Stockton Sand Quarry

Boral Pty Ltd

Stockton Sand Quarry Groundwater Management Plan

IA147700_001f | F

19 December 2019

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Project no: IA147700
Document title: Stockton Sand Quarry Groundwater Management Plan
Document No.: IA147700_001f
Revision: F
Date: 19 December 2019
Client name: Boral Pty Ltd
Client no: -
Project manager: Greg Sheppard
Author: Jonathon Tait
File name: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA147700\21 - Deliverables\IA147700_001f_GWMP_v2.docx

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Document history and status

Revision	Date	Description	By	Review	Approved
A	15 May 2017	Draft for Client Review	JT	GS	
B	19 May 2017	Incorporation of Client Review Comments	GS	GS	
C	30 November 2017	Incorporation of DPI Water Comments	JT	GS	
D	6 December 2017	Include reference to Development Consent Schedule 4, Condition 3	JT	GS	
E	15 February 2018	Incorporation of client comments	JT	GS	
F	3 December 2019	Incorporation of DPIE comments	QB	CC	

Contents

1. Introduction

Jacobs has been engaged by R. W. Corkery and Co Pty Limited (RWC) on behalf of Boral Resources (NSW) Pty Ltd (Boral) to assess and update the existing groundwater monitoring program (GWMP) for the Stockton Dune Sand Quarry (the Quarry).

1.1 Background

The Quarry is located on Lots 1 and 2 / DP 1006399 and Lot 3 / DP 664552, and is accessed via the adjacent Coxs Lane in Fullerton Cove, New South Wales. Boral commenced extraction at the Quarry on 15 October 2008, as approved by Development Approval 140-6-2005 ("DA 140-6-2005"). The Quarry location and the current groundwater monitoring network are shown in **Figure 1**. A network of historical groundwater monitoring bores, that have been destroyed or decommissioned, is shown on **Figure 2**.

DA 140-6-2005 was issued under the *Environmental Planning and Assessment Act 1979* on 24 January 2006, with modifications approved on 10 May 2006 and in June 2011. Activities outlined within DA 140-6-2005 are approved to continue until 15 October 2028.

Quarry operations involve the extraction of dune and windblown sand with a front-end loader, and direct transfer to product trucks with no on-site processing occurring. Rehabilitation activities are limited in active extraction areas due to the nature of the resource and its location (i.e. ongoing replenishment of resource into the extraction areas from windblown sand), despite progressive rehabilitation being undertaken regularly.

The sand dune deposit hosts an unconfined aquifer. In accordance with DA 140-6-2005 and to ensure no direct impact on the groundwater resources, sand is extracted from the unsaturated zone above the unconfined aquifer. DA 140-6-2005 also limits extraction to the sand found above 2.5 m AHD to ensure that no aquifer interference occurs.

The Quarry currently operates under a GWMP approved by DP&E in 2008 (ERM, 2008).

1.2 Purpose of this Report

This report summarises the updated groundwater monitoring program for the Quarry based upon Development Consent DA 140-6-2005 condition requirements, following alterations to the existing groundwater monitoring network (first established in 2007), and the inclusion of additional data into the trigger level assessment. The groundwater monitoring program has been revised following a review and analysis of the monitoring completed since 2007 and in accordance with DA 140-6-2005. Table 1 summarises the relevant consent conditions and the sections in which these conditions are satisfied.

The updated groundwater monitoring program ensures the collection of relevant groundwater data and provides updated impact identification measures to facilitate efficient and effective management practices. The revised GWMP also reflects changes in the groundwater monitoring network following the changes (additions and losses of monitoring bores) since the 2008 GWMP was prepared.

Table 1 : Report details and relevance to consent conditions.

Consent Conditions (DA 140-6-2005)	
Schedule 3	
12 (a) – detailed baseline data on groundwater levels, flows and quality based on statistical analysis, to benchmark pre-quarrying natural variation in groundwater levels and quality.	Section 3
12 (b) – Groundwater impact assessment criteria.	Section 4
12 (c) – A program to monitoring groundwater levels and quality.	Sections 5 & 6
Schedule 4	

Consent Conditions (DA 140-6-2005)	
3 – Each year following the date this consent, the applicant shall prepare and submit an Annual Environmental Management Report (AEMR) to the Director-General and relevant agencies.	Section 7

1.3 Regulatory Consultation

A draft of this report has been provided to DPI Water for review and comment. DPI Water provided review comments on 07 September 2017. The comments provided by DPI water have been considered and the GWMP has been revised accordingly. A copy of DPI Water review is provided in Appendix A.

2. Environmental Setting

The Quarry is located on the coastal sand dunes of Stockton Beach, approximately 10 km north-west of Newcastle, within the Hunter Valley region. The sand dunes comprise windblown (aeolian) sand, which is extracted from the un-vegetated dunes located immediately behind the beachfront (refer Figure 1).

2.1 Climate

The climate in the Hunter Valley region is varied and dependent on proximity to the coast. The coastal areas tend to be subtropical with warm summers and generally mild winters. The nearest Bureau of Meteorology (BOM) rain gauging station is Williamtown RAAF base (station number 061078) and is approximately 4 km north. Long-term rainfall means and medians are summarised in Table 2. Rainfall is greatest in late autumn and early winter with the average annual rainfall at the Williamtown RAAF base is 1,125.3 mm/year.

Table 2 : Long term rainfall

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean (mm)	99.9	118.3	119.8	111.8	110.8	123.0	71.9	73.6	59.7	73.0	82.4	79.0
Median (mm)	77.0	94.6	107.7	97.6	95.5	102.9	63.2	55.8	49.8	56.2	80.2	62.3

Data source - Bureau of Meteorology Station Number 061078; accessed 15/02/2018.

2.2 Hydrogeology

Groundwater in the Quarry area occurs within the coastal sand aquifers of the Stockton Sandbeds Groundwater Source. These coastal sand aquifers typically have significant connection with surface water and there is minimal surface water runoff as the dunes have a high infiltration capacity.

Groundwater residence time in these aquifers is generally short, ranging from days to months. Average groundwater levels for monitoring bores were calculated using groundwater level data from existing and historical monitoring bores. **Figure 3** shows average groundwater level contours for each quarter since monitoring commenced (i.e. Quarter 1 - January, February, March etc.). These contours show that there is little seasonal variation in groundwater levels and/or flow directions. **Figure 3** also shows that groundwater flow is toward the ocean, in the seaward portion of the tenement.

RPS (2016) included a recommendation to install several new monitoring bores to further understand groundwater movement. These monitoring bores were installed in May 2017 in the western area of the tenement. The contours of the combined historical data and the data from the new bores are shown on **Figure 4**. These contours show a groundwater divide that coincides with elevated dune areas (**Figure 4**) with groundwater flow to the southeast towards the ocean and also inland towards Fullerton Cove.

Bore logs show all monitoring bores were installed into sand that coarsen with depth. No monitoring bores have intercepted bedrock. **Figure 5** shows geological cross sections through the quarry, the 2.5 mAHD extraction limit, inferred groundwater levels and relative position of monitoring bores. The cross section shows that the water table is close to ground level in the low lying area to the northwest of the tenement where extraction has previously occurred. The inferred water table is below the 2.5 mAHD extraction limit in the current dune extraction area.

2.3 Potential Groundwater Impacts

No significant groundwater related impacts are anticipated from the current quarry operation. Key arguments for the minimal risk to groundwater are summarised as follows:

- No foreign material is introduced into the Quarry.
- All extraction of windblown sand is from the unsaturated zone of the dune surface adjoining the vegetation cover.
- Extracted sand is in an unsaturated and oxidised state. Extraction therefore presents no risk to acid sulphate soil generation. This view is supported by the baseline pH data in the extraction area which is neutral to alkaline.
- Groundwater is not intercepted or extracted, and water levels are not impacted. This leads to a negligible risk of saltwater intrusion from the surrounding ocean as a result of quarrying activities.

The area inland of the current dune sand extraction area has historically been subjected to mineral sand extraction, which posed a significantly greater risk of groundwater impact than the current operations. Notwithstanding, no significant legacy water quality issues are apparent in the data.

2.3.1 Groundwater Dependent Ecosystems

The closest potential GDEs are located to south-east (seaward) and north-west (inland) of the extraction area in **Figure 5.2** extracted from the ERM 2005 EIS report. The GDEs located to south-east comprise small ephemeral and mobile shallow deflation basin lakes vegetated with a variety of grasses, sedges and reeds. These lakes provide an ephemeral habitat for a number of invertebrates and other species (ERM, 2008). The GDEs located to the north-west are primarily the swamp forests in the dune swales and low lying heath. The previous groundwater assessment (ERM, 2010) stated that the risk of impacting these GDEs is very low given the sand extraction depth restrictions and low evaporation in times of high groundwater.

3. Baseline Monitoring Data

3.1 Monitoring network

The current groundwater monitoring network includes 12 monitoring bores located in the Quarry property (**Figure 1**). All bores are licensed under monitoring license 20BL171772. The monitoring network includes groundwater monitoring bores (MW series bores) that were installed as part of the Stockton Sand Quarry monitoring network, as well as four pre-existing groundwater monitoring bores (GW series bores). Bore construction details are provided on Table 3.

Since the 2008 GWMP, the majority of the historical bores referred to in the 2008 GWMP have been destroyed and an additional eight replacement monitoring bores were installed during 2013. Three of these replacement bores (MW3, MW4 and MW10) have also been destroyed.

In 2013, the monitoring bore network was renumbered to simplify monitoring and the groundwater bores were renumbered sequentially from south to north (**Figure 1**). The GW series bores have retained their original nomenclature. The groundwater monitoring program referred to in this report uses the updated nomenclature. Destroyed and decommissioned bore locations are shown on **Figure 2**.

The current and proposed groundwater and surface water monitoring network, as presented on **Figure 1** and in Table 3, provides comprehensive coverage of groundwater levels and quality in the area of current quarry extractions. Future monitoring bore losses will be assessed on an individual basis to determine whether a replacement bore is deemed necessary.

Table 3 : Stockton Sand Quarry Monitoring Network

Location ID	Easting (MGA94)	Northing (MGA94)	Elevation (m AHD)	Depth (mBGL)	Screened Interval (mBGL)	Status
Current Groundwater Monitoring Network – Figure 1						
MW1	391032.68	6364177.29	4.41	25	19 – 25	Groundwater monitoring program
MW2	391351.81	6363950.74	9.86	25	19 – 25	Groundwater monitoring program
MW5	391588.87	6364388.10	4.89	8	2 – 8	Groundwater monitoring program
MW6	391781.34	6364527.27	3.51	8	2 – 8	Groundwater monitoring program
MW7	392042.74	6364700.52	4.03	8	2 – 8	Groundwater monitoring program
MW8	392242.75	6364807.46	2.98	8	2 – 8	Groundwater monitoring program
MW9	392413.71	6364895.09	5.50	8	2 – 8	Groundwater monitoring program
MW11	392600	6364951	15.5	18	12 – 18	Groundwater monitoring program
GW1	391421	6364854	3.0	N/A	N/A	Groundwater monitoring program
GW2	392028.71	6365103.30	2.99	N/A	N/A	Groundwater monitoring program
GW3	391884.98	6364614.76	4.00	N/A	N/A	Groundwater monitoring program
GW4	390446.05	6364167.1/	3.86	N/A	N/A	Groundwater monitoring program
MW X1	390115.48	6364900.57	6.80	12.2	9.2 – 12.2	Groundwater monitoring program
MW X2	390924.04	6365310.83	6.34			Groundwater monitoring program
MW X3 SHALLOW	390479.73	6364603.76	6.58	11.4	8.4 – 11.4	Groundwater monitoring program
MW X3 DEEP	390480.16	6364605.29	6.97	26.0	5.3 – 26.0	Groundwater monitoring program
MW X4 SHALLOW	391284.01	6365240.54	10.69	12.1	9.1 – 12.1	Groundwater monitoring program
MW X4 DEEP	391283.09	6365240.96	10.52	24.5	21.5 – 24.5	Groundwater monitoring program
MW X5	391434.58	6364460.70	4.17	24.2	21.2 – 24.2	Groundwater monitoring program
MW X6	391825.85	6364646.50	3.83	27.6	24.6 – 27.6	Groundwater monitoring program
MW X7	390509.68	6365494.40	5.11			Groundwater monitoring program
Historical Groundwater Monitoring Network - Figure 2						
MW1	391128	6364095	21.7	22.7	19.7 – 22.7	Destroyed

Location ID	Easting (MGA94)	Northing (MGA94)	Elevation (m AHD)	Depth (mBGL)	Screened Interval (mBGL)	Status
MW2	391331	6364058	23.8	25	22 – 25	Destroyed
MW3 (old)	391457	6364185	21.0	23.5	20.5 – 23	Destroyed
MW3	391428	6364225	19.5	25	19 – 25	Destroyed
MW4	391699	6364229	9.5	10	7 – 10	Destroyed
MW5 (old)	391670	6364404	14.2	NA	NA	Destroyed
MW5A	391677	3634494	6.0	15.8	12.8 – 15.8	Destroyed
MW6	391864	6364375	11.8	14.7	11.7 – 14.7	Destroyed
MW7	392080	6364628	14.1	17.5	14.5 – 17.5	Destroyed
MW8	392274	6364633	14.2	17.5	14.5 – 17.5	Destroyed
MW9	392338	6364846	2.6	5	2-5 – 0	Destroyed
MW10 (old)	392629	6364845	9.4	11.5	8.5 – 11.5	Destroyed
MW10	392604	6364757	11	21	15 – 21	Destroyed
GW5	390705	6365182	na	na	na	Destroyed

* Monitoring location not surveyed, elevations are estimates from google earth.
na: information not available
m AHD: metres above Australian height datum
mBGL: metres below ground level

3.2 Baseline monitoring

Groundwater data used for this assessment was collected at the Quarry via Boral's historical groundwater monitoring network over a period of ten years (2007 to 2017). The groundwater monitoring data includes:

- Groundwater levels (all monitoring bores)
- Field water quality parameters electrical conductivity (EC) and pH (MW series monitoring locations only).
- Laboratory chemical analysis (MW series monitoring locations only).

Groundwater monitoring data is not available for the periods October 2008 to October 2009 and April 2010 to May 2013. These gaps were the result of a lapse in routine monitoring due to an internal restructure within the monitoring company. Monitoring has been undertaken consistently from 2013 to present.

Monitoring data were collected monthly for the period 2007 to 2011 and has been collected quarterly from 2011 onwards.

No groundwater impacts as a result of the Quarry operations have been identified to date, which is as per the 2005 EIS (ERM, 2005). No groundwater impacts are expected as sand extraction has remained above the 2.5 mAHD extraction limit (the groundwater table fluctuates seasonally). It is therefore considered that groundwater data collected to date is representative of baseline conditions.

3.3 Monitoring Results

A brief discussion of groundwater monitoring data to date, for the current monitoring network, is provided in the following sections.

3.3.1 Groundwater levels

Groundwater elevations (in mAHD [Australian Height Datum]) hydrographs are shown on **Figure 6.** It is noted however that ground elevations for the GW series monitoring bores are inferred from topographic data.

The monitoring bores generally display relatively uniform water level response across the site. The MW series bores typically range from 1.4 to 2.7 mAHD. MW1 peaked at 3.6 mAHD in June 2007 in response to significant rainfall totalling 414.2 mm. Higher rainfall occurred in January 2016 (422.4 mm), although monitoring did not capture the peak groundwater elevation due to the data collection frequency. Groundwater levels peaked again in response to above average rainfall (236.6mm) in June 2017. Aside from immediately following extreme rainfall event, groundwater levels generally remain below the limit of sand extraction at 2.5 mAHD.

The GW series monitoring bores show similar magnitude fluctuations in water levels, although actual groundwater elevations are higher with the bores located further from the coast. This highlights the groundwater divide that coincides with the dune crest.

3.3.2 Water Quality

The key points relating to site groundwater quality are summarised in the following paragraphs. **Figure 7** present the field groundwater quality monitoring results. **Figures 8 to 19** present the groundwater quality analytical results.

- Groundwater salinity (refer Figure 7) is typically in the range 180 to 1,000 µS/cm. A number of bores display significant spikes in salinity following large rainfall events, this is attributed to infiltrating rainfall mobilising salt spray from the dune surface. No significant trends in salinity are apparent over the period of monitoring.
- Groundwater pH (refer Figure 7) is typically in the range 6 to 8 pH units. Individual monitoring locations display considerable variability and there are no overriding long term trends. Monitoring bore MW9 shows the greatest variability ranging from 8.3 in July 2007 to 5.5 in October 2009.
- MW1, MW5 and MW7 have displayed variable concentrations of aluminium since 2013/2014 (refer Figure 8). The remaining monitoring location display low aluminium concentrations typically below 0.15 mg/L. Levels at MW2 are often below the laboratory limit of reporting of 0.01 mg/L.
- Arsenic concentrations are generally below 0.03 mg/L. MW1, MW6, MW9, and MW11 display slightly elevated and more variable concentrations, and level at MW9 have historically been higher (up to 0.11 mg/L) (refer Figure 8). MW2, MW5, MW7 and MW8 remain close to or below the limit of reporting of 0.001 mg/L.
- Concentrations of boron are generally stable and below 0.05 mg/L, with the exception of two data points for MW2 (refer Figure 9). Pre-2014 results suggest that the laboratory detection at the time may not have been sufficiently accurate.
- Results for cadmium are typically at or below the limit of reporting (refer Figure 9).
- Calcium concentrations are typically less than 100 mg/L and relatively stable (refer Figure 10). MW11 shows concentrations that are elevated compared to the rest of the monitoring network. Historical data typically show considerably greater variability than data collected since 2013.
- Chromium concentrations are generally low and below 0.005 mg/L, with the majority of monitoring bores close to or below the limit of reporting (usually 0.001 mg/L) (refer Figure 10). MW7 and MW9 display a declining trend since 2013.
- Concentrations of copper are typically at or below the limit of reporting (0.001 mg/L) (refer Figure 11). Minor spikes are observed at MW1, MW2 and MW5 in early 2017.
- Elevated iron concentrations are observed at MW7, MW8, MW11, these monitoring locations also show variable concentrations (refer Figure 11). All other monitoring locations show relatively stable concentrations below 2 mg/L.
- Concentrations of lead are typically at or below the limit of reporting (0.001 mg/L). Historical data show low but more variable concentrations.
- MW5, MW7, MW8 and MW9 show fluctuating magnesium concentrations, the remaining monitoring locations are relatively stable in the range 1 to 8 mg/L (refer Figure 1).
- Concentrations of manganese are relatively stable and below 0.1 mg/L. Historical data from the years 2007 and 2008 show much greater variability and fluctuations with a maximum recorded value of 1.7mg/L in October 2007 at MW4.
- Results for mercury are typically at or below the limit of reporting (0.0001 mg/L) (refer Figure 13). Historical data have a limit of reporting of 0.001 mg/L, as do two more recent analyses from MW1.

- Concentrations of nickel are typically at or below the limit of reporting (0.001 mg/L) (refer Figure 14). Historical data show more variability with an anomalous spike at MW5, MW6 and MW8 in July and September 2010 with the causes unknown.
- Potassium results are generally in the range 0.8 to 6 mg/L (refer Figure 14).
- Results for selenium are typically at or below the laboratory limit of reporting (0.001 mg/L) (refer Figure 15). It is inferred that elevated results for July and November 2013 represent a higher limit of reporting (0.1 mg/L) for those analyses given the consistency for all samples.
- MW5, MW7 and MW8 show fluctuating sodium concentrations peaking at 200 mg/L at MW5, the remaining monitoring locations are relatively stable in the range 9 to 51 mg/L (refer Figure 15).
- Concentrations of zinc are generally low and below 0.03 mg/L (refer Figure 16). MW1 displayed elevated zinc levels up to 0.26 mg/L in April 2017.
- MW5, MW7 and MW8 show fluctuating chloride concentrations peaking at 290 mg/L at MW5, the remaining monitoring locations are relatively stable in the range 18 to 83 mg/L (refer Figure 17).
- Alkalinity is typically in the range 50 to 200 mg/L as $CaCO^3$ (refer Figure 16). MW11 shows slightly higher levels of 300 to 380 mg/L. Water in this range generally has a good buffering potential.
- Hardness as $CaCO^3$ has not been monitored since 2010. Historical data show variable and fluctuating levels generally in the range 100 to 500 mg/L as equivalent $CaCO^3$ (refer Figure 17). Water in this range is classified as hard to very hard.
- Nitrate was not monitored between 2010 and late 2017. Historical monitoring data shows low background concentrations, with nitrate typically below 4 mg/L (refer Figure 18). MW1 displayed elevated but declining concentrations, peaking at 12.5 mg/L. Recent data typically shows nitrates below detectable limits.
- Phosphorous was not monitored between 2010 and late 2017. Historical monitoring data show relatively low background concentrations, with phosphorous typically below 0.1 mg/L (refer Figure 18). Recent data shows spikes in MW6 and MW8 up to 0.70 mg/L.
- Concentrations of sulphate are generally relatively stable and below 50 mg/L (refer Figure 19). Historical data shows greater variability with MW7 and MW8 with peaks at 238 and 223 mg/L, respectively.
- Turbidity has been monitored intermittently since 2010. Turbidity results are generally low as is expected from groundwater monitoring bores in sand dune deposits (refer Figure 19). Historical data show some fluctuation and spikes, possibly related to bore construction and ongoing development with purging. Turbidity in relation to groundwater is typically measured as an indicator of purging adequacy and is indicative of the condition of the monitoring bore as opposed to the aquifer. Presentation of turbidity for determining trigger thresholds is therefore not considered appropriate. A turbidity concentration of 10 NTU or less is generally considered to indicate adequate purging in conjunction with stabilisation of other physical parameters.

4. Trigger Level Review

4.1 Methodology

The methodology used to update the trigger thresholds for this revised GWMP is the same as applied to the original GWMP completed by ERM in April 2008. Threshold limits are calculated by adding or subtracting two standard deviations from the mean and forming an upper and lower threshold limit.

The subtraction of two standard deviations from the mean will often result in lower threshold limits that are either negative or lower than laboratory limits of detection. The following points describe the procedure for assigning trigger thresholds where subtracting two standard deviations results is unsuitable for establishing lower threshold limits:

- If the analyte was not detected above the laboratory quantification limit during the groundwater sampling rounds, the trigger level for those analytes will be set to the laboratory limit of reporting.
- If the calculation of the lower trigger value resulted in a negative value or a value below the laboratory quantification limit, no lower trigger has been applied.

Laboratory limits of reporting (LOR) have been retained in the data set as a numeric value equal to the limit of reporting for the purposes of statistical analyses.

Where current monitoring bore locations are replacements for historical monitoring bores, and where the replacement bore has been installed in close proximity to the original, the water quality record for the historical monitoring bore has been incorporated into the baseline dataset for the original monitoring bore. Due to differences in ground elevations this has not been undertaken for water levels.

4.2 Groundwater Levels

Calculated groundwater level threshold limits are summarised in Table 5. MW series monitoring bore limits have been calculated in mAHD (metres Australian Height Datum) and GW series monitoring bores have been calculated in mBGL (metres below ground level).

Table 4 : Groundwater level threshold limits

Monitoring Location	Units	Upper Limit	Lower Limit	Observation Count
MW1	mAHD	2.92	0.98	35
MW2	mAHD	2.33	1.09	17
MW5	mAHD	2.51	0.77	13
MW6	mAHD	2.66	0.60	17
MW7	mAHD	2.52	1.17	31
MW8	mAHD	2.57	1.23	31
MW9	mAHD	2.56	1.22	30
MW11	mAHD	2.72	1.21	17
GW1	mBGL	7.42	9.04	17
GW2	mBGL	0.27	2.00	27
GW3	mBGL	1.40	2.87	26
GW4	mBGL	1.58	2.86	32

Data encompasses current monitoring bore network and historical in a similar monitoring location

m AHD – meters above Australian Height Datum; mBGL – meters below ground level

tba – to be announced

4.3 Groundwater Quality

Upper and lower thresholds for water quality indicators are summarised in Table 6 to Table 8.

Table 5 : Electrical Conductivity Upper Limits

Monitoring Location	Upper Threshold Limit (µS/cm)	Lower Threshold Limit (µS/cm)	Sample count
MW1	444.4	195.0	35
MW2	719.0	286.6	21
MW5	1015.3	104.8	41
MW6	583.5	115.2	41
MW7	1036.5	469.9	31
MW8	1021.4	453.2	35
MW9	964.7	155.2	32
MW11	915.0	691.4	10

µS/cm : Micro Siemens per centimetre

Table 6 : pH upper and lower limits

Monitoring Location	Upper Threshold Limit (pH Units)	Lower Threshold Limit (pH Units)	Sample count
MW1	7.47	5.67	25
MW2	7.86	7.05	8
MW5	7.68	5.88	29
MW6	7.65	6.60	28
MW7	7.53	6.64	25
MW8	7.59	6.71	29
MW9	8.33	4.93	26
MW11	6.96	6.72	4

Table 7 : Upper and lower threshold limits for laboratory analytes

Analyte	MW1		MW2		MW5		MW6		MW7		MW8		MW9		MW11	
	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit
Turbidity (NTU)	145.4	na	103	na	39.4	na	33.2	na	187	na	25.7	na	74.7	na	nd	nd
Chloride (mg/L)	47	15.8	42.0	13.8	200.5	na	44	3.8	134	na	190.2	na	136.3	na	59.9	8
Sulphate as SO4	48.8	na	60.9	0.12	76.18	na	56.6	na	191.7	na	196	na	41.7	na	61.5	na
Aluminium (mg/l)	0.251	na	0.074	na	1.861	na	0.158	na	0.391	na	0.077	na	1.515	na	0.213	na
Arsenic (mg/L)	0.02	na	0.018	na	0.024	na	0.026	na	0.067	na	0.029	na	0.111	na	0.023	0.002
Boron (mg/L)	0.089	na	0.182	na	0.090	na	0.078	na	0.091	na	0.085	na	0.095	na	0.068	0.003
Calcium (mg/L)	76.2	na	121.0	28.4	141.1	na	102.9	1.86	196.5	5.1	197.2	18.7	140.2	na	162.6	116.5
Cadmium (mg/L)	0.003	na	0.002	na	0.003	na	0.002	na	0.002	na	0.002	na	0.004	na	0.0001	na
Chromium (mg/L)	0.009	na	0.002	na	0.01	na	0.006	na	0.005	na	0.006	na	0.007	na	0.002	0.001
Copper (mg/L)	0.011	na	0.008	na	0.011	na	0.012	na	0.007	na	0.01	na	0.004	na	0.001	na
Iron (mg/L)	1.78	na	1.81	na	2.68	na	3.44	na	8.23	na	10.69	na	7.21	na	3.56	na
Potassium (mg/L)	4.6	na	3	na	5.7	na	2.8	na	5.2	0.4	4.6	0.3	7.1	na	4.4	1.1
Magnesium (mg/L)	9.7	na	8.5	5.3	20	na	7.6	na	14.3	1.8	14.1	1.1	12.1	2.8	7.2	2.3
Manganese (mg/L)	0.03	na	0.43	na	0.32	na	0.06	na	0.82	na	0.32	na	1.32	na	0.07	na
Nitrogen (mg/L)	0.001	na	0.001	na	0.001	na	0.001	na	0.001	na	0.001	na	0.001	na	0.001	na
Sodium (mg/L)	38.6	na	24.9	5.2	173.3	na	26.8	na	99.2	na	127.4	na	78.7	na	39	4.9
Nickel (mg/L)	0.026	na	0.01	na	0.076	na	0.074	na	0.012	na	0.064	na	0.022	na	0.001	na
Lead (mg/L)	0.008	na	0.0028	na	0.022	na	0.010	na	0.009	na	0.014	na	0.008	na	0.001	na

Analyte	MW1		MW2		MW5		MW6		MW7		MW8		MW9		MW11	
	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit
Selenium (mg/L)	0.009	na	0.01	na	0.011	na	0.011	na	0.009	na	0.009	na	0.009	na	0.011	na
Zinc (mg/L)	0.124	na	0.032	na	0.03	na	0.027	na	0.028	na	0.022	na	0.061	na	0.030	0.002
Filterable Reactive P (mg/L)	0.03	na	0.09	na	0.07	na	0.37	na	0.21	na	0.38	na	0.30	na	0.09	0.06
Nitrate -N (mg/L)	10.57	na	2.11	0.75	4.74	na	2.38	0.01	1.36	na	0.91	na	1.04	na	0.01	0.01
Alkalinity (mg CaCO3/L)	157.4	6.2	294.1	47.4	293.3	18.0	246	22.8	313.3	74.6	317.8	71.7	360.32	na	396.6	291
Hardness as CaCO3	170.5	66.4	374.46	278.6	431.2	117.7	274.4	144.2	487.1	274.8	501.1	283.8	484.7	11.1	nd	nd
Mercury (mg/L)	0.0016	na	0.0012	na	0.0016	na	0.0015	na	0.0016	na	0.0016	na	0.0016	na	0.0001	na
Fluoride (mg/L)	0.755	0.002	0.183	0.042	0.753	na	0.726	na	0.732	na	0.746	na	0.736	na	0.1	0.1

Note: na – method results in negative value or value below limit of reporting.
nd – insufficient data
Limit of reporting (LOR) for upper threshold limit indicated by “<”

4.4 Surface Water Management

The Surface Water Management Plan (Boral, 2018) developed a program to monitor the Groundwater Dependent Ecosystems (GDE) within close vicinity of the operational area.

- Two surface water monitoring sites (SW1 and SW2) are located inland of the current extraction area and intermittently contain surface water. The two inland GDEs are the swamp forests in the dune swales and the low lying heath. These sites will be assessed against the ANZECC guideline for freshwater aquatic ecosystems (moderately disturbed)
- Two surface water monitoring sites (SW3 and SW4) are located seaward. These two GDEs comprise of small ephemeral and mobile shallow deflation basins, vegetated with a variety of grasses, sedges and reeds. Due to the variable nature of the foredune system, the locations of the two GDE sites may change between sampling programs. These sites will be assessed against the ANZECC guideline for marine aquatic ecosystems.

Until sufficient data can be collected to develop site specific trigger values, results will be assessed against the respective ANZECC guideline values.

The four surface water monitoring locations are summarised Table 8 and presented in Figure 5.3.

Table 8 Surface water runoff pH thresholds

Surface water	Location	Guideline	Trigger Value
SW1	Eastern Inland Basin	ANZECC Freshwater aquatic ecosystem (moderately disturbed)	TBC
SW2	Western Inland Basin	ANZECC Freshwater aquatic ecosystem (moderately disturbed)	TBC
SW3	Eastern Seaward GDE	ANZECC marine water aquatic ecosystem	TBC
SW4	Western Seaward GDE	ANZECC marine water aquatic ecosystem	TBC

5. Monitoring Program

5.1 Groundwater Monitoring

The current groundwater monitoring network is summarised in Table 3 and shown on **Figure 1**. The ongoing groundwater monitoring program is summarised in Table 9 below.

Table 9 : Groundwater Monitoring Program

Parameter	Frequency	Location
Water level	Monthly	All groundwater monitoring bores
Field water Quality Parameters • pH • EC	Quarterly	MW Series Groundwater Monitoring Bores
Laboratory Chemical Analysis • Na, K, Ca, Mg, HCO3, CO3, Cl, SO4 • Al, As, B, Cd, Cr, Cu, F, Fe, Hg, Mn, Ni, Pb, Se, Zn • Alkalinity, Hardness, Phosphorous, Nitrate-N, Sulphate	Quarterly	MW Series Groundwater Monitoring Bores

5.2 Surface Water Monitoring

The Surface Water Management Plan (Boral, 2018) details the plans and processes of surface water management. A summary of the surface water monitoring program is outlined in Table 10 below.

Table 10 Summary of Surface Water Monitoring Program

Parameter	Frequency	Location
Field water quality parameters • pH • EC	Quarterly	All surface water monitoring sites
Laboratory Analysis • Na, K, Ca, Mg, HCO3, CO3, Cl, SO4 • Al, As, B, Cd, Cr, Cu, F, Fe, Hg, Mn, Ni, Pb, Se, Zn • Alkalinity, Hardness, Phosphorous, Nitrate-N, Sulphate	Quarterly	All surface water monitoring sites
Laboratory Analysis • TPH, BTEX	Annually	All surface water monitoring sites

6. RESPONSE PLAN

6.1 Contingency Measures

In the event of any adverse impacts, or water quality degradation beyond assigned trigger levels, Boral Resources (NSW) Pty Ltd has a responsibility to undertake the following in stages:

- Commission an investigation into the identified impact.
- Develop a staged response program sufficient to mitigate the adverse impact.
- Establish and implement measures to limit further impact.

The identification process and response protocols to potential adverse outcomes are provided in the Trigger Action Response Plan (TARP) outlined in Table 11. The responses proposed incorporate a staged assessment and development of management measures deemed appropriate for each individual event.

The baseline monitoring data provides the basis for assigned trigger levels and takes into account historical natural variations. Specific key monitoring indicators are designed to facilitate the early identification of any changes to groundwater quality outside of normal variation or where parameters do not follow the trends predicted in the 2005 EIS (ERM, 2005).

6.2 Trigger Action Response Plan

The TARP sets appropriate triggers levels and a subsequent response for the management and mitigation of impacts to natural groundwater conditions in a response to the Quarry activities. The monitoring program outlined in Section 4 is designed to detect mining related groundwater impacts to groundwater levels and groundwater quality using assigned trigger level threshold values. The objective of the TARP is to benchmark the natural variation in groundwater levels and quality to the existing groundwater monitoring network and baseline data.

Aspects assessed to be at risk are summarised in Section 2.3 of this report. Groundwater quality and levels will continue to be monitored to support the 2005 EIS prediction (ERM, 2005) that no adverse impacts to groundwater are anticipated due to quarry operations.

Table 11: Trigger Action Response Plan (TARP)

Aspect	Parameter	Frequency	Purpose	Trigger	Trigger Action	Purpose	Trigger Response Action	Responsibility
Groundwater level monitoring	Groundwater level	Monthly	To identify any impacts to the groundwater level due to quarry operations.	Two consecutive monthly observations indicating a steady decline in groundwater levels below the designated lower trigger level threshold (**Table 5**)	Repeat water level monitoring to confirm exceedance. Review data for accuracy. Refer the matter to an independent hydrogeologist / environmental scientist (or similar) to review.	Identify, investigate and report on impacts to groundwater levels. Inform agencies of baseline assessment and monitoring.	Inform relevant regulatory agencies within 7 days of being notified of the exceedance with an exceedance notification letter. Exceedance investigation report to be issued within 60-days of initial notification to authorities.	Boral Resources (NSW) Pty Limited Environmental Officer
Groundwater quality in monitoring bores	EC	Quarterly	To identify any impacts to the groundwater level due to quarry operations.	Two consecutive quarterly EC observations above the designated upper trigger level threshold values (**Table 6**).	Repeat sampling of monitoring bore exceeding trigger. Review data for accuracy. Refer the matter to an independent hydrogeologist / environmental scientist (or similar) to review.	Identify, investigate and report on impacts to groundwater quality. Potentially prompt further investigation and sampling for analytes. Confirm and review trigger levels.		
	pH			Two consecutive quarterly pH observations outside of the designated trigger level threshold values (**Table 7**).				
	Major Ions and Metals			Two consecutive quarterly observations above the designated upper trigger level threshold values (**Table 8**).				

6.3 Response Action

The below response program would be carried out in consultation with regulatory departments such as NSW Department of Planning, Industry and Environment, NSW Office of Water, Environment Protection Authority etc.

In the event of any exceedance of the assigned trigger levels, the following response plan will be initiated:

- When aware of the exceedance, review the circumstances leading to the exceedance event.
  - Repeat the monitoring event to confirm the exceedance. If still in exceedance, issue a notification letter briefly detailing the exceedance to the relevant authorities within 7 days.
- When the trigger notification has been issued, initiate an investigation into the exceedance. The investigation report is to be issued within 60-days from the notification to authorities and be completed by an external consultant such as a hydrogeologist and/or environmental scientist (or similar). The investigation report should consider the following to determine potential causes:
  - Is the data accurate?
  - Similar triggers at other monitoring locations?
  - Anthropogenic / natural impacts responsible?
  - Abnormal weather conditions?
  - Active quarrying within the vicinity?

6.4 Roles and Responsibilities

All employees and contractors of the Quarry are responsible for the ongoing environmental management. Positions within the organisation have roles, responsibility and authority for managing environmental aspects, action plans, programs and controls.

The key responsibilities are provided below:

- Overall responsibility for environmental compliance with Environmental Protection License 10132 and DA 140-6-2005 conditions – Regional Environmental Manager.
- Implementation and adherence to this Groundwater Monitoring Plan – Quarry Manager.
- Delegating tasks associated with this groundwater monitoring Plan in order to achieve compliance – Quarry Manager.

7. Annual Environmental Management Report

Boral currently undertakes an Annual Environmental Management Report (AEMR) for groundwater monitoring completed during the 12-month reporting period in accordance with DA 140-6-2005 (Schedule 4, Condition 3).

The AEMR should report on monitoring locations and requirements detailed in this GWMP. The groundwater monitoring review is to include the following:

- A summary of the monitoring completed over the 12-month reporting period.
- A comparison of the monitoring results with the trigger levels detailed in Section 4, including the identification of any trigger level exceedance.
- Analysis of any non-compliance against trigger levels.
- A description of all management / mitigation measures taken following an identified non-compliance.

Development consent DA 140-6-2005 (Schedule 4, Condition 3) also specifies that, with reference to the groundwater monitoring bores, the report must:

- identify the standards and performance measures that apply to the development;
- describe the works carried out in the last 12 months;
- describe the works that will be carried out in the next 12 months;
- include a summary of the complaints received during the past year, and compare this to the complaints received in previous years;
- include a summary of the monitoring results for the development during the past year;
- include an analysis of these monitoring results against the relevant:
  - impact assessment criteria;
  - monitoring results from previous years; and
  - predictions in the EIS.
- identify any trends in the monitoring results over the life of the development;
- identify any non-compliance during the previous year; and
- describe what actions were, or are being taken to ensure compliance.

8. References

ANZECC, 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environmental and Conservational Council, and Agriculture and Resource Management Council of Australia and New Zealand.

ADWG, 2011. Australian Drinking Water Guidelines 6. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

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Boral, 2018, *Stockton Quarry Surface Water Management Plan,* Boral Resources (NSW) Pty Ltd

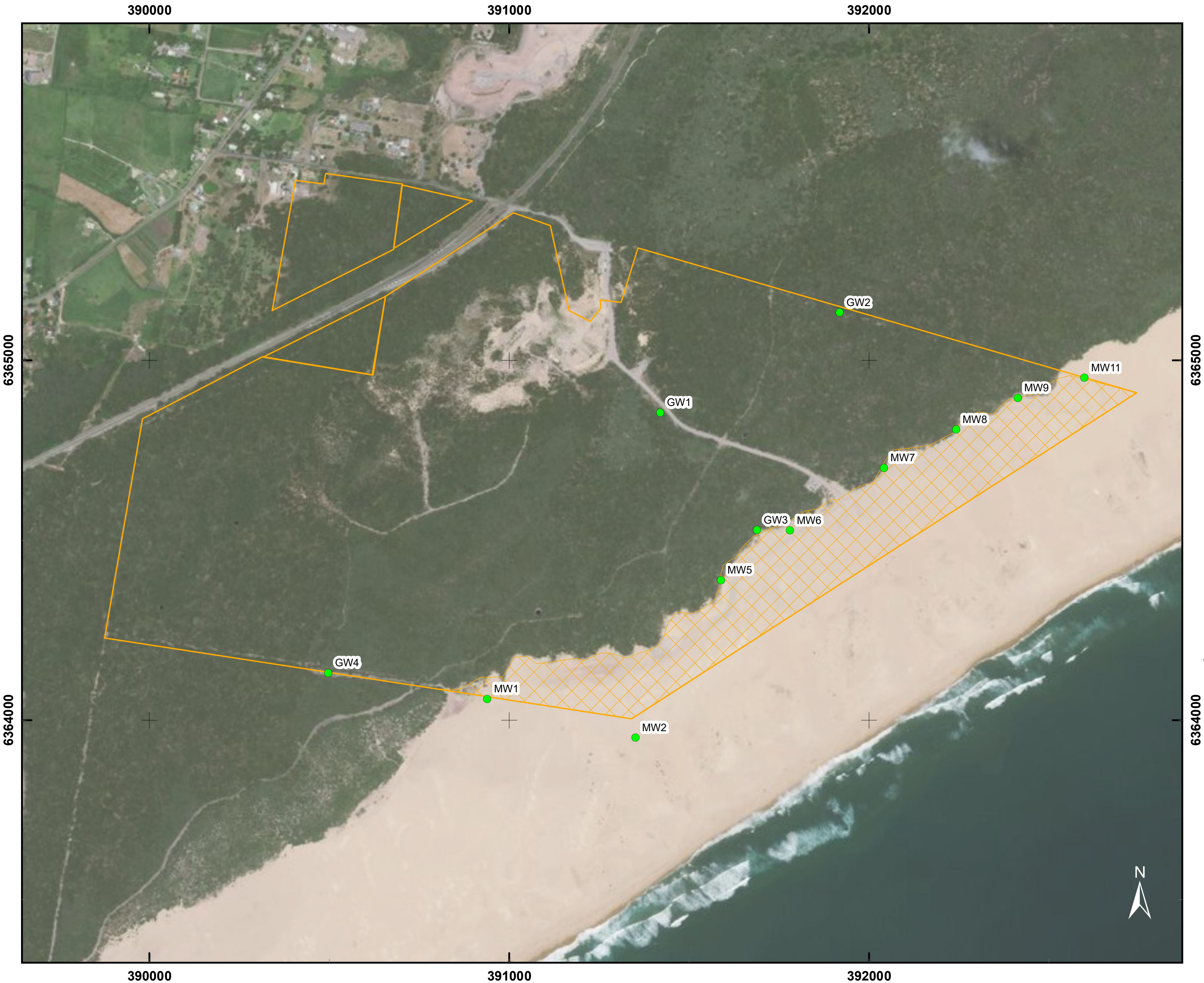
ERM, 2005. *Environmental Impact Statement Stockton Sandpit Windblown Sand Extraction, for Boral Resources (Country) Pty Limited*. Environmental Resources Management Australia Pty Ltd

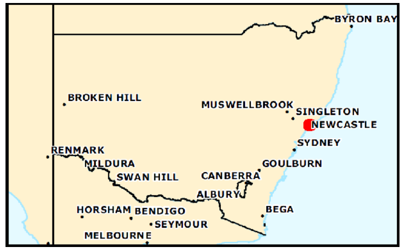
ERM, 2008. Stockton Transgressive Dune Quarry, Groundwater Monitoring Program and Baseline Data. Environmental Resources Management Australia Pty Ltd, Reference 00640400GWMP Final 2, April 2008.

RPS Water, 2016, *Boral Stockton Quarry – Groundwater Gap Analysis.* Consultant report provided for Boral Resources (NSW) Pty Ltd. Reference WS00256B/003a, 26 July 2016.

RPS Aquaterra 2011, *Stockton Sand Quarry Groundwater Monitoring Program*, *Revision 3.*

FIGURES





LEGEND

Active Tenement

Current Extraction Area

Existing Piezometers

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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0 125 250 375 500
Meters

GDA 1994 MGA Zone 56

A4 1:15,000

FIGURE1
Boral Stockton Sand Quarry Existing Groundwater Monitoring Network

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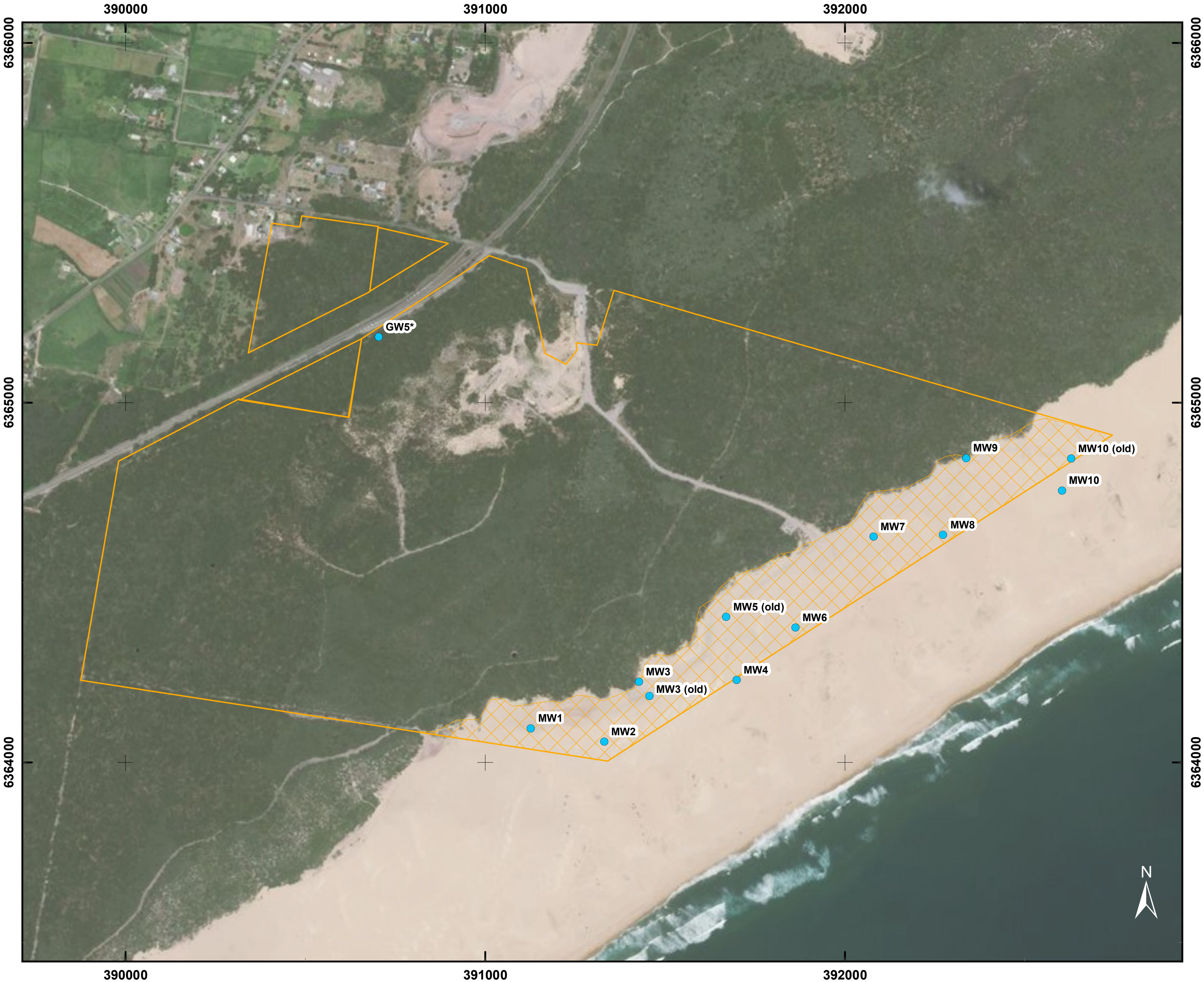

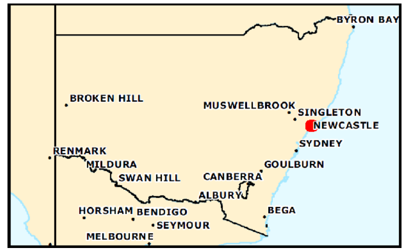

LEGEND

- Active Tenement
- Current Extraction Area
- Historic Piezometers

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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GDA 1994 MGA Zone 56

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FIGURE 2
Boral Stockton Sand Quarry Historic Groundwater Monitoring Network

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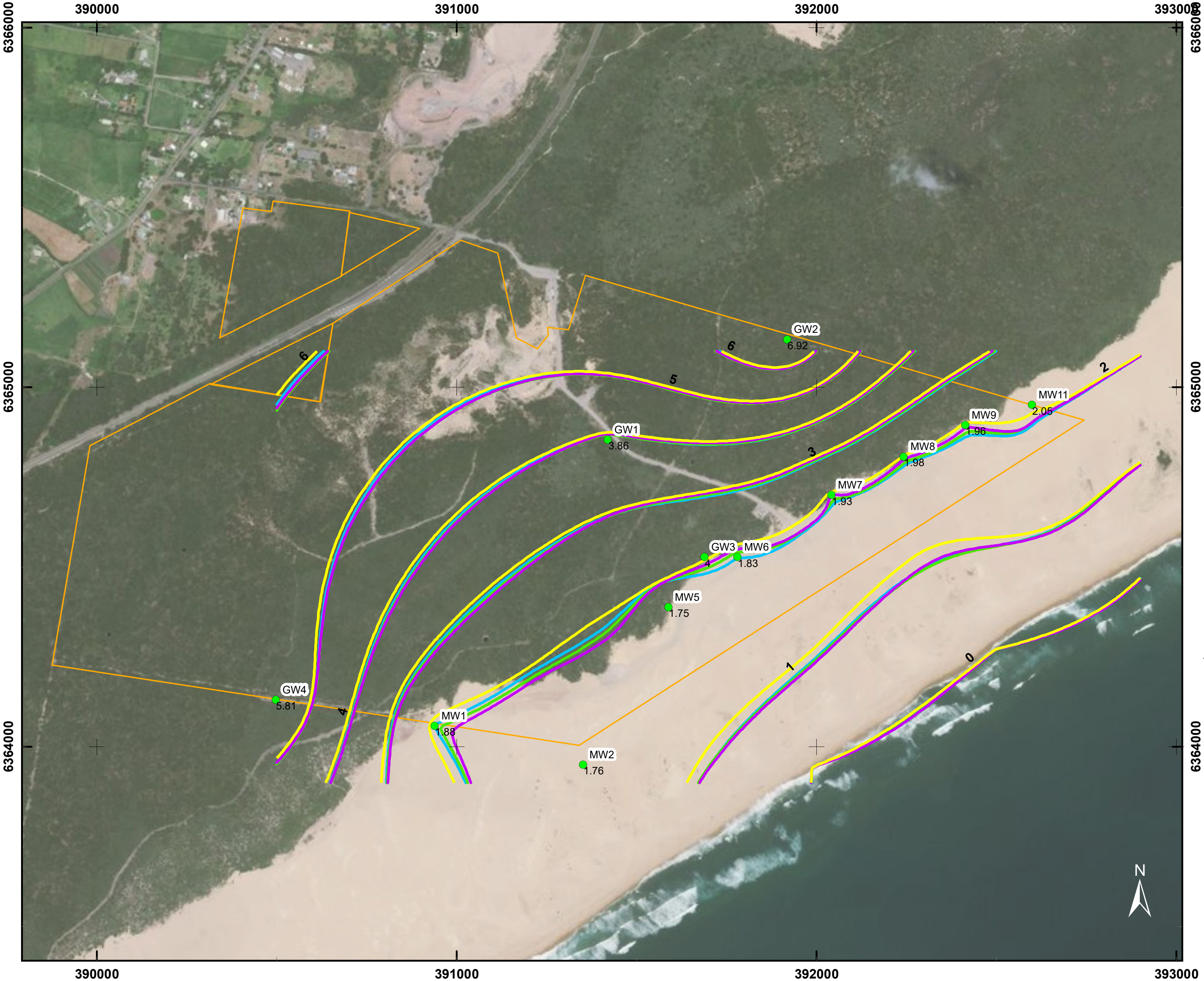

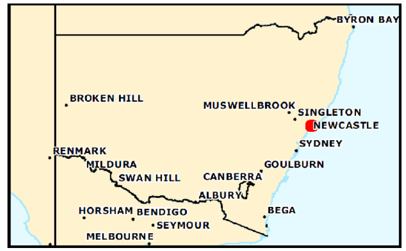

LEGEND

- Active Tenement
- Existing Piezometers
- Quarter 1 Contours
- Quarter 2 Contours
- Quarter 3 Contours
- Quarter 4 Contours

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Meters

GDA 1994 MGA Zone 56

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FIGURE 3
Boral Stockton Sand Quarry
Average Seasonal Groundwater Level Contours

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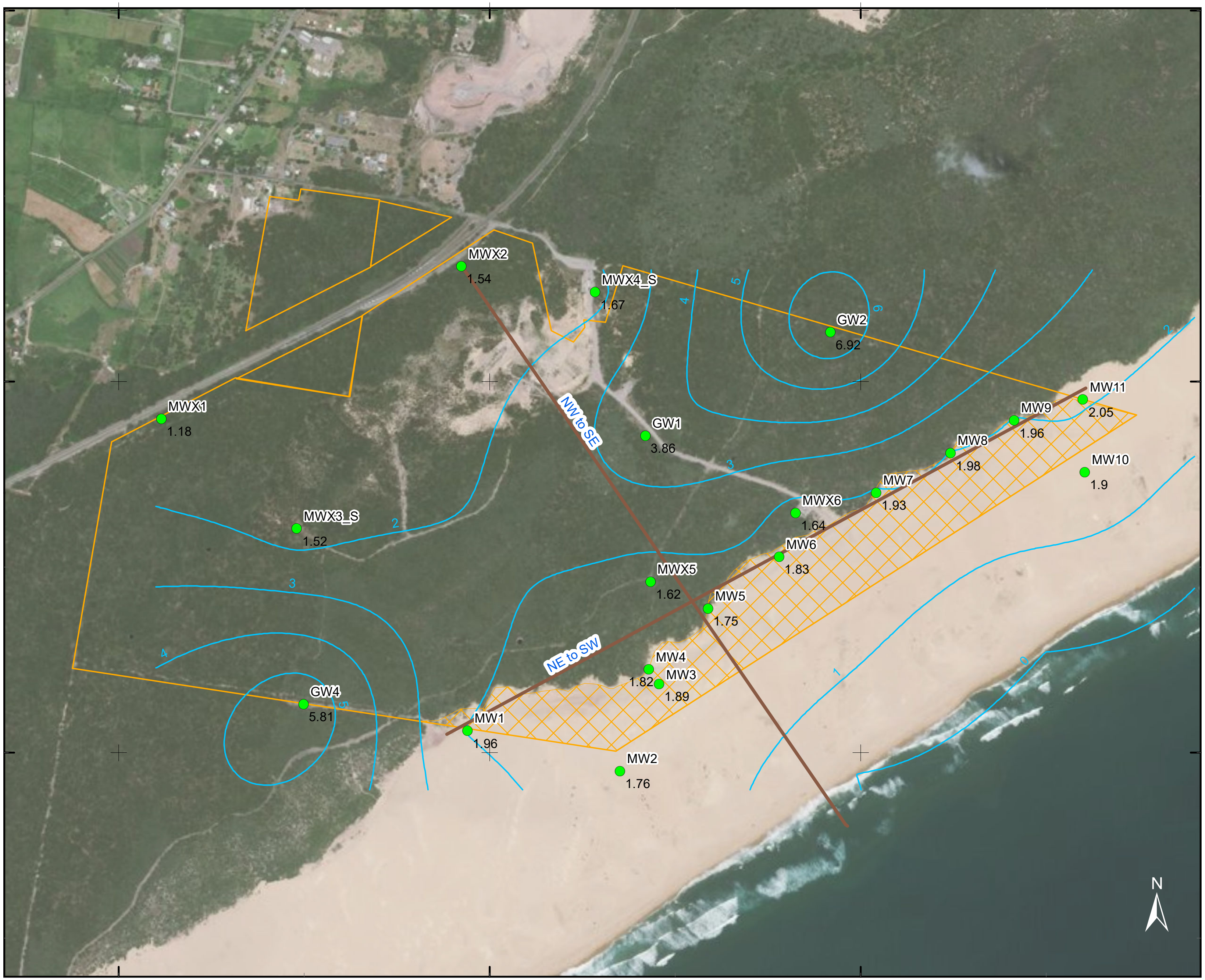

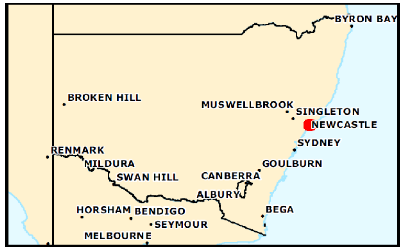

LEGEND

- Active Tenement
- Current Extraction Area
- Groundwater Contours With New Piezos (mAHD)
- Line of Section (approx..) refer to Figure 5

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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0 125 250 375 500
Meters

GDA 1994 MGA Zone 56

A4 1:15,000

FIGURE 4
Boral Stockton Sand Quarry Average Groundwater Level Contours with Newly Installed Piezometers

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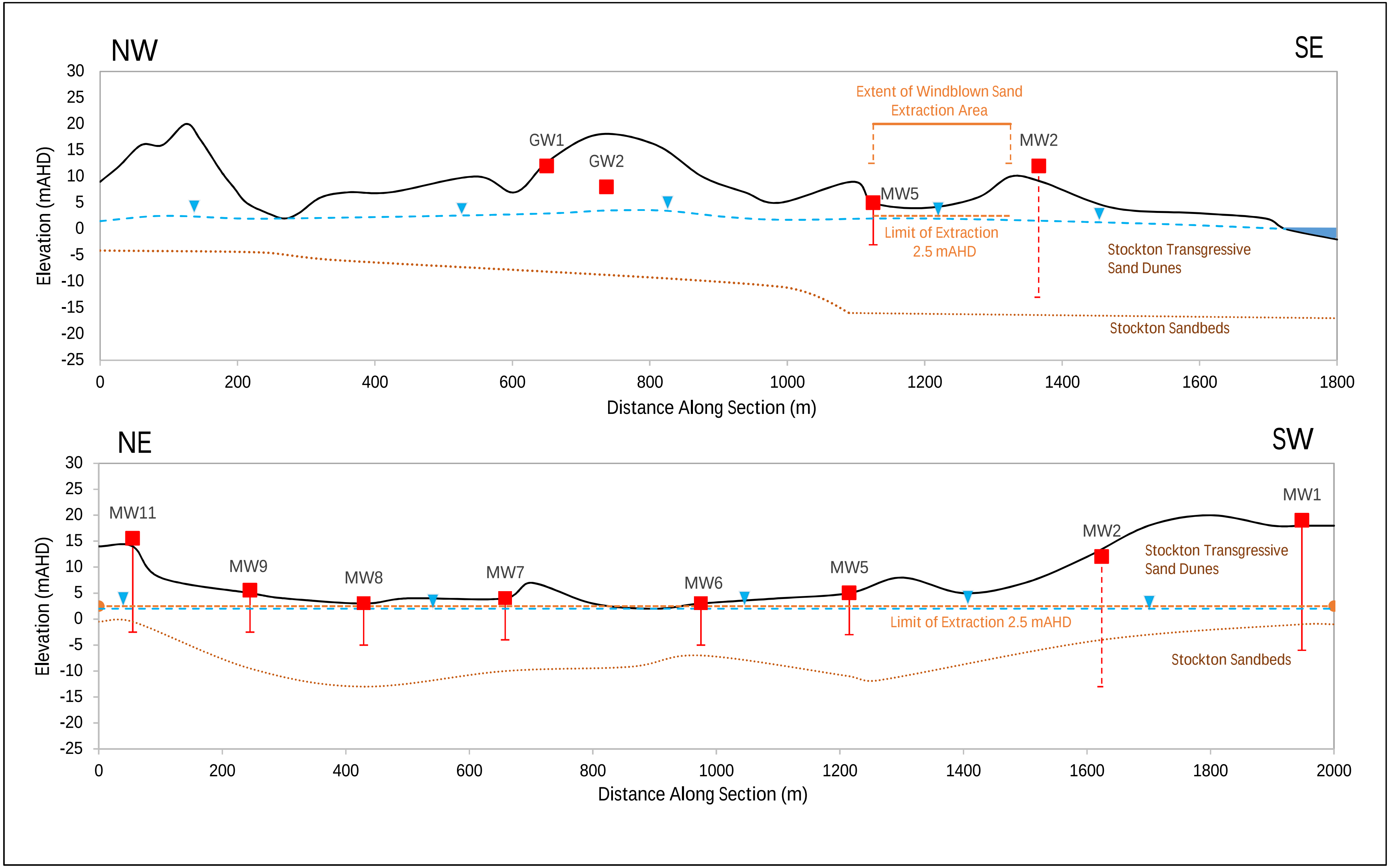

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GEOLOGICAL CROSS SECTION FIGURE 5

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\[Cross Section Stockton - final.xlsx]Figure 5 cross section

Jobs/2005/0027903/EIS - Fg10.1 Vegetation Communities, Survey Sites & Threatened Species .cdr June 2005 JD Environmental Resources Management Australia Pty Ltd

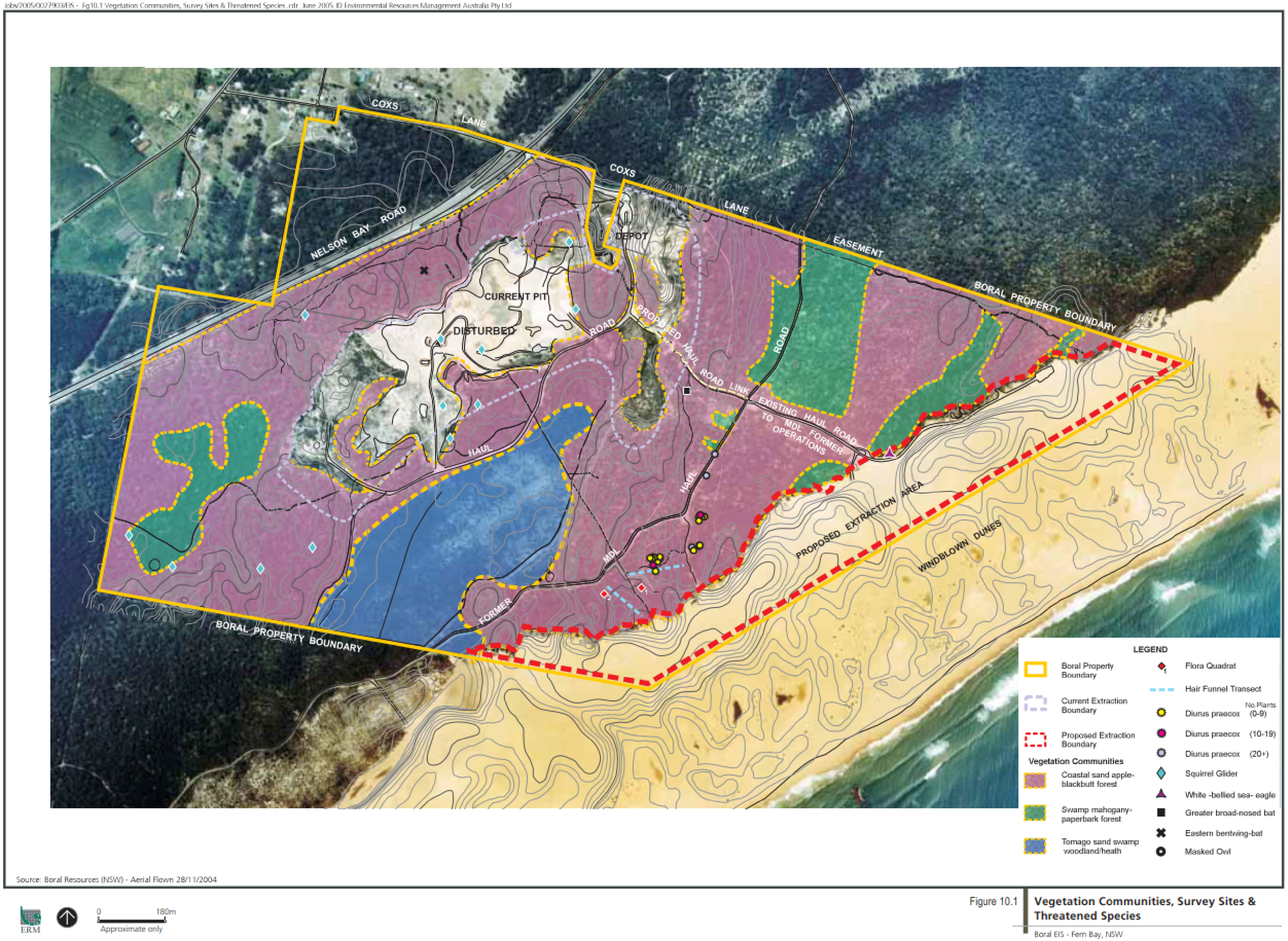
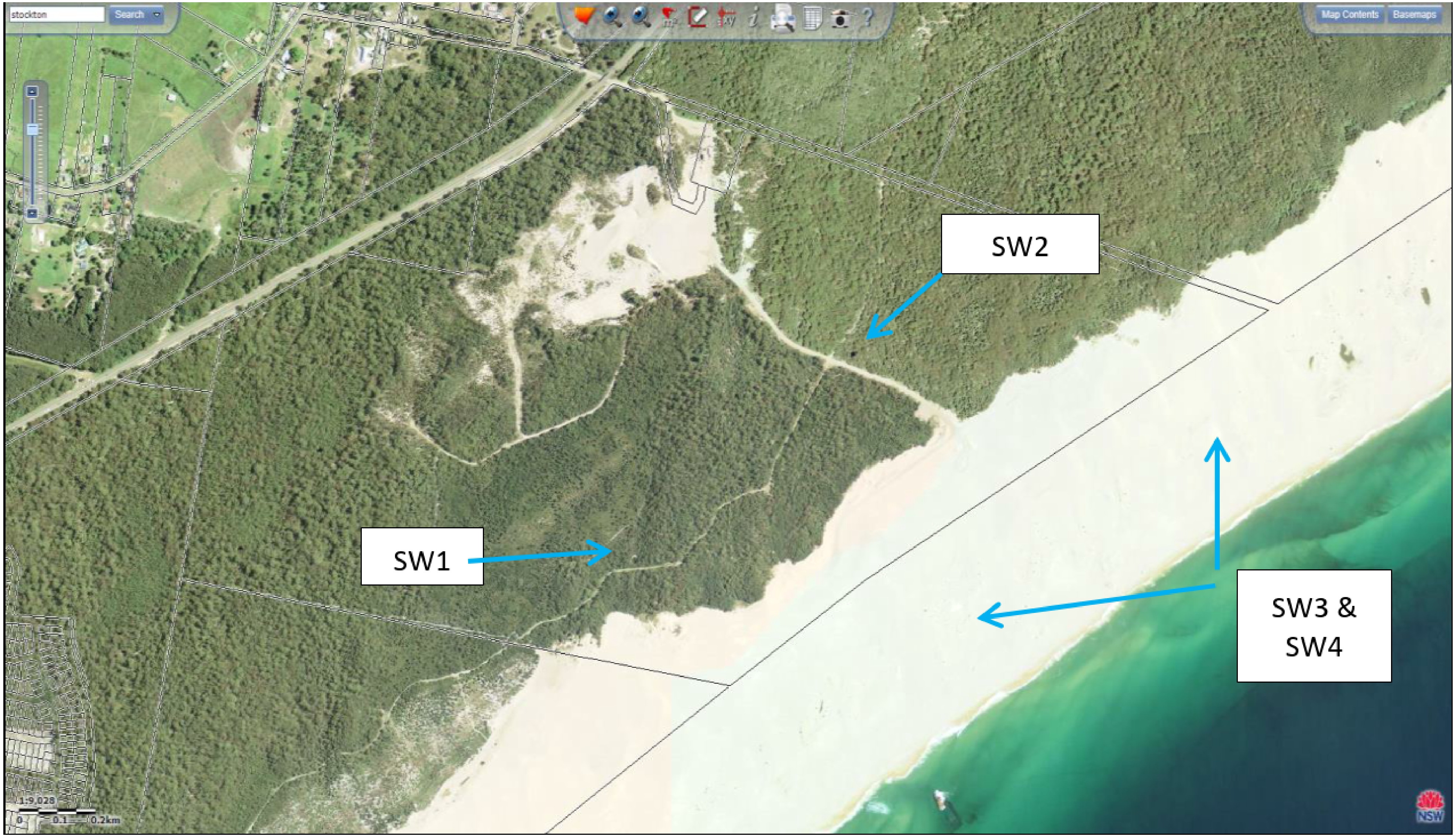


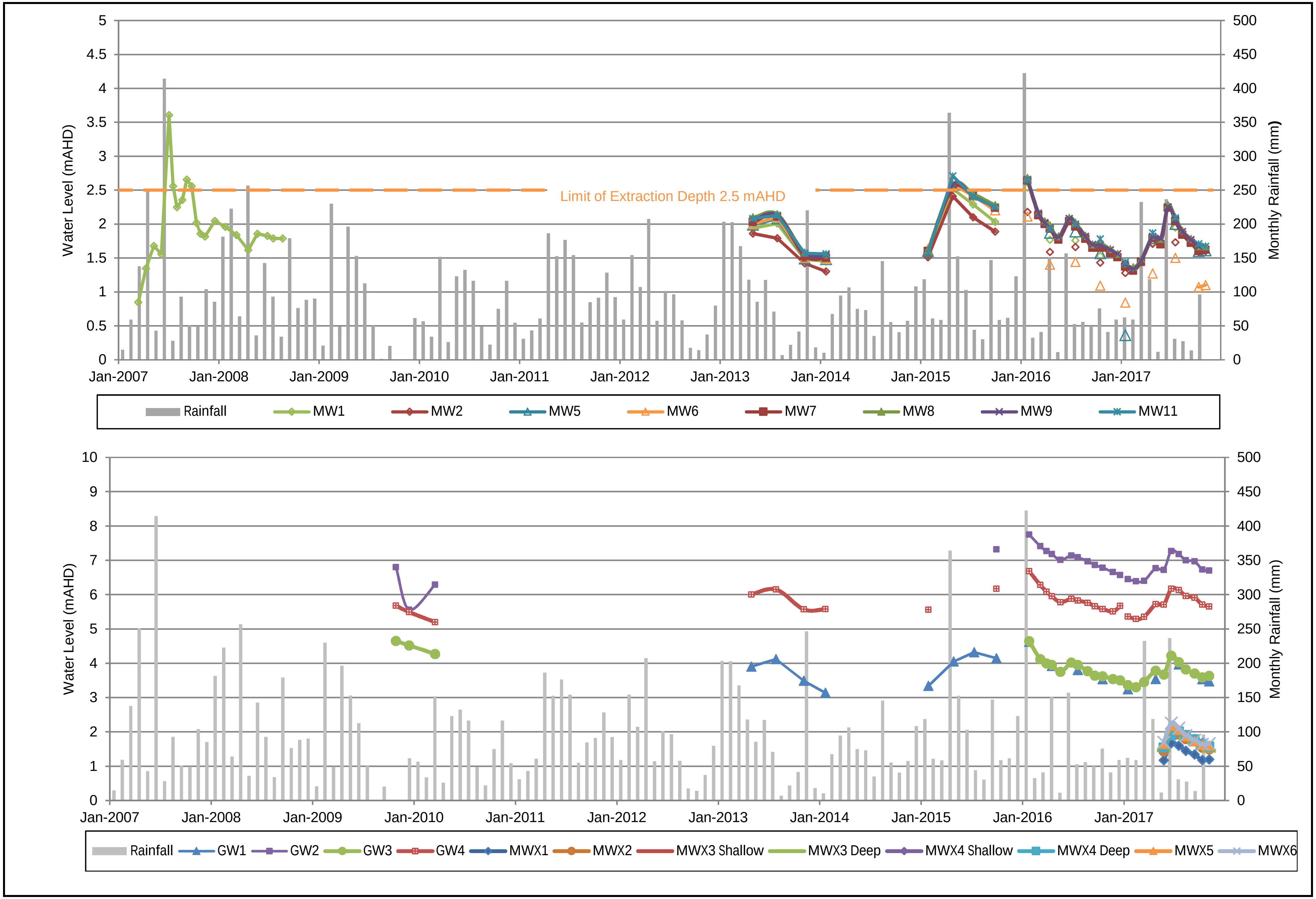
Figure 10.1 **Vegetation Communities, Survey Sites & Threatened Species**

Boral EIS - Fern Bay, NSW

Groundwater Dependent Ecosystems FIGURE 5.2



Surface Water Monitoring Locations FIGURE 5.3



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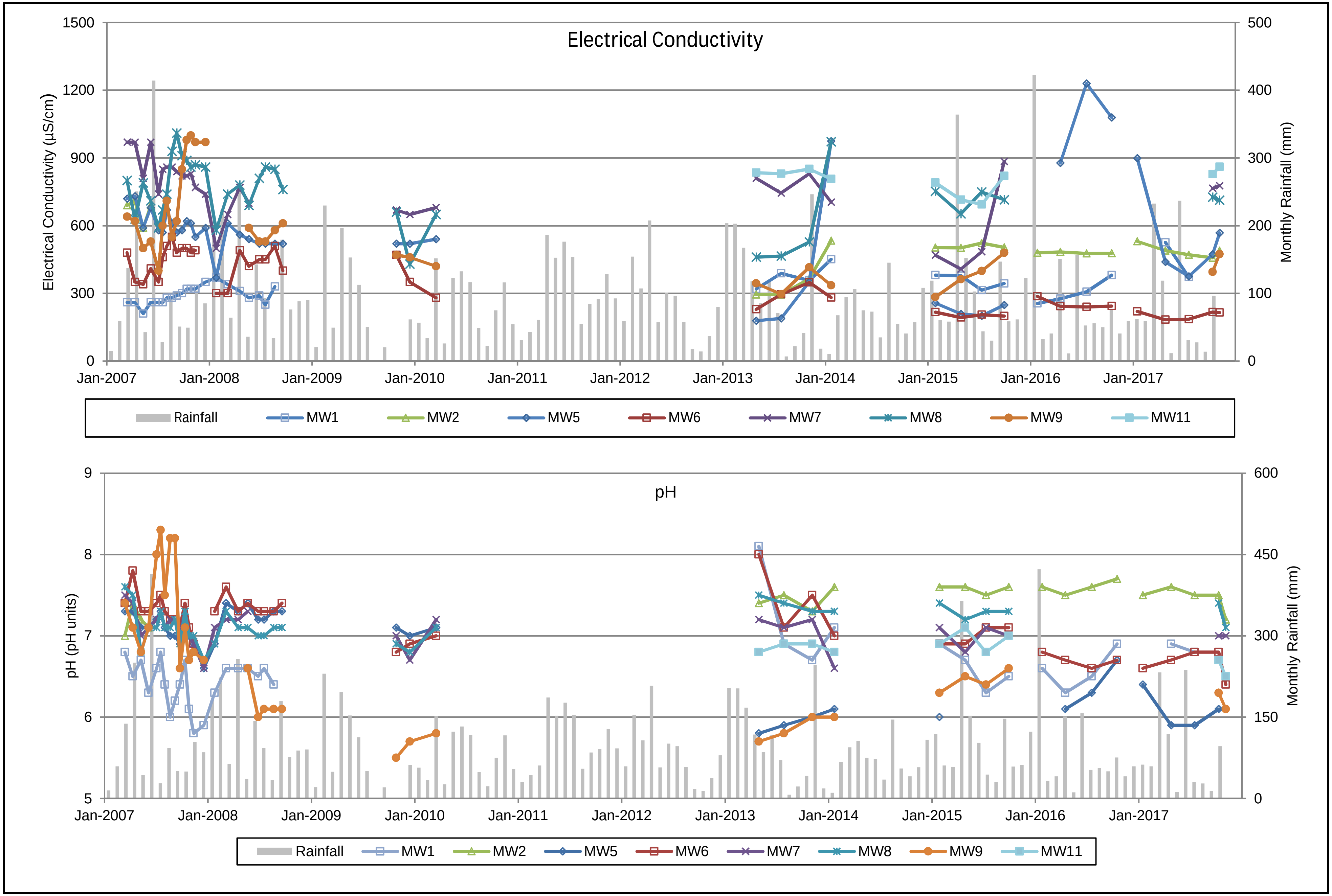
GROUNDWATER LEVELS FIGURE 6

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Groundwater Levels and Field Chem figs.xlsx]Fig 6 GW levels



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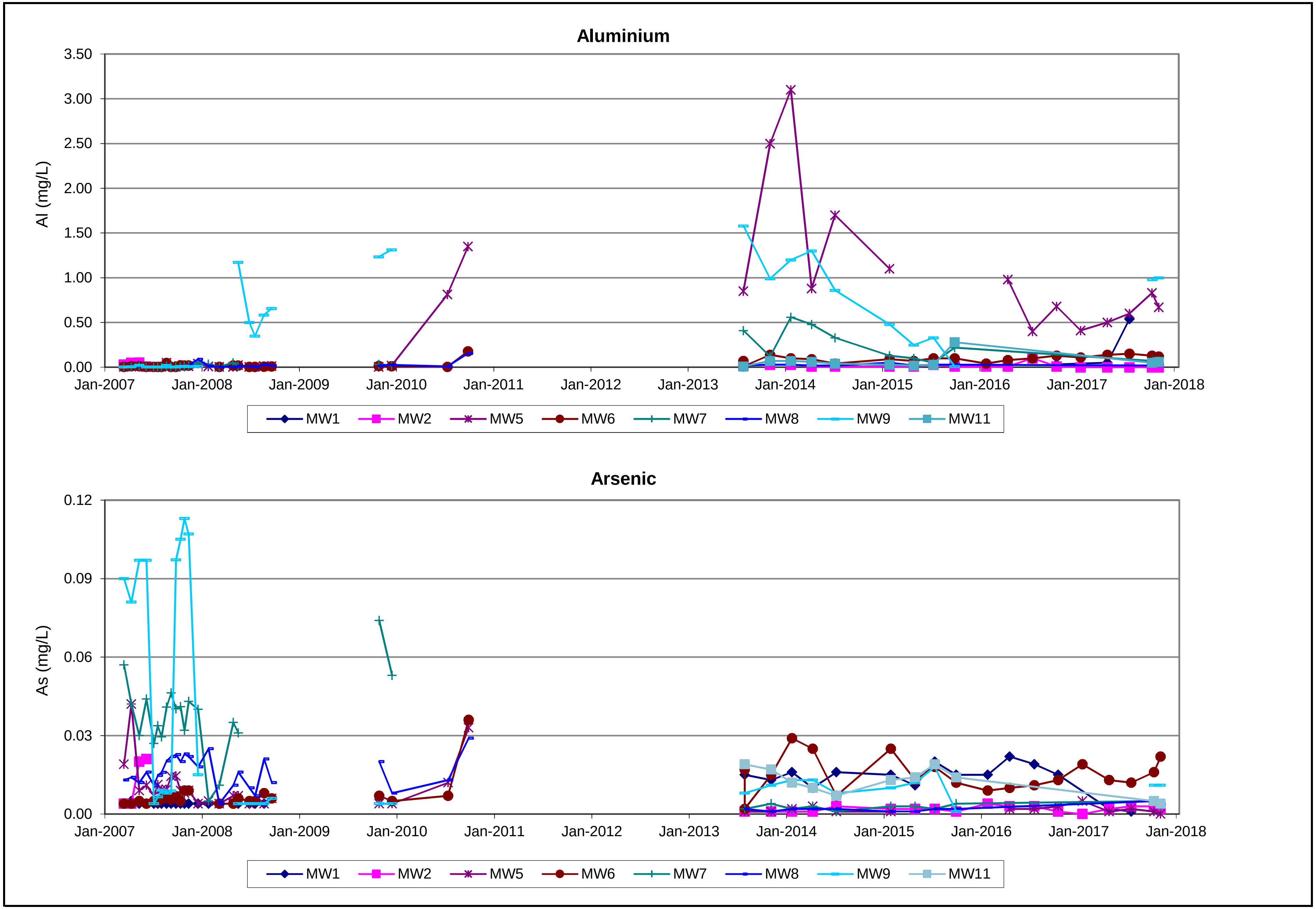
BASELINE FIELD GROUNDWATER QUALITY FIGURE 7

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Groundwater Levels and Field Chem.xlsx]Fig 7 EC pH



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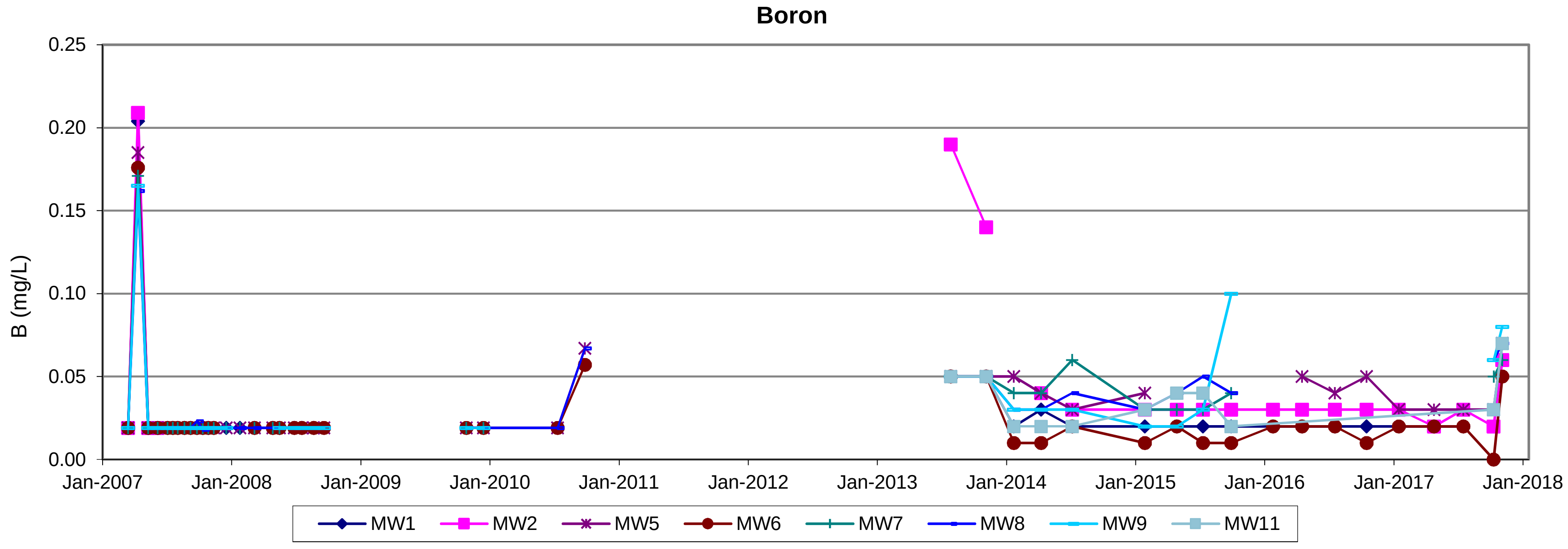
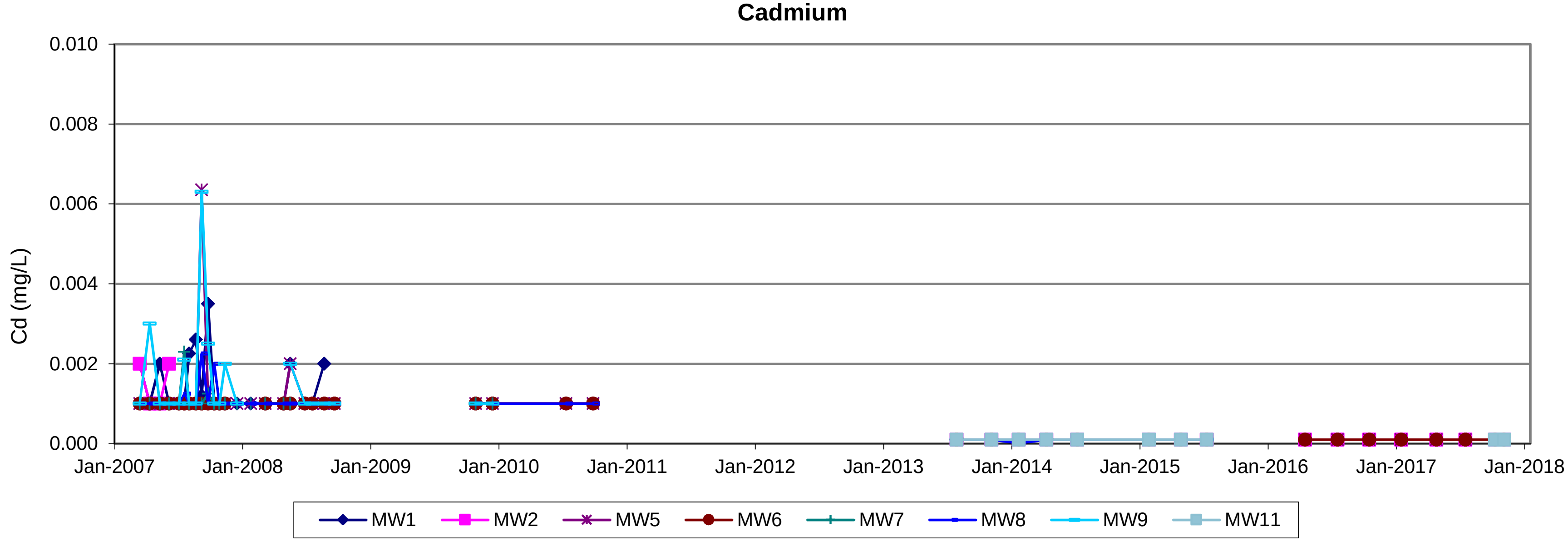
BASELINE GROUNDWATER QUALITY [ALUMINIUM ARSENIC] FIGURE 8

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]Al As





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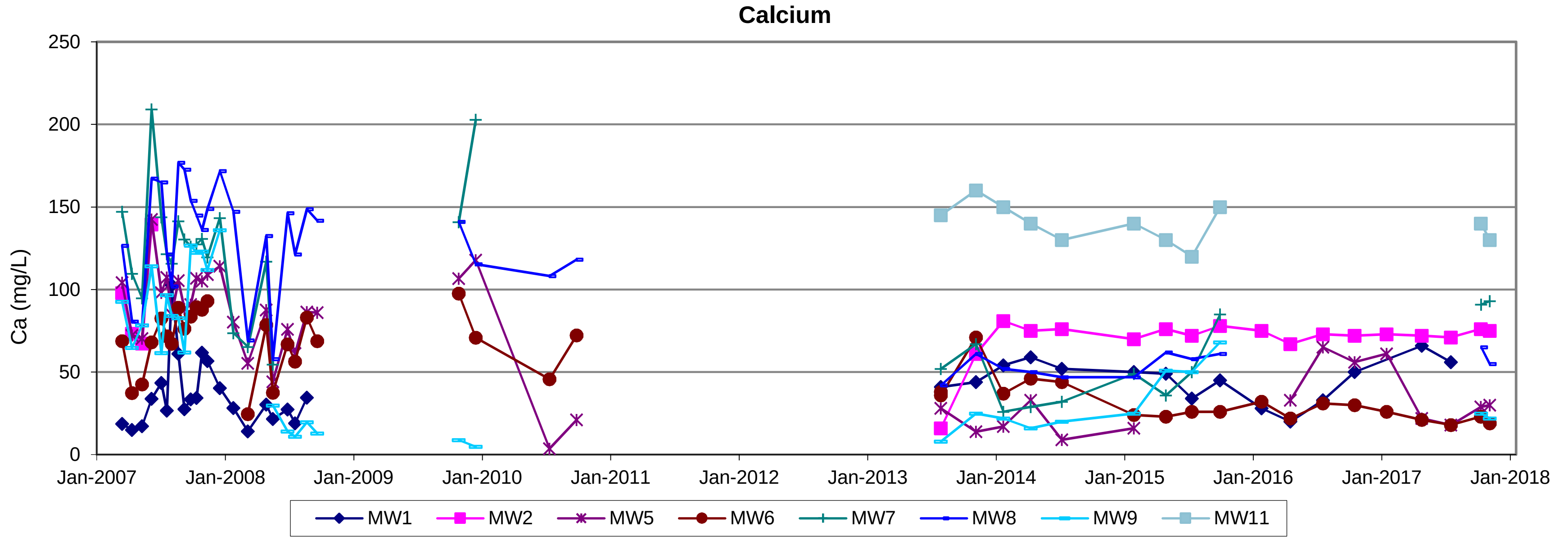
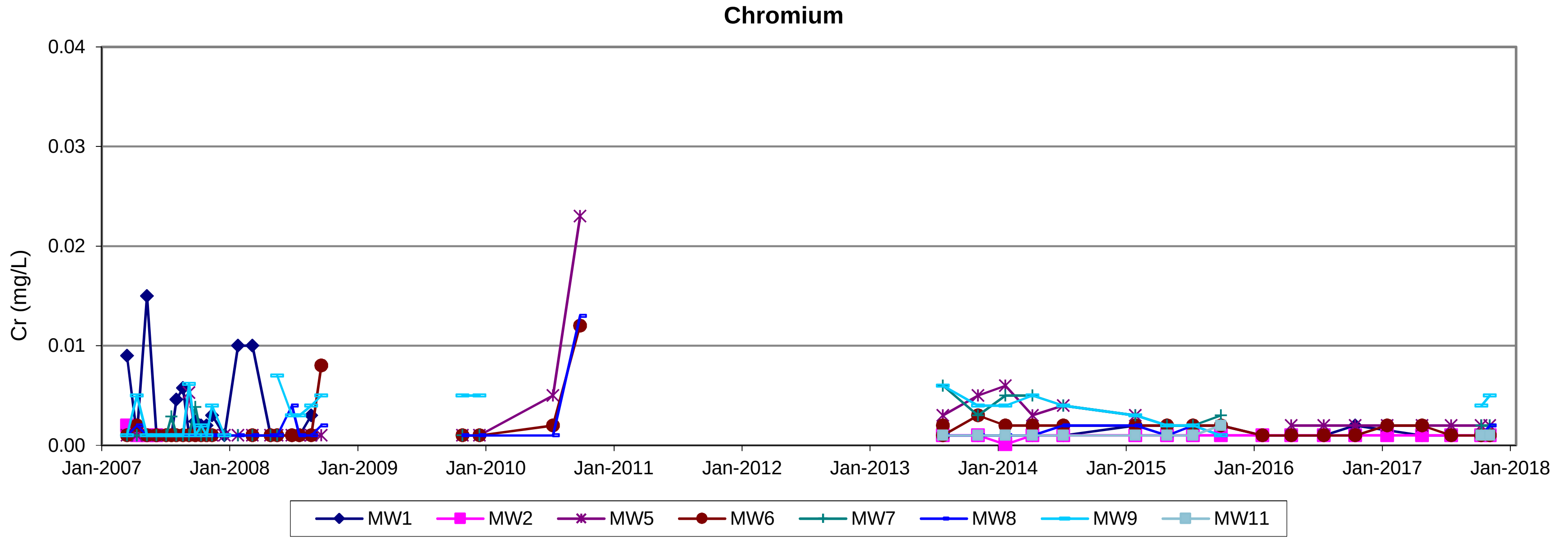
BASELINE GROUNDWATER QUALITY [BORON CADMIUM] FIGURE 9

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]B Cd





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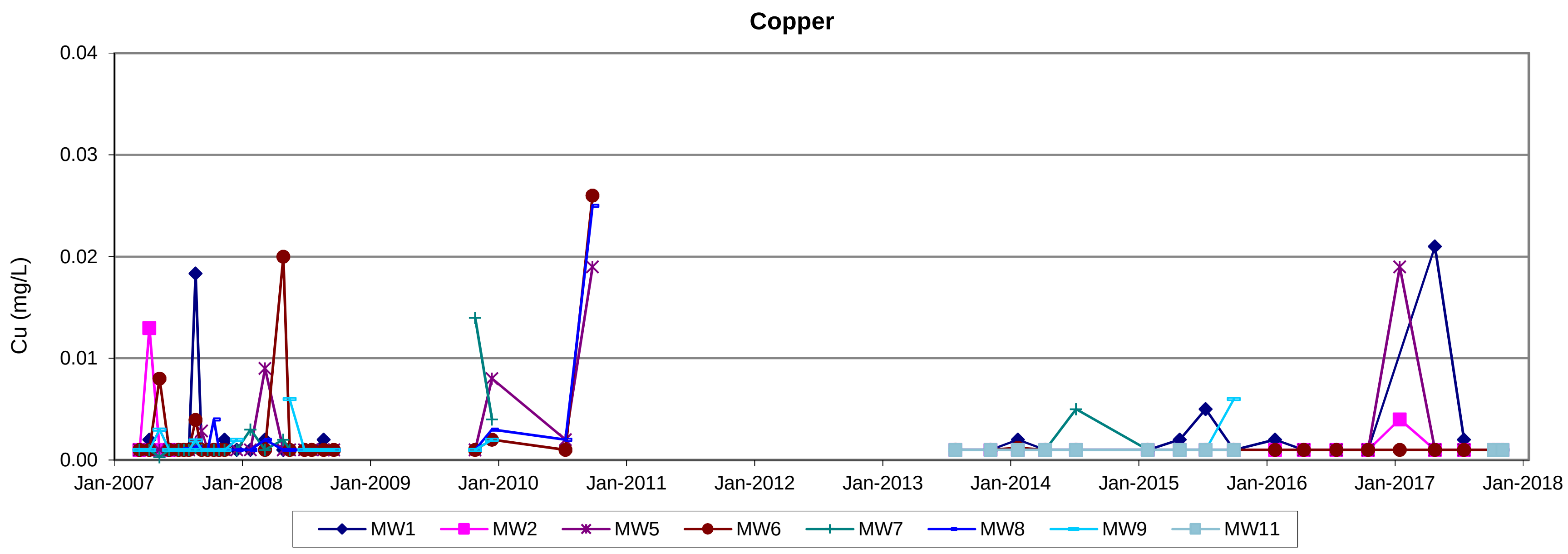
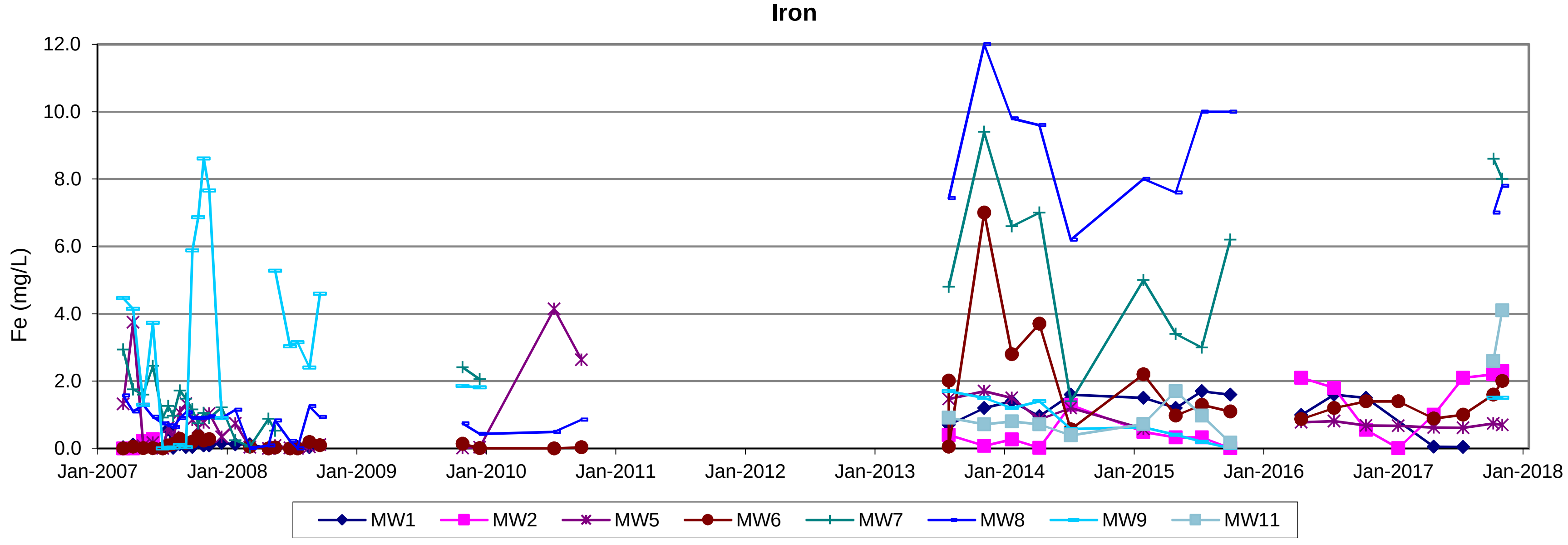
BASELINE GROUNDWATER QUALITY [CALCIUM CHROMIUM] FIGURE 10

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]Ca Cr





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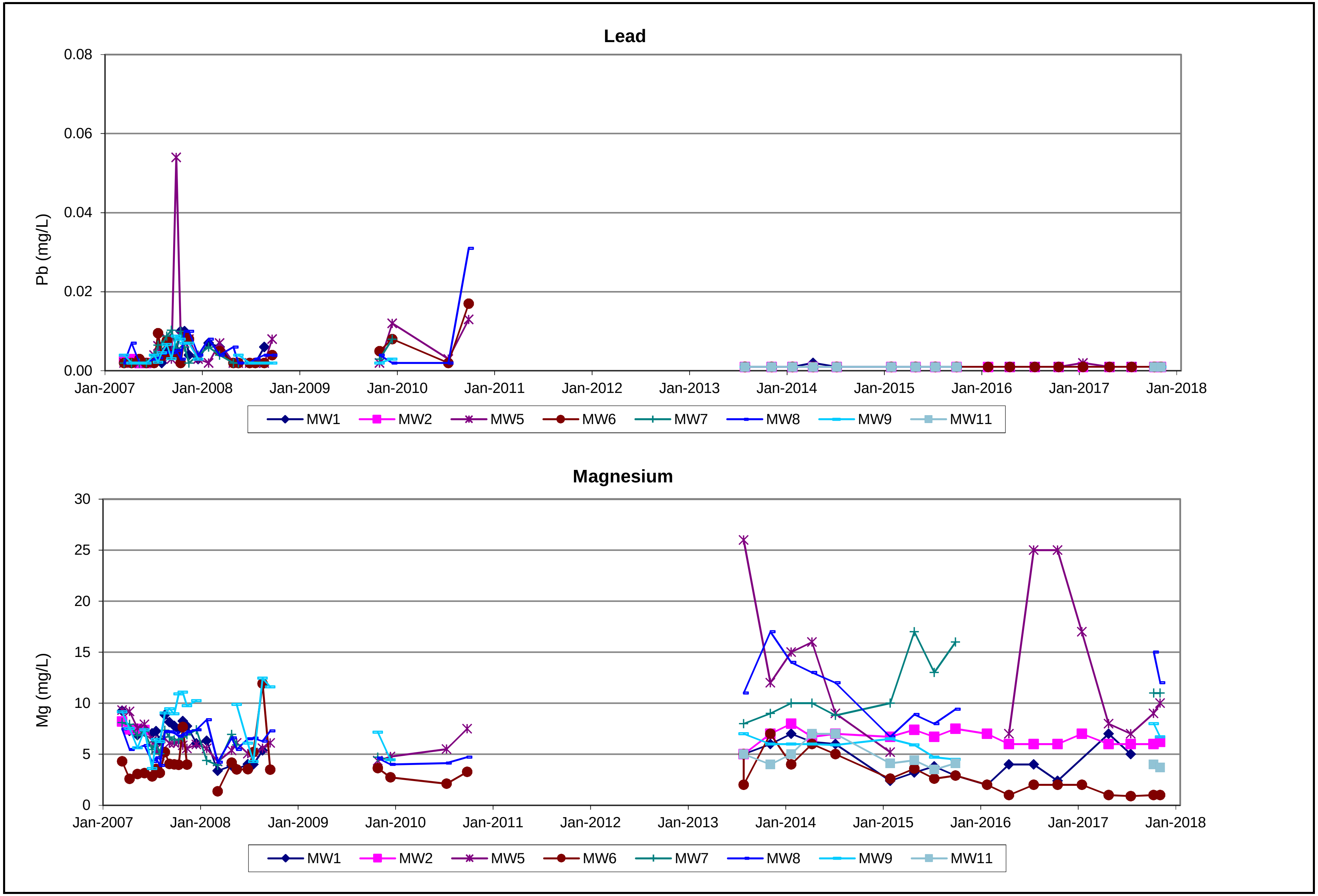
BASELINE GROUNDWATER QUALITY [COPPER IRON] FIGURE 11

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]Fe Cu



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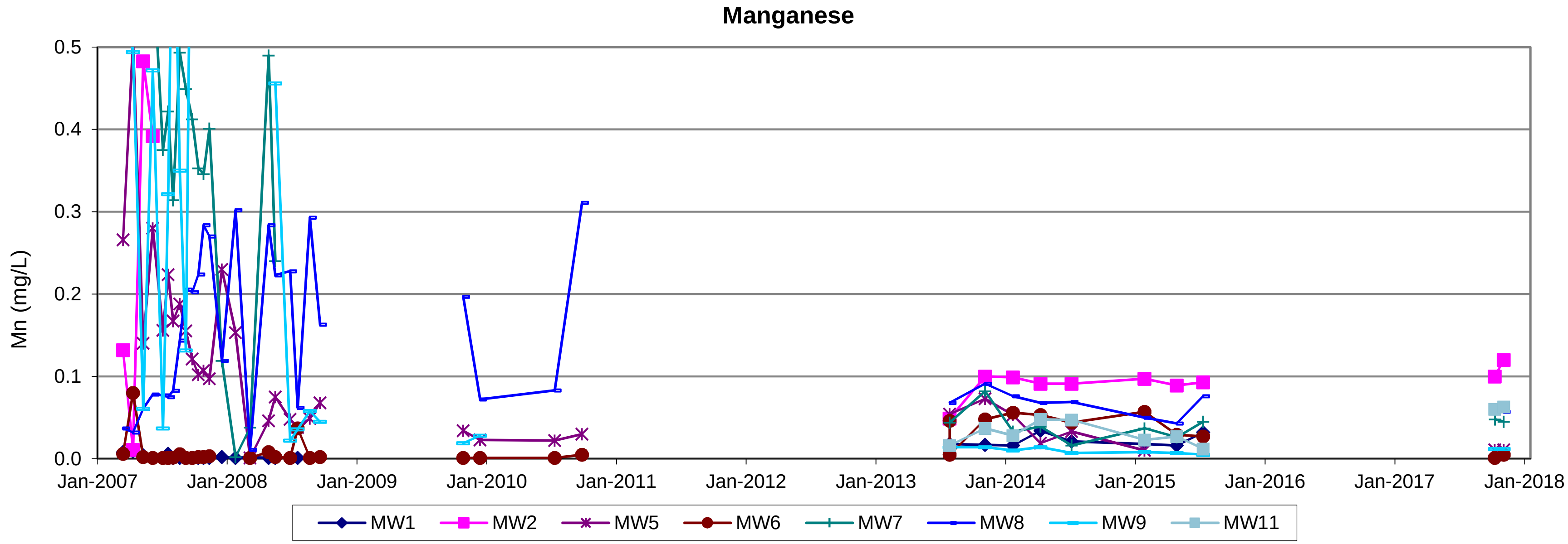
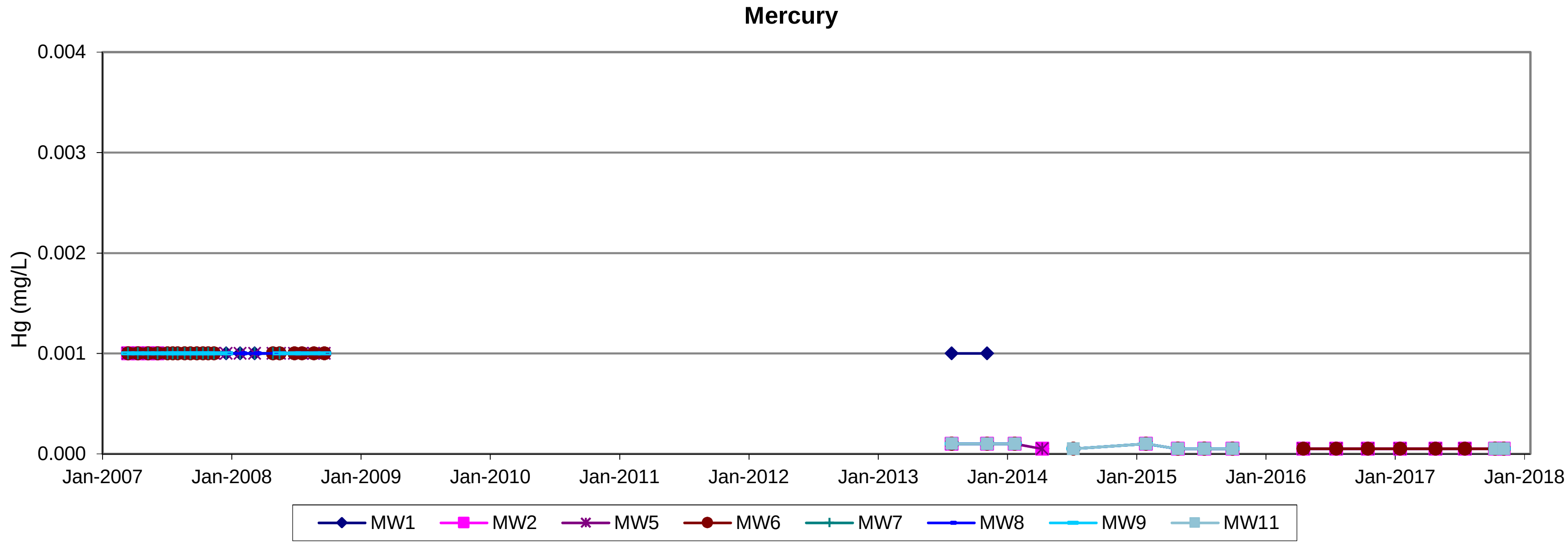
BASELINE GROUNDWATER QUALITY [LEAD MAGNESIUM] FIGURE 12

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]Mg Pb





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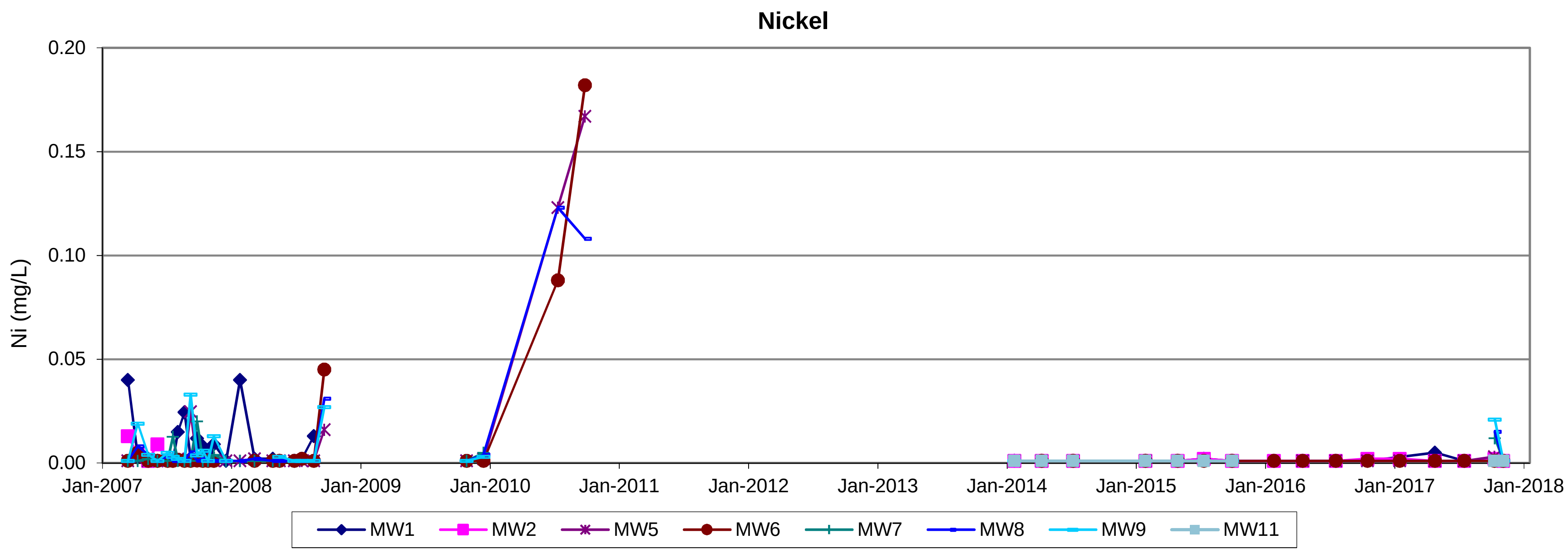
BASELINE GROUNDWATER QUALITY [MANGANESE MERCURY] FIGURE 13

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]Hg Mn


Nickel
Ni (mg/L)
0.20
0.15
0.10
0.05
0.00
Jan-2007
Jan-2008
Jan-2009
Jan-2010
Jan-2011
Jan-2012
Jan-2013
Jan-2014
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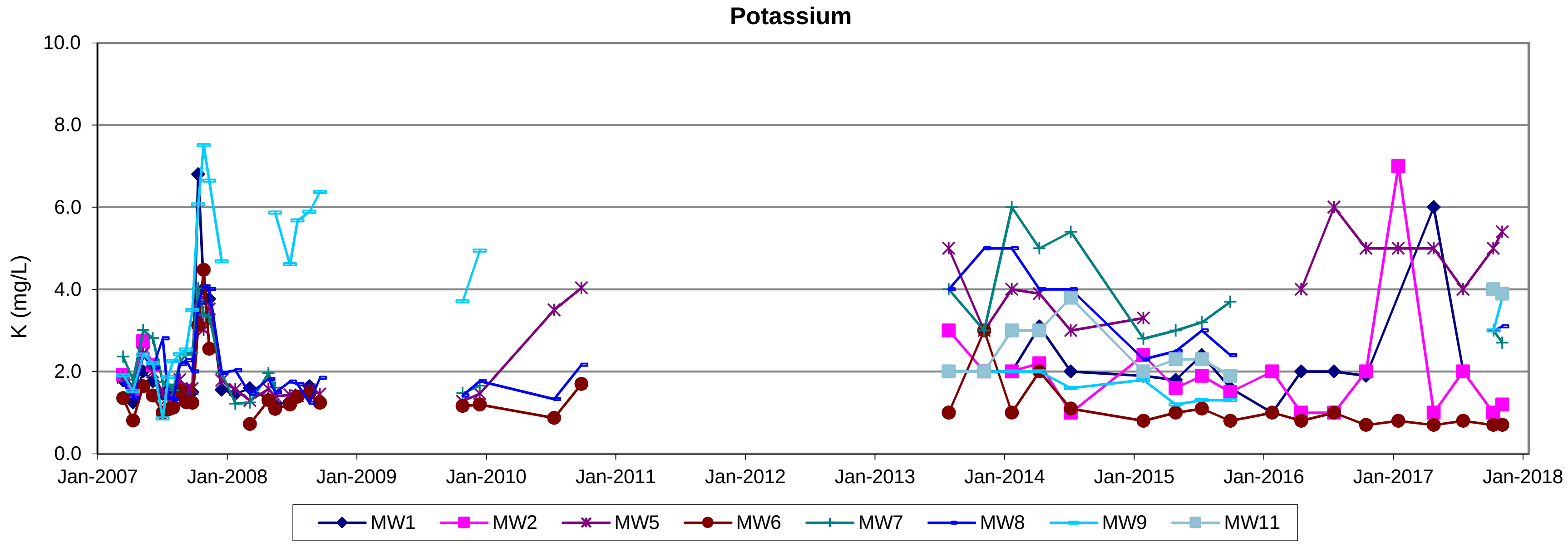
Jan-2016
Jan-2017
Jan-2018
MW1
MW2
MW5
MW6
MW7
MW8
MW9
MW11


Potassium
K (mg/L)
10.0
8.0
6.0
4.0
2.0
0.0
Jan-2007
Jan-2008
Jan-2009
Jan-2010
Jan-2011
Jan-2012
Jan-2013
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Jan-2015
Jan-2016
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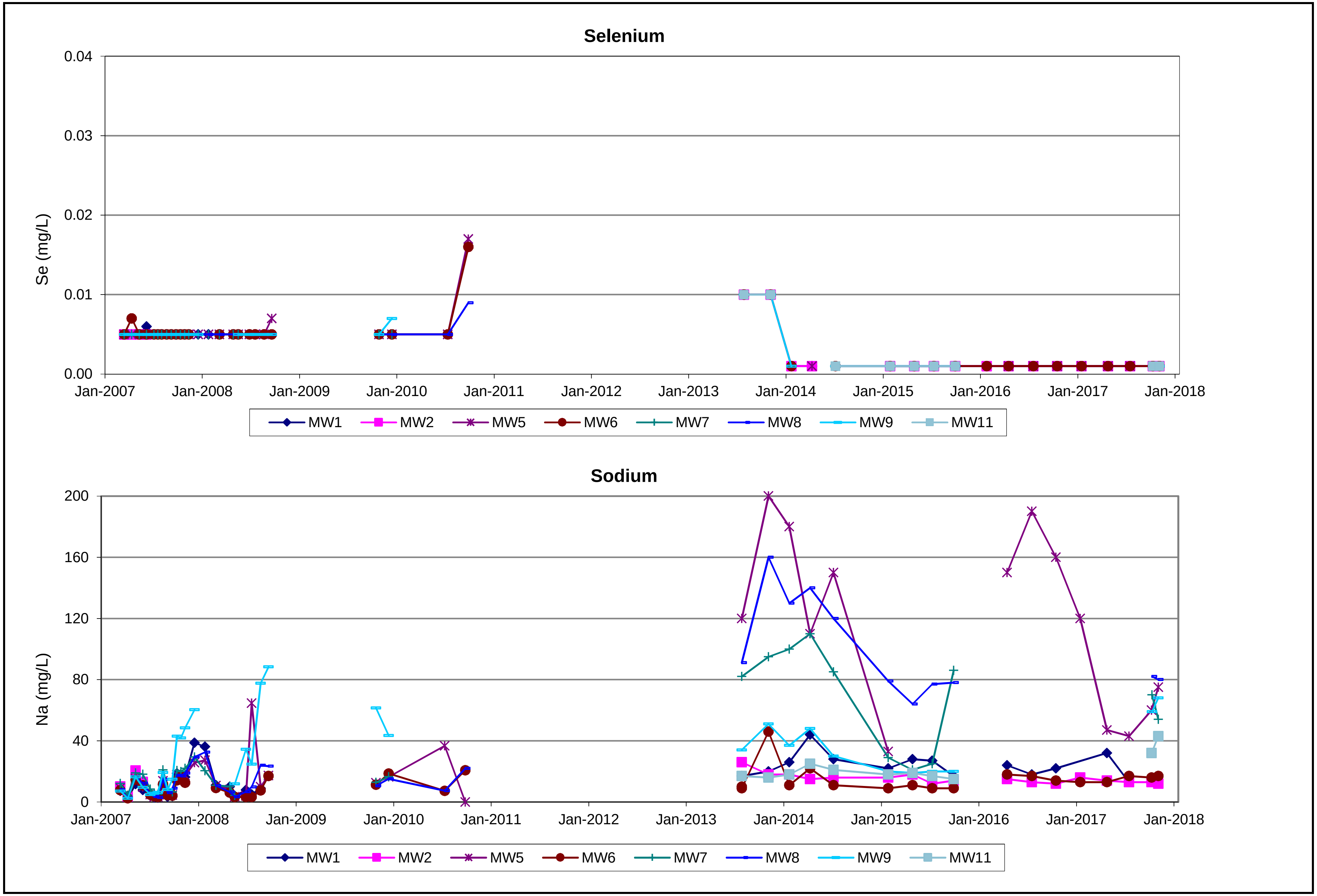
Jan-2018
MW1
MW2
MW5
MW6
MW7
MW8
MW9
MW11



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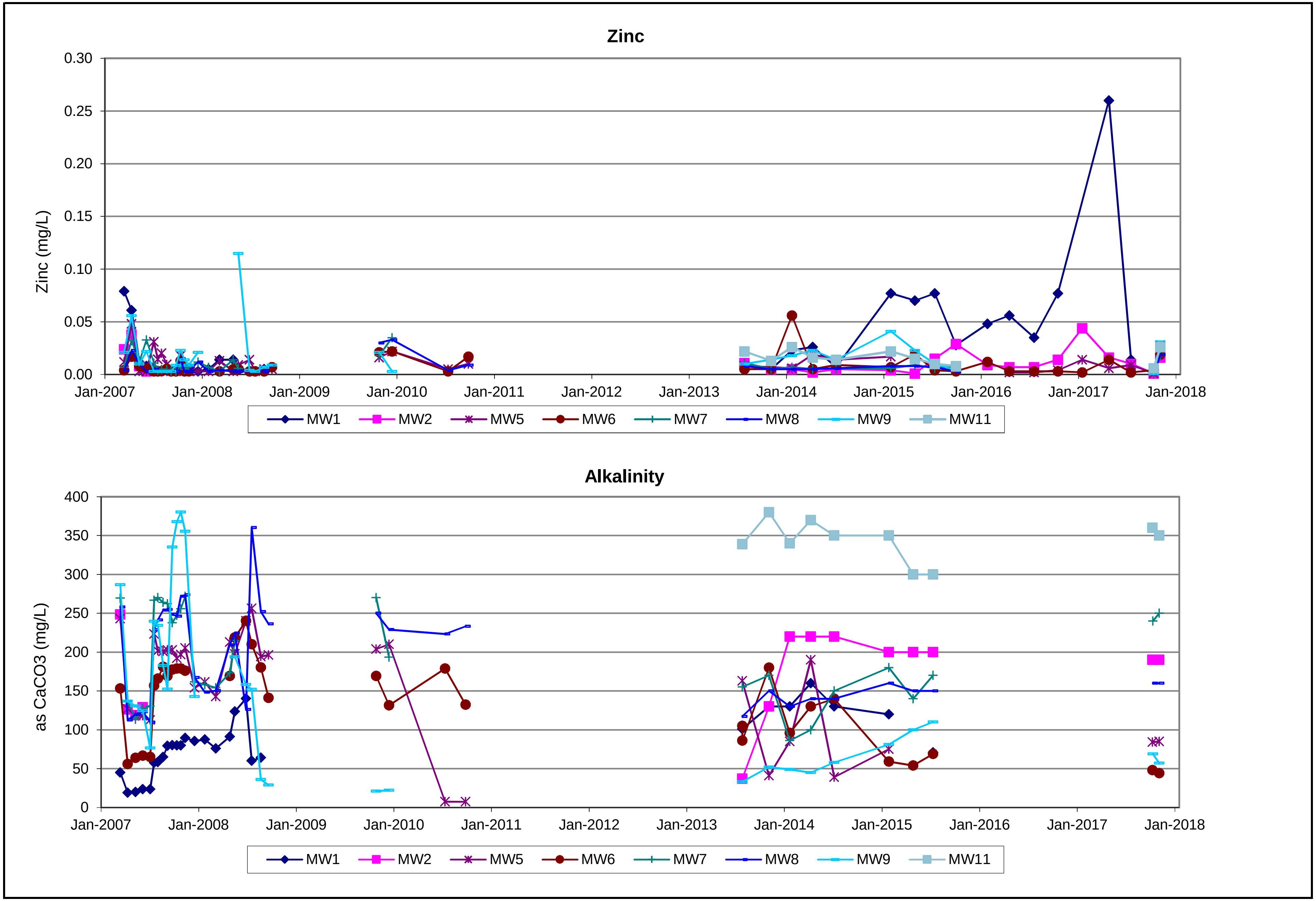
BASELINE GROUNDWATER QUALITY [SELENIUM SODIUM] FIGURE 15

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]Na Se



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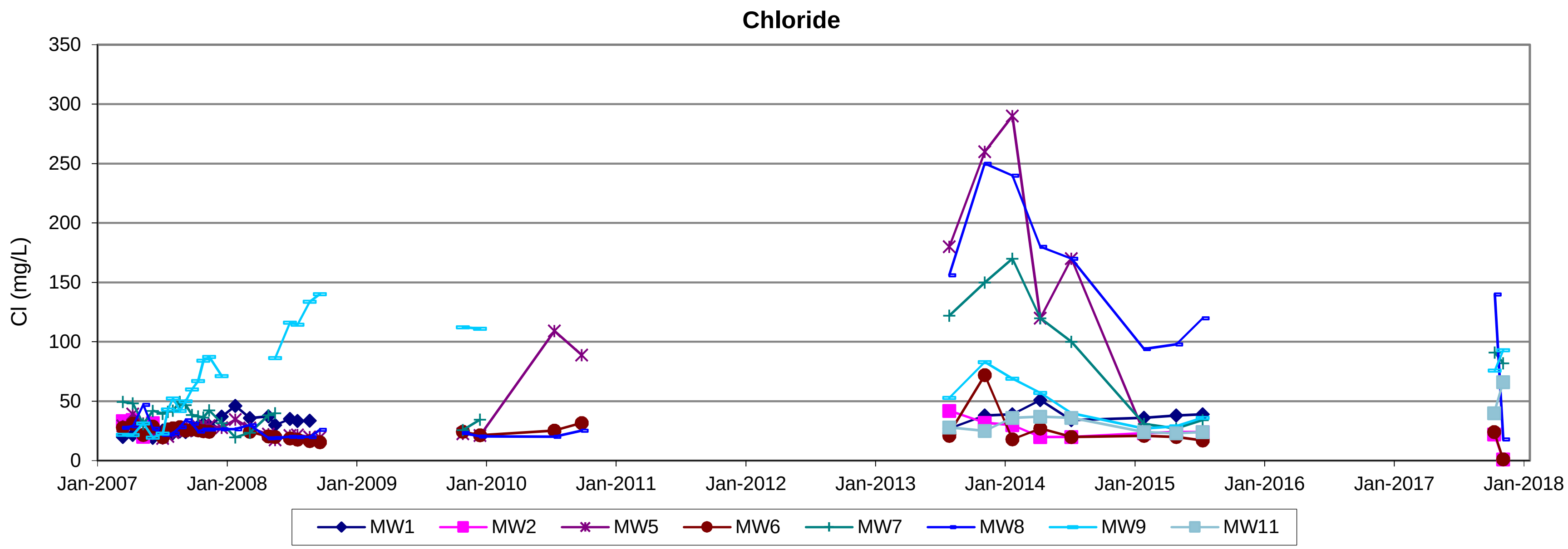
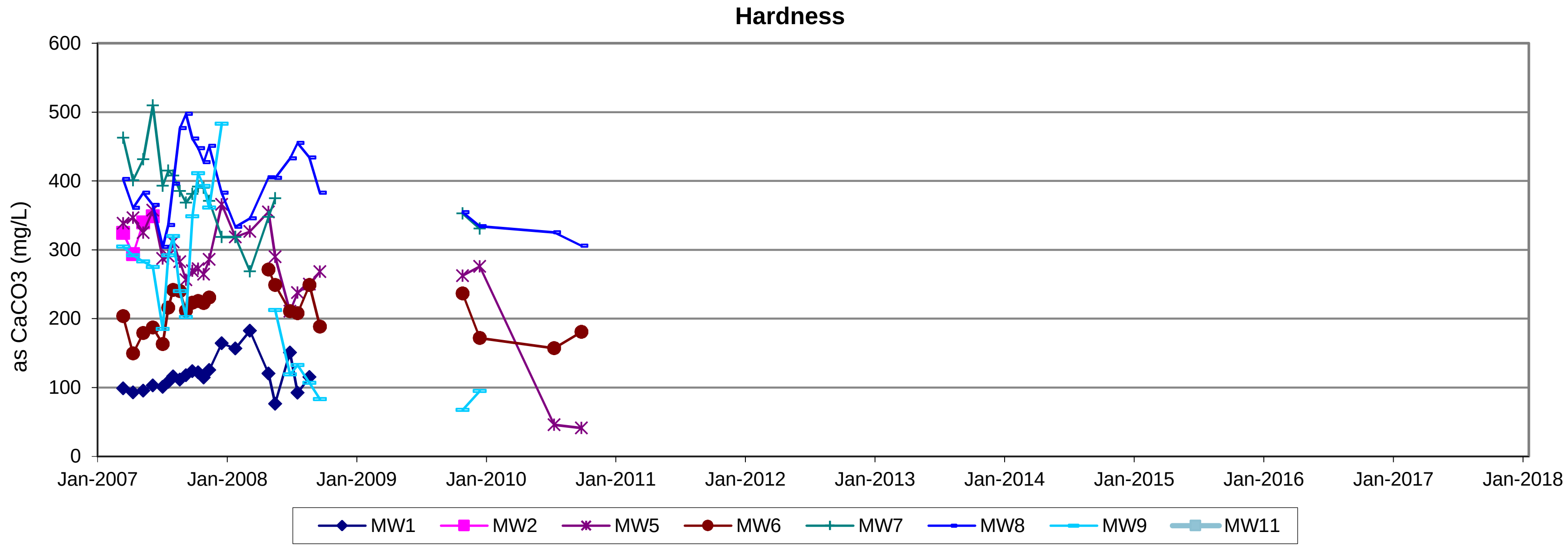
BASELINE GROUNDWATER QUALITY [ZINC ALKALINITY] FIGURE 16

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]CaCO3 Zn





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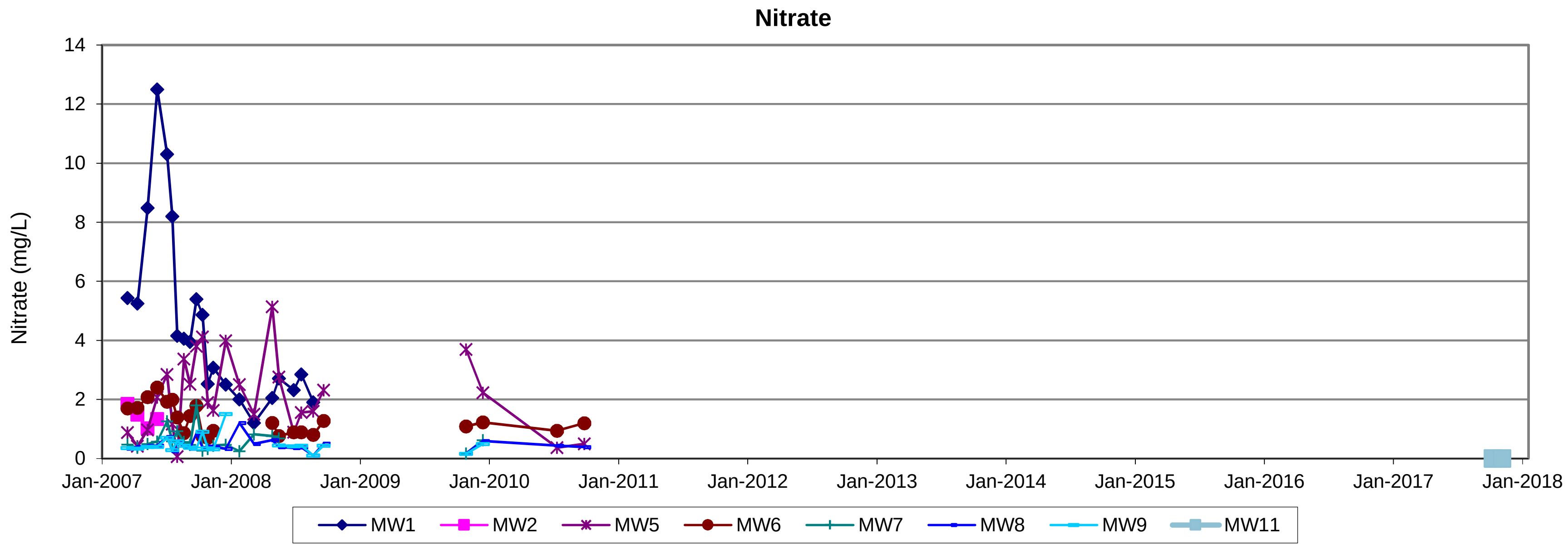
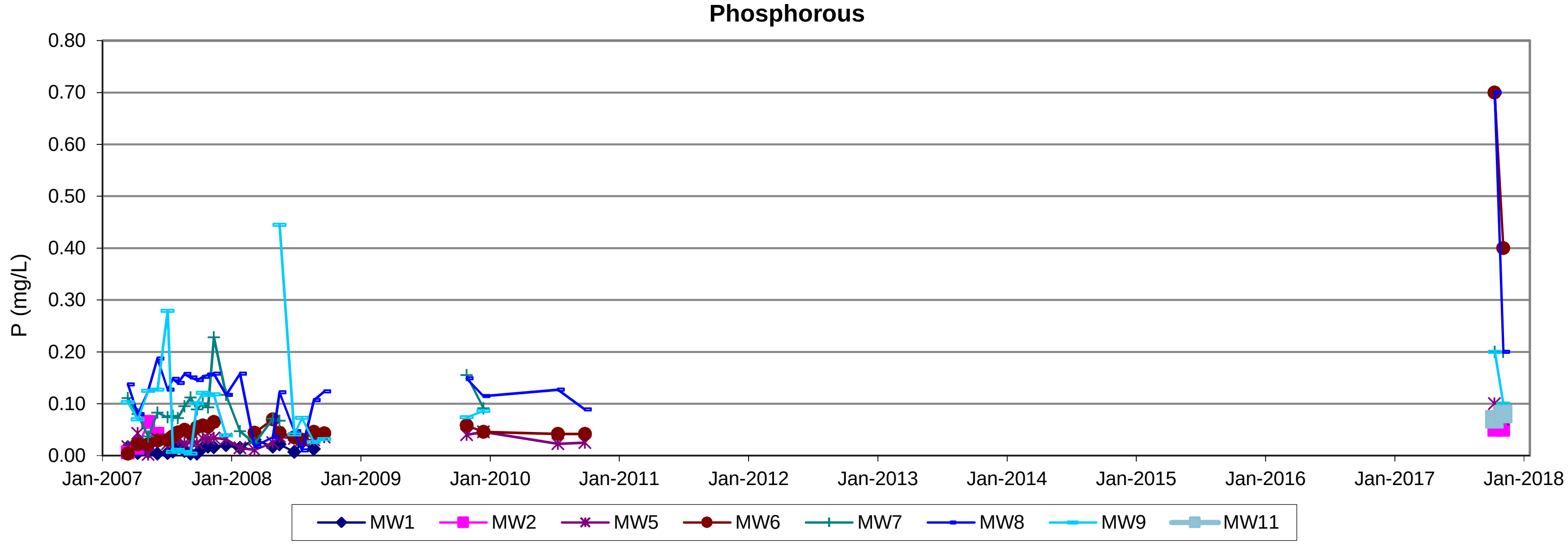
BASELINE GROUNDWATER QUALITY [CHLORIDE HARDNESS] FIGURE 17

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]Hardness Cl

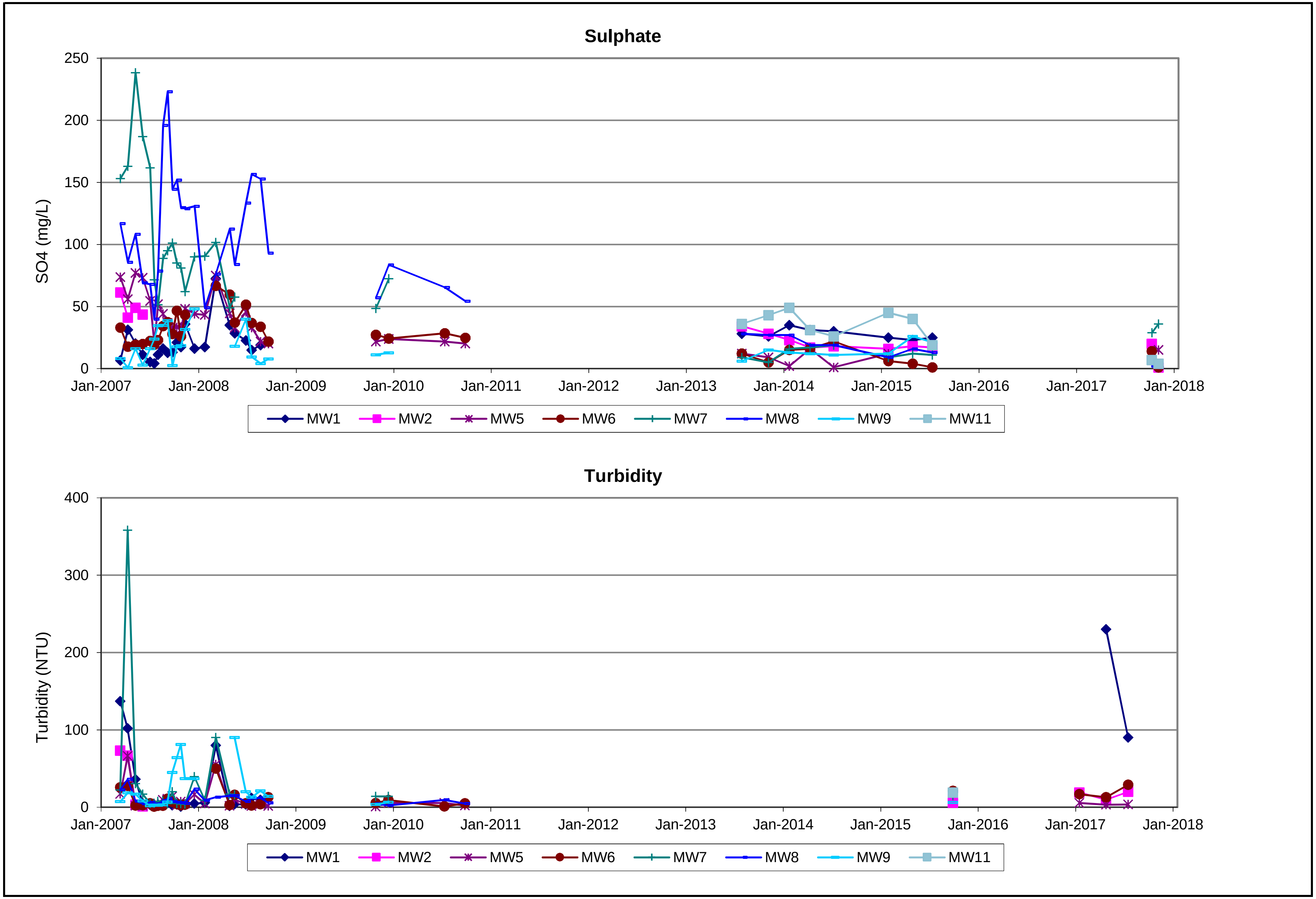




JACOBS

BASELINE GROUNDWATER QUALITY [NITRATE PHOSPHOROUS] FIGURE 18

J:\IE\Projects\04_Eastern\IA147700\02 - Documents\Groundwater Analysis\001c qb\[001c_Comprehensive Water Quality.xlsx]P Nitrate



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BASELINE GROUNDWATER QUALITY [SULPHATE TURBIDITY] FIGURE 19

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Appendix A. DPI Water Review Comments

Department of Primary Industries
Water

Contact Ryan Shepherd
Phone (02) 4904 2650
Email ryan.shepherd@dpi.nsw.gov.au
Our ref OUT17/37203

Rod Johnson
Environmental Operations Manager
Boral
Greystanes House
Lot 107, Clunies Ross Street, Prospect NSW 2148, NSW

via email: Rod.Johnson@boral.com.au

Dear Mr Johnson,

Stockton Sand Quarry- Groundwater Monitoring and Modelling Plan Review

I am writing in reference to your correspondence sent to DPI Water on 27 June 2017, requesting a review of Boral's Stockton Sand Quarry Groundwater Monitoring and Modelling Plan (GMMP). DPI Water has reviewed the GMMP and provides the following comment and recommendations.

The GMMP is lacking in detail for a stand-alone independent document. DPI Water recommends the inclusion of the following.

- A table of the development consent condition which applies to this GMMP and the relevant section in the GMMP with the details outlined and discussed.
- Clearly identify all of the 12 listed monitoring bores on the location figure. It is noted that the current figure only shows 8 new monitoring bores. The older 'GW series' bores are not shown.
- A figure showing the location of the defunct historical monitoring bores.
- Groundwater level, height (m AHD) contour plans or flow nets drawn from the recorded groundwater levels over a series of months or quarters.
- Include cross sections (E-W and N-S) showing groundwater levels, monitoring bores relative position in the section line and levels of extraction.
- Include monitoring of the closest occurrence of both the inland GDE's and the seaward shallow deflation basin lakes GDE's in the water quality monitoring programme.
- Update the Trigger Action Response Plans (TARP) table with timeframes for the actions proposed.
- Note the applicable condition within Schedule 4, Condition 3 which applies to annual reporting. All the points within Condition 3 need to be outlined as required to be addressed with reference to the groundwater monitoring wells.

- Include a note pertaining to the required Independent Environmental Audit in accordance with Schedule 4 Condition 4 of DA 14-6-2005, as a component of reporting in the GMMP.

A DPI Water hydrogeologist can be made available should a meeting be required.

Please contact Ryan Shepherd, Water Regulation Officer (Newcastle) on (02) 4904 2650 or ryan.shepherd@dpi.nsw.gov.au if you have further enquiries regarding this matter.

Yours sincerely

Irene Zinger
Manager
Regulatory Operations - Metro
DPI Water

07 September 2017