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HERVEY BAY CITY COUNCIL

Toon Toon Creek Flood Risk Reduction Study



Report

November 2006

Hervey Bay City Council

Tooan Tooan Creek Flood Risk Reduction Study

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1 Introduction

John Wilson & Partners (JWP) has been commissioned by Hervey Bay City Council (HBCC) to undertake a Flood Risk Reduction Study for the Tooan Tooan Creek Catchment area. The Tooan Tooan Creek catchment comprises two (2) separate study areas known as the Taylor and Stephenson Street Catchments. The purpose of the study includes: -

- Documenting the existing flooding and drainage characteristics throughout the catchment for a range of design flood events;
- Undertaking a board flood risk assessment for the catchments based upon the existing flooding characteristics. This includes the identification of areas of risk within the catchment; and
- Identifying at least in a broad sense the various options for managing and reducing existing flood risks in the catchment. These options will form the basis on which future flood risk reduction strategies will then be developed for the catchment.

It is the intent of this study to form the basis on which existing flooding problems are characterised including the assessment of flood risks for the purposes of providing the base information on which future flood risk reduction activities can be investigated and undertaken for the catchment. The management of catchment flood risks and the various strategies required to reduce these risks is outside the scope of works for this project and thus will be the subject of a more detailed assessment to be undertaken in the future.

The scope of works undertaken for this study has included:

- Consolidation of GIS data;
- The identification of existing drainage patterns including both piped systems (trunk drainage) and major overland flows via a detailed site inspections;
- Undertaking a review of the existing XP-STORM models for both the Taylor and Stephenson catchments as were provided by HBCC. This includes identifying model nodal and cross sectional locations, major drainage paths and systems along with sub-catchment boundaries;
- Model update and incorporation of recently constructed drainage works in the various catchments. These works have included constructed culverts and piped drainage works whereby it was necessary to incorporate into the model to represent the existing case scenario;
- Re-analysis of both catchment models for the 1 in 10, 20, 50 and 100 year ARI design events to ascertain existing case flood information;
- Preparation of summary water surface level results in addition with preparing GIS inundation plans for each of the modelled events across both catchments;
- Utilising the updated flood information, identify the board flood risks throughout the catchments. This included the assessment of flood risk areas of concern in terms of road and property inundation; and
- Prepare a consolidated flood risk report to include both catchments investigated and assessed. The report provides the study documentation and includes the methodology and outcomes prepared as a formal report on the investigation as well as including the outcomes from the flood risk assessment and identification works undertaken.

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

2 Catchment Description and Supplied Data

2.1 Study Area

The Toonan Toonan Creek study area consists of two (2) adjacent catchments known as the Taylor and Stephenson Street catchments. Both catchments are in a state of heavy urbanisation and are located near the centre of the city of Hervey Bay. The natural drainage flow paths present in both catchments are highly modified and are typified by engineered open channels and formalised sub-surface stormwater drainage systems. Both catchments encompass predominantly commercial and industrial areas of the Pialba Precinct with existing tracts of residential and open space areas. The total area of the Toonan Toonan Catchment is approximately 305 hectares. Of this total area, the individual catchment areas of the Taylor Street and Stephenson Street catchments are approximately 200 and 105 hectares respectively.

2.2 Study Data

The works undertaken as part of this study have been prepared based upon a compilation of data sources as provided by Hervey Bay City Council for the purposes of the project. Although JWP were provided with existing hydraulic models for both the Taylor and Stephenson Street catchments, additional data was supplied to assist the investigation which is outlined and discussed separately below.

2.2.1 Topography Data

Topographical data for the study area was provided in the form of contour information at various contour intervals throughout the majority of the built environment of Hervey Bay. As the contour data represents the only available information for the catchment, it was subsequently adopted for the purposes of this study. To facilitate the use of this information, JWP has used the contour information to prepare a Digital Terrain Model (DTM) in order to facilitate data extraction for the various modelling tasks undertaken as part of this study. As the DTM was prepared using the contour information supplied and not from raw data, limitations in the degree of detail afforded by the DTM should be noted.

2.2.2 Model Data

The flood risk assessment of the Toonan Toonan Creek catchment is based on two (2) existing XP-STORM hydraulic models for both the Taylor and Stephenson catchments as were originally developed by Council for infrastructure upgrade purposes. These models represented the existing waterway conditions at the time of the original model development and as such did prescriptively include neither the various catchment changes which have since occurred nor the recent infrastructure upgrades as noted previously. Figure 1 overleaf illustrates the location of each model with regard to the overall Toonan Toonan Catchment study area.

2.2.3 As-Constructed and Pipe Data

Prior to the commencement of the project, JWP was supplied with as-constructed data for the recent infrastructure upgrades now constructed within the Toonan Toonan Catchment. The infrastructure upgrades included new augmented pipe systems along with additional drainage structures within the various waterways. In addition to this data, existing pipe and culvert information throughout the catchment was also provided by Hervey Bay City Council for the purposes of this study. The various drainage information supplied included GIS format data which was extracted directly from Council's existing GIS system.

Details of the existing pipe information was provided through Council supplied GIS data, in addition with the aforementioned field survey data received during the project to confirm pipe sizes and invert level details.

2.3 Site Inspection

As part of the works for this study, JWP have undertaken a site inspection of the catchment. The site inspection was documented by way of site notes and photographs. Together, this information assisted in the definition of the catchment and existing drainage patterns, flow regimes and Council's existing models as well as benefiting in reviewing appropriate roughness parameters and verification of existing hydraulic structures.

3 Hydraulic Modelling

The original hydraulic modelling on the Toaan Toaan Catchment was undertaken by HBCC through the preparation of two (2) separate XP-STORM models. These models were previously developed by Council in order to establish a basis for determining the existing flood characteristics throughout the catchment as well as resulting stormwater infrastructure along with identifying potential areas of flooding problems. These models were supplied to JWP by HBCC along with supporting information in the form of project reports and strategic planning documents.

3.1 Existing Hydraulic Models

Existing hydraulic models for both the Taylor and Stephenson Street Catchments were supplied by Council for the purposes of this study. These models were reviewed and then re-analysed for a range of durations from 20 to 720 minutes to determine any specific modelling issues as well as assisting in the identification of model node and link locations for future GIS mapping activities. The preliminary analysis and review of the base models highlighted the following issues: -

- Some large instabilities in various parts of the model and specifically in links upstream of Old Maryborough Road basin;
- Ground surface levels taken from the Stephenson Street Catchment model and those from the supplied DTM were found to be inconsistent. In some cases, large discrepancies were found to exist between the model inverts versus that of the DTM; and
- The presence of an open drain in various areas in both XP-STORM models was represented by a trapezoidal channel in the modelling environment. The DTM however reflected the fact that the channel was in fact a distinct open channel with different dimensions and configurations to that represented in the model.

The various differences and issues identified in the existing models were primarily due to the fact that the models had been originally prepared some time ago. Consequently, the main differences were a result of different catchment conditions and drainage characteristics that had since changed since the initial model development. These changes resulted in various issues being evident for this current study with the major problem being in the determination of flood extents and depths. The determination of flood extents requires that the reported water surface level at each model node location be draped over the natural cross section extracted using the DTM. As such, the extent generated is not always representative and relies on the fact that the model water depths are taken from the base topography defined in the DTM.

After consultation with HBCC regarding these issues and with consideration of the project scope being a board flood risk assessment study, a decision was made not to undertake a detailed update of the models as part of this study. It is acknowledged however that this work would be required at a future stage where a more detailed assessment of flood reduction strategies and mitigation works is undertaken. For the purposes of this study however, JWP has adopted the existing model as the basis on which constructed infrastructure upgrades of discrete areas have been represented in the model as were advised by Council.

3.2 Hydraulic Model Amendment

To represent the existing conditions and specifically the infrastructure items that have been since constructed, both XP-STORM models have been amended as part of this study. Following the site inspection and a discussion with HBCC, it was apparent that no upgrade works have been constructed or need to be considered in the Stephenson Street Catchment and consequently only the Taylor Street model needed to be amended for the purposes of this study. Table 3.1 below

summarises the structural changes to the Taylor Street model that have been undertaken as part of this project using as-constructed information supplied by Council.

Table 3.1: Model Upgrades - Taylor Street Catchment Model

Location	Model Upgrades
Hervey Bay High School	<ul style="list-style-type: none"> ➤ Insertion of a detention basin in the High School grounds.
Neils St Drainage Plan	<ul style="list-style-type: none"> ➤ Pipe upgrades along Neils Street and along Torquay Road between Stephenson Street and Taylor Street.
Old Maryborough Rd Drainage Works	<ul style="list-style-type: none"> ➤ Create new concrete driveway on lot 84; ➤ Insert three storm water pipes below concrete driveway; ➤ Connect new storm water pipes to existing pipe network.
Pialba Main Drain Upgrade	<ul style="list-style-type: none"> ➤ Construct 2 No. 1500mmx1200mm Reinforced Concrete Box Culverts and insert into the model.
Open Channel Improvements and Pollution Reduction Device Hillyard Street, Pialba	<ul style="list-style-type: none"> ➤ Divert existing 150mm roof water pipes to new manholes; ➤ Create new concrete driveways; ➤ Insert new cast in-situ box culvert.
Drainage Improvements Works, Pialba Main Drain – 'The Village'	<ul style="list-style-type: none"> ➤ Alter existing service pits and pipes to match proposed plans; ➤ Pave areas indicated on Proposed Drainage Improvement Works Plan; ➤ Concrete areas indicated on Proposed Drainage Improvement Works Plan; ➤ Add gardens indicated on Proposed Drainage Improvement Works Plan.

Model upgrades were completed with the assistance of as-constructed plans supplied to JWP by HBCC in addition to relevant documents with regards to proposed drainage improvement works.

3.3 Hydraulic Model Analysis

The hydraulic XP-STORM models for both the Taylor and Stephenson Street catchment areas were subsequently re-analysed following the model updates and revisions outlined above. In all cases, the models were re-analysed for the 1 in 10, 20, 50 and 100 year ARI design events for storm durations ranging from 20 to 720 minutes. The results of the analysis are discussed separately below.

4 Discussion of Existing Results

4.1 Flood Level and Depth Summaries

All calculated water surface levels and flood depths for the Taylor and Stephenson Street existing scenario XP-STORM models are summarised in Appendices A and B respectively. The results are presented based on flood level and discharge reporting locations and these are summarised in detail in tabular formats. The locations of the reporting points are illustrated on the GIS maps (refer separate discussion below).

4.2 GIS Flood Maps

The flood levels have been used as a basis on which GIS flood extent maps for the Taylor Street catchment have been prepared for each of the design events analysed. The flood extent plans for the existing scenario model for the Taylor Street catchment is attached in Appendix C. The extent maps include locations and labels to illustrate the various reporting locations and names to facilitate cross-reference with the tabular summaries presented in Appendix A.

Owing to the problems associated with the differences in the DTM levels compared to that in the XP-STORM model, it was not possible or practical to prepare accurate and representative flood extent plans for the Stephenson Street catchment. Rather, for the purposes of this study detailed plans have been prepared to highlight the water surface levels and depths at each of the model reporting locations throughout the Stephenson Street catchment. The reporting location GIS plans are provided in Appendix D of this report and include locations and labels to facilitate cross-reference with the tabular summaries presented in Appendix B.

4.3 Limitations of GIS Flood Maps

Flood extent maps have been prepared as part of this study to assist in illustrating areas of concern with regards to flooding and flood risk. The plans are presented to demonstrate the anticipated extent of flooding for the 1 in 10, 20, 50 and 100 year ARI events over the study area for the existing case. The flood extent plans have been prepared based upon the DTM and using the outcomes from the hydraulic model. This has been achieved based on the creation of a 3-dimensional (3D) flood surface using the model results within the GIS and the subsequent draping of this surface over the DTM in order to prepare a 3D flood depth surface. The 3D flood depth surface has then been contoured in a manner such that only positive flood depths greater than or equal to zero are displayed which by default defines the extent of flood inundation for the event under question.

The flood extent plans prepared as part of this study include extent of mapping limits as have been identified on the plans. These limits have been included to illustrate the point of which mapping has been prepared and this is based on both the extent of the XP-STORM model along with the extent of the DTM data for the catchment. Limit of mapping lines have also been included in other isolated areas whereby the extent of flooding was undiscernible, inaccurately defined or not representative based upon the information available. In all cases, water is expected to discharge from the catchment in these areas primarily in the form of sheet flows.

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

1. The flood extent and associated flood data prepared as part of this study is based on available survey data as supplied by Hervey Bay City Council. This includes aerial photogrammetric survey, limited field validation survey and stormwater pipe and pit information. The flood extents and flood results will therefore be subject to the accuracy and detail of the background study information and the models supplied to JWP; and
2. Initial model runs showed that ground surface levels in the models were different to that determined using the DTM and were therefore not consistent. In some areas throughout the models, large discrepancies existed between the corresponding ground levels. Other issues between the models versus the DTM included different channel configurations. As such, flood extents prepared as part of this study should be treated with caution and specifically for the Stephenson Street Catchment is the sole reason why flood extent plans have not been prepared.

5 Existing Scenario Risk Identification

5.1 Risk Identification Methodology

The method of evaluating flood risk prepared as part of this study is summarised in the following tables.

Likelihood parameters

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

Consequence parameters (based on 2000 AU\$)

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

Risk Ranking

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

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

In addition to infrastructure lifelines, risk parameters for people, buildings, economic loss and loss of the natural environment are proposed as follows: -

Risk element	Extreme (unacceptable) risk
People	Vulnerability to natural hazards is generally measured by the risk to life and property from known hazards. An area may be prone to a known hazard, but if there is no possible risk to life or property, the vulnerability is low. Where life and property are at risk, the magnitude and likelihood of the hazard combine to create a measure of vulnerability. Unacceptable risks are death, serious injury and major health hazard.
Buildings	The built environment is at risk from a number of known hazards in Hervey Bay. Various regulations have been developed locally (e.g. Local Laws) and at a wider scale (e.g. the Building Code of Australia) to minimise the risk of damage to the built environment. All of these regulations are based on an acceptable level of risk which has been determined either by Council or a wider community of interest (e.g., 1:100 flood immunity). Inevitably there will be extreme events which go beyond the acceptable level of immunity and the only possible way to immunise against these events is avoidance. Unacceptable risks are collapse or damage to buildings requiring demolition.
Economic loss	In all disaster events there is bound to be some form of economic loss. The Federal Government under the Natural Disaster Relief Arrangements provides funding to victims of disaster events. This funding is generally short term and designed to minimise immediate suffering and loss. Businesses need to make their own assessment of potential economic loss through a natural disaster event and make plans accordingly. These would range from building construction, to choice of location to insurance. Unacceptable risks are loss of livelihood for more than 10% of the working community.
Natural environment	The natural environment is at risk from a number of known hazards in Hervey Bay. Unacceptable risks are loss of ecological systems, major habitats or conservation areas. Significant disruption to natural drainage systems.
Risk escalation Risk escalation is likely to happen when initial risk minimisation programs or event response mechanisms do not achieve their intended purpose. The risks outlined in this document may have follow-on or secondary effects (e.g. an earthquake may lead to a dam break, which may lead to flooding, which may lead to injury or isolation). Unacceptable risks arise from the failure of initial risk minimisation and response mechanisms.	
Risk frequency Risks to physical infrastructure are usually incorporated in design parameters (e.g. bridges are designed to withstand certain loads; drains are designed to accommodate mathematically derived flood levels). These are generally based on industry standards of acceptable levels of risk. These standards have until recently had very little legislative basis. The recent adoption of <i>State Planning 1/03 - Mitigating the adverse impacts of Flood, Bushfire and Landslide</i> introduces risk frequency levels (e.g. 1:100 years) which are required to be accommodated in planning and design documents (e.g. planning schemes and infrastructure codes). Unacceptable risks are events which occur within the design capacity of infrastructure or industry accepted measures.	

Legal and social justice implications

Risk management is applied by Council across all parts of its jurisdiction in an equal manner and includes all persons. Council is required to make decisions on an annual basis about prioritising its expenditure on various competing items. Expenditure on risk minimisation is incorporated in most capital works projects by way of an in-built design standard. **Unacceptable risks are deliberate inequality of expenditure against any one group, or any one part of the city.**

Political implications

Council's decisions are subject to scrutiny and influence from various elements and sectors of the community. It is Council's role to make informed and un-biased decisions. **Unacceptable risks are decisions made which reflect unlawful political bias.**

For both models investigated as part of the Toosan Toosan Creek Flood Risk Assessment, specific flood risks were identified through use of the above risk matrix and examination of modelling results as discussed previously in Section 4. The risk matrix was used in conjunction with a detailed assessment that was undertaken for each of the roads contained in the models to determine less obvious flooding risks such as minor overtopping and property inundation and to determine any risk (velocity x depth) issues. A risk ranking for each specific flooding risk was then determined. A description of flooding and risk ranking for each model is presented separately below.

The following tables summarise the risk analysis for each specific model, namely the Taylor Street and Stephenson Street Catchments which together represent the various drainage networks within the Toosan Toosan catchment.

5.2 Taylor Street Catchment

It is evident from the inundation plans that flooding is extensive throughout the Taylor Street Catchment. An examination of the flood inundation maps indicates that large sections of the catchment are inundated during relatively minor rainfall events. The maps prepared have been critically assessed and this has identified a total of nineteen (19) separate critical locations as being seriously inundated and as such has significant risks as are outlined in Table 5.1.

Table 5.1: Critical Areas of Flood Inundation – Taylor Street Catchment

Location	Mapping Node	Model Node	Q10 Depth	Q20 Depth	Q50 Depth	Q100 Depth	Maximum Velocity	Maximum Depth Velocity Ratio
			(m,AHD)	(m,AHD)	(m,AHD)	(m,AHD)	(m/s)	(dxv)
Jack Street	N130	SWP1593	0.21	0.26	0.31	0.35	2.62	0.92
Ripley Street	N125	SWP1611	0.31	0.33	0.34	0.36	0.68	0.24
Romney Street	N164	SWP1906	0.36	0.37	0.39	0.41	1.91	0.78
Winchelsea Street	N122	SWP1606	0.25	0.26	0.27	0.28	1.60	0.45
Old Maryborough Road	N356	OMR-4/1	0.32	0.34	0.37	0.39	2.60	1.01
Nissen Street	N140	SWP1857	0.52	0.55	0.58	0.61	1.60	0.98
Beach Road	N272	SWP4307	0.24	0.26	0.27	0.28	2.99	0.84
Islander Road	N152	SWP1915	0.27	0.29	0.30	0.30	2.71	0.81
Boat Harbour Drive	N84	SWP1657	0.65	0.91	1.04	1.12	0.16	0.18
Alice Street	N73	SWP1116	0.14	0.15	0.16	0.17	2.81	0.48
Charles Street	N61	SWP4182	0.15	0.16	0.17	0.34	1.73	0.59
Main Street	N60	SWP1478	0.00	0.05	0.07	0.21	1.48	0.31
Hunter Street	N37	SWP1095	0.61	0.83	0.86	0.97	2.31	2.24
Taylor Street	N5	SWP1060	0.27	0.28	0.29	0.31	2.12	0.66
Neils Street	N8	SWP1150	0.18	0.23	0.26	0.30	1.27	0.38
Andrew Street	N285	SWP3308	0.48	0.52	0.58	0.63	0.14	0.09
Torquay Road	N203	SWP1409	0.00	0.00	0.00	0.30	2.63	0.79
Bryant Street	N190	Bryant	0.11	0.12	0.13	0.14	1.38	0.19
Hillyard Street	N38	SWP4238	0.09	0.10	0.10	0.11	2.22	0.24

According to section 5.09 of the QUDM, it is recommended that the maximum depth of flow on any road be limited to 300mm and the product of depth (d) and average velocity (V_{ave}) in the kerb and channel should not exceed $0.4 \text{ m}^2/\text{s}$ to limit pedestrian hazards within the roadways. This standard has been adopted for the purposes of this assessment due to the fact that the roads may be used by both pedestrians and vehicles. As highlighted in Table 5.1 above, the majority of the problem areas have depth-velocity ratios that exceed those recommended by the QUDM. The calculated depths in many of these areas also exceed 300mm and as such it can be seen that large sections of the Taylor Street Catchment are either seriously inundated or are at a high risk in terms of inundation. The flood extents also indicate that there is considerable inundation of residential and commercial properties throughout the Taylor Street Catchment and as such it is critical that flood risk reduction measures are implemented. Table 5.2 outlines the flood risk analysis for the critically inundated areas of the Taylor Street Catchment.

Table 5.2 - Flood Risk Analysis – Taylor Street Catchment

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Mitigation Works Required
Jack Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	×	Likely	Minor	High	✓
	Buildings	Q100 immunity	×	Possible	Minor	Medium	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Ripley Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	×	Possible	Minor	Medium	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Romney Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	×	Likely	Minor	High	✓
	Buildings	Q100 immunity	×	Likely	Minor	High	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Mitigation Works Required
Winchelsea Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Possible	Insignificant	Low	×
	Buildings	Q100 immunity	✓	Possible	Minor	Moderate	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Old Maryborough Road	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Moderate	✓
	People - ease of egress	DV Product <0.4	×	Almost Certain	Minor	High	✓
	Buildings	Q100 immunity	×	Almost Certain	Minor	High	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Nissen Street	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Moderate	✓
	People - ease of egress	DV Product <0.4	×	Likely	Insignificant	Moderate	✓
	Buildings	Q100 immunity	×	Possible	Minor	Moderate	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Beach Road	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Moderate	✓
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Moderate	✓
	Buildings	Q100 immunity	×	Likely	Minor	High	✓

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Mitigation Works Required
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Islander Road	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Moderate	✓
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Moderate	✓
	Buildings	Q100 immunity	×	Likely	Minor	High	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Boat Harbour Drive	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Moderate	✓
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	×	Possible	Minor	Moderate	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Alice Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Moderate	✓
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	Low	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Mitigation Works Required
Charles Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Moderate	✓
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	Low	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Main Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	×	Possible	Minor	Moderate	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Hunter Street	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Moderate	✓
	People - ease of egress	DV Product <0.4	×	Likely	Minor	High	✓
	Buildings	Q100 immunity	×	Likely	Minor	High	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Taylor Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Moderate	✓
	Buildings	Q100 immunity	×	Possible	Minor	Moderate	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Mitigation Works Required
Neils Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	Low	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Andrew Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	×	Likely	Minor	High	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Torquay Road	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Moderate	✓
	Buildings	Q100 immunity	×	Possible	Minor	Moderate	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Bryant Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	Low	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Mitigation Works Required
Hillyard Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	Low	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×

5.3 Stephenson Street Catchment

As highlighted previously, in many sections of the existing Stephenson Street Catchment model structural inverts did not match the corresponding levels with the supplied digital terrain model. As such, JWP were unable to create flood extents for the each of the events modelled. However, plans indicating the location of the XP-STORM reporting nodes with annotated water surface levels and depths have been included in Appendix D.

For the purposes of this risk assessment study, an assessment of existing flood risk has been undertaken based upon the available information from the modelling works. While the flood risk assessment could not be undertaken based on the flood extent maps as discussed above, and assessment of flood risk has been prepared based upon the following information: -

- Inspecting the XP-STORM model to ascertain the magnitude of flood depths at various locations throughout the catchment. These depths are the same as that presented on the plans attached in Appendix D. Note that the depths illustrated represent model depths and not depths based on the DTM; and
- Inspection of the XP-STORM model for the purposes of ascertaining average flow velocities along the various links represented in the model.

Using the flood depth information in conjunction with flow velocities based on the XP-STORM model, it was possible to undertake a board assessment of flood risk throughout the Stephenson Street catchment. Table 5.3 below summarises the critical locations identified as being seriously inundated and as such has significant risks for the Stephenson Street catchment.

Table 5.3: Critical Areas of Flood Inundation – Stephenson Street Catchment

Location	Mapping Node	Model Node	Q10 Depth	Q20 Depth	Q50 Depth	Q100 Depth	Maximum Velocity	Maximum Depth Velocity Ratio
			(m,AHD)	(m,AHD)	(m,AHD)	(m,AHD)		
Banksia Park Drive	N46	A55-1-23	0.16	0.16	0.17	0.18	0.50	0.09
Shelley Street	N10	A45-5	0.26	0.27	0.29	0.31	3.88	1.20
Cassia Avenue	N59	A40-2-2-5	0.09	0.10	0.10	0.11	0.28	0.03
Boat Harbour Drive	N5	A25-10	0.39	0.41	0.45	0.48	1.20	0.58
Boat Harbour Drive	N38	A35-1-20	0.19	0.25	0.27	0.31	1.49	0.46
McNally Street	N35	A30-5-50	0.22	0.27	0.31	0.37	0.06	0.02

Table 5.4: Flood Risk Analysis – Stephenson Street Catchment

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Mitigation Works Required
Banksia Park Drive	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	Low	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Shelley Street	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Medium	✓
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Medium	✓
	Buildings	Q100 immunity	×	Possible	Minor	Medium	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Cassia Avenue	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	✓	Unlikely	Insignificant	Low	×
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×

Location	Risk Element	Acceptable standard	Currently meets desired risk standard	Likelihood	Consequence	Risk Ranking	Mitigation Works Required
Boat Harbour Drive (West)	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Medium	✓
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Medium	✓
	Buildings	Q100 immunity	×	Possible	Minor	Medium	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
Boat Harbour Drive (East)	People - drowning	No resultant deaths, injuries or major health hazards	×	Possible	Minor	Medium	✓
	People - ease of egress	DV Product <0.4	×	Possible	Minor	Medium	✓
	Buildings	Q100 immunity	×	Possible	Minor	Medium	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×
McNally Street	People - drowning	No resultant deaths, injuries or major health hazards	✓	Unlikely	Insignificant	Low	×
	People - ease of egress	DV Product <0.4	✓	Unlikely	Insignificant	Low	×
	Buildings	Q100 immunity	×	Possible	Insignificant	Low	✓
	Economic loss	Loss of livelihood for less than 10% of working community	✓	Unlikely	Insignificant	Low	×
	Natural environment	N/A	✓	Unlikely	Insignificant	Low	×

6 Risk Treatment & Flood Mitigation

6.1 Overview of Mitigation

As was mentioned previously, there were some discrepancies resulting from the hydraulic model in terms of both the representation of various waterway systems as well as the differences in inverts compared to the DTM. Given these differences, it was extremely difficult to undertake a prescriptive assessment of mitigation options for the purposes of alleviating or reducing flood risks for all critical areas identified in Section 5 previously. These aspects were discussed with Hervey Bay City Council and it was decided that the prescriptive analysis of mitigation options using the existing models could not be undertaken effectively so as to provide a practical mitigation outcome. As such, no modelling works associated with the assessment of mitigation options have been undertaken for the purposes of this study.

It is noted that future mitigation options will need to be assessed in more detail in order to devise effective strategies for reducing flood risks in the Stephenson and Taylor Street catchments. These works will be scheduled at some future stage. When this work is undertaken the resulting models for both catchments will be revised and updated to reflect the existing catchment conditions and therefore will be suitable for the purposes of undertaking the detailed mitigation assessments as will be required.

For the purposes of this study and in order to maximise the outcomes from the flood risk assessment at least in a board context, JWP have utilised the existing case model results and have made a qualitative assessment of what is considered to be effective and viable mitigation options. While these options will be subject to more detailed scrutiny in the future, this none the less serves to provide a summary of the options that may be appropriate in the various systems. Specifically, flooding areas that were identified as medium risk (Stephenson Street catchment) and high risk (Taylor Street Catchment) have been investigated by means of drainage augmentation or other forms of mitigation works with the aim of an overall reduction of the flooding risk. A separate discussion of the various options is presented in the sections of this report which follow.

6.2 Taylor Street Catchment

The risk rankings for the Taylor Street catchment were generally low to moderate however there are several locations in the catchment whereby a high risk existed. As such, risk standards were not met for all locations and mitigation works are therefore necessary. The key aspect for the Taylor Street catchment is to focus specifically on reducing high flood risk in the first instance as being the greater priority. Therefore, it is recommended that mitigation works be undertaken at discrete locations throughout the catchment at the following locations to assist in reducing high flood risk: -

- Jack Street - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Drainage augmentation works and upgrades of the existing system. This includes augmented pipe systems, pipe diversions and duplicated pipes;
- Romney Street - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Drainage augmentation works and upgrades of the existing system. This includes augmented pipe systems, pipe diversions and duplicated pipes;

- Old Maryborough Road - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Augmenting the existing drainage system in the area. This includes increased pipe capacities and/or duplications and extending these along the road and into the existing lake system further downstream;

- Beach Road - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Augmenting the existing drainage system in the area. This includes increased pipe capacities and/or duplications at strategic locations upstream from Beach Road for the purposes of lowering the overland flow depths and maximising the existing road drainage capacities; and
 - Lowering the existing channel system invert downstream to the lake. This lowering will assist in reducing upstream flood depths in the catchment as well as providing additional conveyance capacity in the lower drainage system reaches;

- Islander Road - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Augmenting the existing drainage system in the area. This includes increased pipe capacities and/or duplications and ensuring that the augmented system connects into the proposed upgrade works associated with Beach Road previously. In particular, the open channel works proposed as part of the Beach Road works will also greatly assist in reducing flood risk along Islander Road where an augmented drainage system is constructed in combination;

- Hunter Street - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Augmenting the existing drainage system in the area. This area of the catchment is reasonably complex and the proposed mitigation works will need to focus specifically on reducing flood risk along Andrew Street with selective and effective drainage augmentation options. There are limited options in this area other than augmented pipe systems and even these will need to be selected carefully to minimise overall costs and maximise benefits;

- Andrew Street (as well as medium flood risk along Torquay Road) - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Augmenting the existing drainage system in the area. This includes increased pipe capacities and/or duplications at strategic and effective locations within the existing system;
 - Strategic pipe diversions. This includes new pipe systems which divert catchment flows directly to the outlet lake system downstream of Hillyard Street. This includes pipe systems collecting water at both Torquay Road as well as extending further upstream to Andrew Street;
 - Construction of the proposed detention basin downstream of Old Maryborough Road. It is noted that a detention basin in this area has been previously proposed by Council and the construction of this basin is considered to result in a beneficial lowering in flood risk in the downstream areas including Andrew Street and Torquay Road.

6.3 Stephenson Street Catchment

The risk rankings for the Stephenson Street catchment were generally low. However, risk standards were not met for all locations and this included areas classified as a medium risk. Therefore, it is recommended that mitigation works be undertaken at discrete locations throughout the catchment at the following locations: -

- Shelly Street - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Upgrade of the existing Shelly Street road crossing;
 - Increasing the effectiveness of the existing detention basin further upstream at Oleander Avenue (i.e. further basin augmentations); and
 - Undertaking channel improvements works both upstream and downstream of Shelly Street. This includes increasing channel conveyance through either widening or deepening.
- Boat Harbour Drive (west) - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Augmenting the existing drainage system in the area. This includes increased pipe capacities or duplications and extending these into the existing lake system further downstream; and
 - Provision of local detention facilities at strategic locations in the sub-catchment. This option is subject to physical site limitations and the existing drainage systems.
- Boat Harbour Drive (east) - Acceptable standards not met for DV Product < 0.4 and Q100 immunity. Possible upgrade options at this location include: -
 - Upgrade of the existing Boat Harbour Drive road crossings; and
 - Undertaking channel improvements works both upstream and downstream of Boat Harbour Drive. This includes increasing channel conveyance through either widening or deepening and ensuring that these works are extended into the downstream lake system.

6.4 Risk Treatment Summary

Whilst the Toosan Toosan Creek system has definitive areas of flood risk, a vast majority of the flooding/inundation experienced and specifically areas of most flood risk occur in the Taylor Street catchment. This catchment is extensively urbanised in a low lying and flat catchment and as such experiences significant inundation. While a majority of the existing flooding in this catchment is sheet flow over board areas and thus represent largely nuisance flooding, there are numerous areas which experience high risks. As such, future mitigation works in the Taylor and Stephenson Street catchments should be prioritised in terms of the risk such that critical and strategic areas are mitigated in a prioritised manner. While various mitigation and augmentation options have been proposed as above, future works will need to include more detailed analyses in order to focus specifically on achieving prioritised augmentation and mitigation upgrades.

7 Future Risk Treatment Works

For the reasons previously mentioned in this report, no detailed assessment of mitigation works has been undertaken as part of this study. Rather, the study has focused on identifying and quantifying flood risk across the Toan Toan Creek catchment in a broad sense. The assessment has also included the identification of possible mitigation options to alleviate the critical flood risk areas of both the Taylor and Stephenson Street catchments. It is important to note that further assessment works for both catchments will be required primarily for the purposes of defining and quantifying in detail the most effective and efficient mitigation options. This work would include more detailed hydraulic assessment works to be undertaken in the future in order to effectively undertake a flood risk treatment strategy.

8 Conclusions

This study has been successful in identifying and quantifying flooding risk for both the Taylor and Stephenson Street catchments. Due to model and GIS data inaccuracies, JWP were unable to develop detailed flood mitigation options for both catchments in order to mitigate flood risk. However, conceptual options for mitigation strategies to address all critical areas of flood risk in both catchments have been identified and discussed as part of this report. Specifically, the works completed have included: -

- The identification and assessment of existing drainage capacities, flow paths and flood information for the 1 in 10, 20, 50 and 100 year ARI design flood events for the Taylor and Stephenson Street catchments;
- Preparation of detailed flood data outputs to document the outcomes from the analysis works including flood summary data and flood extent plans for the Taylor Street catchment (plans for the Stephenson Street catchment included only annotated depth and water surface level values);
- Assessment of flood risk and the preparation of flood risk summaries for both the Taylor and Stephenson Street catchments;
- Identification of conceptual mitigation options for both catchments;
- Preparation of summary tables, models, flood extents, GIS mapping and reporting outputs to formally document the outcomes of the study; and
- Preparation of a report congruous with the Hervey Bay City Council Disaster Mitigation Plan.

JWP recommends that Council utilises the outcomes from this Flood Risk Assessment Study for the Taylor and Stephenson Street catchments in the management of existing and future stakeholders within the catchment in terms of reducing flood risk to an acceptable and manageable standard. Both catchment study areas were found to be adversely inundated by flooding for relatively minor flooding events. Due to the inconsistencies in model and GIS data, it is also recommended that further flood analysis works be instigated for both the Taylor and Stephenson Street catchments to accurately determine the full impacts of flooding on residential properties, road infrastructure and commercial sectors but more importantly for the purposes of focusing on risk treatment measures.

9 References

1. The Queensland Urban Drainage Manual (QUDM).

10 Qualification

1. In preparing the report and estimate of costs JWP has exercised the degree of skill and care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering design principles.
2. JWP has used all reasonable endeavours to inform itself of the parameters and requirements of the project and has taken all reasonable steps to ensure that the report and costs estimate is as accurate and comprehensive as possible given the information upon which it is based.
3. It is not intended that this report and costs estimate represent a final assessment of the feasibility of the project.
4. JWP reserves the right to review and amend all calculations, cost estimates and/or opinions included or referred to in the report if:
 - (a) additional sources of information not presently available (for whatever reason) are provided or become known to JWP; or
 - (b) JWP considers it prudent to revise the estimate in light of any information which becomes known to it after the date of submission.
5. JWP does not give any warranty nor accept any liability in relation to the completeness or accuracy of the report and cost estimate.
6. If any warranty would be implied whether by law, custom or otherwise, that warranty is to the full extent permitted by law excluded.
7. All limitations of liability shall apply for the benefit of the employees, agents and representatives of JWP to the same extent that they apply for the benefit of JWP.
8. This report and cost estimate is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report and cost estimate.
9. If any claim or demand is made by any person against JWP on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report and cost estimate or information therein, JWP will rely upon this provision as a defence to any such claim or demand.

APPENDIX A

Hydraulic Results (Taylor Street XP-STORM Model)

APPENDIX B

Hydraulic Results (Stephenson Street XP- STORM Model)

APPENDIX C

Existing Model Flood Extent Results (Taylor Street Catchment)

APPENDIX D

Existing Model Flood Extent Results (Stephenson Street Catchment)