Parliament Precinct Future Accommodation Strategy (FAS)

Geotechnical Report for Land Use Resource Consent

Parliamentary Service

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1 Introduction

Parliamentary Service (PS) is planning to construct three new buildings at the Parliament Precinct located on Museum Street, Wellington. The project, known as Future Accommodation Strategy (FAS), comprises the Ministerial Annexe, Museum Street Building, Ballantrae Place Building, and associated civil works such as access roads, car parking (basement and open air), and re-routing of services.

PS has engaged Aurecon to carry out geotechnical investigations at the site. This report provides geotechnical comments and recommendations to support Land Use Resource Consent application to Wellington City Council. Urban Perspective Limited will prepare the application.

The scope of work and terms and conditions of our engagement are set out in the Aurecon proposal titled Geotechnical Investigation Variation (SC4), dated 3 November 2020.

2 Ground Investigations

The objective of the ground investigations was to investigate ground and groundwater conditions at the Parliament Precinct. The ground investigations completed to date are summarised in the following:

2.1 Recent Investigations

Aurecon carried out investigations in 2017 for a previous version of this development and most recently (2021) to support strengthening assessments for existing Parliament buildings. The work comprised the following:

- Desktop review of published geotechnical information relevant to the site. This included historic geotechnical reports since the 1960's provided by the client and held in Aurecon files, and regional geological and hazard maps.
- Site walkovers by Aurecon geotechnical engineers with the representatives from PS, Holmes, TBIG and drilling contractor. The purpose of the walkovers was to identify optimal geotechnical testing locations that minimise disruption and risk to existing services, structures and accessways.
- Organising and management of the six geotechnical boreholes (BH-01 (2021) to BH-06 (2021)) and five environmental boreholes (BH-101 to BH-105) in 2021, and five geotechnical boreholes in 2017 (BH-01 (2017) to BH-06 (2017))
- Carrying out downhole shear-wave velocity testing in the deep boreholes BH-01(2021), BH-06 (2021), BH-02 (2017), and BH-05 (2017)
- Carrying out three Lines of Refraction Microtremor (ReMi) geophysical survey in 2017
- Laboratory testing of selected soil samples obtained from the boreholes comprising Triaxial, Particle Size Distribution (PSD), Atterberg Limits, natural moisture content and fines content tests
- Installation of groundwater monitoring piezometers in the boreholes BH-03 (2021), BH-04 (2021), BH-01 (2017), and BH-04 (2017).

2.2 Historic Investigations (desktop study)

A number of site investigations have previously been undertaken in the area by Aurecon, Aurecon's predecessor company (RG Brickell and Brickell and Moss), the Ministry of Works and Development (MWD), the Department of Scientific and Industrial Research (DSIR), and Tonkin & Taylor. These investigations included machine drilled boreholes, cone penetrometer tests (CPT), and geophysical surveys. Some of the past investigations include:

- Ministry of Works and Development (MWD, circa 1960s). No geotechnical reporting was available, only borehole records were available for our review from these investigations.

- RG Brickell (1960s), Proposed Departmental Buildings – Bowen Street Site Investigations: This investigation was for the proposed Departmental buildings (currently Bowen State building and Bolger park). No report was available, only borehole logs and plans were available for our review.
- RG Brickell Moss and Partners (1964), Preliminary Foundation Investigation, Proposed Extension, Parliament Buildings, Wellington: This investigation was for the Beehive site and comprised one borehole (BH4) and five dynamic probe tests.
- Brickell and Moss (1966), Proposed Charles Fergusson building: This investigation was for the development of the Charles Fergusson building.
- Perrin ND (1986), Engineering Geological Report on Investigations for the Proposed Parliamentary Service: This report was prepared for the proposed parliamentary services building on the site west of the Parliament building and east of Bowen State building. Six machine boreholes (PSB1 to PSB6) and one borehole with SPTs (PSB-SPT) were drilled as part of this investigation.
- Tonkin & Taylor (1990), Parliament Building Strengthening Programme Soils Investigation: The purpose of this investigation was to provide geotechnical input for the strengthening and reconstruction of the Parliament and General Assembly Library buildings. The investigation comprised six boreholes and six foundation inspection holes.
- Tonkin & Taylor (1996), Proposed Parliament Ministerial Building Wellington Geotechnical Investigation Report: This investigation was carried out for the proposed ministerial building on the site located between Beehive/Parliament buildings and Bowen State building. It comprised five machine boreholes and five Cone Penetration Tests.
- Connell Wagner (2006), Geotechnical Investigation Report for Parliament Media Studio: It was for a proposed building on the lawn area east of Museum Street. The investigation at the site comprised one machine drilled borehole.
- Aurecon (2015, 2016), Bowen Campus Re-development Geotechnical Investigation Report. The investigation was for the proposed seismic strengthening work of Bowen State and Charles Fergusson Buildings. It comprised six boreholes, four pile proof boreholes (PB-01 to PB-04), and downhole shear wave velocity and Refraction Microtremor (ReMi) surveys.

The approximate investigation locations (recent and historic) are shown in Figure 1. Note that the historic investigation locations and levels may not be accurate as they were approximated from available historical reports and plans, generally with unknown RL, datum, and coordinate records.

3 Site conditions

3.1 Site Description

The Parliament Precinct is bounded by Hill Street to the north, Bowen Street to the south, Molesworth Street to the east and Bowen Campus, Ballantrae Place and residential properties to the west. The site can be accessed from Museum Street (off Bowen Street), Ballantrae Place, Hill Street, and Molesworth Street.

The site is roughly trapezoidal in shape. It is approximately 240m long in the north (east-west direction), 250m long in the south, 180m wide in the west (north-south direction) and 210m wide in the east.

The site currently comprises the New Zealand Parliament buildings such as the Parliament Library, Parliament and Executive Wing / Beehive, and associated structures and amenities such as underground and open-air car parks, accessways, parks, children’s play area and sculptures. The Library building is located on the northern part, Parliament building in the middle and Executive Wing / Beehive on the southern part of the site.

3.2 Proposed Building Sites

A brief description of each of the proposed building sites is given below:

3.2.1 Ministerial Annexe

The Ministerial Annexe (MIN) is located west of the Beehive building. The building footprint on the basement level is approximately 55m x 14m. The site is bounded by an accessway to the north, a slope and Bowen Street to the south, the Service Link building to the east, and lawn area, access ramps and Museum Street to the west. The building occupies the footprint of the existing Press Gallery Annexe building which will be demolished. However, the new basement will extend approximately 4m westwards from the Press Gallery building. The existing Secure Deliveries Building located west of the Service Link Building will also be demolished as part of the development.

The basement level of the existing Press Gallery building is approximately RL7.80m. The lawn area levels vary between RL10m and RL11m (approximately).

3.2.2 Museum Street Building

The proposed Museum Street Building (MUS) has an approximate footprint of 73m x 16m. The site is bounded by a bank to the north (towards upper carpark), Bowen State building basement ramp and Museum Street to the south, Parliament building, basement ramp and open carparking to the east, and open carparking to the west. The site has a gentle slope from the north to south with the elevations varying approximately between RL13m and RL11m. It is mostly used as an open carpark currently with asphalt/brick pavement.

3.2.3 Ballantrae Place Building

The Ballantrae Place Building (BAL) is located on the open carpark at the end (east) of Ballantrae Place. The building footprint is approximately 34m x 13.5m. The building has a small basement (14m x 13.5m in plan) towards the east which connects to the MUS building basement. The site is bounded by a bank to the north, and an open car park to the south, east and west.

The site is relatively flat (except the bank) with the levels varying between RL19m and RL20m.

3.3 Regional Geology

The geology of the Central Wellington area has been mapped and described in the 1:50,000 scale Geological Map of New Zealand – Sheet 22 – Wellington Area Map (Begg and Mazengarb, 1996). This map indicates that the soil underlying the site is *"Alluvium, silty, peat, loess, including Haywards and Kaitoke gravels, and subsurface Moera Gravel; sand; minor tephra, principally Rangitawa Tephra on erosion surface (ln)"*. Greywacke and argillite bedrock is inferred to lie beneath the alluvium soils at a depth of 50m to 90m BEGL (Semmens et al, 2010 and Kaiser et al., 2019).

Semmens et al, 2010 described the surficial (typically < 5m depth) deposits at the site as 'Old Alluvium/Colluvium', Pleistocene alluvial and colluvial deposits consisting of sands, silts, weathered gravels and clays, poorly sorted to well sorted, medium dense to very dense (Vs ~250-700m/s).

Several active and inactive faults lie near the site, the most significant being the active Wellington Fault which lies approximately 450m northwest from the site. The Wellington Fault is categorised as a 'major fault requiring near-fault factors' in NZ Standard NZS1170.5:2004 for locations within 20km distance. Published information indicates that the movement of the Wellington Fault has a recurrence interval of 500-700 years, with a 10% probability of a M7.3 event in the next 100 years (Rhoades et al., 2011). GNS database indicates that the Wellington Fault is a dextral slip type with recurrence interval of less than 2,000 years, high slip rate (5-10mm/year) and moderate single event displacement (1-5m) (*source:*

https://data.gns.cri.nz/af/dataDetails.html?id=2553, last accessed 20/05/2021). The most recent surface-faulting event on the Wellington Fault was 290–440 calendar years Before Present (cal years BP), cal years BP are calendar years before A.D. 1950, and over 300 years separate the timing of the second most recent rupture on the Wellington fault 660–720 cal years BP (Van Dissen and Berryman, 1996).

Another relatively newly mapped fault named Aotea Fault is located approximately 1.5km southeast from the site. Kaiser et al (2019, Appendix 1) indicates that the fault was mapped approximately along Cambridge Terrace across the Basin Reserve in the south and extending offshore from the Lambton Harbour. National Institute of Water and Atmospheric Research (NIWA) characterised and mapped this fault beneath the Wellington harbour (Barnes *et al*., 2014) which reports that this fault is capable of producing earthquakes with magnitudes between Mw 6.8-7.1 every 3500 years. Barnes *et al* (2014) characterised this fault as a reverse structure, with single displacements of up to 2m (potentially up to 4m), slip rates in the order of 0.6 ± 0.3mm per year.

There are also other faults in the vicinity listed as 'inactive faults' in the GNS database, listed below (from GNS database - **https://data.gns.cri.nz/geology/** and Kaiser et al., 2019 maps). Note that the location and information about these faults are very limited:

- Lambton Fault:
  - Mapped to be run from south of Wellington (east of Prince of Wales Park) to Boulcott Street approximately 1km south of the Parliament site.
  - McLintock (1966) described the Lambton Fault, as a splinter of the Wellington Fault
  - Grant-Taylor et al. (1974) characterised this fault as Class II fault, with intervals between movements being very large with little planning importance, though the possibility of a movement in the near future was not denied
  - GNS database (accessed 20 May 2021) described this fault as "inactive and unknown type" with quaternary age movement, it's position 'approximate' and dip angle being vertical.
- Terrace Fault:
  - Mapped to be located from south of Wellington (west of Prince of Wales Park) running almost parallel to Lambton Fault and across the site in approximately southwest - northwest direction. It extends to the Wellington Fault at approximately the northern end of Aotea Quay road.
  - GNS database (accessed 20 May 2021) described this fault as "inactive and unknown type" with quaternary age movement, it's position across the site as 'concealed' and dip angle being vertical.
  - It is noted that the GNS map indicated about 1.6km section of this fault between east end of Aurora Terrace and west end of Able Smith Street as 'accurate' in terms of position, and this fault extended southward ('approximate' position) and ended at the Wakefield Park in the south.
- Happy Valley Fault:
  - Mapped to be located approximately from south of Wellington (Owhiro Bay) running through Happy Valley road northwards Wellington city.
  - The fault then passes through the northwest corner of the Parliament site running southwest to northwest, extending towards the Wellington Fault (approximately the northern end of Thorndon Quay road).
  - GNS database described this fault as "inactive and unknown type" with quaternary age movement, it's position "approximate" and dip angle being vertical.

The Greater Wellington Regional Council Hazard map indicates that the Parliament Campus site has a moderate combined earthquake hazard rating. This combined rating is based on a negligible to variable liquefaction potential, and low to moderate level of ground shaking (source: https://mapping.gw.govt.nz/gwrc/, last accessed 5 May 2021).

It should be noted that the above maps are regional in nature. The geology and hazard potentials indicated on the maps do not necessarily apply to any specific site.

3.4 Subsurface Conditions

We have assessed subsurface conditions at the site based on the previous and recently completed borehole and geophysical investigation logs.

The investigation logs show that the site is typically underlain by fill comprising gravel, sand and silt, overlying undifferentiated alluvial (or colluvial) soil deposits. The bedrock was encountered at an approximate depth of 53m at the BAL and MUS sites and 76m at the MIN site. The subsurface conditions indicated by the logs are generally consistent with the published regional geology and previous investigation information.

Subsoils indicated by each of the borehole logs vary considerably making any interpretation of distinct and/or continuous soil layers below the site difficult. A generalised description of the ground profile is summarised below (also see Figure 2 to Figure 4 for idealised geological sections):

- FILL: The borehole logs BH-01 (2017) to BH-05 (2017), BH-04 (2021) and BH-06 (2021), BH101 to BH105 which were located on or around the proposed building sites show fill between 1.4m and 2.2m depths BEGL. The fill generally comprises silt and gravel. The log BH105 encountered concrete at 0.5m BEGL and was terminated at shallow depth. All 2017 boreholes were vacuum excavated between 1.5m and 1.7m for services. No SPT was carried out in the fill in the boreholes, with shear wave velocity of approximately 200m/s recorded within the fill layer.
- ALLUVIUM / COLLIVIUM: The fill is underlain by undifferentiated alluvium and colluvium soils to bedrock. The soils generally comprise alternating layers of gravels, silts and sands. The soils are generally medium dense to very dense, ‘firm’ to ‘very stiff’ to about 20m depth BEGL (generally uncorrected SPT N of 10 to 50+), then is generally denser / stiffer with depth (generally uncorrected SPT N of 50+ with localised softer layers). The recorded shear wave velocity within this layer is between 200m/s and 800m/s, generally increasing with depth.
- BEDROCK: The alluvium and colluvium soils are underlain by bedrock at 53m to 76m depths as indicated by the borehole logs. The bedrock is logged as orangish brown, moderately weathered, highly fractured, and moderately strong greywacke sandstone. The recorded shear wave velocity within the bedrock is generally between 800m/s and 1000m/s+.

The MWD/DSIR (1986) study mapped the historic Waipiro stream on the middle part of the site. The now infilled stream channel originally flowed from east to west across the existing parliament building. The stream channel was located at a depth of between 4m and 5m below existing ground level. However, this infilled stream channel was not identified in the recent boreholes (BH-06 being the one closest to the historic stream). A report compiled by Nick Perrin (1986) discussed the likely presence of other fossil stream channels across the site which are probably present randomly at all levels within the soils.

3.5 Groundwater

Groundwater was recorded during and following the borehole drilling. Automatic and continuous groundwater recording instruments were installed in the Piezometers BH-03 (2021), BH-04 (2021), BH-01 (2017), and BH-04 (2017) between 17 June 2021 and 10 August 2021.

The recorded groundwater levels shown in terms of RL and hourly rainfall data are presented in Figure 5 to Figure 8. The hourly rainfall data was taken from the closest GWRC rainfall monitoring instruments, located at Te papa.

A summary of the groundwater levels is presented in Table 1 below. The presence of historic flow paths (refer section 3.4 above), may result in localised variation in groundwater behaviour that should be carefully considered for any proposed excavation works. It should be noted that the groundwater levels are subject to seasonal and spatial variations.

Table 1: Groundwater table summary

Borehole and RL	Date and time	Groundwater table BEGL	Groundwater table RL	Comment
2021 BH-03 RL10.88m	17 Feb 2021, 12PM	6.2m	4.68m	Drilling completion
	16 March 2021, 10:30AM	4.8m	6.08m	*Piezo developed (pumped to 10m depth).*
	24 March 2021, 12:15PM	4.97m	5.91m	
	8 April 2021, 11AM	4.97m	5.91m	
	16 April 2021, 12PM	5.02m	5.86m	
	17 June 2021, 11:10AM			Installed Levelogger ID#1 at 7.8m depth.
	10 Aug 2021, 2:40PM	4.71m	6.17m	Levelogger removed
	See Figure 5 for hourly groundwater levels recorded from Levelogger vs hourly rainfall data (from GWRC monitoring site at Te papa)			
2021 BH-04 RL18.11m	3 March 2021, 7:30AM	6.7m	11.41m	Measured during drilling (hole was dry on previous day)
	16 March 2021, 10:30AM	5.6m	12.51m	*Piezo developed (pumped to 9.3m depth).*
	24 March 2021, 12:10PM	5.67m	12.44m	
	8 April 2021, 11AM	5.65m	12.46m	
	16 April 2021, 12PM	5.64m	12.47m	
	17 June 2021, 11AM			Installed Levelogger ID#2 at 7.8m depth, Barologger installed at 0.5m depth.
	10 Aug 2021, 2:45PM	5.57m	12.54m	Levelogger removed
	See Figure 6 for hourly groundwater levels recorded from Levelogger vs hourly rainfall data (from GWRC monitoring site at Te papa)			
2017 BH-01 RL10.2m	22 March 2017	2.6m	7.6m	From past investigation
	8 March 2021, 11AM	2.55m	7.65m	
	9 March 2021, 2:15PM	2.55m	7.65m	*-Piezo developed (pumped to 4.2m depth)* -Piezo noted to be filled with bentonite fluid (likely drilling fluid)
	16 April 2021, 12PM	2.53m	7.67m	
	17 June 2021, 10:40AM			Installed Levelogger ID#4 at 4.5m depth.
	10 Aug 2021, 3:00PM	2.5m	7.7m	Levelogger removed
	See Figure 7 for hourly groundwater levels recorded from Levelogger vs hourly rainfall data (from GWRC monitoring site at Te papa)			
2017 BH-04 RL13.2m	20 March 2017	2.4m	10.8m	From past investigation
	8 March 2021, 11AM	2.8m	10.4m	
	9 March 2021, 2:10PM	2.8m	10.4m	*Piezo developed (pumped to 4.06m depth)*
	16 April 2021, 12PM	2.85m	10.35m	
	17 June 2021, 10:50AM			Installed Levelogger ID#3 at 4.5m depth.
	10 Aug 2021, 2:50PM	2.87m	10.33m	Levelogger removed
	See Figure 8 for hourly groundwater levels recorded from Levelogger vs hourly rainfall data (from GWRC monitoring site at Te papa)			

4 Geotechnical Engineering Considerations

4.1 Proposed Buildings

A brief description of the proposed buildings is given below.

4.1.1 Ministerial Annexe (MIN)

This will be a 55m x 14m (on basement level) and three storey timber and steel structure with a single level basement. The floors cantilever out on the east and west sides above the ground floor to approximately 18m wide. The building will be designed with the Importance Level of IL3 as per the NZ Loading Standards NZS1170.0. The existing Press Annexe Gallery and Secure Delivery buildings will be demolished for its construction. The new building will occupy the Press Galley footprint, but it will extend 4m underground towards the west i.e. below the lawn area. A new retaining wall (basement wall) will be required for the extension. The basement of the existing Press Gallery Building is approximately at RL7.80m. The proposed basement level of the Ministerial Annexe Building is RL7.79m, with ground floor at RL11.25m.

4.1.2 Museum Street Building (MUS)

The Museum Street building will be a six-storey steel/timber structure with a footprint of approximately 74m x 16m. It will have a single storey basement at RL8.10m linked to the Museum Street building on the north west corner. The basement will require retaining walls on all the four sides. The basement and ground floor are extended approximately 30m long x 7m wide towards the east for a foyer entry. The building will be designed with the Importance Level of IL4 as per the NZ Loading Standards NZS1170.0.

4.1.3 Ballantrae Place Building (BAL)

This building is approximately 34m x 13.5m in plan. It is a two-storey structure with a single level basement and likely to have timber framing and floors. This building's basement will be linked with the Museum Street Building's basement. The building will be designed with the Importance Level of IL3 as per the NZ Loading Standards NZS1170.0. The basement will be at RL8.10m and occupies only the eastern part of the building with the plan area of approximately 14m x 13.5m. The basement construction will require retaining walls on the north, south and west sides.

4.2 Land Use Consent Considerations

The foundation types for the MIN, MUS and BAL buildings are yet to be finalised. The potential foundation types for these buildings are shallow raft and deep bored or driven piles. The foundation type and details will be completed during the design stage of the project. For the purpose of this reporting, we have made the following assumptions with regard to the foundations:

- The buildings will have raft foundations. The reason for this assumption is that the raft foundations are likely to generate worst case (for volume / stability) earthworks and the possible need for pumping of ground water from excavations as compared to other types of foundations such as deep bored piles. The earthworks and ground water pumping are some of the key considerations for the Consent application and this report.
- At least 1.5m deep excavation will be required below the basement finished floor levels for the construction of the raft foundations. This gives a subgrade level of RL6.30m for MIN and RL6.6m for MUS and BAL buildings.

The key geotechnical engineering considerations for the Land Use Resource Consent application are as follows:

- Earthworks

- Groundwater table
- Site stability
- Geotechnical hazards (earthquake, liquefaction)

Each of these aspects is discussed below.

4.3 Earthworks

The construction of the basements and foundations will require excavations below the existing ground levels. The excavations will need to be supported with structural elements (temporary or permanent retaining walls) as open excavations on a safe batter are not likely to be achievable due to the proximity of existing banks and the limited availability of space around the building sites. Based on the architectural plans and our preliminary assessments, the rough order sizes of the main bulk excavations for the buildings are as follows:

- Ministerial Annex:

  Assumptions:

  – 55m x 4m excavation for basement extension

  – No excavation on existing building

  – approximate depth of excavation from the existing average ground surface at RL10.5m to the subgrade level at RL6.3m

- Museum Street Building:

  Assumptions:

  – building footprint: 74m x 16m

  – basement extension footprint: 30m x 7m

  – approximate basement link footprint: 730m^2

  – new basement ramp footprint (towards south of BAL): 30m x 7m

  – approximate excavations from the existing average ground surface at RL12m to the subgrade level at RL6.6m

- Ballantrae Place Building:

  Assumptions:

  – building footprint: average length 44m x 13.5m wide. Ground Floor RL12.35m. Ground floor excavation assumed from the existing average ground surface of RL13m to the subgrade level of RL10.85m)

  – basement footprint: 14m x 13.5m, excavation from RL13m (average level of existing ground) to RL6.6m (subgrade level)

  – Bank excavation, approximate area: 400m^2, average from RL15m (average level of top of bank) to RL13m (average level of bottom of bank)

The excavated materials will generally be fill, alluvial or colluvial silts, gravels, and sands. Regular earth moving equipment will be able to carry out excavations on these materials.

4.4 Groundwater Table

The excavations are likely to be below groundwater table for a depth in the order of 1.5m for the Ministerial Annex and 3.5m for the Museum Street and Ballantrae Place buildings. The groundwater will require either pumping or control (i.e. use of secant or sheet pile wall) during the excavations.

4.5 Site Stability

The new construction is not likely to adversely impact the overall stability of the site due to the following reasons:

- The site is relatively flat except the banks on the northern area
- Any excavations below ground or in a proximity of the banks will be retained with appropriate retaining structures (either temporary during construction and or permanent works).

4.6 Earthquakes

Wellington is a seismically active region. Bradley Seismic Limited, on behalf of Parliamentary Service, has carried out a site-specific seismic hazard study for the Parliament Precinct. This study, known as Probabilistic Seismic Hazard Analysis (PSHA) has found increased earthquake load demands for the Parliament site as compared to the NZ Seismic Load Standard NZS1170.5. Reasons for the increased load demand are better understanding of the soil characteristics under building footprints and depths to rock. Also, recent scientific advances around the world have identified shortcomings in many Codes with regards to large earthquakes and associated long period shaking events that PSHA studies better address. Parliament Service has decided that all the new structures in the Precinct are to be designed as per the recommendation from the PSHA study including the site liquefaction hazard analysis.

4.7 Liquefaction

Under cyclic loading loose and non-plastic materials such as sand and coarse silt and very loose gravels tend to decrease in volume due to densification. If these soils are saturated and rapid cyclic loading occurs under un-drained conditions, then the soil densification causes pore water pressure to increase. The increase in pore water pressure results in a loss of soil strength due to a decrease in effective stress, and eventually leads to liquefaction once effective stress drops to near zero. Liquefaction can lead to large displacements of foundations, bearing capacity failure, ground surface settlement, and sand boils.

The three primary factors that contribute to liquefaction are:

- Saturation of soils i.e. high ground water table
- Loose and uniformly graded soils e.g. sand, coarse non-plastic silt, very loose gravels, etc.
- Strong earthquake shaking

Each of these is considered below together with initial conclusions on the site liquefaction potential.

Groundwater

Only saturated soils liquefy. The depth to groundwater was measured between 2.5m and 6m depths below the existing ground surface and soils are therefore potentially liquefiable from this depth based on saturation criterion. We have used various ground water level at different borehole locations for the analysis as the ground contours and borehole levels vary significantly across the site.

Table 2 below shows the groundwater used for liquefaction analysis on each borehole:

Table 2: Groundwater for liquefaction analysis

Borehole	Borehole RL	Assumed Groundwater RL / depth	Comment
BH-01 (2021)	15.54m	RL9.5m / 6.04m	Historic information (Tonkin & Taylor, 1990) shows the Groundwater (GW) levels between RL9m and 14m on the Library site. Also, this borehole is located on high ground, ~4.5m above BH-03.

BH-02 (2021)	11.04m	RL6m / 5.04m	Based on BH-03 (2021) piezometer
BH-03 (2021)	10.88m	RL6m / 4.88m	GWT recorded in piezo 4.8m – 5m BEGL
BH-04 (2021)	18.11m	RL13m / 5.11m	GWT recorded in piezo ~5.6m BEGL
BH-05 (2021)	7.73m	RL7.5m / 0.23m	Parliament refurbishment drawings show GWT at RL7.5m
BH-06 (2021)	13.43m	RL11m / 2.43m	Nearby piezometer BH-04 (2017) recorded GWT at ~2.8m depth
BH-01 (2017)	10.2m	RL8m / 2.2m	GWT recorded in piezo at RL7.6m
BH-02 (2017)	10.3m	RL8m / 2.3m	As per BH-01 (2017) piezometer
BH-03 (2017)	10.6m	RL8m / 2.6m	Based on the nearby BH-04 (2017) and BH-01 (2017) piezometers
BH-04 (2017)	13.2m	RL11m / 2.2m	GWT recorded in piezo ~2.8m BEGL
BH-05 (2017)	12.4m	RL10.5m / 1.9m	Nearby BH-04 (2017) recorded GWT at ~2.8m depth BEGL
BH-01 (2015)	6.7m	RL 5.7m / 1m	Located at underground level of Bowen State building
BH-02 (2015)	13m	RL 10.5m / 2.5m	Nearby BH-04 (2017) recorded GWT at ~2.8m depth BEGL
BH-03 (2015)	13.5m	RL 11.5m / 2m	BH-04 (2017) recorded GWT at ~2.8m depth BEGL
BH-04 (2015)	13.5m	RL 11.5m / 2m	Taken similar to BH-03 (2015) and BH-02 (2015)
BH-05 (2015)	14m	RL 12m / 2m	BH-01 (2017) recorded GWT at 2.5m BEGL
BH-06 (2015)	17.5m	RL16.5m / 1m	Recorded GW during drilling between 1.04m and 1.53m

Soil Composition

The borehole logs indicate that the site is predominantly underlain by dense sand and gravels and very hard silts, which are considered to have a very low to no liquefaction potential. But there are interbedded sand and low plastic silt layers which can be considered to have a liquefaction potential from the compositional criterion.

Earthquake Intensity and Liquefaction Potential Assessment

The level of ground shaking is one of the key factors in determining whether liquefaction will or will not occur. Wellington region is considered to be seismically active with potential for high level of ground shaking. Additionally, there is an active Wellington Fault approximately 450m northwest of site.

We have used the peak ground accelerations and earthquake magnitudes as obtained from the Probabilistic Seismic Hazard Analysis (Bradley Seismic Limited, 2021) as per Table 3 below.

Table 3: Peak Ground Accelerations and Magnitudes

Earthquake Return Period	a_{max}	M
1 in 2500 years	1.51g	8.14
1 in 1000 years	1.081g	7.91
1 in 500 years	0.792g	7.73
1 in 25 years	0.135g	6.5

Liquefaction Calculation Methodology

We assessed the ability of subsoils to resist liquefaction using the SPT and V_s (shear wave velocity) test results. Our key focus was to determine the liquefiable layers under the site and liquefaction induced settlement, if any. The methodologies used in the calculations were as shown in the Table 4 below:

Table 4: Methodology Adopted for Liquefaction Assessment

Test	Liquefaction Assessment Method	Fines Content	Liquefaction Cut Off Assumptions	Liquefaction Settlement Method	Liquefaction Ground Damage Method
SPT	Boulanger and Idriss (2014)	Based on soil description or where available laboratory test results	▪ Soil described as moderately dense gravels (or denser gravels) ▪ Clay-like behaviour, i.e. PI > 12 and Fines content passing 0.075mm sieve > 30% (NZGS, 2016)	Ishihara and Yoshimine (1992)	Ishihara (1985)
V_s	Kayen et al (2014) with a 15% probability of liquefaction, K_o = 0.5 and Age Correction Factor = 1	Based on soil description or where available laboratory test results	▪ Layers with uncorrected SPT > 35 (considered to be too dense to liquefy)	Yoshimine et al (2006) Kayen et al (2014)	Ishihara (1985)

Liquefaction Results Summary

We carried out liquefaction calculations with the SPT and shear wave velocity data from 2021, 2017 and 2015 investigations for the layers that do not meet the cut off assumptions in the Table 4 above. A summary of the calculation results is presented in Table 5 below.

Table 5: Summary of liquefaction potential from borehole logs and SPT and Shear Wave Velocity

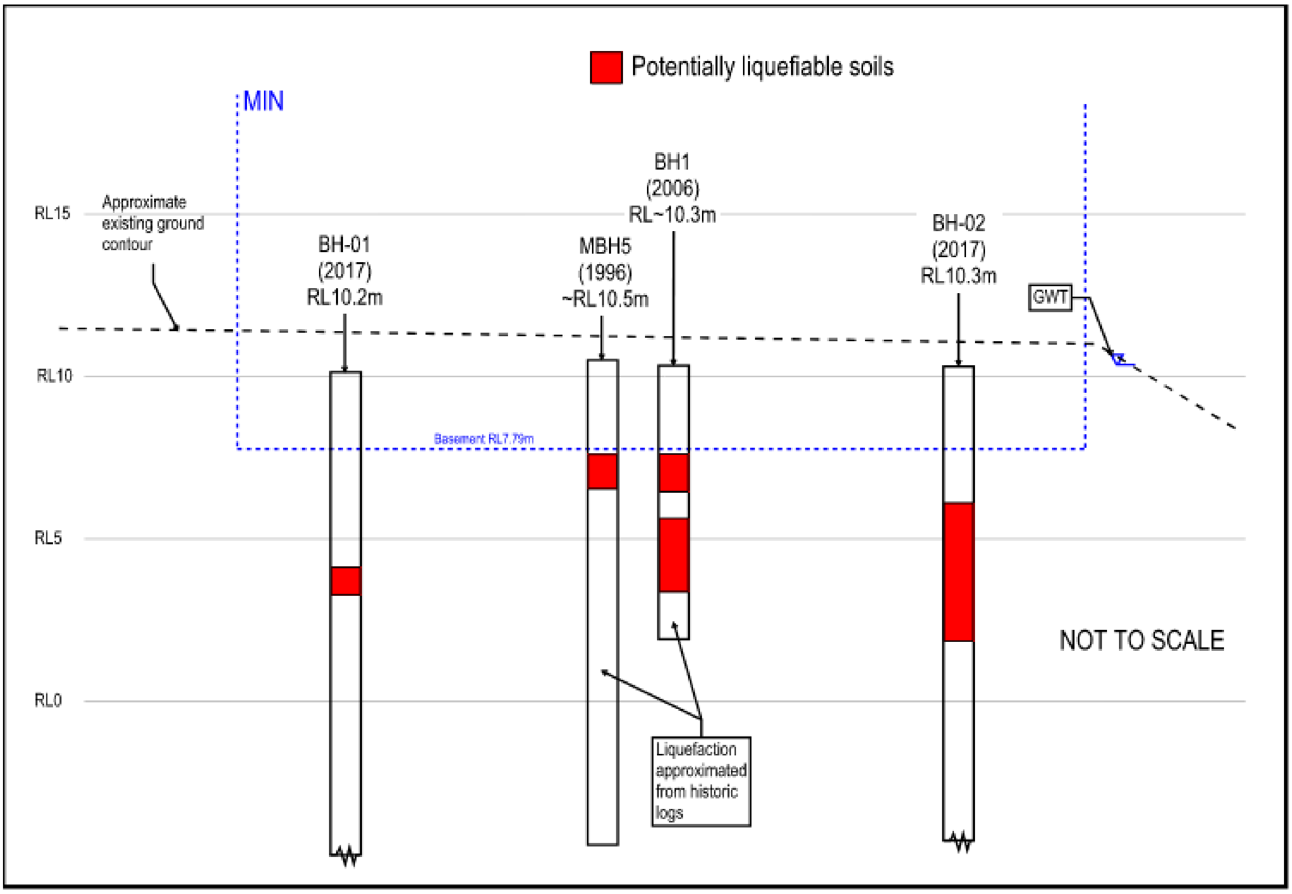
Borehole	Depth	Thickness	Potentially liquefiable layer description	Density	1 in 2500	1 in 1000	1 in 500
BH-01 (2021) **SPT**	10.45m	2m	Sandy SILT, SILT, Silty SAND	Stiff' (Uncorrected N = 18-22)	Potential	Potential	Potential
BH-01 (2021) **Shear-wave**	10.45m	2m	Sandy SILT, SILT, Silty SAND	SW=205m/s to 235m/s)	Potential	Potential (1.5m thick)	Potential (1.5m thick)

Borehole	Depth	Thickness	Potentially liquefiable layer description	Density	1 in 2500	1 in 1000	1 in 500
BH-02 (2021)	-	-	-	-	Unlikely	Unlikely	Unlikely
BH-03 (2021)	4.9m	Thin (~0.5m)	SILT	'Stiff' (Uncorrected N = 16)	Unlikely (one thin layer)	Unlikely (one thin layer)	Unlikely (one thin layer)
	7.9m	1.5m	Sandy SILT	'Stiff' (Uncorrected N = 14-25)	Potential	Unlikely (one thin layer ~0.5m)	Unlikely (one thin layer ~0.5m)
	10.4m	1.6m	SILT	'Stiff' (Uncorrected N = 23)	Potential	Potential	Potential
BH-04 (2021)	6m	1m	SILT, Silty SAND, Sandy SILT	'Firm', med dense (Uncorrected N = 23)	Potential	Marginal	Unlikely
BH-05 (2021)	3.4m	1.4m	Sandy SILT, Gravelly SILT	'Stiff' (Uncorrected N = 16)	Potential	Potential	Marginal
BH-06 (2021) **SPT**	2.4m	1.6m	Sandy SILT,	'Firm to stiff', Medium dense (Uncorrected N = 17)	Potential	Potential	Potential
	5m	0.6m	Sandy SILT	'Firm', (Uncorrected N = 12)	Potential	Potential	Potential
BH-06 (2021) **Shear-wave**	2.4m	1.6m	Sandy SILT	SW=199m/s to 242m/s)	Potential	Potential (reduced thickness : 3.5m-5m)	Potential (reduced thickness : 4m-5m)
BH-01 (2017)	6m	0m.9m	Sandy GRAVEL, Silty SAND	Medium dense (Uncorrected N = 20)	Potential	Marginal	Unlikely
BH-02 (2017) **SPT**	4.2m	4.3m	Silty SAND, gravelly SAND, SILT, Silty GRAVEL	Loose, 'Firm to stiff' (Uncorrected N = 6-11)	Potential	Potential	Potential
BH-02 (2017) **Shear-wave**	5m	1m	-	SW=223m/s	Potential	Marginal	Unlikely
BH-03 (2017)	2.6m	1.2m	Sandy GRAVEL, SILT	Loose, (Uncorrected N = 8)	Potential	Potential	Potential
	13.5m	1m	SILT, Silty SAND	Medium dense (Uncorrected N = 22)	Potential	Potential	Marginal
BH-04 (2017)	3.1m	2.65m	Silty SAND	Very loose to loose (Uncorrected N = 3-5)	Potential	Potential	Potential
	9m	1m	Sandy SILT	'Stiff to very stiff' (Uncorrected N = 18)	Potential	Potential	Potential

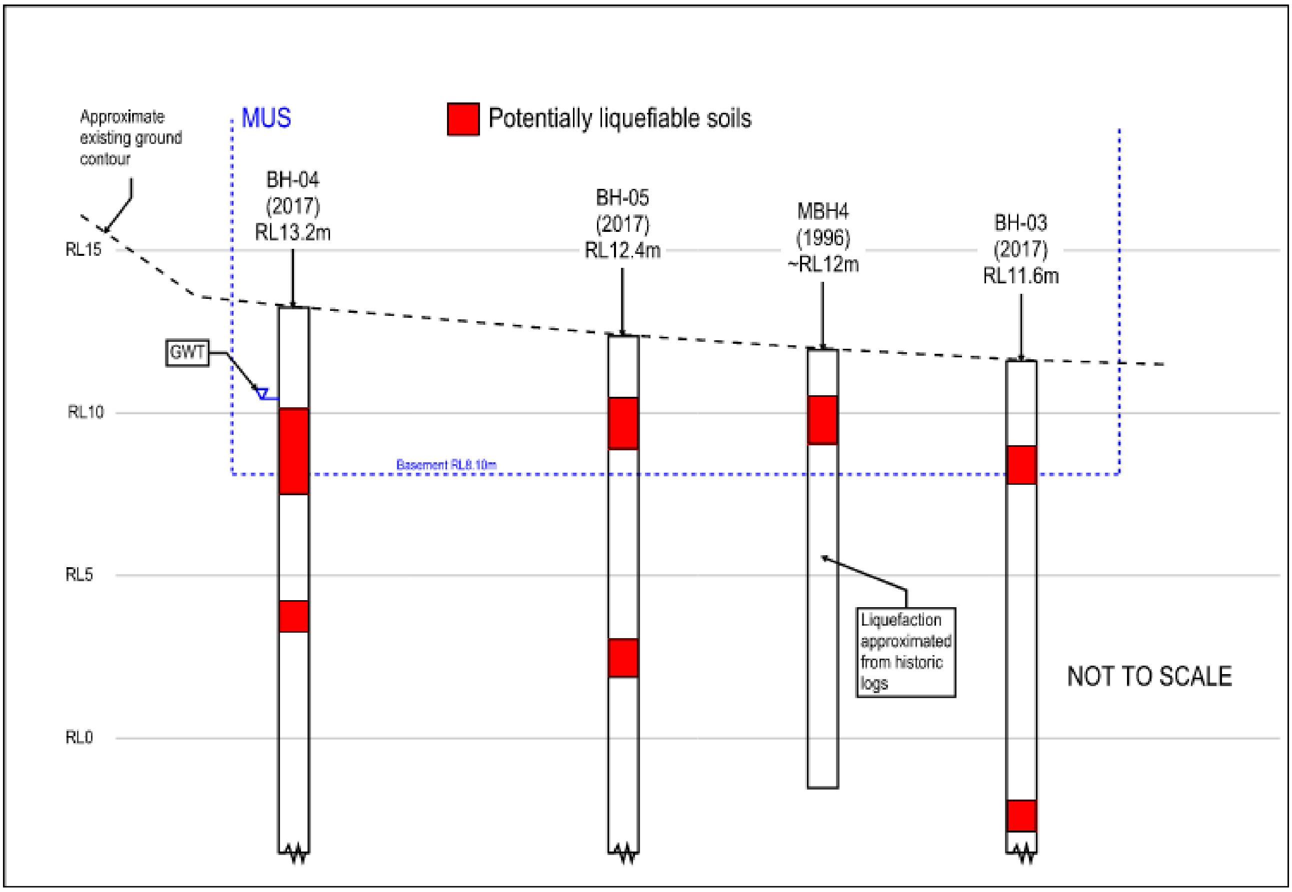
Borehole	Depth	Thickness	Potentially liquefiable layer description	Density	1 in 2500	1 in 1000	1 in 500
BH-05 (2017) **SPT**	1.9m	1.6m	SAND, Sandy SILT	Medium dense, 'Stiff to very stiff' (Uncorrected N = 13-19)	Potential	Potential (thinner 1.2m)	Potential (thinner 1.2m)
	9.3m	1.2m	Sandy SILT	'Stiff to very stiff' (Uncorrected N = 18)	Potential	Potential	Potential
BH-05 (2017) **Shear-wave**	-	-	-	-	Unlikely	Unlikely	Unlikely
BH-01 (2015) **SPT**	-	-	-	-	Unlikely	Unlikely	Unlikely
BH-01 (2015) **Shear-wave**	-	-	-	-	Unlikely	Unlikely	Unlikely
BH-02 (2015)	2.1m	Thin (<0.5m)	Silty SAND, Sandy SILT, SAND	Loose to medium dense, 'Soft' (Uncorrected N = 2)	Unlikely	Unlikely	Unlikely
BH-03 (2015)	-	-	-	-	Unlikely	Unlikely	Unlikely
BH-04 (2015)	2m	Thin, 0.5m	GRAVEL (FC=13%)	Loose (Uncorrected N = 4)	Unlikely (thin gravel dominant layer)	Unlikely (thin gravel dominant layer)	Unlikely (thin gravel dominant layer)
	10.5m	1m	Silty SAND and Sandy SILT	'Very stiff' (Uncorrected N = 22)	Potential	Potential	Potential
BH-05 (2015)	2m	Thin (~0.6m)	Silty GRAVEL, Gravelly SAND	Loose to medium dense (Uncorrected N = 5-12)	Unlikely (thin gravel dominant layer)	Unlikely (thin gravel dominant layer)	Unlikely (thin gravel dominant layer)
	3.5m	1.5m	Gravelly SILT, Sandy SILT	'Firm to stiff' (Uncorrected N = 9-17)	Potential	Potential	Potential
	5m	1.3m	Silty SAND	Medium dense (Uncorrected N = 26)	Marginal	Unlikely	Unlikely
BH-06 (2015)	2.5m	Thin, 0.5m	Sandy SILT	Soft (Uncorrected N = 9)	Unlikely (thin layer)	Unlikely (thin layer)	Unlikely (thin layer)

Liquefaction Conclusions

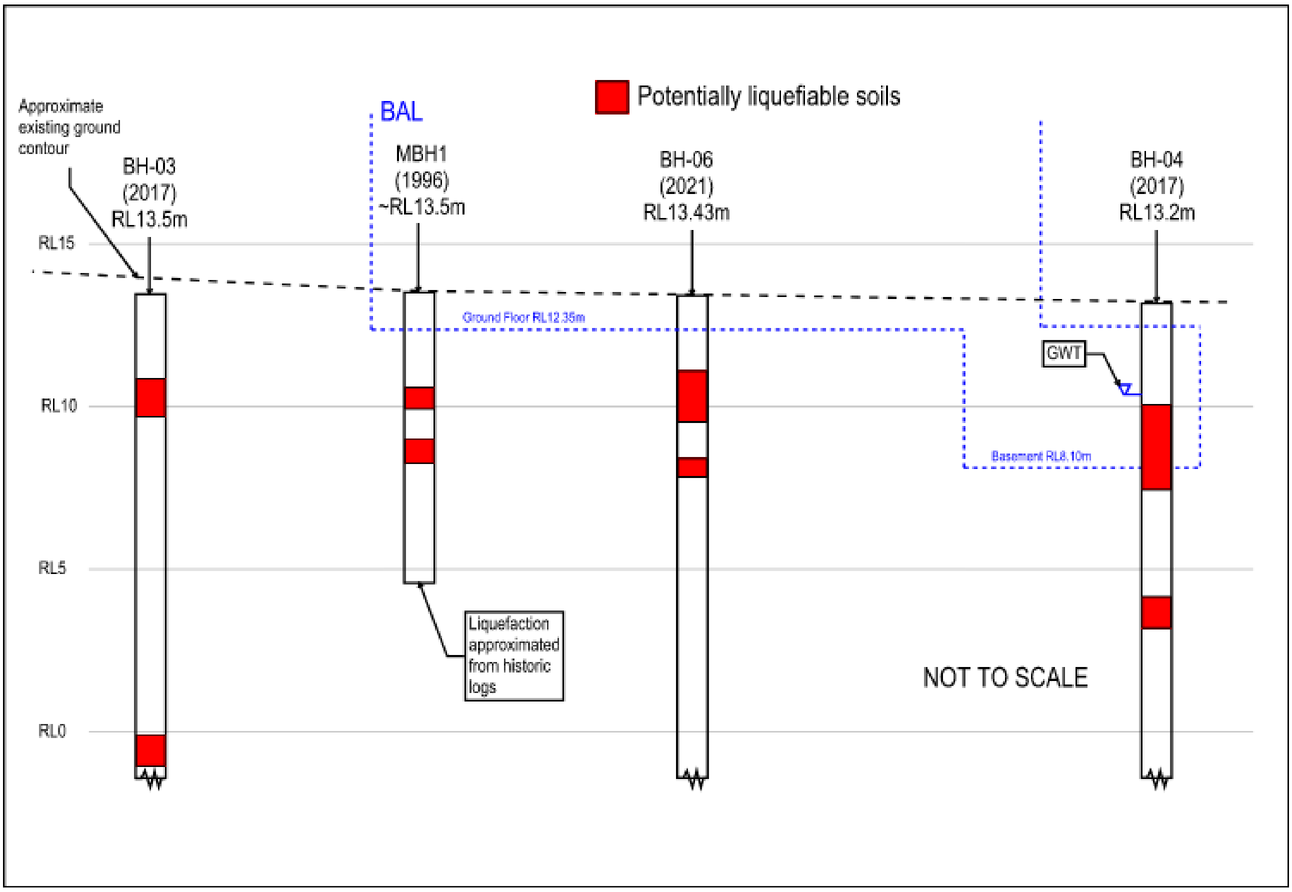
- Out of the 26 liquefaction analyses carried out from the borehole information, the results from 12 analyses show that liquefaction potential is unlikely at the site (see Table 5). The results from 14 analyses indicate that the site has potential / marginal potential for liquefaction. The boreholes located on or near the proposed MIN, MUS and BAL sites generally show liquefaction potential, but the liquefiable layers are present only within the upper alluvial/colluvial deposits. The calculations show that soils below 10m -12m from the existing ground surface are generally unlikely to liquefy. The liquefiable layers are 1m to 3m thick, but they do not seem to be continuous between the test locations indicating no widespread liquefaction risks across the site. The tentative soil layers having liquefaction potential at the MIN, MUS and BAL sites are shown in the Sketch 1 to Sketch 3 below respectively.



Sketch 1: Potentially liquefiable soil layers under the MIN building site



Sketch 2: Potentially liquefiable soil layers under the MUS building site



Sketch 3: Potentially liquefiable soil layers under the BAL building site

- As indicated by the Sketch 2, the potentially liquefiable layers under the Museum Street (MUS) Building site are mostly present above the basement level which will be excavated out for the basement construction. The relatively thin (<1m) potentially liquefiable layers at depth (which will not be excavated out) are unlikely to cause significant impact to the Museum Street Building, however the impact of these layers will be further assessed during the foundation design.
- The Sketches 1 and 3 show that there are potentially liquefiable layers under or close to the proposed raft foundation for the MIN building and proposed ground floor level for the BAL building. These layers have the potential to result in bearing capacity loss and excessive differential settlement, if shallow foundations such as reinforced concrete rafts are used for these buildings. Adoption of standard engineering solutions for non-raft (i.e. piled) solutions or improved ground and raft solutions can mitigate the liquefaction risks if detailed design suggests a raft on unimproved ground is not appropriate.

General Geotechnical Conclusions

- The site geology broadly consists of a layer of surficial fill (1 to 2m deep) over alluvium / colluvium soils comprising alternating layers of gravels, silts and sands. Bedrock underlies the site at variable depths between 53 and 76m.
- Groundwater is present across the site at a depth typically between 2m to 6m below existing ground levels. A buried steam channel is understood to traverse the site west to east and this may also provide preferential groundwater flow paths. There is an expectation that physical groundwater ingress prevention measures will be required to enable formation of the basement and tunnel structures. The most probable method for this is by constructing a cut-off concrete secant pile wall. Other options may be possible and will be considered in detailed design in conjunction with the Contractor.
- All three buildings (MIN, MUS and BAL) can be founded on either piled or raft foundations.
- Liquefaction can occur in some soils under a 1 in 500 year earthquake event, however, it will be not be widespread. The effects of liquefaction that is localised and confined to particular soil layers can be mitigated by either of the piled or raft foundation options by adopting appropriate pile design criteria or ground improving the soft and / or liquefaction prone founding soils under a raft slab.

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6 Explanatory Statement

We have prepared this report in accordance with the brief as provided. The contents of the report are for the sole use of the Client and no responsibility or liability will be accepted to any third party. Data or opinions contained within the report may not be used in other contexts or for any other purposes without our prior review and agreement.

The recommendations in this report are based on data collected at specific locations and by using suitable investigation techniques. Only a finite amount of information has been collected to meet the specific financial and technical requirements of the Client's brief and this report does not purport to completely describe all the site characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgement and it must be appreciated that actual conditions could vary from the assumed model.

Subsurface conditions relevant to construction works should be assessed by contractors who can make their own interpretation of the factual data provided. They should perform any additional tests as necessary for their own purposes.

Subsurface conditions, such as groundwater levels, can change over time. This should be borne in mind, particularly if the report is used after a protracted delay.

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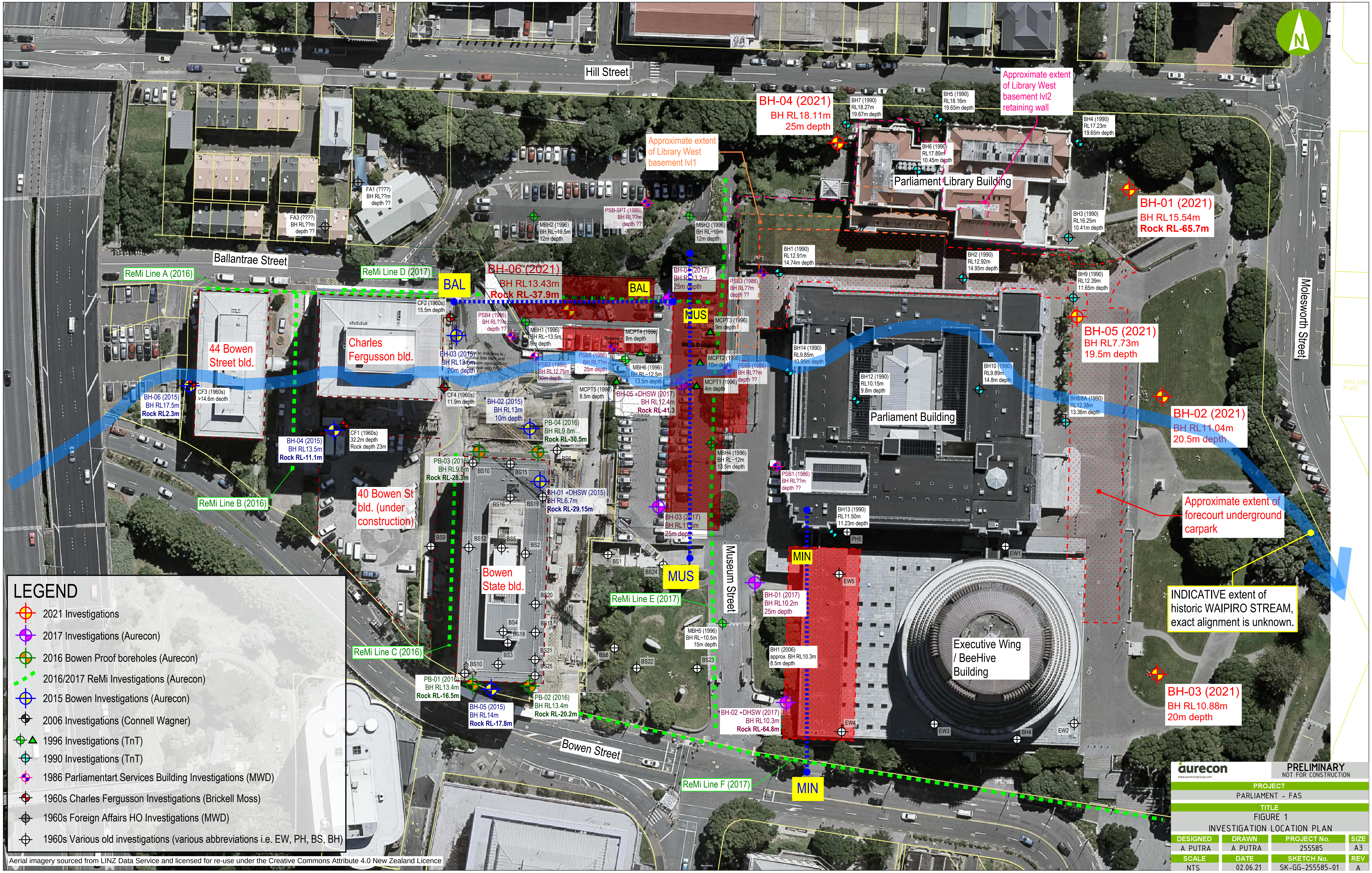
Figures



Hill Street
Ballantrae Street
Bowen Street
Museum Street
Molesworth Street
Parliament Library Building
Parliament Building
Executive Wing / BeeHive Building
44 Bowen Street bld.
Charles Fergusson bld.
40 Bowen St bld. (under construction)
Bowen State bld.
BAL
MUS
MIN
ReMi Line A (2016)
ReMi Line B (2016)
ReMi Line C (2016)
ReMi Line D (2017)
ReMi Line E (2017)
ReMi Line F (2017)
BH-04 (2021) BH RL18.11m 25m depth
BH-01 (2021) BH RL15.54m Rock RL-65.7m
BH-05 (2021) BH RL7.73m 19.5m depth
BH-02 (2021) BH RL11.04m 20.5m depth
BH-03 (2021) BH RL10.88m 20m depth
BH-06 (2021) BH RL13.43m Rock RL-37.9m
Approximate extent of Library West basement lvl2 retaining wall
Approximate extent of Library West basement lvl1
Approximate extent of forecourt underground carpark
INDICATIVE extent of historic WAIPIRO STREAM, exact alignment is unknown.
BH-06 (2015) BH RL17.5m Rock RL2.3m
BH-04 (2015) BH RL13.5m Rock RL-11.1m
BH-03 (2015) BH RL13.5m 20m depth
BH-02 (2015) BH RL13m 10m depth
BH-01 +DHSW (2015) BH RL6.7m Rock RL-29.15m
BH-05 (2015) BH RL14m Rock RL-17.8m
PB-01 (2016) BH RL13.4m Rock RL-16.5m
PB-02 (2016) BH RL13.4m Rock RL-20.2m
PB-03 (2016) BH RL9.8m Rock RL-28.3m
PB-04 (2016) BH RL9.8m Rock RL-30.5m
BH-04 (2017) BH RL13.2m 25m depth
BH-05 +DHSW (2017) BH RL12.4m Rock RL-41.3
BH-03 (2017) BH RL11.5m 25m depth
BH-01 (2017) BH RL10.2m 25m depth
BH-02 +DHSW (2017) BH RL10.3m Rock RL-64.8m
LEGEND
2021 Investigations
2017 Investigations (Aurecon)
2016 Bowen Proof boreholes (Aurecon)
2016/2017 ReMi Investigations (Aurecon)
2015 Bowen Investigations (Aurecon)
2006 Investigations (Connell Wagner)
1996 Investigations (TnT)
1990 Investigations (TnT)
1986 Parliamentart Services Building Investigations (MWD)
1960s Charles Fergusson Investigations (Brickell Moss)
1960s Foreign Affairs HO Investigations (MWD)
1960s Various old investigations (various abbreviations i.e. EW, PH, BS, BH)
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PRELIMINARY
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PROJECT
PARLIAMENT - FAS
TITLE
FIGURE 1
INVESTIGATION LOCATION PLAN
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DRAWN A PUTRA
PROJECT No. 255585
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SCALE NTS
DATE 02.06.21
SKETCH No. SK-GG-255585-01
REV A

SCALE 1:500

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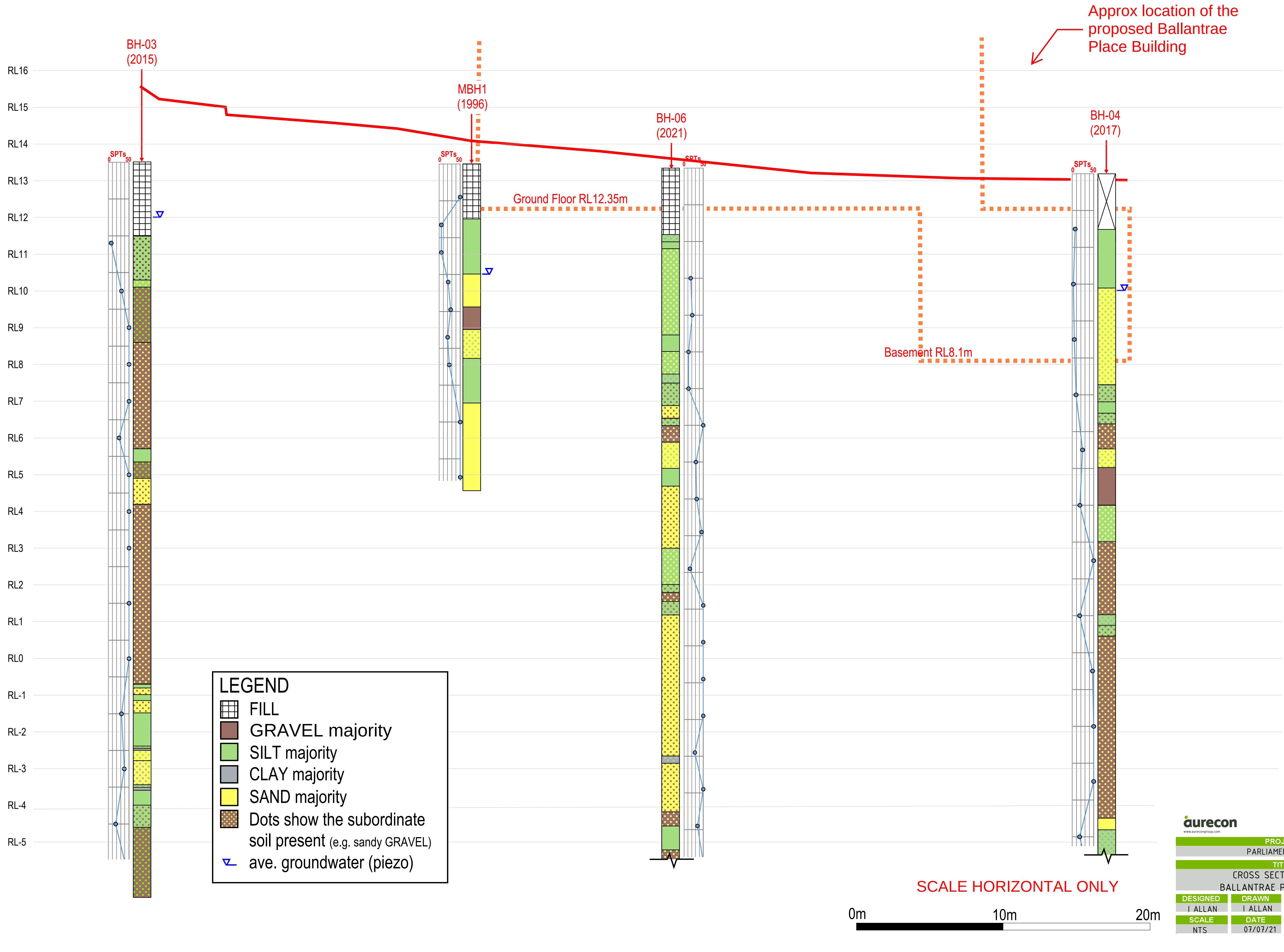

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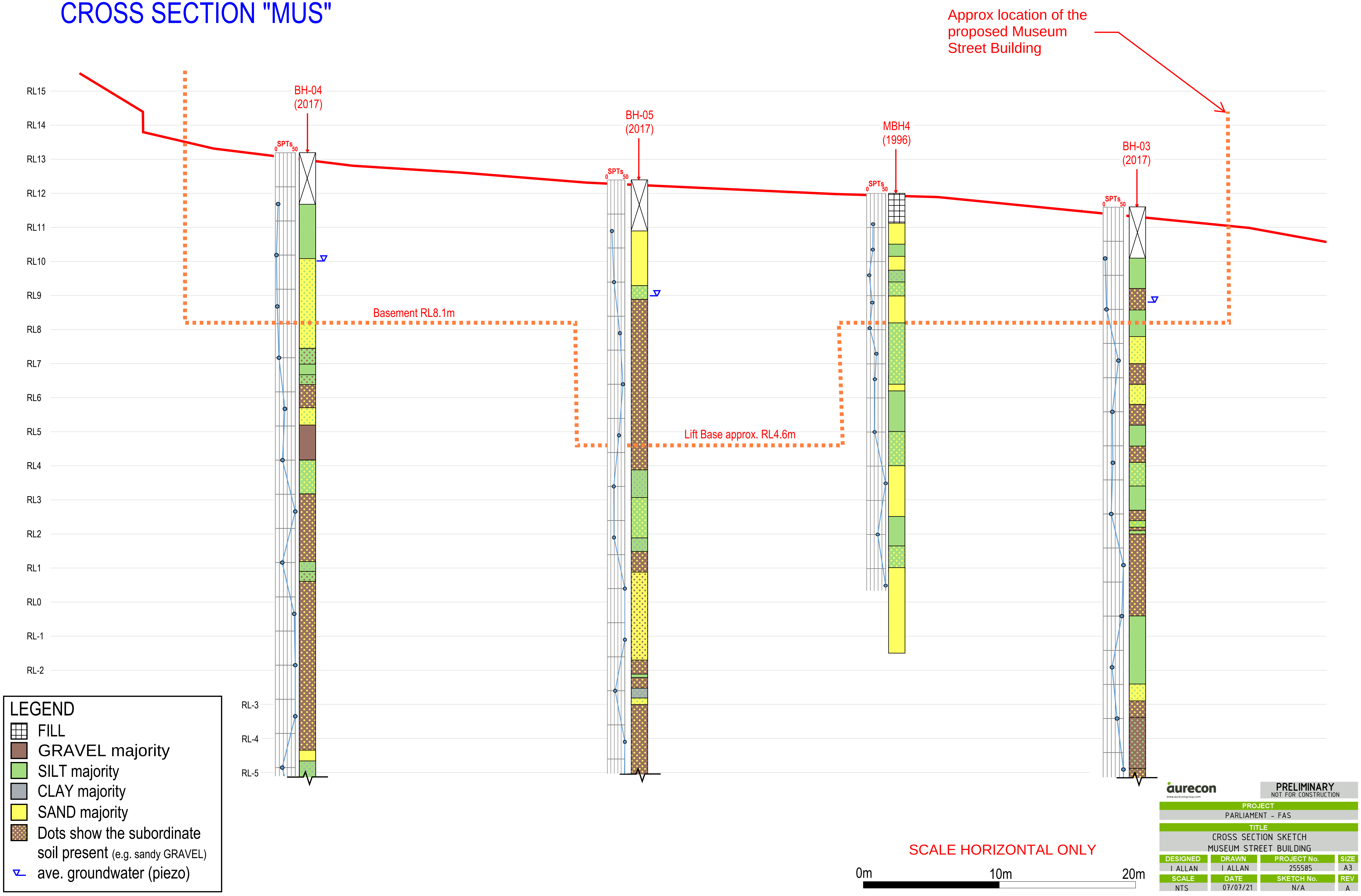

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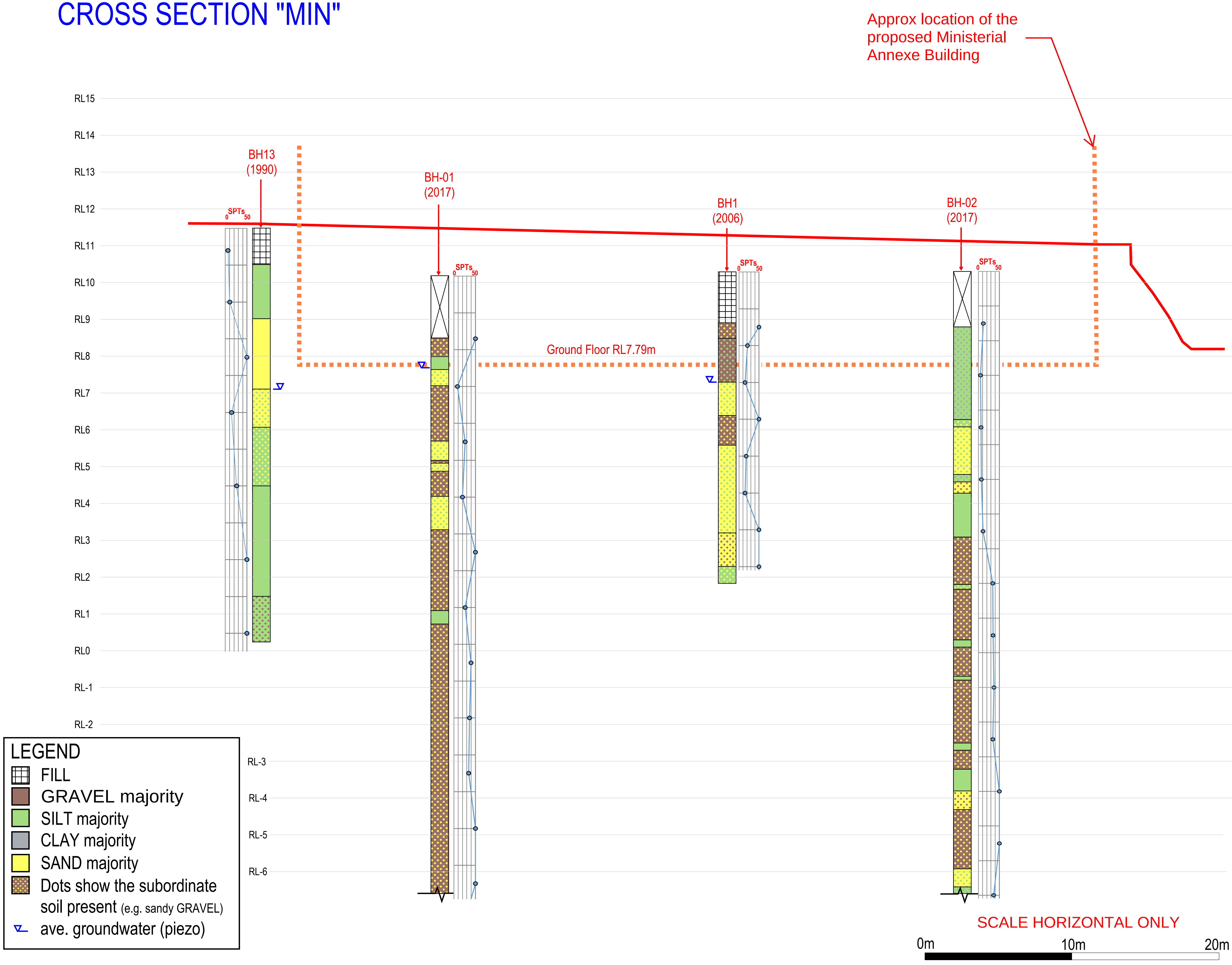

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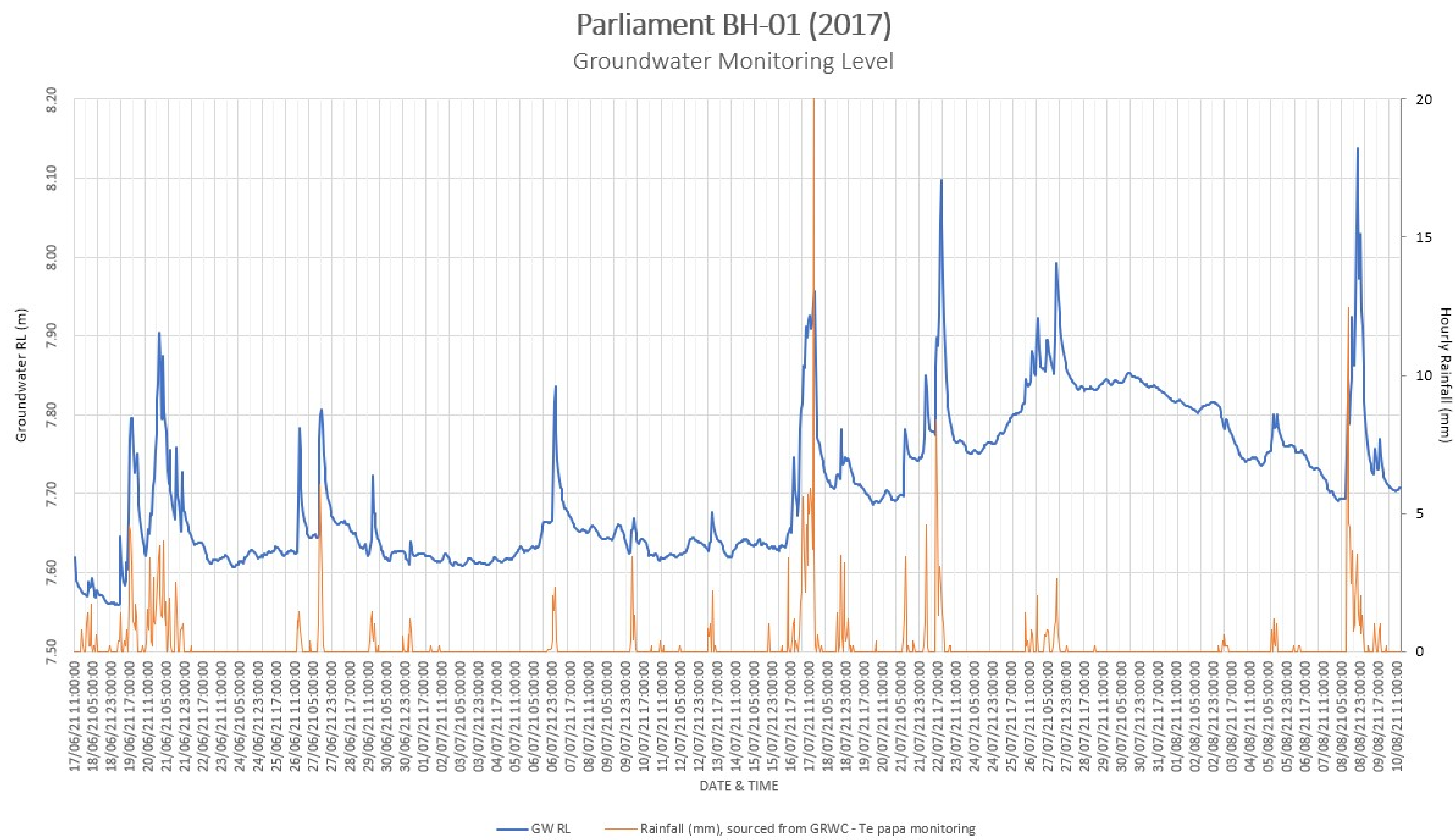

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FIGURE 5 - HOURLY GROUNDWATER RL VS RAINFALL (MM)			
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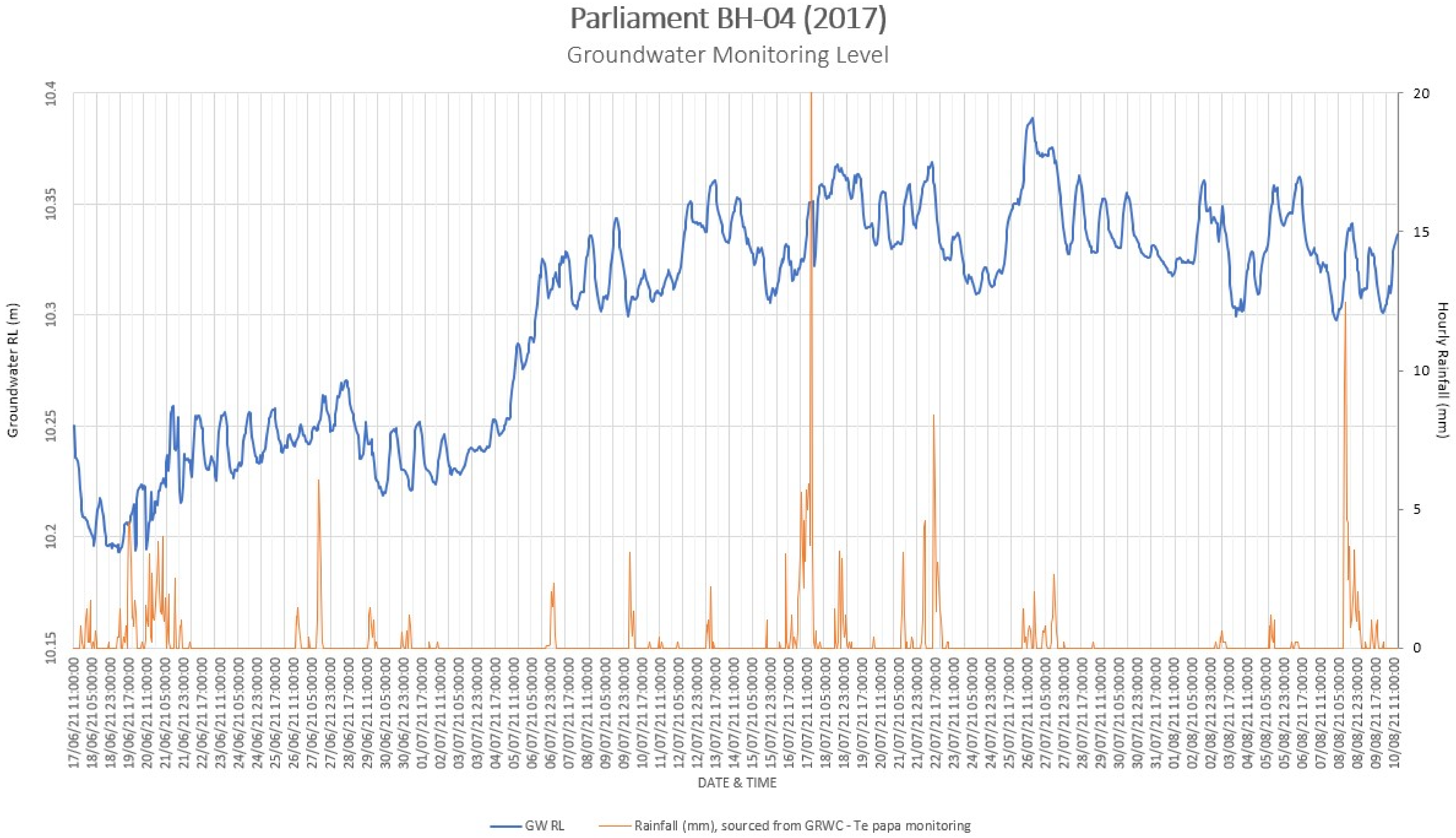

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FIGURE 6 - HOURLY GROUNDWATER RL VS RAINFALL (MM)			
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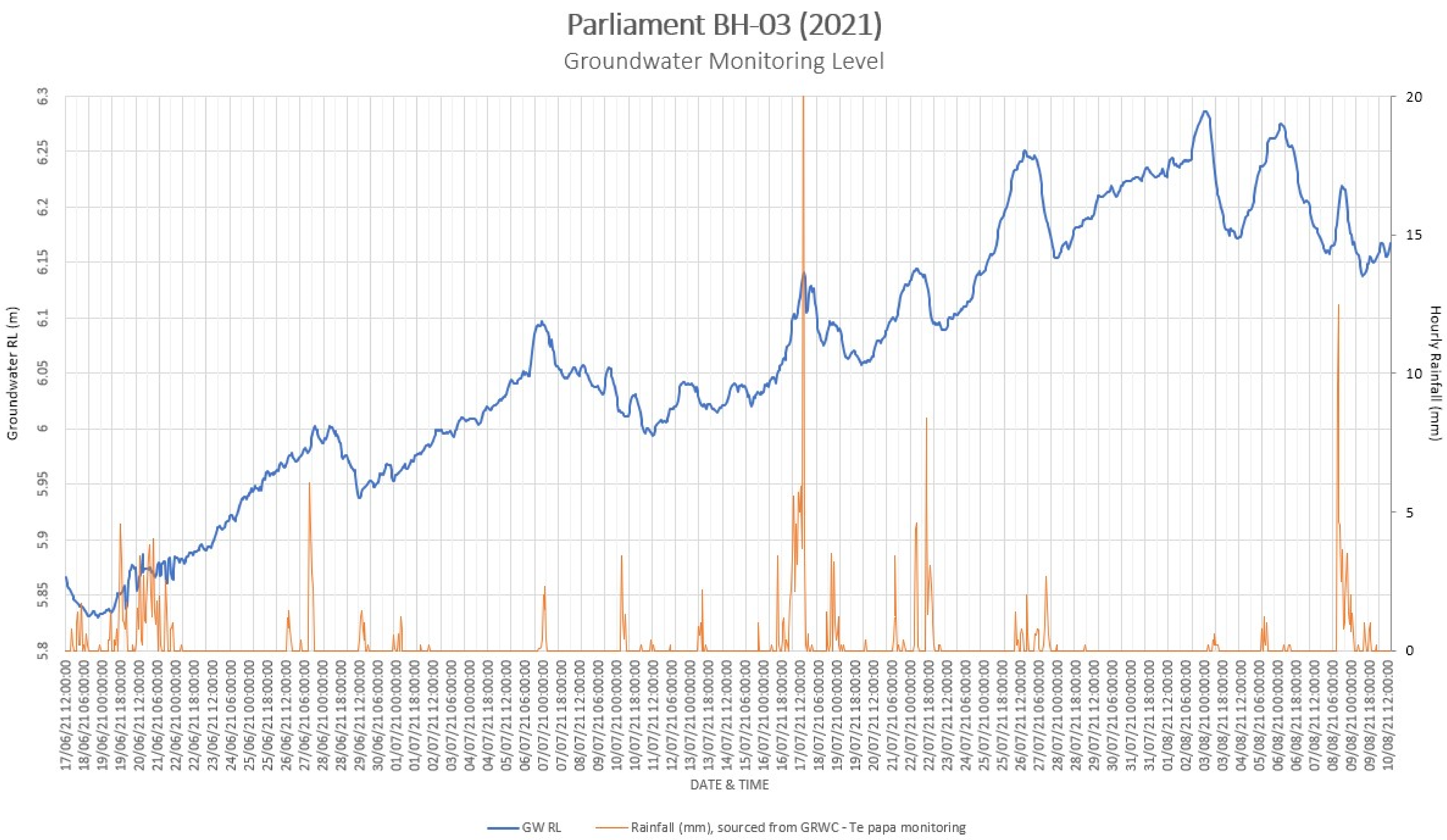

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TITLE			
FIGURE 7 - HOURLY GROUNDWATER RL VS RAINFALL (MM)			
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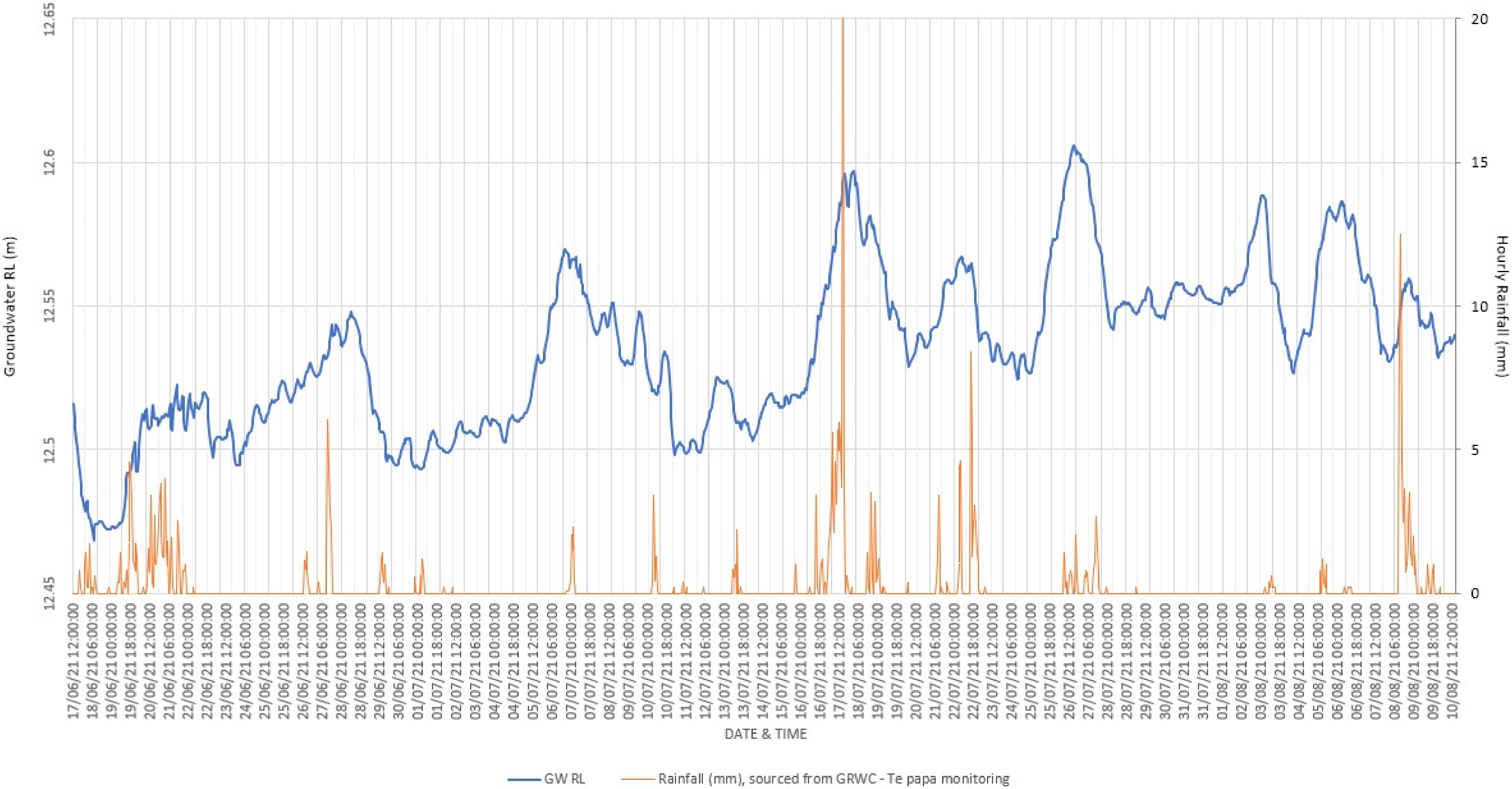
Parliament BH-04 (2021)

Groundwater Monitoring Level



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