HODGSON QUARRY AND PLANT PTY LIMITED

ROBERTS ROAD MAROOTA SAND QUARRY

GROUNDWATER MONITORING PROGRAM

DUNDON CONSULTING PTY LTD

29 SEPTEMBER 2017

(RE-ISSUED 17 JULY 2018)

16-0318-R01D

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1 INTRODUCTION

1.1 Background

The Hodgson Quarry located on Lots 1 & 2, DP228308 and Lot 2, DP312327 at Roberts Road Maroota extracts sand / friable sandstone from the Tertiary aged Maroota Sands Formation paleochannel and the underlying/adjacent Triassic Hawkesbury Sandstone. The quarry has been operating for more than 15 years, under a Development Consent granted by the Minister for Urban Affairs and Planning on 31 May 2000 (DA 267-11-99). The 2000 Consent allowed the quarry to operate for 15 years. A Modification approved on 18 August 2015 (MOD 3) extended the project operation until 31 May 2016.

The original approval was based on an operations plan and resource estimate outlined in the original EIS (Nexus, 1999), but since that time the resource estimate has been increased, and certain of the original extraction methods had proved to be inefficient. A Modification Application was lodged on behalf of the owners on 23 September 2015, which sought to extend the life of the quarry from 15 to 25 years, allowing an extension to 31 May 2025. The Modification also included a number of amendments, which are mostly minor or administrative in nature. This Modification (MOD 2) was approved on 18 March 2016.

Figure 1 shows the status of quarrying as at May 2016. The lowest point in the quarry is currently at about 186 mAHD. This is at the location of the pump suction in the Main Process Dam, as surveyed on 12 September 2017). Maximum depth of excavation reached historically is believed to be approximately 183 mAHD.

1.2 Purpose of this Report

This report is a Groundwater Monitoring Program, which was required under Condition 43 of the Modification Consent dated 18 March 2016. The specific requirements of Condition 43 are detailed in **Section 4.1**.

2 HYDROGEOLOGICAL SETTING

2.1 Rainfall and Evaporation

The monthly average total rainfalls recorded at the nearest Bureau of Meteorology station Number 67014 (Maroota – Old Telegraph Road) are shown in **Table 1**.

Table 1: Monthly Rainfall and Evaporation (mm)

Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	100.1	111.1	102.0	88.3	58.8	91.6	46.0	52.7	53.8	65.2	81.2	80.8	931.6
Median	76.3	79.9	82.2	59.8	43.7	53.0	26.4	22.8	41.3	53.6	70.6	76.6	
Highest	146.1	167.1	220.2	183.1	140.7	172.0	161.0	325.0	110.7	83.1	94.4	92.2	
Mean monthly evaporation	183	138	124	90	65	51	56	84	114	146	150	174	

Station 67014, Maroota (Old Telegraph Road) is located opposite the junction with Roberts Road, and is less than 1 km from the quarry. The station has a long record, covering the period from 1925 to 2016.

The nearest evaporation data available on the BoM website are from Richmond UWS Hawkesbury (Station 067021), and covers the period from 1973 to 2016. Station 067021 is approximately 25 km from the quarry.

2.2 Surface Drainage

The project is located in an incised area of Hawkesbury Sandstone plateau. The topography is therefore quite steeply undulating, with relatively steep valley sides, and massive cliff faces in places.

The natural drainage of the site was originally in a northerly direction, with the local creek system flowing into Coopers Creek approximately 2 km to the north (Woodward-Clyde, 1999). Runoff locally is captured by a number of dams, including two on the quarry property, and the site is therefore largely internal draining.

2.3 Geology

The project is located within the Permian to Triassic Sydney Basin. The quarry recovers sands from the Maroota Sands, which are of Tertiary age and occupy a paleochannel system incised into the underlying Hawkesbury Sandstone and Ashfield Shale basin sediments, as well as from superficial eluvial sands derived from in situ weathering of the Hawkesbury Sandstone. The general stratigraphy for the Maroota area is shown in **Table 2**.

Table 2: Stratigraphic Sequence at the Maroota Project Site (adapted from AGT (2015), after Woodward-Clyde (1999) and Etheridge (1980))

Age	Unit	Lithology	Comment
Quaternary	Soils	Variable	
Tertiary	Maroota Sands	Sand, gravel, clayey sand and clay	-Reworked Hawkesbury Sandstone -Paleochannel sands including clay and ferricrete bands (cemented ironstone) -Outcrops at project site and is the target of quarry activities
Triassic	Ashfield Shale	Shale and laminate	-Not present at project site
	Hawkesbury Sandstone	Quartzose sandstone with shale lenses	-Weathered upper profile (eluvial sands) underlain by competent sandstone -Eluvial sands outcrop to north and west of quarry

2.4 Hydrogeology

Groundwater is present within the Maroota Sands and the underlying Hawkesbury Sandstone. Groundwater in each of these two formations is regionally extensive and forms a regional water table in each. Localised groundwater may also be present in perched aquifers on top of or within the Hawkesbury Sandstone above the regional water table. Thus, localised groundwater may be intersected at elevations above the regional water table levels.

Since the original consent in 2000, two groundwater policies affecting these aquifers have been introduced, namely:

- *The Greater Metropolitan Region Groundwater Sources Water Sharing Plan 2011* (WSP) (NSW Government, 2011); and
- The Aquifer Interference Policy (NSW Office of Water, 2012).

The WSP defines the **Maroota Tertiary Sands Groundwater Source** (MTSGS) which includes the total extent of the Maroota Sands paleochannel formation as well as connected Hawkesbury Sandstone eluvium, as defined by a map contained in the WSP; and the **Sydney Basin Central Groundwater Source** (SBCGS) which includes the Hawkesbury Sandstone formation over an area defined by a map in the WSP. Protection measures for both water sources are detailed in the WSP.

The MTSGS is directly recharged by infiltration of rainfall and local runoff, and downward percolation to the water table. The SBCGS is recharged by infiltration of rainfall and runoff in areas where fresh rock outcrops at the ground surface, or through downward leakage from overlying Maroota Sands, alluvium or eluvium. Groundwater levels in both units display fluctuations that relate to episodic recharge associated with major rainfall events. The recharge response are particularly marked in the Maroota Sands.

No Hawkesbury Sandstone eluvium has been encountered on the Roberts Road Maroota site.

2.5 Groundwater Levels

2.5.1 Maroota Sands

Groundwater levels within the Maroota Sands formation range between approximately 183 mAHD (bore MW11) and 206 mAHD (bore MW1). Bore locations are shown on **Figure 1**.

The deepest reported intersections of Maroota Sands were at MW6, MW10 and MW11, where the top of the Hawkesbury Sandstone was encountered at <173.5 mAHD, 168.1 mAHD and 164 mAHD respectively.

At these locations, the water level in the Maroota Sands on 24 August 2017 was at elevations of 185.3 mAHD, 185.7 mAHD and 184.0 mAHD respectively. All three water levels are lower than the current water level in the main process area dam (Dam 1), where the water level on the same date was 188.1 mAHD. Similar water levels were reported from previous monitoring bores MW3 and MW4 before they were destroyed by the quarry expansion. The water levels in these five bores are believed to be true reflections of the regional water table level within the Maroota Sand aquifer.

Elsewhere on the site, groundwater levels within the Maroota Sands formation are elevated, in the range 192 mAHD to 206 mAHD. These are interpreted to be localised perched groundwater intersections.

2.5.2 Hawkesbury Sandstone

Regional groundwater levels within the Hawkesbury Sandstone range between approximately 170 and 195 mAHD.

The regional groundwater level is interpreted to be at 170-180 mAHD (as illustrated by water levels in bores PB2, GW075003 and GW075004). However, like the Maroota Sands, there is perched groundwater within the Hawkesbury Sandstone, either naturally perched above shale bands or possibly artificially elevated by leakage from the site dams.

2.5.3 Groundwater Level Changes with Time

The groundwater levels are presented as hydrographs in **Figures 2** to **14**, and are discussed in more detail within the discussion of the monitoring results in **Section 4.1**. **Figure 2** is a composite plot of all available manual monitoring data. **Figures 3** to **14** present individual hydrographs plotted against the Monthly Rainfall Cumulative Deviation (RCD) curves for the nearby Maroota BoM rainfall station.

The rainfall cumulative deviation (RCD) curve is derived by calculating the difference between actual monthly total rainfalls and the long-term average monthly rainfalls for the location. These monthly deviations from the average are then accumulated to develop a cumulative deviation curve. A rising trend on the curve results when monthly rainfalls over a period are above the long-term averages, and a downward trend arises when actual rainfalls are below average. The RCD curve for the Maroota BoM station are plotted on **Figures 3** to **14**.

During periods of below average rainfall, the hydrograph of a bore in an aquifer that receives regular recharge shows an overall downward trend, while still showing short-term rises in response to specific rainfall events. In periods of generally above average rainfall, the hydrograph shows an overall rising trend. By comparing the hydrograph with the RCD curve, it is easy to see whether the hydrograph fluctuations are related to rainfall recharge, or other causes, such as an impact from irrigation use or quarry dewatering.

Most hydrographs display a marked fluctuation in response to episodic rainfall recharge and natural discharge. The shallow groundwater responds quite quickly to recharge from larger rainfall events. This is typified by the hydrograph for bore MW1 (**Figure 3**), which shows short-term sharp rises in water level following many of the larger rainfall events, followed by a steady downward recession trend reflecting natural discharge from the shallow perched aquifer. Superimposed on the short-term fluctuations is a longer-term trend, which reflects the overall climatic conditions.

By contrast, the hydrographs for bores in the regional water tables of either the Maroota Sands or the Hawkesbury Sandstone show a much more attenuated response to specific rainfall events. However, even the deeper DPI-Water's Hawkesbury Sandstone bores GW75003 and GW765004 show a clear similarity between their hydrographs and the RCD curves.

There is no evidence from the hydrographs of any trend that could be attributed to any non-climate activity, apart from the possible effect of leakage from the site dams mentioned above.

2.6 Groundwater Quality

Historically, there has been limited sampling for comprehensive laboratory analysis of major ionic composition. MW1 and MW3 were analysed once in 1998, PB2 was analysed once in 2005, MW1 and MW4 annually from 2010 to 2013, and MW5 once in 2013. Groundwater quality was not monitored in any bore between June 2013 and December 2016.

Samples from each of the new monitoring bores MW7 to MW13 were collected in December – January, and submitted to ALS for comprehensive water quality analysis. All monitoring bores, PB1 and the dams were sampled in July 2017 as part of ongoing monitoring.

The results of laboratory analysis for major ion composition are presented in **Table 3**.

Table 3: Laboratory Water Quality Analysis Results

Bore	Aquifer	Date sampled	pH	EC @ 25°C	TDS @ 180°C	OH alkalinity	CO_3 alkalinity	HCO_3 alkalinity	SO_4	Cl	Ca	Mg	Na	K	Total anions	Total cations
Units			pH units	µS/cm	mg/L	mg/L $CaCO_3$	mg/L $CaCO_3$	mg/L $CaCO_3$	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
MW1	Maroota Sands	23 Oct 98	4.96	246	186	<1	<1	4	3	50	3	3	27	3		
		19 Oct 10	4.24	174	150	<1	<1	3.6	4	30	1	6	12	2		
		22 Jun 11	5.18	122	169	<1	<1	4.8	8	143	5	5	19	2		
		20 Jun 12	4.87	174	320	<1	<1	<1	8	31	1	5	13	6		
		19 Jun 13	4.93	312	820	<1	<1	<1	8	59	6	12	22	6	1.83	2.40
		27 Jul 17	4.1	355	247			<5	4	47	5	14	25	4		
MW3	Maroota Sands	23 Oct 98	5.88	381	266	<1	<1	4	3	50	3	9	27	3		
MW4	Maroota Sands	19 Oct 10	4.58	138	100	<1	<1	2.4	1	29	<1	3	16	<1		
		22 Jun 11	3.23	151	99	<1	<1	2.4	2	33	<1	3	17	1		
		20 Jun 12	4.45	141	123	<1	<1	<1	22	26	<1	4	14	1		
		19 Jun 13	4.49	152	95	<1	<1	<1	<1	36	<1	4	16	1	1.02	1.05
MW5	Maroota Sands	19 Jun 13	4.13	140	158	<1	<1	<1	1	34	<1	2	15	<1		
		27 Jul 17	5.1	113	61			5	2	22	1	1	13	2		
MW6	Maroota Sands	27 Jul 17	9.3	103	55			19	<1	18	2	1	12	5		
MW7	Hawkesbury Sandstone	22 Dec 16	7.00	255	282	<1	<1	50	17	27	4	1	46	<1	2.11	2.28
		27 Jul 17	5.3	192	215			12	9	29	<0.5	<0.5	59	<0.5		
MW8	Maroota Sands	20 Jan 17	5.68	161	114	<1	<1	5	1	36	3	3	26	<1	1.14	1.53
		27 Jul 17	5.1	178	118			8	2	37	4	3	26	<0.5		
MW9	Hawkesbury Sandstone	20 Jan 17	6.71	175	134	<1	<1	18	4	32	8	2	25	<1	1.34	1.34
		27 Jul 17	4.9	148	96			<5	2	24	3	2	16	0.8		
MW10	Maroota Sands	20 Jan 17	5.45	184	104	<1	<1	2	<1	42	1	4	30	<1	1.22	1.22
		27 Jul 17	4.7	180	108			<5	<1	39	0.6	4	27	0.6		

Table 3: Laboratory Water Quality Analysis Results

Bore	Aquifer	Date sampled	pH	EC @ 25°C	TDS @ 180°C	OH alkalinity	CO_3 alkalinity	HCO_3 alkalinity	SO_4	Cl	Ca	Mg	Na	K	Total anions	Total cations
MW11	Maroota Sands	20 Jan 17	6.34	169	98	<1	<1	5	7	34	4	2	24	3	1.20	1.20
		27 Jul 17	4.7	154	90			<5	<1	32	<0.5	2	19	1		
MW12	Hawkesbury Sandstone	22 Dec 16	6.12	156	110	<1	<1	8	12	21	2	<1	23	3	1.00	1.18
		27 Jul 17	5.3	96	72			11	7	13	2	0.9	12	<0.5		
MW13	Maroota Sands	16 Dec 16	6.65	204	105	<1	<1	17	5	34	4	2	26	3	1.40	1.57
		27 Jul 17	4.9	134	92			<5	1	27	2	2	16	<0.5		
PB1	Hawkesbury Sandstone	27 Jul 17	4.6	148	88			<5	<1	30	<0.5	3	19	0.7		
PB2	Hawkesbury Sandstone	12 Sep 05	4.52	113	77			<1	<1	34	<1	3	17	<1		
Process Dam 1	-	27 Jul 17	4.5	134	90			<5	4	25	<0.5	2	16	2		
Tailings Dam 2	-	27 Jul 17	4.5	139	75			<5	4	25	<0.5	2	17	3		
Nursery Dam 3	-	27 Jul 17	6.6	133	77			13	9	20	3	3	13	4		
Farm Dam 4	-	27 Jul 17	6.6	116	63			15	3	20	2	3	13	2		
Former Tailings Dam	-	27 Jul 17	4.9	77	49			<5	2	15	<0.5	1	11	1		

3 HISTORICAL GROUNDWATER MONITORING

3.1 Monitoring Bore Network

Monitoring bores were first installed on the site in 1998 as part of the groundwater investigations undertaken to support the EIS for the initial project development application. Further monitoring bores have been installed in subsequent years to either expand the monitoring network or replace bores lost or overtaken by sand extraction activities.

Table 4 list details of all monitoring bores that have been installed over the life of the project.

Table 4 also includes details of two water supply production bores, one of which (PB1) has been used to supply process water to the quarrying operations. The other (PB2) is used for water supply at the nursery located at the north-western corner of the property, and does not form part of the quarry operations. The two production bores are significantly deeper than the base of the quarry, and draw water from the underlying Hawkesbury Sandstone rather than the Maroota Sands aquifer.

Also listed in **Table 4** are details of two DPI-Water monitoring bores, which are located within the property close to MW5 near the south-western property boundary.

The monitoring program undertaken to date has included:

- Water levels measured in monitoring bores both manually and using dataloggers
- Water sampling from bores to enable basic water quality parameters to be measured on a regular basis
- Intermittent measurements of water levels and water quality from water in the pit pond.

The locations of all monitoring bores and other bores on the site are shown on **Figure 1.**

Table 4: Monitoring Bores

Bore	Date Drilled	Registered Bore No	Location (MGA)		Ground Level	Stick-up	Bore Depth	Base of Bore	Screen Interval		Formation Screened	Salinity TDS	Water Level (August 2017)		Current Status
			Easting	Northing	mAHD	m	m	mAHD	mBGL	(mAHD)		mg/L	m BGL	mAHD	
MW1	22 Oct 1998	GW101674	313743	6295740	213.43	0.71	11.9	201.5	4.9-10.9	202.5-208.5	Hawkesbury Sandstone	186	16.71	206.74	Active
MW2	20 Oct 1998	GW101675	313899	6295281	226.89	0.80	26.5	200.4	18.6-24.6	202.3-208.3	Maroota Sands (perched)		>20.8	*203.1	Dry (blocked at 20.8m).
MW3	21 Oct 1998	GW101676	*9802.78	*5916.37	202.43	0.82	21.9	180.53	14.9-20.9	181.5-187.5	Maroota Sands (perched)	266	*18.54	*183.5	Mined out
MW4	Dec 2009	GW114209	314121	6295389	*~212*	0.57	28.5	*~156*	19.5-28.5	*~156-165*	Maroota Sands		*24.8	*187.9	Mined out
MW5	Apr 2013	GW114208	313893	6295286	227.00	0.80	44.0 (open to 35.3m on 24/8/17)	183.0 (drilled) 192.7 (now)	32.0-44.0	183-195	Maroota Sands (perched)		34.35	192.65	No longer monitored (blocked at 25.3m).
MW6	23 Jan 2015		314200	6295366	202.47	0.70	29.0	173.5	24-29	173.5-177.5	Maroota Sands		17.20	185.27	Active
MW7	9 Dec 2016		313761	6295741	212.96	0.48	37.0 (sealed below 36.0)	176.0 (open to 177.0)	30-36	177-183	Hawkesbury Sandstone		28.68	184.28	Active
MW8	6 Dec 2016		313890	6295287	227.01	0.42	49.0 (sealed below 40.0)	178.0 (open to 187.0)	37-40	187-190	Maroota Sands		34.15	192.86	Active
MW9	19 Dec 2016		313916	6295356	225.58	0.53	50.5	175.1	44.5-50.5	175-181	Hawkesbury Sandstone		37.35	188.23	Active
MW10	14 Dec 2016		314122	6295187	217.12	0.48	49.0 (sealed below 47.0)	168.1 (open to 170.1)	44-47	170-173	Maroota Sands		31.45	185.64	Active

Bore	Date Drilled	Registered Bore No	Location (MGA)		Ground Level	Stick-up	Bore Depth	Base of Bore	Screen Interval		Formation Screened	Salinity TDS	Water Level (August 2017)		Current Status
			Easting	Northing	mAHD	m	m	mAHD	mBGL	(mAHD)		mg/L	m BGL	mAHD	
MW11	21 Dec 2016		314176	6295789	192.35	0.71	29.0 (sealed below 28.5)	163.3 (open to 163.8)	24-28.5	164-168.5	Maroota Sands		8.68	183.95	Active
MW12	8 Dec 2016		313902	6295584	210.28	0.47	27 (sealed below 26)	183.3 (open to 184.3)	23-26	184-187	Maroota Sands		15.34	194.94	Active
MW13	7 Dec 2016		313916	6295358	225.50	0.46	31 (sealed below 30.5)	*194.5 (open to 195.0)*	27.5-30.5	195-198	Maroota Sands		26.15	199.35	Active
PT84PB1	6 Jul 1999	GW105835	314116	6295574	*~193.5*	0.70	126.1	*~67.4*	Open hole below 28.8	*<164.7*	Hawkesbury Sandstone		*14.8	*~179.5*	Pumping for water supply
PT84PB2	19 Feb 1999	GW102451	313735	6295514	*~212.5*	0.70	156.5	*~56.0*	Open to sandstone below 53	*<202.1*	Hawkesbury Sandstone		*50.9	*~174.4*	Pumping for water supply
	1 Jul 1997	GW075003	313868	6295299	225.48	0.88	109.0	116.5	72-75	150.5-153.5	Hawkesbury Sandstone	90 µS/cm	*46.1	*179.36	NOW monitor bore
	7 Jul 1997	GW075004	313885	6295286	226.95	0.87	60.0	166.95	54-57	167.0-173.0	Hawkesbury Sandstone	150 µS/cm	40.11	186.84	NOW monitor bore

* Most recent available water levels – MW2 (2000); MW3 (2009); MW4 (2013); PB1 (1999); PB2 (2002); GW075003 (2015).

3.2 Available Monitoring Data

The groundwater monitoring data cover the period 1998 to 2017. Availability of bores through this period of time is detailed in **Table 5**.

Table 5: Monitoring Bore Availability – 1998 to 2017

Year	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	MW12	MW13	PB1	PB2
1998															
1999															
2000															
2001															
2002															
2003															
2004															
2005															
2006															
2007															
2008															
2009															
2010															
2011															
2012															
2013															
2014															
2015															
2016															
2017															

Prior to the drilling of new bores in December 2016, only bores MW1, MW5 and MW6 were still operational. MW2 became obstructed above the water level and was replaced in 2013 by MW5. MW3 and MW4 were mined out, and were replaced in 2015 by MW6.

MW5 has now been removed from the monitoring network, as it was found to be obstructed at a depth about 9m above the original constructed depth, albeit still below the water level in the bore. The new bore MW8 has replaced MW5 in the network, as both are screened in Maroota Sands (MW8 is fully penetrating, but MW5 was not), and both have reported similar water levels and identical trends through the period while both were being monitored.

All the available groundwater levels are presented as hydrographs on **Figures 2 to 14**. The data included both manual and datalogger records. Data from old bores have been reproduced from past reports prepared by URS (formerly known as Woodward-Clyde).

Water levels are recorded manually approximately monthly. Automatic dataloggers have been installed in most bores from time to time, and set to record water level once daily. Dataloggers are currently installed in bores MW1 and MW6 to MW13. It is understood that dataloggers are also installed in the two DPI-Water monitoring bores.

MONITORING REQUIREMENTS

The Modification 2 Consent includes the following in relation to groundwater monitoring:

> *"**Groundwater Monitoring***
>
> *43. The Applicant shall prepare a Groundwater Monitoring Program for the development to the satisfaction of the Secretary. This program must:*
>
> *(a) Be prepared in consultation with DPI-Water and be submitted to the Secretary for approval within four months of the date of approval of Modification 2;*
>
> *(b) Include proposed construction of a network of at least five active monitoring bores around the south-eastern, southern, western and north-western boundaries of the extraction area (but outside of the overall extraction footprint) in proximity to extraction Phases 1 to 6 as identified in Modification 2, to collect groundwater level monitoring data from the regional aquifer;*
>
> *(c) Include proposed construction to deepen (or replace) PT84MW1 in order that a bore in that general area monitors the regional aquifer; and*
>
> *(d) Include potential construction of active monitoring bores within the largest components of at least the two forthcoming extraction Phases (on a rolling basis), each to collect at least 2 years of continuous baseline groundwater monitoring data prior to extraction commencing in that Phase.*
>
> *44. The results of the Groundwater Monitoring Program shall be reported (to) the Department and DPI-Water, using contour plans depicting the surface topography, updated contour maps of the wet weather high groundwater level of the regional aquifer and proposed depth of extraction for each extraction Phase. Reporting is to occur on a six monthly basis for the duration of extractive operations, and throughout rehabilitation of the site, unless otherwise agreed with the Secretary.*
>
> *The Applicant shall implement the Groundwater Monitoring Program as approved from time to time by the Secretary."*

The forward extraction schedule for the site is shown on **Figure 15**. This includes the locations of bores installed within the next two stages planned for extraction at the time the bores were drilled (December 2016).

The term "regional groundwater table" is applied to each of the MTSGS and the SBCGS. The groundwater levels in the respective groundwater sources are different, as there is limited hydraulic connection between the two at the local scale, although regionally the two are probably in reasonable hydraulic connection.

As reported in **Section 2.5**, regional groundwater level in the Maroota Sands is generally between 180 to 185 mAHD, in the Hawkesbury Sandstone between 160 and 185 mAHD. There is also localised perched groundwater present either within or above the Hawkesbury Sandstone at elevations above the regional groundwater table levels. Finally, there is a clay aquitard towards the base of the Maroota Sands which is believed to support perched occurrence above the Maroota Sands regional groundwater level.

Under the Consent Approval, sand extraction within the approved quarry will include predominantly Maroota Sands, but also friable sandstone from the Hawkesbury Sandstone as well. The quarry perimeter is defined generally by the surface extent of the Maroota Sands, and in the deepest parts of the paleochannel, the quarry will extend to a depth short of the base of the Maroota Sands. However, the depth of Maroota Sands reduces away from the central part of the paleochannel, and near the margins, extraction will include an increasing component of sandstone from beneath the base of the sands.

Accordingly, it is interpreted that the above Consent Conditions require the monitoring network to include both the Maroota Sands and the underlying Hawkesbury Sandstone.

3.3 Wet Weather High Groundwater Level

The Development Consent defines the *'Wet weather high groundwater level'* as *'The rolling average of all recorded groundwater level measurements at any monitoring location on the site, as first recorded following any rainfall event of at least 50 mm over any 24-hour period, and as contour mapped using this data'.*

In order to assess the wet weather high groundwater level, the historical daily rainfall records for the nearest BoM rainfall recording station have been analysed to determine the best current understanding of the relevant level at each of the sites that have been monitored over the quarry life.

Since 1999, the recorded rainfall at the nearest BoM station 67014 (Maroota Old telegraph Road) have included approximately 39 days when the total daily rainfall exceeded 50 mm, as listed in **Table 6**. **Table 6** also shows the peak water level measured at each bore after each daily rainfall of 50mm or more. Both current and past bores are included in the table.

All bores are included in **Table 6**, although only those bores which are reporting water levels from the regional groundwater tables of either the Maroota Sands or the Hawkesbury Sandstone aquifer have been used to derive the regional wet weather high groundwater level for the two aquifers.

Contours of the wet weather high groundwater level, as determined after installation of the new monitoring bores in December 2016 and updated in September 2017, are depicted for the Maroota Sands and the Hawkesbury Sandstone on **Figures 16** and **17** respectively.

It is interpreted that the Maroota Sands regional water table is only present within the central part of the property, as the top of the Hawkesbury Sandstone rises above this water table level across the eastern and western parts of the property. Hawkesbury Sandstone is exposed on the eastern flank of the Main Process Dam. The lines marking the limit of saturated Maroota Sands are shown on **Figure 16**. To the west and east of this central deep zone, there is groundwater present in perched zones within the Maroota Sands, but the recent drilling program has shown that these zones are both limited in area and of limited saturated thickness.

The contours on **Figure 16** suggest a relatively gentle gradient to the north/north-northeast, down the likely axis of the palaeovalley.

From **Figure 16**, the wet weather high groundwater level beneath the Main Process Dam, which is the lowest part of the quarry, range between approximately 184.3 mAHD (northern side) and 184.7 mAHD (southern side). The depth of the excavation obscured from view by the water in the Process Dam was determined by a depth survey conducted by boat on 12 September 2017. This survey revealed that the base of water in the dam was between 187.1 mAHD and 187.6 mAHD across the dam floor, apart from a small localised area near the north-west corner adjacent to the water supply pump inlet, where the bottom reaches a low point of 184.8 mAHD.

Accordingly, every part of the quarry excavation is currently above the wet weather high groundwater level for the regional Maroota Sands. Apart from the small localised area around the pump inlet, the quarry floor is at least 3m above the wet weather high groundwater level.

The regional water table (or potentiometric surface) of the Hawkesbury Sandstone has been encountered only in three of the deeper bores on site, namely PB1, PB2 and GW075003. Other monitoring bores completed in Hawkesbury Sandstone are considered to be reporting perched groundwater levels.

Table 6: Maroota Daily Rainfalls Exceeding 50mm – 1999 to 2017

Year	Date	Rainfall	Comment	Peak water level after >50mm/day rainfall (mAHD)												
				MW1	MW2	*MW3	*MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	MW12	MW13
Collar Elevation (mAHD)				213.43	226.89	*202.43	*212.00	227.00	202.47	212.96	227.01	225.58	217.12	192.35	210.28	225.50
Screened Interval (mAHD)				*202-208		*181-187	*183-192	183-195	173-178	177-183	187-190	175-181	170-173	164-168	184-187	195-198
1999	24 October	59.0		208.4	203.1	183.4										
2000	9 March	54.0		208.2		182.8										
	17 November	56.0		207.4		-										
2001	31 January	53.0		207.6		182.9										
	6 February	50.0		207.6		182.9										
	20-21 March	55.0	2 day total	208.2		182.9										
2002	5 February	60.0		207.4		183.3										
	30 March	56.0		207.6		183.3										
	10 December	55.0		207.0		-										
2004	25-26 February	105.0	2 day total	206.6		181.0										
	21-22 October	61.0	2 day total	-		181.0										
2005	2-3 February	50.0	2 day total	-		180.5										
	21 February	60.0		-		180.7										
	23-27 November	55.0	5 day total	-		181.0										
2006	7 September	65.0		205.0		-										
2007	13 February	52.2		205.1		182.1										

Year	Date	Rainfall	Comment	Peak water level after >50mm/day rainfall (mAHD)												
				MW1	MW2	*MW3	*MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	MW12	MW13
	9 June	172.0		206.0		182.1										
	20 July	136.5		206.6		-										
	6 December	50.6		206.7		-										
2008	5 June	51.0		207.8		183.1										
2009	2 April	51.0		206.6		183.5										
	22 May	78.0		206.7		183.5										
2010	7 February	75.0		206.0			*186.6									
2011	20 August	74.5		206.7			-									
2012	18 April	52.0		207.5			*189.3									
2013	29 January	118.0		206.4			*187.9									
	23 February	72.0	154.4 mm over 2 days (23-24 February 2013)	207.2			*187.9									
	24 February	82.4		207.2			*187.9									
2014	19 August	52.6		205.8				*192.6								
	7 December	55.0		205.8				*192.8								
2015	21 April	161.0	279 mm over 2 days (21 to 22 April 2015)	206.9				*192.3	183.4							
	22 April	118.0		206.9				*192.3	183.4							
	22 December	63.6		206.7				192.6	185.4							
2016	5 January	108.0	221.2 mm over 4 days (4 to 7 January 2016)	207.7				*192.6	185.4							
	6 January	68.0		207.7				*192.6	185.4							

Year	Date	Rainfall	Comment	Peak water level after >50mm/day rainfall (mAHD)												
				MW1	**MW2**	***MW3**	***MW4**	**MW5**	**MW6**	**MW7**	**MW8**	**MW9**	**MW10**	**MW11**	**MW12**	**MW13**
	5 June	69.0	147.4 mm over 3 days (4 to 6 June 2016)	206.9				*193.1	185.8							
	6 June	68.0		206.9				*193.1	185.8							
2017	18 March	54.8	149.4 mm over 6 days (14 to 19 March 2017)	206.9				192.6	185.0		192.9	188.8	185.3	183.9	194.7	199.4
	31 March	55.0		206.9				192.6	185.1		192.9	188.8	185.3	183.9	194.7	199.4
Average peak water level after >50mm/day rainfall event				**206.9**	**203.1**	**182.35**	**187.9**	**192.65**	**185.0**	**-**	192.9	188.8	185.3	183.9	194.7	199.4

* Collar elevation not yet surveyed. Elevation estimated from survey contours. MW2 obstructed. MW3 and MW4 now mined out.

The water levels in the three deep bores have been used to construct tentative potentiometric surface contours across part of the site (**Figure 17**). The contours suggest a gradient to the northwest. On the eastern and western parts of the quarry site, the regional Hawkesbury Sandstone potentiometric surface lies below the top of the sandstone, whereas in the central part of the site, the potentiometric surface is above the top of the Hawkesbury Sandstone, and below the base of the quarry.

The contours on **Figure 17** are considered to lack a high degree of precision, due to:

- Lack of recent data – the most recent available data are:
    - PB1 – 19 August 1999
    - PB2 – 5 July 2002
    - GW075003 – 20 August 2015;
- PB1 and PB2 are both completed as open hole through the Hawkesbury Sandstone, and therefoe the water levels may be a composite from a number of separate inflow zones; and
- Accurate survey levels of the collar elevations are not available for these three bores. Collar elevations were estimated from surface topographic contours.

In any case, the water levels in the three Hawkesbury Sandstone bores are all well below the Maroota Sands regional groundwater table, and hence below the quarry floor.

It is recommended that all three be accurately survey levelled, and that attempts be made to enable water level measurement. PB1 and PB2 are currently sealed at the surface by the pump headworks, while the two DPI-Water bores are locked. An approach should be made to DPI-Water to obtain regular downloads of water levels from their bores on a timely basis. These measures would enable the level of precision in the regional groundwater contours to be improved.

4 MONITORING PROGRAM

The monitoring program described below is based largely on the details proposed in Section 5 of AGWT (2015), and modified as required by the Consent Conditions. The program includes monitoring of both groundwater levels and groundwater quality. The objective is to detect any adverse change in water levels or quality of either the Maroota Tertiary Sands or the Sydney Basin Central groundwater sources.

The criteria for assessing adverse impacts are detailed in **Table 7**. These are intended to ensure that management of the groundwater resources complies with the Aquifer Interference Policy (AIP) and The Greater Metropolitan Region Groundwater Sources Water Sharing Plan (WSP), and the specific rules applying to the two water sources present at the quarry site.

Table 7: Impact Assessment Criteria

Potential Impact	Impact Observed	Criteria for Response Action	Response Action – Investigation by Authorised Hydrogeologist
Groundwater inflows to quarry	Observed seepage from the quarry walls or floor	Any observed seepage.	Investigate source to determine whether perched or regional groundwater, or seepage from site dams.
Groundwater levels	Cumulative change in regional groundwater levels greater than the natural pre-quarrying climatic variation	Cumulative change in groundwater levels more than 10% greater than natural climatic variation through the period of monitoring.	Investigate to confirm the quarry as the cause of impact. Develop a mitigation strategy and consult with DPI-Water for approval.
Groundwater quality	Change in water quality	Observed water quality that changes the beneficial use value of a water sample, exhibited by a salinity more than 20% above the long-term maximum salinity value, or pH more than 10% above or below the historical range, in two consecutive monitoring events.	Investigate to confirm the quarry as the cause of impact. Develop a mitigation strategy and consult with DPI-Water for approval.
Other groundwater users	Reported decrease in yield or groundwater level, or water quality	Reported loss of more than 10% of pre-quarrying yield; observed water quality parameter	Investigate to confirm the quarry as the cause of impact. Develop a mitigation strategy and consult with DPI-Water for approval. Mitigation may include provision of replacement water supply, if it demonstrated that quarry has adversely affected yield or quality of an existing neighbour's water supply.

The monitoring regime is detailed in **Table 8**.

Table 8: Monitoring Regime

Monitoring Bores and Ponds	Purpose	Continuous	Weekly	Three-Monthly	Annually
MW1, MW6, MW7, MW8, MW9, MW10, MW11, MW12 and MW13. Process area pond (Dam 1), tailings dam (Dam 2), nursery dam (Dam 3) and farm dam (Dam 4).	Ensure base level of quarry does not exceed 2m above regional wet weather high groundwater levels	Automatic piezometers with datalogger		Manual water level to confirm and calibrate datalogger	
	Ensure water quality of MTSGS and SBCGS are not adversely impacted			Field measure-ments of EC, TDS, pH	Lab analysis of oil and grease
	Ensure no seepage inflows (other than perched groundwater)	Daily observation to detect any seepage	If observed, sample for water quality. If measurable, monitor volume of seepage inflows		
Bores MW9, MW12 and MW13, and future Stage bores as detailed in Consent.	Establish baseline levels of regional water in future quarry stages	Automatic piezometer with datalogger		Manual water level to confirm and calibrate datalogger	

5 REPORTING

The results of the Groundwater Monitoring Program will be reported to the Department of Planning and Environment (DPE) and DPI-Water, in accordance with Condition 44 of the Project Approval, and as detailed in the Groundwater Management Plan (Dundon, 2017)..

A report will be prepared six-monthly during the period of extraction operations and post-project rehabilitation, and will include contour plans of surface topography, updated wet weather high groundwater levels of the regional aquifer, and proposed depth of extraction for each extraction Phase.

6 REFERENCES

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Australian Groundwater Technologies (AGT), 2015. *Hodgson Quarry Groundwater Assessment, Roberts Road, Maroota.* Report prepared 9 April 2015.

Bureau of Meteorology. Daily rainfall data from Station67014, Maroota (Old Telegraph Road).

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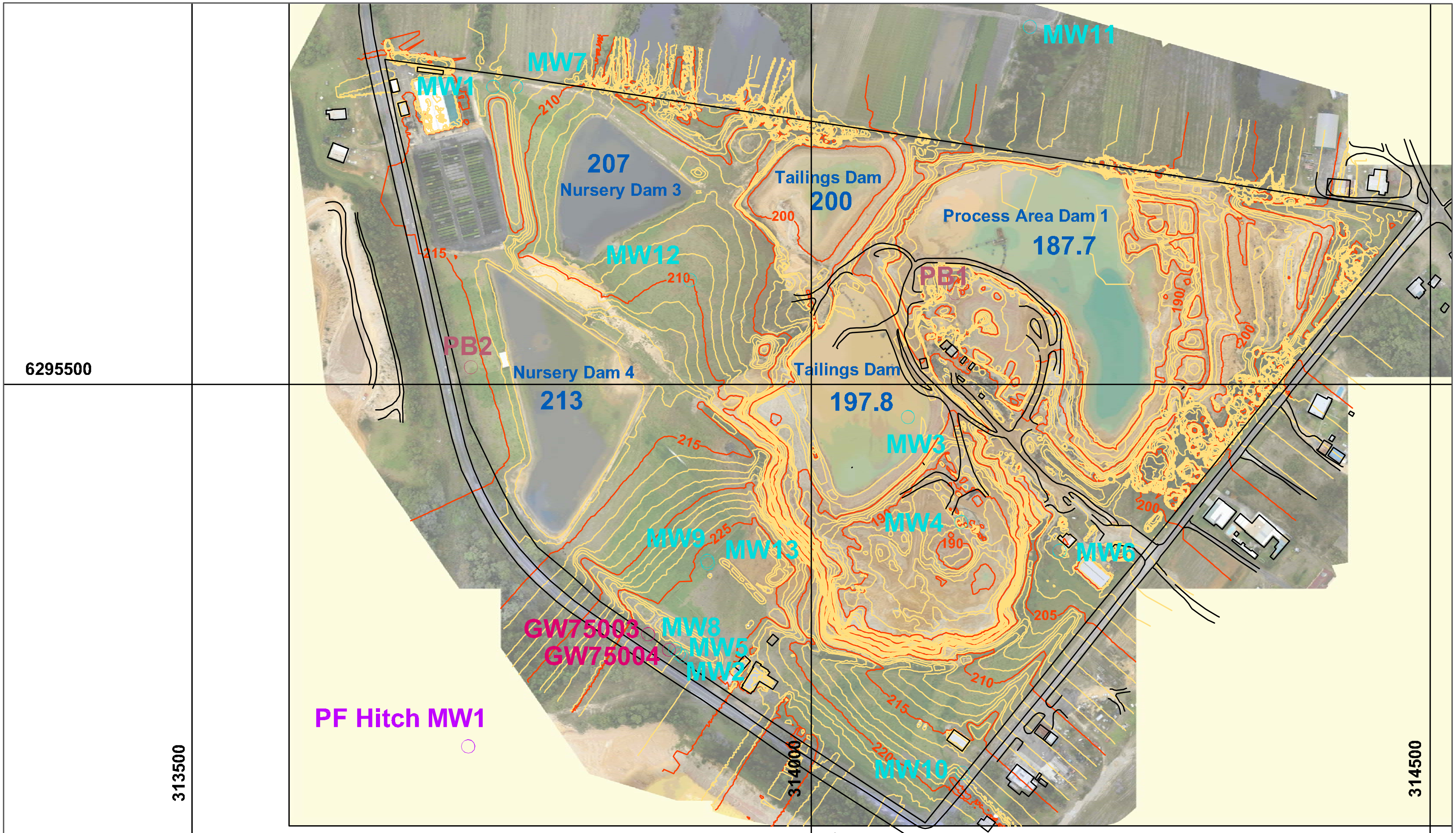


LEGEND:

Surface contorus - 5m
Surface contours - 1m
Dam 4 Site Dams
188 Dam water level (mAHD)

DATE:	23 October 2017	SCALE:	
PROJECT NO:	06-0318	AUTHOR:	PD
DRAWING NO:	06-0318-001b	REVISION:	B

Dundon Consulting Pty Ltd

Hodgson Quarry and Plant Pty Ltd

ROBERTS ROAD MAROOTA SAND QUARRY
Surface Contours and Quarry Status
at June 2016

Figure 1

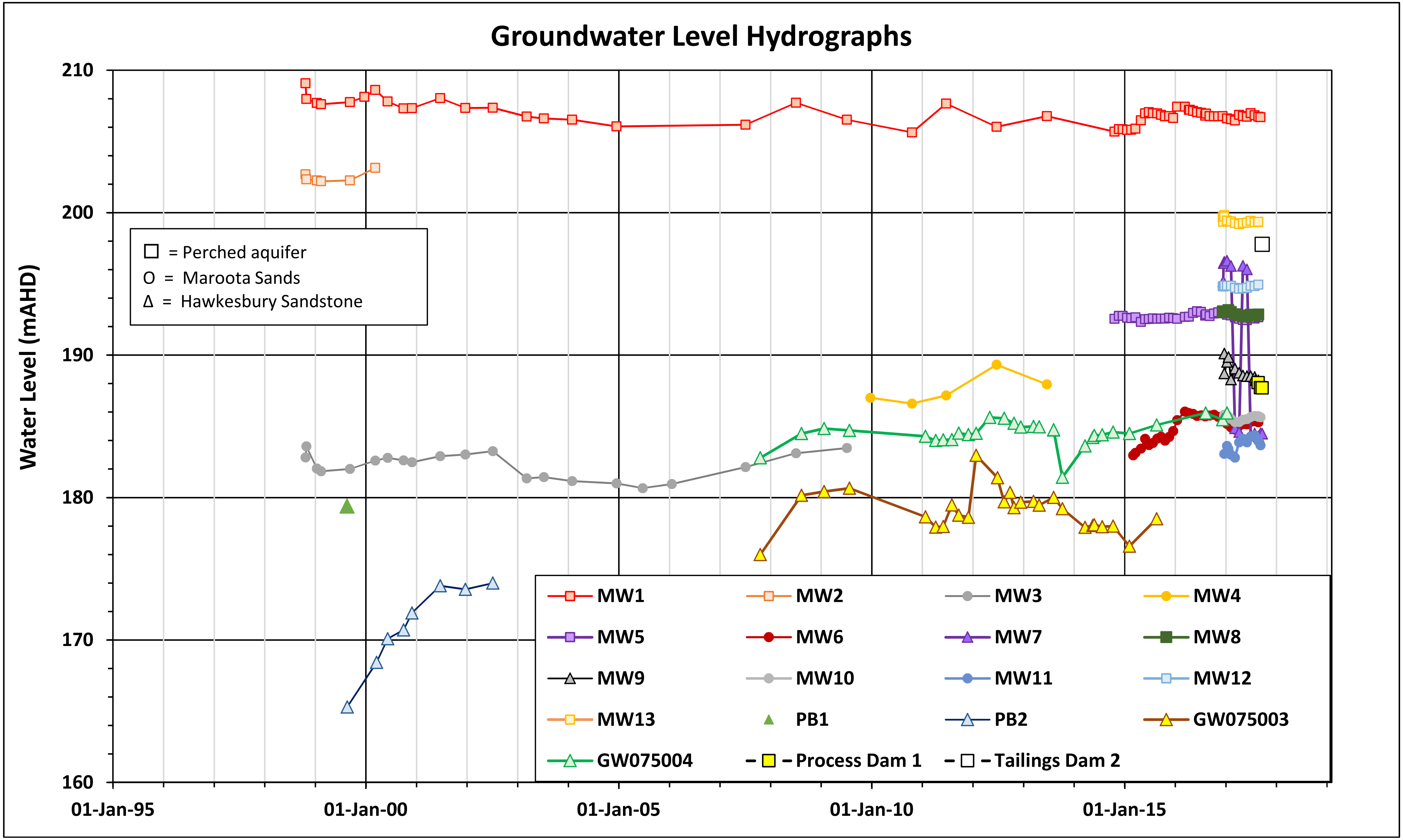


Figure 2: Bore Water Level Hydrographs - Composite Plot

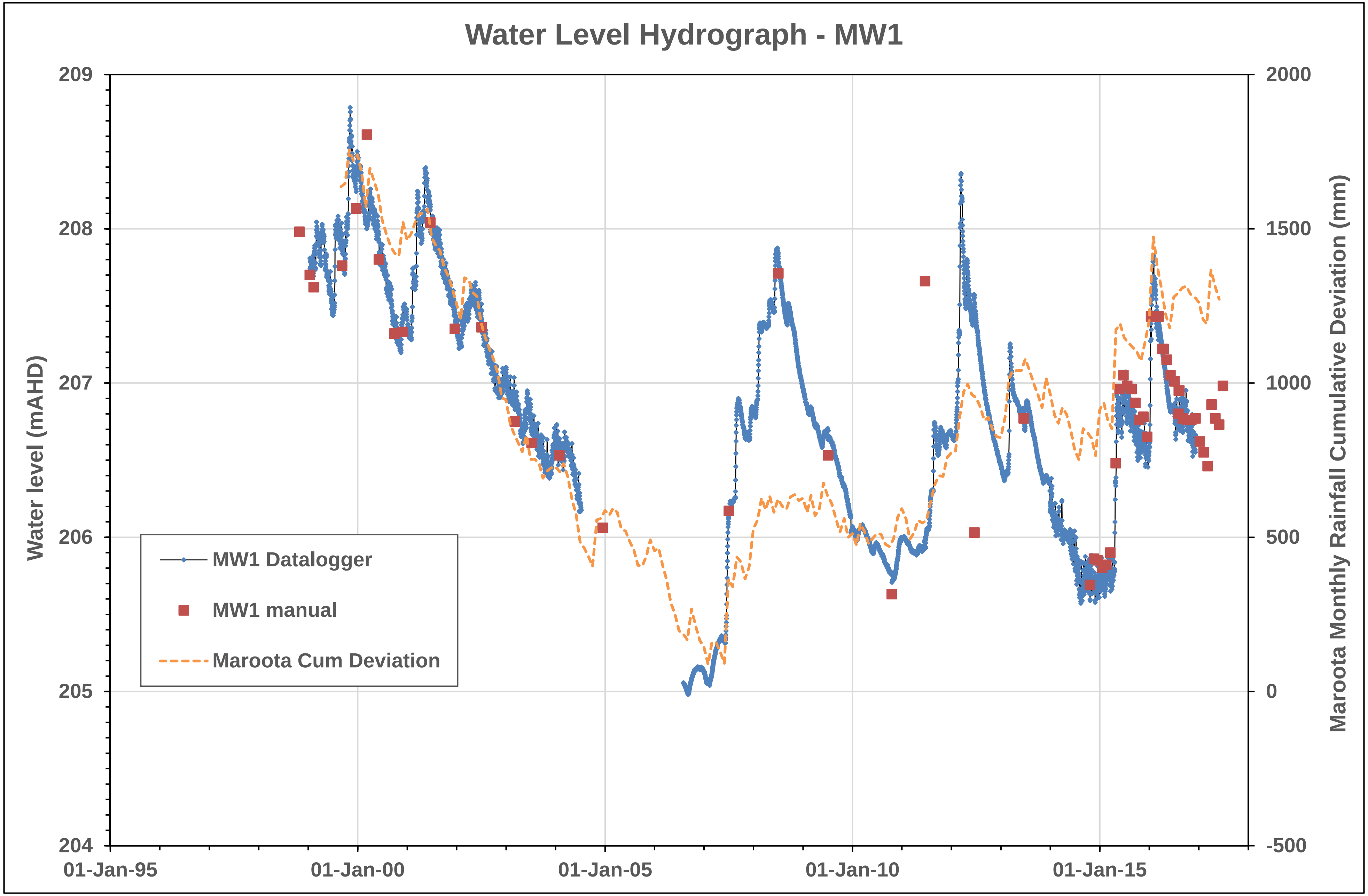


Figure 3: Water Level Hydrograph - MW1

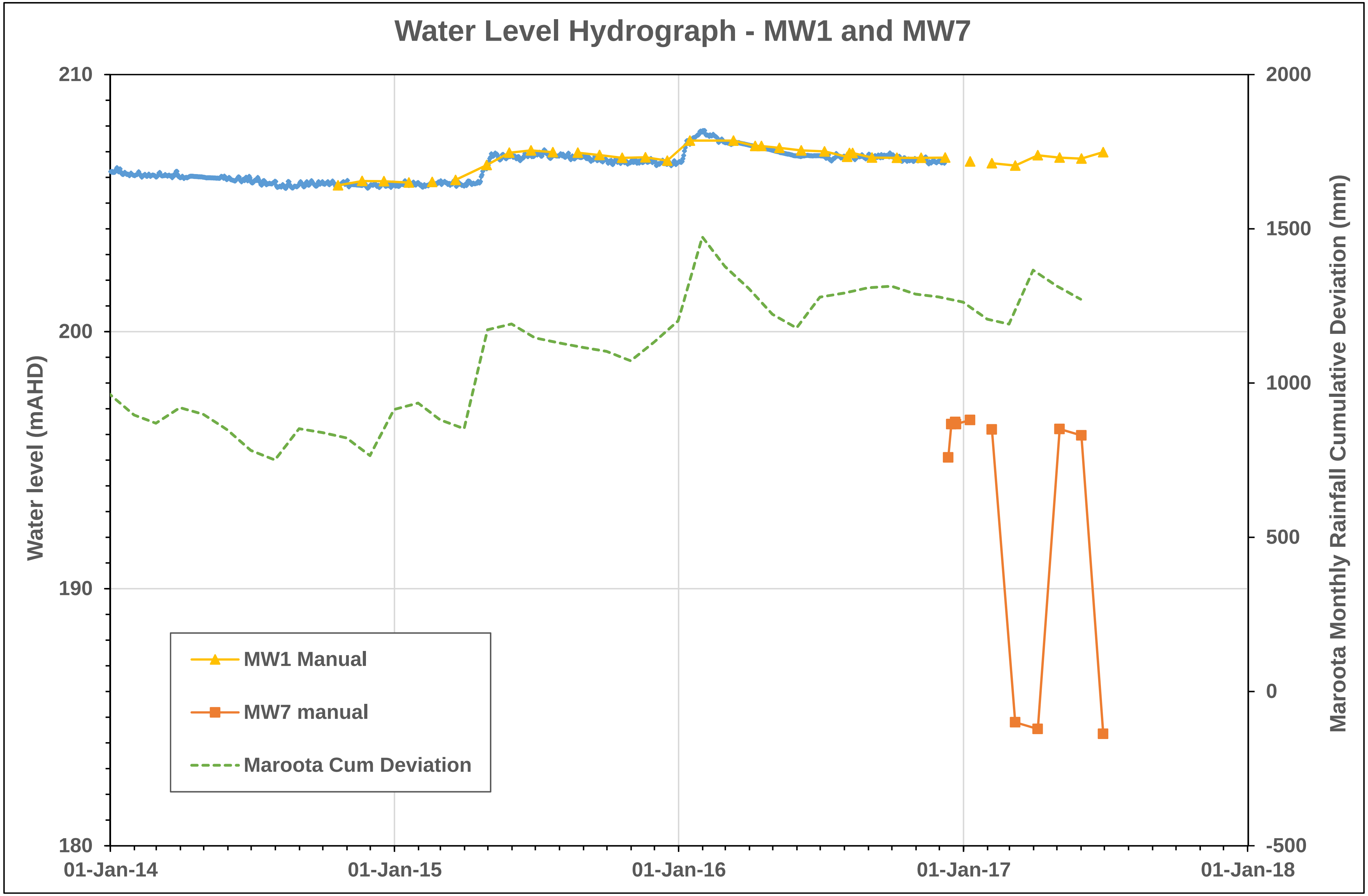


Figure 4: Water Level Hydrographs - MW1 and MW7

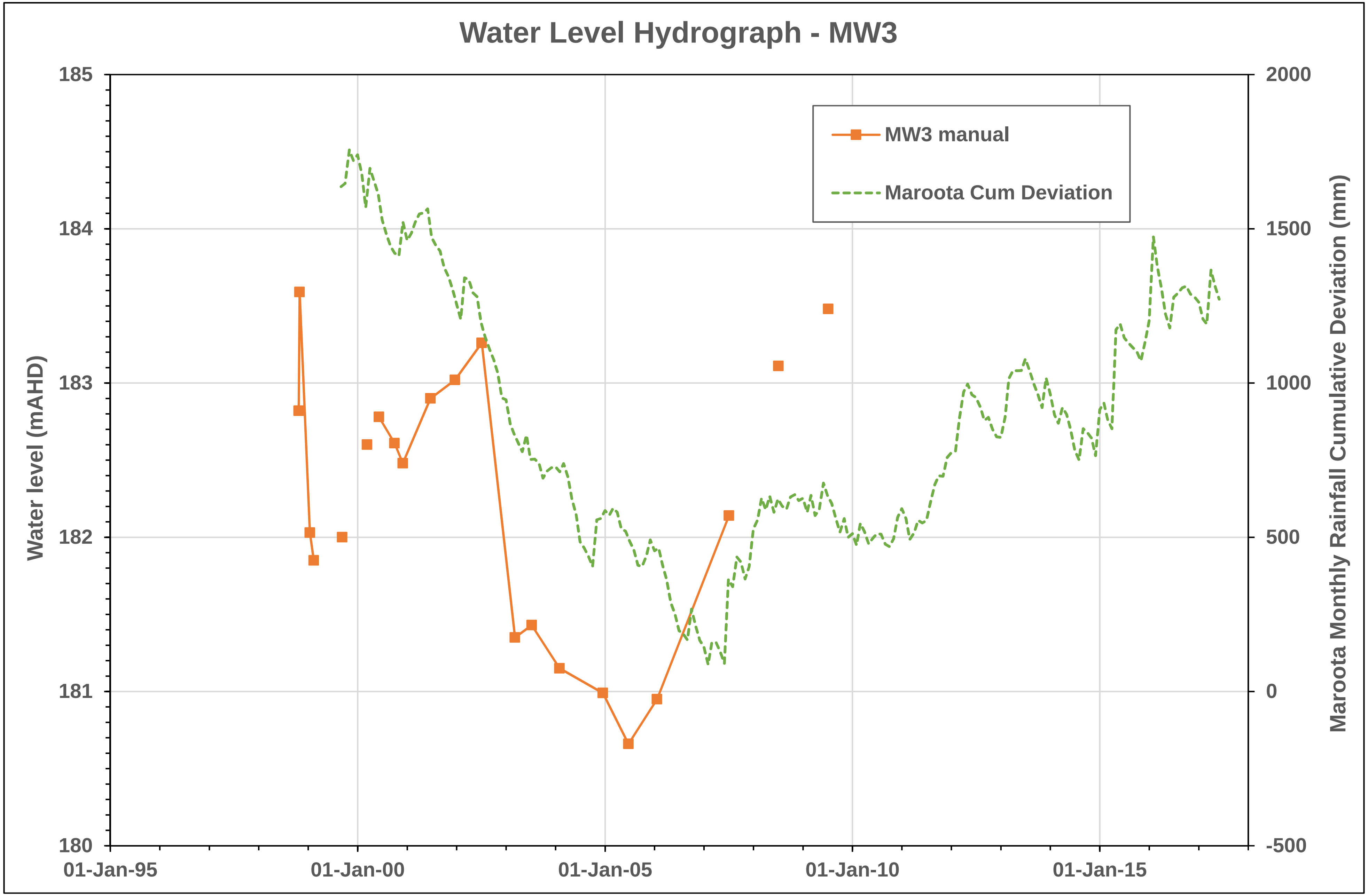


Figure 5: Water Level Hydrograph - MW3

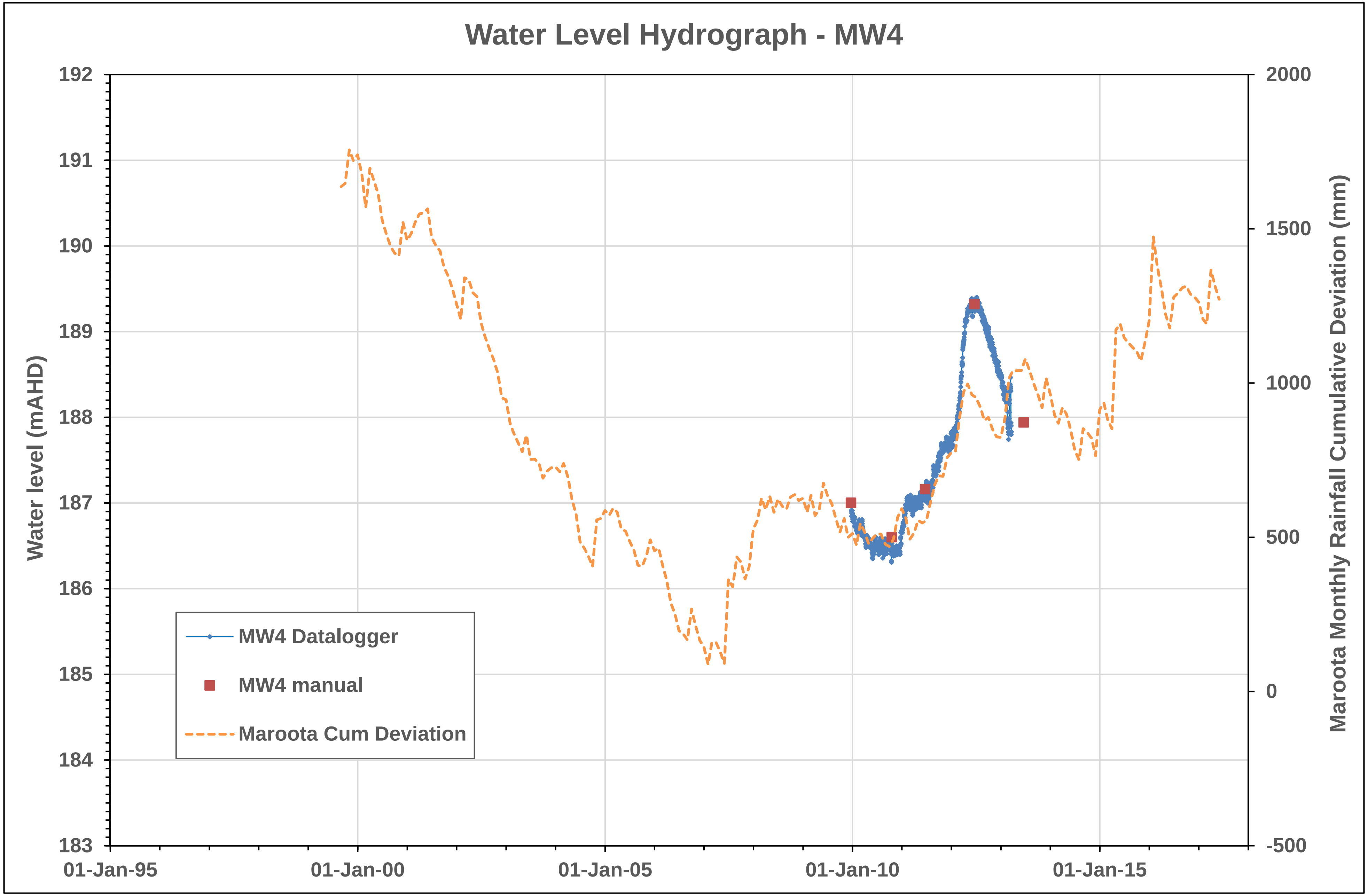


Figure 6: Water Level Hydrograph - MW4

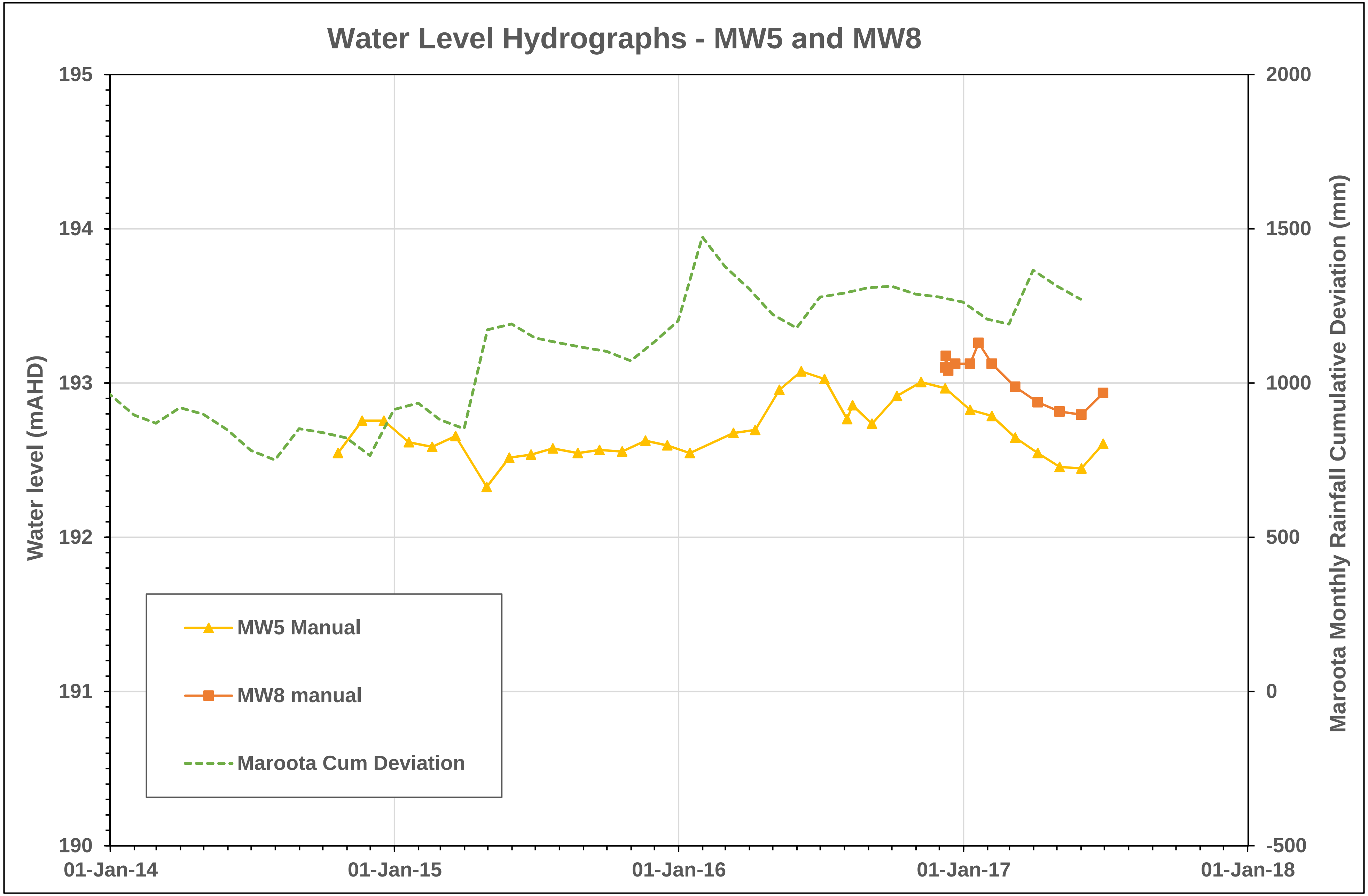


Figure 7: Water Level Hydrographs - MW5 and MW8

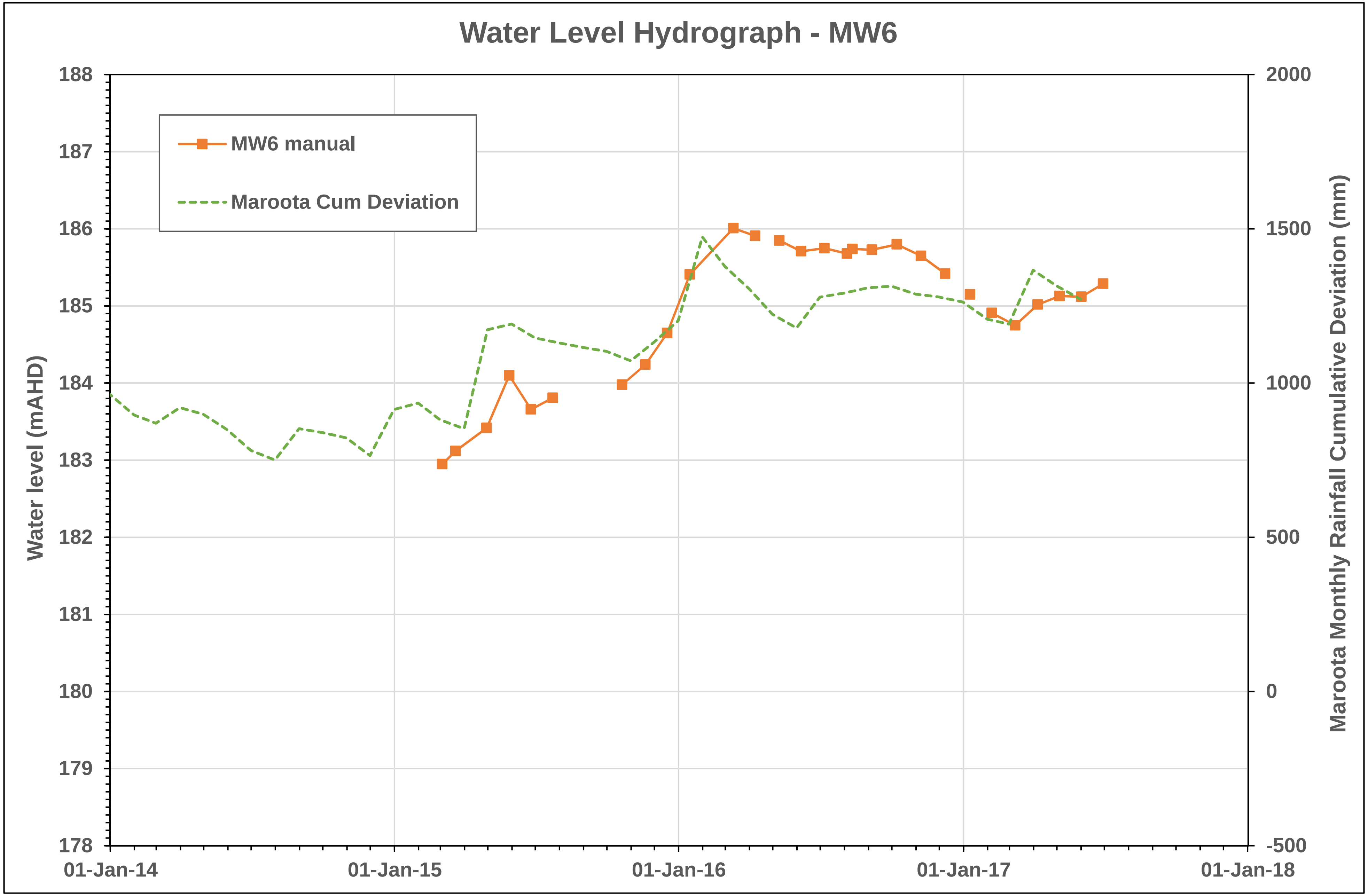


Figure 8: Water Level Hydrograph - MW6

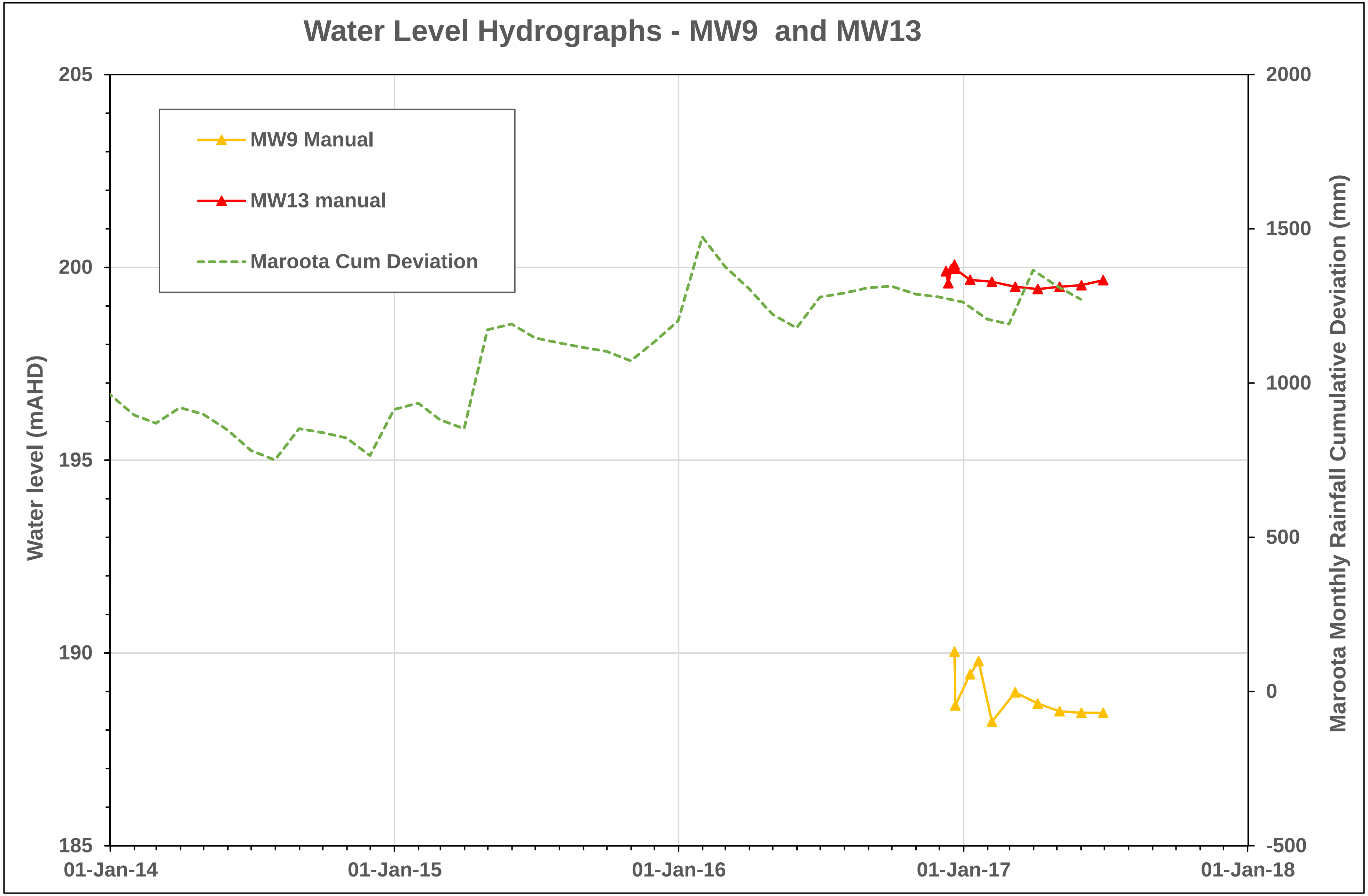


Figure 9: Water Level Hydrographs - MW9 and MW13

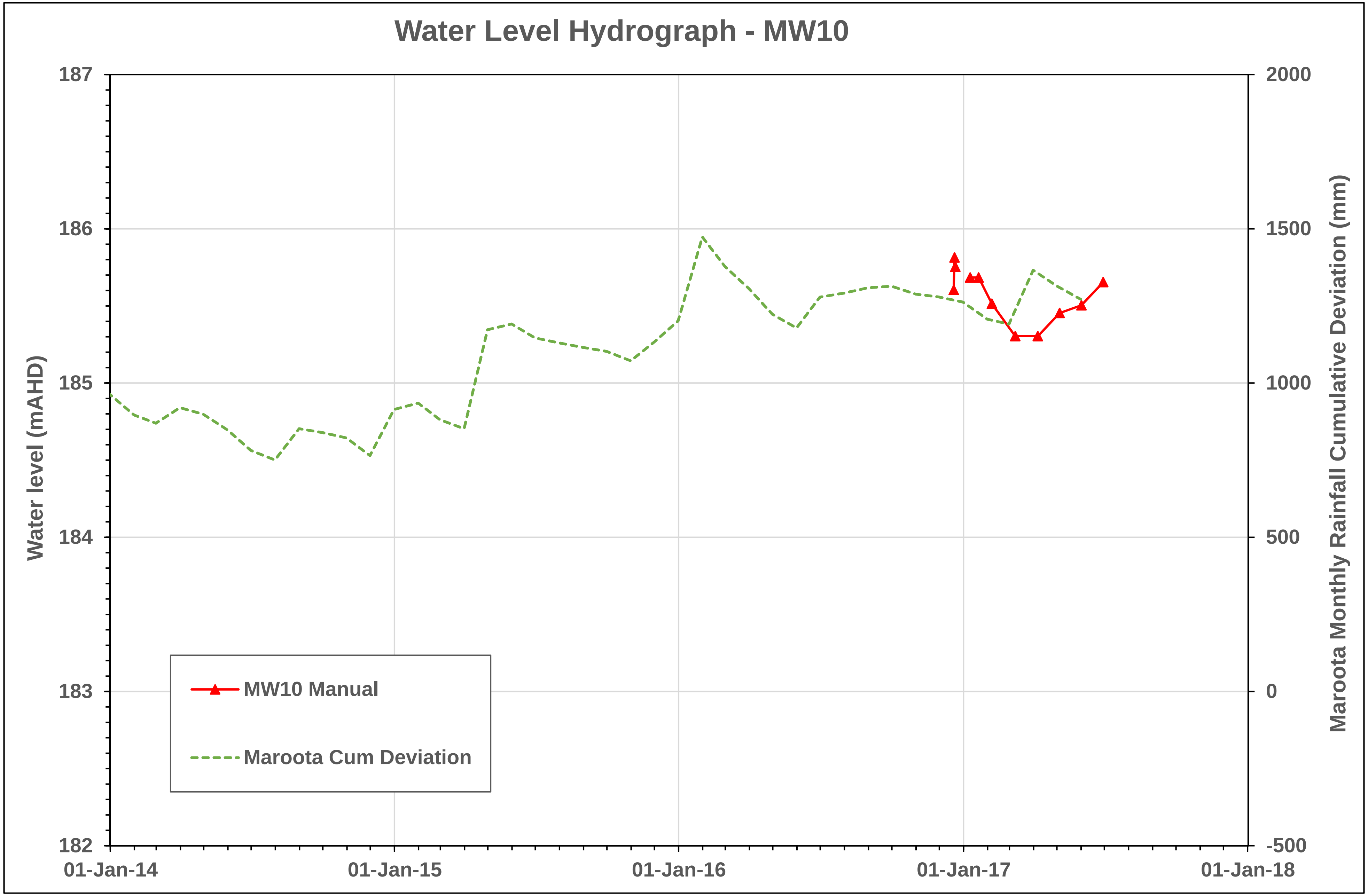


Figure 10: Water Level Hydrograph - MW10

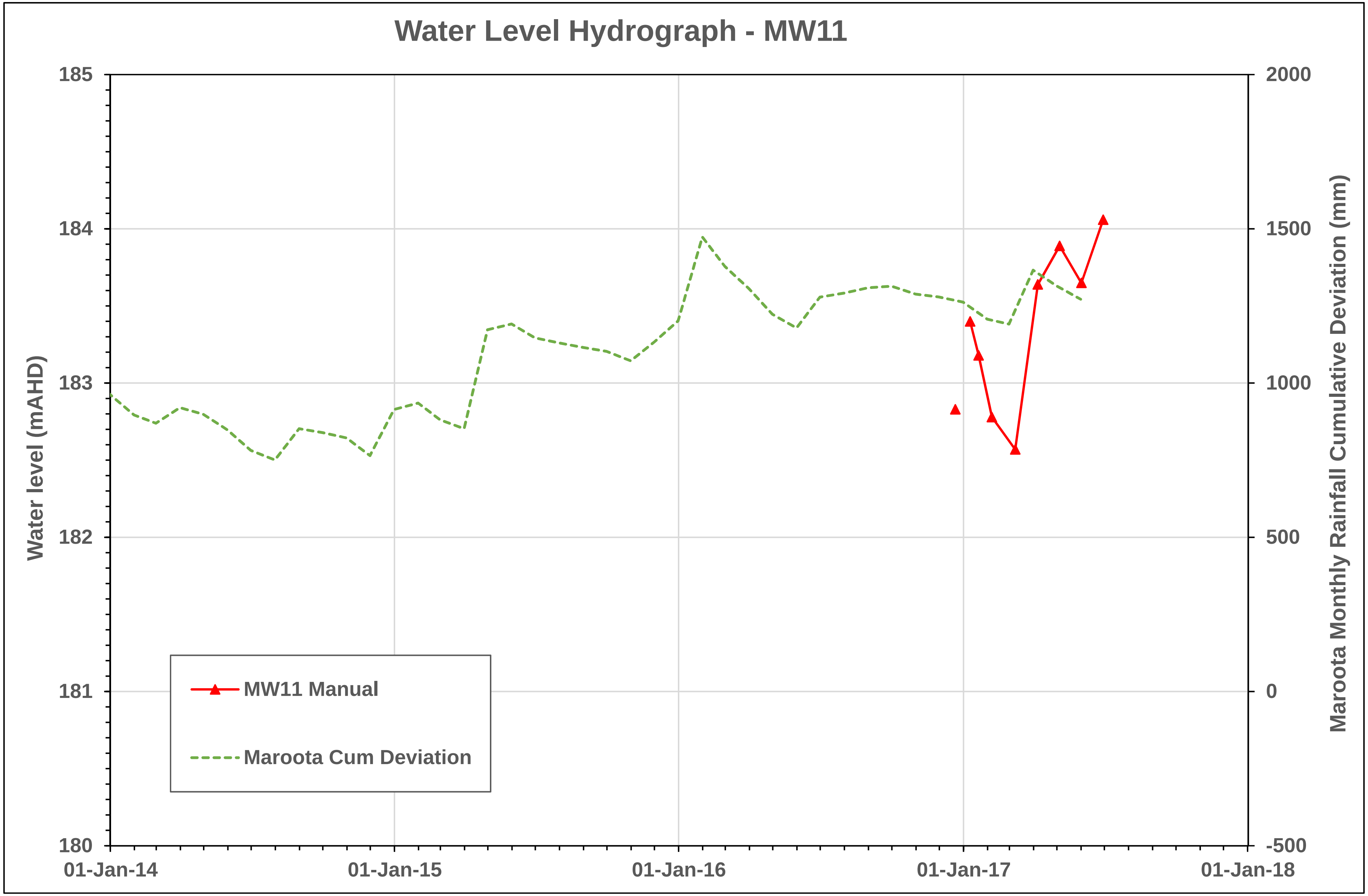


Figure 11: Water Level Hydrograph - MW11

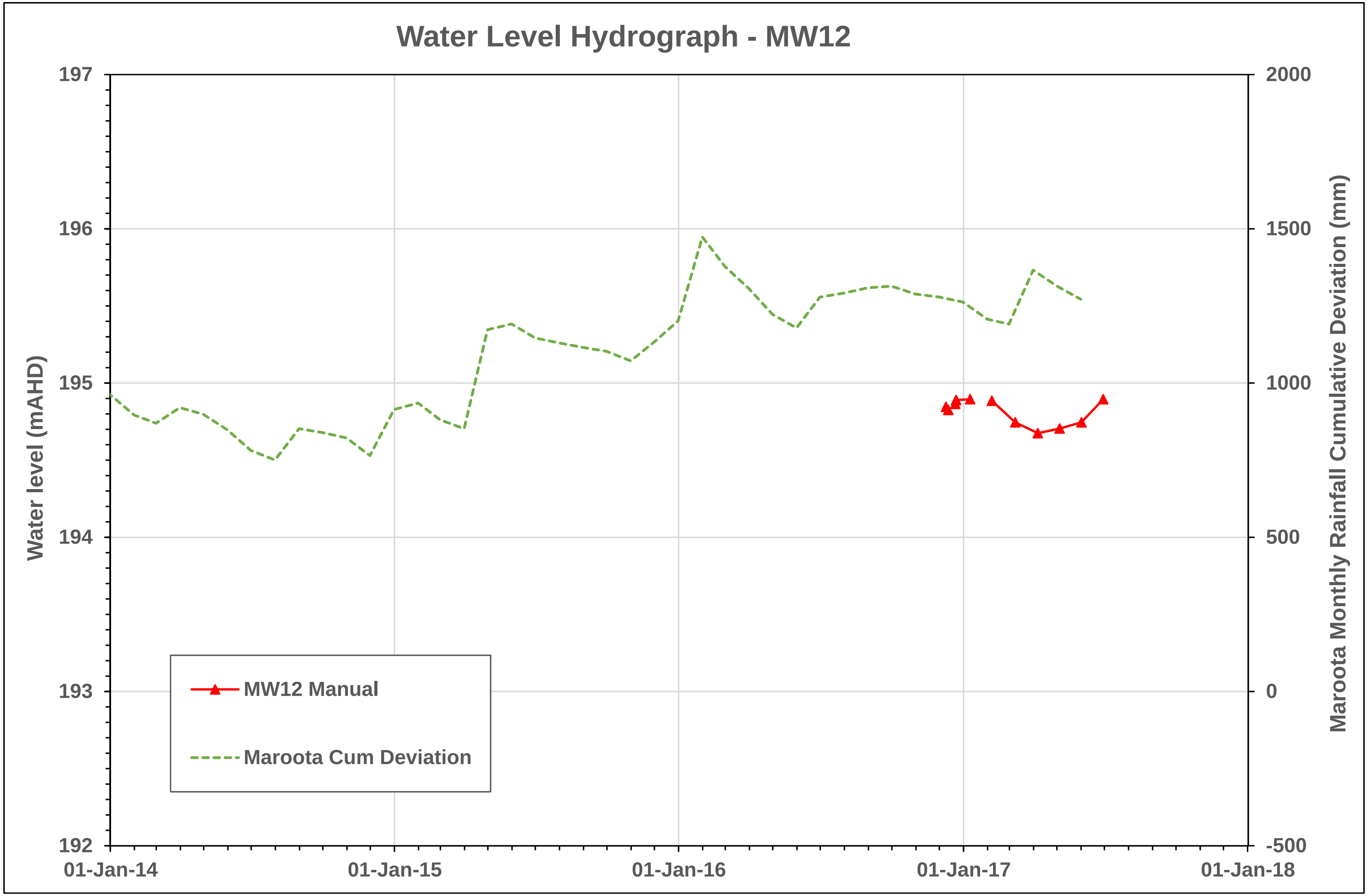


Figure 12: Water Level Hydrograph - MW12

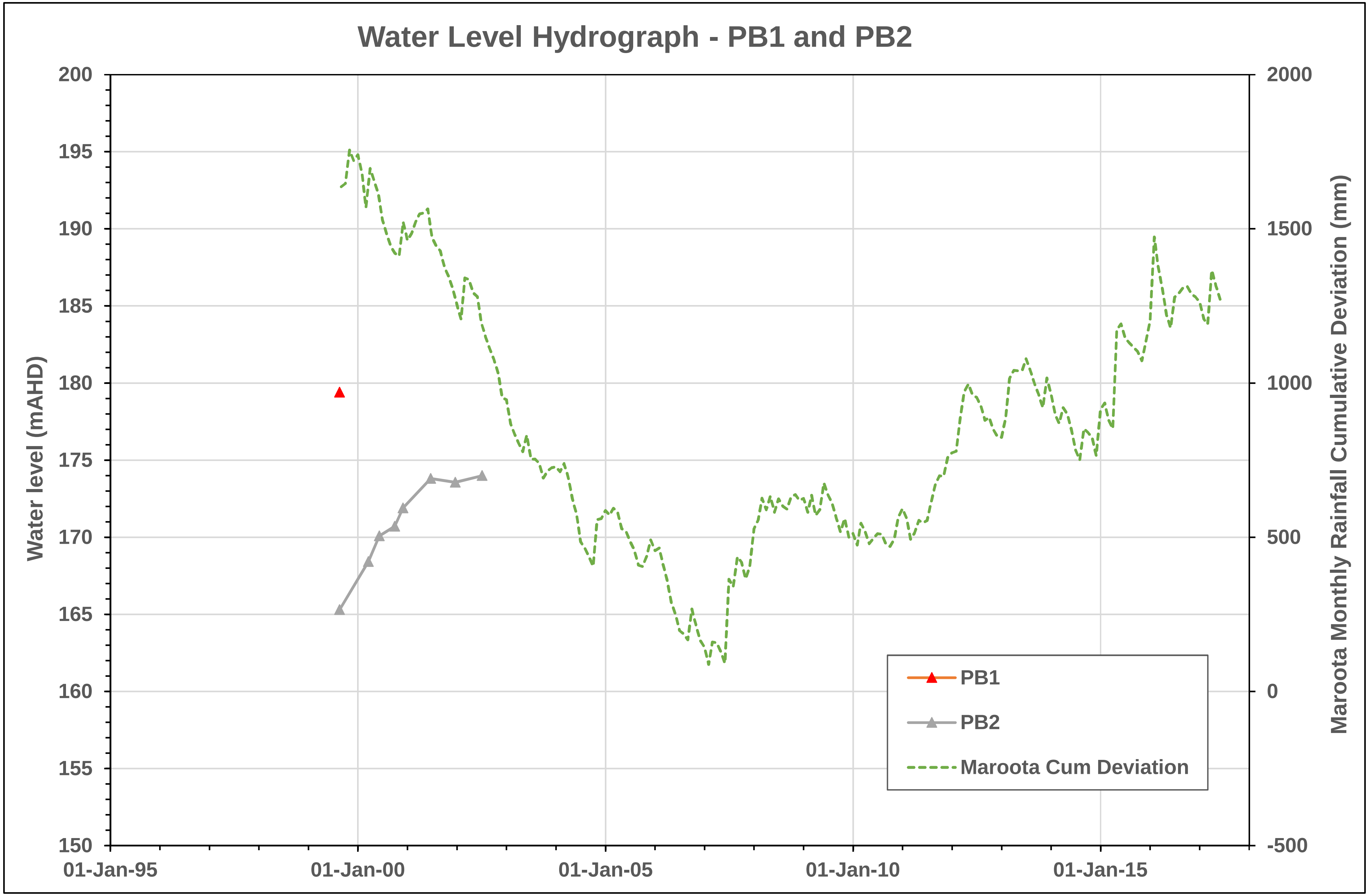


Figure 13: Water Level Hydrographs - PB1 and PB2

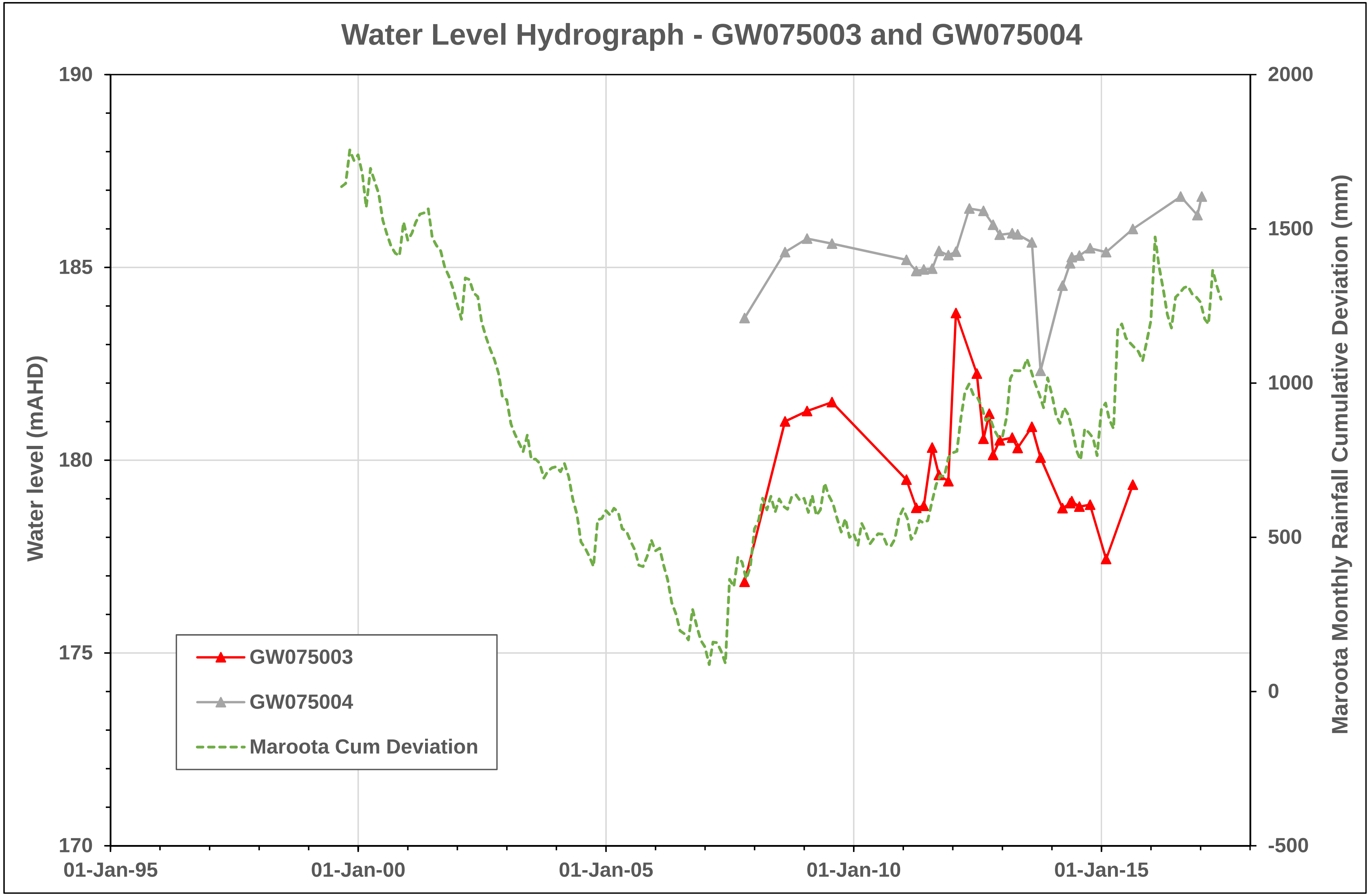
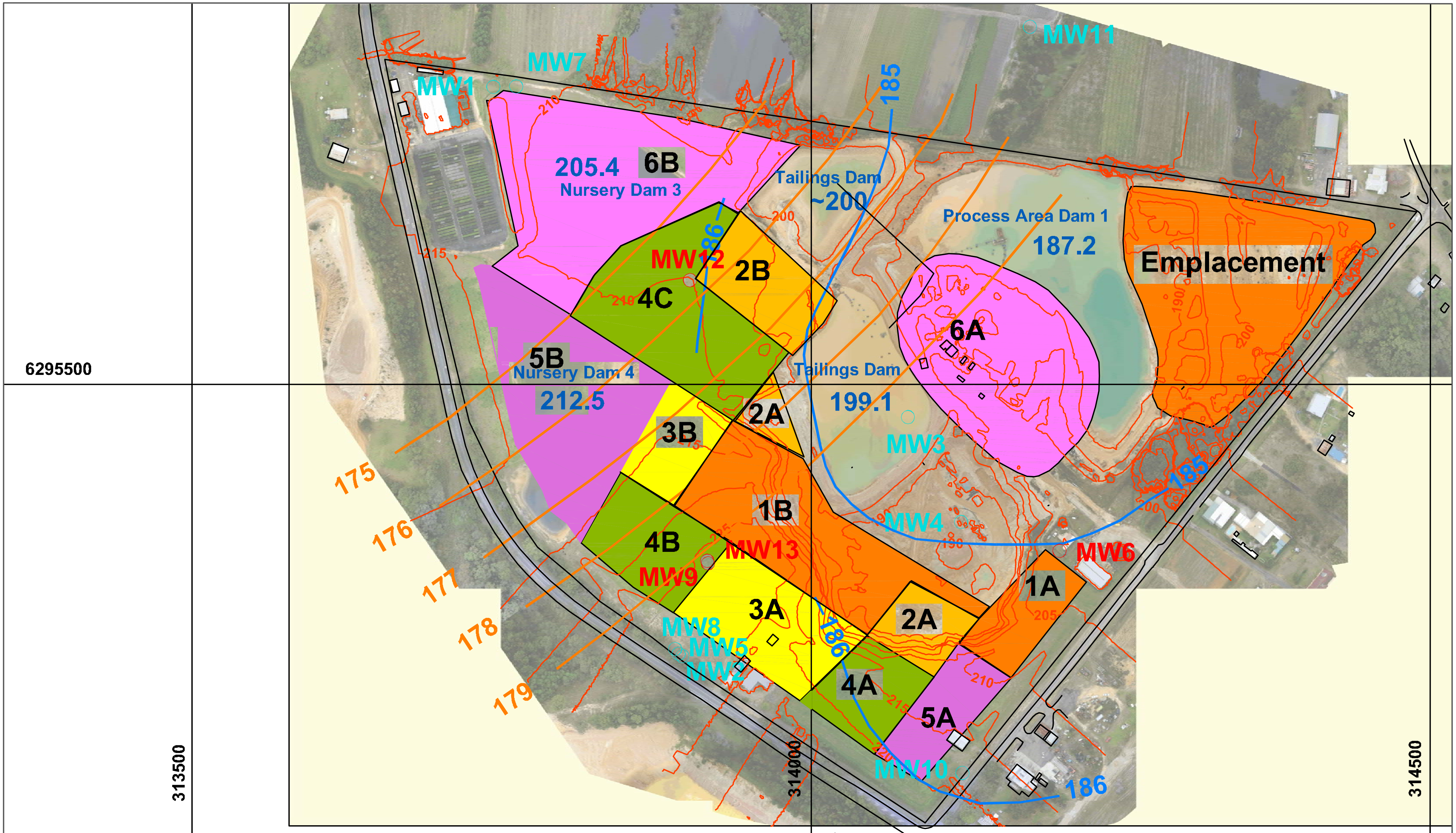


Figure 14: Water Level Hydrographs - GW075003 and GW075004



LEGEND:

(red line)	Surface contours - 5m
Dam 4	Site Dams
188	Dam water level - April 2018 (mAHD)
4A	Extraction Schedule - Phase Number
MW12	Monitoring Bore - Extraction Phases
185	Wet Weather High GW Level - Maroota Sands
176	Wet Weather High GW Level - Hawkesbury Sst

DATE: 15 April 2018 SCALE:

PROJECT NO: 06-0318 AUTHOR: PD

DRAWING NO: 06-0318-071 REVISION: 0

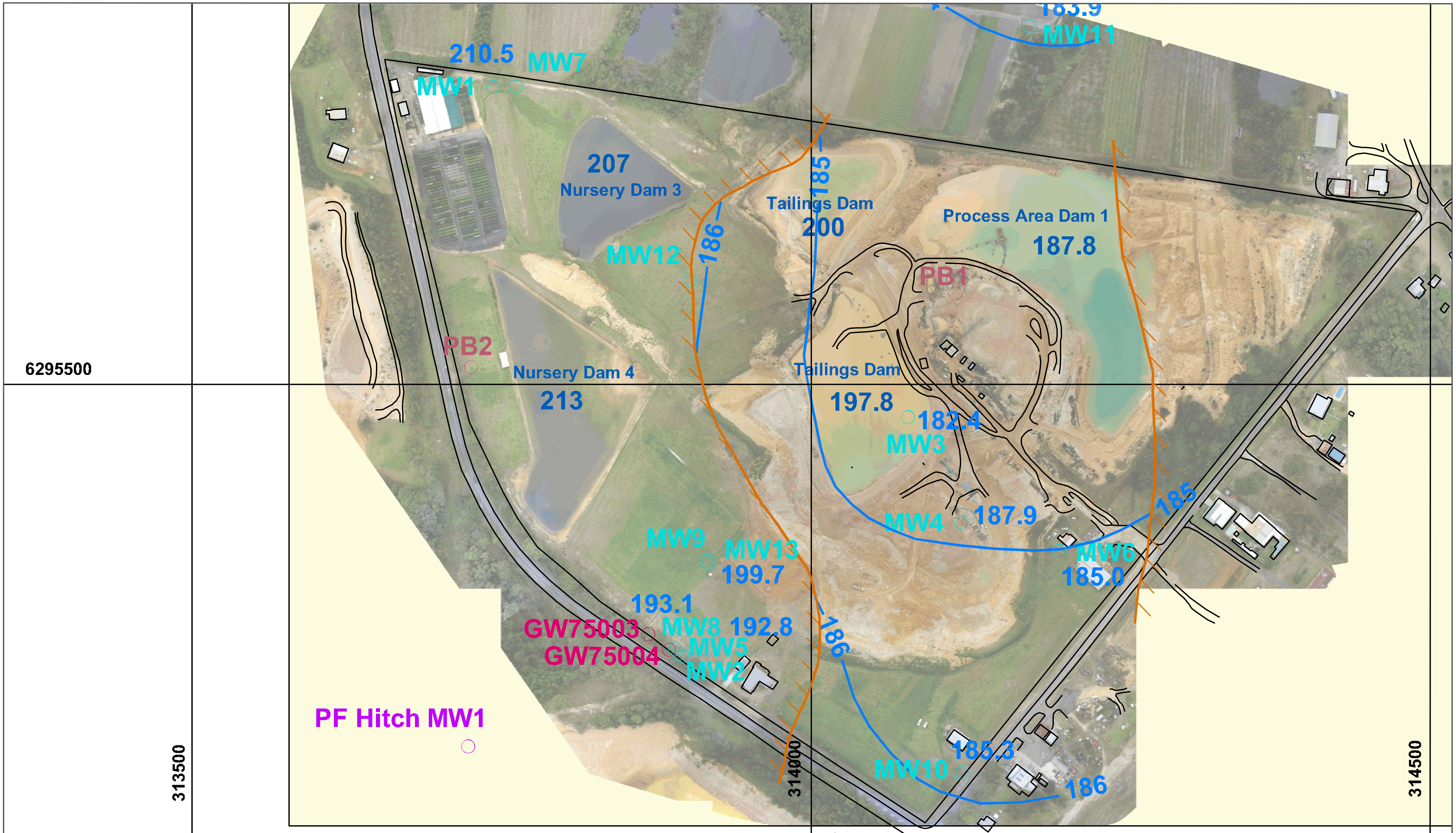
Dundon Consulting Pty Ltd

Hodgson Quarry and Plant Pty Ltd

ROBERTS ROAD MAROOTA SAND QUARRY

Sand Extraction Schedule

Figure 15



LEGEND:

- Hodgson monitoring bore
- Hodgson production bore
- 185.2 Maroota Sands water level
- Contours of wet weather high GW level
- Edge of saturated Maroota Sands

DATE: 23 October 2017	SCALE:
PROJECT NO: 06-0318	AUTHOR: PD
DRAWING NO: 06-0318-020d	REVISION: D

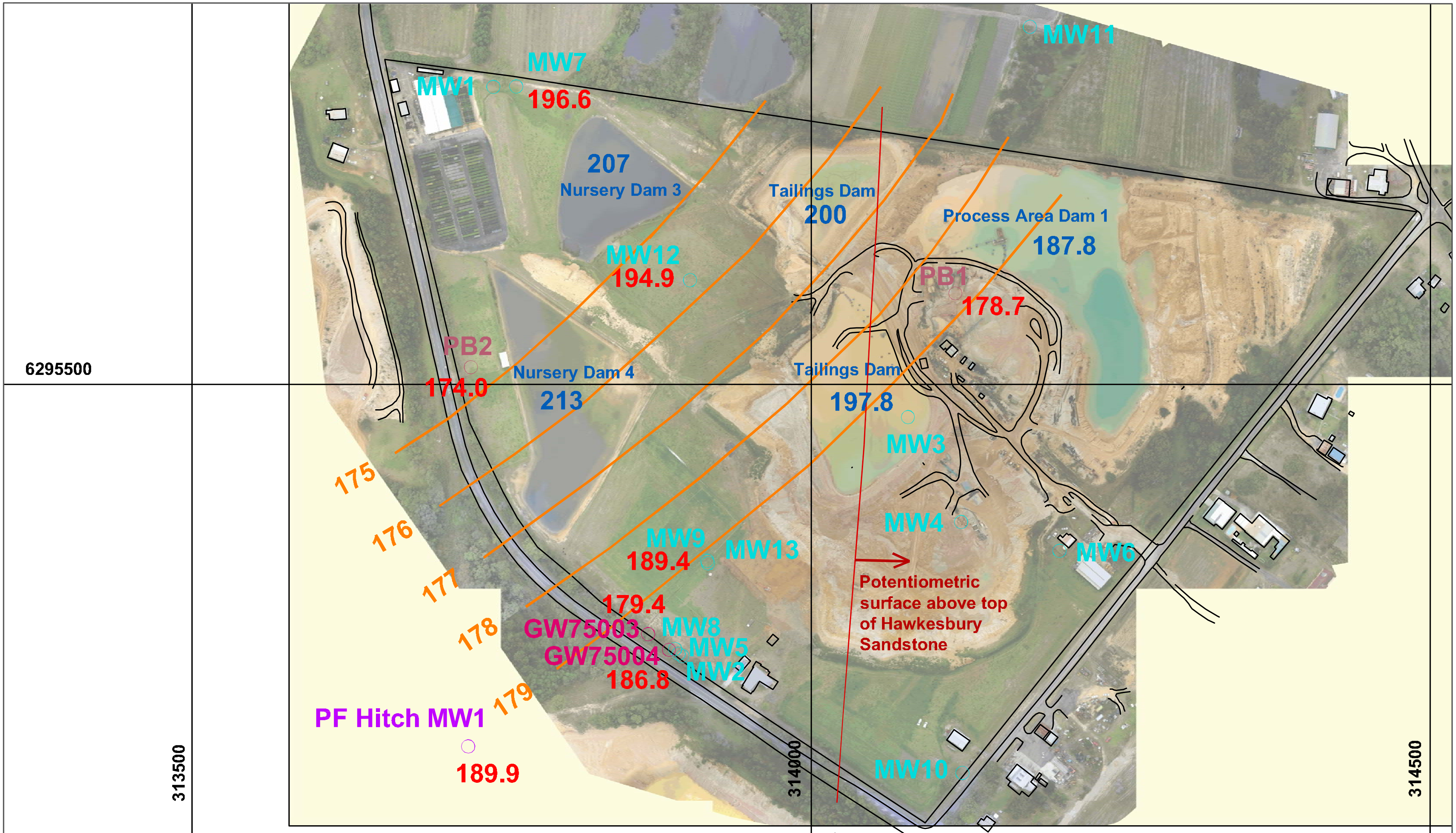
Dundon Consulting Pty Ltd

Hodgson Quarry and Plant Pty Ltd

ROBERTS ROAD MAROOTA SAND QUARRY

Wet Weather High Groundwater Level Maroota Sands (September 2017)

Figure 16



LEGEND:

- Hodgson monitoring bore
- Hodgson production bore
- 174.0 Hawkesbury Sandstone water level
- Contours of wet weather high GW level
- Potentiometric surface above top of HS

DATE: 23 October 2017	SCALE:
PROJECT NO: 06-0318	AUTHOR: PD
DRAWING NO: 06-0318-021d	REVISION: D

Dundon Consulting Pty Ltd

Hodgson Quarry and Plant Pty Ltd

ROBERTS ROAD MAROOTA SAND QUARRY
Wet Weather High Groundwater Level
Hawkesbury Sandstone (September 2017)

Figure 17