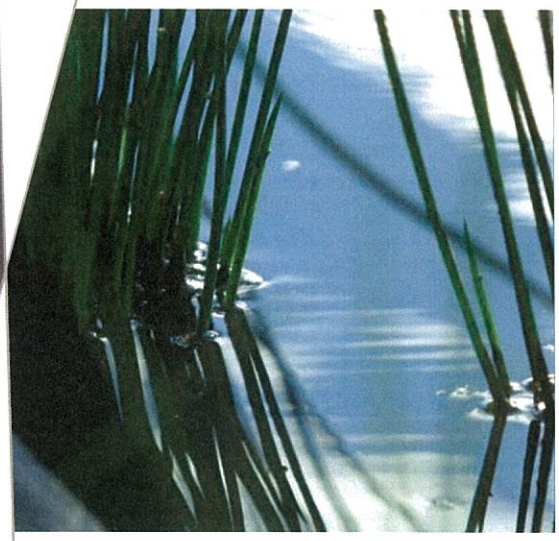
PLANS AND DOCUMENTS
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- 5 MAR 2015
MEDQ

Flagstone City - Stage 1

Stormwater Management Report

7217/43/R2V5



Prepared for
Peet Flagstone City Pty Ltd

21 November 2014

Cardno
Shaping the Future

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1 Introduction

This stormwater management report has been prepared by Cardno (Water Resources and Coastal), specialist water quality, hydrologic and hydraulic consultants, for Peet Flagstone City Pty Ltd to investigate the stormwater management requirements for Stage 1 of Context Area 1 of the Flagstone City development, located in Logan City Council (LCC) under the Department of State Development, Infrastructure and Planning (DSDIP). This report has been prepared in response to a request for additional information from the Department of State Development, Infrastructure and Planning (DSDIP) dated 14 October 2014 (ref DEV2012/402).

The location of the Stage 1, Context Area 1 and the Masterplan extent is shown on Figure 1. The current structure plan layout and staging plan has been provided by RPS and is included in the reference section of this report. Additional detail of Context Area 1 and more specifically Stage 1 has also been provided by RPS and is included in the reference section of this report.

This report provides the detail of the stormwater quality management for Stage 1 in accordance with the framework defined in Cardno's '*Flagstone City – Masterplan Stormwater Management Strategy Report*' dated April 2014 (ref 721743/R10V5), and will minimise the adverse impact of development on the natural water cycle and protect the health of aquatic ecosystems. The key principles of Water Sensitive Urban Design are as follows:

- protect natural systems;
- integrate stormwater treatment into the landscape;
- protect water quality;
- reduce runoff and peak flows; and
- add value while minimising development costs.

This report also provides the management of the water quantity and site flooding for Stage 1, based on the approved Masterplan flood management solution. This masterplan solution presents an integrated approach to the flooding to provide the most cost effective solution both in terms of construction and on-going maintenance. The details of the flood management are contained in Cardno's '*Flagstone City – Masterplan - Flooding Assessment*' dated September 2014 (ref 721743/R1V6). The assessment detailed in this report will consider the impacts of the Stage 1 development and recommend any of the masterplan mitigation measures.

A response to the items raised in the DSDIP letter are contained in Section 11.

2 Purpose and Scope of the Report

The purpose of this report is to evaluate the stormwater management associated with the proposed Stage 1, and to demonstrate to DSDIP that an appropriate stormwater management strategy can be adopted.

A stormwater management plan (SWMP) has been appended to this report in Appendix A for possible inclusion in an overall environmental management plan (EMP). The stormwater management plan is a framework of reference to prevent adverse water quality impacts on the environment throughout the construction and operational phases of the development. The stormwater management plan specifically addresses the following elements and issues for both the construction and operational phases:

- Operational Policy (Objective);
- Performance Criteria;
- Responsibility;
- Implementation Strategy;
- Monitoring;
- Auditing;
- Reporting;
- Identification of incident or failure; and
- Corrective action;

In particular this report will detail measures to ensure:

- appropriate standards are maintained on all stormwater aspects within the site and that pollution control measures are operating and maintained;
- that the surrounding area is not adversely affected nor unduly disrupted by stormwater during construction, operations and maintenance; and
- there is a unified clear and concise plan for stormwater management throughout every step of the development process.

This report will be in effect throughout construction and until all operational conditions set out in the SWMP are met.

3 Existing Site and Proposed Development

3.1 Existing Site Description

The overall Flagstone City site is approximately 1500ha in area. It is located in an area bounded by the existing Brisbane to Sydney railway to the east, and forested property to the west. The Real Property description is

- Lot 1 on RP35155
- Lot 2 on RP47120
- Lot 4 on RP45728
- Lot 5 on S312569
- Lot 9 on S312569
- Lot 10 on SL6002
- Lot 873 on SP166448
- Lot 875 on SP146552
- Lot 907 on RP819216
- Lot 908 on RP819216
- Lot 910 on RP857850
- Lot 911 on RP857870
- Lot 988 on CP857841
- Lot 989 on RP854074

Parish of Mclean, County Stanley. The site currently does not have a street address but is located off Homestead Road, which connects to Teviot Road, Jimboomba.

The site is currently cleared rural land with vegetation maintained along the creeks and gullies that traverse the site. The site drains into Flagstone and Sandy Creeks, or tributaries of these creek systems. Within the site the elevations range from approximately 32.1m AHD to 170.9m AHD, with a predominate direction of flow in an easterly direction prior to discharging under the existing railway.

An aerial of the current site condition is presented on Figure 1.

3.2 Proposed Masterplan Description

Flagstone City is proposed to be a large master planned mix use development consisting of:

- Residential dwellings;
- Super allotments;
- Mixed use lots;
- Town Centre;
- Schools;
- Parks (including regional, district and local facilities); and
- Open Space.

The current structure plan layout and staging plan has been provided by RPS and is included in the reference section of this report.

3.3 Proposed Stage 1 Description

Stage 1 covers an area of approximately 87 ha. As shown on RPS's Stage 1 layout, included in the reference section of this report, this area is to be developed and will consist of:

- Residential Dwellings;
- Town Centre; and
- Parks.

The management of the stormwater will include the use of Bio-retention Systems for quality, local 1 year ARI basin for waterway stability, with no additional management required for regional flooding.

4 Performance Criteria

A number of objectives have been adopted for Flagstone City with respect to the management of flooding and stormwater quality. The framework of the stormwater quality management is presented in Cardno's '*Flagstone City – Masterplan Stormwater Management Strategy Report*' dated April 2014 (ref 721743/R10V5) and the flood management is presented in Cardno's '*Flagstone City – Masterplan - Flooding Assessment*' dated September 2014 (ref 721743/R1V6).

The criterion relating to the quality management for Stage 1 includes:

- protection of stream ecology and geomorphology from impacts of stormwater runoff; and
- adoption of Healthy Waterways '*Concept Design Guidelines for Water Sensitive Urban Design*' (2009) including:
  - Waterway Stability Management; and
  - Stormwater Management.

Healthy Waterways' guidelines (2009) were considered to provide best practice design criteria for the treatment of runoff from the developed areas. The objectives of relevance to stormwater quality are therefore:

- **Waterway Stability Management** - Limit the post developed peak one year ARI event discharge to the pre-developed ARI event discharge; and
- **Stormwater Management** - reduction in pollutant loads:
  - 80% reduction in sediment load;
  - 60% reduction in total phosphorus load;
  - 45% reduction in total nitrogen load; and
  - 90% reduction in gross pollutant load.

The criterion relating to the flood management for Stage 1 includes:

- Adopting the practice of maintaining all future development outside the main floodplain. This will maintain the flood storage within the catchment and river system, whilst also maintaining the ecological characteristics of the creeks and significant tributaries.
- Utilising on-line flood attenuation devices. The mitigation is achieved by providing restricted openings at all future road crossings. There is no additional excavation of the floodplain. This strategy causes a localised raising of flood levels upstream of the crossings with the benefit of reduced flood levels external to and downstream of the site.

The use of this strategy is considered an appropriate approach for a master planned community, with benefits of reduced assets and maintenance requirements, whilst still achieving appropriate flood management. This strategy will be supported by local detention basins located as necessary to meet the required performance criteria.

5 Data

The assessments detailed in this report are based on the following data:

- Aerial LiDAR survey data obtained from the Department of Environment and Heritage Protection (EHP);
- 1:25,000 topographic map ('Undullah'), produced by the Queensland Department of Mapping and Surveying (SUNMAP);
- Site layouts provided by RPS;
- Rainfall Data from the Greenbank Thompson Road station obtained from the Bureau of Meteorology.
- Cardno's '*Flagstone City – Masterplan Stormwater Management Strategy Report*' dated April 2014 (ref 721743/R10V5);
- Cardno's '*Flagstone City – Masterplan - Flooding Assessment*' dated September 2014 (ref 721743/R1V6).

6 Stormwater Management Strategy

6.1 Quality

A wide range of stormwater management practices are available to achieve the principles of Water Sensitive Urban Design. All have been shown to be successful when correctly designed, but selection of the most appropriate practices for a particular development is highly dependent on site conditions. The review of these practises is contained in Cardno's '*Flagstone City – Masterplan Stormwater Management Strategy Report*' dated April 2014 (ref 721743/R10V5). Of the available measures considered the following are considered suitable for Flagstone City:

- gross pollutant traps to collect oil and grease from car park and manoeuvring areas;
- buffer strips;
- grass swales (with or without underlying infiltration systems);
- bio-retention systems;
- detention basins / sediment basins; and
- constructed wetlands.

Based on the suitable measures and the site constraint elements of Stage 1, it is proposed to utilise the following treatment measures as shown on Figure 2.



Plate 6.1 – Typical Bio-Retention System

Bio-Retention Systems – The stormwater will be directed to appropriately located and sized bio-retention basins. These systems will improve the water quality by removing:

- Suspended Solids;
- Nutrients; and
- Metals.

The inlet zones of the bio-retention systems will include a flow velocity dissipater and sediment forebay to provide protection for the bio-retention basins.

6.2 Quantity

The management of the water quantity and site flooding is proposed to be address as a Masterplan solution. This strategy will provide an integrated approach to the flooding to provide the most cost effective solution both in terms of construction and on-going maintenance. The details of the flood management are contained in Cardno's '*Flagstone City – Masterplan - Flooding Assessment*' dated September 2014 (ref 721743/R1V6), which specifies the mitigation is achieved by providing restricted openings at all future road crossings. There is no additional excavation of the floodplain.

The assessment contained in this report will detail which mitigation measures designed for the masterplan are recommended to be included for this stage to ensure the flooding performance criterion (Section 4) are met.

7 Water Quality Assessment

7.1 Approach

The water quality assessments were undertaken utilising MUSIC Version 5.00.11 in accordance with Healthy Waterways '*MUSIC Modelling Guidelines*' (Version 1.0 2010).

The catchment extents adopted for the MUSIC model are presented on Figure 3, with the details of the catchment areas and land uses detailed in Table 7-1 below. A schematic of the MUSIC model layout is provided in Appendix C.

Table 7-1 Modelled Areas

Catchment Label	Land Use Area (ha)							Catchment Total Area (ha)
	Urban Residential			Commercial			Open Space	
	Roof	Ground	Road	Roof	Ground	Road		
1A	1.332	1.742	1.025	0	0	0	0	4.098
1B	4.070	5.322	3.131	0	0	0	0.79	13.314
1C	2.075	2.714	1.596	0	0	0	0.53	6.918
1D	1.309	1.712	1.007	0	0	0	0	4.027
1E	1.055	1.380	0.812	0	0	0	0	3.246
1F	0.541	0.708	0.416	0	0	0	0	1.665
1G	1.588	2.077	1.222	0	0	0	0	4.887
1H	2.132	2.789	1.640	0	0	0	0	6.561
1H1	0.233	0.305	0.180	0	0	0	0	0.718
1J	1.309	1.712	1.007	0	0	0	0	4.029
1K	0.529	0.692	0.407	0	0	0	0	1.629
1K1	0	0	0	0.139	0.056	0.083	0	0.278
1L	0.583	0.763	0.449	0	0	0	0	1.795
1M	0	0	0	4.576	1.830	2.746	0	9.152
1M2	0	0	0	0.445	0.178	0.267	0	0.890

It should be noted that Catchment 1M encompasses parts of future Stage 6 as this area contributes to bio-retention basin 1M, which will be constructed as part of the Stage 1 works.

The rainfall data used in the modelling was the Greenbank Thompson Road station 40659 obtained from the Bureau of Meteorology. A ten year period between 1980 and 1989 was assessed. The potential evapotranspiration details were obtained from the Healthy Waterways 2009 modelling guidelines.

The stormwater quality improvement devices assessed in the MUSIC model include bio-retention systems as discussed above and shown on Figure 2:

The following assumptions were made in the modelling:

- A 6 minute time step was adopted to ensure accurate assessment of the proposed treatment devices;
- The pollutant generation parameters are adopted from Healthy Waterways '*MUSIC Modelling Guidelines*' (Version 1.0, 2010) and can be found in Appendix C;

- The following fraction impervious values were adopted in the MUSIC model:
  - Roofs = 100%
  - Urban Residential Ground = 20%
  - Urban Residential Road (including road reserve) = 60%
  - Commercial Ground = 80%
  - Commercial Road (including road reserve) = 75%
- No flow routing was assumed, which provides a conservative estimate of treatment device efficiency;
- Default MUSIC pollutant removal efficiencies were adopted for all treatment devices;

7.2 Results

Table 7-2 below presents the outcomes from the MUSIC modelling compared to the required load based reductions.

Table 7-2 Pollutant Load Reductions

Pollutant	Annual Load (kg/yr)		Load Reduction - Mitigated to Post-Dev (kg/yr)	Percentage Load Reduction - Mitigated to Post-Dev (%)	Required Load Reduction (%)	Meet Load Reduction Requirement ?
	Post-Development	Mitigated				
TSS	46000	6780	39220	85.3	80	Yes
TP	97.7	39.1	58.6	60.0	60	Yes
TN	613	273	340	55.5	45	Yes
GP	7650	226	7424	97	90	Yes

The above results indicate that the proposed treatment train is predicted to meet the required water quality load based reductions.

Table 7-3 below provides the bio-retention basin filter areas required to meet the load reduction objectives for Stage 1.

Table 7-3 Bio-Retention Basin Parameters

Parameter	1A	1B	1C	1D	1E	1F	1G	1H	1J	1K	1L	1M
Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Surface Area (m^2)	410	1350	700	400	325	170	500	730	400	220	180	1200
Filter Area (m^2)	410	1350	700	400	325	170	500	730	400	220	180	1200
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200	200	200	200	200	200	200	200	200
Filter Depth (m)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
TN Content of Filter Media (mg/kg)	400	400	400	400	400	400	400	400	400	400	400	400
OP Content of Filter Media (mg/kg)	50	50	50	50	50	50	50	50	50	50	50	50
Exfiltration Rate (mm/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Is Based Lined?	No	No	No	No	No	No	No	No	No	No	No	No
Vegetated with Effective Nutrient Removal Plants?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Underdrain Present?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Submerged Zone with Carbon Present?	No	No	No	No	No	No	No	No	No	No	No	No
Overflow Weir Width (m)	6	18	10	6	5	2	6	10	5	3	2	14

In accordance with 'Water by Design' Bio-retention guidelines (updated version of Healthy Waterways' guidelines), bio-retention systems with a filter area greater than 800m^2 are to be split into cells of <800m^2 and provide an inlet pond/basin. This is specifically noted for basin for areas 1B and 1M.

8 Waterway Stability Assessment

8.1 Approach

To determine the volumes required to limit the 1 year post-development flows to the 1 year pre-development conditions, a local WBNM assessment of the local catchment as shown on Figure 3 was undertaken. The required storage volumes for the detention basins were determined in WBNM.

The local WBNM model was calibrated to the Rational Method peak flows for the Stage 1 catchments. For the local catchment modelling, a Lag factor of 1.7, initial loss of 15mm and continuing loss of 2.5mm/hr were adopted. However, as part of the calibration process the initial loss values were adjusted to such that the peak discharges from the model match those calculated based on the Rational method. The adjusted initial loss values are 10mm for catchments A to C and H, and 12mm for catchment F.

The Rational Method peak flow parameters and calculated peak discharges are summarised in Table 8-1 below.

Table 8-1 Rational Method and WBNM Peak Discharges for Stage 1 Catchments

Catchment	Area (ha)	C1	Tc (min)	1 Year Intensity (mm\hr)	1 Year ARI Peak Discharge (m^3/s)	WBNM Peak Discharge (m^3/s)
Stg1A	4.05	0.472	20	63.5	0.34	0.36
Stg1B	14.25	0.472	29	52.1	0.97	0.92
Stg1C	7.34	0.472	22	59.4	0.57	0.57
Stg1D	3.69	0.472	23	58.8	0.28	0.26
Stg1E	3.36	0.472	22	59.6	0.26	0.24
Stg1F	4.57	0.472	24	56.7	0.34	0.36
Stg1G	1.18	0.472	23	58.6	0.09	0.11
Stg1H	7.39	0.472	21	60.6	0.59	0.57
Stg1J	2.27	0.472	25	55.7	0.17	0.18
Stg1K	4.35	0.472	28	53.2	0.30	0.29
Stg1L	1.80	0.472	23	58.7	0.14	0.15
Stg1M	3.82	0.472	27	54.3	0.27	0.27

The 1 Year ARI peak discharges for the existing and developed scenarios predicted by the local WBNM model are summarised in Table 8-2. The results in the table demonstrate that the developed case peak discharges would be increased except for catchment F. Therefore, it is proposed to utilise detention basins to mitigate the increased peak discharges back to the existing peak flow rates.

Table 8-2 1 Year ARI Existing and Developed Case WBNM Peak Discharges

Catchment	Peak Discharge (m^3/s)	
	Existing	Unmitigated
Stg1A	0.36	0.75
Stg1B	0.92	2.08
Stg1C	0.57	1.17
Stg1D	0.26	0.67
Stg1E	0.24	0.55
Stg1F	0.36	0.32
Stg1G	0.11	0.79
Stg1H	0.57	1.25
Stg1J	0.18	0.67
Stg1K	0.29	0.35
Stg1L	0.15	0.32
Stg1M	0.27	1.87

8.2 Results

The local WBNM model was used to determine the detention requirements of Stage 1 catchments. The proposed basins were assumed to have a batter slope of 1(V):4(H), with a depth of 1 meter, except for Catchment K which has a depth of 0.7 meters. It can be noted that the bottom 0.3 meters represents the extended detention depth (EDD) for allocated stormwater quality treatment. For the modelling, it was assumed that each of the proposed detention basins has a starting water level of 0.3 meters, thereby ensuring that the EDD is not available for peak discharge mitigation.

The details of the proposed detentions basins are provided in Table 8-3. The results of the detention basin modelling are provided in Table 8-4. The results demonstrate that the proposed detention basins would mitigate the developed peak discharges back to the existing peak flow rates. Therefore, these detention basins would be incorporated in the regional WBNM model.

Table 8-3 Details of Proposed Detention Basins

Catchment	Base Area (m^2)	Total Depth including 0.3m extended detention Depth (m)	Low Flow Pipe Diameter (mm)	Weir Crest (m)	Weir width (m)
Stg1A	600	1.0	525	0.9	2.5
Stg1B	2,620	1.0	1200	0.9	8.0
Stg1C	1,130	1.0	900	0.9	3.0
Stg1D	675	1.0	450	0.9	1.0
Stg1E	450	1.0	450	0.9	2.0
Stg1G	1,435	1.0	225	0.9	2.0
Stg1H	1,270	1.0	900	0.9	4.0
Stg1J	850	1.0	375	0.9	2.0
Stg1K	220	0.7	625	0.6	4.0
Stg1L	180	1.0	300	0.9	1.5
Stg1M	3,410	1.0	450	0.9	4.0

Table 8-4 Detention Basin Modelling Results

Catchment	1 Year ARI Peak Discharge (m^3/s)			1 Year ARI Peak Flood Depth (m)
	Existing	Unmitigated	mitigated	
Stg1A	0.36	0.75	0.36	0.93
Stg1B	0.92	2.08	0.92	0.94
Stg1C	0.57	1.17	0.56	0.91
Stg1D	0.26	0.67	0.25	0.91
Stg1E	0.24	0.55	0.24	0.90
Stg1G	0.11	0.79	0.09	0.92
Stg1H	0.57	1.25	0.57	0.91
Stg1J	0.18	0.67	0.18	0.90
Stg1K	0.29	0.35	0.29	0.66
Stg1L	0.15	0.32	0.15	0.93
Stg1M	0.27	1.87	0.27	0.91

9 Hydrologic Assessment

A hydrologic assessment has been undertaken to quantify both the pre- and post-development runoff characteristics of the local tributaries. The results of the hydrologic model was used for input into the hydraulic model (TUFLOW).

The flood model established and reported in Cardno's '*Flagstone City – Masterplan - Flooding Assessment*' dated September 2014 (ref 721743/R1V6), was utilised for this flood assessment.

9.1 Methodology

The hydrologic modelling considers the following scenarios:

- **Pre-Development (Case EU02e):** This scenario is the Pre-Development case as detailed in the masterplan assessment (Cardno, Sept 2014 ref 721743/R1V6).
- **Post-Development (Case DU03k):** This scenario assumes the same catchment and land uses as per the Pre-Development Case for areas external to the site. While for the Stage 1 catchments, the fraction impervious factors were applied based on the proposed densities. The sub-catchments were further divided into Stage 1 sub-catchments and the local water way stability basins included. Figure 3 shows the post-development catchment layout.

The hydrologic model was assessed with the output utilised as boundary conditions for the hydraulic modelling.

10 Hydraulic Assessment

Hydraulic analysis has been performed to determine peak flood levels through the site and to ensure development on the site will remain flood free and not adversely impact on other properties external to the site in accordance with the Performance Criteria (Section 4).

The flood model established and reported in Cardno's '*Flagstone City – Masterplan - Flooding Assessment*' dated September 2014 (ref 721743/R1V6), was utilised for this flood assessment.

10.1 Methodology

The previously developed two dimensional (2D) model of the site and surrounds adopted a grid size of 10m. The model extent is shown on Figure 4. The hydraulic assessment of the site has been undertaken using the TUFLOW (Build 2011-09-AF), a linked one-dimensional/two-dimensional (1D/2D) hydraulic model.

The following scenarios have been considered:

- **Pre-Development Case** (Case E21e): The pre-development topography modelled is shown on Figure 4, as is the Pre-Development case as detailed in the masterplan assessment (Cardno, Sept 2014 ref 721743/R1V6).
- **Post-Development** (Case Stg1g): This scenario is as per the pre-development case, but includes the developed Stage 1. As the Stage 1 site is located outside the flooding extent, for the modelling the developed topography was adopted as per the existing topography.

10.2 Hydraulic Model Results

Maps of post-developed peak flood levels and impacts are shown in Appendix C and D, respectively. Table 10-1 below presents the pre- and post-development predicted peak flood levels and impacts for key locations within the model extent (refer Appendix B figures for reporting point locations). The Tables in Appendix E show the predicted peak flood levels and impacts for all the relevant reporting nodes for the 2 Year to 100 Year ARI event. In Appendix F pre and post-developed time series flood levels downstream of the site can be found for all events considered in this report.

Table 10-1 100 Year ARI Predicted Peak Flood Levels

Reporting Node ID	Peak Flood Level (mAHD)		Impact (m)
	Pre-Developed	Post-Developed	
H_SDYCK_DS3_CH9400	24.46	24.44	-0.013
H_SDYCK_DS3_CH8900	25.91	25.89	-0.018
H_SDYCK_DS2_CH7500	29.59	29.58	-0.011
H_SDYCK_CH7000	31.26	31.25	-0.008
H_SDYCK_US1_CH6400	33.11	33.10	-0.007
H_SDYCK_DS1_CH6250	34.12	34.11	-0.013
H_SCBRIDGE_DS_CH5550	36.29	36.27	-0.015
H_SDYCK_BRIDGE1_US_CH5200	37.67	37.66	-0.018
H_SDYCK_CH4900	38.89	38.88	-0.009
H_SDYCK_CH4700	39.41	39.40	-0.009
H_SDYCK_CH4200	41.19	41.19	-0.009
H_SDYCK_CH3700	43.19	43.19	-0.004
H_SDYCK_CH3500	44.10	44.08	-0.017
H_SDYCK_CH3000	45.84	45.83	-0.016
H_SDYCK_CH2650_Trib1	59.70	59.70	0.000
H_SDYCK_CH2650_Trib2	57.40	57.40	0.000
H_SDYCK_CH2400	48.05	48.05	0.000
H_FSTCK_CH10800	21.74	21.74	-0.005
H_FSTCK_CH10200	23.20	23.19	-0.006
H_FSTCK_CH9700	24.38	24.38	-0.005
H_FSTCK_CH9100	26.07	26.07	0.000
H_FSTCK_CH8500	28.52	28.52	0.000
H_FSTCK_CH7500	32.83	32.83	0.000
H_FSTCK_CH7300_trib1	41.88	41.88	0.000
H_FSTCK_CH7300_trib2	40.70	40.70	0.000
H_FSTCK_CH6900	36.33	36.33	0.000
H_FSTCK_CH6700	37.12	37.12	0.000
H_FSTCK_CH6350	39.19	39.19	0.000
H_FSTCK_CH6250	39.83	39.83	0.000
H_FSTCK_CH5100	45.65	45.65	0.000
H_FSTCK_CH3800_Trib1	54.37	54.37	0.000
H_FSTCK_CH3800_Trib2	53.51	53.51	0.000
H_FSTCK_CH3350	54.54	54.54	0.000
H_FSTCK_CH3200	55.67	55.67	0.000
H_FSTCK_CH2800	57.77	57.77	0.000
H_FSTCK_CH2000	61.22	61.22	-0.001
H_FSTCH_CH10650_TEVRD_US	22.18	22.17	-0.005

11 Response to Information Request

The Department of State Development, Infrastructure and Planning (DSDIP) provided an information request dated 14 October 2014 (ref DEV2012/402). The details to the relevant items raise are included below.

5. Earthworks

- *Provide a waterway stability report to determine the extents of dispersive soils and the proposed management strategies to stabilise the waterways. This is required to ensure that there are no impacts on the proposed allotments and infrastructure in accordance with the requirements of the endorsed Earthworks IMP*

The waterway stability management is in accordance with current practise. This strategy collects all stormwater runoff from the development and drains these to local 1 year ARI basins prior to the release into the natural waterway.

Full details of the waterway stability assessment has been detailed in Section 8 of this report. This includes all the sub-catchments within the development, hence the extent of the dispersive soils is irrelevant as an appropriate management method is proposed.

6. Stormwater

- *Please show the Q100 and Q20 lines on the Stormwater Layout Plan, which is to be consistent with the stormwater management plan.*

The 20 and 100 year ARI inundation lines from the hydraulic assessment detailed in this report (Section 10) have been included on the relevant Stormwater Layout Plan.

- *Please confirm the area of land under the Q5 within the regional park is less than 30% of the overall regional park area and that all clubhouses, toilet and amenities blocks and other buildings (and areas designated for these facilities) are above the Q100.*

Relevant details are provided on the Engineering Drawings.

- *Stormwater infrastructure needs to be limited at the rear of the allotments. Where this can't be avoided, please demonstrate how future access can be provided to the rear of these allotments to manage servicing of the infrastructure. It is suggested that the POD is amended to increase the side setback on one side of the lot to allow sufficient access for this to occur.*

Relevant Details are provided on the Engineering Drawings.

- *Stage 1 consists of a new road and two new creek crossings. This does not appear to be modelled in the TUFLOW model. Please update the model to include the new road crossings and an analysis of the impacts.*

The master plan includes the two road crossings as these provide detention storage for the ultimate case. As this detention storage is not required to make Stage 1 work, the modelling did not include these elements on the basis that if either crossing is ultimately not required as part of Stage 1, they can be deleted without affecting the flooding solution.

In other words, if either crossing was not to ultimately be built as part of Stage 1, we would not have to go back to State Government to demonstrate that the crossings are not required from a flooding perspective.

Minimum flood levels for the Stage 1 area are based on the ultimate development, as previously reported, which does include the crossings, so the minimum lot levels would not be affected by the exclusion of the crossings from the Stage 1 analysis.

Thus including the two crossings in the modelling is not considered necessary as the predicted levels would either equal or be slightly less than the ultimate levels.

- *Figure 5 does not show mitigation options, contrary to the report text. Please include a figure with the mitigation options.*

Following from Dot Point 4, Figure 5 shows the mitigation measures (local detention basins) required for Stage 1. It does not include the crossings as the mitigation afforded by the crossings is only required on future stages and not Stage 1. As the crossings are not mitigation measures for Stage 1, they do not need to be included in Figure 5.

- *The hydrograph for SCBRIDGE 5500 shows that the 20 year ARI flood starts earlier than the 10 year ARI flood. However initial losses are the same. Please provide a reasoning why the 20 year ARI flood starts earlier than the 10 year ARI flood.*

This was a minor extraction error that has been fixed. The updated graph is included in Appendix I.

- *Catchment A1 has initial loss of 15, continuing loss of 2 and impervioius loss of 0.5. This appears to be a mistake and is unlikely to have an effect on the overall results however this should be amended in future submissions.*

There is no mistake. When the file is opened with a text editor, the apparently anomalous values of 2 and 0.5. However, the file is opened using WBNM for Windows GUI, the correct values (2.5 and 0) appear.

- *Section 4.3.1 of the 'Flagstone City – Masterplan Stormwater Management Strategy report' (which was endorsed with the Stormwater IMP) states: "no increase in the flow discharged from the Flagstone City area, for the full range of design flood events (1 to 100 year ARI) (Point 2). "Section 8 in this report addresses detention of stormwater flows for a 1 year ARI, however there is no assessment for any storm events greater than a 1 year ARI nor is there any documentation/statement identifying this site as part of a 'regional detention system'. Please provided details or assessment addressing this objective.*

The Waterway Stability section only deals with the 1 year event yet the requirement for the site is for non-worsening to be achieved for the 1 to 100 year events. The reason for this is that the State Planning Policy specifically refers to the 1 year event when considering Waterway Stability (on the reasonable basis that one year events have more influence on the main bed of the channel due to their higher frequency than 100 year events). The section was intended to address waterway stability (the title of the section was hopefully an indicator in this regard) and so only considered the 1 year event. Section 10 of the report and referenced appendices provide the results for the 2 to 100 year events.

- *Section 4.3.2 of the 'Flagstone City – Masterplan Stormwater Management Strategy Report' (which was endorsed with the Stormwater IMP) includes objectives for Frequent Flow management. The Stage 1 application does not provide details of how this objective has been complied with. Please provide details or assessment addressing this objective.*

The Stormwater Management Strategy Report endorsed with the Stormwater IMP reflected best practice at the time the report was prepared. This best practice reflected the requirements of State Planning Policy 4/10 Healthy Waters and supporting guidelines. It has always been the intention that stormwater quality treatment would necessarily reflect best practice and that requirements in this regard would vary over time. Frequent Flow management is a case in point. The new State Planning Policy (December 2013) does not include a requirement with respect to Frequent Flow Management. As this policy is considered to represent current best practice, frequent flow management was not considered for the current situation. In any case, experience with the application of the criterion has indicated that the devices required to meet the water quality objectives will also satisfy the frequent flow management criterion. It is expected that this is the reason the flow management criterion was ultimately deleted from the State Planning Policy.

- *In accordance with 'Water by Design' Bio-retention guidelines (updated version of Healthy Waterways' guidelines), bio-retention systems with a filter area greater than 800m^2 are to be split into cells of <800m^2 and provide an inlet pond/basin. A general statement should be included in Section 7 of the Stage 1 Stormwater Management Report noting that the basin for areas 1B and 1M are to be suitably divided to comply with the design guidelines.*

An appropriate statement has been included.

12 Conclusion

Master Planning is being undertaken with respect to the Flagstone City area. Water sensitive urban design principles are to be adopted to minimise the negative impact of development on the natural water cycle and protect the health of aquatic ecosystems.

Following the definition of suitable performance criteria with respect to the management of stormwater, the options available for achieving the performance criteria were evaluated. The results of the evaluation are summarised below.

- **Quantity**

  The management of the water quantity and site flooding is to be address as a Masterplan solution. This strategy presents an integrated approach to the flooding to provide the most cost effective solution both in terms of construction and on-going maintenance.

  The development of Stage 1 has been demonstrated with the adoption of the local 1 year ARI basins that Stage 1 will not have any adverse flood impact external to the site.

- **Quality**

  A review of available treatment methods indicated several treatment methods were suitable for use. Based on the sites constraints and opportunities, it was determined that to treat Stage 1 the treatment train is to consist of bio-retention systems.

  It is expected that the list of appropriate treatment methods will alter over time as technology advances. Provided that the objectives can still be achieved, the use of improved management techniques is to be encouraged.

  The objectives relating to the quality management for Stage 1 includes:

  - protection of stream ecology and geomorphology from impacts of stormwater runoff; and
  - adoption of Healthy Waterways '*Concept Design Guidelines for Water Sensitive Urban Design*' (2009) including:
    - Waterway Stability Management; and
    - Stormwater Management.

  The modelling detailed in this report confirmed that the proposed development with the proposed treatment train will achieve all of the above objectives. Thereby confirming that the environmental values of downstream watercourses can be protected.

13 References

Cardno, 2014, *'Flagstone City – Masterplan – Flooding Assessment'* (ref 721743/R1V6)

Cardno, 2014, *'Flagstone City – Masterplan Stormwater Management Strategy Report'* (ref 721743/R10V5)

Department of Natural Resources and Water, 2008, *Queensland Urban Drainage Manual*

Healthy Waterways, 2009, *'Concept Design Guidelines for Water Sensitive Urban Design'*

Healthy Waterways, 2010, *'MUSIC Modelling Guidelines'* (Version 1.0)

Bligh Tanner and DesignFlow, 2009, *'Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes'* (report for Queensland Water Commission)

Flagstone City - Stage 1

FIGURES

Figure 1 Site Location and Layout Plan

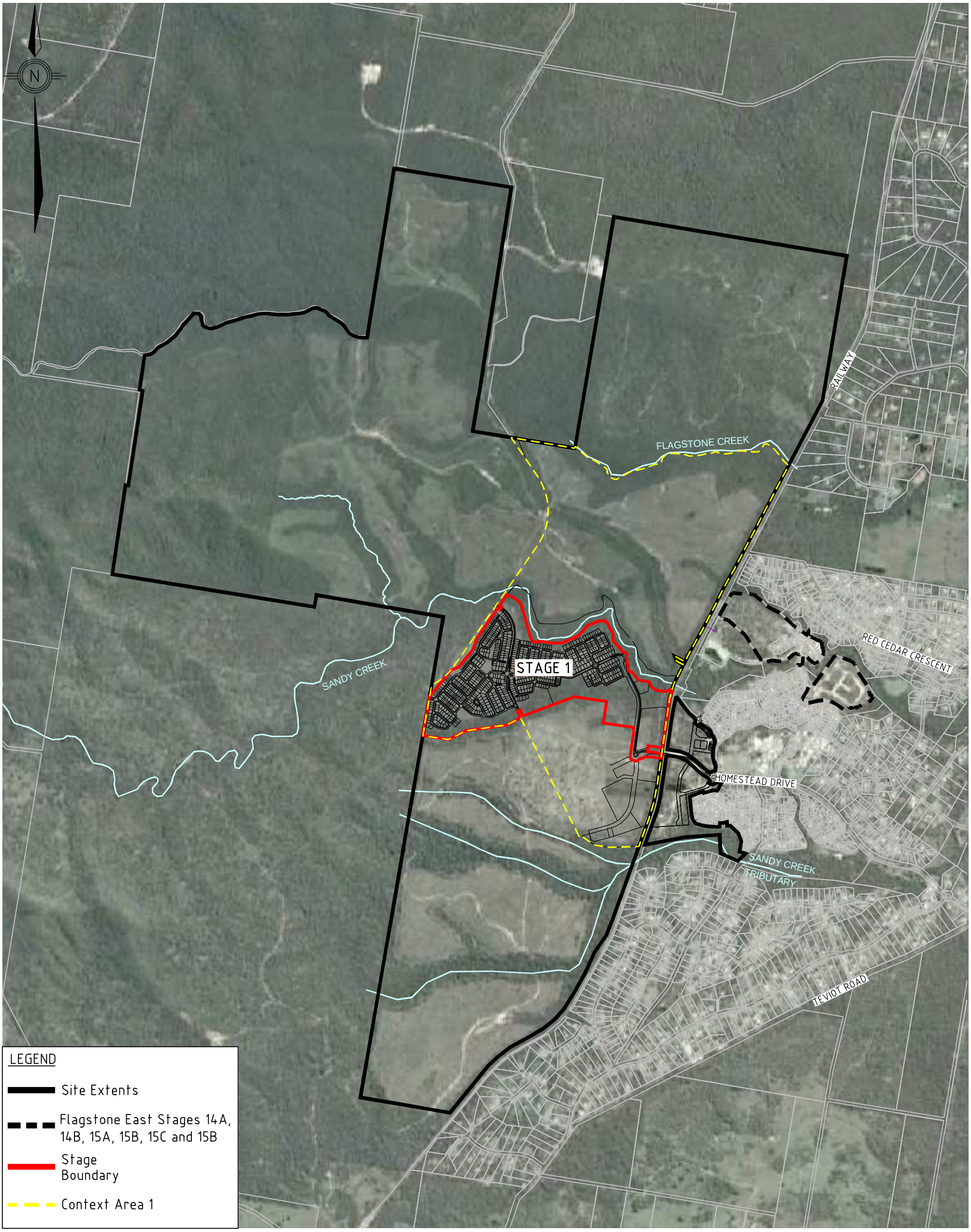
Figure 2 Stormwater Management Strategy

Figure 3 Catchment Plan

Figure 4 Pre-Development Model Topography & Inflow Boundary Locations

Figure 5 Post-Development Model Topography, Inflow Boundary Locations & Mitigation Measures

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Aerial image sourced from Google Earth

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Rev: 1 | **Drawn: J.M.** | **Checked: D.N.** | **Date: 26/08/2014**

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CAD FILE: P:\721743 Flagstone City\11\Cad\02 Figures\Stage 1\Figure 1 - Site Location_v4.dwg
XREF's: X - 721743011_BASE STAGE 1

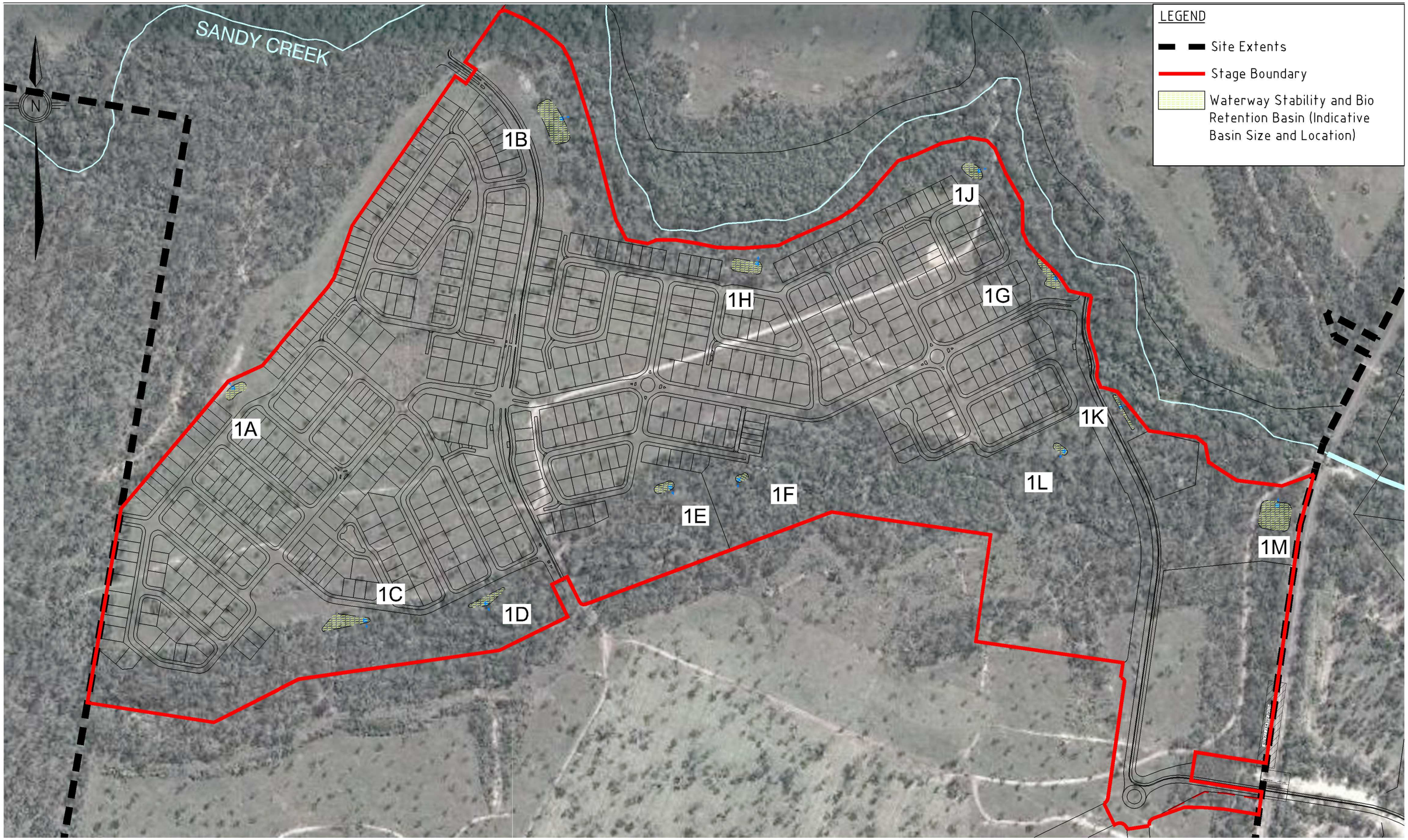
Scale 1:25,000 (A3)

FIGURE 1
SITE LOCATION

Project No.: 7217/43

PRINT DATE: 05 September, 2014 - 12:55pm

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Notes:
- Indicative size and location of basins subject to detailed design

Scale 1:5,000 (A3)

FIGURE 2
STORMWATER MANAGEMENT STRATEGY

Rev: 1 | Drawn: J.M. | Checked: D.N. | Date: 25/08/2014

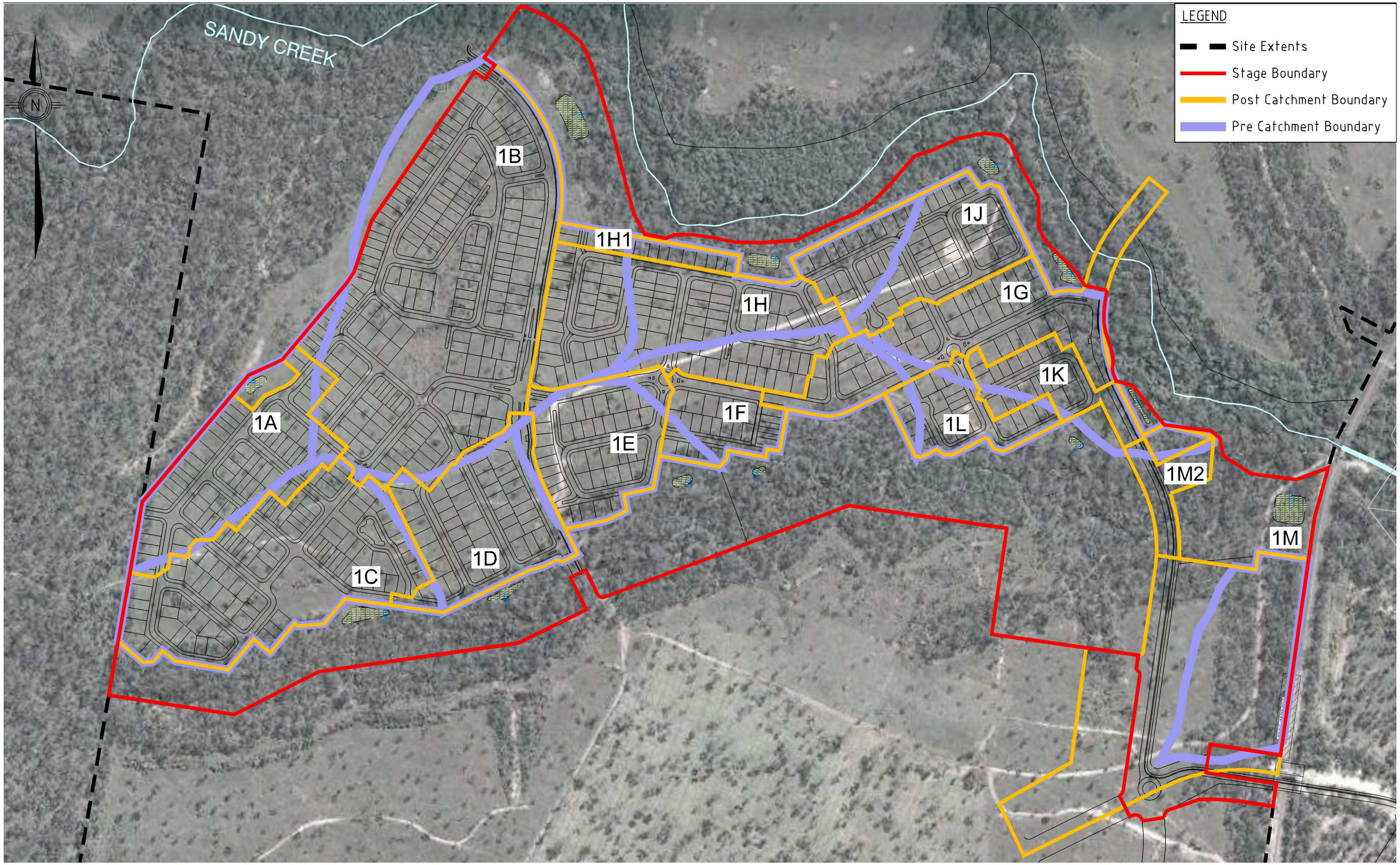
Project No.: 7217/43

Flagstone City Pty Ltd

CAD FILE: P:\7217\43 Flagstone City\11\Cad\02 Figures\Stage 1\Figure 2 - Stormwater Management Strategy_v3.dwg
XREFs: X - 7217\43011_BASE STAGE 1

PRINT DATE: 05 September, 2014 - 12:54pm

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Aerial image sourced from Google Earth

50 0 50 100 150 200 250m
1:5000

Scale 1:5,000 (A3)

FIGURE 3
CATCHMENT PLAN

Rev: 1 | Drawn: J.M. | Checked: D.N. | Date: 25/08/2014

Project No.: 7217/43

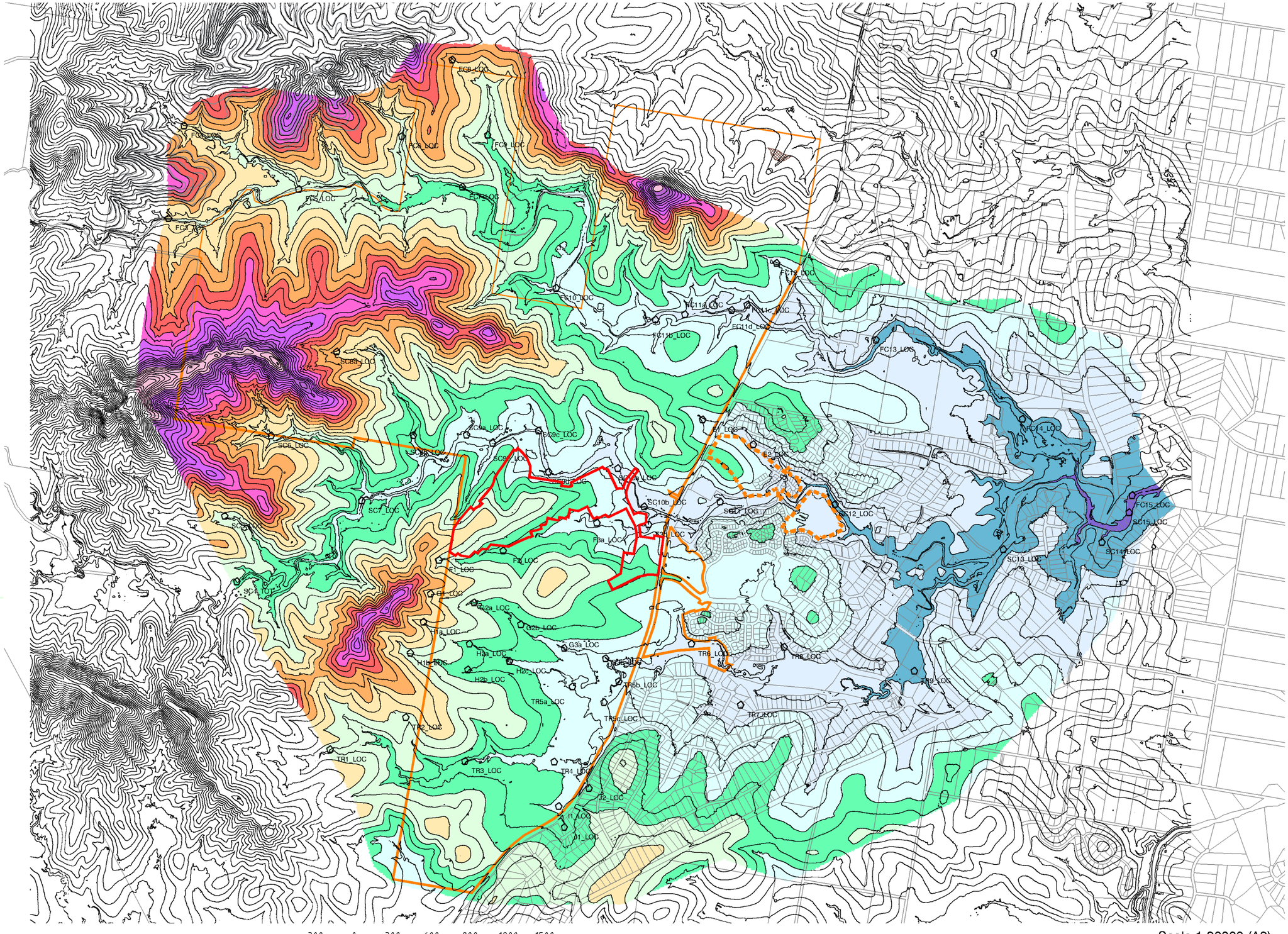
Flagstone City Pty Ltd

PRINT DATE: 05 September, 2014 - 12:55pm

CAD FILE: P:\7217\43 Flagstone City\11\Cad\02 Figures\Stage 1\Figure 3 - Catchment plan_v3.dwg
XREF's: X - 7217\43011_BASE STAGE 1

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LEGEND

- Site Extents
- Stage 1 Site Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- FC3_TOT Inflow Boundary

ELEVATION (mAHD)

- Above 150.00
- 130.00 to 150.00
- 110.00 to 130.00
- 100.00 to 110.00
- 90.00 to 100.00
- 80.00 to 90.00
- 70.00 to 80.00
- 60.00 to 70.00
- 50.00 to 60.00
- 40.00 to 50.00
- 30.00 to 40.00
- 20.00 to 30.00
- 10.00 to 20.00

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300 0 300 600 900 1200 1500m
1:30,000

Scale 1:30000 (A3)

FIGURE 4

TUFLOW Model - Pre-Development Model Topography and Inflow Boundary Locations

Rev: Orig. Date: 02 September 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: O:\7217-43\Phase03\FloodingMasterPlan\ACAD\Figure 4 and Figure.dwg
XREF's: Existing Contours; 110056-73 and 110056-85 combined; Inflow points; Topo_EXG_E18_10m

PRINT DATE: 02 September, 2014 - 1:56pm

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LEGEND

- Site Extents
- Stage 1 Catchment Extent
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Stage 1 Detention Basin
- FC3_TOT Inflow Boundary

ELEVATION (mAHD)

- Above 150.00
- 130.00 to 150.00
- 110.00 to 130.00
- 100.00 to 110.00
- 90.00 to 100.00
- 80.00 to 90.00
- 70.00 to 80.00
- 60.00 to 70.00
- 50.00 to 60.00
- 40.00 to 50.00
- 30.00 to 40.00
- 20.00 to 30.00
- 10.00 to 20.00

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300 0 300 600 900 1200 1500m
1:30,000

Scale 1:30000 (A3)

FIGURE 5

TUFLOW Model - Post-Development Model Topography and Inflow Boundary Locations and Mitigation Measures

Rev: Orig. Date: 02 September 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: O:\7217-43\Phase032FloodingMasterPlan\ACAD\Figure 4 and Figure.dwg
XREF's: Existing Contours; 110056-73 and 110056-85 combined; Inflow points; Topo_EXG_E18__10m

PRINT DATE: 02 September, 2014 - 2:11pm

Flagstone City - Stage 1

REFERENCE DRAWINGS

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PRELIMINARY

LEGEND

- Village Boundary
- Development Outside Site

Residential - Neighbourhoods

- 8 Dwellings/Ha
- 12.5 Dwellings/Ha
- 15 Dwellings/Ha
- 18 Dwellings/Ha

Residential - Town Centre

- 60 Dwellings/Ha
- 3 Storey Apartments - 120 Dwellings/Ha
- 5 Storey Apartments - 200 Dwellings/Ha

Retirement

- 60 Dwellings/Ha

Open Space

- Linear Park
- Regional Recreation Park
- District Sport and Recreation Park
- Conservation
- Local Park / Community Nodes
- Possible Conservation Buffer (subject to ULDA MCU) - line interpretted from Development Scheme

Community

- Town Centre Frame
- Town Centre Core
- District Centre
- Village (Neighbourhood) Centre
- Mixed Use (Residential & Commercial)
- Employment
- Education

Road Hierachy

- North-South Arterial (40m Wide)
- Village Connector Roads (24 - 26m Wide)
- Neighbourhood Streets (18.5 - 21m Wide)
- Private or Public Streets (18m Wide)

PRECINCT THREE

PRECINCT TWO

PRECINCT ONE

PRECINCT FOUR

PRECINCT FIVE

SEE INSET

CULTURAL HERITAGE SITE

INSET
SCALE 1 : 5000

Note:
All dimensions and areas are approximate only, and are subject to survey and Council approval.

Dimensions have been rounded to the nearest 0.1 metres.

Areas have been rounded down to the nearest 5m².

The boundaries shown on this plan should not be used for final detailed engineers design.

Source Information:
Site boundaries: Registered Survey Plan
Adjoining information: DCDB
Contours: Peet

RPS

SCALE 1 : 10,000 @ A0

0 100 200 400 600 800 1000

DATE : 8 August 2012 DWG NAME : 110056-193-STRUCTURE_OPT2H DWG # 110056-193-2

STRUCTURE PLAN - OPTION 2H
FLAGSTONE

Flagstone City - Stage 1

APPENDIX A

Stormwater Management Plan

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Stormwater Management Plan

Water Quality Management – Construction Phase

Issue:	Water Quality Management – Construction Phase
Operational Policy:	To provide a set of guidelines to control the severity and extent of erosion and pollutant transport during firstly the earthworks stage, and then construction.
Performance Criteria:	Water discharges off the site are to comply with the Environmental Protection Act to ensure that no detrimental impacts on water quality and aquatic environment occur during the construction phase. The quality of discharge from the site should not exceed the Water Quality Objectives, as follows: Release Criteria pH – 6.5 - 9.0 (range) Suspended Solids < 50mg/L (90^{th} percentile). DO > 80 % saturation or 6 mg/L (90^{th} percentile). Litter – no visible litter washed from site. Hydrocarbons - No visible sheen on receiving waters
Responsibility:	The owner of the property or their appointed representative & the Construction Contractor. The owner will be responsible for the implementation of the control measures and monitoring during the course of all construction activity.
Implementation Strategy:	A detailed erosion and sediment control plan is to be prepared by the project's civil engineers and will incorporate the following: • Sediment and erosion control is to be in accordance with the Institution of Engineers Australia *'Soil Erosion and Sediment Control -Engineering Guidelines for Queensland Construction Site (June 1996)'*, The International Erosion Control Associastion *'Best Practice Erosion and Sediment Control (2008)'* and current local best practice engineering and environmental management.
	Earthworks will be completed in stages with works restricted to the immediate areas.
	Subsequent stages of development should not commence if prior stages are affected by acid sulphate conditions &/or construction phase water quality objectives are not met.
	Prior to the commencement of any stage construction works temporary sediment basins are to be installed as per the details shown in the stages construction phase stormwater management strategy.
	All disturbed site discharge to pass through temporary sediment basins prior to discharge from the site.
Implementation Strategy (Cont'd):	Catch drains should be installed to divert upstream 'clean' water. Silt fences will be placed along the downstream extents of all earthworks. Check dams will be installed at regular intervals along catch drains.
	Drains and bund walls will be topsoiled and vegetated with suitable vegetation as soon as possible.
	Sediment and sludge trapped in the basins will be removed and mixed with topsoil and reused on site for landscaping purposes.
	Clean-up of general site litter on a weekly basis and after significant rainfall events. (>25mm/24hours)
	Landscaping activities and revegetation will occur as soon as possible during/after the construction phase of the development. Only appropriate herbicides and fertilisers are to be used.

Issue:	Water Quality Management – Construction Phase
Monitoring:	Sediment and erosion control measures will be inspected daily by the site manager during periods of rainfall. (>25mm/24hrs) Establishment and growth of vegetation – to be monitored monthly. No occurrence of excessive sediment deposit - to be monitored weekly or daily during periods of heavy rainfall (>25mm/24hrs). No release of construction material and silt from the site – to be monitored weekly or daily during periods of heavy rainfall (>25mm/24hrs). Vegetation established and growing prior to the rainy season. Erosion monitoring immediately following heavy rainfall. (>25mm) Inspection of silt fences and check dams following heavy rainfall. (>25mm/24hrs) Water quality monitoring shall be carried out following a rainfall event (>25mm of rainfall), and prior to discharge water quality monitoring will be conducted on the waters detained in the sediment basins and at the discharge point for the site. The parameters to be tested shall include: • Surface waters: Rainfall Event • Parameters: Temperature, dissolved oxygen, pH, specific conductance, salinity, turbidity, suspended solids and litter. • Water collected in basins: Prior to release • Parameters: pH, suspended solids. Note that additional water quality monitoring may be required if the WQOs are not being met.
Auditing:	Reviews are to be carried out on a monthly basis to assess the implementation strategy. A checklist is to be completed which assesses the strategies listed above.
Identification of Incident or Failure:	Non compliance with agreed performance criteria will be identified by: • Visual inspections identifying: • build up of sediment on and off the site. • Excessive erosion on the site • Release of construction material from the site • Lack of vegetation establishment • Poorly maintained, damaged or failed control devices. • Deteriorated water quality identified by the Environmental Consultant as being attributable to the construction activities.
Corrective Action:	After any identification of incident or failure, the source is to be located immediately and the following measures implemented: • If vegetation growth fails, new vegetation should be planted and established. Vegetation may require supplementary watering & replanting. • If silt fences fail, replace and monitor more frequently. • If gully erosion occurs, fill, vegetate and install velocity dissipation steps. If release of silt and other material off the site occurs, or water quality monitoring indicates levels not within the WQOs, clean up, inspect all treatment techniques, revise designs and review different alternatives and install, otherwise reduce the rate of excavation. If monitored levels within the sediment basins do not conform to the release criteria for: • Suspended solids: flocculate and retest. • pH: add acid if pH is too high or add hydrated lime if pH is too low and retest.

Issue:	Water Quality Management – Construction Phase
Reporting:	Reports will be submitted monthly during the construction of each stage. The reporting will include: • Construction Contractor site managers report; and • Environmental Consultant water quality monitoring report Reporting will identify performance of the implementation strategy, monitoring, identification of incidents/failure and associated corrective action. Reports will be submitted to the owner (or their appointed representative) monthly for submission to Council.

Water Quality Management Operational Phase

Issue:	Water Quality Management – Operational Phase
Operational Policy:	To provide a concise plan to ensure that the water quality in the waterways remain at an acceptable level as specified in the water quality objectives (WQOs) for the site at all times and to ensure that any waters discharged from the site are of an acceptable quality.
Performance Criteria:	Water discharges off the site should be of a quality, which ensures there is no detriment to the downstream environment. Performance criteria for the site are: - 80% reduction in sediment load; - 60% reduction in total phosphorus load; - 45% reduction in total nitrogen load; and - 90% reduction in gross pollutant load.
Responsibility:	The owner of the property or their appointed representative. The owner will be responsible for a period of 12 months after completion of construction.
Implementation Strategy:	A comprehensive conceptual stormwater runoff management system is proposed for the development, comprising local runoff water quality control. Local catchment runoff water quality control is achieved by: • Rainwater Tanks; and • Bio-retention Systems.
	These controls will: • trap coarse sediment and attached nutrients and heavy metals; and • remove nutrients;
	Periodical monitoring of erosion or sediment deposition within treatment devices.
Implementation Strategy (cont'd):	Periodic maintenance of vegetation within the treatment devices. Inspection of basin for clogging.
Monitoring:	Inspect outflow points from the stormwater outlets and treatment trains to ensure that there are no signs of erosive activity or significant sediment deposits. Monitoring shall include inspection of all treatment devices to ensure they are operating efficiently.
Auditing:	Reviews are to be carried out on a monthly basis to assess the implementation strategy. A checklist is to be completed which assesses the strategy against each of the monitoring points above.
Identification of Incident or Failure:	Non compliance with agreed performance criteria will be identified by: • Visual inspections identifying: • build up of sediment and litter on and off the site. • Excessive erosion on the site • Release of construction material from the site • Lack of vegetation establishment • Poorly maintained, damaged or failed control devices. • Deteriorated water quality identified by the Environmental Consultant as being attributable to the site operations.

Issue:	Water Quality Management – Operational Phase
Corrective Action:	Harvesting of vegetation within the bio-retention systems and re-establishment if vegetation is not healthy. If vegetation fails, new vegetation should be planted and established. Vegetation may require supplementary watering and replanting.
	If erosion occurs, fill, vegetated and/or install velocity dissipation. To be in accordance with the Institution of Engineers Australia *'Soil Erosion and Sediment Control -Engineering Guidelines for Queensland Construction Site (June 1996)*' and the International Erosion Control Associastion *'Best Practice Erosion and Sediment Control (2008)*'.
	If release of silt and other material off the site occurs, clean up, inspect all treatment techniques, revise designs and review different alternatives and install.
	If poor water quality continues to occur, inspect all treatment techniques, revise designs and review different alternatives and install.
Reporting:	An Inspection Report for all water quality monitoring shall be submitted to Council, following a monitoring campaign for up to 2 years after the construction phase.

Flagstone City - Stage 1

APPENDIX B

Maintenance Plans

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1 Introduction

Bio-retention systems are vegetated areas where runoff is filtered through a porous sandy loam filter media as it infiltrates through the system to an arrangement on perforated under-drains and flows to downstream waterways.

Runoff is allowed to temporarily pond to increase the volume of stormwater runoff treated through the bio-retention systems. The temporary ponding level is generally referred to as the extended detention depth.

To protect against possible scour of the bio-retention surface, high flows that exceed the design event are conveyed through an overflow pit or high-flow bypass channel.

2 Function

Bio-retention basins operate by filtering stormwater runoff through densely planted surface vegetation and percolating through a specified filter media. Pollutants within the stormwater runoff are retained through fine infiltration, adsorption and some biological uptake as the runoff percolates through the filter media. The vegetation in a bio-retention system is a vital functional element to the operational effectiveness of the bio-retention system, providing a substrate for biofilm growth within the upper layer of the bio-retention filter media and facilitates the transport of oxygen to the filter media enhancing soil microbiological communities and the biological transformation of pollutants.

Bio-retention basins are not intended to be an infiltration system that discharges the treated stormwater runoff into the surrounding in-situ soils. Bio-retention systems are generally designed to recover stormwater at the base of the filter media in the perforated under-drain and discharge to receiving waters. In order to accommodate this feature an impermeable geotextile fabric is placed between the in-situ soils of the bio-retention walls and base to limit exfiltration to the surrounding soils.

Bio-retention systems can be installed at various scales, including:

- Landscape planter boxes;
- Roadside rain gardens incorporating traffic calming measures;
- Within suburban Parks; and
- At the base of detention basins.

Generally in larger applications a pre-treatment swale or vegetated buffer area is incorporated upstream of the bio-retention system to minimise the maintenance frequency of the bio-retention system.

3 Construction and Establishment

Following the completion of the civil construction phase (i.e. bulk earthworks, roads and services) the site is opened for the build out of each of the individual lots. At this time the works are generally 'uncontrolled' as individual builders not associated with the developer will undertake the individual lot construction. Based on practical experience this stage is usually detrimental to the water quality management and establishment of the water quality treatment devices. The following details a recommended construction and establishment methodology for a bio-retention basin.

3.1 Functional Installation

The Functional Installation of a bio-retention basin occurs at the end of the bulk civil works (i.e bulk earthworks, installation of roads, water, sewage and power services) as part of the landscaping works. The functional installation involves:

- Bulking out and trimming (Basin excavation);
- Installation of the bio-retention basin outlet structures;
- Placement of a geo-textile fabric (between the in-situ basin bed and the drainage layer)
- Installation of the drainage layer and under-drain system;
- Placement of the transition layer and filter media;
- Installation of bio-retention inlet structures;
- Placement of a temporary protective management strategy (Refer to sediment and erosion details below).
- Placement of sediment fences around the boundary of the bio-retention basin to prevent silt entering the filter media and restrict access to the basin.
- The temporary protective management strategies are kept in place throughout the entire construction phase.

3.2 Sediment and Erosion Control

Sediment and Erosion Control involves the placement of temporary protective management strategies for the period where the upstream catchments are not in their final state and are contributing sediment / litter laden waters which may cause the filter media to clog.

3.3 Operational Establishment

Operational Establishment of the bio-retention basin occurs at the completion of the building phase of the development. Operational establishment includes the following works:

- Removal of all accumulated sediment from the sediment fore bay and the basin surface;
- Removal of the temporary turf, topsoil and geotextile fabric;
- Re-profile the bio-retention filter media surface;
- Vegetation of the bio-retention basin in accordance with the landscape design; and
- Regular watering of the vegetation and removal of weeds during the plant establishment phase (generally first two years).

4 Vegetation Establishment

Source: WSUD TDG SEQ 2006 Section 5.5.4

4.1 Weed Control

Conventional surface mulching of bio-retention basins with organic material like tanbark should not be undertaken. Most organic mulch floats and runoff typically causes this material to be washed away with risk of blocking outlet structures. Adopting high plant densities and where necessary applying a suitable biodegradable erosion control matting to the basin batters will help reduce the risk of weed invasion and limit labour intensive maintenance requirements for weed removal. A heavy application of seedless hydro-mulch can also provide short term erosion and weed control prior to planting with nursery stock. No matting or hydro-mulch should be applied to the surface of the bio-retention basin following the construction phase as this will hinder the filtration capacity of stormwater through the filter media.

4.2 Watering

Regular watering of the bio-retention basin vegetation is essential for successful establishment and healthy growth. The frequency of watering to achieve successful plant establishment is dependant upon rainfall, the maturity of the planting stock and the water holding capacity of the soil. The following watering program is generally adequate but should be adjusted (increased) to suit the site conditions:

- Weeks 1-2: 3 Watering campaigns per week;
- Weeks 3-6: 2 Watering campaigns per week; and
- Weeks 7-12: 1 Watering campaigns per week.

After this initial three month watering campaign, watering may still be required, particularly during the first winter (dry period). Watering requirements to sustain healthy vegetation should be determined during ongoing maintenance site visits.

5 Maintenance Requirements

Source: WSUD TDG SEQ 2006 Section 5.6

Vegetation plays a key role in maintaining the porosity of the filter media of a bio-retention basin and strong healthy growth of vegetation is critical to its performance. Therefore the most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required.

Inflow systems and overflow pits require careful monitoring, as these can be prone to scour and litter build up. Debris can block inlets or outlets and can be unsightly, particularly in high visible areas. Inspection and removal of debris should be done regularly, and debris should be removed whenever it is observed on a site. Where sediment forebays are adopted, regular inspection of the forebay is required (3 monthly) with removal of accumulated sediment undertaken as required.

For larger bio-retention basins, it is essential that a maintenance access point is designed or and maintained in the bio-retention basin. The size and complexity of the system will guide its design and may involve provision of a reinforced concrete ramp/ pad for truck or machinery access.

Typical maintenance of bio-retention basin elements will involve:

- Routine inspection of the bio-retention basin profile to identify any areas of obvious increased sediment deposition, scouring from storms, rill erosion of the batters from lateral flows, damage to the profile from vehicles and clogging of the bio-retention basin (generally accompanied by a 'boggy' filter media surface);
- Routine inspection of inflow systems, overflow pits and under-drains to identify and clean any areas of scour, litter build up and blockages;
- Removal of sediment where it is smothering the bio-retention basin vegetation;
- Where a sediment fore bay is adopted, removal of accumulated sediment;
- Repairing any damage to the profile resulting from scour, rill erosion or vehicle damage by replacement of appropriate fill (to match on site soils) and revegetating;
- Tilling of the bio-retention basin surface or removal of the surface layer if there is evidence of clogging;
- Regular watering and irrigation of the basin vegetation until plants are established and actively growing;
- Removal and management of invasive weeds (herbicides should not be used);
- Removal of plants that have died and replacement with plants of equivalent size and species as detailed in the plant schedule;
- Pruning to remove dead or diseased vegetation material and stimulate growth;
- Monitoring and controlling vegetation pests;
- Inspections should be also conducted following any large storm event to check for scour and other damage;
- All maintenance should be carried out only after a reasonably rain free period when the soil in the bio-retention systems is dry; and
- All maintenance works are to be documented using the attached maintenance inspection form.

If a bio-retention system fails to drain adequately after tilling of the basin surface and other remedial maintenance, the bio-retention system may require resetting. Resetting involves the complete reconstruction of the bio-retention system.

5.1 Bio-Retention Typical Maintenance Schedule

SCHEDULE OF SITE VISITS													
Purpose of Visit	**Frequency**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Routine inspection	12/year	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Annual inspection	1/year				✓								
Routine maintenance	2/year				✓						✓		
Routine clean out of sediment	1 / 2 years				✓								

There are three phases to this maintenance plan which are:

- The establishment phase;
- The inspection and monitoring phase; and
- Cleanout and replacement phase

The above schedule is a guideline only. Routine clean out and maintenance should be scheduled based on the outcome of routine inspection.

ESTABLISHMENT	
1.1	The aim of the establishment phase is to ensure appropriate plant establishment within the bio-retention system through adequate weed control and watering.
1.2	Weed control during the establishment phase focuses on weed growth prevention rather than removal. By adopting high planting densities and if necessary, applying a suitable biodegradable erosion control matting to the basin batters.
1.3	Regular watering of the bio-retention basin vegetation is essential for successful establishment of the selected plants. Each site will need specific watering requirements but as a guide during the first two weeks there will need to be three visits each week, after this (weeks 3-6) there will need to be two visits each week. The third and final period of establishment maintenance (weeks 7-12) there is only one visit each week required. The Bio-retention Basin Maintenance Checklist provides the schedule of visits and a tick box to help monitor what stage of the establishment phase they are in and provides a record as to whether proper establishment has occurred.
INSPECTION	
1.	**Routine Inspection**
1.1	Routine inspection should be carried out on a regular monthly basis. The purpose of the inspection is to indicate when maintenance of the Bio-retention system is required.
1.2	Inspections should consider items listed on the Bio-retention Basin Maintenance Checklist
2.	**Event Inspection**
2.1	Following bushfires the bio-retention system shall be inspected for damage to the structure, vegetation and filter media.
2.2	After any significant rainfall events the bio-retention system shall be inspected for damage to the structure, vegetation and filter media.
ROUTINE MAINTENANCE	
1.	**Purpose**
1.1	Maintenance of the bio retention system involves routine inspections of the bio-retention basin profile to identify any areas of obvious increased sediment deposition or scouring. Based on inspections there should be actions taken to remove dead or diseased vegetation, any litter or foreign objects. Filter Media replacement should occur when necessary and any items from checklist that are noted are to be reported to the site manager.

2.	**Weed Management**
2.1	If weeds have been observed during routine inspection, these weeds should be removed from the bio retention system. Weeding generally involves manual removal of perennial species.
2.2	The aim is to remove the weed including the roots when the weeds are less than 3 months old, otherwise weeds infestation rapidly occurs and is difficult to control.
2.3	Herbicides should not be used as they would contaminate the water in the creek.
2.4	The weeds should be disposed offsite at appropriate waste management facility.
2.5	Replant appropriate plant species, where necessary, in areas that have been extensively weeded.
3.	**Litter Management**
3.1	Remove and dispose of litter that may be visible around the bio retention system.
4.	**Dead or Diseased Vegetation**
4.1	Remove or dispose of any dead or diseased vegetation within system.
5.	**Filter Media Replacement**
5.1	Filter Media replacement is recommended when erosion is evident or system looks unattractive or is not draining in 30 days. Conventional surface mulching with organic material like tank bark, should not be undertaken as most mulch floats and is washed away.
6.	**Structural Integrity**
6.1	Report any damage to the structure immediately to the civil engineer
6.2	Report significant scour to the civil engineer
6.3	Ensure that the system is draining correctly via visual inspection of a rainfall event. If poor drainage is observed then inspect the outlet pipe for blockage. If the drainage is still poor then contact the civil engineer and arrange for a permeability test to ensure replacement of filter material is not clogged.
EVENT MAINTENANCE	
1.	**Purpose**
1.1	Event Maintenance of the bio retention system involves undertaking any maintenance to the bio-retention system following an event. Based on the event inspections there should be actions taken to remove dead or diseased vegetation, any litter or foreign objects. Filter Media replacement should occur when necessary and any items from checklist that are noted are to be reported to the site manager. Maintenance is in accordance with the Routine Maintenance guidelines listed above.
CLEANOUT AND REPLACEMENT OF SEDIMENT	
1.	**Setup and Prepare Site for Cleanout**
1.1	Notify adjacent residents of cleanout at least three days prior to date of cleanout.
1.2	Setup equipment onsite.
2.	**Cleanout of Sediment**
2.1	The preferred method of cleanout of the bio-retention system is replacing the clogged medium.
2.2	Position the equipment on the side of the system to allow easy access into the bio retention system and transfer of material into adjacent tipper truck. The truck should be positioned so that water from the truck body drains into the bio retention system.
2.3	Drain waste in the truck thoroughly before proceeding to the disposal point.

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APPENDIX

B1.1

Bio-retention Construction Inspection Checklist

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BIO-RETENTION BASIN CONSTRUCTION INSPECTION CHECKLIST

Asset ID:		Inspected By:	
		Date:	
Site:		Time:	
		Weather:	
Constructed By:		Site Manager:	

Items Inspected	Checked		Satisfactory		Items Inspected	Checked		Satisfactory	
	Y	N	Y	N		Y	N	Y	N
CONSTRUCTION AND ESTABLISHMENT PHASE									
A). FUNCTIONAL INSTALLATION					Structural Components				
Preliminary Works					15). Location and configuration of inflow systems as detailed in plans				
1). Erosion and sediment control plan adopted					16). Location and levels of overflow pits as detailed in plans				
2). Temporary traffic / safety control measures					17). Under-drain connected to overflow pits as detailed in plans				
3). Location as detailed in plans					18). Concrete and reinforcement as detailed in plans				
4). Basin protected from site runoff					19). Set down to correct level for flush kerbs (rain gardens only)				
Earthworks and Filter Media					20). Kerb opening width as detailed in plans (rain garden only)				
5). Basin bed surface correct shape and slope as detailed in plans									
6). Side slope batters as detailed in plans					B). SEDIMENT AND EROSION CONTROL				
7). Bio-retention dimensions and area as detailed in plans					21). Stabilisation immediately following earthworks and planting of terrestrial landscape around basin				
8). Confirm surrounding soils type with design					22). Silt fences and traffic controls in place				
9). Confirm filter media specifications in accordance with latest FAWB Guidelines					23). Temporary protective turf and topsoil in place				
10). Geotextile fabric placed between in-situ soils and filter media (base and walls)									
11). Under-drain installed as detailed in plans					C). OPERATIONAL ESTABLISHMENT				
12). Drainage layer media as specified					24). Sediment removed from fore bay area				
13). Transition layer media as specified					25). Temporary protective turf, topsoil and geotextile fabric removed				
14). Extended detention depth as detailed in plans					Vegetation				
					26). Planting as designed (species and density)				
					27). Weed removal and watering as required				

FINAL INSPECTION									
1). Confirm levels of the inlets and outlets					6). Check for uneven settling of banks				
2). Confirm structural element sizes					7). Confirm under-drain operational and working				
3). Check side batter slopes					8). Confirm inflow systems operational and working				
4). Check vegetation as designed					9). Confirm maintenance access is provided				
5). Check bio-retention filter media surface flat and free of clogging									

COMMENTS ON INSPECTION
ACTIONS REQUIRED
Inspection Officer's Signature:

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APPENDIX

B1.2

Bio-retention Maintenance Checklist

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BIO-RETENTION BASIN MAINTENANCE CHECKLIST

Asset ID:		Inspected By:	
		Date:	
Site:		Time:	
		Weather:	
Constructed By:		Site Manager:	

Items Inspected	Checked		Satisfactory		Action Required
	Y	N	Y	N	
Sediment accumulation an inflow locations?					
Litter within the basin?					
Erosion at inlet or other key structures?					
Traffic / Vehicle damage present?					
Evidence of illegal dumping (e.g. building waste)?					
Vegetation condition satisfactory (density, weeds etc.)					
Watering of vegetation required?					
Replanting require?					
Mowing / Slashing required?					
Clogging of drainage points (sediment or debris)?					
Evidence of ponding?					
Damage / Vandalism to structures present?					
Surface clogging visible?					
Drainage system inspected?					
Resetting of system require?					

COMMENTS ON INSPECTION

ACTIONS REQUIRED

Inspection Officer's Signature:	

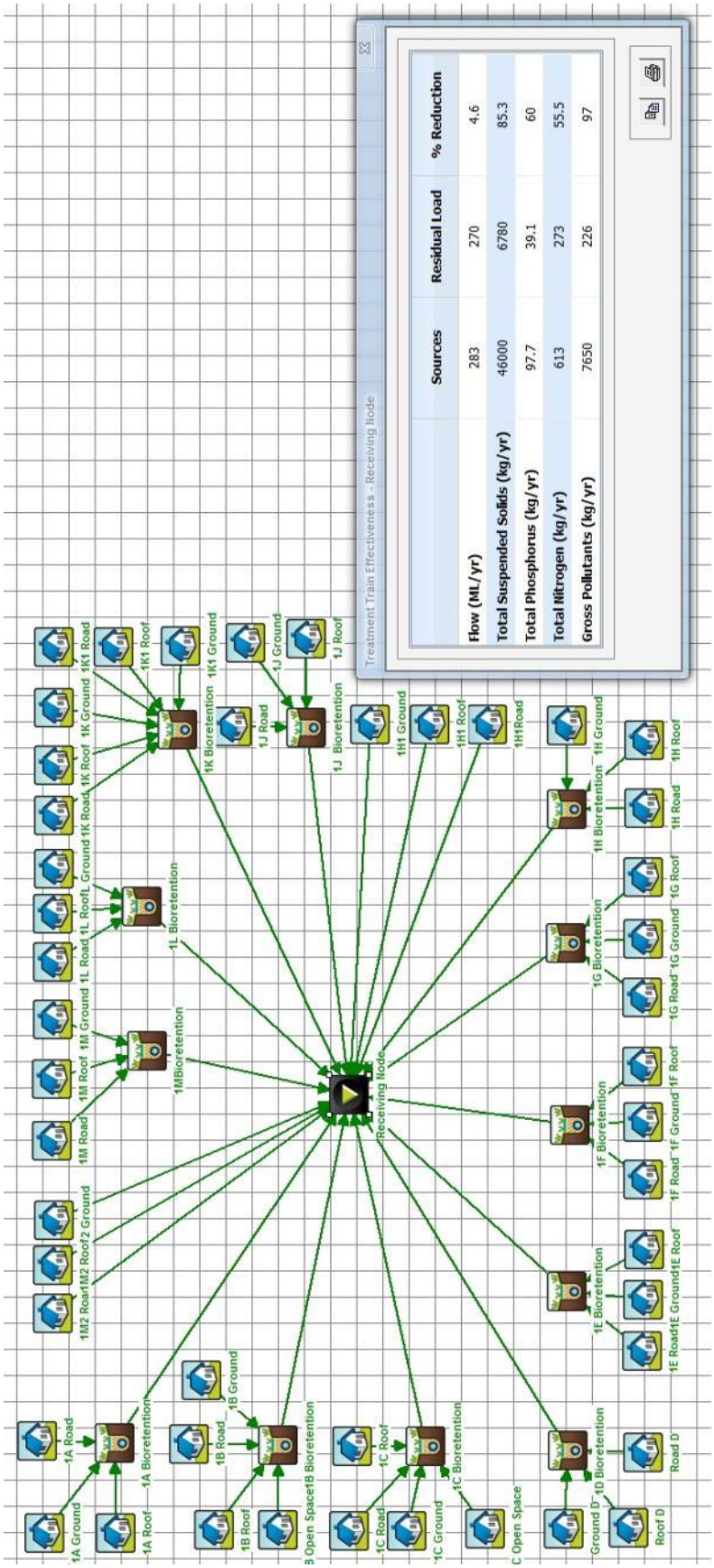
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APPENDIX C

MUSIC Model Schematic & Parameters

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MUSIC Schematic



MUSIC Parameters (excerpts from Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010))

Table 3.5 Typical impervious fraction for split catchment land use (read with Table 3.3)[7]

DEVELOPMENT TYPE	SURFACE TYPE IMPERVIOUS FRACTION (%)		
	ROAD RESERVE	ROOF	GROUND LEVEL
Residential 10 dwellings/ha	60	100	15
Residential 15 dwellings/ha	60	100	20
Residential 40 dwellings/ha	70	100	30
Residential 80+ dwellings/ha	80	100	50
Industrial	75	100	60
Commercial	75	100	80

Table 3.7 Recommended MUSIC rainfall-runoff parameters[9]

PARAMETER	LAND USE			
	URBAN RESIDENTIAL	COMMERCIAL AND INDUSTRIAL	RURAL RESIDENTIAL	FORESTED
Rainfall threshold (mm)	1	1	1	1
Soil storage capacity (mm)	500[10]	18	98	120
Initial storage (% capacity)	10	10	10	10
Field capacity (mm)	200	80	80	80
Infiltration capacity coefficient a	211	243	84	200
Infiltration capacity exponent b	5.0	0.6	3.3	1.0
Initial depth (mm)	50	50	50	50
Daily recharge rate (%)	28	0	100	25
Daily baseflow rate (%)	27	31	22	3
Daily deep seepage rate (%)	0	0	0	0

Table 3.8 Pollutant export parameters for split catchment land use (log^{10} values)

FLOW TYPE	SURFACE TYPE	TSS log^{10} values		TP log^{10} values		TN log^{10} values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
	Urban residential						
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	1.00	0.34	-0.97	0.31	0.20	0.20
	Ground level	1.00	0.34	-0.97	0.31	0.20	0.20
Stormflow parameters	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Roads	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground level	2.18	0.39	-0.47	0.31	0.26	0.23
	Industrial						
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.45	-1.11	0.48	0.14	0.20
	Ground level	0.78	0.45	-1.11	0.48	0.14	0.20
Stormflow parameters	Roof	1.30	0.44	-0.89	0.36	0.25	0.32
	Roads	2.43	0.44	-0.30	0.36	0.25	0.32
	Ground level	1.92	0.44	-0.59	0.36	0.25	0.32
	Commercial						
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.39	-0.60	0.50	0.32	0.30
	Ground level	0.78	0.39	-0.60	0.50	0.32	0.30
Stormflow parameters	Roof	1.30	0.38	-0.89	0.34	0.37	0.34
	Roads	2.43	0.38	-0.30	0.34	0.37	0.34
	Ground level	2.16	0.38	-0.39	0.34	0.37	0.34

Table 3.9 Pollutant export parameters for lumped catchment land uses (log^{10} values)

LANDUSE	FLOW TYPE	TSS log^{10} values		TP log^{10} values		TN log^{10} values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential	Baseflow	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	2.18	0.39	-0.47	0.32	0.26	0.23
Industrial	Baseflow	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial	Baseflow	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	2.16	0.38	-0.39	0.34	0.37	0.34
Rural residential	Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
	Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30
Forest	Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
	Stormflow	1.90	0.20	-1.10	0.22	-0.075	0.24
Agriculture	Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
	Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

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APPENDIX D

Rational Method Detailed Calculations

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Existing Condition - Peak Flow Estimates (Rational Method)

Catchment ID	Coefficient of Runoff								Tc	Intensity (mm/hr)							Area	Discharge (m^3/s)						
	fi	C10	C1	C2	C5	C20	C50	C100	(min)	I1	I2	I5	I10	I20	I50	I100	(ha)	Q1	Q2	Q5	Q10	Q20	Q50	Q100
A	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	10.9	81.9	105.2	132.5	149.0	170.5	200.7	223.2	4.05	0.44	0.59	0.84	0.99	1.19	1.53	1.78
B	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	19.9	62.2	79.8	101.0	113.0	130.0	153.0	171.0	16.98	1.39	1.89	2.67	3.15	3.80	4.90	5.71
C	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	11.0	81.9	105.2	132.5	149.0	170.5	200.7	223.2	7.34	0.79	1.08	1.51	1.79	2.15	2.78	3.22
D	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	13.4	76.4	98.1	123.8	139.0	159.3	187.5	208.7	3.69	0.37	0.50	0.71	0.84	1.01	1.30	1.51
E	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	10.9	81.9	105.2	132.5	149.0	170.5	200.7	223.2	3.36	0.36	0.49	0.69	0.82	0.99	1.27	1.47
F	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	15.5	72.1	92.5	116.8	131.0	150.3	176.9	197.1	4.57	0.43	0.59	0.83	0.98	1.18	1.52	1.77
GJK	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	17.6	67.7	86.9	109.8	123.0	141.3	166.3	185.5	7.79	0.69	0.94	1.33	1.57	1.89	2.44	2.84
H	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	13.2	77.5	99.5	125.5	141.0	161.5	190.1	211.6	4.58	0.47	0.63	0.89	1.06	1.27	1.64	1.91
L	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	17.2	68.8	88.3	111.5	125.0	143.5	168.9	188.4	1.80	0.16	0.22	0.31	0.37	0.45	0.57	0.67
M	0.00	0.59	0.47	0.50	0.56	0.62	0.68	0.71	14.9	73.2	93.9	118.5	133.0	152.5	179.5	200.0	3.82	0.37	0.50	0.70	0.83	1.00	1.29	1.50

Developed Condition - Peak Flow Estimates (Rational Method)

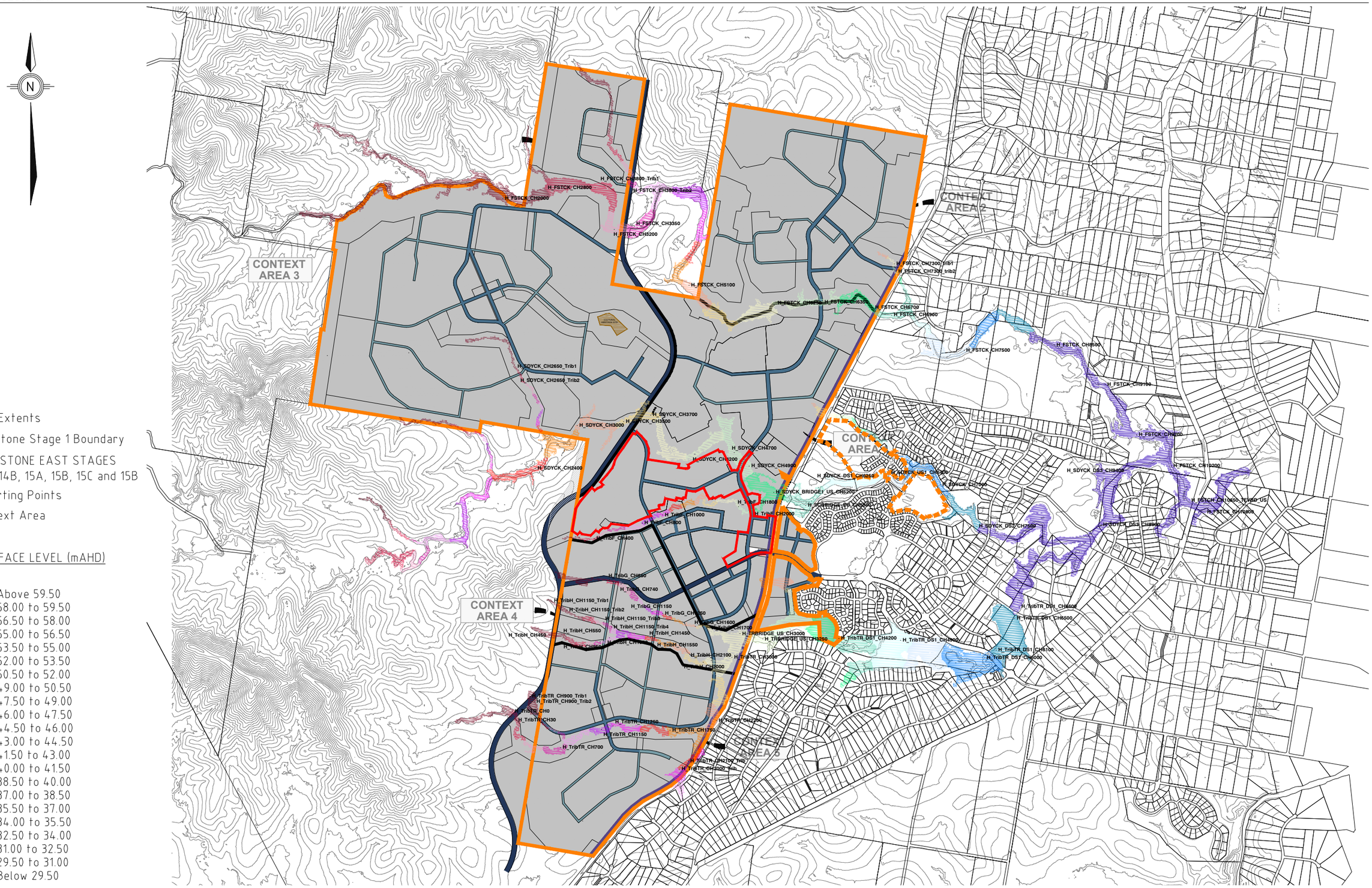
Catchment ID	Coefficient of Runoff								Tc	Intensity							Area	Discharge						
	fi	C10	C1	C2	C5	C20	C50	C100	(min)	(mm/hr)							(ha)	(m^3/s)						
										I1	I2	I5	I10	I20	I50	I100		Q1	Q2	Q5	Q10	Q20	Q50	Q100
A	0.60	0.78	0.62	0.66	0.74	0.82	0.90	0.94	11.4	80.8	103.8	130.8	147.0	168.3	198.1	220.3	4.10	0.57	0.78	1.10	1.31	1.57	2.02	2.35
B	0.58	0.77	0.62	0.66	0.73	0.81	0.89	0.93	13.3	76.4	98.1	123.8	139.0	159.3	187.5	208.7	13.31	1.75	2.38	3.36	3.97	4.78	6.16	7.15
C	0.57	0.77	0.62	0.65	0.73	0.81	0.89	0.92	12.0	79.7	102.4	129.0	145.0	166.0	195.4	217.4	6.92	0.94	1.29	1.81	2.15	2.58	3.32	3.86
D	0.60	0.78	0.62	0.66	0.74	0.82	0.90	0.94	10.9	81.9	105.2	132.5	149.0	170.5	200.7	223.2	4.03	0.57	0.78	1.10	1.30	1.56	2.01	2.34
E	0.60	0.78	0.62	0.66	0.74	0.82	0.90	0.94	11.4	80.8	103.8	130.8	147.0	168.3	198.1	220.3	3.25	0.45	0.62	0.87	1.03	1.24	1.60	1.86
F	0.60	0.78	0.62	0.66	0.74	0.82	0.90	0.94	10.6	83.0	106.6	134.3	151.0	172.8	203.4	226.1	1.67	0.24	0.33	0.46	0.54	0.65	0.84	0.98
G	0.60	0.78	0.62	0.66	0.74	0.82	0.90	0.94	15.2	73.2	93.9	118.5	133.0	152.5	179.5	200.0	4.89	0.62	0.85	1.19	1.41	1.70	2.19	2.54
H	0.60	0.78	0.62	0.66	0.74	0.82	0.90	0.94	12.2	79.7	102.4	129.0	145.0	166.0	195.4	217.4	7.28	1.01	1.37	1.93	2.29	2.75	3.54	4.11
J	0.60	0.78	0.62	0.66	0.74	0.82	0.90	0.94	14.6	74.2	95.3	120.3	135.0	154.8	182.2	202.9	4.03	0.52	0.71	1.00	1.18	1.42	1.83	2.13
K	0.64	0.79	0.63	0.67	0.75	0.83	0.91	0.95	14.0	75.3	96.7	122.0	137.0	157.0	184.8	205.8	1.91	0.25	0.35	0.49	0.58	0.69	0.89	1.04
L	0.60	0.78	0.62	0.66	0.74	0.82	0.90	0.94	14.2	75.3	96.7	122.0	137.0	157.0	184.8	205.8	1.79	0.23	0.32	0.45	0.53	0.64	0.83	0.96
M	0.90	0.87	0.70	0.74	0.83	0.91	1.00	1.00	13.2	77.5	99.5	125.5	141.0	161.5	190.1	211.6	9.15	1.37	1.87	2.64	3.12	3.75	4.83	5.38
GJK	0.61	0.78	0.63	0.66	0.74	0.82	0.90	0.94	15.2	73.2	93.9	118.5	133.0	152.5	179.5	200.0	10.82	1.38	1.88	2.65	3.13	3.77	4.85	5.64

Flagstone City - Stage 1

APPENDIX E

Pre-Development Flooding Conditions (TUFLOW Results)

Cardno
Shaping the Future



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
- 47.50 to 49.00
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- 44.50 to 46.00
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- 40.00 to 41.50
- 38.50 to 40.00
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- 29.50 to 31.00
- Below 29.50

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300 0 300 600 900 1200 1500m
1:30,000

Scale 1:30000 (A3)

FIGURE E1

100 Year ARI - Pre-Development(Stage 1) Case E21e - Peak Water Surface Levels

Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_2256\Sfage 1 Appendix E.dwg
XREF's: Existing Contours; WSL_Reporting points_All_Points_moved; E21eTuflow_Results_20140901; 110056-262-STRUCTURE_OPT2L_grey

PRINT DATE: 05 September, 2014 - 1:31pm

Cardno



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
- 47.50 to 49.00
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1:30,000

Scale 1:30000 (A3)

FIGURE E2

50 Year ARI - Pre-Development (Stage 1)Case E21e - Peak Water Surface Levels

Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_2256\Sfage 1 Appendix E.dwg
XREF's: Existing Contours; WSL_Reporting points_All_Points_moved; E21eTuflow_Results_20140901; 110056-262-STRUCTURE_OPT2L_grey

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Cardno



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
- 47.50 to 49.00
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1:30,000

Scale 1:30000 (A3)

FIGURE E3

20 Year ARI - Pre-Development (Stage 1) Case E21e - Peak Water Surface Levels

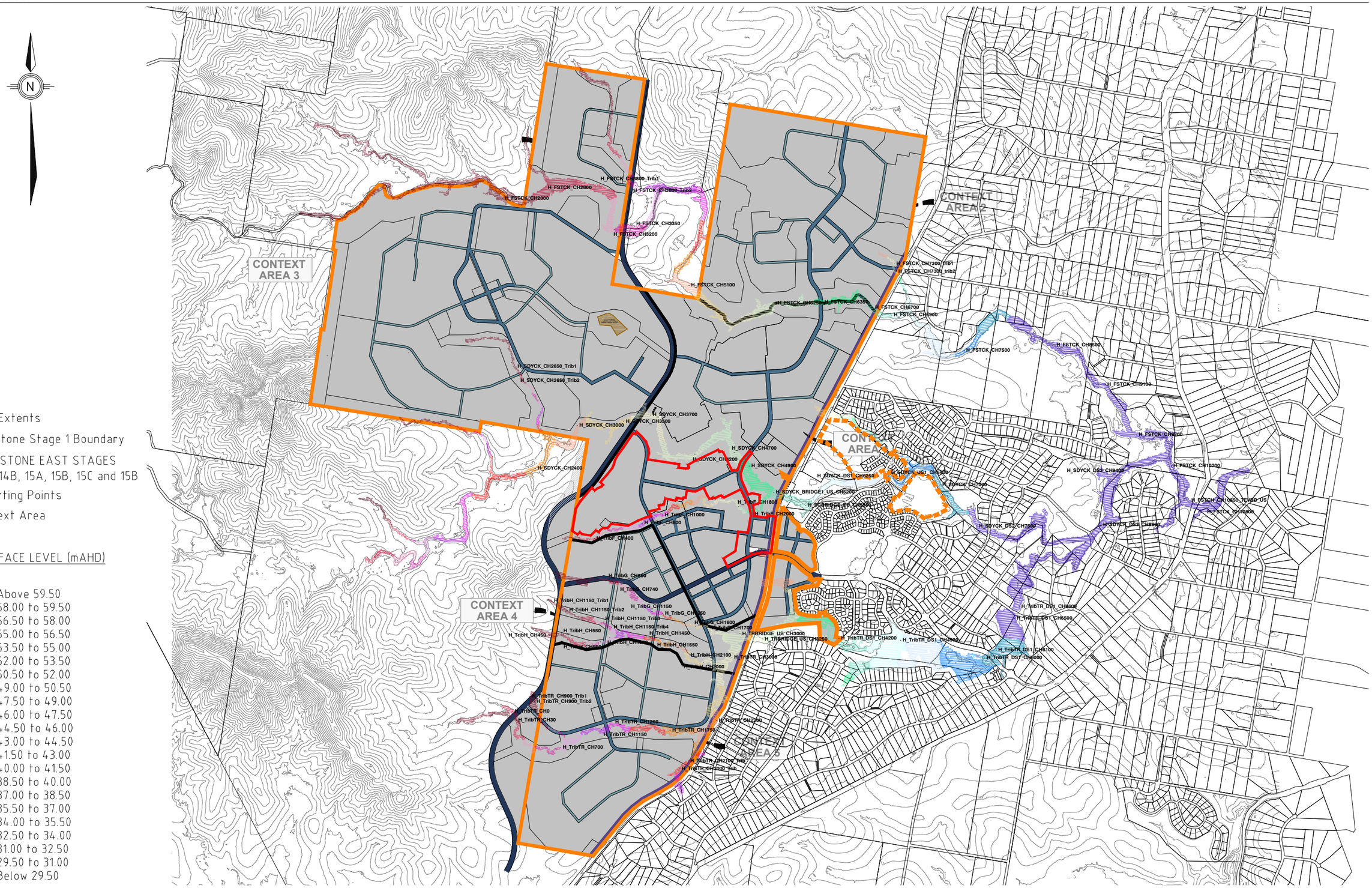
Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

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PRINT DATE: 05 September, 2014 - 1:31pm



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
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300 0 300 600 900 1200 1500m
1:30,000

Scale 1:30000 (A3)

FIGURE E4

10 Year ARI - Pre-Development (Stage 1) Case E21e - Peak Water Surface Levels

Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

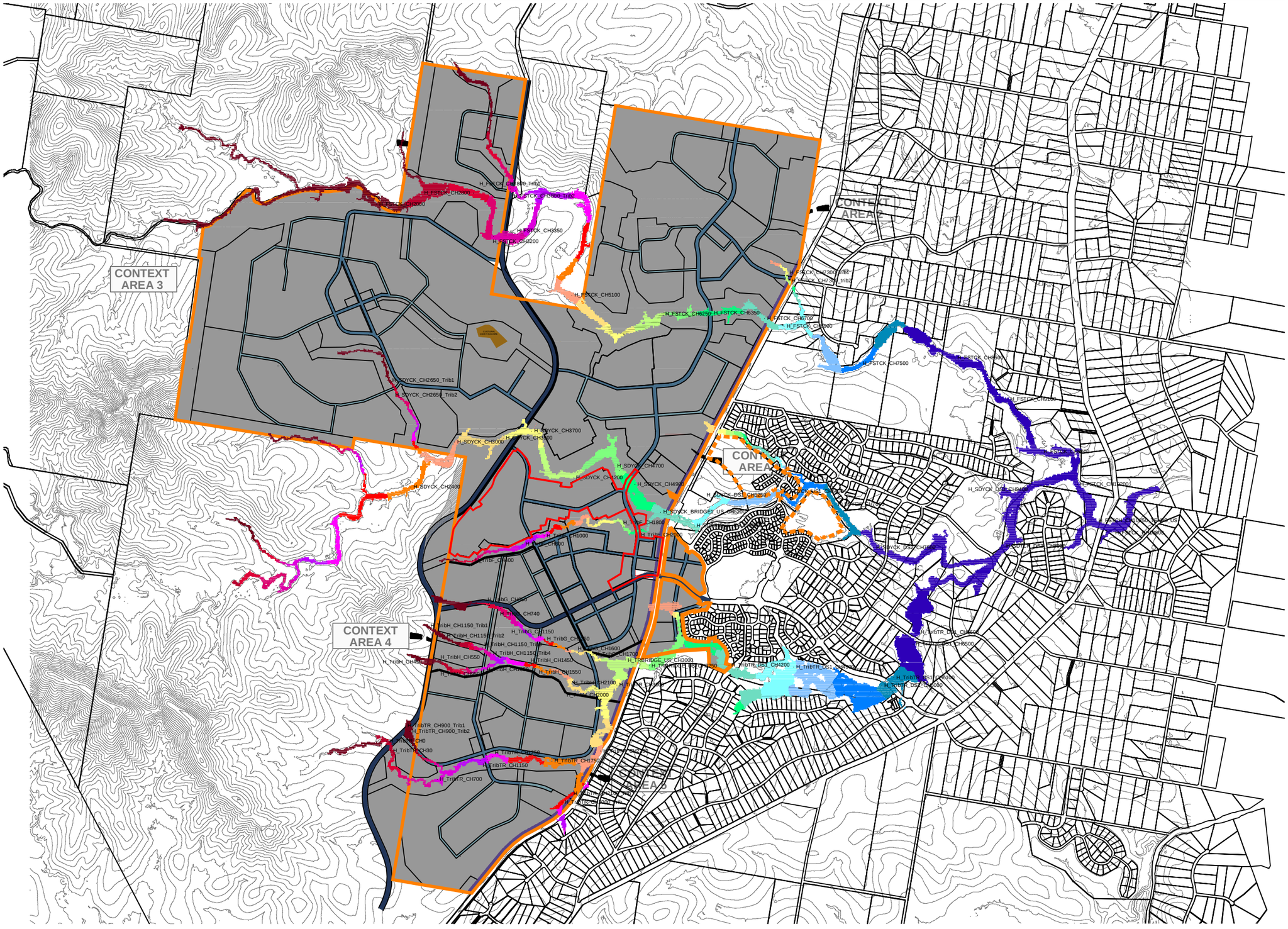
Peet Flagstone City Pty Ltd

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PRINT DATE: 05 September, 2014 - 1:31pm

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LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
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300 0 300 600 900 1200 1500m
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Scale 1:30000 (A3)

FIGURE E5

5 Year ARI - Pre-Development(Stage 1) Case E21e - Peak Water Surface Levels

Rev: Orig. Date: 19 August 2014

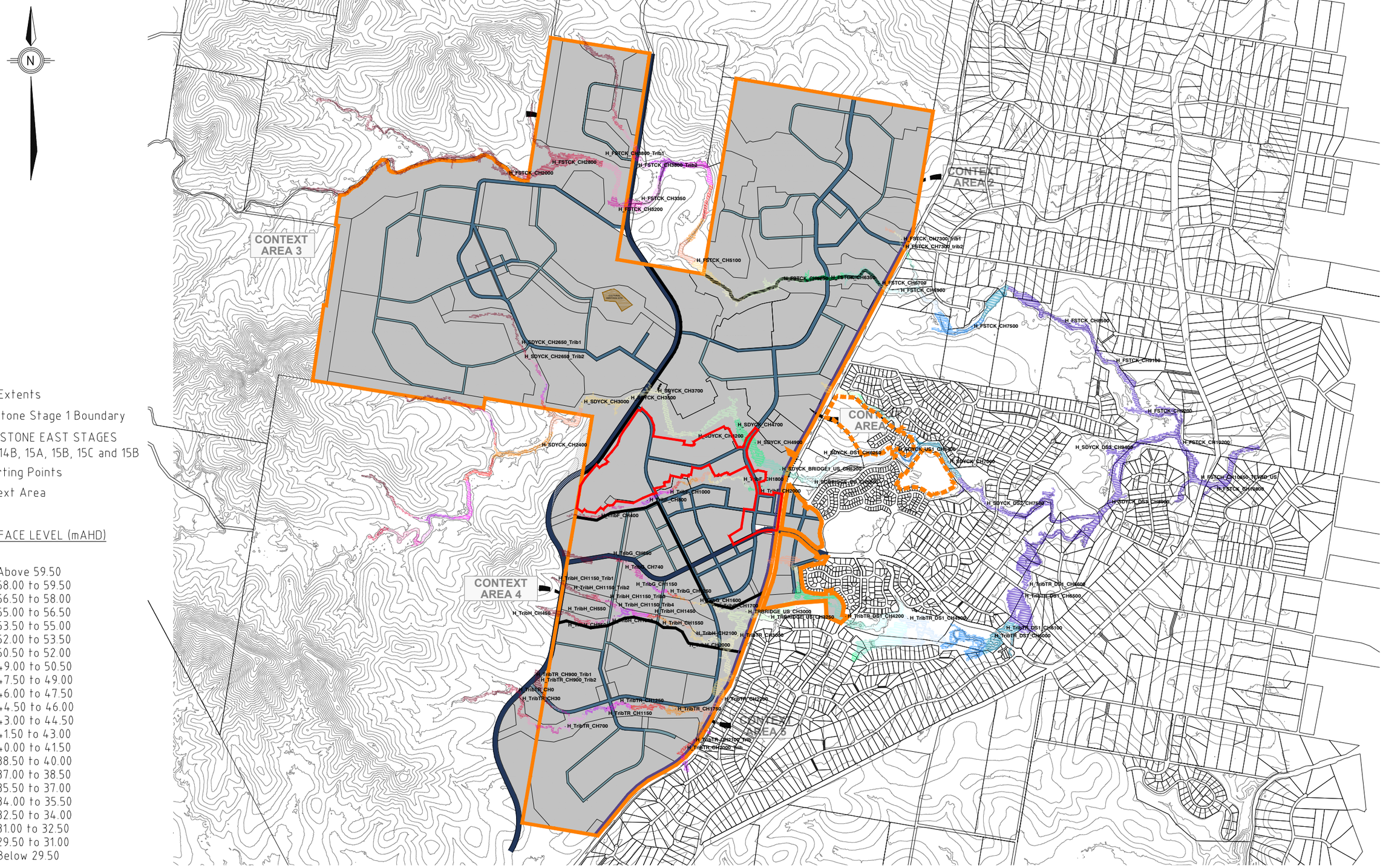
Project No.: 7217/43

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PRINT DATE: 05 September, 2014 - 1:32pm

Cardno



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
- 47.50 to 49.00
- 46.00 to 47.50
- 44.50 to 46.00
- 43.00 to 44.50
- 41.50 to 43.00
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1:30,000

Scale 1:30000 (A3)

FIGURE E6

2 Year ARI - Pre-Development (Stage 1) Case E21e - Peak Water Surface Levels

Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

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CAD FILE: C:\Temp\AcPublish_2256\Sfage 1 Appendix E.dwg
XREF's: Existing Contours; WSL_Reporting points_All_Points_moved; E21eTuflow_Results_20140901; 110056-262-STRUCTURE_OPT2L_grey

PRINT DATE: 05 September, 2014 - 1:32pm

Flagstone City - Stage 1

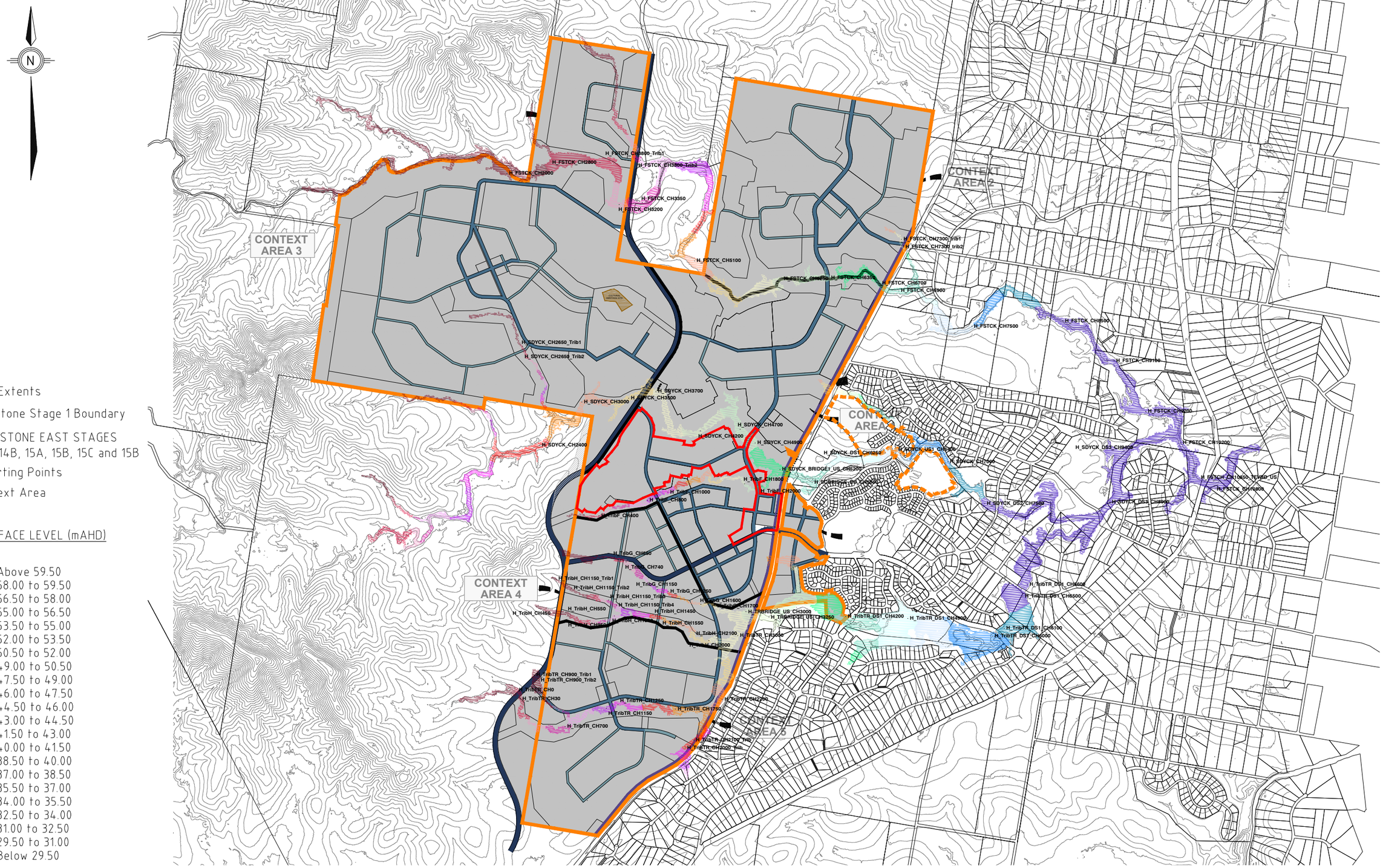
APPENDIX

F

Post-Development Flooding Conditions (TUFLOW Results)

Cardno
Shaping the Future

Cardno



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
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FIGURE F1

100 Year ARI - Post-Development (Stage 1)Case Stg1g - Peak Water Surface Levels

Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

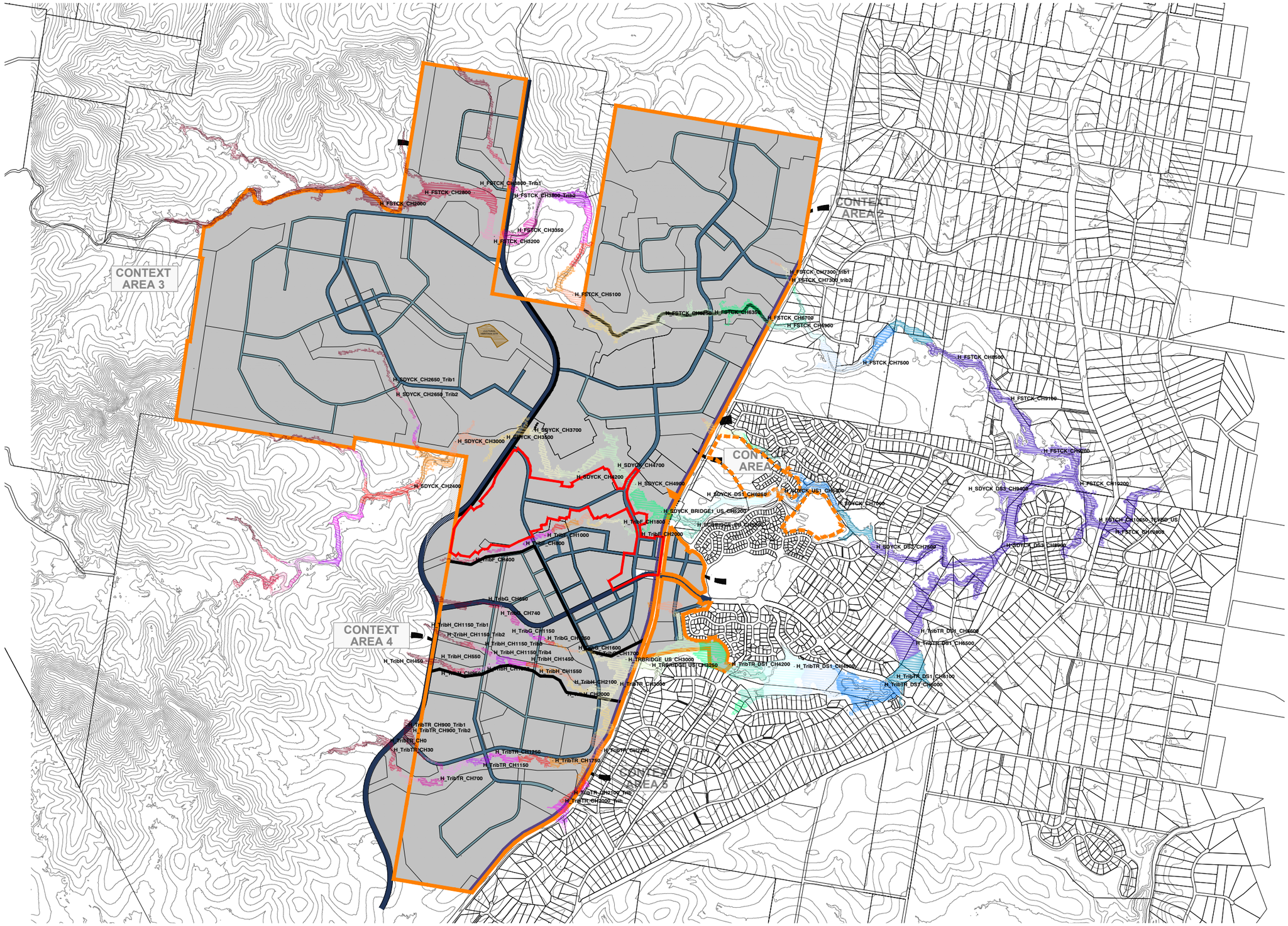
Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_3136\Stage 1 Appendix F.dwg
XREF's: Existing Contours; WSL_Reporting points_All_Points_moved; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

PRINT DATE: 05 September, 2014 - 1:38pm

Cardno





LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
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1:30,000

Scale 1:30000 (A3)

FIGURE F2

50 Year ARI - Post-Development (Stage 1)Case Stg1g - Peak Water Surface Levels

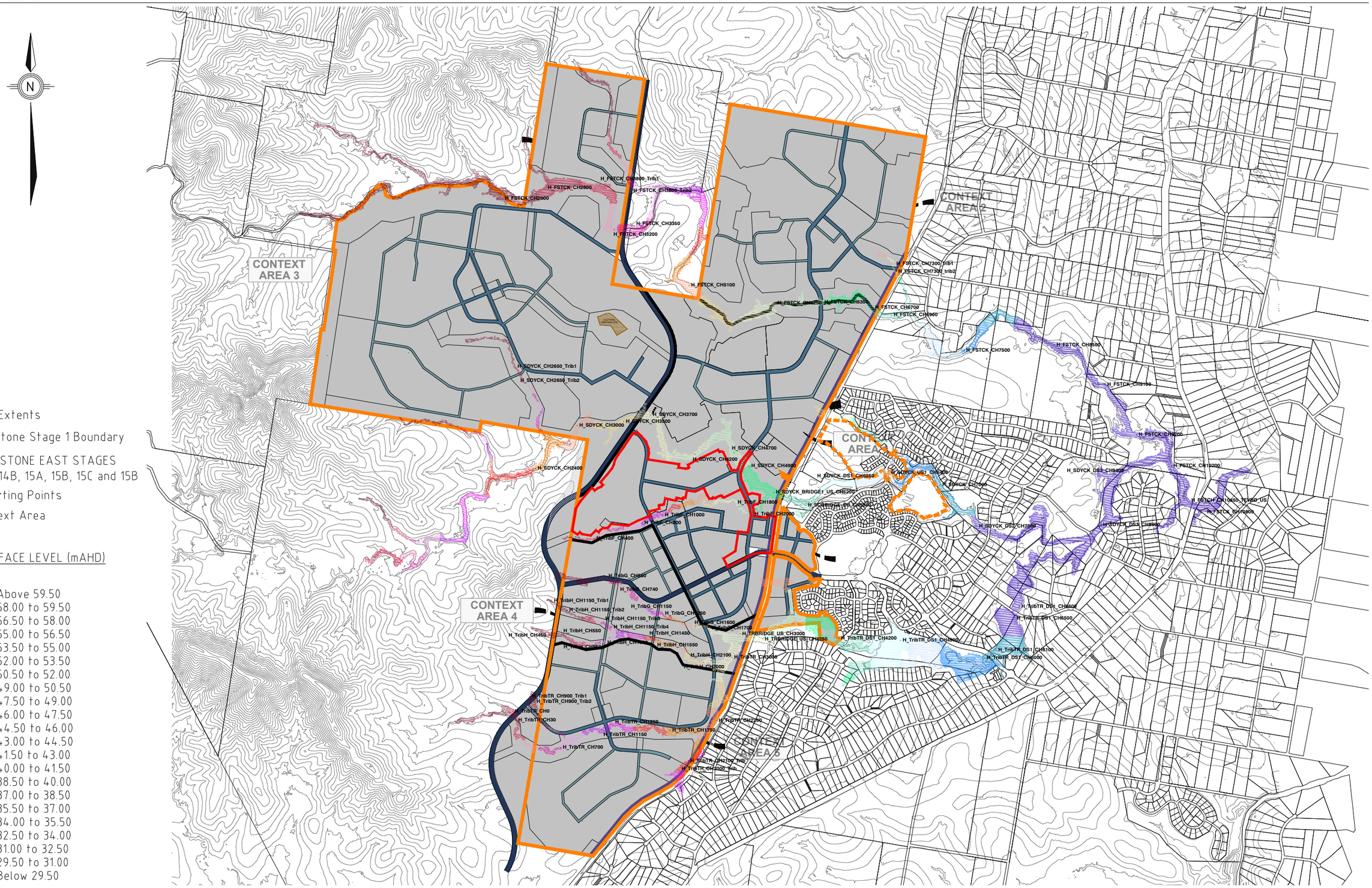
Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_3136\Stage 1 Appendix F.dwg
XREF's: Existing Contours; WSL_Reporting points_All_Points_moved; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

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FIGURE F3

20 Year ARI - Post-Development (Stage 1)Case Stg1g - Peak Water Surface Levels

Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_3136\Sfage 1 Appendix F.dwg
XREF's: Existing Contours; WSL_Reporting points_All_Points_moved; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

PRINT DATE: 05 September, 2014 - 1:38pm

Cardno

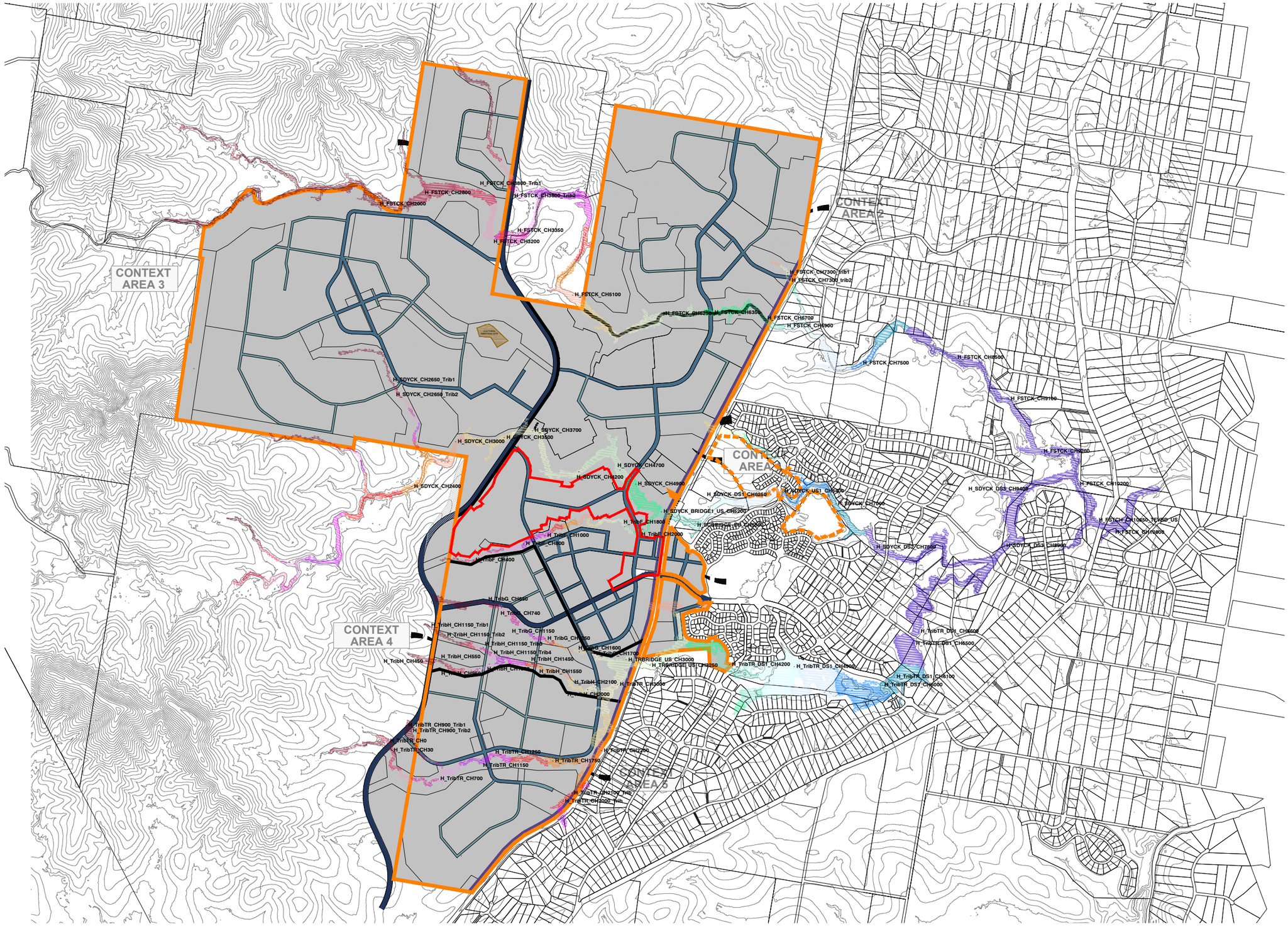


LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
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- 46.00 to 47.50
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- 43.00 to 44.50
- 41.50 to 43.00
- 40.00 to 41.50
- 38.50 to 40.00
- 37.00 to 38.50
- 35.50 to 37.00
- 34.00 to 35.50
- 32.50 to 34.00
- 31.00 to 32.50
- 29.50 to 31.00
- Below 29.50



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Scale 1:30000 (A3)

FIGURE F4

10 Year ARI - Post-Development (Stage 1) Case Stg1g - Peak Water Surface Levels

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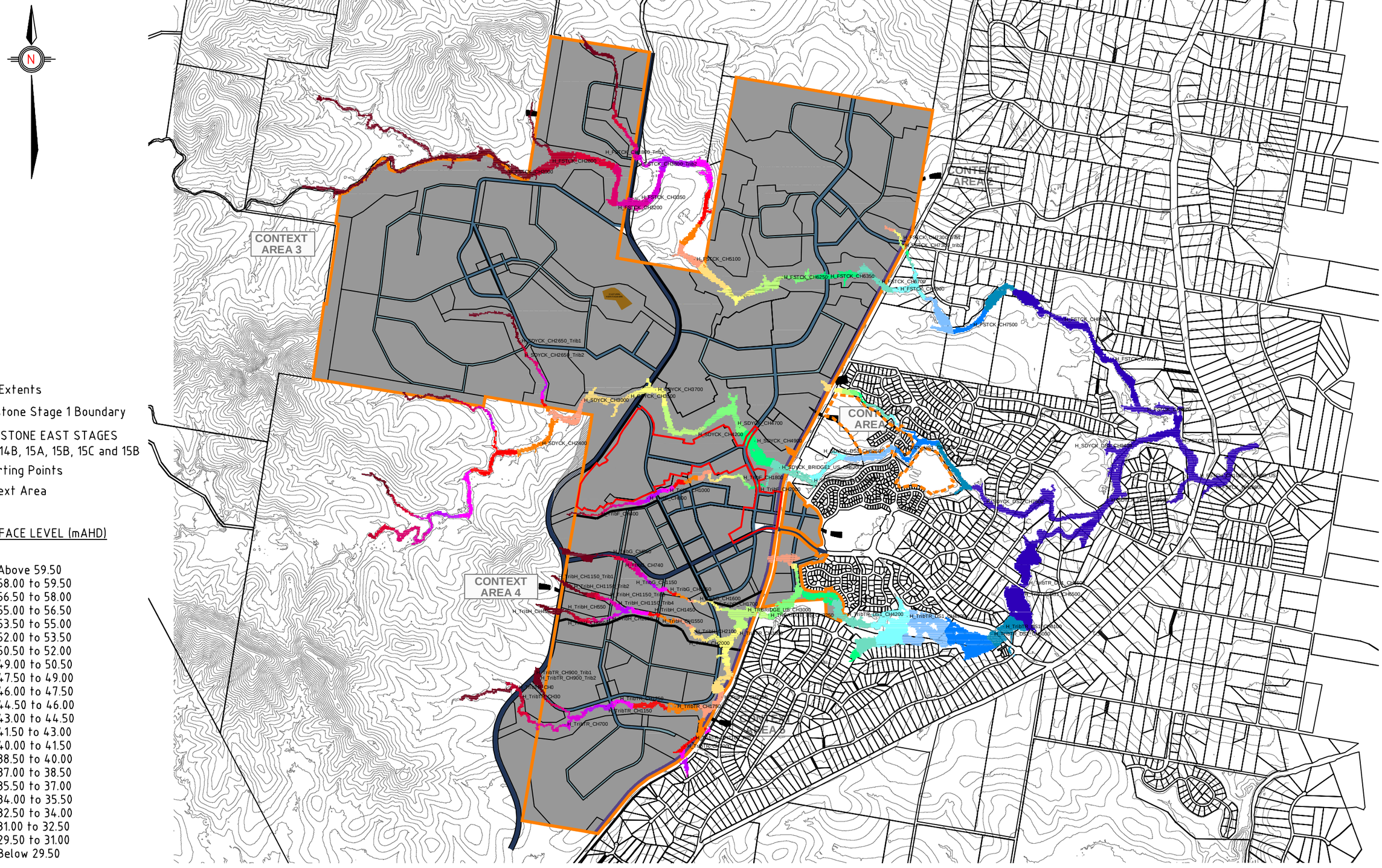
Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_3136\Stage 1 Appendix F.dwg
XREF's: Existing Contours; WSL_Reporting points_All_Points_moved; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

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Scale 1:30000 (A3)

FIGURE F5

5 Year ARI - Post-Development (Stage 1) Case Stg1g - Peak Water Surface Levels

Rev: Orig. **Date: 19 August 2014**

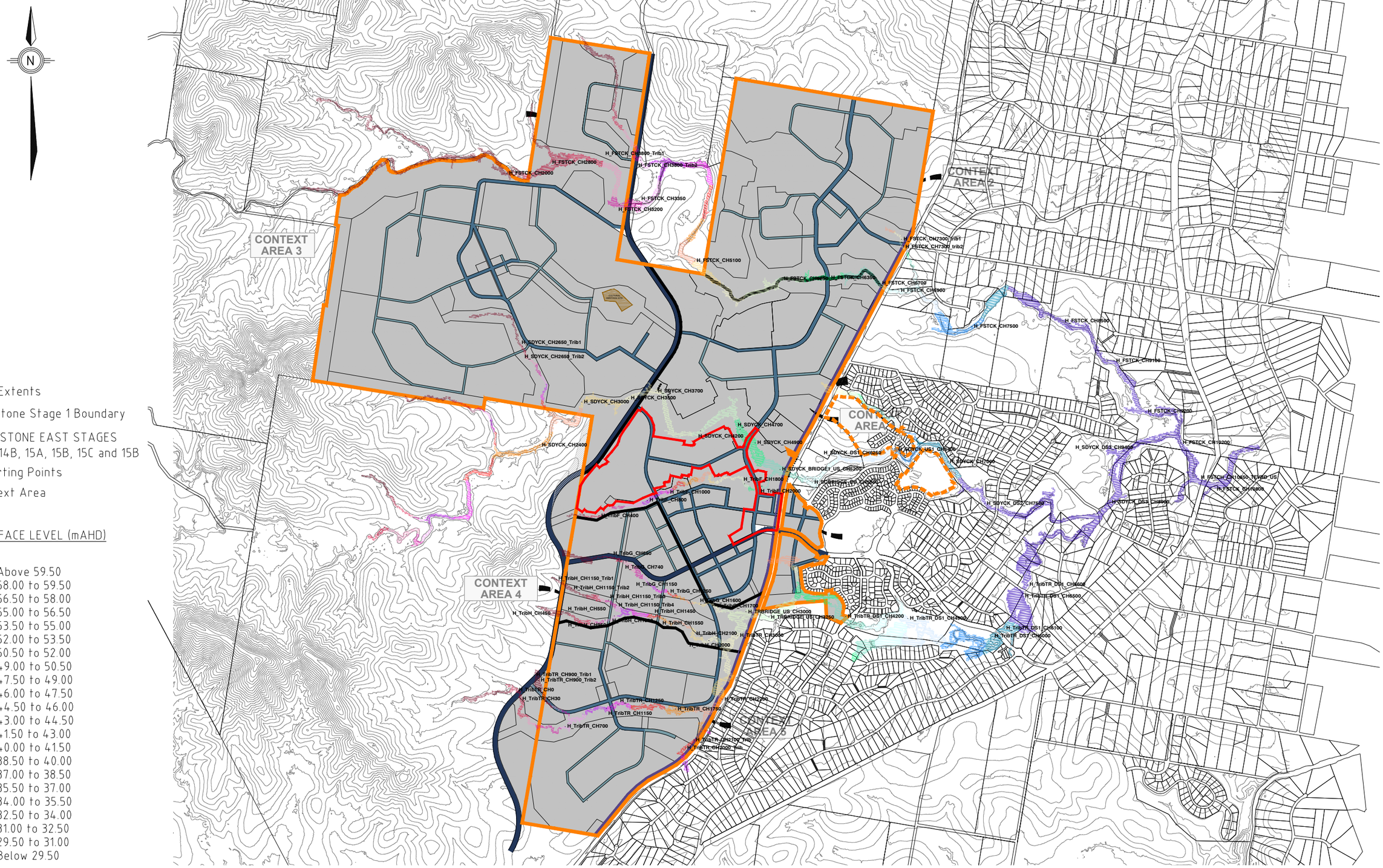
Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: O:\7217-43\Phase03ZFloodingMasterPlan\ACAD\Figures\Stage 1 Appendix F.dwg
XREFs: Existing Contours; WSL_Reporting points_All_Points_moved; TI0056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

PRINT DATE: 05 September, 2014 - 1:39pm

Cardno



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Reporting Points
- Context Area

WATER SURFACE LEVEL (mAHD)

- Above 59.50
- 58.00 to 59.50
- 56.50 to 58.00
- 55.00 to 56.50
- 53.50 to 55.00
- 52.00 to 53.50
- 50.50 to 52.00
- 49.00 to 50.50
- 47.50 to 49.00
- 46.00 to 47.50
- 44.50 to 46.00
- 43.00 to 44.50
- 41.50 to 43.00
- 40.00 to 41.50
- 38.50 to 40.00
- 37.00 to 38.50
- 35.50 to 37.00
- 34.00 to 35.50
- 32.50 to 34.00
- 31.00 to 32.50
- 29.50 to 31.00
- Below 29.50

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300 0 300 600 900 1200 1500m
1:30,000

Scale 1:30000 (A3)

FIGURE F6

2 Year ARI - Post-Development (Stage 1) Case Stg1g - Peak Water Surface Levels

Rev: Orig. Date: 19 August 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_3136\Sfage 1 Appendix F.dwg
XREF's: Existing Contours; WSL_Reporting points_All_Points_moved; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

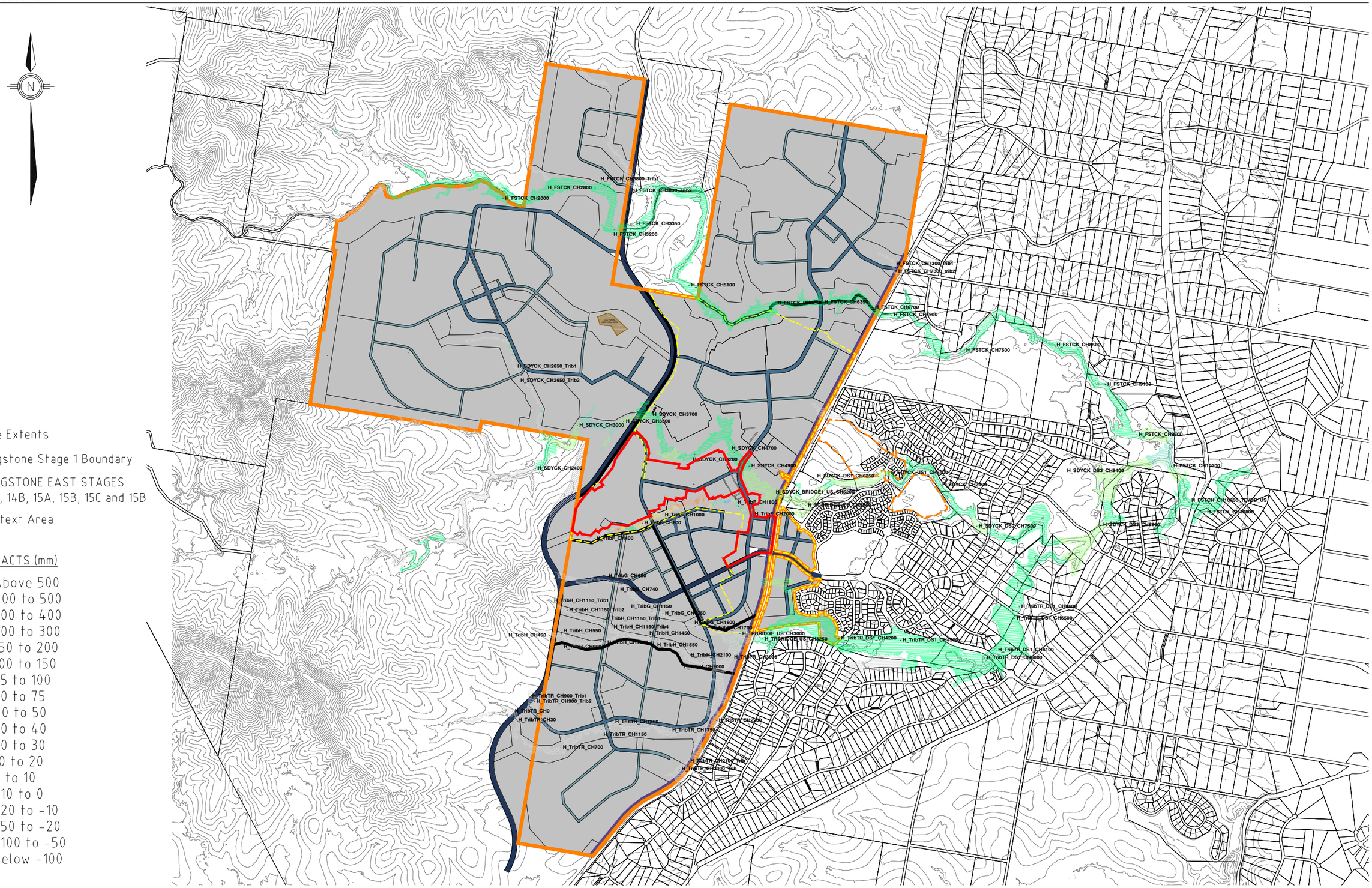
PRINT DATE: 05 September, 2014 - 1:39pm

Flagstone City - Stage 1

APPENDIX G

Pre-Development Predicted Impacts (TUFLOW Results)

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Shaping the Future



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FIGURE G1

100 Year ARI - Post-Development (Stage 1) case Stg1g - Flood Impacts

Rev: Orig. Date: 2 September 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_7680\Sfage 1 Appendix G.dwg
XREF's: Max_WSL_FLAGST_EXG_100Y_E02; Max_DEPTH_EXG_100Y_E02; 110056-73 and 110056-85 combined; WSL_Reporting points_All_Points_moved; Existing Contours; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

PRINT DATE: 05 September, 2014 - 1:01pm

Cardno



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Context Area

FLOOD IMPACTS (mm)

- Above 500
- 400 to 500
- 300 to 400
- 200 to 300
- 150 to 200
- 100 to 150
- 75 to 100
- 50 to 75
- 40 to 50
- 30 to 40
- 20 to 30
- 10 to 20
- 0 to 10
- -10 to 0
- -20 to -10
- -50 to -20
- -100 to -50
- Below -100

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300 0 300 600 900 1200 1500m
1:30,000

Scale 1:30000 (A3)

FIGURE G2

50 Year ARI - Post-Development (Stage 1) case Stg1g - Flood Impacts

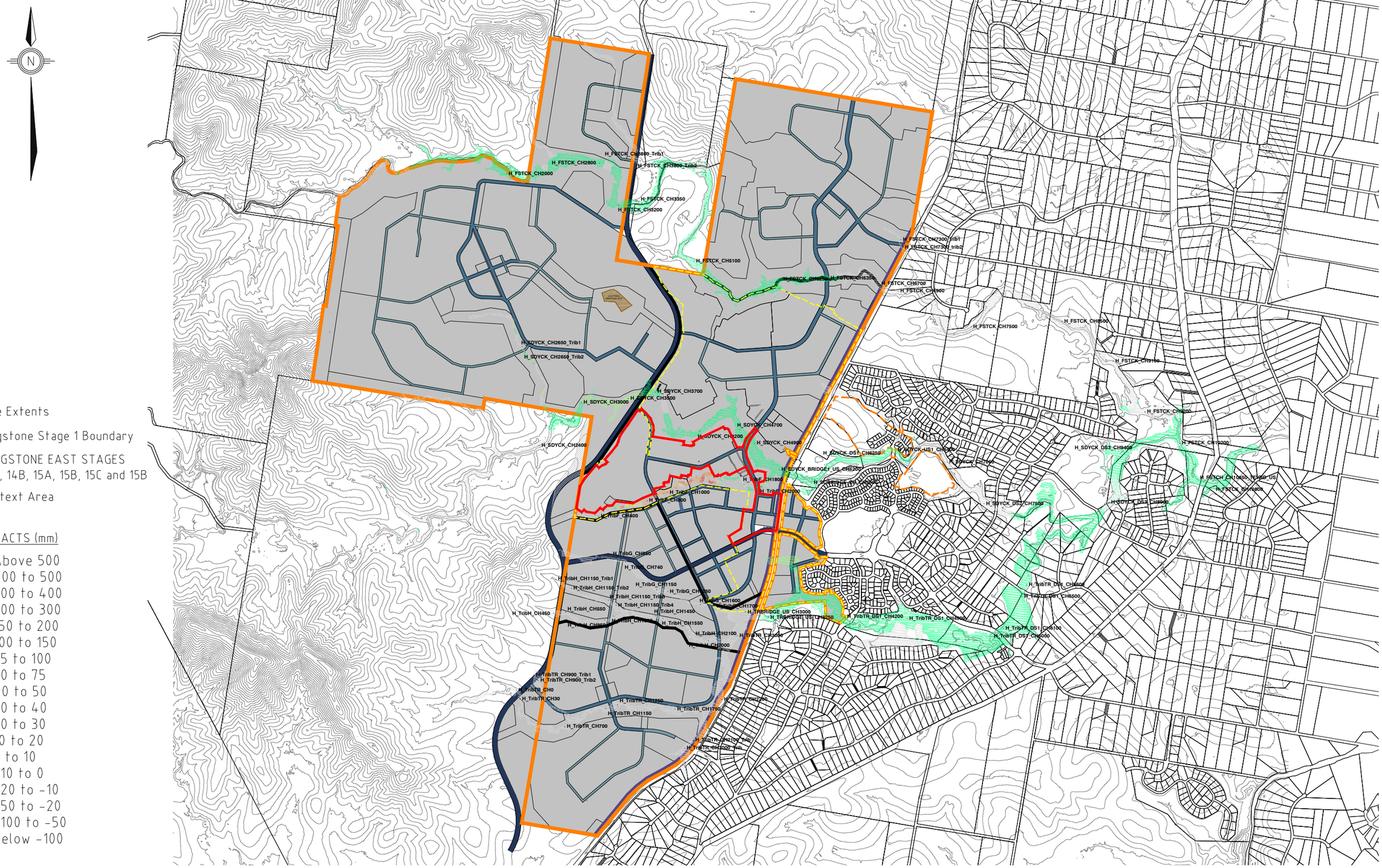
Rev: Orig. Date: 2 September 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

PRINT DATE: 05 September, 2014 - 1:02pm

CAD FILE: C:\Temp\AcPublish_7680\Sfage 1 Appendix G.dwg
XREF's: Max_WSL_FLAGST_EXG_100Y_E02; Max_DEPTH_EXG_100Y_E02; 110056-73 and 110056-85 combined; WSL_Reporting points_All_Points_moved; Existing Contours; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results



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FIGURE G3

20 Year ARI - Post-Development (Stage 1) case Stg1g - Flood Impacts

Rev: Orig. Date: 2 September 2014

Project No.: 7217/43

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CAD FILE: C:\Temp\AcPublish_7680\Sfage 1 Appendix G.dwg
XREF's: Max_WSL_FLAGST_EXG_100Y_E02; Max_DEPTH_EXG_100Y_E02; 110056-73 and 110056-85 combined; WSL_Reporting points_All_Points_moved; Existing Contours; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

PRINT DATE: 05 September, 2014 - 1:02pm

Cardno



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Context Area

FLOOD IMPACTS (mm)

- Above 500
- 400 to 500
- 300 to 400
- 200 to 300
- 150 to 200
- 100 to 150
- 75 to 100
- 50 to 75
- 40 to 50
- 30 to 40
- 20 to 30
- 10 to 20
- 0 to 10
- -10 to 0
- -20 to -10
- -50 to -20
- -100 to -50
- Below -100

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300 0 300 600 900 1200 1500m
1:30,000

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FIGURE G4

10 Year ARI - Post-Development (Stage 1) case Stg1g - Flood Impacts

Rev: Orig. Date: 2 September 2014

Project No.: 7217/43

Peet Flagstone City Pty Ltd

CAD FILE: C:\Temp\AcPublish_7680\Sfage 1 Appendix G.dwg
XREF's: Max_WSL_FLAGST_EXG_100Y_E02; Max_DEPTH_EXG_100Y_E02; 110056-73 and 110056-85 combined; WSL_Reporting points_All_Points_moved; Existing Contours; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

PRINT DATE: 05 September, 2014 - 1:02pm

Cardno



LEGEND

- Site Extents
- Flagstone Stage 1 Boundary
- FLAGSTONE EAST STAGES 14A, 14B, 15A, 15B, 15C and 15B
- Context Area

FLOOD IMPACTS (mm)

- Above 500
- 400 to 500
- 300 to 400
- 200 to 300
- 150 to 200
- 100 to 150
- 75 to 100
- 50 to 75
- 40 to 50
- 30 to 40
- 20 to 30
- 10 to 20
- 0 to 10
- -10 to 0
- -20 to -10
- -50 to -20
- -100 to -50
- Below -100

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300 0 300 600 900 1200 1500m
1:30,000

Scale 1:30000 (A3)

FIGURE G5

5 Year ARI - Post-Development (Stage 1) case Stg1g - Flood Impacts

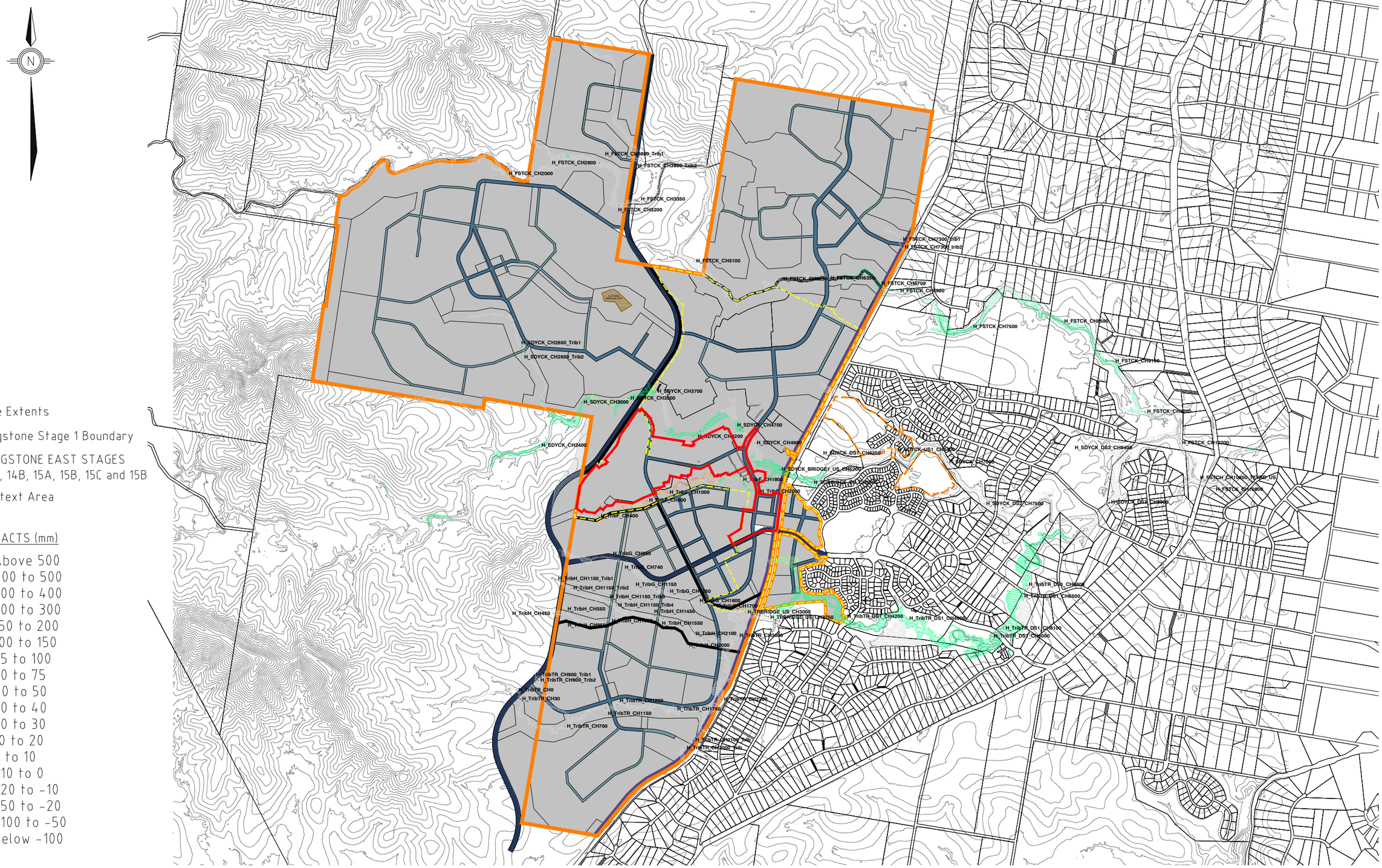
Rev: Orig. Date: 2 September 2014

Project No.: 7217/43

PRINT DATE: 05 September, 2014 - 1:02pm

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CAD FILE: C:\Temp\AcPublish_7680\Stage 1 Appendix G.dwg
XREF's: Max_WSL_FLAGST_EXG_100Y_E02; Max_DEPTH_EXG_100Y_E02; 110056-73 and 110056-85 combined; WSL_Reporting points_All_Points_moved; Existing Contours; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results



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FIGURE G6

2 Year ARI - Post-Development (Stage 1) case Stg1g - Flood Impacts

Rev: Orig. Date: 2 September 2014

Project No.: 7217/43

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CAD FILE: C:\Temp\AcPublish_7680\Sfage 1 Appendix G.dwg
XREF's: Max_WSL_FLAGST_EXG_100Y_E02; Max_DEPTH_EXG_100Y_E02; 110056-73 and 110056-85 combined; WSL_Reporting points_All_Points_moved; Existing Contours; 110056-262-STRUCTURE_OPT2L_grey; FLAGST_10m_Stg1g_DU03J Tuflow_Results

PRINT DATE: 05 September, 2014 - 1:02pm

Flagstone City - Stage 1

APPENDIX H

Post-Development Predicted Impacts (TUFLoW Detailed Results)

Cardno
Shaping the Future

Table H1

Reporting Points - Peak Water Surface Levels and Impacts

Location: O:\7217-43\Phase032FloodingMasterPlan\Excel\Stage 1 Appendix E\Reporting Points Peak WSL_E21e_Stg1g.xlsx

	Post - Developed Peak Water Surface Levels (mAHD)						Pre - Developed Peak Water Surface Levels (mAHD)						Impact (m)					
Reporting point/ARI (Years)	100	50	20	10	5	2	100	50	20	10	5	2	100	50	20	10	5	2
H_SDYCK_DS3_CH9400	24.46	24.22	23.88	23.59	23.36	22.86	24.44	24.2179	23.88	23.59	23.36	22.86	-0.013	0.000	0.000	0.001	0.000	0.002
H_SDYCK_DS3_CH8900	25.91	25.73	25.45	25.21	25.01	24.62	25.89	25.73	25.45	25.21	25.02	24.62	-0.018	0.001	0.000	0.001	0.002	0.001
H_SDYCK_DS2_CH7500	29.59	29.38	29.15	28.89	28.75	28.29	29.58	29.38	29.15	28.89	28.76	28.29	-0.011	0.000	0.000	0.001	0.004	0.002
H_SDYCK_CH7000	31.26	31.06	30.81	30.62	30.38	30.02	31.25	31.06	30.81	30.62	30.38	30.02	-0.008	0.000	0.000	0.001	0.003	0.002
H_SDYCK_US1_CH6400	33.11	32.78	32.58	32.30	32.19	31.68	33.10	32.78	32.58	32.30	32.20	31.68	-0.007	-0.002	0.000	0.000	0.001	0.001
H_SDYCK_DS1_CH6250	34.12	33.94	33.71	33.40	33.20	32.76	34.11	33.95	33.71	33.41	33.21	32.76	-0.013	0.006	-0.001	0.001	0.002	0.002
H_SCBRIDGE_DS_CH5550	36.29	36.08	35.88	35.70	35.52	35.29	36.27	36.07	35.88	35.70	35.52	35.29	-0.015	-0.003	-0.001	0.000	0.001	-0.001
H_SDYCK_BRIDGE1_US_CH5200	37.67	37.46	37.20	36.98	36.81	36.44	37.66	37.45	37.20	36.98	36.81	36.44	-0.018	-0.009	-0.001	-0.001	0.002	-0.001
H_SDYCK_CH4900	38.89	38.70	38.48	38.30	38.15	37.87	38.88	38.70	38.48	38.30	38.16	37.87	-0.009	-0.006	-0.001	0.001	0.006	0.000
H_SDYCK_CH4700	39.41	39.22	38.98	38.79	38.65	38.34	39.40	39.21	38.98	38.79	38.65	38.34	-0.009	-0.006	-0.002	0.001	0.003	0.000
H_SDYCK_CH4200	41.19	40.97	40.67	40.38	40.18	39.81	41.19	40.96	40.67	40.39	40.18	39.81	-0.009	-0.011	-0.005	0.002	0.002	-0.001
H_SDYCK_CH3700	43.19	42.93	42.59	42.34	42.09	41.65	43.19	42.92	42.59	42.35	42.10	41.65	-0.004	-0.002	-0.004	0.002	0.005	-0.001
H_SDYCK_CH3500	44.10	43.85	43.53	43.26	43.04	42.63	44.08	43.83	43.51	43.25	43.04	42.62	-0.017	-0.015	-0.015	-0.010	-0.007	-0.010
H_SDYCK_CH3000	45.84	45.57	45.18	44.93	44.76	44.32	45.83	45.56	45.17	44.93	44.75	44.32	-0.016	-0.007	-0.009	-0.005	-0.003	-0.004
H_SDYCK_CH2650_Trib1	59.70	59.70	59.70	59.70	59.70	59.70	59.70	59.70	59.70	59.70	59.70	59.70	0.000	0.000	0.000	0.000	0.000	0.000
H_SDYCK_CH2650_Trib2	57.40	57.27	57.17	57.21	57.16	57.07	57.40	57.27	57.19	57.21	57.16	57.07	0.000	0.002	0.019	0.000	0.000	0.000
H_SDYCK_CH2400	48.05	47.79	47.45	47.19	46.97	46.51	48.05	47.79	47.45	47.20	46.97	46.51	0.000	0.000	0.002	0.004	0.000	0.000
H_FSTCK_CH10800	21.74	21.47	21.09	20.76	20.47	19.91	21.74	21.47	21.09	20.76	20.47	19.91	-0.005	0.001	0.000	0.000	0.004	-0.001
H_FSTCK_CH10200	23.20	22.94	22.60	22.29	22.01	21.37	23.19	22.94	22.60	22.29	22.01	21.37	-0.006	0.000	0.000	0.001	0.001	0.001
H_FSTCK_CH9700	24.38	24.20	23.96	23.72	23.52	23.20	24.38	24.20	23.96	23.72	23.52	23.20	-0.005	0.000	0.000	0.000	0.001	0.000
H_FSTCK_CH9100	26.07	25.89	25.64	25.42	25.27	24.91	26.07	25.89	25.64	25.42	25.27	24.91	0.000	-0.001	0.001	0.000	0.001	0.000
H_FSTCK_CH8500	28.52	28.29	28.03	27.78	27.56	27.13	28.52	28.29	28.03	27.78	27.56	27.13	0.000	-0.001	0.001	0.001	0.001	0.000
H_FSTCK_CH7500	32.83	32.61	32.32	32.06	31.83	31.45	32.83	32.61	32.32	32.06	31.83	31.45	0.000	-0.001	0.001	0.000	0.002	0.000
H_FSTCK_CH7300_trib1	41.88	41.72	41.62	41.57	41.52	41.42	41.88	41.72	41.62	41.57	41.52	41.42	0.000	0.000	0.000	0.000	0.000	0.000
H_FSTCK_CH7300_trib2	40.70	40.65	40.41	40.36	40.33	40.28	40.70	40.65	40.41	40.36	40.33	40.28	0.000	0.000	0.000	0.000	0.000	0.000
H_FSTCK_CH6900	36.33	36.07	35.76	35.49	35.24	34.78	36.33	36.06	35.76	35.49	35.24	34.78	0.000	0.000	0.001	0.001	0.002	0.000
H_FSTCK_CH6700	37.12	36.85	36.53	36.26	36.02	35.54	37.12	36.85	36.53	36.26	36.02	35.54	0.000	0.000	0.001	0.000	0.002	0.000
H_FSTCK_CH6350	39.19	38.94	38.57	38.29	38.05	37.58	39.19	38.94	38.57	38.30	38.05	37.58	0.000	-0.002	0.000	0.005	0.002	0.000
H_FSTCK_CH6250	39.83	39.58	39.21	38.95	38.73	38.28	39.83	39.58	39.21	38.95	38.74	38.28	0.000	0.000	0.000	0.001	0.005	0.000
H_FSTCK_CH5100	45.65	45.47	45.23	45.02	44.85	44.52	45.65	45.47	45.23	45.01	44.85	44.52	0.000	0.000	0.000	0.000	0.000	0.002
H_FSTCK_CH3800_Trib1	54.37	54.32	54.26	54.20	54.14	53.97	54.37	54.32	54.26	54.20	54.14	53.97	0.000	0.000	0.000	0.000	0.000	0.000
H_FSTCK_CH3800_Trib2	53.51	53.43	53.30	53.21	53.14	53.01	53.51	53.43	53.30	53.21	53.14	53.01	0.000	0.000	0.000	0.000	0.000	0.000
H_FSTCK_CH3350	54.54	54.36	54.10	53.90	53.77	53.48	54.54	54.35	54.10	53.90	53.77	53.48	0.000	-0.001	0.000	0.000	0.000	0.000
H_FSTCK_CH3200	55.67	55.50	55.27	55.09	54.94	54.64	55.67	55.50	55.27	55.09	54.94	54.64	0.000	-0.001	0.000	0.000	0.000	0.000
H_FSTCK_CH2800	57.77	57.59	57.33	57.12	56.95	56.60	57.77	57.59	57.33	57.12	56.95	56.60	0.000	0.000	0.000	0.000	0.000	0.000
H_FSTCK_CH2000	61.22	61.07	60.88	60.70	60.57	60.30	61.22	61.07	60.88	60.70	60.57	60.30	-0.001	0.000	0.000	0.000	0.000	0.000
H_FSTCH_CH10650_TEVRD_US	22.18	21.93	21.57	21.23	20.95	20.38	22.17	21.93	21.57	21.23	20.95	20.38	-0.005	0.001	0.000	0.000	0.003	0.001

Flagstone City - Stage 1

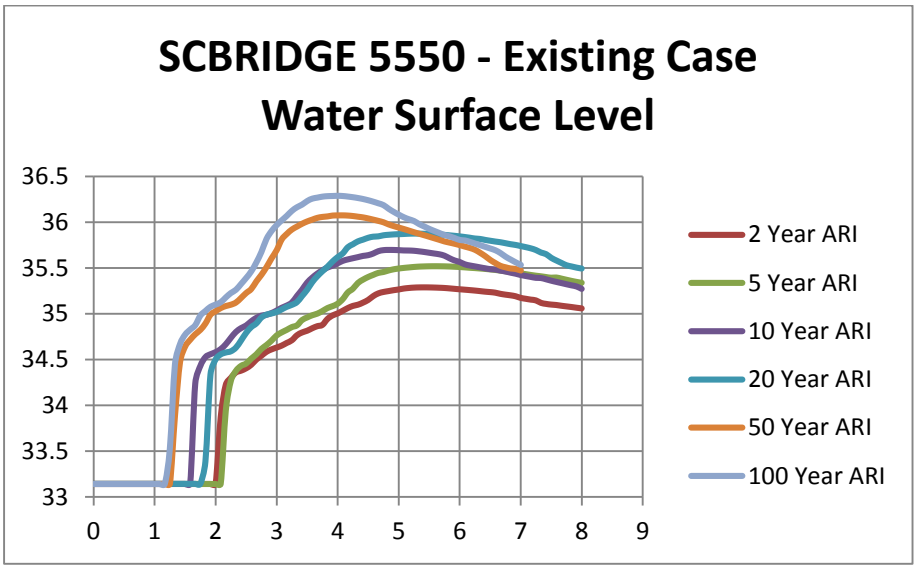
APPENDIX

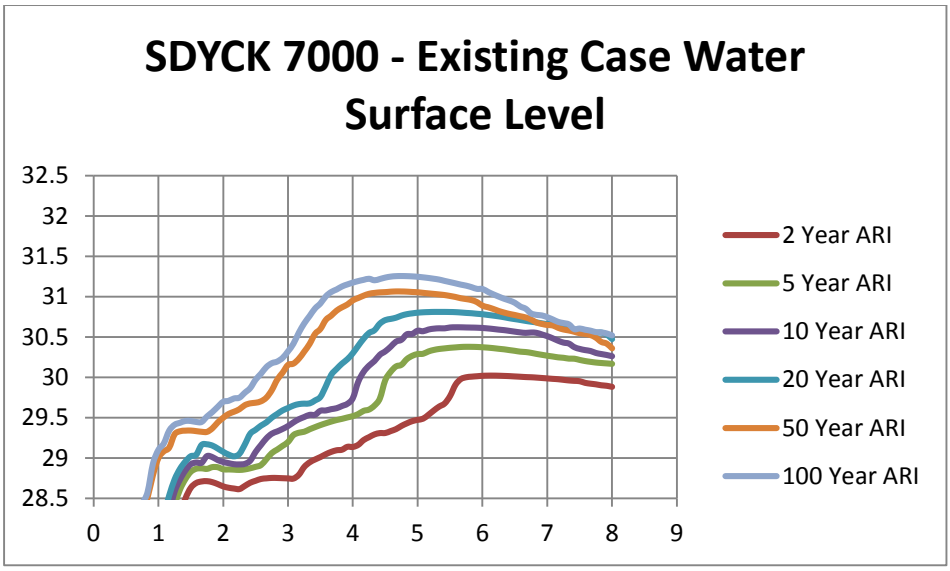
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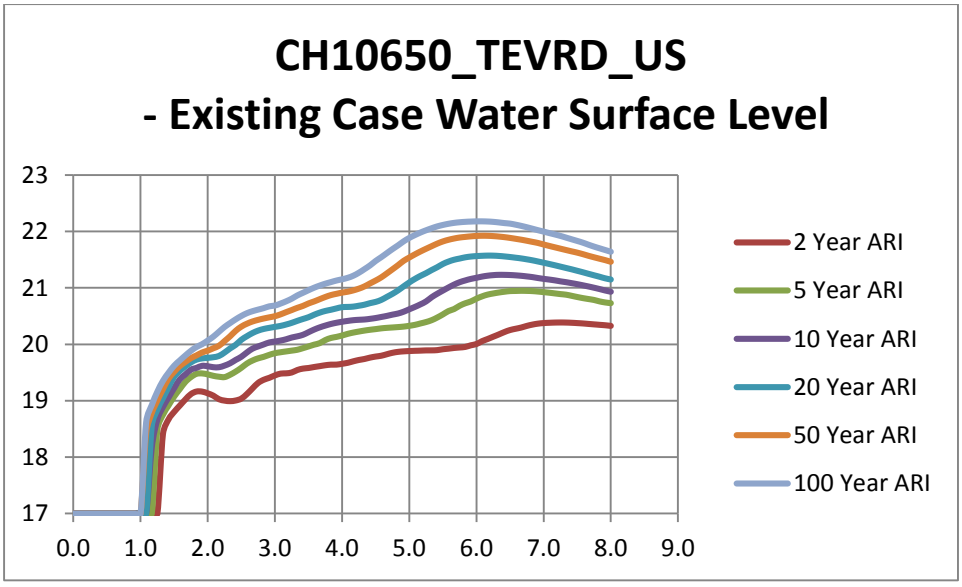
Pre & Post Development Hydrographs

Cardno
Shaping the Future

Pre-Development Time Serious Flood Levels







Post-Development Time Serious Flood Levels

