Appendix F – Moolyyir Creek Catchment Flood Risk Reduction Study

WorleyParsons

resources & energy

Incorporating JWP & Patterson Britton

EcoNomics™

HERVEY BAY CITY COUNCIL

Moolyyir Creek Catchment Flood Risk Reduction Study

Final Report

070050-001

5-Mar-08

Infrastructure
Level 9, 80 Albert Street
Brisbane QLD 4000
Australia
Telephone: +61 7 3221 7444
Facsimile: +61 7 3221 7791
www.worleyparsons.com
ABN 61 001 279 812

EXECUTIVE SUMMARY

WorleyParsons was commissioned by Hervey Bay City Council (HBCC) to undertake a Flood Risk Reduction Study for the Moolyyir Creek Catchment. The purpose of the analysis is to document existing flooding characteristics within the catchment, classify the flooding risks and assess potential mitigation options for reducing flood risk in order to meet HBCC design standards.

Both hydrological and hydraulic models were established using the TUFLOW software package to estimate design flow for the 10, 20, 50 and 100 year Average Recurrence Interval (ARI) events, which were modelled concurrently through the floodplain using fully hydrodynamic two-dimensional (2D) TUFLOW model. The hydrologic / hydraulic TUFLOW model covers the entire catchment.

The DTM information used for the hydraulic model was based on the latest ALS data obtained by HBCC. Limited field survey information were collected for trunk drainage structures where no detail was available within HBCC's GIS system. Some discrete cross section field survey was also undertaken.

The catchment topography is relatively flat with an equal area slope of 0.75% and covers approximately 110 hectares of predominantly urban land with which is zoned mostly low density residential.

Hydrological and hydraulic modelling was undertaken for the design flood events using existing waterway conditions and the ultimate land use scenario as per Councils latest Strategic Plan. The hydraulic model results were mapped and provided both digitally and as hard copy plans for all design events:

1. Flood inundation extents

2. Peak flood depths and water surface levels

The risk assessment analysis shows that the majority of existing flooding issues are classified low risk as velocities are generally within the catchment. However, this study has identified areas in the catchment where the flooding risk exceeds either QUDM trafficability requirements or HBCC design guidelines with respect to property inundation. These areas include downstream of Miller Street, Pulgul Street, upstream and downstream of Boat Harbour Drive, Moolyyir Street, the Esplanade, and from Tristania Crescent to downstream of Limpus Street. The design of for these areas upgrades was carried out with an aim to reduce flooding risk or road trafficability to meet design requirements. These mitigation options were simulated within the TUFLOW model, with the results predicitng most

upgrades achieve depths and velocities within the design guideline range. Mitigation measures assessed at the Boat Harbour Drive areas did not reduce the risk to an acceptable range. Council is aware of this problem area and conditional development approval will be administered to eliminate these flooding issues.

It is recommend that Council proceeds with the proposed upgrades throughout the catchment whilst asserting conditional development approval items with respect to flooding on the land parcels upstream and downstream of Boat Harbour Drive.

Preliminary analysis of required total capital expenditure to alleviate flooding within the entire Moolyyir Creek catchment to meet both QUDM and HBCC design requirements is $2,640,000.

Disclaimer

PROJECT 070050-001 - MOOLYYIR CREEK CATCHMENT FLOOD RISK REDUCTION STUDY

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Issued for internal review	P. Crichton	E. Reid	N/A	13-Feb-08	N/A	
0	Issued for client	P. Crichton	E.Reid	N/A	5-Mar-08	N/A	

HERVEY BAY CITY COUNCIL
MOOLYYIR CREEK CATCHMENT FLOOD RISK REDUCTION STUDY
FINAL REPORT

CONTENTS

Appendices

1. INTRODUCTION

Worley Parsons (WP) has been commissioned by Hervey Bay City Council (HBCC) to undertake a Flood Risk Reduction Study for the Moolyyir Creek Catchment. The purpose of the analysis is to document existing flooding characteristics within the catchment, assess potential mitigation options for reducing flood risk and meet HBCC design standards in the area. The study will be used for managing both existing and future development within the catchment based upon the reduction of flood risk.

This study represents the first comprehensive study of the entire Moolyyir Creek catchment using the latest 2D modelling techniques and includes a broad scale hydrologic and hydraulic analysis of the catchment.

The major components of works undertaken for this study have included:

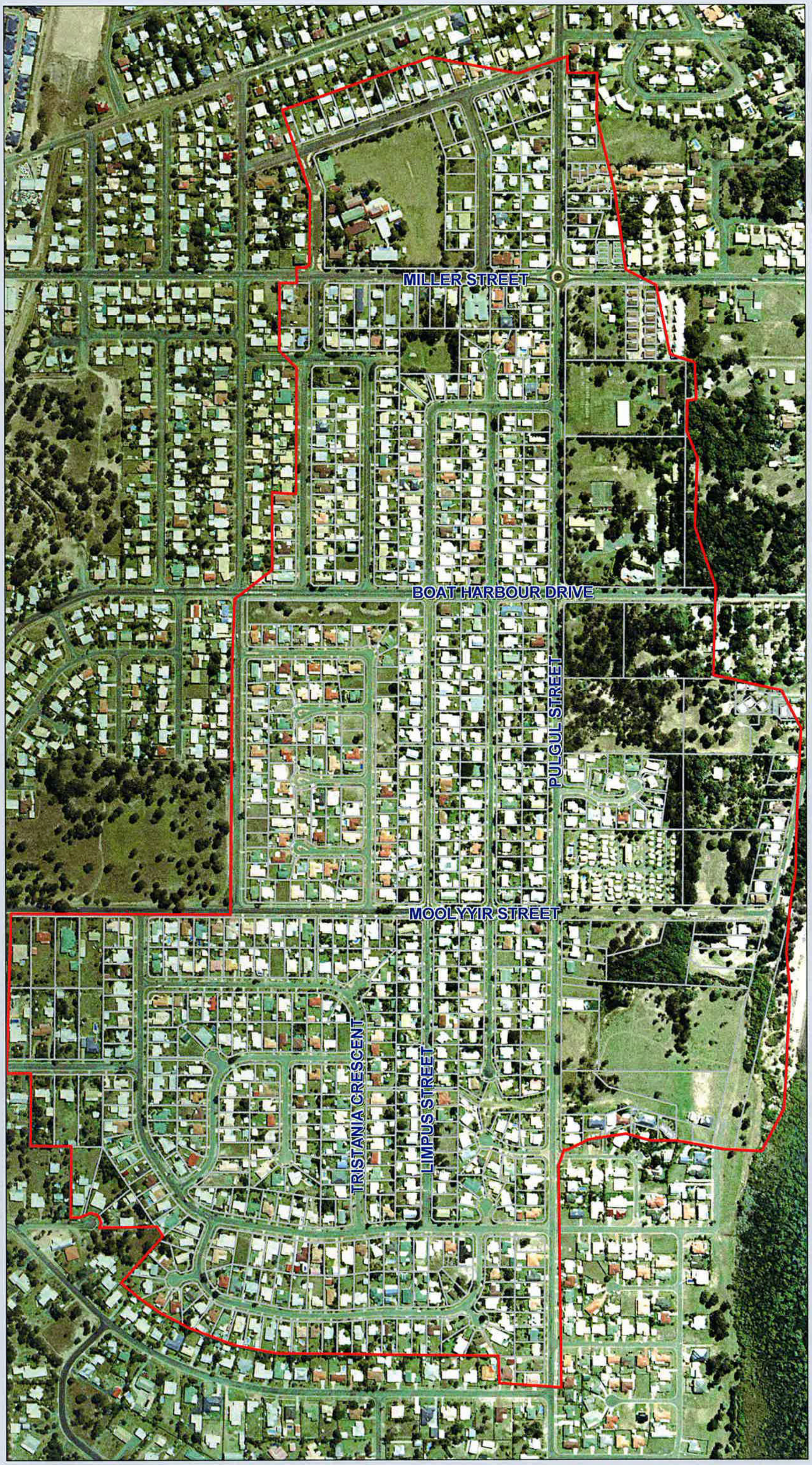
- The identification of existing drainage patterns including both piped systems (trunk drainage) and major overland flowpaths
- Construction of a fully integrated 1-dimensional (1D) and 2-dimensional (2D) TUFLOW hydraulic model
- Hydrological and hydraulic model analysis to define flood levels, flow directions and drainage problems in the catchment for the 10, 20, 50 and 100 year ARI design flood events
- Determination and analysis of mitigation options for the purposes of flood risk reduction
- Preliminary construction cost estimates for the mitigation options
- Documentation of the study methodology and outcomes as part of a formal report on the investigation including a risk management report

The following sections of this report aim to fully document the analysis works undertaken as part of this investigation.

2. STUDY AREA

The Moolyyir Creek catchment is bounded by Cooloola Crescent, Hansen Street and Aimee Drive to the west, Edward Street to the north, Pulgul Street and Hervey Bay to the east, and Cassandra Crescent to the south. The overall catchment area is approximately 110 hectares. There have been significant areas to the east of the catchment of infill development and reconfiguration from either future or low density residential to medium density residential, and from medium density to high density residential. However vast areas of the catchment remain classified as low density residential. As a result of the zoning changes to land use and the limited coverage of previous studies, a revised flood study covering the entire catchment is required.

Figure 2.1 shows the Moolyyir Creek catchment boundary, model boundary and study area.



Legend

TUFLOW Model & Catchment Boundary

Cadastre

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 2.1

CATCHMENT LOCATION & STUDY AREA

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 2.1.wor

Projection Trans. Merc. MGA56(GDA 94)

3. STUDY DATA

The works undertaken as part of this study, particularly the establishment of the TUFLOW model of the catchment have been prepared based upon a compilation of data sources provided by Hervey Bay City Council, as well as additional survey. Specifically, the models have been developed using a range of data sources and information, each of which are outlined and discussed separately below.

3.1 Topography Data

Topographical data for the catchment was provided in the form of raw Aerial Laser Survey (ALS) data supplied by HBCC. WP have prepared a Digital Elevation Model (DEM) from the ALS data supplied to accommodate data extraction for the various modelling tasks undertaken as part of this study. The DEM as prepared using the MapInfo Vertical Mapper software is illustrated in Figure 3.1, clearly showing the catchment location and topographical variation.

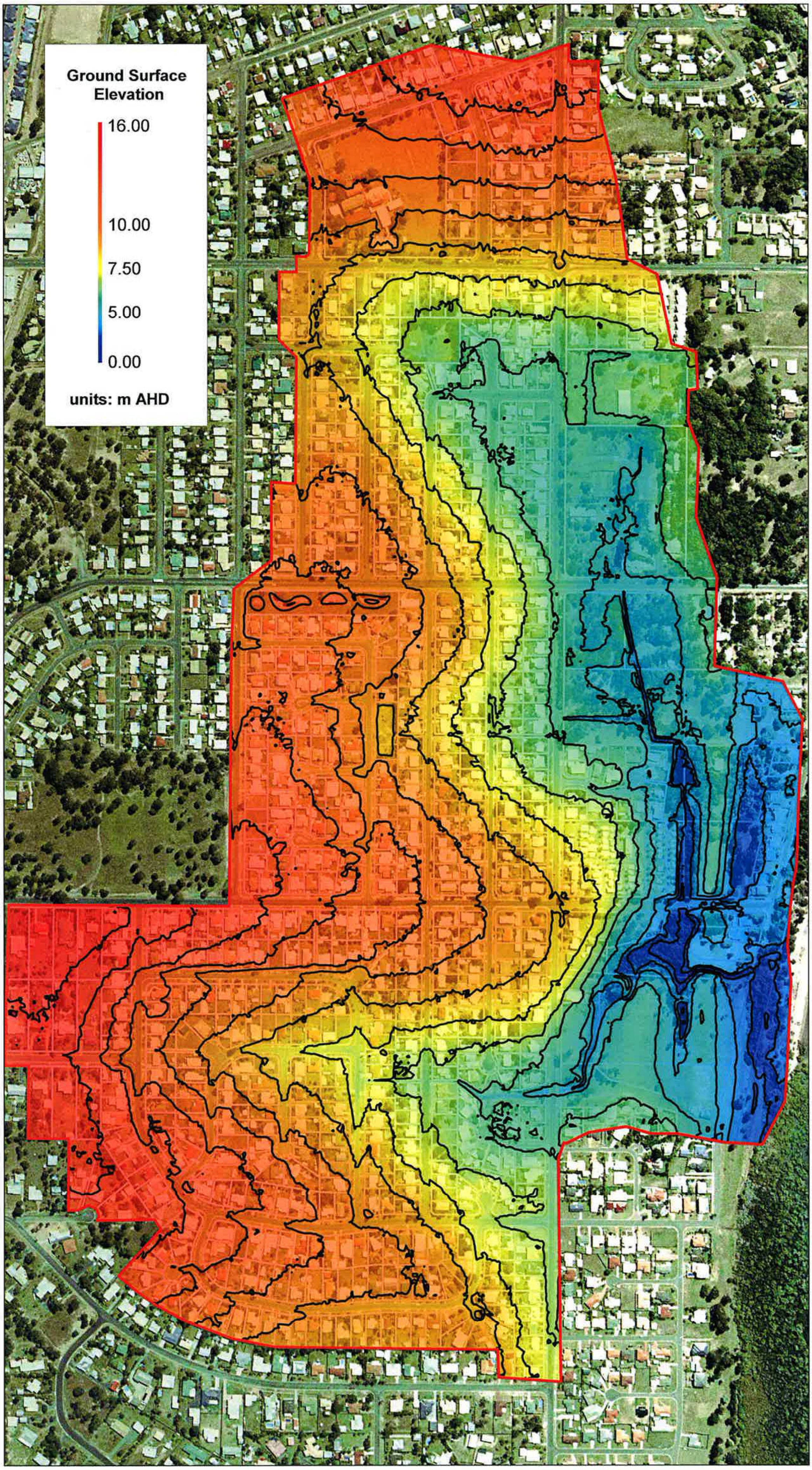
The 2D modelling approach utilises the entire DEM across the model area. The DEM is sampled at increments corresponding to the 2D hydraulic model grid size chosen. The grid size is described in detail in Section 5.4. The raw ALS data provided by council is somewhat coarse, and it is possible that some key drainage features are poorly defined in the DTM. These areas have been highlighted for ground survey.

3.2 Survey Data

Collection of limited field survey data for the catchment has been undertaken as part of this project. The intent of the field survey data collection was to infill missing information, obtain structure details and to provide more detailed topographical information at discrete and critical locations throughout the study area. Areas where more detailed survey information was required were defined by WP following a detailed assessment and review of the information initially provided. As part of the study, WP were responsible for management of these works which included the preparation of detailed survey briefs, calling of survey tenders and managing the field collection data.

All detailed survey works collected for this project were undertaken by Cullen & Couper Pty Ltd, a locally based and independent survey company in Hervey Bay. This information was collected using both traditional and GPS survey techniques and was provided in a digital AutoCAD format. WP utilised this information to update the various drainage network details within the model.

The survey data also included cross-sections at specific locations in the catchment. As the survey data was only collected at discrete locations the data was not used to update or compile a more accurate DEM for the catchment however, was included in the TUFLOW model to enhance the hydraulic representation of the catchment.



N E S W

Legend

TUFLOW Model & Catchment Boundary

Cadastre

Ground Surface Contour (1m)

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 3.1

CATCHMENT TOPOGRAPHY

HERVEY BAY CITY COUNCIL

WorleyParsons resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\07050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 3.1.wor

Projection Trans. Merc. MGA56(GDA 94)

3.3 Pipe Data

Existing pipe and culvert crossing data throughout the catchment was provided through Council supplied GIS data. This data was supplemented using detailed survey information collected at discrete areas, as discussed in Section 3.2.

All the available information as supplied for the study was consolidated to prepare the existing pipe system details within the TUFLOW model. Through liaison with Council it was agreed to model culverts larger than 450mm in diameter. In some cases pipes smaller than 450mm were included where the nature of the system meant that the infrastructure was critical for flood level determination.

3.4 Site Inspection

As part of the works for this study, WP have undertaken a detailed and comprehensive site inspection of the Moolyyir Creek catchment. The site inspection also included an extensive project inception meeting with HBCC.

The site inspection was documented by way of site notes and photographs. Outcomes from the inspection included:

- Assessment of physical catchment parameters including appropriate roughness parameters
- Verification of crossings and existing hydraulic structures
- A comprehensive investigation of the waterway
- Understanding of the flow dynamics of the catchment area and major waterway systems

4. CATCHMENT MODELLING

4.1 Hydrological Modelling

For the analysis of runoff from within the entire 2D model area, rainfall was applied directly to the delineated modelling area using TUFLOW. This recently developed function in the TUFLOW software is particularly useful for flat, urbanised catchments, where ill defined flow paths makes catchment delineation and the accurate application of associated hydrographs difficult. This function was considered suitable for use in this study.

TUFLOW undertakes this hydrologic simulation by applying a rainfall hyetograph. The hyetograph was created manually using the HBCC IFD data and the procedures set out in Australian Rainfall & Runoff (AR&R, 2001). The rainfall time-series data is entered into the model in millimetres, and is converted to a hydrograph to smooth the transition from one rainfall period to another. The approach applies a rainfall depth to every active cell within the model, and essentially replaces the need to use a separate hydrological model. Initial and continuing losses are applied on a material-by-material basis.

Model parameters have been selected from recommended design values for various categories of landuse types based upon the provisions of the HBCC Development Guidelines, Queensland Urban Drainage Manual (QUDM, 1992), Natural Channel Design Guidelines (BCC, 2003) and also based on the following sources:

- **Impervious and pervious areas** – Strategic planning information for the catchment as obtained from HBCC

- **Catchment roughness values** – Determined in accordance with the hydrologic parameter values recommended by Council for various land use classifications, site visit and aerial photography

- **Intensity-Frequency-Duration (IFD) values** – HBCC Development Manual

4.2 Model Parameters

As mentioned previously, the adopted initial and continuing losses and associated roughness parameters are applied to the TUFLOW model on a material by material basis.

Design loss parameters for the TUFLOW model were based on guideline values as recommended by Hervey Bay City Council. These loss rates are consistent with AR&R (2001) which recommends a continuing loss of 2.5 mm/hr and an initial loss of between 15-35 mm be applied in eastern Queensland. The baseline values adopted for this study are summarised in Table 4-1.

These loss values were manipulated to represent the percentage imperviousness of each landuse type. For example, low density residential land use is classified as 45% impervious according to the HBCC Development Guidelines (adopted 40% due to exclusion of roads). This then equates to an initial loss of 9mm/hr, and a continuing loss of 1.5mm/hr.

These values are then adjusted to represent zoning changes (existing to ultimate case) whilst still representing existing case hydraulic parameters (mannings 'n').

The adjusted loss values for the various land use classifications throughout the modelling area are summarised in Table 4-2.

Table 4-1: Adopted Rainfall Loss Parameters

Pervious Area		Impervious Area	
Initial Loss (mm/hr)	Continuing Loss (mm)	Initial Loss (mm/hr)	Continuing Loss (mm)
15	2.5	0	0

Table 4-2: Site / Study Area Material Parameters

Description	% Impervious	Roughness (Manning's 'n')	Initial Loss (mm/hr)	Continuing Loss (mm/hr)
Low Density Residential (Including Buildings/ Fencing) (Excluding Roads)	45	0.500	8.25	1.375
Medium Density Residential (Including Buildings/ Fencing) (Excluding Roads)	60	0.650	6	1
High Density Residential (Including Buildings/ Fencing) (Excluding Roads)	90	0.750	1.5	0.25
Grass / Open Space	0	0.030	15	2.5
Grass / Light Trees	0	0.045	15	2.5
Grass / Medium Trees	0	0.600	15	2.5
Thick Trees	0	0.700	15	2.5
Mangroves	0	0.100	15	2.5
Roads	70	0.025	4.5	0.75
Water Body	0	0.015	0	0
Special Purpose	40	0.150	9	1.5
Building Footprint	100	1.000	0	0

4.3 Design Rainfall

The design rainfall Intensity-Frequency Duration (IFD) data for Hervey Bay was used for the creation of the hyetograph for use within the TUFLOW model. Design IFD data for Hervey Bay was extracted from the HBCC Development Manual. A copy of the HBCC IFD table is attached in Appendix 1.

4.4 Time of Concentration Analysis

To enable the direct rainfall simulation within TUFLOW, a time of concentration for the catchment needs to be determined. This is required to obtain the correct duration rainfall data from HBCC's IFD table for conversion into a hyetograph, using the procedures set out in AR&R (2001). Various equations as described in Section 5.05 of QUDM were used in combination to determine the time of concentration for the catchment. It was calculated that the time of concentration for the catchment was approximately 59 minutes (60 minutes adopted for use in this study). Table 4-3 summarises the geographic details adopted for determining the time of concentration for the catchment:

Table 4-3: Site Details

Description	Value
Total Path Length	1400m
Equal Area Slope	0.75 %
Overland Sheet Flow Length	50m
Overland Sheet Flow Time	13 minutes
Street / Pipe Flow Length	650m
Street / Pipe Flow Travel Time	8 minutes
Natural Channel Length	700m
Natural Channel Travel Time	23 minutes
Inlet Add On	15 minutes
Total Time of Concentration	59 minutes

4.5 Hydrological Flow Verification

Comparisons between peak flows obtained by the Rational Method and the flows generated in TUFLOW are not comparable throughout a majority of the catchment due to the nature of the modelling undertaken. Peak flows from the catchment created in the TUFLOW model are affected by hydraulic controls as well as significant areas of local storage effects within the local terrain.

However, a mass balance analysis for the model has been undertaken, with a peak cumulative mass error typically around +3%. Whilst this is slightly higher than typical peak values, this is considered acceptable given the nature of modelling undertaken (direct rainfall). TUFLOW models with significant areas of complex, steep flows, that use the direct rainfall approach, and/or rapid wetting and drying usually experience higher mass errors than those with predominately more benign sub-critical flows. (TUFLOW manual, 2007)

5. HYDRAULIC MODELLING

5.1 General Overview

WP have undertaken detailed two dimensional (2D), hydrodynamic flood modelling of the catchment to provide accurate and detailed flood information for the entire waterway system. The following information provides details of the software, topographic data and other parameters used in the hydraulic modelling of the catchment.

5.2 Modelling Software

Hydraulic analysis of the study area has been undertaken using the coupled one dimensional (1D) and two dimensional (2D) finite difference model TUFLOW, an industry accepted, Australian owned and commercially available software package highly suited to the investigation of flood behaviour in complex flow scenarios. The model can simulate unsteady hydrodynamic flow in two directions on a rectilinear grid as well as one dimensional unsteady hydrodynamic flow through waterway structures such as culverts. The model is based on a robust finite difference solution scheme able to compute both sub critical and supercritical flow regimes.

The TUFLOW 1D/2D model is suited to simulation of dynamic hydraulic behaviour of overland flow in urban areas. Based on this and TUFLOW's ability to couple hydraulic structures such as culverts and bridges at road crossings in a stable and verified manner, the modelling system was considered the most appropriate investigative tool for the characteristics of Moolyyir Creek and the surrounding urban areas.

Major advantages of a combined 1D and 2D modelling approach over traditional 1D approaches include:

- Full topographic survey terrain models are used, rather than selected, discrete cross sections
- Flow patterns are dictated by the influence of topography and surface roughness conditions rather than by 'forced' flow paths, as used in quasi-two-dimensional networks
- Flow directions and paths can vary with stage and flow conditions (c/f 'rigid' networks forcing flow paths in quasi-two-dimensional models)

- Production of detailed output of flow patterns, flood rise and fall animations, and output suitable for direct GIS interfacing. This allows production of accurate depth of flooding, velocity and hazard maps as well as area of influence maps

Major advantages of a combined 1D and 2D approach over an exclusive 2D approach include:

- Regions lying outside the area of interest that have to be modelled (e.g. to apply boundary conditions) do not necessarily have to be modelled in full 2D. This dramatically decreases the required computational time, leaving more room for detailed modelling of the area of interest

- The behaviour of hydraulic structures such as culverts and bridges can be simulated in a more detailed and robust way using a traditional 1D approach. Also, overtopping of bridges can be reliably modelled as the weir flow component of flood flow including the blockage of handrails at crossings can take place within the 2D environment whereas the flow through the hydraulic structure can be modelled in 1D

5.3 Model Construction

The 2D TUFLOW model constructed for Moolyyir Creek consists of the following elements, each of which are described in more detail in the sections of this report which follow:

- A two-dimensional (2D) curvilinear grid representing the topographic levels within the area of interest extracted directly from the DTM constructed using supplied raw ALS data as outlined in Section 3.1

- One-dimensional (1D) elements within the 2D grid extent that represent hydraulic structures and fine scale drainage elements

- Downstream water level boundary applied at the model outlet

- Rainfall boundary condition simulating catchment response within the 2D modelling area

Figure 5.1 illustrates the layout and extent of the hydraulic model constructed for this study.

5.4 2D Topographic Grid

The 2D model topography was derived using the Digital Elevation Model (DEM) constructed from contour data as supplied by Council (Refer Section 3.1). A balance between the number of computational points, level of modelling detail and model run times was required to deliver suitably accurate outcomes in a timely and efficient manner. The decision on the grid spacing to adopt in the 2D model is critical and is based on knowledge of the catchment, the pertinent drainage areas, and previous experience. A grid size of 2m was selected. This grid spacing allows for sufficient detail to be achieved in the urban environment whilst maintaining realistic model run times. The extent of hydraulic modelling is shown in Figure 5.1.

Real world co-ordinate systems have been used for all modelling. The 2D hydraulic model is based on **MGA94 Zone 56** horizontally and **AHD** vertically.

5.5 1D Hydraulic Structure Elements

In a full 2D modelling environment it is often not possible to accurately describe the hydraulic behaviour of structures such as culverts and bridges. This is due to the fact that grid cell sizes often exceed the dimensions of various structures in addition with the grid cells only representing bottom friction and consequently no roof friction or specific hydraulic structure losses. As a result, hydraulic structures are typically more accurately modelled in a 1D modelling environment, thus allowing prescriptive modelling of the exact characteristics of the various structures.

Within the 2D model, 1D elements have been introduced in order to enable the prescriptive modelling of various floodplain structures. Each of the structures has been modelled based on the following data sources:

- Council's pipe network information GIS layers
- Verification of structure details and configurations by way of a detailed site inspection including photographic records compiled by WP

All structures have been represented using a combination of 1D and 2D domains. Flow through the culverts is modelled using the 1D component of TUFLOW whilst the overland and weir flow, both around the structure and over the road, are modelled purely in the 2D scheme. Pipe networks (drainage) are shown in Figure 5.1.

5.6 Model Boundary Conditions

Two types of boundaries have been applied to the model. The first, direct rainfall application is applied across the entire model. Flows are applied to every cell within the model boundary (rather than at point locations).

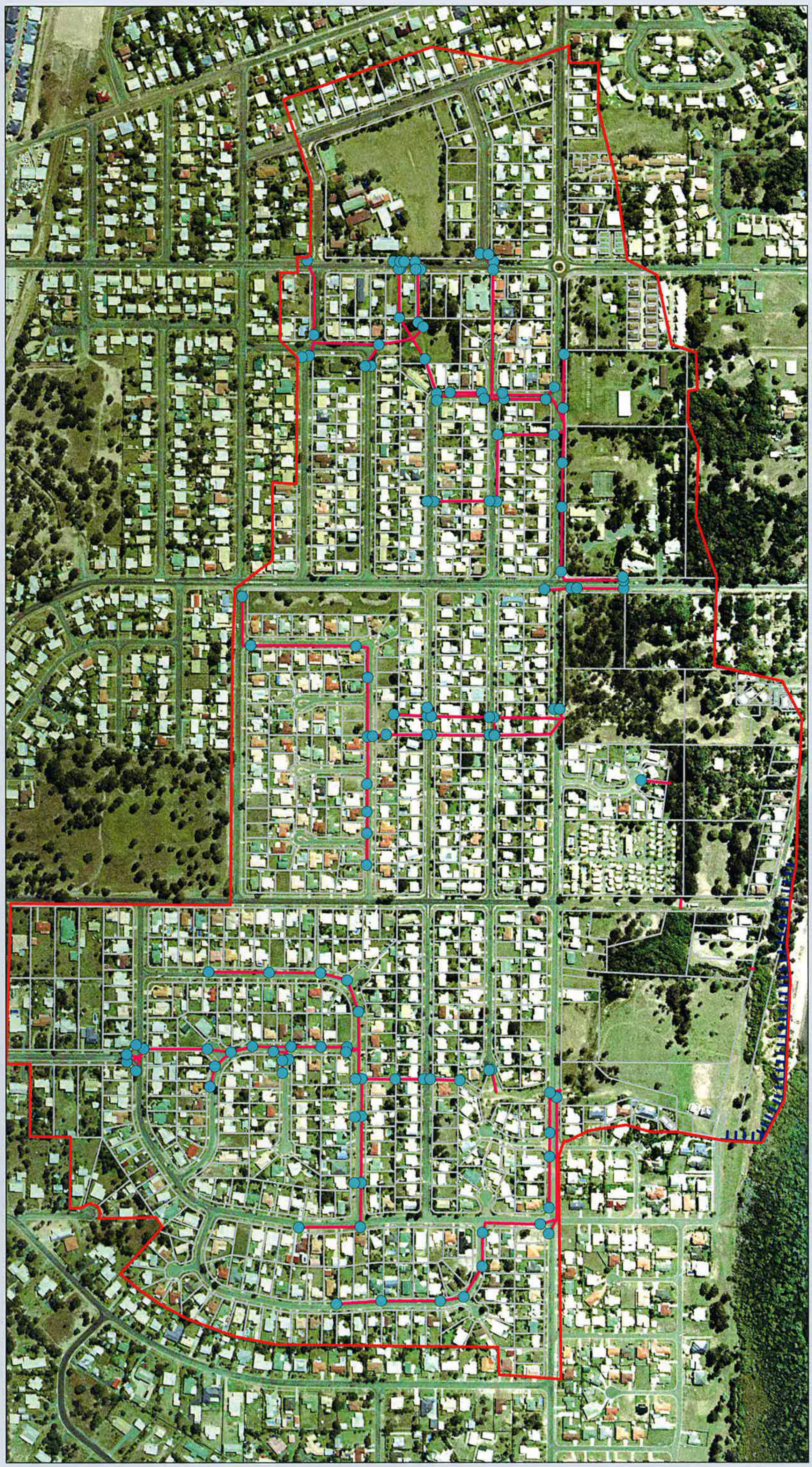
The second, tail water boundaries have been applied to the downstream edge of the model. For all design events, a Highest Astronomical Tide (HAT) level of 2.15 m AHD has been applied and was determined from review of the supplied Hervey Bay Storm Tide Study and the James Cook University Website. The Hervey Bay Storm Tide Study final report as prepared by Lawson & Treloar Pty Ld, 2002, states *"few historical cyclones have caused significant storm tide levels in the Hervey Bay region during the period of record, since they have been generally less than the HAT."*

A sensitivity analysis of the model boundary condition has been undertaken and is discussed separately in Section 6 of this report.

5.7 2D Model Roughness

A GIS land use map covering the entire study area was created for the purposes of defining the hydraulic roughness across the floodplain. Each grid cell is assigned a Manning's 'n' roughness value based upon land use defined on the map. The GIS layer of existing land use was generated using a combination of aerial photography, the HBCC DCDB, and utilising observations as well as oblique photography from the detailed site inspection.

Roughness values for each land use type were assigned based on site observations and using previous experience in 2D hydraulic modelling applications. The Manning's "n" roughness parameters adopted in the model ranged from 0.015 for open water bodies through to 0.75 for residential areas with ineffective flow paths blocked by buildings, fences and other obstructions. These values are typical of those adopted for floodplain roughness for studies of this nature, and are in accordance with those supplied by HBCC in the brief for this study. Table 5-1 documents roughness parameters assigned to each land use.



Legend

TUFLOW Model & Catchment Boundary

Cadastre

Lintel / Inlet Pit

Sub Surface Trunk Drainage Network

Downstream Boundary

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 5.1

DETAILED TUFLOW HYDRAULIC MODEL

WorleyParsons
resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 5.1.wor

Projection Trans. Merc. MGA56(GDA 94)

Table 5-1: Adopted Roughness Parameters

Land Use Type	Manning's "n" Roughness Parameter
Low Density Residential (Inc Buildings/ Fencing) (Excluding Roads)	0.50
Medium Density Residential (Inc Buildings/ Fencing) (Excluding Roads)	0.65
High Density Residential (Inc Buildings/ Fencing) (Excluding Roads)	0.75
Grass / Open Space	0.03
Grass / Light Trees	0.045
Grass / Medium Trees	0.06
Thick Trees	0.07
Mangroves	0.10
Roads	0.025
Water Body	0.015
Special Purpose	0.15
Building Footprint	1.00

5.8 Model Design Runs

The TUFLOW hydraulic model was analysed for the 10, 20, 50 and 100 year ARI design flood events for the critical 60 minute storm event. The results from the analysis for the existing case (ultimate catchment development) model are discussed separately in the following section of this report.

6. EXISTING CASE ANALYSIS RESULTS

6.1 Verification of Model to Previous Study Results

A process of verification was undertaken to ensure that the model constructed as part of this assessment was behaving in an appropriate manner. Peak flood levels for the existing case 100 year ARI event were compared at a number of key locations throughout the study area to previous modelling undertaken by GHD in 1995 using URBS and the HEC-RAS 1D modelling package.

Table 6-1 presents comparisons between flood levels reported in the “Hydrology & Hydraulic Report - Moolyyir Creek” (April 1995) and levels obtained using the 2D hydraulic model constructed for use in this study. It is noted that the downstream boundary condition used in the GHD study is unknown, and may contribute to differences between reported levels. Figure 6.1 shows the location of the comparison points.

Table 6-1: Comparison of Peak Flood Level, 100 Year ARI

Location	100 Year ARI Flood Levels		
	GHD Moolyyir Catchment Drainage Study (1996) (m AHD)	TUFLOW Model (m AHD)	Difference (m)
Junction D/S Pulgul St & Boat Harbor Drive	4.74	4.87	+ 0.13
Moolyyir St Foodway	4.04	3.67	- 0.37
Junction D/S Moolyyir St & Pulgul St	4.03	3.66	- 0.37
Esplanade	2.85	2.93	+ 0.08

Table 6-1 demonstrates that flood levels obtained using the newly constructed model compare well with the previously reported levels. Flood levels are shown to be lower in the lower end of the catchment, where available flood storage in the local topography is better represented in the 2D model utilised for this study.

Some difference in modelled flood levels is always expected due to the nature of the models used as the previous modelling adopted a one-dimensional approach whilst the current model uses a fully two-dimensional scheme. It is also noted that a different hydrology model has been used in this study than was used in GHD's 1995 study, leading to possible differences in peak flow rates.

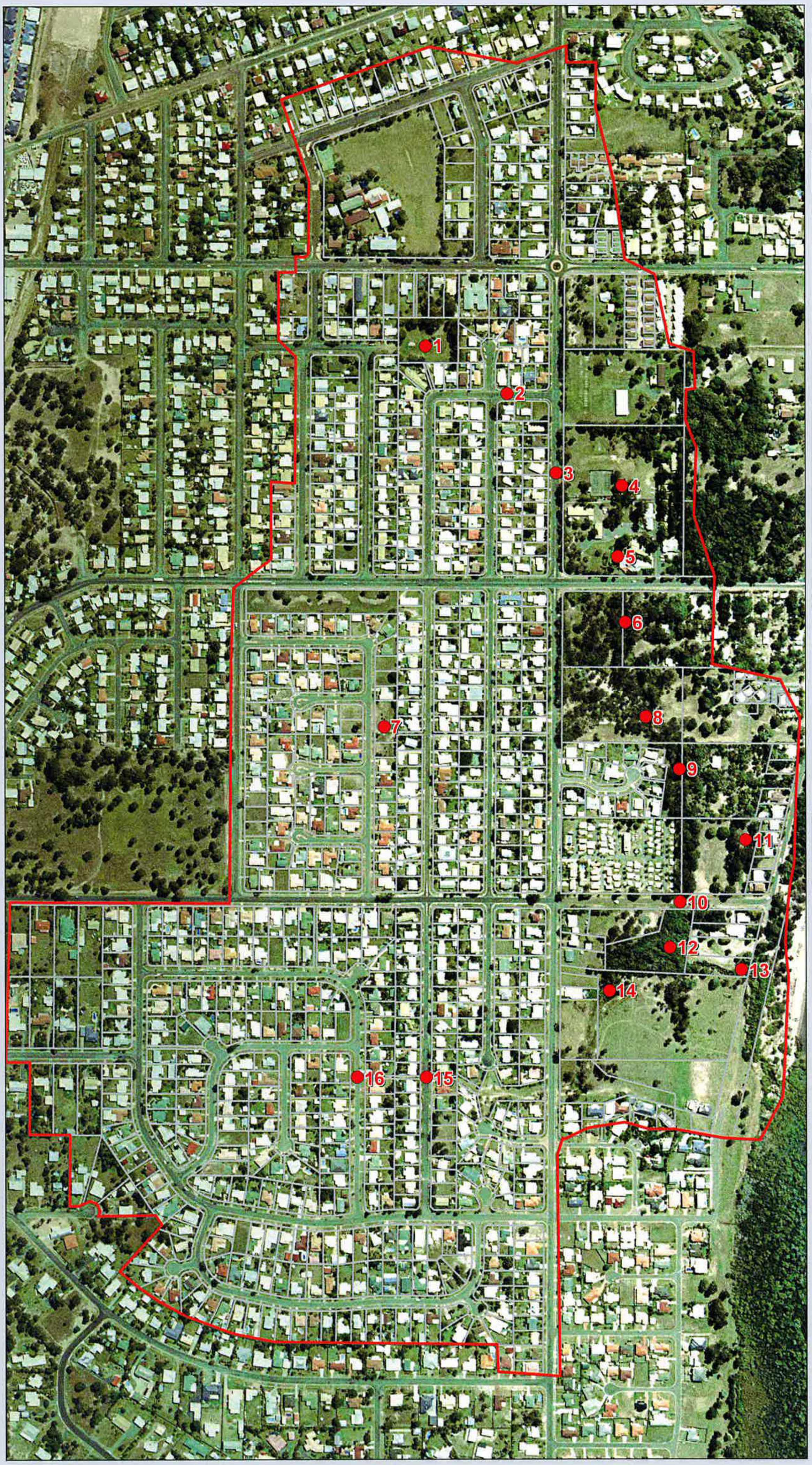
WP consider that the comparison in flood levels between the previous work and that carried out in this study shows satisfactory results. As such, the 2D TUFLOW model has been adopted for the determination of flooding behaviour within the study area.

6.2 Boundary Condition Sensitivity Analysis

A sensitivity analysis has been undertaken on the tidal levels adopted at the downstream boundary of the models.

The sensitivity analysis was undertaken on the 100 year ARI event using the HAT tidal level and a ±0.3m variation (RL 2.15 m and RL 2.45 / 1.85m AHD respectively) based on the 60 minute storm event.

The modelling demonstrates that the impacts from varying the tail water level has negligible impacts on flooding within the catchment, as flooding levels are controlled by the Esplanade embankment and culvert system. As such varying the downstream boundary condition does not effect flooding on properties or roadways, as these issues are dominated by catchment flooding.



N
E
S
W

Legend

TUFLOW Model & Catchment Boundary

Cadastre

Flood Level Reporting Location

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.1

FLOOD LEVEL REPORTING LOCATIONS

Hervey Bay City Council

WorleyParsons resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

6.3 Results

The TUFLOW, 2D model was adopted for the purposes of estimating flood levels and flood inundation throughout the study area under the 10, 20, 50 and 100 year ARI design flood events. These analyses were undertaken using the existing site topography which excluded any proposed flood mitigation works. The results therefore represent the "existing case" model results.

The results of the existing case (ultimate catchment conditions) model are provided in this report. The results provided include the following flood reporting information:

- Flood depths for all events
- Flood level contours for all events
- Flood inundation extents
- Flood levels at key locations (Figure 6.1 & Table 6-2)

Mapping for all events are presented in Figures 6.2 to 6.13.

6.3.1 Flood Levels

Water levels are calculated at the cell centre and cell sides for all cells within the 2D model, which equates to some 1,140,000 points within this modelling area. It is therefore not practical to tabulate flood levels for all computation points throughout the model. Flood levels for the 2D scheme are commonly best presented using flood surface and extent maps created in a GIS environment.

For the purposes of this report, a summary table has been generated detailing peak water levels directly upstream of all major road crossings and throughout the waterway between crossings. Figure 6.1 illustrates the locations of the flood reporting locations summarised as part of this study. Peak water levels for each location illustrated in Figure 6.1 are presented in Table 6.2. Table 6.2 documents a small distribution of flood levels in the area and it should be noted that detailed flood level information is available through the GIS mapping provided to HBCC. The GIS information enables flood level queries to be undertaken at any location within the flow path for all of the events analysed.

Table 6-2 Peak Design Flood Levels (mAHD)

Reporting Location	Design Flood Event (ARI) Water Surface Level (m AHD)			
	10yr	20yr	50yr	100yr
1	6.75	6.81	6.87	6.91
2	5.84	5.87	5.92	5.95
3	5.08	5.14	5.24	5.29
4	5.52	5.57	5.61	5.63
5	5.34	5.41	5.49	5.54
6	4.85	4.91	4.99	5.05
7	9.01	9.05	9.12	9.21
8	4.67	4.74	4.82	4.87
9	3.86	3.93	4.00	4.05
10	3.37	3.44	3.58	3.63
11	3.38	3.44	3.58	3.63
12	3.37	3.43	3.58	3.62
13	2.84	2.87	2.92	2.94
14	4.79	4.83	4.96	4.98
15	7.00	7.02	7.15	7.17
16	7.88	7.90	8.16	8.19

6.4 Flood Mapping

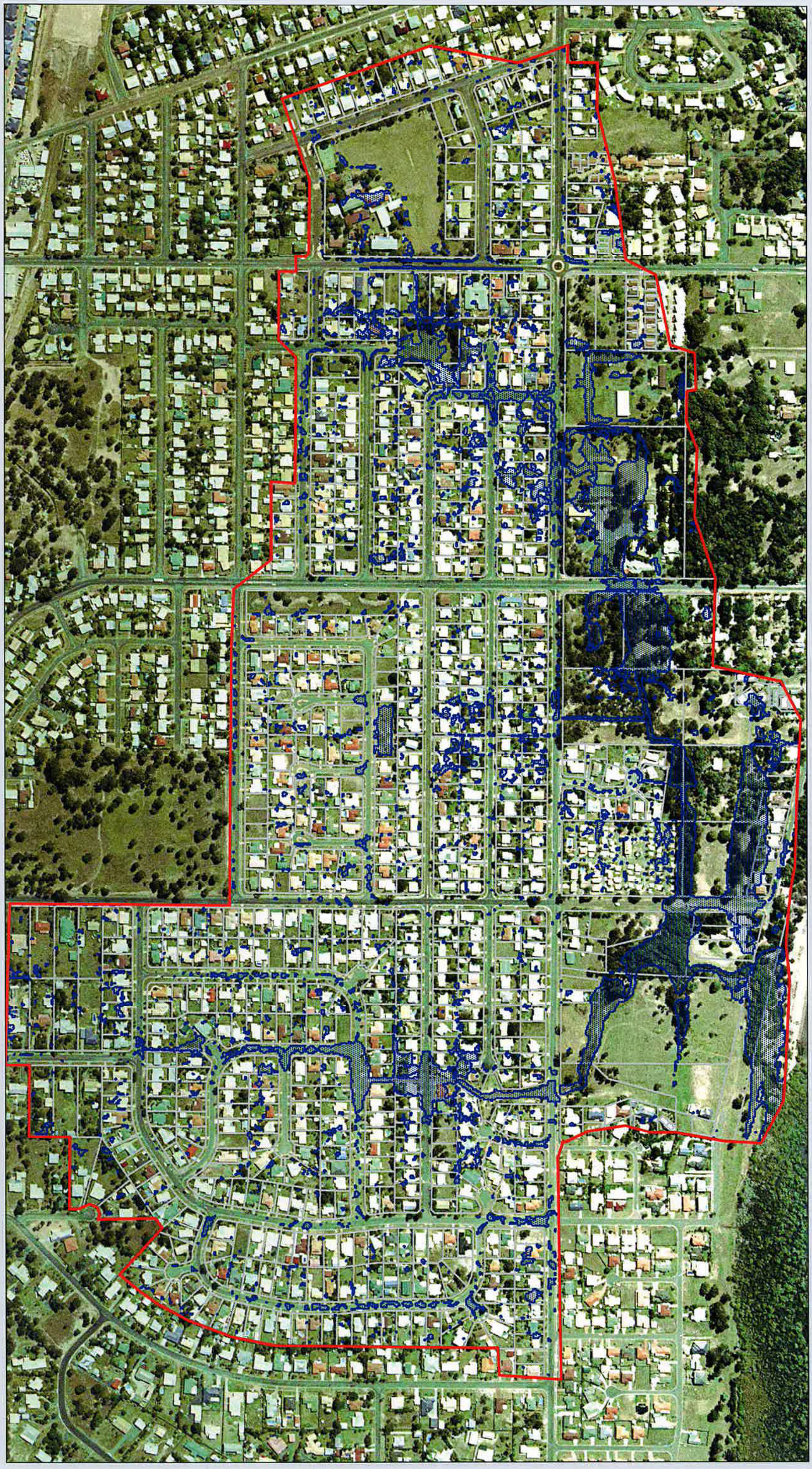
Figures 6.2 to 6.13 display the results for the design event analysis. A total of twelve (12) flood plans have been prepared as part of this study. The plans are presented to illustrate the 10, 20, 50 and 100 year ARI anticipated extent of flooding, flood depths and flood levels over the study area for the existing case (ultimate development).

The flood inundation mapping prepared as part of this study is subject to the following notations:

1. The flood extent and associated flood data prepared as part of this study is based on available survey data as supplied by Hervey Bay City Council. This includes aerial photogrammetric survey, limited field validation survey and stormwater pipe and pit information. The flood extents and flood results will therefore be subject to the accuracy and detail of the background study information. Drainage conditions may also have changed since the collection of the survey information.

2. A buffer of 0.1m has been applied to the derivation of the flood extent such that, depths less than 0.1m are not shown. This has been done in agreement with Council to remove the local drainage and sheet flow that is outside the scope and detail of the study.

3. All flood extents prepared as part of this study have been prepared based upon the DEM formed for the study area. Where critical information such as open channels have not been adequately represented in the DEM as a result of the original photogrammetric data captured, calculated flood extents may vary from those on the ground . The accuracy of the flood extents prepared from this study is subject to the accuracy of the topographical representation contained within the DEM.



Legend

TUFLOW Model & Catchment Boundary

Cadastre

10YR ARI Existing Case Flood Extent

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.2

10YR ARI EXISTING CASE FLOOD EXTENT

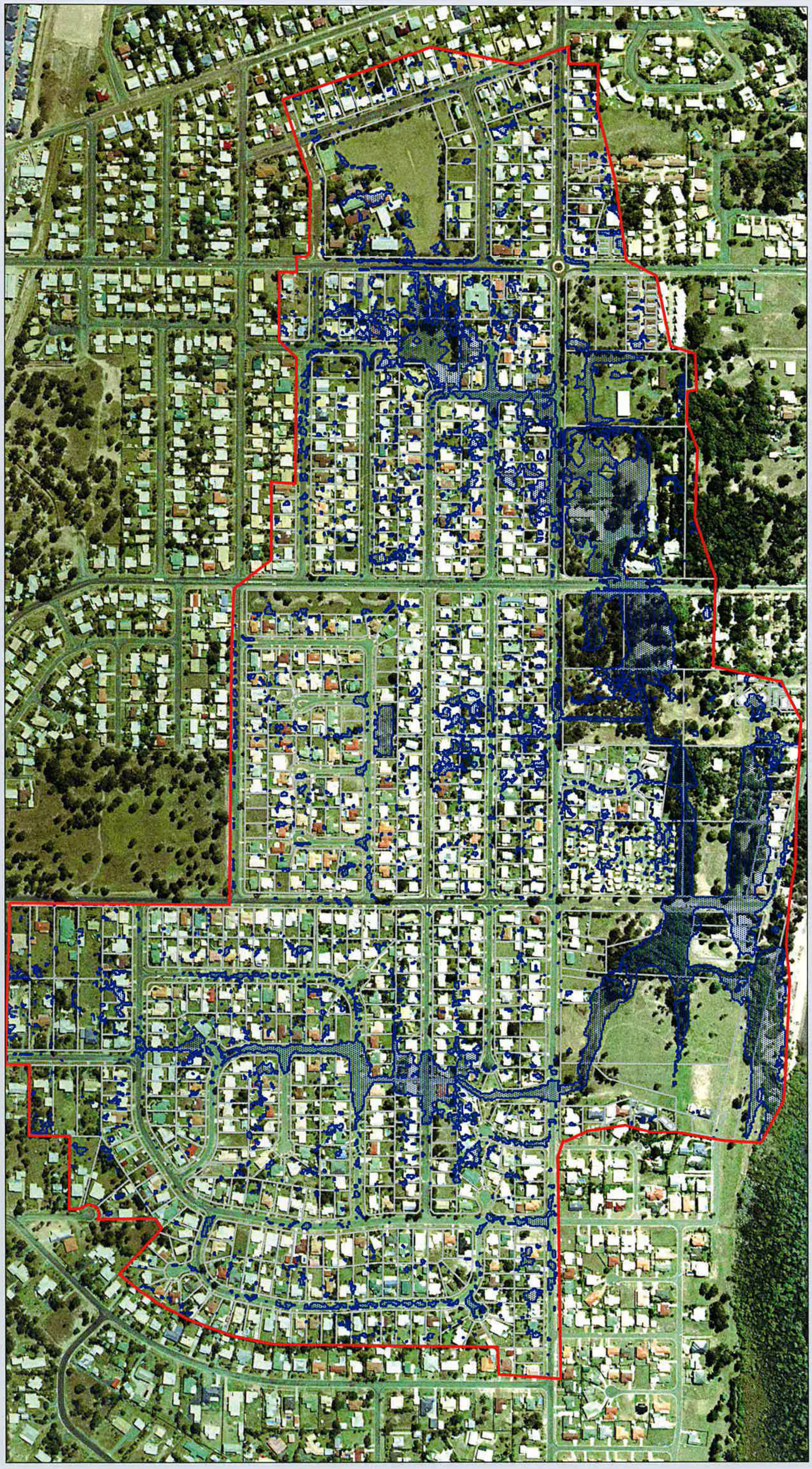
WorleyParsons

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.2.wor

Projection Trans. Merc. MGA56(GDA 94)



Legend

TUFLOW Model & Catchment Boundary

Cadastre

20YR ARI Existing Case Flood Extent

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.3

20YR ARI EXISTING CASE FLOOD EXTENT

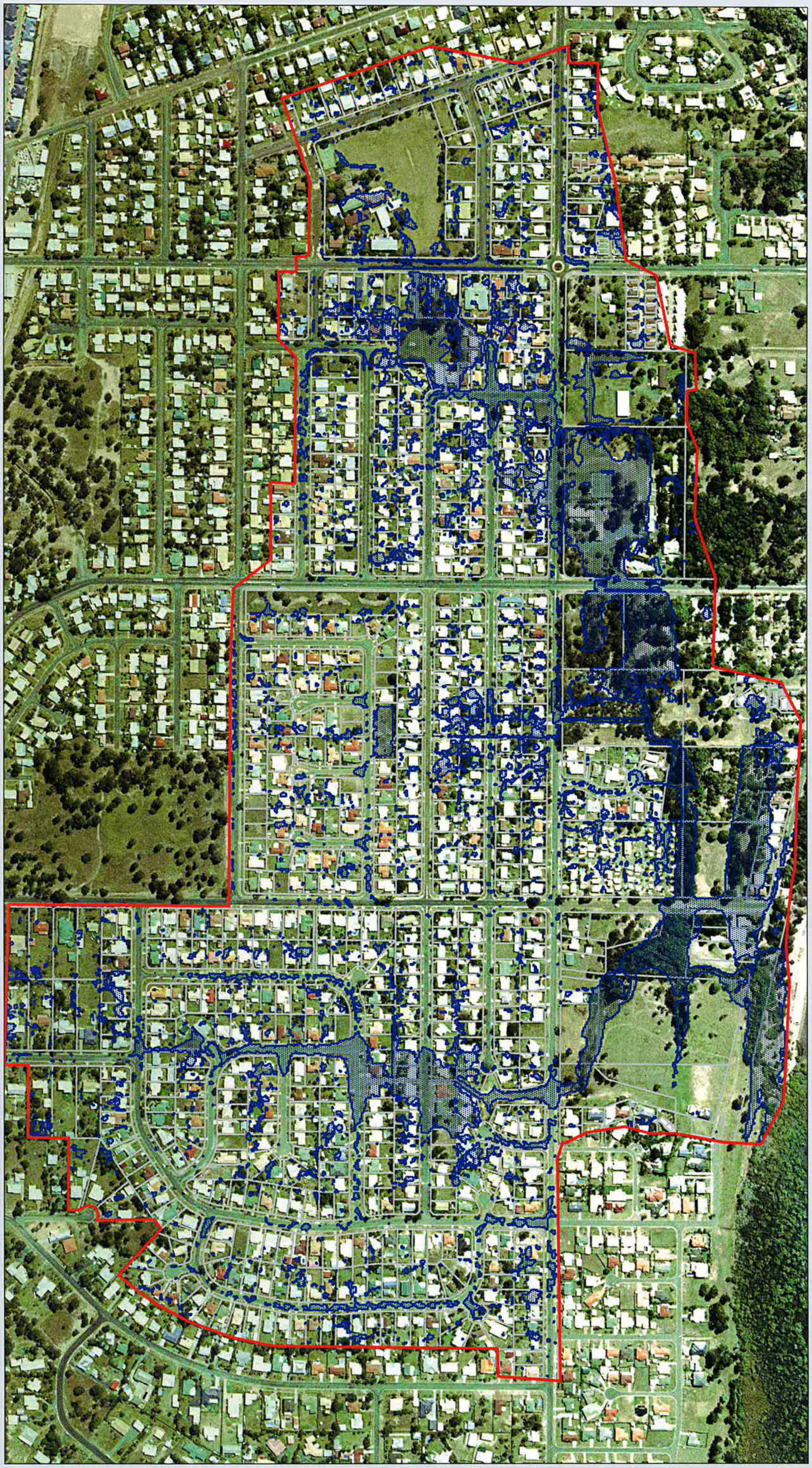
WorleyParsons

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wvays\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.3.wor

Projection Trans. Merc. MGA56(GDA 94)



N
E
S
W

Legend

TUFLOW Model & Catchment Boundary

Cadastre

50YR ARI Existing Case Flood Extent

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.4

50YR ARI EXISTING CASE FLOOD EXTENT

WorleyParsons

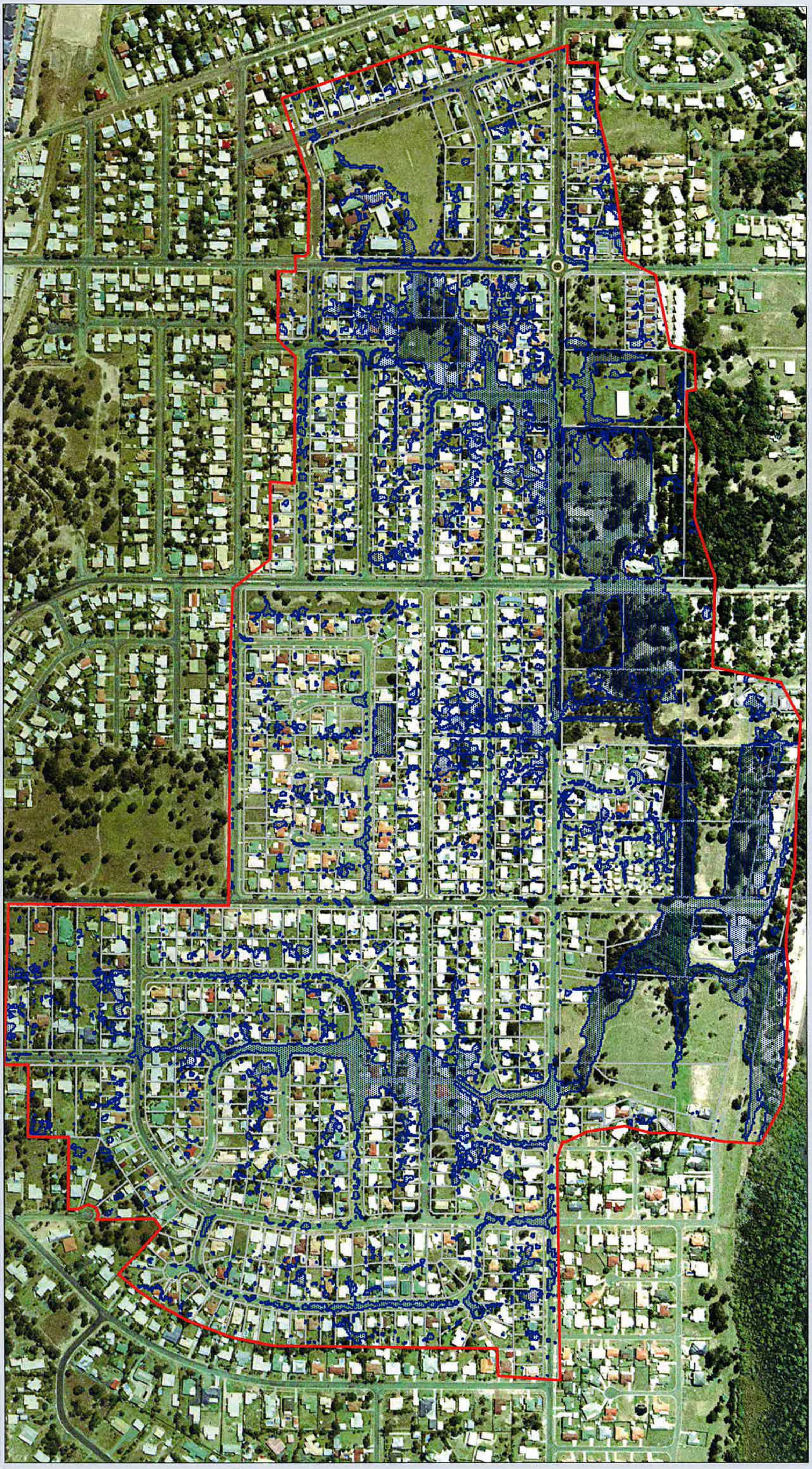
resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\07050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.4.wor

Projection Trans. Merc. MGA56 (GDA 94)



Legend

TUFLOW Model & Catchment Boundary

Cadastre

100YR ARI Existing Case Flood Extent

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.5

100YR ARI EXISTING CASE FLOOD EXTENT

HERVEY BAY CITY COUNCIL

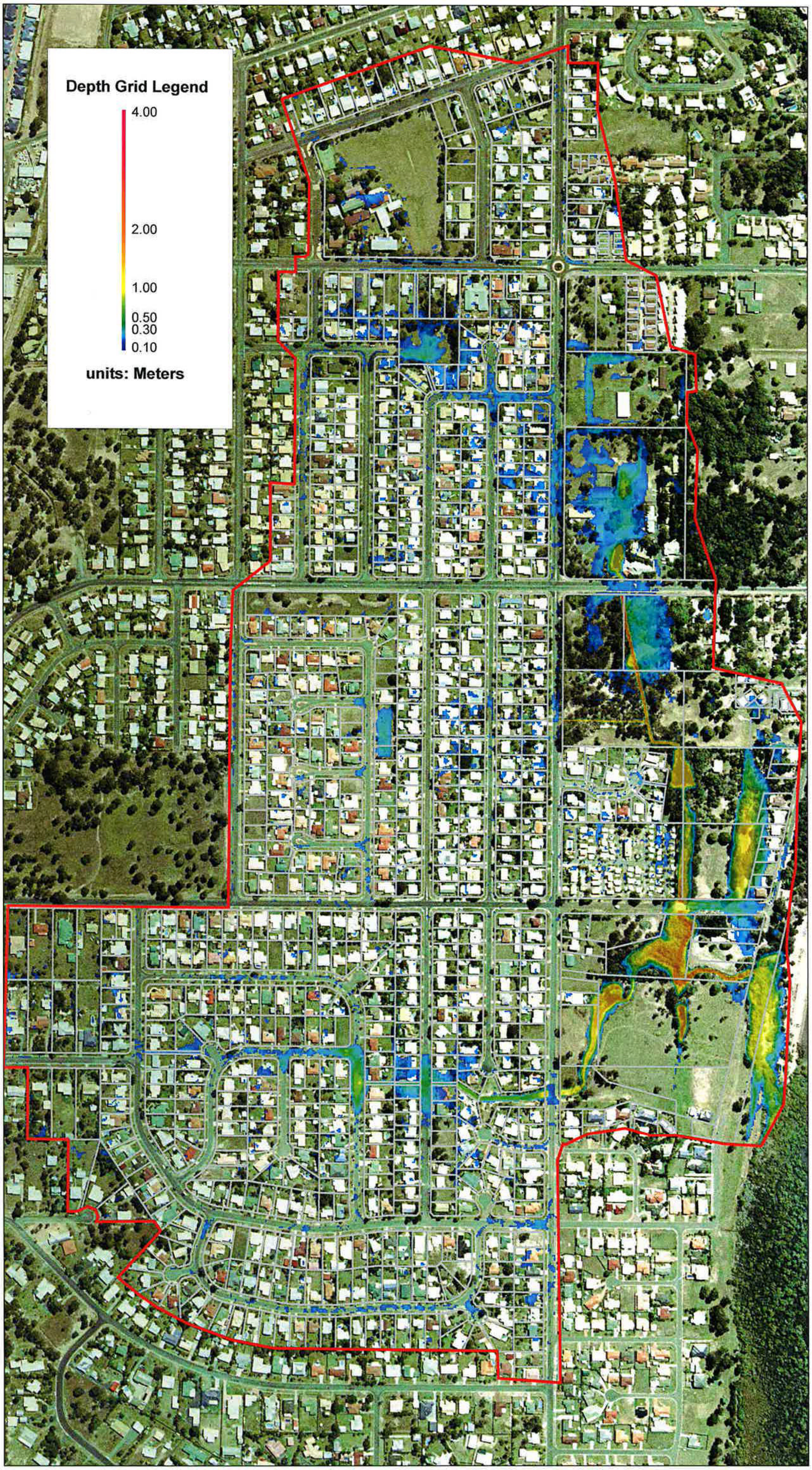
WorleyParsons resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.5.wor

Projection Trans. Merc. MGA56(GDA 94)



N
E
S
W

Legend

TUFLOW Model & Catchment Boundary

Cadastre

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.6

10YR ARI EXISTING CASE FLOOD DEPTH

HERVEY BAY CITY COUNCIL

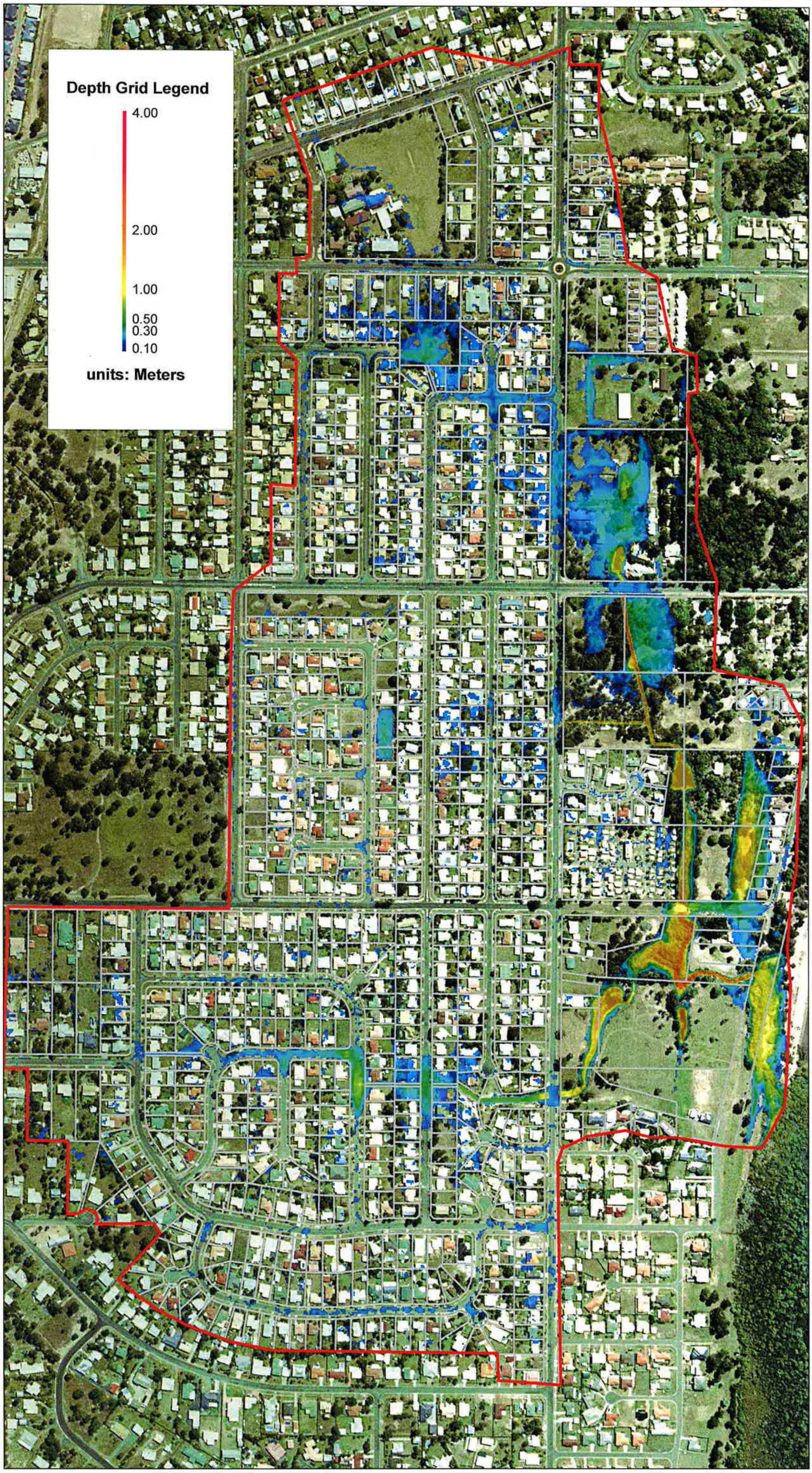
WorleyParsons
resources & energy

OneWay
to zero harm

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-\Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.6.wor

Projection Trans. Merc. MGA56(GDA 94)



N
E
S
W

Legend

TUFLOW Model & Catchment Boundary

Cadastre

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.7

20YR ARI EXISTING CASE FLOOD DEPTH

WorleyParsons

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.7.wor

Projection Trans. Merc. MGA56(GDA 94)

N E S W

Legend

TUFLOW Model & Catchment Boundary

Cadastre

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.8

50YR ARI EXISTING CASE FLOOD DEPTH

WorleyParsons

resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.8.wor

Projection Trans. Merc. MGA56(GDA 94)

Legend

TUFLOW Model & Catchment Boundary

Cadastre

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.9

100YR ARI EXISTING CASE FLOOD DEPTH

WorleyParsons

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.9.wor

Projection Trans. Merc. MGA56(GDA 94)

N
E
S
W

Legend

TUFLOW Model & Catchment Boundary

Cadastre

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.10

10YR ARI EXISTING CASE FLOOD LEVEL

HERVEY BAY CITY COUNCIL

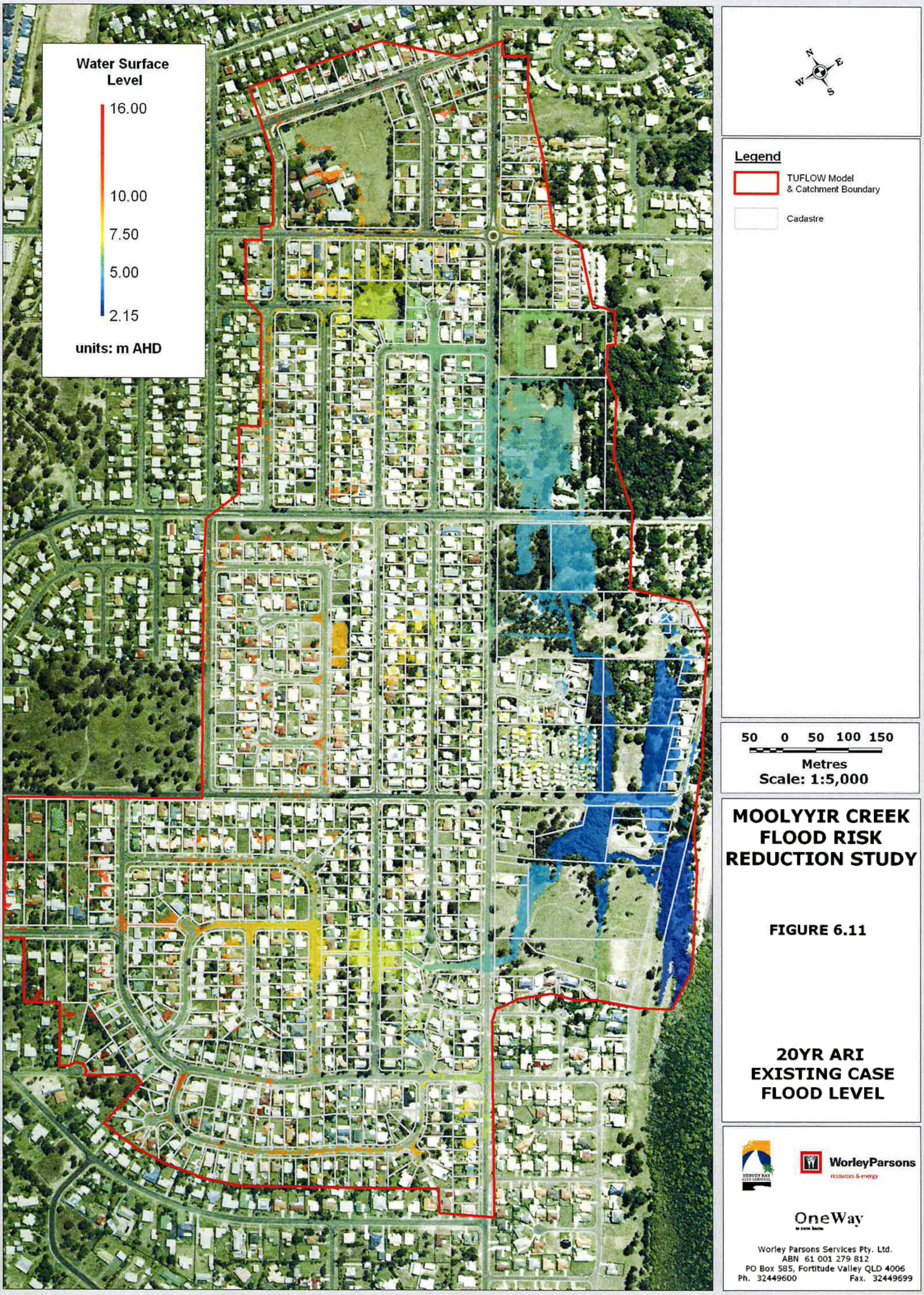
WorleyParsons resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.10.wor

Projection Trans. Merc. MGA56(GDA 94)



MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.11

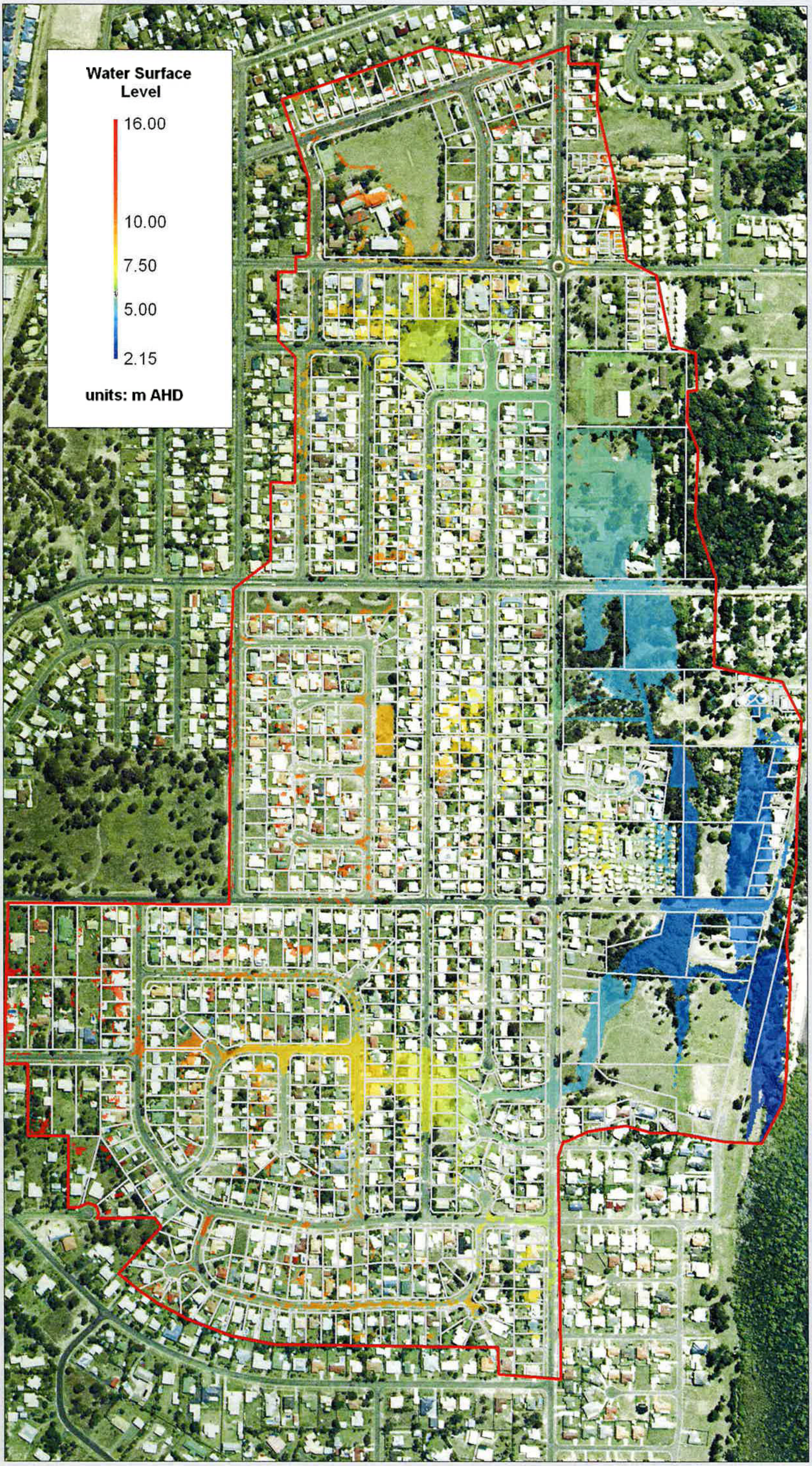
20YR ARI EXISTING CASE FLOOD LEVEL

HERVEY BAY CITY COUNCIL

WorleyParsons resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699



N
E
S
W

Legend

TUFLOW Model & Catchment Boundary

Cadastre

50 0 50 100 150

Metres

Scale: 1:5,000

MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.12

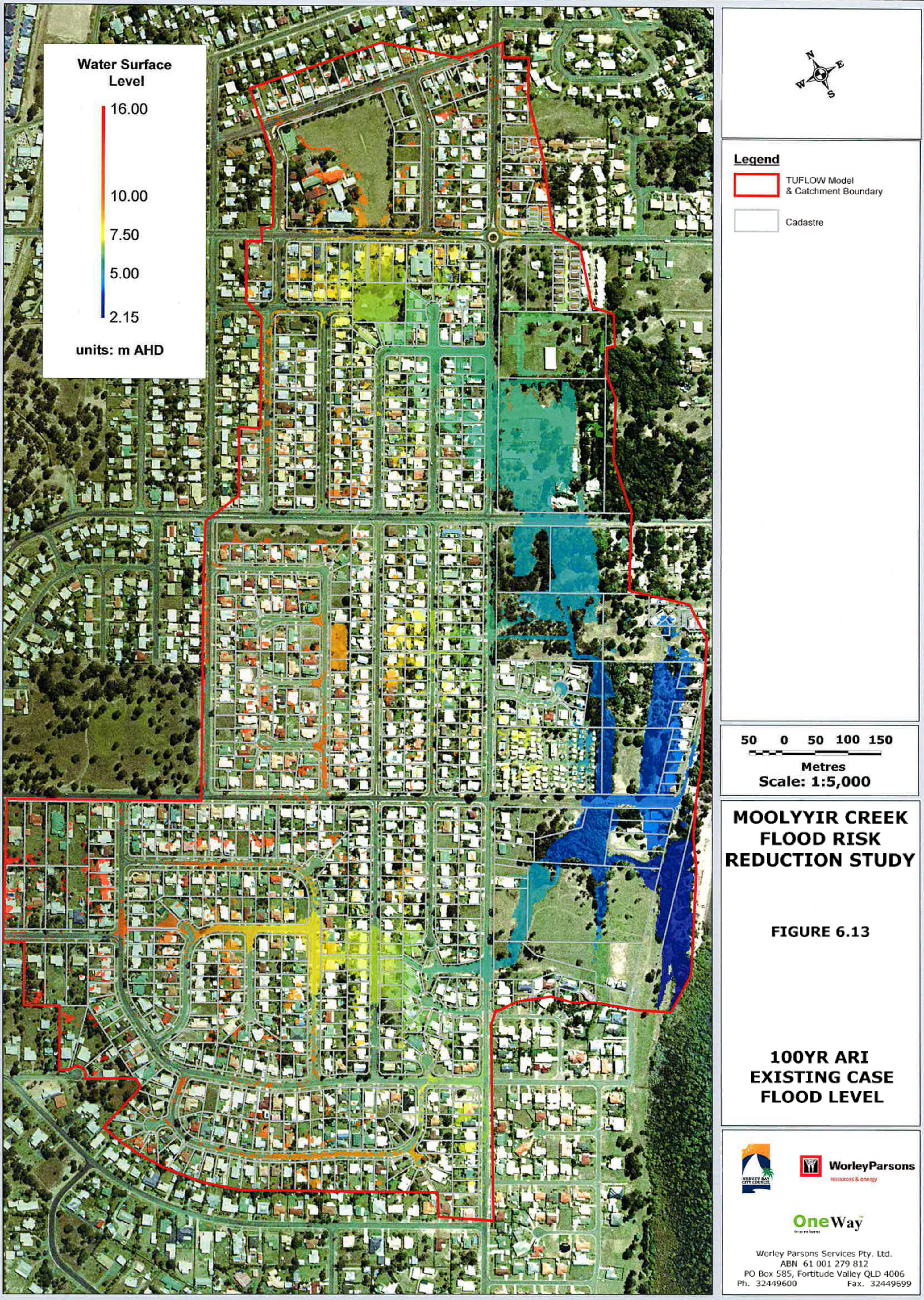
50YR ARI EXISTING CASE FLOOD LEVEL

HERVEY BAY CITY COUNCIL

WorleyParsons
resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699



MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 6.13

100YR ARI EXISTING CASE FLOOD LEVEL

WorleyParsons
resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

File Path : Z:\42-Wways\070050-001 Moolyyir Creek Flood Study\GIS\MapInfo\Figures\Report\Figure 6.13.wor

Projection Trans. Merc. MGA56(GDA 94)

7. EXISTING SCENARIO RISK IDENTIFICATION & PRIORITISATION

7.1 Risk Identification Methodology

In liaison with HBCC a procedure for the evaluation and prioritisation of risks was developed. Risks are evaluated and prioritised using two methodologies, Queensland Urban Drainage Manual (QUDM) and the risk ranking matrix. Identification of overtopping and hazard at road crossings was defined using the QUDM design criteria for roads as shown in Table 7-1 below.

Table 7-1: QUDM design criteria for roads

Criteria	Limit
For Vehicle and Pedestrian Safety	0.6m^2/s (0.4 m^2/s if the area is known to have high pedestrian usage or has safety issues)
Maximum depth of flow on any Road	300mm

Prioritisation and risk for the identified crossings was evaluated using the risk ranking matrix. The risk ranking matrix considers the likelihood and consequence of the risk occurring and defines a risk ranking for each risk. Table 7-2 and 7-3 provides the classification of likelihood and consequence respectively. Table 7-4 shows the resulting risk ranking derived from the relationship of likelihood and consequence.

Table 7-2: Likelihood parameters

Almost certain	A 99.5% chance of a hazard being exceeded in a 50 year period – a 1 in 10 year event
Likely	Probability of exceedance is greater than 50% in a 50 year period, but less than 99.5% - a 1 in 50 year event
Possible	Probability of exceedance is greater than 20% in a 50 year period, but less than 50% - a 1 in 100 - 200year event
Unlikely	Probability of exceedance is greater than 5% in a 50 year period. but less than 20% - a 1 in 500 year event
Rare	Probability of exceedance is less than 5% in a 50 year period - a 1 in 500 year event

Table 7-3: Consequence parameters (based on 2000 AU$)

Insignificant	Natural hazards are experienced and cause some stress on community lifelines. Community agencies cope with some effort and total community financial loss is less than $1.0m
Minor	No disaster is officially declared and effects lead to temporary failure of lifelines other than energy supply for up to 24 hours. Total community financial loss is less than $10m
Moderate	Disruption lasts for more than 5 days including energy disruption. Recovery takes 14 – 21 days. Vulnerable elements are severely affected and all major agencies are involved. Hospitalisation of victims occurs and total community financial loss is less than $50m. State of emergency is declared during the event.
Major	All lifelines affected. Energy is disrupted for up to 14 days. Recovery takes 4 – 6 weeks. At least one death is suffered and temporary evacuation of area is required. State of Disaster is declared and total community loss is up to $200m.
Catastrophic	Effects are severe and all lifelines are affected. No energy for up to 8 weeks and recovery takes 6 – 24 months. At least 10 deaths suffered and significant evacuation required. Total community financial loss in hundreds of millions.

Table 7-4: Risk Ranking

Return period	Consequence Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
10	Almost certain	H	H	E	E	E
50	Likely	M	H	H	E	E
100/200	Possible	L	M	H	E	E
500	Unlikely	L	L	M	H	E
1000	Rare	L	L	M	H	H

Where: E = extreme risk H = high risk M = moderate risk L = low risk

In addition to infrastructure lifelines, risk parameters for people, buildings, economic loss and loss of the natural environment are proposed as shown in Table 7-5.

Table 7-5: Risk Parameters for People, Buildings, Economic Loss and Natural Environment

Risk element	Extreme (unacceptable) risk
People	Vulnerability to natural hazards is generally measured by the risk to life and property from known hazards. An area may be prone to a known hazard, but if there is no possible risk to life or property, the vulnerability is low. Where life and property are at risk, the magnitude and likelihood of the hazard combine to create a measure of vulnerability. **Unacceptable risks are death, serious injury and major health hazard.**
Buildings	The built environment is at risk from a number of known hazards in Hervey Bay. Various regulations have been developed locally (e.g. Local Laws) and at a wider scale (e.g. the Building Code of Australia) to minimise the risk of damage to the built environment. All of these regulations are based on an acceptable level of risk which has been determined either by Council or a wider community of interest (e.g., 1:100 flood immunity). Inevitably there will be extreme events which go beyond the acceptable level of immunity and the only possible way to immunise against these events is avoidance. **Unacceptable risks are collapse or damage to buildings requiring demolition.**
Economic loss	In all disaster events there is bound to be some form of economic loss. The Federal Government under the Natural Disaster Relief Arrangements provides funding to victims of disaster events. This funding is generally short term and designed to minimise immediate suffering and loss. Businesses need to make their own assessment of potential economic loss through a natural disaster event and make plans accordingly. These would range from building construction, to choice of location to insurance. **Unacceptable risks are loss of livelihood for more than 10% of the working community.**
Natural environment	The natural environment is at risk from a number of known hazards in Hervey Bay. **Unacceptable risks are loss of ecological systems, major habitats or conservation areas. Significant disruption to natural drainage systems.**

Risk escalation	Risk escalation is likely to happen when initial risk minimisation programs or event response mechanisms do not achieve their intended purpose. The risks outlined in this document may have follow-on or secondary effects (e.g. an earthquake may lead to a dam break, which may lead to flooding, which may lead to injury or isolation). **Unacceptable risks arise from the failure of initial risk minimisation and response mechanisms.**
Risk frequency	Risks to physical infrastructure are usually incorporated in design parameters (e.g. bridges are designed to withstand certain loads; drains are designed to accommodate mathematically derived flood levels). These are generally based on industry standards of acceptable levels of risk. These standards have until recently had very little legislative basis. The recent adoption of *State Planning 1/03 - Mitigating the adverse impacts of Flood, Bushfire and Landslide* introduces risk frequency levels (e.g., 1:100 years) which are required to be accommodated in planning and design documents (e.g. planning schemes and infrastructure codes). **Unacceptable risks are events which occur within the design capacity of infrastructure or industry accepted measures.**
Legal and social justice implications	Risk management is applied by Council across all parts of its jurisdiction in an equal manner and includes all persons. Council is required to make decisions on an annual basis about prioritising its expenditure on various competing items. Expenditure on risk minimisation is incorporated in most capital works projects by way of an in-built design standard. **Unacceptable risks are deliberate inequality of expenditure against any one group, or any one part of the city.**
Political implications	Council's decisions are subject to scrutiny and influence from various elements and sectors of the community. It is Council's role to make informed and un-biased decisions. **Unacceptable risks are decisions made which reflect unlawful political bias.**

For the Moolyyir Creek Flood Risk Identification Study, specific flood risks were identified through use of the above risk matrix and examination of modelling results as discussed in Chapter 6. Where modelling identified a hazard, an analysis of the various risk elements was undertaken using the risk matrix above. A risk ranking for the hazard was determined based on the likelihood and the consequences of the hazard occurring. For elements such as people, not only the potential to suffer injury or death as a result of property inundation was analysed, but also the ease of egress from the property through the determination of velocity x depth products and road overtopping as defined in QUDM. These parameters are shown in Table 7-6.

A risk ranking for each specific flooding risk was determined. This risk ranking can be used to prioritise mitigation options within the total catchment and is discussed in more detail in Chapter 8. A description of flooding and risk ranking for key areas across the catchment is provided in the following text. Based on the derived risk ranking and the flooding characteristics of each location the upgrade and immunity requirements are presented in Tables 7-7.

Risk elements were further defined by flood hazard and road overtopping. The following sections provide existing case flooding information for key areas across the catchment. These areas include road overtopping and areas of inundation. Road overtopping has been assessed in accordance with QUDM (1992). The following parameters were used in the assessment of road crossings.

An overall summary of both roadway and property Inundation is shown in Figure 7.1.

7.2 Risk Identification

Risks have been identified based on the QUDM road design guidelines and the risk ranking matrix. Key risk elements are defined in the following sections.

7.2.1 QUDM Classification

As discussed in the previous section, QUDM defines road trafficability based on the depth of inundation and the velocity x depth product across the road. All crossings in the catchment have been assessed against these parameters and the outcomes are shown in Table 7-6.

7.2.2 Risk Ranking Matrix

All crossings and key areas were assessed to define the risk ranking. Table 7-7 shows the risk ranking matrix.

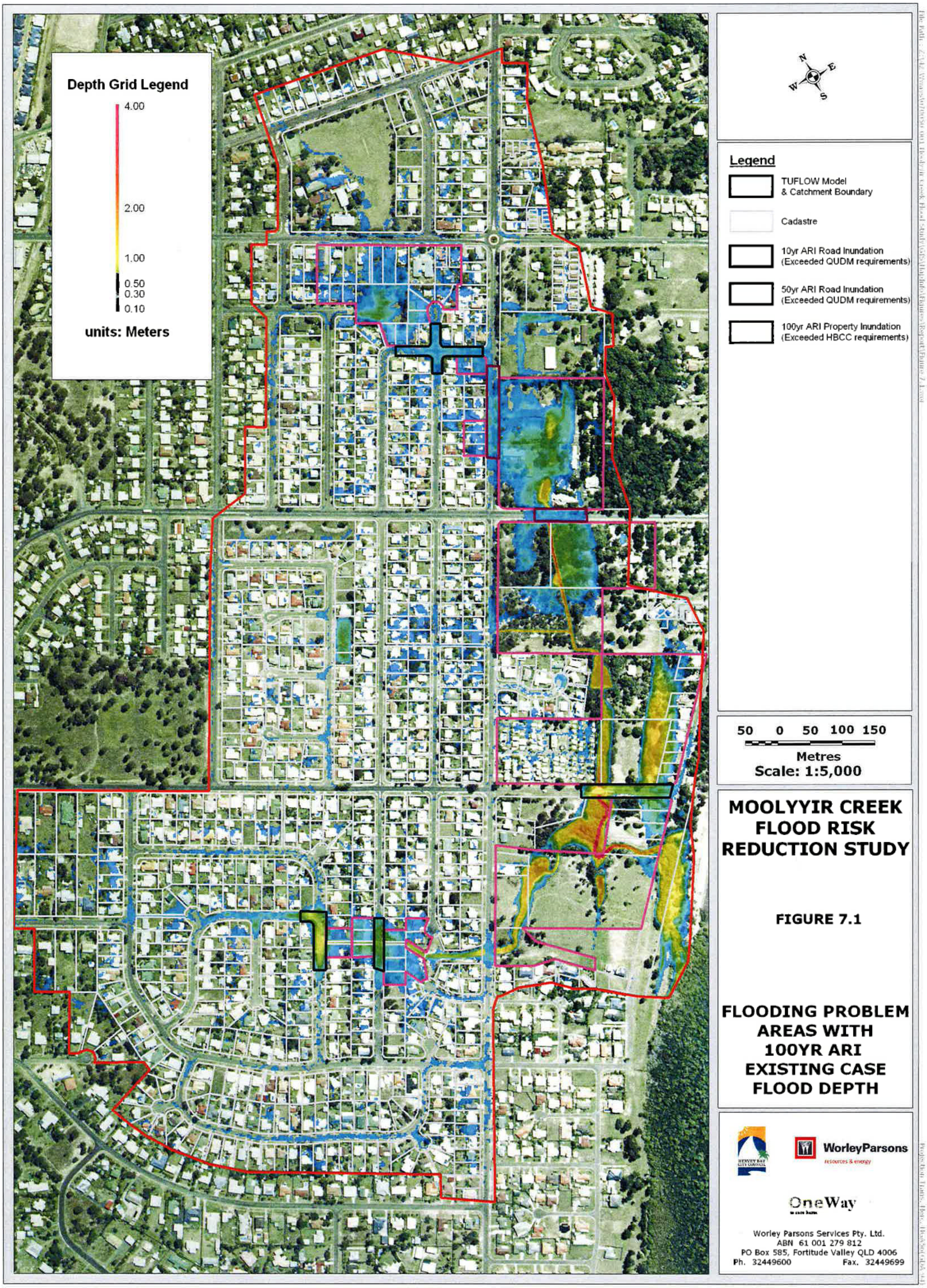

Depth Grid Legend
4.00
2.00
1.00
0.50
0.30
0.10
units: Meters
N
E
S
W
Legend
TUFLOW Model & Catchment Boundary
Cadastre
10yr ARI Road Inundation (Exceeded QUDM requirements)
50yr ARI Road Inundation (Exceeded QUDM requirements)
100yr ARI Property Inundation (Exceeded HBCC requirements)
50 0 50 100 150
Metres
Scale: 1:5,000
MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY
FIGURE 7.1
FLOODING PROBLEM AREAS WITH 100YR ARI EXISTING CASE FLOOD DEPTH
WorleyParsons
resources & energy
OneWay
Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600
Fax. 32449699

Table 7-6: QUDM Road Trafficability Assessment

Name	Road Type	Q10 Depth	Q20 Depth	Q50 Depth	Q100 Depth	Q10 vxd	Q20 vxd	Q50 vxd	Q100 vxd
Miller Street	Minor	0.25	0.25	0.25	0.25	< 0.10	< 0.10	< 0.10	0.15
Limpus Street	Minor	0.25	0.25	0.30	0.35	< 0.10	< 0.10	0.10	0.15
Pulgul Street	Major	0.20	0.25	0.30	0.35	< 0.10	< 0.10	< 0.10	0.10
Boat Harbour Drive	Major	0.20	0.20	0.25	0.25	< 0.10	< 0.10	0.10	0.15
Moolyyir Street	Minor	0.95	1.05	1.20	1.25	0.35	0.40	0.45	0.50
Deloraine Avenue	Minor	0.60	0.60	0.80	0.95	0.25	0.35	0.40	0.50
Tristania Crescent	Minor	0.75	0.80	1.00	1.05	0.25	0.25	0.35	0.60
Limpus Street 2	Minor	0.50	0.55	0.65	0.70	0.30	0.35	0.50	0.55
Pulgul Street 2	Major	0.15	0.20	0.25	0.30	< 0.10	0.10	0.20	0.20

070050-001 : Rev 0 : 5-Mar-08
070050-001 : Rev 0 : 5-Mar-08

Name	Road Type	Q10 Depth	Q20 Depth	Q50 Depth	Q100 Depth	Q10 vxd	Q20 vxd	Q50 vxd	Q100 vxd
The Esplanade	Minor	0.30	0.35	0.40	0.45	0.25	0.25	0.30	0.35

070050-001 : Rev 0 : 5-Mar-08
070050-001 : Rev 0 : 5-Mar-08

Table 7-7: Flood Risk Analysis

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Upgrade recommended
Miller Street (Between Miller St & Limpus St)	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	×	Likely	Minor	**High**	✓
	Buildings	Q100 immunity	×	Likely	Minor	**High**	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×
Upstream of Boat Harbour Drive	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	×	Almost Certain	Minor	**High**	×
	Buildings	Q100 immunity	×	Almost Certain	Minor	**High**	×

070050-001 : Rev 0 : 5-Mar-08
070050-001 : Rev 0 : 5-Mar-08

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Upgrade recommended
(Caravan Park)	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×
Downstream of Boat Harbour Drive (Lot 6 SP157206 & Lot 3 U5004)	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	×	Almost Certain	Minor	**High**	×
	Buildings	Q100 immunity	×	Almost Certain	Minor	**High**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×
Between Tirstinia Crescent & Limpus St	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	×	Likely	Minor	**High**	✓

070050-001 : Rev 0 : 5-Mar-08
070050-001 : Rev 0 : 5-Mar-08

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Upgrade recommended
	Buildings	Q100 immunity	×	Almost Certain	Minor	**High**	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×
Downstream of Limpus Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of egress	DV Product <0.6 D<300mm	×	Almost Certain	Insignificant	**High**	✓
	Buildings	Q100 immunity	×	Almost Certain	Minor	**High**	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×
Bewteen Pulgul Street & The Esplanade	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	**Low**	×
	People - ease of	DV Product <0.6 D<300mm	✓	Unlikely	Insignificant	**Low**	×

070050-001 : Rev 0 : 5-Mar-08
070050-001 : Rev 0 : 5-Mar-08

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Upgrade recommended
	egress						
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	**Low**	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	**Low**	×
	Natural environment	N/A	✓	Unlikely	Insignificant	**Low**	×

070050-001 : Rev 0 : 5-Mar-08
070050-001 : Rev 0 : 5-Mar-08

7.2.3 Key Risk Elements

Modelling of the Moolyyir Creek catchment identified a number of key risk elements as outlined in Sections 7.2.4 – 7.2.7 as follows. Based on this preliminary assessment, it was determined whether further analysis of the areas is warranted.

7.2.4 Downstream of Miller Street

Overtopping of Miller Street is predicted to occur during all events. Although the frequency of overtopping is common, flow depths and hazards remain quite low within affected private land parcels. Flooding depths remain greatest within the designated parkland area. Long shallow weir flow from the road carriageway into downstream properties results in nuisance flooding and discrete ponding of flows within the local terrain between Miller Street and Limpus Street, as well as contributing to flooding downstream in Pulgul Street.

In the 100 year ARI flood event velocity x depth products within this area are predicted to be less than $0.2m^2/s$. The modelling has predicted that the hazard from flooding is not high. However due to land use characteristics in the area and the frequency of nuisance flooding, further mitigation assessment of this area is warranted.

7.2.5 Pulgul Street (Downstream of Limpus Street)

Modelling results suggest longitudinal overland flow down Pulgul Street results in ponding of flows in the sag point before the intersection with Boat Harbour Drive. This area is typical of a trapped sag scenario, where inadequate subsurface drainage coupled with backwater constrictions on the drainage network result in ponding depths of greater than 300mm in the 50yr ARI design event. Table 7-8 shows peak depths of inundation within Pulgul Street for each design event and demonstrates that based on QUDM, Pulgul Street is not trafficable in events greater than and including the 50 year ARI. Velocity x depth products remain within Council guidelines for all the design events modelled. Pulgul Street is classified as a major road, and as such, further mitigation assessment of this crossing is warranted.

Table 7-8: Inundation depths on Pulgul Street

Design Event	Depth of Inundation (mm)
10	220
20	260
50	300
100	330

7.2.6 Boat Harbour Drive Caravan Park

The modelling predicts that this area is subject to nuisance flooding during all the design events modelled. The area in question is situated on one of the two major overland flow paths within the catchment, and as such significant ponding of flows is shown to occur behind the Boat Harbour Drive embankment during all events. This was deemed due to both insufficient sub surface drainage capacity, as well as significant backwater effects. A long section from upstream of Boat Harbour Drive to the esplanade is shown in Figure 7.1, highlighting major features and graphically showing the regions affected by backwater conditions.

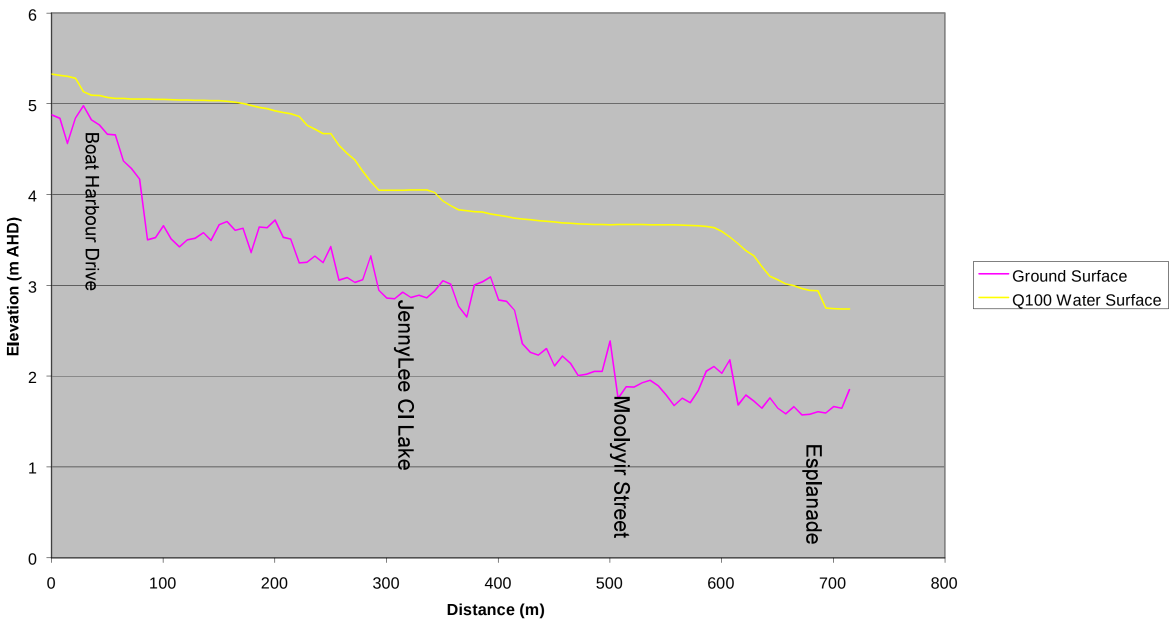
Average peak inundation depths for the design flood events are shown in Table 7-9. These depths represent peak flood depths above the initial water level within the lake immediately upstream of Boat Harbour Drive (as represented in the ALS data).

Table 7-9: Inundation depths in Caravan Park

Design Event	Depth of Inundation (mm)
10	900
20	950
50	1050
100	1100

In the 100 year ARI flood event velocity x depth product across the site is predicted to be less than $0.2m^2/s$. The modelling has predicted that the hazard from flooding is not high. However due to land use characteristics in the area and the frequency of nuisance flooding, further mitigation assessment of this area is warranted.

Figure 7.1 Long Section From Upstream of Boat Harbour Drive to Outlet



7.2.7 Downstream of Boat Harbour Drive

Inundation of properties immediately downstream of Boat Harbour Drive is predicted in all design events. Review of modelling results suggests this is due to capacity limitations of the natural channel which drains the area. The flat topography and sharp bends within the natural channel alignment further downstream before the lake leads to significant ponding of flows, whilst also contributing to backwater effects within the upstream drainage network. Representative ponding depths within the adjacent property (Lot 6 SP157206) for all design events modelled are shown below in Table 7-10. . A long section from upstream of Boat Harbour Drive to the esplanade is shown in Figure 7.1, highlighting major features and graphically showing the regions affected by backwater conditions.

Table 7-10: Inundation depths in Lot 6 SP157206

Design Event	Depth of Inundation (mm)
10	350
20	450
50	500
100	550

Whilst flooding issues within this area have been identified, HBCC has highlighted that this area will be assessed in subsequent studies for development application in the area. As such this area has not been investigated further.

7.2.8 Moolyyir Street Floodway to The Esplanade

Modelling results suggest extensive overtopping of the Moolyyir Street floodway during all of the ARI events modelled. Representative over road flooding depths for all design events modelled are shown below in Table 7-11. Not only is the road easily overtopped during the design event, but flows travel eastward along Moolyyir Street and enter a low lying area behind properties on The Esplanade. This results in significant ponding and property inundation during the 10yr ARI event and above.

Flooding within this area is dominated by backwater controlled conditions. This is a result of inadequate capacity of the Esplanade culvert system and adjacent upstream channel. This also results in 300mm of flow overtopping of the Esplanade during the 10yr ARI event.

Due to flooding depths and hazards exceeding HBCC guidelines for both the Moolyyir Street and Esplanade culvert systems and the associated hydraulic impacts between the systems, further mitigation assessment of these systems is warranted.

Table 7-11: Inundation depths of Moolyyir Street

Design Event	Depth of Inundation (mm)
10	950
20	1050
50	1200
100	1250

7.2.9 Deloraine Ave / Tristania Crescent to Downstream Limpus Street

Ponding of overland flows is predicted to occur during all events within Tristania Crescent (and adjacent Deloraine Avenue). Whilst property inundation only occurs during rarer events (50yr & 100yr ARI), ponding depths of greater than 700mm are recorded at the sag location in the 10yr ARI event.

Flows continue to pond within the Limpus Street sag, and whilst slightly shallower flooding depths are recorded (500mm in the 10yr ARI event), similar problems to those in the Tristania Crescent sag point are shown to occur.

Due to land use characteristics in the area and the frequency of nuisance flooding, further mitigation assessment of this area is warranted.

8. RISK TREATMENT AND FLOODING MITIGATION

Treatment of flooding risks as identified in Chapter 7 of this report have been investigated and are summarised below. Specifically, flooding areas that were identified as high risk were mitigated by means of drainage augmentation or other forms of mitigation works with the aim of an overall reduction of the flooding risk. Where flow depths were identified as failing to meet Council design guidelines, mitigation options have been suggested to alleviate flooding depths and ensure compliance to Council design requirements (QUDM).

Mitigation options have only been considered where necessary and to provide a beneficial outcome in terms of reducing flooding and flood risks. At this point, limited consideration has been given to the likely cost implications associated with these options. Figure 8.1 illustrates the locations of the drainage mitigation options investigated as part of this study. A brief description of each of these options is provided below. Detailed design measures are not included and are outside the scope of works of this study.

8.1 Downstream of Miller Street

To meet HBCC design requirements, the overtopping of Miller Street during all events needs to be eliminated or measures put in place to control overland flows.

Given the extremely flat nature of the terrain, that local drainage upgrades have already been undertaken to cater for the smaller ARI events, and that the downstream sub surface drainage network is already at capacity, it was agreed with HBCC that a detention basin be investigated within the parkland area to help both control overland flows within this discrete area, as well as helping reduce flooding in Pulgul Street.

The drainage easement between Miller Street and the parkland area was modified to allow ponded flows in Miller Street to easily travel to the detention basin. The existing sub surface drainage network was considered adequate when the overland drainage upgrade was undertaken. It is noted survey of driveway elevations on the downstream side of Miller Street may be required to confirm no other possible flow breakouts from Miller Street can occur.

Preliminary cost estimates for the mitigation works are $250,000.

8.2 Pulgul Street

This mitigation option was investigated to provide a reduction to the inundation of Pulgul Street to a level that meets QUDM and HBCC trafficability requirements.

Two options were investigated to achieve a solution in combination with the Miller Street detention basin. The first option consisted of a table drain running from slightly upstream of the sag point of Pulgul Street southwards into Boat Harbour Drive, before joining into the culvert inlet structure immediately upstream of Boat Harbour Drive. The second option was augmentation of the existing sub surface drainage network from the sag point of Pulgul Street to the outlet downstream of Boat Harbour Drive.

Modelling results suggested the table drain provided insufficient reductions in flooding depths within the sag point of Pulgul Street. Upgrading of the existing drainage network not only provided reduced flooding depths within Pulgul Street, but also helped improve performance of the Miller street detention basin. Given the complex nature of this discrete system between Miller Street and Boat Harbour Drive, it is recommended a detailed analysis of this system be undertaken in the future.

Preliminary cost estimates for the mitigation works are $850,000.

8.2.1 Upstream & Downstream of Boat Harbour Drive

A reduction of flooding within the properties immediately upstream of Boat Harbour Drive is required to achieve conformity to HBCC design requirements, which require flood immunity for houses during the 100yr ARI event.

Initial consideration was given to culvert upgrade and local drainage augmentation to achieve a flooding solution, however it was soon clear from review of modelling results that significant backwater issues dominate flooding in this area (refer Figure 7.1). As a result, upgrades to drainage features had minimal impact on achieving a flooding solution, whilst also contributing to increased flooding immediately downstream of Boat Harbour Drive.

It is therefore recommended that upgrades downstream of Boat harbour Drive be undertaken in conjunction with development approvals within the area. This will not only alleviate flooding downstream of Boat Harbour Drive, but also upstream as well. Modelling results predeict increased open drain capacity and alignment straightening from Boat Harbour Drive to the Jennylee Close lake would assist in reducing flood levels in this area.

This option was not costed as Council has suggested current conditional development approvals for the area will be based on alleviating flooding within the area.

8.2.2 Moolyyir Street to The Esplanade

Moolyyir Street, classified as a minor road, suffers from flooding from all ARI events modelled. Upgrading of the floodway is required to achieve acceptable trafficability of Moolyyir St and to reduce risks to pedestrians.

Road raising and culvert upgrades were investigated in unison to both improve culvert capacity and to eliminate effects of backwater overtopping the road embankment. Raising the road to 3.5m AHD at this location along with 3/ 2400 x 1200mm RCBC culverts were found to achieve acceptable flooding immunity for the road. Modelling results also suggested this upgrade eliminated flows entering the low lying topography behind properties on The Esplanade. Whilst some ponding still occurs, this was merely a result of local sub catchment flows ponding in the area.

These upgrades were done with concurrent upgrades to The Esplanade culverts and upstream channel. Minor channel widening and 6/ 2100 x 1200mm RCBC culverts were shown to reduce backwater levels for upstream systems and thus improve flow regimes.

Preliminary cost estimates for the mitigation works in Moolyyir Street & The Esplanade are $480,000 & $480,000 respectively.

8.2.3 Tristania Crescent to Limpus Street

Tristania Crescent and Limpus Street, both classified as minor roads, suffer from flooding for all ARI events modelled.

Elimination of ponding in both Tristania Crescent and Limpus Street are a key aim of the upgrades, as well as elimination of property inundation during the larger ARI events.

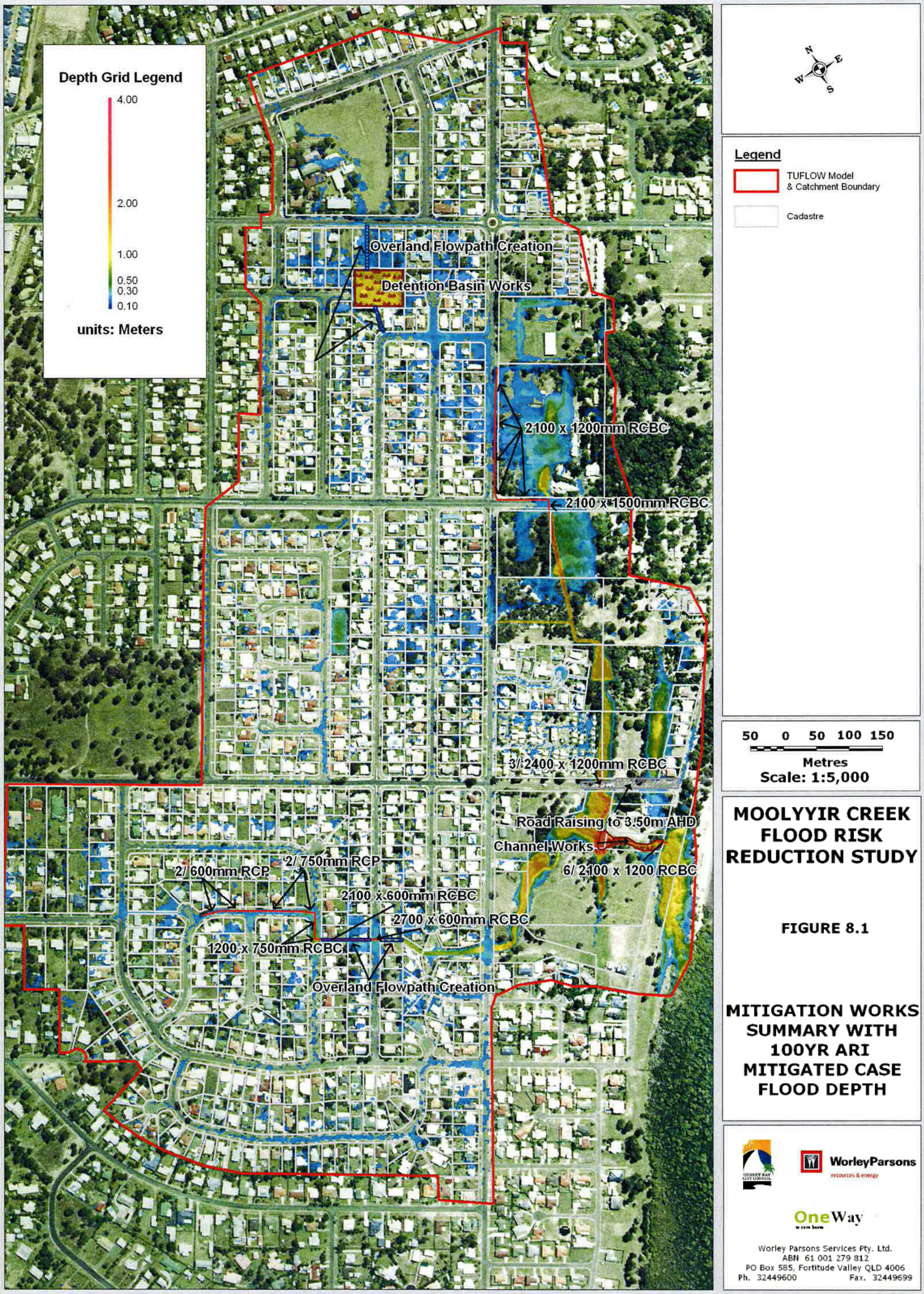
After discussions with council, it was agreed both sub surface drainage augmentation and creation of unrestricted overland flow paths was essential to allow ponded water to drain downstream.

As such, upgrades from Tristania Crescent to Limpus Street included both subsurface drainage augmentations from Deloraine Avenue to Limpus Street. In addition to this, an overland flow path was created, with the top of the RCBC acting as the invert of the overland flow path.

Upgrades within Limpus St were based on culvert upgrades under the road, with the existing sub surface network downstream of Limpus St removed in favour of an open channel system linking into the existing parkland open channel.

These upgrades provided both Tristania Crescent and Limpus Street with the required trafficability in the 10yr ARI event, and also eliminated most property inundation.

Preliminary cost estimates for the mitigation works are $580,000.



MOOLYYIR CREEK FLOOD RISK REDUCTION STUDY

FIGURE 8.1

MITIGATION WORKS SUMMARY WITH 100YR ARI MITIGATED CASE FLOOD DEPTH

WorleyParsons
resources & energy

OneWay

Worley Parsons Services Pty. Ltd.
ABN 61 001 279 812
PO Box 585, Fortitude Valley QLD 4006
Ph. 32449600 Fax. 32449699

8.3 Risk Treatment Summary

Generally, a vast majority of the flooding / inundation experienced throughout the Moolyyir Creek catchment is largely nuisance flooding i.e., Boat Harbour Drive caravan park. However, this study has identified several areas in the catchment where the flooding risk (from road overtopping) is considered high. Mitigation options have been assessed to lower the risk. Development of defined overland flow paths, creation of a detention basin and sub surface drainage augmentation are shown to reduce flooding issues from Miller Street to Pulgul Street. Similarly, overland flow path creation and subsurface drainage augmentation have also been shown to reduce flooding within the Tristania Crescent and Limpus Street areas. These upgrades have enabled trafficability of the aforementioned roads to meet QUDM requirements, whilst also eliminating most property inundation.

Sub surface drainage augmentation and channel upgrade options were initially investigated for the areas immediately upstream and downstream of Boat Harbour Drive. However, these options showed little benefit due to the controlling backwater conditions, and it is recommended that further analysis be carried out in these areas. After consultation with HBCC it was agreed detailed drainage investigations and appropriate upgrades within this discrete area would need to be enforced as part of conditional development approvals.

9. CONCLUSIONS

This study has been successful in quantifying key risk areas and providing mitigation options in the Moolyyir Creek Catchment for the primary purposes of reducing existing flood risks in the area. Specifically, the works completed have included:

- The assessment and identification of existing drainage capacities, flow paths and flood information for the 1 in 10, 20, 50 and 100 year ARI ultimate design flood events
- Preparation of detailed flood data outputs to fully document the outcomes from the analysis works including flood summary data and flood extent plans
- A sensitivity analysis on the starting tail water level from the catchment including the analysis of a HAT ± 0.3m as requested in the project brief
- Identification of potential drainage augmentation options for the catchment
- Formal hydrological and hydraulic assessment of the agreed drainage augmentation options for the catchment including the preparation of detailed outputs to fully document the outcomes from the mitigation works
- Identification of a preferred augmentation options for the catchment which has be shown to provide a beneficial outcome for the study in terms of lowering flood levels, reducing flood inundation and consequently flood risk. These include;
  - Creation of a detention basin within the parkland area downstream of Miller Street, including defined overland flow path creation
  - Sub surface drainage augmentation from Pulgul Street to the outlet downstream of Boat Harbour Drive.
  - Culvert upgrade and road raising of the Moolyyir Street crossing
  - Culvert upgrade of the Esplanade culverts
  - Sub surface drainage upgrade from Deloraine Avenue to Limpus Street including overland flow path creation

- Preparation of preliminary establishment cost estimates for the preferred work options
- Assessment of flood risk and the preparation of flood risk summaries
- Preparation of summary tables, models, flood extents, GIS mapping to formally document the outcomes of the study

WP recommends that Council utilises the outcomes from this Flood Risk Assessment Study for the Moolyyir Creek catchment in the management of existing and future development within the catchment in terms of reducing flood risk to an acceptable and manageable standard. In addition, it is also recommended that further works be instigated to proceed with the detailed design of the preferred mitigation works such that flood risks throughout the catchments can be significantly reduced. This would also include programming these works and securing future allocations under Council's Capital Works Program or alternatively through other funding arrangements.

10. REFERENCES

1. The Queensland Urban Drainage Manual (QUDM);

2. Australian Rainfall and Runoff (AR&R - 2001 edition);

3. James Cook University – Storm Surge Water Level Return Period website :

   http://mmu.jcu.edu.au/water_level_return_periods/SEQ/hervey_bay/UranganHarbour.html

4. Moolyyir Creek Hydrology & Hydraulic Report, GHD, April 1995

11. QUALIFICATION

1. In preparing the report and estimate of costs WorleyParsons has exercised the degree of skill and care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering design principles.

2. WorleyParsons has used all reasonable endeavours to inform itself of the parameters and requirements of the project and has taken all reasonable steps to ensure that the report and costs estimate is as accurate and comprehensive as possible given the information upon which it is based.

3. It is not intended that this report and costs estimate represent a final assessment of the feasibility of the project.

4. WorleyParsons reserves the right to review and amend all calculations, cost estimates and/or opinions included or referred to in the report if:

   (a) additional sources of information not presently available (for whatever reason) are provided or become known to WorleyParsons; or

   (b) WorleyParsons considers it prudent to revise the estimate in light of any information which becomes known to it after the date of submission.

5. The report and cost estimate are preliminary only and restricted in that certain information is obtained from external sources and has not been independently verified.

6. WorleyParsons does not give any warranty nor accept any liability in relation to the completeness or accuracy of the report and cost estimate.

7. If any warranty would be implied whether by law, custom or otherwise, that warranty is to the full extent permitted by law excluded.

8. All limitations of liability shall apply for the benefit of the employees, agents and representatives of WorleyParsons to the same extent that they apply for the benefit of WorleyParsons.

9. This report and cost estimate is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report and cost estimate.

10. If any claim or demand is made by any person against WorleyParsons on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report and cost estimate or information therein, WorleyParsons will rely upon this provision as a defence to any such claim or demand.

Appendix 1– Rainfall IFD Table

Hervey Bay

Duration (mins, hrs)	Duration (mins)	1 Year ARI (mm/hour)	2 Year ARI (mm/hour)	5 Year ARI (mm/hour)	10 Year ARI (mm/hour)	20 Year ARI (mm/hour)	50 Year ARI (mm/hour)	100 Year ARI (mm/hour)
5 min	5	115	148	186	209	239	280	311
5.5 min	5.5	112	143	180	202	232	270	300
6 min	6	108	139	175	196	224	262	291
6.5 min	6.5	105	135	170	190	218	254	282
7 min	7	102	131	165	185	212	247	275
7.5 min	7.5	100	128	161	180	206	241	267
8 min	8	97	125	157	176	201	235	261
8.5 min	8.5	95	122	153	171	196	229	254
9 min	9	93	119	150	168	192	224	248
9.5 min	9.5	91	116	146	164	188	219	243
10 min	10	89	114	143	160	184	214	238
11 min	11	85	109	138	154	176	206	228
12 min	12	82	105	132	148	170	198	220
13 min	13	80	102	128	143	164	191	212
14 min	14	77	98	124	138	158	185	205
15 min	15	75	95	120	134	153	179	198
16 min	16	72	93	116	130	149	174	193
17 min	17	70	90	113	126	145	169	187
18 min	18	69	88	110	123	141	164	182
19 min	19	67	85	107	120	137	160	177
20 min	20	65	83	105	117	134	156	173
21 min	21	64	81	102	114	131	152	169
22 min	22	62	80	100	112	128	149	165
23 min	23	61	78	98	109	125	145	161
24 min	24	60	76	95	107	122	142	158
25 min	25	58	75	94	105	120	139	154
26 min	26	57	73	92	102	117	136	151
27 min	27	56	72	90	100	115	134	148
28 min	28	55	70	88	99	113	131	145
29 min	29	54	69	87	97	111	129	143
30 min	30	53	68	85	95	109	127	140
32 min	32	51	66	82	92	105	122	135
34 min	34	49.8	64	80	89	102	118	131
36 min	36	48.3	62	77	86	99	115	127
38 min	38	46.9	60	75	84	96	111	123
40 min	40	45.6	58	73	81	93	108	120
45 min	45	42.8	55	68	76	87	101	112
50 min	50	40.4	52	64	72	82	96	106
55 min	55	38.3	48.9	61	68	78	90	100
1 hrs	60	36.5	46.5	58	65	74	86	95
1.25 hrs	75	31.7	40.5	51	57	65	75	83
1.5 hrs	90	28.2	36	45.2	51	58	67	75
1.75 hrs	105	25.5	32.6	41	45.9	53	61	68
2 hrs	120	23.4	29.9	37.7	42.2	48.3	56	63
2.25 hrs	135	21.6	27.7	34.9	39.1	44.9	52	58
2.5 hrs	150	20.2	25.9	32.7	36.6	42	49	54
2.75 hrs	165	19	24.3	30.7	34.5	39.5	46.2	51
3 hrs	180	17.9	23	29	32.6	37.4	43.8	48.6
3.25 hrs	195	17	21.8	27.6	31	35.6	41.6	46.3
3.5 hrs	210	16.2	20.8	26.3	29.5	33.9	39.7	44.2
3.75 hrs	225	15.5	19.9	25.2	28.3	32.5	38	42.3
4 hrs	240	14.8	19	24.1	27.1	31.2	36.5	40.6
4.5 hrs	270	13.7	17.6	22.4	25.2	28.9	33.9	37.8
5 hrs	300	12.8	16.4	20.9	23.5	27.1	31.7	35.4
6 hrs	360	11.4	14.6	18.6	21	24.1	28.3	31.6
7 hrs	420	10.3	13.2	16.8	19	21.9	25.7	28.7
8 hrs	480	9.4	12.1	15.5	17.4	20.1	23.7	26.4
9 hrs	540	8.7	11.2	14.3	16.2	18.7	22	24.5
10 hrs	600	8.12	10.5	13.4	15.1	17.5	20.6	23
11 hrs	660	7.63	9.83	12.6	14.3	16.5	19.4	21.7
12 hrs	720	7.21	9.29	11.9	13.5	15.6	18.4	20.5
14 hrs	840	6.52	8.43	10.9	12.4	14.4	17	19.1
16 hrs	960	5.97	7.75	10.1	11.5	13.4	15.9	17.9
18 hrs	1080	5.53	7.19	9.44	10.8	12.6	15	16.9
20 hrs	1200	5.15	6.72	8.88	10.2	11.9	14.3	16.1
22 hrs	1320	4.84	6.32	8.4	9.68	11.4	13.6	15.4
24 hrs	1440	4.57	5.98	7.98	9.22	10.8	13	14.8
30 hrs	1800	3.93	5.17	6.99	8.13	9.62	11.6	13.2
36 hrs	2160	3.46	4.57	6.25	7.32	8.7	10.6	12.1
42 hrs	2520	3.11	4.12	5.68	6.69	7.98	9.76	11.2
48 hrs	2880	2.82	3.75	5.22	6.17	7.39	9.08	10.4
54 hrs	3240	2.58	3.45	4.83	5.74	6.89	8.5	9.79
60 hrs	3600	2.39	3.19	4.5	5.37	6.47	8.01	9.24
66 hrs	3960	2.22	2.97	4.22	5.04	6.1	7.57	8.76
72 hrs	4320	2.07	2.78	3.97	4.76	5.77	7.19	8.34

Appendix 2– Site Photos

Photo 1: Downstream of Pulgul Street Culverts

Photo 2: JennyLee Cl Lake

Photo 3: Esplanade Culverts

Photo 4: Downstream of Limpus Street outlet

Appendix 3– Preliminary Cost Estimates

Regional Flooding Mitigation - Deloraine Avenue - Limpus Street

Costings Speadsheet

Description	Unit	Rate	Quantity	Cost
Project Establishment				**$49,000.00**
Site Establishment	Item	$25,000.00	1	$25,000.00
Provision for Traffic	Item	$15,000.00	1	$15,000.00
Soil Testing for Road Pavement Design	Item	$4,000.00	1	$4,000.00
Potholing of Existing Services	Item	$5,000.00	1	$5,000.00
Site Preparation				**$4,000.00**
Clearing & Grubbing	Item	$2,000.00	1	$2,000.00
Stockpile Topsoil on Site for Later Reinstatement	Item	$2,000.00	1	$2,000.00
Earthworks				**$73,200.00**
Excavation Through Road and Stockpile Locally for Reuse	m^3	$40.00	600	$24,000.00
Allowance for Disposal of Material Off-Site	Item	$6,000.00	1	$6,000.00
Excavation of Embankment End Walls / Culvert Headwalls and Stockpile Locally	m^3	$20.00	300	$6,000.00
Allowance for Gravel / Cruched Rock to Base of Pipe Trench (ground support to base of concrete slab)	m^3	$50.00	250	$12,500.00
Earthworks to Make Good After Pipe Install - Outside Road Area	m^3	$15.00	220	$3,300.00
Earthworks to Make Good After Pipe Install - Within Road	m^3	$40.00	460	$18,400.00
Replace Topsoil, Trim and Lightly Compact	Item	$1,500.00	1	$1,500.00
Surface trimming/contouring at ends of culvert and make good	Item	$1,500.00	1	$1,500.00
Pavements / Surfacing				**$18,430.00**
Grade, Compact and Form Road (380m x 2.0m x 0.25m)	m^3	$25.00	190	$4,750.00
2 Coat bitumen surfacing (380m x 2.0m)	m^2	$18.00	760	$13,680.00
Concrete Lining - Overland Flow	m^3	$40.00	35	$1,400.00
Pipes, Culverts, Pits & Headwalls				**$254,423.76**
Remove & Stack existing pipes	m	$20.00	400	$8,000.00
Pipe - supply & install - 600mm RCP	m	$377.00	80	$30,160.00
Pipe - supply & install - 750mm RCP	m	$446.00	91	$40,586.00
Box Culverts - supply & install - 1200 x 750mm RCBC	m	$669.14	44	$29,442.16
Box Culverts - supply & install - 2100 x 600mm RCBC	m	$1,285.57	84	$107,987.88
Box Culverts - supply & install - 2700 x 600mm RCBC	m	$1,981.98	14	$27,747.72
Break & Remove Existing Concrete Headwalls & Re-form to Suit	Item	$7,500.00	1	$7,500.00
Scour Protection to Culvert Outlets	Item	$3,000.00	1	$3,000.00
Landscaping				**$5,500.00**
Seeding & Hydromulch	Item	$2,000.00	1	$2,000.00
Allowance for Re-vegetation	Item	$2,000.00	1	$2,000.00
Maintenance of Vegetation Works (during establishment period)	Item	$1,500.00	1	$1,500.00
Miscellaneous				**$41,000.00**
Provision for Sediment & Erosion Control During Construction	Item	$7,500	1	$7,500.00
Allowance for Survey Setout of Works	Item	$7,500	1	$7,500.00
Survey and As Constructed Plans	Item	$6,000	1	$6,000.00
Provisional Item - Allowance for Service Relocations / Conflict Resolutions	Item	$20,000	1	$20,000.00
Sub-Total				**$445,553.76**
Contingencies at 30%				$133,666.13
Total for Works (Excl. GST)				**$579,219.89**
SAY				**$580,000.00**

Regional Flooding Mitigation - Esplanade

Costings Speadsheet

Description	Unit	Rate	Quantity	Cost
Project Establishment				**$13,000.00**
Site Establishment	Item	$10,000.00	1	$10,000.00
Provision for Traffic	Item	$2,000.00	1	$2,000.00
Potholing of Existing Services	Item	$1,000.00	1	$1,000.00
Site Preparation				**$7,000.00**
Clearing & Grubbing	Item	$4,000.00	1	$4,000.00
Stockpile Topsoil on Site for Later Reinstatement	Item	$3,000.00	1	$3,000.00
Earthworks				**$106,000.00**
Excavation Through Road and Stockpile Locally for Reuse	m^3	$40.00	300	$12,000.00
Allowance for Disposal of Material Off-Site	Item	$12,000.00	1	$12,000.00
Excavation of Embankment End Walls / Culvert Headwalls and Stockpile Locally	m^3	$20.00	100	$2,000.00
Allowance for Gravel / Cruched Rock to Base of Pipe Trench (ground support to base of concrete slab)	m^3	$50.00	850	$42,500.00
Earthworks to Make Good After Pipe Install - Outside Road Area	m^3	$15.00	100	$1,500.00
Earthworks - Channel Works Upstream	m^3	$15.00	2000	$30,000.00
Replace Topsoil, Trim and Lightly Compact	Item	$3,000.00	1	$3,000.00
Surface trimming/contouring at ends of culvert and make good	Item	$3,000.00	1	$3,000.00
Pipes, Culverts, Pits & Headwalls				**$197,616.40**
Remove & Stack existing pipes	m	$20.00	80	$1,600.00
Box Culverts - supply & install - 6/ 2100 x 1200mm RCBC	m	$1,445.97	120	$173,516.40
Break & Remove Existing Concrete Headwalls & Re-form to Suit	Item	$15,000.00	1	$15,000.00
Scour Protection to Culvert Outlets	Item	$7,500.00	1	$7,500.00
Landscaping				**$16,000.00**
Seeding & Hydromulch	Item	$4,000.00	1	$4,000.00
Allowance for Re-vegetation	Item	$8,000.00	1	$8,000.00
Maintenance of Vegetation Works (during establishment period)	Item	$4,000.00	1	$4,000.00
Miscelaneous				**$23,000.00**
Provision for Sediment & Erosion Control During Construction	Item	$10,000	1	$10,000.00
Allowance for Survey Setout of Works	Item	$2,000	1	$2,000.00
Survey and As Constructed Plans	Item	$6,000	1	$6,000.00
Provisional Item - Allowance for Service Relocations / Conflict Resolutions	Item	$5,000	1	$5,000.00
Sub-Total				**$362,616.40**
Contingencies at 30%				$108,784.92
Total for Works (Excl. GST)				**$471,401.32**
SAY				**$480,000.00**

Regional Flooding Mitigation - Miller Street Detention Basin

Costings Speadsheet

Description	Unit	Rate	Quantity	Cost
Project Establishment				**$22,000.00**
Site Establishment	Item	$15,000.00	1	$15,000.00
Provision for Traffic	Item	$5,000.00	1	$5,000.00
Potholing of Existing Services	Item	$2,000.00	1	$2,000.00
Site Preparation				**$7,000.00**
Clearing & Grubbing	Item	$4,000.00	1	$4,000.00
Stockpile Topsoil on Site for Later Reinstatement	Item	$3,000.00	1	$3,000.00
Earthworks				**$91,250.00**
Allowance for Disposal of Material Off-Site	Item	$5,000.00	1	$5,000.00
Excavation of Detention Basin (Inc Embankment End Walls / Culvert Headwalls) and Stockpile Locally	m^3	$20.00	4000	$80,000.00
Earthworks to Make Good After Pipe Install - Outside Road Area	m^3	$15.00	50	$750.00
Replace Topsoil, Trim and Lightly Compact	Item	$4,000.00	1	$4,000.00
Surface trimming/contouring at ends of culvert and make good	Item	$1,500.00	1	$1,500.00
Pipes, Culverts, Pits & Headwalls				**$7,100.00**
Remove & Stack existing pipes	m	$20.00	105	$2,100.00
Concrete Headwall & Re-form	Item	$2,000.00	1	$2,000.00
Scour Protection to Culvert Outlets	Item	$3,000.00	1	$3,000.00
Landscaping				**$22,000.00**
Seeding & Hydromulch	Item	$6,000.00	1	$6,000.00
Allowance for Re-vegetation	Item	$10,000.00	1	$10,000.00
Maintenance of Vegetation Works (during establishment period)	Item	$6,000.00	1	$6,000.00
Miscelaneous				**$42,000.00**
Provision for Sediment & Erosion Control During Construction	Item	$10,000	1	$10,000.00
Allowance for Survey Setout of Works	Item	$3,000	1	$3,000.00
Survey and As Constructed Plans	Item	$9,000	1	$9,000.00
Provisional Item - Allowance for Service Relocations / Conflict Resolutions	Item	$20,000	1	$20,000.00
Sub-Total				**$191,350.00**
Contingencies at 30%				$57,405.00
Total for Works (Excl. GST)				**$248,755.00**
SAY				**$250,000.00**

Regional Flooding Mitigation - Moolyyir Street

Costings Speadsheet

Description	Unit	Rate	Quantity	Cost
Project Establishment				**$31,000.00**
Site Establishment	Item	$15,000.00	1	$15,000.00
Provision for Traffic	Item	$12,000.00	1	$12,000.00
Soil Testing for Road Pavement Design	Item	$2,000.00	1	$2,000.00
Potholing of Existing Services	Item	$2,000.00	1	$2,000.00
Site Preparation				**$4,000.00**
Clearing & Grubbing	Item	$2,000.00	1	$2,000.00
Stockpile Topsoil on Site for Later Reinstatement	Item	$2,000.00	1	$2,000.00
Earthworks				**$73,750.00**
Excavation Through Road and Stockpile Locally for Reuse	m^3	$40.00	350	$14,000.00
Allowance for Disposal of Material Off-Site	Item	$2,000.00	1	$2,000.00
Excavation of Embankment End Walls / Culvert Headwalls and Stockpile Locally	m^3	$20.00	100	$2,000.00
Allowance for Gravel / Cruched Rock to Base of Pipe Trench (ground support to base of concrete slab)	m^3	$50.00	40	$2,000.00
Earthworks to Make Good After Pipe Install - Outside Road Area	m^3	$15.00	50	$750.00
Earthworks to Make Good After Pipe Install - Within Road	m^3	$40.00	1200	$48,000.00
Replace Topsoil, Trim and Lightly Compact	Item	$2,000.00	1	$2,000.00
Surface trimming/contouring at ends of culvert and make good	Item	$3,000.00	1	$3,000.00
Pavements / Surfacing				**$120,750.00**
Grade, Compact and Form Road (150m x 10m x 0.25m)	m^3	$25.00	3750	$93,750.00
2 Coat bitumen surfacing (150m x 10m)	m^2	$18.00	1500	$27,000.00
Pipes, Culverts, Pits & Headwalls				**$84,310.80**
Remove & Stack existing pipes	m	$20.00	72	$1,440.00
Box Culverts - supply & install - 2400 x 1200mm RCBC	m	$1,726.93	30	$51,807.90
Break & Remove Existing Concrete Headwalls & Re-form to Suit	Item	$15,000.00	1	$15,000.00
Link Slab	m	$570.86	15	$8,562.90
Scour Protection to Culvert Outlets	Item	$7,500.00	1	$7,500.00
Landscaping				**$9,000.00**
Seeding & Hydromulch	Item	$2,000.00	1	$2,000.00
Allowance for Re-vegetation	Item	$4,000.00	1	$4,000.00
Maintenance of Vegetation Works (during establishment period)	Item	$3,000.00	1	$3,000.00
Miscelaneous				**$42,500.00**
Provision for Sediment & Erosion Control During Construction	Item	$7,500	1	$7,500.00
Allowance for Survey Setout of Works	Item	$6,000	1	$6,000.00
Survey and As Constructed Plans	Item	$9,000	1	$9,000.00
Provisional Item - Allowance for Service Relocations / Conflict Resolutions	Item	$20,000	1	$20,000.00
Sub-Total				**$365,310.80**
Contingencies at 30%				$109,593.24
Total for Works (Excl. GST)				**$474,904.04**
SAY				**$480,000.00**

Regional Flooding Mitigation - Pulgul Street

Costings Speadsheet

Description	Unit	Rate	Quantity	Cost
Project Establishment				**$38,500.00**
Site Establishment	Item	$17,500.00	1	$17,500.00
Provision for Traffic	Item	$15,000.00	1	$15,000.00
Soil Testing for Road Pavement Design	Item	$2,000.00	1	$2,000.00
Potholing of Existing Services	Item	$4,000.00	1	$4,000.00
Site Preparation				**$4,000.00**
Clearing & Grubbing	Item	$2,000.00	1	$2,000.00
Stockpile Topsoil on Site for Later Reinstatement	Item	$2,000.00	1	$2,000.00
Earthworks				**$94,050.00**
Excavation Through Road and Stockpile Locally for Reuse	m^3	$40.00	1600	$64,000.00
Allowance for Disposal of Material Off-Site	Item	$4,000.00	1	$4,000.00
Excavation of Embankment End Walls / Culvert Headwalls and Stockpile Locally	m^3	$20.00	50	$1,000.00
Allowance for Gravel / Cruched Rock to Base of Pipe Trench (ground support to base of concrete slab)	m^3	$50.00	250	$12,500.00
Earthworks to Make Good After Pipe Install - Outside Road Area	m^3	$15.00	50	$750.00
Earthworks to Make Good After Pipe Install - Within Road	m^3	$40.00	220	$8,800.00
Replace Topsoil, Trim and Lightly Compact	Item	$1,500.00	1	$1,500.00
Surface trimming/contouring at ends of culvert and make good	Item	$1,500.00	1	$1,500.00
Pavements / Surfacing				**$19,400.00**
Grade, Compact and Form Road (320m x 2.5m x 0.25m)	m^3	$25.00	200	$5,000.00
2 Coat bitumen surfacing (320m x 2.5m)	m^2	$18.00	800	$14,400.00
Pipes, Culverts, Pits & Headwalls				**$452,757.55**
Remove & Stack existing pipes	m	$20.00	350	$7,000.00
Box Culverts - supply & install - 2100 x 1200mm RCBC	m	$1,445.97	280	$404,871.60
Box Culverts - supply & install - 2100 x 1500mm RCBC	m	$1,525.73	15	$22,885.95
Break & Remove Existing Concrete Headwalls & Re-form to Suit	Item	$15,000.00	1	$15,000.00
Scour Protection to Culvert Outlets	Item	$3,000.00	1	$3,000.00
Landscaping				**$4,500.00**
Seeding & Hydromulch	Item	$1,000.00	1	$1,000.00
Allowance for Re-vegetation	Item	$2,000.00	1	$2,000.00
Maintenance of Vegetation Works (during establishment period)	Item	$1,500.00	1	$1,500.00
Miscellaneous				**$38,000.00**
Provision for Sediment & Erosion Control During Construction	Item	$5,000	1	$5,000.00
Allowance for Survey Setout of Works	Item	$7,000	1	$7,000.00
Survey and As Constructed Plans	Item	$6,000	1	$6,000.00
Provisional Item - Allowance for Service Relocations / Conflict Resolutions	Item	$20,000	1	$20,000.00
Sub-Total				**$651,207.55**
Contingencies at 30%				$195,362.27
Total for Works (Excl. GST)				**$846,569.82**
SAY				**$850,000.00**