Port Pirie Flood Study

Flood Inundation Mapping Report

Port Pirie Regional Council

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a better approach

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1 Introduction

The Port Pirie Regional Council has engaged Tonkin Consulting to undertake a flood study for six catchments across the Port Pirie Township, including the city centre. The study area is shown in Figure 1.1 following. This report outlines the methodology, assumptions and results of the flood study.

Figure 1.1 Port Pirie Study Area

2 Hydrological Modelling

2.1 Study Area Description

The study area is approximately 6.7 km in size and encompasses the central developed area of the township, including residential areas, the commercial city centre and eastern industrial precinct. The study area is relatively flat in nature and drains via an underground drainage network either directly to the Port Pirie River (Gulf St Vincent) or to four detention basins that are either pumped or drain to the Port Pirie River. A Levee bank has been constructed to protect the township from seawater intrusion during extreme tidal events.

2.2 Hydrological modelling Process

The base hydrological data required to produce inflow hydrographs was adopted from the Port Pirie Stormwater Management Plan (Tonkin Consulting, 2011). This data has been approved by the Department of Planning, Transport and Infrastructure. This data included delineated sub-catchments, with travel time and runoff coefficients. This data was created for DRAINS modelling of flows within the main drainage networks. This data was reviewed and updated to ensure its accuracy, to bring it up to date with the current Development Plan (10 January 2013) and to tailor it for TUFLOW floodplain modelling.

While all of the sub-catchments ended at a stormwater drain or similar, some of the upstream catchments were relatively large. The review included breaking down larger sub-catchments, where there was limited stormwater infrastructure, to increase the resolution of the inflow hydrographs. All urban sub-catchments that were greater than 10 hectares were split to provide inflows within the original sub-catchment area, with inflows being applied directly onto the street network.

As part of the review and updating of the stormwater drainage infrastructure, individual pits (SEP's, grates, headwalls, etc) were updated to match their actual location, with many new to pits being added to the drainage data. This review also involved updating the sub-catchment delineation to take account of the updated pit locations and new pits. This greatly increased the quality of the sub-catchment delineation, with the number of sub-catchments for the study area increasing from 211 in the original data set to 312 in the updated data. This provided much greater accuracy in the inflow hydrographs that were applied to each stormwater inflow pit.

Once the review and updating of the sub-catchment data was completed, hydrographs were produced for each of the 312 sub-catchments using an ILSAX routine (time-area method) for each ARI and storm duration to be modelled. The durations ranged from 0.5 to 48 hours for the 5, 20 and 100 year ARI storm events.

2.3 Parameter Selection

This section provides a summary of the key hydrological parameters that were adopted for this study.

2.3.1 Rainfall Parameters

The rainfall Intensity-Frequency-Duration (IFD) data was taken from the Australian Bureau of Meteorology at the approximate centroid of the study area. The parameters used to generate the IFD data for this study are as shown following.

Table 2.1 Port Pirie Rainfall Intensity Frequency Duration Parameters

Parameter	2yr ARI	50yr ARI
1 hour Rainfall Intensity (mm/hr)	15.15	39.87
12 hour Rainfall Intensity (mm/hr)	2.8	6.36
72 hour Rainfall Intensity (mm/hr)	0.7	1.6
Average Skew Coefficient	0.44	
Short Duration Geographic Factor F2	4.43	
Short Duration Geographic Factor F50	15.00	
Latitude	-33.1881	
Longitude	138.0082	

2.3.2 Rainfall Loss Parameters

Hydrographs were created using an ILSAX routine (time-area method) for each sub-catchment, based on the rainfall temporal data, loss model and the time of concentration specific to that sub-catchment. Pervious area losses are based on an initial and continuing loss model. ILSAX determines the rainfall losses for the pervious area of each sub-catchment by subtracting the initial and continuing losses from the rainfall hyetograph. The adopted rainfall loss parameters are presented in Table 2.2.

Table 2.2 Rainfall 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

2.3.3 Impervious Area Coefficients

The long-term (30-50 year time horizon) Impervious Area Coefficient (IAC) for each sub-catchment was adopted from the Port Pirie Stormwater Management Plan (Tonkin Consulting, 2011). The IAC's were reviewed and updated based on recent known development and the current Development Plan (10 January 2013). The key major updates to the runoff coefficients were as follows:

- IAC's were reduced for the area north of Frederick Street, as soil contamination means this area is being abandoned as urban development.
- IAC's were increased for the Feeley Street and Geddes Street catchments (approx. east of Port Germein Road) to take account of the industrial zoning and ongoing development.
- IAC's were increased to take account of Industrial zoning for the currently vacant land between Grey Terrace and Esmond Road.
- IAC's were increased to take account of commercial zoning south and west of Alpha Terrace and west of Wandearah Road by Grey Terrace.

The review and splitting of the sub-catchments into smaller areas allowed the Impervious Area Coefficients to be specified in greater detail. The final adopted Impervious Area Coefficients are presented in Appendix A

2.3.4 Times of Concentration

For the urban sub-catchments, the time of concentration (tc) is the time after the commencement of rainfall at which the whole sub-catchment is contributing to flow at the inlet. For each sub-catchment this was calculated based on the gutter slope and maximum length of gutter flow to the inlet. An additional 5 minutes for roof-to-gutter flow travel time for residential sub-catchments (10 minutes for commercial/industrial) was added as recommended in “Stormwater Drainage Design in Small Urban Catchments: A Handbook for Australian Practice” (John Argue 1986). The resultant urban tc’s varied from 5 to 67 minutes.

2.4 Calibration of Ungauged Catchments

The modelled catchment is ungauged and therefore it is not possible to calibrate the model against known flows. Due to the lack of available calibration data, the hydrology study was carried out with parameters chosen based on best practice and local experience to provide an estimate of the actual flows.

The flood inundation maps resulting from this hydrology study based on future development conditions were compared to Council’s known flooding issues to provide some validation of the floodplain mapping results. Council decided that the preparation of flood inundation maps based on current levels of development for validation purposes was not warranted.

3 Flood Inundation Modelling

3.1 Introduction

A detailed 1D/2D TUFLOW model was created using MapInfo. The model was run within the TUFLOW software package to simulate storm events within the study area and generate flood inundation maps.

3.2 TUFLOW Modelling

The modelling was carried out using the TUFLOW computer program jointly funded and developed by WBM Oceanics Australia Pty Ltd and The University of Queensland. The program simulates depth averaged, two and one-dimensional free surface flows such as those that occur from floods and tides (WBM Oceanics Australia Pty Ltd, 2005).

TUFLOW (Two-dimensional Unsteady FLOW) has the ability to dynamically link to its 1D network component ESTRY, enabling the user to set up a model containing both 1D and 2D domains. GIS is used for much of the model setup, as well as for viewing and managing the results of TUFLOW simulations. The TUFLOW program is based on the Stelling (1984) solution scheme, which is a finite difference, alternating direction implicit (ADI) scheme solving the full 2D free surface flow equations. The ESTRY component is based on a numerical solution of the unsteady momentum and continuity fluid flow equations (WBM Oceanics Australia Pty Ltd, 2005).

TUFLOW was initially developed to model tidal estuaries. However, Tonkin Consulting assisted in pioneering the use of TUFLOW for urban flood inundation mapping. The drainage network is modelled in 1D and dynamically linked at each inlet/outlet structure to the 2D floodplain. This allows for the integrated modelling of the drainage network and floodplain.

The model area is divided into fixed rectangular cells. The model had the ability to simulate the variation in water level and flow inside each cell once information regarding the ground resistance, topography and boundary conditions is entered.

3.3 Existing Stormwater Drainage Infrastructure

3.3.1 Existing Infrastructure

The drainage network for the study area predominantly comprised of an underground drainage network, with a small number of open channels. The open channels are listed as follows:

- Open channel linking Grey Terrace to Wandearah Rd
- Open Swale by Port Germein Road (between Wattle St & Copinger Rd)
- Channel system linking culverts under Warnertown Road & Boundary Road

The drainage infrastructure data (drains and inlet structures) that was used for modelling was provided by the Port Pirie Regional Council. The data was originally created for DRAINS modelling of flows in main drainage systems, but was not accurate down to the individual pit level. While the data set could have been used as is, it was extensively reviewed and updated to provide an accurate model that included all drainage infrastructure within the study area.

As part of the review and updating of the stormwater drainage infrastructure, individual pits (SEP's, grates, headwalls, etc) were updated to match their actual location, with many new pits being added to the drainage data. Google Streetview, site visits and the original drainage design drawings (Lang, Dames and Campbell, 1991, etc) were used to accurately locate and size every inlet pit within the study area. This increased the number of inlet pits in the GIS data base from 230 to 353.

The drainage network was then updated to match the pit locations. Where new drains were added or there were uncertainties within the drainage database, locations and sizes were

discussed with Council and either confirmed on site or taken from the design drawings. Where invert information was not available, inverts were created based on the DTM level and 0.6 m cover. In addition to the above, the drainage information was checked for consistency as follows:

- Pipe diameters and box culvert sizes were reviewed to check for consistency and that they were increasing in the downstream direction.
- From a modelling point of view, all drains must be drawn in the downstream direction, so that the start and end inverts are applied at the correct end of the pipe & the flow results are positive values. Checks were carried out to ensure all drains were digitised in the correct direction.
- Checks were also carried out to ensure all drains snapped correctly at nodes.

In addition to reviewing the database, the following recent drainage infrastructure upgrade projects were added to the model from the construction drawings:

- Wandearah Road Stormwater Upgrade (between the pump station and Esmond Road)
- Port Pirie Lifestyle Village (see Section 3.3.3)

This review and updating resulted in a greatly improved GIS data base of drainage infrastructure for the study area, and allowed the TUFLOW model to accurately represent the drainage infrastructure.

3.3.2 Modelling of Inlet Pits

Inlet pits were modelled using head-flow relationships to provide a good estimate of the inlet capacity of each pit. The head-flow relationships adopted were based on standard “Transport SA” pit databases. Different curves were entered for single and double side entry pits (SEP’s) and grates. A Google Street View review of each inlet pit, combined with a site visit allowed each pit to be classified into its pit type and the data added to the inlet pit database.

3.3.3 Detention Basins and Pump Stations

The study area included three pumped detention basins, one gravity drained detention basin, a pumped underground storage and a pumping main inflow from an external catchment. Details of each detention basin and pump station are outlined following. Pump station details can be found in Table 3.1.

Wandearah Road

The Wandearah Wetlands form the main detention storage for the study area, detaining a catchment of 317 hectares. Inflows into the wetlands are directed to three sedimentation basins, designed to reduce the sediment load on the main basin. The western sedimentation basin had been relocated in recent years to make room for an extension to the racecourse. The DTM data did not reflect the relocated basin and was manually modified to include the sedimentation basin in the correct location. When modelling the wetland system in TUFLOW, the initial basin water level was assumed to be 0.085 mAHD. This was the level in the basin at the time of DTM capture, which was assumed to provide a reasonable estimate of the working level of the basin.

The Wandearah wetlands are pumped to an outfall into the Port Pirie River, via a pump station that is situated by Wandearah Road. Details of the pump station can be found in Table 3.1. While there are currently two pumps operating, Council stated that a third pump had been purchased, however the limited capacity of the pumping main had prevented its use.

The Wandearah Road pump station along with the Dead Horse Creek, Moppett Road and Harris Road pump stations are linked into the Flygt AquaView SCADA system, providing real time monitoring of the pump station levels and operation.

Dead Horse Creek

The Dead Horse Creek detention basin captures flows from The Terrace and the northern part of the town centre. While the basin has a gravity outfall to the Port Pirie River, there is also a pump station, with a pumping main running north along The Terrace and Coombe Road, discharging to the North-West. Details of the pump station can be found in Table 3.1. The initial basin water level was assumed to be 0.2 mAHD. This was the level in the basin at the time of DTM capture, which was assumed to provide a reasonable estimate of the working level of the basin.

Alpha Terrace

The Alpha Terrace detention basin receives and treats flows from the upstream portion of the Alpha Terrace catchment. It is drained via a gravity outfall to the Port Pirie River. The basin was not present in the DTM data, and so was input into the DTM based on design drawings. The basin was assumed to be empty prior to each storm event modelled.

Flinders Industrial Subdivision

The Flinders Industrial Subdivision is a recent subdivision that was later than the date of the DTM data available, excluding the possibility of modelling the subdivision in detail. The ongoing development in this area (including site filling) further reduces the applicability of the current mapping. To provide a representation of the development, the DTM data was modified to include the detention basin that was formed as part of the development. The inflows from the local catchment were then applied directly into the detention basin (assumed to be empty prior to the storm event) and the pump station modelled. Details of the pump station and rising main can be found in Table 3.1 following.

Harris Road Outfall

While the Harris Road catchment, detention basins and pumping station are outside of the study area, the pumping main outfall is located within the Geddes Street catchment. In order to correctly model the ponding within the Geddes Street catchment, the Harris Road pumping main outfall was included in the TUFLOW model. The pumping main outfall is directed into the culverts under Warnertown Road, near boundary Road. An analysis of the Harris Road pumping regime was carried out using the DRAINS model that was created for the Port Pirie SMP (Tonkin Consulting, 2011). The pumping regime was seen to vary with each ARI and duration storm event, and is dependent on the levels of development within the Harris Road catchment. As a simplification for the current modelling, it was assumed that for all storm events the pumps start operating 0.5 hours into the storm event (average existing start time across the durations modelled), and continue operating past the end of the modelled storm duration. The result of the extra 200 L/s pumped into the Geddes Street catchment channel was seen to only have a minimal impact on the extent of local ponding present.

Port Pirie Lifestyle Village

The Port Pirie Lifestyle Village has its own internal drainage system including oversized pipes leading to a 450 m^3 underground storage. As the DTM didn't include the recently constructed village road network, the drainage network wasn't modelled in detail down to each individual inlet pit. Drains with a diameter of 600 mm or greater and the underground storage were modelled to provide an accurate representation of the storage volume available. The pump station and rising main to the SEP in Wandearah Road were modelled. Details of the pump station and rising main can be found in Table 3.1 following.

Table 3.1 Modelled Pump Stations

Pump Station	Flow Rate	Comment
Wandearah Road	130 L/s	There are 2 pumps, each with a duty point of 67 L/s. Pumps start at 1.1 & 1.2 mAHD respectively. Size of pumping main is unknown, but is in poor condition restricting an effective pump station upgrade.
Dead Horse Creek	150 L/s	There are 2 pumps, each with a duty point of 80 L/s. Pumps start as 1.47 & 1.57 mAHD respectively. Size of pumping main is unknown.
Flinders Industrial Subdivision	200 L/s	There are 2 pumps, each with a duty point of 100 L/s. Pump start levels are unknown (modelled at 1.0 & 1.1 mAHD respectively). The pumping main is 250 mm diameter.
Harris Road	200 L/s	The pumping main outfall is directed into the culverts under Warnertown Road, near boundary Road.
Port Pirie Lifestyle Village	40 L/s	There are two pumps with a combined duty point of 40 L/s. The pumping main is a 250 mm diameter HDPE, connected into the SEP on Wandearah Road.

3.3.4 Levee Bank

Construction is currently being completed on a levee bank to mitigate the risk of tidal flood inundation of the Port Pirie Township. The levee bank was included in the model and it was assumed that construction of the levee was complete. The levee bank has a minimum height of 3.4 mAHD, being designed to contain a 100 year ARI tide (inc. 0.3 m of sea level rise) of 3.06 mAHD. The modelling assumed that the 100 year ARI tide was contained and that there were flap gates on all drainage outlets that pass under the levee bank. There are currently drainage outlets in the Feeley Street and Geddes Street catchments that do not incorporate flap gates.

3.4 Modelling Parameters

3.4.1 Digital Terrain Model

The Digital Terrain Model (DTM) was prepared by Aerometrex using photogrammetric techniques for this flood study. Aerometrex combined two data sets, an existing DTM (ground truthed to Australian Height Datum (AHD) levels, including breaklines) of the city centre area dated March 2006, and a larger DTM of the rest of the study area (not ground truthed or breaklined) dated February 2011. Aerometrex travelled to Port Pirie to ground truth the 2011 DTM data, and then combined the two DTM data sets to provide one continuous DTM data set for the entire study area that was ground truthed to accurate AHD levels.

Breaklines were then created by Aerometrex for the areas of the new DTM that did not contain breaklines. This allowed the street curb lines and channel/basin banks to be accurately defined, helping the TUFLOW model to accurately define surface flood flows within the street network, etc.

The DTM/breakline data was based on the 2006/2011 aerial photography. This resulted in several areas where curb lines had been realigned after the aerial photography date, mostly around the city centre and Grey Terrace. For these areas, the DTM levels were adjusted in the TUFLOW model to reflect the current curb alignment. The southern sedimentation basin for the Wandearah Wetlands had also been moved since the aerial photography date, and had to be manually recreated within the TUFLOW model to reflect the current situation.

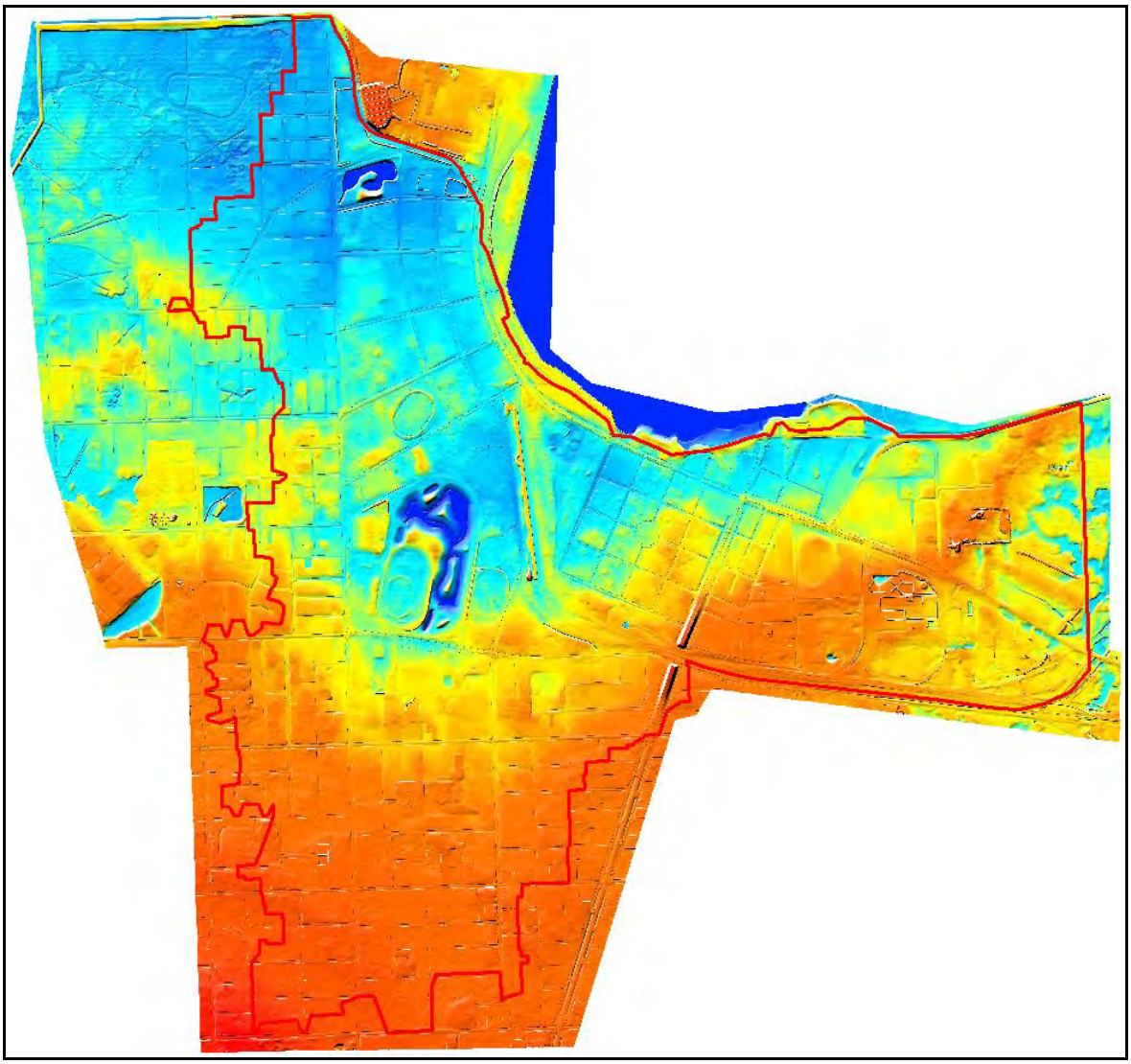

Figure 3.1 Port Pirie Digital Terrain Model

3.4.2 2D Cell Size

Determining an appropriate 2D cell size to be used by TUFLOW requires a compromise between the resolution of floodplain mapping and the computer time and memory required to run the models. Smaller 2D cell sizes more accurately reproduce detailed topography and the hydraulic behaviour, but significantly increase the amount of memory and computational power required to run the model. An understanding of the specific requirements for each study is needed in order to select an appropriate 2D cell size.

A cell size of 4 m is considered an average value for many studies previously undertaken by Tonkin Consulting as a good compromise between resolution and computational power. Smaller cell sizes are adopted if possible when modelling the complete river and floodplain system in 2D, to allow for a greater accuracy of hydraulic behaviour and interaction between the channel and floodplain to be modelled. A 2 m cell size is the minimum size recommended by the TUFLOW developers to produce stable results.

A 3 m cell size was adopted for the Port Pirie Township. This was made possible due the small size of the study area, allowing for a detailed model to be created while still achieving good model run times.

3.4.3 Roughness Coefficients

The TUFLOW model utilises a GIS layer of roughness coefficients (Manning's n values) to define the bed resistance used in calculating the flow and hence the water depth at any location within the model domain. In GIS, the aerial photograph was used to define roughness coefficient regions throughout the model domain.

The Manning's n roughness coefficients used in modelling are specified in Table 3.2.

Table 3.2 Adopted Manning's n Roughness Coefficients

Type of Land Use	Manning's n
Houses/Residential areas, obstructions to flow	0.200
Medium density residential and commercial	0.300
Parklands with scattered trees	0.045
Grassed areas and bare ground	0.035
Roads (including verges)	0.030
Concrete channels & box culverts	0.013
Concrete Pipes	0.011

3.4.4 Time Step

The selection of a time step for the 2D domain of TUFLOW is important as it is inversely proportional to the running time of the model. Larger time steps allow iterations to "bounce" which decreases the accuracy of results and possibly leads to model instabilities. The choice of a smaller time step increases the accuracy of results and also increases the model running time.

A 2D domain time step of 1 second was adopted for all modelled catchments and events. The smaller model size allowed for this time step to be used while still achieving fast model run times. 99% of the computational effort is in solving the 2D surface flow equations and hence the 1D domain time step has a negligible impact on simulation times. A small 1D domain time step of 0.1 second was used, greatly improving the 1D network stability of the models.

3.4.5 Inflows

Inflow hydrographs were generated for each ARI and duration storm event to be analysed, as outlined in the Section 2.2. The inflows for each sub-catchment were applied to each inlet pit/grate/headwall throughout the catchment. Inlet capacity tables were used to provide an approximate inlet capacity for each single and double side entry pit and grate. This allowed the inflows to pass directly into the drainage network until the pit capacity or HGL levels were exceeded, with the excess spilling into the street network (2D floodplain). Where no drainage infrastructure was present within the sub-catchment (i.e. for large sub-catchments that had been split to increase the inflow resolution), the inflow was applied directly to the street network.

3.4.6 Boundary Conditions

The drainage systems modelled ultimately drain into the Port Pirie River (Gulf St Vincent). An investigation into the appropriate tidal boundary condition was undertaken. While the Port Pirie Township is protected from the 100 year ARI tide by a levee bank, it is unreasonable to assume that the 100 year ARI tide will coincide with the 100 year ARI storm event. Stormwater drainage design and analysis of local drainage systems has generally adopted the Mean High Water Springs (MHWS) tide level as the boundary condition for systems that drain into the gulf. This caters for a storm event of a duration about the same duration as a tidal cycle (a few hours) occurring coincidentally with a period of spring tides. This is considered a reasonable (and slightly conservative) approach for catchments with a similar critical duration.

For the Port Pirie Township, a MHWS tide level of 0.77 mAHD was adopted. However, the flood study is an analysis of the long-term flood inundation scenario. For this reason, 0.5 m of sea level rise was also modelled. This resulted in a long-term Port Pirie River boundary condition of 1.27 mAHD being applied to all recurrence interval storms modelled.

3.4.7 Modelling Assumptions

- It was assumed that construction of the levee bank (designed to provide protection to the township from high tide events) was completed and that the 100 year ARI tide event is contained.
- Flap gates were assumed on all drainage outlets that pass under the levee bank, such that high tide events would be contained.
- While roughness coefficients were applied to the creek channels and culverts based on the current conditions, no allowance was made for any blockage that may occur during storm events. During large storm events, objects could be swept into inlet pits, headwalls and creek channels, exacerbating flooding in the local area. Siltation could also reduce the capacity or form a blockage to the drainage network, exacerbating flooding in the local area.
- Roughness values of urban development were based on cadastral information and aerial photography. Building footprints were not taken into account meaning that within the model it is possible for water to flow through buildings. The high bed resistance values applied to residential and commercial areas make an allowance for the obstructions created by buildings.
- The floodplain model does not provide for dynamic changes to the DTM due to erosion that can occur and possibly change the distribution of flow by altering flow paths.

3.5 Tuflow Runs

3.5.1 Events Modelled

Design storms for three different Annual Recurrence Intervals (ARI) were modelled for each catchment. For each ARI, various storm durations were modelled in order to obtain the peak flood level at different points within the catchment. Table 3.3 outlines the ARI's and durations that were run for each catchment. For each catchment, the 100 year ARI critical duration was generally the 1 - 3 hr events for the street network, with the detention basins peaking in the 24 - 36 hr events.

Table 3.3 Modelled ARI's and storm durations

Event	Storm Durations Modelled
5 year ARI Long-term	0.5hr, 1hr, 3hr, 6hr, 9hr, 12hr, 18hr, 24hr, 36hr
20 year ARI Long-term	0.5hr, 1hr, 3hr, 6hr, 9hr, 12hr, 18hr, 24hr, 36hr
100 year ARI Long-term	0.5hr, 1hr, 3hr, 6hr, 9hr, 12hr, 18hr, 24hr, 36hr, (48hr*)

** The 48 hr duration storm event was only run once to ensure that the peak level in the detention basins had been reached.*

This resulted in 28 sets in inflow hydrographs and 28 model runs being carried out for each catchment to produce a set of flood inundation maps.

3.5.2 Flood Inundation Mapping

For each model run, flood depths and levels (AHD) were output for each time step. Upon completion of each model run, the maximum flood depths were calculated & outputted into a GIS layer. For each ARI, the GIS results from each duration were then spliced together to provide an umbrella floodplain map of the maximum flood depth.

4 Flood Inundation Results

4.1 TUFLOW Runs

The TUFLOW runs were successfully carried out for all 28 model runs. Analysis of the flood inundation results and peak flows at the downstream ends of the main drains demonstrated that the critical durations were 3 to 6 hrs for street ponding, while the detention basins peaked in the 24 to 36 hr storm events. Analysis of the detention basins and key flooding locations are discussed in Section 5.

4.2 Validation of Results

Validation was carried out through several iterations of the model to ensure that the drainage network, inlets, pumps, boundary conditions, etc were operating as expected within the model and to resolve any inconsistencies in the input data.

Draft flood inundation results were discussed with the Port Pirie Regional Council and areas of expected and unexpected flooding identified. These locations were then scrutinised in the model and either updated or verified to achieve the accurate representation and performance of the model. The modelling was carried out based on the ultimate development within the study area, limiting the scope for calibration against known flooding issues.

4.3 Flood Inundation Mapping

Flood inundation maps were produced so that the impact of flooding could be visually analysed. The flood inundation maps were overlayed onto the aerial imagery, with the drainage network and street names shown to allow for easy location and assessment of flooding. The flood depth data was contoured into discreet intervals to allow for easy discrimination of flood depths. Flood depths of less than 25 mm have been trimmed from the flooding as they provide an unrealistic representation of sheet flow through properties.

5, 20 and 100 year ARI flood inundation maps that were produced for the study area. These were all produced as A1 drawings, and provided as GIS floodplain data according to the Port Pirie Regional Council's data requirements. The A1 flood inundation maps are presented scaled to A3 in Appendix B of this report.

4.4 Development Guidelines

The flood study has resulted in GIS layers for the 100 year ARI extent of flooding and 100 year ARI flood contours being provided to Council. These GIS layers provide the Port Pirie Regional Council with the tools to assess individual site development and to set finished floor levels based on a set freeboard above the 100 year ARI flood level, taking into account future development conditions. For new development, a freeboard of 300 mm above the levels shown in the 100 year ARI flood contours is recommended.

5 Assessment of Key Flooding Locations

5.1 Key Flooding Locations

The flood inundation results show that the drainage system works well for the 5 year ARI storm event, with most of the flooding confined to the street network, with the only major flooding location occurring in the Feeley Street catchment between Port Germein Road and Wattle Street.

An analysis of the 100 year ARI flood inundation results immediately identifies the Wandearah Road and Dead Horse Creek detention basins as the key flooding locations within the study area. These along with the Alpha Terrace detention basin are discussed in detail in Section 5.2.

The few breakouts from the street network in the 5 year ARI storm event provide an insight into the key flooding locations during larger storm events. The key flooding locations have been identified as follows:

- Federation Road, Dead Horse Creek Catchment,
- Florence Street to Gertrude Street, City Centre Catchment,
- Grey Terrace, east of Wandearah Road, Wandearah Catchment,
- Balmoral Road, from Murdock Street to South Street, Wandearah Catchment,
- Alpha Terrace, Alpha Terrace Catchment,
- Wattle Street and Copinger Road, Feeley Street Catchment.

Major development works are expected within the Geddes Street catchment, which will alter site levels and incorporate new drainage infrastructure. For this reason, the Geddes street catchment has been excluded until such time as the development catchment can be assessed in detail.

The key flooding locations are discussed following:

5.1.1 Federation Road, Dead Horse Creek Catchment

There is currently no underground drainage in Federation Road, while the catchment has an area of approximately 10 ha. This results in surface flood flows exceeding the capacity of the street network and inundating properties around Poynton Street in the 5 year AIR storm event. During the 20 year AIR storm event the inundation had increased, with ponding on Rodda Street also becoming significant.

To mitigate the property inundation risk and aid surface flow capture, it is recommended to extend the underground drainage network up Federation Road to the intersection with Rodda Street. This recommendation is in line with the drainage upgrades proposed by Lange, Dames & Campbell (1990).

5.1.2 City Centre Catchment

Surface ponding and property inundation are a significant issue for the city centre catchment during the 20 year ARI storm event and greater. The most significant ponding is centred around the block formed by Gertrude, Florence, David & Alexander Streets.

There are several possible mitigation options, and further investigation is warranted to identify the recommended option. These options may include an upgrade to the existing drainage systems down David Street or Alexander Street as proposed by Lange, Dames & Campbell (1991). An alternative option would be to direct flow into the Dead Horse Creek detention basin. However for this to be a viable option, the basin would have to be upgraded to lower the peak ponding level allowing the city centre catchment to effectively drain into the basin. If the basin was extended to the southern side of George Street, this may become the recommended option. The Dead Horse Creek Detention Basin is discussed in Section 5.2.2.

5.1.3 Grey Terrace, Wandearah Catchment

There is a low point in Grey Terrace between Wandearah Road and Clayton Street that results in ponding and property inundation to the south of Grey Terrace. While this is only shallow inundation during the 5 year ARI event, it becomes a more significant in the 20 year ARI storm event. While there has been recent drainage upgrades to Wandearah Road to the north and west, these haven't addressed the ponding occurring in this location.

Surface flood flows are currently collected by a 300 mm diameter stormwater drain leading to the open channel to the north. It is recommended that the drainage capacity for this area be upgraded. Lange, Dames & Campbell recommended a 750 mm diameter drainage network linking to the existing Grey Terrace drainage to the west. It may also be viable to continue draining to the north and enlarge the open channel into a detention basin, providing a storage volume to reduce the surface ponding, while limiting the impact of the drainage upgrade on the Wandearah Road/Grey Terrace drainage networks.

5.1.4 Balmoral Road, Wandearah Catchment

While there is an underground drainage network running up Wandearah Road to capture surface flood flows along Balmoral Road, there is currently no underground drainage network for Balmoral Road around The Terrace (except for a small bubble up system at the intersection). The 25 ha catchment upstream of Balmoral Road at this location results in the capacity of the road network being exceeded and shallow property inundation occurring north of Balmoral Road by The Terrace and Halley Street in the 5 year ARI storm event. In the 100 year ARI storm event the inundation expands to form significant surface flood flow paths through residential property.

Lange, Dames & Campbell recommended that the Esmond Road drainage network be extended up The Terrace to capture flows at Balmoral Road. It is recommended that these works be undertaken to mitigate the inundation risk to residential property. Further investigation would be warranted to assess the viability of a detention basin in Woodward Park, to limit the impact of these drainage upgrades on the downstream system.

5.1.5 Alpha Terrace, Alpha Terrace Catchment

Ponding is occurring by the intersection of Alpha Terrace and King Street. While the ponding is acceptable in the 5 year ARI storm event, the 20 year ARI storm event results in property inundation which in the 100 year ARI storm event increases to a depth of 0.5 m. The ponding is due to the level in the Alpha Terrace detention basin limiting the effectiveness of the drainage network. The Alpha Terrace detention basin is discussed in Section 5.2.3.

5.1.6 Wattle Street and Copinger Road, Feeley Street Catchment

The inundation occurring around Wattle Street and Copinger Road is the most significant property inundation occurring during the 5 year ARI storm event. During the 20 and 100 year ARI storm events, the ponding depth increases showing that the limited drainage and outfall through the Port Germein Road are significantly under capacity. The drainage network at this location was not included in Council's GIS data base or in the SMP study and hence this key flooding location was not previously been identified.

Currently there is a 450 mm diameter outfall pipe through Port Germein Road. Lange, Dames & Campbell recommended a 650 mm diameter outfall at this location in 1991. Given the extent of industrial development that is occurring in this area, a larger outfall would now be recommended. The drainage network also needs to be upgraded to efficiently transfer surface flood flows in Wattle Street and Copinger Road to the outfall. The outfall also does not currently include a flap-valve, which will be required during a 100 year AIR tide event for the levee bank to be effective.

5.2 Detention Basins

5.2.1 Wandearah Road Wetlands

While the Wandearah Road Wetlands operate efficiently during the 5 year ARI storm event, surface ponding to a depth of 0.45 m is seen in Wandearah Road during the 10 year ARI storm event. During the 100 year ARI storm event the basin capacity is exceeded and results in the most significant inundation seen in the study area, ponding to a depth of 1 m in Wandearah Road and inundating the John Pirie Secondary School.

An upgrade to the pump station is recommended to mitigate the significant flooding risk. An upgrade to the pumping main may also be required for efficient pump operation (see Section 3.3.3). An additional option is to increase the bank height around the north-eastern side of the Wandearah Road Wetlands. This would allow the basin to reach a higher level before inundation to the surrounding area occurred.

5.2.2 Dead Horse Creek Detention Basin

Modelling shows that during the 5 year ARI storm event, the Dead Horse Creek detention basin is seen to operate efficiently, resulting in no property inundation. However, ponding to a depth of 0.3 m is observed in The Terrace and George Street. This ponding is at the same level as the level in the Dead Horse Creek detention basin, demonstrating that the level in the basin is restricting the efficient operation of The Terrace and George Street drainage networks. During the 20 year ARI storm event ponding along The Terrace becomes more significant with property inundation occurring. By the 100 year ARI storm event the property inundation has spread to the city centre catchment around George Street.

The Dead Horse Creek detention basin currently has a 900 mm diameter gravity outfall to the Port Pirie River and a pump station pumping 150 L/s down The Terrace and discharging to the north-west. The gravity outfall is efficient at draining smaller storm events, limiting the use of the pump station.

The Port Pirie SMP recommends that the storage capacity of the detention basin be increased, possibly by acquiring land to the south of George Street. This would also facilitate the drainage of part of the City Centre catchment into the basin. Pump station upgrades are also recommended as they would reduce the volume of detention storage required. Further investigation into the Dead Horse Creek detention basin is recommended to assess the optimal combination of additional storage and upgraded pump rates to achieve efficient flood mitigation.

5.2.3 Alpha Terrace Detention Basin

The Alpha Terrace detention basin has an invert level of -0.5 mAHD. As this basin has a gravity outfall its storage capacity will be heavily influenced by the tide level restricting outflow from the basin. The flood modelling shows that during the 100 year ARI storm event, the basin is overtopping and significant flooding is experienced in Alpha Terrace, immediately upstream of the basin. The basin's peak level was reached during the 24-36hr storm events.

Additional storage could be achieved be enlarging the basin; however the low invert of the basin means that the tide level may limit the effectiveness of the expanded storage. A preferred option may be to include a pump station, such that the full storage in the basin can be efficiently utilised without tidal influence.

5.3 Assessment of the Port Pirie Stormwater Management Plan

While the Port Pirie Stormwater Management Plan (SMP) was focused on DRAINS modelling to identify areas of the drainage network that were under capacity, the TUFLOW modelling undertaken for this flood study allows the surface flooding to be quantified, showing where the drainage capacity limitations result in significant flooding. The flood study provides the opportunity to assess and prioritise the recommendations from the SMP.

The recommendations arising from this flood study generally align well with the recommendations of the SMP. However the flood study does show that some of the SMP recommendations are unwarranted as the limited drainage is not resulting in any significant inundation. The recommendations from the SMP are discussed as follows:

5.3.1 Dead Horse Creek

The results of the flood study verify the findings of the Port Pirie SMP, showing that the top priorities are the upgrading of the Dead Horse Creek detention basin and extending the underground drainage network up the lower half of Federation Road.

5.3.2 City Centre

Generally the results of the flood study verify the findings of the Port Pirie SMP for the City Centre catchment and support its recommendations. However modelling of the 100 year ARI storm event did not see flood flows transferring from the Wandearah Road Wetlands to the Dead Horse Creek Detention basin. A much larger ARI storm event would be required for this to occur.

5.3.3 Wandearah

The Port Pirie SMP recommends a significant upgrade to the pump station for the Wandearah Road Wetlands. The Flood Study emphasises the need for this upgrade showing that the overtopping of the Wandearah Road Wetlands results in the most significant inundation within the study area.

The Port Pirie SMP identifies a number of locations for drainage upgrades within the Wandearah catchment. The Flood Study highlights two of these upgrades as a priority to mitigate flooding within the catchment. These are the upgrading of the Grey Terrace drainage and the extension of the Esmond Road drain up The Terrace to Balmoral Road.

5.3.4 Alpha Terrace

While the Port Pirie SMP focuses in underground drainage network, the Flood Study has shown that the levels in the Alpha Terrace detention basin are critical to the efficient operation of the underground drainage network. It would be recommended to assess the performance of the Alpha Terrace detention basin further prior to undertaking underground drainage upgrades.

5.3.5 Feeley Street

The Port Pirie SMP focuses on the performance of the existing drainage network for the Feeley Street catchment. While the flood study verifies the SMP's recommendations, it highlights that the key flooding location is around Wattle Street and Copinger Road. This drainage system was not identified in the SMP study, but it is recommended that upgrades to this system should be prioritised.

5.4 Costing of Mitigation Options

Indicative costs have been prepared for the key upgrade recommendations provided in this Flood Study. As preliminary sizing of works proposed in this study has not been carried out, these costs should be considered as "order of magnitude" only. We would recommend that a more detailed investigation and preliminary sizing of the works be carried out for budgeting and funding purposes. The cost estimates are presented in Table 5.1 following.

Table 5.1 Order of Magnitude Costs of Mitigation Options

Catchment	Location	Option	Indicative Cost
Dead Horse Creek	Dead Horse Creek Detention Basin	Detention Basin expanded south of George Street, upgraded pump station and rising main.	$2,000,000
Dead Horse Creek	Federation Road	New underground drain to Rodda Street.	$700,000
City Centre	City Centre	Upgraded and linked Alexander Street outfall and connection to an upgraded Dead Horse Creek detention basin.	$1,200,000
Wandearah	Wandearah Road Wetlands	Pump Station upgrade to 600 L/s, new rising main and bank around north-eastern side of wetlands.	$1,500,000
Wandearah	Grey Terrace	Extend drainage network to collect flows from low point east of Wandearah Road.	$400,000
Wandearah	Balmoral Road	Extending the Esmond Road drainage up The Terrace to capture flows on Balmoral Road.	$900,000
Alpha Terrace	Alpha Terrace Detention Basin	Pump station installation (assuming 300 L/s, utilising existing outfall).	$400,000
Feeley Street	Wattle Street and Copinger Road	Upgrading of outfall under Port Germein Road and new drainage to Copinger Road and Wattle Street.	$400,000

Appendix A

Sub-Catchment Runoff Coefficient Maps

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Revision: A
Date: 20/6/2013
Drawn: TDC

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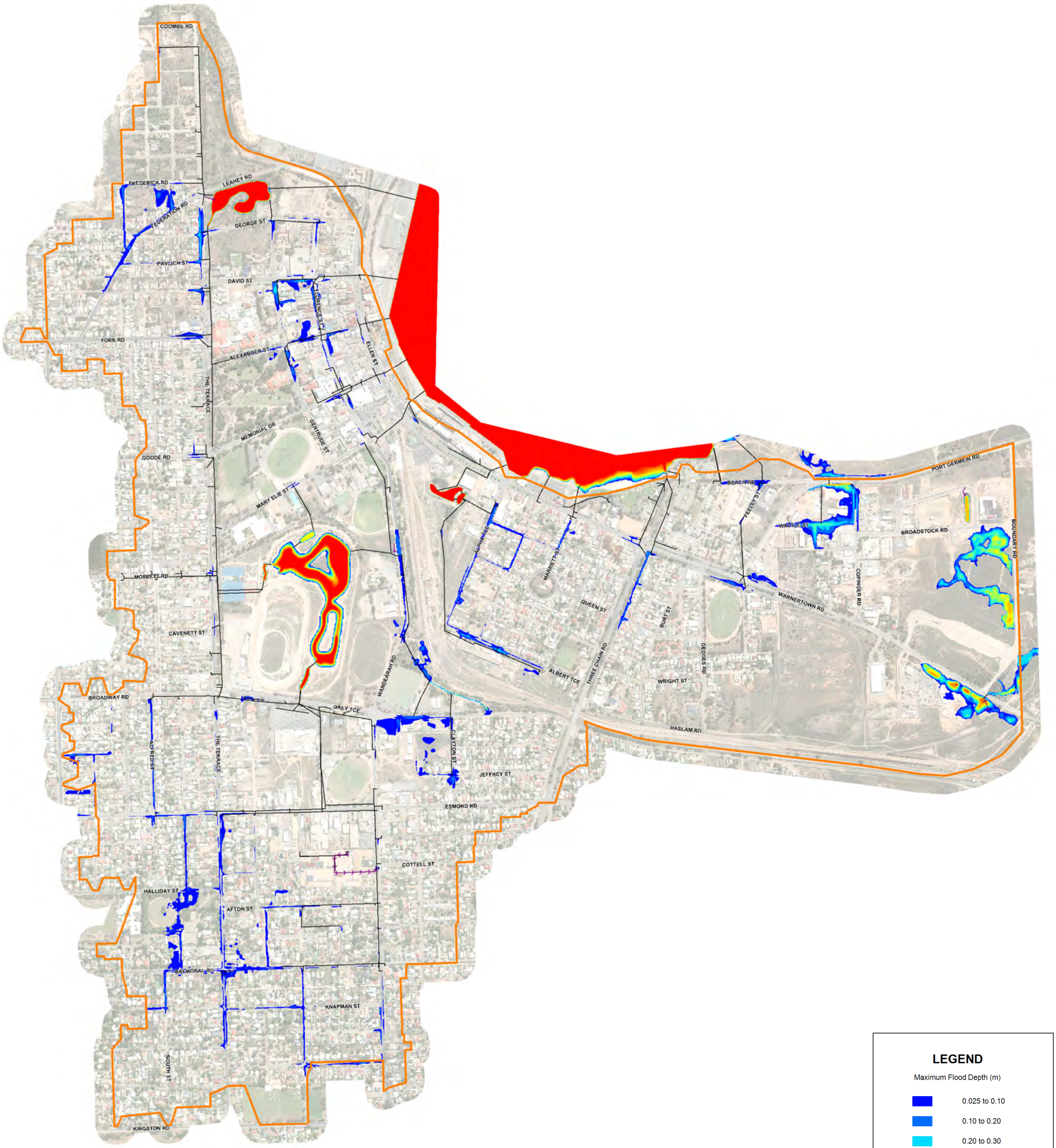
PORT PIRIE ULTIMATE RUNOFF COEFFICIENTS

Appendix A

Appendix B

Flood Inundation Maps



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N W E S

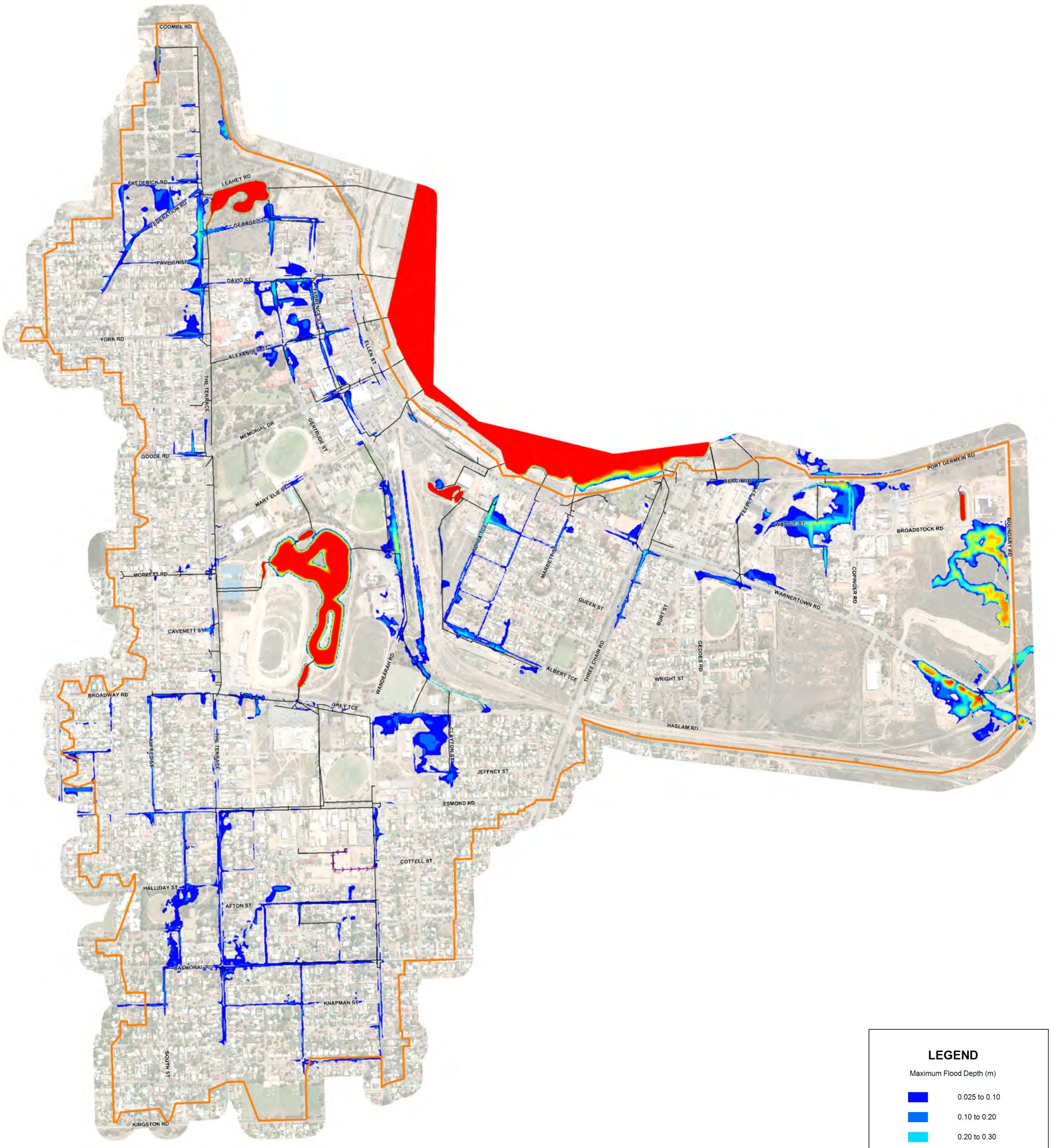
Scale: 1:7,500
Projection: GDA 94 (MGA, Zone 54)

Job Number: 2013.0090
Filename: Pirie_LT_5yr_A1.wor
Revision: C
Date: 19/06/2013
Drawn: TDC

Port Pirie Regional Council

5 YEAR LONG-TERM FLOOD INUNDATION PORT PIRIE TOWNSHIP

Map No. - 1 of 3



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Revision: A
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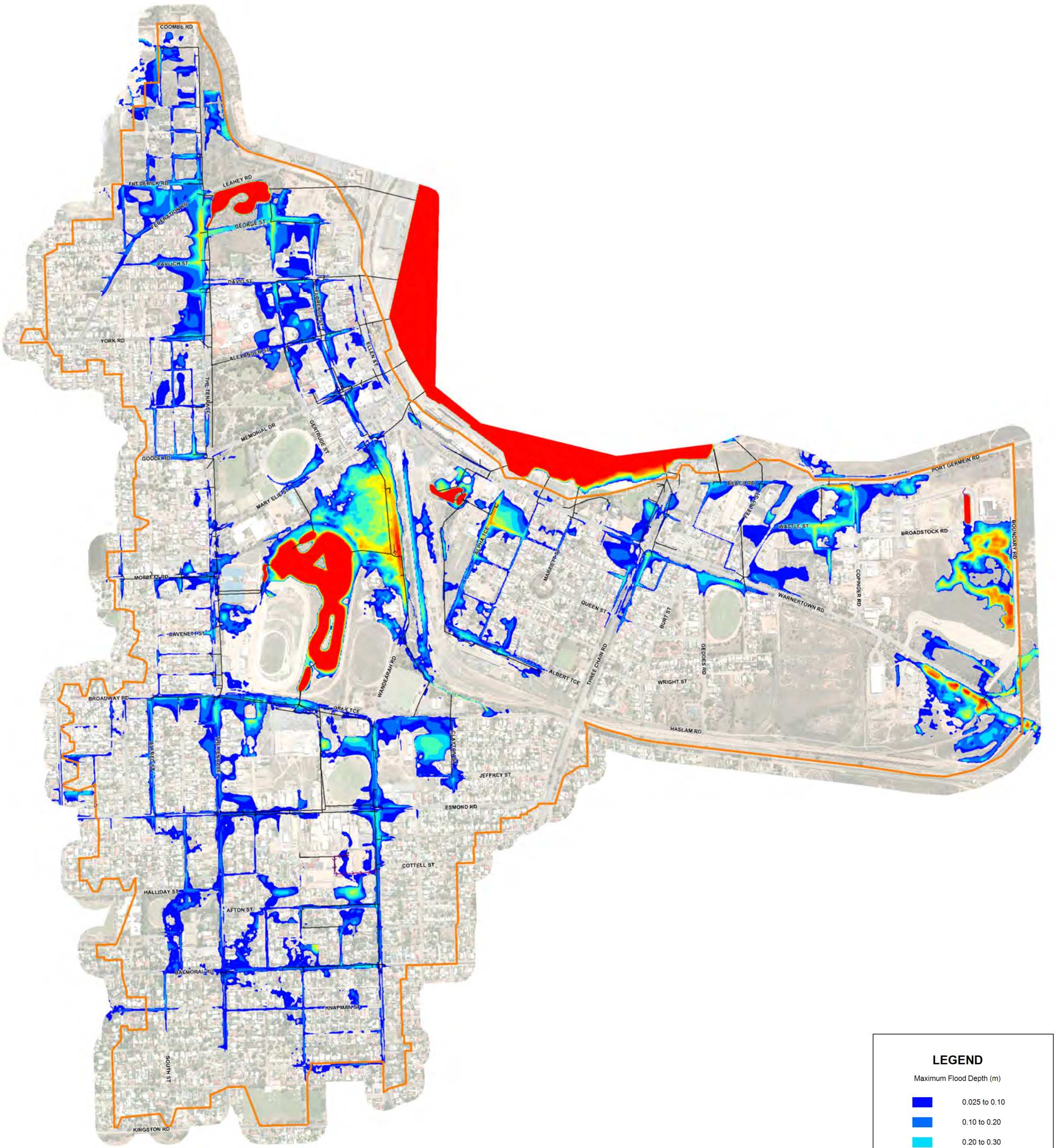
Port Pirie Regional Council

20 YEAR LONG-TERM FLOOD INUNDATION PORT PIRIE TOWNSHIP

Map No. - 2 of 3



LEGEND

Maximum Flood Depth (m)

- 0.025 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- 1.00 and over
- Drainage Network
- Pumping Mains
- Study Area Boundary

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N W E S

Scale: 1:7,500
Projection: GDA 94 (MGA, Zone 54)

Job Number: 2013.0090
Filename: Pirie_LT_100yr_A1.wor
Revision: C
Date: 19/06/2013
Drawn: TDC

Port Pirie Regional Council

100 YEAR LONG-TERM FLOOD INUNDATION PORT PIRIE TOWNSHIP

Map No. - 3 of 3