PROJECT

PRELIMINARY FLOOD ASSESSMENT STAGE 1 PREFERRED PROJECT APPLICATION KINGS FOREST NEW SOUTH WALES

PREPARED FOR

PROJECT 28 PTY LTD

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SYNOPSIS This report describes assessments of flooding characteristics for the proposed Kings Forest development under existing and proposed developed conditions in support of the Stage 1 Preferred Project Application.

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SUMMARY

Project 28 Pty Ltd, a subsidiary of Leda Developments (LEDA), commissioned Gilbert & Sutherland Pty Ltd (G&S) to undertake specialist studies and prepare a Flood Assessment report in support of the Kings Forest Stage 1 Project Application. This report addresses the amended Director General's Environmental Assessment Requirements (DGR's) for Project Application No. 08_0194, dated 23 December 2010.

The Stage 1 Project Application was lodged with the NSW Department of Planning and Infrastructure in December 2011. Following its public exhibition between December 2011 and January 2012, a total of 302 public and 10 agency submissions were received in response to the application. As a result of the submissions, amendments to the project have been made. This Flood Assessment was revised in response to relevant submissions and to reflect the latest revision to the development layout, including preliminary design and assessment of the impacts of the major crossings proposed over Blacks Creek.

This report describes assessments of flooding characteristics associated with the site under existing and proposed developed conditions. This includes assessments of the standard Design Events (ARI 5 to 100 years) and extreme flood events (ARI 500 year and PMF) to facilitate flood evacuation planning for the development.

An assessment of potential climate change impacts on flood levels was carried out. The sensitivity assessments have been revised in accordance with the DGR's and consider the combination of +0.91m rise in sea level and a 10% increase in rainfall intensity over the entire catchment.

Also described in this report is an assessment of regional flooding in combination with storm surge for the lower Cudgen Creek catchment, including the Kings Forest site, based on Tweed Shire Council's Coastal Creeks Flood Model.

CONTENTS

LIST OF DRAWINGS

DRAWING NO.	DESCRIPTION
10927-001	Site location
10927-002	Surface roughness
10927-003	Cudgen Creek sub-catchment plan
10927-004	TUFLOW model extent
10927-005	Existing topography
10927-006	TUFLOW model water surface level reporting points
10927-007	Developed topography & flow management strategy
FLOOD MAPS (APPENDIX 6)	
10927-MAP-01	100 Year ARI Existing Case Flood Levels
10927-MAP-02	100 Year ARI Existing Case Critical Storm Analysis
10927-MAP-03	100 Year ARI Developed Case Flood Levels
10927-MAP-04	100 Year ARI Developed Case Critical Storm Analysis
10927-MAP-05	100 Year ARI Developed Case Flood Depths
10927-MAP-06	100 Year ARI Developed Case Flood Impacts
10927-MAP-07	50 Year ARI Existing Case Flood Levels
10927-MAP-08	50 Year ARI Existing Case Critical Storm Analysis
10927-MAP-09	50 Year ARI Developed Case Flood Levels
10927-MAP-10	50 Year ARI Developed Case Critical Storm Analysis
10927-MAP-11	50 Year ARI Developed Case Flood Depths
10927-MAP-12	50 Year ARI Developed Case Flood Impacts
10927-MAP-13	20 Year ARI Existing Case Flood Levels
10927-MAP-14	20 Year ARI Existing Case Critical Storm Analysis

DRAWING NO.	DESCRIPTION
10927-MAP-15	20 Year ARI Developed Case Flood Levels
10927-MAP-16	20 Year ARI Developed Case Critical Storm Analysis
10927-MAP-17	20 Year ARI Developed Case Flood Depths
10927-MAP-18	20 Year ARI Developed Case Flood Impacts
10927-MAP-19	10 Year ARI Existing Case Flood Levels
10927-MAP-20	10 Year ARI Existing Case Critical Storm Analysis
10927-MAP-21	10 Year ARI Developed Case Flood Levels
10927-MAP-22	10 Year ARI Developed Case Critical Storm Analysis
10927-MAP-23	10 Year ARI Developed Case Flood Depths
10927-MAP-24	10 Year ARI Developed Case Flood Impacts
10927-MAP-25	5 Year ARI Existing Case Flood Levels
10927-MAP-26	5 Year ARI Existing Case Critical Storm Analysis
10927-MAP-27	5 Year ARI Developed Case Flood Levels
10927-MAP-28	5 Year ARI Developed Case Critical Storm Analysis
10927-MAP-29	5 Year ARI Developed Case Flood Depths
10927-MAP-30	5 Year ARI Developed Case Flood Impacts
10927-MAP-31	PMF Existing Case Flood Levels
10927-MAP-32	PMF Existing Case Critical Storm Analysis
10927-MAP-33	PMF Developed Case Flood Levels
10927-MAP-34	PMF Developed Case Critical Storm Analysis
10927-MAP-35	PMF Developed Case Flood Depths
10927-MAP-36	PMF Developed Case Flood Impacts
10927-MAP-37	500 Year ARI Existing Case Flood Levels

DRAWING NO.	DESCRIPTION
10927-MAP-38	500 Year ARI Existing Case Critical Storm Analysis
10927-MAP-39	500 Year ARI Developed Case Flood Levels
10927-MAP-40	500 Year ARI Developed Case Critical Storm Analysis
10927-MAP-41	500 Year ARI Developed Case Flood Depths
10927-MAP-42	500 Year ARI Developed Case Flood Impacts
10927-MAP-43	100 Year ARI Climate Change Existing Case Flood Levels
10927-MAP-44	100 Year ARI Climate Change Existing Case Critical Storm Analysis
10927-MAP-45	100 Year ARI Climate Change Developed Case Flood Levels
10927-MAP-46	100 Year ARI Climate Change Developed Case Critical Storm Analysis
10927-MAP-47	100 Year ARI Climate Change Developed Case Flood Depths
10927-MAP-48	100 Year ARI Climate Change Developed Case Flood Impacts

1 Introduction

1.1 Background

1.1.1 Previous reports

Project 28 Pty Ltd, a subsidiary of Leda Developments (LEDA), commissioned Gilbert & Sutherland Pty Ltd (G&S) to undertake specialist studies in support of the Kings Forest Concept Plan Application (ref: 06_0318). The G&S report prepared for that purpose was titled *'Flood Assessment, Kings Forest, Kingscliff'* and dated December 2009.

The flood modelling undertaken for the Concept Plan Application was subsequently revised for the Stage 1 Project Application (ref: 08_0194). This revised modelling was described in the June 2011 G&S report in support the Project Application, titled '*Flooding and Flood Management Assessment, Kings Forest Stage 1 Project Application, Kings Forest New South Wales'*.

The Kings Forest Stage 1 Project Application No. MP 08_0194 was lodged in November 2011. The Application and Environmental Assessment Report was advertised from December 2011 to January 2012, following which 302 public submissions and 10 agency submissions were received.

1.1.2 Current report

This report was prepared in response to the submissions and to support the Preferred Project Application. It revises previous flood modelling to consider and address:

- The latest revision to the development layout and earthworks plan.
- Revisions to the hydraulic modelling described in the June 2011 Flood Management report.
- A field assessment of the Manning's 'n' roughness coefficients across the site.
- Analysis of the major crossings proposed over Blacks Creek and preliminary design of hydraulic structures.
- Response to submissions for the Stage 1 Project Application (described herein).

This assessment has been based on Tweed Shire Council's (TSC) Coastal Creeks flood model (prepared by BMT WBM) and existing survey data and preliminary civil design details for the proposed works provided by Mortons Urban Solutions.

1.2 Submissions to the Stage 1 Project Application

With respect to the flood assessments and associated modelling for the proposed development, the following items were raised in the submissions to the Stage 1 Project Application and are addressed within this report.

1.2.1 NSW Office of Water (NOW)

The NOW submission dated 13 February 2012 raised concerns regarding the maintenance regime proposed for Blacks Creek. NOW recommended that a natural channel design approach be adopted, recognising the benefits of retaining woody debris within the stream rather than its removal.

G&S's flood modelling was revised to consider an 'unmaintained' channel (i.e. channel maintained in an equivalent state to its present condition) by adopting the same Manning's 'n' value for both the 'existing' and 'developed' case models, and thus not relying on channel maintenance to mitigate hydraulic impacts of the development. Furthermore, a field assessment on Manning's 'n' was carried out using the Cowan method (described in Section 4 of this report). The results were included in the revised modelling.

1.2.2 Tweed Shire Council

In response to TSC's letter dated 24 January 2012, the following items have been addressed within this report:

- TSC's concerns with the long term hydraulic operation of Blacks Creek were addressed by revising the Manning's roughness coefficient adopted in the modelling.
- The internal hydraulic management strategy for flows throughout the site was revised to

reduce offsite impacts in the lower ARI events (up to 10 years) to acceptable levels.

- Flood impact maps for the probable maximum flood (PMF) and 100 year ARI climate change scenario have been included in Appendix 3.
- The incorrect use of the phrase 'flood prone lots' was noted and addressed in the revised Flood Management report (for concurrent submission with this Flood Assessment).

1.2.3 NSW Environmental Protection Agency

The NSW EPA submission (dated 6 February 2012) found the flooding assessments to be adequate, but also noted that changes to the proposed maintenance regime for Blacks Creek could impact on the modelling.

As per TSC's concern, this has been addressed by a revision to the Manning's 'n' roughness coefficient adopted in the modelling.

1.2.4 NSW Department of Primary Industries

The NSW DPI submission dated 25 January 2012 advised that the proposed maintenance regime for Blacks Creek, aimed at improving or enhancing the hydraulic capacity of the stream, was not acceptable.

The hydraulic modelling was revised to include use of the same roughness coefficient for both the existing and developed case models and design of an alternative strategy for mitigating the impacts of the proposed earthworks within the floodplain. These changes are described herein.

2 Site description and proposal

2.1 Location

Kings Forest is located on the far north coast of New South Wales, approximately 20km south of the NSW/QLD border, 4km south of Kingscliff and directly west of the coastal development of Casuarina, as shown on Drawing No. 10927-001.

The site has an area of approximately 870ha and is situated within the Tweed Shire Council (TSC) local government area. It is bounded by agricultural landuses to the north, west and south-west and the wetlands of Cudgen Creek Nature Reserve to the east and south-east. The site can be accessed from the north-east via Depot Rd.

2.2 Receiving environment

The land ranges in elevation from approximately RL0m Australian Height Datum (AHD) to RL55m AHD, with the majority of the site occupying low-lying land within the floodplain of Cudgen Creek.

Runoff from the development generally drains to the central Blacks Creek via a number of unnamed ephemeral gullies. Blacks Creek runs west to east through the site and discharges into SEPP14 wetlands comprising Cudgen Nature Reserve and subsequently into Cudgen Creek.

Cudgen Creek drains a total catchment area of approximately 6,147ha and flows in a northerly direction from Cudgen Lake (which lies to the south-east of the site) to its mouth at Kingscliff, approximately 4.5km north-east of the site.

2.3 Existing development

The site has been selectively cleared and has historically been used for sand mining, turf production, dairy farming, small cropping and grazing and sugar cane production. Most recently, the site was used for a pine plantation, which has been harvested and removed.

There are a small number of dwellings and farm sheds on the subject land.

2.4 Proposed development

The Concept Plan for the Kings Forest development was approved on 19 August 2010 and consents to the following development:

- residential development for approximately 4500 dwellings
- town centre and neighbourhood centre for future retail and commercial uses
- community and education facilities
- employment land
- golf course
- open space
- wildlife corridors
- protection and rehabilitation of environmentally sensitive land
- utility services infrastructure
- water management areas and lake and
- roads and pedestrian and bicycle paths.

The Stage 1 Project Application, lodged in November 2011 and amended in response to the submissions, now includes the following elements (NB: these elements will be revised and updated as the amended project is finalised):

- subdivision to create new lots for future development
- bulk earthworks across the site
- road works comprising:
  - construction of the entrance road into the site and associated intersection works on Tweed Coast Road
  - alignment and construction of the proposed Kings Forest Parkway from Tweed Coast Road via Precincts 4 and 5 through to the western precincts and
  - alignment and part construction of two proposed roads through SEPP 14 areas to access the southern precincts.
- development of 2,036 m^2 of floor space for rural supplies development and access arrangements within Precinct 1
- construction of subdivision and infrastructure works along the Kings Forest Parkway and within Precincts 1 and 5
- the Plan of Development for Precinct 5.

3 Field assessment of Manning's roughness

3.1 Method

A field assessment was carried out to estimate Manning's roughness coefficients for the major channels and across the floodplain within the Kings Forest site.

The field assessment adopted the procedure developed by Cowan (1956) and described in Appendix C of Brisbane City Council's Natural Channel Design Guidelines (November 1993). This method adopts the following parameters to represent different physical characteristics of the channel or floodplain:

- n_b channel/floodplain material
- n_1 degree of irregularity
- n_2 variation in cross-section
- n_3 effect of obstructions (excluding vegetation)
- n_4 amount of vegetation
- m degree of channel meandering

The value of Manning's 'n' is subsequently calculated by:

$$n = (n_b + n_1 + n_2 + n_3 + n_4)\, m$$

Tables C.2 and C.4 from the BCC Guidelines (included in Appendix 2) provide a framework for estimating each of these parameters.

3.2 Results

Calculations of Manning's 'n' for the channel reaches along the major flowpaths and for selected areas of the floodplain are provided in Table 3.2.1. The resulting surface roughness map for the site is given on Drawing No. 10927-002.

Table 3.2.1 Estimation of Manning's n roughness coefficient by Cowan method

Reference location	Channel material (n_b)	Degree of irregularity (n_1)	Variation in channel cross section (n_2)	Effect of obstructions (n_3)	Amount of vegetation (n_4)	Degree of channel meandering (m)	Manning's n
Channel roughness							
1, 2, 5 & 14	0.024	0.006	0	0.010	0.006	1	0.046
3 & 4	0.024	0.006	0	0.015	0.006	1	0.051
6	0.024	0.006	0	0.01	0.008	1	0.048
7	0.024	0.006	0	0.005	0.015	1	0.05
8	0.024	0.008	0	0.002	0.006	1	0.035
9	0.024	0.005	0	0.005	0.01	1	0.044
10	0.024	0.003	0	0.003	0.01	1	0.040
11 & 12	0.024	0.002	0.002	0.01	0.02	1	0.058
13	0.024	0.002	0	0.002	0.006	1	0.034
Floodplain roughness							
A	0.024	0.005	0	0.01	0.1	1	0.139
B	0.024	0.005	0	0.002	0.025	1	0.056
C	0.024	0.003	0	0.002	0.01	1	0.039
D	0.024	0.002	0	0.03	0.01	1	0.066
E	0.024	0.002	0	0.004	0.02	1	0.050
F	0.024	0.002	0	0.03	0.025	1	0.081
G	0.024	0.002	0	0.008	0.006	1	0.040
H	0.024	0.002	0	0.015	0.05	1	0.091

4 Catchment hydrology

An assessment of the regional hydrology for the Cudgen Creek catchment (along with Cudgera, Mooball and Marshalls creeks) was undertaken by BMT WBM as outlined in the *'Tweed-Byron Coastal Creeks Flood Study Final Report'* dated November 2009 (herein referred to as the BMT WBM report). The sub-catchments for Cudgen Creek are shown on Drawing No. 10927-003.

The BMT WBM assessment was undertaken using the rainfall-runoff routing program XP-RAFTS to estimate runoff hydrographs from each sub-catchment within the model domain, for selected rainfall events.

Hydrographs representing both the local catchment runoff and total catchment discharge for each sub-catchment were supplied as a component of the TUFLOW model prepared by BMT WBM for TSC.

The regional model hydrology assessed the 6 hour, 24 hour and 36 hour duration storm events for ARI's of 5, 10, 20, 50, 100 and 500 years, the estimated PMF and climate change scenarios for the 10 and 100 year ARI's (incorporating a 10% increase in rainfall intensity). These hydrographs were applied (both by BMT WBM and G&S) as inflows to the TUFLOW model for an assessment of regional flooding in combination with storm surge in Cudgen Creek.

5 Flood assessment methodology

5.1 Overview

A hydraulic assessment was undertaken to quantify, and subsequently mitigate, the impacts of the proposed development on flood levels upstream of, within and downstream of the site. The assessment also aimed to define flood levels during extreme flood events and under predicted climate change conditions to facilitate planning for evacuation routes during such events.

To assess the extent of flooding across the site, G&S has utilised the Tweed-Byron Coastal Creeks TUFLOW 2D flood model, developed by BMT WBM on behalf of TSC. A full description of the model is presented in the BMT WBM report.

Hydraulic modelling was carried out using the BMT WBM's TUFLOW one-dimensional/two-dimensional hydrodynamic flood modelling system, utilising both the one and two-dimensional modelling features. The two-dimensional component caters for flow over the floodplain whilst the one-dimensional components represent main channels and various structures within the model area.

The modelling described in this report provides a 'regional' assessment of flooding within the Cudgen Creek catchment (including the site) in combination with a storm surge ocean boundary condition.

In the future, additional modelling of the Kings Forest site will be carried out using a higher resolution local model to provide a more accurate assessment of the hydraulic behaviour within the major flowpaths across the site and to facilitate detailed design of the proposed structures at major creek crossings.

5.2 Regional (Cudgen Creek) flooding

Previous modelling carried out in support of the Part 3A Project Application for Kings Forest and subsequent revisions had utilised the complete Tweed-Byron Coastal Creeks TUFLOW model, which includes the Cudgen Creek catchment (containing the site) and also the catchments of Cudgera Creek, Mooball Creek and Marshalls Creek to the south of the site, herein referred to as the CCMM model.

A review of the CCMM model extent indicated that the Cudgen Creek catchment predominantly functions independently of the remaining catchments and thus a truncated version of the model was set up and utilised to reduce model run-time. The approach used in setting up the model is described in the following sections.

5.2.1 Establish an existing case model

An existing case model was set up by isolating the Cudgen Creek domains within the existing case CCMM model to create a stand-alone model for the catchment within which the site lies, herein referred to as the Kings Forest (or KF) model. Drawing No. 10927-004 shows the extent of the KF model.

In the CCMM model, the only connection between the Cudgen Creek catchment and the Cudgera Creek catchment (immediately to the south) is a single road crossing, at Kanes Road, Round Mountain. A rating curve for the crossing was calculated based on the structures contained in the CCMM model and was applied at the new model boundary.

The existing case model topography (which utilises a 30m grid resolution across the site) was updated to include the site survey supplied by Mortons Urban Solutions (consistent with the modelling carried out for previous assessments).

The model was concurrently modified to utilise the elevations at the cell mid-sides (and corners) for hydraulic calculations, thus providing a better representation of the surveyed topography within the site for control of flow between grid-cells. The model topography for the existing case model is shown on Drawing No. 10927-005.

Additionally the revised surface roughness map for the site, based on the field assessment of Manning's 'n' assessment described in Section 3, was included in the modelling.

5.2.2 Run and verify hydraulic model results

The KF model was run for the full range of design storm events and the resulting flood levels were verified against previous modelling (by G&S) and compared to the flood maps from the BMT WBM report. The comparison with the BMT WBM work was to ensure model results were not altered due to the model truncation and remained consistent with the previously calibrated CCMM model.

Inflows (for all modelled storm events) were adopted from the RAFTS outputs in the supplied CCMM model as described in Section 4.

Flood levels at a number of reporting points (shown on Drawing No. 10927-006) were used to verify the model results. The results of this verification for a range of storm events are presented in Appendix 3. When compared to the previously reported model results (G&S June 2011), differences in flood levels in Cudgen Creek (external to the site) are generally less than 20mm. This is within the accuracy of the defined flood levels for Tweed Shire, which are reported to the nearest 0.1m (refer to BMT WBM flood maps in Appendix 4). The primary reason for these differences is the use of cell mid-side elevations in the hydraulic calculations, which is considered to be appropriate for the scope of this assessment.

Differences in levels within the local Kings Forest catchment are due to the adoption of the (lower) Manning's n values from the field assessment. This is considered to be an appropriate assumption with respect to the current state of the site.

5.2.3 Create a developed case model

The model topography within the KF model was modified to incorporate the proposed development. In accordance with the most recent DGEAR's, the surface roughness within the channel was left unchanged from the revised existing case model to represent an unmaintained channel. The model topography for the developed case model is shown on Drawing No. 10927-007.

Model inflows from the existing case modelling were maintained as local offline detention structures will be provided to mitigate any increases in peak discharge from the proposed areas of development back to pre-developed rates prior to discharge into the site's major flowpaths.

The developed case model was run to establish impacts of the proposed development, then re-run using an iterative approach including revision to the layout and earthworks design (carried out by Mortons Urban Solutions). This process informed the initial selection and testing of suitable flow management measures to mitigate any identified impacts. The final choice of flow management measures are included on Drawing No. 10927-007.

The major road crossings proposed within the site (as indicated on Drawing No. 10927-007) were included in the model and sized to cater for local catchment runoff to ensure no worsening in flood levels external to the site. Details of the major crossings included in the preliminary modelling are provided in Table 5.2.1. These details may be refined at the detailed design phase of the project.

Table 5.2.1 Kings Forest modelled road crossing details

Crossing ID	Type	Invert level (mAHD)	Width (m)	Height (m)	No. of barrels	Road level (mAHD)
P5-GC	RCBC	1.8	3.0	1.5	11	4.1
	Bridge	0.2*	40	-	-	3.8
P4-P7	RCBC	1.3	3.0	1.8	7	4.4
P7-GC	RCBC	0.1	3.0	1.5	7	2.4
	Causeway	-	250	-	-	2.4
P12 (internal)	RCBC	2.0	3.6	2.4	1	6.0

*Note: minimum IL at bridge crossing is approximately RL0.2mAHD, ground surface level varies across cross-section.

Table 5.2.2 Design combination of Rainfall and Storm Surge Events

Design Event	Catchment Inflow Rainfall Event	Ocean Boundary Storm Surge Event	Ocean Boundary Peak Tailwater Level (mAHD)
5 year ARI	5 year ARI	5 year ARI	0.8
10 year ARI	10 year ARI	10 year ARI	1.5
20 year ARI (envelope)	20 year ARI	10 year ARI	1.5
	10 year ARI	20 year ARI	2.2
50 year ARI (envelope)	50 year ARI	10 year ARI	1.5
	10 year ARI	50 year ARI	2.4
100 year ARI (envelope)	100 year ARI	20 year ARI	2.2
	10 year ARI	100 year ARI	2.6
500 year ARI	500 year ARI	100 year ARI	2.6
PMF	PMF	100 year ARI	2.6

5.2.4 Model simulations

The model was run under existing and developed conditions for a range of rainfall and storm surge event combinations, as outlined in Table 5.2.2. For each modelled storm event, the 6, 24 and 36 hour duration rainfall events were assessed. For the 20, 50 and 100 year ARI Design Events, an envelope approach was adopted to include peak flood levels resulting from both rainfall and storm surge dominated inundation.

5.3 Rare and extreme events

In addition to examining flood impacts during the standard (up to 100 year ARI) Design Events, model simulations were carried out for the 500 year ARI Design Event and the Probable Maximum Flood (PMF), as shown in Table 5.2.2, to facilitate planning for flood evacuation routes and refuges.

Simulations for the Q500 and PMF events were carried out using the model described in Section 5.2 for the 6, 24 and 36 hour duration storms.

5.4 Climate change scenarios

Modelling for predicted Climate Change impacts was carried out in accordance with the DGR's for the Kings Forest Stage 1 Project Application (ref: 08_0194) dated 23 December 2010 and will be used to ensure that habitable floor levels within the development are set with suitable freeboard above predicted future flood levels. The climate change scenario modelled includes a sea level rise of 0.91m and a 10% increase in rainfall intensity. A design envelope including both rainfall and storm surge dominated events was assessed.

Climate change simulations have been carried out in accordance with the previous modelling by BMT WBM, included in the supplied CCMM TUFLOW model and described in Table 5.3.1. We note that the ocean boundary peak tailwater levels (prior to sea level rise) described in Table 5.3.1 differ from the 20 and 100 year ARI storm surge levels adopted in the regional modelling for the standard Design Events (Table 5.2.2). Justification for this assumption is provided in the BMT WBM report.

Table 5.3.1 Climate Change combination of Rainfall and Storm Surge Events

Design Event	Catchment Inflow Rainfall Event	Ocean Boundary Storm Surge Event	Ocean Boundary Peak Tailwater Level (mAHD)
Climate Change 100 year ARI (envelope)	100 year ARI +10% rainfall intensity	20 year ARI + 0.91m	2.0 + 0.91 (2.91)
	10 year ARI +10% rainfall intensity	100 year ARI + 0.91m	2.2 + 0.91 (3.11)

6 Flood assessment results

Peak water surface levels extracted from all flood model simulations at each of the reporting points shown in Drawing No. 10927-007 are presented in table form in Appendix 5 of this report. Flood maps depicting these levels are included in Appendix 6.

6.1 Standard design events

Estimated flood levels and the model reporting points for the standard ARI storm events are presented in Appendix 5.1.

An analysis of the critical storm duration for each Design Event was undertaken and is included in the flood maps in Appendix 6. The results indicate that flood levels within and upstream of the site are generally controlled by runoff events from the Cudgen Creek catchment (inclusive of site runoff), whilst downstream of the site (to the north-east of the Tweed Coast Road crossing), ocean storm surge controls flood levels within the creek.

The results predict that the development will result in no adverse impacts (i.e. >20mm afflux) on flood levels external to the site for the standard ARI design events.

Preliminary design of the sportsfields in Precinct 10 was carried out to provide conveyance capacity and flood storage for the overall site flow management strategy. Flood depth plots for the developed case model simulations are included. These plots demonstrate that the flood storage within the proposed sportsfields does not exceed 1m depth during a 100 year ARI flood event. They also provide estimates of inundation depths of the remaining ARI's.

6.2 Extreme flood events

Results (existing, developed and impacts) for the extreme events, 500 year ARI and Probable Maximum Flood (PMF) are provided in Appendix 5.3 and will be used for planning purposes to design suitable evacuation routes and refuge areas addressed in a separate Flood Management Assessment.

6.3 Climate change impacts

The predicted flood levels for the existing and proposed developed cases and corresponding flood level impacts under future climate change conditions are provided Appendix 5.3.

The results of the Climate Change assessment were used to ensure habitable floor levels are set with suitable freeboard above predicted future flood levels. Additionally, a depth plot was prepared for the Climate Change scenario to confirm that flood storage within the sportsfields during a future 100 year ARI event does not exceed the 1m design depth criteria.

6.4 Summary

In summary, the analysis described demonstrates that the earthworks for the proposed development will have no adverse impacts on peak flood levels external to the site under the range of Design Events considered.

7 Conclusions

A flood assessment was prepared in support of the Kings Forest Stage 1 Preferred Project Application, addressing the design for Precincts 1 and 5 and conceptual design for the remainder of the site, in order to facilitate an assessment of anticipated future flood behaviour. The assessment investigated the impacts of the ultimate proposed development on flood levels internal and external to the site. The assessment considered an earthworks design (carried out by Mortons Urban Solutions) and tested hydraulic management measures selected to ensure no adverse offsite impacts result from the development under the range of standard design storm events assessed (5 to 100 year ARI).

The assessment has also included an analysis of flood levels and associated impacts during extreme flood events (500 year ARI and the probable maximum flood) to facilitate the planning of appropriate flood evacuation routes and refuges. Additionally, flood levels under a future climate change scenario were assessed for the purpose of ensuring development levels are flood-proof against predicted sea level rise and increased rainfall intensity in combination with the highest standard design event being the 100 year ARI event.

The analysis carried out in this report has specifically addressed flood level impacts resulting from the earthworks (including filling) proposed within the site. Consideration of the increased runoff resulting from an increase in impervious area within the development is not within the scope of this report. Impacts of the proposed development on peak flows discharging from each precinct will be addressed concurrently with the stormwater quality management measures outlined in the Integrated Water Cycle Management Plan for each development stage.

Suitable local offline detention capacity will be included within the proposed stormwater treatment devices, as combined bioretention/ detention devices to ensure no-worsening in peak discharge from the site and thus no adverse hydraulic impacts.

Based on the analysis described herein, the proposed Kings Forest development results in no adverse impacts on peak flood levels external to the site under the full range of design storm events considered.

8 Limitations

This report has been prepared by G&S specifically for Project 28 Pty Ltd, a subsidiary of LEDA Manorstead Pty Ltd, to provide advice on flooding in relation to the Stage 1 Project Application for Kings Forest. As such its use is limited to this purpose and may not be applicable beyond this scope. Third parties should therefore seek advice from G&S on applicability for any other use.

In preparing this report, we have relied on information by others including:

- Tweed-Byron Coastal Creeks flood model and corresponding report prepared by BMT WBM.
- Site survey supplied by Land Surv.
- Preliminary civil design carried out by Mortons Urban Solutions.

The accuracy of this report is limited to the accuracy of the supplied information, the adopted modelling methods and the necessary assumptions. The accuracy of the modelling should be viewed in the context of cumulative error associated with base data, assumptions, design scale and software models.

While this report provides a thorough assessment of hydraulic impacts resulting from the proposed development, the actual estimated flood levels across the site may differ from the modelled estimated flood levels due to errors inherited from the input data and the numerical modelling methods adopted. Furthermore the modelling carried out assesses flooding from standard design events which may vary from future observed rainfall events.

Our analysis and overall approach has been specifically designed to cater for the particular requirements of LEDA and may not be applicable beyond this scope.

9 Appendix 1 – Drawings

ORIENTATION
NORTH

SCALE
400 800 1200 1600 2000
metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND
Site boundary

SOURCES
Image sources:
NSW Department of Lands
1:25000 Topographic Maps Series
Murwillumbah 9641-2N (1987)
Cudgen 9641-3N (2002)

PROJECT	CLIENT	DRAWING
KINGS FOREST STAGE 1 FLOOD ASSESSMENT	PROJECT 28 PTY LTD	SITE LOCATION

SCALE	DATE	DRAWN	CHECKED	PROJECT NO	DRAWING NO
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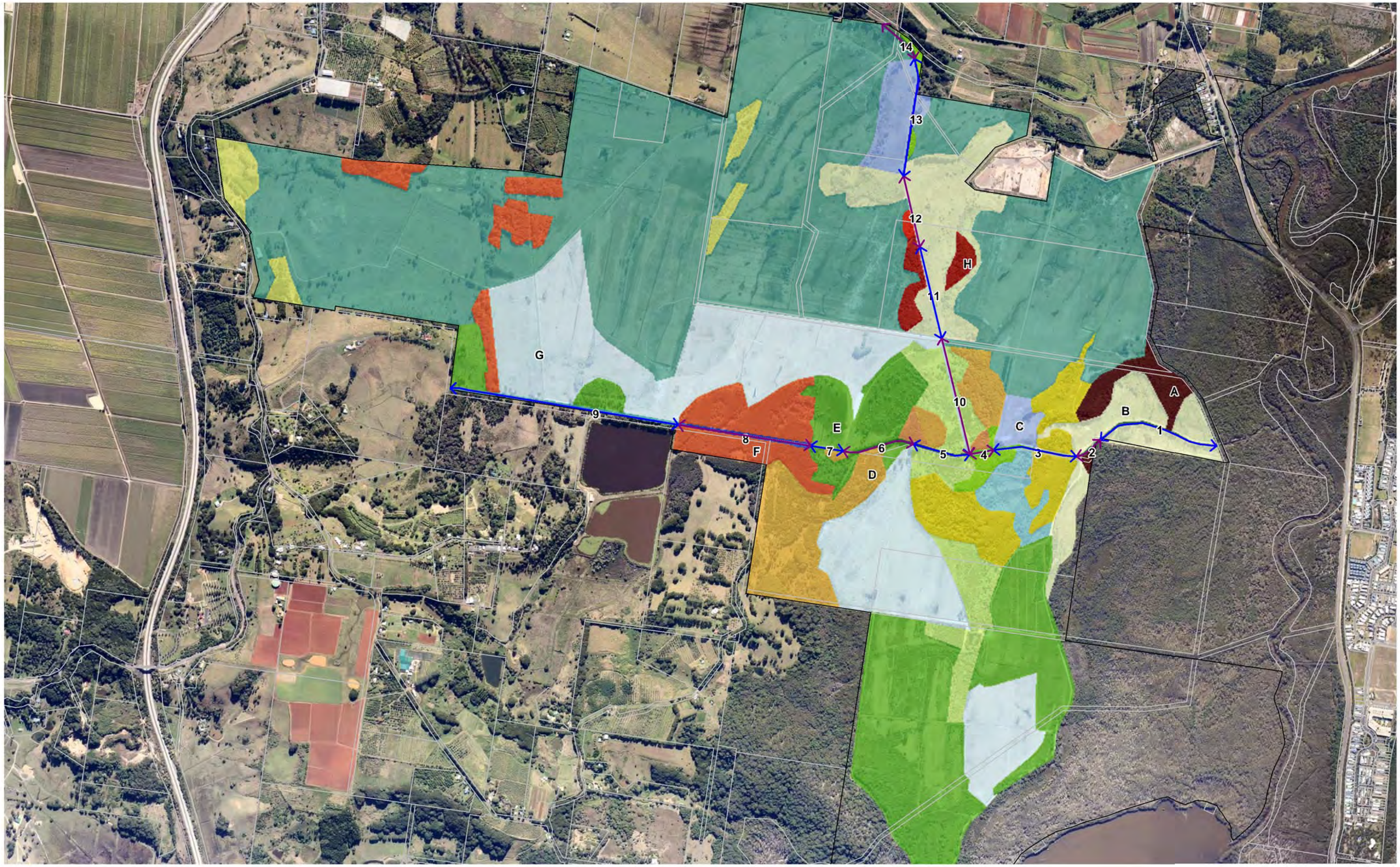

ORIENTATION
NORTH

SCALE
160 320 480 640 800
metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND

Surface roughness - Mannings 'n'

0.034	0.045	0.053	0.081
0.037	0.046	0.056	0.086
0.039	0.048	0.060	0.091
0.040	0.050	0.062	0.139
0.042	0.051	0.066	
0.044	0.052	0.079	

SOURCES

Image source: Nearmap (2012)

PROJECT
KINGS FOREST
STAGE 1
FLOOD ASSESSMENT

CLIENT
PROJECT 28
PTY LTD

DRAWING
SURFACE
ROUGHNESS

SCALE	DATE	DRAWN	CHECKED	PROJECT NO	DRAWING NO
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ORIENTATION
NORTH

SCALE
500 1000 1500 2000 2500
metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND
- Site boundary
- Sub-catchment boundary

SOURCES
Image sources:
NSW Department of Lands
1:25000 Topographic Maps Series
Murwillumbah 9641-2N (1987)
Cudgen 9641-3N (2002)

Catchment boundaries supplied in TSC TUFLOW model

PROJECT	CLIENT	DRAWING
KINGS FOREST STAGE 1 FLOOD ASSESSMENT	PROJECT 28 PTY LTD	CUDGEN CREEK SUB-CATCHMENTS

SCALE	DATE	DRAWN	CHECKED	PROJECT NO	DRAWING NO
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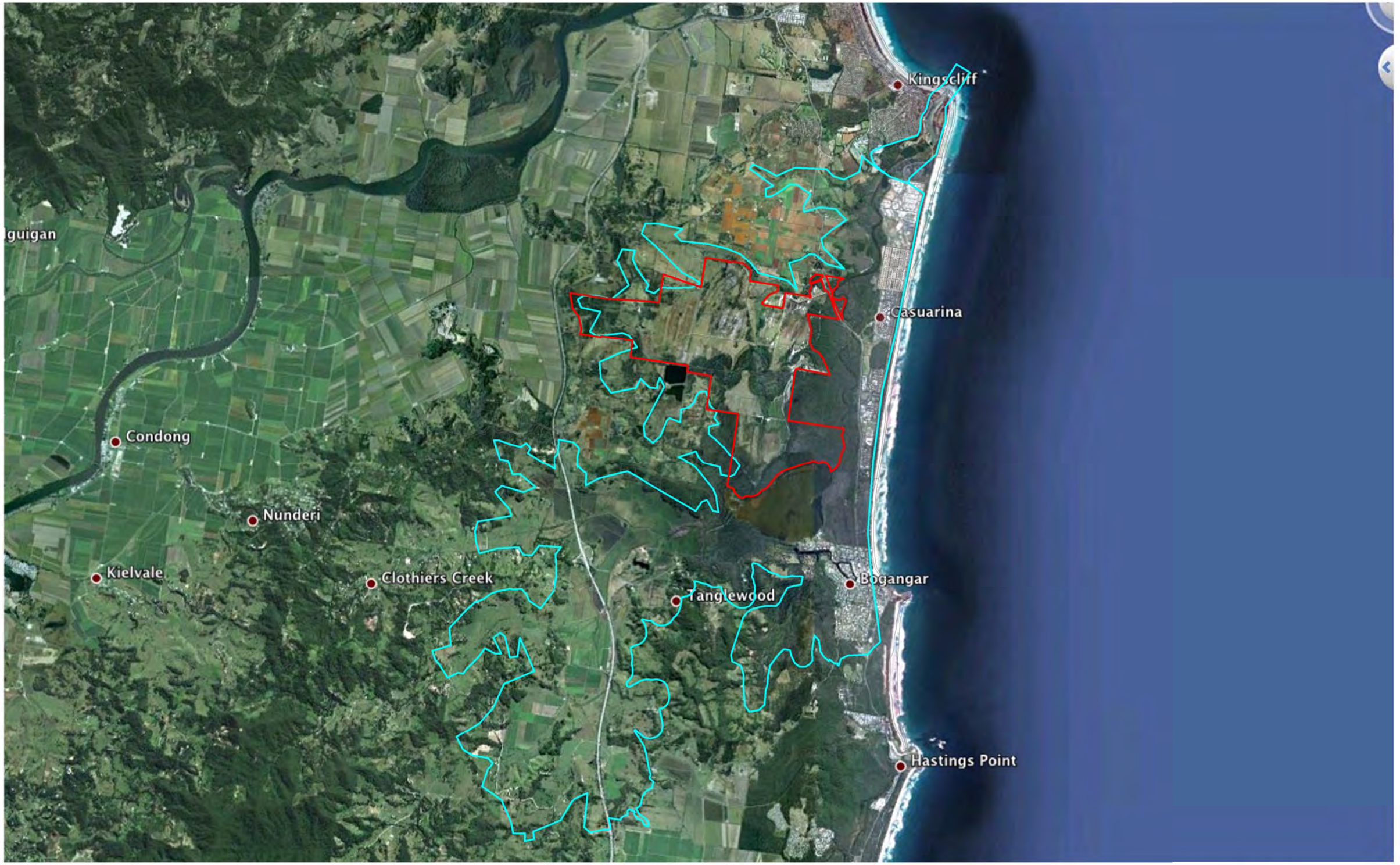

ORIENTATION
NORTH

SCALE
500 1000 1500 2000 2500
metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND
- Site boundary
- TUFLOW model boundary

SOURCES
Image sources:
Google Earth (Image date: 13 May 2010)

PROJECT	CLIENT	DRAWING
KINGS FOREST STAGE 1 FLOOD ASSESSMENT	PROJECT 28 PTY LTD	TUFLOW MODEL EXTENT

SCALE	DATE	DRAWN	CHECKED	PROJECT NO	DRAWING NO
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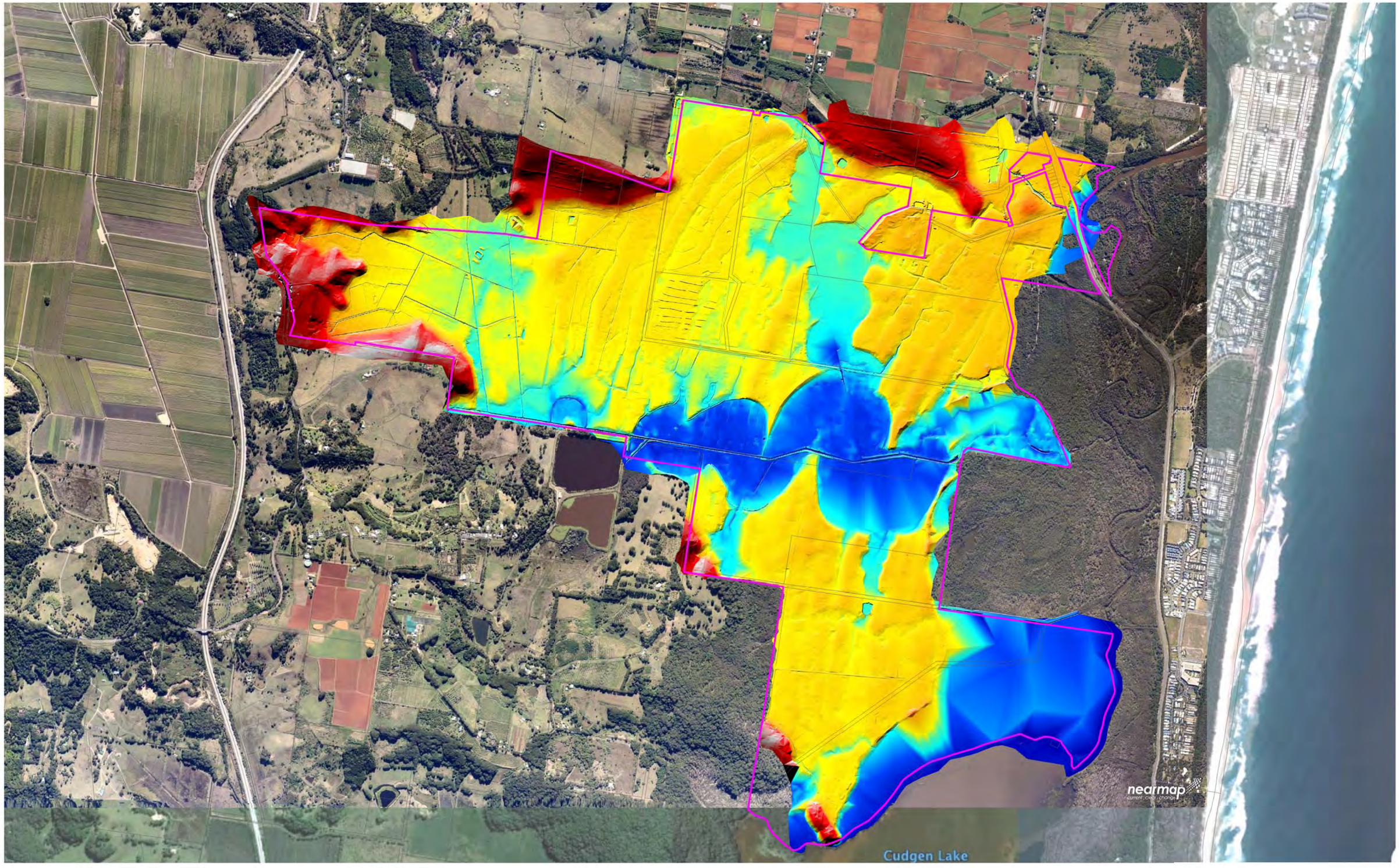

ORIENTATION
NORTH

SCALE
200 400 600 800 1000
metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND
Site boundary

Elevation (mAHD)
-2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 50.0

SOURCES
Image sources:
Nearmap (Image date: 14 June 2012)
Google Earth (Image date: 13 May 2010)

PROJECT
KINGS FOREST
STAGE 1
FLOOD ASSESSMENT

CLIENT
PROJECT 28
PTY LTD

DRAWING
EXISTING SITE
TOPOGRAPHY

SCALE	DATE	DRAWN	CHECKED	PROJECT NO	DRAWING NO
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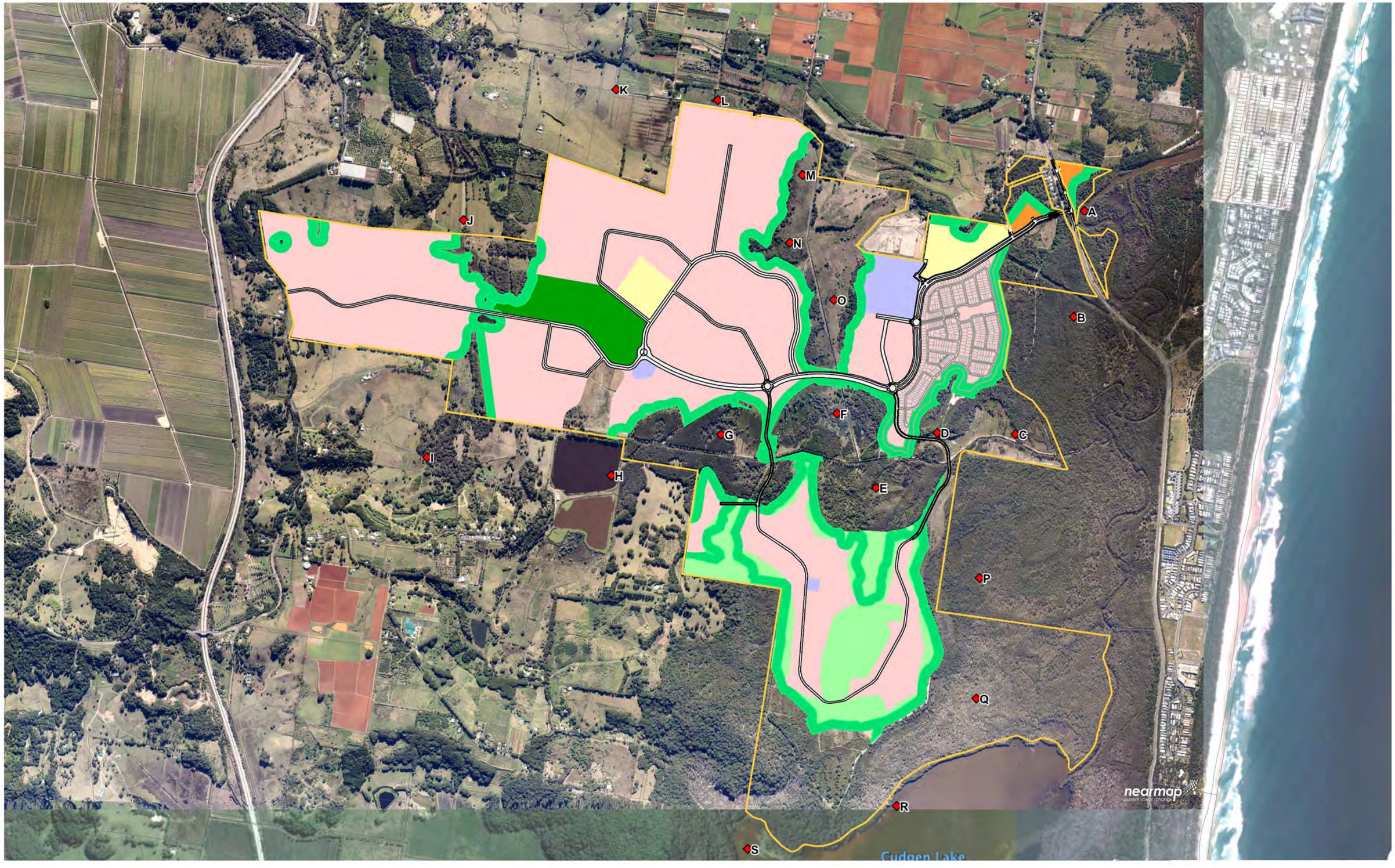

ORIENTATION
NORTH

SCALE
200 400 600 800 1000
metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND

- Site boundary
- A TUFLOW reporting point ID
- Town Centre / Neighbourhood Centre
- Residential
- Community Facilities / Education
- Employment Land
- Structured Open Space (Active)
- Golf Course Area
- 50m Ecological Buffer

SOURCES

Image sources:
Nearmap (Image date: 14 June 2012)
Google Earth (Image date: 13 May 2010)

PROJECT	CLIENT	DRAWING
KINGS FOREST STAGE 1 FLOOD ASSESSMENT	PROJECT 28 PTY LTD	TUFLOW MODEL REPORTING POINTS

SCALE	DATE	DRAWN	CHECKED	PROJECT NO	DRAWING NO
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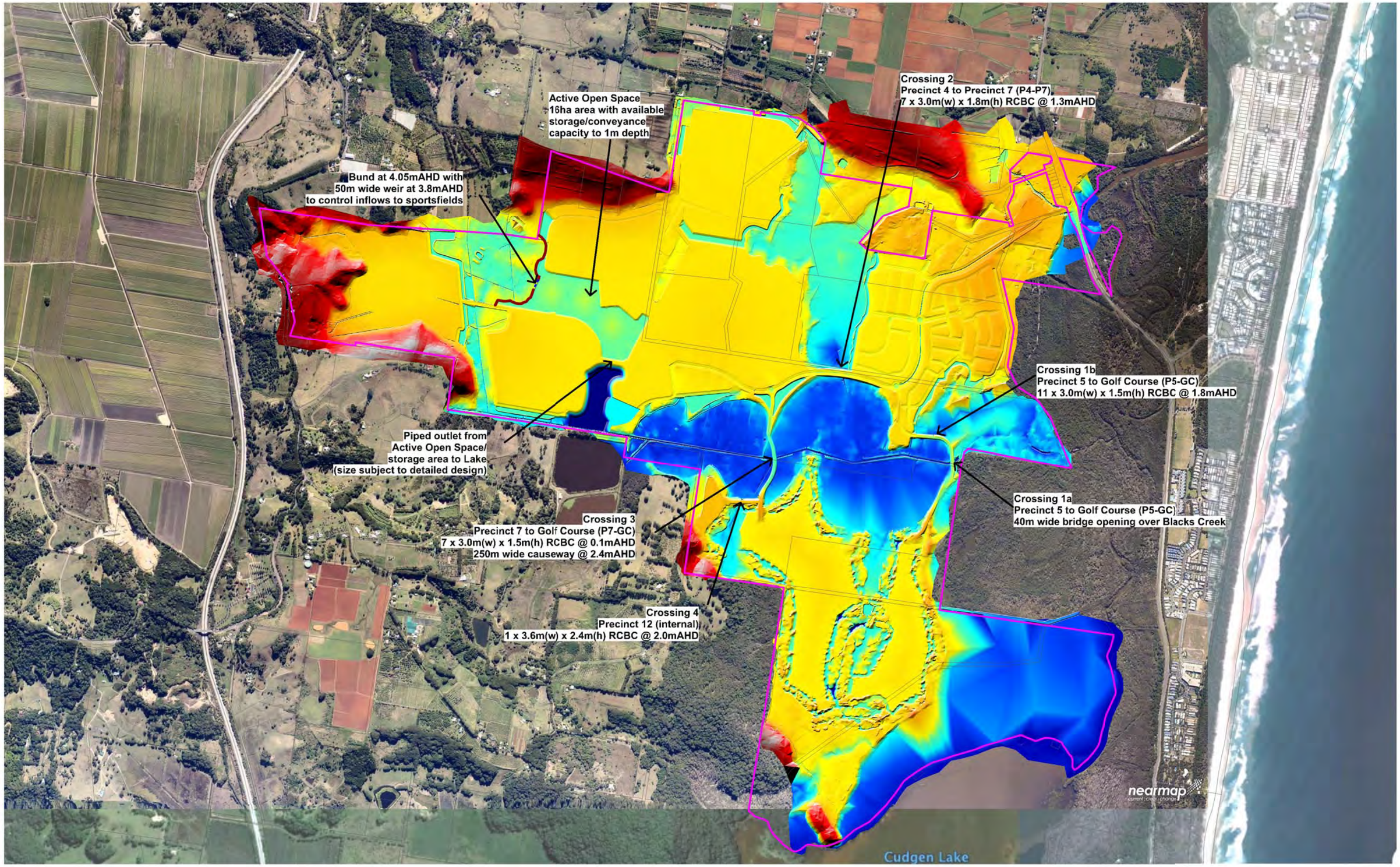

ORIENTATION
NORTH

SCALE
200 400 600 800 1000 metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND
Site boundary

Elevation (mAHD)
-2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 50.0

SOURCES
Image sources:
Nearmap (Image date: 14 June 2012)
Google Earth (Image date: 13 May 2010)

PROJECT
KINGS FOREST
STAGE 1
FLOOD ASSESSMENT

CLIENT
PROJECT 28
PTY LTD

DRAWING
DEVELOPED SITE
TOPOGRAPHY &
FLOW MANAGEMENT
CONCEPT

SCALE	DATE	DRAWN	CHECKED	PROJECT NO	DRAWING NO
1:20 000@A3	03/09/2012	AJF	NTZ	10927	007

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10 Appendix 2 – Cowan method for surface roughness

Table C.2 Modified Cowan method for determining channel roughness

Manning's n = $(n_b + n_1 + n_2 + n_3 + n_4)\, m$

Channel condition		n and m values	Description
Channel material (n_b)	Earth	0.020	Clay-based channels.
	Bed rock	0.025	Channels cut into bed rock.
	Sand–fine gravel	0.024*	Sandy creeks.
	Coarse gravel	0.026	Gravel-based creeks (otherwise use Eqn C.1).
Degree of irregularity (n_1)	Smooth	0.0	Smooth channel.
	Minor	0.001–0.005	Excavated channels in good condition.
	Moderate	0.006–0.010	Channels with considerable bed roughness and some bank erosion.
	Severe	0.011–0.020*	Natural' channels: pools and riffles, exposed tree roots, boulders, and/or irregular banks.
Variation in channel cross section (n_2)	Uniform	0.0	Near-uniform channel section.
	Gradual	0.001–0.005*	Large and small cross sections alternate occasionally (eg. typical NCD n_2 = 0.003).
	Severe	0.010–0.015	Large and small cross sections alternate frequently (eg. a significant pool-riffle system).
Effect of obstructions (n_3) excluding vegetation	Negligible	0.0–0.004	A few scattered obstructions (boulders, trees, logs) that occupy less than 5% of the channel.
	Minor	0.005–0.015*	Obstructions occupy 5–15% of the channel and the obstructions are generally isolated.
	Appreciable	0.020–0.030	Obstructions occupy 15–50% of the channel.
	Severe	0.040–0.050	Obstructions occupy more than 50% of the channel (eg. severe debris collection).
Amount of vegetation (n_4) Consideration should be given to the obstruction caused by vegetation relative to channel width and depth	Small	0.002–0.010	Grasses and/or weeds with the flow at least three times the height of the vegetation.
	Medium	0.010–0.025*	Grass and/or weeds with the flow one to two times the height of the vegetation; or reeds or tree seedlings growing with the flow two to three time the vegetation height; or minor bed vegetation with medium bank vegetation.
	Large	0.025–0.050	Grasses and/or weeds with flow depth equal to vegetation height; or weedy beds with thick bank vegetation; or moderate shrub growth across the bed and banks.
	Very Large	0.050–0.100	Grass and/or weeds more than twice the height of flow depth; or dense, strong reed growth; or significant shrub growth within the channel; or significant inflexible vegetation within channel.
Degree of channel meandering (m)	Minor	1.00	Channel sinuosity is 1.0 to 1.2
	Appreciable	1.15*	Channel sinuosity is 1.2 to 1.5
	Severe	1.30	Channel sinuosity is greater than 1.5 or; m = 0.57 + 0.43 (Sinuosity), but $\geq$ 1.30

(*) Typical NCD channel roughness n = (0.024 + 0.003 + 0.012 + 0.005 + 0.015) 1.15 = 0.068

Table C.4 Modified Cowan method for floodplain roughness

Manning's $n = (n_b + n_1 + n_2 + n_3 + n_4)\, m$

Floodplain condition		n and m values	Description
Floodplain material (n_b)	Earth	0.020*	Clay-based soil.
	Bed rock	0.025	Smooth, flat rock floodplains.
	Sand	0.024	Sandy soils.
	Gravel	0.026	Gravel-based soils (otherwise use Eqn C.1)
Degree of irregularity (n_1)	Smooth	0.0	Smooth, flat, floodplains.
	Minor	0.001–0.005	Slightly irregular shape. A few rises and dips.
	Moderate	0.006–0.010*	Regular rises and dips.
	Severe	0.011–0.020	Very irregular floodplains. Pasture furrows perpendicular to the flow.
Variation in floodplain cross section (n_2)		0	Not applicable.
Effect of obstructions (n_3) excluding vegetation	Negligible	0.0–0.004	A few scattered obstructions (debris, stumps, logs, boulders) occupying less than 5% of the floodplain flow area.
	Minor	0.005–0.015*	Obstructions occupy 5–15% of the flow area.
	Appreciable	0.020–0.030	Obstructions occupy 15–50% of the flow area.
Amount of vegetation (n_4) Consideration should be given to the obstruction caused by vegetation relative to the depth of flow.	Small	0.002–0.010	Grasses and/or weeds with the flow at least twice the height of the vegetation.
	Medium	0.010–0.025	Grass and/or weeds with the flow one to two times the height of the vegetation; or tree seedlings growing with the flow two to three time the vegetation height.
	Large	0.025–0.050	Grasses and/or weeds with flow depth equal to vegetation height, or irregular shrub growth across the floodplain.
	Very large	0.050–0.100*	Grass and/or weeds more than twice the height of flow depth; or significant shrub growth, woody weeds, or other inflexible vegetation growing across the floodplain.
	Extreme	0.100–0.200	Dense bushy shrub growth, or heavy stands of trees with understorey vegetation and a few fallen trees, or a heavy stand of trees with branches below flood level.
Floodplain meander (m)		1	Not applicable.

(*) Example calculation: $n = (0.020 + 0.008 + 0.0 + 0.012 + 0.090)\, 1.0 = 0.130$

11 Appendix 3 – TUFLOW model verification

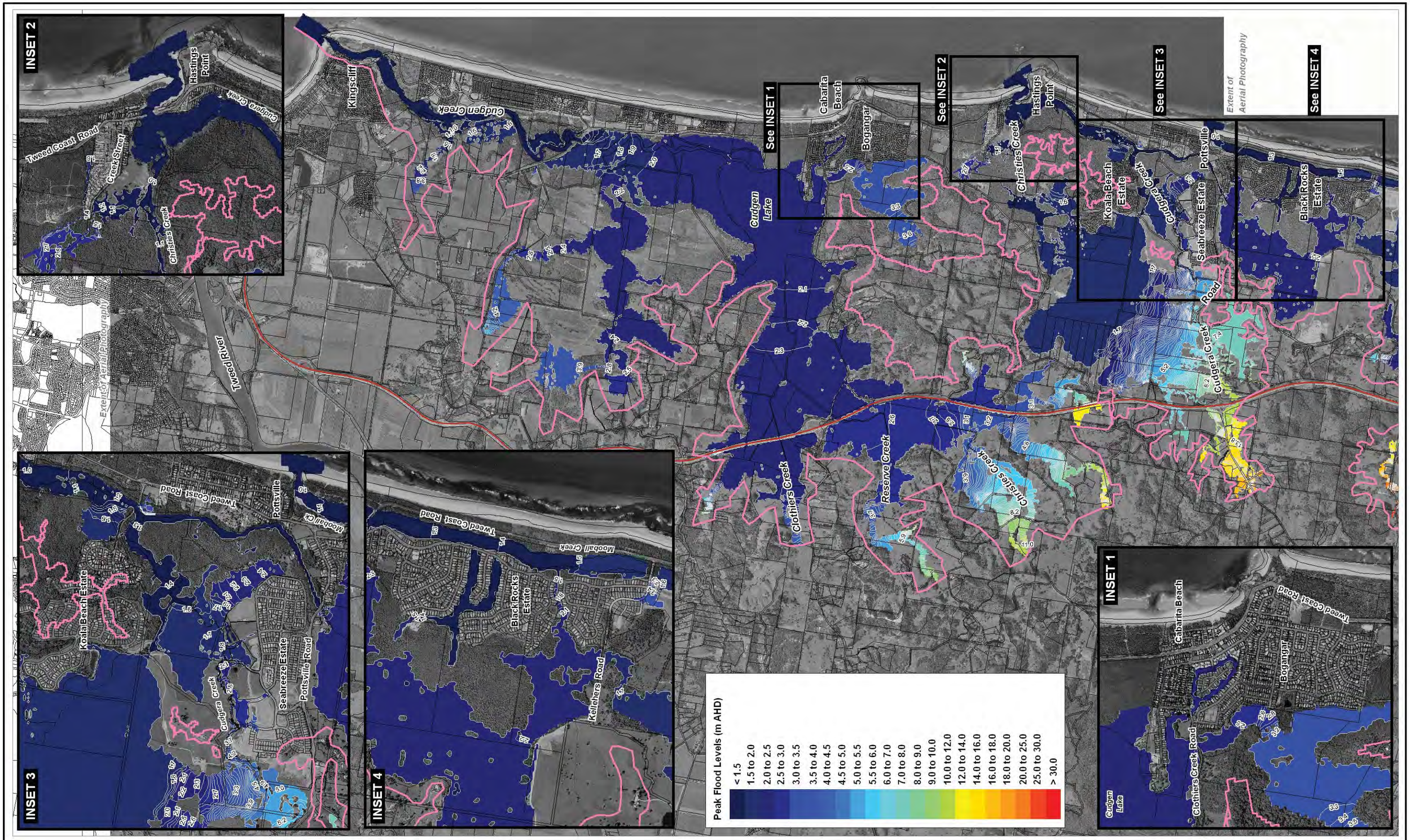
Table A3.1.1 Model verification of water levels from truncated Kings Forest model (KF) against previous modelling for site under existing conditions (G&S June 2011)

Reporting Point ID	5 Year ARI Design Event			10 Year ARI Design Event			20 Year ARI Design Event		
	CCMM (mAHD)	KF (mAHD)	Difference (m)	CCMM (mAHD)	KF (mAHD)	Difference (m)	CCMM (mAHD)	KF (mAHD)	Difference (m)
Cudgen Creek (downstream of site discharge)									
A	0.868	0.873	0.005	1.535	1.536	0.001	1.537	2.116	0.579
B	1.689	1.683	-0.006	1.765	1.876	0.111	2.057	2.053	-0.004
C	2.019	2.018	-0.001	2.078	2.157	0.079	2.354	2.336	-0.018
Kings Forest local catchment									
D	2.312	2.115	-0.197	2.381	2.256	-0.125	2.654	2.410	-0.244
E	2.319	2.118	-0.201	2.388	2.259	-0.129	2.669	2.413	-0.256
F	2.321	2.119	-0.202	2.391	2.261	-0.130	2.672	2.414	-0.258
G	2.325	2.121	-0.204	2.394	2.263	-0.131	2.677	2.417	-0.260
H	2.328	2.125	-0.203	2.398	2.269	-0.129	2.682	2.422	-0.260
I	2.412	2.318	-0.094	2.469	2.426	-0.043	2.707	2.518	-0.189
J	4.052	3.953	-0.099	4.093	4.002	-0.091	4.155	4.056	-0.099
K	4.338	4.349	0.011	4.352	4.355	0.003	4.391	4.370	-0.021
L	4.193	4.087	-0.106	4.255	4.145	-0.110	4.332	4.219	-0.113
M	3.293	3.342	0.049	3.326	3.377	0.051	3.368	3.421	0.053
N	3.193	3.187	-0.006	3.223	3.216	-0.007	3.261	3.255	-0.006
O	2.720	2.662	-0.058	2.750	2.683	-0.067	2.789	2.715	-0.074
Cudgen Creek (upstream of site discharge)									
P	2.049	2.064	0.015	2.122	2.249	0.127	2.432	2.448	0.016
Q	2.075	2.089	0.014	2.149	2.279	0.130	2.470	2.486	0.016
R	2.082	2.096	0.014	2.156	2.287	0.131	2.479	2.496	0.017
S	2.083	2.097	0.014	2.156	2.287	0.131	2.479	2.496	0.017
	50 Year ARI Design Event			100 Year ARI Design Event			Probable Maximum Flood		
Cudgen Creek (downstream of site discharge)									
A	1.705	2.328	0.623	2.173	2.418	0.245	5.291	5.304	0.013
B	2.275	2.273	-0.002	2.556	2.553	-0.003	5.411	5.420	0.009
C	2.572	2.551	-0.021	2.766	2.743	-0.023	5.608	5.617	0.009
Kings Forest local catchment									
D	2.843	2.600	-0.243	2.992	2.769	-0.223	5.649	5.636	-0.013
E	2.862	2.602	-0.260	3.014	2.771	-0.243	5.662	5.641	-0.021
F	2.867	2.604	-0.263	3.020	2.771	-0.249	5.665	5.642	-0.023
G	2.872	2.605	-0.267	3.026	2.772	-0.254	5.666	5.643	-0.023
H	2.878	2.610	-0.268	3.032	2.774	-0.258	5.667	5.643	-0.024
I	2.897	2.653	-0.244	3.049	2.795	-0.254	5.668	5.643	-0.025
J	4.199	4.097	-0.102	4.235	4.136	-0.099	5.668	5.643	-0.025
K	4.426	4.384	-0.042	4.471	4.411	-0.060	5.668	5.644	-0.024
L	4.390	4.267	-0.123	4.449	4.327	-0.122	5.668	5.644	-0.024
M	3.400	3.452	0.051	3.441	3.484	0.043	5.667	5.643	-0.024
N	3.293	3.282	-0.011	3.338	3.310	-0.028	5.667	5.643	-0.024
O	2.896	2.741	-0.155	3.040	2.794	-0.246	5.666	5.643	-0.023
Cudgen Creek (upstream of site discharge)									
P	2.669	2.677	0.008	2.864	2.868	0.004	5.670	5.658	-0.012
Q	2.714	2.726	0.012	2.912	2.922	0.010	5.714	5.702	-0.012
R	2.725	2.738	0.013	2.924	2.935	0.011	5.728	5.715	-0.013
S	2.726	2.739	0.013	2.925	2.936	0.011	5.732	5.720	-0.012

Notes:

1. 10 year ARI results reviewed and difference is attributed to error in previous modelling
2. Results at point A reviewed and KF model levels governed by storm surge event, not included in previous modelling.

12 Appendix 4 – BMT WBM Cudgen Creek Flood Maps



LEGEND

- Model Extent
- Peak Flood Level Contours (m AHD) (0.1m interval for 1.0 to 6.0m AHD then 1.0m interval for 6.0 to 30.0m AHD)
- Pacific Highway (approximate location)
- Cadastral Boundaries

Title:

5 Year ARI Peak Flood Levels Cudgen/Cudgera Creeks Catchments

Figure: Flood Map 1

Rev: B

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2km
Scale - Main Map

0 0.5 1km
Scale - Insets

BMT WBM
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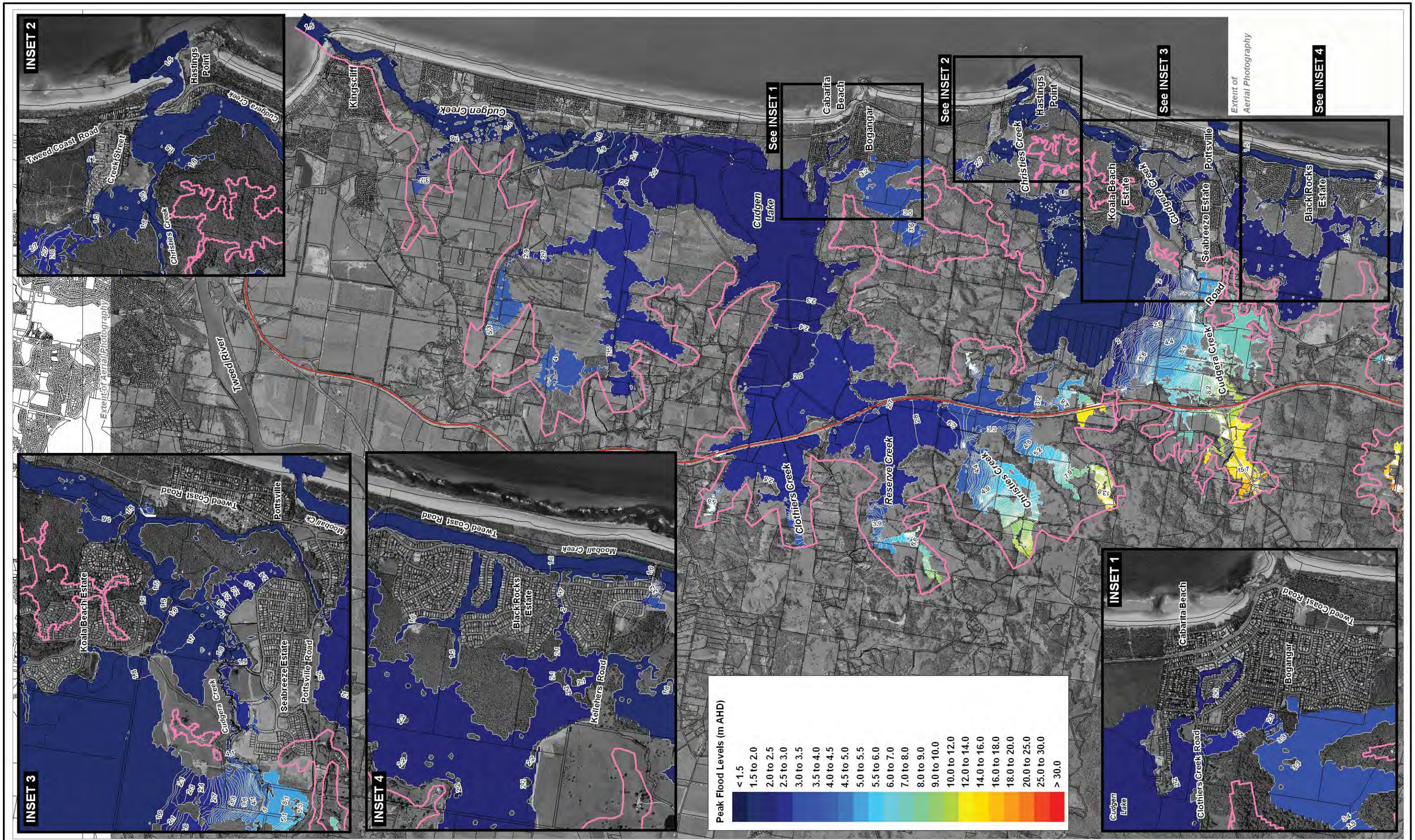
Filepath : I:\B16790_I_BRH Tweed Byron GJR\DRG\FLD_046_090706_CC 5Y Flood Levels RevB.WOR



LEGEND

- Model Extent
- Peak Flood Level Contours (m AHD) (0.1m interval for 1.0 to 6.0m AHD then 1.0m interval for 6.0 to 30.0m AHD)
- Pacific Highway (approximate location)
- Cadastral Boundaries

Title:

10 Year ARI Peak Flood Levels Cudgen/Cudgera Creeks Catchments

Figure: Flood Map 4

Rev: B

Scale - Main Map: 0 1 2km

Scale - Insets: 0 0.5 1km

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