flood Planning Level (FPL) for the majority of areas across New South Wales has been traditionally based on the 100 year ARI flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 - 0.5 m.

Pretty Beach Floodplain is also affected by the water level rise in Brisbane Water (BW). The minimum flood planning level based on water level rise in BW is 2.45m AHD. This level is derived from the observed water level of 1.95m AHD in BW during the 1974 event at some locations along the foreshore. Since the 1974 event was a very large flood event, the observed flood level has been designated as the 100 year ARI flood level for BW. The flood planning level, which is based on 100 year ARI flood level, is obtained by adding 0.5m freeboard to the observed level of 1.95m AHD. The 100 year ARI flood level, however, may change in the light of the ongoing Brisbane Water Foreshore Flood Study (BWFFS) by Cardno Lawson Treloar, thereby warranting a revision in the flood planning levels in the foreshore areas including Pretty Beach. The BWFFS aims to determine the design flood level(s) in BW foreshore more accurately with the help of new data and techniques that have become available over the last 30 years.

A variety of factors are worthy of consideration in determining an appropriate FPL. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use need to be accounted for in the setting of an FPL.

The Floodplain Development Manual (2005) identifies the following issues to be considered:

- risk to life
- long term strategic plan for land use near and on the floodplain
- existing and potential land use
- current flood level used for planning purposes
- land availability and its needs
- FPL for flood modification measures (levee banks etc.)
- changes in potential flood damages caused by selecting a particular flood planning level
- consequences of floods larger than the flood planning level
- environmental issues along the flood corridor
- flood warning, emergency response and evacuation issues
- flood readiness of the community (both present and future)
- possibility of creating a false sense of security within the community
- land values and social equity
- potential impact of future development on flooding
- duty of care.

These issues are dealt with collectively in the following sections.

7.2 LIKELIHOOD OF FLOODING

As a guide, Table 7.1 has been reproduced from the Floodplain Development Manual (2005) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Table 7.1: Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70 years)

Likelihood of Occurrence in any year (ARI)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
1 in 10	99.9	99.3
1 in 20	97	86
1 in 50	75	41
1 in 100	50	16
1 in 200	30	5

Analysis of the data presented in Table 7.1 gives a perspective of the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1 in 100 year event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1 in 100 year flood event as the basis for the flood planning level. Given the social issues associated with a flood event and the non-tangible effects (such as stress and trauma), it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 1 in 200 year magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

7.3 LAND USE AND PLANNING

With regard to the long-term strategic plan for land use and existing and potential land use within the catchment, it is understood that the area will be retained as a residential area in its current form. The upper parts of the catchment, being part of the Bouddi National Park, would also be retained as such. Therefore the hydrological regime of the catchment is not likely to change and as such no additional freeboard on flood levels will be required for the lower floodplain area.

The only scenario that can change the catchment behaviour would be the outbreak of fire in the Bouddi National Park in the catchment. In such a scenario, the peak flow in the creek through the residential area is likely to increase. Hence consideration may be given to provide a free-board based on the results of the sensitivity analysis of design flood levels.

Council's current practice for residential areas sets the flood planning level at the 100 year ARI level + 0.5 m. However, Council has adopted no specific policy for this purpose.

The current DCP No 115 .Building in Flood Liable Land. does not define the flood planning level. It is recommended that the DCP No 115 be amended, providing definition of the FPL for various landuses (residential, commercial, industrial etc) in the LGA.

7.4 DAMAGE COST DIFFERENTIAL BETWEEN EVENTS

Based on the existing flood behaviour and the assessment of flood damages, the incremental difference in damage for different recurrence intervals is shown in Table 7.2.

Table 7.2: Damage Differential Costs – All Damages Unprepared Case

Event	Total Damage	Difference PMF	Difference 200 yr	Difference 100 yr	Difference 50 yr	Difference 20 yr
PMF	$720,008	-	-	-	-	-
200 Year ARI	$320,726	$399,282	-	-	-	-
100 Year ARI	$314,041	$405,967	$6,685	-	-	-
50 Year ARI	$293,135	$426,872	$27,591	$20,905	-	-
20 Year ARI	$276,857	$443,151	$43,869	$37,184	$16,279	-
5 Year ARI	$192,429	$527,579	$128,297	$121,612	$100,707	$84,428

Table 7.2 indicates that there is a significant difference between the economic effects of the 200 year ARI flood and the PMF whereas the difference between the 200 year ARI flood and the 20 year ARI flood is approximately only $128,000.

7.5 INCREMENTAL HEIGHT DIFFERENCE BETWEEN EVENTS

Consideration of the average height difference between various design flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour (Section 3) The incremental peak height difference between events as averaged across the catchment for the existing case is shown in Table 7.3. Details of design flood levels are presented in Appendix E.

Table 7.3: Relative Differences between Design Flood Levels

Event	Diff PMF (m)		Diff 200yr (m)		Diff 100yr (m)		Diff 50yr (m)		Diff 20yr (m)	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
200 year	0.54	0.26	-	-	-	-	-	-	-	-
100year	0.58	0.27	0.04	0.02	-	-	-	-	-	-
50 year	0.63	0.29	0.09	0.04	0.05	0.02	-	-	-	-
20 year	0.68	0.31	0.15	0.07	0.1	0.05	0.06	0.02	-	-
5 year	0.84	0.36	0.3	0.11	0.25	0.1	0.21	0.08	0.15	0.06

Avg - Average Difference SD- Standard Deviation of Differences

Table 7.3 indicates that the maximum difference between the PMF event and other design events gradually increases up to the 20 year ARI event (0.54m to 0.68m). However, there is a significant increase in difference for the 5 year ARI event (0.84m).

The average difference between the other design events excluding PMF and the 5 year ARI events is of the order of 0.1m. In particular the difference between the 200 year and the 100 year events is only 0.04m. In addition, the adoption of the 200 year ARI level as the flood planning level is only marginally different from the 100 year ARI event and not considerably different from the 20 year ARI event (0.15m). Thus adoption of 200 year ARI event would provide an increased level of risk reduction for a small increase in elevation (see table 7.1). The adoption of the PMF as the flood planning level results in a more significant increase in level over the 200 year ARI event (0.54 m) and would therefore potentially present an issue for the setting of habitable floor levels for the floodplain.

7.6 CONSEQUENCE OF ADOPTING THE PMF AS A FLOOD PLANNING LEVEL

Table 7.3 indicates that the PMF is, on average, 0.58 m above the 100 Year ARI flood level. Should the PMF be adopted as the flood planning level, 15 properties would have floor levels lower than the planning level ranging from 0.16m to 0.59m. If the 200 year ARI flood was adopted as the flood planning level, 5 properties would have floors lower than the planning level

ranging from 0.06m to 0.22m and if the 100 year ARI event was adopted, 5 properties would have floors lower than the planning level ranging from 0.04m to 0.20m.

Given the risk of exposure outlined in Table 7.1, it is recommended that emergency response facilities be located outside of the floodplain and any other likely critical facilities be limited to areas outside of the floodplain. Other critical facilities/infrastructure is suggested to have a floor level at the PMF.

7.7 ENVIRONMENTAL ISSUES

Given that the flood corridor is entirely within the private ownership, there are no significant environmental issues that control the flood planning level. The likely issue could be a variation in design flood levels due to creek rehabilitation works. This issue would need to be considered in estimating the freeboard requirements for the FPL.

7.8 READINESS, WARNING, RESPONSE AND EVACUATION

The community has not been exposed to a significant flood since 1990 and as such the state of readiness is expected to be low in the catchment. Given the short critical duration for the catchment, the potential for warning, response and evacuation is very limited.

As such, the adoption of a flood planning level that is elevated and rarer in occurrence (such as the 200 year ARI event) could be an appropriate choice with regard to these factors. Given this recommendation, it is important that the community is reminded of the possibility of floods rarer than the FPL event occurring in the catchment. It is therefore important that suitable information for rarer floods (PMF) is provided to the community such as the information presented in this report.

7.9 CLIMATE CHANGE . SEA LEVEL RISE

Engineers Australia (2004) provide an estimate for projected sea level increases as a result of the .greenhouse effect. to 2100 with a central figure of 0.5 m (a range of 0.1 . 0.9 m). These estimates are produced from a range of scenarios. Engineers Australia (2004) also report a central projected sea level rise for a 20 year planning period (i.e. to 2030) to be of the order of 0.1 m.

Thus, any freeboard allowed for in the assignment of flood planning levels should include a consideration of the potential impact of sea level rise.

7.10 CLIMATE CHANGE . CHANGE IN RAINFALL PATTERNS

There are very limited quantitative studies to produce likely rainfall patterns under climate change scenarios. However, all of the global circulation models predict an increase in the total level of precipitation (Lowe, 2005). Hennessy et al (2004) considered events from the 1 in 5 year event through to a 1 in 40 year event for the whole of NSW for a 1 day event duration and a 3 day event duration. These event durations are outside of the Turo Creek floodplain critical duration of 2 hours. Only limited information is available for durations shorter than 1 day.

For the south-east region, Hennessy et al (2004) found that there are likely to be increases in 1 day event rainfall (~10%) out to 2070 in spring, summer and autumn and decreases in winter. In the case of 3 day events, a projected decrease in intensity was identified for coastal regions for autumn, winter and spring but an increase (~20%) for summer to 2070.

Thus, the consideration of the order of a 20% change in rainfall (assuming an equal translation to a 20% increase in runoff) appears to be reasonable as an upper bound of the likely change in rainfall intensity for the critical duration event based on the available data.

7.11 FREEBOARD SELECTION

As outlined above, a freeboard ranging from 0.3 - 0.5 m is commonly adopted in determining the FPL. It should be realised that the freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. This consideration may result in the adopted FPL being higher than the PMF in certain cases. However, given the purpose of freeboard i.e. its use as safety factor, the FPL should still be used in such cases.

The freeboard generally accounts for factors such as:

- changes in the catchment
- changes in the creek/channel vegetation
- accuracy of model inputs (e.g. accuracy of ground survey, accuracy of design rainfall inputs for the area)
- model sensitivity
- local flood behaviour (e.g. such as wave wash by passing cars/emergency vehicles),
- climate change.

The accuracy of ground survey used in the modelling is generally of the order of ±0.01 m for each point surveyed. The accuracy of the rainfall inputs is more difficult to translate to a level accuracy. Instead, the effects of the overall hydrological response of the catchment on levels were considered via assessments of model sensitivity to changes in hydrological inputs and floodplain condition. The model sensitivity was generally found to be of the order of 0.1 m (Appendix F).

The impact of various elements factored into a freeboard can be summarised as follows:

- Uncertainty in flood modelling (~0.2 m)
- Afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1m) (adopted from Gillespie (2005))
- Local wave action (~0.1 m) (truck wash etc)
- Climate change . Sea Level Rise (0.1 m).

Generally no allowance has been made in estimates to date to address changes in rainfall as a result of climate change. However, to address the likely increase in the rainfall, it is assumed that the outcome of increased rainfall would be an increase in catchment discharge of 20%. Based on the sensitivity analysis of the model results, this increase in discharge would result in a maximum increase of 0.15m in the Turo Creek floodplain.

The impact of potential wind waves for foreshore properties is not included in the above analysis nor any allowance been made for the potential wind set-up and wave run-up associated with the wind waves generated. The local waves and the wind waves along with the wave run-up are not likely to occur at the same time and as such the allowance for local waves can also serve to provide a partial allowance for wind waves/wave run-up, which are likely to produce much higher increase in the water level.

Note that the provision for climate change is recommended for review on a periodic basis (at least every 5 years), as new information from research becomes available.

In the light of the above discussion, a freeboard of 0.5m would be appropriate for properties not affected by the Brisbane Water. However an additional freeboard would be required for the foreshore properties. Estimation of this component of the freeboard can be undertaken after completion of the ongoing Brisbane Water Foreshore Flood Study, which would establish wind-wave climate for various locations along the foreshore, including Pretty Beach.

The above recommendation does not include impact of climate change on rainfall. If this factor were to be included in the freeboard determination, an additional allowance of 0.15m would be required as discussed above.

7.12 RECOMMENDED FLOOD PLANNING LEVELS AND FREEBOARDS

In light of the information presented in Sections 7.1 - 7.11, it is recommended that:

- The flood planning level (FPL) for residential areas be based on the 100 year ARI flood event with the adoption of an appropriate freeboard as discussed above. The minimum FPL in the entire floodplain is 2.45 m AHD, which is derived from Brisbane Water flooding. This FPL is subject to modification following completion of the ongoing Brisbane Water Foreshore Flood Study.
- For residences where the adopted FPL is higher than the PMF, the FPL should be used
- As a result of the residential FPL, it should be ensured that the habitable floor levels in all new development are above the 100 year ARI + 0.5 m.
- The FPL for Special Use areas be set at the PMF or the 200 year ARI +0.5m, whichever is higher. The minimum FPL in the entire floodplain is 2.45 m AHD, which is derived from Brisbane Water flooding. This FPL is subject to modification following completion of the ongoing Brisbane Water Foreshore Flood Study.
- Emergency services and flood evacuation centres should be prohibited in the floodplain.

8 ENVIRONMENTAL AND SOCIAL CHARACTERISTICS OF FLOODPLAIN

8.1 CATCHMENT TOPOGRAPHY

The Turo Creek catchment lies to the south of Gosford and drains a catchment area of approximately 44 ha from Bouddi National Park to the south to Brisbane Water in the north-west. The catchment, shown in Figure 1.2, is characterised by a low-lying coastal zone east of Brisbane Water, rising steeply to an escarpment. The escarpment rises to a height of 112 m AHD, with grades in the upper catchment of greater than 25 %. The lower part of the catchment is moderately flat (approximately 2 - 3 % gradient).

Residential development is primarily located in the lower lying areas of the catchment.

8.2 CREEK CHARACTERISTICS

Turo Creek is located behind Pretty Beach at Wagstaff. It flows through private properties at the lower end of the floodplain and then into Brisbane Water via a box culvert located under Pretty Beach Road near Turo Reserve. The creek divides the properties fronting Venice Road and most of the owners have constructed footbridges across the creek to gain access to the rear section of the properties.

8.3 CATCHMENT AND CREEK DEBRIS

Debris sources range through the catchment from natural materials that become entrained in flood flows or sediment that is scoured from banks/beds of natural creek systems. Where creek banks or bed areas are unstable (e.g. due to the removal of vegetation), the potential for debris materials to be generated during a flood event is high. Other sources of debris include illegally dumped waste and even rubbish bins (if a flood event occurs on a waste collection night). Essentially, any items that lie within the flow path which are not fixed items can become debris.

A survey of local residents, undertaken by Patterson Britton and Partners in 2000, indicates that the pedestrian bridges have often blocked to various degrees in the past. Debris is noted to have been an issue at Como Parade (primarily due to access bridges), Pretty Beach Road Bridge and the pedestrian bridge upstream (Patterson Britton and Partners, 2000).

8.4 RECEIVING WATERS - BRISBANE WATER

Brisbane Water forms the downstream boundary of the study area. Existing tidal information has been summarised in Table 8.1. This data has been extracted from a study by Manly Hydraulics Laboratory (2004) on tidal data collection in Brisbane Water Estuary in 2004. The information in Table 8.1 is approximated using .Site 2. and .Site 4. data. Site 2 is located at Ettalong (permanent water level recorder) and Site 4 is located at Booker Bay (temporary water level recorder 450 m downstream from the Rip Bridge)

Table 8.1: Tidal Planes – Woy Woy Inlet (MHL 2004)

Tidal Phase	Water Level (m AHD)
High High Water	0.75
Medium High Water Spring	0.5
Medium High Water	0.45
Medium High Water Neap	0.35
Medium Tide Low	0.1
Medium Low Water Neap	-0.15
Medium Low Water	-0.25
Medium Low Water Spring	-0.3
Indian Spring Low Water	-0.5

8.5 GEOLOGY, SOILS, SEDIMENTS AND GEOMORPHOLOGY

The general area surrounding Turo Creek is gently sloping in the low-lying areas with a steep escarpment rising to the east. The Bouddi Peninsula is based upon two sedimentary rock types; Hawkesbury sandstone and the Terrigal formation of the Narrabeen group.

The lower floodplain coastal beach area is described as Cockle Bay soil landscape by the 1:100,000 soil landscape map for Gosford . Lake Macquarie (DCLM, 1993). This consists commonly of a saturated grey, light sandy clay loam to a medium clay with apedal massive structure and a dense fabric. Landscape limitations are described as flood hazard (localised), seasonal waterlogging, permanent waterlogging (localised) and water erosion hazard. This soil type has low permeability.

The escarpment is a combination of colluvial (Watagan and Hawkesbury soils) and erosional (Erina soils) landscapes. The geology consists of Hawkesbury and Narrabeen Group Sandstone, medium to coarse-grained quartz sandstone with minor shale and laminate lenses. The Terrigal formation of the Narrabeen Group consists of lithic and quartz sandstone and siltstone, minor sedimentary breccia, claystone and conglomerate. Some of these sandstones are highly weathered and friable.

The soil limitations of the above mentioned soil types are a combination of stoniness of the topsoil, low available water capacity and low permeability, with only Hawkesbury soil type (ha1 . topsoil) consisting of high permeability amongst its characteristics (DCLM, 1993).

Acid Sulfate Soils

The Broken Bay Acid Sulfate Soil Risk Map . Edition 2 (DLWC, 1997) indicates that there is high probability of occurrence of acid sulfate soil materials within the soil profile within 1 m of the ground surface and between 1 and 3 m below the ground surface at Pretty Beach. The environment of deposition has been suitable for the formation of acid sulfate soil materials. Acid sulfate soil materials are widespread or sporadic and may be buried by alluvium or windblown sediments. Figure 8.1 shows the distributions of low, high and no known occurrence or acid sulfate soils available from Council.

Contaminated Soils

The existing environment consists of Residential; Business (General); Open Space (recreation); Conservation; National Parks; and Restricted Development (steep land). The surrounding vicinity incorporates Bouddi National Park. The subject area has not been exposed to industrial activity and it is unlikely that this land would be contaminated. A search of the EPA Contaminated Land Register showed no known contaminated sites within the catchment or surrounding area (EPA, March 2005).

8.6 WATER QUALITY

The existing stormwater drainage system is mainly located in High View Road and Pretty Beach Road with Venice Road partly serviced and Como Parade having no formal piped drainage system (Patterson Britton, 2003).

The existing drainage systems comprises of eleven pipe networks, nine of which directly discharge to Brisbane Water and two of which discharge to Turo Creek before discharging to Brisbane Water (Figure 8.2).

Sources of pollutants to impact upon water quality include:

- Point Sources - Discharges from premises licensed by the DEC (EPA) within the catchment under the Protection of the Environment Operations Act (1997)
- Non Point Sources . Discharges from diffuse sources (such as build up of pollutants on road surfaces, runoff from fertilised gardens).

There are no identified point sources within the catchment. Non-point sources are primarily related to the residential development. No specific water quality data is available for Turo Creek.

8.7 FLORA, FAUNA AND RIPARIAN AREAS

8.7.1 Flora

The Turo Creek catchment consists partly of urban land use with associated landscaping as the general vegetation type. However, the surrounding area incorporating Bouddi National Park consists of a variety of vegetation types.

Figure 8.3 shows the various types of vegetation, including mangroves and seagrass within the study catchment and surrounding area. The vegetation listed that is located within the study catchment consists of Urban; Disturbed . canopy only; Bouddi Sandstone Coastal Heath; Wagstaff Spotted Gum Ironbark Forest and Exposed Hawkesbury Woodland.

A search of the Atlas of NSW Wildlife (DEC, 2005) revealed 20 species as listed under the Threatened Species Conservation Act 1995 in the Gosford LGA. There were none recorded in the vicinity of the Turo Creek catchment.

Native plant communities within Bouddi National Park identified by National Parks (DEC, 2004) are as follows:

- Heathlands . low, shrubby plant community. Several distinct types exist reflecting various soil types and aspects;

- Woodlands . usually the name given to plant communities with trees 5 . 30 m high, with sparse cover. There are several types of woodland on the Bouddi Peninsula due to the differences in soil types and exposure to extreme winds; and

- Eucalypt forests . open forest communities dominated by black butt (Eucalyptus pilularis), grey gum (E. punctata) and Sydney red gum (Angophora costata) occur in sheltered locations, mainly on south and east facing aspects. These forests occur on the north side of Scenic Road (DEC, 2004).

Heathlands:

The heath community on Hawkesbury sandstone, especially at Box Head, consists of casuarina (Allocasuarina distyla), heath-leaved banksia (Banksia ericifolia), dagger hakea (Hakea teretifolia) and the uncommon Rulingia hermanniifolia.

Woodlands:

Woodland species are most likely to be found on ridges, plateaus and exposed slopes on sandy soils of the Hawkesbury sandstone. The main tree species are as follows:

- Red bloodwood (Corymbia gummifera)
- Scribbly gum (Eucalyptus haemastoma)
- Sydney red gum (Angophora costata)
- Sydney peppermint (Eucalyptus piperita)
- Forest oak (Allocasuarina torulosa).

On shale soils (Narrabeen sandstone), the main tree species are bastard mahogany (Eucalyptus umbra), grey ironbark, red gum and turpentine (Syncarpia glomulifera). On perched sand dunes it is more common to find Sydney red gum, bastard mahogany and casuarina (Allocasuarina distyla).

Eucalypt Forests:

Palm-dominated open forest exists in sheltered gullies such as behind Maitland Bay and Little Beach. This community may consist of species such as bangalow palm (Archontophoenix cunninghamiana), mountain blue gum (Eucalyptus deanei) and forest oak (Allocasuarina torulosa) as well as scattered ferns and scattered shrubs.

Introduced Species:

General weeds species introduced to this area, predominantly in the Bouddi National Park are as follows:

- Bitou Bush . common behind beach areas and along exposed cliff faces;
- Lantana . more common in disturbed areas such as picnic areas, adjacent to tracks and throughout the urban interface;
- Blackberry;
- Crofton weed;
- Pampas grass;
- Asparagus fern; and
- Coral tree.

8.7.2 Fauna

Bouddi National Park provides a natural habitat for a variety of fauna. The following section describes the type of native animals that have been noted by the National Parks (DEC, 2004) as utilising this area.

Mammals:

Bouddi National Park, bordering the Turo Creek catchment provides habitat for such mammals as possums, gliders, bandicoots, antechinuses and swamp wallabies. These species forage amongst the various types of vegetation.

There have been twelve species of micro-bats recorded on the Bouddi Peninsula (DEC, 2004). These include four species listed as threatened under the Threatened Species Conservation Act 1995, which are:

- Yellow-bellied sheath tail bat;
- Common bent-wing bat;
- Little bent-wing bat; and
- Large-eared pied bat.

Other species include:

- White-striped mastiff bat;
- Gould's long-eared bat;
- Gould's wattled bat;
- Eastern forest bat;
- Little forest bat;
- Little broad-nosed bat;
- Little freetail bat; and
- Eastern horseshoe bat.

A number of marine mammals appear on an irregular basis, with fur seals on a rare occasion visiting beaches and coastal platforms.

Birds:

There have been over 150 bird species recorded on the Bouddi Peninsula, reflecting the diversity of habitats found within the area. The heathlands are important feeding areas for migratory honeyeaters, which visit the Central Coast during winter (DEC, 2004).

Palm-dominated rainforest provides an important food source for the uncommon migratory rainforest fruit-eating pigeons. Other locally restricted species are as follows:

- White-bellied sea-eagle;
- Peregrine falcon, which nests on sea cliffs;
- Brush bronzewing;
- Tawny-crowned honeyeater and the southern emu-wren, which live on low coastal heaths; and
- Reef egret, which is found in small numbers on the coastal rock platforms.

Reptiles and Amphibians:

Lizards of this area range from tiny skinks and geckos to enormous lace monitors (goannas). Other species found in this vicinity are bearded dragons, mountain dragons, eastern water dragons, jacky lizards and blue-tongued lizards (DEC, 2004).

There are a variety of snake species also located in this area, such as the diamond python and the brown tree snake. These two species most likely to be found in trees where as species such as the red-bellied black snake and marsh snake are found in moist areas around swamps and creeks. The Kreffts dwarf snake, which is rare, and the golden crowned snakes prefer moist forested areas.

Six species of frog have been recorded in the vicinity, however as many as 16 are potentially thought to occur (DEC, 2004). The six species that have been recorded are as follows:

- The common eastern toadlet;
- The striped marsh frog;
- The whistling tree frog;
- The dwarf tree frog;

- Perons tree frog; and
- The threatened red-crowned toadlet.

8.7.3 Fish

A variety of common fish species are likely to occur within the coastal zone of the catchment. A desktop search on the NSW Fisheries database revealed that there are no known threatened species listed in this catchment.

Invertebrates:

A variety of invertebrates are likely to occur within the coastal rock platforms of the catchment.

8.8 RECREATIONAL USE

The Brisbane Water foreshore area caters for a variety of human users. These users can be categorised into .active. users (those users who require a vehicle, equipment or watercraft for their activity) and .passive. users (those users not requiring a watercraft, vessel or specialised equipment) (KBR, 2005). The majority of users of reserves and open space areas along the foreshore are passive users. The weekend and summer period are when peaks in usage occur.

Recreational activities that take place in this area are as follows:

- Passive use of reserves and open space
- Shore-based recreational fishing
- Picnicking
- Bushwalking
- Sightseeing
- Bird watching
- Walking and jogging
- Cycling
- Dog exercising
- Organised / team sports
- Other recreational (eg yoga, tai chi).

Recreational facilities / areas at Wagstaff are primarily National Park, Reserves and Parks, Picnic Areas (including public toilets) and beach.

8.9 ABORIGINAL AND EUROPEAN CULTURAL HERITAGE

8.9.1 Indigenous Cultural Heritage

A desktop review of the National Parks and Wildlife . Cultural History site was undertaken (DEC, 2004) which revealed that the Bouddi National Park contains over 100 recorded Aboriginal sites. The recorded sites include the following:

- Middens;
- Rock engravings;
- Axe grinding grooves;
- Rock shelters with drawings / paintings; and

- Other archaeological deposits.

No specific Aboriginal sites were identified within the floodplain area from this desktop review.

8.9.2 Non-indigenous Heritage Items

A desktop review of non-indigenous heritage was undertaken for the study site. Searches were undertaken on a number of databases to determine the cultural heritage within this area. Databases searched include:

- NSW Heritage Office . State Heritage Inventory Search; and
- Australian Heritage Database (incorporates World Heritage List; National Heritage List; Commonwealth Heritage List; Register of the National Estate).

There were a total of 11 records listed under the State Heritage Inventory for the Gosford LGA and 38 records listed under the Australian Heritage Database. None of these sites were shown to exist in the vicinity of the floodplain.

8.10 VISUAL AMENITY

The existing conditions within Turo Creek catchment are a mixture of urban development amongst a coastal setting. The surrounding area consists of National Park to the south east and Brisbane Water to the north both these areas would be considered to have significant pleasing visual amenity.

There are features within Turo Creek catchment that the local community considers to be visually pleasing, in particular the waterfalls, which develop from the top of the escarpment after a rain event. The scenic character of the catchment has been described as a desired character in DCP 159 (Character Statement for Pretty Beach).

8.11 DEMOGRAPHIC CHARACTERISTICS

Demographic characteristics of the Gosford Local Government Area (LGA) were derived from the Australian Bureau of Statistics from the 2001 census. Relevant data to assist with describing the characteristics of the Pretty Beach area (which are assumed to be represented by the statistics for the wider local government area) are shown in Table 8.2.

The State of the Environment Report 2003 for Gosford City Council states that the 2001 census recorded the population for the LGA to be 154,654. Council resolved to cap the population for the area at 169,000, which is the predicted population figure for 2011 as advised by The Department of Planning (Gosford City Council, 2003).

Table 8.2: Demographic Data for Gosford LGA (2001 Census*)

Details	Proportion of Population
Aged 14 years and younger	20.9 %
Aged 15 years to 44 years	38.7 %
Aged 45 years to 64 years	23.0 %
Aged 65 years and over	17.4 %
Median Age	38 years
Total Indigenous Persons	1.4 %
Australian born	80.2 %
Main Other Countries of Origin	UK, New Zealand, Germany
English Speaking Only	91.7 %
Living in a Private Dwelling	69.5

* note that total persons in Gosford Statistical Area was 154, 654.

The local population is small with approximately 75 allotments within the catchment area zoned residential. This local area has low population density.

These figures are relevant and useful for the assessment of emergency response modification options.

9 OPTIONS FOR MANAGING FLOOD RISK – GENERAL

9.1 OVERVIEW OF AVAILABLE MEASURES

Flood risk can be defined as being existing, future or residual risk:

- Existing flood risk - the existing problem refers to existing buildings and developments on flood prone land. Such buildings and development by virtue of their presence and location, are exposed to an 'existing' risk of flooding.
- Future flood risk - the future problem refers to buildings and developments that may be built on flood prone land in the future. Such buildings and developments may be exposed to a 'future' flood risk, i.e. a risk would not materialise until the developments occur.
- Continuing risk of flooding - the continuing problem refers to the 'residual' risk associated with floods that exceed management measures already in place, i.e. unless a floodplain management measure is designed to withstand the Probable Maximum Flood, it will be exceeded by a sufficiently large flood at some time in the future.

Measures available for the management of flood risk can be categorised according to the approach adopted to manage the risk. The alternative approaches to managing risk are outlined in Table 9.1 (after SCARM, 2000):

Table 9.1: Flood Risk Management Alternatives

Preventing/Avoiding risk	i.e. setting the planning level at the Probable Maximum Flood or not allowing development to be within the floodplain
Reducing likelihood of risk	i.e. implementing structural measures to reduce risk. The potential for implementation of flood modification options is limited by economic, social and environmental constraints
Reducing consequences of risk	i.e. using development controls - design of structures to withstand flooding, allows a floodplain to be developed in lower areas
Transferring risk	via insurance - not viable given the non-insurability of most flood-prone areas
Financing risk	through natural disaster funding
Accepting risk	regardless of the options implemented, a continuing risk will be present.

As a result, there are three types of measures for the management of flooding:

- Flood Modification Measures (for the existing risk)
- Property Modification Measures (for the future risk)
- Emergency Response Modification Measures (for the residual risk).

9.2 OPTIONS IDENTIFIED BY THE COMMUNITY

A community survey was undertaken and the residents identified a number of flood management options (Section 2). These options are listed in Table 9.2 starting with the most desired by the residents.

Table 9.2: Resident Identified Flood Modification Options

Location	Option
Como Parade, Pretty Beach Road	Culvert Enhancement
Turo Creek from Como Parade to Pretty Beach	Channel Widening/Deepening
Improved street drainage and overland flow in the catchment	Improved Overland Flowpaths
Catchment wide	Planning Controls
Along Turo Creek	Levee Banks
Upstream of Como Parade	Retarding or Detention Basin

In addition to those options identified in Table 9.2, a number of other options were identified during the course of the study. These options are described in the Sections 10, 11 and 12. Assessment of these options is undertaken in Section 13.

10 OPTIONS FOR MANAGING FLOOD RISK – FLOOD MODIFICATION OPTIONS

Based on historical flood information, flood study results and field inspections of the catchment, possible flood modification options (i.e. structural options) for various locations within the floodplain were identified. Table 10.1 lists all of the flood modification options identified in the catchment (option identifier .FM. for Flood Modification). The list includes options identified by the residents.

Table 10.1: Flood Modification Options Summary

ID	Location	Option
FM1a*	Pretty Beach Road and Pedestrian Crossing	Culvert Enhancement (Double Existing Culvert Capacity)
FM1b*	Pretty Beach Road and Pedestrian Crossing	Culvert Enhancement (Triple Existing Culvert Capacity)
FM2*	Between Como Parade and Pretty Beach Rd	Removal of all private access bridges and replacement with causeways
FM3*	Between Como Parade and Pretty Beach Rd	Creek Enhancement (creek widened to 5m) and private access bridges replaced with arched bridges
FM4*	Between Como Parade and Pretty Beach Rd	Creek Enhancement (creek widened to 5m) and Realignment with private access bridges removed
FM5*	Upstream of Como Parade	Detention Basin
FM6a*	Lower reaches of Creek upstream of Pretty Beach Rd	Creek Enhancement (creek widened to 5m) in the lower reaches of Creek and private access bridges removed and replaced with causeways.
FM6b*	Lower reaches of Creek upstream of Pretty Beach Rd	Creek Enhancement (creek widened to 5m) in the lower reaches of Creek and private access bridges removed and replaced with causeways. Pretty Beach Culverts enhanced (from 2 cells to a total of 6 culvert cells)
FM6c*	Lower reaches of Creek upstream of Pretty Beach Rd	Creek Enhancement (creek widened to 5m) in the lower reaches of Creek and private access bridges removed and replaced with causeways. Pretty Beach Culverts enhanced (from 2 cells to a total of 12 culvert cells)
FM7	Between Como Parade and Pretty Beach Road	Levee Banks
FM8	Catchment wide	Improvement of Drainage Infrastructure, including Improved Overland Flowpath along Venice Road
FM9	Catchment Wide	Improvement/Preservation of Overland Flowpaths
FM10*	Upstream of Como Parade.	Implementation of a Bypass Culvert - Upstream of Como Pde to Brisbane Water.

**Indicates detailed hydraulic modelling of this option was undertaken.*

Constraints associated with these options include:

- Works potentially not being able to be undertaken on private land (e.g. creek widening)
- Significant cost

- Environmental impacts.

The above options are discussed below in detail, where results of hydraulic analysis of Options FM1a to FM6c and FM10 are presented (indicated in Table 10.1 above). Hydraulic modelling was also undertaken for some of the drainage components in FM8. Details of this analysis are also provided. The assessment of each option is outlined below.

10.1 FM1A - PRETTY BEACH CULVERT AND PEDESTRIAN BRIDGE ENHANCEMENT - DOUBLE CULVERT CAPACITY

The Culvert at Pretty Beach Road currently consists of 2 cell culvert with each cell 2.4m wide by 1.2m high. The hydraulic modelling of the existing case shows that the floodwaters from Turo Creek build up behind Pretty Beach Road. This is due to the limited conveyance capacity of the existing culverts under Pretty Beach Road. This option considers enhancing the culverts at Pretty Beach Road by two additional cells (the same dimensions as the existing cells), thereby doubling the culvert capacity.

This would require works such as excavation, diversion of flows, laying of concrete culverts, public utility adjustment and resurfacing of Pretty Beach Road, among other works.

The hydraulic model was modified to represent additional culvert cells. The modelling results show that this option does not provide a significant benefit in decreasing flood levels. The maximum reduction in flood levels in the 100 year ARI event is 8cm. This occurs at the very downstream sections of Turo Creek and provides some benefit for the properties located along Pretty Beach Road.

This option is presented in Figure 10.1 and Figure 10.2 shows the impact of this option on the 100 Year ARI flood levels.

10.2 OPTION FM1B - PRETTY BEACH CULVERT AND PEDESTRIAN BRIDGE ENHANCEMENT - TRIPLE CULVERT CAPACITY

This option is similar to Option FM1a and would enhance the culverts at Pretty Beach Road by four additional cells (the same dimensions as the existing cells). This would triple the culvert capacity.

This option would require works such as excavation, diversion of flows, laying of concrete culverts, public utility adjustment and resurfacing of Pretty Beach Road, among other works.

Hydraulic modelling of this option shows a greater benefit than that provided by doubling the culvert capacity. The greatest reduction in flood levels achieved was 24cm. However, as with option FM1a the reduction in levels only occur in the very downstream reaches and as such did not provide a significant benefit to many of the current flood prone properties.

This option is presented in Figure 10.1 and Figure 10.2 shows the impact of this option on the 100 Year ARI flood levels.

10.3 OPTION FM2 - REMOVAL/MODIFICATION OF UNAPPROVED PRIVATE ACCESS BRIDGES

There are a number of private access bridges across Turo Creek in the properties located along Venice Road. The bridges generally result in an increase in flood levels, especially when blockage occurs. As such this option assessed the benefit of removing or modifying these bridges.

As the access bridges are on private property the removal and/or modification of these bridges is the responsibility of the land owners. It is recommended that rather than enforcing an immediate compulsory removal of the bridges, no maintenance works on these bridges be allowed. Therefore, as the bridges become dilapidated, they will require removal. Any replacement of these bridges will be subject to the DA process including hydraulic assessment.

For the purpose of modelling this option it was assumed that the bridges would either be removed or reconfigured (causeway) as to have a negligible impact on flood levels.

Hydraulic modelling of this option showed a significant reduction in flood levels. The largest reduction was seen downstream of Como Parade (up to 52cm). However, this section of Turo Creek does not have many properties with floor levels below the 100 Year ARI flood event and as such the reduction in levels in this location does not provide a significant benefit to over-floor flooding. However, there is a significant benefit to property flooding and hence a reduction in garden damage.

The limited reduction in levels in the mid to lower reaches of the creek would suggest that the creek is too narrow in these locations. That is, the narrow creek section rather than the access bridges governs the flood levels.

This option is presented in Figure 10.1 and Figure 10.3 shows the impact of this option on the 100 Year ARI flood levels.

10.4 OPTION FM3 - CREEK ENHANCEMENT AND REPLACE ACCESS BRIDGES WITH ARCHED BRIDGES

The analysis of the removal or modification of the private access bridges (Option FM2) concluded that the mid and lower reaches of the creek limit the flow conveyance. This option assesses the benefits of increasing the capacity of the channel by widening the channel to 5m (between top of banks). This option assumes removal of existing bridges and provision of arch bridges at a level above the 100 year ARI flood level for access across the creek.

There would be significant earthworks associated with this option and the environmental implication of the works would need to be investigated thoroughly.

This option has been incorporated into the model by updating the cross sections to widen the channel section. The model was further modified to represent arched bridges. Due to the adoption of Council's blockage policy (Section 3.7), the arched bridges have been modelled as fully blocked. However, it is unlikely that these types of crossings would block entirely, due to the span and height of the bridges.

Hydraulic modelling of this option showed a slight reduction of levels along some of the Venice Road properties (maximum reduction of 12cm). Due to the blockage policy the levels did not reduce significantly, as the flood waters were held up behind the blocked bridges.

Whist the model results are limited by Council's blockage policy, widening of the creek is not the preferred option in terms of environmental impacts, as it requires significant excavation and modification of existing creek channel. This would result in the disturbance of existing habitats. Upon completion of the works an attempt can be made to reinstate the habitats and ecosystems; however, this is not always successful.

This option is presented in Figure 10.1 and Figure 10.4 shows the impact of this option on the 100 Year ARI flood levels.

10.5 OPTION FM4 - CREEK ENHANCEMENT AND REALIGNMENT WITH REMOVAL OF PRIVATE ACCESS BRIDGES

Turo Creek currently flows through the backyards of the Venice Road properties. To allow access across the divided backyard, property owners have constructed pedestrian bridges over the creek channel. This option proposes to realign the creek towards the rear boundary of the properties. The realignment would involve amplification of the creek channel to enhance the channel flow capacity. As the creek would no longer run through the Venice Rd properties there would be no need for the access bridges except for the most downstream bridge located at 38 Venice Road. The access bridge at this location would be replaced with a causeway.

This option would involve a large amount of earthworks, including excavation of the realigned creek channel and fill of the existing channel. As for Option FM3, the significant disturbance to the existing creek habitats and ecosystems is not considered acceptable.

The hydraulic modelling for this option was undertaken by widening the appropriate cross sections to represent the enhanced channel and the private access bridges were removed.

Hydraulic modelling of this option resulted in significant flood level reduction (up to 0.8m) in the reach between Como Pde and just downstream of 44 Venice Rd (approximately chainage 100 . 200m, see Figure 3.2). However, flood level reductions in this reach do not provide a significant benefit to over-floor flooding and hence damages. There was little impact on the flood levels in the downstream reach of Turo Creek, suggesting that the flood levels in the downstream reach are controlled by the Pretty Beach Road culverts and bridge and not predominantly by the conveyance capacity of Turo Creek.

This option is presented in Figure 10.1 and Figure 10.5 shows the impact of this option on the 100 Year ARI flood levels.

10.6 OPTION FM5 - DETENTION BASIN UPSTREAM OF COMO PARADE

Turo Creek currently runs from the upper catchment, through predominantly forested land until it passes under Como Parade. Under existing conditions Como Parade is overtopped in all design events exceeding the 5yr ARI event. As such, Como Parade does not provide any restriction to flow. This option would involve construction of an embankment on the upstream side of Como Parade. For the purposes of hydraulic modelling, the embankment height was assumed to be 4 m AHD, which is the level at which Como Parade would connect with Venice Road.

This option does not involve the specific excavation of a detention basin. Instead, the detention of flood waters would occur within the existing terrain behind the elevated embankment. There would be construction works and some cut and fill to allow for the construction of the embankment, which would act as a weir during a major flood event.

Hydraulic modelling of this option shows that the area upstream of Como Parade would flood to a depth of up to approximately 3m for all design events for an extended period of time. Although, the area is predominantly undeveloped land, the stored waters could pose a safety issue.

Hydraulic modelling of this option shows that there is little or no difference from the existing flood levels. As such, this option does not provide any benefit to the properties in the floodplain.

This option is presented in Figure 10.1 and Figure 10.6 shows the impact of this option on the 100 Year ARI flood levels.

10.7 OPTION FM6A - CREEK WIDENING IN LOWER REACHES ONLY, REPLACE PRIVATE ACCESS BRIDGES WITH CAUSEWAYS

The analysis of Option FM2 concluded that the middle and lower reaches of the creek have limited flow conveyance. As with options FM3-FM5, this option assesses the benefits of increasing the capacity of the channel by widening the channel to 5m (between top of banks) and replacing the private access bridges with causeways. However, modelling of other creek amplification options concluded that creek widening in the reach downstream of Como Parade did not provide a significant benefit for over-floor flooding. As such this option assesses the impact of widening only the lower reaches of the creek starting approximately at model chainage 226 (Figure 3.2) to the Pretty Beach Road culverts.

It is assumed that any private access bridges located within the reach proposed for widening will be removed and replaced with causeways or arched bridges. Due to steep bank slopes and limited width of the creek, the gradient of the causeway in most properties may not be suitable for pedestrian crossing. Therefore, additional channel widening may be required at the crossing locations for suitable gradients. These crossings are referred to as causeways.

There would be significant earthworks associated with this option and the environmental implication of the works would need to be investigated thoroughly.

This option was incorporated into the hydraulic model by widening the cross sections and removing some of the footbridges and replacing those with the causeways.

The hydraulic modelling results within the lower reach for this option were similar to those for Option FM4, due to the fact that there were no bridges to form hydraulic controls to the flow. Whilst there was some reduction in flood levels, there was no significant benefit to properties.
This option would involve a large amount of earthworks, including excavation. As for previous options where creek works are significant, the disturbance to the existing creek habitats and ecosystems may not be considered acceptable. In particular, the impact on the mangroves and the potential for Acid Sulphate runoff are considerable environmental impacts which are possible outcomes of this option.

This option is presented in Figure 10.1 and Figure 10.7 shows the impact of this option on the 100 Year ARI flood levels.

10.8 OPTION FM6B - CREEK WIDENING IN LOWER REACHES ONLY, REPLACE PRIVATE ACCESS BRIDGES WITH CAUSEWAYS, INCREASE PRETTY BEACH CULVERTS TO 6 CELLS

The analysis of Option FM6a concluded that widening the creek alone does not provide significant benefit to flood affected properties. This is due to the fact that the Pretty Beach Road bridge causes flood flows to be detained in the lower reaches of Turo Creek. This option assesses the advantages of increasing the current 2 cell culvert under Pretty Beach Road to 6 cells.

There would be significant excavation associated with this option to widen the creek and increase the capacity of the Pretty Beach Road Bridge. As for Option FM6a the disturbance to the existing creek habitats and ecosystems may not be considered acceptable. In particular, the impact on the mangroves and the potential for Acid Sulphate runoff are considerable environmental impacts which are possible outcomes of this option.

The hydraulic modelling of this option was undertaken in a similar manner as for Option FM6a with the addition of 2 additional culvert cells at Pretty Beach Road and an enhancement of the pedestrian bridge at Pretty Beach Road.

Hydraulic modelling showed that the flood levels were reduced further than those in Option FM6a, providing a greater benefit for flood affected properties with a maximum reduction in flood levels of 0.24m at Pretty Beach Road. The greatest reduction in flood levels which will impact on property flooding is just upstream of Pretty Beach Road. The reduction in flood levels for these properties is up to 0.2m.

This option is presented in Figure 10.1 and Figure 10.7 shows the impact of this option on the 100 Year ARI flood levels.

10.9 OPTION FM6C - CREEK WIDENING IN LOWER REACHES ONLY, REPLACE PRIVATE ACCESS BRIDGES WITH CAUSEWAYS, INCREASE PRETTY BEACH CULVERTS TO 12 CELLS

This option employs a similar arrangement as Option FM6b. The Pretty Beach Road Culverts in this option were modelled as 12 cells.

Hydraulic modelling showed this option to have the greatest reduction in flood levels in the lower reaches. As such, this option would provide the greatest benefit in term of reducing over floor flooding. The greatest reduction in flood levels which will benefit inundated properties is just upstream of Pretty Beach Road, with a reduction in flood levels of up to 34cm. This option results in most properties no longer experiencing over-floor flooding.

However, the issues relating to major creek modification works also apply to this option.

This option is presented in Figure 10.1 and Figure 10.7 shows the impact of this option on the 100 Year ARI flood levels.

10.10 OPTION FM7 . LEVEE BANKS

This option has limited practical application in the floodplain and has not been assessed.

10.11 OPTION FM8 - IMPROVEMENT OF DRAINAGE INFRASTRUCTURE, INCLUDING IMPROVED OVERLAND FLOWPATH ALONG VENICE ROAD

Gosford City Council undertook the Pretty Beach Drainage Study (PBP, 2003) to develop a conceptual drainage management plan. The plan made a number of recommendations to overcome the deficiencies in the drainage system. These recommendations can be included as part of flood management in the Turo Creek catchment. However, as discussed in the drainage study, the improvement works would carry less priority than the flood management options for properties directly affected by Turo Creek flooding. In addition, some of the recommendations made in the drainage study will be superseded based on the results presented in this study.

The provision of grassed swales has been given a high priority in the drainage study. It is recommended that the grass swale along the west side of Venice Road be given priority as this swale is likely to provide benefit during a major flood event in Turo Creek where the floodwaters are likely to flow along Venice Road. Provision of a formalised swale would provide efficient discharge of these floodwaters.

This option is presented in Figure 10.1.

10.11.1 Proposed Drainage Upgrade Assessment

During the preparation of this study, some of the drainage works proposed in the Pretty Beach Drainage Study were approved and Council required the designs for these drainage works to be assessed in terms of flooding benefits. Therefore, the proposed drainage upgrade for networks

N2, N3 and N12 (shown in Figure 10.8) have been incorporated into both the hydrological and hydraulic models to assess any impacts on flooding. The drainage network N5 was not assessed as it represents a minor upgrade at Pretty Beach Road. In addition, the adopted drainage upgrade proposed along High View Rd (N2) that discharges into Turo Creek at Como Parade, was modified by Council to merge with the proposed Venice Road drainage upgrade (N3) with the combined drainage discharging directly into Brisbane Water.

The assessment was undertaken assuming that the draining networks would be designed to convey the 100 Year ARI flood flows as suggested by the Council. As such, the hydrological flows up to the 100 Year ARI capacity were removed from the hydrological and hydraulic modelling.

The hydraulic assessment indicates that the drainage upgrades would have a maximum reduction in flood flows of 4cm in the 100 Year ARI flood event and no instances of increased flood levels for all design events. To obtain this result it should be noted that the drainage networks discharge directly to the Pretty Beach and do not re-enter Turo Creek at any location.

10.12 OPTION FM9 - IMPROVEMENT/PRESERVATION OF OVERLAND FLOWPATHS

This option was generally derived from the recommendations of the Pretty Beach Drainage Study where formalised overland flowpaths are recommended. Other important drainage flowpaths that were not identified in the drainage study are those that convey flow from the waterfalls. It is important that these flowpaths be identified and preserved to prevent any future drainage issues. The flowpath preservation can be achieved through Council's DA assessment process.

10.13 OPTION FM10 - IMPLEMENTATION OF A BYPASS CULVERT - UPSTREAM OF COMO PDE TO BRISBANE WATER

Hydraulic modelling of Turo Creek found that the channel down stream of Como Parade has limited capacity to convey design flood flows as the creek is bounded by residential development. This is the reach of Turo Creek where most if not all flood damages are incurred. In addition, various flood management options have limited benefit in the lower reaches of the floodplain. It is therefore proposed to implement a bypass culvert to divert flows from Turo Creek in order to minimise flood impacts along the entire reach of Turo Creek. The flows would be bypassed approximately 20m upstream of Como Parade using a 2m x 1m box culvert. This culvert would run underground parallel to Venice Road, then under the reserve on Pretty Beach Road and finally discharge directly to the Bay.

It is proposed that the culvert inlet be located approximately 0.5m above the creek bed. The Inlet invert would be located at 2 m AHD. This level allows for two provisions. Firstly, by not placing the culvert inlet at the channel bed level, low flows are allowed to pass downstream along Turo Creek. These low flows are vital for the creek health.

Secondly, the culvert inlet should be at a level that provides sufficient culvert slope to enable efficient conveyance of flood flows. The proposed culvert is approximately 260m long and would have an average slope of 0.8%. The proposed layout is shown on Figure 10.1 and the assumed design specifications are shown in Table 10.2. An increased Manning's n value has been used in the hydraulic modelling to simulate the hydraulic losses due to bends in the culvert.

Table 10.2: Bypass Culvert Design Specifications

	Chainage*				
	0	22	102	162	257
Invert (m AHD)	2	1.82	1.18	0.7	-0.058**
Roughness (Manning's n)	0.02				

* Chainage shown in Figure 10.1

*derived from 0.8% slope over a length of 257m with a starting elevation of 2 m AHD. This level is similar to the surveyed level of -0.29 m AHD at pretty Beach Road culverts.

Results of hydraulic modelling of this option resulted in a significant decrease in flood levels at most locations along Turo Creek. The bypass culvert carries approximately 5 m^3/s out of the total 11 m^3/s in Turo Creek upstream of Como Parade in a 100 year ARI event. The greatest reduction in flood levels was just upstream of the bypass culvert inlet (up to 1.37m). However, decreases in flood levels at this location do not benefit existing properties in the floodplain. Within the vicinity of the existing residential properties (downstream of Venice Road to Pretty Beach Road), the reduction in flood levels varies from 0.44m to 0.95m. A comparison of existing peak water levels with those obtained under this option is presented in Appendix I. There is a significant reduction in over-floor flooding and an overall reduction in Average Annual Damages of approximately $150,000.

It is noted that no blockage has been assumed for this culvert. This is due to the fact that the culvert is laid at a short acute angle to the flow direction and is not likely to provide obstruction to the passing debris. However a debris control structure would be required to prevent debris from flowing into the culvert.

Figure 10.9 shows the impact of this option on the 100 Year ARI flood levels. Figure 10.10 shows the design flood profiles for this option.

11 OPTIONS FOR MANAGING FLOOD RISK – PROPERTY MODIFICATION OPTIONS

Property modification options identified as being suitable for the floodplain are:

- Strengthening planning and development controls (PM1)
- House Raising Program (PM2)
- Voluntary Purchase Program (PM3)
- On Site Detention Policy (PM4)
- Data Collection Strategies (PM5)
- Local Community to Prepare a Catchment Action Plan for Turo Creek and the Catchment (PM6).

Each option has an identifier assigned as .PM. for Property Modification.

11.1 PLANNING AND DEVELOPMENT CONTROLS (OPTION PM1)

Council's current planning and development controls are outlined in Section 6. Strengthening of existing controls and development of new controls is recommended with details outlined in Section 6. It is also recommended that the continued revision and updating of these documents occur on an as-needed basis. A general review should be undertaken at least every five years.

In addition to the recommendation for Council's general planning instruments, a number of development controls have been recommended for the Turo Creek Catchment and Floodplain. These development controls are presented below:

11.1.1 Turo Creek, Pretty Beach Development Controls

General:

- Flood Planning Level (FPL) for setting habitable floor levels to be 100 year ARI flood level + mm freeboard. The minimum FPL in the entire floodplain is 2.45 m AHD, which is derived from Brisbane Water flooding. This FPL is subject to modification following completion of the ongoing Brisbane Water Foreshore Flood Study.
- No development allowed in high hazard area or floodway of 100 year ARI flood event.
- No development allowed in the 100 year floodplain that is likely to obstruct overland flow or reduce the storage area of the floodplain. Certain types of development may be permissible such as carports and in-ground swimming pools.
- Increase in dwelling density (dual occupancy, subdivision etc) not allowed for properties lying entirely within the floodplain. Properties lying partially in the floodplain may intensify dwelling density provided there is no increase in the flood risk.
- No fences to be erected where they would obstruct overland flowpath. Where allowed, acceptable fence type would be preferably post and wire strand or grid mesh with not less than 150 mm spacing.
- No development allowed to the creek side of the building setback lines.
- All electrical fixtures to be located above the PMF level or FPL whichever is the highest.
- All proposed development located in proximity of watercourses to address structural stability issues.
- All development within 40m from the top of banks of Turo Creek will require separate approval from the Department of Environment and Climate Change under Rivers and Foreshore Improvement Act.
- No development allowed that increases flood risk eg risk to increased flood damages, risk to life both for occupants and emergency crew accessing floodplain, etc.

- Mangrove planting or growth should be controlled to the current levels in the lower reaches of Turo Creek to avoid possible flood impact. New mangrove or other flora planting is allowed only after detailed flood impact analysis.
- In addition to the controls presented here, all development to comply with DCP115 "Building in Flood Liable Areas" and other relevant Council policies/ DCP/documents.
- Council may request preparation of a localised flood study to determine the impact of the proposed development.
- All development on piers to have minimum pier spacing of 2.0 m. No enclosure or storage of equipment or materials in underfloor area permitted in flood plain. Offsets for individual piers in rows parallel to the flow shall be no more than 100 mm. Cladding below floor level, irrespective of type, is not permitted.
- All bank and bed protection work requires Council approval.
- All permissible development in the PMF floodplain not to adversely affect overland flows.

Redevelopment is also subject to specific controls for various management areas identified in this study. The management areas are shown in Figure 3.1 of the Turo Creek, Pretty Beach Floodplain Risk Management Plan. Details of the proposed development controls are listed below.

Pretty Beach Road Management Area:

- Flood Planning Level (FPL) varies across the properties. Highest FPL to be adopted for any development within the property.
- No habitable development allowed in the public reserve fronting Pretty Beach Road that lies within the 100 year ARI flood extent.
- No filling or obstruction allowed in the public reserve fronting Pretty Beach Road that will divert flows or remove any part of the storage area of the 100 year ARI floodplain. Lot filling not to adversely affect adjoining properties particularly with regard to overland flooding.
- All development related to building extensions or reconstructions, which lies within the 100 year ARI floodplain, to be located above FPL and on piers to allow the free passage of floodwaters under the building.
- Filling at Pretty Beach Road frontage permitted to gain 100 year ARI flood free access to the new garages or carports only after all flood mitigation works identified under the plan have been completed and provided that the fill area is outside the defined flood storage area.
- Proposed carports, garages and vehicular access not to impede the flood flows through to Brisbane Water. If redeveloped, greater area for flow to be allowed, where practical.
- Lot filling that is allowed cannot be higher than existing Pretty Beach Road level, which acts as a weir during flood events.
- No raising of Pretty Beach Road allowed that would increase the weir level in the floodplain, resulting in adverse impact on upstream properties.

Venice Road Management Area:

- Redevelopment of properties to the east of Venice Road to be encouraged to relocate building footprint closer to Venice Road frontage to improve access during flood emergency and move away from high risk areas of the floodplain. Council to consider relaxing of building setbacks from the road to the front of the houses where appropriate. Applications to be assessed on their merit.
- All development related to building extensions or reconstruction, which lies within the 100 year ARI floodplain, to be located above FPL and on piers to allow the free passage of floodwaters under the building.
- For complete redevelopment of the site, filling at Venice Road frontage is permitted to gain year ARI flood free access to new garages or carports only after all building

development on property has been raised on piers above FPL. This should not result in net decrease in floodplain storage ie the volume of fill should be less than or equal to the volume made available under the existing building footprint. If Venice Road is not flood free in the 100 year event at the site of the development, then habitable floor levels to be at the PMF level.

- No habitable development is permitted on the portions of properties on the eastern side of Venice Rd that lies to the east of Turo Creek due to access difficulties in a flood emergency and due to its location in high hazard area of the floodplain.
- Erosion protection and bank stabilisation of Turo creek to be addressed through Rivercare initiative of Natural Heritage Trust or similar group.

Como Parade Management Area:

- All developments to consider design that reduces flood risk eg risk to life and damage to property etc. All development to have safe 100 year flood free access out of the floodplain to Como Parade.

Upper Catchment Management Area (Generally above Highview Road and Como Parade):

- Overland flow paths to be preserved and maintained through properties. The significant local feature of Waterfall to be preserved where appropriate.
- Minimum floor level should be established at least 0.5 m above the finished ground level, making sure that any earthwork does not adversely affect the adjoining properties with regard to overland flooding.

11.2 HOUSE RAISING PROGRAM (OPTION PM2)

House raising is a possible option to reduce the incidence of over-floor flooding in properties. Whilst house raising can reduce the occurrence of flooding, there are issues related to the practice including:

- the potential for damage to items on a property other than the raised dwelling (such as gardens, sheds and their contents, garages, cars, etc)
- unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists (i.e. there will be a residual risk)
- evacuation may be required (e.g. medical emergency during a flood event) even if no above floor flooding occurs. This evacuation is likely to be hampered by floodwaters surrounding a property
- need to ensure the new footings and piers can withstand flood-related forces, house raising is generally only suitable for low hazard areas, however all properties have been considered as part of this assessment
- potential conflict with height restrictions imposed for a specific zone or locality within the local government area (for properties to be raised a significant level, e.g. greater than 1m).

To identify which properties would be suitable for house raising, information on the nature of the construction of each property within the floodplain was provided by the Council (Section 4.2).

The following criteria was applied to determine the properties that are eligible for house raising:

- occurrence of above floor flooding in the 100 year ARI flood event,
- foundation construction type - only piered structures considered, cost of raising slab on ground would be prohibitive or impractical (where the footing type was unknown it was assumed at this stage to include the building in the house raising assessment).
- single storey dwellings only.

Table 9.4 presents all houses with over-floor flooding in the 100 Year ARI flood event. The foundation construction type and suitability for house raising is also shown. For those houses for which their suitability for house raising is .unknown., they have been assumed to be included in the proposed house raising programme. It is proposed that these houses are raised above the PMF, since the differences in flood levels between more frequent events and the PMF is not significant for house raising purposes.

Table 11.1: Properties with Over-floor Flooding in 100 Year ARI Flood Event

Property	Over-floor Flooding 100 Year ARI	Foundation Construction Type	Suitable for House Raising
20 Pretty Beach Road	0.04m	Unknown	Unknown[1]
21 Pretty Beach Road	0.11m	Brick Piers	Yes
24 Pretty Beach Road	No Floor Level	Unknown	Unknown[1,2]
38 Venice Road	0.20m	Brick Piers	Yes
42 Venice Road	0.12m	Slab on Ground	No

[1] The foundation construction type should be verified before inclusion of this property in the House Raising Programme.
[2] The floor level should be obtained to verify that over-floor flooding occurs in the 100 Year ARI flood event before inclusion of this property in the House Raising Programme.

A breakdown of the numbers of identified properties and associated costs are listed in Table 11.2. An assumed cost in the order of $45,000 is considered reasonable for house raising of each property as a preliminary assessment.

Table 11.2: Breakdown of Properties for House Raising

Street	Number of Properties Identified	Likely Total Cost
Pretty Beach Road	3	$135,000
Venice Road	2	$90,000
Total	**5**	**$225,000**

The success of such the house raising program is contingent on joint funding from the Department of Natural Resources and the meeting of the relevant subsidy criteria as applied by the Department.

An economic assessment of this option is discussed in Section 13.

11.3 VOLUNTARY PURCHASE PROGRAM (OPTION PM3)

In high hazard areas of the floodplain an alternative to the construction of flood modification options is the use of voluntary purchase (VP) of flood affected properties. This option would free both residents and emergency service personnel from the hazard of future floods. This can be achieved by the purchase of properties and the removal/demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be rezoned to a flood compatible use, such as recreation or parkland (NSW Government, 2005) or possibly redeveloped in a manner that is consistent with the flood hazard.

The recommended criteria to determine properties that are eligible for voluntary purchase are:

- property located totally in the combined high hazard/floodway area for the 100 year ARI flood.
- Property access totally inundated by 100 Year ARI high hazard and/or floodway.
- occurrence of above floor flooding in the 20 year ARI flood event, and
- economic value of damages for a particular property is comparable to the property market value.

The first criterion is met by a number of properties in the floodplain. However, none of the properties in the Turo Creek Floodplain are completely affected by high hazard and/or floodway for the 100 Year ARI. All properties have a significant portion still available for flood sensitive development, as detailed in the proposed development controls in Section 11.1

No properties have their access completely inundated by the 100 Year ARI High hazard and/or Floodway. However, the portion of 38 Venice Rd which lies on the eastern side of the creek has this limitation. In a flood emergency the access to this part of the property could be extremely dangerous.

Based on economic criteria alone, it would appear that none of the properties are suitable for VP. However, Council may consider purchasing the house only on the eastern portion of 38 Venice Road and then limiting development in this portion as per the development controls proposed in Section 11.1.

Whilst voluntary purchase of most properties does not seem economically feasible, it has been included for assessment against other factors such as social and environmental factors. Two options have been identified for Voluntary Purchase. The first option is to only include, for purchase, the house on the eastern portion of 38 Venice Road. It has been assumed that the cost of purchasing this house would be $500,000. The second option is to include all high hazard and floodway affected properties in the 100 Year ARI flood event. These properties are listed below:

- 38 Venice Road
- 40 Venice Road
- 42 Venice Road
- 44 Venice Road
- 46 Venice Road
- 48 Venice Road
- 50 Venice Road
- 52 Venice Road
- 22 Pretty Beach Road
- 23 Pretty Beach Road
- 24 Pretty Beach Road

Council may consider the option of VP for properties in the high hazard area and use that land for creating a local park for Turo Creek catchment and neighbouring communities. The success of such a program is contingent on joint funding from the Department of Natural Resources and the meeting of the relevant subsidy criteria as applied by the Department.

An alternative to pure voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land in a non-flood prone area (e.g. an existing park) for the flood prone land with the appropriate transfer of park facilities to the acquired site. After voluntary purchase, Council would then arrange for demolition of the building and have the land rezoned to open space. The land swap approach may result in a significant saving on the land component of the voluntary purchase costs. It is recommended that this approach be investigated first before voluntary purchase proceeds. However, it is understood that there is a limited scope for land swap in the catchment.

11.4 LOCAL ON SITE DETENTION POLICY (PM4)

On site detention (OSD) for new or redeveloped areas is a means of managing the increased rate of runoff from the site that is generated as a result of the development. A variety of different approaches have been formulated and adopted across New South Wales as an attempt to ensure that existing flood conditions are not worsened by incremental development throughout a catchment. On site detention works on the principle of controlling the peak discharge from a site, but generally does not address the additional volume of runoff generated. Stormwater retention and reuse is a means of managing the additional volume generated as a result of additional impervious surfaces within a new development.

Currently Gosford Council currently has an LGA-wide OSD policy (Draft) to harness the flood management benefits of on site detention systems. This policy should be supported by catchment specific studies to evaluate its efficacy and if found useful, the volume and discharge requirements specific to each catchment should be established.

11.5 DATA COLLECTION STRATEGIES (OPTION PM5)

Floodplain Management is an ongoing process and involves collection of historic flood data that can be used in future review and update of the Floodplain Risk Management Plan. It is therefore imperative that data collection strategies are put in place for this vital component of the floodplain management process. This would involve the preparation of a flood data collection form and use of this form following a flood event.

12 OPTIONS FOR MANAGING FLOOD RISK – EMERGENCY RESPONSE MODIFICATION OPTIONS

The following emergency response modification options are suitable for the floodplain:

- Revision of Gosford City Local Flood Plan by SES (a sub-plan of DISPLAN) (EM1)
- Information Transfer to SES by Council (EM2)
- Public Awareness and Education by SES (FloodSafe Brochure for the Locality) (EM3)
- Public Awareness and Education by SES (Schools Package) (EM4)
- Depth markers at major road crossings by SES (EM5).

12.1 REVISION OF DISPLAN BY SES (EM1)

Details of the current DISPLAN are outlined in Section 5. The following amendments are recommended:

- It is recommended that the Gosford Local Emergency Management Committee consider incorporating special provisions for small catchments in the LGA in the Gosford City Local Flood Plan. For example flood warning systems for small catchments like Turo Creek, where flash flooding occurs.
- Considering that the recovery operation in Turo Creek floodplain by the SES would need to be in place in a matter of few hours after the onset of a major flood event, it is recommended that a nearby community building is nominated as temporary shelter, where the residents can move immediately after the event, before the Gosford Local Emergency Management Committee can mobilise further assistance.
- Reference to the timing of flooding for small catchments like Turo Creek should be included in the plan (e.g. 15min to 30min for various design events).
- More emphasis should be placed on educating the community for small catchments like Turo Creek where evacuation is not feasible.
- Numbers of properties inundated are detailed in this report and as such DISPLAN can be updated with this information.

12.2 INFORMATION TRANSFER TO SES BY COUNCIL (EM2)

The findings of the flood study provide an extremely useful data source for the State Emergency Service. Information could be provided from the findings of the flood study in two forms:

- Electronic information (flood extent mapping and flood hazard mapping in geographic information system format).
- Laminated plans (hard copies of flood extent and hazard mapping) in laminated plan format for use in the operations centre to assist with directing teams to the most likely affected localities. This can also help to overcome any issues associated with power loss or difficulty with accessing information in an emergency.

12.3 PUBLIC AWARENESS AND EDUCATION BY SES (EM3, EM4)

Flood awareness is an essential form of communication for people residing on a floodplain. The affected community must be made aware, and need to remain aware, of their role in the overall floodplain management strategy for their area. This includes the defence of their property and their own evacuation if required. Given the short duration of flooding and the hazardous nature of a number of roads within the area, residents should be encouraged to seek refuge via vertical evacuation, where possible.

Flood awareness is an ongoing issue and requires continuous effort of related organisations (e.g. Council and SES). The major factor determining the degree of awareness within the community is the frequency of moderate to large floods in the recent

history of the area. The more recent and frequent the flooding, the greater the awareness.

One difficulty with flood emergency planning is to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program needs to be enforced to ensure new residents are informed, the level of awareness within long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments. An effective awareness program requires ongoing commitment.

It is recommended that the following awareness campaigns be considered for the floodplain:

- Preparation of a FloodSafe brochure by the SES (EM3). Such a brochure with a fridge magnet may prove to be a more effective means of ensuring that people retain necessary information
- Development of a Schools Package from existing materials developed by the SES and distribution to schools accordingly (EM4).

The meeting of local Community groups could be used to arrange flood awareness programs on regular intervals.

Information dissemination is recommended to be included in Council rates notices for all affected properties on a regular basis.

Once prepared, the FloodSafe brochure can then be uploaded to the SES website (www.ses.nsw.gov.au) in portable document format (PDF) where it is available under the .information for local communities. section.

12.4 DEPTH MARKERS AT MAJOR ROAD CROSSINGS BY SES (EM5)

Flood depth markers provide guidance as to the depth of flooding at a specific location. Depth markers are commonly located on roads that are periodically inundated and present a traffic or pedestrian hazard.

In addition to providing guidance to drivers and pedestrians on the depth hazard, the markers can also be used by roaming crews of the SES to provide updates on the nature of the changing flood threat in an area for a relatively large duration event.

A flood depth marker is recommended to be installed at the Turo Creek crossing of Pretty Beach Road and Como Parade. It is recommended that twin-sided markers be installed at these locations.

13 ASSESSMENT OPTIONS

Options have been assessed in either of the following two ways:

- hydraulic modelling (Section 10) and detailed economic assessment (Section 13.2) - (detailed economic assessment was carried out for selected flood modification options only),
- multi-criteria matrix assessment (all options) (Section 13.3).

For the selected flood modification options, hydraulic modelling results were used to calculate reduction in Average Annual Damage (AAD).

In the multi-criteria matrix assessment the results of the hydraulic modelling and detailed economic analysis were utilised where available. Qualitative methods were used for the other options. This method has been used to inform the selection of options for the Floodplain Risk Management Plan (Cardno Lawson Treloar, 2006).

13.1 PRELIMINARY COSTING OF OPTIONS

Preliminary costs of the proposed options have been prepared to undertake an economic assessment of these options. The costs for flood modification options were prepared with the assistance of the Cordell Building Cost Guide. It should be noted that the costing for these options assume that no services (such as electricity, telephone, water, sewer etc) would need to be relocated.

The cost for property modification and emergency response modification options was based on approximate estimates and is indicative only.

It is recommended that prior to implementing any option, a detailed analysis and design of the options is carried out to allow for a more accurate assessment of the overall cost. Detailed rates and quantities will also be required at the detailed design phase.

13.1.1 Costing of Flood Modification Options

A summary of the estimated capital and recurrent (e.g. maintenance) costs of each option are listed in Table 13.1. Costing for options that were assessed by modelling was prepared in more detail and is presented in Appendix H. Cost for the rest of the options are based on approximate estimates.

Table 13.1: Preliminary Capital and Recurrent Costs of Flood Modification Options

Option ID	Capital Cost	Recurrent Cost	Description
FM1a	$330,000	$5,000	Pretty Beach Culvert and Pedestrian Bridge Enhancement - Double Culvert Capacity.
FM1b	$470,000	$8,000	Pretty Beach Culvert and Pedestrian Bridge Enhancement - Triple Culvert Capacity.
FM2	$90,000	$1,000	Removal/Modification of unapproved private access bridges.
FM3	$460,000	$5,000	Creek Enhancement and replacing access bridges with arched bridges.
FM4	$480,000	$5,000	Creek Realignment and removal of Access Bridges.
FM5	$60,000	$1,000	Detention Basin Upstream of Como Parade.
FM6a	$390,000	$10,000	Creek widening in lower reaches and replacing access bridges with causeways.

Option ID	Capital Cost	Recurrent Cost	Description
FM6b	$690,000	$12,000	Creek widening in lower reaches and replacing access bridges with causeways - increase Pretty Beach Culverts to 6 cells.
FM6c	$1,140,000	$15,000	Creek widening in lower reaches and replacing access bridges with causeways - increase Pretty Beach Culverts to 12 cells.
FM7	Not suitable		Levee Banks
FM8	$500,000	$20,000	Improvement of Drainage Infrastructure, including Improved Overland Flowpath along Venice Road
FM9	$15,000	$10,000	Improvement/Preservation of Natural Overland Flowpaths in the Upper Catchment
FM10	$1,242,000	$5,000	Bypass Culvert – Upstream of Como Parade to divert flow from Turo Creek directly to the Bay.

*An example of recurrent cost includes inspections and clearing of debris on an annual basis

13.1.2 Costing of Property Modification Options

A summary of the likely costs of the proposed property modification options is provided in Table 13.2.

Table 13.2: Preliminary Capital and Recurrent Costs of Property Modification Options

ID	Option	Likely Implementation Capital/Recurrent Cost
PM1	Planning and development controls	$15,000 (CI) $1,000 (RI)
PM2	House Raising Program	$225,000 (C)
PM3a	Voluntary Purchase of only the House on the Eastern Portion of 38 Venice Rd.	$50,000 (C)
PM3b	Voluntary Purchase of all Flood Affected Properties	$8,800,000 (C)
PM4	Local On Site Detention Policy	$20,000 (C), $2,000 (R)
PM5	Data Collection Strategies	$5,000 (C), $2,000 (R)

*where C - Capital Cost
R - Recurrent Cost
I - Internal Council or Identified Organisation Cost

13.1.3 Costing of Emergency Response Modification Options

A summary of the likely costs of the proposed emergency response modification options is provided in Table 13.3.

Table 13.3: Preliminary Capital and Recurrent Costs of Emergency Response Modification Options

ID	Option	Likely Implementation Capital/Recurrent Cost
EM1	Revision of DISPLAN	$15,000 (C), $2,000 (R)
EM2	Information Transfer to SES	$2,000 (CI)
EM3	Public Awareness and Education - Locality Based Floodsafe Brochure	$10,000 (C), $2,000 (R)
EM4	Public Awareness And Education - Schools Package	$10,000 (C), $2,000 (R)
EM5	Depth markers at major road crossings ($2,000 per marker)	$6,000 (C)

*where C - Capital Cost
R - Recurrent Cost
I - Internal Council or Identified Organisation Cost

13.2 DETAILED ECONOMIC ASSESSMENT OF MODELLED FLOOD MODIFICATION OPTIONS

The flood modification options that were assessed by modelling provided an opportunity for detailed economic assessment. The economic evaluation (methodology detailed in Section 4) of these options was carried out by considering the reduction in the amount of Average Annual Damage (AAD) and comparing this value with the cost of the option. Two property modifications options (House Raising and Voluntary Purchase) are also included in the analysis as these options enable AAD reduction to be calculated for the floodplain.

The existing condition was used as the base case to compare the performance of options assessed by modelling. The PMF, 200 year, 100 year, 50 year, 20 year, and 5 year ARI events were considered for this evaluation. Preliminary costs of each option were prepared and a benefit cost analysis of each option was undertaken on a purely economic basis.

13.2.1 Annual Average Damage for Options

In a similar fashion to establishing the existing damages (Section 4), the total damage costs were evaluated for each of the options assessed by modelling.

The economic assessment results, presented in Table 13.4, indicate a significant reduction in average annual damage (AAD) for a number of the options. Option FM10 has the greatest reduction with approximately $150,000 reduced from the existing case.

Whilst the AAD may be reduced for some options, this reduction needs to be offset against the capital and recurrent costs of the option. Thus, each option has a benefit cost ratio that provides an indication of the economic viability of the option. This is described below.

13.2.2 Benefit Cost Ratio of Modelled Options

Table 13.4 summarises the overall economics of each option assessed by modelling. The indicator adopted to rank options on economic merit is the benefit cost ratio (B/C). Where the B/C is close to or greater than 1 the option is more economically viable than other options. If the B/C is negative then there is an economic disadvantage in proceeding with that option.

Table 13.4: Summary of Economic Assessment of Major Structural Options

	Average Annual Damage	Reduction In AAD	NPV of Benefit	Capital Cost	Recurrent Cost	NPV of Option	Benefit Cost Ratio	Rank
Existing	$208,088	-	-	-	-	-	-	-
FM1a – PB culvert	$156,471	$51,617	$712,351	$330,000	$5,000	$399,004	1.79	5
FM1b – PB culvert	$146,299	$61,789	$852,734	$470,000	$8,000	$580,406	1.47	7
FM2 – Access bridges	$187,461	$20,627	$284,661	$90,000	$1,000	$103,801	2.74	3
FM3 – Creek widening and bridge replacement	$163,167	$44,920	$619,933	$460,000	$5,000	$529,004	1.17	9
FM4 – Creek widening and realign	$132,685	$75,402	$1,040,610	$480,000	$5,000	$549,004	1.90	4
FM5 – Detention basin	$207,344	$743	$10,260	$60,000	$1,000	$73,801	0.14	13
FM6a – Creek widening, access bridges and PB culverts	$163,542	$44,546	$614,762	$390,000	$10,000	$528,007	1.16	10
FM6b - Creek widening,	$132,774	$75,313	$1,039,380	$690,000	$12,000	$855,609	1.21	8

	Average Annual Damage	Reduction In AAD	NPV of Benefit	Capital Cost	Recurrent Cost	NPV of Option	Benefit Cost Ratio	Rank
access bridges and PB culverts								
FM6c - Creek widening, access bridges and PB culverts	$119,451	$88,637	$1,223,258	$1,140,000	$15,000	$1,347,011	0.91	11
FM10 – Bypass Culvert	$57,182	$150,905	$2,082,608	$1,242,000	$5,000	$1,311,004	1.59	6
House Raising	$158,246	$49,842	$687,851	$225,000	$0	$225,000	3.06	2
Voluntary Purchase – Option 1	$158,109	$49,978	$689,739	$500,000	$0	$500,000	1.38	1
Voluntary Purchase – Option 2	$66,659	$141,428	$1,951,814	$8,800,000	$0	$8,800,000	0.22	12

NPV - Net Present Value is calculated using 7% interest over 50 yrs

The benefit cost analysis shown in Table 13.4 indicates that there were a number of options with a benefit cost ratio greater than 1. However all options must also be assessed for the social and environmental viability. This is undertaken in the multi-criteria matrix assessment in Section 13.3.

13.3 MULTI-CRITERIA MATRIX ASSESSMENT

13.3.1 Overview

A multi-criteria matrix assessment approach was adopted for the comparative assessment of all options identified using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach to assessing the merits of various options uses a subjective scoring system. The principle merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition it makes the assessment of alternatives .transparent. (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute .right. answer as to what should be included in the Floodplain Risk Management Plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion.

13.3.2 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain as well as the community preferences.

The criteria adopted include:

- Technical — Likely Overall Hydraulic Improvement
- Economic — Capital and Operating Costs
Reduction in Risk to Property
- Social — Reduction in Social Disruption
Reduction in Risk to Life
- Environmental — Flow and Water Quality Objectives
Fauna/Flora

- Community Community Support
- Authority Council/Agency/SES Support
- Policy/Legislation Compatible with Policies and Plans.

The scoring system is shown in Table 10.3 for the above criteria.

Table 13.5: Details of Scoring System Adopted

Criteria	Score				
	-2	-1	0	1	2
Likely overall hydraulic improvement	Negative impact (> 0.2 m increase in peak flood level at any location)	Negative impact (> 0.1 m increase in average peak flood level at any location)	Negligible improvement or only local improvement	Flood level decrease (0.1 - 0.5 m decrease in peak average flood level across the floodplain)	Flood level decrease (>0.5 m decrease in peak average flood level across the floodplain)
Capital and Operating Costs	Extreme (eg >$1 million)	High $500,000 - $1 million	Medium $200,000 - $500,000	Low $50,000 - $200,000	Low $10,000 - $50,000
Reduction in Risk to Property*	Major increase in AAD (> 25% of existing AAD)	Slight increase in AAD (up to 25% of existing AAD)	No Improvement	Slight decrease in AAD (up to 25% of existing AAD)	Major decrease in AAD (> 25% of existing AAD)
Reduction in Risk to Life**	-	-	No change in risk to life	Slight reduction of risk to life	Major reduction of risk to life
Reduction in Social Disruption	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption
Compatible with Water Quality and Flow Objectives	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Fauna/flora impact	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit
Community attitude	Strong disagreement	Disagreement	Neutral/no response	Support	Strong support
Council/state agency attitude	Strong disagreement	Disagreement	Neutral/no response	Support	Strong support
Compatible with Policies and Plans	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible

*Values of likely AAD reduction assumed where actual assessment not undertaken

** Any option resulting in increase in risk to life would be disqualified as being viable option.

Likely Overall Hydraulic Improvement

In general the overall hydraulic improvement was a maximum lowering in design flood level of 0.33m near Pretty Beach Road. Issues related to the reduction of flood hazard and related social disruption and risk to life are considered as separate criteria. Where an option was not modelled, engineering judgement as to the likely overall improvement was applied by experienced floodplain hydraulic specialists.

Economic Assessment Overview

The economic assessment involved an appreciation of both:

- Capital and Operating Costs
- Reduction in Risk to Property.

Capital and operating costs for major structural options were assessed as described in Section 13.1, whilst a judgement of the likely capital and recurrent costs was made by experienced engineers. However, it should be noted that these costs are preliminary only and have been devised for use only in the economic assessment of the options as part of this study.

Social Impact Assessment

The social impact assessment involved an appreciation, based on the information collated of both:

- Reduction in Social Disruption
- Reduction in Risk to Life.

The social disruption of flooding (via the effects of property inundation, loss of access and traffic disruption) is an important factor for consideration. Similarly, the reduction in the risk to life is an important criterion. However, this criterion is highly subjective, as it is difficult to assess the behaviour of persons under extreme conditions such as flooding.

Environmental Assessment

The environmental impact assessment involved an appreciation, based on the information, of both:

- Water Quality and Flow Impact
- Fauna/Flora Impact.

It is important to recognise that the watercourses of the area need to be managed in a sustainable way, in recognition of the modified nature of the system.

The environmental impacts of works such as creek rehabilitation are likely to be all positive since the system is currently degraded in terms of flora and fauna due to erosion resulting in bank slumping, sedimentation, weed growth and associated loss of habitat. The modification process will result in bank stabilisation and associated reduction of erosion and sedimentation, weed removal and replacement with local indigenous vegetation and associated habitat. This modification will seek to result in improved habitat corridor linkages as well as provide a small buffer zone for water quality purposes to improve the quality of runoff reaching the creek in dry weather/low flow conditions.

Community

Community scores were derived from the responses received from the consultation period. These scores will be revised based on the submissions received during the exhibition period.

Authority

The attitude of different organisations such as Council, State Agencies and the SES to different options were subjectively assessed based on discussions with representatives over the course of the study.

Policy/Legislation

A single Policy/Legislation criterion was applied such that the option should be compatible with current Policies and Plans. This was based on an assessment of related policies and plans.

13.4 SCORES

The total score for each option was calculated by equally weighting each consideration and adding the total.

A rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are shown in Table 13.6.

This ranking is used as the basis for prioritising the components of the Floodplain Risk Management Plan (Cardno Lawson Treloar, 2006). It must be emphasised that the scoring shown in Table 13.6 is not .absolute. and the proposed scoring and weighting should be reviewed carefully as part of the process of finalising the Floodplain Risk Management Plan.

ID	Locality	Type of Measure	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 50 years)	Reduction in AAD	NPV of Reduction in AAD	Benefit - Cost Ratio	Peak Reduction in Water Levels	Likely Overall Hydraulic Improvement	Capital and Operating Costs	Reduction in Risk to Property	Reduction in Risk to Life	Reduction in Social Disruption	Water Quality and Flow	Fauna & Flora	Community Criteria	Council/ Agency/ SES/etc	Compatible with Policies and Plans	TOTAL SCORE	RANK on TOTAL SCORE
FM1a*	Pretty Beach Road and Pedestrian Crossing	Culvert Enhancement (Double Culvert Capacity)	$330,000	$5,000	$399,004	**$51,617**	$712,351	**1.79**	0.08	0	0	1	0	0	0	0	2	1	1	**5**	**14**
FM1b*	Pretty Beach Road and Pedestrian Crossing	Culvert Enhancement (Triple Culvert Capacity)	$470,000	$8,000	$580,406	**$61,789**	$852,734	**1.47**	0.24	1	-1	2	0	0	0	0	2	1	1	**6**	**11**
FM2*	Between Como Parade and Pretty Beach Rd	Removal/Modification of all unaproved private access bridges	$90,000	$1,000	$103,801	**$20,627**	$284,661	**2.74**	0.52	2	0	1	0	1	0	0	0	2	2	**8**	**4**
FM3*	Between Como Parade and Pretty Beach Rd	Creek Enhancement (creek widened to 5m) and private access bridges replaced with arched bridges.	$460,000	$5,000	$529,004	**$44,920**	$619,933	**1.17**	0.12	1	-1	1	0	1	1	-1	0	-2	-2	**-2**	**22**
FM4*	Between Como Parade and Pretty Beach Rd	Creek Enhancement (creek widened to 5m) and Realignment with private access bridges removed	$480,000	$5,000	$549,004	**$75,402**	$1,040,610	**1.90**	0.12	1	-2	2	1	1	0	-2	0	-2	-2	**-3**	**23**
FM5*	Upstream of Como Pde	Detention Basin	$60,000	$1,000	$73,801	**$743**	$10,260	**0.14**	0.00	0	1	1	0	0	0	0	1	1	-1	**3**	**19**
FM6a*	Lower reaches of Creek upstream of Pretty Beach Rd	Creek Enhancement (creek widened to 5m) and private access bridges removed and replaced with causeways.	$390,000	$10,000	$528,007	**$44,546**	$614,762	**1.16**	0.08	0	-1	1	0	0	0	-1	0	-2	-2	**-5**	**24**
FM6b*	Lower reaches of Creek upstream of Pretty Beach Rd	Creek Enhancement (creek widened to 5m) and private access bridges removed and replaced with causeways. Pretty Beach Culverts enhanced (total 6 culvert cells)	$690,000	$12,000	$855,609	**$75,313**	$1,039,380	**1.21**	0.24	1	-1	2	1	1	0	-1	0	-2	-2	**-1**	**20**
FM6c*	Lower reaches of Creek upstream of Pretty Beach Rd	Creek Enhancement (creek widened to 5m) and private access bridges removed and replaced with causeways. Pretty Beach Culverts enhanced (total 12 culvert cells)	$1,140,000	$15,000	$1,347,011	**$88,637**	$1,223,258	**0.91**	0.51	2	-2	2	1	1	0	-1	0	-2	-2	**-1**	**20**
FM7	Between Como Parade and Pretty Beach Road	Levee Banks	NOT SUITABLE																		
FM8	Catchment wide	Improvement of Drainage Infrastructure, including Improved Overland Flowpath along Venice Road	$500,000	$20,000	$776,015	**-**	-	-	-	0	-1	1	0	1	1	0	1	1	1	**5**	**14**
FM9	Catchment Wide	Improvement/Preservation of Natural Overland Flowpaths in the Upper Catchment	$200,000	$10,000	$338,007	**-**	-	**-**	-	0	0	1	0	0	1	0	1	1	1	**5**	**14**
FM10	Upstream of Como Pde to an outlet at the Bay	Bypass Culvert to divert flows from Turo Creek	$1,242,000	$5,000	$1,311,004	**$150,905**	$2,082,608	**1.59**	1.37	2	-1	2	1	1	0	0	1	1	1	**8**	**4**
PM1	Catchment Wide	Planning and development controls	$15,000	$1,000	$28,801	**-**	-	**-**	-	0	2	2	1	1	0	0	1	1	2	**10**	**2**
PM2	Properties with over floor flooding in the 100 Year ARI Event (4 houses)	House Raising Program - Houses Raised above the PMF	$225,000	$0	$225,000	**$49,842**	$687,851	**3.06**	-	1	0	1	1	1	0	0	0	1	1	**6**	**11**
PM3a	Floodplain	Voluntary Puchase of House on Eastern Portion of 38 Venice Rd	$50,000	$0	$50,000	**$49,978**	$689,739	**13.79**	-	0	-1	1	2	1	0	0	0	1	1	**5**	**14**
PM3b	Floodplain	Voluntary Purchase Program (of all houses with high hazard within property)	$8,800,000	$0	$8,800,000	**$141,428**	$1,951,814	**0.22**	-	1	-2	2	2	2	0	0	0	0	1	**6**	**11**
PM4	Catchment wide	Review of On Site Detention Policy	$20,000	$2,000	$47,601	**-**	-	**-**	-	0	2	0	0	0	2	1	1	1	1	**8**	**4**
PM5	-	Data Collection Strategies	$5,000	$2,000	$32,601	**-**	-	**-**	-	0	2	0	0	0	0	0	0	2	1	**5**	**14**
PM6	Catchment wide	Catchment Action Plan - Rivercare	$20,000	$2,000	$47,601	**-**	-	**-**	-	0	2	0	0	0	2	2	1	2	2	**11**	**1**
EM1	-	Revision of DISPLAN	$15,000	$2,000	$42,601	**-**	-	**-**	-	0	2	0	1	0	0	0	1	1	2	**7**	**8**
EM2	-	Information Transfer to SES	$2,000	$0	$2,000	**-**	-	**-**	-	0	2	0	1	0	0	0	1	1	2	**7**	**8**
EM3	Catchment wide	Public Awareness and Education - Locality Based Floodsafe Brochure	$10,000	$2,000	$37,601	**-**	-	**-**	-	0	2	1	1	1	0	0	1	1	2	**9**	**3**
EM4	-	Public Awareness And Education - Schools Package	$10,000	$2,000	$37,601	**-**	-	**-**	-	0	2	1	1	1	0	0	1	1	1	**8**	**4**
EM5	Pretty Beach Road and Como Parade	Depth markers at major road crossings	$6,000	$0	$6,000	**-**	-	**-**	$0	0	2	1	1	0	0	0	1	1	1	**7**	**8**

** Indicates hydraulic model and detailed economic assessment used*

14 QUALIFICATIONS

This report has been prepared by Cardno Lawson Treloar for Gosford City Council and as such should not be used by a third party without prior approval.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The results of the study are based on the following assumptions/conditions:

- Flood estimation and assessment of flood management options is based on local catchment flooding only, the impact of Brisbane Water flooding has not been accounted for in this study.
- Design flood extents, hydraulic categories and hazard categories are approximate between cross sections of the model. Where surveyed levels are not available, flood extents are based on the 2m LIC contour data provided by Council and the interpolation of model results.
- The local pit and pipe stormwater drainage system is not modelled.
- The report relies on the accuracy of the survey data provided by Council.
- Cost estimates provided for options in this report are preliminary only and more detailed cost estimates should be prepared during the detailed design phase.

Study results should not be used for purposes other than those for which they were prepared

15 ACKNOWLEDGMENTS

The assistance of the residents of the Pretty Beach area, Hardys Bay Resident's Group Inc, Gosford City Council and the Department of Natural Resources is gratefully acknowledged.

This study was funded under the State Government's Floodplain Management Program through the Department of Natural Resources on a 2:1 (State:Council) ratio.

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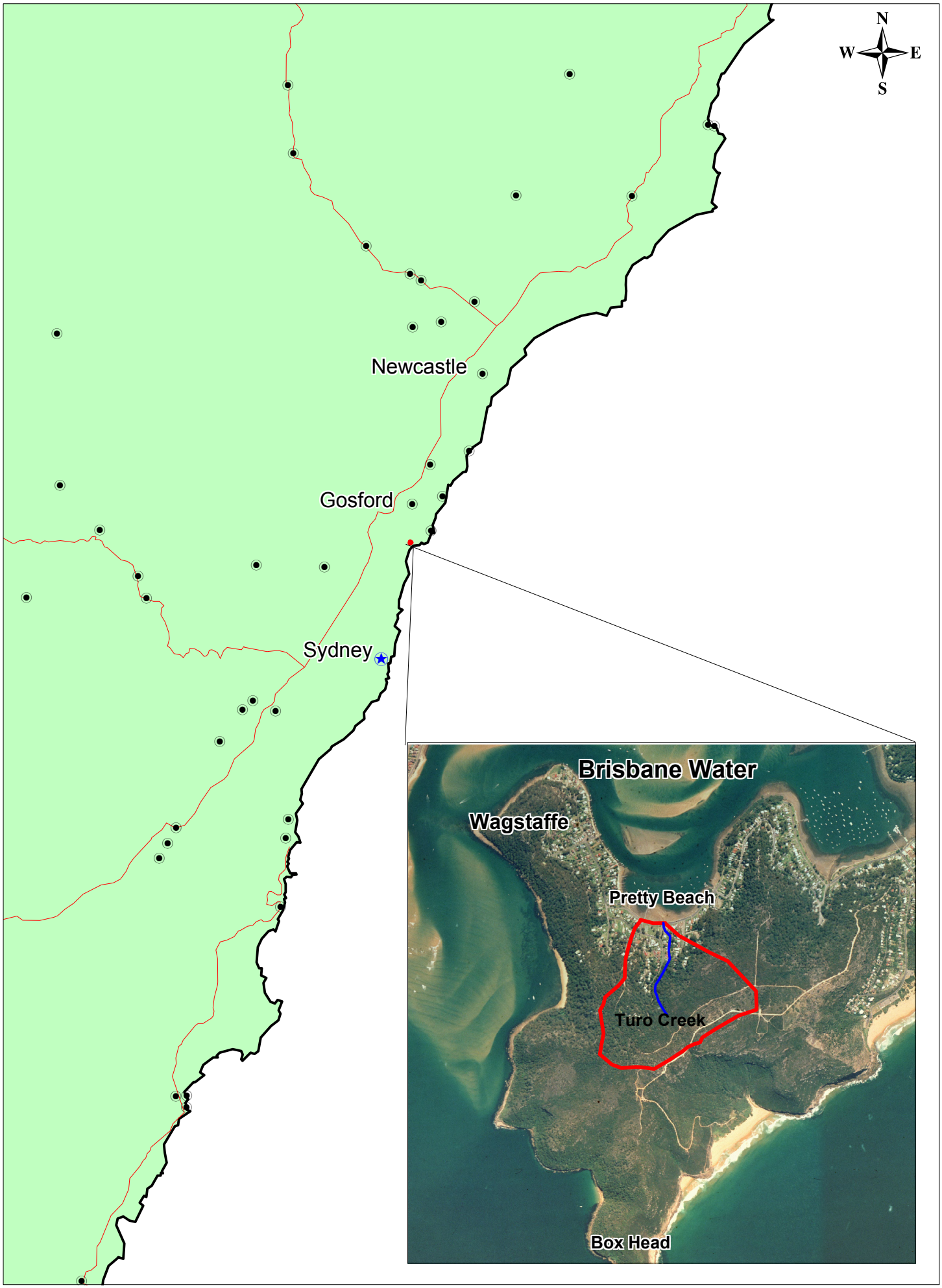
FIGURES



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October 2006

Turo Creek Pretty Beach Floodplain Risk Management Study

FIGURE 1.1
LOCATION MAP

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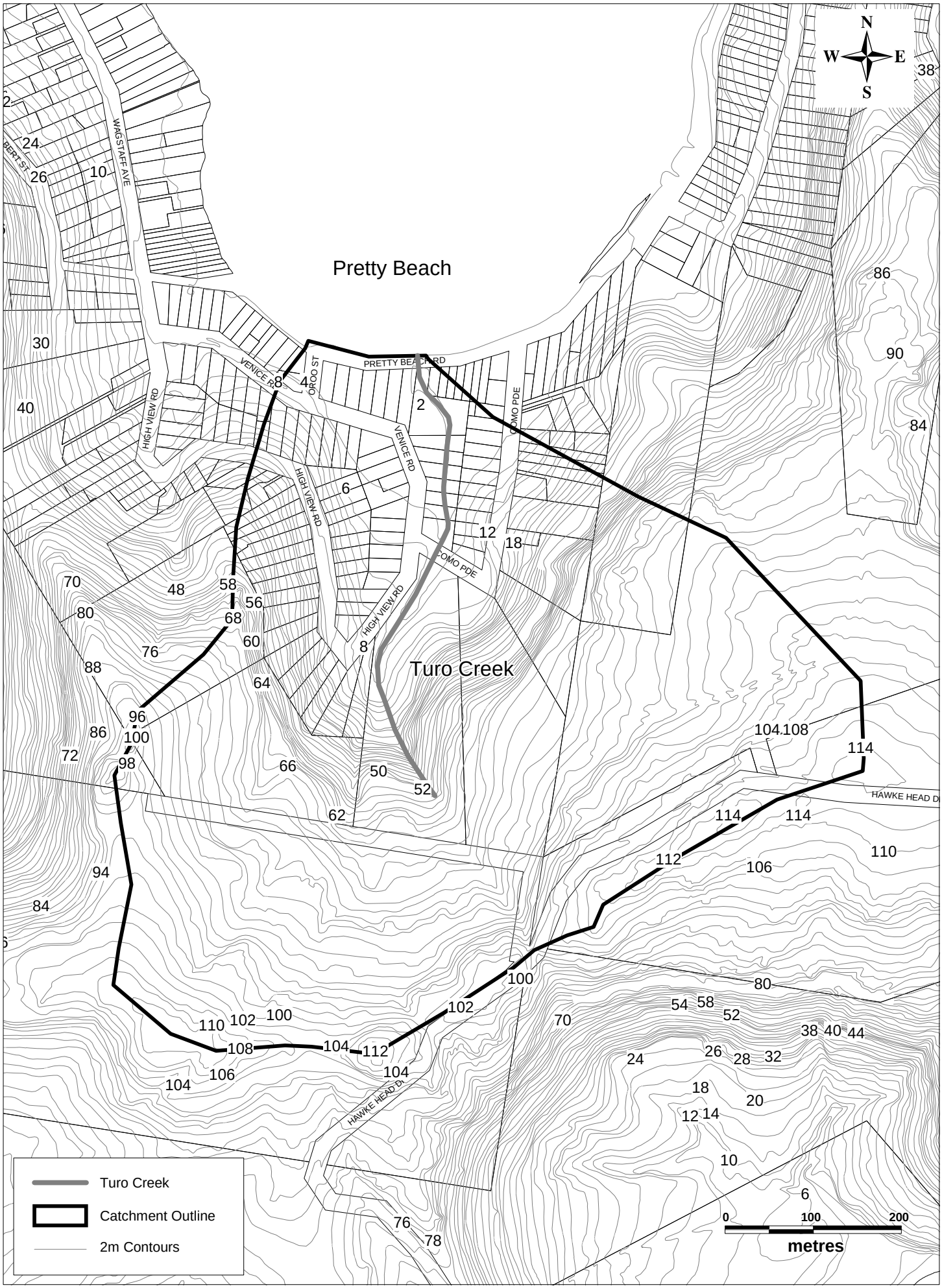

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FIGURE 1.2
CATCHMENT OUTLINE

J2313/R2182/V6
July 2007

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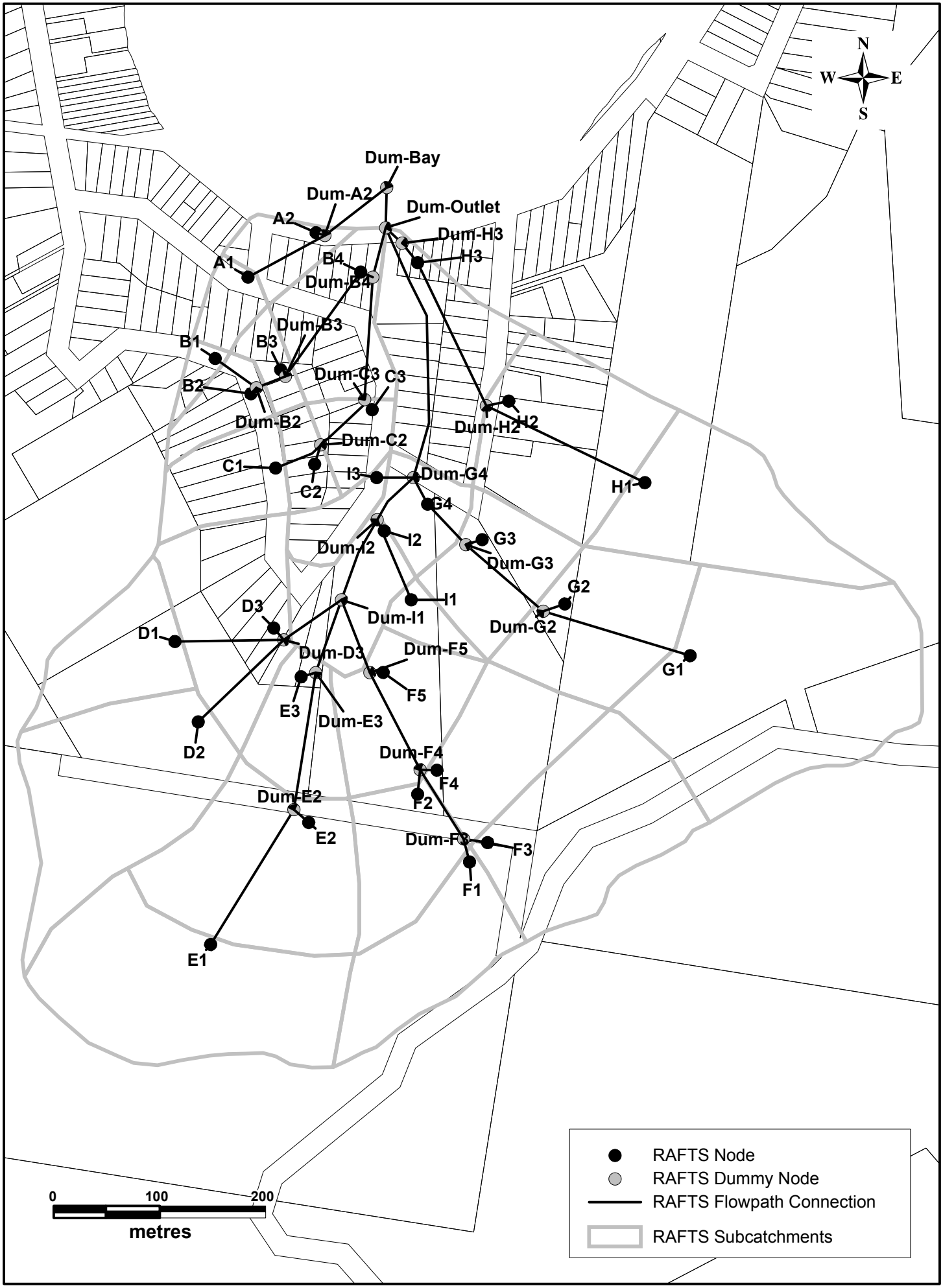

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October 2006

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FIGURE 3.1
RAFTS LAYOUT

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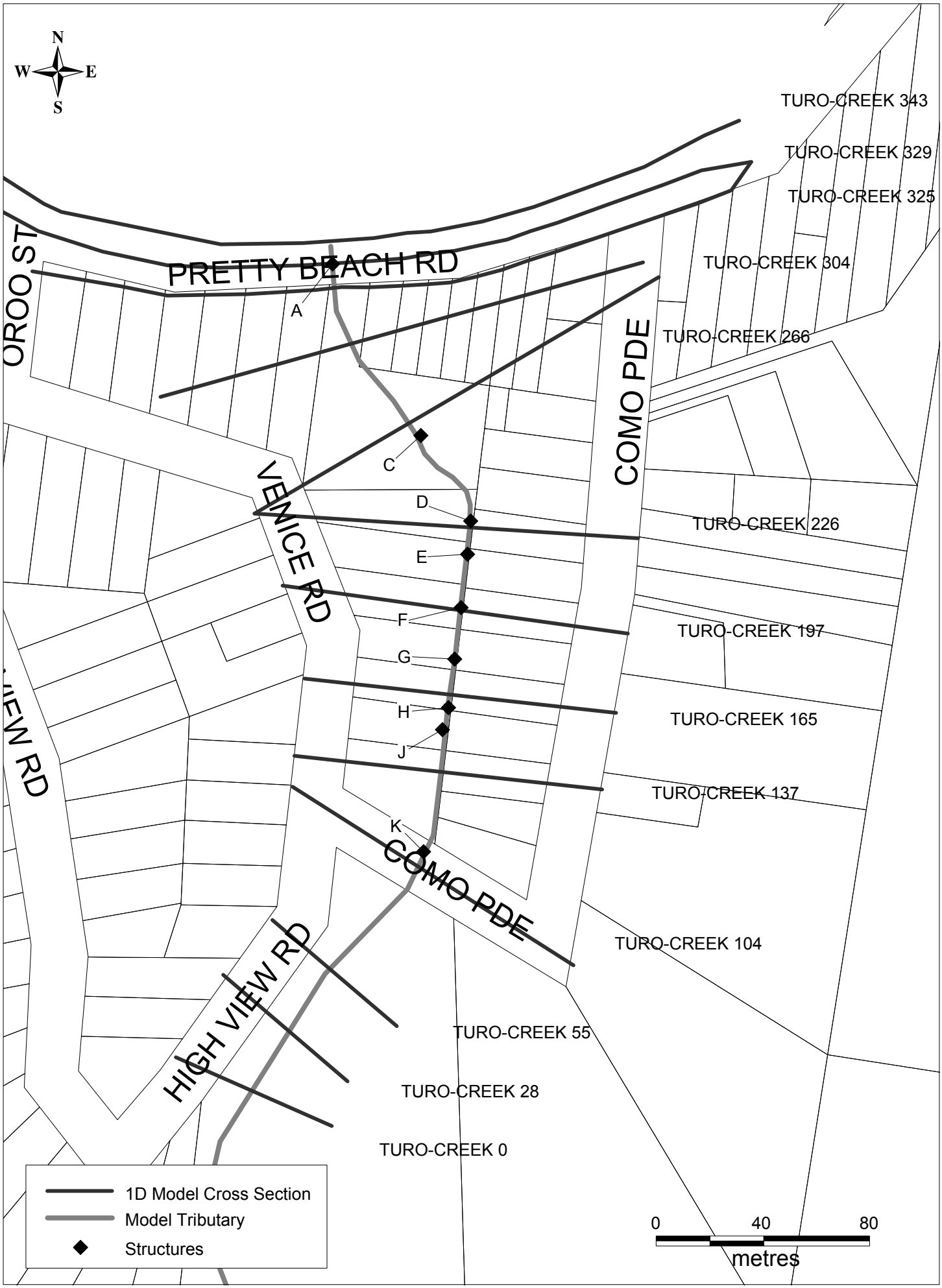

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October 2006

Turo Creek Pretty Beach Floodplain Risk Management Study

FIGURE 3.2
1D MODEL LAYOUT

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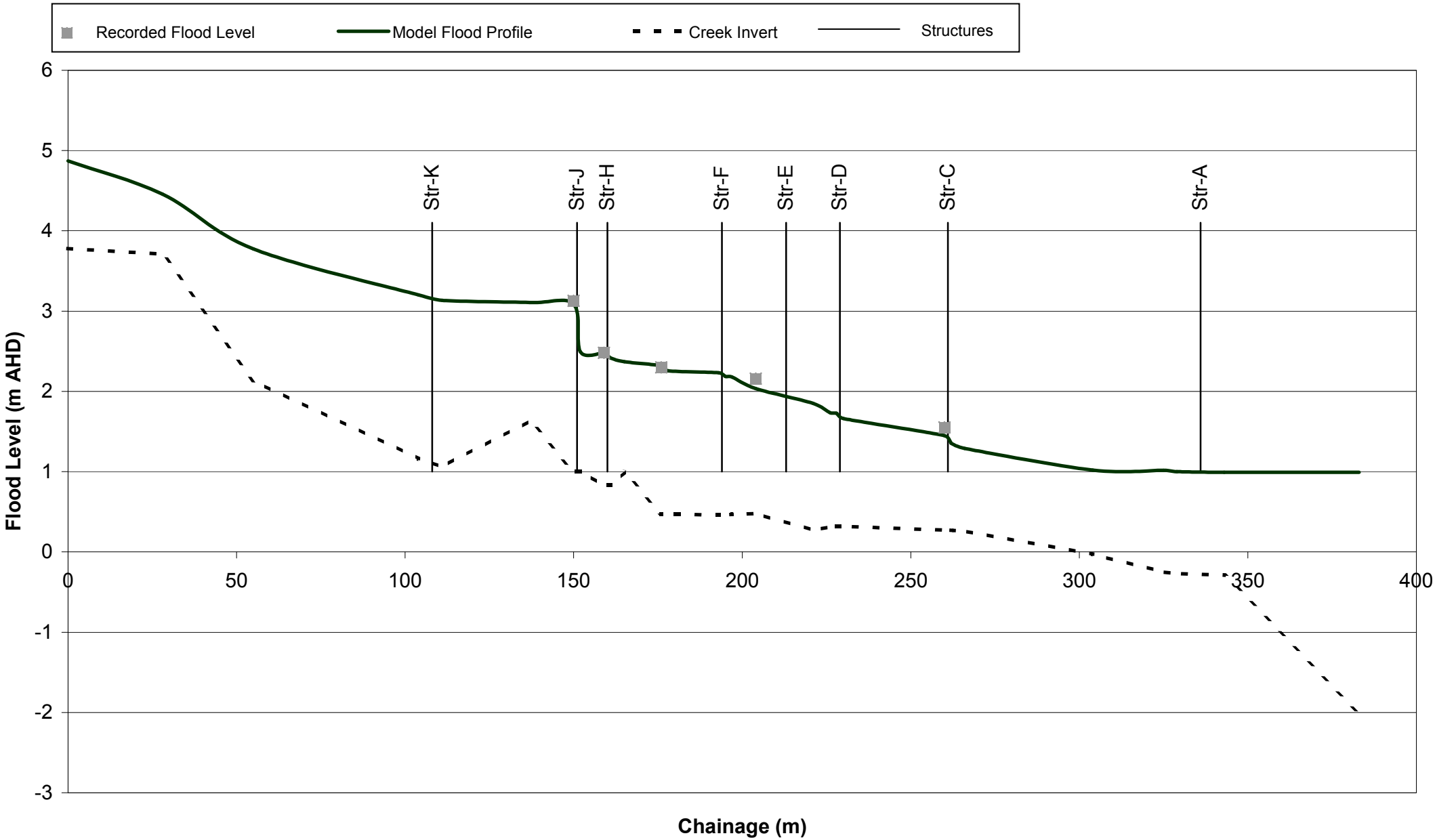
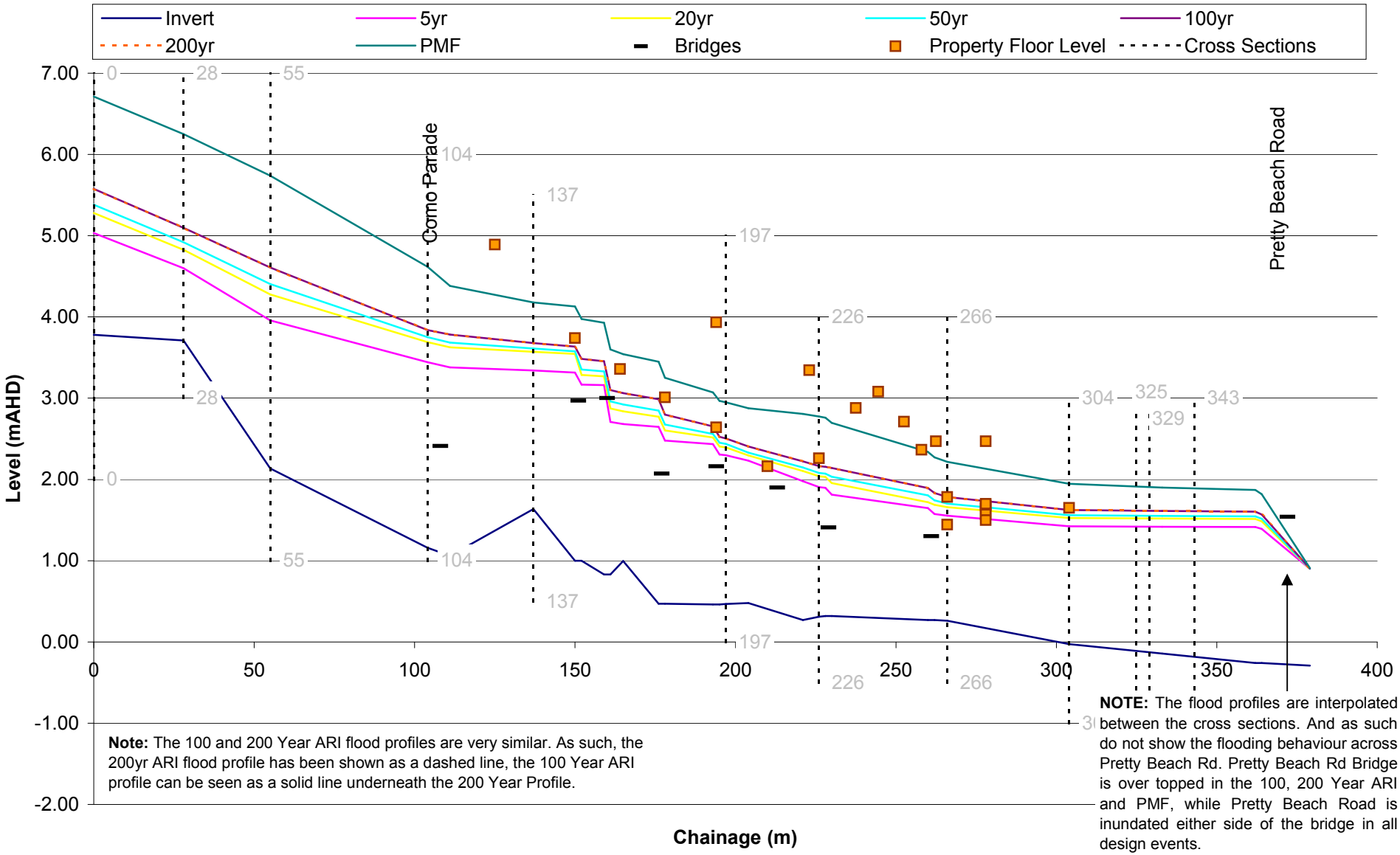
February 1990 Calibration Flood Profile



DESIGN FLOOD PROFILES



Turo Creek Pretty Beach Floodplain Management Study and Plan

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October 2006

FIGURE 3.4
TURO CREEK DESIGN FLOOD PROFILE
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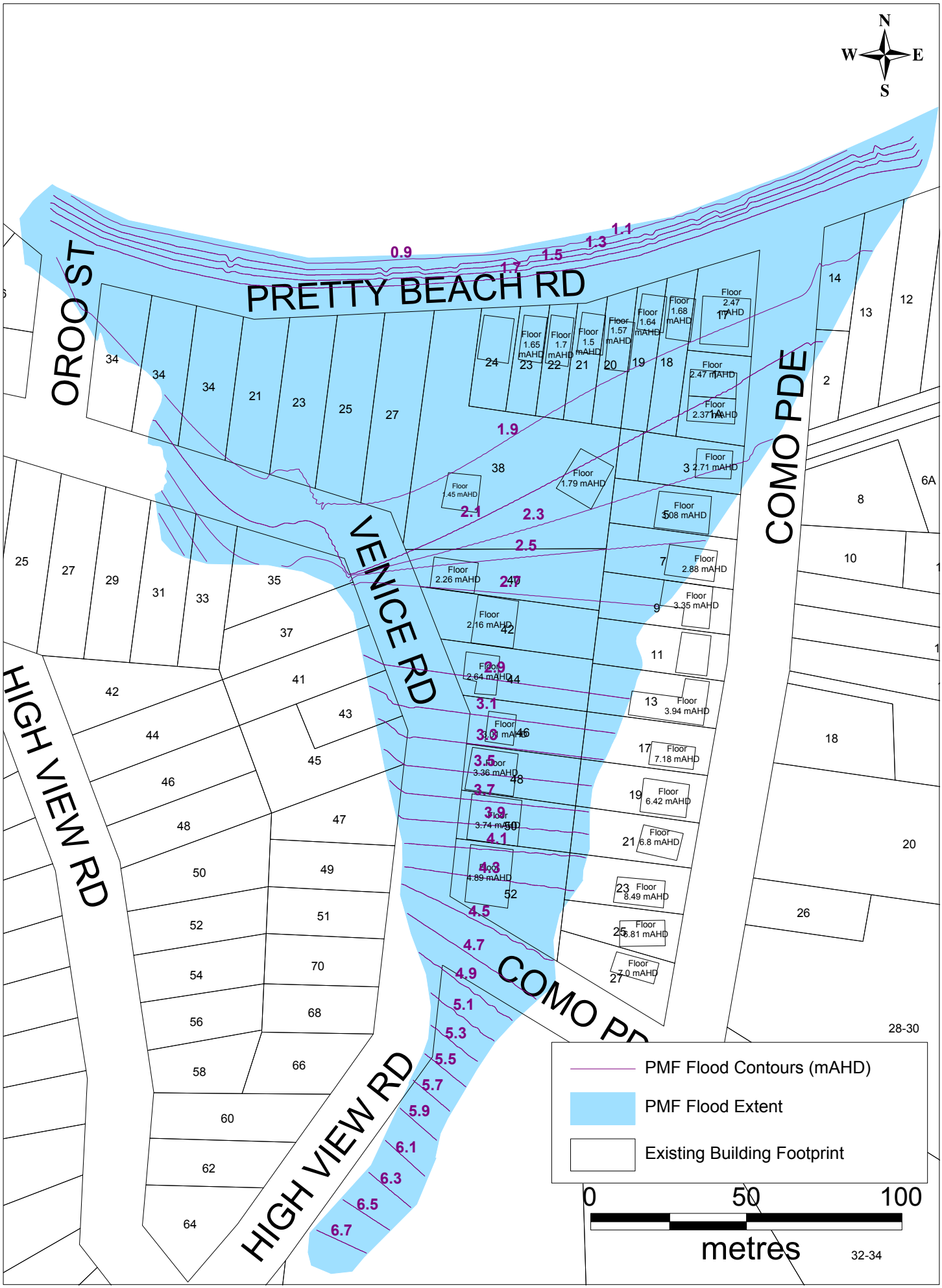

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FIGURE 3.5
PMF EXTENT

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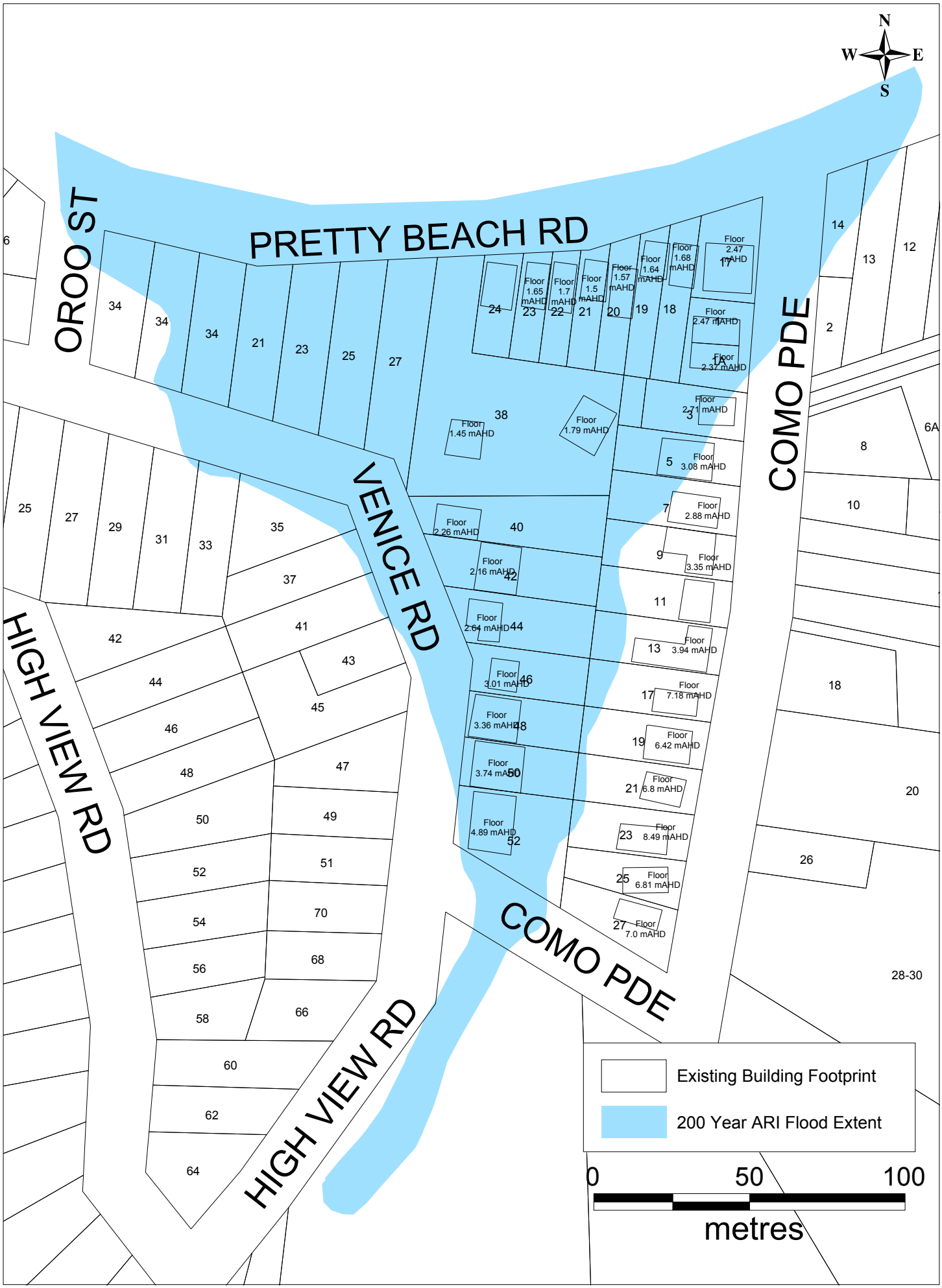

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FIGURE 3.6
200 YEAR ARI FLOOD EXTENT

J2313/R2182/V6
October 2006

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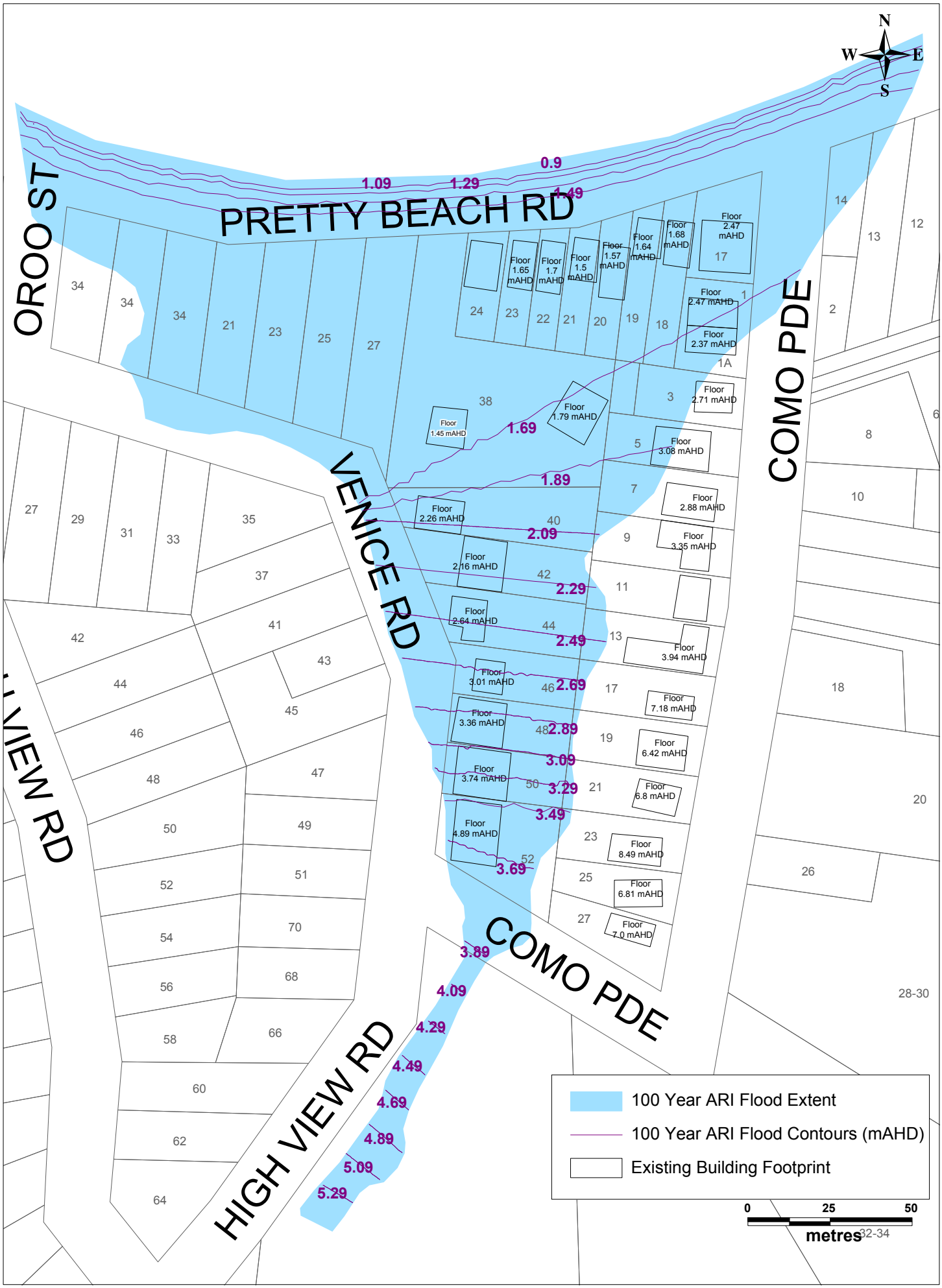

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Turo Creek Pretty Beach Floodplain Risk Management Study

FIGURE 3.7
100 YEAR ARI FLOOD EXTENT

J2313/R2182/V6
October 2006

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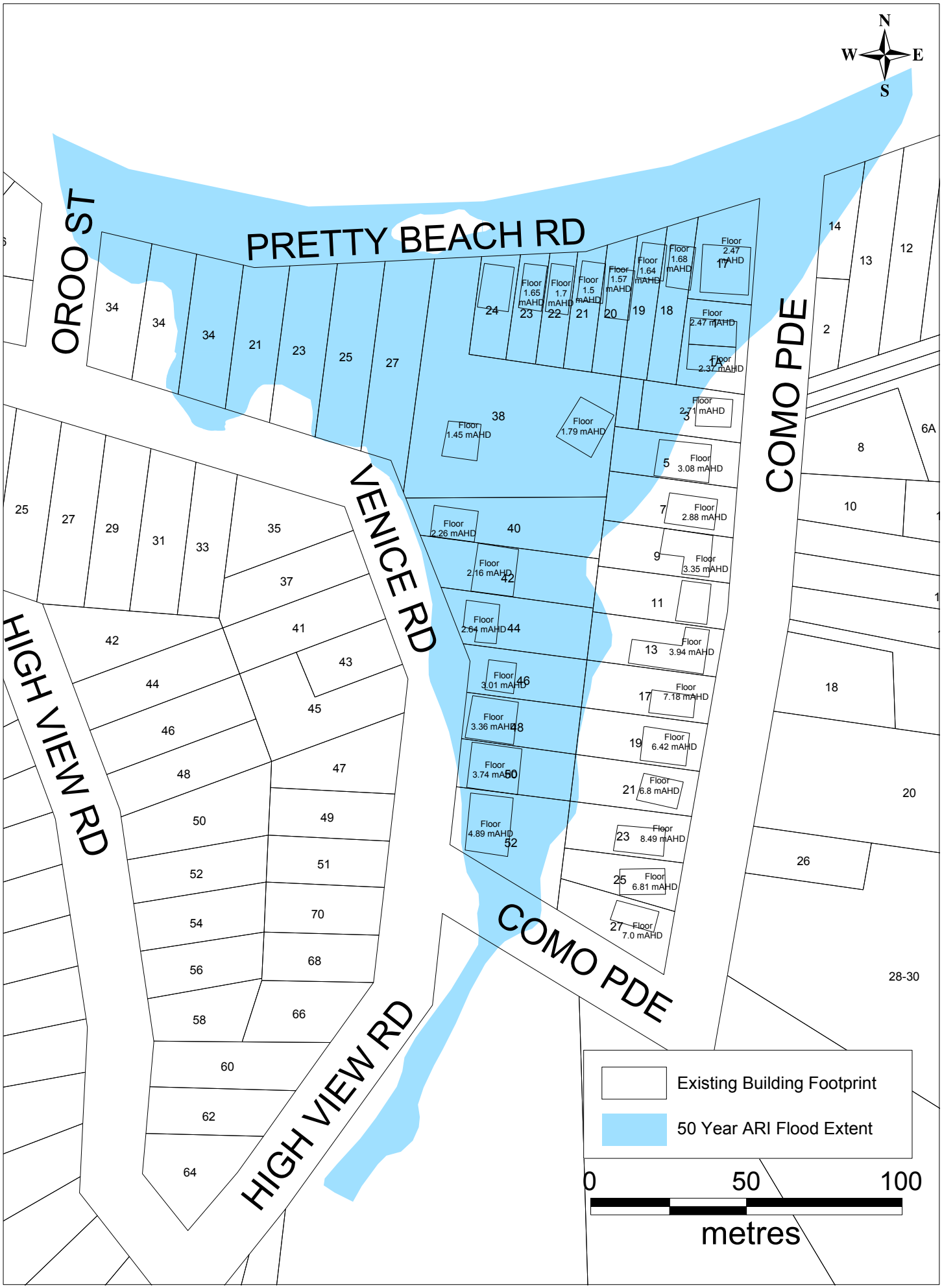

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FIGURE 3.8
50 YEAR ARI FLOOD EXTENT

J2313/R2182/V6
October 2006

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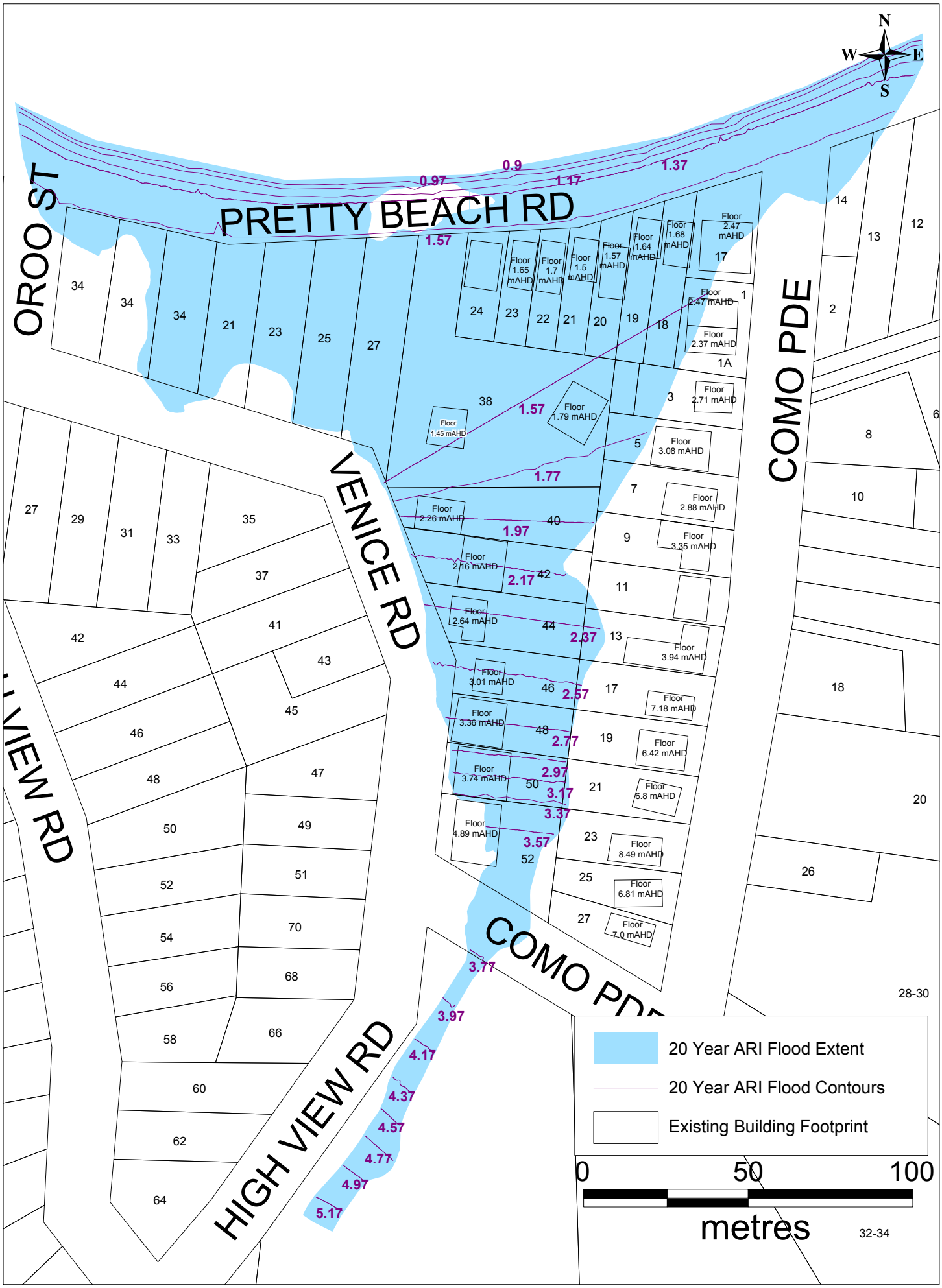

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FIGURE 3.9
20 YEAR ARI FLOOD EXTENT

J2313/R2182/V6
October 2006

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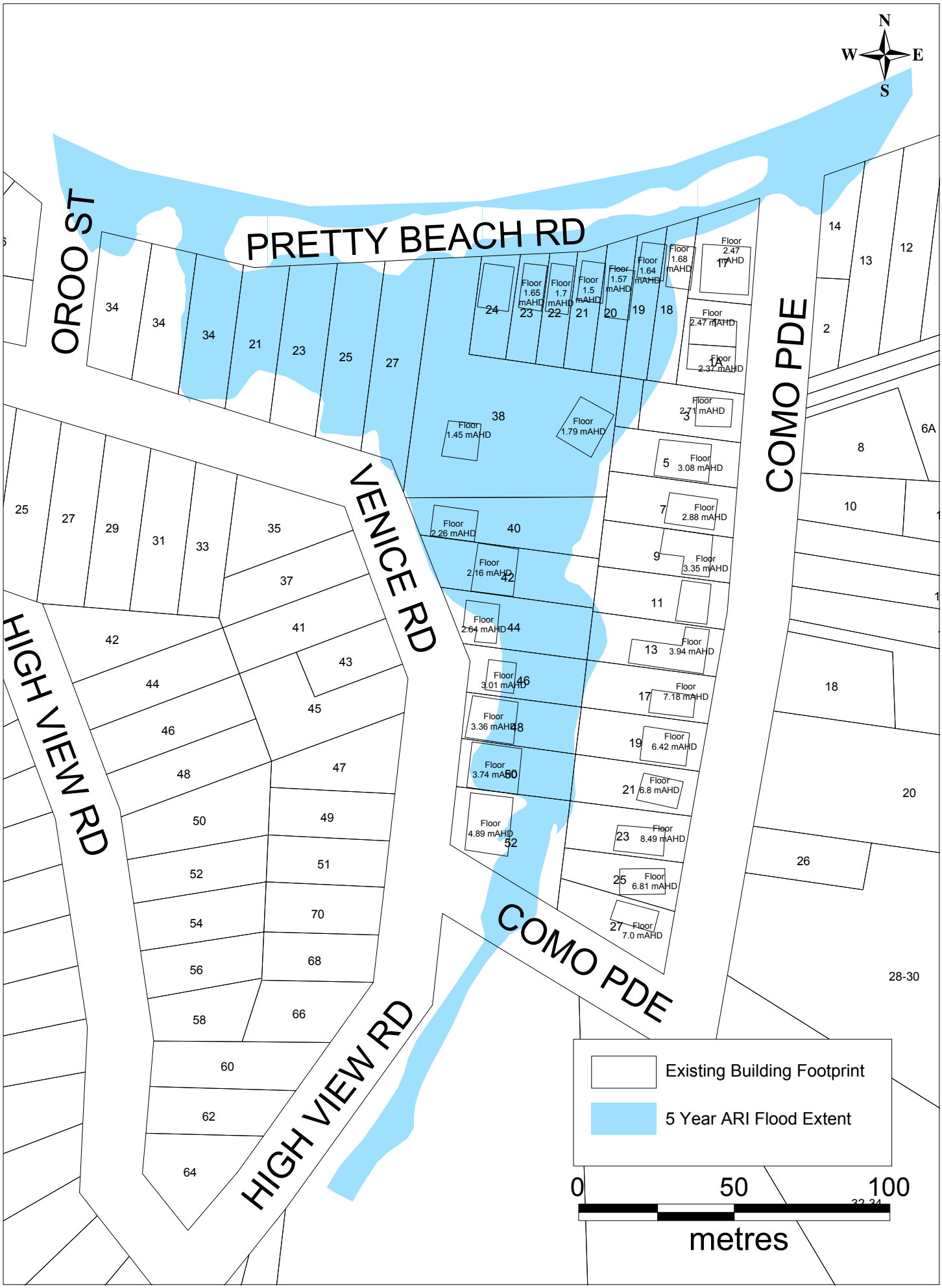

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FIGURE 3.10
5 YEAR ARI FLOOD EXTENT

J2313/R2182/V6
October 2006

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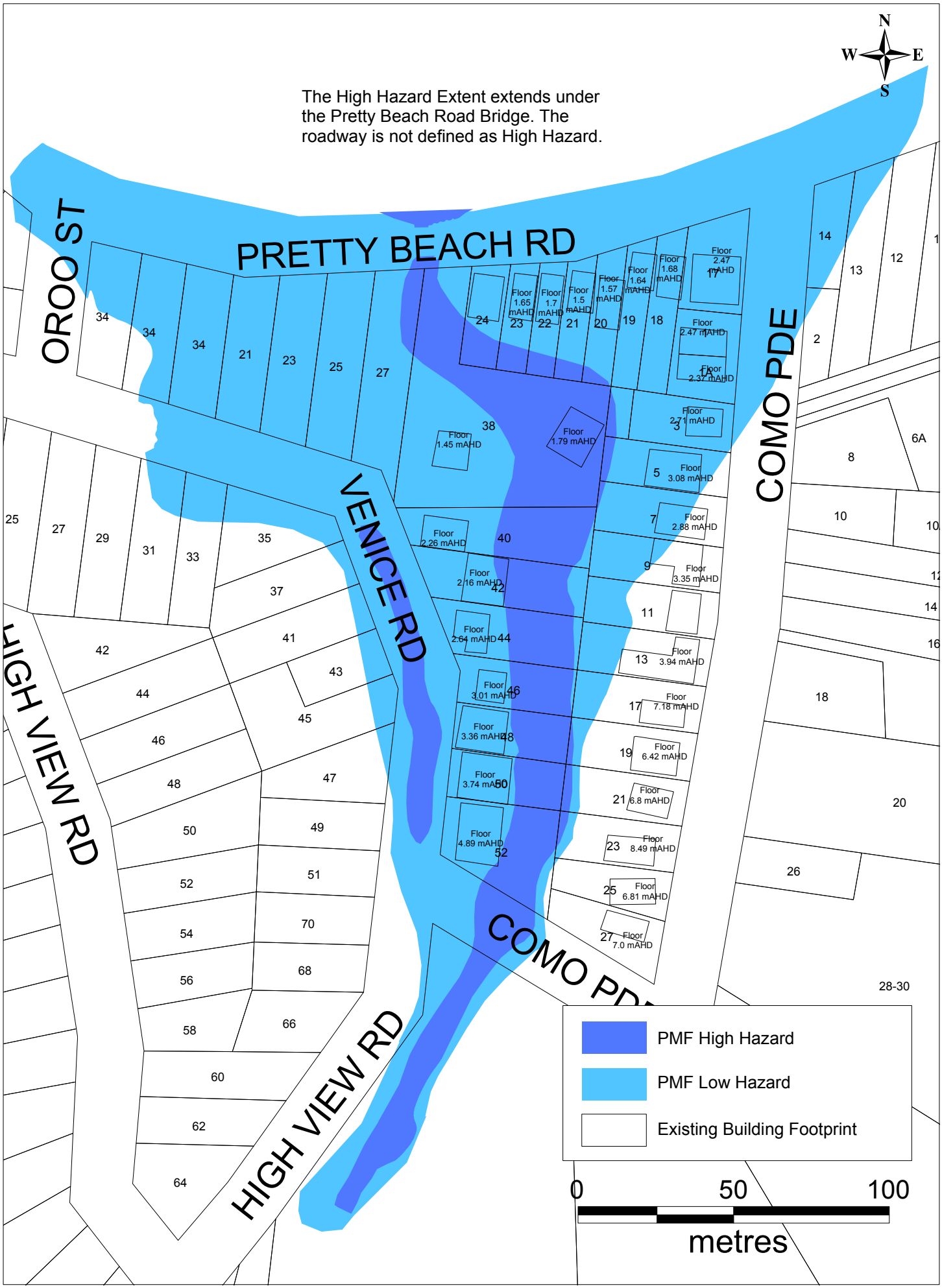

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FIGURE 3.11
PMF HAZARD

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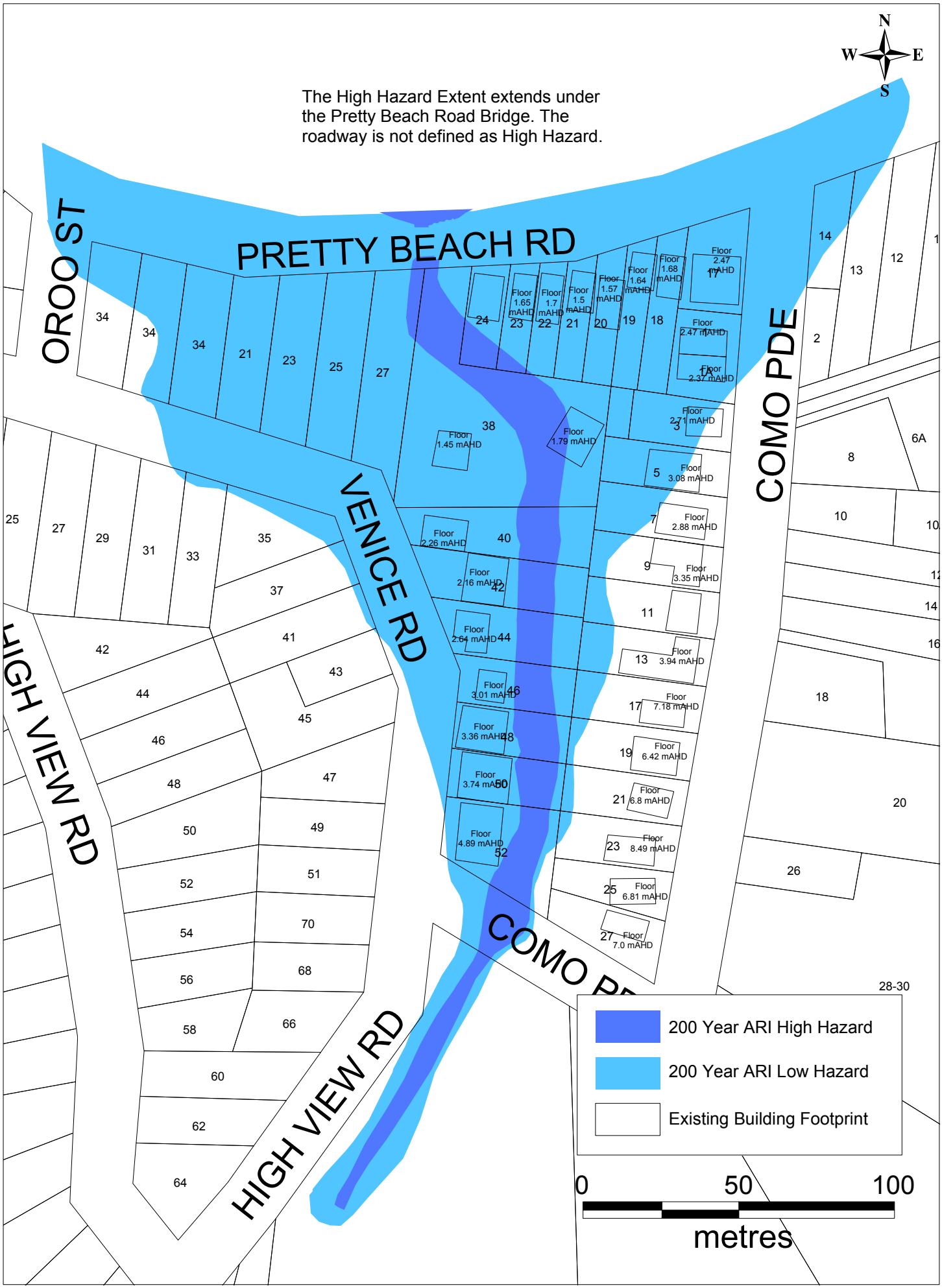

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FIGURE 3.12
200 YEAR ARI FLOOD HAZARD

J2313/R2182/V6
October 2006

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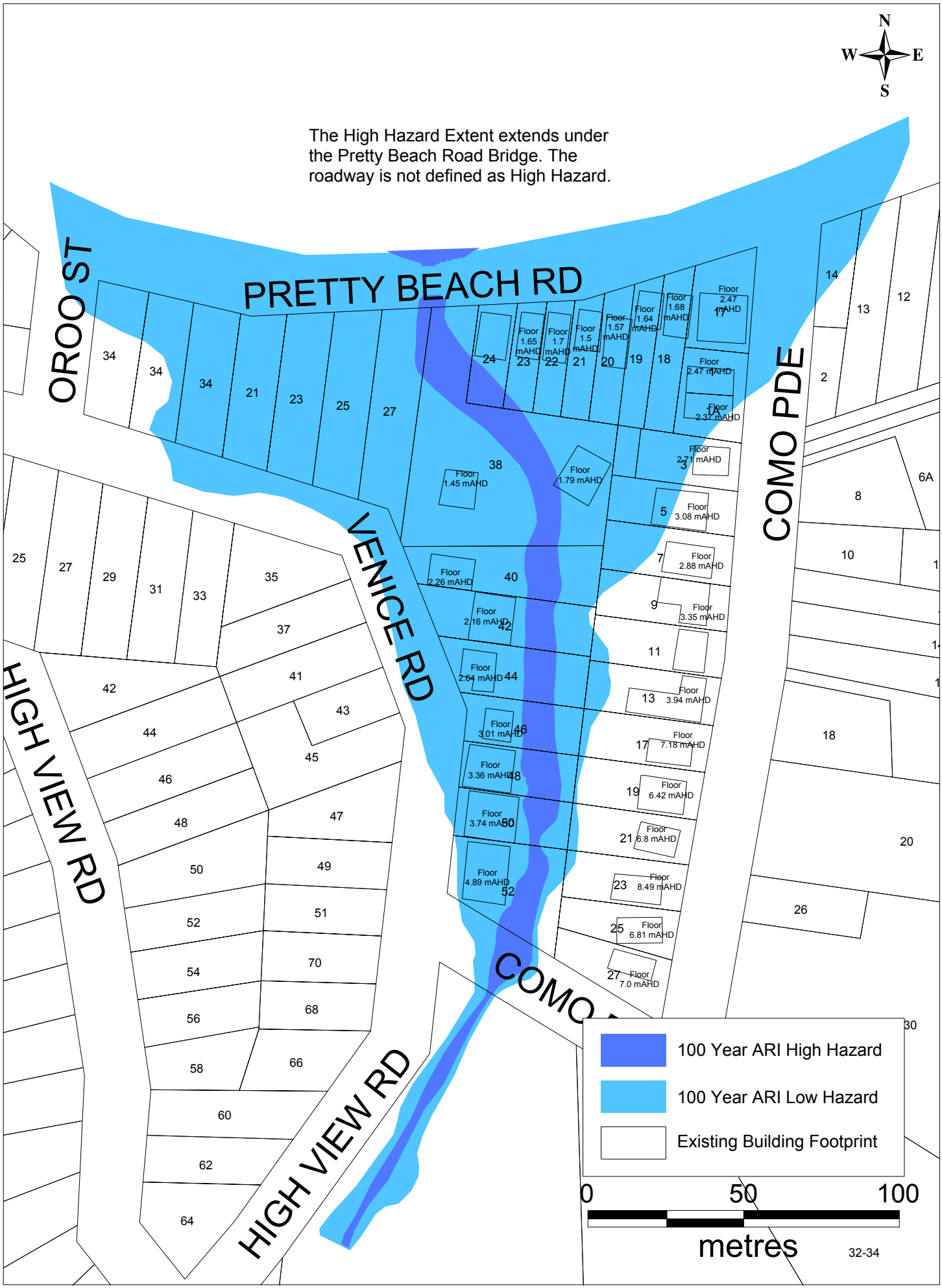

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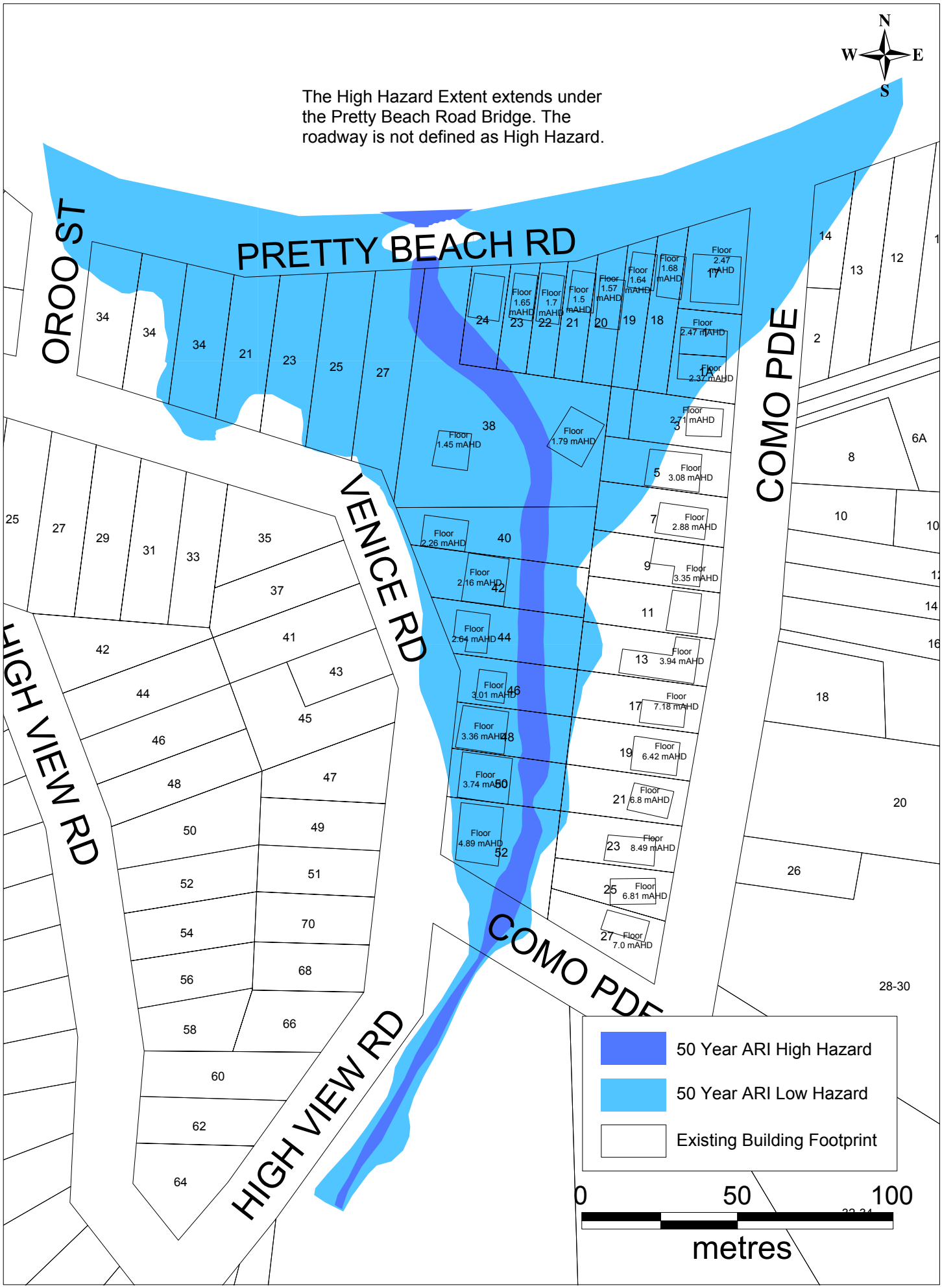
FIGURE 3.13
100 YEAR FLOOD HAZARD

J2313/R2182/V6
October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.13 100yr Flood Hazard.Wor



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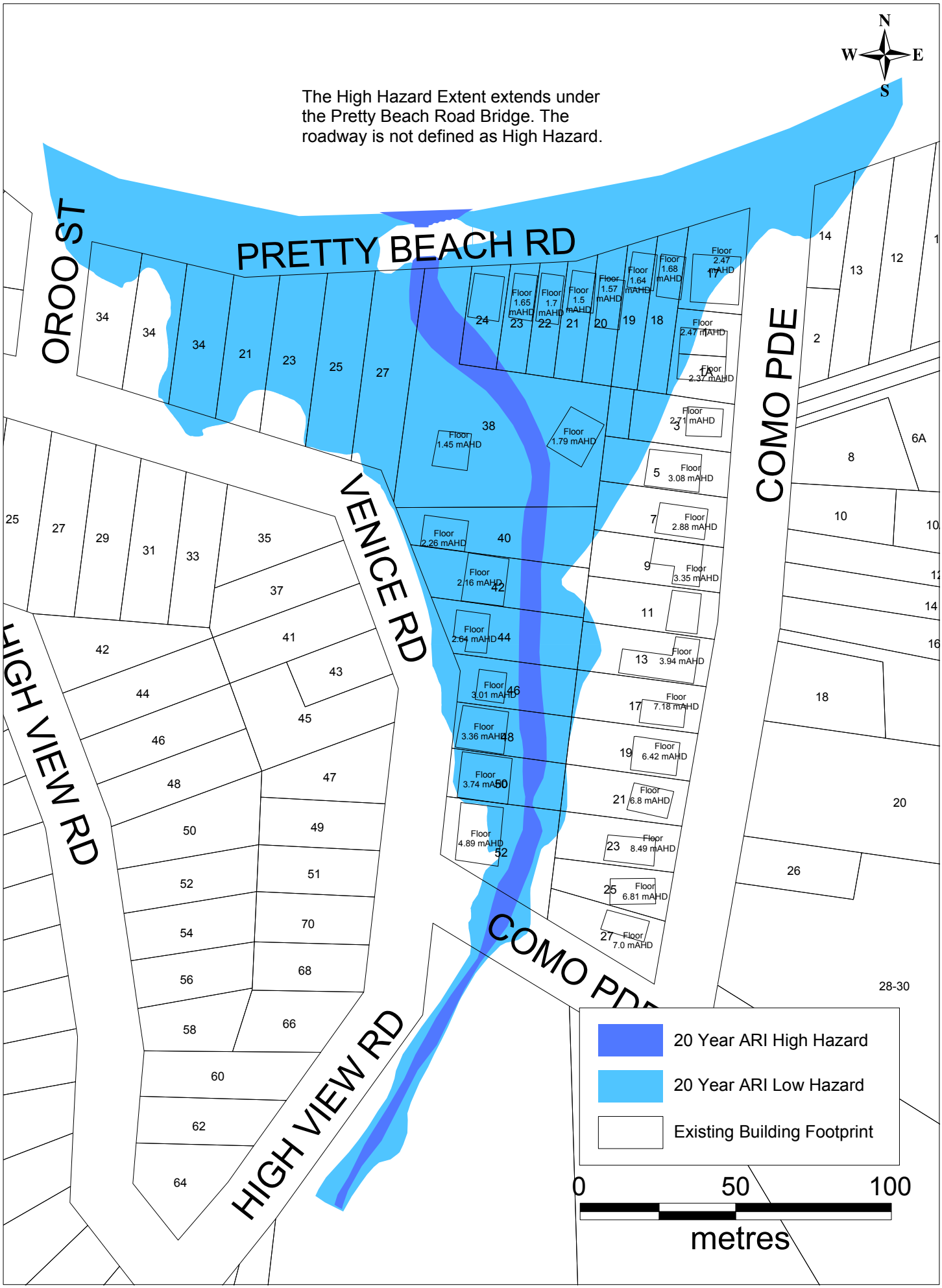
Turo Creek, Pretty Beach, Floodplain Risk Management Study

FIGURE 3.14
50 YEAR ARI FLOOD HAZARD

J2313/R2182/V6
October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2`182\V6\Figures\Figure 3.14 50yr Flood Hazard.Wor



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October 2006

Turo Creek Pretty Beach Floodplain Risk Management Study

FIGURE 3.15
20 YEAR ARI FLOOD HAZARD

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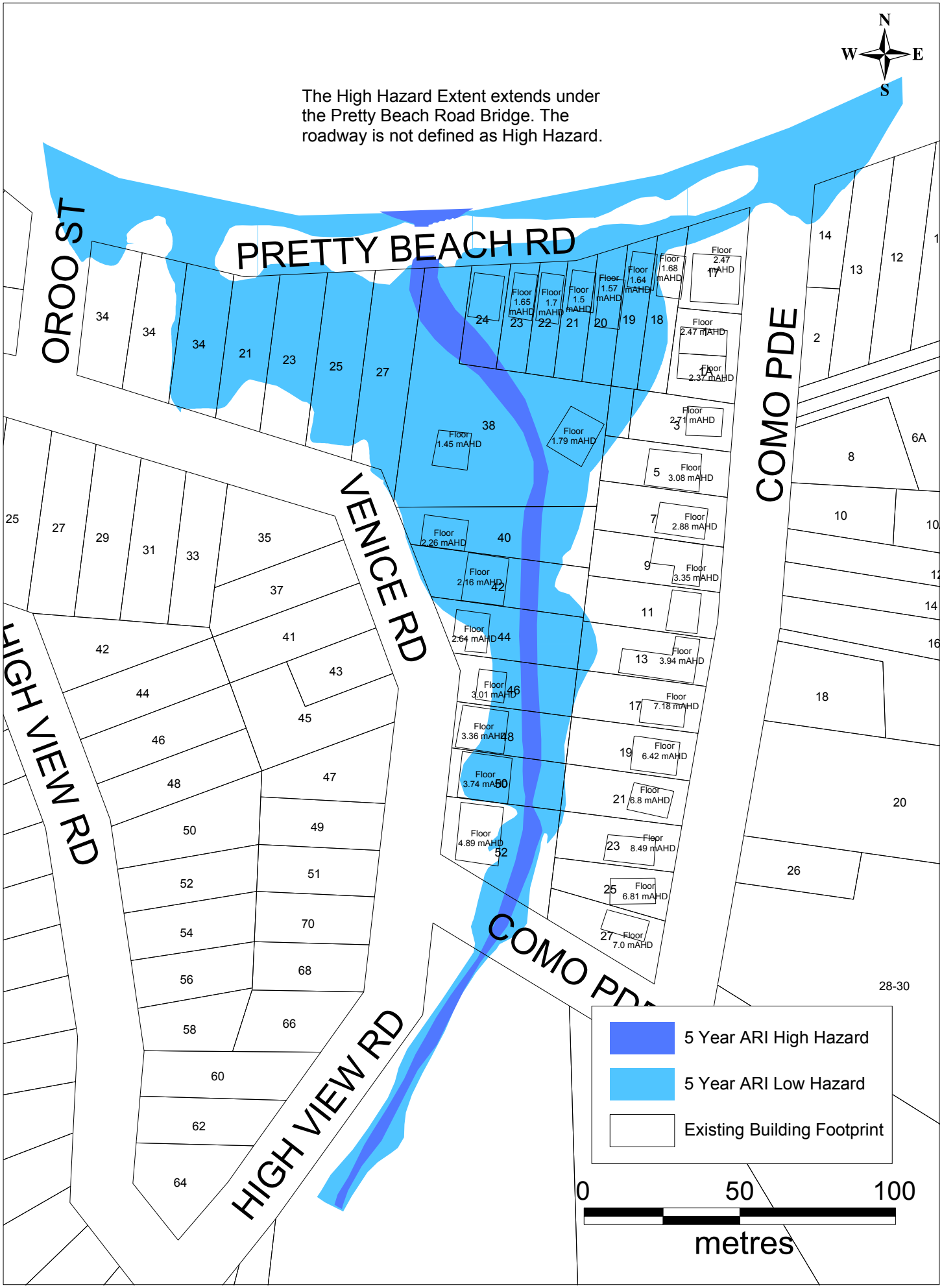

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FIGURE 3.16
5 YEAR ARI FLOOD HAZARD

J2313/R2182/V6
October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.16 5yr Flood Hazard.Wor

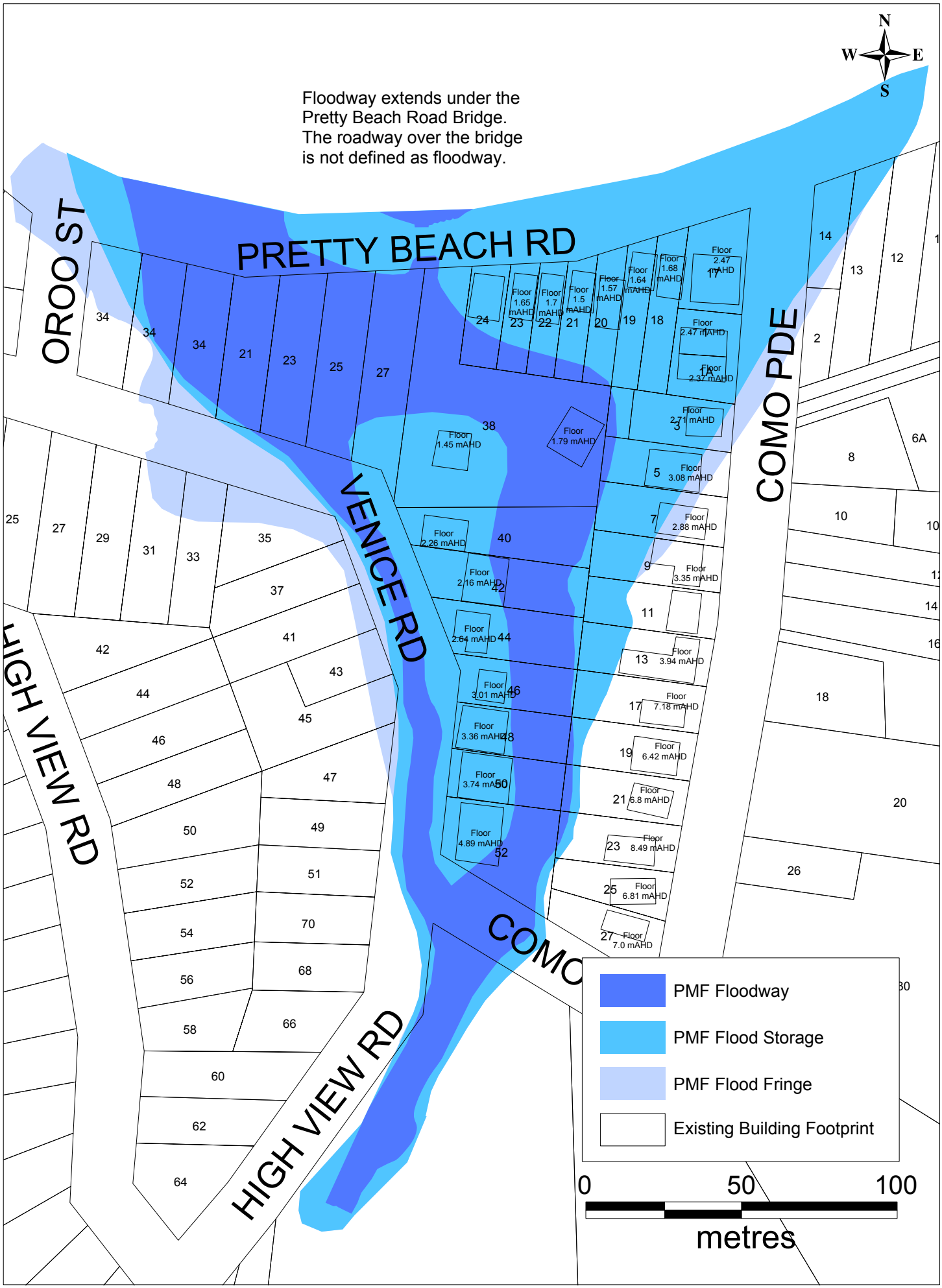

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FIGURE 3.17
PMF HYDRAULIC CATEGORIES

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October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.17 PMF Hydraulic Categories.Wor

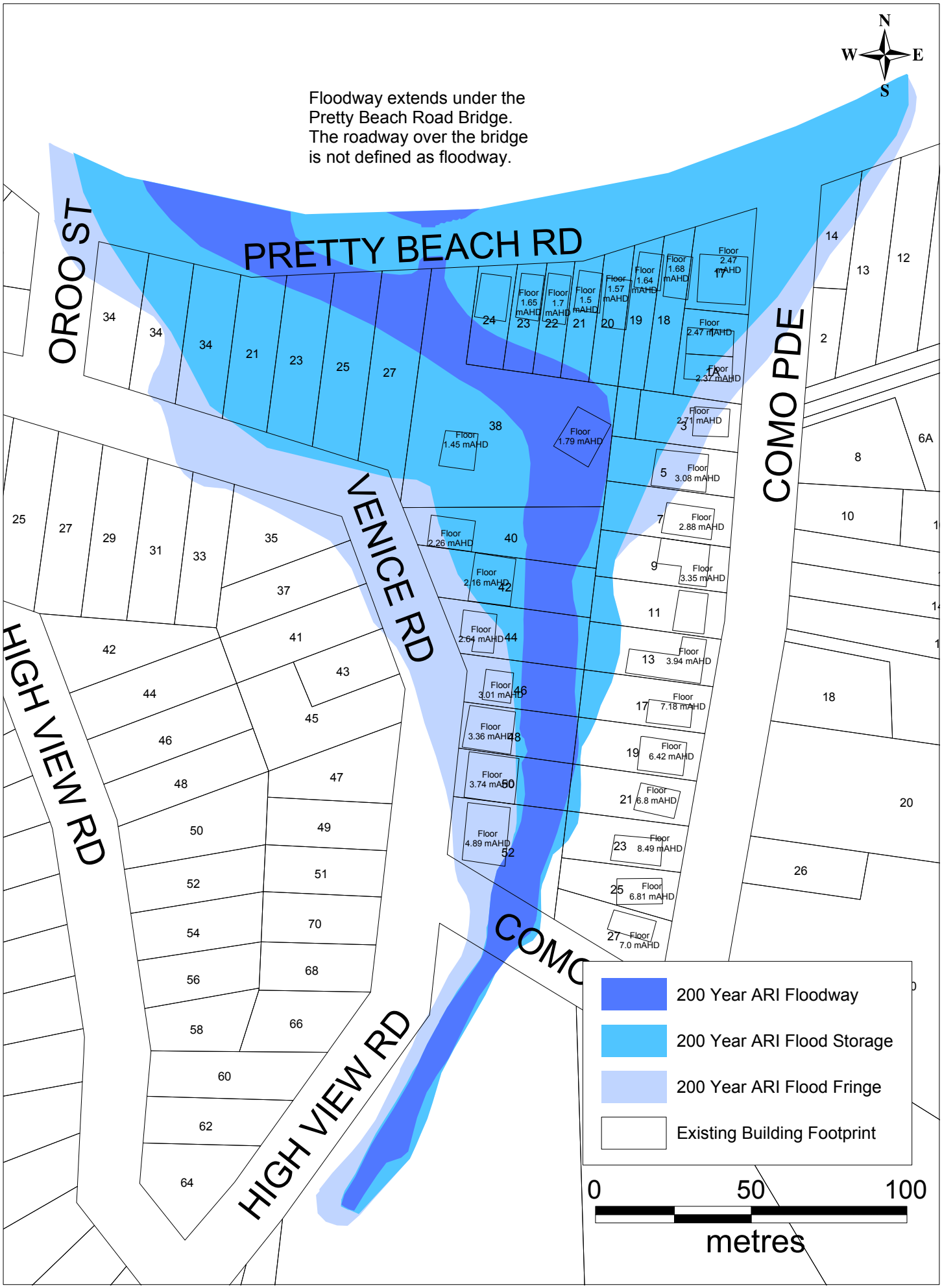

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FIGURE 3.18
200 YEAR ARI HYDRAULIC CATEGORIES

J2313/R2182/V6
October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.18 200yr Hydraulic Categories.Wor

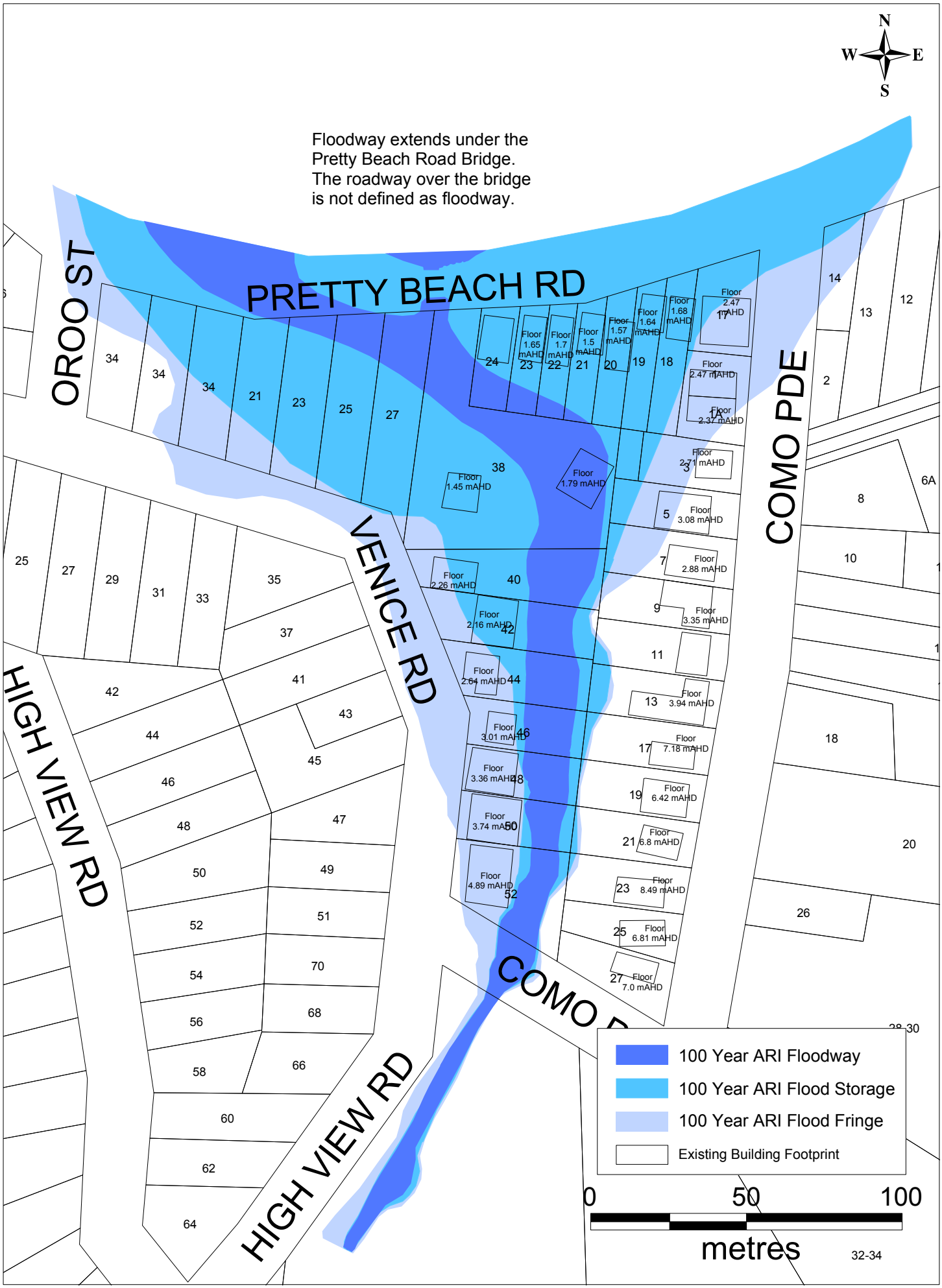

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FIGURE 3.19
100 YEAR ARI HYDRAULIC CATEGORIES

J2313/R2182/V6
October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.19 100yr Hydraulic Categories.Wor

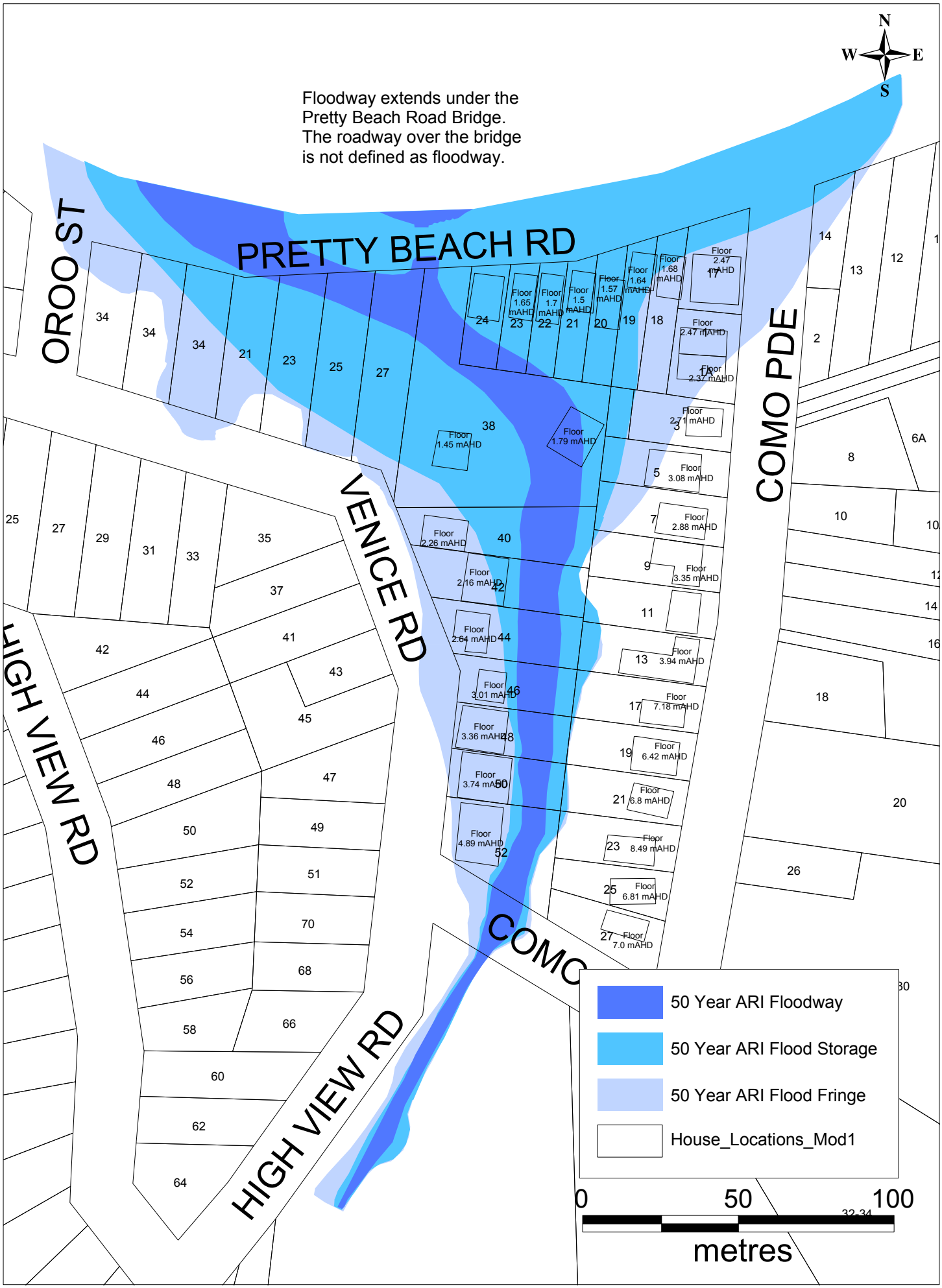

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FIGURE 3.20
50 YEAR ARI HYDRAULIC CATEGORIES

J2313/R2182/V6
October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.20 50yr Hydraulic Categories.Wor

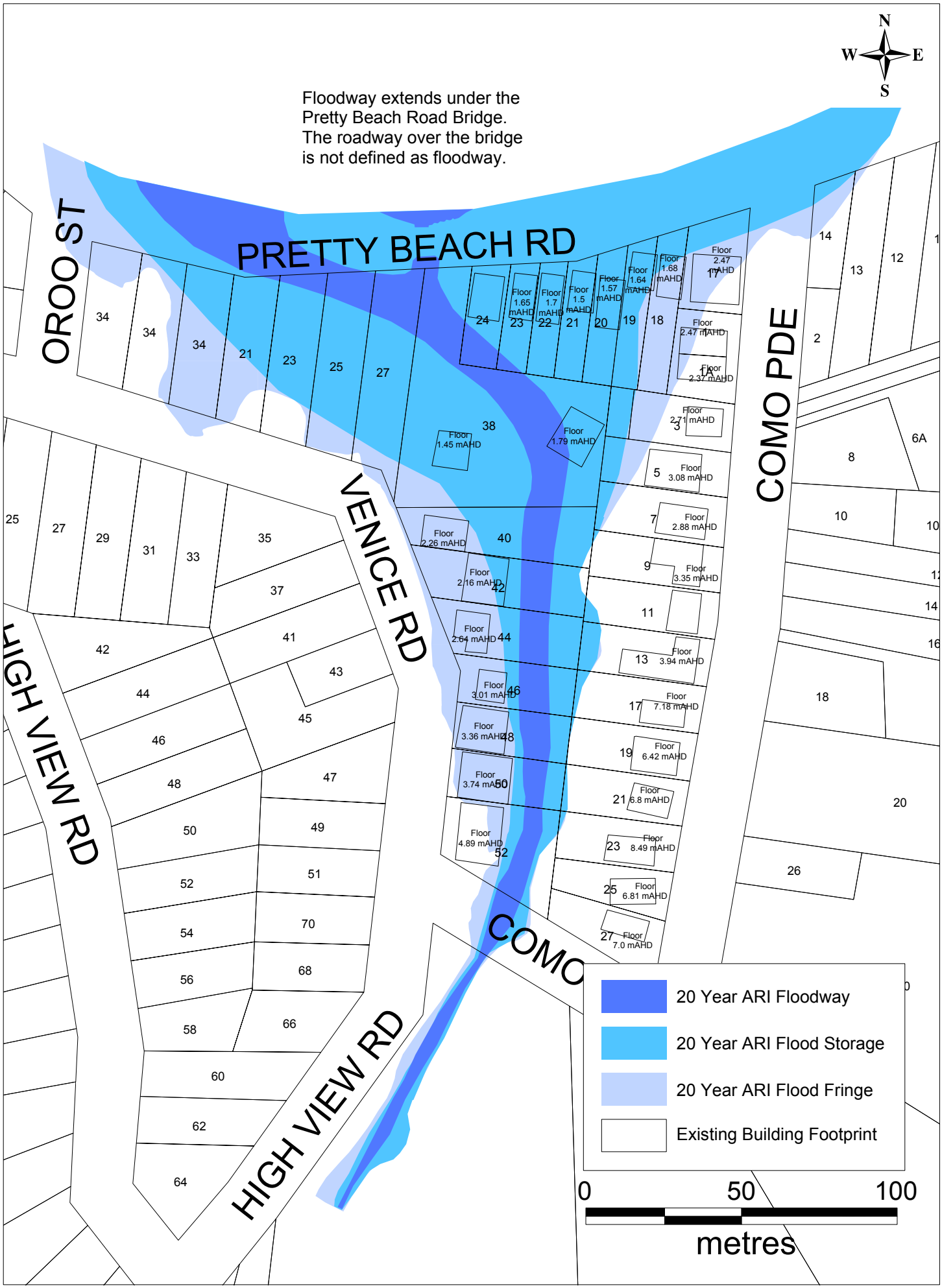

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FIGURE 3.21
20 YEAR ARI HYDRAULIC CATEGORIES

J2313/R2182/V6
October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.21 20yr Hydraulic Categories.Wor

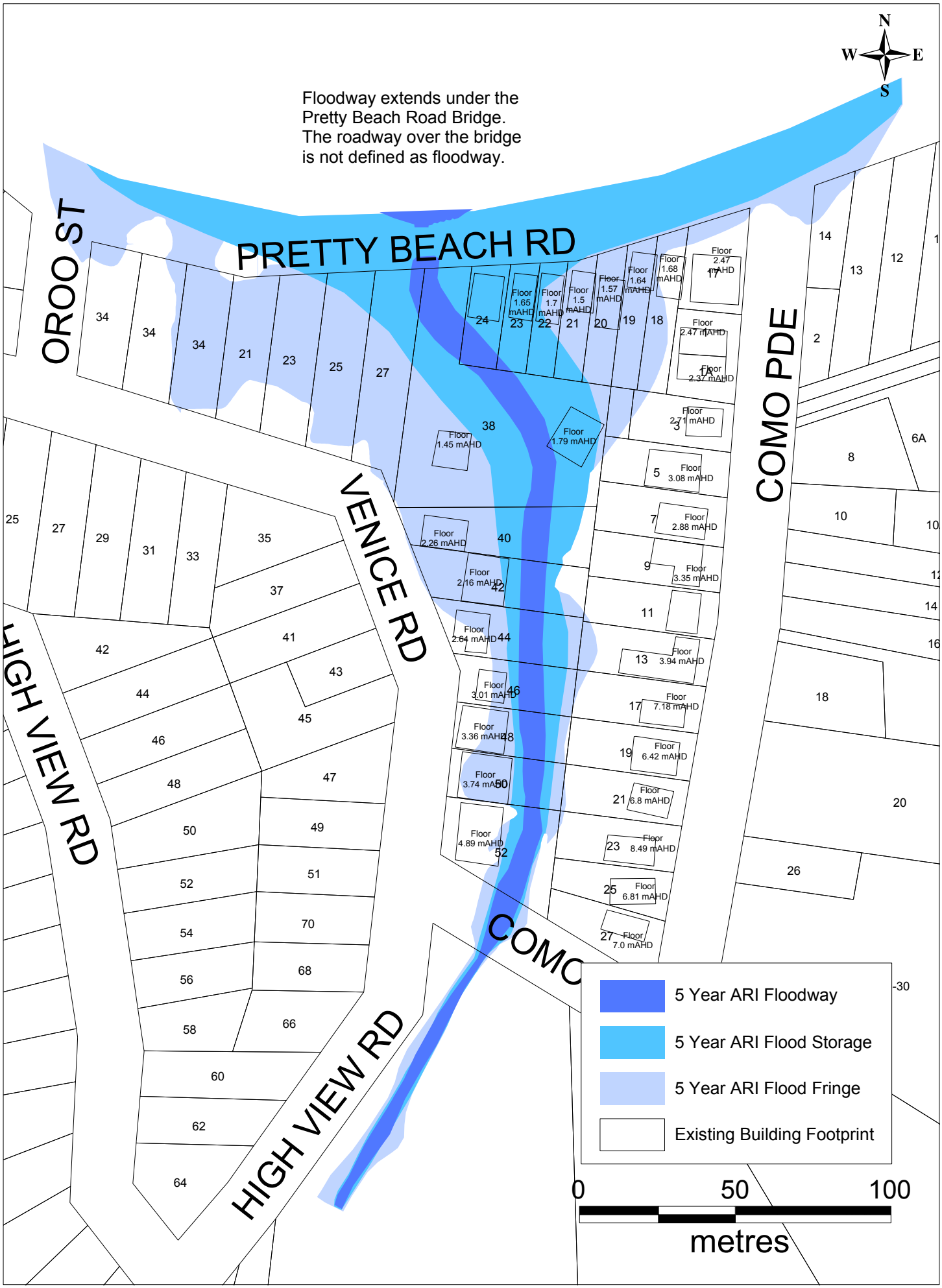

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FIGURE 3.22
5 YEAR ARI HYDRAULIC CATEGORIES

J2313/R2182/V6
October 2006

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.22 5yr Hydraulic Categories.Wor

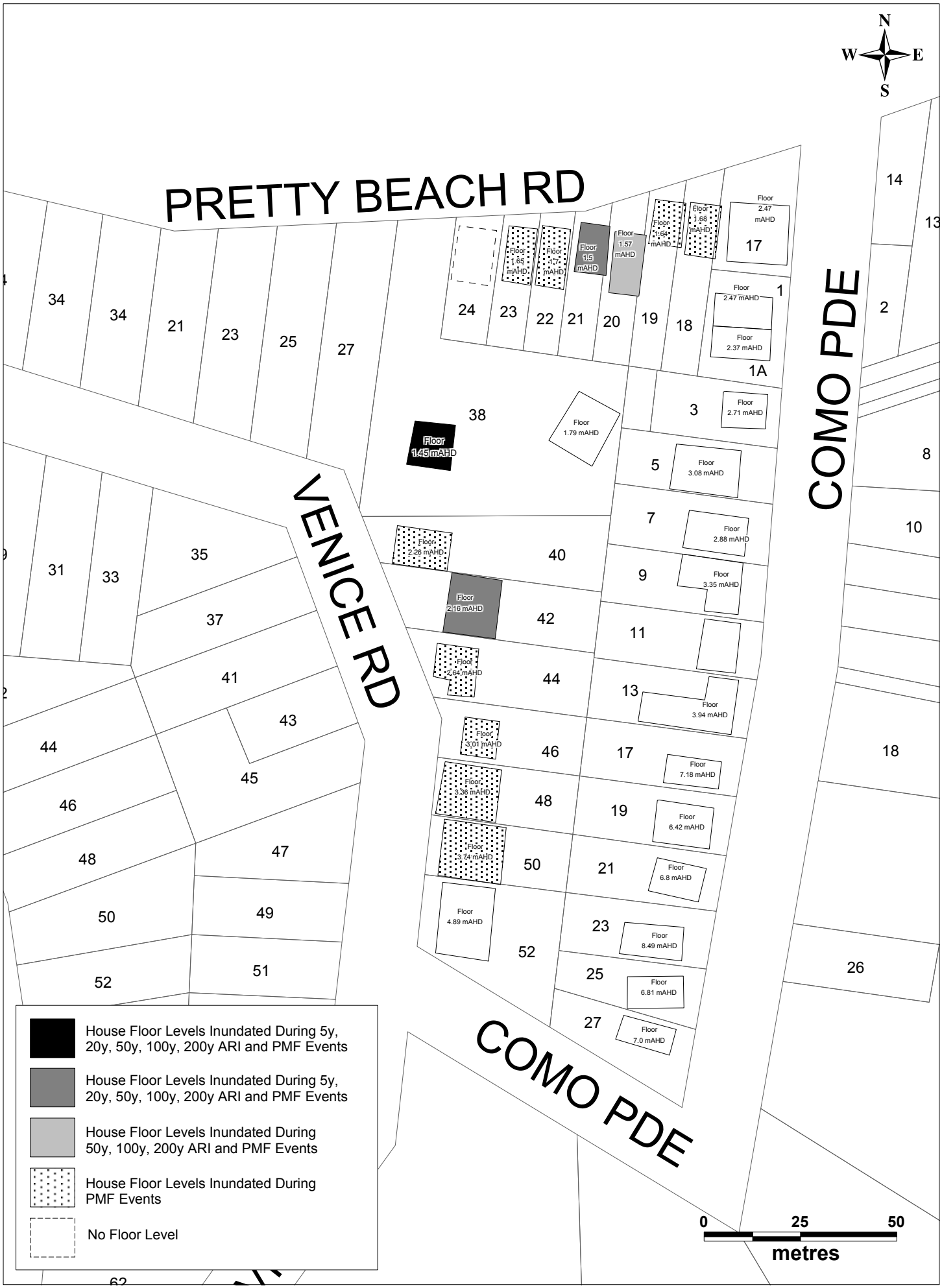

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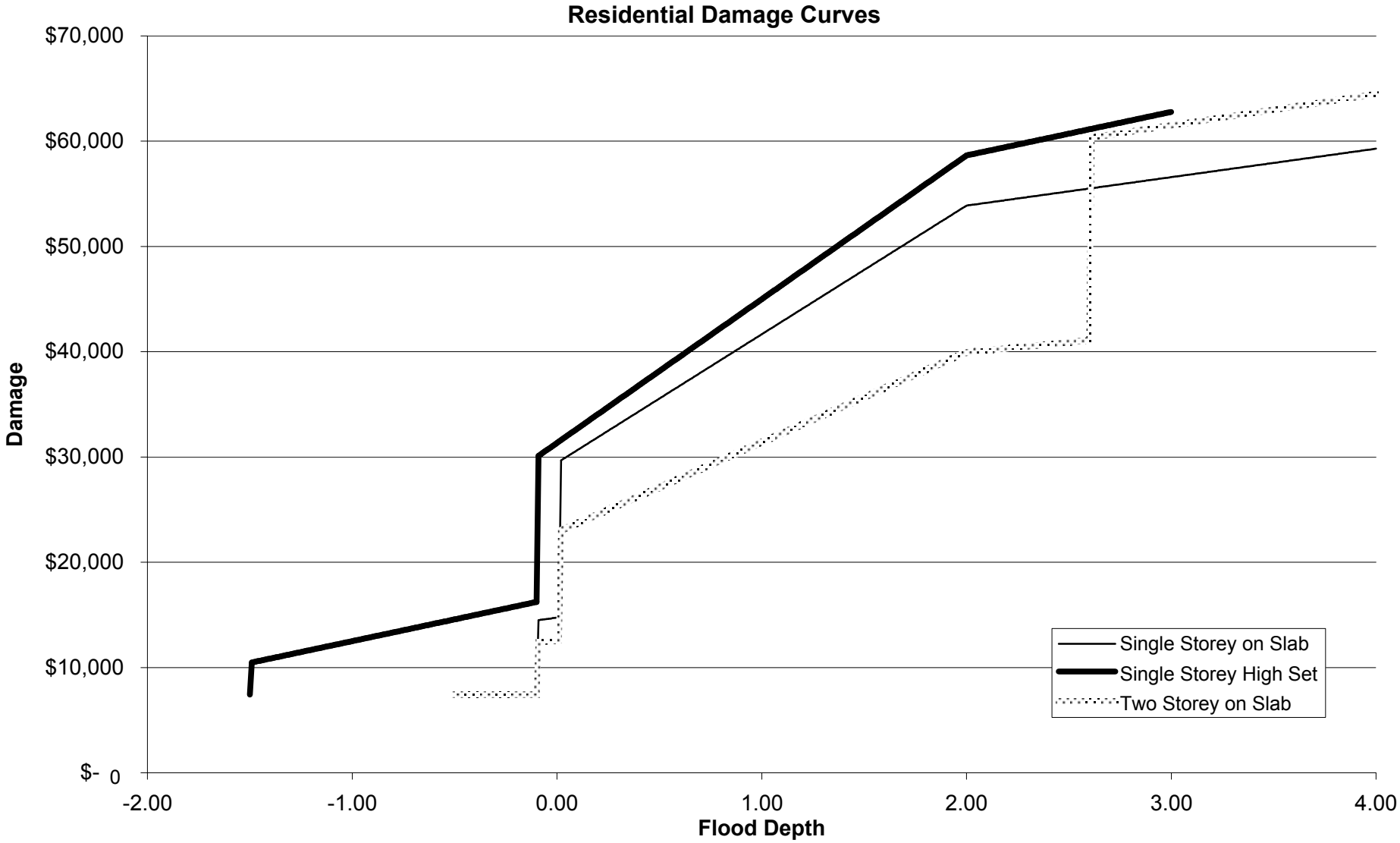
FIGURE 3.23
PROPERTIES AFFECTED BY DESIGN FLOOD EVENTS

J2313/R2182/V6
October 2006

J:\WR\J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.23 Props Affected.WOR



Turo Creek Pretty Beach Floodplain Risk Management Study and Plan

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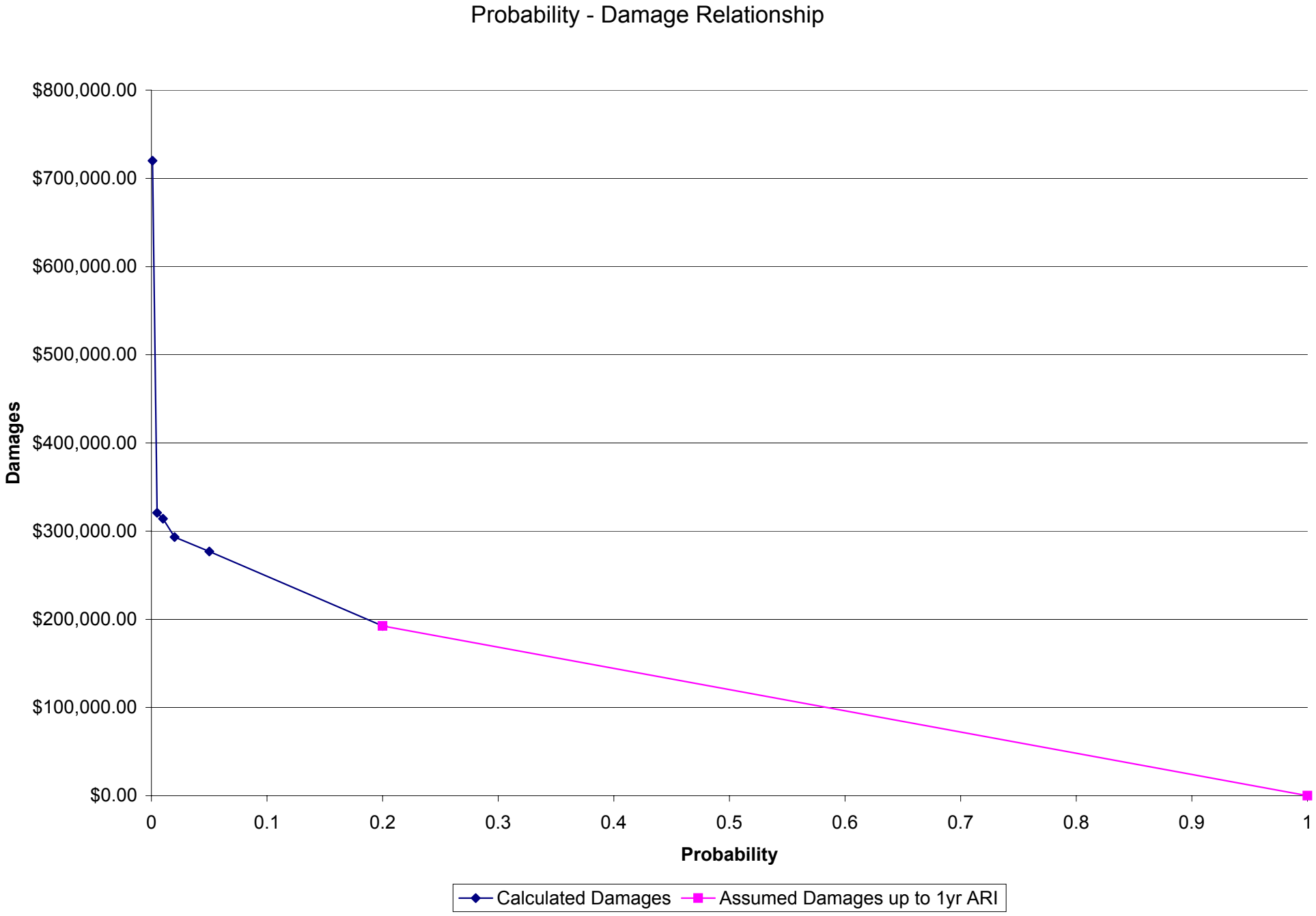
October 2006

FIGURE 4.1
ADOPTED RESIDENTIAL DAMAGE CURVES
J:\WR\J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 4.1 Residential Damage curves.xls



Turo Creek, Pretty Beach, Floodplain Risk Management Study

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October 2006

FIGURE 4.2
TRUO CREEK DAMAGES

J:\WR\J2313 - Turo Creek FS\Damages\J2313 - Property Damage Calcs - existing with updated house details - 0-9bnd v3.xls

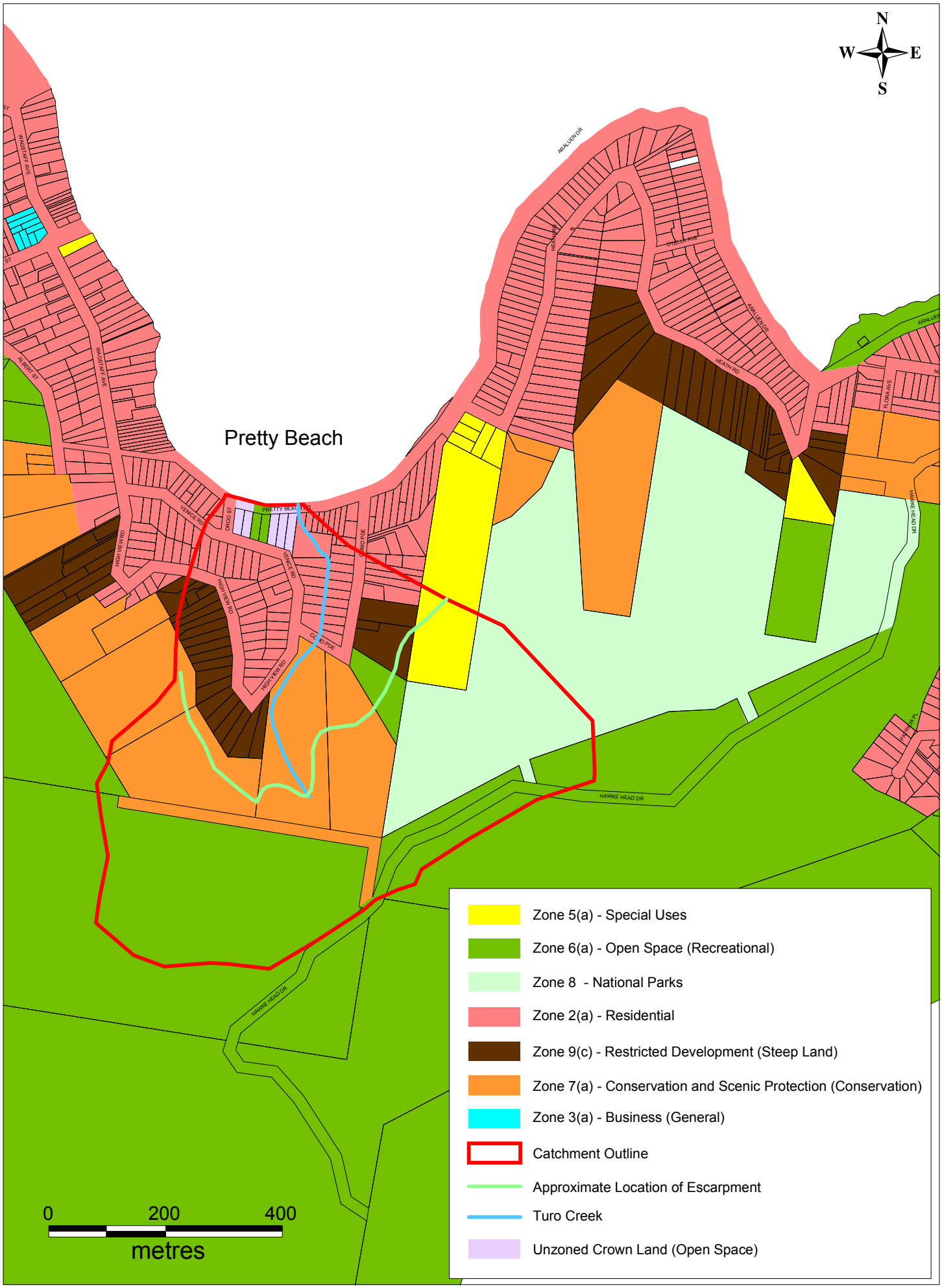

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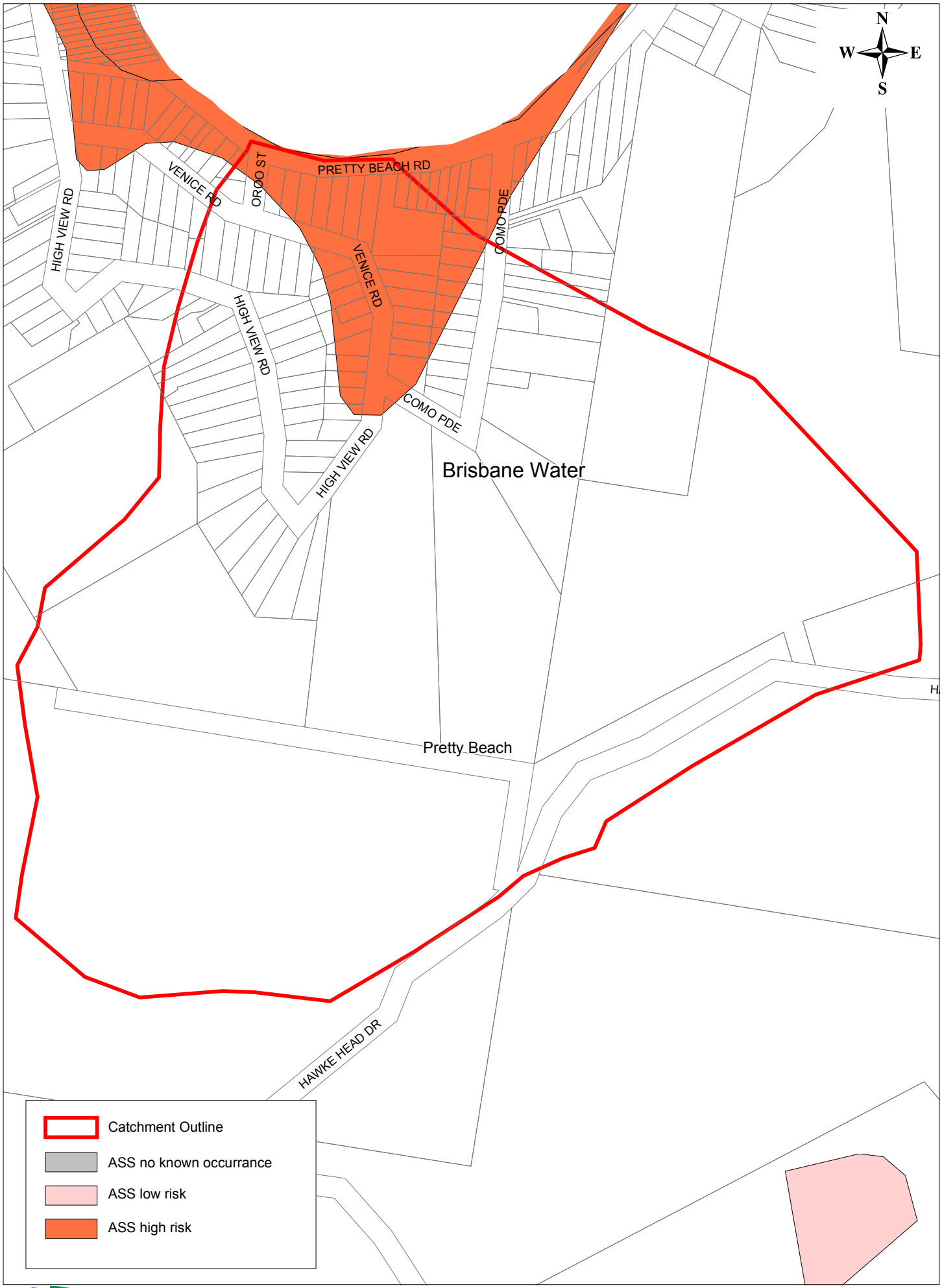
FIGURE 6.1
LAND USE ZONING

J2313/R2182/V6
October 2006

J2313\Figures and Appendices\R2182\V6\Figures\Figure 6.1 Land Use Zoning.Wor



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J2313/R2182/V6
October 2006

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FIGURE 8.1
ACID SULFATE SOIL (ASS) RISK

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 8.1 PASS.Wor

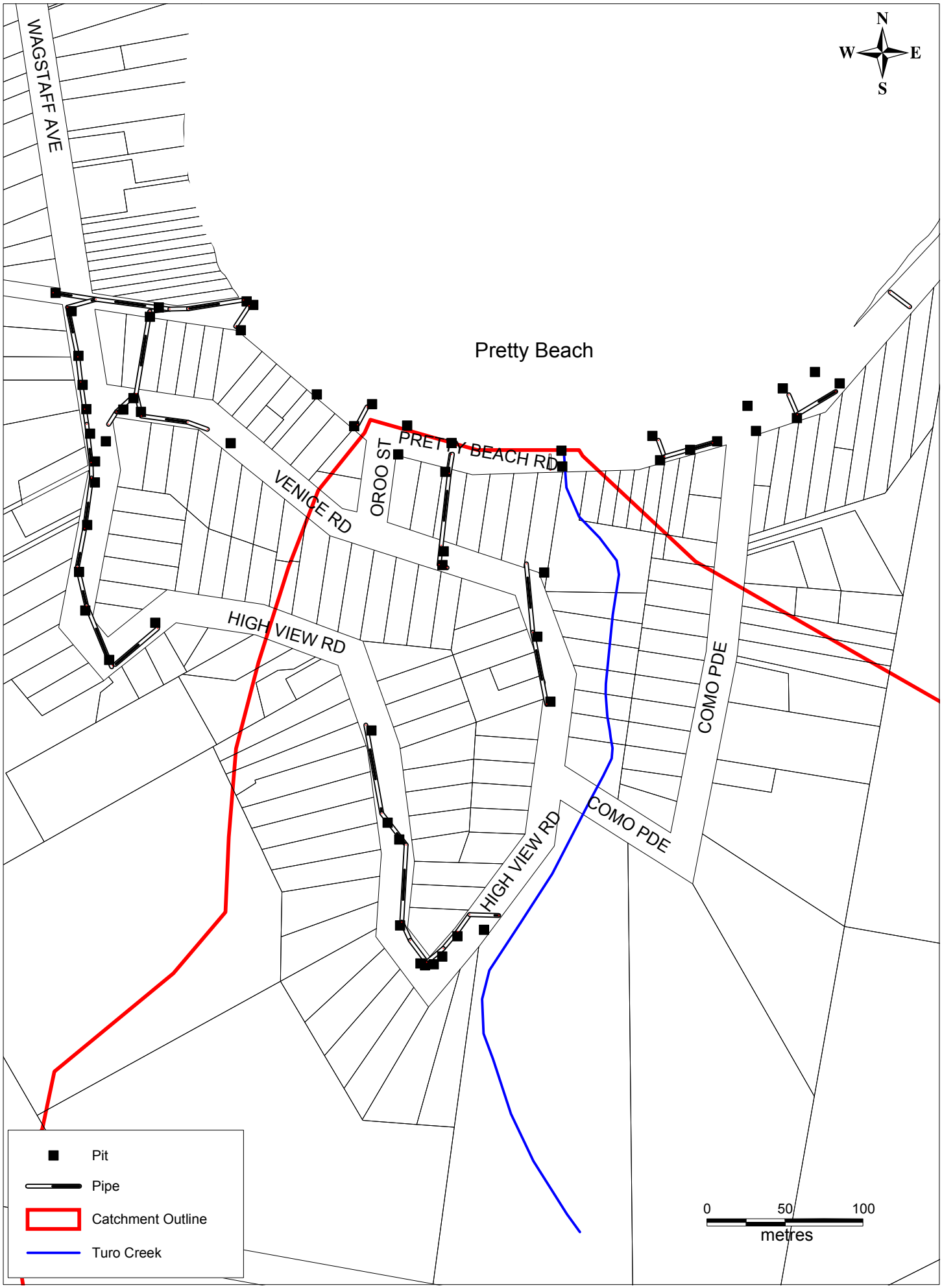

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FIGURE 8.2
EXISTING PIT AND PIPE LAYOUT

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J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 8.2 Pit and Pipes.Wor

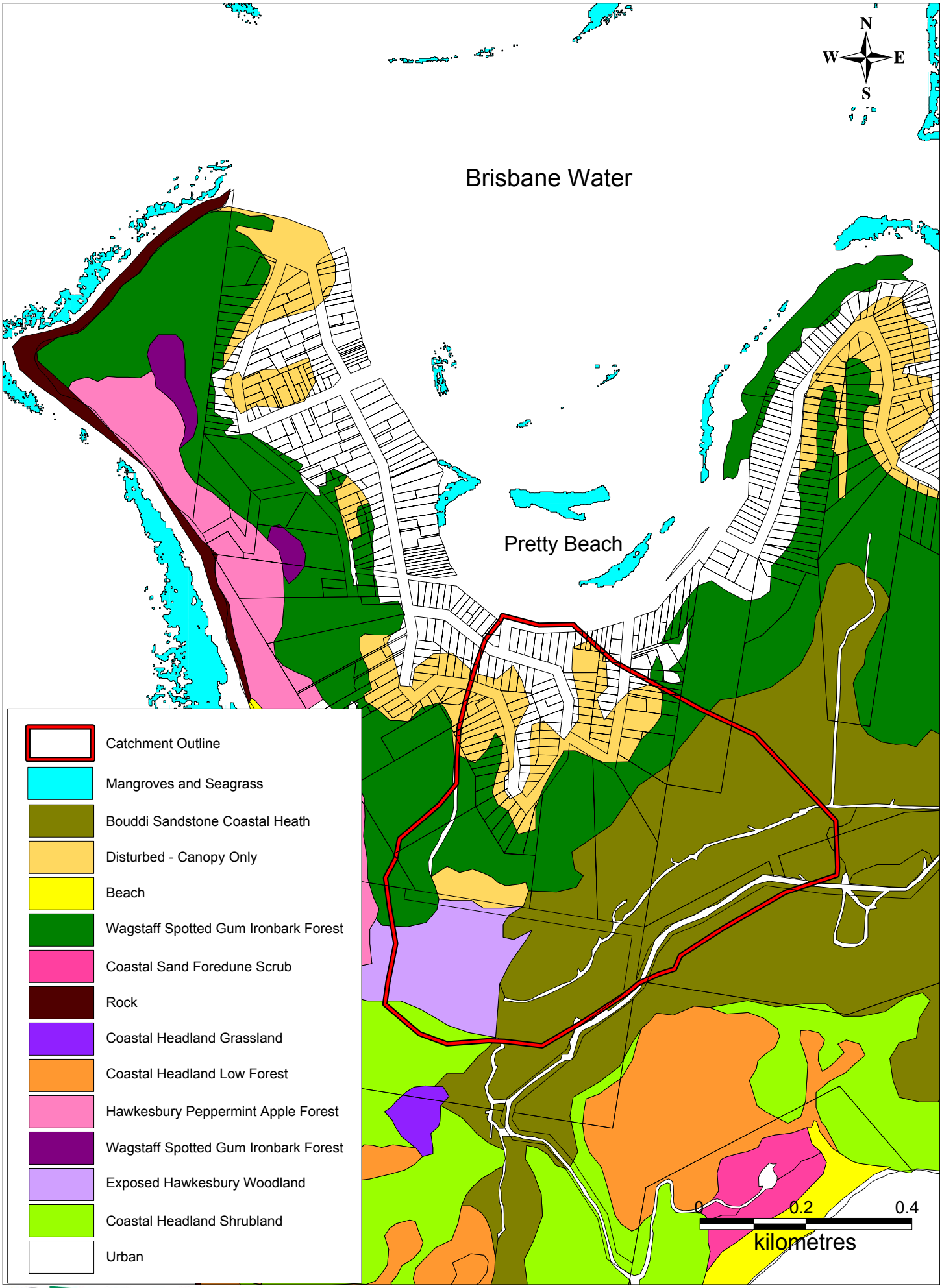

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FIGURE 8.3
VEGETATION TYPES WITHIN THE CATCHMENT

FM1a - Culvert Enhancement (Double Culvert Capacity)

FM1b - Culvert Enhancement (Triple Culvert Capacity)

FM6a - Creek enhancement (creek widened to 5m) and private access bridges removed and replaced with causeways.

FM6b - Creek enhancement (creek widened to 5m) and private access bridges removed and replaced with causeways. Pretty Beach Culvert enhanced to 6 culvert cells (double current capacity).

FM6c - Creek enhancement (creek widened to 5m) and private access bridges removed and replaced with causeways. Pretty Beach Culvert enhanced to 12 culvert cells (triple current capacity).

FM3 - Creek Enhancement (creek widened to 5m) and private access bridges replaced with arched Bridges

FM8 - Improvement of Drainage Infrustructure, including Improved Overland Flow Path along Venice Road

FM2 - Removal of all private access bridges

FM4 - Creek Enhancement (creek widen to 5m) and Realignment with private access bridges removed.

FM10 - BYpass Culvert

FM5 - Detention Basin

CH 257.0m

CH 102.0m

CH 102.0m

CH 22.0m

CH 0.0m

PRETTY BEACH RD

VENICE RD

OROO ST

HIGH VIEW RD

COMO PDE

COMO PDE

HIGH VIEW RD

N

W E

S

0 50 100

metres

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October 2006

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FIGURE 10.1
FLOOD MODIFICATION OPTIONS

J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figure 10.1 Flood Modification Options.wor

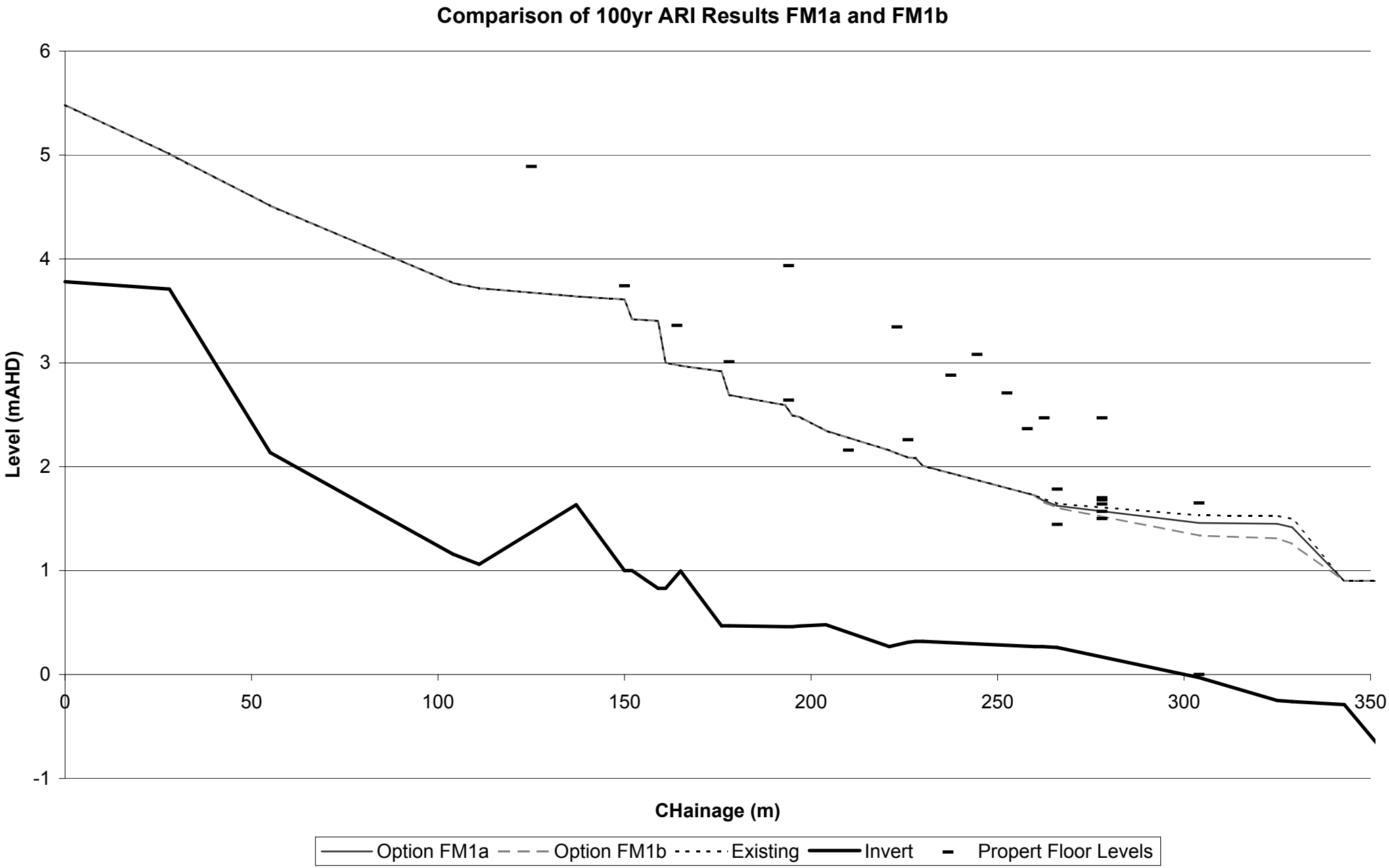

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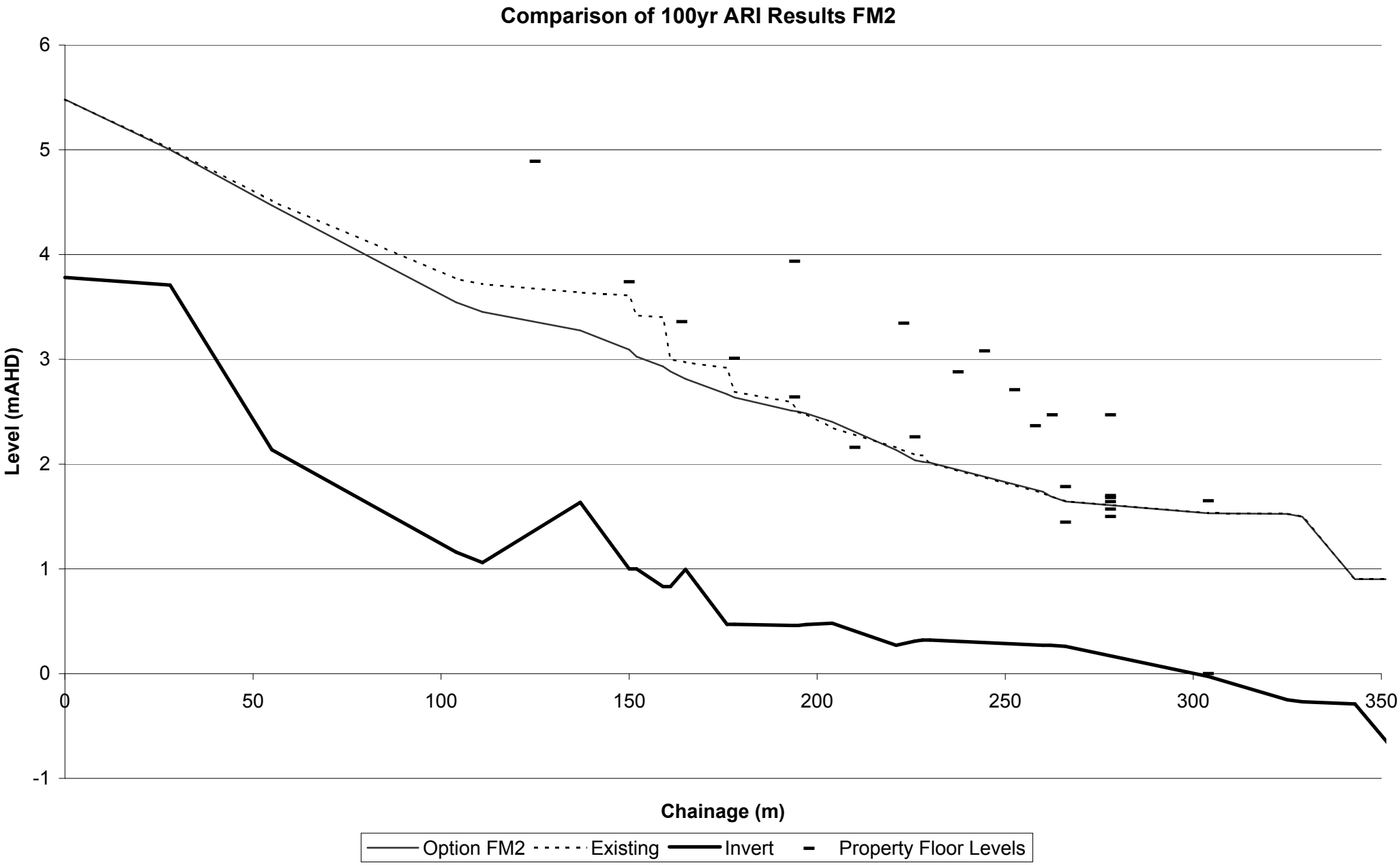
FIGURE 10.2
FLOOD MODIFICATION OPTIONS FM1A AND FM1B
IMPACT ON 100 YEAR ARI FLOOD LEVELS

J:\WR\J2313 - Turo Creek FS\Mike11\Updated Boundary File May 2006\Option Runs\Option 1\Results - Option 1.xls



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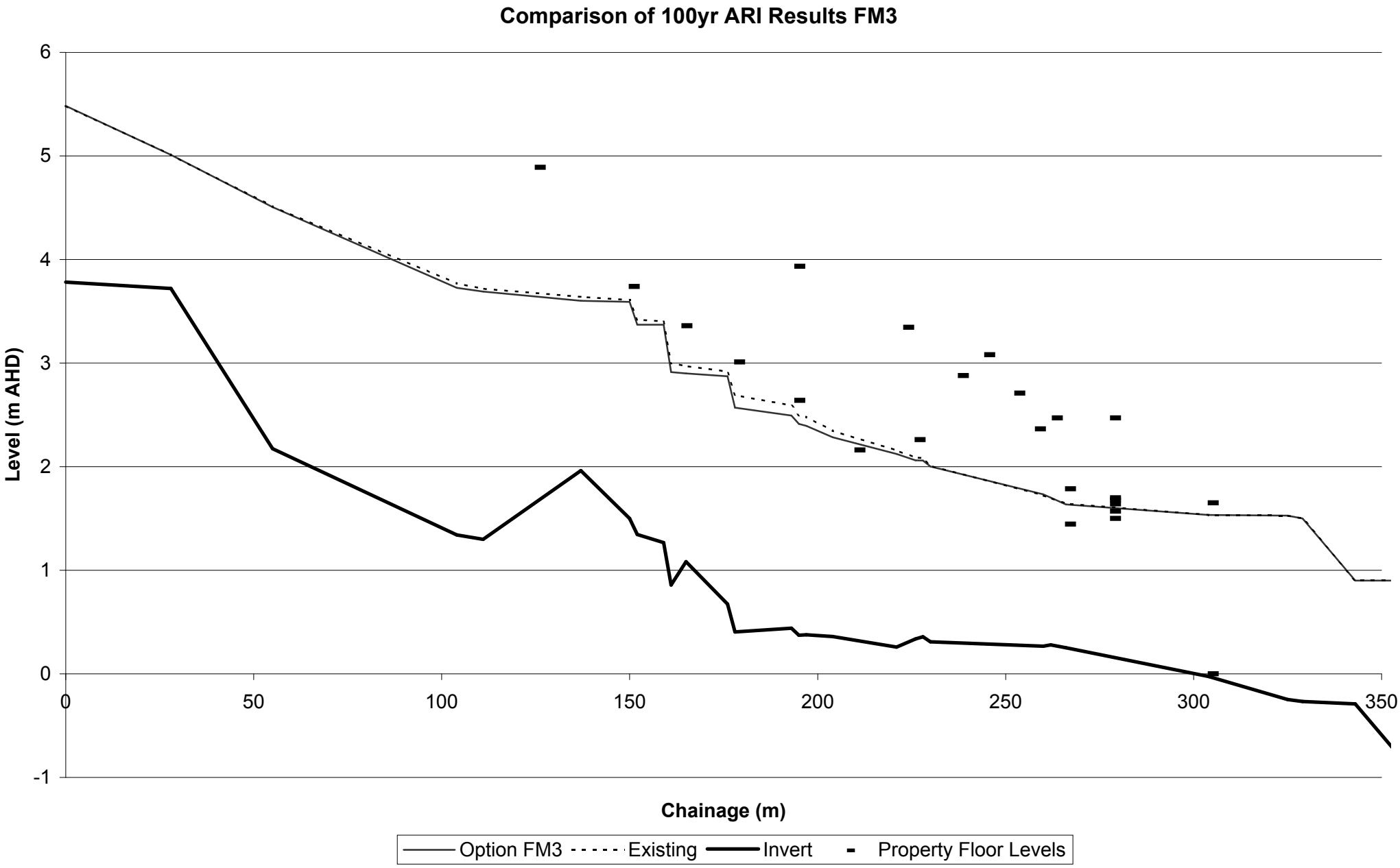
Turo Creek, Pretty Beach, Floodplain Risk Management Study

FIGURE 10.3
FLOOD MODIFICATION OPTION FM2
IMPACT ON 100 YEAR ARI FLOOD LEVELS

J:\WR\J2313 - Turo Creek FS\Mike11\Updated Boundary File May 2006\Option Runs\Option 2\Results - Option 2.xls



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Turo Creek, Pretty Beach, Floodplain Risk Management Study

FIGURE 10.4
FLOOD MOIFICATION OPTION FM3
IMPACT ON 100 YEAR ARI FLOOD LEVELS

J:\WR\J2313 - Turo Creek FS\Mike11\Updated Boundary File May 2006\Option Runs\Option 3\Results - Option 3.xls

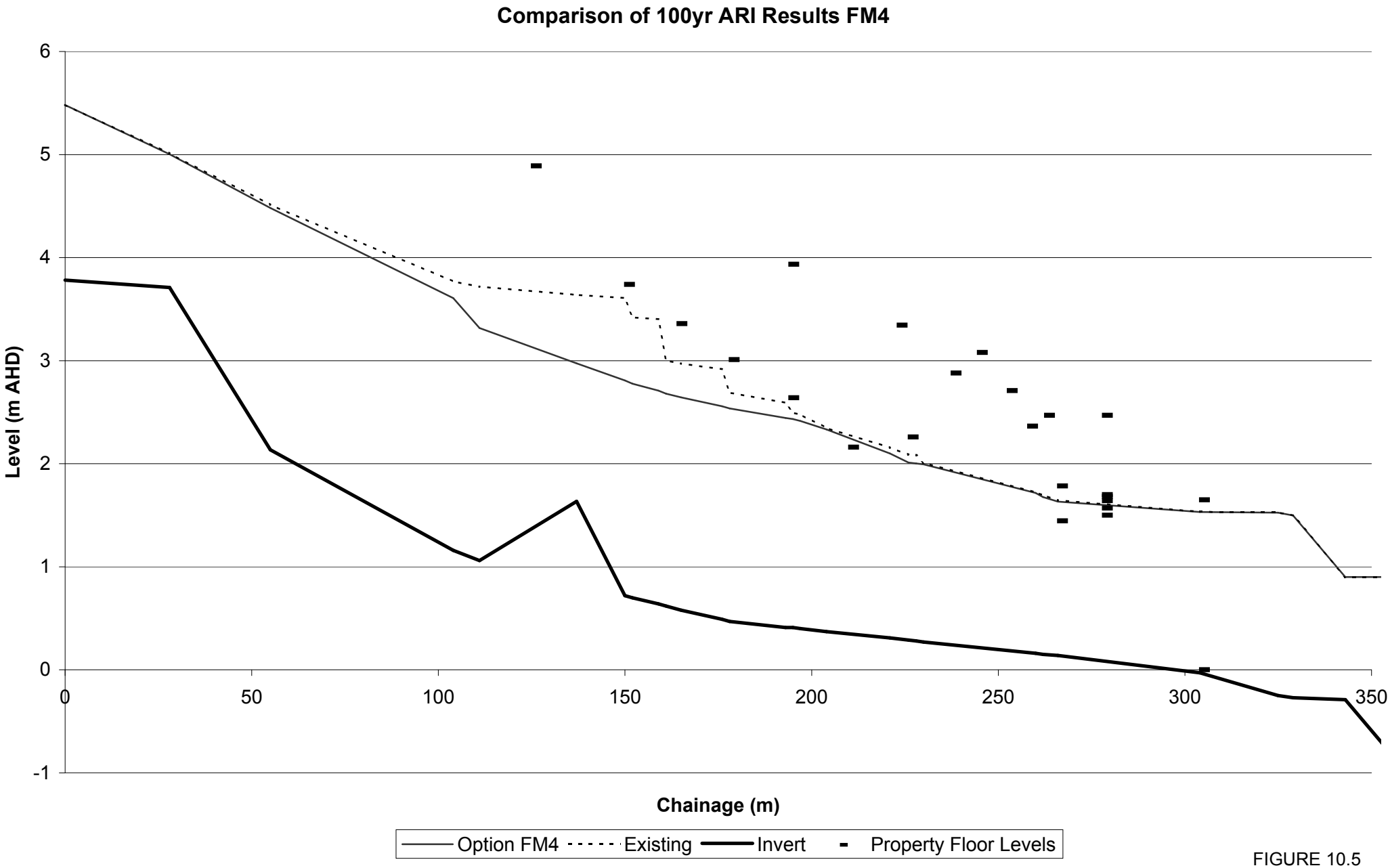

FIGURE 10.5
FLOOD MODIFICATION OPTION FM4
IMPACT ON 100 YEAR ARI FLOOD LEVELS

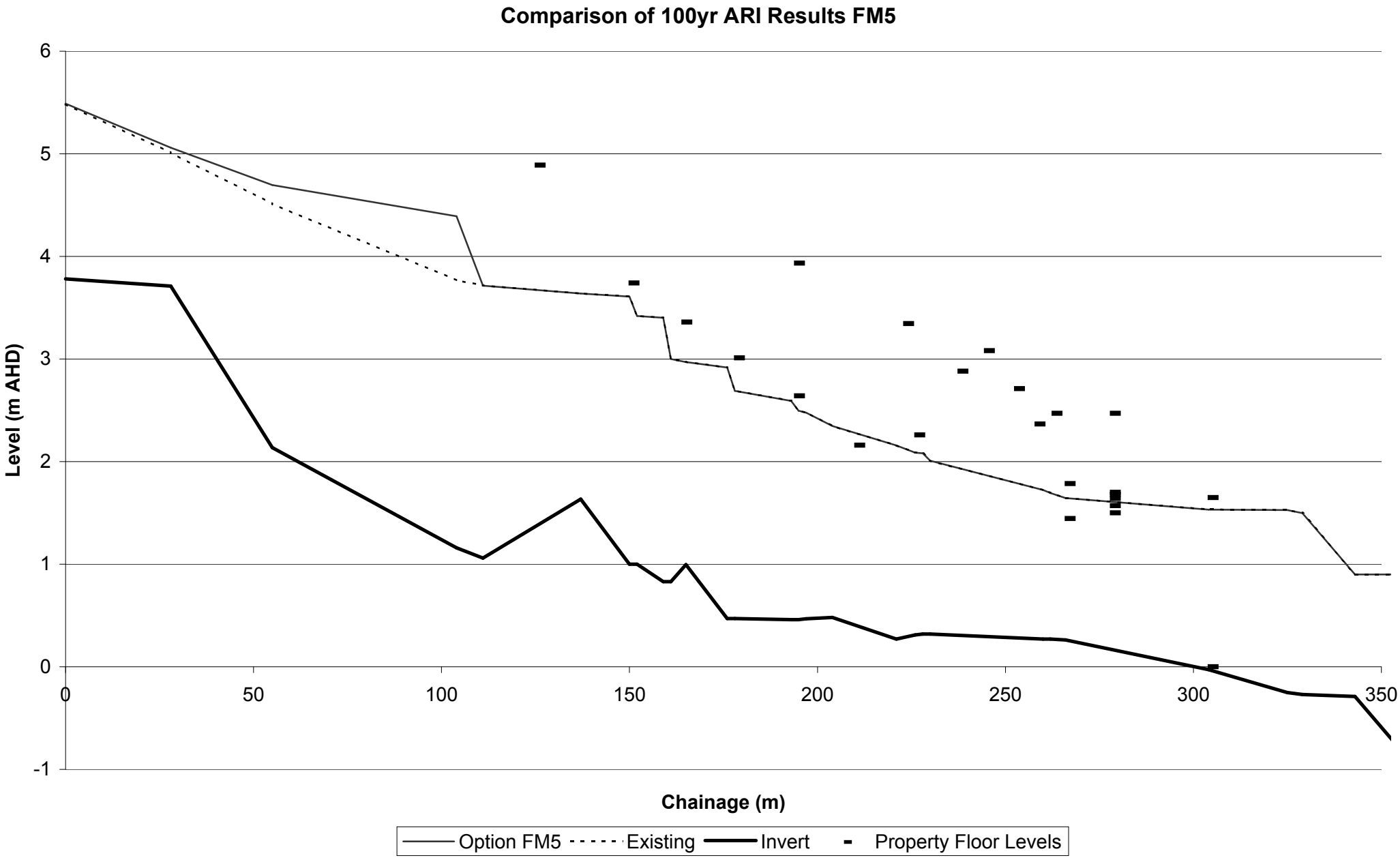

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FIGURE 10.6
FLOOD MODIFICATION OPTION FM5
IMPACT ON 100 YEAR ARI FLOOD LEVELS

J:\WR\J2313 - Turo Creek FS\Mike11\Updated Boundary File May 2006\Option Runs\Option 5\Results - Option 5.xls

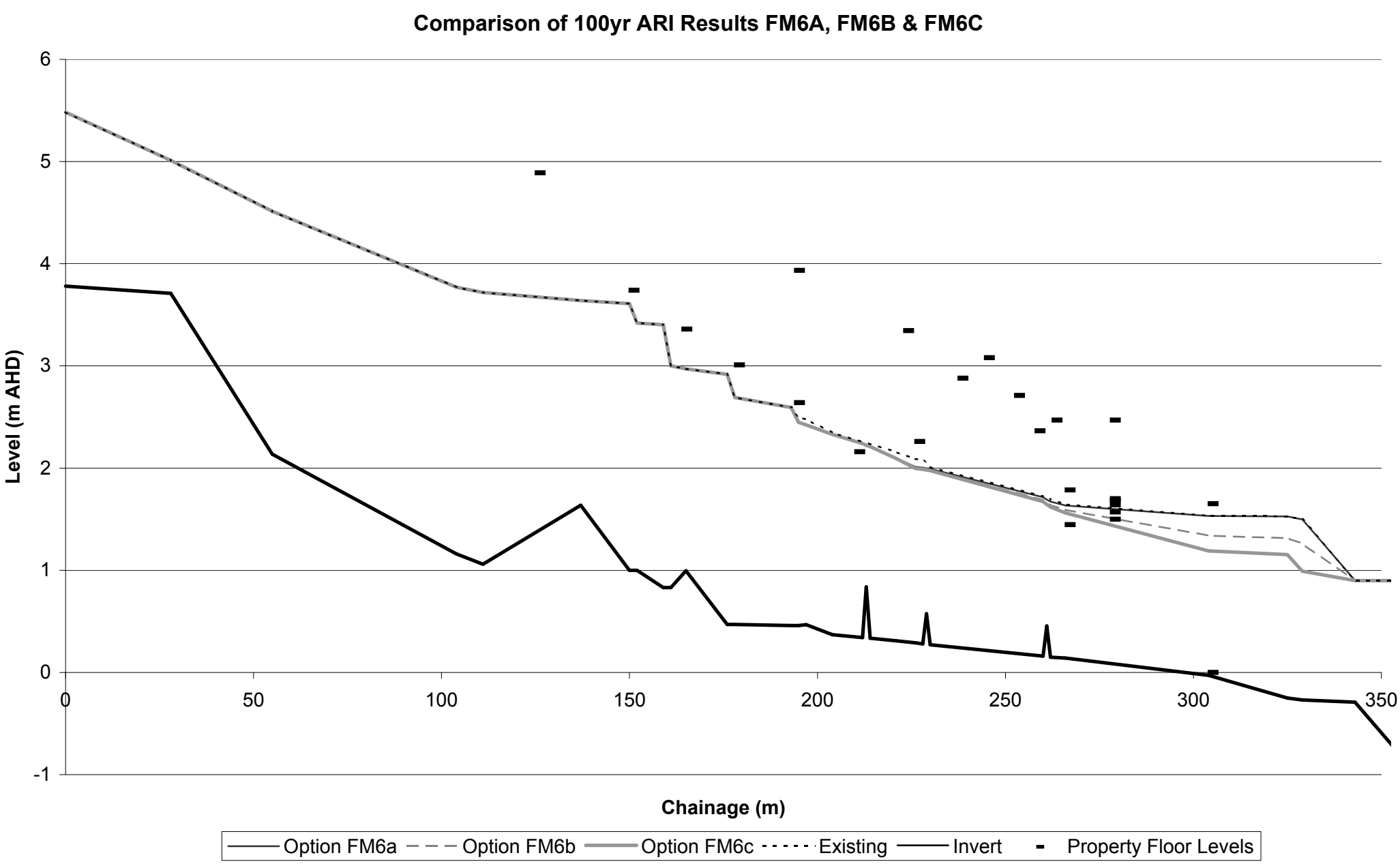

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FIGURE 10.7
FLOOD MODIFICATION OPTIONS FM6A, FM6B FM6C
IMPACT ON 100 YEAR ARI FLOOD LEVELS

J:\WR\J2313 - Turo Creek FS\Mike11\Updated Boundary File May 2006\Option Runs\Option 6\Results - Option 6.xls

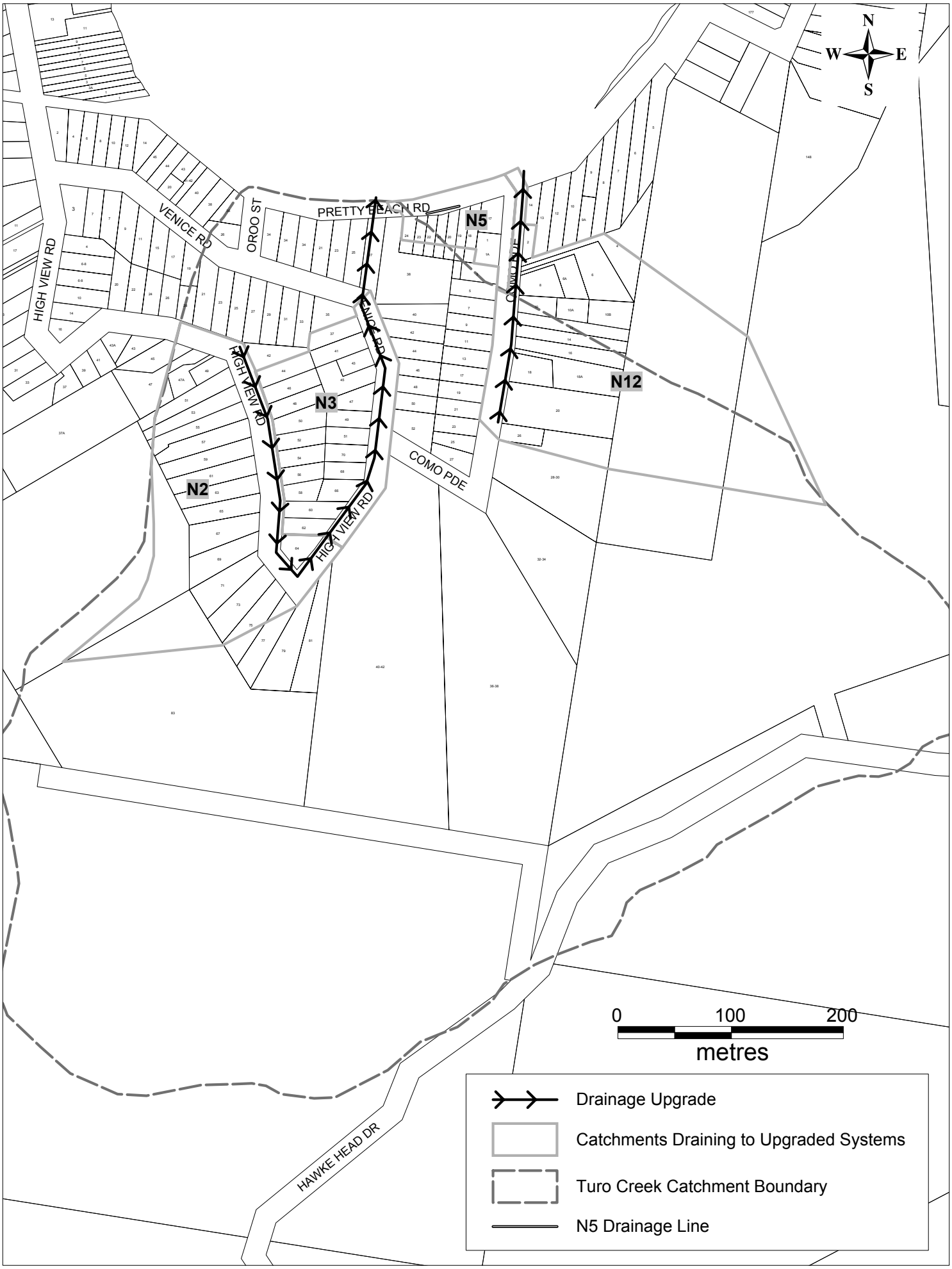

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FIGURE 10.8

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PROPOSED DRAINAGE UPGRADE

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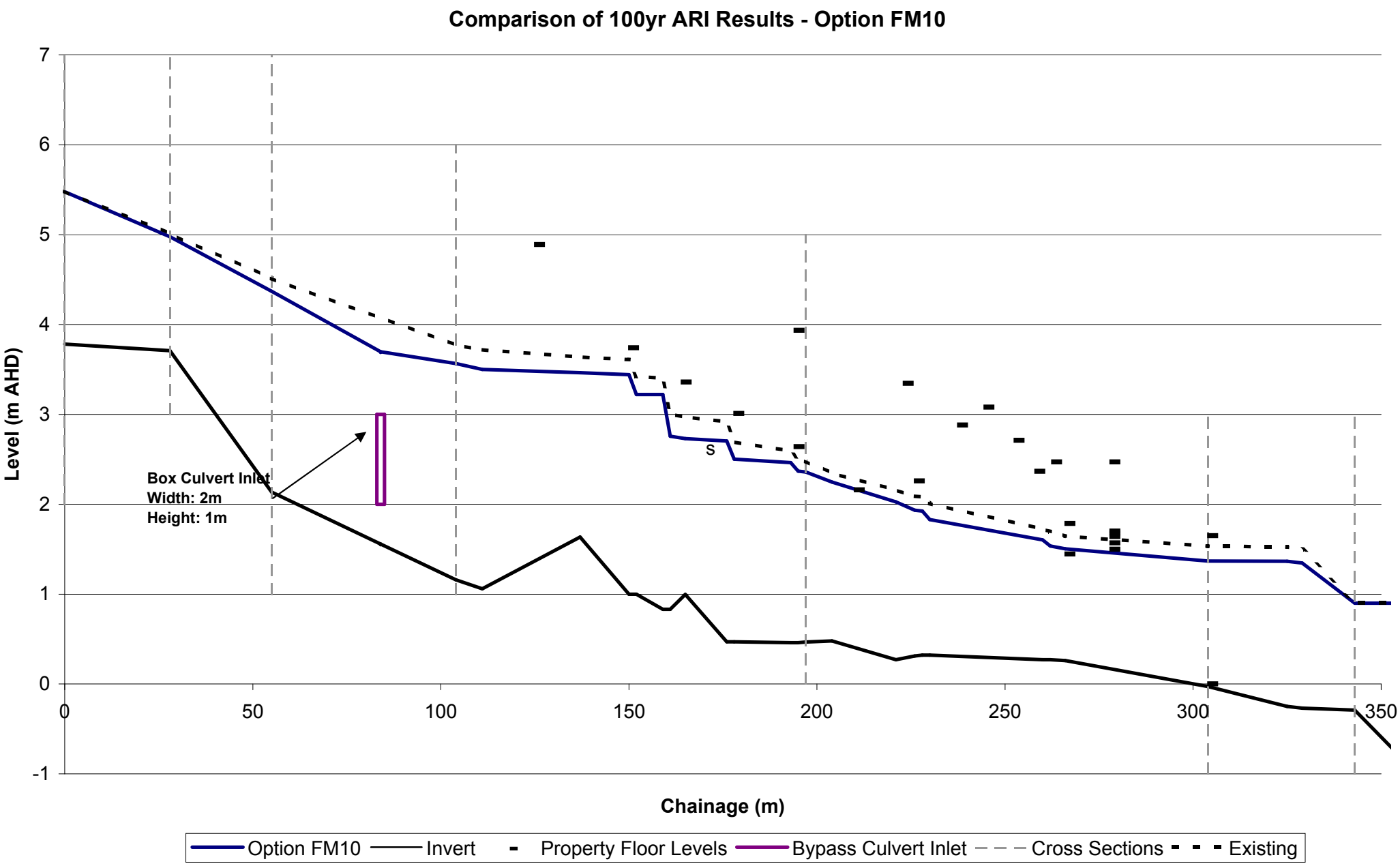
J:\WR\J2313 - Turo Creek FS\Figures & Appendices\R2182\V6\Figures\Figure 3.5 PMF Extent.Wor



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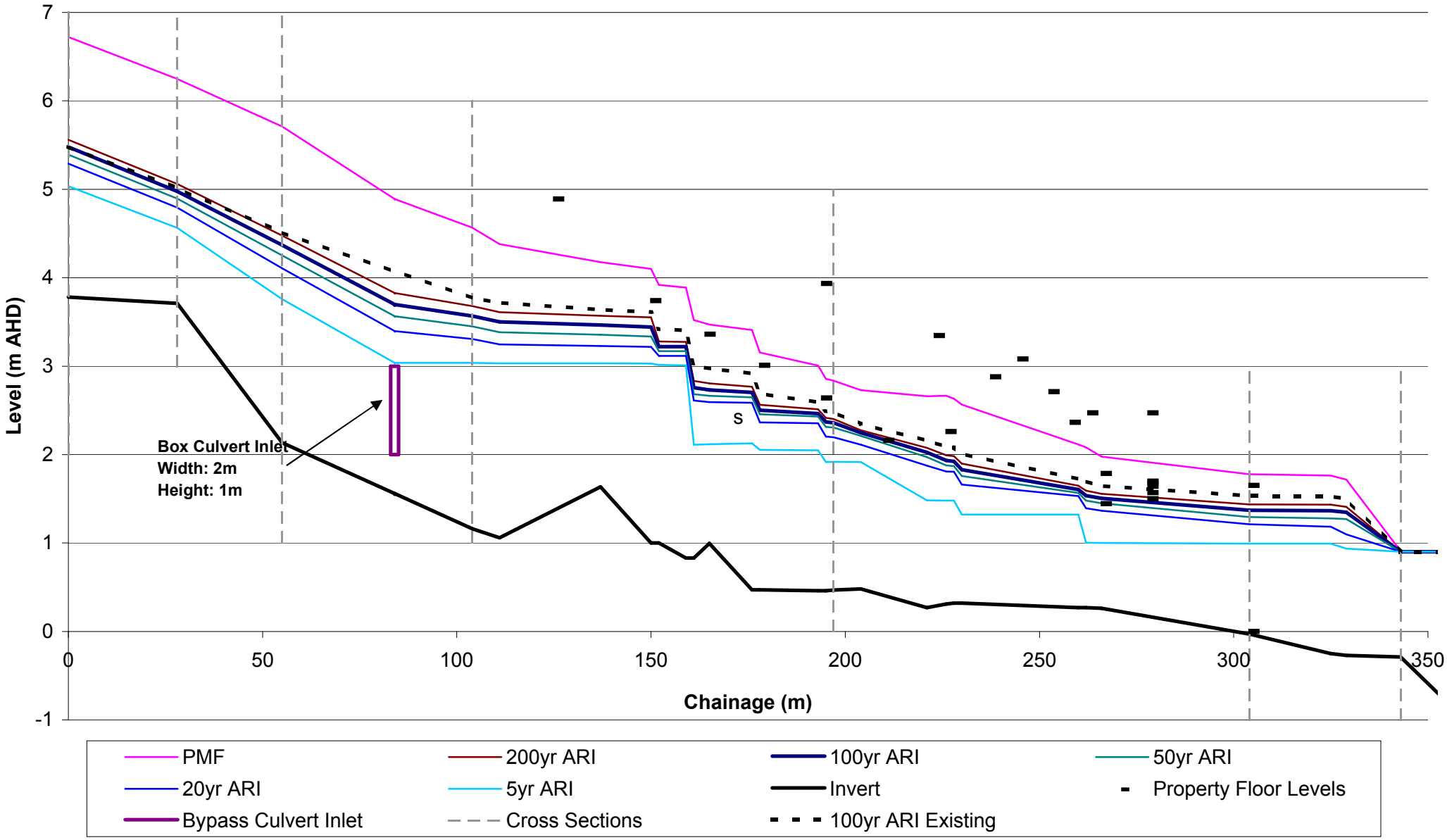
J2313\R2241\V6
October 2006

Turo Creek, Pretty Beach, Floodplain Risk Management Study

FIGURE 10.9
FLOOD MODIFICATION OPTION FM10
IMPACT ON 100 YEAR ARI FLOOD LEVELS

J:\WR\J2313 - Turo Creek FS\Mike11\Updated Boundary File May 2006\Option Runs\Bypass Culvert\Results - Bypass Culvert.xls

Design Flood Profiles for Option FM10



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J2313\R2241\V6
October 2006

Turo Creek, Pretty Beach, Floodplain Risk Management Study

FIGURE 10.10
FLOOD MODIFICATION OPTION FM10
DESIGN FLOOD LEVELS

J:\WR\J2313 - Turo Creek FS\Mike11\Updated Boundary File May 2006\Option Runs\Bypass Culvert\Results - Bypass Culvert.xls

APPENDIX A

Photographic Montage of Key Floodplain Features

Pretty Beach Road bridge

Channel carrying stormwater pipe flow from Turo Creek Catchment

Pretty Beach Road culverts

Como Parade culvert

Turo Creek through the properties

Stormwater drainage channel

A view of the escarpment

Another view

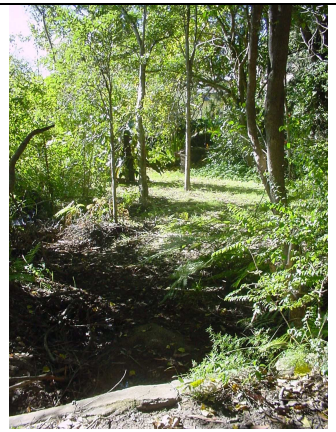
Culvert blockage at Como Parade

Sediment Deposit at the mouth of Turo Creek

Turo Creek downstream of Como Parade

Pedestrian Bridge, Pretty Beach Road

Waste water pumping station



Turo Creek downstream of Como Parade

View of Turo Creek Catchment from Bouddi National Park

Turo Creek Vegetation

APPENDIX B

Community Consultation

	Q1		Q2		Q3		Q4			Q5		Q6		Q7	Q8	
Survey Ref. No	Street	Suburb	Months at Address	Years at Address	Property Flooded	Inconvenienced	Recall Flood Date	Flood Date	Details of Flood	Evidence of flood (Y/N)	Details of Information	Type of property Flooded	Area of property Flooded	Location on Map (Y/N)	Additional Information	Question 9 - Proposed Options - Suggested Location and Comments
1	Venice Road	Pretty Beach		20	Yes		No	1988 or 1989	**Photocopies enclosed.** Water entered south-west corner of next door (Lot 33, 70 Highview) and swept across our back yard south to north.	Yes	A waterfall appeared at the rear of properties around 73 Highview Rd, the flow came across the road and around the corner near No. 64. The fast flow bypassed the drain usually catching rainwater and continued on down Highview into Venice and some flooding occurred at No. 42 Venice Rd after the flow crossed the road. Why did council attempt to drain all of the stormwater from Highview under the road near No. 64 into Turo Creek? I believe this has contributed to flooding at the rear of some properties on the even side of Venice Rd. Surely an underground drain from No. 64 high view down Venice Rd to link up with the one already existing from 47 Venice to the bay would have been better.	Residential, Roads & Paths	Backyard, building (above floor level), front yard	Yes	On map I have shown flow at rear of our property, coming out at No. 33 Venice which was flooded at the time (around 1988/1989). I recall the owner had the SES attend & provide sand bags to prevent the water entering the house. Since then development at the rear of No. 33 and No. 35 has resulted in the flow of water being diverted down an unofficial easement along the fence line between Nos. 41 & 37 Venice Rd.	
2	Como Parade	Pretty Beach		7	No	No										Culvert/Pipe Enlarging - Como Parade and Pretty Beach Road
3	Venice Road	Pretty Beach		24	No	No	No							Yes		Get rid of the mangroves at the mouth of the creek. These only catch debris and form a wall preventing the release of water, its plain enough.
4	Como Parade	Pretty Beach		12	No	No	No									1. Absorptive surfaces of indigenous groundcover to create habitat and also allow controlled and gradual rain infiltration. 2. Levee Banks - No - will concentrate stormwater, increase water volume and increase erosion in a "canal" like watercourse - this would reduce rain infiltration and lead to siltation of bay. Planning controls - Restrict size of residences/building at DA stage so that stormwater is reduced i.e. restrict roof area and paved areas so that maximum rainfall infiltration is achieved. Prohibit subdivisions and dual occupancies to reduce the area of non-porous surfaces.
5	Venice Road	Pretty Beach		50	Yes	Yes	Yes	1974	A big tide, constant heavy rain. Creek overflowed came into my house up to skirting boards on my verandah approx. 5 inches over skirting boards into my kitchen and the front bedroom.	Yes	I have photos of the 1974 flooding which I will send to you. There should be a file of the mail I have sent to Gosford Council which should have information in it that may help you. There has been part flooding of this property.	Residential, parks, roads & paths	Backyard, building (below floor level), front yard & garage	Yes	A car or vehicle could not be driven on Pretty Beach Rd when it is flooding. There has been some flooding over the front of this property, perhaps my file would help if the council will give it to you.	All options ticked - levee banks for around this property.
6	Como Parade	Pretty Beach		20	No	Yes	Yes	1990 and 1998	Each time it has flooded our backyard and garden shed have been inundated with torrents of water, because of creek being blocked by having been built over by decking and corrugated iron enclosing entirely, one particular backyard section of the creek. This causes flood to bank back and spread out widely where it never used to flood.	Yes	Could help you by indicating where flooding has occurred	Residential, parks, roads & paths	Backyard	Yes	This creek has always had some flooding when we have big rains combined with king tides, but has been so much worse since drainage was diverted from Highview Rd into creek. Originally most of this water drained through park. We also believe that the present culverts under Pretty Beach Rd are inadequate. Also because of the huge amounts of water from mountain, there are many times when Como Parade is flooded at the end of the road and across Pretty Beach Rd. There have been many times when water has rushed down our driveways and entered garages and at times even entered lower floors because our gutter on lower side of street is non-existent.	All options ticked - levee banks for around this property. Clearing creek of obstructions and attention to gutters on lower side of Como Parade.
7	Como Parade	Pretty Beach		7	No	No					Never seen any floods				The ____ of the high tides and the bridge by the park cannot be changed. Occasionally rain run-off my coincide with a high tide but that is just part of living in Pretty Beach	Culvert/Pipe Enlarging - If this option would control the mosquito problem in the summer months, this would be doubly advantageous to the Pretty Beach residents. Other - I suggest we leave it to nature to sort out.
8	Como Parade	Pretty Beach		30	No	No									My house is on the side of the hill. Well above houses along Pretty Beach Rd and water gets away quickly, well drained.	

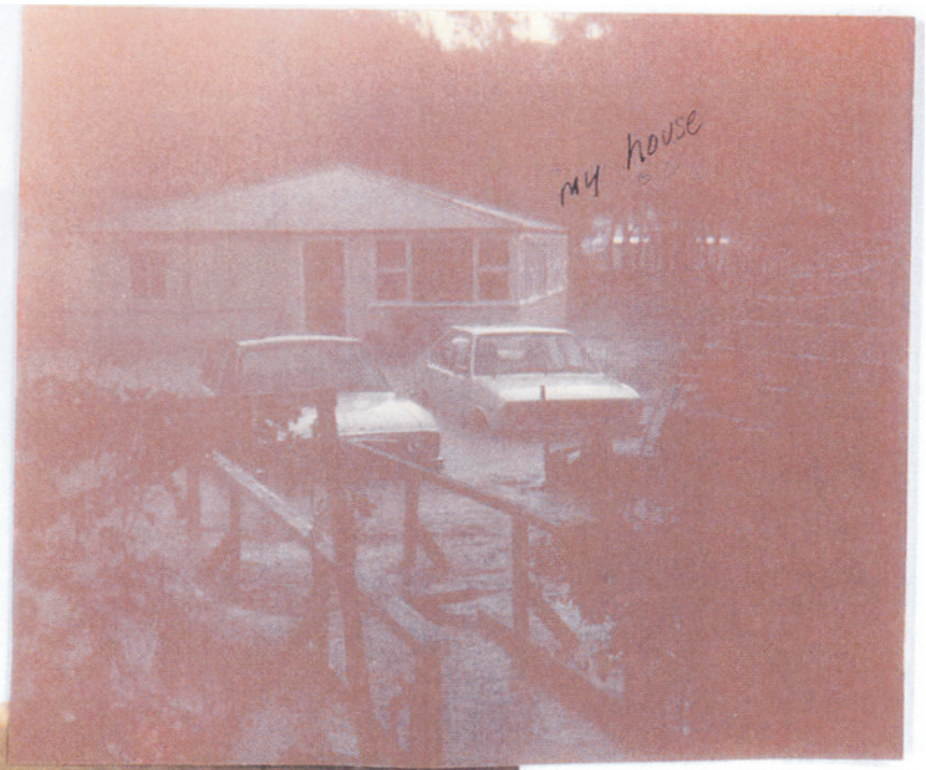
	Q1		Q2		Q3		Q4			Q5		Q6		Q7	Q8	
Survey Ref. No	Street	Suburb	Months at Address	Years at Address	Property Flooded	Inconvenienced	Recall Flood Date	Flood Date	Details of Flood	Evidence of flood (Y/N)	Details of Information	Type of property Flooded	Area of property Flooded	Location on Map (Y/N)	Additional Information	Question 9 - Proposed Options - Suggested Location and Comments
9		Pretty Beach							Most of the flooding is from the bay not the creek. He recalls the flooding being worse when he was a kid. He will speak to his Mum in the next couple of weeks and get some more history. They are looking at building a new place and he was wondering how long before they got floor levels. I told him that council was trying to get this finalised by December. Even last night he went for a walk and the tide was ??2m - was bubbling out of the drain at Como Parade (u/s of park)							
10	Venice Road	Pretty Beach							Asked that the study area is not defined. Asked if we can identify his property to be affected by flooding. Told him that the study area is usually larger than the flood affected area. We include more area and consequently more properties to target a wider community who may have knowledge of the flooding area. Told him that we are progressing with the study and in 3 months time we should have the flood effected properties identified in the catchment.							
11	Venice Road	Pretty Beach		6	No	Yes	Yes	1998	1. Nature strip in front of garage became a bog despite attempts to install extra drainage. Driveway finally fixed by tarmac - but this is subsiding. 2. Grass on our nature strip continues to be lush despite current drought (of course no watering) (possibly related to the underground telecom lines).	Yes	One week after arrival on 4th August, at about 7 o'clock stream was running about 1 metre deep, just under our footbridge. Triangular cross section would have been about 3 metres wide at top. Water speed estimated to have been about 10 metres in 2-4 secs. Since the, during 'normal' heavy rain water depth is typically about 1 metre. Our (now deceased) elderly neighbor at No. 46 related how, in the past, water levels had reached but not entered the rear of her house.				Regarding the "Impressive Escarpment" mentioned under "Study Area", you should be aware that even after moderate rain a substantial amount of water can be seen cascading over the rim from the plateau above. Most of this has to be handled by Turo Creek. Concurrently, this creek must also deal with the water from High View Road, which formerly would have taken a more direct route to the Bay. Such water has been routed under Venice Road. Hence the necessity for completing the partial stormwater drain on the west side of Venice Rd. The unfinished road "Como Pde" that I have labeled "track only" carried a great deal of water - dug a 2m deep channel.	Improved overland flow paths - yes. Culvert/Pipe enlarging - Yes. Complete Venice Road Line. Remove Line under Venice Road. It is quite wrong to blame the private bridges over Turo Creek for the problem. The tunnel under the "Pretty Beach Road" is inadequate under the extreme conditions. 1.9m High Tides are already at road level.
12	Venice Road	Pretty Beach		50	No	No	No		Just comes and goes and does not hurt anything. Just cleans up rubbish. Does not come in house.	No	The only reason for flooding is because we may get approx. 10" of rain in an hour and one half period. Then you get a flood which does not affect too much. I myself would like council to shape ___ ___ in creek. This would help considerably. I have seen the property underwater for about ten minutes about 3 times in 20 years. It runs over road to get away.	Residential, parks, roads & paths	Backyard & front yard			Culvert/Pipe enlarging - yes
13	Como Parade	Pretty Beach		11	Yes	Yes	Yes	Jun-05	When we were building the house. Water came off the road straight down the drive-way. There is no curb or guttering and therefore no drainage. The problem still exists, as there are no pipes or work being done to take the water away. Before I built the house part of my land at the front had a 10 foot by 15 foot gully running through it. We pay $1300/year in rates but don't get any drainage - - its appalling.	Yes	As explained earlier! It is self-evident - all you have to do is come and look, or talk to any local who lives in Como Parade, Pretty Beach. They can show you evidence of flooding for the past couple of hundred years. I have filled in the gully on my property, but right next door is the existing 15 foot gully caused by flooding.	Residential	Backyard & front yard	Yes	Instead of the council coming out and building a temporary cheap solution that is going to need fixing again, why not put drain pipes in, like most other areas have, with similar problems. The temp cheap solution was to dig some dirt channels that eventually silt up and get clogged. This is long overdue, please don't make it a temporary solution. Its been tried before. Drainage in this area is disgraceful.	1. No idea what this is? 2. Useless! 3. Tried it!. 4. Useless 5. Why not 6. The best result could be this 7. A plan would be good. I have been here 11 years and virtually nothing has been done. One trench has been dug, now fully overgrown. A more permanent solution is required.
14	Como Parade	Pretty Beach		28	No	No	No					Residential & Parks	Backyard	Yes		Levee Banks - yes Channel widening - yes
15	Pretty Beach Road	Pretty Beach	10		No	No	No									
16	Pretty Beach Road	Pretty Beach		5	No	No	No									Channel widening -Turo Creek outflow area. Culvert/Pipe Enlarging - Down Como parade and Highview/Venice and Oroo - out flowing to Pretty Beach
17	Venice Road	Pretty Beach		10	No	No										

	Q1		Q2		Q3		Q4			Q5		Q6		Q7	Q8	
Survey Ref. No	Street	Suburb	Months at Address	Years at Address	Property Flooded	Inconvenienced	Recall Flood Date	Flood Date	Details of Flood	Evidence of flood (Y/N)	Details of Information	Type of property Flooded	Area of property Flooded	Location on Map (Y/N)	Additional Information	Question 9 - Proposed Options - Suggested Location and Comments
18	Pretty Beach Road	Pretty Beach		7	No	No										Turo Creek Deepening, Check culvert/pipes along Pretty Beach Road, Planning Controls
19	Como Parade	Pretty Beach		3	No	No	No				I looked at No. 38 Pretty Beach Rd which was for sale around the time I purchased my property. It struck me that it was obviously subject to tidal and/or creek flooding. Rather than try to stop this happening I felt an ideal solution would be for council to purchase that block and turn it into a wetland park which would adjoin the existing park & playground area. The idea is probably financially unrealistic but it would be a tremendous long term asset to the area.					Improved overland low paths - yes. Other - I have insufficient knowledge to comment intelligently other than to express a preference for minimal physical intervention in favor of sensible planning. In other places there has been a move to rehabilitate streams and creeks that have been previously redirected, dammed or piped underground. There projects have resulted in considerable improvement in water quality, wild life and amenity to residents. The existing situation does seem to result in areas of stagnant water, particularly around where Turo Creek crosses Como Parade. Possibly this is aggravating the growing mosquito problem in the area. My preference would be to have the creek returned as far as possible to its natural course, with any new building being designed to accommodate the water flow rather than preventing or re-directing it.
20	Venice Road	Pretty Beach	9	9	No	No	No									Channel widening or deepening through lower lots, adjacent to park and east side Venice Road. Widen Creek, remove backyard obstacles- Culvert Pipe enlarging at Pretty beach Road, Planning controls via Council LEP
21	Venice Road	Pretty Beach	18												As our address is 49 Venice Rd it would appear to be positioned out of the study area (Fig 1 in brochure does not clearly define properties in study area). When we purchased the property last year there was no mention of flooding on councils 149 certificate, but we were aware other properties further down Venice Rd could possibly be affected by Turo Creek. As stated in this study report we have not witnessed any flooding and are unable to give information on past flooding problems in relation to Turo Creek.	
22	Pretty Beach Road	Pretty Beach		6					The only high water level noticed has been seen coming back through the drains on the street. This subsides when the tide has dropped. With regards to your proposed options - we are not sure what the best solution would be to alleviate this concern. Our other concern would be the levee banks on the waters edge. Despite cement being layered around the top row of rocks - the wall seems to be very low in height. I suspect the wall has dropped lower over time.							
23 (See No. 30 - also for this address)	Pretty Beach Road	Pretty Beach		32	Yes		No		Backyard floods when rain combines with "King tide".	Yes	When we re-carpeted the house the old floor coverings were taken up. Salt was seen on the floorboards of the sunroom but not the rest of the house. The sunroom is a little lower than the rest of the house (approx 1-20mm).	Residential, Parks	Backyard, building (below floor level)	No	The tide is important to flooding of properties. I was at the house on Sunday 1/8/04. At high tide the water was backing up in the drain on the corner of Como Parade and Pretty Beach Road. If heavy rain is swelling the creek at a very high tide there is nowhere for water to go. We have gradually built up the level in our backyard and have not had any problems for some years.	Culvert/Pipe enlarging - we have no drainage in front of the house. A drain to the creek or bay would help.
24	Pretty Beach Road	Pretty Beach		3	No	No										Channel widening or deepening - yes. Culvert/Pipe enlarging - yes.
25	Como Parade	Pretty Beach									This is an investment property. Therefore we have never lived in the house, however when purchasing the property no search revealed any problems and in the 3 years we have owned the property there have been no problems.					
26	Como Parade	Pretty Beach		10	No	No										Dredging bay to approx 20m from shore to clear silt built up over years

	Q1		Q2		Q3		Q4			Q5		Q6		Q7	Q8	
Survey Ref. No	**Street**	**Suburb**	**Months at Address**	**Years at Address**	**Property Flooded**	**Inconvenienced**	**Recall Flood Date**	**Flood Date**	**Details of Flood**	**Evidence of flood (Y/N)**	**Details of Information**	**Type of property Flooded**	**Area of property Flooded**	**Location on Map (Y/N)**	**Additional Information**	**Question 9 - Proposed Options - Suggested Location and Comments**
27	Pretty Beach Road	Pretty Beach		15	No	No					Around Turo Creek and also where road retaining wall was below high water level on "peak" tides i.e. ___ wave was below road level in parts of Pretty Beach road	Residential, Roads & Paths	South of Turo Park Tennis courts	Yes	Part of the problem is that 1. Storm water drains are either too small or blocked 2. Sea wall not high enough (in part) 3. No curbing or guttering 4. Bay is being filled in outside Turo Creek . Issue is more than composing more D/A restrictions. Both proper management of council outflows and regulation and improvement of bay water movements and Pretty Beach flat management to remove soils washed down due to road and sewerage works of council. ??	1. Need to stop sand escaping into bay causing new sand ___ and sand basins
28	Pretty Beach Road	Pretty Beach		15	No	No			No flooding from "sea wall" has occurred for at least 14 years. Part of sea wall is too low for a ___ high tide and sea water ___.??	Yes	Turo Creek due to wind/tidal effect prevented "storm water" running into bay. Regularly existing drainage system extended beyond capacity - Needs enlarged diameter piping and/or cleaning. Parts of road sea wall should be released above road level drain on shore side should be cleaning (improved) and curb and guttering laid as a preventative measure - siltation ??	Residential, Roads & Paths				
29	Venice Road	Pretty Beach		15	No	No				No						
30 (See No. 23 - also this address)	Pretty Beach Road	Pretty Beach		30	Yes	Yes			I cannot give specific dates as our house is a holiday house but over the years I have spent long periods there as have other members of the Hill Family	Yes	Our family have owned No. 22 Pretty Beach Road since 1972 and experienced flood water problems. Most of our floods came from water flowing like a waterfall over the escarpment to the south, down Como Parade and followed the natural fall, through our properties 21,22,23,24 down to the creek - 21 was later raised and rebuilt. Tides in the creek were a lesser problem except for the King tides which flooded at times from the creek and covered our backyards. On one occasion an exceptionally high tide came acrooss the road, stalled cars and came up to our front doors. That happened only once ever since we occupied No. 22. Ours being a holiday house we were not in residence all the time but spent a lot of time there. When we replaced the floor covering on our front sun room, which is about 5" lower than the main rooms, there was evidence of salt residue on the floor from previous flooding - Pre 19?. During high tide flood mentioned above, many lost washing machines, mowers, etc housed in out buildings, ruined by the salt. These properties have no drainage provided and we have piped roof overflow down to the creek by courtesy of No. 38 behind us.	Residential, Roads & Paths	Backyard, front yard, building (below floor level) almost to floor levee. Water continues to lie under our houses after any flooding	Yes		1.Creek deepening - it has silted up over years. Deep drain on west side of Como Parade to carry water to water front. 2. A dish drain to take runoff of water from roadway into creek instead of flooding front of our properties. 3. When we installed septic tanks, before the sewage system was connected, the soil displaced was spread over our yard and 6" slightly improved run-off flooding. ?

APPENDIX C

Historical Flooding Photos


my house


Bridge
WATER COURSE


Bridge
my yard


REAR OF (LOT 33)
TO HIGHVIEW RD
WATER ENTERING
HERE


← SOUTH → NORTH
REAR OF (LOT 32)
SIVENICE RD

The front of 47 Venice Rd

Front of 47 Venice Rd

D/A 20034 REAR PROPERTY

D/A 20035 FRONT PROPERTY

50 Venice Road (resident)

(creek)

Was at one time a natural water course until the council piped the water from High View Road into it. Now a raging torrent when heavy rain and high tide meet. And now council have made a channel into it from Como Parade. It's not fair to the people whose property it runs through.

PRETTY BEACH BASIN IN FLOOD

94 Vol 5 - 96.

COMO PARADE AND VENICE ROADS VIEWS - FLOODING - IN EXTREME EVENTS

Courtesy of Ms Gwen Perrie of Pretty Beach Wagstaffe & District Association (09/12/2004)

These photos taken during a moderate to heavy rain event, show the active waterfalls on the eastern and south-eastern escarpments in Pretty Beach. Water from these falls flow towards Turo Creek through natural gullies. Water flowing towards Como Parade is collected by the drainage network.

APPENDIX D

Ground Survey and Cross Sections for Flood Modelling

The location of the surveyed cross sections is shown on the survey sheet on the next page. Surveyed cross sections number 2 to 10 were utilised in the MIKE 11 model. Four additional cross sections were developed from the raw survey data. The location of these additional cross sections is provided in Figure 3.2.

The coordinates for cross sections used in the MIKE 11 model are provided below (please refer to Figure 3.2 for location of all the cross sections):

XS Chainage	End	Coordinates MGA (Zone 56)	
		X	Y
0	East	346451.65	6288729.40
	West	346509.88	6288703.77
28	East	346469.31	6288760.17
	West	346515.77	6288720.40
55	East	346487.69	6288780.71
	West	346534.14	6288741.08
104	East	346495.25	6288830.52
	West	346600.15	6288763.78
137	East	346495.96	6288842.08
	West	346610.85	6288829.46
165	East	346499.75	6288870.91
	West	346616.11	6288858.07
197	East	346491.54	6288905.62
	West	346620.53	6288887.75
226	East	346481.02	6288932.56
	West	346624.31	6288923.30
266	East	346481.02	6288932.56
	West	346632.10	6289020.93
304	East	346445.93	6288976.16
	West	346626.15	6289026.40
325	East	346398.06	6289023.07
	West	346666.56	6289063.97
329	East	346384.72	6289046.54
	West	346666.56	6289063.97
343	East	346386.24	6289058.62
	West	346662.10	6289079.39

BENCH MARK B232
GIN & ALUM TAG IN
SANDSTONE SEAWALL 0.69 A.H.D

SSM 94483
3.05 A.H.D

BENCH MARK B238
GIN & ALUM. TAG IN DRIVE
OF No. 42 1.77 A.H.D

RECORDED FLOOD
LEVEL RL 2.48

RECORDED FLOOD
LEVEL RL 3.13

RECORDED FLOOD
LEVEL RL 1.545

RECORDED FLOOD
LEVEL RL 2.3

RECORDED FLOOD
LEVEL RL 2.16

FLOOR LEVEL NOT SURVEYED
(RESIDENT OBJECTION)

900mm%%C RCP
RL INV 1.16
RL YOUT 1.06

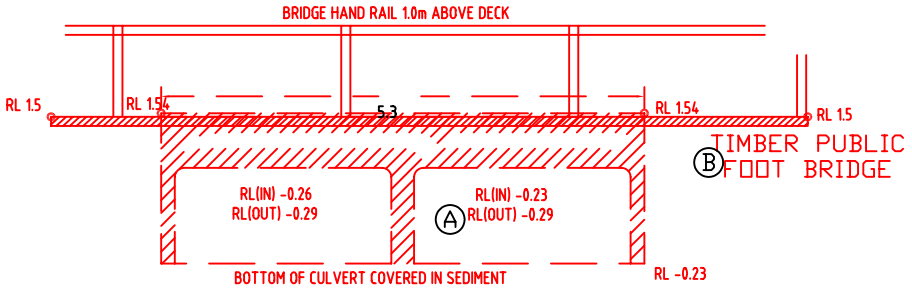
SEWER PUMPING
STATION

BRISBANE
WATER

N

DETAIL PLAN OF TURO CREEK

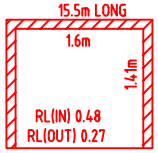
SCALE 1:500	DATUM AHD	FLOOD STUDY AND DRAINAGE SURVEY OF TURO CREEK PRETTY BEACH	STEPHEN THORNE & ASSOCIATES PTY LTD REGISTERED SURVEYORS SUITE 8, 42 MANN STREET, GOSFORD Phone 43231255 Fax 43242226	3737 3 OF 6
DATE 08/06/00	CONTOURS 1m			
DRAWN BY CSK-CAD	AMENDED			



CONCRETE
CULVERT
2 x 1.2m x 2.4m

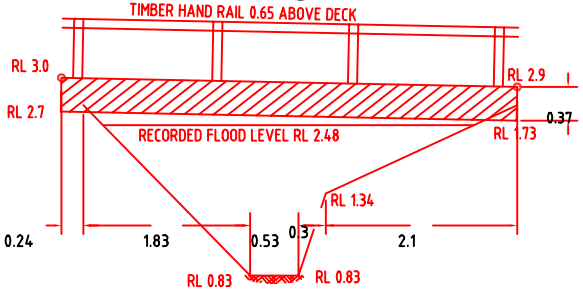
Ⓑ TIMBER PUBLIC FOOT BRIDGE

Ⓔ



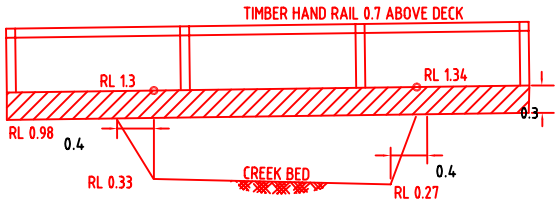
PRIVATE
TIMBER CULVERT

Ⓗ



PRIVATE
TIMBER FOOT BRIDGE

Ⓒ



PRIVATE
TIMBER FOOT BRIDGE

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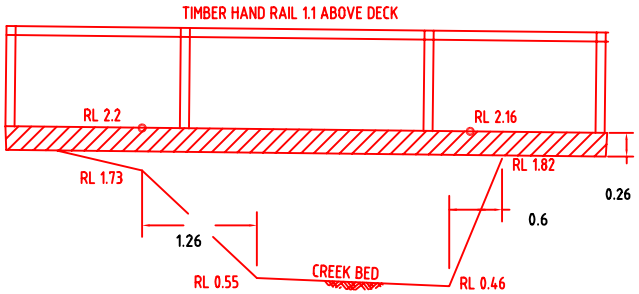

PRIVATE
TIMBER FOOT BRIDGE

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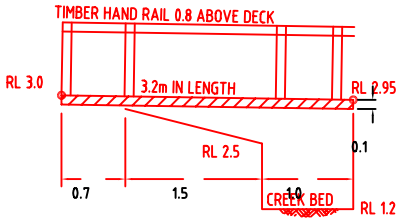

PRIVATE
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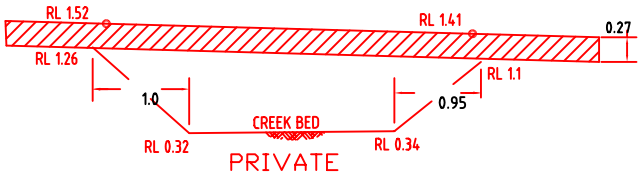
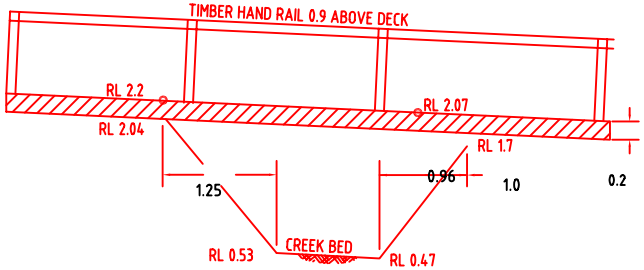


PRIVATE
TIMBER FOOT BRIDGE

Ⓖ



PRIVATE
TIMBER FOOT BRIDGE

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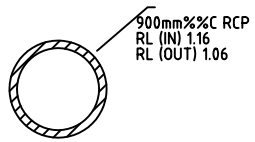

SKETCHES OF DRAINAGE STRUCTURES

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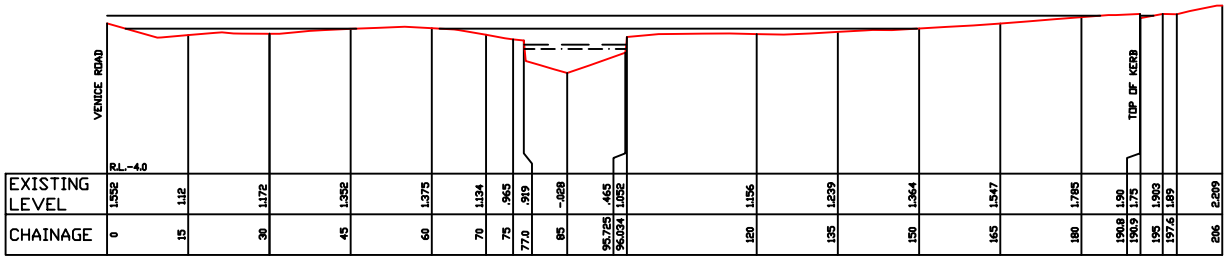
DATE 08/06/00	CONTOURS 1m		
DRAWN BY CSK-CAD	AMENDED		

3737
4 OF 6



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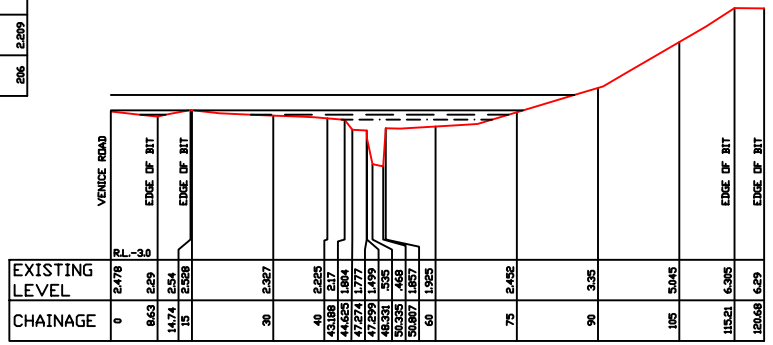

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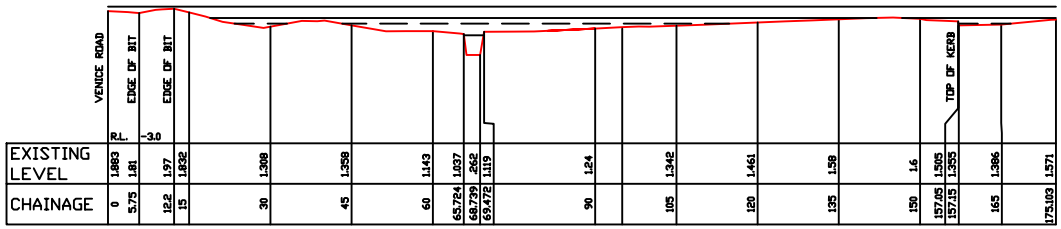

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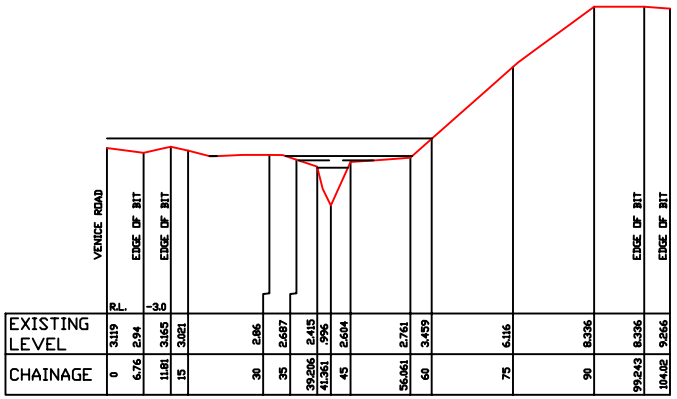

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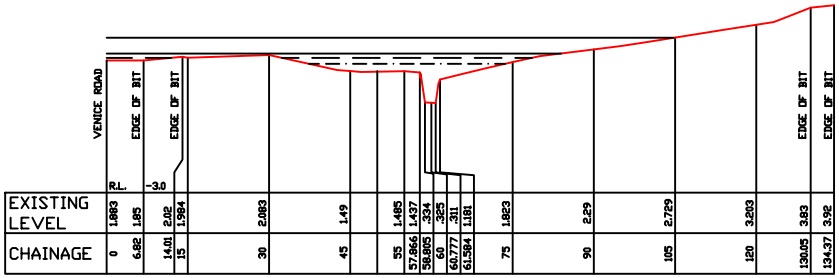

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CROSS SECTIONS AS SHOWN ON SHEET 3

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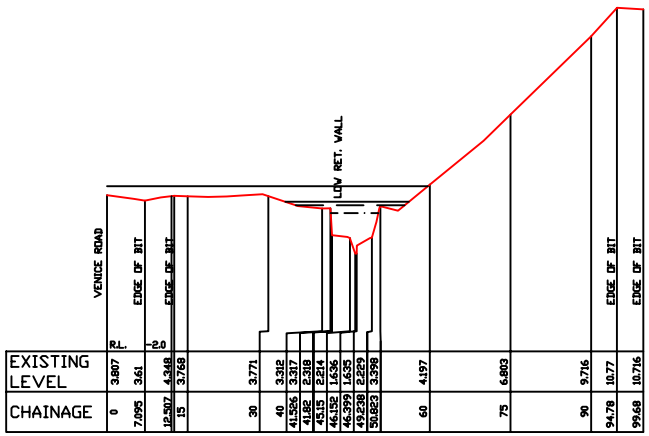
DATE 08/06/00	CONTOURS 1m		
DRAWN BY CSK-CAD	AMENDED		

3737

5 OF 6



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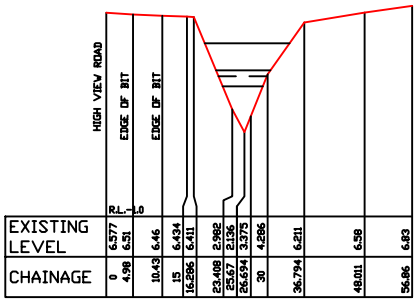

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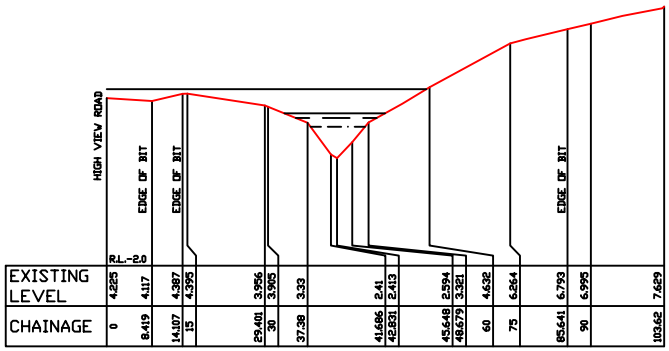

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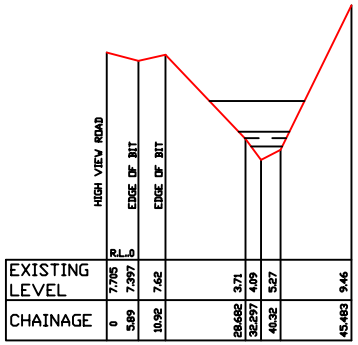

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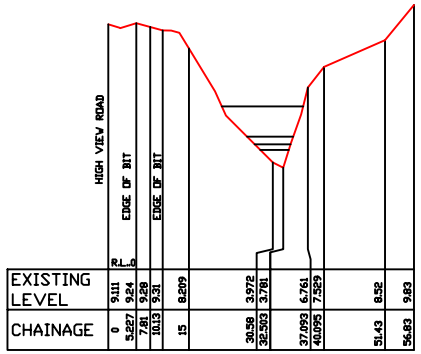

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CROSS SECTIONS AS SHOWN ON SHEET 3

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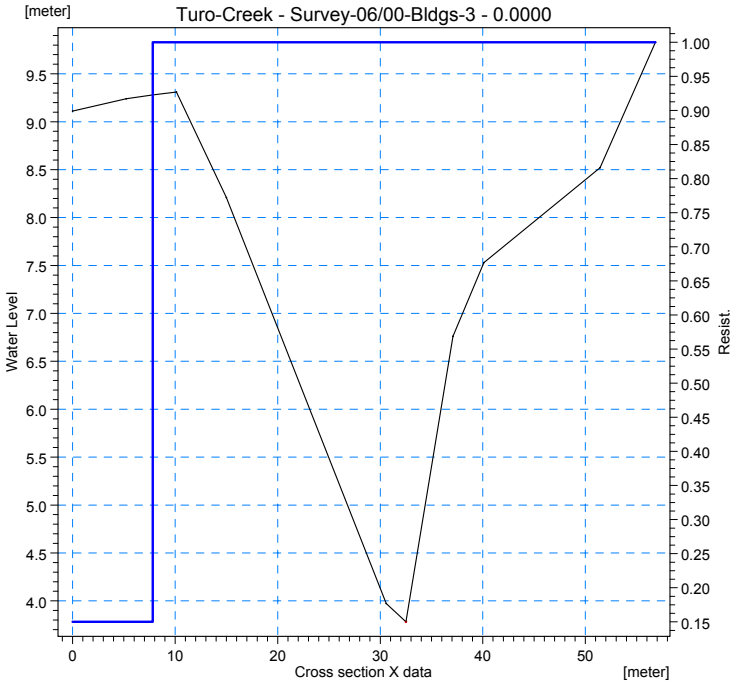
DATE 08/06/00	CONTOURS 1m			
DRAWN BY CSK-CAD	AMENDED			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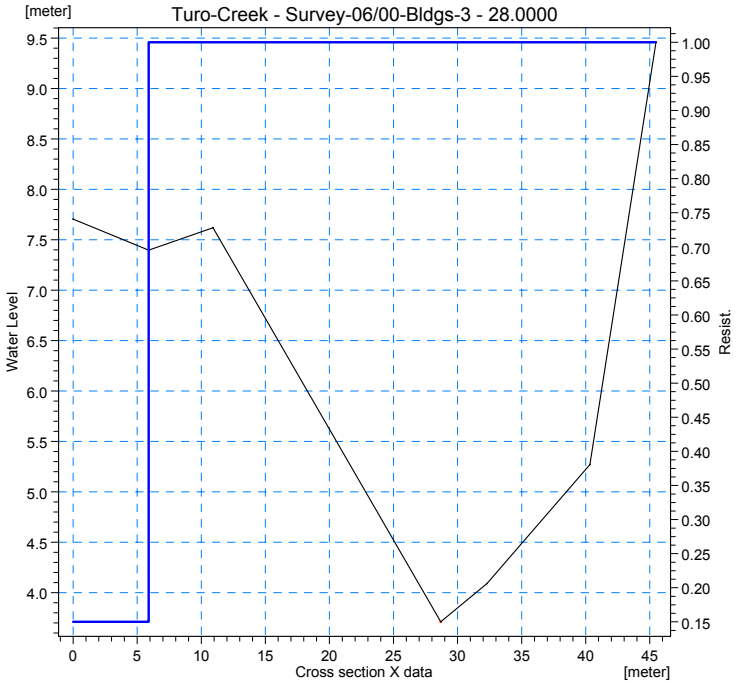
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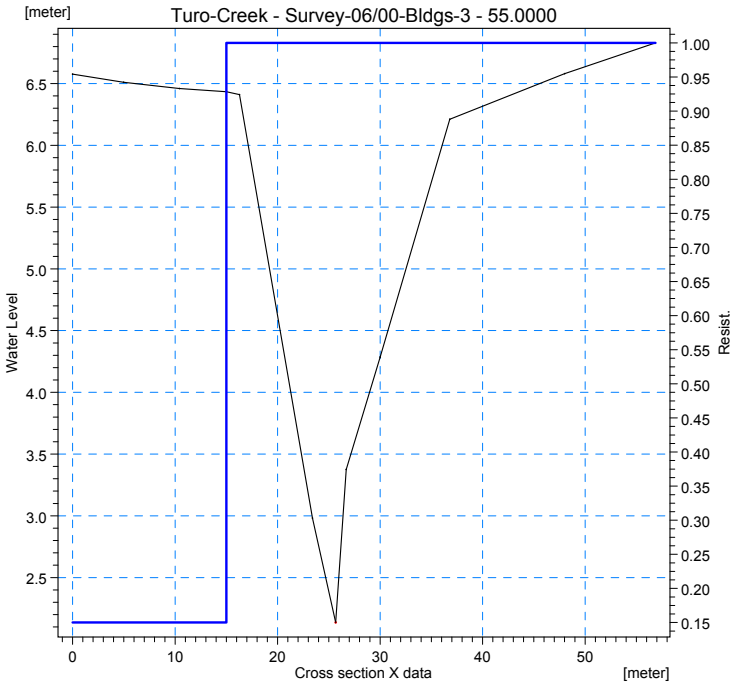
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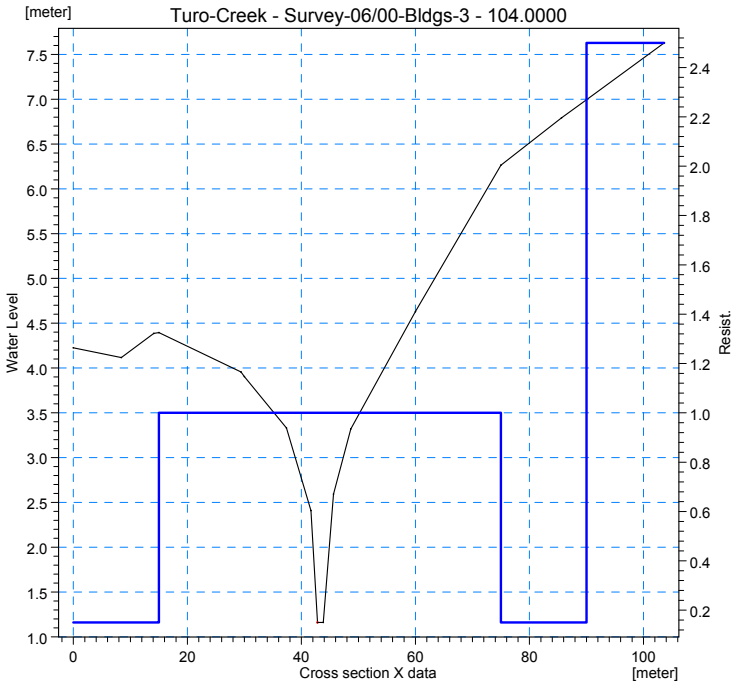
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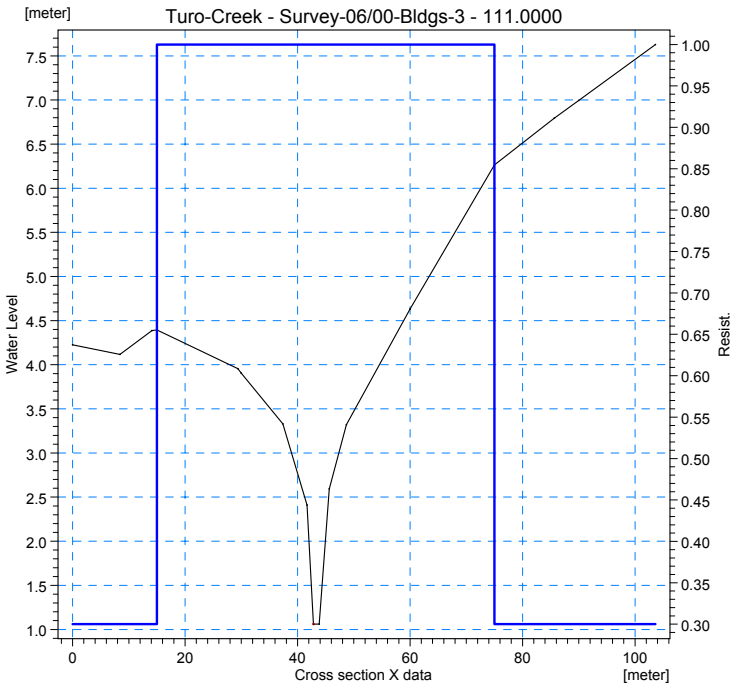
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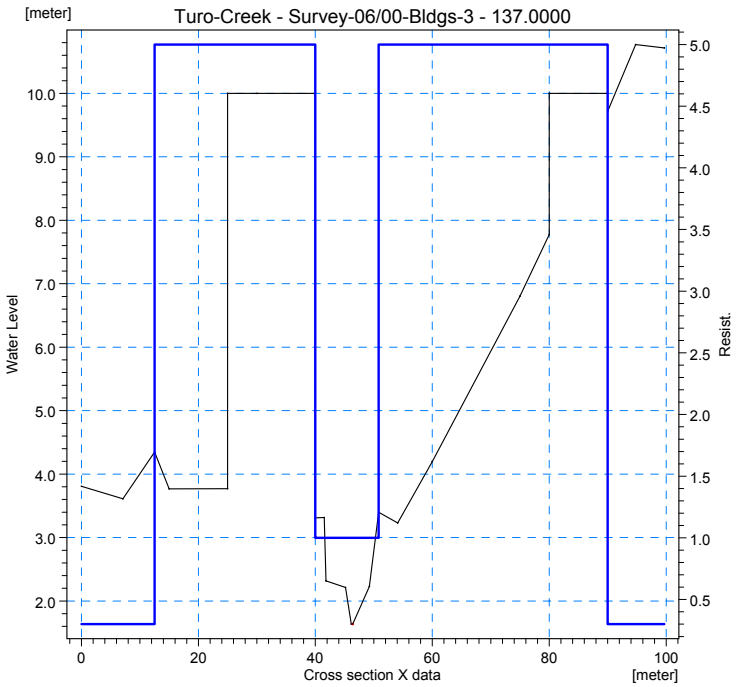
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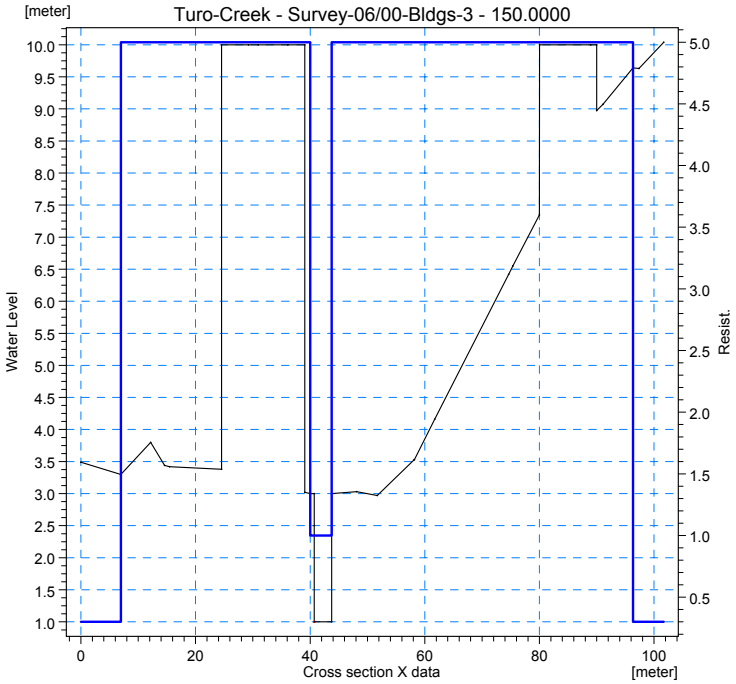
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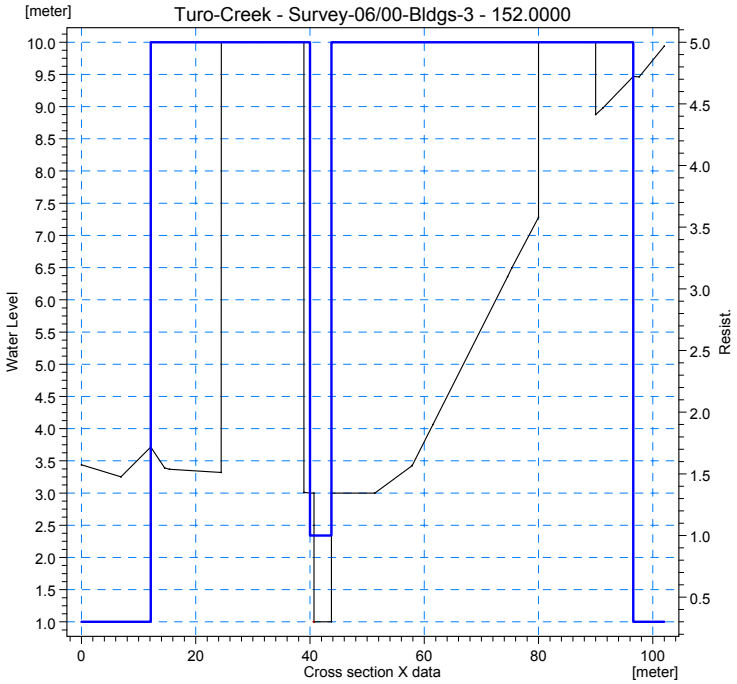
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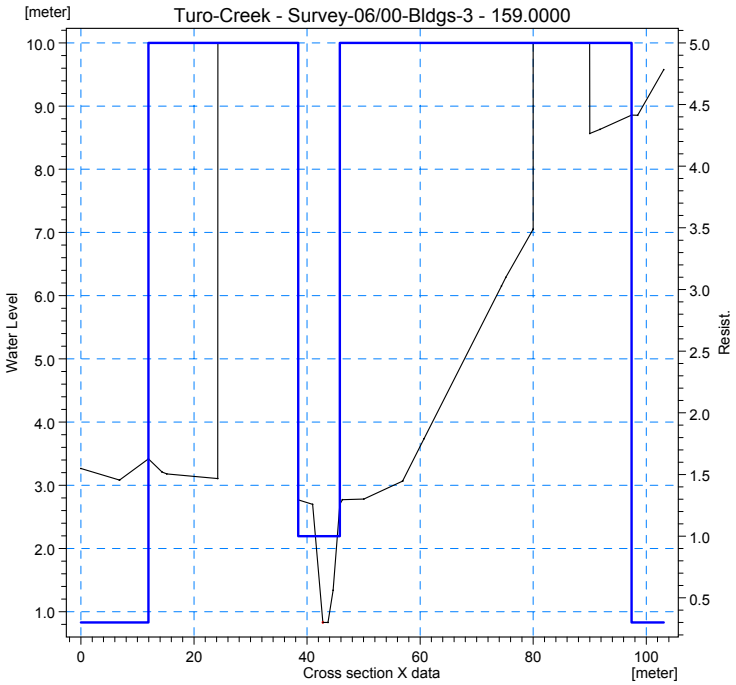
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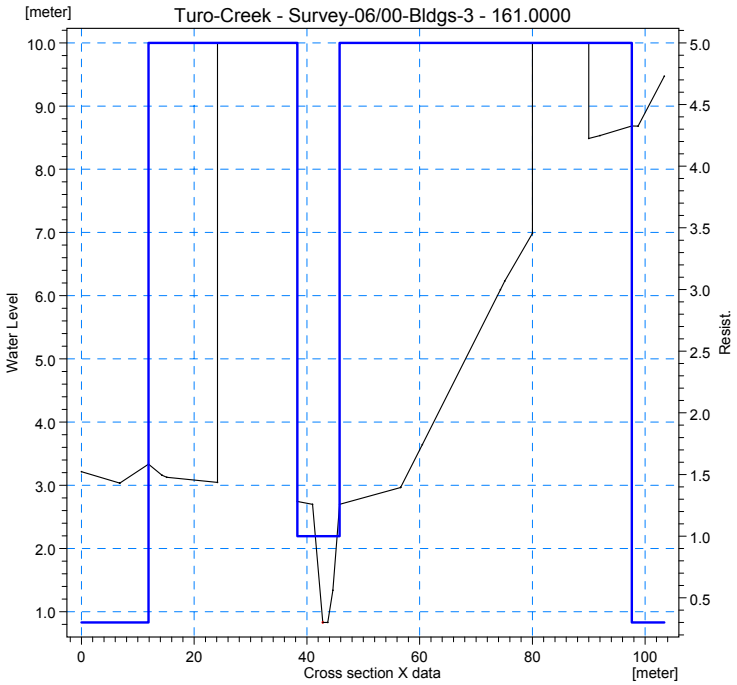
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Water Level
Resist.
Cross section X data
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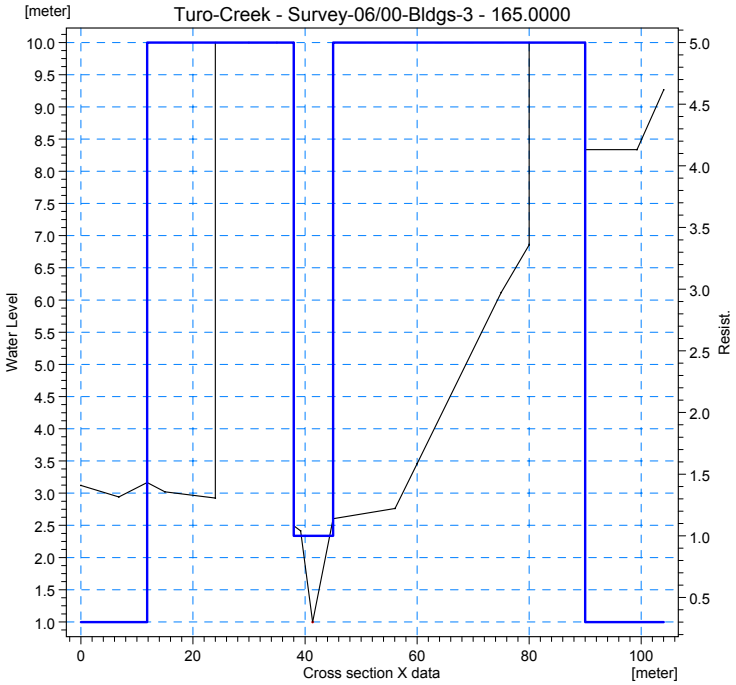
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Water Level
Resist.
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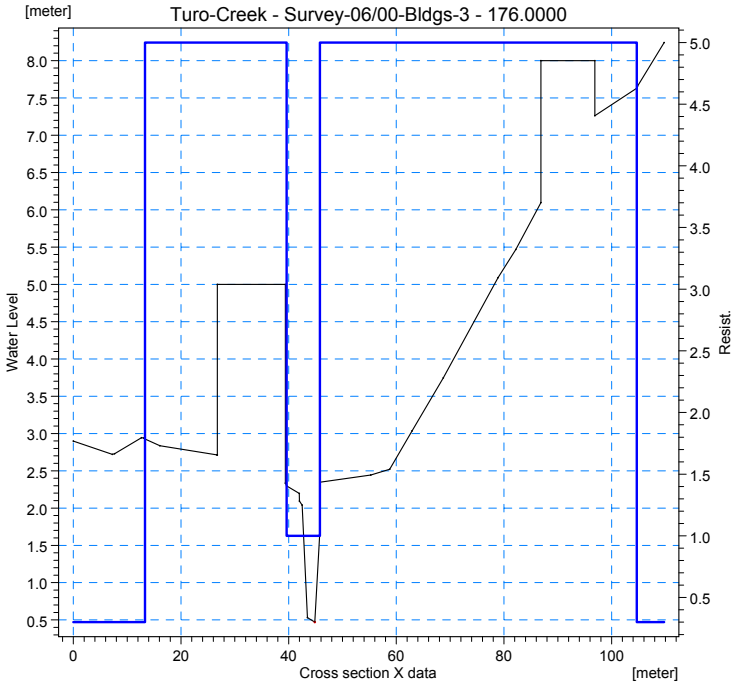
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Water Level
Resist.
Cross section X data
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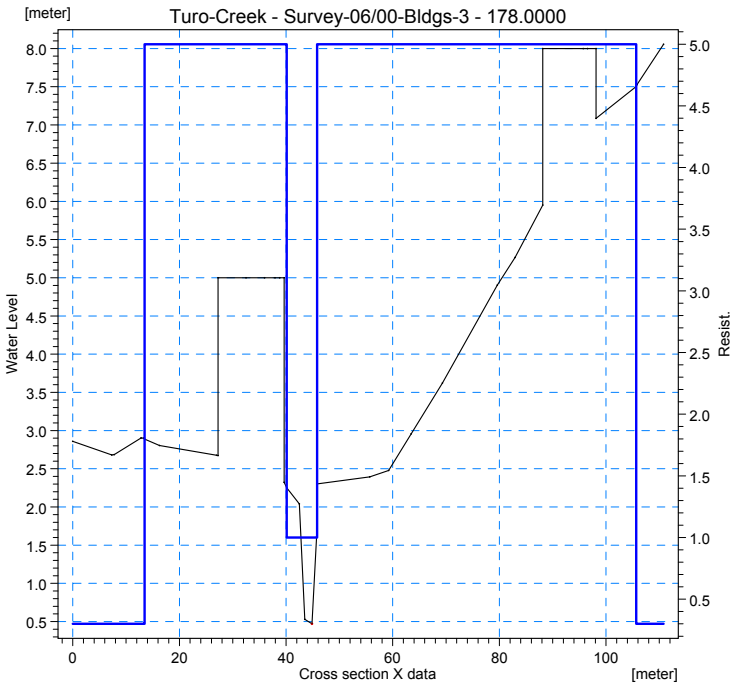
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Water Level
Resist.
Cross section X data
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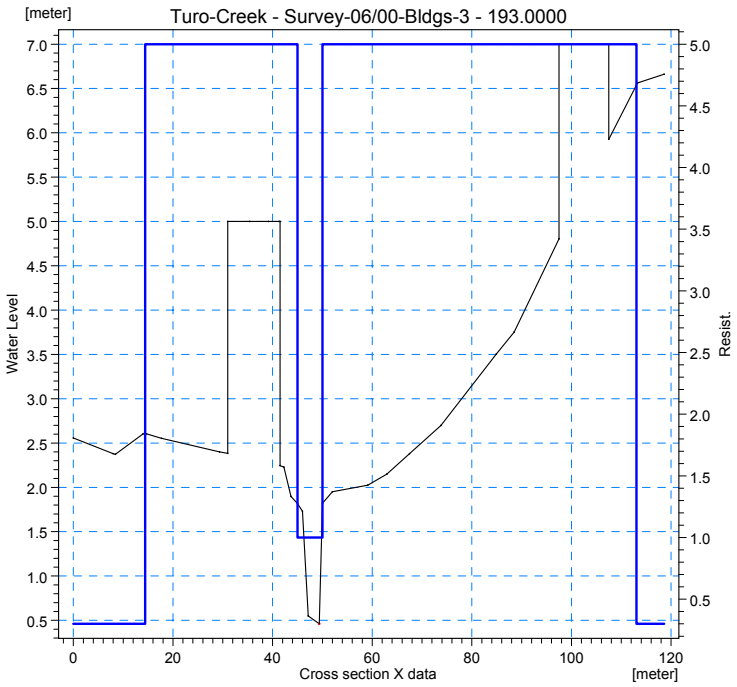
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Water Level
Resist.
Cross section X data
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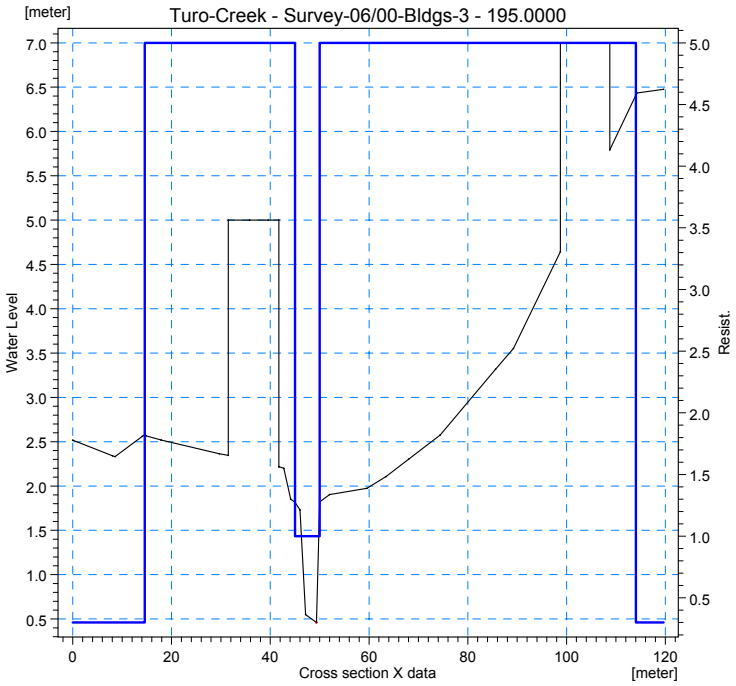
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Water Level
Resist.
Cross section X data
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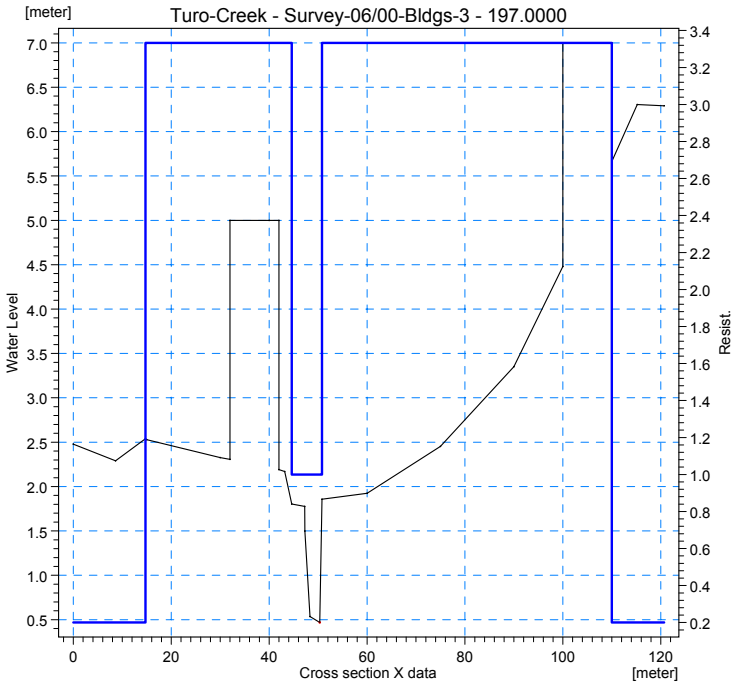
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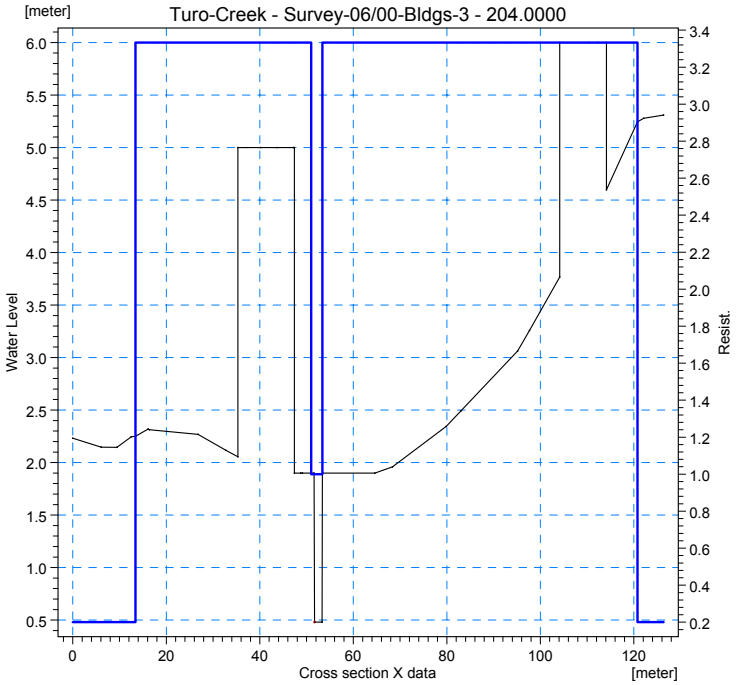
Water Level
Resist.
Cross section X data
[meter]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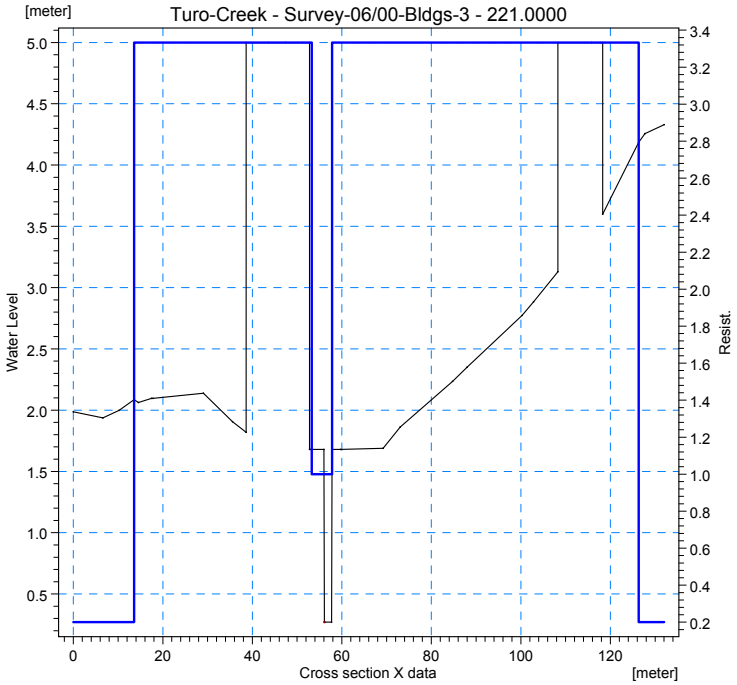
Water Level
Resist.
Cross section X data
[meter]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Water Level
Resist.
Cross section X data
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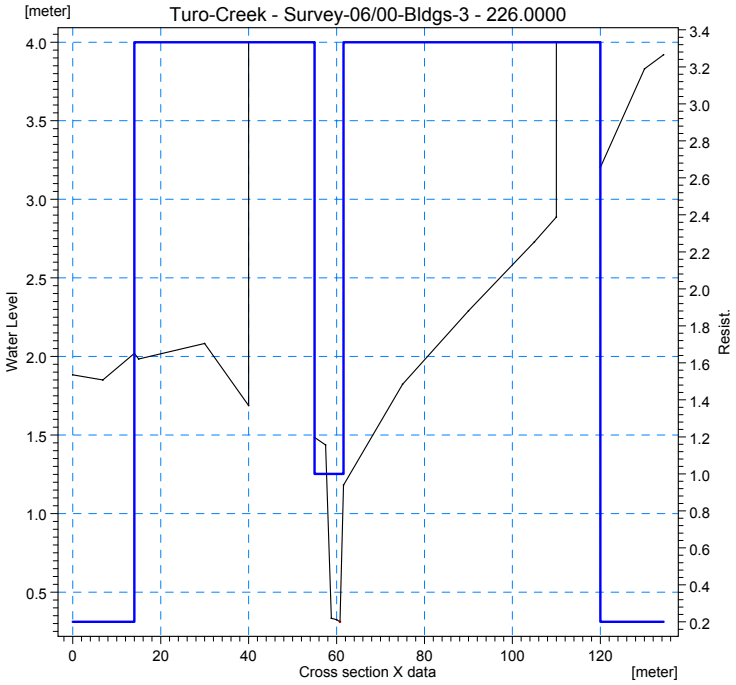
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Cross section X data
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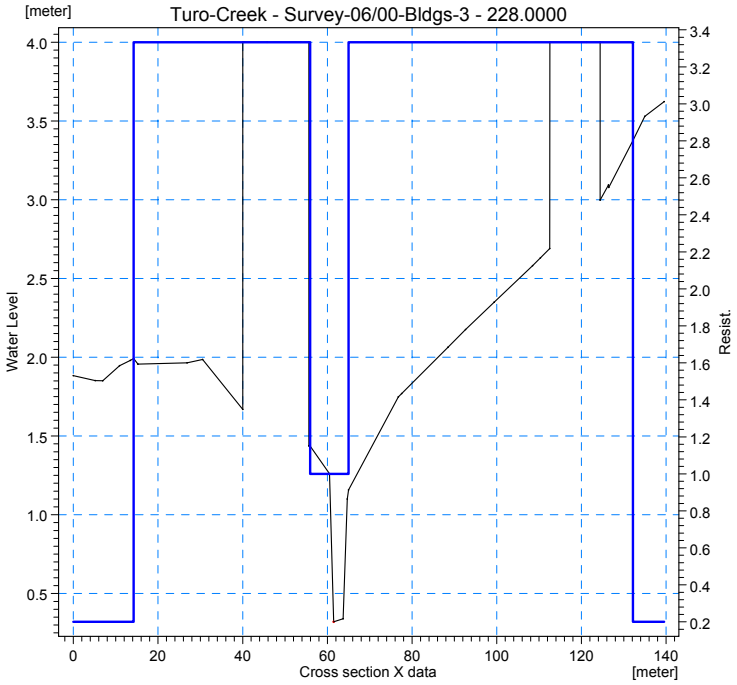
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Cross section X data
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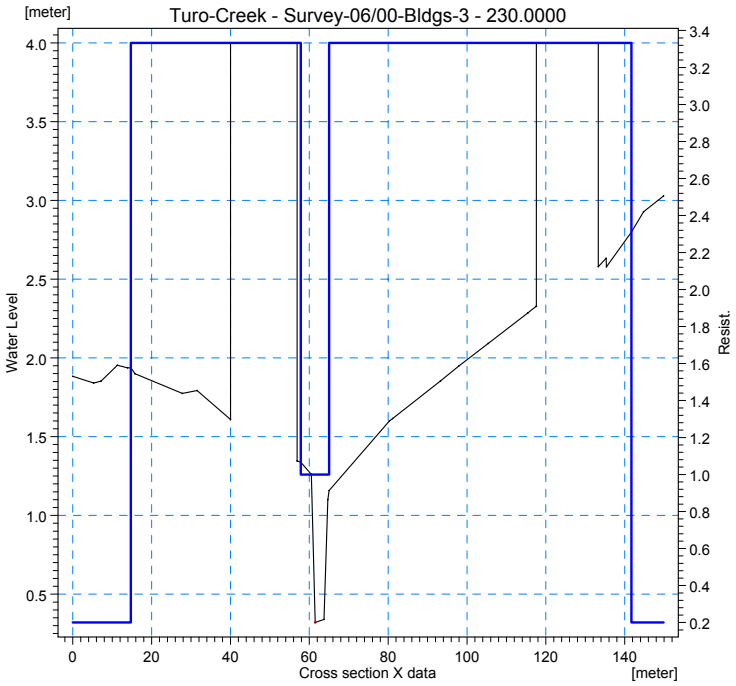
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Resist.
Cross section X data
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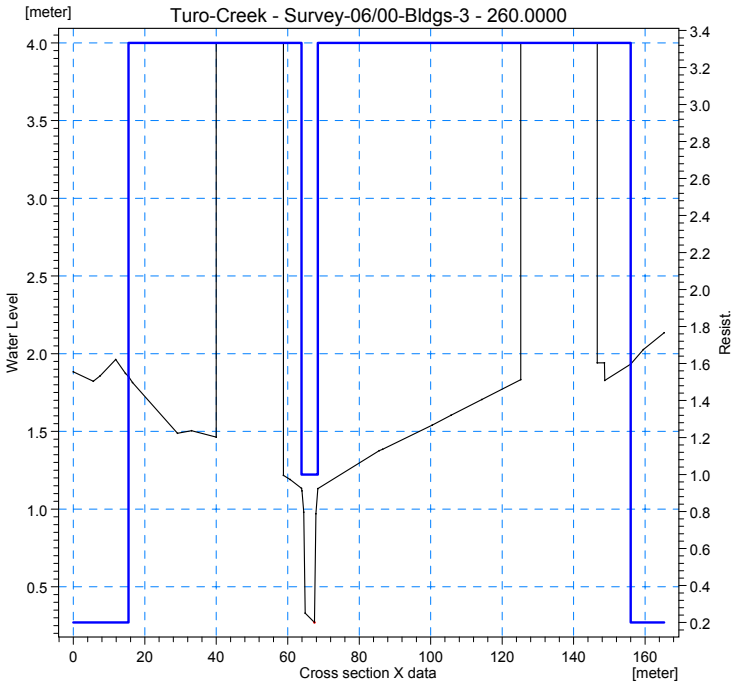
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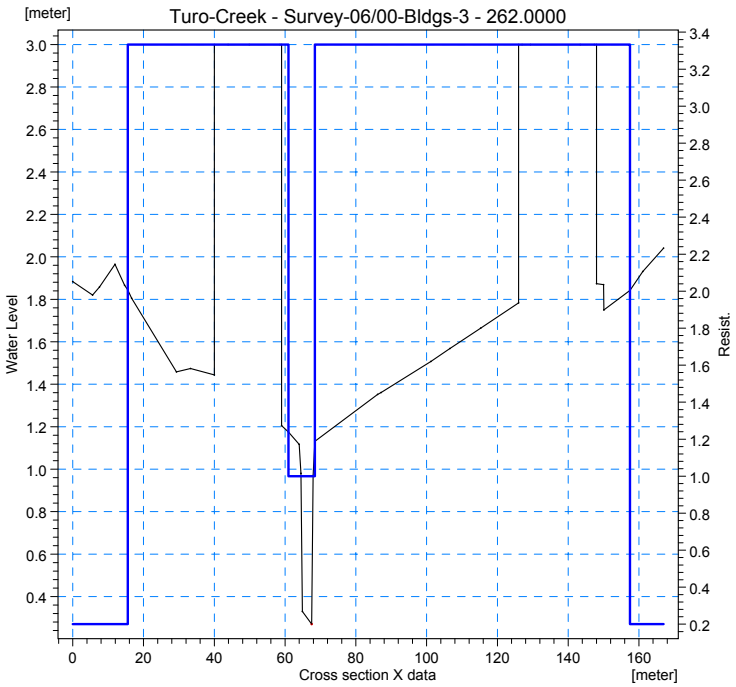
Water Level
Resist.
Cross section X data
[meter]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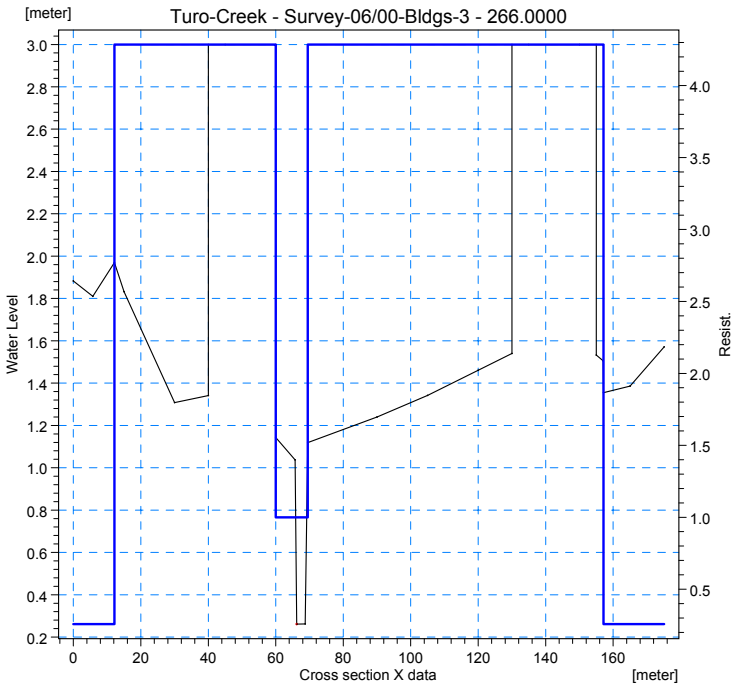
Turo-Creek - Survey-06/00-Bldgs-3 - 262.0000
Water Level
Resist.
Cross section X data
[meter]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Water Level
Resist.
Cross section X data
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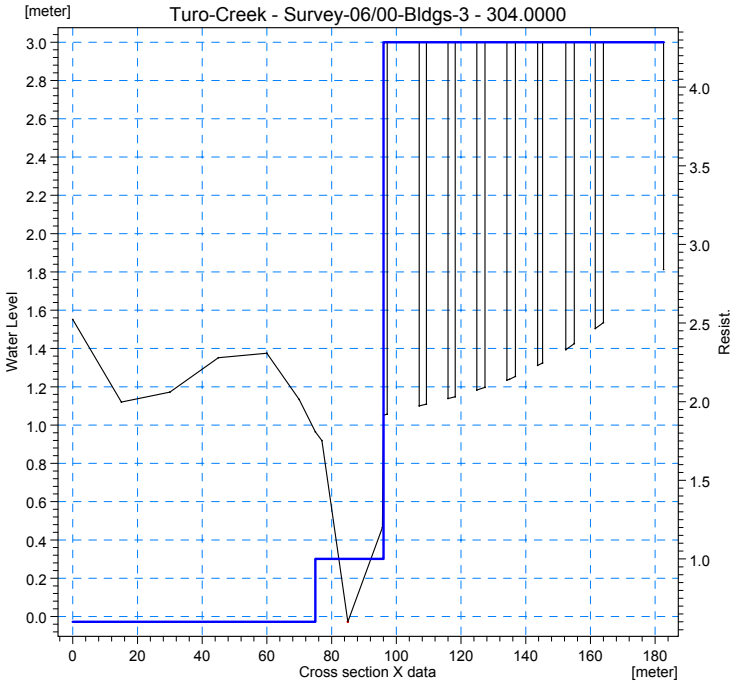
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Turo-Creek - Survey-06/00-Bldgs-3 - 304.0000
Water Level
Resist.
Cross section X data
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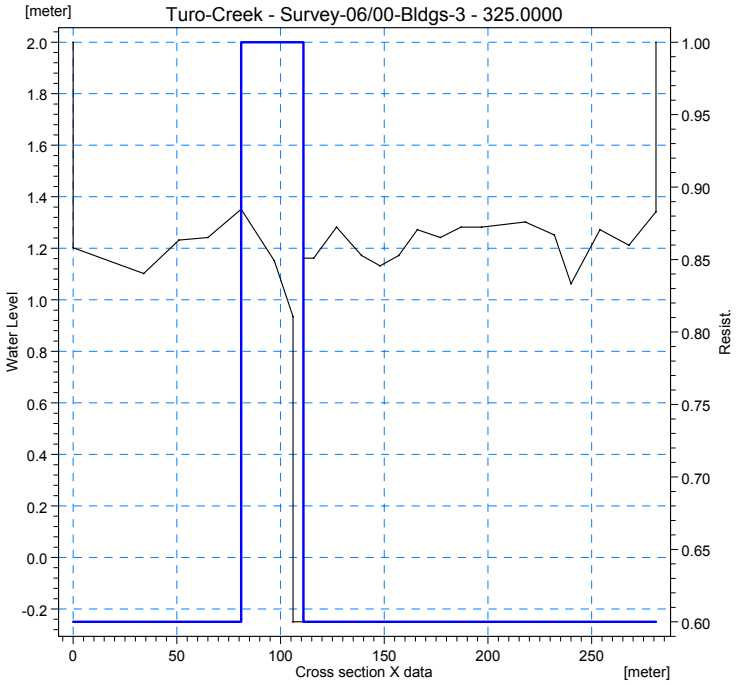
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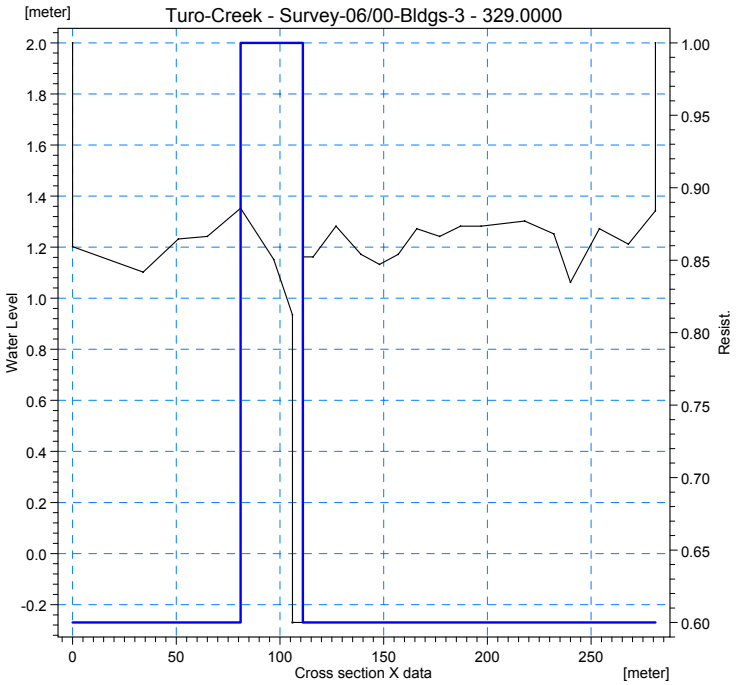
Water Level
Resist.
Cross section X data
[meter]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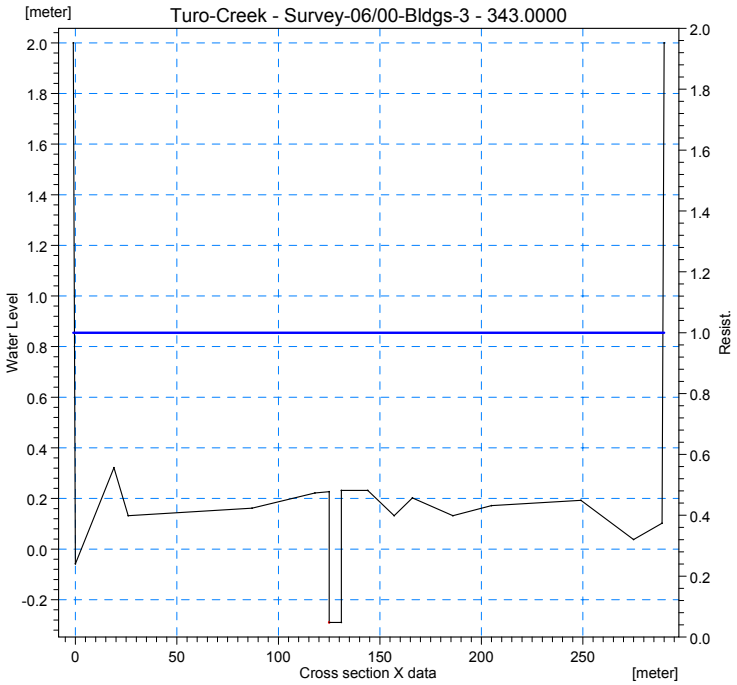
Water Level
Resist.
Cross section X data
[meter]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Water Level
Resist.
Cross section X data
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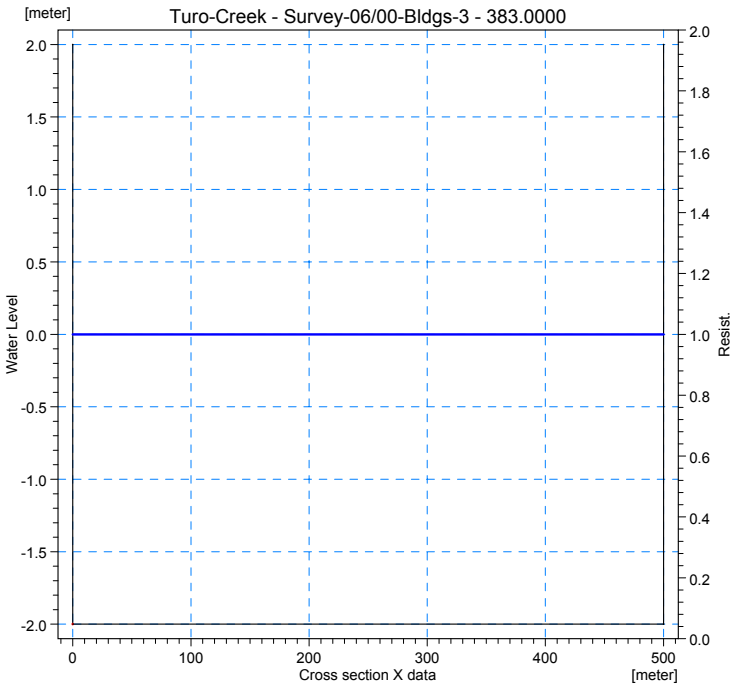
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Turo-Creek - Survey-06/00-Bldgs-3 - 383.0000
Water Level
Resist.
Cross section X data
[meter]

APPENDIX E

MIKE 11 Design Flood Modelling Results

	PMF			200 Year ARI			100 Year ARI			50 Year ARI			20 Year ARI			5 Year ARI		
	Water Level	Velocity	Discharge	Water Level	Velocity	Discharge	Water Level	Velocity	Discharge	Water Level	Velocity	Discharge	Water Level	Velocity	Discharge	Water Level	Velocity	Discharge
Cross Section ID	m	m/s	m^3/s	m	m/s	m^3/s	m	m/s	m^3/s	m	m/s	m^3/s	m	m/s	m^3/s	m	m/s	m^3/s
TURO-CREEK 0	6.73	1.63	42.79	5.57	1.03	10.82	5.48	0.99	9.51	5.39	0.94	8.20	5.29	0.88	6.76	5.04	0.72	4.07
TURO-CREEK 28	6.26	1.22	44.81	5.09	0.92	11.41	5.01	0.89	9.99	4.93	0.87	8.58	4.83	0.85	7.09	4.61	0.78	4.26
TURO-CREEK 55	5.74	1.72	48.40	4.61	1.03	12.38	4.51	0.98	10.80	4.41	0.93	9.29	4.29	0.87	7.62	3.97	0.73	4.58
TURO-CREEK 104	4.64	1.11	55.01	3.81	0.94	17.27	3.77	0.90	15.82	3.74	0.62	10.50	3.68	0.54	8.60	3.44	0.44	5.13
TURO-CREEK 111	4.45	1.37	57.31	3.76	1.01	17.66	3.72	0.96	16.13	3.67	0.68	10.94	3.62	0.59	8.95	3.38	0.50	5.34
TURO-CREEK 137	4.24	1.57	57.95	3.67	0.93	14.82	3.64	0.84	12.96	3.61	0.75	11.09	3.57	0.64	9.07	3.35	0.51	5.40
TURO-CREEK 150	4.15	1.28	58.44	3.64	0.70	15.02	3.61	0.64	13.11	3.58	0.58	11.21	3.55	0.53	9.16	3.33	0.50	5.45
TURO-CREEK 152	3.99	1.52	60.07	3.48	0.97	15.45	3.42	0.97	13.47	3.36	0.96	11.51	3.29	0.91	9.40	3.17	0.65	5.59
TURO-CREEK 159	3.96	1.21	59.30	3.46	0.61	15.26	3.40	0.60	13.31	3.35	0.58	11.39	3.28	0.55	9.29	3.17	0.43	5.53
TURO-CREEK 161	3.58	1.89	60.46	3.06	1.43	15.57	3.00	1.41	13.57	2.93	1.36	11.61	2.85	1.29	9.48	2.68	1.01	5.63
TURO-CREEK 165	3.52	1.75	60.88	3.04	1.25	15.68	2.97	1.24	13.67	2.90	1.22	11.70	2.82	1.18	9.54	2.67	0.97	5.67
TURO-CREEK 176	3.46	1.21	60.14	2.98	0.74	15.51	2.92	0.73	13.51	2.85	0.73	11.58	2.78	0.71	9.46	2.65	0.55	5.61
TURO-CREEK 178	3.21	1.61	61.90	2.74	1.17	15.97	2.69	1.17	13.91	2.64	1.09	11.91	2.58	1.02	9.72	2.46	0.81	5.77
TURO-CREEK 193	3.06	1.14	60.88	2.63	0.62	15.73	2.59	0.60	13.69	2.56	0.55	11.74	2.52	0.50	9.58	2.43	0.37	5.69
TURO-CREEK 195	2.90	1.33	61.86	2.52	0.75	15.98	2.50	0.69	13.91	2.47	0.63	11.92	2.42	0.58	9.73	2.31	0.45	5.78
TURO-CREEK 197	2.89	1.17	62.59	2.50	0.71	16.17	2.48	0.67	14.08	2.45	0.61	12.06	2.41	0.55	9.84	2.31	0.44	5.84
TURO-CREEK 204	2.78	1.17	62.78	2.38	0.76	16.24	2.35	0.75	14.13	2.32	0.74	12.11	2.28	0.69	9.88	2.21	0.57	5.86
TURO-CREEK 221	2.70	1.04	62.49	2.19	0.80	16.19	2.16	0.78	14.10	2.13	0.75	12.07	2.09	0.72	9.81	1.98	0.67	5.83
TURO-CREEK 226	2.67	0.99	65.42	2.12	0.65	16.29	2.09	0.64	14.19	2.06	0.60	12.13	2.01	0.57	9.85	1.88	0.49	5.87
TURO-CREEK 228	2.67	1.07	76.50	2.12	0.54	16.44	2.08	0.52	14.32	2.05	0.49	12.24	2.00	0.48	9.94	1.87	0.41	5.92
TURO-CREEK 230	2.61	0.96	80.65	2.06	0.50	16.73	2.01	0.49	14.57	1.97	0.48	12.45	1.91	0.46	10.11	1.77	0.42	6.01
TURO-CREEK 260	2.16	0.86	51.84	1.77	0.64	18.72	1.72	0.55	14.48	1.69	0.51	12.36	1.67	0.47	10.01	1.57	0.38	5.97
TURO-CREEK 262	2.07	0.90	55.94	1.74	0.65	18.21	1.70	0.64	14.81	1.66	0.63	12.62	1.61	0.64	10.22	1.49	0.62	6.09
TURO-CREEK 266	2.01	0.79	63.78	1.67	0.54	17.84	1.65	0.56	14.94	1.61	0.53	12.73	1.58	0.55	10.30	1.47	0.56	6.14
TURO-CREEK 304	1.81	0.83	66.52	1.55	0.33	16.85	1.53	0.31	14.81	1.51	0.29	12.36	1.47	0.28	9.84	1.34	0.23	5.97
TURO-CREEK 325	1.79	0.40	66.90	1.55	0.33	16.91	1.53	0.32	14.80	1.50	0.33	13.18	1.46	0.32	12.74	1.34	0.32	10.48
TURO-CREEK 329	1.74	0.56	68.35	1.52	0.55	17.26	1.50	0.54	15.09	1.48	0.55	12.86	1.44	0.54	12.02	1.32	0.52	10.20
TURO-CREEK 343	0.91	0.31	68.26	0.90	0.08	17.22	0.90	0.07	15.06	0.90	0.06	12.22	0.90	0.05	9.66	0.90	0.03	5.42
TURO-CREEK 383	0.90	0.05	68.85	0.90	0.01	17.36	0.90	0.01	15.20	0.90	0.01	12.33	0.90	0.01	9.74	0.90	0.00	5.46

APPENDIX F

MIKE 11 Sensitivity Analysis Modelling Results

Branch	chainage	**Deisign** 100yr 2hr Maximum	**Boundary + 20%** 100yr 2hr Maximum	Diff	**Boundary - 20%** 100yr 2hr Maximum	Diff	**Roughness + 20%** 100yr 2hr Maximum	Diff	**Roughness -20%** 100yr 2hr Maximum	Diff	**Flow + 20%** 100yr 2hr Maximum	Diff	**Flow - 20%** 100yr 2hr Maximum	Diff
TURO-CREEK 0.00	0	5.482	5.48	0.00	5.48	0.00	5.60	0.12	5.35	-0.13	5.57	0.08	5.35	-0.13
TURO-CREEK 28.00	28	5.011	5.01	0.00	5.01	0.00	5.12	0.11	4.89	-0.12	5.25	0.24	4.89	-0.12
TURO-CREEK 55.00	55	4.513	4.51	0.00	4.51	0.00	4.64	0.12	4.37	-0.14	4.93	0.41	4.37	-0.15
TURO-CREEK 104.00	104	3.769	3.77	0.00	3.77	0.00	3.83	0.06	3.73	-0.04	4.01	0.24	3.72	-0.05
TURO-CREEK 111.00	111	3.718	3.72	0.00	3.72	0.00	3.76	0.04	3.67	-0.05	3.97	0.25	3.65	-0.07
TURO-CREEK 137.00	137	3.639	3.64	0.00	3.64	0.00	3.66	0.02	3.62	-0.01	3.82	0.18	3.60	-0.04
TURO-CREEK 150.00	150	3.61	3.61	0.00	3.61	0.00	3.61	0.00	3.61	0.00	3.77	0.16	3.57	-0.04
TURO-CREEK 152.00	152	3.42	3.42	0.00	3.42	0.00	3.44	0.02	3.41	-0.01	3.63	0.21	3.33	-0.09
TURO-CREEK 159.00	159	3.403	3.40	0.00	3.40	0.00	3.40	0.00	3.40	0.00	3.61	0.21	3.32	-0.08
TURO-CREEK 161.00	161	3.001	3.00	0.00	3.00	0.00	3.05	0.05	2.96	-0.04	3.22	0.22	2.90	-0.10
TURO-CREEK 165.00	165	2.972	2.97	0.00	2.97	0.00	3.01	0.03	2.94	-0.03	3.17	0.20	2.87	-0.10
TURO-CREEK 176.00	176	2.917	2.92	0.00	2.92	0.00	2.92	0.00	2.92	0.00	3.09	0.17	2.82	-0.09
TURO-CREEK 178.00	178	2.691	2.69	0.00	2.69	0.00	2.73	0.04	2.65	-0.04	2.92	0.23	2.62	-0.07
TURO-CREEK 193.00	193	2.592	2.59	0.00	2.59	0.00	2.59	0.00	2.59	0.00	2.80	0.20	2.55	-0.04
TURO-CREEK 195.00	195	2.495	2.50	0.00	2.50	0.00	2.53	0.04	2.45	-0.04	2.63	0.14	2.45	-0.04
TURO-CREEK 197.00	197	2.478	2.48	0.00	2.48	0.00	2.51	0.04	2.44	-0.04	2.61	0.13	2.44	-0.04
TURO-CREEK 204.00	204	2.347	2.35	0.00	2.35	0.00	2.35	0.00	2.35	0.00	2.52	0.17	2.30	-0.04
TURO-CREEK 221.00	221	2.157	2.16	0.00	2.16	0.00	2.18	0.02	2.14	-0.02	2.39	0.23	2.12	-0.04
TURO-CREEK 226.00	226	2.089	2.09	0.00	2.09	0.00	2.12	0.03	2.09	0.00	2.35	0.26	2.04	-0.05
TURO-CREEK 228.00	228	2.082	2.08	0.00	2.08	0.00	2.09	0.01	2.08	0.00	2.33	0.24	2.04	-0.05
TURO-CREEK 230.00	230	2.009	2.01	0.00	2.01	0.00	2.07	0.06	1.97	-0.04	2.25	0.24	1.95	-0.06
TURO-CREEK 260.00	260	1.723	1.72	0.00	1.72	0.00	1.78	0.05	1.72	0.00	1.89	0.17	1.69	-0.04
TURO-CREEK 262.00	262	1.696	1.70	0.00	1.70	0.00	1.73	0.03	1.65	-0.04	1.87	0.17	1.64	-0.06
TURO-CREEK 266.00	266	1.645	1.65	0.00	1.65	0.00	1.67	0.02	1.62	-0.03	1.76	0.12	1.60	-0.04
TURO-CREEK 304.00	304	1.533	1.54	0.01	1.53	0.00	1.53	0.00	1.53	0.00	1.63	0.09	1.49	-0.04
TURO-CREEK 325.00	325	1.527	1.54	0.01	1.53	0.00	1.52	0.00	1.53	0.00	1.62	0.09	1.49	-0.04
TURO-CREEK 329.00	329	1.499	1.51	0.01	1.50	0.00	1.50	0.00	1.50	0.00	1.58	0.08	1.46	-0.04
TURO-CREEK 343.00	343	0.901	1.08	0.18	0.72	-0.18	0.90	0.00	0.90	0.00	0.90	0.00	0.90	0.00
TURO-CREEK 383.00	383	0.9	1.08	0.18	0.72	-0.18	0.90	0.00	0.90	0.00	0.90	0.00	0.90	0.00

APPENDIX G

Property Details

						Construction Type			
Street No	Street Name	Comm (C), Indust (I), Resid (R), Public (P), Vacant (V)	Premises Size (S,M,L	No of Storeys	Do people live on ground floor? (Y or N)	**Floor** [Slab on Ground-S or Brick Piers-Bp]	**Walls** [Brick-B, Brick Vaneer-Bv, Fibro-F, Weather Board-Wb, Cladded-C]	General Condition of Structure (Poor, Average, Excellent)	Garden Construction (Poor, Average, Excellent)
31	Venice Rd	R	L	2	N	?	B	A	A
33	Venice Rd	R	L	2	Y	S	F/Wb	A	A
35	Venice Rd	R	L	2	Y	S	B	E	E
38	Venice Rd	R	S	1	Y	Bp	F/Wb	P	P
40	Venice Rd	R	S	1	Y	Bp	F/Wb	A	A
37	Venice Rd	R	M	2	Y	S	B	A	A
42	Venice Rd	R	M	2	Y	S	B	E	E
41	Venice Rd	R	S	1	Y	S	F/Wb	A	A
44	Venice Rd	R	S	1	Y	Bp	C	P	A
43	Venice Rd	R	S	1	Y	Bp	Wb/C	A	A
45	Venice Rd	R	S	1	Y	S	Wb/C	A	A
46	Venice Rd	R	S	1	Y	Bp	Wb/C	P-A	A
47	Venice Rd	R	S	1	Y	S	B	E	E
48	Venice Rd	R	S	1	Y	S	B	E	E
50	Venice Rd	R	S	1	Y	Bp	Wb/C	A	A
52	Venice Rd	R	M	1	Y	Bp	Wb/C	E	E
49	Venice Rd	R	S	1	Y	S	B	E	E
27	Como Pde	R	M	2	Y	Bp	Wb/C	A	A
25	Como Pde	R	M	2	Y	?	B/Wb/C	A	A
23	Como Pde	R	M	2	Y	?	F/Wb/C	A	A
21	Como Pde	R	M	2	Y	S	B	E	E
19	Como Pde	R	M	2	Y	Bp	F/Wb/C	E	E
17	Como Pde	R	S	2	Y	Bp	Wb/C	A	A
13	Como Pde	R	M	2	Y	Bp	Wb/C	E	E
11	Como Pde	R	L	2	Y	S	B	E	E
9	Como Pde	R	L	2	Y	S	B/Wb/C	E	E
7	Como Pde	R	M	1	Y	Bp	Wb/C	A	A
5	Como Pde	R	M	1	Y	Bp	Wb/C	A	A
3	Como Pde	R	S	1	Y	?	Wb/C	P	P
1	Como Pde	R	L	2	Y	Bp	Wb/C	E	E
16	Pretty Beach Rd	R	L	2	Y	Bp	Wb/C	A	A
17	Pretty Beach Rd	R	L	2	Y	Bp	Wb/C	A	A
13	Pretty Beach Rd	R	S	1	Y	Bp	Wb/C	A	A
14	Pretty Beach Rd	R	S	1	Y	Bp	Wb/C	A	A
18	Pretty Beach Rd	R	M	2	Y	S	B	E	E
19	Pretty Beach Rd	R	S	1	Y	Bp	Wb/C	P	P
20	Pretty Beach Rd	R	M	2	Y	?	Wb/C	A	A
21	Pretty Beach Rd	R	S	1	Y	Bp	Wb/C	A	A
22	Pretty Beach Rd	R	S	1	Y	?	Wb/C	A	A
23	Pretty Beach Rd	R	S	1	Y	?	Wb/C	A	A
24	Pretty Beach Rd	R	S	1	Y	?	Wb/C	A	A
36	Pretty Beach Rd	R	L	2	Y	S	B	A	A

1. Size - relates to each premises and not the complex (e.g. block of units). SMALL (S) = one bedroom, MEDIUM = 2 to 3
3. Floor Construction - enter code : (1) slab on ground (2) Piers
4. Wall Construction - enter code : (1) Brick (2) Brick Veneer (3) Fibro (4) Weather Board (5) Cladded
5. General conditions of structure - enter code (1) Poor (2) Average (3) Excellent
9. Garden Construction - enter code - (1) Poor (2) Average (3) Excellent

NOTE: The information contained in this appendix was derived from photographs taken on 6 October 2005 and therefore, some information contained herein may require updating as and when the more accurate information becomes available. However, it is believed that such updating of information will have very little, if any, effect on the overall study results

APPENDIX H

Flood Mitigation Options Costing

Preliminary Costing of Floodplain Management Option

FM1a **Pretty Beach Culvert and Pedestrian Bridge Enhancement - Double Culvert Capacity**
Total 4 Culverts (2 additional culverts)

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	50,000	1	50,000
2	Survey, Geotech Investigations etc	Item	15,000	1	15,000
3	Detailed Design	Item	25,000	1	25,000
4	Review of Environmental Factors	Item	20,000	1	20,000
5	Permits	Item	5,000	1	5,000
6	Site Establishment (fencing/Office/amenities)	Item	2,000	1	2,000
7	Erosion and Sediment Control Works	Item	5,000	1	5,000
8	Clearing Site	m^2	9	20	180
9	Flow diversions	Item	5,000	1	5,000
10	Traffic Management	Item	5,000	1	5,000
11	Excavation	m^3	55	90	4,950
12	Laying of culverts (concrete)	m	4,000	26	104,000
13	Revegetate/Landscape	m^2	20	20	400
14	Disestablish Site	unit	2,000	1	2,000
15	laying of pavement on road	m^2	24	62.4	1,498
16	Kerb and gutter	m	36	9.6	346
17	Footpath	m^2	40	14	576
	GST				24,595
	Contingency 20%				54,109
	Total				**$324,653**
				Say	**$320,000**

Preliminary Costing of Floodplain Management Option

FM1b **Pretty Beach Culvert and Pedestrian Bridge Enhancement - Tripple Culvert Capacity**
Total 6 Culverts (4 additional culverts)

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	50,000	1	50,000
2	Survey, Geotech Investigations etc	Item	15,000	1	15,000
3	Detailed Design	Item	25,000	1	25,000
4	Review of Environmental Factors	Item	20,000	1	20,000
5	Permits	Item	5,000	1	5,000
6	Site Establishment (fencing/Office/amenities)	Item	2,000	1	2,000
7	Erosion and Sediment Control Works	Item	5,000	1	5,000
8	Clearing Site	m^2	9	30	270
9	Flow diversions	Item	5,000	1	5,000
10	Traffic Management	Item	5,000	1	5,000
11	Excavation	m^3	55	180	9,900
12	Laying of culverts (concrete)	m	4,000	52	208,000
13	Revegetate/Landscape	m^2	20	30	600
14	Disestablish Site	unit	2,000	1	2,000
15	laying of pavement on road	m^2	24	124.8	2,995
16	Kerb and gutter	m	36	19.2	691
17	Footpath	m^2	40	29	1,152
	GST				35,761
	Contingency 20%				78,674
	Total				**$472,043**
				Say	**$470,000**

Preliminary Costing of Floodplain Management Option

FM2 Removal of access bridges

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	20,000	1	20,000
2	Survey, Geotech Investigations etc	Item	15,000	1	15,000
3	Review of Environmental Factors	Item	10,000	1	10,000
4	Permits	Item	2,000	1	2,000
5	Site Establishment (fencing/Office/amenities)	Item	2,000	1	2,000
6	Erosion and Sediment Control Works	Item	5,000	1	5,000
7	Site Clearing	m^2	9	70	630
8	Excavation	m^3	55	7	385
10	Existing Bridge Demolition/Disposal	m^3	200	28	5,600
11	Revegetate/Landscape	m^2	20	100	2,000
12	Disestablish Site	Item	5,000	1	5,000
13	GST (10%)				6,762
	Contingency (20%)				14,875
					$89,252
				Say	**$90,000**

Preliminary Costing of Floodplain Management Option

FM3 Creek Enhancement and replacing access bridges with arched bridges

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	100,000	1	100,000
2	Survey, Geotech Investigations etc	Item	50,000	1	50,000
3	Detailed Design	Item	50,000	1	50,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	5,000	1	5,000
6	Site Establishment (fencing/Office/amenities)	Item	5,000	1	5,000
7	Erosion and Sediment Control Works	Item	15,000	1	15,000
8	Flow diversions/coffer dams	Item	5000	1	5,000
9	Existing Bridge Demolition/Disposal	m^3	200	28	5,600
10	Creek Excavation	m^3	50	750	37,500
11	Revegetate/Landscape	m^2	20	600	12,000
12	Replacement Arched Bridges	m^2	5,000	7	35,000
13	Disestablish Site	unit	2,000	1	2,000
	GST				35,210
	Contingency 20%				77,462
	Total				**$464,772**
				Say	**$460,000**

Preliminary Costing of Floodplain Management Option

FM4 Creek Realignment and removal of Access Bridges

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	100,000	1	100,000
2	Survey, Geotech Investigations etc	Item	50,000	1	50,000
3	Detailed Design	Item	50,000	1	50,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	5,000	1	5,000
6	Site Establishment (fencing/Office/amenities)	Item	5,000	1	5,000
7	Erosion and Sediment Control Works	Item	15,000	1	15,000
8	Flow diversions/coffer dams	Item	5000	1	5,000
9	Existing Bridge Demolition/Disposal	m^3	200	24	4,800
10	Creek Excavation	m^3	50	1,058	52,875
11	Fill old creek channel (with excavated material)	m^3	25	540	13,500
12	Revegetate/Landscape	m^2	20	1,500	30,000
13	Disestablish Site	unit	2,000	1	2,000
	GST				36,318
	Contingency 20%				79,899
	Total				**$479,391**
				Say	**$480,000**

Preliminary Costing of Floodplain Management Option

FM5 Detention Basin Upstream of Como Parade

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	10,000	1	10,000
2	Survey, Geotech Investigations etc	Item	10,000	1	10,000
3	Detailed Design	Item	10,000	1	10,000
4	Review of Environmental Factors	Item	5,000	1	5,000
5	Permits	Item	2,000	1	2,000
6	Site Establishment (Fencing/Office/amenities)	Item	1,000	1	1,000
7	Erosion and Sediment Control Works	Item	2,000	1	2,000
8	Weir Construction (Concrete)	m	700	2	1,400
9	Revegetate/Landscape	m^2	20	20	400
10	Disestablish Site	unit	1,000	1	1,000
	GST (10%)				4,280
	Contingency (20%)				9,416
	Total				**$56,496**
				Say	**$60,000**

Preliminary Costing of Floodplain Management Option

FM6a Creek widenning in lower reaches and replacing access bridges with causeways

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	100,000	1	100,000
2	Survey, Geotech Investigations etc	Item	50,000	1	50,000
3	Detailed Design	Item	50,000	1	50,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	5,000	1	5,000
6	Site Establishment (fencing/Office/amenities)	Item	5,000	1	5,000
7	Erosion and Sediment Control Works	Item	15,000	1	15,000
8	Flow diversions	Item	10000	1	10,000
9	Existing Access Bridge Demolition/Disposal	m^3	200	12	2,400
10	Creek Excavation	m^3	50	458	22,913
12	Revegetate/Landscape (creek line)	m^2	20	260	5,200
13	Disestablish Site	unit	2,000	1	2,000
	GST				29,751
	Contingency 20%				65,453
	Total				**$392,717**
				Say	**$390,000**

Preliminary Costing of Floodplain Management Option

FM6b Creek widenning in lower reaches and replacing access bridges with causeways - increase Pretty Beach Culverts to 6 cells

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	100,000	1	100,000
2	Survey, Geotech Investigations etc	Item	50,000	1	50,000
3	Detailed Design	Item	50,000	1	50,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	5,000	1	5,000
6	Site Establishment (fencing/Office/amenities)	Item	5,000	1	5,000
7	Erosion and Sediment Control Works	Item	15,000	1	15,000
8	Flow diversions	Item	10000	1	10,000
9	Existing Access Bridge Demolition/Disposal	m^3	200	12	2,400
10	Creek Excavation	m^3	50	458	22,913
12	Revegetate/Landscape (creek line)	m^2	20	260	5,200
8	Clearing Site	m^2	9	30	270
10	Traffic Management	Item	5,000	1	5,000
11	Excavation	m^3	55	180	9,900
12	Laying of culverts (concrete)	m	4,000	52	208,000
13	Revegetate/Landscape	m^2	20	30	600
15	laying of pavement on road	m^2	24	124.8	2,995
17	Footpath	m^2	40	15	600
18	Handrails	m	66	30	1,980
13	Disestablish Site	unit	2,000	1	2,000
	GST				52,686
	Contingency 20%				115,909
	Total				**$695,452**
				Say	**$700,000**

Preliminary Costing of Floodplain Management Option

FM6c **Creek widenning in lower reaches and replacing access bridges with causeways - increase Pretty Beach Culverts to 12 cells**

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	100,000	1	100,000
2	Survey, Geotech Investigations etc	Item	50,000	1	50,000
3	Detailed Design	Item	50,000	1	50,000
4	Review of Environmental Factors	Item	30,000	1	30,000
5	Permits	Item	5,000	1	5,000
6	Site Establishment (fencing/Office/amenities)	Item	5,000	1	5,000
7	Erosion and Sediment Control Works	Item	15,000	1	15,000
8	Flow diversions	Item	10000	1	10,000
9	Existing Access Bridge Demolition/Disposal	m^3	200	12	2,400
10	Creek Excavation	m^3	50	458	22,913
12	Revegetate/Landscape (creek line)	m^2	20	260	5,200
8	Clearing Site	m^2	9	75	675
10	Traffic Management	Item	5,000	1	5,000
11	Excavation	m^3	55	450	24,750
12	Laying of culverts (concrete)	m	4,000	130	520,000
13	Revegetate/Landscape	m^2	20	30	600
15	laying of pavement on road	m^2	24	320	7,680
17	Footpath	m^2	40	30	1,200
18	Handrails	m	66	60	3,960
13	Disestablish Site	unit	2,000	1	2,000
	GST				86,138
	Contingency 20%				189,503
	Total				**$1,137,018**
				Say	**$1,140,000**

Preliminary Costing of Floodplain Management Option

FM10 Culvert Option

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	5,000	1	$ 5,000
2	Survey, Geotech Investigations etc	Item	10,000	1	$ 10,000
3	Detailed Design	Item	15,000	1	$ 15,000
4	Review of Environmental Factors	Item	5,000	1	$ 5,000
5	Permits	Item	3,000	1	$ 3,000
6	Site Establishment (Fencing/Office/amenities)	Item	3,000	1	$ 3,000
7	Traffic Control	Item	10,000	1	$ 10,000
8	Erosion and Sediment Control Works	Item	10,000	1	$ 10,000
9	Supply of Culvert (concrete) and Place	m	1,800	450	$ 810,000
10	Excavation	m^3	55	900	$ 49,500
11	Additional Entry Pit	Item	1,000	1	$ 1,000
12	Wingwall on Outlet and energy dissipation works	Item	2,000	1	$ 2,000
13	Headwalls	Item	2,000	2	$ 4,000
14	Revegetate/Landscape	m^2	20	900	$ 18,000
15	Disestablish Site	unit	2,000	1	$ 2,000
16	Re-establish Venice Road at two locations (30 m^2)	m^2	250	30	$ 7,500
	GST (10%)				$ 95,500
	Contingency (20%)				$ 191,000
	Total				**$ 1,241,500**
				Say	**$ 1,242,000**

APPENDIX I

Comparison of Existing Peak Water Levels with Bypass Culvert Option

Comparision of Existing Water Levels with Option FM 10 Water Levels (mAHD)

	PMF-15min			200yr-2hr			100yr-2hr			50yr-2hr			20yr-2hr			5yr-2hr		
Chainage	Existing	Option FM 10	WL Difference	Existing	Option FM 10	WL Difference	Existing	Option FM 10	WL Difference	Existing	Option FM 10	WL Difference	Existing	Option FM 10	WL Difference	Existing	Option FM 10	WL Difference
0	6.728	6.723	-0.005	5.565	5.56	-0.005	5.482	5.478	-0.004	5.394	5.391	-0.003	5.292	5.29	-0.002	5.041	5.034	-0.007
28	6.262	6.249	-0.013	5.093	5.061	-0.032	5.011	4.977	-0.034	4.928	4.894	-0.034	4.834	4.793	-0.041	4.608	4.564	-0.044
55	5.742	5.71	-0.032	4.605	4.477	-0.128	4.513	4.369	-0.144	4.414	4.253	-0.161	4.289	4.107	-0.182	3.967	3.759	-0.208
104	4.641	4.565	-0.076	3.805	3.678	-0.127	3.769	3.566	-0.203	3.738	3.45	-0.288	3.683	3.308	-0.375	3.44	3.036	-0.404
111	4.448	4.379	-0.069	3.758	3.61	-0.148	3.718	3.5	-0.218	3.668	3.384	-0.284	3.617	3.247	-0.37	3.376	3.032	-0.344
137	4.237	4.176	-0.061	3.671	3.569	-0.102	3.639	3.464	-0.175	3.607	3.355	-0.252	3.573	3.229	-0.344	3.346	3.033	-0.313
150	4.15	4.099	-0.051	3.637	3.551	-0.086	3.61	3.442	-0.168	3.582	3.335	-0.247	3.553	3.218	-0.335	3.326	3.029	-0.297
152	3.989	3.918	-0.071	3.481	3.279	-0.202	3.42	3.221	-0.199	3.357	3.17	-0.187	3.289	3.115	-0.174	3.17	3.013	-0.157
159	3.959	3.889	-0.07	3.462	3.275	-0.187	3.403	3.22	-0.183	3.345	3.17	-0.175	3.282	3.116	-0.166	3.168	3.01	-0.158
161	3.575	3.52	-0.055	3.064	2.834	-0.23	3.001	2.757	-0.244	2.931	2.683	-0.248	2.848	2.612	-0.236	2.684	2.113	-0.571
165	3.524	3.47	-0.054	3.036	2.804	-0.232	2.972	2.731	-0.241	2.902	2.665	-0.237	2.82	2.594	-0.226	2.667	2.116	-0.551
176	3.458	3.41	-0.048	2.982	2.767	-0.215	2.917	2.704	-0.213	2.851	2.648	-0.203	2.778	2.586	-0.192	2.647	2.127	-0.52
178	3.207	3.153	-0.054	2.742	2.564	-0.178	2.691	2.501	-0.19	2.642	2.455	-0.187	2.578	2.364	-0.214	2.457	2.054	-0.403
193	3.059	3.007	-0.052	2.633	2.511	-0.122	2.592	2.464	-0.128	2.563	2.431	-0.132	2.52	2.353	-0.167	2.431	2.049	-0.382
195	2.901	2.855	-0.046	2.523	2.414	-0.109	2.495	2.369	-0.126	2.467	2.313	-0.154	2.423	2.203	-0.22	2.314	1.916	-0.398
197	2.885	2.836	-0.049	2.503	2.402	-0.101	2.478	2.36	-0.118	2.452	2.305	-0.147	2.411	2.197	-0.214	2.308	1.917	-0.391
204	2.778	2.728	-0.05	2.379	2.275	-0.104	2.347	2.247	-0.1	2.316	2.21	-0.106	2.283	2.111	-0.172	2.214	1.915	-0.299
221	2.702	2.66	-0.042	2.186	2.075	-0.111	2.157	2.025	-0.132	2.127	1.972	-0.155	2.086	1.876	-0.21	1.976	1.482	-0.494
226	2.672	2.664	-0.008	2.123	1.993	-0.13	2.089	1.933	-0.156	2.055	1.877	-0.178	2.008	1.809	-0.199	1.88	1.481	-0.399
228	2.668	2.633	-0.035	2.117	1.983	-0.134	2.082	1.923	-0.159	2.048	1.869	-0.179	1.999	1.805	-0.194	1.873	1.48	-0.393
230	2.605	2.566	-0.039	2.057	1.899	-0.158	2.009	1.83	-0.179	1.966	1.757	-0.209	1.911	1.66	-0.251	1.767	1.323	-0.444
260	2.155	2.115	-0.04	1.77	1.649	-0.121	1.723	1.604	-0.119	1.692	1.566	-0.126	1.668	1.532	-0.136	1.57	1.321	-0.249
262	2.071	2.081	0.01	1.739	1.592	-0.147	1.696	1.535	-0.161	1.656	1.479	-0.177	1.61	1.393	-0.217	1.494	1.002	-0.492
266	2.013	1.978	-0.035	1.669	1.555	-0.114	1.645	1.505	-0.14	1.614	1.449	-0.165	1.575	1.366	-0.209	1.465	1	-0.465
304	1.805	1.777	-0.028	1.552	1.437	-0.115	1.533	1.369	-0.164	1.507	1.293	-0.214	1.465	1.212	-0.253	1.343	0.994	-0.349
325	1.79	1.762	-0.028	1.545	1.434	-0.111	1.527	1.366	-0.161	1.503	1.278	-0.225	1.461	1.185	-0.276	1.337	0.992	-0.345
329	1.744	1.718	-0.026	1.516	1.409	-0.107	1.499	1.347	-0.152	1.477	1.272	-0.205	1.435	1.098	-0.337	1.323	0.937	-0.386
343	0.911	0.909	-0.002	0.901	0.9	-0.001	0.901	0.9	-0.001	0.9	0.9	0	0.9	0.9	0	0.9	0.9	0
383	0.9	0.9	0	0.9	0.9	0	0.9	0.9	0	0.9	0.9	0	0.9	0.9	0	0.9	0.9	0