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.

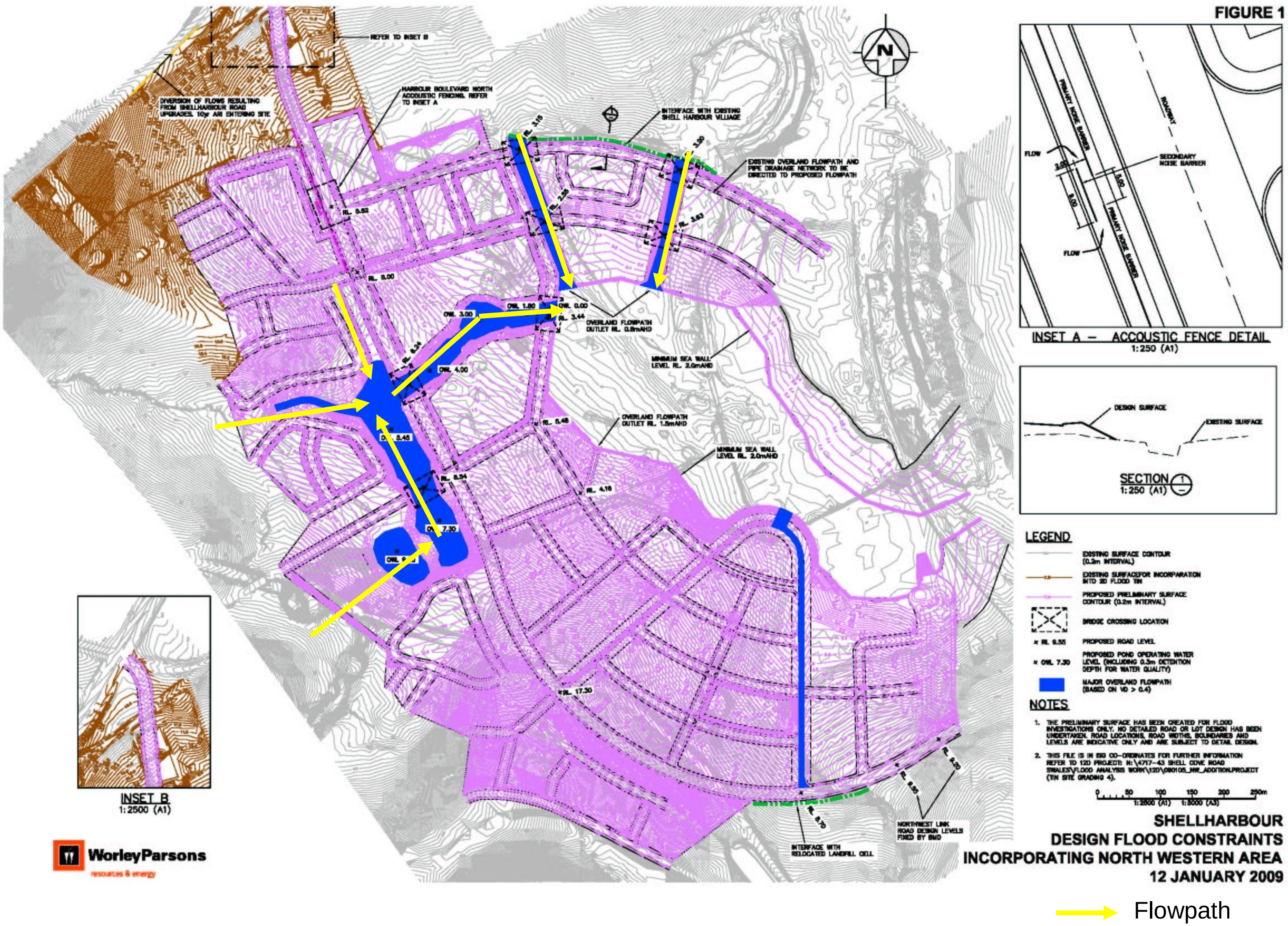

Figure 2.1 Formalised Flowpaths in the Proposed Development

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).

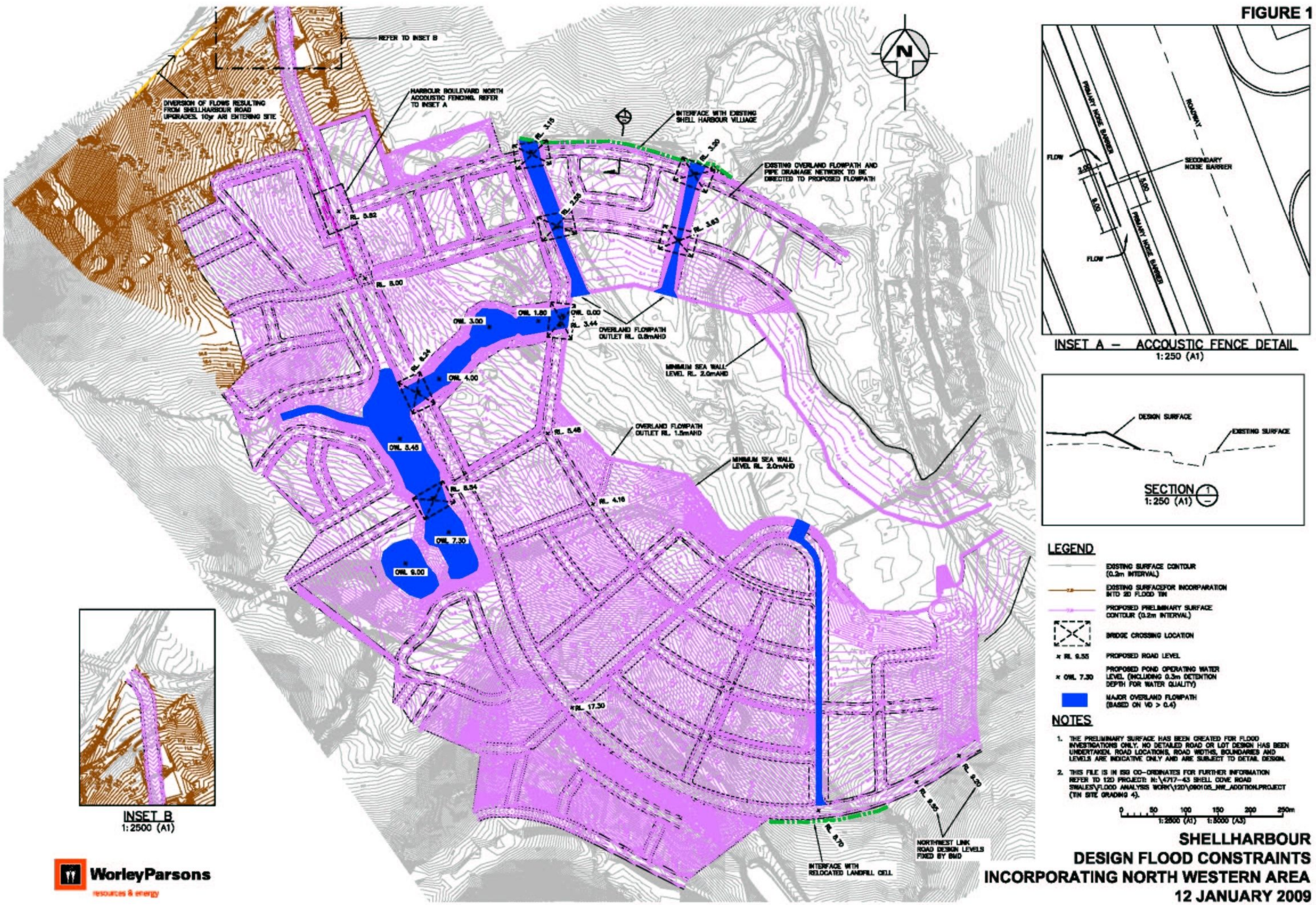

Figure 3.1 Proposed Grading Plan Provided by Worley Parsons

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

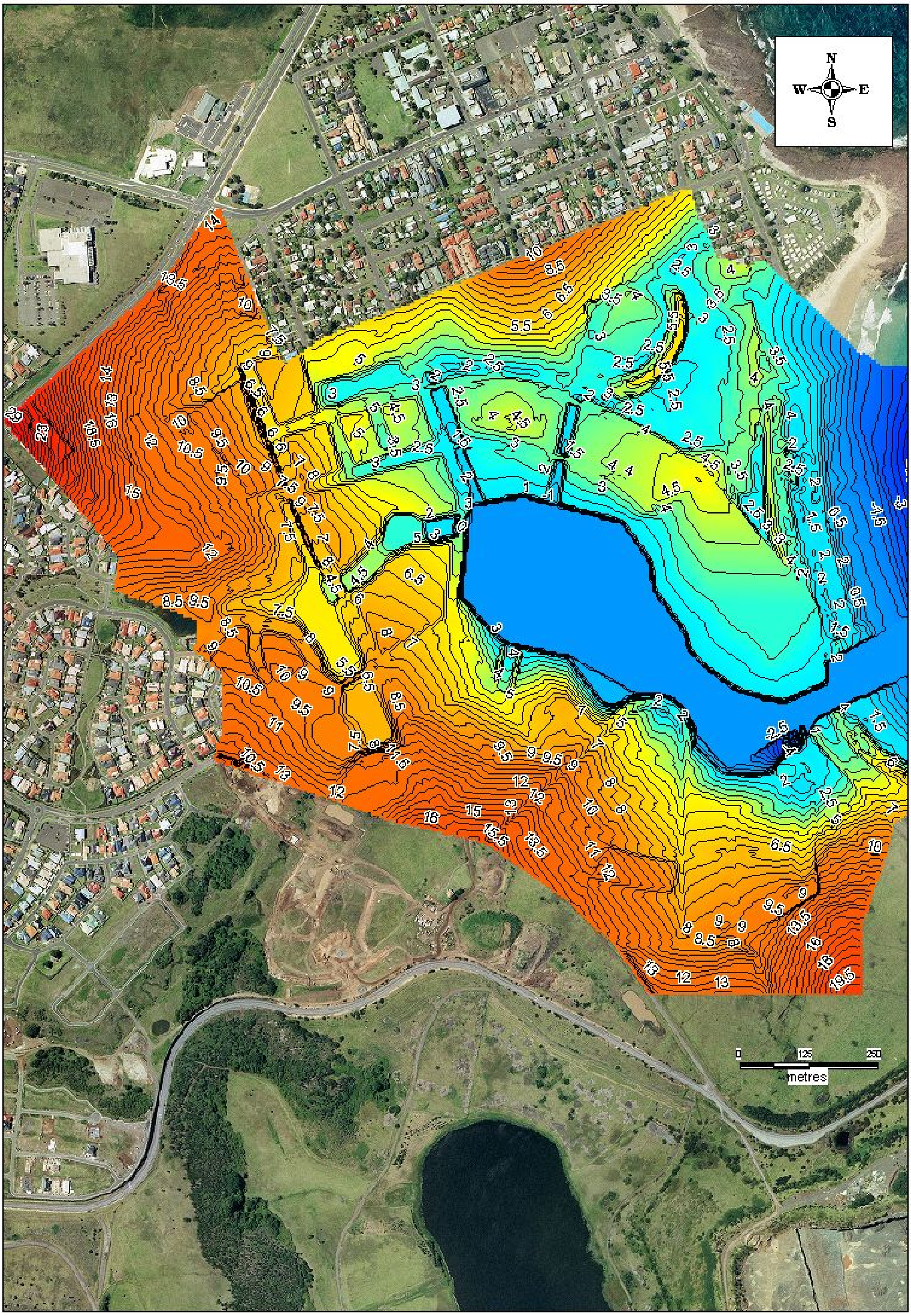

Figure 5.1 2D Design Terrain

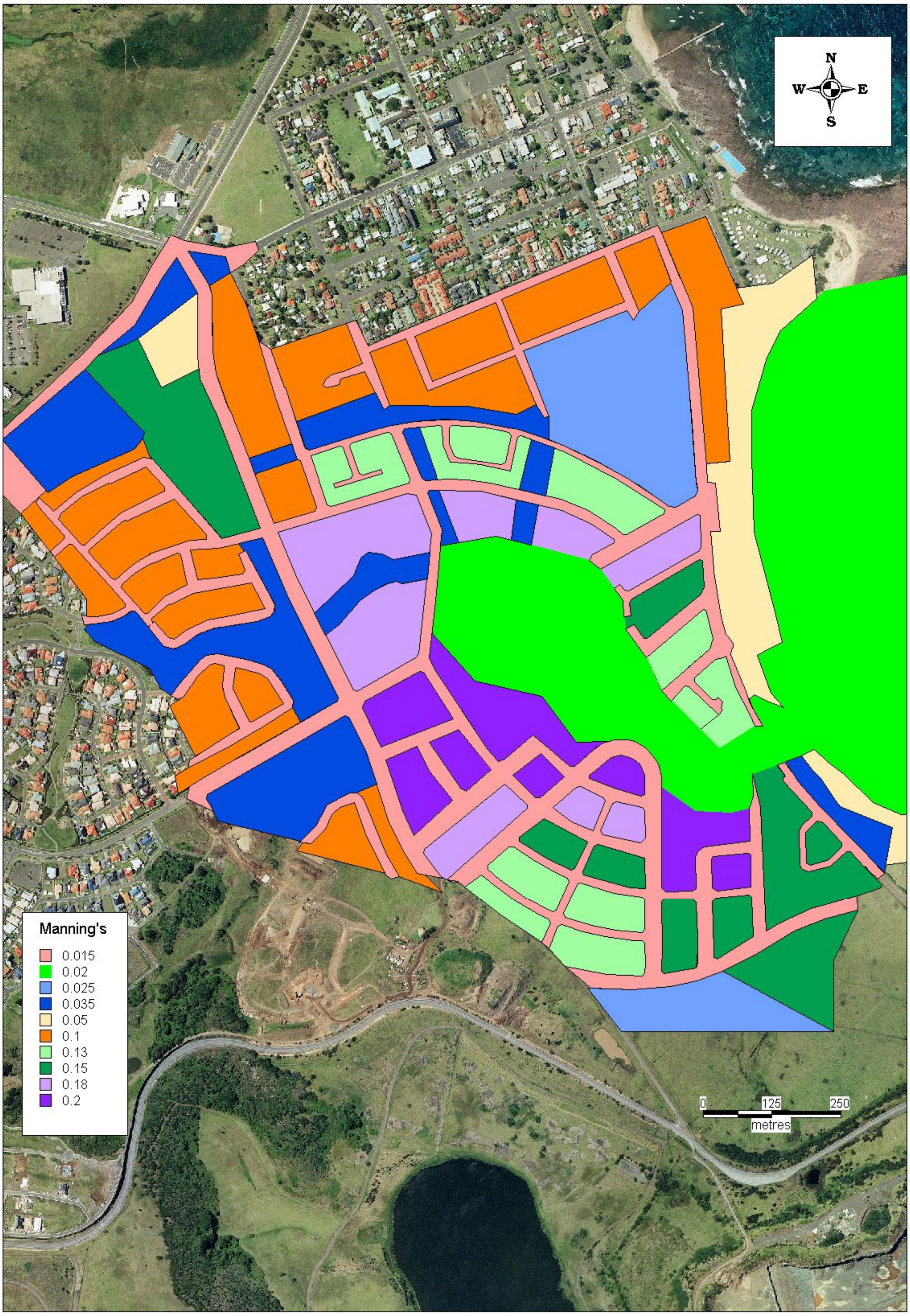

Figure 5.2 2D Roughness Values Adopted

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.