

9 August 2021

GeoLINK Pty Ltd
PO Box 119
Lennox Head NSW 2478

Attention: Veronica Silver

Dear Veronica,

Re: Soil moisture data 19 November 2020 to 31 May 2021 – Epiq residential development, Lot 104 on DP1241817, Lennox Head, New South Wales

GeoLINK Pty Ltd (GeoLINK) commissioned Gilbert & Sutherland Pty Ltd (G&S) to monitor and analyse soil moisture data for the Epiq residential development at Lennox Head, New South Wales ('the site'). This letter provides and interprets soil moisture monitoring data collected between 19 November 2020 and 31 May 2021 (the 'current monitoring period'). The results from the current monitoring period add to historical data gathered between 7 December 2015 and 18 November 2020 (herein referred to as the 'previous monitoring period').

Data quality

We note that data downloaded in the previous monitoring period was intermittent due to ongoing equipment and programming issues. Troubleshooting of these issues between G&S and the equipment supplier has been ongoing and on 30 July 2020 the soil moisture monitoring equipment at BMP1, MP1, MP2 and MP3 were reinstalled to allow reprogramming and equipment upgrades. Despite these upgrades it is evident that the programming issues have not been successfully resolved and the data gathered from the current reporting period is also similarly affected.

Given the persistent issues with the equipment we would recommend complete replacement of the equipment and we are currently liaising with the supplier in this regard. Accordingly, this report discusses the available data for the current reporting period and provides a comparison against data collected during the previous monitoring period in the context of the identified data quality limitations.

This report covers data from the previous monitoring report to the following dates:

- BMP1: 1 April 2021 (one final record at 950 mm on 15 May 2021)
- MP1: 7 December 2020
- MP2: 22 December 2020
- MP3: 30 March 2021

Background

The site is formally described as Lot 234 on DP1104071 and has an approximate area of 87 hectares (ha). When complete, the Epiq development will consist of residential lots, a neighbourhood centre, a future retirement community, open space (including parks and a conservation zone) and associated roads and service infrastructure.

The presence of two threatened flora species has been identified within the freshwater wetland areas on the site: Square-stemmed Spike-rush (*Eleocharis tetraquetra*) and Hairy Joint Grass (*Arthraxon hispidus*), listed under the *Biodiversity Conservation Act 2016* (replaced the repealed *Threatened Species Conservation Act 1995*) and the *Environment Protection and Biodiversity Conservation Act 1999*, respectively.

'Freshwater Wetlands' – a listed endangered ecological community (EEC) under the *Biodiversity Conservation Act 2016* was also found to occur within the site.

To ensure the protection and maintenance of these threatened species and EEC, a conservation zone has been designated covering the area(s) in which they occur. The conservation zone has an area of approximately 14.07 ha. Four vegetation communities have been identified within the conservation zone – freshwater wetland, littoral rainforest, swamp sclerophyll forest and exotic-dominated grassland.

G&S prepared a Stormwater Management Plan (SWMP) for the site in December 2012, which was included as part of the Conservation Zone Management Plan (CZMP) prepared by GeoLINK. Together, those reports addressed the specific requirements of Condition B2 of the concept approval (details pertaining to soil moisture monitoring reproduced below) and outlined a management strategy to ensure the maintenance of ecological values at the site.

B2 Conservation Zone Management Plan

(7) A Water Management Plan that addresses the manner in which the hydrological regime of the Freshwater wetlands EEC and the associated threatened species will be maintained throughout the life of the project and is to include, but not be limited to:

- a. An assessment of the pre-developed hydrological regime including surface and groundwater inflows and outflows;*
- b. Measures to be implemented to ensure the pre-development hydrological regime is maintained;*

c. Mapping of the extent of the seepage areas and measures to ensure their ongoing protection; and

d. Detailed design, installation and maintenance methods of the proposed weirs and other infrastructure identified in Illustration C7 dated 14/8/2008 to ensure the maintenance of the existing hydrological regime.

Soil moisture monitoring methodology

Extra-tidal hydrosol soils were identified within the conservation zone. Hydrosols are defined as soils that are saturated in the major part of the solum for at least 2-3 months in most years.¹

Hairy Joint Grass and Square-stemmed Spike-rush favour the properties of hydrosols, particularly the soil moisture characteristics.

The SWMP recommended that a portion of the runoff from within the development be captured, stored and treated in bio-retention basins and then discharged via infiltration trenches to a nominated target seepage area. This system helps to maintain the pre-development soil moisture conditions of the hydrosols (specifically, the requirement to maintain soil moisture between field capacity and permanent wilting point).

In order to monitor the soil moisture conditions within the conservation zone, four Sentek encapsulated soil moisture probes were installed at selected locations within the site, as depicted on Drawing No. 11726.01 (included in Attachment 1). The probes were installed in December 2015 with three of those probes situated in the vicinity of the freshwater wetland (MP1, MP2 and MP3), and within an area with comparable soil depth and slope (reference site, labelled BMP1).

The original installation proposal was for all probes to be installed to a nominal depth of 1,200 mm below ground level (BGL), with sensors engaged to monitor soil moistures at a target depth of 950 mm BGL. To assist with interpretation of the collected data the probes also record data at depths of 150 mm, 350 mm, and 650 mm BGL).

During the installation of the probes into the drilled borehole, resistance within the strata prevented the probe from reaching the full installation depth of 1,200mm. Accordingly, the actual target monitoring depths for each location are as follows:

- Location MP1 – 950 mm BGL
- Location MP2 – 940 mm BGL
- Location MP3 – 935 mm BGL
- Location BMP1 – 925 mm BGL.

¹ Isbell, R.F. (1996) *The Australian Soil Classification (Revised Edition)*. CSIRO Publishing.

The probes automatically log soil moisture content in % of volume on a programmed time interval. During the previous reporting period soil moisture was logged twice per day at 12 am and 12 pm. As a result of the reprogramming works in July 2021, the logging frequency was increased to hourly to facilitate troubleshooting.

Update to the proposed target criteria for the 950 mm BGL depth

A review of aerial imagery (included as part of the reporting of data from 1 February to 30 June 2017; G&S ref: 11726_SMM-2017-H1_LGC1F) found impervious surfaces occupied greater than 15% of the land upslope of MP1 to MP3.² That report established initial percentile target values for % soil moisture at 950 mm BGL for MP1 to MP3.

During the current reporting period, the impervious percentage of the area upslope of BMP1 remained less than 15%. Nonetheless, the percentile values for BMP1 should continue to be updated as more data is collected until the BMP1 catchment land use is changed to more than 15% impervious surfaces. It should be noted that although the percentage impervious did not change during the current period, earthworks commenced within the upslope catchment, and internal roads were constructed which has the potential to affect the recorded results.

Table 1 details updated criteria for BMP1³ and the 20th and 80th percentile target criteria for MP1 to MP3.⁴ The target criteria for MP1 to MP3 are assessment measures for monitoring and management purposes of the wetland.

Table 1 – 20th and 80th percentiles target criteria for 950 mm BGL for BMP1, MP1, MP2 and MP3

Monitoring location	Target criteria (% moisture) at 950 mm BGL	
	20 th Percentile	80 th Percentile
BMP1	47.8 (+0.5)	55.9 (+2.8)
MP1	51	54
MP2	53	57
MP3	30	32

Note: Change relative to previous target criteria is noted within brackets.

The SWMP procedures for the operation of the infiltration trenches (using the target criteria as stated above) remain unchanged. These procedures are included in Attachment 2, together with the historical context of the target monitoring criteria for this project.

² Google Earth Pro, aerial image date 22 August 2018.

³ Based on available data between 8 December 2015 and 30 June 2019.

⁴ Based on data captured between 8 December 2015 and 31 January 2017.

Soil moisture data analysis at target depth ~ 950 mm BGL

Daily soil moisture monitoring results for the current monitoring period, logged from the three freshwater wetland monitoring locations (MP1, MP2 and MP3) and the reference point (BMP1), are depicted graphically in Figure 1. The measured daily rainfall data (in mm, recorded at Ballina Airport (source: Bureau of Meteorology (BOM) Station No. 58198) is also shown on the right side vertical axis of Figure 1.

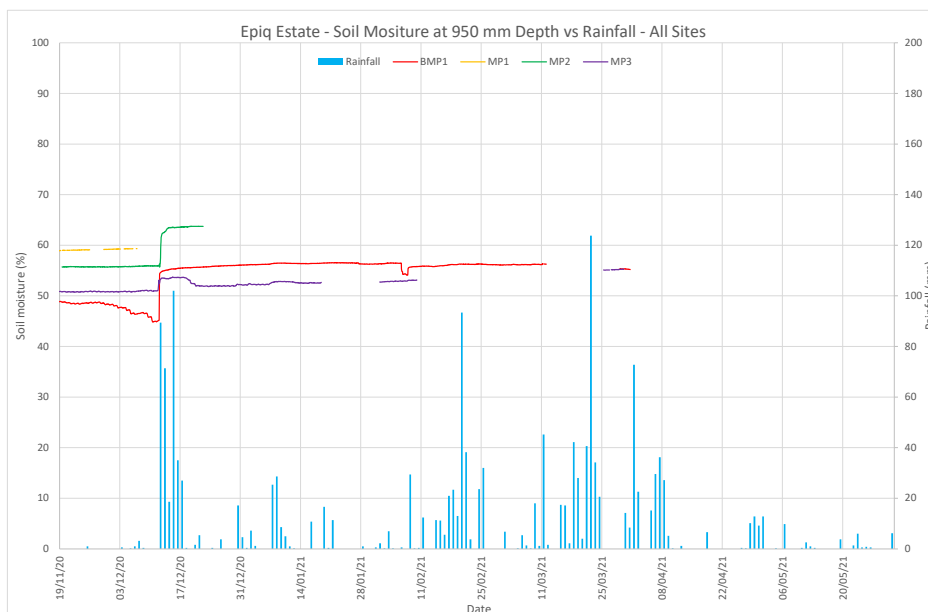


Figure 1 – Soil moisture data and daily rainfall, 19 November 2020 to 31 May 2021.

The historical data for the site is displayed on Figure 1 in 12 hourly intervals. In comparison, the available data for the current monitoring period is displayed in one hourly intervals.

Initially, all four soil moisture probs were consistent, showing a gradual decrease in late November 2020 corresponding with an absence of rainfall. BMP1, MP2 and MP3 responded to a large rainfall event of approximately 340mm in late December, leading to an approximate 10% increase, 3% increase and 8% increase in soil moisture respectively. The equipment at MP1 ceased logging on 7 December 2020 and MP2 ceased logging on 22 December 2020 (likely due to equipment malfunction).

From mid-December 2020 until 20 February 2021 there were no substantial rainfall events, with BMP1 and MP3 remaining relatively consistent throughout this period.

Attachment 3 includes the plotted 20th and 80th percentile target criteria for 950 mm BGL. Detailed descriptions for each monitoring location are outlined below.

BMP1

The soil moisture equipment was reinstalled in July 2020 and successfully logged data until 1 April 2021 (one reading at 950mm on 15 May 2021).

Soil moisture at BMP1 fluctuated between 44% and 57% during the current reporting period, displaying a slight overall increase in moisture when compared to the previous monitoring period. During this timeframe, a total of 1,559 mm of rainfall was recorded. Soil moisture percentage showed a sharp increase following the rainfall event in late December 2020 and a more subdued response to smaller rainfall events occurring after this date. The data recorded at BMP1 indicates that soil moisture saturation occurs between 50% to 52%.

During the current monitoring period, the results for BMP1 remained mostly within the derived 20th (47.8%) and 80th (55.9%) percentile values at the target depth of ~950 mm BGL. Figure 1 shows the soil moisture levels over time.

MP1

Equipment failure at MP1 resulted in limited monitoring records for the current monitoring period. Field maintenance was conducted on 7 June 2021 and troubleshooting with the supplier has been ongoing but thus far has not been successful in rectifying the issue. We recommend that the equipment at this location be removed and replaced as soon as possible. G&S is currently liaising with the supplier to gain a quote for the replacement works.

Although limited, the recorded data exceeded the 80th percentile target for that location indicating elevated soil moisture levels. Whilst above the target percentile, the data for the current reporting period remained within historical minimum and maximum values.

MP2

Equipment failure at MP2 resulted in a limited dataset for the current monitoring period. Field maintenance was conducted on 7 June 2021 and troubleshooting with the supplier has been ongoing but thus far has not been successful in rectifying the issue. We recommend that the equipment at this location be replaced as soon as possible. G&S is currently liaising with the supplier to gain a quote for the replacement works.

The available data for the current monitoring period shows the soil moisture response from a major rainfall event on 12 December 2020, indicating an approximately 7.7% increase, then remaining constant until data ceases (due to equipment failure in late December 2020). Available data indicates soil moisture levels above the 80th percentile. but within historical minimum and maximum values for this location.

MP3

Equipment failure at MP2 resulted in a limited dataset for the current monitoring period. Field maintenance was conducted on 7 June 2021 and troubleshooting with the supplier

has been ongoing but thus far has not been successful in rectifying the issue. We recommend that the equipment at this location be replaced as soon as possible. G&S is currently liaising with the supplier to gain a quote for the replacement works.

Available data is intermittent but showed an increase in soil moisture following rainfall events and a gradually decrease in soil moisture following these events. Soil moisture was consistently above the 80th percentile value. This is consistent with previous monitoring periods. However, the data collected during the current monitoring round is disparate from the previous periods in that soil moisture levels have remained consistently above approximately 45% and have not decreased as has been historically typical for this location. Figure 1 shows this relationship over time.

Soil moisture data analysis – Multi-depth

Following recommendations made in the G&S report dated 6 December 2016 (ref: 11726_SMMQ3_LGC1F), the 20th and 80th percentiles target criteria for soil moisture were calculated for 150 mm, 350 mm and 650 mm BGL to assist in providing criteria relevant to the root zone. Although the 20th and 80th percentiles target criteria for 950 mm BGL have been fixed for MP1 to MP3 based on data collected up until 31 January 2017, the previous G&S report ('11726_SMM-2017-H1_LGC1F') recommended the inclusion of data captured until 30 June 2017, prior to setting the MP1 to MP3 20th and 80th percentiles target criteria for 150 mm, 350 mm and 650 mm BGL. As per the 950 mm BGL depth, the 20th and 80th percentiles target values for BMP1 should continue to be updated as more data is collected until the BMP1 catchment land use is changed to result in more than 15% impervious surfaces in upgradient areas.

The 20th and 80th percentiles target criteria for soil moisture at 150 mm, 350 mm and 650 mm BGL are detailed in Table 2.

Table 2 – 20th and 80th percentiles target criteria for 150 mm, 350 mm and 650 mm BGL for BMP1, MP1, MP2 and MP3

Monitoring location	Target criteria (soil moisture %) by location and depth					
	150 mm BGL		350 mm BGL		650 mm BGL	
	20 th Percentile	80 th Percentile	20 th Percentile	80 th Percentile	20 th Percentile	80 th Percentile
BMP1	26.29 (-1.17)	44.44 (+2.44)	38.52 (+0.52)	46.23 (+2.23)	46.47 (+0.47)	51.77 (+1.77)
MP1	28	38	42	47	43	51
MP2	25	33	30	36	45	55
MP3	29	37	33	40	32	35

Note: Change relative to previous target criteria is noted within brackets.

During the current monitoring round the soil moisture probes at all locations recorded multi-depth soil moisture data at 150 mm, 350 mm, 650 mm (as well as the target depth of ~ 950 mm BGL discussed above). The limited data for all four locations did not permit a full analysis for the current reporting period.

Selected depths (150 mm, 350 mm and 650 mm BGL) were plotted in a similar manner to the 950 mm BGL assessment. In summary, the results indicate:

- **150 mm BGL** – Fluctuations following rainfall events were observed within available data for all locations. Increases in soil moisture percentage following rainfall totals as low as 4 mm in a 24-hour period were observed. The large rainfall event in December 2020 showed a rapid response to rainfall in all available data for all monitoring locations. BMP1 recorded the most data and displayed a response to rainfall immediately following most events that occurred in the current reporting period. At this shallow depth, these immediate responses to rainfall are expected.
- **350 mm BGL** – Fluctuations following rainfall events were observed at all available locations during the current reporting period. BMP1 fluctuated after most rainfall events, recording the second highest soil moisture percentage for the current reporting period of 54% following the large rainfall event in December 2020. Although limited data is available for MP2, there is evidence of moisture percentage responding to one rainfall event, leading to the highest soil moisture reading of 58%. Again, these immediate responses to rainfall are expected at these depths within these soils.
- **650 mm BGL** – During the current reporting period, soil moisture levels at BMP1, MP2 and MP3 increased following rainfall events (noting that limited data did not enable a full analysis of rainfall response). The large rainfall event late December 2020 resulted in the soil moisture percentage at BMP1, MP2 and MP3 increasing markedly. BMP1 and MP3 remained at a more consistent level following the rainfall event indicating a more subdued response to rainfall. Soil moisture levels at MP3 appeared to react immediately following rainfall events, and returned to pre-rainfall levels within days. This could indicate a higher permeability soil in the vicinity of the MP3 monitoring location.

Fluctuations at this depth following rainfall events were observed at all locations, however, such fluctuations were less distinct (with the exception of MP3) than those recorded at shallower depths. Similar to the 350 mm BGL data, all locations recorded decreasing soil moisture during periods of low rainfall.

Attachment 4 contains the plots depicting the available soil moisture data for the selected depths at each monitoring location.

Conclusions and recommendations

Despite upgrades and ongoing troubleshooting it is evident that the programming issues at BMP1, MP1, MP2 and MP3 have not been successfully resolved and the data gathered for the current reporting period has been limited by these issues. Given the persistent equipment reliability issues, we would recommend complete replacement of the equipment. We are currently liaising with the supplier in this regard.

Following analysis of the available soil moisture data and required fieldwork during the current reporting period, it is concluded that:

- The monitoring locations are representative of their localised conditions and are independent of each other.

- Soil moisture levels at most locations were above the 80th percentile target throughout the current reporting period.
- No action was necessary throughout the monitoring period in regard to discharging stormwater to increase soil moisture levels.
- During the monitoring period, there were dry periods, although soil moisture remained within the historical maximums and minimums and was often above the 20th percentile target (relevant for each location).
- Most locations and monitoring depths responded to rainfall events, suggesting that each location continues to approximate natural soil water fluxes.
- The catchments of MP1, MP2 and MP3 exceeded the critical limit of 15% impervious surface during the 1 February to 30 June 2017 reporting period. Therefore, the 20th and 80th percentile target values for the 150 mm, 350 mm, 650 mm and 950 mm BGL depths were fixed in the G&S report '11726_SMM-2017-H1_LGC1F'.
- The catchment of BMP1 has less than 15% impervious surfaces and 20th and 80th percentile target values will continue to be updated in response to further data collection and increases in impervious fraction.

Accordingly, it is recommended that:

- the faulty soil moisture equipment at monitoring locations BMP1, MP1, MP2 and MP3 be replaced;
- soil moisture percentage at BMP1 be monitored to assess the relevant 20th and 80th percentiles for groundwater assessment and management; and
- monitoring at all locations should continue at the additional depths (150 mm, 350 mm and 650 mm BGL) in addition to the long-term monitoring at the target depth of 950 mm BGL to assist in providing data relevant to the root zone.

We trust this information is sufficient for your current requirements. Please do not hesitate to contact should you need to discuss this matter any further.

Yours sincerely,



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Sarah McGhee
Environmental Scientist
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Author Sarah McGhee and Erin Holton

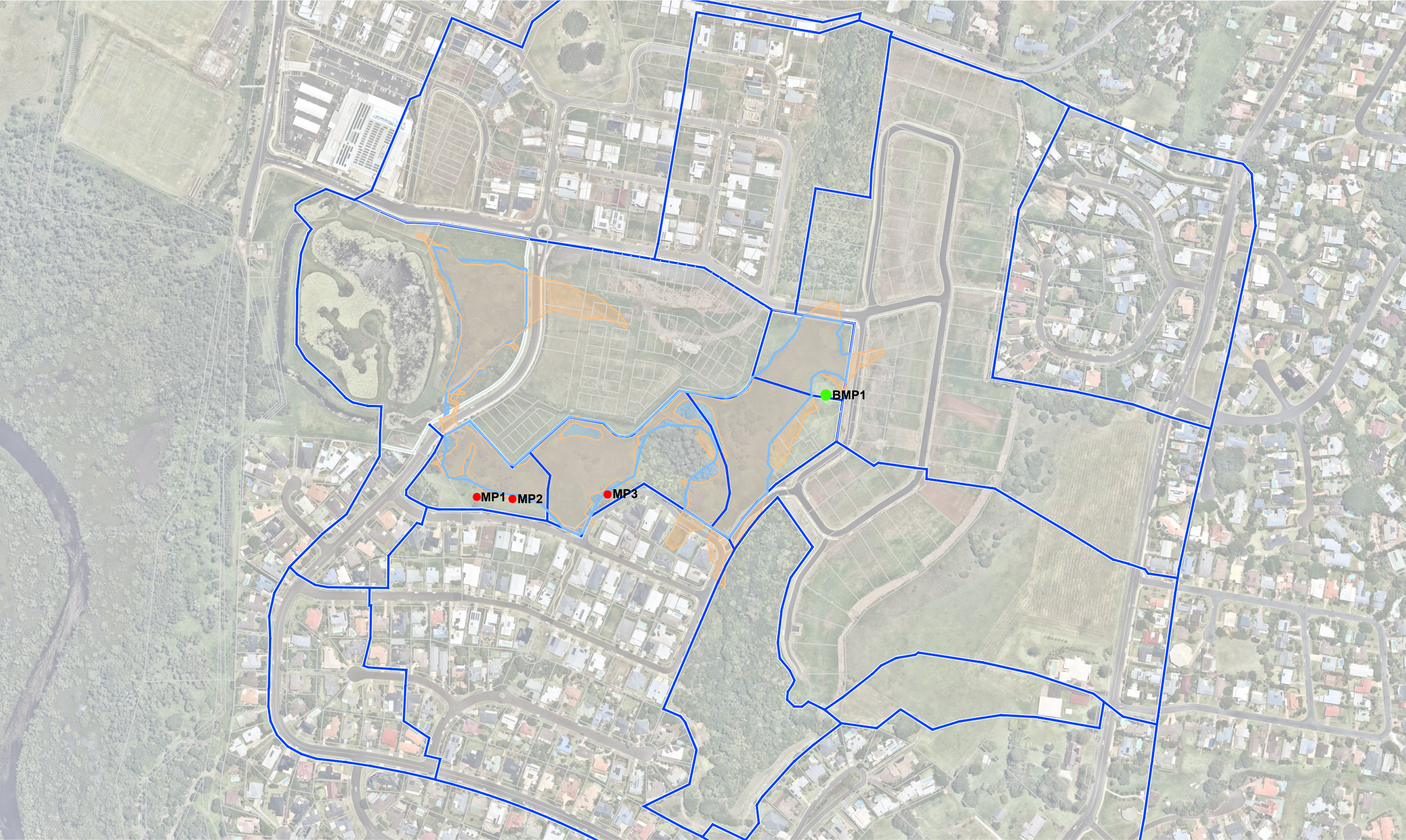
Our Reference 11726_SMM_2020_Jul-Nov_SAM3.docx

Your Reference Epiq Estate Lennox Head Soil Moisture

By ☐ Courier ☒ Email ☐ Facsimile ☐ Post

Enclosures Attachments 1 to 4 as referenced

Attachment 1 – Drawing



ORIENTATION
NORTH

SCALE
40 80 120 160 200 metres

ROBINA
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www.access.gs

LEGEND

- Pre-developed Wetland Area (5.2ha)
- Post-developed Residual Wetland Area (4.6ha)
- Catchment Boundaries (91ha)
- Background Monitor Location
- Monitor Location

SOURCES
Image base: Near Map, Image dated 15 January 2021.

PROJECT
EPIQ
LENNOX HEAD
NSW

CLIENT
GEOLINK PTY LTD

DRAWING
SOIL MOISTURE
SENSOR LOCATIONS

SCALE 1:4 000@A3	DATE 04/02/2021	DRAWN WPS/SWP	CHECKED GLH	PROJECT NO 11726	DRAWING NO 01
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Attachment 2 – Soil moisture target criterion history and recommended procedure for the Stormwater Management Plan operations

The original CZMP recommends soil moisture for the freshwater wetland be maintained in the range of +/- 15% in comparison to the reference probe (BMP1). If the moisture probes indicate variation outside this range, the infiltration trenches can be adjusted to increase or decrease infiltration rates.

Review of the findings from the monitoring results between inception (8 December 2015) and 31 October 2016⁵ identified significant differences in the baseline behaviour of each location. The data indicated that the general baseline condition for BMP1 was about 48% moisture, MP1 – 54%, MP2 – 52% and MP3 – 30%. Fluctuations in the data recorded at BMP1 were not mirrored in the data recorded at MP1, 2 or 3 and therefore, there appeared to be no comparability between monitoring sites. Consequently, the nominated target criterion and the use of a reference site (BMP1) was not appropriate for the management of the soil water in the conservation zones through the construction and operational phases of the development.

The original intent of monitoring location BMP1 was to act as a reference condition to aid in the assessment of the wetland monitoring bores MP1 to MP3. It was concluded that the location of BMP1 was such that it was not directly affected by the infiltration devices nor similar enough in its characteristics to the monitoring bores to be applicable to the management of the wetland.

Following these conclusions, G&S's monitoring report (ref:11726_SMMQ3_LGC1F, dated 6 December 2016) recommended that a 20th and 80th percentile range be set for each monitoring location and would be reviewed as more data was collected during the construction phase. When the percentage of the site covered by impervious surfaces reached 15%⁶ surrounding each monitoring location, the 20th and 80th percentiles target criteria would be 'fixed' and used for the remainder of the construction and operational phases of the development.

The 20th and 80th percentiles target criteria were developed under the following assumptions:

- The area of pervious surfaces were still significant and natural rainfall infiltration would continue to occur for the majority of the site, although some construction activities have occurred during the monitoring period.

⁵ G&S has extensively reviewed the monitoring data to date, which constitutes 11 months of 1-hourly interval data (mid-night and midday readings are used in the assessment), to propose an alternative criterion which can be practically used moving forward. This 11 months of data provides a good understanding of seasonal influences and corresponding fluctuations in soil moisture levels at the site.

⁶ In accordance with the NSW policy for groundwater dependant ecosystems.

- As the infiltration trenches' return point is approximately 950 mm BGL, the derived 20th and 80th percentiles target criteria were relevant to soil moisture data at that depth.

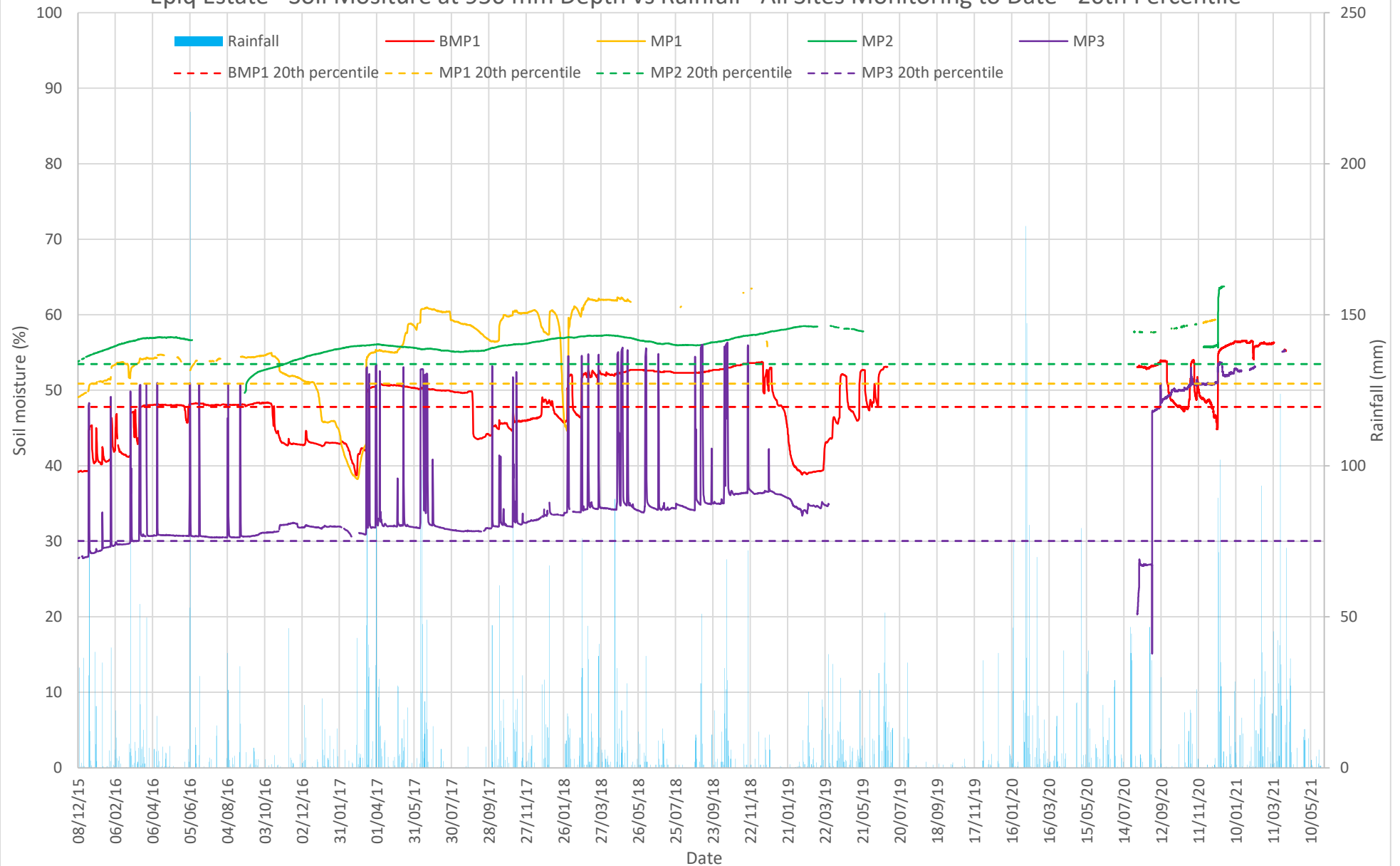
Based on this percentile approach, it was recommended that the procedure for the SMP operations for the infiltration trenches be as follows and apply to the 'fixed' target criteria:

- When soil moisture is between the 20th and 80th percentiles target criteria, there is no action to be taken.
- Soil moisture levels below the 20th percentile target criteria are to be reviewed daily for a two-week period. If at day 14 soil moisture levels remain below the 20th percentile target criteria, treated stormwater runoff will be discharged via the infiltration trenches until soil moisture levels return to a level higher than the 80th percentile target criteria for a period of 5 days. At this point the discharge of water will cease.
- Where the monitoring data detects soil moisture levels above the 80th percentile target criteria, no discharging will be undertaken and soil moisture levels will be observed. Excess soil moisture in the conservation zone is not considered detrimental and will naturally flow downslope (via seepage) and discharge off site as it currently does.

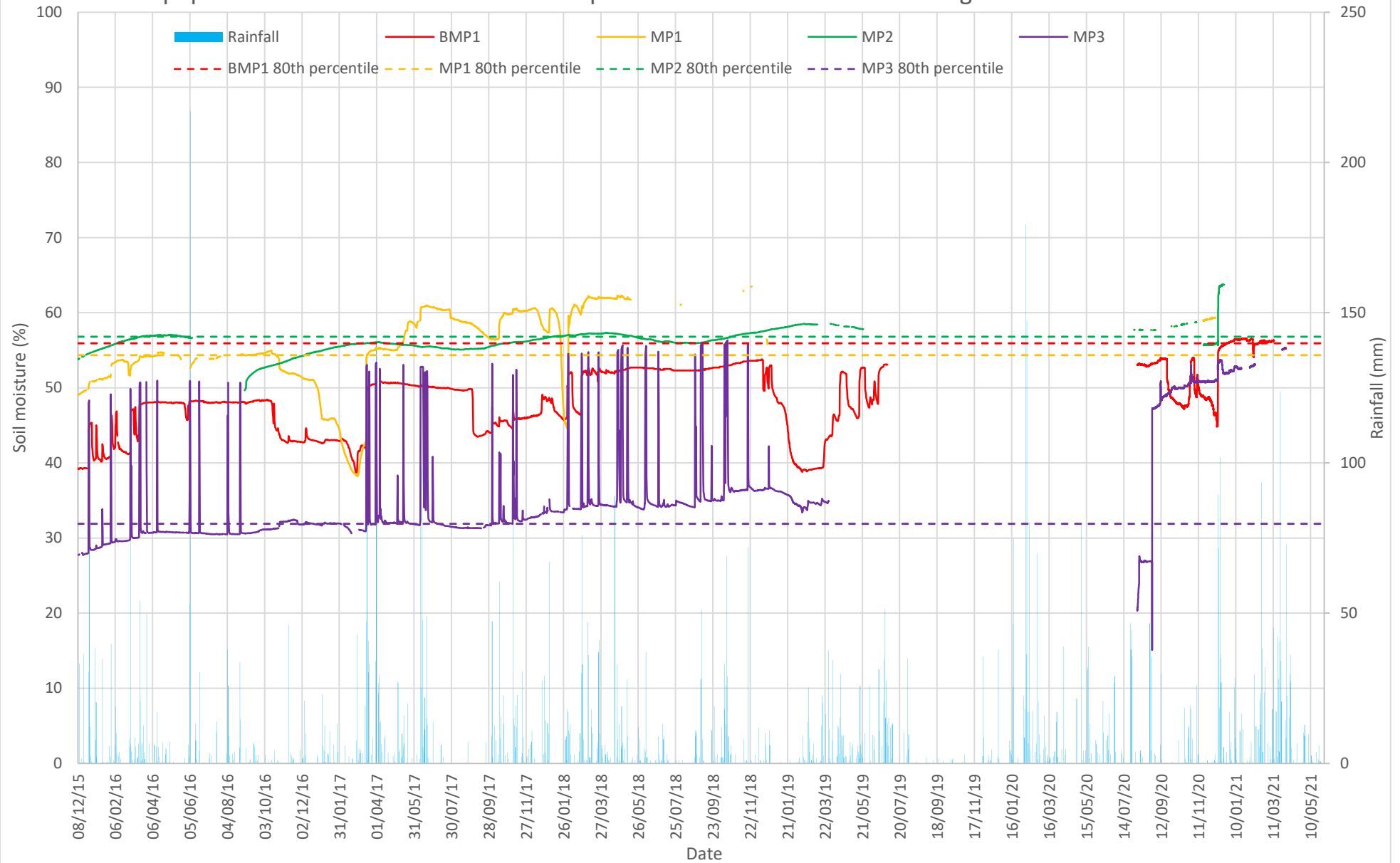
The proposed target criteria and the procedure for operations for the infiltration trenches, as detailed above, were accepted by the Department of Planning and Environment ('DPE') on 2 February 2017.

Attachment 3 – Plot of 20th and 80th percentile target criteria for 950 mm BGL

Epiq Estate - Soil Mositure at 950 mm Depth vs Rainfall - All Sites Monitoring to Date - 20th Percentile

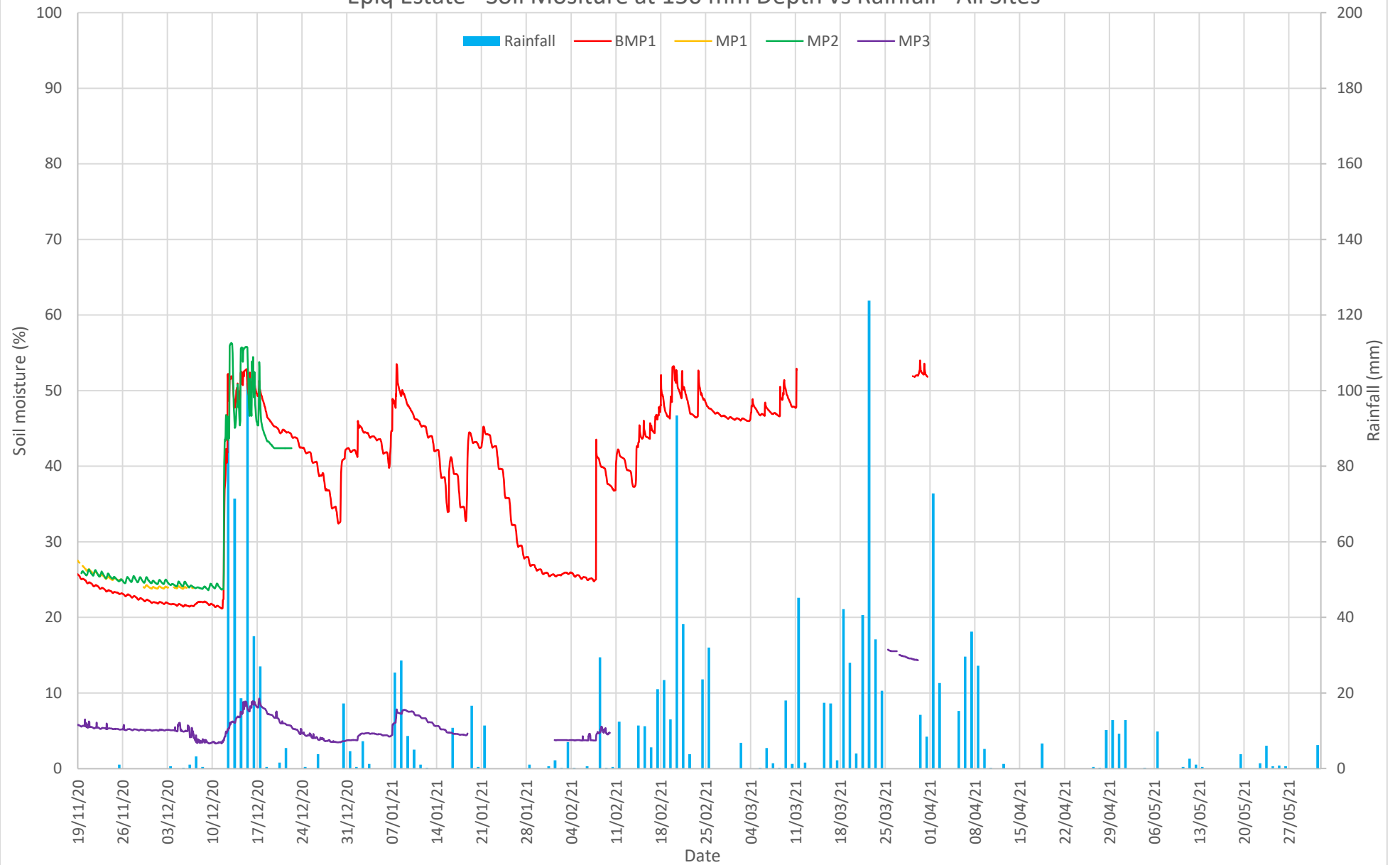


Epiq Estate - Soil Moisture at 950 mm Depth vs Rainfall - All Sites Monitoring to Date - 80th Percentile

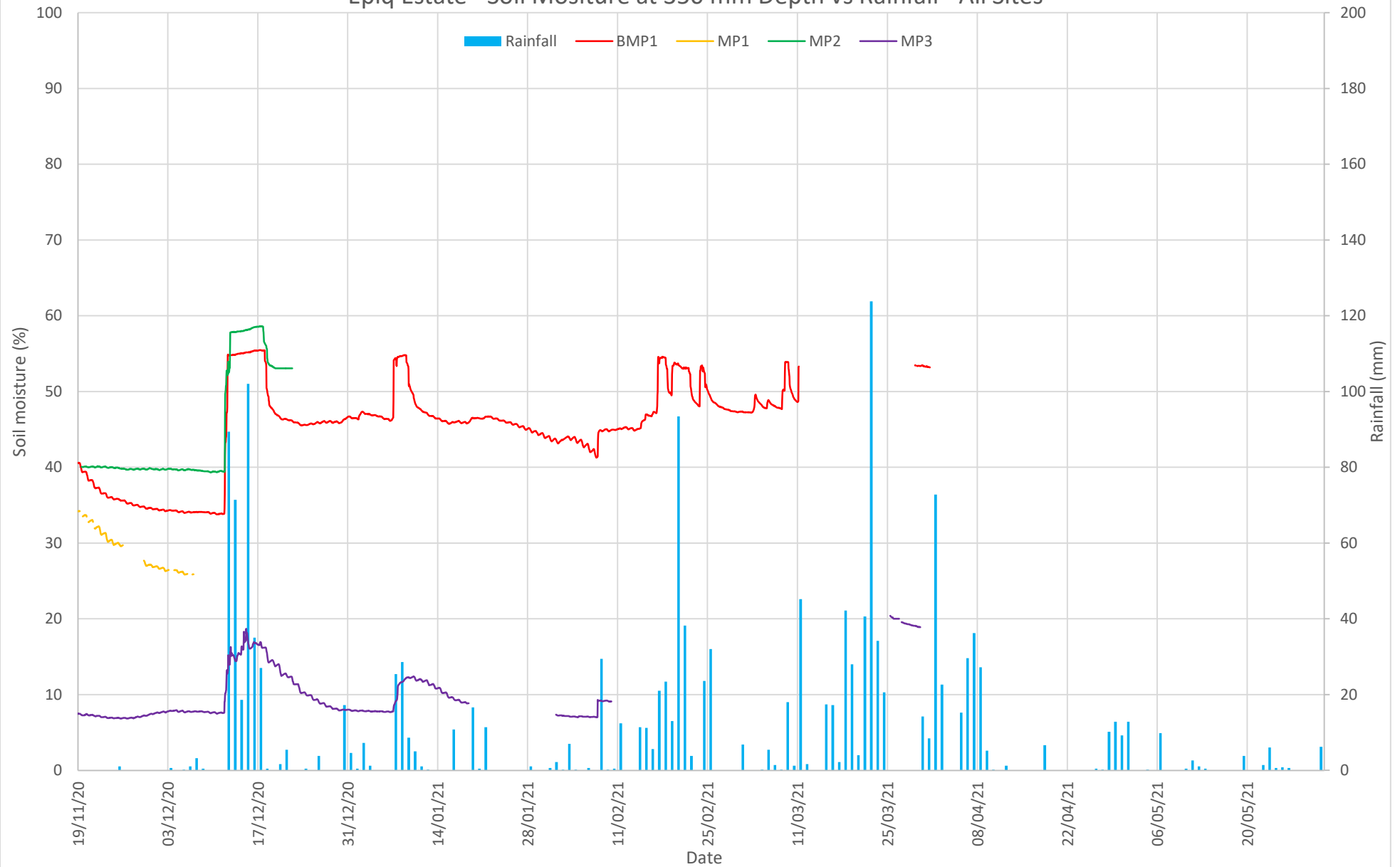


Attachment 4 – Multi-depth soil moisture monitoring plots (18 November 2020 to 31 May 2021)

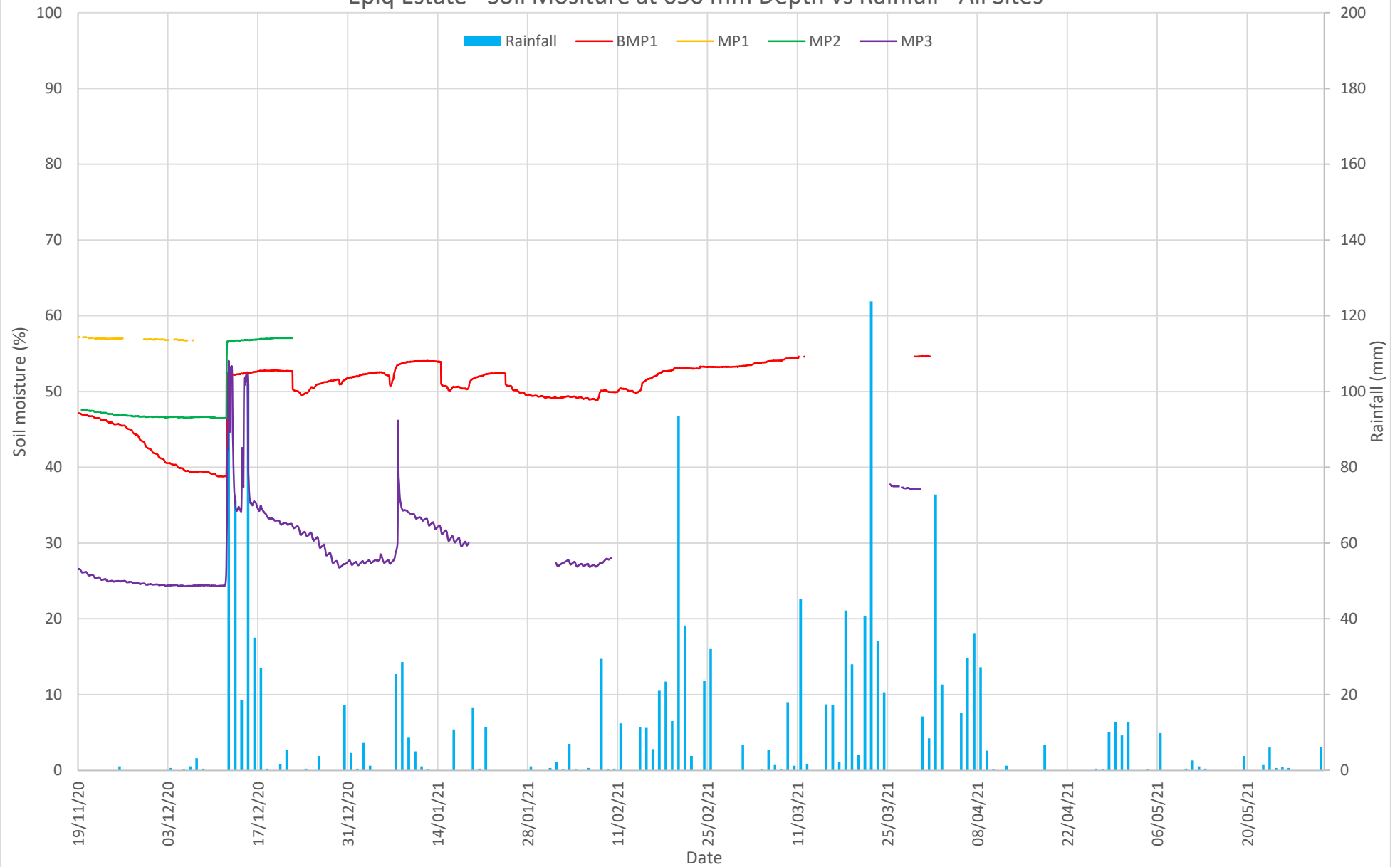
Epiq Estate - Soil Mositure at 150 mm Depth vs Rainfall - All Sites



Epiq Estate - Soil Mositure at 350 mm Depth vs Rainfall - All Sites



Epiq Estate - Soil Mositure at 650 mm Depth vs Rainfall - All Sites



Epiq Estate - Soil Mositure at 950 mm Depth vs Rainfall - All Sites

