Mollers Lane Development Lake Connewarre Impact Assessment Final Report

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Prepared for: Mollers Lane Development Pty Ltd
Mollers Lane Holdings Pty Ltd
PAMAS Property Pty Ltd

In association with lloydenvironmental

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1 Introduction

1.1 Background

The Mollers Lane Residential Development (Development Site) is a proposed urban sub-division located in Leopold estuary to the south-east of Geelong in Victoria. The area is south of the Bellarine Highway bounded by Mollers Lane to the east, farm zoned properties to the west and the existing Leopold residential area to the north, as shown in Figure 1-1.

The Development Site is currently farm land and is located within a catchment that drains to Lake Connewarre. Lake Connewarre is part of the Bellarine Peninsula Ramsar Wetland system, which also includes Reedy Lake, Hospital Swamp, Salt Swamp and Murtnaghurt Lagoon. Ramsar wetlands are a protected matter of national environmental significance under the EPBC Act[1]. Any development likely to have a significant impact on a matter protected by the Act requires approval from the Australian Government Environment Minister.

Mollers Lane Developments Pty Ltd, Mollers Lane Holdings Pty Ltd, and PAMAS Property Pty Ltd have engaged Venant Solutions and Lloyd Environmental to prepare this report. The purpose of this report is to provide information for the referral agencies regarding the potential impacts on Lake Connewarre resulting from changes in the hydrological regime due to the proposed development. Curriculum Vitae for key staff contributing to this report are provided in Appendix A.

This report documents the modelling of the relevant catchment and the predicted changes in runoff volume to Lake Connewarre, the environmental character of Lake Connewarre and an assessment of the impact of the changed hydrological regime on the environmental character of Lake Connewarre. The report does not assess the environmental values or impacts at the Development Site itself.

1.2 Scope of Works

The primary purposes of this report is to describe the changes to catchment runoff volume into Lake Connewarre resulting from urbanisation of the Development Site and an assessment of the impact of the additional runoff on the ecological character of Lake Connewarre. In assessing the impact on the environmental character, both the catchment foreshore and the broader Lake Connewarre environment have been assessed.

Lake Connewarre operates under a complex hydrological regime with inflows from local catchment runoff, tidal flushing, inflow from the Barwon River during freshes, and possibly inflow from groundwater. Urbanisation of a catchment increases the percentage of impervious surfaces which invariably leads to an increase in the peak overland flow rate during rainfall events, and can also lead to an increase in the total runoff volume because less rainfall infiltrates into the soil. As part of the engineering design of the development, the peak flow rate will be attenuated to match pre-development conditions using stormwater management devices such as retarding basins and wetlands, but these devices are not as effective in managing increase in runoff volume. Therefore, the focus of this assessment is the increase in runoff volume rather than peak flow rates.

There is insufficient flow or level data for Lake Connewarre to be able to model the complete water balance of the system. Therefore, this study focused on the changes in local catchment runoff component of inflows to the area of Lake Connewarre potentially impacted by the development.

[1] Environmental Protection and Biodiversity Conservation Act, 1999, Sections 16 and 17B

Water balance models of the various catchments flowing to the northern part of Lake Connewarre were developed so as to quantify the change in the runoff characteristics due to the proposed development. These models represented and compared the existing and ultimate levels of development. The existing case represents the catchment condition prior to development of the Development Site and was used as the base against which the ultimate case was assessed.

Because there is significant variability in rainfall patterns from year to year, the analysis was done using continuous daily rainfall data series for the last 125 years. The model determined the runoff volume on a daily basis across the 125 years for each of the cases being investigated. A statistical analysis of the model output was undertaken to establish the monthly means as well as the 10th, 25th, 75th and 90th percentile runoff volumes.

An assessment of monthly flow volumes rather than a daily or annual was adopted so that the effect on monthly and seasonal variation could be understood. These are of importance to inform potential changes to wetting/drying cycles in the lake and foreshore area that occur across the year. Annual mean flow values may mask differences in the magnitude of change in different seasons/months and an analysis on a daily timescale is not appropriate, being too short for the purposes of an ecological assessment.

The results for the existing and ultimate case were compared to understand the changes in runoff volume over the full 125-year period of time. By doing so, the analysis provides a good indicator of the natural variability in runoff volumes under existing conditions.

The water balance model provides a good understanding of changes to runoff volume reaching Lake Connewarre. The greater watershed draining to the northern section of Lake Connewarre consists of several separate catchments each with its own waterway reaching the Lake. The Development Site is located within one of these catchments and it is this catchment from which the increased flow will enter Lake Connewarre. Just prior to entering Lake Connewarre, the waterway is controlled by a private dam. The private dam outlets into a small waterway which conveys the water across the foreshore area. The waterway does not continue across the shoreline and into the Lake so runoff will disperse across the shoreline and into the Lake. To understand changes in inundation characteristics of this foreshore area caused by increased flow from the development, a hydraulic model was developed to assess existing inundation patterns and inundation patterns with additional flow from the development.

The scope of this study can be summarised as follows:

- Describe the Ecosystem and Ramsar Values;
- Prepare water balance models of the catchment flowing into the north-eastern basin of Lake Connewarre to assess stormwater runoff volumes under:
    - pre-development conditions; and
    - ultimate conditions;
- Analyse the change to monthly surface flow volumes to Lake Connewarre and the foreshore;
- Use a hydraulic model to map changes to inundation extent and duration on the foreshore area before the runoff enters Lake Connewarre;
- Assess potential Ecosystem Changes; and
- Identify mitigation options if required.

It is beyond the scope of this study to assess the overall hydraulic process in Lake Connewarre. The study aims to present an understanding of the current inflow regime to the north-eastern

corner of the Lake to allow an assessment of the potential impact on the ecological character. The water balance models developed as part of this study is suitable for this purpose, based on available data.

Title:
Mollers Lane, Leopold
Locality Plan

Figure:	Rev:			By:
1-1	A	N	0 0.75 1.5km Approx. Scale	DR

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

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2 Catchment Characteristics

The catchments included in the water balance modelling are shown in Figure 2-1 and Figure 2-2. As previously discussed, these are catchments from which runoff will make its way to the area of Lake Connewarre and its foreshore that are potentially influenced by the proposed development and hence do not include all of the inflows feeding Lake Connewarre such as the Barwon River system. Two separate water balance models were analysed to compare existing and developed cases for both catchment scales:

- A model of the greater catchment area feeding the north area of Lake Connewarre (Figure 2-1), and
- Model of the catchment containing the Development Site, feeding the existing farm dam storage which drains and overflows to Lake Connewarre (Figure 2-2).

Catchment C represents the Lake, and shows the assumed boundary of influence for assessing the impact of changed inflows from surface runoff to the northern section of Lake Connewarre. Rainfall onto the lake itself has been included in order to represent the direct rainfall component to the Lake inflows. The catchments feeding this northern section of Lake Connewarre extend across the Bellarine Highway to Portarlington Road and are primarily rural or low density residential zonings, with some existing residential development in the suburb of Leopold.

2.1 Proposed Development

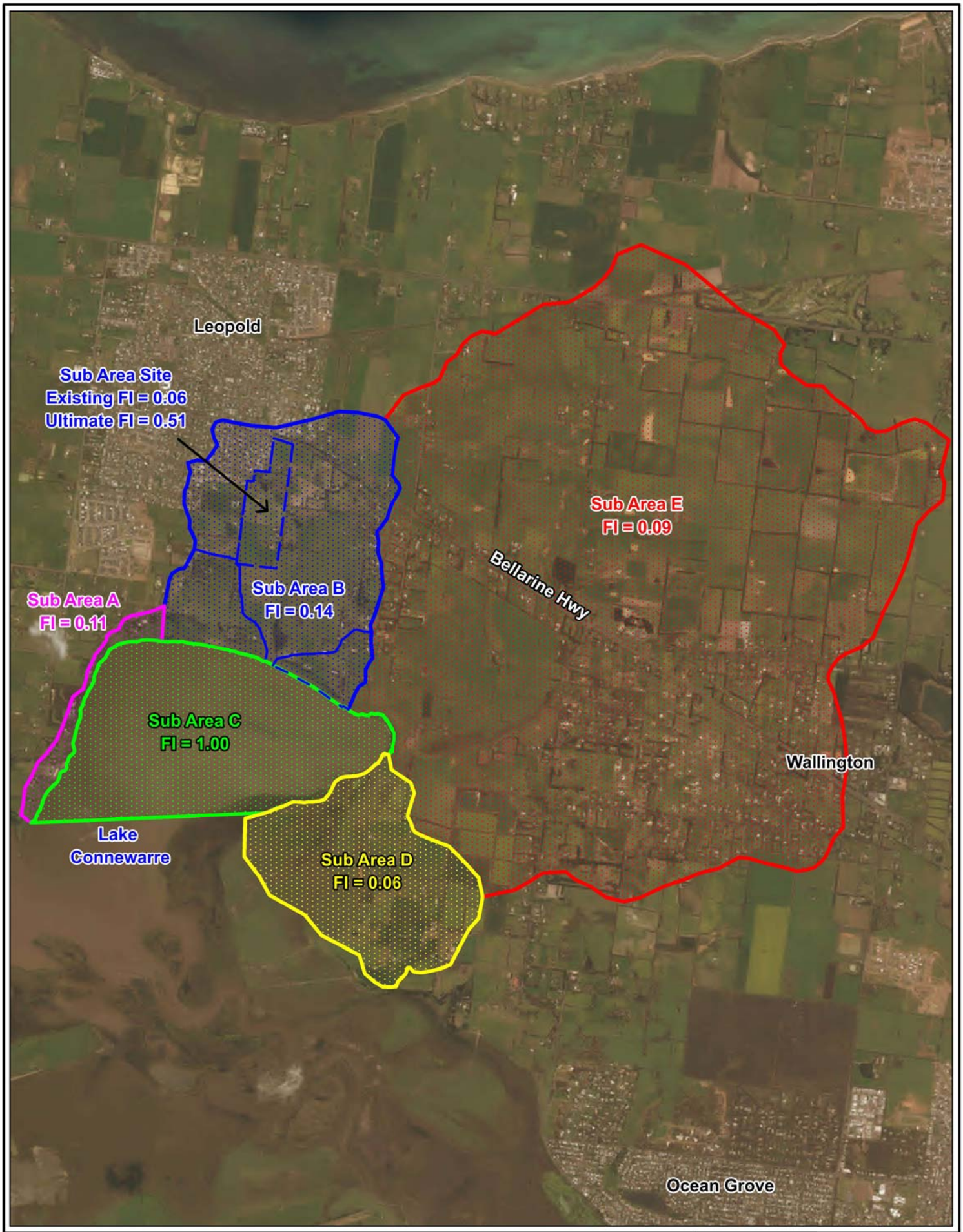
The proposed overall development plan is shown in Appendix B and the associated changes to surface characteristics resulting from the proposed urbanisation were applied in the ultimate case scenario.

2.2 Fraction Impervious

The fraction impervious (FI) of the catchment is required as an input to the water balance model (MUSIC). The FI was calculated for each node in the MUSIC models based on the mix of landuse within the node. The FI estimate was guided by the Melbourne Water MUSIC Guidelines and refined using a combination of cadastral (property) information and aerial photography. Impervious area percentages were found for a small and typical sample of properties in each catchment. The FI for each catchment (and MUSIC node) was then calculated and area weighted. The adopted FI for existing and ultimate cases are summarised in Figure 2-1 and Table 2-1. It can be seen that for the full catchment the increase in FI from the pre-existing to ultimate case is only 0.5% from 19.8% to 20.3%.

Table 2-1 Catchment Areas and Fraction Impervious

Catchment	Area (Ha)	Existing Case FI	Ultimate Case FI
A	40.6	10.5 %	10.5 %
B	462.8	13.1%	17.1%
B – Development Site	41.0	6.1 %	51.3 %
B - Remainder	421.8	13.8 %	13.8 %
B1 - Remainder	317.3	15.1%	15.1%
C - Lake	416.8	100 %	100 %
D	295.5	6.4 %	6.4 %
E	2,497.1	9.4 %	9.4 %
Total	**3,713**	**19.8 %**	**20.3 %**



Title:

Mollers Lane, Leopold
Model Catchments and Fraction Impervious

Figure:	Rev:			By:
2-1	A	N 0 0.75 1.5km Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	DR
				Date: Jan 2017

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Title:
Mollers Lane, Leopold
Site Catchment Analysis

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2-2	A	N	0 200 400m Approx. Scale	DR

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2.3 Local Climate

SILO Drill data[2] of rainfall and potential-evapotranspiration were used in this assessment to represent local climatic conditions. The SILO data was used as it provided a continuous time series of daily values for rainfall (Figure 2-3) and potential-evapotranspiration based on the location of the Development Site. The SILO data drill consists entirely of interpolated values from a gridded dataset. As shown in Table 2-2, Mean annual rainfall (MAR) values for BOM sites in the vicinity of the catchment show significant variation. As there was no long-term record at or directly adjacent to the Development Site, the interpolated values provide the most suitable dataset for this study.

The Silo data is considered appropriate for use in this case and the MAR for the data compares satisfactorily with the pattern of surrounding stations holding long-term records. The Avalon airport record MAR could be expected to be lower as it has a shorter record length and the drought years from 1999-2009 have a more significant influence on the mean. Figure 2-3 shows the adopted daily rainfall time-series.

Figure 2-4 shows mean monthly rainfall totals across the time series for the Development Site location.

A daily potential-evapotranspiration time series was used in the water balance modelling. The mean annual evaporation over the silo drill dataset time series (mm) is 949.3 mm/year.

Table 2-2 Comparison of SILO data drill and BOM rainfall

STATION	MAR (mm)	Record Length	Distance from Development Site
Avalon Airport (BOM)	459.8	1971	18 km
Sheoaks (BOM)	495.3	1971 -	34 km
Durdidwarah (BOM)	676.7	1874 -	39 km
Aireys Inlet (BOM)	626.4	1994 -	41 km
SILO data drill	***545.0***	***1889 -***	

[2] SILO Climate Data: https://www.longpaddock.qld.gov.au/silo/

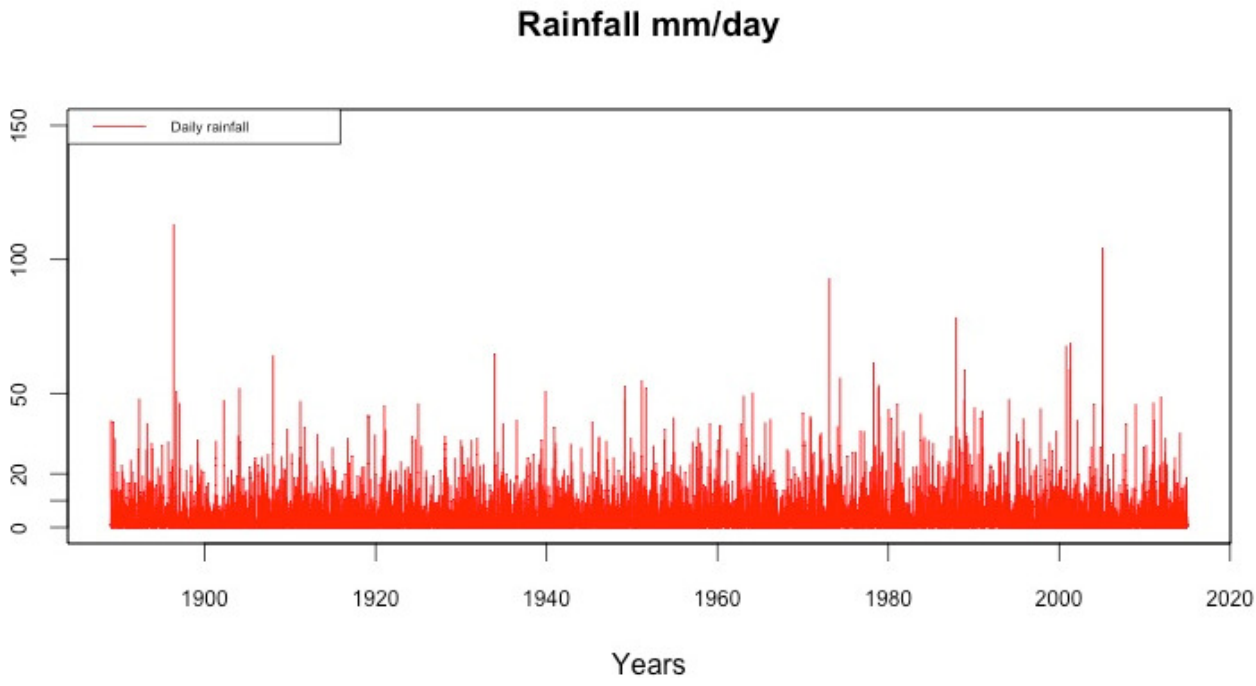

Figure 2-3 - Daily Rainfall Series

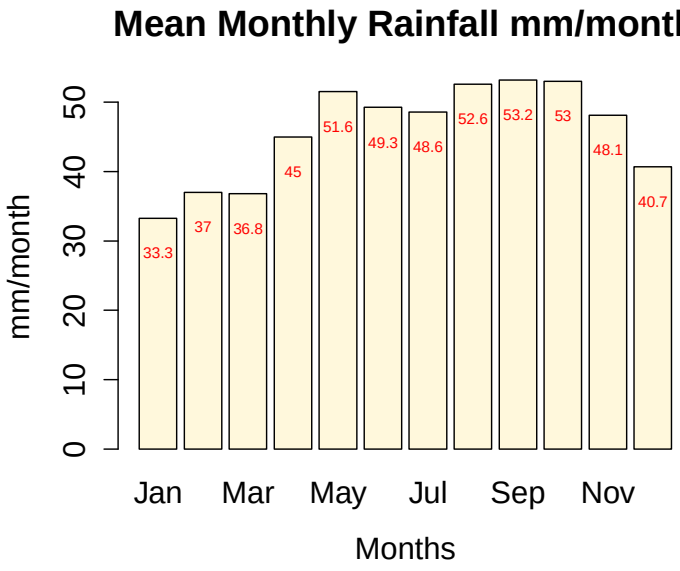

Figure 2-4 - Mean Monthly Rainfall Pattern

3 Ramsar and Environmental Values

3.1 Ramsar Values

The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site is multi-location wetland system which are along western shoreline of Port Philip Bay from Point Cook (an outer suburb of Melbourne) to areas near Geelong, Victoria, Australia. The Ramsar Site comprises six distinct areas that include Point Cook/Cheetham, Werribee/Avalon, Point Wilson/Limeburners Bay, Swan Bay, Mud Islands, and the Lake Connewarre Complex, each with their own unique values (Parks Vic and DSE, 2003).

The part of Ramsar Site which could potentially be affected is a small area and margin of Lake Connewarre. The tidal range within the Lake Connewarre Complex is dampened in amplitude compared to the Barwon River and the Bass Strait, adjacent to the mouth, due to the narrow opening of the Barwon Heads. The Ramsar Site supports a variety of wetland types ranging from shallow marine waters to seasonal freshwater swamps and extensive sewage ponds. Wetland areas include freshwater lakes, estuaries, mangrove, saltmarshes, intertidal mudflats and seagrass beds. This Ramsar Site is a major area in Australia for migratory waders and the most important in Victoria. Large numbers of bird species including Pied Oystercatchers, Banded Stilts, Red-necked Stint, Sharp-tailed Sandpiper, Fairy Tern, Australasian Shoveler, Red-necked Avocets, Blue-billed Duck, and Freckled Duck, have been recorded at the Ramsar Site (Parks Vic and DSE, 2003).

The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site meets four of the nine criteria for Ramsar listing (Parks Victoria and DSE, 2003).

Table 3-1Listing Criteria met by the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site (Parks Victoria and DSE, 2003)

Criterion No.	Description/evidence
Criterion 1	Port Phillip Bay (Western Shoreline) and Bellarine Peninsula includes a range of marine and inland wetlands characteristic of the South East Coastal Plain bioregion as well as artificial wetlands. Within the Ramsar Site there are good examples of saltmarshes, estuarine wetlands and a shallow marine embayment and nearshore areas. A major unique feature of the Ramsar Site is the Mud Islands, which are sand islands that have been formed through the interactions of bird guano and marine waters to anchor the islands in the shifting sands.
Criterion 3	The Ramsar Site is one of the most important sites in Victoria for migratory shorebirds and the Avalon-Werribee Wetlands regularly support tens of thousands of Straw-necked Ibis. Additionally, 137 native plants and 135 bird species have been recorded in the Lake Connewarre State Game Reserve.
Criterion 5	Wetlands in the Ramsar Site regularly support more than 20,000 waterbirds, including large numbers of migratory waders, thousands of Black Swans, ducks, ibis and cormorants. In particular, Lake Connewarre, Reedy Lake and the Water Treatment Plant support significant numbers of waterbirds during the summer months.
Criterion 6	Port Phillip Bay (Western Shoreline) and Bellarine Peninsula regularly supports more than 1% of the known Australian population of fourteen species: Pied Oystercatcher; Grey, Lesser Golden, Mongolian and Double-banded Plovers; Banded Stilt; Red-necked Avocet; Ruddy Turnstone; Eastern Curlew; Greenshank; Marsh, Sharp-tailed and Curlew Sandpipers, and Red-necked Stint.

While the Lake Connewarre Complex is quite important to the ecological character of the Ramsar Site, and the first three of the listing criteria apply to Lake Connewarre in general, the specific habitat found at the receiving environment (Foreshore Site) which is the most important would be the saltmarshes and estuarine wetlands which support international significant numbers of Curlew Sandpipers (*Calidris ferruginea*) and Sharp-tailed Sandpipers (*Calidris acuminata*), which is part of listing criteria 1 and 6 (Parks Vic and DSE, 2003, DotE 2016a, DotE 2016b).

The major values of the Ramsar Site are described by the Strategic Management Plan (Parks Victoria and DSE 2003) of the Ramsar Site and are summarised below. The key environmental values of the broader Port Phillip Bay Ramsar Site are those for which it was listed under the Ramsar program include representativeness, function, rarity, flora and fauna, and waterbirds.

The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site includes areas of all eight wetland types recognised in Victoria and is dominated by two of these wetland types: Permanent Saline and Semi-Permanent Saline wetland types, which are the best represented of the eight wetland types in Lake Connewarre and across the whole Ramsar Site.

The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site maintains the genetic and ecological diversity of the flora and fauna of the region. The Ramsar Site hosts some 579 non-marine flora species, of which at least 335 are native plants. There are some 304 species of fauna and only 19 of which are non-indigenous (Parks Victoria and DSE, 2003). There are two nationally threatened plant species and 22 Victorian threatened species recorded in the Ramsar Site on the DSE Victorian Flora Information System as a whole. In terms of fauna, the Ramsar Site supports 29 species which are listed under the Flora and Fauna Guarantee Act 1988 (Parks Victoria and DSE, 2003).

The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site was designated primarily in recognition of its high value as habitat for waterbirds. The Ramsar Site hosts 36 bird species under JAMBA and 40 species under CAMBA (and a similar number of species listed under the recently recognised ROKAMBA agreement) and is an important drought refuge for a number of species when other lakes and wetlands dry out.

3.2 Foreshore Site Values

The creek which takes flows from the Development Site joins Lake Connewarre about 1.1 km downstream. Prior to discharging to Lake Connewarre the creek enters a large terminal dam on private property (Figure 3-1). Outflow from the dam is via a number of pipes which outlet into a gully which makes its way towards Lake Connewarre. The gully passes through a small area of the Ramsar Site along the foreshore which could potentially be affected by increased runoff from the proposed development. There is no clear gully line across the shoreline to Lake Connewarre and flood modelling (refer Section 4) has shown that water disperse across the shoreline into Lake Connewarre at a number of locations. The modelling has shown that the area of foreshore affected is about 0.6 ha and there is less than 150m of shoreline affected.

This is an area of saltmarshes and estuarine wetlands (samphire, saltbush and lignum vegetation type as well as the sandy shoreline of Lake Connewarre) which potentially affected by the development at the end of small creek system. The Development Site covers about 41ha which is about 9% of the total catchment for this creek (refer Table 2-1); the Development Site is about 1% of the greater catchment draining to the northern section of Lake Connewarre.

The shoreline habitat (most of which is private land) is in poor condition due to grazing, weeds and upstream flow and habitat alterations (Figure 3-2). Rainfall and groundwater flows (and tidal

events) are likely to be the major hydrologic drivers of the system as opposed to stream flows which appear to be captured in multiple large dams in the catchment.

To place this potential impact into a Ramsar Site context, this area (0.6ha) of potential impact comprises two of eight wetlands types in the Ramsar Site. These wetland types are the “Permanent Saline” and “Semi-Permanent Saline” wetland types, which are the best represented of the eight wetland types in Lake Connewarre and across the whole Ramsar Site, making up just over 5000 ha, or 23% of the whole 22,897 ha Ramsar site. Therefore, the potentially affected area is less than 0.01% of these wetland types within the Ramsar Site.

There were no flora or fauna species at all, recorded on the Victorian Biodiversity Atlas in the potentially impacted foreshore zone in the Ramsar Site (VBA Search Jan 2017).

The riparian and littoral habitat of the Lake Connewarre section of the Ramsar Site is known to support international significant numbers of Curlew Sandpipers and Sharp-tailed Sandpipers (Parks Vic and DSE, 2003), although these are not recorded at the Foreshore Site (VBA Search Jan 2017).

Title: Mollers Lane, Leopold
Receiving Environment

Figure:	Rev:			By:	
3-1	A	N 0 25 50m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	DR	
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Figure 3-2 - Habitats and vegetation types in the potentially affected zone of Lake Connewarre shoreline and riparian lands (4th August 2016; L.N. Lloyd)

4 Flows Assessment

The proposed development increase the fraction impervious which will result in increased peak flow rates and runoff volumes. As part of the engineering design of the development, the peak flow rate will be attenuated to match pre-development conditions using stormwater management devices such as retarding basins and wetlands, but these devices are not as effective in managing increase in runoff volume. Therefore, the focus of this assessment is the increase in runoff volume rather than peak flow rates.

Water balance models were created to investigate the change in surface runoff flow volumes between the existing and developed cases. Two separate catchment scales were modelled:

- the greater catchment area feeding the northern extent of Lake Connewarre; and
- the local creek catchment containing the Development Site, feeding an existing farm dam which drains and overflows to Lake Connewarre.

These two different models assess the impact of increased flow volume to Lake Connewarre and to the local creek catchment foreshore, in order to better understand potential impacts on environmental values.

4.1 Methodology

The assessment was carried out according to the following methodology for each of the two catchment scales described above

- a water balance model of the catchment was created to represent:
    - the existing case (previous to any development); and
    - the proposed development case of the Development Site.
- Daily time series of surface runoff flows were taken from the model outputs for further analysis;
- Analysis of flows was carried out on a monthly basis and compared to quantify how changes to the catchment fraction impervious impact on the hydrological regime in terms of magnitude of mean monthly flow volumes.

4.1.1 Water Balance Models

Water balance models of the catchments were created using the MUSIC conceptual modelling software program.

There is no flow data available appropriate for use in calibrating the catchment runoff response in the model and hence the adopted modelling parameters were based on standard parameters typical for catchments of this nature. With this in mind, it is important to note that this assessment focuses on the relative changes in hydrological regime between the scenarios. In order to model absolute flow volumes with greater confidence, further modelling would need to be undertaken with a calibrated model. This will only be possible if flow and level monitoring data for Lake Connewarre catchments becomes available.

4.1.1.1 MUSIC Modelling Parameters

A daily time-step analysis was used over the climate data set of 125 years to calculate the timeseries of flows discharging to Lake Connewarre. The MUSIC models use the recommended

soil property parameter values as set out by the City of Greater Geelong MUSIC Guidelines: Soil Storage Capacity = 30mm, and Field Capacity = 20 mm. The remaining soil parameters were set to the default values.

A MUSIC node representing the Lake water body was created in order to estimate the mean annual volume of water entering the lake through rainfall directly on the lake. This is in line with the modelling philosophy for this study of comparing the change in the surface runoff components of the water balance. The rainfall threshold is set to zero in this case to simulate all rainfall as 'runoff' over the simulated Lake surface area.

The sub-catchment delineation can be seen in Figure 2-1 and Figure 2-2.

GIS analysis was used to calculated the fraction impervious (FI) for both the existing and the ultimate cases as previously described in Section 2.2.

The existing private dam storage is modelled in MUSIC in the smaller scale catchment model for the catchment containing the Development Site. Relationships for dam stage-storage, culvert outlet and weir outlets were deduced from the digital terrain model, survey information and from TUFLOW hydraulic model (see Section 4.1.3) outputs.

4.1.2 Runoff flows

The analysis of the water balance model outputs use the runoff flow timeseries from the catchment. MUSIC allows the separation of baseflow and runoff components of flow from catchment nodes. MUSIC calculates baseflow as a proportion of the volume that enters the soil profile through infiltration into pervious surfaces. The volume of water not lost to evaporation or to deep seepage is modelled as water that passes through the soil profile to the receiving body of water as baseflow, in this case Lake Connewarre, with the excess water expressed as runoff. The runoff timeseries is used for the analysis in both catchment scale models.

This allows the presentation of data with respect to changes in the mean monthly and daily totals for larger runoff events. These aspects of hydrological regime provide insight into wetland wetting/drying cycles, the average size of inundation events, and duration of inundation (indicated by characteristics of larger runoff events such as mean volume of events).

This is considered an appropriate methodology for analysing the changes in hydrologic characteristics of the flow series for this proposed development.

4.1.3 Flow Extent Mapping

The private dam downstream of the development is located approximately 100 metres from the edge of Lake Connewarre. To map the flow extent from the overflow from the dam to Lake Connewarre a hydraulic model of the area was created. The model was developed using the industry standard TUFLOW hydraulic modelling software program. TUFLOW hydraulic models are used where the determination of flow width, depth, height and velocity are considerations.

The model extended from the downstream embankment of the dam to the edge of Lake Connewarre; the dam was included in the model as a storage node. The model was developed with a 1.0m grid resolution with ground levels based on state aerial survey data (LiDAR). Ground surface roughness was set as unmaintained grass (Manning's n roughness of 0.04).

Initial water level conditions in the dam were set to the full supply level (invert of the culverts) which is conservative in this analysis. Water levels in Lake Connewarre were set to mean sea level.

The inflow to the model was based on the mean daily flow determined from the water balance model. Lloyd Environmental requested an analysis of inundation extent of the foreshore for the months of January and September. September 1963 and January 1978 were selected for the analysis as their monthly flows were similar to mean monthly flow for the respective months derived from the water balance model analysis of the 126 year period. Other months could also have been chosen based on the monthly means and so a review of the daily flow means was also undertaken. January 1978 and September 1963 were found to be most comparable to the 126 year mean for daily flows for January and September.

The model was run under both existing and developed conditions.

The daily runoff flow volume from the water balance model could have been input into the model as a daily time series, but this was considered to be unrealistic (non-conservative) for the inundation mapping; the flows would more typically be associated with a storm event rather than a continuous rainfall event across 24 hours.

To convert the daily runoff to storm events the time of concentration was calculated for the catchment down to the farm dam. The time of concentration was estimated at 75 minutes using the VicRoads methodology. It was assumed that inflows returned to zero after 2.5 times the time of concentration. Back calculating from the mean daily flow volume to a 75 minute storm event, the peak flow rate into the farm dam was determined. This calculation was performed for every day within the month, thereby creating a continuous sub-daily time series.

Controlling the rate of outfall from the farm dam are two 450mm diameter culverts (pipes) under the access road. The details of these culverts were supplied by TGM surveyors. These were modelled as imbedded elements in the model and convey the flows from the farm dam to the downstream area where the flow is discharged to the surface and allowed to flow to Lake Connewarre.

4.2 Assessment of Flow Changes to Lake Connewarre

This section describes the comparison of the existing and ultimate cases runoff flow series, at the scale of both the greater catchment to Lake Connewarre and the Development Site catchment.

4.2.1 Annual Runoff Flow Series

In order to gain an initial appreciation of how flows into Lake Connewarre would be affected by urban development, daily runoff time series were generated for both cases. Average annual total flow volumes in ML/year are shown for each case in Table 4-1, averaged across the 126 years of data.

Table 4-1 Average Annual Total Runoff Volumes to Lake Connewarre

	Existing (ML/yr)	Ultimate (ML/yr)
Greater Catchment	5,590	5,650
Catchment containing Development Site	417.4	483.1

The development shows an average annual increase in flow of approximately 60 ML/yr or about a 1% increase in the surface flow runoff to Lake Connewarre. The total runoff volume from the greater catchment also includes rainfall falling directly onto the northern section of Lake Connewarre. The mean annual input from rainfall directly onto the Lake is 2,290 ML/yr, which is

about four times the inflow from the catchment containing the Development Site and contributes about 40% of the total inflow from the greater catchment.

4.2.2 Monthly Flow Series

As has previously been documented in this report the ecological characteristics of the receiving environment are more likely to be affected by changes in the hydrological regime on a monthly and seasonal basis, rather than annual changes. Accordingly the detailed analysis in this chapter is presented at a monthly time scale: daily runoff volumes from the model are aggregated to give total ML/month for each month.

Figure 4-1 and Figure 4-2 show the comparison of the flow timeseries in ML/month for each month, for both the existing and the ultimate scenarios. For these boxplot graphs to follow, note:

- the box extents plotted are the 25% and 75% percentiles;
- the dark horizontal bar in the box is the median value;
- the 'cross-hair' points indicate the 10th and 90th percentile values; and
- the text describes the existing mean and the change in mean monthly flow values for each month.

4.2.2.1 Assessment of Flow Changes to Lake Connewarre – Greater Catchment

Figure 4-1 shows the comparison of the mean monthly 'runoff flow' in ML/month. The figure shows that the mean monthly runoff flow total has a general trend of increase over all seasons. The increase in mean monthly runoff flows ranges from 1 % to 1.4 % with the greatest increase seen between the months of September to December.

The general trend of increased runoff mean monthly totals can be expected due to the increased fraction impervious in the catchment.

4.2.2.2 Assessment of Flow Changes to Local Catchment Foreshore

Figure 4-2 shows the comparison of the mean monthly 'runoff flow' in ML/month. The figure shows that the mean monthly runoff flow total has a general trend of increase over all seasons. The increase in mean monthly runoff flows ranges from 13.2% to 21.8 % with the greatest increase seen between the months of September to December.

The general trend of increased runoff mean monthly totals can be expected due to the increased fraction impervious in the catchment.

4.2.3 Flow Extent Mapping

The change in flood extent is presented in Figure 4-3 and Figure 4-4 for the month of September 1963 and January 1978 respectively. In these figures the lemon colour represents the peak flow extent during the monthly simulation under existing conditions, and the pink shaded areas represent the additional area wetted as a result of the increased runoff from the proposed development.

Depth vs Time plots for three points are presented in Figure 4-5 and Figure 4-6 for the month of September 1963 and January 1978 respectively. The location of these points is shown in Figure 4-3 and Figure 4-4. These plots show a small increase in depth as a result of the proposed development, but no significant change in the duration of inundation.

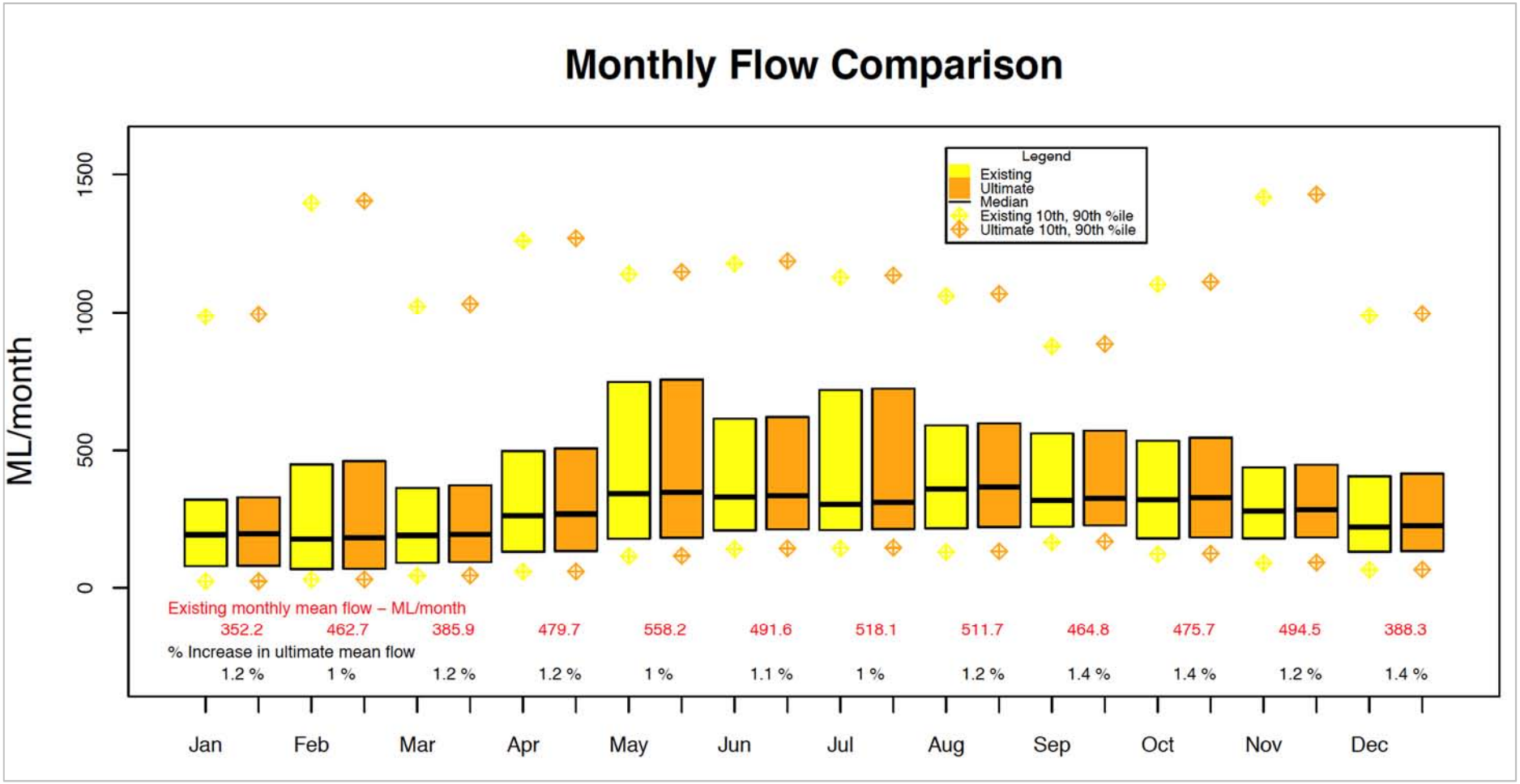


Figure 4-1 - Monthly Runoff flow Comparison – Existing v Ultimate –Lake Connewarre Greater Catchment

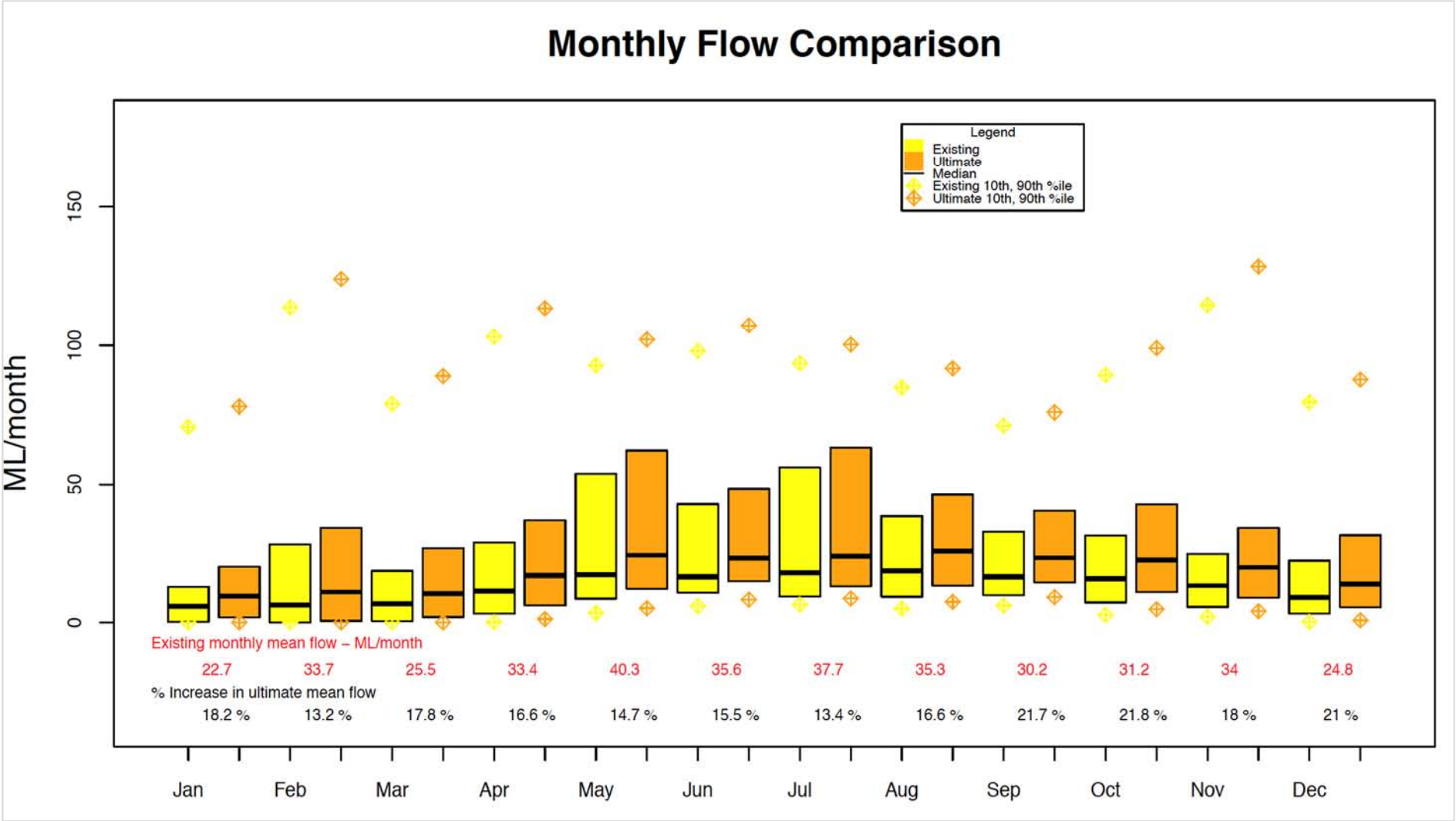
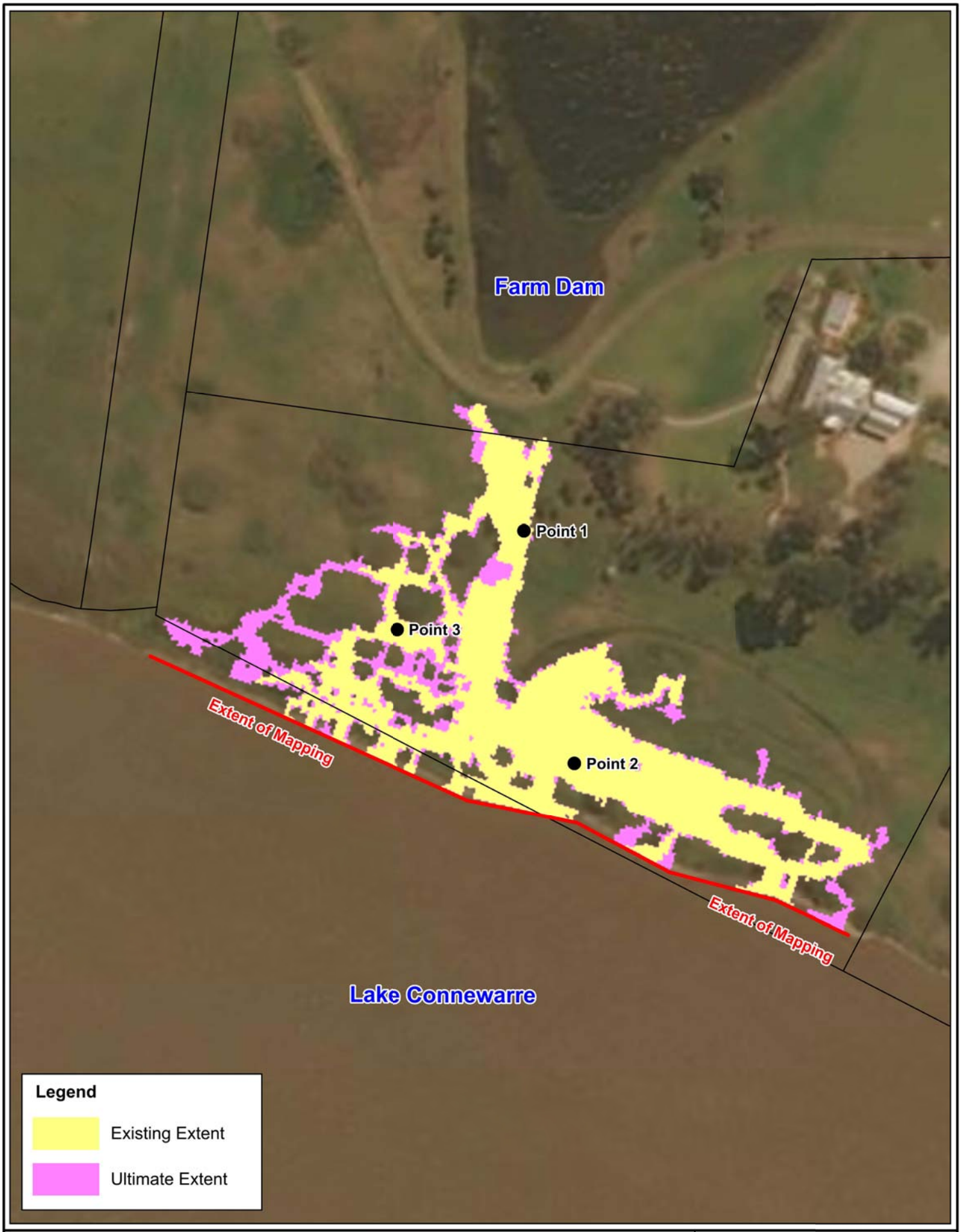


Figure 4-2 - Monthly Runoff flow Comparison – Existing v Ultimate – Local Catchment Foreshore



Title: Mollers Lane, Leopold
September 1963 - Flow Extent Comparison - Existing vs Ultimate

Figure:	Rev:			By:
4-3	A	N 0 25 50m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	DR
				Date: Jan 2017

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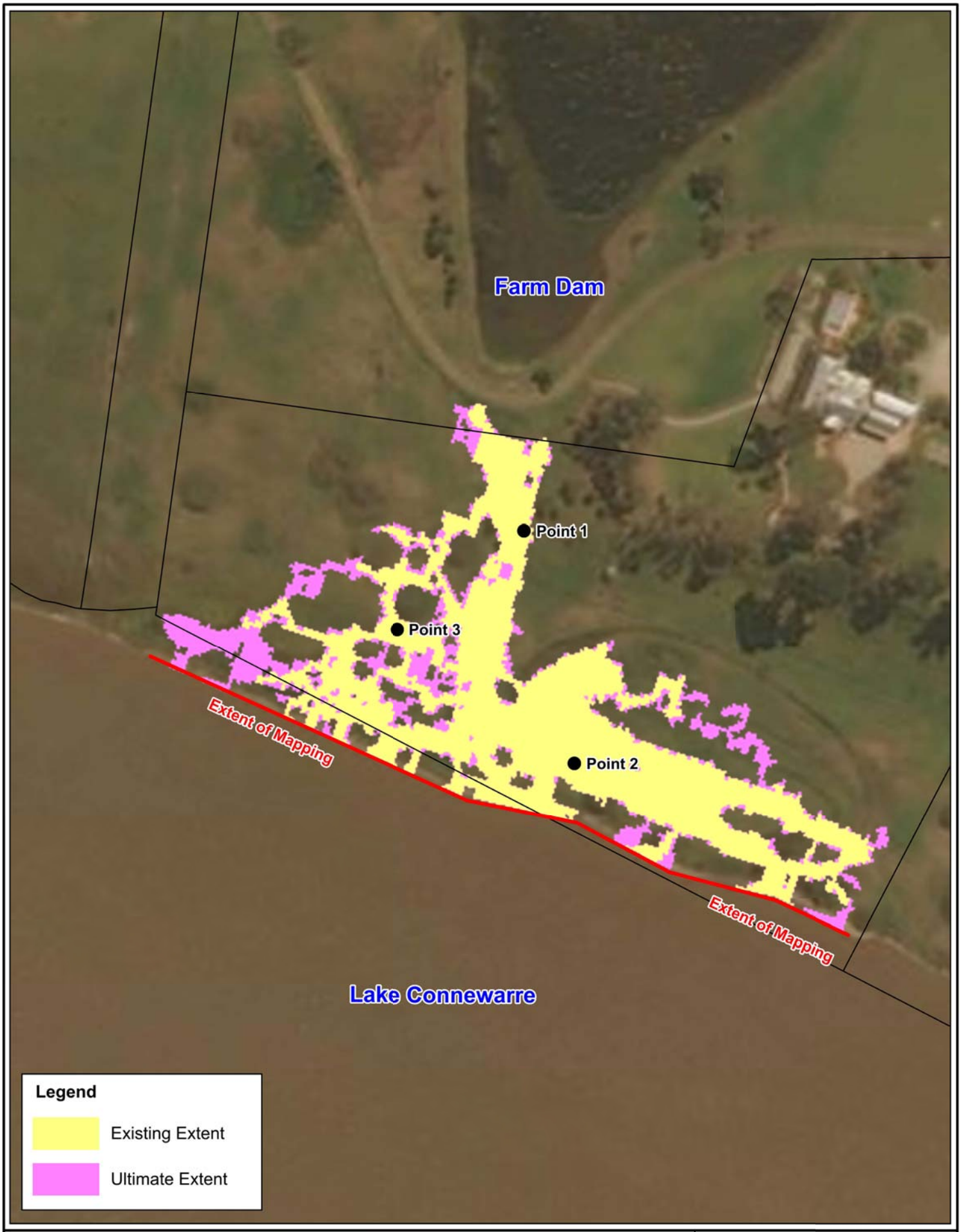
Filepath: D:\Dropbox\M00087.MJ.Mollers Rd EPBC\GIS\Drawings\R.M0087.001.SELGA\Fig4-3_Sep63.WOR



Title:
Mollers Lane, Leopold
January 1978 - Flow Extent Comparison - Existing vs Ultimate

Figure:	Rev:			By:
4-4	A	N 0 25 50m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	DR
				Date: Jan 2017

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Figure 4-5 – September 1963 - Daily Flow Depth Comparison – Existing v Ultimate

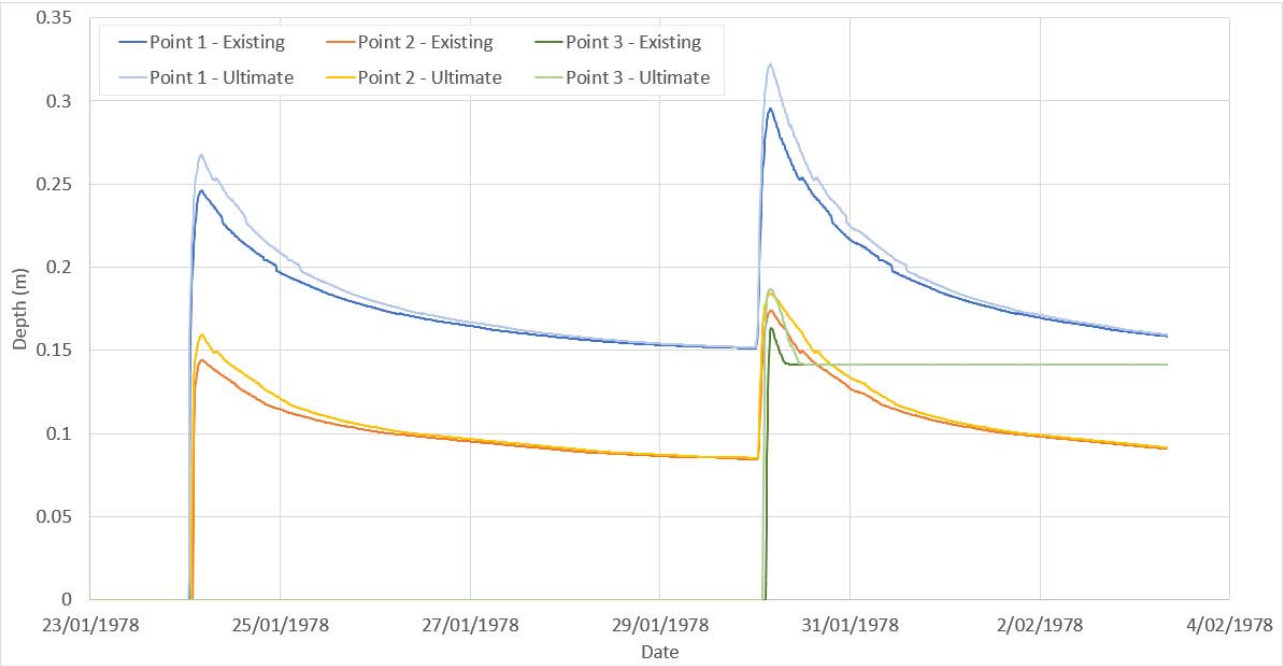

Figure 4-6 – January 1978 - Daily Flow Depth Comparison – Existing v Ultimate

5 Potential Ecosystem Changes

5.1 Lake Connewarre

The modelling shows that there is likely to be a slight increase in flows reaching Lake Connewarre of 1% to 1.4% throughout the year. Further given this is a very small total volume compared to the volume of water Lake Connewarre, it is unlikely to be noticed by any of the ecological components. The effective increases in flows are less than 7 ML/month at most during any month and are minor compared to the flows of ~352-518 ML/month from the catchment itself and almost negligible compared to the overall volumes, tidal exchange and mixing within Lake Connewarre.

Further assessment of the consequences of this development to the foreshore outfall area are discussed below.

5.2 Foreshore Outfall Area

5.2.1 Ramsar and EPBC Act Impacts

The outfall of the creek system into Lake Connewarre potentially affects is about 150m of shoreline and up to only about 0.6ha in total area. The habitats within this zone consist of samphire and lignum swamp with an active shoreline which includes exposed sand and muds and very little aquatic vegetation which receives minimal freshwater flows from the current drainage line but is an active shoreline with sand and sediment movement with waves and tides (that is moving sands and silt make it hard for aquatic vegetation to establish; see Figure 3-2.

The current condition of samphire and lignum swamp is also poor in the potentially affected zone due to clearance, grazing and weeds (as it is private land). The samphire and lignum vegetation community on either side of the potential impact site (foreshore zone) is much more extensive, and in healthier condition. This means the vegetation is already made up of tolerant species and is unlikely to change further with the small flow changes in flow predicted.

The small flow changes are unlikely to lead to significant changes to water quality or geomorphology of the Foreshore Site. That said, nutrient and sediment changes into this section of Lake Connewarre could have localised impacts if not mitigated. However, given the very small area of the Ramsar Site affected, even under extreme changes and whatever the impacts are, there is low risk to Ramsar values.

The international significant birds, Curlew Sandpipers (*Calidris ferruginea*) and Sharp-tailed Sandpipers (*Calidris acuminate*), which are listed for the Ramsar Site (although not specifically recorded at the Foreshore Site – VBA Search Jan 2017), do prefer feeding in the exposed muddy and sandy margins of wetlands particularly those that are regularly inundated and exposed alternately, such as the margin of Lake Connewarre (Parks Vic and DSE, 2003, DotE 2016a, DotE 2016b). This habitat is at low risk of being affected by this development (given it small scale) but mitigation measures such as Water Sensitive Urban Design (WSUD), which will be installed within the development in accordance with the separate stormwater management plan, habitat improvements upstream and creation of wetlands to detain and treat stormwater will ensure no impacts occur to these species or their habitat.

In summary, the EPBC Act (Australian Government 1999) deems a significant action to be one which will have a significant impact on the ecological character of a declared Ramsar wetland if there is a real chance or possibility that it will result in one or more of five criteria. These are listed in Table 5-1.

Table 5-1Criteria for determining of an action is likely to have a significant impact on ecological character (Australian Government 1999)

No.	Criteria for determining of an action is likely to have a significant impact on ecological character	Assessment
1	Area of the wetland being destroyed or substantially modified.	The area of saltmarsh potentially affected by the development is small, about 0.6 hectares. This is in poor ecological condition due to grazing, weeds and upstream alterations. Rainfall and groundwater (baseflows) flows (and tidal events) are likely main hydrologic drivers the system, rather than surface waters.
2	A substantial and measurable change in the hydrological regime of the wetland, for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland.	Modelling shown that the development will cause up to about 20% increase in flows to the Foreshore Site in summer but less in other times of the year (see section 4.2.2.2). This may have some impacts on the Foreshore Site but only over a small area. The modelling shows that the extent of flooding is a small increase in depth as a result of the development upstream, but no significant change in the duration of inundation at the foreshore site (see section 4.2.2.3). Water Sensitive Urban Design (WSUD) will reduce the possible water quality impacts.
3	The habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetland being seriously affected.	The area of saltmarsh potentially affected by the development is small, about 0.6ha. Sandpipers which are listed and important for that part of the Ramsar Site, do prefer feeding in the exposed muddy and sandy margins of wetlands, such as the margin of Lake Connewarre. These species are not recorded at the Foreshore Site however. This habitat is at low risk of being affected by this development (given its scale) but mitigation measure such as WSUD within the development, habitat improvements upstream and creation of wetlands to detain and treat stormwater will ensure no impacts occur to these species or their habitat.
4	A substantial and measurable change in the water quality of the wetland – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland, or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	The small creek system has relatively small inflows 352-518 ML/month compared to Barwon flows of the 10000s ML/month. These inflows are unlikely to affect the whole of Lake Connewarre. Furthermore, the increase in flow is less than 7ML/month. While localised impacts may occur, they will be infrequent and WSUD mitigation measures are likely to reduce these risks.
5	An invasive species that is harmful to the ecological character of the wetland being established (or an existing invasive species being spread) in the wetland.	The development is unlikely to facilitate the establishment of invasive species. In fact, rehabilitation of the Development Site upstream, may reduce risks from invasive species, that could be controlled in rehabilitating the creek environment.

It is unlikely that this development would trigger provisions under the EPBC Act (Australian Government 1999) as the development:

- Only affects a small area of wetland which is unlikely to be substantially modified;
- Does not have a substantial change in the hydrological regime of the wetland, and those changes are unlikely to have a large effect on volumes, durations or extent of flows;
- Only affects a small area of the Foreshore Site and these minor impacts mean that the habitat or lifecycle of native species, will not be seriously affected;
- Is unlikely to affect water quality of Lake Connewarre at all and only potentially affects the water quality of the Foreshore Site in a minor way and WSUD measure will reduce these impacts;
- Will not cause invasive species establishing or expanding at Lake Connewarre or the Foreshore Site.

5.2.2 State Impact Assessment

The Ministerial guidelines for assessment of environmental effect under the Environment Effects Act 1978 (Department of Sustainability and Environment 2006) sets out what might a 'significant effect on the environment' be? The criteria for assessing the potential for a development to cause a significant effect on the environment includes the following:

- significance of the environmental assets affected is influenced by the:
  - character of the potentially affected environmental assets;
  - geographic occurrence of the environmental assets; and
  - values or importance of the assets;
- potential magnitude, extent and duration of adverse effects on environmental assets in the short, medium and longer term; and
- potential for more extended adverse effects in space and time.

These guidelines are assessed on essentially the same criteria as the Ramsar/EPBC requirements as these are the most significant values of the region but other values are considered (Table 5-2).

Table 5-2 Criteria for assessing if a development has a significant Impact on the environment (Department of Sustainability and Environment2006)

Criteria for assessing if a development has a significant Impact on the environment	**Assessment of Moller's Lane Development**	
	Lake Connewarre	Foreshore Site
Significance of the environmental assets affected is influenced by the: o character of the potentially affected environmental assets;	While there are many significant species and habitat in Lake Connewarre, the changes to hydrology are minute. There may	A small area of the foreshore is part of the The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site. Two internationally significant birds, Curlew Sandpipers (*Calidris ferruginea*) and Sharp-tailed Sandpipers (*Calidris acuminate*) are

Criteria for assessing if a development has a significant Impact on the environment	Assessment of Moller's Lane Development	
	Lake Connewarre	Foreshore Site
o geographic occurrence of the environmental assets; and o values or importance of the assets.	be short term and very localised impacts in terms of water quality but these would not see any change to values of importance to the whole lake.	present in the Ramsar Site in habitat similar to the foreshore zone but these species, have not been recorded at the Foreshore Site. The area of saltmarsh potentially impacted is in poor ecological condition due to grazing, weeds and upstream alterations.
Potential magnitude, extent and duration of adverse effects on environmental assets in the short, medium and longer term	The potential changes to Lake Connewarre are so minute they would not be measurable. It is unlikely they will have any impacts in short, medium or the long term.	The area of saltmarsh potentially affected by the development is small, about 0.6 hectares. Flow modelling has shown there could be increases in man monthly flow in the range 13.2% to 21.8 % across the year and with up to about 21% increase in flows in summer (see section 4.2.2.2). This may have some impacts on the Foreshore Site but only over a small area. The modelling shows that the extent of flooding is a small increase in depth and extent as a result of the development upstream, but no significant change in the duration of inundation at the Foreshore Site (see section 4.2.2.3). The small impacts observed will occur over the long term as once the development is built this will permanently convert this area of catchment to an urban catchment.
Potential for more extended adverse effects in space and time	There is no potential for potential impacts to extend in area or over time.	It is not expected that the potential impacted predicted do not have potential for more extended adverse effects in space and time, due the extent of possible impacts and the limited nature of the impacts affecting environmental assets.

It is unlikely that this development would trigger Victoria's EES provisions due to the limited nature of impacts occurring, the low number of significant environmental assets potentially affected and the limited impacts across space.

5.3 Mitigation Options

Impacts to either Lake Connewarre or the Foreshore Site associated with an increase in the volume of runoff caused by the development are considered to negligible and hence mitigation measures are not required.

The development will be conditioned by Council to require compliance with Victorian guidelines for best practice management of water quality. Mitigation of the most of risks identified will occur with good WSUD practice. This risks are all low with changes to hydrology, water quality (mainly nutrients and sediment and invasive species).

WSUD will aim to slow water flows from the estate, hold and treat stormwater using treatment measures such as wetlands, raingardens, and swales. In addition to controlling weeds and pest species with the development and its open spaces, broader habitat rehabilitation upstream, and within the saltmarsh-area, such as habitat enhancement (woody debris and structural elements), upstream water quality and quantity treatment, and native plant revegetation will enhance the habitat elements and reduce risk levels even further.

6 Summary of Impacts

Our assessment shows that while there are potential some changes to a small area of wetland habitat along the Foreshore of Lake Connewarre, this is unlikely to invoke the Matters of National Environmental Significance provisions of the EPBC Act (Australian Government 1999) nor any State EES provisions (DSE 2006).

EPBC Act Provisions

It is unlikely that this development would trigger provisions under the EPBC Act (Australian Government 1999) as the development:

- Only affects a small area of wetland which is unlikely to be substantially modified;
- Does not have a substantial change in the hydrological regime of the wetland, and those changes are unlikely to have and large effect on volumes, durations or extent of flows;
- Only affects a small area of the Foreshore Site and these minor impacts means that the habitat or lifecycle of native species, will not be seriously affected;
- Is unlikely to affect water quality of Lake Connewarre at all and only potentially affects the water quality of the Foreshore Site in a minor way and WSUD measure will reduce these impacts;
- Will not cause invasive species establishing or expanding at Lake Connewarre or the Foreshore Site.

Victoria's EES Provisions

It is unlikely that this development would trigger Victoria's EES provisions due to the limited nature of impacts occurring, the low number of significant environmental assets potentially affected and the limited impacts across space.

Appendix A: Curriculum Vitae

Lance Lloyd, B.Sc., M.Sc.

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Lance Lloyd has **over 30 years** practical experience across SE Australia, and recently in the Pacific Islands, in freshwater, estuarine, coastal and inland environments in ecology and management requirements.

Natural resource management and **habitat conservation** are his passions and he has published widely in **ecology**, water, **wetland management**, and environmental management in scientific papers and management reports. He has substantial expertise and experience in **fish biology**, general **fauna ecology**, and habitat assessment of freshwater, estuarine and coastal ecosystems across SE Australia (Qld, New South Wales, Victoria, Tasmania and South Australia). He currently chairs the Fisheries Victoria "Translocation Evaluation Panel" (which evaluates risks from fish translocations in Victoria) and the Great Australian Bight RAG (Australian Fisheries Management Authority; AFMA), and is a member of two other AFMA committees.

Skills and Expertise

He played a key role in developing **environmental water** concepts and applying these to over 30 rivers, wetlands and estuaries. He has developed widely adopted methodologies for environmental water requirement (EWR) assessments for rivers, wetlands and estuaries for the Victorian and Australian Governments. He was the co-author of FLOWS, the Victorian state-wide guidelines for environmental flow assessments of rivers and contributed to FLOWS Edition 2. He led the development and refinement of EEFAM, the estuary environmental flow assessment methodology for Victoria.

Lance has been an innovator in the **Ramsar** process, having been appointed by the Department of the Environment (then SEWPaC) to a panel for 'The Development and Technical Review of Ramsar Wetland Documentation', working closely with the Department to update and refine the Guidelines for the preparation of Ecological Character Descriptions (ECD), preparation of ECDs and Ramsar Information Sheets (RIS), and reviewing multiple ECDs, RISs and Ramsar Management Plans. Lance has undertaken ecological or environmental studies at each of Victoria's Ramsar sites over the last 24 years.

He led the teams which developed the Riverland Ramsar Site and Floodplain Lower Ringarooma Ramsar Site **Ecological Character Descriptions**. Further, he developed ECDs for Ramsar sites including Lavinia (King Island), Little Waterhouse Lake, Jocks Lagoon, Bool & Hacks Lagoons, Gippsland Lakes and Corner Inlet. In 2013 (and previously), he provided technical advice to DotE on "Limits of Acceptable Change and Notifying Change in Ecological Character of Australian Ramsar Sites (under Article 3.2 of the Ramsar Convention)". In 2013 and 2014, he was an active contributor to the PAGES International Ramsar Conference, contributing to innovations in Ramsar processes and was co-author of a recently accepted journal paper examining "Limits of Acceptable Change in the Riverland Ramsar Site" and he is currently co-authoring a journal paper examining trajectories of change at the Flood Plain Lower Ringarooma Ramsar Site.

In **strategic planning**, Lance has developed skills in evaluating and identifying the management and research needs of clients. He has advised CMAs, water authorities, and the MDBA on management structures to achieve research or on-ground NRM outcomes. Lance's experience has enabled him to provide strategic advice to senior managers on the directions of environmental programs, assessment approaches, research and development needs, risk assessments, and the potential environmental impacts of operations.

A key component of his work has been **stakeholder and community consultation**. Management strategies require commitment from stakeholders to be successful in terms of implementation and local ownership. Consultation includes several levels of involvement, such as: information exchange, stakeholder involvement and stakeholder participation. Having stakeholders participate in decision making and risk assessment is critical to the acceptance of any management plan.

Positions Held

Current:

Principal Ecologist & Director, Lloyd Environmental Pty Ltd (1998 on)

Research Fellow, Federation University Australia (2014 on)

Chair, Translocation Evaluation Panel, Fisheries Victoria, DPI (2004 on)

Chair, Great Australian Bight Resource Assessment Group, AFMA (2013 on)

Member, Great Australian Bight Management Advisory Committee, AFMA (2013 on)

Member, Southern and Eastern Scalefish and Shark Fishery RAG, AFMA (2013 on)

Previous:

Science Advisor, Water Quality Advisory Panel, MDBA (2005 – 2012)

Member, Fisheries Co-Management Council, Victoria (2002-2005)

Member, FRDC Fisheries Research Advisory Board, Victoria (2003-2005)

Rivers Program Co-ordinator, SI & E Program, Consultant to the Murray Darling Basin Commission (1998-2005)

Divisional Manager, Environmental Services Division, WATER ECOscience Pty Ltd (1994-1998)

Principal Scientist, Environmental Assessment Section, State Water Laboratory (1992-1994)

Senior Wetland Ecologist & Team Leader, Floodplain Ecology, Dept of Cons & Envt. (1990-92)

Research Officer, River Murray Laboratory, Uni of Adelaide (1986-1989)

Professional Affiliations

Australian Society of Fish Biology (Member, 1981 on)

Australian Institute of Biology (Member since 1989; President, 2005 on)

Australian Society for Limnology (Life Member, 1981 on)

River Basin Management Society (Life Member, 2015 on; Member, 1990 on; President, 1999-2002)

Education & Qualifications:

Master of Science, University of Adelaide, 1987
Bachelor of Science, University of Adelaide, 1981
MAIBiol [Member, Australian Institute of Biology, 1989]

Further Study:

Repair, Upgrade and Build Personal Computers (VisonFix 2006 & 2007)
Media Training Course, Econnect Communications Pty Ltd (2004)
Project Management Matrix System Workshop (MDBC 2003)
Short Course on Stormwater Management (Monash Uni/CRCCH 1999)
Prince2 Project Management Course (Tanner James - 1998)
Peak Performance Leadership (LBA Consulting - 1998)
Financial Management Skills (APESMA - 1995)
Strategic Marketing Skills (APESMA - 1995)
Project Management (Training Interventions Australia - 1994)
AEAM Computer Model Training Course (DCNR, Melbourne – 1992/1994)
REALM Computer Model Training Course (DWR, Melbourne -1992)

OTHER POSITIONS:

Lead Judge**, World Environment Day Awards, United Nations Association of Victoria, (2005 - 2015)**
Member**, Water Quality & River Health Working Group, MDBC ('92 – '95)**
Member**, WQ Monitoring & Reporting Working Group, DPIE, ('92 – '95)**
Member**, Water Resources Council of South Australia, South Australian Government ('88 – '89)**
Member**, Community Advisory Committee, MDB Ministerial Council ('89 & '90)**
President, **Mount Waverley North Primary School Council (1995–2001; 2004-2009)** and Council Member **(1993-2010)**

Project Experience

Lance has been involved in many strategically important projects in SE Australia for over 30 years. Some examples include:

- Corner Inlet Ramsar Site Ecological Character Description.
- Dealing with inevitable change in ecological character of Ramsar sites.
- Department of the Environment (Commonwealth) Reviewer for Ramsar Wetland Documentation (2009-2011).
- Ecological Character Description for Bool and Hacks Lagoons Ramsar Site.
- Ecological Character Description for Jocks Lagoon Ramsar Site.
- Ecological Character Description for the Flood Plain Lower Ringarooma Ramsar Site.
- Ecological Character Description for the Lavinia Ramsar Site.
- Ecological Character Description for the Little Waterhouse Lake Ramsar Site.
- Ecological Character Description for the Riverland Ramsar Site.
- Ecological Character Descriptions for the Gippsland Lakes Ramsar Site.
- EEFAM, the estuary environmental flow assessment methodology for Victoria (2008-2011)
- Environmental Flow Options for the Hattah Lakes (2005)
- Environmental Water Requirements of the Bass River including a Risk Assessment of the Estuary (2009).
- Flow/ecology relationships and scenarios for the Lower Barwon Wetlands environmental entitlement Project (2011-12).
- Barmah-Millewa Water Management Plan.
- Co-author of FLOWS methodology for EWR determination in rivers in Victoria (2002)
- FLOWS – A Method for Determining Environmental Water Requirements in Victoria.
- Gippsland Lakes Environmental Strategy (2012).
- Gippsland Lakes Environmental Strategy Business Implementation Plan.
- Gunbower Creek Environmental Flows Study.
- Gunbower Forest Flooding Enhancement Projects (multiple 2001 - 2015)
- Gunbower Forest Water Management Options.
- Hattah Lakes Ecological Operations Plan (2012)
- Implications of Environmental Trajectories for Limits of Acceptable Change at the Riverland Ramsar Site, South Australia.
- Integrated Watering Strategy for Mid-Murray Wetlands, including flood characteristics and water management options for Hattah Lakes, Barmah and Gunbower Forests (1990-92)
- Lake Condah Water Restoration Project: Hydrological Feasibility Study (for Glenelg-Hopkins CMA, 2006).
- Lake Condah Weir Fishway Design (DSE; 2008)
- Mallee Floodplain Wetlands Works and Measures Program (2012-2013)
- Mallee SDL Offset Works Risk Assessment Project (2014).
- Priorities for determining the environmental freshwater requirements of estuaries in the Port Phillip and Westernport region.
- Strategic Management Plan for the Kerang Ramsar Wetlands Site.
- Wimmera Terminal Lakes Environmental Flow Determination Project (2004)

Publications

Lance Lloyd has established a substantial publication record with over 150 publications in local and international journals, books and management reports, some examples are below:

Arthington, A.H. & L.N. Lloyd. 1989. Introduced Poeciliids in Australia and New Zealand. In: Meffe, G.K. & K.F. Snelson (Eds). *Ecology and Evolution of Livebearing Fishes (Poeciliidae).* Prentice Hall, New Jersey, USA.

Boulton, A.J. & L.N. Lloyd. 1991. Aquatic macroinvertebrate assemblages in floodplain habitats of the lower River Murray. Regulated Rivers, 6: 183-201.

Boulton, A.J. & L.N. Lloyd. 1992. Flooding frequency and invertebrate assemblages emerging from floodplain sediments at Chowilla, lower River Murray, SA. *Regulated Rivers 7*: 137-151.

Bunn, S.E., P.I.Boon, M.A.Brock, N.J.Schofield, J.W.Bennett, J.A.Davis, C.M.Finlayson, R.H.Froend, R.Hall, L.N.Lloyd ,G.Lukacs, S.Moore ,M.McDonald, D.S.Mitchell, R.G.Pearson, J.Roberts and K.Schlusser. (1997). *National Wetlands R&D Program Scoping Review*. Land and Water Resources R&D Corporation Occasional Paper 01/97.

Cooling, M. L. Lloyd, D. Rudd & R. Hogan. (2002). Environmental Water Requirements and Management Options in Gunbower Forest, Victoria. Aust. J. Water Resources 5 (1): 75-88.

Lloyd, L. and Newall, P. (2009). Translocation risk assessment for Devilbend and Bittern Reservoirs for stocking select recreational fish species. Lloyd Environmental, for Fisheries Victoria, DPI Victoria.

Lloyd, L.N. & J.F. Tomasov. 1985. Taxonomic status of the mosquitofish. *Gambusia affinis* (Poeciliidae), in Australia. *Aust. J. Mar. Freshw. Res. 36*: 447-51.

Lloyd, L.N. & K.F. Walker. 1986. The distribution and conservation status of small fish in the River Murray in S.A. *Trans. Roy. Soc. S.A. 110*(2):49-57.

Lloyd, L.N. & Walker, K.F. 1989. Management of snags (woody debris) and river and floodplain vegetation for native fish in the Murray-Darling River System. In: Lawrence, B. (Ed.) 1989. Proc. of the Native Fish Management Workshop. Murray-Darling Basin Commission, Canberra, Australia.

Lloyd, L.N. 1986. An alternative to insect control by "mosquitofish*", Gambusia affinis*. In: St. George, T.D., B.H. Kay & J. Blok, *Arbovirus Research In Australia*. Proceeding of the 4th Australian Arbovirus Symposium, Brisbane. 1986.

Lloyd, L.N. 1990. Ecological interactions of *Gambusia holbrooki* with Australian native fish. In: Pollard, D.A. ASFB *Workshop on introduced and translocated fishes and their ecological effects*. Bureau of Rural Resources Proceedings No. 8, AGPS, Canberra.

Lloyd, L.N. 1990. Fish Communities. In: O'Malley, C. & F. Sheldon. *Chowilla Floodplain Biological Study*. Nature Conservation Society of South Australia, Adelaide, SA.

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Shirley, M., B. Abernethy, P. Close, L. Lloyd, R. Nathan, G. Quinn & B. Zampatti. (2002). A method for determining environmental water requirements in Victoria. Report to DNRE Melb., Vic.

Dr Mark Jempson

Director

Qualifications and Accreditations

PhD in Civil Engineering, Hydraulics, University of Queensland.

Master of Engineering Science, University of Queensland.

Bachelor of Civil Engineering, Queensland University of Technology

Member, Engineers Australia

Chartered Professional Engineer (CPEng)

National Professional Engineers Register (NPER)

Registered Professional Engineer of Queensland, Civil (RPEQ)

Past Chair, Engineers Australia Victorian Water Engineering Branch

Summary

Mark has twenty-eight years industry experience in hydrological, hydraulic and multidisciplinary environmental investigations, construction and bridge design. Mark has worked in both the government and private sectors; 10 and 18 years respectively.

Mark is recognised as one of Australia's leading experts in flood and stormwater modelling, floodplain management and road and bridge hydraulics. He has undertaken studies across Victoria, Queensland, New South Wales, Tasmania, South Australia and the UK involving hydrologic and hydrodynamic modelling and flood management of estuaries, rivers and floodplains, water quality investigations and environmental assessments.

Mark is regularly called on as a peer reviewer and expert witness by government agencies and the private sector in QLD, NSW and Victoria. Mark has excellent communication skills, honed from many years of community consultation, and is able to effectively communicate complex flooding issues and analysis techniques to those without a technical background.

Mark's PhD research topic was *Flood and Debris Loads on Bridges*. Mark was the author of the hydrodynamic and debris load chapters in the Australian Bridge Design Standard.

Mark has hands-on experience in many of the key hydrologic and hydraulic modelling packages including XP-RAFTS, RORB, WBNM, URBS, HEC-RAS, TUFLOW, and MIKEFLOOD / MIKE21 / MIKE11.

Employment History

Current:	Venant Solutions, Director and Founder, Melbourne
2003 – 2013:	BMT WBM Water & Environment Business Unit Manager, Melbourne
1999 – 2002:	BMT WBM Senior Engineer, Brisbane
1988 – 1998:	QLD Department of Main Roads

Areas of Expertise

- Hydrodynamic modelling (1D and 2D)
- Flood hydrology
- Urban and rural flood modelling and mapping
- Floodplain Management
- Expert Witness/Peer Review
- Road and Bridge Hydraulics - author of flood and debris loads in Australian Bridge Design Standard
- Stormwater Quality and Quantity Management
- GIS Mapping

Contact Details

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E: mark.jempson@venantsolutions.com.au

Postal: PO Box 877, Macleod, VIC 3085

Key flood management experience

Rural flood and floodplain management studies

These projects typically required the development of a survey brief, hydrologic modelling, two-dimensional hydraulic modelling, hydraulic and economic assessments of structural and non-structural floodplain management options, review of flood warning systems, community and stakeholder consultation, sedimentation assessments, and preparation of floodplain management plans. Following is a list of project in which Mark has been involved either as project manager, project director or technical reviewer.

- Herbert River Flood and Floodplain Management Study (Qld)
- Johnstone River Flood and Floodplain Management Study (Qld)
- River Tamar and North Esk River Flood Study (Tas)
- Mt William Creek Flood Investigation (Vic)
- Upper Wimmera Flood Investigation (Vic)
- Macalister River Flood Study – Stage 1 (Vic)
- Bacchus Marsh Flood and Floodplain Management Study (Vic)
- Yarriambiack Creek Flood Investigation (Vic)
- Lower Kiewa River Flood and Floodplain Management Study (Vic)
- Casterton Flood Intelligence and Warning Improvement Study (Vic)
- Glenelg River Sand Management Hydraulic Modelling Study (Vic)

Urban flood mapping

These studies involve the development of detailed hydrologic and 1D/2D hydraulic models to establish existing flood characteristics, and to provide input into economic and flood damages assessments. Some studies required the assessment of mitigation options and benefit-cost analyses. Clients include Melbourne Water, City of Greater Geelong and City of Greater Dandenong. This list of projects undertaken includes the Western Treatment Plant, Shakespeare Grove and Byron Street Main Drains, Sweetwater Creek, Kilsyth and Bungalook Main Drains, Barwon Heads, Bridge Street and Western Gully, Port Arlington, and Dandenong CBD.

Herbert River Levee Management Study

There has been a significant change in flooding patterns on the Herbert River floodplain since the 1960's as a result of construction of levees by landholders. The construction of the levees, or the expansion of existing levees, continues as landholders respond to increased flooding on their properties. The Herbert River Improvement Trust recognises the need to control future growth of levees if a disaster is to be avoided. This study used flood modelling of future hypothetical levee construction to demonstrate the future impact on flooding. Consultation with landholders and stakeholders was then undertaken to kick start an on-going and long-term education process.

Melbourne Water Development Services Schemes

These projects involve hydrologic, hydraulic and water quality modelling and the preparation of a development services strategy. Functional design of stormwater management measures such as retarding basins and bio-retention systems were undertaken. Quantities and costs of works are determined as input into Melbourne Water's Development charges. Projects undertaken include Central Creek, New Gisborne, Romsey, Riddells Creek, Loch and Nyora.

Impacts of Pontoons and Jetties on Flooding on the Coomera and Nerang Rivers

The Gold Coast City Council was concerned that the on-going construction of pontoons and jetties on the Nerang and Coomera Rivers may impact of flood levels. The Computational Fluid Dynamics (CFD) software Fluent was used to assess the near field effects of the pontoons and jetties. Data obtained from the CFD analysis was used to inform the far-field 2D modelling undertaken using TUFLOW.

Insurance Assessments

Mark worked on hydrology reports for insurance companies following the Victorian floods in 2012 and the Queensland flood in 2013.

Key road and bridge drainage assessments

These studies involved the development of detailed hydrologic and hydraulic models to assist in route selection and the establishment of the road grade and bridge and culvert requirements to meet flood serviceability requirements such as flood impact and time of closure. Bridge scour assessments are sometimes required. Recent major projects include:

- Bruce Highway Upgrade, Haughton River, Preliminary Evaluation Study (Qld)
- Bruce Highway Upgrade, Ingham to Cardwell Range Planning Study (Qld)

- Bruce Highway Upgrade, Frances and Cattle Creeks - Link Study, Business Case and Detailed Design phase
- Bruce Highway Upgrade – Larsens Street to Lannercost Street (Qld)
- Gold Coast Intra-Regional Transport Corridor (Qld)
- Western Highway Duplication – Carpenter Road to Box's Track (Vic)
- Springvale Road - Railway level crossing removal (Vic)

During Mark's 10 years at the QLD Department of Main Roads he spent 8 years working in the flood group undertaking flood assessments on bridge and road project across most parts of Queensland.

Key land development projects

Planning system requirements associated with developing on a floodplain can be complex with regards to flood and stormwater management. Mark has worked for both developers and approval authorities (review and technical advisor role) on many complex development proposals in both Victoria and Queensland from concept through to detailed design and as an expert witness in planning submissions and appeals. A selection of these projects includes:

- Queens Wharf Brisbane (Qld)
- Grand Lakes (Vic)
- Seabank Estate (Vic) – winner of the 2007 UDIA award for WSUD
- Manzeene Avenue (Vic)
- Gold Coast Convention Centre (Qld)
- Pacific View Estate (Qld)
- Gold Coast International Marine Precinct (Qld)

The Queens Wharf Development is a multi-billion dollar redevelopment of the north bank of the Brisbane River in the CBD. The project is a State initiative and Mark worked as a Technical Advisor (flooding) to the State through the 18 month procurement process. This included the preparation of tender documentation, development of a TUFLOW model for use by the Proponents during tendering, assisting with Proponent questions during tendering, technical review of tenders, advising the State on planning matters.

Key environmental modelling projects

River Tamar Estuary Modelling Study

Mark was the Project Manager responsible for the development of a calibrated tidal hydrodynamic, water quality and cohesive sediment transport model of the Tamar River estuary for the Launceston City Council. The modelling was performed using the RMA10S and RMA11 software packages. Cohesive sediment transport and siltation modelling was an important focus of this study which seeks to develop a tool for modelling the ongoing siltation problem within the upper Tamar estuary and for predicting the flood scour which is likely to occur. The model was also used to assess the impact of changes to the Council's wastewater treatment system on the water quality of the Estuary.

Gold Coast International Marine Precinct EIS

An expansion to the marine precinct on the Coomera River is proposed. It is deemed to be a project of state significance by the State. The precinct is in an environmentally sensitive and flood prone area. Mark was responsible for the following assessments: flood and tidal; receiving water quality; sediment accumulation; dredge plume dispersion; sediment impacts on aquatic ecology. The assessments were undertaken on a range of modelling packages including a TUFLOW FV for tide, advection dispersion model (dredge plume dispersion), and sediment accumulation. MIKE21 was used for the flood assessment.

Woollooman Creek Weir

The impact of a proposed weir in combination with an in-stream sand extraction operation on the sediment transport processes within the Creek were assessed. Long-term sediment transport processes, catchment yield and sediment capacity were assessed. Recommendations were developed for mitigating the impacts.

Maroochy River Eutrophication Modelling

The effects on sewage discharges on receiving water quality and estuarine ecological health and proposed plant augmentations were assessed using MIKE11. The eutrophication model investigated nutrient cycling, growth of phytoplankton and zooplankton as well.

Construction and bridge design experience

During his time at QLD Department of Main Roads, Mark spent nearly two years working in road construction and bridge design.

Key peer review experience

Inquiry into Flood Mitigation Infrastructure in Victoria, Parliament of Victoria

Following the Victorian floods of 2010 and of 2011, the Victorian Government established a parliamentary enquiry into flood mitigation

infrastructure in Victoria. Mark was the technical adviser for the enquiry report.

Hawkesbury-Nepean Valley Flood Management Strategy

Infrastructure NSW is proposing a significant investment in a range of flood management strategies for the Hawkesbury-Nepean Valley. The NSW State Government requires that the strategic business case for the next phase of the scheme be independently reviewed to satisfy the requirements of its Gateway Review Process. Mark was a member of the Gateway peer review panel established by NSW Treasury.

Brisbane River Pedestrian Riverwalk, Peer Review

The Riverwalk pedestrian bridge on the Brisbane River was washed away during the 2011 floods. To minimise the risk of a future failure, the Brisbane City Council's consultant undertook 3D hydrodynamic modelling to determine flow velocities and physical modelling to determine flood force coefficients; the coefficients were required to establish the flood loads.

Mark's PhD research was in flood and debris loads on bridge structures, and so the Council engaged Mark to review the physical modelling and derivation of the force coefficients.

Flemington Racecourse Flood Wall

The Victorian Racing Club proposed the construction of a flood wall around the Flemington Racecourse to reduce the risk of the Melbourne Cup being affected by flooding. Concerns were raised as to the effects of the flood wall on existing developments along the Maribyrnong River floodplain. The City of Melbourne, Moonee Valley City Council and Maribyrnong City Council engaged Mark to complete an independent peer review of the modelling, proposal and mitigation works.

Brisbane Airport Link and Busways, Peer Review of Hydraulic Modelling

The Airport Link and Busways project in Brisbane required the construction of a complex array of bridges/overpasses over Breakfast Creek at Herston. This resulted in a large number of piers in creek and floodplain. With a large number of flood prone houses upstream, it was important that the modelling reliably estimated the impacts of the piers and that appropriate mitigation was implemented. Brisbane City Council engaged Mark to peer review the modelling undertaken by the Proponents' consultants.

Salacia Waters Marina Development, Gold Coast, Qld

Mark undertook an independent peer review of modelling and associated impacts of a proposed marina at Salacia Waters development. The review was done in order to assist in resolving a dispute between Council and the proponent with regards to the representation in the model of hydraulic losses around the marina structures.

Florina Gardens Development, Gold Coast

The Florina Gardens development on the Gold Coast is located on the Nerang River floodplain. Gold Coast City Council engaged Mark to complete a peer review of the hydraulic modelling done by the proponent and an assessment against the planning scheme.

Key expert witness experience

Mark regularly prepares expert witness statements for both government and private sector clients in relation to flooding and Stormwater matters. The list below is a mix of VCAT and Planning Panel work in Victoria, Planning & Environment Court in Queensland and Land and Environment Court in NSW.

- Ibbotson St Development, St Leonards, VIC
- Mills Crescent Development at Port Fairy, VIC
- Implementation of Special Building Overlay into planning scheme, City of Greater Geelong
- Masters Development at Corio, VIC
- Development at San Remo, VIC
- Halcyon Waters, Gold Coast, QLD
- Masters Development at Corio, VIC
- Eastern Golf Course at Yering, VIC
- St Patricks School, Macksville, NSW
- Claremont Street, South Yarra, VIC
- Great Ocean Green, Apollo Bay, VIC
- Grand Lakes Development at Lara, VIC
- Caddys Road Rezoning at Lara, VIC
- Manzeene Ave Development at Lara, VIC
- Subdivision at Metung, VIC
- Subdivision at Aireys Inlet, VIC
- Flooding appeal at Gardiner Rd Hawthorn
- Sheehan & Berry appeal, Gold Coast, QLD
- Dunns Creek Road Dromana, VIC
- Development at Walcourm Court, Launceston, TAS
- Pizzolato Development, Innisfail, QLD
- Celledoni Development, Innisfail QLD
- Barwon Heads Road Development, VIC

Articles, papers and presentations

Jempson, M.A. and Apelt, C.J. (1992), Hydrodynamic forces on partially and fully submerged bridge superstructures, *Proc. 16th ARRB Conference, 9-12 November, Perth, Australia, v3, pp67-82.*

Jempson, M.A. (1994), Hydrodynamic forces on partially and fully submerged bridge superstructures, *Master of Engineering Science Thesis, The University of Queensland*

Jempson, M.A. and Apelt, C.J. (1995), Flood loads on bridge superstructures, *Proc. Bridges into the 21st Century, 2-5 October 1995, Hong Kong*, pp.1025-1032. (Hong Kong Institution of Engineers).

Jempson, M.A. and Apelt, C.J. (1997), Debris loadings on bridge superstructures and piers, *Proc. Bridging the Millennia, AUSTROADS 1997 Bridge Conference, 3-5 December, Sydney, Australia, v2, pp3-17.*

Jempson, M.A. and Apelt, C.J. (1997), Flood loads on submerged and semi-submerged bridge superstructures, *Proc. Bridging the Millennia, AUSTROADS 1997 Bridge Conference, 3-5 December, Sydney, Australia, v2, pp19-33.*

Penfold, P.S and Jempson, M.A. (1997), New Survey Requirements for Bridge Sites, *Proc. Mining in the Third Millennium, 10th ISM and 23 IESMA Conference, 3-6 November 1997, Perth, Australia.*

Jempson, M.A. (1998), Oakey Bypass and La Niña - Mutually Exclusive Events? *Main Roads Department Southern Symposium, October 1998, Roma.*

Jempson, M.A. (2000), Flood and Debris Loads on Bridges, *Institution of Engineers Australia, Technical Seminar, March 2000, Brisbane.*

Jempson, M.A. (2000), Flood and Debris Loads on Bridges, *PhD Thesis, The University of Queensland*

Neilsen, C.F, Barton, C.L., Jempson, M.A. (2001), The Application of Three Dimensional Finite Element Modelling to Flood Flows in a River Channel *6th Conference on Hydraulics in Civil Engineering, Hobart, Tas, 2001.*

Jempson, M.A. and Alam, K. (2003), Flood risk management and community consultation – A Queensland perspective, *43rd NSW Floodplain Management Conference, Forbes.*

Jempson, M.A., Maxwell, N.D., Apelt, C.J. (2004), Application of CFD Modelling to Free Surface Flow Around Bluff Bodies – A Case Study Using a Bridge Superstructure, 8th National Conference on Hydraulics In Water Engineering, Gold Coast, Australia, July 2004.

Gillam, P, Jempson, M.A., Rogencamp, G.J., (2005), The importance of combined 2D/1D modelling of complex floodplains – Tatura Case Study, *4th Victorian Floodplain Management Conference*, Shepparton, Victoria, 2005

Jempson, M.A., Rogencamp, G.J., (2006), The Application and Benefits of 2D/1D Flood Modelling in Urban Developments, 1st *Association of Land Development Engineers Conference*, Gold Coast, Queensland, August 2006

Caddis, B.M, Jempson, M.A, Syme, W.J. and Ball, J.E. (2008) *Incorporating Hydrology into 2D Hydraulic Models – The Direct Rainfall Approach.* Proceedings of Hydraulics in Water Engineering Conference, Darwin, Australia

Leister, J.G. and Jempson, M.A. (2010), *Backwater Effects of Piers and Abutments in a 2D Hydraulic Model*, Victorian Floodplain Managers Conference, Bendigo, November 2010

Leister, J.G. & Jempson, M.A., (2011), *Backwater Effects of Bridge Piers and Abutments in 2D – Replication of Physical Model Tests in a 2D Hydrodynamic Model*, 34th International Association of Hydraulic Research (IAHR) World Congress, Brisbane, Australia, June 2011.

Jempson, M.J., Leach, B. and Trotter, D., (2011), *A review of the implementation of floodplain management plans on the Herbert and Johnstone Rivers in North Queensland Australia*, 5th International Conference on Flood Management, Tokyo, Japan, September 2011

Jempson, M.J., Leach, B. and Trotter, D., (2013), *On the implementation of floodplain management plans on the Herbert and Johnstone Rivers*, IAHS Publication No. 357 (2013), ISBN 978-1-907161-35-3

Jempson, M.J., South, M.E., and Kim, Y.J., (2014), *The influence of localised upwelling at a bridge on overtopping and road closure: a case study using vertical 2D CFD and horizontal 2D flood models*, 5th International Symposium on Hydraulic Structures, Brisbane, June 2014.

Jane McArthur

Senior Engineer

Qualifications and Accreditations

First Class Honours in Civil Engineering, Hydraulics, University of Tasmania.

Bachelor of Civil Engineering, University of Tasmania

Summary

Jane has 13 years experience as a Civil engineer, specialising in hydraulics and hydrology for the past 8 years. She has excellent verbal and written communication skills and works with integrity and creativity, to ensure high quality solutions.

Her experience is principally in the areas of Integrated Urban Water Management encompassing options analysis, Stormwater Management Planning, hydrological assessment and catchment analysis, flood studies, and urban drainage. Her skill base includes the many facets of integrated stormwater management planning, including project and client management, technical modelling skills across a range of software's, hydraulic design of Water Sensitive Urban Design (WSUD) systems, urban flood detention, and data analysis.

She is currently working as a contractor, on a number of projects regarding statistical analysis of hydrological characteristics (such as frequency analysis and seasonal trends), flood mitigation and stormwater quality improvement options assessments. She was previously employed at BMT WBM on projects of this nature – most recently working with Councils to develop SMPs, to improve management frameworks and enable a pro-active, integrated approach to stormwater management. She was initially enlisted at BMT WBM in her capacity as a hydrologist/hydraulic engineer as part of the testing and development team working on the eWater software product, Urban Developer.

She commenced her career with Hydro Tasmania and pitt&sherry, developing her modelling and management skills, on projects concerning mini-hydro, climate risk to infrastructure, and coastal risk from storm surge and rising sea level.

Jane has experience in the following hydrologic and hydraulic modelling packages: MUSIC, SOURCE IMS, DRAINS, RORB, Urban Developer, HEC-RAS, and the statistical analysis package, R.

Employment History

Current:	Contractor to Venant Solutions
	Contractor to the Bureau of Meteorology (Water Information Services team)
	Contractor to BMT WBM
2010 – 2014:	BMT WBM Project Engineer, Water & Environment team, Melbourne
2004 – 2010:	Pitt&Sherry, Project Engineer
2002 - 2004:	Hydro Tasmania

Areas of Expertise

- Catchment Analysis and modelling
- Hydrological Analysis
- WSUD hydraulic design
- Concept design and Options Assessments for IUWM solutions
- Stormwater Quality and Quantity Management Planning
- Integrated Urban Water Management
- Project Management
- Data analysis and statistical assessments

Key Integrated Urban Water Management experience

- Flood mitigation and water quality improvement options assessment, Victoria Barracks (2015)
- Regional Stormwater Management Strategy Development, NRM North (2013/14)
- WSUD Implementation Decision Support Tool (2013)
- Analysis and Optimisation Water Tank Assessment OEH (2013)
- City of Greater Bendigo Urban Stormwater Management Plan (2012)
- Sorell Council (Tasmania) Stormwater Management Plan (2011)

Key Hydrological Assessments

- Armstrong Creek water balance modelling to understand the impacts of urbanisation on long term hydrological inputs to the Hospital Swamps wetland (2016)
- Peak flow frequency analysis and seasonal hydrological assessment for 'Take & Use' license, BMT WBM (2015)
- Decision Support Tool development – climatic assessment and tool development, NRM North (2013)

Water Sensitive Urban Design/Options Analysis

- WSUD Implementation Decision Support Tool (2013)
- Melbourne Water PSP, Kalkallo Wetland conceptual design (2012)
- WSUD for Kingston Bypass, Tasmania (2009)
- WSUD for Brighton Bypass and Transport Hub, Tasmania (2008)
- WSUD for the DHHS Community Housing Project, Chigwell, Tasmania (2008)
- WSUD and storm water harvest and re-use design, Scamander Sanctuary (2007)
- WSUD and storm water harvest and re-use design for SOLIS Greg Norman golf course, Orford (2007)
- Dilston Bypass WSUD assessment (2007)
- Bass Highway WSUD (2006)
- Mitre 10 Bicheno, WSUD design (2006)
- Cygnet subdivision WSUD assessment (2005)
- Water re-use assessment, Royal Botanical Gardens, Hobart (2005)

Integrated Water Management Software Development experience

- Urban Developer eWater Development team member (2010-2012)
- SourceIMS software Development team (2011)

Key hydraulic design experience

- Independent Hydrology Assessment of the Gippsland flood events for IAG (2012)
- Drainage design for Kingston Bypass, Tasmania (2009)
- Drainage design for Brighton Bypass and Transport Hub, Tasmania (2008)
- Flood mitigation for the DHHS Community Housing Project, Chigwell, Tasmania (2008)
- Drainage and storm water harvest and re-use design, Scamander Sanctuary (2007)
- Storm water harvest and re-use hydraulic design for SOLIS Greg Norman golf course, Orford (2007)
- Dilston Bypass drainage design and flood modelling (2007)
- Bass Highway drainage design and flood modelling (2006)
- Mitre 10 Bicheno drainage design (2006)
- Sorrell Council Urban drainage planning (2006–2009)

Expert advice/Peer Review experience

- Independent Hydrology Assessment of the Gippsland flood events for IAG (2012)

Key Climate Change/Coastal Impact Assessment experience

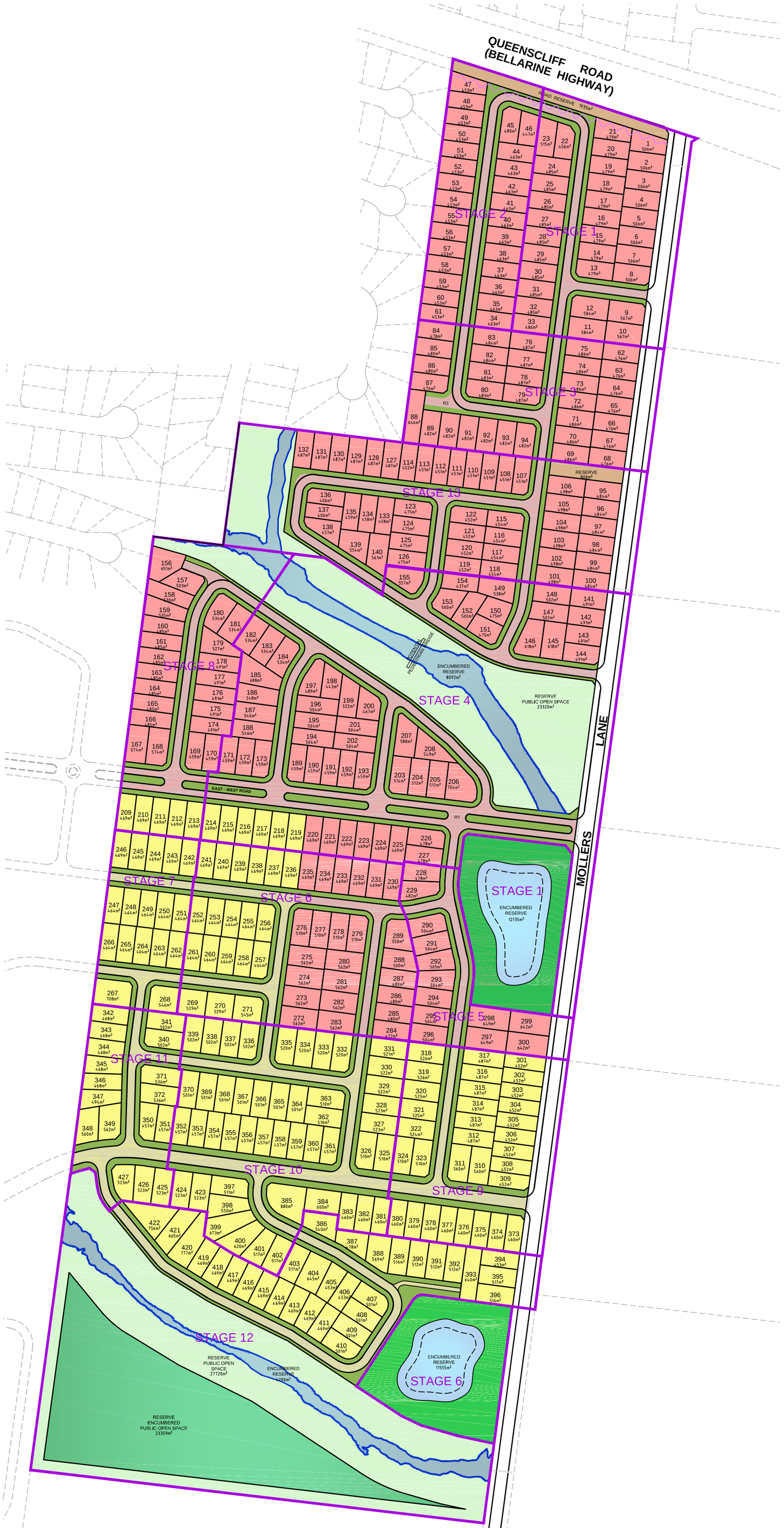
- St Georges Bay flood assessment (2009)
- Tranmere residential coastal impact assessment due to sea level rise and storm surge (2009)
- DPIW coastal risk assessment and management template development team (2008)
- Climate Futures for Infrastructure, development team (a software package which combines high resolution climate predictions for Tasmania with a management tool for civil infrastructure (2008)

Articles, papers and presentations

McArthur, J., Developing a Catchment WSUD Strategy – SMP and Decision Support Tool, (NRM North Regional Stormwater Management Strategy and WSUD DST), 2013, WSUD Conference, Melbourne.

Rand et.al. *Climate Change Impacts on George River Floodplain, St Helens, North East Tasmania* Practical Responses to Climate Change National Conference 2010, Melbourne.

Appendix B: Overall Development Plan



DEVELOPMENT ANALYSIS

TOTAL SITE AREA	**41.02 ha**
ENCUMBERED RESERVES	3.607 ha
ENCUMBERED OPEN SPACE	2.336 ha
ROAD RESERVE	0.194 ha
TELSTRA RESERVE	0.080 ha
TOTAL	**6.217 ha**
TOTAL DEVELOPABLE AREA	**34.80 ha**
PUBLIC OPEN SPACE (UNENCUMBERED)	5.104 ha (12.4%)
TOTAL LOTS (APPROX.)	427
LOTS PER DEVELOPABLE HA	12.3

Rev.	Revision	Date
-	-	-

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DEVELOPMENT FEATURES

STAGE BOUNDARY

STAGED PLAN OF SUBDIVISION

MOLLERS LANE, LEOPOLD

MOLLERS LANE DEVELOPMENTS PTY. LTD. & PAMAS PTY. LTD.

Job Number: 15196-100
Sheet: 1 of 1
Date of Survey: - -

Date of Issue 11/10/2016

SCALE 1:2000
20 0 20 40 60 80 100
LENGTHS ARE IN METRES

At Size A1

Survey: -- **Drawn:** J.S. **Checked:** R.D.

DWG: **ODP REV.10** **VERSION:** **1**