



Expert Opinion

Amendment C391 to the Greater Geelong Planning Scheme

Eastern Ash Pty Ltd

Panel Hearing

November 2021





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CONTENTS

1	REPORT AUTHOR	5
2	REPORT CONTRIBUTORS	6
3	SCOPE OF REPORT	7
4	BASIS OF THIS REPORT	8
5	INTRODUCTION	9
6	BACKGROUND	10
6.1	Locality	10
6.2	Site Visit	13
6.3	Proposed Amendment	24
6.4	Planning Permit Application	24
6.5	Alternative Layout	25
7	REVIEW OF STORMWATER MANAGEMENT PLAN	28
7.1	Stormwater Runoff Management	28
7.1.1	Proposed Drainage Assets	30
7.1.2	Waterway Management	31
7.2	Lake Connewarre Analysis	32
7.2.1	Overview	32
7.2.2	Lake Connewarre Impact Assessment	32
7.2.3	Foreshore Impact Assessment	33
8	LAKE CONNEWARRE FLUSHING CHARACTERISTICS	35
9	STORMWATER DRAINAGE OUTLET FROM SELGA	36
10	SUBMISSIONS	37
10.1	The Department of Environment, Land, Water and Planning	41
10.2	Corangamite Catchment Management Authority (CCMA)	41
11	CONCLUSIONS	43
12	DECLARATION	44



LIST OF FIGURES

Figure 6-1	Subject Site	10
Figure 6-2	Subject Site - Topography	11
Figure 6-3	Current Zoning	12
Figure 6-4	South East Leopold Framework Plan	13
Figure 6-5	Photo Locations	23
Figure 6-6	Aerial Image April 2021, evidence of erosion in Unnamed Waterway (Source: MetroMap)	24
Figure 6-7	Development Layout (Tract, October 2020)	25
Figure 6-8	Alternative Subdivision Layout (source: Tract, June 2021)	26
Figure 6-9	DDO46 Concept Plan	27
Figure 7-1	Indicative Drainage Infrastructure (Spiire, October 2020)	29
Figure 7-2	Frog Habitat & Stormwater Wetland Design	31
Figure 7-3	Pre- and Post-Comparison Map January 1935 (Source: Venant Solutions, December 2019)	34
Figure 10-1	1% AEP Flood Afflux (source: Spiire, February 2020)	40
Figure 10-2	20% AEP Flood Afflux (source: Spiire, February 2020)	40

LIST OF TABLES

Table 8-1	Estimated Tidal Flushing Characteristics	35
Table 10-1	Summary of Matters Raised in Submissions	37



1 REPORT AUTHOR

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- 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, 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 C391 to the Greater Geelong Planning Scheme.



2 REPORT CONTRIBUTORS

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- 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 C391 to the Greater Geelong Planning Scheme, I have been engaged to act as an independent expert on stormwater management issues relevant to the proposed rezoning of the Farming Zone (FZ) land to General Residential Zone Schedule 1 (GRZ1) with a Design and Development Overlay and planning permit PP-39-2019 for 87-101 & 103-127 Ash Road, Leopold.

I have been asked to review the material provided to me and prepare an expert witness statement in respect to Amendment C391 to the Greater Geelong Planning Scheme and the above planning permit. Specifically, I have been requested to:

- Peer Review the Stormwater Management Plan (SMP) prepared by Spiire;
- Consider and confirm what changes would be required to the SMP to account for the revised subdivision layout;
- Prepare evidence and appear as an expert witness on behalf of Eastern Ash Pty Ltd at the Panel Hearing.



4 BASIS OF THIS REPORT

This report is based on a review of Amendment C391 to the Greater Geelong Planning Scheme supporting information and technical reports, including:

- Permit Application and other supporting report, including:
 - The Stormwater Management Plan (SMP), prepared by Spiire (February 2020).
 - Ash Road Development Flows to Lake Connewarre Impact Assessment, prepared by Venant Solutions Pty Ltd (December 2019).
 - Ash Road Development Site Hydrology Modelling – Technical Memorandum, prepared by Cardno TGM (October 2019).
- Eastern Ash Pty Ltd's submission to the exhibited Amendment, including a revised subdivision layout in seeking to respond to the draft planning permit conditions exhibited by council.
- Review of additional available information, including:
 - LiDAR (survey) and VicMap data
- Submissions received in respect to Amendment C391 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:
 - Council Meeting Minutes (28 September 2021)
- Lower Barwon Wetlands Hydraulic Modelling for the Environmental Entitlement, Water Technology, July 2011

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.



5 INTRODUCTION

I have been instructed by Maddocks on behalf of Eastern Ash Pty Ltd to provide expert evidence in relation to relevant drainage and flooding matters associated with the proposed Amendment C391 to the Greater Geelong Planning Scheme and Planning Permit PP-39-2019.



6 BACKGROUND

6.1 Locality

The subject site consists of 5 parcels of land located within Leopold, as shown in Figure 6-1. The proposed Amendment applies to 73-85 Ash Road, Leopold, 87-101 Ash Road, Leopold, 103-127 Ash Road, Leopold, 129-141 Ash Road, Leopold and 143-155 Ash Road, Leopold. The planning permit applies to 87-101 Ash Road and 103-127 Ash Road, Leopold.

The amendment area is approximately 29 ha and abuts Ash Road to the west, Mollers Lane Development (i.e., Amendment C367 land) to the east and is immediately adjacent to existing urban residential areas to the north and west.



Figure 6-1 Subject Site

The land is currently zoned Farming Zone (FZ), as shown in Figure 6-3, and has been identified for future residential development in the South East Leopold Framework Plan (Figure 6-4), prepared in 2016 to guide the rezoning and development of approximately 80 ha south of the Bellarine Highway between Ash Road and Mollers Lane.

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The site topography is shown in Figure 6-2 below. This highlights that the land generally slopes from north to south and west to east. The un-named waterway catchment that flows into Lake Connewarre is highlighted with tributaries through the subject site and the balance of the SELGA land. For the purposes of this report I have named the northern waterway through the SELGA land Tributary 1 and the southern waterway Tributary 2. The land associated with Amendment C391 primarily drains to Tributary 2.

The highest elevations on the site are approximately 52 m AHD in the north-west corner and the lowest is at the waterway on the boundary with the Mollers Lane development area, near the south-east corner of the site at approximately 32 m AHD.

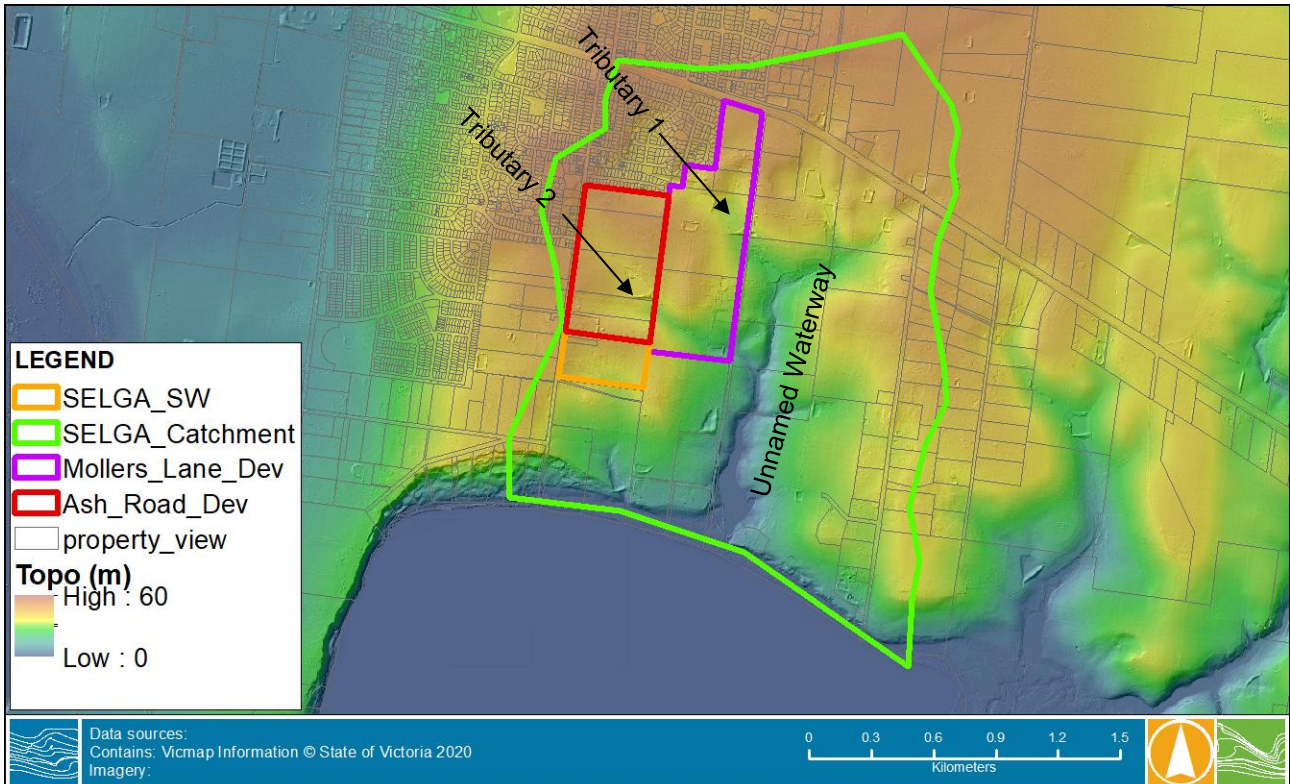


Figure 6-2 Subject Site - Topography



Figure 6-3 Current Zoning

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Figure 6-4 South East Leopold Framework Plan

6.2 Site Visit

A site visit was conducted on 5 November 2021. The weather was fine. There had been rain in the preceding days and the area was generally wet. I was able to view the general area and land down to Lake Connawarre. Photos 1 to 15 are provided below with a guide to the locations shown in Figure 6-5. Some points noted from this inspection:

- All the dams observed had significant areas of matted algae at the surface, indicating high nutrient loads. This could be from a combination of untreated urban runoff and rural land practices.
- There was no evidence of waterway erosion. I observed the waterways from public access areas and hence could not see all of the waterway reaches. It is evident from aerial imagery, as shown on Figure 6-6, that there is a section of channel in the unnamed waterway that appears to have experienced channel erosion and has a much deeper profile than the waterway reaches in the rest of the area. This section of deeper channel appears to have been present for many years and has not advanced further upstream (from review of Google Earth imagery). The valley in this location is narrower and the channel form may be a response to topography and not necessarily a sign of significant future erosion risk.
- Some local erosion along Mollers Lane was observed due to recent heavy rainfall and landscape works on a property on the east side of the road.
- The area at the end of Mollers Lane, where the unnamed tributary meets Lake Connawarre was very wet. This suggests the area already experiences significant freshwater flows during the winter/spring

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period. The vegetation in this area appears to be influenced by this current water regime as there was an absence of saltbush along this section of the shoreline.

- Stormwater from the upstream reaches of the Tributary 1 catchment is not presently well treated as there appears to be no water quality treatment on this waterway. This is consistent with the age of the development which was likely before these measures were required.



Photo 1 – View south-east over Lake Connewarre from end of Ash Road



Photo 2 – View east along Lake Connewarre shoreline from end of Ash Road, salt-bush in foreground



Photo 3 – View south from Mollers Lane over dam at end of catchment

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Photo 4 – Panorama View from Mollers Lane over dam at end of catchment, significant algae observed on surface, indicative of poor water quality



Photo 5 – View from end of Mollers Lane, area between dam and shore, appearance of freshwater marsh



Photo 6 – View east from end of Mollers Lane over access track/dam spillway at end of catchment

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Photo 7 – View east from end of Mollers Lane at shore, significantly surface ponding of rain/runoff



Photo 8 – View west from Mollers Lane at upstream side of Tributary 2 crossing. Culverts in foreground and farm dam background

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Photo 9 – View east from Mollers Lane at downstream side of Tributary 2 crossing, looking towards the Unnamed Waterway. No evidence of erosion in this waterway.

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Photo 10 – View north on Mollers Lane from Tributary 1 crossing. Evidence of erosion and sediment deposition from recent rain



Photo 11 – View north on Mollers Lane (east side) from north of Tributary 1 crossing. Evidence of erosion and from recent rain

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Photo 12 – View east from Mollers Lane at Tributary 1 crossing, looking downstream. Evidence of sediment deposition but no bed erosion with good vegetation cover in channel.



Photo 13 – View west from Mollers Lane at Tributary 1 dam decommissioning works.

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Photo 14 – View east at Myuna Street retarding basin.



Photo 15 – View south at waterway downstream of Myuna Street retarding basin (Tributary 1), just before dam. Evidence of litter build up and gross pollutants.

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Figure 6-5 Photo Locations

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Figure 6-6 Aerial Image April 2021, evidence of erosion in Unnamed Waterway (Source: MetroMap)

6.3 Proposed Amendment

The Amendment proposes to rezone the Farming Zone land to allow for conventional residential development. The Amendment will rezone the five parcels to the General Residential Zone Schedule 1, with an accompanying Design and Development Overlay.

6.4 Planning Permit Application

A concurrent planning permit application (PP-39-2019) is being considered with the Amendment, for a multi-lot subdivision and removal of native vegetation for only the land at 87-101 Ash Road and 103-127 Ash Road Leopold, with the development layout plan for this site shown in Figure 6-7. The planning application was supported by a Stormwater Management Plan (SMP) prepared by Spiire (February 2020), which I discuss in Section 7.

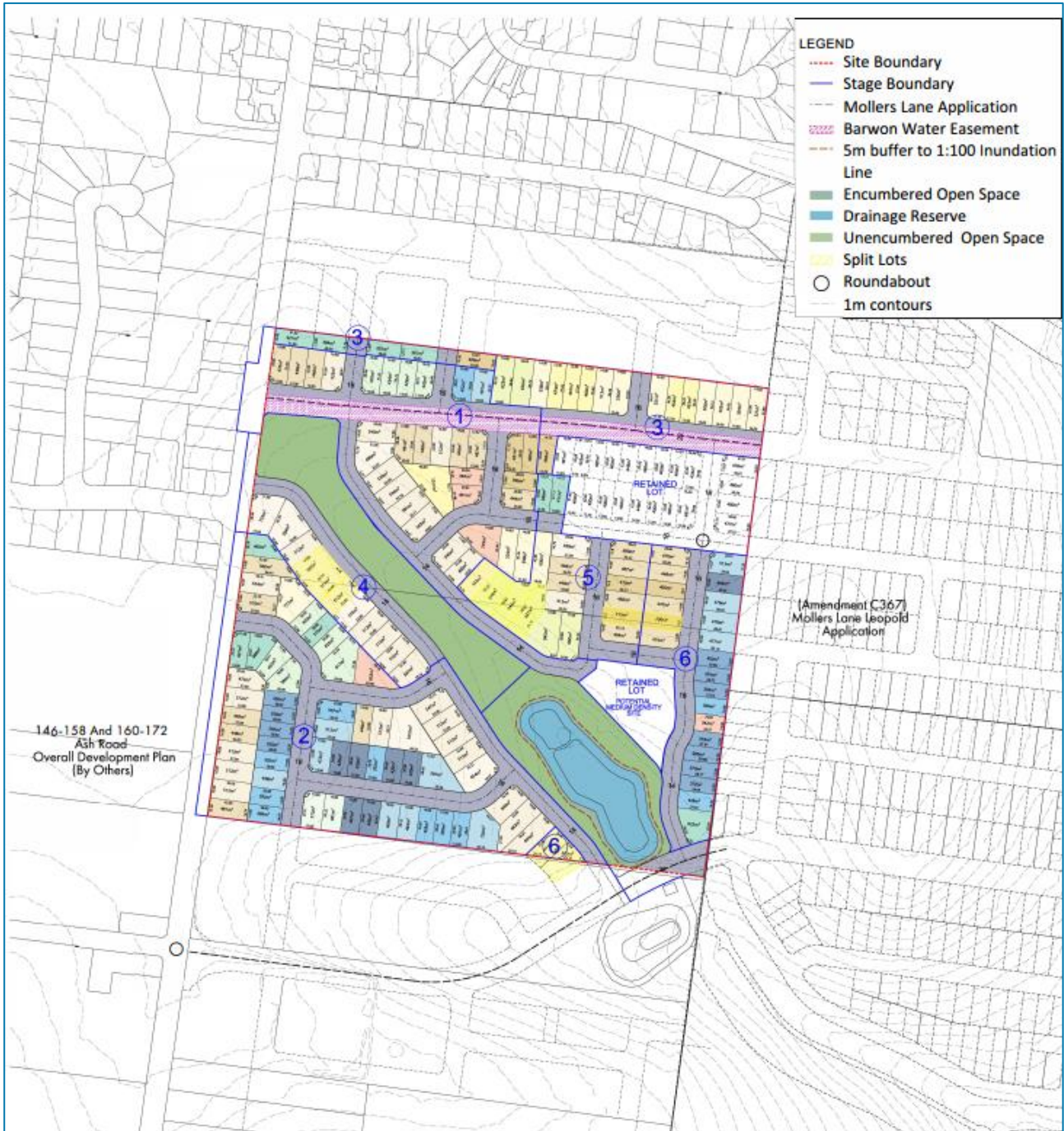


Figure 6-7 Development Layout (Tract, October 2020)

6.5 Alternative Layout

I understand that the proponent has, in response to the draft planning permit conditions exhibited by Council, reconfigured the area of open space and is proposing a change to the subdivision layout to enable this. As shown in Figure 6-8, the alternative development layout would incorporate a 1 ha public open space near Ash Road, but a narrower linear reserve connecting this larger reserve to the drainage reserve near the site outlet (i.e., south-east of site). The alternative layout would provide for two 1 ha parks (the other one being in the south-east corner, adjacent to the proposed drainage reserve) generally in the locations illustrated in the DDO46 concept plan (Figure 6-9).

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Figure 6-8 Alternative Subdivision Layout (source: Tract, June 2021)

The stormwater management will be based on the same approach documented in the current SMP, namely that the stormwater runoff will be piped across the open space, with major flows conveyed via an open channel and the road network:

- I understand that the design will aim to avoid creating encumbered land, including across the 1 ha public open space;
- This may necessitate the pipes and channel conveying runoff from the upstream catchment to circumvent the reserve and follow the adjacent road reserve to the south (as the Barwon Water Bellarine Transfer Mains pass to the north of the reserve).

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It must be noted that it is not uncommon for proposed concept site layouts to change as the development progresses. Net Developable Area increases by about 0.7 ha in the revised subdivision layout. This increase in imperviousness area would need to be catered for in the design of the pipes and drainage assets.

The SMP (further discussed in section 7) would need to be updated to confirm the size of water quality assets and retardation basin in light of the proposed changes in landuse (i.e., fraction imperviousness)¹. Given that the overall density is not significantly altered, I do not anticipate that the changes will have a significant impact on the design of the drainage and water quality assets. That is, the location and general configuration of the retarding basin/wetland will not change and any alterations to the detailed design and sizing would be minor.



Figure 6-9 DDO46 Concept Plan

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¹ Pipe size can be considered at the functional/detailed design stage

7 REVIEW OF STORMWATER MANAGEMENT PLAN

This section documents the findings of my review of the SMP prepared by Spiire (February 2020), in particular, the proposed mitigation measures and potential impact on flood risk and water quality. I have focused my review on the development shown in Figure 6-7, noting that the SMP also considers the parcels immediately to the south and north. Where applicable I have also addressed the proposed alternative layout in Section 6.5.

Given the level of detail provided in the Stormwater Management Plan, further detailed review of specific model files was not considered necessary for this review.

7.1 Stormwater Runoff Management

The SMP identifies mitigation measures to:

- Limit 1% AEP peak design discharge from the developed areas of the site to pre-development level peak flows using a retarding basin, to protect the downstream environment (both built and natural) from flooding and erosion.
- Design roads or open space reserves to act as overland flow paths and to ensure safe conveyance of local flows across the site; and
- Adopt Water Sensitive Urban Design Best Practice.

Risks were assessed using water quality and hydrological modelling. The SMP also documents the proposed drainage infrastructure to meet the peak outflow targets applicable to the site and the Water Sensitive Urban Design (WSUD) assets proposed to treat runoff from the development and protect waterway health values and the downstream environment.

A series of drainage infrastructure assets would provide both stormwater quantity and quality control for the site:

- 1% AEP (Annual Exceedance Probability) flow will be conveyed across the site via underground pipes (minor flows) and/or road reserve (major flows);
- An end-of-line 6,550 m³ retarding basin would temporarily store stormwater on-site and release stormwater runoff at a reduced rate (equivalent to pre-development conditions) to ensure there is no detrimental off-site impact from increased impervious areas, as per standard practice and the current version of the Infrastructure Design Manual (<https://www.designmanual.com.au/download-idm>).
- WSUD assets are intended to treat stormwater runoff to meet Best Practice Environmental Management Guidelines (BPEMG) objectives before being discharged to the downstream designated waterway.
 - A combination of WSUD assets would treat stormwater runoff from the permit site, including:
 - A 1,000 m² sediment basin
 - A 2,800 m² wetland.
 - A 6,550 m³ retarding basin, with the sediment basin and wetland located at the base.
 - A high flow piped bypass, around the sediment pond and wetland, to provide scour protection to the planting of these assets
 - The southern drainage reserve comprises:

I note that there is a designated waterway crossing the site. Whilst there was originally a linear reserve along its alignment, I understand that Council's Open Space department indicated that "*it was preferable to keep open stormwater drainage separate from the linear open space to create a less encumbered, and usable space for the future community*" (Spiire, February 2020). Corangamite Catchment Management Authority (CCMA) indicated they would be agreeable to this arrangement, however, "*water quality treatment provided to the proposed development would need to "exceed" best practice*" (Spiire, February 2020). I discuss this issue in Section 7.1.2.

It is also noted that no treatment has been proposed for the small northern catchment. This would either need to be accommodated by a small treatment area within that part of the development at a later permit stage, or some agreement reached with the Mollers Lane development to accommodate this flow and treat it within their works.

The site is within a catchment contributing to Lake Connewarre. Lake Connewarre is part of the Bellarine Peninsula Ramsar Wetland system, and, consequently, a protected area of national environmental significance under the *Environmental Protection and Biodiversity Conservation Act 1999*. This was considered in the SMP and informed by a detailed hydrological and ecological study undertaken by Venant Solutions. I discussed this issue in Section 7.2.2.

7.1.1 Proposed Drainage Assets

My comments in relation to the proposed drainage assets are as follows:

- The Stormwater Management Plan documents proposed drainage infrastructure to meet the peak outflow targets applicable to the site. This consists of one retardation basin located within the proposed residential subdivision.
 - I note that the existing dam will be decommissioned and replaced with a new asset. Its design will be subject to an ANCOLD assessment, which I consider appropriate to occur at the functional/detailed design stage. This can be covered by a suitably worded planning permit condition.
 - Hydrological modelling using RORB was undertaken to establish the site hydrological regime under current and future conditions and inform the concept design of the retarding basin (i.e., storage volume and area).
 - The hydrologic modelling was in accordance with the 1987 Australian Rainfall and Runoff (ARR) Guidelines, noting that the ARR Guidelines have since been updated (in 2019).
 - I understand that ARR87 was used to align with the methodology adopted for the Mollers Lane assessment (which at the time of this assessment was already endorsed by Council).
 - Both the City of Greater Geelong and the CCMA requested that the modelling for the Ash Road development be directly comparable to the earlier modelling undertaken for the adjacent developments at Mollers Lane.
 - Based on previous experience, I do not anticipate the change in hydrology method would have a significant impact on the results and the use of hydrology consistent with the Mollers Lane investigation is appropriate.
 - Two-dimensional overland flow modelling (TUFLOW) was also undertaken to further demonstrate the retarding basin performed as designed.
- The MUSIC water quality modelling demonstrated that Best Practice objectives are met and exceeded by the proposed water quality treatment train:

- I consider that the proposed water quality treatment train (i.e., constructed wetland) is appropriate to meet Best Practice objectives. I note that the [Infrastructure Design Manual](#) and VPP refer to the BPEMG objectives.
- I note that DELWP, in their submission to the panel, recommend an amendment to draft permit condition 17, to include design standards that meet Growling Grass Frog Habitat Design Standards in any new WSUD landscape elements. This has not been considered in the SMP however, it would be appropriate for this to be considered at the functional/detailed design stage:
 - The wetland design can be adjusted to integrate Growling Grass Frogs (as shown in Figure 7-2), noting this may increase the footprint of the asset and, possibly, encumbered land.

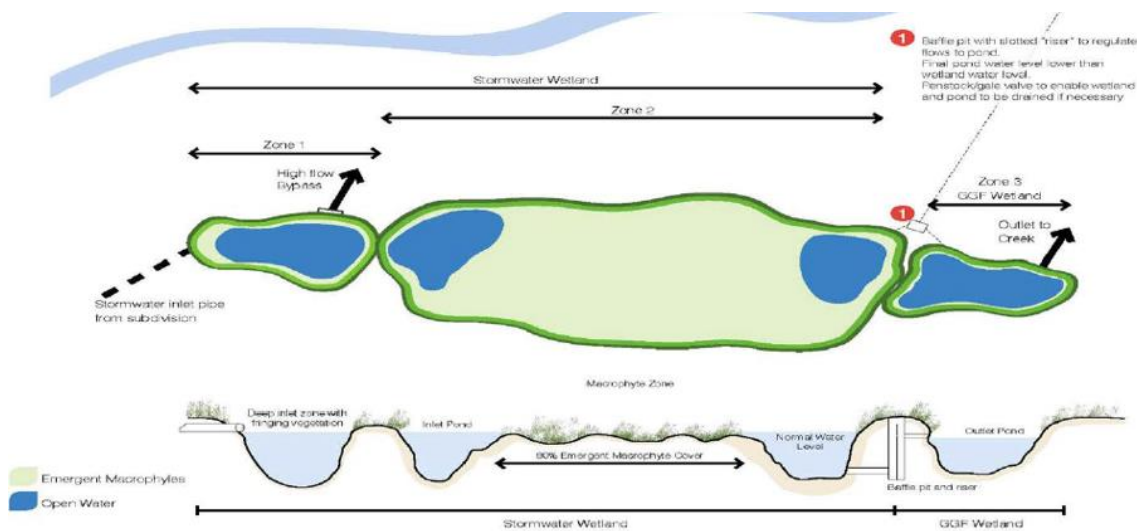


Figure 7-2 Frog Habitat & Stormwater Wetland Design²

7.1.2 Waterway Management

There is a designated waterway located within the subject site and it is proposed for this waterway to be piped across the site, to the end-of-line retarding basin. This is not typical for new development, noting that the current Planning Scheme supports the preservation and enhancement of waterway values for existing streams. The Victorian Planning Scheme Provision 14.02-1S (Catchment planning and management) requires natural drainage corridors to be retained with vegetated buffer zones at least 30 metres wide along each side of a waterway to:

- Maintain the natural drainage function, stream habitat and wildlife corridors and landscape values,
- Minimise erosion of stream banks and verges, and
- Reduce polluted surface runoff from adjacent land uses.

I understand that the proposed piping arrangement is partly driven by Council's Open Space department "to create a less encumbered, and usable space for the future community". I would typically expect an open channel to be maintained, with a re-vegetated waterway buffer to promote native species and designed to relevant standards. The CCMA has given its *in-principle support for the planned piping of the short ephemeral waterway* provided that BPEMG objectives are exceeded and piping of the waterway does not represent a decrease in stormwater treatment (CCMA, January 2020). I note that the MUSIC model presented in the SMP

² Rockbank North PSP - Conservation Management Plan for Growling Grass Frog (Ecology & Heritage, 2012)

shows that these BPEMG objectives are exceeded. Based on this background information I consider the proposed solution is appropriate in this context.

7.2 Lake Connewarre Analysis

7.2.1 Overview

The site is within the SELGA which ultimately discharges to Lake Connewarre. Given Lake Connewarre is a RAMSAR wetland and it has a higher level of protection, as Ramsar wetlands are a protected matter of national environmental significance under the *Environmental Protection and Biodiversity Conservation Act 1999*.

Venant Solutions and Lloyd Environmental were engaged to assess *the potential impacts on Lake Connewarre resulting from changes in the hydrological regime due to the proposed development*. Venant Solutions developed a water balance model to assess expected changes in surface runoff flow volumes and the impact on the Lake Connewarre hydrological regime, as a result of the proposed development. It accounted for both the Ash Road (i.e., subject site) and Mollers Lane Development sites (proposed development to the east). The report commented on changes to the Lake Connewarre littoral zone and the local creek catchment near the foreshore.

7.2.2 Lake Connewarre Impact Assessment

The water balance analysis relied on:

- 126 years of daily time-step analysis, using MUSIC and SILO (Bureau of Meteorology) data; and
- Quantitative assessment of changes to mean monthly flow volumes.

The water balance modelling shows, as expected, there is likely to be an increase in flows reaching Lake Connewarre, estimated to be less than 6% throughout the year, with the greatest increase expected between November and January. It is important to note that the 6% change takes into account other freshwater inflows from the broader catchment area (outside SELGA) and rain falling directly on the lake. The volumetric increase in runoff from the SELGA would therefore be greater than 6%. I estimate an increase of around 15% in flows from the unnamed waterway due to the SELGA development. This increase would not change the conclusions of the Lake Connewarre impact assessment and is more relevant to the potential impact on the unnamed waterway. I consider the approach adopted by Venant Solutions is appropriate.

The Venant Solutions report considered that, relative to the wider catchment contributing flows to Lake Connewarre, the increase is minor and would likely be further buffered by tidal influences and the Barwon River.

In light of the small scale of hydrological changes from increased run-off, Venant Solutions and Lloyd Environment concluded that the development would likely not trigger provisions under the EPBC Act (Australian Government 1999) or the Victoria's EES provisions. I agree with this assessment, noting that no detailed assessment of the hydrodynamics of Lake Connewarre was undertaken. I have undertaken preliminary estimates of the tidal flushing within Lake Connewarre as documented in Section 8. This confirms that the expected change in Lake Connewarre flow volumes will be negligible.

Although the conclusions regarding the provisions of the EPBC Act and the ecological values of Lake Connewarre are outside my areas of expertise, I consider that the adopted approach to model the potential impact of the development on Lake Connewarre provides a reasonable level of information to inform the assessment. I note that:

- The models are uncalibrated as there is no data available for this purpose.

- The key purpose of this exercise is to identify trends and in particular the difference between existing and developed conditions. This type of model (MUSIC water balance) is typically more reliable for predicting changes (between scenarios) compared to predicting absolute water level values.
- The model is appropriate for the purposes of defining catchment landuse change impacts.

7.2.3 Foreshore Impact Assessment

Both Ash Road and Mollers Lane developments drain to an existing farm dam storage, located immediately north of Lake Connewarre. Any changes to the dam's hydrological regime, driven by the increase in impervious areas in the SELGA development area, may impact about 0.6 ha of foreshore habitat directly downstream of the dam. This habitat contains samphire and lignum swamp.

The water balance model was supplemented with a detailed hydraulic model of the foreshore area, using TUFLOW. Two scenarios were tested, for months considered representative of the mean monthly flow for the respective months derived from the water balance model analysis over a 126-year period. Existing and post-development conditions were modelled, for comparison.

The post-development water balance modelling suggests that increases *in mean monthly runoff flows ranges from 76 % to 93 % with the increase fairly even across all months*. The hydraulic modelling also confirmed there would be an increase in inundation extent along the foreshore during the two months tested. The flood extent would increase by 0.22 ha in one of the scenarios tested (see Figure 7-3). There would be however, no significant change in the duration of inundation.

The report notes that the samphire and lignum habitat is in poor condition in the area affected by clearance, grazing and weeds (i.e., on private land) but much more extensive on the foreshore zone. It is inferred from this that the foreshore vegetation is composed of tolerant species and is likely to be resilient to the small changes in flow predicted. I am not in a position to comment on the vegetation response, however I note that in this localised area, the hydrologic impact is significant.

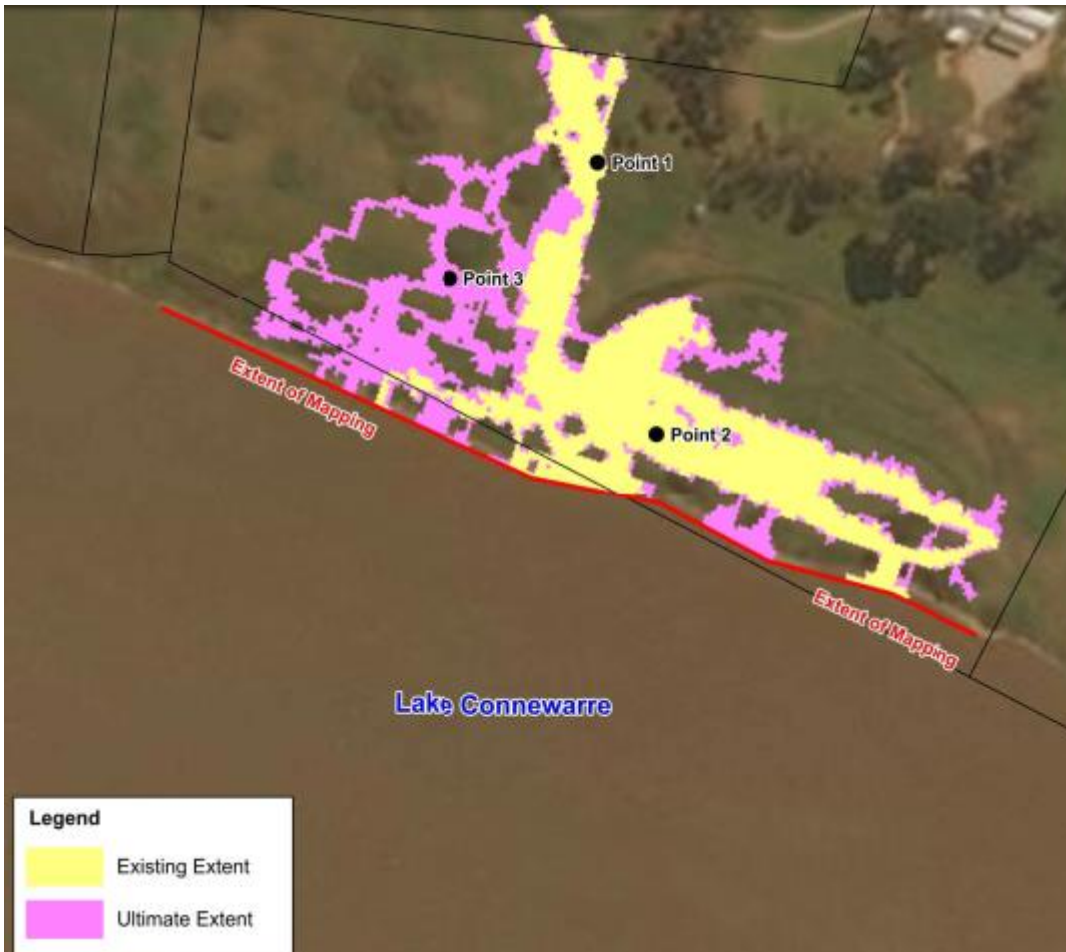


Figure 7-3 Pre- and Post-Comparison Map January 1935 (Source: Venant Solutions, December 2019)

The Venant Solutions report acknowledges that these changes are likely to lead to significant changes to water quality or ecology of the foreshore habitat in a small area (of approximately 0.5 ha) adjacent to Lake Connewarre. On the other hand, and relative to the overall Ramsar size, the predicted changes would represent a low risk to the Ramsar wetlands.

A number of mitigation measures are recommended to address the risk to the foreshore habitat, including:

- Stormwater re-use within the developments, such as rainwater tanks and irrigation of public open space;
- Flow diversion via a pipe;
- Modification to the dam outlet; and/or
- Instream works to mitigate against potential for increased erosion.

The above mitigation measures would aim to mitigate the entire SELGA impact, including erosion to the gully system, between Mollers Lane and Lake Connewarre. I understand however, there is still some uncertainty around what the future SELGA outlet design will be and how it will be funded. This is discussed in a following section.

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8 LAKE CONNEWARRE FLUSHING CHARACTERISTICS

In order to further investigate the Lake Connewarre hydrologic impact I have undertaken a review of previous work completed by Water Technology, the Lower Barwon Wetlands Hydraulic Modelling for the Environmental Entitlement, July 2011, for the Corangamite CMA. A copy of this report is provided in Appendix B.

This study undertook analysis of data and hydrodynamic modelling of the estuary. The main points that can be considered from this study are:

- Lake Connewarre is a shallow (<2 m) tidal lagoon that is connected to the ocean at Barwon Heads via a sinuous tidal channel.
- The tidal range reduces from approximately 2 m at Barwon Heads to approximately 0.3 m in Lake Connewarre.
- Due to the lagoon's shallow depths, wind driven mixing is an important process operating in Lake Connewarre and has a significant impact on circulation.
- The salinity in Lake Connewarre shows a relatively high degree of spatial and temporal variation.
- Salinity varies in response to:
 - freshwater inflows from the Barwon River and local run-off;
 - tidal and surge driven marine flows;
 - evapo-concentration during summer in particular
- Mean water levels within Lake Connewarre are generally 0.2 m above mean sea level due to shallow water hydrodynamic effects associated with the propagation of the astronomical tide along the Lower Barwon estuary. This phenomenon is known as tidal pumping.

Based on the information in this report I have undertaken calculations to estimate the tidal prism. This is the average volume of water expected to be exchanged in Lake Connewarre each tidal cycle. These values are summarised in Table 8-1 below. This shows the impact of the change in development on total volume in Lake Connewarre is negligible.

Table 8-1 Estimated Tidal Flushing Characteristics

Lake Characteristic	Parameter Value
Mean Tidal Range	0.3 m
Mean Lake Area	999 ha
Tidal Prism	2997 ML
Estimated average annual increase in flow from development	190 ML/year or 0.521 ML/day
Estimated daily average increase in flow from development as a percentage of tidal prism volume	0.02%

9 STORMWATER DRAINAGE OUTLET FROM SELGA

The impact on the Lake Connewarre foreshore and the waterway/gully downstream of the subject site is dependent on both this site (Ash Road Development) and the Mollers Lane development (to the east) securing a suitably designed outfall. One of the options considered is a diversion pipe to convey excess volumes directly to Lake Connewarre, however, I understand there is no set design at this time. If such a design was feasible, this would be an effective means of protecting the waterway. Whilst the volumetric impact of stormwater discharge to Lake Connewarre has been assessed as acceptable, the diversion would require a sensitive outlet design to convey water to the lake. This would either need to be via a land or lake outfall. Both these cases would require careful design to manage erosion and environmental risks.

I also understand that the proponent for the planning permit application at Ash Road Leopold accepts that the SELGA drainage outfall should be a shared cost, split between all land parcels that drain into this asset.

A design of the outfall will need to be settled upon, with in-principal support from relevant stakeholders including private landowners, DELWP and CCMA prior to this development proceeding. I note that the draft planning permit conditions do cover this eventuality, namely requiring for an addendum to the SMP detailing the constructed outfall infrastructure to Lake Connewarre (draft planning permit condition 4). This will likely require the creation of an easement, noting this is covered in the draft planning permit condition 8:

8. Unless otherwise approved in writing by the Responsible Authority, prior to certification of each relevant stage of the Plan of Subdivision, the following easements and/or reserves must be created and registered with Land Victoria, or there must be an agreement in writing to the satisfaction of the Responsible Authority which secures their creation:

A) Drainage easements and/or reserves as required by the land use between the subject site and the outfall at Lake Connewarre.

The creation of this easement would also likely require Council to:

- Consider that the economical and efficient servicing of the land requires the holder of the permit or owner of the land to acquire an easement in favour of Council **between the subject site and the outfall at Lake Connewarre.**
- Council to consider that the acquisition will not result in an unreasonable loss of amenity in the area affected by the acquisition.

The above conditions would empower the permit holder to acquire the easement in accordance with Section 36 of the Subdivision Act 1988, should it be required. This may include an easement over downstream land, in the event it is not developed (noting that a planning permit has already been granted for Mollers Lane development, immediately to the east).

Based on the above, I consider there are sufficient safeguards within the proposed permit conditions to ensure the design and construction of the SELGA outlet is addressed prior to the development progressing at the subject site. I note the existing permit conditions for the Mollers Lane development also require the design of “off-site drainage works” to manage stormwater. Clearly a combined and integrated solution to drainage, shared by the Mollers Lane and Ash Road areas, is needed to appropriately address stormwater management for the SELGA.

10 SUBMISSIONS

I have responded to issues raised by submissions related to Amendment C391, 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>Submissions 7, 11, 13, 15 - Potential detrimental impacts of stormwater runoff into the Lake Connewarre State Game Reserve, a part of Port Phillip Bay (Western Shoreline) and Bellarine Ramsar site</p> <p>Development impact of freshwater flows into the Lake require careful management and may require a separate application to the Commonwealth Government for approval under the EPBC Act</p>	<p>Investigations have demonstrated that changes to freshwater inflows to Lake Connewarre will be negligible in the context of overall flushing and lake turnover. Water quality aspects will be managed through WSUD designs as appropriately described in the Stormwater Management Plan.</p>
<p>Submission 10 - ANCOLD assessment is required for the retarding basin proposed within the site</p>	<p>The existing dam will be decommissioned and replaced with a new asset. Its design will be subject to an ANCOLD assessment, which I consider appropriate to defer to the functional/detailed design stage. It can be ensured by a suitably worded planning permit condition.</p>
<p>Submission 10 - Stormwater infrastructure should not result in open space being encumbered</p>	<p>I understand that the proposed drainage infrastructure, including the piped waterway, will be located within the road reserve and would not encumber open space land. This will need to be confirmed at the design stage, to ensure that the proposed pipes can circumvent future public open space reserves (e.g., 1 ha POS), as piping through unencumbered open space is not supported by Council.</p>

<p>Submissions 10, 17 - Detrimental impact on adjacent land, which are not mitigated by the proposed drainage infrastructure proposed in the Stormwater Management Plan (Spiire, February 2020).</p>	<p>The modelling to-date, which includes a range of events, provide confidence that the potential adverse impacts can be mitigated as part of the detailed design. The hydraulic modelling shows some increase in flood levels (i.e., afflux) on adjacent properties. This afflux is generally contained within drainage and waterways reserves and/or road reserves (as shown in Figure 10-1 and Figure 10-2).</p> <p>It is desirable that a flood impact analysis be undertaken over a range of design flows, not just the extreme flood range. Whilst a range of events were modelled, impacts from the development was only assessed for the 20% and 1% AEP events. I expect the afflux information could be readily extracted for other events (e.g., 50% AEP) from the model results.</p> <p>I consider the critical aspect for the impact assessment at the planning stage is to determine whether feasible mitigation strategies exist to mitigate those impacts identified by the modelling. The results presented in Spiire's SWMP, and Corangamite CMA "no objection" position, provide confidence that mitigation solutions</p>
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Concerns Raised	Comments
	<p>can be achieved for the development. The details of which will be finalised as the project design progresses and could be addressed in the SWMP to be submitted to Council with the detailed design. In the case where some residual afflux above acceptable limits remains (e.g., that may change, affect or limit the future development potential of adjacent properties), the design solution can be refined and resolved through the detailed design process in compliance with Council's and Corangamite CMA's requirements. Some level of residual afflux could also be discussed with and accepted by the relevant authority or any affected property owners.</p> <p>I note that Council, in its response to the submissions, indicated that <i>the proponent will be required to further quantify the impact and amend the SWMP to demonstrate how this will be mitigated</i>. A number of conditions (e.g., # 4, #6, #17) are included in the draft planning permit that would provide suitable control to ensure additional details (and other clarifications required in the SWMP) are provided, prior to Certifications.</p> <p>I also note that proposed infrastructure to service the areas not covered by the planning permit application is conceptual only. This will need to be confirmed by the proponents for these parcels, as part of future planning permit application. The information provided in Spiire's SWMP provides suitable confidence that the overall C391 can be serviced once developed, though details may need to be refined for the other parcels. I would anticipate that site-specific Stormwater Management Plans would be prepared, to support other future planning permit application(s).</p>

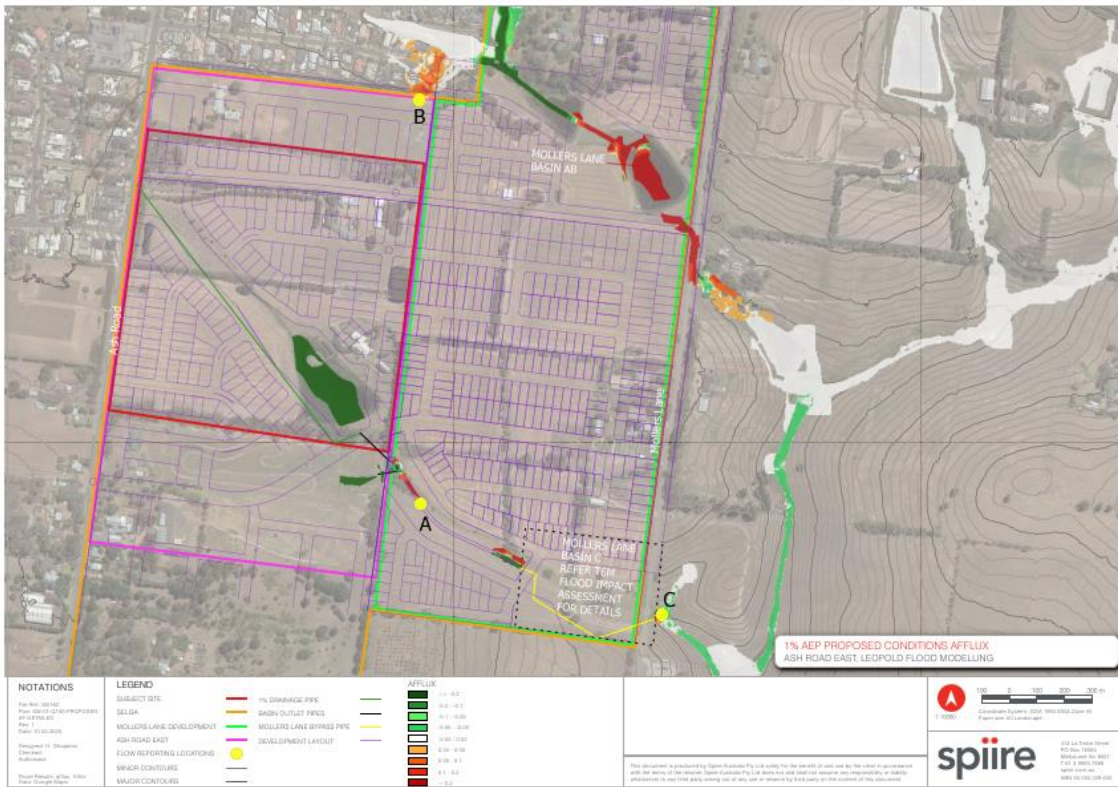


Figure 10-1 1% AEP Flood Afflux (source: Spiire, February 2020)

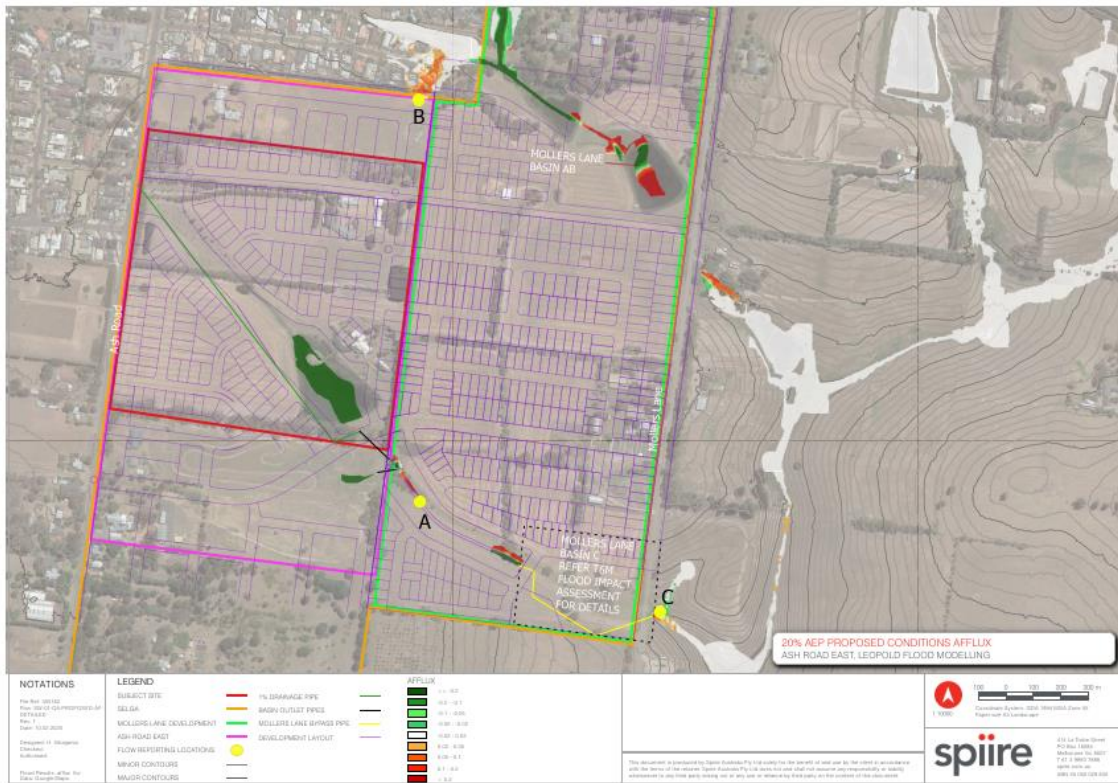


Figure 10-2 20% AEP Flood Afflux (source: Spiire, February 2020)

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10.1 The Department of Environment, Land, Water and Planning

The Department of Environment, Land, Water and Planning (DELWP) generally supports the proposed planning scheme amendment C391 and does not object to the granting of a permit PP-39-2019, subject to conditions relative to native vegetation offsets.

DELWP considers that impacts of freshwater flowing into the Lake Connemarre ecosystem, including cumulative impacts associated with other developments proposed in the local area must still be addressed. Importantly, the development must incorporate Water Sensitive Urban Design assets to:

- Retard additional stormwater volumes and rates as close to pre-development levels as possible:
 - As discussed in section 7, a retarding basin is proposed to retard stormwater on-site and release stormwater runoff at a reduced rate (equivalent to pre-development conditions).
 - The other readily available avenues to reduce volume would be through rainwater tanks and re-use at the lot scale, and stormwater harvesting and irrigation of open space areas.
- Retard additional water volumes and rates during the summer months, as the lake foreshore vegetation will be more sensitive to periods of inundation at this time of year
- Meet stormwater quality requirements of the Planning Scheme (Clause 56):
 - Water quality objectives are proposed to be met via a combination of WSUD assets, including an end-of-line wetland system.
- Promote the establishment of habitat suitable for Growling Grass Frog and other fauna species such as the migratory species that the RAMSAR lakes systems supports:
 - Wetland design can be adjusted to integrate Growling Grass Frogs, as discussed in section 7.1.1.

DELWP considers that the above requirements can be addressed by a planning permit condition. Consideration should also be given to stormwater and sediment control measures during construction and DELWP considers that this can be conditioned by the preparation of a Construction Environmental Management Plan.

Given the results of the stormwater volume impact analysis, I consider additional measures to reduce stormwater volume are not necessary. Whilst additional stormwater harvesting and re-use would be beneficial, it is not necessary in this context.

10.2 Corangamite Catchment Management Authority (CCMA)

The CCMA does not object to the adoption of the amendment C391, noting however, that the outfall for the South East Leopold Growth Area is still unconfirmed. CCMA therefore recommends that “*the issue of the pipeline be resolved as soon as possible*”. Once a solution is confirmed, the *Lake Connemarre Impact Assessment* completed by Venant Solutions may need to be updated, to confirm impacts from the fully developed catchment are mitigated.

The CCMA notes that the piping of the waterway is not normally agreed but in this circumstance is acceptable, but should not be seen as a precedent. I agree with this assessment and note that part of this waterway is already piped.

The CCMA does not object to the planning permit application, subject to conditions:

- Stormwater Management Infrastructure must be constructed in accordance with the details provided in Spiire Stormwater Management Plan submitted with the application

- Construction techniques must incorporate the provisions within the Guidelines for Environmental Management – Doing it right on Subdivisions (EPA Publication 960).
- The requirements of Standard C25 (Clause 56.07-4 of the Planning Scheme) must be met for the subdivision.

The CCMA also strongly recommends that:

- *“volume reduction (for example, stormwater harvesting for irrigation of public space) is explored further, as increased freshwater flows to Lake Connewarre have been identified as a threat to the RAMSAR listed wetlands”.*
- An assessment of the freeboard for the retarding basin under increased rainfall intensity to 2100 is undertaken and 300mm freeboard provided for the future projected scenario noting however that, there is currently no policy direction requiring this assessment.

I consider that the CCMA requirements can be met through implementation of the Stormwater Management Plan design and in accordance with the proposed permit conditions.

11 CONCLUSIONS

With respect to the proposed Amendment C391 to the Greater Geelong Planning Scheme and surface water management issues, I make the following conclusions:

- The stormwater management plan produced for the amendment and planning permit is comprehensive and can be considered to be in accordance with best practice industry standards.
- The hydrologic and hydraulic investigations in the SMP are appropriate and demonstrate there will be no adverse impacts on peak flows for the immediate downstream catchment under developed conditions.
- The water quality analysis shows that the proposed treatment measures will exceed best practice standards. This should ensure that adequate water quality will be maintained in the receiving waterway and Lake Connewarre.
- The Lake Connewarre impact assessment has been undertaken to an appropriate level of detail and shows that hydrologic impacts on the lake from the development, will be minimal.
- The final design of the measures to mitigate the impact of increased flow volumes on the waterway downstream of the SELGA (including the subject site) has not been finalised. Whilst feasible options have been put forward, it is necessary for the design to be finalised and construction and cost apportionment to be determined. Conditions on both this development and the Mollers Lane development will require co-ordination by council and a collaborative approach by both developers to ensure a satisfactory outcome is achieved.

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

15 November 2021

APPENDIX A – CV



WARWICK BISHOP

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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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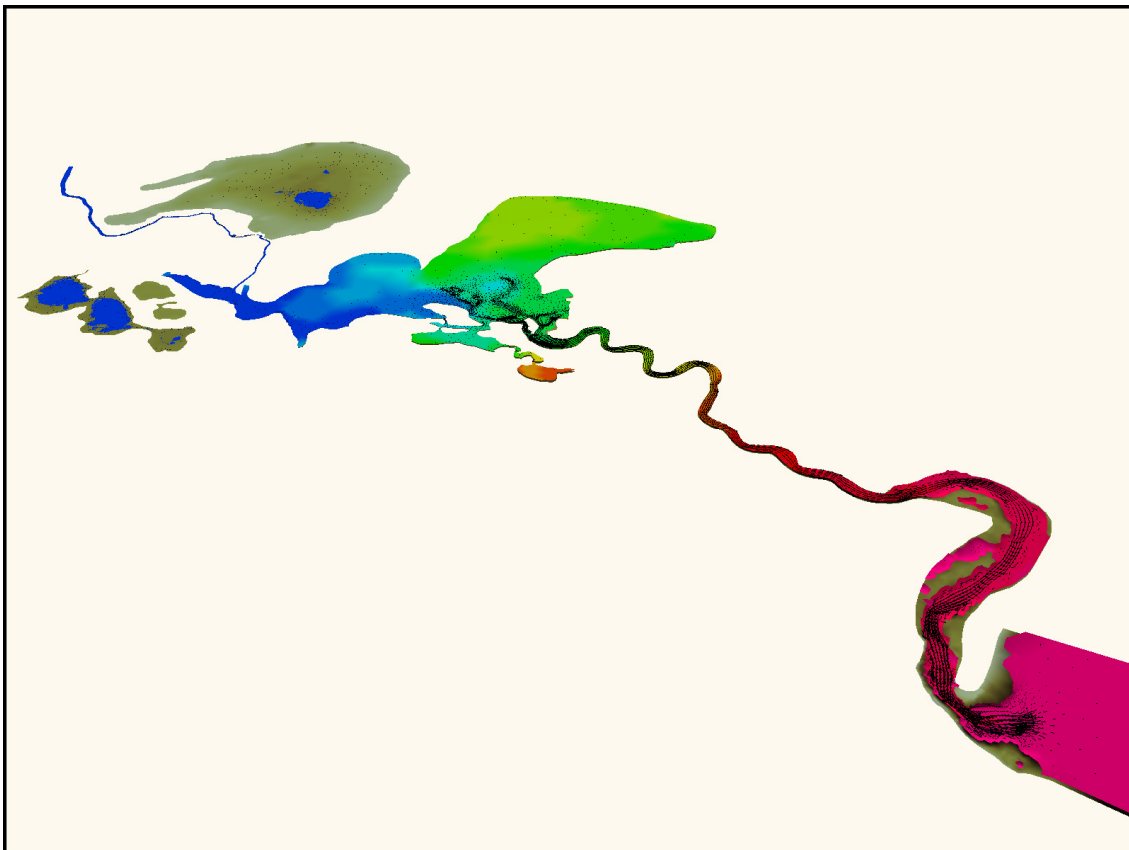
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APPENDIX B – LOWER BARWON REPORT

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Lower Barwon Wetlands Hydraulic Modelling for the Environmental Entitlement



July 2011



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TABLE OF CONTENTS

1.	Introduction	1
2.	Lower Barwon Wetland System Overview	2
2.1	Barwon River & Lower Barrage	2
2.2	Reedy Lake	3
2.3	Hospital Swamp.....	5
2.4	Lake Connewarre.....	6
3.	Hydrology	6
3.1	Barwon River	6
3.1.1	Overbank Flow Spells Analysis.....	7
3.1.2	Low Flow Spells Analysis	9
3.2	Estuarine Storm Surge & Tidal Water Levels.....	10
4.	Key Ecology/Flow Relationship Watering Scenario Modelling	12
4.1	‘Wet’ Watering Scenario Modelling	13
4.1.1	Regulator Settings.....	13
4.2	‘Maximum Variation’ Watering Scenario Modelling	14
4.2.1	Regulator Settings.....	14
4.3	‘Dry’ Watering Scenario Modelling.....	14
4.3.1	Regulator Settings.....	14
4.4	Scenario Modelling Results	15
4.4.1	Reedy Lake Water Levels and Flows	15
4.4.2	Hospital Swamp Water Levels and Flows.....	16
4.4.3	Hospital Swamp and Reedy Lake Water Use.....	17
4.4.4	Lake Connewarre Salinity Impact	18
4.4.5	Inundation Extents and Durations	19
5.	Conclusion	23
Appendix A	Field Data Collection	25
	Topographic and Hydraulic Structure Survey	26
	Water Level and Water Quality Monitoring Data	26
	Monitoring 2008.....	27
	Monitoring 2010 – 2011	30
Appendix B	Digital Elevation Model	31
Appendix C	Hydrodynamic Model Development and Calibration	34
	Introduction	35
	Model Topography	35
	Boundary Conditions	36
	One Dimensional Elements and Hydraulic Structures	36
	Bed Resistance	36
	Eddy Viscosity.....	37
	Dispersion Coefficients	37
	Hydrodynamic and Salinity Model Calibration	37
	Overview	37

Calibration Period.....	37
2008 Calibration Results	37
Validation Period	40
2010 Validation Results	40

LIST OF FIGURES

Figure 1-1	Lower Barwon Wetlands.....	1
Figure 2-1	Lower Barrage	3
Figure 2-2	Reedy Lake Inlet Regulator Structure	4
Figure 2-3	Reedy Lake Outlet Regulator Structure	4
Figure 2-4	Hospital Swamp Inlet Regulator Structure.....	5
Figure 2-5	Hospital Swamp Outlet Regulator Structure	6
Figure 3-1	Overbank Flow Spells Analysis (1955 – 2010)	8
Figure 3-2	Mean Number of Overbank Flow Days (1955-2010)	8
Figure 3-3	Temporal distribution of sub-overbank flow spells greater than 365 days (1955 – 2010)	9
Figure 3-4	Comparison of Lorne and Lake Connewarre instantaneous and tidal residual water levels	11
Figure 4-1	Barwon River Inflows of the Water Management Scenario	13
Figure 4-2	Comparison of Predicted Reedy Lake Water Levels	15
Figure 4-3	Comparison of Predicted Reedy Lake Inflows and Outflows	16
Figure 4-4	Comparison of Predicted Hospital Swamp Water Levels.....	17
Figure 4-5	Comparison of Predicted Hospital Swamp Inflows.....	17
Figure 4-6	Comparison of Predicted Reedy Lake and Hospital Swamp Water Use	18
Figure 4-7	Comparison of Predicted Lake Connewarre Salinity.....	19
Figure 4-8	Wet Scenario Predicted Inundation Characteristics	20
Figure 4-9	Maximum Variation Scenario Predicted Inundation Characteristics.....	21
Figure 4-10	Dry Scenario Predicted Inundation Characteristics	22
Figure 5-1	2008 Monitoring Data.....	27
Figure 5-2	Overview of Extent of Topographic and Structural Field Survey.....	28
Figure 5-3	Hydrologic Monitoring Locations	29
Figure 5-4	Logged Water Levels 2010 – 2011	30
Figure 5-5	Logged Salinity Level, Lake Connewarre Entrance to Lower Barwon River 2010 - 2011	30
Figure 5-6	Digital Elevation Model of the Lower Barwon Wetland Complex.....	33
Figure 5-7	Hydrodynamic Model Domain	35
Figure 5-8	Calibrated Water Level Comparisons on the Lower Barwon	38
Figure 5-9	Calibrated Water Level Comparisons in Lake Connewarre	38
Figure 5-10	Calibrated Water Level Comparisons on the Barwon River upstream of the Lower Barrage.....	39
Figure 5-11	Calibrated Water Level Comparison in Reedy Lake.....	39
Figure 5-12	Calibrated Salinity Comparison in Lake Connewarre at Taits Point.....	39
Figure 5-13	Lake Connewarre and Barwon River Water Level Validation.....	40
Figure 5-14	Lake Connewarre Salinity Validation	41

Figure 5-15 Predicted Overbank Flooding Extent into Reedy Lake during January 2011 Flood Event 41

LIST OF TABLES

Table 3-1 Longest sub-overbank flow spells greater than 365 days (1955 -2010) 9
Table 3-2 Relevant Storm Surge and Tidal Water Level Planes for Lake Connewarre..... 11
Table 4-1 Key Ecology/Flow Relationship Water Scenarios 12
Table 4-2 Summary of Topographic and Structural Field Survey Data Sources 26

1. INTRODUCTION

Water Technology was commissioned by the Corangamite Catchment Management Authority (CCMA) to develop a hydrodynamic model of the Lower Barwon Wetlands (LBW). The hydrodynamic model is to be used to allow scenarios for future management and changes to the annual watering plan of these wetland systems to be modelled to facilitate the development of a more robust and legally supported watering regime for the LBW.

The LBW are located on the lower reaches of the Lower Barwon River and include the following main physical components listed below and displayed in Figure 1-1:

- Lake Connewarre
- Reedy Lake
- Hospital Swamp
- Barwon River
- Salt Swamp

The field data collection program undertaken to support the hydrodynamic model development is documented in Appendix A.

The development of the continuous digital elevation model for the study area is documented in Appendix B.

The hydrodynamic model development and calibration is documented in Appendix C.

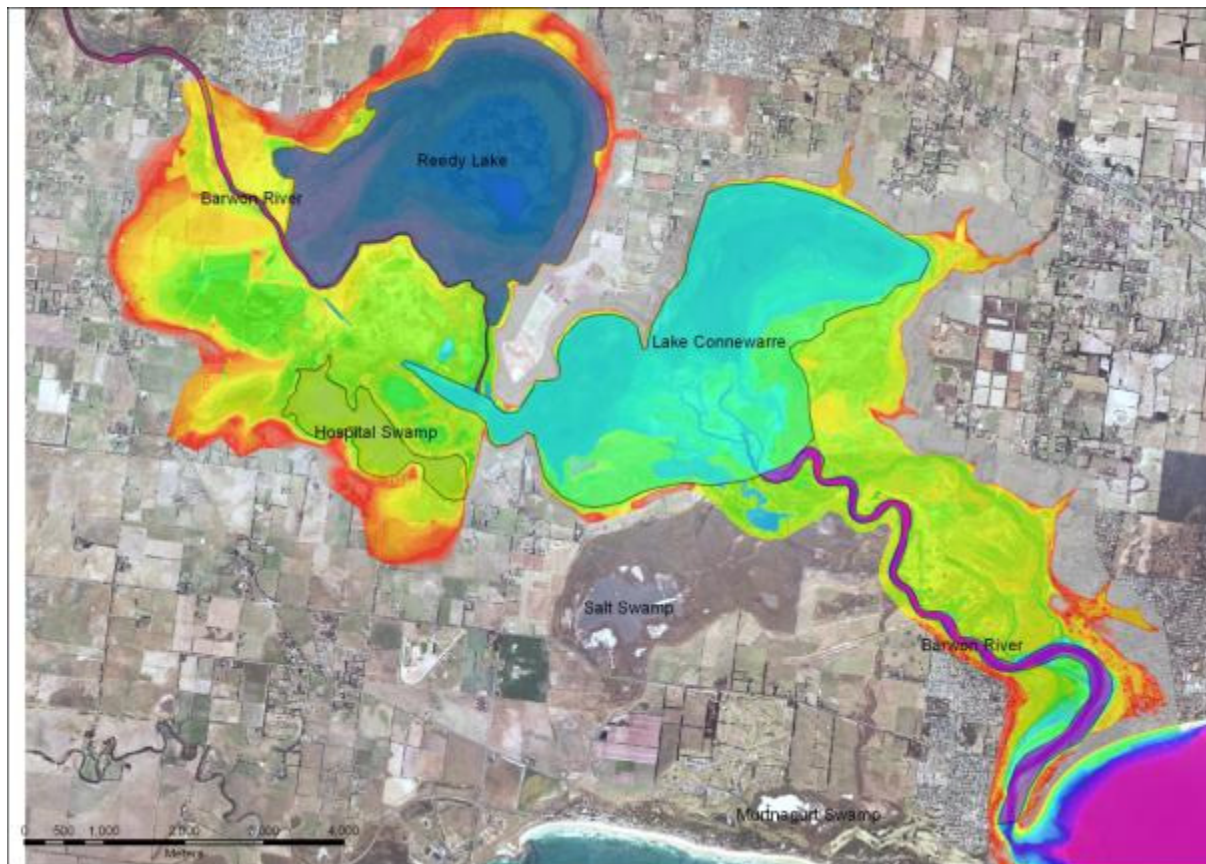


Figure 1-1 Lower Barwon Wetlands

2. LOWER BARWON WETLAND SYSTEM OVERVIEW

2.1 Barwon River & Lower Barrage

The Barwon River channel flows from north-west to south-east on the southern margin of Reedy Lake. The river channel is confined by natural levees and silt jetties that extend into Lake Connewarre into which the river discharges.

Prior to European settlement, saline water originating in Lake Connewarre could encroach upstream along the Barwon River channel, in the form of a salt wedge, to as far as South Geelong. To prevent the saline water moving upstream and enable the river to be used for irrigation and water supply, a tidal breakwater weir was constructed in 1898. The weir prevented the incursion of saline water upstream and raised water levels in the river channel upstream, promoting more frequent overbank inflow events into Reedy Lake.

In the 1950s flood waters from Lake Corangamite were diverted into the river via the Woody Yaloak Diversion Scheme with a resulting increase in flows down the Barwon River. To minimise the flooding impact from the increased flow, a floating gate arrangement was designed and installed. The gates were designed to maintain the functionality of the breakwater by preventing the saline water incursion up the river, whilst also increasing the volume of water that is able to pass through the structure during high flows.

The existing Lower Barrage structure is displayed in Figure 2-1 and the components of the structure can be summarised as follows:

- **A fixed crest weir** - The fixed crest weir is comprised of steel sheet piling with reinforced concrete. The component of the weir extends from the southern embankment across the river until it intersects the twin gate weir structure. The crest height of the weir is 0.85 m AHD.
- **An adjustable weir structure, consisting of two floating steel gates** – The gates each comprise a door of 1.65 m height and 4.9 m wide hinged at the bottom edge and supporting a steel drum at the full width of the gate and 760 mm in diameter. The steel drum floats on the tail water pool (the downstream pool).
- **A counterweight** - The counterweight is a cylinder located at the head of each of the weir gates.

A 2008 refurbishment of the structure exposed that the counterweight assemblies need replacing and that significant volumes of water can leak past the sides of the weir gates. (This has a significant impact on the maintenance of the weir pool during prolonged low flow periods) At present, the gates are permanently closed during times of dry weather and one gate is manually opened upon wet weather. The second gate is inaccessible due to the lack of safe access and occupational health and safety requirements.



Figure 2-1 Lower Barrage

2.2 Reedy Lake

Reedy Lake is a large wetland located adjacent to the northern bank of the Barwon River. Inundation of Reedy Lake can be generated by overbank flooding from the Barwon River, local catchment runoff and groundwater discharges.

Before European settlement, the spill of Barwon River floodwaters into Reedy Lake was controlled by natural levees. The construction of the lower barrage in 1898 raised levels along the Barwon River promoting more frequent overbank flow events into Reedy Lake (Lloyd et al, 2005).

The construction of the floating gate structures on the Lower Barrage to mitigate flooding impacts reduced the frequency of overbank flooding into Reedy Lake. A regulated channel was therefore cut between the Barwon River and Reedy Lake, upstream of the lower barrage to provide a regular inflow of freshwater to Reedy Lake.

Inflows into Reedy Lake are currently controlled via the operation of a hydraulic structure consisting of a series of box culverts and associated penstocks at the head of the cut channel connecting Reedy Lake to the Barwon River within the Lower Barrage weir pool. The inlet regulator structure to Reedy Lake is displayed in Figure 2-2.

The water levels in Reedy Lake can be controlled via the operation of a hydraulic structure consisting of a series of box culverts and associated penstocks located near the exit of a cut channel connecting Reedy Lake to Lake Connewarre. The outlet regulator structure to Reedy Lake is displayed in Figure 2-3.

The following flow and water level thresholds are considered relevant to Reedy Lake:

- The natural levees separating the Barwon River, upstream of the Lower Barrage, from Reedy Lake are overtopped by levels in the Barwon River of approximately 1.7m AHD. Hydrodynamic modeling of the Lower Barwon and Reedy Lake undertaken as part of the

Barwon River Lower Breakwater Management Options study (Water Technology, 2010) found that flows in the Barwon River of approximately 3,500ML/d were required to initiate significant overbank flooding into Reedy Lake above the Lower Barrage.

- The natural levees separating Lake Connewarre from Reedy Lake are overtopped by levels of approximately 0.9m AHD .



Figure 2-2 Reedy Lake Inlet Regulator Structure



Figure 2-3 Reedy Lake Outlet Regulator Structure

2.3 Hospital Swamp

Hospital Swamp comprises 5 basins that can potentially receive water from the overbank flooding of the Barwon River, local catchment runoff associated with Armstrong Creek, potentially elevated water levels in Lake Connewarre and shallow groundwater discharges.

Hospital Swamp can be regulated through diversions from the Barwon River via a regulated channel through Sparrowvale Farm. The regulator has an invert of 0.3m AHD. The Hospital Swamp inlet penstock is displayed in Figure 2-4. Overbank flooding into Hospital Swamp from the Barwon River commences at levels of approximately 1.4m AHD.

Banks separating Hospital Swamp and Lake Connewarre are overtopped at a level of approximately 0.5m AHD. The wetland can be drained using a regulated pipe with an invert of 0.2m AHD. The Hospital Swamp regulated pipe outlet is displayed in Figure 2-5.



Figure 2-4 Hospital Swamp Inlet Regulator Structure



Figure 2-5 Hospital Swamp Outlet Regulator Structure

2.4 Lake Connewarre

Lake Connewarre is a shallow (<2m) tidal lagoon that is connected to the ocean at Barwon Heads via a sinuous tidal channel. Lake Connewarre is separated from the tidal channel by a flood tide delta system that extends into the lake. The tidal range reduces from approximately 2m at Barwon Heads to approximately 0.3m in Lake Connewarre. Due to the lagoon's shallow depths, wind driven mixing is an important process operating in Lake Connewarre.

The salinity in Lake Connewarre shows a relatively high degree of spatial and temporal variation. Salinity varies in response to freshwater inflows from the Barwon River and local run-off, tidal and surge driven marine flows and evapo-concentration.

3. HYDROLOGY

3.1 Barwon River

Analysis of a historical streamflow series for the Barwon River at Geelong has been undertaken to quantify, at a relatively broad scale, the historical magnitude, duration, frequency and timing of overbank flows into Reedy Lake and Hospital Swamp from the Barwon River.

The historic daily streamflow series was derived from a REALM model of the Barwon River catchment developed by SKM (2005). The streamflow series from this model was utilised as part of the Environmental Flow Determination for the Barwon River study (Lloyd et al, 2005). This streamflow series covers the period 1st January 1955 to 30th June 2004. To extend the timeseries up to present day, the McIntyre Bridge gauged streamflow data was appended to the timeseries to provide a continuous daily streamflow series through to 1st January 2010.

The historic daily streamflow series has been analysed to specifically provide an indication of the following components of the LBW hydrology:

- The historical frequency of significant overbank flooding and inundation of Reedy Lake and Hospital Swamp from the Barwon River.
- The annual duration of significant overbank flooding into Reedy Lake and Hospital Swamp
- The historic monthly distribution of overbank flooding events into the wetlands.

- The historic frequency and duration of low streamflow periods that would not have resulted in overbank flooding and inundation of Reedy Lake and Hospital Swamp.

3.1.1 Overbank Flow Spells Analysis

The historic daily streamflow series has been analysed to determine the number of events (spells) in which the mean daily Barwon River flows equalled or exceeded 3,500ML/d. Previous hydrodynamic analysis undertaken as part of the Barwon River Lower Breakwater Management Options study (Water Technology, 2010) determined this streamflow threshold for initiating significant overbank flooding into Reedy and Hospital Swamp. It is however recognized that a degree of uncertainty exists around the precise flow magnitude at which overbank flooding would be initiated into these wetlands. To provide an indication of the sensitivity that the overbank flow threshold estimate has on the number of overbank flow spells calculated, the spells analysis has considered streamflow thresholds approximately 15% higher and lower than the best estimate of 3,500ML/d. Overbank flow spells were considered independent if they were greater than 7 days apart. In addition to the determination of the number overbank flow threshold flow spells, the total annual duration of overbank flows into these wetlands has been calculated.

Figure 3-1 displays the results of the overbank flow spells analysis in relation to the historic daily streamflow series as follows:

- The second timeseries displays the annual number of independent overbank flow spells. The upper and lower whiskers display the sensitivity of the overbank streamflow threshold estimate when it was decreased and increased by 15% respectively.
- The third timeseries displays the total annual duration of overbank flows into the wetlands. The upper and lower whiskers display the sensitivity of the overbank streamflow threshold estimate when it was decreased and increased by 15% respectively.

The following comments are provided based on the results of the overbank flow spells analysis displayed in Figure 3-1.

- The median number of annual overbank flow events into Reedy Lake and Hospital Swamp has been estimated at approximately 3 historically.
- Uncertainty in the precise flow magnitude at which overbank flooding commences into these wetlands is not considered to significantly affect the estimation of the annual overbank flow spells.
- The total annual duration of overbank flows into Reedy Lake and Hospital Swamp has been estimated as 10 days historically.

The distribution of days in which the streamflows exceeded the overbank flow threshold of 3,500ML/d has been determined from the streamflow series and is displayed in Figure 3-2. Figure 3-2 shows that overbank flows are concentrated over the months of July through to October.

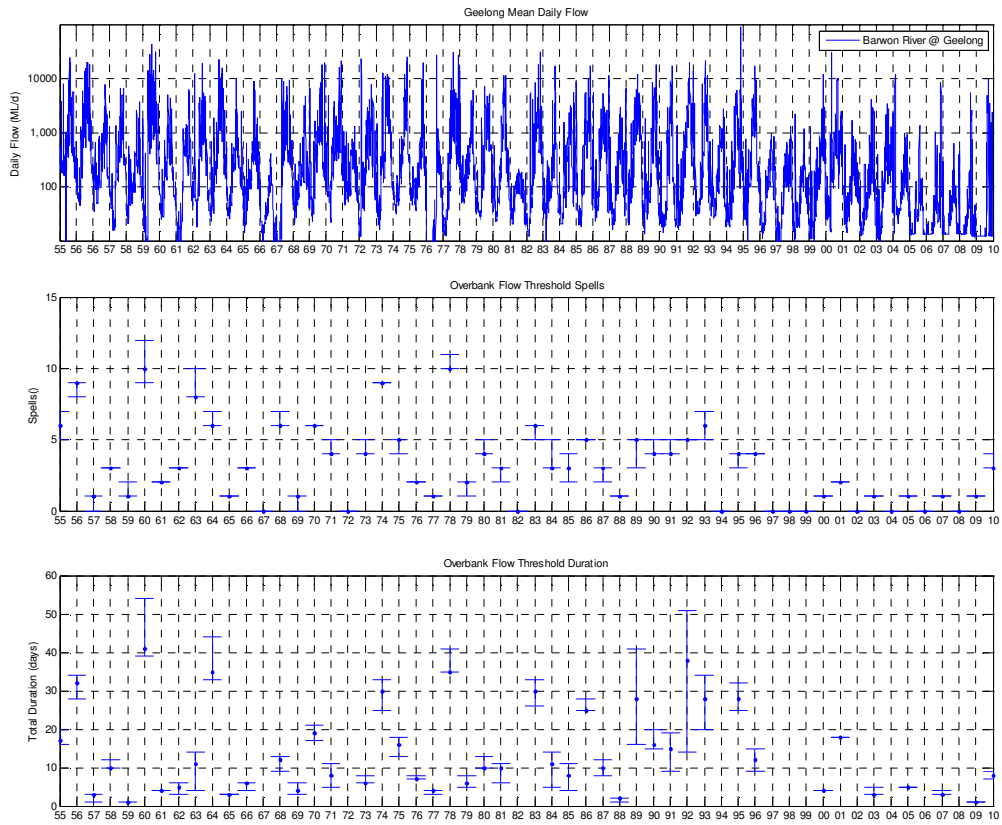


Figure 3-1 Overbank Flow Spells Analysis (1955 – 2010)

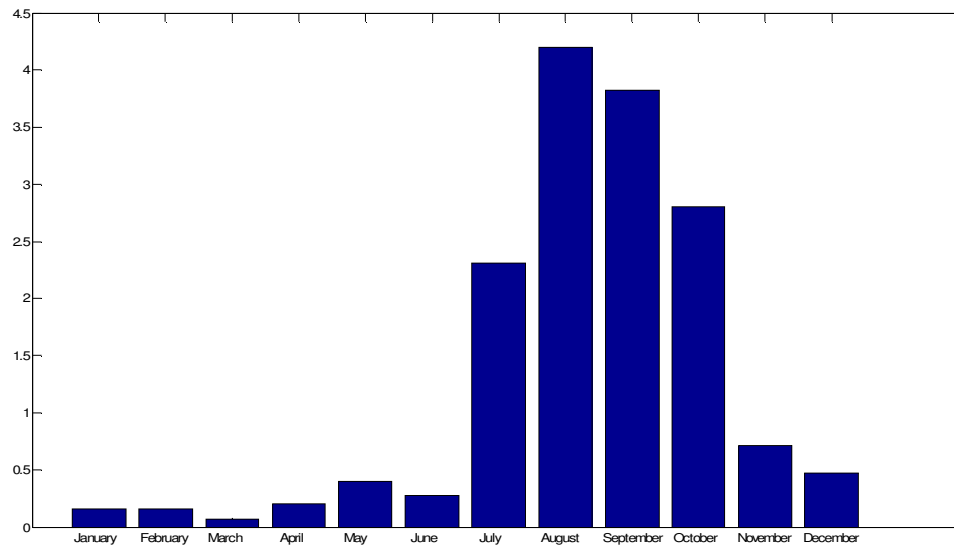


Figure 3-2 Mean Number of Overbank Flow Days (1955-2010)

3.1.2 Low Flow Spells Analysis

The historic daily streamflow series has been analysed to determine the number of events (spells) in which the consecutive mean daily Barwon River flows were less than 3,500ML/d for 365 days or greater. These prolonged low flow periods are considered to provide an indication of potential historical dry phases of Reedy Lake and Hospital Swamp, where Barwon River streamflows were not significant enough to cause overbank flooding into these wetlands. Figure 3-3 displays the temporal distribution of the 365 day or greater, sub-overbank flow spells over the historic daily streamflow series. Table 3-1 displays the start and end date and length of the longest sub-overbank flow spells greater than 365 days.

Based on the analysis of the sub-overbank flow spells, it is considered that on average, dry or partially dry phases may naturally occur in Reedy Lake and Hospital Swamp on average once every 5 years.

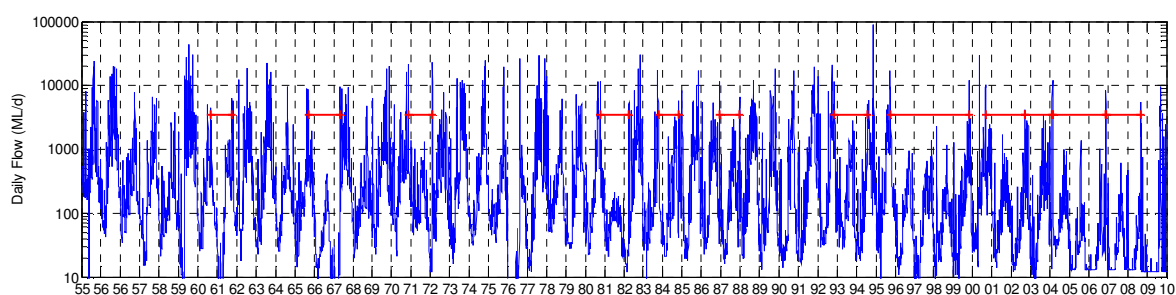


Figure 3-3 Temporal distribution of sub-overbank flow spells greater than 365 days (1955 – 2010)

Table 3-1 Longest sub-overbank flow spells greater than 365 days (1955 -2010)

Start Date	End Date	Duration (Days)
7-Oct-96	26-Oct-00	1480
9-Feb-05	28-Oct-07	991
28-Aug-01	27-Aug-03	729
10-Nov-07	27-Aug-09	656
11-Nov-93	18-Jul-95	614
19-Sep-66	30-Apr-68	589
9-Oct-81	26-Mar-83	533
30-Aug-03	4-Feb-05	524
12-Nov-71	6-Feb-73	452
26-Aug-61	25-Sep-62	395
8-Oct-84	27-Oct-85	384
8-Dec-87	12-Dec-88	370

3.2 Estuarine Storm Surge & Tidal Water Levels

The relative elevations of the wetland complexes in the study area and their proximity to tidally connected Lake Connewarre provides the potential that the natural hydrology of the wetlands could be influenced by inundation associated with storm surge and/or astronomical tidal water level variations in Bass Strait propagating into Lake Connewarre. This mechanism of inundation of Hospital Swamp and Reedy Lake is potentially significant as the inundation from Lake Connewarre is likely to be of brackish or even potentially marine salinity, depending on the antecedent conditions in Lake Connewarre.

Storm surges are meteorologically induced coastal water level variations caused by atmospheric pressure fluctuations and frictional action of wind on the ocean surface. Storm surges generally have periods of approximately 24-48 hours in Bass Strait. The combination of storm surge and the astronomical tide gives rise to the observed coastal water level variations.

To provide an understanding of the relevant storm surge and astronomical water level variations and probabilities in Lake Connewarre, the instantaneous water level records at Lorne and in Lake Connewarre have been compared over an approximate 2 month period from June to July 2008. The comparison is displayed in Figure 3-4. Note that this period includes a significant storm surge event in Bass Strait that occurred in the first week of July. The second timeseries comparison in Figure 3-4 displays the instantaneous residual water level at these two locations after the astronomical tidal component has been removed from the two water level signals. These two water level timeseries comparisons are considered to highlight the following aspects of the estuarine water level variations in Lake Connewarre compared to the open coast:

- The higher frequency astronomical tidal component of the coastal water level variations on the open coast at Lorne is significantly attenuated within the estuarine reach of the Lower Barwon such that the astronomical tidal range in Lake Connewarre is only approximately 15% (0.2m) of the range on the coast at Barwon Heads.
- The low frequency storm surge component of the coastal water level variations with periods of 24-48 hours are able to propagate into Lake Connewarre with minimal attenuation such that the storm surge component of the coastal water level variations are essentially fully transmitted into Lake Connewarre.
- Mean water levels within Lake Connewarre are generally 0.2m above mean sea level due to shallow water hydrodynamic effects associated with the propagation of the astronomical tide along the Lower Barwon estuary.

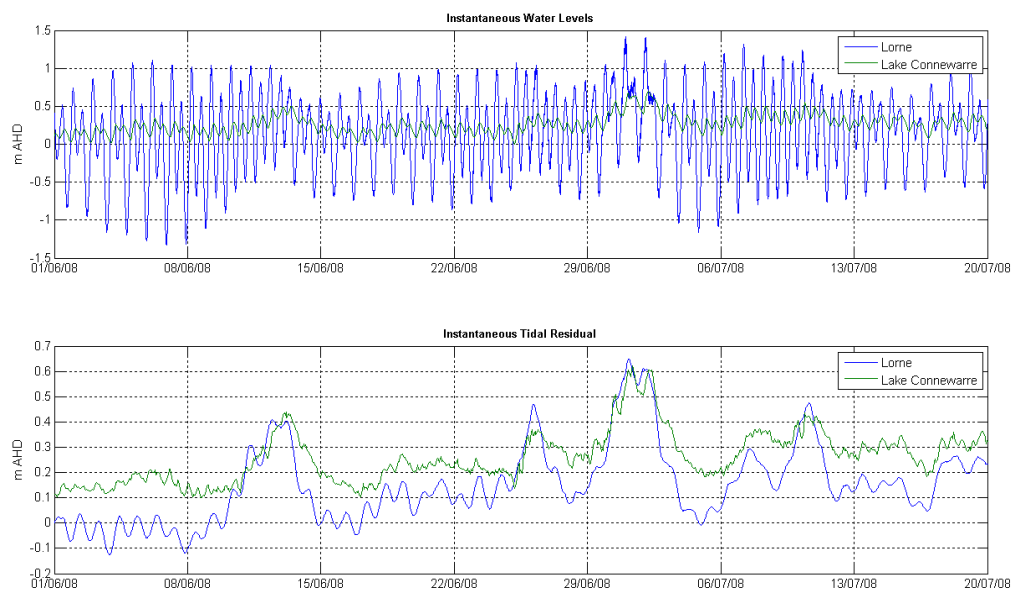


Figure 3-4 Comparison of Lorne and Lake Connearre instantaneous and tidal residual water levels

Estimates of the exceedance probability of different storm surge levels at Lorne have been developed by CSIRO (2009). The estimates provided for Lorne are considered applicable to Lake Connearre, based on the analysis of the water levels displayed previously in Figure 3-4. To provide an estimate of peak storm tide levels in Lake Connearre, an additional 0.1m has been added to the storm surge estimates based on the observed tidal range within Lake Connearre. An estimate of mean high water in Lake Connearre has also been provided in Table 3-2.

Table 3-2 Relevant Storm Surge and Tidal Water Level Planes for Lake Connearre

Relevant Water Level	Lake Connearre Water Levels (m AHD)
MHW	0.40
100% AEP	0.60
10% AEP	0.76
5% AEP	0.78
2% AEP	0.8
1% AEP	0.81

The following comments are provided in relation to the potential for storm surge and/or astronomical tidal water level variations to cause inundation of Reedy Lake and Hospital Swamp:

- The height of the natural banks separating Lake Connearre and Hospital Swamp are approximately 0.5m AHD. Based on the analysis of the storm surge planes for Lake Connearre displayed in Table 3-2, these banks would be overtopped on average once per year or greater to a depth of 0.1m. This would potentially enable significant inundation of these wetlands and in particular the northern most two basins of Hospital Swamp from Lake Connearre.
- The natural banks separating Lake Connearre from Reedy Lake are at their lowest point approximately 0.9m AHD. Based on the levels summarised in Table 3-2, significant overbank

inundation from Lake Connewarre into Reedy Lake is considered unlikely and would be an extremely rare occurrence.

- The outlet channels and regulator sill levels of both Reedy Lake and Hospital Swamp are below mean high water in Lake Connewarre and inundation to a level of approximately 0.4m AHD in these wetlands could theoretically be achieved by operation of the regulators to allow the ingress of estuarine water from Lake Connewarre into these wetlands.

4. KEY ECOLOGY/FLOW RELATIONSHIP WATERING SCENARIO MODELLING

In order to improve the understanding of the potential ecological responses within the LBW to different water management regimes, a number of water management scenarios were simulated in the hydrodynamic model. The watering scenario simulations were largely focused on options to manage inundation in Reedy Lake through changes to the operation of the existing regulating structures. Following an all day workshop involving a number of technical specialists and land manager representatives, a range of 3 potential water management scenarios were identified for Reedy Lake.

These key ecology/flow relationship water management scenarios relate to the main characteristics of the inundation that would occur within Reedy Lake following their implementation. The 3 water management scenarios are presented in Table 4-1 and discussed in more detail in the following sections.

Table 4-1 Key Ecology/Flow Relationship Water Scenarios

Water Management Scenario	Inlet Regulator Operation	Outlet Regulator Operation
Wet	Permanently Open	Permanently Closed
Maximum Variation	Open winter/spring Close summer/autumn	Close winter/spring Open summer/autumn
Dry/Salty	Permanently Closed	Open whenever water enters Reedy lake

A 12 month sequence of streamflows, ocean water levels, rainfall, evaporation and wind forcing conditions derived 2008-2009 observed data sources was simulated in the model under 3 different Reedy Lake regulator operation conditions representing the Wet, Maximum Variation and Dry/Salty water management scenarios. The Barwon River inflows to the LBW over the 12 month period used in the scenario modelling are displayed in Figure 4-1. As can be seen from Figure 4-1, inflows in the Barwon River were very low for extensive periods over the 12 month scenario. Additionally, temperatures and evaporation rates were also considered relatively high compared to long term average conditions. The 12 month period tested in the model therefore provides an indication of the response of the system to various different water management options under drought type conditions and this should be considered when evaluating the results of the water management option scenarios.

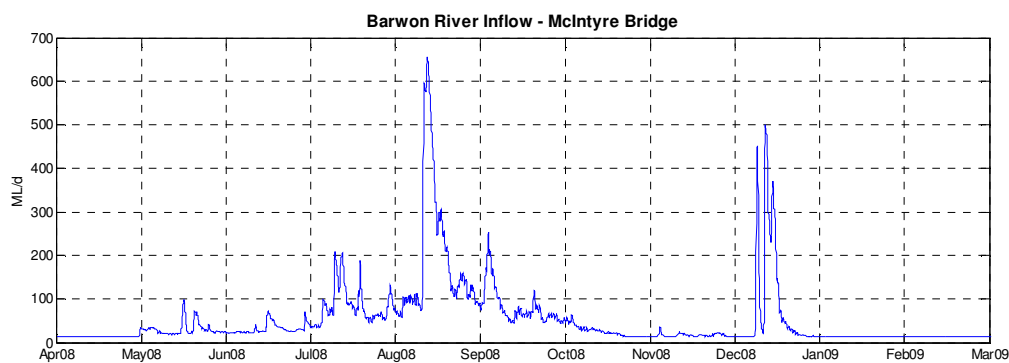


Figure 4-1 Barwon River Inflows of the Water Management Scenario

The model results from each of the water management scenarios simulations have been processed to provide a range of temporal and spatial outputs describing the predicted flows, volumes, levels and inundation extents and durations resulting from the different water management scenarios. The results from the water management scenario simulations are presented in Section 4.4.

4.1 'Wet' Watering Scenario Modelling

The intent of the wet watering scenario modelling is to improve the understanding of the inundation, flow and water level conditions that could be expected to occur within Reedy Lake under a wet as possible water management regime for this wetland.

The boundary conditions and regulator structure operations adopted for the Wet watering scenario are discussed in Section 4.1.1.

The results of the Wet watering scenario simulation are presented in Section 4.4.

4.1.1 Regulator Settings

Reedy Lake Regulator Operations

The following regulator operation logic was incorporated into the Reedy Lake regulators for the Wet watering scenario:

- Reedy Lake inlet regulator was permanently open over the 12 month scenario
- Reedy Lake outlet regulator was permanently shut over the 12 month scenario.

Hospital Swamp Regulator Operations

The following regulator operation logic was incorporated in the Hospital Swamp regulators for the Wet watering scenario:

- Hospital Swamp inlet regulator was opened on 1st September
- Hospital Swamp was filled to 0.5m AHD and the regulator was operated to maintain a water level no greater than 0.5m AHD until 1st November
- Hospital Swamp inlet regulator was closed on 1st November.
- Hospital Swamp outlet regulator remained closed and Hospital Swamp was allowed to dry via evaporation over summer.

4.2 'Maximum Variation' Watering Scenario Modelling

The intent of the maximum variation watering scenario modelling is to improve the understanding of the degree of variation in the inundation, flow and water level conditions that can be manipulated within Reedy Lake with the present regulating structures for this wetland.

The boundary conditions and regulator structure operations adopted for the maximum variation watering scenario are discussed in Section 4.2.1.

The results of the maximum variation watering scenario simulation are presented in Section 4.4.

4.2.1 Regulator Settings

Reedy Lake Regulator Operations

The following regulator operation logic was incorporated into the Reedy Lake regulators for the maximum variation scenario:

- Reedy Lake inlet regulator was opened on 1st May to commence filling of Reedy Lake
- Reedy Lake was allowed to be filled to between 0.5 – 0.9m AHD until 1st November
- Reedy Lake outlet regulator opened on 1st November to enable drawdown and drying over summer

Hospital Swamp Regulator Operations

The following regulator operation logic was incorporated in the Hospital Swamp regulators for the maximum variation scenario:

- Hospital Swamp inlet regulator was opened on 1st September
- Hospital Swamp was filled to 0.5m AHD and the regulator was operated to maintain a water level no greater than 0.5m AHD until 1st November
- Hospital Swamp inlet regulator was closed on 1st November.
- Hospital Swamp outlet regulator remained closed and Hospital Swamp was allowed to dry via evaporation over summer.

4.3 'Dry' Watering Scenario Modelling

The intent of the dry watering scenario is to improve the understanding of the degree in which flows and resulting inundation can be excluded from Reedy Lake with the existing regulating structures on this wetland.

The boundary conditions and regulator structure operations adopted for the maximum variation watering scenario are discussed in Section 4.3.1.

The results of the maximum variation watering scenario simulation are presented in Section 4.4.

4.3.1 Regulator Settings

Reedy Lake Regulator Operations

The following regulator operation logic was incorporated into the Reedy Lake regulators for the dry scenario:

- Reedy Lake inlet regulator was permanently closed over the 12 month scenario
- Reedy Lake outlet regulator was opened only if Reedy Lake water levels were greater than Lake Connewarre water levels.

Hospital Swamp Regulator Operations

The following regulator operation logic was incorporated in the Hospital Swamp regulators for the maximum variation scenario:

- Hospital Swamp inlet regulator was opened on 1st September
- Hospital Swamp was filled to 0.5m AHD and the regulator was operated to maintain a water level no greater than 0.5m AHD until 1st November
- Hospital Swamp inlet regulator was closed on 1st November.
- Hospital Swamp outlet regulator remained closed and Hospital Swamp was allowed to dry via evaporation over summer.

4.4 Scenario Modelling Results

The following sections document the comparisons between the different watering scenario simulations in terms of the following;

- Reedy Lake water levels and inflows and outflows
- Hospital Swamp water levels and inflows
- Hospital Swamp and Reedy Lake Water Use
- Lake Connewarre Salinity Impact
- Inundation Extent and Durations

4.4.1 Reedy Lake Water Levels and Flows

Figure 4-2 displays the predicted water levels Reedy Lake for each water management option over the duration of the 12 month scenario. The following observations regarding the comparisons of the Reedy Lake water levels displayed in Figure 4-2 are provided:

- At times during the Scenario, inflows in the Barwon River were insufficient to maintain the weir pool above the lower Barwon Barrage. The reduced inflows into Reedy Lake limited the ability to maintain fully inundated conditions in Reedy Lake over the course of the Wet scenario due to the relatively high evaporation losses that occur from this wide and shallow water body, particularly in the warmer months. The potential inability to maintain fully inundated conditions in Reedy Lake during dry years should be considered in the development of the water management plan for Reedy Lake.

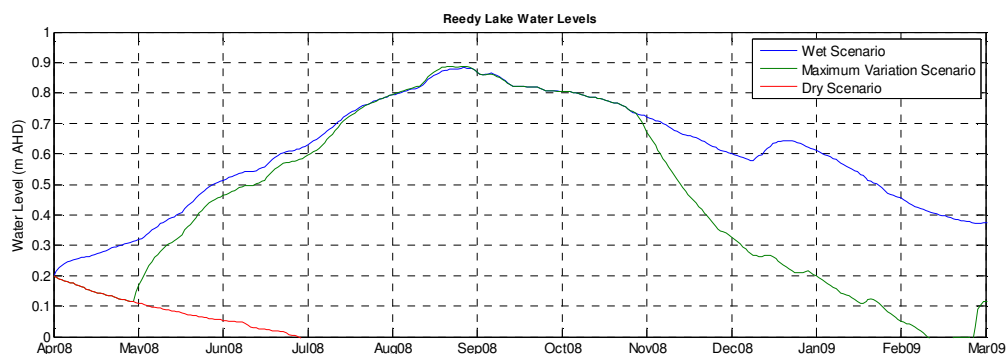


Figure 4-2 Comparison of Predicted Reedy Lake Water Levels

Figure 4-3 displays the predicted inflow and outflow timeseries in Reedy Lake for each water management option over the duration of the 12 month scenario. The following observations regarding the comparisons of the Reedy Lake water levels displayed in Figure 4-3 are provided:

- The difference between the Reedy Lake inlet regulator inflows under the Wet and Maximum Variation Scenario were relatively minor over the 12 month scenario. This is largely due to the small Barwon River inflows which were insufficient to maintain the weir pool above the Lower Barrage at times.
- The Reedy Lake outlet regulator can experience periodic flow reversals due to tidal variations in Lake Connewarre when water levels in Reedy Lake are low. The tidal influence from Lake Connewarre on Reedy Lake water levels is however not significant as the tidal signature is significantly attenuated along the outlet channel.

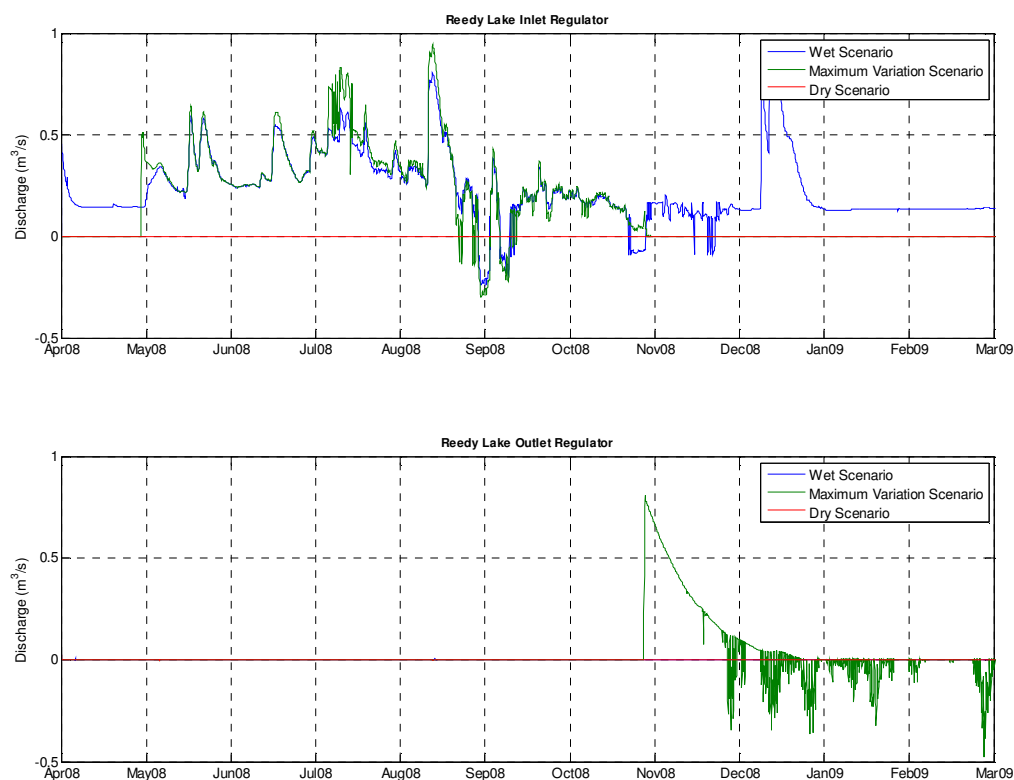


Figure 4-3 Comparison of Predicted Reedy Lake Inflows and Outflows

4.4.2 Hospital Swamp Water Levels and Flows

Figure 4-4 displays the predicted water levels Reedy Lake for each water management option over the duration of the 12 month scenario. The following observations regarding the comparisons of the Reedy Lake water levels displayed in Figure 4-4 are provided:

- No significant difference in the water level variation or flows into Hospital Swamp are predicted in the model between the various water management regime scenarios simulated in the model for Reedy Lake. It is therefore considered that changes to the Reedy Lake water management regime will not significantly impact Hospital Swamp.

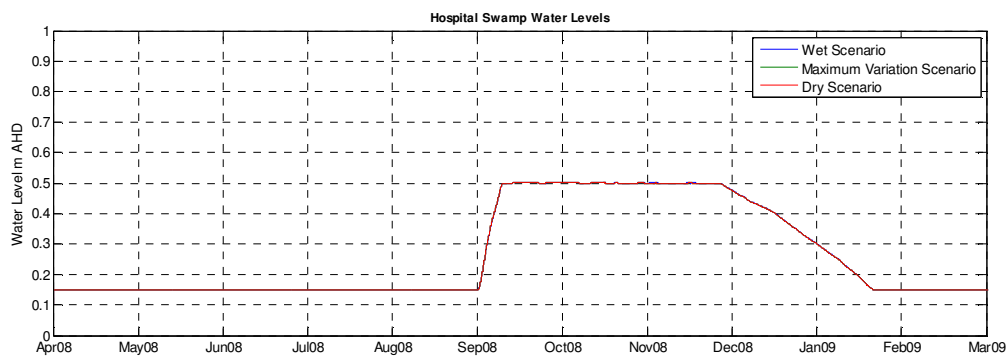


Figure 4-4 Comparison of Predicted Hospital Swamp Water Levels

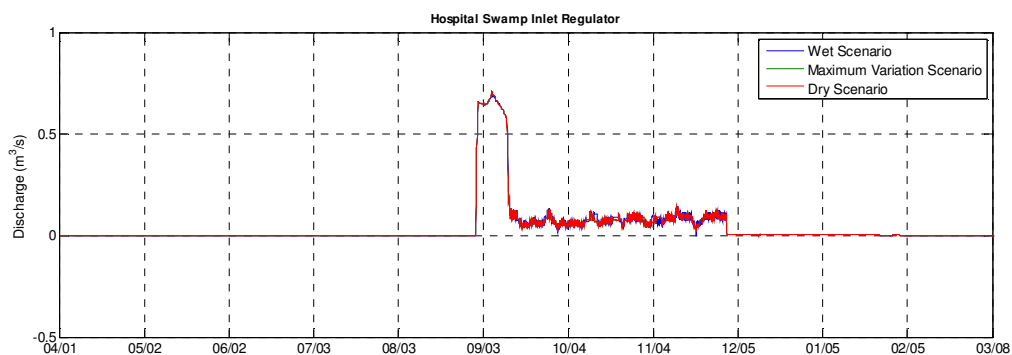


Figure 4-5 Comparison of Predicted Hospital Swamp Inflows

4.4.3 Hospital Swamp and Reedy Lake Water Use

Figure 4-6 displays the predicted cumulative inflows to Reedy Lake and Hospital Swamp for each water management option over the duration of the 12 month scenario. The following observations regarding the comparisons of the Reedy Lake cumulative inflows displayed in Figure 4-6 are provided:

- The cumulative inflows into Reedy Lake under the Wet Scenario are predicted at approximately 6,900ML over the 12 month period.
- The cumulative inflows into Reedy Lake under the Maximum Variation Scenario are predicted at approximately 4,700ML over the 12 month period
- The cumulative inflows into Reedy Lake under the Dry Scenario are 0ML over the 12 month period

The following observations regarding the comparisons of the Hospital Swamp cumulative inflows displayed in Figure 4-6 are provided:

- The different water management scenarios for Reedy Lake are not predicted to affect the Hospital Swamp water use.
- The cumulative inflow to Hospital Swamp under all scenarios is predicted at approximately 1,150ML over the 12 month period.

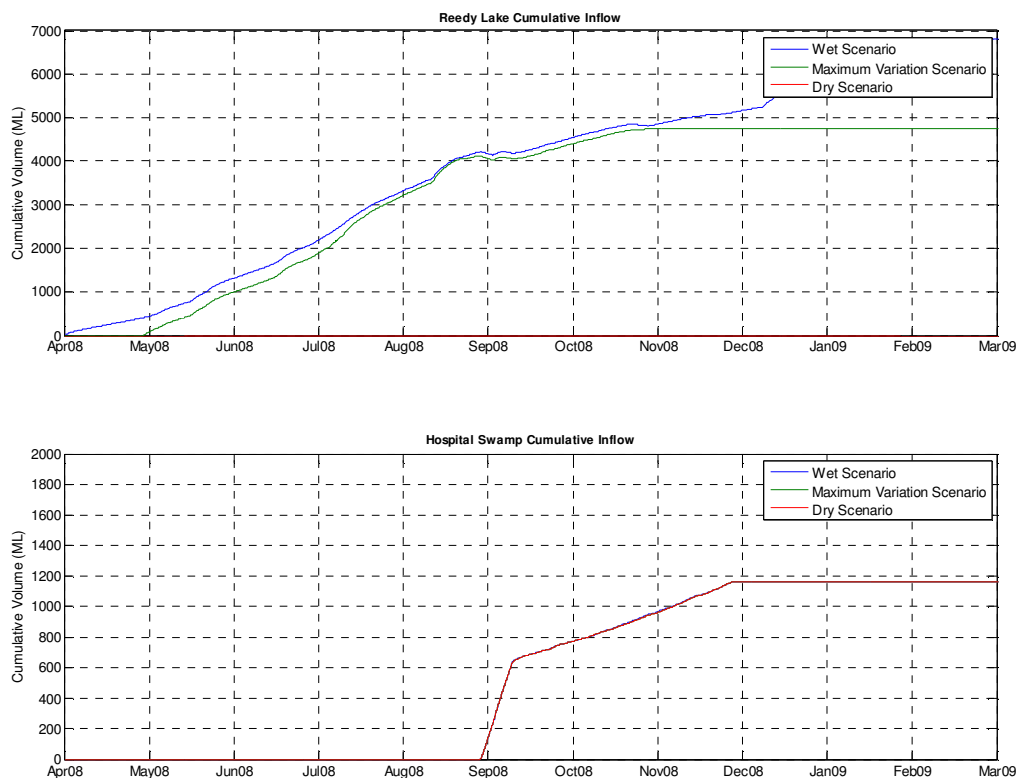


Figure 4-6 Comparison of Predicted Reedy Lake and Hospital Swamp Water Use

4.4.4 Lake Connearre Salinity Impact

Figure 4-7 displays the predicted impact on salinity at locations representative of western and eastern sections of Lake Connearre for each of the different Reedy Lake water management regimes scenarios over the duration of the 12 month scenario.

It should be noted that the limited long term salinity data was available with which to calibrate the hydrodynamic model. The accuracy of the salinity predictions from the model are therefore not considered particularly reliable. However, the model precision is such that relative changes in salinity between different scenarios are considered to be relatively reliably predicted.

The following observations regarding the relative comparisons of the Lake Connearre salinities displayed in Figure 4-7 are provided:

- Only minimal differences between predicted salinities in the western and eastern sections of Lake Connearre are predicted between the Wet and Maximum Inundation scenarios.
- The Dry scenario is however expected to result in a significant reduction in relative salinities in both the western and eastern sections of Lake Connearre.
- The model results indicate that the diversions into Reedy Lake from the Barwon River under the wet and maximum variation scenario are potentially significant to salinity in Lake Connearre, particularly when Barwon River inflows are very low. Under the 2008 scenario tested in the model, diversions into Reedy Lake exceeded the Barwon River inflows at times, resulting in the lower breakwater weir pool lowering below the weir crest. During these periods, the only freshwater inflows into Lake Connearre were due to leakage around the breakwater structure. Under these conditions the impact of the flow diversions into Reedy

Lake appears to be particularly significant to the salinity in the western section of Lake Connewarre.

- The model indicates that importance of the Barwon River inflows in maintaining the estuarine character of Lake Connewarre, particularly over dry and warm periods when evapo-concentration of salinity is high and hyper saline conditions can persist for multiple months within Lake Connewarre.

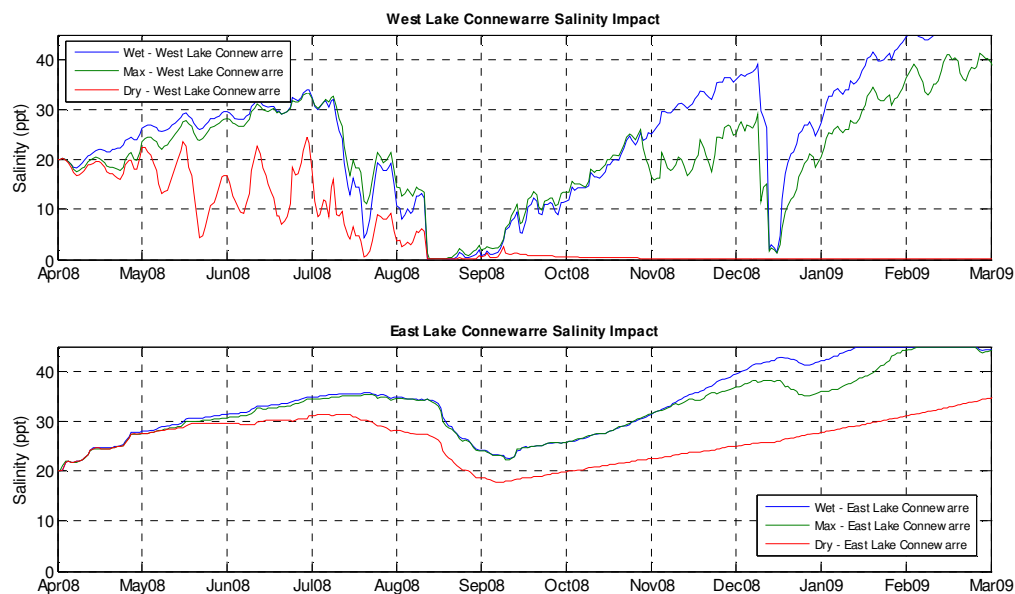


Figure 4-7 Comparison of Predicted Lake Connewarre Salinity

4.4.5 Inundation Extents and Durations

The predicted extents of inundation and the depth/duration characteristics of the inundation have been processed from the scenario simulation results. The following summaries of the inundation characteristics have been provided:

- The total extent and duration of inundation
- The extent and duration of inundation greater than 0.5m depth.

The summaries of the inundation characteristics for each scenario are provided in the following figures.

The following observations regarding the comparisons of the predicted inundation depth and duration characteristics presented in following figures are provided:

- The Wet scenario increases the duration of flooding greater than 0.5m depth in the deepest sections of Reedy Lake by up to approximately 90 days compared to the Maximum Variation scenario.
- The Wet scenario increases the total duration of flooding in shallower areas by up to approximately 60 days compared to the Maximum Variation scenario.

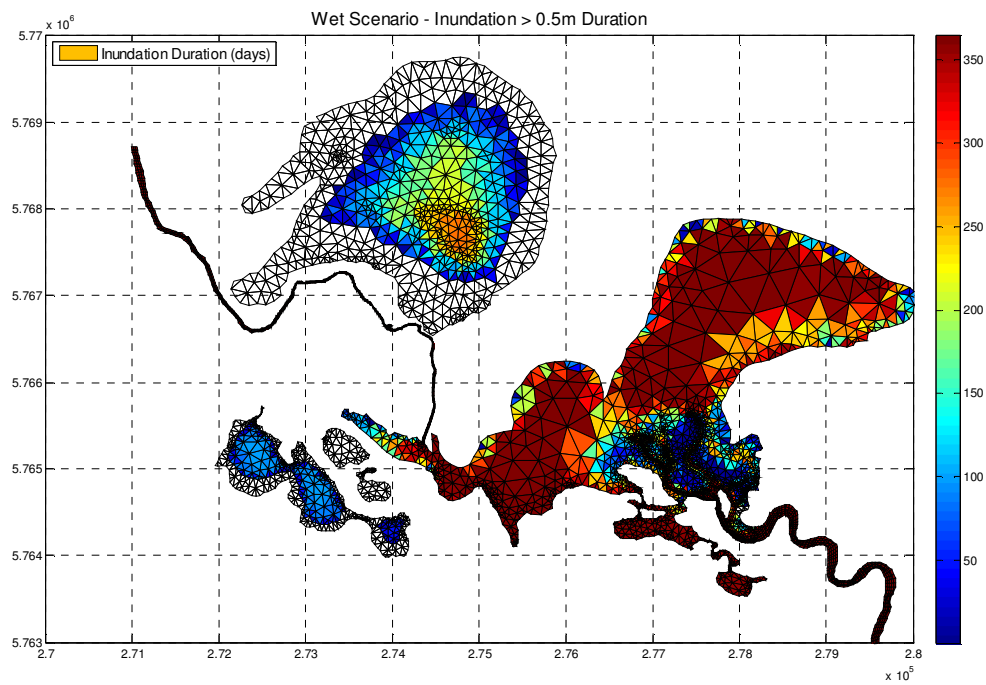
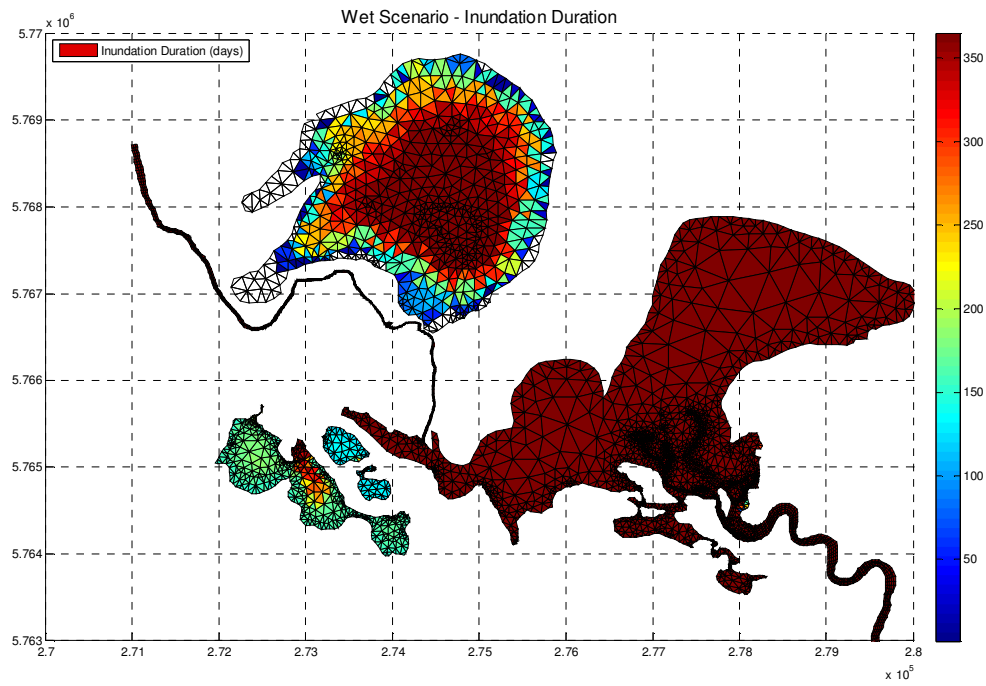


Figure 4-8 Wet Scenario Predicted Inundation Characteristics

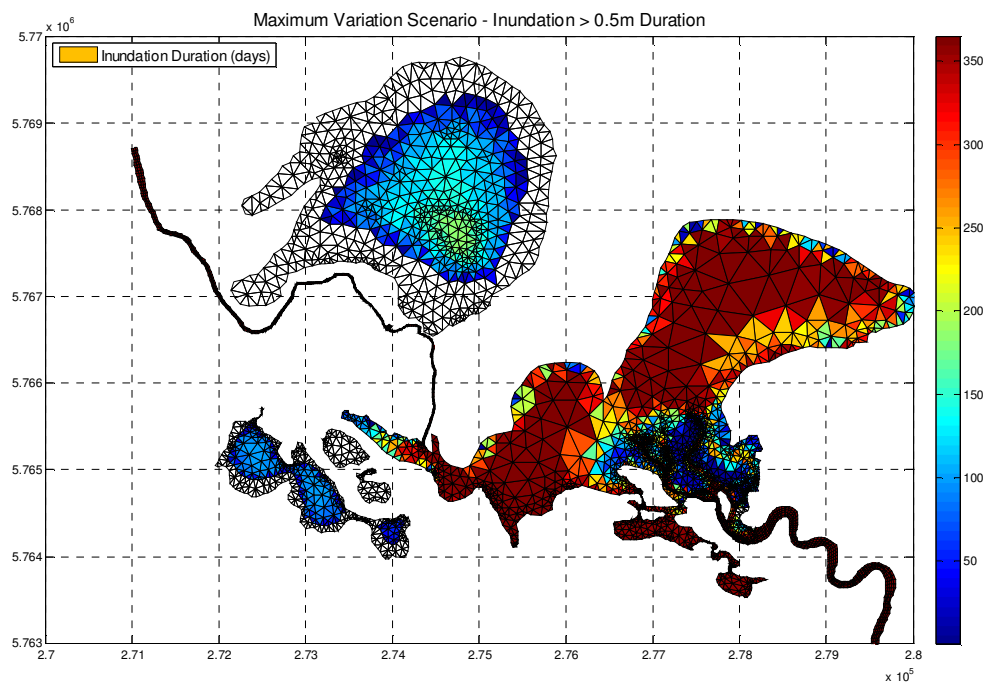
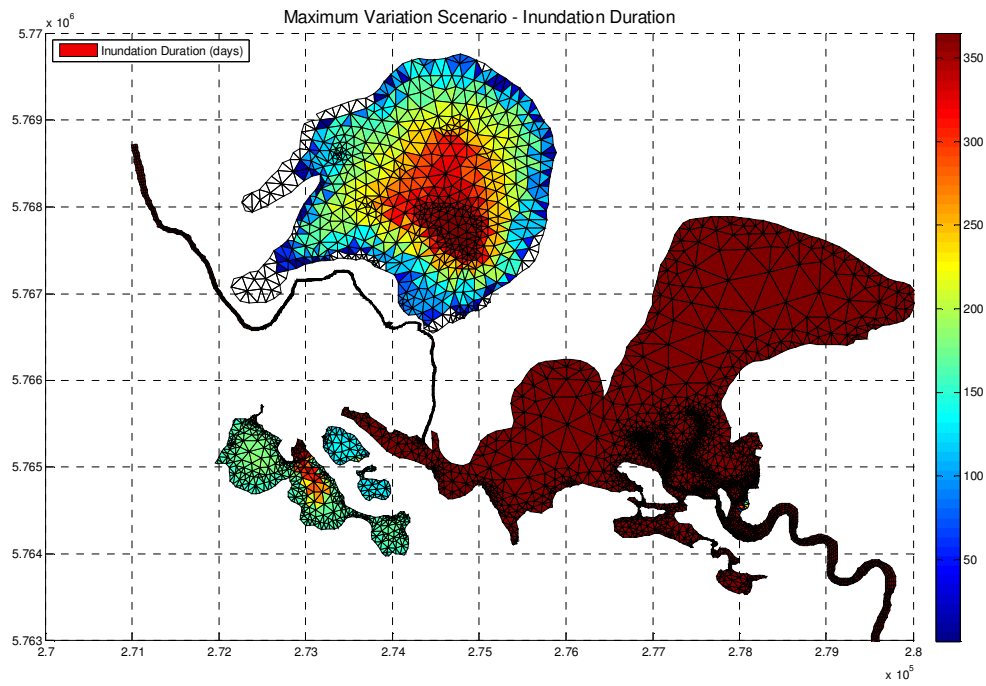


Figure 4-9 Maximum Variation Scenario Predicted Inundation Characteristics

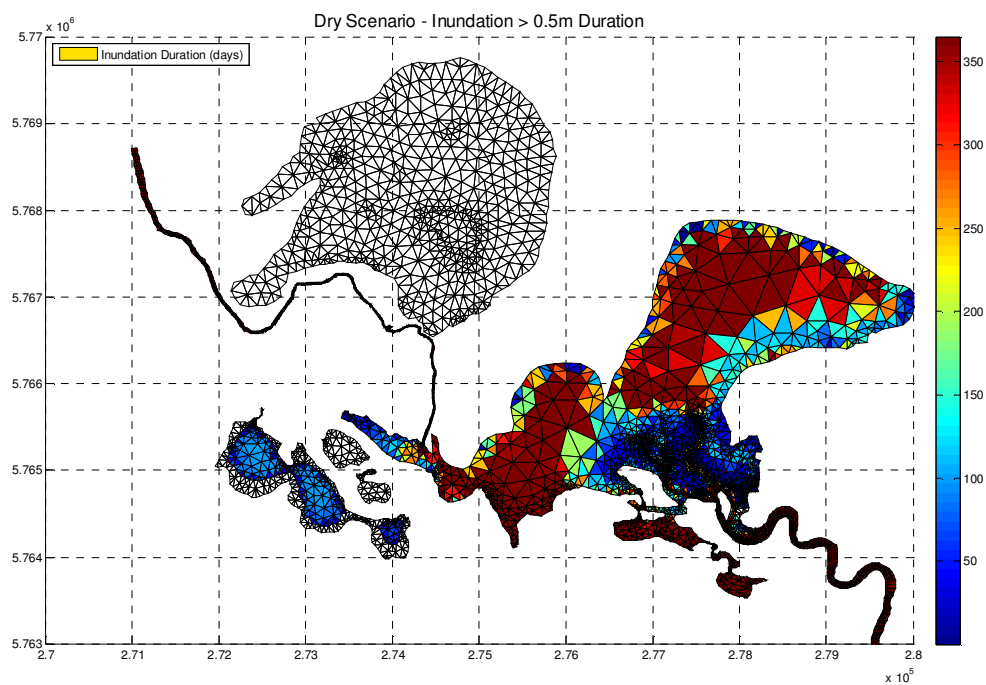
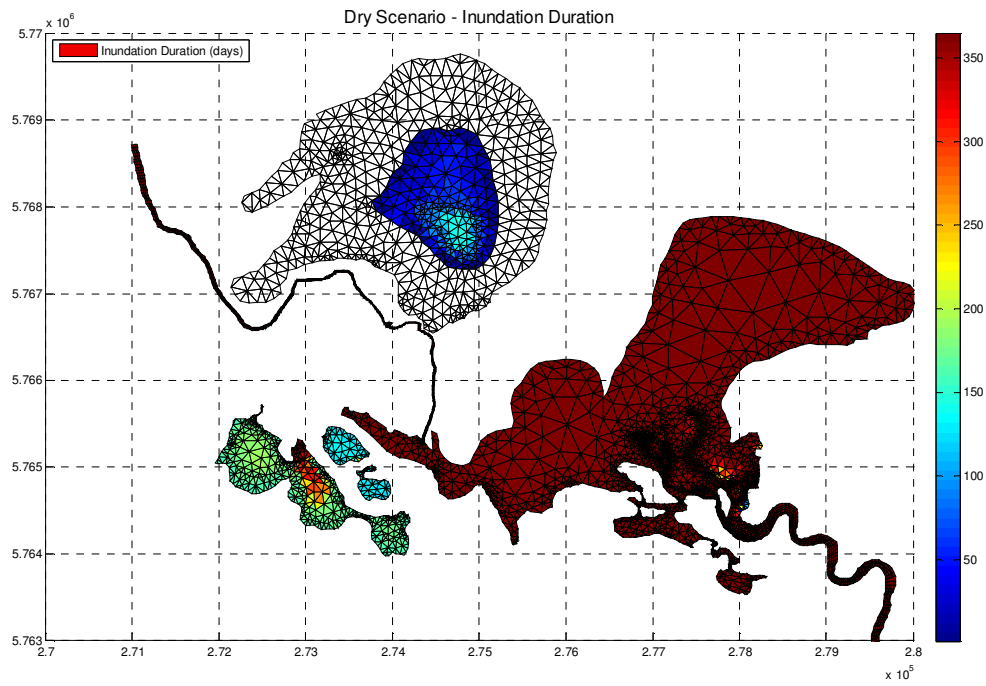


Figure 4-10 Dry Scenario Predicted Inundation Characteristics

5. CONCLUSION

The following summarises the main conclusions from the LBW modelling for the Environment Entitlement:

- Hydrodynamic modelling and subsequent validation from water level records available during an overbank flooding event that occurred in January 2011, determined that a flow rate of approximately 3,500ML/d initiated sustained overbank flooding into Reedy Lake and Hospital Swamp.
- Analysis of long term historical streamflow time series for the Barwon River at Geelong provided estimated annual overbank flow frequencies of approximately 3 events per year. The frequency of overbank flow events over the last approximate 10 years has however been well below the long term average.
- The total annual duration of overbank flows into Reedy Lake and Hospital Swamp has been estimated as 10 days historically. Overbank flow events are strongly concentrated over the months of July through to October.
- Historically, sub-overbank flow spells greater than 365 days occur on average, once every 5 years.
- The height of the natural banks separating Lake Connewarre and Hospital Swamp are approximately 0.5m AHD. Based on the analysis of the storm surge planes for Lake Connewarre, these banks would be overtopped on average once per year or greater to a depth of 0.1m. This would potentially enable significant inundation of these wetlands and in particular the northern most two basins of Hospital Swamp from Lake Connewarre.
- The natural banks separating Lake Connewarre from Reedy Lake are at their lowest point approximately 0.9m AHD. Significant overbank inundation from Lake Connewarre into Reedy Lake is considered unlikely and would be an extremely rare occurrence.
- The outlet channels and regulator sill levels of both Reedy Lake and Hospital Swamp are below mean high water in Lake Connewarre and inundation to a level of approximately 0.4m AHD in these wetlands could theoretically be achieved by operation of the regulators to allow the ingress of estuarine water from Lake Connewarre into these wetlands.

A number of water management scenarios were simulated in the hydrodynamic model to improve the understanding of the potential ecological responses within the LBW to different water management regimes in Reedy Lake. 'Wet', 'Maximum Variation' and 'Dry' water management scenarios for Reedy Lake were simulated in the hydrodynamic model over a 12 month sequence of Barwon River streamflows, tidal water level variations, rainfall, wind and evaporation. The following main observations from the results of the scenario modelling are provided:

- The scenario modelling results indicate that fully inundated conditions in Reedy Lake may not be achieved consistently during periods of low Barwon River streamflows. Relatively high evaporation losses occur from Reedy Lake due its large surface area and shallow depths during the warmer months.
- No significant difference in the water level variation or flows into Hospital Swamp are predicted in the model between the various water management regime scenarios simulated in the model for Reedy Lake. It is therefore considered that changes to the Reedy Lake water management regime will not significantly impact the existing Hospital Swamp water management regime.
- The cumulative inflows into Reedy Lake under the Wet Scenario are predicted at approximately 6,900ML over a 12 month period. The cumulative inflows into Reedy Lake under the Maximum Variation Scenario are predicted at approximately 4,700ML over a 12 month period
- The cumulative inflow to Hospital Swamp under all scenarios is predicted at approximately 1,150ML over a 12month period.

- The Wet scenario can potentially increase the duration of flooding greater than 0.5m depth in the deepest sections of Reedy Lake by up to approximately 90 days on average compared to the Maximum Variation scenario. The Wet scenario potentially increases the total duration of flooding in shallower areas by up to approximately 60 days on average compared to the Maximum Variation scenario.
- The scenario modelling results indicate that the diversions into Reedy Lake from the Barwon River under the Wet and Maximum Variation scenarios during low flow/drought type conditions in the Barwon River are potentially significant to the salinity of Lake Connewarre. The scenario modelling results highlight the importance of the Barwon River inflows in maintaining the estuarine character of Lake Connewarre, particularly over dry and warm periods when evapo-concentration of salinity is high and hyper saline conditions can persist for multiple months within Lake Connewarre.
- Longer term, continuous salinity data in Lake Connewarre is required to assist in calibrating the hydrodynamic model and to enable analysis of the long term salinity regime of Lake Connewarre. This analysis is required to allow the impact of the water management options on the salinity in Lake Connewarre to be more definitively assessed.

APPENDIX A FIELD DATA COLLECTION

To support the development of the hydrodynamic model and provide a monitoring data set for model calibration and validation, a range of field data was collated from existing sources and/or collected as part of this project. The main components of the field data collection program were the following:

- Topographic and Hydraulic Structure Survey
- Water Level and Water Quality Monitoring

The details of the field data collection program are discussed in more detail in the following sections.

Topographic and Hydraulic Structure Survey

Survey data was available from a range of different sources and previous projects in the study area. Available survey data was collated and reviewed in order to identify gaps and subsequently prepare a survey scope to fill these gaps. Additional field and hydraulic structure survey was undertaken for this project to fill the identified survey gaps. The additional field survey undertaken for this project included details of Hospital Swamp bed, the constructed inlet and outlet channels to Hospital Swamp and details of the culverts and penstocks used to control flows through these channels.

Table 5-1 lists the main topographic and structural survey data sources collated as part of this project used to assist in the model development. Figure 5-2 displays the location of these topographic and structural field survey data sources.

Table 5-1 Summary of Topographic and Structural Field Survey Data Sources

Data	Source	Note
VICMAP Future Coast Elevation LiDAR	DSE	1m LiDAR Survey
Upper Barwon River Channel Survey	Water Technology	Survey commissioned previously
Lower Barwon River Channel Survey	Barwon Water	Hydrographic and field survey
Lake Connewarre Spot Level Survey	Barwon Water	Hydrographic and field survey
As constructed Channel Dimensions	Ian McLachlan, Barwon Water, Field and Game	Field survey, construction drawings
Hospital Swamp Spot Level Survey	Ian McLachlan	Field survey
Reedy Lake Spot Level Survey	CCMA	CCMA's Barwon Barrage assessment

Water Level and Water Quality Monitoring Data

Suitable hydrologic and water quality monitoring data was collated from previous and ongoing project work in the study area. This data was reviewed to identify historical periods with the most extensive and up to date monitoring datasets of the LBW to ensure the most rigorous calibration of the hydrodynamic model possible was undertaken.

From this review, the following main suitable monitoring datasets and sources were identified.

- Lake Connewarre Values Hydrodynamic Modelling Project

- University of Ballarat Groundwater Monitoring Project

Monitoring 2008

From these data sources, the most extensive and complete series of suitable measurements for model calibration were identified as occurring from a period beginning June 2008 to March 2009. Over parts of this period, concurrent tidal water levels, Lake Connewarre salinity, Reedy Lake and Barwon River water level data was available. This period also includes a flooding and partial drying of Reedy Lake and is considered to provide a good test of the hydrodynamic models ability to reproduce this aspect of the Reedy Lake hydrology.

The relevant data collated from these monitoring sites over this period is displayed in Figure 5-1. The locations of the monitoring sites from these two main data sources are displayed in Figure 5-3.

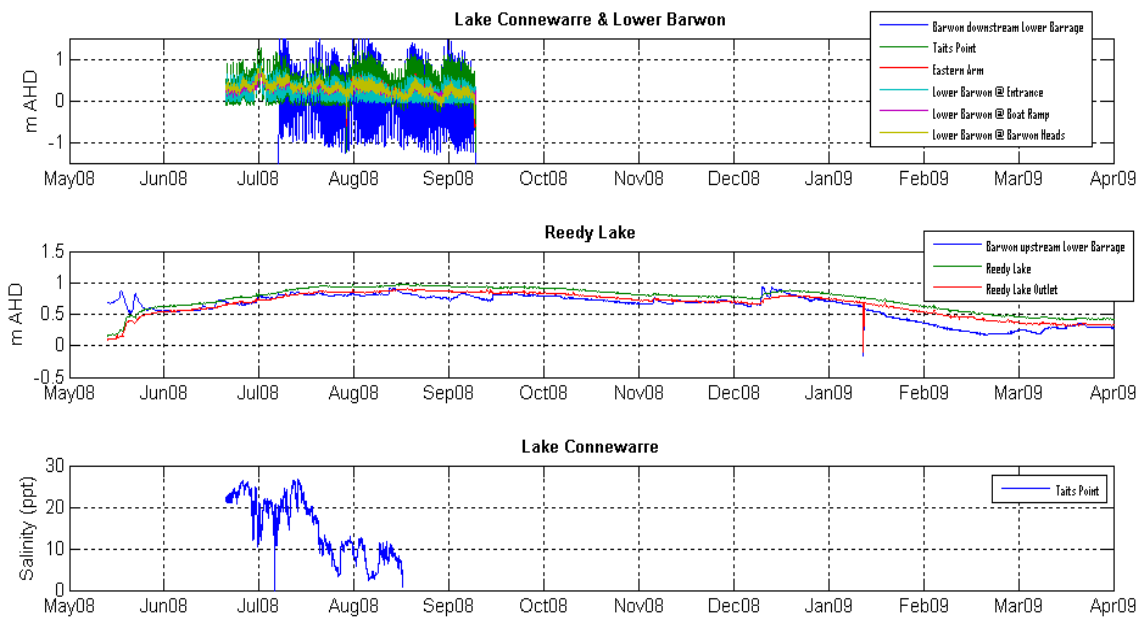


Figure 5-1 2008 Monitoring Data

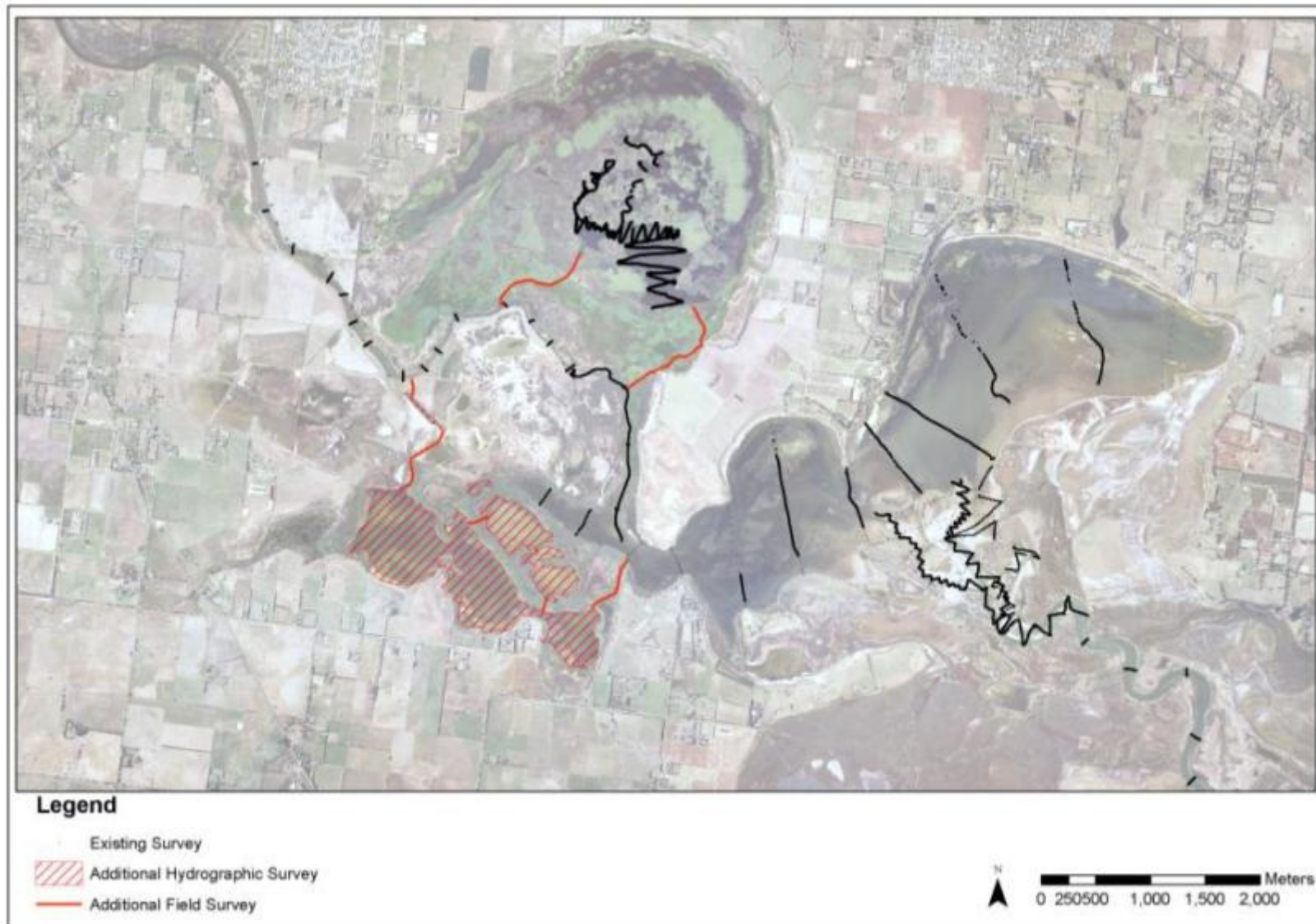


Figure 5-2 Overview of Extent of Topographic and Structural Field Survey



Figure 5-3 Hydrologic Monitoring Locations

Monitoring 2010 – 2011

Continuous (6-10 min) pressure observations were logged at 2 locations within Lake Connewarre during the summer of 2010 – 2011. The locations are displayed in Figure 5-3. Where required, the pressure observations were adjusted for barometric pressure variations based on the Geelong AWS recorded barometric pressures, and the adjusted pressures converted to water depths.

The loggers were deployed on the 23rd November 2010 and retrieved on the 4th February 2011. An interim data download was undertaken on 23rd December 2010. Water level loggers in the first deployment were drowned and returned no usable results; however two continuous records were obtained for the salinity monitoring at the Lake Connewarre entrance to the Lower Barwon.

Figure 5-4 and Figure 5-5 display the recorded water level and salinity respectively at the monitoring locations.

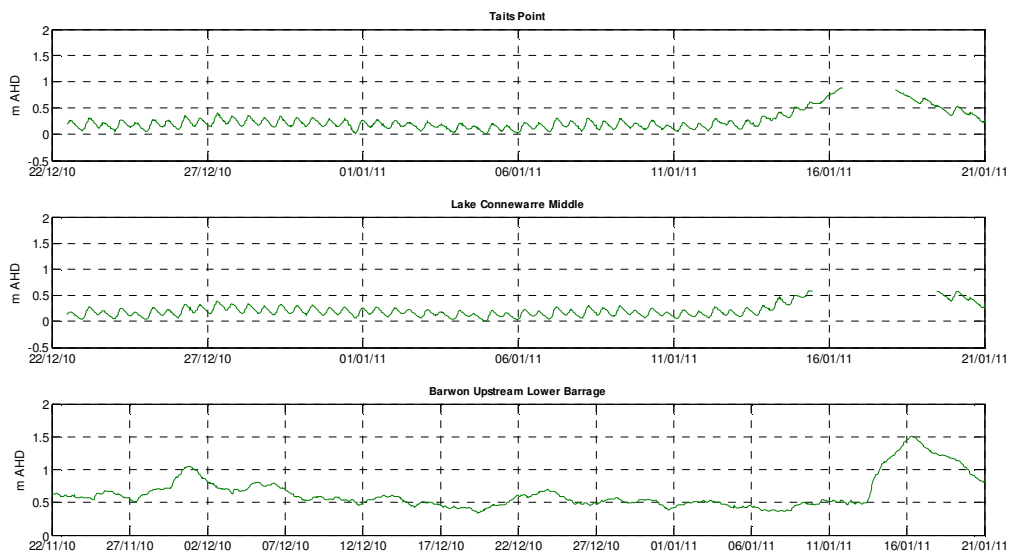


Figure 5-4 Logged Water Levels 2010 – 2011

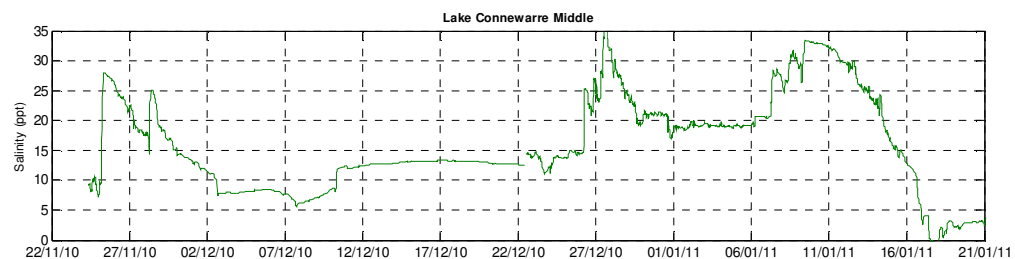


Figure 5-5 Logged Salinity Level, Lake Connewarre Entrance to Lower Barwon River 2010 - 2011

APPENDIX B DIGITAL ELEVATION MODEL

To support the hydrodynamic model development, a continuous digital terrain model (DTM) of the LBW has been constructed by combining the various sources of terrain information discussed in Appendix A.

The main objective of the DTM development was to ensure the various tidal channels and small constructed channels into Reedy Lake and Hospital Swamp were properly resolved as these features are considered critical to the hydrodynamic behaviour of the LBW.

Figure 5-6 displays an overview of the continuous DTM including the bathymetry of Lake Connewarre, Reedy Lake and Hospital Swamp.

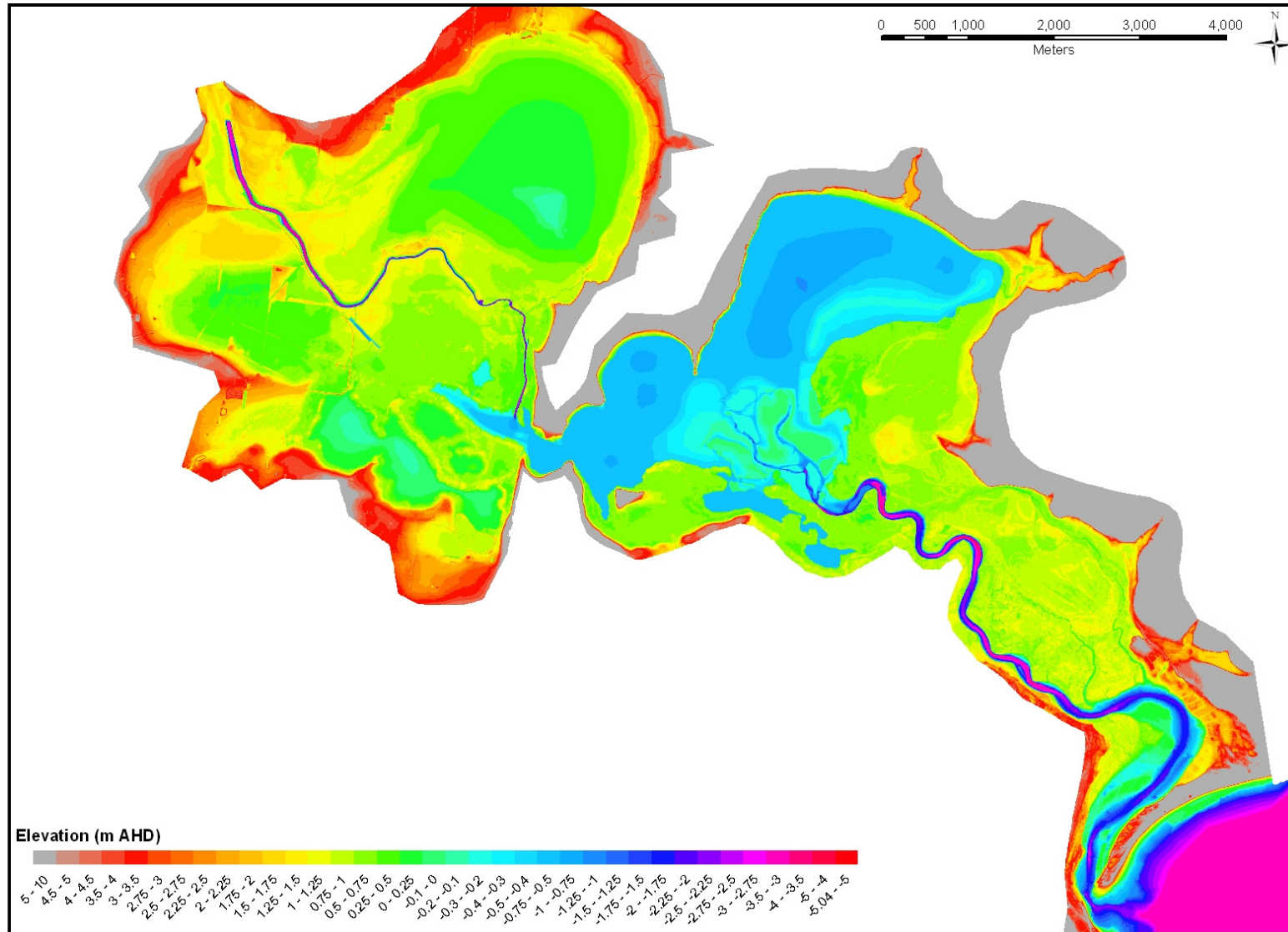


Figure 5-6 Digital Elevation Model of the Lower Barwon Wetland Complex

APPENDIX C HYDRODYNAMIC MODEL DEVELOPMENT AND CALIBRATION

Introduction

Numerical modelling is the process of creating an equation or system of equations that describes or predicts, with an appropriate degree of accuracy, some physical situation.

The governing equations for the flow and transport of scalar variables (salinity) in an estuary can be achieved by combining the Reynolds form of the Navier Stokes equations, the volume continuity equation, the advection diffusion equation for salinity and an equation of state relating water density to salinity.

The model supports a range of boundary conditions including spatially and temporally varying tide, river inflow, wind, rainfall and evaporation. The model allows use of a range of eddy viscosity formulations including the Smagorinsky closure methodology.

Model Topography

The horizontal spatial domain of the model is comprised of quadrilateral and triangular elements. Linear features such as the Lower Barwon Estuary channel and the Barwon River were resolved as quadrilateral elements to improve computational efficiency and numerical resolution of the hydrodynamics of these features. The wetlands and other topographic features are resolved as triangular elements of varying size to adequately resolve areas of high hydraulic gradients and minimise unnecessary computational points in other areas. The two dimensional computational mesh of the entire model is displayed in Figure 5-7.

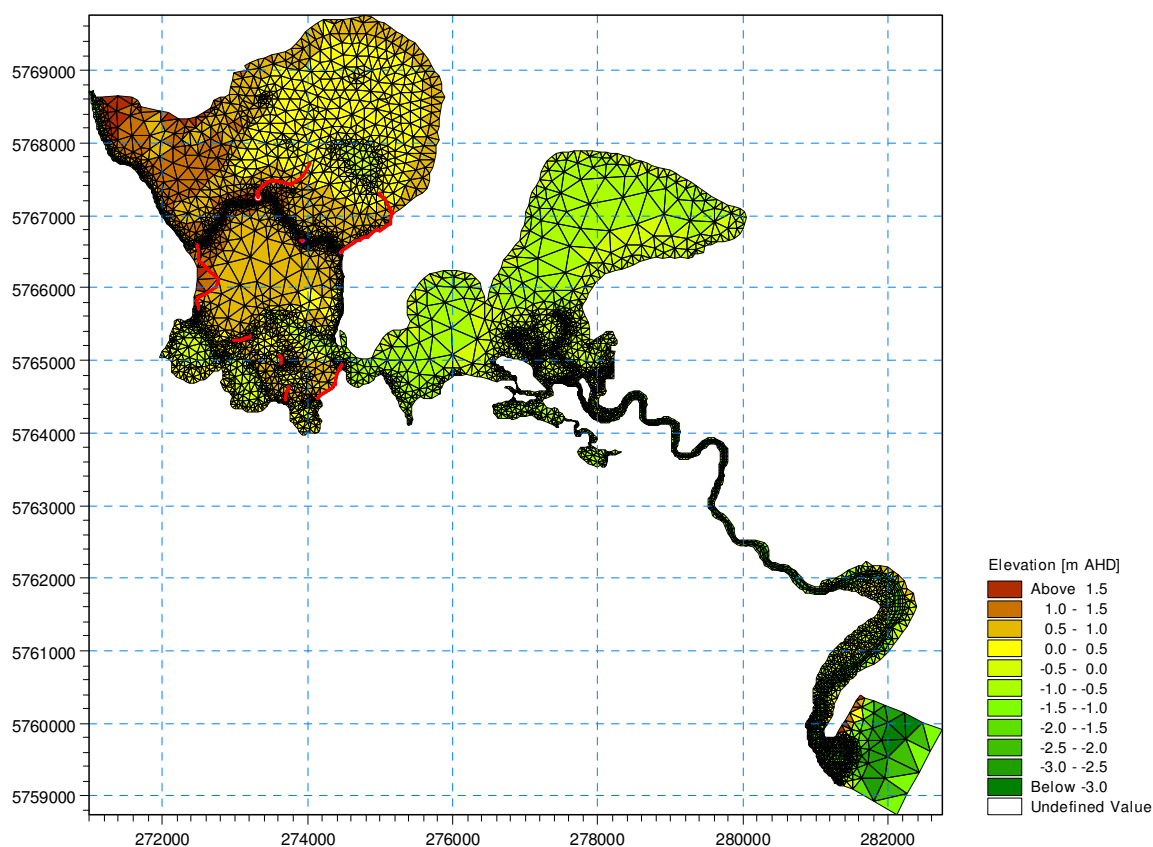


Figure 5-7 Hydrodynamic Model Domain

Boundary Conditions

Tidal Boundary

A tidal water level boundary is specified offshore of the entrance to the Lower Barwon at Barwon Heads. Water level variations at this boundary are a function of astronomical and meteorological forcing conditions.

From the results of previous analysis of the comparison of the astronomical tide between Lorne and Barwon Heads (Water Technology, 2008) it was found that the observed water level record at Lorne provided a suitable description of the ocean boundary condition at Barwon Heads after a slight adjustment of the amplitude of the diurnal M2 component of the tide.

The tidal boundary was specified with a constant ocean salinity of 35ppt.

Barwon River

Freshwater inflows in the Barwon River are specified at a location approximately 6 kilometres upstream of the Lower Barrage. The closest available streamflow gauge on the Barwon River is at the McIntyre Bridge gauge in Geelong. The gauge is however approximately a further 4 kilometres upstream of the model boundary location and uncertainty remains in the estimation of the flows at the models upstream boundary.

Wind

Wind driven circulation and mixing is an important component of the hydrodynamic behaviour of Lake Connewarre in particular. 10 minute average, hourly wind speed and direction observations were derived from the Geelong AWS and applied to the modelled water surface.

Evaporation

The air–sea exchange of heat and water across the surface of the LBW determines changes in temperature and salinity in wetlands and estuaries. For the purposes of this study, the impact of evaporation on salinities and water levels has been simply accounted for by applying a time varying (negative) fresh water flux from the model surface area based on appropriately factored daily pan evaporation rates sourced from the Bureau of Meteorology.

Rainfall

Direct rainfall is applied to the surface layer of the model as a time varying fresh water flux. Observed rainfall data has been derived from the Geelong AWS and was uniformly applied spatially across the model domain.

One Dimensional Elements and Hydraulic Structures

Sub element scale features and structures on the floodplain not efficiently resolved in the two dimensional computational mesh were incorporated within the model schematisation by the incorporation of one dimensional, cross sectional elements and structures which were then dynamically linked to the two dimensional mesh. This approach reduces the computational overhead, flexibility and numerical stability of the model. One dimensional elements and structures were used to define the inlet and outlet channels to Reedy Lake and Hospital Swamp and associated regulating structures on these channels as well as to define the Lower Barwon Barrage.

Bed Resistance

Bed resistance was specified as a Manning's n , roughness coefficient that was varied spatially over the model domain to reflect changes in bed roughness within the LBW and as a fine tuning parameter for the model calibration.

Eddy Viscosity

The transfer of momentum through sub-grid scale turbulence was modelled through the inclusion of horizontal eddy viscosity. The horizontal eddy viscosity is given by the Smagorinsky formulation. This expresses the effects of sub-grid scale turbulence by an effective eddy viscosity related to a characteristic length scale and the local spatial current variations.

Dispersion Coefficients

The transport of salinity is a function of molecular and other flow processes that are not explicitly resolved in the finite volume flow model. The effects of non-resolved processes on the transport of salinity in the model has been incorporated by adoption of dispersion coefficients that were derived as part of the model calibration process.

Hydrodynamic and Salinity Model Calibration

Overview

The development of a hydrodynamic model of the LBW requires a rigorous calibration process to ensure the model accurately reproduces observed hydrodynamic behaviour of the study area. The calibration process consists of systematically comparing observed hydrodynamic behaviour within the study area against the hydrodynamic models reproduction of that behaviour. This process generally incorporates comparisons between observed water level variations and other available water quality measurements i.e. salinity. Where the model does not adequately represent the observed behaviour, reasons for the discrepancies are identified and inputs to the model adjusted. This process is repeated until a satisfactory result is achieved.

Calibration Period

The hydrodynamic model has been calibrated to the observed water level and salinity variations captured by the field monitoring program in Lake Connearre and Lower Barwon between the 21/06/2008 and 10/09/2008. Following calibration of the tidal components of the LBW, the model was calibrated to the Barwon River and Reedy Lake water level timeseries provided by Peter Dalhaus and the University of Ballarat over the period June 2008 through May 2009.

2008 Calibration Results

Tidal Water Level Variation

Tidal water levels within the model have been compared to those observed within the LBW. The comparisons presented below in Figure 5-8 and Figure 5-9 are considered to indicate that the model provides a good reproduction of the tidal dynamics within Lake Connearre and the Lower Barwon estuary.

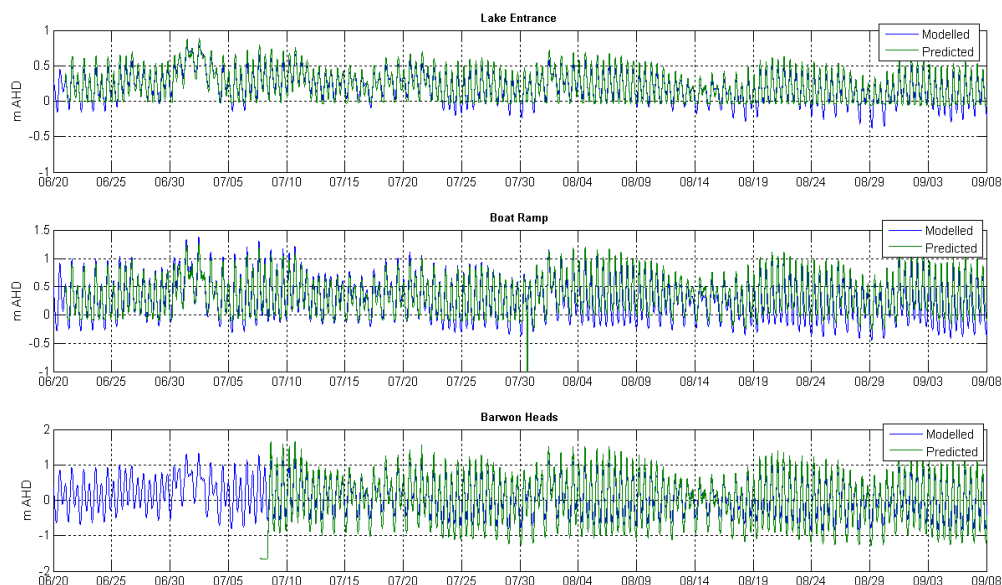


Figure 5-8 Calibrated Water Level Comparisons on the Lower Barwon

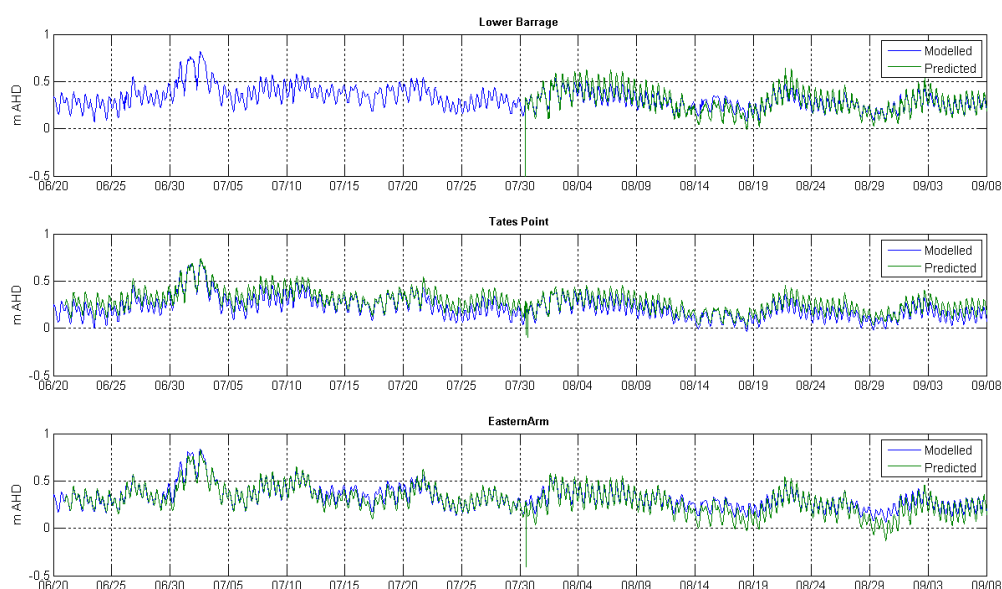


Figure 5-9 Calibrated Water Level Comparisons in Lake Connearre

Reedy Lake and Barwon River Calibration

Figure 5-10 shows the water level measured in the Barwon River at a location approximately 1 km upstream of the Lower Barrage compared with those simulated in the model at the same location.

The results are considered to indicate that in general the model accurately reproduces water levels within the Barwon River upstream of the barrage in response to varying Barwon River inflows. Towards the end of the calibration period over the summer months, the modelled weir pool above the Lower Barrage does not fall to the same extent as was observed. This discrepancy is attributed to leakage past the floating gates on the Lower Barrage which is difficult to define accurately within the hydrodynamic model.

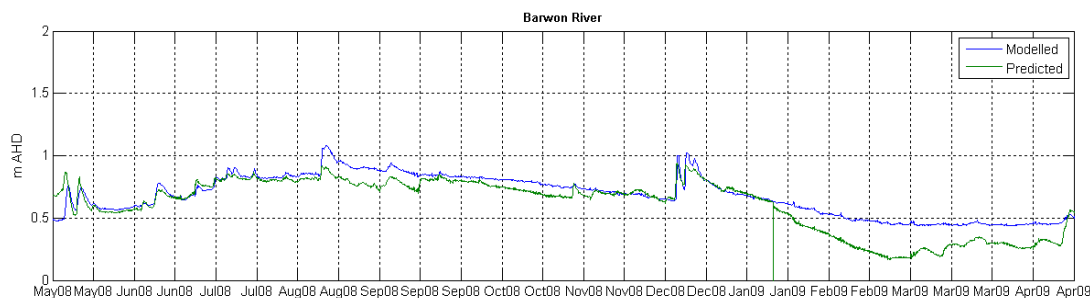


Figure 5-10 Calibrated Water Level Comparisons on the Barwon River upstream of the Lower Barrage

The comparison of the observed Reedy Lake water level timeseries and the model prediction is displayed in Figure 5-11. The comparison displayed in Figure 5-11 is considered to show the model is in excellent agreement with observed filling and drying sequence observed in Reedy Lake.

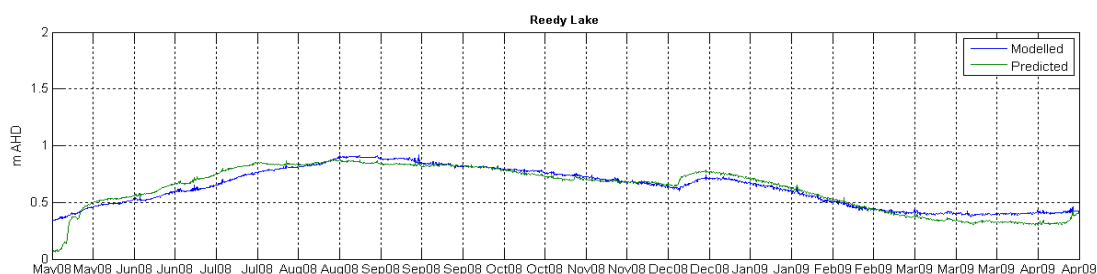


Figure 5-11 Calibrated Water Level Comparison in Reedy Lake

Lake Connewarre Salinity

The observed variation in salinity in Lake Connewarre at Taits Point has been compared to the modelled results over an approximate 2 month period during 2008 in Figure 5-12.

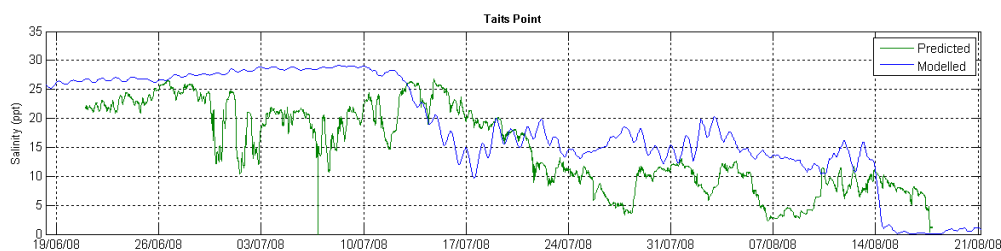


Figure 5-12 Calibrated Salinity Comparison in Lake Connewarre at Taits Point

Discussion

The following broad observations are made regarding the level of agreement achieved between the modelled and observed water level variations in the Lower Barwon wetlands:

- The attenuation of the tide and shift in phase along the length of the Lower Barwon is considered to be well resolved in the model.
- The attenuation of the tide and impact on mean water levels in Lake Connewarre associated with the passage of the tide across the flood tide delta is considered to be reproduced quite well in the model.

- The influence of the large storm surge event in Bass Strait around the 1st July on water levels in Lake Connewarre is accurately reproduced by the model.
- The influence of small freshes on water levels in the Barwon River upstream of the barrage is reproduced well by the model.
- Evaporation within Reedy Lake is reproduced well within the model.

Validation Period

The hydrodynamic model has been validated to observed water level and salinity variations captured by an additional field monitoring program in Lake Connewarre and Lower Barwon between December 2010 and January 2011. The period is noteworthy in that it includes two high flow events, the second of which occurred in mid January and resulted in significant overbank flooding into Reedy Lake and Hospital Swamp. Figure 5-15 displays the simulated overbank flooding into Reedy Lake close to the peak of the January flood event.

2010 Validation Results

Tidal Water Level Variation

Tidal water levels within the model have been compared to those observed within the LBW. The water level comparisons are presented below in Figure 5-13. It should be noted that due to the magnitude of the flood in January, the atmospheric pressure correction breather on the water level loggers in Lake Connewarre was overtopped and the instrument did not record meaningful data during the peak of this flood event.

The water level comparisons displayed in Figure 5-13 are considered to validate the hydrodynamic model configuration and demonstrate the ability of the model to reproduce overbank flooding from the Barwon River into Reedy Lake and Hospital Swamp.

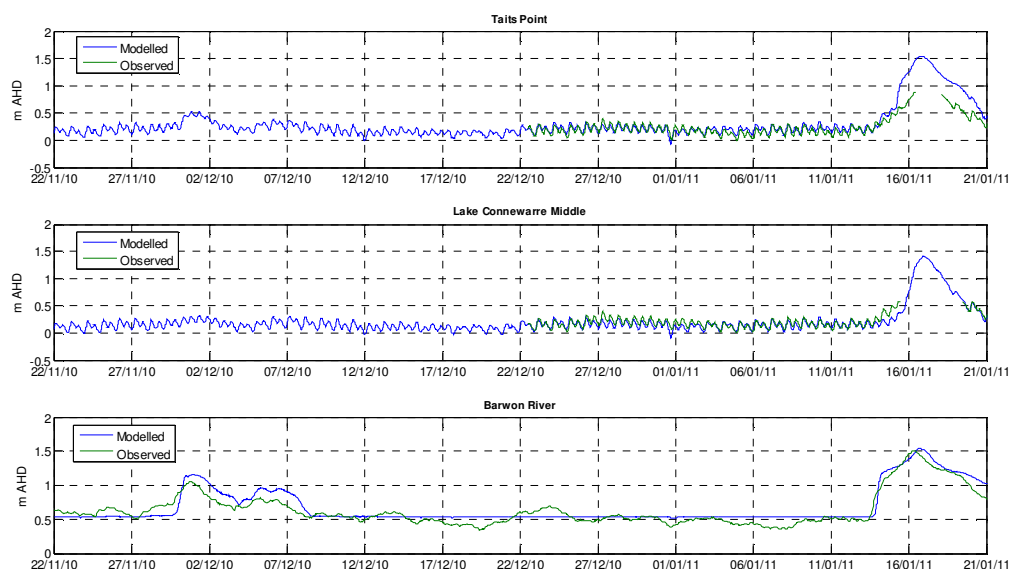


Figure 5-13 Lake Connewarre and Barwon River Water Level Validation

Lake Connewarre Middle Salinity

The observed variation in salinity in Lake Connewarre has been compared to the modelled results over an approximate 2 month period between December 2010 and January 2011 in **Error! Reference source not found.**

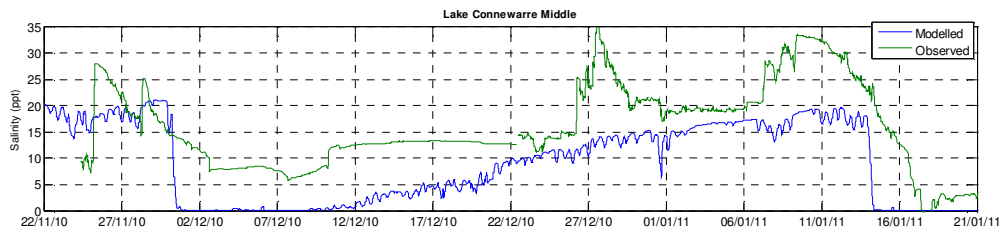


Figure 5-14 Lake Connewarre Salinity Validation

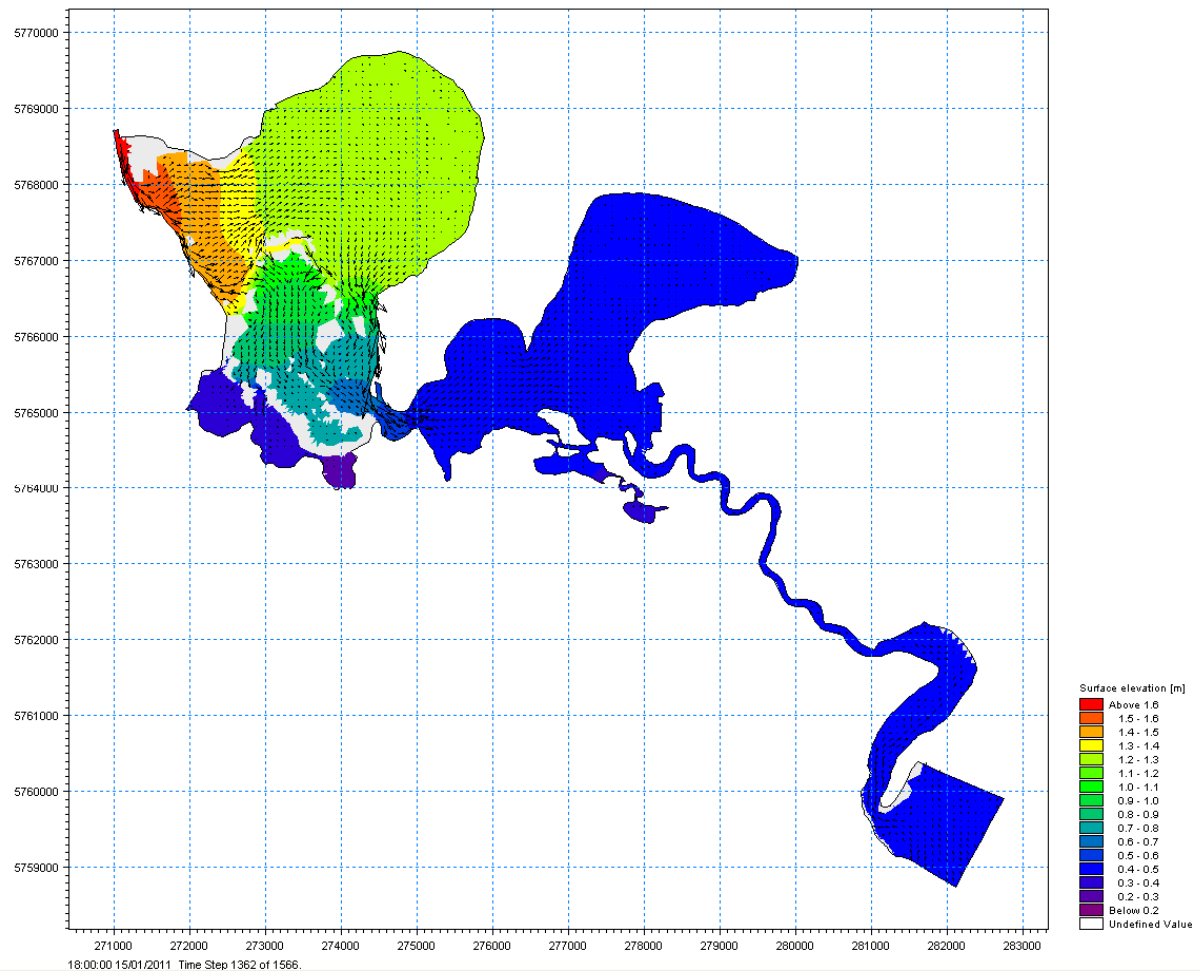


Figure 5-15 Predicted Overbank Flooding Extent into Reedy Lake during January 2011 Flood Event