South Rockhampton Flood Levee Project
Rockhampton Regional Council
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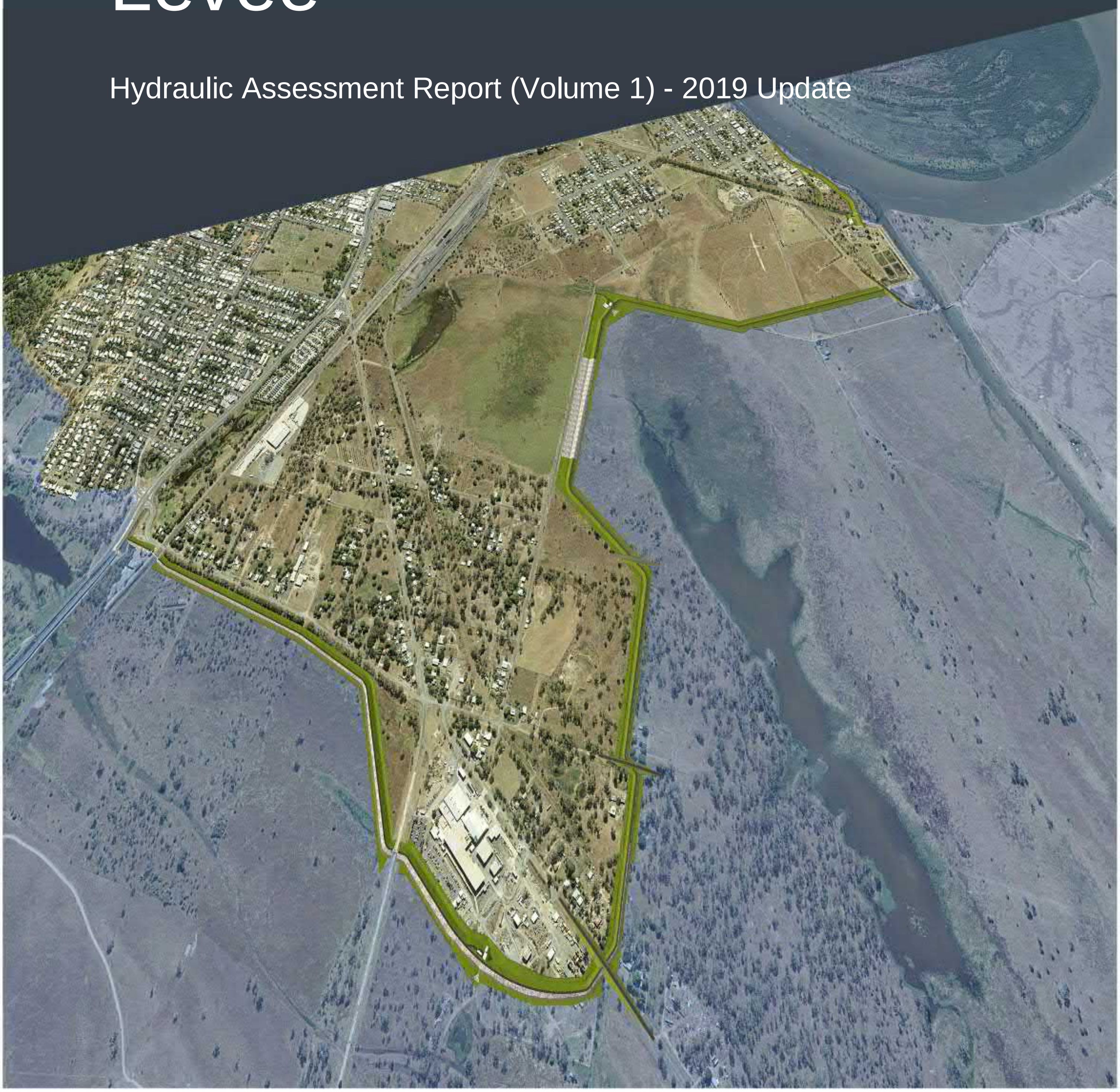
South Rockhampton Flood Levee

Hydraulic Assessment Report (Volume 1) - 2019 Update



South Rockhampton Flood Levee

Hydraulic Assessment Report (Volume 1) - 2019 Update

Client: Rockhampton Regional Council

ABN: 59 923 523 766

Prepared by

AECOM Australia Pty Ltd
Level 1, 130 Victoria Parade, PO Box 1049, Rockhampton QLD 4700, Australia
T +61 7 4927 5541 F +61 7 4927 1333 www.aecom.com
ABN 20 093 846 925

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Quality Information

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Prepared by Jordan Maultby

Reviewed by Richard Corbett

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A	23-Jun-2014	FINAL ISSUE	Jim Niehoff Project Manager	Original Signed
B	18-Mar-2019	Draft for Client Review - 2019 Design	Ben McMaster Project Manager	Original Signed
C	21-Mar-2019	Updated Draft for Client Review - 2019 Design	Ben McMaster Project Manager	Original Signed
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E	14-May-2019	Revised Final Issue - 2019 Design	Ben McMaster Project Manager	Original Signed

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Glossary / Abbreviations

AECOM	AECOM Australia Pty Ltd
AEP	Annual Exceedence Probability = 1 – exp $(\frac{-1}{ARI})$
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
CMPS&F	Camp Scott and Furphy
DEM	Digital Elevation Model
DFE	Defined Flood Event
DNRM	Department of Natural Resources and Mines
FM	Flexible Mesh
FFA	Flood Frequency Analysis
FRFS	Fitzroy River Flood Study (Aurecon, 2011)
FRFRPS	Fitzroy River Floodplain and Road Planning Study (AECOM, 2012)
GIS	Geographical Information Systems
IDAS	Integrated Development Assessment System
LFCSH	Layered Flow Constriction Shape
LiDAR	Light Detecting and Ranging
MIKE FLOOD	1D / 2D hydraulic modelling software
NDRRA	National Disaster Relief and Recovery Arrangements
PMF	Probable Maximum Flood
QR	Queensland Rail
RFMS	Rockhampton Flood Management Study (CMPS&F, 1992)
RL	Reduced Level
RRC	Rockhampton Regional Council
SAT	Scheme Assessment Tool
SRFL	South Rockhampton Flood Levee
SRSTP	South Rockhampton Sewage Treatment Plant
TMR	Queensland Department of Transport and Main Roads
TOS	Time of Submergence
TUFLOW	1D / 2D hydraulic modelling software
WSE	Water Surface Elevation

Note: **Rockhampton Flood Gauge Datum = AHD + 1.448 m**

Executive Summary

E1 Overview

The primary objective of the South Rockhampton Flood Levee (SRFL) is to protect residential and commercial properties within areas of Port Curtis, Depot Hill and the Rockhampton CBD against Fitzroy River flooding. These areas are to be protected up to and including the 1% Annual Exceedance Probability (AEP), which has been adopted as the Defined Flood Event for the project.

The levee is approximately 8.74km long generally consisting of earthfill embankment, with portions being crib wall, vertical flood walls and temporary flood barrier systems (refer to Figure E1 below and summary in Table E1).

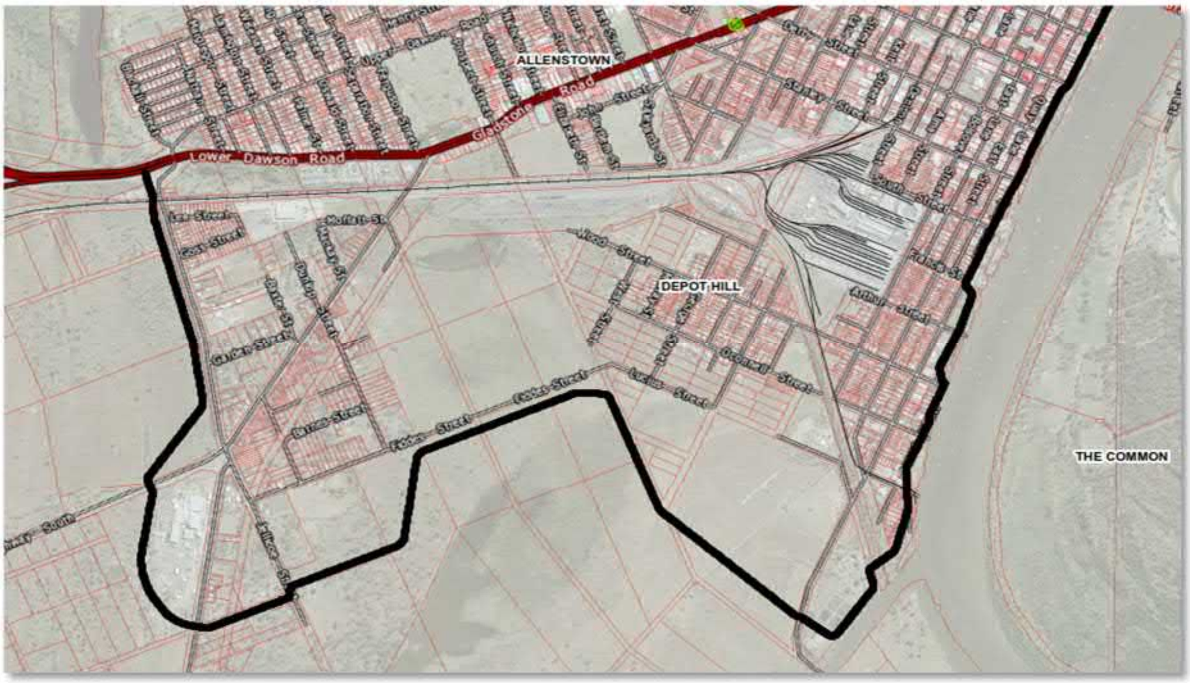


Figure E1 SRFL Horizontal Alignment (2019 design)

Table E1 Levee Wall Type Summary (2019 design)

Levee Type	Length (m)
Temporary Fully Demountable Wall	732
Composite Demountable / Permanent Levee Wall	967
Levee Emergency Spillway	420
Earth Embankment (incl. road ramps and gates)	5,892
Crib Retaining Wall	729
Total Levee Length	**8,740**

In 2014, Rockhampton Regional Council (RRC) engaged AECOM Australia Pty Ltd (AECOM) to undertake planning and design of the SRFL project. This included a range of technical studies and investigations, including detailed hydraulic analysis and assessment of potential impacts of the levee structure.

E2 Need for this 2019 Update

This report represents the latest Hydraulic Impact Assessment for the SRFL project (referred to as the 2019 update). The 2019 update has been required for the following reasons:

1. The previously adopted 2014 levee alignment has been refined in 2018/19 based on further landholder consultation and discussions with key stakeholders.
2. Extensive updates have been made to the baseline TUFLOW hydraulic model previously adopted in 2014. The updated model will be used by both RRC and the Department of Transport and Main Roads (TMR) for various infrastructure projects planned in the Fitzroy River floodplain and has been adopted for the SRFL project.

Each of these factors are discussed below.

E3 Levee Modifications (Post-2014)

A freeboard allowance of 0.9m was initially allowed for in the 2014 SRFL design, in accordance with the Freeboard Report (AECOM, 2014). The freeboard allowance has since been reduced to 0.6m, due to revised hydraulic modelling which makes use of latest data, including the 2015/16 Rockhampton LiDAR.

The 2014 levee alignment, configuration and crest levels were developed and optimised through a comprehensive design and consultation process, including workshops with Council and other key stakeholders. Through ongoing discussions with affected landholders and other key stakeholders in 2018/19, the following minor alignment refinements were approved by RRC:

- **Littler-Cum-Ingham Park.**
  - New levee alignment traverses the eastern side of the park, adjacent to the Fitzroy River. The levee will provide recreational and social benefits for the community.
- **Hastings Deering.**
  - Minor modification to the levee alignment adjacent to Hastings Deering's existing infrastructure to minimise operational impacts.
- **Fiddes Street.**
  - Modification to the levee alignment within the backwater area of the floodplain to allow landholder to better utilise land adjacent to the levee structure.
- **South Rockhampton Sewage Treatment Plant.**
  - Modification of the alignment to protect the entire treatment plant site (including the lagoons) to provide greater protection to existing assets.

The final 2019 alignment overview is provided in Figure E2. Due to changes made to the levee alignment, the previous 2014 Hydraulic Assessment Report required a comprehensive update.

Figure E2 SRFL levee type overview

E4 Baseline Model Updates

Prior to the commencement of the updated SRFL Hydraulic Assessment (this report), the previous 2014 TUFLOW hydraulic model (as outlined in the Hydraulic Model Development and Comparison report (AECOM, 2014)) was updated to include the following key changes:

- Re-assessment of the 2014 Flood Frequency Assessment using the latest data and TUFLOW FLIKE in accordance with ARR16.
    - Statistical analysis was undertaken to show that inclusion of the additional 5 years of flood data and use of ARR16-complaint TUFLOW FLIKE result in minimal change to the probabilistic estimates of the 2%, 1% and 0.5% AEP peak discharges. Whilst increasing disparity was observed for other flood magnitudes, all were within 5% of the previously estimated quantiles.
    - Given the statistical rigor of the previous FFA and negligible change to the 2%, 1% and 0.5% AEP flood magnitudes in the 2019 FFA, the estimated peak flood quantiles determined in the original FFA were maintained.
- Adoption of the TUFLOW GPU HPC solution scheme, which includes an explicit solver for the full 2D Shallow Water Equations (SWE) and sub-grid scale eddy viscosity.
- Refinement of the grid resolution from 25m to 15m.
- Incorporation of the latest topographic datasets, including the 2015/16 Rockhampton LiDAR Project, Yeppen North and South Bridges As Constructed survey and bathymetric survey at the Pink Lily meander.
- Improved 1D-2D interface at the downstream model boundary.
- Refinement of the hydraulic roughness delineation.

Following inclusion of the abovementioned updates the model was calibrated to the 2017 flood event and re-validated to the 2011 and 1991 flood events. The 2017 flood event was selected as the calibration event due to the significant recorded flood height and extent dataset captured by RRC throughout the duration of the event, which included 879 reference points, 421 being proximal to the peak. A strong calibration was achieved to the 2017 event throughout the model extent with 88% of modelled points within ±0.15m of recorded flood heights.

The model was then validated to the 2011 and 1991 major flood events using the same model parameter, aside from:

- Inflows (based on actual gauge data at The Gap station).
- Pre-Yeppen North and South Bridge topography (2009 LiDAR).
- Pre-development topography at quarries within the western floodplain.
- Pre-2017 topography at the Pink Lily meander (2015/16 LiDAR).

A strong validation of the model performance was achieved for the 2011 and 1991 events, with 86% of modelled levels being within the ±0.30m tolerance for both events.

The abovementioned updates made to the Baseline TUFLOW model have been reported separately in the 2019 Fitzroy River TUFLOW Model Update Report (AECOM, 2019).

Once the TUFLOW model was deemed suitable for use in the SRFL hydraulic assessment, Basecase simulations were completed for various flood events. Maps showing the peak depths and flood extents, peak water surface elevations, peak velocity and peak hazard for the Basecase simulations are included in Hydraulic Assessment Report – Volume 2 (AECOM, 2019).

E5 Updated Levee Impact Assessment

The 2019 levee alignment and levels were represented in the TUFLOW Developed Case model and various design event simulations were completed. Mapping of the Developed Case results is included in the Volume 2 report.

Further detailed hydraulic analysis was carried out in order to demonstrate the viability of the SRFL, the likely hydraulic impacts and the hydraulic parameters required for civil and structural detailed design activities.

A number of design flood events were simulated and impacts have been summarised for each. Design flood events included the 5%, 2%, 1%, 0.5%, 0.2%, 0.05% AEP and Probable Maximum Flood. The principal hydraulic parameters for assessing the hydraulic impact of the SRFL were:

- **Increase in Predicted Water Surface Levels**: The post-development increase in water level has been extensively analysed. In particular, the increase in predicted Water Surface Elevation at the Bruce Highway, Rockhampton Airport, the Blackwater Rail Line, North Coast Rail Line and in the Fairy Bower and North Rockhampton regions (where many of the flood affected properties are located) was considered.
- **Property Impacts**: Potential impacts to properties were considered with respect to surveyed floor levels, undeveloped property levels and property type. The number of properties affected by the new works was considered.
- **Affected Population**: The affected population in accordance with Section 5.4 of the 'DNRM Regulation of Levee Banks - Guidelines for Categories 2 and 3 Levees'.
- **Time of Submergence (TOS)**: The impact of TOS changes on the Blackwater Rail and North Coast Rail lines was assessed along with the TOS of the Rockhampton Airport and Bruce Highway.
- **Peak Velocity**: Peak velocities were extracted and used to assess the need for scour protection of the earth embankment sections of the levee.
- **Change in Velocity and Flow Regime**: Flow direction and magnitude results from the post-development simulation were compared to the pre-development flow direction and magnitude results. Post-development velocity results were used to assess levee surface protection requirements.

The Lower Fitzroy River floodplain is broad and flat and as such, the SRFL will present a significant control on flood levels throughout the western, and to a lesser extent, the northern areas of the floodplain.

Optimisation of the levee alignment has minimised hydraulic impacts as much as practicable without compromising the overall objectives of the project. Other requirements including geotechnical, civil / structural, environmental, cultural heritage and visual amenity were also considered in selecting the final location of the alignment.

Ultimately there is a trade-off between the flood protection benefits and the impacts posed to people and infrastructure outside of the levee. Whether the impacts are acceptable or not did not form part of this technical assessment.

E6 Recommendations

In undertaking this assessment, a number of key recommendations have been made and are summarised below.

- It is recommended that changes in topography are monitored within the Pink Lily meander and western floodplain as aerial datasets become available in order to understand the impact of ongoing anthropogenic activities and channel migration.
- It is recommended that the Pink Lily meander be stabilised to minimise the risk of long-term alterations to control levels which could increase breakout flows to the western floodplain. It is not yet which (combination of) organisations should be responsible for undertaking this works. This recommendation aligns with the previous Priority 3 structural mitigation measure recommended in the RFMS (CMPS&F, 1992).
- Council could consider undertaking bathymetric survey of the Fitzroy River at specified locations downstream of Rockhampton for incorporation into the hydraulic model. For consistency, it is suggested that these locations correspond to current cross section locations adopted in the hydraulic model. This would also aid in comparison to assess any long term fluvial changes.
- As detailed in Section 6.6.3, the floor level data used to assess building and population impacts of the SRFL, is predominantly based on GIS estimation methods. It is recommended that Council undertake site survey of impacted buildings and structures to confirm the assessment. This will be necessary to provide a higher degree of confidence when disseminating information to affected building owners.

E7 Residual Flood Risk

Unless the SRFL is designed to the PMF level, there is a residual risk that the levee will be overtopped. Furthermore, a decline in flood awareness and preparedness may result from the future perception of flood ‘protection’ offered by the levee. This could significantly influence flood damage costs, evacuation efficiency and overall community mindset.

It is highly recommended that Council clearly communicate this residual flood risk to the community via awareness campaigns and education materials.

1.0 Introduction

1.1 Overview

In October 2018, Rockhampton Regional Council (RRC) re-engaged AECOM Australia Pty Ltd (AECOM) to deliver concept, detailed design updates and support the obtainment of Statutory Approvals for the South Rockhampton Flood Levee (SRFL) project.

1.2 Location and Context

Rockhampton is a large regional city located on the Fitzroy River approximately 640 kilometres north of Brisbane. The Rockhampton Regional Council area has a population of some 80,000 people and is a major service centre for the wider Central Queensland region. In addition to serving a range of industries including agriculture and mining, Rockhampton provides a full range of retail, education, health, social, government and professional services to a broad catchment.

The wider Central Queensland region that Rockhampton services and supports is experiencing continuing growth in mining and resources sectors, including Liquid Natural Gas and coal mining in particular. As a consequence, interruptions to logistics and services resulting from flooding in Rockhampton impact to varying degrees on the broader region and its industries.

The Central Queensland region is a world ranked producer and exporter of black coal and a major centre for mineral processing. The region hosts the coal-bearing Bowen and Galilee basins and also produces gold, silver, limestone, coal seam gas, magnesite and gemstones. There are currently 50 coal mines, 25 mineral mines and 30 medium to large (>50 000 tonnes per year) extractive quarries operating in Central Queensland.

1.3 Flooding from Fitzroy River Events

The Fitzroy River, which flows through the city of Rockhampton in the state of Queensland, drains a catchment of approximately 142,000 km^2 and is one of the largest catchments on the east coast of Australia. The catchment extends from the Carnarvon Gorge National Park in the West to Rockhampton on the central Queensland coast and is predominantly dominated by agriculture (grazing, dry land cropping, irrigated cotton and horticulture) and by mining (coal, magnesite, nickel and historically gold and silver).

Due to its immense size and fan-like shape, the Fitzroy River catchment is capable of producing severe flooding following heavy rainfall events in any of its major tributaries. These are the Dawson, Nogoa-Mackenzie and Connors-Isaacs Rivers which rise in the eastern coastal ranges and the Great Dividing Range and join together about 100 kilometres west of Rockhampton. Major floods can result from either the Dawson or the Connors-Mackenzie River catchments. Significant flooding in the Rockhampton area can also occur from heavy rain in the local area below Riverslea.

Rockhampton is the largest urban centre in Central Queensland and is located approximately 60 kilometres from the mouth of the Fitzroy River at Keppel Bay. The Fitzroy River at Rockhampton and adjacent townships has a long and well documented history of flooding with flood records dating back to 1859. The highest recorded flood occurred in January 1918 and reached 10.11 metres (8.65m AHD) on the Rockhampton flood gauge.

It must be noted that extensive social and economic impacts are also experienced in more frequent, flood events. As examples:

- Low lying areas of Port Curtis and Depot Hill are inundated at a gauge height of 7.0m which is equivalent to the Minor Classification given by BOM.
- The Depot Hill community is isolated at a gauge height of 7.5m which is equivalent to the Moderate Classification given by BOM.
- The Bruce Highway at Lower Dawson Road is cut at a gauge height of approximately 8.4m.
- Low lying areas of Allenstown are inundated at a gauge height of 8.5m which is equivalent to the Major Classification given by BOM.

- Depot Hill and Port Curtis have been impacted by 33 historical flood events over 7.0m in gauge height since records commenced in 1859.
- There have been 17 historical flood events over a gauge height of 8.0m in which the Bruce Highway (Lower Dawson Road) has been cut.

1.4 The South Rockhampton Flood Levee

The SRFL project represents one of the most significant regional flood mitigation projects currently proposed in Queensland. The SRFL was identified as a Priority 1 Structural Mitigation Measure in the 1992 Rockhampton Flood Management Study (CMPS&F, 1992). Construction of the levee will significantly reduce flood damage and social impacts for a large portion of the urban area in South Rockhampton.

The SRFL will be approximately 8.74km long, running from the Rockhampton CBD in the north (Fitzroy Street and Quay Street), to Jellicoe Street and Port Curtis Road in the south, and Upper Dawson Road (Yeppen North) in the west (refer to Figure 1). It will consist of sections of earth embankment, crib wall, vertical flood wall and temporary demountable levee structures (component lengths are summarised in Table 1).

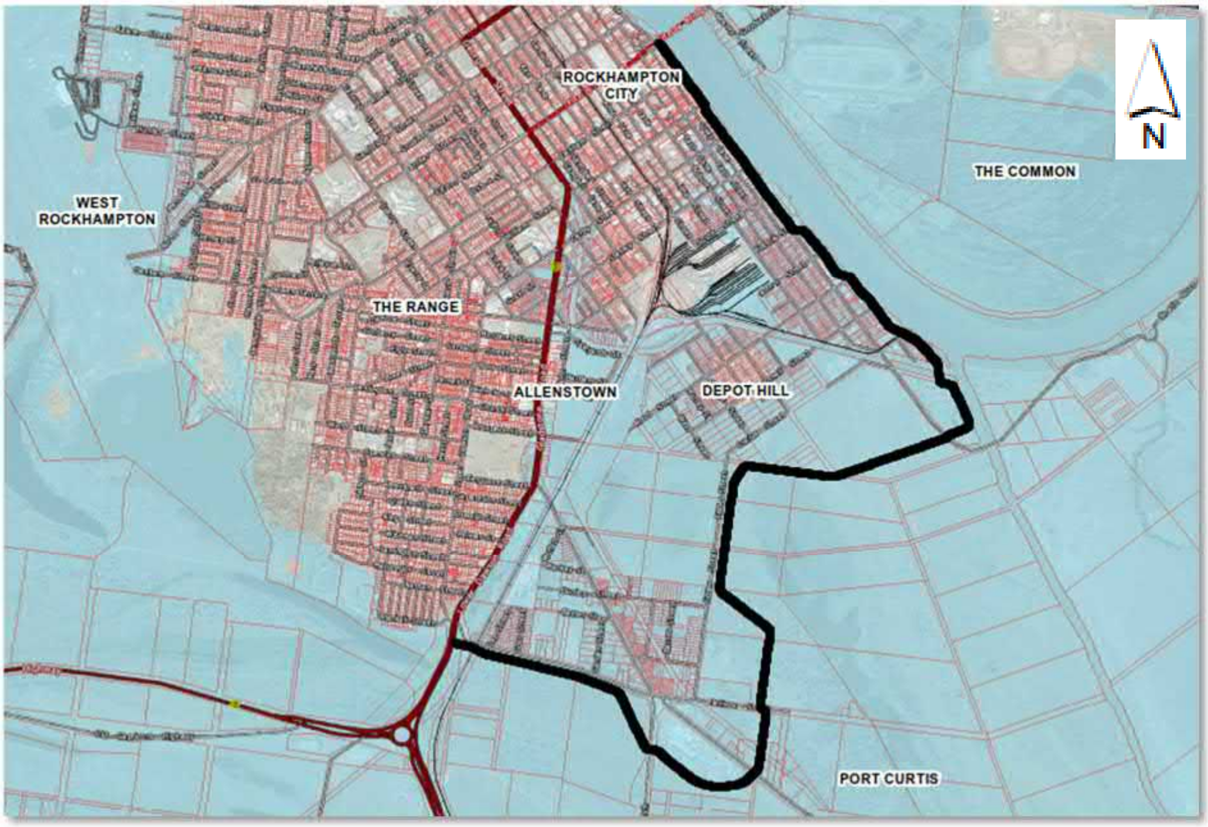


Figure 1 Location of the Proposed SRFL (Baseline Fitzroy River 1% AEP Flood Extents Shown)

The levee will be constructed to 1% Average Exceedance Probability (AEP) or 100 year Average Recurrence Interval (ARI) flood immunity with 600 mm freeboard. This will be equivalent to a 9.89 m gauge level (post SRFL construction).

The levee will incorporate flood gates on the major drainage channels and existing piped drainage networks that discharge outside the levee will be fitted with non-return devices to prevent river back-up. A system of landside drainage channels and three interior pump stations will discharge local catchment runoff should local rainfall events coincide with a regional Fitzroy River flood event.

Table 1 SRFL Component Lengths

Levee Type	Length (m)
Temporary Fully Demountable Wall	732
Composite Demountable / Permanent Levee Wall	967
Levee Emergency Spillway	420
Earth Embankment (incl. road ramps and gates)	5,892
Crib Retaining Wall	729
Total Levee Length	**8,740**

1.5 Project Delivery

The SRFL project is being delivered in two distinct stages, as detailed below.

1.5.1 Stage 1: Early Works (Pre-construction services)

Prior to construction starting on the SRFL project, early works will be completed. The works include land acquisition, stormwater, water and sewage relocations, river bank protection works and drainage works. Early works are anticipated to commence in 2019, and will be undertaken progressively throughout the year.

1.5.2 Stage 2: Main Contract

Council is committed to finalising the consultation, environmental and planning approvals, technical investigations and design of the SRFL project, to facilitate tendering and construction. The SRFL construction works are anticipated to start in late 2019.

The SRFL project has been declared a prescribed project by the Minister for State Development, Manufacturing, Infrastructure and Planning. Approvals for the project are yet to be obtained, and will be facilitated through the Infrastructure Designation process under the *Planning Act 2016*. This will include the preparation and exhibition of an Environment Assessment Report (EAR).

1.6 Scope of Works

This Fitzroy River Hydraulic Assessment Report has been undertaken as part of the Concept Design Phase for the SRFL project to support the EAR submission.

The scope of this hydraulic assessment is as follows:

- Provide a brief description of the hydraulic model adopted for the project and a description of the flooding mechanisms relevant to the concept design of the SRFL.
- Present updated Baseline and Developed Case flood depths and extents, water surface elevations, velocities and flood hazard across the range of AEP events.
- Provide a brief summary of the previous options analysis and the preferred option.
- Describe the likely hydraulic impacts of detailed refinements of the preferred option undertaken during the detailed design phase.
- Discuss the legislation and guidelines relevant to the project and confirm the parameters adopted in undertaking the assessment.
- Provide mapping and data to show the predicted impact of the SRFL on existing assets (buildings and public infrastructure) for a range of AEP events.
- Address the requirements of Sections 6.5 and 6.6 of the Department of Natural Resources and Mines (DNRM) Regulation of Levee Banks - Guidelines for the Construction or Modification of Category 2 and 3 Levees (DNRM, 2014).
- Assess the potential impacts of the SRFL in **riverine flood events** and summarise the results in this report to support the Infrastructure Designation approvals process and satisfy the Ministers Guidelines and Rules under the *Planning Act 2016.*

- Offer recommendations relevant to the assessment.

It is noted that only riverine hydraulic processes are covered in this report. The following are not addressed:

- Internal hydraulic processes such as seepage, wave induced pore pressure and consolidated induced pore pressure are not discussed. They are the subjects of a separate Geotechnical Report.
- The local drainage network and effects of interior catchment flooding. These are addressed in the SRFL Interior Drainage Assessment Report (AECOM, 2019).

1.7 Report Structure

The SRFL hydraulic assessment has been delivered in two volumes. This report (and the associated appendices) represents Volume 1. Volume 2 incorporates the A3 mapping.

This Volume 1 report is structured as follows:

- Section 2.0: Discussion on the existing flood conditions.
- Section 3.0: Overview of key studies undertaken prior to this report.
- Section 4.0: Design criteria associated with the hydraulic assessment made within this report.
- Section 5.0: Details the preferred levee option development process and adopted design as of 2019.
- Section 6.0: Discussion on the predicted hydraulic impacts of the preferred levee option.
- Section 7.0: Discussion on the sensitivity of the modelled hydraulic results.
- Section 8.0: Conclusion and Recommendations.
- Section 9.0: References.

2.0 Existing Flooding Condition

2.1 Flooding from Fitzroy River Events

As described in Section 1.3, the Fitzroy River catchment is capable of producing severe flooding following heavy rainfall events in any of its major tributaries. The most notable floods on record have been listed in order of severity below.

1. January 1918 – 10.11mRGD (8.65mAHD)
2. February 1954 – 9.40mRGD (7.95mAHD)
3. January 1991 – 9.30mRGD (7.85mAHD)
4. January 2011 – 9.20mRGD (7.75mAHD)
5. April 2017 – 8.90mRGD (7.45mAHD).

To the northwest of Rockhampton, at the Pink Lily meander, significant overbank flow occurs in major flood events where the discharge exceeds 6,200 m^3/s (approximately 1 in 6-year AEP). This results in flood flows spreading over a broad floodplain to the west and south of Rockhampton. This floodwater re-joins the Fitzroy River south of the city at Gavial Creek.

The inundation of the floodplain can result in the closure of Rockhampton Airport, the Bruce and Capricorn Highways and the North Coast Rail Line. The Bruce Highway and North Coast Rail Line can also be cut by floodwaters at the Alligator Creek Crossing near Yaamba (30 kilometres north of Rockhampton). As major floods can last for several weeks there is often an extensive disruption to road, rail and air traffic that results in extensive indirect losses. Extensive property damage can also occur within Rockhampton during flood events which can result in significant direct losses and pose a safety risk to the population.

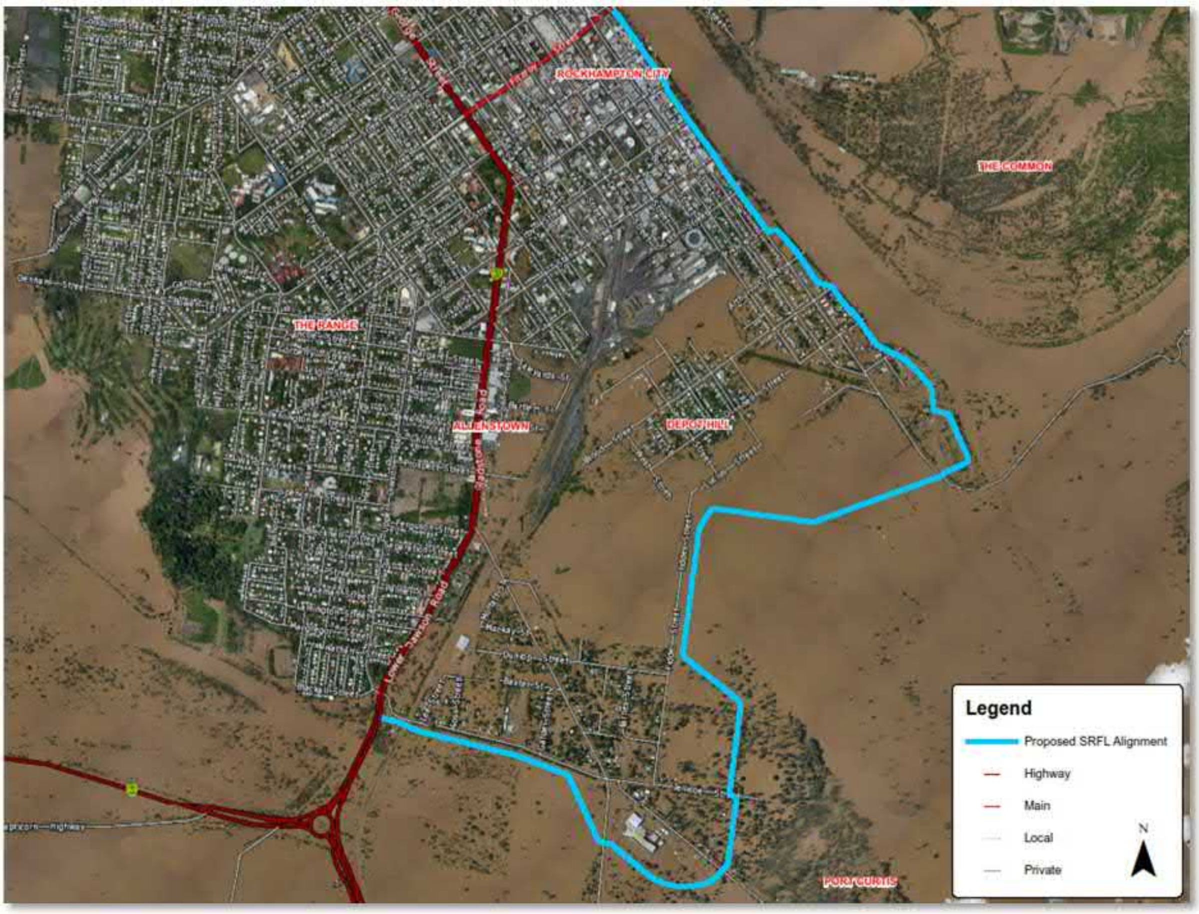


Figure 2 2011 Fitzroy River Flood Extent with SRFL Alignment

2.2 Local Creek Catchment Flooding

There are a number of local tributaries which drain local runoff to the Fitzroy River. These local tributaries, which typically have main channel widths of 10 m to 20 m and main channel depths of less than 4 m, include:

- Alligator Creek.
- Limestone Creek.
- Etna Creek.
- Ramsay Creek.
- Splitters Creek.
- Lion Creek.
- Moores Creek.
- Frenchmans Creek and Thozets Creek.
- Neerkol Creek.
- Scrubby Creek.
- Gavial Creek.

Significant quantities of runoff can be conveyed by the local tributaries following high rainfall in the local Rockhampton area. In some cases this runoff can intensify flooding at Rockhampton, however the local catchment runoff generally discharges through to the ocean prior to peak Fitzroy River floodwaters reaching Rockhampton from the major upstream tributaries.

A broad scale hydrologic model was developed to simulate runoff characteristics of the local catchments between Yaamba and Port Alma, as part of the Fitzroy River Floodplain and Road Planning Study (FRFRPS). This study indicated critical storm durations between 18 hours and 24 hours for the majority of the local catchments.

The local catchment encompasses Rockhampton, Gracemere and Bouldercombe and covers varying land uses such as grazing areas, developed and rural residential areas, industrial areas, bushland, state forests and floodplain. The catchment is characterised by low lying areas across the floodplain to the west of Rockhampton and mountainous ranges to the east. Runoff from the local catchment is conveyed via local tributaries, all of which discharge into the Fitzroy River.

2.3 Coincidental Flooding

Due to the large extent of the wider Fitzroy River catchment, flood flows take approximately 10 -14 days to reach the Rockhampton area following rainfall events in the upper catchments. As noted above, flood flows from local tributaries generally discharge to the ocean during this period so it is uncommon for local and wider catchment tributaries to contribute to the flooding regime simultaneously.

Nevertheless, detailed sensitivity analysis was undertaken as part of the FRFRPS hydraulic assessment in 2011 to evaluate the impact of a local catchment event coinciding with a wider Fitzroy catchment event. The 1% AEP Fitzroy River flood event was modelled with the inclusion of the local catchment inflows as source points within the MIKE FLOOD model domain and compared to the results of the existing Baseline 1% AEP flood event. The peak of the local catchment discharge hydrographs were applied to coincide with the Fitzroy River flood peak, representing a worst case scenario.

The relative increase caused by the additional local inflow was found to be negligible. On this basis, it was concluded that velocities and discharges from a Fitzroy flood event are the ‘worst case’ and should be adopted for the hydraulic assessment of the SRFL.

Figure 3 shows a comparison between the 1% AEP Fitzroy River inflows and the 1% AEP local catchment inflows.

It is noted that no assessment was undertaken on flood timings and the effect of local catchment flooding on Fitzroy River flood rise and fall timings.

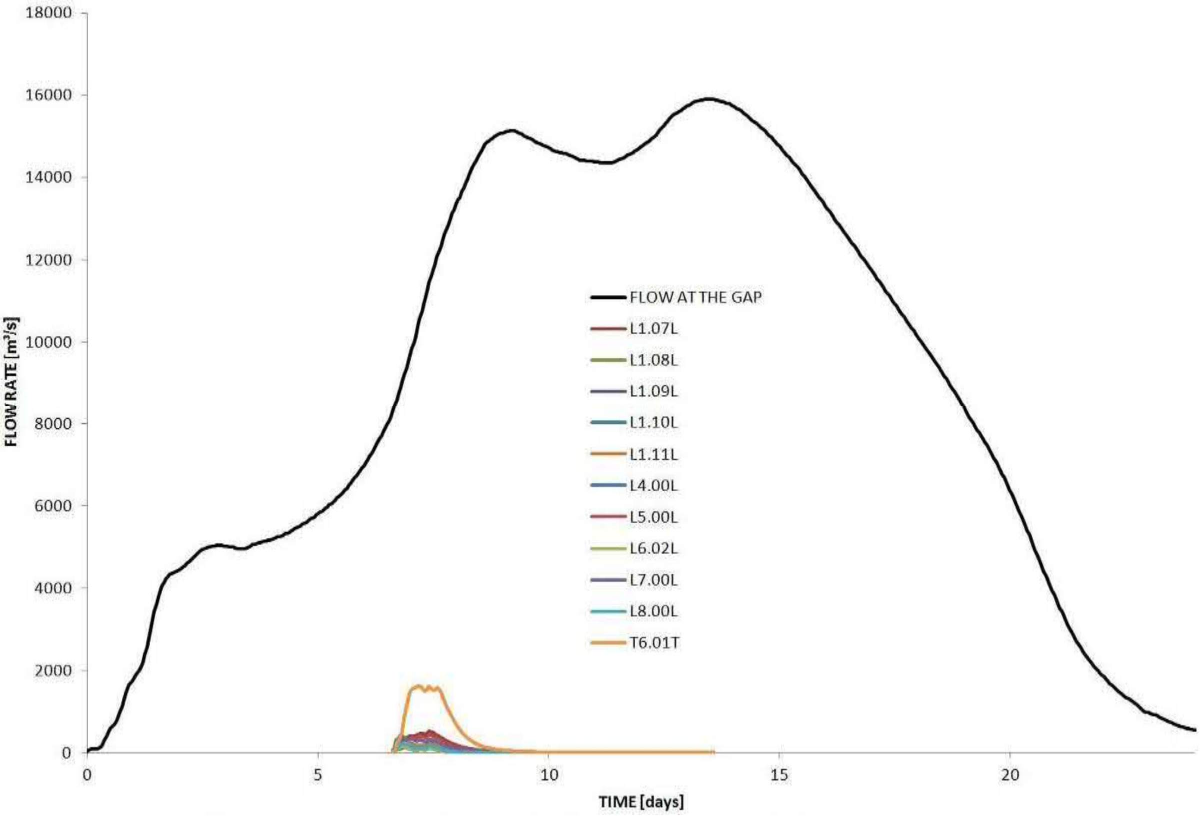


Figure 3 1% AEP Fitzroy River Flow at the Gap and 1% AEP Local Catchment Inflows (reproduced from FRFRPS Volume 3 report)

2.4 Flooding from Interior Catchment Events

Due to the complex nature of interior catchment flooding, a separate report has been produced which documents the interior drainage strategy, and discusses:

- The development of baseline hydrologic and hydraulic models.
- The assessment of various levee interior drainage scenarios.
- Design of drainage infrastructure, including major stormwater pump stations.

The SRFL Internal Drainage Assessment Report (AECOM, 2019) should be read in conjunction with this report.

3.0 Previous Studies

3.1 Overview

The following are reference documents to this Volume 1 report with those discussed in further detail highlighted in bold text:

- **Rockhampton Flood Management Study (CMPS&F, 1992).**
- **Fitzroy River Flood Study (Aurecon, 2011).**
- **Fitzroy River Floodplain and Road Planning Study (AECOM, 2012).**
- **South Rockhampton Flood Levee Feasibility Assessment, Preliminary Design and Detail Design (AECOM, 2014):**
    - Hydraulic Assessment Report (AECOM, 2014) (antecedent of this Report).
    - Inflow Hydrograph Review (AECOM, 2014).
    - Freeboard Report (AECOM, 2014).
    - Hydraulic Model Development and Comparison Report (AECOM, 2014).
    - Internal Drainage Assessment report (AECOM, 2014).
    - Operations and Maintenance Manual (AECOM, 2014).
    - Preliminary Economic Evaluation Report (AECOM, 2014).
    - Failure Impact Assessment Report (AECOM, 2014).
    - Tangible Flood Damage Assessment Report (AECOM, 2014).
- **2019 Fitzroy River Baseline Model Update Report (AECOM, 2019).**
- **SRFL Internal Drainage Assessment Report 2019 Update (AECOM, 2019).**

3.2 Rockhampton Flood Management Study (1992)

Following the January 1991 Fitzroy River flood event, which resulted in flood damage and closure of transport links causing major economic and social problems in the Rockhampton region, the RFMS was undertaken. Local, state and federal government agencies agreed that a study would enable better management of the Fitzroy River floodplain at Rockhampton.

The Queensland Water Resources Commission engaged Camp Scott and Furphy (CMPS&F) to undertake the study, which was to consider aspects of existing and future flood management, in order to make recommendations aimed at reducing the impact of future floods in Rockhampton.

The study included:

- Investigating the characteristics of Fitzroy River flooding including flood mechanisms, flood hydrology and extreme floods.
- Flood damage assessment including flood damage modelling to estimate direct flood damages for a range of flood levels; and indirect losses from transport link closures causing disruption to business capacity.
- Appraisal of current flood management issues and options for future flood management.

The study was delivered in two phases, the first of which included:

- A study into the characteristics of Fitzroy River flooding;
- Assessment of flood damages;
- Flood management options appraisal;
- Future flood management recommendations and Community consultation.

Options identified in Phase 1, which were deemed to warrant further study, were investigated in Phase 2. Non-structural flood management recommendations (which could be implemented immediately) and structural mitigation works were also detailed, costed and prioritised in Phase 2.

A summary of the findings and recommendations of the study are detailed below:

- Flood Damages
  - The study estimated that the total cost of flood damages resulting from the 1991 flood event was approximately $50 million, although this figure was said to be imprecise. Of the $50 million, it was estimated that the cost as a result of direct damages was $15 million. By way of contrast, the cost as a result of indirect damages was approximated to be $35 million.
  - The annual average damage (the long term average of flood damage over a period of time which includes the likely range of floods) was estimated to be $5.2 million per annum at 1992 prices. This represented the annual cost to the national economy of doing nothing to improve flood management or mitigate flood damage.
- Recommendations for Non-Structural Flood Management Measures
  - Flood maps were prepared as part of the study and showed the extent of inundation for 2%, 1% and 0.5% AEP floods. These were recommended to be used by the Rockhampton City Council on an interim basis before the adoption of formal maps for planning purposes.
  - It was recommended that a flood standard of the 1% AEP flood be adopted for planning purposes. It was also recommended that no new developments be permitted in designated floodways. Where new development is permitted in other flood prone areas, the minimum habitable floor level should be 0.5 m above the 1% AEP flood level.
  - Various other management measures were recommended for immediate implementation, including: flood warning measures, counter disaster planning, operations measures and other measures to increase public flood preparedness and community flood response.
- Recommendations for Structural Flood Mitigation Measures
  - Improving the flood immunity of the Yeppen Crossing was regarded the highest priority. The hydraulic model study demonstrated that the flood immunity could be improved to 2% AEP by doubling the bridge waterway area which would involve increasing the length of the bridges from 420 m to 840 m, together with raising the highway/rail embankment sections between the bridges. The cost of the upgrades was estimated to be $15.6 million on the basis of the 1992 road width.
  - Constructing a levee to protect Lower Dawson Road, Port Curtis, Depot Hill and the Lower CBD was also recommended as a high priority measure. The construction of a levee was recommended to follow the proposed improvement to Yeppen Crossing for hydraulic reasons. The levee was recommended to protect up to the 1% AEP flood and would significantly reduce flood damage and social impacts for the bulk of the urban area on the south side of the river.
  - The construction of a levee to protect the Rockhampton Airport was recommended, but with a lower level of priority. It was noted that the levee would be difficult to justify in an economic sense.
  - Lower level priority works which were also recommended: a levee to prevent direct overflow from the Fitzroy River into Splitters Creek, the stabilisation of the high bank at Pink Lily, the fitting of flood gates on creeks on the northern river bank and the fitting of flood valves on the storm drainage outlets.

The RFMS consolidated all previous reports as well as available historical flood information and was the base source of knowledge for hydrology and hydraulic assessments in the Rockhampton area until the completion of the FRFS and FRFRPS projects (discussed below).

3.3 Fitzroy River Flood Study (2011)

Commencing in 2008, RRC engaged Aurecon to undertake the Fitzroy River Flood Study, having received funding through the Federal and State Governments under the Natural Disaster Mitigation Program (NDMP).

RRC indicated that the FRFS would be vital to provide a modern tool for emergency management and would help to understand flood hazard risk and assist the local Disaster Management Group to plan emergency evacuations.

One aim of the FRFS was to update the previous flood study conducted by Camp Scott and Furphy in 1992. This was achieved by using updated modelling tools to define the flood behaviour in the area and taking into account changes that have occurred in the floodplain. This was followed by assessment of the resultant flood hazard.

The objective of the FRFS was to provide floodplain mapping of the Rockhampton region, to assist Council in future development assessment and emergency management planning activities.

The study entailed the:

- collection of survey and topographic data in the area;
- review and analysis of existing flood data;
- preparation of mapping including flood levels, depths and velocities;
- identification of key areas at risk during flood events; and
- refinement of existing emergency management procedures.

The following provides a summary of the modelling:

- The hydraulic model was developed using the computer software package TUFLOW.
- The model boundaries were approximately 10km upstream and downstream of the urban area of the city.
- The study / model’s inputs include LIDAR of the Rockhampton urban area and immediate surrounds.
- The model was calibrated to the 1988, 1991 and 2008 flood events.

The FRFS concluded in July 2011 with the delivery of a detailed hydraulic report, associated flood mapping and a two-dimensional TUFLOW numerical hydraulic model, which utilised a 50m Cartesian grid.

3.4 Fitzroy River Floodplain and Road Planning Study (2012)

In June 2009, the Australian Federal government announced the commencement of a three-year study to identify the preferred alignment for future road and rail transport in Central Queensland.

The Fitzroy River Floodplain and Road Planning Study (FRFRPS), led by the Department of Transport and Main Roads (TMR), was undertaken in order to identify and evaluate options to address the issues of flood immunity, traffic capacity, freight movement and amenity of the Bruce Highway through Rockhampton.

Flood immunity and flood impacts associated with the FRFRPS was extensively investigated. Outcomes of the hydraulic investigations were reported in four report volumes which made up the Hydraulic Assessment Report, as follows:

- Volume 1 – Data Compendium
  - Summarised data relevant to lower Fitzroy River flooding at Rockhampton.
  - Described the major historical floods and flood behaviour.
  - Identified changes over time within the catchment and floodplain likely to impact on flooding (infrastructure and river geometry).
  - Critically examined all data to be used in subsequent hydrologic / hydraulic model development.
- Volume 2 – Hydrology
  - Reviewed the Fitzroy River catchment hydrologic mechanisms associated with flooding at Rockhampton.
  - Determined the design inflow hydrographs for application to the hydraulic model.
- Volume 3 – Preliminary Hydraulics
  - Detailed the development of the MIKE FLOOD hydraulic model that was subsequently used to determine design parameters for the proposed road alignments and to assess impacts of the proposed design.
  - Detailed the sensitivity analyses undertaken for the hydraulic model as part of the model development process.
  - Outlines calibration and validation works undertaken using data from major historical Fitzroy River flood events.
  - Provided baseline flooding conditions for a range of design flood events.
- Volume 4 – Hydraulic Analysis of Options and Preferred Option.
  - Assessment of hydraulic impacts associated with potential upgrade options within the overall framework of the study.

Recommendations of the study included upgrades to Yeppen North, Yeppen South, Capricorn Highway and the Rockhampton Ring Road. These projects are at various stages of development and have necessitated further detailed hydraulic analysis, which have been reported separately.

Upon review of the FRFS TUFLOW model and associated data, it was found that:

- Development of the TUFLOW model associated with the FRFS was still ongoing at the commencement of the FRFRPS and the finalised model was not available in timeframes required for the study.
- The adopted TUFLOW model grid size was deemed too large to adequately represent the existing and proposed road alignments required as part of the FRFRPS.
- The model extent was focussed on the Rockhampton urban area (for emergency management purposes) and the proposed road alignments for the FRFRPS were found to be in close proximity to the model extents. As a result it was likely that the TUFLOW model would need to be extended to ensure the model boundaries would not influence flooding at the proposed road alignments.

Based on the outcomes of the review of the FRFS model, it was agreed with TMR Hydraulics Branch that a MIKE FLOOD Flexible Mesh (FM) hydraulic model be developed and utilised for the FRFRPS.

3.5 SRFL Feasibility Assessment, Preliminary and Detailed Design (2014)

The South Rockhampton Flood Levee (SRFL) project represents one of the most significant regional flood mitigation projects currently proposed in Queensland. The SRFL was identified as a high priority mitigation measure that was strongly recommended in the Rockhampton Flood Management Study (CMPS&F, 1992). Construction of the levee will significantly reduce flood damage and social impacts for the majority of the urban area in South Rockhampton.

The SRFL feasibility assessment, preliminary design and detail design was completed by AECOM (2014) as a joint initiate of RRC, the Queensland Government and the Australian Federal Government.

The primary objective of the SRFL was to protect residential and commercial properties within areas of Port Curtis, Depot Hill and the Rockhampton CBD against Fitzroy River flooding. These areas are to be protected up to and including the 1% AEP event, which is the Defined Flood Event for RRC.

A key task was the update and further development of RRC's existing TUFLOW hydraulic model of the Fitzroy River, to ensure the model was suitable to inform and assess the SRFL infrastructure. The updated hydraulic model setup is detailed in the SRFL Hydraulic Model Development and Comparison Report (AECOM, 2014).

3.6 2019 Fitzroy River Baseline Model Update Report (2019)

As a component of the Rockhampton Ring Road Preliminary Evaluation and Business Case, TMR commissioned AECOM to update the baseline Fitzroy River TUFLOW model in liaison with RRC. The update was staged to include the following key changes:

- Re-assessment of the FFA using the latest data and TUFLOW FLIKE in accordance with ARR16.
  - Statistical analysis was undertaken to show that inclusion of the additional 5 years of flood data and use of ARR16-complaint TUFLOW FLIKE result in minimal change to the probabilistic estimates of the 2%, 1% and 0.5% AEP peak discharges. Whilst increasing disparity was observed for other flood magnitudes, all were within 5% of the 2012 expected quantiles. It is also noted than events less frequent than a 0.5% AEP event are subject to rapidly increasing uncertainty due to extrapolation of the probability distribution.

    Given the statistical rigor of the 2012 FFA and negligible change to the 2%, 1% and 0.5% AEP flood magnitudes in the 2017 FFA, **the estimated peak flood quantiles determined in the 2012 FFA were maintained**.
- Adoption of the TUFLOW GPU HPC solution scheme, which includes an explicit solver for the full 2D Shallow Water Equations (SWE) and sub-grid scale eddy viscosity.
- Refinement of the grid resolution from 25m to 15m.
- Incorporation of the latest topographic datasets, including the 2015/16 Rockhampton LiDAR Project, Yeppen North and South Bridges As Cons and bathymetric survey at the Pink Lily meander.
- Improved 1D-2D interface at the downstream model boundary.
- Refinement of the hydraulic roughness delineation.
- Inclusion of all major bridge and culvert structures, with form losses in accordance with Hydraulics of Bridge Waterways HDS (FHWA, 1978).

Following inclusion of the abovementioned updates the model was re-calibrated to the 2017 flood event and re-validated to the 2011 and 1991 flood events. The 2017 flood event was selected as the calibration event due to the significant recorded flood height and extent dataset captured by RRC throughout the duration of the event, which included 879 reference points, 421 being proximal to the peak. A strong calibration was achieved to the 2017 event throughout the model extent with 88% of modelled points within ±0.15m of recorded flood heights.

The model was then validated to the 2011 and 1991 major flood events using the same model parameter, aside from:

- Inflows (based on actual gauge data at The Gap station).
- Pre-Yeppen North and South Bridge topography (2009 LiDAR).
- Pre-development topography at quarries within the western floodplain.
- Pre-2017 topography at the Pink Lily meander (2015/16 LiDAR).

A strong validation of the model performance was achieved for the 2011 and 1991 events, with 86% of modelled levels being within the ±0.30m tolerance for both events.

Updates to the Fitzroy River TUFLOW model were found to result in changes to the expected peak flood heights for design events across the modelled 2D extent. This has potential implications for infrastructure projects within the Lower Fitzroy Catchment. The change in expected peak flood height at the SRFL was identified to range from +0.30m to +0.38m.

As such it is important to understand the factors driving this change. These are summarised as follows:

- **Topographic Datasets:** ground levels within the 2015/16 LiDAR data are generally 0.18m higher than the 2009 LiDAR data.
- **Pink Lily Meander Migration**: continued lateral migration of the Pink Lily meander has resulted in increased flows entering the western floodplain, increasing peak flood heights until Gavial Creek (downstream of the Yeppen Crossing)
- **Hydraulic Structures:** improved digitisation of hydraulic structures, especially the Fitzroy River Barrage and low-level Yeppen North bridges (road and rail) has increased peak flood heights within the western floodplain between Ridgelands Road and the Yeppen crossing.
- **Hydraulic Roughness:** changes to ground roughness related to more recent aerial imagery and model re-calibration generally saw an increase in roughness throughout the western floodplain.
- **Downstream Model Boundary:** depositional processes were noted near the downstream boundary which effectively reduces the capacity of the channel-floodplain for a given flood stage. Updating the 1-D / 2-D boundary to match 2015/16 LiDAR has resulted in increased flood levels which influence the water surface near the SRFL and Yeppen Bridges due to limited energy gradient between the lower Fitzroy Reach at Rockhampton and the downstream 2-D model boundary.
- **Improved Model Resolution**: improved digitisation of key channels provided more accurate channel conveyance characteristics.

As a result of the model update it was recommended that:

- Changes in topography are monitored within the Pink Lily meander and western floodplain as aerial datasets, become available in order to understand the impact of ongoing channel migration. Stabilisation of the meander is strongly recommended and is aligned to recommendations made in the 1992 Rockhampton Flood Management Study.
- The model is validated to future flood events as recorded flood data allows. If an opportunity arises, it is recommended that the model is validated or re-calibrated to a flood event close to the 1% AEP magnitude in order to confirm model performance during the DFE.
- Changes in peak flood levels, behaviour and extents are communicated to key stakeholders and that infrastructure projects within the modelled Fitzroy River extents utilise the updated Fitzroy River model as the basis for design.
- TMR and RRC maintain consistent use of the updated TUFLOW model and any major floodplain changes are recorded and included in the model in a structured manner.

The 2019 TUFLOW hydraulic model will be used by RRC and TMR moving forward and is the base model for this Updated Hydraulic Assessment.

4.0 Design Criteria

The following sections outline the design criteria and assumptions adopted in undertaking the SRFL hydraulic assessment. This includes a discussion on:

- Adopted Defined Flood Event (DFE).
- QLD Levee Guidelines (DNRME).
- Ministers Requirements.

4.1 Adopted Design Flood Immunity

At the commencement of the SRFL project in 2014, the intended level of protection for the levee was the 0.5% AEP flood height plus freeboard. This was aligned to the recommendation made in the Rockhampton Flood Management Study (1992).

During the preliminary design phase, the following factors were considered by RRC and the project team when selecting the final level of protection for the levee:

- Community safety.
- Required level of service for hydraulic performance.
- Anticipated reduction in tangible flood damage.
- Maintenance requirements.
- Construction and operating costs.
- Visual amenity.
- Interface requirements with other floodplain infrastructure projects (i.e. Bruce Highway Upgrades).

The flood immunity was subsequently revised to the 1% AEP flood height which was adopted as the design level for the SRFL, plus an allowance for freeboard based on the assessment undertaken. A freeboard allowance of 0.9m was initially allowed for in the 2014 SRFL design.

It should be noted that the freeboard allowance has since been reduced to 0.6m, due to revised Fitzroy River hydraulic modelling which makes use of the latest data, including the 2015/16 Rockhampton LiDAR (refer to the Fitzroy River Hydraulic Assessment Report for further information).

The adopted design flood immunity is the 1% AEP event with a freeboard of 0.6m.

4.2 QLD Levee Guidelines (DNRME)

The Queensland Government has introduced laws to regulate the construction or modification of levee banks. These laws became effective on 16 May 2014. A second revision (Version 2.0) was published in December 2018 which incorporates amendments consistent with current water and planning legislation.

The *Water Act 2000* defines a levee as follows:

> *A levee is an artificial embankment or structure which prevents or reduces the flow of overland flow water onto or from land.*

A levee includes levee-related infrastructure, which is defined as infrastructure that is:

a. connected with the construction or modification of the levee or

b. used in the operation of the levee to prevent or reduce the flow of overland flow water onto or from land.

Proponents must meet the requirements under the *Sustainable Planning Regulation 2009* (the regulation) for the construction of new levees and modification of existing levees.

The *Guidelines for the Construction or Modification of Category 2 and 3 Levees* (the Guidelines) provide information relating to the following codes:

- Integrated Development Assessment System (IDAS) Code for development applications for construction or modification of particular levees (Schedule 10 of the Water Regulation 2016).
- Construction or modification of levees state code as part of the State Development Assessment Provisions (SDAP) State Code 19.

For the purposes of regulation, levees in Queensland are classified into three categories based on their potential level of impact. The categorisation ensures that the level of assessment that a levee application will need to go through is proportionate to the level of risk that the levee poses to people, property and the catchment. The three categories and their respective assessment level are as follows:

Table 2 Levee Categories (DNRME, 2018)

Category	Definition	Level of Assessment	Assessor
1	A levee that has no off-property impact	Self-assessment	Applicant
2	A levee that has an off-property impact and for which the affected population is less than 3	Code assessment	Local government
3	A levee that has an off-property impact and for which the affected population is at least 3	Impact assessment	Local government with Queensland Government as referral agency

The Guidelines note that a typical hydraulic assessment process for a levee includes the following requirements:

- Develop hydrologic and hydraulic models of the catchment.
- Assess the range of floods under the pre-levee conditions using the flood models.
- Assess the flooding associated with identified levee options using the flood models.

The SDAP State Code 19 notes that a range of flood event scenarios should be assessed, including the 10, 20, 30, 40, 50 and 100 year average recurrence interval (ARI) design events, the DFE and an overtopping scenario that will result in the largest impact on people and properties as a result of the category 3 levee's construction.

The Guidelines also suggest that the levee proponent should consult relevant methodologies for hydraulic assessments. As an example, the steps that should be undertaken for a category 3 levee proposal are:

1. Review existing flood studies and available models.
2. Collect available data.
3. Develop and calibrate a hydrologic model for the catchment.
4. Undertake a flood frequency analysis (FFA).
5. Reconciliation of the hydrologic model and the FFA results to derive design flood hydrographs for the 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP, 0.1% AEP and 0.01% AEP design flood events, as well as the Probable Maximum Flood (PMF) design event.
6. Develop hydraulic model for the catchment.
7. Calibrate the hydraulic model (using same flood events as in hydrologic model).
8. Assess the extent and impact of flooding under existing floodplain conditions (pre-levee) for the range of design events described above.
9. Assess the impact of flooding for the identified levee options.

2014 modelling and assessment determined that the SRFL will be Category 3. This has been confirmed through this 2019 update.

The QLD Levee Guidelines state that the affected population needs to be calculated in order to classify a levee as category 2 or 3. The affected population, for a levee, means the total number of persons occupying the building or buildings on which the levee has a significant impact.

The QLD Levee Guidelines classify a significant impact for a levee on a building as:

- **An increase, caused by the levee, of more than 5 cm in the flow height of water over the floorboards of the building.**
- **An increase, caused by the levee, of more than 0.2 m/s in the flow velocity of water over the height of the floorboards of the building.**

The Guidelines note that hydraulic models should be run against a range of scenarios. The flood events should include a range of floods up to the flood protection height of the levee and a range of events that exceed the levee height.

The modelling should show the extent of inundation, flood heights and velocities associated with the different levee options and flood events. The incremental change to flow velocity and height will determine the number of occupied buildings that are affected by the construction or modification of the levee.

The incremental change is identified by comparing the results of the modelling of the flood extent and impacts under existing pre-levee conditions with the flood extent and impacts after the construction of the levee. The number of occupied buildings affected by above floor flooding for pre and post levee will indicate the category of levee.

Incremental change is identified by comparing the flood extent and impacts under existing pre-levee conditions with the flood extent and impacts after construction of the levee.

The QLD Levee Guidelines classify a significant impact for a levee on a building as +5cm in flood height or +0.2m/s in flood velocity over the height of the floorboards of the building.

4.3 Minister's Requirements

RRC are currently obtaining statutory approvals, including an Infrastructure Designation for the Project. As part of this process, this report aims to meet the Flooding elements of the Project required to satisfy the Ministers Guidelines and Rules under the *Planning Act 2016* and relevant items listed in the Minister's Requirements (summarised in Table 3 below).

Table 3 Minister's Requirements Summary

MID Requirement
Illustrate and assess the hydraulic effects of the proposed infrastructure such as changes to flood path, flow velocity, flooded area, and flood height.
Describe the benefits and impacts to people and property from a range of flood events (01 - 0100), including overtopping, for premises affected by changes in the hydraulic regime.
Flooding Identify any significant impacts on upstream and downstream properties and the affected population, suchas: • >5cm increase in water depth over floorboards • >0.2 m/s increase in flow velocity over floorboards.
Flooding • Describe how risks associated with levee failure, levee seepage, and/or with overtopping of the structures will be avoided, minimised or mitigated to protect people, property and the environment.

MID Requirement
Transport infrastructure • Provide additional information to demonstrate the full range of impacts resulting from the stormwater and flooding management of the proposed infrastructure to the railway corridor in at least the following flood and stormwater events: 50%, 20%, 10%, 5%, 2% and 1% AEP (equivalent to 2, 5, 10, 20, 50 and 100 year ARI events). • Stormwater and flooding impacts from the proposed infrastructure must be identified for the railway corridor, including rail transport infrastructure, caused by peak discharges, flood levels, frequency/duration of flooding, flow velocities, water quality, sedimentation and scour effects. Hydraulic conveyance and flood storage capacity should also be identified.
Transport infrastructure • The South Rockhampton Flood Levee Hydraulic Assessment - Volumes 1 and 2 indicates that the project will result in reduced flood immunity or freeboard and increases in the Time of Submergence to the North Coat Rail Line and Blackwater Line. Therefore, further information is required to quantify these impacts. In particular, the following should be addressed: • all flood impact mapping should be revised to more clearly identify the impacts on the relevant railway corridors by ensuring they adequately encompass the railway corridors and show appropriate inset maps and numeric values • afflux maps should be provided to clearly illustrate the pre-development scenario, and the post development impacts for all relevant design events up to a 1% AEP. These maps should adequately encompass the North Coast Line and Blackwater Line and clearly indicate the impacts to these railway corridors • the flooding impacts of the proposed development should be clearly conveyed in relation to the potential impacts on rail transport infrastructure such as the railway formation (for example, embankment), ballast, track levels, bridges, drainage features (such as culverts) and other relevant rail transport infrastructure. Railway tracks are constructed using specifically designed pavement structural layers. Increased inundation must not result in soaking of the underlying layers in the railway corridor. Cross sections should be provided showing the flood impact in the railway corridor at regular intervals and critical sections in relation to the rail transport infrastructure. The cross sections should show the registered levels (RLs) of the rail transport infrastructure and pre and post peak water levels (change in flood height) for all relevant design events. As-constructed drawings of the railway corridor or alternatively a survey of the railway corridor is likely to be required for this analysis. Please contact the Department of Transport and Main Roads (RAPTTA@tmr.qld.gov.au) should you need any further assistance with this matter.

4.3.1 Adopted Criteria

The principal hydraulic parameters for assessing the hydraulic impact of the SRFL are:

- **Increase in Predicted Water Surface Levels**: The post-development increase in water level has been extensively analysed. In particular, the increase in predicted Water Surface Elevation (WSE) at the Bruce Highway, Rockhampton Airport, the Blackwater Rail Line, North Coast Rail Line and in the Fairy Bower and North Rockhampton regions (where many of the flood affected properties are located) was considered.
- **Change in Velocity and Flow Regime**: Flow direction and magnitude results from the post-development simulation were compared to the pre-development flow direction and magnitude results. Post-development velocity results were used to assess levee surface protection requirements.
- **Property Impacts**: Potential impacts to properties were considered with respect to surveyed floor levels, undeveloped property levels and property type. The number of properties affected by the new works was considered.
- **Affected Population**: The affected population in accordance with Section 5.4 of the 'DNRM Regulation of Levee Banks - Guidelines for Categories 2 and 3 Levees'.
- **Time of Submergence (TOS):** The impact of TOS changes on the Blackwater Rail and North Coast Rail lines was assessed along with the TOS of the Rockhampton Airport and Bruce Highway.

5.0 Design Overview

5.1 SRFL Options Analysis and Alignment Selection (2014)

Detailed planning and design of the SRFL has been undertaken in 2014 which involved significant refinement of the levee alignment originally developed in the RFMS. This refinement involved the identification of other alternative alignments, assessment of these alignments against a range of criteria and selection of the preferred option which balanced the levee's benefits with its potential impacts.

5.1.1 Issues and Constraints

An 'Issues and Constraints Workshop' was held on 23 January 2014 with key stakeholders to identify and discuss potential concerns relating to the SRFL project. Specific issues were identified by the stakeholders and these were documented by the project team for consideration during concept development of the levee alignment options.

5.1.2 Options Assessment Framework

A subsequent 'Options Analysis Workshop' was held on the 19 February 2014 to present invited stakeholders with an overview of the concept levee alignment options developed based on the issues and constraints identified in the first workshop.

Technical assessments on each of the alignment options were presented by the project team before undertaking a detailed multi-criteria analysis which involved scoring each option against an agreed framework. A spreadsheet based Scheme Assessment Tool (SAT) was adopted which focussed on considerations and factors pertaining to the SRFL project.

The following sets out the objectives of the SAT:

- It has been developed to be easily communicable to a large number of users.
- It is transparent enough for decision makers to use without having to sift through the technical detail.
- It takes into account a wide range of criteria, some technical and some planning related.

For all of the above reasons the SAT was designed to be multi-layered. There was a certain level of detail required to appraise the performance of each option but the results needed to be reported at an aggregate level in order that each could be compared against the others in a subjective way.

The SAT comprised three levels of detail:

- **High Level Tests** – three overarching headings which brought together impacts, feasibility/costs and public acceptance.
- **Second Level Themes** – a number of themes which fit under each high level heading.
- **Measurable Criteria** – a means of measuring or scoring each option against the themes.

The following describes these three levels in detail.

5.1.2.1 Level 1: High Level Tests

To ensure that all criteria for a 'successful' levee scheme are taken into account it was suggested that three distinct questions be asked, which examined the three main areas of successful delivery:

1. Will the solution meet the targets and objectives set for the project?
2. Will the solution be buildable and cost effective?
3. Will the solution be 'acceptable' publically and politically?

Out of these questions come three high level tests, designed to generate answers to the above:

a. ***Effectiveness*** – matches the anticipated impacts of the levee scheme with the objectives and targets set by Council.

The effectiveness measure is a test of how well a levee scheme could contribute to the priorities identified by Council. The 'problems' associated with and the objectives or vision set for the project area were developed based on the initial Issues and Constraints Workshop. This formed the basis for the effectiveness test; meaning that the more 'effective' a levee option is to enabling the Council to meet its objectives then the higher its weighting should be.

b. ***Feasibility*** – sets out the timescales, potential costs and funding issues, as well as the engineering constraints.

The feasibility measure is focused on costs, timescales and engineering feasibility. It was not the intention to eliminate particularly costly schemes or those which could be delivered until the medium or long term. If the potential benefits of an option are significant enough to warrant the costs or the wait then it could be taken forward as a priority. However, costs and timescales are always an issue, particularly if funding streams are limited or tied to a particular timeframe. These issues were identified separately from the impacts of the option.

c. ***Acceptability*** – examines a levee option's 'fit' with objectives, as well as taking into account the views of stakeholders and the implications of other planned interventions in the area.

This is an important measure because large infrastructure projects are often held up or have to make expensive revisions because they are considered unacceptable either locally or politically. Therefore, it was deemed to be extremely useful to identify any potential acceptability issues at an early stage.

5.1.2.2 Level 2: Second Level Themes

Within each of the high-level tests there will need to be, still at a relatively broad level, a number of themes or headings under which the measurable criteria are fitted. These themes will be tailored to meet the requirements of the study to ensure that all aspects of an option are considered. The themes will also link directly with the overarching test. Examples for this study include:

Effectiveness:

- Alignment

Feasibility:

- Cost
- Constructability
- Environmental
- Alignment

Acceptability:

- Environmental
- Hydraulic Impacts
- Community

5.1.2.3 Level 3: Measurable Criteria

For any multi-criteria assessment, it is important to be able to quantify the impacts of an option so that it can be fairly compared against others. Therefore, it was the intention of the SRFL SAT to include definitively measurable criteria where possible. However, it was recognised that some would inevitably have to be qualitative criteria.

5.1.2.4 The Scoring and Weighting of Criteria

In order to rank the levee options, it was necessary to develop a scoring and weighting mechanism. The scoring mechanism ensures that each option can be ranked against its alternatives. The weighting mechanism allowed those criteria directly relevant to the objectives of the study to be elevated in importance when compared with other criteria. This mechanism was used by the participants at the 'Options Analysis Workshop' and enabled a justifiable identification of the preferred levee alignment.

Each criterion was given a score on a seven point scale:

Assessment	Score
Strongly Positive	3
Moderately Positive	2
Slightly Positive	1
Neutral	0
Slightly Negative	-1
Moderately Negative	-2
Fatal Flaw	-3

The project team agreed that some of the criteria were more or less important to the project than others. This led to a need to implement a weighting mechanism in order to raise the importance of certain criteria within the overall framework. The method chosen raises or lowers the initial score given to the criterion by an amount which was dependent on the weighting given to it. For example:

- A very high weighting criterion doubled the original score.
- A high weighting criterion raised the original score by 50%.
- A medium weighting criterion retained the original score.
- A low weighting criterion lowered the original score by 50%.

Where a very high or high weighting criterion was given a negative score by the stakeholder group then the weighting mechanism factored the score further downwards, to reflect the importance of achieving positive scores in those criteria. If a negative value was given to a 'Low' weighting criterion, then the weighting mechanism actually raised that value. This ensured that the overall option score was not skewed downwards by a score given to a criterion of relatively low importance to the project.

5.1.2.5 Adopted Framework

The multi-criteria options assessment framework and criteria weighting used to identify the preferred levee alignment option is shown in Figure 4. This framework was developed with Council staff and reviewed with the key stakeholders to ensure acceptability.

High Level Test	Second Level Theme	Criterion ID	Criteria	Measure	Weighting
Effectiveness	Alignment	E.01	Protects significant infrastructure (Sewage Treament Plant, Schools, Parks, Roads, Rail Lines, Bruce Hwy)	Flood protection extends around key facilities and access routes	VH
		E.02	Protects residences against flooding due to design storm event	Extent of flood protection - numbers of homes protected	VH
		E.03	Protects commercial areas against flooding due to design storm event	Extent of flood protection - numbers of employees impacted	VH
Feasibility	Costs	F.01	Total Cost	Relative cost	VH
	Constructibility	F.02	Quantity of fill soils required	Relative volume of borrow materials needed for levee construction	L
		F.03	Transport Crossings	Floodgate requirements at road and railway crossings	M
		F.04	Powerline Crossings	Clearance requirements beneath powerlines	VH
		F.05	Construction Difficulty	Avoids areas of high water table and soft soils	H
		F.06	Drainage Crossings	Number of crossings required	M
	Environmental	F.07	Regulatory Issues	Alignment option does not require extended review periods or other significant and costly measures to obtain regulatory approvals	H
	Alignment	F.08	Acquisition Issues	Number of properties crossed and degree of fragmentation	M
Acceptability	Environmental	A.01	Impact on environmentally sensitive areas	Quality and severity of area impacted	H
	Hydrology and Hydraulics	A.02	Impacts to Private Properties	Velocity increases, afflux	H
		A.03	Impacts on Roads	Afflux on roadways exterior to protected area	H
		A.04	Impacts on Rail Lines	Afflux on rail lnes exterior to protected area	H
	Community	A.05	Impacts on residential property	Anticipated community reaction	VH
		A.06	Amenities	Visual impact of levee/floodwall near residential areas	H
		A.07	Business Impacts	Anticipated business reaction	VH

Figure 4 Multi-criteria options assessment framework and criteria weighting

5.1.3 Options Development

Seven conceptual levee alignment options were developed based on initial technical assessments undertaken by each of the project disciplines (i.e. hydraulics, environment, geotechnical, visual amenity, etc). The options were developed based on stakeholder feedback received in the initial 'Issues and Constraints Workshop'.

Table 4 provides a high level description of the seven options evaluated.

Table 4 SRFL Alignment Options Summary

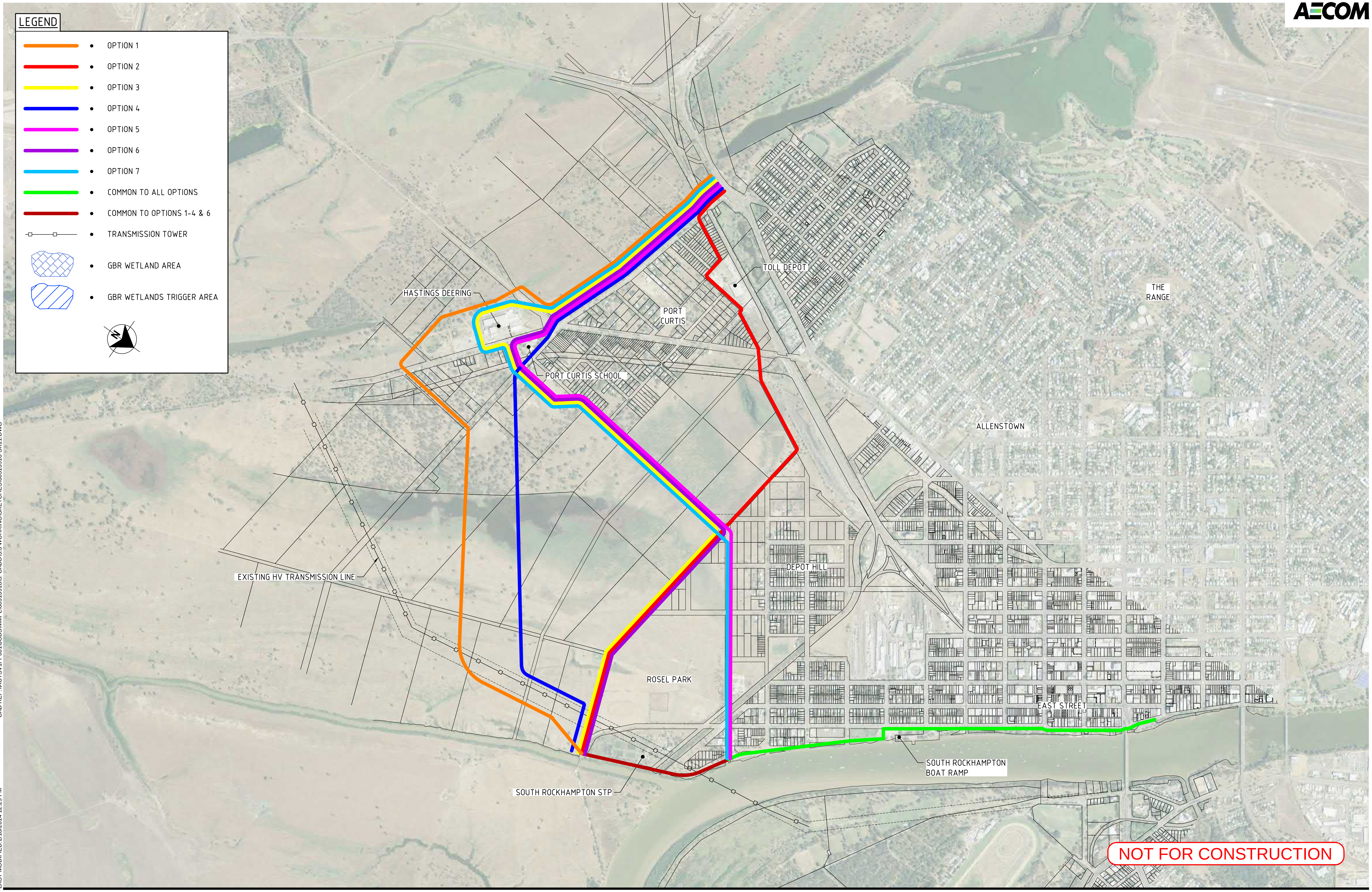
Option	Key Features	Key Constraints & Considerations
1	Original 1992 alignment encompassing a large area which includes: • Public infrastructure • Residential properties • Commercial properties	• Presence of environmentally sensitive wetlands • Presence of regional power transmission lines • Magnitude of afflux to roads, rail and properties exterior to the protected area
2	Truncated alignment encompassing: • Sewage Treatment Plant • Rosel Park • Depot Hill • Rockhampton CBD	• Avoids most environmental issues • Excludes large residential and commercial areas • Excludes Port Curtis and associated homes and business • Limits afflux to roads, rail and other properties exterior to the protected area
3	Tightened alignment encompassing: • All major public infrastructure • Key residential and commercial properties in Depot Hill, Port Curtis and CBD	• Avoids most environmental issues • Protects developed properties • Presence of regional power transmission lines • Moderate afflux impacts

Option	Key Features	Key Constraints & Considerations
4	Similar to the original 1992 alignment (Option 1) but excludes: • Port Curtis School • Major commercial property	• Poses challenges due to the presence of environmentally sensitive wetlands • Moderate afflux to roads, rail and properties exterior to the protected area
5	Alignment encompasses residential and commercial businesses in: • Port Curtis • Depot Hill • CBD	• Avoids most environmental issues • Moderate afflux to roads, rail and properties exterior to the protected area • Key infrastructure and some commercial properties are not protected
6	Alignment is similar to Option 5 but also encompasses: • Sewage Treatment Plant • Rosel Park	• Avoids most environmental issues • Moderate afflux to roads, rail and properties exterior to the protected area • Major commercial property not protected
7	Alignment encompasses • Residential areas of Depot Hill and Port Curtis • Major commercial property protected	• Avoids most environmental issues • Moderate afflux to roads, rail and properties exterior to the protected area • Rosel Park and Sewage Treatment Plant not protected

Figure 5 shows the seven SRFL alignment options.

Preliminary hydraulic assessment was undertaken for each of the alignment options using the MIKE FLOOD Flexible Mesh hydraulic model developed by AECOM for TMR. This model was adopted to provide initial results whilst Council's TUFLOW hydraulic model was further developed (refer to the Hydraulic Model Development and Comparison Report for further information).

Figure 6 to Figure 19 shows the individual levee alignment map and the predicted difference in water surface elevation for each of the seven options.



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Rockhampton Regional Council

ROCKHAMPTON REGIONAL COUNCIL
FLOOD LEVEE ALIGNMENT OPTIONS
ALL OPTIONS
Figure 5

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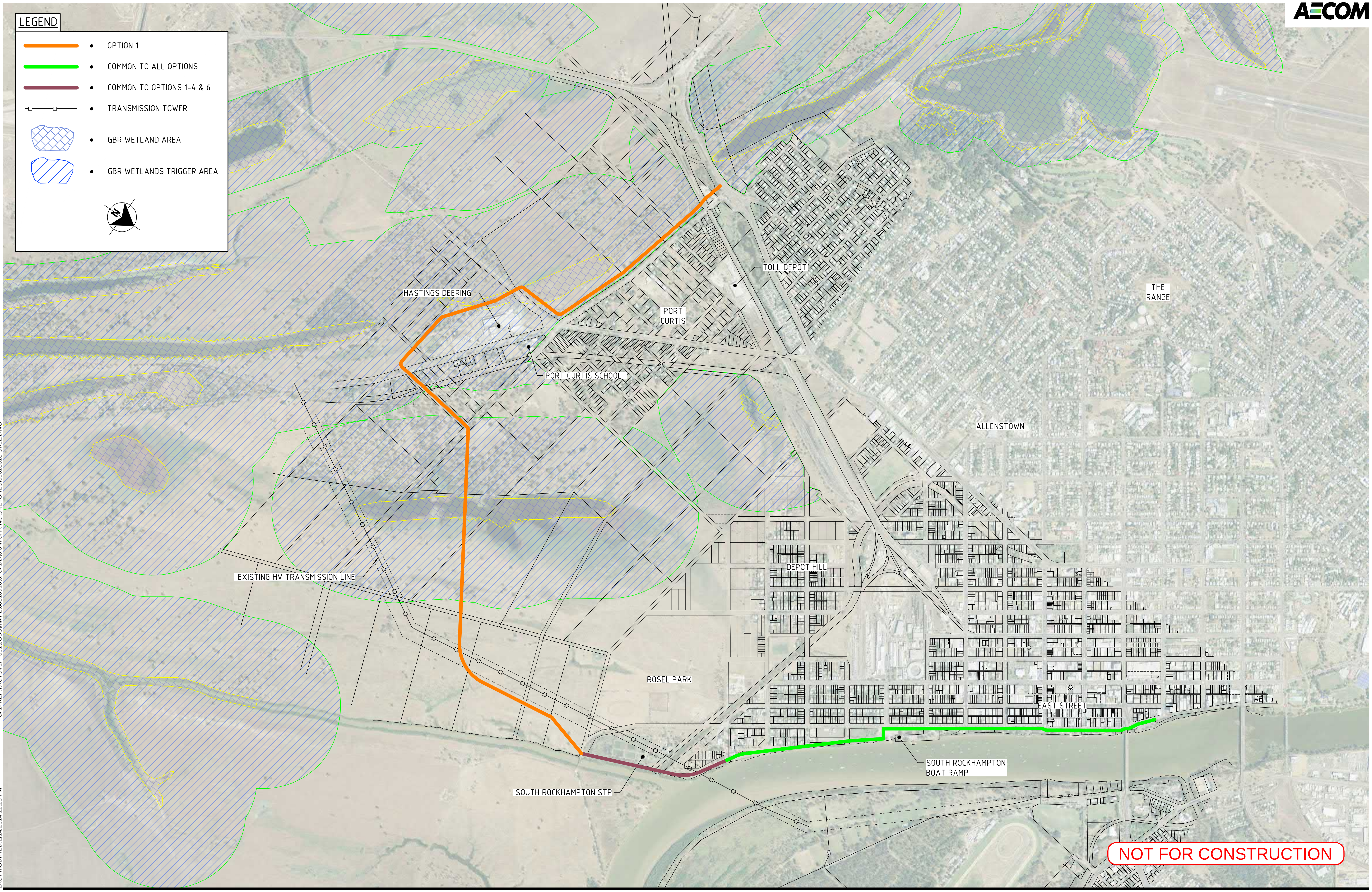

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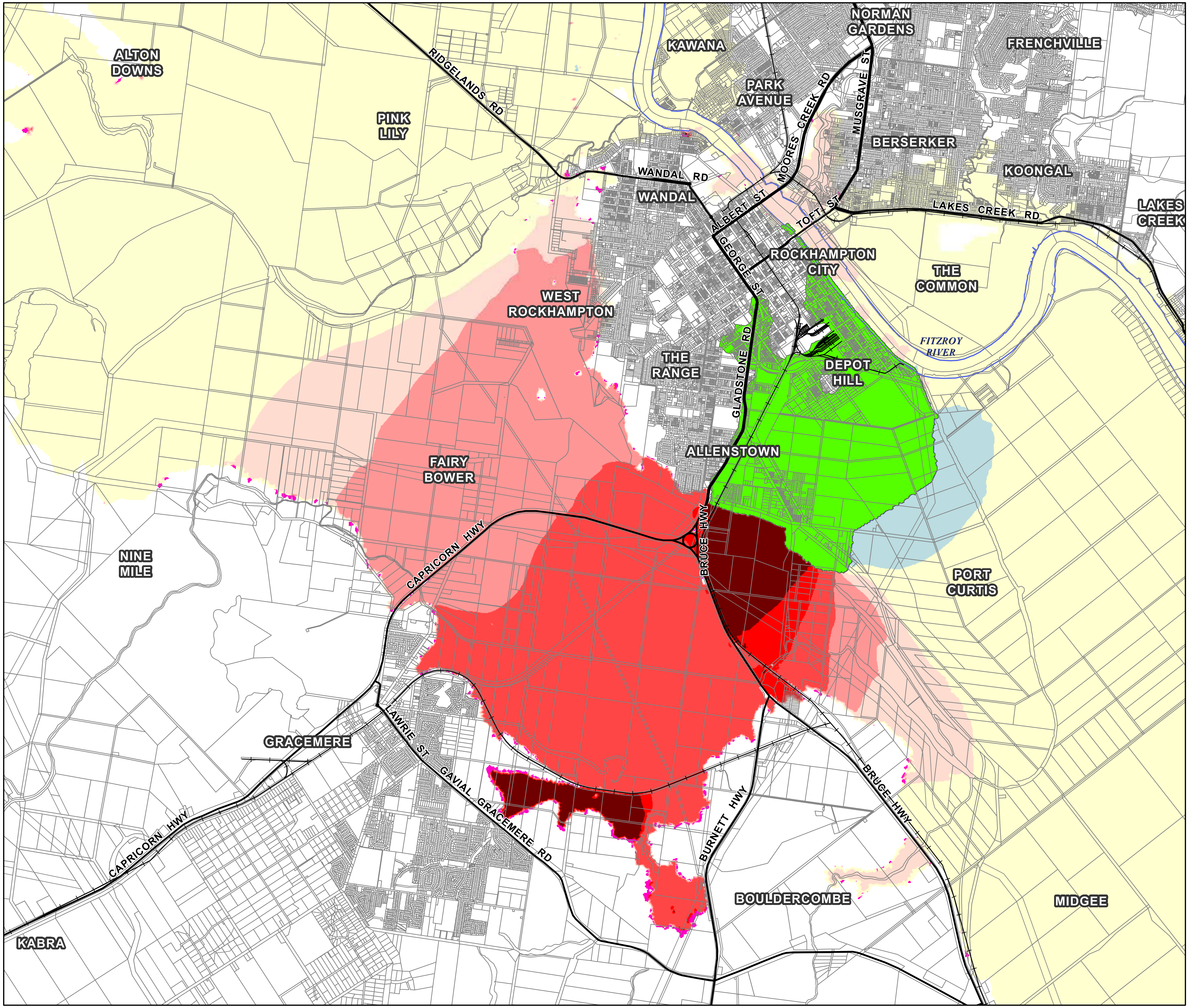
Rockhampton Regional Council

ROCKHAMPTON REGIONAL COUNCIL
FLOOD LEVEE ALIGNMENT OPTIONS
OPTION 1

Figure 6



SOUTH ROCKHAMPTON FLOOD LEVEE

Options Analysis
Flood Depth Difference
Option 1 compared to Base Case
1% AEP
Figure 7

Afflux (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.025
- -0.025 to 0.025
- 0.025 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

N

Scale: 1:50,000 (when printed at A3)

0 250 500 1,000 1,500
Metres

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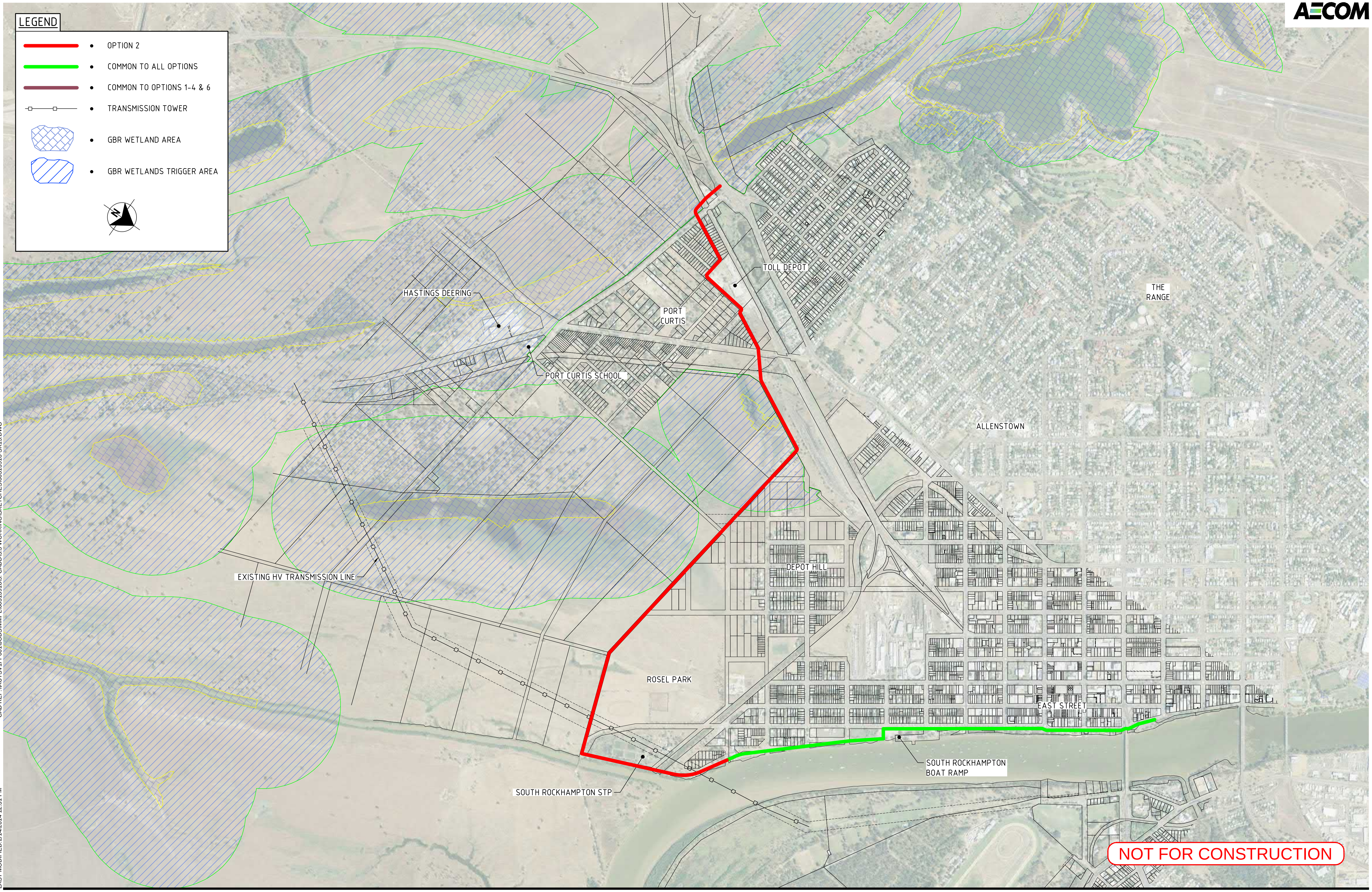
LAST MODIFIED CFS 20-Aug-2013
FILE NAME 004_WR_60313918_v1_Option_1_A3

AECOM



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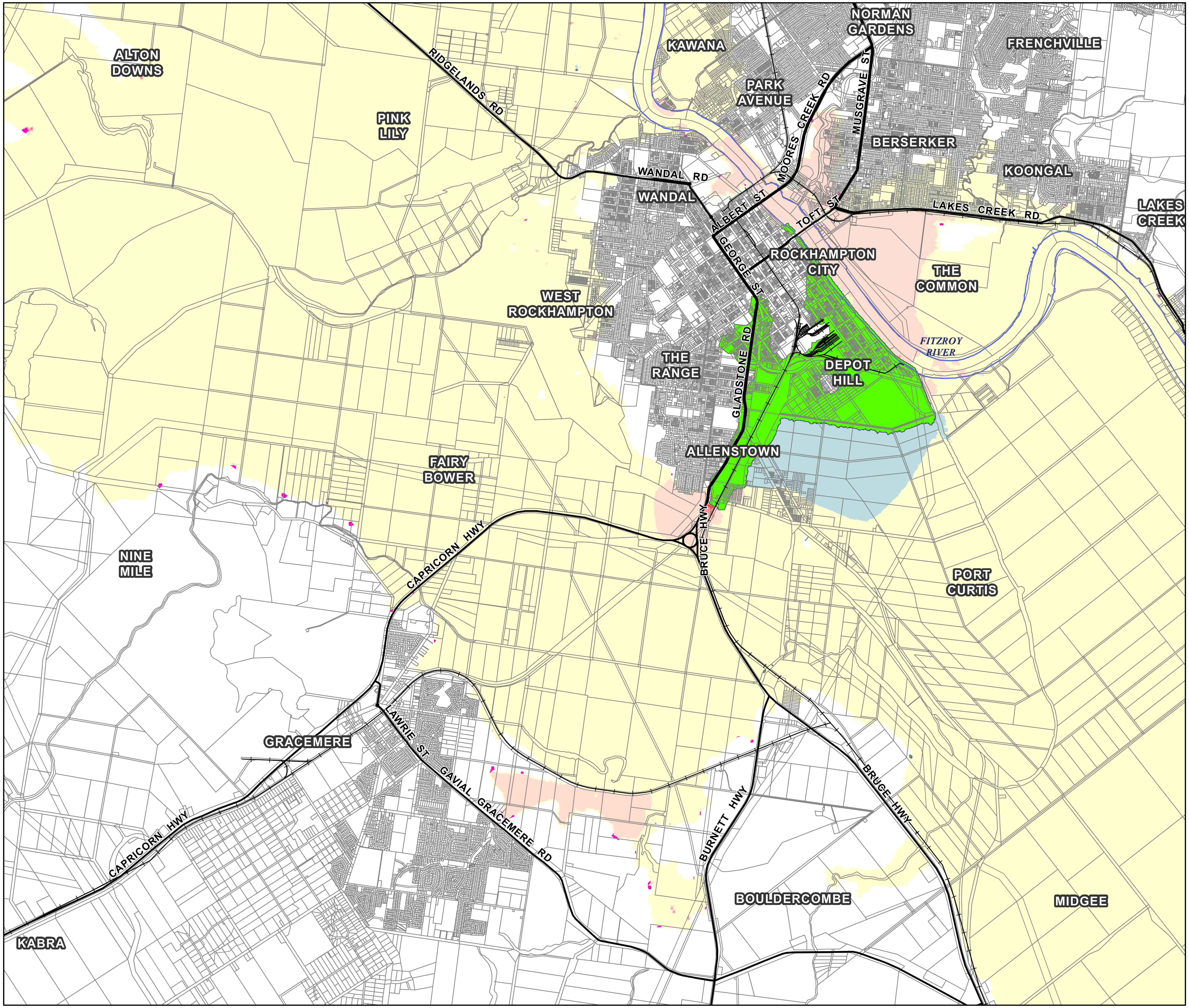
ROCKHAMPTON REGIONAL COUNCIL
FLOOD LEVEE ALIGNMENT OPTIONS
OPTION 2
Figure 8

SOUTH ROCKHAMPTON FLOOD LEVEE

Options Analysis
Flood Depth Difference
Option 2 compared to Base Case
1% AEP
Figure 9



Afflux (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.025
- -0.025 to 0.025
- 0.025 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

N

Scale: 1:50,000 (when printed at A3)

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Metres

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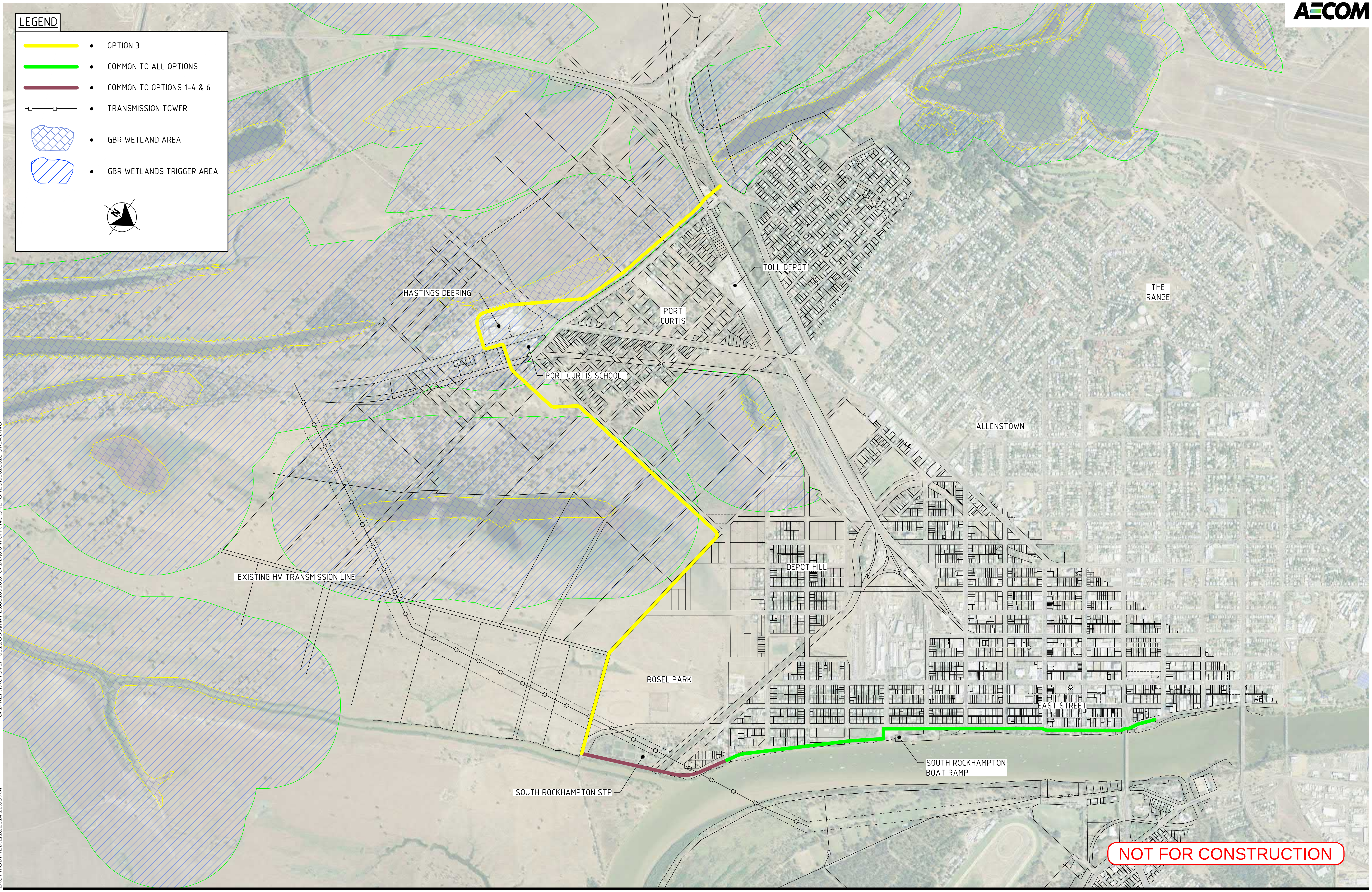

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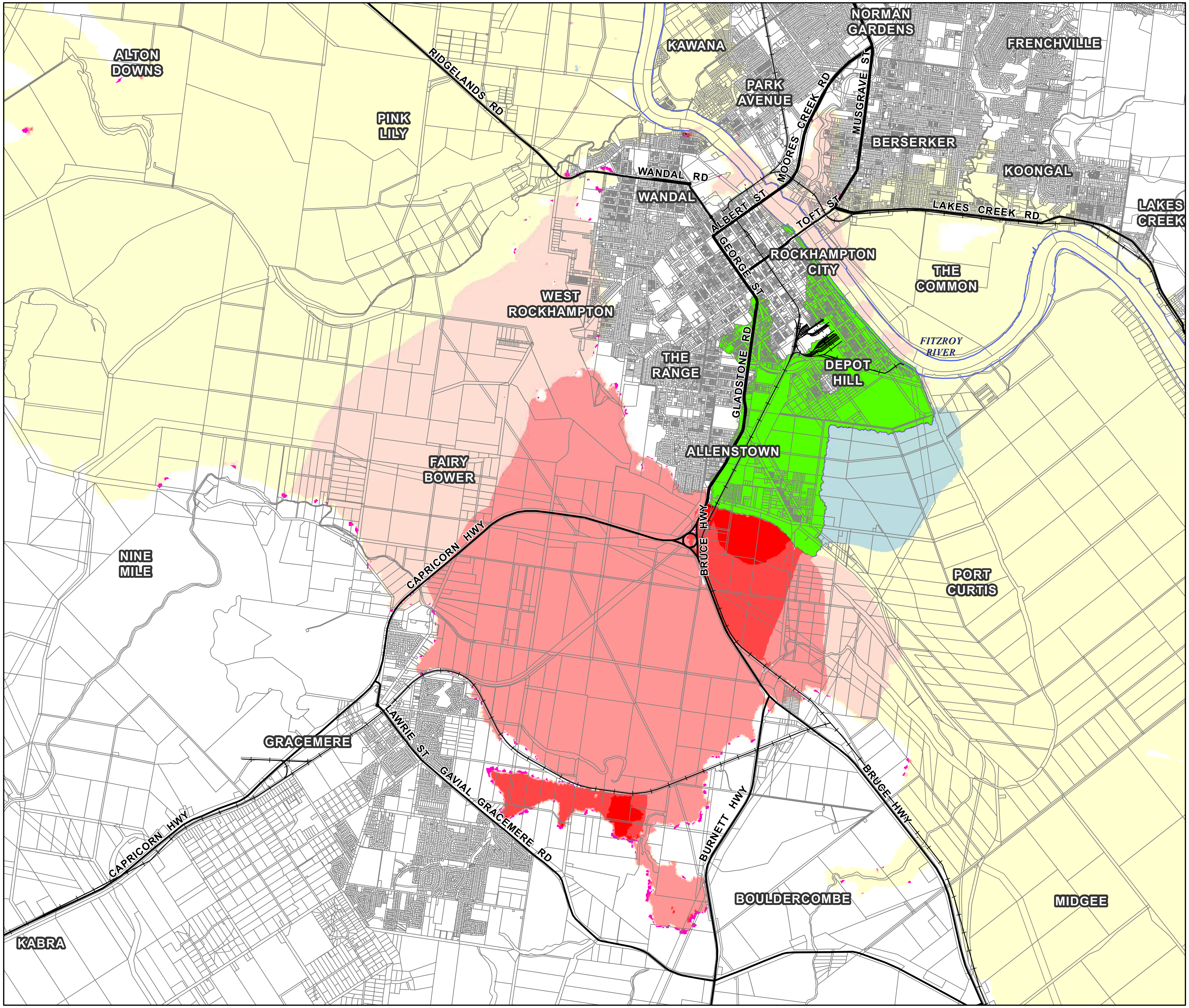
Rockhampton Regional Council

ROCKHAMPTON REGIONAL COUNCIL
FLOOD LEVEE ALIGNMENT OPTIONS
OPTION 3

Figure 10



SOUTH ROCKHAMPTON FLOOD LEVEE

Options Analysis
Flood Depth Difference
Option 3 compared to Base Case
1% AEP
Figure 11

Afflux (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.025
- -0.025 to 0.025
- 0.025 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

N

Scale: 1:50,000 (when printed at A3)

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Metres

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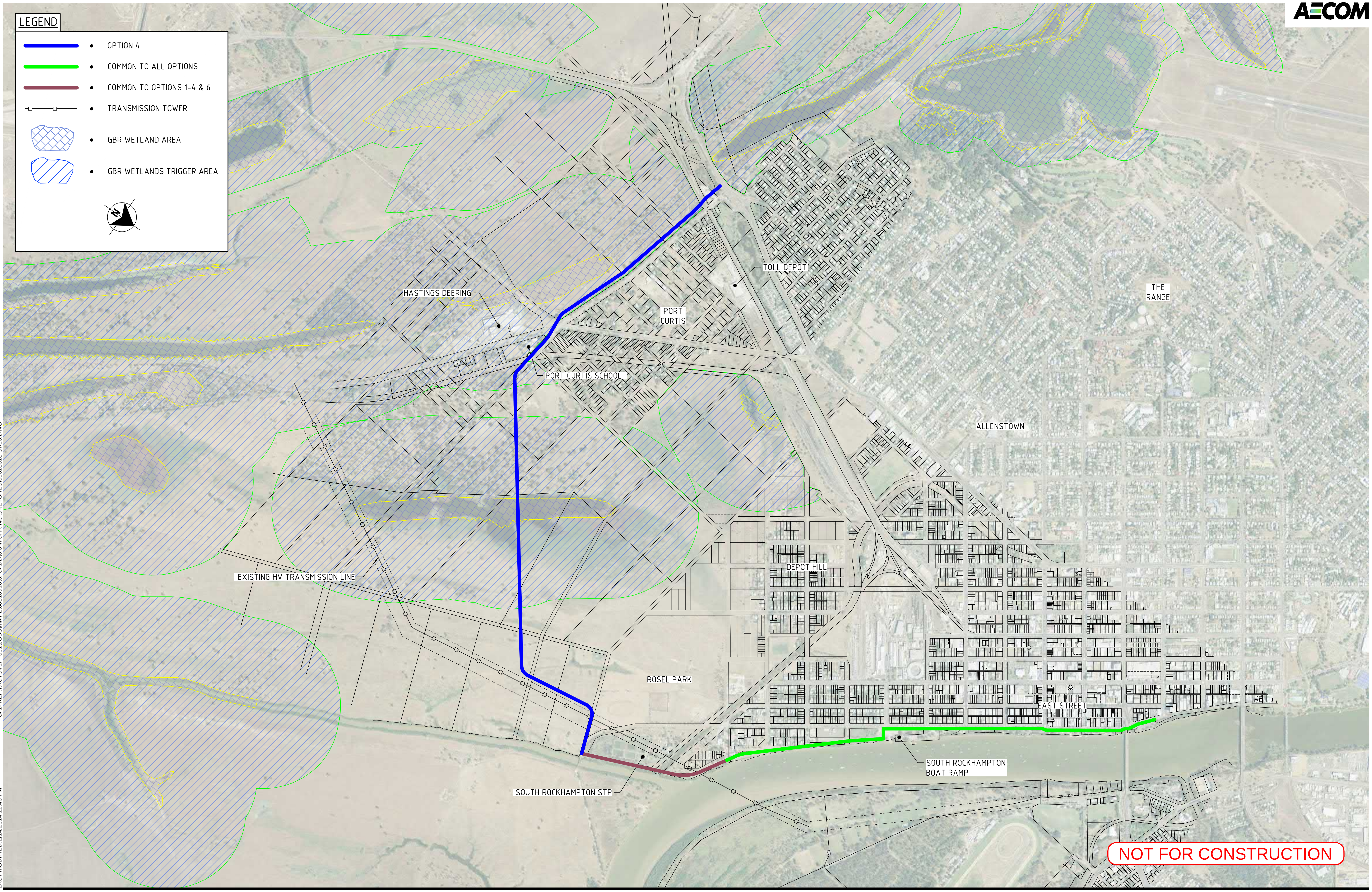

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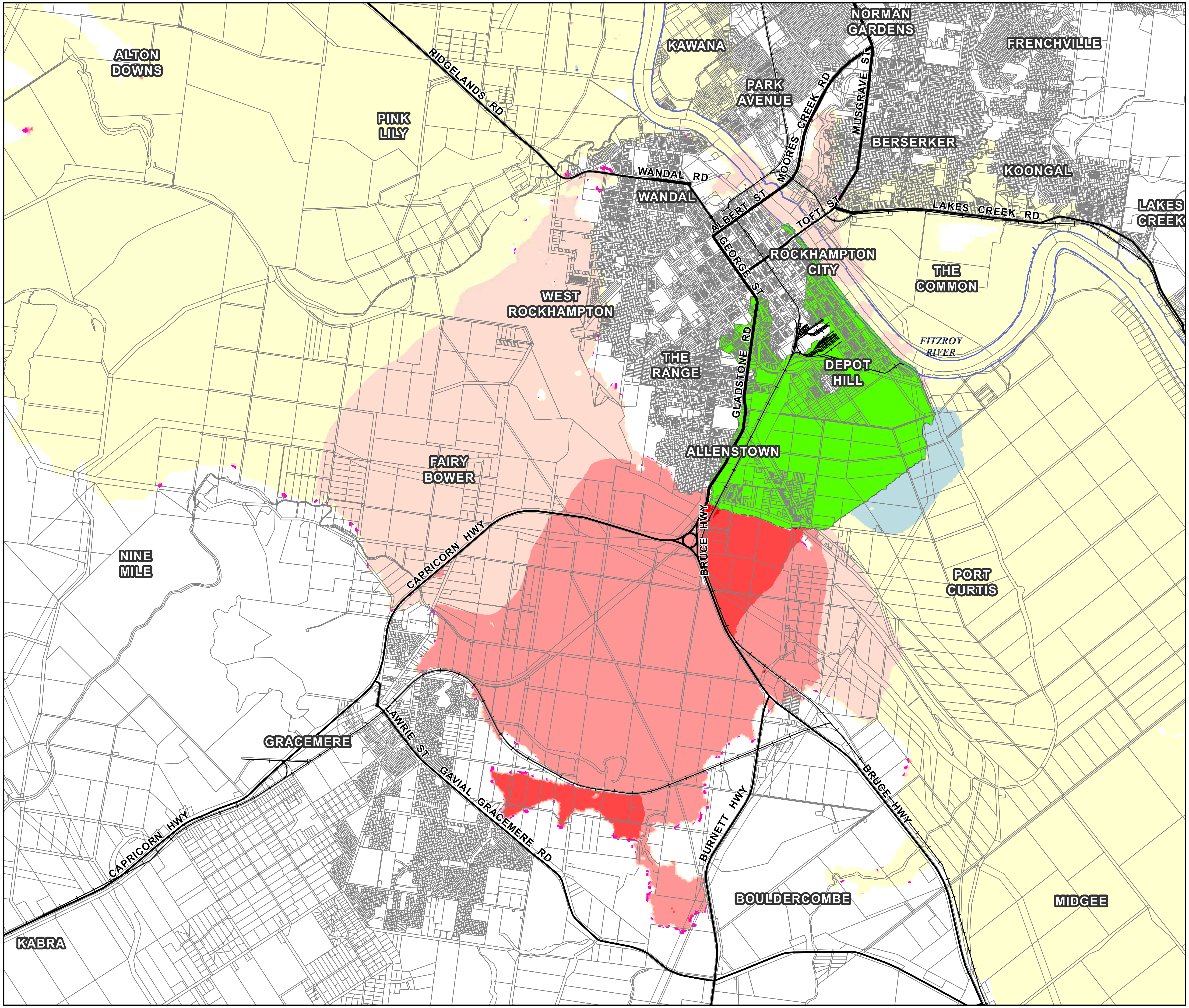
Rockhampton Regional Council

ROCKHAMPTON REGIONAL COUNCIL
FLOOD LEVEE ALIGNMENT OPTIONS
OPTION 4
Figure 12



SOUTH ROCKHAMPTON FLOOD LEVEE

Options Analysis
Flood Depth Difference
Option 4 compared to Base Case
1% AEP
Figure 13

Afflux (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.025
- -0.025 to 0.025
- 0.025 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

N

Scale: 1:50,000 (when printed at A3)

0 250 500 1,000 1,500
Metres

PROJECT ID 60287942
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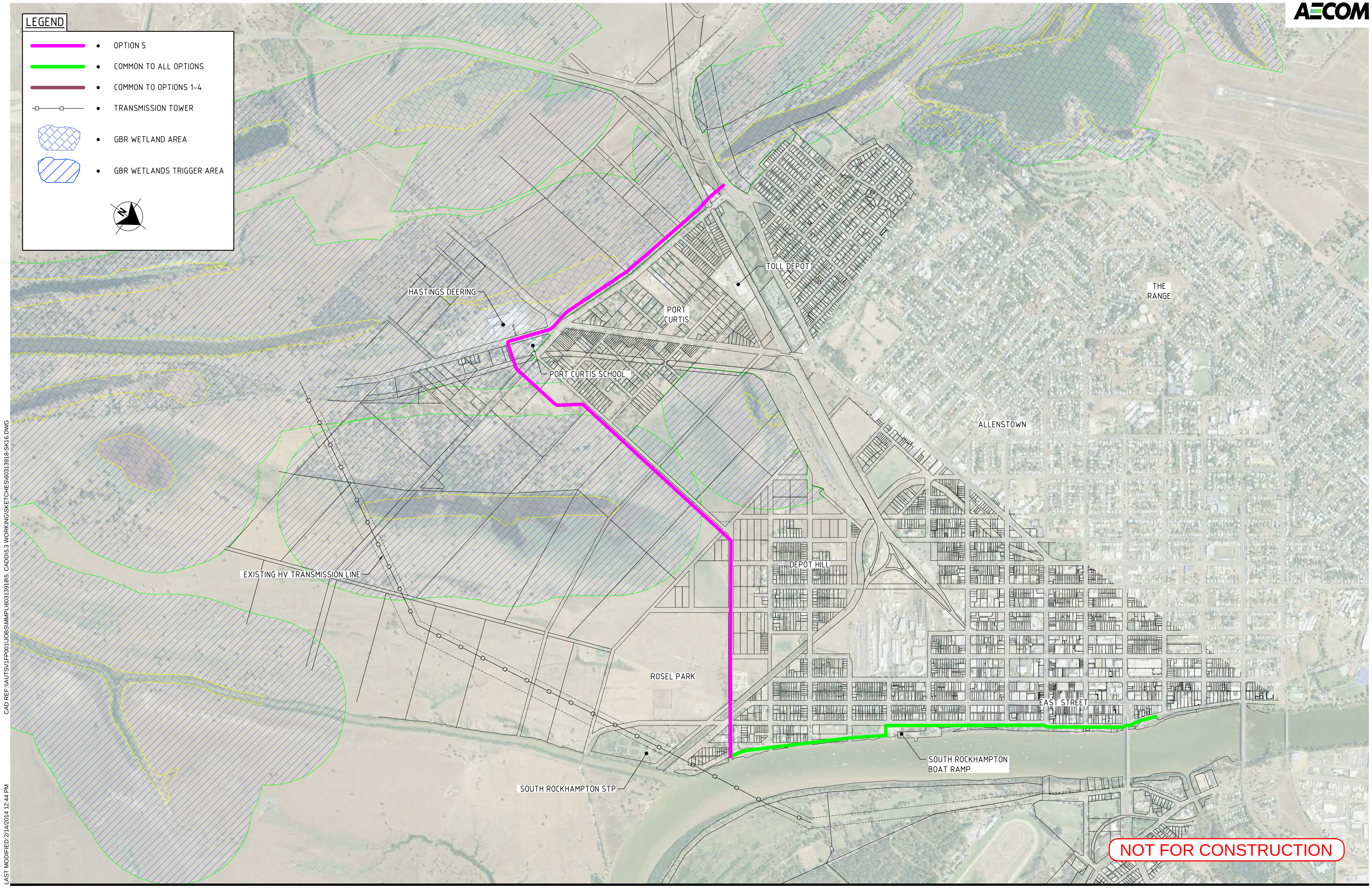

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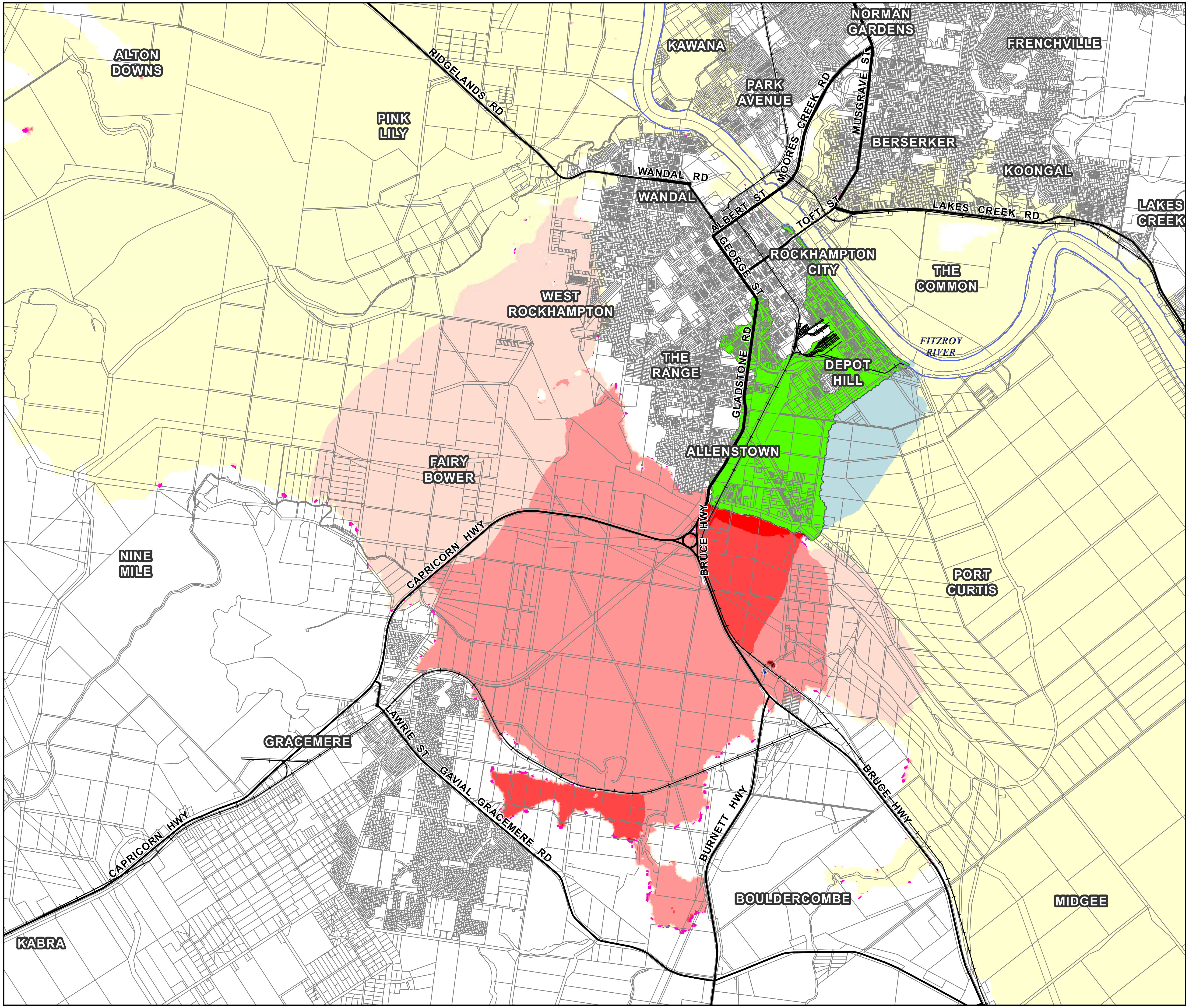
ROCKHAMPTON REGIONAL COUNCIL
FLOOD LEVEE ALIGNMENT OPTIONS
OPTION 5

Figure 14

SOUTH ROCKHAMPTON FLOOD LEVEE

Options Analysis
Flood Depth Difference
Option 5 compared to Base Case
1% AEP
Figure 15



Afflux (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.025
- -0.025 to 0.025
- 0.025 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

Scale: 1:50,000 (when printed at A3)

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Metres

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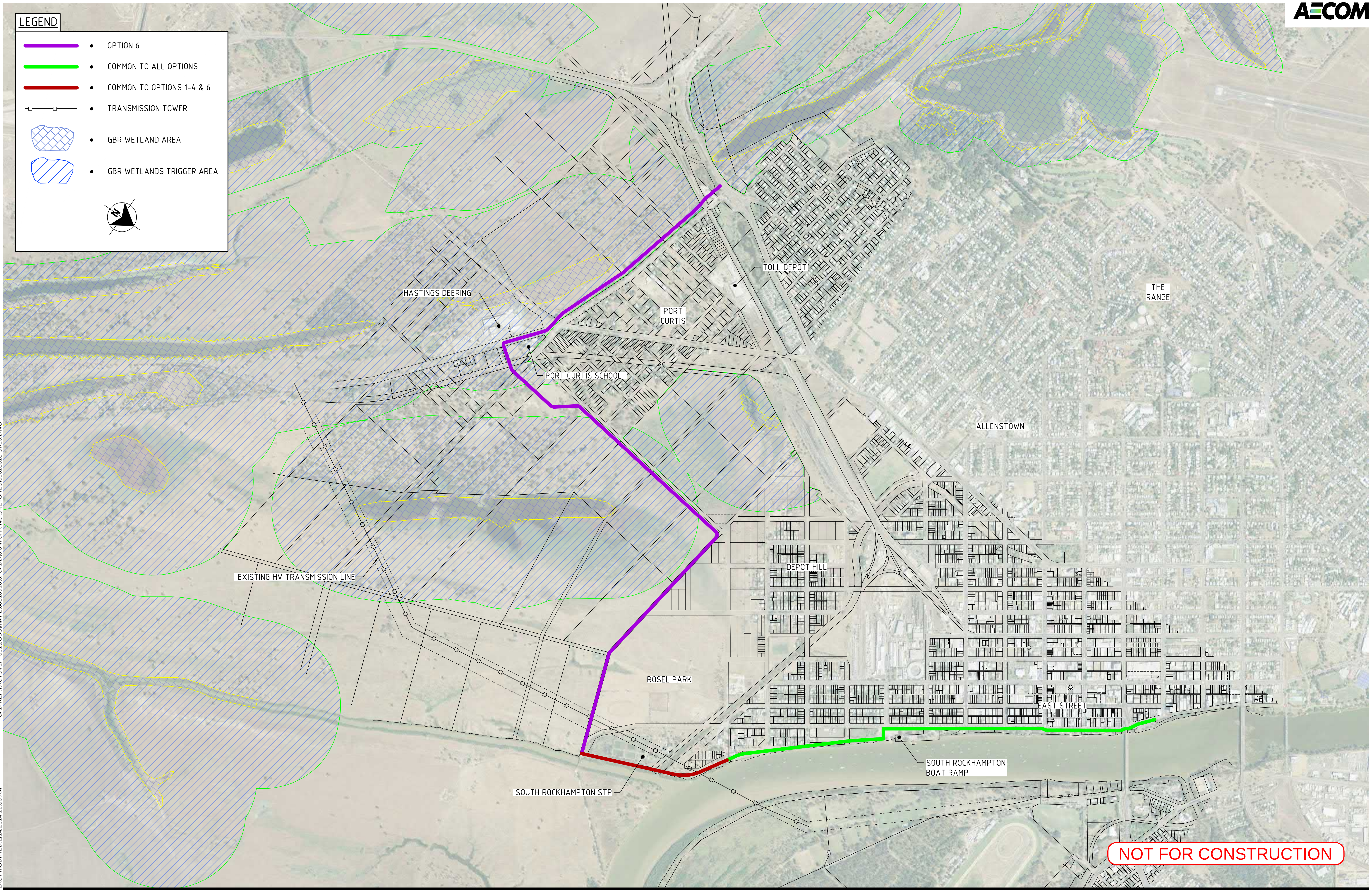

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ROCKHAMPTON REGIONAL COUNCIL
FLOOD LEVEE ALIGNMENT OPTIONS
OPTION 6
Figure 16

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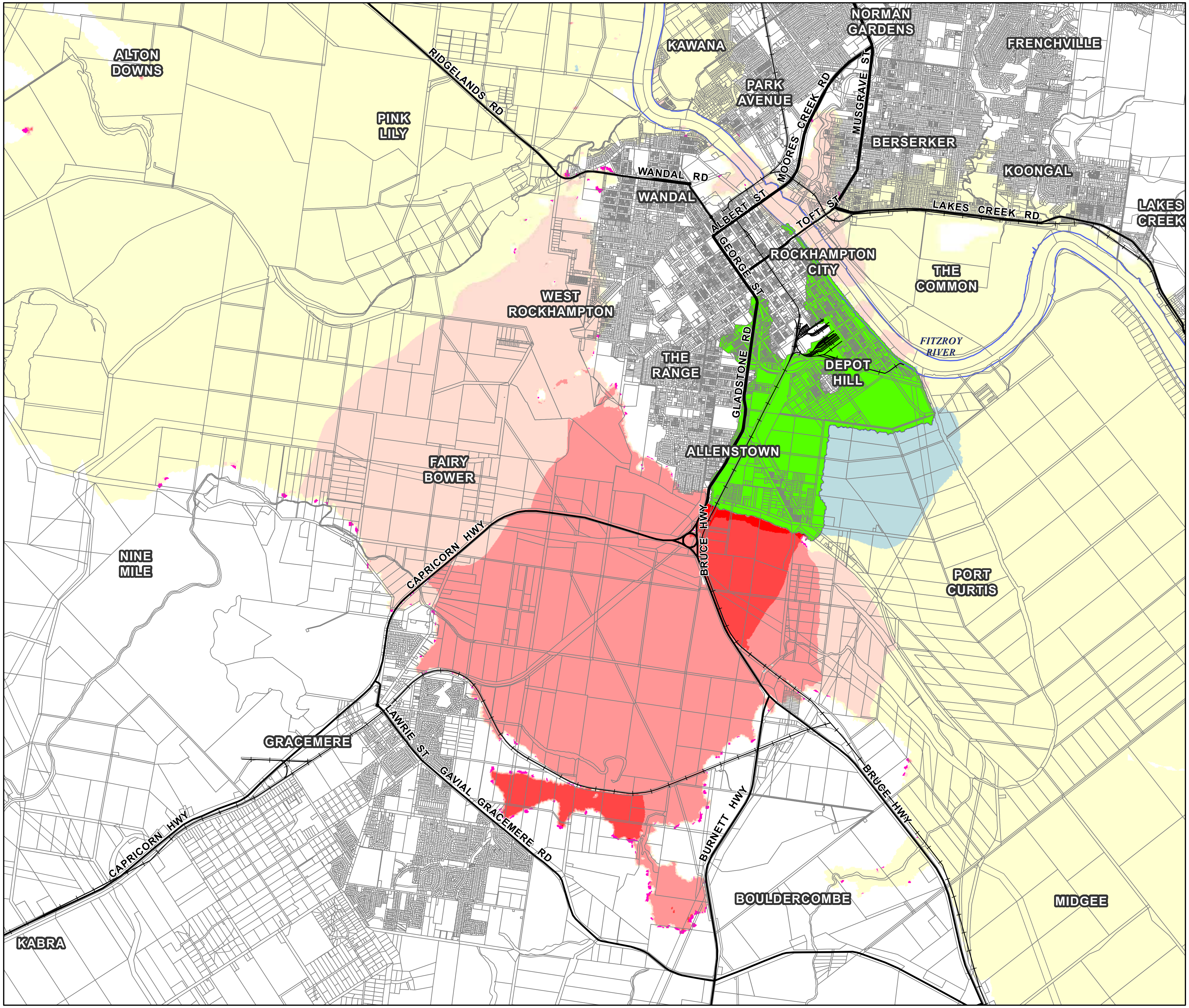
SOUTH ROCKHAMPTON FLOOD LEVEE

Options Analysis
Flood Depth Difference
Option 6 compared to Base Case
1% AEP
Figure 17



Afflux (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.025
- -0.025 to 0.025
- 0.025 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

N

Scale: 1:50,000 (when printed at A3)

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Metres

PROJECT ID 60287942
LAST MODIFIED CFS 20-Aug-2013
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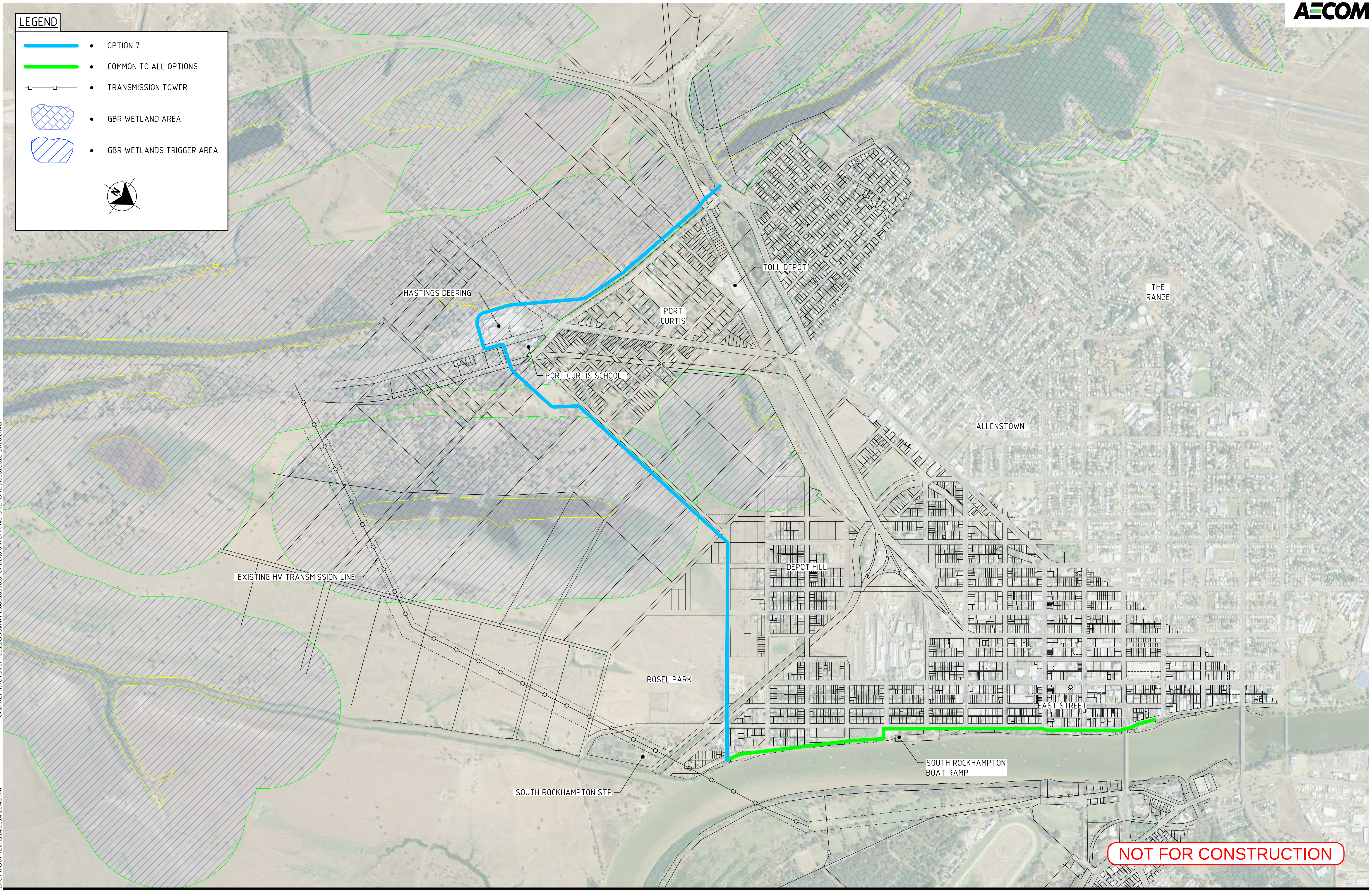

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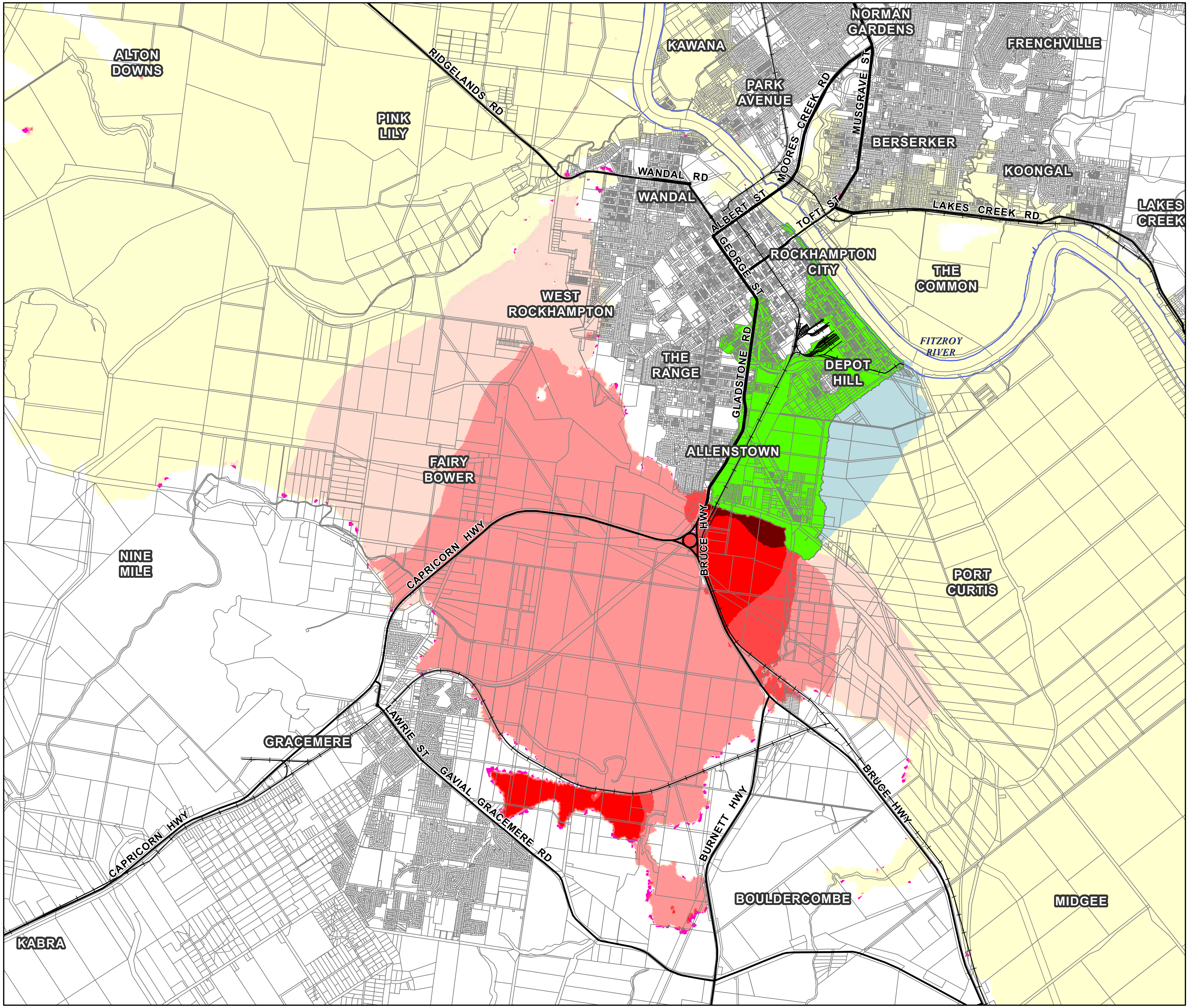
Rockhampton Regional Council

ROCKHAMPTON REGIONAL COUNCIL
FLOOD LEVEE ALIGNMENT OPTIONS
OPTION 7

Figure 18

SOUTH ROCKHAMPTON FLOOD LEVEE

Options Analysis
Flood Depth Difference
Option 7 compared to Base Case
1% AEP
Figure 19



Afflux (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.025
- -0.025 to 0.025
- 0.025 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

N

Scale: 1:50,000 (when printed at A3)

0 250 500 1,000 1,500
Metres

PROJECT ID 60287942
LAST MODIFIED CFS 20-Aug-2013
FILE NAME 011_WR_60313918_v1_Option_7_A3

5.1.4 Preferred Option Selection

Key stakeholders and the project team scored each of the seven levee alignment options during the 'Options Analysis Workshop'. The workshop attendees identified the top three ranked options for further technical assessment and evaluation. These were:

- Option 3 (rank 1)
- Option 6 (rank 2)
- Option 5 (rank 3)

A workshop was held on the 17 March 2014 to present the three levee alignment options. Option 3 was recommended by the project team for further consideration. A Special Council meeting was convened on the 18 March 2014, at which the Council resolved:

1. that the information be noted in relation to the status of the South Rockhampton Flood Levee project and the flood mitigation investigations for the North Rockhampton area; and
2. that the Council endorse for further investigation and subsequent funding application, the general alignment identified at the workshop held 17 March 2014.

Key features of the Option 3 alignment include:

- Protecting key infrastructure including the South Rockhampton Sewerage Treatment Plant and Rockhampton Pound facilities.
- Protecting residential areas and key industrial businesses in Depot Hill and Port Curtis.
- Avoiding conflict with the Powerlink high voltage transmission lines into Rockhampton.
- Minimising afflux, where possible, on key infrastructure and dwellings on the floodplain including (but not limited to):
  - Bruce Highway along Gladstone Road and Lower Dawson Road.
  - Bruce Highway between Jellicoe Street and Rockhampton Roundabout.
  - Bruce Highway between Rockhampton Roundabout and Burnett Highway.
  - North Coast Rail Line.
  - Blackwater Rail Line.
  - Rockhampton Airport.
- Avoiding, to the greatest extent, environmentally sensitive areas.

5.1.5 Selected Option Refinement

In undertaking the preliminary hydraulic assessment, it was noted that the predicted impacts of the levee were predominantly the result of:

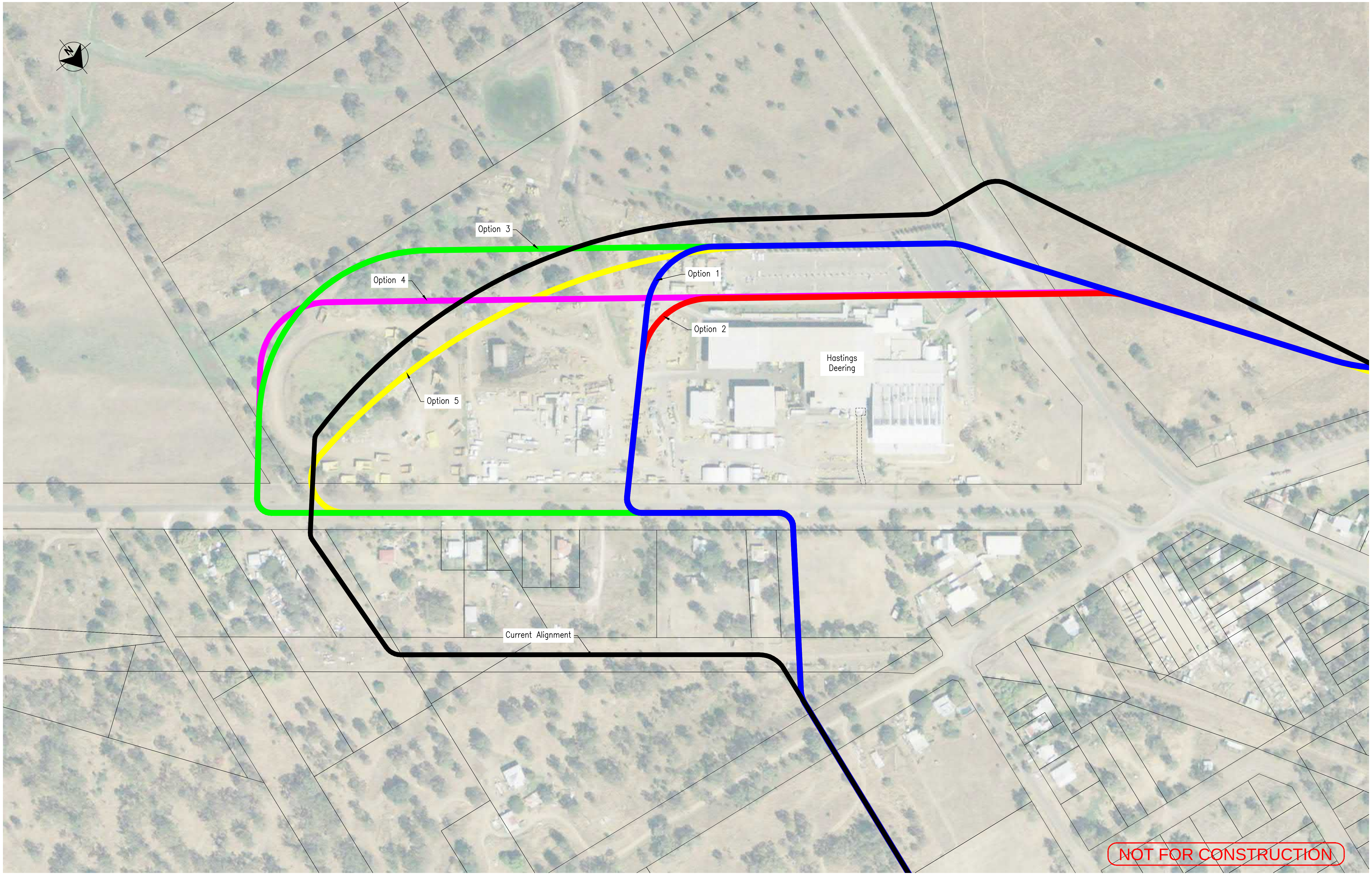
- Encroachment into the Yeppen North flow path.
  - The Yeppen North area represents a primary flow path for the western floodplain which conveys a proportion of the floodplain discharge through the existing road and rail crossings.
  - The proposed levee will encroach into this flow path which results in an increase in peak water surface levels in the upstream western floodplain.
- Encroachment into the Gavial Creek flow path.
  - The Gavial Creek channel represents a secondary flow path where flows from the western floodplain re-join flows from the main river channel.
  - The proposed levee will encroach into this flow path and result in increases in peak water surface levels in North Rockhampton.

- Constriction of the main river channel flow path.
    - The main river channel represents a primary flow path which is characterised by high velocities and flood depths.
    - The proposed levee will traverse the high bank and run parallel with the river for approximately 3 km. The levee will constrict the breakout which can occur along the western high bank and result in an increase in peak water surface levels in North Rockhampton.

Having identified these three critical areas, a number of iterations were undertaken to minimise the hydraulic impact of the levee. Alterations made to the levee alignment as a result of this optimisation are outlined below:

- Several options were identified for the levee alignment around the existing Hastings Deering site in Port Curtis.
    - Results of the hydraulic analysis showed that adoption of a horizontal taper in the levee alignment reduced upstream impacts by ensuring a smoother transition of the Yeppen North flow path around the levee.
    - The levee alignment was also altered to run in close proximity to the southern areas of the site to minimise encroachment into the flow path.
    - It is noted that the current modelled alignment is presently under discussion with Hastings Deering. Any further alterations to the alignment will be updated in the hydraulic model.
- Hydraulic analysis was undertaken on the levee alignment around the South Rockhampton Sewage Treatment Plant (SRSTP).
    - Results of the analysis showed that alignments which traversed the high bank of Gavial Creek resulted in an upstream increase in water levels which affects areas of North Rockhampton.
    - Impacts were minimised by protecting only the critical portions of Rosel Park and the SRSTP site which resulted in approximately 0.2 km of levee traversing the high bank rather than 0.7 km of levee shown in the original Option 3 alignment.
- Hydraulic analysis was undertaken on the portion of the levee alignment which traverses the high bank of the Fitzroy River.
    - In most cases, the levee alignment was offset sufficiently from the high bank to limit hydraulic impacts, improve geotechnical stability, improve visual amenity, etc.
    - Improvements were made to the alignment, where possible, to minimise abrupt changes in horizontal alignment. Transitions were adopted in several locations to smooth flow and minimise upstream impacts.

Refer to Figure 20 and Figure 21 for levee refinements made at Hastings Deering, the SRSTP and along the Fitzroy River.



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1 : 3000 (A3) 1 : 1500 (A1)

ROCKHAMPTON REGIONAL COUNCIL
SOUTH ROCKHAMPTON FLOOD LEVEE
HASTINGS DEERING LEVEE ALIGNMENT (ALL OPTIONS)

Figure 20

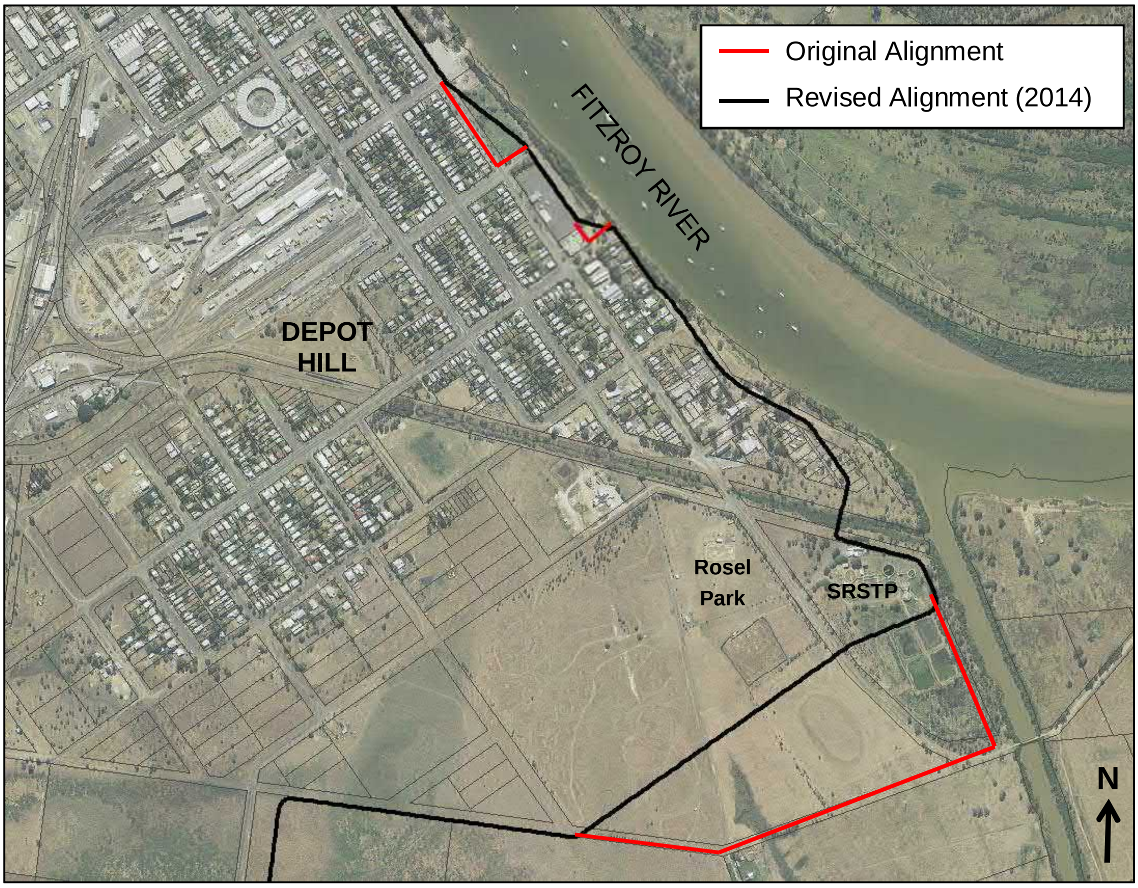


Figure 21 Levee Refinement – Rosel Park, South Rockhampton STP and Fitzroy River

5.2 Further Levee Alignment Modifications (2019)

Several levee alignment refinements which came about as a result of recent design workshops, stakeholder involvement and landholder consultation have been incorporated in to the 2019 levee design update and consequent hydraulic assessment. Each of these is discussed further below.

5.2.1 Alignment Refinements

Littler-Cum-Ingham Park: The alignment has migrated towards the eastern extent of Littler-Cum-Ingham Park in order to maximise the useability of the park, which is regularly used for markets, circuses and the like. Hydraulic impacts of the altered alignment were shown to be minimal during a 1% AEP event, when compared to the previous levee alignment. An architectural landscape sketch of the adopted layout is shown in Figure 22.

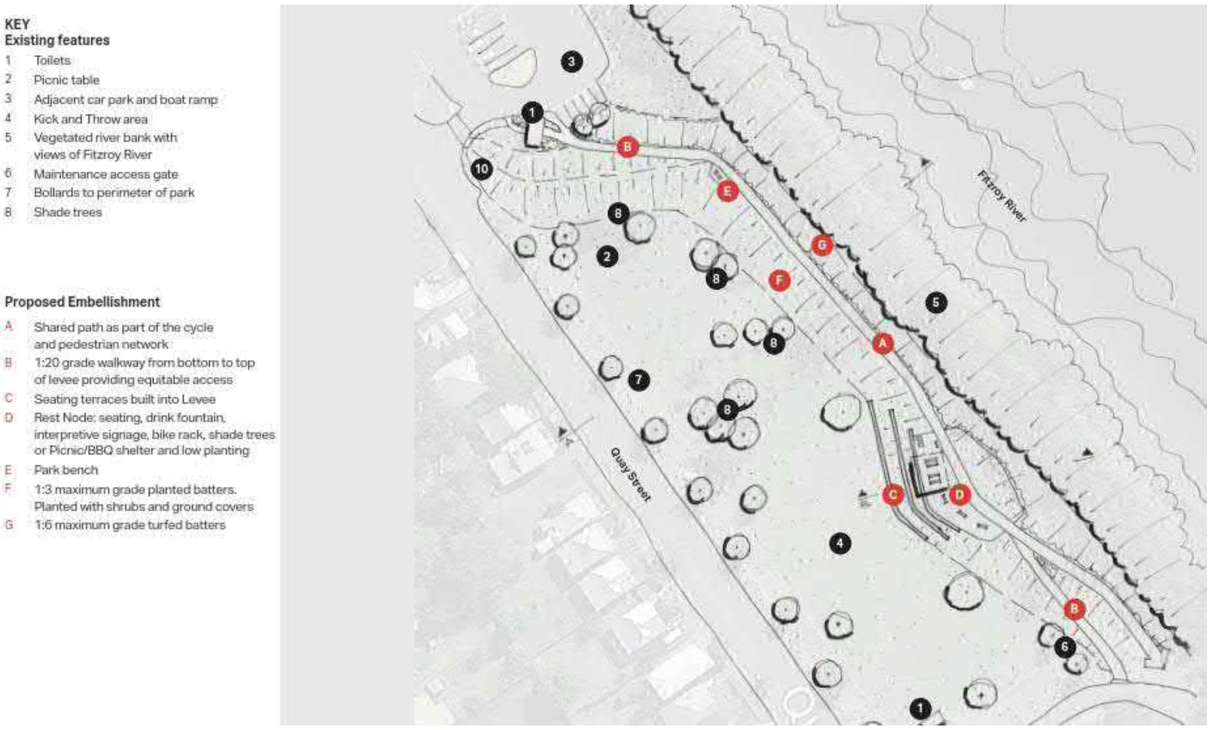


Figure 22 Architectural landscape sketch of SRFL alignment at Littler-Cum-Ingham Park

Hastings Deering: The SRFL alignment at Hastings Deering is highly sensitive to change at the southern boundary of Hastings Deering due to confinement of the Yeppen North flow path. However, in order to maintain operations, Hastings Deering required slight augmentation (generally 5m) of the alignment to ensure access could be maintained to existing facilities. The effect of the SRFL impacts during a 1% AEP flood event (before and after refinement) is shown in Figure 23.

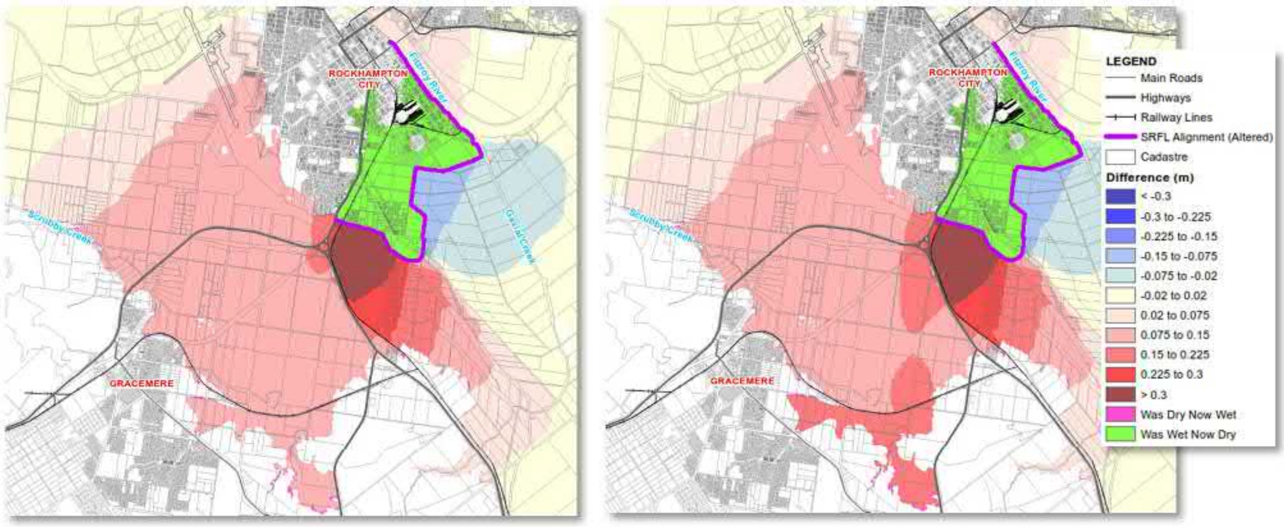


Figure 23 1% AEP Difference in Peak Flood Height (LHS = original | RHS = post-refinement)

Fiddes Street: Ongoing landholder consultation identified an opportunity to capture additional benefits within the backwater area at Port Curtis without worsening encroachment of wetlands of high ecological significance. Refinement of the levee saw an additional residence protected and the useability of others improved. The re-alignment is shown in Figure 24.

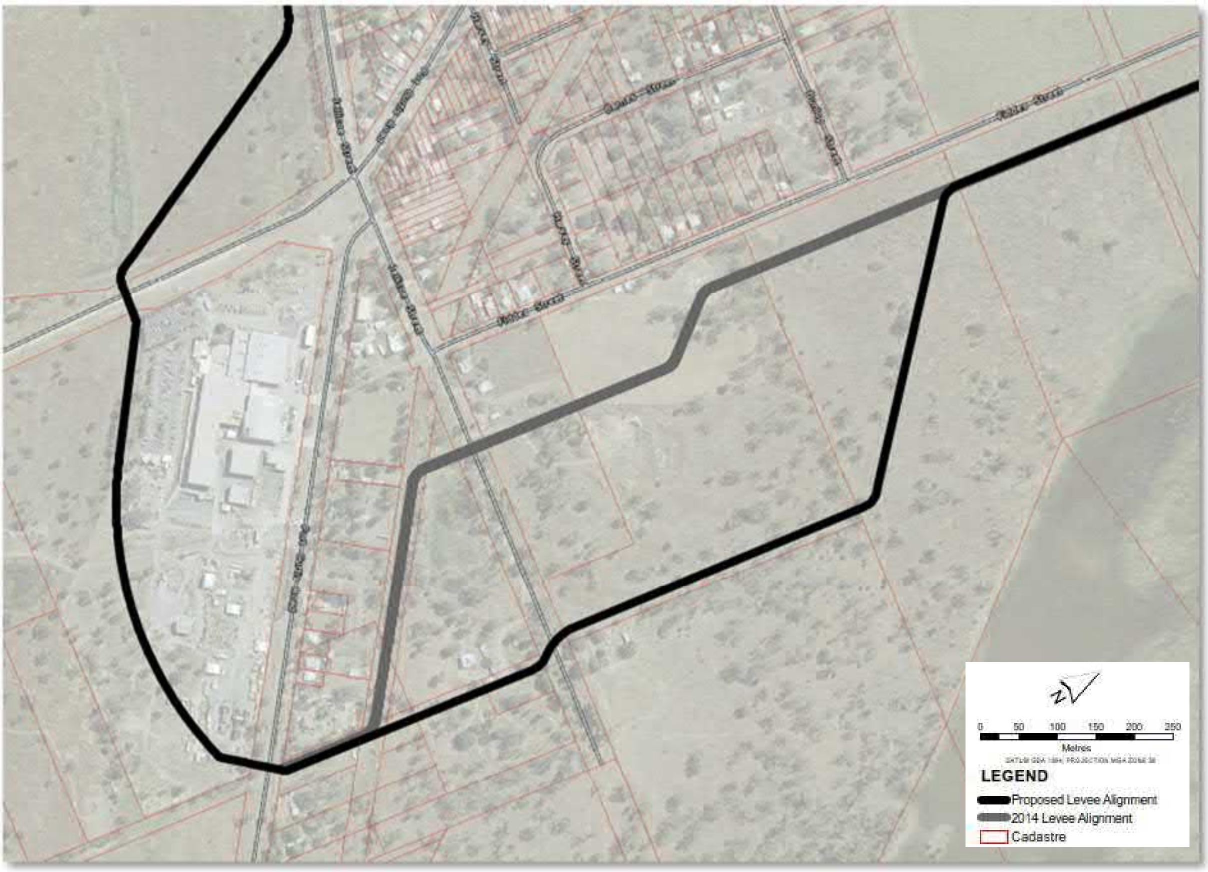


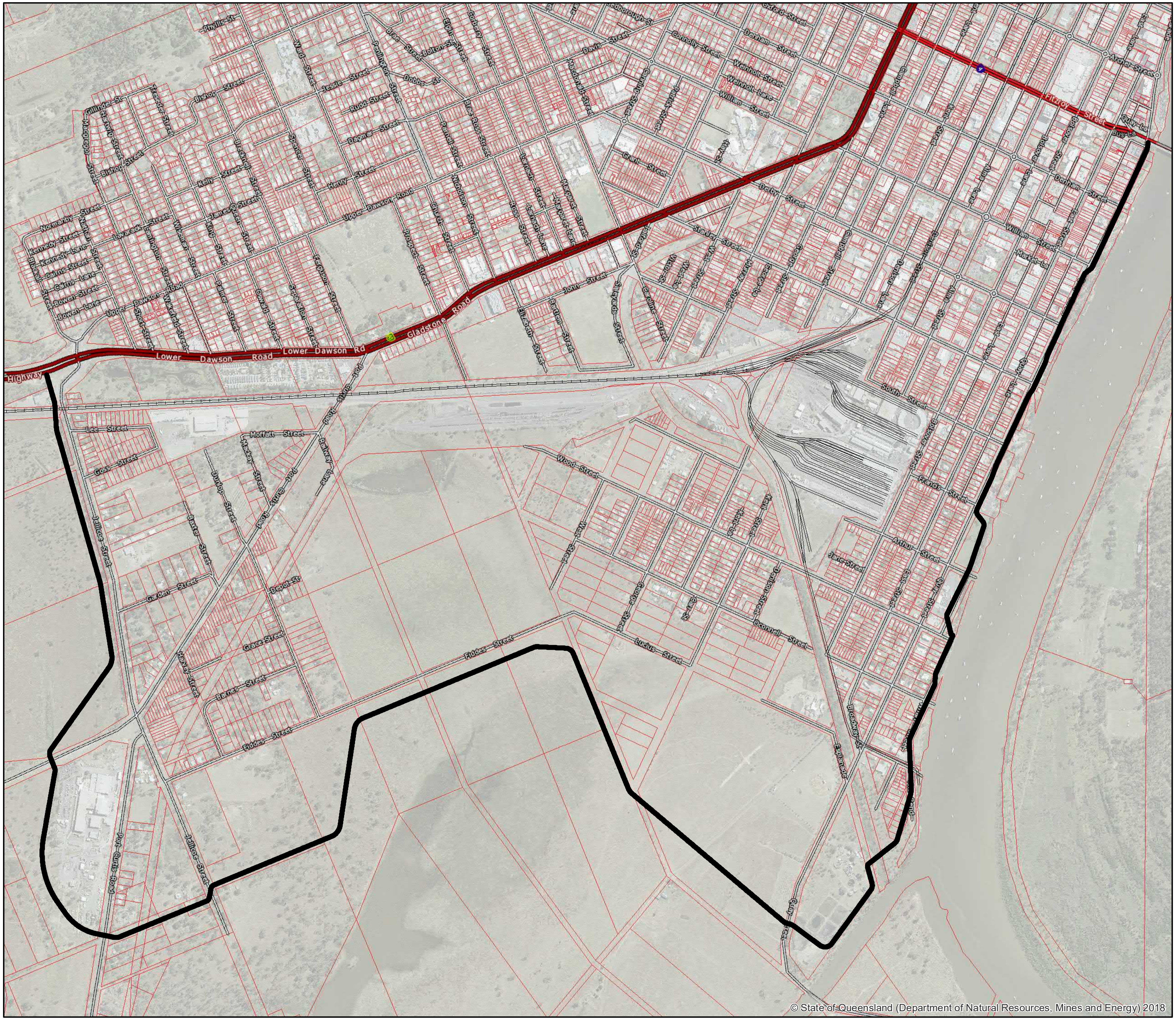
Figure 24 SRFL alignment refinement at Fiddes Street

South Rockhampton Sewage Treatment Plant (SRSTP): A notable refinement was made to the alignment at the SRSTP in liaison with FRW. The refinement was designed to improve protection of the existing sludge lagoons. In addition the re-alignment of the SRFL at Quay Street saw added benefits of improving the vertical clearance to High Voltage (HV) power lines, which was a prominent risk identified in Early Works design. Hydraulic impacts of the re-alignment were insignificant due to the changes being generally within a backwater area. The re-alignment is shown in Figure 25.

Figure 25 SRFL Alignment Refinement at SRSTP

5.2.2 Final 2019 Horizontal Alignment

The adopted SRFL horizontal alignment is presented in Figure 26. This alignment includes refinements noted in Section 5.2.1 and is the configuration modelled in the updated Fitzroy River TUFLOW model.



Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400 500
Metres

1:12,500
(when printed at A3)

AECOM
www.aecom.com

LEGEND

- Proposed Levee Alignment
- Railway Lines
- Cadastre

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

South Rockhampton Flood Levee

Horizontal Alignment Overview

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	2/04/2019
VERSION:	1

Figure 26

Filename: P:\605x\60589157\900_CAD_GIS\920_GIS\MXD's\Hydraulic Assessment Report\SRFL Overview.mxd

5.2.3 Levee Types

The levee system utilises six different levee types, ranging from permanent earth embankments and structural walls to temporary demountable walls that are installed at designated trigger levels. Table 5 presents the lengths associated with each type of levee section which are shown spatially in Figure 27.

Table 5 Levee Wall Type Summary

Levee Wall Type	Length (m)
Temporary Fully Demountable Wall	732
Composite Demountable / Permanent Levee Wall	967
Levee Emergency Spillway	420
Earth Embankment (incl. road ramps and gates)	5,892
Crib Retaining Wall	729
Total Levee Length	**8,740**

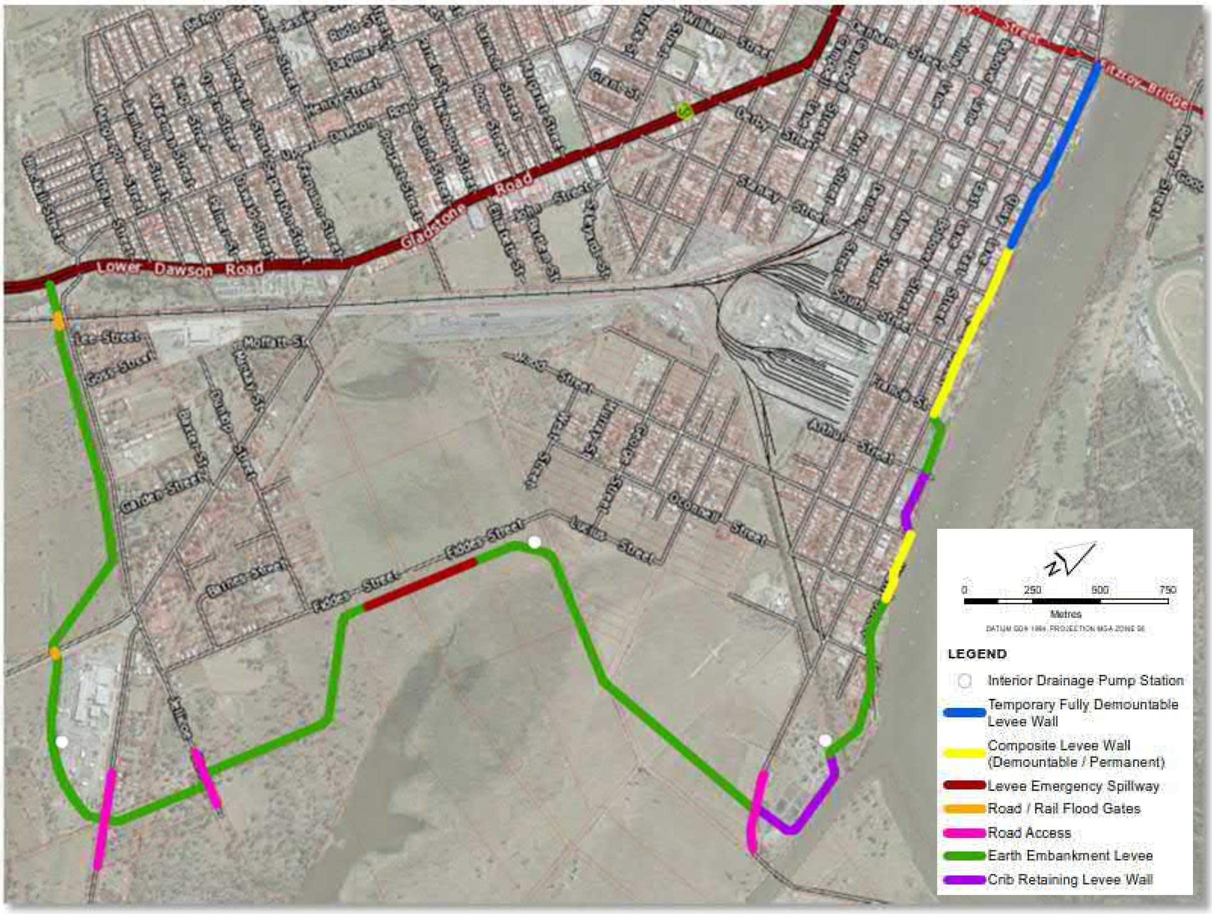


Figure 27 SRFL levee type overview

5.2.4 Vertical Alignment

The adopted SRFL vertical alignment is presented in Figure 28. This alignment includes refinements noted in Section 5.2.1 and is the configuration modelled in the updated Fitzroy River TUFLOW model.

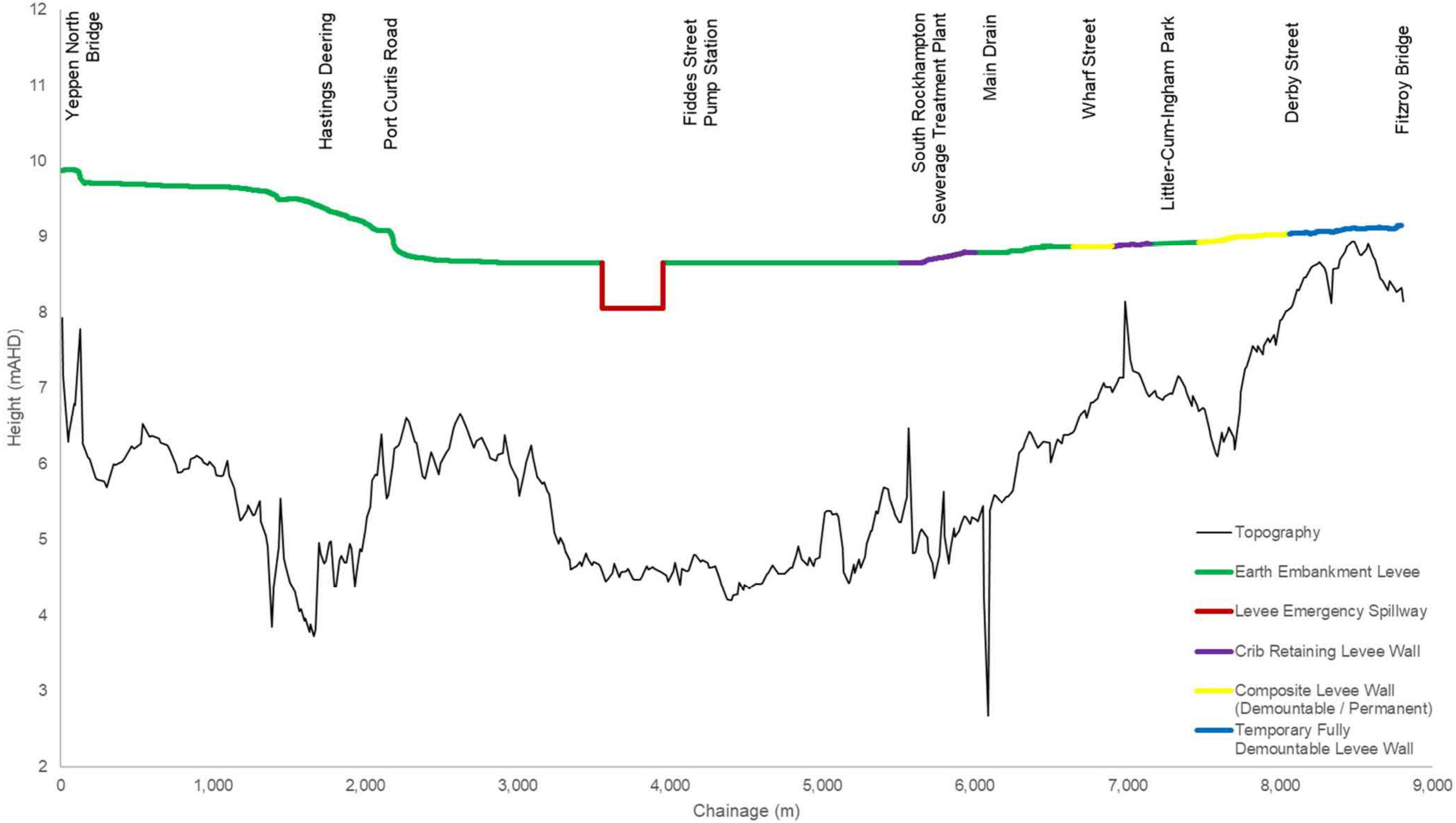


Figure 28 SRFL vertical alignment

6.0 Hydraulic Assessment

6.1 Overview

This section of the report discusses the hydraulic assessment undertaken for the SRFL for a range of Fitzroy River design flood events. The Developed Case results have been compared to the Baseline results and an assessment has been undertaken against the criteria discussed in Section 4.0.

It is noted that all modelling outputs provided in this report are based on an assumption of no levee breach failure. It is likely that a levee breach failure would change the model output results. The impact of levee breach scenarios is discussed in a separate Failure Impact Assessment report (AECOM, 2014).

6.2 Hydraulic Model History

There is a long history of hydraulic investigations undertaken for the Fitzroy River:

- Fitzroy River Barrage Study (Department of Local Government, 1964).
- The Yeppen Model (Capricornia Institute of Advanced Education, 1977).
- Rockhampton Flood Management Study (CMPS&F, 1992).
- Rockhampton Floodplain Management Policy (Willing & Partners, 1999).
- Lower Splitters Creek Flood Study (Fisher Stewart, 2001).
- Fitzroy River Flood Study (Aurecon, 2011).
- Fitzroy River Floodplain and Road Planning Study (AECOM, 2012).
- SRFL Planning and Design (AECOM, 2014).

Hydraulic modelling of the Fitzroy River at Rockhampton has been undertaken by various consultants, using a number of different modelling software packages. Table 6 provides a chronological order of numerical hydraulic modelling undertaken since the original Rockhampton Flood Management Study.

Table 6 Hydraulic Model Development History

<table>
<tr><th>Year</th><th>Software</th><th>Study</th><th>Commissioned By</th><th>Developed By</th></tr>
<tr><td>1992</td><td>MIKE11</td><td>Rockhampton Flood Management Study</td><td>Queensland Water Resources</td><td>Camp Scott and Furphy</td></tr>
<tr><td>2011</td><td>TUFLOW Classic</td><td>Fitzroy River Flood Study</td><td>RRC</td><td>Aurecon</td></tr>
<tr><td>2011</td><td>MIKE FLOOD</td><td>FRFRPS</td><td>TMR</td><td>AECOM</td></tr>
<tr><td>Oct 2013</td><td colspan="4">Memo prepared by AECOM for TMR & RRC –
Technical Comparison of the RFMS, FRFS and FRFRPS.</td></tr>
<tr><td rowspan="3">2014</td><td>TUFLOW Classic</td><td rowspan="2">SRFL Planning and Design</td><td>RRC</td><td rowspan="2">AECOM</td></tr>
<tr><td>MIKE FLOOD</td><td>TMR</td></tr>
<tr><td colspan="4">SRFL Model Development and Comparison Report prepared by AECOM, for RRC and TMR.</td></tr>
<tr><td>2014-2017</td><td>TUFLOW Classic</td><td>Number of model refinements</td><td>RRC</td><td>AECOM</td></tr>
<tr><td>Dec 2017</td><td colspan="4">Decision made by TMR Hydraulics Branch to adopt the TUFLOW model moving forward</td></tr>
<tr><td>2018/19</td><td>TUFLOW GPU HPC</td><td>Rockhampton Ring Road Planning</td><td>TMR</td><td>AECOM</td></tr>
</table>

The updated Fitzroy River TUFLOW model developed and outlined in the 2019 Fitzroy River Baseline Model Update Report (AECOM, 2019) will be used by TMR and RRC for all current and future design / planning projects relating to SRFL, Rockhampton Ring Road, Rockhampton Airport Levee (RAL) and Splitters Creek Levee (SCL).

6.3 Baseline Model Development

6.3.1 Key Changes

As detailed in Section 3.6, a number of updates have been made to the 2014 Fitzroy River TUFLOW model in order to ensure the best available datasets are utilised along with the latest industry-adopted technology. This includes:

- Re-assessment of the FFA using the latest data and TUFLOW FLIKE in accordance with ARR16.
- Adoption of the TUFLOW GPU HPC solution scheme, which includes an explicit solver for the full 2D Shallow Water Equations (SWE) and sub-grid scale eddy viscosity.
- Refinement of the grid resolution from 25m to 15m.
- Incorporation of the latest topographic datasets, including the 2015/16 Rockhampton LiDAR Project, Yeppen North and South Bridges As Cons and bathymetric survey at the Pink Lily meander.
- Improved 1D-2D interface at the downstream model boundary.
- Refinement of the hydraulic roughness delineation.
- Inclusion of all major bridge and culvert structures, with form losses in accordance with Hydraulics of Bridge Waterways HDS (FHWA, 1978).

Detailed survey of the ‘As Constructed’ Yeppen North and Yeppen South infrastructure has been included in the Baseline model.

6.3.1.1 Inclusion of Yeppen Road Works in the SRFL Baseline Model

TMR received funding for the Yeppen South Project which was identified as a high priority in the Queensland Government’s Bruce Highway Action Plan (2012). Construction commenced in early 2014 and was completed in late 2015. The works include 2.1 km of new bridging across the Yeppen Floodplain which provide immunity up to and including a 1% AEP Fitzroy River Flood event.

The Yeppen South connects with the previously constructed Yeppen North project. Together, the projects consist of:

- Raised embankment at the intersection of Lower Dawson Road and Jellicoe Street.
- A high level 420 m bridge between Jellicoe Street and the Rockhampton Roundabout (Yeppen North Bridge).
- A short section of high level embankment between the Yeppen North Bridge and the Yeppen South slip-lane bridge.
- A high level 570 m slip-lane bridge on the eastern side of the Rockhampton Roundabout, as a connection between the Yeppen North and Yeppen South projects.
- High level embankment between the slip-lane bridge and the Yeppen South bridge.
- A high level 1600 m bridge from the Rockhampton Roundabout to the southern side of Scrubby Creek, just north of the Burnett Highway intersection with the Bruce Highway (Yeppen South Bridge).

6.3.2 Calibration and Validation

The updated Fitzroy River TUFLOW model was re-calibrated to the 2017 flood event and re-validated to the 2011 and 1991 flood events. The 2017 flood event was selected as the calibration event as it was the most recent event where Yeppen infrastructure was in place, coupled with the significant recorded flood height and extent dataset captured by RRC throughout the duration of the event.

This included 879 reference points with 421 being proximal to the peak. A strong calibration was achieved to the 2017 event throughout the model extent with 88% of modelled points within ±0.15m of recorded flood heights. Figure 29 shows the distribution of differences between modelled and recorded peak flood heights for the calibration.

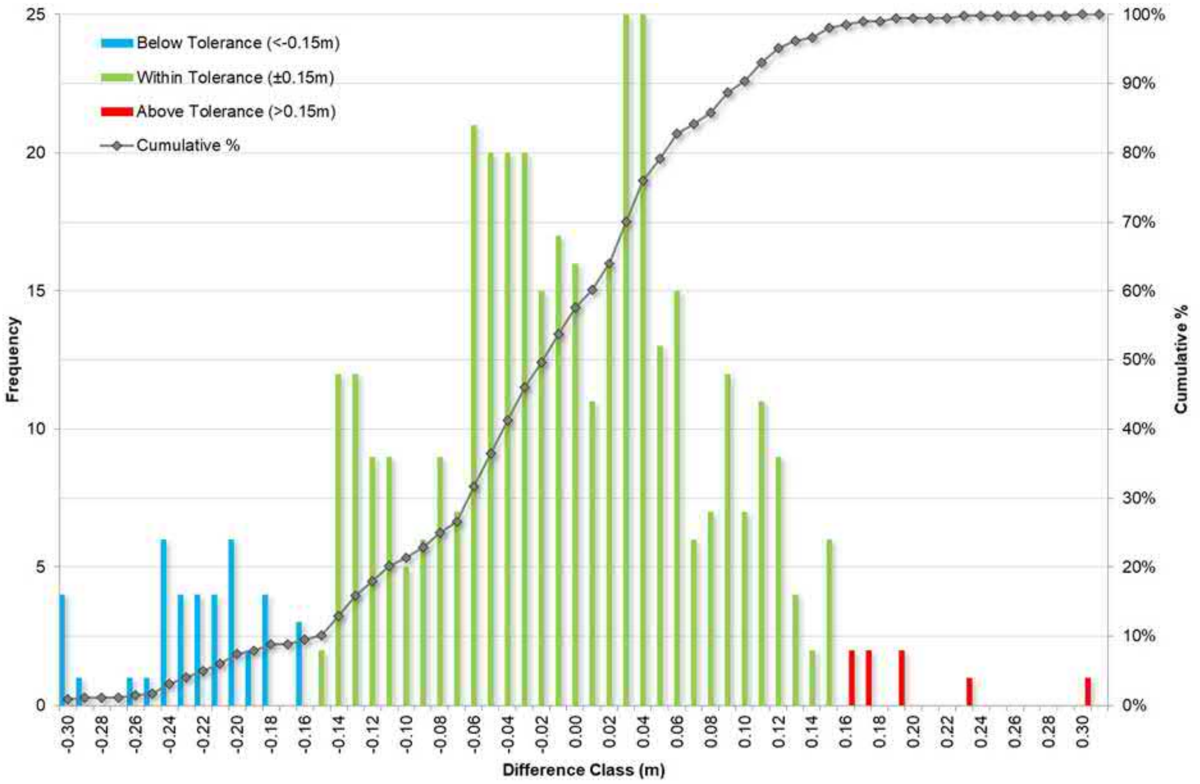


Figure 29 2017 Event Calibration Histogram

The model was then validated to the 2011 and 1991 major flood events using the same model parameters, aside from:

- Inflows (based on actual gauge data at The Gap station).
- Pre-Yeppen North and South Bridge topography (2009 LiDAR).
- Pre-development topography at quarries within the western floodplain.
- Pre-2017 topography at the Pink Lily meander (2015/16 LiDAR).

A strong validation of the model performance was achieved for the 2011 and 1991 events, with 86% of modelled levels being within the ±0.30m tolerance for both events. Figure 30 and Figure 31 show the distribution of differences between modelled and recorded peak flood heights for the 2011 and 1991 validation events respectively.

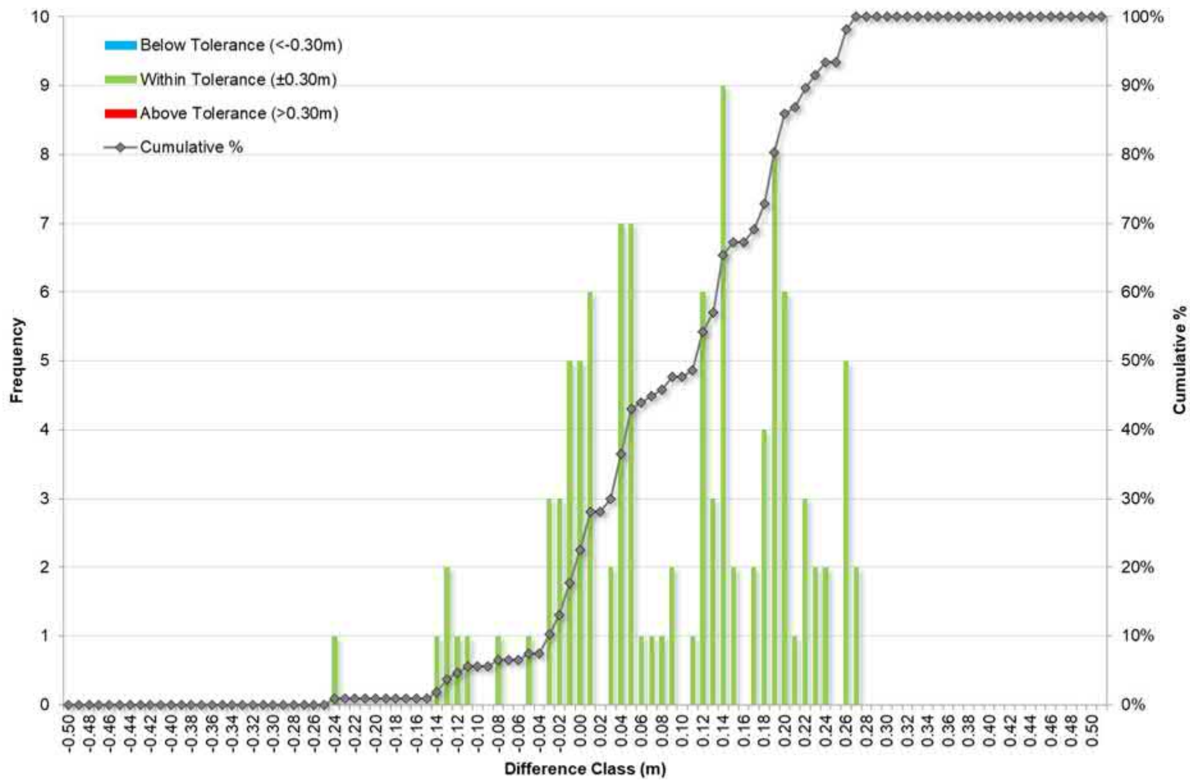


Figure 30 2011 Event Calibration Histogram

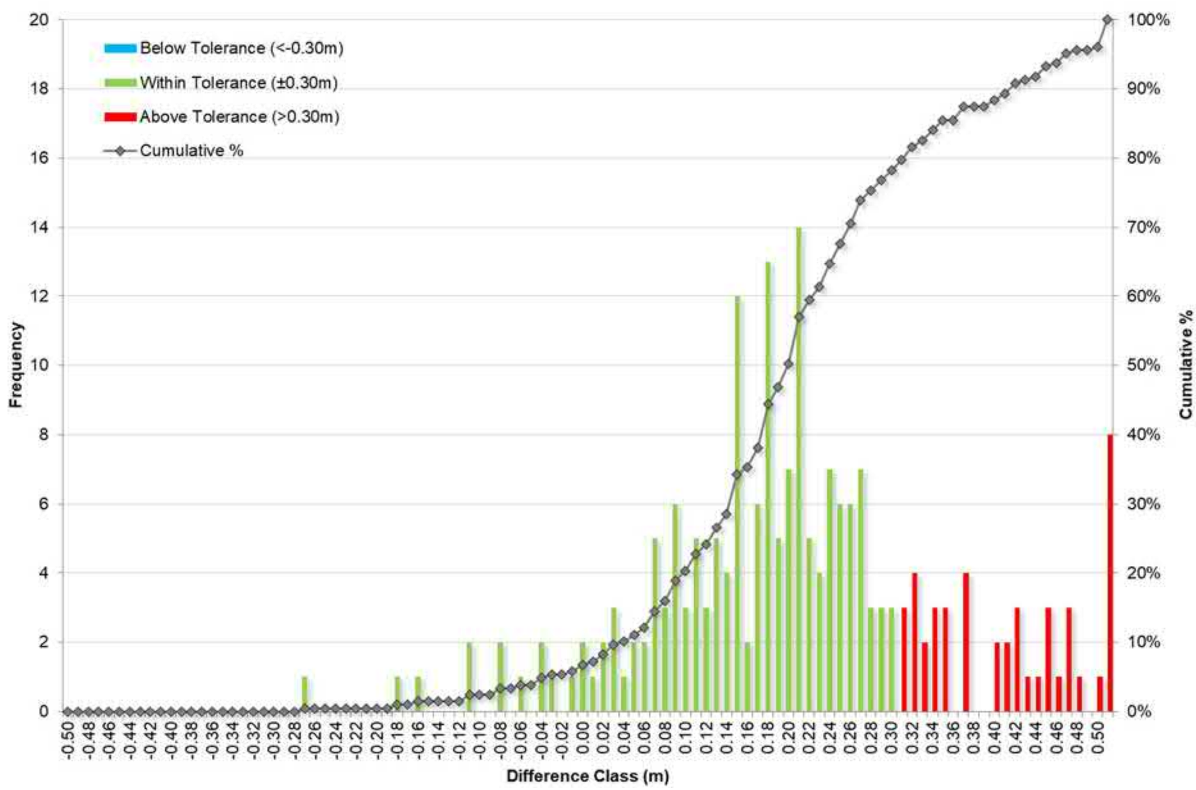


Figure 31 1991 Event Calibration Histogram

6.3.3 Model Simulations

The Baseline and Developed Case models were run for the 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP, 0.05% AEP and PMF design events. This suite of design events is anticipated to satisfy the relevant requirements specified in Section 4.0 as:

- A range of events up to the 1% AEP are included.
- The DFE (adopted as 1% AEP; see Section 4.1) is included.
- Overtopping scenarios:
  - Aside from the 1% AEP event, the 0.5% and 0.2% AEP events are anticipated to show the highest impacts for both peak flood heights and velocities.
- PMF is included.

As noted in the 2019 Fitzroy River Baseline Model Update Report (AECOM, 2019), the design peak discharges and inflow hydrographs were adopted as per the 2012 FFA and historical hydrograph scaling technique documented in the FRFRPS project.

The design discharge inflow hydrographs were applied at Yaamba, as the upstream boundary to a one-dimensional network. The peak design discharges are summarised in Table 7.

Table 7 Peak Design Discharges at Yaamba

Design Event AEP (%)	Peak Discharge (m^3/s)
5	10,771
2	14,133
1	16,676
0.5	19,219
0.2	22,581
0.05	27,667
PMF	56,713

6.3.4 Baseline Model Results

The suite of design events (5% AEP to PMF) for the baseline scenario have been mapped and included in Volume 2 of this report. Volume 2 encompasses:

- **Peak Flood Depths and Extents:** Maps 1, 5, 9, 13, 17, 21 and 25.
- **Peak Flood Heights:** Maps 2, 6, 10, 14, 18, 22 and 26.
- **Peak Flood Velocities:** Maps 3, 7, 11, 15, 19, 23 and 27.
- **Peak Flood Hazards:** Maps 4, 8, 12, 16, 20, 24 and 28.
- **Inundation Extent Comparison:** Map 29.

6.4 Developed Case Model Development

6.4.1 SRFL Developed Case Model Schematisation

The SRFL has been schematised in the Developed Case model by a layered combination of the levee footprint (in the form of a DEM) superimposed with a thin break line (TUFLOW Z Shape) representing the crest of the levee alignment, including freeboard. The thin break line method raises model cell sides, effectively blocking flood flows up to the assigned elevation. This approach accounts for loss of floodplain storage and conveyance due to the levee footprint, although this is expected to be negligible given the TUFLOW model's 15m grid resolution.

The levee crest elevations were adopted based on water surface elevations from the 1% AEP Developed Case simulation with the freeboard of 0.6m added. The levee crest varies in elevation from approximately 9.87mAHD at the Yeppen North connection point to 8.05 mAHD at the spillway near Fiddes Street. The crest gradually rises to an elevation of 9.15mAHD at the most northern section of the levee alignment, near the Fitzroy River Bridge connection.

A fixed crested spillway has been adopted at RL 8.05 mAHD. The spillway elevation is position at the 1% AEP water surface level and is located along Fiddes Street between chainage 3,550m and chainage 3,950m. Further details on the spillway selection process and hydraulic design can be found in the Failure Impact Assessment report (AECOM, 2014).

6.4.2 Developed Case Model Results

The suite of design events (5% AEP to PMF) for the SRFL design scenario have been mapped and included in Volume 2 of this report. Volume 2 encompasses:

- **Peak Flood Depths and Extents:** Maps 30, 34, 38, 42, 46, 50 and 54.
- **Peak Flood Heights:** Maps 31, 35, 39, 43, 47, 51 and 55.
- **Peak Flood Velocities:** Maps 32, 36, 40, 44, 48, 52 and 56.
- **Peak Flood Hazards:** Maps 33, 37, 41, 45, 49, 53 and 57.
- **Inundation Extent Comparison:** Map 58.

6.4.3 Predicted Differences in Peak Water Surface Elevations

Table 8 presents the predicted Developed Case peak flood levels at the Rockhampton Gauge alongside 2019 Baseline levels. It is noted that the inclusion of Yeppen North and Yeppen South infrastructure does not increase predicted water surface elevations at the Rockhampton Gauge.

Table 8 Summary of Predicted Design Event Gauge Levels

Flood Event AEP (%)	Predicted Peak Flood Level (m Rockhampton Gauge Datum)		Difference (m)
	Baseline Scenario	SRFL Design Scenario	
5	9.05	9.08	+0.03
2	9.54	9.57	+0.03
1	9.86	9.89	+0.03
0.5	10.16	10.19	+0.03
0.2	10.53	10.56	+0.03
0.05	11.02	11.02	-
PMF	13.28	13.28	-

For the suite of design events (5% AEP to PMF) the incremental change in peak flood height (SRFL design minus Baseline) has been mapped and included in Volume 2 of this report. Volume 2 encompasses:

- **Difference in Peak Flood Height:** Maps 61 - 67

An overview of each map is included in Figure 32 to Figure 38.

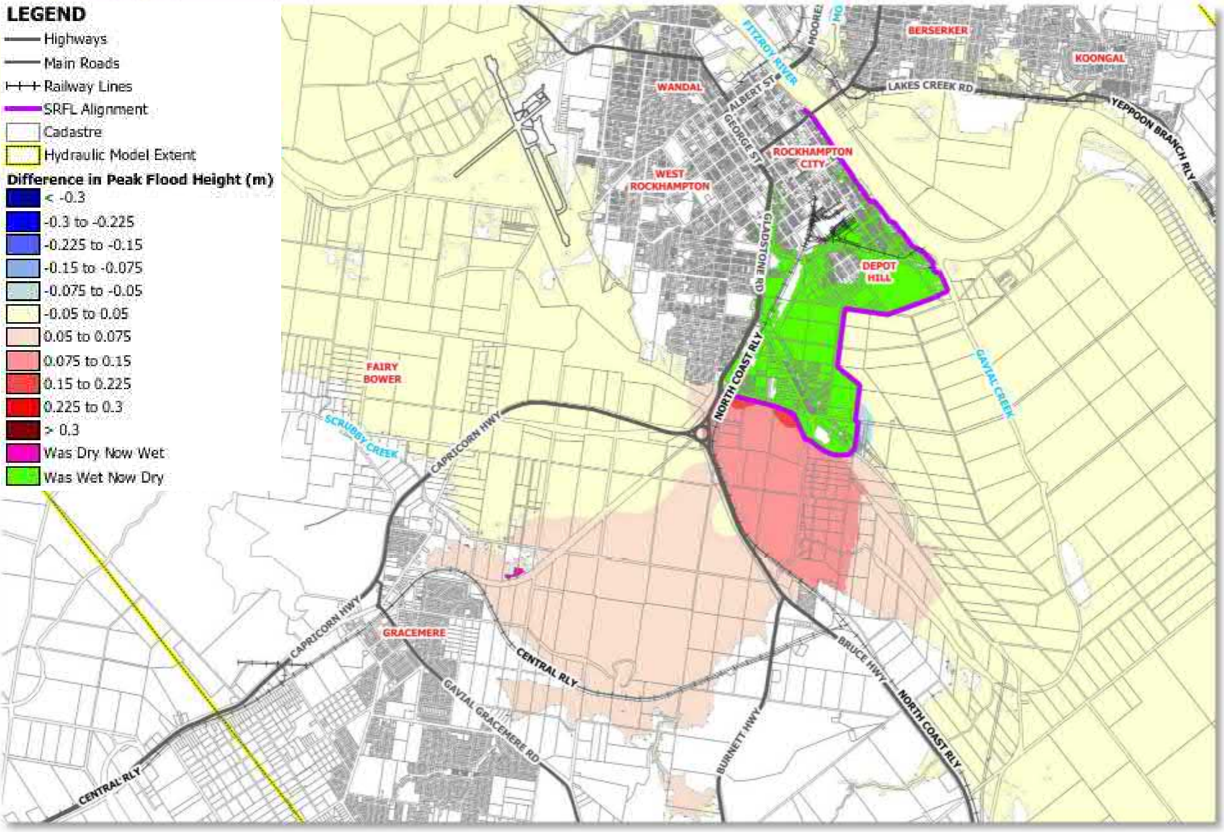


Figure 32 5% AEP Difference in Predicted Peak Flood Heights

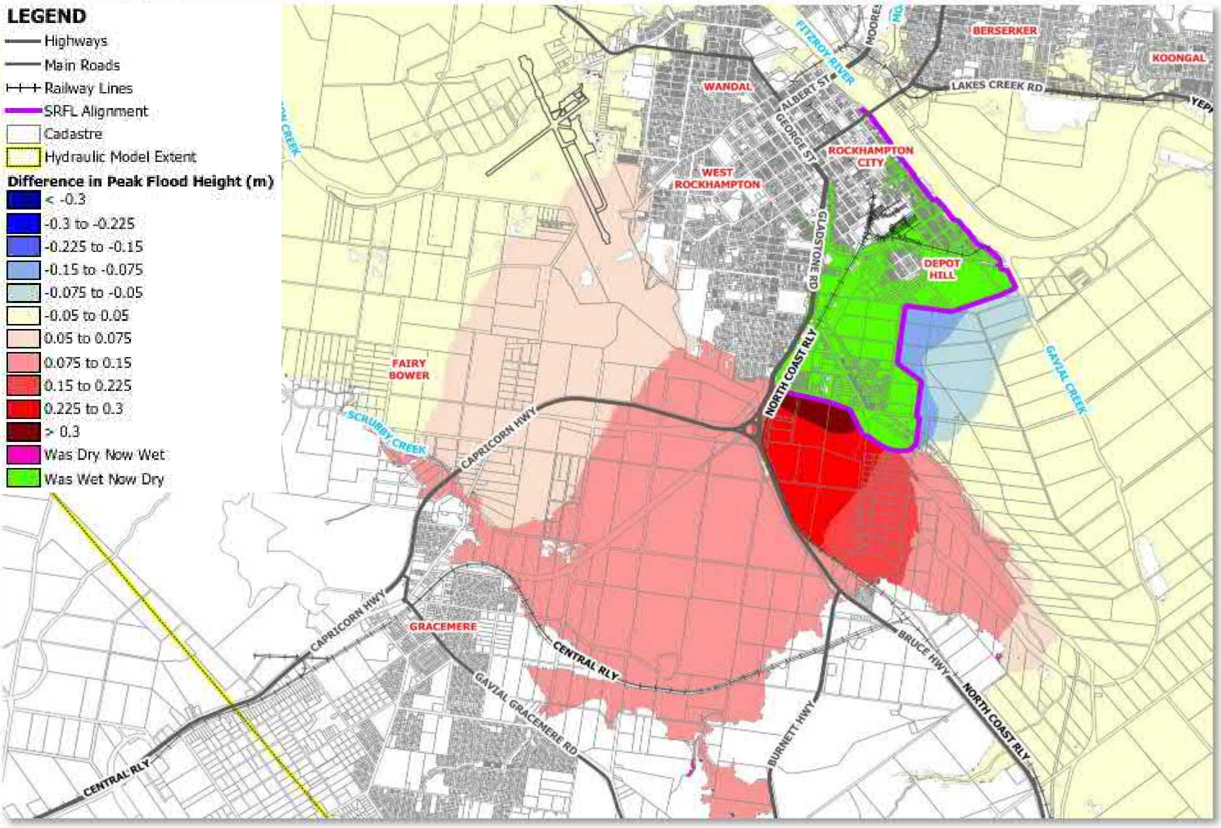


Figure 33 2% AEP Difference in Predicted Peak Flood Heights

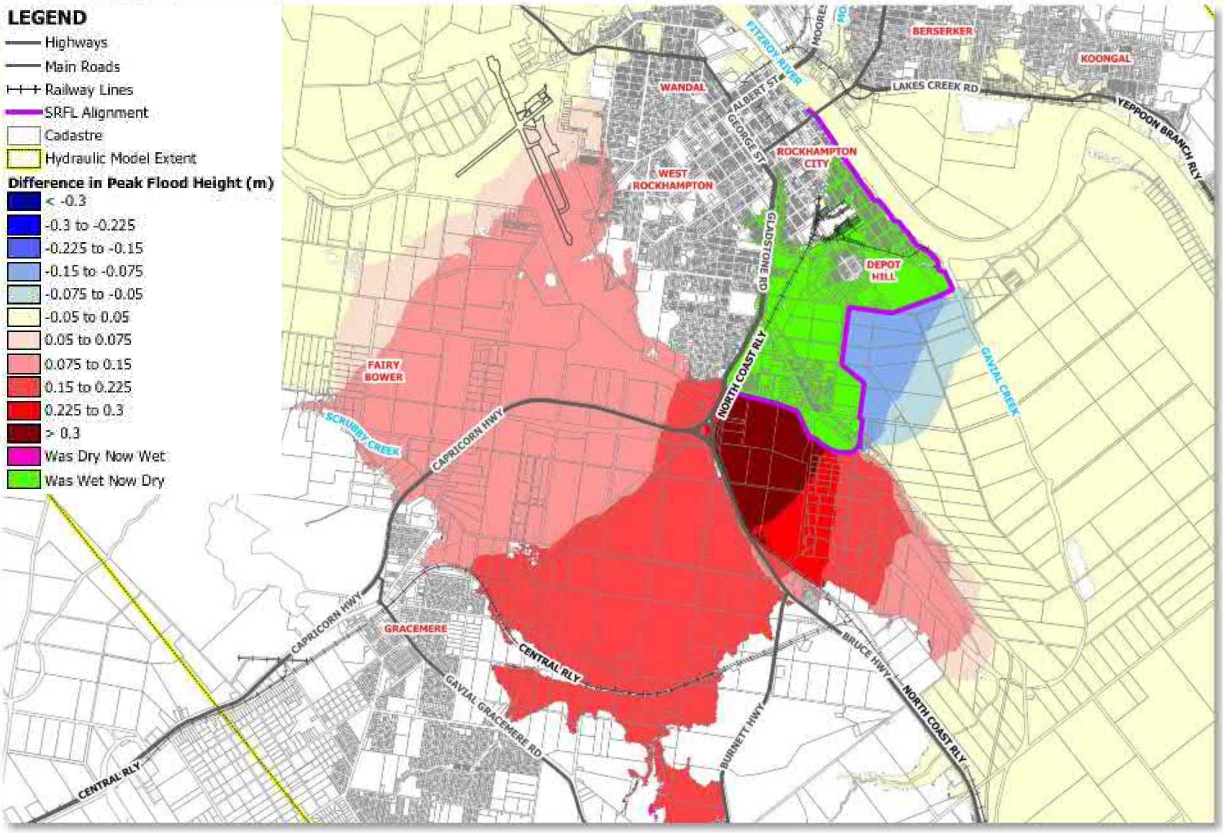


Figure 34 1% AEP Difference in Predicted Peak Flood Heights

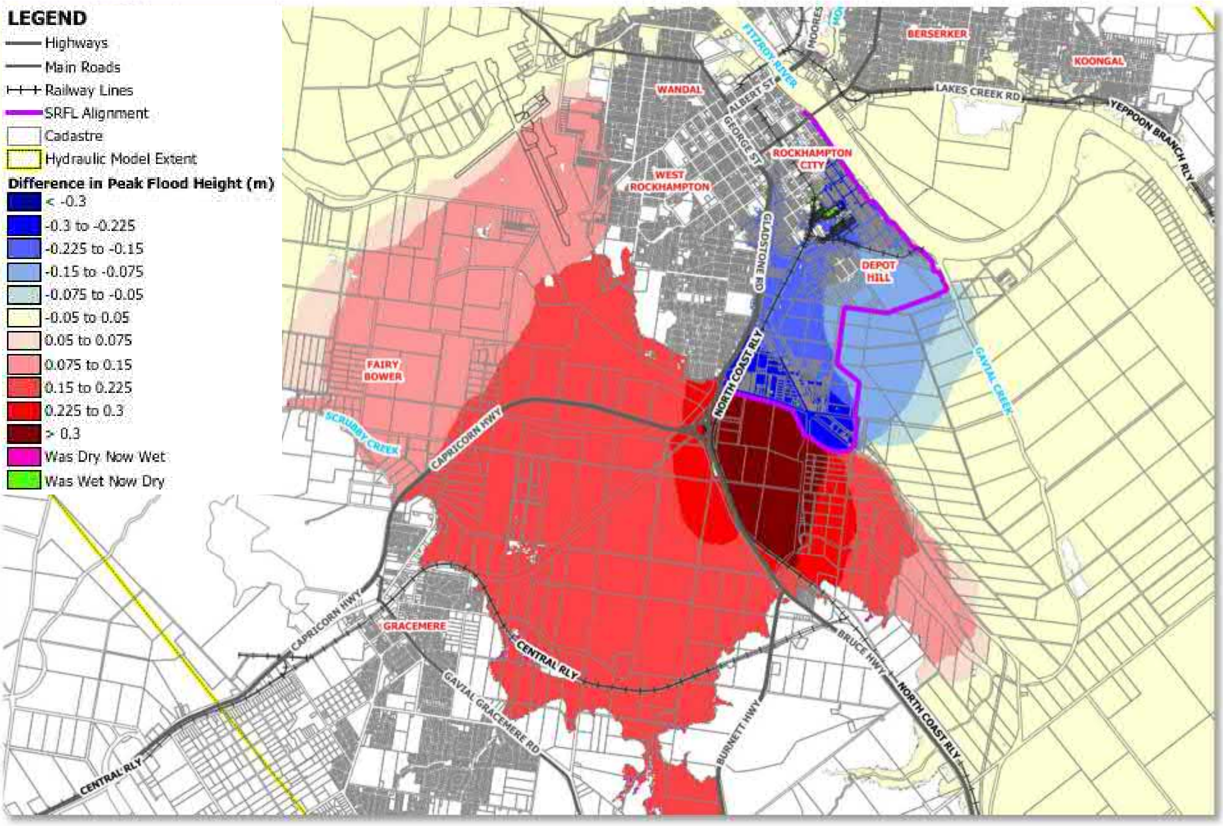


Figure 35 0.5% AEP Difference in Predicted Peak Flood Heights

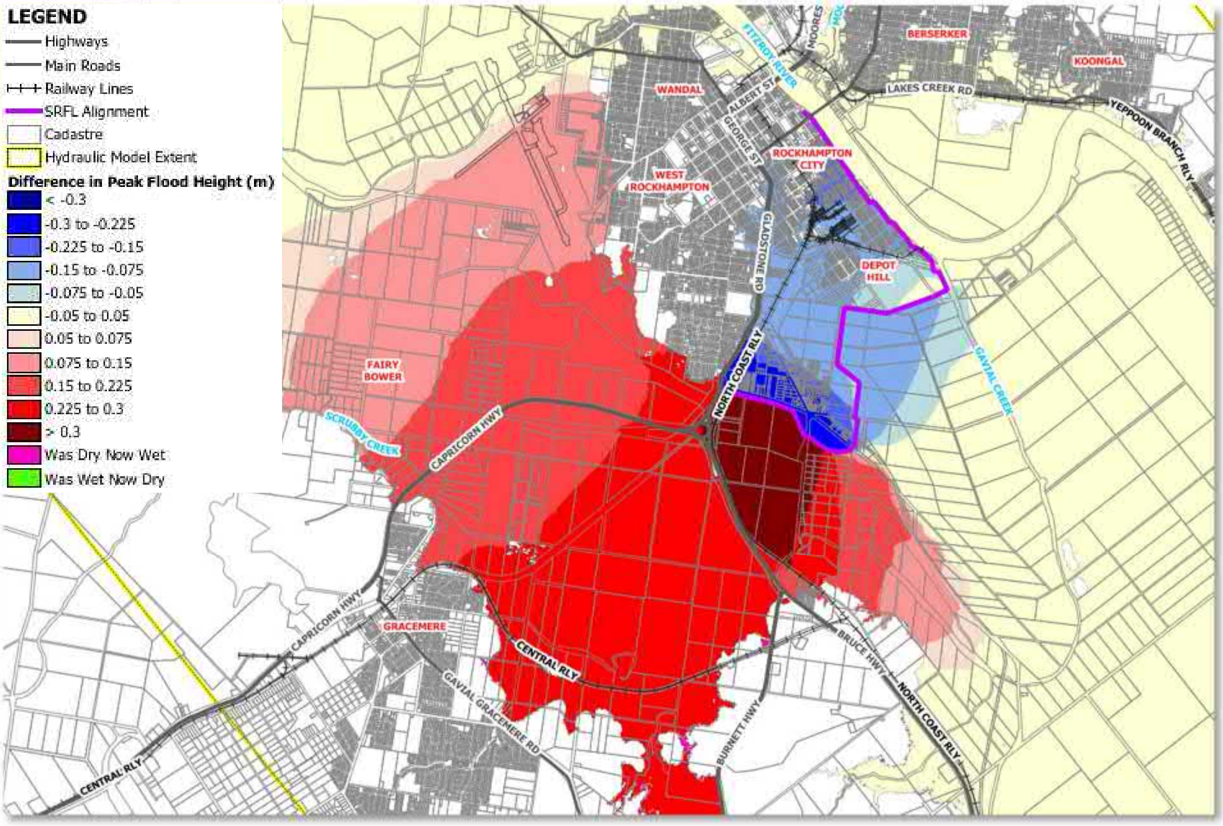


Figure 36 0.2% AEP Difference in Predicted Peak Flood Heights

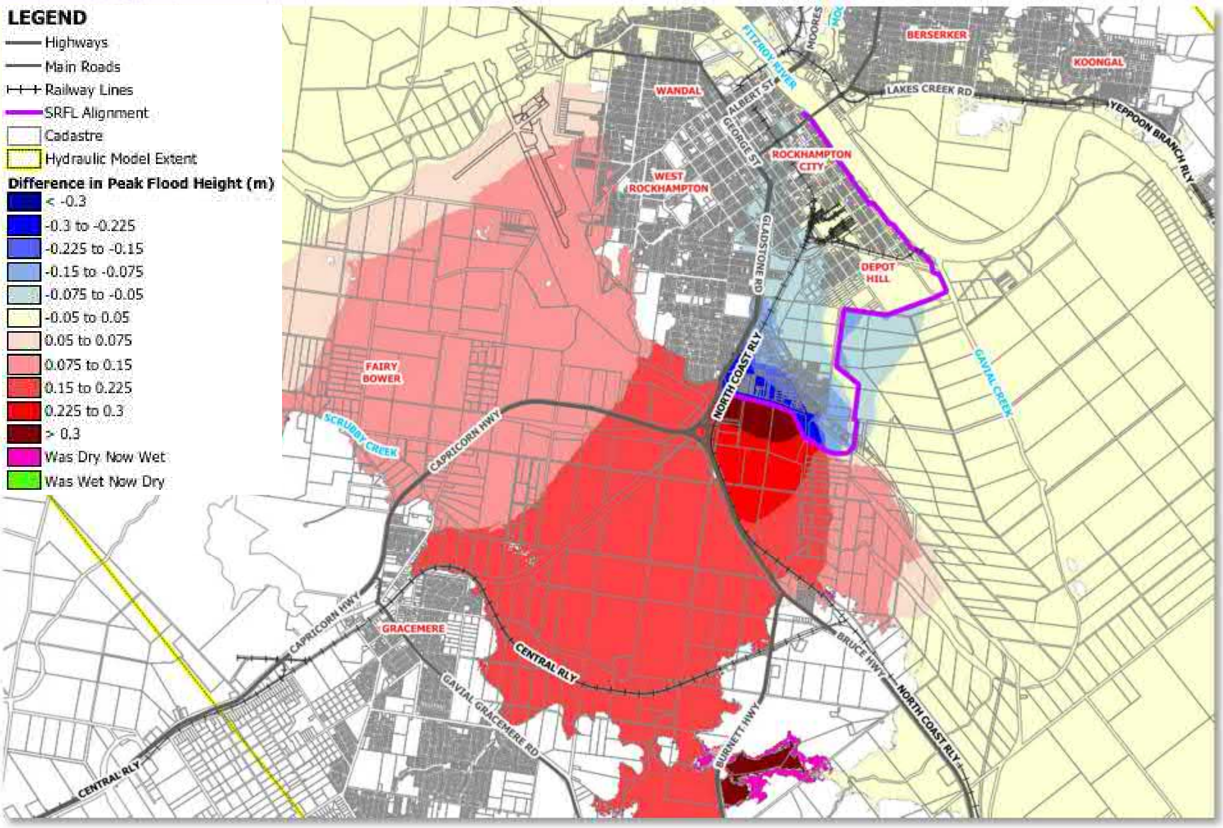


Figure 37 0.05% AEP Difference in Predicted Peak Flood Heights

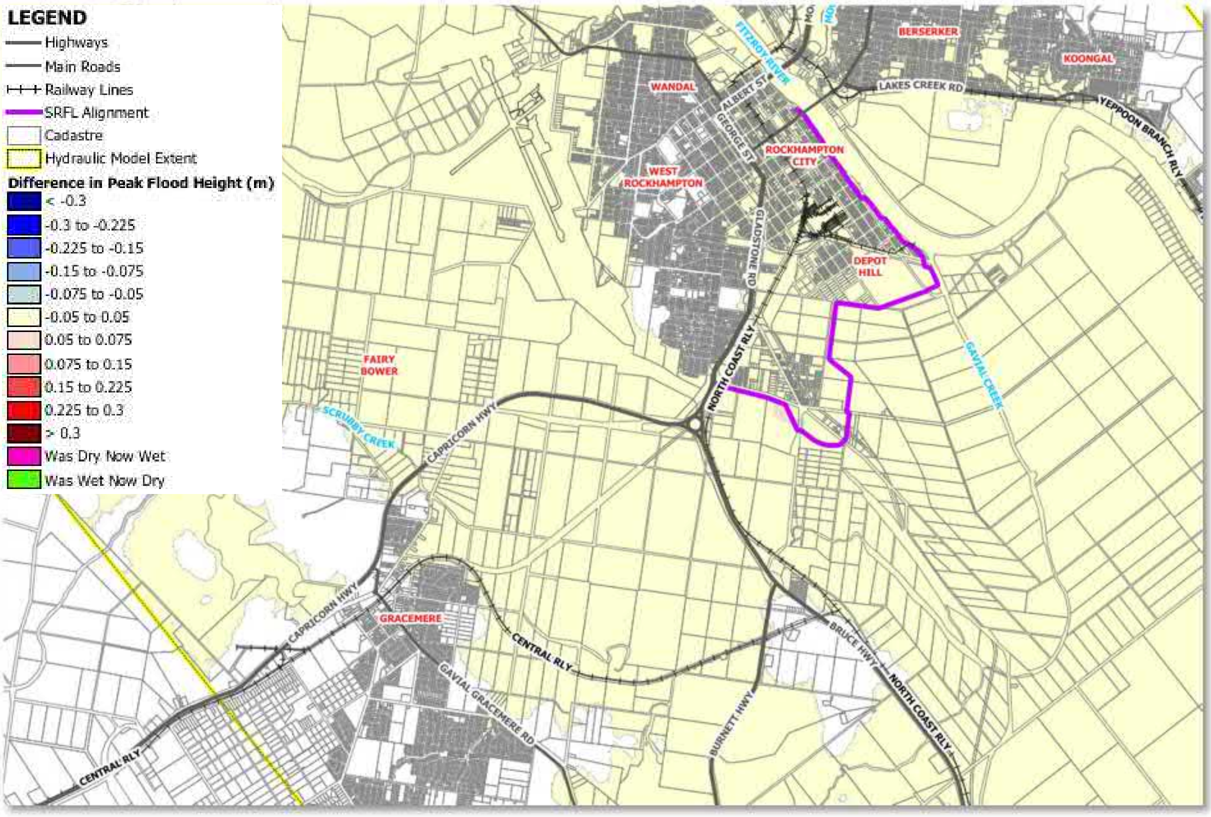


Figure 38 PMF Difference in Predicted Peak Flood Heights

The following key points are noted with reference to the Developed Case mapping:

- The SRFL will provide protection up to the 1% AEP Fitzroy River flood event.
- In the 0.5% AEP flood event:
  - As the spillway crest is positioned at the 1% AEP water surface elevation, the simulation shows that the spillway crest is the first point of overtopping with a predicted peak depth over spillway of 0.24m in the 0.5% AEP flood event.
  - The second point of overtopping point is at the Jellicoe Street / Lower Dawson Road / Upper Dawson Road intersection. At peak the flood depth across Upper Dawson Road is predicted to reach up to 0.33m.
  - It should be noted that the hydraulic modelling provides still water levels and does not account for wave run up and other local factors which could contribute to higher water levels at the spillway.
  - No other sections of the levee are anticipated to overtop during the 0.5% AEP event.
- In the 0.2% AEP flood event:
  - The spillway concentrates and controls overflow into the large natural basin adjacent to the Fiddes Street (inside the levee). Inundation of the interior initially occurs as a result of the spillway discharge.
  - Overtopping of the levee crest occurs along the southern portion of the alignment between the Yeppen North bridge and Port Curtis Road (chainage 0 m to chainage 2000 m). Differential water surface levels are predicted to be up to 1.0m at the point of overtopping (i.e. external water surface levels are 9.9 m AHD and internal ground surface levels is 8.9 m AHD).

  - Minor overtopping of the levee crest later occurs along the northern portion of the levee alignment. Differential water surface levels are predicted to be up to 0.30m at the point of overtopping (i.e. external water surface levels are 9.10mAHD and internal ground surface levels is 8.80mAHD).
  - At the peak, the majority of the levee is anticipated to overtop by:
    - 0.05 – 0.10m along the Fitzroy River face of the levee.
    - 0.20m between the SRSTP and Port Curtis Road.
    - 0.80m over the spillway.
    - 0.25m between Port Curtis Road and the Yeppen North Bridge.
  - It is likely that some additional overtopping of this portion of the levee would occur during the peak of the event due to wave run up and other local factors.
- In the 0.05% AEP flood event:
  - The spillway concentrates and controls overflow into the large natural basin adjacent to the Fiddes Street (inside the levee). Inundation of the interior initially occurs as a result of the spillway discharge.
  - Overtopping of the levee crest occurs along the southern portion of the alignment between the Yeppen North bridge and Port Curtis Road (chainage 0 m to chainage 2000 m). Differential water surface levels are predicted to be up to 1.4m at the point of overtopping (i.e. external water surface levels are 9.9 m AHD and internal ground surface levels is 8.5 m AHD).
  - Broad overtopping of the levee crest later occurs along the northern portion of the levee alignment. Differential water surface levels are predicted to be up to 0.40m at the point of overtopping (i.e. external water surface levels are 9.10mAHD and internal ground surface levels is 8.60mAHD).
  - At the peak, the majority of the levee is anticipated to overtop by:
    - 0.50 – 0.60m along the Fitzroy River face of the levee.
    - 0.80m between the SRSTP and Port Curtis Road.
    - 1.40m over the spillway.
    - 0.70m between Port Curtis Road and the Yeppen North Bridge.
  - It is likely that some additional overtopping of this portion of the levee would occur during the peak of the event due to wave run up and other local factors.
- In the PMF event:
  - The spillway concentrates and controls overflow into the large natural basin adjacent to the Fiddes Street (inside the levee) during the initial phase of the event.
  - Minimal controlled inundation of the interior area occurs prior to overtopping of the levee crest which occurs along the southern portion of the alignment. This is the result of the increased rate of rise associated with this event.
  - Overtopping of the crest is expected to occur along the entire levee alignment. The maximum depth of crest inundation (outside the emergency spillway) is predicted to be 2.6m in the vicinity of Jellicoe Street.
- Other points to note:
  - The emergency spillway is predicted commence overtopping between in events greater than the % AEP magnitude (overtopping expected to commence at 9.95m at Rockhampton Flood Gauge Height).

- The Bruce Highway, near the intersection of Jellicoe Street and Upper Dawson Road, is predicted to be inundated between the 1% and 0.5% AEP flood event at a gauge height of 10.00m (Rockhampton Gauge datum).
- The Fitzroy River is predicted to overtop the western bank in the vicinity of the Neville Hewitt Bridge western abutment between a 0.2% and 0.05% AEP flood event. This corresponds to a gauge level of 10.62 m (Rockhampton Gauge datum). Overflows tend in a southerly direction through the main CBD and re-join flows along the main drain.

6.4.3.1 Hydraulic Performance during Overtopping Events

The first point of overtopping for the SRFL is the Emergency Spillway which controls initial filling of the interior area prior to broad-scale overtopping of the levee crest in very rare flood events. The purpose of this report section is to outline the hydraulic performance during a 0.2% AEP event which overtops the levee crest. Note that this assessment is subject to the flow hydrograph's rate of rise which is expected to vary from the adopted design hydrographs for actual flood events. As such, this assessment is comparative and for information only.

As shown in Figure 39 and Figure 40, a significant volume of floodwater is expected to overtop the levee spillway prior to the overtopping of Upper Dawson Road (Yeppen North). This floodwater expands and covers an extent equal to 86% (5.2km^2) of the peak 0.2% AEP extent within the levee interior. This increases to 93% (5.6km^2) prior to overtopping of the levee crest, during which time Upper Dawson Road is overtopped.

This shows that for a 0.2% AEP overtopping event:

- 86% of the flooded extent behind the levee is filled during controlled overtopping of the emergency spillway.
- 93% of the flooded extent behind the levee is filled prior to overtopping of the levee crest.
- Following overtopping of the levee crest the flood footprint within the leveed area only increases by 7% (0.4km^2).
- Inflows via the emergency spillway will result in elevated tailwater conditions on the dry side of the levee which will largely dissipate the energy of flows overtopping the levee crest.

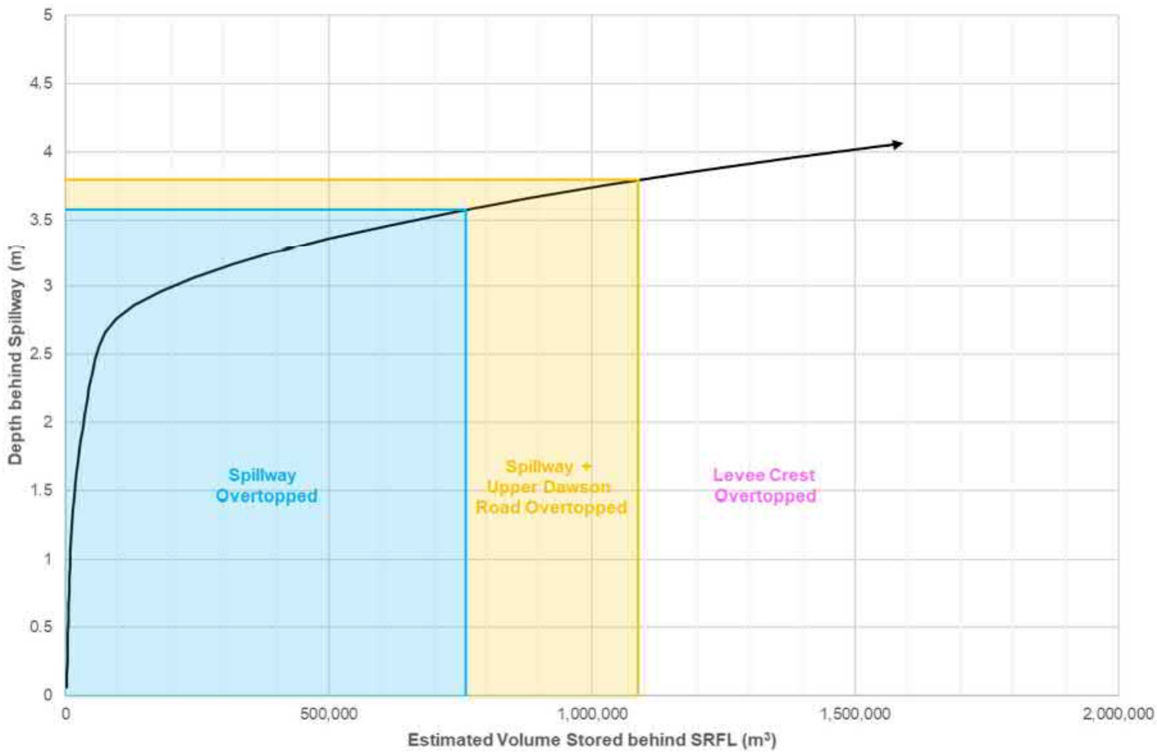


Figure 39 Emergency Spillway Performance

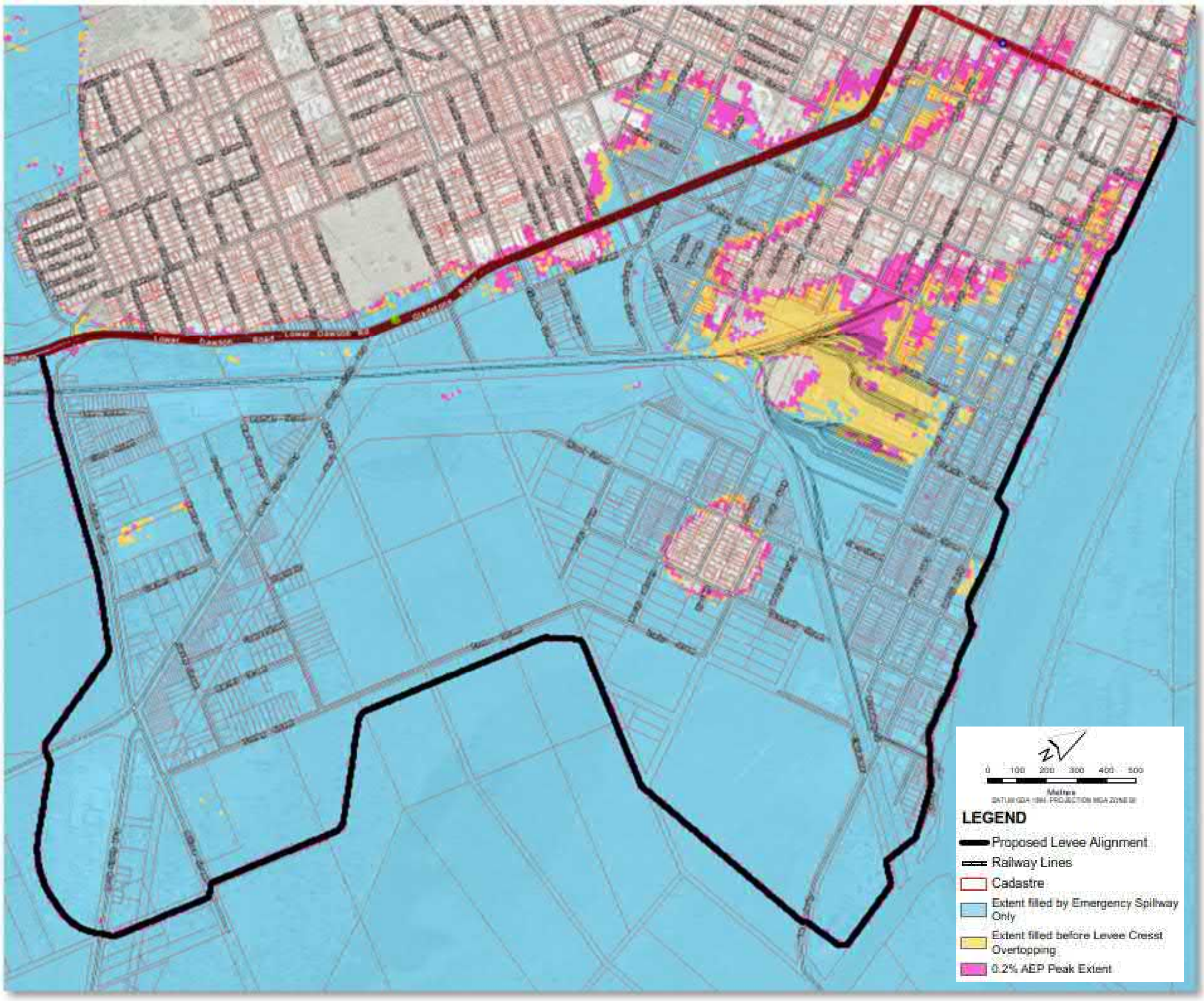


Figure 40 Interior Filling Extents

6.4.4 Predicted Differences in Velocities

Detailed peak depth averaged velocity mapping has been undertaken for the SRFL in order to demonstrate any alterations to the velocity regime within the project area.

For the suite of design events (5% AEP to PMF) the incremental change in peak flood velocity (SRFL design minus Baseline) has been mapped and included in Volume 2 of this report. Volume 2 encompasses:

- **Difference in Peak Flood Velocity:** Maps 68 - 74

An overview of each map is included in Figure 41 to Figure 47.

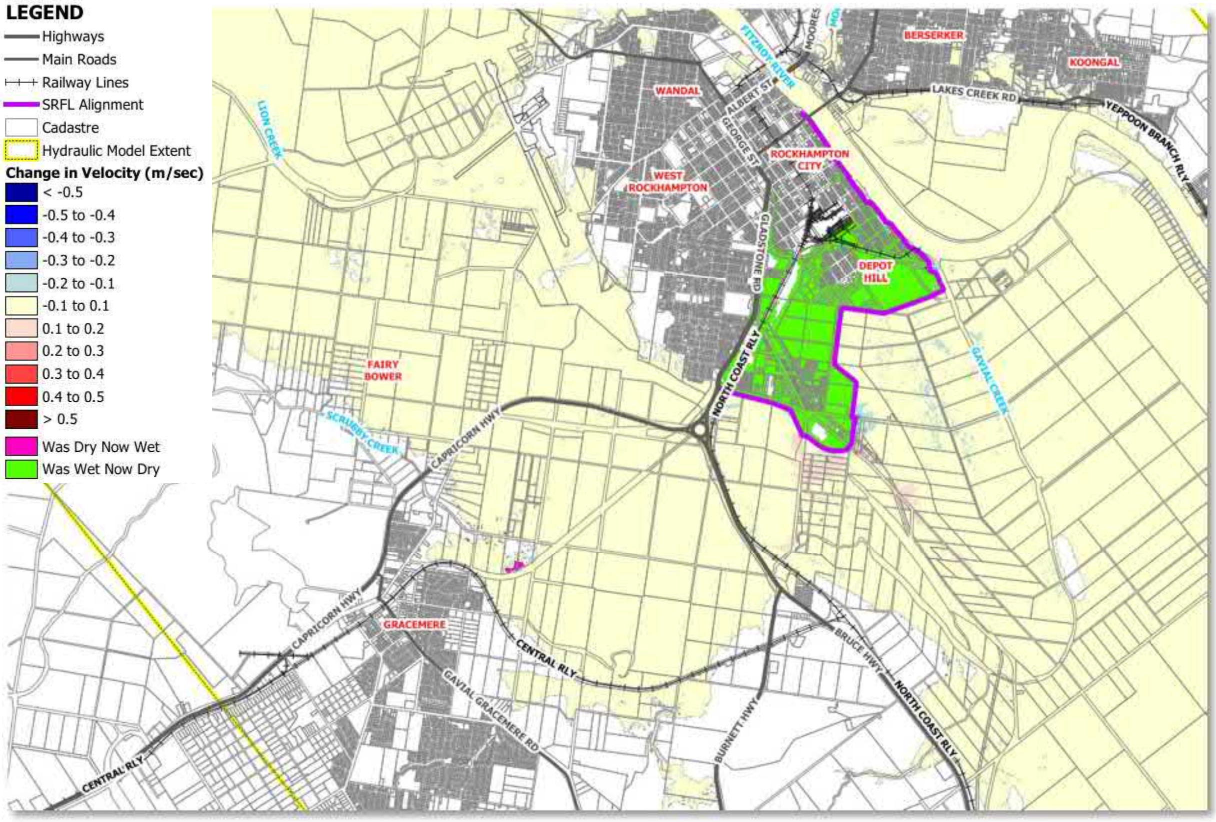


Figure 41 5% AEP Difference in Predicted Peak Flood Velocities

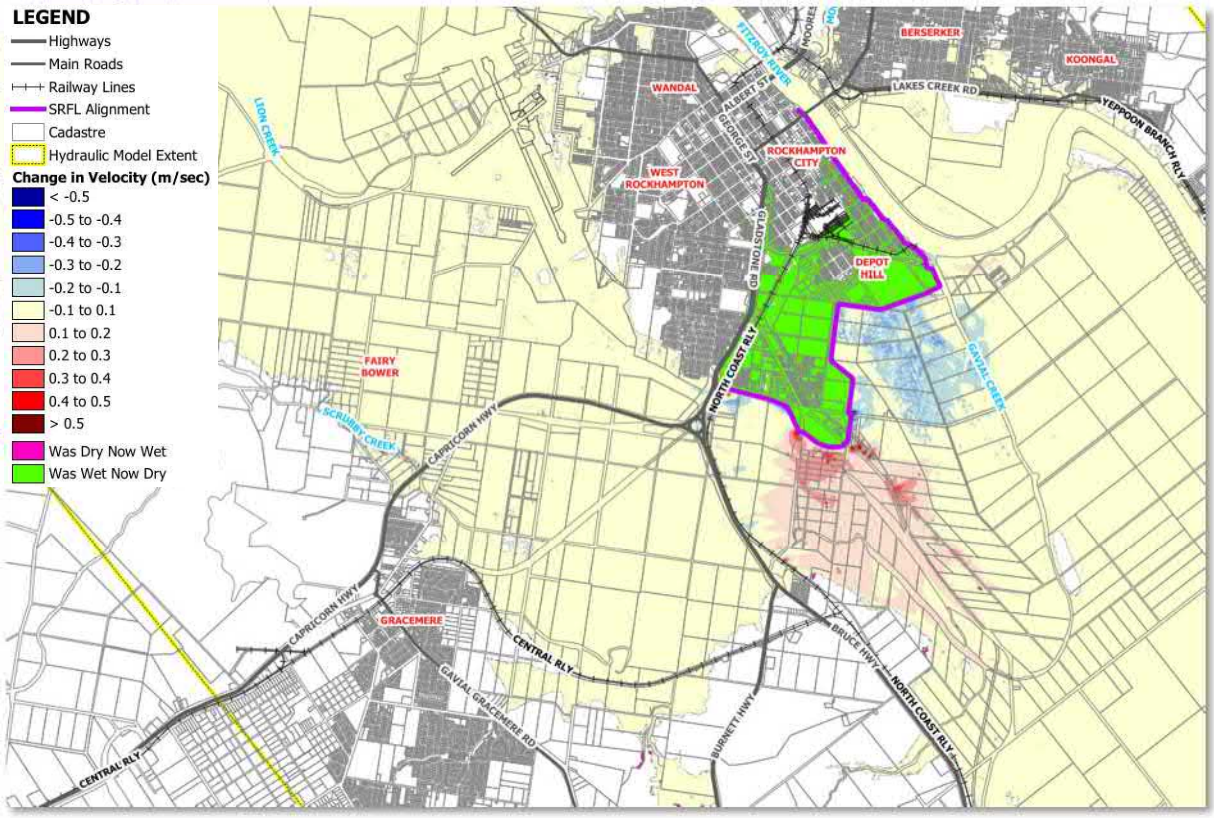


Figure 42 2% AEP Difference in Predicted Peak Flood Velocities

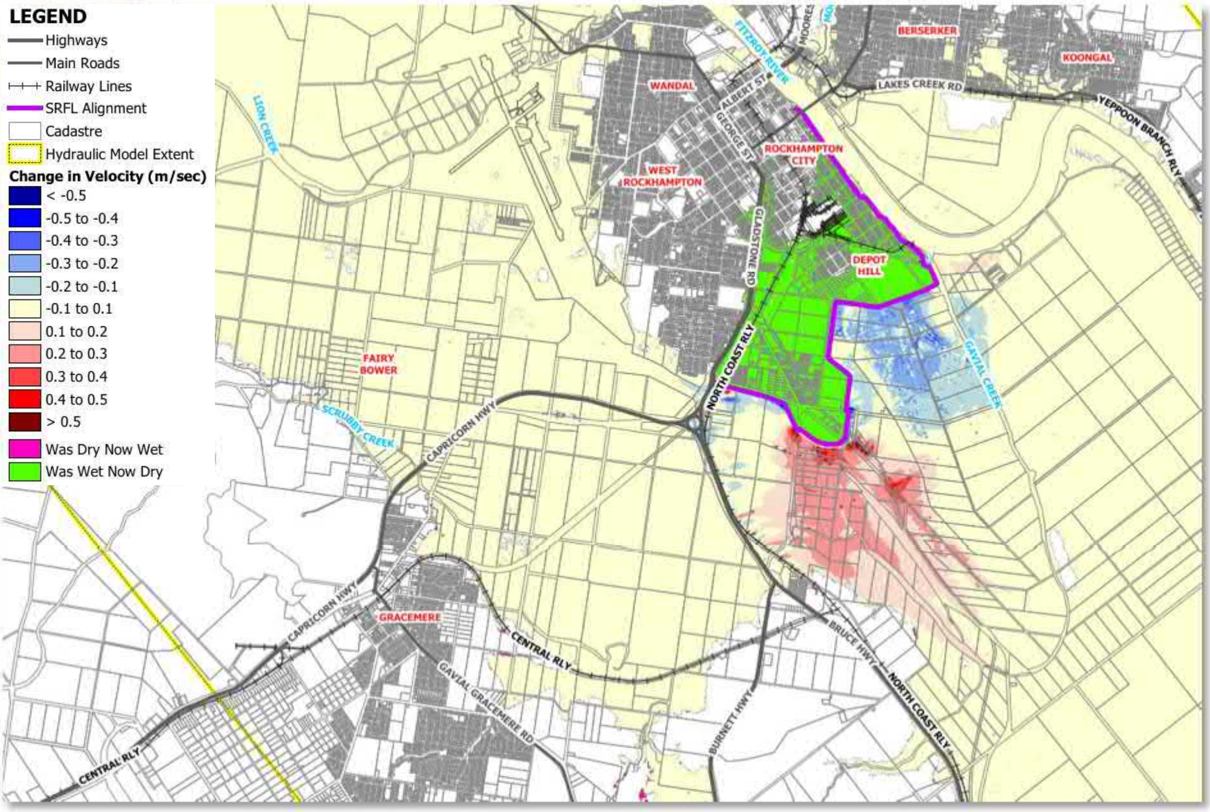


Figure 43 1% AEP Difference in Predicted Peak Flood Velocities

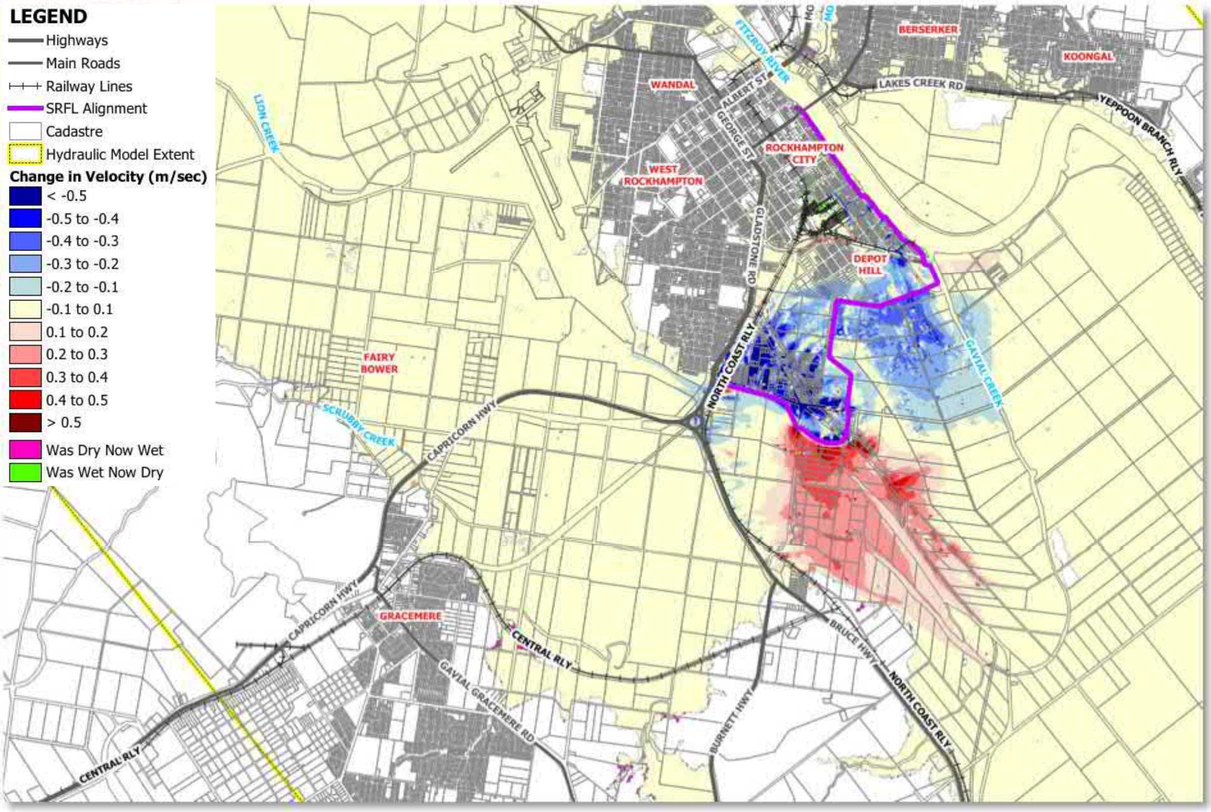


Figure 44 0.5% AEP Difference in Predicted Peak Flood Velocities

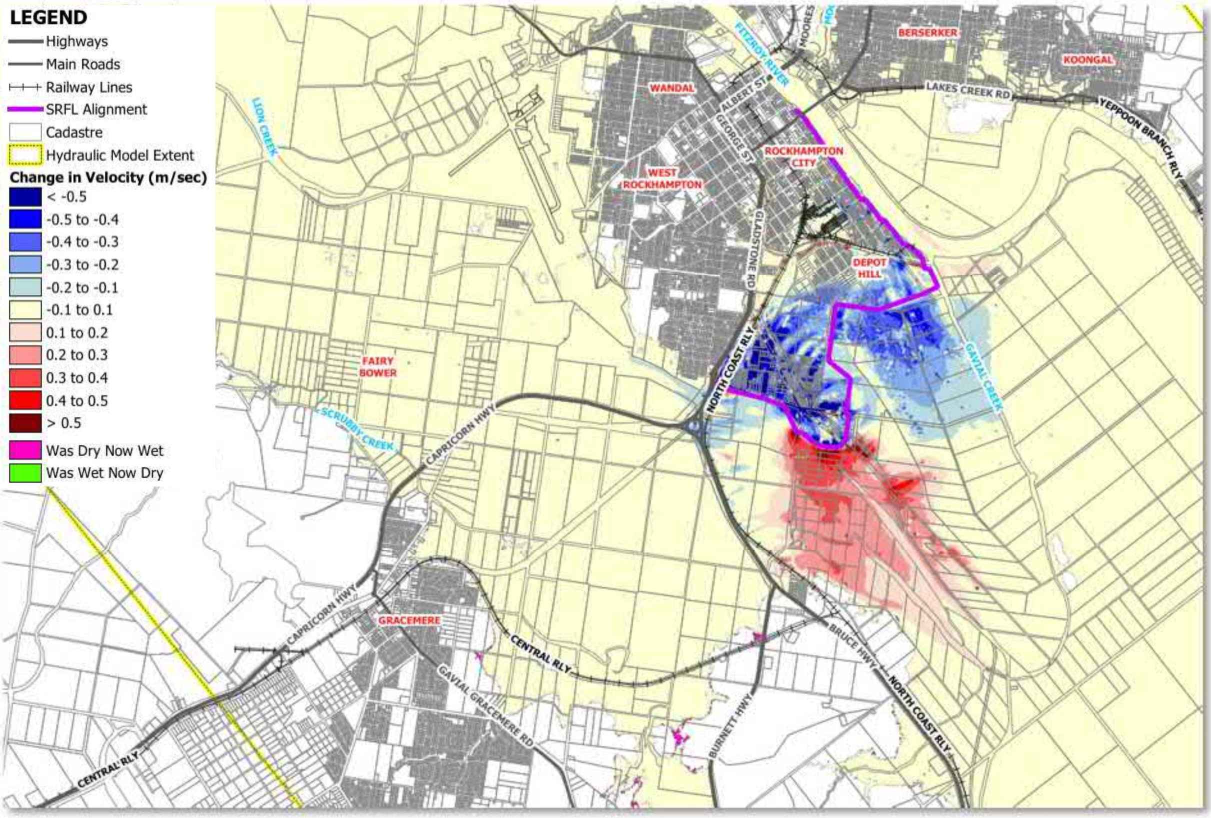


Figure 45 0.2% AEP Difference in Predicted Peak Flood Velocities

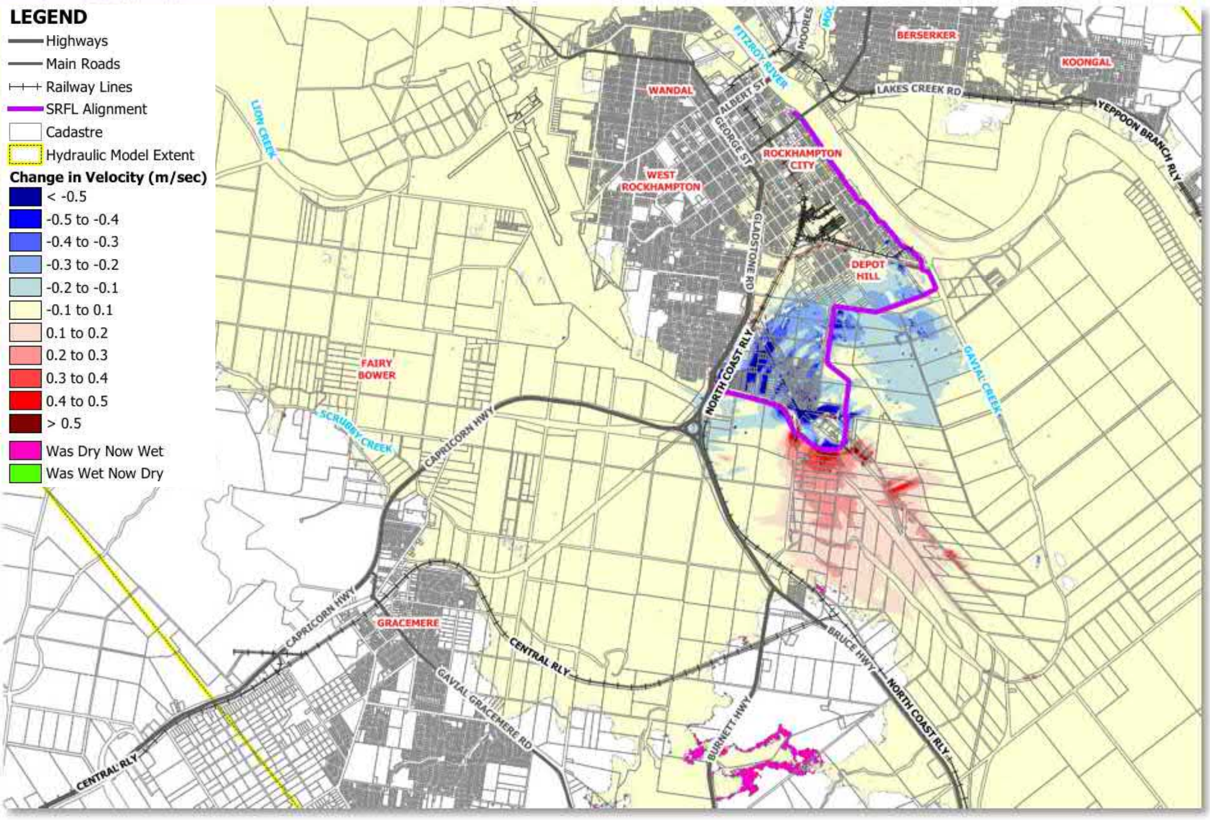


Figure 46 0.05% AEP Difference in Predicted Peak Flood Velocities

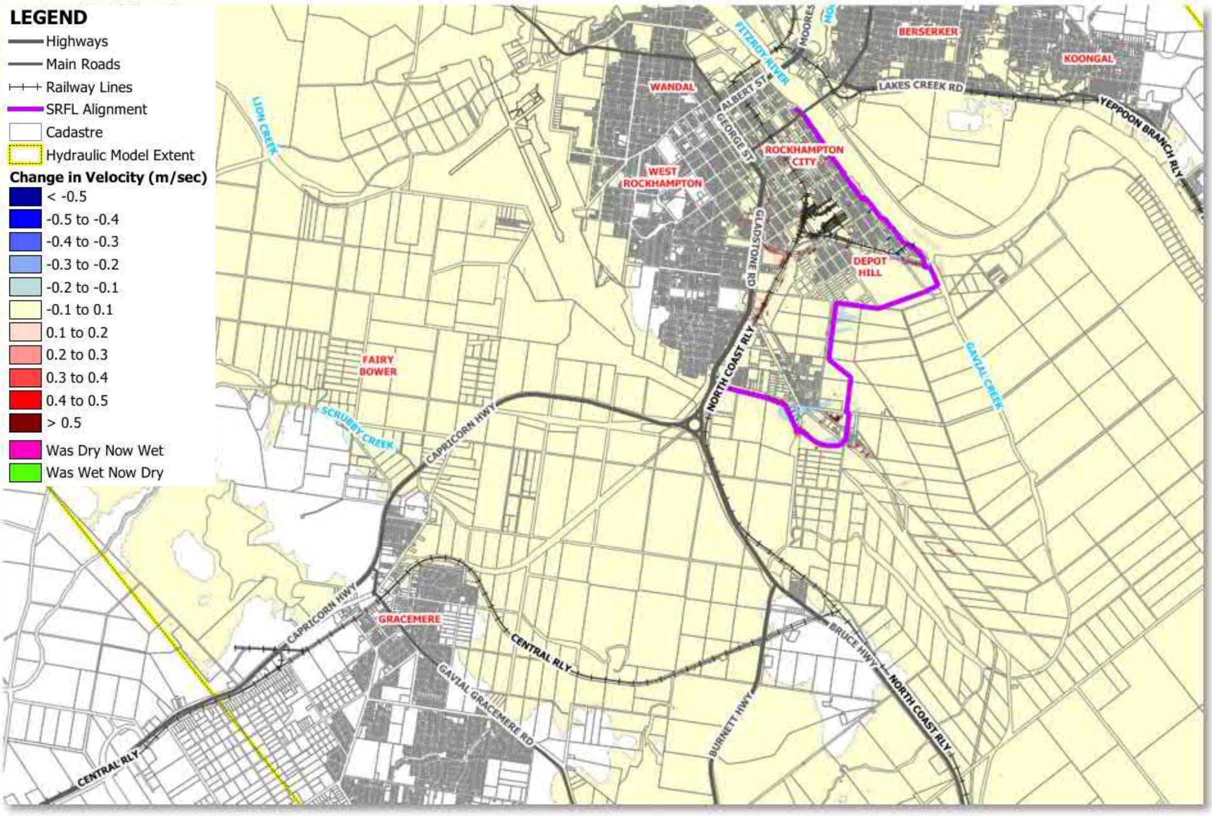


Figure 47 PMF Difference in Predicted Peak Flood Velocities

The difference maps highlight the following:

- Floodplain velocities are expected to increase in areas adjacent to the southern portion of the levee alignment between chainage 1200 m and chainage 2300 m (south of Hastings Deering).
  - This is the result of constriction of the Yeppen North flow path.
  - Modelling indicates that the difference in floodplain velocities will increase in response to increased western floodplain discharge until wide scale overtopping of the levee crest occurs (which is expected to occur in the 0.05% AEP events).
- Floodplain velocities upstream of the southern portion of the levee (between chainage 0 m and chainage 1200 m) are expected to reduce in response to the downstream constriction of the Yeppen North flow path. This is particularly evident at the Rockhampton Roundabout and Yeppen Lagoon road and rail crossing.
- Floodplain velocities adjacent to the central portions of the levee (between Port Curtis Road and the SRSTP) are expected to reduce due to the redistribution of flows to this area as a result of the southern portion of the levee alignment.
- There is predicted to be some increase in floodplain velocity on the northern and southern banks of the lower river meander, adjacent to the Gavial Creek confluence.
- Velocities in the remainder of the floodplain are expected to remain unchanged with reference to the Baseline conditions (± 0.1 m/s difference in velocity).

6.5 Impacts to Key Receptors

6.5.1 Changes to Peak Water Surface Elevations

The predicted Baseline water surface elevations were subtracted from the Developed Case predicted water surface elevations for the 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP, 0.05% AEP and PMF design events, to produce a difference map for each.

Relative water surface elevations were also extracted at the following key receptors:

Table 9 Key Receptor Extraction Locations

Location	Easting (m)	Northing (m)
Existing Low Level Bruce Highway	244,746	7,407,263
Bruce Highway (Yeppen North)	244,479	7,408,991
Blackwater Rail Line	241,524	7,405,803
North Coast Rail Line	244,597	7,408,813
Rockhampton Airport	242,287	7,411,360

It is noted that the increase in water surface elevations vary, however the abovementioned locations have been selected to show the largest predicted increase in water surface levels as a result of the SRFL.

Two Bruce Highway points have been included, the first at the lowest point on the existing low level Bruce Highway and the other adjacent to the raised Jellicoe Street intersection (near the northern abutment of the Yeppen North Bridge). Figure 52 shows the location of the key receptor extraction points.

6.5.1.1 Existing Low Level Bruce Highway

The difference in predicted WSE at the existing low level Bruce Highway is provided in Table 10.

Table 10 Difference in WSE at Existing Bruce Highway

Flood Event	Existing Road Shoulder Level	Baseline WSE (mAHD)	Dev Case WSE (mAHD)	Increase (m)
5%	**7.60mAHD**	8.26	8.31	**+0.05**
2%		8.83	8.91	**+0.08**
1%		9.13	9.29	**+0.16**
0.5%		9.43	9.67	**+0.25**
0.2%		9.81	10.08	**+0.26**
0.05%		10.35	10.53	**+0.19**
PMF		12.61	12.63	**+0.02**

Increases in WSE of up to 0.16 m are predicted in the 1% AEP event, at the lowest point along the existing low level Bruce Highway between the Rockhampton Roundabout and the Burnett Highway intersection. While the predicted impact is less for more frequent events (up to 0.08 m in the 2% AEP event), the increase in WSE is predicted to be larger in less frequent events (up to 0.26 m in the 0.2% AEP event). The predicted impact reduces as the design event approaches the PMF, due to the levee being overtopped and submerged.

This indicates that impacts on WSE at this location are worst in events ranging from 1% AEP to 0.05% AEP magnitude, with the maximum predicted increase being 0.26 m. It is noted however that the existing low level Bruce Highway is inundated at approximately 7.60 mAHD, resulting in 1.53 m of flood depth in a Baseline 1% AEP event. This is predicted to increase to 1.69 m during the Developed Case 1% AEP event.

Associated increases in time of submergence are discussed in Section 6.5.2.

6.5.1.2 Bruce Highway (Yeppen North)

The difference in predicted WSE at the Upgraded Bruce Highway is provided in Table 11.

Table 11 Difference in WSE at Bruce Highway (Yeppen North)

Flood Event	Existing Road Shoulder Level^	Baseline WSE (mAHD)	Dev Case WSE (mAHD)	Increase (m)
5%	**9.50mAHD**	8.29	8.34	**+0.05**
2%		8.90	9.00	**+0.10**
1%		9.24	9.41	**+0.17**
0.5%		9.58	9.82	**+0.24**
0.2%		10.01	10.27	**+0.27**
0.05%		10.63	10.82	**+0.19**
PMF		13.22	13.24	**+0.02**

^Contraflow traffic conditions can occur up to this flood height at the Jellicoe Street intersection.

Due to the concentration of flows through Yeppen North, in comparison to Yeppen South, the predicted increase in WSE is higher at the Yeppen North section of the Bruce Highway than at the existing low level Bruce Highway noted above. As per the design of the Yeppen North crossing, there is no inundation predicted up to and including the 1% AEP Developed Case. Therefore the design flood immunity for the Yeppen Crossing Upgrade will still be retained after construction of the SRFL.

Predicted impacts in WSE during the 0.5% AEP event show that the Jellicoe Street intersection would be inundated during both Baseline and Developed Case conditions. Increases of up to 0.27 m are predicted in the 0.2% AEP event. The predicted impact again reduces as the design event approaches the PMF.

6.5.1.3 Rockhampton Airport

The difference in predicted WSE at the Rockhampton Airport is provided in Table 12.

Table 12 Difference in WSE at Rockhampton Airport

Flood Event	Existing Runway Level	Baseline WSE (mAHD)	Dev Case WSE (mAHD)	Increase (m)
5%	**8.10mAHD**	8.61	8.64	**+0.03**
2%		9.42	9.48	**+0.05**
1%		9.91	9.99	**+0.08**
0.5%		10.34	10.46	**+0.12**
0.2%		10.84	10.97	**+0.13**
0.05%		11.51	11.60	**+0.09**
PMF		14.33	14.34	**+0.01**

The Rockhampton Airport key receptor point is located at the southern extent of Runway 15. This location is inundated at a level of 8.10 mAHD and is therefore predicted to experience flood depths of up to 1.81 m during a Baseline 1% AEP event. This is predicted to increase to 1.89 m in a 1% AEP Developed Case event.

The pattern on increased WSE mirrors other key receptor locations discussed above, whereby the highest increase is predicted during for events ranging from the 1% AEP to 0.05% AEP. Lesser impacts are predicted in more frequent events, with the impact again dropping away as the design event approaches the PMF.

Time of submergence changes are discussed in Section 6.5.2.

6.5.1.4 Blackwater Rail Line

The difference in predicted WSE at the Blackwater Rail Line is provided in Table 13.

Table 13 Difference in WSE at Blackwater Rail Line

Flood Event	Existing Formation Level	Baseline WSE (mAHD)	Dev Case WSE (mAHD)	Increase (m)
5%	7.68mAHD	8.29	8.34	+0.05
2%		8.94	9.03	+0.09
1%		9.31	9.46	+0.15
0.5%		9.66	9.88	+0.22
0.2%		10.11	10.34	+0.24
0.05%		10.75	10.92	+0.17
PMF		13.39	13.41	+0.01

Inundation of rail lines is commonly taken as the point at which flood levels reach Formation level. For the Blackwater Rail Line the lowest Formation level within the SRFL impact area is 7.68 mAHD. As can be seen in Table 13 the Blackwater Rail Line formation level is predicted to experience 1.71 m of flood depth during the Baseline 1% AEP event. This is predicted to increase to 1.78 m in the Developed Case 1% AEP event.

Predicted increases in WSE are largest in events ranging from 0.5% AEP to 0.05% AEP, with more frequent events showing lower predicted impacts. As has been the case for all other key receptors, the predicted impact again drops away as the design event approaches the PMF

Time of submergence changes are discussed in Section 6.5.2.

6.5.1.5 North Coast Rail Line

The difference in predicted WSE at the North Coast Rail Line (NCRL) is provided in Table 14.

Table 14 Difference in WSE at North Coast Rail Line

Flood Event	Existing Formation Level	Baseline WSE (mAHD)	Dev Case WSE (mAHD)	Increase (m)
5%	6.88mAHD	8.08	8.21	+0.13
2%		8.64	8.90	+0.26
1%		8.96	9.30	+0.35
0.5%		9.25	9.70	+0.44
0.2%		9.63	10.10	+0.48
0.05%		10.16	10.52	+0.36
PMF		12.39	12.44	+0.04

As noted above, the inundation level for rail lines has been taken as Formation level. Difference in WSE was extracted at three locations along the NCRL between Jellicoe Street and Burnett Highway (refer Figure 48 to Figure 51). The lowest of these is location 2, which has a Formation level of 6.88 mAHD. The difference in WSE reported in Table 14 has been extracted from this lowest location. It can be seen that Formation level is predicted to be inundated in all events of 5% AEP magnitude and larger, for both Baseline and Developed Case conditions.

The largest increases in WSE are predicted during events from 1% AEP to 0.05% AEP, with the impact during a 1% AEP event predicted to be 0.35 m, rising to 0.48 m in the 0.2% AEP event. Lesser impacts are predicted in the 5% AEP and PMF events. An inundation depth above Formation of 2.08 m in the Baseline 1% AEP event is predicted to increase to 2.42 m in the Developed Case 1% AEP.

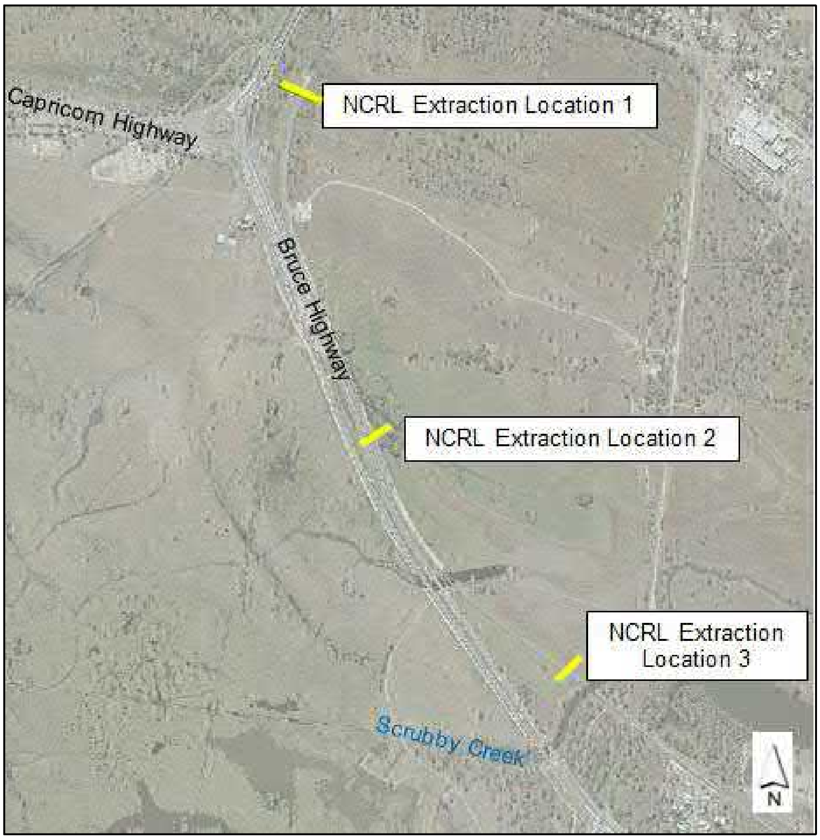


Figure 48 North Coast Rail Line Data Extraction Locations

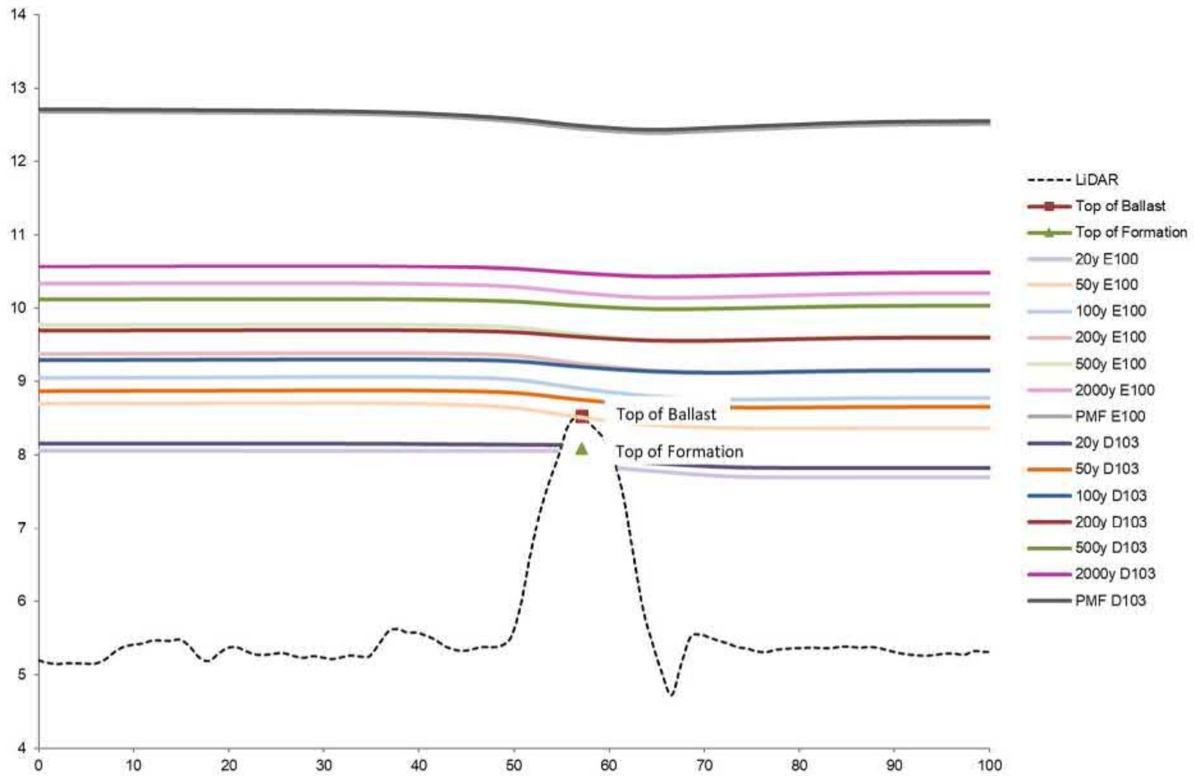


Figure 49 WSE at NCRL Extraction Location 1

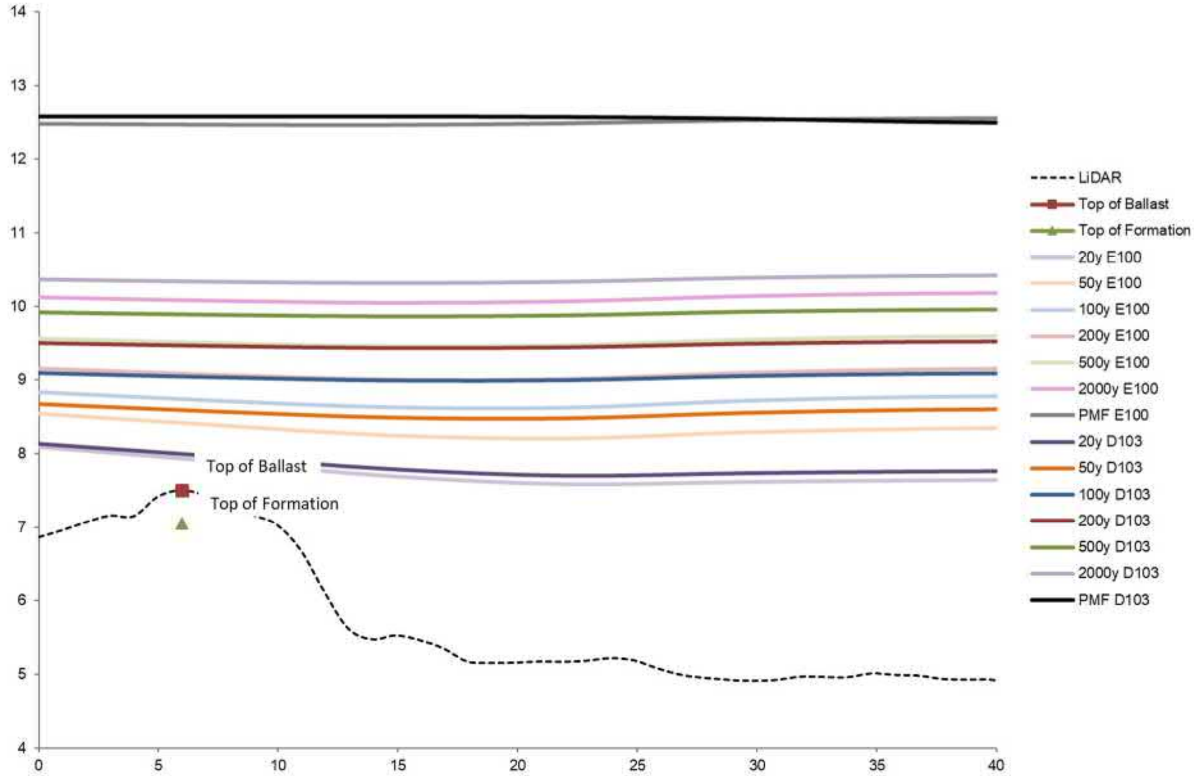


Figure 50 WSE at NCRL Extraction Location 2

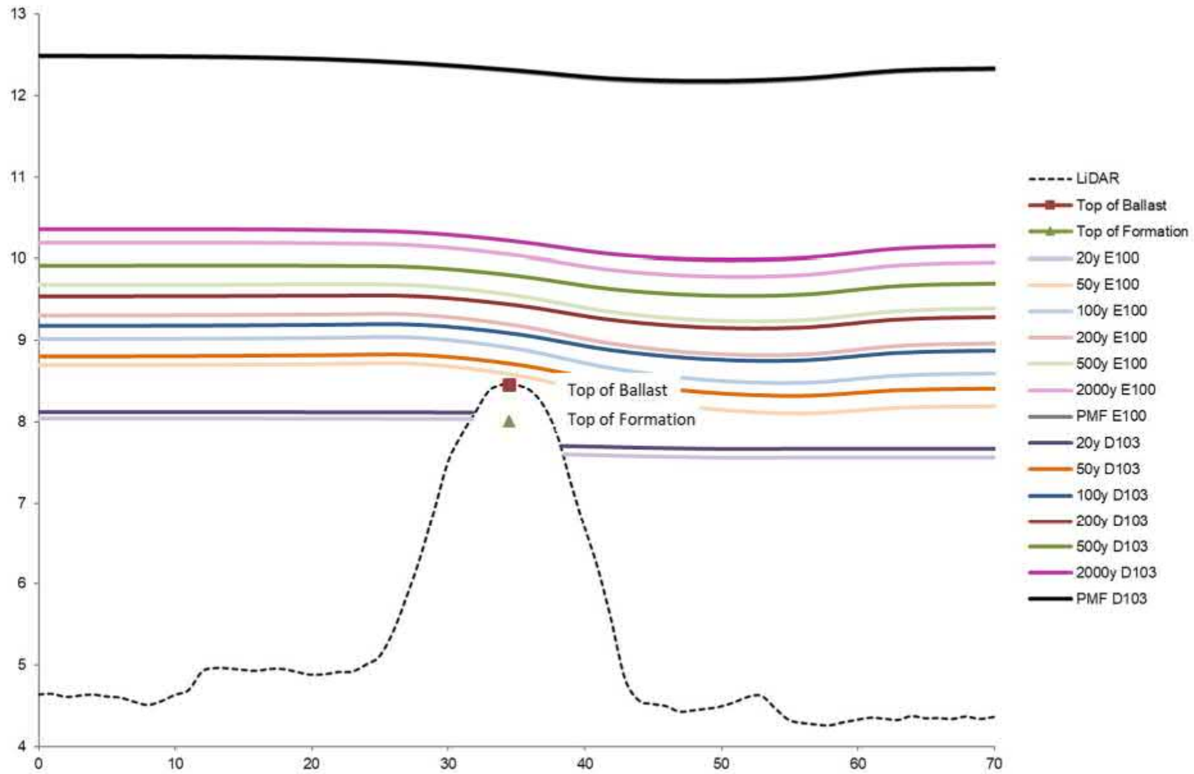
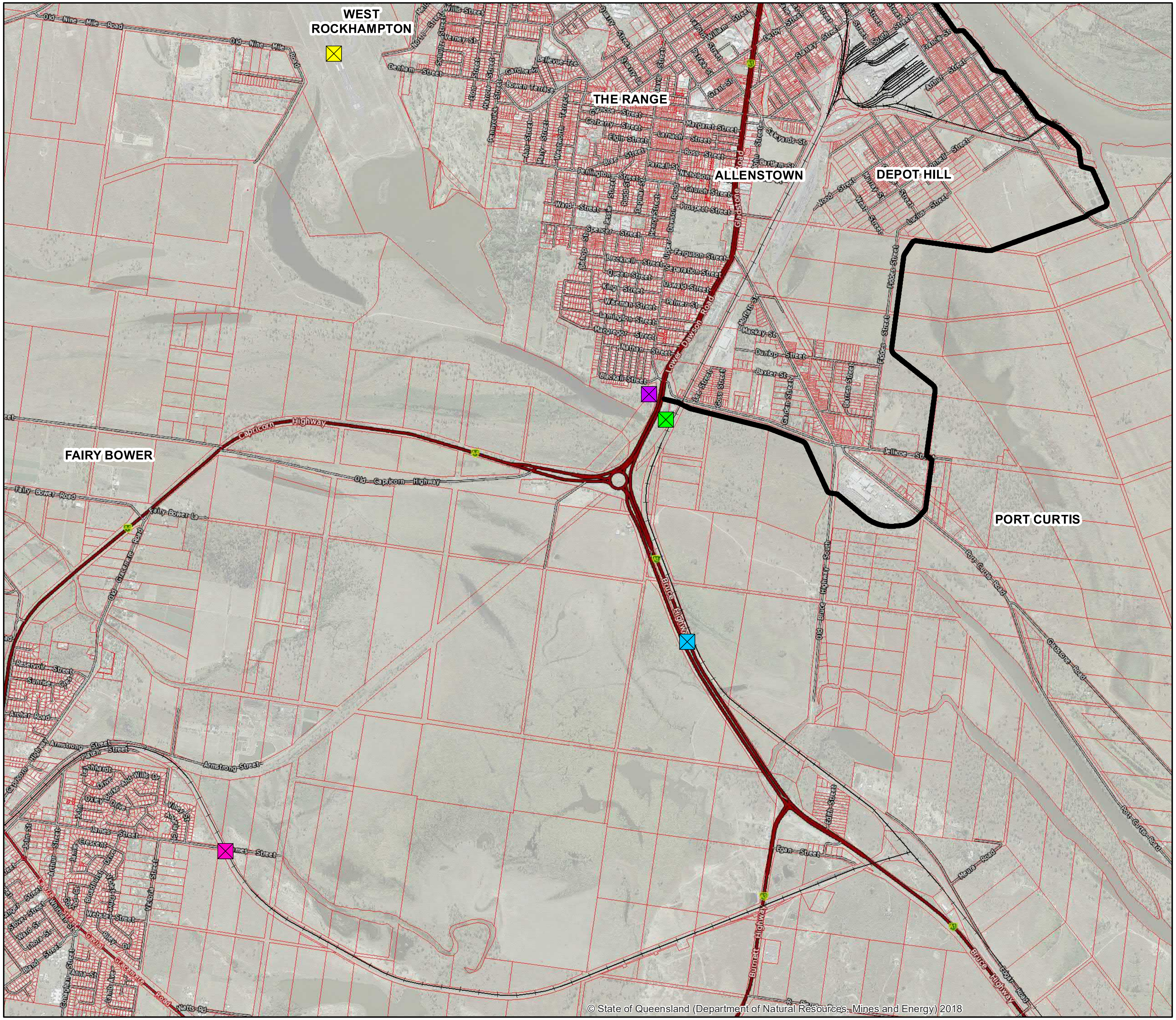


Figure 51 WSE at NCRL Extraction Location 3



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LEGEND

Key Receptor Extract Locations

- Blackwater Rail Line
- Bruce Highway (Yeppen North)
- Existing Low Level Bruce Highway
- North Coast Rail Line
- Rockhampton Airport
- Proposed Levee Alignment
- Cadastre

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

SOUTH ROCKHAMPTON FLOOD LEVEE

Key Receptor Extraction Locations

PROJECT ID	60589157
CREATED BY	maultbyj
LAST MODIFIED	21/03/2019
VERSION:	1

Figure 52

Filename: P:\605x\60589157\900_CAD_GIS\920_GIS\MXD's\Hydraulic Assessment Report\Key Receptor Extraction Locations.mxd

6.5.2 Changes to Time of Submergence

Whilst maintaining existing flood immunity is an important consideration for an asset owner, the actual disruption to transport (road, rail or air) depends on the frequency and duration of submergence. An increase in water surface elevation associated with the SRFL is expected to have an impact to the submergence times experienced in the floodplain. This is a particularly important factor due to the long submergence times generally experienced in Fitzroy River flood events.

Five key receptors have been identified in which the change in TOS has been calculated for the 5% AEP, 2% AEP and 1% AEP events. Values for the extreme events have not been included, as the estimation of TOS for these events requires the extrapolation of the hydrograph duration and volume frequency curves beyond the limit of the recorded data (refer to the Inflow Hydrograph Review Report for further information). This would result in considerable uncertainty in the reported values. Table 15 summarises the predicted change to TOS at each receptor for each of the design flood events.

The key receptors are outlined below:

- Existing Low Level Bruce Highway (244746E, 7407263N), between the Rockhampton Roundabout and Burnett Highway.
- High Level Yeppen North Bridge (244479E, 7408991N), Jellicoe Street intersection near northern abutment.
- Blackwater Rail Line (241524E, 7405803N), between Burnett Highway and Gracemere.
- North Coast Rail Line (244597E, 7408813N), between the Rockhampton Roundabout and Burnett Highway.
- Rockhampton Airport (242287E, 7411360N).

Table 15 Time of Submergence Summary (5% AEP to 1% AEP)

Location	Trigger Level (mAHD)	5% AEP TOS (days)		TOS Change (hours)	2% AEP TOS (days)		TOS Change (hours)	1% AEP TOS (days)		TOS Change (hours)
		Baseline	Design		Baseline	Design		Baseline	Design	
Existing Low Level Bruce Highway	7.60*	7.9	8.0	+2	10.8	11	+4	12.2	12.3	+4
Yeppen North (Jellicoe Street intersection)	9.50	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
Blackwater Line	7.68#	7.5	7.7	+2	10.7	10.8	+2	12.2	12.3	+4
North Coast Line	6.88#	7.8	8.0	+4	12.5	12.6	+4	13.7	13.8	+4
Rockhampton Airport	8.10	8.5	8.5	-	11.2	11.3	+2	12.3	12.4	+2

* Submergence level is taken on the existing Bruce Highway alignment – i.e. not the new Yeppen North / Yeppen South works.

Submergence level taken as 0.72 m below top of rail level.

6.5.3 Implications for the Bruce Highway

Whilst there is expected to be an increase in TOS for the existing low level Bruce Highway, a key consideration is any change to the expected flood immunity of the Yeppen North and Yeppen South projects resulting from the construction of the SRFL.

The existing Yeppen Crossing (Bruce Highway) has been extensively investigated by TMR as part of the Fitzroy River Floodplain and Road Planning Study, Yeppen North and Yeppen South projects. The existing low level Bruce Highway has less than 5% AEP immunity and has historically been inundated for long periods of time during Fitzroy River flood events. The Yeppen North and South Bridges are a 1% AEP immune road link across the Yeppen floodplain.

With reference to Section 6.5, the SRFL is predicted to increase water surface levels adjacent to the Jellicoe Street intersection by 0.30 m in the 1% AEP flood event. Whilst an increase in flood level is predicted, the proposed levee is not expected to result in overtopping of the bridges or embankment associated with the Yeppen North and Yeppen South projects in a 1% AEP flood event.

The hydraulic modelling shows that the 1% AEP peak water surface elevations at the proposed Yeppen North and Yeppen South embankments vary between 9.35 mAHD and 9.47 mAHD. A comparison between the 1% AEP Developed Case water surface elevations and adopted design levels for each of the high level road embankments has been provided below.

Table 16 Comparison between Water Surface Elevations at Yeppen North / Yeppen South High Level Embankments

Yeppen North / Yeppen South High Level Embankment	Minimum Design Level (m AHD)	1% AEP Water Surface Elevation with SRFL (m AHD)
Jellicoe Street Intersection	9.50	9.41
Yeppen North Transition Embankment	10.80	9.43
Yeppen South Transition Embankment	9.90	9.39
Burnett Highway Intersection	9.60	9.36

6.5.4 Rail Line Track Closure Criteria

The North Coast Rail Line, adjacent to the Bruce Highway, is the single rail route connecting Brisbane to Cairns (a Queensland Rail asset). The Blackwater Rail Line, which tracks around the southern edge of the floodplain, is the main western line connecting major industry west of Rockhampton to the export facilities on the coast (an Aurizon asset). Both of these rail lines are anticipated to be affected by the SRFL.

Previous consultation with QR and AURIZON noted that track closure is to be taken to occur where floodwaters reach the formation level (0.72 m below top of rail).

6.5.5 Maintenance Implications for the Blackwater Rail Line

During consultation with Aurizon in 2014, the following additional information has been requested for the assessment of potential maintenance implications:

- The additional length of track which will now be impacted as a result of the SRFL, where flood water is above the formation level.
- The additional length of track which will now be submerged as a result of the SRFL, where additional scour protection may be required.

Water surface levels were extracted from the hydraulic model along the existing Blackwater Rail Line alignment under Baseline and Developed Case scenarios. These flood heights were compared to existing rail levels shown on drawings previously provided, in order to determine the additional length of track which would be affected by the SRFL in the 5% AEP, 2% AEP and 1% AEP flood events.

A summary of the findings for the Blackwater Rail line are as follows:

- No track submergence is predicted in a Baseline or Developed Case 5% AEP flood event.
- An additional 40 m of rail formation is likely to be submerged as a result of the SRFL in a 2% AEP flood event.
- An additional 40 m of rail formation is likely to be submerged as a result of the SRFL in a 1% AEP flood event.

Drawings showing the Blackwater Rail Line inundation extents have been included as Appendix A.

6.6 Building Impact Assessment

6.6.1 Adopted Approach

The following approach has been adopted to determine the expected building impacts as a result of the SRFL project:

- A building database was developed based on the following available building databases (refer to Section 6.6.2 for further details):
  - **TMR:** surveyed structures (buildings and major sheds) throughout the western floodplain.
  - **RRC:** surveyed and GIS-derived structures throughout the urban flood fringes (within the PMF flood event)
  - **DNRME:** QLD building database used as a logical check against the abovementioned databases to ensure key structures were captured in the final database.
- Water surface elevations and velocities were extracted from the Baseline and Developed Case model simulations at each of the buildings included in the database. The incremental changes to flow velocity and flood height have been summarised for the range of flood events simulated.
- The number of predicted buildings deemed to be impacted by the levee was determined based on the impact classifications stipulated in the QLD Levee Guidelines and Minister’s Requirements.
- Limitations and sensitivities have been clearly identified.

6.6.2 Building Database

A building database was developed in order to estimate the predicted impacts to existing buildings external to the proposed levee. The database was developed based on the following available data sets:

- Existing SRFL dataset (mixture of surveyed and GIS-derived floor heights).
- Post-2014 TMR surveyed floor levels (297).
- Post-2014 RRC surveyed floor levels (4,180). RRC have undertaken broad-scale Mobile Laser Scanning (MLS) and imagery capture of properties and floor levels throughout floodplain areas (up to 0.2% AEP).
- DNRME’s QLD buildings (serving as a check for missing structures).

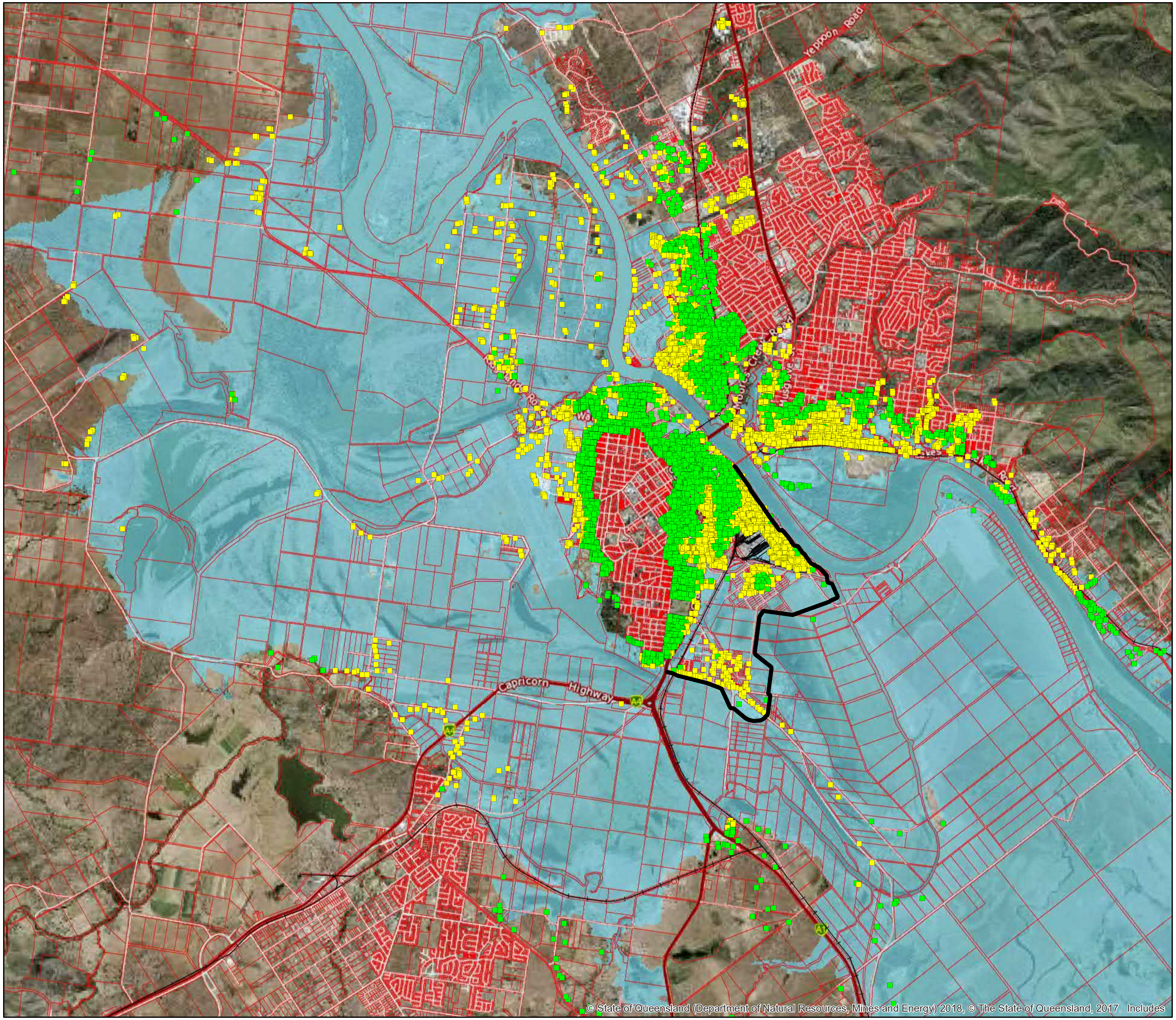
In addition, a high-level review of recent developments was undertaken to capture additional structures within the modelled flood extents. Where surveyed flood levels were unavailable, the ground level was estimated based on the 1m (horizontal spacing) 2015/16 LiDAR DEM. Low set residential buildings and commercial buildings were assumed to have a floor level 0.1m above ground level. High-set structures were estimated using Google street-view and were assumed to have a floor level 1.8m above the ground.

The final database included **9,767 buildings**, representing the majority of structures within the PMF flood extent. Figure 53 shows the spatial distribution of the buildings and type of data adopted (RRC / TMR survey or GIS estimation etc).

6.6.3 Limitations

As noted above, there are a number of existing buildings which are predicted to be affected by the levee which were not included in the surveyed database provided by RRC and TMR. Due to timing and cost constraints, supplementary survey of these buildings was not feasible and therefore a GIS based method was adopted. In preparing the building survey database, there were a number of limitations that are noted below:

- Large building complexes, e.g. shopping centres, strip malls and warehouses were digitized as multiple buildings where a clear delineation between individual buildings could readily be identified. If a group of buildings could not be digitized separately based on the aerial image, this could skew the estimate of impacted structures.
- For multi-floor buildings, only the lowest floor level elevation was estimated.



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LEGEND

Proposed Levee Alignment

Building Floor Levels

Surveyed

GIS-Derived

Cadastre

1% AEP Flood Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

SOUTH ROCKHAMPTON FLOOD LEVEE

Building Database Overview

PROJECT ID 60589157
CREATED BY maultbyj
LAST MODIFIED 3/04/2019
VERSION: 1

Figure 53

Filename: P:\605x\60589157\900_CAD_GIS\920_GIS\MXD's\Hydraulic Assessment Report\Surveyed Buildings.mxd

6.6.4 Building Impacts and Benefits (Minister's Requirements)

The buildings deemed to be impacted by the levee were determined based on the impact classifications provided in the QLD Levee Guidelines:

- The building is flooded above floor in the SRFL design case;
- The increase in flooding is >50mm above the floor; **or**
- The increase in velocity above the floor is >0.2m/s.

The results are summarised in Table 17.

Table 17 Summary of Impacted Buildings

Flood Event AEP (%)	Buildings where >50mm Increased Water Surface Levels Above Floor Level	Buildings where >0.2m/s Increased Velocities Above Floor Level	Total Number of Buildings Affected *
5	5	0	5
2	47	1	48
1	127	1	128
0.5	168	3	171
0.2	212	12	224
0.05	252	20	272
PMF	0	51	51

* Buildings affected by increased flood height have been cross checked against increased velocities to prevent double counting.

6.6.4.1 Estimated Affected Population and Categorisation

The QLD Levee Guidelines are not clear on the design event used to determine the levee category. It is noted that building impacts (and therefore estimated population affected) varies depending on the design flood event adopted.

In any case, it is clear that the SRFL is predicted to impact 2 or more buildings in each design flood event and consequently the SRFL will result in an affected population greater than 2 (with reference to the default population values assigned in Appendix E of the QLD Levee Guidelines).

Therefore, the SRFL is a Category 3 levee with reference to the QLD Levee Regulations.

6.6.5 Detailed Building Impact Assessment

Building impacts were investigated further in order to gain an appreciation for the predicted benefits and impacts associated with building floor levels. Five categories have been defined to assess the benefit / consequence and are summarised in Table 18.

Table 18 Building Impact Categories

Category	Description
1	**Category 1 – No Change / Building Not Flooded in Baseline or Design Case Scenarios^**
2	**Category 2 – Building inundated above floor level in Baseline Scenario, but not inundated above floor level in the Design Case Scenario**
3	**Category 3 – Building inundated above floor level in Baseline Scenario and receives a flood depth decrease of >=10mm in the Design Case Scenario^**
4	**Category 4 – Building not inundated above floor level in Baseline Scenario, but is inundated above floor level in the Design Case Scenario**
5	**Category 5 – Building inundated above floor level in Baseline Scenario and receives a flood depth increase of >=10mm in the Design Case Scenario^**

^ Note: Category 1, 3 and 5 buildings have been omitted from the building impact maps within this report.

A spatial assessment of the building impacts for each scenario is provided in the building impact maps presented in Volume 2 of this report.

6.6.5.1 Benefited Buildings

The number of benefited buildings is determined based on the criteria for Category 2 and 3, where:

- **Category 2** describes the **removal** of above floor flooding for the defined flood magnitude; and
- **Category 3** describes the **decrease** of flood height above floor (building remains flooded).

The total number of buildings determined to be within these categories due to construction of the SRFL are presented in Table 19.

Table 19 Building Benefits due to SRFL

Event	Category 2		Category 3	
	Buildings	Sheds	Buildings	Sheds
5% AEP	74	1	0	0
2% AEP	165	1	5	0
1% AEP	312	1	24	0
0.5% AEP	139	0	496	1
0.2% AEP	119	0	788	1
0.05% AEP	48	0	1,772	1
PMF	0	0	10	0

Category 2 buildings are shown spatially in Figure 55 to Figure 61.

6.6.5.2 Impacted Buildings

The number of impacted buildings are determined based on the criteria for Category 4 and 5, where:

- **Category 4** describes the **addition** of above floor flooding for the defined flood magnitude; and
- **Category 5** describes the **increase** of flood height above floor.

The total number of buildings determined to be within these categories due to construction of the SRFL are presented in Table 19.

Table 20 Building Impacts due to SRFL

Event	Category 4		Category 5	
	Buildings	Sheds	Buildings	Sheds
5% AEP	1	0	58	8
2% AEP	7	0	114	18
1% AEP	10	0	223	31
0.5% AEP	26	0	601	75
0.2% AEP	33	0	1085	145
0.05% AEP	12	0	1058	149
PMF	0	0	305	19

Category 4 buildings are shown spatially in Figure 55 to Figure 61.

The buildings predicted to experience additional above floor impacts during the 1% AEP event (design flood immunity) have been further investigated in Table 21. This detailed analysis reveals the following key points:

- **All impacted buildings are anticipated to have 50mm or less of flooding above floor during the 1% AEP post-SRFL construction scenario.**
- One of the structure's floor height was predicted to be level with the 1% AEP baseline peak flood height. It is noted that this height is static and does not include provision for debris, wave run-up or velocity head which may increase the peak flood height during an actual event.

Table 21 1% AEP Impacted Buildings Detail

Building Unique ID	Floor Height (mAHD)	Peak Flood Height (mAHD)		Baseline Depth Below Floor (m)	Post-SRFL Construction Depth Above Floor (m)
		Baseline	Post-SRFL Construction		
7929	9.99	9.91	10.00	-0.08	+0.01
5724	10.29	10.26	10.30	-0.03	+0.01
7042	10.01	9.95	10.03	-0.06	+0.02
7238	10.00	9.94	10.02	-0.06	+0.02
7146	9.99	9.94	10.02	-0.05	+0.03
7149	9.99	9.94	10.02	-0.05	+0.03
9654	9.66	9.57	9.69	-0.09	+0.03
2631	8.68	8.68	8.71	-	+0.03
6347	10.08	10.06	10.13	-0.02	+0.05
9684	9.12	9.02	9.17	-0.10	+0.05

6.6.5.3 Summary of Building Inundation

The anticipated number of buildings flooded above floor for the range of simulated design events is tabulated in Table 22 and plotted alongside the **Category 2** benefits and **Category 4** impacts. Of key note is:

- Additional above floor impacts are absent during the 5% AEP event.
- The number of benefited buildings heavily outweighs impacted buildings, especially during frequent events.

Table 22 Summary of Buildings Flooded Above Floor

Flood Event AEP (%)	Number of Buildings Flooded Above Floor^		Category 2: Above Floor to Not Flooded	Category 4: Not Flooded to Above floor	Net Difference
	Baseline	Post-SRFL Construction			
5	239	165	75	1	-74
2	507	348	166	7	-159
1	906	603	313	10	-303
0.5	1536	1423	139	26	-113
0.2	2369	2283	119	33	-86
0.05	3534	3498	48	12	-36
PMF	7607	7607	0	0	-

^ Note: Buildings to be demolished prior to construction of the SRFL have been excluded from the analysis.

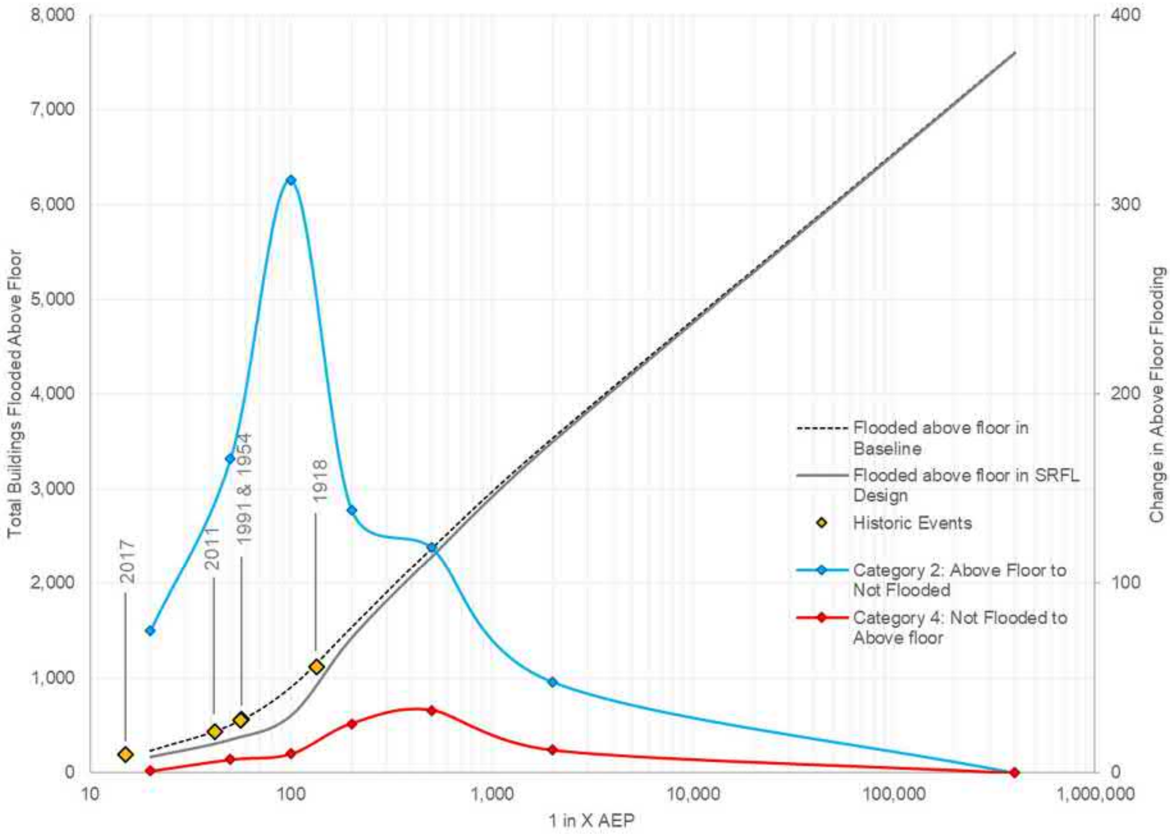

Figure 54 Number of buildings flooded above floor vs. impacts and benefits

6.6.6 Impact and Benefits Mapping

Category 2 benefits and **Category 4** impacts associated with construction of the SRFL are presented in Figure 55 to Figure 61.

As can be observed, benefits are generally limited to the area protected by the SRFL. Some additional benefits are anticipated within North Rockhampton during the 0.05% AEP event (see Figure 60) due to minor (<50mm) reductions in peak flood height, resulting in removal of the flood extent from the building footprint.

Impacts generally well-spread across areas where the increase in peak flood height is expected to be <50mm (Wandal and North Rockhampton). This indicates that these impacted structures are close to flooding above floor in the relative baseline flood event. Remaining impacts generally propagate in clusters where increase in peak flood height is expected to be >50mm. These primary areas of impacts are summarised as:

- Fairybower, along the fringes of the western floodplain.
- West Rockhampton, between Kalare Street and Denham Street.

Other impacted areas include properties on the flood fringe at Blackall Street (The Range), Edith Street (east of the Yeppen South Bridge southern entrance) and Port Curtis Road, southeast of the SRFL. Each figure should be inspected alongside the data presented in Table 22.

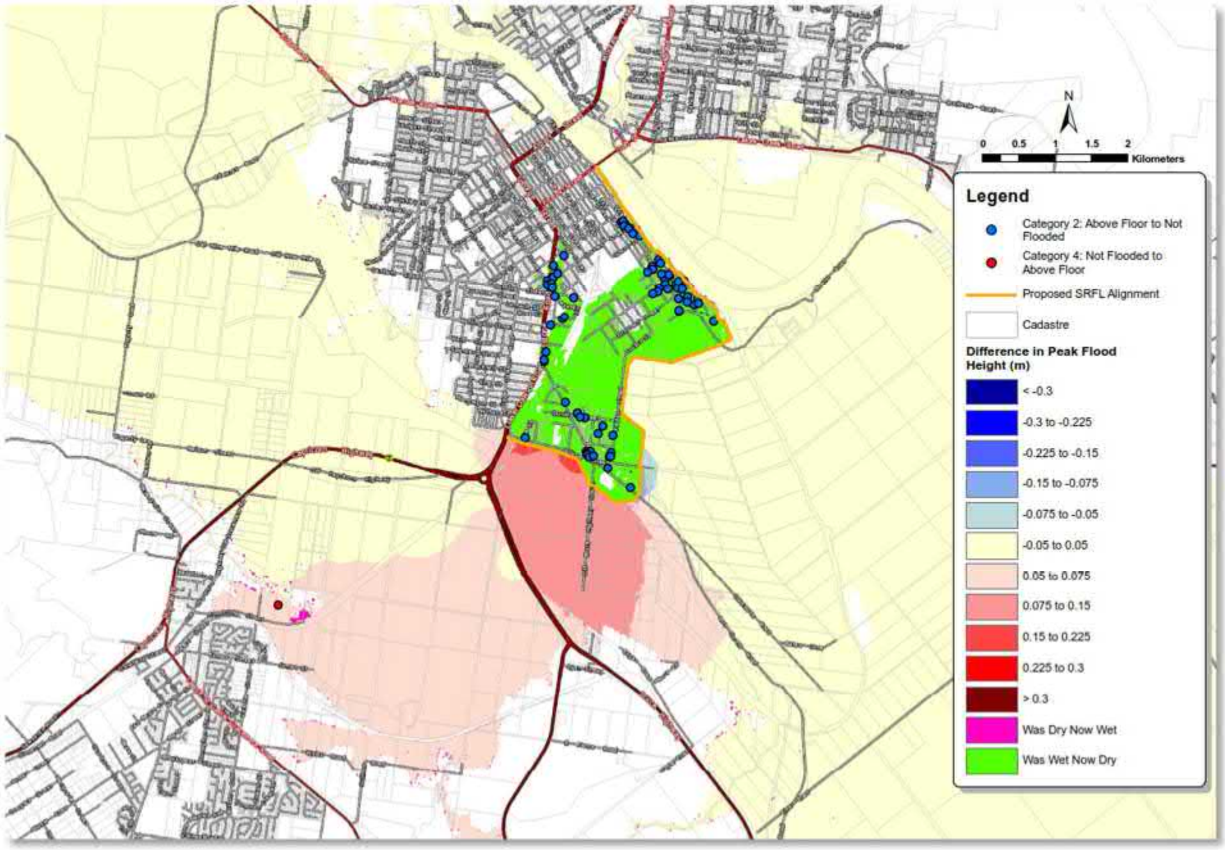

Figure 55 Spatial distribution of impacted and mitigated buildings (5% AEP)

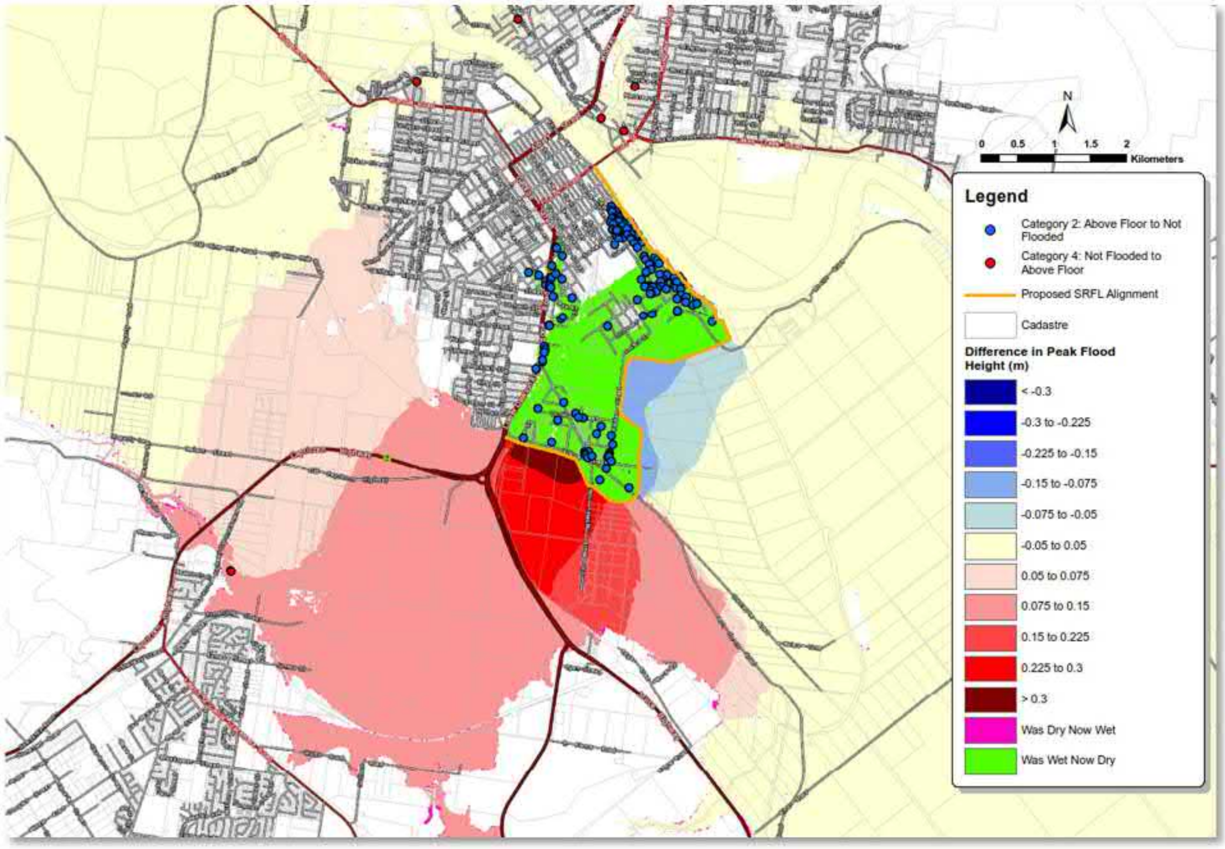

Figure 56 Spatial distribution of impacted and mitigated buildings (2% AEP)

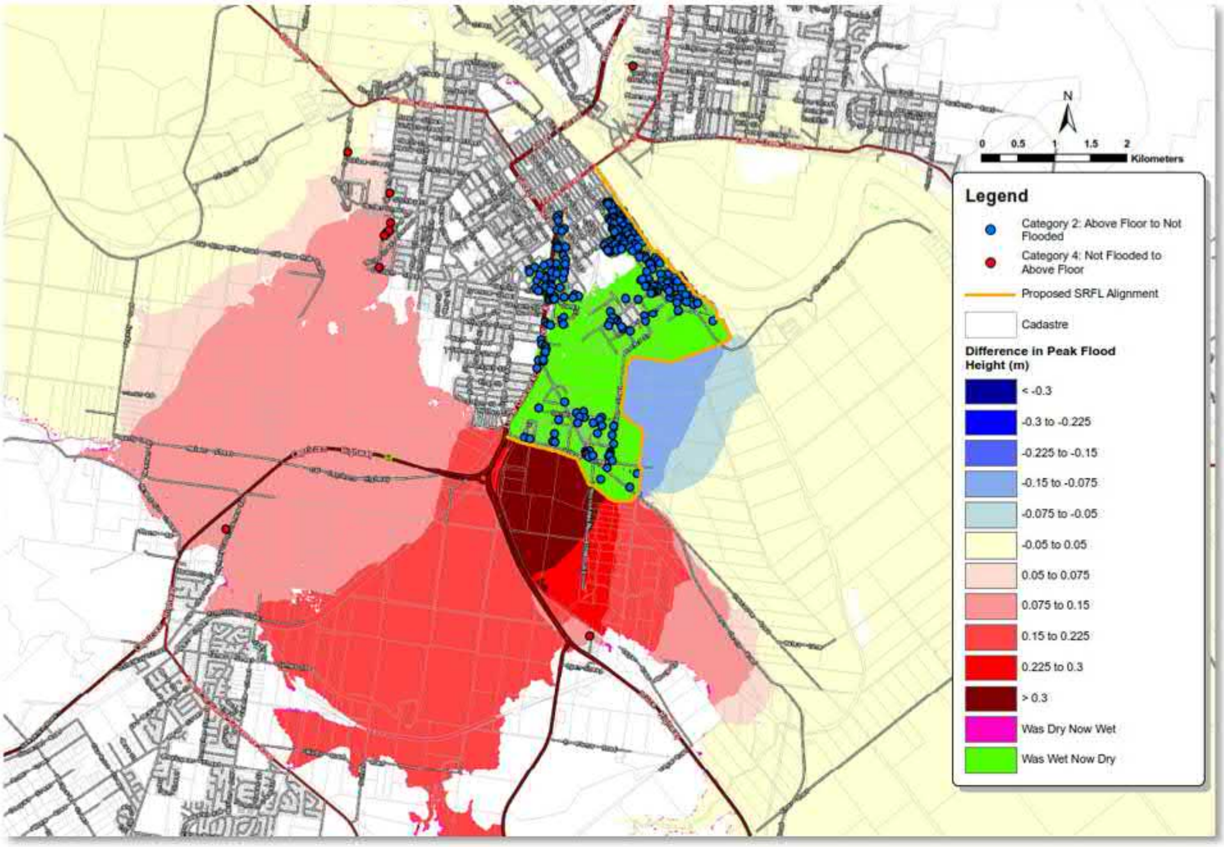

Figure 57 Spatial distribution of impacted and mitigated buildings (1% AEP)

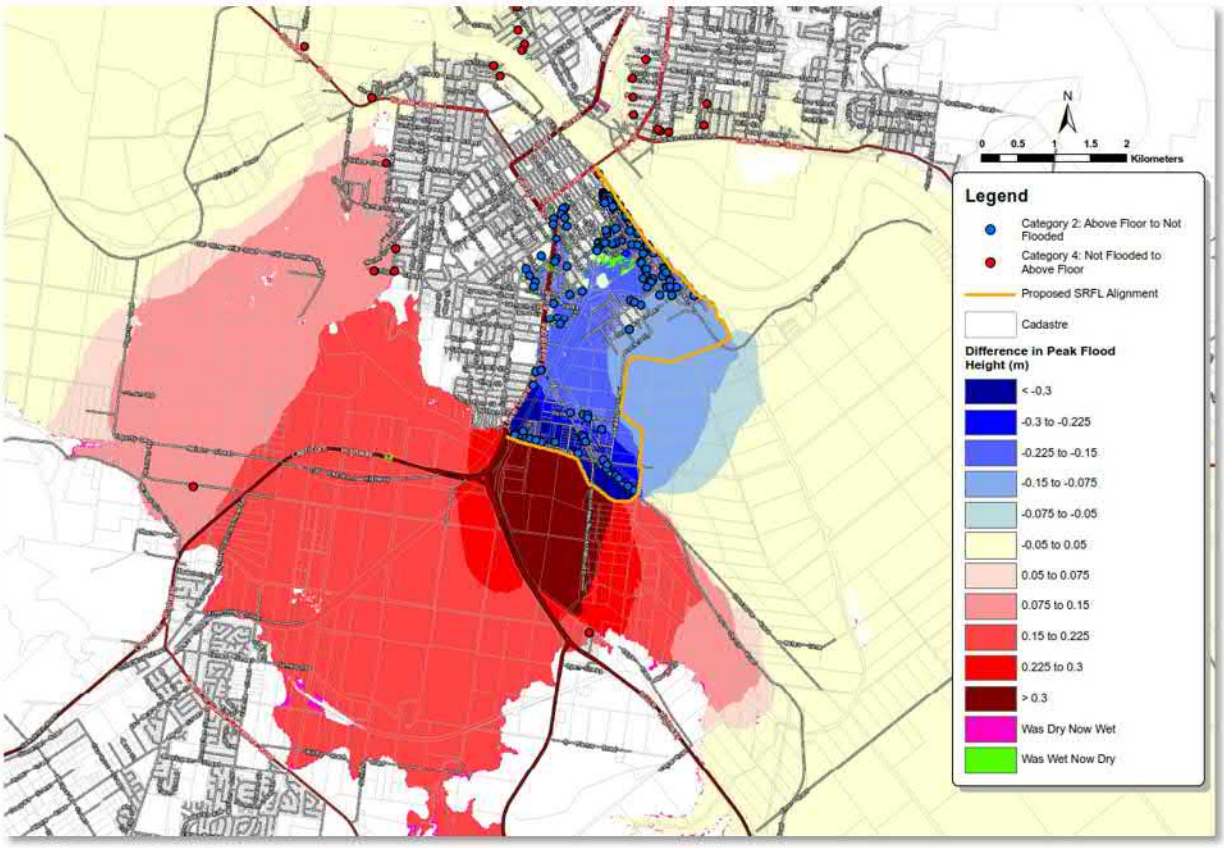

Figure 58 Spatial distribution of impacted and mitigated buildings (0.5% AEP)

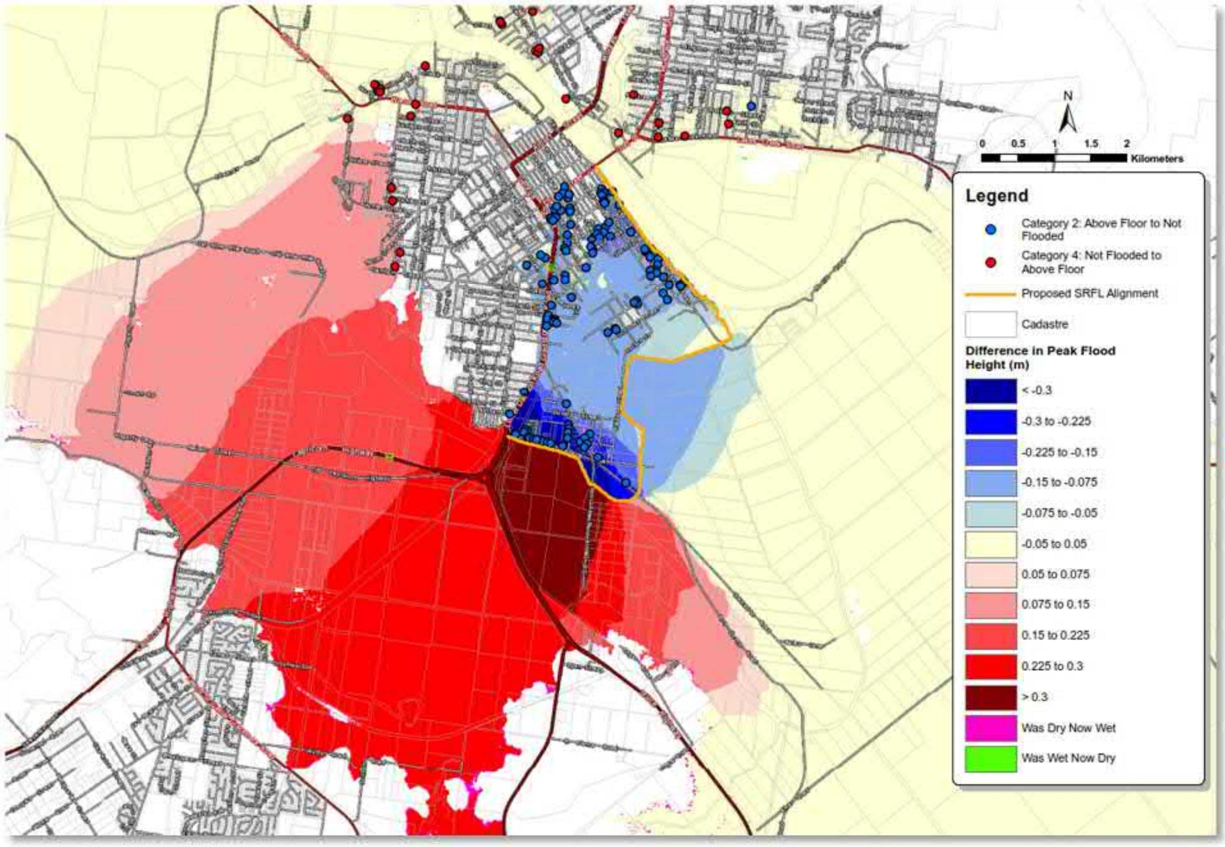

Figure 59 Spatial distribution of impacted and mitigated buildings (0.2% AEP)

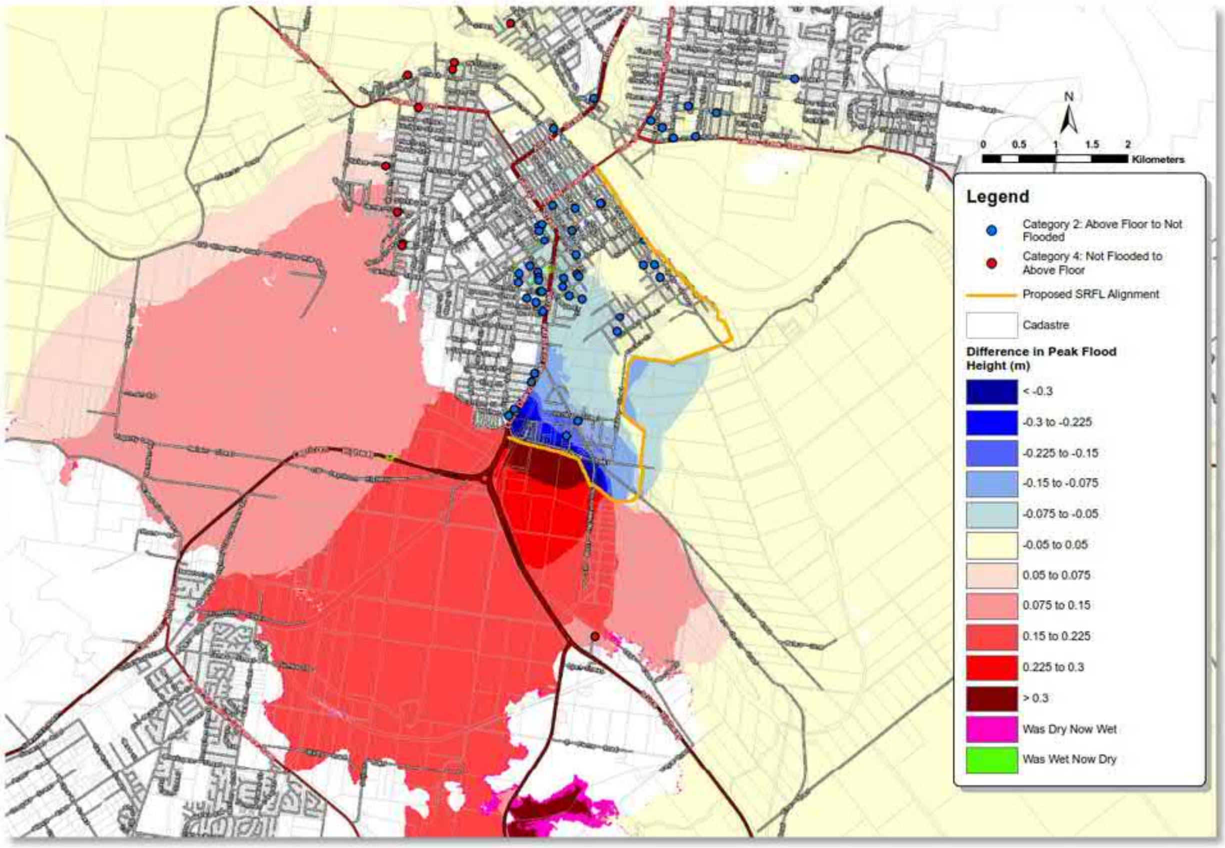

Figure 60 Spatial distribution of impacted and mitigated buildings (0.05% AEP)

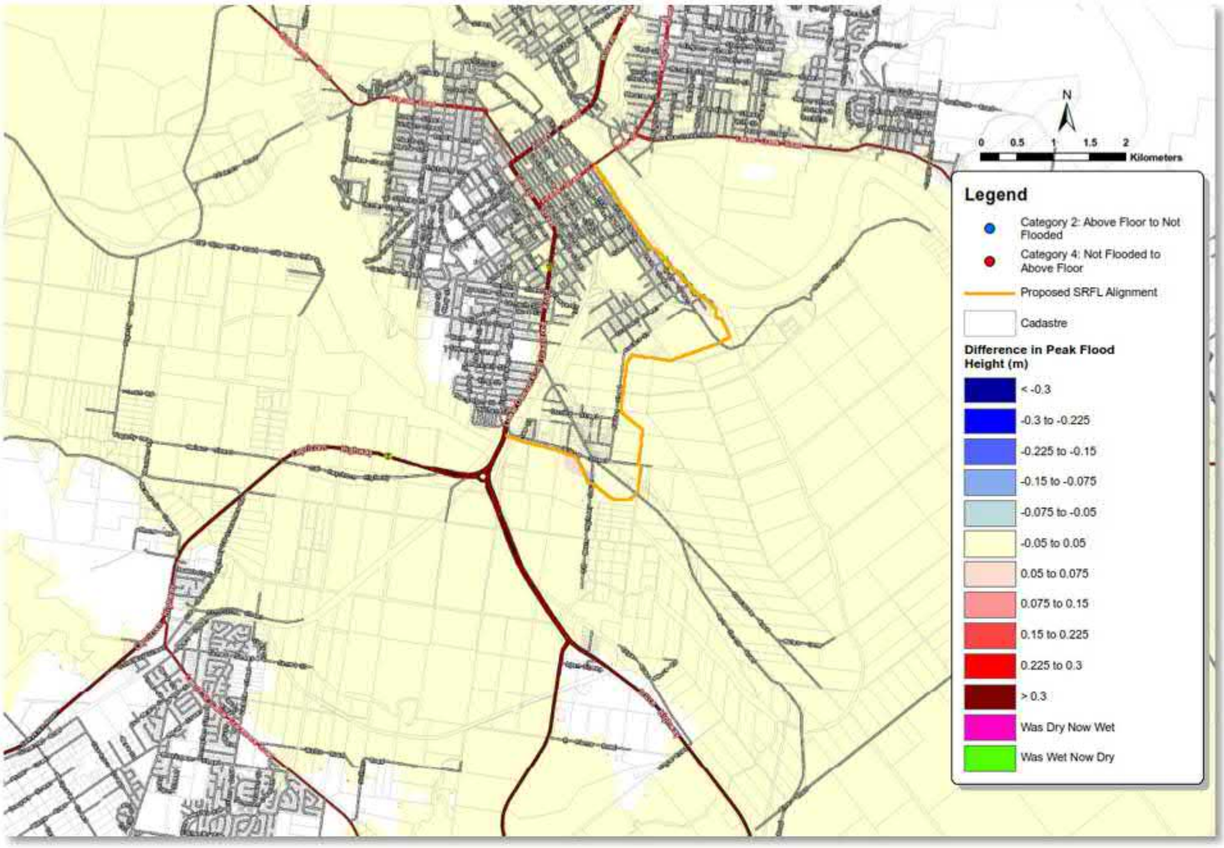

Figure 61 Spatial distribution of impacted and mitigated buildings (PMF)

6.6.7 Acceptability

Whether an impact on people or buildings is acceptable or not or the change in hydraulic effects is acceptable or not is dependent on:

- the context in which the levee is built;
- the measures put in place to mitigate the impacts;
- the extent of public consultation; and
- any compensation measures that are put in place to deal with the impacts of the levee.

The QLD Levee Guidelines note that the acceptability of a change will typically rely on a negotiation between the applicant, the Assessment Manager and any impacted parties. The final decision on the acceptability of the impacts is to be made by the Assessment Manager, the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP).

Whether the SRFL represents an acceptable impact on people and buildings is outside the scope of this technical assessment, however additional information is provided in the Tangible Flood Damage Assessment Report (AECOM, 2014), which estimates the anticipated reduction in tangible damages due to the SRFL. The associated economic appraisal is outlined in the Preliminary Economic Evaluation Report (AECOM, 2014) which shows the economic benefits of the SRFL.

It is recommended that both documents be reviewed by the Assessment Manager when considering the acceptability of the predicted SRFL impacts.

6.7 Comparison to 2014 Impact Assessment Results

Comparison of the 2014 and 2019 predicted building impacts and benefits has been made through comparison of the results presented in Section 6.6.5 and the Tangible Flood Damage Assessment Report (AECOM, 2014). There are a number of significant differences in data and conditions used for each assessment. The primary differences are as follows:

- Number of surveyed building floor levels in database:
  - 2014 Assessment = 210 (out of 9,276 buildings)
  - 2019 Assessment = 4,687 (out of 9,767 buildings)
- Updated hydraulic model and associated impacts due to construction of the SRFL.
  - This is includes changed operation of the spillway during overtopping events. The spillway crest is now set at the 1% AEP peak flood height whereas it was previously 0.30m proud of the 1% AEP. This has a large effect on the volume of water entering the interior side of the levee during an overtopping event (0.5% AEP or rarer).
- Inclusion of Dowling Street Levee in 2019 baseline model; and
- Inclusion of North Rockhampton Flood Mitigation Scheme Stage 1 in 2019 baseline model.

Implications of each change vary in magnitude; however, it is expected that the additional 4,477 surveyed floor levels are the most significant driver of change. Figure 62 and Figure 63 illustrate the significant differences between the 2014 and 2019 building databases. Analysis of the data reveals:

- ~84% of floor levels surveyed after the 2014 assessment have increased from the GIS-derived result.
- Of the floor levels which have risen to match surveyed levels, the average increase was 0.45m.

Consequently, a lower number of buildings predicted to be inundated during equivalent baseline conditions.

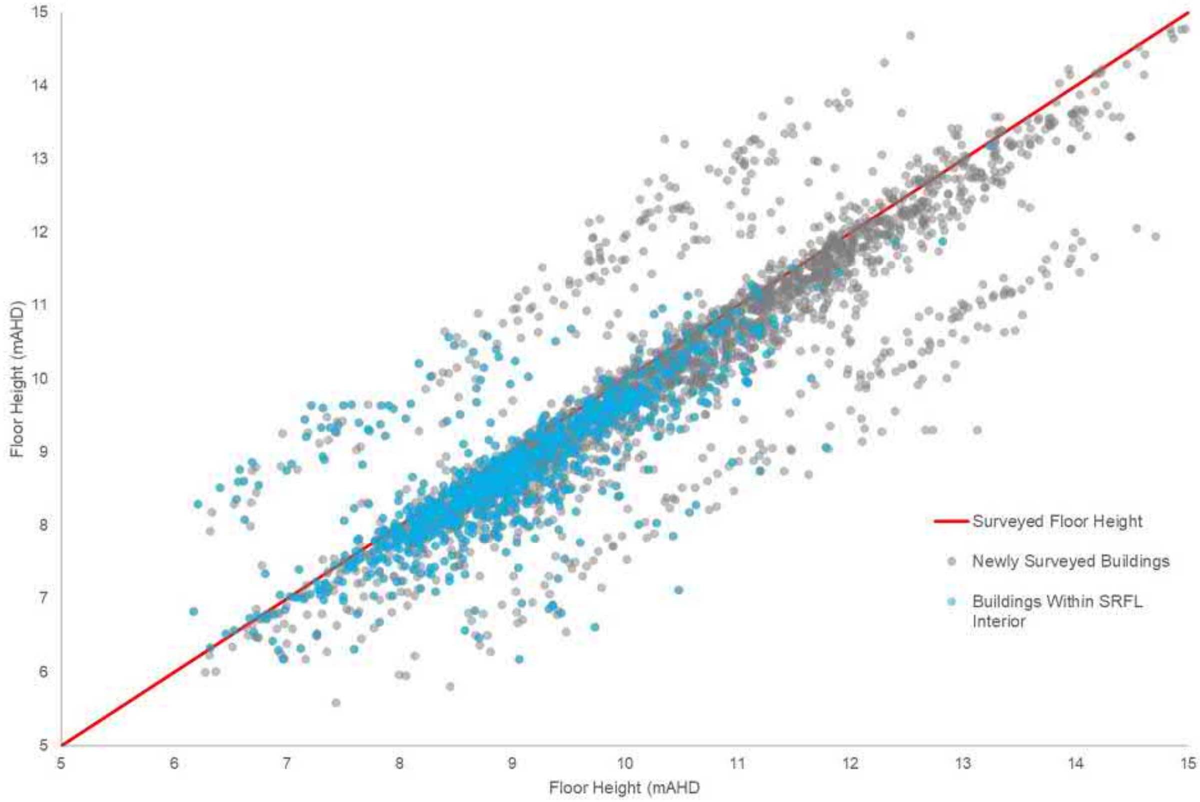

Figure 62 Scatter Plot of GIS-Derived Floor Levels (2014) vs. Surveyed Floor Levels (2019)

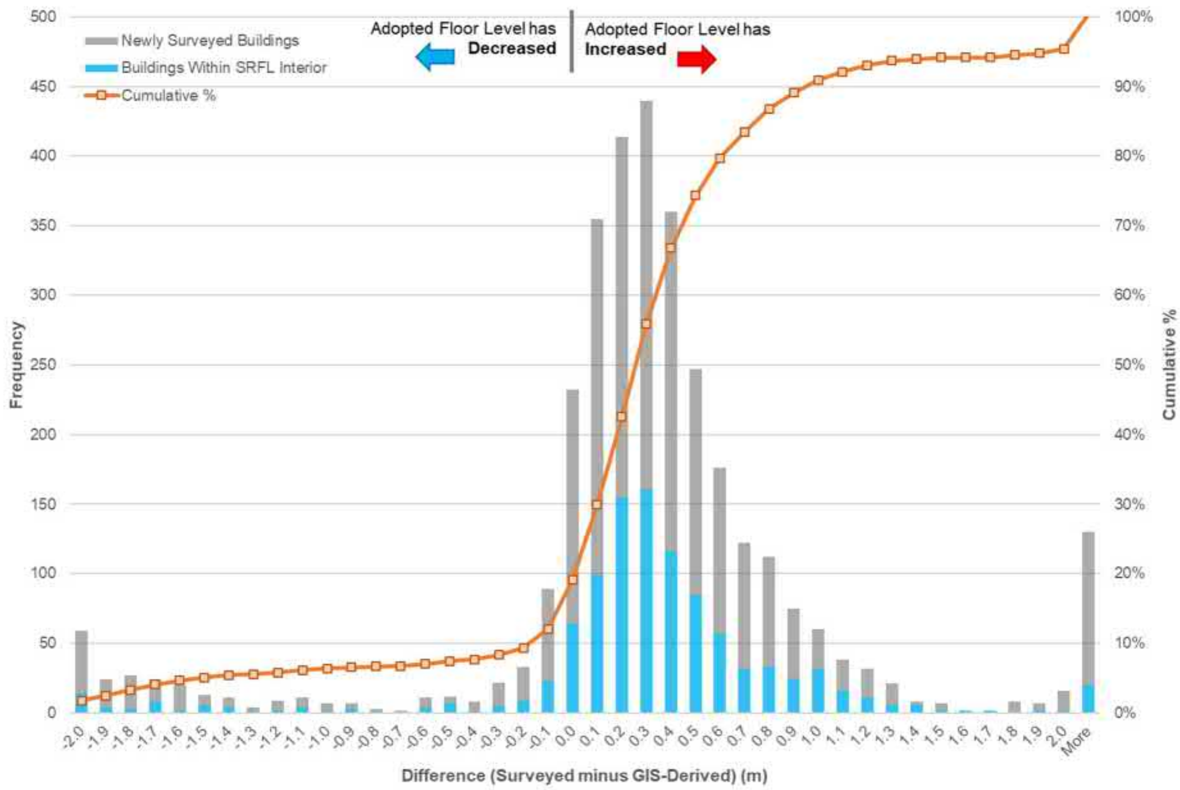

Figure 63 Histogram of Difference in Floor Height between 2014 and 2019 Building Databases

A comparison of the 2014 and 2019 results are presented in Table 23 alongside Figure 64. The comparison shows:

- A reduction in buildings predicted to be inundated under baseline conditions for the range of events.
- A lower number of buildings with mitigated above floor flooding as a result of the SRFL.
    - In particular, a significant decrease in the benefited buildings is noted in the 0.5% AEP event. This is primarily a result of increased overtopping of the spillway as predicted by the 2019 Fitzroy River TUFLOW Model.

Table 23 Comparison of 2014 and 2019 Building Impact Assessments

AEP (%)	2014 Assessment			2019 Assessment			2019 minus 2014		
	Existing	Developed	Change	Existing	Developed	Change	$\Delta_{Existing}$	$\Delta_{Developed}$	Δ_{Change}
10	220	93	-127						
5	1,148	655	-493	239	165	-75	-909	-490	+418
2	1,579	943	-636	507	348	-156	-1072	-595	+480
1	2,189	1,340	-849	906	603	-301	-1283	-737	+548
0.5	2,772	1,771	-1,001	1,536	1,423	-111	-1236	-348	+890
0.2	3,571	3,526	-45	2,369	2,283	-82	-1202	-1243	-37
0.1	4,079	4,022	-57						
0.05				3,534	3,498	-34			
0.01	5,529	5,504	-25						
PMF	8,003	8,001	-2	7,607	7,607	0	-396	-394	+2

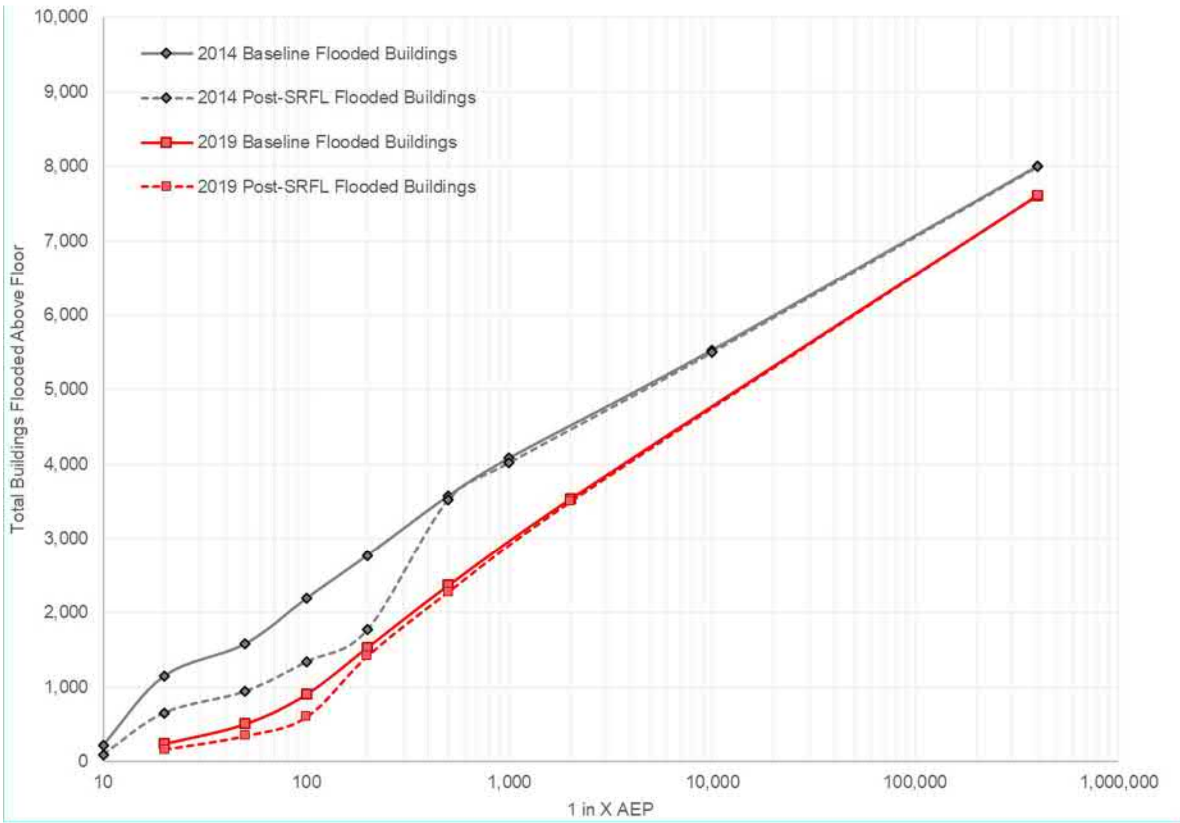

Figure 64 Number of buildings flooded above floor | 2014 vs. 2019 assessments

6.8 Summary

The Lower Fitzroy River floodplain is broad and flat and as such, the SRFL will present a significant control on flood levels throughout the western, and to a lesser extent, the northern areas of the floodplain.

Optimisation of the levee alignment has minimised hydraulic impacts as much as practicable without compromising the overall objectives of the project. The final alignment has seen additional refinement since the 2014 works as a result of additional stakeholder and community consultation. Other requirements including geotechnical, civil / structural, environmental, cultural heritage and visual amenity were also considered in selecting the final location of the alignment.

Ultimately there is a trade-off between the flood protection benefits and the impacts posed to people and infrastructure outside of the levee. Whether the impacts are acceptable or not does not form part of this technical assessment.

6.9 Residual Flood Risk

Unless the SRFL is designed to the PMF level, there is a residual risk that the levee will be overtopped. Furthermore, a decline in flood awareness and preparedness may result from the future perception of flood 'protection' offered by the levee. This could significantly influence flood damage costs, evacuation efficiency and overall community mindset.

Figure 65 has been provided to show the percentage likelihood of a 1% AEP flood event (or greater) occurring during a 30 year, 50 year and 100 year period. The 1% AEP represents the Design Flood Event for the SRFL.

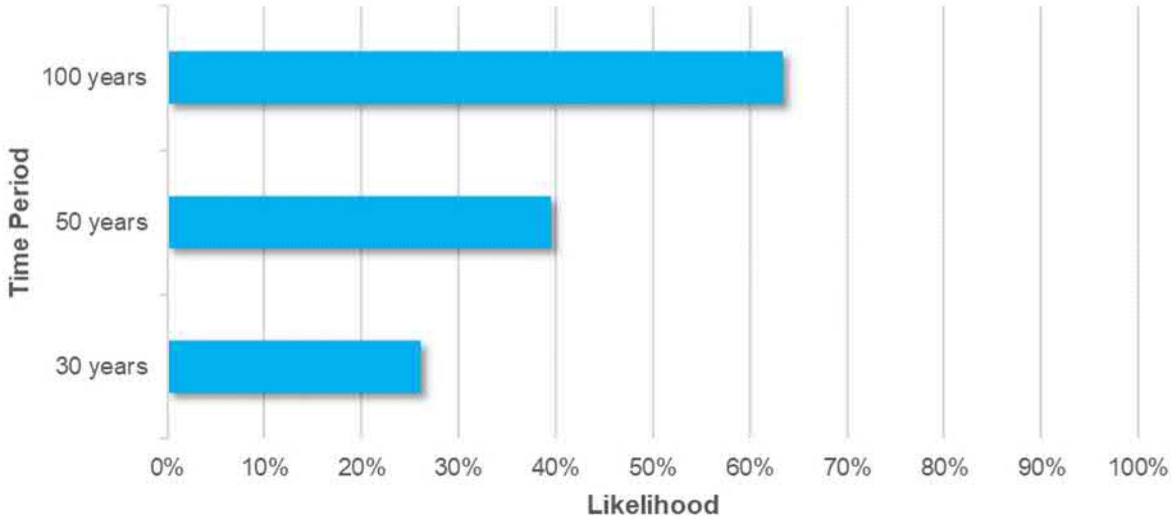

Figure 65 Likelihood of a flood event exceeding the 1% AEP during the specified number of years

Figure 66 has been provided to show the percentage likelihood of a 0.2% AEP flood event (or greater) occurring during a 30 year, 50 year and 100 year period. The 0.2% AEP flood event represents the design flood event at which overtopping of the levee crest is predicted to occur. Further information is provided in Section 6.4.2.

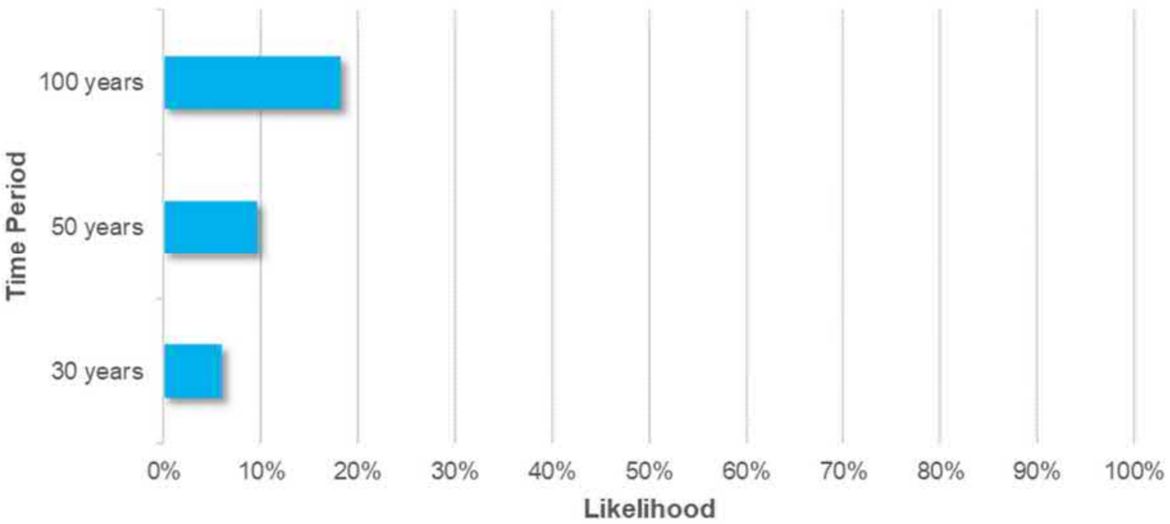

Figure 66 Likelihood of a flood event exceeding the 0.2% AEP during the specified number of years

The figures show:

- There is a 26% chance that a 1% AEP flood event (or greater) will occur in the 30 years following construction of the SRFL.
- There is a 39% chance that a 1% AEP flood event (or greater) will occur in the 50 years following construction of the SRFL.
- There is a 63% chance that a 1% AEP flood event (or greater) will occur in the 100 years following construction of the SRFL.
- There is a 6% chance that a 0.2% AEP flood event (or greater) will occur in the 30 years following construction of the SRFL.
- There is a 10% chance that a 0.2% AEP flood event (or greater) will occur in the 50 years following construction of the SRFL.
- There is a 18% chance that a 0.2% AEP flood event (or greater) will occur in the 100 years following construction of the SRFL.

The period of 30 years has been chosen to align with typical residential mortgage timeframes and 100 years has been chosen as it represents the design life of the SRFL.

It is highly recommended that Council clearly communicate this residual flood risk to the community via awareness campaigns and education materials. ‘So you live behind a levee’ (American Society of Civil Engineers) is a good example of public education and awareness materials adopted in other communities protected by levee structures.

7.0 Sensitivity Analyses

7.1 Climate Change

The following climate change sensitivities have been simulated for the 1% AEP Developed Case, as per the methodology adopted in the FRFS (Aurecon, 2011):

- Sensitivity 1: Climate Change (+20%) – represents a 20% increase in rainfall intensity.
- Sensitivity 2: Climate Change (+30%) – represents a 30% increase in rainfall intensity.

These climate change sensitivities are based on the Queensland Guidelines for Preparing a Climate Change Impact Statement (CCIS) which was published by the Queensland Office of Climate Change, Environmental Protection Agency (now DERM) in 2008.

In order to establish climate change inflow hydrographs, the 1% AEP discharge hydrographs were scaled to match the climate change peak discharges determined from runoff routing modelling undertaken in the FRFS (Aurecon, 2011).

The climate change sensitivity 1 (20% increase in rainfall intensity) peak discharge of 22,095 m^3/s represents a 32.5% increase in peak discharge from the 1% AEP peak discharge of 16,680 m^3/s. The climate change sensitivity 2 (30% increase in rainfall intensity) peak discharge of 28,446 m^3/s represents a 70.5% increase in peak discharge from the 1% AEP peak discharge of 16,680 m^3/s.

The 1% AEP and climate change inflow hydrographs are represented graphically in Figure 67.

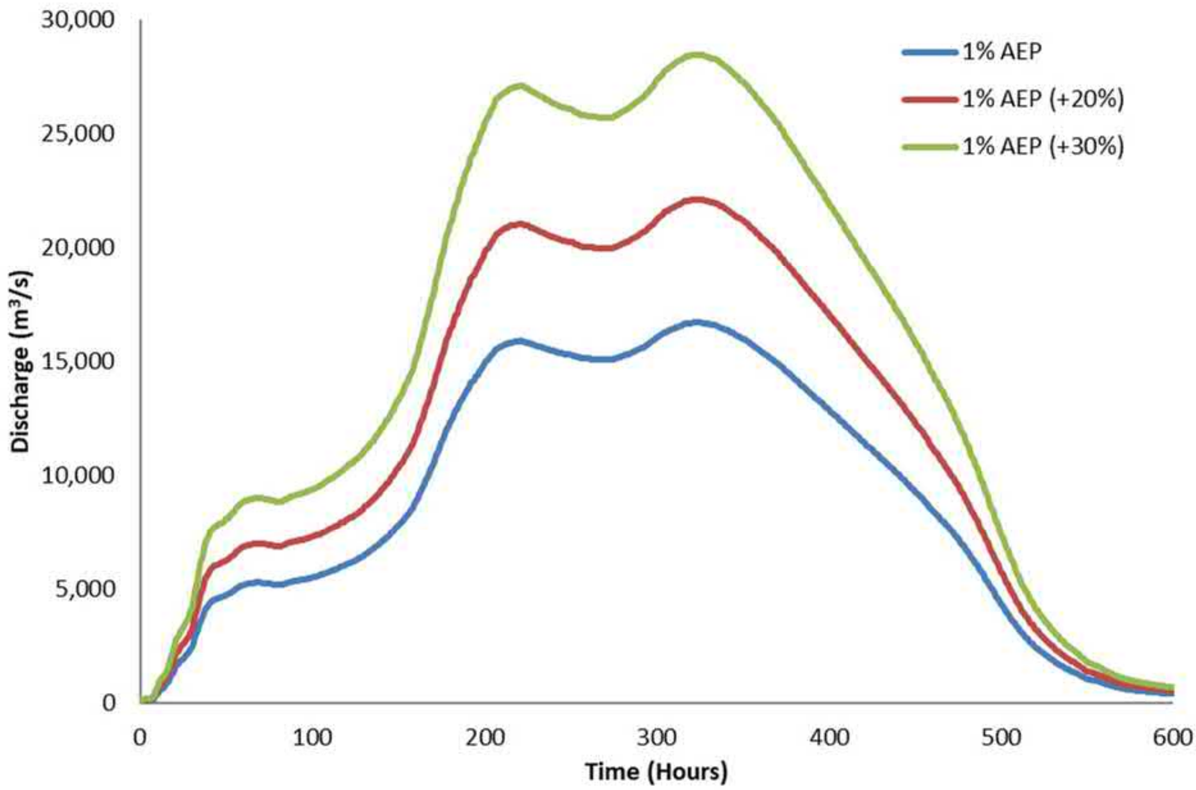

Figure 67 Climate Change Scenario Inflow Hydrograph

Map 73 shows the difference in peak water surface elevations for sensitivity 1 (20% increase in rainfall intensity). When a 20% increase in rainfall intensity due to climate change is applied to the developed case, the difference (compared to the original developed case results) in peak water surface elevation are generally increased by 0.8m adjacent to the southern section of the SRFL alignment. Peak water surface elevation increases along the northern section of the SRFL alignment are generally 0.6 m to 0.65 m.

The predicted increase in water surface elevation associated with climate change sensitivity 1 would result in overtopping of the spillway. Inundation of the interior occurs as a result of the spillway discharge.

Map 74 shows the difference in peak water surface elevations for sensitivity 2 (30% increase in rainfall intensity). When a 30% increase in rainfall intensity due to climate change is applied to the developed case, the difference (compared to the original developed case results) in peak water surface elevation are generally increased by 1.3m adjacent to the SRFL alignment.

The predicted increase in water surface elevation associated with climate change sensitivity 2 would result in overtopping of the spillway. Inundation of the interior occurs as a result of the spillway discharge. Overtopping of the crest is expected to occur along the entire levee alignment. The maximum depth of crest inundation is predicted to be 0.7 m in the vicinity of Jellicoe Street.

It is noted that no consideration for sea-level rise was included in this assessment.

7.2 Hydraulic Roughness

Testing of the model sensitivity to seasonal changes in roughness was undertaken for the 1% AEP Developed Case, using both an increase and decrease in the Manning Roughness Coefficient by 15% across all material types. The sensitivity was implemented by increasing and decreasing all manning's roughness values listed in the TUFLOW materials file.

The following maps represent the results of the sensitivity testing.

- 15% Increase in Roughness → **Map 75**
- 15% Decrease in Roughness → **Map 76**

Map 75 indicates that with a uniformly increased roughness value across all material types compared to the developed case results, peak flood heights will generally increase by between 0.2 m and 0.3 m adjacent to the SRFL alignment. Freeboard for the levee would therefore be reduced to range between 0.3 m and 0.4 m.

The result from the sensitivity analysis which applies a 15% decrease in manning's roughness values are shown in **Map 76** compared to the developed case results. The decrease in roughness predicts that peak flood heights will generally decrease between 0.22 m and 0.32 m adjacent to the SRFL alignment. Freeboard for the levee would therefore be increased to a range between 0.82 m to 0.92 m.

The sensitivity analysis has shown that increases in hydraulic roughness could raise water surface elevations adjacent to the levee. It is noted however that:

- The comprehensive calibration and verification process undertaken for the TUFLOW model (refer to the Fitzroy River Baseline Model Update Report, AECOM 2019) provides some certainty in the spatially varying roughness values adopted in the TUFLOW model.
- An increase in freeboard allowance is not deemed to be necessary based on the above.

7.3 Pink Lily Meander Level Changes

An important feature of the flooding regime in the Rockhampton area is the Pink Lily meander (refer Figure 68). When river discharge exceeds approximately 6,200 m^3/s, a breakout occurs at the Pink Lily meander which inundates the western floodplain. The floodplain flows tend in north-west to south-east direction through the Yeppen Crossing before re-joining main river channel flows south of the city.

Figure 68 Location of Pink Lily Meander

As detailed in the RFMS (CMPS&F, 1992) the Pink Lily meander has been migrating in a southerly direction, due to the natural erosive processes at the meander whereby outer banks experience erosion and inner banks experience deposition.

A natural levee is situated along the southern bank of the Pink Lily meander which dictates the timing and conveyance of the breakout flows. Ongoing migration of the meander has threatened the integrity of the natural levee. As the levee crest provides a hydraulic control for breakout flows, continued erosion of the Pink Lily meander and natural levee may result in the breakout flow threshold being reduced and a larger proportion of flood flows being directed through the Yeppen Crossing and ultimately towards the southern portions of the SRFL.

Extensive discussion on the ongoing fluvial processes at the Pink Lily meander is included in the 'Fitzroy River Erosion in the Pink Lily Area' report, prepared by Cameron McNamara for the Queensland Water Resources Commission in 1981. The report estimated that erosion of the concave bank would continue to progress at approximately 3 m per year based on recorded survey data obtained undertaken since 1865. The RFMS noted that the actual rate of erosion had slowed considerably since the tidal effects were excluded by the construction of the barrage. Nonetheless, it was recommended that the control section be stabilised to preserve Ridgelands Road and ensure floodplain breakout characteristics are maintained.

River bank erosion rates between 1948 and 1991 were consolidated in the RFMS, which is reproduced in Figure 69.

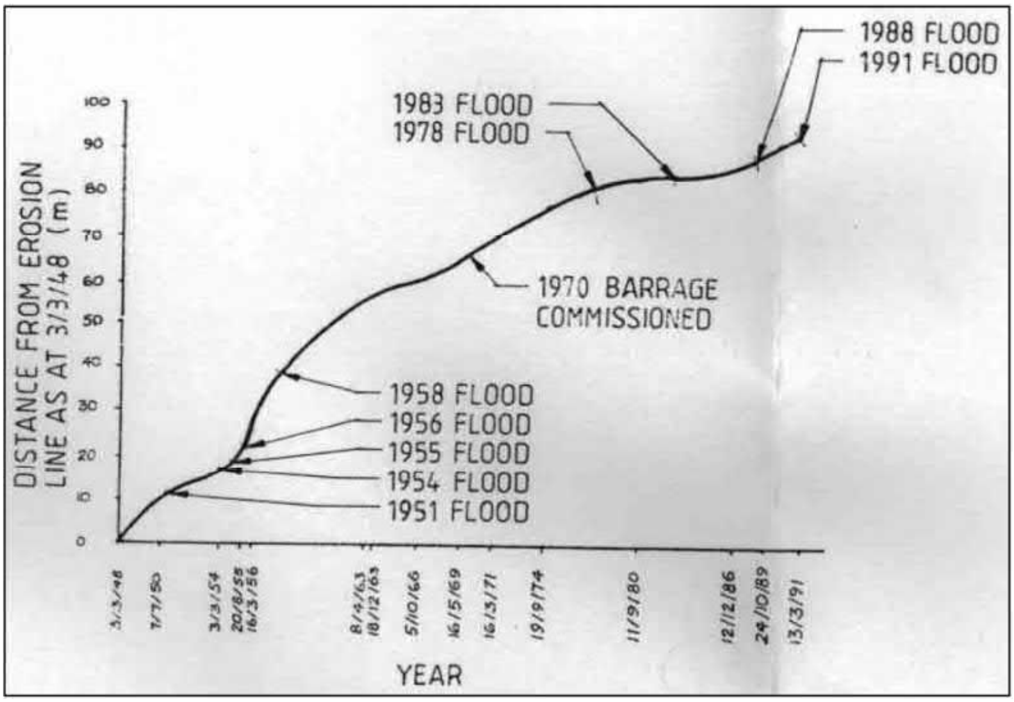

Figure 69 Pink Lily River Bank Erosion Rates between 1948 and 1991 (source: RFMS, 1992)

Figure 69 shows that migration of the bank has historically occurred in response to major flood events, particularly in the period post-barrage where tidal effects have been excluded. The Pink Lily meander has laterally migrated approximately 90 m in the 43-year period shown.

A preliminary assessment has been carried out on the basis that river stabilisation works are not carried out at the Pink Lily meander during the design life of the SRFL. Based on the abovementioned information, it is conceivable that the river bank could migrate another 100 m in a southerly direction during the design life of the SRFL.

The 1% AEP Developed Case model was altered to estimate the effects of a 100 m southerly migration of the Pink Lily meander. **Map 78** shows the predicted difference in water surface elevations for this sensitivity when comparing developed case results. **Map 78** demonstrates that there is minimal change in peak flood heights due to the migration of the Pink Lily meander; therefore the migration of the meander is not predicted to significantly impact the SRFL design.

7.4 Reduction in Downstream Conveyance

The rate at which flood waters are conveyed to the Fitzroy River outlet at Port Alma is proportional to the combined conveyance area of the river channel and adjacent floodplain. It is possible that the lower floodplain and river channel may experience aggradation over time, as particulate materials from floodwaters are deposited.

Historical bathymetric survey of the Fitzroy River was not available which could have been used to identify long term trends in sediment transport and deposition. In the absence of this data, the Geomorphology and Sediments of the Fitzroy River Coastal Sedimentary System Study (Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, 2006) was reviewed.

The report assessed the sediment accumulation data for depositional zones in the Fitzroy River coastal system using dated cores supplemented by numerical modelling. The study subdivided the Fitzroy River coastal sediment basin as shown in Figure 70.

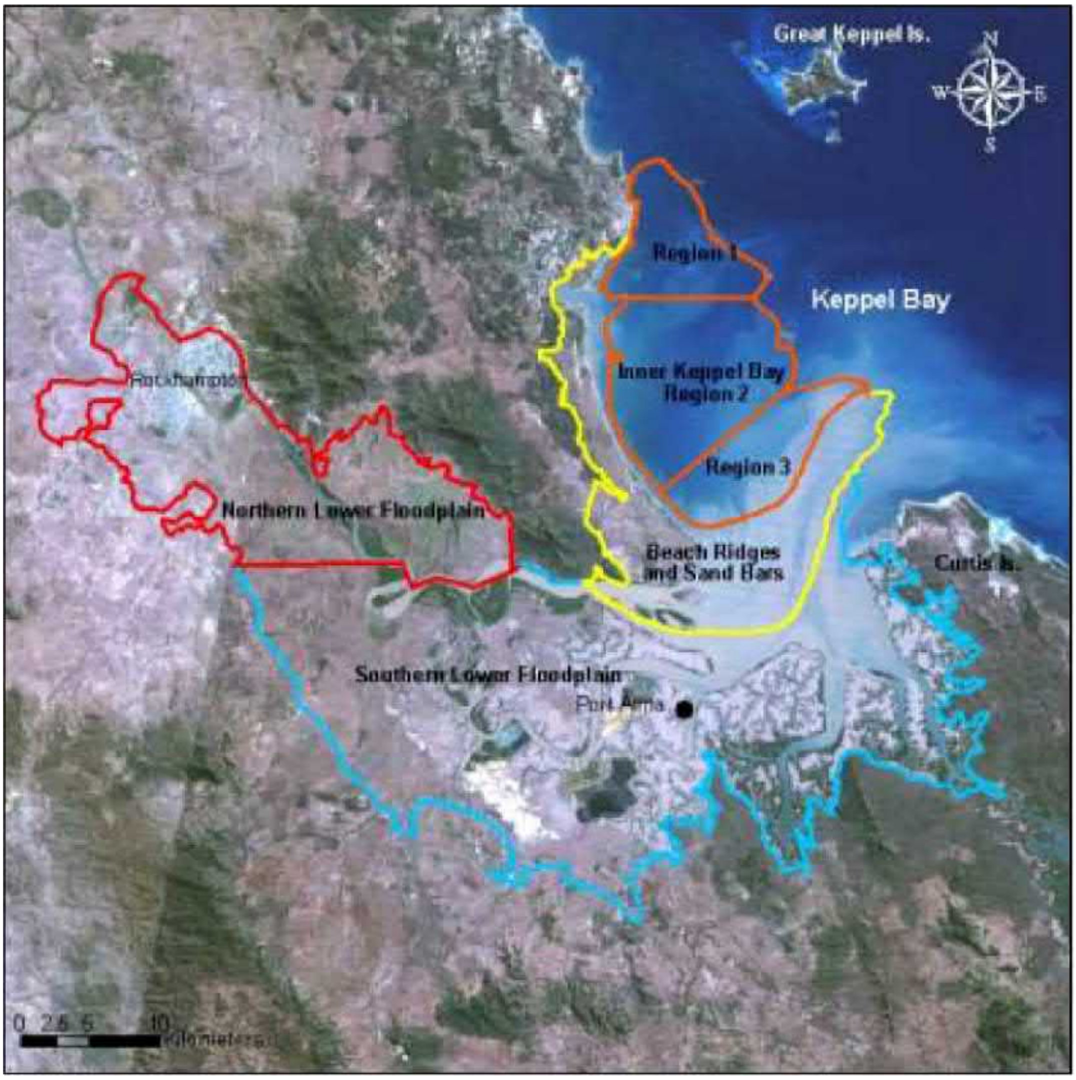

Figure 70 Subdivision of the Fitzroy River coastal sediment basin (source: CRC for Coastal Zone, Estuary and Waterway Management, 2006)

Modelled modern average annual rates of sedimentation were obtained from the report for the northern and southern lower floodplain areas. A rate of 0.1 cm/year was estimated in the study for both areas.

Two sensitivities were assessed for the 1% AEP Developed Case. These are outlined below:

- Sensitivity 6: Downstream conveyance reduction (+50 mm) – representing a 50 mm aggradation across all downstream one-dimensional model cross sections.
- Sensitivity 7: Downstream conveyance reduction (+100 mm) – representing a 100 mm aggradation across all downstream one-dimensional model cross sections.

Map 83 shows the predicted difference in peak water surface elevations as a result of the downstream reduction in conveyance associated with Sensitivity 6. **Map 83** shows a minimal change in peak water surface elevations due to 50mm aggradation, compared to the original developed case results. It is anticipated that 50mm aggradation will not impact the SRFL design.

Map 84 shows the predicted difference in peak water surface elevations as a result of the downstream reduction in conveyance associated with Sensitivity 7. **Map 84** also shows a minimal change in peak water surface elevations due to 100mm aggradation, compared to the original developed case results. It is anticipated that 100mm aggradation will not impact the SRFL design.

7.5 Summary

The sensitivity analyses undertaken have highlighted the following key points:

- A long-term change to river channel conveyance is unlikely to have significant effects on the hydraulic performance of the SRFL.
- Increases in hydraulic roughness could raise water surface elevations adjacent to the levee.
    - The comprehensive calibration and verification process undertaken for the TUFLOW model (refer to the Fitzroy River Baseline Model Update Report, AECOM 2019) provides some certainty in the spatially varying roughness values adopted in the TUFLOW model.
    - An increase in freeboard allowance is not deemed to be necessary based on the above.
- Climate change may have a significant impact on flood levels at Rockhampton which would also impact the design flood immunity of the levee:
    - The increased 1% AEP discharge associated with a 20% increase in rainfall intensity (Sensitivity 1) would take up the entire 0.6 m freeboard allowance and would reduce the design immunity of the levee.
    - Future upgrades may be required to retain the original level of protection should the adopted climate change scenarios transpire within the design life of the levee.

8.0 Conclusion and Recommendations

8.1 Conclusion

The hydraulic assessment of the SRFL was undertaken for a range of Fitzroy River design flood events to clearly demonstrate the benefits and impacts of the proposed SRFL alignment. Difference in Peak Water Surface Elevation and Peak Depth Averaged Velocity mapping were produced and included in the Volume 2 report, for the 5%, 2%, 1%, 0.5%, 0.2% 0.05% AEP and PMF events.

Expected impacts (peak WSE and TOS) were extracted at the key locations of Rockhampton Flood Gauge, existing low level Bruce Highway, Yeppen North, Blackwater Rail Line, North Coast Rail Line and the Rockhampton Airport. The predicted difference in PWSE across the range of design events at the Rockhampton Flood Gauge is shown in Table 24 with key receptor impacts during the 1% AEP event shown in Table 25.

Table 24 Summary of Predicted Design Event Gauge Levels

Design Flood Event AEP (%)	Predicted Peak Flood Level (m Rockhampton Gauge Datum)		Difference (m)
	Baseline Scenario	SRFL Design Scenario	
5	9.05	9.08	+0.03
2	9.54	9.57	+0.03
1	9.86	9.89	+0.03
0.5	10.16	10.19	+0.03
0.2	10.53	10.56	+0.03
0.05	11.02	11.02	-
PMF	13.28	13.28	-

Table 25 Difference in WSE and TOS at Key Receptors (1% AEP Event)

Key Receptor	Baseline WSE (mAHD)	Dev Case WSE (mAHD)	Increase (m)	Baseline TOS (days)	Increase (hrs)
Existing Low Level Bruce Highway	9.13	9.29	+0.16	12.2	+4
Bruce Highway (Yeppen North)	9.24	9.41	+0.17	0.0	-
Blackwater Rail Line	9.31	9.46	+0.15	12.2	+4
North Coast Rail Line	8.96	9.30	+0.35	13.7	+4
Rockhampton Airport	9.91	9.99	+0.08	12.3	+2

A building Impact Assessment was undertaken to quantify the predicted number of building impacted and benefitted from the SRFL project. The buildings deemed to be impacted by the levee were determined based on the impact classifications provided in the QLD Levee Guidelines:

- The building is flooded above floor in the SRFL design case;
- The increase in flooding is >50mm above the floor; **or**
- The increase in velocity above the floor is >0.2m/s.

The results are summarised in Table 26.

Table 26 Summary of Impacted Buildings

Flood Event AEP (%)	Buildings Affected by Increased Water Surface Levels Above Floor Level (> 50 mm)	Buildings Affected by Increased Velocities Above Floor Level (> 0.2 m/s)	Total Number of Buildings Affected *
5	5	0	5
2	47	1	48
1	127	1	128
0.5	168	3	171
0.2	212	12	224
0.05	252	20	272
PMF	0	51	51

* Buildings affected by increased flood height have been cross checked against increased velocities to prevent double counting.

The effect of the proposed SRFL design on above floor flooding was investigated further through categorical analysis. The number of benefited and impacted buildings was determined as follows:

- **Category 2** describes the **removal** of above floor flooding; and
- **Category 4** describes the **addition** of above floor flooding.

The total number of buildings determined to be within these categories due to construction of the SRFL are presented in Table 27. Of key note is:

- Additional above floor impacts are absent during the 5% AEP event.
- The number of benefited buildings heavily outweighs impacted buildings, especially during frequent events.

Table 27 Summary of Mitigated Buildings

Flood Event AEP (%)	Category 2: Above Floor to Not Flooded	Category 4: Not Flooded to Above floor	Net Difference
5	**75**	**1**	**-74**
2	**166**	**7**	**-159**
1	**313**	**10**	**-303**
0.5	**139**	**26**	**-113**
0.2	**119**	**33**	**-86**
0.05	**48**	**12**	**-36**
PMF	**0**	**0**	-

Whether the SRFL represents an acceptable impact on people, property and other assets is outside the scope of this technical assessment. However, it is expected that this report will be read in conjunction with other key technical reports referenced in Section 3.0 when assessing the acceptability of the impacts.

Optimisation of the levee alignment has minimised hydraulic impacts as much as practicable without compromising the overall objectives of the project. The final alignment has seen additional refinement since the 2014 works as a result of additional stakeholder and community consultation. Other requirements including geotechnical, civil / structural, environmental, cultural heritage and visual amenity were also considered in selecting the final location of the alignment.

Ultimately there is a trade-off between the flood protection benefits and the impacts posed to people and infrastructure outside of the levee. Whether the impacts are acceptable or not does not form part of this technical assessment.

8.2 Recommendations

In undertaking this assessment, a number of key recommendations have been made and are summarised below.

- It is recommended that changes in topography are monitored within the Pink Lily meander and western floodplain as aerial datasets become available in order to understand the impact of ongoing anthropogenic activities and channel migration.
- It is recommended that the Pink Lily meander be stabilised to minimise the risk of long-term alterations to control levels which could increase breakout flows to the western floodplain. It is not yet known which (combination of) organisations should be responsible for undertaking this works. This recommendation aligns with the previous Priority 3 structural mitigation measure recommended in the RFMS (CMPS&F, 1992).
- Council could consider undertaking bathymetric survey of the Fitzroy River at specified locations downstream of Rockhampton for incorporation into the hydraulic model. For consistency, it is suggested that these locations correspond to current cross section locations adopted in the hydraulic model. This would also aid in comparison to assess any long-term fluvial changes.
- It is highly recommended that Council clearly communicate this residual flood risk to the community via awareness campaigns and education materials.

9.0 References

American Society of Civil Engineers (2013), *So, You Live Behind a Levee!,* 2013.

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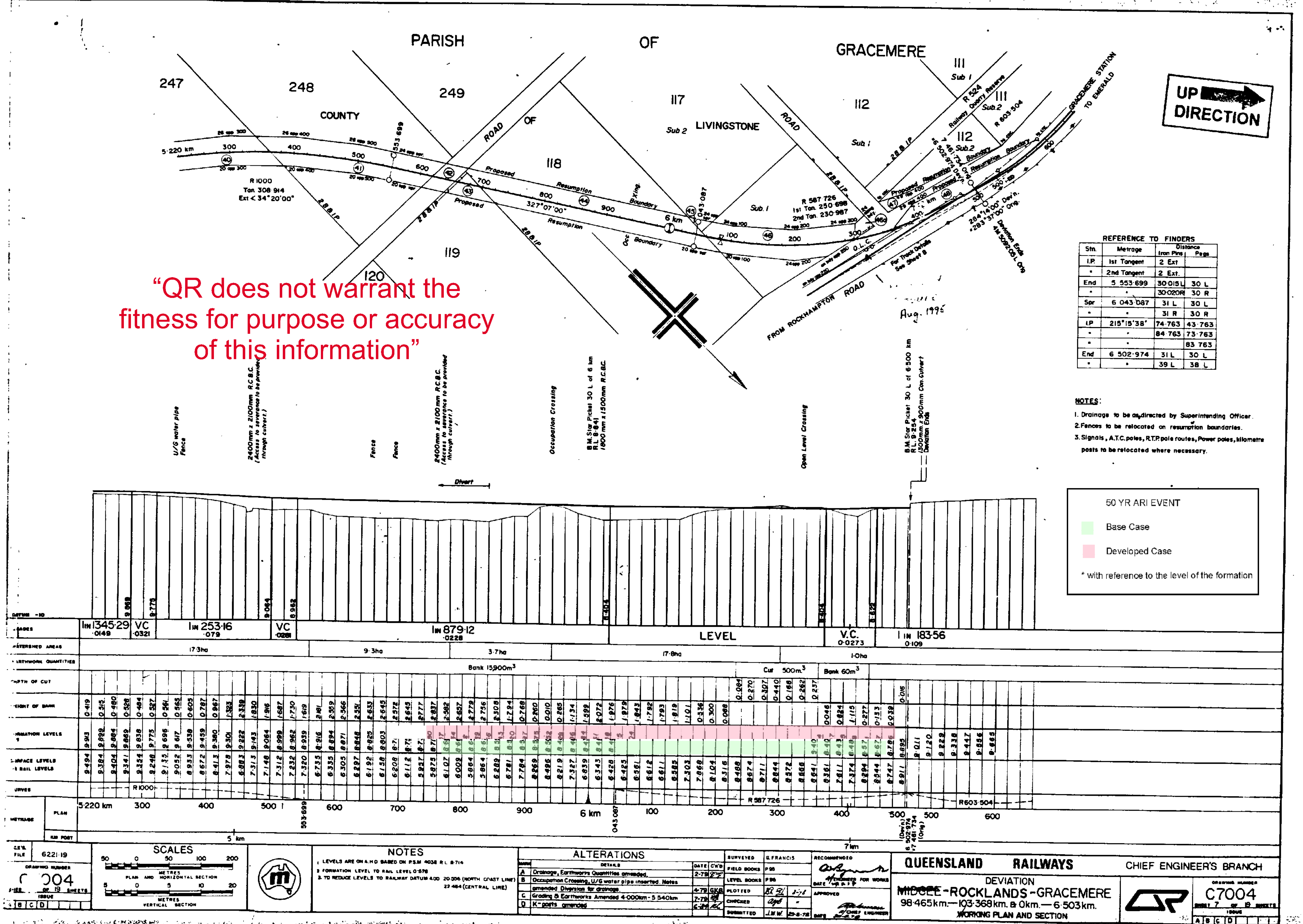
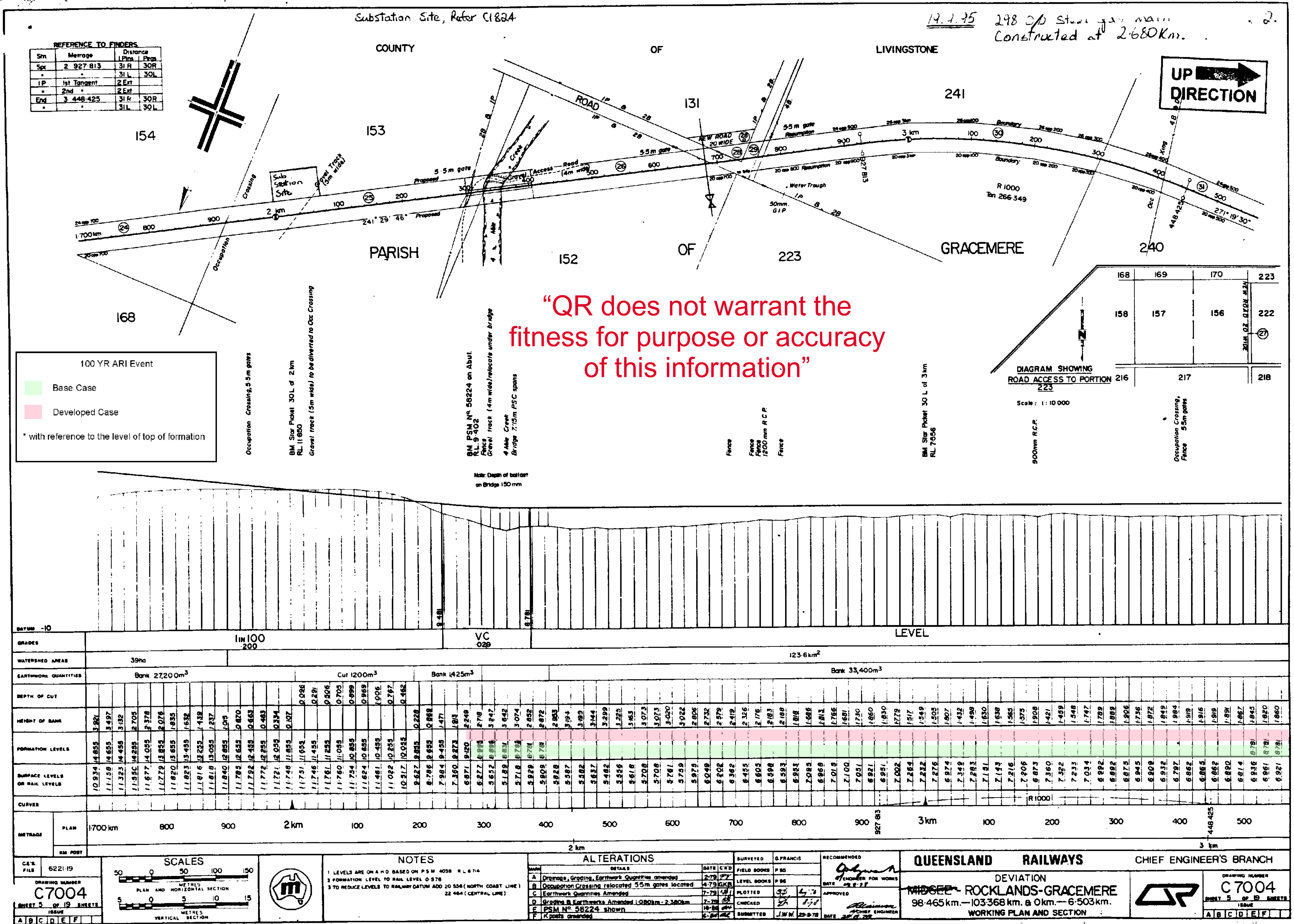
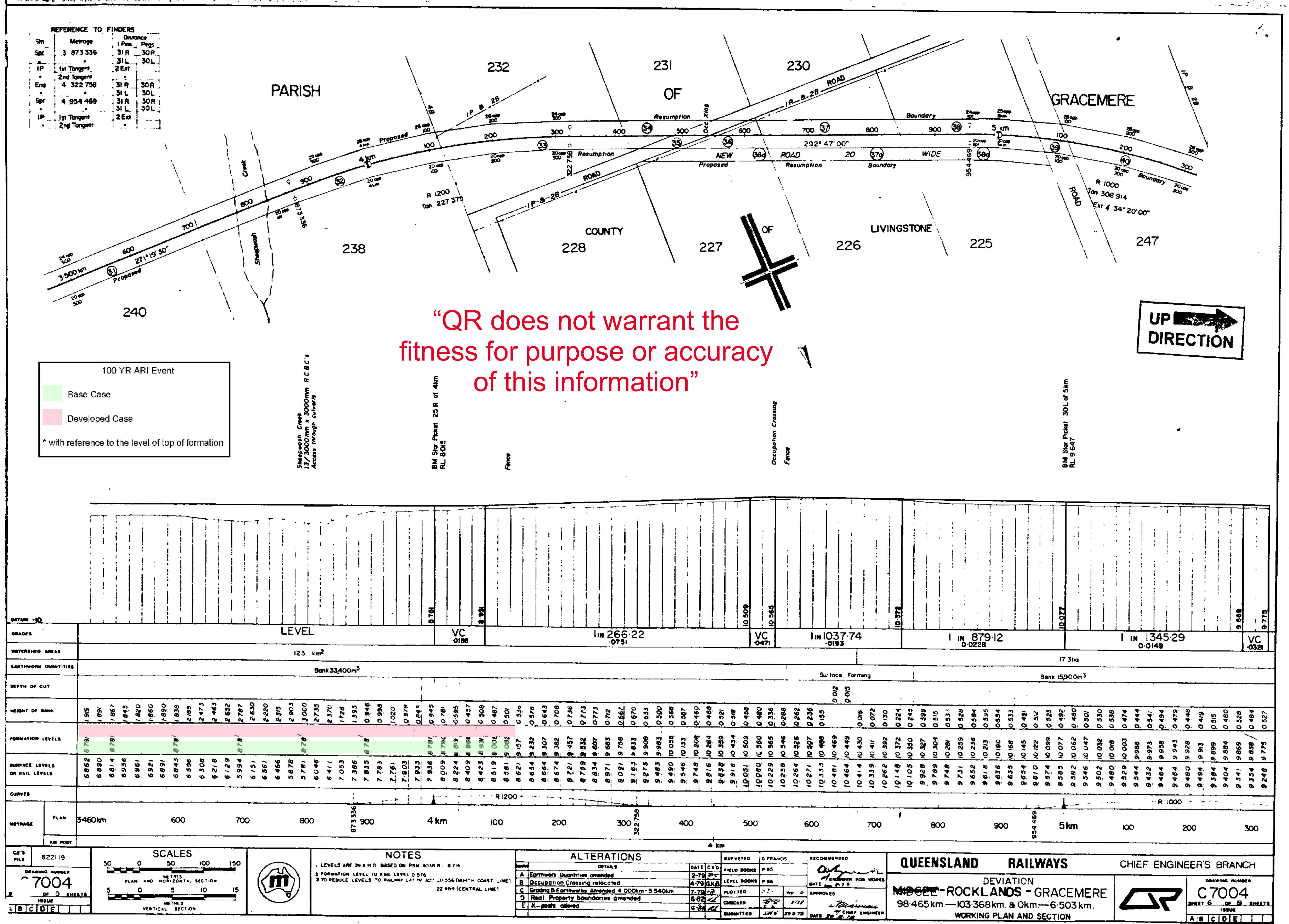
Appendix A

Blackwater Rail Line Profiles

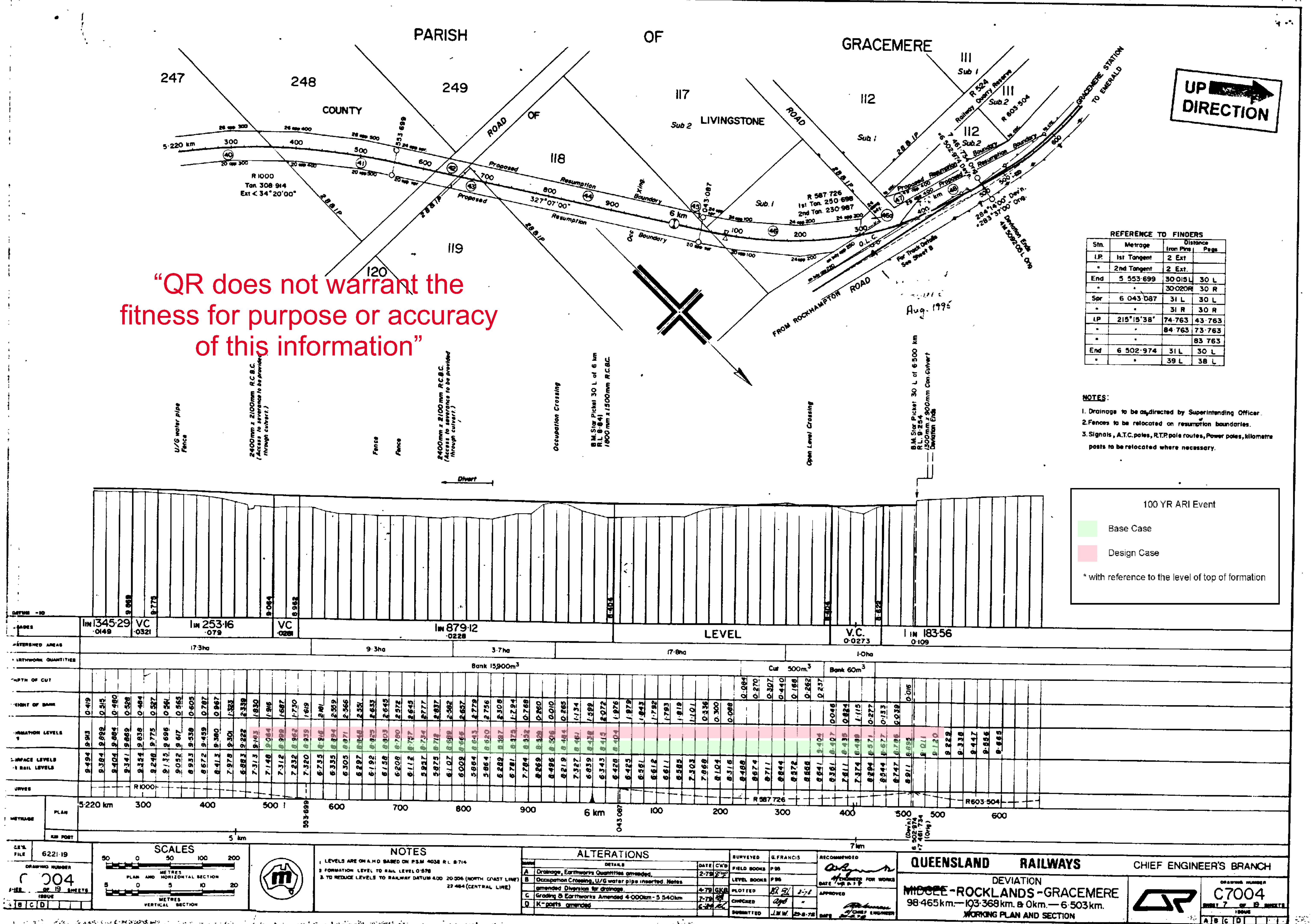

PARISH OF GRACEMERE
COUNTY OF LIVINGSTONE
UP DIRECTION
TO EMERALD
GRACEMERE STATION
FROM ROCKHAMPTON ROAD
"QR does not warrant the fitness for purpose or accuracy of this information"
REFERENCE TO FINDERS
NOTES:
1. Drainage to be as directed by Superintending Officer.
2. Fences to be relocated on resumption boundaries.
3. Signals, A.T.C. poles, R.T.P. pole routes, Power poles, kilometre posts to be relocated where necessary.
50 YR ARI EVENT
Base Case
Developed Case
* with reference to the level of the formation
LEVEL
Bank 15900m³
Cut 500m³
Bank 60m³
5·220 km
6 km
7 km
SCALES
NOTES
1. LEVELS ARE ON A.H.D. BASED ON P.S.M. 4038 R.L. 8·714
2. FORMATION LEVEL TO RAIL LEVEL 0·578
3. TO REDUCE LEVELS TO RAILWAY DATUM ADD 20·506 (NORTH COAST LINE) 22·464 (CENTRAL LINE)
ALTERATIONS
A Drainage, Earthworks Quantities amended.
B Occupation Crossing, U/G water pipe inserted. Notes amended. Diversion for drainage.
C Grading & Earthworks Amended 4·000km - 5·540km
D K-posts amended
QUEENSLAND RAILWAYS
CHIEF ENGINEER'S BRANCH
DEVIATION
MIDGEE-ROCKLANDS-GRACEMERE
98·465km.—103·368km. & 0km.—6·503km.
WORKING PLAN AND SECTION
C7004
SHEET 7 OF 19 SHEETS
6221·19



Substation Site, Refer C1824
14.1.75 298 C/D Steel gas main Constructed at 2.680Km.
COUNTY OF LIVINGSTONE
PARISH OF GRACEMERE
UP DIRECTION
REFERENCE TO FINDERS
100 YR ARI Event
Base Case
Developed Case
* with reference to the level of top of formation
"QR does not warrant the fitness for purpose or accuracy of this information"
DIAGRAM SHOWING ROAD ACCESS TO PORTION 223
Scale: 1:10 000
NEW ROAD 20 WIDE
R 1000
Tan 266·349
BM PSM Nº 58224 on Abut. RL 9·402
BM Star Picket 30 L of 2 km RL 11·650
BM Star Picket 30 L of 3 km RL 7·556
Gravel track (5m wide) to be diverted to Occ Crossing
Occupation Crossing, 5·5m gates
4 Mile Creek Bridge 7/15m PSC spans
Note: Depth of ballast on Bridge 150 mm
LEVEL
1 in 100
VC
123·6km²
Bank 27,200m³
Cut 1200m³
Bank 1425m³
Bank 33,400m³
DATUM -10
GRADES
WATERSHED AREAS
EARTHWORK QUANTITIES
DEPTH OF CUT
HEIGHT OF BANK
FORMATION LEVELS
SURFACE LEVELS OR RAIL LEVELS
CURVES
METRAGE
PLAN
KM POST
SCALES
NOTES
ALTERATIONS
QUEENSLAND RAILWAYS
CHIEF ENGINEER'S BRANCH
DEVIATION
ROCKLANDS-GRACEMERE
98·465 km.—103·368 km. & 0 km.—6·503 km.
WORKING PLAN AND SECTION
C7004
SHEET 5 OF 19 SHEETS
C.E.'S FILE 6221·19



"QR does not warrant the fitness for purpose or accuracy of this information"
100 YR ARI Event
Base Case
Developed Case
* with reference to the level of top of formation
REFERENCE TO FINDERS
PARISH OF GRACEMERE
COUNTY OF LIVINGSTONE
UP DIRECTION
Sheepwash Creek
13/3000mm x 3000mm R.C.B.C's
Access through culverts
BM Star Picket 25 R of 4km
RL 8·015
Occupation Crossing
Fence
BM Star Picket 30 L of 5km
RL 9·647
NEW WIDE ROAD
Proposed Resumption Boundary
R 1200
Tan 227·375
R 1000
Tan 308·914
Ext 4·34° 20' 00"
292° 47' 00"
271° 19' 30"
LEVEL
VC ·0188
1 IN 266·22 ·0751
VC ·0471
1 IN 1037·74 ·0193
1 IN 879·12 0·0228
1 IN 1345·29 0·0149
VC ·0321
123 km²
17·3 ha
Bank 33,400m³
Surface Forming
Bank 15,900m³
DATUM -10
GRADES
WATERSHED AREAS
EARTHWORK QUANTITIES
DEPTH OF CUT
HEIGHT OF BANK
FORMATION LEVELS
SURFACE LEVELS OR RAIL LEVELS
CURVES
METRAGE
PLAN
KM POST
3460km
4 km
5km
SCALES
PLAN AND HORIZONTAL SECTION
VERTICAL SECTION
NOTES
1 LEVELS ARE ON A.H.D. BASED ON PSM 4038 R.L. 8·714
2 FORMATION LEVEL TO RAIL LEVEL 0·576
3 TO REDUCE LEVELS TO RAILWAY DATUM
ALTERATIONS
A Earthwork Quantities amended
B Occupation Crossing relocated
C Grading & Earthworks Amended 4·000km - 3·540km
D Real Property boundaries amended
E K-posts altered
QUEENSLAND RAILWAYS
CHIEF ENGINEER'S BRANCH
DEVIATION
ROCKLANDS - GRACEMERE
98·465km.—103·368km. & 0km.—6·503km.
WORKING PLAN AND SECTION
C7004
SHEET 6 OF 19 SHEETS


PARISH OF GRACEMERE
COUNTY OF LIVINGSTONE
247
248
249
117
112
118
119
120
111
UP DIRECTION
TO EMERALD GRACEMERE STATION
FROM ROCKHAMPTON ROAD
5·220 km
6 km
R 1000
Tan 308·914
Ext < 34°20'00"
327°07'00"
R 587·726
1st Tan 250·698
2nd Tan 230·987
Proposed Resumption
Occ Boundary
Aug. 1995
“QR does not warrant the fitness for purpose or accuracy of this information”
REFERENCE TO FINDERS
NOTES:
1. Drainage to be as directed by Superintending Officer.
2. Fences to be relocated on resumption boundaries.
3. Signals, A.T.C. poles, R.T.P. pole routes, Power poles, kilometre posts to be relocated where necessary.
U/G water pipe
Fence
2400mm x 2100mm R.C.B.C. (Access to severance to be provided through culvert.)
Occupation Crossing
B.M. Star Picket 30 L of 6 km R.L. 8·841
1800 mm x 1500mm R.C.B.C.
Open Level Crossing
B.M. Star Picket 30 L of 6·500 km R.L. 9·254
1300mm x 900mm Con. Culvert
Deviation Ends
Divert
100 YR ARI Event
Base Case
Design Case
* with reference to the level of top of formation
LEVEL
Bank 15900m³
Cut 500m³
Bank 60m³
SCALES
NOTES
ALTERATIONS
QUEENSLAND RAILWAYS
CHIEF ENGINEER'S BRANCH
DEVIATION
MIDGEE-ROCKLANDS-GRACEMERE
98·465 km.—103·368 km. & 0 km.—6·503 km.
WORKING PLAN AND SECTION
C7004
SHEET 7 OF 19 SHEETS