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Annexures to the statement of

PAUL ANDREW EAGLES

to the Queensland Floods Commission Inquiry

dated 09 September 2011

JM

QFCI

Date: 21/09/11

Exhibit Number: 579

STATEMENT	
Prepared by: [redacted]	**Date:** 9.9.2011
Name: Paul Andrew Eagles	
Address: C/- Level 4 229 Elizabeth Street Brisbane	
Occupation: Chief Executive Officer	

I, PAUL ANDREW EAGLES Chief Executive Officer of the Urban Land Development Authority (ULDA), state:

1. I have been asked to make this statement to the Queensland Floods Commission of Inquiry and this statement responds to the requests set out in the letter from Her Honour Justice Catherine E Holmes dated 25 August 2011.
2. I was appointed the inaugural Chief Executive Officer of the Urban Land Development Authority (ULDA) in December 2007. Prior to this appointment I held senior development management positions with Stockland and Delfin Lend Lease.

[redacted]

3. The Minister responsible for administering the *Urban Land Development Authority Act 2007* (Act) is responsible for declaring an urban development are (UDA), setting the boundaries of the UDA and making the interim land use plan (ILUP) although the ULDA provides assistance in investigating sites and preparing ILUPS.

4. While the ULDA is not responsible for the declaration of a UDA, nor has any powers in an area until a UDA is declared, UDA staff do assist the Department by providing advice, resources and support in the preparation of the submissions prior to declaration of a UDA.

5. At the time of preparation of this statement fourteen UDAs had been declared with a further one in the process of being declared. As the size and characteristics of each UDA varies markedly, the amount of analysis and investigation prior to declaration can vary significantly.

Process used by the ULDA and considerations taken into account by the ULDA (specifically with reference to flood risk) when:

Investigating sites to be declared UDAs and selecting the boundaries of the UDA

6. A UDA is declared by regulation under s.7 of the *Urban Land Development Authority Act 207* (Act).

7. Examples of the process and considerations for different types of UDAs include:

- For the UDAs of Woolloongabba, Bowen Street Roma and Clinton, their small size and location well away from water courses and flood impacts meant that the investigation in relation to flood risk was not required.
- For UDAs which may have the potential for flood risk, the typical processes the ULDA undertakes in investigating potential UDAs, include:
  a) A initial desk top review of site characteristics/issues. This is usually conducted [redacted] review of relevant planning documents including the local government planning

Witness: [redacted] - Solicitor, ULDA 229 Elizabeth Street, Brisbane	JP/Solicitor/Commissioner for Declarations

schemes, regional plans, State planning and management documents. A critical element of this review is the consideration of Council flood and storm surge maps in the planning scheme and the associated flood studies;

b) Preliminary discussions with the local authority staff and councilors;

c) Site visits;

d) Preparing and distribution of a background report to State and local government agencies requesting comments; and

e) Conducting government agency briefing sessions and workshops with local authority staff.

When preparing an ILUP

8. Section 8 of the Act requires that when a UDA is declared, the declaration regulation must make an ILUP and that the ILUP regulates development until such time as a development scheme for the UDA takes effect.

9. When preparing the content for an ILUP, the ULDA would typically:

    a) Consider the information obtained through the preliminary site evaluation/assessment and feedback from the interagency briefing sessions and Council;

    b) Prepare a development "vision" for the UDA;

    c) Identify potential early development areas. Areas subject to flooding or potential flooding would not typically be identified as early development areas;

    d) Prepare interim development assessment criteria to apply to the early development areas and distribute the draft ILUP to State agencies and local government for comment; and

    e) Prepare a final draft ILUP for consideration by Department of Local Government and Planning and the Minister.

[redacted]

Witness [redacted] [redacted] Solicitor, ULDA 229 Elizabeth Street, Brisbane	**JP/Solicitor/Commissioner for Declarations**

When preparing a proposed development scheme for a UDA

10. Section 24 of the Act requires the ULDA to prepare a proposed development scheme for the UDA.

11. When preparing a development scheme for a UDA, the ULDA would typically -

   a) Undertake a detailed site evaluation and assessment of flood impacts. At this stage the ULDA would consider whether additional flood information was required prior to preparing the development scheme. In the case of UDAs with little available Council data or known complex waterways the ULDA has commissioned independent expert advice during the preparation of the development scheme. Hydraulic studies were commissioned by the ULDA prior to the gazettal of the Fitzgibbon, Oonoonba and Caloundra South UDAs for these reasons;

   b) In the case of Caloundra South UDA, the ULDA commissioned an independent flooding and water quality review to test both the landowner and the Council's flood solutions. Annexed to this statement and marked PE1 is copy of this review;

   c) The land use pattern and preferred development scenario for the UDA is chosen to take into account the existing information, and any additional analysis, on flooding. Typically areas known to flood are designated as open space;

   d) In addition when drafting the development scheme consideration is given to what development controls and assessment criteria are needed in relation to flood impacts and risk;

   e) Prior to the draft development schemes being put on public display a range of activities are undertaken to ensure the schemes are technically sound documents, including:

      i. Circulation to State and local government agencies requesting feedback[redacted] and

ii. Meetings with key stakeholders such as the local authority and landowners;

f) During the statutory notification of the proposed development scheme the draft development scheme and supporting information (including any supporting information) is put on public display for comment and allows the opportunities for submissions; and

g) Upon the close of the statutory notification submission period, a submissions report is prepared which provides a comment and recommendation in relation to each submission which must be considered by the ULDA Board prior to submitting the development scheme to the Minister for consideration.

When assessing development applications and considering flood risk.

Statutory process

12. Section 57 of the Act sets out the considerations that must be taken into account when the ULDA makes a decision in relation to a development application.

13. Section 58 of the Act permits the ULDA to impose conditions on a development approval.

Administrative process

14. UDAs encompass areas that vary greatly from inner urban redevelopment areas such as Bowen Hills UDA to the major Greenfield areas, such as Ripley Valley. The risk of flooding can occur via different mechanisms e.g. riverine, overland flow and local drainage.

15. In addition to the provisions of the ILUPs and development schemes, the ULDA has published a number of guidelines which outline the standards for development in UDAs and therefore play an important role in development assessment. These guidelines will also include Draft ULDA Guideline no.15 (Protection from Flood and Storm tide Inundation) (Draft Guideline). Annexed to this statement and marked PE2 is a copy of

[redacted]

Witness: [redacted] - Solicitor, ULDA 229 Elizabeth Street, Brisbane	JP/Solicitor/Commissioner for Declarations

the Draft Guideline.

16. UDA development applications require the submission of sufficient engineering details to determine if the site is flood affected or if the development of the site will adversely affect adjoining properties. The ULDA adopt a 'non-worsening' approach to all developments.

17. Where flooding impacts are possible based on information obtained from council or a flood study:

    a) The developer is requested to submit a detailed flood study with the application, which assesses the existing flooding situation and proposed flooding post development;

    b) These studies are then forwarded to external consultants for review on behalf of the ULDA. Comments are received from the consultants;

    c) The ULDA then will either arrange a meeting with the developer and their consultants, to discuss the submitted flood study or a 'Request for Further Information' will be forwarded to the developer seeking a response to specific concerns; and

    d) Development approval is only issued once the ULDA is satisfied that the flood model and the works proposed will ensure that the development of the site is not precluded by any flood impacts and no other properties are adversely affected in terms of flooding by the development.

18. The following examples provide details on how alternative sites from different UDA are assessed -

RNA Site, Bowen Hills

19. Flooding within Bowen Hills can occur due to excess rainfall within local catchments combined with inadequate underground drainage systems and poorly defined overland flow paths.

[redacted]

20. For example, the existing RNA site floods as a result of rainfall within the existing catchment exceeding the capacity of the underground stormwater system resulting in overland flow within Water Street, this flow then ponds on the RNA site.

21. A Flood Report was prepared for the existing site and for the proposed development. Annexed to this statement and marked PE3 is a copy of this flood report. The report showed that the developer was required to provide alternative flood storage to ensure that 'no worsening' occurred to the downstream properties. This alternative flood storage will be achieved by an underground tank. The flood report has been assessed by external consultants acting on behalf of the ULDA.

Ripley Valley

22. The Ripley Valley is bisected by Bundamba Creek, which drains through Ipswich to the Bremer River. Any increase in flooding due to the development in Ripley Valley will adversely affect the existing residents of Ipswich.

23. Map 3a in the Ripley V alley UDA Submitted Development Scheme reflects Ipswich City Council's flooding information for Ripley Valley and identifies land potentially impacted by a 1:100 flood event. Annexed to this report and marked Annexure PE4 is a copy of the submitted development scheme.

24. Ipswich City Council has instigated the preparation of a flood model for Ripley Valley, thereby allowing developments to be assessed against the model to ensure that separately or when combined achieved a 'no-worsening' to the existing residents of Ipswich.

25. This model will be finalised in the near future and every development submitted to the ULDA will be assessed against the model to ensure compliance.

The extent to which State Planning Policy 1/03 forms any part of the ULDA's considerations in determining land use.

26. Appropriate development schemes reference the Queensland Government's policy position set out in State Planning Policy 1/03 in relation to flooding.

[redacted]

Witness: [redacted] Clinton James Hanney - Solicitor, ULDA 229 Elizabeth Street, Brisbane	**JP/Solicitor/Commissioner for Declarations**

27. State Planning Policy 1/03 is also referenced in Draft ULDA Guideline 15 (Protection from Flood and Storm Tide Inundation) and the following UDA development schemes where indicated. The relevant development schemes are annexed to this statement and marked as indicated in the 3rd column:–

UDA	References to State Planning Policy 1/03	Annexure No.
Bowen Hills	Clause 3.7 Urban Design and Sustainability, Community Safety and Well Being p 13 Footnote 2 Clause 3.10 Lot Design. p 19 Footnote 10	PE5
Northshore Hamilton	Clause 3.7 Urban Design and Sustainability, Community Safety and Well Being p 12 Footnote 2 Clause 3.10 Lot Design. p 18 Footnote 14	PE6
Fitzgibbon Brisbane	Clause 3.12 Lot Design p 14 Footnote 10. Sub Precinct 1b p 31 Footnote 23	PE7
Yarrabilba (Submitted Development Scheme)	Clause 3.3.9, p 14	PE8
Greater Flagstone (Submitted Development Scheme)	Clause 3.3.9, p 15	PE9
Ripley Valley (Submitted Development Scheme)	Clause 3.3.9, p 12	PE10
Caloundra South (Submitted Development Scheme)	Clause 3.3.9, p 16	PE11

The development controls in place in UDA development schemes to manage or mitigate [redacted]

Witness: [redacted] Solicitor, ULDA 229 Elizabeth Street, Brisbane	**JP/Solicitor/Commissioner for Declarations**

the risk of floodingPE8

28. All UDA development schemes contain UDA-wide criteria requiring development to ensure that people and property are safe from potential hazards from flooding where flooding was identified as a risk in the UDA at the time the development scheme was created. The development schemes for the UDAs of Moranbah, Blackwater, Greater Flagstone, Yarrabilba, Ripley Valley and Caloundra South also make reference to the current Queensland Floods Commission of Inquiry.

The following table identifies those development schemes that contain flooding criteria and those do not for the reason mentioned above, and those references.

UDA	Development Constraints/Controls in Development Schemes relating to flooding	Annexure No.
Bowen Hills	Clause 3.7, p 13 Clause 3.10, p 19	PE5
Northshore Hamilton	Clause 3.7, p 12 Footnote 2 p 12 Clause 3.10 , p 18 Footnote 14 p 18 P 46 precinct outcomes	PE6

[redacted]

Witness: [redacted] - Solicitor, ULDA 229 Elizabeth Street, Brisbane	JP/Solicitor/Commissioner for Declarations

UDA	Development Constraints/Controls in Development Schemes relating to flooding	Annexure No.
Fitzgibbon, Brisbane	Flood Immunity pg 11 Clause 3.12 , p 14. Land Use Plan 3.0 p 26 Land Use Plan 3.0 p 29 Footnote 17 Footnote 20 Land Use Plan 3.0 Precinct 1, sub precinct intent p 30 Footnote 22 Sub precinct outcomes p 31 footnote 23 Sub precinct outcomes p 33, footnote 25 Sub precinct outcomes p 34, Footnote 26 Land Use Plan precinct 2 p 39 Footnote 30 Land Use Plan precinct 3 pg 42 Footnote 31 Land Use Plan precinct 4 , transport p 45 Infrastructure Plan Flood Mitigation p 60	PE7
Oonoonba, Townsville	Clause 2.3, p 4 Environment and Sustainability p 9 Footnote 3 p 9 Clause 3.4.1, p 10	PE12
Clinton, Gladstone	Nil	PE13
Andergrove Mackay	Nil	PE14

[redacted]

Witness: [redacted] Solicitor, ULDA 229 Elizabeth Street, Brisbane	**JP/Solicitor/Commissioner for Declarations**

UDA	Development Constraints/Controls in Development Schemes relating to flooding	Annexure No.
Woolloongabba, Brisbane	Nil	PE15
Blackwater	Clause 3.3.8 (viii), p 12 Open Space Zone intent, p 13 Preparing a UDA development application, p 26	PE16
Moranbah	Clause 3.3.6 (v), p 10 Clause 3.3.6 (v), p 10 Precinct 2 (ix), p 23 Precinct 2 (xiv), p 23 Preparing a UDA development application, p 29	PE17
Roma	Nil	PE18
Yarrabilba (Submitted Development Scheme)	Background, p2 Clause 3.3.8, p 13 Clause 3.3.9, p 14	PE8
Greater Flagstone (Submitted Development Scheme)	Clause 3.3.8, p 14 Clause 3.3.9, p 15 Environmental Protection Zone, p 24	PE9
Ripley Valley (Submitted Development Scheme)	Clause 3.3.8, p 12 Clause 3.3.9, p 12 Clause 3.4.1, p17 (zone provisions) Environmental Protection Zone, p 20	PE10
Caloundra South (Submitted Development Scheme)	Clause 3.3.8, p 14 Clause 3.3.9, p 15 Clause 3.3.9, p 16 Environmental Protection Zone, p 26	PE11

[redacted]

Witness: [redacted] - Solicitor, ULDA 229 Elizabeth Street, Brisbane	**JP/Solicitor/Commissioner for Declarations**

I make this statement of my own free will believing its contents to be true and correct.

(1) This written statement by me dated 9/9/11 and contained in the pages numbered 1 to 12 is true to the best of my knowledge and belief; and

(2) I make it knowing that, if it were admitted as evidence, I may be liable to prosecution for stating anything that I know is false.

.... [redacted] ...... Signature

Signed at Brisbane this 9th day of September 2011

Before me: [redacted]

Solicitor

[redacted]

Witness: [redacted] Solicitor, ULDA 229 Elizabeth Street, Brisbane	**JP/Solicitor/Commissioner for Declarations**

PE 1

Cardno
Shaping the Future

Caloundra South

Review of Flood Risk Management Strategy and Stormwater Quality Management

Project Number: J10048

Prepared for ULDA

17 March 2011

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1	22 December 2010	[redacted]	MG	[redacted]	MD
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TABLE OF CONTENTS

1 INTRODUCTION

The Urban Land Development Authority (ULDA) is completing master planning with respect to the Caloundra South area. Stockland, the major landowner in the Caloundra South area, has prepared a Flood Risk Management Strategy and a Stormwater Quality Management Master Plan in support of its proposed urban footprint.

This footprint is greater than that previously derived by the Sunshine Coast Regional Council. Further, the solution developed by Stockland would result in a greater proportion of the footprint being available for the creation of lots by virtue of the measures necessary to ameliorate the impact of development on flooding being located within the proposed waterway corridors rather than within the urban development footprint.

Stockland also propose to locate a number of water quality improvement devices within the waterway corridors provided for the conveyance of flow.

Cardno was commissioned by the ULDA to complete the following tasks:

- review the flood solutions developed by Sunshine Coast Regional Council and Stockland;
- consider whether the larger footprint proposed by Stockland could be achieved without causing unacceptable flood impacts;
- consider whether the use of measures within the waterway corridor will offset the impact of development on flooding upstream and downstream of the site;
- identify any additional flood modelling required to confirm the footprint proposed by Stockland; and
- review the potential for stormwater treatment measures to be located within the waterway corridor.

The commission has considered flooding and stormwater management issues associated with the development of the Caloundra South land. Saunders Havill has considered other potential environmental impacts for the ULDA.

2 SCOPE OF REVIEW

2.1 Work Reviewed

The review undertaken by Cardno focussed on the following documents relating to the Caloundra South urban development area.

- BMT WBM (2010), *Caloundra Downs Development: Flood Risk Management Strategy*, November.
- BMT WBM (2010), *Caloundra Downs Stormwater Quality Management Master Planning Advice*, November.
- Sinclair Knight Merz (2010). *Caloundra South Flood Study*, Version 1, April.

It can be noted that there is no dispute in relation to the work completed in support of the Sinclair Knight Merz report. The purpose of the commission was to peer review the BMT WBM flood risk management strategy and proposed stormwater quality management.

A brief overview of the reports is provided in the following sections.

Although a request was made to access the computer model prepared in support of the BMT WBM flood study, it was not possible to obtain the model within the time available for the review. The review has therefore been based on the work as presented in the reports.

2.2 BMT WBM Flood Risk Management Strategy

BMT WBM completed a flood study on behalf of Stockland to consider the impact of development and available mitigation strategies. As noted in the report, the flood risk management strategy is broad-scale and preliminary in nature. Additional investigations will be undertaken as the development proceeds to define the flood solution for the site. The flood modelling completed by BMT WBM is based on the hydrology and ground level information used in the Sinclair Knight Model of the area that was developed for Council (refer Section 2.4).

The main difference in approach between the BMT WBM modelling and that completed by Sinclair Knight Merz is the proposed use of waterway corridors (those areas to be left undeveloped to allow the passage of flow within existing creek systems), and channels to mitigate both the impact of development on the peak flow discharged from developed areas and the impact of filling within the 100 year flood extent.

This approach, if successful, would allow a larger footprint to be achieved compared to that proposed in the Sinclair Knight Merz study completed for Council.

2.3 BMT WBM Stormwater Quality Management Master Planning Advice

On behalf of Stockland, BMT WBM developed an overall strategy for the management of stormwater runoff from its Caloundra South site. The solution derived involves the following (p6-13):

- education;
- rainwater tanks;
- streetscape bioretention; and
- ephemeral wetlands.

The report envisages that it will be necessary to treat runoff via streetscape bio-retention systems followed by ephemeral (i.e. subject to wetting and drying depending on weather conditions) wetlands in order to meet the stringent requirements of the Water Quality Objectives adopted for Pumicestone Passage under Schedule 1 of the Environmental Protection (Water) Policy (EPP Water). The Department of Environment and Resource Management publication *Environment Protection (Water) Policy 2009, Pumicestone Passage Environmental Values and Water Quality Objectives, Basin 141 (part), including waters of Bribie Island and Bells, Coochin, Dux, Elimbah, Mellum, Ningi, and Tibrogargan Creeks* (July 2010), which is included under Schedule 1 of the EPP Water, specifies that for the northern part of Pumicestone Passage, the water quality objective is to maintain existing water quality (20^{th}, 50^{th}, and 80^{th} percentiles).

To demonstrate that this water quality objective can be achieved, the Master Plan has determined the works required to achieve no worsening in terms of annual pollutant export from the site compared to current conditions. This has resulted in the need for a considerably higher level of treatment than the load based reduction targets stipulated in both the *South East Queensland Regional Plan 2009–2031 Implementation Guideline No. 7 Water Sensitive Urban Design: Design Objectives for Urban Stormwater Management* (Department of Infrastructure and Planning, November 2009) and the guidelines of the former Caloundra City Council (now part of Sunshine Coast Regional Council).

For example, whereas the standard requirement for the reduction in Total Nitrogen load from urban development is 45 percent, to achieve no increase compared to existing conditions, a reduction of between 80 and 87 percent is required (p6-8). It can be noted that BMT WBM is currently completing sampling with respect to the quality of the runoff that currently occurs from the site in order to allow a more accurate base line assessment of the current quality of runoff from the site to be completed.

Due to the need to achieve a higher level of treatment, the master plan makes recourse to the use of bio-retention systems followed by wetlands. The master plan notes that the bio-retention systems would be integrated into the streetscape, suggesting that the wetlands would be located within waterway corridor areas (p6-18).

The initial estimate of the overall footprint of the wetlands is 5 percent of the total developable area, plus the area occupied by pre-treatment devices (if required). Given an assumed total land usage of 1,600 hectares (subject to definition of final development area), wetlands with an area of at least 80 hectares would need to be provided within the waterway corridors. If this was ultimately not possible, it would be necessary to incorporate basins into the development footprint, thereby reducing the area available for the creation of lots.

2.4 Sinclair Knight Merz Caloundra South Flood Study

Sinclair Knight Merz completed detailed hydraulic modelling of the Caloundra South area on behalf of Sunshine Coast Regional Council. Based on the results of modelling, flood hazard mapping (with areas of low, medium, high and extreme flood hazard defined based on the depth and velocity of flow) was completed.

Based on the flood hazard mapping, options for development within the floodplain were considered. The report considered a number of layouts (Scenarios A to F in Section 6.2.2 of the report).

The report recommended that development footprints be derived based on allowing development (and associated earthworks) to occur in the following areas.

- ***Land above the existing 100 year flood level***

  Earthworks in areas above the 100 year flood extent will not impact 100 year flood levels and therefore unrestricted earthworks would be permitted in this area.

- ***Land within low and medium flood hazard areas***

  As the depth and velocity of flooding in areas defined as having a low or medium flood hazard are relatively low, it is likely that earthworks can occur in such areas to provide land above the 100 year flood level which, combined with appropriate ameliorative works, will not impact on flood levels to an unacceptable degree.

  The report indicated that any earthworks would need to be compensatory in nature (i.e. any filling occurring between existing ground levels and the 100 year flood level will need to be matched by an equal volume of excavation) and that it would need to be demonstrated that any earthworks would not produce flooding or environmental impacts that would cause actionable nuisance on adjacent properties.

- ***Land within high and extreme flood hazard categories***

  For the purposes of the report, it was considered that it would not be appropriate to fill land presently within high and extreme flood hazard areas for urban purposes. The only exception to this would be the creation of roads and other infrastructure within high and extreme hazard areas. Even then, it will be necessary to achieve the same outcomes as defined for earthworks within low and medium flood hazard areas.

The report therefore envisaged that filling will occur within the extent of flooding produced by the 100 year event, provided that a balanced earthworks operation is undertaken (together with any other works required to mitigate flood impacts) to ensure that there is no reduction in the overall volume available beneath the 100 year flood level for the storage of flood waters.

It can be noted that the development footprints subsequently analysed in the report assume filing of areas of low, medium and high flood hazard without compensatory earthworks.

For the analysis, it was assumed that the peak flow rates derived for the existing (undeveloped) case would be applicable to the developed site. In practice, this would be achieved by the use of detention basins (or other methods providing temporary storage of flow) to attenuate the peak flow rate discharged from developed areas to match that occurring prior to development. The basins would be sited within the urban footprint and would reduce the area available for the creation of lots. Based on previous experience by Cardno with similar projects, it is estimated that approximately five percent of the total developable area (approximately 80 hectares assuming that a development footprint of 1,600 hectares is achieved) would be occupied by detention basins.

The most recent layout considered in the flood report (Scenario F) was compared to that modelled by BMT WBM. The development footprint proposed in the BMT WBM report is larger than that considered in the Sinclair Knight Merz study. Further, provided it can be demonstrated that the footprint can be achieved without producing unacceptable flood level impacts, the BMT WBM solution would not require a reduction in developable area for the provision of detention basins.

3 DETAILED COMMENTS IN RELATION TO REPORTS

3.1 Hydrology

As there is no stream gauge on any of the watercourses that pass through the Caloundra South area, it is not possible to calibrate a runoff routing model for Lamerough Creek, Bells Creek, or any of their tributaries. BMT WBM has installed stream gauges and will be able to calibrate models to recorded values following the occurrence of significant flood events.

For the Sinclair Knight Merz study, recourse was made to an existing stream gauge on the Upper Maroochy River. The parameters derived from calibrating a runoff routing model to the peak flows predicted at the gauge (based on a flood frequency analysis and the consideration of a historic verification event) were applied to the model of the catchments related to Caloundra South. The Caloundra South model was used to derive runoff hydrographs for use in the hydraulic model for a range of flood events and storm durations.

A review of the modelling suggests that the peak flows predicted by the use of the parameters will be conservatively high. However, it is noted that a check of the reasonableness of the peak flow predicted to occur from each subcatchment of the model using the empirical Rational Method was not completed. Such a check would have provided additional confidence with respect to the quantum of the predicted flow from each subcatchment.

Based on the report prepared by BMT WBM, it is understood that their runoff modelling was based on the same parameters adopted for the Sinclair Knight Merz flood study.

Of the parameters adopted for the investigation, the adopted loss rates are of relevance. For both analyses, an initial loss of 10 mm, followed by a continuing loss rate of 5 mm per hour was adopted for pervious areas. For impervious areas, zero initial and continuing losses were adopted. Typically, and more conservatively, an initial loss of zero followed by a continuing loss of 2.5 mm per hour is adopted for the modelling of design events. It is therefore anticipated that the modelling will result in the calculation of flood levels that are slightly lower than those obtained through the use of reduced loss rates. However, it is also expected that the use of such loss rates will increase the relative impact of development on peak flow rates compared to existing conditions by virtue of the transition of pervious areas (with initial and continuing loss rates of 10 mm and 5 mm/h respectively) to impervious areas (with zero rainfall loss). It would be suggested that as a sensitivity case the peak flood levels obtained by the use of lower initial and continuing losses be calculated to confirm that adequate flood immunity is provided for development.

In this case, the issue of initial loss is potentially of more importance when considering the impact of development. As noted in Section 2.4, the modelling of development completed by Sinclair Knight Merz assumed that detention measures would be provided within the development footprint to offset the impact of development and provide peak flow rates that match those calculated for the existing situation.

This approach does not take into account potential changes in the time at which the peak discharge occurs from each basin or changes in hydrograph shape (i.e. the variation in flow over time throughout an event) that occur as a result of development. While the inclusion of a detention basin may allow the magnitude of the peak flow from developed areas to be limited to match that of the existing case, the peak flow may occur at a slightly different time to that estimated for the existing case, and the shape of the hydrograph may also alter. Despite this, it needs to be acknowledged that it is simply not possible to predict the location, size, and outlet configuration of detention basins at this point in the development process. Recourse is generally necessary to the assumptions made for the Sinclair Knight Merz study.

However, in this case the use of runoff hydrographs calculated for the existing situation will reflect the losses associated with the pervious areas rather than the reduced losses associated with the impervious areas introduced as part of development. The runoff hydrographs used in the Sinclair Knight Merz modelling will therefore underestimate the volume of runoff from those areas identified for development.

In the case of the BMT WBM modelling, it is intended that the detention necessary to achieve a non-worsening outcome will be provided within the waterway corridors. This allowed the runoff routing model to be revised to reflect the losses associated with the developed case and revised hydrographs applied to the hydraulic model.

The only concern in relation to this approach is with regard to the temporal patterns (which specify the distribution of rainfall over time) used to derive the runoff hydrographs. *Australian Rainfall and Runoff* (Institution of Engineers Australia) nominates design temporal patterns for use when modelling design storms. As the overall objective of the hydraulic study is to confirm that development can proceed without producing unacceptable flood level impacts, it is necessary to ensure that the outcome is not affected by the relative timing of peak flows in the system (i.e. runoff from the site compared to that from the larger catchment). It would therefore be desirable to complete a sensitivity analysis using alternate temporal patterns to confirm that the result obtained is not particularly sensitive to the temporal pattern used for the analysis.

3.2 Hydraulics

3.2.1 Sinclair Knight Merz Study for Sunshine Coast Regional Council

As noted in Section 2.4, the development solution developed by Sinclair Knight Merz for Sunshine Coast Regional Council involved the completion of balanced earthworks in areas of low and medium flood risk to increase the area above flood level available for development.

Based on the results presented in Appendix L of the report, it would appear that the development footprints identified in the report could be made to work following the completion of more detailed modelling.

The report notes that excavation would occur to compensate for any proposed filling. As the report contains no details with respect to the proposed location, area or volume of fill, it is not possible to comment in relation to the potential impact of the works compared to those detailed in the BMT WBM report.

Further, as the Sinclair Knight Merz report does not provide information in relation to the Mannings 'n' (i.e. level of vegetation) assumed within areas of cut, it is not possible to provide comparative advice in relation to potential maintenance costs associated with maintaining areas where excavation has occurred. For example, it would be expected that the long term maintenance requirements for an area that is thoroughly revegetated would be less than those for an area which needs to be maintained with a certain level of vegetation in order for the adopted hydraulic solution to be achieved.

3.2.2 BMT WBM Study for Stockland

In order to minimise flood level impacts associated with filling and development without the use of internal detention basins, the BMT WBM study recommends the construction of a number of drainage channels, high flow flood relief channels, the excavation of an additional flood storage area, the creation of a maintained grassed area, and the construction of an embankment (with associated culverts).

As the model used in the analysis was not provided for review, it was not possible to confirm the design assumptions made in relation to the flood control measures (for example, the actual width of channels, the level of vegetation assumed in the channels, and the fall of the channels). Further, it was not possible to confirm that the additional storage area will be free draining. The results presented in the report suggest that a fall has been applied to the storage area. However, given the size of the area involved, the ability for the final surface of the storage area to drain will need to be confirmed (or alternatively a different treatment adopted in the storage area).

For the BMT WBM analysis, the 100, 50, and 5 year events were considered.

The results presented in the report indicate that the proposed development will not produce significant off-site impacts for the 100 year event, with a reduction in flood level obtained downstream of the developed area. As noted in the report, a slight increase in level is predicted in the vicinity of the flood prone Koala Court. However, it is agreed that the increase can be ameliorated by the completion of localised works. There is also a small increase in level upstream of the Bruce Highway at the Bells Creek North crossing. Again, this is considered to be a relatively localised increase that could be resolved with further modelling.

For the 50 year event, a similar result is achieved.

For the 5 year event, an increase in level of between 40 and 90 mm is predicted to occur downstream (to the east) of the development. The report argues that this is acceptable on the basis of the fact that the resultant levels are well below the 100 year flood and storm surge levels used for the definition of minimum development levels in the Pelican Waters area. It is agreed that the increase in level would not affect the existing flood immunity of the Pelican Waters development.

To provide a simplistic representation of the proposed solution, the analogy of a detention basin can be considered. The outlet and storage of a typical detention basin are designed to reduce the peak flow rate discharged from the basin to match that predicted for the undeveloped catchment for a range of flood events. For small events, the use of a small outlet will effectively throttle peak flows. However, the same small outlet will overly restrict discharge for larger events, resulting in a greater depth and volume of ponding in the basin than would normally be required.

Similarly, if a relatively large outlet is adopted in order to minimise the depth and volume of water stored in the basin for large events, the relatively large outlet will allow a relatively greater flow to discharge from the basin for small events.

In this case, consideration also needs to be given to the location of the development area within the catchment. In the lower reaches of a catchment (such as the location of Pelican Waters), it is beneficial to discharge runoff from a developed site without the use of detention basins because the peak flow will be discharged prior to the peak flow occurring from the catchment as a whole.

The Caloundra South development area is located in the middle of the catchment. Although there is some benefit to be had by the release of discharge without detention, there is still the requirement to provide detention storage (in this case proposed within the waterway corridors) to ensure that peak flows downstream of the site are not increased to any significant degree.

Based on the solution presented in the BMT WBM report, it is considered that the latter detention basin approach described above has been achieved. The proposed works will provide adequate control over flood levels and flows for large events and not cause an increase in level in upstream areas, with a small increase in flow rate and flood level predicted downstream of the site for the lesser 5 year event.

Whilst it is agreed that the identified impact associated with the 5 year event is minor, it is considered that additional consideration needs to be paid to more frequent events to ensure that the proposed solution will not adversely impact on the stability of downstream waterways.

For instance, the *South East Queensland Regional Plan 2009–2031 Implementation Guideline No. 7 Water Sensitive Urban Design: Design Objectives for Urban Stormwater Management* (Department of Infrastructure and Planning, November 2009) contains a waterway stability criterion which indicates that the peak flow in a stream should not increase for an event with a recurrence interval of 1 year in order to ensure the stability of the watercourse.

While it is considered likely that the impact of the development on the peak flow in the Lamerough and Bells Creek system will be small, it is recommended that additional modelling of the 1 and 2 year recurrence interval events be undertaken to assess the impact of development on flow rates and flow velocities. The impact would need to consider increases in magnitude as well as duration. It can be noted that it is considered that adequate control over runoff produced by events with recurrence intervals of less than one year will be obtained by virtue of the stormwater management system proposed for the site.

Overall, provided the additional modelling detailed above confirms the viability of the proposed development footprint, it is considered that the development area identified in the BMT WBM report can be achieved.

The required additional modelling is summarised in Section 4.

3.3 Stormwater Management- Wetlands

The BMT WBM Caloundra Downs Stormwater Quality Management Master Planning Assistance report (2010, refer Section 2.3) includes the use of ephemeral wetlands within the waterway corridor for the treatment of runoff from the site. Based on the initial sizing presented in the report, a total area of up to 80 hectares could be required within the waterway corridors for the provision of wetlands (assuming that the overall development area that is achieved is 1,600 hectares). It can be noted that the sizing completed to date is also based on an assumed infiltration rate of 25 mm/h. While this is a relatively low infiltration rate, given the clay soils present on site the actual rate of infiltration may be less than this value, which in turn could affect the required wetland area. As noted in the BMT WBM report, a geotechnical investigation is required to confirm the actual infiltration rate across the site.

In general, it is considered that no significant issues exist with respect to the placement of wetlands within waterway corridors due to the complementary nature of wetlands and waterway corridors. However, additional consideration is required in relation to their placement in terms of their operation and maintenance and the potential impact of wetlands on flooding.

A number of guidelines exist with respect to the design of wetlands. A typical guideline is contained in Section 6 of the Healthy Waterways *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Version 1, June 2006). The wetlands described in the guideline consist of an inlet zone, followed by a macrophyte zone. The purpose of the inlet zone is to settle out coarse sediment and provide a means to limit the flow transferred to the macrophyte zone (high flows greater than the peak flow for the 1 year event are directed away from the macrophyte zone (p 6-4). In this case, it is uncertain whether the sediment function will be required if runoff is first passed through a bio-retention system.

Within the macrohpyte zone, a maximum extended detention depth of 0.5 metres is recommended. To preclude the potential for the resuspension of pollutants and the loss of biofilms, a low velocity of flow is preferred. The Healthy Waterways guidelines suggest a limiting velocity of 0.05 m/s (p 6-18). Although it is considered that this design velocity is conservatively low, consideration will need to be given to the acceptable velocity within wetlands during flood events.

Given the above, consideration will need to be given to the placement of wetlands within waterway corridors. As noted in the Healthy Waterway guidelines, it is possible to have wetlands subject to flood inundation provided the duration of inundation is relatively short and does not affect the health of vegetation (p 6-5). Further, it is desirable for flooding of wetlands to occur by backwater flooding to minimise the potential for scour.

In terms of their placement within waterway corridors, the wetlands and any protective bunds need to be set at a level sufficiently high to prevent inundation and damage during relatively small events in Lamerough Creek and Bells Creek. Inundation during relatively minor events could also result in sedimentation occurring and the consequent need to complete more frequent maintenance than would normally be the case.

At the same time, if a bund is used to prevent inundation from occurring, the area inside the bund will not be part of the effective storage of the waterway corridor until the bund is overtopped. There is a consequent potential impact on at least minor event flooding if it is necessary to place bunds around wetlands to provide immunity to frequent creek flooding. Alternatively, if it is possible to locate wetlands in relatively high overbank areas it may not be necessary to use a protective bund. In such a case, there would be no adverse impact on available flood storage and conveyance.

To confirm that wetlands can be successfully incorporated into waterway corridors, it is necessary to complete a preliminary assessment of the level of flood immunity against creek flooding to be provided to wetlands to minimise maintenance costs and to then locate wetland areas accordingly.

Depending on whether bunding is required around the wetland areas to achieve the required level of flood immunity, additional flood modelling will be required to confirm that the impact of the wetlands on flood conditions for a range of events.

4 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Based on a review of the flooding and stormwater management reports completed in relation to the development of the Caloundra South area, subject to the additional modelling detailed in the following section, the following conclusions are made.

- The development footprint identified in Figure 1-5 of the BMT WBM *Caloundra Downs Development: Flood Risk Management Strategy* (2010) can be achieved without producing unacceptable flood level impacts. It can be noted that the modelling reported in the Sinclair Knight Merz study for Sunshine Coast Regional Council is not in dispute.

- Hydraulically, the location of wetlands as stormwater treatment measures within waterway corridors can be achieved provided sufficient flood immunity is provided for the wetlands. Further, flow conditions during flood events sufficient to cause inundation of macrophyte areas will need to be such that the inundation does not cause the resuspension of sediment or damage to vegetation.

4.2 Recommendations

In order to confirm the conclusions made in Section 6.1, additional flood modelling is required.

The required flood modelling is described below.

- *Alternate temporal patterns*

  To confirm that the solution developed by BMT WBM is not sensitive to the choice of temporal pattern, the model should be rerun with alternate temporal patterns.

- *Sensitivity analysis- loss rates*

  As a sensitivity analysis, the impact on flood levels associated with the use of a zero initial loss followed by a continuing loss rate of 2.5 mm/h should be considered for pervious areas.

- *Review of runoff model*

  The peak flows predicted for each catchment should be checked for reasonableness using alternate methods such as the Rational Method if appropriate.

- *Flood Storage*

  Additional comment should be provided in relation to the impact of the development on the available flood storage within the Lamerough and Bells Creek systems.

- *Minor flood events*

  It is noted that an increase in flow is predicted to occur for the 5 year event. Given this, the 1 and 2 year events need to be modelled to confirm that the impact of the proposed development and drainage works on the Lamerough and Bells Creek systems for smaller events is not significant. The assessment will need to consider peak flows and velocities and the duration over which any increase in flow or velocity occurs relative to existing conditions and the stability of existing creek banks.

- *Wetlands*

  Following the preliminary location of the wetlands proposed for the waterway corridor (refer below), potential impacts on flood levels and required additional flood mitigation measures will need to be assessed.

The required additional work in relation to the location of the wetlands is described below.

- *Required flood immunity level*

  Consideration will need to be given to the required flood immunity level for wetlands against creek flooding to minimise maintenance costs.

- *Location of wetlands*

  To inform the additional flood modelling, the location and level of any bunds required around proposed wetlands will need to be defined at a preliminary level.

- *Permissible velocities in wetland areas*

  The flood modelling undertaken including wetland areas will need to be reviewed and the potential impact of calculated peak flow velocities upon wetland areas assessed with respect to the potential for damage to vegetation or resuspension of sediment to occur.

urban land development authority

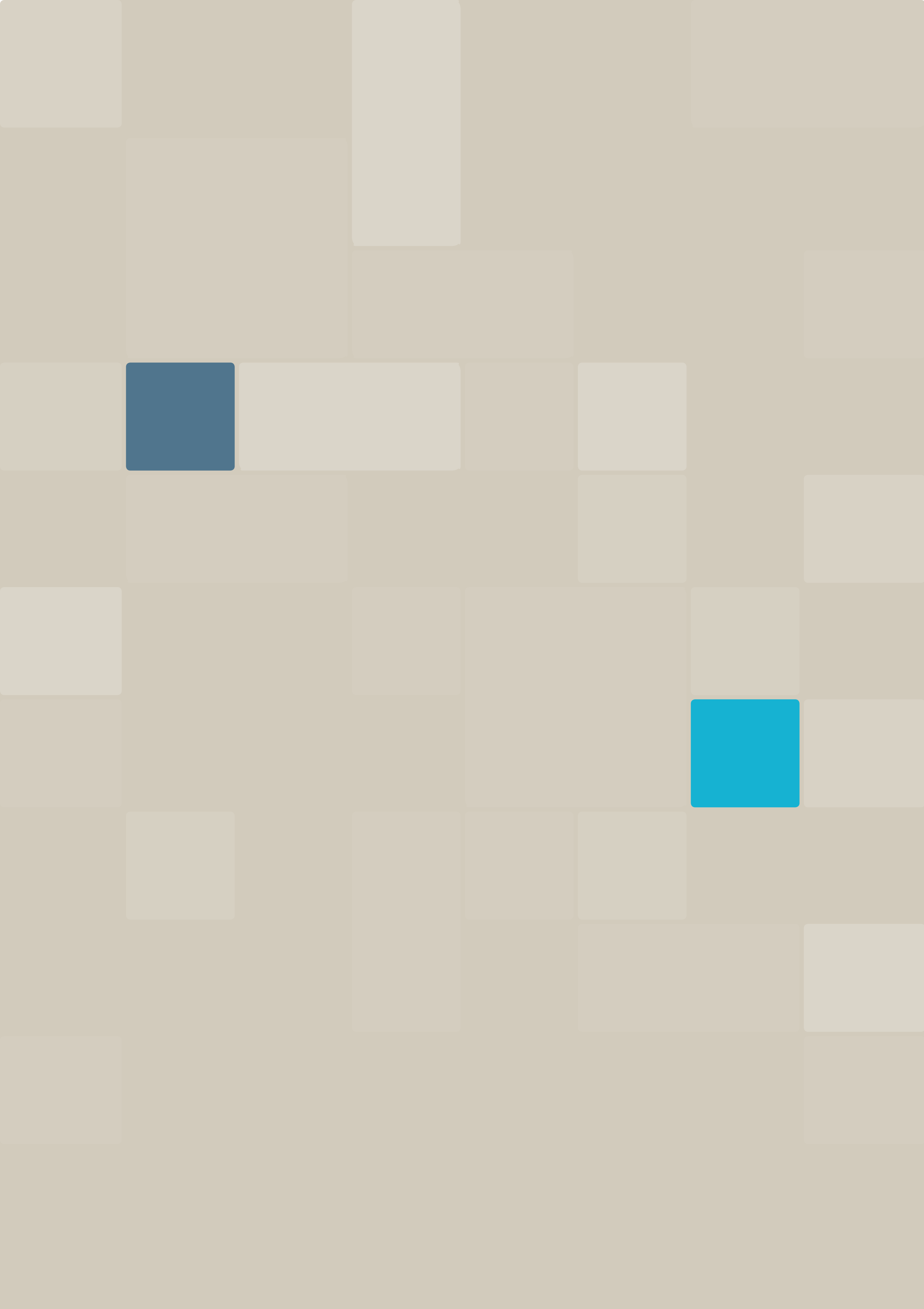
Protection from flood and storm tide inundation

ULDA guideline no. 15

Draft for consultation - not government policy
August 2011

www.ulda.qld.gov.au

Contents

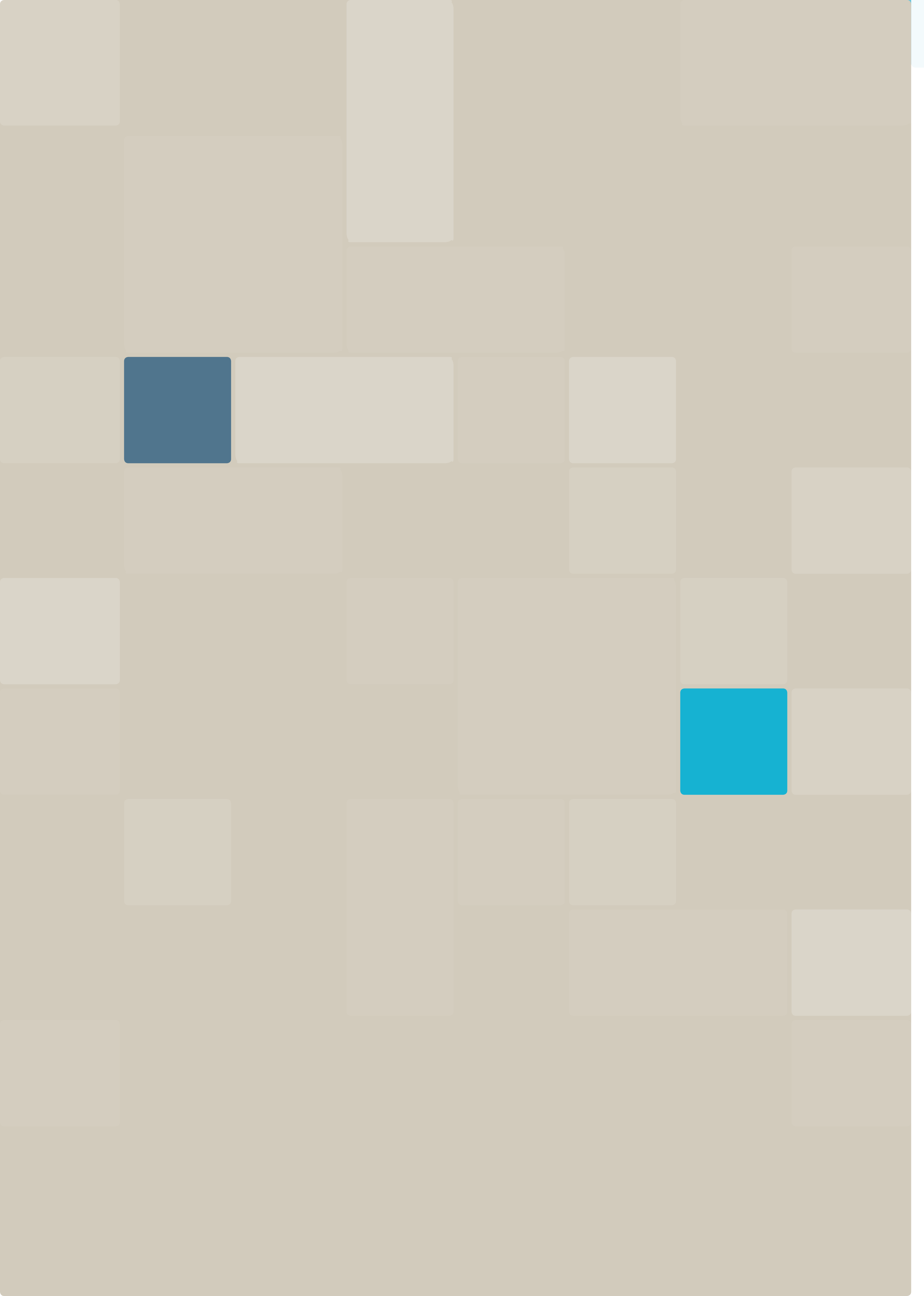


Introduction

Purpose of guideline

This guideline outlines the Urban Land Development Authority (ULDA) standards for protection of development from flooding and storm tide inundation in Urban Development Areas (UDA's) in Queensland.

This guideline should be read in conjunction with the provisions of UDA development schemes and Interim Land Use Plans (ILUPs). A development scheme or ILUP may specify a different standard.



Background

State Planning Policy 1/03

The Queensland Government's position in protecting people and property from the adverse impacts of flooding is set out in State Planning Policy (SPP) 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide, and the associated SPP 1/03 Guideline.

The State Planning Policy (SPP) provides guidance on how these hazards should be addressed through the planning and development assessment process, and is intended to be implemented primarily through the incorporation of appropriate measures consistent with the SPP in local government planning schemes.

SPP 1/03 introduces the term "natural hazard management area" as the area defined for the management of a natural hazard such as flooding. Annex 3 of the SPP states that a natural hazard management area (flood) is land inundated by a Defined Flood Event (DFE)[1] and identified in a planning scheme. This means that, in relation to flood hazard, SPP 1/03 does not have effect in a particular area until the local government adopts a DFE for that area. In practice, virtually all local governments have adopted DFEs for existing and future urban areas.

Annex 3 of SPP 1/03 also sets out the Queensland Government's position *"... that, generally, the appropriate flood event for determining a natural hazard area (flood) is the 1% Annual Exceedance Probability (AEP) flood. However, it may be appropriate to adopt a different DFE depending on the circumstances of individual localities. This is a matter that should be reviewed when preparing or undertaking relevant amendments to a planning scheme. Local governments proposing to adopt a lower DFE in their planning scheme to determine a natural hazard management area (flood) for a particular locality will be expected to demonstrate to the satisfaction of the Department of Emergency Services (DES) and the Department of Natural Resources and Mines (NR&M) that the proposed DFE is appropriate to the circumstances of the locality"*.

1 A DFE is the flood event adopted for the management of development in a particular locality.

SPP 1/03 requires development in a natural hazard management area to be compatible with the nature of the natural hazard except where it is a development commitment[2] or there is overriding need for the development in the public interest and no other site is suitable and reasonably available for the proposed development.

Annex 4 of the SPP sets out the specific outcomes that must be achieved for development to be compatible with the nature of the natural hazard. For flood, these outcomes are:

1. Development maintains the safety of people on the development site from all floods up to and including the DFE.
2. Development does not result in adverse impacts on people's safety or the capacity to use land within the flood plain.
3. Development minimises the potential damage from flooding to property on the development site.
4. Public safety and the environment are not adversely affected by the detrimental impacts of floodwater on hazardous materials manufactured or stored in bulk.
5. Essential services infrastructure (e.g. on-site electricity, gas, water supply, sewerage and telecommunications) maintains its function during a DFE.

Appendix 2 of the SPP Guideline provides guidance on how to undertake a natural hazard assessment for flood, and to determine an appropriate DFE. The Guideline notes that the matters to be addressed in undertaking a flood assessment include tide and storm surge, and the potential impacts of climate change. These issues are discussed separately below.

Table A in Appendix 5 of the SPP Guideline sets out example detailed measures that should be incorporated in planning schemes to ensure development achieves these outcomes. The SPP Guideline states that, where the SPP has not been appropriately reflected in a planning scheme, these measures should be used to assist interpreting the SPP in development assessment.

SPP 1/03 also requires that, wherever practicable, important

2 Development commitment is defined in the glossary of SPP 1/03. In practical terms it means development that either already has a development approval or does not require a development approval.

community infrastructure is located and designed to function effectively during and immediately after natural hazard events commensurate with a specified level of risk. Appendix 9 of the SPP Guideline sets out specific measures for achieving this outcome included recommended flood immunity levels for specific infrastructure. These measures can also be varied in planning schemes to reflect local circumstances.

Coastal plans

The Department of Environment and Resource Management (DERM) has prepared a Draft Queensland Coastal Plan that addresses the outcomes of a review of the existing State Coastal Management Plan (SCMP)[3].

The Draft Queensland Coastal Plan contains two policy components:

» Draft State Policy for Coastal Management - provides policy direction and guidance for maintaining, rehabilitating, and protecting coastal land, and managing activities undertaken on it, with particular emphasis on managing public coastal land.

» Draft State Planning Policy Coastal Protection - outlines criteria for land-use planning and assessment of development to manage development in the coastal zone.

One of the outcomes sought by the draft SPPCP is that development in the coastal zone ensures the protection of people and property from coastal hazards taking into account the predicted effects of climate change.

The draft SPPCP, if adopted, will require regional plans or local planning instruments to identify storm tide[4] inundation areas (among other things) and to avoid allocating land for urban or rural residential purposes within these areas.

Annexe 2, Table 2.1 of the draft SPPCP sets out the following minimum assessment factors for determining storm tide inundation areas for general planning purposes:

3 The existing State Coastal Management Plan and Regional Coastal Management Plans will remain in force until the new Queensland Coastal Plan is released.

4 The draft SPPCP defines storm tide as 'the effect on coastal water of a storm surge combined with the normally occurring astronomical tide'.

» planning period of 100 years

» projected sea level rise of 0.8 metres by 2100 due to climate change (relative to 1990 value)

» adoption of the 100 year average recurrence interval extreme storm event/ or water level

» increase in cyclone intensity by 10% (relative to maximum potential intensity) due to climate change.

The Draft Queensland Coastal Hazards Guideline sets out the methodology for determining a storm tide inundation area, and states that if a storm tide inundation assessment has not been completed in relation to a proposed development then the storm tide inundation area is taken to be all land between high water mark and a minimum default defined storm tide event level of:

» 1.5 metres above the level of highest astronomical tide (HAT) in South-East Queensland; or

» 2 metres above the level of HAT in the rest of Queensland.

Annexe 3 of the Draft SPPCP provides a development assessment code for various coastal hazards and values including storm tide inundation. Annexe 6 sets out recommended storm tide event levels for essential community service infrastructure.

Climate change impacts on inland flooding

As outlined above the Draft SPPCP sets out climate change assessment factors for coastal areas. Increasing Queensland's resilience to inland flooding in a changing climate: Final report on the Inland Flooding Study (Office of Climate Change, DERM et al, 2010) documents the Queensland Government's response to a request from the Local Government Association of Queensland (LGAQ) to provide a benchmark figure for taking climate change into account when assessing inland flooding risk.

The report makes a number of policy and general recommendations for government consideration as part of the review of SPP1/03, and the following three scientific recommendations that are relevant to the conduct of flood risk assessments:

- Recommendation 1 - Local governments should factor a 5 per cent increase in rainfall intensity per degree of global warming into the 1 per cent (Q100), 0.5 per cent (Q200) and 0.2 per cent (Q500) AEP flood events recommended in SPP 1/03 for the location and design of new development.
- Recommendation 2 - The following temperatures and timeframes should be used for the purposes of applying the climate change factor in Recommendation 1:
  - 2°C by 2050
  - 3°C by 2070
  - 4°C by 2100
- Recommendation 3 - The Queensland Government will review and update this climate change factor when a national position on how to factor climate change into flood studies is finalised as part of the current review of AR&R (Australian Rainfall and Runoff, Engineers Australia Publication).

Habitable floor levels

The Queensland Building Regulation 2006 (Part 3, Section 13) allows a local government to designate part of its area as a natural hazard management area (flood) and declare the level to which the floor levels of habitable rooms as defined under the Building Code of Australia must be built. Most local governments in Queensland have adopted this approach in their planning schemes. For example Brisbane City Plan requires an additional 500mm of 'freeboard' above the DFE to allow for a factor of safety, uncertainty and localised events (Brisbane City Council Joint Flood Taskforce Report, March 2011, p17).

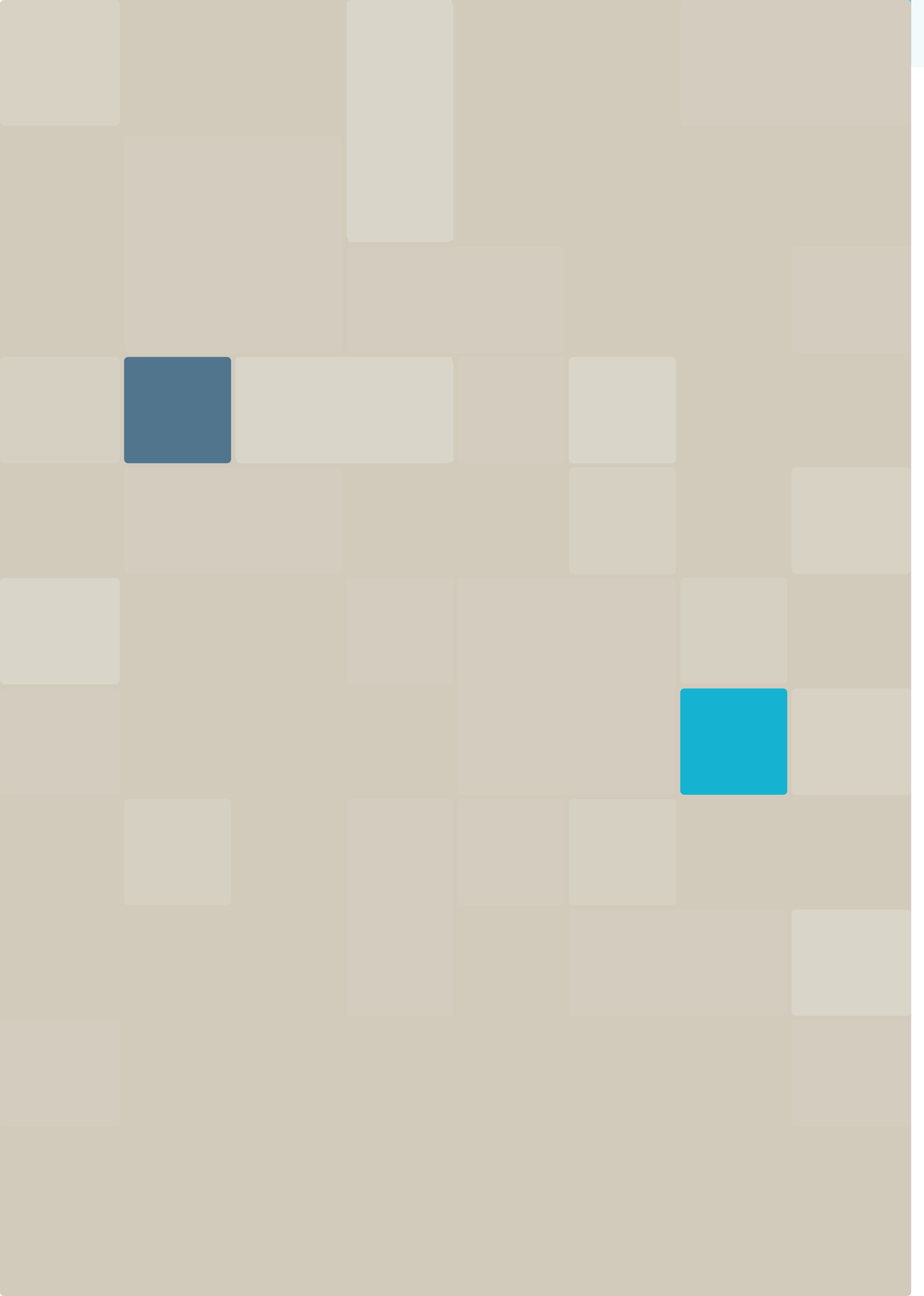
The Queensland Urban Drainage Manual (Table 7.03.1) requires freeboard of not less than 300mm below the finished floor level (FFL) of adjoining properties when designing major drainage infrastructure.

Possible changes in response to 2011 flood

The Queensland Government has established the Queensland Floods Commission of Inquiry to investigate the January 2011 flood disaster, including a review of the existing town planning provisions relating to flooding and flood risk mitigation.

Several local governments are also undertaking separate investigations into the flooding. The Brisbane City Council Joint Flood Taskforce has already made several recommendations for changes in the way flood issues are addressed in Brisbane City including adopting the actual 2011 flood event as the new interim standard on which Council bases decisions on development, and a move away from the Q100 mentality to a risk management approach.

The findings of these investigations and the final report of the Commission may recommend other changes to planning schemes and changes to SPP 1/03.



ULDA Position

The ULDA adopts the Queensland Government's policy position set out in SPP1/03 in relation to flooding and the position set out in the Draft SPPCP in relation to storm tide inundation. This position will be reviewed and revised to take account of recommended changes to flood policy arising from the Queensland Floods Commission of Inquiry, and any changes between the Draft SPPCP and the SPPCP adopted by Government.

The following tables set out the ULDA's requirements to ensure development is adequately protected from flood and storm tide inundation.

Table 1: ULDA requirements for flood protection

<table>
<tr><th></th><th colspan="2">ULDA Requirement</th></tr>
<tr><td rowspan="3">Defined Flood Event (DFE)</td><td colspan="2">1. The DFE adopted[5] by the relevant Council for the area[6], or</td></tr>
<tr><td>2. Where 1 is not available, the DFE adopted by the Council for a similar area, or</td><td rowspan="2">For options 2 and 3 the DFE will be identified through a flood study undertaken by an appropriately qualified professional engineer in accordance with the preferred methodology set out in Appendix 2 of the SPP 1/03 Guideline and adopting as appropriate:
» the minimum assessment factors from Annexe 2 of the Draft SPPCP or
» recommendations 1 and 2 from Increasing Queensland's resilience to inland flooding in a changing climate: Final report on the Inland Flooding Study</td></tr>
<tr><td>3. Where 2 is not available, the 1% AEP flood.</td></tr>
<tr><td rowspan="3">Habitable floor level (or 'freeboard')</td><td colspan="2">1. The habitable floor level or freeboard adopted by the relevant Council for the area, or</td></tr>
<tr><td colspan="2">2. Where 1 is not available, the habitable floor level or freeboard adopted by the Council for a similar area, or</td></tr>
<tr><td colspan="2">3. Where 2 is not available, 300 mm above the DFE adopted for the area.</td></tr>
<tr><td rowspan="2">Development assessment criteria</td><td colspan="2">1. Where the Minister for Local Government and Planning has endorsed the Council planning scheme as adequately reflecting SPP 1/03, the relevant provisions in the planning scheme, or</td></tr>
<tr><td colspan="2">2. Where the Minister for Local Government and Planning has not endorsed the Council planning scheme as adequately reflecting SPP 1/03, the solutions set out in Table A of Appendix 5 of the SPP Guideline, and, for the specified community infrastructure, the solutions for Specific Outcome 1 in Appendix 9 of the SPP Guideline.</td></tr>
</table>

5 Adopted means adopted by a resolution of Council or by incorporation in a planning scheme.
6 For the purposes of this guideline 'area' means all or part of a UDA.

Table 2: ULDA requirements for storm tide protection

	ULDA requirement
Storm tide inundation area	1. The storm tide inundation area adopted by the relevant Council, or 2. Where 1 is not available, the storm tide inundation area identified through a coastal hazard risk assessment undertaken by an appropriately qualified professional engineer in accordance with the preferred methodology set out in the draft Guideline Coastal Hazards, and adopting the minimum assessment factors from Annexe 2 of the Draft SPPCP, or 3. Where 2 is not available the relevant default defined storm tide event level set out in the Draft Queensland Coastal Hazards Guideline.
Habitable floor level (or 'freeboard')	1. The habitable floor level or freeboard adopted by the relevant Council for the area, or 2. Where 1 is not available, 300 mm above the storm tide inundation level.
Development assessment criteria	1. Where the Minister for Local Government and Planning has endorsed the Council planning scheme as adequately reflecting Draft SPPCP (once adopted), the relevant provisions in the planning scheme, or 2. Where the Minister for Local Government and Planning has not endorsed the Council planning scheme as adequately reflecting Draft SPPCP (once adopted), the relevant parts of the Development Assessment Code in Annexe 3 of the Draft SPPCP.

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Cardno
Shaping the Future

RNA REDEVELOPMENT

FLOODING AND DRAINAGE REPORT- STAGE 1 COMPLIANCE A

Job Number 3503/78

Prepared for Lend Lease

21 April 2011

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RNA REDEVELOPMENT

FLOODING AND DRAINAGE REPORT - STAGE 1 COMPLIANCE A

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1 INTRODUCTION

The RNA exhibition grounds at Bowen Hills are to be redeveloped. Cardno was commissioned to complete a detailed flooding investigation to confirm the extent of flooding of the site that occurs at present and to develop a drainage solution that will allow development to proceed without adversely impacting on upstream or downstream areas.

According to the Brisbane City Council *Subdivision and Development Guidelines* (2008), the design events applicable to the site are:

- Minor Event 10 Year ARI
- Major Event 50 Year ARI

In addition to considering the 50 year event, the 100 year event was also modelled as a sensitivity case to confirm that the proposed solution would function acceptably for events in excess of the major design event.

It is proposed to develop Lot 484 and 486 on SL4553, Lot 487 on SP196776, Lot 485 on SP 192466, Lot 481 on SP196765, Lot 3 on SP190738, Lot 641 on SP196755, Lot 2 on SP144596 and the Alexandria Street road reserve. The location of the site is shown in Figure 1. The total area of the site is approximately 22 hectares.

The eastern half of the site is located in an overland flow path and as such the development of the site must allow for the conveyance of existing flow without adverse impacts to neighbouring properties.

To model the flow through the site, and quantify the impacts of the development, a combined one-dimensional/ two-dimensional TUFLOW model was setup of the study area.

Based on consultation undertaken with Council, the drainage solution developed for the site must achieve a non-worsening compared to the existing situation. In practice, this will require:

- no increase in water level at Water Street (upstream boundary of site);
- no increase in peak flow discharged across St Pauls Terrace;
- no increase in peak flood depth across St Pauls Terrace; and
- no increase in level in Gregory Terrace.

In addition to the need to achieve a non-worsening outcome, consideration was also given to the ability to provide a solution that will allow future relief drainage works to occur. Council has identified the need to complete relief drainage works in the Water Street catchment (which contains the RNA site). The proposed works for the catchment are defined in the report completed for Council by the Tod Group titled *Brisbane City Council, Water-Campbell Streets Catchment, Relief Drainage Investigation, Final Report* (circa 1997). The works include the construction of additional stormwater drainage works to improve flooding for minor events. The works were predicted to reduce the flood level in Water Street and, in particular, reduce the peak flow discharged to the south across St Pauls Terrace. Reducing this flow was considered to be attractive as it would reduce the overall flow occurring further downstream in the already flood prone Stratton Street catchment in Fortitude Valley.

For the analysis, the runoff from the Water Street catchment was modelled together with the runoff from the large catchment to the north that includes Victoria Park. Subsequent to the completion of the Tod Group report, the construction of the Inner City Bypass redirected the runoff from the Victoria Park catchment. The effective reduction in catchment area achieved by the redirection improved the drainage of the Water Street catchment. In particular, the peak flow discharged to the south across St Pauls Terrace decreases significantly as a result of the redirection of flow.

As noted above, one of the key benefits associated with the relief drainage works proposed for the Water Street catchment was the reduction in flow ultimately draining to Stratton Street across St Pauls Terrace. The extent of the reduction afforded by the Victoria Park catchment redirection is such that it is uncertain whether additional relief drainage in the Water Street catchment is warranted with respect to further improving conditions at Stratton Street.

Although the redirection of runoff from the Victoria Park catchment improved flow conditions in the lower part of the RNA site, the improvement obtained is virtually nil in Water Street at the upstream end of the RNA site. There would still therefore be a desire on the part of Council to complete relief drainage works to alleviate the minor event flooding experienced in Water Street.

As part of the solution developed for the RNA site, the proposed drainage works were sized to achieve the same reduction in flood level for minor events at the upstream end of the site (i.e. in Water Street) as nominated in the Tod Group report. The works, in conjunction with the works proposed for the site, will result in a considerable reduction in the depth of inundation experienced in the Alexandria Street road reserve.

This report details the modelling undertaken to calculate the flood levels and flows for the existing case and the works necessary to offset the impact of development and provide a solution that matches the relief drainage desires of Council.

This report provides an updated version of the previous master flooding and drainage report completed with respect to the site in support of the Compliance A reporting required for Stage 1 of the development and includes amendments to the previous drainage design to facilitate development of the site.

Condition 24 of the MCU approval issued for the development (ULDA Reference DEV2010/047) details the Compliance A requirements for stormwater infrastructure. The requirements of the condition and the response to each requirement are detailed below.

'a) ***Submit for compliance assessment by the nominated assessing authority, concept plans of the stormwater management proposed to service the precinct including the proposed stormwater treatment train.'***

The concept drainage plan is shown on Figure 7 of the report.

'The stormwater solution for the precinct must be prepared within the context of an overarching stormwater strategy for the entire site and be accompanied by:-

'(ii) details of the proposed treatment measures to manage and treat stormwater from those parts of the site being developed to meet Brisbane City Council (BCC) load based water quality objectives. Stormwater from the external catchment that is conveyed through the site does not require treatment.'

Details of the proposed treatment measures to meet Brisbane City Council load based reduction criteria are provided in the Cardno report *Stormwater Management Plan- Stage 1 Compliance A Report*.

'(iii) evidence that the stormwater runoff from the site does not adversely impact on flooding or drainage for all events up to the 50 year Average Recurrence Interval (ARI) of properties that are upstream, downstream or adjacent to the site.'

The results of the detailed modelling presented in this report demonstrate that stormwater runoff from the site will not adversely impact on flooding or drainage for all events up to the 50 year event external to the site.

‘(iv) Evidence that the stormwater solution is based on a minor event (pipe design) with a recurrence interval of 10 years and a major event (for setting flood levels) with a recurrence interval of 50 years.’

Modelling, as described in this report, has allowed the derivation of a stormwater solution based on a 10 year minor event and a 50 year major event.

‘(v) an indicative timetable for the delivery of the solution and’

Based on a review of the likely staging of the works, it is considered that the trigger for the completion of the works is the realignment of Alexandria Street.

‘(vi) where the stormwater design impacts on individual property owners – approval in principle from the affected owners, agreeing to the constructing of the stormwater.’

The stormwater design is wholly contained within the RNA site and the current Alexandria Street road reserve.

2 SITE DESCRIPTION AND CATCHMENT DESCRIPTION

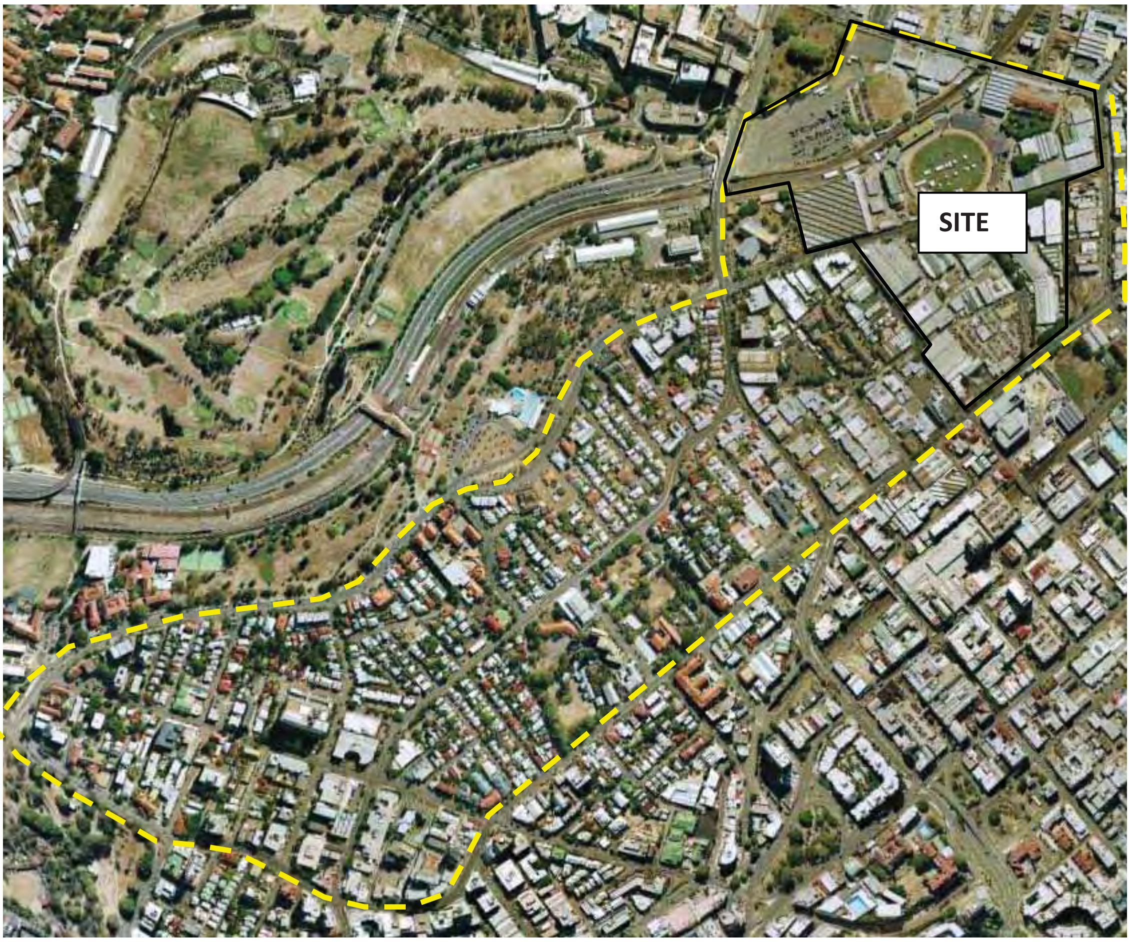
2.1 Site Description

The site is currently used for commercial purposes. An aerial photograph showing the current development of the site is shown in Figure 1.

The levels within the site range from less than 6 mAHD to 21 mAHD. The site drains to a low point located in the middle of the site along Alexandria Street. As the contours show (refer Appendix A) the southern half of the site is situated in a major overland flow path.

2.2 Catchment Description

The site is located at the downstream end of densely developed area known as the Water Street catchment. The area of the catchment is of the order of 90 hectares.



Water Street Catchment

Water Street currently terminates at the western boundary of the site at the intersection of Water Street with Constance Street and Costin Street. As the catchment is fully developed and is an older style of catchment (i.e. all flow is piped), rainfall is rapidly converted to runoff which in turn is transported quickly via the piped drainage system. From the start of heavy rainfall, the flow arriving at the RNA site can peak in the order of 15 to 30 minutes. Significant local flooding can therefore occur with very little warning.

It can be noted that while the site is potentially subject to local flooding, existing ground levels across the site are sufficiently high for the site to be immune to flooding from the Brisbane River.

3 HYDROLOGY

3.1 Rational Method Calculations

The flows used for the TUFLOW model were derived using a RAFTS rainfall runoff model of the catchment. The model parameters were adjusted until a good agreement was obtained between predicted peak flow rates and those calculated using the Rational Method calculations as outlined in the Brisbane City Council (BCC) *Subdivision & Development Guidelines* and the *Queensland Urban Drainage Manual* (QUDM). This approach was considered to be acceptable due to the uniformity of the catchment and the relatively small subcatchment areas used for the comparison.

3.1.1 Rainfall Intensities

The rainfall intensities provided in Table BA2.7.1 of the BCC *Subdivision & Development Guidelines* were used to determine the peak flows.

3.1.2 Catchment Areas

The catchment area was broken up into 29 smaller sub catchments in the existing case and 33 smaller sub-catchments in the developed case to allow for a good representation of the input of flows into the model. The areas of each catchment for both the existing and developed cases are shown below in Table 1 and Table 2. The catchment areas for the existing and developed cases are shown in Figure 3 and Figure 4 respectively.

Table 1 Catchment Areas – Existing Case

Name	Area (ha)	Name	Area (ha)	Name	Area (ha)	Name	Area (ha)
A0	34.83	A8	2.360	A16	1.340	A24	6.200
A1	6.180	A9	1.670	A17	2.740	A25	1.890
A2	5.550	A10	1.790	A18	6.200	B1	1.720
A3	4.540	A11	1.440	A19	4.100	B2	1.410
A4	7.940	A12	3.050	A20	2.120	B3	1.820
A5	2.210	A13	2.450	A21	3.620		
A6	1.860	A14	0.450	A22	1.580		
A7	1.580	A15	0.570	A23	6.730		

Table 2 Catchment Areas – Developed Case

Name	Area (ha)	Name	Area (ha)	Name	Area (ha)	Name	Area (ha)
A0	34.83	A8	2.360	B1	1.720	D26	0.500
A1	6.180	A9	1.670	B2	1.410	D27	2.950
A2	5.550	A10	1.790	B3	1.820	D28	2.470
A3	4.540	A14	0.450	D21	2.080	D29	3.870
A4	7.940	A22	1.580	D22	1.000	D30	2.120
A5	2.210	A23	6.730	D23	0.820	D31	6.200
A6	1.860	A24	6.200	D24	1.050	D32	4.100
A7	1.580	A25	1.890	D25	0.500		

3.1.3 Runoff Coefficient Values

The ultimate level of development for each sub catchment external to the site, determined from the Brisbane City Council Planning Scheme has been used to identify the corresponding runoff coefficients. The runoff coefficients provided in Table B2.2 of Brisbane City Council Subdivision and Development Guidelines were used for the corresponding land uses. The three main land uses with the Water Street catchment and the corresponding runoff coefficients used are listed below in Table 3.

Table 3 Runoff Coefficients

Developed Category	C_{10}
High Density Residential	0.87
Low/Medium Density Residential	0.85
Commercial	0.88

3.1.4 Times of Concentration

The times of concentration were determined using the standard inlet times based on the characteristics of the catchment and assuming a pipe velocity of 2 m/s. A summary of the calculations for both the existing and developed cases are shown below in Table 4 and Table 5 respectively.

Table 4 Time of Concentration Calculations – Existing Case

Catchment	Standard Inlet time (min)	Pipe Flow			Channel Flow			Total Tc (min)
		Length (m)	Velocity (m/s)	Time (min)	Length (m)	Velocity (m/s)	Time (min)	
A0	5	890	2	7.42	-	-	-	12.42
A1	5	240	2	2.00	-	-	-	7.00
A2	5	-	-	-	300	1.5	3.33	8.33
A3	5	-	-	-	200	1.5	2.22	7.22
A4	5	-	-	-	290	1.5	3.22	8.22
A5	5	135	2	1.13	-	-	-	6.13
A6	5	130	2	1.08	-	-	-	6.08
A7	5	200	2	1.67	-	-	-	6.67
A8	5	30	2	0.25	-	-	-	5.25
A9	5	65	2	0.54	-	-	-	5.54
A10	5	-	-	-	-	-	-	5.00
A11	5	60	2	0.50	-	-	-	5.50
A12	5	240	2	2.00	-	-	-	7.00
A13	5	190	2	1.58	-	-	-	6.58
A14	5	100	2	0.83	-	-	-	5.83
A15	5	100	2	0.83	-	-	-	5.83
Catchment	**Standard Inlet time (min)**	**Pipe Flow**			**Channel Flow**			**Total Tc (min)**
		Length (m)	**Velocity (m/s)**	**Time (min)**	**Length (m)**	**Velocity (m/s)**	**Time (min)**	
A17	5	335	2	2.79	-	-	-	7.79
A18	5	140	2	1.17	180	1.5	2.00	8.17
A19	5	-	-	-	215	1.5	2.39	7.39
A20	5	-	-	-	110	1.5	1.22	6.22
A21	5	-	-	-	160	1.5	1.78	6.78
A22	5	38	2	0.32	-	-	-	5.32
A23	5	350	2	2.92	-	-	-	7.92
A24	5	360	2	3.00	-	-	-	8.00
B2	5	-	-	-	260	1.5	2.89	7.89
B3	5	310	2	2.58	-	-	-	7.58
Friends Equation								
Catchment	**Length (m)**		**Slope (%)**		**Manning's' 'n'**			**Total Tc (min)**
A16	100		2		0.03			10.79

Catchment	Standard Inlet time (min)	Pipe Flow			Channel Flow			Total Tc (min)
		Length (m)	Velocity (m/s)	Time (min)	Length (m)	Velocity (m/s)	Time (min)	
A25	125		6.5		0.045			16.58
B1	150		1.3		0.045			24.24

Table 5 Time of Concentration Calculations – Developed Case

Catchment	Standard Inlet time (min)	Pipe Flow			Channel Flow			Total Tc (min)
		Length (m)	Velocity (m/s)	Time (min)	Length (m)	Velocity (m/s)	Time (min)	
A0	5	890	2	7.42	-	-	-	12.42
A1	5	240	2	2.00	-	-	-	7.00
A2	5	-	-	-	300	1.5	3.33	8.33
A3	5	-	-	-	200	1.5	2.22	7.22
A4	5	-	-	-	290	1.5	3.22	8.22
A5	5	135	2	1.13	-	-	-	6.13
A6	5	130	2	1.08	-	-	-	6.08
A7	5	200	2	1.67	-	-	-	6.67
A8	5	30	2	0.25	-	-	-	5.25
A9	5	65	2	0.54	-	-	-	5.54
A10	5	-	-	-	-	-	-	5.00
A14	5	100	2	0.83	-	-	-	5.83
A22	5	38	2	0.32	-	-	-	5.32
A23	5	350	2	2.92	-	-	-	7.92
A24	5	360	2	3.00	-	-	-	8.00
B2	5	-	-	-	260	1.5	2.89	7.89
B3	5	310	2	2.58	-	-	-	7.58
D41	5	100	2	0.83	-	-	-	5.83
D42	5	130	2	1.83	-	-	-	6.08
D43	5	100	2	0.83	-	-	-	5.83
D44	5	60	2	0.50	-	-	-	5.50
D45	5	125	2	1.04	-	-	-	6.04
D46	5	50	2	0.42	-	-	-	5.42
D47	5	125	2	1.04	-	-	-	6.04
D48	5	210	2	1.75	-	-	-	6.75
D49	5	240	2	2.00	-	-	-	7.00

Catchment	Standard Inlet time (min)	Pipe Flow			Channel Flow			Total Tc (min)
		Length (m)	Velocity (m/s)	Time (min)	Length (m)	Velocity (m/s)	Time (min)	
D29	5				160	1.5	1.78	6.78
D30	5				110	1.5	1.22	6.22
D31	5	140	2	1.17	180	1.5	2.00	8.17
D32	5				215	1.5	2.39	7.39

Friends Equation

Catchment	Length (m)	Slope (%)	Manning's' 'n'	Total Tc (min)
A25	125	6.5	0.045	16.58
B1	150	1.3	0.045	24.24

3.1.5 Peak Flows

The peak flows were calculated for the 10, 50 and 100 year events. The results for both the existing and developed cases are shown below in Table 6 and Table 7.

Table 6 Rational Method Peak Flow – Existing Case

Catchment	Contributing Area (ha)	Coefficients of Runoff C_{10}	Rainfall Intensity (mm/h)			Peak Flow (m^3/s)		
			100 year ARI	50 year ARI	10 year ARI	100 year ARI	50 year ARI	10 year ARI
A0	34.83	0.86	233.67	208.67	153.33	22.61	19.97	12.76
A1	6.180	0.85	288.00	258.00	190.00	4.94	4.33	2.77
A2	5.550	0.85	270.67	242.00	178.33	4.17	3.65	2.34
A3	4.540	0.85	284.67	254.78	188.78	3.59	3.14	2.02
A4	7.940	0.85	271.78	243.33	179.22	5.99	5.25	3.36
A5	2.210	0.88	301.50	270.50	200.13	1.85	1.66	1.08
A6	1.860	0.88	302.33	271.33	200.75	1.56	1.40	0.91
A7	1.580	0.88	293.00	262.33	194.33	1.29	1.15	0.75
A8	2.360	0.88	319.00	286.00	211.25	2.09	1.87	1.22
A9	1.670	0.88	313.17	277.17	205.17	1.45	1.29	0.84
A10	1.790	0.88	325.00	291.00	215.00	1.62	1.45	0.94
A11	1.440	0.88	314.00	281.00	208.00	1.26	1.12	0.73
A12	3.050	0.88	288.00	258.00	190.00	2.44	2.19	1.42
A13	2.450	0.87	294.25	263.25	195.17	2.00	1.79	1.16
A14	0.450	0.88	307.33	275.50	203.67	0.38	0.34	0.22
A15	0.570	0.90	307.33	275.50	203.67	0.49	0.44	0.29
A16	1.340	0.82	246.08	220.25	162.25	0.90	0.77	0.50

Catchment	Contributing Area (ha)	Coefficients of Runoff C10	Rainfall Intensity (mm/h)			Peak Flow (m^3/s)		
			100 year ARI	50 year ARI	10 year ARI	100 year ARI	50 year ARI	10 year ARI
A17	2.740	0.88	277.08	248.08	183.08	2.11	1.89	1.23
A18	6.200	0.86	272.33	244.00	179.67	4.69	4.16	2.66
A19	4.100	0.84	282.17	253.11	187.11	3.21	2.78	1.79
A20	2.120	0.86	299.67	268.67	198.78	1.76	1.56	1.01
A21	3.620	0.85	291.33	261.22	193.22	2.93	2.57	1.65
A22	1.580	0.88	317.67	284.67	210.25	1.39	1.25	0.81
A23	6.730	0.88	275.25	246.83	181.83	5.15	4.61	2.99
A24	6.200	0.88	274.00	246.00	181.00	4.72	4.24	2.74
A25	1.890	0.72	208.51	185.67	135.67	0.95	0.81	0.51
B1	1.720	0.78	177.06	157.53	114.53	0.79	0.68	0.43
B2	1.410	0.88	275.67	247.11	182.11	1.08	0.97	0.63
B3	1.820	0.88	279.25	250.25	185.17	1.41	1.27	0.82

Table 7 Rational Method Peak Flow – Developed Case

Catchment	Contributing Area (ha)	Coefficients of Runoff C10	Rainfall Intensity (mm/h)			Peak Flow (m^3/s)		
			100 year ARI	50 year ARI	10 year ARI	100 year ARI	50 year ARI	10 year ARI
A0	34.83	0.860	233.67	208.67	153.33	22.61	19.97	12.76
A1	6.180	0.850	288.00	258.00	190.00	4.94	4.33	2.77
A2	5.550	0.850	270.67	242.00	178.33	4.17	3.65	2.34
A3	4.540	0.850	284.67	254.78	188.78	3.59	3.14	2.02
A4	7.940	0.850	271.78	243.33	179.22	5.99	5.25	3.36
A5	2.210	0.880	301.50	270.50	200.13	1.85	1.66	1.08
A6	1.860	0.880	302.33	271.33	200.75	1.56	1.40	0.91
A7	1.580	0.880	293.00	262.33	194.33	1.29	1.15	0.75
A8	2.360	0.880	319.00	286.00	211.25	2.09	1.87	1.22
A9	1.670	0.880	313.17	280.17	207.58	1.45	1.30	0.85
A10	1.790	0.880	325.00	291.00	215.00	1.62	1.45	0.94
A14	0.450	0.880	307.33	275.50	203.67	0.38	0.34	0.22
A22	1.580	0.880	317.67	284.67	210.25	1.39	1.25	0.81
A23	6.730	0.880	275.25	246.83	181.83	5.15	4.61	2.99
A24	6.200	0.880	274.00	246.00	181.00	4.72	4.24	2.74
A25	1.890	0.720	208.51	185.67	135.67	0.95	0.81	0.51
B1	1.720	0.782	177.06	157.53	114.53	0.79	0.68	0.43

Catchment	Contributing Area (ha)	Coefficients of Runoff C_{10}	Rainfall Intensity (mm/h)			Peak Flow (m^3/s)		
			100 year ARI	50 year ARI	10 year ARI	100 year ARI	50 year ARI	10 year ARI
B2	1.410	0.880	275.67	247.11	182.11	1.08	0.97	0.63
B3	1.820	0.880	279.25	250.25	185.17	1.41	1.27	0.82
D41	1.310	0.880	307.33	275.50	203.67	1.12	1.00	0.74
D42	1.093	0.880	302.33	271.33	200.75	0.92	0.82	0.61
D43	0.986	0.880	307.33	275.50	203.67	0.84	0.75	0.56
D44	0.440	0.880	314.00	281.00	208.00	0.38	0.34	0.25
D45	0.720	0.880	303.17	272.17	201.38	0.61	0.54	0.40
D46	0.435	0.880	315.67	282.67	208.83	0.38	0.34	0.25
D47	1.060	0.880	303.17	272.17	201.38	0.89	0.80	0.59
D48	2.470	0.880	291.75	261.50	193.50	2.00	1.79	1.33
D49	2.850	0.880	288.00	258.00	190.00	2.28	2.04	1.50
D29	3.870	0.850	291.33	261.22	193.22	3.13	2.74	1.77
D30	2.120	0.860	299.67	268.67	198.78	1.76	1.56	1.01
D31	6.200	0.860	272.33	244.00	179.67	4.69	4.16	2.66
D32	4.100	0.840	282.17	253.11	187.11	3.21	2.78	1.79

3.2 Hydrologic Modelling

A RAFTS hydrologic model of the catchment was setup to determine the discharge hydrographs from each of the sub catchments at their outlet points. RAFTS is an urban and rural rainfall runoff routing program that can be used to determine the peak stormwater flows for a catchment, based on parameters such as area, fraction impervious, slope and catchment storage.

Two RAFTS models were setup to represent the existing and developed cases. Both models were compared to the results obtained with the Rational Method for the 100 year ARI event. RAFTS model parameters such as Manning's n, slope and Bx were varied within reasonable limits until an acceptable agreement was obtained between the RAFTS and Rational Method flow estimates for the 100 year ARI event. This approach was considered to be acceptable given the relatively small size of the catchments considered and their uniform nature. The results and comparisons to the Rational Method are presented below in Table 8.

A Bx value of 1.0 was adopted for the RAFTS model for the existing catchment conditions.

The RAFTS model was run for a range of storm durations from 15 minutes to 6 hours to determine the peak flow rate for a given ARI event. Rainfall losses of zero initial and continuing loss were adopted for impervious areas and a zero initial loss and continuing losses of 2.5 mm/h were adopted for pervious areas.

Given the results presented in Table 8, it was considered acceptable to use the RAFTS model to calculate the discharge hydrographs at the outlet points of the catchment.

Table 8 RAFTS Model Calibration – 100 Year ARI Event

Catchment	Rational Method	RAFTS	Difference (%)	Catchment	Rational Method	RAFTS	Difference (%)
Existing Case							
A0	22.61	22.62	0.0	A15	0.49	0.49	0.0
A1	4.94	4.87	-1.4	A16	0.90	0.90	0.0
A2	4.17	4.21	1.0	A17	2.11	2.13	0.9
A3	3.59	3.56	-0.8	A18	4.69	4.75	1.3
A4	5.99	5.98	-0.2	A19	3.21	3.13	-2.6
A5	1.85	1.84	-0.5	A20	1.76	1.73	-1.7
A6	1.56	1.57	0.6	A21	2.93	2.89	-1.4
A7	1.29	1.29	0.0	A22	1.39	1.37	-1.5
A8	2.09	2.07	-1.0	A23	5.15	5.18	0.6
A9	1.45	1.43	-1.4	A24	4.72	4.75	0.6
A10	1.62	1.55	-4.5	A25	0.95	0.93	-2.2
A11	1.26	1.25	-0.8	B1	0.79	0.76	-3.9
A12	2.44	2.46	0.8	B2	1.08	1.11	2.7
A13	2.00	2.01	0.5	B3	1.41	1.42	0.7
A14	0.38	0.40	5.0				
Developed Case							
A0	22.61	22.62	0.0	B1	0.79	0.76	-3.9
A1	4.94	4.87	-1.4	B2	1.08	1.11	2.7
A2	4.17	4.21	1.0	B3	1.41	1.42	0.7
A3	3.59	3.56	-0.8	D41	1.12	1.11	-0.75
A4	5.99	5.98	-0.2	D42	0.92	0.92	0.23
A5	1.85	1.84	-0.5	D43	0.84	0.82	-2.65
A6	1.56	1.57	0.6	D44	0.38	0.37	-3.72
A7	1.29	1.29	0.0	D45	0.61	0.6	-1.06
A8	2.09	2.07	-1.0	D46	0.38	0.36	-5.95
A9	1.45	1.43	-1.4	D47	0.89	0.86	-3.80
A10	1.62	1.55	-4.5	D48	2.00	2.02	0.90
A14	0.38	0.40	5.0	D49	2.28	2.24	-1.79
A22	1.39	1.37	-1.5	D29	3.13	3.06	-2.35
A23	5.15	5.18	0.6	D30	1.76	1.71	-3.20
A24	4.72	4.75	0.6	D31	4.69	4.68	-0.22
A25	0.95	0.93	-2.2	D32	3.21	3.15	-2.02

The calibrated model was used to derive runoff hydrographs for the 10, 50 and 100 year events. The hydrographs were input to the hydraulic model to enable peak flows and flood levels within the study area to be calculated.

4 HYDRAULIC ANALYSIS

4.1 Data Sources

The sources of the data used as part of the flood assessment of the subject site are listed below:

- Survey – external to the site, aerial laser survey data (collected in 2002) ; and within the site, detailed survey completed by Jensen Bowers
- Aerial Photography – Aerial photography of the site was obtained from the Brisbane City Council's (BCC) eBimap (2009).

4.2 Drainage Network

At present the current flooding situation is exacerbated by the inadequate existing pipe and overland drainage network. If designed today, the underground system would be sized to convey the 10 year event flow (i.e the flow that can be expected to occur on average every 10 years). The current system can convey slightly less than the 2 year flood flow.

Runoff produced by small floods in the Water Street catchment is piped firstly to Alexandria Street, then piped in a north-westerly direction to Gregory Terrace. The flow is then piped beneath Gregory Terrace and beneath the No.1 Show Ring before crossing the railway, skirting the No.2 Show Ring and reaching the northern boundary of the site at O'Connell Terrace. The piped flow ultimately discharges to Breakfast Creek. No overland or surface flow occurs between Gregory Terrace and O'Connell Terrace due to the presence of high ground levels at certain locations.

As noted above, the capacity of the piped drainage system is relatively small. When rainfall producing runoff that is in excess of the capacity of the drainage system occurs, the Alexandria Street road reserve and the RNA site are flooded.

For any rainfall causing a flow greater than the capacity of the underground drainage system, the remaining flow is conveyed overland. In the case of the Water Street catchment, the overland flow occurs along Water Street, with a consequent flooding of properties located on either side of the street.

Overland flow reaching the intersection of Water Street and Constance Street/Costin Street first ponds at the western boundary of the RNA site before entering and flowing through the site between the Nicklin Pavilion and the Agricultural Pavilion.

There is a low point in St Pauls Terrace at the intersection of St Pauls Terrace and the existing alignment of Alexandria Street. Water will pond within the Alexandria Street road reserve and the RNA site until the water level matches the level of St Pauls Terrace. At this point, runoff entering the site from the Water Street catchment will start to drain across St Pauls Terrace to the south east. Water ponded on the RNA site is then drained via the pipe system across Gregory Terrace to the north and via overland flow across St Pauls Terrace.

The existing stormwater drainage system is shown in Figure 6. The pipe details such as size, length and invert levels for the existing drainage network in the catchment were taken from the BCC's eBimap and stormwater drainage drawings obtained from the BCC Plan Custodian. This data was verified against information listed in a previous study completed for Council (Tod Group, circa 1997) and detailed survey completed by Jensen Bowers. As sections of the existing drainage network are quite old, some of the required information was not available. In these instances the best estimates were taken, e.g by assuming slope of the pipes matched the surface slope. Details of the existing pipes are shown in Appendix B. Appropriate manhole losses were adopted based on the recommendations of the *Queensland Urban Drainage Manual (QUDM 2007).*

The naming convention used in the TUFLOW model for the stormwater pipes was based on where the pipe is located within the catchment and the pipe's plan number. The Water Street Catchment was split into 4 main sections labelled 1-4 as shown in Figure 5. Each pipe was labelled based on which section of catchment it was located in and the pipe's plan number followed by a number to identify each section of pipe within that plan. For example, the first section of pipe on plan D1331 located in section 2 would be labelled 2D1331_01. As there is a limit of 10 characters for names in MapInfo the full eBimap description could not be used.

A key consideration in modelling is the interaction of the surface and underground drainage networks. Allowing water to freely transfer between the two networks (a common modelling assumption) can lead to erroneous results as the quantum of water transferred (for instance in an area where the capacity of the piped drainage system is reduced) can be unrealistic.

To overcome this issue, particular care was taken to model the gully pits and small pipes that connect the pits to the trunk drainage system. All gully inlets for the entire catchment area were surveyed during the site visit. In the region of greatest interest (i.e downstream of Baxter Street), each gully pit was modelled individually to allow the restriction to flow afforded by the drainage system to be properly accounted for. Upstream of Baxter Street, some amalgamation of gully pits was assumed.

4.3 Existing Case TUFLOW Model Setup

4.3.1 Model Data

The stormwater drainage through the subject site was modelled using the linked one-dimensional/two-dimensional hydraulic model TUFLOW (Build 2009-07-AB). TUFLOW was considered to be suitable for use in this case due to its ability to model the underground drainage network one-dimensionally while allowing a detailed representation of the overland flow via a two-dimensional grid.

A digital terrain model (DTM) of the study site was setup based on ground level survey obtained from BCC for areas external to the site and from Jensen Bowers for areas internal to the site. The extent of the TUFLOW study area is shown in Figure 8. Due to the urban nature of the study area, a grid with a spacing of 3 metres (i.e. ground levels being represented every 3 metres) was adopted.

Stormwater pipes and gully inlets were modelled as one dimensional links, connected to the two dimensional domain.

4.3.2 Roughness Values

The Manning's n roughness values for the study area were derived from aerial photographs and site inspection. The values adopted for the model are listed below in Table 9. Different land use areas were defined for the existing and developed cases. Only land uses within the site were altered between the existing and developed cases to reflect the proposed level of development. Based on site inspection certain brick buildings and brick fences within the site which were deemed to block the flow, were modelled as blockages to provide an accurate representation of the flow patterns.

Table 9 Roughness Values

Land Use	Manning's n
Residential/ Commercial Areas	0.20
Roads and Carparks	0.02
Open Space and Parks	0.04
Fences and Gates	0.08

4.3.3 Inflows

The discharge hydrographs calculated for the catchments using the RAFTS model were used in the TUFLOW model (refer to Section 3). The location of the inflow points in the TUFLOW model are shown in Figure 8.

4.3.4 Tail water Conditions

A tail water level was applied to the downstream boundary of the model at the point where the main trunk drainage line discharges into the Breakfast Creek. A water level of 1.35 mAHD, equal to Mean High Water Springs (MHWS) plus 300 millimetres to allow for the effect of greenhouse, was assumed.

A normal depth corresponding to a slope of one percent was assumed as the tail water condition occurring at the eastern boundary of the model (corresponding to the slope of the tributary downstream of the railway line). A water level of 1.715 mAHD, equal to obvert of the pipe at the downstream end of the model along the eastern boundary, has been adopted for the one dimensional drainage network.

4.3.5 Time Step

The time step used for the one dimensional/ two dimensional model was one second. This relatively short time step was required to increase the model stability and reduce the continuity error within the model.

4.3.6 Storm Events

The storm events used in the analysis were the 20 minute, 30 minute, 60 minute and 90 minute storm events. Longer duration events were initially run, but they resulted in lower peak water levels.

4.4 Developed Case TUFLOW Model Setup

4.4.1 Model Data

The developed case model used the same data and setup as for the existing case model. The only differences to the model were that the Manning's roughness values and ground levels were altered to reflect the proposed developed case.

The development footprint necessitates the removal of the existing drain between Water Street and Alexandria Street. Consequently, it was not possible to model the development combined with the existing drainage system as a first pass analysis and then to determine the works necessary to achieve the design constraints affecting the site. The developed case modelling included a preliminary drainage design which was refined during the course of modelling (refer Figure 7).

4.4.2 Inflows

The inflows for the developed case were revised as outlined in Section 3 to reflect the level of development proposed within the site. The flows calculated from the roofed areas within catchments D42 and D47 were directed straight into the pipe network all other flows within the site were applied to the 2D domain.

4.4.3 Proposed Trunk Drainage

The development layout Masterplan completed by Lend Lease (8th April 2011, Issue 8) was used as the basis of assessing the drainage requirements for the site.

As noted in Section 4.2, runoff entering the site for small events is currently discharged to the north via a piped drainage system. For larger events, flow ponds in the Alexandria Street road reserve and into the RNA site. For these larger events, water is drained via the piped drainage system to the north and by overland flow to the south-east across St Pauls Terrace. The depth and velocity of flow currently conveyed overland through the site is well in excess of acceptable limits. For the purposes of the current study, it has been assumed that additional drainage will be required to minimise the flow (and the depth of flow) conveyed overland.

Realistically, there is no real opportunity to complete works downstream of St Pauls Terrace. The ability to discharge across St Pauls Terrace is therefore governed by the flood level reached within the site. Reducing this flood level would also reduce the flow discharged across St Pauls Terrace. To minimise the depth of flooding in the developed case, it is necessary to raise the level of the site while maintaining the overall flood level at the current low point in the site. However, raising the level of the ground also reduces the ability to store water in the Alexandria Street road reserve and the site. To compensate for this loss of flood storage, it is necessary to include an underground storage.

To minimise the size of the required underground drainage works, the drainage solution has sought to maintain a flow similar in magnitude to that conveyed at present across St Pauls Terrace in the long term.

The preliminary drainage solution for the site therefore involves the following elements:

- a grate inlet within the site boundary at the south-eastern corner of the intersection of Water and Costin/ Constance Streets to collect the overland flow in Water Street;
- an increased pipe capacity downstream of Water Street to minimise the flow conveyed overland;
- a 10 ML underground storage tank located between Little Water Street and Gregory Terrace near Alexandria Street to offset the loss in flood storage caused by raising Alexandria Street and the RNA site;
- retention of the existing piped drainage system to the north (the proposed drainage line down Water Street will connect to the existing line); and
- an underground drainage system combined with surcharge pits to discharge flow across St Pauls Terrace to closely resemble the current distribution of flow.

With respect to the inlet proposed at the upstream end of the site, it is proposed to provide an inlet to one side of Little Water Street rather than in Little Water Street on safety grounds. An inlet in Little Water Street would take the form of a large horizontal grate at the point of entry to the site. Given the depth of flooding that occurs in even minor events, there was a concern that during a flood pedestrians (and particularly children) could be pinned against the grate and drown. There is also a risk of a horizontal grate being blocked by debris.

To overcome this, it is proposed to locate the inlet to one side of Little Water Street. Although flow would enter the drainage system via a horizontal inlet, it is intended to surround the inlet with an inclined grate which minimises the potential for blockage and allows people to climb to the top of the grate and to provide a deck (or other structure) over the inlet to preclude direct access to the grate. The inclined grate and cover allow for the visual impact of the inlet to be minimised.

It is considered that this inlet configuration provides the best possible outcome with respect to safety, minimised potential for blockage, and improved visual amenity while also providing for the necessary transition of flow from overland to underground.

As described in the following sections, the proposed works will achieve Council's relief drainage aspirations with respect to Water Street and, in combination with the relocation of the Alexandria Street road reserve, achieve a considerable reduction in the incidence of flooding in the Alexandria Street road reserve.

It can be noted that it is proposed to construct the new stormwater drainage system to the site boundary. This will allow the future construction of relief drainage works by Council in Water Street without the need to access the site.

The ground surface levels at the points where runoff from Water Street enters the site have been raised to limit the amount of flow entering the site. At the intersection of Little Water Street and Constance/ Costin Street it is proposed to raise the existing entrance to a level of 8.30 mAHD to limit the flow through the site to that allowable for roadways under Council guidelines for major events. The inlet to be provided at this location will allow for the collection of flow that would otherwise enter the site as overland flow, ensuring that the development will not cause a significant impact on peak water levels at the intersection of Water and Costin/ Constance Street. At the intersection of Grand Parade and St Pauls Terrace, it is proposed to raise existing levels to 6.25 mAHD at a grade of 1 in 30 from St Pauls Terrace to limit the amount of runoff flowing back into the site.

The extent of the proposed stormwater drainage is shown in Figure 7.

The resultant depth of flooding and peak water levels for the 10, 50 and 100 year events are shown in Appendix C.

4.5 Proposed Internal Drainage

As noted in Section 1, the design standard for the internal drainage system will be the 10 year event in accordance with Brisbane City Council's *Subdivision and Development Guidelines* (2008).

The internal drainage network will be based on the catchment boundaries defined in Figure 4 to drain to the trunk drainage network.

5 TUFLOW MODEL RESULTS

5.1 Existing Case Results

The 50 year ARI storm event is the design standard applicable under the Brisbane City Council's *Subdivision and Developed Guidelines.* However the 100 year ARI storm event has also been considered as a sensitivity case.

The TUFLOW model described above was used to determine the 10, 50 and 100 year flood levels in the vicinity of the subject site.

The existing case was run for the 10, 50 and 100 year ARI 20, 60 and 90 minute storm events. The combined resultant 100 year ARI peak depths from the three storms events are shown in Appendix C.

Points around the site area were selected (refer to Figure 9) so that the peak water levels, flows and velocities for the existing and developed cases could be easily compared. The resultant water levels and flows at each point are shown in Table 10.

Table 10 Peak Water Levels and Peak Flows – Existing Case

Point of Interest	Location	Peak Flood Levels (mAHD)		
		10 Year Event	50 Year Event	100 Year Event
A	Corner of Royal and Quarry St	20.113	20.204	20.239
B	Intersection of Kennigo St and Water St	16.63	16.757	16.783
C	Brunswick St	14.148	14.301	14.381
D	Upstream of where Baxter St intersects with Water St	10.986	11.171	11.244
E	Upstream of where Costin St intersects with Water St	8.437	8.680	8.768
F	Intersection of Water of Constance St/ Costin St	8.319	8.586	8.710
G	Corner of Water and Costin St within the site boundary	8.100	8.174	8.228
H	Downstream of corner of Water and Costin St	7.775	7.903	7.960
I	Downstream of Agricultural Pavilion	7.113	7.163	7.202
J	Corner of Water & Grand Pde	6.709	6.762	6.864
K	Corner of Little Water Street and Alexandria St	6.463	6.763	6.866
L	Upstream of Corner of Alexandria & Water St	6.463	6.765	6.868
M	Proposed Park Area	7.023	7.023	7.023
N	Intersection of Gregory Tce and current Alexandria St	6.671	6.764	6.868
O	Railway Underpass west of main oval	7.384	7.479	7.513
P	Corner of current Alexandria & St Pauls Tce	6.457	6.738	6.831
Q	St Pauls Tce	6.458	6.732	6.819
R	Downstream of the Railway Line East of the site	5.194	5.791	5.938

Point of Interest	Location	Flow Rates (m^3/s)		
		10 Year Event	50 Year Event	100 Year Event
A	Corner of Royal and Quarry St	12.5	17.5	20.7
B	Intersection of Kennigo St and Water St	13.6	21.8	25.1
C	Brunswick St	9.3	17.2	21.8
D	Upstream of where Baxter St intersects with Water St	10.0	17.7	23.2
E	Upstream of where Costin St intersects with Water St	12.5	20.9	26.0
G	Corner of Water and Costin St within the site boundary	12.3	20.4	24.6
I	Downstream of Agricultural Pavilion	12.2	20.3	24.4
L	Upstream of Corner of Alexandria & Water St	0.8	1.2	1.5
N	Intersection of Gregory Tce and current Alexandria St	0.8	0.9	0.9
O	Railway Underpass west of main oval	1.1	1.5	1.7
Q	St Pauls Tce	2.6	10.7	14.3
R	Downstream of the Railway Line East of the site	0.3	5.3	9.7

5.2 Developed Case Results

The TUFLOW model described above was used to determine the 10, 50 and 100 year flood levels in the vicinity of the subject site.

Based on the *Subdivision & Development Guidelines*, the design events for the development are:

- Minor event - 10 year; and
- Major event – 50 year.

The developed case was run for the 10, 50 and 100 year ARI 20, 30, 60 and 90 minute storm events. The combined resultant 100 year ARI peak depths from the four storms events are shown in Appendix C.

Points around the site area were selected (refer to Figure 9) so that the peak water levels, flows and velocities for the existing and developed cases could be easily compared. The resultant water levels and flows at each point are shown in Table 11.

Table 11 Peak Water Levels and Peak Flows – Developed Case

Point of Interest	Location	Peak Flood Levels (mAHD)		
		10 Year Event	50 Year Event	100 Year Event
A	Corner of Royal and Quarry St	20.117	20.203	20.247
B	Intersection of Kennigo St and Water St	16.634	16.759	16.785
C	Brunswick St	14.152	14.307	14.423
D	Upstream of where Baxter St intersects with Water St	10.991	11.174	11.242
E	Upstream of where Costin St intersects with Water St	8.410	8.607	8.726
F	Intersection of Water of Constance St/ Costin St	8.192	8.429	8.677
G	Corner of Water and Costin St within the site boundary	8.018	8.470	8.720
H	Downstream of corner of Water and Costin St	-	-	-
I	Downstream of Agricultural Pavilion	7.043	8.269	8.429
J	Corner of Water & Grand Pde	-	-	-
K	Corner of Little Water Street and Alexandria St	7.146	7.148	7.149
L	Upstream of Corner of Alexandria & Water St	6.611	6.749	6.880
M	Proposed Park Area	7.023	7.023	7.023
N	Intersection of Gregory Tce and current Alexandria St	6.533	6.727	7.159
O	Railway Underpass west of main oval	7.444	7.517	7.551
P	Corner of current Alexandria & St Pauls Tce	6.207	6.675	6.814
Q	St Pauls Tce	6.207	6.672	6.813
R	Downstream of the Railway Line East of the site	4.853	5.634	5.827
Point of Interest	**Location**	**Flow Rates (m^3/s)**		
		10 Year Event	**50 Year Event**	**100 Year Event**
A	Corner of Royal and Quarry St	12.7	17.2	21.1
B	Intersection of Kennigo St and Water St	13.6	21.9	25.2
C	Brunswick St	9.4	17.4	21.9
D	Upstream of where Baxter St intersects with Water St	9.5	18.8	22.7
E	Upstream of where Costin St intersects with Water St	12.0	20.6	25.6
G	Corner of Water and Costin St within the site boundary	2.5	4.9	9.7
I	Downstream of Agricultural Pavilion	0.0	1.5	5.6
L	Upstream of Corner of Alexandria & Water St	0.0	0.3	0.7
N	Intersection of Gregory Tce and current Alexandria St	0.0	0.2	0.2
O	Railway Underpass west of main oval	0.9	1.2	1.4
Q	St Pauls Tce	0.8	8.3	13.5
R	Downstream of the Railway Line East of the site	0.0	2.9	6.2

A comparison of the above results to the existing conditions (as shown in Table 10) is shown in Table 12.

Table 12 TUFLOW Model Results – Afflux

Point of Interest	Location	Change in Peak Flood Levels (m)		
		10 Year Event	50 Year Event	100 Year Event
A	Corner of Royal and Quarry St	0.004	-0.001	0.008
B	Intersection of Kennigo St and Water St	0.004	0.002	0.002
C	Brunswick St	0.004	0.006	0.042
D	Upstream of where Baxter St intersects with Water St	0.005	0.003	-0.002
E	Upstream of where Costin St intersects with Water St	-0.027	-0.073	-0.042
F	Intersection of Water of Constance St/ Costin St	-0.127	-0.157	-0.033
G	Corner of Water and Costin St within the site boundary	-0.082	0.296	0.492
H	Downstream of corner of Water and Costin St	-	-	-
I	Downstream of Agricultural Pavilion	-0.07	1.106	1.227
J	Corner of Water & Grand Pde	-	-	-
K	Corner of Little Water Street and Alexandria St	0.683	0.385	0.283
L	Upstream of Corner of Alexandria & Water St	0.148	-0.016	0.012
M	Proposed Park Area	0	0	0
N	Intersection of Gregory Tce and current Alexandria St	-0.2	-0.037	0.001
O	Railway Underpass west of main oval	0.06	0.038	0.038
P	Corner of current Alexandria & St Pauls Tce	-0.25	-0.063	-0.017
Q	St Pauls Tce	-0.251	-0.06	-0.006
R	Downstream of the Railway Line East of the site	-0.328	-0.157	-0.111
Point of Interest	**Location**	**Change in Flow Rates (m^3/s)**		
		10 Year Event	**50 Year Event**	**100 Year Event**
A	Corner of Royal and Quarry St	0.2	-0.3	0.4
B	Intersection of Kennigo St and Water St	0.0	0.1	0.0
C	Brunswick St	0.2	0.2	0.1
D	Upstream of where Baxter St intersects with Water St	-0.5	1.1	-0.5
E	Upstream of where Costin St intersects with Water St	-0.5	-0.2	-0.4
G	Corner of Water and Costin St within the site boundary	-9.8	-15.6	-14.8
I	Downstream of Agricultural Pavilion	-12.2	-18.8	-18.8
L	Upstream of Corner of Alexandria & Water St	-0.8	-0.9	-0.8
N	Intersection of Gregory Tce and current Alexandria St	-0.8	-0.7	-0.7
O	Railway Underpass west of main oval	-0.2	-0.3	-0.3
Q	St Pauls Tce	-1.8	-2.4	-0.9
R	Downstream of the Railway Line East of the site	-0.3	-2.4	-3.4

As shown in the results outlined above the proposed stormwater drainage network does not have a significant impact on peak water levels and peak flows within the vicinity of the site.

Points A, B, C, D, E and F are located upstream of the site along Water Street. As the tables show, the impact of the proposed development has been negligible for all events. For the 100 year sensitivity event there is a decrease in peak water levels of up to 33 millimetres at the intersection of Water Street and Constance Street directly upstream of the subject site.

The development does not have a significant impact at St Pauls Terrace (Point P) or Gregory Terrace (Point N) located to the east and west of the site. The peak water level along St Pauls Terrace decreases by 60 millimetres and the peak flow across the road is reduced by 2.4 m^3/s for the 50 year design event. For all 10 year event the development improves the immunity of the road. The proposed surcharge pits discharging flow along the eastern boundary of the site adjacent to St Pauls Terrace will not adversely impact on the existing level of immunity of St Pauls Terrace (and will provide a slight improvement in conditions).

The increased capacity of the proposed stormwater drainage network allows for the majority of the flow to be piped beneath the subject site, significantly reducing the rate of overland flow within the site (points G and I). The storage afforded by the underground drainage system provides a sufficient volume to offset the loss in above ground flood storage in the Alexandria Street Road Reserve and the RNA site due to the development.

Finally, it is noted that Table 12 lists an increase in flood level compared to the level calculated for the existing case at points G, I, and K. However, these points are within the area affected by works and the ground level at each location is to be raised significantly. The change in level therefore does not reflect an increase in flood depth as the flood depth will be less than that calculated for the existing case. The increased flood level is simply a reflection of the lower depth added to the higher ground level.

To confirm that the storage provided by the underground drainage system is of an appropriate size, the volume of floodwater stored above ground in the vicinity of Alexandria Street was calculated. For the existing case, a volume of 11,325 m^3 was calculated. For the developed case, a volume of 750 m^3 was calculated. Adding the storage provided by the underground drainage system resulted in an overall volume of 11,990 m^3, which is slightly greater than the volume calculated for the existing case.

Figures showing the peak water levels, depth of flooding and change in peak water levels within the vicinity of the site, for the 10, 50 and 100 year events are shown in Appendix C.

5.3 Water and Constance Street/ Costin Street Intersection

A previous drainage investigation of the Water and Campbell Street catchments has been under taken by the Tod Group. This report (*Water – Campbell Streets Catchments Relief Drainage Investigation – Final Report*, circa 1997) determined water levels at the intersection of Water and Constance Street/ Costin Street for the existing case and with proposed relief drainage options in place.

A comparison of the results at the intersection of Water and Costin Street obtained by the Tod Group and Cardno for both the existing case and with the proposed relief drainage options in place are shown below. The reporting points for the current model have been placed in approximately the same location as those in the Tod Group report.

Table 13 Corner of Water and Costin Streets – Peak Water Levels

Point of Interest	Location	Existing Case		Developed Case With Relief Drainage in Place	
		10 Year Event	50 Year Event	10 Year Event	50 Year Event
TOD Group reported results					
1/7	Corner of Water and Costin Street	8.16	8.48	7.98	8.08
Cardno Results					
PWL 1/7	Corner of Water and Costin Street	8.35	8.61	7.95	8.45

As shown in the results presented in Table 13, both of the relief drainage options reduce the peak water levels for the 10 Year event by a considerable amount, with the Cardno level slightly lower than that reported in the TOD Group report. The proposed works will therefore provide a significant flood benefit for minor events to existing premises in Water Street.

Given this, it can be concluded that the proposed design will deliver the relief drainage outcomes identified in the Tod Group report and adopted by Council. Relief drainage works can therefore subsequently be constructed by Council in Water Street upstream of the site and achieve the same flood level benefits as nominated in the Tod report.

It is also noted that the drainage works and the realignment of Alexandria Street will result in a substantial improvement in the flood immunity of the Alexandria Street road reserve. At present, the road reserve subject to regular flooding (and damage to vehicles parked in the street). This regular flooding will be eliminated as a result of development.

6 CONCLUSION

The proposed development is situated within an overland flow path. Development of the site will need to occur in a manner that achieves acceptable public safety with regards to flooding and desirably achieves an outcome that takes advantage of the presence of water as an element of the landscape.

A combined one-dimensional/two dimensional TUFLOW model of the catchment area was set-up. Details of stormwater culverts and gully inlets were included in a one-dimensional system, which was linked to the two-dimensional model of the catchment area to model the overland flow paths. This high level of detail was necessary to realistically determine the existing flow patterns of the catchment and adequately model the impact of the development.

The results of the TUFLOW model shown in Table 10, Table 11 and Table 12 indicate that the proposed development does not adversely impact of peak flood levels upstream or downstream of the subject site and will achieve the flood mitigation objectives of Council with respect to Water Street, and provide a slight reduction in water level at St Pauls Terrace. The works, in combination with development of the site, will also achieve a significant reduction in the incidence of flooding in the Alexandria Street road reserve.

Within the site, the drainage system will ensure that the depth and velocity of overland flow within new roads will meet current Council and state design standards.

In relation to the timing of the works, the recommended trigger for the completion of the drainage works is the realignment of Alexandria Street.

FIGURES

Rev: Orig. Date: December 2009

Lend Lease
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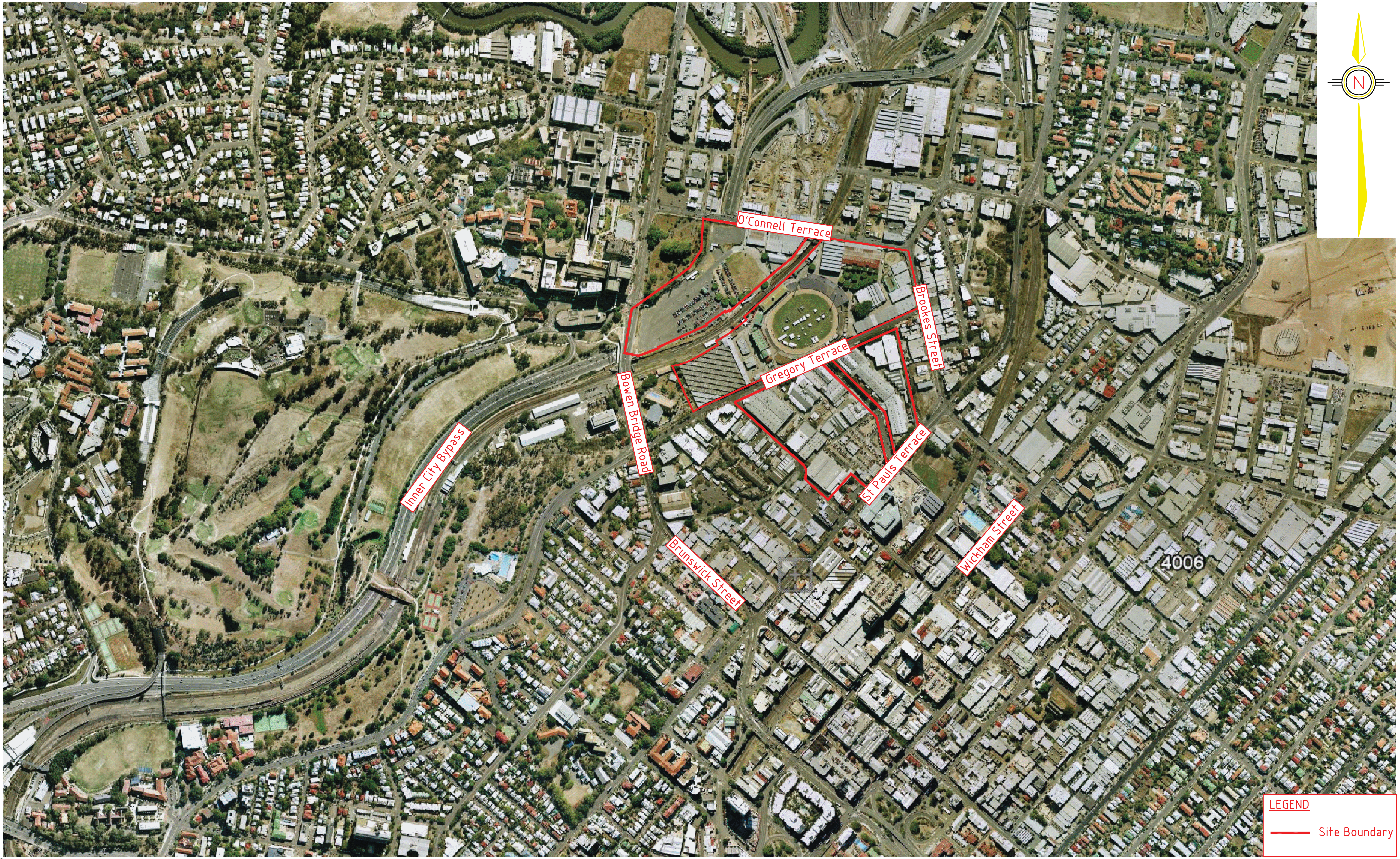
XREF's:

Scale 1:7,500 (A3)

FIGURE 1
LOCALITY PLAN

Project No.: 3503-78

PRINT DATE: 22 March, 2010 - 9:57am



Rev: Orig. Date: December 2009

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FIGURE 2
AERIAL PHOTO

Project No.: 3503-78
PRINT DATE: 22 March, 2010 - 9:58am

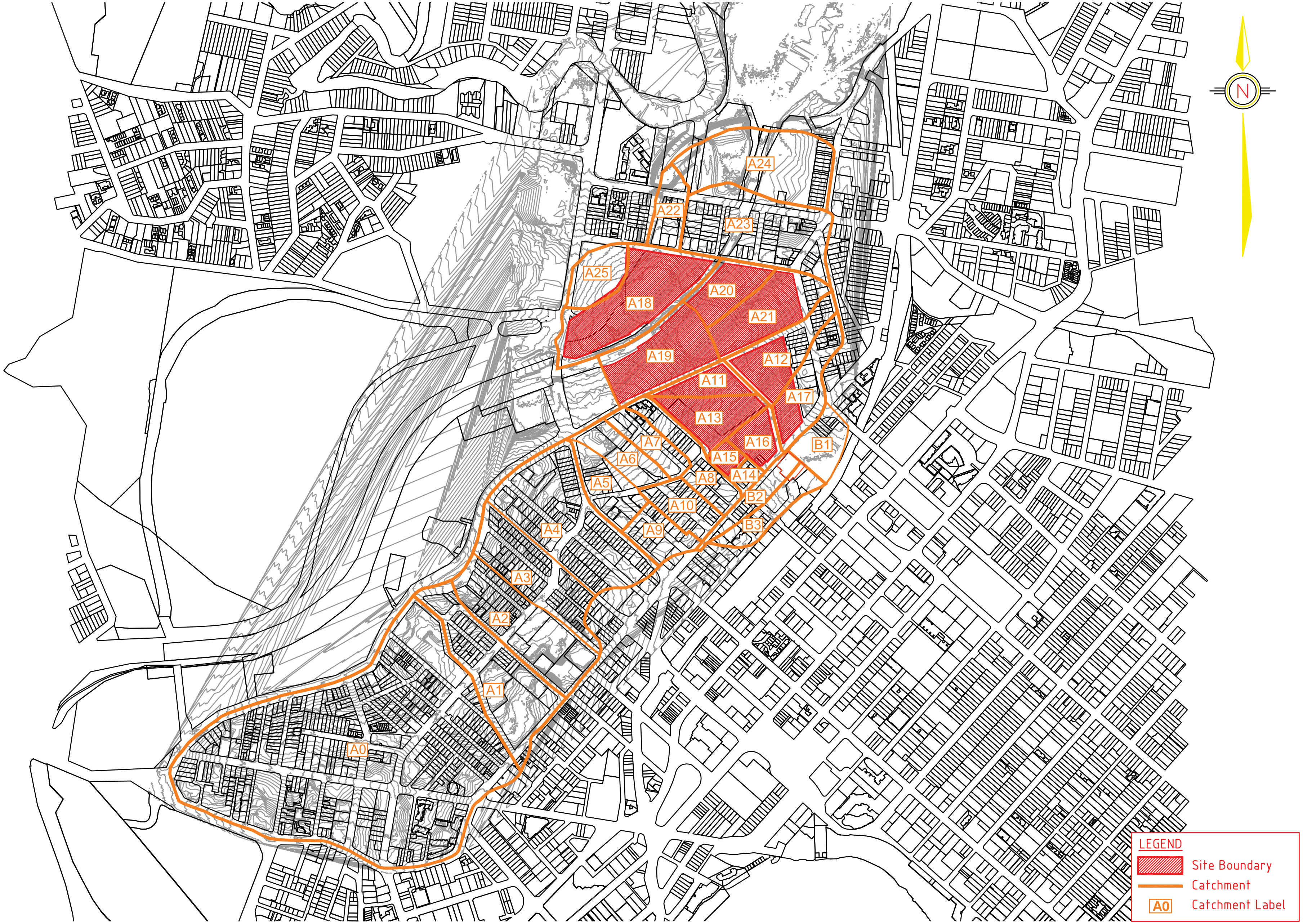

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FIGURE 3
CATCHMENT AREAS - EXISTING CASE

Rev: Orig. Date: December 2009

Project No.: 3503-78

PRINT DATE: 22 March, 2010 - 10:47am

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Map 3a - Development constraints