**Earthworks**
**Validation Report**
Proposed Residential Development
Herbert Road
Newport

Phases 2 - 4

**Prepared for:**
Keepmoat

**October 2017**

terrafirma

| | | |
|---|---|---|
| **REPORT TITLE** | : | **Earthworks Validation Report: Herbert Road, Newport, Phases 2 - 4** |
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## *Executive Summary*

*In order to comply with current Government directives and the Flood Consequence Assessment (FCA) approved by NRW the site has been raised from its original level to 9.20m AOD.*

*Riversee Limited undertook the majority of the fill works to a level below the piling mat. Keepmoat completed the fill works with placement of the piling mat. Filling has been achieved by importation of soils from various sources.*

*All imported materials have been chemically screened and confirmed suitable use in accordance with Terra Firma Remediation Strategy, or in agreement with Newport City Council and National Resources Wales.*

*In-situ geotechnical testing has confirmed the effectiveness of the compaction process.*

*In-situ monitoring of settlement with in-situ piezometers and settlement pins is on-going.*

*Eight settlement monitoring pins were installed at the beginning of the earthworks (July 2015) to measure settlement occurring within the underlying alluvial and peat deposits as a result of filling. Results from these pins up to December 2016 are available. Based on these results predicted settlement between December 2016 and 2045 is between 0mm and 38mm. Predicted settlement between 2000 days from the start of the development to 2045 is between 0mm and 20mm.*

*Eight new monitoring pins were installed in 2017. Any predictions going forward may be based upon these, but at present only limited data is currently available. Based on data from these pins approximate total predicted settlement remaining between October 2017 and 2045 is between 5mm and 30mm.*

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# SECTION 1 Introduction

## 1.1 General

In order to comply with current Government directives and the Flood Consequence Assessment (FCA) approved by NRW the site has been raised from its original level to 9.20m AOD.

Riversee Limited undertook the majority of the fill works to a level below the piling mat. Keepmoat completed the fill works with placement of the piling mat. Filling has been achieved by importation of soils from various sources.

The following sections provide a summary of the site, details both chemical and geotechnical validation of the imported fill, and presents the findings of settlement monitoring to date.

## 1.2 Limitations and Exceptions

The Earthworks Validation Report has been prepared for Keepmoat. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Terra Firma (Wales) Limited. If an unauthorised third party comes into possession of this report they rely on it at their peril and the authors owe them no duty of care and skill.

The report represents the findings and opinions of experienced geo-technical and geo-environmental consultants. Terra Firma (Wales) Limited does not provide legal advice and the advice of lawyers may also be required.

# SECTION 2 Site Summary

## 2.1 Geotechnical and Geo-environmental Site Investigation

Investigation of the site was previously undertaken by Terra Firma (Wales) Limited. The details of the investigation were reported on in March 2013 (Geo-environmental and Geo-technical Report No. 12032). A copy of this report is provided in **Annex A**.

The site investigation was carried out between the 31st of October and the 8th of November 2012 comprising 19 trial pits and 6 cable percussive boreholes and 3 mini percussive boreholes.

In March 2014 additional testing of groundwater was performed.

### 2.1.1 Ground Conditions

The ground conditions encountered beneath the site prior to earthworks can in general be summarised as made ground to between 0.2m ad 3.3m depth, underlain by soft grey and brown clay with bands of peat and intermittent sand and gravel deposits. Below 5.9m/10.3m depth firm becoming very stiff red brown gravelly clay prevails, grading into red mudstone between 10m to 12.7m depth.

### 2.1.2 Foundation Solution

Construction of shallow traditional foundations upon un-compacted made ground over soft clay bands beneath the site would lead to high total and differential settlements.

Precast concrete driven piles founded within the underlying very weak red brown and grey mudstone with a suspended floor slab were therefore recommended.

### 2.1.3 Contamination and Human Health Risk Assessment

During the intrusive investigation, small disturbed soil samples were collected for contamination screening from trial pits (TP). A number of contaminants of concern were identified when comparing results to current residential (not including plant uptake) threshold levels, as summarised below:

**Table 2.1 Summary of Contaminants of Concern in Soil**

| Hole and depth (m bgl) | Chemical | Guideline (mg/kg) | Exceedance (mg/kg) |
|---|---|---|---|
| TP5 1.3m | Arsenic | 32 | 40 |
| TP2 0.90m | Cyanide | 8 | 10 |
| TP8 0.50m | Benzo(a)anthracene<br>Benzo(a)pyrene<br>Benzo(b)fluoranthene<br>Dibenzo(a,h)anthracene | 11<br>2.7<br>3.3<br>0.28 | 13<br>11<br>9<br>1.6 |
| TP6 1.8m<br>TP7 0.20m | Chrysotile – Loose Bundles | - | - |
| TP13 0.60m | PCB<br>2,4,4'-Trichlorobiphenyl<br>2,2',5,5'-Tetrachlorobiphenyl | 0.08<br>0.08<br>0.08 | 0.16<br>0.12<br>0.05 |

### 2.1.3 Contamination and Human Health Risk Assessment (Continued)

In the human health risk assessment construction workers and future site residents were considered as potential receptors to contamination in site soils.

It was concluded that future site users will be protected by the thick layer of fill to be imported and that construction workers could be protected by good site management, COSHH, good standards of hygiene and appropriate health & safety on site, with personal protection equipment (PPE) and dust suppression where appropriate.

Upon development all garden and landscaped areas will be finished with a minimum of 600mm of clean imported subsoil and topsoil.

Comparison of in-situ gas monitoring results with CIRIA report C665 confirmed that gas protection measures will be required. It was concluded that gas protection to a 'gas characteristic situation 2' level may be adequate. However, further on-site gas monitoring from flux boxes is to be undertaken upon completion of the earthworks by the developer to confirm that this level of protection will be suitable.

Basic radon protection measures will be incorporated into all new buildings on site.

### 2.1.4 Environmental Risk Assessment

Groundwater wells were installed and groundwater samples were also retrieved for testing. Samples from the drainage reen were taken and analysed in June 2013. Petroleum hydrocarbons, zinc and fluoranthene were found as contaminants in groundwater and the reen. Two rounds of groundwater testing in March 2014 identified only a single exceedence of zinc, in one location.

Monitoring of groundwater level in boreholes in January 2014 over a tidal cycle confirmed that there was no tidal influence on groundwater in the underlying sands and gravel and consequently no hydraulic continuity between groundwater and the River Usk. The River Usk and hydrological environment are not therefore considered to be at risk.

## 2.2 Remediation Strategy

Following the Geotechnical and Geo-environmental Site Investigation a Remediation Strategy Report was prepared in December 2013. This has been updated several times, reflecting the proposed site works.

A copy of the August 2015 Remediation Strategy Report is provided in **Annex B**.

In general, the following remedial measures proposed to ensure no risks to human health and the environment were:

1. Raising the site above the flood plain with imported engineered fill.

2. Upon completion of the development placement of 600mm capping of clean soil (subsoil and topsoil) in garden and landscaped areas.

3. Installation as a minimum a 2000 gauge membrane suitable for protection against ground gas, radon gas and PCB vapours in all new buildings. Passive under-floor venting and taping and sealing of all joints will also be required. Dependant on further on-site flux box gas monitoring more robust gas protection measures may be required.

4. Sampling and analysis of groundwater prior to and following initial fill works.

5. New water supply pipes to be chosen in accordance with UKWIR Report Ref No 10/WM/03/21 ‘Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites’.

## 2.3 Earthworks

To date the site levels have been raised to 9.2m AOD by Riversee Limited and Keepmoat in accordance with the Remediation Strategy.

The following sections detail validation works completed on the imported engineered fill.

## SECTION 3 Chemical Validation Imported Engineering Fill

A summary of the materials imported is provided in **Table 3.1** below.

**Table 3.1 Summary of Imported Materials**

| Soil Source | Estimated Volume Imported ($m^3$) | Date Imported on to Site | Soil Validation Test Results |
|---|---|---|---|
| Upper Half of Riversee Limited Stockpile (Adjacent Herbert Road Site) | 14,000 | June and July 2015 | DETS test certificates 27313-1 & 27519-2 **Annex C** |
| Lower Half of Riversee Limited Stockpile (Adjacent Herbert Road Site) | 9000 | July 2015 | DETS test certificates 40034-2 & 40314 **Annex D** |
| Taylor Wimpey Citivision Site | 1000 | August 2015 | DETS test certificate 47308-1 **Annex E** |
| Taylor Wimpey Citivision Site | 500 | October 2015 | DETS test certificate 46635 **Annex E** |
| Soils taken from area of site north of the drainage reen | 500 | October 2015 | DETS test certificate 77110 **Annex F** |
| Soils sourced from Green Lane and Hawes Lane, Wentloog | 12,000 | November & December 2016 | Contained within soils Risk Assessment Report **Annex H** |
| Soils sourced from Green Lane and Hawes Lane, Wentloog | 3000 | April/May 2017 | Contained within soils Risk Assessment Report **Annex H** |
| Material Sourced from Neal Soils (Piling Mat) | 5000 | June 2017 | Contained within Risk Assessment Correspondence **Annex I** |

All soils were tested for a range of substances and compared to regulatory soil and leachate guidelines values in accordance with Terra Firma Remediation Strategy. The soil test certificates are appended, as detailed in **Table 3.1**.

The Riversee Limited stockpile was sampled and tested in two halves. Each half was tested prior to import.

Other soil sources were sampled and tested once imported, except the Green Lane and Hawes Lane soils which were sampled at source and prior to import whilst stockpiled on land adjacent to site.

The soil and leachate test results (except Green Lane and Hawes Lane soils) are summarised in table format, please refer to **Annex G**. On occasion some soil samples exhibiting exceedences of chemicals above their respective soil or water threshold level were identified. Newport City Council Environmental Protection officer and the NRW were contacted and acceptance of the soils confirmed in these instances.

## SECTION 3 Chemical Validation Imported Engineering Fill (Continued)

Green Lane and Hawes Lane soil results were subject to a site specific risk assessment as requested by NRW, see **Annex H**. This assessment was approved by NRW and Newport City Council prior to import.

Similarly, the piling mat materials from Neal Soils were approved for import by NRW and Newport City Council following site specific assessment, see **Annex I**.

**Table 3.2** below and **Annex J** detail correspondence between Terra Firma, the NRW and Newport Council during fill works.

**Table 3.2 Summary of Correspondence**

| From | To | Format | Date | Subject | Annex J Ref |
|---|---|---|---|---|---|
| TFW | Riversee Limited | letter | 22.06.2015 | Chemical summary of soils from upper part of Riversee stockpile. Concludes soils should be acceptable provided appropriate bespoke permit granted from the NRW to allow asbestos | 1 |
| TFW | Newport Council Planning | Email | 22.06.2015 | Sent copy of letter on upper part of stockpile (as above) for approval | 2 |
| TFW | Riversee Ltd<br><br>Copied to NRW and Newport Council Pollution Control | letter | 06.08.2015 | Summary of chemistry of lower part of Riversee stockpile and updated Remediation Strategy. Riversee Limited stockpile material permitted for use on site. Remediation Strategy updated to include remedial measures required to protect against asbestos in fill material as requested by Newport Council Contaminated Land | 3a&b |
| NRW | Newport Council Planning | Letter | 14.08.2015 | Response to letter regarding leachate chemistry of lower part of Riversee stockpile | 4 |
| NRW | TFW | let20 | 19.08.2015 | Response to NRW letter dated 14.08.2015. Stockpile chemical summary - suggestion place Riversee stockpiled soils at least 50m from reen | 5 |
| TFW | Newport Council Pollution Control | Email | 13.10.2015 | Query of high lead exceedence in Citivision (Aberbargoed – wrongly named) soils | 6 |
| Newport Council Pollution Control | TFW | Email | 15.10.2015 | Response to TF email 13.10.2015 | 7 |
| TFW | NRW | Email | 27.10.2015 | Regarding Citivision soil and leachate results | 8 |
| NRW | TFW | Email | 12.11.2015 | Reply to TFW email 27.10.2015 | 9 |
| TFW | Newport Council Pollution Control | Email | 17.11.2015 | Regarding asbestos and lead in Citivision soils | 10 |
| TFW | NRW | let 21 | 18.11.2015 | Citivision source leachate results - TFW justification for acceptance | 11 |
| Newport Council Planning | TFW | Email | 25.11.2015 | Council/NRW inform that they are not recommending discharge of condition. Request info by 02.12.2015 | 12 |
| TFW | NRW | Email | 26.11.2015 | Regarding above Newport Council correspondence 25.11.2015 and reference to Let20 | 13 |
| NRW | NRW | Email | 26.11.2015 | Confirmed received TFW let20 and agreed informally that proposal to place Lower Riversee Stockpile material 50m from reen was acceptable | 14 |

## SECTION 3 Chemical Validation Imported Engineering Fill (Continued)

### Table 3.2 Summary of Correspondence (Continued)

| From | To | Format | Date | Subject | Annex J Ref |
|---|---|---|---|---|---|
| NRW | TFW and Newport Council Planning | Email with letter (SE-2015-119016-03-L02) | 02.12.2015 | NRW formal response to TFW let20<br><br>Partial discharge of condition 5 & 6 (remediation strategy) following receipt of TFW let20 | 15 |
| NRW | TFW | Email | 02.12.2015 | Questioning how will know which part of the stockpile deposited where on site and placement of geotextile membrane | 16 |
| TFW | Newport Council Planning | Let 22 | 10.12.2016 | Response to email 02.12.2015 (Annex Ref 14). Confirmation of fill placement and outline of intended remediation and validation procedures | 17 |
| Newport Council Pollution Control | TFW | Email | 22.01.2016 | Response to TFW email 18.11.2015 regarding Citivision soils<br>Newport Council confirm Citivision soils are acceptable | 18 |
| Newport Council Pollution Control | TFW | Email | 24.10.2016 | Confirmation Risk Assessment Report on Green Lane and Hawes Lane soils is acceptable provided risk from ground gas considered<br><br>Reference to proposed flux box testing subsequently added | 19 |
| TFW | NRW | Email | 04.11.2016 | Provision of Risk Assessment Report on Green Lane and Hawes Lane soils | 20 |
| NRW | TFW | Email | 11.11.2016 | Confirmation from NRW that Risk Assessment Report on Green Lane and Hawes Lane soils is acceptable and that soils are permitted to be imported | 20 |
| TFW | NRW and Newport Council Pollution Control | Email | 24.08.2017 | Provision of risk assessment report for Neal Soils piling mat material | - |
| | | | | **Official response from NRW and NCC pending** | |

## SECTION 4 Verification of Fill Compaction

The Riversee Limited stockpile was geotechnically tested prior to import to enable an Earthworks Compaction Specification Report to be provided.

The Compaction Specification Reports for the top half of this stockpile (Report No. 12032/CS1, dated July 2015) and bottom half (Report No. 12032/CS2, dated July 2015) are provided in **Annex K**.

A small portion of the top of the Riversee Limited stockpile was imported on to site prior to official commencement of the earthworks. This was placed across the southern end of the site. This fill was subject to plate testing and sand replacement density (SRD) tests on the 24th July 2015. A number of tests were also performed on the in-situ ground across the northern part of the site at this time.

'North' of the site refers to the area north of the track (see original topographic plan in **Figure 2.1**). 'South' is the area below the track.

As the fill levels were raised further plate load and SRD tests were completed to verify the adequacy of the compaction.

The testing completed is summarised in **Table 4.1** on the following page.

Test result certificates are provided in **Annex L.** Where any unsatisfactory results were identified the fill was stripped or broken up to allow further drying before re-rolling and testing.

## SECTION 4 Verification of Fill Compaction (Continued)

**Table 4.1 Summary of In-situ Geotechnical Tests**

| Fill Location and Details | Source | Date Imported | Date Tested | Test Type |
|---|---|---|---|---|
| Fill placed in south and northwest of site<br><br>Max 600mm fill thickness | Top of Riversee Limited Stockpile | June 2015 | 24.07.2015 | Plate tests<br>SRDs |
| 400mm (2 layers) across north of site<br><br>200mm fill across southeast quadrant of site | Top of Riversee Limited Stockpile including previously imported bund | 30.07.2015 – 04.08.2015 | 05.08.2015 | Plate tests<br>SRDs |
| Small mound placed along eastern half of southern site edge | Bottom of Riversee Limited Stockpile | 05.08.2015 | 18.08.2015<br>19.08.2015 | Plate tests |
| Fill stockpiled then spread in southwest quadrant of site (400mm thick)<br><br>Small mound in south spread over southeast quadrant (200mm thick) | Bottom of Riversee Limited Stockpile | 07.08.2015 | | |
| Fill spread over north of site (200mm) | Bottom of Riversee Limited Stockpile | 10.08.2015 - 11.08.2015 | | |
| Fill now 600mm in north and 400mm in south<br><br>Eastern half of site tested following period of stipping / drying / replacing material previously tested and spread of mound in southeast quadrant 05.08.2015 | | | | |
| Fill spread over eastern half of site | Bottom of Riversee Limited Stockpile | 19.08.2015 | | |
| Fill stockpiled in northwest corner of site | First batch of Citivision soils | 08.09.2015 – 10.09.2015 | | |
| Fill placed across the site, Northern area, the haul road and southern area. | - Fill from North/CV<br>- Fill from S.pile<br>- Fill from S.pile | | 11.09.2015 | Plate tests |
| SRD 1 – Centre North<br>SRD 2 – Southwest<br>SRD 3 – South | - Fill from North<br>- Fill from S.pile<br>- Fill from S.pile | | 14.09.2015 | SRDs |
| Placed in north of the site | Material taken from north of the reen | 16.09.2015 – 18.09.2015 | - | |
| Placed in central south of site | Bottom of Riversee Limited Stockpile | 28.09.2015 & 02.10.2015 | - | |
| Placed in south of the site | Second batch of Citi-vision soils and soils from north of reen | 05.10.2015 | - | |
| Across entire site | Hawes Lane and Green Lane Soils | 15.11.2016 – May 2017 | 03.05.2017<br>09.05.2017<br>10.05.2017 | Plate tests |
| | | May 2017 | 26.05.2017 | Plate tests |
| Across entire site | Piling Mat – Neal Soils sourced material | June 2017 | **Plate Tests to be performed prior to piling** | |

## SECTION 5 Settlement Monitoring

During July 2015 six vibrating wire piezometers and eight settlement monitoring pins were installed across the site. In June 2017 eight new settlement pins were installed to replace the original pins that, with the exception of one, had been damaged through site activity.

The location of these monitoring points is illustrated in **Figure 5.1** below.

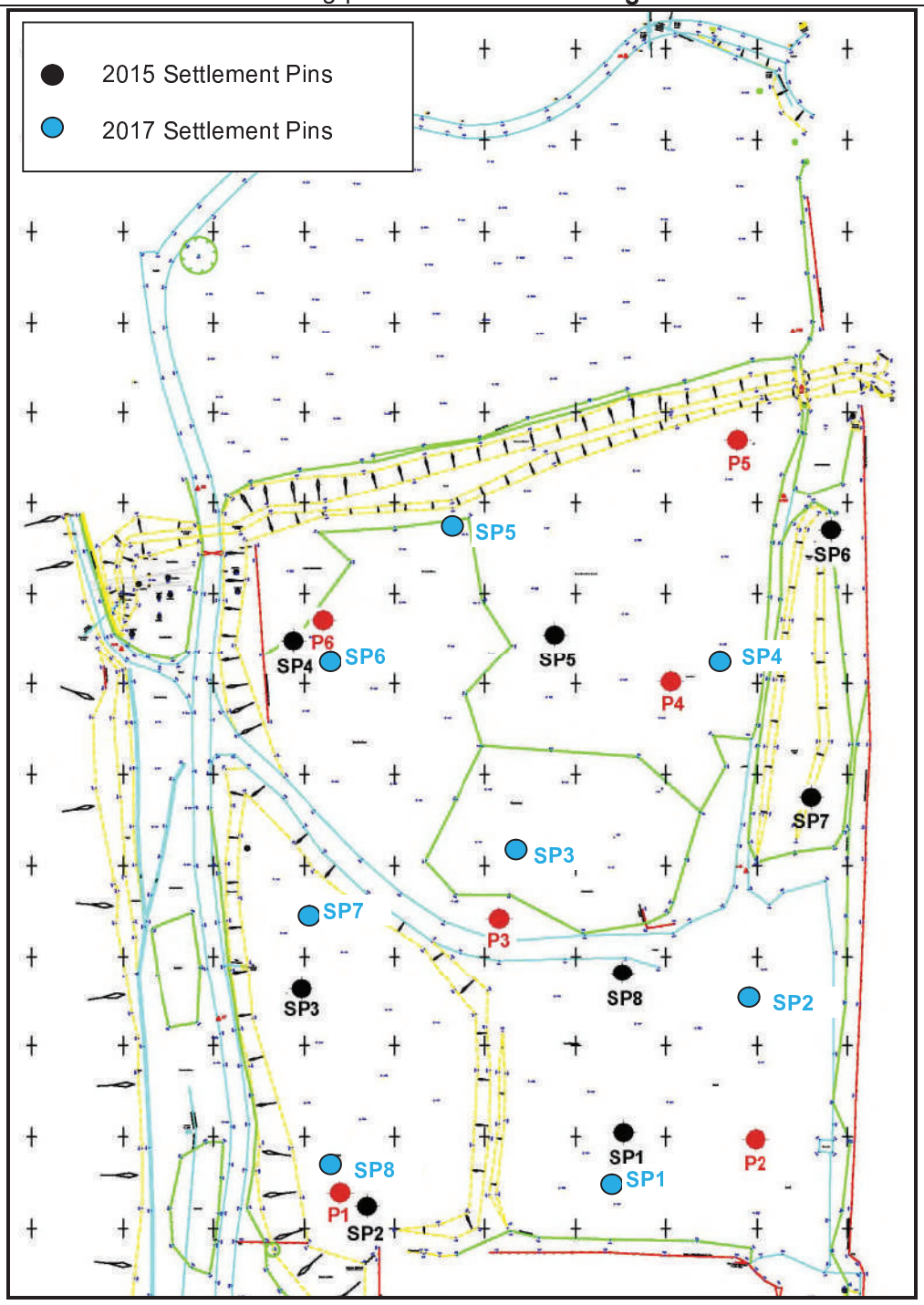



**Figure 5.1: Approximate Piezometer (P1 – P6) and Settlement Pin (SP1 – SP8) Locations**

## SECTION 5 Settlement Monitoring (Continued)

The piezometers and settlement pins are being monitored and surveyed at regular intervals during the earthworks.

With raising ground levels settlement is expected to occur on site in three phases, instantaneous and primary settlement, primary consolidation settlement and secondary consolidation settlement.

During instantaneous settlement the soil experiences only shear deformation resulting into change in shape without volumetric deformation. The loss of pore pressure in the soil is zero. Since this settlement is instantaneous it can only be monitored via monitoring pins as the pore pressure cannot be measured (zero).

During primary consolidation / settlement the soil is deformed by movement and compression of soil particles which overall results in volume change. Water held in pores of a saturated soil will migrate to pores of lower pressure (The process of consolidation). Primary settlement is time dependent on a logarithmic scale and stops when pore water pressure returns to baseline level.

Secondary consolidation / settlement occurs following the fall of pore water pressure. Secondary consolidation / settlement includes but is not limited to the following factors;

- Creep: With increasing pressure the grains may become so tightly packed that they will deform causing the soil mass to continue to reduce in volume
- Viscous behaviour of water between particles and pore water: During secondary compression the highly viscous water between the points of contact of soil particles is squeezed out.
- Compression and degradation of organic matter,

Consolidation is a process by which soils decrease in volume by decreasing water content within a saturated soil without replacement of water by air. Consolidation occurs when water is expelled under long term static loads. When a stress or surcharge is applied to a saturated soil the soil particles can compact, therefore reducing its bulk volume and excess water will be “squeezed out”. As a soil consolidates excess pore water pressure will fall.

Vibrating wire piezometers were used to monitor pore water pressures (a pressure correlating to meters of water). Vibrating wire piezometers convert fluid pressures on a sensitive diaphragm into a frequency signal. The signals are capable of long transmission distances without degradation, tolerant of wet conditions and resistant to external electrical noise.

To measure settlement baseline data is required, as shown in **Table 5.1**.

## SECTION 5 Settlement Monitoring (Continued)

**Table 5.1 Installation details of Piezometers**

| Piezometer | Depth | Strata Description | Initial Reading | | Possible Baseline Reading | |
|---|---|---|---|---|---|---|
| | | | $mH_2O$ | Date | $mH_2O$ | Date |
| P1 | 6.30mbgl | Peat | 2.05 | 14/7/15 | 4.45 | 23/7/16 |
| P1A | 7.0mbgl | Peat | 5.887 | 9/6/17 | 5.90 | 27/6/17 |
| P2 | 2.60mbgl | Clay | 0.017 | 15/7/15 | 2.20 | 24/7/16 |
| P3 | 3.70mbgl | Clay | 2.429 | 16/7/15 | 2.20 | 24/7/16 |
| P4 | 4.95mbgl | Peat | 0.358 | 16/7/15 | 4.10 | 22/7/16 |
| P4A | 8.3mbgl | Peat | 4.756 | 9/6/17 | 4.67 | 27/6/17 |
| P5* | 2.90mbgl | Peat | 0.324 | 17/7/15 | 1.95 | 29/7/16 |
| P6 | 5.00mbgl | Clay | 4.087 | 22/7/15 | 4.50 | 28/7/16 |

The possible baseline readings are considered representative although project program would not permit prolonged monitoring to refine the baseline pressures further. Piezometers P1A and P4A were installed, replace P1 and P4 which had been lost.

During the establishment of a baseline the piezometers were monitored for changes in pore pressure coinciding with changes in tide level. The tidal range of the River Usk in Newport can extend over 13m. Tide information from The United Kingdom Hydrographic Office for Newport, Wales was used to identify low tide and high tides. Despite the significant tidal range the effect on piezometers was slight / negligible.

As confirmation the piezometers were measured again from low tide to high tide, (a 10.3m tidal range) between 11:00 and 17:00 on 27/5/2016. The data is summarised below.

**Table 5.2 Tidal Effect on Piezometers**

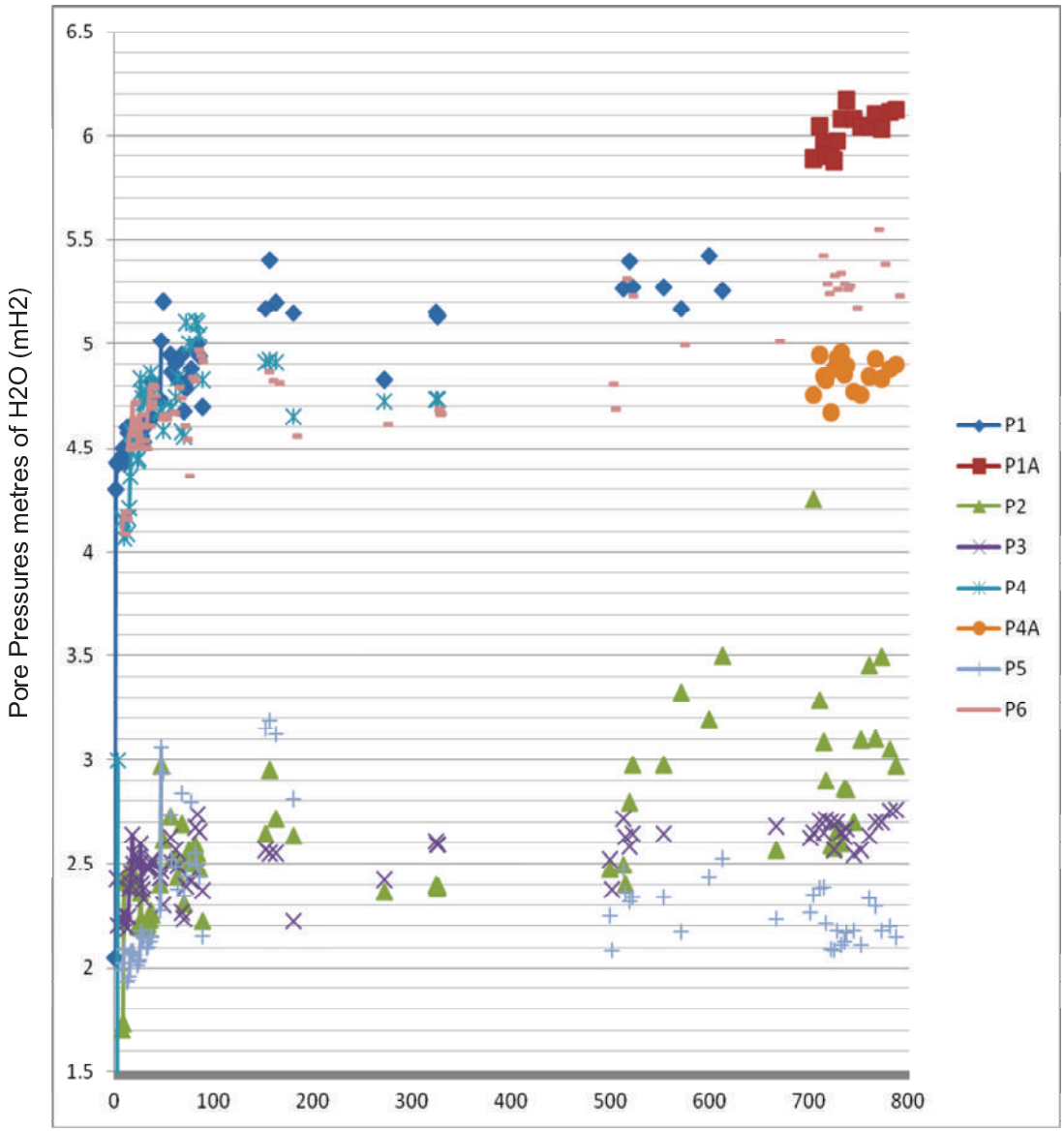
| Time | 11:00 | 14:00 | 17:00 | Maximum measured Change in Pore Pressure |
|---|---|---|---|---|
| Tide Description | Low Tide | Rising Tide | High Tide | |
| P1 | 5.151573 | 5.13387 | 5.13387 | -0.018$mH_2O$ |
| P2 | 2.3939187 | 2.3825055 | 2.3882121 | -0.011$mH_2O$ |
| P3 | 2.6096248 | 2.5912062 | 2.5912062 | -0.018$mH_2O$ |
| P4 | 4.7355286 | 4.7355286 | 4.7355286 | 0$mH_2O$ |
| P5 | Not recorded | | | |
| P6 | 4.6853254 | 4.6593008 | 4.6646852 | -0.026$mH_2O$ |
| Pore Pressures reported in $mH_2O$. | | | | |

Pore water pressure would be anticipated to increase at high tide with rising water levels however this does not appear to be evident. The equivalent of under 30mm groundwater change was observed between low tide and high tide in this instance. It is considered that the groundwater beneath the site is unlikely to be significantly influenced by the high tidal range of the Usk.

Pore water pressure was monitored daily during the period of full time supervision and significant activity on site. Full time supervision was between 14/7/2015 through to 20/8/2015. Monitoring continued beyond this point on a less frequent basis, typically once or twice a week, to reflect reduced site activity.

## SECTION 5 Settlement Monitoring (Continued)

**Graph 5.1 : Piezometer Monitoring Results**

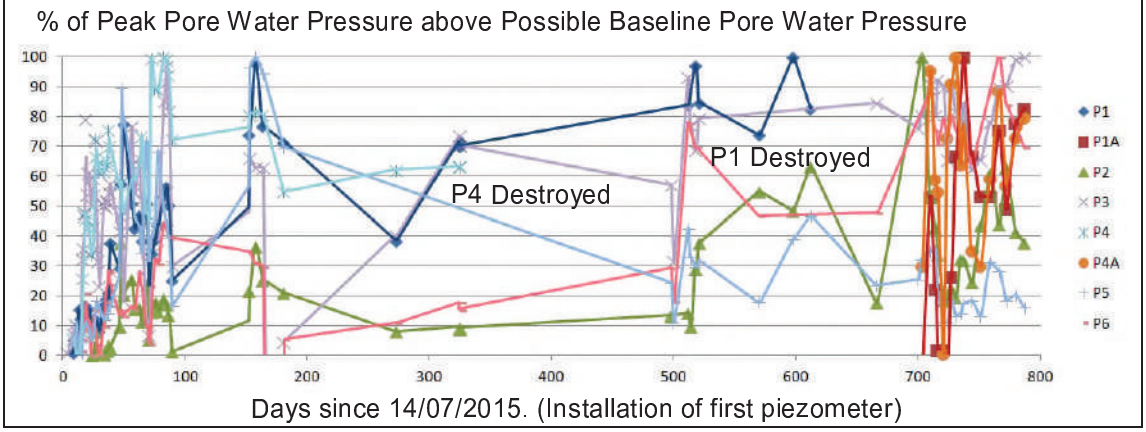



During full time supervision the increasing pore water pressures observed from the piezometers appeared to correlate with the placement of fill. As evidenced by jumps in pore water pressure over the day. Peak pore water pressure dissipated initially quickly but the rate of dissipation reduced resulting in jumps of pore water pressure.

## SECTION 5 Settlement Monitoring (Continued)

During settlement pore water pressure dissipates as water is squeezed out of consolidating material. The graph below shows the generation of peak pore water pressure generated by the placement of fill typically between 3 and 5 months after the commencement of the earthworks.

**Graph 5.2 : Dissipation of Peak Pore Water Pressure**




Pore water pressure has been observed to be dissipating, evidence of consolidation and settlement. However the monitoring of pore water pressure dissipation has been disrupted by filling events.

Pore water pressure dissipation of a single filling event should produce a single curve. However multiple filling events are likely to explain for the peaks and troughs of pore water dissipation suggesting that following the initial placement of the assessed stockpile further material has been placed on site.

A summary of pore water pressure dissipation 800 days or 2.2years after commencement of the earthworks is presented below;

## SECTION 5 Settlement Monitoring (Continued)

### Table 5.3 Summary of Piezometer Monitoring

| | | |
|---|---|---|
| Piezometer 1 | Strata:<br>Peat (6.30mbgl) | Location: South-western Corner of Site<br>(Near River Usk Embankment) |
| Piezometer P1 initially achieved peak water pressure after ~150days. Pore water pressure appears to have steadily dissipated to ~40% of peak pore water pressure after ~200 days. However, placement of fill has raised pore water pressure to a new peak after ~600 days. Shortly after Piezometer P1 was subsequently lost, however it is expected that a further ~200days (800 days) pore water would return to ~40% of peak pore water pressure. | | |
| Piezometer P1 was destroyed and replaced by Piezometer P1A.<br>Maximum pore water pressure was achieved at ~730days. Pore water pressure appears to be falling with pore water pressure ~80% of maximum after 800 days. | | |
| Piezometer 1A | Strata:<br>Peat (7.0mbgl) | Location: South-western Corner of Site<br>(Near River Usk Embankment) |
| Maximum pore water pressure was achieved at ~730days. Pore water pressure appears to be falling with pore water pressure ~80% of maximum after 800 days. | | |
| Piezometer 2 | Strata:<br>Clay (3.70mbgl) | Location: South-eastern Corner of Site<br>(Near Rail Embankment) |
| Piezometer P2 dissipated initially but established a new peak pore water pressure after ~700 days after a new fill event. After 100days pore water pressure has dissipated to <40% of maximum. Water pressure has previously appeared to dissipated to ~30% of peak pore water pressure after ~50 days and 20% after ~100 days. | | |
| Piezometer 3 | Strata:<br>Clay (2.60mbgl) | Location: Southern Centre of Site |
| Piezometer P3 like Piezometer P1 also dissipated to 40% of peak water pressure taking ~200 days.<br><br>Piezometer P3 has recently increased to a new peak pore water pressure after ~800days.<br><br>Pore water pressure does not appear to be dissipating as fast as initially. Following the previous peak pore water pressure was still ~85% of peak pore water pressure after 150days. | | |
| Piezometer 4 | Strata:<br>Peat (4.95mbgl) | Location: North-Centre of Site |
| Piezometer P4 initially achieved peak water pressure after ~100days. Pore water dissipated to ~55% of peak pore water pressure after a further ~100 days. However shortly after ~300days Piezometer P4 was destroyed and no further observations could be made. | | |
| Piezometer P4 was destroyed and replaced by Piezometer P4A | | |
| Piezometer 4A | Strata:<br>Peat (8.3mbgl) | Location: North-Centre of Site |
| Maximum pore water pressure was achieved at ~730days. Pore water pressure appears to be falling with pore water pressure ~80% of maximum after 800 days. | | |
| Piezometer 5 | Strata:<br>Peat (2.90mbgl) | Location: North-eastern corner of Site<br>(Near Rail Embankment) |
| Piezometer 5 achieved peak pore water pressure after ~200days. Despite multiple filling events pore water pressure has typically dissipated, reaching <20% of peak pore water pressure within 800 days. | | |
| Piezometer 6 | Strata:<br>Clay (5.00mbgl) | Location: North-western corner of Site<br>(Near River Usk Embankment) |
| Piezometer P6 dissipated initially but established a new peak pore water pressure after ~500days after a new fill event. Since then pore water pressure has appeared to dissipate to ~60% of peak pore water pressure after a further ~150 days.<br>A new maximum pore water pressure was achieved at ~750days. Pore water pressure appears to be falling with pore water pressure ~70% of maximum after a further ~50 days. | | |
| Observations:<br>There are difficulties observing pore water dissipation when there have been multiple filling events. Normally peak pore water pressure is achieved following placement of a single fill event. However, in this case limited dissipation has occurred only for further fill events to increase pore water pressure to new peaks.<br><br>Primary settlement is not complete since pore water pressure continues to fall since the last fill event. Dissipation of pore water pressure appears faster in the peat layers than in the clay. Peat is known to be a more susceptible material to change than clay.<br><br>The percentage change to pore water pressure in some cases equates to small groundwater level change in real terms, see Graph 5.1. Peak pore water pressure was not as high as initially envisaged because the earthworks were spread over a longer duration than anticipated.<br><br>Pore water change has been slight in P1A and P4A since very little additional load has been generated since their installation. There is very little difference between peak pore water pressure and base line water pressure and therefore even a small change can cause a high proportional change. | | |

## SECTION 5 Settlement Monitoring (Continued)

The original (2015) settlement monitoring pins were installed targeting the following areas;
Monitoring Pin 1: South-eastern Corner of the site, near rail embankment,
Monitoring Pin 2: South-western Corner of the site, near River Usk Embankment,(Destroyed)
Monitoring Pin 3: Western Edge of the site, near River Usk Embankment,(Destroyed)
Monitoring Pin 4: North-western Corner of the site, near River Usk Embankment,(Destroyed)
Monitoring Pin 5: Northern edge of the site, near reen,
Monitoring Pin 6: North-eastern corner of the site, near rail embankment,(Destroyed)
Monitoring Pin 7: Eastern Edge of the site, near rail embankment,
Monitoring Pin 8: Centre of site

Unfortunately half of the original monitoring pins were disturbed during the earthworks during 2015 and 2016 causing the loss of corresponding baseline information for settlement monitoring. A summary of all survey data to date is presented in **Table 5.4** below.

**Table 5.4 Summary of Survey Data (mAOD)**

| | Round 1 | Round 2 | Round 3 | Round 4 | Round 5 | Round 6 | Round 7 | Round 8 | Round 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Pin** | 17/7/15 | 24/7/15 | 7/8/15 | 17/8/15 | 24/8/15 | 2/10/15 | 29/12/15 | 17/3/16 | 15/12/16 |
| **P1** | 9.435 | 9.435 | 9.435 | 9.435 | 9.424 | 9.427 | 9.4187 | 9.418 | 9.414 |
| **P2** | **D** | 10.069 | **D** | **D** | **D** | **D** | **D** | **D** | **D** |
| **P2A** | - | - | 10.071 | 10.064 | 10.055 | 10.059 | 10.0464 | 10.0429 | **D** |
| **P3** | 9.136 | 9.136 | 9.137 | **D** | **D** | **D** | **D** | **D** | **D** |
| **P3A** | - | - | - | 9.195 | **D** | **D** | **D** | **D** | **D** |
| **P3B** | - | - | - | - | - | 9.708 | 9.6882 | 9.68 | 9.682 |
| **P4** | 8.772 | 8.773 | 8.771 | **D** | **D** | **D** | **D** | **D** | **D** |
| **P4A** | - | - | - | - | 9.009 | 9.013 | 8.9902 | 8.982 | 8.977 |
| **P5** | 9.195 | 9.195 | 9.198 | 9.195 | 9.186 | 9.178 | 9.1563 | 9.149 | 9.145 |
| **P6** | 9.22 | **D** | **D** | **D** | **D** | **D** | **D** | **D** | **D** |
| **P6A** | - | 9.268 | 9.267 | 9.271 | 9.264 | 9.274 | 9.2721 | 9.263 | 9.264 |
| **P7** | 8.954 | 8.954 | 8.955 | 8.955 | 8.945 | 8.935 | 8.9125 | 8.91 | **D** |
| **P8** | 9.209 | 9.209 | 9.207 | 9.208 | 9.199 | 9.202 | Anomalous Result | 9.185 | 9.180 |

- = not present, **D** = Destroyed, Green filled cells indicate pins with a mostly complete set of monitoring data

Justification of Survey Rounds:

| | |
|---|---|
| Round 1, 17/7/15. | Initial Survey (P2 damaged - not surveyed) |
| Round 2, 24/7/15. | Initial Survey of P2 and P6A |
| Round 3, 7/8/15, | Initial Survey of P2A |
| Round 4, 17/8/15, | Initial Survey of P3A and survey of damaged P2A |
| Round 5, 24/8/15, | Initial Survey (P3A damaged - not surveyed) |
| Round 6, 2/10/15 | Initial Survey of P3A |
| Round 7, 29/12/15 | Follow up survey |
| Round 8, 17/3/15 | Follow up survey |
| Round 9, 15/12/16 | Follow up survey |

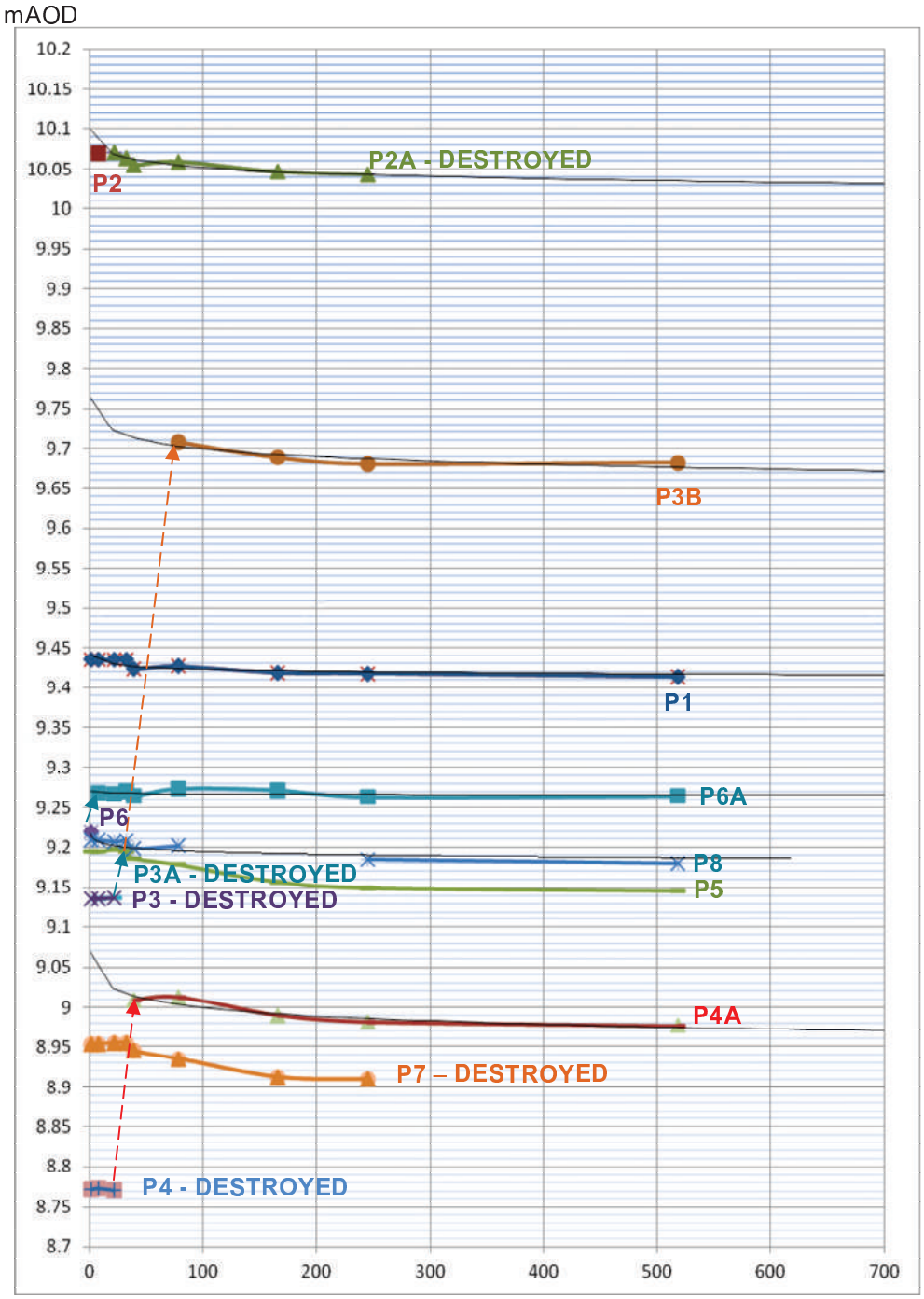
The following extrapolations are based on measured settlement over a period of ~530days. Monitoring pins were replaced following this assessment.

The settlement monitoring pins have since been replaced. Not a single pin has dropped by 1mm in the last 80 days. This is to be expected as the rate of settlement is anticipated to be slow and less than 1% of the predicted settlement by 2045. Monitoring of the settlement pins, if undisturbed, could be used to support / refine current estimates of settlements. The recent change at monitoring pins will be summarised at the end of this section.

## SECTION 5 Settlement Monitoring (Continued)

The graph below shows all of the surveyed original monitoring pins on an arithmetic time scale. When a monitoring pin was damaged or destroyed an effort was made to replace the pin. When a monitoring pin was damaged / destroyed it was given a sequential alphabetical designation.

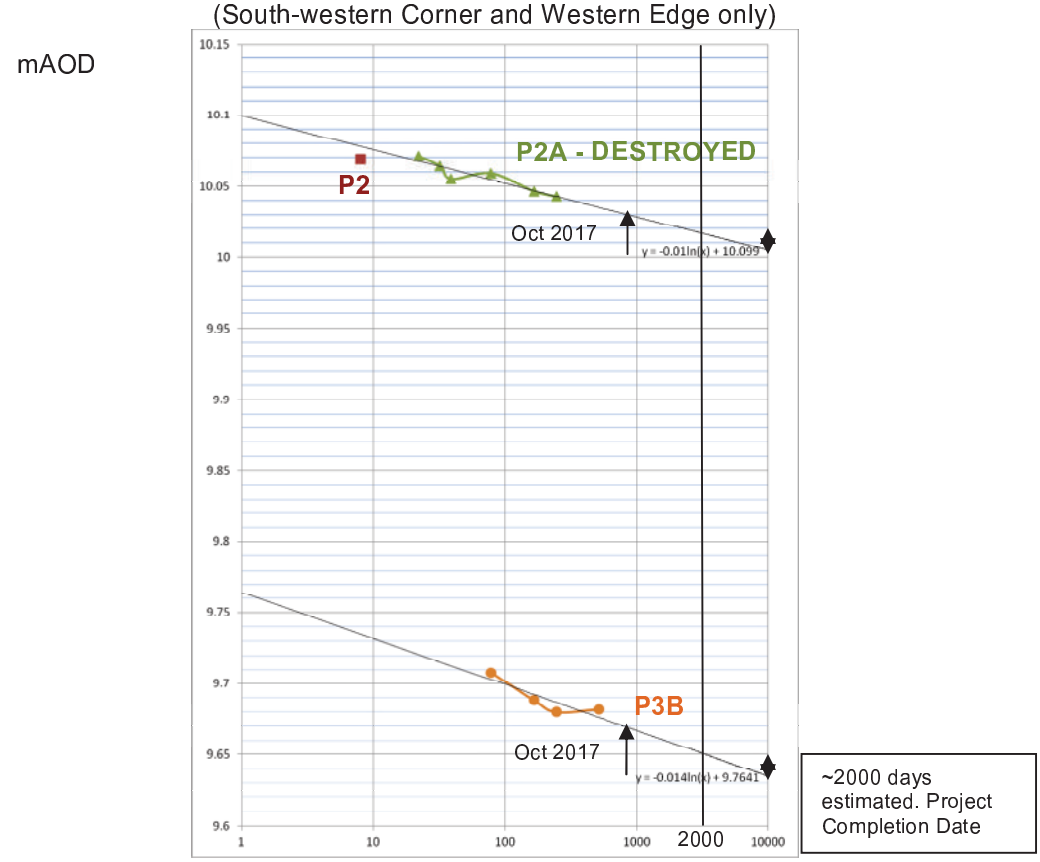
**Graph 5.3 : Settlement Monitoring Pin Results**



## SECTION 5 Settlement Monitoring (Continued)

In principle secondary settlement is infinite with settlement rates dropping on a logarithmic scale. However in practice the increase in settlement after $10^4$ days (~30years) appears to be generally "complete".

**Graph 5.4 Settlement at Monitoring Pins P2A and P3B**
(South-western Corner and Western Edge only)




Days since 17/07/2015. (First survey of Settlement Pins) – Log base 10
* Note Original Pins of P2, P3 and P3A were lost or damaged.

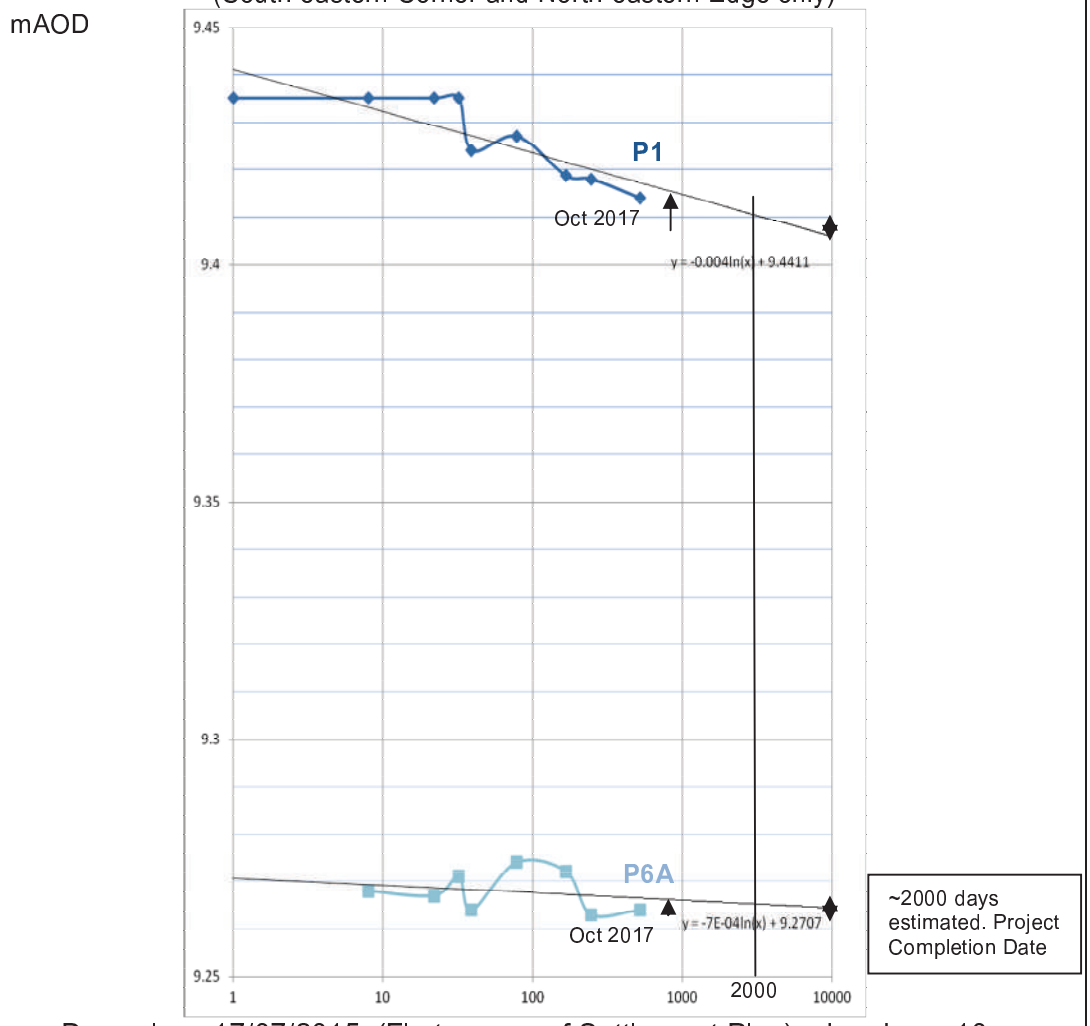
Monitoring Pin 2
Unfortunately baseline conditions for Monitoring Pin 2 (located within the south-western corner of the site) were lost as the pin was destroyed following the placement of fill. Monitoring Pin 2A however recorded ~28mm of settlement over 223 days. Whilst the initial readings may be lost and the monitoring point has been destroyed it may be possible to conjecture future settlement from the data obtained.

Following the current trend of settlement the above graph indicates that levels may settle to 10.005mAOD after $10^4$ days (~30years or 2045). With the last survey indicating levels of 10.043m a further 0.035m (35mm) should be anticipated under the current surcharge by 2045 or ~20mm after project completion.

Monitoring Pin 3
Unfortunately baseline conditions for Monitoring Pin 3 (located on the western edge of the site) were following the placement of fill. Monitoring Pin 3A was similarly lost. It is considered that any attempt to assess future settlement from Monitoring Pin 3B would be open to too much error and inaccuracy to predict. 28mm settlement was measured over 440days. Future settlement at this location may be slightly greater than at Monitoring Pin 2A but still less than 50mm or ~20mm after project completion.

## SECTION 5 Settlement Monitoring (Continued)

**Graph 5.5 Settlement at Monitoring Pins P1 and P6A**
(South-eastern Corner and North-eastern Edge only)




Days since 17/07/2015. (First survey of Settlement Pins) – Log base 10
* Note Original Pin of P6 was lost.

Monitoring Pin 1

Data for Monitoring Pin 1 (located near the South-eastern Corner of the site) is complete and to date indicates settlement of ~21mm over 517 days. Conjecturing future settlement from the data obtained indicates that levels may settle to 9.405mAOD after $10^4$ days (~30years or 2045). With the last survey indicating levels of 9.414m a further 0.010m (10mm) should be anticipated under the current surcharge by 2045 or ~5mm after project completion.

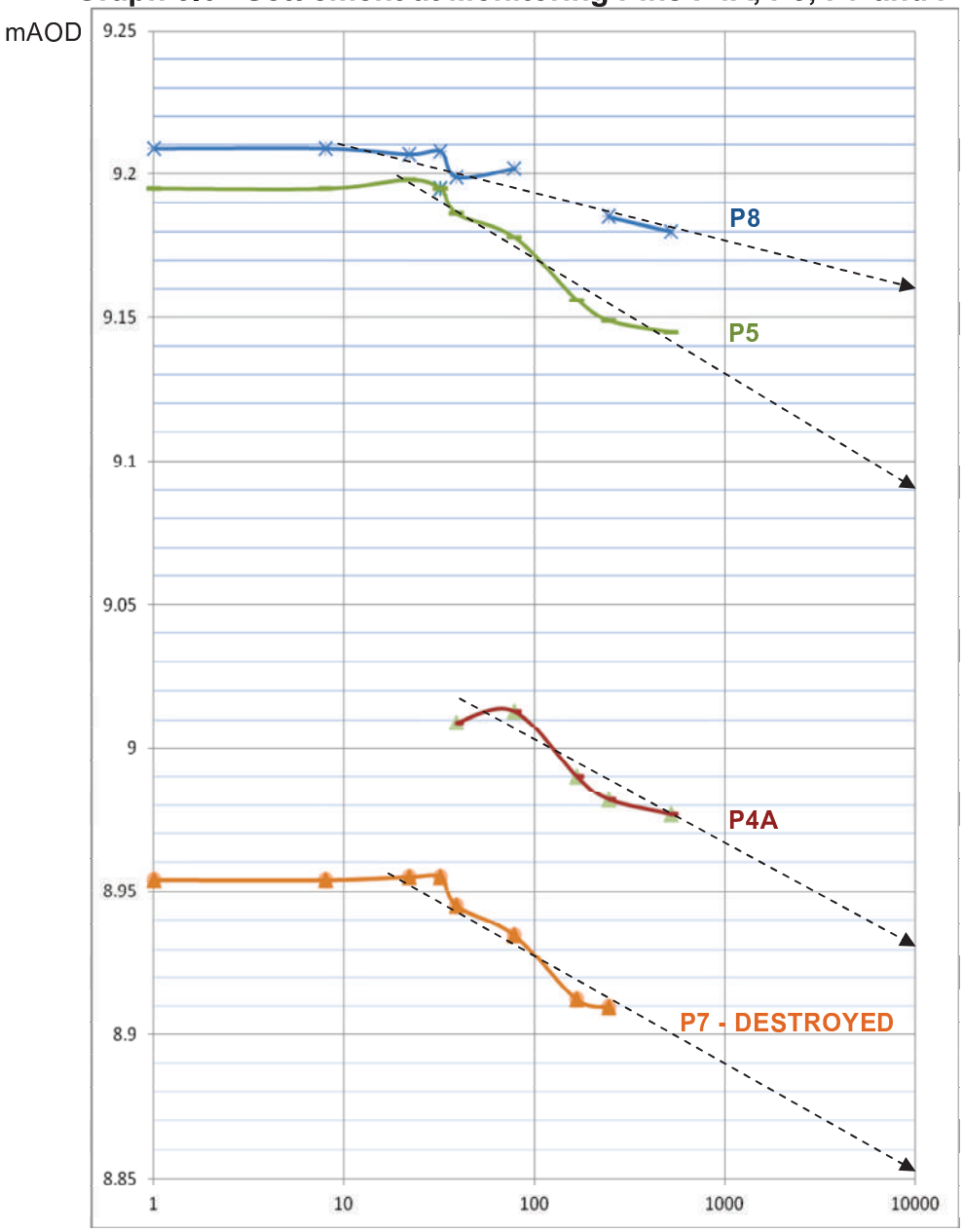
Monitoring Pin 6

Unfortunately baseline conditions for Monitoring Pin 6 (located within the North-eastern corner of the site) were lost as the pin was destroyed. Monitoring Pin 6A has however recorded ~5mm of settlement over 510 days. Whilst the initial readings may be lost it may be possible to conjecture future settlement from the data obtained.

Following the current trend of settlement the above graph indicates at that levels may have settled at 9.27mAOD after $10^4$ days (~30years or 2045). With the survey indicating fluctuating levels of 9.263m no further settlement is anticipated under the current surcharge by 2045.

## SECTION 5 Settlement Monitoring (Continued)

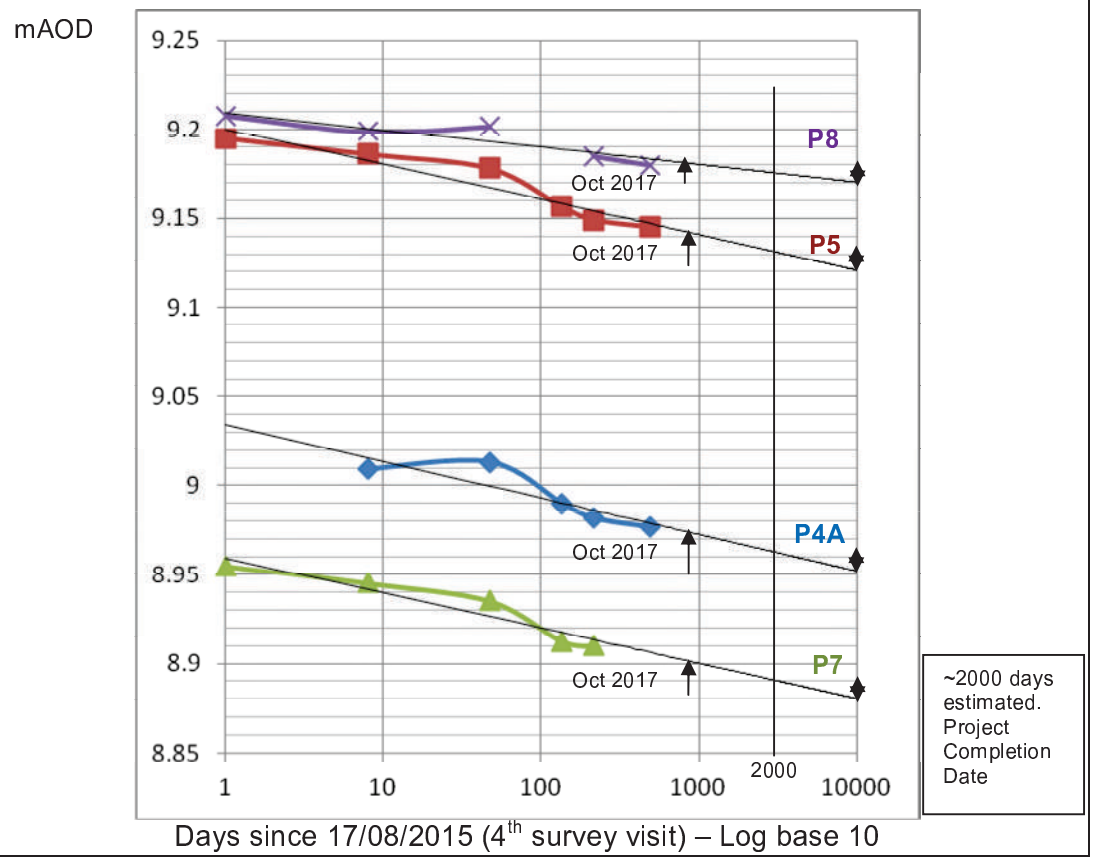
**Graph 5.6 Settlement at Monitoring Pins P4A, P5, P7 and P8**




Days since 17/07/2015. (First survey of Settlement Pins) – Log base 10
* Note Original Pin of P4 was lost.

## SECTION 5 Settlement Monitoring (Continued)

**Graph 5.7 2 Week Adjusted fit of Logarithmic Settlement Curve Due to Earthworks Delay for Monitoring Pins 4A, 5, 7 and 8.**




Monitoring Pin 4A

Unfortunately baseline conditions for Monitoring Pin 4 (located within the North-western corner of the site) were lost as the pin was destroyed. Monitoring Pin 4 recorded 1mm of settlement within ~20 days. It is considered that any attempt to assess future settlement at Monitoring Pin 4A would be open to too much error and inaccuracy to predict.

It is noted that following the current trend of settlement the graph indicates at that levels may settle to 8.950mAOD after $10^4$ days (~30years or 2045). With the most recent survey indicating levels of 8.978mAOD a further ~30mm settlement is anticipated under the current surcharge by 2045 or ~20mm after project completion.

Monitoring Pin 5,

Monitoring Pin 5 from the northern centre of the site follows a logarithmic settlement curve fairly closely. In an effort to predict settlement the existing trend, which may be inaccurate, indicate a possible settlement to ~9.12mAOD, a further ~25mm settlement from recent level or ~20mm after project completion.

## SECTION 5 Settlement Monitoring (Continued)

Monitoring Pin 7

Monitoring Pin 7 from the eastern edge of the site follows a logarithmic settlement curve fairly closely. In an effort to predict settlement the existing trend, which may be inaccurate, indicate a possible settlement from ~8.91mAOD to ~8.88mAOD, a further ~30mm settlement from recent level or ~20mm after project completion.

Monitoring Pin 8

Monitoring Pin 8 from the southern centre of the site follows a logarithmic settlement curve fairly closely. In an effort to predict settlement the existing trend, which may be inaccurate, indicate a possible settlement to ~9.18 to ~9.17mAOD, a further ~10mm settlement from recent level or ~5mm after project completion.

**Table 5.5 Summary of Predicted Settlements**

| Monitoring Pin | Initial Survey mAOD | Measured Settlement | Predicted Settlement after $10^4$ days (from July 2015 - 2045)* | | Predicted Settlement Remaining after December 2016 until 2045)* | Predicted Settlement between 2000days to 2045* |
|---|---|---|---|---|---|---|
| Monitoring Pin 1 (SE Corner) | 9.435 | - 21mm (517 days) | - 30mm (approx) | 9.405 mAOD | - 9mm (approx) | -5mm (approx) |
| Monitoring Pin 2 (SW Corner) | 10.069 | Not Achieved | N/A | | N/A | |
| Monitoring Pin 2A (SW Corner) | 10.071 | - 28mm (223 days) | - 66mm (approx) | 10.005m AOD | - 38mm (approx) | -20mm (approx) |
| Monitoring Pin 3 (W Edge) | N/A | + 1mm (21 days) | N/A | | N/A | |
| Monitoring Pin 3A (W Edge) | 9.195 | Not Achieved | N/A | | N/A | |
| Monitoring Pin 3B (W Edge) | 9.708 | - 28mm (440 days) | N/A | | N/A | |
| Monitoring Pin 4 (NW Corner) | 8.772 | - 1mm (21 days) | N/A | | N/A | |
| Monitoring Pin 4A** (NW Corner) | 9.009 | - 32mm (479 days) | - 59mm (approx) | 8.950 mAOD | - 27mm (approx) | -20mm (approx) |
| Monitoring Pin 5** (N Edge) | 9.195 | - 50mm (517 days) | - 75mm (approx) | 9.120 mAOD | - 25mm (approx) | -20mm (approx) |
| Monitoring Pin 6 (NE Corner) | 9.220 | Not Achieved | N/A | | N/A | |
| Monitoring Pin 6A (NE Corner) | 9.268 | - 5mm (510 days) | 0mm (approx) | 9.264 mAOD | 0mm (approx) | 0mm (approx) |
| Monitoring Pin 7** (E Edge) | 8.954 | - 44mm (244 days) | 74mm (approx) | 8.880 mAOD | - 30mm (approx) | -20mm (approx) |
| Monitoring Pin 8** (Centre) | 9.209 | - 29mm (517 days) | 39mm (approx) | 9.17 mAOD | - 10mm (approx) | - 10mm (approx) |

Assumptions:
Earthworks are instantiations with settlement beginning on Day 1. (Or 17/08/2015 for Monitoring Pins 4A, 5, 7 and 8.)
Settlement is logarithmic.

Known Inaccuracies:
Earthworks was not instantaneous and in reality took longer than anticipated.
Earthworks has not occurred equally across the site, notably:

- Some areas have more fill placed than others.
- Additional fill has been placed during the settlement process sometimes months later through intermittent earthworks post supervision.

Notes:
* Assuming no further fill is placed
** Monitoring Pins 4a 5, 7 and 8 do not conform with a logarithmic settlement curve. A better fit is achieved when the start date is set back. Estimates for these Monitoring Pins therefore discounts any settlement during the first three survey rounds.
N/A = Not achievable, insufficient baseline information.

## SECTION 5 Settlement Monitoring (Continued)

A series of new settlement monitoring pins were installed 6th June 2017 to replace the original series which were unserviceable for future phases of earthworks. 80 days has passed, however this does not appear to have been a long enough period of time to demonstrate further settlement.

Not a single pin has dropped by 1mm in the last 80 days. This is to be expected as the rate of settlement is anticipated to be slow and less than 1% of the time.

A summary of settlement and remaining settlement for the new series of Monitoring Pins is presented in **Table 5.6** below. It should be noted that this does not take future fill events into consideration.

**Table 5.6 Summary of Predicted Settlements (From Replacement Series of Monitoring Pins)**

| Monitoring Pin | Predicted Settlement Remaining from October 2017 to 2045*- from original series | Initial Survey mAOD | Lowest Result mAOD | Measured Settlement since New Monitoring Pins Installed | Current Predicted Settlement Remaining* (2045) - measured settlement subtracted from predicted settlement from original series |
|---|---|---|---|---|---|
| Monitoring Pin 1 (SE Corner) | - 5mm (approx) | 10.175 | 10.173 | - 0mm (80 days) | - 5mm (approx) |
| Monitoring Pin 2 (SW Corner) | - 30mm (approx) | 10.168 | 10.167 | - 0mm (80 days) | - 30mm (approx) |
| Monitoring Pin 3 (W Edge) | N/A | 10.254 | 10.253 | - 0mm (80 days) | N/A |
| Monitoring Pin 4 (NW Corner) | - 25mm (approx) | 10.279 | 10.278 | - 0mm (80 days) | - 25mm (approx) |
| Monitoring Pin 5 (N Edge) | - 20mm (approx) | 8.608 | 8.608 | +1mm (80days) | - 20mm (approx) |
| Monitoring Pin 6 (NE Corner) | - 0mm (approx) | 10.181 – destroyed 9.17 – 20/7/17 | 9.17 | - 0mm (42 days) | - 0mm (approx) |
| Monitoring Pin 7 (E Edge) | - 20mm (approx) | 10.118 – destroyed 9.109 – 20/7/17 | 9.108 | - 0mm (42 days) | - 20mm (approx) |
| Monitoring Pin 8 (Centre) | - 10mm (approx) | 9.81– destroyed 8.81 – 26/7/17 | 8.81 | - 0mm (36 days) | - 10mm (approx) |

Assumptions:
Settlement is logarithmic.

Known Inaccuracies:
Earthworks was not instantaneous and in reality took longer than anticipated.
Earthworks has not occurred equally across the site, notably:

- Some areas have more fill placed than others.
- Additional fill has been placed during the settlement process sometimes months later through intermittent earthworks post supervision.

Notes:
* Assuming no further fill is placed
N/A = Not achievable, insufficient baseline information.

# SECTION 6 Groundwater and Reen Monitoring

## 6.1 Groundwater

Sampling and testing of the deep groundwater was scheduled to be carried out prior to earthworks, and two rounds following completion of the intended Riversee Limited fill works or no later than 6 months of earthworks commencement.

Six water monitoring wells were installed, BH1 to BH6, as illustrated in **Figure 6.1** below.

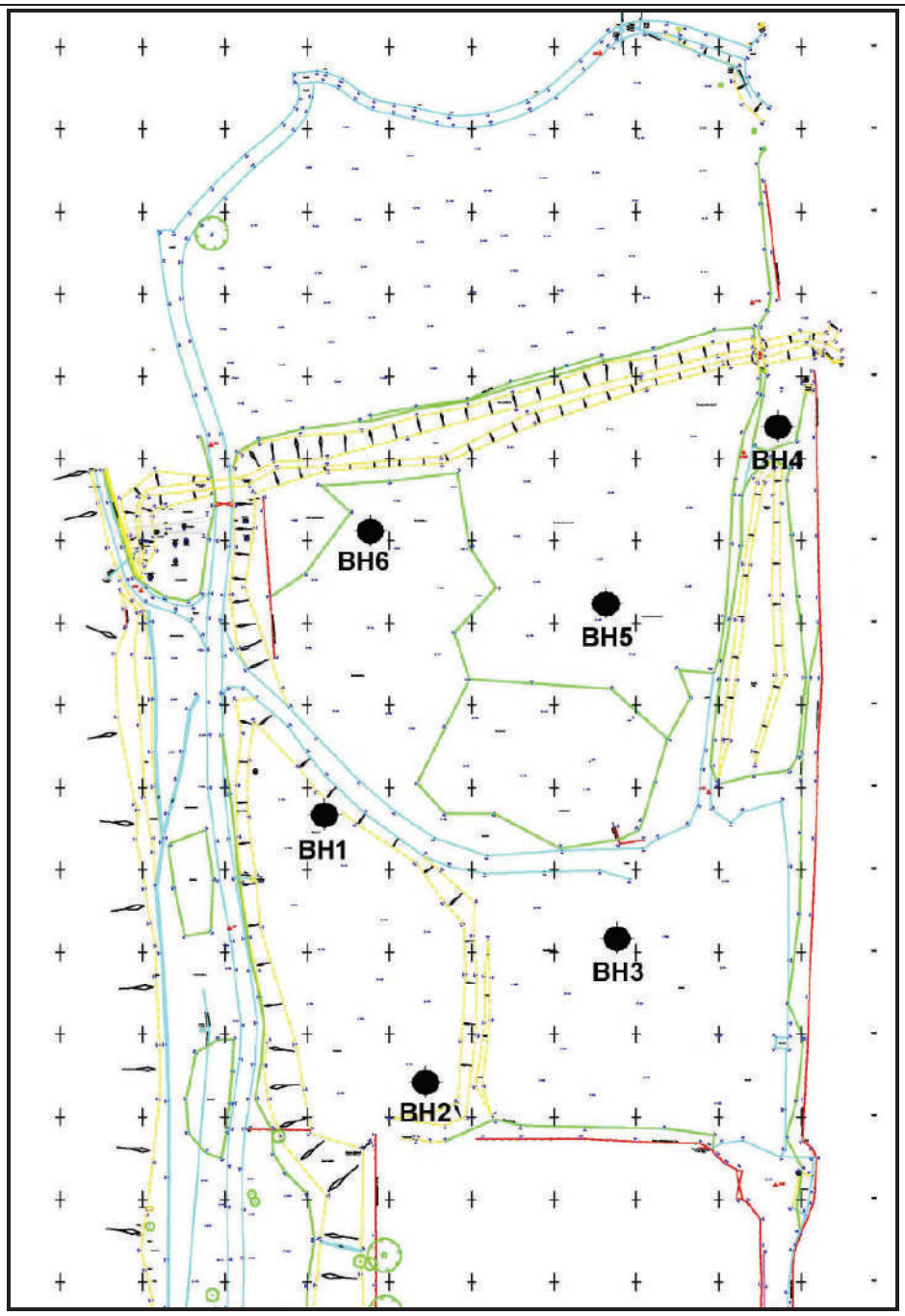



**Figure 6.1: Water Monitoring Well Locations**

## 6.1 Groundwater (Continued)

The pre-earthworks monitoring round was carried out in July 2015.

The second monitoring round was undertaken in January 2016, and the third followed in February 2016.

All groundwater results were acceptable, displaying no notable variation to the previously established water quality.

The results were presented to the NRW in Letter 25, dated 30th August 2016. A copy of this letter is presented in **Annex M**.

This letter proposed that no further groundwater monitoring was required.

The NRW subsequently agreed that this would be acceptable in an email dated 1st September 2016. A copy of this email may be found in **Annex N**.

## 6.2 Reen Water

Reen water was tested prior to earthworks and in January and February 2016, at the same time as the groundwater analysis described in **Section 6.1**.

Soils sourced from Green Lane and Hawes Lane were determined to have a low risk to the drainage reen. However, testing of reen waters during fill works was carried out in January and February 2017. A further test was performed in May 2017.

Following assessment of the Neal Soils material it was proposed that reen monitoring continue with sampling rounds scheduled for August, September, October and November 2017. To date the August testing has been completed.

The reen test results may be found in **Annex O** and are summarised below in **Table 6.1**. Those substances found to be in exceedence of threshold levels are highlighted.

Results seem to be fairly consistent but additional exceedences were noted in August 2017 following placement of the piling mat. Whether these exceedences are isolated occurrences or are related to the piling mat materials will be assessed once further testing rounds have been completed.

## Table 6.1 Summary of Reen Water Chemical Test Results

| Substance | Threshold ug/l | Source | Measured Concentrations of Tested Substances (ug/l) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Jul 2015 | Jan 2016 | Feb 2016 | Jan 2017 | Feb 2017 | May 2017 | Aug 2017 |
| Arsenic | 25 | WFD | 1.6 | 1.6 | 1.8 | 1.8 | 0.83 | 1.2 | 57 |
| Cadmium | 0.25 | WFD | <0.03 | <0.03 | 0.05 | <0.03 | <0.03 | <0.03 | 7.3 |
| Total Chromium | - | - | <0.25 | <0.25 | 0.88 | - | - | - | - |
| Chromium III | 4.7 | WFD | - | - | - | <1.0 | 5.4 | 2.7 | 7.1 |
| Chromium VI | 0.6 | WFD | - | - | - | <7.0 | <7.0 | <7.0 | <7.0 |
| Copper | 1.0 | WFD | <0.4 | 1.2 | 2.1 | 2.3 | 3.3 | 1.6 | 11 |
| Lead | 1.2 | WFD | 0.18 | 0.14 | 0.29 | 2.7 | 2.0 | 0.26 | 1.7 |
| Mercury | 0.07 | WFD | <0.01 | 0.01 | <0.01 | <0.01 | 0.02 | 0.11 | 0.1 |
| Nickel | 4.0 | WFD | <0.5 | 1.0 | 2.0 | 1.4 | 1.2 | 0.6 | 15 |
| Selenium | 10 | DWD | 2.0 | 1.2 | 2.0 | 1.1 | 0.89 | 1.3 | <0.25 |
| Zinc | 13.1 | WFD | <1.25 | 27 | 23 | 9.0 | 11 | 9.0 | 26 |
| Cyanide | 1.0 | WFD | <40 | <40 | | <40 | <40 | <40 | <40 |
| Phenol | 7.7 | WFD | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| pH | - | - | 7.6 | 7.5 | 7.4 | 7.6 | 7.4 | 7.6 | 7.6 |
| | | | | | | | | | |
| Naphthalene | 2.0 | WFD | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Acenaphthylene | - | - | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Acenaphthene | - | - | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 |
| Fluorene | - | - | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Phenanthrene | - | - | <0.01 | <0.01 | <0.01 | 0.05 | 0.01 | <0.01 | <0.01 |
| Anthracene | 0.1 | WFD | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 |
| Fluoranthene | 0.0063 | WFD | <0.01 | <0.01 | <0.01 | 0.08 | 0.02 | 0.03 | 0.02 |
| Pyrene | - | - | <0.01 | <0.01 | <0.01 | 0.07 | 0.02 | 0.02 | 0.01 |
| Benzo(a)anthracene | - | - | <0.01 | <0.01 | <0.01 | 0.03 | <0.01 | <0.01 | <0.01 |
| Chrysene | - | - | <0.01 | <0.01 | <0.01 | 0.05 | <0.01 | <0.01 | <0.01 |
| Benzo(b)fluoranthene | 0.017 | WFD | <0.01 | <0.01 | <0.01 | 0.07 | <0.01 | <0.01 | <0.01 |
| Benzo(k)fluoranthene | 0.017 | WFD | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 |
| Benzo(a)pyrene | 0.00017 | WFD | <0.01 | <0.01 | <0.01 | 0.04 | <0.01 | <0.01 | <0.01 |
| Indeno(123cd)pyrene | - | - | <0.01 | <0.01 | <0.01 | 0.04 | <0.01 | <0.01 | <0.01 |
| Dibenzo(ah)anthracene | - | - | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Benzo(ghi)perylene | 0.0082 | WFD | <0.01 | <0.01 | <0.01 | 0.05 | <0.01 | <0.01 | <0.01 |

**Table 6.1 Summary of Groundwater Chemical Test Results** (Continued)

| Substance | Threshold ug/l | Source | Measured Concentrations of Tested Substances (ug/l) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Jul 2015 | Jan 2016 | Feb 2016 | Jan 2017 | Feb 2017 | May 2017 | Aug 2017 |
| PH C5 – C6 Ali | 10 | TC | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PH C6 – C8 Ali | 10 | TC | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PH C8 – C10 Ali | 10 | TC | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PH C10 – C12 Ali | 10 | TC | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| PH C12 – C16 Ali | 10 | TC | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| PH C16 – C21 Ali | 10 | TC | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | 2.2 | <1.0 |
| PH C21 – C35 Ali | 10 | TC | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | 7.3 | <1.0 |
| | | | | | | | | | |
| PH C5 – C7 Arom | 10 | TC | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PH C7 – C8 Arom | 10 | TC | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PH C8 – C10 Arom | 10 | TC | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PH C10 – C12 Arom | 10 | TC | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| PH C12 – C16 Arom | 10 | TC | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| PH C16 – C21 Arom | 10 | TC | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| PH C21 – C35 Arom | 10 | TC | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |

Notes:

- WFD – Water Framework Directive
- DWD – Drinking Water Directive
- TC – Target Concentration