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Attachment 1

Western Adelaide Region Climate Change Adaption Plan

Coastal and Inundation Modelling Phase 3 Report

City of Charles Sturt

City of Port Adelaide Enfield

City of West Torrens

February 2018

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Document History and Status

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Executive Summary

Background

The Western Adelaide Region Councils together with the SA Coast Protection Board, SA Department of Environment, Water and Natural Resources (DEWNR) and South Australian Fire and Emergency Services Commission (SAFECOM) have developed a regional Climate Change Adaptation Plan for the western suburbs of Adelaide. As a part of this study, Tonkin Consulting have been commissioned to undertake modelling of the impacts of climate change on tidal and storm water flooding around the most vulnerable coastal locations in the Western Region.

The investigation has been undertaken in three stages. Stage 1 of the project involved a scoping investigation to identify key assets at highest risk of inundation as a result of climate change. Stage 2 involved a definition of modelling requirements to assess this risk and Stage 3 (this current Stage) involved modelling of the coastal systems and identification of potential adaptation options to mitigate the adverse impacts of climate change on coastal flooding.

Systems Examined

There are many drainage systems discharging to the coast within the Study Area. The scoping investigations carried out in Stage 1 identified many of these as being at low risk of impact due to rising sea level due to:

- Land within their catchments being high enough above the anticipated rises in sea level so as to be largely unaffected by any increase; and
- Catchments already being served by stormwater pumping stations and therefore being unaffected by rises in sea level.

Catchments meeting the above criteria were excluded from further analysis.

In addition, catchments on the Lefevre Peninsula were excluded from analysis as these systems were being investigated as part of the Lefevre Peninsula Stormwater Management Plan (Southfront, 2016).

Following this initial analysis, three key coastal stormwater systems were identified as being most vulnerable to the impacts of rising sea level. These were:

- The *Gillman* Basin System, as it is currently low lying and high tides can prevent the discharge of stormwater.
- The *West Lakes* System, as it is low lying and is similar to the Gillman system in that high tides can prevent the outflow of stormwater. West Lakes also relies on tidal flushing and a rise in sea level will have significant impacts on day-to-day flushing flows through of the lake.
- The *Patawalonga* System, as it has a large upstream catchment, a tidally affected outfall and is surrounded by low lying land.

In addition to the above, modelling of flooding within three low lying catchments along the Gulf St Vincent coast has been undertaken, these catchments being at:

- Gilmore Road
- Henley Beach Road
- Iluka Place

Modelling of Impact of Sea Level Rise on Average Water Levels

For the Gillman, West Lakes and Patawalonga systems, the modelling initially involved an examination of the impacts of sea level rise on the day to day operation of these systems. A continuous simulation of water levels was undertaken using historical data on tide, rainfall, evaporation and runoff for the period from 1971 to1991 for the Gillman and West Lakes systems. This period was chosen as it precedes the baseline year from which current predictions of sea level rise have been based. For the Patawalonga, the period from 1995 to 2005 was chosen for the baseline analysis due to missing data within the period 1971 to 1991.

The simulations were run using the USEPA SWMM model. The results from the simulations were used to establish a baseline average water level in the various systems.

The simulations were then re-run assuming sea level rises of 300, 500 and 1000 mm, in conjunction with anticipated increases in runoff due to future development. The results from these simulations were used to assess the likely change in average water level in the various systems.

The modelling showed that the average level of the Gillman and West Lakes systems would exhibit a rise as a result of increasing sea level, but that the Patawalonga (which currently operates at a higher level than these other systems) would be able to be maintained at its existing level. The modelling also showed that with increasing sea level, flushing of West Lakes would become more difficult under its current gravity operation, and under a sea level rise of 1 m, flushing would rarely occur.

Modelling of Storm – Tide Interaction

All of the catchments examined in this investigation are low lying and exhibit a potential for interaction between tides and floods. This interaction was modelled using the TUFLOW hydrodynamic flood model to determine the likely changes in 100 year ARI flood levels brought about by sea level rise.

For Gillman and West Lakes, a tide cycle corresponding to the Mean High Water Springs tide (MHWS) tide was chosen to be modelled in combination with the occurrence of a 100 year ARI flood event. Such a combination provides a balance between the probability of a flood and the probability of a high tide occurring at the same time.

At the Patawalonga, the most severe flooding in a 100 year event is expected to result from a 100 year ARI tide, in combination with some rainfall. For the purposes of the modelling a 1 yr ARI rainfall event was selected to occur in conjunction with this tide.

For flood modelling of the selected local catchments both of the above event combinations were modelled as it was unclear which would be critical.

For all of the flood modelling, current sea levels and rises of 300, 500 and 1000 mm were considered. The modelling of increased sea levels was undertaken in conjunction with inflows that were adjusted to account for the effects of increasing future rainfall intensity and development. Initial water levels in the various flood storages were based on increases predicted by the earlier SWMM modelling.

Floodplain maps showing the extent of flooding for each of the scenarios examined are contained in the Appendicies to the report. Broadly, the modelling has shown that:

- At Gillman, flood levels in a 100 year ARI event are expected to rise by approximately 150 mm above existing levels with 1 m of sea level rise.
- At West Lakes, flood levels in a 100 year ARI event are expected to rise by 0.84 m with 1 m of sea level rise. While such a rise is significant, the lower increases in flood level produced by sea level rises of up to 500 mm are contained to the current Lake.

- Areas surrounding The Patawlonga (but outside the Western Region) have the potential to be significantly impacted by flooding as a result of sea level rise during events having a combination of high tide and some inflow. Increased areas of flooding within the Western Region brought about by sea level rise are largely contained to undeveloped land.
- The impacts of sea level rise on flooding of the three local catchments examined in this investigation are relatively minor.

Adaptation Options

A number of possible options to mitigate the impacts of sea level rise have been identified. These are outlined below and have been broadly categorised under the headings of protection, planning and monitoring. The approximate timing and trigger points for these actions has also been identified.

City of Port Adelaide Enfield

- *Protection* – Magazine Creek tidal gate upgrade to mitigate increased water levels in Gillman basins: 2020-2025 (structural assessment), 2050 – 2070 (gate replacement)
- *Protection* – Port Adelaide Sea Wall construction: 2025-2030 (physical construction)
- *Planning* – Gillman development planning for recommended development extents, building floor levels and gate upgrades: timeframe depends on land development
- *Planning* – Control of floor levels for new development in low lying areas of Rosewater to allow for sea level rise impacts: ongoing
- *Planning* – Port Adelaide Sea Wall to protect properties from sea surges: 2020-2025 (funding arrangements finalized, planning and commencement of design / construction)
- *Planning* – Continued stormwater flood modelling to keep flood maps up to date with current climate change predictions and undertake critical asset vulnerability analysis: (ongoing)
- *Monitoring* – Monitoring of inflows to the Gillman system by monitoring flows in Eastern Parade and Hanson Road to gauge the impact of ongoing development: ongoing
- *Monitoring* – Gillman infrastructure within basin system observed to be deteriorating and needs ongoing checking and maintenance: 2020 – 2025 (initial assessment and ongoing)

City of Charles Sturt

- *Protection* – West Lakes tidal gate upgrade to mitigate increased water levels in West Lakes: 2050 – 2070 (gate replacement for flood mitigation purposes)
- *Protection* – West Lakes pump installation to mitigate decrease in flushing in West Lakes: 2020 – 2025 (further water quality studies which will form basis for future planning)
- *Protection* – Port Adelaide Sea Wall Construction: 2025-2030 (physical construction)
- *Planning* – Continued stormwater flood modelling to keep flood maps up to date with current climate change predictions and undertake critical asset vulnerability analysis: (ongoing)
- *Monitoring* – Monitoring of inflows to West Lakes at Port Road and Trimmer Parade to gauge the impact of ongoing development: ongoing

- *Monitoring* – It should be ensured that West Lakes water quality monitoring and recording is undertaken to provide planning data: 2020 – 2025 (initial assessment and ongoing)

City of West Torrens

- *Planning* – Areas within Adelaide Airport land in the vicinity of Patawalonga Creek will become more susceptible to flooding with future increases in sea level. Development of this land should consider this potential increase in flooding: 2020 – 2025 (planning)
- *Planning* – Some small areas of Adelaide Airport land (Morphettville Precinct) will become more susceptible to flooding with future increases in sea level. Development of this land should consider this potential increase in flooding: 2020 – 2025 (planning)
- *Planning* – Continued stormwater flood modelling to keep flood maps up to date with current climate change predictions and undertake critical asset vulnerability analysis: (ongoing)
- *Monitoring* – Accurate recording of major Patawalonga inflows from major catchments should be undertaken for future planning: 2020 – 2025 (initial assessment and ongoing)

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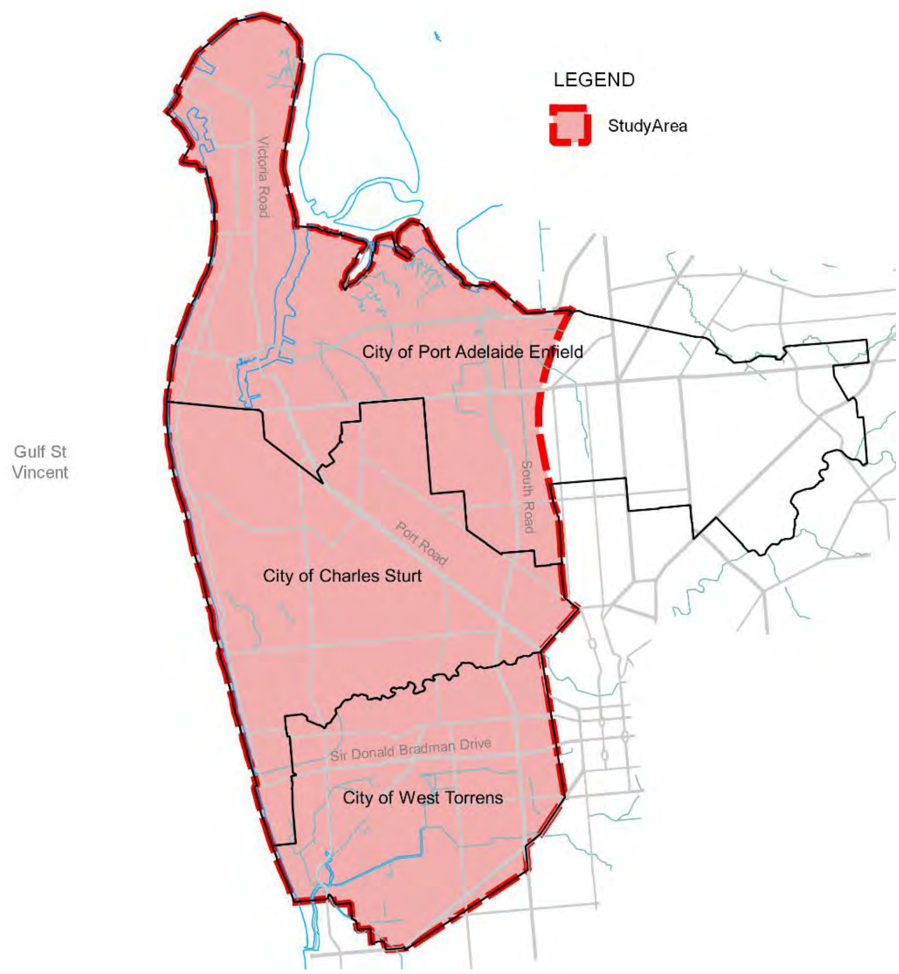
1 Introduction

The Western Adelaide Region Councils together with the SA Coast Protection Board, SA Department of Environment, Water and Natural Resources (DEWNR) and South Australian Fire and Emergency Services Commission (SAFECOM) have completed an Integrated Vulnerability Assessment (IVA) for the Western Adelaide Region. The Study Area adopted for the assessment is shown in below.

Figure 1.1 Study Area



The key output from the IVA was the development of a Regional Climate Change Adaptation Plan (URPS, 2016).

A key element of the overall project has been the development of high resolution inundation mapping due to sea water and storm water flooding within the area, based on climate change projections for the region. The aim has been to use these results to assess, at a high level, potential climate change mitigation strategies from an engineering perspective. The modelling for adaptation options considered in this report aligns to some of the adaption options considered in the following AdaptWest Report chapters:

- Chapter 4.2 Business and industry
- Chapter 4.4 Estuarine waters

- Chapter 4.7 Public coastal built assets
- Chapter 4.8 Stormwater management infrastructure
- Chapter 4.11 West Lakes

The modelling and mapping component of the project has been undertaken in three Phases.

The first Phase of the project has involved collating existing sea water and storm water flooding information relating to the Study Area, assessing this data and defining any gaps in information. The modelling required to fill the identified information gaps was also identified in this first Phase of the project.

The second Phase of the project involved the development of a detailed specification of the required modelling identified in Phase 1.

This report forms the output from the third Phase and contains:

- Reporting on the modelling process
- Results from the modelling process
- Identification of potential adaptation options

2 Objective and Scope of Work

2.1 Objective

The objective of the investigation has been to quantify the impact of climate change on sea water and stormwater flooding in potentially sensitive coastal catchments. Once these impacts were quantified, potential mitigation options have been considered.

2.2 Scope of Work

Reporting from Stage 2 of this study (Tonkin, 2015c) highlighted three main coastal systems which could potentially be susceptible to climate change impacts on stormwater / sea water interactions. These included:

- Magazine Creek / Range / Gillman System
- West Lakes System
- Patawalonga System

Continuous simulations have been run to determine the long-term average water levels for each of the three systems. This modelling was undertaken using SWMM. The aim of the modelling was to determine the impact of climate change on the average water level in each system. Determination of these average water levels is important as they define the likely water level in these systems at the start of a flood event. An increase in average water level brought about as a result of rising sea level will reduce the storage available for capturing storm water in the event that a flood coincides with a high tide.

Flood modelling of each system was then undertaken using TUFLOW. This modelling considered the interaction of a flood occurring during a high tide cycle.

The need to model other key catchments within the western area of Adelaide was considered in Stage 1 of this study (Tonkin, 2015b). Modelling of these catchments was not undertaken for the reasons outlined in this previous report. These catchments included the Torrens River Catchment, Coastal Catchments (including LeFevre Peninsula) and the Barker Inlet Wetland Catchment.

Floodplain modelling has also been undertaken as part of this current Study to determine the potential impacts of climate change on the ability of three local low lying catchments to discharge stormwater with rising sea level. These catchments included:

- Gilmore Road
- Henley Beach Road
- Iluka Place

This current study also involved manual extension of existing tidal inundation mapping for the Port Adelaide Seawater Flooding Study into the City Charles Sturt.

The outputs derived from the above investigations have been used to identify potential adaptation options.

3 SWMM Modelling

3.1 Background

Modelling has been undertaken to assess the impact of rising sea levels on the average pool level in the ponding systems at Gillman, West Lakes and the Patawalonga. An increase in average pool level will result in a reduction in available flood storage in these systems which in turn could impact on upstream flooding.

The modelling was undertaken by carry out a continuous simulation of water levels in the three systems using the USEPA SWMM model. This model has the capability to undertake the type of analysis required for these systems having modules to determine catchment runoff (based on rainfall, soil type and imperviousness), storage behaviour (based on a given height – volume relationship), evaporation, outflows through a hydraulic structure and a hydraulic analysis engine that is capable of routing flows through a tidal gate structure. The model has further capabilities associated with pump modelling as well as complex operating rules for gates and other structures.

The following tasks were undertaken as part of the modelling:

- Preparing the models including compilation of data such as catchment runoff parameters, rainfall time series data, evaporation time series data, tide level time series and data describing the hydraulic characteristics of the gates and storages.
- Running the model for the existing tide regime to establish a base line water level series in the various basin systems (nominally for the period 1971 to 1991); and
- Re-running the model for sea level rises of 300 mm (current CPB policy), 500 mm (possible 2070 level), and 1000 mm (possible 2100 level) to determine the water level regime in the ponding basins with these increased levels.

The data used in the modelling, the modelling process and model results are described below.

3.2 Tidal Data

3.2.1 Background

Modelling of outflows from the Gillman and West Lakes systems utilized tidal data for the Port River. The Gillman and West Lakes systems discharge to the Port River through flap gates. Flow to the River is driven by the water level difference between the River and the upstream flood storage, with the flap gates preventing any tidal backflow into the flood storage. The gates have been modelled within SWMM using the Port River tidal time series as the downstream water level boundary for determining the hydraulics of the outlets. Flap gates were placed at each outlet in the model to prevent tidal back flow.

Modelling of inflows to the West Lakes system and the Patawalonga utilized Gulf St Vincent tidal data. Flow into West Lakes is driven by tide levels in Gulf St Vincent and controlled by tidal gates which allow water into the southern end of West Lakes at high tide. This water flows south to north through West Lakes and out into the Port River through another set of tide gates.

Runoff discharge and tidal flushing within the Patawalonga system is determined by tide levels in Gulf St Vincent at either the Barcoo Outlet or the Glenelg Gates.

Recorded tidal data for the period 1971 to 1991 has been chosen for the Gillman and West Lakes modelling as this period immediately precedes the baseline year (1991) against which sea level rise is currently being reported. However, the tidal data for the Patawalonga modelling was chosen from 1993 to 2005, due to a lack of quality data (creek inflows) in the earlier time period.

The tidal data for the Port River was chosen from the Port Adelaide Inner Harbour Gauge as this is the best available data to reflect water levels at the Gillman and West Lakes outlets. The tide levels in Gulf St Vincent closely correlate to Outer Harbour tide levels which have been used in modelling sea levels at the West Lakes inlet and the Patawalonga system. The tidal data was provided at hourly intervals which provides sufficient resolution to undertake the continuous simulation.

3.2.2 Data conversion to AHD

Data provided for the period before 2001 was recorded in Old Harbour Datum. This data required conversion to the Australia Height Datum (AHD) by subtracting 1.723m from the measured water levels.

3.2.3 Missing Data

The Inner Harbour tidal data set contained a total of approximately 150 days of missing data over the 20-year analysis period from 1971 to 1991. If the Outer Harbour tidal data set contained measured tide levels correlating to the missing data, this data was adjusted as described below and inserted into the Inner Harbour tidal data set. If there was no data measured by either the Inner Harbour Gauge or the Outer Harbour Gauge, data from surrounding days was filled into the gap to complete the record. The case where there was no data across both gauges occurred within under 0.5% of the record, and hence the approximation of tide levels to fill these gaps is likely to have minimal impact on the overall results.

The Outer Harbour data set contained approximately 135 days of missing data over the period between 1971 and 2005. Missing data was filled using the same process as outlined above for the Inner Harbour tidal data set.

In order to determine the relationship between Outer Harbour and Inner Harbour tide levels, (for use in patching missing data) fourteen years of correlating data was chosen where both Inner and Outer Harbour Data existed. Part of this data is plotted in Figure 3.1.

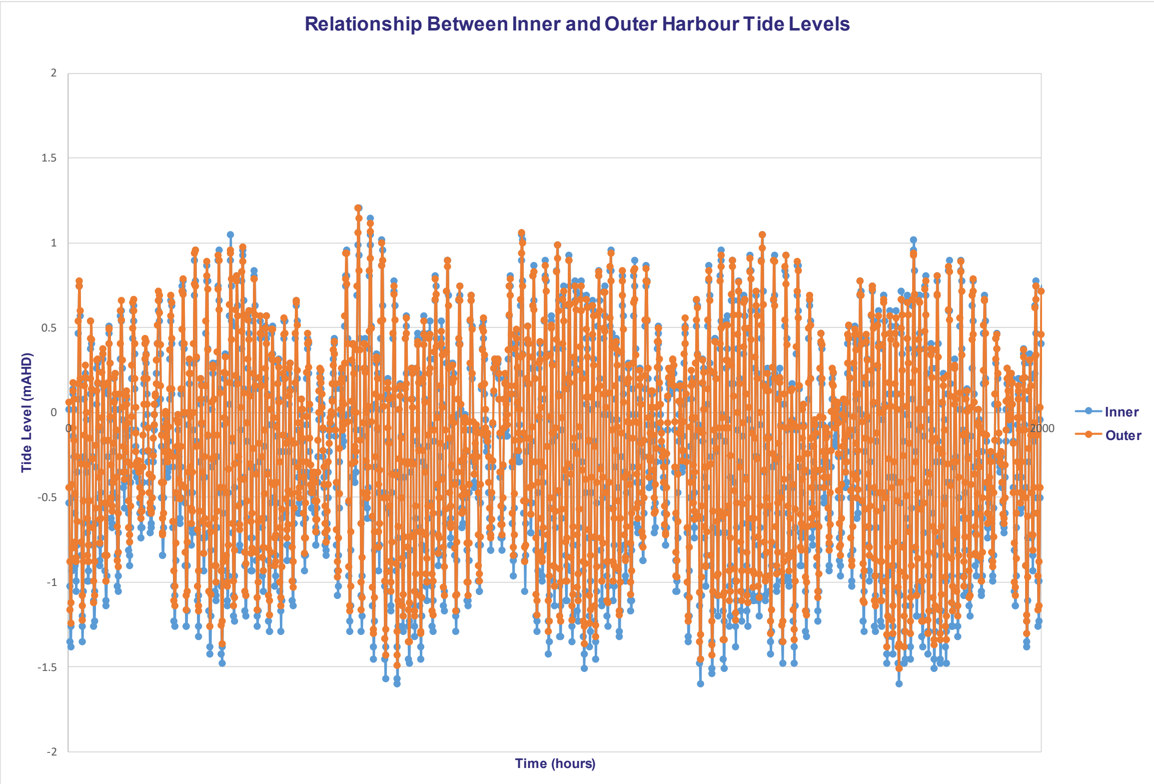


Figure 3.1 Time Series of Inner and Outer Harbour Tides

Figure 3.1 indicates a relationship where Inner Harbour tides are slightly lower than Outer Harbour tides at low tide and Inner Harbour tides are slightly higher than Outer Harbour tides at high tide. A plot of the Inner and Outer Harbour tide levels against each other is provided in Figure 3.2 below.

A line of best fit was plotted through the data. This gave the following relationship:

$Inner\ Harbour\ Tide\ Level = 1.06\ Outer\ Harbour\ Tide\ Levels + 0.0091$ (all levels in metres).

This equation was then used to adjust Outer Harbour tides to Inner Harbour tides in the case where there was no Inner Harbour tide data or to adjust Inner Harbour tides to Outer Harbour tides in the case where there was no Outer Harbour tide data.

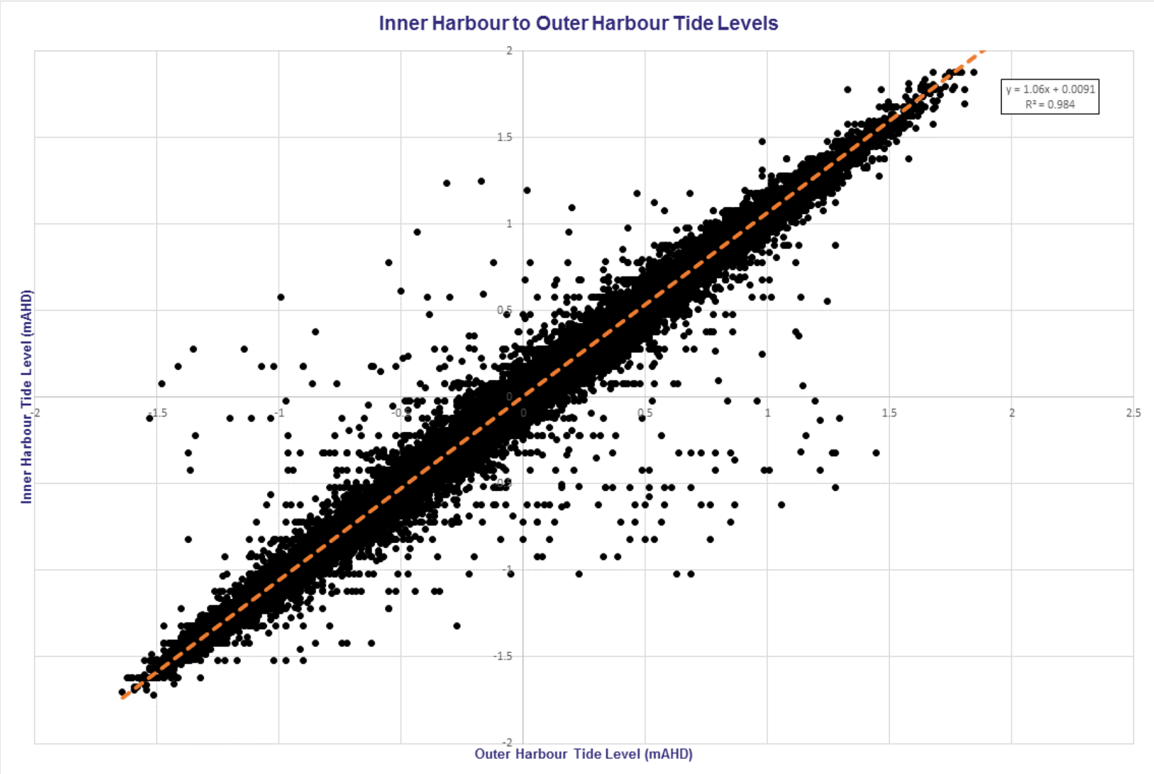


Figure 3.2 Relationship between Inner and Outer Harbour Tides

3.2.4 Final Data Processing

The final tidal data was exported to a text file with the formatting required for a SWMM time series import. This tidal data was also duplicated and modified to reflect sea level rises of 300 mm, 500 mm and 1000 mm as required by the scenarios chosen.

3.3 Rainfall Data

3.3.1 Background

Rainfall data from the Bureau of Meteorology Adelaide Airport pluviograph was chosen as the base for continuous modelling of runoff from the Western Adelaide Region catchments. This was because it contained a long-term quality record of 6 minute rainfall data for the base modelling period of 1971 to 2005, and is the closest pluviograph to the area.

While sea level rise associated with climate change was modelled in the SWMM runs, no change in rainfall has been modelled.

Climate change modelling has suggested the peak rainfall intensities will increase in the future and average rainfall will generally decrease. The continuous simulations being run in SWMM examine the impact of long term average water levels in the various storages, which are more likely to be impact by average rainfall rather than peak intensities. The modelling of no increase in rainfall is therefore considered to be a conservative assumption.

3.3.2 Gillman Rainfall Adjustment

Due to the spatial variation of average rainfall across Adelaide, the rainfall measured at Adelaide Airport has been factored to match the likely rainfall over the Gillman catchment. This was undertaken by comparing average annual rainfall totals for Adelaide Airport with annual totals for stations in close proximity to the Gillman catchment.

There are four daily read rainfall gauges in the immediate vicinity of the catchment. The approximate location of each gauge is shown in Figure 3.3 below.

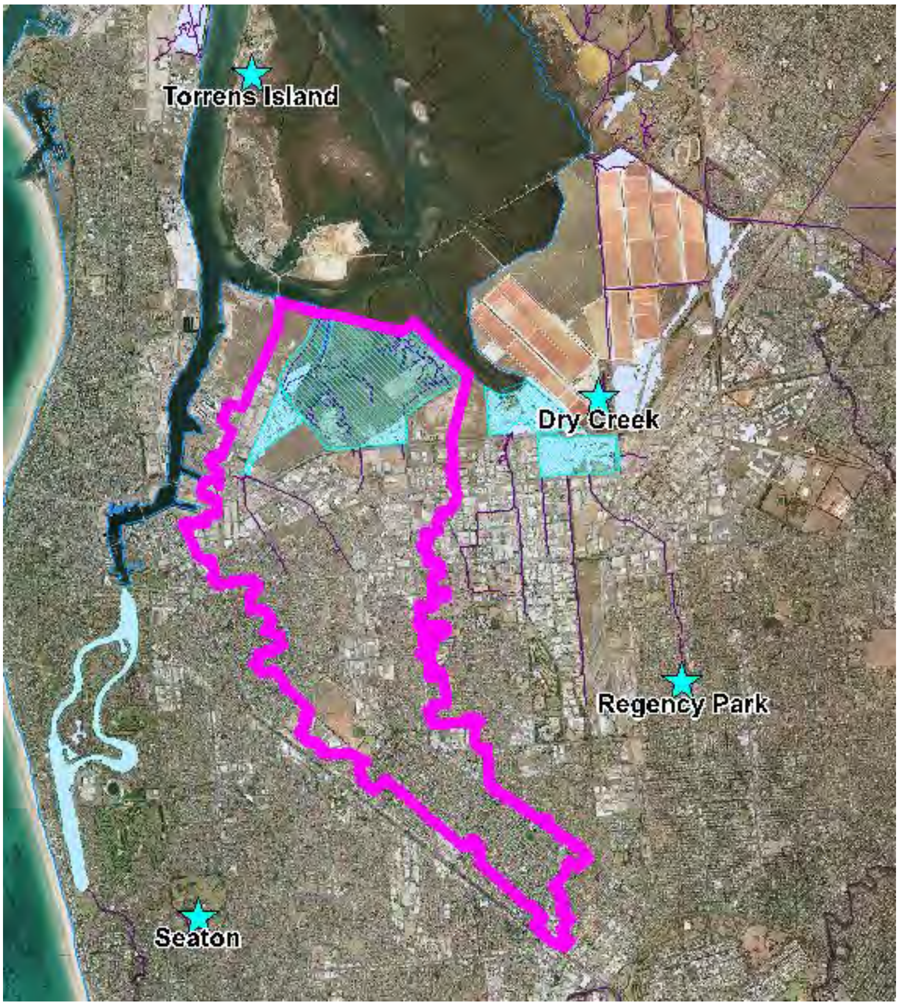


Figure 3.3 Approximate Location of Gillman Rain Gauges

Table 3.1 below contains average annual rainfall totals for the various gauges. It can be seen from the data in the Table that the westerly gauges (Seaton and Torrens Island) have similar total annual rainfalls compared with Adelaide Airport. However, the easterly gauges (Dry Creek and Regency Park) have total annual rainfalls of approximately 80% of Adelaide Airport's total annual rainfall. Based on the above, a rainfall factor of 0.9 was chosen for the Gillman catchment.

Table 3.1 Analysis of Rain Gauges in the Vicinity of the Gillman Catchment

Rain Gauge	Gauge Number	Record Period	Annual Rain (mm) Total	Annual Rain (mm) 2007 to 2015
Adelaide Airport	023034	1955-2015	439.2	389.7
Seaton	023024	1912-2015	442.5	420.8
Torrens Island	023018	1928-2013	433.1	448.1
Dry Creek (Wingfield)	023138	2007-2015	337.3	337.3
Regency Park	023137	2007-2015	364.3	364.3

3.3.3 West Lakes Rainfall Adjustment

The only daily read rainfall gauge within the West Lakes catchment is at Seaton. Figure 3.4 shows the location of gauges.

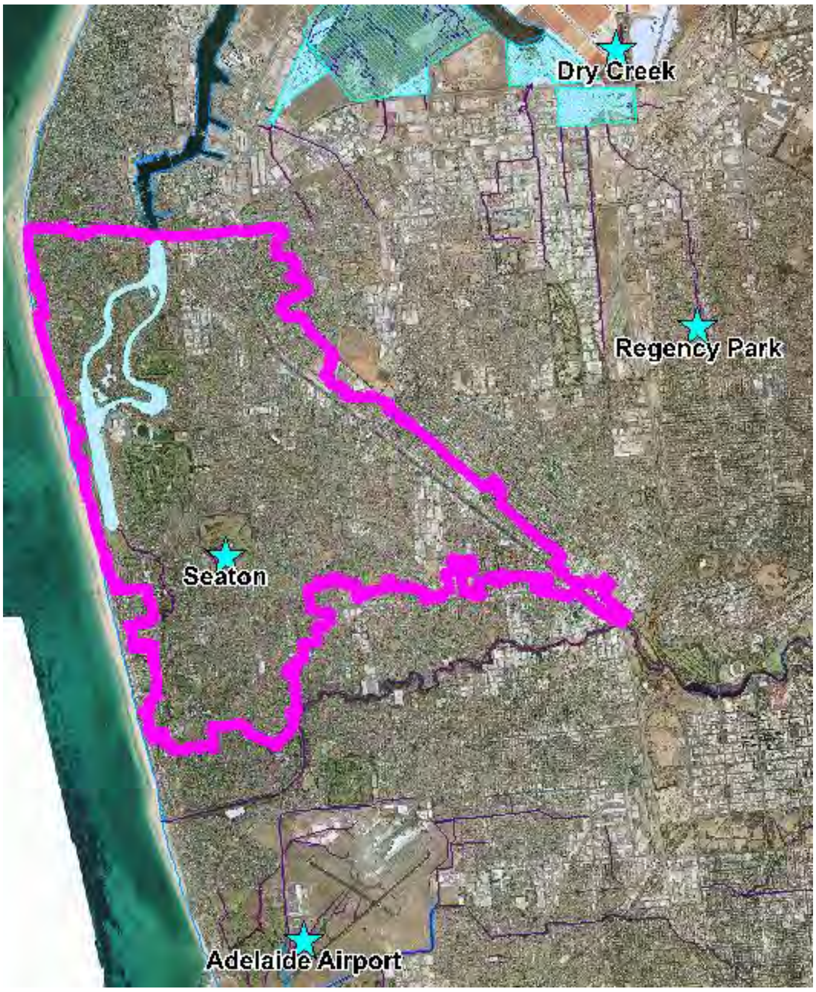


Figure 3.4 Approximate location of West Lakes rain gauges

The rainfall factor applied to modelling runoff from the West Lakes catchment was calculated by comparing the annual rainfall from the Adelaide Airport gauge with the annual rainfall from the Seaton gauge as shown in Table 3.2 below.

Table 3.2 Analysis of Rain Gauges in Vicinity of West Lakes catchment

Rain Gauge	Gauge Number	Record Period	Annual Rain (mm) Total	Annual Rain (mm) 2007 to 2015
Adelaide Airport	023034	1955-2015	439.2	389.7
Seaton	023024	1912-2015	442.5	420.8

A rainfall factor of 1.0 chosen for the West Lakes catchment as there is little long-term difference between the rainfall at Seaton and the rainfall at Adelaide Airport.

3.3.4 Patawalonga Rainfall Adjustment

The Patawalonga catchment is extensive and has significant spatial variability in rainfall. However, the use of flow data from streamflow gauges on Brown Hill Creek and the Sturt River eliminates the need to undertake rainfall-runoff modelling for the majority of the catchment. The Airport Drain, West Beach (Coast), Glenelg North and Drain 18 (Holdfast Bay) catchments are not covered by the streamflow data and hence will require rainfall-runoff modelling within SWMM.

As the Adelaide Airport pluviograph lies approximately in the centre of these catchments as shown in Figure 3.5 below, data from this gauge has been adopted for the modelling with no factoring.

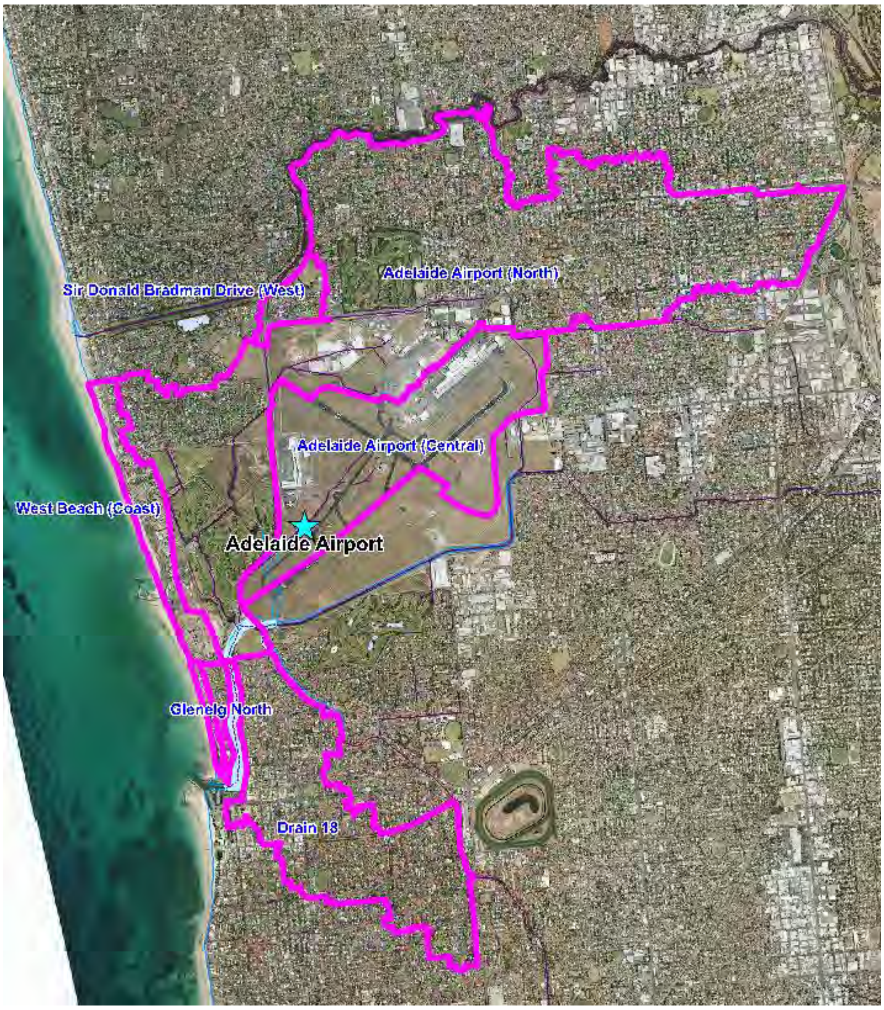


Figure 3.5 Patawalonga Local Catchments around Adelaide Airport

3.4 Evaporation Data

The key evaporation process modelled within the SWMM simulation was evaporation from the surface of the various storages.

Evaporation will have an impact on water levels in all the systems, but this impact will be most evident in the Gillman basins. Evaporation will have a much less evident impact on average water levels in the West Lakes and Patawalonga systems as water levels are constantly being replenished by tidal circulation.

In the West Lakes system, evaporation was not simulated as the system was modelled as an open channel to account for differences in measured water levels at the inlet and outlet. Calibration of West Lakes water levels was undertaken with respect to the measured data from the Department of Planning, Transport and Infrastructure(DPTI) to ensure the model accurately represented water levels in the lake.

At Gillman and in the Patawalonga, the evaporation rate was modelled using average monthly pan evaporation rates for Adelaide published by the Bureau of Meteorology. The average monthly evaporation rates are shown in Table 3.3 below. A lake factor of 0.8 was used to convert the pan evaporation to actual evaporation.

Table 3.3 Average Monthly Pan Evaporation Rates for Adelaide

Month	Evaporation Rate (mm/day)
January	8.50
February	8.19
March	6.04
April	3.92
May	2.37
June	1.63
July	1.74
August	2.38
September	3.30
October	4.82
November	6.65
December	7.80

3.5 Storage Basin Data (Digital Terrain Model)

Ponding areas were analysed within SWMM as storage units in order to model water levels. A Digital Terrain Model (DTM) was used to develop contours within each basin which were then used to determine a height – storage relationship of each basin. The relationships were developed at height increments of 0.1 m. The invert level of each basin was estimated based on the DTM, known inverts of inlets and outlets and design drawings.

3.5.1 Gillman Basins

Four storage areas within the Gillman pond system were analysed within SWMM as discreete storage units, in order to model the long-term water level. These basins were the Range wetland, Range Basin, Magazine Creek wetland and the Magazine Basin as shown in Figure 3.6 below. The basin system was modelled using the existing layout and does not incorporate future Gillman development and associated drainage systems.

Figure 3.6 Gillman Basin Locations

3.5.2 Patawalonga Basins

Four storage basins within the Patawalonga pond system have been modelled within SWMM as storage units. These basins are the Patawalonga Lake, Diversion Pond, Collection Pond and Sturt River Pond (ponding area upstream of Sturt River Weir) as shown in Figure 3.7 below.

Figure 3.7 Patawalonga Basin Locations

3.6 Sub-Catchment Boundary Delineation

3.6.1 Gillman Sub-Catchments

In order to model runoff into the Gillman system in SWMM, the upstream catchment was subdivided into twenty-two sub-catchments. Sub-catchments within the urban area were delineated based on major pipe network data. These sub catchments were modelled to feed the pipe network which then conveyed water to the Gillman basins. The urban sub-catchment breakdown is shown in Figure 3.8 below. Pond catchments and sub-catchments adjacent to the ponds feed their water directly into the ponds.

Figure 3.8 Gillman Sub-Catchments

3.6.2 West Lakes Sub-Catchments

The West Lakes catchment was subdivided into seventeen sub-catchments as shown in Figure 3.9 below. Many of the sub-catchments within this area feed directly into West Lakes. Catchments which do not feed directly into West Lake were delineated based on the arrangement of the trunk drainage network. These smaller catchments were modelled to feed the pipe network which then conveyed water into West Lakes.

Figure 3.9 West Lakes Sub-Catchments

3.6.3 Patawalonga Sub-Catchments

The key catchments upstream of the Patawalonga are the Sturt River and Brown Hill Creek catchments. These larger catchments were modelled in SWWM using recorded streamflow data as outlined in Section 3.7.

In order to model the runoff from the remaining parts of the catchment, which do not contribute to flows at the Sturt River and the Brown Hill Creek gauges, the area was subdivided into nine sub-catchments as shown in Figure 3.10 below. Sub-catchments within this area were delineated based on the arrangement of the trunk drainage network.

The sub-catchments shown in Figure 3.10 include:

- Patawalonga Creek / West Beach (SC5 and GC)
- Adelaide Airport Drains (AC1 to 3)
- Mile End / Cowandilla Drains (SC3 and 4)
- Drain 18 catchment (SC1)
- Sturt River / Brown Hill Creek Catchments downstream of flow gauges (SC2)

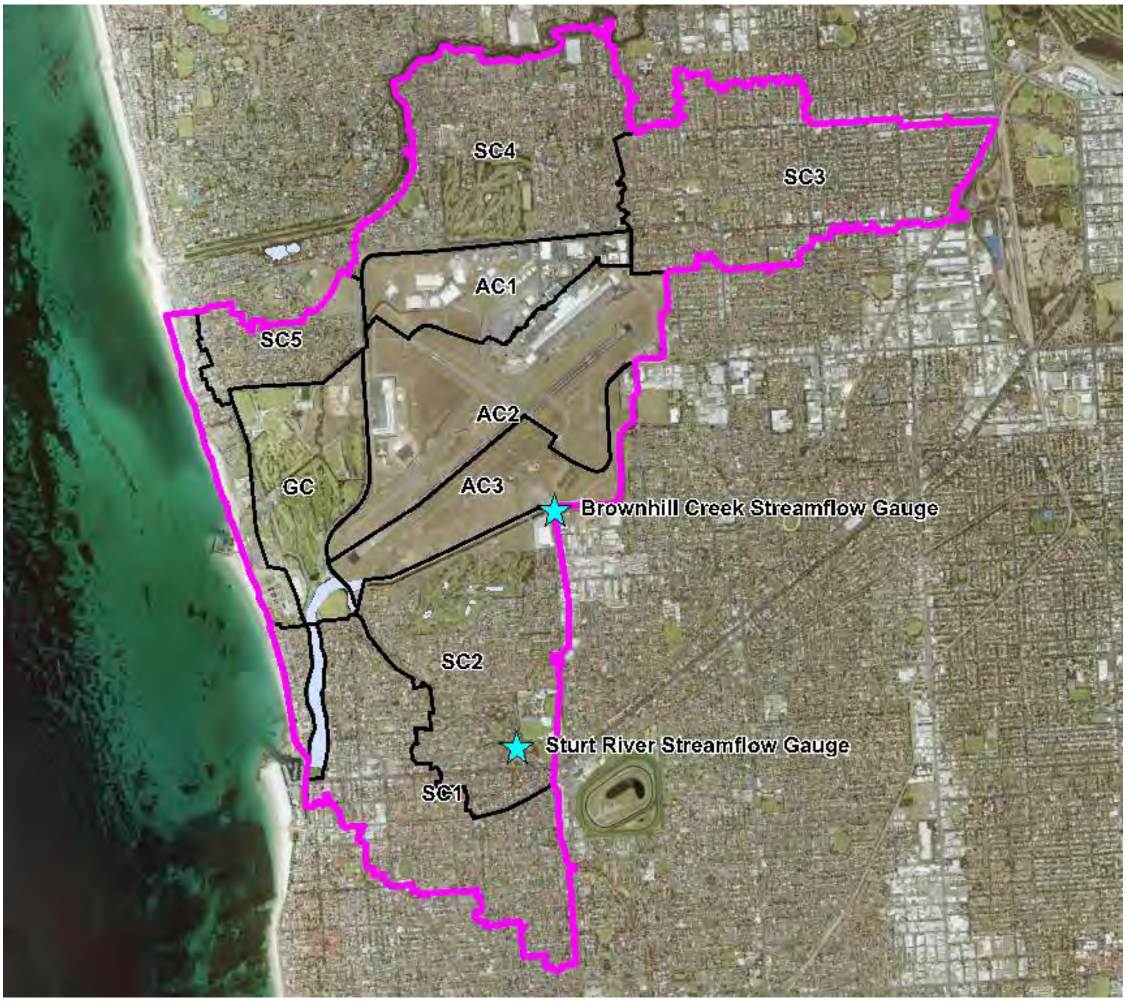


Figure 3.10 Lower Patawalonga Sub-Catchments

3.7 Streamflow Data

Runoff from the Sturt River and Brown Hill Creek catchments was modelled within SWMM using recorded streamflow data. Over the period between 1993 and 2005, there is streamflow data with a rating of sufficient quality for both Brown Hill Creek and Sturt River, to undertake the modelling of inflows to the Patawalonga Lake.

The stream flows have been factored up by 30% to account for an increase in future runoff due to development as discussed in Section 3.8.3.

3.7.1 Sturt River Data

Sturt River has multiple streamflow gauges along its length which can be used for streamflow analysis. The most downstream gauge is station A5040549, located downstream of the Anzac Highway (see Figure 3.10 above for approximate gauge location). Hourly flow data for this gauge was obtained from Water Data Services Pty Ltd. This data contained a continuous record of flows from November 1993 to the end of 2005.

A breakdown of data quality is provided in Table 3.4 below. With the vast majority of the data (approximately 89%) from November 1993 to December 2005 being rated as good or fair, the data set has been assessed to have sufficient quality for use in the rainfall runoff analysis.

Table 3.4 Sturt River Data Quality

Quality Record	% of Data (Nov 1993 to Dec 2005)
Good Record	81.6
Fair Record	0.7
Fair-Estimated Record	6.7
Smoothed Data Record	1.4
Poor Record	8.2
Poor – Theoretical Rating Record	0
Quality Unknown Record	1.3
Unverified Telemetry Data Record	0
Missing Record	0

3.7.2 Brown Hill Creek Data

Brown Hill Creek has multiple streamflow gauges along its length which can be used for streamflow analysis. The most downstream gauge is station A5040583, located at Adelaide Airport (see Figure 3.10 above for approximate gauge location). Hourly flow data for this gauge was obtained from Water Data Services Pty Ltd. This data contained a continuous record of flows from November 1993 to the end of 2005, apart from an approximately three and a half month gap in the recorded data between October 1995 to January 1996.

The missing data was filled by synthesising flows for this period using a SWMM model of the catchment upstream of the gauge. The process used for patching the data involved calibrating the SWMM model to flows recorded during a summer period with similar rainfall to the period of missing data. The calibrated model was then run for the rainfall during the period October 1995 to January 1996 to generate flows which were used to patch the recorded flow data series.

A breakdown of data quality is provided in Table 3.5 below. With the vast majority of data (above 91%) from November 1993 to December 2005 being rated as good or fair, the data set has been assessed to have sufficient quality for use in the rainfall runoff analysis.

Table 3.5 Brown Hill Creek Data Quality

Quality Record	% of Data (Nov 1993 to Dec 2005)
Good Record	57.3
Fair Record	32.3
Fair-Estimated Record	1.9
Smoothed Data Record	5.0
Poor Record	0
Poor – Theoretical Rating Record	0.3
Quality Unknown Record	0.7
Unverified Telemetry Data Record	0
Missing Record	2.4

3.7.3 Final Data Processing

The final streamflow data was exported to text file with the formatting required for a SWMM time series import.

3.8 Sub-Catchment Hydrology

The hydrological model used within SWMM differs from the time-area method used in models such as ILSAX and DRAINS.

SWMM models sub-catchments as a rectangular surface with a constant slope and uniform width which drains into a single outlet channel through the centre of the catchment. The conceptual model is shown in Figure 3.11 below. The width value is generally difficult to calculate directly when modelling large urban catchments and correlates (conceptually) to the time of concentration used in hydrological models based on the time-area method. For large-scale urban modelling, the catchment width needs to be calibrated such that the model produces a hydrograph of the required timing, peak and shape.

Each sub area can be assigned an impervious area and infiltration parameters for pervious areas in a similar manner to the ILSAX and DRAIN models.

As there is no available streamflow data for the catchments being modelled using SWMM in this study, the approach taken was to calibrate the SWMM model for a representative catchment to flows generated by DRAINS for the same catchment. In addition, outputs from SWMM for West Lakes were validated against recorded water level data from DPTI to ensure the model produced a reasonable representation of runoff from the urban catchments.

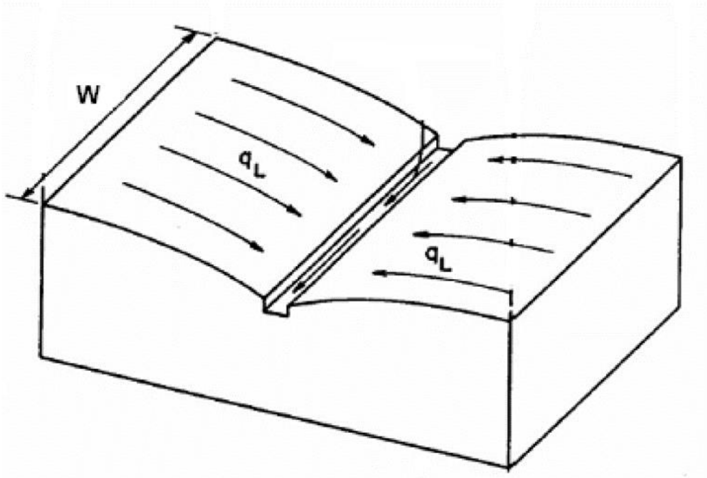


Figure 3.11 Conceptual Diagram of SWMM Catchment Model (SWMM Reference Manual, 2016)

3.8.1 Sub-Catchment Width and Routing

For the calibration catchment, the catchment width was evaluated by considering a 9 hour ARR storm pattern and a 25 minute ARR storm pattern in order to capture the effects of events of different durations.

The following process was undertaken within the calibration process for both the SWMM and DRAINS model:

- Input the same Horton infiltration parameters for modelling pervious areas;
- Input the same depression storage for both pervious and impervious areas;
- Assume the same directly connected impervious area across both models;
- Assume the same catchment area;
- Assume the same routing process:
  - DRAINS models areas as contributing directly to the pipe system.

– SWMM models three sorts of catchment routing. The "Outlet" option was chosen as this routes runoff from the impervious area and pervious area directly to the sub-catchment outlet.

For the DRAINS model, the time of concentration for the catchment was estimated for the paved area (30 minutes) and the grassed area (45 minutes). The model was then run producing the two hydrographs.

For the SWMM model, the model was run with a catchment roughness appropriate for overland flows within an urban area and the catchment slope calculated from the digital terrain model of the test catchment. By varying the catchment width, the runoff hydrograph was calibrated to the outputs of the DRAINS model considering hydrograph timing, peak flows and flow volumes.

The analysis indicated that the optimum catchment length was 115 m. This value represents an estimate of the average distance water has to flow in the catchment until it reaches a drainage system, and given the nature and development of the underground drainage system within most of the catchments being modelled seemed to be a reasonable estimate of this length. The calibrated hydrographs are shown in Figure 3.12 below.

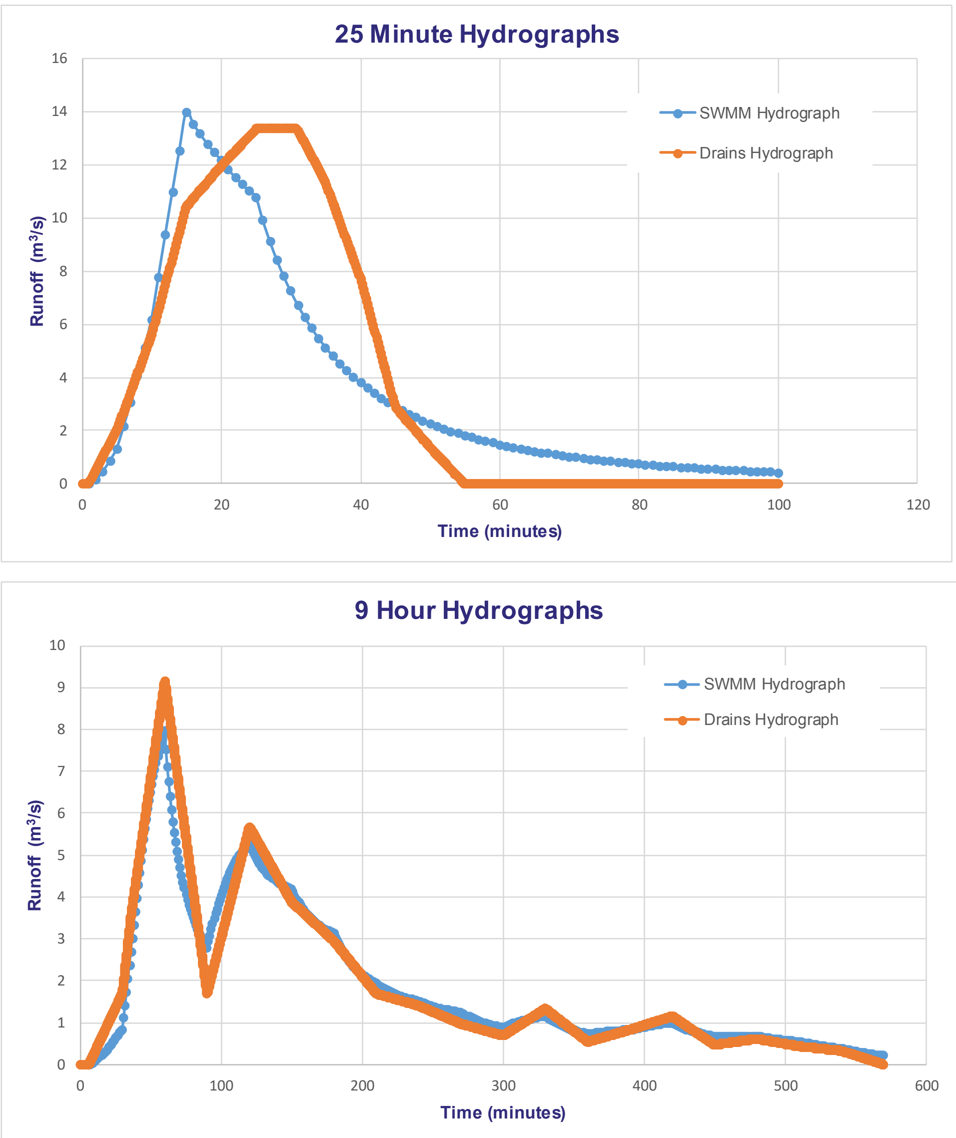


Figure 3.12 Calibration of SWMM Hydrologic Model to DRAINS

3.8.2 Sub-Catchment Slope

Sub-catchment slope was estimated using the average slope across each sub-catchment. This slope was calculated from the digital terrain model of the area.

3.8.3 Impervious Area Parameters

Impervious areas within the urban catchments considered in this study are expected to increase as a result of ongoing development. This increase in impervious area is expected to result in an increase in runoff. Modelling undertaken as a part of this Study has been based on estimates of runoff using projected increases in impervious area as described below.

Within the Gillman catchment, impervious areas have been based on development levels as outlined in the 30 Year Plan for Greater Adelaide. The existing and future impervious area fractions were assessed as part of the development of the Stormwater Management Plan for the catchment (Tonkin, 2015a). The existing average impervious area fraction for all the sub-catchments draining to the Gillman basins was estimated to be 0.45. This impervious area fraction was estimated to increase to 0.56 within the planning horizon of the 30 Year Plan, an increase of 24%. A breakdown of the estimated future sub-catchment impervious area fractions is provided in

Table 3.6 below and was used in the SWMM modelling.

Table 3.6 Gillman Sub-Catchment Impervious Area Fractions

Sub-Catchment	Area (ha)	Future Impervious Area Fraction
1	115.2	0.48
2	58.1	0.42
3	53.3	0.48
4	62.4	0.50
5	43.1	0.74
6	126.0	0.48
7	105.3	0.56
8	116.5	0.62
9	152.6	0.60
10	249.6	0.50
11	121.2	0.46
12	120.6	0.66
13	52.5	0.72
14	151.1	0.60
15	89.5	0.64
16	107.6	0.62

In the West Lakes catchment, impervious area fractions were calculated from projections of increased urban density due to development over a 50 year horizon. The existing and future impervious area fractions were estimated as a part of floodplain mapping work undertaken for the City of Charles Sturt. The existing average impervious area fraction for all the sub-catchments draining to West Lakes was estimated to be 0.35. This impervious area fraction was estimated to increase to 0.44 over the 50 year planning horizon, an increase of 26%.

A breakdown of the estimated future impervious area fractions is provided in Table 3.7 below and these were used in the SWMM modelling. The values for the Wellington Street catchment (Sub-catchment 4), Royal Adelaide Golf Course catchment and SA Water Port Adelaide Pump Station catchment were estimated manually as these were outside the area analysed as part of the previous Charles Sturt floodplain mapping.

Table 3.7 West Lakes Sub-Catchment Impervious Area Fractions

Sub-Catchment	Area (ha)	Future Impervious Area Fraction
1	204.5	0.45
2	121.5	0.45
3	101.0	0.48
4	205.8	0.55
5	329.1	0.48
6	327.2	0.48
7	165.4	0.36
8	279.9	0.40
9	120.5	0.35
10	164.9	0.42
11	158.4	0.43
12	98.5	0.46
13	395.5	0.45
14	296.8	0.45
15	306.9	0.42
Royal Adelaide Golf Course	0	0
SA Water PA Pump Station	14.1	0.25

Within the greater Patawalonga catchment, there is little data on the expected increase in impervious area due to development, especially in relation to the Sturt River.

In the absence of any data, flows from the Sturt River and Brown Hill Creek were increased by 30% (cf. 24 and 26% used for Gillman and West Lakes) to conservatively allow for the effects of future development.

Impervious area fractions used for modelling of local catchments around the Patawalonga were developed from data contained in the Holdfast – Marion Stormwater Management Plan, past modelling of the Airport Drain catchment and manual calculation. The future impervious fractions for the various sub-areas are provided in Table 3.8 below and were used in the SWMM modelling.

Table 3.8 Patawalonga Sub-Catchment Impervious Area Fractions

Sub-Catchment	Area (ha)	Future Impervious Area Fraction
1	338.7	0.59
2	329.9	0.42
3	386.0	0.61
4	348.4	0.51
5	95.5	0.45
6	76.5	0.60
Airport1	145.8	0.70
Airport2	344.1	0.50
Airport3	153.8	0.20
Adelaide Shores Golf Park	181.3	0.10

3.8.4 Pervious Area Infiltration

Infiltration within the pervious portion of each subarea was modelled using the Horton Infiltration Curve. The soil type was assumed conservatively as Type C (or 3) which has slow infiltration rates when well wetted (NRCS, 2009, Chapter 7). The Horton parameters were chosen based on this soil type as outlined in

Table 3.9 below (from DRAINS Manual p5.11). Being a continuous simulation, the antecedent moisture condition will be determined by previous rainfall events. Typical drying times used in SWMM range from 2 to 14 days (Chiwater manual p123) and the assumed drying time has been conservatively assumed at 14 days.

Table 3.9 Horton Infiltration Model Parameters

Factor	Symbol	Unit	Value
Initial Rate	f_0	mm/hr	125
Final Rate	f_c	mm/hr	6
Shape Factor	k	hr^{-1}	2
Drying Time	-	days	14

3.9 Hydraulic Assumptions and Modelling

3.9.1 Gillman System

The Gillman Basin system collects runoff from the Torrens Road Catchment. Within the SWMM model, runoff from the various sub areas within the catchment was routed through a pipe network comprising the main spines of the trunk drainage network. Data on pipe sizes and grades were obtained from GIS data provided by the City of Charles Sturt and the City of Port Adelaide Enfield.

The general arrangement of the Gillman system is shown in Figure 3.13 below.

Figure 3.13 Gillman Basin System Overview

Water from the Torrens Road Catchment enters the Gillman basin system through two main wetland systems, the Magazine Creek wetland and the Range wetland.

Water entering the Magazine Creek wetland flows into the Magazine Basin and out to sea via a set of flap gates. There are currently three rectangular tide gates which have a 2.44 m width,1.52 m height and 6 m length. The tide gates have an estimated invert of -1.7 mAHD. A weir separates the wetland and the basin to the north of the wetland. This weir has a width of approximately 50 m and a crest level of -0.6 mAHD.

When water levels in the Magazine Basin are greater than the tide level in the North Arm, water from the basin flows out of the tide gates. The flap gates prevent backflow of sea water into the basin when tide levels are higher than the water level in the basin.

Water entering the Range Wetland from the Torrens Road Catchment discharges over a weir into the Range Channel which directs flows into the Range Basin. The weir has a width of 20 m and an estimated crest level of 0.23 mAHD.

There is a pipe outlet with a flap gate to direct floodwaters from the Range Basin to the Magazine Basin, but from site investigations, it is believed that the outlet is blocked. As of such, there is no existing outlet for the Range Basin, with flows thought to dissipate via a combination of evaporation and infiltration

For SWMM modelling of this system, the top of bank between the Range Basin and the Magazine Basin was modelled as the weir level above which water was allowed to escape from the Range Basin to the Magazine Basin. Due to the level of this bank and the considerable upstream storage, overflow did not occur during the modelled period between 1971 and 1991, with all flows lost via evaporation. Further consideration of the impact of this blocked pipe on peak levels during a 100 year ARI flood is provided in Section 4.

Groundwater flows into the basins as well as interactions between the basins and the Port River are possible. However, these potential interactions were not modelled.

3.9.2 West Lakes System

West Lakes is a man-made lake with a significant urban catchment shown in Figure 3.9. The lake is flushed by sea water with tidal flows through the lake being controlled by tidal gates at the lake inlet and outlet as shown in Figure 3.14 below. The southern inlet to West Lakes is supplied by an underground 3.5 m diameter conduit from the sea. The northern gates (three gates which are 1.52 m high and 2.44 m wide at an invert of -1.97 mAHD) discharge into the Port River. Drawings of these structures were obtained from DPTI.

Figure 3.14 Schematic of Configuration of West Lakes

The Department of Planning, Transport and Infrastructure currently own and operate infrastructure associated with the Lake and carry out monitoring of water levels and water quality as part of their operations responsibilities.

While DPTI own and operate the infrastructure, the City or Charles Sturt has responsibility for care and control of the Lake, which includes issuing of permits for use of the Lake and access. Council is also responsible for the maintenance of the various beaches around the Lake. The Council Environmental Health Team responds to community concerns regarding Lake water quality and partner with DHA and the EPA in this regard when required, for example, to issue media releases and to identify pollutant sources.

Day to day operation of the tidal gates is managed by DPTI. The current operating principles of the lake as outlined by DPTI (West Lakes Tidal Flushing System, 2014) are as follows:

- *Normal lake level is controlled by the inlet gates (at Trimmer Parade)*

- *The inlet gates are opened automatically to allow sea water to flow into the lake whenever the lake is below its preset target height and the sea level is above the lake level at the time*
- *The inlet gates will close when the lake reaches its target height or the sea level falls below lake level before the target height is reached*
- *When the level in the Port River falls below lake level the flap gates at the outlet (at Bower Road) are pushed open and water flows out of the lake*
- *Water will continue to flow out of the lake until the level in the Port River rises again and the flap gates are pushed shut*
- *If the lake level falls below the preset low level then the hydraulic slide gates will close to prevent water flowing out. The gates will automatically open once the Port River rises above the lake level*

Within the SWMM model, runoff from the various sub areas within the West Lakes catchment was routed through a pipe network comprising the main spines of the trunk drainage network. Data on pipe sizes and grades were obtained from GIS data provided by the City of Charles Sturt and the City of Port Adelaide Enfield.

The lake was modelled as an open channel system within SWMM to allow for observed differences in level between the inlet and outlet to be simulated. The channel surface area was matched to the Lake surface area in order to properly model the storage behaviour of the Lake.

Tidal boundaries were applied at either end of the lake (Outer Harbour data at the southern end and Inner Harbour data at the northern end as outlined in Section 3.2.1) and sub-catchment inflows were applied at nodes along the total channel length.

The tidal operation rules were coded into SWMM to simulate the operation of the gates under normal tidal operation as well as in a storm event. However, it should be noted that manual draining of the lake for cleaning or to improve lake storage before a large storm has not been modelled over the twenty years of analysis. These manual interventions will have a negligible impact on the average lake levels over a period of twenty years and their exclusion is likely to result in conservative predictions of lake level.

DPTI have advised that the target level of the lake ranges between -0.35 mAHD and -0.65 mAHD. However, inspection of recorded lake level data indicated that the high lake level regularly fluctuates with a maximum water level of approximately -0.25mAHD being achieved. DPTI have indicated that while the inlet gate is set to close at a level of -0.35mAHD, it takes around half an hour for the gate to close and hence the lake regularly fills to a higher level. Because SWMM applies gate closure instantaneously, the operational rules set in SWMM were adjusted such that the target water threshold had a high water level of -0.25mAHD and a low water level of -0.65mAHD.

Any groundwater interactions within the Lake have not been modelled. These are assumed to be negligible for the purposes of the calculation of the long-term average water level, as the West Lakes water level is mainly controlled by tide levels.

3.9.3 Patawalonga System

The Patawalonga is a complex man-made system with dual functionality of stormwater dissipation and tidal flushing as shown in Figure 3.15 below. It has a significant urban / rural stormwater catchment of over 200 km^2 and collects water from Brown Hill Creek and Sturt River and other local catchments.

Drawings of key infrastructure within the system were obtained from DEWNR. Key data relating to the system is provided in Table 3.10 below.

Figure 3.15 Schematic of Configuration of the Patawalonga

Table 3.10 Key Patawalonga Infrastructure Data

Name	Type	Number	Width (m)	Height (m)	Diameter (m)	US Invert (mAHD)	DS Invert (mAHD)
Main Duct	Arched Duct	1	-	-	~5.3	0.1	-8.425
Secondary Duct	Box Culvert	1	2.7	2.5	-	-2	-4.205
Underduct	Box Culvert	1	3	3	-	-4.25	-4.25
Sturt River Weir	Weir	1	100	~2	-	0.8	0.8
Weir No. 2	Gates	10	3.2	3.15	-	-1.15	-1.15
Glenelg Gates	Gates	8	~5.5	~3.7	-	-0.44	-0.44

In stormwater dissipation mode as shown in Figure 3.16 below, flows from Brown Hill Creek and the Sturt River back up behind the Sturt River Weir until water levels reach 0.8 mAHD. At this level, stormwater flows into the Diversion Pond where it usually flows out to sea via the Barcoo Outlet Main Duct when the sea level is below the Diversion Pond level. If the Main Duct has insufficient capacity for flows and water in the Diversion Pond reaches a level in the range of 1.8 mAHD to 2.2 mAHD, then Weir 2 is opened. The Patawalonga Lake then acts as a storage basin (if the sea level is above the Patawalonga level) or a stormwater conduit to the Glenelg Gates where flood flows are discharged if sea level is below the Patawalonga level.

Figure 3.16   Schematic of Patawalonga in Stormwater Dissipation Mode

Stormwater from the Airport, Mile End / Cowandilla, West Beach and Patawalonga Creek catchments enter the system via the Collection Pond. In low flow events, this stormwater is discharged through the Secondary Duct via a venturi into the Barcoo Outlet Main Duct. In events where the Secondary Duct has insufficient capacity, stormwater flows from the Collection Pond directly to the Patawalonga Lake via an underduct.

In tidal flushing mode as shown in Figure 3.17, sea water at high tide is let into the Patawalonga Lake via the Glenelg Gates. The water flows through the lake and Weir 2 where it enters the Diversion Pond and flows out to sea at low tide through the Barcoo Outlet Main Duct. DEWNR have indicated that it takes approximately five days for water held in the lake to be completely exchanged using this mode of operation.

Figure 3.17   Schematic of Patawalonga in Tidal Flushing Mode

Within the SWMM model the calculated runoff from catchments immediately surrounding the Patawalonga was routed through a pipe network comprising the main spines of the trunk drainage network. Data on pipe sizes and grades were obtained from GIS data provided by the

City of West Torrens. Gauged runoff from the catchments of Brown Hill Creek and Sturt River were added to these inflows to obtain the total flow entering the system.

The tidal boundaries at the Glenelg Gates and the Barcoo Outlet Main Duct were modelled using the Outer Harbour tide data.

Operating rules for the system were coded into SWMM to simulate the operation of the lake under normal conditions as well as in a storm event. It is noted that manual draining of the Lake (for cleaning or to improve lake storage before a large storm) or lake filling (for community or recreational activities) have not been modelled over the twelve years of analysis. These manual interventions will not have a significant impact on the modelled lake level frequency over a period of twelve years.

DEWNR specify that the target level for the lake ranges between 0.1 mAHD and 0.6 mAHD. The operating rules set in SWMM modelled the tidal fluctuations within this range.

Any groundwater interactions within the Patawalonga have not been modelled. These are assumed to be negligible for the purposes of the calculation of the long-term average water level, as levels in the Patawalonga are mainly controlled by tide levels.

3.10 SWMM Model Validation

3.10.1 Gillman System

No recorded data is currently available to validate long-term water level modelling from the Gillman system. However, some confidence is gained from the fact that the Gillman hydrology and modelling assumptions are the same as the West Lakes system where good validation was achieved.

3.10.2 West Lakes System

The West Lakes model was able to be validated as recorded historical water levels were provided by DPTI. Two scenarios were checked:

- West Lakes operation under tidal flows
- West Lakes operation under storm event flows

Tidal behaviour validation was chiefly to ensure the model accurately captured the DPTI operation of the lake when there was little or no rain. In this case, lake levels and flows were controlled by the inlet and outlet sea levels. The validation generally returned good correlation to DPTI recorded lake levels with a sample shown in Figure 3.18 below.

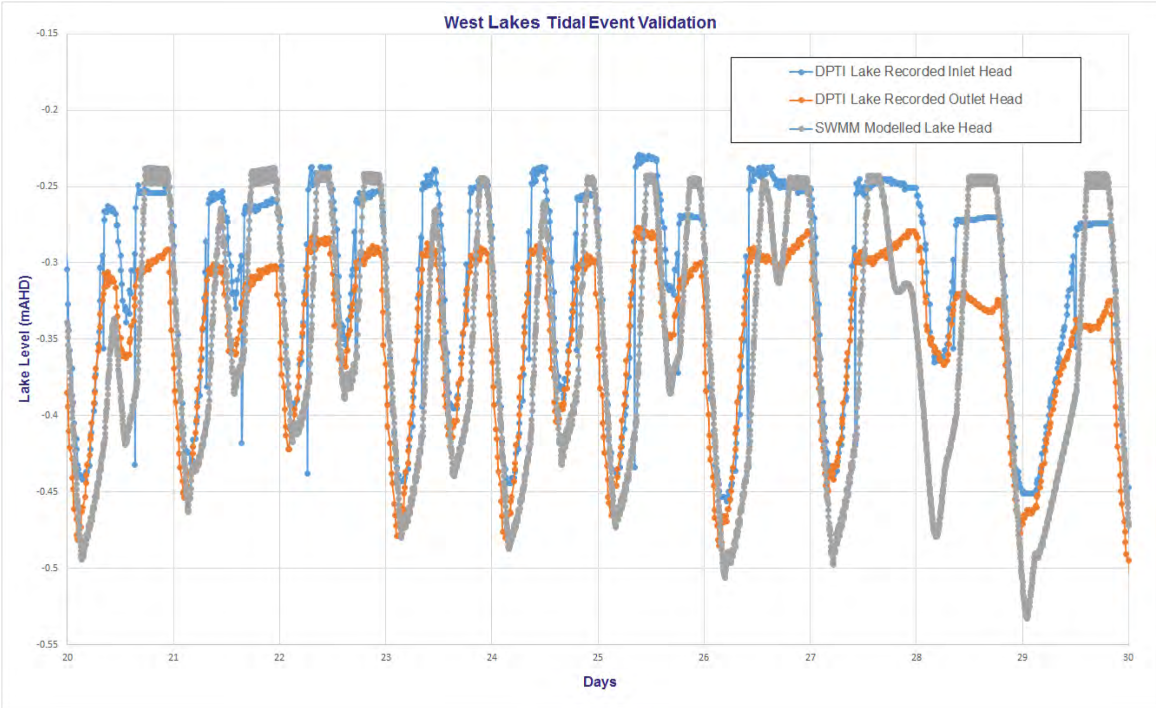


Figure 3.18 West Lakes Tidal Event Validation Sample

Storm event validation was chiefly undertaken to ensure the SWMM model properly simulated rainfall-runoff events within the West Lakes catchment. Under these conditions, lake levels are controlled by tide levels and inflows to the system. The validation generally returned a good correlation to DPTI recorded lake levels as shown in Figure 3.19 below, although the model tended to slightly over-estimate runoff. This is likely to be partly due to the use of runoff coefficients for future catchment conditions for the modelling.

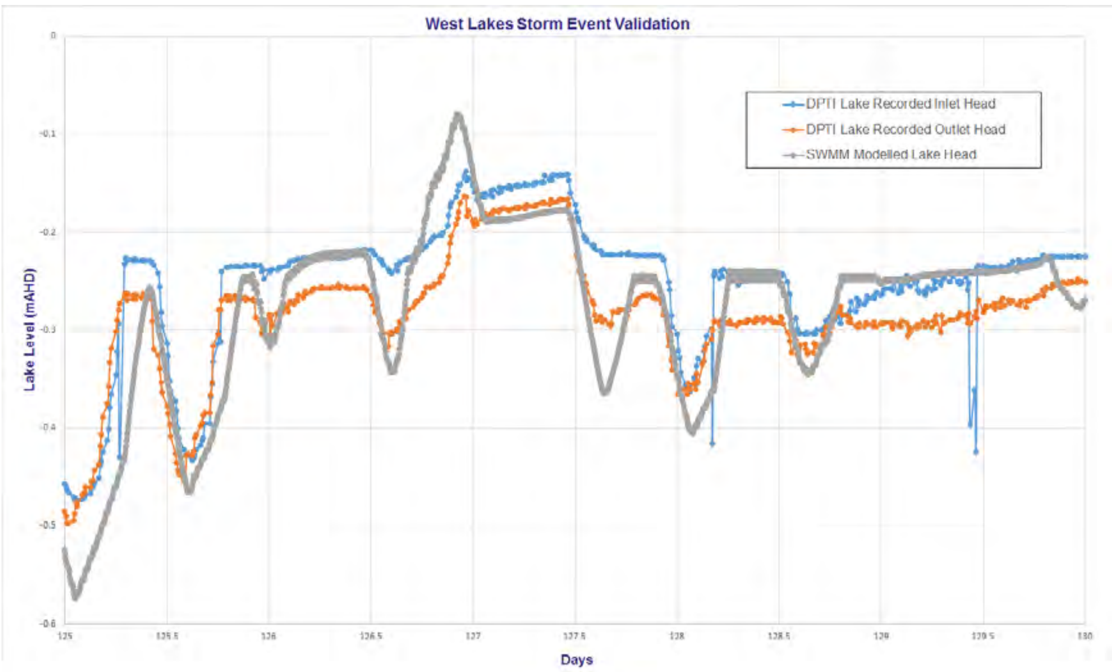


Figure 3.19 West Lakes Storm Event Validation Sample

3.10.3 Patawalonga System

The Patawalonga model was able to be generally validated for tidal flow events with information provided by DEWNR. Storm event calibration was not undertaken due to the complex nature of spatially varied storms within the total Patawalonga catchment and the fact that long-term average water levels are mainly controlled by sea level and tidal interactions.

The first validation criteria undertaken for the Patawalonga model was to ensure that target water levels under tidal operation range between 0.1 mAHD and 0.6 mAHD. Figure 3.20 below indicates the SWMM operating rules of the system accurately capture this criteria.

The second validation criteria undertaken for the Patawalonga model was to ensure that the lake flushes its own volume roughly every five days. Without incorporating manual intervention, the SWMM model calculates the lake is flushed just over every five days, suggesting the model reasonably accurately captures the tidal flushing of the system.

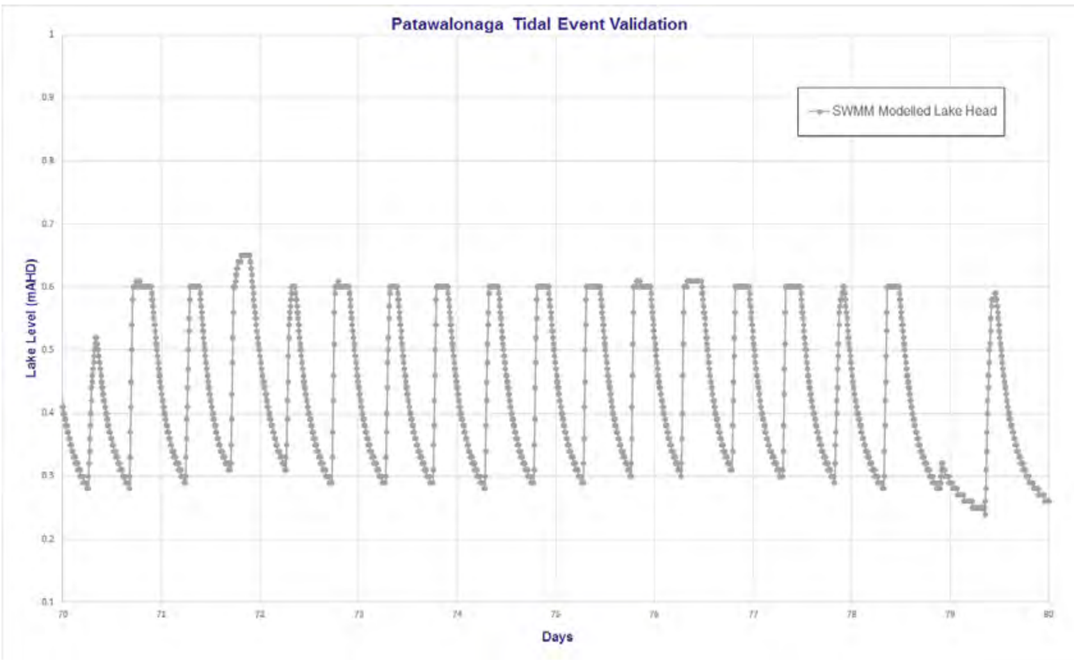


Figure 3.20 Patawalonga Tidal Event Validation Sample

3.11 Scenarios Analysed

Four scenarios were analysed using SWMM to determine average water levels for each of the three systems. The four scenarios that were modelled are outlined below:

- Existing Sea Level with Future Development
- 300 mm Sea Level Rise with Future Development
- 500 mm Sea Level Rise with Future Development
- 1000 mm Sea Level Rise with Future Development

Availability of data as discussed above dictated that the simulations were run for time periods as outlined below as the baseline (or existing) condition.

- Gillman System 1971 to 1991
- West Lakes System 1971 to 1991
- Patawalonga System 1993 to 2005

3.12 SWMM Results

3.12.1 Gillman System

The key output from the SWMM modelling was a time series of water levels within the Magazine Creek wetland and basin over the 20 year simulation period. This time series was analysed to determine the average water level in the system under each of the sea level rise scenarios discussed in Section 3.11 above. Figure 3.21 below shows the results. The results indicate that for sea level rises up to 500 mm, the system is likely to be able to be maintained at an average water level of -0.6 mAHD. However, sea level rises above this value are likely to have a more significant impact on average levels in the system, with the average level rising to -0.35 mAHD for a sea level rise of 1000 mm.

The average water levels for each of the sea level rise scenarios shown in Figure 3.21 were used to set the initial water level in the Magazine Creek system for modelling of flooding in a 100 year ARI event with TUFLOW.

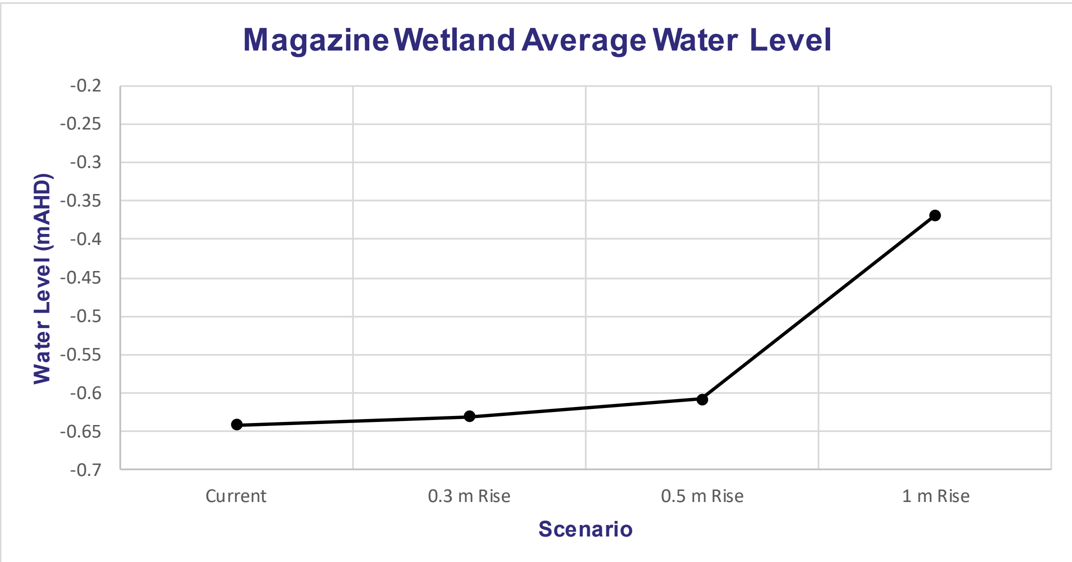


Figure 3.21 Average Water Levels in the Magazine Creek Wetland

The Range wetland and basin, operate at a much higher average level of 0.2 mAHD and as a result are relatively unaffected by changes in sea level. They are also currently isolated from the effects of sea level fluctuations due to blockage of the existing outlet. Flood modelling of these systems has be undertaken been undertaken with an initial water level of 0.2 mAHD for each of the sea level rise scenarios.

3.12.2 West Lakes System

The time series of water levels in West Lakes produced by SWMM was analysed to determine the average water level in the system, under the range of sea level scenarios described in Section 3.11. Figure 3.22 below shows the increase in average water level in the system for each of the sea level rise scenarios considered.

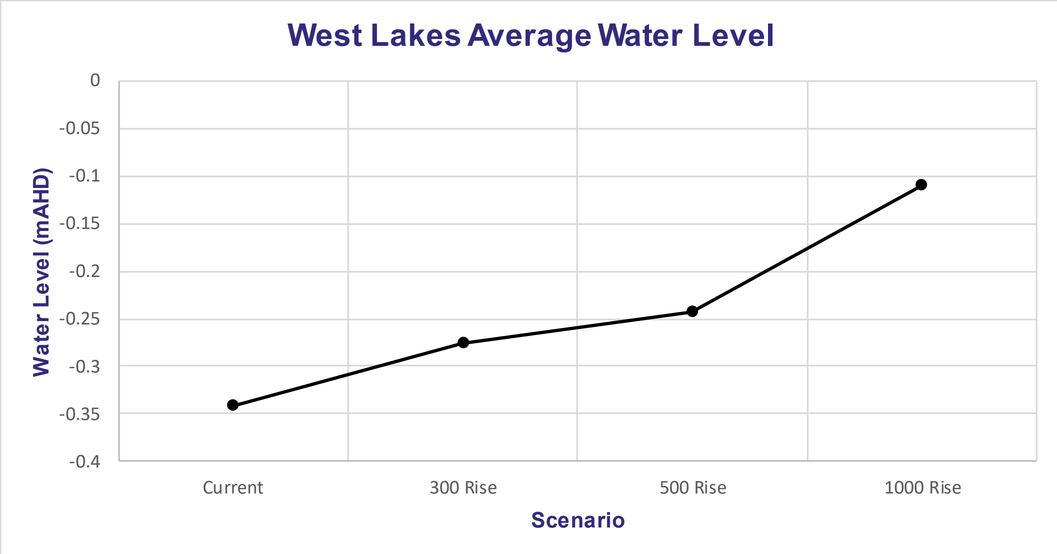


Figure 3.22 Average Water Levels in West Lakes

The results indicate an increase in average level of approximately 250 mm with a 1000 mm rise in sea level, as the impact of rises in sea level is buffered by the operation of the inlet and outlet to the Lake.

The average water levels for each of the sea level rise scenarios shown in Figure 3.22 were used to set the initial water level in the West Lakes system for modelling of flooding in a 100 year ARI event with TUFLOW. It is noted that DPTI undertake pre-draining of the Lake prior to forecast significant rainfall events, which will provide additional storage to contain flood waters. The use of the average Lake level as the initial water level for the flood modelling is therefore considered to be slightly conservative.

The main climate change impact highlighted by the SWMM modelling was the impact of rising sea levels on the ability to regularly flush the Lake. While this was not the focus of the modelling, rising sea levels will decrease the ability of West Lakes to be flushed by gravity operation and may result in a decrease in water quality within the Lake.

A more detailed analysis of changes to lake turnover times and flushing would require more detailed bathymetry for the Lake than was available for this Study, and consequently, modelling of water residence times in the Lake has not been undertaken as a part of this project.

Figure 3.23 illustrates the relationship between water levels in the Lake and tide levels under a range of sea level rise scenarios. The current tidal regime (shown in orange in the Figure) provides approximately equal periods during which tides are either above or below Lake level. This provides reasonable opportunity for flows to be allowed to enter and leave the Lake at high or low tide respectively. As sea level rises, the opportunity to release water from the Lake (when the tide is below Lake level) become shorter. With 1 m rise in level, there are very few periods during which flow can be discharged, with water effectively trapped in the Lake.

It is noted that the modelling assumes the current West Lakes operating range over all sea level rise scenarios. The operating range of West Lakes could potentially be raised to help mitigate the decrease in flushing due to climate change. However, this will result in a decreased storage for flood events in comparison with current operating levels.

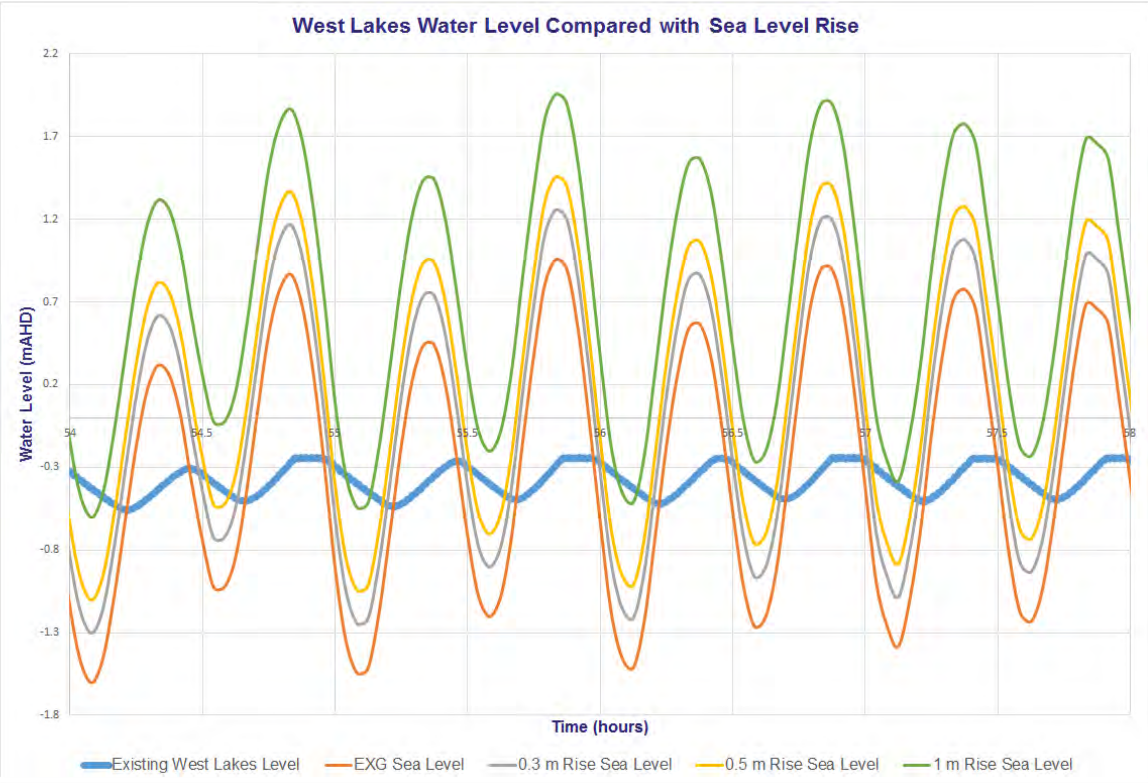


Figure 3.23 West Lakes Existing Tidal Range with Change in Tidal Regime

3.12.3 Patawalonga System

The time series of water levels in the Patawalonga produced by SWMM was analysed to determine the average water level in the system under the range of sea level scenarios described in Section 3.11. Figure 3.24 below shows the increase in average water level in the system for each of the sea level rise scenarios considered.

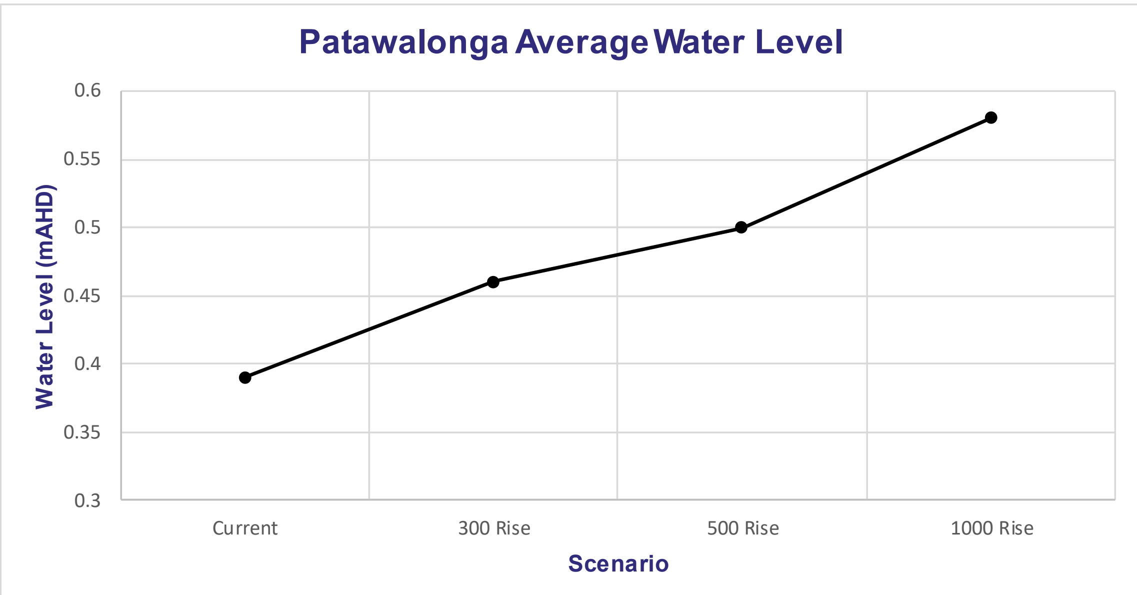


Figure 3.24 Average Water Levels in the Patawalonga

The data shown in Figure 3.24 indicate that even with sea level rise, the average Lake level will remain within DEWNR's target water level range of 0.1 mAHD to 0.6 mAHD.

The Patawalonga is a closely managed system, with DEWNR undertake pre-draining of the lake before large storm events and monitoring of lake levels during storm events. However, in such a regulated system, scenarios can arise where the lake may not be able to be drained effectively. Furthermore, smaller flood events (such as the 1 year ARI event that is being modelled for this investigation) are not always anticipated by operators as being problematic and requiring pre-draining.

Due to the above complexities, the top level of DEWNR's normal operating range (0.6 mAHD) has been adopted as a reasonable estimate of the initial water level for TUFLOW modelling of all of the sea level rise scenarios.

4 TUFLOW Modelling

4.1 Background

Floodplain modelling within TUFLOW was undertaken to determine the interaction between flood waters from the Western Region catchments and tide under various sea level rise scenarios. The following systems were selected for modelling as a part of Stage 2 of this Study (Tonkin, 2015c):

- Gillman System
- West Lakes System
- Patawalonga System
- Local catchments (Gilmore Road, Henley Beach Road, Iluka Place)

Due to the uncertainty surrounding modelling climate change, and the time scales over which predictions of changes in development and rainfall are being made, the floodplain modelling results should be treated as being indicative of broad-scale sea level rise induced trends in flooding. The objective of the modelling is to identify these flood impacts on a general scale and results should not be used as a detailed guide to localized flooding.

4.2 Tidal Regimes

Two different tidal regimes were used in the modelling; the Mean High Water Springs tide (MHWS) cycle and the 100-year ARI tide cycle.

The MHWS tide cycle was used in conjunction with modelling of 100-year ARI flood event to investigate the impacts of such an event in conjunction with an 'average' (but still reasonably high) tide.

The 100-year ARI tide cycle was modelled in conjunction with a 1-year ARI storm event to investigate the impacts of such a tide event, in combination with a small amount of rainfall.

The above combinations of flooding and tide provide a balanced modelling approach between accounting for potential rainfall and tidal interactions without creating an overly extreme event combination of excessively high tide levels combined with a 100-year ARI storm event.

The MHWS tidal parameters used in the modelling are provided in Table 4.1 below. The 100-year ARI tide cycle was modelled based tide curves from the Port Adelaide Seawater Flooding Study (Tonkin, 2005a). This combines a 100-year astronomical tide with storm surge to give a 100-year storm surge tide.

Table 4.1 Mean High Water Springs Tidal Cycle Modelling Parameters

Parameter	Unit	MHWS
Peak Water Level	mAHD	1.02
Mean Water Level	mAHD	0
Amplitude	m	1.02
Period	hrs	12.4

4.3 Rainfall Intensities

The previous edition of Australian Rainfall and Runoff (ARR) was first published in 1987. In late 2016, a new edition of Australian Rainfall and Runoff (ARR) was released. This revision contains an update to rainfall Intensity-Frequency-Duration (IFD) data by the Bureau of Meteorology and advice relating to projected changes in rainfall intensity due to climate change.

4.3.1 2016 Intensity-Frequency-Duration Data

All previous hydrological and flood modelling of catchments within the Western Adelaide Region have been based on the 1987 IFD data. These hydraulic models form the base of models used in this investigation.

A comparison of design rainfall depths for 5-year and 100-year ARI events over a suite of durations is provided in Figure 4.1 below. The data is taken at the centroid of the Western Adelaide Region (Woodville) and shows that the updated (2016) rainfall depths are less than those derived in 1987 for events having durations of greater than 15 minutes.

The stormwater drainage systems likely to be impacted by rising sea levels such as the Gillman Ponding Basins, West Lakes and Patawalonga all have critical storm durations well in excess of 15 minutes. Given the lower IFD values derived in the most recent work by the Bureau of Meteorology, it is likely that if all other factors are equal, the previous hydrological investigations of these systems have marginally over-estimated inflow volumes and peaks.

Consequently, the use of 1987 IFD data is slightly conservative in estimation of volumes and peaks and will only have minimal impacts on results. As a result, the 1987 IFD data is suitable for TUFLOW modelling of the base (existing) flooding scenario of the Western Adelaide Region catchments.

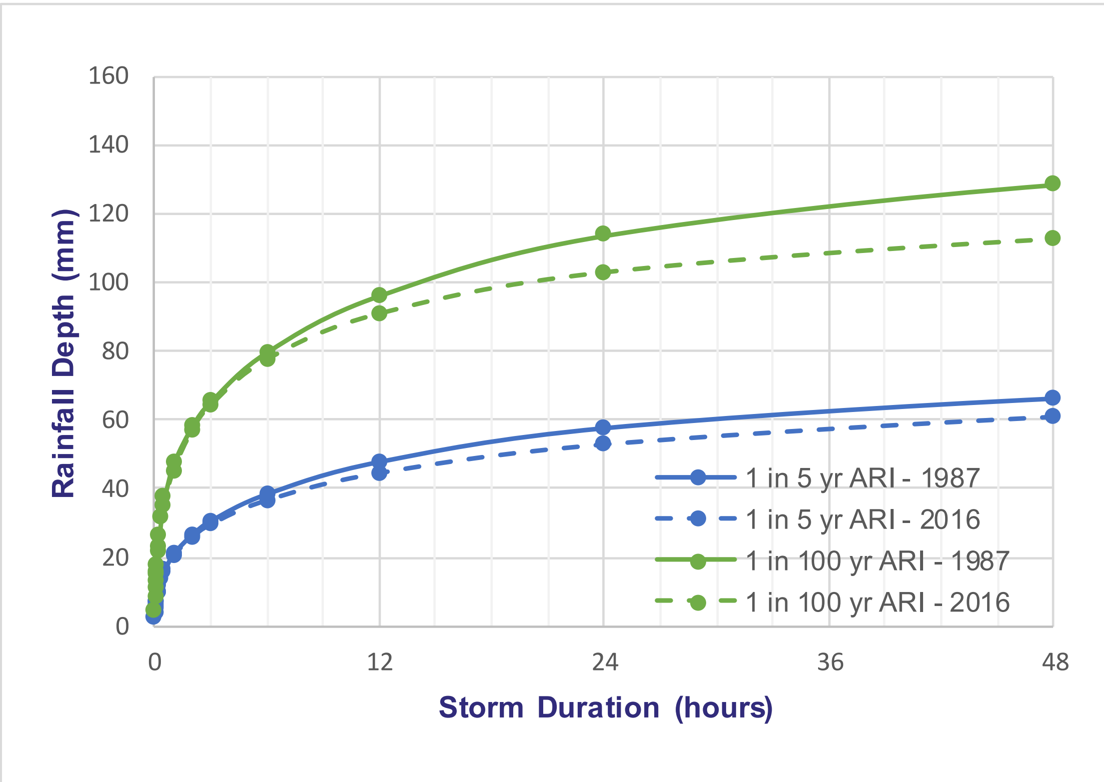


Figure 4.1 Comparison of 1987 and 2016 Design Rainfalls for Woodville

4.3.2 2016 Australian Rainfall and Runoff Analysis of Climate Change

Climate change modelling suggests that rainfall intensities in peak events will generally increase. The TUFLOW floodplain modelling of urban catchments is event-based modelling and inherently depends on peak rainfall intensity to accurately predict floodplain extents, velocities and depths. As a result, rainfall intensities will need to be adjusted according to ARR 2016 factors for each of the future scenarios considered in the TUFLOW modelling.

ARR 2016 specifies that rainfall IFD relationships will be likely impacted by climate change and planning should account for these changes. However, there is currently wide-spread uncertainty in the modelling of rainfall variations within the climate change models. There is more confidence in climate change projections of changes in temperature than changes in rainfall. Consequently, ARR 2016 currently recommends an increase of 5% in rainfall intensity per °C of localized warming.

ARR 2016 contains a data tool, which returns the current climate change projections relating to temperature for a given location. The centroid of the Western Region catchments (Woodville) was entered into this tool to gain the local climate change intensity factors which were used in the modelling. These are outlined in Figure 4.2 below.

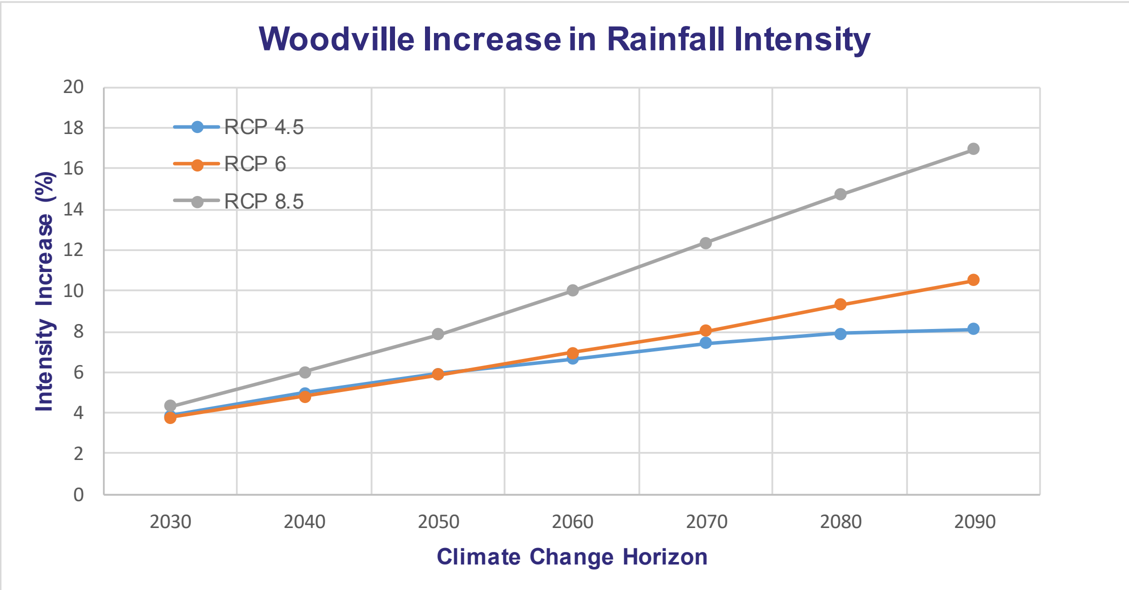


Figure 4.2 ARR 2016 Climate Change Intensity Adjustment for Woodville

In order to select the final rainfall adjustments, each sea level rise scenario needs to be linked to a time frame such that a rainfall adjustment factor can be chosen from Figure 4.2 above. This relationship can be developed using the IPCC climate change Representative Concentration Pathways (RCPs) as outlined in Figure 4.3 below.

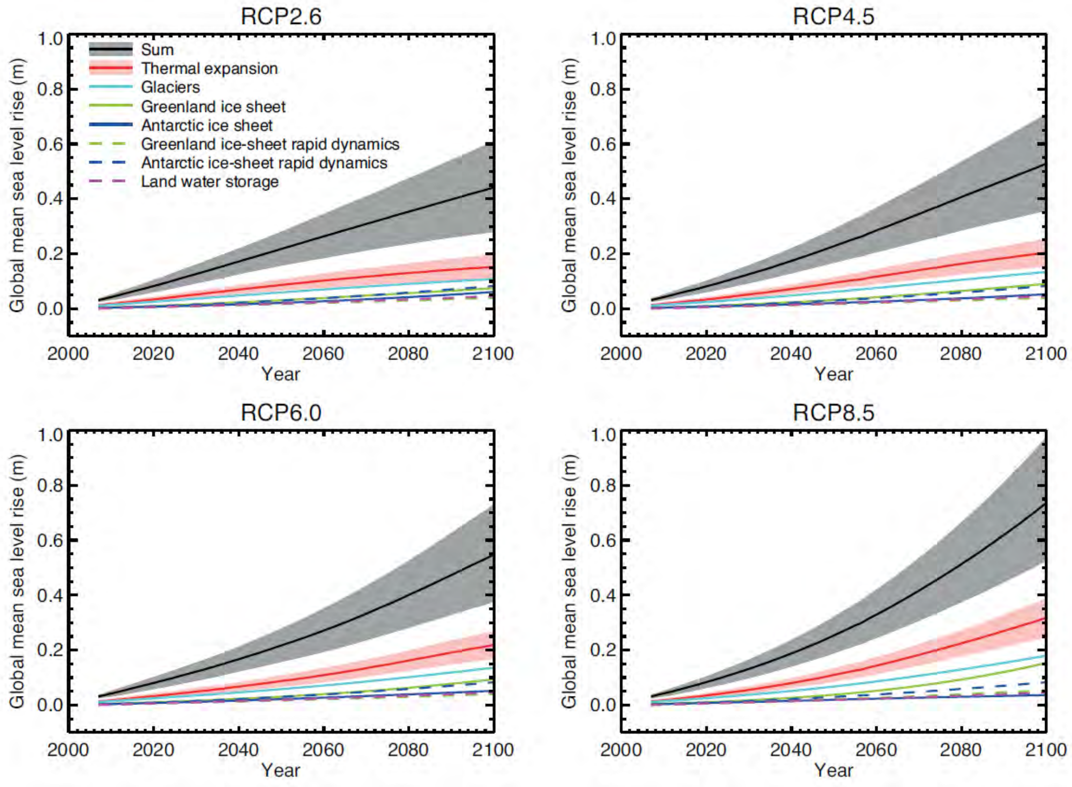


Figure 4.3 Projections of GMSL Rise (extracted from IPCC, 2013)

The Coast Protection Board have adopted a precautionary approach in which their requirements for planning for sea level rise. This approach is closely aligned with the upper bound of RCP 8.5 (this is the IPCC scenario relating to the most accelerated sea level rise). Using Figure 4.3 above to relate each sea level scenario to a future time horizon and then using Figure 4.2 to link the time horizon to a projected increase in rainfall, a relationship between each scenario and rainfall intensity factor can be developed. This is outlined in Table 4.2 below.

Table 4.2 Summary of Rainfall Intensity Factors for each Modelling Scenario

Scenario	Projected Year	Rainfall Intensity Factor
Current Sea Level	2020	0
0.3 m Sea Level Rise	2050	1.078
0.5 m Sea Level Rise	2070	1.124
1 m Sea Level Rise	2100	1.189

The modelling assumed that the increase in intensity directly correlated to the same increase in runoff. While this is not the case in all catchments, this assumption generally holds in relatively developed urban catchments. Considering the uncertainty around the current intensity adjustment factors and the variable effects of climate change in general, this approach provides a reasonable approach to undertaking a sensitivity analysis of potential increases in runoff due to increases in rainfall intensity brought about by climate change.

4.4 Catchment Imperviousness

Impervious areas within the various catchments modelled using TUFLOW are expected to increase due to development and will result in greater stormwater runoff.

Increases in impervious area adopted to model changes in peak flow due to ongoing development were the same as those used in the SWMM modelling as outlined in Section 3.8.3.

4.5 Hydrological Analysis

The Gillman, West Lakes and Local Catchments have previously been divided into subareas draining to each inlet of the underground drainage system. Hydrographs from each of these subareas were generated using the time-area method with an ILSAX type runoff model using subarea specific direct, supplementary and pervious area proportions and times of concentration. Losses applied to the pervious areas are shown in

Table 4.3 below. Rainfall data used for modelling flooding associated with the sea level rise scenarios was factored in accordance with data provided in Section 4.3.2.

Table 4.3 Summary of Loss Parameters

Parameter	Unit	Value
Paved (impervious) area depression storage	mm	1
Supplementary area depression storage	mm	1
Pervious area depression storage for urban areas (Initial loss, IL)	mm	45
Continuing loss	mm/hr	3

For the Patawalonga catchment, a RORB model was used to calculate inflows to the system from Brown Hill Creek and the Sturt River in a 1 yr ARI event. The model was derived from data contained in the Patawalonga Lake Level Frequency Study (AWE,2006). The remaining inflows for the Patawalonga model were calculated using lumped catchment DRAINS models for each of the main inflows. These models were based on ILSAX models of the Adelaide Airport and Cowandilla / Mile End Catchments prepared for the design of the Cowandilla – Mile End Drain Upgrade (Tonkin, 2004).

4.6 Modelling

4.6.1 Gillman TUFLOW Modelling

The aim of urban floodplain modelling in TUFLOW for this system was to determine the impact of sea level rise, increasing rainfall intensity and increasing initial water levels on flooding within the Gillman basins and upstream catchments.

Floodplain modelling of this catchment was previously undertaken for the Torrens Road Stormwater Management Plan (Tonkin, 2015a). This model was used for the current investigation, with adjustment of inflow hydrographs, initial water level and tidal boundary conditions to reflect the various climate change scenarios that were modelled.

The impact of possible development within the Gillman area was also modelled, to determine desirable development extents, required changes in the numbers of outlet gates and changes to the configuration of the system.

Modelling of each flood event was undertaken such that the tide was timed to rise with the rising water level in the basin system. This simulates the situation where the beginning of the main storm outflow coincides with the rise of the first high tide, a situation which is most likely to result in the highest flood level in the upstream storage.

The model was run with the 100-year ARI storm event in combination with a Mean High Water Springs tide cycle. As described above, the following four sea-level rise scenarios were considered:

- Current Sea Level
- 0.3 m Sea Level Rise
- 0.5 m Sea Level Rise
- 1 m Sea Level Rise

4.6.2 West Lakes TUFLOW Modelling

The aim of urban floodplain modelling in TUFLOW for this system was to determine the impact of sea level rise, increased rain intensity and increasing initial Lake water levels on flooding within West Lakes and the surrounding areas.

Urban floodplain modelling of West Lakes was undertaken by amalgamating five TUFLOW models of catchments contributing flows into West Lakes. These were previously completed for the City of Charles Sturt. These models include West Lakes (Tonkin, 2009), Port Road (Tonkin, 2005b) Trimmer Parade (Tonkin, 2005c), Meakin Terrace (Tonkin, 2005c) and Henley Grange (Tonkin, 2005c). Catchments for these models are shown in Figure 4.4 below.

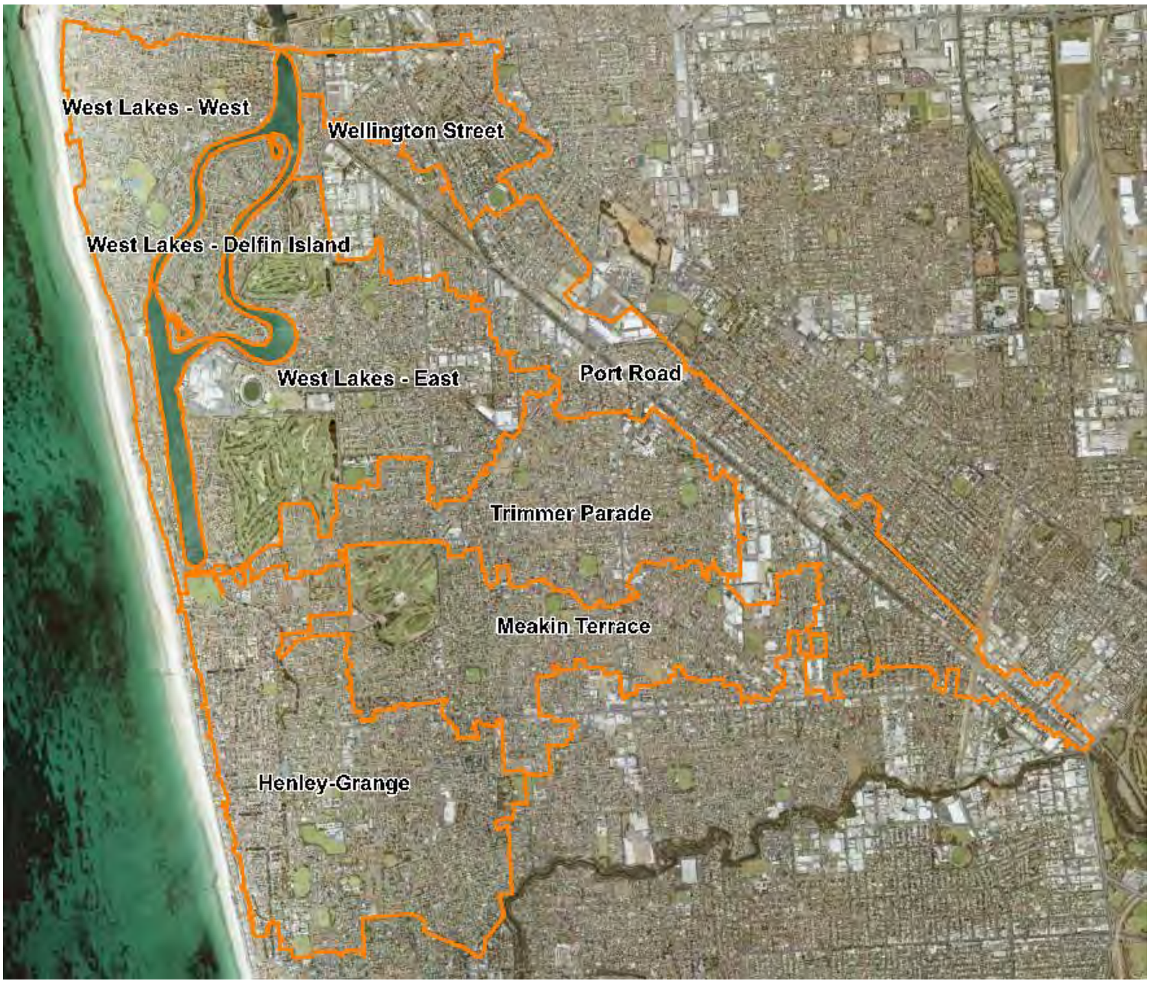


Figure 4.4 Main Catchments Contributing Stormwater to West Lakes

The Port Road stormwater system has undergone significant upgrades in recent years. These upgrades are continuing at the present time. The Port Road model used in this project incorporates a number of basins and pipe upgrades along Port Road as proposed in the Stormwater Management Plan for the catchment.

The City of Port Adelaide Enfield provided a DRAINS model of the Wellington Street catchment which discharges into West Lakes via a pumped outlet. Inflows to West Lakes from the Wellington Street pump were directly applied to the Lake to ensure the impact of flows from this catchment on flood levels within the Lake were modelled. Localized flooding within this catchment has not been modelled in TUFLOW.

West Lakes was assumed to have an invert of -2 mAHD in the absence of accurate lake bathymetry. This invert is based on the level of the outlet gates. The assumed invert will have no impact on projected flood levels as the initial water level determines the Lake's capacity to store stormwater runoff.

Modelling of each flood event was undertaken such that the tide was timed to rise with the rising water level in the Lake system. This simulates the situation where the beginning of the main storm outflow coincides with the rise of the first high tide, a situation which is most likely to result in the highest flood level in the upstream storage.

The model was run for a 100-year ARI storm event in combination with a Mean High Water Springs tide cycle. As described above, the following four sea level rise scenarios were considered:

- Current Sea Level
- 0.3 m Sea Level Rise
- 0.5 m Sea Level Rise
- 1 m Sea Level Rise

4.6.3 Local Catchments TUFLOW Modelling

The aim of urban floodplain modelling in TUFLOW was to determine the impact of sea level rise and increased rainfall intensity on flooding of localized low-lying catchments. The three catchments identified for investigation were low lying areas around Gilmore Road, Henley Beach Road and Iluka Place.

The low-lying area near Gilmore Road and Henley Beach Road lies within City of Charles Sturt Patawalonga Catchment model (Tonkin, 2012). The low-lying area near Illuka Place was analysed as part of the West Lakes modelling.

The model for each catchment was run for a 100-year ARI storm event in combination with a Mean High Water Springs tide cycle. The catchments were also analysed for a 1-year ARI storm in combination with a 100-year ARI tide cycle. Storms ranging from a 1 hour to a 9 hour duration were considered.

The following four sea-level rise scenarios were considered:

- Current Sea Level
- 0.3 m Sea Level Rise
- 0.5 m Sea Level Rise
- 1 m Sea Level Rise

4.6.4 Patawalonga TUFLOW Modelling

The aim of modelling using TUFLOW for this system was to determine the impact of sea level rise, increased rain intensity and increasing initial water levels on flooding within the

Patawalonga system and surrounding areas. Flood modelling of the Patawalonga was undertaken using inflows from the catchments shown in Figure 4.5 below.

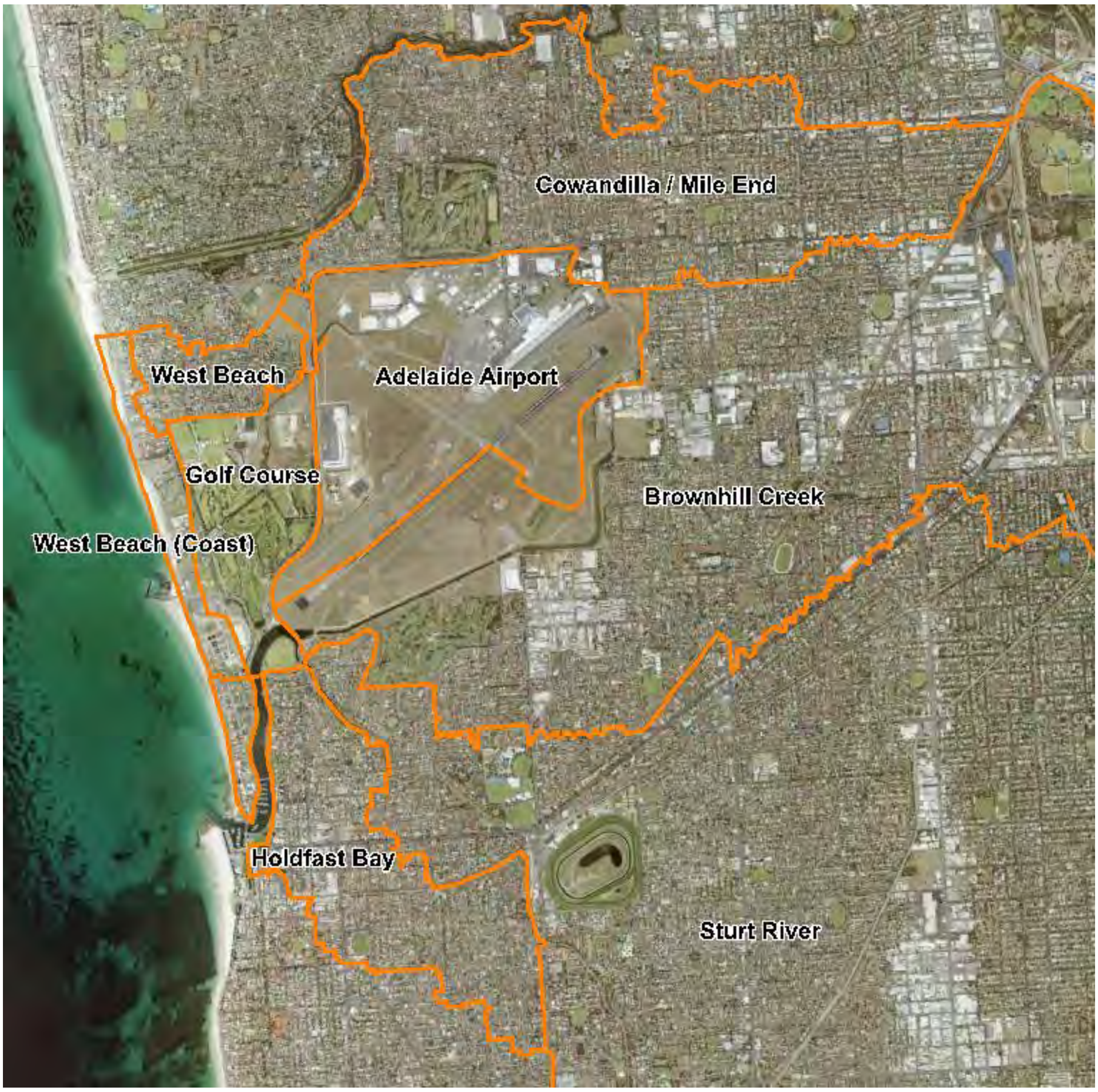


Figure 4.5 Main Catchments Contributing Stormwater to the Patawalonga

The TUFLOW model of the Patawalonga covered the urban catchments draining directly into the Lake from the City of Holdfast Bay. The model extended north to cover areas within the suburb of West Beach, as well as the Cowandilla Mile-End outfall downstream of Sir Donald Bradman Drive. The most eastward extent of the model was along Brown Hill Creek to the drop weir at Morphett Road.

Inflow hydrographs from the main upstream catchments were applied at the boundaries of the model at Donald Bradman Drive (Cowandilla – Mile End system), Morphett Road (Brown Hill Creek system), the outfall channels from the Airport and at the upstream end of the Sturt River weir (Sturt River system).

The model included walls along the northern side of the Mile End-Cowandilla Drain upstream of West Beach Road (top level 3.0 mAHD), as well as the recently constructed West Beach Ponding Basin and pumps.

The Patawalonga Lake was assumed to have an invert of -1.8 mAHD in the absence of accurate lake bathymetry. This level was based on design drawings for the Lake.

The behaviour of the Patawalonga Lake is different to the systems at Gillman and West Lakes, both of which have significant storage to buffer the effects of a small flood in combination with an extreme tide. The peak flood levels in these systems are more likely to be caused by large floods in combination with moderate tides, the modelling of which has been described above. Due to the lack of storage, the Patawalonga, is likely to be most severely impacted by an extreme tide in combination with a small amount of rainfall.

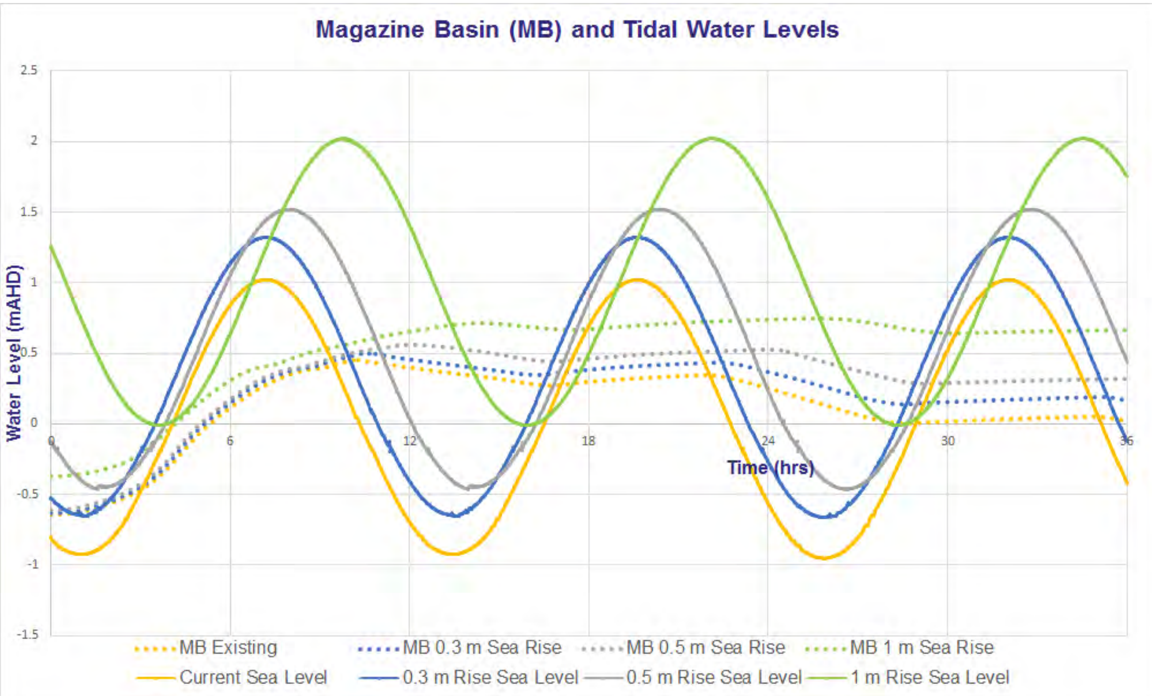
To simulate the effects of such an event, the TUFLOW model was run for a 1-year ARI storm event in combination with a 100-year tide cycle. Storms ranging from a 1 hour to a 36 hour duration were considered in combination with the following sea-level rise scenarios:

- Current Sea Level
- 0.3 m Sea Level Rise
- 0.5 m Sea Level Rise
- 1 m Sea Level Rise

4.7 Results

4.7.1 Gillman System

The TUFLOW modelling has indicated that a 36 hour duration storm will produce the peak water level in the Gillman Basins for the 100-year ARI event. Figure 4.6 below shows the modelled relationship between the sea level, Magazine Creek wetland water level and Magazine Creek Basin water level in the critical event.



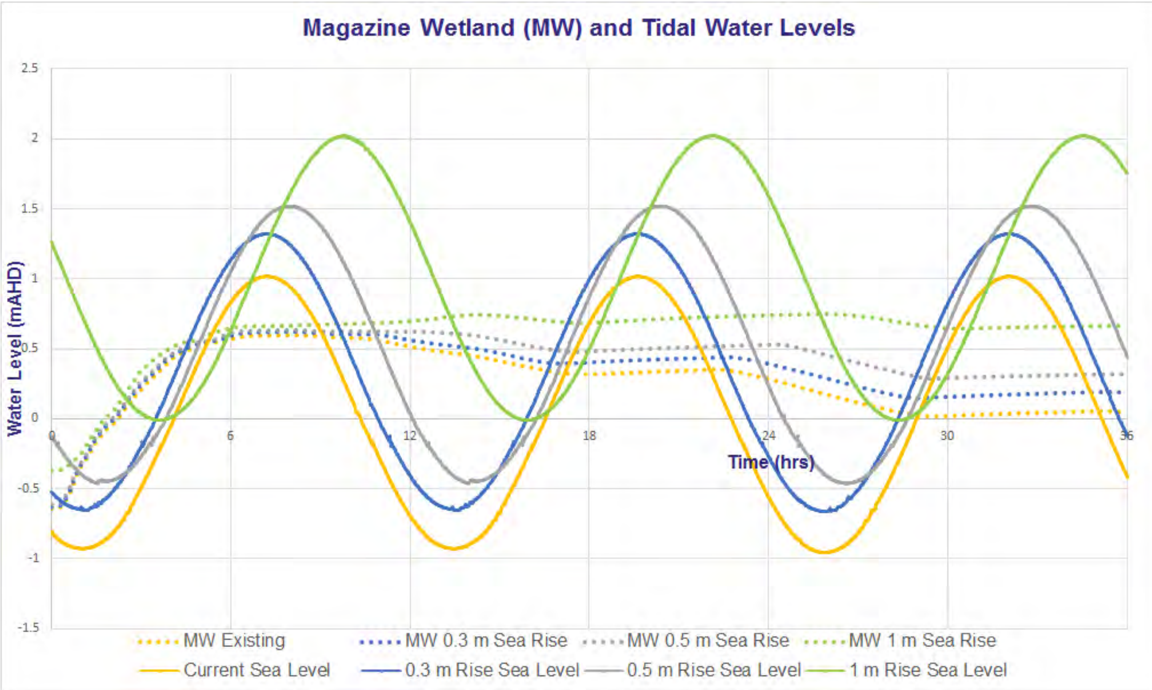


Figure 4.6 Gillman Stormwater - Tide Interaction - 36hr event

Data from Figure 4.6 was analysed to extract the peak water level reached in the Magazine Creek wetland and the Magazine Creek basin under the various sea level rise scenarios investigated. This data is shown in Figure 4.7 below. Of note is the current difference in peak water level in both basins. Peak flood levels in the Magazine Creek wetland will govern flooding in the upstream catchment. The modelling has shown that the peak flood level reach in the wetland is relatively unaffected by sea level rises up to 500 mm, with most of the impact of these rises in sea level being taken up by increasing flood levels in the Magazine Creek Basin downstream of the wetland.

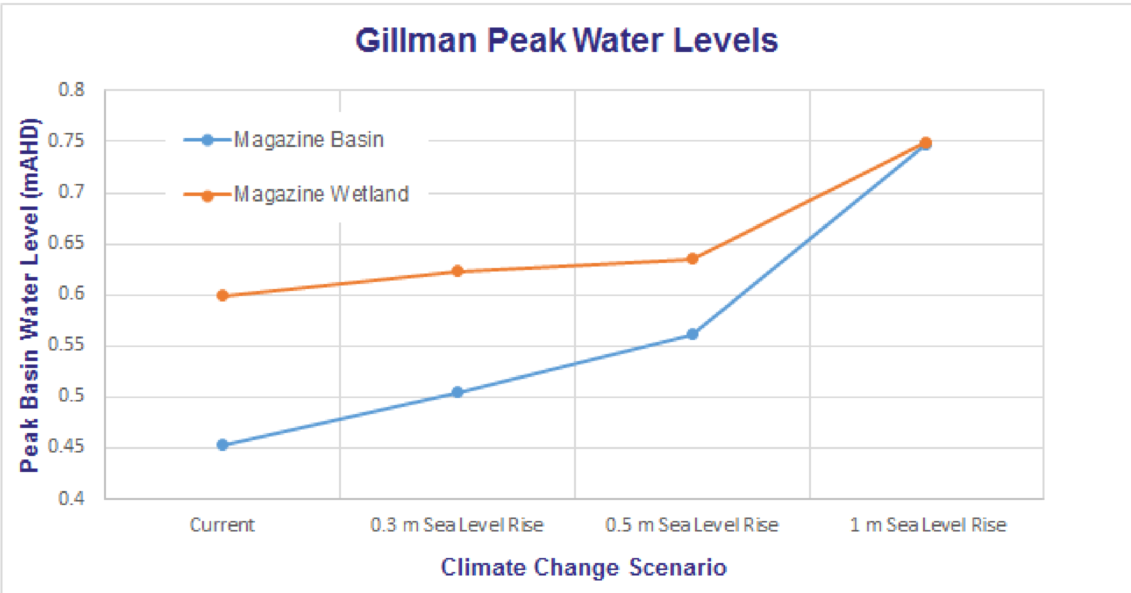


Figure 4.7 Sea Level Rise Impacts on 100-year ARI Gillman Peak Water Levels

For sea level rises above 500 mm, the impact on Magazine Creek wetland flood levels is more significant. The modelling has indicated that 1 metre of sea level rise will result in the 100-year ARI peak water level in the Magazine Creek Basin to rise by 300 mm and the 100-year ARI peak water level in the Magazine Creek wetland to rise by 150 mm.

The higher 100 year ARI flood level in the Gillman system will cause some increased flooding upstream of the basins. Appendix A contains flood maps showing the impact of rising sea levels on flooding around the Gillman basin system.

Under all the scenarios investigated, flood levels in the Range wetland and further upstream are relatively unaffected by sea level rise, primarily due to their higher level and the fact that they are currently isolated from Magazine Creek by a dividing bank and blocked outlet pipe. The impact of unblocking the existing outlet was investigated and found to have a minimal impact on 100 year ARI flood levels due to its relatively limited capacity.

4.7.2 Gillman Development

Development of the Gillman area has been proposed including filling within the area currently used for flood storage. Investigations have previously been undertaken for Renewal SA to examine the impact of this development on flood levels and to develop a strategy to mitigate these impacts. The proposed management strategy involved:

- Limiting the extent of filling within the current ponding areas;
- Upgrading the Magazine Creek outlet gates and improving the capacity of the channel downstream of the Magazine Creek wetland;
- Separating the Magazine Creek and Range Basins to allow floodwaters to pond to a greater level in the Range Basin;
- Constructing a new outlet for the Range Basin

These works are described in the current Gillman Masterplan prepared by Renewal SA. At the time this strategy was developed, it had been assumed that the starting water level in the Magazine Creek system would be unaffected by sea level rise.

Work undertaken for this current Study has shown that average water levels in the Gillman system are likely to increase as a result of sea level rise (refer Section 3.12.1). The proposed management strategy has therefore been reviewed by adjusting the proposed maximum extents of filling to create additional flood storage to offset this increase. Modelling of the adjusted extents of filling was undertaken in TUFLOW for the various sea level rise scenarios, with the peak water level plotted in Figure 4.8 below.

The maximum extents of filling and gate upgrade requirements as determined by the modelling is outlined in Section 6.2.1 below with the other climate change mitigation options. With these filling and gate upgrade constraints, all sea level rise scenarios up to a 1 m increase will have negligible or no adverse impact on water levels upstream of the Magazine Creek wetlands in comparison to the existing configuration.

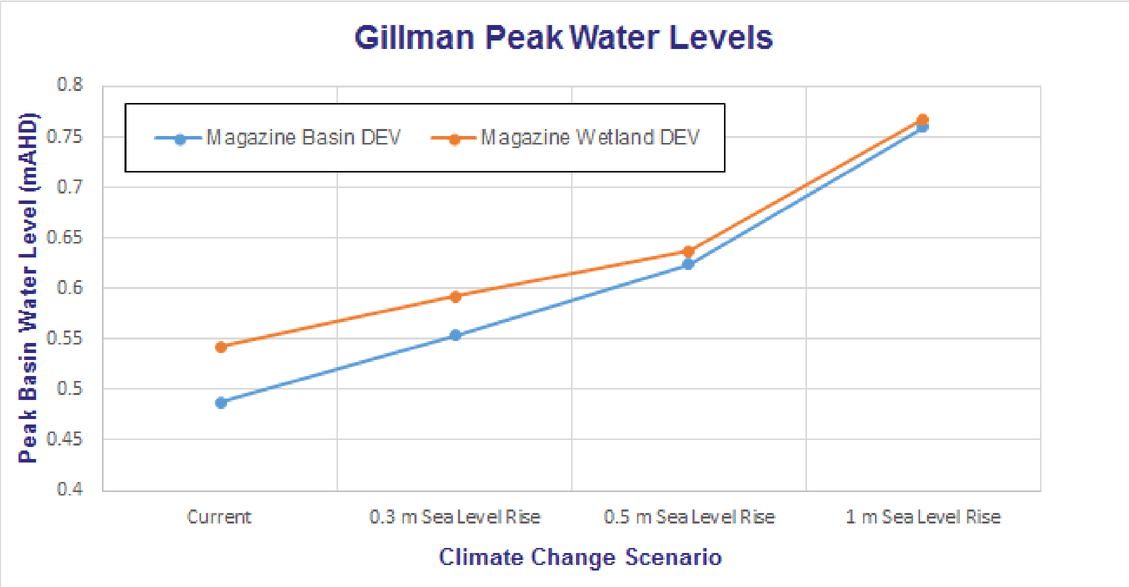


Figure 4.8 Sea Level Rise Impacts on 100-year ARI Gillman Peak Water Levels – With Gillman Development and Mitigation Strategies

4.7.3 West Lakes System

The TUFLOW modelling has indicated that a 36 hour duration storm will produce the peak water level in the West Lakes system for the 100-year ARI event. Figure 4.9 below shows the modelled relationship between the sea level and West Lakes level in the critical event.

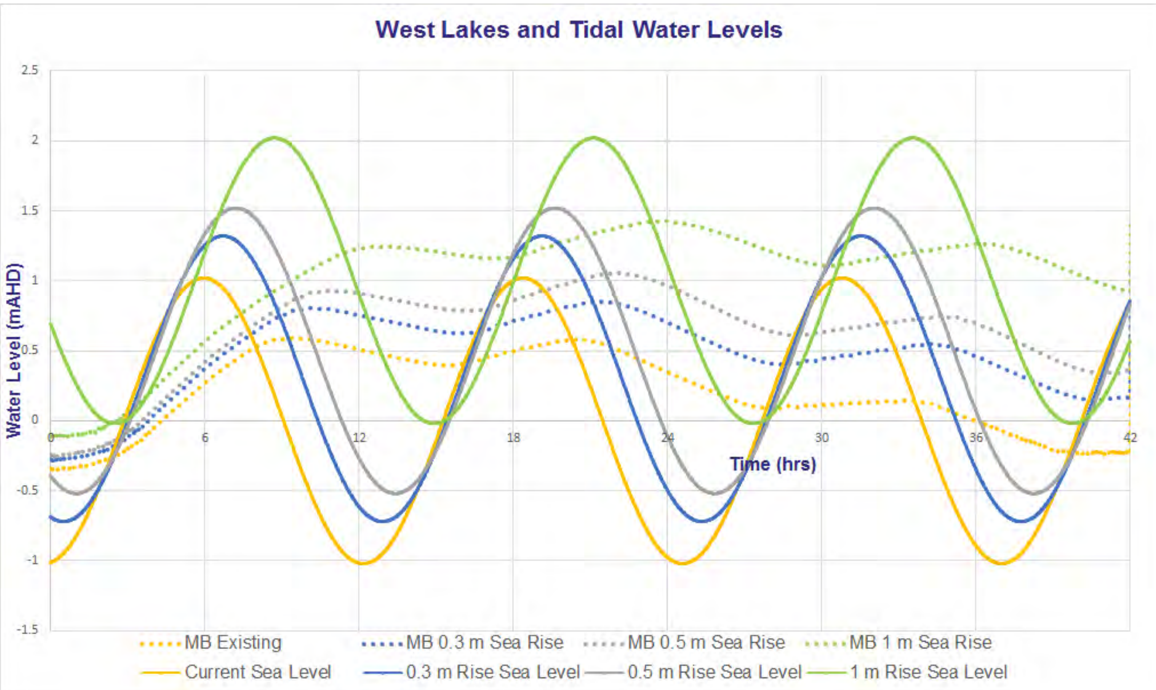


Figure 4.9 West Lakes Stormwater – Tide Interaction – 36hr event

Figure 4.10 below indicates the peak 100 year ARI water level reached in West Lakes in the critical event for each of the sea level rise scenarios considered. The modelling has indicated that a metre of sea level rise causes the 100-year ARI peak water level in West Lakes to rise by 840 mm.

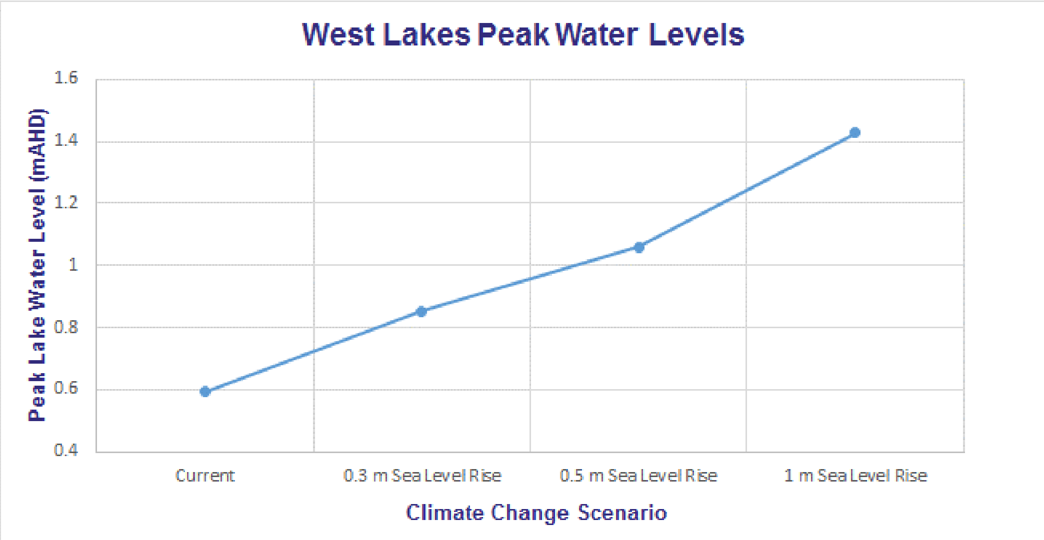


Figure 4.10 Sea Level Rise Impacts on 100-year ARI West Lakes Peak Water Levels

The higher flood levels in West Lakes will cause increased flooding around the Lake, especially for the 1 m sea level rise scenario. The lowest point around the Lake is at a level of approximately 1.2 mAHD. Appendix B contains flood maps showing the impact of the higher flood levels.

4.7.4 Local Catchments

Modelling of the Henley Beach Road and Gilmore Road catchments indicated that in the scenario of the 100-year tide combined with 1-year ARI storm, there is a small increase in flooding, mainly on East Terrace with 1 m of sea level rise. The flood maps and a summary of modelling scenarios are provided in Appendices C.1 to C.4.

Modelling of the Henley Beach Road and Gilmore Road catchments indicated that in the scenario of a MHWS tide cycle combined with 100-year ARI storm, there is a moderate increase in flooding, mainly along Military Road and East Terrace. The flood maps and a summary of modelling scenarios are provided in Appendices C.5 to C.8.

Modelling of the Iluka catchment indicated only small increases in flooding for the various scenarios examined. The flood maps and a summary of modelling scenarios are provided in Appendices C.9 to C.16.

4.7.5 Patawalonga System

The TUFLOW modelling has indicated that for current conditions, a 3 hour duration storm event will produce the peak water level in the Patawalonga Lake for the 1-year ARI event coinciding with a 100 year ARI tide. In all three sea level rise scenarios, the Lake capacity will be exceeded with a 100 year ARI tide coinciding with a 1 year ARI rainfall event. The critical storm duration for these scenarios was a 12 hour event.

Figure 4.11 below demonstrates the modelled relationship between sea level and the Patawalonga Lake water level in the 12 hour event. For the 3 hour event with current sea levels, a slightly higher peak water level in the lake of 2.14 mAHD was be produced (cf 2.01 mAHD for the 12 hour event).

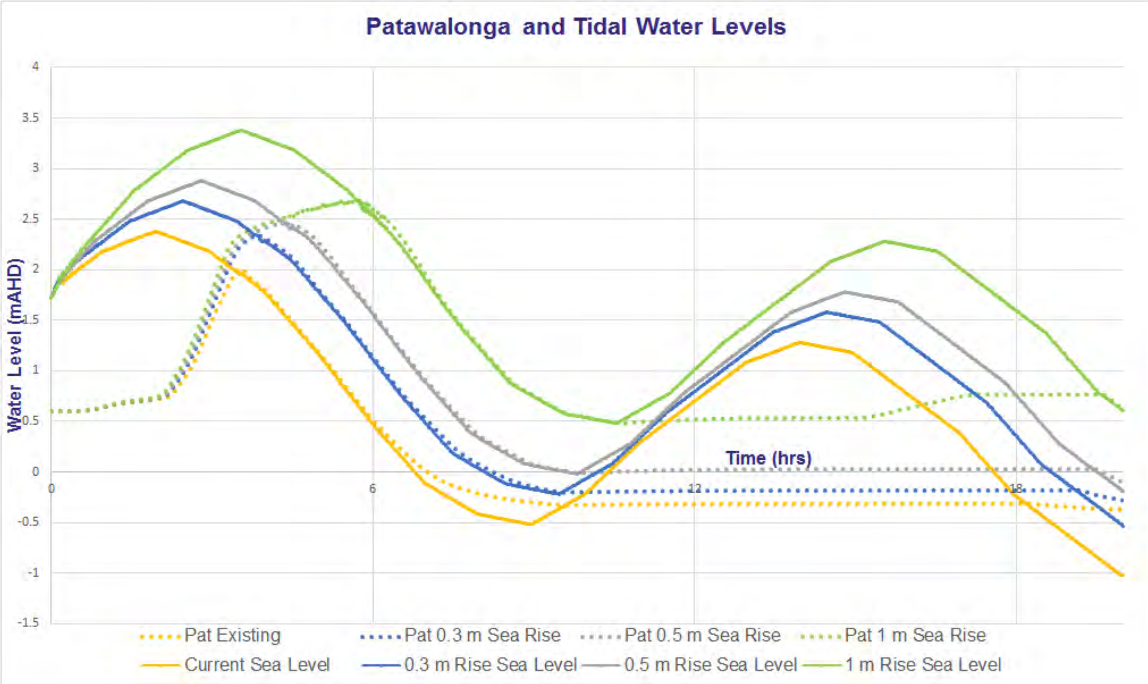


Figure 4.11 Patawalonga Lake Stormwater - Tide Interaction – 3hr event

Figure 4.12 below provides the peak water levels in the Patawalonga Lake for the various sea level rise scenarios analysed using TUFLOW. The modelling has indicated that 1 metre of sea level rise will cause the peak water level in the Patawalonga to rise significantly if a 100 year ARI tide were to coincide with a 1 yr ARI rainfall event. Such an event will cause extensive flooding within Glenelg North, east of the Sturt River, within the City of Holdfast Bay.

Areas within the City of West Torrens appear to be less effected by the increase, with the greatest impact being within the West Beach Golf Course.

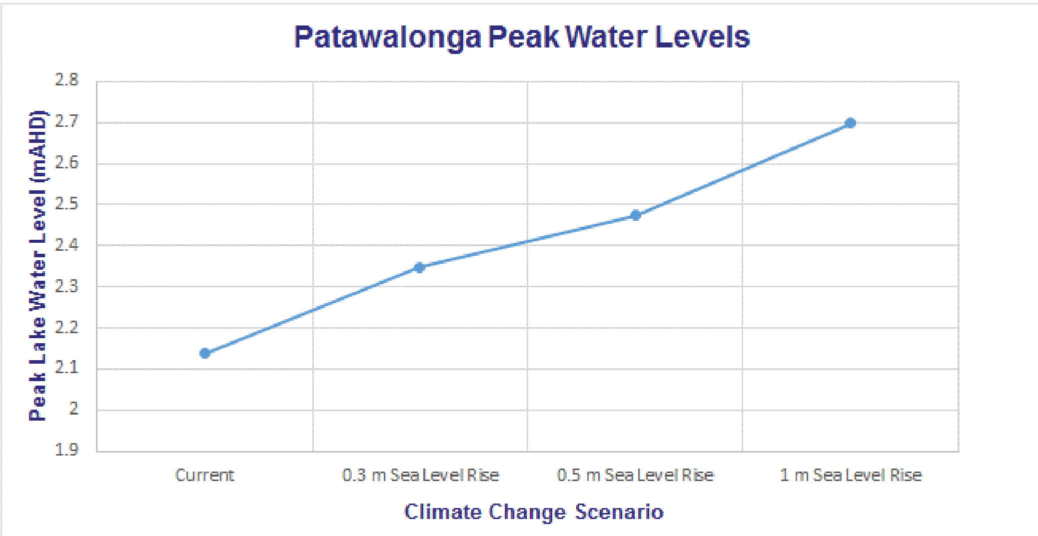


Figure 4.12 Sea Level Rise Impacts on Peak Patawalonga Flood Levels for a 100 yr ARI Tide in Combination with a 1 yr ARI Rainfall Event

Appendix B contains flood maps and a summary of the modelling scenarios showing the impact of sea level rise on flooding around the Patawalonga.

5 Extension of Tidal Inundation Mapping

5.1 Background

Extension of tidal inundation mapping from the Port Adelaide Seawater Flooding Study (Tonkin, 2005a) was undertaken to project inundation levels into the City of Charles Sturt. This process was undertaken by determining tidal inundation levels just north of the council boundary and then projecting these uniformly across the City of Charles Sturt area. This type of analysis will produce a conservative assessment of flooding caused by high tide as it does not take into account the attenuation of flows due to storage effects.

The Port Adelaide Seawater Flooding Study modelled three sea level rise scenarios as listed below and shown in Figure 5.1.

- S1 (yellow): 0.3 m sea level rise, 50 years of land subsidence
- S3 (green): 0.5 m sea level rise, 100 years of land subsidence
- S4 (red): 0.88 m sea level rise, 100 years of land subsidence.

Figure 5.1 Excerpt from Port Adelaide Tidal Inundation Mapping (Tonkin 2005a)

The S1 scenario results suggest that overland flows in this event would not result in significant flooding into the City of Charles Sturt. Under this scenario, inundation appears to be contained to the area north of Bower Road and east of Old Port Road, although some overflow could occur near the intersection of Old Port Road and Frederick Road. The S3 scenario results suggested that north of Bower Road, the inundation would reach a level of 2.2 mAHD. In areas east and west of the West Lakes outlet, floodwaters at such a level will be able to cross into the City of Charles Sturt. The resulting extension of the flood inundation map using S3 flood levels can be found in Appendix E.

It is noted that ongoing development along the Inner Harbour waterfront is being constructed at a level of 3.2 mAHD. This development will act to partly contain high tides to the Port River and forms part of a sea defence system contemplated in the Port River Seawater Flooding Study to provide protection from extreme tide events, including the impact of sea level rise. The current extent of this development will not prevent the breakout of high tides as shown on the mapping.

6 Adaptation Options

The final part in this investigation has involved the identification of adaptation options to alleviate the adverse effects of climate change on sea water and stormwater flooding. These options have been divided into the following categories:

- Protection – relates to existing, directly threatened assets requiring safeguarding from adverse effects of climate change impacts on sea water and stormwater flooding
- Planning – relates to future development requiring controls to mitigate adverse effects of climate change impacts on sea water and stormwater flooding
- Monitoring – relates to existing or future assets requiring regular checking to progressively assess any potential adverse effects of climate change impacts on sea water and stormwater flooding

The adaptation options are presented below for each Council area.

6.1 Protection Options - City of Port Adelaide Enfield

6.1.1 Magazine Creek Tidal Gate Upgrade

Due to the adverse effects of climate change on the dynamics of the Gillman basin system, the Magazine Creek tidal gates will require upgrading. Incorporating increased rainfall intensities, higher basin initial water levels and higher sea levels due to climate change, the peak 100 year ARI water level at the upstream end of the Magazine Wetland is expected to rise as outlined in Figure 4.7. This will result in an increase in flood risk in the upstream catchment.

From previous site investigations, it appears that the condition of the Magazine Creek Tidal Gates is deteriorating. In the future, these gates will require replacement from a structural perspective as well as a capacity perspective.

Figure 6.1 Existing Gillman Tidal Gates

Three potential *trigger points* are envisaged for the upgrade of the Magazine Creek tidal gates.

The gates should be upgraded when:

- The gates require replacement from a structural perspective. An assessment of any potential required works and timeframes should be undertaken relatively soon as part of this protection option.
- The Gillman site is developed. Any development of the Gillman site which involves filling of the flood storage will require expanding the tidal gates to offset potential storage losses. This is further discussed in Section 6.2.1.
- The increase in Magazine Wetland water levels brought about by rising sea level causes an increase in upstream flood risk as indicated in Figure 4.7. For all scenarios up to the 0.5 m sea level rise, the increase in flood risk in a 100 year ARI event is relatively small, with the Magazine Wetland water level rising by under 50 mm. However, in the 1 m sea level rise scenario, the Magazine Wetland water level increases by approximately 150 mm. It is proposed the gate upgrade occurs before the increase in peak Magazine Wetland water levels exceeds 50 mm in a 100 year ARI event. Hence, once the mean sea level is measured to have risen by 300 - 500 mm (i.e. to the 2050 - 2070 level), a gate upgrade should be considered.

The following *timeframes* are assumed in alignment with the above trigger points as outlined in Table 6.1 below. The base year has been assumed as 2020. The timeframes have been linked to future dates using the analysis in Table 4.2.

Table 6.1 Summary of Potential Timeframes for Magazine Creek Tide Gate Upgrade

Trigger Point	Time Frame (years)	Date Range
Existing Gate Structural Assessment	1-5	2020 - 2025
Gate Replacement (Gillman Development)	5-10	2020 - 2025
Gate Replacement (Increase in flood risk)	30-50	2050 - 2070

The first action will be to undertake a structural assessment to ascertain the remaining life of the existing gates and whether they can be remediated. Depending on the results of this assessment, and the timing of development within Gillman, it may be appropriate to simply replace the existing gates (with provision for future expansion) or to undertake replacement with a partial increase in capacity (say to cater for 300 mm sea level rise with development of Gillman).

6.1.2 Port Adelaide Sea Wall

Inundation of properties by sea water flooding around the Port River has been previously modelled and investigated by Tonkin Consulting (Tonkin, 2005a). An outcome of these investigations was the identification of the need for upgrading the existing sea defences between Outer Harbour and Gillman to protect the area from tidal flooding. A subsequent more detailed investigation of proposed sea defences was undertaken which included an examination of land requirements, environmental considerations including protection and enhancement of the existing mangrove and samphire communities near the wall alignment, implications for planning policy and engineering requirements was undertaken with the outcomes contained in the Port Adelaide River Sea Wall Study (Tonkin, 2013).

A summary of the recommended seawall levels is found in Table 6.2 below.

Table 6.2 Summary of Required Sea Wall Levels

Sea Wall Protection Time Frame	Inner Harbor (mAHD)	Outer Harbor (mAHD)	Gillman (mAHD)
2050	3.4	3.3	3.7
2100	4.1	4	4.4

Inner Harbor seawall levels are slightly higher than Outer Harbor levels to account for Inner Harbor tidal amplification. Gillman seawall levels are recommended higher again to account for predicted long-term land subsidence.

It is understood that the City of Port Adelaide Enfield has implemented mechanisms within its Development Plan to ensure land is reserved for the construction of this wall in the future. However, responsibilities for funding any works and coordinating the construction have not been resolved.

Construction of the entirety of this seawall is critical to the protection of assets around both Inner Harbour and Outer Harbour in Port Adelaide as well as protecting the Gillman area and preventing sea water entering the City of Charles Sturt. A funding and construction plan needs to be developed between relevant stakeholders to ensure the full construction of the sea wall and hence protection of affected assets.

Recent and historical tidal flooding within the Port Adelaide Inner Harbor area, highlights the importance of establishing responsibilities for construction of the wall, particularly in this area. This option is therefore considered to be of high importance. Consequently, the *trigger point* has been assumed to have already been reached and the *timeframe* for funding arrangements to be finalized and works to be planned and begin should be in the 1-5 year timeframe, which correlates to 2020-2025.

6.2 Planning Options - City of Port Adelaide Enfield

6.2.1 Gillman Development

It is anticipated that the general area around the current Gillman basins will undergo significant development. This has the potential to significantly reduce the amount of storage within the basins. Consequently, based on modelling results from Section 4.7.2, any filling into the basin area associated with any development should be limited, the Gillman tidal gates should be upgraded at the Magazine Creek outlet, the Range and Magazine Creek basins should be separated and a new Range Creek outlet should be constructed.

Development extents in the Gillman area should not exceed the boundaries marked in Figure 6.2 below as determined by modelling undertaken as a part of this investigation. The development should also involve some channel works to improve flow through the area.

An upgrade of the existing outlet gates will be required. There are currently three rectangular tide gates at the Magazine Creek outlet which are 2.44 m wide,1.52 m high and 6 m long. Modelling has suggested that nine of the same sized gates will be required to offset the development impacts of encroaching into the existing basin area as outlined in Figure 6.2 above. Additionally, two new gates, 1.8 m wide by 0.9 m high, will be required at the new Range Creek outlet.

Any final development planning should involve modelling of proposed fill and upgraded gate systems to determine the extent of flood impact. There may be some scope to reduce gate upgrade requirements, depending on the final design of the development.

In addition to the above, the development will need to implement measures to provide protection from seawater flooding in accordance with the Coast Protection Board requirements. This would most logically involve the raising of the existing seawall along the northern boundary of the area.

The *trigger point* and *timeframe* for this planning option will be determined the rate of sale and development of the land.

Figure 6.2 Limit of Development within Gillman Site

6.2.2 Port Adelaide Sea Wall

Current planning regulations for developments around the Port River are based on recommended sea wall levels for a sea level rise scenario corresponding to the year 2050 as found in Table 6.2. However, existing regulations also ensure sufficient provision is made to allow sea defences to be modified to provide protection for up to 1 m sea level rise.

The main long-term planning consideration relates to the timeframe under which a higher sea wall defence level is chosen. The *trigger point* to raise the planning requirements for the sea wall above the 2050 level is recommended to be based on mean sea level. Once mean sea level rises up to 300 mm (i.e. to the 2050 level), a higher sea wall level is to be recommended by planners. Based on current modelling this would likely occur over a long-term *timeframe* of 10-30 years, in the years 2030 - 2050.

6.2.3 Floor Level Management

Floodplain maps for the area upstream of the Gillman basins have been produced as part of the Torrens Road Stormwater Management Study. These floodplain maps show flooding of low lying areas in the general area of Rosewater, upstream of the Magazine Creek wetland. Modelling undertaken for this investigation has indicated the potential for flood levels in this area to increase by up to 150 mm as a result of sea level rise.

It is proposed that flood levels for new development in this area should be set with a minimum floor level based on the currently predicted 100 year flood level, plus freeboard, plus an additional allowance of 150 mm to cater for the above increase.

6.2.4 Localized Flooding

While the adverse impacts of climate change on the water levels within the Gillman basin system can be mitigated by upgrades in the tidal gates, increased flash flooding of all catchments across the council area due to increased rainfall intensity needs to be considered in the long term. Consequently, as Stormwater Management Plans are revised the effects of increased rainfall intensity should be considered. This planning should involve a vulnerability and damage assessment of specific critical assets as part of any hazard analysis.

6.3 Monitoring Options - City of Port Adelaide Enfield

6.3.1 Gillman Culvert System

Currently the Gillman system has a pipe and flap gate at the downstream end of the Range Basin within the tidal wall as outlined in Section 3.9.1. However, it appears from site visits that this is currently blocked and will not allow any stormwater outflow.

It is recommended that better monitoring and maintenance is undertaken of the existing stormwater system, as well as of any development stormwater system. This will ensure the system will operate as designed which could potentially reduce flooding in the Gillman area. There is no recommended *trigger point* for this option as it should be implemented immediately, so the assumed *timeframe* for this option is around 1-5 years, in the years 2020 - 2025.

6.3.2 Stormwater Flow Monitoring

One of the most significant unknowns within the modelling, has been the estimation of the impact of increasing development on runoff. It is recommended that flow gauging stations be constructed on the Eastern Parade and Hanson Road drains to enable monitoring of changes in flow with time.

6.4 Protection Options - City of Charles Sturt

6.4.1 Water Quantity - West Lakes Tidal Gate Upgrade

Modelling has shown that increased rainfall intensities, rising average water levels and higher sea levels due to climate change, will increase the peak 100 year ARI flood level in West Lakes. The impact has been shown in Figure 4.10. This will result in an increase in flood risk in the upstream catchment.

In order to mitigate the impact of sea level rise on the peak 100 year ARI water level, an increase in size of the Bower Road outlet could be undertaken. Increasing the gate size will result in more water being able to be discharged from the lake during flood events when the tide is sufficiently low for outflows to occur. This could be used to offset the impact of higher tide levels, higher average lake levels and increased runoff associated with climate change.

The *trigger point* for investigation for the gate upgrade is recommended to be based on mean sea level. Once the mean sea level is measured to have risen by 300 mm (i.e. to the 2050 level), a gate upgrade should be considered by operators, as at this point the peak water level in West Lakes potentially will have risen by around 260 mm. This correlates to a lake peak water level of approximately 0.85 mAHD which is still well below the top of the lake. Based on current modelling this would likely occur over a *timeframe* beyond 30 years, in the years beyond 2050.

6.4.2 Water Quality - West Lakes Pumping Option

SWMM modelling of the long term behaviour of West Lakes as outlined in Figure 3.23 has demonstrated that flushing of the lake decreases to the point that with 1 m sea level rise, flushing will not occur. It is envisaged that installation of a pump combined with altered lake operating rules will be required to flush the lake.

It should be also noted that to assist in managing water quality issues, the operating level of West Lakes could be raised to improve the ability to carry out flushing into the sea. Such an option would decrease the lake storage available for flood storage. Pre-draining before large storms could help manage this, but the pre-draining may not be as effective with higher future sea levels. The flooding impacts associated with operating the lake at a raised level could be offset by an increase in gate size, to enable the Lake to be drained at a faster rate at low tide. This widening would be in addition to the widening required to offset flooding impacts from the rising sea level as discussed in Section 6.4.1.

The *trigger point* for dealing with water quality issues within West Lakes is uncertain on two fronts:

- Uncertainty surrounding the quantity of flushing within the lake currently as well as in the future under different climate change scenarios.
- Uncertainty around measurement of acceptable water quality in West Lakes. DPTI have suggested that phytoplankton levels could potentially be used as a measure of water quality (DPTI, 2014). Clarification of DPTI's measurement of acceptable water quality targets should be undertaken. If necessary DPTI should undertake a study to develop a framework and methodology to quantify water quality targets.

The *timeframe* for the installation of the pump, based on Figure 3.23 appears to be beyond the 30 year timeframe, which correlates to post-2050. This assumes the magnitude of flushing is not significantly decreased by a 0.3 m rise in sea level as, under this tidal regime, the tide still drops well below the low level of the West Lakes operating range.

However, studies relating to the clarification of the water quality trigger points in terms of flushing capacity and water quality should be undertaken in the next 1-5 years, during 2020-2025. This will provide a basis to adequately monitor the lake over the time period up to 2100 and determine the trigger point to plan, cost and upgrade the lake infrastructure with respect to a new pump and intake structure.

6.4.3 Port Adelaide Sea Wall

Construction of the Port Adelaide Inner Harbour sea wall as outlined in Section 6.1.2 will have some benefit to City of Charles Sturt as it provides protection against sea storm surges entering the City of Charles Sturt area. The City of Charles Sturt should be involved in stakeholder discussions relating to construction of this wall as outlined in Section 6.1.2.

6.5 Planning Options - City of Charles Sturt

6.5.1 Floor Level Management

The analysis suggests that assets around West Lakes will likely be able to be protected against the impact of up to a metre of sea level rise by upgrading the Bower Road gates to discharge stormwater in a 100 year ARI event as outlined in Section 6.4.1. Hence, no particular land use planning requirements are currently proposed for the West Lakes area.

6.5.2 Localized flooding

While the adverse impacts of climate change on the water levels within the West Lakes system can be mitigated by upgrades in the tidal gates, increased flash flooding of all catchments across the council area due to increased rainfall intensity needs to be considered in the long term.

Consequently, as Stormwater Management Plans are revised the effects of increased rainfall intensity should be considered. This planning should involve a vulnerability and damage assessment of specific critical assets as part of any hazard analysis.

6.6 Monitoring Options - City of Charles Sturt

6.6.1 West Lakes Water Quality

Overall, it appears that DPTI have an inspection and maintenance schedule for the management of the infrastructure and hydraulics of West Lakes. However, because water quality will likely become an issue over the long-term horizon, it should be ensured that monitoring and recording of the water quality in West Lakes is also undertaken regularly. This will provide data to assess any impacts of climate change on the water quality in West Lakes and provide the basis to determine when augmentation of the lake flushing is required.

6.6.2 Stormwater Flow Monitoring

One of the most significant unknowns within the modelling, has been the estimation of the impact of increasing development on runoff. It is recommended that flow gauging stations be constructed on the main outfall drains into the Lake (at Trimmer Parade and Port Road) to enable monitoring of changes in flow with time.

6.7 Protection Options - City of West Torrens

No specific protection options have been identified within the City of West Torrens as existing development in the Council area appears to be largely unaffected by the impacts of rising sea level.

6.8 Planning Options - City of West Torrens

6.8.1 Patawalonga Creek

A portion of the Patawalonga Creek land south of the suburb of West Beach is within Adelaide Airport. The Airport's 2014 Masterplan (AAL, 2014) has classified this area as the West Beach Precinct. This Precinct is zoned as an area for commercial development as well as an area reserved for a future parallel runway. A second area adjacent to Brown Hill / Keswick Creek is denoted as the Morphettville Precinct and is also been earmarked for future development

The floodplain maps in Appendix D indicate that parts of both these areas will become more susceptible to flooding with future increases in sea level. Any planning and development associated with this land should therefore ensure that consideration is given to setting floor levels (in particular) to provide protection from the impacts of these future increases as well as considering the impacts of loss of flood storage in this area on the ability to contain runoff from small rainfall events that may coincide with an extreme tide.

This planning should be undertaken as soon as possible to ensure future development is compatible with long-term sea level rise. The proposed timeframe for this work is 1-5 years, such that it will occur before 2025.

6.8.2 Glenelg North

The TUFLOW modelling has shown that extensive flooding outside of the Study Area could occur in Glenelg North as a result of a relatively small flood event in combination with an extreme tide and sea level rise.

This flooding cannot be addressed by enlarging the existing gravity driven outlets as it is caused by high tide levels preventing stormwater outflows, resulting in flooding of the low lying areas around the Patawalonga. The affected areas are outside of the area covered by the Adaptwest Climate Adaptation Plan, lying within the City of Holdfast Bay.

Flooding of this area under elevated tide conditions has previously been identified within the Coastal Catchments Stormwater Management Plan, prepared for the Cities of Holdfast Bay and Marion (Tonkin, 2014). The modelling undertaken as part of this current investigation should be provided to the City of Holdfast Bay to assist in the preparation of their Adaptation Plan.

6.8.3 Localized flooding

Increased flash flooding of all catchments across the West Torrens council area due to increased rainfall intensity needs to be considered in the long term. Consequently, as Stormwater Management Plans are undertaken the effects of increased rainfall intensity should be considered. This planning should involve a vulnerability and damage assessment of specific critical assets as part of any hazard analysis.

6.9 Monitoring Options – Patawalonga Lake

The Patawalonga Lake is currently managed by DEWNR. Extensive resources are currently directed at monitoring and managing the lake during large rainfall events. The current flow management and monitoring regime is able to track water levels within the Patawalonga system itself, but does not appear to have an accurate measurement of lake inflows. Consequently, upgrades and ongoing maintenance to the flow gauging at the main inlets to the lake is recommended to gain quality inflow data on which to base future works.

There is no recommended *trigger point* for this option as it should be implemented in the short term such that the improved data can be obtained for monitoring and analysis of the system over the next decades. Hence the assumed *timeframe* for this option is around 1-5 years, in the years 2020 - 2025.

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Appendix A

Gillman Flood Mapping

Appendix A.1 (Gillman Existing Scenario)

Gillman Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve - Existing
- Rainfall Intensity - existing
- 100 year ARI storm event
- Existing mean basin water level set as initial water level
- Storm Duration 1hr to 36 hr (36 hr critical for basin level)
- Results show existing flood impact of this event on the downstream end of the Torrens Road catchment. Flooding is caused in the immediate catchment upstream of the basins where water is unable to enter the drainage systems. Flooding also occurs in the existing Gillman Basin system which stores stormwater until it can discharge to sea. Due to the size of the basin system and upstream catchment, the greatest flooding extents are caused by high volume events (critical event is 36 hours) which take over two tide cycles for the system to start to significantly lower stormwater levels in the basin system.
- Associated mitigation option: Magazine Creek Tidal Gate Upgrade (Section 6.1.1)

Appendix A.2 (Gillman 2050 Scenario)

Gillman Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve - 0.3 m tide rise
- Rainfall Intensity - 2050
- 100 year ARI storm event
- 2050 mean basin water level set as initial water level
- Storm Duration 1hr to 36 hr (36 hr critical for basin level)
- Results show a slight increase in flood impact of this event with a 0.3 m tide rise on top of the existing MHWS Tide Curve. Both the basin and the Torrens Road catchment directly upstream have slightly greater flood extents. This is because the higher tide prevents stormwater exiting the basin for a longer period, and hence more volume is required to store this water. As a result, the basin peak water level is slightly higher. Higher water levels in the basin system cause slightly more flooding in catchments around the basin as water cannot drain away as quickly. It should be noted there will also be some more flooding in the upper catchment due to the increase in rainfall intensity in this scenario.
- Associated mitigation option: Magazine Creek Tidal Gate Upgrade (Section 6.1.1)

Appendix A.3 (Gillman 2070 Scenario)

Gillman Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve – 0.5 m tide rise
- Rainfall Intensity - 2070
- 100 year ARI storm event
- 2070 mean basin water level set as initial water level
- Storm Duration 1hr to 36 hr (36 hr critical for basin level)
- Results show a noticeable increase in flood impact of this event with a 0.5 m tide rise on top of the existing MHWS Tide Curve. Both the basin and the Torrens Road catchment directly upstream have slightly greater flood extents. This is because the higher tide prevents stormwater exiting the basin for a longer period, and hence more volume is required to store this water. As a result, the basin peak water level is slightly higher. Higher water levels in the basin system cause slightly more flooding in catchments around the basin as water cannot drain away as quickly. It should be noted there will also be some more flooding in the upper catchment due to the increase in rainfall intensity in this scenario.
- Associated mitigation option: Magazine Creek tidal gate upgrade (Section 6.1.1)

Appendix A.4 (Gillman 2100 Scenario)

Gillman Floodplain Model with:

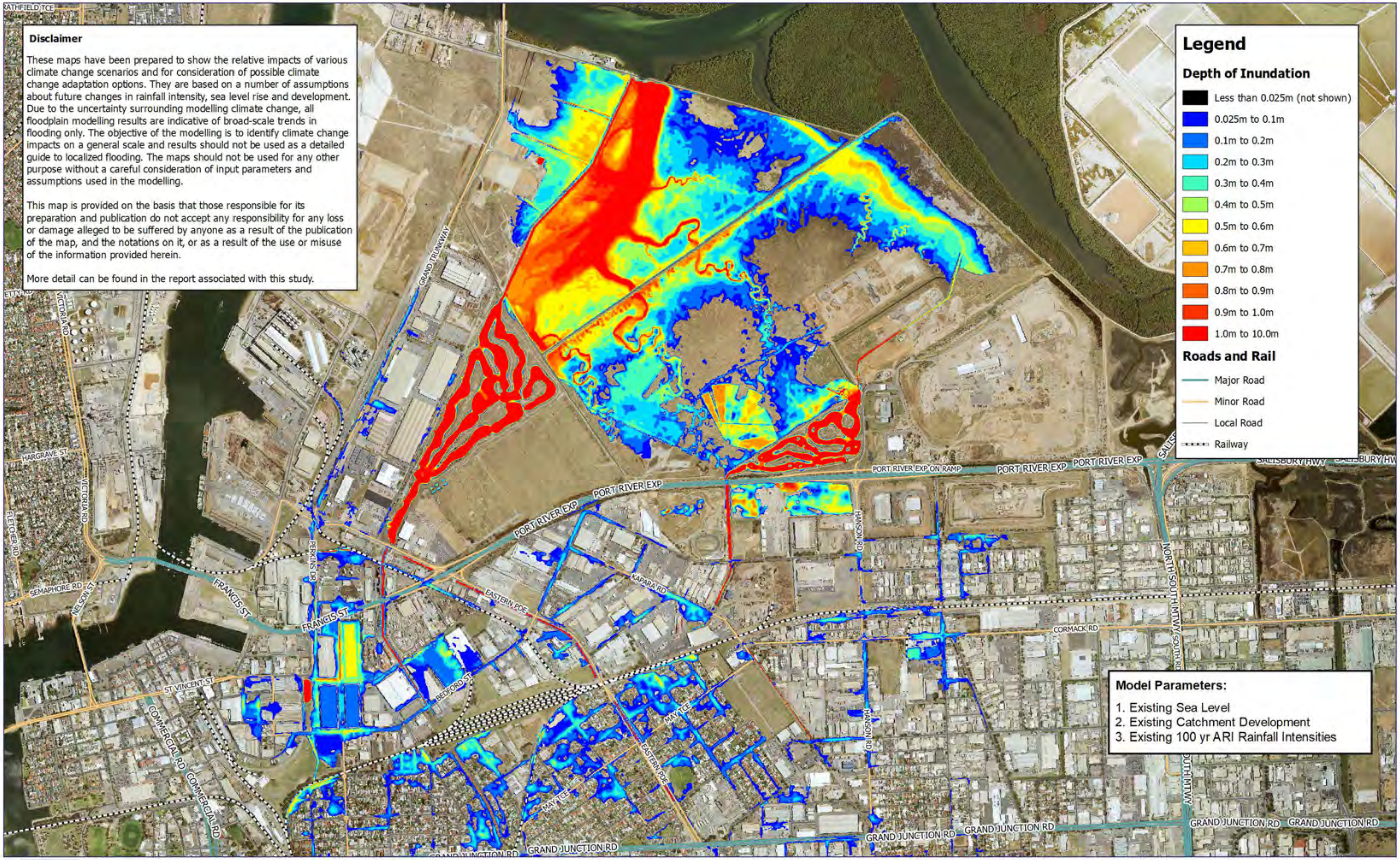
- Mean High Water Springs (MHWS) tide curve – 1 m tide rise
- Rainfall Intensity - 2100
- 100 year ARI storm event
- 2100 mean basin water level set as initial water level
- Storm Duration 1hr to 36 hr (36 hr critical for basin level)
- Results show a moderate increase in flood impact of this event with a 1 m tide rise on top of the existing MHWS Tide Curve. Both the basin and the Torrens Road catchment directly upstream have slightly greater flood extents. This is because the higher tide prevents stormwater exiting the basin for a longer period, and hence more volume is required to store this water. As a result, the basin peak water level is slightly higher. Higher water levels in the basin system cause slightly more flooding in catchments around the basin as water cannot drain away as quickly. It should be noted there will also be some more flooding due to the increase in rainfall intensity in this scenario.
- Associated mitigation option: Magazine Creek Tidal Gate Upgrade (Section 6.1.1)

Disclaimer

These maps have been prepared to show the relative impacts of various climate change scenarios and for consideration of possible climate change adaptation options. They are based on a number of assumptions about future changes in rainfall intensity, sea level rise and development. Due to the uncertainty surrounding modelling climate change, all floodplain modelling results are indicative of broad-scale trends in flooding only. The objective of the modelling is to identify climate change impacts on a general scale and results should not be used as a detailed guide to localized flooding. The maps should not be used for any other purpose without a careful consideration of input parameters and assumptions used in the modelling.

This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damage alleged to be suffered by anyone as a result of the publication of the map, and the notations on it, or as a result of the use or misuse of the information provided herein.

More detail can be found in the report associated with this study.



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Job Number:	2014.0329
Filename:	2014.0329GQ011_GillmanMapping_02
Revision:	C
Date:	07/02/2018
Drawn:	PDS

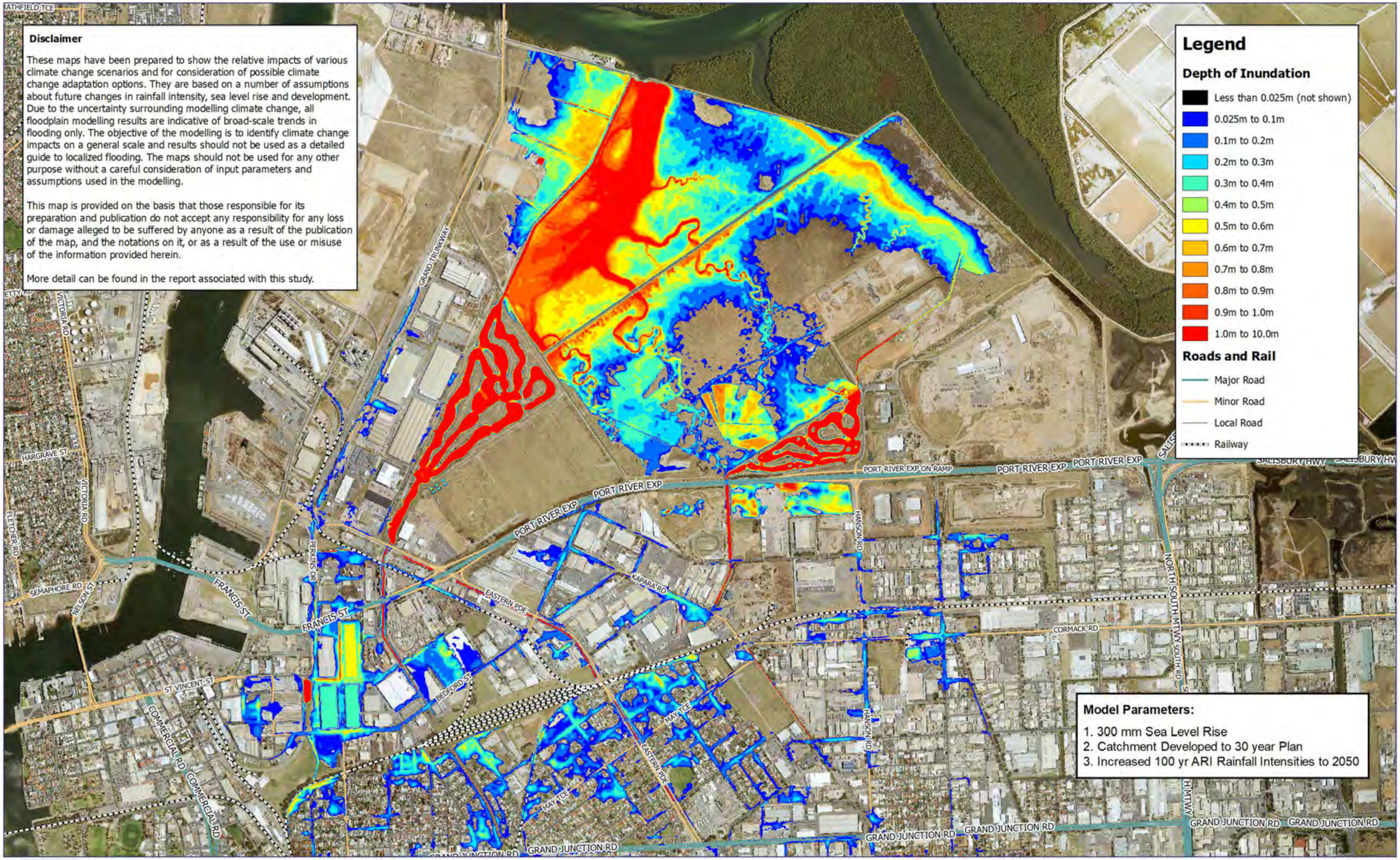
Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Charles Sturt / City of Port Adelaide Enfield / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan

Gillman Inundation Map - 100 yr ARI Flood Interaction With MHWS Tide (Existing Sea Level)

Appendix A.1



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More detail can be found in the report associated with this study.

Model Parameters:

1. 300 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2050

0 250 500 750 1000 m

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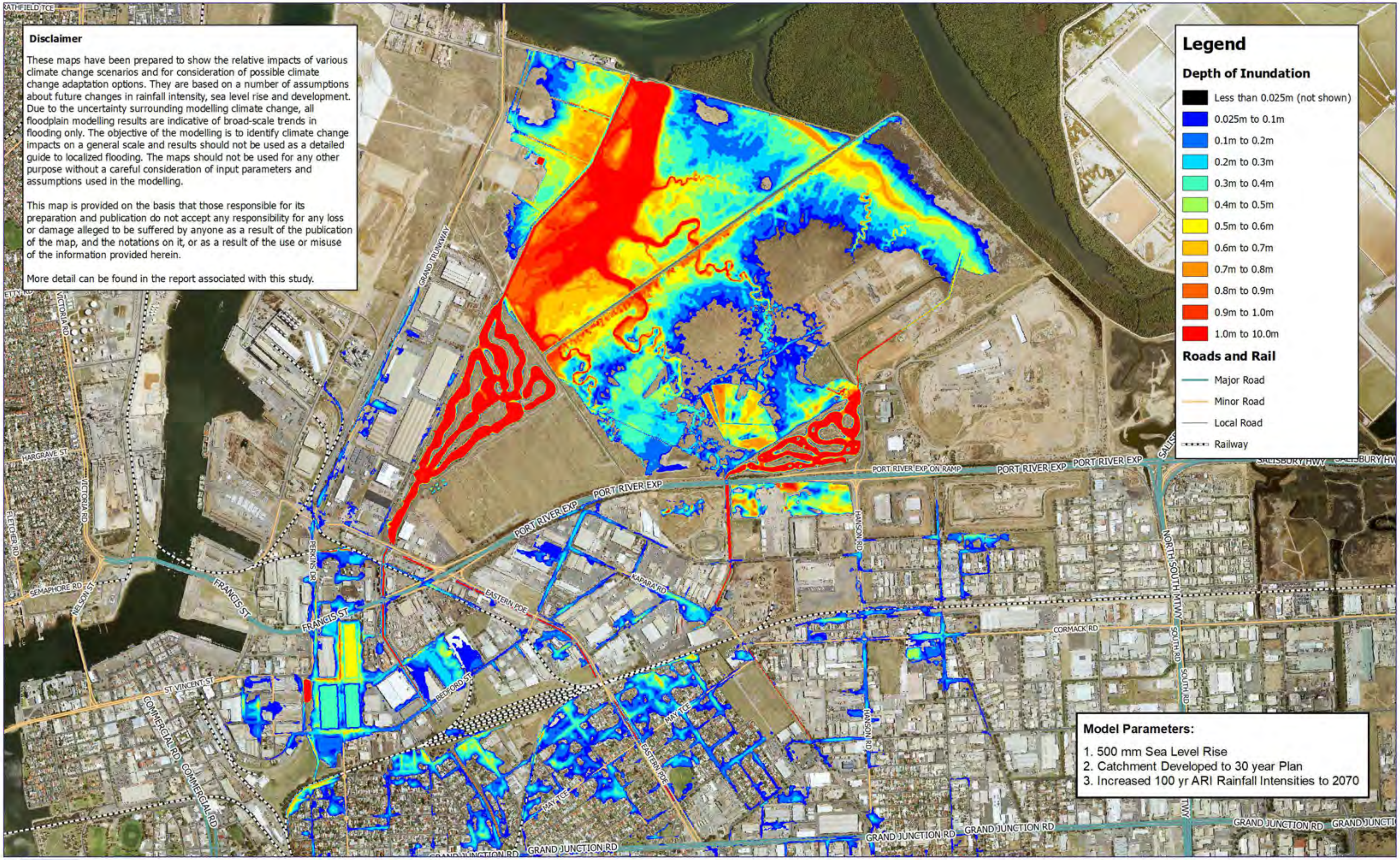
Western Adelaide Region Climate Change Adaptation Plan
Gillman Inundation Map - 100 yr ARI Flood Interaction With MHWS Tide (300 mm Sea Level Rise - 2050)

Appendix A.2



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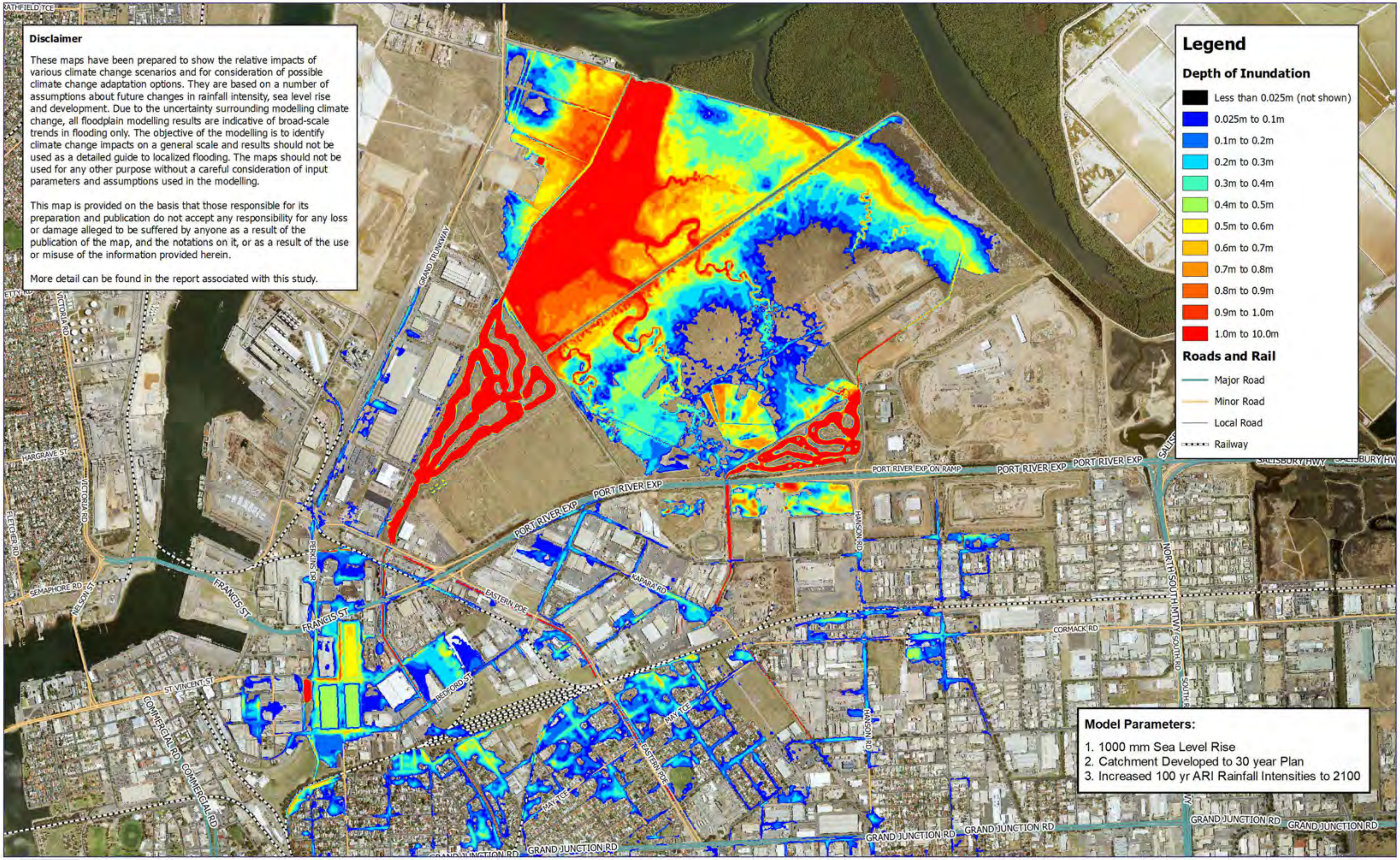
Filename: 2014.0329GQ011_GillmanMapping_02
Revision: C
Date: 7/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Charles Sturt / City of Port Adelaide Enfield / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Gillman Inundation Map - 100 yr ARI Flood Interaction With MHWS Tide
(500 mm Sea Level Rise - 2070)

Appendix A.3



Disclaimer

These maps have been prepared to show the relative impacts of various climate change scenarios and for consideration of possible climate change adaptation options. They are based on a number of assumptions about future changes in rainfall intensity, sea level rise and development. Due to the uncertainty surrounding modelling climate change, all floodplain modelling results are indicative of broad-scale trends in flooding only. The objective of the modelling is to identify climate change impacts on a general scale and results should not be used as a detailed guide to localized flooding. The maps should not be used for any other purpose without a careful consideration of input parameters and assumptions used in the modelling.

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More detail can be found in the report associated with this study.

Model Parameters:

1. 1000 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2100

Tonkin CONSULTING
a better approach

Job Number:	2014.0329
Filename:	2014.0329GQ011_GillmanMapping_02
Revision:	C
Date:	07/02/2018
Drawn:	PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Charles Sturt / City of Port Adelaide Enfield / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Gillman Inundation Map - 100 yr ARI Flood Interaction With MHWS Tide (1000 mm Sea Level Rise - 2100)

Appendix A.4

Appendix B

West Lakes Floodplain Mapping

Appendix B.1 (West Lakes Existing Scenario)

West Lakes Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve - existing
- Rainfall Intensity - existing
- 100 year ARI storm event
- Existing mean lake water level set as initial water level
- Storm Duration 1hr to 36 hr (36 hr critical for lake level)
- Results show existing flood impact of this event on West Lakes and its surrounding catchments. Flooding is caused in the surrounding catchments where water is unable to enter the surrounding drainage systems. The lake fills until it can discharge to sea. Due to the size of the lake system and surrounding catchments, the greatest flooding extents are caused by high volume events (critical event is 36 hours) which take over two tide cycles for the system to start to significantly discharge stormwater out of the lake.
- Associated mitigation option: West Lakes Tidal Gate Upgrade (Section 6.4.1)

Appendix B.2 (West Lakes 2050 Scenario)

West Lakes Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve - 0.3 m tide rise
- Rainfall Intensity - 2050
- 100 year ARI storm event
- 2050 mean lake water level set as initial water level
- Storm Duration 1hr to 36 hr (36 hr critical for lake level)
- Results show a slight increase in flood impact of this event with a 0.3 m tide rise in addition to the existing MHWS Tide Curve. Both the lake and the surrounding catchment directly upstream have slightly greater flood extents. This is because the higher tide prevents stormwater being discharged from the lake for longer, and hence more volume is required to store this water. As a result, the lake peak water level is slightly higher and causes slightly more flooding around the lake. It should be noted there will also be some more flooding in the upper catchment due to the increase in rainfall intensity in this scenario.
- Associated mitigation option: West Lakes Tidal Gate Upgrade (Section 6.4.1)

Appendix B.3 (West Lakes 2070 Scenario)

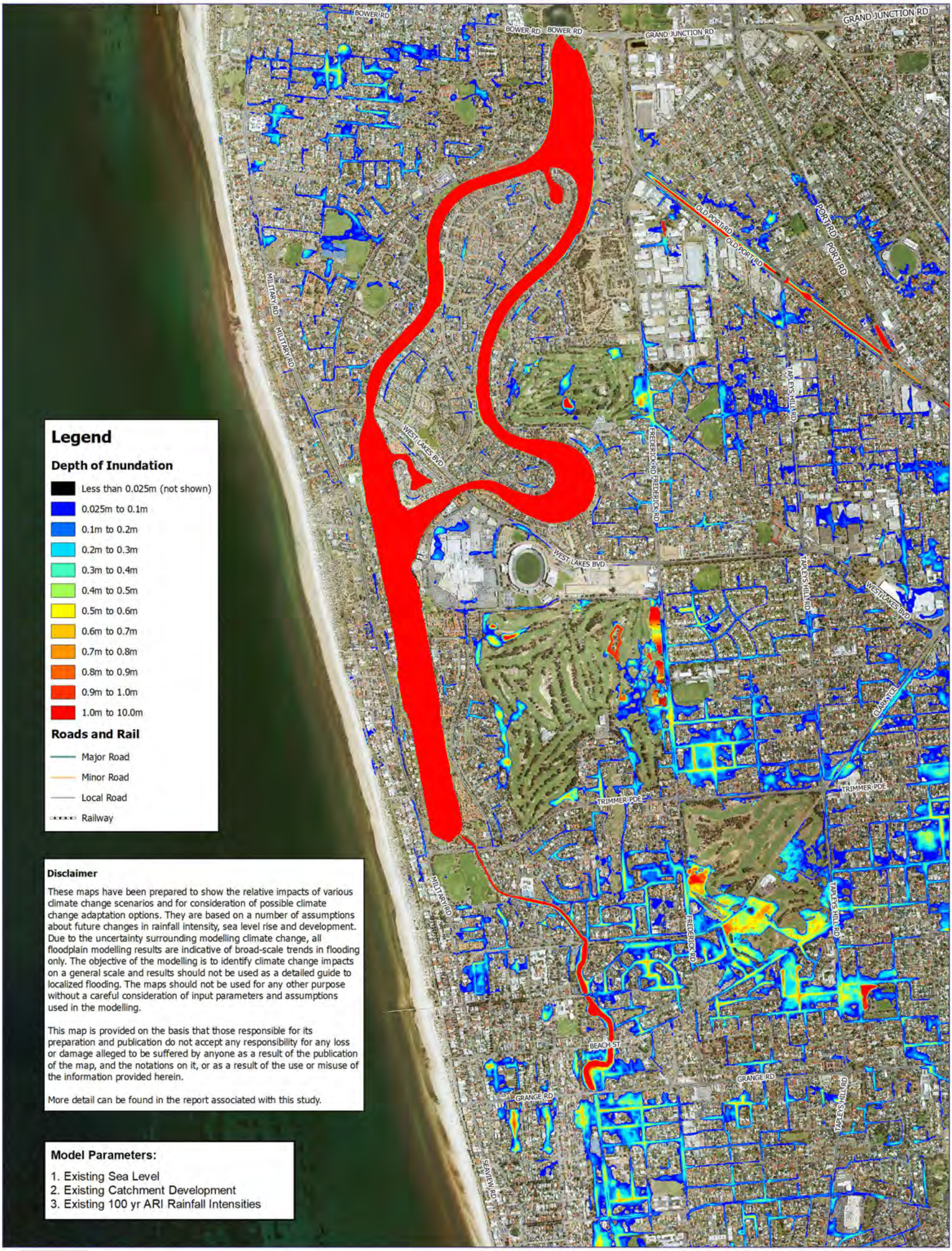
West Lakes Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve – 0.5 m tide rise
- Rainfall Intensity - 2070
- 100 year ARI storm event
- 2070 mean lake water level set as initial water level
- Storm Duration 1hr to 36 hr (36 hr critical for lake level)
- Results show a noticeable increase in flood impact of this event with a 0.5 m tide rise in addition to the existing MHWS Tide Curve. This is because the higher tide prevents stormwater being discharged from the lake for longer, and hence more volume is required to store this water. As a result, the lake peak water level is slightly higher and causes slightly more flooding around the lake. It should be noted there will also be some more flooding in the upper catchment due to the increase in rainfall intensity in this scenario.
- Associated mitigation option: West Lakes Tidal Gate Upgrade (Section 6.4.1)

Appendix B.4 (West Lakes 2100 Scenario)

West Lakes Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve – 1 m tide rise
- Rainfall Intensity - 2100
- 100 year ARI storm event
- 2100 mean lake water level set as initial water level
- Storm Duration 1hr to 36 hr (36 hr critical for lake level)
- Results show a marked increase in flood impact of this event with a 1 m tide rise compared with the existing MHWS Tide Curve. Both the lake and the surrounding catchment directly upstream have greater flood extents, especially around Delphin Island where it appears the lake will break out of its banks. This is because the higher tide prevents stormwater being discharged from the lake for longer, and hence more volume is required to store this water. As a result, the lake peak water level is higher and causes flows to escape from the Lake. It should be noted there will also be some more flooding in the upper catchment due to the increase in rainfall intensity in this scenario.
- Associated mitigation option: West Lakes Tidal Gate Upgrade (Section 6.4.1)



Legend

Depth of Inundation

- Less than 0.025m (not shown)
- 0.025m to 0.1m
- 0.1m to 0.2m
- 0.2m to 0.3m
- 0.3m to 0.4m
- 0.4m to 0.5m
- 0.5m to 0.6m
- 0.6m to 0.7m
- 0.7m to 0.8m
- 0.8m to 0.9m
- 0.9m to 1.0m
- 1.0m to 10.0m

Roads and Rail

- Major Road
- Minor Road
- Local Road
- Railway

Disclaimer

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More detail can be found in the report associated with this study.

Model Parameters:

1. Existing Sea Level
2. Existing Catchment Development
3. Existing 100 yr ARI Rainfall Intensities

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200 0 200 400 600 m

N

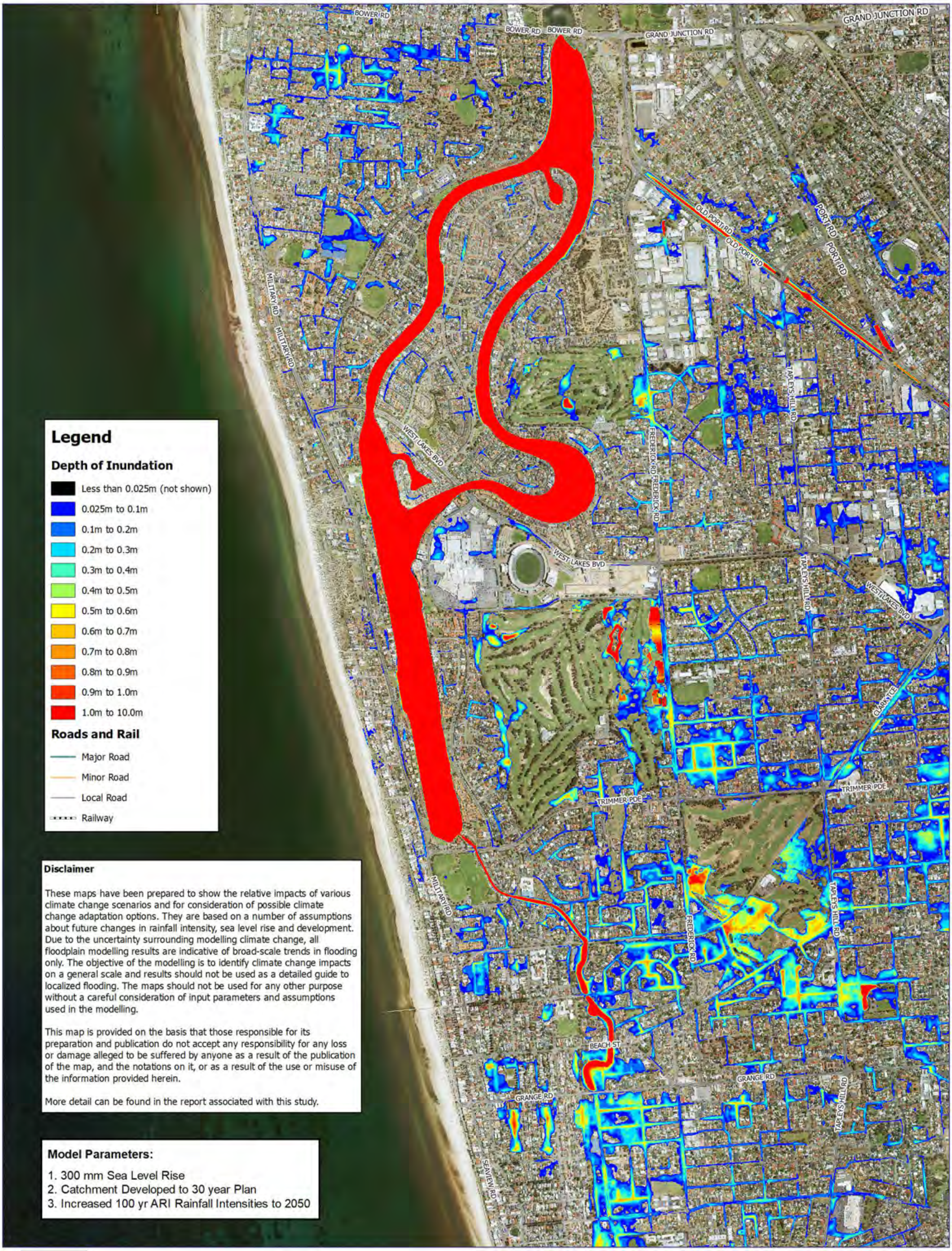
Job Number: 2014.0329
Filename: 2014.0329GQ012_WestLakesMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
West Lakes Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide (Existing Sea Level)

Appendix B.1



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More detail can be found in the report associated with this study.

Model Parameters:

1. 300 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2050

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Job Number: 2014.0329
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Revision: C
Date: 07/02/2018
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Data Acknowledgement:
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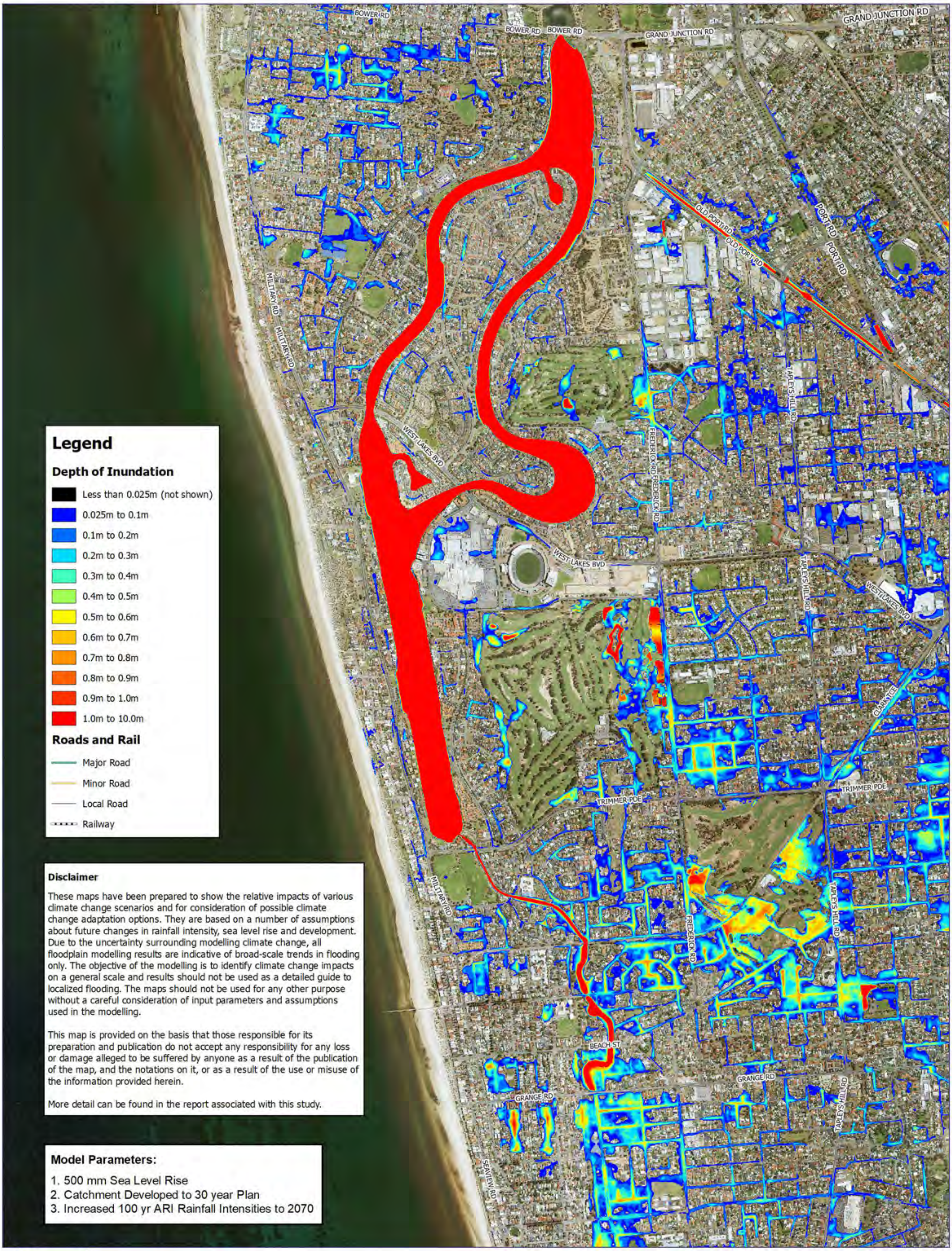
City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
West Lakes Inundation Map - 100 yr ARI Interaction with MHWS Tide
(300 mm Sea Level Rise - 2050)

Appendix B.2



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Model Parameters:

1. 500 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2070

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200 0 200 400 600 m

Job Number: 2014.0329
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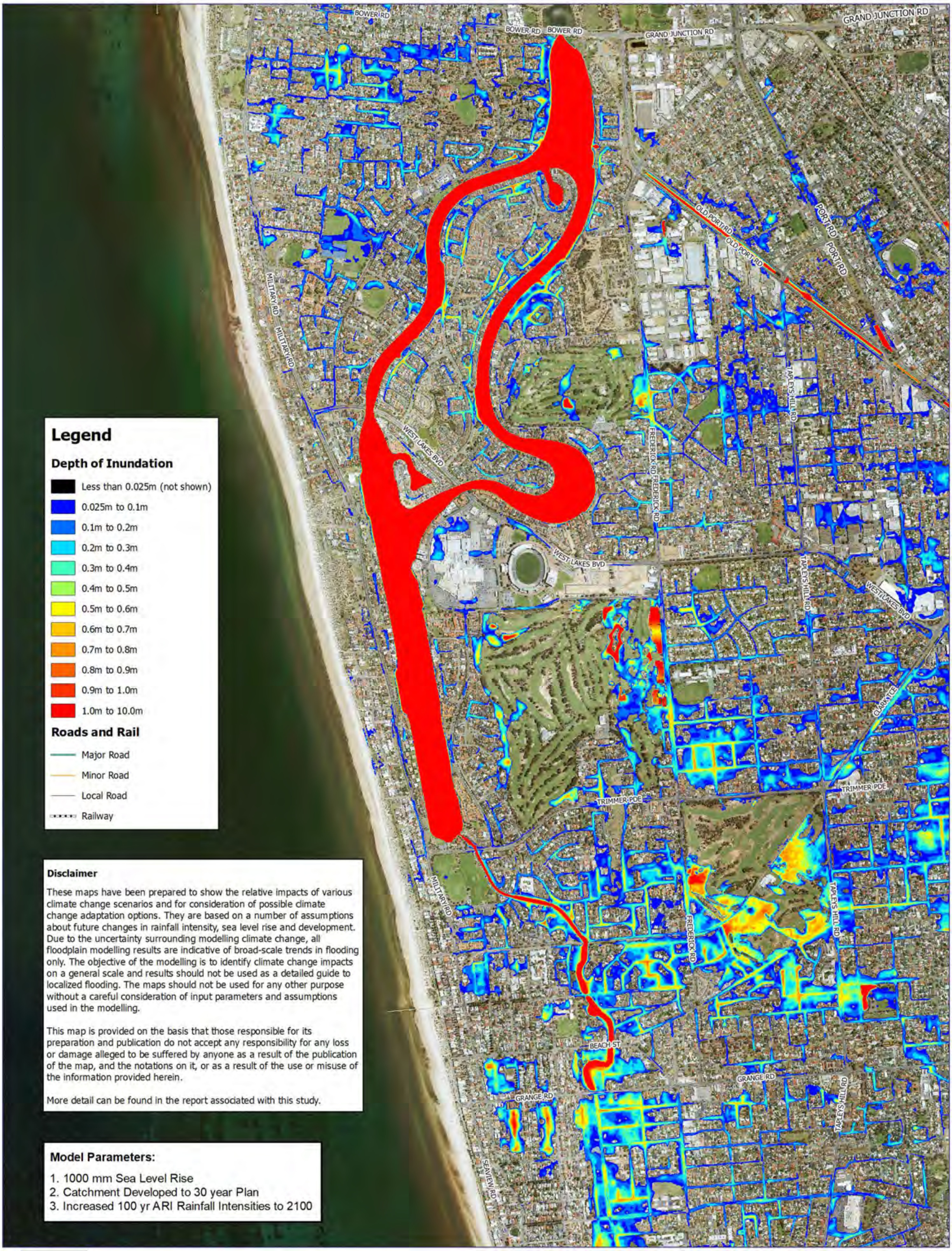
City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
West Lakes Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide
(500 mm Sea Level Rise - 2070)

Appendix B.3



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Model Parameters:

1. 1000 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2100

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200 0 200 400 600 m

Job Number: 2014.0329
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Revision: C
Date: 07/02/2018
Drawn: PDS

N

Data Acknowledgement:
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City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
West Lakes Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide
(1000 mm Sea Level Rise - 2100)

Appendix B.4

Appendix C

Local Catchments Floodplain Mapping

Appendix C.1 (Gilmore Rd / Henley Beach Rd Existing Scenario)

Gilmore Road / Henley Beach Road Floodplain Model with:

- 100 year tidal curve - existing
- Rainfall Intensity - existing
- 1 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show minimal existing flood impact of this event around Gilmore Road / Henley Beach Road. This is because the 1 year ARI storm in combination with the small size of the catchment generates sufficiently small volumes of water that all flows appear to be able to drain to sea even with the 100 year tide.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.2 (Gilmore Rd / Henley Beach Rd 2050 Scenario)

Gilmore Road / Henley Beach Road Floodplain Model with:

- 100 year tidal curve - 0.3 m tide rise
- Rainfall Intensity - 2050
- 1 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show minimal existing flood impact of this event around Gilmore Road / Henley Beach Road. This is because the 1 year ARI storm in combination with the small size of the catchment generates sufficiently small volumes of water that all flows appear to be able to drain to sea even with the higher 100 year tide.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.3 (Gilmore Rd / Henley Beach Rd 2070 Scenario)

Gilmore Road / Henley Beach Road Floodplain Model with:

- 100 year tidal curve – 0.5 m tide rise
- Rainfall Intensity - 2070
- 1 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show minimal existing flood impact of this event around Gilmore Road / Henley Beach Road. This is because the 1 year ARI storm in combination with the small size of the catchment generates sufficiently small volumes of water that all flows appear to be able to drain to sea even with the higher 100 year tide.

- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.4 (Gilmore Rd / Henley Beach Rd 2100 Scenario)

Gilmore Road / Henley Beach Floodplain Model with:

- 100 year tidal curve – 1 m tide rise
- Rainfall Intensity - 2100
- 1 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show an increased flood impact of this event around Gilmore Road / Henley Beach Road. This is because the 1 year ARI storm flows cannot discharge to sea due to the levels of the 100 year tide cycle with 1 m of sea level rise. However, the resulting increase in flooding is not significant.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.5 (Gilmore Rd / Henley Beach Rd Existing Scenario)

Gilmore Road / Henley Beach Road Floodplain Model with:

- Mean High Water Springs (MHWS) tide level - existing
- Rainfall Intensity - existing
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show existing flood impact of this event around Gilmore Road / Henley Beach Road. Inundation is caused by localized flash flooding in a 100 year ARI event.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.6 (Gilmore Rd / Henley Beach Rd 2050 Scenario)

Gilmore Road / Henley Beach Road Floodplain Model with:

- Mean High Water Springs (MHWS) tide level - 0.3 m tide rise
- Rainfall Intensity - 2050
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a minimal increase in flood impact of this event around Gilmore Road / Henley Beach Road due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment to the sea for slightly longer, resulting in slightly greater flood extents.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.7 (Gilmore Rd / Henley Beach Rd 2070 Scenario)

Gilmore Road / Henley Beach Road Floodplain Model with:

- Mean High Water Springs (MHWS) tide level – 0.5 m tide rise
- Rainfall Intensity - 2070
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a noticeable increase in flood impact of this event around Gilmore Road / Henley Beach Road due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment, resulting in greater flood.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.8 (Gilmore Rd / Henley Beach Rd 2100 Scenario)

Gilmore Road / Henley Beach Road Floodplain Model with:

- Mean High Water Springs (MHWS) tide level – 1 m tide rise
- Rainfall Intensity - 2100
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a noticeable increase in flood impact of this event around Gilmore Road / Henley Beach Road due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment, resulting in greater flood.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.9 (Iluka Place Existing Scenario)

Iluka Place Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve - existing
- Rainfall Intensity - existing
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show existing flood impact of this event around Iluka Place. Inundation is caused by localized flash flooding in a 100 year ARI event.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.10 (Iluka Place 2050 Scenario)

Iluka Place Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve -0.3 m tide rise
- Rainfall Intensity - 2050
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a small increase in flood impact of this event around Iluka Place due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment to the sea for slightly longer, resulting in slightly greater flood extents.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.11 (Iluka Place 2070 Scenario)

Iluka Place Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve – 0.5 m tide rise
- Rainfall Intensity - 2070
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a small increase in flood impact of this event around Iluka Place due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment to the sea for slightly longer, resulting in slightly greater flood extents.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.12 (Iluka Place 2100 Scenario)

Iluka Place Floodplain Model with:

- Mean High Water Springs (MHWS) tide curve – 1 m tide rise
- Rainfall Intensity - 2100
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a small increase in flood impact of this event around Iluka Place due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment to the sea for slightly longer, resulting in slightly greater flood extents.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.13 (Iluka Place Existing Scenario)

Iluka Place Floodplain Model with:

- 100 year tidal curve - existing
- Rainfall Intensity - existing
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show existing flood impact of this event around Iluka Place. Inundation is caused by localized flash flooding in a 100 year ARI event.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.14 (Iluka Place 2050 Scenario)

Iluka Place Floodplain Model with:

- 100 year tidal curve - 0.3 m tide rise
- Rainfall Intensity - 2050
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a small increase in flood impact of this event around Iluka Place due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment to the sea for slightly longer, resulting in slightly greater flood extents.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.15 (Iluka Place 2070 Scenario)

Iluka Place Floodplain Model with:

- 100 year tidal curve – 0.5 m tide rise
- Rainfall Intensity - 2070
- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a small increase in flood impact of this event around Iluka Place due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment to the sea for slightly longer, resulting in slightly greater flood extents.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Appendix C.16 (Iluka Place 2100 Scenario)

Iluka Place Floodplain Model with:

- 100 year tidal curve – 1 m tide rise
- Rainfall Intensity - 2100

- 100 year ARI storm event
- Storm Duration 1hr to 9 hr
- Results show a small increase in flood impact of this event around Iluka Place due to the rise in MHWS tide level from existing levels. The increase in flood extents is caused by the higher tide which prevents outflows from the catchment to the sea for slightly longer, resulting in slightly greater flood extents.
- Associated mitigation option: Ongoing Localized Flood Modelling and Planning (Section 6.5.2)

Disclaimer

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More detail can be found in the report associated with this study.

Model Parameters:

1. Existing Sea Level - 100 yr ARI Tide
2. Existing Catchment Development
3. Existing 1 yr ARI Rainfall Intensities

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Job Number: 2014.0329
Filename: 2014.0329GQ013_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Gilmore & Henley Beach Rd Inundation Map - 1 yr ARI Flood Interaction with 100 yr ARI Tide (Existing Sea Level)

AppendixC.1

Disclaimer

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Model Parameters:

1. 300 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 1 yr ARI Rainfall Intensities to 2050

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0 20 40 60 m

N

Job Number: 2014.0329
Filename: 2014.0329GQ013_LCMapping_02
Revision: C
Date: 07/02/2018
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Data Acknowledgement:
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City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Gilmore & Henley Beach Rd Inundation Map - 1 yr ARI Flood Interaction with 100 yr ARI Tide (300 mm Sea Level Rise - 2050)

AppendixC.2

Disclaimer

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Model Parameters:

1. 500 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 1 yr ARI Rainfall Intensities to 2070

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City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Gilmore & Henley Beach Rd Inundation Map - 1 yr ARI Flood Interaction with 100 yr ARI Tide (500 mm Sea Level Rise - 2070)

Job Number: 2014.0329
Filename: 2014.0329GQ013_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
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Road and Rail data by PBI, 2014

AppendixC.3

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More detail can be found in the report associated with this study.

Model Parameters:

1. 1000 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 1 yr ARI Rainfall Intensities to 2100

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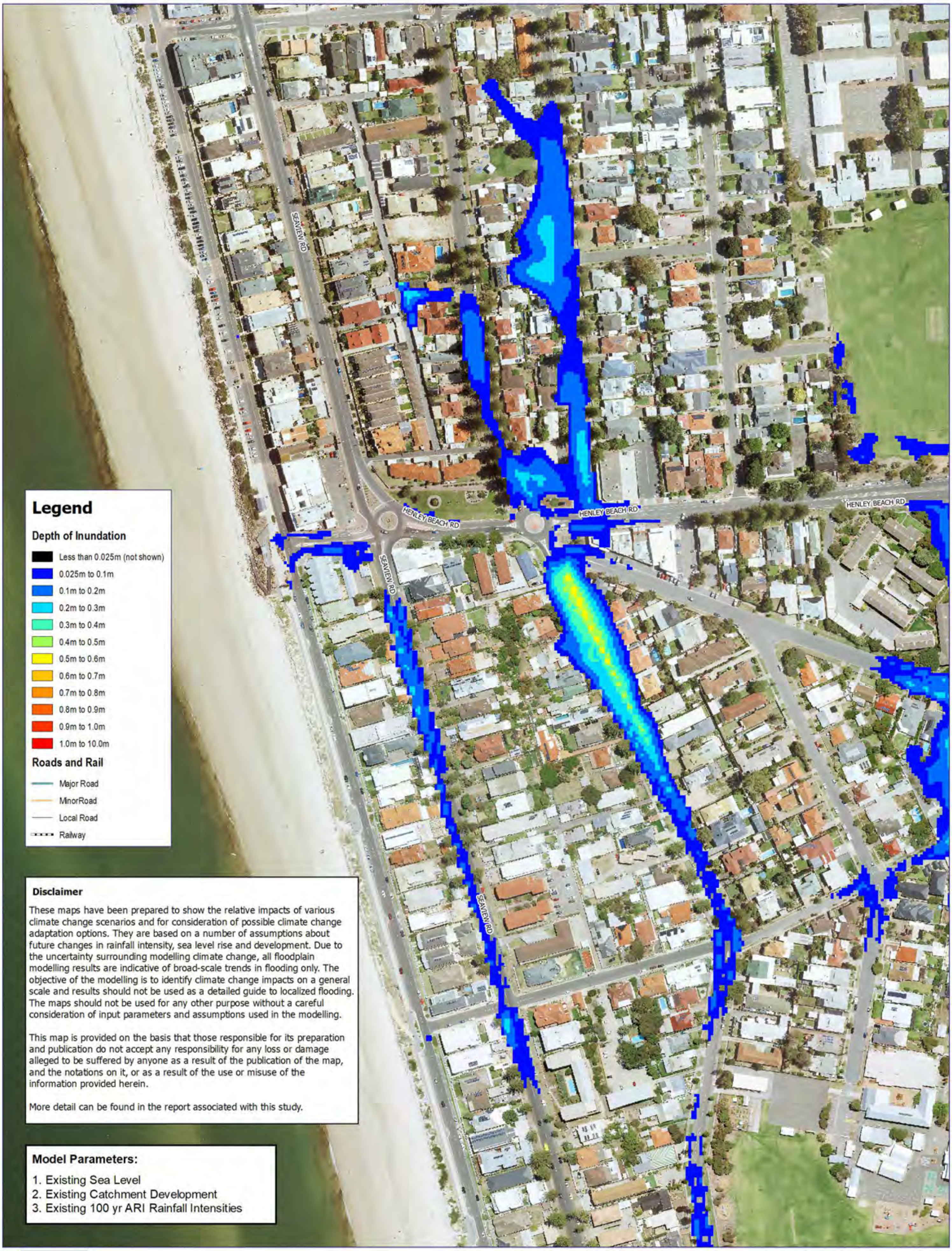
City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan

Gilmore & Henley Beach Rd Inundation Map - 1 yr ARI Flood Interaction with 100 yr ARI Tide (1000 mm Sea Level Rise - 2100)

AppendixC.4



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Model Parameters:

1. Existing Sea Level
2. Existing Catchment Development
3. Existing 100 yr ARI Rainfall Intensities

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0 20 40 60 m

N

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

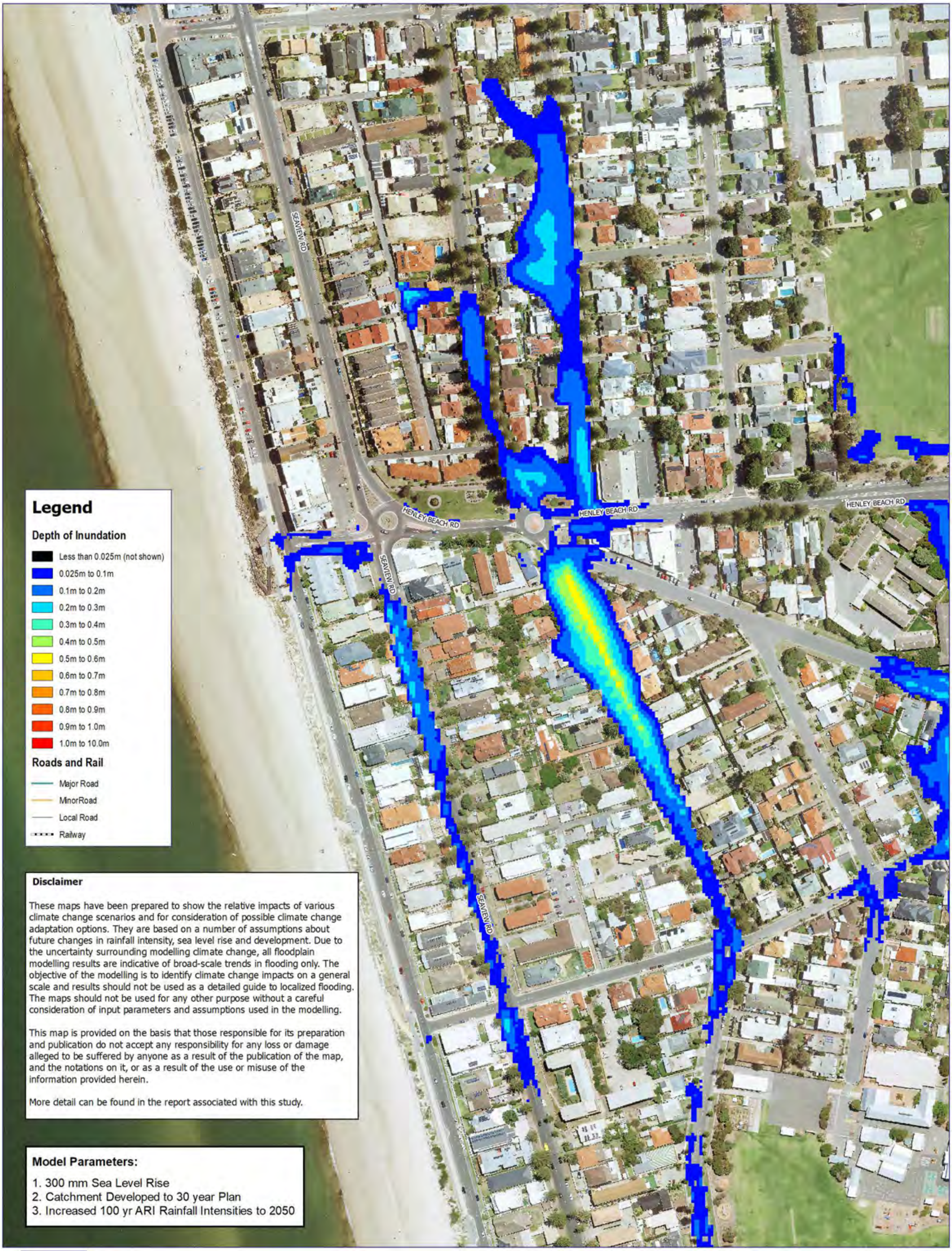
Western Adelaide Region Climate Change Adaptation Plan

Gilmore & Henley Beach Rd Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide (Existing Sea Level)

Job Number: 2014.0329
Filename: 2014.0329GQ013_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

AppendixC.5



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2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2050

Tonkin CONSULTING

a better approach

0 20 40 60 m

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Date:	07/02/2018
Drawn:	PDS

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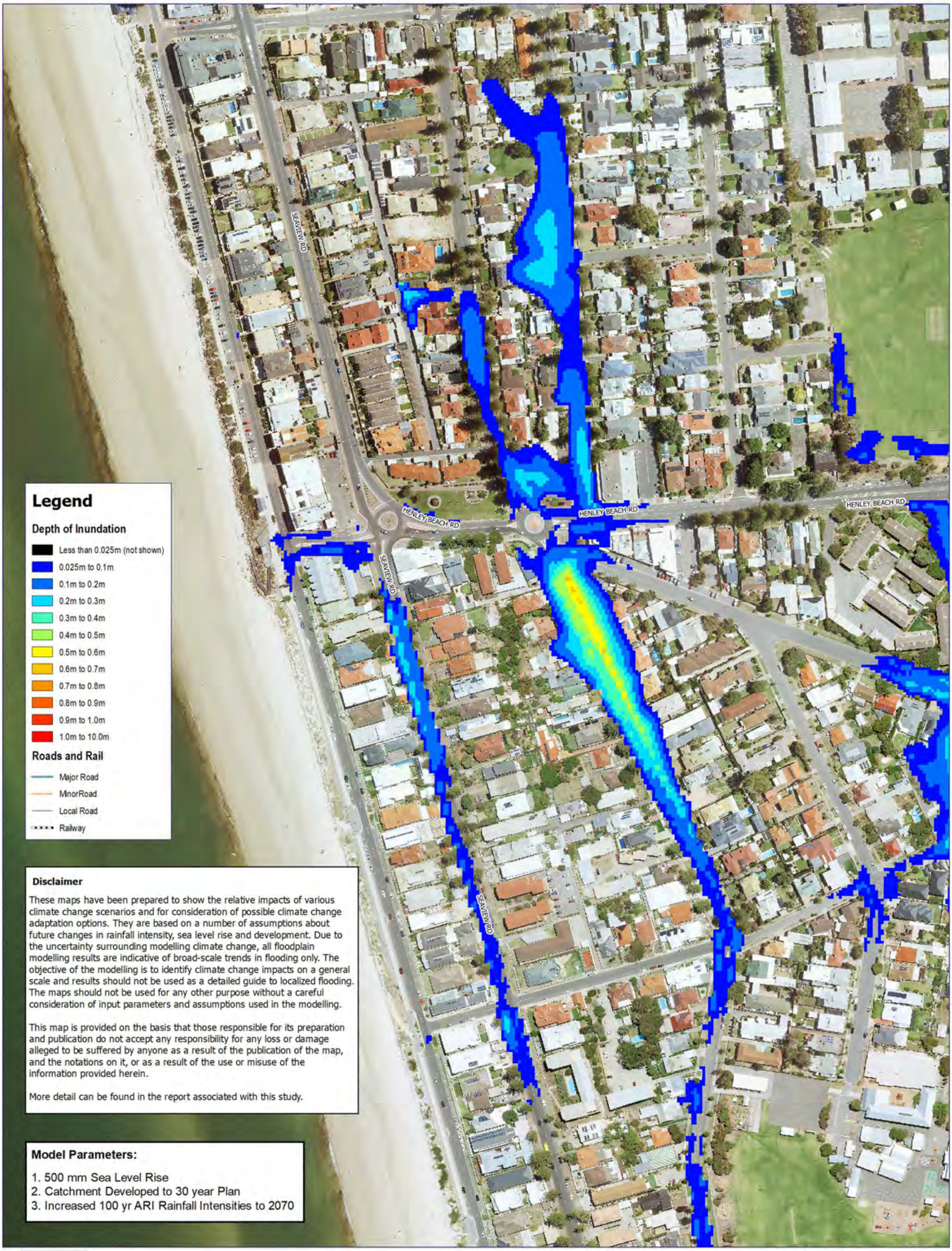
City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan

Gilmore & Henley Beach Rd Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide (300 mm Sea Level Rise - 2050)

AppendixC.6



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2. Catchment Developed to 30 year Plan
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0 20 40 60 m

N

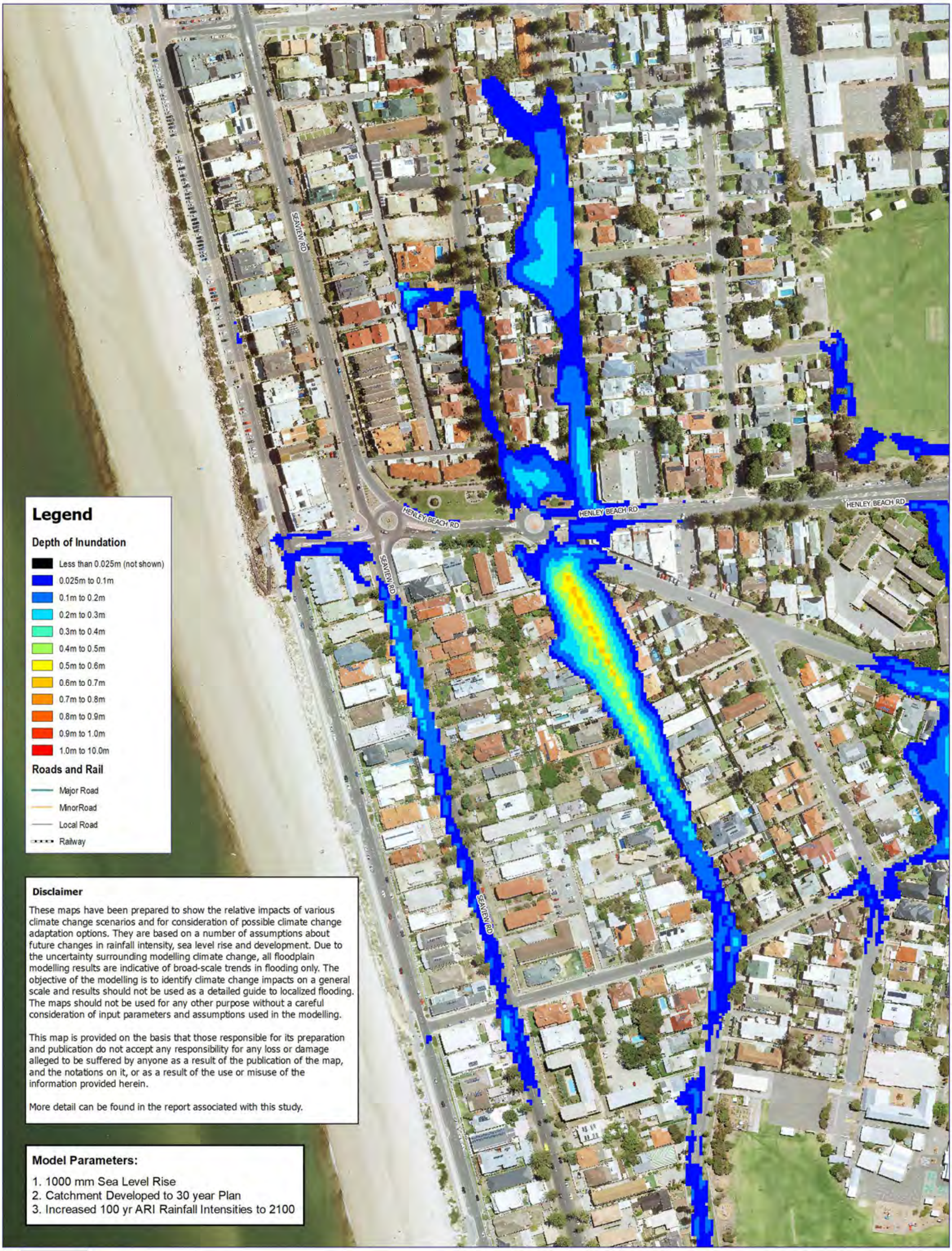
City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Gilmore & Henley Beach Rd Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide (500 mm Sea Level Rise - 2070)

Job Number: 2014.0329
Filename: 2014.0329GQ013_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

AppendixC.7



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More detail can be found in the report associated with this study.

Model Parameters:

1. 1000 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2100

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Job Number: 2014.0329
Filename: 2014.0329GQ013_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan

Gilmore & Henley Beach Rd Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide (1000 mm Sea Level Rise - 2100)

AppendixC.8

Legend

Depth of Inundation

- Less than 0.025m (not shown)
- 0.025m to 0.1m
- 0.1m to 0.2m
- 0.2m to 0.3m
- 0.3m to 0.4m
- 0.4m to 0.5m
- 0.5m to 0.6m
- 0.6m to 0.7m
- 0.7m to 0.8m
- 0.8m to 0.9m
- 0.9m to 1.0m
- 1.0m to 10.0m

Roads and Rail

- Major Road
- Minor Road
- Local Road
- Railway

Disclaimer

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More detail can be found in the report associated with this study.

Model Parameters:

1. Existing Sea Level
2. Existing Catchment Development
3. Existing 100 yr ARI Rainfall Intensities

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10 0 10 20 30 m

N

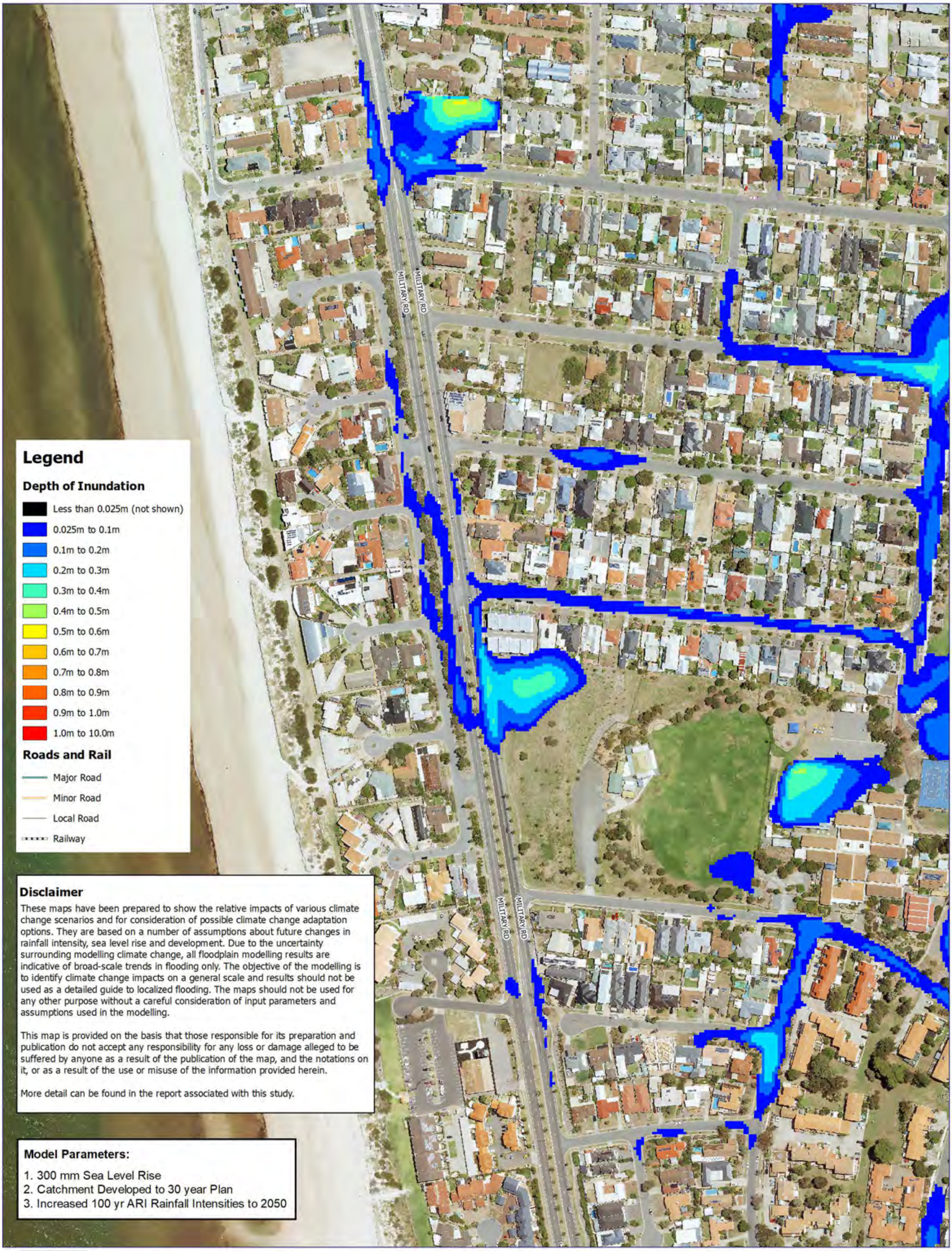
Job Number: 2014.0329
Filename: 2014.0329GQ015_LCMapping_02
Revision: C
Date: 07/02/2017
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Iluka Place Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide
(Existing Sea Level)

Appendix C.9



Disclaimer

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More detail can be found in the report associated with this study.

Model Parameters:

1. 300 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2050

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10 0 10 20 30 m

N

Job Number: 2014.0329
Filename: 2014.0329GQ015_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Iluka Place Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide
(300 mm Sea Level Rise - 2050)

Appendix C.10

Legend

Depth of Inundation

- Less than 0.025m (not shown)
- 0.025m to 0.1m
- 0.1m to 0.2m
- 0.2m to 0.3m
- 0.3m to 0.4m
- 0.4m to 0.5m
- 0.5m to 0.6m
- 0.6m to 0.7m
- 0.7m to 0.8m
- 0.8m to 0.9m
- 0.9m to 1.0m
- 1.0m to 10.0m

Roads and Rail

- Major Road
- Minor Road
- Local Road
- Railway

Disclaimer

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More detail can be found in the report associated with this study.

Model Parameters:

1. 500 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2070

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10 0 10 20 30 m

N

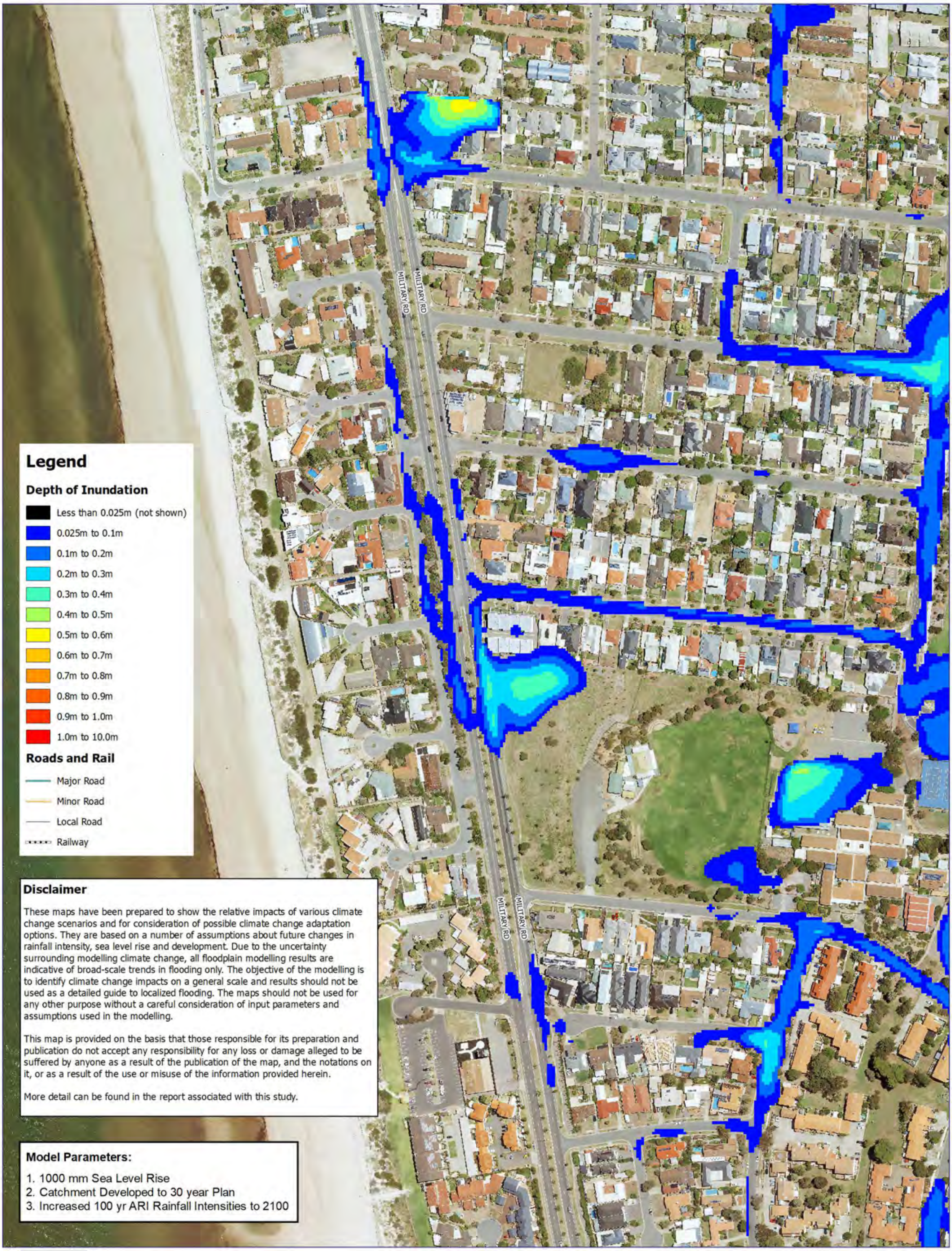
Job Number: 2014.0329
Filename: 2014.0329GQ015_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Iluka Place Inundation Map - 100 yr Flood Interaction With MHWS Tide
(500 mm Sea Level Rise - 2070)

Appendix C.11



Legend

Depth of Inundation

- Less than 0.025m (not shown)
- 0.025m to 0.1m
- 0.1m to 0.2m
- 0.2m to 0.3m
- 0.3m to 0.4m
- 0.4m to 0.5m
- 0.5m to 0.6m
- 0.6m to 0.7m
- 0.7m to 0.8m
- 0.8m to 0.9m
- 0.9m to 1.0m
- 1.0m to 10.0m

Roads and Rail

- Major Road
- Minor Road
- Local Road
- Railway

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More detail can be found in the report associated with this study.

Model Parameters:

1. 1000 mm Sea Level Rise
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2100

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10 0 10 20 30 m

Job Number: 2014.0329
Filename: 2014.0329GQ015_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

N

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Iluka Place Inundation Map - 100 yr ARI Flood Interaction with MHWS Tide (1000 mm Sea Level Rise - 2100)

Appendix C.12

Disclaimer

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More detail can be found in the report associated with this study.

Model Parameters:

1. Existing Sea Level - 100 yr ARI Tide
2. Existing Catchment Development
3. Existing 100 yr ARI Rainfall Intensities

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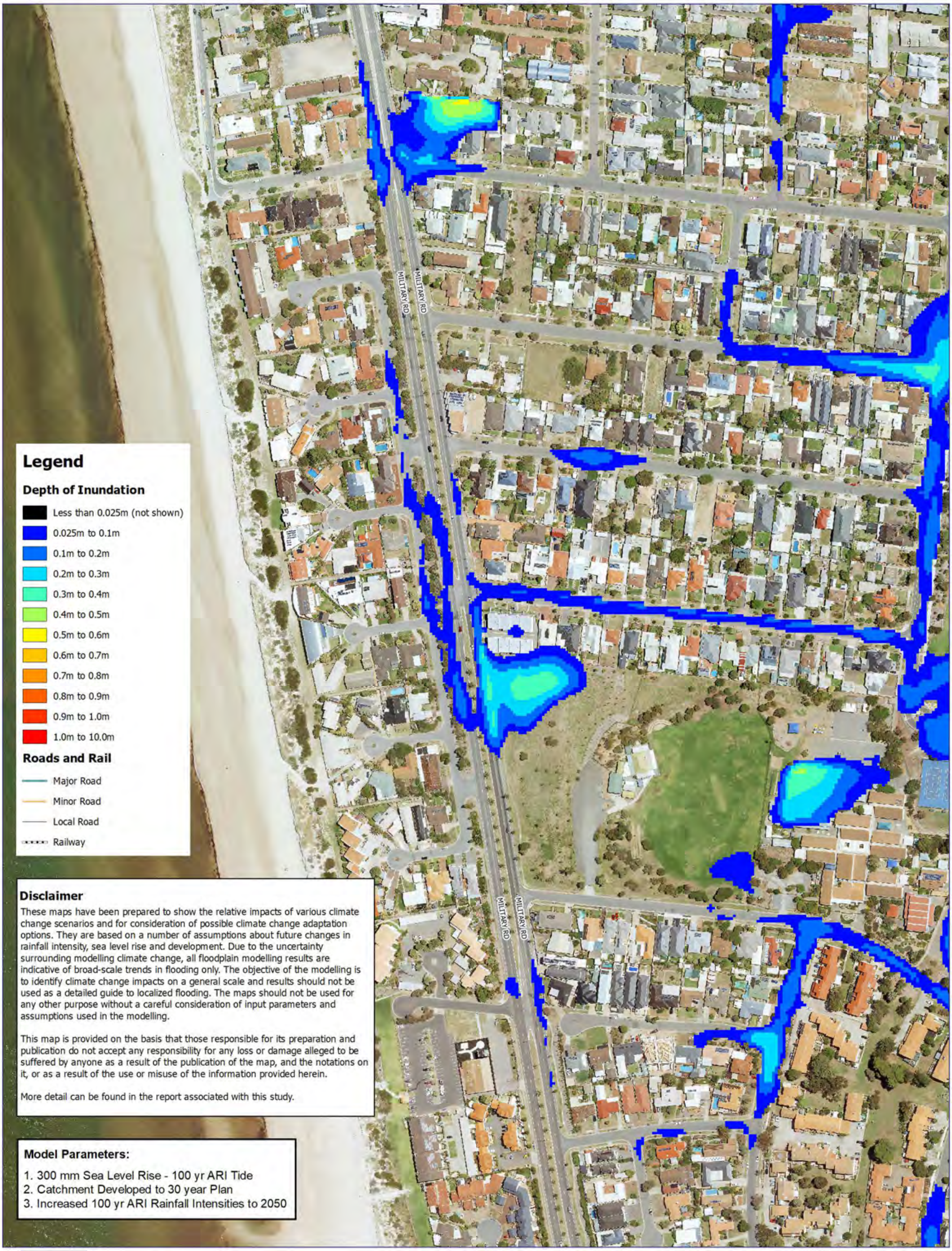
Job Number: 2014.0329
Filename: 2014.0329GQ015_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Iluka Place Inundation Map - 100 yr ARI Flood Interaction with 100 yr ARI Tide (Existing Sea Level)

Appendix C.13



Disclaimer

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More detail can be found in the report associated with this study.

Model Parameters:

1. 300 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2050

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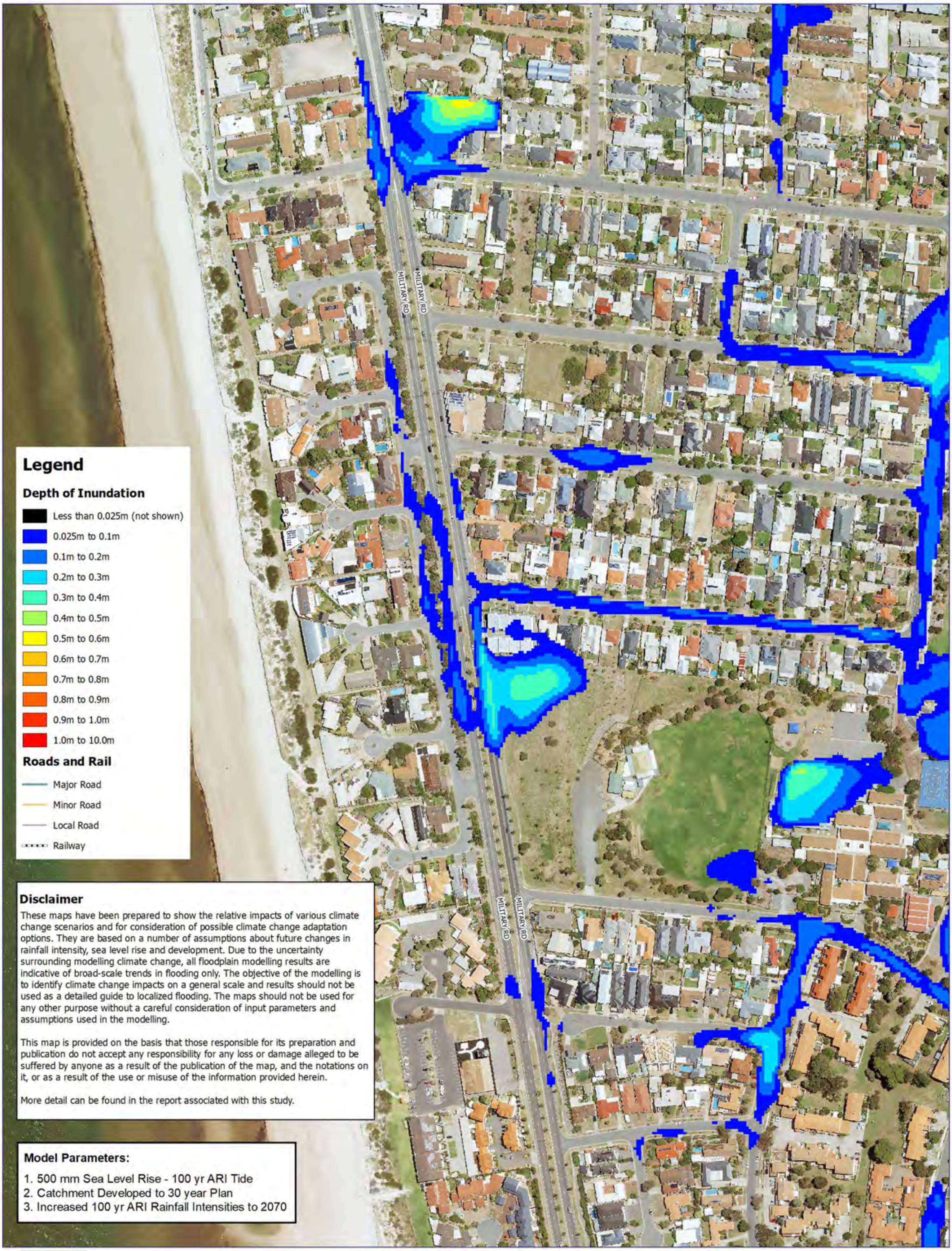
Job Number: 2014.0329
Filename: 2014.0329GQ015_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Iluka Place Inundation Map - 100 yr ARI Flood Interaction with 100 yr ARI Tide (300 mm Sea Level Rise - 2050)

Appendix C.14



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More detail can be found in the report associated with this study.

Model Parameters:

1. 500 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2070

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10 0 10 20 30 m

N

Job Number: 2014.0329
Filename: 2014.0329GQ015_LCMapping_02
Revision: C
Date: 07/26/2018
Drawn: PDS

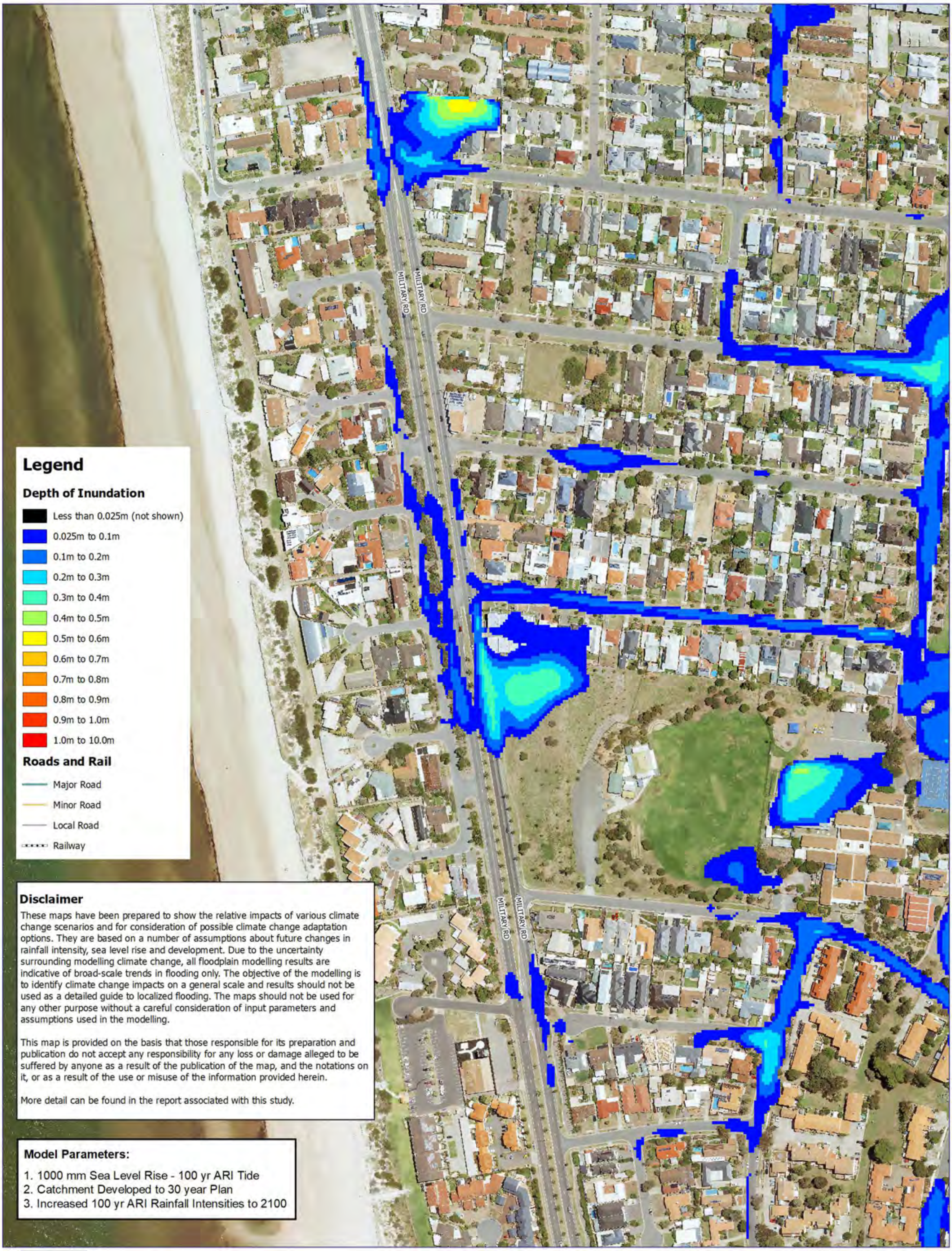
City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan

Iluka Place Inundation Map - 100 yr ARI Flood Interaction with 100 yr ARI Tide (500 mm Sea Level Rise - 2070)

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

Appendix C.15



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Model Parameters:

1. 1000 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 100 yr ARI Rainfall Intensities to 2100

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10 0 10 20 30 m

N

Job Number: 2014.0329
Filename: 2014.0329GQ015_LCMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaptation Plan
Iluka Place Inundation Map - 100 yr ARI Flood Interaction with 100 yr ARI Tide (1000 mm Sea Level Rise - 2100)

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

Appendix C.16

Appendix D

Patawalonga Floodplain Mapping

Appendix D.1 (Patawalonga Existing Scenario)

Patawalonga Floodplain Model with:

- 100 year tidal curve - existing
- Rainfall Intensity - existing
- 1 year ARI storm event
- Mean lake water level assumed to be set at 0.6 mAHD
- Storm Duration 1hr to 36 hr (3 hr critical for lake level)
- Results show the existing flood impact of this event on the Patawalonga and its local surrounding catchments. Flooding is caused in the surrounding catchments where water is unable to enter the surrounding drainage systems. The lake fills and stores flows until they can be discharged to sea. Currently in this event, the lake does not overtop. Due to the small size of the lake and the existing tide cycle peaking at a level of 2.38 mAHD, water levels in the lake reach 2.14 mAHD which is just below the estimated top of bank. The greatest flooding extents are caused by an event which can fill the lake before the tide recedes, allowing the lake to drain (critical event in this case is 3 hours).
- Associated mitigation options: Check / Upgrade Glenelg North flap gates (Section **Error! Reference source not found.**), planning for future development relating to Patawalonga Creek, Glenelg North and localized flooding around council area (Section 6.8)

Appendix D.2 (Patawalonga 2050 Scenario)

Patawalonga Floodplain Model with:

- 100 year tidal curve - 0.3 m tide rise
- Rainfall Intensity - 2050
- 1 year ARI storm event
- Mean lake water level assumed to be set at 0.6 mAHD
- Storm Duration 1hr to 36 hr (12 hr critical for lake level)
- Results show an increase in flood impact of this event with a 0.3 m tide rise in addition to the existing 100 year tide curve. There is a marked increase in flooding of Glenelg North. This is because the higher tide prevents stormwater being discharged from the Lake for longer, and hence more volume is required to store this water. As a result, the peak water level is slightly higher and causes the lake to flood its banks. There is also a noticeable increase in flooding within the Patawalonga Creek area. It should be noted there will also be more flooding in the upper catchment due to the increase in rainfall intensity in this scenario.
- Associated mitigation options: Check / Upgrade Genelg North flap gates (Section **Error! Reference source not found.**), planning for future development relating to

Patawalonga Creek, Glenelg North and localized flooding around council area (Section 6.8)

Appendix D.3 (Patawalonga 2070 Scenario)

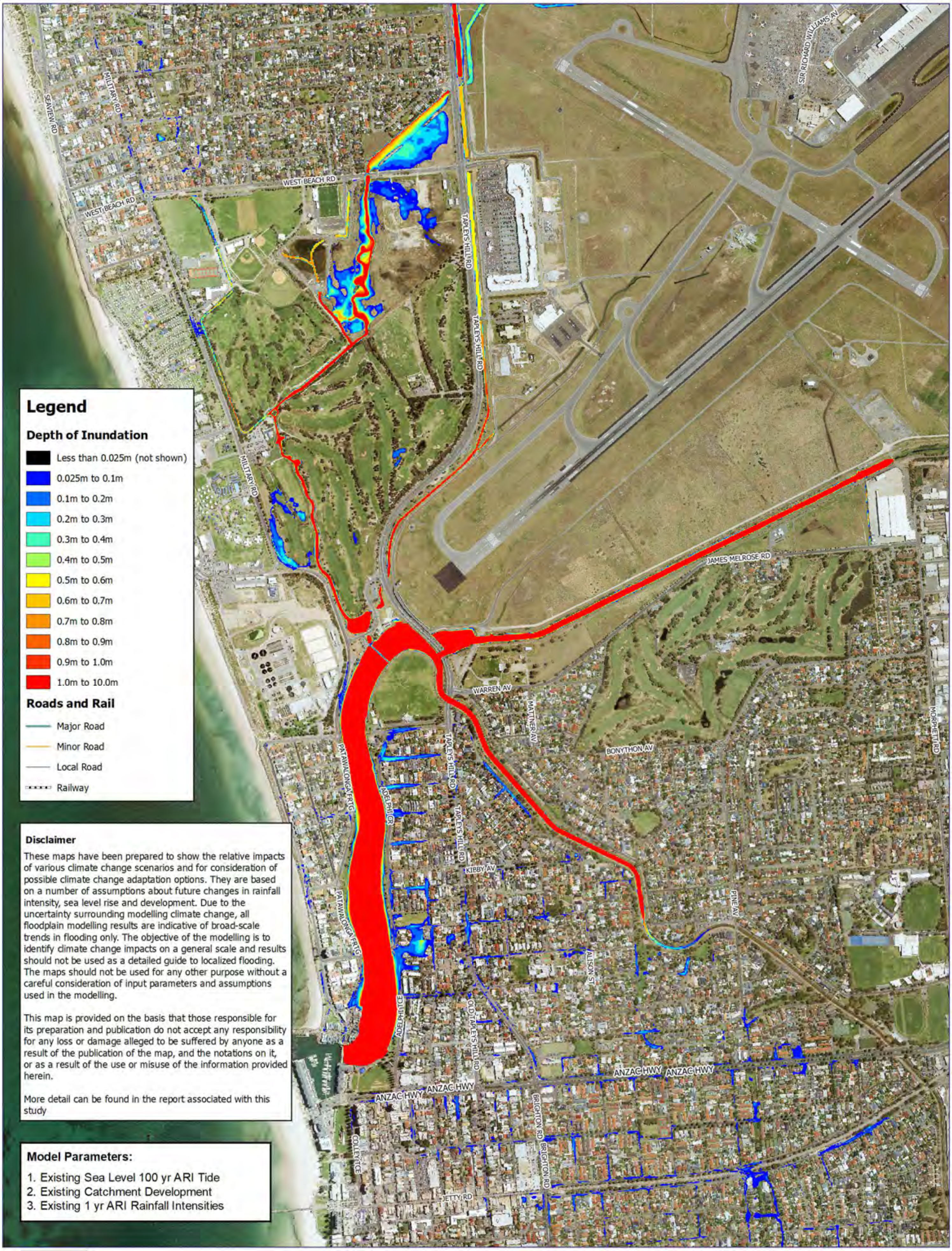
Patawalonga Floodplain Model with:

- 100 year tidal curve – 0.5 m tide rise
- Rainfall Intensity - 2070
- 1 year ARI storm event
- Mean lake water level assumed to be set at 0.6 mAHD
- Storm Duration 1hr to 36 hr (12 hr critical for lake level)
- Results show an increase in flood impact of this event with a 0.5 m tide rise in addition to the existing 100 year tide curve. There is a marked increase in flooding of Glenelg North. This is because the higher tide prevents stormwater being discharged from the Lake for longer, and hence more volume is required to store this water. As a result, the peak water level is slightly higher and causes the lake to flood its banks. There is also a noticeable increase in flooding within the Patawalonga Creek area. It should be noted there will also be more flooding in the upper catchment due to the increase in rainfall intensity in this scenario.
- Associated mitigation options: Check / upgrade Genelg North flap gates (Section **Error! Reference source not found.**), planning for future development relating to Patawalonga Creek, Glenelg North and localized flooding around council area (Section 6.8)

Appendix D.4 (Patawalonga 2100 Scenario)

Patawalonga Floodplain Model with:

- 100 year tidal curve – 1 m tide rise
- Rainfall Intensity - 2100
- 1 year ARI storm event
- Mean lake water level assumed to be set at 0.6 mAHD
- Storm Duration 1hr to 36 hr (12 hr critical for lake level)
- Results show an increase in flood impact of this event with a 1 m tide rise in addition to the existing 100 year tide curve. There is an extensive increase in flooding of Glenelg North. This is because the higher tide prevents stormwater being discharged from the Lake for longer, and hence more volume is required to store this water. As a result, the peak water level is slightly higher and causes the lake to flood its banks. There is also a noticeable increase in flooding within the Patawalonga Creek area. It should be noted there will also be more flooding in the upper catchment due to the increase in rainfall intensity in this scenario.
- Associated mitigation options: Check / Upgrade Genelg North flap gates (Section **Error! Reference source not found.**), planning for future development relating to Patawalonga Creek, Glenelg North and localized flooding around council area (Section 6.8)



Disclaimer

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More detail can be found in the report associated with this study

Model Parameters:

1. Existing Sea Level 100 yr ARI Tide
2. Existing Catchment Development
3. Existing 1 yr ARI Rainfall Intensities

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100 0 100 200 300 m

N

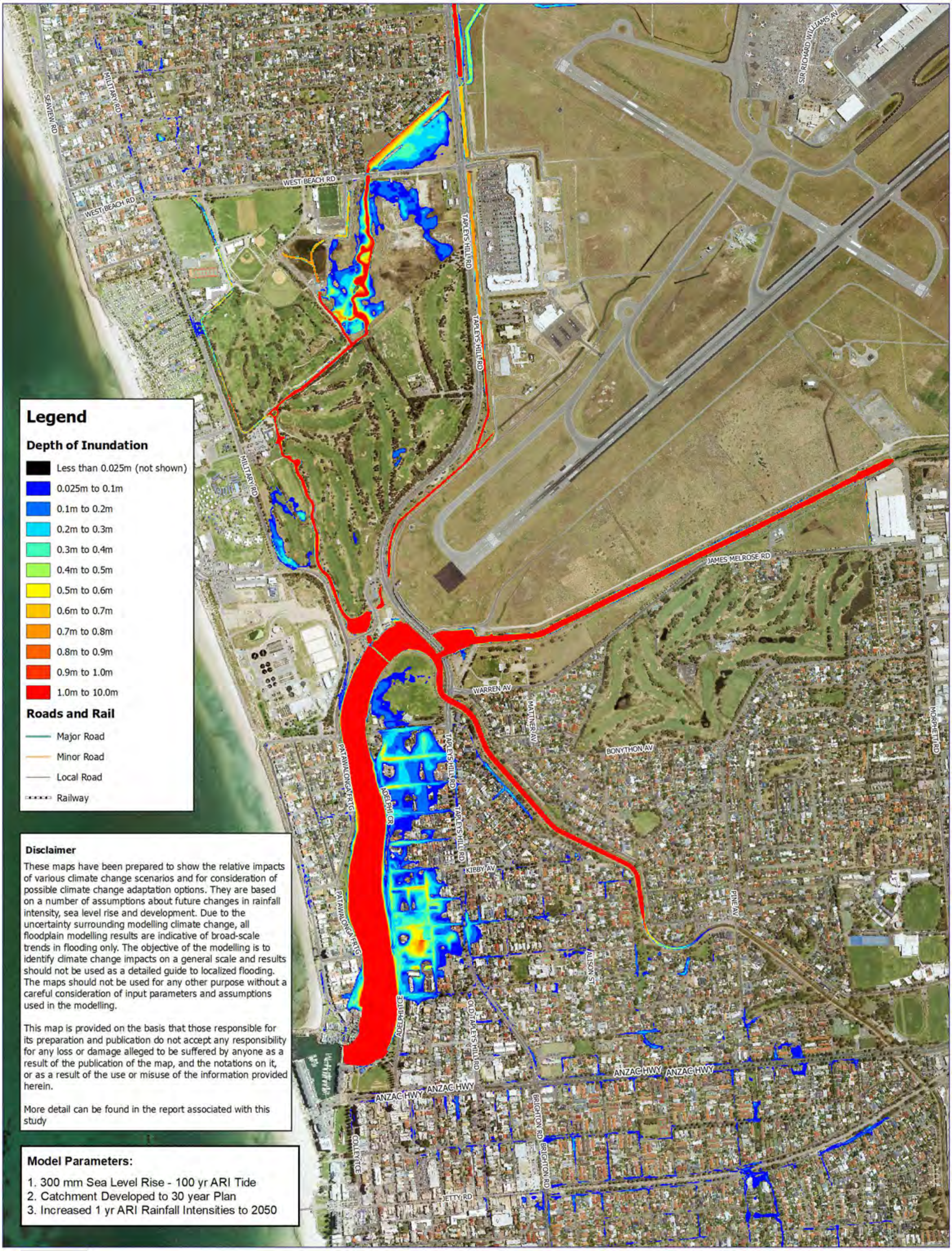
Job Number: 2014.0329
Filename: 2014.0329GQ014_PatawalongaMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaption Plan
Patawalonga Inundation Map - 1 yr ARI Flood Interaction with 100 yr ARI Tide (Existing Sea Level)

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

Appendix D.1



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More detail can be found in the report associated with this study

Model Parameters:

1. 300 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 1 yr ARI Rainfall Intensities to 2050

Tonkin CONSULTING

a better approach

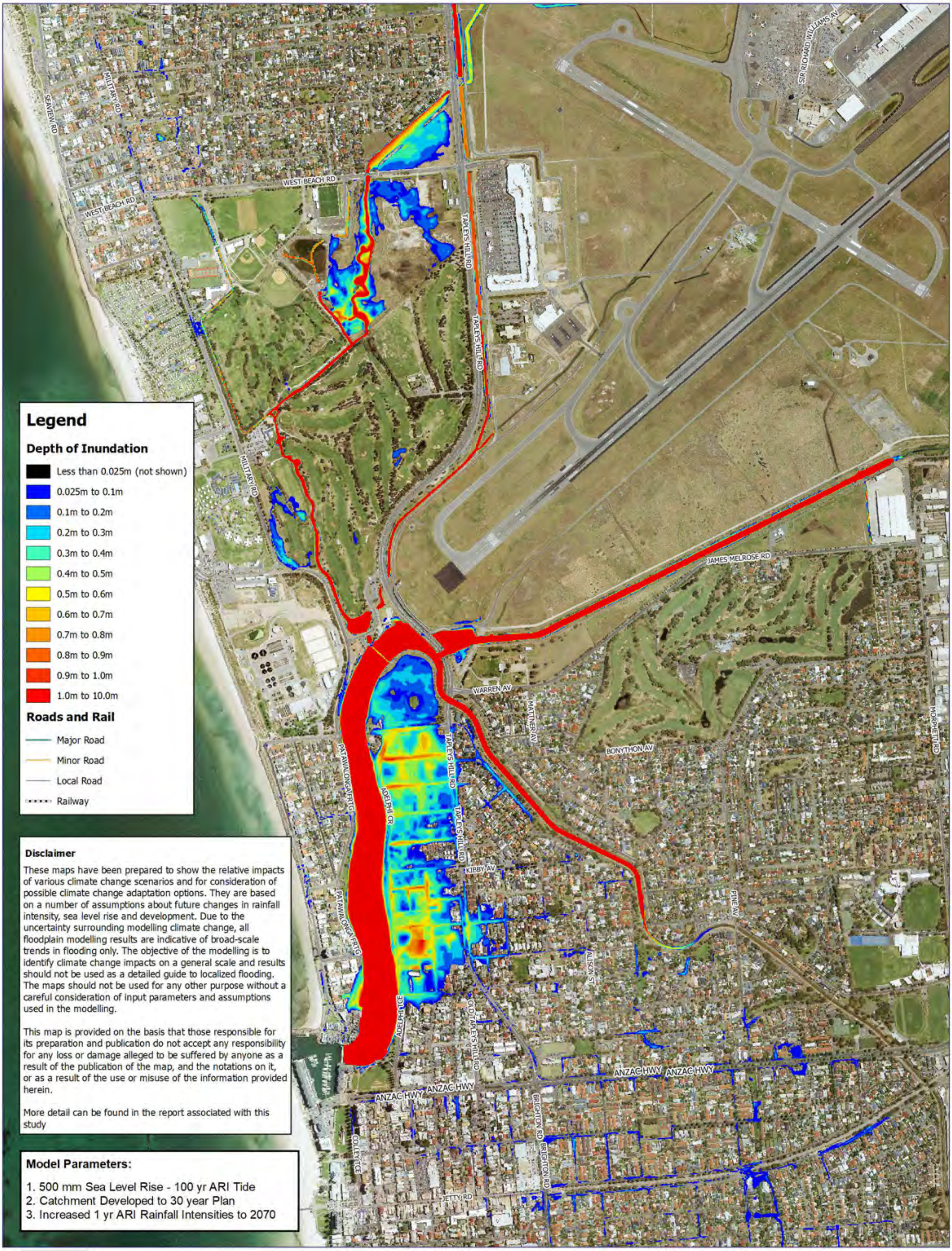
Job Number: 2014.0329
Filename: 2014.0329GQ014_PatawalongaMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaption Plan
Patawalonga Inundation Map - 1 yr ARI Flood Interaction with 100 yr ARI Tide (300 mm Sea Level Rise - 2050)

Appendix D.2



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More detail can be found in the report associated with this study

Model Parameters:

1. 500 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 1 yr ARI Rainfall Intensities to 2070

Tonkin CONSULTING

a better approach

Job Number:	2014.0329
Filename:	2014.0329GQ014_PatawalongaMapping_02
Revision:	C
Date:	07/02/2018
Drawn:	PDS

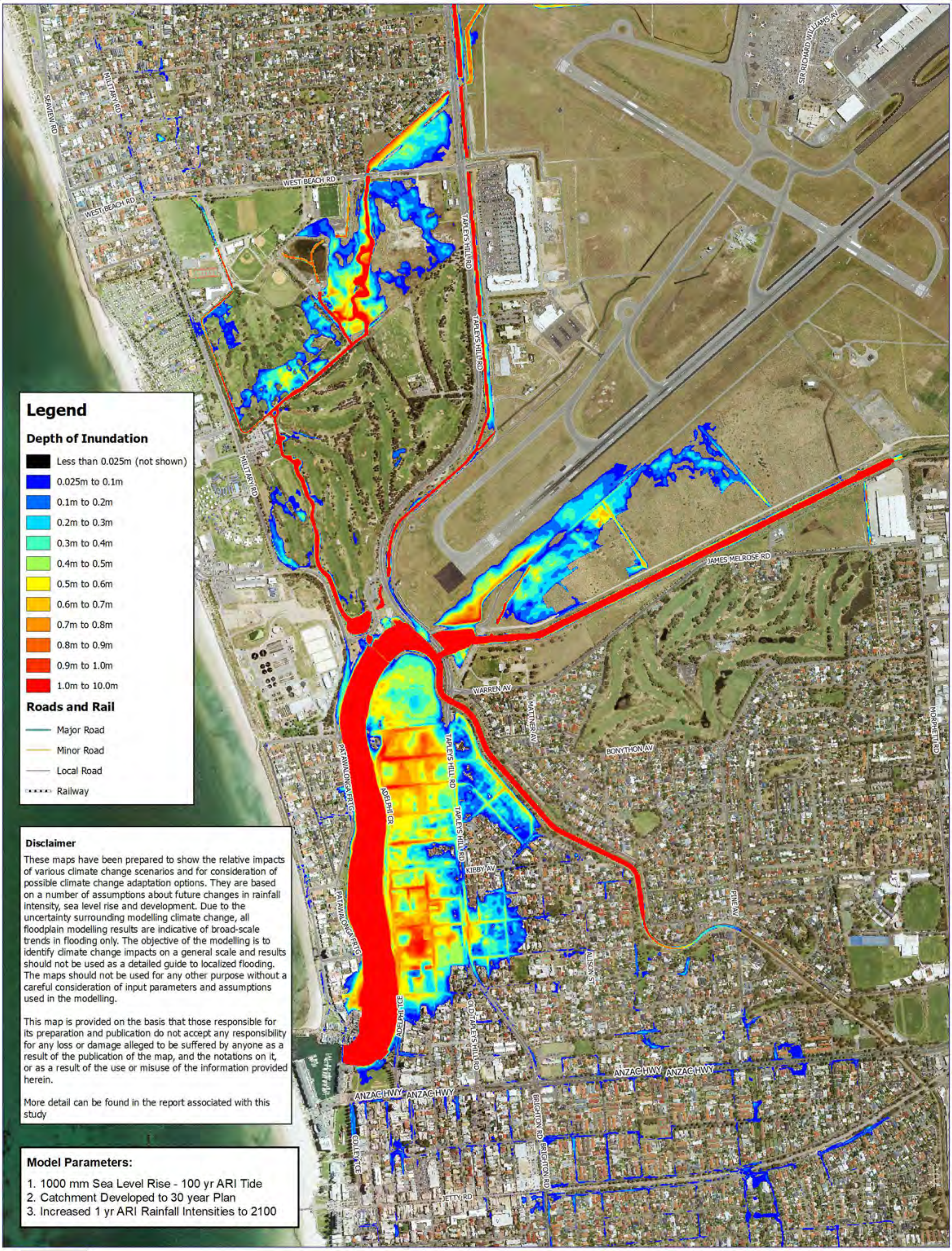
Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaption Plan

Patawalonga Inundation Map - 1 yr ARI Flood Interaction with 100 yr ARI Tide (500 mm Sea Level Rise - 2070)

Appendix D.3



Legend

Depth of Inundation

- Less than 0.025m (not shown)
- 0.025m to 0.1m
- 0.1m to 0.2m
- 0.2m to 0.3m
- 0.3m to 0.4m
- 0.4m to 0.5m
- 0.5m to 0.6m
- 0.6m to 0.7m
- 0.7m to 0.8m
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- 0.9m to 1.0m
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Roads and Rail

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Disclaimer

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This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damage alleged to be suffered by anyone as a result of the publication of the map, and the notations on it, or as a result of the use or misuse of the information provided herein.

More detail can be found in the report associated with this study

Model Parameters:

1. 1000 mm Sea Level Rise - 100 yr ARI Tide
2. Catchment Developed to 30 year Plan
3. Increased 1 yr ARI Rainfall Intensities to 2100

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100 0 100 200 300 m

N

Job Number: 2014.0329
Filename: 2014.0329GQ014_PatawalongaMapping_02
Revision: C
Date: 07/02/2018
Drawn: PDS

Data Acknowledgement:
Aerial Photography from MetroMap, 2017
Road and Rail data by PBI, 2014

City of Port Adelaide Enfield / City of Charles Sturt / City of West Torrens

Western Adelaide Region Climate Change Adaption Plan
Patawalonga Inundation Map - 1 yr ARI Flood Interaction with 100 yr ARI Tide
(1000 mm Sea Level Rise - 2100)

Appendix D.4

Appendix E

Tidal Inundation Mapping

Appendix E (Tidal Inundation Mapping)

City of Charles Sturt Storm Surge Extension Map

- S3 – 0.5 m sea level rise, 100 years of land subsidence
- Associated mitigation option: Port Adelaide Sea Wall (Section 6.1.2, Section 6.4.3)

Disclaimer

The extent of inundation shown on this map has been extrapolated from tidal inundation levels at Bower Road determined as part of the Port Adelaide Seawater Flooding Study. Hydrodynamic modelling has not been undertaken to determine the effects of floodplain storage on the propogation of flooding. The flood extent therefore provides a conservative estimate of flooding for this event and has been produced to show areas that could be protected from tidal inundation by a sea wall in Port Adelaide.

These maps have been prepared to show the relative impacts of various climate change scenarios and for consideration of possible climate change adaptation options. They are based on a number of assumptions about future changes in rainfall intensity, sea level rise and development. Due to the uncertainty surrounding modelling climate change, all floodplain modelling results are indicative of broad-scale trends in flooding only. The objective of the modelling is to identify climate change impacts on a general scale and results should not be used as a detailed guide to localized flooding. The maps should not be used for any other purpose without a careful consideration of input parameters and assumptions used in the modelling.

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Western Adelaide Region Climate Change Adaptation Plan
Tidal Inundation Mapping - 100 yr ARI Tide with 500 mm Sea Level Rise

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Data Acknowledgement:
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Appendix E