Llanelli Station Road Tunnel Recovery

Hydrogeological Impact Assessment for Temporary Construction Dewatering

Issue | 30 November 2018

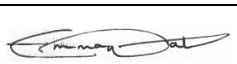
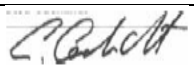
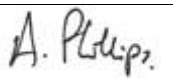
Job number 241250-00

Ove Arup & Partners Ltd
13 Fitzroy Street
London
W1T 4BQ
United Kingdom
www.arup.com

ARUP

Document Verification

ARUP

Job title		Llanelli Station Road Tunnel Recovery			**Job number** 241250-00
Document title		Hydrogeological Impact Assessment for Temporary Construction Dewatering			**File reference**
Document ref					
Revision	**Date**	**Filename**	Llanelli_HIA_TechnicalReport_draft.docx		
Draft 1	13 Nov 2018	**Description**	Llanelli Tunnel Recovery- HIA for Temporary Construction Dewatering (First Draft)		
			Prepared by	Checked by	Approved by
		Name	Emma Watts	Gerd Cachandt	Aled Phillips
		Signature			
Issue 1	30 Nov 2018	**Filename**	Llanelli_HIA_TechnicalReport.docx		
		Description	Llanelli Station Road Tunnel Recovery- HIA for Temporary Construction Dewatering (Issue)		
			Prepared by	Checked by	Approved by
		Name	Emma Watts	Gerd Cachandt	Aled Phillips
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

Tables

Figures

Appendices

1 Introduction

1.1 Purpose of this Report

This report presents a Hydrogeological Impact Assessment (HIA) of temporary construction dewatering activities required for the realignment of a storm sewer tunnel at Llanelli in Carmarthenshire, Wales.

Construction works at Llanelli, more specifically depressurising of a confined aquifer to enable an open cut excavation, could impact on the surrounding aquifer and nearby water receptors and may require an abstraction licence to proceed. The introduction of new legislation in England and Wales regarding abstraction licensing has introduced the need for abstraction licences for temporary construction dewatering activities.

This report presents the hydrogeological understanding of the site, summarises the findings of additional ground investigation, considers the potential connection and risk of impact on nearby sensitive environmental receptors, and outlines a conceptual hydrogeological model of the construction site. The conceptual model has then been used to inform a Tier-1 HIA following NRW guidelines[1].

It is intended that the HIA developed within this report will be submitted, alongside the pre-application enquiry, to NRW as part of the Proposal Summary section.

1.2 Legislative Background

The enabling of the full provisions of the Water Act 2003 from January 2018, with the introduction of the 'Water Abstraction and Impounding (Exemptions) Regulations 2017' in England and Wales has introduced a need to licence temporary construction dewatering activities in certain situations.

Traditionally, abstraction of groundwater for construction dewatering was exempt from licensing control, but the Water Act 2003 removed that exemption. It was some time before the 2003 Act was "enabled" but as of 1st January 2018, new regulations regarding Water Abstraction and Impounding came into force across England and Wales. All large-scale groundwater abstractions required for construction dewatering of an aquifer now require a licence to carry out these operations. These regulations have been brought into motion to help create a fairer system for all abstractors as well as enable the Regulator to manage water resources more effectively.

The new regulations are cited as the 'Water Abstraction and Impounding (Exemptions) Regulations 2017'[2]. Under Part 2, Section 5 (entitled 'Small scale dewatering in the course of building or engineering works') of these Regulations, the following exemptions to groundwater abstraction licencing are identified:

"Small scale dewatering in the course of building or engineering works"

5.(1) The restriction on abstraction does not apply to an abstraction or series of abstractions of water carried out in the course of building or engineering works for the purpose of dewatering from a sump or excavation if:

> *(a) the abstraction or series of abstractions are temporary and in any event carried out over a period of less than six consecutive months beginning with commencement of the first abstraction;*
>
> *(b) each abstraction does not cause or is not likely to cause damage to a conservation site or specific features in such a site;*
>
> *(c) each abstraction does not cause or is not likely to cause damage to protected species; and,*
>
> *(d) either:*
>
> > *(i) the water abstracted is immediately discharged to a soakaway; or,*
> >
> > *(ii) the volume of water abstracted is less than 100 cubic metres of water per day and there is no intervening use of that water before discharge.*

5.(2) Where the abstraction is undertaken within 500 metres of a conservation site or within 250 metres of a spring, well or borehole used to supply water for any lawful use, paragraph (1)(d)(ii) applies in respect of that abstraction as if the reference to 100 cubic metres of water per day were a reference to 50 cubic metres of water per day."

All of these provisions listed above must be satisfied to qualify for an abstraction licence exemption. All abstractions less than 20 m^3/d, for whatever use, will still (as of April 2005) not need to undergo an application for an abstraction licence.

1.3 Description of Proposed Construction Activities

The Station Road storm water trunk sewer in Llanelli, South Wales was proposed as part of a scheme to remove storm water flows from the combined sewer network in the Northumberland catchment. Due to the urban setting of the alignment, the majority of the 1500mm diameter pipe was proposed to be installed by trenchless techniques or tunnelling methods.

However, in the vicinity of the Llanelli train station, problems arose during construction resulting in a misalignment of tunnel invert levels. An open cut excavation has been proposed as part of a solution to realign this tunnel invert level.

Dewatering is needed to depressurise sub-artesian conditions within sandstone bedrock and facilitate the excavation and realignment of a tunnel invert level. The current dewatering proposal uses four dewatering wells (two vertical, two inclined) to reduce water levels to beneath the tunnel invert level for safe, stable working conditions. Total abstraction quantities have been estimated by Stuart

Wells Limited, the dewatering contractor, as between 3.2 to 4 l/s, see **Appendix 1** for further details.

The proposed dewatering activities, including construction phases of excavation and installation will be temporary and are currently programmed to be a maximum of 20 consecutive weeks duration.

1.4 Need for an Abstraction Licence

It is anticipated that an abstraction licence will be required to permit the dewatering at the Llanelli Station Road Site because the estimated daily abstraction rates ranges between 277 m3/d to 346 m3/d (3.2 to 4 l/s), exceeding the 100 m^3/d threshold as cited in the regulations.

NRW have stated that an application for an abstraction licence must be accompanied by a HIA. The HIA methodology is described in 'Hydrogeological Impact Appraisal for dewatering abstractions'[1]. The HIA methodology is composed of a series of 14 steps as follows:

1. Establish the regional water resource – see Section 2;
2. Develop a conceptual model for the dewatering operation and the surrounding area – see Section 3;
3. Identify all potential water features which are susceptible to flow impacts – see Section 4.1;
4. Apportion the likely flow impacts to the water features – see section 4.2;
5. Mitigate the flow impacts – see Section 4.3;
6. Assess the significance of the net flow impacts – see Section 4.4;
7. Define the search area for drawdown impacts – see Section 5.1;
8. Identify all potential water features which could be impacted by drawdown – see Section 5.2;
9. Predict the likely drawdown impacts – see Section 5.3;
10. Mitigate the drawdown impacts – see Section 5.4;
11. Assess the significance of net drawdown impacts – see Section 5.5;
12. Assess the water quality impacts – see Section 6;
13. Redesign the mitigation measures to minimise flow and drawdown impacts – see Section 7;
14. Develop a monitoring strategy – see Section 8.

2 Regional Water Resource Status

The Site is located within the lower Afon Lledi surface water catchment. Surface water and groundwater resources are classed as "limited water available" at Q30 according to the 'Carmarthen Bay Abstraction Management Strategy 2014'[3].

3 Development of the Conceptual Model

3.1 Site Location and Topography

The Llanelli tunnel recovery scheme, also known as "the Site", is located close to the existing Llanelli railway station (approximate grid reference SS 5069 9942) within the urban area of Llanelli in Carmarthenshire, Wales. The proposed dewatering activities will take place around the railway line at this location, as shown in the site plan in **Figure 1**.

The topography of the site is relatively flat with elevations ranging between 6 mAOD and 7 mAOD.

3.2 Published Geology

3.2.1 Superficial geology

The superficial deposits underlying the Site comprise Glacial Till from the Devansian Period. British Geological Survey (BGS) logs in the vicinity suggest this till is composed of loamy clay, silty clay or clayey silt with stones and cobbles. These borehole logs suggest the glacial till is approximately 9m in thickness close to the site. Although not shown on geological maps, Made Ground is expected to be common in the area due to the urban nature and history of previous development of the area surrounding the Site[4].

Across the wider area, Alluvium is also present along river beds and raised storm beach deposits are present to the south of the Site, along the coast[5].

3.2.2 Bedrock geology

The bedrock outcropping beneath the site is dominantly the Hughes Member[6], part of the Pennant Sandstone Formation of the Upper Coal Measures (Carboniferous). These rocks are typically composed of alternating sequences of sandstone beds interbedded with mudstone, siltstone and sandstone beds.

Coal seams are commonly present within the sequence. Detailed desk studies, coal mining risk assessments and multiple ground investigations[7] have been undertaken across the tunnel alignment. The nearest coal seam (Swansea 2ft bushy) and recorded coal mine entries are more than approximately 300m north of Llanelli railway line at the Station. Furthermore, coal seams dip approximately 30^{o} to the north, further away from the railway line. Coal mining risk south of the

Swansea 2ft (Bushy) significantly diminishes to the south. The coal mining risk beneath the site and within the vicinity is considered to be negligible.

3.2.3 Structural geology

The bedrock is heavily faulted around the Site. Faults dominantly run in a north-south or east-west direction. One fault trending in an east-west direction is positioned just south of the Site. It is not known if these structural features act as barriers or conduits to flow.

3.3 Ground Investigation

3.3.1 Previous ground investigation

Two phases (Phase 1 & Phase 2) of ground investigation have been undertaken between 2012 and 2014 along the proposed Station Road alignment to inform the design of the Station Road tunnel construction. A total of 18No. cable percussive boreholes with rotary follow-on and 22No. trial pits were excavated.

A total of four boreholes were excavated either side of the railway line. BH5 and BH6 were excavated to the north and BH18 and BH7 were excavated to the south of the railway line. **Table 1** below summarises the borehole depths and the methods used and **Figure 2** below shows the location of these ground investigation boreholes.

Table 1: Phase 1 and 2 excavation method and depth in vicinity of the railway line

Borehole	Location	Overall depth	Cable percussive (terminated)	Rotary core	Rotary open hole
North of railway line					
BH05 (Phase 1)	Drive length	10.5m	0-4.8 (boulder)	4.8-10.5m	-
BH06 (Phase 1)	Shaft 4 – Reception Pit	15.2m	0-9.1m (bedrock)	9.1-15.2m	-
South of railway line					
BH18 (Phase 2)	Drive length	10m	0-8.5m (bedrock)	8.5-10m	-
BH07 (Phase 1)	Shaft 5	15.1m	0-5.8m (boulder)	5.8-15.1m	-

The encountered ground conditions in the vicinity of the railway line are provided below in **Table 2**.

Table 2: Summary of encountered ground conditions in vicinity of railway line

Borehole/trial pit	Made Ground base (m)	Alluvium base (m)	Glacial Till base (m)	Bedrock	Final depth (m)
BH05	1.3	2.3	5	Sandstone	10.5
BH06	2.3	2.6	8	Sandstone	15.2
BH18	5	-	7.9	Sandstone	10
BH07	1.6	2.5	4.7	Sandstone	15.1

In summary, Made Ground is typically 1.3m to 2.3m thick, except for 5.0m in BH18 associated with historical building constructions of transport depot and Penros works. Made ground is underlain by a thin layer of Alluvium described as a soft grey / brown silty clay. This in turn is underlain by Glacial Till described as a firm to stiff - very stiff grey and brown sandy gravelly clay with some siltstone and sandstone cobbles and boulders.

The upper surface of bedrock is weathered sandstone recovered as a gravel of sandstone. Bedrock was encountered at between 8.0 and 7.9m in BH06 and BH18 to the north and south of the railway line.

3.3.2 Recent ground investigation

A pumping test was carried out on Site by Stuart Wells Limited to determine the dewatering requirements for the tunnel recovery. The factual report is presented in **Appendix 1**. Two wells were drilled for the purpose of this test; one monitoring well and one pumping well, the geology encountered in both is shown in **Table 3**.

Table 3: Summary of Well Ground Conditions

Stratum	Top Level of Stratum in Pumping Well (mBGL)	Top Level of Stratum in Monitoring Well (mBGL)
Tarmac	0.0	0.0
Made ground	0.2	0.2
Grey to yellow sandy clay	1.5	1.2
Weathered grey sandstone	8.0	8.0
End of Borehole	14.0	NA

This supports the previous ground investigation in the area showing Made Ground of 1.5m in thickness and bedrock encountered at 8.0 mBGL.

3.4 Hydrogeology

3.4.1 Ground investigation

Groundwater strikes in boreholes were generally encountered at depths ranging from 2.0 to 10.5m and were encountered within the made ground, glacial till and weathered bedrock. The groundwater encountered in the glacial till was generally observed to be encountered in more permeable zones of the glacial till, with groundwater usually present within sandy horizons. Where groundwater strikes were encountered in the glacial till or weathered bedrock, most showed a rise after 20 minutes. Generally, moderate groundwater flows are encountered within the Glacial Till with faster inflows encountered within the bedrock. Around the Site, fast sub-artesian groundwater inflows were observed within the sandstone beds at approximately 7.0 to 10.0 mBGL[7].

In-situ rising and falling head permeability testing from Phase 1 of the ground investigation suggests maximum permeabilities of 2.89 x 10^{-4} m/s and 2.38 x 10^{-4} m/s respectively for a water-bearing horizon within the glacial till and the bedrock in the vicinity of the Site (from BH06 and BH07)[7].

A pumping test was carried out on Site during November 2018 to determine the dewatering requirements for the tunnel recovery. The drilling of the boreholes for this pumping test show the sandstone bedrock to be water-bearing and confined beneath a 6.5m thick layer of sandy clay (assumed Glacial Till) within which no groundwater was recorded. Initial water tables within the sandstone prior to pumping were shown to be sub-artesian, with levels rising above the confined aquifer to between 2.3 and 1.8 mBGL (between 4.1 and 4.6 mAOD), see **Appendix A** and **Appendix B**.

Monitoring during ground investigation has shown the groundwater beneath the Site is not tidally influenced.

3.4.2 Conceptual Model

The bedrock is anticipated to be the main water-bearing aquifer, with permeable lenses within the overlying Glacial Till deposits also yielding moderate amounts of groundwater. The bedrock aquifer is confined with sub-artesian pressure heads to approximately 2.0 mBGL. Recharge of the aquifer is assumed to be from the north of the site, where bedrock is exposed at a higher elevation.

From the published hydrogeological map of the area[8] the Afon Lliedi to the west of the site is expected to be in hydraulic connection with groundwater in the superficial deposits and acts as a major sink for groundwater across the area. The connection between this surface watercourse with the underlying bedrock is unknown, though the bedrock is expected to be in connection to permeable superficial deposits (i.e. where glacial till is not present or where the glacial till has a high permeability). A figurative conceptual model is shown in **Figure 3**.

3.5 Ground Settlement

Morgan Sindall have carried out settlement calculations to assess the likely ground movements caused as a result of dewatering. Lowering the water table will result in a change in the vertical effective earth pressures, which - depending on the permeability of the ground and duration of dewatering - will lead to consolidation settlement that may impact the surrounding structures and assets.

Ground models were developed based on available information and settlement calculations were calculated in accordance with the approach given in CIRIA Report C750 (Groundwater Control: Design and Practice, Second Edition). Consolidation settlements will take place in the ground as the excess porewater pressure dissipates. Assuming a consolidation time of three months and reasonable soil parameters for the underlying ground, limited settlements due to dewatering were predicted. Nonetheless, an observational approach is proposed during the works to ensure that nearby structures and assets are not affected by the works. This will include setting up a monitoring strategy, to be implemented during the works to cover both, groundwater levels and surface settlements and comparing actual values with those from the calculations.

3.6 Short-term Construction Activities Associated with Removal of Groundwater

The proposed construction programme at the Site includes phases of deep excavation. Because of the high sub-artesian groundwater levels, depressurising for this excavation will be required. Dewatering will be required ahead and during the remedial works, planned for the new underground surface water trunk sewer, to allow breaking through the existing invert and construction of a U-shaped concrete lining to match the design vertical alignment. The dewatering programme will be temporary, with a scheduled duration of less than 20 consecutive weeks. The location and description of the proposed works are provided in more detail on **Figure 1**.

4 Flow Impacts

4.1 Water Features Susceptible to Flow Impacts

The following features have been considered as part of a desk study to determine all water-dependent receptors that have potential to be affected by flow impacts:

- **Conservation sites:** There are no known conservation sites within 500m of the excavation[9].
- **Surface watercourses:** The Afon Lliedi river is located 650m west, and downgradient, of the excavation[9]. It is predicted to be in hydraulic connectivity with the groundwater in the alluvium which is likely to provide some baseflow to the river. The connection of this river to the sandstone bedrock is unknown, so for a worst-case analysis the river is assumed to also be in hydraulic connection with the bedrock. Due to the

distance of this receptor from the planned dewatering works it is not anticipated to be impacted by these activities.

- **Local springs:** A desk-based assessment of water features indicates that there are no known springs within 500m of the excavation[9].
- **Local licensed and unlicensed abstractions:** Two water wells are shown on BGS Geoindex[4], 140m to the west of the Site. These abstract from the Pennant Sandstone Formation and were constructed in the mid-1920's. The BGS borehole logs suggest these were both drilled for the Llanelli Ice and Cold Storage Company[4]. After further study it is thought that these boreholes are no longer in use due to the presence of a building overlying their location[10]. The 2012 Envirocheck report[11] for the project also has not identified any groundwater abstraction licences in the vicinity. Discussion with the local authority also indicates there are no private abstractions on record in the area[12].

4.2 Apportioning of the Flow Impacts

It is not considered necessary to apportion possible flow impacts because no receptors are deemed to be impacted.

4.3 Mitigation of Flow Impacts

No mitigation is deemed necessary.

4.4 Significance of Net Flow Impacts

No significant flow impacts anticipated.

5 Drawdown Impacts

5.1 Search Area for Drawdown Impacts

The distance-drawdown graph generated by Stuart Wells Limited and shown in **Appendix A** suggests that the drawdown radius of influence each borehole at the Site will be approximately 35m when pumped at the proposed rate of 0.83 l/s. Four wells will pump at this from two different locations, the radius of influence is therefore considered from both locations. Additionally, for a conservative approach, the dewatering radius for this HIA has been considered as double this distance.

5.2 Water Features Susceptible to Drawdown Impacts

The following features have been considered as part of a desk study to determine all water-dependent receptors that have potential to be affected by drawdown impacts:

- **Conservation sites:** There are no known conservation sites within the radius of influence of the dewatering works[9].
- **Surface watercourses:** The are no known rivers or surface water features within the radius of influence of the dewatering works[9].
- **Local springs:** A desk-based assessment of water features indicates that there are no known springs within the radius of influence of the dewatering works[9].
- **Local licensed and unlicensed abstractions:** There are no known groundwater abstractions within the radius of influence of the dewatering works[4][11].

5.3 Prediction of Maximum Drawdown Impacts

The maximum radius of influence from each borehole is anticipated to be 35m, as estimated from the pumping test. For a conservative approach, all possible receptors within 70m of the works have been considered in this HIA. There are no known receptors within 70m of the dewatering works.

5.4 Mitigation of Drawdown Impacts

No mitigation is deemed necessary.

5.5 Significance of Drawdown Impacts

No significant drawdown impacts anticipated.

6 Water Quality Impacts

The contractor will adhere to the conditions of the Environmental Permit (temporary discharge consent - application underway) to ensure that the rate and quality of any discharge to the watercourse does not cause adverse effects to the wider environment. The method of treatment will be explained in detail in the Construction Environmental Management plan (CEMP) which will be produced prior to any activities on site. Contamination of water bodies should be prevented by best practice (following Guidance for Pollution Prevention[13]).

A settlement tank will be used to allow settling in the abstracted water to limit levels of silt that might be released to the environment. In addition, the use of a 2mm-5mm silica filter pack within each wellpoint is being considered, which will act as an additional treatment barrier by allowing the filtration of the groundwater prior to it reaching the surface.

7 Redesign Mitigation Methods

Currently it is proposed to discharge all of the abstracted water directly to a nearby surface watercourse. Discharge to the river will be via a settlement tank to

prevent excess siltation, and no negative impacts on water quality in the river are anticipated.

It is not proposed to discharge the water to ground via a soakaway, which would negate the need for an abstraction licence, as it is not considered feasible due to the low permeability of the near-surface deposits.

8 Monitoring and Reporting Plan

Regular monitoring of abstraction volumes will be undertaken throughout the duration of the dewatering works. The discharge quality will also be monitored visually to check that quality and turbidity is suitable for discharge to the surface watercourse.

9 Conclusions

This report presents an HIA that follows the methodology outlined in NRW guidelines. The assessment concludes that a temporary abstraction licence will be required for the proposed construction dewatering activities at Llanelli Station Road. This is because the estimated abstraction volume will exceed 100 m^3/d, the maximum permitted abstraction volume when water is not discharged to soakaway.

The assessment has reviewed all possible impacts to any local water features and concluded there are none.

In addition, no changes to the existing hydrological regime are anticipated post-construction to any water-dependent habitats as a result of the construction works.

As a result, no further tiers of investigation are considered necessary, given the temporary nature of the abstraction.

10 References

[1] Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report - SC040020/SR1

[2] The Water Abstraction and Impounding (Exemptions) Regulations 2017. 2017 No. 1044, PART 2, Regulation 5. https://www.legislation.gov.uk/uksi/2017/1044/regulation/5/made Accessed 29/20/2018

[3] The Carmarthen Bay Abstraction Licensing Strategy. May 2014. https://cdn.naturalresources.wales/media/681625/carmarthen-bay_strategy_english.pdf?mode=pad&rnd=131596369480000000. Accessed 17/10/2018

[4] BGS Geoindex webmap http://mapapps2.bgs.ac.uk/geoindex/home.html. Accessed 14/05/2018

[5] BGS Sheet 247: Swansea– Solid and Drift http://www.largeimages.bgs.ac.uk/iip/mapsportal.html. Accessed 31/10/2018

[6] BGS Sheet 247: Swansea– Solid http://www.largeimages.bgs.ac.uk/iip/mapsportal.html. Accessed 31/10/2018

[7] Morgan Sindall, 2013. Station Road: Geotechnical Interpretative Report Phase 1 Ground Investigation. Report No: 13/8984

[8] British Geological Survey (BGS) https://www.bgs.ac.uk/research/groundwater/datainfo/hydromaps/hydro_maps_scanviewer.html. Accessed 12/11/2018

[9] Magicmap. http://magic.defra.gov.uk/MagicMap.aspx. Accessed 12/11/2018

[10] Google Maps. https://www.google.co.uk/maps. Accessed 12/11/2018

[11] Envirocheck, 2012. BGS Boreholes Datasheet. Llanelli, Camarthenshire.

[12] Iles, Katherine. 2018. Email to Emma Watts and Gerd Cachandt, 12/11/2018

[13] Guidance for Pollution Prevention http://www.netregs.org.uk/environmental-topics/pollution-prevention-guidelines-ppgs-and-replacement-series/guidance-for-pollution-prevention-gpps-full-list/. Accessed 30/05/2018

Figures

Figure 1: Llanelli Station Road Site layout and proposed dewatering works

A3

02/04/2012 13:28:15

Legend

- Site Corridor
- Llanelli Tunnel Recovery Site

Issue	Date	By	Chkd	Appd
I1	15-11-2018	EW	GC	

ARUP

4 Pierhead Street
Cardiff CF10 4QP
Tel +44 29 2047 3727 Fax +44 29 2047 2277
www.arup.com

Client
Morgan Sindall

Job Title
Station Road

Metres
0 300 600 1,200

Site Location Plan and Proposed Dewatering Works

Scale at A3
1:25,000

Job No	Drawing Status
224717-01	For information

Drawing No	Issue
Figure 1	I1

MXD Location

Figure 2: Geological Cross-section from Ground Investigation

DISTANCE ALONG BASELINE (m)

REDUCED LEVEL (m OD)

GREAT WESTERN RAILWAY

BELOW GROUND TANKS

OPEN CUT SECTION

MADE GROUND

GLACIAL TILL (BOULDER CLAY)

WEATHERED BEDROCK

BEDROCK

STRONG SANDSTONE

VERY SOFT ALLUVIUM ENCOUNTERED IN BH12 & BH13

OTHER AREAS OF ALLUVIUM ENCOUNTERED IN BH1, BH5, BH6 & BH7 (INDICATED BY 'A'

SCALE 1:222V 1:3889H @ A3L

LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID

(Offset)

SPT N value, * denotes N extrapolated by gINT:
* from main blows
** from seating blows

N20*

Water strikes during boring / excavation

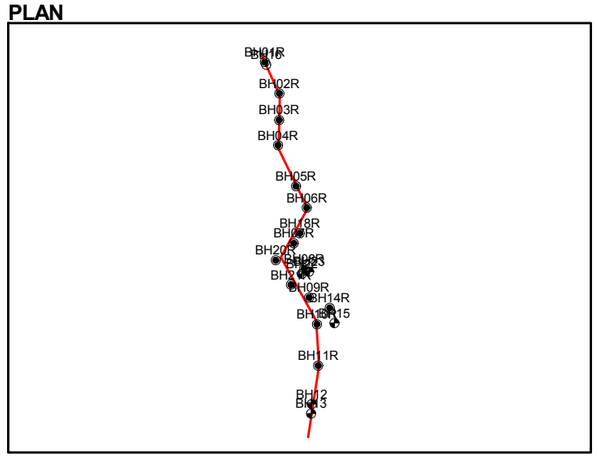
Time for reported water rise and flow rate remarks

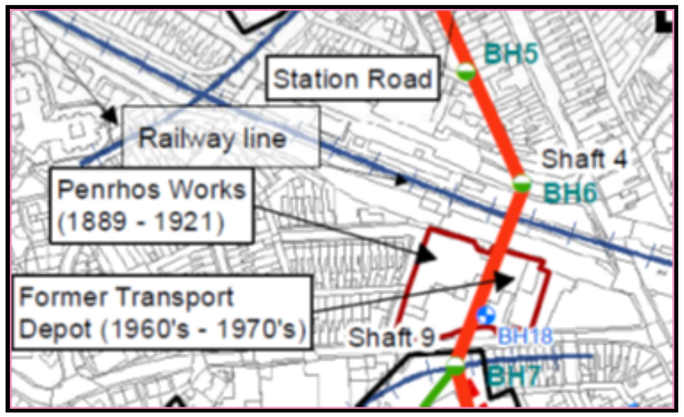
Level that water rose to

Level of water strike

20min. Steady flow

PLAN





Station Rd
GEOLOGICAL CROSS SECTION WITH GROUNDWATER DATA

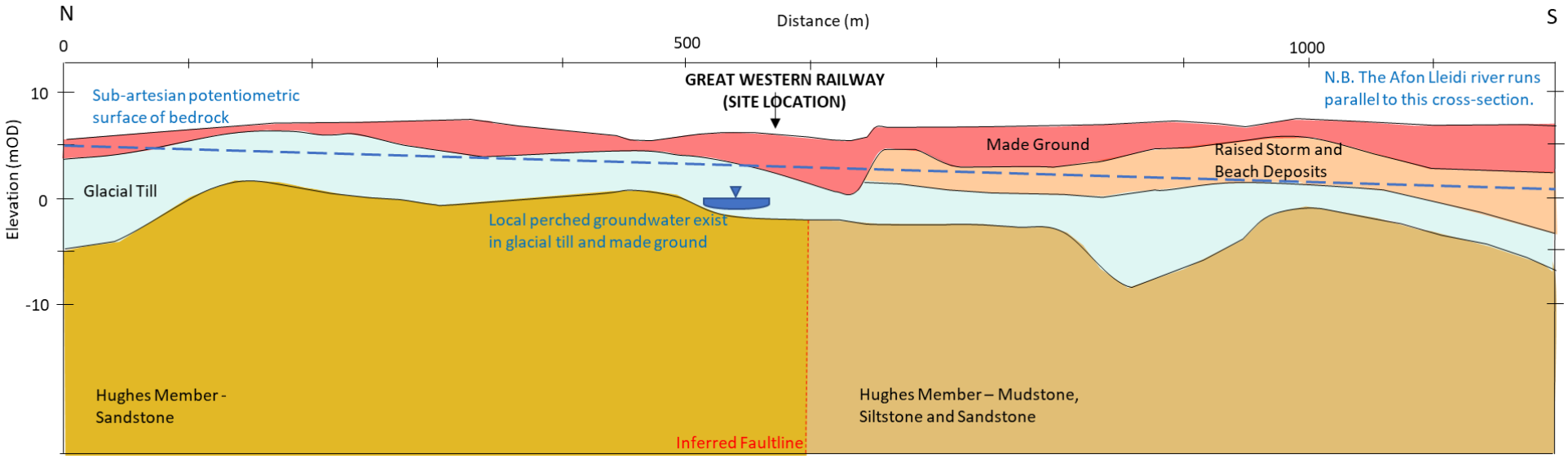
241250-00

FIGURE 2

Source data status: of holes
Database check status : Full check (A) = 0% Partial/selective check (B) = 0% Minimum check (C) = 0% Unchecked (U) = 100% of holes

Figure 3: Conceptual site model of the proposed dewatering works

*(cross-section line as per **Figure 2**)*



Appendices

Appendix A

Stuart Wells Pumping Test Factual Report and Dewatering Proposal

PUMPING TEST FACTUAL REPORT

Contract Name:	Llanelli Tunnel 48hr Constant Rate Groundwater Pumping Tests nr. Station Road, Llanelli
Client Name:	Morgan Sindall (MS)
Groundwater Pumping Test & Dewatering Specialist:	Stuart Wells Ltd (SWS)
Report No	SWC8129-PT

Revision	Date	Description	Prepared By (SWS)	Checked By (SWS)
1	27/09/2018	Submission	MW	DW

For:	Contact:
Morgan Sindall Northumberland Avenue SPS Copperhouse Road Neville's Dock SA15 2HD	Mark Thomas Project Manager Mob: 07812961884 Email: Mark.Thomas@margansindall.com
By:	**Contact:**
Stuart Wells Ltd Hargham Road Shropham Norfolk NR17 1DT	Martin Welsford Contract Engineer Phone: 07971602952 Email: martin.welsford@stuartwells.co.uk

Contents

1. Introduction

In September 2018 Stuart Wells Ltd was appointed by Morgan Sindall to undertake a pumping test in accordance with BS ISO 14686:2003 as part of Llanelli Tunnel Recovery works.

The pumping test comprised of pumping from a single pumping well while groundwater levels were monitored using 1no monitoring well.

The pumping test was undertaken with the following objectives in mind.

- Determine the hydraulic properties of the aquifer (permeability and boundary conditions, if possible).
- To generate information to confirm any additional dewatering requirements and design
- To generate information to enable robust assessment of dewatering impact for future application for dewatering abstraction and discharge permit requirements

This factual report details the activities and the results of the testing carried out.

Figure 1: Site Location Map

2. Summary of Ground Conditions

The ground conditions at PW1 are summarised as follows by the drillers borehole logs, as undertaken by DANBAR Drilling Services Ltd on behalf of Stuart Wells Ltd.

Stratum	Top level of stratum (mAOD)
Tarmac	0.00
Made Ground	0.26
Grey to yellow, sandy, CLAY	1.50
Weathered, grey, SANDSTONE	8.00
End of Borehole	14.00

Table 1: Summary of Pumping Well Ground Conditions

3. Field Work

The programme of works undertaken at site can be summarised as follows:

Date	Activity
14th September – 19th September 2018	Background monitoring
14th September 2018	Equipment Test
19th September – 21st September 2018	Constant Drawdown Test (48 hours)
21st September – 24th September 2018	Recovery Test

Table 2: Programme of works

Equipment used during testing is summarised as follows:

- A duty and standby CRI50/3(5.5kW) electrical submersible borehole pump was utilised for the testing after proving suitable during the equipment test on 14th September.
- A duty and standby Stuart Power 20kVA generator with automatic changeover panel were used to power the borehole pump.
- Electronic Dataloggers were used at each Well to record continuous water level readings for the duration of the testing period.
- Manual water level readings were recorded using a Manual Dip Tape.
- Flow rate was monitored using 2no mechanical flow meters.

The layout of the wells is shown in figure 2, and the well installation details provided in table 5.

4. Results

4.1. Background monitoring

Before undertaking the pumping test, the water level was monitored by Stuart Wells for a period of 5 days from 14th to 19rd September 2018 to observe any natural fluctuations in the water table. See as follows a summary of the data.

Well Name	Water Level (mAOD)
PW1	4.08 to 4.79
MW1	4.21 to 4.53

Table 3: Background monitoring data

4.4. Constant Rate Test

The result of the constant rate test can be summarised as follows pumping at a flow rate of approximately 0.83lts/sec.

	Start of Test	End of Test (48.5 hrs)		
Well Name	Water Level (mAOD)	Water Level (mAOD)	Drawdown (m)	Distance to PW1 (m)
PW1	4.75	-3.72	8.49	n/a
MW1	4.50	4.098	0.42	32.3

Table 4: Summary of constant rate test results

The results showing the response of the water table relative to the pumping rate, time of pumping and the radial distance away from the pumping well are presented in figures 3, 4 and 5. The full data set (table8) including all manual data is presented in excel format along with the report.

4.5. Other Groundwater Observations

On Thursday 20th September ~12:50 AM (approximately 28.5 hours into the constant rate test). Morgan Sindall operatives entered the tunnel and opened up bleed probes within the tunnel. Our understanding is that groundwater was not encounted until approximately 17.5m distance from Shaft S4. From this we would estimate a drawdown of ~4.7m to a level of -0.1m AOD was achieved at nominal 17.5m radial distance from the PW1 pumping well.

Yours faithfully,

Martin Welsford
Contracts Engineer
For & behalf of **Stuart Well Services Limited**

David Wright CGeol
Director & Principal Groundwater Engineer
For & behalf of **Stuart Well Services Limited**

Figure 2: Well location plan

				Screened Sections				
	Easting	Northing	Ground Level	Top	Bottom	Borehole Size	Liner Size	Distance from Pumping Well ABH1
Well Name	m	m	mAOD	mAOD	mAOD	mm	mm	m
PW1 (Pumping Well)	250719	199436	6.4	6.67	-7.6	250mm	165 x 155	n/a
MW1	250739	199413	6.4	6.57	-7.6	250mm	165 x 155	32.3

Table 5: Well Detail

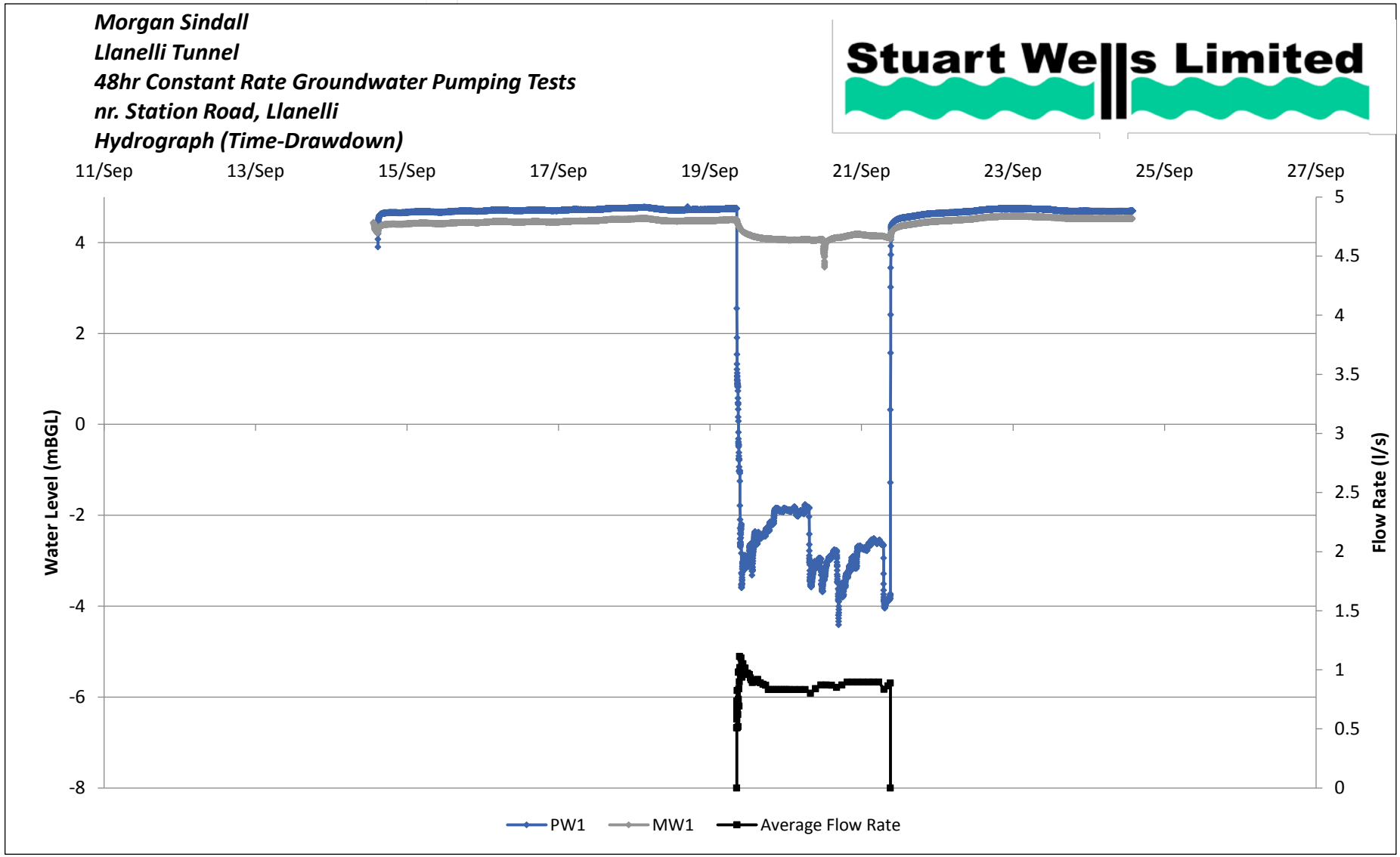


Figure 3: Time-water level

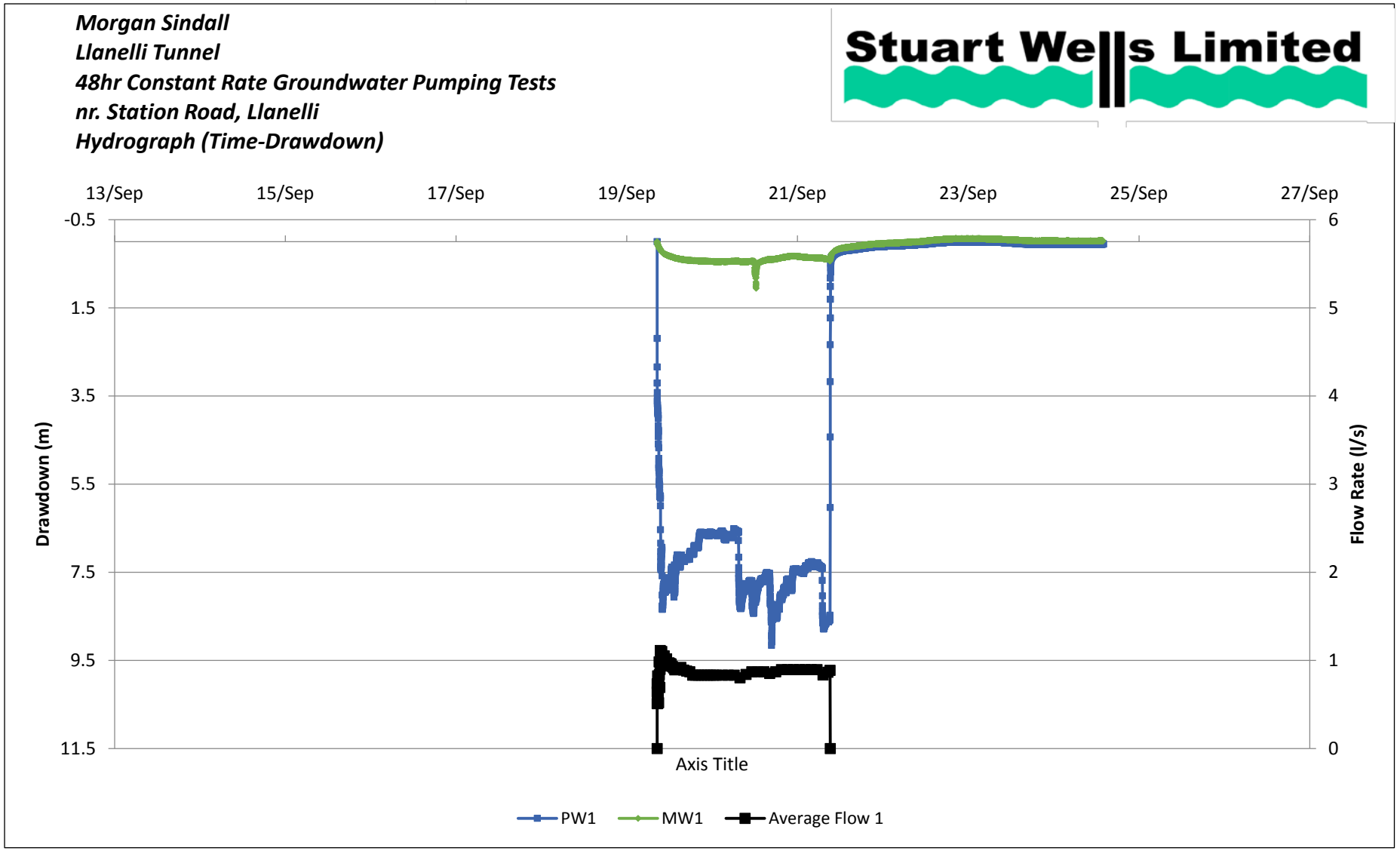


Figure 4: Time-drawdown graph

Figure 5 Distance Drawdown graph

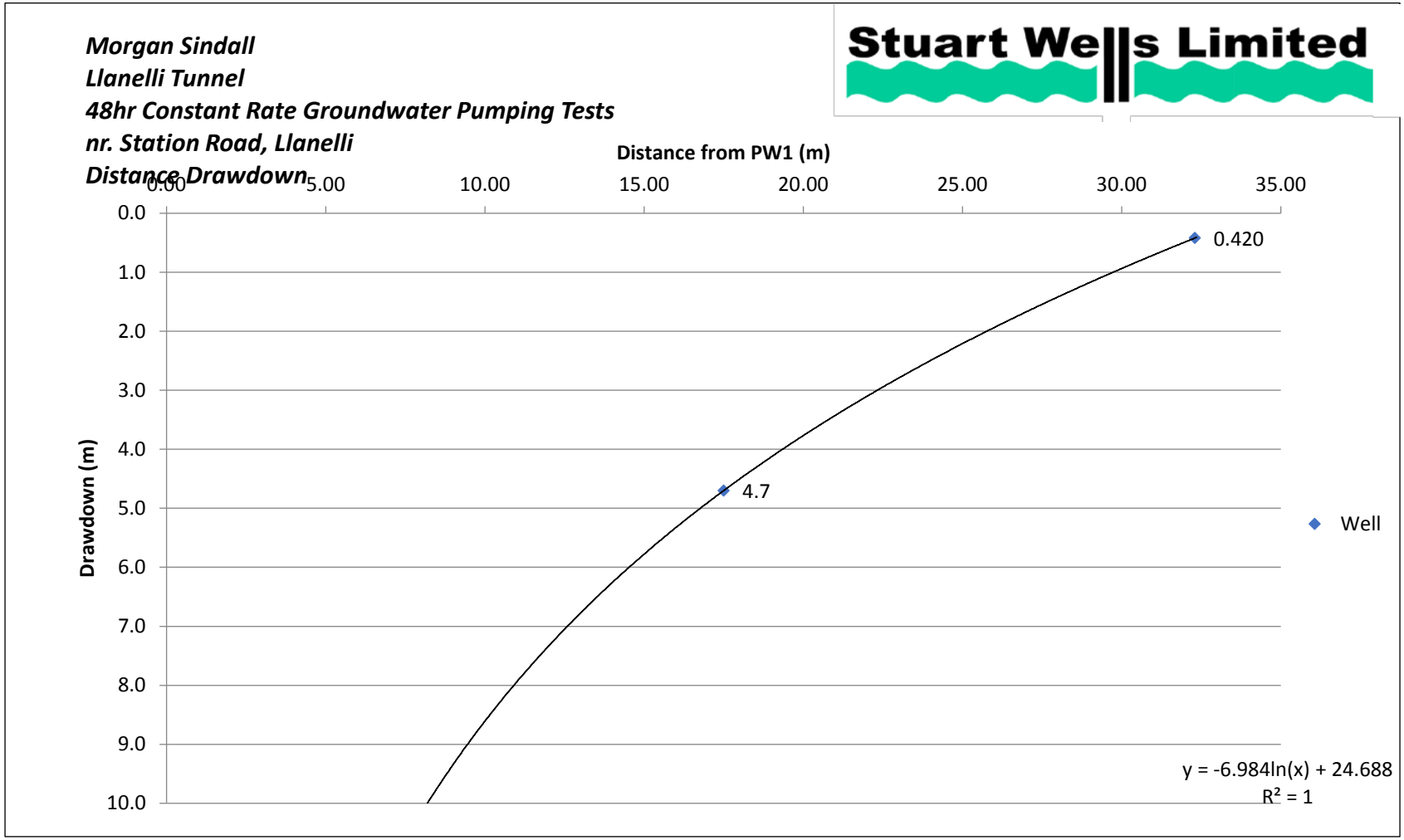


Table 4: Table of Pump Test Data

Appendix – Drillers BH Logs (Description Only)

DANBAR Drilling Services Ltd	5 Leopold Street Lamberhead Ind Estate Pemberton Wigan WN5 8DH	Telephone: 01942 216924 www.danbardrilling.com	**DAILY DAYWORKS & STANDING TIME**	SITE: Station Road, Llanelli	JOB NO:
				DATE: 4.9.A	BOREHOLE NO: PW1

TYPE	TIME FROM	TIME TO	REASON
			on Site 7.45AM
Dw	9.00	10.00	Retrieve Skip Fish up
Dw	2.30	3.30	Flush Hole
Dw	3.30	7.30 pm	Install
			GL Tarmac
			0.26 Tarmac/Hardcore
			1.50 Grey Yellow Sandy Clay
			4.00 Weathered grey Sandstone
			14.m Gradual Bit
			9m Plain
			6m Slotted

	DW = DAYWORKS	ST = STANDING TIME	DRILLER	Rhian
			CLIENT	SWS

DANBAR
Drilling Services Ltd

5 Leopold Street
Lamberhead Ind Estate
Pemberton
Wigan
WN5 8DH

Telephone:
01942 216924

www.danbardrilling.com

DAILY DAYWORKS & STANDING TIME

SITE: Station Road, Ulverston

JOB NO:

DATE: 6.9.18

BOREHOLE NO: MW1

TYPE	TIME FROM	TIME TO	REASON
			On Site @ 8.00
DW	8.00	10:00	Fill up Water
	4.50	5.00	Pump Down off site getting tools
			GL Tarmac
			0.20 Iron Slag Fill
			1.20 Grey Clay
			5m Weathered Sandstone

DW = DAYWORKS

ST = STANDING TIME

DRILLER: Kieran

CLIENT: SWS

Stuart House, Hargham Road, Shropham, Norfolk NR17 1TD
Telephone: 01953 454540 Fax: 01953 451451 www.stuartwells.co.uk

Ref: SWC8129C

Date: 12th October 2018

To: Morgan Sindall Engineering Solutions Ltd
Cold Meece
Swynnerton
ST15 0UD

F.A.O: Roger Margerison
email: roger.margerison@morgansindall.com
mobile: 07808 905605
tel: 01785 763262

From: David Wright
Mobile: 07831 121123

email: david.wright@stuartwells.co.uk
Direct Line: 01953 458984

Revised Dewatering Proposals & Quotation: Llanelli Tunnel Recovery

Further to completion of the pumping test and corresponding discussions on dewatering, please find enclosed our revised proposed scope of works and quotation for the provisional requirements for temporary dewatering requirements to achieve depressurisation of sub-artesian conditions and enable construction of proposed trough at invert level as part of tunnel recovery, in stable conditions.

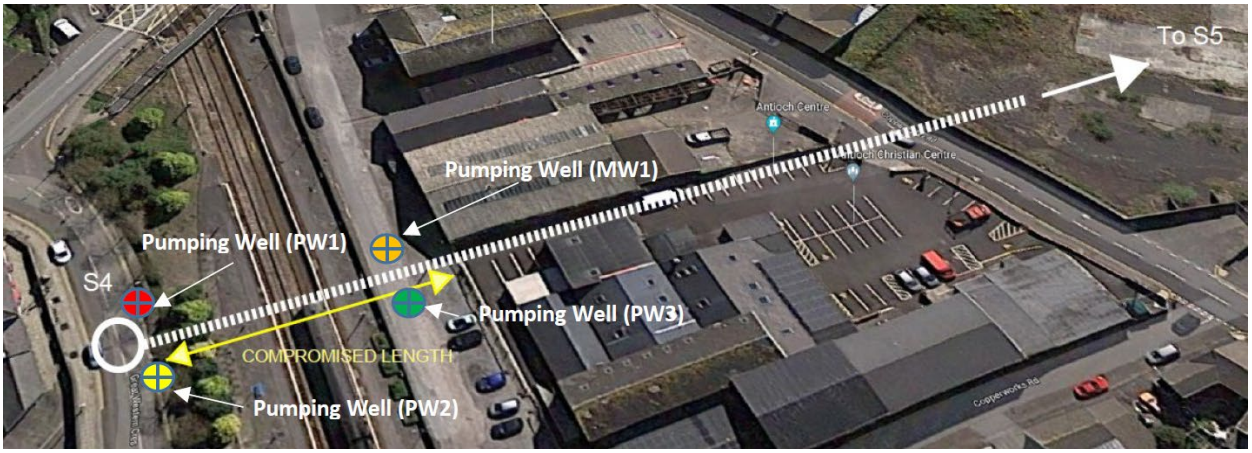
Works Detail

- Existing Tunnel Plan & Section: As per Drawing No: 2UI120-LSR-UnPS-GEN-XX-DR-YX-00094 Rev P01.1
- Realignment Sequence: As per Drawing No: 2UI120-LSR-UnPS-GEN-XX-DR-YX-00103 Rev P02
- Tunnel & Geological Section: As per S4 Section pdf.
- Site Plan: As per Aerial Sketch
- Existing Ground Level: +6.4m AOD
- S4 Shaft Invert Level: -2.3m AOD
- S4 Realignment Level -0.12m AOD
- Realingment Section: nominal 42.5m lin.n from S4

Ground & Groundwater Conditions

- As per Quantum Geotechnical BH06R & ground conditions observed for pump test.
- Groundwater Level: Sub-artesian in bedrock upto +4.75m AOD (observed in PW1)

Comments
With an objective to reduce and maintain groundwater level along the whole realignment section throughout remedial works. We propose abstracting from a total of 4no dewatering wells, with the installation of 2no inclined wells either side of the railway line. See proposed location picture below:



Stuart Wells Limited

Stuart House, Crows Hall Lane, Attleborough, Norfolk NR17 1AD
Telephone: 01953 454540 Fax: 01953 451451 www.stuartwells.co.uk

S4 Shaft:

1no vertical well (using existing PW1 – installed as part of pumping test)
1no inclined well (PW2) – Installed the other side of the shaft at an inclined angle of between 15° – 20° terminating at nominal -8.0m AOD and approximately 4m-5m horizontal distance from PW1

Other side of Railway (nominal 32 lin.m from Shaft S4):

1no vertical well (using existing MW1 – installed as part of pumping test)
1no inclined well (PW3) – Installed the other side of tunnel line from MW1 at an inclined angle of between 15° to 20° terminating at nominal -8.0m AOD and approximately 4m-5m horizontal distance from PW1

We propose drilling the additional inclined wells using rotary drilling methods (as per the pumping test wells). With the installation of nominal 100mm Ø well liner with a pre-formed bonded filter pack around the screen section. In addition we will manually install any further filter pack and bentonite pellets to form a seal against the Glacial Till and Bedrock.

We propose operating an independent 2no pump system either side of the railway and have submitted options to either power the borehole pump using generators or from 415V mains supply provided FOC by yourselves. On other point is that we would look to redevelop (airlift) all wells again prior to abstracting to maximise well efficiency.

Dewatering Proposals - Deep Wells

We propose installing a submersible borehole pump and abstracting from the 4no wells, with an independent pumping set up at each location. We would anticipate total abstraction flow to between 3.2 to 4 lts/sec.

After well development individual max 2.2 kW submersible borehole pumps would be installed within each well. In turn these will be connected with individual 2" W/A hoses for final discharge via a v-notch settlement tank to site outfall. At this stage we have allowed for 30m of discharge at each location.

Discharge Assumptions: Shaft S4 to a utility outfall along Great Western Road – TBC

Other side of Railway – assumed to utility outfall along access road – TBC

We have assumed you will be applying for both abstraction and discharge concent, although we can assist in submission data.

Power Options:

We have submitted separate costs for provision of independent generator supply. This would consist of a 415V 20 kVA silenced diesel generator unit with bunded fuel tank (5 day) c/w long-leads at each location. We have submitted optional rates for the provision of a standby generator with AMF facility. For your information the fuel consumption of each generator is ~3.5 lts/hour. We would look to place the generator close to the well locations.

The alternative is that you provide 415V mains supply FOC. For this we would require a 415V 32 AMP 5 –pin isolated socket at each location, into which the pump DOL starter would plug diectly into.

Stuart House, Crows Hall Lane, Attleborough, Norfolk NR17 1AD
Telephone: 01953 454540 Fax: 01953 451451 www.stuartwells.co.uk

Programme	Mobilisation:	January/February 2019
	Lead-In:	min 2 week
	Drilling (2no wells)	1.5 week
	Installation & Commission:	1 week
	Contract Hire Period:	20 weeks (assumed)

Regulatory Position

Abstraction – Please note as from January 2018 the regulatory position on groundwater abstraction from a dewatering system has changed, with the requirement to have an abstraction permit from NRW. There are some exception conditions, however the expected flow rate of this system is outside the exempt level and abstraction consent will be required. On the assumption that water is discharged to a Welsh Water outfall we would strongly recommend that you apply for a full type abstraction permit. Please go to the following link for more information:

https://www.gov.uk/guidance/water-management-apply-for-a-water-abstraction-or-impoundment-licence

Discharge – On the assumption that all abstracted water will be discharged to a water course and that the pumping period is less than 3 months, at this stage we assume that the proposed dewatering will be exempt from NRW discharge licence requirements

Commercial

Please find attached our schedule of rates together with our main exclusions and terms of conditions against which we are prepared to enter into a subcontract arrangement.This quotation includes an allowance for design and RAMS, which we would look to submit upon instruction to proceed with the works.

We assume any dewatering works would be a variation to our existing subcontract.

Stuart Wells are committed to quality and service. We are 1SO 9001 accredited and have systems in place to ensure and maintain the quality of all equipment and plant operating on any of our contracts. We offer a single number 24 hour call-out service.

Stuart Wells are committed to safeguarding the Health & Safety of our employees (OHSA 18001 accredited), subcontractors, all site staff and the public. We have an experienced workforce who are trained and qualified to appropriate standards. We are CHAS accredited and committed to further reducing hazards and risks and improving working practises. We welcome the opportunity to participate in any H&S initiatives or schemes you have, and can undertake tool box talks on the dewatering operation, if required. For your information we have recently been accredited ISO 22301: Business Continuity Management System.

Should you require any clarification or further details please do not hesitate to contact us. In the meantime we would be pleased to visit your office or site to discuss matters at your convenience.

Yours faithfully

David Wright CGeol
Director & Principal Groundwater Engineer
For & behalf of **Stuart Wells Limited**

Stuart Wells Limited

Stuart House, Crows Hall Lane, Attleborough, Norfolk NR17 1AD
Telephone: 01953 454540 Fax: 01953 451451 www.stuartwells.co.uk

Schedule of Rates

SCHEDULE A – Revised Schedule of Rates –Dewatering: Llanelli

Item	Description	Unit	Qty	Rate (£)	TOTAL (£)
1.	**Preliminaries/Mobilisation/Demobilisation**				
1a.	Mobilisation/Demob of drilling rig & materials			sum	£3,250.00
1b.	Intersite movement of drilling rig			sum	£1,200.00
1c.	Mobilisation of dewatering equipment (assuming 1no visit)			sum	£800.00
1d.	Demobilisation upon completion			sum	£800.00
1e.	Mob/Demob labour			sum	£450.00
1f.	Preliminaries			sum	£1,250.00
				Total item 1.	**£7,750.00**
2.	**Installation & Commissioning of Deep Wells** (assuming 2no well installed for pump test can be reused)				
2a.	To set up, drill & install Dewatering Wells (inclined)	no	2	£3,875.00	£7,750.00
2b.	Standing Time/Dayworks	hour	1	£225.00	Rate Only
2c.	To Airlift Develop 4no Wells			sum	£930.00
2d.	To set up, develop, commission	no	4	£695.00	£2,780.00
				Total item 2.	**£11,460.00**
3.	**Hire of Deep Well Dewatering System**				
3a.	Hire of 4no 415V borehole pumps & control panels	week	20	£500.00	£10,000.00
3b.	Hire of collection pipework & fittings plus discharge	week	20	£184.00	£3,680.00
3c.	Hire of 2no v-notch settlement tank	week	20	£100.00	£2,000.00
				Total item 3.	**£15,680.00**

Estimated Dewatering Costs £34,890.00
(based on estimated 20 week contract period)

Other Optional Provision & Costs

4.	**Provision of Generator Power** (1no location only)				
4a.	Hire of 1no 20kVA duty silenced diesel generator	week	1	£120.00	Rate Only
4b.	Hire of 1no 2300 litres bunded fuel tank c/w long leads	week	1	£35.00	Rate Only
4c.	Hire of 1no standby 20 kVA generator c/w AMF facility	week	1	£190.00	Rate Only
4d.	Fuel Charge (all pumps delivered full of fuel)	litre	1	£1.15	Rate Only
4e.	To undertake repair/site visit for reasons beyond our control	hour	1	£55.00	Rate Only

Stuart Wells Limited

Stuart House, Crows Hall Lane, Attleborough, Norfolk NR17 1AD
Telephone: 01953 454540 Fax: 01953 451451 www.stuartwells.co.uk

SCHEDULE B – Main Exclusions: Dewatering Llanelli

We have not allowed for the following items which we require the Main Contractor to provide free of charge and in such manner as to not delay our works. If requested, we can adjust our quotation should you be unable to provide such assistance's.

Item	Description	Client	SWS
1	Secure and adequate storage of the company's plant, materials, equipment and offices etc., including mains power and water services to any on site office or accommodation, in accordance with current Health & Safety legislation, at no cost to Stuart Well Services.	✓	
2	Shared welfare facilities and provision of 1st aid	✓	
3	Carriage (movement) of equipment whilst on site and loading/offloading from our transportation.	✓	
4	Provision of all fuel	✓	
5	Suitable cranage and assistance's for the installation and any subsequent removal of any equipment required during the works	✓	
6	Breakout and remove any hard standing, hard layers or obstructions that may impede or delay our works.	✓	
7	Provide suitable firm, clear, unobstructed drive on access to our working location.	✓	
8	Provide all fuel, oil and lubricants for pump sets, and generators. All equipment and plant supplied full of fuel to be returned full, any shortfall to be charged at rate submitted in Schedule of Rates.	✓	
9	Continuity of work. Delays will be charged at the rate submitted in Schedule of Rates.	✓	
10	Provision of any hoarding, fencing and task lighting, if required	✓	
11	Adequate disposal point for water generated	✓	
12	Provision of site security during the hours the site is unattended	✓	
13	Carry out reinstatement work upon completion including backfilling or plugging of boreholes	✓	
14	All plant & equipment on hire in accordance with current CPA conditions. Any damages to be charged at replacement cost + 7.5%	✓	

Stuart Wells Limited

Stuart House, Crows Hall Lane, Attleborough, Norfolk NR17 1AD
Telephone: 01953 454540 Fax: 01953 451451 www.stuartwells.co.uk

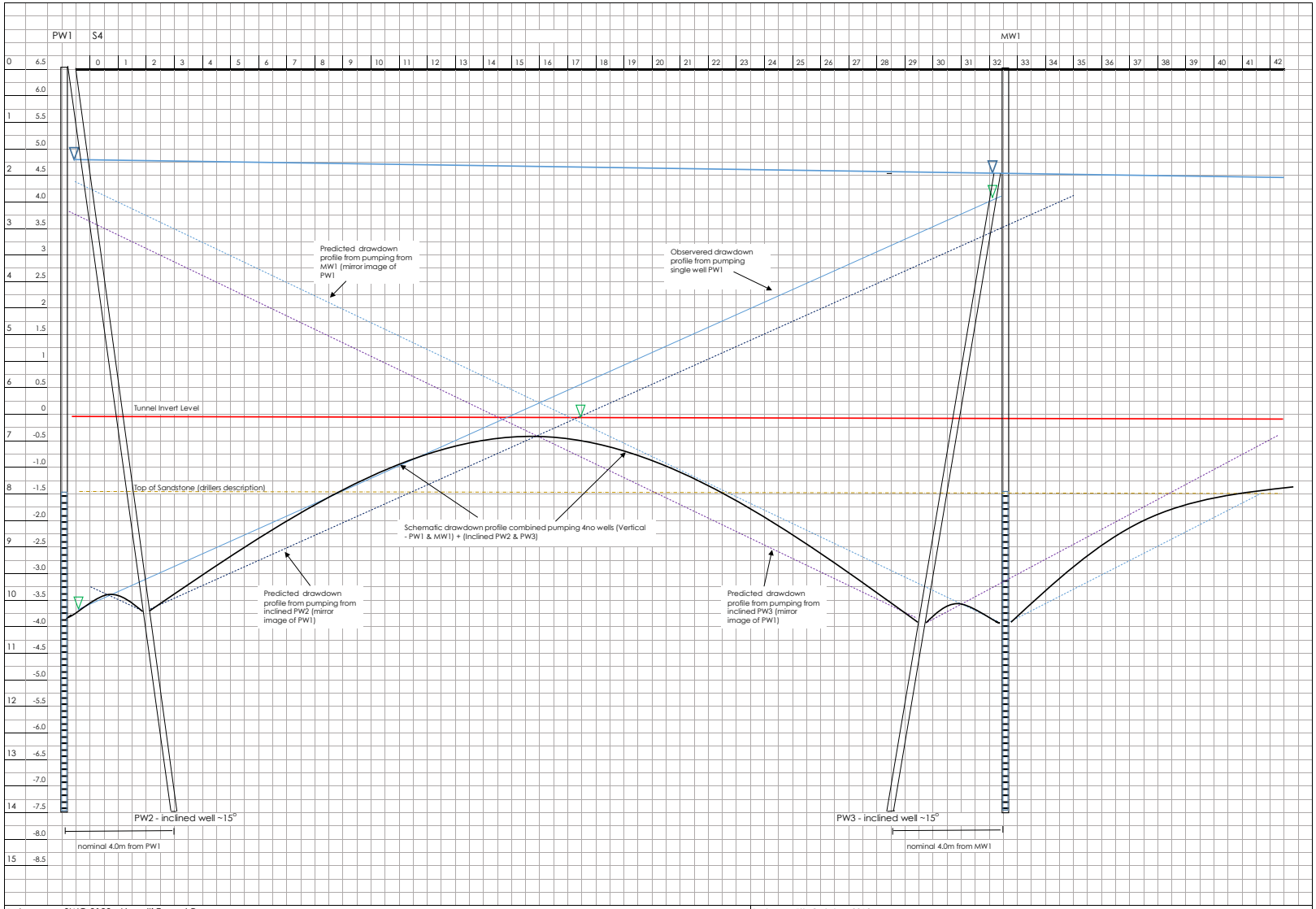
Conditions of Contract for Dewatering Works

1. This quotation is subject to and should be read in conjunction with our Standard Terms & Conditions of sale & hire E& O E (http://stuartgroup.ltd.uk/downloads/corporate/tc.pdf)and further amended to include the following.
2. This quotation is based on ground conditions described within and again any SI information submitted by the client at tender stage, or that may be reasonably foreseen from.
3. We are committed to work together with the client to achieve a satisfactory completion of the works. However, ground conditions are seldom adequate enough for an adequate design that represents conditions across the whole works area. We do not guarantee that the groundwater drawdown will be totally satisfactory. Should problems arise we will work with the client and apply the full depth of our knowledge and experience in advising the most appropriate remedial measures that may be needed.
4. Our installation rates and indicate programme are based on details supplied from the client or our interpretation of programme based on experience or similar projects and/or ground conditions. The programme depends on required access, unbroken provision of items within Schedule C – Main Exclusions and any other matters that enable us to undertake the works efficiently. Our installation and hire rates are on a re-measureable basis
5. We shall not have any responsibility for the settlement of the ground or of any adjacent structures due to the removal of groundwater.
6. We shall not be held responsible for any damage or loss directly or indirectly arising from the discharge of water from an agreed point of discharge, or for the removal of water from that point.
7. The client shall provide adequate protection of our plant or plant hired in from us and indemnify us against any damaged caused to it by themselves or third parties.
8. Our Public Liability insurance is £10M for any one occurrence. If we are required to have additional cover or any further insurance cover or performance bonds. We are to be reimbursed the cost of the additional premium plus 15%, with the sum included in the 1st or next application/invoice.
9. Payment terms strictly 35 days and as per to the Construction Act including amendments
10. This quotation is based against no discounts, deductions or retention.
11. The amount of liquidated damages, if any, for which we may become liable shall not exceed 5% of our sub-contract price.
12. Title of goods supplied shall not pass to the client and the goods will remain the absolute property of the Stuart Group until payment has been made of the full or agreed contract price. In the case of non-payment by the due date, or the client having a liquidation order made against him, or having a receiver appointed, Stuart Group shall be entitled to reprocess or trace of goods, or proceeds of the sale from the customer, liquidator or receiver.
13. In the unfortunate event of any dispute arising between ourselves and the client, it shall be referred to adjudication under the terms of the ICE Adjudication Procedure.
14. This quotation is open to acceptance for a maximum period of 3 months

Stuart House, Crows Hall Lane, Attleborough, Norfolk NR17 1AD
Telephone: 01953 454540 Fax: 01953 451451 www.stuartwells.co.uk

Stuart Wells Services Ltd

Stuart House, Hargham Road, Shropham, Norfolk NR17 1DT
Telephone: 01953 454540 Fax: 01953 451451 www.stuartwells.co.uk



Ref:	SWC 8129 - Llanelli Tunnel Recovery	Date:	5th October 2018
Title:	Schematic Drawdown profile using combined 4no dewatering wells (2no vertical & 2no inclined)	By:	David Wright

Appendix B

Stuart Wells Pumping Test Raw Data