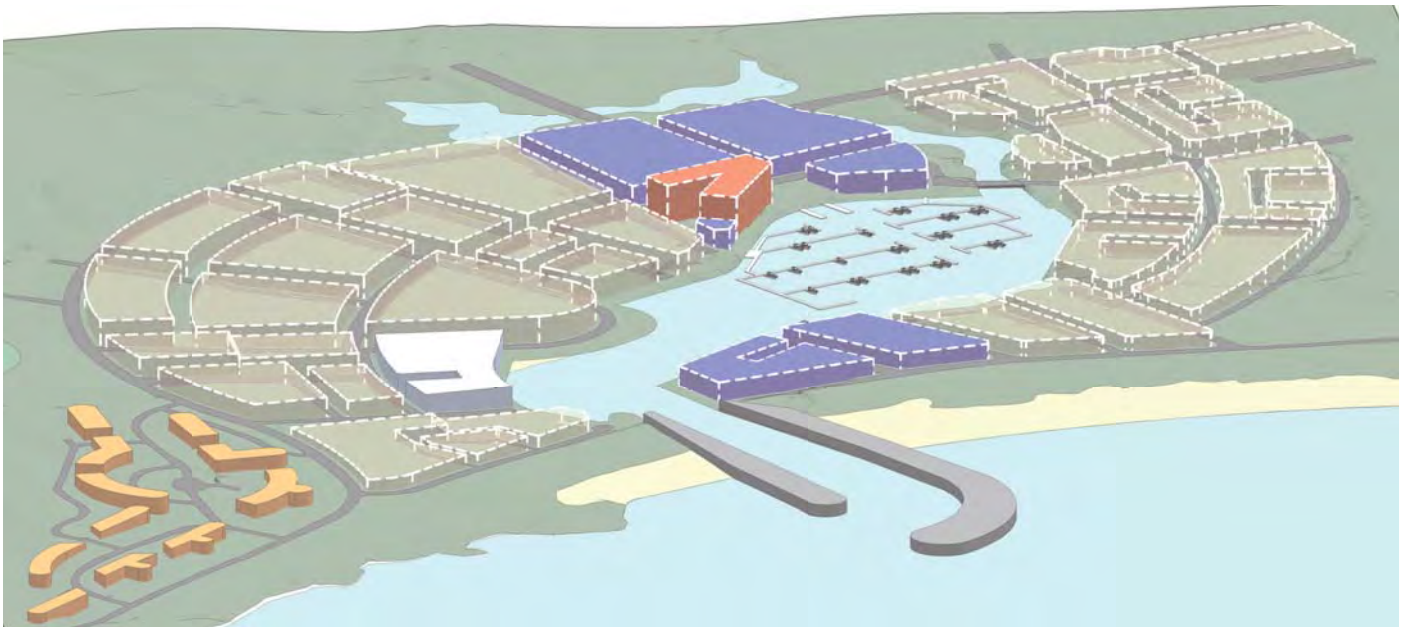

Shell Cove
Boat Harbour Precinct

Concept Plan Application
and Environmental Assessment
Appendix F - Flood Management Assessment

prepared by LFA (Pacific) Pty Ltd

date February 2010

resources & energy

AUSTRALAND

SHELL COVE - BOAT HARBOUR PRECINCT

Flood Management Assessment

4717-43 – rp4717-43part3A-cjm-081127

28 July 2009

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AUSTRALAND
SHELL COVE - BOAT HARBOUR PRECINCT
FLOOD MANAGEMENT ASSESSMENT

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PROJECT 4717-43 - SHELL COVE - BOAT HARBOUR PRECINCT

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Draft for Client Review	CJM	MST	MST	30-Oct-08	N/A	
B	Final Incorporating Client Comment and Internal Review	CJM	MST	MST	10-DEC-08		
C	FINAL	AEW	CJM	MST	28-JUL-09		

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AUSTRALAND
SHELL COVE - BOAT HARBOUR PRECINCT
FLOOD MANAGEMENT ASSESSMENT

1. EXECUTIVE SUMMARY

This report has been prepared for inclusion in a Concept Plan Application for the development of the Shell Cove Boat Harbour Precinct. The report addresses issues relating to flooding including the issues outlined in the Director General's Environmental Assessment Requirements dated 9 November 2007. The findings regarding the key flooding issues are summarised under the DGR issue headings below:

DGR Issue 5.7

Provide an assessment of any flood risk on site in consideration of any relevant provisions of the NSW Floodplain Development Manual (2005) and Flood Policy of Shellharbour City Council.

This Flood Management Assessment addresses the relevant provisions outlined in the Floodplain Development Manual (2005) as follows:

Flood Impact

The proposed development would not result in a significant increase in flood levels for the 5 year ARI, 100 year ARI and the PMF event on adjacent properties. The proposal reduces flood levels in some areas of adjacent property for the 100 year ARI and PMF event. The proposed development will be designed such that flooding would not have an adverse impact on the proposed development.

Flood Hazard

The proposed development manages areas of high hazard such that avoidable risk to life is minimised. High flood hazards are restricted to the main flow channels. Safe pedestrian access is available 60 minutes after the peak PMF flood levels occur. The proposed development reduces the extent of existing high hazard areas within Shellharbour Village.

Flood Planning Levels

A Flood Planning Level including the 100 year ARI flood level, 0.55m increase in sea level due to climate change plus an allowance of 0.5m freeboard has been adopted for all development adjacent to major overland flowpaths.

Flood Emergency Response

The Flood Emergency Response is to remain on site during the relatively short duration of all major events up to and including the PMF event. Safe pedestrian access is available 60 minutes after the peak PMF flood level is achieved. Safe vehicular access routes out of the area would be available to all residents in the 100yr ARI flood. If necessary the site can be traversed by a heavy vehicle during a PMF event.

Impacts of Climate Change

Both the DECC guideline, “Practical Consideration of Climate Change” October 2007 and the Department of Planning “Draft Sea Level Rise Policy Statement” February 2009 have been considered. The DECC guideline, “Practical Consideration of Climate Change” 25/10/2007 recommends sensitivity testing of flood behaviour over a designated range of climate change induced impacts on sea levels and rainfall intensity. Even adopting a combination of the highest sea level rise and highest rainfall intensity rise, the resultant 100yr ARI flood level can be accommodated within the adopted freeboard of 0.5m. As such, the adopted flood planning levels are considered adequate to accommodate possible climate change induced effects on flooding.

This Flood Management Assessment addresses the policy objectives for the relevant provisions as outlined in the Shellharbour City Councils Floodplain Risk Management DCP April 2006 as follows:

a) *To ensure the proponents of development and the community in general are fully aware of the potential flood hazard and consequent risk associated with the use and development of land within the floodplain;*

The Cardno Flood Study and this Flood Management Assessment (FMA) identifies potential flood hazard associated with the proposed development and adjoining existing areas within the floodplain to enable the proponents and community to be fully aware of the associated risks.

b) *Allow development with a lower sensitivity to the flood hazard to be located within the floodplain, subject to appropriate design and siting controls, provided the the potential consequences that could still arise from flooding remain acceptable having regard to the State Government’s Flood Policy and the likely expectations of the community in general;*

The FMA identifies appropriate design and sighting controls having regard to the State Governments Flood Policy. These include flood impact, flood hazard, flood planning levels, flood emergency response and impacts of climate change.

A Flood Planning Level including the 100 year ARI flood level, 0.55m sea level rise due to climate change plus an allowance of 0.5m freeboard has been adopted for all development adjacent to major overland flowpaths.

c) *To prevent any intensification of the use of High Flood Risk Precinct or floodways, and wherever appropriate and possible, allow for their conversion to natural waterway corridors.*

The proposal avoids intensification of use of high risk precincts and contains floodways within engineered and natural waterway corridors.

The proposal mitigates high flood risk precincts within the existing adjoining areas of Shellharbour Village.

d) To ensure that design and siting controls required to address the flood hazard do not result in unreasonable impacts upon the amenity or ecology of an area;

The design and siting controls do not cause unreasonable impact on the amenity or ecology of the area.

The waterway corridors used as floodways would be designed on Water Sensitive Urban Design principles and would contribute to the improved ecological value of these corridors.

The proposed floodways incorporate wetlands, natural creeklines and open space areas to manage and contain flood hazards. These areas will enhance the ecology and the visual and recreational amenity of the development under regular conditions..

e) To minimise the risk to life by ensuring the provision of appropriate access from areas affected by flooding up to extreme events;

The proposed development manages areas of high hazard such that avoidable risk to life is minimised as a result of the proposed development. Furthermore, the extent of high hazard within the existing Shellharbour Village is reduced as a result of the proposed development.

The flood emergency response is to remain on site during the relatively short duration of all major events up to and including the PMF event. Safe pedestrian access is available 60 minutes after peak PMF flood levels occur. If necessary the site can be traversed by a heavy vehicle during a PMF event. Safe vehicular access routes out of the area would be available to all residents in the 100yr ARI event.

DGR Issue 5.8

Address the impact of flooding on the proposed development, the impact of the development on flood behaviour and the impact of flooding on the safety of people/users of the development, factors that may affect flooding on the site and flood planning levels. Implications of climate change and sea level on flooding and a range of flood events (up to and including the probable maximum flood) should be considered.

The requirements of DGR Issue 5.8 have been addressed in this Flood Management Assessment by applying the relevant provisions of the Floodplain Development Manual, refer DGR Issue 5.7 above.

DGR Issue 5.9

Include an assessment of the sensitivity of flood model parameters (hydrologic and hydraulic).

An assessment of the sensitivity of flood levels to the hydrologic and hydraulic parameters has been undertaken, in part, in the DECC recommended climate change analysis. This sensitivity analysis examined 20% and 30% increases in rainfall intensities and sensitivities of tailwater conditions (different sea level rises). The combined increase on intensities of 30% and tailwater conditions of 0.91m results in an increase in peak 100yr ARI water levels of 0.36m for flood waters in the harbour however this quickly dissipates with distance away from the harbour edge.

Further sensitivity analysis was undertaken to examine the influence of hydraulic roughness and brudge waterway blockage. Sensitivity analysis of the hydraulic roughness for the proposed development has been undertaken with an increase in hydraulic roughness of 20% resulting in an increase in flood levels across the site up to a maximum of 0.15m in the 100 year ARI event.

Sensitivity analysis for blockage of the proposed bridges through the development has been undertaken. The blockage scenario demonstrates within the study area increases in flood level in the range of 0.1-0.5m in the 100 year ARI event.

The proposed freeboard adopted in the flood planning level is able to accommodate all the increases in flood level due to the sensitivity scenario testing. This indicates that the freeboard allowance is robust and appropriate for the site and the proposed development.

DGR ISSUE 5.10

Consider the potential impacts of any filling of the flood regime on the site and adjacent lands.

The proposed development would not result in a significant increase in flood levels on adjacent properties. Some adjacent properties benefit from a reduction in flood levels as a result of the proposed development.

This result is due to the adequate provision of major flowpaths and the beneficial effect of the boat harbour entrance in mitigating wave runup and tailwater conditions.

2. BACKGROUND

The Shell Cove Boat Harbour Precinct site is located 17 km south of Wollongong within the Illawarra region, immediately south of the existing Shellharbour Village. The site comprises approximately 100ha of land that surrounds the Shell Cove Boat Harbour / Marina development and includes the foreshore of Shellharbour South Beach (*refer **Figure 1***).

Development of the Shell Cove Boat Harbour Precinct will involve residential, commercial, retail, hotel, marina facilities (on land), public parklands, technology park and subdivision. The development has been declared a project to which Part 3A of the *Environmental Planning and Assessment Act 1979* applies.

Accordingly, the Department of Planning has issued Director General's Environmental Assessment Requirements (DGRS) for preparation of a Concept Plan Application for the project.

WorleyParsons have been commissioned by Australand Holdings Ltd to coordinate the flood study by Cardno (refer Appendix 1) and prepare a Flood Management Assessment (FMA) for the proposed Boat Harbour Precinct at Shell Cove, NSW. This flood analysis and FMA is to be included as part of the environment assessment undertaken in support of a Concept Plan Application under Part 3A (Major Projects) of the NSW Environmental Planning & Assessment Act 1979 (*amended 2005*).

3. OBJECTIVES

This FMA seeks to address the Director General's Environmental Assessment Requirements (DGRs) that relate to flooding as attached to the Department of Planning's letter dated 9th November 2007.

In addition a review of the Shellharbour City Council Floodplain Risk Management DCP has been undertaken to ensure consistency with the DGRs and the proposed development.

3.1 Director Generals Environmental Assessment Requirements

The DGRs were attached to the letter from the Department of Planning dated 9th November 2007. The key issues relating to flooding were contained in Issue 5 Hazard Management and Mitigation. The issues are detailed below and the manner in which the proposed development addresses these issues are described in **Section 6**.

DGR ISSUE 5.7

Provide an assessment of any flood risk on site in consideration of any relevant provisions of the NSW FloodPlain Development Manual (2005) and Flood Policy of Shellharbour City Council.

DGR ISSUE 5.8

Address the impact of flooding on the proposed development, the impact of the development on flood behaviour and the impact of flooding on the safety of people/users of the development, factors that may affect flooding on the site and flood planning levels. Implications of climate change and sea level on flooding and a range of flood events (up to and including the probable maximum flood) should be considered.

DGR ISSUE 5.9

Include an assessment of the sensitivity of flood model parameters (hydrologic and hydraulic).

DGR ISSUE 5.10

Consider the potential impacts of any filling of the flood regime on the site and adjacent lands.

3.2 Shellharbour City Council Floodplain Risk Management DCP

The Shellharbour City Council Flood Risk Management DCP outlines the following relevant policy objectives for developments subject to flood risk:

a) *To ensure the proponents of development and the community in general are fully aware of the potential flood hazard and consequent risk associated with the use and development of land within the floodplain;*

b) *Allow development with a lower sensitivity to the flood hazard to be located within the floodplain, subject to appropriate design and siting controls, provided the potential consequences that could still arise from flooding remain acceptable having regard to the State Government's Flood Policy and the likely expectations of the community in general;*

c) *To prevent any intensification of the use of High Flood Risk Precinct or floodways, and wherever appropriate and possible, allow for their conversion to natural waterway corridors.*

d) *To ensure that design and siting controls required to address the flood hazard do not result in unreasonable impacts upon the amenity or ecology of an area;*

e) *To minimise the risk to life by ensuring the provision of appropriate access from areas affected by flooding up to extreme events;*

4. STUDY METHODOLOGY

The issues listed in the DGR's and Council's Floodplain Risk Management DCP have been addressed in an integrated and co-ordinated fashion in the formulation of this flood management assessment (FMA) for the proposed development. The general approach and methodology employed to develop this FMA involved:

- compilation and review of available information including the flood study, proposed masterplan of the development, details of proposed bridge crossings and other hydraulic structures;
- site inspections and review of aerial photography to establish major flow locations catchment roughness and existing land-use;
- the development of design constraints for input into a flood model to simulate the transfer of rainfall into runoff during the flood and simulate the movement of floodwaters through the proposed development to the proposed harbour (Cardno report, 17 July 2009 – refer **Appendix 1**); and
- preparation of a flood management assessment report based on a review of the Cardno flood study to establish flood impact, flood hazard, flood planning levels and preparation of a flood emergency response plan using definitions provided in the *'Floodplain Development Manual'* (*2005*).

4.1 Design Constraints

As a result of the compilation and review of available information and site inspections, the following design constraints have been developed for incorporation into the design flood study. Each of these constraints have been identified on **Figure 1**.

4.1.1 Flows from Shellharbour Road

Shellharbour Road forms the north western catchment boundary of the Shell Cove site with the exception of a portion of catchment containing the Shellharbour Workers Club. This external catchment is currently directed over Shellharbour Road and conveyed to the Shell Cove site via a channel adjacent to Shellharbour General Cemetery. Upgrades to Shellharbour Road were being undertaken by the RTA at the time of preparation of this report. These upgrades will cut off the overland flow connection for all events above the 10 year ARI pipe flow.

Therefore the flood modelling is to direct all external flood flows exceeding the 10 year ARI pipe capacity at this location to the north along Shellharbour Road.

4.1.2 Existing Shellharbour Township

The proposed Shell Cove site abuts the existing Shellharbour Township along the northern boundary of the site. Runoff from part of this urban area drains to the south towards the Shell Cove site. There is an existing channel aligned in an east west direction which has been constructed to collect and redirect this runoff to the east towards the beach.

It is proposed to formalise the existing channel along the boundary, maintaining existing levels along the northern edge and tying into a proposed road on the southern side of the augmented channel. Flood relief would be provided at two key locations in the form of dedicated overland flow paths directed to the proposed harbour (*refer **Section 4.1.7** below*).

In addition, the augmented channel and two overland flow paths would be designed to perform a water quality function.

Flows from the catchments draining to Ron Costello Oval and the adjacent Keith Hockey Oval are to be directed to the proposed overland flow path connected to the proposed harbour.

The augmented channels have been incorporated into the proposed development for flood analysis as illustrated on **Figure 1**.

4.1.3 Harbour Boulevard North Acoustic Fencing

A potential option has been identified to construct acoustic fencing along Harbour Boulevard North. It will be necessary to provide flood relief through any acoustic fencing to prevent potential trapping of floodwaters at a low point on the eastern side of Harbour Boulevard North. This flood relief will enable floodwaters to be directed to the east, and ultimately the proposed harbour.

The arrangement of the optional acoustic fencing at this location has been incorporated into the hydraulic component of the flood model as illustrated on **Figure 1**.

4.1.4 Harbour Boulevard South Proposed Finished Surface Levels

The proposed finished road surface levels of Harbour Boulevard South required specific consideration with respect to the flood study.

The road is adjacent to a newly constructed landfill cell. It is therefore desirable to minimise cut in this area.

In addition, the proposed levels have been set in order to divert flows away from a proposed road that has limited potential to convey overland flows to the harbour. The proposed levels create a crest to minimise the run-off directed to this road.

The proposed road levels have been incorporated into the proposed development for flood analysis as illustrated on **Figure 1**.

4.1.5 Proposed Bridge Crossings

There are a number of locations within the site that require bridges, refer **Figure 1** for locations. All bridges are proposed to have a minimum span of 10m between 0.5m wide piers. The bridge beam and pavement depth would comprise a total thickness of 0.65m.

The above assumptions are based on general structural advice and need to be confirmed during the detailed design process.

These physical constraints were incorporated into the hydraulic components of the flood model.

4.1.6 Proposed Wetlands / Water Bodies

There are a number of wetlands and water bodies that will improve water quality and be a feature of the proposed development. The still water levels of these wetlands and water bodies have been set with consideration of the amenity to adjacent road levels and the required hydraulic capacity of the bridges.

It is proposed that the still water level of the wetlands and water bodies will be controlled by a series of weirs and drop structures. The conceptual still water levels have been incorporated into the proposed development for flood analysis as illustrated on **Figure 1**.

4.1.7 Proposed Major Overland Flowpaths

There are several flowpaths required to accommodate major overland flows from the development and external urban areas through the development as illustrated on **Figure 1**. The flowpaths will improve water quality. These flow paths are proposed to be dedicated as part of the open space or are contained within a proposed road reserve.

Preliminary design work was undertaken to estimate the width and invert levels of these flow paths to ensure sufficient capacity and no significant impact on adjacent existing urban development. The dedicated flow paths have been incorporated into the proposed development, for flood analysis, with preliminary batter slopes of 1V:3H back to adjoining levels.

The road cross section for the southern loop road includes a central swale to improve water quality and provide additional flow area. This detail has been incorporated into the proposed development for the flood analysis.

4.2 Design Surface Development for Flood Analysis

WorleyParsons developed a design surface of the proposed development area for the flood analysis. This design surface incorporates the requirements outlined in **Section 4.1.2**, **4.1.4**, **4.1.6** and **4.1.7** above and some basic civil design assumptions. These assumptions include the following:

- Minimum road longitudinal grade of 0.5%;
- Road reserve widths have been adopted as follows;
  - General Roads: carriageway 12m and verge 3m (including footway);
  - Harbour Boulevard: carriageway 18m and verge 3m (including footway); and
  - Southern Loop Road: carriageway 2x11m, central swale 8m and no footway.
- No detailed road or intersection design has been undertaken;
- The proposed finished surface levels along the perimeter are designed to match existing surface levels based on existing contours provided by BMD;
- No lot benching has been incorporated. Lots grade evenly between roads;
- The proposed levels for the boat ramp and associated carpark on the southern side of the harbour have been adopted from preliminary designs; and
- A minimum harbour edge land level of RL 2m AHD has been adopted for its entire length other than at flow path or water course outlets.

5. POST DEVELOPED FLOOD ANALYSIS

5.1 Background

Two previous flood studies for the Shell Cove site have been undertaken:

- *Shell Cove Boat Harbour Catchment Flood Study, Cardno Lawson Treloar Pty Ltd, September 2005; and*
- *Shell Cove Boat Harbour Catchment Flood Study PMF Analysis for Preliminary Design, Cardno Lawson Treloar Pty Ltd, April 2006.*

The objective of the September 2005 study was to determine the existing flood behaviour at the proposed development site.

The objective of the April 2006 study was to provide a preliminary analysis of the post-development Probable Maximum Flood (*PMF*) behaviour, based on a preliminary and now superseded Masterplan.

5.2 Shell Cove Boat Harbour – Post Developed Flood Analysis

A post developed flood analysis has been undertaken by Cardno for the proposed development of the Boat Harbour Precinct, 17 July 2009, refer **Appendix 1**. This flood study provides detailed information on flood behaviour for a range of flood events up to and including the PMF. The data provided includes an assessment of flood impact, hazard, peak flood levels and velocities. In addition, the impact of climate change, hydrologic and hydraulic sensitivities have been assessed.

The results of the flood analysis for the proposed development have been used to develop this Flood Management Assessment described in **Section 6**.

6. FLOOD MANAGEMENT ASSESSMENT

This Flood Management Assessment provides an assessment of the flood risk on site and how it can be adequately managed in accordance with the requirements of the *NSW Government Floodplain Development Manual* (*2005*).

The NSW Government's Floodplain Development Manual supports the wise and rational development of flood prone land. This is achieved by the strategic consideration of a number of key risks relating to protecting existing and future occupants from the ramifications of flooding. The issues associated with these risks include:

- Flood Impact;
- Flood Hazard;
- Flood Planning Levels;
- Emergency Response; and
- Impacts of Climate Change.

The following sections describe the consideration of the above issues and the application of strategies to address them.

6.1 Flood Impact

The flood impact considered includes both the impact of flooding on the proposed development as well as the impact of the development on flooding in adjacent areas. This impact has been assessed by considering a range of flood severities including the 5 year ARI, 100 year ARI and PMF events in the flood analysis. The analysis is conservative for the 5 year ARI and 100 year ARI events because no pipe flow was assumed. This assumption results in all flow being as overland flow leading to higher predicted flood flows and levels.

6.1.1 5 Year ARI Event

There are some predicted minor increases in flood levels external to the site in the 5 year ARI event (*refer **Figure 6.19** in Flood Analysis – refer **Appendix 1***). The areas affected external to the site are in the vicinity of Boollwarroo Parade, Ron Costello Oval, and a small portion along the northern boundary. Minor increases also occur in a localised section within the north western corner of the site.

The increases external to the site are 0.07m on Boollwarroo Parade, in the range of 0.01 to 0.02m on the northern part of Ron Costello Oval, near the existing properties and 0.04m along the northern boundary. Increases of this magnitude are not considered to be significant, noting that the flood study conservatively assumes no flow in the stormwater pipes.

The increase of 0.08m in a localised area within the north west corner of the site can be managed through the design process.

6.1.2 100 Year ARI Event

There are some predicted minor increases as well as decreases in flood levels in the 100 year ARI event (*refer **Figure 6.20** in the Flood Analysis*). The areas affected are along the northen boundary of the site within the existing Shell Harbour Village, Boollwarroo Parade to the north of Ron Costello Oval and a localised section within the north western corner of the site.

The increases external to the site are in the range of 0.01m to 0.02m on Boollwarroo Parade, and 0.02m to 0.03m to the north of Ron Costello Oval near the properties. Increases of this magnitude are not considered to be significant, noting that the flood study conservatively assumes no flow in the stormwater pipes.

The decreases in flood level are in the range of 0.01m to 0.05m along the northern boundary of the site and part of Boollwarroo Parade.

6.1.3 PMF Event

During the PMF event there are predicted minor increases as well as decreases in flood levels in some areas (*refer **Figure 6.21** in the Flood Analysis*). The areas affected are along the northern boundary of the site within the existing Shellharbour Village, Ron Costello Oval, Boollwarroo Parade and the local area within the north western and south eastern corners of the site.

The decreases are significant within the existing Shellharbour Village. Flood levels decrease in the range of 0.15 to 0.5m along the northern boundary of the site, Boollwarroo Parade and to the north of Ron Costello Oval.. The development significantly reduces the flood hazard within Shellharbour Village (*refer **Figures 7.3 and 7.6** in the Flood Analysis*).

The minor increases are within the north western and south eastern corners of the site. The increases are in the range of 0.01m to 0.10m. Increases of this magnitude are not considered to be significant, noting that the flood study conservatively assumes no flow in the stormwater pipes. These impacts are within the area to be developed and can be managed through the design process.

6.1.4 Discussion

The flood modelling conservatively assumes no pit and pipe drainage system.

In the 5 year and 100 year ARI events minor increases and minor decreases in flood levels occur adjacent to the site, within Shellharbour village. The increases are not significant.

During the PMF event a significant reduction in flood level and flood hazard occurs within the Shellharbour Village.

The overall flood impact is satisfactory. In broad terms, this is due to the adequate provision of major flow paths and the beneficial effect of lower tail water conditions created by the boat harbour entrance.

6.2 Flood Hazard

The New South Wales Government Floodplain Development Manual defines flooding in terms of two hazard categories, i.e. Low Hazard and High Hazard, with a zone of transition between the two which is dependent on the particular site conditions. The hazard is referred to as provisional as it only takes into account the velocity depth relationships.

Flood hazard relates to the degree of difficulty that pedestrians, motor cars and other vehicles will have traversing the flooded areas. At Low Hazard, passenger cars and pedestrians *(adults)* are able to traverse the flooded areas. At High Hazard, wading becomes unsafe, cars are immobilised and damage to light timber-framed houses could occur.

The provisional flood hazard as set out in **Figure L2** of the Floodplain Development Manual and velocity depth product for the development has been assessed for the 5 year ARI, 100 year ARI and PMF events in the flood analysis.

6.2.1 5 Year ARI Event

There are areas of provisional High Hazard identified in the assessment of the 5 year ARI event flood conditions (refer **Figure 7.4** in the Flood Analysis). The areas of provisional High Hazard are restricted to the major overland flow paths contained within the proposed open space system. A public road proposed in the southern catchment also contains provisional High Hazard flows which are restricted to a central drainage swale.

The provision of pit and pipe drainage through the design process will reduce the extent and duration of high hazard flows, particularly in the central drainage swale in the southern catchment.

6.2.2 100 Year ARI Event

There are areas of provisional High Hazard identified in the assessment of the 100 year ARI event flood conditions, (refer **Figure 7.5** in the Flood Analysis). The areas of provisional High Hazard are again restricted to the major overland flow paths. The public road proposed in the southern catchment contains provisional High Hazard flows which are restricted to a central drainage swale.

The provision of pit and pipe drainage through the design process will reduce the extent and duration of high hazard flows, particularly in the central drainage swale in the southern catchment.

6.2.3 PMF Event

There are areas of provisional High Hazard identified in the assessment of the PMF event flood conditions, (refer **Figure 7.6** in the Flood Analysis). The areas of provisional High Hazard extend further into additional roads away from the major overland flowpaths in the 100 year ARI event.

The proposed development reduces the area of provisional High Hazard within sections of Shellharbour Village.

6.2.4 Discussion

The flood hazard for a range of events up to and including the PMF event have been considered in the development of strategies to manage areas of hazard. In addition, the velocity depth relationship has been considered (refer **Figures 7.7**, **7.8** and **7.9** in the Flood Analysis).

The provision of pit and pipe drainage through the design process will reduce the extent and duration of high hazard flows.

The proposed development reduces the area of provisional High Hazard within sections of Shellharbour Village.

100 YEAR ARI EVENT FLOOD HAZARD MANAGEMENT STRATEGY

In events up to and including the 100 year ARI event, the areas of provisional High Hazard are restricted to the major overland flow paths including the central wetland corridor, major overland flow paths and the eastern portion of the southern loop road. The risk in each of these areas will be managed as follows:

CENTRAL WETLAND CORRIDOR

The central wetland corridor comprises of the two wetlands to the west of Harbour Boulevard and the series of wetlands that flow east from Harbour Boulevard to the proposed harbour. This corridor contains areas of High Hazard in the 100 year ARI event. The wetlands are permanent areas of High Hazard due to the proposed water depths even in dry weather.

The corridor is an extension of the Shell Cove linear open space system, providing dual-use open space and drainage functions. It is appropriate that High Hazard flood flows occur in these areas. In order to appropriately manage the hazard it is proposed to incorporate the following strategies:

- The side batter slopes are to be a maximum of 1V:6H, unless fenced;

- Safe crossing points over the central wetland are available at Cove Boulevard and Harbour Boulevard during the 100 year ARI event; and
- The corridor will contain permanent water bodies and creek line attributes that raise awareness of the potential for flooding. To ensure consistency with the existing dual-use open space system, signage is not proposed.

Major Overland Flow Paths

Major overland flowpaths comprise of the two northern flow paths allowing external flows to propagate in a controlled manner from Shellharbour Village through to the proposed harbour. The flow paths contain areas of High Hazard in the 100 year ARI event.

It is proposed that these flowpaths are contained within multipurpose drainage reserves and public open space areas. These areas shall provide amenity during dry weather conditions but shall be marked with appropriate signage to reinforce the public's knowledge of their purpose and that these areas may be flood hazardous to the public. These areas will also be utilised to improve water quality. This will be achieved by the frequent discharge of low flows which will reinforce public awareness. In order to appropriately manage the hazard it is proposed to incorporate the following strategies:

- The side batter slopes are to be a maximum of 1V:6H, unless fenced;
- Signage is to be provided warning of the potential for flooding;
- Safe Crossing Points over these overland flow paths are available at four locations through the internal road network during the 100 year ARI event; and
- Multiple egress points be provided along either edge of the flow paths.

Eastern portion of the southern loop road

The eastern portion of the southern loop road contains a central swale. The central swale will contain areas of High Hazard in the 100 year ARI event. It is appropriate that high hazard flood flows occur in this designated area which will be marked with appropriate signage. The swale will also be utilised to improve water quality. This will be achieved by the frequent discharge of low flows which will reinforce public awareness. In order to appropriately manage the flood hazard it is proposed to incorporate the following strategies:

- side batter slopes are to be a maximum of 1V:6H, unless fenced;
- signage is to be provided warning of the potential for flooding;
- the roadways do not contain areas of High Hazard; and
- safe egress is available through the surrounding road network.

PMF EVENT FLOOD HAZARD MANAGEMENT STRATEGY

The strategies employed to manage hazard in the 100 year ARI event described above will have facilitated the public to move out of areas subject to hazard in the PMF event. The Flood Emergency Response Strategy will require that the public move back to their residences or areas of higher ground, refer **Section 6.4**. The flood emergency response is to remain on site during the relatively short duration of all major events up to and including the PMF event.

6.3 Flood Planning Levels

Flood planning levels (FPLs) are an important tool in the management of flood risk. They are derived from a combination of an estimated peak flood level for a flood event and a freeboard.

The NSW Floodplain Development Manual recommends that for new residential development the FPLs are based on the 100 year ARI event.

The Shellharbour Floodplain Risk Management Development Control Plan Schedule 1 specifies that appropriate freeboard to habitable floor levels be 0.5m.

6.3.1 Discussion

The FPL for the precinct will be the 100 year ARI level, including the adopted mid range 0.55m sea rise, plus a freeboard of 0.5m. The FPL would be applied to all development adjacent to a major overland flow path as identified on **Figure 1**, unless final design reduces the extent of High Hazard through underground drainage. Habitable floor levels would have a minimum level at the FPL to provide an appropriate level of protection against flood damages.

All roadways within the development will be designed to convey the 100 year ARI event within the road reserve.

Sensitivity analysis has confirmed that the FPL is satisfactory for all scenarios modelled including high range sea level rise.

6.4 Flood Emergency Response

Both the PMF and the 100 year ARI flood have been considered in order to provide a comprehensive assessment of the flood risk. The PMF event has been considered for assessment of a continuing flood risk beyond the design storm of the 100 year ARI. This is to address concerns for personal safety which need to be managed through the flood emergency response plan for the development.

The *NSW Floodplain Development Manual* states that

> *'Analysing the PMF provides an upper bound of flood behaviour and consequences for emergency response planning.'*

6.4.1 Discussion

Flood emergency response measures will begin when Bureau of Meteorology issues an extreme weather warning prior to inundation. Once rainfall begins it is expected that runoff will quickly accumulate into flooding waters.

Major flooding is expected to occur at the site during a critical storm duration of 90 minutes. During this time flood waters shall travel through the designated overland flowpaths causing a rapid rise in water level within these areas. Residents are to remain indoors and not attempt to traverse flow path crossings.

Bridges overtop during the peak PMF and these areas will be hazardous to both cars and pedestrians at this time. However floodwaters are expected to recede rapidly. Residents must wait 1 hour after waters have overtopped bridges before attempting to cross floodways. This guidance is to mitigate risk of hazard to residents.

It is feasible in an emergency that a heavy vehicle could traverse the site if necessary during a PMF event.

The extent and depth of flooding and Provisional Hazard during a PMF event in the proposed development has been estimated (refer to **Figures 6.12, 6.15 and 7.6** in the Flood Analysis). The maximum depth of flow over any road in the PMF event is 0.75m located over the southern bridge on the western of the two northern flow paths.

6.5 Impact of Climate Change

In order to assess the likely effects of climate change, the following two publications have been considered:

- DECC - Floodplain Risk Management Guidelines, Practical Consideration of Climate Change (October 2007)
- DoP – Draft Sea Level Rise Policy Statement (February 2009)

The DECC in their Floodplain Risk Management Guidelines, Practical Consideration of Climate Change (October 2007) provide advice on the assessment of climate change on flood estimation. The guideline requires sensitivity testing of flood levels resulting from a range of predicted sea level rises and increases in rainfall intensity predicted to occur up to 2100, whilst the DoP policy states the predicted maximum increase at two points in the future, 2050 and 2100.

6.5.1 Elevated Sea Levels

The DECC guidelines provide a range of low, medium and high values for estimated sea level rise resulting from thermal expansion, ice sheet melt and local (NSW) conditions for sensitivity analysis. These values are:

- Low, 0.18m;
- Medium, 0.55m; and
- High, 0.91m.

DoP guidelines state that sea level will rise up to 0.4m by 2050 and up to 0.9m by 2100.

6.5.2 Increases in Rainfall

The DECC guidelines recommend sensitivity analysis of the impact of climate change on rainfall intensities. The range of sensitivities recommended includes increases in peak rainfall and storm volume of:

- Low, 10%;
- Medium, 20%; and
- High, 30%.

DoP does not provide any quantitative recommendation with regards to potential changes to rainfall patterns.

6.5.3 Discussion

Given the proposed development contains a boat harbour directly connected to the ocean the consideration of the impacts of climate change is critical. Therefore the Flood Analysis has assessed the most conservative DECC recommended joint probability scenario including a combination of a 0.91m increase in sea level and a 30% increase in rainfall intensity.

The result of this analysis has estimated a worst case increase of 0.36m in peak flood levels around the boatharbour edge however this increase dissipates quickly with distance into the development from the edge (refer **Figure 8.2** in the Flood Analysis). The maximum increase in flood level could be accommodated within the 0.5m freeboard recommended in the flood planning level (which includes the mid range 0.55m sea level rise), refer **Section 6.3.1**.

As the DECC recommended range of climate change influences on flood level can be readily accommodated within the freeboard adopted for the development, the adopted flood planning level is considered appropriate for existing and future planning horizons.

7. CONCLUSIONS

This Flood Management Assessment provides strategies to manage flood risk to protect existing and future occupants from the ramifications of flooding associated with the proposed development of the Boat Harbour Precinct.

These key risks and strategies include the following:

Flood Impact

The proposed development would not result in a significant increase in flood levels for the 5 year ARI, 100 year ARI and the PMF event on adjacent properties. The proposal reduces flood levels in some areas of adjacent property for the 100 year ARI and PMF event. The proposed development will be designed such that flooding would not have an adverse impact on the proposed development.

Flood Hazard

In the 100 year ARI event the areas of provisional High Hazard are restricted to the central wetland corridor, major overland flow paths and the central swale in the eastern portion of the southern loop road. The risk in each of these areas will be managed as follows:

- The side batter slopes are to be a maximum of 1V:6H, unless fenced;
- Signage is to be provided where it is necessary to raise awareness of the potential for flooding; and
- Multiple egress points along either edge of the flow paths.

In the PMF, the strategies employed to manage hazard in the 100 year ARI event described above will have facilitated the public to move out of areas subject to hazard in the PMF event. The Flood Emergency Response Strategy will require that the public move back to their residences or areas of higher ground.

Flood Planning Levels

The FPL for the precinct will be the 100 year ARI including a 0.55m sea level rise due to climate change plus a freeboard of 0.5m. The FPL would be applied to all development adjacent to a major overland flow path as indentified on **Figure 1**.

Flood Emergency Response

The flood emergency response is to remain on site during the relatively short duration of all major events up to and including the PMF event. Safe pedestrian access would be available 60 minutes after the peak PMF flood levels. If necessary the site can be traversed by a heavy vehicle during a PMF event. Safe vehicular access routes out of the area would be available to all residents in the 100yr ARI event.

Impacts of Climate Change

The Flood Analysis has adopted a 0.55m increase in sea level to set flood planning levels for the development. A sensitivity analysis assessed the most conservative joint probability climate change scenario including a combination of a 0.91m increase in sea level and a 30% increase in rainfall intensities. The result of this sensitivity analysis has estimated a worst case increase of 0.36m in peak flood levels at the harbour waters edge with the increase dissipating quickly with distance away from the edge. This worst case scenario would be readily accommodated within the 0.5m freeboard recommended in the flood planning level. The adopted FPL is therefore considered to be appropriate for both existing and future planning horizons.

The above key issues relating to flooding have been adequately addressed in accordance with Director General Environmental Assessment Requirements and the Council's Floodplain Risk Management DCP.

8. REFERENCES

1 Floodplain Development Manual, NSW Government, 2005.

2 Floodplain Risk Management Development Control Plan, Shellharbour City Council, April 2006.

3 Floodplain Risk Management Guideline, "Practical Consideration of Climate Change", DECC, 25/10/2007.

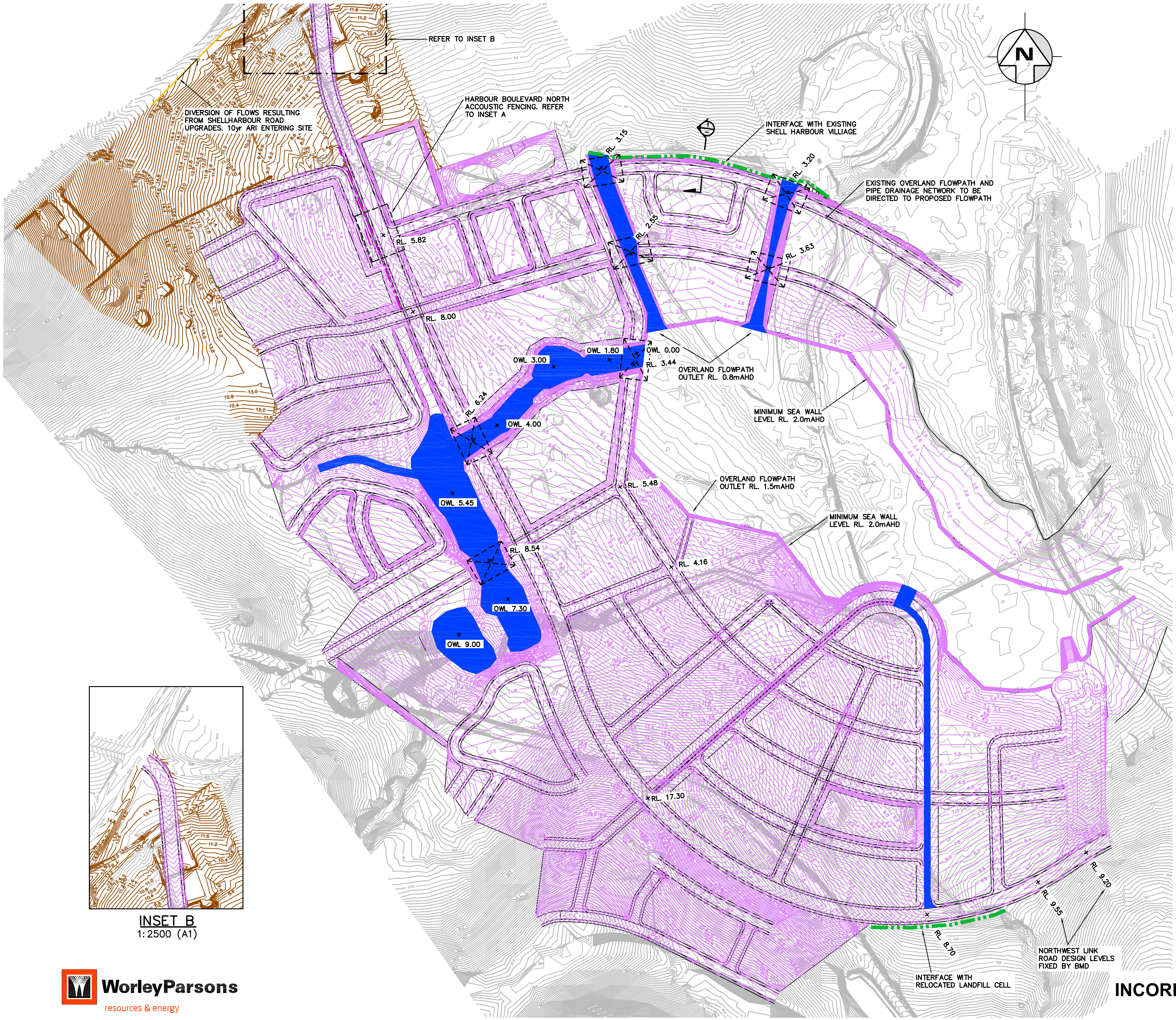
4 Shell Cove Boat harbour Post Development Flood Analysis, Cardno Lawson and Treloar, June 2009.

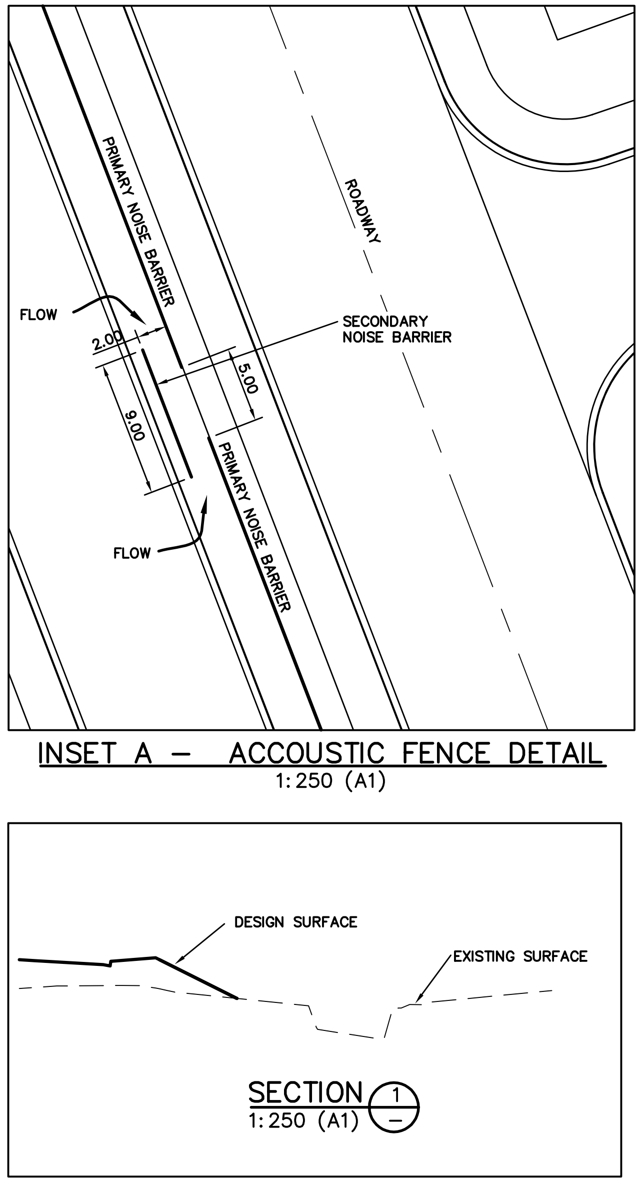
5 Draft Sea Level Rise Policy Statement, Department of Planning, February 2009

AUSTRALAND
SHELL COVE - BOAT HARBOUR PRECINCT
FLOOD MANAGEMENT ASSESSMENT

FIGURES

FIGURE 1





LEGEND

	EXISTING SURFACE CONTOUR (0.2m INTERVAL)
	EXISTING SURFACEFOR INCORPARATION INTO 2D FLOOD TIN
	PROPOSED PRELIMINARY SURFACE CONTOUR (0.2m INTERVAL)
	BRIDGE CROSSING LOCATION
× RL 9.55	PROPOSED ROAD LEVEL
× OWL 7.30	PROPOSED POND OPERATING WATER LEVEL (INCLUDING 0.3m DETENTION DEPTH FOR WATER QUALITY)
	MAJOR OVERLAND FLOWPATH (BASED ON VD > 0.4)

NOTES

1. THE PRELIMINARY SURFACE HAS BEEN CREATED FOR FLOOD INVESTIGATIONS ONLY. NO DETAILED ROAD OR LOT DESIGN HAS BEEN UNDERTAKEN. ROAD LOCATIONS, ROAD WIDTHS, BOUNDARIES AND LEVELS ARE INDICATIVE ONLY AND ARE SUBJECT TO DETAIL DESIGN.
2. THIS FILE IS IN ISG CO-ORDINATES FOR FURTHER INFORMATION REFER TO 12D PROJECT: N:\4717-43 SHELL COVE ROAD SWALES\FLOOD ANALYSIS WORK\12D\090105_NW_ADDITION.PROJECT (TIN SITE GRADING 4).

0 50 100 150 200 250m
1:2500 (A1) 1:5000 (A3)

WorleyParsons
resources & energy

SHELLHARBOUR
DESIGN FLOOD CONSTRAINTS
INCORPORATING NORTH WESTERN AREA
12 JANUARY 2009

Appendix 1 - Shell Cove Boat harbour Post Development Flood Analysis

Cardno LawsonTreloar

Shaping the Future

SHELL COVE BOAT HARBOUR POST DEVELOPMENT FLOOD ANALYSIS

Report Prepared for

AUSTRALAND

17 July 2009
W4733

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Version	Status	Date	Author		Reviewer	
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3	Final	12 November 2008	Rhys Thomson	RST	Louise Collier	LCC
4	Working Draft	25 February 2009	Rhys Thomson	RST	Louise Collier	LCC
5	Final	20 June 2009	Rhys Thomson	RST	Louise Collier	LCC
6	Final	30 June 2009	Rhys Thomson	RST	Louise Collier	LCC
7	Final	17 July 2009	Rhys Thomson	RST	Louise Collier	LCC

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Front cover: LFA (2006)

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APPENDICES

1. INTRODUCTION

Shell Cove is located approximately 17km south of Wollongong within the Shellharbour City Council Local Government Area. The study area has a catchment of 3.45km^2 and extends from Shellharbour South Beach to Shellharbour Road in the north west. Figure 1.1 shows the study catchment.

Existing development is located in the northern and western portions of the catchment. The northern developed area is part of the existing Shellharbour Village. The western portion of the catchment includes residential areas that have previously been developed in Shell Cove.

In 2005, Cardno Lawson Treloar previously completed a detailed flood study of the area, with its findings presented in the report titled *Shell Cove Boat Harbour Flood Study* (Cardno Lawson Treloar, [1] 2005). The flood study established the catchment flood behaviour in its existing state (based on ground survey undertaken in 2003).

The flood assessment undertaken in this report considers the flood behaviour of the proposed development in the central portion of the catchment. This existing central portion of the catchment includes a disused golf course and Shellharbour Swamp. The proposed development incorporates a harbour together with commercial and residential areas (Figure 1.2).

The purpose of this study is to define the flood behaviour under the proposed development conditions, including:

- Peak water levels, depths and velocities;
- Provisional hazard;
- Hydraulic categories.

In addition, the development condition has been compared with the existing scenario, to ensure that the proposed development does not significantly impact the flood behaviour on adjacent properties.

This analysis has been undertaken utilising the flood models established by Cardno Lawson Treloar [1] (2005). The models have been updated to incorporate the proposed development and approved Boat Harbour design supplied by WorleyParsons.

Figure 1.1 Study Area – Catchment Boundary

Figure 1.2 Proposed Shell Cove Development

2. BACKGROUND

2.1 Catchment Description

The study area has a catchment area of 3.45km^2 and is located within the Shellharbour Council Local Government Area. The contributing catchment is made up of rural and residential areas and discharges to the ocean through Boollwarroo Parade Bridge. The study area rises to an elevation of 60m AHD in the upper reaches of the catchment down to ocean level at the outlet.

At the downstream end of the catchment is the Shellharbour Swamp that drains to the ocean via a sand berm. Past berm level surveys indicate that the Shellharbour Swamp is typically closed to the ocean. However, it has the potential to open, quite possibly for brief periods of time, resulting in the Shellharbour Swamp becoming tidal.

A more detailed description of the catchment and the existing mechanisms is provided in the Shell Cove Boat Harbour Catchment Flood Study (Cardno Lawson Treloar, [1] 2005).

2.2 Proposed Development

The proposed development incorporates a harbour area, surrounded by residential and commercial development.

From a hydraulic perspective, the proposed design includes three formalised major flowpaths to convey the flows through the site. Two northern flowpaths, which convey the flows arriving from the existing Shellharbour Village and Ron Costello Oval areas, and a single western flowpath, which combines the two major western inflows. These flowpaths are shown in Figure 2.1.

There are also some additional local flows which are conveyed along the road network within the site.

2.3 Scenarios for Assessment

Two scenarios are evaluated within this report:

- Existing Scenario - For the purposes of the study, the existing scenario is defined as the catchment conditions in 2003. These are representative of the date of survey and aerial photography that was utilised in the flood study (Cardno Lawson Treloar, 2005).
- Developed Scenario – this scenario assumes the full development, as per the proposed development and approved Boat Harbour designs supplied by WorleyParsons and Australand. It also incorporates the changes to the upstream portions of the catchment as a result of the development of Shell Cove since 2003.

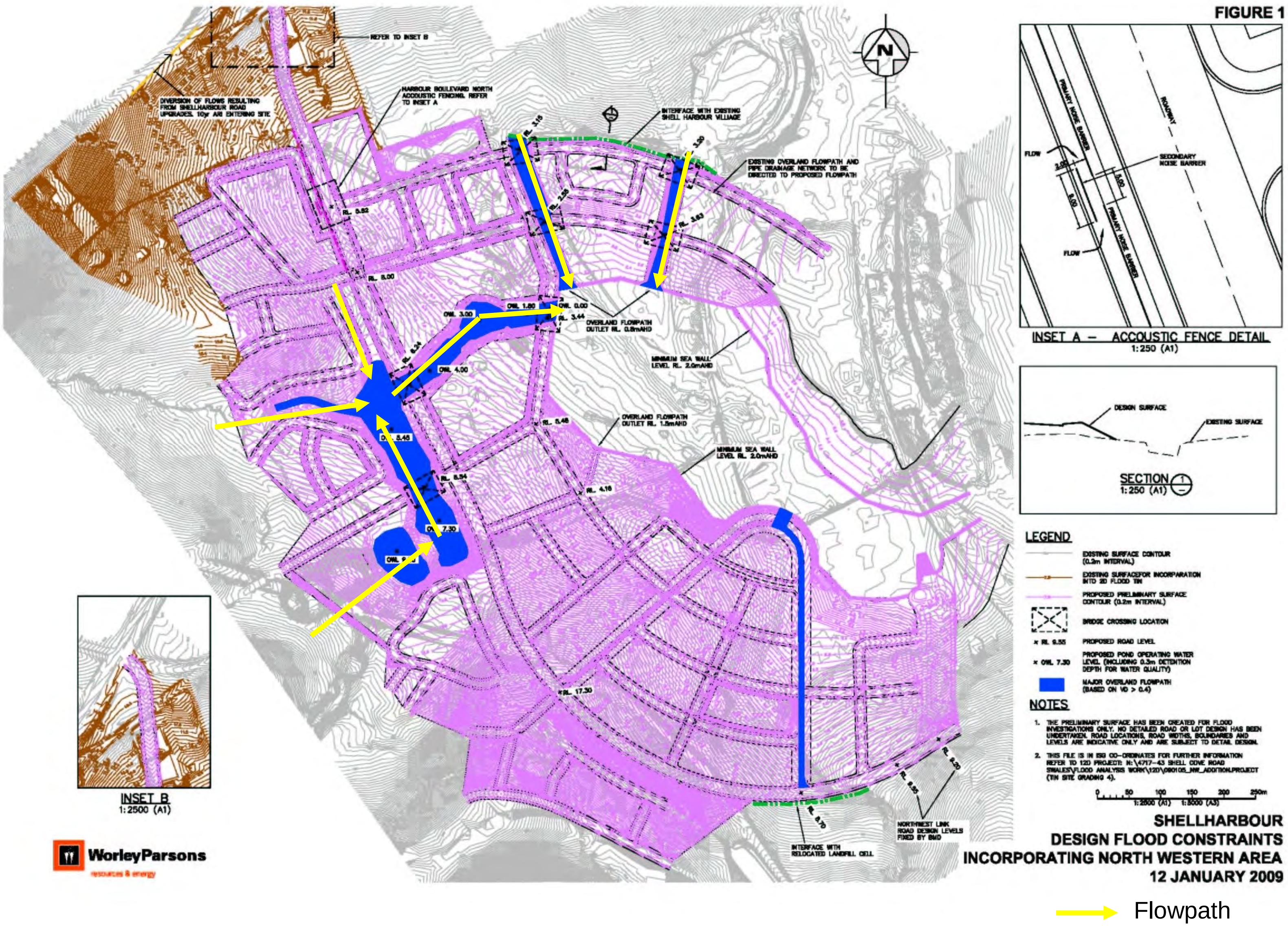


Figure 2.1 Formalised Flowpaths in the Proposed Development

3. DATA

3.1 Previous Reports

Cardno Lawson Treloar have previously prepared two reports for the study area:

- *Shell Cove Boat Harbour Catchment Flood Study* (Cardno Lawson Treloar, 2005). This study defines the existing flood behaviour for the study area.
- *Shell Cove Boat Harbour Catchment Flood Study : PMF Analysis for Preliminary Design* (Cardno Lawson Treloar, 2006). This study was undertaken based on a previous superceded masterplan being investigated in the area. This previous report is effectively superceded by the findings of this current report.

Two additional studies are relevant to the study area. However, these studies were primarily utilised in establishing the existing flood behaviour, as described in Cardno Lawson Treloar [1] (2005):

- *Shell Cove, Shellharbour Village, Stormwater Drainage Infrastructure Report* (BMD Consulting Pty Ltd, 2004).
- *Elliot Lake – Little Lake Flood Study* (Cardno Lawson Treloar [2], 2005).

3.2 Design Details

Design details were supplied by Worley Parsons. The following data was utilised in the creation of the design model:

- Preliminary 3D surface provided by WorleyParsons on 16 January 2009 (Site Grading 4 tin and models.12da) – refer Figure 3.1. Following some initial reviews on version 3 of this report, the modelled area was extended in the north west portion of the site. This extended portion is shown in brown contours in Figure 3.1.
- Modifications to existing catchments, figure provided by WorleyParsons on 19 August 2008 (catchment alterations 190808.pdf)
- Preliminary HEC-RAS model provided by WorleyParsons on 25 March 2008 (sent140308.prj)
- Land use plan and densities supplied by Australand on 31 March 2008 (Request to BMD for changes 29.2.08.pdf).

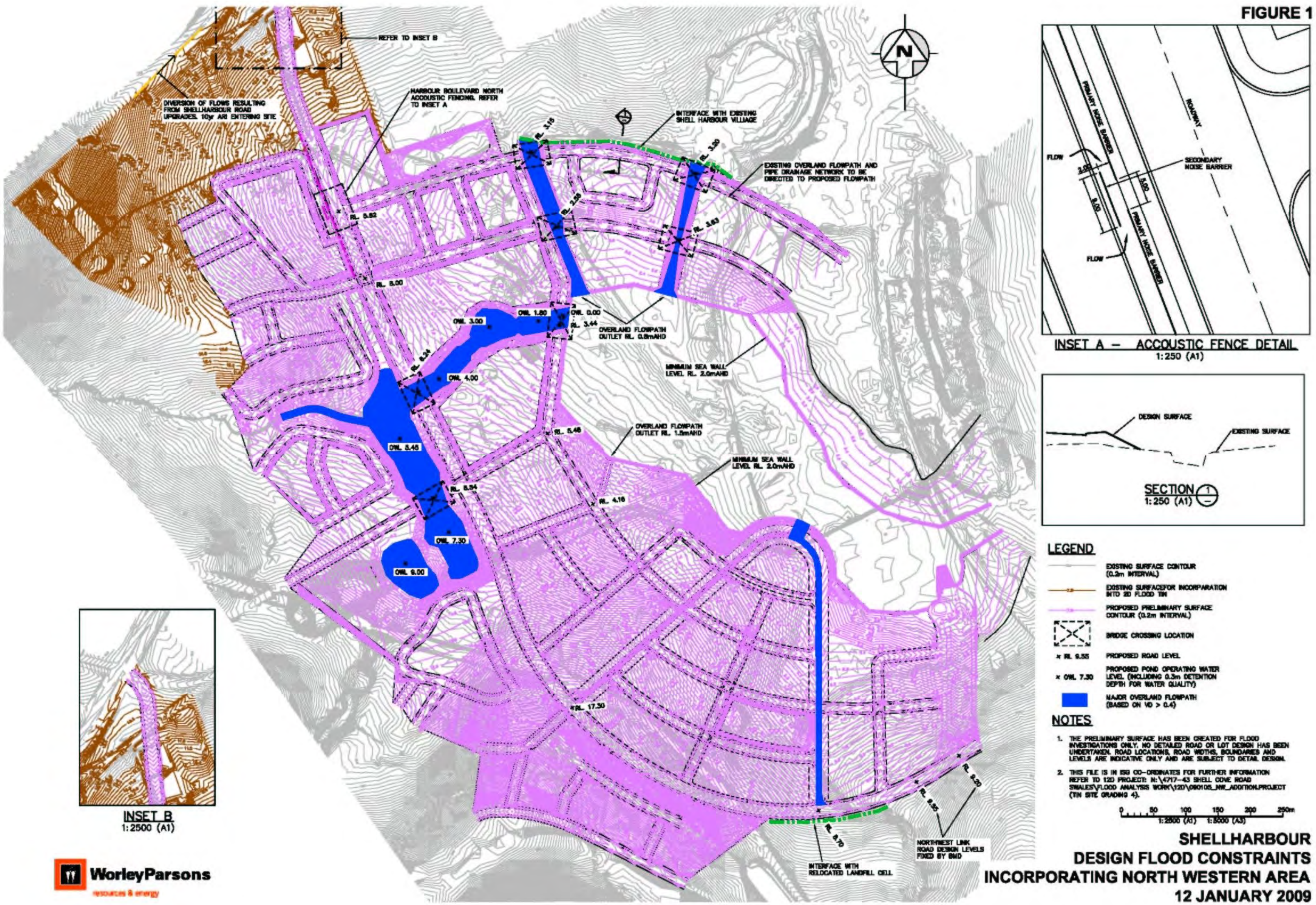


Figure 3.1 Proposed Grading Plan Provided by Worley Parsons

4. HYDROLOGICAL MODELLING

4.1 Existing Scenario

Hydrological modelling of the existing scenario for those sub-catchment areas outside of the 2D hydraulic grid was undertaken as reported by Cardno Lawson Treloar [1] (2005). This model is representative of the catchment conditions at the time of the aerial photography, dated 2003. No changes have been made to the existing hydrological model as a part of this study.

4.2 Design Scenario

In order to represent the design scenario, a number of changes were made within the hydrological model for those sub-catchments areas outside of the 2D hydraulic grid:

- Increase in impervious area for those areas where development either has been undertaken since 2003, or will be undertaken as a part of the proposed design.
- Incorporation of detention basin on the south western flowpath. This basin was constructed as a part of the overall Shell Cove development, and was constructed after the aerial photography was taken in 2003. This has been incorporated in the design scenario only as it is part of the overall Shell Cove strategy, and attenuates some of the impact of the new developments mentioned above.
- Modification of catchment 4A. The catchment was split into three portions, on advice from Worley Parsons (per comm., Chris Moon, 19 August 2008). Sub-catchment 4A and 4A-1 both discharge directly to the proposed development. However, as a part of the new development, all flows from catchment 4A-2 above the 10 year ARI flow are diverted along Shellharbour Road.
- Modification to catchment 1K. The portion upstream of the road is diverted due to the creation of a mound (per comm., Chris Moon, 19 August 2008).

These modifications are shown in Figure 4.1.

All parameters utilised in the modelling were applied as per Cardno Lawson Treloar (2005).

4.3 Rainfall on the Grid

Under both scenarios, rainfall was applied directly to the 2D hydraulic model for the portions of the catchment covered by the 2D hydraulic model grid, rather than utilising traditional hydrology as was used for the rest of the catchment. A full description of this can be found in Cardno Lawson Treloar [1] (2005).

Rainfall losses were adjusted accordingly under the design scenario to reflect the increase in imperviousness as a result of the proposed development.

Following a review of the version 3 of this report, the 2D hydraulic modelling extent was extended in the north western corner of the site, covering sub-catchment 4A and 4A-1 in Figure 4.1. This modification was undertaken in both the existing scenario and design scenario models. Catchment 4A and 4A-1 were therefore modelled with rainfall on the grid, rather than through traditional hydrological modelling.

Figure 4.1 Catchment Modifications for Design Scenario

5. HYDRAULIC MODELLING

5.1 Model Schematisation

A fully dynamic one and two dimensional hydraulic model was established for the proposed development condition using the SOBEK modelling system. The model was based on the model developed for the existing catchment in the Shell Cove Boat Harbour Flood Study (Cardno Lawson Treloar [1], 2005).

The assessment assumes that all drainage infrastructure within the catchment is fully blocked. This is a conservative assumption, and will produce a conservative estimate of the flood levels within and adjacent to the proposed development.

5.1.1 1D Model Setup

Under the existing scenario, the major creeks and swales are modelled in the 1D component of the model, as per Cardno Lawson Treloar (2005). This is primarily a function of their size, where the width of the creek is such that the channel shape cannot be adequately defined in the 5 metre grid of the 2D portion of the model.

Under the design scenario, there are several key flowpaths (Figure 2.1). Each of these flowpaths is generally wide, and it is therefore unnecessary to define these with the 1D portion of the model.

The exception to this are the bridges in the study area. These have initially been defined based on the HEC-RAS model that was provided by Worley Parsons (Section 3.2). Since then, modifications have been made to the bridge dimensions based on preliminary results of the hydraulic modelling.

Should the bridges be modified to culvert structures, then a Council blockage policy may apply. To ensure that the culverts behave in a similar manner to the bridges, it is recommended that the open area of the culverts be increased by the same proportion as the blockage policy (e.g. a 25% blockage policy results in a 25% increase in open area of the culvert).

5.1.2 2D Model Setup

The 2D model was defined based on the proposed design terrain provided by Worley Parsons (Section 3.2). Areas outside of this proposed design terrain were based on the existing model, which is discussed in Cardno Lawson Treloar [1] (2005).

Both the design terrain and existing terrain were extended in the north western corner of the site, following a review of version 3 of this report. This extended portion of the terrain covers sub-catchment 4A and 4A-1 in Figure 4.1.

Figure 5.1 shows the terrain that was utilised for the modelling, and is based on a 5 metre grid. Detailed design levels should be obtained from the original WorleyParsons terrain model (Section 3.2).

5.2 Hydraulic Roughness

Hydraulic roughness values for the design model were initially based on the adopted values for the existing model (Cardno Lawson Treloar [1], 2005). Values were determined based on the expected densities in each of the lots. These densities were provided by Australand, as per Section 3.1.

Figure 5.2 shows the adopted roughness values for the design modelling.

5.3 Design Events

The 100 year ARI, 5 year ARI and PMF design events were assessed as a part of this study.

5.4 Downstream Boundary

The downstream boundary of the model in the 2005 Flood Study was based on the levels derived for the Draft Elliot Lake – Little Lake Flood Study (Cardno Lawson Treloar [2], 2005).

5.4.1 Climate Change

Since the 2005 Flood Study, additional advice has been provided on the likely increase in ocean levels as a result of climate change. The *Practical Considerations of Climate Change* (DECC, 2007) suggests that three ocean level scenarios should be considered:

- Low Level Rise – 0.18m
- Medium Level Rise – 0.55m
- High Level Rise – 0.91m.

Based on this advice, the Medium Level Rise scenario (increase in ocean level of 0.55m) has been adopted for the design events for the modelling, with sensitivity testing being conducted on the High Level Rise scenario (Section 8.1). This is compared with the previous allowance for climate change of 0.2m in the 2005 Flood Study (i.e there is an 0.35m increase in downstream water level in the existing scenario when compared to the 2005 Flood Study as a result of the revisions to the climate change estimates).

5.4.2 Wave Set-up

In both the existing and design scenarios, a 5% AEP wave set-up is assumed to occur with the 100 year ARI flood, while a 100% AEP wave set-up is assumed to occur with the 5 year ARI design flood, as per Cardno Lawson Treloar [2] (2005). However, the wave set-up height reduces in the design scenario due to the presence of the harbour. Under the design scenario, water depth is about 6m at the harbour entrance in design ocean conditions where wave set-up is smaller and a conservative height of 0.4m has been adopted for the 5% AEP wave set-up height.

The adopted wave set-up heights for the design modelling are provided in Table 5.1.

Table 5.1 Adopted Wave Set-up Heights for Design Modelling (m)

Modelling Scenario	5 year ARI Design Flood	100 year ARI Design Flood
Existing	0.2	0.8
Design	0	0.4

5.4.3 Summary

The adopted ocean water levels (downstream water level boundary) for the design modelling are comprised of an elevated ocean level (storm tide level not exceeded for more than 1% of the time), wave set-up and climate change components. The adopted levels are provided in Table 5.2.

Table 5.2 Ocean Water Levels Adopted for Design Modelling (m AHD)

Design Flood Event	2005 Flood Study	Existing Scenario – Updated	Design Scenario
5 year ARI	1.40	1.55	1.55
100 year ARI	2.00	2.35	1.95
PMF	2.10	2.45	2.05

5.5 Berm Levels

The adopted berm level for the entrance to the lagoon from the 2005 Flood Study was 1.6m AHD, based on survey data available at the time. This level was utilised for the flood modelling in the 2005 Flood Study.

In general, it is expected that berm heights for lagoon entrances would increase by the same amount as the increase in sea level as a result of climate change (Hanslow et al., 2000). However, the berm level can also be affected by potential changes to the direction of the wave approach and the frequency and intensity of the storms under a climate change scenario (Hanslow et al., 2000).

The increase in berm height as a result of climate change would also result in a shift landward. An inspection of the width of the beach near the berm would suggest that there is sufficient distance for this horizontal shift.

For the existing scenario runs undertaken in this report, a medium level climate change rise has been assumed, with a resulting increase in ocean level of 0.55m AHD. Therefore, it has been assumed that the berm height under this scenario would increase by the same amount, resulting in a new berm level of 2.15m AHD.

In the 2005 Flood Study, it was assumed that Shellharbour Swamp was full at the start of the design storm. The same approach has been adopted in this report. Based on this, the adopted water levels within Shellharbour Swamp at the start of the storm are identified in Table 5.3. It should be noted that in the 100 year ARI design event the ocean level exceeds the berm level, so the resulting starting level in Shellharbour Swamp is equal to the ocean water level.

Table 5.3 Starting Water Level in Shellharbour Swamp

Design Event	Starting Swamp Water Level
5 year ARI	2.15
100 year ARI	2.35
PMF	2.45

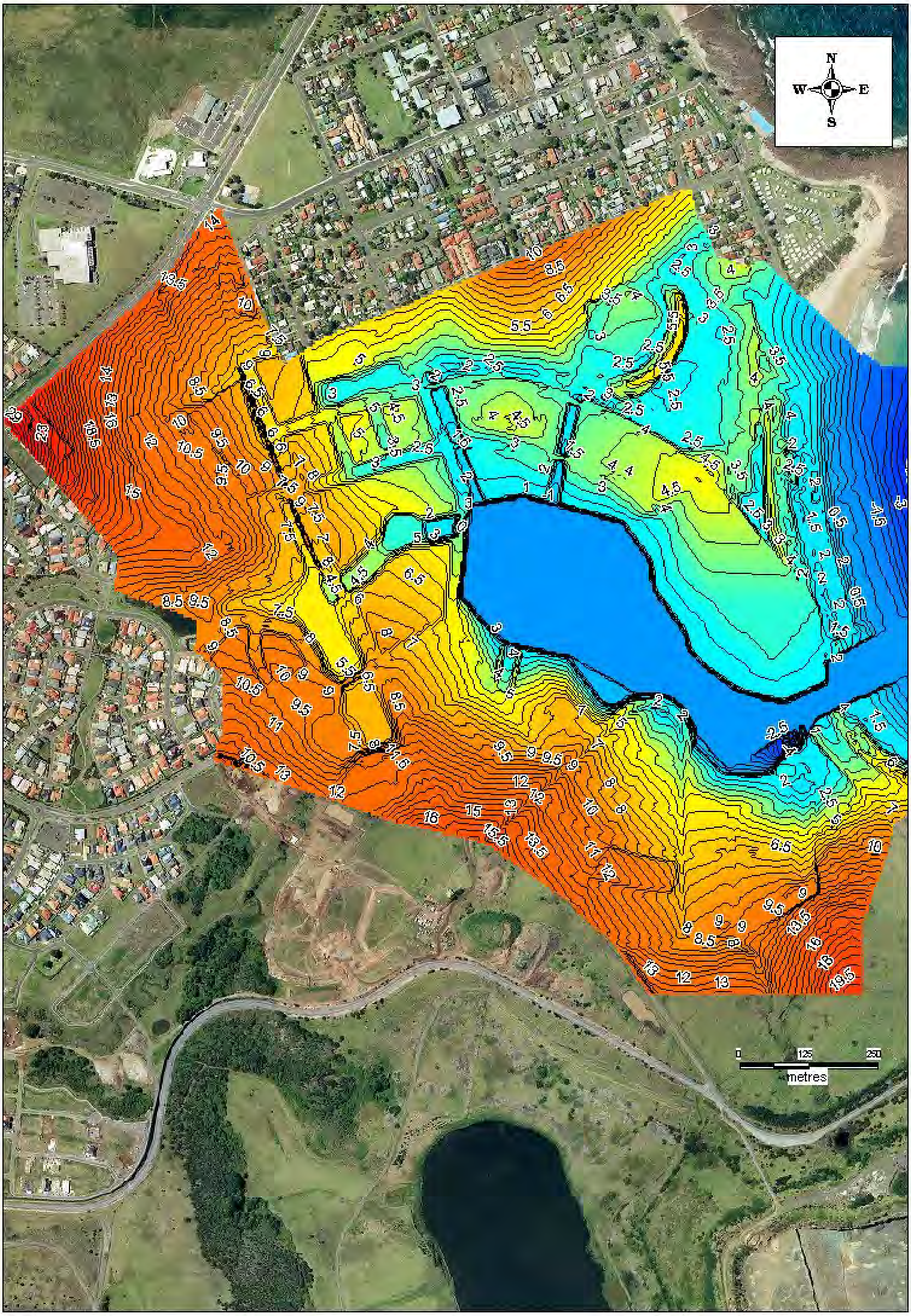


Figure 5.1 2D Design Terrain

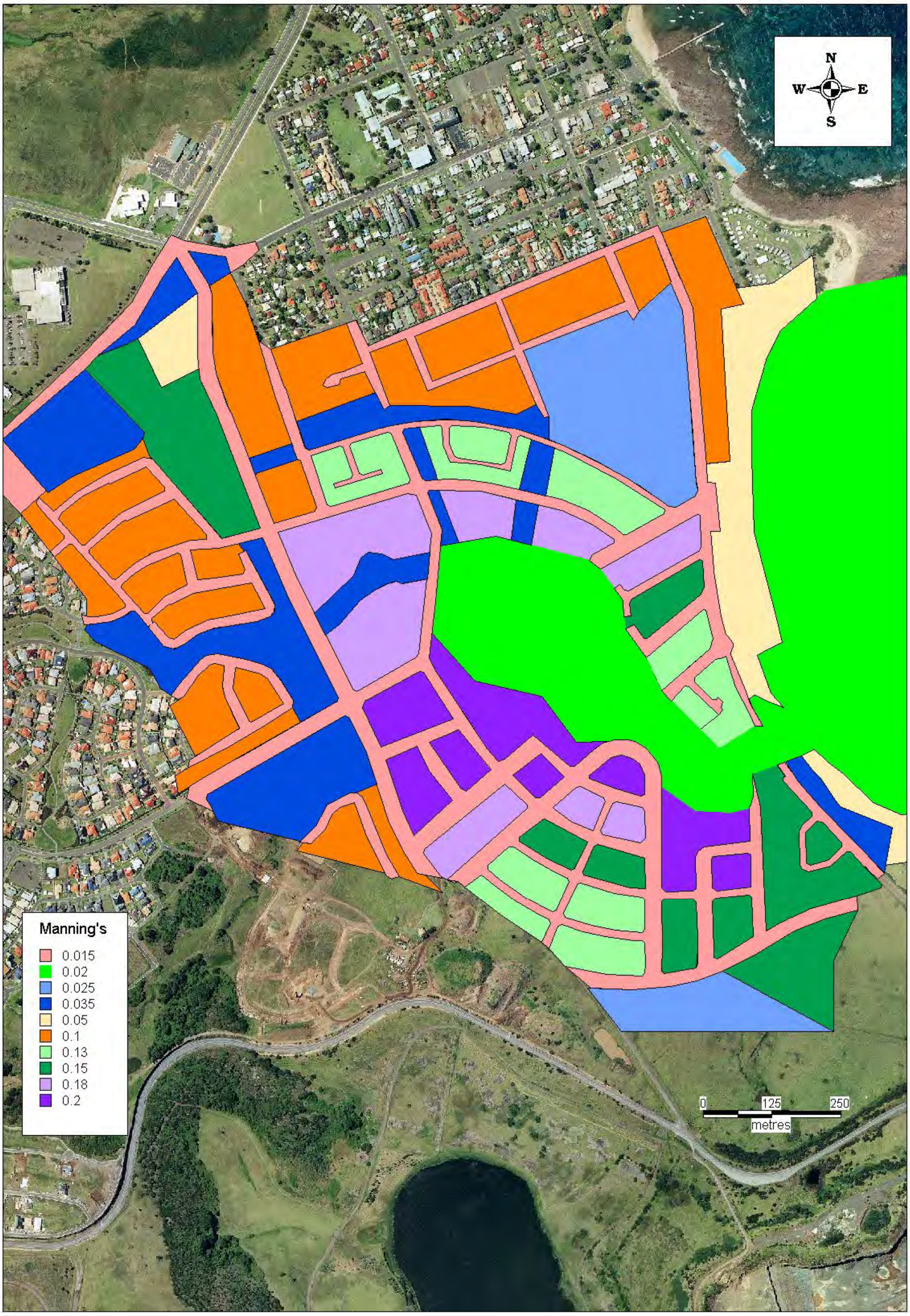


Figure 5.2 2D Roughness Values Adopted

6. RESULTS

6.1 Existing Scenario

The results from the existing scenario, which incorporate the changes to the downstream boundary, are presented in Figure 6.1 to Figure 6.9.

A detailed description of the existing catchment flooding behaviour can be found in Cardno Lawson Treloar [1] (2005). Some changes have occurred in this report as a result of the revision to climate change levels.

6.2 Changes near Bowling Club

Following the completion of the version 3 of this report, minor earthworks were undertaken near the Bowling Club which altered the terrain in this area. A summary of the localised effect of the earthworks near the Bowling Club is described in Appendix A. For the purposes of this assessment, the existing scenario is assumed to be prior to the minor earthworks in this area.

6.3 Design Scenario

The results from the design scenario are presented in Figure 6.10 to Figure 6.21.

It should be noted that the terrain over the proposed lakes within the development is representative of the operational water level of these lakes. Therefore, the depths and velocities reported are for the water above this operational level.

6.4 Filtering of Results

The Rainfall on the Grid approach has been adopted in this flood assessment, as per Cardno Lawson Treloar [1] (2005). By definition, this approach has rainfall falling on every grid cell and therefore every grid cell is effectively wet. A filter is therefore required in order to remove very shallow sheet flow. The following approach has been adopted for the study:

- A 0.05m filter has been applied to the majority of the study area (i.e. depths below 0.05m are not considered to be flooding).
- A 0.10m depth filter has been applied to flowpaths in the upper 5ha of a sub-catchment. In these areas, it is assumed that the flow generated is primarily overland flow and a 0.05m filter may be considered inappropriate. This filter affects primarily the area within the Bowling Club catchment (4A-1). Where ponding or flooding is occurring due to multiple sources of flow (such as Boollwaroo Parade near Ron Costello Oval), this filter has not been applied.

6.5 Discussion

Overland flows within the study area are generally contained within designated flow paths or along proposed roads.

The impact analysis shows that the proposed development does have some impact on the existing flood behaviour. In the 5 year event, impacts on peak water levels are observed in the Ron Costello Oval area (refer Figure 6.19). These impacts are in the range of 0.07m on Boollwarroo Parade and 0.01-0.02m on the northern part of Ron Costello Oval, near the existing properties. These impacts are the result of the north eastern flowpath in the proposed development being elevated higher than the existing channel at the same location. This effectively creates an obstruction to the flow, creating additional ponding upstream.

These impacts may also be partially attributed with the reduction in rainfall losses in the model. As a constant rainfall loss is applied to the model, the lower loss in the design scenario results in a slightly higher volume of runoff.

Impacts of up to approximately 0.04m are observed along the swale that runs on the northern boundary of the development. These impacts are likely to be a result of the absence of drainage infrastructure within the model, together with the reduction in rainfall losses in the model. As this area is governed by storage, the difference in rainfall loss is emphasised at this location.

In the 100 year ARI event, decreases are observed along the northern swale and Boollwarroo Parade whilst the impacts are primarily limited to the northern portion of Ron Costello Oval (refer Figure 6.20). These impacts are in the range of 0.02 to 0.03m to the north of Ron Costello Oval, near the properties. The outlet of the pipe which drains this area discharges in the vicinity of the north eastern flowpath in the proposed development. The high invert of this north eastern flowpath reduces the efficiency of this pipe, and results in the increases observed in the north of Ron Costello Oval.

Whilst this impact is not considered significant, it could be addressed by either:

- Reducing the invert of the north eastern overland flow path, to increase the efficiency of the outlet, or;
- Providing a pipe connecting upstream of the north eastern flowpath to the harbour area.

In the PMF design event, there are primarily decreases in the peak water levels observed in the Ron Costello Oval area and along the northern swale (refer Figure 6.21). However, there are some increases in peak water levels in both the south east and north west of the proposed development. In both of these areas, the increases are in areas which would form part of the new development. As such, these impacts could be managed through the design process.

In the PMF, 100 year ARI event and the 5 year ARI event there are increases in peak water levels within the cemetery, in the north western corner of the study area. These impacts are up to approximately 0.08m in the 5 year ARI design event and 0.10m in the 100 year ARI event.

It is also noted that the absence of pits and pipes within the proposed development in the model produce conservative estimations of the flood behaviour in the study area.

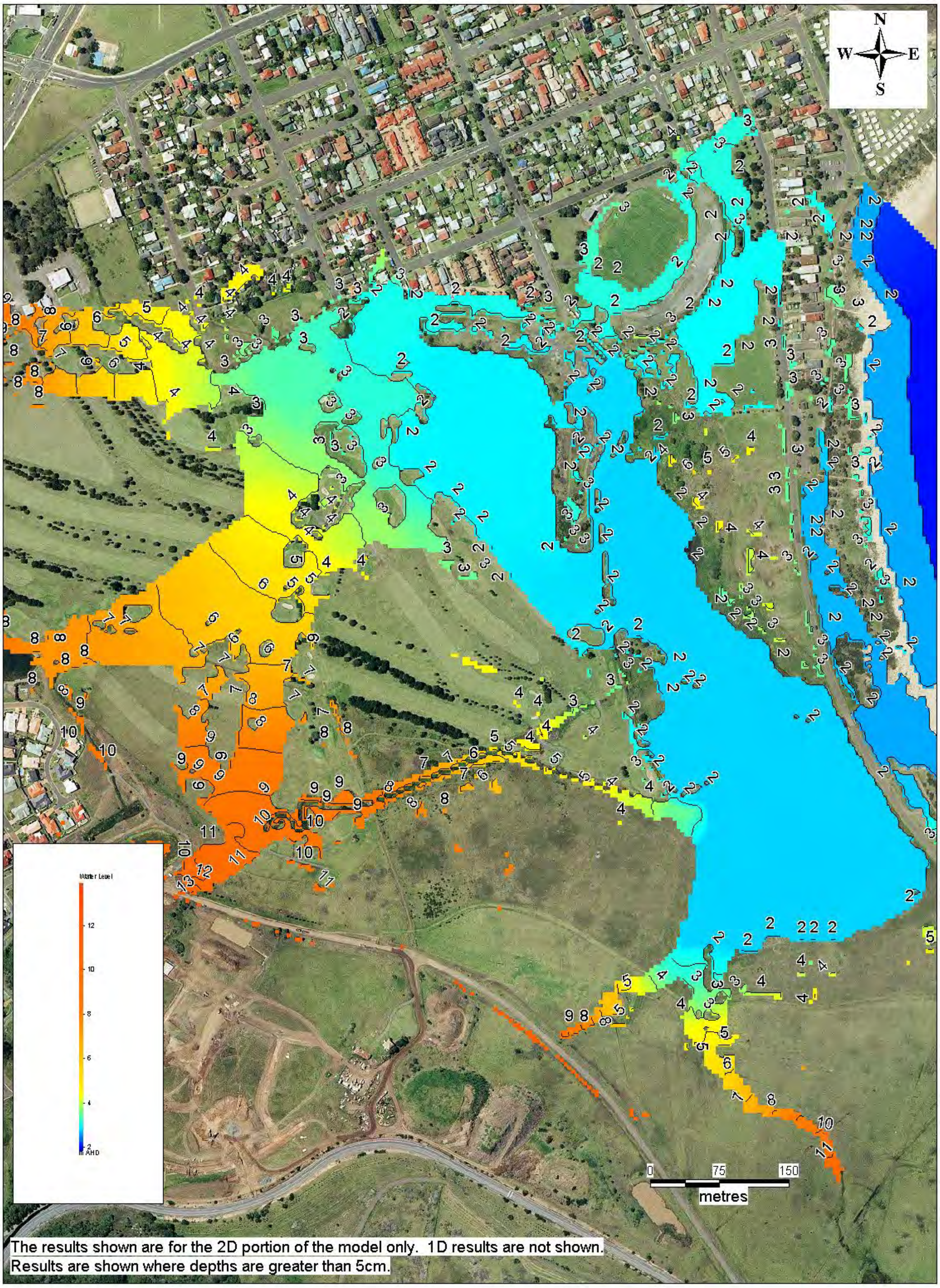


Figure 6.1 5 year ARI Peak Water Level - Existing Scenario

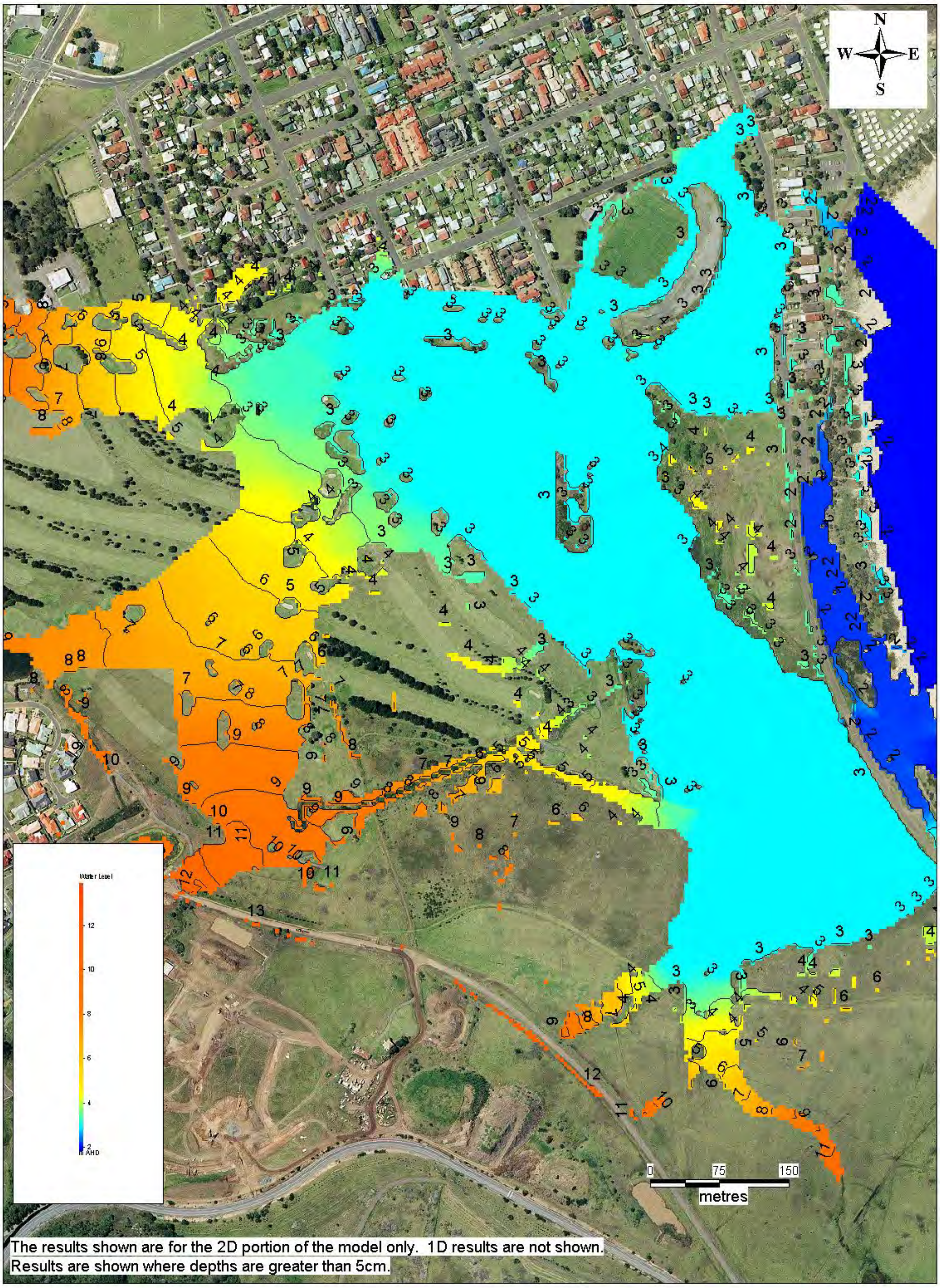


Figure 6.2 100 year ARI Peak Water Level - Existing Scenario

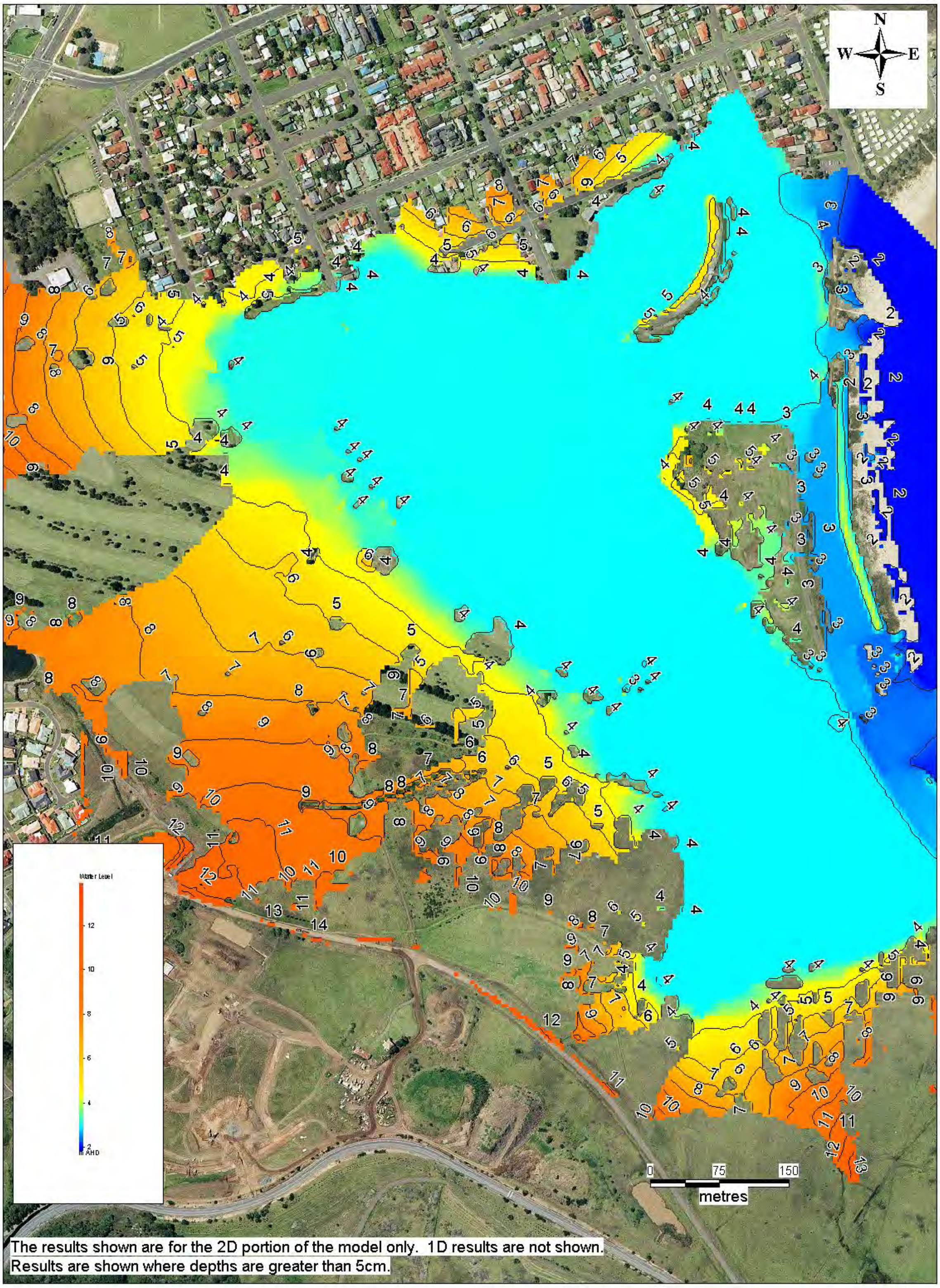


Figure 6.3 PMF Peak Water Level - Existing Scenario

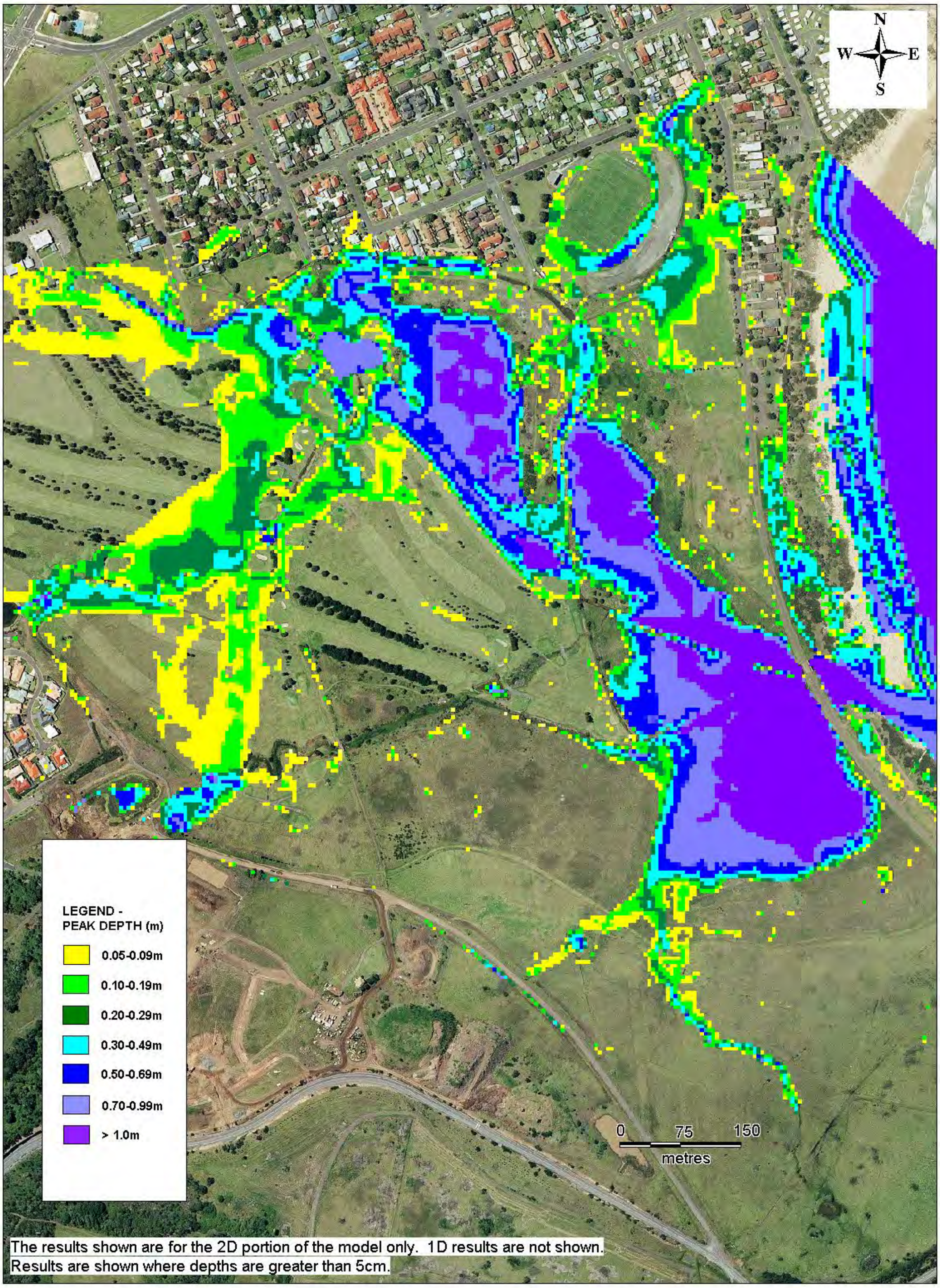


Figure 6.4 5 year ARI Peak Depth - Existing Scenario

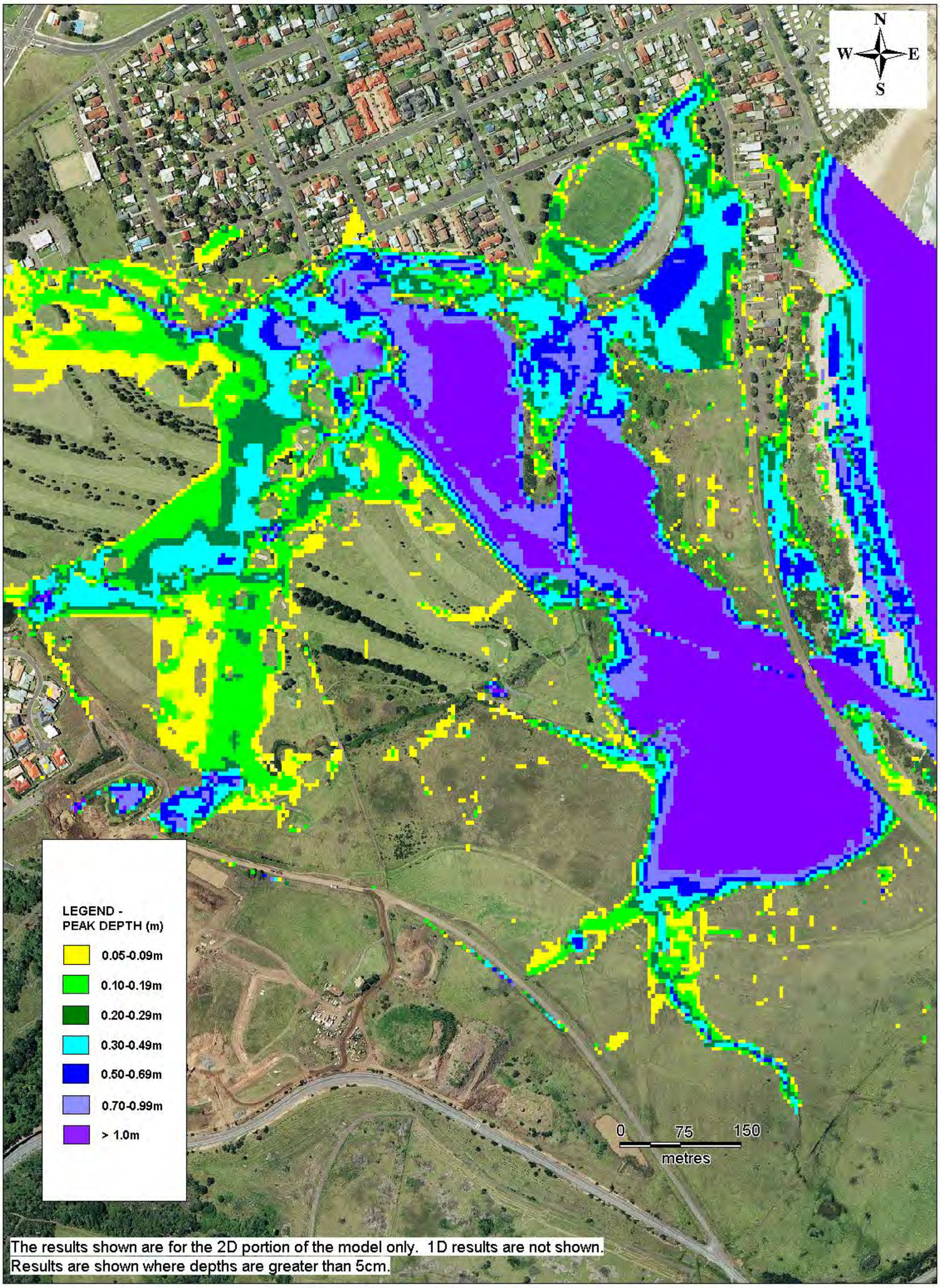


Figure 6.5 100 year ARI Peak Depth - Existing Scenario

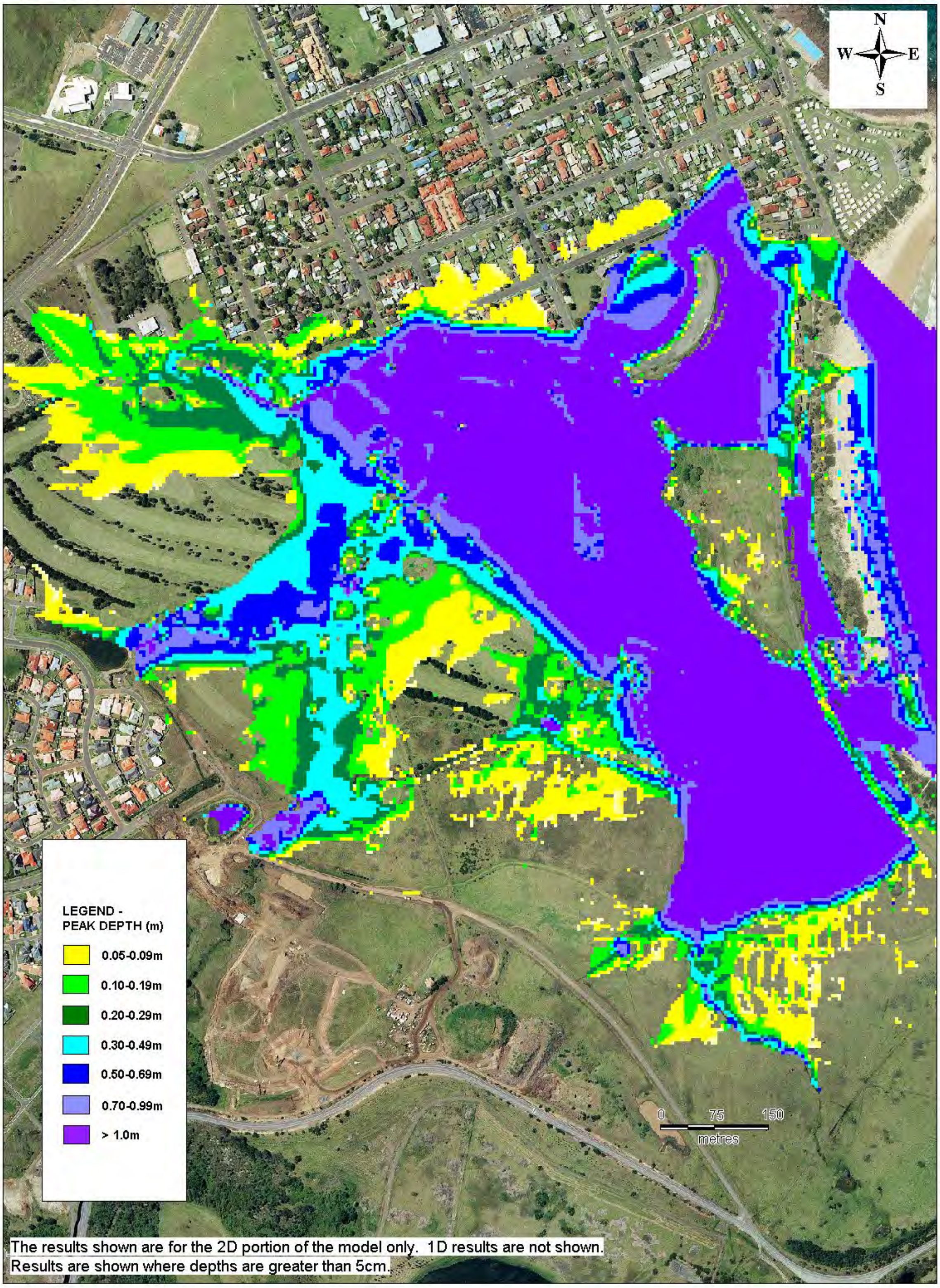


Figure 6.6 PMF Peak Depth - Existing Scenario

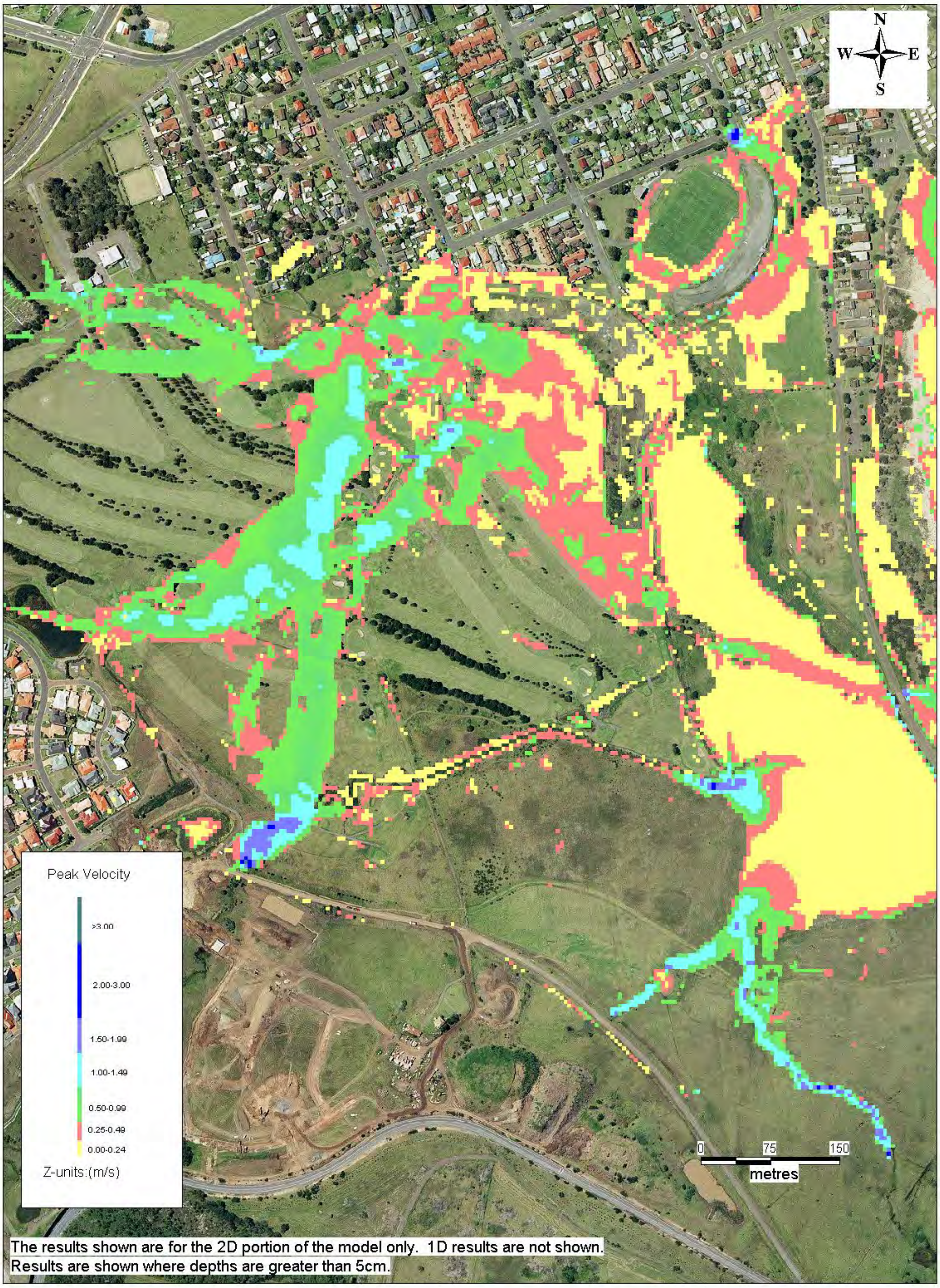


Figure 6.7 5 year ARI Peak Velocity - Existing Scenario

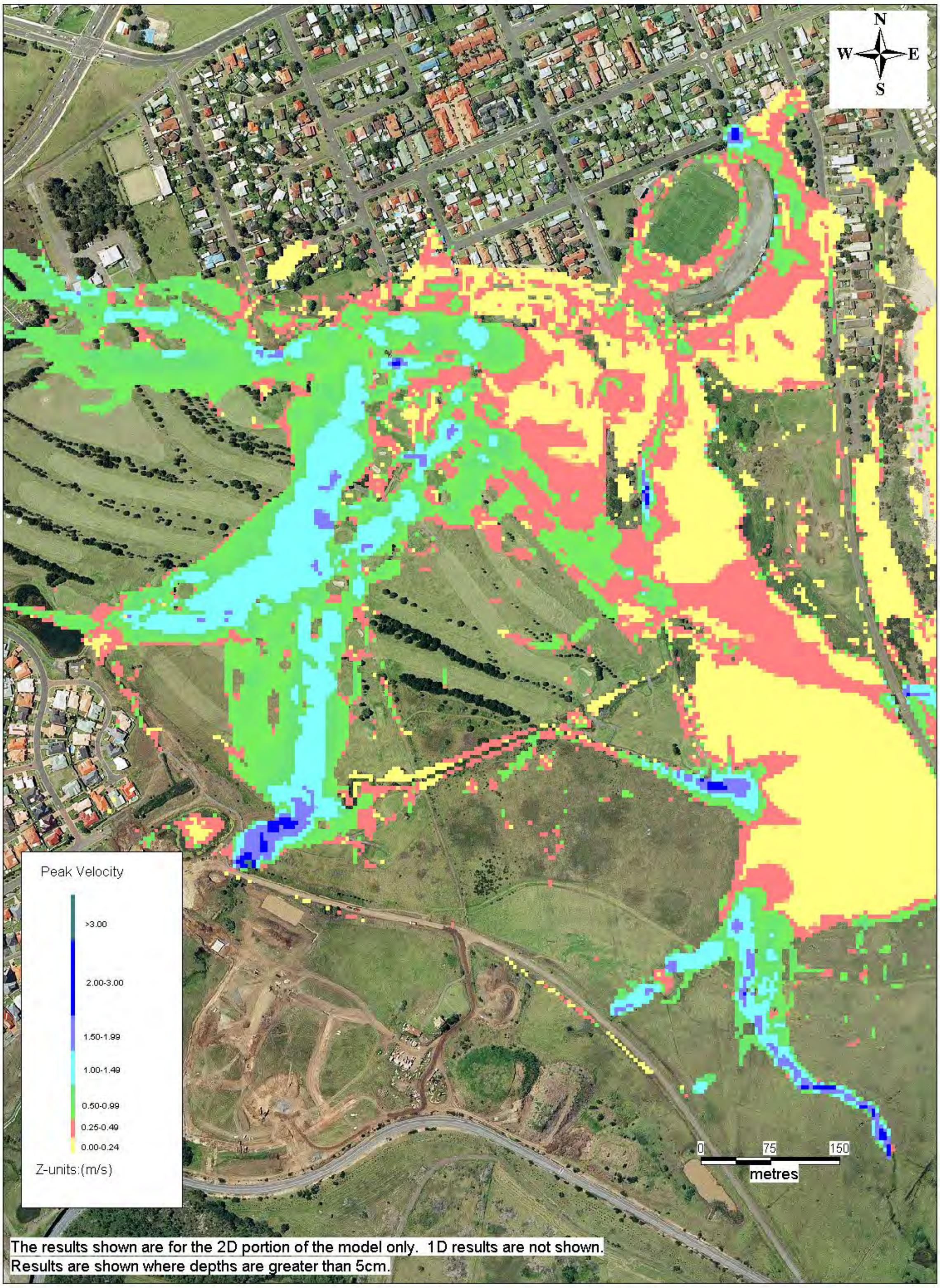


Figure 6.8 100 year ARI Peak Velocity - Existing Scenario

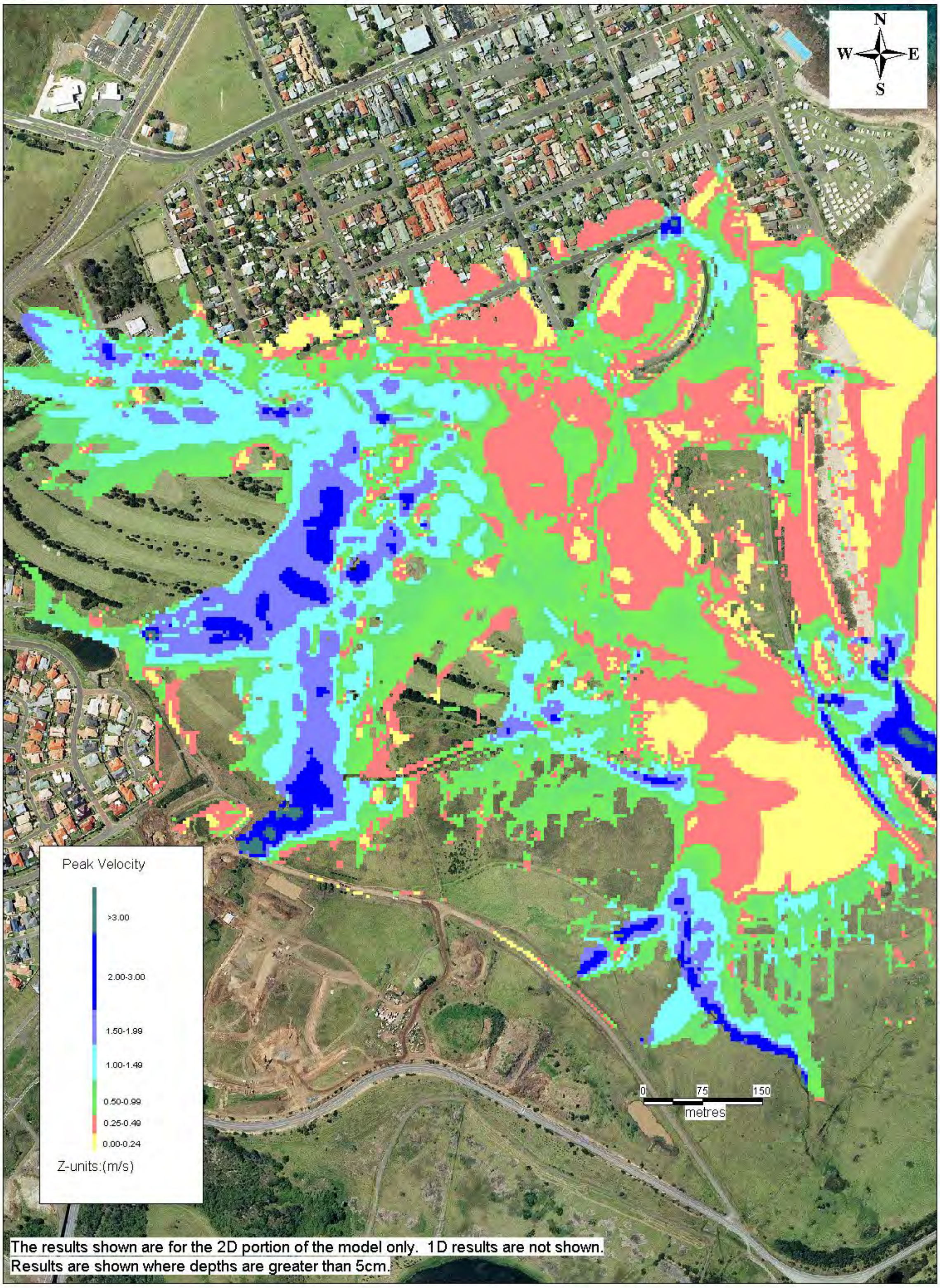


Figure 6.9 PMF Peak Velocity - Existing Scenario

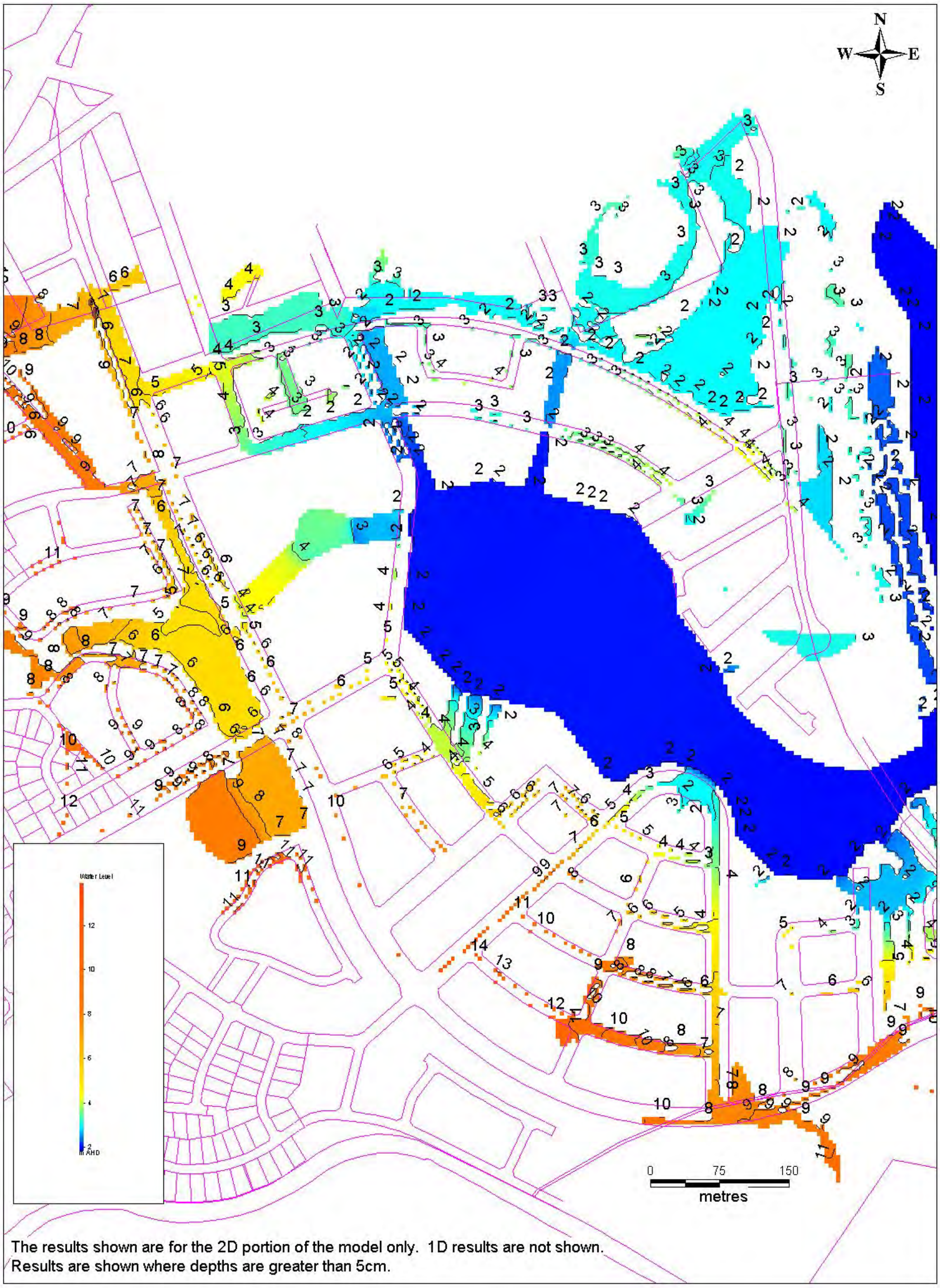


Figure 6.10 5 year ARI Peak Water Levels - Proposed Development

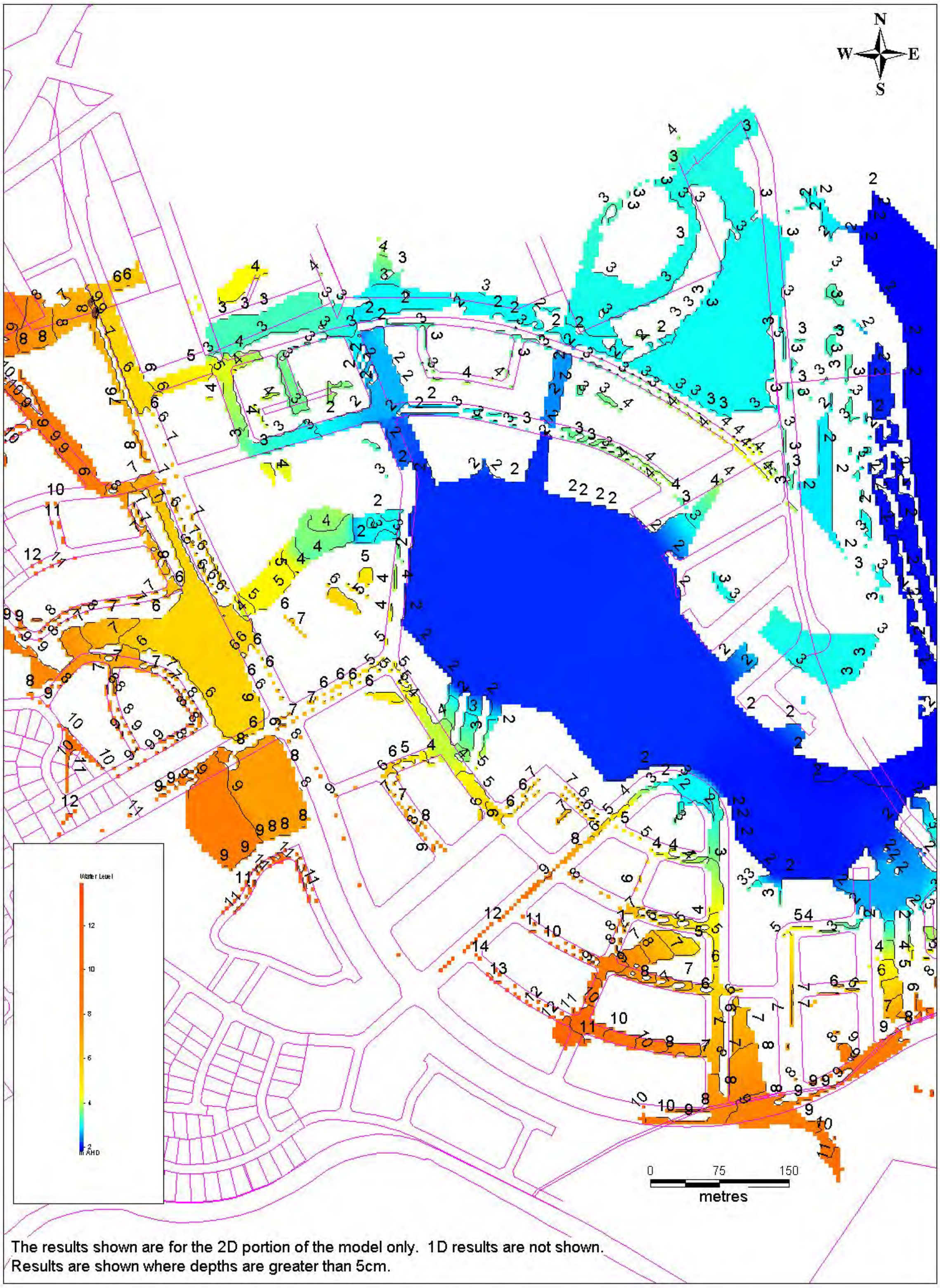


Figure 6.11 100 year ARI Peak Water Level - Proposed Development

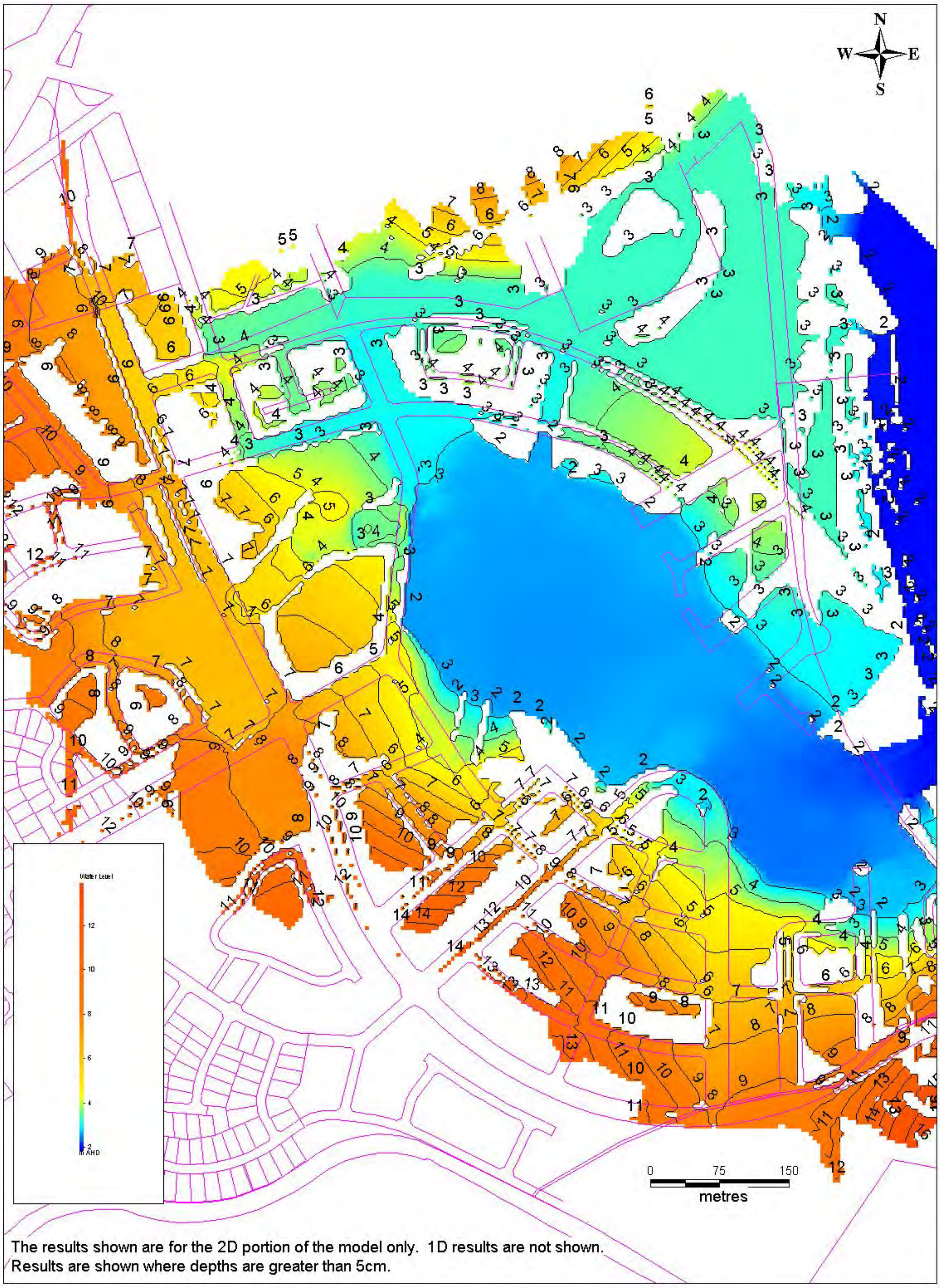


Figure 6.12 PMF Peak Water Level - Proposed Development

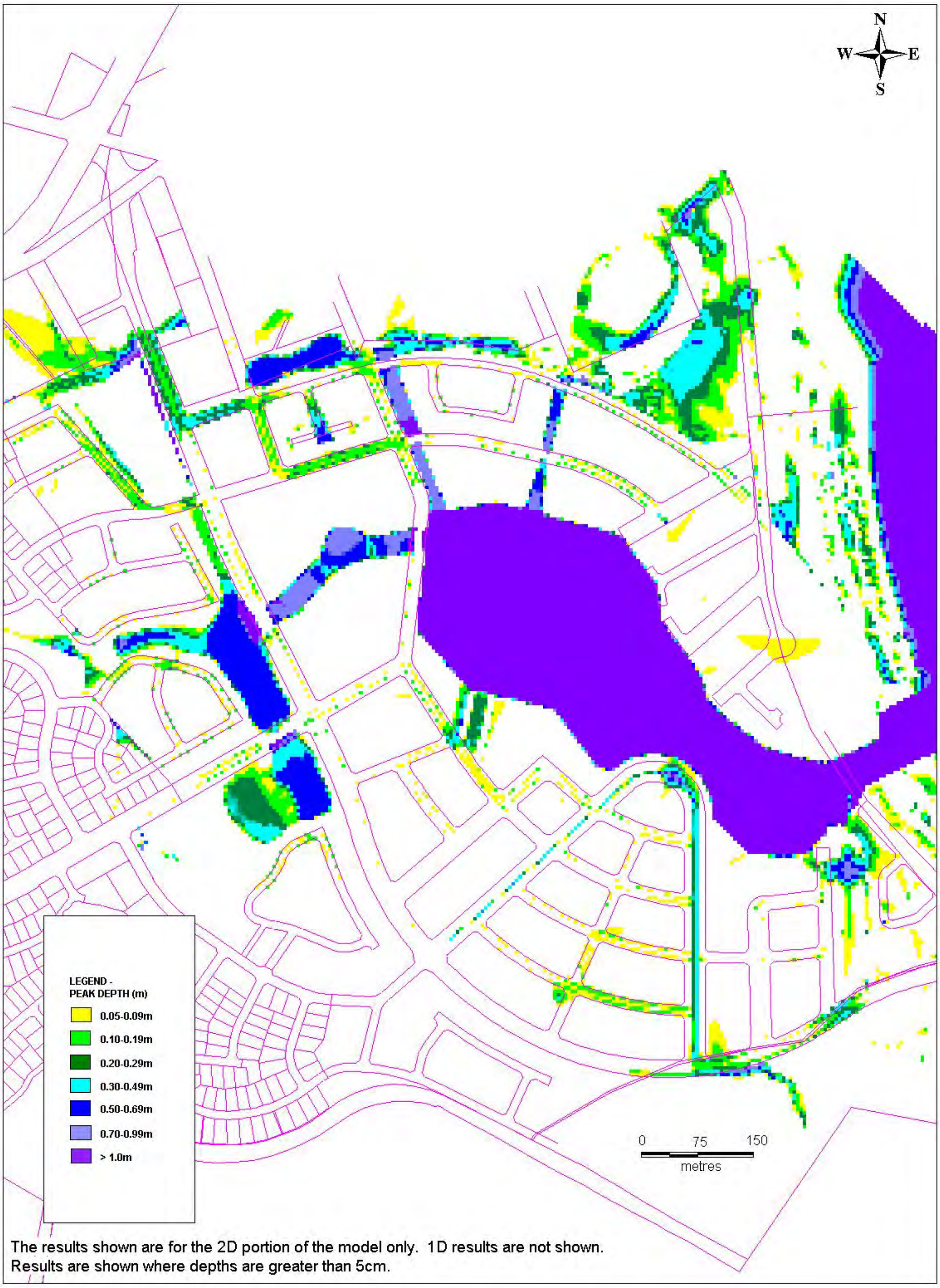


Figure 6.13 5 year ARI Peak Depth - Proposed Development

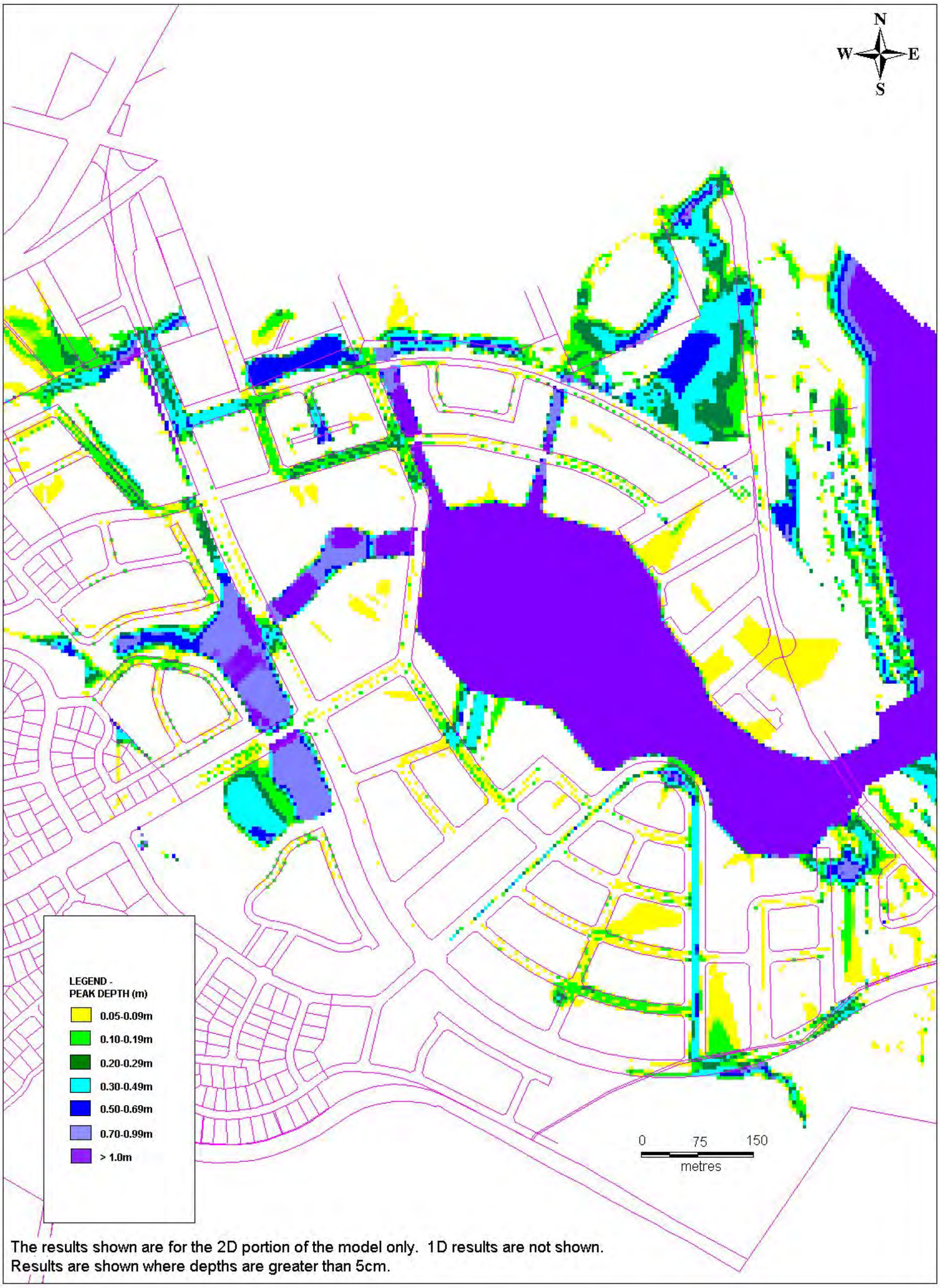


Figure 6.14 100 year ARI Peak Depth - Proposed Development

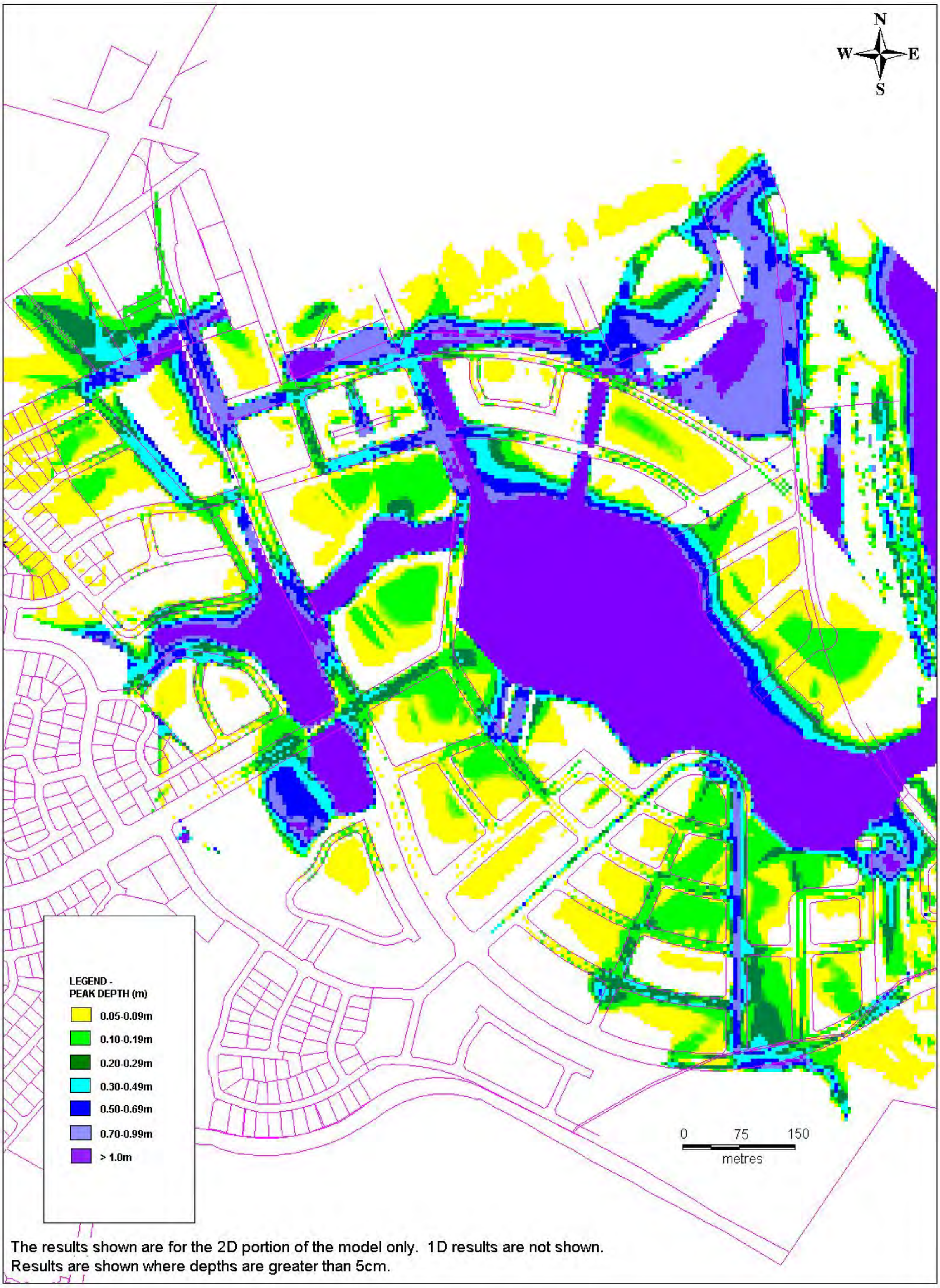


Figure 6.15 PMF Peak Depth - Proposed Development

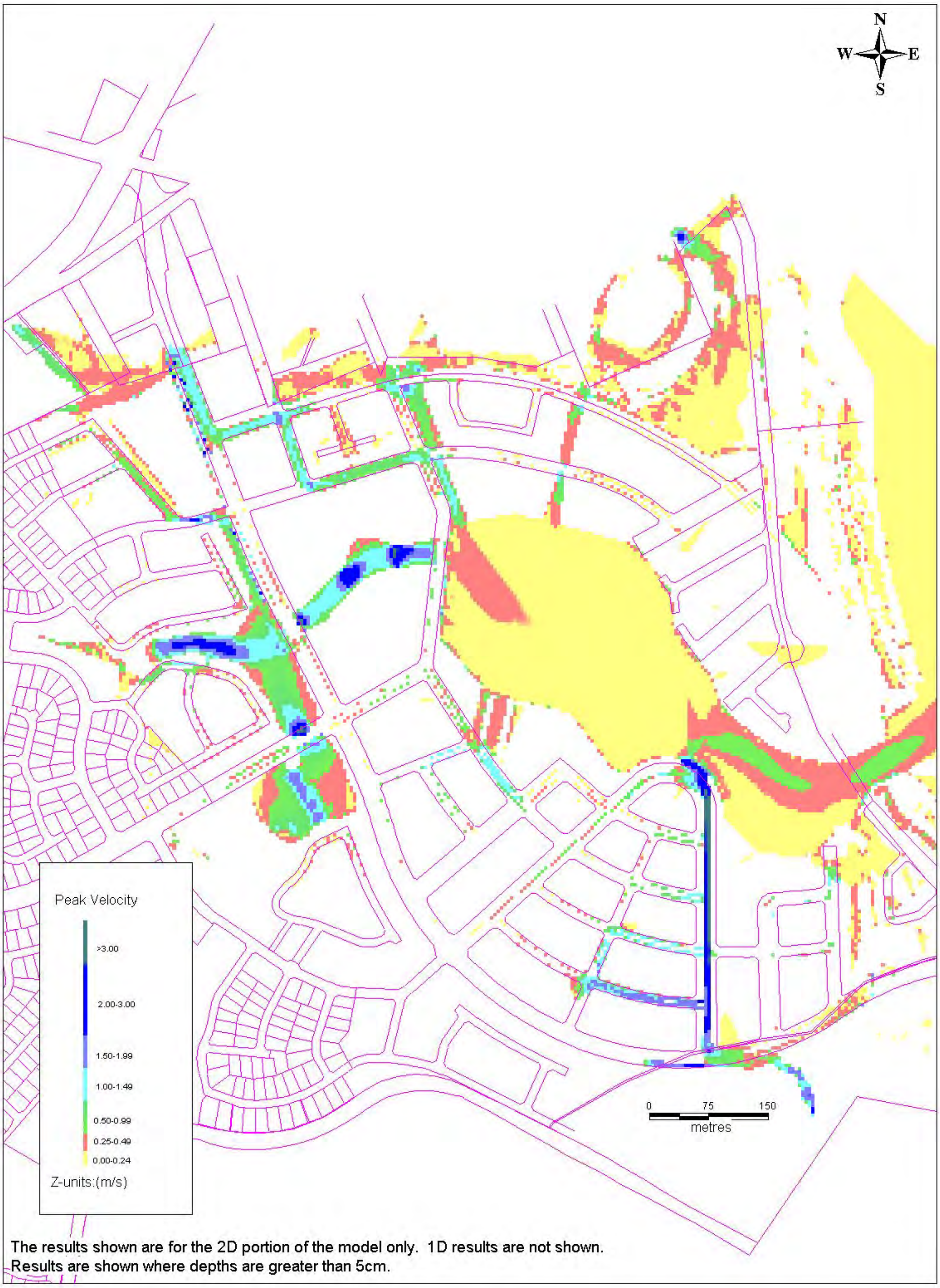


Figure 6.16 5 year ARI Peak Velocity - Proposed Development

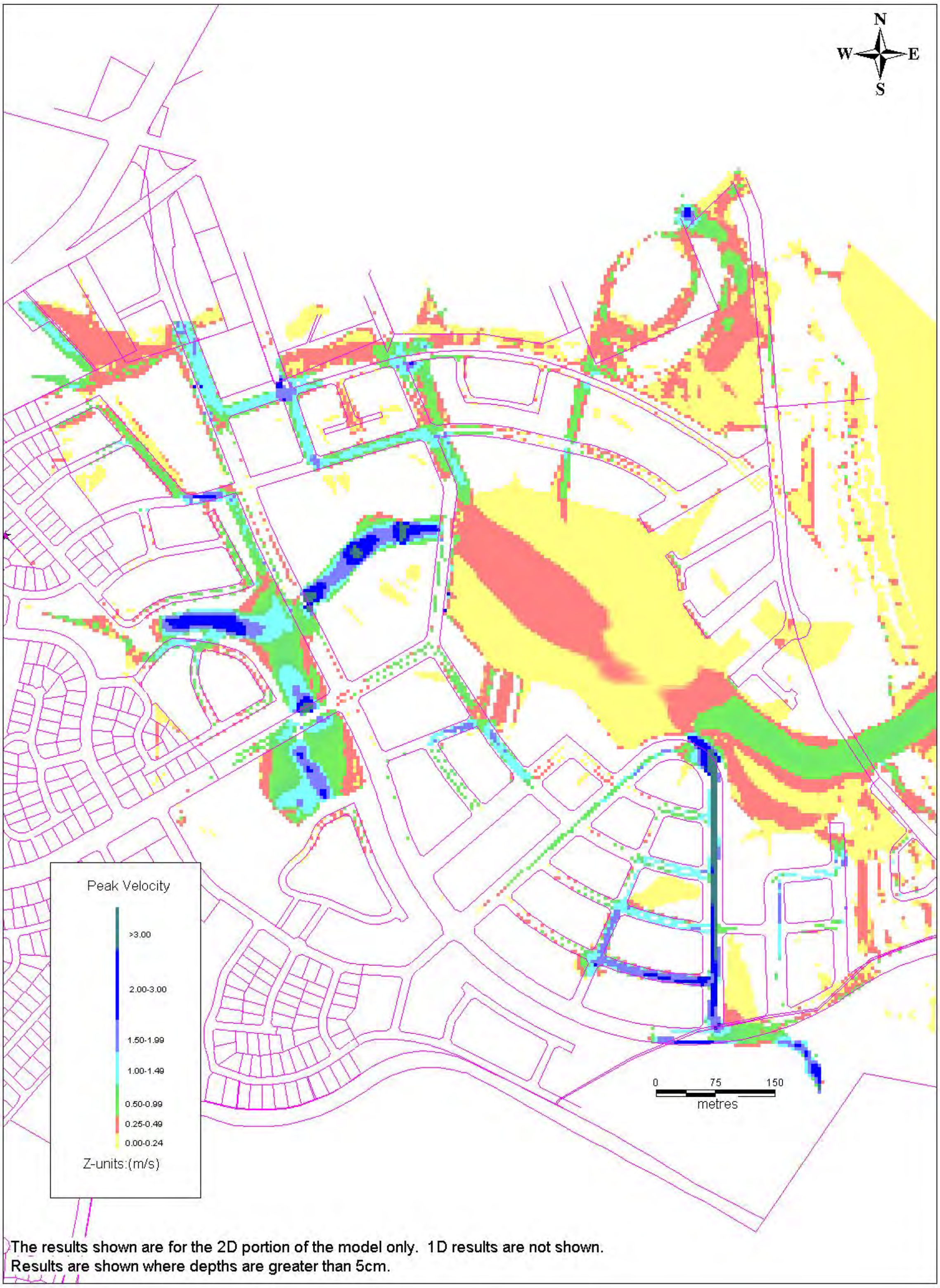


Figure 6.17 100 year ARI Peak Velocity - Proposed Development

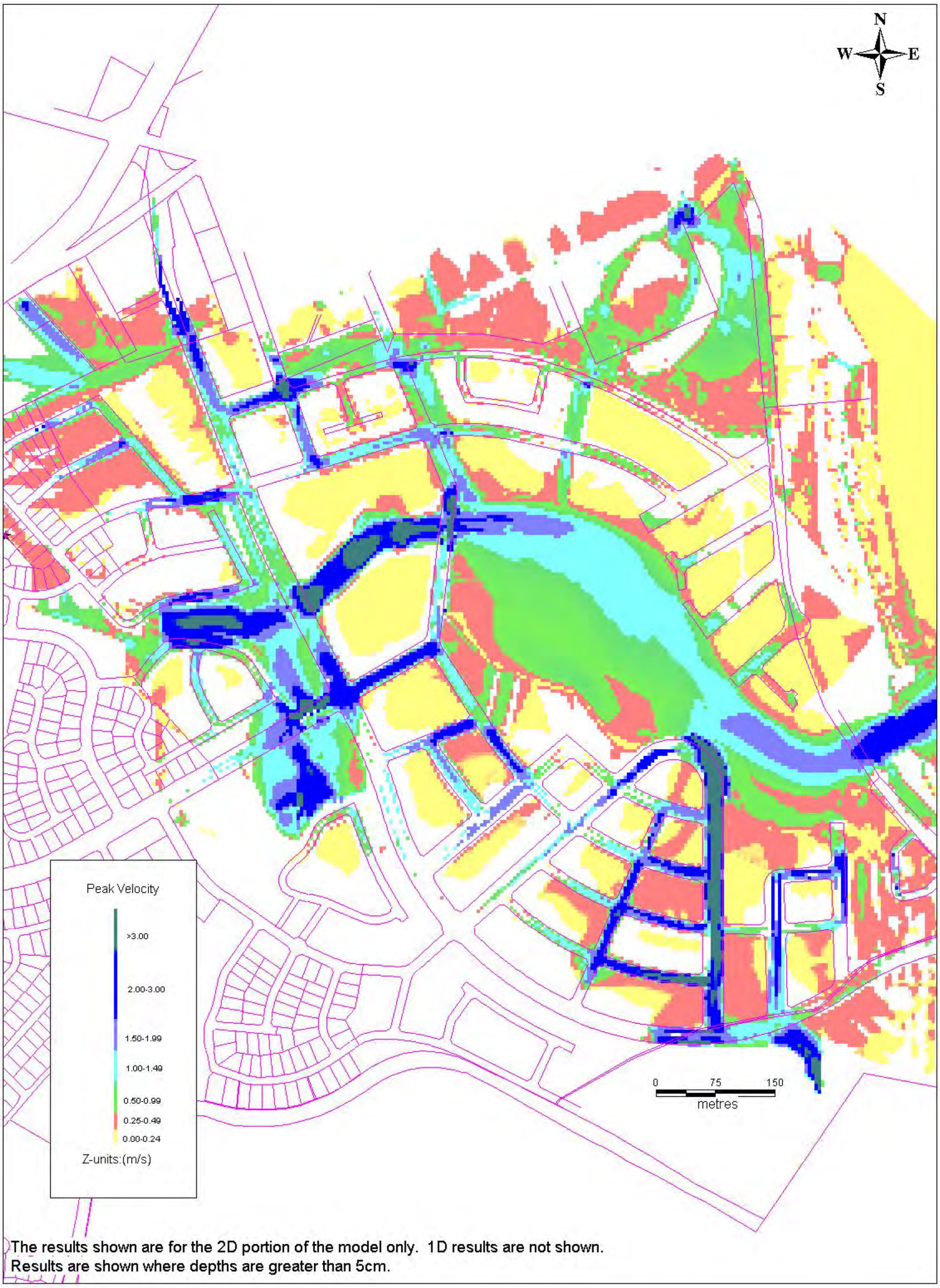


Figure 6.18 PMF Peak Velocity - Proposed Development

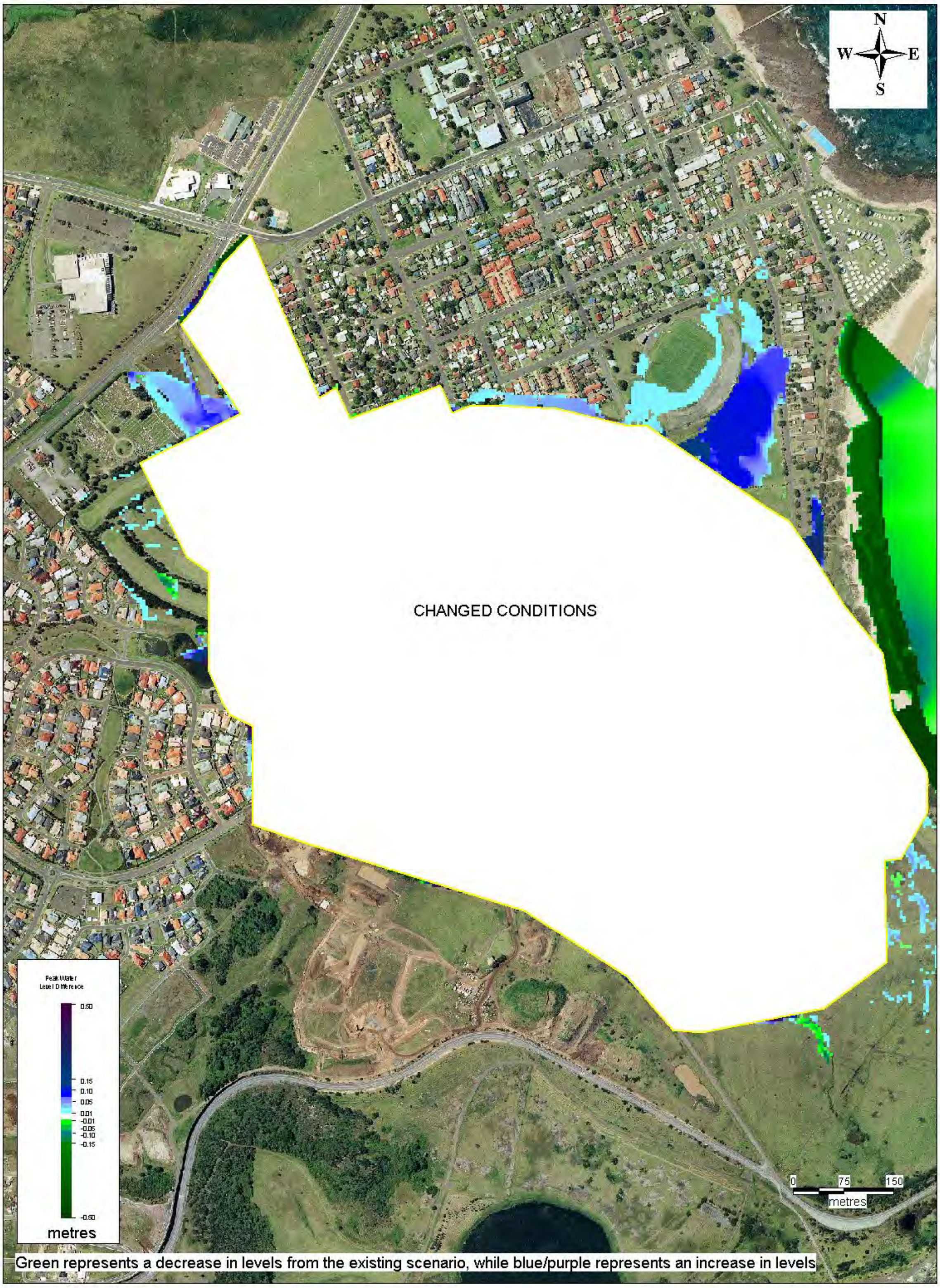


Figure 6.19 5 year ARI Impact of the Proposed Development on Existing Flood Behaviour

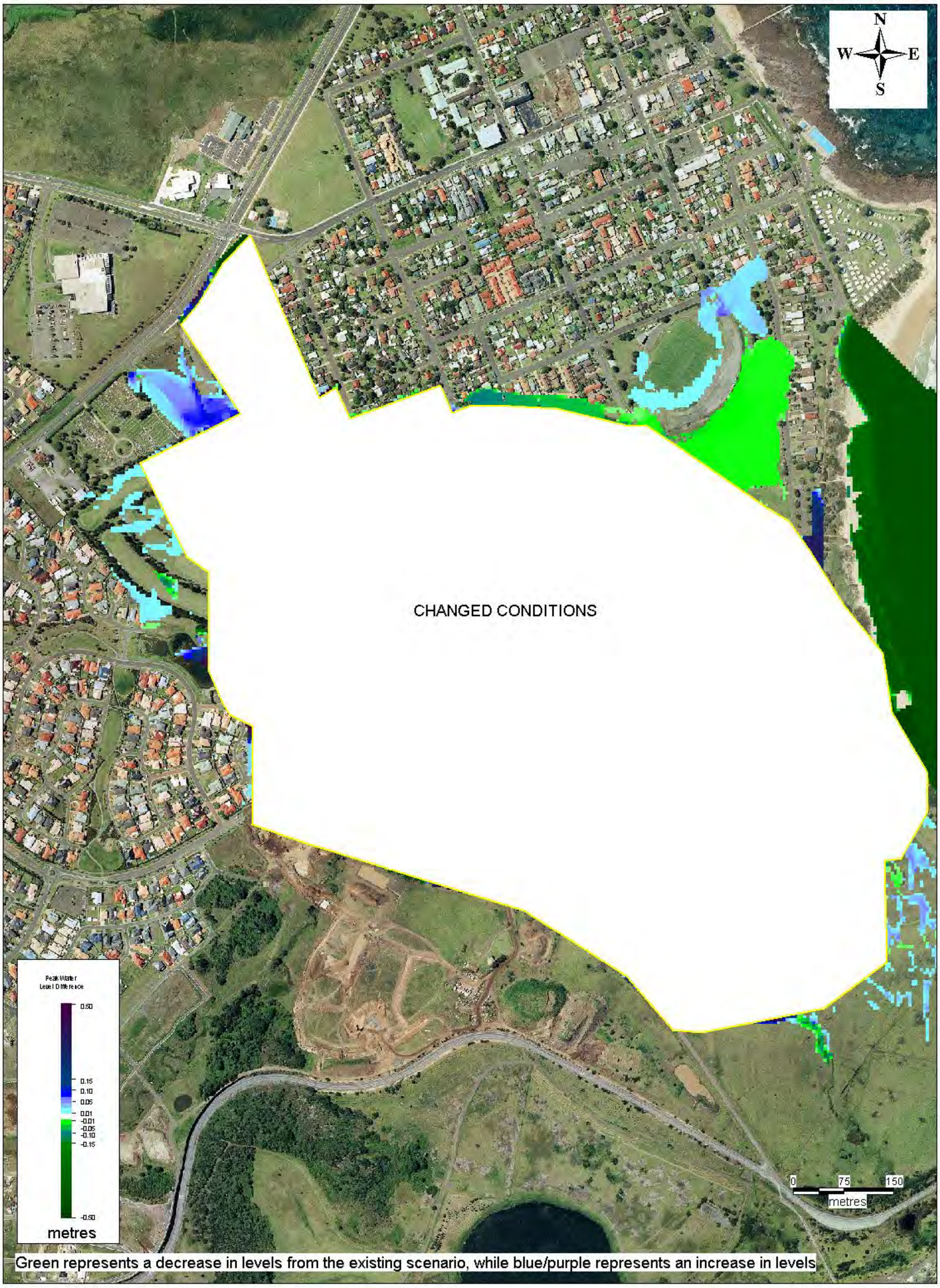


Figure 6.20 100 year ARI Impact of the Proposed Development on Existing Flood Behaviour

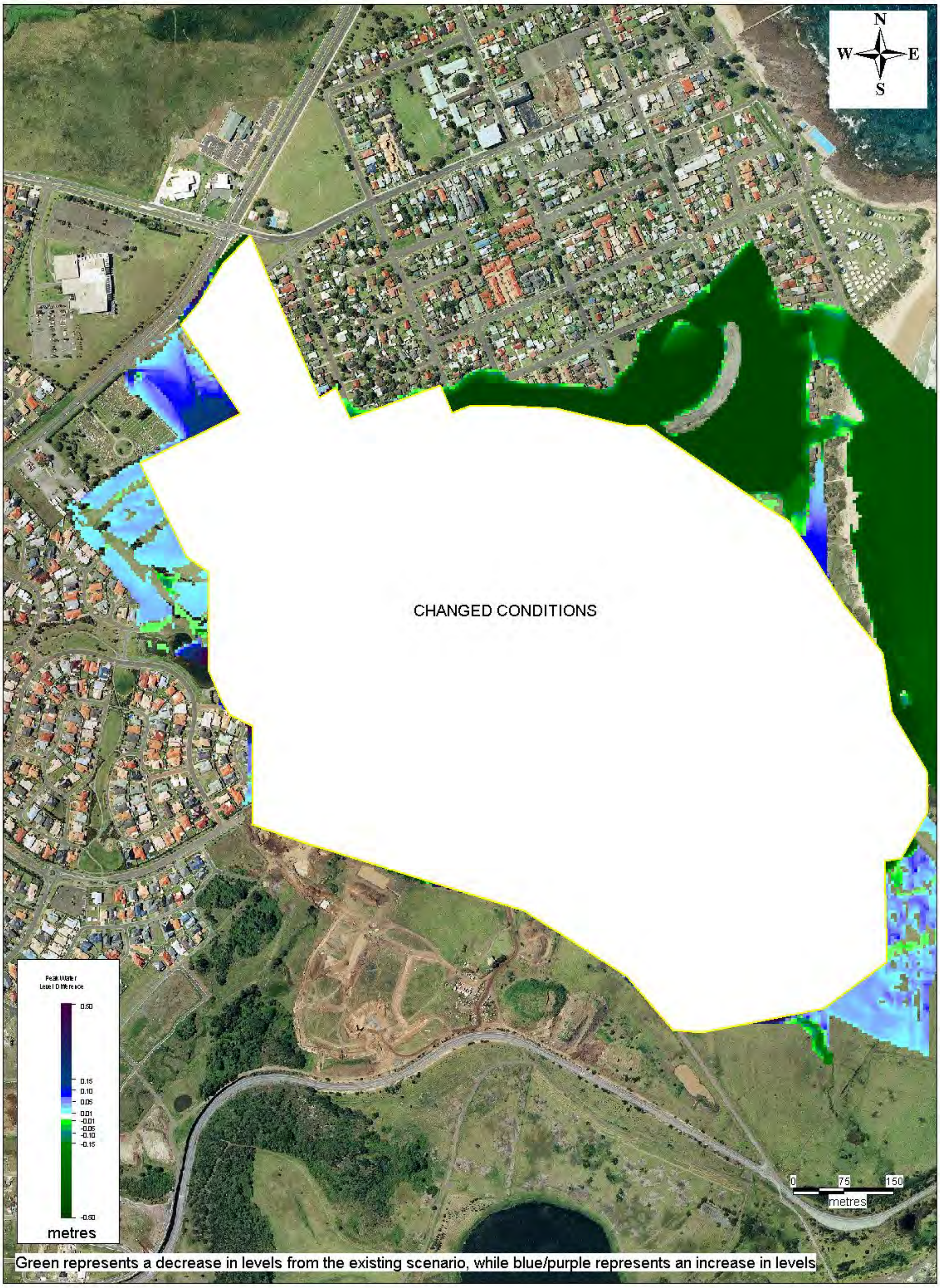


Figure 6.21 PMF Impact of the Proposed Development on Existing Flood Behaviour

7. FLOOD HAZARD AND HYDRAULIC CATEGORY MAPPING

7.1 Flood Hazard Mapping

The flood hazard mapping undertaken for this study is provisional, and only takes into account the velocity – depth relationship of hazard in accordance with Figure L2 of the Floodplain Development Manual (NSW Government, 2005). No account has been made of the other factors that form part of a True Hazard mapping assessment as described in Appendix L of the Floodplain Development Manual (NSW Government, 2005).

7.1.1 Existing Conditions

The provisional hazard for the existing scenario is shown in Figure 7.1 to Figure 7.3.

The existing hazard behaviour is described in detail in Cardno Lawson Treloar [1] (2005). The increases in downstream water level as a result of the revision in climate change estimates does not significantly impact on the hazard within the study area.

7.1.2 Design Conditions

The provisional hazard for the post development scenario is shown in Figure 7.4 to Figure 7.6.

The provisional high hazard for the post development conditions is primarily limited to the formalised overland flow paths in the area.

It is understood that it is intended to create open space areas in the northern flow paths. Based on the existing modelling, these northern flowpaths are exposed to provisional high hazard. It is not uncommon to have open space areas that are also exposed to high hazard (such as dual purpose detention basins/ ovals). It is recommended to incorporate suitable grades on the sides of these flow paths to allow for ease of evacuation should a flood event occur. Similar measures should be applied to any parkland areas in the vicinity of the proposed lakes.

Additional provisional high hazard occurs along one of the southern roads within the proposed development, which forms the main flowpath for the catchments in the south. This high hazard is generally contained within a proposed 8m wide swale down the centre of the road. As a 5m grid cell size is utilised, this swale is only coarsely defined in the model. If the swale were adequately defined, then it is likely that the high hazard would be wholly contained within the swale. It is noted that this hazard may be reduced if the stormwater pipe network were accounted for in the model. However, it would be difficult to remove this hazard completely given the grades of this road.

When compared with the existing conditions, the PMF provisional high hazard areas reduce in the Ron Costello area, part of the existing Shellharbour Village. There are no increases in provisional high hazard in the PMF, 5 year ARI or 100 year ARI design events as a result of the development.

The velocity depth multiple is provided in Figure 7.7 to Figure 7.9. The velocity times depth relationship is commonly used in the design phase of a project. In general, designs should aim for a v×d of less than 0.4.

The majority of the proposed developed experiences v×d of less than 0.4. The exception to this are the major flowpaths, which would be expected to have high v×d, and the southern road in the development. As discussed in Section 5, all pits and pipes within the proposed development have been assumed to be 100% blocked. As such, the quantity of flow down the southern road would likely decrease, and may result in a decrease in the v×d.

7.2 Hydraulic Category Mapping

Hydraulic category mapping has been undertaken in accordance with the Floodplain Development Manual (2005). The three hydraulic categories defined for flood prone lands, floodway, flood storage and flood fringe, are described in Appendix L of the Manual.

The following methodology was adopted to identify the hydraulic categories in the model results. This methodology has been used in a number of flood studies previously.

Floodways were determined by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below.

Floodway – As a minimum, the floodway was assumed to follow the creek line from bank to bank. Floodway has also been defined where ever the following depth and velocity criteria has been satisfied:

- Velocity * Depth must be greater than 0.25 m^2/s **and** velocity must be greater than 0.25 m/s **OR**
- Velocity is greater than 1 m/s.

Flood Storage – was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharge anywhere to increase by more than 10%. The flood storage has been identified as follows.

Previous analysis of flood storage in 1D cross sections assumed that if the cross sectional area is reduced such that 10% of the conveyance is lost, the criteria for flood storage would be satisfied. To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.2 m (Howells et at, 2003). Thus the criteria used to determine the flood storage is:

- Depth greater than 0.2m
- Not classified as floodway.

Flood Fringe – All areas that were not categorised as Floodway or Flood Storage, but still fell within the flood extent are represented as Flood Fringe.

7.2.1 Existing Conditions

The hydraulic categories for the existing conditions are shown in Figure 7.10 to Figure 7.12.

These update the previous figures provided in Cardno Lawson Treloar [1] (2005). Only minor adjustments have occurred as a result of the revisions in climate change ocean levels.

7.2.2 Design Conditions

The hydraulic categories for the design conditions are shown in Figure 7.13 to Figure 7.15.

As with the provisional hazard (Section 7.1.2), the floodway areas are primarily limited to the major overland flowpaths and some of the roads in the 100 year ARI design event. As discussed in Section 5, all pits and pipes within the proposed development have been assumed to be 100% blocked. As such, the extent of floodway areas within the roads would likely decrease.

The design does not adversely affect the classification of floodways external to the proposed development. A reduction in PMF floodway is observed in the Ron Costello Oval area and part of the existing Shellharbour Village.

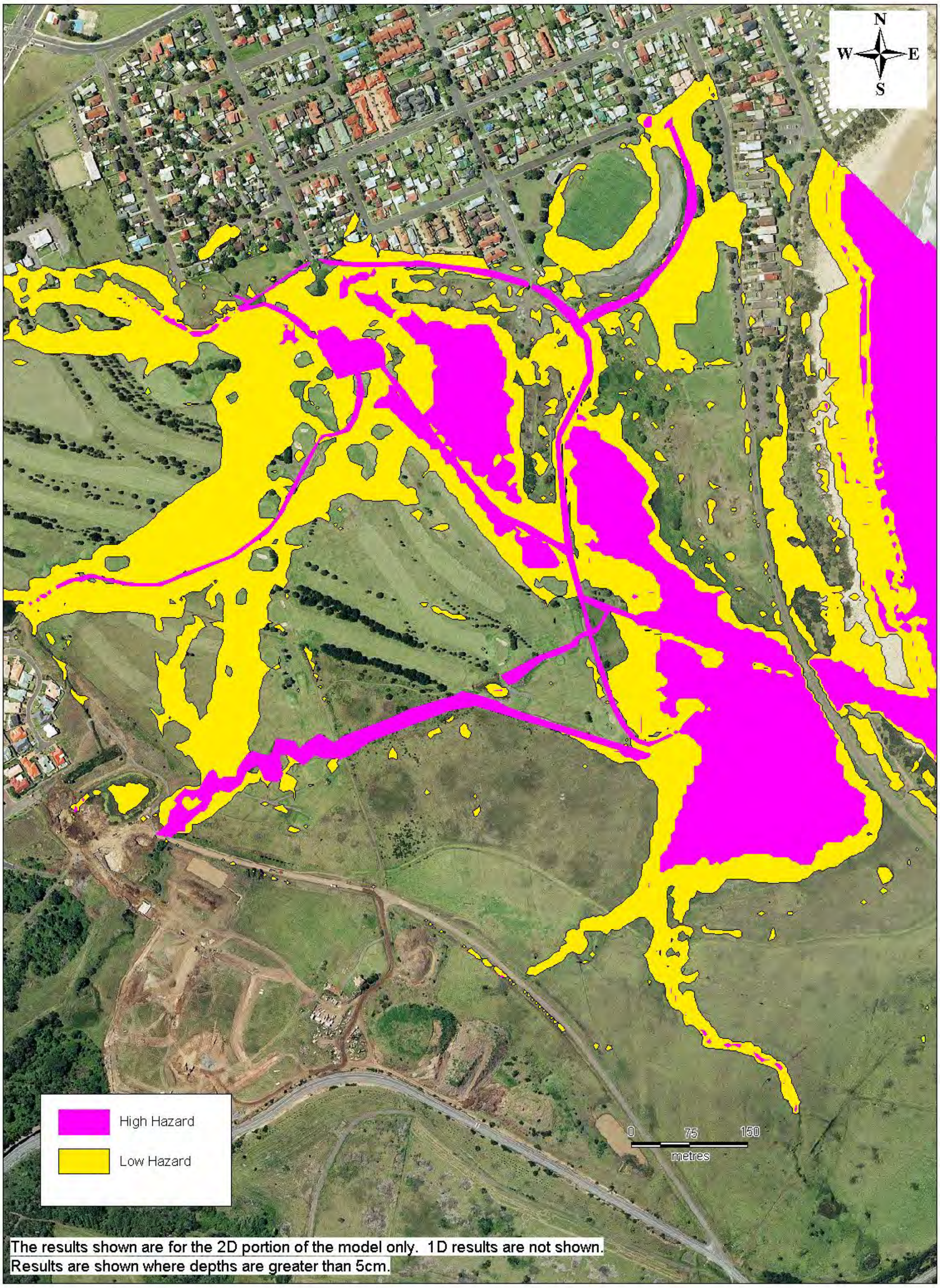


Figure 7.1 5 year ARI Provisional Hazard - Existing Scenario

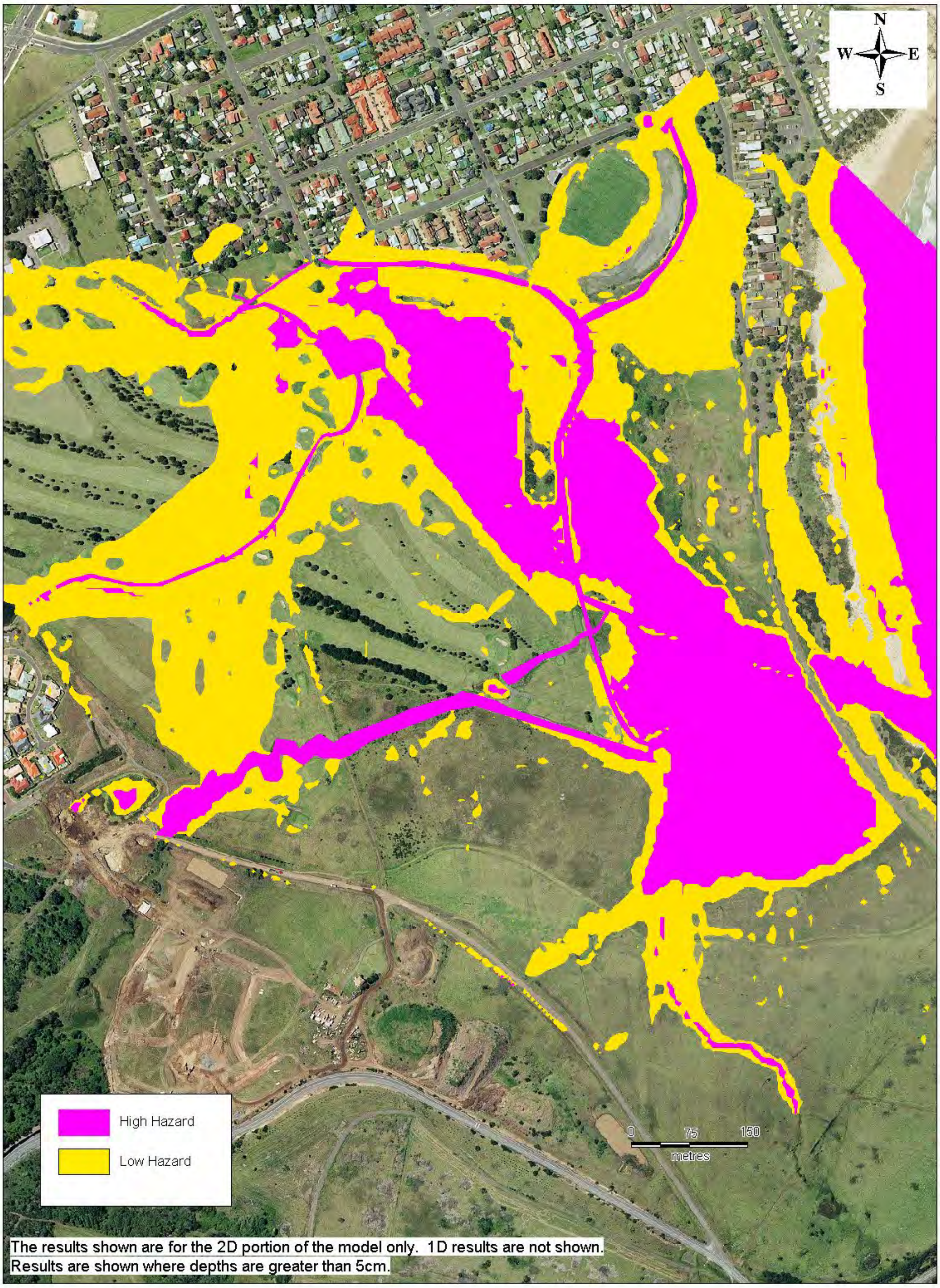


Figure 7.2 100 year ARI Provisional Hazard - Existing Scenario

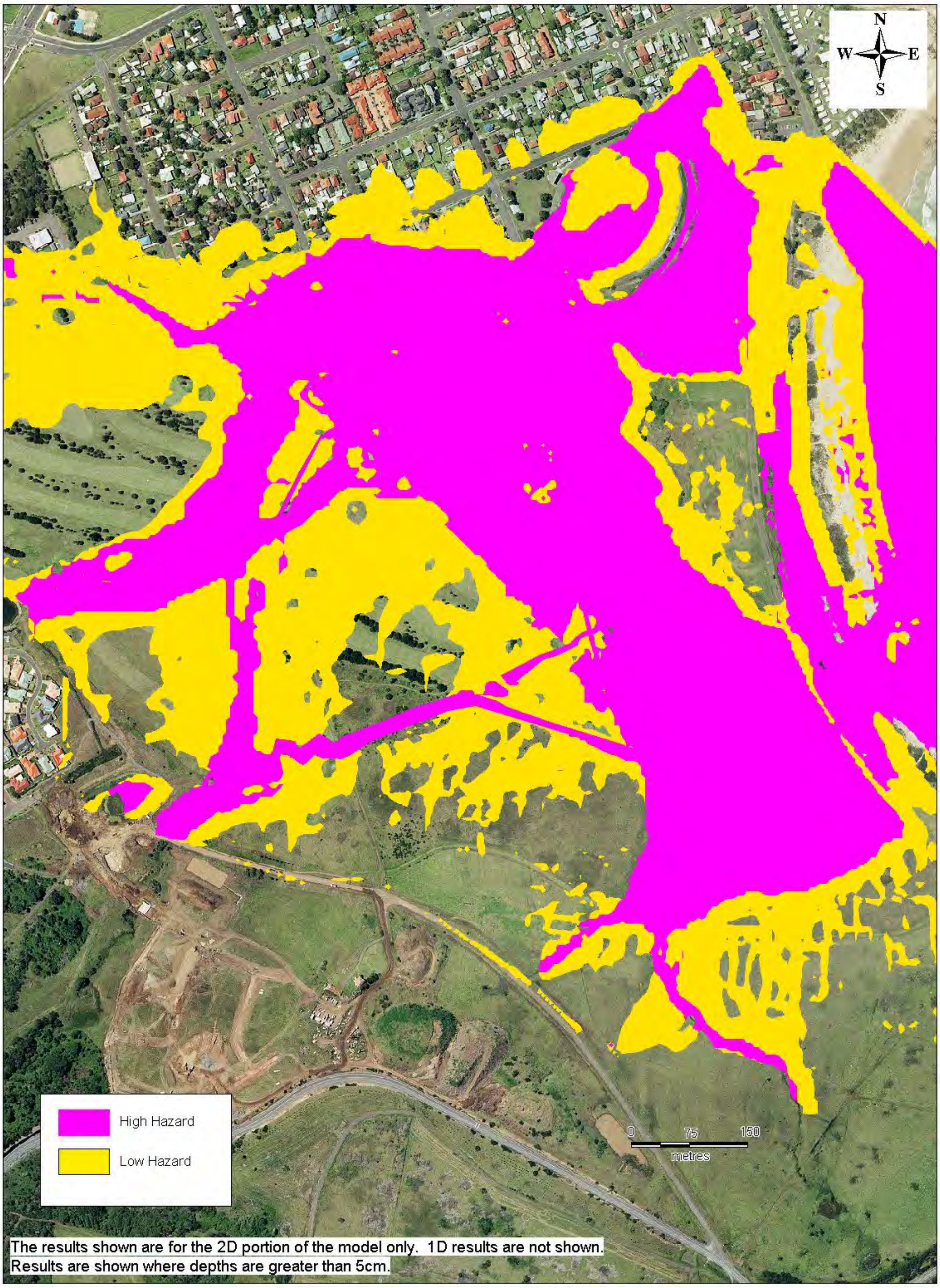


Figure 7.3 PMF Provisional Hazard - Existing Scenario

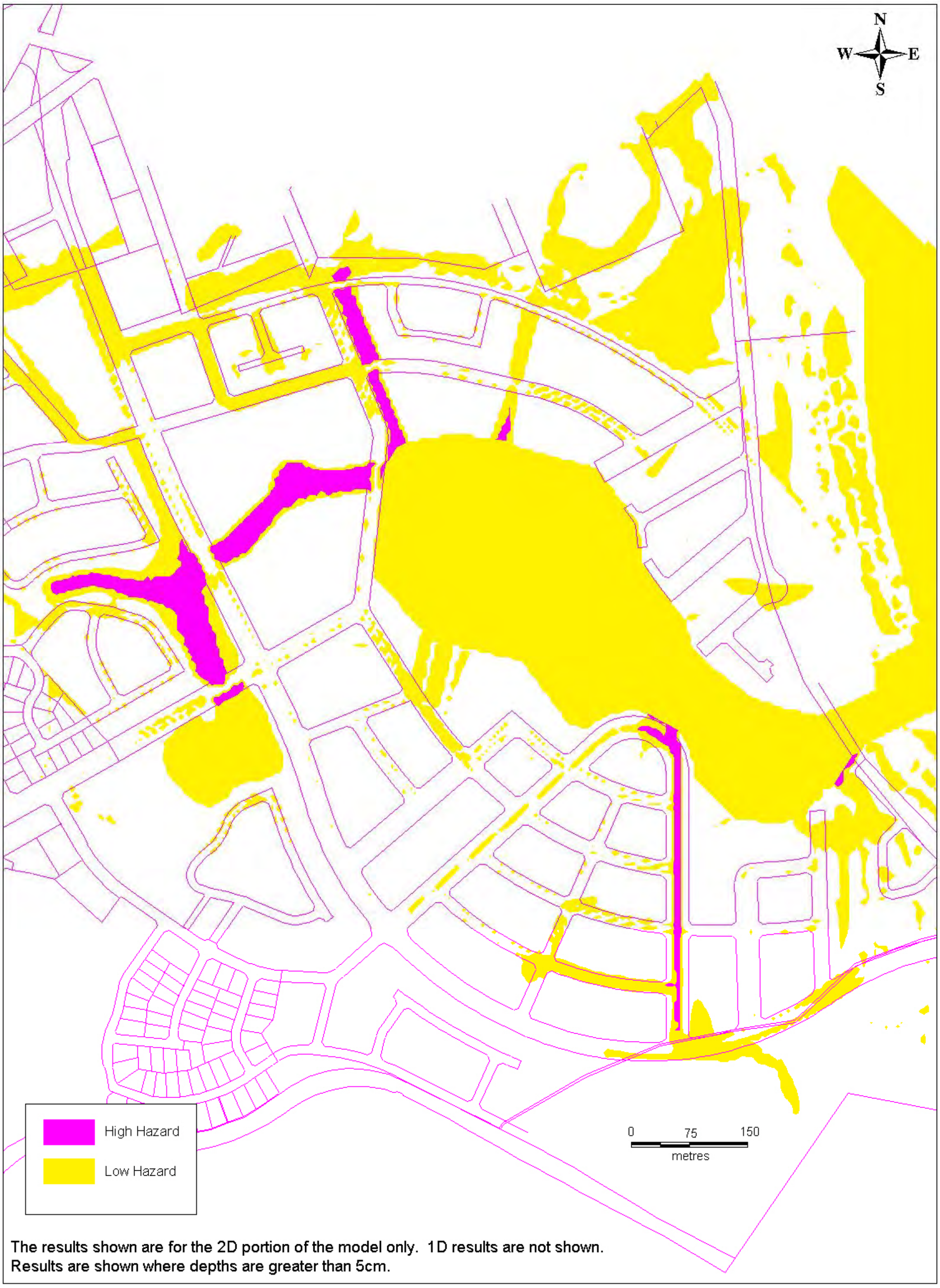


Figure 7.4 5 year ARI Provisional Hazard - Proposed Development

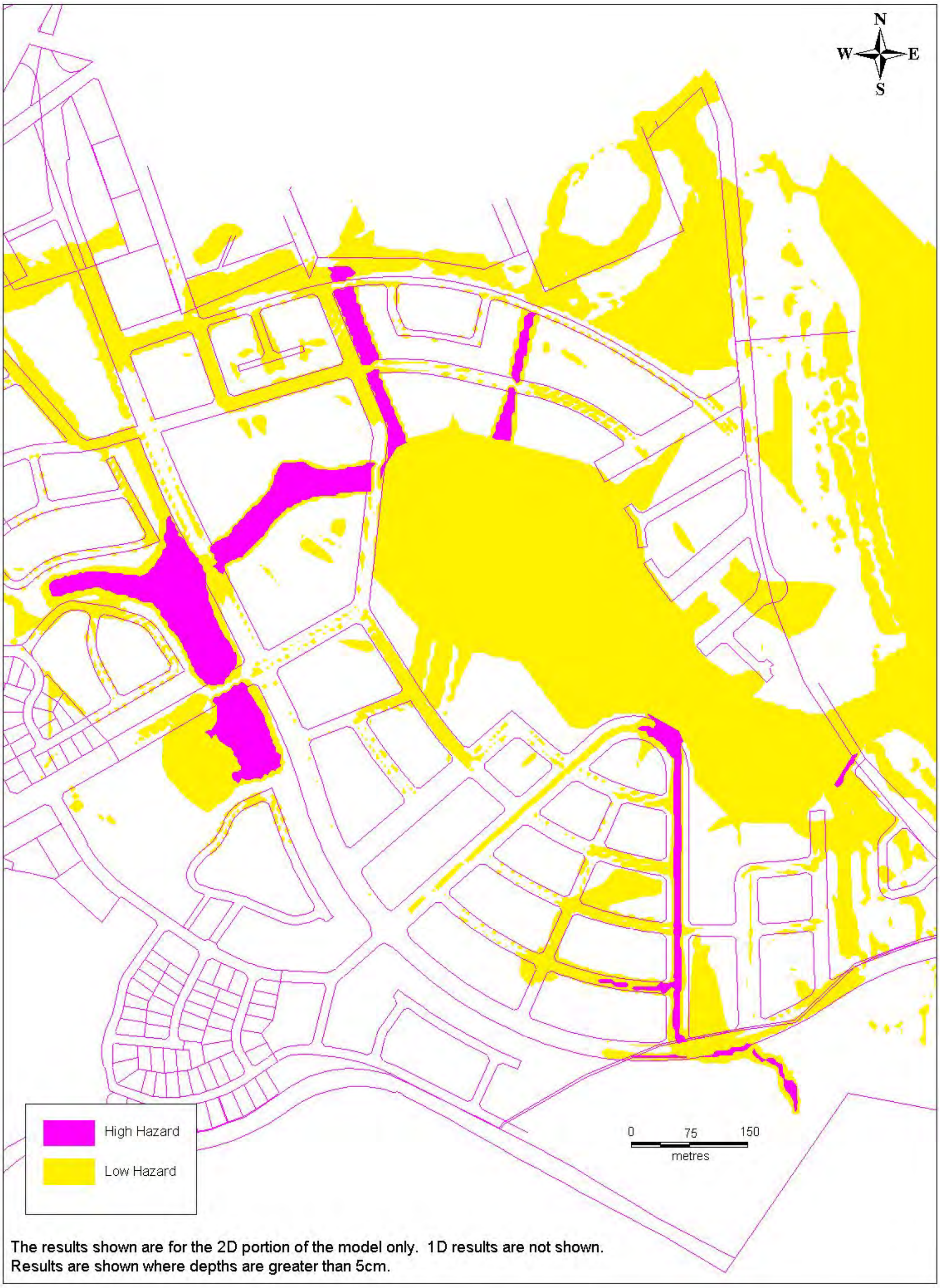


Figure 7.5 100 year ARI Provisional Hazard - Proposed Development

Figure 7.6 PMF Provisional Hazard - Proposed Development

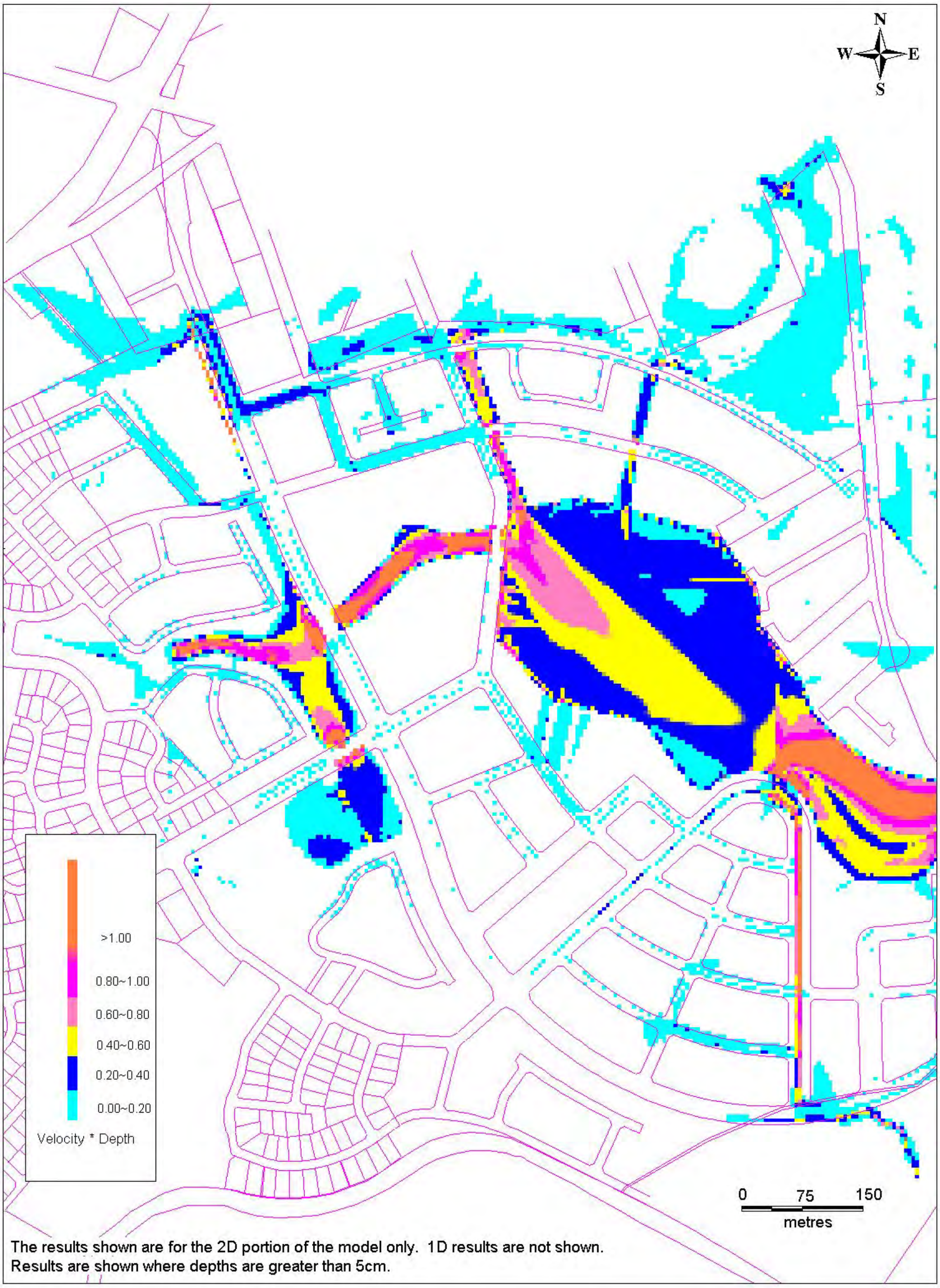


Figure 7.7 5 year ARI Velocity Depth Relationship (V×D) - Design Scenario

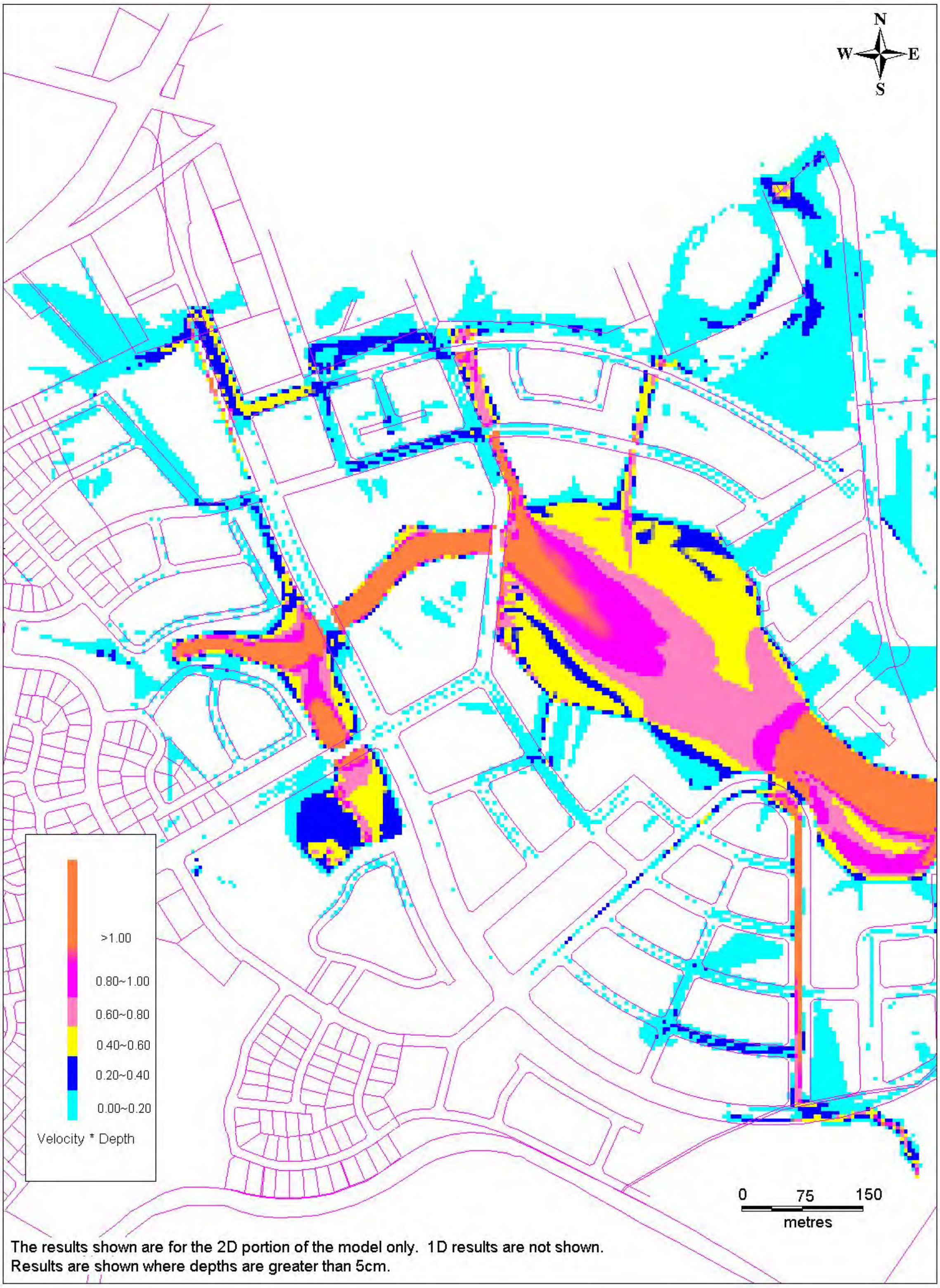


Figure 7.8 100 year ARI Velocity Depth Relationship (V×D) - Design Scenario

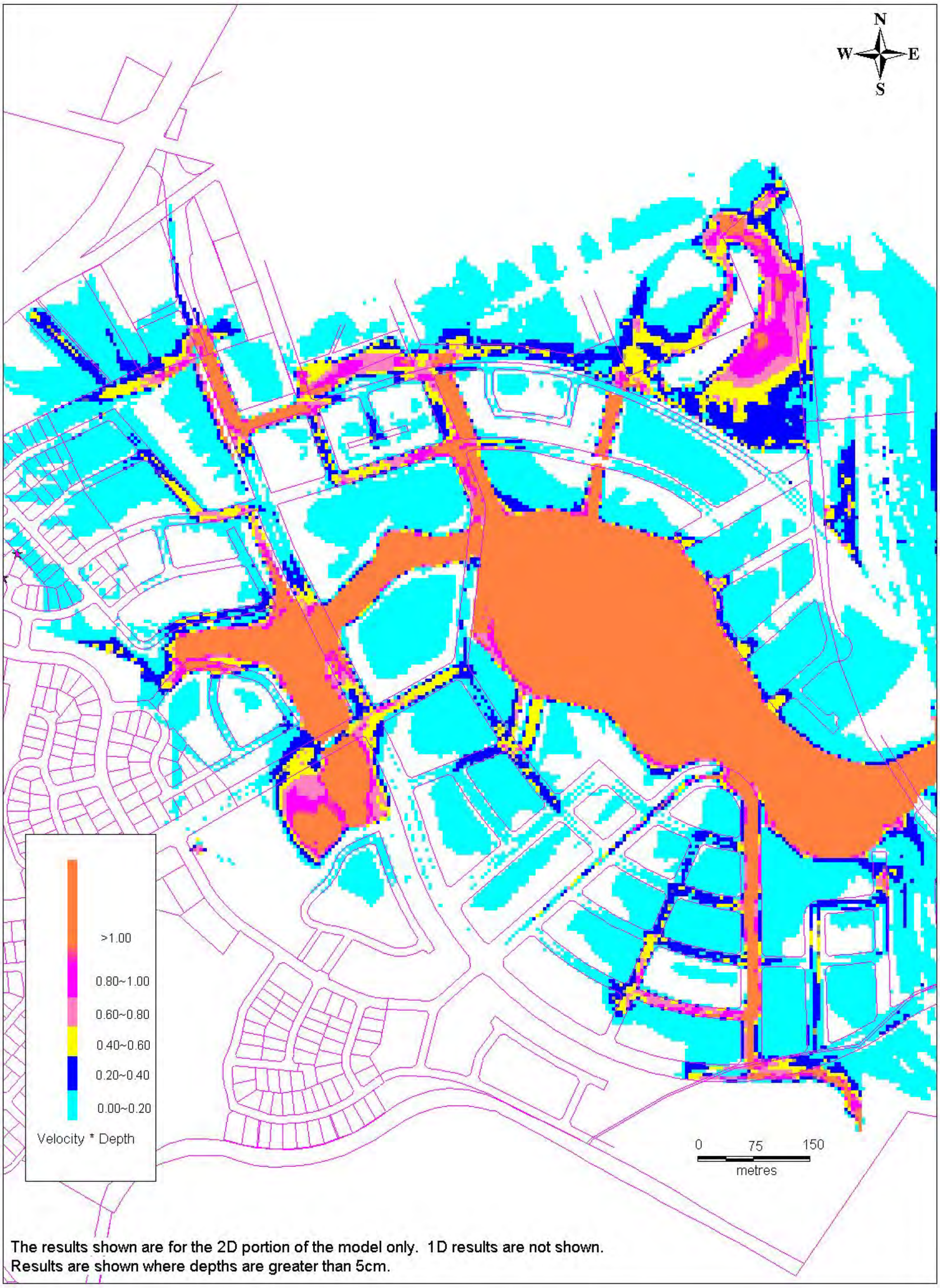


Figure 7.9 PMF Velocity Depth Relationship (V×D) - Design Scenario

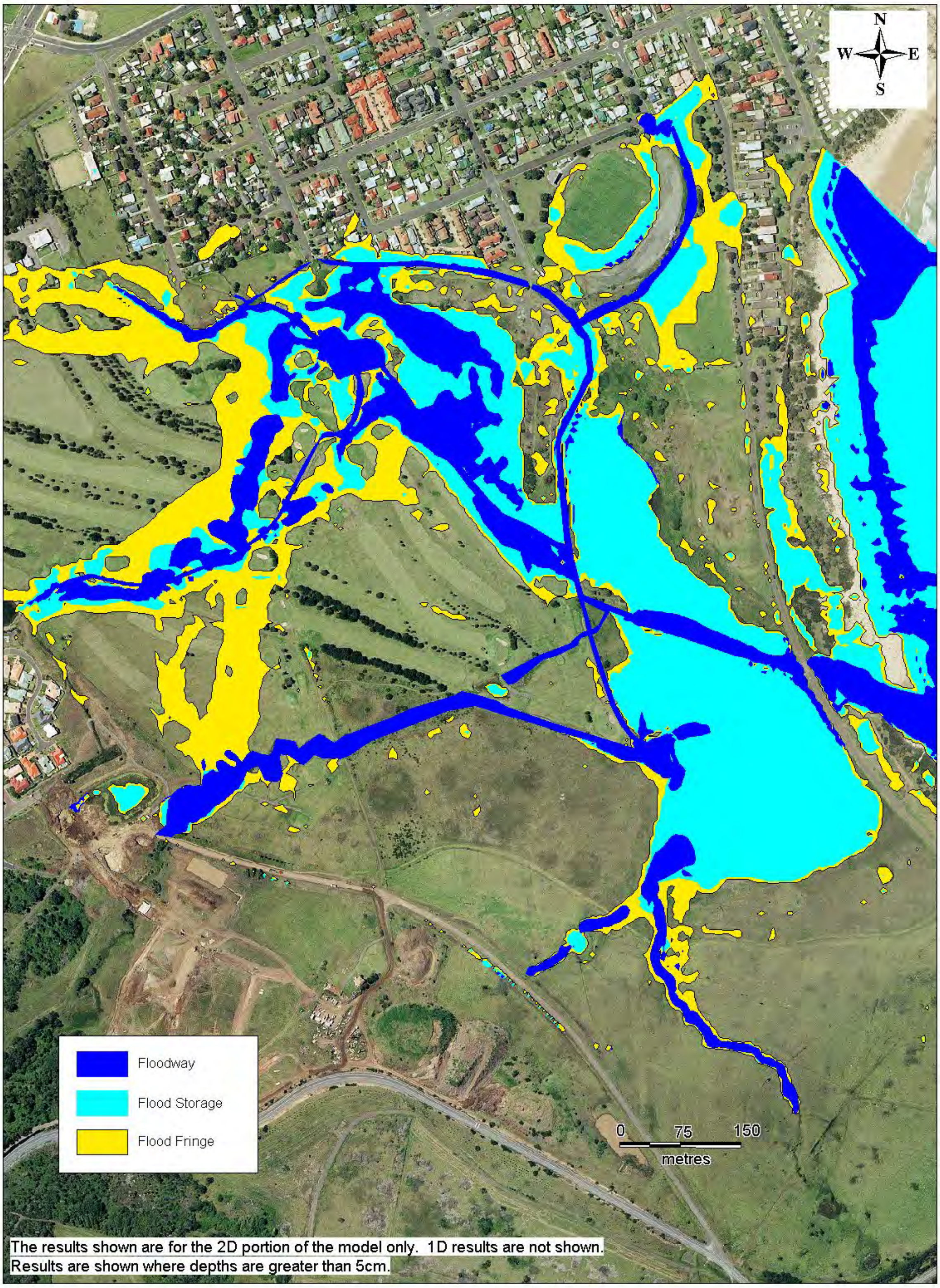


Figure 7.10 5 year ARI Hydraulic Categories - Existing Scenarios

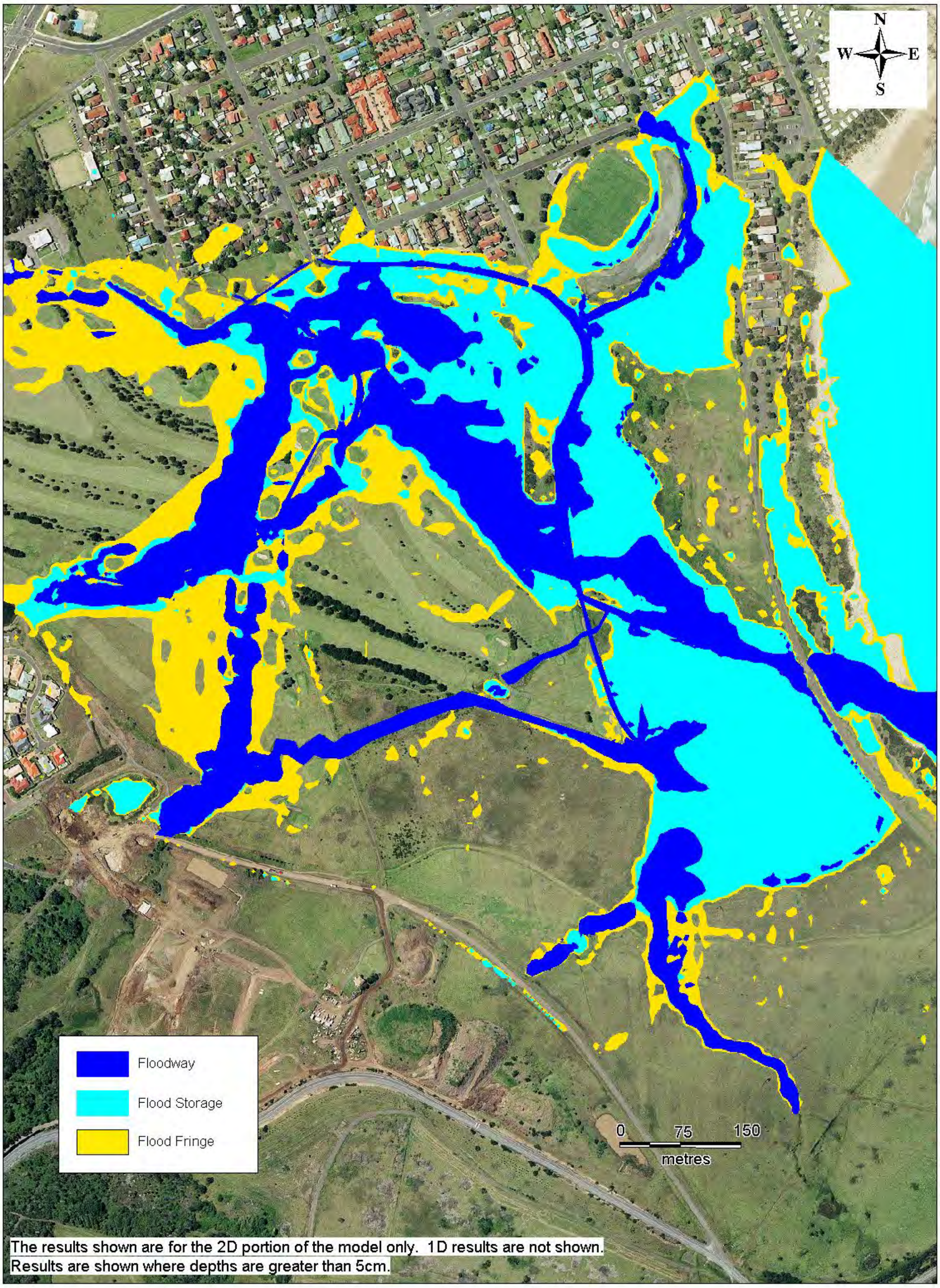


Figure 7.11 100 year ARI Hydraulic Categories - Existing Scenario

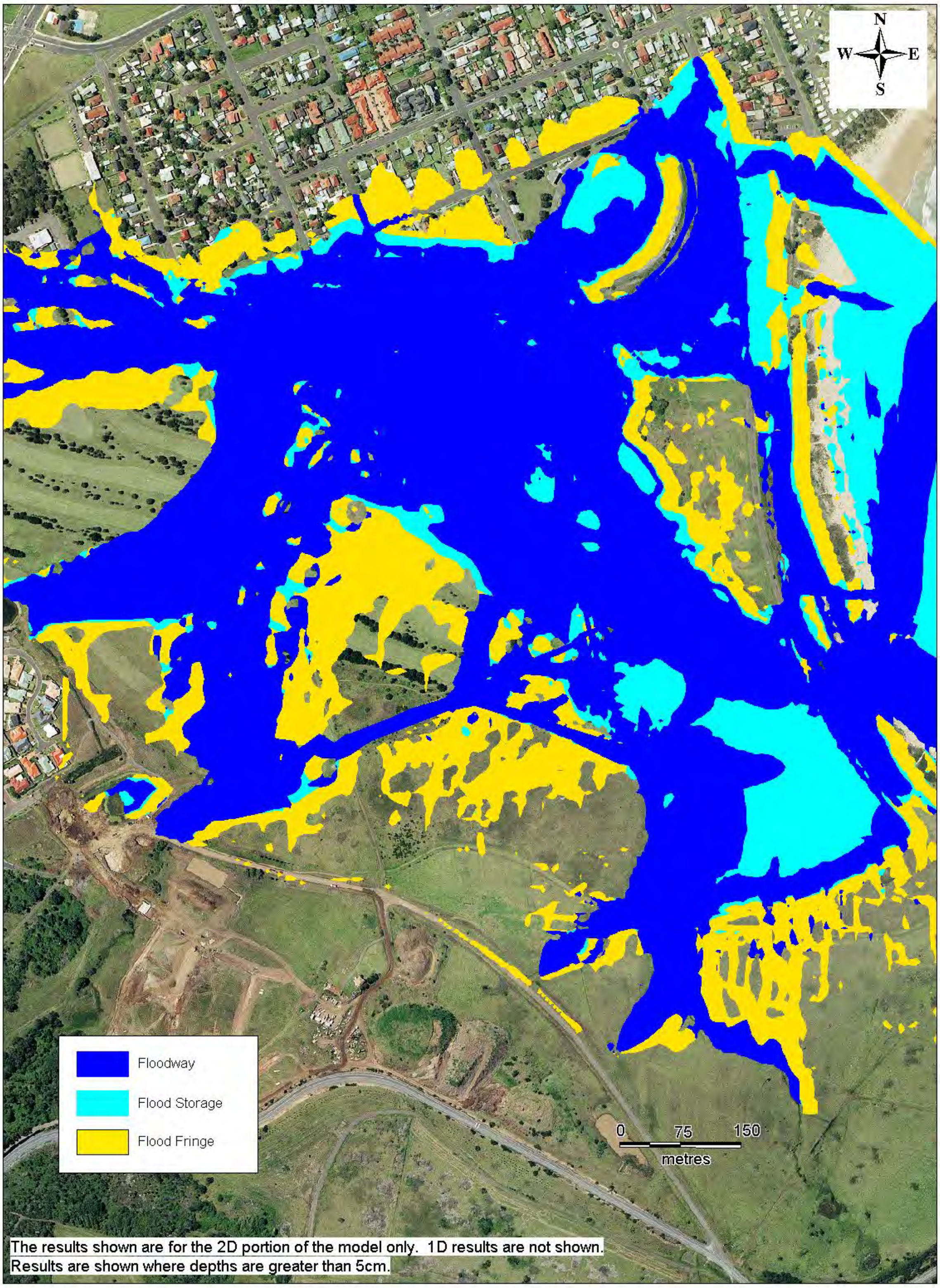


Figure 7.12 PMF Hydraulic Categories - Existing Scenario

Figure 7.13 5 year ARI Hydraulic Categories - Design Scenario

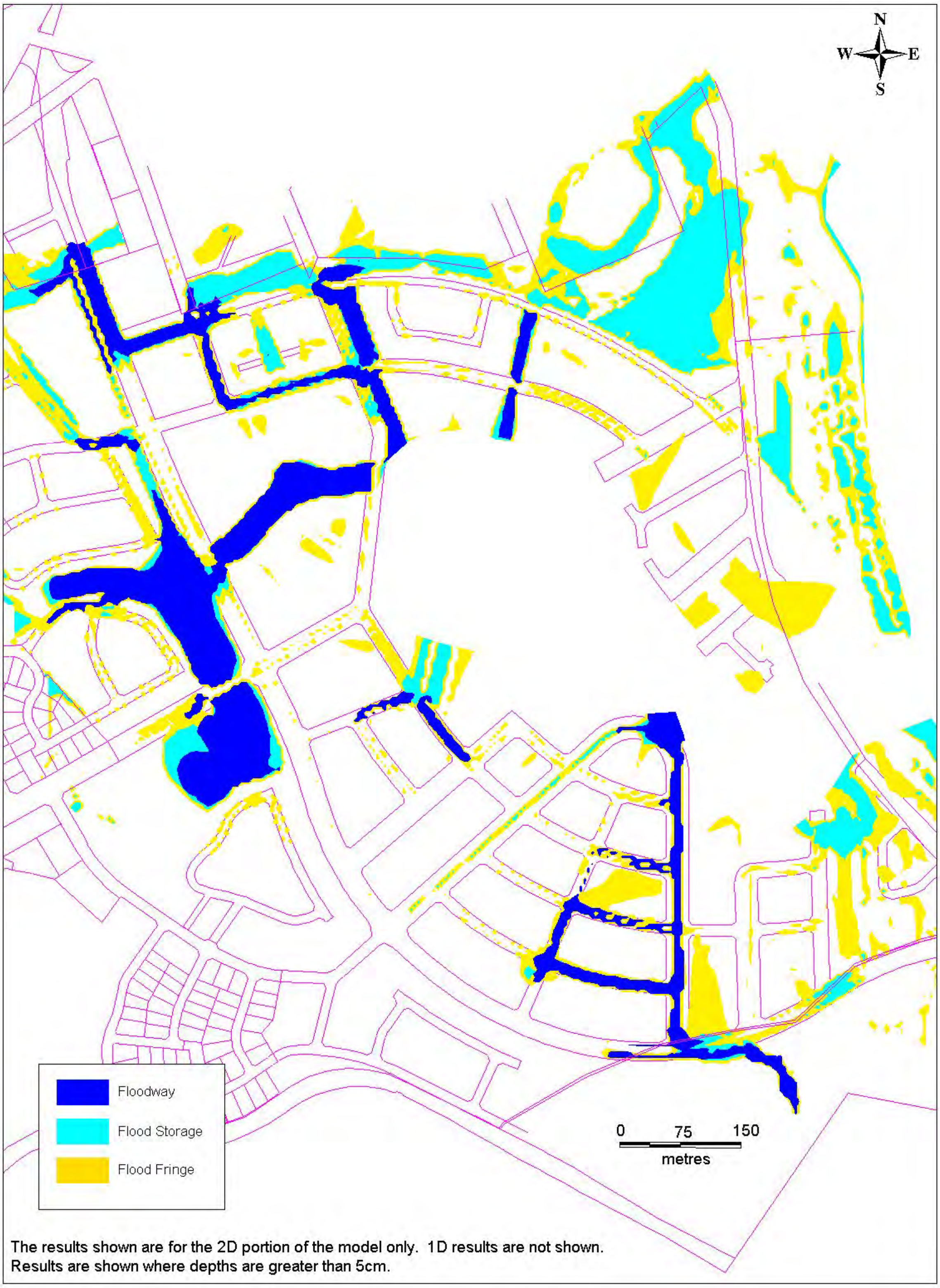


Figure 7.14 100 year ARI Hydraulic Categories - Design Scenario

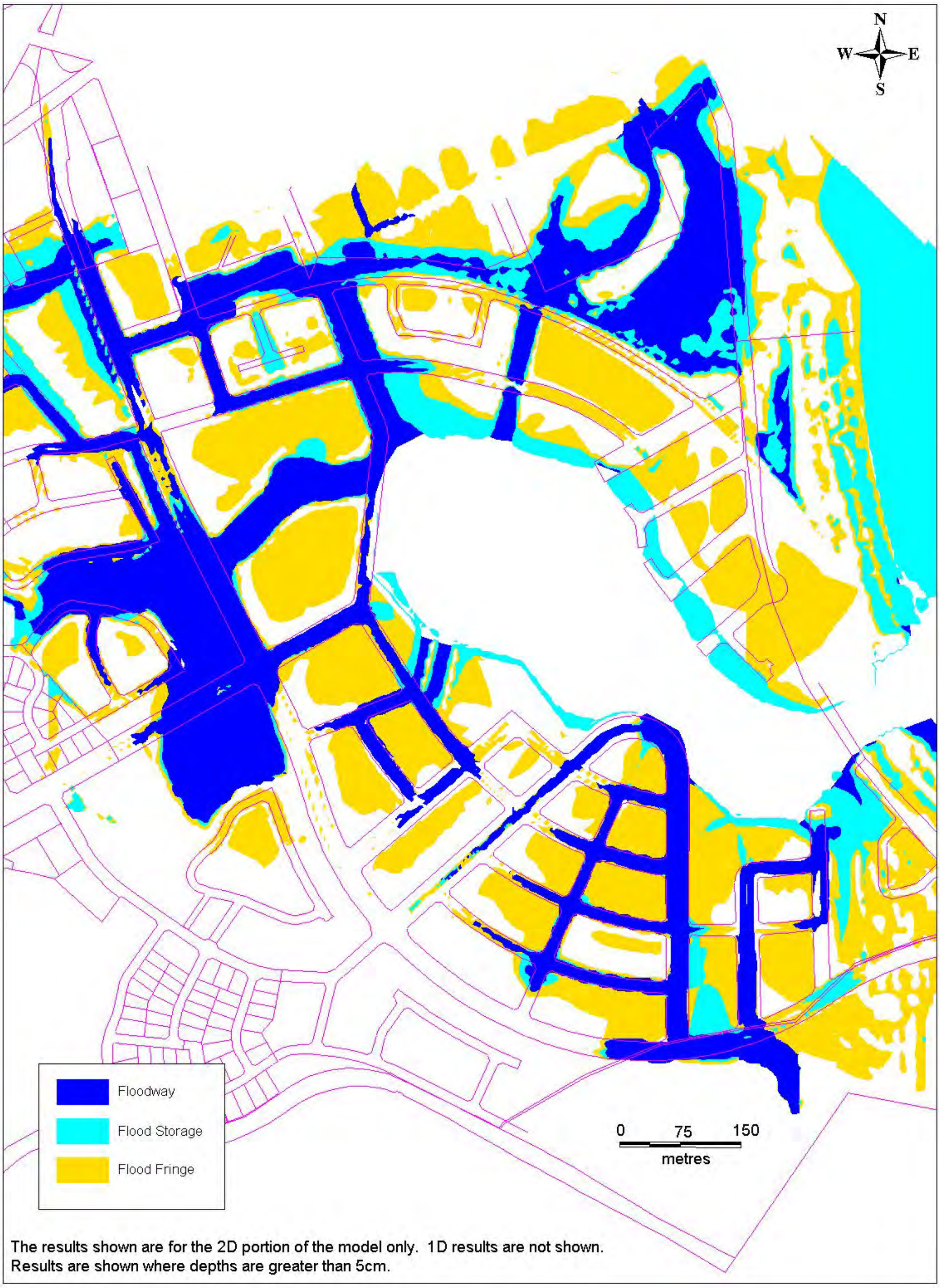


Figure 7.15 PMF Hydraulic Categories - Design Scenario

8. SENSITIVITY ANALYSIS

8.1 Climate Change

DECC (2007) recommends that climate change be considered in floodplain management. In particular, it recommends the consideration of three different rainfall scenarios and three different ocean level scenarios.

For the purposes of this study, two different scenarios were evaluated:

- Mid Range – Ocean level increase of 0.55m and 20% increase in rainfall
- High Range – Ocean level increase of 0.91m and 30% increase in rainfall.

These scenarios were evaluated utilising the 100 year ARI, 90 minute duration storm. This storm is generally critical for the proposed development area.

It is noted that the ocean level increase in the mid range scenario is the adopted level for the design events. Therefore, the mid-range sensitivity effectively assesses the impact of a 20% increase in rainfall.

The results of the climate change sensitivity runs are provided in Figure 8.1 and Figure 8.2.

Under the mid range scenario, peak water levels increase by between approximately 0.03 to 0.13m. Under the high range scenario, peak water levels increase by between approximately 0.04 to 0.36m (in the harbour area).

The climate change impacts are assessed between the design scenario with climate change and the design scenario under current conditions. No assessment has been undertaken on the impact of climate change on the existing site conditions. The assessment of climate change is focused on the adaptation of a design to the potential environmental changes that will occur in the future. As such, the existing site conditions under a climate change scenario were not assessed.

8.2 Hydraulic Roughness

A sensitivity analysis was undertaken on the assumed hydraulic roughness for the proposed development for the 100 year ARI design event. Two scenarios were analysed:

- 20% increase in hydraulic roughness
- 20% decrease in hydraulic roughness

The results of the hydraulic roughness sensitivity are shown in Figure 8.3 and Figure 8.4.

A reduction in hydraulic roughness of 20% results in a general reduction in peak water levels across the site, up to a maximum of approximately 0.25m. Localised increases are also observed as a result of hydraulically more efficient flowpaths, with a maximum of around 0.05m.

An increase in hydraulic roughness of 20% results in a general increase in the peak water levels across the site, up to a maximum of approximately 0.15m. The reduction in efficiency of the flowpaths also results in localised decreases, up to a maximum of approximately 0.10m.

It is noted that changes to the assumed roughness values to not alter the expected flooding in the existing Shellharbour Village

8.3 Culvert Blockage

A sensitivity analysis was undertaken on the potential impact of culvert blockage within the development for the 100 year ARI design event.

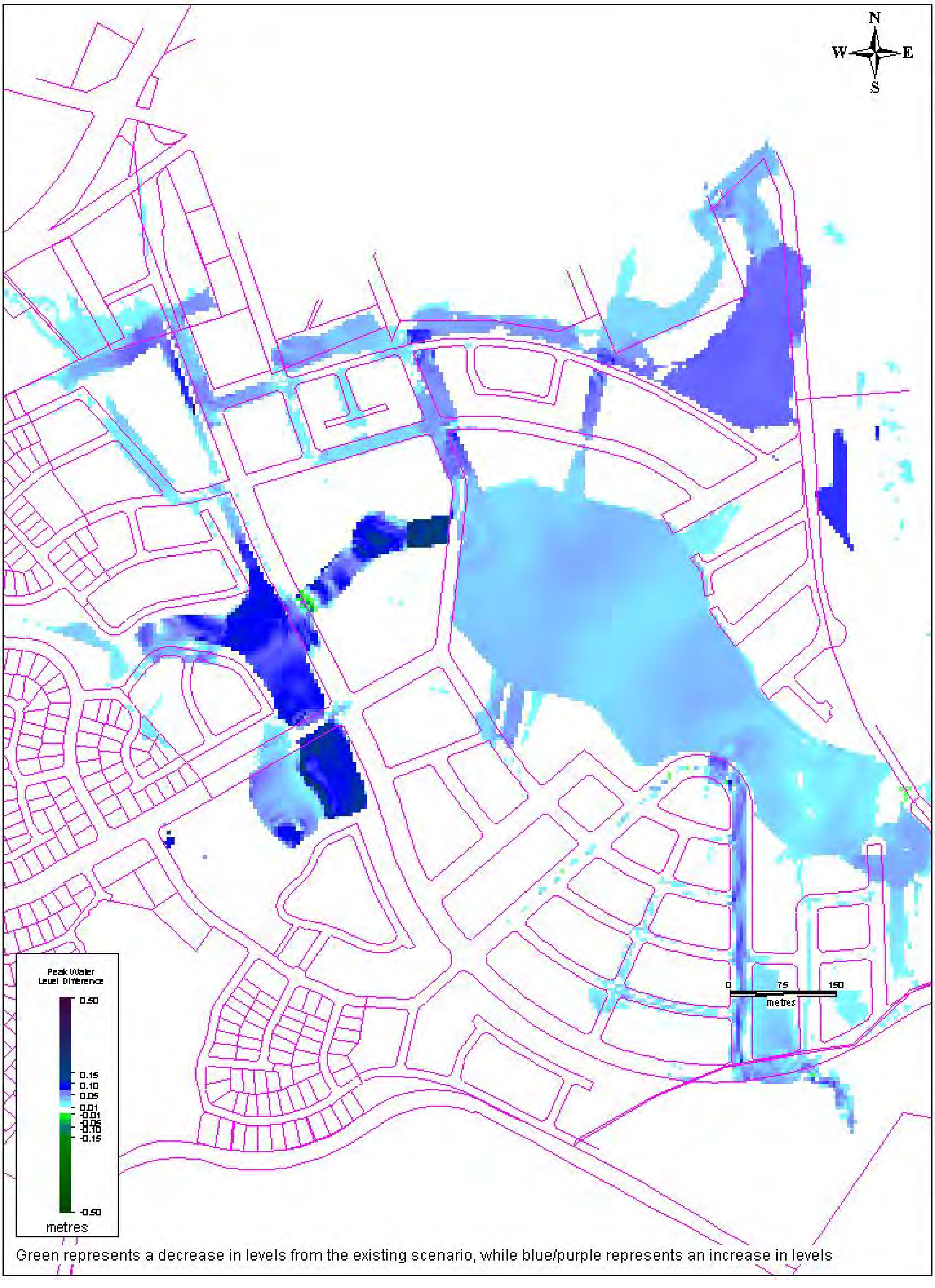
The existing pipe under the Ron Costello Oval area was assumed to be 100% blocked for the purposes of the analysis. However, given the relatively large dimensions of the proposed bridges and culverts within the proposed development, it was conservatively assumed that these were 50% blocked.

The results of the culvert blockage analysis are shown in Figure 8.5.

The culvert blockage scenario shows an increase in peak water levels upstream of the culverts within the study area, with increases generally less than 0.10m and a maximum increase of approximately 0.50m on the main western flowpath near the discharge point to the Boat Harbour. There is also the potential for culvert blockage to affect the existing Shellharbour Village, with a blockage in the two northern culverts resulting in an increase in peak water levels in this area of between 0.05 to 0.10m.

It is recommended that potential sources of debris be assessed and options be investigated to reduce the risk of blockage of these culverts. These options might include periodic cleaning of debris from local channels as well as trash racks or relatively large culvert dimensions.

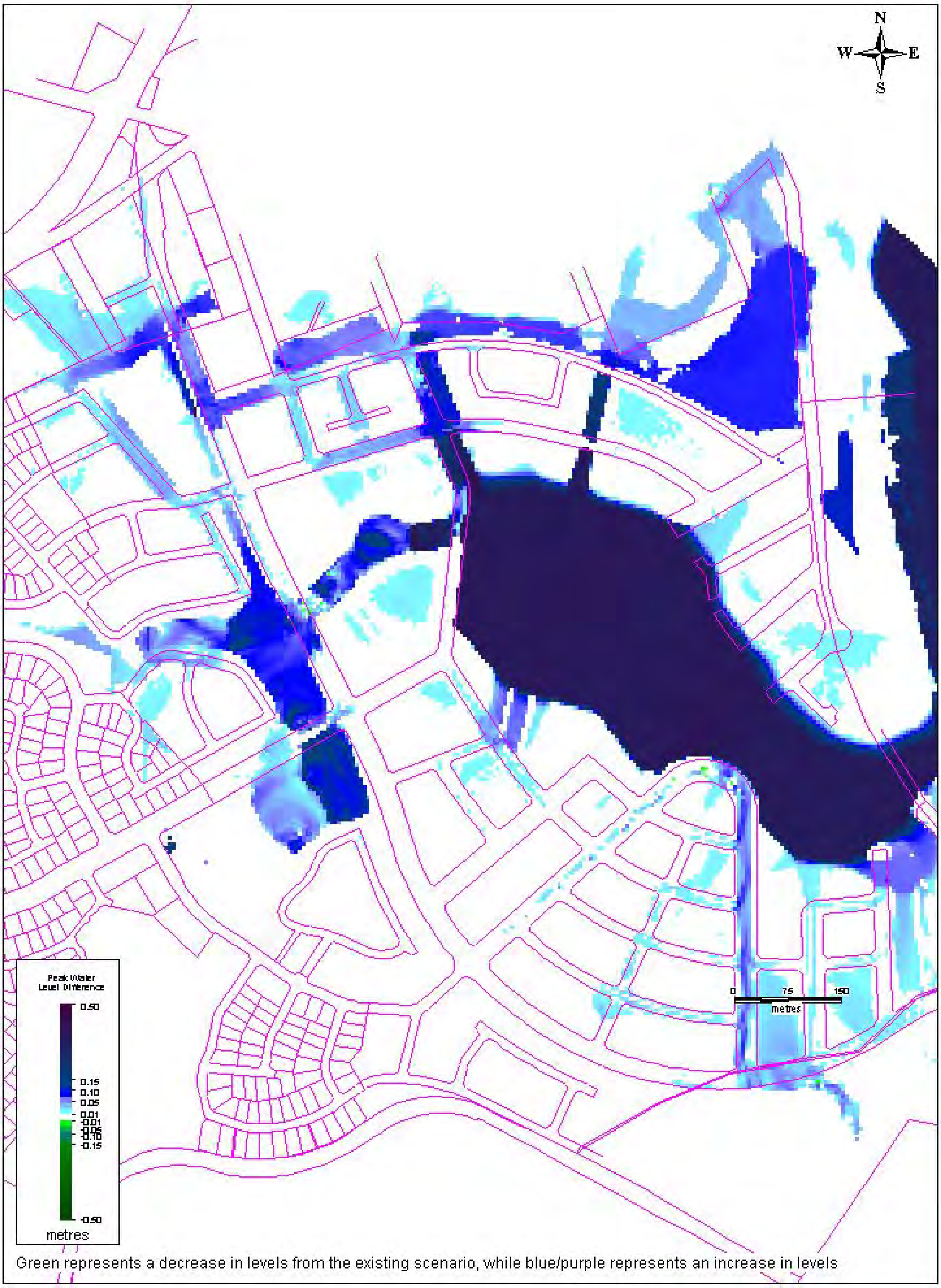
It should be noted that the increases in peak water levels in the Ron Costello Oval area would primarily be the result of the blockage of the pipes in this area, which are not part of the proposed development.



Blue represents an increase in peak water levels as a result of climate change

Figure 8.1 100 year ARI Climate Change Impacts on Developed Scenario - Mid Range

Mid Range = 20% increase in rainfall intensity, 0.55m increase in ocean level
Base Case = 0.55m increase in ocean level



Blue represents an increase in peak water levels as a result of climate change

Figure 8.2 100 year ARI Climate Change Impacts on Developed Scenario - High Range

High Range = 30% increase in rainfall intensity, 0.91m increase in ocean level
Base Case = 0.55m increase in ocean level

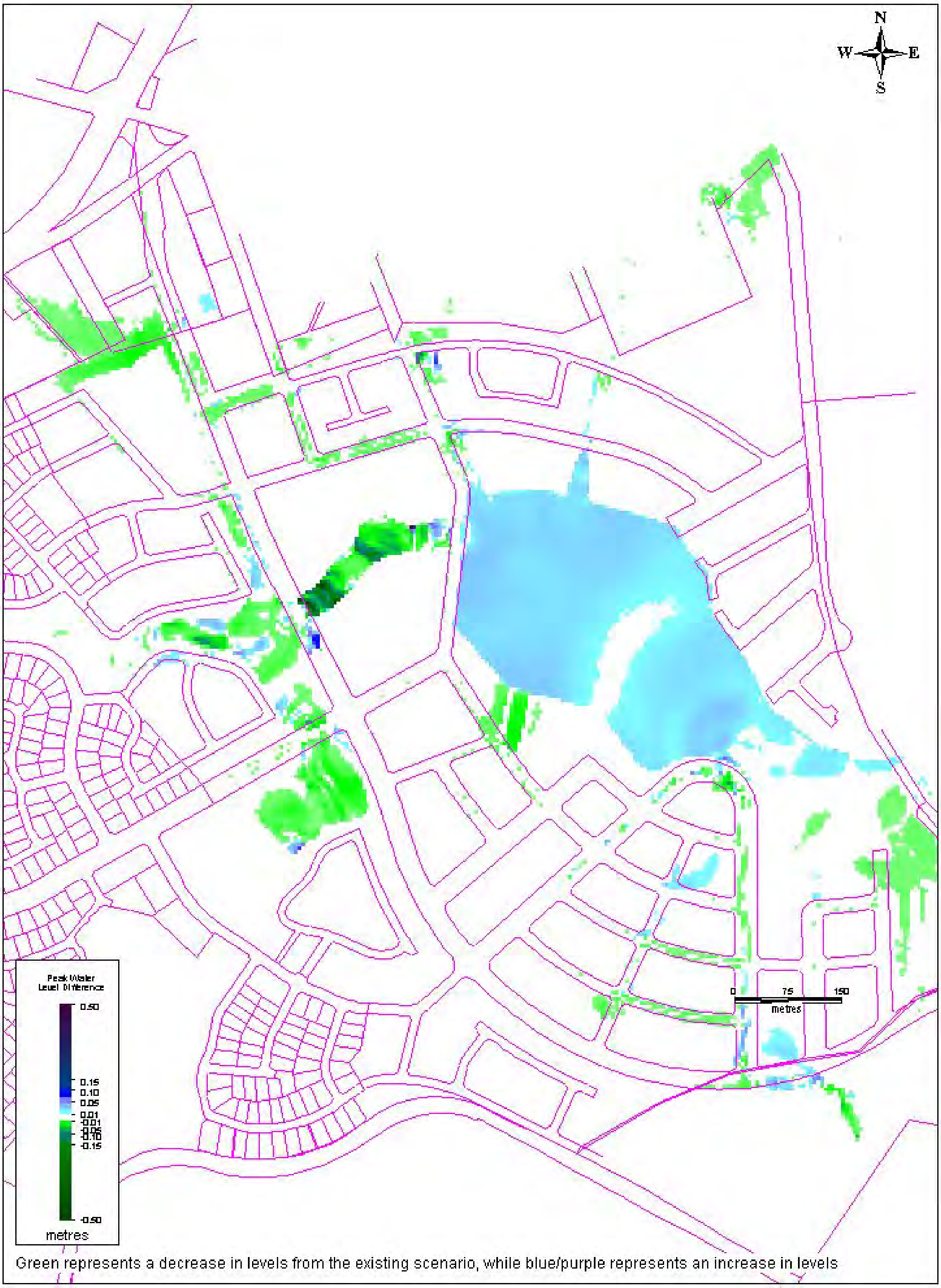


Figure 8.3 100 year ARI Sensitivity – 20% Reduction in Roughness

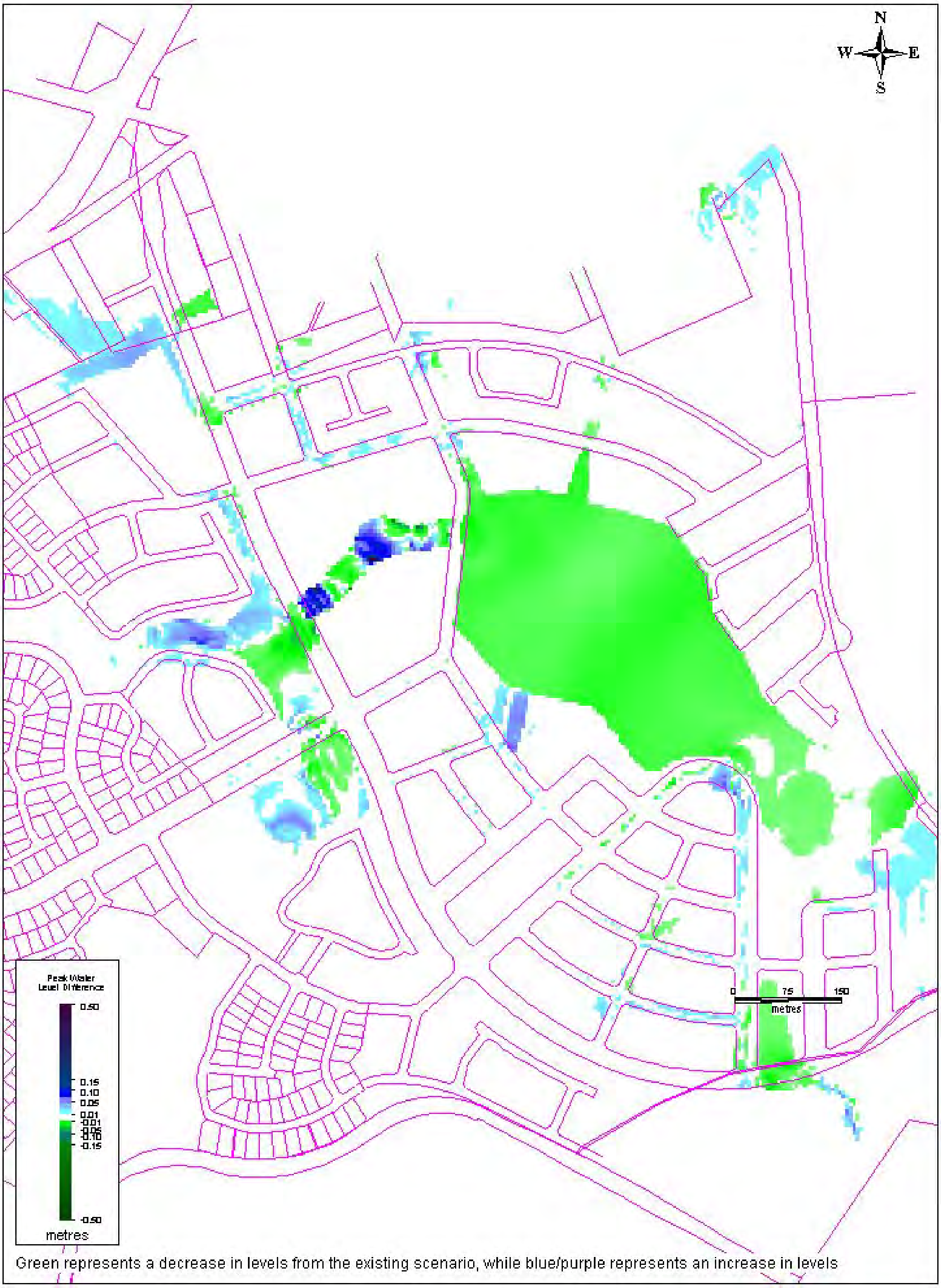


Figure 8.4 100 year Sensitivity - 20% Increase in Roughness

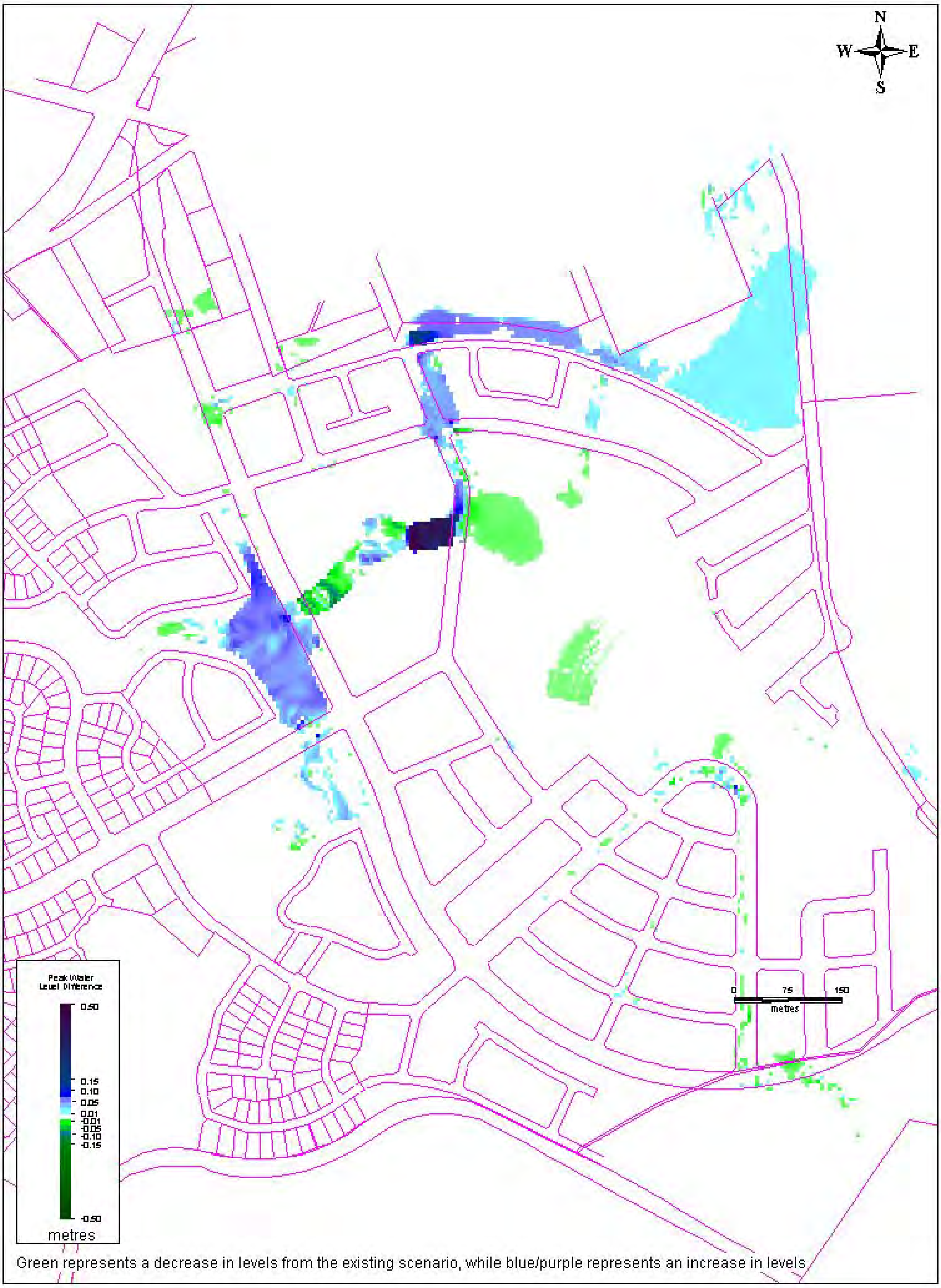


Figure 8.5 100 year ARI Sensitivity - Culvert Blockage

9. CONCLUSIONS

A flood analysis has been undertaken on the proposed development, as provided by Australand and Worley Parsons. This analysis was undertaken utilising a model that was developed for the study area as a part of a previous project (Cardno Lawson Treloar [1], 2005).

The results of the analysis suggest that the proposed development would impact on flood levels in the 100 year and 5 year events, in the vicinity of Ron Costello Oval. Whilst this impact is not considered significant, it could be addressed by either

- Reducing the invert of the north eastern flowpath, or;
- Providing a pipe, connecting upstream of the north eastern flowpath with the harbour.

Impacts in the PMF event are observed in the north west and south east of the proposed development. However, in both cases the impacts are within future development areas, and should be able to be managed as a part of the design process. It is noted that the proposed development would reduce the peak water levels in the existing Shellharbour Village.

An analysis of the provisional hazard in the study area shows that the high hazard, as defined by the Floodplain Development Manual (NSW Government, 2005), is primarily limited to the designated overland flow paths in the 5 year ARI and 100 year ARI design events. It is noted that the two northern flowpaths, which are intended for open space areas, should provide suitable grades to allow for adequate evacuation of these areas during a design flood event.

There is also an area of high provisional hazard in the 100 year ARI event along one of the roads in the southern portion of the proposed development. As discussed in the report, the hazard may be reduced by the inclusion of a stormwater network but the grades in this area would make it difficult to remove this area of high hazard completely. However, this area of high hazard is primarily contained with a central swale in the road, specifically designed for this purpose.

A sensitivity analysis for climate change, hydraulic roughness and culvert blockage has been undertaken. Peak water level increases, both within the development and within the existing Shellharbour Village, are generally between 0.03 to 0.23m. Maximum increases of approximately 0.36m occur as a result of climate change within the boatharbour waterway. Under a culvert blockage scenario, maximum increases of approximately 0.50m are observed on the main western flowpath near the discharge point to boatharbour. It is recommended to investigate options for debris control to minimise the risk of culvert blockage.

10. QUALIFICATIONS

- This report is subject to the same assumptions and qualifications as per Cardno Lawson Treloar [1] (2005).
- This report has been based upon design information supplied by both Worley Parsons and Australand (refer Section 3.2). The accuracy of the results are therefore dependent on the accuracy of the data supplied.
- The results of this report only apply to the design as stated. Any changes to the design will result in changes to the expected flood behaviour.

11. REFERENCES

BMD Consulting Pty Ltd (2004). *Shell Cove, Shellharbour Village, Stormwater Drainage Infrastructure Report*, November, prepared for Australand Pty Ltd.

Cardno Lawson Treloar (2006). *Shell Cove Boat Harbour Catchment Flood Study : PMF Analysis for Preliminary Design*, April, J2407/R2263/v1, prepared for Australand.

Cardno Lawson Treloar [1] (2005). *Shell Cove Boat Harbour Catchment Flood Study*, November, Issue No. 2, Final, J2407/R2208/v2, prepared for Australand.

Cardno Lawson Treloar [2] (2005). *Elliot Lake – Little Lake Flood Study*, July, Issue No. 4, LJ1959/R1974/V4, Final Draft, prepared for Shellharbour City Council.

Department of Environment & Climate Change [DECC] (2007). *Practical Considerations of Climate Change*, October.

Hanslow D, Davis G, You B & Zastawny J (2000). *Berm Height at Coastal Lagoon Entrances in NSW*, November, 10th Annual NSW Coastal Conference, Yamba.

NSW Government (2005). *Floodplain Development Manual*, April.

Appendix A

Revised Bowling Club Assessment

Revised Flood Assessment near Bowling Club

In May 2009, minor maintenance works were undertaken to drainage channels in the vicinity of an area to the south of the Shellharbour Bowling Club. A detailed survey was subsequently undertaken in this area reflecting the completed maintenance works and a more accurate ground survey in this location.

The ground survey (SCSTG8RV.DXF) was provided to Cardno Lawson and Treloar on 15 May 2009. The survey was incorporated into the existing model to assess the impacts of the updated information. The model was run for the 100 year 90 minute duration, which is the critical duration for this area.

Overall, there is a general reduction in peak water levels within the area (Figure A1). Reductions of up to 0.5m in peak water level are observed, generally as a result of the revised survey data. Some increases in peak water level are observed but these impacts are localised. The maximum increase in peak water level is 0.1m.

Generally, the changes to the 100 year flood extent are minimal. However, it is noted that the reductions in peak flood levels in the area have resulted in the Bowling Club property being excluded from the 100 year flood extent (refer Figure A2).

Revised extents and results for this area are provided in the following figures:

Figure A1 – 100 year 90 minute Peak Water Level Difference
Figure A2 – 100 year 90 minute Extent – post May 2009 Ground Survey
Figure A3 – 100 year 90 minute Peak Water Level – post May 2009 Ground Survey
Figure A4 – 100 year 90 minute Peak Depth – post May 2009 Ground Survey
Figure A5 – 100 year 90 minute Peak Velocity – post May 2009 Ground Survey

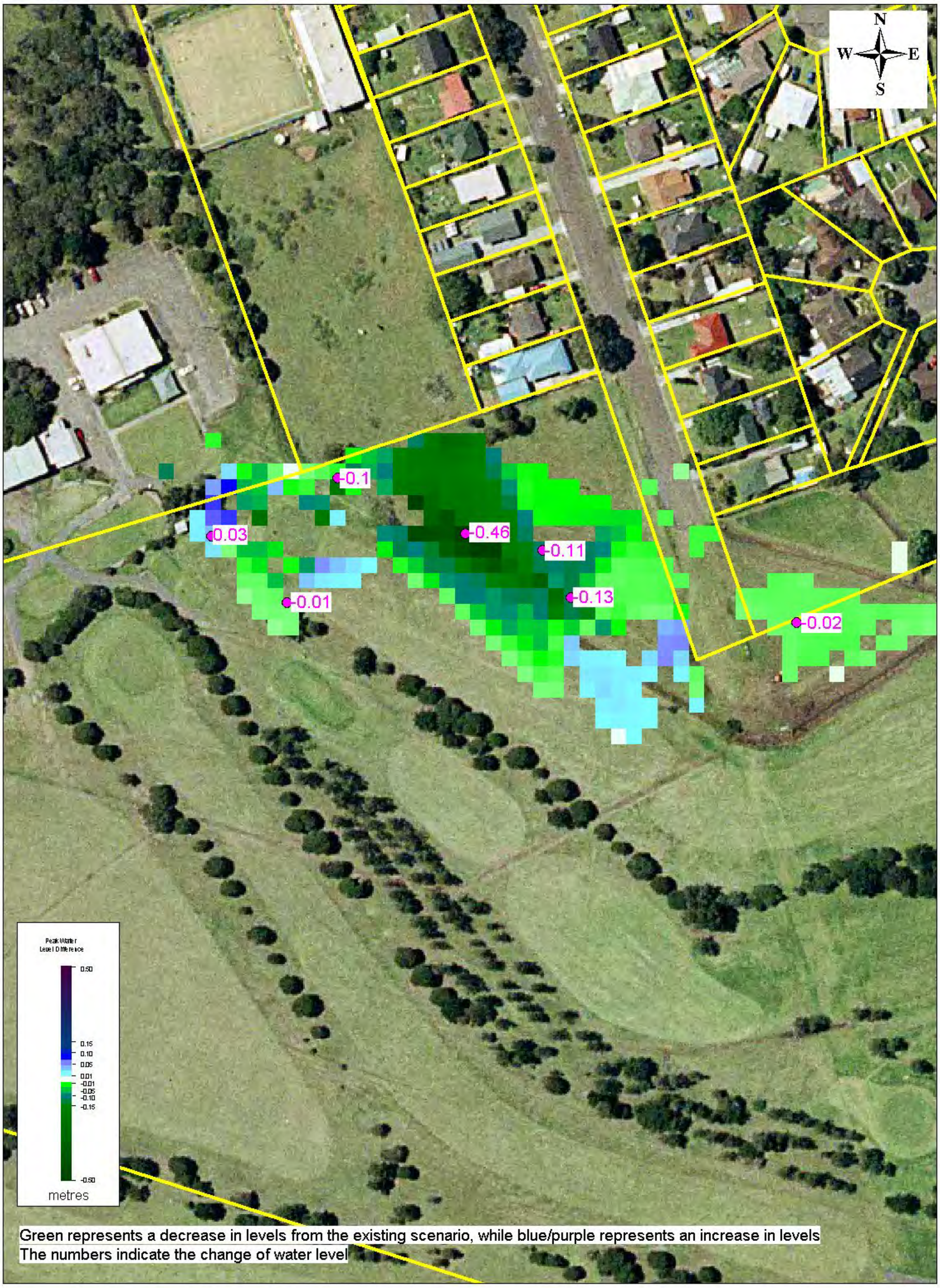


Figure A1. 100 year 90 minute Peak Water Level Difference – post May 2009 Ground Survey

Figure A2. 100 year 90 minute Extent – post May 2009 Ground Survey

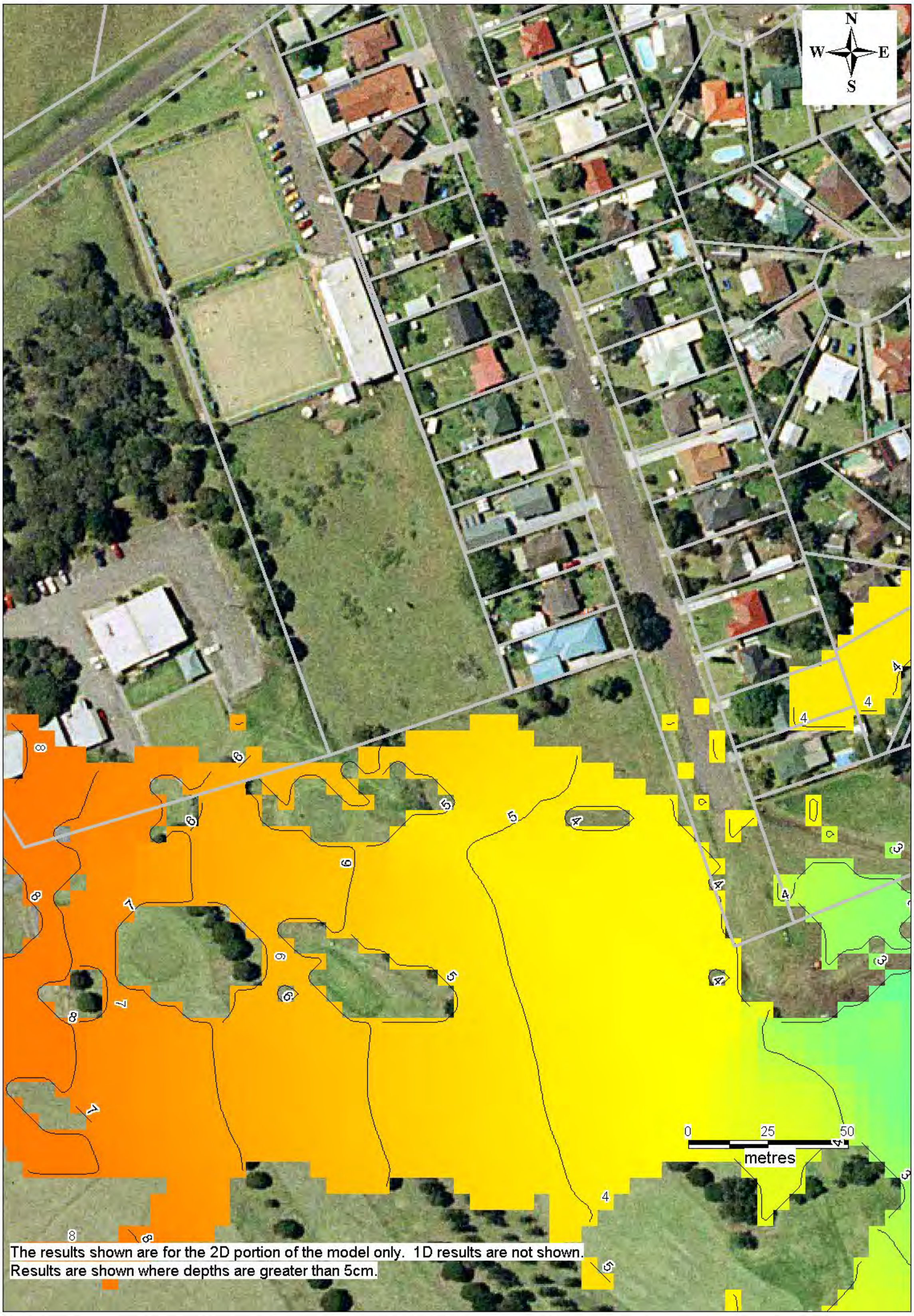


Figure A3 – 100 year 90 minute Peak Water Level – post May 2009 Ground Survey

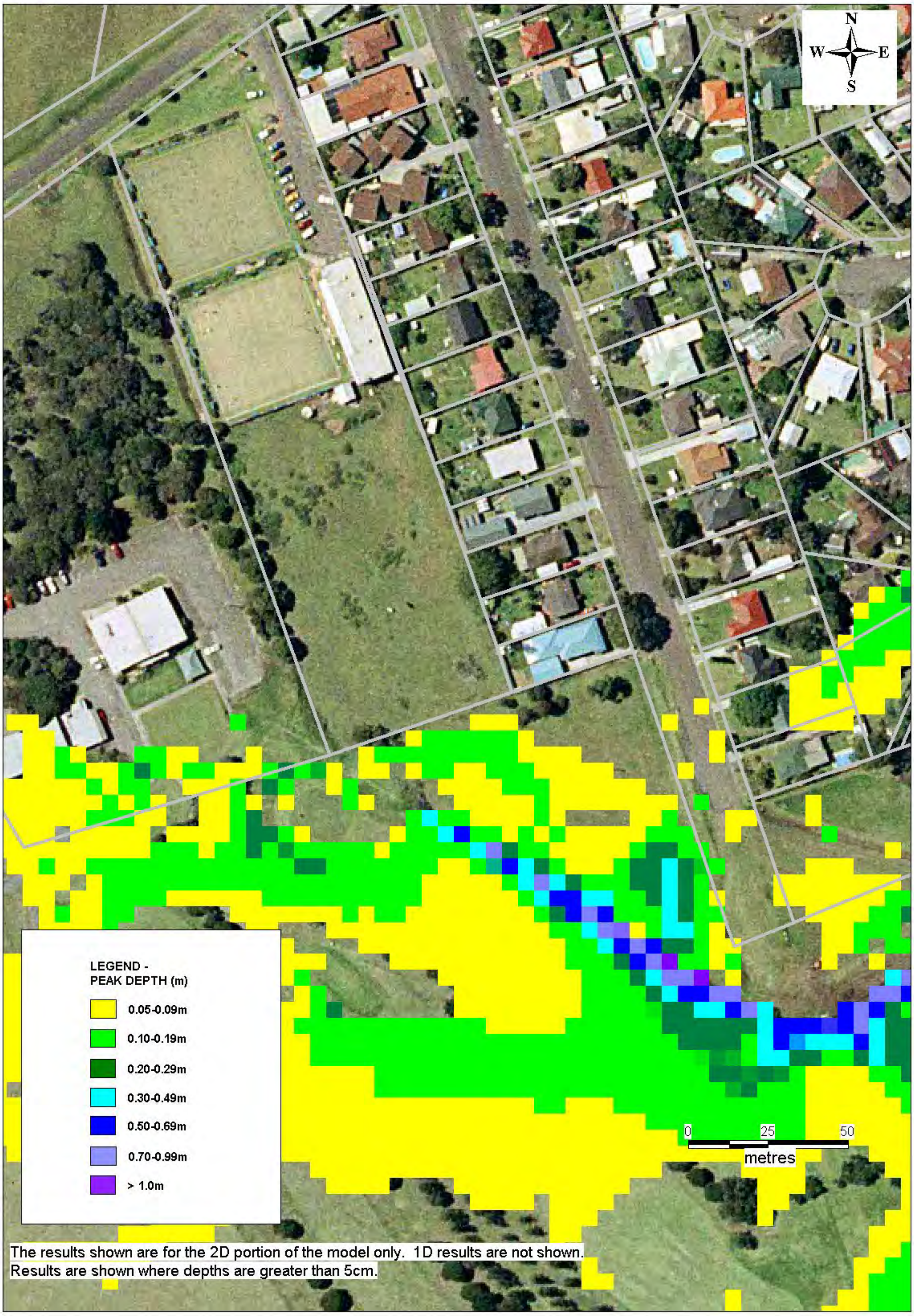


Figure A4 – 100 year 90 minute Peak Depth – post May 2009 Ground Survey

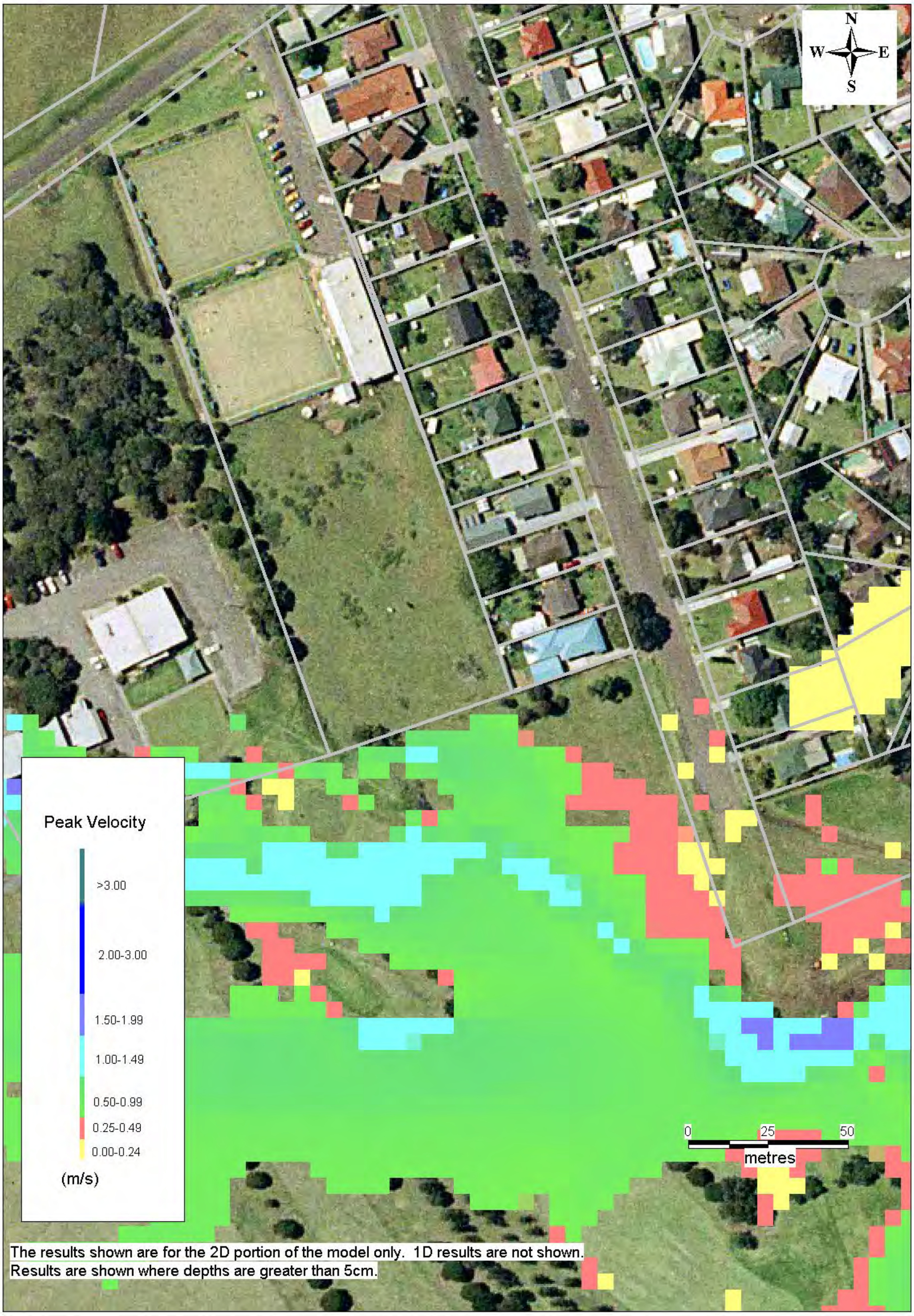


Figure A5 – 100 year 90 minute Peak Velocity – post May 2009 Ground Survey