



# Expert Opinion

## Amendment C363 to the Greater Geelong Planning Scheme

McLeods Developments Pty Ltd

Panel Hearing

August 2020





<b>Report Author:</b>	Warwick Bishop
<b>Title:</b>	Expert Opinion Report
<b>Location:</b>	Central Road, Drysdale
<b>Report Prepared For:</b>	McLeods Developments Pty
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# 1 REPORT AUTHOR

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### ***Qualifications:***

- B.E. (Hons), University of Melbourne, 1993
- MEngSci, Monash University, 2000

### ***Affiliations:***

- Fellow, Institution of Engineers Australia, Chartered Professional Engineer.
- Member, River Basin Management Society
- Member, Engineers Australia, Victorian Water Engineering Branch Committee
- Member, Society for Sustainability and Environmental Engineering of Engineers Australia
- Member, Stormwater Victoria
- Member, Australian Water Association
- Member, International Association for Hydraulic Research

### ***Area of Expertise***

Key areas of expertise relevant to this report are summarised below.

- Assessment of drainage and flood related issues;
- Expert witness for drainage and flood related issues at environmental effects panels, planning panels and civil hearings.

### ***Statement of Expertise***

With my qualifications and experience, I believe that I am well qualified to provide an expert opinion on drainage and flood matters relative to Amendment C363 to the Greater Geelong Planning Scheme.



## 2 REPORT CONTRIBUTORS

**Bertrand Salmi**

Principal Engineer

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***Qualifications:***

- Bachelor (Hons) of Ecological Sciences (Environmental Sciences), University of Edinburgh 2006
- Master of Sciences, Water Resource Engineering Management, Heriot Watt University 2007

***Area of Expertise:***

Key areas of expertise relevant to this report are summarised below.

- Assessment of flood and stormwater management;
- Application of GIS.

***Scope of contribution:***

Bertrand assisted in the preparation of the report, including data review and figure preparation, under my supervision.



### 3 SCOPE OF REPORT

In relation to Amendment C363 to the Greater Geelong Planning Scheme, I have been engaged to act as an independent expert on drainage and flooding issues relevant to the proposed rezoning of the Rural Living Zone (RLZ) land to General Residential Zone Schedule 1 (GRZ1) and associated changes to schedules.

I have been asked to review the material provided to me and prepare an expert witness statement in respect to Amendment C363 to the Greater Geelong Planning Scheme. Specifically, I have been requested to:

- Provide an overview of the preparation of the Stormwater Management Plan and the Wetland Functional Design Report, including the methodology used in the preparation of these materials;
- Respond to issues raised by submissions related to the Stormwater Management Plan and the Wetland Functional Design Report, as relevant to my expertise including the issues raised in submission 27;
- Outline the capacities allowed for in the interim and ultimate arrangement of the retarding basins and the basis for this arrangement; and
- Outline any recommended changes to the Amendment and respond to the submissions.



## 4 BASIS OF THIS REPORT

This report is based on:

- Review of Amendment C363 to the Greater Geelong Planning Scheme supporting information and technical reports, including:
  - Explanatory Report
  - Drysdale Clifton Springs Structure Plan 2010
  - Stormwater Management Plan (Water Technology, 2019)
  - Wetland Functional Design Report (Water Technology, 2018)
  - Planning Report (St Quentin, 2017)
  - Urban Infrastructure Servicing Report (St Quentin, 2019)
  - Draft Development Contributions Plan (Urban Enterprise, 2019)
  - Landscape Masterplan Report (Tract, 2019)
- Review of additional available information, including:
  - LiDAR (survey) and VicMap data
  - Memo to St Quentin “Central Road Drysdale – Flood Risk and Stormwater - Stage 1 – Preliminary Results”, (Water Technology, 16 September 2016)
- Submissions received in respect to Amendment C363 to the Greater Geelong Planning Scheme;
- Relevant guidelines and standards, including:
  - DELWP’s *Guidelines for Development in Flood Affected Areas* (2019)
  - Infrastructure Design Manual
  - *Urban stormwater : best practice environmental management guidelines*(Victorian Stormwater Committee, 1999)
- Council material, including:
  - Ordinary Council Meeting Minutes (10 December, 2019)
  - Ordinary Council Meeting Minutes (28 January, 2020)

This report has been prepared in accordance with the relevant procedures and practice notes applied by Planning Panels Victoria on Expert Evidence. I have read the “Guide to Expert Evidence” and am aware of my overriding duty to assist the Panel on matters relevant to my expertise.

I have had no direct input to the development of the proposal or the supporting documents submitted as part of the amendment. As Regional General Manager, I was not significantly involved in any technical input or review but have provided some support in respect to project management. I have therefore undertaken a peer review of the previous Water Technology reports, independent of the previous work, and undertaken further analysis to inform my response to instructions.



My colleague, Bertrand Salmi, was involved in the development of two of the technical reports, namely the Stormwater Management Plan and the Wetland Functional Design Report.

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## 5 INTRODUCTION

I have been instructed by Maddocks on behalf of McLeods Developments Pty Ltd to provide expert evidence in relation to relevant drainage and flooding matters associated with the proposed Amendment C363 to the Greater Geelong Planning Scheme.



## 6 BACKGROUND

### 6.1 Locality

The subject site consists of 30 parcels of land located within Drysdale, as shown in Figure 6-1. The subject site is located in Drysdale, with a small part of the site extending into the southern edge of Clifton Springs. The site is bounded by Jetty Road to the west, Wyndham Street to the south, Thomas Street and existing residential development to the north, and a mixture of developed and vacant residential land to the east. Central Road passes through the site in a north-south direction approximately two thirds of the way from west to east. The Amendment also applies to parcels at 1 Sheileen Court, 2-20 Sheileen Court and 23 Marsh Court, Drysdale (the Sheileen Land).

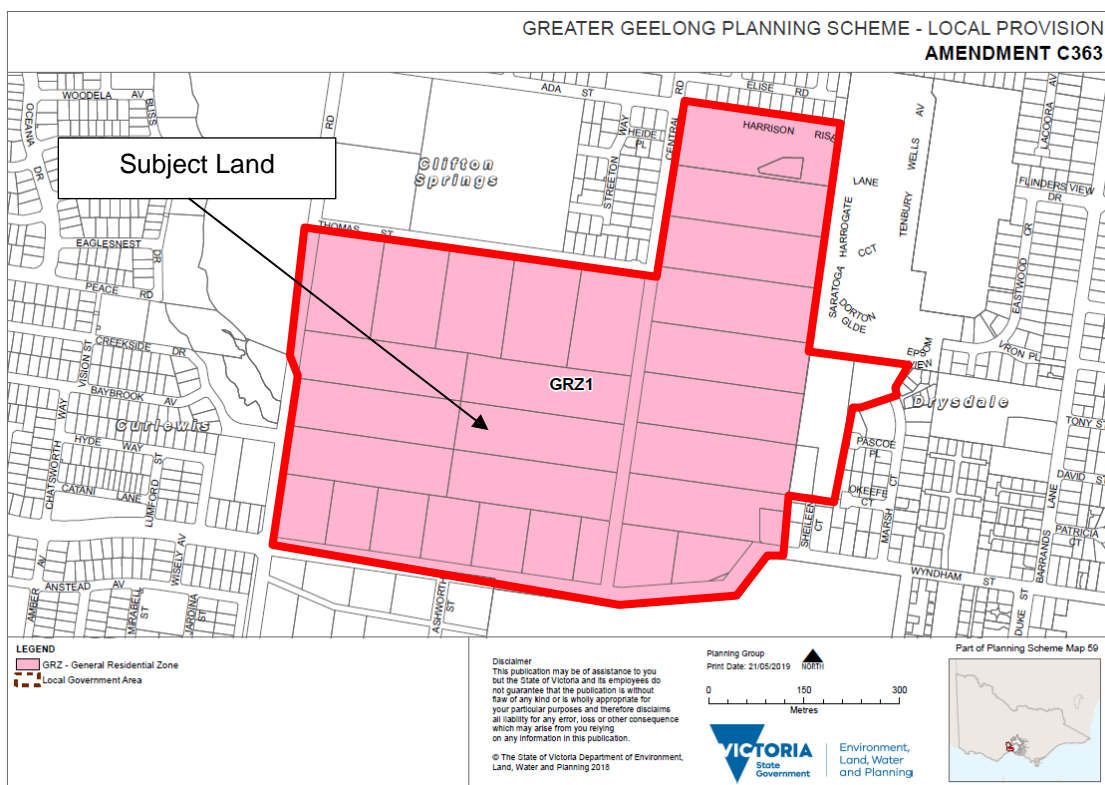


Figure 6-1 Subject Site

The land is currently zoned Rural Living Zone (RLZ) or General Residential Zone (GRZ), as shown in Figure 6-2, and has been identified for future residential development in the Drysdale Clifton Springs Structure Plan 2010.



Figure 6-2 Current Zoning

## 6.2 Existing Flood Risk

Current flood mapping available from the City of Greater Geelong (CoGG) has identified the site as being subject to flooding from Griggs Creek and its tributaries. The Corangamite Catchment Management Authority (CCMA) has also provided information which indicates that two designated waterways pass through the site. This was confirmed by modelling in 2016 (Water Technology, September 2016), as shown in Figure 6-3.

Four overland flow paths were identified by Water Technology in the catchment within or around the site. Three of them (Flow paths 1, 2 and 3) are associated with external catchments while one is attributed to local run off (Flow path 4). Two regions of significant ponding were also identified within the site, including:

- Central Road (150 m north of Wyndham Street) - Flooding as a result of water pooling is on both sides of the road and (excluding the farm dam) shows low areas inundated to depths greater than 1.5 m. This inundation is due to ponding within a depression that has no free drainage outlet; and
- Jetty Road (From Wyndham Street to the Griggs Creek crossing under Jetty Road) - Flooding in this area is experienced on the east side of the road (inside the study area) and is greater than 1.2 m deep in channelised sections of the flow path.

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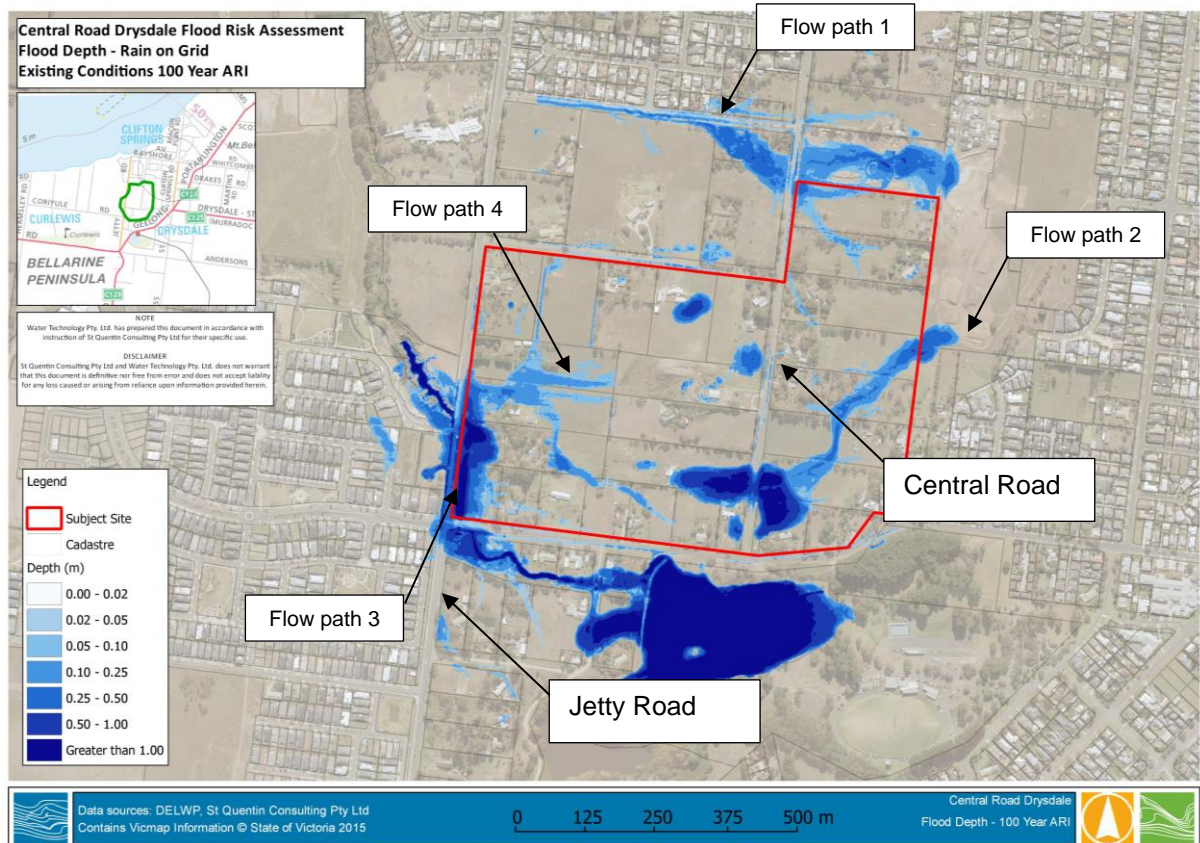


Figure 6-3 Preliminary 1% AEP Flood Modelling Results Extent (source: Water Technology 2016)

As a result of the flood risk identified, the relevant drainage authorities, namely Corangamite Catchment Management Authority (CCMA) and the City of Greater Geelong (CoGG), will not permit:

- Flood afflux (increase in flood levels) for a range of design floods up to and including the 1% AEP design storm; and
- A net loss of flood storage within the site.

This was considered in the Stormwater Management Plan, with additional flood modelling undertaken to support the proposed development plan for the area.

## 6.3 Proposed Amendment

The Amendment proposes to rezone the rural living land to allow for conventional residential development (approximately 550 lots) and apply a design and development overlay to adjoining residential land to ensure connectivity between the two areas. The Amendment will:

- Rezone all the land in the Rural Living Zone to the General Residential Zone Schedule 1.
- Insert a new Schedule 44 to Clause 43.02 Design and Development Overlay that will apply to 1 Sheileen Court, 2-20 Sheileen Court and 23 Marsh Court, Drysdale.

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- Insert a new Schedule 37 to Clause 43.04 Development Plan Overlay that will apply to the land being rezoned, except for 91-101 Central Road, Drysdale.
- Insert a new Schedule 8 to Clause 45.06 Development Contributions Plan Overlay that will apply to the land being rezoned, except for 91-101 Central Road, Drysdale.
- Amend Clause 72.04 Schedule to Documents Incorporated in this Planning Scheme to include the Central Road Drysdale Development Contributions Plan

The proposed Framework Plan for the subject site is shown in Figure 6-4. It is generally consistent with the Concept Plan shown in the Drysdale Clifton Springs Structure Plan (September 2010), though I note the drainage reserves currently proposed appear to be larger than what was allowed for in the Structure Plan.



Figure 6-4 Framework Plan (source: Amendment C363 exhibited documentation)

# 7 REVIEW OF STORMWATER MANAGEMENT PLAN

## 7.1 Overview

This section documents the findings of my review of the Water Technology Stormwater Management Plan (May 2019), in particular the potential impact on flood risk, water quality and proposed mitigation measures.

The Stormwater Management Plan investigated flood risk at the site arising from two potential mechanisms:

- Increased stormwater runoff from the subject site, due to increased impervious area (hard or paved surfaces such as roofs, roads, paths and driveways); and
- Fluvial flooding from the external catchment and waterway flowing through the subject site (Flow Path 3, Griggs Creek).

Both risks were assessed using detailed hydrological and hydraulic modelling. Design recommendations including mitigation measures were then determined from the results.

The Stormwater Management Plan also detailed the Water Sensitive Urban Design (WSUD) strategy proposed to treat runoff from the development and protect river health values and the downstream environment.

I note that the Stormwater Management Plan has regard to the parcels currently zoned Rural Living Zone (RLZ) and not the Sheileen Land covered by proposed Schedule 44 to Clause 43.02 Design and Development Overlay.

## 7.2 Flood Risk

### 7.2.1 Local Catchment Flooding

The Stormwater Management Plan documents proposed drainage infrastructure to meet the peak outflow targets applicable to the site. This consists of two detention basins located within the proposed residential subdivisions.

Hydrological modelling using RORB was undertaken to establish the site hydrological regime under current and future conditions and inform the concept design of the two retarding basins (i.e. storage volume and area). The hydrologic (RORB) modelling was in accordance with the 1987 Australian Rainfall and Runoff (ARR) Guidelines. This aligns with best practice approaches at the time, noting that the ARR Guidelines have since been updated (in 2019).

A review of these models indicated that:

- The model schematisation (sub area's / reaches) is consistent with industry approaches, however I note that, while external catchment areas were included in the preliminary flood analysis, they were excluded from the site stormwater analysis (discussed in Section 7.2.1.1):

- For the developed conditions, the model parameters for the subject site were appropriately adjusted to consider the proposed extent of urbanisation;
- Model parameterisation (loss estimates, impervious fraction estimates, and routing parameters) are consistent with industry approaches; and
- The retarding basins were modelled in RORB to ensure that peak post-development flow rates do not exceed the pre-development discharges for the 1% AEP design storm.

It is standard practice and as per the current version of the Infrastructure Design Manual (<https://www.designmanual.com.au/download-idm>) for new developments to detain stormwater on-site (as it currently proposed) to ensure there is no detrimental off-site impact from increased imperviousness areas.

I note that additional details for these two retarding basins have been provided in the Wetland Functional Design Report (see Section 8). It is not common for this level of detail to be provided for a Planning Scheme Amendment, particularly as specific design details and treatment performance calculations can generally be determined at the detailed design stage and subject to the satisfaction of council through conditions.

#### 7.2.1.1 External Catchments

Part of the catchment areas for flow paths 1 and 2 are located east of the subject site. These external catchment areas are identified in the May 2019 Stormwater Management Report (Figure 3-1 of that report and reproduced as Figure 7-2 below). These external areas were not included in the hydrological modelling for the retarding basin designs in the Water Technology report for the reasons set out below:

- The external catchment area designated E2 in Figure 7-2 is mostly covered by an existing special charge scheme (see Figure 7-1) for drainage purposes. This area was therefore excluded from the analysis as future drainage infrastructure in this area, along with the natural topography, will direct flows away from the subject site. Figure 7-3 shows the relationship between the site, the external catchment areas (east of the site), the Sheileen Land and Special Charge Scheme;
- The eastern properties known as the Sheileen Land (within catchment E1 in Figure 7-2, namely 1 Sheileen Court, 2-20 Sheileen Court and 23 Marsh Court) are already zoned for residential development and not part of the DCP area. Hence it was assumed that they are not intended to be treated by the proposed water management measures for the DCP.

Previous catchment flood analysis showed that the Sheileen Land is within External Catchment E1. These properties are therefore likely to contribute to Flow Path 2 within the subject site, albeit to a minor degree. For this reason, I believe External Catchment E1 should be included in the RORB modelling for the retarding basins. I note that, as described above, I believe the retarding basins are not required to mitigate developed flows from this area.

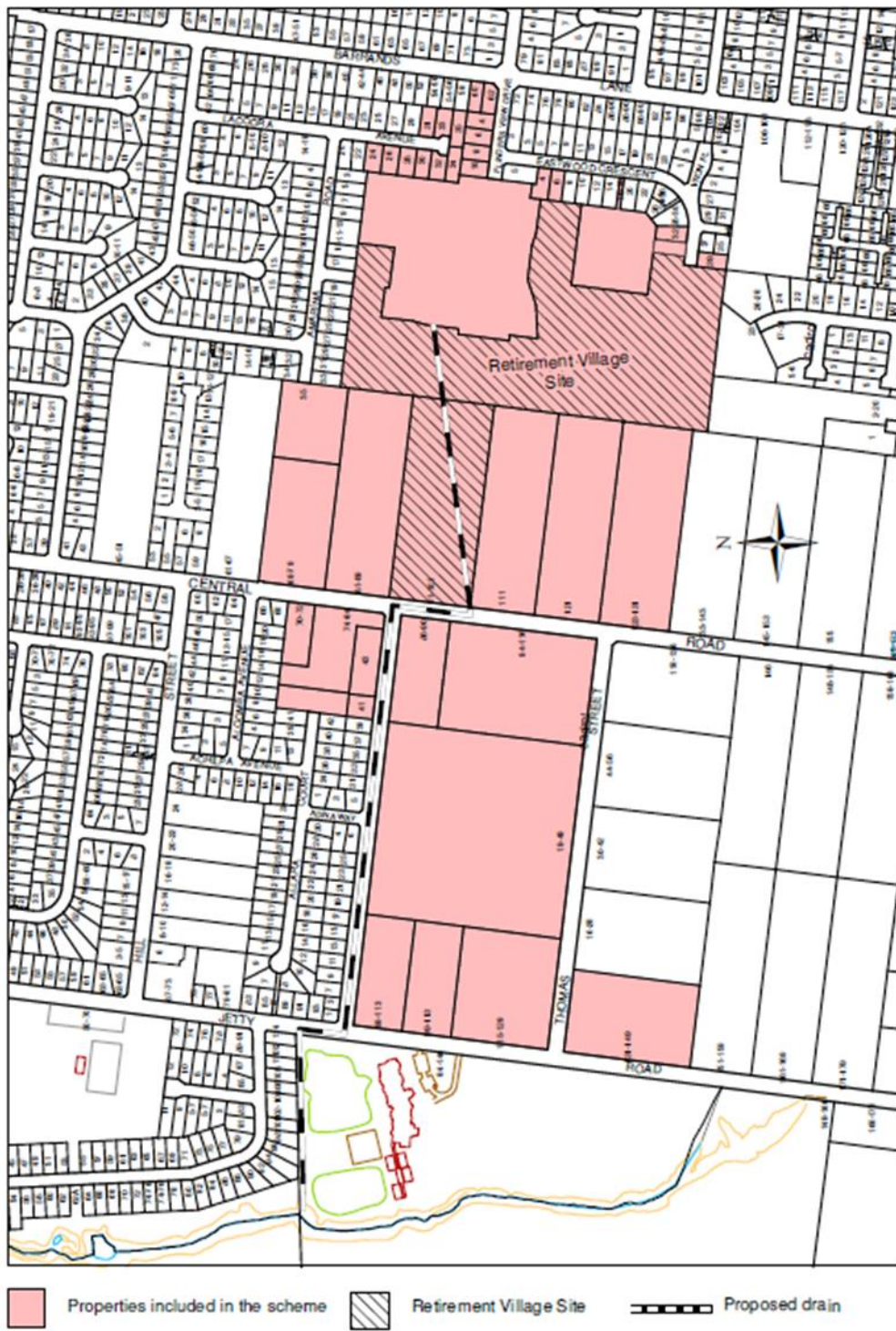


Figure 7-1 Northern Properties within Special Charge Scheme

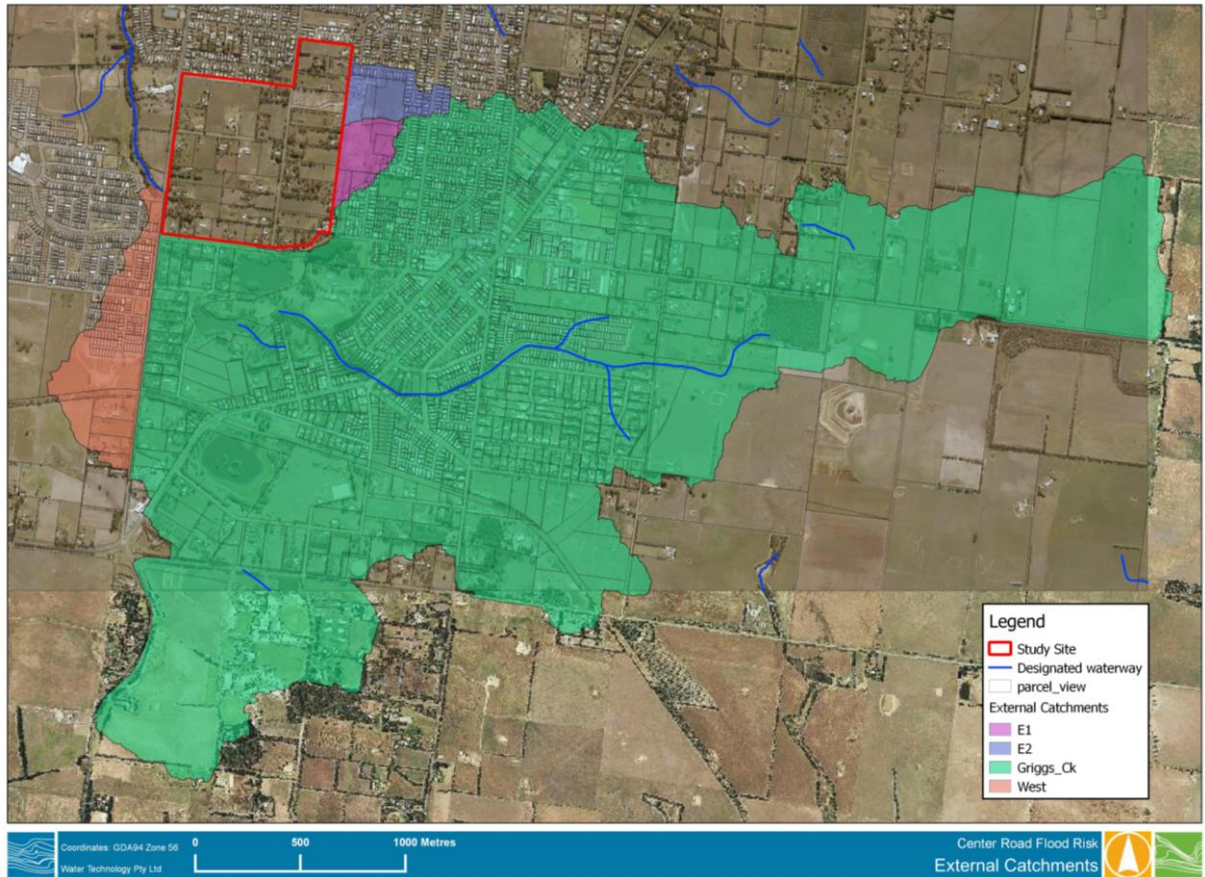


Figure 7-2 Upstream Catchment Delineation



In order to assess how the two proposed retarding basins would behave, allowing for the additional runoff from the external catchment, I have undertaken additional hydrological modelling. The analysis is independent of the water modelling in the previous reports but did make use of the existing RORB model for the site and wider catchment. Two scenarios were tested:

- 1) Greenfield (existing) conditions are assumed for the external catchments with flows directed towards the two retarding basins.
- 2) The area is assumed developed with 2.9 ha of the external catchment directed towards the two proposed retarding basins, with the remaining areas diverted away as part of the northern Special Charge Scheme.

The first scenario provides an assessment of the performance of the two retarding basins against existing conditions, assuming Catchment E1 (about 8.3 ha) is undeveloped and Flow Path 2 is maintained through to the proposed retarding basins.

The second scenario allows their performance to be assessed with the Special Charge Scheme in place, allowing for some conservatism in the assumptions, including:

- The external area draining to the two retarding basins (the Sheileen Land) was considered to be developed (fraction imperviousness of 45% representing traditional residential development, compared to 20% under existing conditions); and
- No mitigation measures (i.e., retarding basin or on-site detention) were allowed for in the Sheileen Land.

The modelling shows post-development flows at Jetty Road do not exceed the adopted maximum permissible site discharge (existing conditions design peak flow), for both scenarios. It is noted that pre-development flows would be notionally larger if allowing for the external catchment area, east of the site. Furthermore, flood storage volumes for the Jetty Road retarding basin were comparable to those reported in the previous reports.

Although flood storage (and 1% AEP design flood levels) increases in the retarding basin east of Central Road, any impact on flood risk could be mitigated either by minor modifications to the design such as changes to the outlet. The hydrologic modelling suggests the proposed retarding basin system retards stormwater runoff to pre-development levels downstream of the subject site (west of Jetty Road), allowing for runoff from the Sheileen Land.

It will be necessary to maintain an overland flow path between the eastern properties and the overall site, to allow Flow Path 2 to be conveyed post-development. A pedestrian pathway could readily act as a designated overland flow path to safely convey flood flows. I note that a road connection is shown on the development plan (see Figure 6-4). According to the Council Minutes of 28 January 2020 Council now supports the removal of a road connection between Marsh Court and the subject site in preference to a pedestrian-only link. Accordingly, land will be set aside as a pedestrian, bicycle and drainage link. This link can act as a designated overland flow path for runoff from the Sheileen Land and could be designed to safely convey overland flow. This overland flow path should be incorporated to connect the Sheileen Land to the retarding basins, as the removal of the existing flow path would detrimentally impact the drainage of 1 Sheileen Court, 2-20 Sheileen Cort and 23 Marsh Court.

Based on the above, I consider that the retarding basins are appropriately sized. There will also be opportunities to further optimise their design during the detailed design stage. Appropriate performance standards are a requirement of the planning scheme, however any particular concerns can be addressed through requirements for the development plan. I have reviewed the proposed Schedule 37 to Clause 43.04 Development Plan Overlay and consider the requirements to be generally appropriate. A requirement should be added to ensure an overland flow path is maintained from the eastern properties under DDO 43.

## 7.2.2 Flooding

### 7.2.2.1 Overview

There is a significant overland flow path (Flow Path 3 shown on Figure 6-3) that passes through the south-west corner of the site. The CCMA indicated that the development layout must maintain conveyance capacity of this flow path. As a result, a minimum 30 m buffer was nominated for public open space east of Jetty Road to:

- Maintain conveyance capacity and the drainage function of Flow Path 3 (Griggs Creek); and
- Maintain/enhance landscape values of the existing drainage corridor.

Flood modelling was undertaken as part of the Stormwater Management Plan, to demonstrate that the proposed development would not have detrimental impact on fluvial flooding within the subject site and on adjacent properties.

### 7.2.2.2 Flood Modelling

A flood impact assessment was undertaken to quantify existing flood risk and assess potential impacts from the development on surrounding properties and environment. The methodology adopted relied on two industry standard modelling software tools commonly used in Victoria:

- RORB was used as the hydrological package, in accordance with the 1987 Australian Rainfall and Runoff Guidelines (applicable at the time):
- TUFLOW was used as the hydraulic modelling software to determine flood levels, depths and velocities across the site:
  - 1% AEP flood modelling was undertaken for a short duration (1 hour) and a long duration (12 hour) event.

The modelling undertaken for the report incorporated fill of proposed residential parcels, with roads conveying peak 1% AEP design flood flows. The proposed concept site layout may change as the development progresses. I note that there were slight differences in the road layout between the preliminary framework plan and the modelled road layout, which was acknowledged in the Stormwater Management Plan. Provided that the overall density and layout are not significantly altered, minor revisions to the layout will not impact the drainage and water quality drainage concept design presented in this report. Underground drainage infrastructure (pipes) which would ultimately service the site, have generally not been modelled. As a result, the flood model likely over-estimates overland flooding post-development.

I consider the approach and modelling methodology to be appropriate to understand flood risk at the site.

### 7.2.2.3 Modelling Results

Detailed hydraulic modelling of the 1% AEP design flood was completed for existing and proposed conditions. The results from both scenarios were compared to determine if the proposed development has the potential to alter flooding through the areas adjacent to, upstream or downstream of the subject site. This type of analysis is consistent with industry best practice.

As required by the CCMA, the development should not divert floodwaters or increase flood levels to the detriment of adjoining properties. Whilst the proposed development results in localised afflux for the 1% AEP design flood (1 hour and 12 hour duration storms), the proposed drainage system and retarding basin result in a reduction in flood depths along Flow Path 3 and, importantly, in an adjacent property. Any afflux (increase in flood levels due to the amendment) is limited to road infrastructure and the waterway and, given the reduction in flood depths observed elsewhere, the proposed stormwater strategy provides an improvement compared to the existing conditions. This is illustrated in Figure 7-4 and Figure 7-5. These show the difference in peak 1% AEP design flood depths for the 1 hour and 12 hour duration design storms respectively. Areas that are blue and green represent a reduction in flood depth compared to existing conditions (improvement). Areas that are red and yellow represent an increase in flood depths (detriment). Areas within the subject site are not of significant concern with respect to changes in flood depth as revised ground levels as part of future development will accommodate for any changes compared to existing conditions.

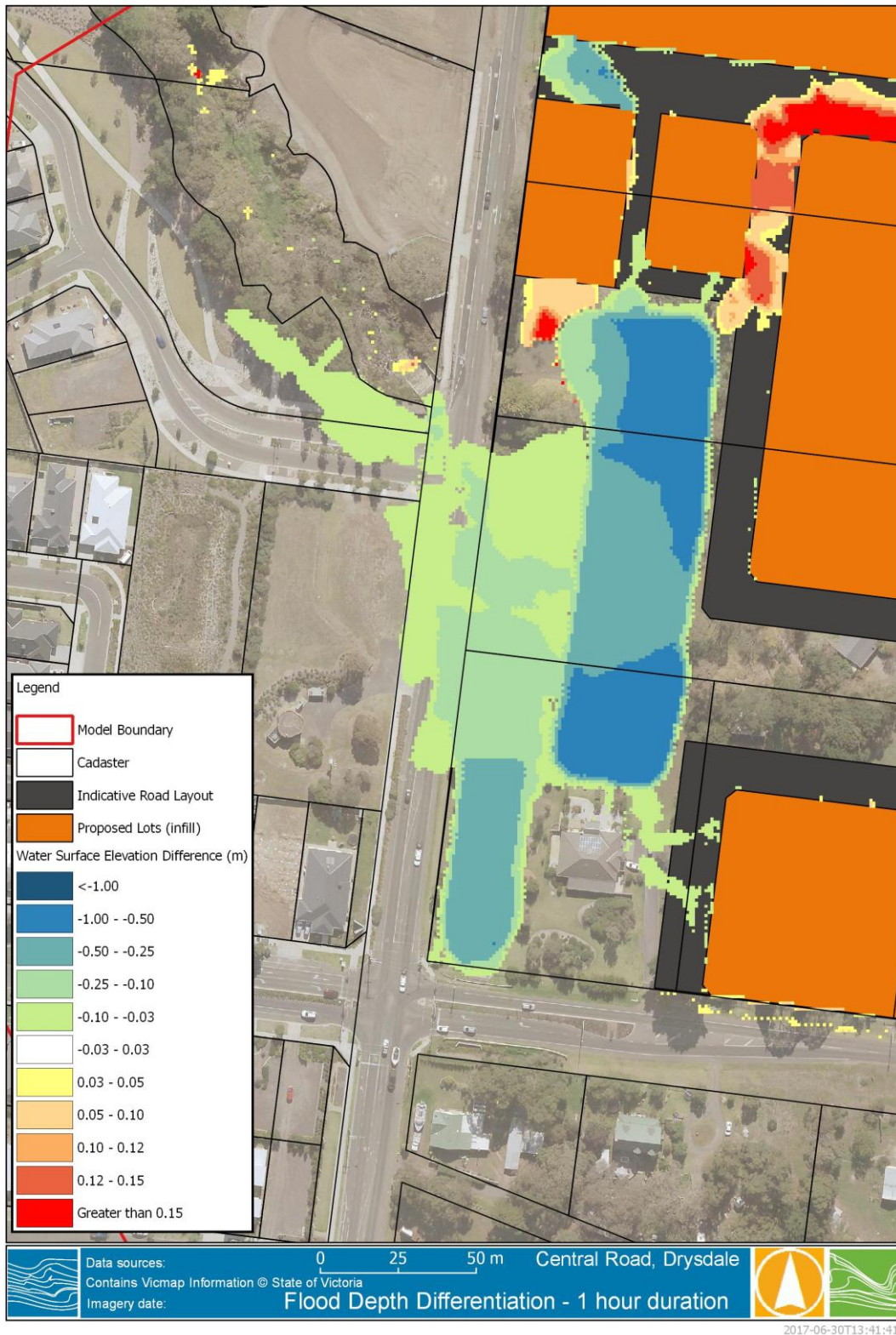


Figure 7-4 Water Surface Elevation Difference Plot between Existing and Developed Conditions (1 hour)

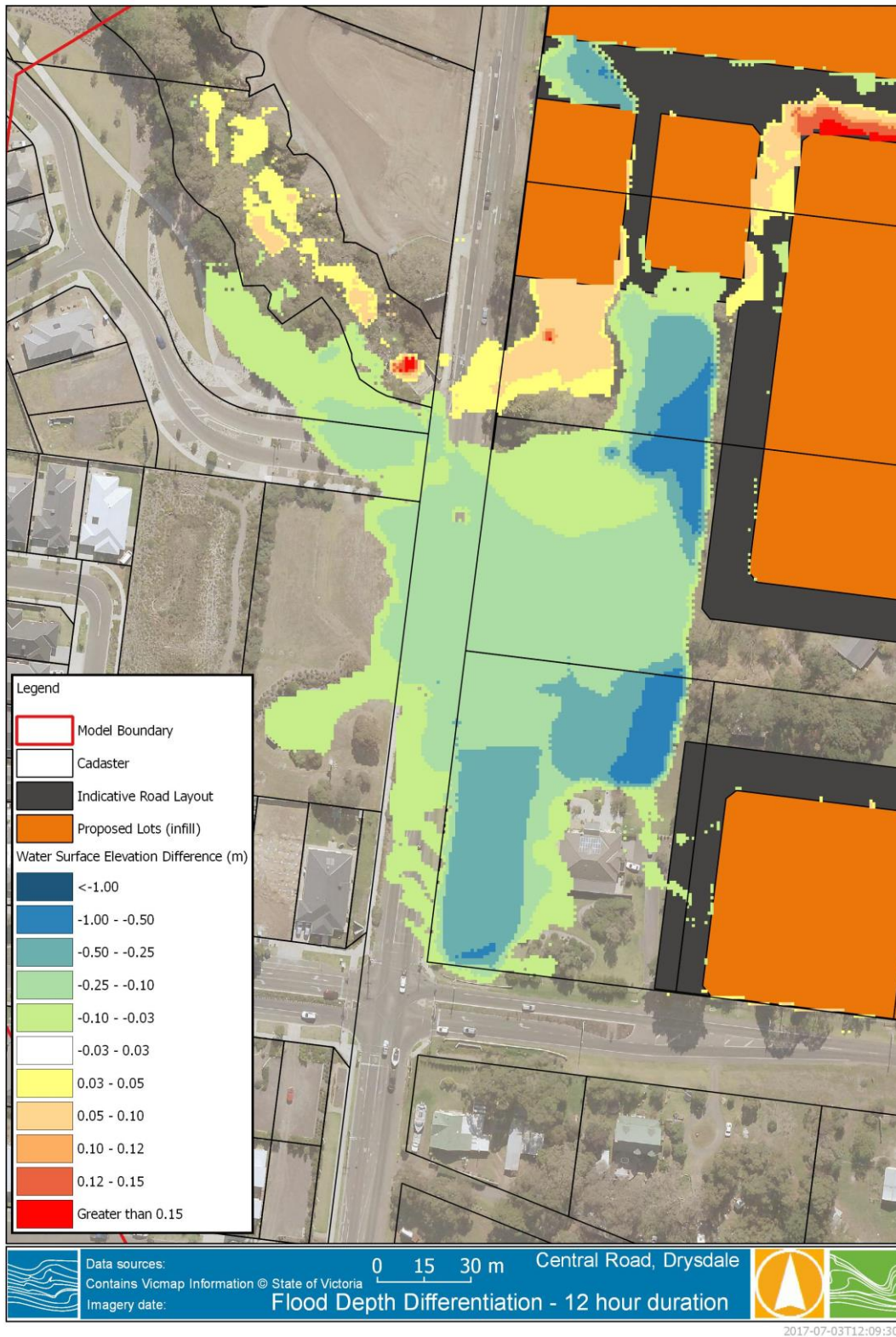


Figure 7-5 Water Surface Elevation Difference Plot between Existing and Developed Conditions (12 hour)

The flood model also confirmed that:

- The development layout maintains conveyance capacity of Flow Path 3;
- There is no net loss of flood storage within the site;
- Peak post-development flow rates do not exceed the pre-development discharges for the 1% AEP design storm; and
- All new lots are filled and outside the post developed mapped 1% AEP design flood extent.

The Stormwater Management Plan also considered flood safety and recommended road closure at Jetty Road during a large flood as Jetty Road is unsafe under existing conditions. Other design details, such as batter slopes and spillways, will need to be further refined at detailed design stage, to allow for safety requirements. This is typical practice for development, with detailed design occurring once a planning permit has been granted. Should there be any concerns regarding details of the proposed works, these can be addressed through the development plan schedule or appropriate permit conditions.

### 7.3 Water Sensitive Urban Design Strategy

For developments across Victoria, water quality treatment targets are established by the Urban Stormwater Best Practice Environmental Management Guidelines (CSIRO, 1999) are applied as a minimum to protect river health values and receiving environments. The removal rate targets for key pollutants are as follows:

- 80% of total suspended sediments;
- 45% of total nitrogen;
- 45% total phosphorous; and
- 70% gross pollutants.

It is proposed to meet these water quality objectives through 2 constructed wetlands, including sedimentation basins. Constructed wetlands are widely used to meet water quality objectives in greenfield development.

A review of the MUSIC model (Model for Urban Stormwater Improvement Conceptualisation), used to design the water quality treatment performance measures and assess the proposed concept design against Best Practice criteria, showed that Best Practice would be met by the proposed water quality treatment train.

I consider that the proposed water quality treatment train (i.e., constructed wetlands) is appropriate to meet Best Practice objectives. I note that the [Infrastructure Design Manual](#) and the State Environment Protection Policy (Waters) refer to the Best Practice Environmental Management Guidelines objectives. The exclusion/inclusion of the External Catchment E1 is not expected to have any influence on these results. Future development at 1 Sheileen Court, 2-20 Sheileen Court or 23 Marsh Court, Drysdale, would be expected to address its own water quality and quantity.

Preliminary MUSIC modelling indicates that water quality treatment of the Sheileen Land could largely be accommodated within the subject site, with only a small shortfall in nitrogen removal compared to best practice standards (43% removal compared to 45% removal target). Additional treatment within the Sheileen Land could be accommodated through rainwater tanks or a small raingarden (approximately 60 m<sup>2</sup>). I emphasise that the treatment of the Sheileen Land is not a requirement on the current site but may provide a logical way forward for council and landowners in that area to address future stormwater management.

The Stormwater Management Plan notes that it would be likely that some property owners will construct rainwater tanks (RWT) on their lot. These assets will reduce stormwater runoff volumes by capturing rainwater from roofs for toilet flushing, laundry and possibly irrigation. Rain water tanks would provide additional water quality benefits at the development scale, noting that these benefits were not considered in the Stormwater Management Plan.

The concept design adheres to the Infrastructure Design Manual and I note that it has been further progressed to Functional Detail Design, as discussed in Section 8.

## 7.4 SWMP Conclusions

The Stormwater Management Plan shows that, in accordance with the CCMA's requirements:

- The development layout maintains conveyance capacity of Flow Path 3 (Griggs Creek) via a 30 m buffer along Jetty Road;
- The proposed development layout ensures there is no net loss of flood storage within the site; and
- No new lots are created within the post developed mapped 1% AEP design flood extent.

Whilst hydraulic modelling showed localised afflux for the 1% AEP design flood (1 hour and 12 hour duration storms), the proposed drainage system and retarding basin would generally result in reduction in flood depths along Flow Path 3 (Griggs Creek). Additionally, this afflux is limited to road infrastructure and the downstream waterway and does not impact on flood depths on downstream properties. Flood hazard is generally reduced within the site and along Jetty Road.

Water quality management is achieved through two constructed wetlands which are also compatible with existing drainage features.

Water Technology concluded that the proposed development would not have any unacceptable impacts on flood safety and water quality. Following this review I agree with those findings. The design was subsequently progressed to Functional Design.

# 8 REVIEW OF WETLAND FUNCTIONAL DESIGN REPORT

## 8.1 Overview

This section documents the findings of my review of Water Technology’s Wetland Functional Design Report (July 2018). The Stormwater Management Plan preceded the Wetland Functional Design Report. Although the latest version of the Stormwater Management Plan is dated May 2019, the latest changes to the report were associated with the staging of the development and the interim asset and proposed lot triggers for the delivery of the ultimate basins. As a result of these changes, the Stormwater Management Plan aligns with the Wetland Functional Design Report.

## 8.2 Updated Asset Configurations

The Wetland Functional Design Report included updating the configurations of the proposed wetlands and retarding basins, shown in Figure 8-1.

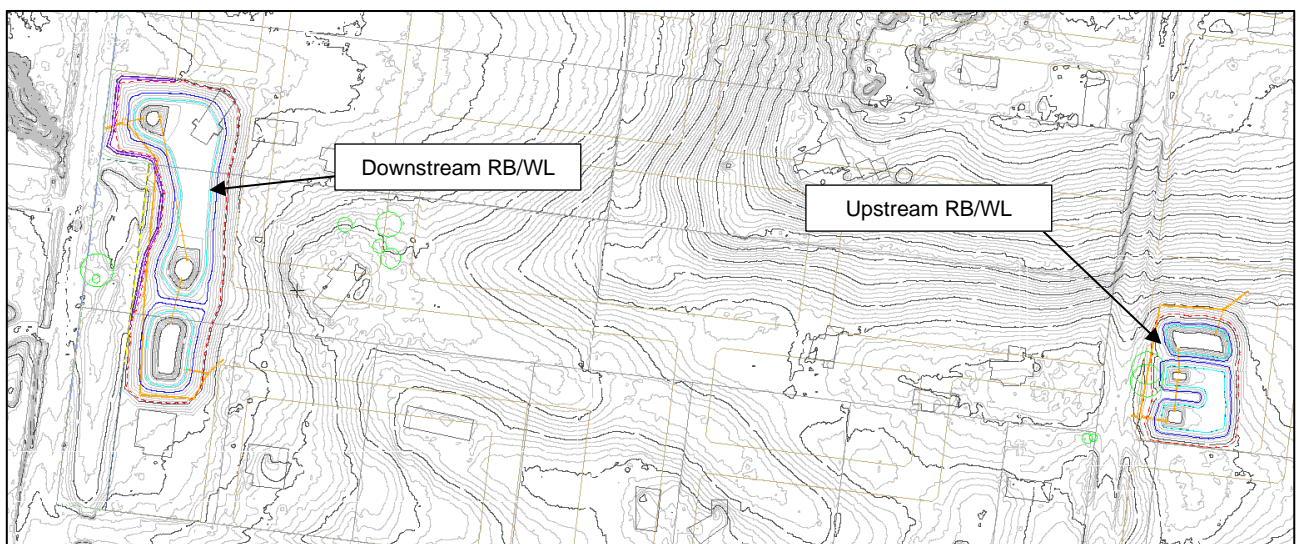


Figure 8-1 Proposed Constructed Wetlands and Retarding Basins – Overall Plan

Any differences between the overall design values presented in the Stormwater Management Plan and the Wetland Functional Design Report is due to the refinement of the design at the functional stage, noting that:

- The hydrological RORB model was updated, to reflect revised asset design and confirm that the peak post-development flow rates do not exceed the pre-development discharges for the 1% AEP design floods;
- Water quality analysis was conducted in MUSIC, noting that asset footprints generally match those reported in the Stormwater Management Plan and Best Practice targets are therefore met; and
- The Functional Design Report provides additional details relative to:

- Inlet, outlet and bypass arrangements;
- Macrophyte Zones;
- Edge treatment; and
- Maintenance aspects, including access and dewatering area.

### 8.3 Impact on Downstream Environment

Whilst the proposed development has the potential to influence the water regime within the catchment, measures have been taken to mitigate any impacts. These are:

- The construction of drainage assets, to meet best practice targets:
  - Increase in surface water runoff volumes will be mitigated by the construction of the two retarding basins;
  - The two constructed wetlands and, potentially, on-lot rainwater tanks, will ensure water quality objectives are achieved;
- There will be improvement to the downstream surface water environment, as shown in Table 8-1;
  - Phosphorus and sediment loads to surface waters decrease compared to current conditions;
  - There is a small increase in Nitrogen loads to surface water however, Best practice targets are met;
- A landscape plan for revegetation of the wetland and all water quality works will be developed as part of the proposed development.

Table 8-1 Water Quality Modelling Pre- and Post-Development

Mean Annual Loads (at LPD)	Existing Conditions	Post-Development	Best Practice Residual Load	Best Practice Achieved
Total Suspended Solids (t/year)	7.1	2.8	3.7	YES
Total Phosphorus (Kg/year)	19.0	10.4	20.7	YES
Total Nitrogen (Kg/year)	133.0	146.0	146.0	YES

## 8.4 Wetland Functional Design Report Conclusions

The functional design report demonstrates that the proposed wetlands and retarding basins for the site are founded on best practice principles and meet Best Practice Guidelines for water quality treatment.

The designs are based on the current Melbourne Water Guidelines<sup>1</sup> for constructed wetlands rather than the IDM. Notwithstanding specific requirements of local councils outside Melbourne, these guides are a defacto standard for wetland design across Victoria and are appropriate to use as a guide in the Greater Geelong area. The report acknowledged there are some aspects that do not fully comply with the Melbourne Water guidelines due to site specific conditions. It would be appropriate for Council to advise the proponent which guidelines it would prefer to be applied for the detailed design.

I believe that further details of the proposed drainage assets are not required at this stage. It would be appropriate for the design of these assets to be finalised at the detailed design stage. Should there be any concerns regarding details of the proposed works, these can be addressed through the development plan or appropriate permit conditions.

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<sup>1</sup> Melbourne Water (2015). Melbourne Water, Design, Construction and Establishment of Constructed Wetlands: Design Manual, updated 2017.

## 9 INTERIM STAGE

The stormwater assets detailed in the Wetland Functional Design Report (and Stormwater Management Plan) allow for the whole site to be developed (42 ha as denoted Future Residential in the Framework Plan, shown in Figure 6-4). However, it is likely that the development will occur in stages.

Both the Stormwater Management Plan and Wetland Functional Design Report considered how the construction of the proposed wetlands and retarding basins could be progressed sequentially. It was identified that:

- The retarding basin/wetland immediately upstream (east) of Central Road (as shown in Figure 8-1) may be constructed as a standalone asset, to service the area east of Central Road (about 9.5 ha);
- A smaller interim basin immediately upstream (east) of Jetty Road may also be constructed as a standalone asset. This, in conjunction with the Central Road Retarding Basin/Wetland, could service up to 25.5 ha (including the 9.5 ha east of Central Road) during the interim stage (see below).

Both reports discuss a possible interim arrangement, to allow a staged development, and also reflect land ownership:

- The interim basin would be constructed on 171 and 161 Jetty Road only, as those parcels are currently owned by the proponent, McLeods Developments Pty Ltd, with no work to occur on 164-168 Wyndham Street (see Figure 9-1):
  - Up to 16 ha (between Jetty Road and Central Road as shown in Figure 9-2) may be serviced by the Jetty Road wetland/retarding basin, if constructed as a standalone asset (i.e., no asset east of Central Road); or
  - Up to 25.5 ha (over the entire site) if the wetland/retarding basin immediately upstream (east) of Central Road is also constructed (that is an additional 9.5 ha east of Central Road).

The design of these assets will need to tie into the surrounding design levels, including future development roads and parcels to the north and east.

This is likely to be beneficial from a water quality perspective as it would minimise the risk of the proposed treatment wetland receiving insufficient inflows during the early stage of development.

The interim arrangement also allows for the excavation and construction of the temporary sedimentation basin, and the wetlands being fully planted later, when sediment loading from the upstream catchment would not result in adverse impacts: The critical driver of stormwater treatment in constructed wetlands has been found to be the proportion of Emergent Aquatic Vegetation within the macrophyte zones. Excessive sediment may damage macrophyte vegetation and thus compromise long-term treatment performance of a constructed wetland.

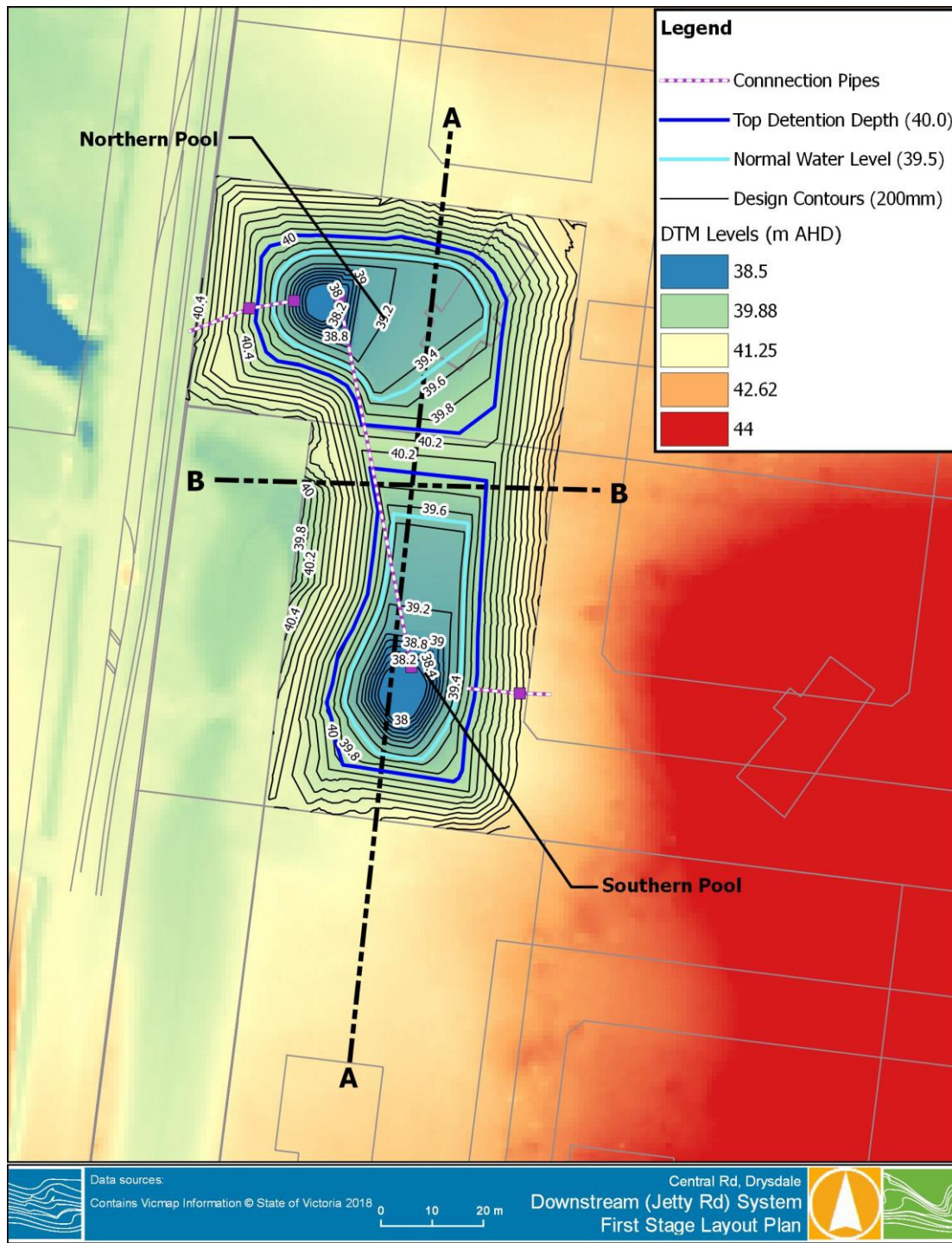


Figure 9-1 Interim Jetty Road Retarding Basin/Wetland

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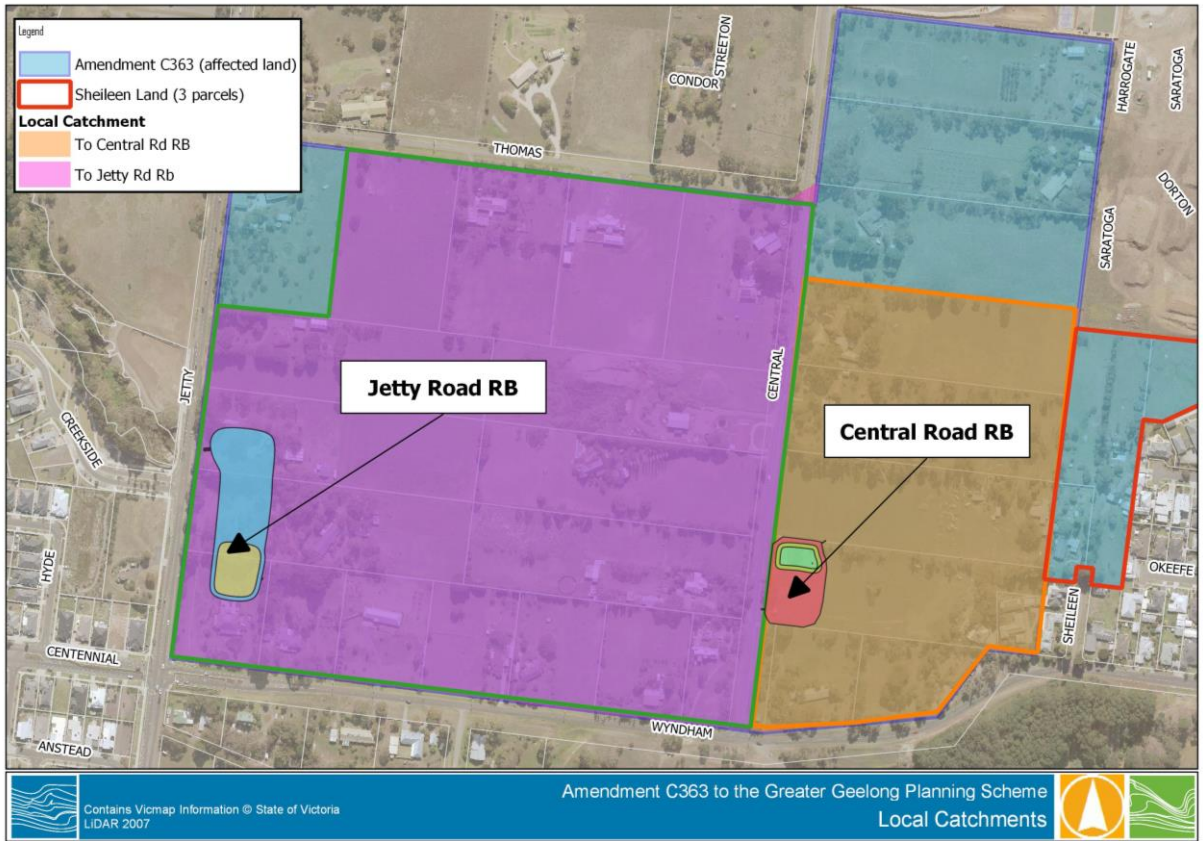


Figure 9-2 Interim development areas

# 10 SUBMISSIONS

I have responded to issues raised by submissions related to Amendment C363, the Stormwater Management Plan and Wetland Functional Design Report, as relevant to my expertise, in Table 10-1. Please note that I have grouped similar flooding and drainage issues together, where appropriate.

Table 10-1 Summary of Matters Raised in Submissions

Concerns Raised	Comments
<p>Submission re: drainage of DD043 not currently considered. Land at the end of Marsh Court slopes down to a low point compared to surrounding land. Insufficient infrastructure (existing flood issues within Marsh Court).</p> <p>The Sheileen Land is subject to flooding.</p>	<p>I acknowledge that drainage of DD043 is not considered in the current Stormwater Management Plan. I understand that the City of Greater Geelong instigated the Amendment for this area, independently of the work commissioned by McLeods Development Pty Ltd.</p> <p>Existing drainage and flood issues affecting these three properties are likely to be reduced in the future, as a majority of the catchment draining to the existing low point at the corner of 2-20 Sheileen Court will be diverted away by the proposed Special Charge Scheme (see Figure 7-1).</p> <p>As discussed in Section 7.2.1.1, the area is hydraulically connected to the remaining area covered by the Amendment however, its flows will likely have negligible impacts on proposed drainage assets. The development of DD043 will necessitate construction of additional drainage infrastructure or contribution to the measures proposed in this amendment, to ensure increase in impervious areas is mitigated.</p> <p>It will be necessary for a Stormwater Management Plan to be prepared to ensure appropriate drainage infrastructure services for 1 Sheileen Court, 2-20 Sheileen Court and 23 Marsh Court, including on-site detention and water quality assets (or alternative arrangements), service any future development. This can be addressed through appropriate conditions on a permit for the development of that land.</p>
<p>The Sheileen Land is subject to flooding and that this land which is thought to be some 10-20 metres below the high point of Marsh Court which is adjacent to 26 Marsh Court may be subject to a gradual caving in, due to excavation during construction</p>	<p>The development of the area will necessitate appropriate construction and sediment management measures to be implemented. The preparation of an Environmental Management Plan or Construction Management Plan should ensure that construction risks are identified and mitigated. This can be addressed through appropriate conditions.</p>

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Concerns Raised	Comments
<p>Impact on 164-168 Wyndham Street, Drysdale as a result of the proposed wetland (upstream of Jetty Road).</p>	<p>I note that the Stormwater Management Plan indicates "careful design of the retarding basin upstream of Jetty Road should permit for the existing dwelling to be maintained.". On review of the material including the functional design, I consider that it would be possible for the dwelling at 164-168 Wyndham Street to be retained in the interim, with the interim wetland footprint (as shown in Figure 9-1).</p> <p>However in the ultimate scenario, I believe it is not possible to retain the dwelling or design around it for the following reasons:</p> <ul style="list-style-type: none"> <li>■ A minimum offset of 15 m from the wetland's Normal Water Level (NWL) is typically required according to industry guidelines. I note that the setback from the Normal Water Level to the existing dwelling would be about 13.3 m according to the current plans.</li> <li>■ Even if the wetland edge is 15 m from the dwelling, the wetland would be constructed within the lot and they would lose their backyard. The 15 m buffer includes the batter slope above the top water level and planting/landscaping around the basin, typically including a pedestrian path and maintenance access.</li> <li>■ Part of the balance of the lot is designated to be open space in the development plan.</li> <li>■ The impact on the amenity of the dwelling at 164-168 Wyndham Street may be significant from construction activities.</li> </ul>
<p><b>Response to Bellarine Catchment Network Submission</b></p>	

Concerns Raised	Comments
<p>SWMP (May 2019) report sets out a recommended stormwater management plan for 3 of the 4 water flows paths within the 40 ha.</p>	<p>Flow path 3 is associated with an external catchment (to the south) and the development layout maintains this (as demonstrated by the flood modelling), as per CCMA’s requirements.</p> <p>Flow path 1 is associated with an external catchment (to the north). Associated area within the re-zoning is covered by an existing special charge scheme.</p> <p>Flow path 2 is maintained through to the proposed retarding basins.</p> <p>Flow path 4 is the result of local runoff. Local roads will be required to be designed to safely convey flood flows (e.g., up to 1% AEP storm). The SWMP provides sufficient confidence that a suitable design can be achieved to maintain safe conditions and overland flow path 4 via the road network. It is appropriate for the detailed of the major drainage infrastructure (i.e., overland flows) to be confirmed at detailed design stage.</p>
<p>The report states that this covers 25.5 ha and allows for the development of 255 lots approx. This leaves in excess of 14 ha with no supporting documentation.</p>	<p>This is a misinterpretation of the report, especially section 3.3. (i.e., “Interim Arrangement”). The stormwater assets detailed in the Wetland Functional Design Report (July 2018) and Stormwater Management Plan (May 2019) allow for the whole site (i.e., 40 ha) to be developed. Both reports however, also provide additional details regarding interim assets, to allow a staged development and reflect land ownership. Bellarine Catchment Network quote maximum development potential if the interim retarding basin upstream of Jetty Road is constructed. As aforementioned, construction of both the ultimate retarding basins upstream of Jetty Road and Central Road will allow for the whole development considered in the SWMP.</p> <p>As discussed in my expert witness report, the two retarding basins would also allow development of the eastern properties known as the Sheileen Land (namely 1 Sheileen Court, 2-20 Sheileen Court and 23 Marsh Court), therefore an area greater than the 40 ha considered in the SWMP (May 2019).</p>
<p>Flow path 1 will increase run off through existing housing and there are known problem areas (flooding of properties north of Jetty Road Reserve, Bay Shore Av. discharge points into the bay, etc.).</p>	<p>Flow path 1 is associated with an external catchment (to the north). Associated area within the re-zoning area is covered by an existing special charge scheme.</p> <p>Flow path 1 is located within the area proposed for re-zoning covered by an existing special charge scheme for drainage purposes. This area was therefore excluded from the analysis, as future drainage infrastructure in this area will direct flows away from the subject site. I understand that the special charge scheme will be used to fund drainage infrastructure, which should be designed to mitigate potential flood and stormwater impact.</p>

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# 11 CONCLUSIONS

With respect to the proposed Amendment C363 to the Greater Geelong Planning Scheme and surface water management issues, I make the following conclusions.

- The stormwater management concept presented in the Stormwater Management Plan and the Wetland Functional Design Report follows industry standard methods and practices. The techniques and standards applied in the reports are appropriate. They provide an appropriate level of investigation for on-site stormwater treatment for the proposed development.
- The proposed development would not have any unacceptable impacts on flood safety and flood risk and meet CCMA's requirements.
- The development layout maintains conveyance capacity of Flow Path 3 (Griggs Creek).
- There is no net loss of flood storage within the site.
- Any off-site afflux is limited to road infrastructure and the downstream waterway and does not impact on flood depths on downstream properties.
- The proposed level of stormwater treatment, both quality and quantity will mitigate any potential downstream impacts as a result of the development and protect hydrologic values.
- Peak post-development flow rates do not exceed the pre-development discharges for the 1% AEP design storms;
- The proposed stormwater treatment measures will comply with best practice standards for stormwater management.
- Assets can be delivered in a staged manner, to reflect development progress and land ownership.
- Development of 1 Sheileen Court, 2-20 Sheileen Court and 23 Marsh court, Drysdale, would need to be supported by a Stormwater Management Plan to ensure it is consistent with the Amendment requirements.

## 12 DECLARATION

I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance which I regard as relevant have, to my knowledge, been withheld from the Planning Panel.



**Warwick A Bishop**

**B.E. (Hons), MEngSci, FIEAust**

10 August 2020

APPENDIX A – CV



# WARWICK BISHOP

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Phone: 03 8526 0800 | 0403 055 338

**Director**

**BE (Hons), MEng Sci (Water)**

**FIEAust, CPEng, NER**



## QUALIFICATIONS

- Bachelor of Engineering with Honours (Civil), University of Melbourne, 1992
- Masters of Engineering Science (Water), Monash University, 1999

## AFFILIATIONS

- Fellow, Institution of Engineers, Australia, Chartered Professional Engineer
- Member, International Association for Hydraulic Research
- Member, Australian Water Association
- Member, River Basin Management Society
- Member, Stormwater Victoria
- Member, Engineers Australia Victorian Water Engineering Branch Committee

## SUMMARY

Warwick is a Director of Water Technology and has over 25 years' experience in hydrologic and hydraulic investigations, specialising in the development and calibration of rural and urban hydrologic and hydrodynamic models and their application to flooding, water quality, sediment transport and environmental values. He also has extensive experience in coastal and estuary modelling including wave, current and oil spill investigations. He has worked extensively in the Murray Darling Basin, principally on environmental hydraulic investigations for the Living Murray Program. Warwick was contributed to the most recent revision of Australian Rainfall and Runoff, providing input to the reference document on 2D hydraulic modelling of rural and urban areas. Warwick worked in the Flood Intelligence Unit of SES during the 2011 floods and is regularly called on to provide expert evidence in surface water matters at VCAT and planning panels.

## PROFESSIONAL HISTORY

2009 to present	Director, Senior Principal Engineer, Water Technology Pty Ltd
2003-2009	Senior Engineer, Water Technology Pty Ltd
2001-2003	Victorian Water Resources Manager, Lawson and Treloar Pty Ltd
1997-2001	Senior Engineer, Lawson and Treloar Pty Ltd
1993-1997	Engineer, Lawson and Treloar Pty Ltd

## SPECIALIST AREAS OF EXPERTISE

- Wetland, WSUD and water quality investigations
- Surface water investigations of urban and rural floodplains, rivers and wetlands
- Modelling of flooding, environmental flows, water quality and sediment transport
- Urban flood mapping, flood mitigation and stormwater treatment
- Integrated Water Management
- Investigations of estuary and coastal hydraulics
- Expert witness reports

## RECENT MAJOR PROJECTS

### STORMWATER PROJECTS (FLOODING, DRAINAGE AND WSUD) WATER TECHNOLOGY

Glen Eira WSUD Opportunities – Project director for an options study looking at the potential effectiveness of WSUD measures for flood mitigation. A local case study was undertaken with preliminary hydrologic and hydraulic modelling.

PNG LNG Condensate Fate Modelling – Project Director for hydrologic and hydraulic assessment of potential condensate spill scenarios for Gas Pipeline Development. One and two-dimensional models as well as mixing zone calculations were performed.

Buckland Park Development, Lower Gawler River – Detailed hydraulic investigation of a large new residential area in a floodplain environment. Development of flood mitigation measures including levees and channels.

Inverloch, Broadbeach Resort – Management of flooding issues related to a coastal development on the South Gippsland Coast. Hydrodynamics of the ocean, estuary, creek and township drainage systems have been taken into account to develop an overall flood risk assessment and appropriate land development level. Also included full drainage and WSUD design for the development.

Hoppers Lane (Werribee) – Development of a surface water management strategy for a mixed-use development including full WSUD treatment.

Keysborough South – Development of surface water management strategy for a large residential rezoning. This strategy has been adopted by Melbourne Water as input to their drainage scheme.

Stamford Park – Floodplain and wetland design for an industrial development adjoining a community park area for Knox Council.

The Strand Traralgon – Development of surface water models and WSUD design (wetlands) to provide treatment for a challenging site, constrained by existing drainage infrastructure and major easements.

Ocean View Lakes Entrance Stormwater Management Plan - Project director for development plan for a residential subdivision. Included design of wetland systems and retarding basin controls.

Cowes WEMP – Project Director in the development of a Water Efficiency Management plan for development in Cowes, use of probabilistic rainfall model PURRS.

Darebin Creek –1d Model (HEC-RAS) construction of waterway and analysis of bridge level assessment for Darebin Creek. Project Director.

Azola Waters, Pakenham – Functional design of Wetlands system for retirement village. Ongoing water quality assessment using various monitoring equipment. Project Manager/Director.

Cuttriss Street Flood investigation, Inverloch – Use of Mike Storm Pipe (Mouse) and two-dimensional (Mike21) linked model for urban storm water flooding. Project Director.

Brookfield Lakes, Bairnsdale, Stormwater Management Plan - Development plan for residential subdivision. Included design of wetland systems and retarding basin controls. Project Director.

Donga Road main drain catchments drainage study (City of Greater Geelong) - GIS analysis and hydraulic modelling of urban floodplain. Use of TUFLOW as predominate 2d/1d modelling package. Project Director.

#### **STORMWATER PROJECTS (FLOODING, DRAINAGE AND WSUD) LAWSON AND TRELOAR**

Sanctuary Lakes Water Quality – Management of a detailed water quality investigation including complex eutrophication modelling of the large lake system and analysis of the upstream wetlands

Sandhurst Estate – Management of hydrologic, hydraulic and water quality investigations for a large residential and golf course development in Melbourne's SE. This investigation included two-dimensional hydraulic analysis, a dynamic-pump system for lake top-up and eutrophication modelling in order to predict future water quality impacts.

Knox Golf Course – Development, calibration and application of a detailed MIKE 21 model of Monbulk Creek/Ferny Creek floodplain to assess flood impacts of a proposed golf course.

Oyster Cove Development, Coomera River QLD – Development of detailed MIKE 21 sub-models to calibrate roughness over residential developments.

Nerang River Floodplain – Major involvement in the development and application of a large, detailed 2-dimensional model of the Nerang River Floodplain. Analysis of impact of developments on flooding and investigation of mitigation options.

Heritage Golf and Country Club – Development of a MIKE 11 model to assess flood conditions in the Yarra River floodplain for design input.

Graceburn Creek, Healesville – development and application of a two-dimensional numerical model of a floodplain for risk assessment, regarding a proposed development. Believed to be the first application of two-dimensional hydraulic modelling on a floodplain in Victoria (1994).

#### **FLOODPLAIN INVESTIGATIONS WATER TECHNOLOGY**

Project Director for a hydraulic modelling study of the Pike River floodplain (SA MDB NRM Board). Development and calibration of a MIKE FLOOD model of the floodplain and use to inform the concept design of environmental regulators.

Project Director for a hydraulic modelling study of the South Australian Katfish Demonstration Reach (DEH). Development and calibration of a MIKE FLOOD model of the floodplain. This model was used to test a number of management scenarios.

Lyndhurst Drainage Strategy - Project Director of modelling waterway works for design of Retarding basins and wetlands for the Lyndhurst drainage scheme. Innovative use of linear waterways/wetlands for storage using two-dimensional hydraulic modelling.

Chowilla Floodplain Hydrodynamic Model – Supervision of the provision of detailed modelling services for this important floodplain system on the Murray River in South Australia, near the Victorian/NSW Border.

Port Fairy Flood Regional Study – A comprehensive review of flood risk to the township of Port Fairy and surrounding areas was undertaken. This included detailed hydrologic and hydraulic modelling, mapping and flood damages analysis. In addition, an extensive investigation of the potential impacts of climate change was undertaken.

Boggy Creek Wetland Review – Hydrologic and hydraulic review of translocated high-value wetland plots in Seaford adjacent to major road development. Working with ecologists to determine appropriate hydrologic regime.

Swan Hill Levee Audit – Investigation of the status of the existing town levee around Swan Hill through the use of a detailed two-dimensional hydraulic model. Assessment of levee system performance and recommendations for future flood mitigation works.

Beaufort Flood Study – Management of a comprehensive hydrologic and hydraulic study of the Beaufort township including investigation of 4 creeks that flow through the town. Resolution of complex design hydrology inputs to the township.

Dennington Flood Study – Detailed two-dimensional hydraulic model developed to describe inundation of the Merri River floodplain and provide planning information for future growth area near Warrnambool in south-west Victoria.

Applying Modelling Tools to Investigate Water Management in the Gunbower Forest – Project manager for the development of a detailed hydraulic model of Gunbower Forest. The model has been calibrated against a number of historic flood events and will be used to assess the effectiveness of a number of potential water management options. These options seek to improve the flooding regime of the forest through the use of environmental flow allocations. The required flooding is determined through a set of ecological objectives. Working closely with ecologists to determine hydrologic regime.

Hydraulic Modelling for Lindsay, Mulcra and Wallpolla Islands – This project involves the development of a linked one and two-dimensional model of these important floodplain and wetland environments that are included as one of the significant environmental assets or “icon sites” along the Murray River. This area has significant environmental values that suffer from reduced flooding due to river regulation. The hydraulic model will be used to test different management scenarios for floodplain improvement.

Murray River Regional Flood Study – Cobram to Tocumwal – Specialist modelling input is being provided for this project with an extensive one and two-dimensional model being developed including the Murray River channel and floodplain. The study area features many man-made controls such as levee banks and irrigation supply channels that dominate the topography. Once established the modelling will be used to develop flood management scenarios on a regional scale.

Investigations into Preferred Water Management Options in Gunbower Forest, 2D Modelling - Project management of the hydraulic modelling of the impact and effectiveness of proposed management options to improve watering of the wetlands and floodplain within Gunbower Forest.

Glenelg Hopkins CMA Rural Drainage Areas, Water Quality Impact Studies – Hydrologic and water quality analysis of four rural drainage areas specifically to examine the impacts of rural drainage on stream health of the main receiving waters.

Living Murray Hydraulic Investigation, Environmental flow for Barmah Millewa Wetland System – Project and technical management of this significant study within the Murray River system. The project involves the development and calibration of a detailed one and two-dimensional hydrodynamic model of the Barmah Millewa Forest for the purposes of determining the impact and effectiveness of various environmental flow management scenarios.

Lower Gawler Flood Mitigation Study – Detailed hydraulic modelling of the Lower Gawler River floodplain to investigate the effectiveness of various flood mitigation measures. A combined one and two-dimensional hydraulic model was employed.

Scoping Study for Best Management Options for Rural Drainage, Eumeralla and Nullawarre Drainage Areas – Major rural drainage study covering some 18,000 Hectares in south-west Victoria. Processing of ALS/Lidar survey data to assist in detailed hydrologic and hydraulic modelling. Investigation of water quality and environmental impacts of drainage practices and options for implementation of best management practices.

South Warrnambool Flood Study – Management of an urban hydraulic and flood mapping study of a major coastal township. Integration of a variety of survey data sources and a development of a two-dimensional hydrodynamic model.

Geelong Bypass Hydrology and Hydraulics – Management of the investigations of waterway requirements for this major freeway planning study. Numerous crossings analysed with a variety of techniques ranging from simple one-dimensional to fully two-dimensional models.

#### **FLOODPLAIN INVESTIGATIONS LAWSON AND TRELOAR**

Point Roadknight Drainage Investigation – Development of a detailed pipe and overland flow model for the assessment of flood extents and investigation of potential mitigation options.

Lake Burrumbeet and Burrumbeet Creek Floodplain Management Plan – Project and technical management of a comprehensive hydrologic and hydraulic modelling study. Assessment of economic, social and environmental impacts also determined.

Morambro Creek Surface Water Allocation – A rigorous hydrological approach was applied to a large catchment in south-east SA utilising a spatially distributed, GIS based hydrologic Model (SWAT). The results will be used in determining future allocation of water rights in the catchment.

Glass's Creek and Bell Street Flood Mitigation Studies – Detailed hydrology and hydraulic modelling has been undertaken in order to develop appropriate mitigation strategies for two densely developed urban areas in Melbourne. The two-dimensional overland flood models are coupled with detailed pipe network modelling to provide a robust and accurate analysis tool.

Princes Freeway (Pakenham Bypass), Cardinia Creek Crossing – Detailed hydrologic and hydraulic investigation of a proposed crossing of a particularly sensitive creek environment was undertaken. This involved fine-grid two-dimensional modelling.

Little Lang Lang River Waterway Mapping – A combined one and two-dimensional hydrodynamic model of this rural catchment was developed and results integrated into Melbourne Water's GIS system.

Albury-Wodonga Bypass Hydrology and Hydraulics – Development of a detailed two-dimensional hydraulic model for the assessment of alignment options. The development of detailed hydraulic performance criteria for alignment assessment was also undertaken.

City of Kingston, Flood Mitigation Assessment – Detailed flood modelling of various mitigation options. Utilising local catchment hydrologic and hydraulic models requiring detailed assessment at the block level combined with complex pump systems.

Breakwater Road Hydrology and Hydraulics – Review of hydrology and detailed hydraulic modelling of a proposed crossing of the Barwon River floodplain. An innovative hydraulic design was necessary in order to provide zero afflux within this sensitive floodplain area.

Shepparton Floodplain Management Investigation for Shepparton City Council – Project management of the hydraulic modelling aspects of the largest rural township flood study undertaken in Victoria.

Princes West Project - Detailed hydrologic and hydraulic assessment of the existing status of the Princes West freeway between Melbourne and Geelong via VicRoads. Crossing upgrades were designed for varying levels of immunity and various configurations.

Data Consistency Project Stages 7-10 – These projects involved detailed one and two-dimensional urban flood modelling of stormwater surcharges from the various main drain systems.

City of Kingston – Flood Mapping of various locations to supplement Melbourne Water Mapping. Development of local catchment hydrologic and hydraulic models requiring detailed assessment at the block level.

Data Consistency Project Stage 6 – This project involved detailed two-dimensional urban flood modelling of stormwater surcharges from the main drain system. This work formed a pilot study in which Melbourne Water were able to evaluate the benefits of applying two-dimensional modelling to urban areas.

Tambo River Geomorphic Investigation – The 1998 Tambo River event caused significant damage in the floodplain. Specialist two-dimensional hydraulic modelling was undertaken as part of an integrated study approach considering flooding, longer term geomorphological processes and potential waterway management options.

Tuppal and Bullatale Creek Flood Study – Development and calibration of an extensive model of the Tuppal/Bullatale Creek system as well as the Murray and Edward Rivers between Tocumwal and Deniliquin. This model was set-up for the subsequent analysis of floodplain management options through DLWC (NSW).

Strathmerton Route Investigation – Development and calibration of hydraulic models (ranging from steady state backwater to full two-dimensional unsteady models) for subsequent hydraulic design. Both Murray River and floodplain areas have been investigated.

Swan Hill Regional Flood Strategy – Extensive MIKE 11 modelling of Murray/Loddon River system upstream of Swan Hill to assess effects of proposed regional flood strategies.

Traralgon Floodplain Management Study for Shire of Traralgon – As for the Euroa Study, a comprehensive understanding of the flooding mechanisms is being gained through this state of the art fully two dimensional, dynamic flooding investigation.

Euroa Floodplain Management Study for Shire of Strathbogie – This Floodplain Management Study aimed initially at providing a comprehensive understanding of the damaging and complex flooding regime at Euroa, and subsequently at assessing potential flood protection measures (mitigation schemes, both structural and non-structural and flood warning systems). Full two-dimensional hydraulic modelling was undertaken.

Wangaratta Flood Study, Stage 2 – Application of MIKE 11 model to assess various flood mitigation measures.

Cairns Airport Drainage Study – Development and application of a detailed 2-dimensional model of the Cairns Airport and Lower Barron Delta in order to assess flood/cyclone hydrodynamic conditions at the Airport. Analysis of mitigation options.

Wangaratta Flood Study, Stage 1 – Development and calibration of a MIKE 11 model covering the extensive Ovens/King Rivers floodplain.

Yarra River, Melbourne – Development of a detailed MIKE 21 (two-dimensional) model of the Yarra River to investigate the hydraulic features of a small turning basin/wharf.

Gippsland Lakes System – One-dimensional model developed to analyse the potential impact of sea-level rise on lake levels.

Yarra River, Yarra Glen (VicRoads) – Set up and calibration of both one and two-dimensional models to investigate the impact of a proposed bridge replacement on flood levels.

Lower Loddon River Flood Study – development and calibration of MIKE 11 model covering an extensive floodplain network.

#### **COASTAL/ESTUARINE INVESTIGATIONS WATER TECHNOLOGY**

Gippsland Lakes Coastal Hazard Assessment – Project manager for a major hazard assessment project looking at impacts of sea level rise on coastal vulnerability throughout the Gippsland Lakes and Ninety Mile Beach.

Environmental Water Requirements of the Gippsland Lakes – Managed the input of scientific knowledge around hydrodynamics of the lakes and the freshwater/saltwater interface as well as the impacts of reduced freshwater inputs on these flow mechanisms.

Ecological Characterisation of the Gippsland Lakes – Provided hydrodynamic input to a broader characterisation project looking at the various habitats and bio-dependencies in the Gippsland Lakes.

Numerous Coastal Hazard Vulnerability Risk Assessments – assessing the change in risk to coastal inundation and stability due to sea level rise and the resulting change in coastal processes.

#### **COASTAL/ESTUARINE INVESTIGATIONS LAWSON AND TRELOAR**

Bass Strait – Three-dimensional model (Delft3D) development and calibration for pipeline design currents prediction.

Tropical Cyclone Thelma, Three-dimensional Current Model – This project involved the set-up and calibration of a three-dimensional hydrodynamic model of the Timor Sea and extraction of currents data.

Mooney Ponds Creek three-dimensional Water Quality Modelling – This project involved modelling of the detailed hydrodynamics of the fresh/salt-water interface in the Yarra River and how this effected the movement of pollutants from storm-water inflows.

Port Catherine Development, W.A. – Detailed three-dimensional hydrodynamic and water quality modelling of a proposed harbour development south of Perth.

Palm Springs Marina, Malaysia – Development of a two-dimensional model to assess effects of marina on local hydraulics.

Corio Bay Sediment Model Verification – Comparison of model predicted and recorded sediment plumes in Corio Bay during channel dredging.

Lake Illawarra/Botany Bay – Application of a two-dimensional water quality model to two large waterways. Long term water quality simulations performed and analysed for risk assessment.

South China Sea – Two and three-dimensional modelling to determine design currents for oil/gas pipelines.

Manila Bay – Analysis of flood behaviour, dredged sediment impacts and flushing characteristics of a proposed area of reclamation in Manila Bay, using one and two-dimensional models.

West Point Wilson hazardous chemicals storage facility – Environmental Effects Statement. Investigation of proposed facilities effect on nearby coastal processes.

East Coast Armaments Complex – Set up of two-dimensional current and wave models to investigate the impacts of proposed port facility.

Port Hedland – Set up and operation of numerical model to investigate Cyclone driven winds and wave set up.

Western Port – Two-dimensional model investigations of the dispersion of pollutants and the flushing characteristics of Western Port under tidal and wind driven currents.

Oil Spill Modelling/Response – Development of oil spill response procedures to perform real-time modelling of oil slick movements in Bass Strait and Western Port.

Western Port – Set up and calibration of a numerical model for the development of tidal and wind driven current fields as input to oil spill modelling.

Port of Geelong – Application of a two-dimensional numerical model to assess impact of a proposed dredging program on suspended sediment loads in Corio Bay.

Bass Strait – Numerical modelling of the flushing characteristics of Bass Strait over a typical year.

#### **EXPERT WITNESS REPORTS**

Adams Creek, Lang Lang – Expert evidence related to rural flooding and drainage issues

Donald, NW Victoria – Expert evidence and analysis of flooding issues related to channel networks on farmland in the Wimmera area

St Georges Road Northcote - Expert advice and modelling of an apartment development within SBO

Duncans Road South Werribee – Review of hydraulic conditions, flooding and drainage for a horticulture area. Provision of expert evidence report.

Nunawading – Expert evidence on flooding issues including modelling, for a multi-storey apartment building in a floodway zone

Hagen Park Bangholme – Expert advice and modelling of drainage issues in SE Melbourne

Noonan Grove Woodend - Expert advice and report on surface water management for a residential subdivision

Industrial Subdivision Shepparton/Mooroopna – Expert advice on drainage and flooding issues for land valuation purposes

Dandenong Valley, Scoresby – Expert modelling and report on flooding issues and development capability for land valuation

Coastal Development Paynesville – Expert report and evidence at VCAT on coastal hazard vulnerability for a residential subdivision

School Site Monbulk – Expert report on drainage issues in the Dandenong Ranges

Broken River, Stewarton – Expert modelling/report and evident at VCAT for a rural flooding issue

Toorak Road South Yarra – VCAT report and evidence in relation to redevelopment of a site within an urban area subject to flooding

Hopkins River Warrnambool – Flooding and coastal hazard vulnerability expert report and VCAT evidence

Apartment Development Port Fairy – Expert report on flooding issues associated with a proposed apartment complex

Port Fairy (2014) – Expert evidence to VCAT on coastal hazard and flooding for a proposed sub-division in Port Fairy.

Kerang East (2014) – Expert evidence to VCAT on flooding issues along Pyramid Creek arising from 2011 floods.

Woodend (2014) – Expert evidence to VCAT regarding flooding from Five Mile Creek and local stormwater impacts at a development site within Woodend.

Port Fairy Planning Scheme Amendment (2014) – Provided Expert Evidence on flooding to Planning Panels Victoria for Moyne Shire.

Victoria Street Richmond (2016) – Expert Evidence to VCAT on flooding issues related to a multi-storey apartment development next to the Yarra River.

Donnybrook/Woodstock PSP (2016) – Expert evidence to panel hearing in relation to drainage issues for a large greenfield development area.

Manningham (2016) – Provision of peer review of modelling and expert advice to City of Manningham regarding a planning scheme amendment to implement SBO layers into their planning scheme.

Amendment C121 Planning Panel - Leneva Baranduda Precinct – expert advice to the City of Wodonga

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## PUBLICATIONS

### CONFERENCE PRESENTATIONS

BISHOP, W.A., McCOWAN, A. D., SUTHERLAND, R. J., WATKINSON, R. J. - “Application of Two-Dimensional Numerical Models to Urban Flood Studies”, 2nd International Symposium on Urban Stormwater Management, Melbourne 1995.

SOMES, N.L.G., BISHOP, W.A., WONG, T.H.F. - “Numerical Simulation of Wetland Hydrodynamics”, MODSIM 97 International Congress on Modelling and Simulation, Hobart.

BISHOP, W.A., COLLINS, N. I., CALLAGHAN, D. P., and CLARK, S. Q. - “Detailed Two-Dimensional Flood Modelling of Urban Developments”, 8th International Conference on Urban Storm Drainage, Sydney 1999.

SOMES, N.L.G., BISHOP, W.A., WONG, T.H.F. - “Numerical Simulation of Wetland Hydrodynamics”, Environment International, Vol. 25, No. 6/7 pp. 773-779, 1999.

BISHOP, W.A. – “Two-dimensional Modelling for Urban Flood Mapping and Drainage Analysis”, Proceedings, Victorian Flood Management Conference, 2001.

BISHOP, W.A. and CATALANO, C.L., “Benefits of Two-dimensional Modelling for Urban Flood Projects”, 6th Conference on Hydraulics in Civil Engineering, Hobart 2001.

McCOWAN, A.D., BERTON, F.M. and BISHOP, W.A. – “The Application of a Three-dimensional Variable Density Model to Assess Water Quality in an Urban Waterway”, 6th Conference on Hydraulics in Civil Engineering, Hobart 2001.

REHMAN, H.U., ZHANG, S.Y., BISHOP, W.A., BERKFELD, J., “Water Resources Assessment using Soil Water Assessment Tool - A Case Study”, in Proceedings of ICam Catchment Management Conference, University of Western Sydney, Australian Water Association, Sydney, 26-28 November 2003.

McMASTER, M.J., PROVIS, D.G., GRAYSON, R.B. & BISHOP, W.A., “Calibration and testing of a hydrodynamic model of the Gippsland Lakes” in Proceedings of MODSIM 2003, Townsville, Australia 14-17 July 2003.

BISHOP, W.A., WOMERSLEY, T.J. & TIERNEY, G, “Flooding Forests - the Hydraulics of Environmental Flows”, Proceedings, 4th Victorian Flood Management Conference, Shepparton 2005.

MUNCASTER, S.H., BISHOP, W.A. and MCCOWAN, A.D., “Design flood estimation in small catchments using two-dimensional hydraulic modelling –A case study”, 30th Hydrology and Water Resources Symposium, Launceston, TAS, December 2006.

BISHOP, W.A. and WOMERSLEY, T.J., “The use of hydraulic models to inform the management of flood dependent ecosystems on the River Murray, South-Eastern Australia”, 6th International Symposium on Ecohydraulics, Christchurch, February 2007.

MUNCASTER, S. H., BISHOP, W. A. and DUGGAN, S.J., “Making the best with what you have - Design flood estimation with and without observed data”, 5th Victorian Flood Management Conference, Warrnambool, October 2007

BISHOP, W.A., CHARTERIS, A.B., MUNCASTER, S.H., WOMERSLEY, T.J., “Impacts of Climate Change on Floodplain Management in Coastal Communities”, 5th Victorian Flood Management Conference, Warrnambool, October 2007.

BISHOP, W.A. and TATE, B. “The Use of Eco-Hydraulics in Managing the River Murray”, 17th QLD Water Symposium, Griffith University, November 2008.

BISHOP, W.A. and WOMERSLEY, T.J., “Port Fairy Regional Flood Study - Dealing with Risk in a Coastal Floodplain”, Joint 49th Annual Floodplain Management Authorities Conference (NSW) & 6th Biennial Victorian Flood Conference, Albury, February 2009.

BISHOP, W.A., RUSSELL, K.L. and LITTLE, M.J., “Impacts of Sea Level Rise on Flooding in an Estuarine Environment”, Climate Change 2010: Practical Responses to Climate Change Conference, Melbourne, 2010.

MARTIN, J.C., ARROWSMITH, C.L., and BISHOP, W.A., Hydraulic Implications associated with the Placement of Timber Snags in a Developing Anabranch. Proceedings of the Sixth Australian Stream Management Conference, Canberra, Australian Capital Territory, 2011.

BISHOP, W.A., LAW, S.E., NEWTON, J.L., GODFREY, M., “Integrated Water Management Opportunities for Inner Suburban Areas”, WSUD 2013, 8th International Water Sensitive Urban Design Conference, Gold Coast, November 2013.

WOMERSLEY, T.J., LEAHY, C., HUDSON, K., ANDERSON, B., KAZAZIC, E., BISHOP, W.A., & MAWER, J., “Proof of concept hydrodynamic model and marine and atmospheric forecast data integration for flood forecasting in the Gippsland Lakes”, 54th Floodplain Management Association Conference, 20-23 May 2014, Deniliquin RSL Club, Deniliquin, NSW

MCCOWAN, A.D., LAUHLAN-ARROWSMITH, C., BISHOP, W.A., “Estimating Future Coastal Inundation and Erosion Hazards”, Australian Coastal Councils Conference, March 2015

COUSLAND, T.J., and BISHOP, W.A., “Transport modelling to verify constructed wetland residence times”, Stormwater 16 – National Stormwater Association Conference, Gold Coast, QLD, September 2016.

CLARK, S., BISHOP, W., CUNNINGHAM, L., TATE, B., DALY, A., “Utilising Hydraulic Grade Line rather than water surface levels for Flood Planning Levels”, 13<sup>th</sup> Conference on Hydraulics in Water Engineering, Sydney, Nov 2017.

CLARK, S., CUNNINGHAM, L., TATE, B., DALY, A., BISHOP, W., “Flood Planning Levels: Incorporating residual risk considerations”, 13<sup>th</sup> Conference on Hydraulics in Water Engineering, Sydney, Nov 2017.