Crighton Properties

Preliminary Hydrogeological Study and Concept Groundwater Management Plan,Riverside,Tea Gardens, NSW

martens consulting engineers

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

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Head Office
6/37 Leighton Place
Hornsby, NSW 2077, Australia
ACN 070 240 890 ABN 85 070 240 890
Phone: +61-2-9476-9999
Fax: +61-2-9476-8767
Email: mail@martens.com.au
Web: www.martens.com.au

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Author(s)	Reviewer(s)	Project Manager	Signature
Mr Ben Rose, Dr D. Martens	Dr D. Martens	Dr D. Martens	

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All enquiries regarding this project are to be directed to the Project Manager.

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1 Overview

1.1 Project Background

This report outlines preliminary groundwater investigations and the development of a Concept Groundwater Management Plan (CGMP) to assist the proposed residential development of 'Riverside' at Tea Gardens, NSW. We understand that the report was commissioned to support a Concept Proposal Application under Part 3a of the EP&A Act (1979).

A range of groundwater investigation works have been previously undertaken on the site dating back to Coffey (February, 1996). These works were undertaken in relation to various development proposals for the site.

This report seeks to collate and extend the previous groundwater investigation works undertaken at the site and assess groundwater related impacts in light of the current proposed development concept plan. The investigation also responds to Planning Assessment Commission (PAC) and NSW Department of Planning (DoP) comments which were made in relation to a previous Part 3a Application which was withdrawn in early 2010.

1.2 Study Scope

The project scope is summarised as follows:

1. Summarise available site groundwater level and quality data.
2. Prepare a preliminary groundwater model based on available data with groundwater modelling works to include:
    i) Preparation of a preliminary existing-development groundwater model.
    ii) Calibration of existing-development model to site Groundwater Monitoring Bore (GMB) data.
    iii) Preparation of a post-development groundwater model based on concept proposed development plans.
    iv) Preparation of pre and post-development mass budgets and flows to the SEPP 14 wetlands in the east of the site.
    v) Assessment of the impact of potential climate change induced sea level rise on groundwater levels.
3. Preparation of an interim Conceptual Groundwater Management Plan (CGWMP) covering the following:
    i) Aquifer characteristics.

ii) Management objectives.

iii) Management methods for aquifer recharge incorporating the surface water management strategy.

iv) Post-development monitoring and contingency planning.

v) Water quality trigger values for management.

1.3 Development Proposal Description

We understand that concept plan approval is sought for the following key elements:

1. Creation of 920 dwellings comprising of 855 residential dwellings, 50 Tourist Precinct lodges and 15 Tourist Precinct houses;
2. Internal road network;
3. Water Sensitive Urban Stormwater Design (WSUD); and
4. Creation of areas dedicated to open space, public recreation, stormwater management and wildlife movement corridors.

Refer to the site Preliminary Environmental Assessment (PEA) (ERM, August, 2010) for further detail with regards to the proposed concept plan.

1.4 Study Area Description

The site forms part of a much larger, approximately northeast – southwest aligned Pleistocene and Holocene coastal barrier mass. The site consists typically of low-lying land (<5 mAHD) bound by the Myall River to the east, Myall Way to the west, existing residential development to the south and Shearwater Residential Estate to the north. A proposed development concept plan is presented in Figure 1.

Margins of the site bordering the Myall River are subject to tidal inundation and are designated wetlands under State Environmental Planning Policy (SEPP) 14.

The site was formerly a forest plantation that ceased operation and is currently undeveloped with vegetation comprising a variety of coastal vegetation communities.

1.5 Proposed Surface Water System

The proposed surface water system (modified from previous concepts) has been formulated by Cardno and is broadly summarised by the following:

1. Does not extend the existing brackish lake (previously proposed).
2. Does not maintain a direct connection to the existing brackish lake (ie. is a fresh water system).

3. Does not require any new channels through the wetland (previously proposed) nor augmentation of the existing channel.
4. Has reduced the area of open window water bodies from that previously proposed.
5. Treats surface water to equal to or better than groundwater quality through a range of primary water quality devices such as dry swales, bio filtration, lined wetlands and lined ponds prior to any connection with the water table.
6. Provides additional surface water treatment through two freshwater (window) lakes and a major swale that conveys outflows from the northern freshwater lake south to the brackish lake. This swale replaces two large window ponds previously proposed upstream of the western arm of the brackish lake.
7. Has been designed to function under a 0.9 m sea level rise (including the effects of groundwater rise) and a climate change scenario comprising a 10% decrease in average annual rainfall.
8. Includes a recharge swale which buffers the SEPP14 wetland.

2 Hydrogeological Investigation

2.1 Previous Investigations

A review of previous site investigations relating to groundwater was undertaken. Documents that were reviewed included:

- Coffey Partners International (February, 1996), Myall Quays Development Groundwater and Surface Water Study.
- Coffey Partners International (June, 1996), Myall Quays Development Groundwater and Surface Water Study Estuarine Lake Option.
- Coffey Geotechnics (October, 2007), Groundwater Assessment Riverside Development, Tea Gardens.
- Coffey Geotechnics (March, 2009), Riverside Estate Project: Groundwater Response Summary – Draft for Comment.
- Coffey Geotechnics (August, 2009), Additional Groundwater Studies 2009, Crighton Properties Riverside Development, Tea Gardens.
- ERM (July, 2008), Riverside at Tea Gardens Phase 1 Environmental Site Assessment.
- Hunter Wetlands Research (January, 2009), Wetlands Assessment for Riverside, Tea Gardens.
- Martens and Associates (April, 2009), Groundwater Comments, Riverside Estate Project Proposal, Tea Gardens, NSW.
- Martens and Associates (July, 2009), Request for Additional Groundwater Information, Riverside Site, Tea Gardens, NSW.

2.2 Site Groundwater Monitoring Bores (GMBs)

Over the course of previous investigations a total of 20 GMBs have been installed on the site (including a standpipe installed to monitor lake levels).

Vandalism and/or loss of 4 GMBs (GMBs 1, 2, 3 and 7) between 2004 and 2007 has reduced the number of existing site GMBs to 16.

GMBs are summarised in Table 1 with locations shown on Figure 2.

Table 1: Summary of site GMBs.

Installer, Year	GMB I.D	Bore Depth (mBGL)	Screened Depth (mBGL)	Ground Elevation (mAHD)
DJD, 1994	2 [2]	5.0	2.5 - 4.5	2.370
DJD, 1994	3 [2]	5.0	2.5 – 4.5	0.845
DJD, 1994	4	10.0	7.5 – 9.5	2.045
DJD, 1994	5	5.0	2.5 – 4.5	2.608
DJD, 1994	6	5.0	2.5 – 4.5	0.861
DJD, 1994	7 [2]	5.0	2.5 – 4.5	2.963
DJD, 1994	8	5.0	2.5 – 4.5	2.598
DJD, 1994	9	6.0	3.5 – 5.5	2.859
DJD, 1994	10	5.0	2.5 – 4.5	1.490
DJD, 1994	11	5.0	2.5 – 4.5	3.395
DJD, 1994	12	5.0	2.5 – 4.5	3.261
DJD, 1994	13	10.5	7.5 – 10.5	- [3]
Coffey, 2006	21	3.0	1.0 – 3.0	1.026
Coffey, 2006	22	3.1	1.0 – 3.0	1.095
Coffey, 2006	23	3.1	1.1 – 3.1	1.111
Coffey, 2006	24	3.0	1.0 – 3.0	0.834
MA, 2009	1A	1.69	0.69 – 1.69	1.708
MA, 2009	2A	3.04	2.04 – 3.04	2.479
MA, 2009	25	2.28	1.28 – 2.28	1.798
MA, 2009	26 (lake)	NA	NA	0.492 [5]

Notes:

1. GMB details sourced from Coffey (October, 2007) and Martens and Associates field investigations.
2. GMB reported as lost or vandalised sometime between 2004 and 2007 (includes GMB 1).
3. Ground elevation not known.
4. DJD = DJ Douglas. MA = Martens and Associates.
5. Lake bed level at standpipe location.

2.3 Water Bearing Strata

The aquifer in the vicinity of the site generally comprises silty sand and fine to medium grained sand with some cemented layers (Coffee rock) and peaty bands with basement sandstone rock at approximately 10 to 20 mBGL (Coffey, October, 2007).

2.4 Aquifer Boundaries

The aquifer is bounded by elevated bedrock to the north of Toonang Drive, Port Stephens associated bays and creeks to the south/west and Myall River to the east.

2.5 Aquifer parameters

Review of pump test and recovery test results (DJ. Douglas and Partners, 1994), and adopted values for previous site groundwater models (Coffey, October, 2007), indicates that aquifer Hydraulic conductivity (K) is likely to typically be of the order of 10 m/d. Deviation from this value is expected in localised areas based on review of Bish (1995) which reported K values ranging from 0.7 to 37 m/d for a nearby Hawkes Nest aquifer.

Specific Yield (S_y) is likely to be of the order of 0.1 to 0.14 based on review of Coffey (February, 1996) and our experience with similar aquifers.

The mechanism for aquifer recharge is via direct rainfall infiltration. Despite the permeable soils, recharge is expected to be somewhat limited due to typically shallow groundwater levels which have the impact of reducing aquifer storage potential and increasing the likelihood of aquifer exposure to increased evapotranspiration (ET) rates near ground level. No further background research with regards to recharge was undertaken as this parameter is calibrated in the site groundwater model.

2.6 Groundwater Levels

2.6.1 Manual and Automatic Measurements

Groundwater level measurements taken to date both manually and automatically are summarised in Table 2. Refer to Attachment B for the data that was used to compile Table 2.

Table 2: Groundwater level summary.

GMB	Ground Level (mAHD)	Minimum Groundwater Level (mAHD)	Median Groundwater Level (mAHD)	Maximum Groundwater Level (mAHD)	Min Depth (m) to Groundwater
GMB1	1.02	0.24	0.63	0.93	0.09
GMB2	2.37	0.69	1.02	2.02	0.36
GMB3	0.85	0.06	0.74	0.79	0.06
GMB4	2.05	0.82 [4]	1.07 [4]	1.30 [4]	0.74 [4]
GMB5	2.61	1.14	1.66	2.56	0.05
GMB6	0.86	0.28 [3]	0.67 [3]	0.77 [3]	0.09 [3]
GMB7	2.96	1.55 [2]	2.42 [2]	2.82 [2]	0.15 [2]
GMB8	2.60	0.73	1.78	2.46	0.14
GMB9	2.86	1.16 [2]	1.71 [2]	2.11 [2]	0.75 [2]
GMB10	1.49	0.39	0.89	1.23	0.26
GMB11	3.40	1.35	2.01	3.01	0.39
GMB12	3.26	1.37	2.12	3.05	0.21
GMB13	-	-	-	-	-
GMB21	1.03	0.78	0.80	0.81	0.21
GMB22	1.10	0.83	0.85	0.88	0.22
GMB23	1.11	0.76 [2]	0.93 [2]	0.93 [2]	0.18 [2]
GMB24	0.83	0.63	0.65	0.68	0.15
GMB1A	1.71	0.72 [1]	0.82 [1]	1.06 [1]	0.65 [1]
GMB2A	2.48	1.13 [1]	1.20 [1]	1.32 [1]	1.16 [1]
GMB25	1.80	0.78 [1]	0.86 [1]	1.00 [1]	0.80 [1]
GMB26 (lake) [5]	0.49	0.63 [1]	0.70 [1]	0.90 [1]	NA [1]

Notes:
1. Derived based on continuous data logging data (04/06/2009 to 06/07/2009).
2. Derived based on dipped data and continuous data logging data (04/06/2009 to 06/07/2009).
3. Derived based on dipped data and continuous data logging data (late July, 1994 to mid November, 1994).
4. Derived based on dipped data and continuous data logging data (late July, 1994 to late September, 1994).
5. Lake bed level at standpipe location.

2.6.2 *Automatic Measurements*

Continuous monitoring of groundwater levels has been undertaken by Coffey (February, 1996) for GMB 4 and 6, and by Martens and Associates (July, 2009) for GMB 1A, 2A, 7, 9, 23, 25 and 26 (lake). A summary of Martens and Associates (July, 2009) results is provided in Table 3 with a continuous groundwater level plot provided in Figure 3.

Table 3: Summary of continuous groundwater level monitoring.

GMB	1A [1]	2A [1]	4 [2]	6 [3]	7 [1]	9 [1]	23 [1]	25 [1]	26 (lake) [1]
Ground Level (mAHD)	1.708	2.479	2.045	0.861	2.963	2.859	1.111	1.798	0.492
Max Level (mAHD)	1.057	1.319	1.500	0.750	3.030	2.665	1.163	0.997	0.900
Min Level (mAHD)	0.717	1.132	0.500	0.250	2.687	2.142	1.001	0.777	0.629
Range (m)	0.341	0.188	1.000	0.500	0.343	0.523	0.162	0.220	0.272
Median Level (mAHD)	0.821	1.197	1.100	0.500	2.910	2.398	1.103	0.862	0.703

Notes:
1. Martens and Associates (July, 2009) continuous data logging (04/06/2009 to 06/07/2009) at 0.5 hr logging frequency.
2. Coffey (February, 1996) continuous data logging (late July, 1994 to late September, 1994) at unknown logging frequency, estimated based on visual interpretation of plot.
3. Coffey (February, 1996) continuous data logging (late July, 1994 to mid November, 1994) at unknown logging frequency, estimated based on visual interpretation of plot.

2.6.3 *Summary*

The following comments are made based on review of site groundwater level data:

1. Groundwater levels are generally shallow (typically <1 mBGL).

2. Groundwater reached the surfaces at times at GMBs 7 and 23 during the Martens and Associates (July, 2009) continuous data logging period.

3. Short-term groundwater level fluctuation is likely to typically be <1 m.

4. Lake levels are consistently lower than groundwater levels and therefore suggest that groundwater discharges to the lake in the vicinity of the existing GMBs. Discharge of groundwater to the lake is expected to occur around the majority of the lake based on likely groundwater gradients.

5. Groundwater response to rainfall appears to be relatively rapid and occurs within 1-2 days of incident rainfall. Groundwater responses appear more substantial at higher ground elevations.

2.7 Groundwater Quality

2.7.1 *Laboratory Data*

Groundwater quality data to date has been collated for key analytes and presented in Attachment C with a summary provided below in Table 4.

Table 4: Summarised groundwater quality data.

Analyte	Site GMB Median [1]	Lake Median [1]
pH	5.60	6.07
TDS (mg/L)	220.00	5564.50
Chloride (mg/L)	65.00	2918.70
Sulphate (mg/L)	33.00	431.00
Magnesium (mg/L)	7.80	181.50
Calcium (mg/L)	4.60	59.00
EC (us/cm)	264.00	7091.00
TN (mg/L)	3.80	0.72
TP (mg/L)	1.12	0.08

Notes:
1. Excludes values below laboratory detection limits. Data used to calculate median comprises samples collected on 06.07.2009, 30.03.2007, 29.03.2007 and the mean value of 7 samples collected between 13.12.1994 and 29.08.1995.

2.7.2 *Automatic Measurements*

Continuous monitoring of groundwater and lake EC concentrations was undertaken concurrently with groundwater level monitoring by Martens and Associates (July, 2009) for GMB 1A, 2A, 25 and 26 (lake). A summary of results is provided in Table 5 with a continuous groundwater EC plot provided in Figure 4. Results indicated that saline/brackish lake water was not migrating from the lake to the local groundwater system. This is expected given that the groundwater gradient is towards the lake.

Table 5: Summary of continuous groundwater EC (µS/cm) concentration monitoring.

GMB	1A [1]	2A [1]	4	6	7 [1]	9 [1]	23 [1]	25 [1]	26 (lake) [1]
Mean	255	155	-	-	-	-	-	229	10285
Minimum	240	140	-	-	-	-	-	180	7830
Maximum	260	150	-	-	-	-	-	380	13150
Range	20	10	-	-	-	-	-	200	5320

Notes:
1. Martens and Associates (July, 2009) continuous data logging (04/06/2009 to 06/07/2009) at 0.5 hr logging frequency.

2.7.3 *Summary*

The following comments are made based on review of site groundwater quality data:

1. Groundwater quality is not to a standard to meet a potable quality in accordance with the Australian Drinking Water Guidelines (NHMRC, 2004), primarily on the basis of acid levels, variable salinity and elevated concentrations of a range of analytes (Martens and Associates, April, 2009).

2. The most significant beneficial uses for groundwater in some locations of the site are for irrigation and ecosystem maintenance (Coffey, October, 2007).

3. The median EC and TDS concentration within the lake is higher than in GMBs and is indicative of saline water. This is expected as the invert level of the lake's drain is reported to be at an approximate elevation of 0.66 mAHD (Coffey, October, 2007). Based on review of Fort Denison tidal data such an elevation can be expected to be breached by tides approximately 25 days per year.

4. The median EC and TDS concentration within GMBs is indicative of fresh water.

5. Monitoring data indicates that lake nutrient concentrations are lower than those observed in nearby GMBs.

2.8 Preliminary Groundwater Modelling

2.8.1 Model Development Approach

To assist with determining the spatial extent and variability of groundwater resources below the site, a series of preliminary steady state groundwater models of the study area were developed using Visual MODFLOW Pro 2009.1. Modelling works extended a concept model previously prepared by Coffey (October, 2007 and August, 2009) which was modified and calibrated by Martens and Associates to include the following:

- o Site GMB calibration data;
- o Additional GMBs (more calibration locations)
- o A larger active domain area;
- o Slightly modified layer terrain in the north of the model to reduce the potential for dry cells due to abrupt changes in elevation; and
- o Changes to aquifer/boundary condition properties as follows:
  - The constant head boundary used to represent Port Stephens associated bays and creeks and the Myall River was decreased from 0.045 mAHD to 0 mAHD.
  - The bulk of the aquifer's K value was increased from 8 m/d to 10 m/d. We note that a K value of 10 m/d is consistent with the DJ Douglas Partners (1994) K estimate for the site which was derived from a pump test.
  - The existing brackish lake was modelled as a constant head of 0.7 mAHD. We note this level is consistent with the median level observed during Martens and Associates (July, 2009) continuous monitoring of lake levels.
  - A pond associated with a quarrying excavation approximately 1.6 km west of the site was modelled as a constant head of -1.7 mAHD. We note this level is consistent with survey records and anecdotal evidence.
  - Re-distribution of recharge zones and reform of recharge estimation method (a net recharge approach was pursued over separate calibration of recharge/ET).

The following scenarios were modelled as part of this investigation:

<u>Model 1 (M1)</u>: <u>Pre-development Conditions (steady state)</u>
Using available site geotechnical data, a calibrated single layer steady state model M1 was developed. The primary purpose of the model was to provide a base case for development footprint and climate

change impact assessment purposes.

<u>Model 2 (M2)</u>: <u>Post - development Conditions (steady state)</u>

Model M2 was developed to provide a preliminary assessment of the likely impact of the proposed development footprint on steady state groundwater conditions. In particular, model M2 reduced recharge rates over the proposed development and locally increased recharge rates at unlined site stormwater basins and along the swale which abuts the SEPP14 wetland boundary. The model included proposed-development terrain (provided by Tattersall Lander).

<u>Model 3 (M3)</u>: <u>Post-development Conditions with Sea Level Rise (steady state)</u>

Model M3 was developed using the developed conditions as documented in model M2, but modified to examine the impact that potential climate change induced sea level rise of 0.9 m would have on groundwater levels within the development footprint (including the proposed surface water management system).

2.8.2 Model Discretisation

Model discretisation is summarised in Table 6.

Table 6: MODFLOW model discretisation.

Property	Value / Details
Model Area	6 km x 5 km
Approximate Proportion of Model Area Designated as Active	35%
Grid cell size	50 m x 50 m (refined to 25 m x 25 m over site)
Layer thickness	Generally 15 m in area of site (layer terrain adopted from Coffey (October, 2007) model.
Topography	Surface terrain adopted from Coffey (October, 2007 and August, 2009) model. Proposed development terrain used in M2 and M3 integrated into model based on proposed development terrain data provided by Tattersall Lander (2010).
Calibration Period	Median GMB levels from between 1994 and 2009 (steady state model M1) (see Attachment C).

2.8.3 Boundary Conditions for Model M1

A constant head of 0 mAHD was applied along the eastern, southern and western fringes of the active model domain to represent the Port Stephens associated bays and creeks to the south/west of the site and Myall River to the east of the site.

A constant head of -1.70 mAHD was applied in the area of a quarry pit located in the west of the model domain based on anecdotal survey data.

A constant head of 0.70 mAHD was applied in the area of the existing lake located to the south of the site. This elevation was assigned based on review of monitoring data and in light of the lake's drain invert level of approximately 0.66 mAHD.

2.8.4 *Calibration of Model M1*

Steady state calibration of model M1 was undertaken using a homogeneous K zone of 10 m/d. This value is consistent with the DJ Douglas Partners (1994) K estimate for the site which was derived from a pump test.

Recharge was estimated iteratively for undeveloped areas of the model and developed areas of the model. Developed areas where assigned a recharge rate 50% lower than the undeveloped areas to take into account the impact of impervious areas. A recharge rate of 0 mm/yr was applied in the area where Coffey mapping (October, 2007) identified surface clay deposits.

Final calibration (Figure 5) required a recharge rate of 135 mm/yr for undeveloped areas and 67.5 mm/yr for developed areas. This resulted in a calibrated residual mean of -0.03 m (i.e the model is marginally under-predicting groundwater head). The normalized RMS was 9.4% which is below the typical industry accepted upper threshold of 10%.

In light of the available data, modelling results indicate that the steady state model (M1) is sufficiently calibrated to allow its use for preliminary assessment.

2.8.5 *Boundary Conditions for Models M2 and M3*

Boundary conditions utilised in M1 were modified as follows:

<u>M2</u>

a) M2 recharge rates were decreased by 50% in areas of proposed development to simulate decreased recharge due to increased impervious areas. A reduction in recharge was not applied to the tourist lodgings precinct as this proposed area appears to have relatively less impervious area when compared to other proposed development areas. We note that should the impervious area percentage deviate from 50% then further modelling will be required to model the correct impervious area percentage.

b) Recharge rates were increased over areas of proposed unlined stormwater basins. Recharge rates were assigned based on basin area and annual stormwater flow to the basin (recharge = annual flow to basin/basin area) which were based on MUSIC modelling data provided by Cardno. Drain boundary conditions were used to model the affect of stormwater outflows from the unlined stormwater basins.

c) Drain boundary conditions were set to occupy the areas of the site that contained proposed unlined basins. Drain levels were based on estimated basin operating levels provided by Cardo with drain conductance set infinitely high to represent efficient discharge of basin water.

d) A preliminary developed surface terrain file was prepared by Tattersall Lander Pty Ltd and incorporated in the model domain.

e) Increased recharge at the swale which abuts the SEPP14 wetland boundary was modelled by applying 5% of the average annual surface water flow (provided by Cardno, 2010) over the area of the proposed swale.

<u>M3</u>

a) Boundary conditions generally remained as per M2 with the following modifications.

b) The constant head of 0 mAHD that was applied along the eastern, southern and western fringes of the active model domain to represent the Port Stephens associated bays and creeks to the south/west of the site and Myall River to the east of the site was increased to 0.9 mAHD to represent climate change induced sea level rise. This boundary was also relocated to occupy the 0.9 mAHD land surface contour within the model to take into account shoreline transgression.

c) The lake constant head was increased to 0.9 mAHD to coincide with its connection to the Myall River under sea level rise conditions.

d) The drain boundary condition levels for the unlined basins were raised from 1.05 mAHD (Flake1) and 0.9 mAHD (Flake2) to 1.4 mAHD (Flake1 and Flake 2) in accordance with estimated levels that were provided by Cardno.

e) The western quarry standing water level was raised by 0.9 m to – 0.8 m AHD to model the impact of potential climate change induced sea level rise. This approach maintains a similar head differential between current sea level and mean quarry standing water level. This is taken as a reasonable interim assumption in light of the limited information [regarding quarry water levels and groundwater processes] available at the time of report preparation.

2.8.6 *Modelled Groundwater*

Steady state groundwater modelling results are discussed below:

Model 1 (M1): Existing Conditions (steady state)

Simulation results are provided in Figure 6 which indicate that groundwater flows from the north west to the south east in the area of the site and discharges to the Myall River.

Model 2 (M2): Developed Conditions (steady State)

Simulation results outlining groundwater head and drawdown (using M1 output for initial head) are provided in Figure 7 and Figure 8 respectively. Results indicate that the proposed development is likely to reduce groundwater levels in the area of the proposed unlined lakes by up to approximately 0.5 m due to interception of groundwater. Results also indicate that groundwater levels over the adjacent SEPP14 wetlands are likely to remain unchanged with modelled draw-downs of <0.05 cm, which is within the resolution of modelling. Changes to groundwater flow direction at the site boundaries and within adjoining wetlands are negligible.

Model 3 (M3): Developed Conditions with Sea Level Rise (steady State)

Simulation results outlining groundwater head and drawdown (using M2 output for initial head) are provided in Figure 9 and Figure 10 respectively. Results indicate that sea level rise will lead to inundation of the majority of the SEPP14 wetland area adjacent to the site. Groundwater levels in the area of the site where development is proposed are modelled to increase by a maximum of 0.35 - 0.4 m.

2.8.7 *Preliminary Zone Budgets*

The site was separated into the following zones for water budgeting assessment purposes.

1. Site Zone – this zone comprises the development site and external areas within the model domain which are not occupied

by wetland.

2. SEPP 14 Wetland Zone – this represents SEPP14 wetland areas to the east of the site.

Zone locations are provided in Figure 11. Zone budget results were developed based on model M1 and M2 results and are provided in Table 7.

Comments are as follows:

1. On the basis of current groundwater data, there may be a minor reduction (approximately 5%) in net groundwater recharge to the fringing wetland. This is within expected existing annual water balance fluctuations and comes about through a marginal decrease in net recharge within the development site.

2. The modelled reduction is well within expected annual discharge fluctuation and is considered an acceptable outcome.

3. Further minor modification of the stormwater system could be undertaken at the project phase to elevate discharge rates to the SEPP14 wetland should that be required.

Table 7: Annual wetland groundwater zone budgets (ML/year).

Zone	Existing Conditions (Model M1) (ML/year)	Developed Conditions (Model M2) (ML/year)	Net Change (%)
Wetland Zone Inflow	266	254	- 5

2.8.8 *Preliminary Nutrient Fluxes*

Using the zone water budgets defined above, nitrogen and phosphorus fluxes were estimated based on the limited existing groundwater chemistry data. Results are provided in Table 8 with comments as follows:

1. Results provide an overview of mass transport rates to the fringing wetlands and hence to the receiving waters.

2. Developed conditions show minor reductions to nutrient fluxes.

3. Impacts of stormwater loads to the groundwater system have not at this stage been included in the nutrient flux analysis but should be included in the more detailed modelling at a later stage. We note that the brackish lake's total nitrogen and total phosphorous concentrations are lower than those of the

groundwater system and therefore the lake will not provide a source of nutrients for the groundwater system.

Table 8: Average annual nutrient fluxes for wetland groundwater zone.

Zone	Existing Conditions (TN / TP tonnes/year)	Developed Conditions (TN / TP tonnes/year)	Net Change (TN / TP%)
Wetland Zone Inflow	1.01 / 0.30	0.97 / 0.28	- 5 / -5

Notes: 1. Total Nitrogen (TN), Total Phosphorous (TP). 2. Flux calculations based on assumed groundwater TN concentration of 3.8 mg/L and TP concentration of 1.12 mg/L (Table 4).

2.9 Potential Impacts on Wetlands

In 2007 Coffey Partners compiled a groundwater model in respect of proposed development at Riverside. The Groundwater model was based on the previously proposed development scheme at Riverside, which incorperated a substantial saline lake extension and extensive freshwater "window" lakes. The Coffey Partners work also responded to a new connection to the Myall River (which was proposed at that time). We understand that the Coffey Partners model, in conjunction with surface water modelling provided by Cardno (2008) was reported upon by Winning in the Wetlands Assessment for Riverside, Tea gardens (2009).

Winning (2009) reported that the fringing wetlands were dependent on existing groundwater levels and that the drawdown modelled by Coffey Partners (2007) was not likely to affect ecosystems. The current modelling, which incorporates the Cardno 2010 surface water management scheme (fewer window lakes, no lake extension, no increased connection to the Myall River), demonstrates a similar but further reduced drawdown at the wetland boundary to that modelled by Coffey Partners (2007). From this we conclude:

1. Groundwater levels within the wetlands will remain essentially at their current level.
2. There will be no significant changes in groundwater flow budgets to the wetlands.
3. Existing groundwater flow paths within the wetlands will remain.
4. There will be no saline groundwater intrusion within the wetlands.

3 Preliminary Concept Groundwater Management Plan

3.1 Overview

This preliminary concept groundwater management plan provides advice on the following:

1. Existing aquifer characteristics
2. Potential aquifer risks
3. Risk management objectives
4. Risk management methods
5. Further Investigation Requirements

3.2 General Aquifer Characteristics

Based on limited investigation and modelling of the aquifer, the following interim characteristics define the Riverside site aquifer:

5. The aquifer is sand-dominated and highly permeable;
6. The groundwater system is coupled with the Port Stephens estuary/Myall River and is responsive to tidal fluctuations;
7. The aquifer is highly responsive to recharge events. Reasonably rapid groundwater level fluctuations of the order of 500 mm to 1000 mm can occur in response to rainfall;
8. Aquifer recharge is local and is predominantly controlled by incident rainfall; and
9. Based on available groundwater quality data, groundwater is likely to be of a low-value resource due to TDS, pH, chloride, sodium and ammonia concentrations which exceed Australian Drinking Water Guidelines (NHRMC, 2004).

3.3 Primary Risk Identification

Whilst this document does not present a comprehensive analysis of risks to the sites aquifer, the following broad scale potential risks are identified in association with the release of urban land.

1. Untreated stormwater discharge to groundwater resulting in groundwater contamination.

2. Changes to groundwater level which come about through modifications to surface infiltration and recharge properties at the site.

3. Changes to groundwater flow direction which come about through modifications to surface infiltration and recharge

properties at the site.

4. Significant modifications to groundwater flow budgets to groundwater dependent ecosystems and the receiving waters.

5. Locally increasing groundwater levels though excessive recharge resulting in surface water losses from the groundwater system.

3.4 Risk Management Objectives

On the basis of identified risks, the following risk management objectives are provided:

1. Development is to be undertaken in such a way so as to ensure that groundwater table drawdown is minimised.

2. Development should not result in a degradation of the existing aquifer water quality.

3. Development should not significantly alter the flow directions of ground water at the site.

4. Insure the surface and groundwater system is maintained such that the integrity of groundwater dependent ecosystems is preserved or enhanced.

3.5 Risk Management Methods

The following methods are recommended in order that the risk management objectives can be met:

1. Ensure all stormwater management systems treat stormwater to a level equal to or better than existing groundwater quality prior to discharge to any groundwater body.

2. Minimise [but do not necessary preclude] the exposure of groundwater to surface water systems.

3. Ensure that where groundwater recharge has been locally reduced, that recharge is increased in other areas of the site to compensate for any potential water budget short falls.

4. Recharge treated stormwater throughout the site in such a way so as to enable distributed recharge rather than single point recharge. This will ensure that groundwater flow gradients, levels and directions are maintained at/close to pre-development levels. It is noted that that current proposal features a recharge swale that buffers the SEPP14 wetland.

3.6 Groundwater pH Management

Existing groundwater pH levels at the site are variable and may typically range between say 5.0 and 6.5 depending on specific location, local soil and geology, and antecedent rainfall conditions. Samples from GMB returned the lowest pH value of 3.99.

Rainfall pH levels for coastal NSW are generally acidic due to the disassociation of CO_2 to form carbonic acid and may range between say 5.5 and 7.0. Lower levels [to say pH of 4.5] can be experienced in coastal areas near larger urban centres or closer to industrial centres (such as Newcastle in the case of this site) (Bridgman, 1989).

Contrasting the depressed pH of rainfall, urban runoff, notably from concrete and other pavement surfaces, has the potential to maintain a slightly elevated pH of say 6.5 – 7.5. In the case of this development, we do not expect any changes to background groundwater pH levels at the fringing wetlands for the following reasons:

1. There will be minimal concrete pavements / surfaces within the development relative to other surfaces (ie. pervious surfaces and roofs) and therefore limited potential for significant production of alkaline urban runoff.

2. Rainwater will remain the primary source of acidity within urban runoff and there will continue to be significant opportunity within the development footprint and within the proposed surface drainage system for contact between rainwater and *in-situ* soil prior to percolation to the groundwater system.

3. Local soils within and adjoining the fringing wetlands have a significant capacity to maintain stable pH levels given the high levels of organic matter and buffering capacity of local soils (Murphy, 1995).

3.7 Recycled Water Usage

We provide the following preliminary comments in relation to the risks that any potential irrigation of recycled water over the site would pose.

1. Indicative nutrient concentrations in recycled water would be 6 mg/L TN and 2.2 mg/L TP. These values are comparable to existing groundwater conditions, particularly nitrogen levels. We note there may be scope to reduce these concentrations with additional water treatment.

2. On the basis that lots will be of the order of 600 m^2 with irrigated garden beds and/or lawns being in approximately 200 m^2, some 90-100 KL/ET/year (say 100 KL/dwelling/year) of recycled water would

be expected to be used for outdoor purposes (assuming a total water consumption rate of 210 KL/ET/year).

3. Irrigation nutrient loads to the yard areas will therefore be of the order of 0.60 kg/year TN and 0.22 kg/year TP. It is important to note that these loads would be irrigated during dry times and generally onto unsaturated soils and not directly into the groundwater system. During times of high groundwater, there would be no need to provide additional irrigation water. Risks of direct recharge are therefore negligible.

4. Broad acre nutrient consumption rates for lawns and landscaped gardens are of the order of 200 kg/ha/year and 15 kg/ha/year phosphorus. On this basis, demand for nutrients in irrigated yard and landscaped areas will be of the order of 4 kg/year TN and 0.3 kg/year TP.

5. The above demonstrates that demand for nutrients in garden areas alone far outstrips that which can be supplied by the recycled water. In the case of nitrogen, demand is 660 % of expected supply, and in the case of phosphorus, demand is 136 % of expected supply. In the case of phosphorus, these preliminary estimates do not account for the significant sorption of phosphorous that would occur within soils.

6. The preliminary calculations are conservative as they do not account for the opportunity for nutrient uptake in areas outside those being irrigated, nor do they account for nutrient transformation which will occur within the unsaturated and saturated portions of the soil (eg. denitrification losses).

4 References

ANZECC (2000) National Water Quality Management Strategy. *Australian Guidelines for Urban Stormwater Management*

Bish, S. (1995) *Hydrogeological and Hydrochemical Characteristics of a Sand Dune Aquifer System at Hawkes Nest, NSW. Master of Applied Science Thesis, UNSW*

Bridgman, H. A. (1989) *Acid Rain Studies in Australia and New Zealand*, Archives of Environmental Contamination and Toxicology 18, p137-146

Coffey Geotechnics (October, 2007) *Groundwater Assessment Riverside Development, Tea Gardens*

Coffey Partners International (February, 1996) *Myall Quays Development Groundwater and Surface Water Study*

Coffey Partners International (June, 1996) *Myall Quays Development Groundwater and Surface Water Study Estuarine Lake Option*

DJ. Douglas Partners (October, 1994) Piezometer Installation – Myall Quays Residential Community, Tea Gardens, Report No. 16967

ERM (August, 2010) Riverside at Tea Gardens Concept Plan - Preliminary Environmental Assessment

ERM (July, 2008) Riverside at Tea Gardens Phase 1 Environmental Site Assessment

Murphy, C. L. (1995) *Soil Landscapes of the Port Stephens 1:100 000 Sheet*, Soil Conservation Service of NSW

5 Attachment A – Figures

Item	Description
1	Extent of concept plan area 'Riverside' at Tea Gardens.
2	Existing 7(a) wetland zone.
3	Existing 7(b) buffer zone.
4	Wildlife movement corridor.
5	Water management & open space corridors.
6	Community parks incorporating walking/cycle ways, BBQs, children's play area equipment.
7	Community pocket parks.
8	Not Applicable
9	Not Applicable
10	Existing detention and water quality lake.
11	New fresh water, water quality management & detention ponds.
12	Existing residential development.
13	Precinct community facilities.
14	Future precinct community facilities.
15	Site area currently owned by Great Lakes Council.
16	Separate medium density/commercial precinct (not part of this application-current waiver issued by DoP.)
17	Tourist lodgings precinct.
18	Additional land proposed for conservation.
19	Proposed residential lot development to be developed under community title.
20	Future development site.
21	Existing house.
22	DCP buffer.
23	Location of known midden & buffer.
24	Existing drain outlet to Myall River.
25	Existing drainage swale
26	Existing shopping centre/medium density approvals
27	Future connecting road

Land Use Legend

Total Site	Ha	%
Open Space		
- Wetlands (zoned 7a)	28.6	12.9
- Buffer Zones (zoned 7b)	21.0	9.4
- Additional Conservation Buffer	17.8	8.0
- Wildlife Corridors	41.9	18.8
- Drainage Corridors, Ponds & Large Parks	23.1	10.4
- Pocket Parks	2.6	1.2
- Existing detention & water quality lake	6.7	3.0
Total	141.7 Ha	63.7%
Built Upon Area		
- Residential (including roads & community facilities)	67.1	30.2
- Tourist/Residential (Lodgings)	8.1	3.6
Total	75.2 Ha	33.8%
Future Development Site		
Total	5.6 Ha	2.5%
Total	222.5 Ha	100%

Riverside
Tea Gardens Australia

DRAWING TITLE
CONCEPT PLAN

0m 500m

Part 3a Submission to N.S.W. D.O.P.

November 2011 | 1:4000 @ A1 | R.C. -03 | N

CRIGHTON PROPERTIES

N

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	NA – see plan	RIVERSIDE PROPOSED DEVELOPMENT CONCEPT PLAN	Drawing No: FIGURE 1
Approved:	NA – see plan		
Date:	NA – see plan		
Scale:	NA – see plan		Job No: P0902346

Note:
Image shows location of all installed GMBs to date. GMBs 1, 2, 3 and 7 were lost, vandalised or destroyed sometime between 2004 and 2007 and are therefore are no longer currently present.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

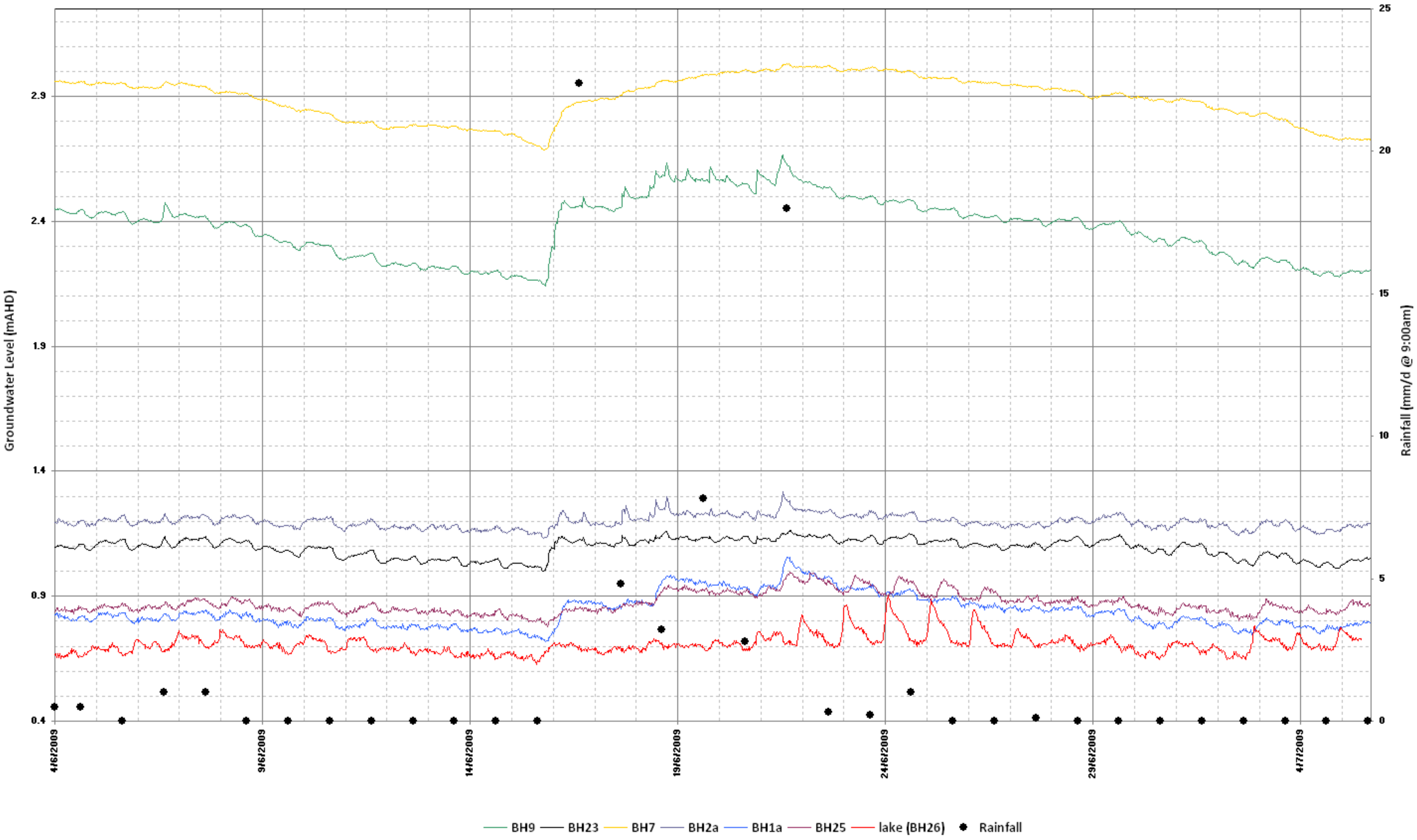
Drawn:	BR
Approved:	DMM
Date:	05.11.2010
Scale:	Approx 1: 13,125

SITE GROUNDWATER MONITORING BORES (GMBS)

Drawing No:

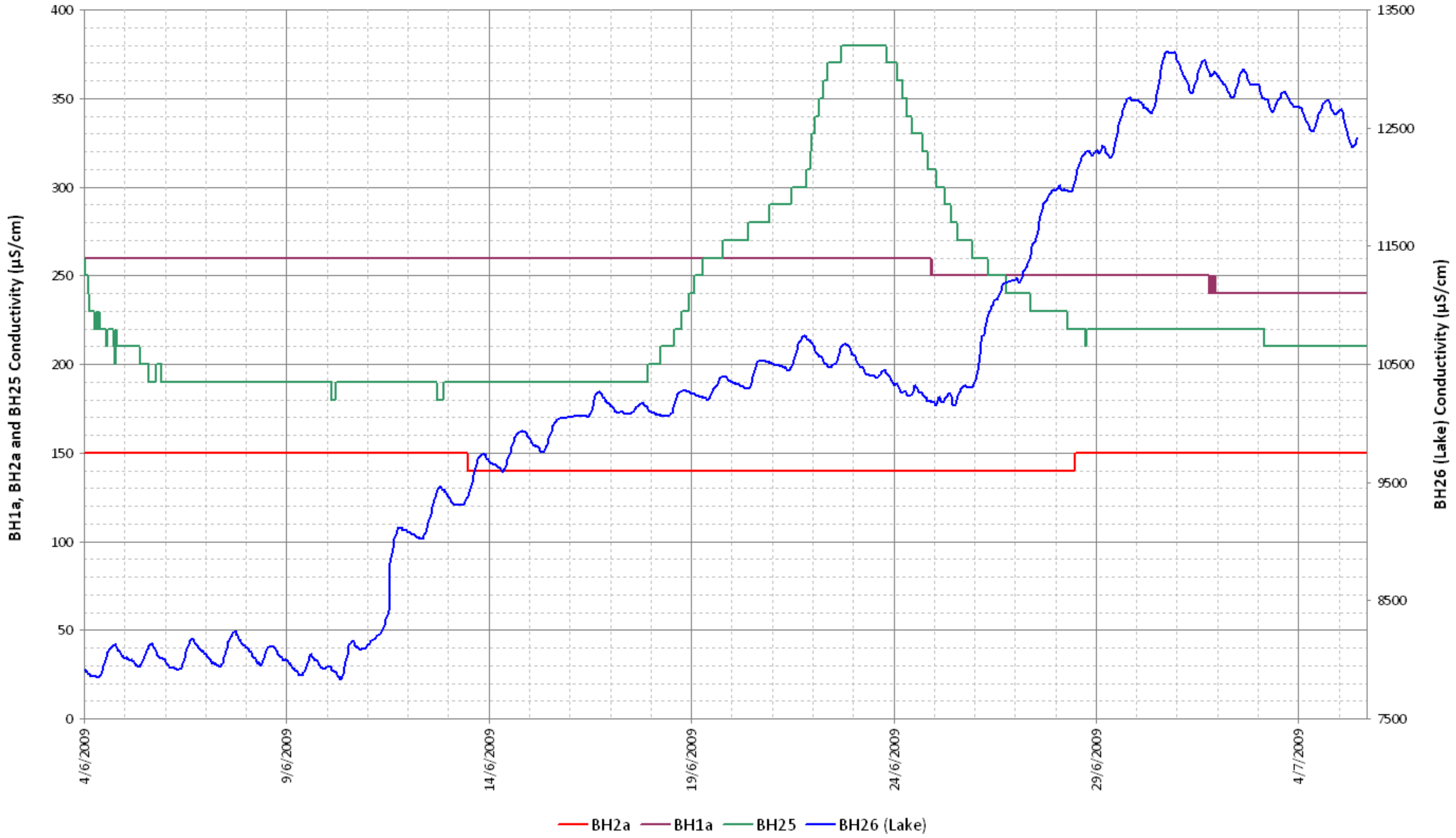
FIGURE 2

Job No: P0902346



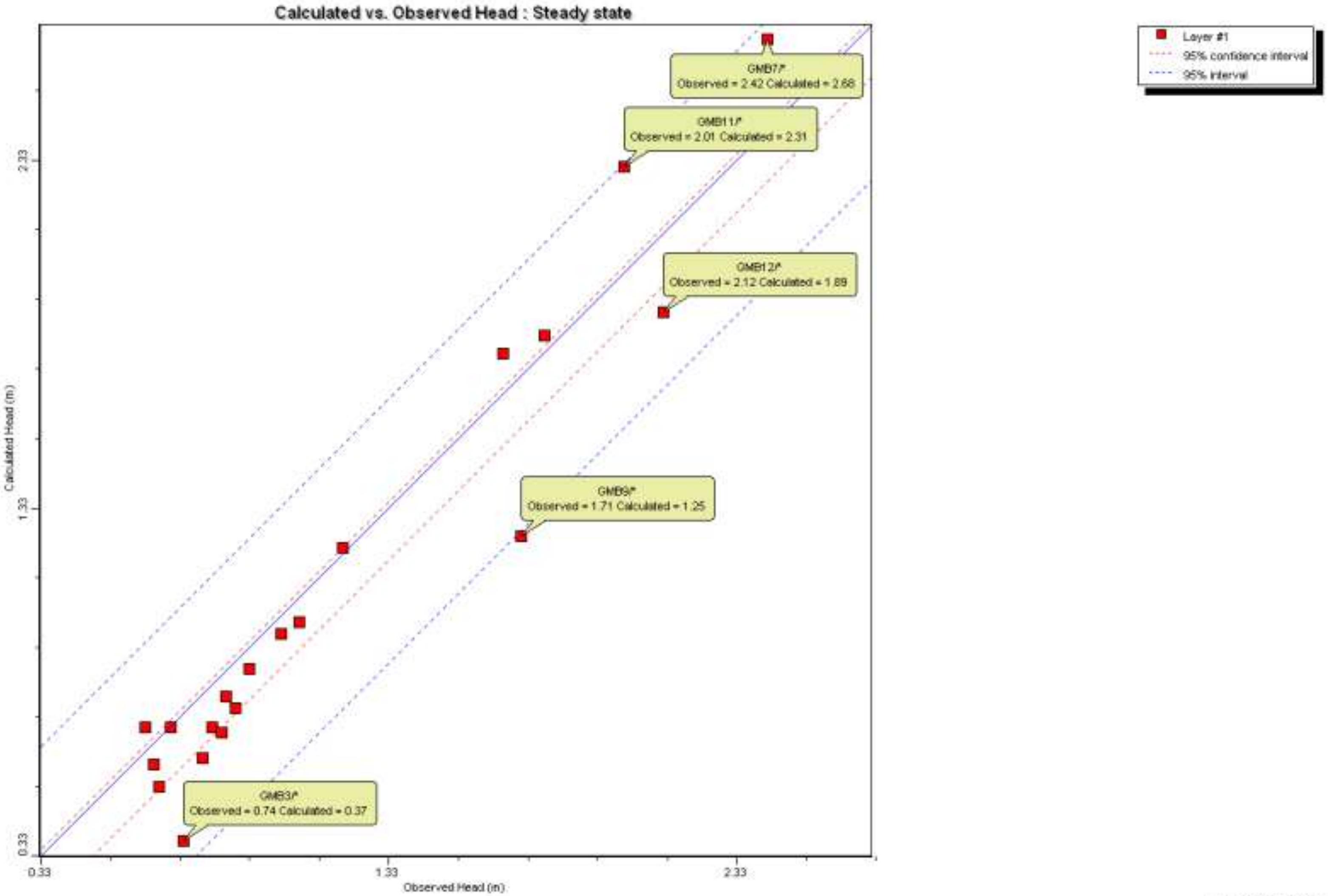
martens

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	**RIVERSIDE GROUNDWATER LEVEL OBSERVATIONS: BORES 1A, 2A, 7, 9, 23, 25 AND 26 (Lake) PERIOD: 04/06/09 – 06/07/09**	Drawing No: **FIGURE 3**
Approved:	DMM		
Date:	31.07.2009		
Scale:	N/A		Job No: P0902346



martens

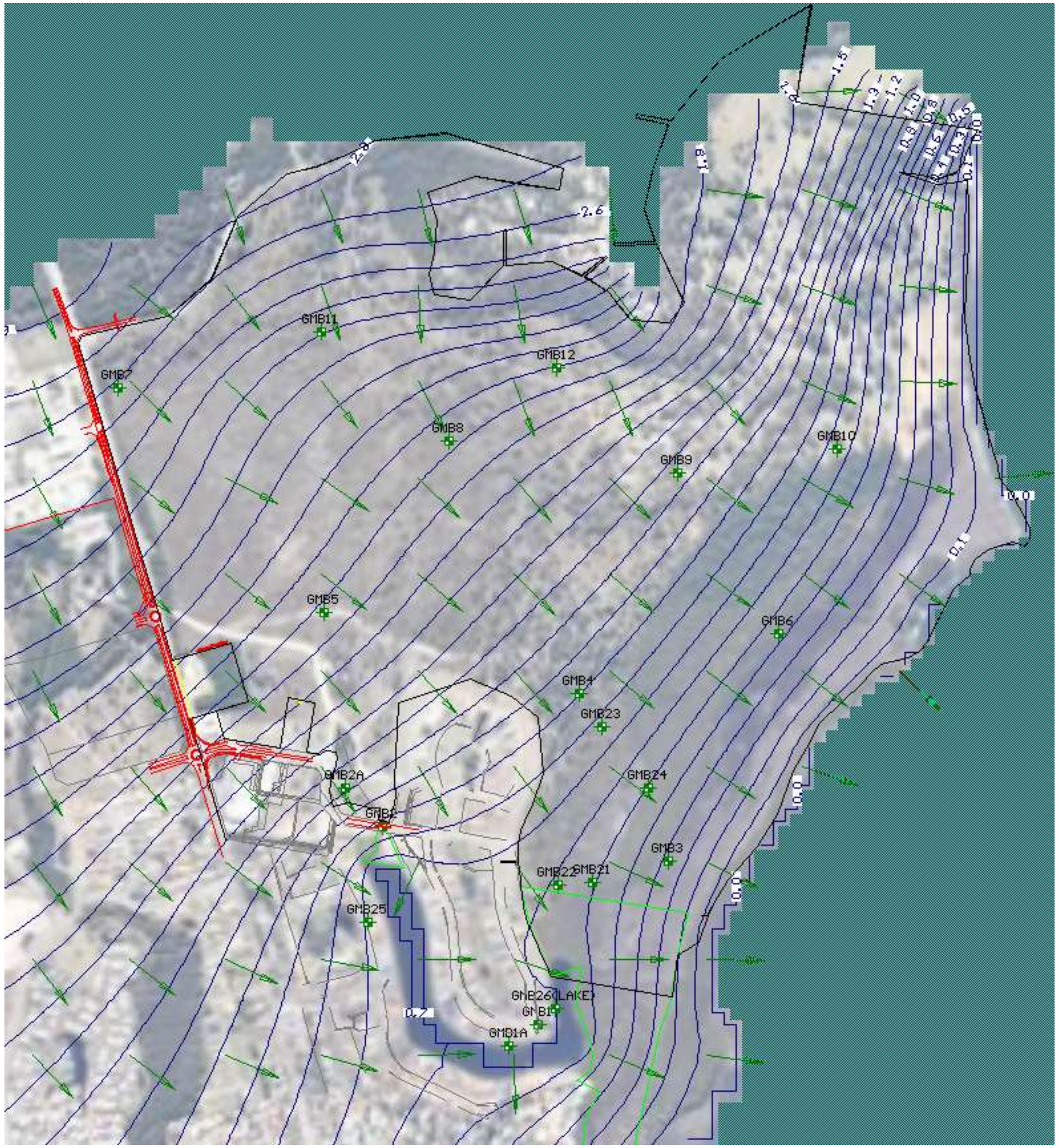
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**RIVERSIDE GROUNDWATER EC (µS/CM) OBSERVATIONS: BORES 1A, 2A, 25 AND 26 (Lake) PERIOD: 04/06/09 – 06/07/09**	Drawing No: **FIGURE 4**
Approved:	DMM		
Date:	31.07.2009		
Scale:	N/A		Job No: P0902346



Max. Residual: -0.459 (m) at GMB9/*
Min. Residual: -0.003 (m) at GMB26(LAKE)/*
Residual Mean : -0.065 (m)
Abs. Residual Mean : 0.147 (m)

Num. of Data Points : 20
Standard Error of the Estimate : 0.041 (m)
Root Mean Squared : 0.189 (m)
Normalized RMS : 10.552 (%)
Correlation Coefficient : 0.965

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	**M1 CALIBRATION**	Drawing No: **FIGURE 5**
Approved:	DMM		
Date:	05.11.2010		
Scale:	NA		Job No: P0902346



martens

Key
Blue lines - Head equipotential (0.1 m contour interval)
Green Flow direction

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**M1- EXISITNG CONDITIONS: STEADY STATE PIEZOMETRIC SURFACE**	Drawing No: **FIGURE 6**
Approved:	DMM		
Date:	04.11.2010		
Scale:	Approx 1: 16,110		Job No: P0902346

As per main figure but with proposed development layer turned on (approx scale 1: 22,070).

N

martens

Key
Blue lines - Head equipotential (0.1 m contour interval)
Green Flow direction

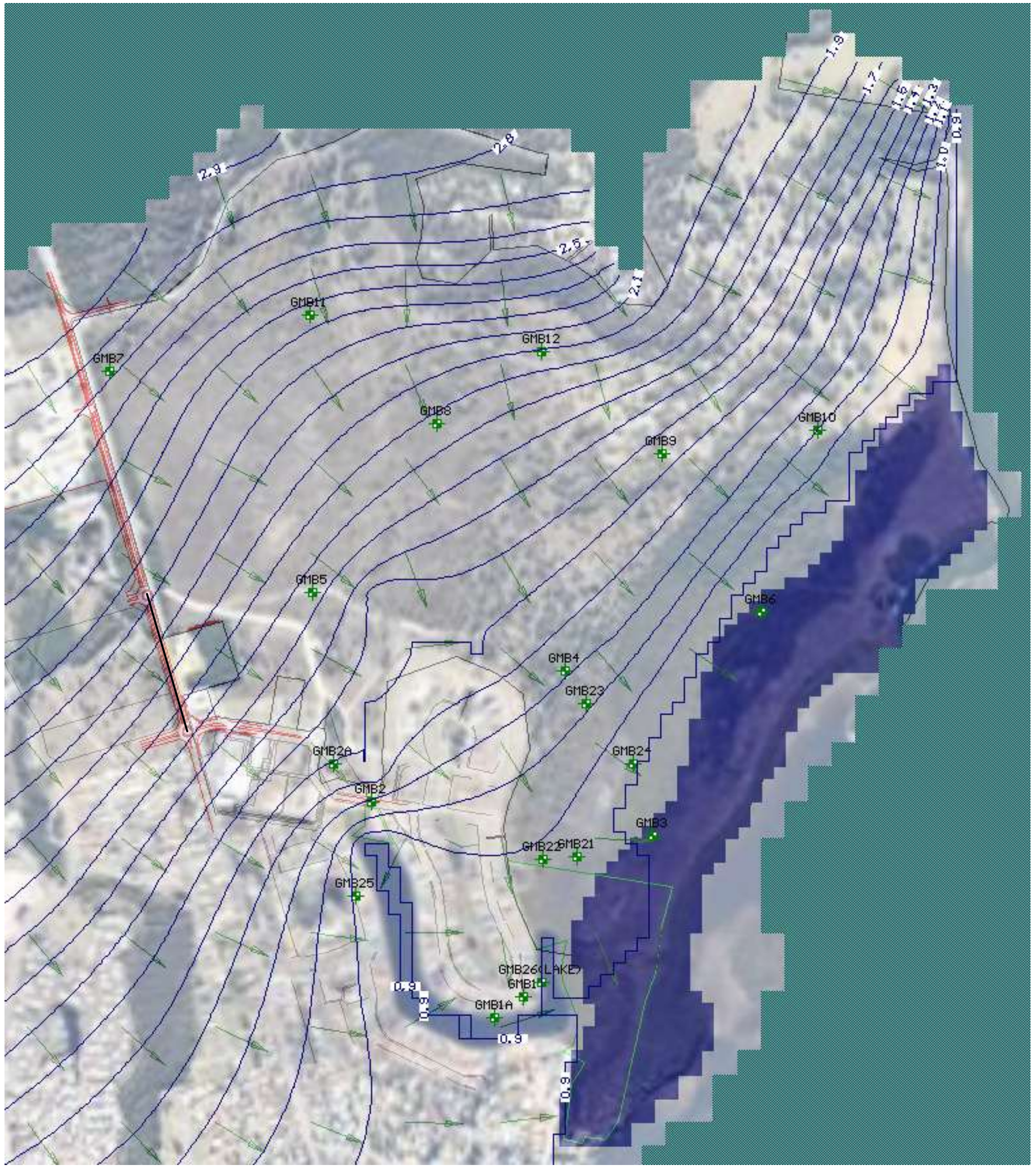
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**M2 - DEVELOPED CONDITIONS: STEADY STATE PIEZOMETRIC SURFACE**	Drawing No: **FIGURE 7**
Approved:	DMM		
Date:	02.12.2011		
Scale:	Approx 1: 16,110 UON		Job No: P0902346

Key

Purple lines - Drawdown contour (0.05 m contour interval)

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**DRAWDOWN PLOT BETWEEN DEVELOPED (M2) AND EXISITNG (M1) CONDITIONS**	Drawing No: **FIGURE 8**
Approved:	DM		
Date:	04.11.2010		
Scale:	Approx 1: 16,730		Job No: P0902346

martens

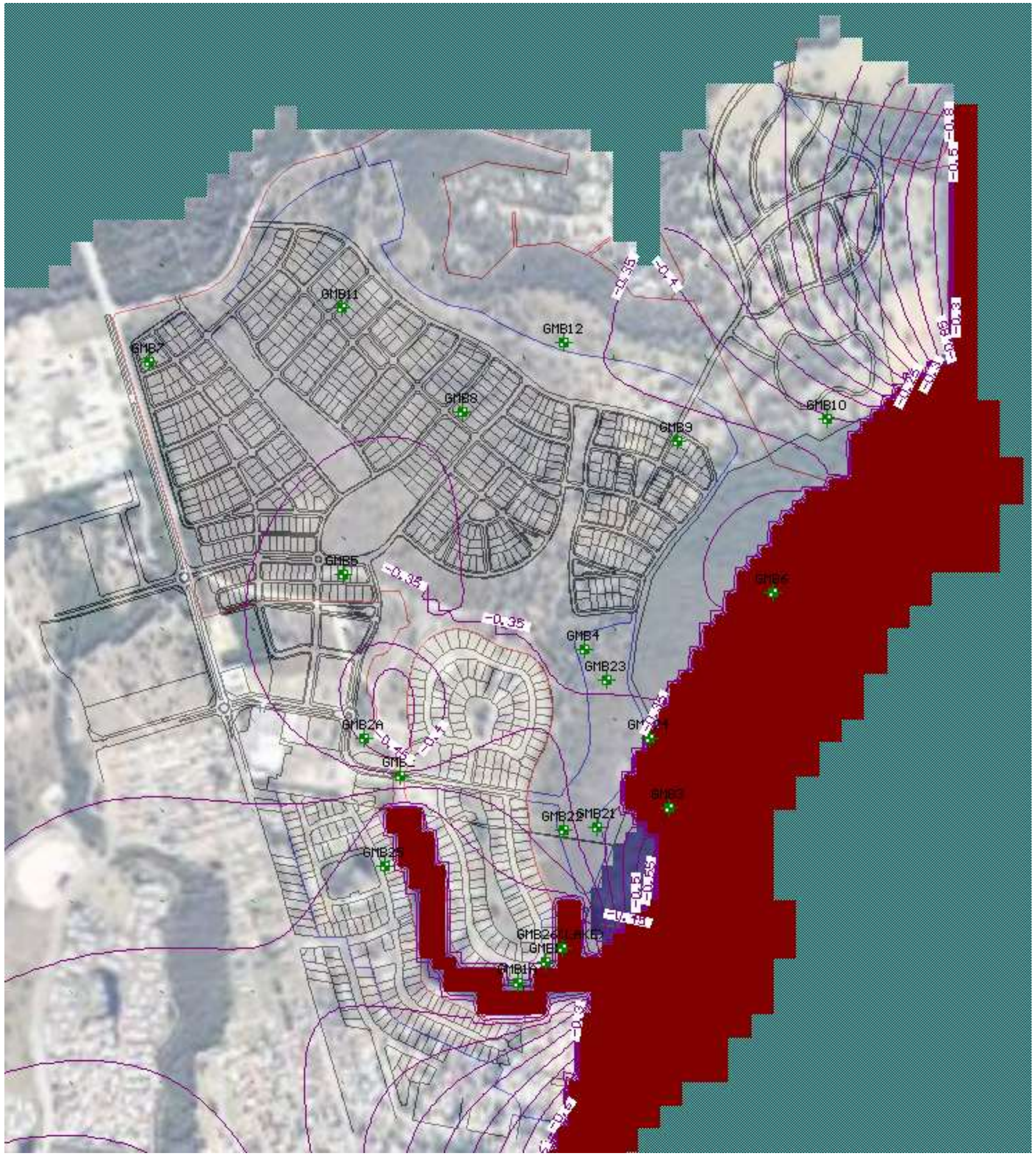


As per main figure but with proposed development layer turned on (approx scale 1: 16,730).

N

Key
Blue lines - Head equipotential (0.1 m contour interval)
Green Flow direction

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	M3 - DEVELOPED CONDITIONS WITH 0.9 m SEA LEVEL RISE: STEADY STATE PIEZOMETRIC SURFACE	Drawing No: FIGURE 9
Approved:	DMM		
Date:	02.12.2011		
Scale:	Approx 1: 16,920		Job No: P0902346



N

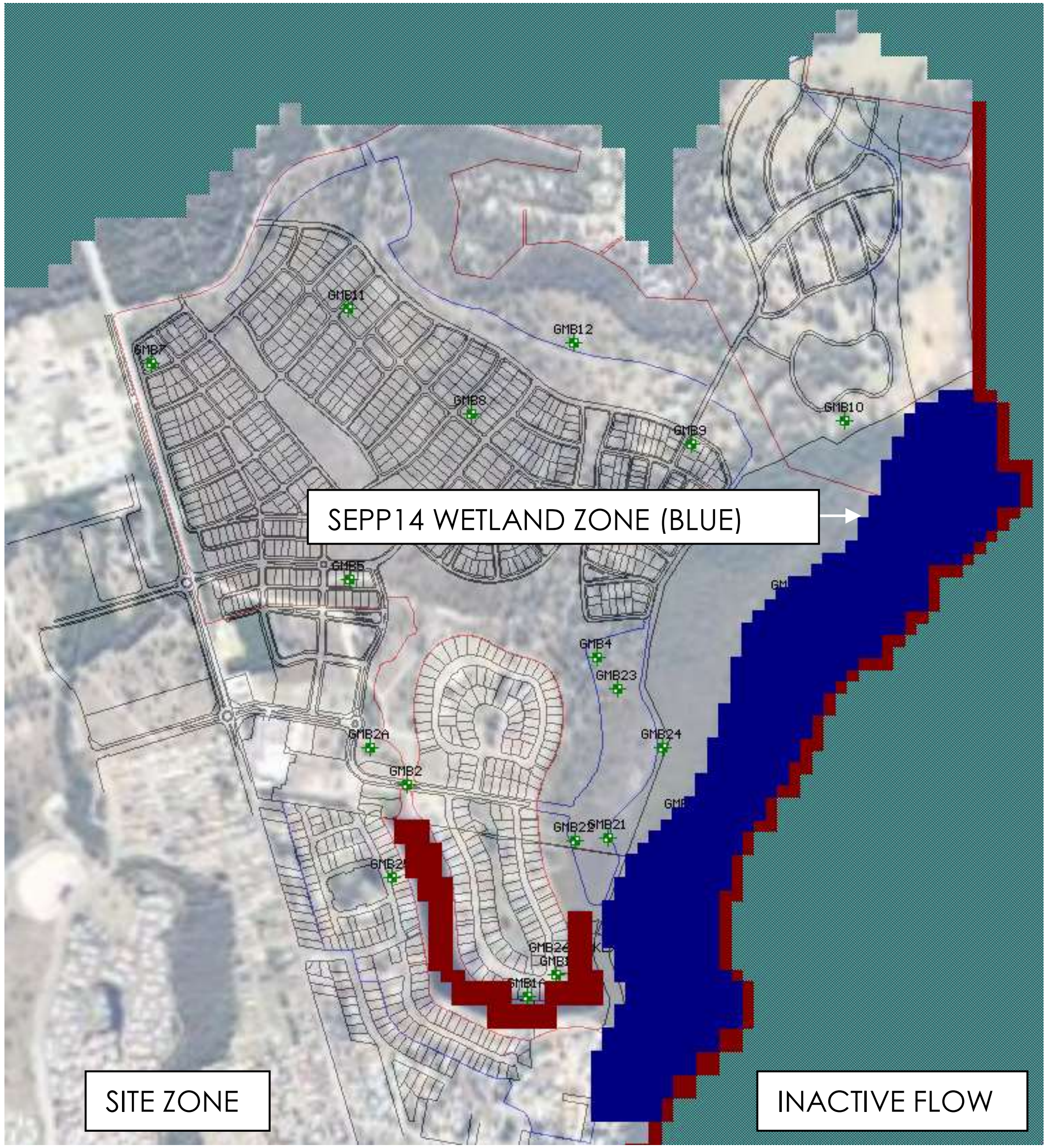
martens

Key

Purple lines - Drawdown contour (0.05 m contour interval)

Note:
Surface levels over existing development in the south east portion of the model domain which have been conservatively assigned the 0.9 mAHD constant head boundary should be confirmed with further survey.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**DRAWDOWN PLOT BETWEEN DEVELOPED (M2) AND DEVELOPED WITH SEA LEVEL RISE (M3) CONDITIONS**	Drawing No: **FIGURE 10**
Approved:	DMM		
Date:	02.12.2011		
Scale:	Approx 1: 17,110		Job No: P0902346



Note:
Red zone comprises constant head cells.

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	GROUNDWATER WATER ZONES DELINEATED FOR WATER ZONE BUDGETING	Drawing No: FIGURE 11
Approved:	DMM		
Date:	02.12.2011		
Scale:	Approx 1: 16,730		Job No: P0902346

martens

6 Attachment B – Collated Groundwater Level Data

Source	GMB	GMB1 [5]	GMB2 [5]	GMB3 [5]	GMB4	GMB5	GMB6	GMB7 [5]	GMB8	GMB9	GMB10	GMB11	GMB12	GMB13	GMB21	GMB22	GMB23	GMB24	GMB1A	GMB2A	GMB25	Lake 26
	Ground level (mAHD)	1.020	2.370	0.845	2.045	2.608	0.861	2.963	2.598	2.859	1.490	3.395	3.261	- [4]	1.026	1.095	1.111	0.834	1.708	2.479	1.798	0.492
	Concrete cap level (mAHD)	1.020	2.375	0.840	2.131	2.638	1.020	3.163	2.598	2.909	1.310	3.547	3.311									
Source	Date																					
Coffey (feb, 1996)	8/11/1994	0.570	0.850			1.488			1.388	1.459	0.700	1.837	1.951									
	24/11/1994	0.410	0.785	0.260		1.338		1.713	1.268	1.319		1.657	1.761									
	6/12/1994	0.300	0.735	0.300		1.268		1.593	1.188	1.319		1.597	1.621									
	22/12/1994	0.250	0.685	0.060		1.188		1.553	1.108	1.229	0.390	1.457	1.481									
	6/01/1995	0.650	0.835	0.720		1.298		1.733	1.258	1.449	0.620	1.437	1.591									
	21/02/1995	0.570	0.765	0.550		1.138		1.563	1.078	1.329	0.480	1.347	1.371									
	8/03/1995	0.240	1.525	0.550		1.658		2.568	0.728	1.159	0.760	2.047	2.332									
	14/03/1995	0.855	1.295	0.780		2.278		2.593	2.098	1.749	0.800	2.127	2.421									
	31/03/1995	0.595	1.020	0.660		1.713		2.243	1.578	1.549	0.615	1.952	1.921									
	19/04/1995	0.440	0.985	0.525		1.433		1.938	1.328	1.399	0.485	1.717	1.646									
	2/05/1995	0.370	0.800	0.250		1.363		1.803	1.218	1.329	0.395	1.562	1.486									
	17/05/1995	0.910	0.995	0.760		1.823		2.133	1.628	1.429	0.830	1.697	1.831									
	18/05/1995	0.930	1.375	0.760		2.328		2.403	2.258	1.699	0.910	2.237	1.601									
	19/05/1995	0.900	1.365	0.760		2.358		2.443	2.208	1.699	0.890	2.067	1.681									
	22/05/1995	0.925	1.795	0.790				2.703	2.458	1.859	1.110	2.257	2.761									
	23/05/1995	0.920	1.825	0.780		2.558		2.723	2.408	1.899	1.070	2.337	2.971									
	24/05/1995	0.920	1.715	0.780		2.538		2.733	2.368	1.859	1.030	2.337	3.051									
	25/05/1995	0.910	1.685	0.780		2.548		2.763	2.348	1.839	1.020	2.477	2.931									
	26/05/1995	0.920	1.695	0.770		2.548		2.743	2.368	1.829	1.050	2.447	2.951									
	21/06/1995	0.880	2.015	0.785				2.803	2.428	1.969	1.210	2.777	3.041									
	13/07/1995	0.710	1.965	0.760		2.228		2.713	2.188	1.939	1.230	2.747	2.721									
	26/07/1995	0.640	0.925	0.740		1.898		2.413	1.958	1.749	1.030	3.007	2.521									
	11/08/1995	0.580	0.825	0.720	1.071	1.608	0.670	2.183	1.778	1.719	0.970	1.967	2.261									
	28/08/1995	0.510		0.460	0.821	1.478	0.280	1.953	1.528	1.559	0.760	1.837	2.071									
	19/09/1995	0.600		0.740		2.328		2.423	2.328	1.869	1.160	2.377	2.491									
	20/09/1995	0.620		0.750	1.301	1.598	0.750	2.603	2.278	1.929	1.140		2.641									
	Late July 1994 - mid Nov 1994						0.500 [1]															
	Late July 1994 - late Sept 1994				1.100 [1]																	
Coffey (Oct, 2007)	7/04/2004			0.298	1.144	2.043	0.768	2.816	2.314	2.111	1.101	2.562	2.708									
	11/05/2004			0.232	0.928	1.451		2.081	1.774	1.880	0.836	1.939	2.120		0.778	0.876	0.930	0.681				
	29/03/2007				0.823	1.303			1.534	1.657	0.541	1.689	1.655		0.813	0.826	0.760	0.628				
Martens and Associates (July, 2009)	04/06/2009 - 6/7/2009							2.910 [2]		2.398 [2]							1.103 [2]		0.821 [2]	1.197 [2]	0.862 [2]	0.703 [2]
	Minimum Level (mAHD)	0.240	0.685	0.060	0.821	1.138	0.280	1.553	0.728	1.159	0.390	1.347	1.371		0.778	0.826	0.760	0.628				
	Median Level (dip values and median diver value in calc) (mAHD) [3]	0.630	1.020	0.740	1.071	1.658	0.670	2.418	1.778	1.709	0.890	2.007	2.120		0.796	0.851	0.930	0.655	0.821	1.197	0.862	0.703
	Maximum Level (mAHD)	0.930	2.015	0.790	1.301	2.558	0.768	2.910	2.458	2.398	1.230	3.007	3.051		0.813	0.876	1.103	0.681				
	Min Depth (m) to GW	0.090	0.355	0.055	0.744	0.050	0.093	0.053	0.140	0.461	0.260	0.388	0.210		0.213	0.219	0.008	0.153				

Notes: [1.] Estimated median value based on visual observation of continuous monitoring data plot. [2.] Median value derived from continuous monitoring data. [3.] Value used for groundwater model (M1) calibration. [4.] Elevation not known. [5.] GMB lost, destroyed or vandalised sometime between 2004 and 2007.

7 Attachment C – Collated Groundwater Quality Data

Source	Sample date		GMB1 [3]	GMB2 [3]	GMB3 [3]	GMB4	GMB5	GMB6	GMB7 [3]	GMB8	GMB9	GMB10	GMB11	GMB12	GMB13	GMB21	GMB22	GMB23	GMB24	GMB1A	GMB2A	GMB25	Lake 26	Lake
Coffey (Feb, 1996)	Average result 13/12/94 to 29/8/1995 [1]	pH	6.40	5.30	6.20			6.00				5.60	6.00	5.30										
		TDS (mg/L)	490.00	190.00	13900.00			1900.00				420.00	2300.00	220.00										
		Chloride (mg/L)	220.00	82.00	7600.00			1100.00				150.00	1200.00	60.00										
		Sulphate (mg/L)	33.00	16.00	1200.00			170.00				<5	170.00	25.00										
		Magnesium (mg/L)	36.00	6.00	540.00			76.00				8.40	85.00	5.20										
		Calcium (mgLL)	9.00	1.20	160.00			33.00				7.20	22.00	2.20										
Coffey (Oct, 2007)	29/03/2007	pH				5.32								5.02		5.62	6.05	5.60	5.46					
		TDS (mg/L)				155.00								1210.00		11500.00	1350.00	212.00	2250.00					
		Chloride (mg/L)				50.40								64.60		5300.00	430.00	58.70	800.00					
		Sulphate (mg/L)				10.00								22.00		702.00	39.00	6.00	344.00					
		Magnesium (mg/L)				4.00								6.00		420.00	23.00	7.00	54.00					
		Calcium (mgLL)				2.00								2.00		126.00	11.00	3.00	31.00					
		EC (us/cm)				202.00								268.00		15500.00	1610.00	234.00	2730.00					
		TN (mg/L)				0.93								3.07		12.13	7.24	2.51	9.33					
		TP (mg/L)				0.14								0.76		1.38	0.79	0.32	1.12					
Coffey (Oct, 2007)	30/03/2007	pH									3.99													5.83
		TDS (mg/L)									200.00													129.00
		Chloride (mg/L)									34.40													37.40
		Sulphate (mg/L)									13.00													12.00
		Magnesium (mg/L)									3.00													3.00
		Calcium (mgLL)									<1													8.00
		EC (us/cm)									178.00													182.00
		TN (mg/L)									2.53													0.72
		TP (mg/L)									1.00													0.08
Martens and Associates (July, 2009)	6/07/2009	pH									4.30							5.70		6.20	5.10	5.60	6.30	
		TDS (mg/L)									96.00							180.00		170.00	120.00	160.00	11000.00	
		Chloride (mg/L)									37.00							65.00		30.00	50.00	25.00	5800.00	
		Sulphate (mg/L)									<5							<5		39.00	<5	5.00	850.00	
		Magnesium (mg/L)									2.90							7.80		8.20	3.40	4.40	360.00	
		Calcium (mgLL)									0.30							3.60		5.60	1.20	3.60	110.00	
		EC (us/cm)									160.00							280.00		280.00	200.00	260.00	14000.00	
		TN (mg/L)									1.00							<0.6		7.10	3.80	30.00	<0.6	
		TP (mg/L)									1.90							<0.05		6.10	2.80	1.20	<0.05	

Notes: [1] Comprised 7 individual monitoring rounds. [2] Refer to source for laboratory report and results for additional analytes. [3] GMB lost, destroyed or vandalised sometime between 2004 and 2007.