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Revised Local Flooding and Flood Impact Assessment Cobaki, NSW

Prepared for:
LEDA Manorstead Pty Ltd

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Document control

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Synopsis:	This report describes assessments of local hydrologic conditions within the Cobaki catchment under existing and proposed developed conditions. The report also addresses design of appropriate hydraulic control structures needed to regulate flows within the catchment under developed conditions.	

Revision History

Revision #	Date	Edition By		Approved By	
1	05/11/09	AJF	NIC	NIC	LJV
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Distribution

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Distribution	1	2	3	4	5	6	7	8	9	10
LEDA Manorstead Pty Ltd	1									
G&S library and file	1									

Summary

Gilbert & Sutherland Pty Ltd (G&S) was commissioned by Leda Manorstead Pty Ltd (LEDA) to undertake specialist studies and assessments in support of a Part 3A Project Application. These studies have been undertaken to provide responses to the Director General's Environmental Assessment Requirements for Project Application No. 08_0200, dated November 5, 2008.

This Assessment was revised to consider changes to the design which has been amended in consideration of submissions made to the Project Application. The revised proposal constitutes the Preferred Project Application, which is described elsewhere by JBA Urban Planning.

This report describes assessments of local flooding in the central drain which traverses the site. Details of flooding assessments of the development in relation to the site and in particular in relation to regional flooding in the Lower Tweed River Catchment are detailed in separate reporting.

A hydrologic assessment has been undertaken using the Rational Method and the Watershed Bounded Network Model (WBNM) to estimate peak flows within the site under existing conditions and the impact which the proposed development will have on these flows.

A one-dimensional flood model has been developed for the central drain using Delft Hydraulics model for 1-d flood simulation, SOBEK, to estimate existing local flood levels across the site, to determine the impact of the proposed development on flood levels and flows within the site and to size appropriate flow control structures.

The proposed development has also been assessed against potential climate change impacts for both the local and regional flood events. The sensitivity assessments were based on those outlined in the NSW Department of Environment, Climate Change and water (DECC) publication, 'Practical Consideration of Climate Change', 2007. The scenario used for the sensitivity analysis included the combination of +0.91m rise in sea level and a 10% increase in rainfall intensity over the entire catchment.

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1) Introduction

Gilbert & Sutherland Pty Ltd (G&S) was commissioned by Leda Manorstead Pty Ltd (LEDA) to undertake specialist studies and assessments in support of a Part 3A Project Application. These studies have been undertaken to provide responses to the Director General's Environmental Assessment Requirements (DGRs) for Project Application No. 08_0200, dated November 5, 2008 and to support the associated project application in relation to the management of local flooding.

This revised flood assessment has been undertaken to consider changes resulting from submissions made to the Project Application, and now constitutes the Preferred Project Application.

This report describes assessments of the hydrologic and hydraulic impacts of the proposed Cobaki Lakes development on local flows from the site and along the central site drain, and advice on the design of control structures within this drainage path.

The report comprises two main sections:

- A hydrologic analysis of local catchment flows; and
- A hydraulic assessment of the proposed central open space drainage area.

This assessment has been based on existing survey data and civil design details for the proposed works provided by Yeats Consulting.

2) Site description and proposal

2.1 Location

The site for the proposed development occupies approximately 596ha and is located in Cobaki, immediately south of the NSW/Queensland border and approximately 2km west of the coastal township of Kirra.

The site location is shown on Drawing No. HJ0090.2.1.

2.2 Receiving environment

The land ranges in elevation from approximately RL0m Australian Height Datum (AHD) to approximately RL100m AHD.

The site lies within the Lower Tweed River Basin. Runoff from this development flows via a number of ephemeral gullies to the central drain which traverses the site. The central drain generally flows in a south-easterly direction towards Cobaki Creek, which runs along the south-eastern site boundary, and directly into Cobaki Broadwater. Cobaki Broadwater drains to and adjoins the Tweed River which discharges into the Pacific Ocean at Tweed Heads.

2.3 Existing development

The majority of the site is an extensively cleared closed-swamp complex with areas of grass, sedge and rushland. Some open Eucalyptus forest is concentrated around sections of the south-west edge and northern ridge and there is a scattering of scribbly gums around the natural low sand ridge in the middle and lower eastern parts of the site.

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

2.4 Proposed development

The proposed development involves bulk cut/fill earthworks and the construction of a system of roads to provide access to approximately 3500 residential lots. The balance of the site would be dedicated to open space and land zoned environmental protection.

Given that the present application is for approval of a concept plan, detailed road and allotment layouts have not been completed for the whole of the project, however preliminary bulk earthworks design, site grading and drainage design has been prepared. The proposed concept plan layout is provided in Drawing No. HJ0090.2.2.

The ultimate proposed development includes the construction and/or installation of the following components:

- site earthworks
- roads / trafficable areas
- stormwater drains
- sewer reticulation mains
- water reticulation mains
- underground electricity distribution cables
- telecommunications cables
- other ancillary services
- construction/building works
- landscaping.

3) Hydrologic assessment method

A hydrological assessment was undertaken to develop hydrographs for flows within the site's central drainage catchment, at various points along the central site drain, under a range of rainfall events using the Rational Method and the Watershed Bounded Network Model (WBNM) computer modelling software.

3.1 Rational Method

The Rational Method (Section 4.03 QUDM 2007) is flexible in its data requirements and is able to produce satisfactory estimates of peak discharges from a site with the following data input:

- local intensity frequency duration data
- catchment areas
- runoff coefficients.

Discharge using the Rational Method is calculated by:

$$Q = \frac{F_Y C_{10} I A}{360}$$

where: Q = Peak flow (m^3/s)
F_Y = Frequency factor
C_{10} = Runoff coefficient (10yr)
I = Rainfall intensity (mm/hr)
A = Catchment area (ha)

Peak discharges were estimated for the pre-developed and post-developed case, for the central drain which transects the site and discharges across Sandy Lane near the southern site boundary, for events with average recurrence intervals (ARI) between 1 and 100 years.

3.1.1 Time of concentration

The time of concentration for the pre-developed catchment was calculated using the method for Eastern New South Wales described in Section 1.4.1 in Book 4 of AR&R (1987):

$$t_c = 0.76 A^{0.38}$$

where: t_c = Time of concentration (hours)
A = Area (km^2)

A catchment plan is provided in Drawing No. HJ0090.2.3.

The catchment area draining to the central site drain is 541.4ha, yielding a time of concentration of 86.6minutes.

3.1.2 Local intensity frequency

Rainfall intensities for the simulation of design rainfall events at the site were calculated in accordance with ARR for the site (28°10'30.00"S, 153°28'40.00"E) using the IFD tool on the Bureau of Meteorology website to generate IFD coefficients. A copy of the IFD table generated for Cobaki Lakes is provided in Appendix 1.

3.1.3 Runoff coefficients

The runoff coefficient for the 10 year (C_{10}) average recurrence interval (ARI) was adopted based on recommendations QUDM (2007).

Using Table 4.05.3(b) from QUDM, an average value of 0.68 was calculated for the site under existing conditions.

3.2 WBNM modelling

The Watershed Bounded Network Model (WBNM) is an event-based hydrologic model which calculates flood hydrographs from storm rainfall hyetographs. It can be used for modelling natural, partially developed and fully developed catchments.

For developed catchments, it calculates runoff from pervious and impervious surfaces and routes it through the major system of open water courses. WBNM does not model the details of piped drainage systems. It can be used to generate hydrographs from an actual storm event and or a design storm utilising Intensity – Frequency – Duration data together with dimensionless storm temporal patterns.

The WBNM model is flexible in its data requirements and is able to produce satisfactory results with the following data input:

- local intensity frequency duration data
- design temporal patterns
- sub-catchment areas
- impervious areas.

The model was calibrated by adjusting the model losses and lag parameter (C) values to closely replicate the runoff estimated by using the Rational Formula.

3.2.1 Storm data

The rainfall intensities for the simulation of the design rainfall events were calculated in accordance with Book 2 of Australian Rainfall and Runoff 1998 (AR&R) as described in Section 3.1.2. The temporal patterns used were those provided in Attachment 3.5D of the GCCC Land Development Guidelines, in accordance with the Tweed Shire Council's Development Design Specification D5.

Losses used in the modelling were estimated in order to replicate the flows calculated using the rational method.

Losses were also determined in conjunction with the recommendations contained in the XP-RAFTS reference manual and those published in Australian Rainfall and Runoff 1998, Book 2, Design Rainfall Considerations, Section 3.4.

The losses adopted for this catchment are shown in Table 3.2.1 with different pervious loss rates being adopted for the portion of the site with a sandy sub-soil as infiltration rates will be higher in this area.

3.3 Peak flow site characteristics

The physical characteristics of the catchment were described in Section 2 of this report. In its current state, the catchment may be described as rural, with a total area of 541.4ha.

For the purpose of the modelling, this was divided into a number of sub-catchments representing flows along the main stream and its tributaries.

Table 3.2.1 Model losses

Storm ARI (years)	Pervious Initial loss (mm)		Pervious Continuing loss (mm)	Impervious Initial loss (mm)
	Sand	Balance		
1	30	25	2.5	0.5
2	30	25	2.5	0.5
5	30	25	2.5	0.5
10	30	20	2.5	0.5
20	20	10	2.5	0.5
50	10	5	2.5	0.5
100	0	0	2.5	0.5

4) Hydrologic assessment results

4.1 Rational Method peak flows

The assumptions adopted to determine the peak flow rates discharging from catchment in its present condition are listed below:

- Runoff coefficient C_{10} 0.68
- Time of concentration t_c 86.6min
- Catchment area A 541.4ha

The resultant peak flow rates to the downstream site discharge point of the central drain over the standard ARI events are shown Table 4.1.1.

Table 4.1.1 Pre-developed peak flows by Rational method

ARI (yrs)	$C_Y=F_Y.C_{10}$	I (mm/hr)	Q (m^3/s)
1	0.46	32.4	22.2
2	0.55	41.5	34.4
5	0.63	52.7	49.6
10	0.68	59.1	60.5
20	0.73	67.8	74.2
50	0.80	79.0	94.6
100	0.87	87.6	114.6

4.2 WBNM modelling results

The inputs and assumptions detailed above were incorporated into the WBNM model to generate hydrographs for the subject site.

Peak catchment discharges were estimated for storms with durations ranging from 5 minutes to 2 days for each ARI.

The lag parameter (C) was adjusted and a value of 1.90 was found to produce results that most closely replicated the rational method flows at the downstream end of the catchment for storms with an ARI up to 20 years, with a value of 1.60 found to produce the best results for storms with an ARI greater than 20 years.

The peak flows to the downstream site discharge point of the central drain from the generated hydrographs for the catchment in its present state under a range of rainfall events are shown in Table 4.2.1 for comparison with the peak flows previously determined by the rational method.

Table 4.2.1 Rational method and WBNM modelled peak flow comparison

ARI (years)	Rational method calculated flow (m^3/s)	WBNM modelled flow (m^3/s)
1	22.2	22.0
2	34.4	33.9
5	49.6	50.4
10	60.5	61.4
20	74.2	76.1
50	94.6	96.2
100	114.6	114.7

It is considered that a good correlation was achieved for the model for storm events up to and including the Q100 peak flow rate.

The model was then modified to incorporate the proposed development to generate inflow hydrographs for use in the flood modelling.

Peak flows for the same catchment under developed conditions are shown in Table 4.2.2, below.

Table 4.2.2 WBNM modelled peak flows (developed case)

ARI (years)	Developed WBNM modelled flow (m^3/s)
1	29.2
2	43.7
5	61.8
10	73.6
20	89.1
50	114.9
100	134.2

Design flood flow hydrographs were derived for hydraulic/flood level assessments.

5) Hydraulic assessment

A hydraulic assessment was undertaken to estimate developed flood levels along the central drainage channel and major tributaries within the site under a range of design flood events. The assessment addressed the proposed developed site, (including areas of fill, formalisation of the central drainage channel and inclusion of a number of hydraulic structures at major crossings along Sandy Lane) to ensure that proposed ground levels within the development achieve the necessary level of flood immunity and to aid in the design of the sports field to achieve the specified inundation criteria.

The catchment contributing to the central drainage channel is defined to the north, west and south-west by a ridge which generally aligns with the site boundary. The eastern catchment boundary lies west of Cobaki Parkway as shown on Drawing No. HJ0090.2.3. The central drainage channel discharges across the southern site boundary. Accordingly, no catchments external to the site contribute runoff to the central drainage channel.

Runoff from within the site drains via a number of unnamed ephemeral gullies to the central drainage channel, which runs north-south through the site, discharging to Cobaki Creek. Cobaki Creek runs west to east adjacent to the southern site boundary and discharges into the Cobaki Broadwater.

Proposed structures along the main drainage path includes a bank of culverts at each of the northern and southern Sandy Lane crossings. Proposed culvert crossings for two tributaries, joining the main channel from the west and southwest, have also been included in the modelling.

No flow attenuation devices are proposed for the development as the adjacent creek and estuary system provides a major buffer, and because regional creek and river floods dominate critical flooding at the site.

5.1 Approach

To analyse the proposed development in relation to local flooding, a detailed fully dynamic flood model has been established using the Deltares (formerly the Delft Hydraulics Institute) one dimensional flood modelling package.

The model was setup incorporating the proposed post-development scenario for the site. The analysis presented assesses the development proposed for the Part 3A Project Application (as revised to consider submissions to the Project Application) which includes preliminary finished design gradings for the site.

The approach used in setting up the model is described in the following sections.

5.1.1 Update base model

Previous flood modelling considered the undeveloped site. For this report, the assessment of water levels within the proposed central open space area was revised to consider the revised proposal following submissions to the Project Application. The changes considered included removal of the proposed lake and weir structure, inclusion of a newly-proposed culvert crossing at the northern Sandy Lane, revised fill levels, altered sub-catchment boundaries and other incidental changes. Cross sectional profiles for the main channel and each of the major tributaries were created using ground survey data for the site, supplied by Yeats Consulting Engineers.

Adopted tailwater levels for the model were the Q5 regional flood level (for events with an ARI of 20 years or longer) and the HAT level for smaller, more frequent events, in accordance with industry practice.

5.1.2 Run the model

The updated model was run for a range of design storm events based on flow hydrographs from WBNM for the ARI 1 to 100 year events to establish flood levels.

The updated model was adjusted to incorporate the proposed development based on the Concept Plan supplied by LEDA and channel design details supplied by Yeats Consulting.

The updated model was run for the same flood events as run for the base model described in the previous report. The updated SOBEK model layout is shown on Drawing No. HJ0090.2.4.

5.1.3 Size control structures

The updated model was iteratively adjusted (in conjunction with Yeats Consulting Engineers) by modifying the characteristics of the four culvert crossings under Sandy Lane, to meet the design criteria for land within the main channel floodplain (i.e. sports fields must be elevated no more than 1m below the Q100 flood level) and to ensure that predicted flood levels remain below the roads and development pads adjacent to the central drainage reserve.

5.1.4 Tide and storm tide control structure

The use of engineered tidal floodgates installed on appropriately sized culverts enables tide and storm tides to be controlled, hence managing the extent and duration of site inundation due to tidal influence.

To meet the design objective specified above, culvert configurations as shown on Drawing No HJ0090.2.4 were adopted. For the southern Sandy Lane crossing, the culverts will be fitted with tidal gates to prevent backwater from Cobaki Creek entering the site during normal tide fluctuations and external catchment (i.e. upstream, Cobaki Creek) flood events.

5.2 Results

Estimated Flood inundation levels for the site are shown on Drawing No. HJ0090.2.5. Water surface profiles along the proposed central open space drainage channel are provided in Appendix 2 for the updated model. A summary of peak water surface level, flow and velocity results is also provided in Appendix 2.

In summary, the results demonstrate that for the design flood events, ARI 1 to 100 years, the proposed drainage channel can adequately convey site runoff to the discharge point without inundating the adjacent roads or building areas.

5.3 Climate change impacts

To assess the predicted impacts of future climate change, modifications were made to both the updated model in accordance with the NSW Climate Change Policy, including a 10% increase in rainfall intensity and 0.91m provision for sea level rise.

The 10% increase in rainfall intensity was achieved by increasing the values in the IFD table by 10% and re-running the WBNM model to generate increased flows for input into the SOBEK model. The modified IFD table for climate change is presented in Appendix 1.

The 0.91m provision for sea level rise was included by increasing the external tail water level, both Q5 regional (obtained from the WBM/BMT Tuflow flood model) and HAT by 0.91m, as the site lies within the tidal limit of Cobaki Creek and is therefore subject to sea level rise assessment.

Estimated flood inundation levels for the site, under the predicted climate change scenario are shown on Drawing No. HJ0090.2.6. A water surface profile plot of the peak levels along the main channel, under the predicted climate change scenario, is provided in Appendix 2.

This analysis shows that habitable floor levels remain safe under this extreme upper case scenario.

6) Conclusions

A revised hydrologic and hydraulic analysis of the site has been undertaken to examine local flooding and flood impacts along the central site drain at Cobaki Lakes and to assist in the design of hydraulic control structures, at each major road crossing within the site.

This assessment demonstrates that the proposed development is viable in terms of local flooding and site runoff can be satisfactorily managed within the central drainage channel for all flows up to and including the Q100 storm event.

The results of the assessment also indicate that under the proposed climate change scenario, habitable floor levels would remain safe during the proposed Q100 peak event.

7) Qualification

This report has been prepared by G&S specifically for LEDA Manorstead Pty Ltd to provide advice on flooding in relation to the Project Application for the Cobaki Lakes development, located in Cobaki, NSW. As such its use is limited to this purpose and may not be applicable beyond this scope. Third parties should therefore seek advice from G&S on applicability for any other use.

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

- Site survey supplied by Yeats Consulting
- Site Plan prepared by Yeats Consulting
- Regional Flood Assessment prepared by Aurecon.

The accuracy of this report is limited to the accuracy of this information. While G&S's report accurately assesses flooding from design storms, future observed flood levels may vary from the predicted, depending on the accuracy of rainfall/runoff.

Our analysis and overall approach has been specifically to cater for the particular requirements of LEDA and may not be applicable beyond this scope. For this reason any third parties are not authorised to utilise the report without further input and advice from G&S.

8) Appendix 1 – IFD tables for Cobaki Lakes

Rainfall IFD for Cobaki Lakes, Cobaki
Geographic Location: 28°10'30.00"S 153°28'40.00"E

Generated from BOM online IFD coefficients 3/08/2009

Duration (mins)	1 Year ARI (mm/hour)	2 Year ARI (mm/hour)	5 Year ARI (mm/hour)	10 Year ARI (mm/hour)	20 Year ARI (mm/hour)	50 Year ARI (mm/hour)	100 Year ARI (mm/hour)
5	130.12	164.43	201.06	221.18	249.31	285.46	312.45
5.5	125.85	159.08	194.63	214.16	241.42	276.46	302.70
6	121.96	154.20	188.79	207.81	234.31	268.39	293.95
6.5	118.40	149.74	183.47	202.03	227.86	261.08	286.03
7	115.13	145.64	178.58	196.74	221.96	254.41	278.80
7.5	112.11	141.86	174.08	191.86	216.52	248.28	272.16
8	109.31	138.35	169.90	187.34	211.50	242.60	266.01
8.5	106.70	135.09	166.01	183.14	206.82	237.33	260.30
9	104.26	132.03	162.38	179.21	202.46	232.41	254.97
9.5	101.98	129.18	158.98	175.53	198.37	227.80	249.97
10	99.84	126.49	155.78	172.07	194.52	223.47	245.27
11	95.91	121.56	149.91	165.72	187.46	215.51	236.64
12	92.38	117.15	144.64	160.02	181.12	208.36	228.88
13	89.20	113.16	139.88	154.86	175.38	201.88	221.84
14	86.30	109.52	135.53	150.15	170.13	195.95	215.41
15	83.65	106.19	131.55	145.82	165.31	190.50	209.49
16	81.21	103.13	127.88	141.83	160.86	185.47	204.01
17	78.95	100.30	124.47	138.13	156.73	180.79	198.92
18	76.86	97.66	121.31	134.69	152.88	176.43	194.18
19	74.90	95.21	118.36	131.47	149.28	172.35	189.74
20	73.07	92.91	115.59	128.45	145.91	168.52	185.57
21	71.36	90.75	112.99	125.61	142.73	164.92	181.64
22	69.75	88.72	110.54	122.94	139.73	161.51	177.93
23	68.23	86.81	108.23	120.41	136.90	158.29	174.41
24	66.79	85.00	106.04	118.02	134.22	155.24	171.08
25	65.43	83.28	103.96	115.74	131.67	152.34	167.92
26	64.13	81.66	101.99	113.58	129.24	149.57	164.90
27	62.91	80.11	100.11	111.52	126.93	146.94	162.02
28	61.73	78.63	98.32	109.56	124.72	144.42	159.28
29	60.62	77.22	96.61	107.68	122.61	142.02	156.65
30	59.55	75.88	94.98	105.89	120.59	139.71	154.13
32	57.55	73.36	91.91	102.52	116.80	135.38	149.40
34	55.72	71.04	89.08	99.41	113.30	131.38	145.02
36	54.02	68.90	86.47	96.53	110.06	127.67	140.96
38	52.44	66.91	84.04	93.85	107.04	124.22	137.18
40	50.98	65.06	81.77	91.36	104.23	120.99	133.65
45	47.72	60.94	76.72	85.78	97.94	113.78	125.74
50	44.93	57.41	72.38	80.99	92.52	107.56	118.92
55	42.51	54.34	68.61	76.81	87.79	102.12	112.96
60	40.38	51.64	65.28	73.13	83.62	97.33	107.70
75	35.29	45.19	57.29	64.27	73.58	85.75	94.98
90	31.52	40.40	51.33	57.65	66.07	77.08	85.45
105	28.59	36.68	46.69	52.49	60.20	70.31	77.98
120	26.25	33.69	42.96	48.33	55.48	64.84	71.96
135	24.32	31.24	39.89	44.91	51.57	60.32	66.97
150	22.71	29.18	37.31	42.02	48.29	56.52	62.78
165	21.33	27.43	35.10	39.56	45.49	53.26	59.19
180	20.14	25.91	33.20	37.44	43.06	50.44	56.07
195	19.11	24.59	31.53	35.57	40.93	47.98	53.35
210	18.20	23.42	30.06	33.93	39.06	45.79	50.94
225	17.39	22.39	28.75	32.46	37.39	43.85	48.79
240	16.66	21.46	27.58	31.15	35.89	42.11	46.86
270	15.42	19.87	25.56	28.89	33.30	39.10	43.53
300	14.38	18.55	23.89	27.02	31.15	36.60	40.76
360	12.77	16.48	21.26	24.07	27.77	32.66	36.39
420	11.56	14.92	19.28	21.84	25.23	29.68	33.09
480	10.61	13.71	17.73	20.10	23.22	27.34	30.50
540	9.85	12.73	16.48	18.69	21.61	25.45	28.40
600	9.23	11.93	15.45	17.53	20.27	23.88	26.66
660	8.70	11.25	14.58	16.55	19.14	22.56	25.18
720	8.25	10.67	13.84	15.71	18.17	21.42	23.92
840	7.52	9.73	12.62	14.34	16.59	19.57	21.86
960	6.95	8.99	11.67	13.26	15.35	18.11	20.23
1080	6.48	8.39	10.90	12.39	14.34	16.93	18.91
1200	6.10	7.89	10.26	11.66	13.50	15.94	17.81
1320	5.78	7.47	9.72	11.05	12.79	15.10	16.87
1440	5.50	7.11	9.25	10.51	12.17	14.37	16.06
1800	4.84	6.26	8.15	9.26	10.72	12.66	14.15
2160	4.36	5.64	7.34	8.34	9.65	11.40	12.74
2520	3.98	5.15	6.70	7.61	8.82	10.40	11.63
2880	3.67	4.74	6.17	7.02	8.13	9.59	10.72
3240	3.40	4.40	5.73	6.52	7.54	8.90	9.95
3600	3.17	4.10	5.34	6.08	7.04	8.31	9.28
3960	2.97	3.84	5.00	5.69	6.59	7.78	8.70
4320	2.79	3.61	4.70	5.35	6.20	7.31	8.17

Rainfall IFD for Cobaki Lakes incorporating predicted 10% increase in rainfall intensity under Climate Change
Geographic Location: 28°10'30.00"S 153°28'40.00"E

Generated from BOM online IFD coefficients 3/08/2009

Duration (mins)	1 Year ARI (mm/hour)	2 Year ARI (mm/hour)	5 Year ARI (mm/hour)	10 Year ARI (mm/hour)	20 Year ARI (mm/hour)	50 Year ARI (mm/hour)	100 Year ARI (mm/hour)
5	143.14	180.88	221.16	243.30	274.24	314.00	343.70
5.5	138.44	174.98	214.09	235.58	265.56	304.11	332.97
6	134.16	169.62	207.67	228.59	257.74	295.23	323.35
6.5	130.24	164.72	201.82	222.24	250.65	287.19	314.64
7	126.65	160.21	196.44	216.41	244.15	279.85	306.68
7.5	123.32	156.05	191.48	211.04	238.18	273.10	299.37
8	120.24	152.19	186.89	206.07	232.65	266.86	292.61
8.5	117.37	148.59	182.61	201.45	227.50	261.07	286.33
9	114.69	145.24	178.62	197.13	222.70	255.66	280.46
9.5	112.18	142.09	174.87	193.08	218.20	250.58	274.97
10	109.82	139.14	171.35	189.28	213.97	245.82	269.80
11	105.50	133.72	164.90	182.30	206.21	237.07	260.31
12	101.62	128.86	159.11	176.02	199.24	229.20	251.77
13	98.12	124.47	153.86	170.34	192.91	222.06	244.03
14	94.93	120.48	149.08	165.16	187.14	215.55	236.95
15	92.01	116.81	144.70	160.41	181.84	209.55	230.43
16	89.33	113.44	140.66	156.02	176.94	204.02	224.41
17	86.85	110.33	136.92	151.95	172.40	198.87	218.82
18	84.54	107.43	133.44	148.16	168.17	194.08	213.60
19	82.39	104.73	130.19	144.62	164.21	189.59	208.71
20	80.38	102.20	127.15	141.30	160.50	185.38	204.12
21	78.50	99.83	124.29	138.18	157.00	181.41	199.80
22	76.72	97.60	121.60	135.23	153.71	177.67	195.72
23	75.05	95.49	119.05	132.45	150.59	174.12	191.86
24	73.47	93.50	116.64	129.82	147.64	170.76	188.19
25	71.97	91.61	114.36	127.32	144.83	167.57	184.71
26	70.55	89.82	112.19	124.94	142.17	164.53	181.39
27	69.20	88.12	110.12	122.68	139.62	161.63	178.23
28	67.91	86.49	108.15	120.52	137.20	158.87	175.20
29	66.68	84.95	106.27	118.45	134.88	156.22	172.31
30	65.51	83.47	104.47	116.48	132.65	153.68	169.54
32	63.31	80.69	101.10	112.77	128.48	148.92	164.33
34	61.29	78.14	97.99	109.35	124.63	144.52	159.52
36	59.42	75.79	95.11	106.18	121.07	140.44	155.06
38	57.69	73.60	92.44	103.24	117.75	136.64	150.90
40	56.08	71.56	89.95	100.49	114.65	133.09	147.01
45	52.49	67.03	84.39	94.36	107.73	125.16	138.32
50	49.42	63.15	79.62	89.09	101.77	118.31	130.82
55	46.76	59.77	75.47	84.49	96.57	112.34	124.26
60	44.42	56.81	71.81	80.44	91.98	107.06	118.47
75	38.82	49.71	63.02	70.69	80.94	94.33	104.48
90	34.67	44.44	56.47	63.41	72.67	84.79	93.99
105	31.45	40.34	51.36	57.74	66.22	77.34	85.78
120	28.87	37.06	47.26	53.17	61.02	71.32	79.15
135	26.75	34.36	43.88	49.40	56.73	66.35	73.67
150	24.98	32.10	41.04	46.23	53.12	62.17	69.05
165	23.46	30.17	38.61	43.52	50.04	58.59	65.10
180	22.16	28.50	36.52	41.18	47.37	55.49	61.68
195	21.02	27.05	34.68	39.13	45.03	52.77	58.68
210	20.02	25.77	33.07	37.32	42.96	50.37	56.03
225	19.12	24.63	31.63	35.71	41.12	48.24	53.66
240	18.33	23.61	30.34	34.27	39.47	46.32	51.54
270	16.96	21.86	28.12	31.78	36.63	43.01	47.88
300	15.82	20.40	26.28	29.72	34.27	40.26	44.84
360	14.05	18.13	23.38	26.47	30.55	35.92	40.03
420	12.72	16.42	21.21	24.03	27.75	32.65	36.40
480	11.68	15.08	19.50	22.11	25.55	30.08	33.55
540	10.84	14.01	18.13	20.56	23.77	28.00	31.24
600	10.15	13.12	16.99	19.28	22.30	26.27	29.32
660	9.57	12.37	16.04	18.20	21.05	24.82	27.70
720	9.08	11.74	15.22	17.28	19.99	23.57	26.31
840	8.27	10.70	13.89	15.77	18.25	21.53	24.04
960	7.64	9.89	12.84	14.59	16.89	19.92	22.26
1080	7.13	9.23	11.99	13.63	15.78	18.62	20.80
1200	6.71	8.68	11.29	12.83	14.86	17.53	19.59
1320	6.35	8.22	10.69	12.15	14.07	16.61	18.56
1440	6.05	7.82	10.18	11.57	13.39	15.81	17.67
1800	5.32	6.89	8.96	10.19	11.80	13.92	15.56
2160	4.79	6.20	8.07	9.17	10.62	12.54	14.01
2520	4.37	5.66	7.37	8.38	9.70	11.45	12.79
2880	4.03	5.22	6.79	7.72	8.94	10.55	11.79
3240	3.74	4.84	6.30	7.17	8.30	9.79	10.94
3600	3.49	4.51	5.88	6.69	7.74	9.14	10.21
3960	3.27	4.23	5.50	6.26	7.25	8.56	9.57
4320	3.07	3.97	5.17	5.88	6.81	8.05	8.99

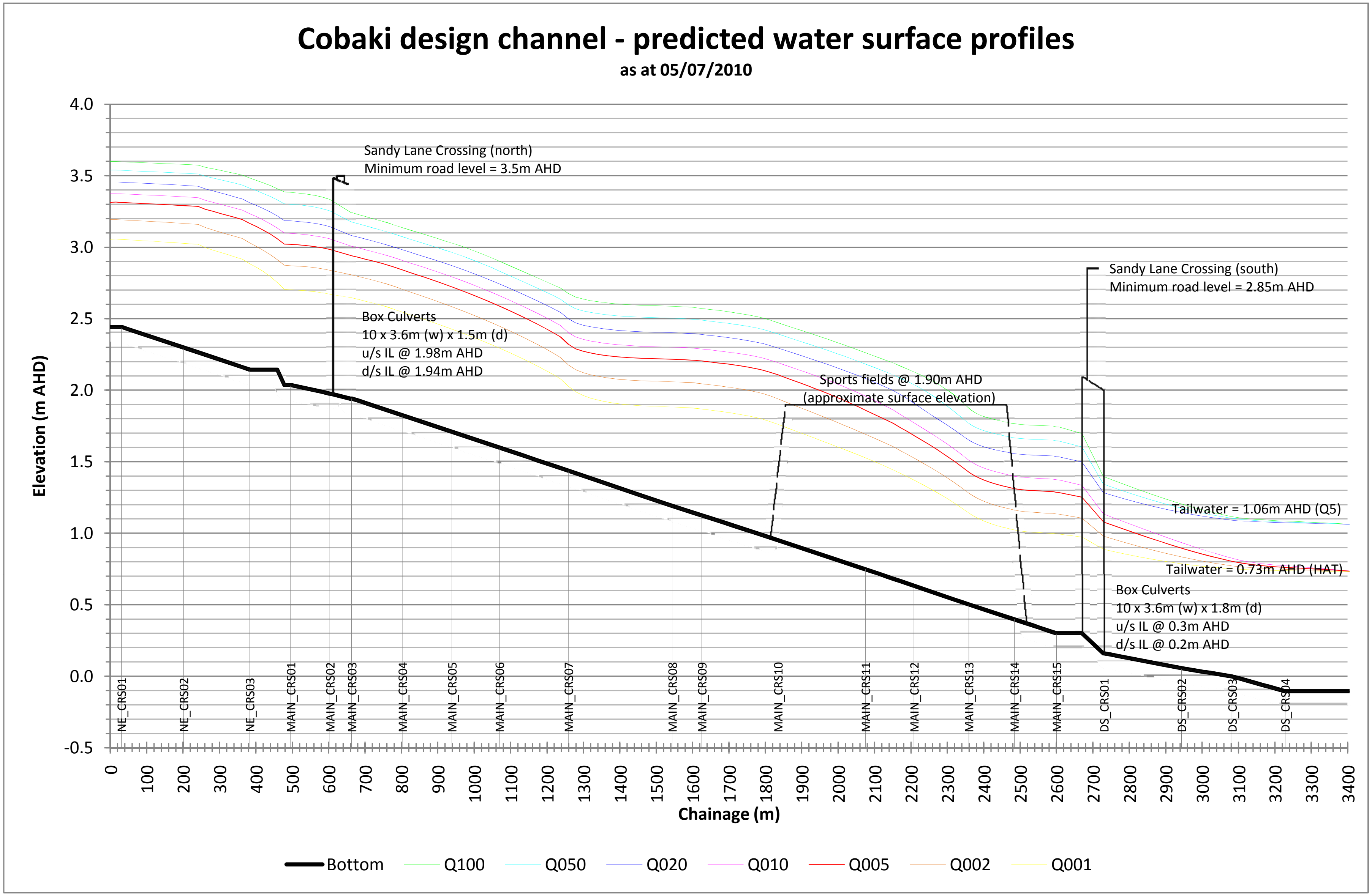
9) Appendix 2 – SOBEK Model results

Job No.	HJ0090-1
Project:	Cobaki Lakes local flood assessment
Date:	7/07/2010
Description:	Water surface elevations in channel (under ordinary conditions)
	Tailwater conditions:
	Q5 regional tailwater (RL 1.06m) for ARI ≥ 20 years
	HAT tailwater (RL 0.73m) for ARI < 20years

	Average Recurrence Interval, ARI (years)						
Cross Section ID	**100y**	**50y**	**20y**	**10y**	**5y**	**2y**	**1y**
North-Western Tributary							
NW_CRS01	7.495	7.429	7.343	7.281	7.227	7.134	7.045
NW_CRS02	5.143	5.078	4.988	4.925	4.873	4.778	4.687
NW_CRS03	3.942	3.888	3.808	3.749	3.690	3.570	3.458
North-Eastern Tributary							
NE_CRS01	3.597	3.537	3.454	3.373	3.312	3.190	3.054
NE_CRS02	3.578	3.517	3.432	3.352	3.290	3.166	3.027
NE_CRS03	3.483	3.412	3.310	3.233	3.166	3.029	2.885
Main Channel							
MAIN_CRS01	3.383	3.300	3.184	3.096	3.020	2.871	2.702
MAIN_CRS02	3.334	3.254	3.143	3.058	2.984	2.839	2.671
MAIN_CRS03	3.241	3.176	3.081	3.007	2.940	2.806	2.646
MAIN_CRS04	3.137	3.073	2.982	2.908	2.841	2.706	2.546
MAIN_CRS05	3.028	2.963	2.870	2.792	2.722	2.583	2.426
MAIN_CRS06	2.902	2.833	2.743	2.661	2.588	2.448	2.295
MAIN_CRS07	2.677	2.596	2.500	2.404	2.322	2.178	2.027
MAIN_CRS08	2.586	2.503	2.402	2.301	2.216	2.058	1.883
MAIN_CRS09	2.572	2.489	2.389	2.288	2.204	2.045	1.869
MAIN_CRS10	2.472	2.393	2.295	2.193	2.107	1.939	1.761
MAIN_CRS11	2.262	2.183	2.082	1.959	1.860	1.692	1.526
MAIN_CRS12	2.129	2.038	1.910	1.771	1.683	1.526	1.371
MAIN_CRS13	1.874	1.768	1.651	1.511	1.427	1.281	1.142
MAIN_CRS14	1.764	1.666	1.556	1.398	1.312	1.161	1.022
MAIN_CRS15	1.743	1.645	1.535	1.373	1.286	1.135	0.996
Western Tributary							
W_CRS01	2.617	2.532	2.432	2.332	2.255	2.122	2.002
W_CRS02	2.601	2.517	2.410	2.308	2.223	2.065	1.891
W_CRS03	2.595	2.511	2.406	2.305	2.220	2.063	1.889
South-Western Tributary							
SW_CRS01	2.461	2.369	2.269	2.152	2.051	1.854	1.641
SW_CRS02	2.423	2.331	2.233	2.116	2.015	1.821	1.610
SW_CRS03	2.365	2.274	2.176	2.058	1.954	1.759	1.548
SW_CRS04	2.145	2.089	2.023	1.926	1.833	1.660	1.470
SW_CRS05	2.074	2.012	1.934	1.818	1.735	1.568	1.386
SW_CRS06	1.991	1.912	1.822	1.712	1.630	1.470	1.298
Downstream of Sandy Lane							
DS_CRS01	1.395	1.341	1.282	1.134	1.078	0.979	0.887
DS_CRS02	1.204	1.174	1.144	0.934	0.896	0.834	0.786
DS_CRS03	1.116	1.103	1.091	0.825	0.803	0.772	0.751
DS_CRS04	1.085	1.079	1.073	0.773	0.762	0.747	0.738

Job No. HJ0090-1
Project: Cobaki Lakes local flood assessment
Date: 7/07/2010
Description: Water surface elevations in channel incorporating Climate Change adaptations for sea level rise (0.91m increase in tailwater level) and increased rainfall intensity (+30%)
Tailwater conditions:
Adjusted regional Q5 tailwater (RL 1.97m) for ARI ≥ 20 years
Adjusted HAT tailwater (RL 0.73m) for ARI < 20years

	Average Recurrence Interval, ARI (years)						
Cross Section ID	**100y_CC**	**50y_CC**	**20y_CC**	**10y_CC**	**5y_CC**	**2y_CC**	**1y_CC**
North-Western Tributary							
NW_CRS01	7.544	7.476	7.383	7.319	7.265	7.169	7.078
NW_CRS02	5.187	5.126	5.027	4.964	4.910	4.812	4.721
NW_CRS03	3.982	3.927	3.843	3.787	3.732	3.614	3.500
North-Eastern Tributary							
NE_CRS01	3.641	3.582	3.498	3.416	3.357	3.238	3.108
NE_CRS02	3.623	3.563	3.477	3.395	3.336	3.214	3.082
NE_CRS03	3.537	3.466	3.361	3.282	3.216	3.082	2.940
Main Channel							
MAIN_CRS01	3.446	3.363	3.242	3.151	3.075	2.929	2.769
MAIN_CRS02	3.395	3.315	3.200	3.112	3.039	2.896	2.738
MAIN_CRS03	3.293	3.227	3.131	3.054	2.989	2.859	2.711
MAIN_CRS04	3.189	3.126	3.033	2.955	2.891	2.761	2.613
MAIN_CRS05	3.086	3.021	2.929	2.843	2.776	2.642	2.494
MAIN_CRS06	2.972	2.903	2.812	2.717	2.648	2.511	2.367
MAIN_CRS07	2.787	2.709	2.610	2.481	2.405	2.266	2.129
MAIN_CRS08	2.715	2.635	2.535	2.390	2.313	2.174	2.033
MAIN_CRS09	2.702	2.623	2.523	2.378	2.302	2.163	2.023
MAIN_CRS10	2.618	2.543	2.449	2.293	2.220	2.084	1.947
MAIN_CRS11	2.473	2.400	2.315	2.116	2.048	1.918	1.811
MAIN_CRS12	2.411	2.337	2.254	2.007	1.937	1.827	1.748
MAIN_CRS13	2.340	2.264	2.185	1.860	1.812	1.744	1.697
MAIN_CRS14	2.301	2.227	2.153	1.820	1.780	1.725	1.687
MAIN_CRS15	2.292	2.219	2.147	1.813	1.774	1.721	1.684
Western Tributary							
W_CRS01	2.743	2.662	2.558	2.415	2.338	2.204	2.079
W_CRS02	2.730	2.649	2.543	2.397	2.320	2.180	2.038
W_CRS03	2.723	2.642	2.539	2.394	2.317	2.178	2.037
South-Western Tributary							
SW_CRS01	2.615	2.490	2.421	2.252	2.178	2.033	1.892
SW_CRS02	2.585	2.460	2.394	2.221	2.150	2.011	1.877
SW_CRS03	2.545	2.417	2.355	2.174	2.105	1.974	1.849
SW_CRS04	2.349	2.278	2.215	2.047	2.000	1.900	1.801
SW_CRS05	2.336	2.263	2.194	1.993	1.945	1.852	1.768
SW_CRS06	2.320	2.247	2.176	1.936	1.886	1.808	1.740
Downstream of Sandy Lane							
DS_CRS01	2.016	2.006	2.000	1.679	1.670	1.663	1.658
DS_CRS02	2.000	1.998	1.996	1.661	1.657	1.654	1.653
DS_CRS03	1.992	1.992	1.992	1.653	1.653	1.653	1.652
DS_CRS04	1.989	1.989	1.989	1.653	1.653	1.653	1.653


Cobaki design channel - predicted water surface profiles
as at 05/07/2010
Elevation (m AHD)
Chainage (m)
Sandy Lane Crossing (north)
Minimum road level = 3.5m AHD
Box Culverts
10 x 3.6m (w) x 1.5m (d)
u/s IL @ 1.98m AHD
d/s IL @ 1.94m AHD
Sports fields @ 1.90m AHD
(approximate surface elevation)
Sandy Lane Crossing (south)
Minimum road level = 2.85m AHD
Tailwater = 1.06m AHD (Q5)
Tailwater = 0.73m AHD (HAT)
Box Culverts
10 x 3.6m (w) x 1.8m (d)
u/s IL @ 0.3m AHD
d/s IL @ 0.2m AHD
NE_CRS01
NE_CRS02
NE_CRS03
MAIN_CRS01
MAIN_CRS02
MAIN_CRS03
MAIN_CRS04
MAIN_CRS05
MAIN_CRS06
MAIN_CRS07
MAIN_CRS08
MAIN_CRS09
MAIN_CRS10
MAIN_CRS11
MAIN_CRS12
MAIN_CRS13
MAIN_CRS14
MAIN_CRS15
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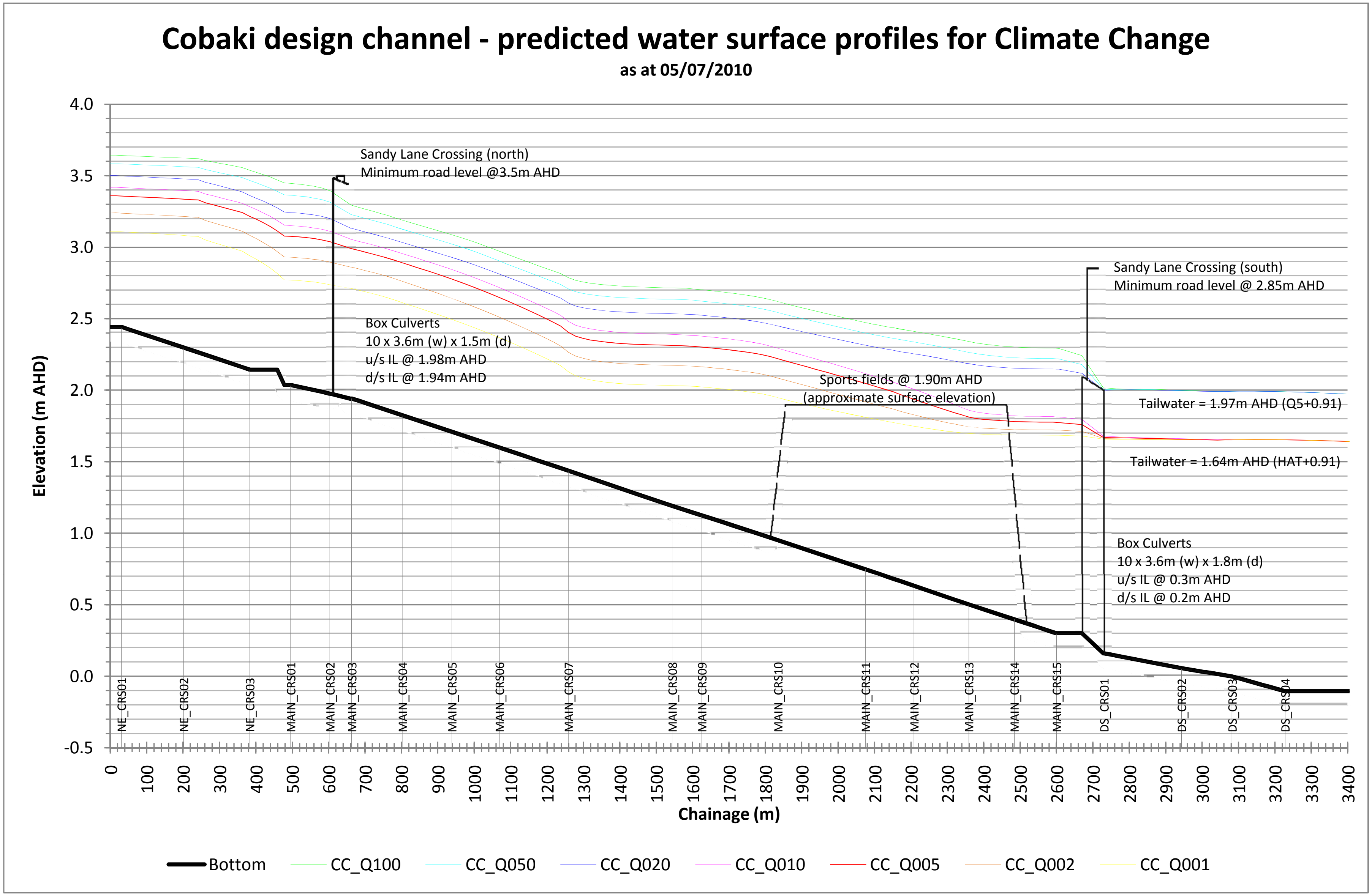
Q010
Q005
Q002
Q001



Cobaki design channel - predicted water surface profiles for Climate Change
as at 05/07/2010
Elevation (m AHD)
Chainage (m)
Sandy Lane Crossing (north)
Minimum road level @3.5m AHD
Box Culverts
10 x 3.6m (w) x 1.5m (d)
u/s IL @ 1.98m AHD
d/s IL @ 1.94m AHD
Sports fields @ 1.90m AHD
(approximate surface elevation)
Sandy Lane Crossing (south)
Minimum road level @ 2.85m AHD
Tailwater = 1.97m AHD (Q5+0.91)
Tailwater = 1.64m AHD (HAT+0.91)
Box Culverts
10 x 3.6m (w) x 1.8m (d)
u/s IL @ 0.3m AHD
d/s IL @ 0.2m AHD
NE_CRS01
NE_CRS02
NE_CRS03
MAIN_CRS01
MAIN_CRS02
MAIN_CRS03
MAIN_CRS04
MAIN_CRS05
MAIN_CRS06
MAIN_CRS07
MAIN_CRS08
MAIN_CRS09
MAIN_CRS10
MAIN_CRS11
MAIN_CRS12
MAIN_CRS13
MAIN_CRS14
MAIN_CRS15
DS_CRS01
DS_CRS02
DS_CRS03
DS_CRS04
Bottom
CC_Q100
CC_Q050
CC_Q020
CC_Q010
CC_Q005
CC_Q002
CC_Q001