Shaping the Future

LOT 1 DP 374315 & LOT 4 DP 615261

DGR Flood Assessment

Job Number 7135/01-005

Prepared for Milland Pty Ltd & Seawide Pty Ltd

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1 SCOPE OF DOCUMENT

1.1 Development Application Identification

This document deals with a Part 3A Development Application identified as follows:

MP 07_0010	LOT 1 DP 374315 & LOT 4 DP 615261 & Part Crown Reserves (R82555 and R754444), Ocean Drive, Lake Cathie	Part A: Concept Plan Approval (Residential, Commercial and Tourist Development); Part B: Project Application Approval (Stage 1 'Environmental Works')

This site is referred to as the Milland/Seawide (or MS) site. The limits of the site are shown on Figure 2.

1.2 Executive Summary

This Flood Assessment addresses DGR 6.6 and 6.7 and draws on the flood assessments undertaken on the adjoining St Vincents Foundation (SVF) site.

The assessment confirms that, while the subject property is not designated as flood prone, the low lying nature of the SW corner of Lot DP 374315 results in occasional inundation from local storm events in Duchess Gully.

The flood assessment addresses flood risk from those storm events which cross property boundaries between the subject site and the adjoining SVF site (the subject of Development Applications MPO6-0085 and MPO7-0001) and includes consideration of:

- The requirements of the NSW Floodplain Management Manual;
- Potential future climate change sea level rises and increases in rainfall intensity.

The Flood Assessment undertaken includes the following key methodology components and findings:

- Determination of the peak discharge from Duchess Gully using the Probabilistic Rational Method (PRM) from Australian Rainfall and Runoff (1987);
- Setting up of a Watershed Bounded Network Model (WBNM) for Duchess Gully catchment which reproduces the peak flood discharges predicted by the PRM procedure. The SW corner of the subject Milland property is within sub area 18 of the WBNM model;
- Modification of the WBNM model to allow for existing development and proposed development of the subject site and adjoining SVF site;
- Setting up of a MIKE-II hydrodynamic model of Duchess Gully stream to simulate the behaviour for the 1% AEP (100 year ARI) design event and other lesser events;
- Adoption of RL 2.3mAHD ocean level at the mouth of Duchess Gully as the tailwater level for the MIKE-11 model. An ocean level of RL 2.6mAHD was also modelled for a sensitivity analysis. The higher ocean levels did not affect inundation levels at the site.
- Modelling was undertaken of an "Existing Development" scenario and a "Future Urban Development with Constructed Wetland" (on the adjoining SVF site) scenario respectively. The new constructed wetland on the adjoining SVF site is I 0.5ha in area and will be connected to both the existing Lagoon on the adjoining SVF site arid to the middle reaches of Duchess Gully (downstream of the SW corner of the Milland property);
- The 'Future Urban Development Conditions' model included proposed hydraulic outlet structures and channel improvements (at Ch.80 to Ch.250 of the Upper Tributary) on the adjoining SVF site;

- The MIKE-11 model allows for the detention and attenuation of storm runoff in the proposed constructed wetland on the adjoining SVF site and assumed that no detention basin is required on the Milland/Seawide site;
- The MIKE-11 model shows that under Developed Conditions the 1% AEP (100 year ARI) event flood level is RL 4.47mAHD at the SW corner of the Milland property which corresponds to a 110mm increase in flood level at the southern boundary of the subject site (at Ch.835 on Branch DUCH-N). This afflux reduces to zero at a point 85 metres further upstream within the Milland property at Ch.750;
- The Flood Assessment also includes MIKE-11 Model results for 5 year, 10 year and 20 year ARI events and peak discharges for each of these events (refer Table 18 and Table 19);
- MIKE-11 modelling of the impact of climate change (CC) (with a 20% increase in rain intensity and an ocean tailwater level of RL 3.2 mAHD) gave a “100 year + Climate Change” flood level of RL 4.74mAHD at the SW corner of the site (refer Table 24);
- The Flood Assessment considered the impact of filling over an area of 470m2 of the Duchess Gully catchment within the SW corner of the Milland property to a minimum level of RL 5.0 mAHD. This modelling found that the fill will have no effect on the conveyance at this location and will not increase local flood levels (refer Section 2.5.9, Figure 24 and Figure 25);
- Section 2.6 of the Flood Assessment deals with Floodplain Management Issues and confirms that:
    - Inundation levels in existing residential areas along the southern boundary of the SVF site are not worsened by the proposed development of the Milland/Seawide properties:
    - Future residential floor levels should be at least RL 5.27mAHD being 800mm above the 1% AEP (100 year ARI) event level;
    - Evacuation routes exist to the north via the internal road system to Ocean Drive;
    - Inundation hazard conditions are shown on Figure 21 of the report. The hazard conditions within the SW corner of the Milland property fall into the ‘low hazard’ category except for the channel proper of Duchess Gully which is categorised as ‘high hazard’ (Section 2.6.3.4).
    - Probable Maximum Flood (PMF) flood levels were calculated to be RL 4.8 mAHD within the Constructed Wetland on the SVF site and at the SW corner of the Milland property. The study confirms that fill levels in the SW corner of the Milland property will be above the PMF and access paths to higher ground will still be available (Section 2.6.3.7).

2 HAZARD MANAGEMENT – FLOOD RISK

2.1 DGR Item References

The following DGR (Environmental Assessment) items are addressed in this section:

Item	Topic
6.6	Provide an assessment of any flood risk on site (for the full range of floods, including events greater than the design flood, up to probable maximum flood, and from coastal inundation, catchment based flooding or a combination of the two) and having consideration of any relevant provisions of the *NSW Floodplain Manual 2005*. The assessment should determine: the flood hazard in the area; address the impact of flooding on the proposed development, address the impact of the development (including filling) on flood behavior of the site and adjacent lands; and address adequate egress and safety in a flood event.
6.7	Assess the potential impacts of sea level rise and an increase in rainfall on the flood regime of the site and adjacent lands with consideration of *Practical Considerations of Climate Change – Floodplain Risk Management Guideline (DECC, October 2007)*.

This document addresses flood risk from storm runoff events that cross property boundaries between the site above and the land parcels which are the subject of Development Applications MP06-0085 and MP07-0001, namely Part Lot 123 DP 1106943 and Lot 5 DP 25886 referred to as the St Vincents Foundation or SVF site. The limits of these parcels are also shown on Figure 2.

This document draws on flood assessments carried out for the St Vincents Foundation (SVF) site.

2.2 Potential Development Impacts

Potential hazards which have been raised in the DGR documents and which are investigated in this section of the report include:

- Flooding and the requirements of the NSW Floodplain Management Manual.
- Potential future climate change sea level rises and rainfall increases.

With regard to flooding risk, it should be noted that the Section 149 Planning Certificate for the site provided by Port Macquarie Hastings Council states that the site is not "flood-prone".

2.3 Existing - Waterway Features

The watercourses of Duchess Gully and its tributaries are the central features of an open space corridor which extend through the SVF site. Most reaches of Duchess Gully have been extensively modified by man-made drainage channel improvements and additions. Parts of the lower reaches of Duchess Gully, particularly through the south-west corner of the Milland/Seawide site and along the eastern boundary of the SVF site, retain areas of original forested habitat.

These existing water features are shown in Figure 2, Figure 5 and Figure 6. Significant catchments west of Ocean Drive drain into the "upper" reach of Duchess Gully and into the Upper Tributary entering from the north. The man-made elements then direct flows into a large existing man-made lagoon which was constructed during previous development south of the site. Flows from this lagoon bypass the original "middle" reach flow path of Duchess Gully via a man-made culvert discharging to an overflow channel connected directly to the "lower" reach of Duchess Gully.

The middle reach of Duchess Gully passes across the south-west tip of the Milland/Seawide development site which lies adjacent to the north-east boundary of the St Vincents Foundation land. Approximately 10.23 hectares of the Milland/Seawide development site drains into Duchess Gully at this point.

2.4 Proposed Development - Waterway Features

Proposed development on the Milland/Seawide site consists primarily of a residential subdivision on the higher ground with revegetation works along Duchess Gully in the south-west corner of the site. A bioinfiltration basin is proposed for this area along with a minor amount of fill (approximately 470 cubic metres volume) to raise residential development above flood levels.

The main proposed development features of the waterways within the open space corridor on the SVF site are highlighted in Figure 7 and Figure 8. The most prominent added feature is the 10.5 hectare constructed wetland located on the SVF site adjacent to the “middle” reaches of Duchess Gully. Flows will be re-directed from the existing lagoon through the new constructed wetland by means of a new culvert connecting the two water bodies.

The new constructed wetland will be provided with a culvert outlet discharging into the defined “middle” reach channel of Duchess Gully as shown in Figure 8 and the existing lagoon overflow culvert will be upgraded to better handle larger flows. The banks of the both the existing lagoon and the new constructed wetland will be regraded in selected areas to allow major storm event flows to discharge over the banks in a safe controlled fashion.

The development strategy for the SVF site aims to provide an area of coastal freshwater lagoons and marshes and non-tidal freshwater forested constructed wetlands with habitats for a diverse range of animals throughout all seasons including water birds, frogs, invertebrates, fish and with aquatic plants including sedges, rushes and various tree species native to the area.

Additional plantings will enhance the landscape, biodiversity, hydrology and natural processes of the site. A mosaic of plant communities has significant value for biodiversity. Melaleuca swamps provide nesting and roosting habitat for egrets, herons and ibis. Reedy margins provide breeding areas for native waterfowl. Vegetation in shallow pond margins provides foraging sites for shorebirds.

This vegetation plays a vital role in hydrological processes. Wetland plants stabilise shorelines, reducing soil erosion. They filter and trap sediment from stormwater inflows, reducing turbidity and sedimentation in the receiving waters of Duchess Gully.

The waterways will be flanked by riparian habitats incorporating facilities suitable for visitors and passive recreation.

2.5 Major Storm Runoff Events

2.5.1 Introduction

This flood study has been carried out to determine the impact of the proposed developments on the flood behaviour of Duchess Gully and in particular that section of Duchess Gully passing through the development site of DA MP 07_0010.

Flood levels on the south-west corner of the Milland/Seawide development site are dictated by the behavior of Duchess Gully stream which in turn is controlled by waterway development features on the St Vincents Foundation site. This study considers all development on the two sites together as a single hydraulic system as a result.

Urban development tends to increase the magnitude of runoff, and reduce the response time. This study quantifies the effects of urbanisation of parts of the catchment of Duchess Gully, and investigates the mitigating effect of the creation of the constructed wetland.

2.5.2 Catchment Description

The catchment area of Duchess Gully is 782 hectares. The boundaries of the catchment are shown in Figure 9.

The western boundary of the catchment is formed by a ridge approximately 2 km west of Ocean Drive with elevations varying from about 80 metres to 200 metres AHD. The drainage is fairly well defined west of Ocean Drive, but poorly defined east of Ocean Drive. A number of shallow drains have been constructed east of Ocean Drive to drain this area.

West of Ocean Drive, the catchment is generally timbered and uncleared, except for a rural residential subdivision which occupies around 33 hectares. East of Ocean Drive, the catchment area is generally cleared. There are some areas of residential subdivision near the southern boundary of the catchment east of Ocean Drive. The development is evident in the aerial view of Figure 3.

2.5.3 Development Scenarios

This assessment has considered the catchment in three conditions of development as follows:

- **Natural State** – no development
- **Existing Development**, including rural residential subdivision west of Ocean Drive (about 33 hectares), residential development to south of the SVF site, but within the catchment area of Duchess Gully (about 28 hectares), and the existing lagoon on the SVF site (about 6.8 hectares in area).
- **Proposed Development** of the SVF and MS sites. As above, but including an additional 89.5 hectares of residential development on the St Vincents Foundation site, with an additional constructed wetland of 12.7 hectares in area plus urban development on LOT 4 DP 615251 & LOT 1 FP 374315 (Milland/Seawide site) of which 10.23 hectares drains to Duchess Gully. The extent of the proposed residential subdivision is shown on the catchment subarea plan Figure 9.

2.5.4 Methodology

Design storm events have been estimated for the site by the design storm-loss rate-runoff routing method. The Watershed Bounded Network Model (WBNM) has been used. This model was used in previous drainage studies of the SVF site, and has been used for this flood study to maintain consistency with previous studies. 5-year, 10-year, 20-year, and 100-year ARI event hydrographs were estimated for a range of storm durations, and catchment development conditions. A runoff-routing model was used so that complete hydrographs for the whole storm event could be obtained for use as input to a hydrodynamic model (based on MIKE11) of the Duchess Gully watercourse.

The WBNM was "calibrated" against peak discharges estimated by the Probabilistic Rational Method. The PRM method is the most appropriate to use in these circumstances because:

- There are no actual recorded storm events for this catchment, which could be used for model calibration.
- Regional parameters for the probabilistic rational method have been developed using a significant amount of recorded storm data. Regional parameters are available for this area (EngAust 1987).

The hydrographs derived from the WBNM were used as input to a hydrodynamic model of the Duchess Gully and its tributaries in the reach downstream of Ocean Drive extending to the ocean outlet. A hydrodynamic model rather than a steady state backwater model was considered preferable for the hydraulic modelling so as to be able to model explicitly changes in the low-lying area storage, and the creation of additional water bodies.

The MIKE-11 model was used for the hydraulic modelling. This model was used to estimate the peak flood levels, the peak velocities along Duchess Gully for the 1% AEP storm event, and the changes to the these levels and velocities resulting from the proposed catchment development including the construction of an additional wetland on the SVF site.

A number of constructed wetland configurations were modelled in order to find a combination which would result in no worsening of the peak discharges, levels, and velocities along Duchess Gully downstream of the existing lagoon on the SVF site.

2.5.5 Hydrology Modelling and Results

2.5.5.1 Probabilistic Rational Method

The probabilistic rational method (PRM) from Australian Rainfall and Runoff 1987 edition (AR&R) (EngAUst 1987) was used to determine the peak discharge at the outlet of Duchess Gully for the 1% AEP storm event for the catchment in its natural (pre-development) state. The probabilistic rational method is the method recommended in Australian Rainfall and Runoff 1987 edition for estimating peak flows in small to medium size rural catchments in eastern New South Wales. The method is well-supported by recorded flow data from over three hundred streams in the eastern NSW region. AR&R states: “the only methods that can really be considered as approaching a satisfactory status are those based on observed flood data in the region of interest”. The catchments external to the SVF site (ie. Upstream of Ocean Drive) do not have any unusual hydraulic characteristics and are typical of catchments from which calibration data was drawn for the PRM.

The following values in Table 1 were determined by applying this method.

Table 1 Catchment Runoff – Probabilistic Rational Method PRM)

Parameter	
Catchment Area	782 hectares at Duchess Gully ocean outlet
Time of Concentration	1.68 hours
C100	0.39
Peak Discharge for 1% AEP event	63.3 m3/sec (undeveloped catchment)

This estimate agrees with the probabilistic rational method estimate for the catchment as reported in the SMC December 1994 report (SMC 1994).

The Probabilistic Rational Method was also used to estimate the 1% AEP peak discharge at the Ocean Drive southern culverts (Node 8 NODE8) in Figure 9. A peak discharge of 29.5 m3/sec was estimated at this point for the natural catchment.

The Cordery-Webb unit-hydrograph method had been applied to the catchment to determine design discharges for an earlier study (GMA Feb 1983). The peak discharge for the ocean outlet from the natural catchment had been estimated to be 62.3 m3/sec for the critical 6 hour storm duration. This estimate is consistent with the probabilistic rational method estimate, although it should be noted that design rainfall information would have changed since the time of application of the Cordery-Webb procedure.

2.5.6 Watershed Bounded Network Model (WBNM)

A watershed bounded network model was set up for the Duchess Gully catchment. The subdivision of the catchment into subareas was the same as the subdivision used for the SMC December 1994 study (SMC 1994). The subareas are shown in Figure 9.

Table 2 lists the subcatchment subareas.

The Milland/Seawide site lies within Subarea 18 of the catchment.

Table 2 WBNM Catchment Model - Subareas

Subarea ID		Area (ha)
No	Name	
1	SUB1	73.36
2	SUB2	68.83
3	SUB3	21.17
4	SUB4	56.88
5	DNODE5	0
6	SUB6	19.69
7	SUB7	54.92
8	DNODE8	0
9	SUB9	50.16
10	SUB10	94.84
11	SUB11	63.13
12	SUB12	78.44
13	SUB13	53.28
14	SUB14	27.27
16	DNODE16	0
15	SUB15	45.16
17	LAKE17	0
18	SUB18	73.36
19	SUB19	25.63

2.5.6.1 Water Bodies

The existing lagoon on the SVF site was included in the WBNM model for the existing and future development scenarios. This lagoon is 6.3 hectares in area. The relationship between storage elevation, spillway discharge, and storage volume was obtained from the SMC December 1994 Report Appendix D.

2.5.6.2 WBNM Model Calibration

To “calibrate” the model to the 1% AEP probabilistic rational method estimate, it was necessary to adjust the lag coefficient “c” to a value of 1.95, and to specify linear routing for the full range of discharges. With the above values, the model predicted the discharges as shown in Table 3.

Table 3 Comparison of PRM and WBNM Model – Calculated Discharges

Location	Prob. Rational Method	WBNM	
	Peak Discharge (m^3/sec)	Peak Discharge (m^3/sec)	Critical Duration (hrs)
Ocean Drive (DNODE8)	29.5	31.1	2
Ocean Outlet (SUB19)	63.3	63.4	9

The "calibrated" WBNM was then modified to account for both existing development and the possible future development of both the SVF and the Milland/Seawide (MS) sites.

The existing urban and rural residential areas are shown on Figure 9. This figure also shows the areas which are planned to be developed as residential areas in the future.

The manner in which the lag parameter for overland flow, stream lag factor and losses were modified to account for urbanisation is as follows:

2.5.6.3 Lag Parameter for Overland Flow

The lag parameter for overland flow was reduced to account for urbanisation using the following relationship:

$$L = L_{nat}(1 + U)^{-2}$$

Where
L = Lag parameter for developed catchment
L_{nat} = Lag parameter for undeveloped catchment
U = Fraction of catchment urbanised.

This relationship originates from the work of Aitken (1975), and is used in other runoff routing models such as URBS (BCC 1993) to account for the decrease in subcatchment runoff delay time caused by urbanisation. The relationship leads to the result that the lag in overland flow for a fully urbanised catchment is one-quarter of the lag of an equivalent urban catchment.

For determining the change in the lag parameter for the rural residential part of the catchment, it was assumed that the rural residential area was equivalent to 1/3 of a similar urban area in terms of its effect on the lag parameter for overland flow. This assumption was used in previous hydraulic studies for this catchment (SMC 1994) and is reasonable considering the lower density of rural residential subdivisions when compared with medium density residential subdivisions.

2.5.6.4 Stream Lag Factor

In the WBNM, changing the lag parameter for overland flow also changes the stream channel lag correspondingly. With the proposed development, it is intended to maintain a drainage corridor of approximately 60 metres width with a low flow channel similar to a natural channel. The stream channel lag would not be expected to change significantly with the proposed developments. Therefore, to maintain the same stream channel lag before and after development, the stream lag factor was adjusted to compensate for any changes resulting from changes in the overland flow lag parameter.

The lag coefficients and the stream lag factors for the WBNM are shown in Table 4.

Table 4 WBNM Model Subarea Continuing Losses – 1% AEP Event

	Natural		Existing					Future Development Scenario		
SUBAREA	AREA	Lag	AREA	Area	Area	Mod	Compens	Area to be	Modified	Compens
		Coeff c		Rural Res	Urban	Lag Coeff	Adjust to	urbanised	Lag Coeff	Adjust to
						(Note1)	Stream lag factor		(Note 2)	Stream lag factor
	(ha)		(ha)	(ha)				(ha)		
SUB1	73.36	1.95	73.36	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB2	68.83	1.95	68.83	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB3	21.17	1.95	21.17	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB4	56.88	1.95	56.88	0.00	0.00	1.95	1.00	0.00	1.95	1.00
DNODE5	0	1.95	0	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB6	19.69	1.95	19.69	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB7	54.92	1.95	54.92	21.17	0.00	1.53	1.27	0.00	1.53	1.27
DNODE8	0	1.95	0	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB9	50.16	1.95	50.16	0.00	9.10	1.40	1.40	21.60	0.75	2.60
SUB10	94.84	1.95	94.84	7.97	0.00	1.85	1.06	0.00	1.85	1.06
SUB11	63.13	1.95	63.13	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB12	78.44	1.95	78.44	2.03	0.00	1.92	1.02	0.00	1.92	1.02
SUB13	53.28	1.95	53.28	1.80	0.00	1.91	1.02	28.00	0.83	2.36
SUB14	27.27	1.95	27.27	0.00	0.00	1.95	1.00	25.60	0.52	3.76
DNODE16	0	1.95	0	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB15	45.16	1.95	38.66	0.00	0.47	1.90	0.00	8.40	1.29	0.00
LAKE17	0	1.95	6.5	0.00	0.00	1.95	1.00	0.00	1.95	1.00
SUB18	73.36	1.95	73.36	0.00	0.00	1.95	1.00	36.20	0.87	2.23
SUB19	25.63	1.95	25.63	0.00	0.00	1.95	1.00	0.00	1.95	1.00
Totals	806.12			32.97	9.57			119.80		

2.5.6.5 Initial and Continuing Losses

The initial loss was assumed to be zero. The continuing loss for the natural catchment was assumed to be 2.5 mm/hour. For the developed parts of the catchment, the continuing loss for each subarea was decreased to take account of the zero losses which would occur on the impervious area within that subarea. The impervious area was assumed to be 45% of the urbanised part of the subarea, and 14.7% of the rural residential part of the subarea.

The adopted continuing losses are also shown in Table 4.

As peak discharges for ARI's less than 100-year were required, additional calibration of the WBNM model was necessary to ensure that the modelled discharges for these more frequent events were also compatible with peak discharges estimated using the probabilistic rational method. This additional calibration was carried out by adjustment of the pervious area initial and continuing losses for the design rainfall events that were used in WBNM to derive the peak discharges.

The rainfall losses were adjusted so that the peak discharges at Duchess Gully for the catchment area in its natural (no development) state predicted by WBNM were equivalent to the peak discharges predicted by the Probabilistic Rational Method. The peak discharges and the losses are summarised in Table 5.

Table 5 Calibration of WBNM Model - All Events

Design Event (ARI)	Design Rainfall Event Losses for pervious areas		Peak Discharge at Duchess Gully outlet (natural catchment) (m^3/sec)	
	Initial Loss (mm)	Continuing Loss (mm/hr)	WBNM Estimate	Prob. Rational Method Estimate
5	25	6.5	25.3	25.0
10	20	6.0	31.7	31.1
20	20	5.5	39.7	38.9
100	0	2.5	62.8	62.9

Hydrographs from the calibrated WBNM model for the design events were used as input to the hydraulic model.

2.5.6.6 WBNM Model Calculated Peak Discharges

The peak discharges predicted by WBNM for the existing and future development scenarios are listed for selected points in Table 6. The peaks shown are for the critical storm duration at the ocean outlet of 9 hours.

Table 6 Peak Discharge – 1% AEP 9 hour Duration Storm

Development Condition	Peak Q at Ocean Drive – southern culverts	Peak local discharge from subarea:		
	(Node 8)	9	14	18
Natural	30.5	6.26	3.8	8.42
Existing	31.1	6.99	3.8	8.42
Future Scenario	31.1	8.15	5.4	10.99

The model predicted a 1.2% increase in the 1% AEP peak outflow to the ocean for the future development scenario, when compared with the existing development, even though the peak discharges from some individual subareas had increased by up to 40%. A reason for this is the timing of the peak discharges. The areas proposed for future development are in the downstream part of the Duchess Gully catchment, and are only around 15% of the total catchment area. Peak discharges from the downstream subareas occur earlier than the routed peak from the upstream subareas, and therefore do not have a significant effect on the peak outflow from the whole catchment.

2.5.7 Hydraulic Modelling and Results

2.5.7.1 Hydraulic Model Setup

The MIKE-11 hydrodynamic model was used to simulate the hydraulic behaviour for the 1% AEP design event and other lesser events. The model extends from Ocean Drive down to the ocean outlet, and includes the existing lagoon on the SVF site. A diagram showing the network layout of the model is included as Figure 10.

2.5.7.2 Network – Existing Conditions

Information on the model branches is given in Table 7.

Table 7 MIKE11 Network Model Description - Existing Conditions

Branch Name	Branch Length (m)	Description
Duch-N	1250	"Middle" reaches of Duchess Ck, joining with Duch-L branch, 154 metres upstream of junction of Duch-S and Duch-L branches. This branch passes through the south-west corner of the Milland/Seawide development site.
Duch-S	1700	"Upper" reaches of Duchess Gully extending from southern set of culverts under Ocean Drive, through existing lagoon to the junction with Duch-L branch
Duch-U	870	Upper Tributary of Duchess Gully, extending from the northern set of culverts under Ocean Drive to the junction with Duch-S, just upstream of the existing lagoon
Duch-L	1465	"Lower" reaches of Duchess Gully, extending from 154 metres upstream of the junction with the "Overflow", to the ocean outlet
Dlink-N-S	400	Flow link between the "upper" reaches and "middle" reaches of Duchess Gully
Dlink-U-S	140	Flow link between the "upper" reaches of Duchess Gully and the Upper Tributary

2.5.7.3 Cross Sections

The cross section information for the MIKE-11 model was sourced from the following information:

- Cross sections surveyed by GMA for its June 1986 study of Duchess Gully for a proposed resort development (GMA 1986).
- Survey transects taken across the low-lying areas of Duchess Gully by Luke & Company, as described in the SMC December 1994 Investigation Report (SMC 1994).

The chainages of the cross sections and the source of each cross section used in the MIKE-11 model are listed in Table 8.

Table 8 MIKE11 Model - Cross Section Derivations

Existing (2000) Development			
Branch	**Cross Section Chainage**	**Cross Section Data Source**	**Comment**
Duch-N	20	Luke 1050	Part of transect only
Duch-N	185	Luke 1050	Part of transect only
Duch-N	315	Luke 1150	Part of transect only
Duch-N	445	Luke 1250	Part of transect only
Duch-N	565	Luke 1350	Part of transect only
Duch-N	675	Luke 1450	Part of transect only
Duch-N	835	GMA 35	Cross Section extended using contour plan
Duch-N	915	GMA 34	Cross Section extended using contour plan
Duch-N	1000	GMA 33	Cross Section extended using contour plan
Duch-N	1090	GMA 32	Cross Section extended using contour plan
Duch-N	1170	GMA 26	Cross Section extended using contour plan
Duch-N	1250	GMA 25	Cross Section extended using contour plan
Duch-S	0	Luke 70 Baseline 2	
Duch-S	70	Luke 0 Baseline 2	
Duch-S	160	Luke 150	Part of transect only, contours used also
Duch-S	280	Luke 250	Part of transect only, contours used also
Duch-S	540	Luke 350	Part of transect only
Duch-S	660	Luke 450	Part of transect only
Duch-S	780	Luke 550	Part of transect only
Duch-S	900	Luke 650	
Duch-S	1000	Luke 850	
Duch-S	1120	Luke 850	Part of transect only
Duch-S	1230	Luke 950	Part of transect only
Duch-S	1360	Luke 1100	Part of transect only
Duch-S	1440	Luke 1150 + 0/CS11	Part of transect only, plus 1983 study Cross section 11
Duch-S	1550	GMA 30	
Duch-S	1600	GMA 29	
Duch-S	1650	GMA 28	
Duch-S	1700	GMA 27	
Duch-U	0	Luke 60 Baseline 3	
Duch-U	80	Luke 0 Baseline 3	
Duch-U	150	Luke 50	Part of transect only, contour plan use also
Duch-U	300	Luke 150	Part of transect only, contour plan use also
Duch-U	440	Luke 250	Part of transect only, contour plan use also
Duch-U	550	Luke 350	Part of transect only, contour plan use also
Duch-U	650	Luke 450	Part of transect only, contour plan use also
Duch-U	780	Luke 550	Part of transect only
Duch-L	0	GMA 25	Cross Section extended using contours
Duch-L	70	GMA 24	Cross Section extended using contours
Duch-L	120	GMA 23	Cross Section extended using contours
Duch-L	160	GMA 22	Cross Section extended using contours
Duch-L	210	GMA 21	Cross Section extended using contours
Duch-L	320	GMA 20	Cross Section extended using contours
Duch-L	370	GMA 19	Cross Section extended using contours
Duch-L	420	GMA 18	Cross Section extended using contours
Duch-L	470	GMA 17	Cross Section extended using contours
Duch-L	530	GMA 16	Cross Section extended using contours
Duch-L	580	GMA 15	Cross Section extended using contours
Duch-L	625	GMA 14	Cross Section extended using contours
Duch-L	675	GMA 13	Cross Section extended using contours
Duch-L	725	GMA 12	Cross Section extended using contours
Duch-L	780	GMA 11	Cross Section extended using contours
Duch-L	830	GMA 10	Cross Section extended using contours
Duch-L	885	GMA 9	Cross Section extended using contours
Duch-L	935	GMA 8	Cross Section extended using contours
Duch-L	985	GMA 7	Cross Section extended using contours
Duch-L	1035	GMA 6	Cross Section extended using contours
Duch-L	1085	GMA 5	Cross Section extended using contours
Duch-L	1135	GMA 4	Cross Section extended using contours
Duch-L	1235	GMA 3	Cross Section extended using contours
Duch-L	1355	GMA 2	Cross Section extended using contours
Duch-L	1465	GMA 1	Cross Section extended using contours

2.5.7.4 MIKE11 Model Calibration

It was not possible to calibrate the hydrodynamic model as there was lack of recorded discharge and water level data for the drainage system. Flow roughness factors were determined from the vegetation and channel characteristics of the area. Aerial photography and photos of Duchess Gully (eg Figure 3) were available for this. The flow roughness factors (Mannings n values) chosen are listed in Table 9.

Table 9 MIKE11 Model - Mannings n Roughness - Existing Conditions

River Reach	Manning's n values			Comment
	Left Bank	Main Channel	Right Bank	
Duch-U 0 to 870	0.07	0.07	0.07	
Duch-S 0 to 900	0.07	0.07	0.07	
Duch-S 900-1360	0.07	0.035	0.07	Existing lagoon
Duch-S 1360- 1700	0.08	0.06	0.08	
Duch-N 0-700	0.07	0.07	0.07	
Duch-N 700-1250	0.08	0.07	0.08	
Duch-L 0-180	0.1	0.06	0.1	
Duch-L 180-800	0.1	0.05	0.1	
Duch-L 800-900	0.08 – 0.09	0.04	0.08 - 0.09	
Duch-L 900-1465	0.07 – 0.08	0.035	0.07 – 0.08	

2.5.7.5 Existing Lagoon Outlet

Water levels in the existing lagoon (SVF site) during major storm events are controlled by the level of an existing gravel track crossing of the creek downstream of the lagoon. The SMC December 1994 report indicates the level of this track is from RL 4.5 to 4.8 metres. The report also states that there are a number of small pipes under the track, with inverts ranging from RL 2.5 to 2.8 m AHD.

The track crossing has been modelled as a weir with the following width versus crest length relationship, as determined from the available survey information.

Table 10 MIKE11 Model - Existing Lake Outlet

Level (mAHD)	Width (m)
4.5	0.0
4.8	50
5.0	100
5.5	150

The pipes under the road have been ignored in the hydraulic analysis, as they have a very small capacity, and it is probable that that the lake level would have risen to the road level prior to any significant design storm event.

2.5.7.6 Model Boundary Conditions

The inflow hydrographs for the 1% AEP design events were provided by the WBNM model. The source of the inflow hydrographs and the location of their input to the MIKE-11 model for the existing development scenario are listed in the Table 11.

Table 11 MIKE11 Model - Inflow Hydrographs – Existing Conditions

WBNM flow hydrogaph	Location of inflow	Comment
Total runoff at node 8 outlet	Duch-S 0.00	Flow from area upstream of Ocean Drive southern culverts
Total runoff at Subarea 13 outlet	Duch-U 0.00	Flow from area upstream of Ocean Drive northern culverts
Local runoff from subarea 9	Duch-S 280	
Local runoff from subarea 14	Duch-U 550	
Local runoff from subarea 15	Duch-S 1120	
Local runoff from subarea 18	Duch-N 60	In cases with the new constructed wetland, runoff is assumed directly to new wetland
Local runoff from subarea 19	Duch-L 725	
Local runoff from subarea 17	Duch-S 950	Rain directly on existing lagoon

An ocean level at Duchess Gully outlet is required for the modelling. The mean high water springs level (MHWS) for the area is approximately RL 0.65 m AHD. A 1% AEP storm tide level of 2.6 m AHD is recommended for the area in recent planning guidelines (DECCW 2009b).

The probability of the 1% AEP peak discharge and the 1% AEP storm tide level occurring simultaneously is expected to be much less than 1% AEP, therefore it is reasonable to assume a lower ocean level than the 1% AEP storm tide level during the 1% AEP event for Duchess Gully. Planning guidelines (DECCW 2009b) recommend that the 5% AEP (20 year ARI) ocean level of RL 2.3 be adopted as likely to coincide with the 1% AEP storm runoff. A level of RL 2.3 mAHD has therefore been assumed as the tailwater level at the mouth of Duchess Gully for the modelling.

The higher level of RL 2.6 m AHD was modelled also as part of a sensitivity analysis.

2.5.8 Development Scenarios Modelled

The model was used to determine the peak levels, discharges and velocities for the 1% AEP 9 hour duration storm event. This duration produced the peak discharge at the ocean outlet, and the peak levels from the existing lagoon to the ocean outlet.

A number of development scenarios were modelled, and descriptions of the relevant scenarios follow:

2.5.8.1 Existing Development

This case (RB-Exist1) modelled the existing situation which included the existing 6.8 hectare lagoon and the outlet arrangement on the SVF site. The existing residential development includes a total of about 9 hectares of urban development in sub-area 9 and about 33 hectares of rural residential development in the catchment upstream of Ocean Drive. The Mike-11 model setup for this case has been described previously.

The peak outflow to the ocean was estimated at 63.3 m3/sec, and the peak level reached in the Existing Lagoon was estimated at 5.45 m AHD for the 9 hour 1% AEP event. Summary details of the results including peak discharges, peak velocities and peak water levels at each of the cross sections is included in later tables.

2.5.8.2 Future Urban Development with Constructed Wetland

For this case, (case RB-DEV24C) it was assumed that a new wetland would be constructed on the St Vincents Foundation site north and east of the existing lagoon. The new constructed wetland would also be a local source of fill material for the proposed residential areas on the SVF site. The new constructed wetland is 10.5 hectares in area with approximate dimensions of 266 metres width and 500 metres length (including adjoining stormwater treatment water bodies), and connected to both the existing lagoon and the "middle" reaches of Duchess Gully (at Duch-N 1090).

The proposed constructed wetland has been modelled as a branch "Newlake2" with 8 cross sections. A diagram showing the network layout of this model is given in Figure 11.

A description of the model branches for the proposed development is given in Table 12.

Table 12 MIKE11 Model Network - Proposed Development

Branch Name	Branch Length (m)	Description
Duch-N	431	"Middle" reaches of Duchess Ck, joining with Duch-L branch, 154 metres upstream of junction of Duch-S and Duch-L branches.
Duch-S	1700	"Upper" reaches of Duchess Gully extending from southern set of culverts under Ocean Drive, through existing lagoon then continuing via the "Overflow" channel to the junction with Duch-L branch.
Duch-U	870	Upper Tributary of Duchess Gully, extending from the northern set of culverts under Ocean Drive to the junction with Duch-S, just upstream of the existing lagoon.
Duch-L	1465	"Lower: reach of Duchess Gully, extending from 154 metres upstream of the junction with the Overflow, to the ocean outlet.
Dlink-U-S	140	Flow link between Duch-U and Duch-S branches.
Newlake2	847	Proposed Constructed Wetland, connecting with Dutch-S branch.
Lakelink2	20	Flow link between Newlake2 and Duch-N branches.

2.5.8.3 Proposed Outlet Structures

The normal top water level in the new constructed wetland was assumed to be RL 3.0 m AHD. This level will be maintained by a constructed "base flow" channel at the northern end of the constructed wetland connecting to "middle" reach of Duchess Gully at the south-west corner of the Milland/Seawide site (see Figure 14). This low-capacity channel is only sufficient to carry base flows from the catchment and small runoff events.

A new weir structure with a crest level of RL 3.4 m AHD will be provided to connect the constructed wetland to the existing lagoon and divert base flows from the existing lagoon through the new constructed wetland. This connection is shown in Figure 17. These control structures will serve to re-establish the original flow path of Duchess Gully.

Minor event flows discharging from the constructed wetland up to and including the 5 Year ARI events will be controlled by a weir structure with a crest level of RL 3.7 m AHD and 25 metres crest length which connects to Duchess Gully further downstream in the "middle" reach. The location and layout for this weir are shown in Figure 12. The level of this weir is dictated by the level of services pipelines which run north-south along the western bank of Duchess Gully as shown in Figure 12. The outlet channel from this weir structure passes over the pipelines which will be protected with reinforced concrete surround at this section as shown in Figure 13.

Minor event flows (up to 5 Year ARI) from the existing lagoon on the SVF site will be divided equally between the constructed wetland and the existing "Overflow" channel which connects directly to the "lower" reach of Duchess Gully by providing another new weir with a crest level of RL 3.5 to replace the existing pipe culvert under the existing gravel track. This structure is shown in Figure 15. The length of this weir and the "connection" weir are each 5 metres which provides sufficient capacity to pass 5 Year ARI flows.

During major rainfall events exceeding 5 Year ARI, flows from the existing lagoon and the constructed wetlands will overtop the banks around the water bodies along selected sections of the banks which will be regraded level to control and evenly distribute the flow. The lengths of the level regraded sections of the banks were adjusted so that maximum head on the banks for the 100 year ARI storm event is no greater than 300 mm. This limit ensures that the flow velocity across the banks is limited and does not exceed the scour velocity for grassed surfaces. The arrangement of these bank overflow sections are shown in Figure 12 and Figure 15 .

The dimensions of these weir structures and bank overflow sections are summarised in Table 13.

Table 13 MIKE11 Model – Flow Control Structures – Development Conditions

Flow Control Description	ID	Dimensions			
		Low Flow Weir		Bank high flow overflow	
		Level (mAHD)	Length (m)	Level (mAHD)	Length (m)
Existing lagoon outlet to "Overflow"	S3	3.5	5	4.85	100
New constructed wetland outlet to "middle" reaches of Duchess Gully	S4, S5	3.7 (S4)	25 (S4)	4.1 (S5)	150 (S5)
Connection between existing lagoon and new constructed wetland	S2	3.4	5	4.85	100

This arrangement of weirs provides a "minor/major" system of controls which satisfies Port Macquarie Hastings Council's drainage guidelines (AUS-SPEC 2003) and the NSW Floodplain Development Manual (DIPNR 2005) by segregating and confining flows up to 5 Year ARI in defined structures and only allowing controlled overland flows for more severe major storm events.

2.5.8.4 Proposed Channel Improvements

In addition to the new constructed wetland, the "Development Conditions" case also incorporated changes to the cross sections of the drains comprising the Upper Tributary, upstream of the existing lagoon on the SVF site. To counteract loss of conveyance from encroachment of the proposed sports fields, a channel diversion with a trapezoidal section of 1 metres bed width and bed level 0.5 metres below the existing bed level was assumed over a 170 metre length from Ch 80 to Ch 250. This diversion channel was sufficient to maintain "Development" flood levels at Ocean Drive at no greater than the "existing" flood levels.

2.5.8.5 Conditions on the Milland/Seawide Property

The MIKE-11 model allows for detention and attenuation of storm runoff in the proposed constructed wetlands on the St Vincents Foundation (SVF) property but the model conservatively assumes no detention of runoff on the neighbouring properties. That is, the MIKE-11 model allows for a conservative post development (urban) scenario on the Milland/Seawide property with no detention basins being required on those properties for the SVF proposals.

2.5.8.6 Results for 100 Year ARI Rainfall Event – Developed Conditions

The peak outflow to the ocean for this case was estimated at 62.7 m3/sec (about 5% less than for the existing), and the peak lake level in the Existing Lagoon was estimated as RL 5.15 m AHD. The peak lake level in the new wetland was estimated as RL 4.56 m AHD. In the "lower" reach of Duchess Gully downstream of the "overflow" junction, peak levels were up to 70 mm lower and peak velocities slightly less than for the existing situation.

The 100 Year ARI rainfall event maximum water levels for "Developed Conditions" are tabulated in Table 14 and shown plotted in Figure 20.

The peak outflow from the existing lagoon to the "lower" reaches of Duchess Gully has been decreased by about 45%. The reason for this decrease is that flow also occurs from the existing lagoon through the new constructed wetland and into the "middle" reaches of Duchess Gully. The peak flow in the "middle" reaches of Duchess Gully between the new wetland outlet and the junction with the "overflow" has increased approximately three-fold (from 9 m3/sec to 30 m3/sec). The peak velocities in this reach are still significantly less than the peak velocities in the "lower" reaches of Duchess Gully downstream of the "overflow" junction.

The 100 Year ARI peak flows for "Developed Conditions" are tabulated in Table 15. Plots of the discharge hydrographs at the mouth of Duchess Gully for the existing (RB-exist1), and developed with 12.7ha lake (RB-dev24C) cases are shown in Figure 18.

Stormwater and stream water level gradients throughout Duchess Gully are shown plotted in Figure 20. Water levels are presented for three separate longitudinal profiles, namely:

- Profile "A' – Tracking water levels along the edge of the proposed reclamation areas on the SVF site and through the constructed wetlands then along the lower reach of Duchess Gully;
- Profile 'B' – Water levels along the upper reach of Duchess Gully then following the "overflow" channel into Duchess Gully;
- Profile 'C' – Water levels in the lower reach of Duchess Gully extending upstream to the Milland/Seawide site.

The location and alignments of these three profiles are shown in Figure 19.

Stormwater and stream water levels are not worsened in the "upper" reaches of Duchess Gully adjacent to the existing residential areas. Maximum water levels are also not worsened at the western boundary of the SVF site at either of the culverts under Ocean Drive.

Water levels are increased by 110 mm at the boundary of the Milland/Seawide property to the north-east of the SVF site (Chainage 835 DUCH-N branch on the MIKE11 model) but this afflux reduces to zero only 85 metres further upstream within the Milland/Seawide property. This impact is considered minor and does not adversely affect any future use of the Milland Seawide property. The topography of the land in the area means that only small volumes of site fill are required to offset the effects of the afflux. This impact is described in detail in Section 2.5.8.9

The MIKE11 modelling shows a "Developed Conditions" inundation level of RL 4.47 mAHD on the Milland/Seawide site.

Figure 21 shows stream velocities and flood depths throughout the low-lying areas of Duchess Gully. The resulting hazard conditions are discussed further in Section 2.6.3.3.

Table 14 MIKE11 Model Results - 100Yr ARI Event – Maximum Water Levels

Catchment development		*Existing*	*Site developed*
U/S exist Lagoon		*Existing*	*Excavated+Fill*
Existing Lagoon level S3		*RL 4.5 m*	*RL 3.5 - (outlet weir)*
New Wetland outlet S5		*Na*	*RL 3.0 - (outlet channel)*
Connection S2		*Na*	*RL 3.4 - (invert)*
Tailwater Level		*RL 2.3*	*RL 2.3*
Storm ARI & Duration		*100yr 9hr*	*100yr 9hr*

Branch & Chainage		***Max WL RL m***	***Max WL RL m***	***Afflux Mm***
DUCH-S 0.00		6.685	6.669	-16
DUCH-S 70.00		6.474	6.411	-63
DUCH-S 160.00		5.968	5.915	-53
DUCH-S 280.00		5.772	5.782	10
DUCH-S 540.00		5.540	5.497	-43
DUCH-S 540.00		5.540	5.497	-43
DUCH-S 660.00		5.492	5.382	-110
DUCH-S 780.00		5.461	5.175	-286
DUCH-S 800.00		5.458	5.145	-313
DUCH-S 800.00		5.458	5.145	-313
DUCH-S 900.00		5.444	5.128	-316
DUCH-S 1000.00		5.442	5.124	-318
DUCH-S 1120.00		5.442	5.124	-318
DUCH-S 1230.00		5.441	5.123	-318
DUCH-S 1360.00		5.441	5.123	-318
DUCH-S 1360.00		5.441	5.123	-318
DUCH-S 1440.00		5.394	4.474	-920
DUCH-S 1550.00		4.693	4.461	-232
DUCH-S 1600.00		4.507	4.388	-119
DUCH-S 1650.00		4.363	4.340	-23
DUCH-S 1700.00		4.139	4.275	136
DUCH-L 0.00		4.142	4.358	216
DUCH-L 70.00		4.140	4.311	171
DUCH-L 120.00		4.139	4.290	151
DUCH-L 154.87		4.139	4.275	136
DUCH-L 154.87		4.139	4.275	136
DUCH-L 160.00		4.130	4.266	136
DUCH-L 210.00		4.070	4.202	132
DUCH-L 320.00		3.875	3.996	121
DUCH-L 370.00		3.782	3.898	116
DUCH-L 420.00		3.763	3.880	117
DUCH-L 470.00		3.720	3.835	115
DUCH-L 530.00		3.649	3.763	114
DUCH-L 580.00		3.574	3.683	109
DUCH-L 625.00		3.526	3.633	107

DUCH-L 675.00	3.416	3.518	102
DUCH-L 725.00	3.316	3.413	97
DUCH-L 780.00	3.251	3.342	91
DUCH-L 830.00	3.192	3.281	89
DUCH-L 885.00	3.113	3.199	86
DUCH-L 935.00	3.052	3.135	83
DUCH-L 985.00	3.025	3.106	81
DUCH-L 1035.00	2.970	3.047	77
DUCH-L 1085.00	2.905	2.979	74
DUCH-L 1135.00	2.824	2.890	66
DUCH-L 1235.00	2.711	2.765	54
DUCH-L 1355.00	2.561	2.596	35
DUCH-L 1465.00	2.300	2.300	0
DUCH-U 0.00	6.958	6.909	-49
DUCH-U 80.00	6.642	6.501	-141
DUCH-U 150.00	6.283	6.144	-139
DUCH-U 300.00	5.627	5.587	-40
DUCH-U 440.00	5.542	5.490	-52
DUCH-U 550.00	5.533	5.460	-73
DUCH-U 550.00	5.533	5.460	-73
DUCH-U 650.00	5.516	5.406	-110
DUCH-U 750.00	5.494	5.333	-161
DUCH-U 870.00	5.458	5.145	-313
DLINK-U-S 0.00	5.533	5.460	-73
DLINK-U-S 140.00	5.540	5.497	-43
DUCH-N 750.00	4.46	4.47	10
DUCH-N 835.00	4.360	4.47	110
DUCH-N 915.00	4.298	4.474	176
DUCH-N 1000.00	4.204	4.474	270
DUCH-N 1090.00	4.146	4.474	328
DUCH-N 1090.00	4.146	4.474	328
DUCH-N 1170.00	4.143	4.474	331
DUCH-N 1250.00	4.142	4.474	332
NEWLAKE2 0.00		5.123	
NEWLAKE2 22.00		4.548	
NEWLAKE2 43.00		4.548	
NEWLAKE2 110.00		4.548	
NEWLAKE2 207.00		4.548	
NEWLAKE2 331.00		4.548	
NEWLAKE2 419.00		4.548	
NEWLAKE2 508.00		4.548	
NEWLAKE2 508.00		4.548	
NEWLAKE2 581.00		4.548	
NEWLAKE2 647.00		4.548	
LAKELINK2 0.00		4.548	
LAKELINK2 20.00		4.474	

Table 15 MIKE11 Model Results - 100Yr ARI Event - Peak Discharges

Catchment development		*Existing*	*Site developed*
U/S Existing Lagoon		*Existing*	*Excavated+Fill*
Existing Lagoon level S3		*RL 4.5 m*	*RL 3.5 - (outlet weir)*
New Wetland S5		*na*	*RL 3.0 - (outlet weir)*
Connection S2		*na*	*RL 3.4 - (invert)*
Tailwater Level		*RL 2.3*	*RL 2.3*
Storm ARI & Duration		*100yr 9hr*	*100yr 9hr*

Branch & Chainage		***Peak Q (m3/sec)***	***Peak Q (m3/sec)***	***% Change***
DUCH-S 35.00		31.0	31.1	0%
DUCH-S 115.00		31.1		
DUCH-S 220.00		30.9	30.9	0%
DUCH-S 410.00		36.6	37.3	2%
DUCH-S 600.00		19.6	26.0	33%
DUCH-S 720.00		19.1	26.0	36%
DUCH-S 790.00		18.8	25.9	38%
DUCH-S 850.00		55.5	63.0	13%
DUCH-S 950.00		54.8	62.8	15%
DUCH-S 1060.00		54.7	63.2	16%
DUCH-S 1175.00		57.2	67.2	17%
DUCH-S 1295.00		56.7	67.1	18%
DUCH-S 1430.00		55.9	32.9	-41%
DUCH-S 1495.00		55.9	32.5	-42%
DUCH-S 1575.00		55.9	32.4	-42%
DUCH-S 1625.00		55.9	32.4	-42%
DUCH-S 1675.00		55.9	32.4	-42%
DUCH-L 35.00		6.1	36.8	507%
DUCH-L 95.00		6.1	36.9	507%
DUCH-L 137.43		6.1	36.9	507%
DUCH-L 157.43		61.9	67.5	9%
DUCH-L 185.00		61.9	67.5	9%
DUCH-L 265.00		61.9	67.5	9%
DUCH-L 345.00		61.9	67.5	9%
DUCH-L 395.00		61.9	67.5	9%
DUCH-L 445.00		61.9	67.5	9%
DUCH-L 500.00		61.9	67.5	9%
DUCH-L 555.00		61.9	67.5	9%
DUCH-L 602.50		61.9	67.5	9%
DUCH-L 650.00		61.9	67.5	9%
DUCH-L 700.00		61.9	67.5	9%
DUCH-L 752.50		63.3	69.3	10%
DUCH-L 805.00		63.3	69.3	10%
DUCH-L 857.50		63.3	69.3	10%
DUCH-L 910.00		63.3	69.3	10%
DUCH-L 960.00		63.3	69.3	10%
DUCH-L 1010.00		63.3	69.3	10%
DUCH-L 1060.00		63.3	69.3	10%
DUCH-L 1110.00		63.3	69.3	10%

DUCH-L 1185.00		63.3	69.3	10%
DUCH-L 1295.00		63.3	69.3	10%
DUCH-L 1410.00		63.3	69.3	10%
DUCH-U 40.00		25.3	24.7	-2%
DUCH-U 115.00		25.3	24.7	-2%
DUCH-U 225.00		25.3	24.7	-3%
DUCH-U 370.00		25.0	24.7	-1%
DUCH-U 495.00		24.8	25.0	1%
DUCH-U 600.00		39.5	37.4	-5%
DUCH-U 700.00		38.5	37.3	-3%
DUCH-U 810.00		37.6	37.2	-1%
DLINK-U-S 70.00		0.1	0.0	
DUCH-N 827.00			3.3	
DUCH-N 875.00			3.3	
DUCH-N 957.50			3.0	
DUCH-N 1045.00			2.8	
DUCH-N 1130.00			36.6	
DUCH-N 1210.00			36.7	
NEWLAKE2 11.00			34.2	
NEWLAKE2 32.50			34.0	
NEWLAKE2 76.50			33.5	
NEWLAKE2 158.50			32.9	
NEWLAKE2 269.00			32.4	
NEWLAKE2 375.00			36.2	
NEWLAKE2 463.50			35.4	
NEWLAKE2 544.50			2.4	
NEWLAKE2 614.00			0.7	
LAKELINK2 10.00			40.4	

2.5.8.7 Comparison of results – 5, 10, 20, and 100 Year ARI Events

The summary details for the 5, 10, 20 and 100 Year ARI events at selected locations are tabulated in Table 16 and Table 17. Peak heights and peak discharges at each cross section are shown in Table 18 and Table 19.

Results are shown for all events including 5-year, 10-year, 20-year, and 100-year ARI events. The peak levels and discharges for selected locations are also summarised in the tables.

Table 16 MIKE11 Model - Peak Levels at Selected Locations

Location		Peak Water level (RL m AHD) At location for various ARI of:			
Description	**Branch & Chainage**	**5 year**	**10 year**	**20 year**	**100 year**
Existing Lagoon	Duch-S 1360	4.62	4.94	5.00	5.12
Constructed Wetland	Newlake2 331	4.06	4.23	4.33	4.54
Near upstream boundary Existing Lagoon	Duch-S 540	5.29	5.33	5.39	5.50
Ocean Drive - Northern Culverts	Duch-U 0.00	6.71	6.75	6.80	6.91
Ocean Drive – Southern Culverts	Duch-S 0.00	6.51	6.54	6.59	6.69

Table 17 MIKE11 Model – Peak Discharges at Selected Locations

Location		Peak Discharge (m^3/sec) At location for various ARI of:			
Description	**Branch & Chainage**	**5 year**	**10 year**	**20 year**	**100 year**
Duchess Ck Outlet	Duch-L 1410	14.7	31.7	44.4	69.3
Outlet from Existing Lagoon to "overflow" (S3)	Duch-S 1495	7.6	14.6	19.7	32.5
Outlet from constructed wetland (S5)	Lakelink2 10	7.5	17.2	24.6	40.2
Ocean Drive - Northern Culverts	Duch-U 40	10.6	13.1	16.2	24.7
Ocean Drive – Southern Culverts	Duch-S 35	6.2	17.1	21.4	36.8

Table 18 MIKE11 Model Results - 5, 10, 20Yr ARI Events - Max Levels

Catchment development	*Site developed*	*Site developed*	*Site developed*
U/S Existing Lake	*Excavated+Fill*	*Excavated+ Fill*	*Excavated+ Fill*
Existing Lagoon level S3	*RL 3.5 - (outlet weir)*	*RL 3.5 - (outlet weir)*	*RL 3.5 - (outlet weir)*
New Wetland S5	*RL 3.0 - (outlet weir)*	*RL 3.0 - (outlet weir)*	*RL 3.0 - (outlet weir)*
Connection S2	*RL 3.4 - (invert)*	*RL 3.4 - (invert)*	*RL 3.4 - (invert)*
Tailwater Level	*RL 2*	*RL 2*	*RL 2*
Storm ARI & Duration	*5yr 9hr*	*10yr 9hr*	*20yr 9hr*

Branch & Chainage	***Max WL RL m***	***Max WL RL m***	***Max WL RL m***
DUCH-S 0.00	6.34	6.52	6.57
DUCH-S 70.00	6.16	6.30	6.34
DUCH-S 160.00	5.66	5.79	5.83
DUCH-S 280.00	5.42	5.59	5.65
DUCH-S 540.00	5.20	5.32	5.38
DUCH-S 540.00	5.20	5.32	5.38
DUCH-S 660.00	5.11	5.22	5.28
DUCH-S 780.00	4.84	5.00	5.06
DUCH-S 800.00	4.62	4.95	5.02
DUCH-S 800.00	4.62	4.95	5.02

DUCH-S 900.00	4.62	4.94	5.01
DUCH-S 1000.00	4.62	4.94	5.01
DUCH-S 1120.00	4.62	4.94	5.01
DUCH-S 1230.00	4.62	4.94	5.00
DUCH-S 1360.00	4.62	4.94	5.00
DUCH-S 1360.00	4.62	4.94	5.00
DUCH-S 1440.00	2.87	3.52	3.88
DUCH-S 1550.00	2.87	3.52	3.87
DUCH-S 1600.00	2.79	3.45	3.81
DUCH-S 1650.00	2.73	3.39	3.76
DUCH-S 1700.00	2.63	3.33	3.70
DUCH-L 0.00	2.68	3.40	3.77
DUCH-L 70.00	2.65	3.35	3.73
DUCH-L 120.00	2.64	3.34	3.71
DUCH-L 154.87	2.63	3.33	3.70
DUCH-L 154.87	2.63	3.33	3.70
DUCH-L 160.00	2.63	3.32	3.69
DUCH-L 210.00	2.59	3.27	3.63
DUCH-L 320.00	2.51	3.14	3.47
DUCH-L 370.00	2.48	3.08	3.40
DUCH-L 420.00	2.46	3.05	3.37
DUCH-L 470.00	2.44	3.02	3.33
DUCH-L 530.00	2.40	2.96	3.27
DUCH-L 580.00	2.38	2.91	3.21
DUCH-L 625.00	2.36	2.88	3.17
DUCH-L 675.00	2.32	2.80	3.07
DUCH-L 725.00	2.27	2.73	2.98
DUCH-L 780.00	2.25	2.69	2.93
DUCH-L 830.00	2.31	2.64	2.87
DUCH-L 885.00	2.25	2.56	2.79
DUCH-L 935.00	2.22	2.51	2.74
DUCH-L 985.00	2.20	2.49	2.71
DUCH-L 1035.00	2.18	2.45	2.66
DUCH-L 1085.00	2.16	2.41	2.60
DUCH-L 1135.00	2.14	2.36	2.53
DUCH-L 1235.00	2.11	2.29	2.43
DUCH-L 1355.00	2.06	2.18	2.28
DUCH-L 1465.00	2.00	2.00	2.00
DUCH-U 0.00	6.71	6.75	6.80
DUCH-U 80.00	6.12	6.22	6.35
DUCH-U 150.00	5.81	5.88	6.06
DUCH-U 300.00	5.36	5.41	5.47
DUCH-U 440.00	5.26	5.31	5.36
DUCH-U 550.00	5.24	5.28	5.34
DUCH-U 550.00	5.24	5.28	5.34
DUCH-U 650.00	5.18	5.22	5.28
DUCH-U 750.00	5.11	5.15	5.22
DUCH-U 870.00	4.90	4.95	5.02
DLINK-U-S 0.00	5.24	5.28	5.34
DLINK-U-S 140.00	5.29	5.32	5.38

DUCH-N 819.00		2.95	3.53	3.90
DUCH-N 835.00		2.93	3.53	3.90
DUCH-N 915.00		2.92	3.53	3.90
DUCH-N 1000.00		2.92	3.53	3.90
DUCH-N 1090.00		2.92	3.53	3.90
DUCH-N 1090.00		2.92	3.53	3.90
DUCH-N 1170.00		2.84	3.45	3.83
DUCH-N 1250.00		2.81	3.40	3.77
NEWLAKE2 0.00		4.86	4.94	5.00
NEWLAKE2 22.00		4.06	4.30	4.34
NEWLAKE2 43.00		4.06	4.30	4.34
NEWLAKE2 110.00		4.06	4.30	4.34
NEWLAKE2 207.00		4.06	4.30	4.34
NEWLAKE2 331.00		4.06	4.30	4.34
NEWLAKE2 419.00		4.06	4.30	4.34
NEWLAKE2 508.00		4.06	4.30	4.34
NEWLAKE2 508.00		4.06	4.30	4.34
NEWLAKE2 581.00		4.06	4.30	4.34
NEWLAKE2 647.00		4.06	4.30	4.34
LAKELINK2 0.00		4.06	4.30	4.34
LAKELINK2 20.00		2.92	3.53	3.90

Table 19 MIKE11 Model Results - 5, 10, 20Yr ARI Events - Peak Discharges

Catchment development		*Site developed*	*Site developed*	*Site developed*
U/S Existing Lagoon		*Excavated+ Fill*	*Excavated+ Fill*	*Excavated+ Fill*
Existing Lagoon level S3		*RL 3.5 - (outlet weir)*	*RL 3.5 - (outlet weir)*	*RL 3.5 - (outlet weir)*
New Wetland S5		*RL 3.0 - (outlet weir)*	*RL 3.0 - (outlet weir)*	*RL 3.0 - (outlet weir)*
Connection S2		*RL 3.4 - (invert)*	*RL 3.4 - (invert)*	*RL 3.4 - (invert)*
Tailwater Level		*RL 2*	*RL 2*	*RL 2*
Storm ARI & Duration		*5yr 9hr*	*10yr 9hr*	*20yr 9hr*
Branch & Chainage		***Peak Q (m3/sec)***	***Peak Q (m3/sec)***	***Peak Q (m3/sec)***
DUCH-S 35.00		6.2	17.1	21.4
DUCH-S 115.00				
DUCH-S 220.00		6.1	17.0	21.2
DUCH-S 410.00		10.0	20.6	25.7
DUCH-S 600.00		6.1	12.3	16.1
DUCH-S 720.00		6.0	12.2	16.0
DUCH-S 790.00		6.0	12.0	15.9
DUCH-S 850.00				
DUCH-S 950.00		18.6	31.8	40.6
DUCH-S 1060.00		18.0	31.7	40.8
DUCH-S 1175.00		18.4	32.9	43.0
DUCH-S 1295.00		17.5	32.6	42.8
DUCH-S 1430.00		8.0	15.7	20.8
DUCH-S 1495.00		7.6	14.6	19.7
DUCH-S 1575.00		7.6	14.6	19.7
DUCH-S 1625.00		7.6	14.5	19.7
DUCH-S 1675.00		7.6	14.5	19.7

DUCH-L 35.00		7.6	17.1	24.1
DUCH-L 95.00		7.7	17.1	24.1
DUCH-L 137.43		7.7	17.1	24.1
DUCH-L 157.43		14.5	31.4	43.7
DUCH-L 185.00		14.5	31.4	43.7
DUCH-L 265.00		14.5	31.4	43.7
DUCH-L 345.00		14.5	31.4	43.7
DUCH-L 395.00		14.5	31.4	43.6
DUCH-L 445.00		14.5	31.4	43.6
DUCH-L 500.00		14.5	31.4	43.6
DUCH-L 555.00		14.5	31.3	43.6
DUCH-L 602.50		14.5	31.3	43.6
DUCH-L 650.00		14.5	31.3	43.6
DUCH-L 700.00		14.5	31.3	43.6
DUCH-L 752.50		14.7	31.7	44.4
DUCH-L 805.00		14.7	31.7	44.4
DUCH-L 857.50		14.7	31.7	44.4
DUCH-L 910.00		14.7	31.7	44.4
DUCH-L 960.00		14.7	31.7	44.4
DUCH-L 1010.00		14.7	31.7	44.4
DUCH-L 1060.00		14.7	31.7	44.4
DUCH-L 1110.00		14.7	31.7	44.4
DUCH-L 1185.00		14.7	31.7	44.4
DUCH-L 1295.00		14.7	31.7	44.4
DUCH-L 1410.00		14.7	31.7	44.4
DUCH-U 40.00		10.6	13.1	16.2
DUCH-U 115.00		10.6	13.1	16.2
DUCH-U 225.00		10.6	13.1	16.2
DUCH-U 370.00		10.6	13.1	16.2
DUCH-U 495.00		10.8	13.2	16.4
DUCH-U 600.00		14.9	21.8	25.8
DUCH-U 700.00		14.7	21.1	25.4
DUCH-U 810.00		14.3	20.6	25.2
DLINK-U-S 70.00		0.2	0.0	0.0
DUCH-N 827.00		1.9	0.2	0.2
DUCH-N 875.00		1.9	0.2	0.2
DUCH-N 957.50		1.9	0.2	0.2
DUCH-N 1045.00		1.9	0.2	0.3
DUCH-N 1130.00		7.6	17.2	24.2
DUCH-N 1210.00		7.6	17.1	24.1
NEWLAKE2 11.00		9.1	16.9	22.0
NEWLAKE2 32.50		8.9	16.7	21.9
NEWLAKE2 76.50		8.6	16.5	21.8
NEWLAKE2 158.50		8.2	16.3	21.7
NEWLAKE2 269.00		7.8	16.1	21.7
NEWLAKE2 375.00		7.9	17.4	24.7
NEWLAKE2 463.50		7.7	17.3	24.6
NEWLAKE2 544.50		1.7	2.2	2.4
NEWLAKE2 614.00		0.5	0.6	0.7
LAKELINK2 10.00		7.5	17.2	24.6

2.5.8.8 Flows at Hydraulic Control Structures

Peak flows at the flow control structures for "Developed" Conditions are shown in Table 20.

Table 20 MIKE11 Model Results – Flows at Hydraulic Control Structures – "Developed" Conditions

Location	Code		5 Yr ARI	10 Yr ARI	20 Yr ARI	100 Yr ARI
Existing Lagoon Connection to Wetlands	S2	Low Flow Weir	9.1	13.0	13.7	15.3
		High Flow Overflow	0.0	3.9	8.3	18.8
Existing Lagoon "Overflow"	S3	Low Flow Weir	8.0	11.7	12.5	14.0
		High Flow Overflow	0.0	3.9	8.2	18.8
Wetlands Outlet	S4	Low Flow Weir	7.5	13.5	15.4	16.8
	S5	High Flow Overflow	0.0	3.7	9.2	23.4

For minor runoff events, most of the outflow occurs through the water level control "low flow" weir structures;

- Overflow across the embankments only occurs for major storm events.
- For both the existing lagoon and the constructed wetland, the recurrence interval (ARI) for embankment overflow is 5 years ARI. This is in accordance with Council's "major/minor" recommendations for drainage design.
- The flows through the "low flow" control structures increase only moderately as the storm severity increases.
- Flow conditions on the embankments during overflows in major storm events are generally within the non-scouring limit for grassed surfaces with velocities of less than 1.8 m/sec.
- The frequency of inundation of the frog habitat on the north bank of the existing lagoon is reduced. With development, this habitat is only inundated by events in excess of the 5 Year ARI storm event (which has a maximum water level of RL 4.62) whereas the habitat is inundated by lesser events under existing conditions.

2.5.8.9 Impacts on Milland/Seawide Property

As noted previously in Section 2.5.8.6, inundation levels for the design storm event are increased as a result of the proposed development by 110 mm at the boundary between the Milland/Seawide property and the north-east corner of the St Vincents Foundation site (Chainage 835 DUCH-N branch on the MIKE11 model) but this afflux reduces to zero only 85 metres further upstream within the Milland/Seawide property (Chainage 750).

Figure 22 indicates "Existing Inundation Limits", "Developed Inundation Limits" and "Development Inundation Limits with +20% Rainfall Intensity due to Climate Change" within the Milland/Seawide site. The relevant water levels at various chainages along the stream, including the boundaries of the Milland/Seawide property, for the different scenarios are listed in the following Table 21.

Table 21 Inundation Water Levels within the Milland/Seawide Property

Model Configuration	Stream Chainage (Figure 10)			
	915 (SVF site)	835 (boundary)	750 (boundary)	675 (SVF site)
"Existing" (100 yr rain; Ocean RL 2.3)	4.3	4.36	4.46	4.55
"Developed" (100 yr rain; Ocean RL 2.3)	4.47	4.47	4.47	4.47
Afflux caused by development (mm)	+170	+110	+10	-100
"Developed with Climate Change" (100 yr rain + 20%; Ocean RL 3.2)	4.74	4.74	4.74	4.74

These impacts on the Milland/Seawide site are considered minor and do not adversely affect any future use of that property. The topography of the land in the area means that only small volumes of site fill are required to offset the effects of the afflux. Most of the Milland/Seawide site is not affected by this afflux

The proposed constructed wetlands re-establishes the original natural flow path of Duchess Gully discharging into the northern end of the defined channel of the lower reach of Duchess Gully.

The hydrodynamic modelling to date has not simulated these original natural flow conditions. Nonetheless, flows in the northern end of the Duchess Gully channel (through the Milland/Seawide property) under proposed "Developed Conditions" will be less than for the original natural conditions. This is because, under the current development proposals, the existing man-made "Overflow" channel on the SVF site (constructed in the early 1900's along the northern boundary of Council's STP) is being retained. This channel will continue to bypass some storm flow directly to the lower reach of Duchess Gully which would otherwise have flowed via the northern end of the Duchess Gully channel under original natural conditions.

2.5.9 Effects of Proposed Fill on the Milland/Seawide Site

A small area of fill is proposed on the Milland/Seawide development site adjacent to the Duchess Gully channel where it passes through the south-west corner of the MS site. The extent of the proposed fill zone is shown on Figure 22.

2.5.9.1 Impacts of the Fill on Constructed Wetlands Hydraulic Performance

This fill does not change the predicted flood levels within the proposed constructed wetland on the St Vincents Foundation site as shown in Table 16 because the MIKE11 flood modeling assumed that all the runoff from Subarea 18 (which includes the Milland/Seawide site) flowed directly into the constructed wetland water body, bypassing the section of Duchess Gully between Chainage 750 and Chainage 835 where the proposed fill is located.

If some of the runoff from the Milland/Seawide site actually flows directly to Duchess Gully instead of the wetland water body, then flood levels in the wetland will be slightly lower than the levels given in Table 16.

2.5.9.2 Impacts of the Fill on Flood levels within the Milland/Seawide Site

Although the proposed fill was not modeled explicitly in the "Development" scenario, information from the "Existing Conditions" model run can be used to assess the likely impact of the fill on flow conditions in Duchess Gully at this location under the proposed development conditions for the St Vincents Foundation and the Milland/Seawide sites.

Figure 24 shows the flow ratings at two cross sections in Duchess Gully in the vicinity of the fill during the 100 year design flood for “Existing” conditions. That is, the water levels reached at the various flow rates which occurred during the event. These water levels and flows reflect typical conditions at this location given the available flow area, stream gradient, channel roughness and storage attenuation to that point in the catchment.

Flow rates under “Developed” conditions will be less than the maximum flow rates in Figure 24 because much of the catchment runoff from Subarea 18 which flows past this location under “Existing” conditions is diverted directly into the proposed constructed wetland on the SVF site under development proposals. It is estimated that only 30% of the runoff from Subarea 18 could flow directly to the Duchess Gully under “Developed” conditions, mainly derived from the Milland/Seawide site.

The resulting flows in the vicinity of the fill zone for various 100 year storm durations are shown in Table 22. The actual peak flow rates at the fill zone are in fact likely to be less than shown in the last column of the table because some channel attenuation of these local flows will occur under “Developed” conditions though it will be less than that shown in the table for “Existing” conditions.

Table 22 Flow Conditions at the Milland/Seawide Property Fill Site

	“Existing”		“Developed”	
Storm Duration (hr)	**WBNM model Subarea 18 Peak Runoff (m^3/s)**	**MIKE11 model Aver. Attenuated Peak at Fill Site (m^3/s)**	**WBNM model Subarea 18 Peak Runoff (m3/s)**	**30% of WBNM Peak Flow (m^3/s)**
1	10.0	n/a	17.8	5.3
2	10.3	n/a	18.1	5.4
3	9.5	n/a	15.2	4.6
4.5	9.6	n/a	14.6	4.4
6	9.4	n/a	12.8	3.8
9	9.1	6.0	11.2	3.4

The flow conditions at the fill location for both “Existing” and “Developed” scenarios are illustrated in Figure 25. This diagram shows the stream cross section at Chainage 835 with the water levels corresponding. Local flood peak flows are expected to be of the order of RL 3.4 m^3/s, allowing for some channel attenuation, with a corresponding water level of approximately RL 4.2 mAHD. The extent of the fill is superimposed on these conditions in Figure 25.

Figure 25 shows that the fill will have no effect on the conveyance at this location and will not increase local runoff flood levels. Runoff flows in this reach of Duchess Gully (that is, passing through the south-west corner of the Milland/Seawide site) under the “Developed” scenario are greatly reduced by diversion of much of the local subcatchment (Subarea 18) directly into the constructed wetland.

It should be noted that flood runoff from the constructed wetland proposed for the SVF site results in higher water levels within the south-west corner of the Milland/Seawide site. This will govern the final reclamation fill surface levels required in this area (see Sections 2.5.8.9 and 2.6.3.2).

2.5.10 Sensitivity Testing of Hydraulic Models

2.5.10.1 Storm Duration

The results reported above are for a 9 hour duration storm, which duration is critical for the whole catchment. Some sensitivity testing was carried out for shorter (6 hr) and longer (12hr) duration storm events. As expected, the attenuation achieved by the proposed constructed wetland on the SVF site was greater for the 6 hour storm event and less for 12 hour storm event. However as the peak discharges and levels were greatest for the 9 hour storm at all locations downstream of the water bodies, the results for the 9 hour duration storm event are relevant for the comparison of development cases in these areas including the Milland/Seawide site.

2.5.10.2 Ocean Storm Surges – "Tailwater" Level in Duchess Gully

The tailwater level adopted for all the cases above was RL 2.0 mAHD. A case was run with a higher tailwater level of RL2.6 m AHD (equivalent to a 1% AEP storm surge level) for the proposed developments including a constructed wetland on the St Vincents Foundation site. When compared with the 2 m AHD tailwater assumption, the constructed wetland water levels were found to be the same, and the peak level in Duchess Gully just downstream of the "Overflow" confluence (Duch-L 160) was found to be approximately 20 mm higher. This is an insignificant difference.

2.5.10.3 Low Tide Conditions

The mean high water spring tide for the ocean at this location is 0.65 m AHD. A case was run with this lower tailwater level. The constructed wetland level was the same as for the high tailwater levels. The peak level in Duchess Gully downstream of the "overflow" junction (Duch-L 160) was found to be 14 mm lower, again an insignificant difference. It appears therefore that the tailwater level does not affect peak water levels upstream of the "overflow" junction of Duchess Gully, including the Milland/Seawide site.

2.5.10.4 Climate Change Impacts

It is a requirement of recent NSW state government policies (DECCW 2007, DECCW 2009d, DECCW 2009a, and DECCW 2009b) that planning and development assessments must include consideration of the potential impacts of recommended benchmark climate changes.

The relevant factors for the proposed development arising from climate change are:

- sea level rises
- catchment runoff flow rates
- catchment runoff volumes

Sea Level Rise

NSW State Government Sea Level Rise Policy (DECCW 2009d) requires that inundation risk assessment allow for a projected 0.9 metres rise in average sea level by 2100. This requirement is incorporated in other recent NSW guidelines including the Floodplain Risk Management Guideline Practical Consideration of Climate Change (DECCW 2007).

In accordance with this requirement, the MIKE11 storm event model was re-run with a boundary ocean level of RL 3.2, i.e. the adopted boundary level of RL 2.3 mAHD (see Section2.5.7.6) plus a sea level rise of 0.9 metres.

The hydraulic controls incorporated into the lagoon and wetland systems proposed for the SVF site which control the water levels in the water bodies during major floods are located at elevations of RL 3.5 mAHD and higher. An increase in the adopted sea level used in storm modelling to RL 3.2 mAHD should not materially alter the behaviour of the hydraulic systems in the development site because the raised sea level at the outlet of Duchess Gully is still below the hydraulic control structures.

Catchment Runoff Flow Rates and Rainfall Intensities

Catchment runoff rates are directly affected by rainfall intensities. Runoff flow rates will change in proportion to any change in rain intensities. Water levels in the streams bordering the development are in turn affected by the runoff flow rates.

It is often suggested that rainfall intensities, storm intensities and storm frequency will be affected by climate changes resulting from global greenhouse warming. All these effects are reflected in the "IFD" curves (Intensity Frequency Duration curves) derived from rainfall data. The authoritative reference for IFD curves is the publication "Australian Rainfall and Runoff" which is revised from time to time to allow for improved estimation procedures.

At the present time there are no proposals to amend the current recommended IFD curves to allow for climate changes apparently because trends in rainfall intensity changes are not evident in the data and are uncertain in prediction models.

The NSW “Floodplain Risk Management Guideline Practical Consideration of Climate Change” (DECCW 2007) recommends that flood modelling should include sensitivity testing with rainfall intensities increased by up to +30%.

These guidelines also quote recent estimates from the CSIRO of indicative changes in future extreme rainfall rates in the region of the site as listed in Table 23.

Table 23 Indicative Changes in Extreme 1-day Rainfall Totals

Catchment Location	2030	2070
Hunter – Central Rivers	-10% to +12%	-7% to +10%
Northern Rivers	-10% to +5%	+5% to +10%

Catchment Runoff Volumes

Catchment runoff volumes could also be affected by climate changes. The Bureau of Meteorology "trend maps" of rainfall totals from 1970 to the present for New South Wales show a decrease in wet days and heavy rain days. Other published trends show declines in average rainfall totals in several regions of Australia including NSW.

Increasing runoff volumes do not pose an increased risk of inundation because the water bodies within the catchment of Duchess Gully are provided with overflows which rapidly discharge any excess runoff. The standing water levels in the water bodies are strictly limited by these overflows.

Increasing runoff volumes could lead to some increased accumulation of erosion damage in the water courses and streams.

Results for Storm Modelling with Climate Change

The MIKE11 model of “Developed Conditions” was run with a sea level of RL 3.2 mAHD and catchment model runoff hydrographs incorporating +30% greater rainfall intensities in order to estimate the sensitivity of maximum inundation levels to rainfall changes.

The resulting water levels are shown plotted in Figure 23. The maximum flood level in the south-west corner of the Milland/Seawide development site for this condition is RL 4.87.

With the increased rainfall rates, there are increases in flows and velocities in the lower reach of Duchess Gully (from the constructed wetlands outlet to the ocean) which may resulting in some increased erosion damage during major flood events.

Inundation Levels on the Milland/Seawide Property with Climate Change

Inundation levels in the south-west corner of the Milland/Seawide development site for varying amounts of rainfall intensity increase with climate change are shown in the following Table 24.

Table 24 Inundation Levels on Milland/Seawide Site with Climate Change Rainfall Increase

% Rainfall Intensity Increase	100 year Flood Level at S-W Corner of the Site (mAHD)
0%	RL 4.47
+20%	RL 4.74
+30%	RL 4.87

The proposed fill level in this area will RL 5.00 mAHD. This was adopted to provide a construction platform which will allow house slabs to comply with Council's Section 117 requirement for slabs to be a minimum of 800 mm above the 100 year flood level of RL 4.47 (a slab level of RL 5.27).

2.5.11 Summary of Hydraulic Modelling Results

Proposed urban development within the site and the adjoining SVF site will increase the quantity of runoff, increase the rate of runoff response and increase peak discharges from the developed areas for major storm events.

However, modelling has shown that is possible to develop these sites without external impact, (that is, without increasing flood levels or discharges upstream or downstream of the sites) by changing the existing lagoon outlet geometry, and incorporating an additional constructed wetland of 10.5 hectares in the development on the St Vincents Foundation property

It can be concluded that the hydraulic impacts of proposed urban development can be satisfactorily ameliorated by construction of an additional water body (the constructed wetland) on the SVF site. Consequently these issues do not limit the development potential of the two sites.

The proposed constructed wetlands re-establishes what we believe is the original natural flow path of Duchess Gully discharging into the northern end of the defined channel of the lower reach of Duchess Gully where it flows through the south-west corner of the Milland/Seawide development site.

The hydrodynamic modelling to date has not simulated these original natural flow conditions. Nonetheless, flows in the northern end of the Duchess Gully channel (through the Milland/Seawide property) under proposed "Developed Conditions" will be less than for the original natural conditions. This is because, under the current development proposals, the existing man-made "Overflow" channel (constructed in the early 1900's along the northern boundary of Council's STP) is being retained. This channel will continue to bypass some storm flow directly to the lower reach of Duchess Gully which would otherwise have flowed via the northern end of the Duchess Gully channel under original natural conditions.

The attached diagram Figure 22 indicates "Existing Inundation Limits", "Developed Inundation Limits" and "Development Inundation Limits with +20% Rainfall Intensity due to Climate Change". The relevant water levels at various chainages along the stream, including the boundaries of the Milland/Seawide property, for the different scenarios are listed in Table 21.

2.6 Floodplain Management

2.6.1 Regulatory Requirements (Floodplain Management Manual)

DGR Item 6.6 requires an assessment of any flood risk on site under any relevant provisions of the NSW Floodplain Management Manual (DIPNR 2005).

The site is not mapped as "flood-prone" (as defined in the Interim Flood Policy of April 2007, PMHC 2007) on the Section 149 Planning Certificate issued for the site.

2.6.2 Development Strategy

Although the development site is not classed as "flood prone", the low-lying nature the south-west corner of the Milland/Seawide site gives rise to occasional inundation from local severe storm events at this ocation. As a result, the development has been conservatively designed so as to meet all of Council's usual requirements and performance criteria for flood-prone land.

The resulting objectives of this section of the assessment are to:

- Demonstrate that the development proposals satisfy the requirements for flood-prone land.
- Demonstrate that the development satisfies the requirements of the Floodplain Management Manual.
- Demonstrate that the proposed development minimises inundation risk.

To meet these objectives it is necessary for this assessment to:

- Assess storm event and inundation risks within the development site area allowing for site-specific factors.
- Document features of the proposed development designed to mitigate risks and enhance the management of high rainfall risks.
- Document management options appropriate to the proposed development in a form suitable for incorporation in a Floodplain Risk Management Plan.

A Floodplain Risk Management Plan must address:

- Existing stormwater or inundation risk for existing development;
- Future risk for likely proposed development;
- Continuing risks after allowing for the effects of any structural stormwater or flood controls.

It is not within the scope of this assessment document or within the scope of development proposals to prepare a Floodplain Risk Management Plan. This assessment does however assist with all the necessary background data required for such a risk management plan including:

- Stream velocity and depth hazards;
- Inundation extents;
- Housing inundation immunity; and

- Evacuation routes.

2.6.3 Development Impacts on Floodplain Risk Management Issues

2.6.3.1 Existing Development Inundation Immunity

It is shown in Section 2.5 that inundation levels in existing residential areas along the southern boundary of the site on Duchess Gully are not worsened by the proposed developments within the Duchess Gully catchment including the present development proposals for the Milland/Seawide site and .

2.6.3.2 Development Reclamation (Fill) Levels

Inundation levels in Duchess Gully for the 100 Year ARI event (1% AEP) are calculated in Section 4.3 and are shown plotted in Figure 20 and Figure 21. Council's Interim Flood Policy (PMHC 2007) requires that the minimum level of residential lots must be at least equal to these 100 Year ARI levels.

Reclamation fill levels in the proposed residential areas will be constructed to a freeboard of 0.5 metres above these 100 Year ARI event water levels or higher. This conservative approach minimises inundation risk beyond the normal required standard.

Residential lots will also be constructed to a freeboard of 0.5 metres above local 100 Year ARI water levels for drainage systems designed in accordance with Port Macquarie Hastings Council requirements under AUS-SPEC 2003.

Road crossings over flow paths within the proposed development will be designed to provide 100 Year ARI event immunity.

It is a requirement of Council's Interim Flood Policy (PMHC 2007) that house floor levels be constructed with a freeboard of 0.8 metres above the 100 Year ARI event water levels. This requirement ensures that house floor levels will generally be higher than the surrounding allotment fill levels.

2.6.3.3 Evacuation Access Routes

The contours for the proposed development site plotted in Figure 2 show that for all significant rainfall events there are inundation-free evacuation routes via the internal road system to higher ground along Ocean Drive. This applies also to the coastal eco-tourism zone of the SVF property lying immediately south of the Milland/Seawide property.

Local roads may be partly inundated during major storm events to the extent allowed under drainage design limits set out in AUS-SPEC 2003.

2.6.3.4 Public Safety- Flood Hazard for Development Conditions

Inundation hazard conditions expressed as depth and velocity for the 100 Year ARI as defined in the Floodplain Management Manual are shown plotted in Figure 21. This figure also shows the 100 Year ARI water levels throughout the Duchess Gully floodplain and the major stormwater flow paths.

The plotted data shows that the open space corridor through the SVF site is a “hydraulic floodway” or flow path throughout its length but conditions of velocity and depth fall into the “low hazard” category everywhere in the low-lying areas except for the following areas categorised as “high hazard”:

- the channel proper of Duchess Gully including the section flowing through the south-west corner of the Milland/Seawide site. Depths may exceed two metres and velocities may exceed 1.0 metres/sec In the “lower” reaches of Duchess Gully;
- the water bodies of the existing lagoon and the constructed wetland on the SVF site where depths exceed two metres;
- at the control structures on the existing lagoon and the constructed wetland on the SVF site and immediately downstream of these structures;
- at the overflow sections of the embankments surrounding the existing lagoon and the constructed wetland on the SVF site.

These “high hazard” areas are shown shaded in Figure 21. “High hazard” areas may need to be suitably signed to alert pedestrian and cycling traffic. Public risk issues within the Open Space Corridor are discussed further elsewhere.

The data plotted in Figure 21 also show that flow paths within the residential areas are “low hazard hydraulic floodways”.

There are no areas of “flood storage” or “flood fringe” areas in the proposed development site.

There are no levees in the proposed development since all residential areas are reclaimed to heights above the designated inundation levels.

There are no island areas within the proposed residential development areas.

2.6.3.5 Future Development Inundation Risk

Inundation risk within the development site is not likely to be increased with further future development in external catchment areas west of Ocean Drive because it is feasible to apply a development condition to these areas requiring that peak storm runoff rates are not increased by development. This condition is incorporated in Council’s flood policies.

2.6.3.6 Continuing Inundation Risk

There is no continuing flood/inundation risk under the proposed development because all residential areas are reclaimed to heights above the designated levels.

2.6.3.7 Probable Maximum Flood (PMF) Conditions

PMF conditions were calculated in accordance with procedures given in Bureau of Meteorology publications BOM (2003a) and BOM (2003b).

The estimated 9 hour duration PMP rainfall intensity was 100 mm/hour and the estimated peak flow rate for the PMF at the outlet of Duchess Gully was 208 m^3/sec.

At this flow rate water levels are governed by the hydraulic capacity of the embankments surrounding the existing lagoon and the constructed wetland on the adjoining SVF property. The resulting maximum inundation levels are shown in Table 25.

Table 25 PMF Maximum Water Levels

Location	Peak PMF Flood Level mAHD
Existing Lagoon	5.5
Constructed Wetland	4.8

The water level shown for the "Constructed Wetland" location will apply to the south-west corner of the Milland/Seawide development site.

The proposed development on the Milland/Seawide site will still be free of inundation at these water levels and access paths to higher ground will still be available.

3 CONCLUSIONS

This Flood Assessment addresses DGR 6.6 and 6.7 and draws on the flood assessments undertaken on the adjoining StVincents Foundation (SVF) site.

The assessment confirms that, while the subject property is not designated as flood prone, the low lying nature of the SW corner of Lot DP 374315 results in occasional inundation from local storm events in Duchess Gully.

The flood assessment addresses flood risk from those storm events which cross property boundaries between the subject site and the adjoining SVF site (the subject of Development Applications MPO6-0085 and MPO7-0001) and includes consideration of:

- The requirements of the NSW Floodplain Management Manual;
- Potential future climate change sea level rises and increases in rainfall intensity.

The Flood Assessment undertaken includes the following key methodology components and findings:

- Determination of the peak discharge from Duchess Gully using the Probabilistic Rational Method (PRM) from Australian Rainfall and Runoff (1987);
- Setting up of a Watershed Bounded Network Model (WBNM) for Duchess Gully catchment which reproduces the peak flood discharges predicted by the PRM procedure. The SW corner of the subject Milland property is within sub area 18 of the WBNM model;
- Modification of the WBNM model to allow for existing development and proposed development of the subject site and adjoining SVF site;
- Setting up of a MIKE-II hydrodynamic model of Duchess Gully stream to simulate the behaviour for the 1% AEP (100 year ARI) design event and other lesser events;
- Adoption of RL 2.3mAHD ocean level at the mouth of Duchess Gully as the tailwater level for the MIKE-11 model. An ocean level of RL 2.6mAHD was also modelled for a sensitivity analysis. The higher ocean levels did not affect inundation levels at the site.
- Modelling was undertaken of an “Existing Development” scenario and a “Future Urban Development with Constructed Wetland” (on the adjoining SVF site) scenario respectively. The new constructed wetland on the adjoining SVF site is I 0.5ha in area and will be connected to both the existing Lagoon on the adjoining SVF site arid to the middle reaches of Duchess Gully (downstream of the SW corner of the Milland property);
- The ‘Future Urban Development Conditions’ model included proposed hydraulic outlet structures and channel improvements (at Ch.80 to Ch.250 of the Upper Tributary) on the adjoining SVF site;
- The MIKE-11 model allows for the detention and attenuation of storm runoff in the proposed constructed wetland on the adjoining SVF site and assumed that no detention basin is required on the Milland/Seawide site;
- The MIKE-11 model shows that under Developed Conditions the 1% AEP (100 year ARI) event flood level is RL 4.47mAHD at the SW corner of the Milland property which corresponds to a 110mm increase in flood level at the southern boundary of the subject site (at Ch.835 on Branch DUCH-N). This afflux reduces to zero at a point 85 metres further upstream within the Milland property at Ch.750;
- The Flood Assessment also includes MIKE-11 Model results for 5 year, 10 year and 20 year ARI events and peak discharges for each of these events (refer Table 18 and Table 19);
- MIKE-11 modelling of the impact of climate change (CC) (with a 20% increase in rain intensity and an ocean tailwater level of RL 3.2 mAHD) gave a “100 year + Climate Change” flood level of RL 4.74mAHD at the SW corner of the site (refer Table 24);
- The Flood Assessment considered the impact of filling over an area of 470m2 of the Duchess Gully catchment within the SW corner of the Milland property to a minimum level

of RL 5.0 mAHD. This modelling found that the fill will have no effect on the conveyance at this location and will not increase local flood levels (refer Section 2.5.9, Figure 24 and Figure 25);

- Section 2.6 of the Flood Assessment deals with Floodplain Management Issues and confirms that:
  - Inundation levels in existing residential areas along the southern boundary of the SVF site are not worsened by the proposed development of the Milland/Seawide properties:
  - Future residential floor levels should be at least RL 5.27mAHD being 800mm above the 1% AEP (100 year ARI) event level;
  - Evacuation routes exist to the north via the internal road system to Ocean Drive;
  - Inundation hazard conditions are shown on Figure 21 of the report. The hazard conditions within the SW corner of the Milland property fall into the 'low hazard' category except for the channel proper of Duchess Gully which is categorised as 'high hazard' (Section 2.6.3.4).
  - Probable Maximum Flood (PMF) flood levels were calculated to be RL 4.8 mAHD within the Constructed Wetland on the SVF site and at the SW corner of the Milland property. The study confirms that fill levels in the SW corner of the Milland property will be above the PMF and access paths to higher ground will still be available (Section 2.6.3.7).

4 REFERENCES

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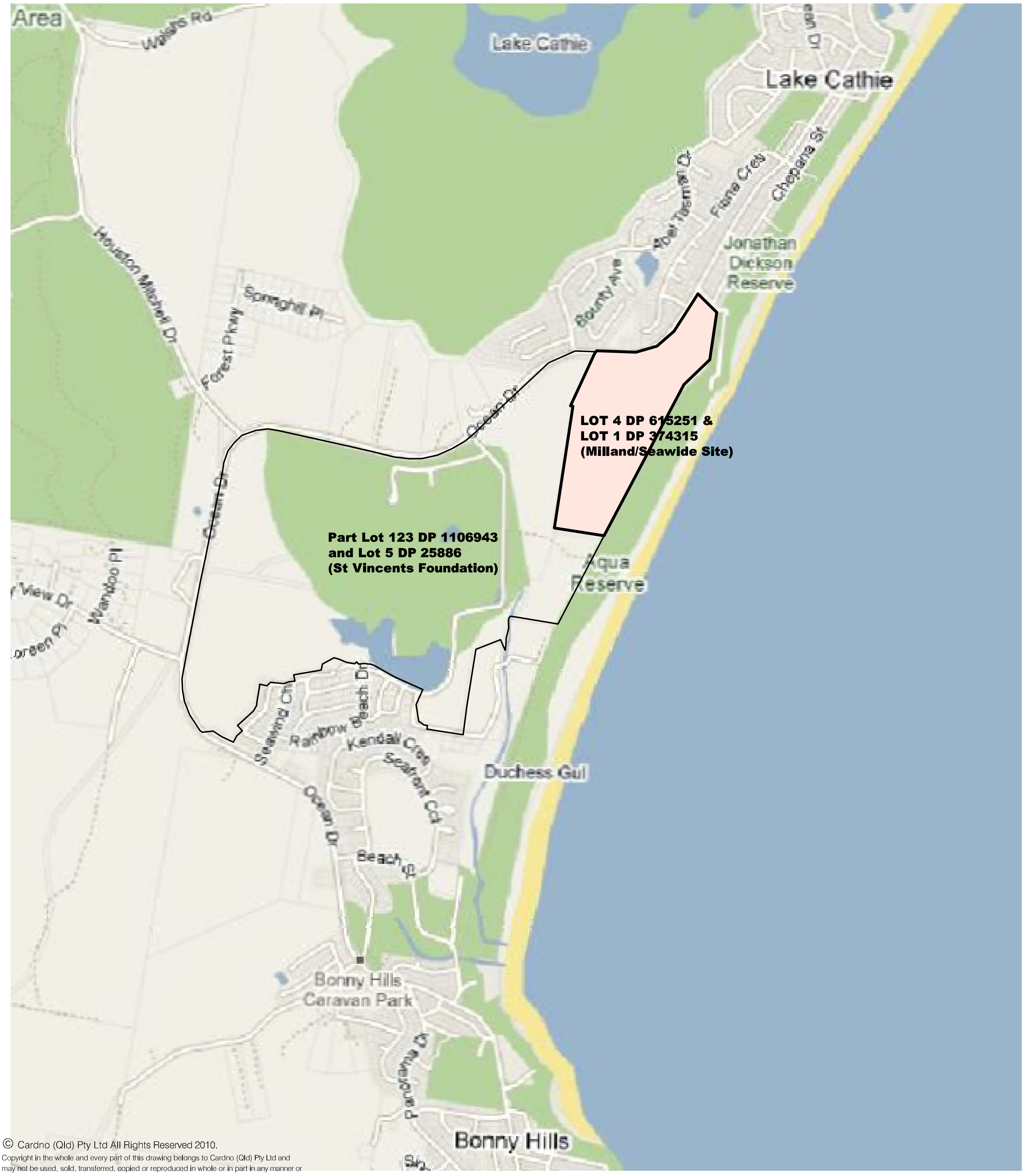
FIGURES

Shaping the Future
Cardno (Qld) Pty Ltd
ACN: 051 074 992
Level 11 Green Square North Tower
515 St Paul's Terrace Fortitude Valley QLD 4006
Locked Bag 4006 Fortitude Valley QLD 4006
Email: cardno@cardno.com.au
Ph (07) 3369 9822
Fax (07) 3369 9722



1	09/07/2010	JDB				
Ver.	Date	Drwn	Appr.	Description	Job No.	7135/01

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 1 Locality Plan.dwg
XREF's:
IMAGE's: L:\7135-01\images\locality by Google Maps.JPG;

DATE PLOTTED: 09 July, 2010 - 10:44am

Locality Plan

FIGURE 1

EXISTING TERRAIN MODEL

Datum: AHD
(MGA Ground Distance)

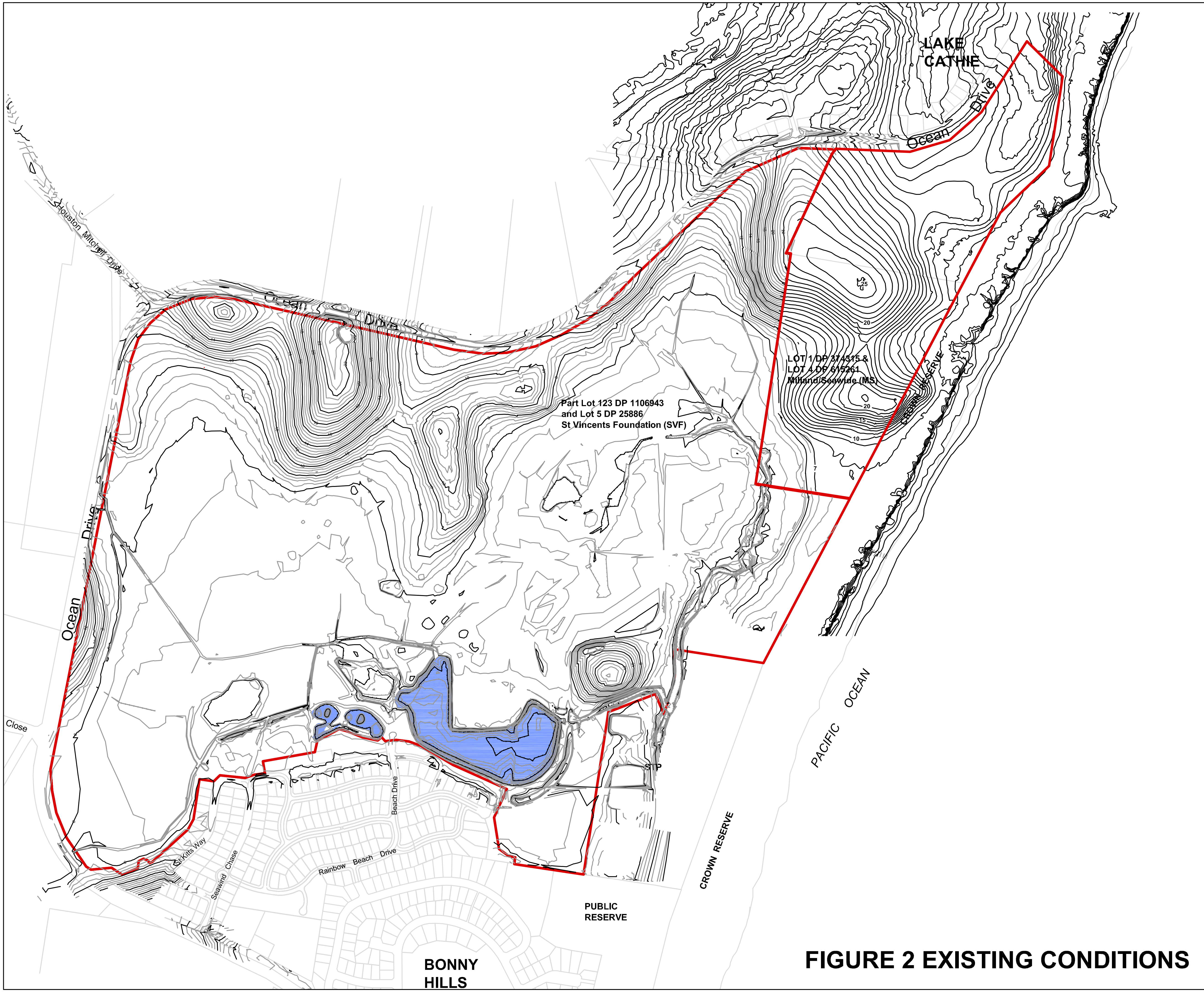


FIGURE 2 EXISTING CONDITIONS

SUBJECT LAND

EXISTING CONTOURS

Scale:
1:1000@A3 1:500@A1

The stated scale of this drawing maybe altered by copying. The scale should be verified prior to deriving measurements from this drawing

0 20 40 100 200 400(M)

AERIAL PHOTO

REVISIONS
A: 21.10.08

Rainbow Beach Estate
Property Management Plan Series
Job. No. 4509:ND Dwn: RM
Luke and Company Pty Ltd

FIGURE 3 SITE AERIAL PHOTO 2008

LEGEND

- EXTENT OF CONCEPT PLAN APPLICATION
- EXISTING CADASTRAL BOUNDARIES
- SEPP 26 BOUNDARY (AS GAZETTED)
- EXCLUSION FENCE AND HEDGE
- REVEGETATION AREA
- EXISTING VEGETATION TO BE RETAINED
- PROPOSED AREA TO BE FILLED
- BIOFILTRATION AND BIORETENTION BASIN - SEDGE PLANTING IN BASIN
  - JUNCUS USITATUS
  - CARESSA APPRESSA
- STORMWATER DETENTION BASIN WITH BIOFILTRATION
- 1.0m CONTOUR - SOURCE PORT MACQUARIE HASTINGS COUNCIL

CAUTION

This plan has been prepared for the purpose of a concept plan application. The information shown herein is only reliable for the above purpose. It should not therefore be used for any other purpose without verification.

N

FIGURE 4

K+C REF: L:14898_MILLAND_SEAWIDE Planning 4898P_Exhibits.dwg - A3(L)- FloodImpact, 08- Jul- 2010, michaelw

KING + CAMPBELL

King & Campbell Pty Ltd
www.kingcampbell.com.au
A: PO Box 243 Port Macquarie NSW 2444
T: 02 6586 2555
F: 02 6583 4064
E: info@kingcampbell.com.au

REV.	DATE	DESCRIPTION
A	21.06.2010	ISSUED FOR INFORMATION
B	06.07.2010	FLOOD LINE BASED ON SURVEY DATED 30.06.2010
C	07.07.2010	AMMENDED AREA, NOTES AND LEGEND

DATUM: AHD SCALE: 1:4000 @ A3

0 100

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PROJECT NO:	4898
DA NO.:	
DESIGNED BY:	DAT
DRAWN BY:	DV
CHECKED BY:	KM
DATE CREATED:	FEB 2010

DRAWING TITLE:	SUBDIVISION CONCEPT PLAN - FLOOD IMPACT ASSESSMENT
PROJECT:	LOT 1 DP 374315 & LOT 4 DP615261 OCEAN DRIVE, PORT MACQUARIE
CLIENT:	MILLAND PTY LTD & SEAWIDE PTY LTD

DRAWING NO:	SHEET:	REVISION:
4898P_Exhibits.dwg	1	C

50 0 50 100 150 200 250m
1:5000

Scale 1:5000 (A3)

LEGEND

Site Boundary

+B Existing wetlands surface water sampling locations

FIGURE 5

OPEN SPACE CORRIDOR PLAN - EXISTING WATER FEATURES (WEST)

Ver 1 Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 5&6 - Open space Corridor & Existing Water Features.dwg
XREF's: Contours for weirs 21-2-08; wetland outline; 4898P_FloodImpact

PRINT DATE: 27 June, 2010 - 6:51am

LEGEND

Site Boundary

+B Existing wetlands surface water sampling locations

Scale 1:5000 (A3)

FIGURE 6

OPEN SPACE CORRIDOR PLAN - EXISTING WATER FEATURES (EAST)

Ver 1 Date: 26 June 2010

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 5&6 - Open space Corridor & Existing Water Features.dwg
XREF's: Contours for weirs 21-2-08; wetland outline; 4898P_FloodImpact
PRINT DATE: 28 June, 2010 - 4:40pm

LEGEND

[red box]	Site Boundary
[green box]	Open Space Corridor Boundary

50 0 50 100 150 200 250m 1:5000

Scale 1:5000 (A3)

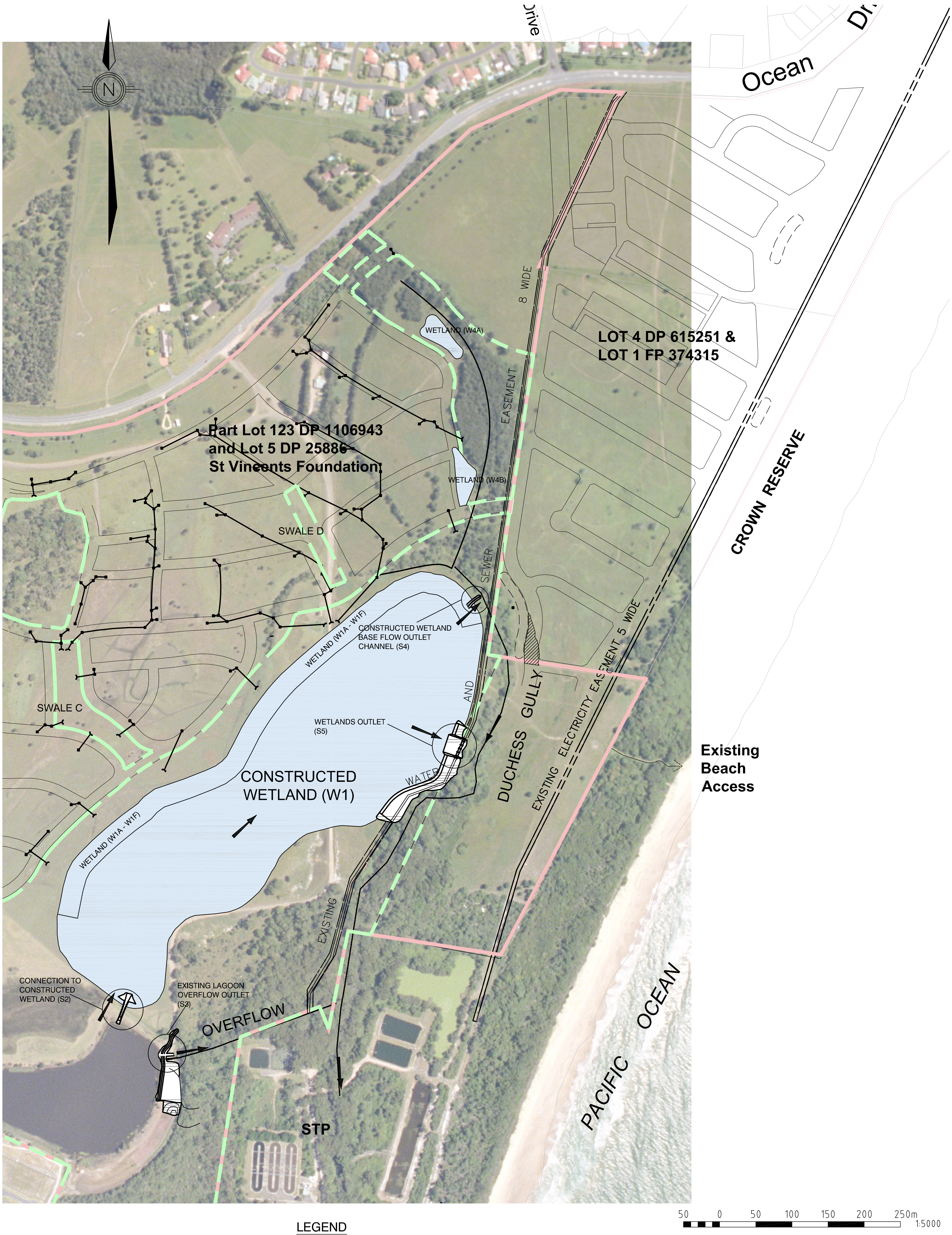
FIGURE 7
OPEN SPACE CORRIDOR PLAN - PROPOSED DEVELOPMENT WATER FEATURES - WEST

PRINT DATE: 28 June, 2010 - 4:53pm

Ver 1 Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 7&8 Open space Corridor Plan - Proposed Dev Conditions.dwg
XREF's: wetland outline; 4898P__FloodImpact



Scale 1:5000 (A3)

LEGEND

Site Boundary

Open Space Corridor Boundary

FIGURE 8

OPEN SPACE CORRIDOR PLAN - PROPOSED DEVELOPMENT WATER FEATURES - EAST

PRINT DATE: 28 June, 2010 - 4:54pm

Ver 1 Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 7&8 Open space Corridor Plan - Proposed Dev Conditions.dwg
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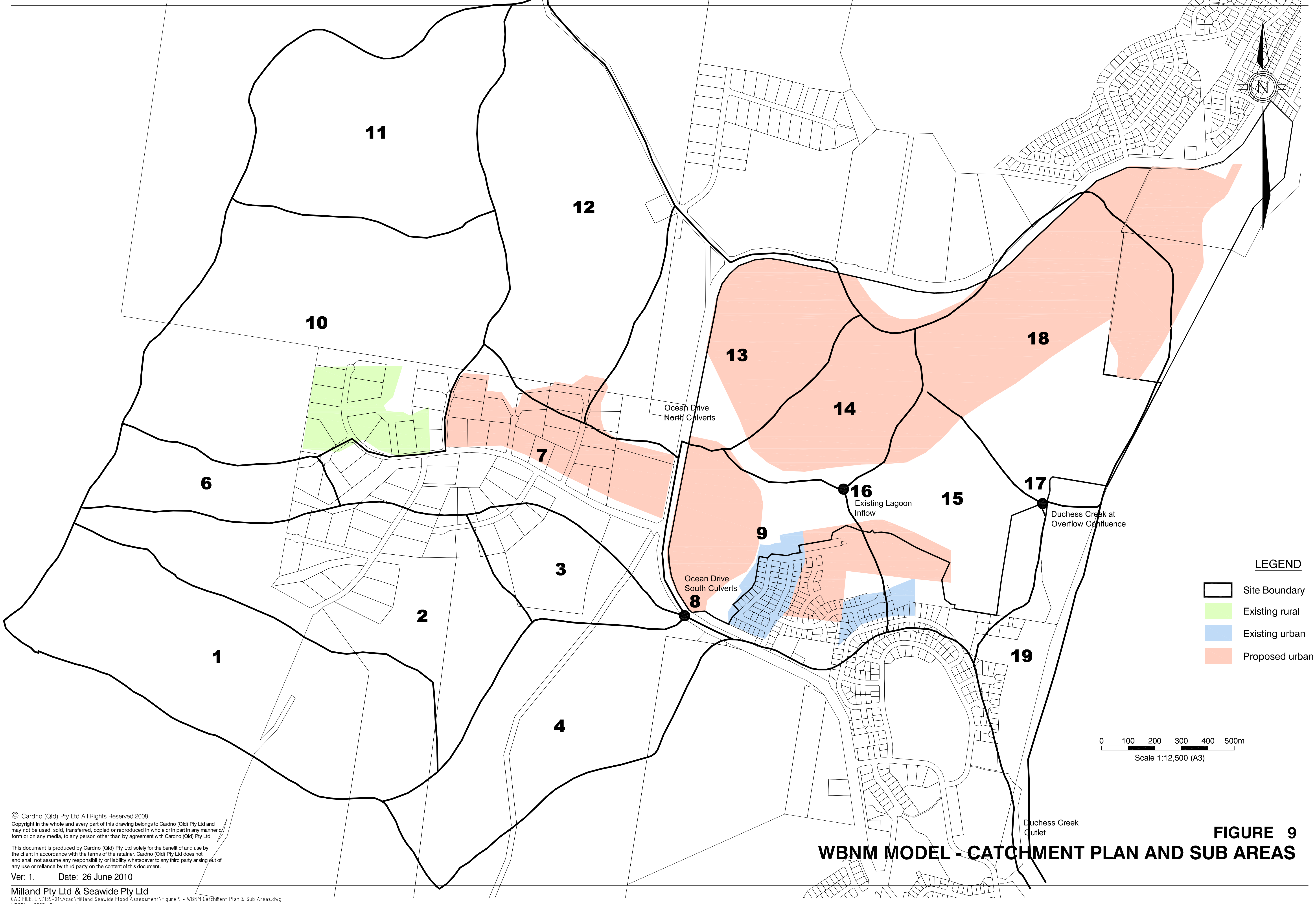


Ver: 1. Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd
CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 9 - WBNM Catchment Plan & Sub Areas.dwg
XREF's: 4898P__FloodImpact

PRINT DATE: 28 June, 2010 - 6:45am

FIGURE 9
WBNM MODEL - CATCHMENT PLAN AND SUB AREAS

Cardno

75 0 75 150 225 300 375m 1:7500

Scale 1:7500 (A3)

FIGURE 10

MIKE 11 MODEL NETWORK LAYOUT PLAN - EXISTING CASE

PRINT DATE: 27 June, 2010 - 7:10am

Ver 1 Date: 26 June 2010

St. Vincents Foundation Pty Ltd

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 10 - MIKE Model Existing.dwg
XREF's:

Scale 1:7500 (A3)

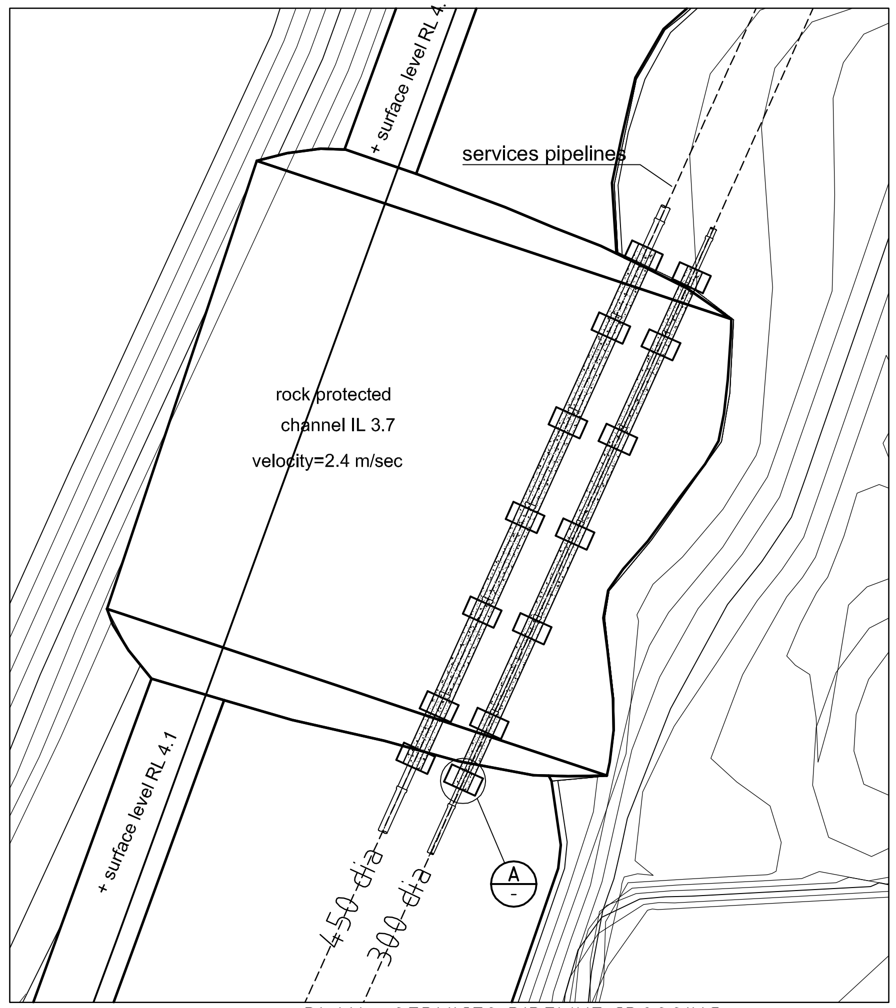
FIGURE 11

MIKE 11 MODEL NETWORK LAYOUT PLAN - DEVELOPED CASE

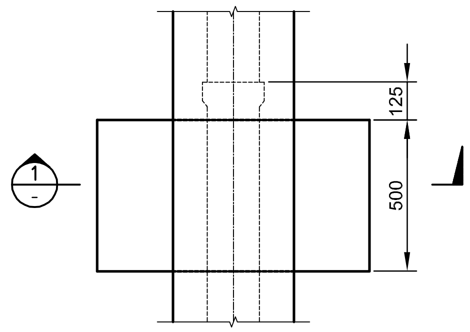
Ver 1 Date: 26 June 2010

Refer to Figure 13 for
Detail of cross sections

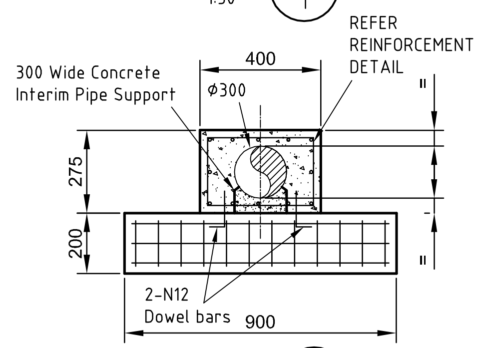
PLAN – CONSTRUCTED WETLAND OUTLET
1:1000



PLAN – SERVICES PIPELINE CROSSING
1:400



DETAIL A 1
1:50



SECTION 1 -
1:50

Scale: as indicated (A3)

FIGURE 12

CONSTRUCTED WETLANDS OUTLET CONTROL STRUCTURE S5 PLAN

PRINT DATE: 22 July, 2010 – 3:29pm

Ver 1. Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd
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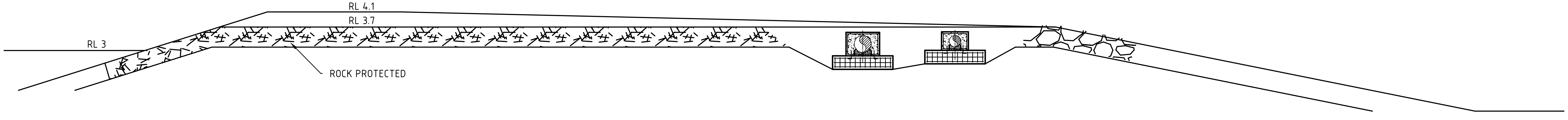
XREF's: wetland outline; Contours for weirs 21-2-08



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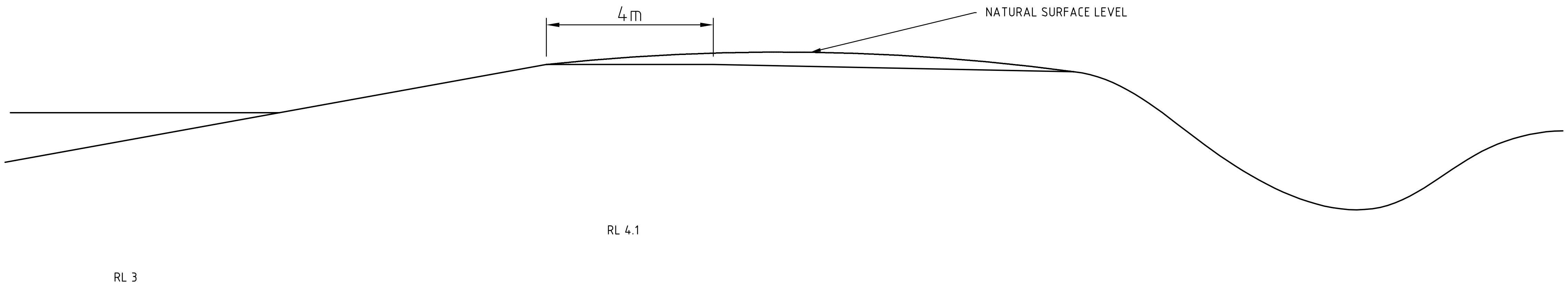

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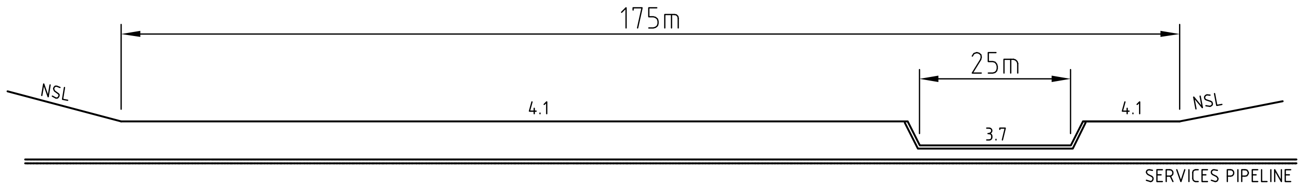


SECTION 3
1:1250
-

Scale: as indicated (A3)

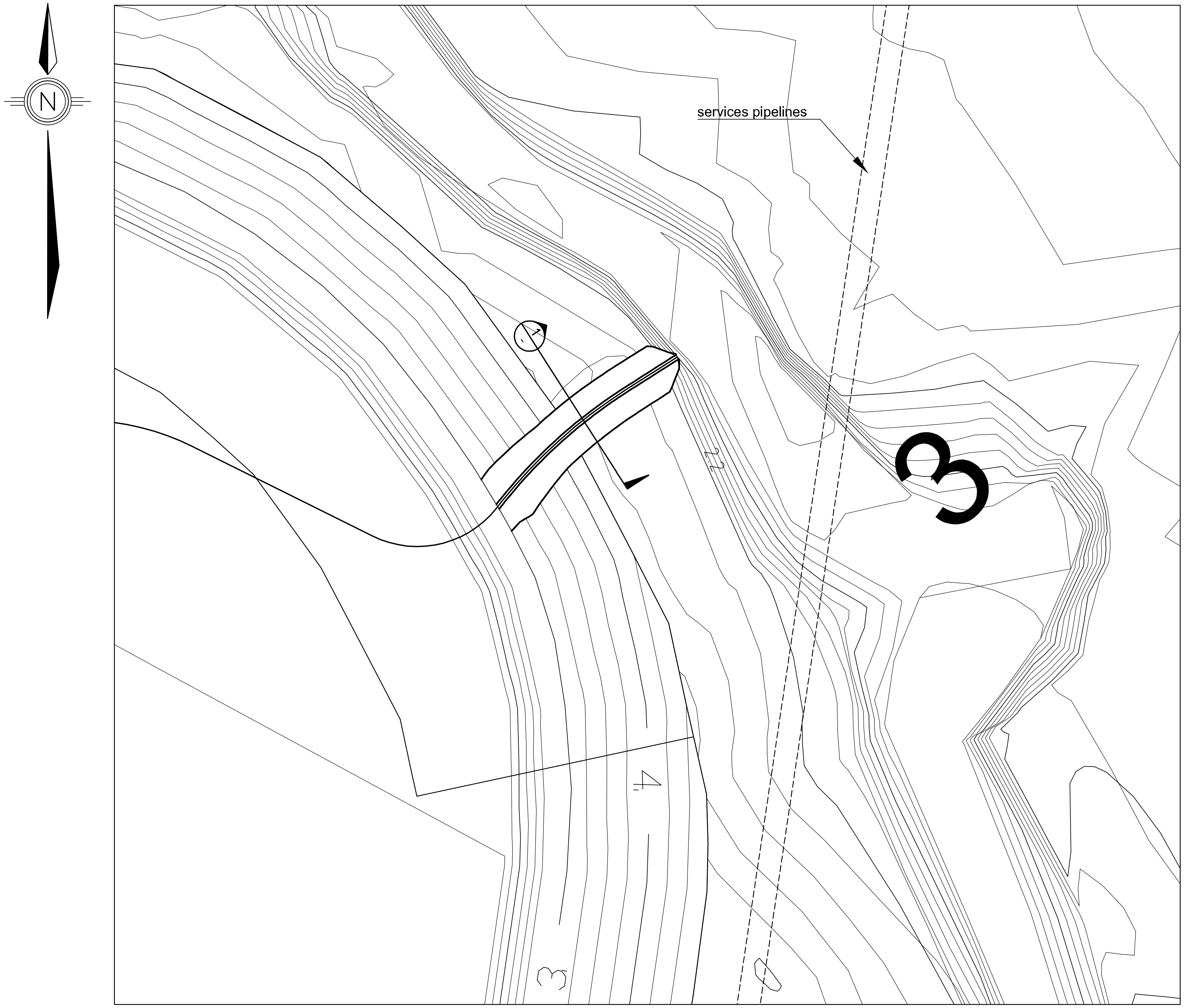
FIGURE 13

CONSTRUCTED WETLANDS OUTLET CONTROL STRUCTURE S5 SECTIONS

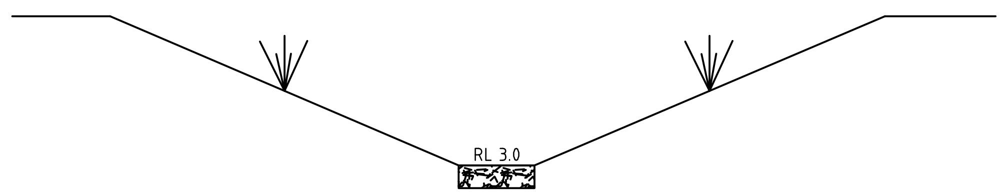
Ver 1. Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 12 - 17 Outlet weirs.dwg
XREF's: wetland outline; Contours for weirs 21-2-08



PLAN - CONSTRUCTED WETLAND BASE FLOW OUTLET S4 CHANNEL
1:500



SECTION 1
1:50

Scale: as indicated (A3)

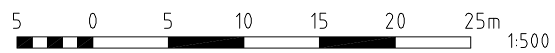
FIGURE 14

CONSTRUCTED WETLANDS BASE FLOW OUTLET STRUCTURE S4 CHANNEL

Ver 1. Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd
CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 12 - 17 Outlet weirs.dwg
XREF's: wetland outline; Contours for weirs 21-2-08

Refer to Figure 16 for
Detail of cross sections



Scale 1:500 (A3)

FIGURE 15
EXISTING LAGOON "OVERFLOW" OUTLET CONTROL STRUCTURE S3 PLAN

PRINT DATE: 22 July, 2010 - 3:27pm

Ver 1. Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd
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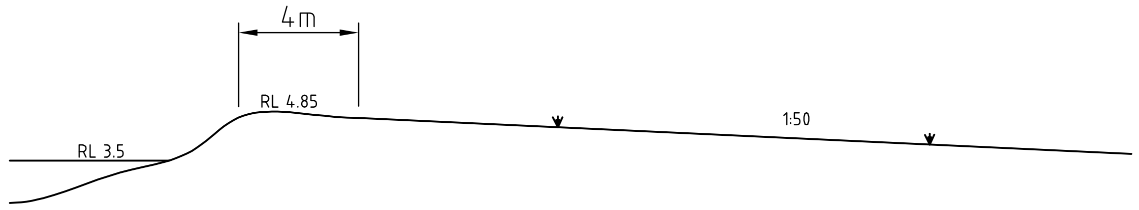
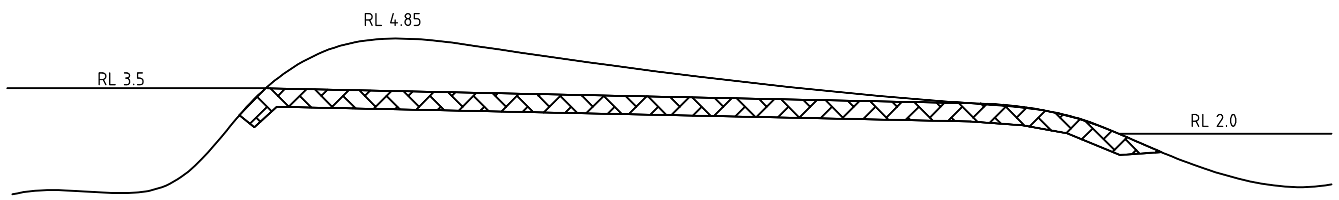
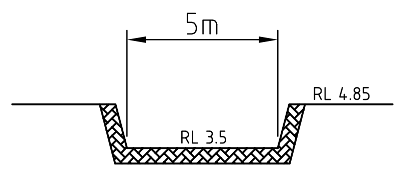


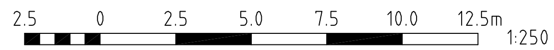
SECTION 3
1:250



SECTION 2
1:250



SECTION 4
1:250



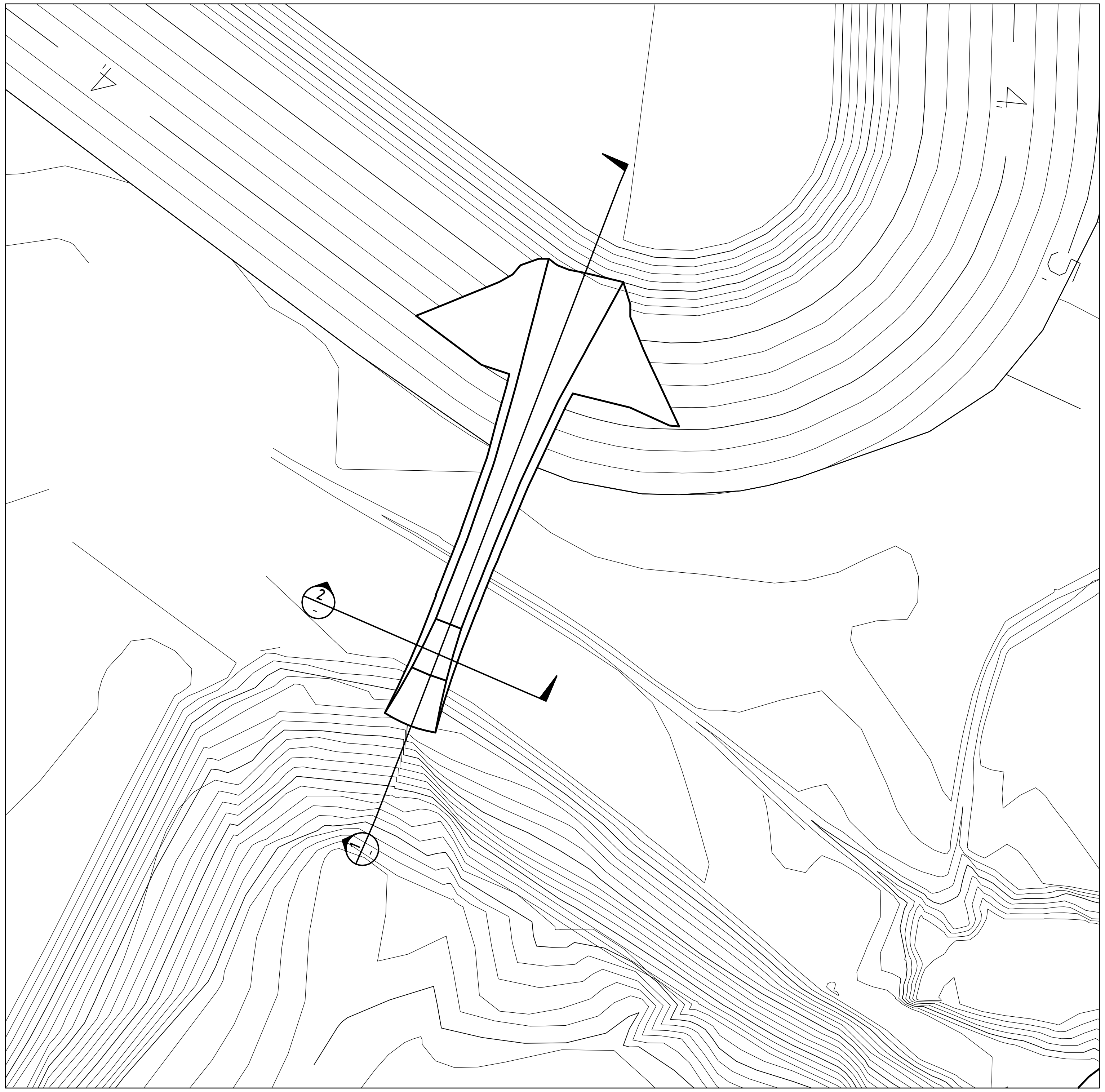
Scale 1:250 (A3)

FIGURE 16
EXISTING LAGOON "OVERFLOW" OUTLET CONTROL STRUCTURE S3 - SECTIONS

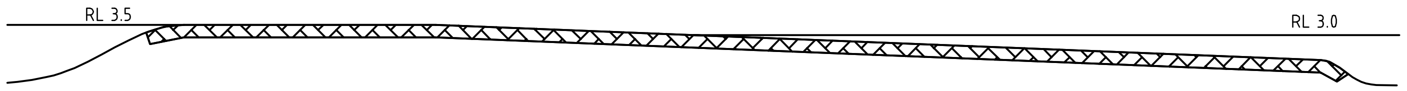
PRINT DATE: 27 June, 2010 - 8:12am

Ver 1. Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd
CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 12 - 17 Outlet weirs.dwg
XREF's: wetland outline; Contours for weirs 21-2-08



PLAN - "CONNECTION" CONTROL STRUCTURE S2
1:500



SECTION 1
1:300

SECTION 2
1:250

PRINT DATE: 22 July, 2010 - 3:26pm

Ver 1. Date: 26 June 2010

Scale: as indicated (A3)

FIGURE 17

"CONNECTION" CONTROL STRUCTURE S2 PLAN AND DETAILS

Milland Pty Ltd & Seawide Pty Ltd
CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 12 - 17 Outlet weirs.dwg
XREF's: wetland outline; Contours for weirs 21-2-08

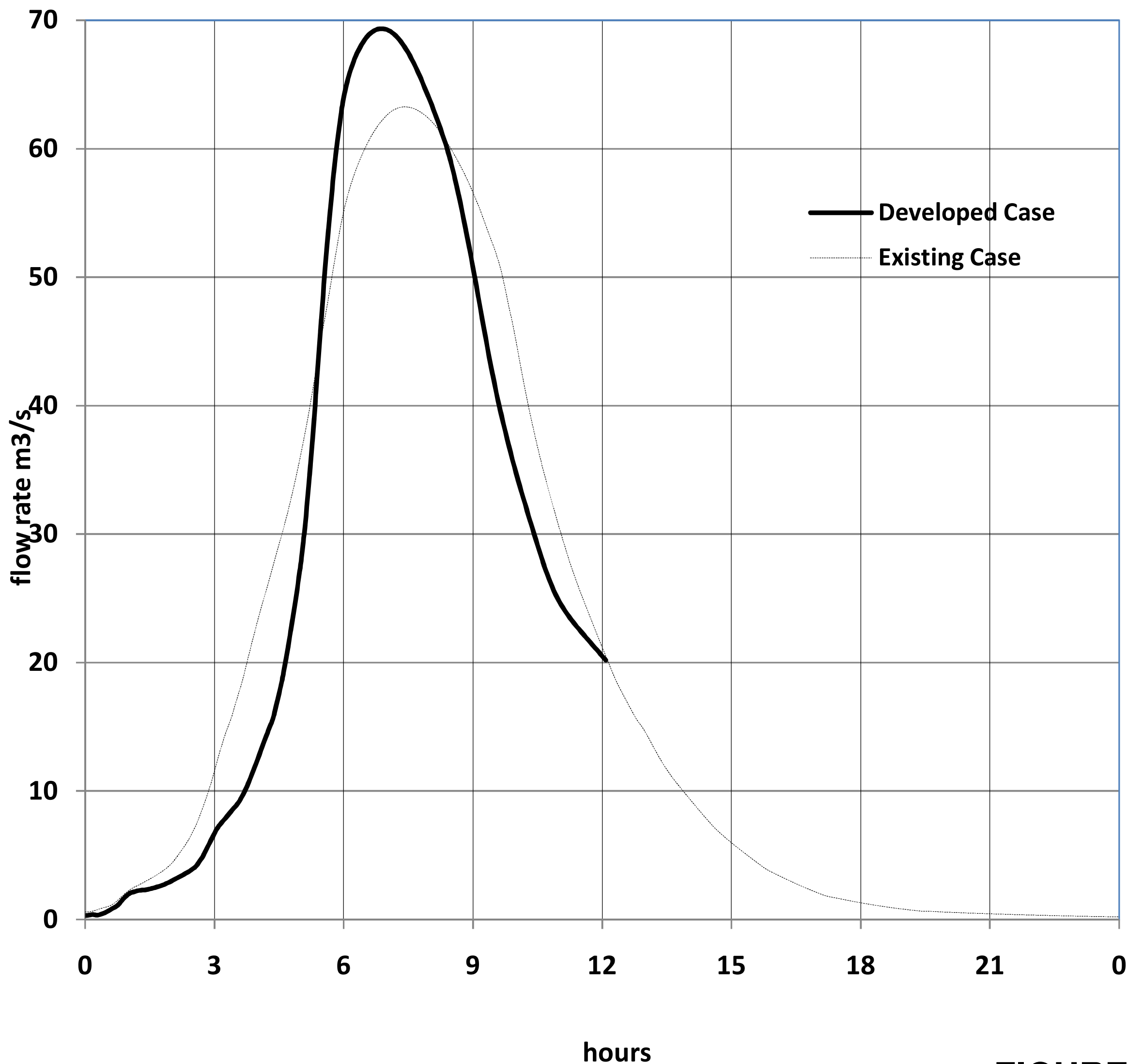
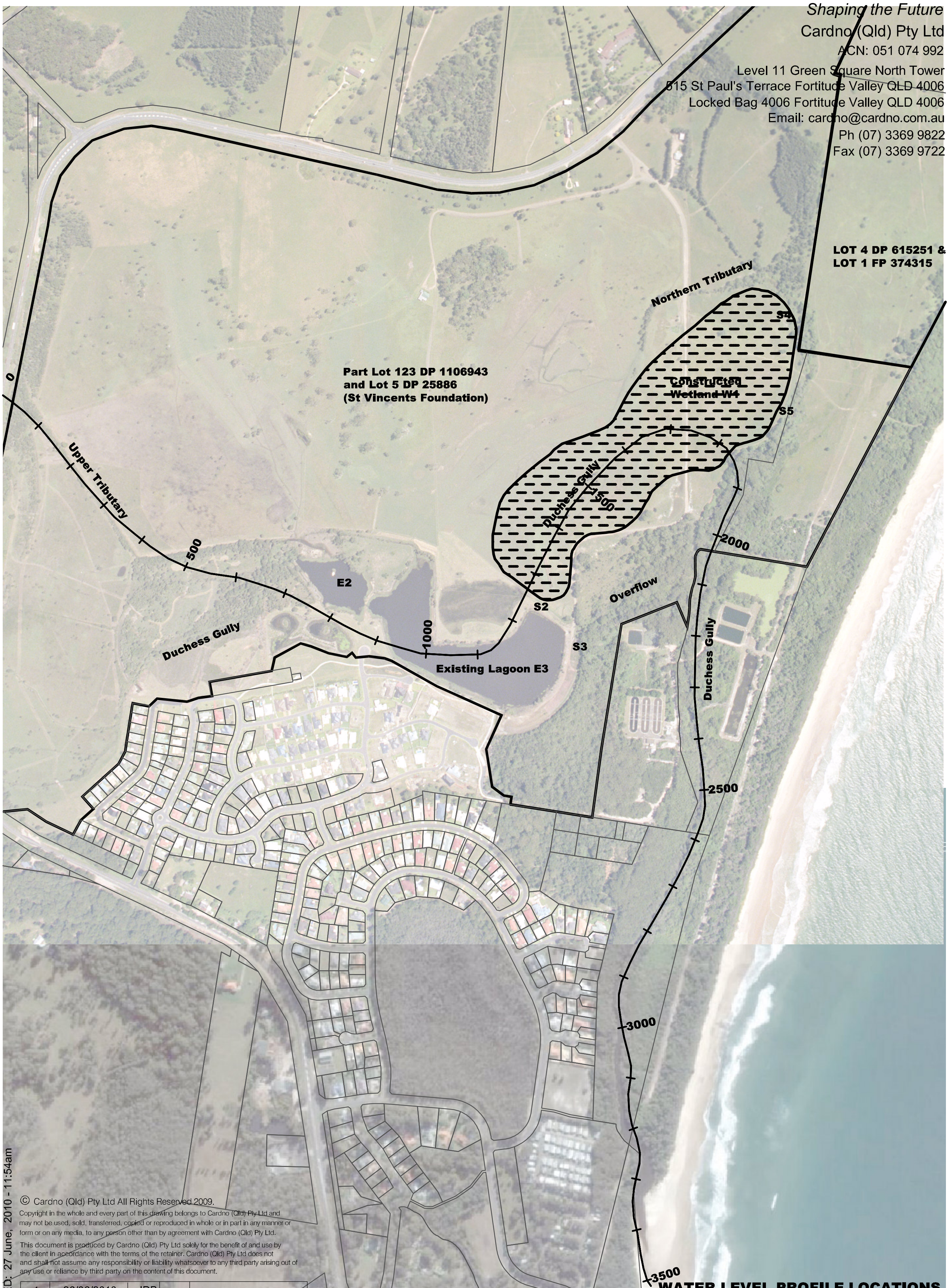

70
60
50
40
30
20
10
0
flow rate m3/s
0
3
6
9
12
15
18
21
0
hours
Developed Case
Existing Case

FIGURE 18

Shaping the Future
Cardno (Qld) Pty Ltd
ACN: 051 074 992
Level 11 Green Square North Tower
515 St Paul's Terrace Fortitude Valley QLD 4006
Locked Bag 4006 Fortitude Valley QLD 4006
Email: cardno@cardno.com.au
Ph (07) 3369 9822
Fax (07) 3369 9722



DATE PLOTTED: 27 June, 2010 - 11:54am

Ver.	Date	Drwn	Appr.	Description
1	26/06/2010	JDB		

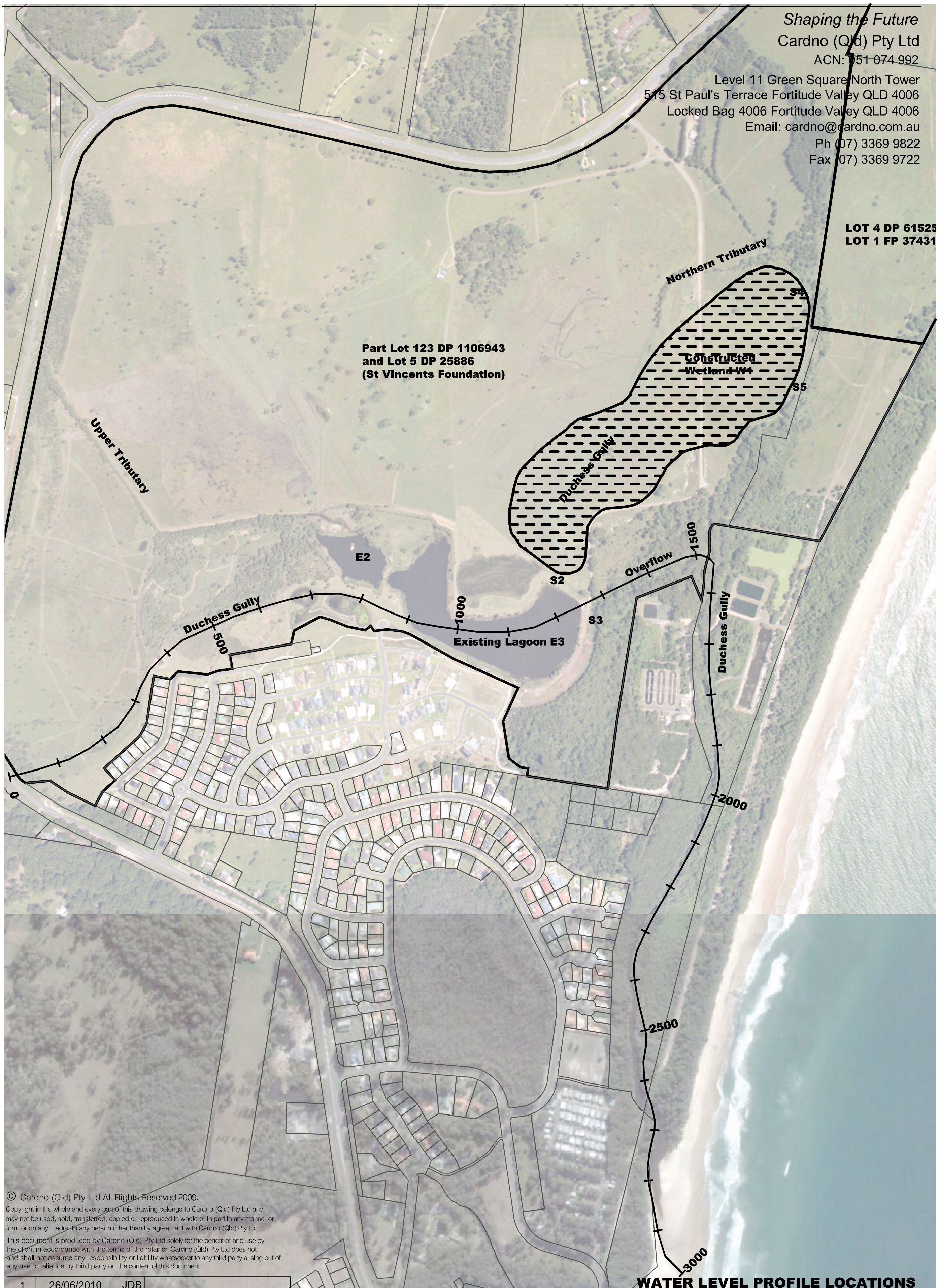
Job No. 7135/01

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 19 Profile Locations.dwg
XREF's: 4898P_FloodImpact
IMAGE's: L:\7135-01\images\google south.jpg; L:\7135-01\images\IT Dept - MX3501N_20080815_115241.tif; L:\7135-01\images\StVincents_Jan2008_RECT.jpg;

WATER LEVEL PROFILE LOCATIONS
PROFILE 'A'

FIGURE 19A

Cardno



1	26/06/2010	JDB				
Ver.	Date	Drwn	Appr.	Description	Job No.	7135/01

WATER LEVEL PROFILE LOCATIONS

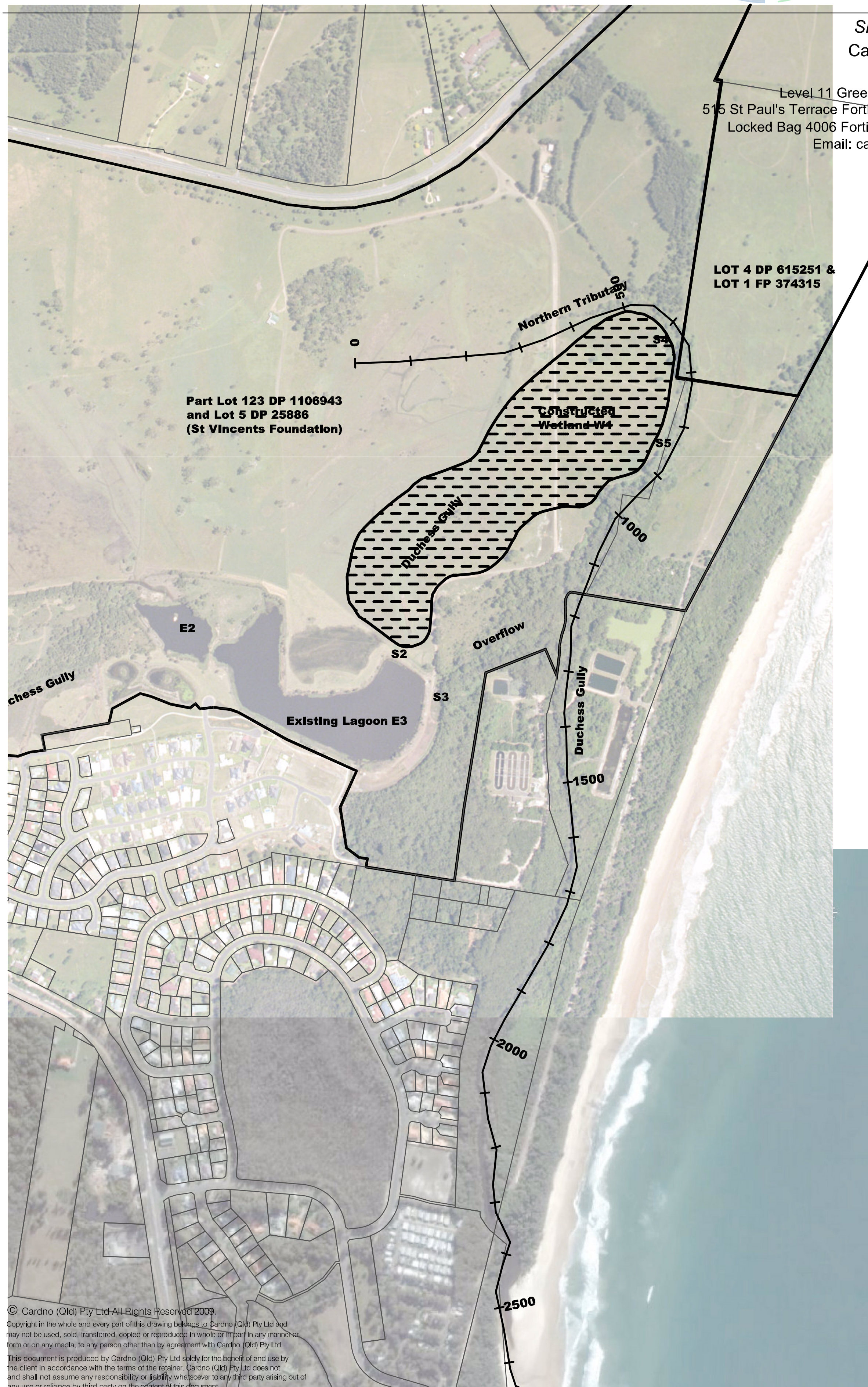
PROFILE 'B'

FIGURE 19B

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 19 Profile Locations.dwg
XREF's: 4898P_FloodImpact
IMAGE's: L:\7135-01\images\google south.jpg; L:\7135-01\images\IT Dept - MX3501N_20080815_115241.tif; L:\7135-01\images\StVincents_Jan2008_RECT.jpg;

DATE PLOTTED: 27 June, 2010 - 11:54am

Cardno
Shaping the Future
Cardno (Qld) Pty Ltd
ACN: 051 074 992
Level 11 Green Square North Tower
515 St Paul's Terrace Fortitude Valley QLD 4006
Locked Bag 4006 Fortitude Valley QLD 4006
Email: cardno@cardno.com.au
Ph (07) 3369 9822
Fax (07) 3369 9722



Ver.	Date	Drwn	Appr.	Description
1	26/06/2010	JDB		

Job No. 7135/01

WATER LEVEL PROFILE LOCATIONS

PROFILE 'C'

FIGURE 19C

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 19 Profile Locations.dwg
XREF's: 4898P_FloodImpact
IMAGE's: L:\7135-01\images\google south.jpg; L:\7135-01\images\IT Dept - MX3501N_20080815_115241.tif; L:\7135-01\images\StVincents_Jan2008_RECT.jpg;

DATE PLOTTED: 27 June, 2010 - 11:55am

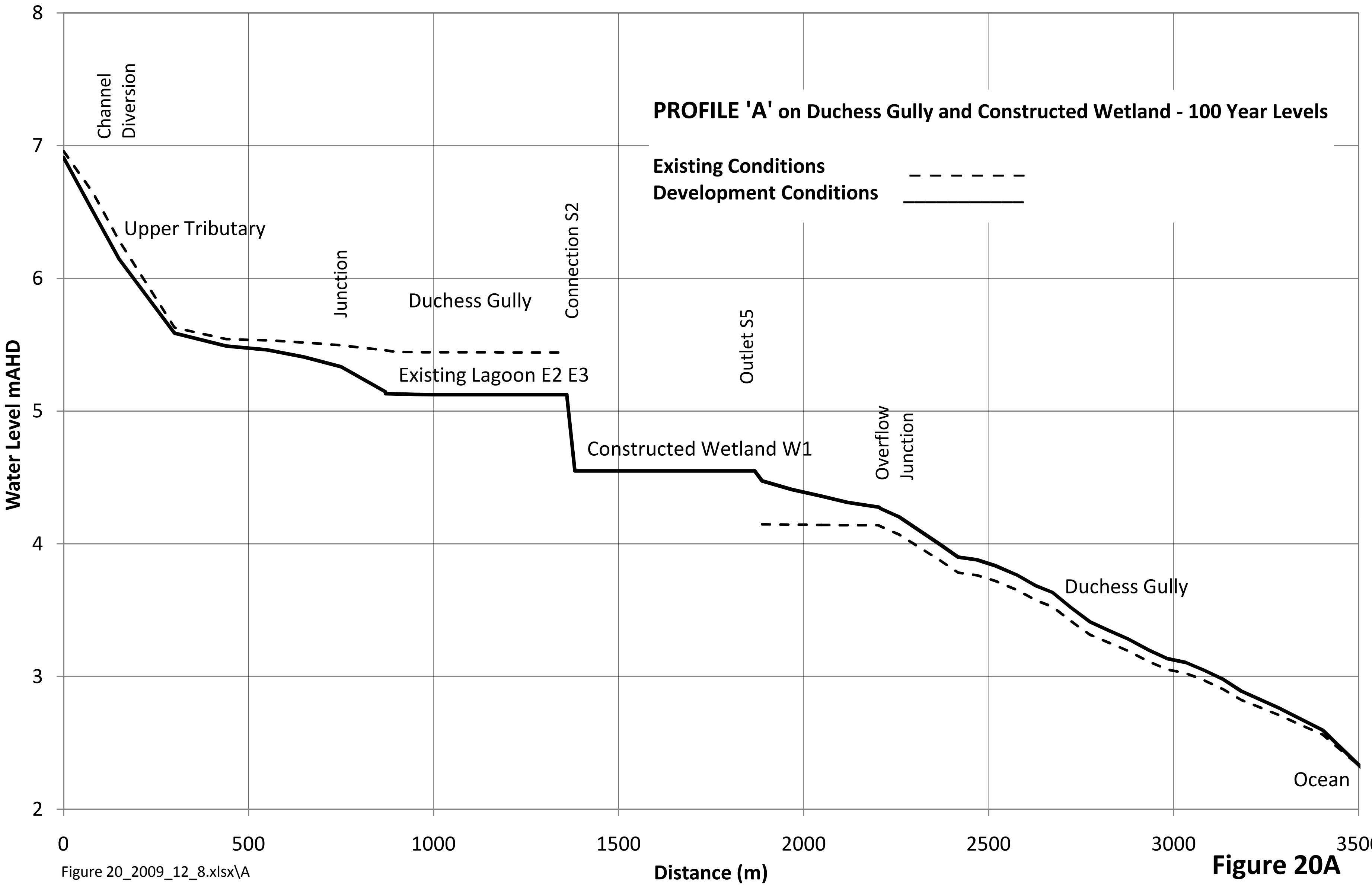


Figure 20_2009_12_8.xlsx\A

Figure 20A

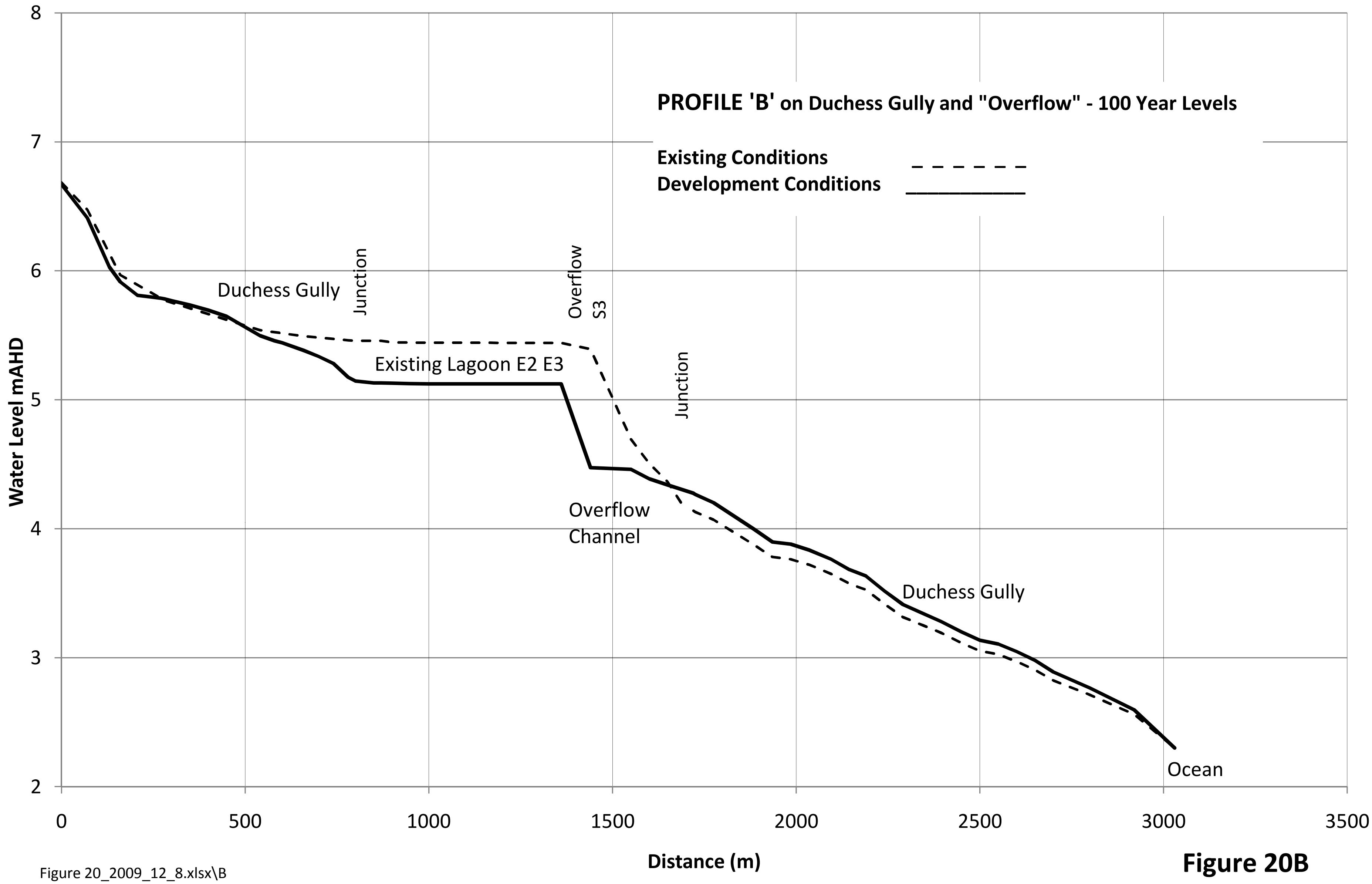


Figure 20_2009_12_8.xlsx\B

Figure 20B

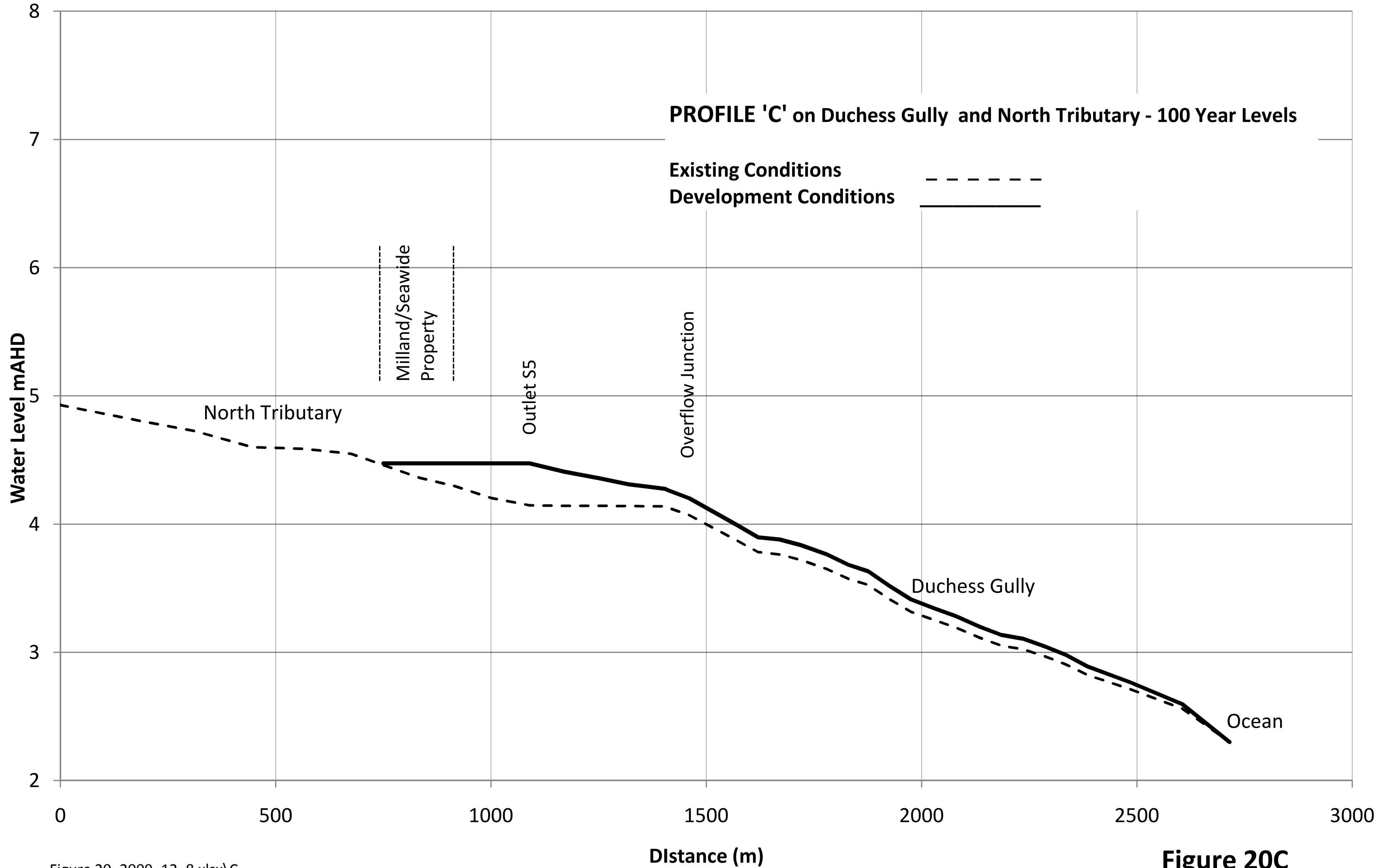
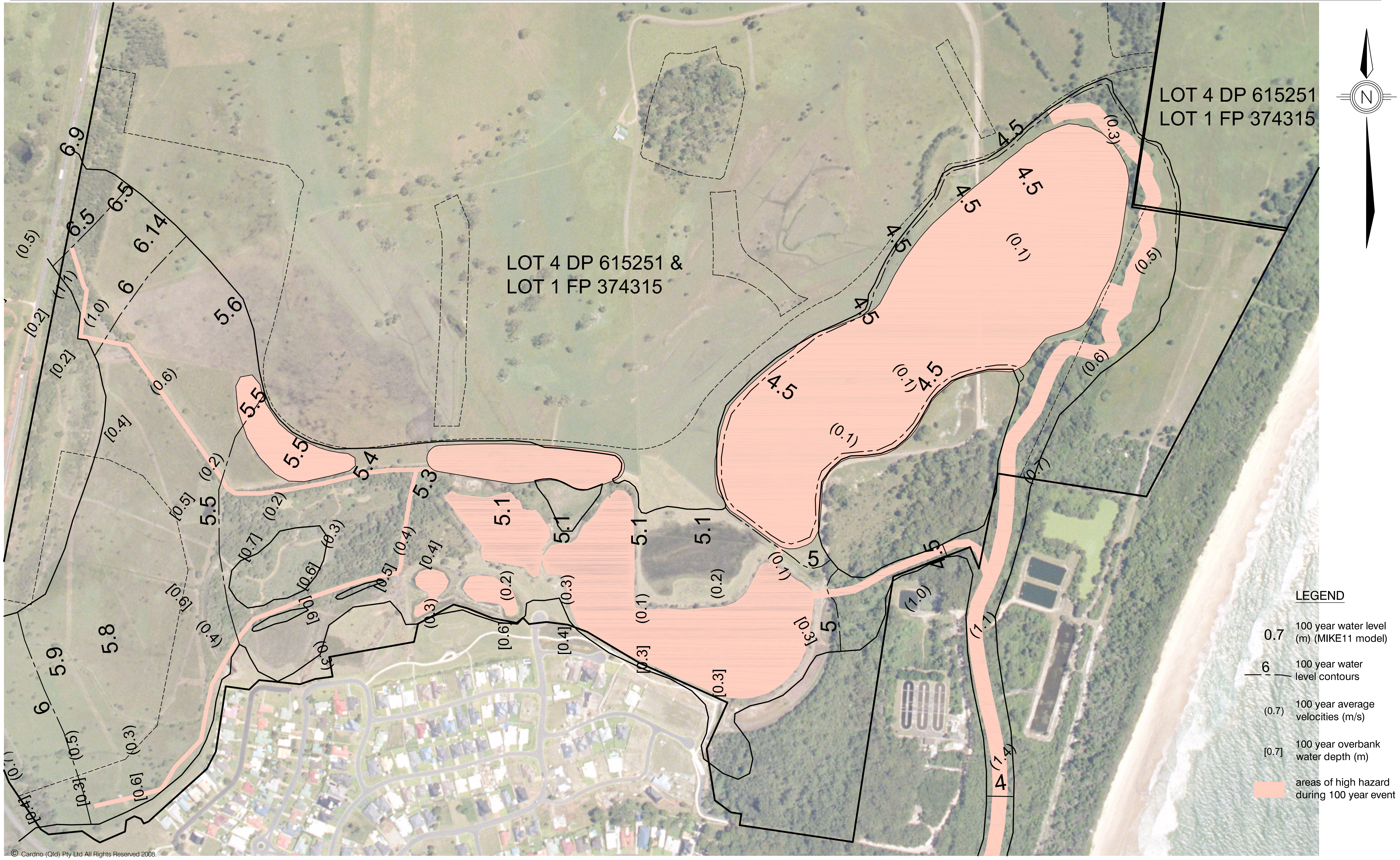


Figure 20_2009_12_8.xlsx\C

Figure 20C

Cardno



LEGEND

0.7	100 year water level (m) (MIKE11 model)
6	100 year water level contours
(0.7)	100 year average velocities (m/s)
[0.7]	100 year overbank water depth (m)
	areas of high hazard during 100 year event

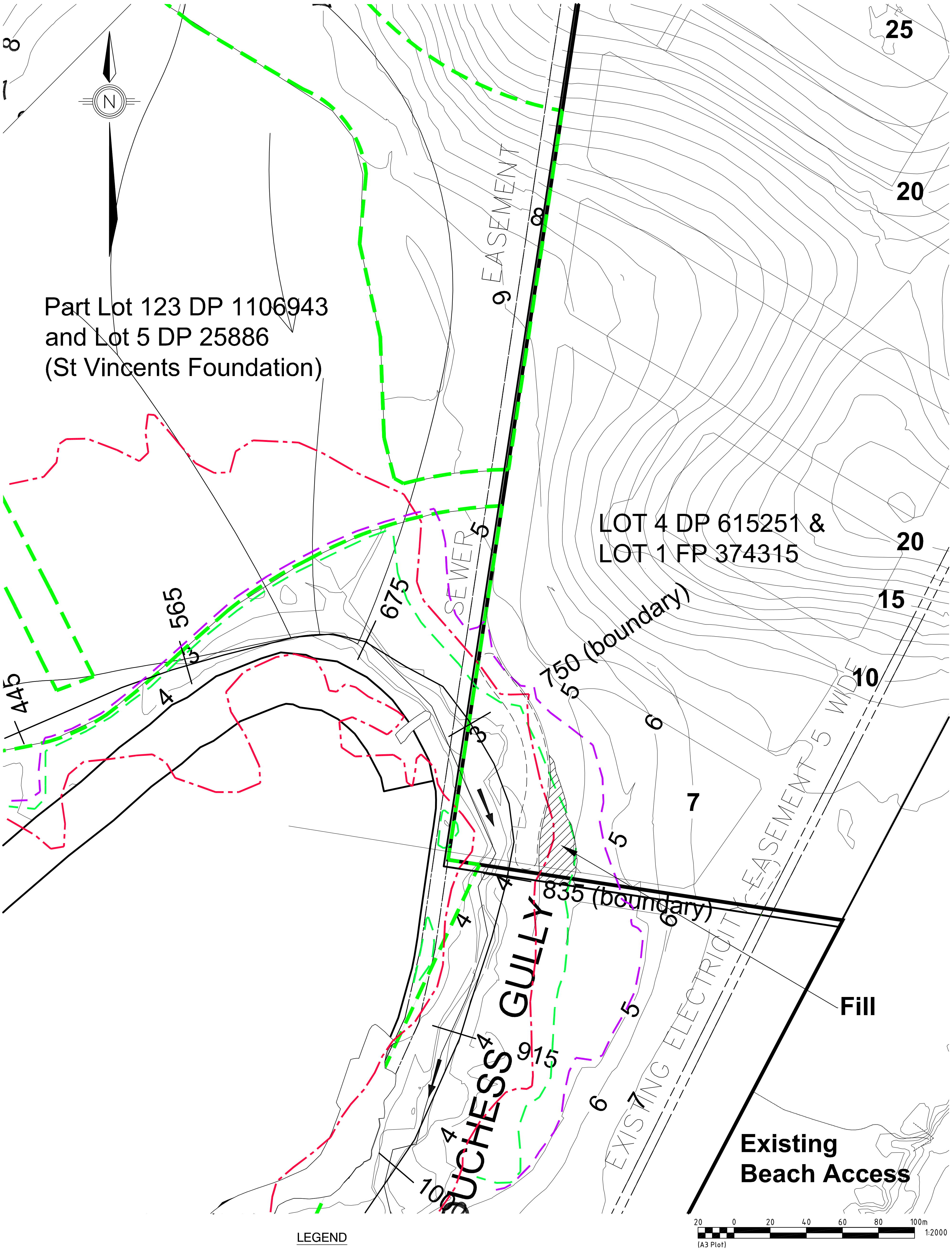
Scale 1:5000 (A3)

FIGURE 21
FLOOD HAZARD CONDITIONS - 100 YEAR ARI STORM EVENT

Ver 1 Date: 26 June 2010

PRINT DATE: 27 June, 2010 - 12:10pm

Milland Pty Ltd & Seawide Pty Ltd
CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 21 - Flood Hazard Conditions Plan.dwg
XREF's: Contours for weirs 21-2-08; 4898P_FloodImpact



LEGEND

- Site Boundary
- Existing inundation limit
- Development inundation limit
- Development inundation limit with +20% climate change increase in rainfall intensity

FIGURE 22
INUNDATION LEVELS ON ADJOINING MILLAND LAND

Ver 1 Date: 26 June 2010

Milland Pty Ltd & Seawide Pty Ltd

CAD FILE: L:\7135-01\Acad\Milland Seawide Flood Assessment\Figure 22 - Inundation Levels on Milland Property.dwg
XREF's: Contours for weirs 21-2-08; wetland outline; 4898P__FloodImpact

PRINT DATE: 09 July, 2010 - 12:18pm

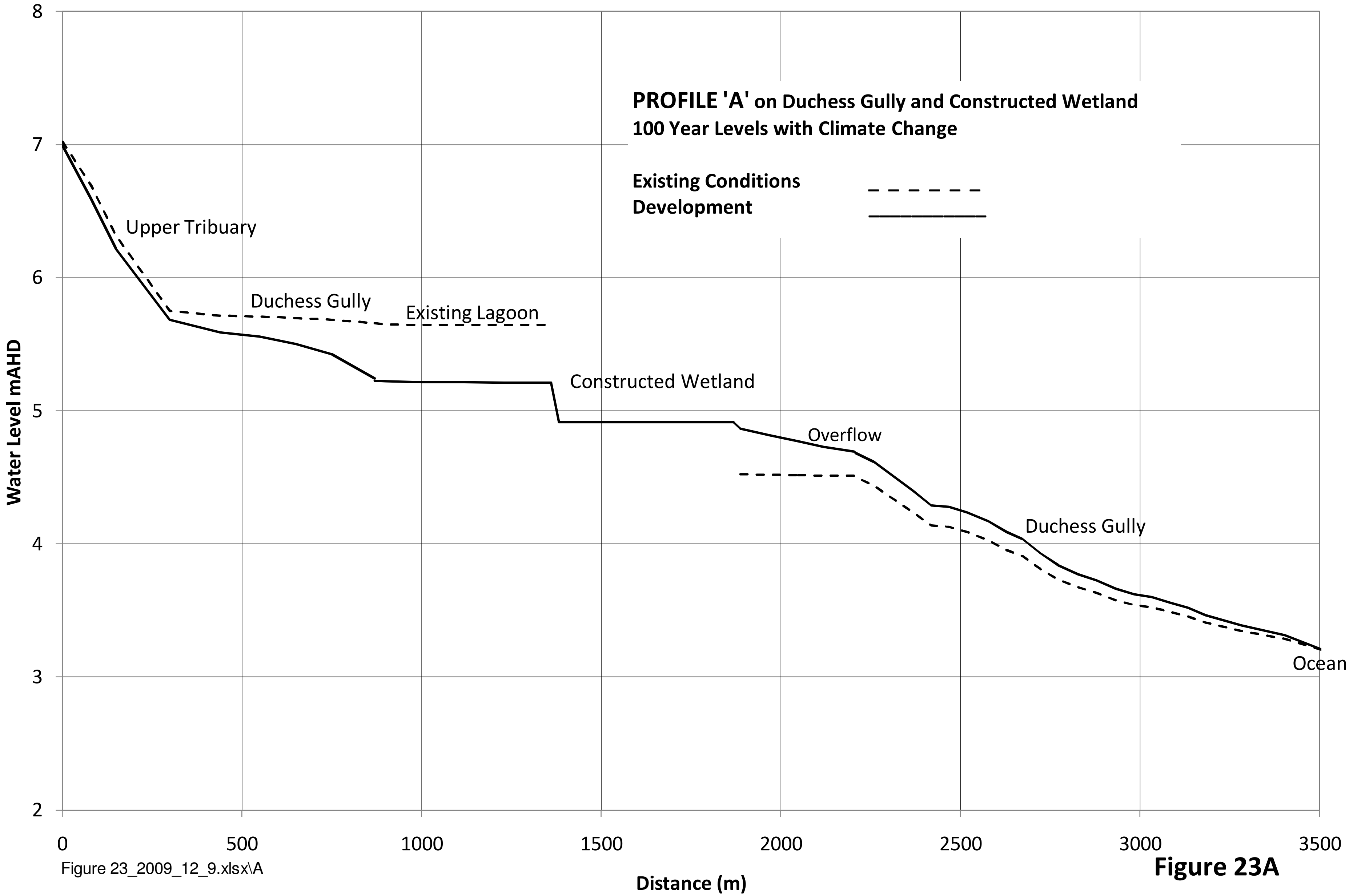


Figure 23_2009_12_9.xlsx\A

Figure 23A

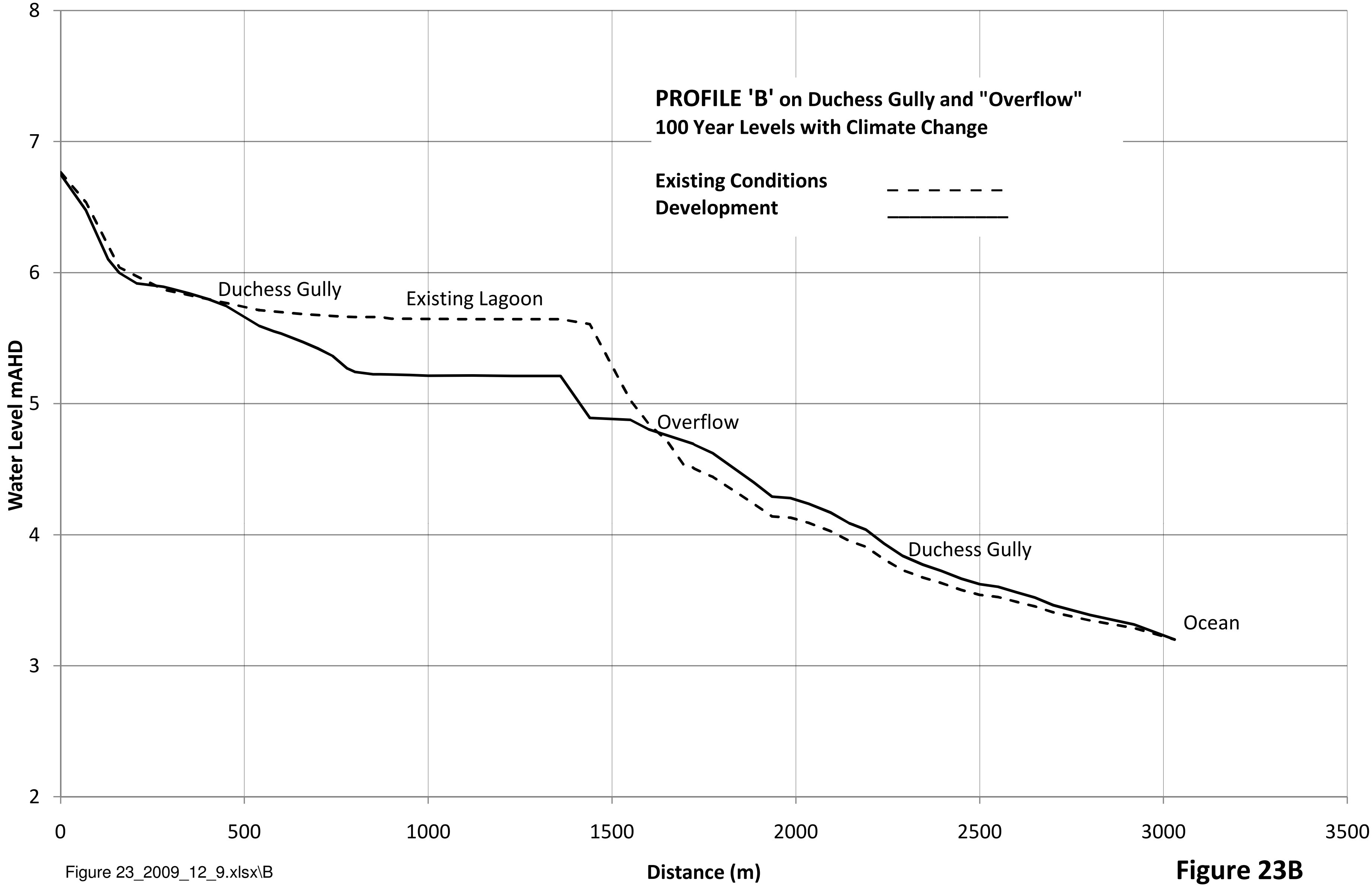


Figure 23_2009_12_9.xlsx\B

Figure 23B

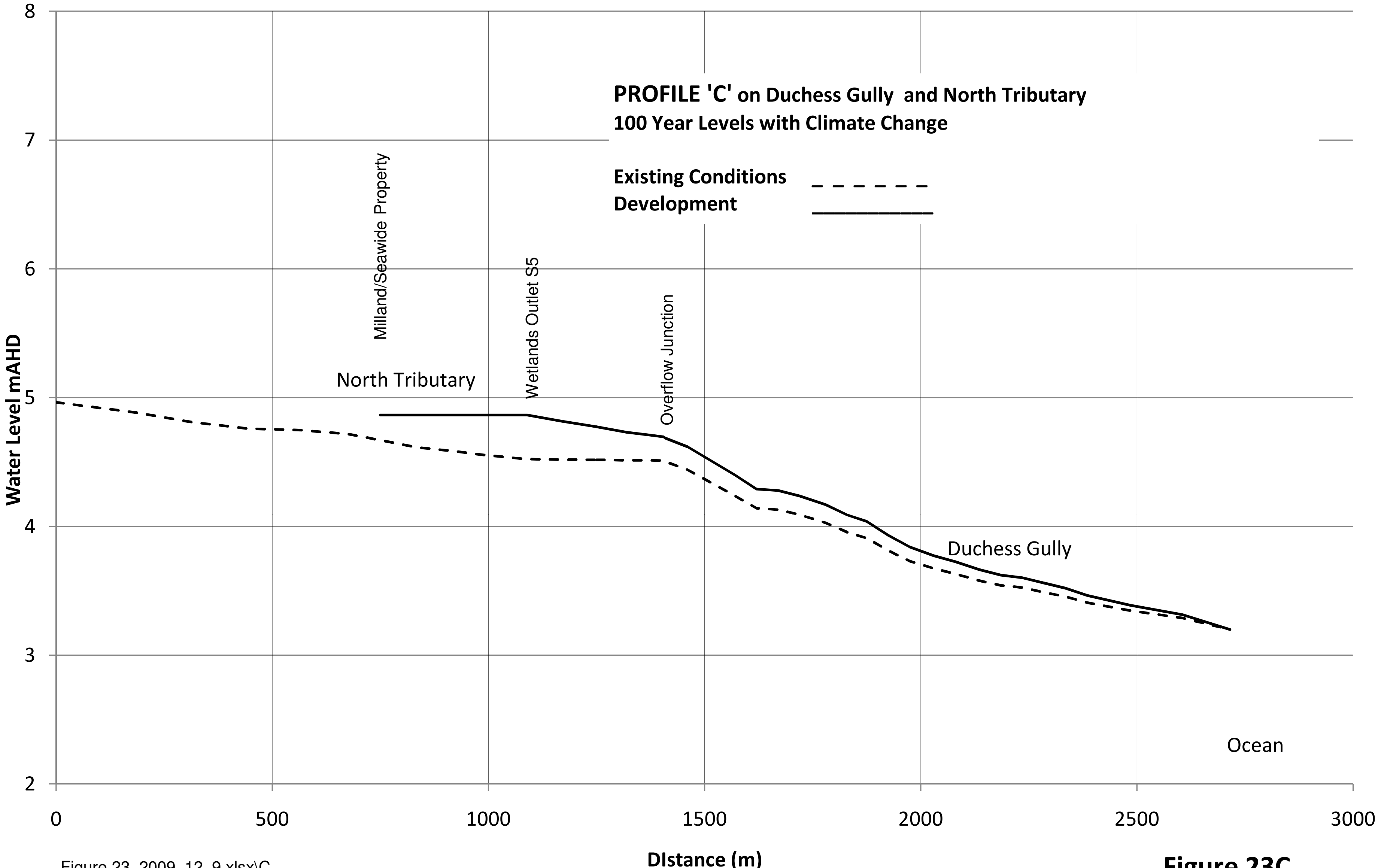
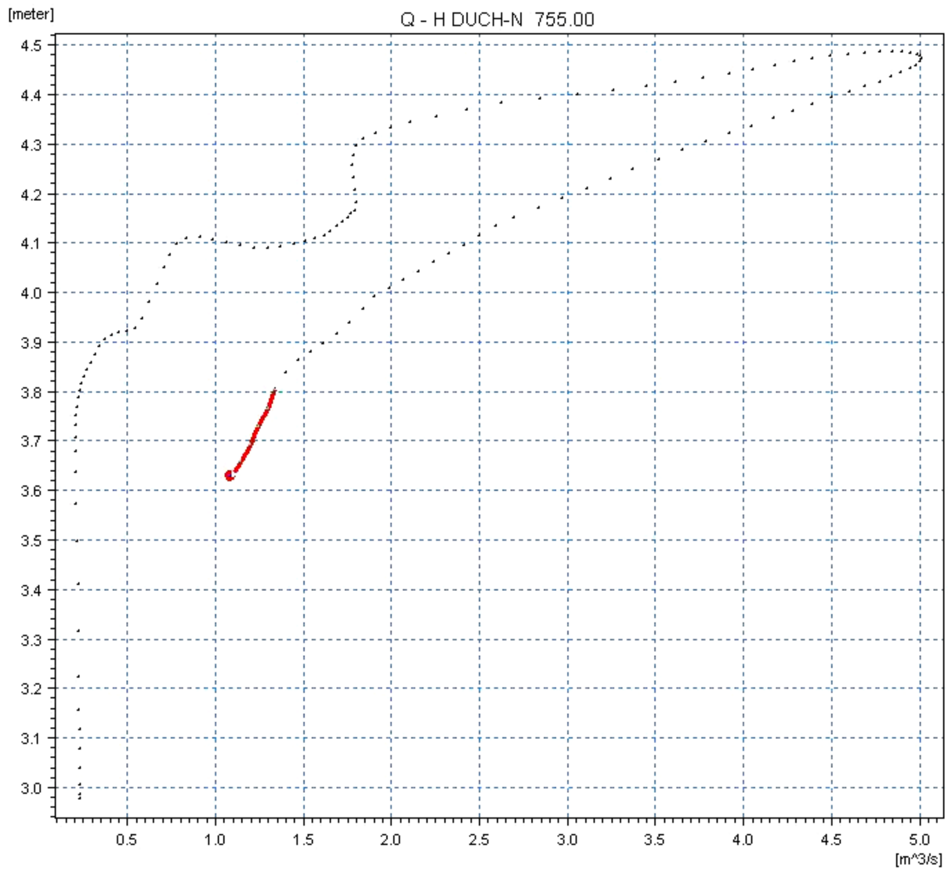


Figure 23_2009_12_9.xlsx\C

Figure 23C


[meter]
Q - H DUCH-N 755.00
4.5
4.4
4.3
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
[m^3/s]

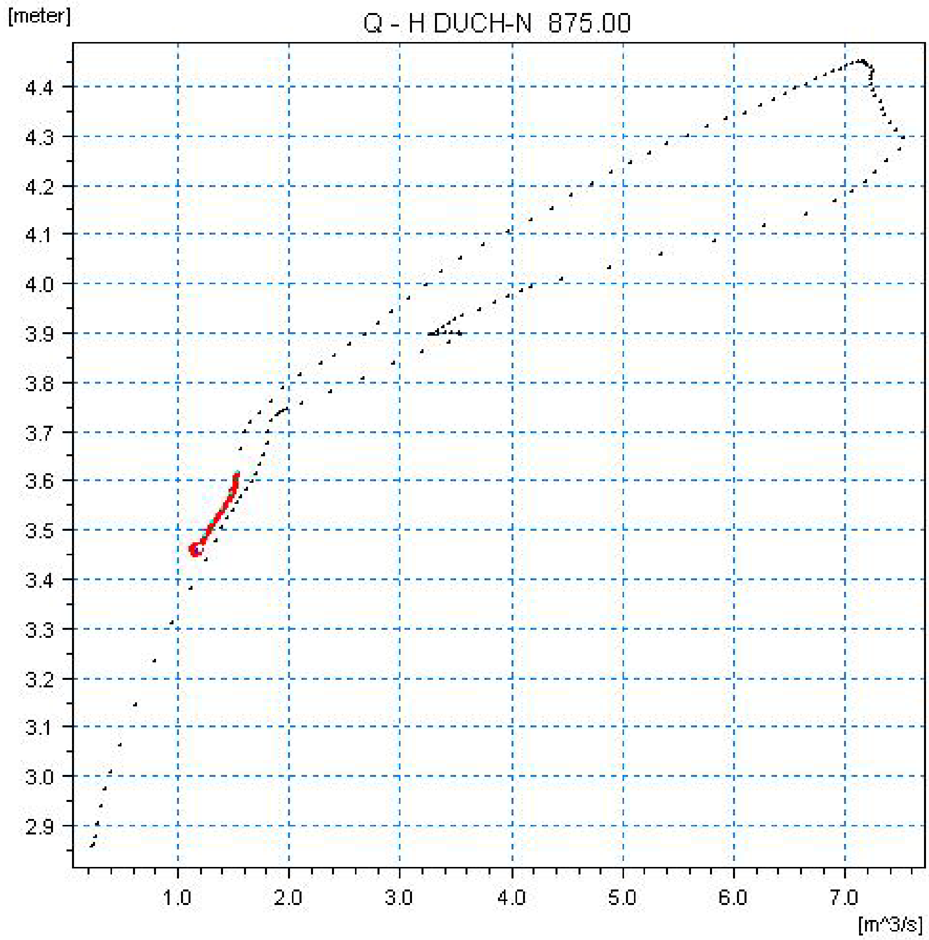

[meter]
Q - H DUCH-N 875.00
4.4
4.3
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
1.0
2.0
3.0
4.0
5.0
6.0
7.0
[m^3/s]

FIGURE 24

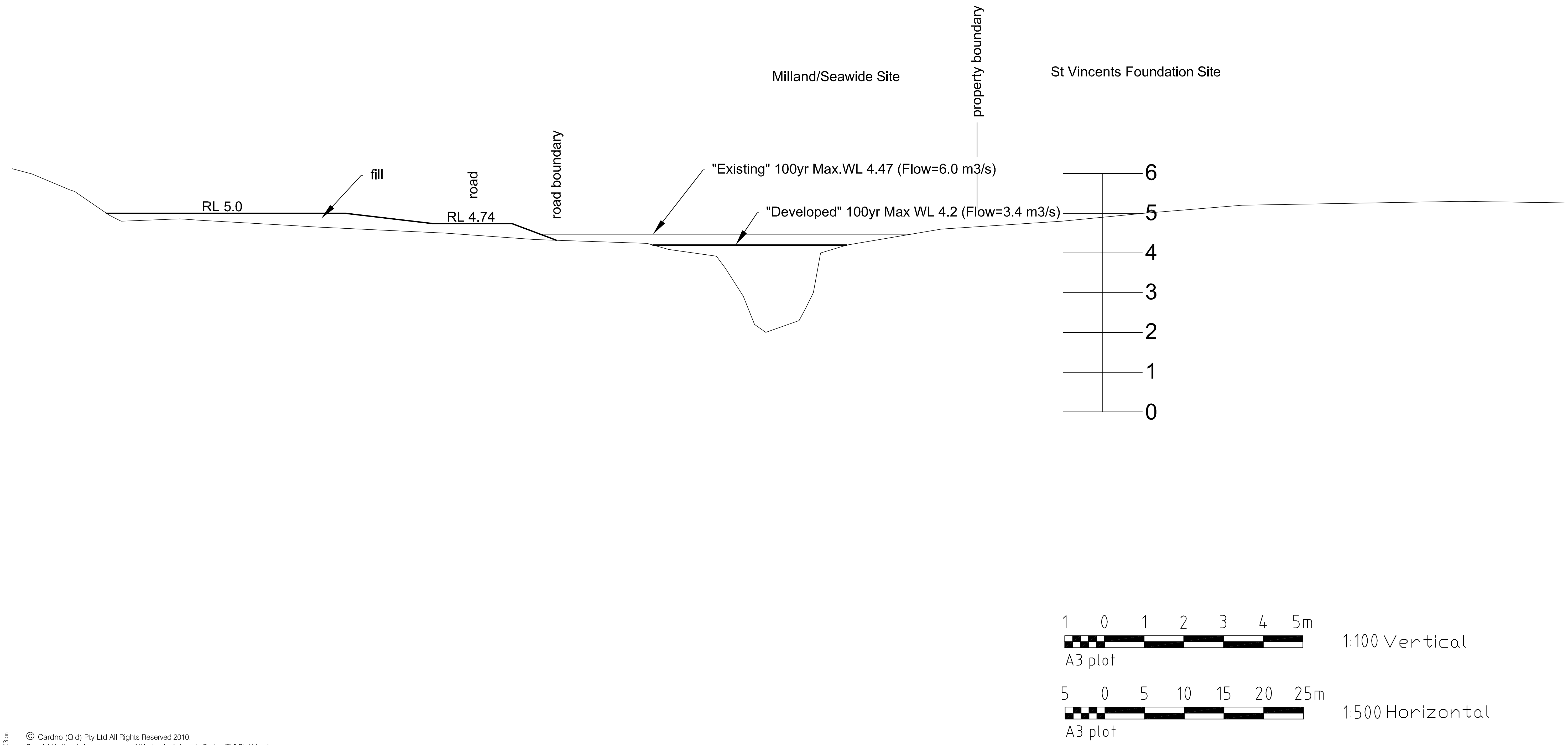


FIGURE 25

DUCHESS GULLY CROSS SECTION AT CH 835

PRINT DATE: 08 July, 2010 - 9:03pm
Ver: 1. Date: 7 JuLY 2010