Case Study – HST Shaft: Llanberis WwTW

Abstract
An 9no. deep well dewatering system for a 12.5m Ø shaft at Llanberis WwTW in Gwynedd. The shaft formed part of a new Humus Sedimentation Tank within the existing works and was constructed to 5.9m depth. Ground conditions consisted of Alluvium Fan Deposits with course Sand and Gravels overlying the Llanberis Slate Formation. Groundwater level was at nominal 2.0m BEGL. Groundwater level was sensitive to both with hydraulic connection to the Llyn Padarn and Afon Seiont around 220m from the shaft location, which also acted as the discharge point for abstracted water; together with recharge from rainfall. This case study details the dewatering appraisal and design together with details on the methods used for a successful operation.

Scope of Works

- Client: A E Yates Trenchless Solutions Ltd
- Main Contractor: J N Bentley/Mott MacDonald
- Excavation: Humus Sedimentation Tank (HST)
- Shaft Dimension: 12.5m Ø x 5.9m deep
- Construction Method: Segmented Rings by driven caisson method (1m x 2m collar)
- Existing Ground Level: 105.0m AOD
- Excavation Level: 99.01m AOD (5.99m deep)

Ground & Groundwater Conditions

Ground Conditions: As per Ground Investigation report by Quantum Geotechnical, July 2015
Hydrogeology: Alluvium Fan overlaying Llanberis Slate Formation
Groundwater Level: Initial groundwater strruck at 4.0m rising quickly to 2.0m (103m AOD)

Ground conditions inferred from BH1501 being representative of the HST Shaft. BH1501 only terminated 9.0m BEGL, however it is assumed the Alluvium Fan Gravels extend to 11m as proven in BH1502 (PST area). During the excavation works the ground conditions expected to be encountered were:

Made Ground up to 104.2m AOD - gravelly CLAY
Alluvium Sand up to 102.8m AOD - gravelly SAND w. cobbles becoming silty CLAY at depth
Alluvium Gravel to a known depth of 96.5m AOD - silty sandy GRAVEL – assumed extend to 94m AOD

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Design Risk Assessment

Prior to undertaking a dewatering design a design risk assessment was undertaken to highlight risks and any shortfalls in available information

Project	Llanberis WwTW (Humus Tank)	Quote No:	SWC5271	Date: 1st December 2015
Client	AE Yates	Document Ref No:	DesignRA/SWC5271/00	Distribution: SWS Staff Main Contractor Staff
Location	Llanberis. LLLL55 4UR	Assessor:	Rory Cripps	
Discipline	Dewatering	Checked By:	David Wright	

No.	Description	Detail	Initial Risk	Potential			Action Required Yes/No	Action/Comments	Risk Potential after Action		
				H	M	L			H	M	L
1	Site Location	Rural – Snowdonia National Park. Existing & Working WwTW	External Dewatering Effects. Damage to dewatering by other site operation.		M		Yes	Calculate Radius of Influence (Ro) – Undertake settlement assessment. Robust equipment. Adequate access to maintain dewatering system			L
2	Radius of Influence	Base on individual pumping operation at any one time	External Dewatering Effect on adjacent structures, Any water supply wells in area.		M		Yes	Establish Radius of Influence			L
3	Settlement	Consolidation of compressible &/or loose strata. Removal of fines upon pumping. Excessive recharge	External effects on adjacent structures		M		Yes	Undertake settlement assessment. Well design assessment. Wells to be airlift developed prior to pumping. Monitoring of discharge quality. Settlement Monitoring			L
4	Heave	Basal heave during construction phase	Excavation Instability. Flooding of excavation		M		Yes	Undertake heave assessment.			L
5	Discharge	Adequate Discharge point	Inability to remove water off site. Discharge Permit NRW/Utility throughout contract period. Silting up of discharge outfall			L	Yes	Discharge TBC – assumed within WwTW works or River Confirmation required on any permit status and conditions. Well design assessment. Wells to be airlift developed prior to pumping. Monitoring of discharge quality			L
6	Boundary Condition	River. Faults. Confined Alluvium Fan?	Any boundary conditions that could affect dewatering		M		Yes	Undertake desk top study to include NRW & local BGS records			L
7	Level of SI	Available Information	Inadequate Information. Possible Unforeseen conditions		M		Yes	Ground Conditions proven during drilling			L
8	Unforeseen Ground Conditions	Available Information.	PST lower Gravel proved to 15m Humus Tank deepest BH to 9m No PST for lower Gravel	H			Yes	Outline Risk that if bedrock found at higher level and reduces wetted length of deep wells additional, shallower wells will be required			L
9	Permeability	Available Information	Inadequate Information. Large Range 10-3 to 10-6. Unforeseen conditions		M		Yes	Short Pump Test during commission stage			L
10	Groundwater Level(s)	Available Information	Inadequate Information. Unforeseen conditions			L	Yes	None			L
11	Contamination	TP Soil Analysis	No groundwater analysis. Existing WwTW – Ammonia?		M		Yes	Sample discharge water			L
12	Pumping Water Quality	Pumping Dirty Water	Contamination & pumping silts at outfall. Blocked pipework		M		Yes	Undertake filter design			L
13	Construction Method	Segmented Shaft	Damage to dewatering by other site operation.		M		Yes	Outline risk to client			L

The Design Risk Assessment indicated the limited information available to establish an accurate permeability valve and boundary conditions.

In addition with sensitivity on discharge with flow limitations on what could be discharged within the WwTW works and concerns on discharge quality if discharge was to go into the river. Design was to establish estimated flow range and mitigation measures in relation to pumping fines.

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Permeability Assessment

- Assessment of permeability values for the Alluvium Gravel. The only available PST curves are from high level trial pits (TP502 – 2.5m & TP503 – 1.5m).
- Permeability assessment using available PSD curves. Valves inferred from Kozeny-Carmen, Slitcher and Terzaghi method

Hazen	Useful for grains between fine sand and gravel, U<5, D10 between 0.1 - 3mm
Kozeny-Carmen	Not good for effective grain size over 3mm and clayey soils
Breyer	Good for heterogeneous medium that is poorly sorted, U between 1 and 20, D10 between 0.06 and 0.6mm
Slitcher	Used for grains sizes between 0.01 and 5mm
Terzaghi	Use for ONLY large grained sands
USBR	Used for ONLY medium grain sand with U<5
Alyamani	Good for a well graded soil U>5 (wide PSD curve

Io = xaxis intercept of straight line

Sample No.	BH No.	Depth	d10	d20	d50	d60	Io	Uniformity Coeff	Porosity
1	TP502	2.5	0.03	0.52	3.5	5.4	0.009	180.0	0.26
2	TP503	1.5	1.3	3	12	18	0.9	13.85	0.27

All Values in m/s

Hazen	Kozeny-Carmen	Breyer	Slitcher	Terzaghi	USBR	Alyamani
3.85E-06	1.67E-06	1.80E-06	7.56E-07	1.03E-06	8.00E-04	1.38E-04
8.70E-03	4.13E-03	1.19E-02	1.81E-03	2.62E-03	4.51E-02	2.05E-02

Sample No.	BH No.	Depth	d10	d20	d50	d60	Io	Uniformity Coeff	Porosity	Density
1	TP502	2.5	0.03	0.52	3.5	5.4	0.009	180.0	0.26	0.8
2	TP503	1.5	1.3	3	12	18	0.9	13.85	0.27	0.7

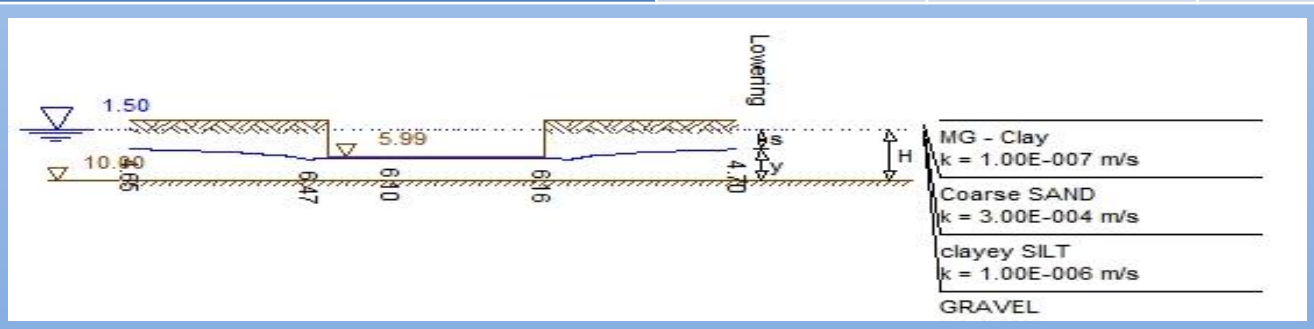
Hazen	Kozeny-Carmen	Breyer	Slitcher	Terzaghi	USBR	Alyamani
3.45E-06	1.5E-06	1.6E-06	6.78E-07	9.203E-07	7.17E-04	1.24E-04
5.97E-03	2.8E-03	8.1E-03	1.24E-03	1.79E-03	3.09E-02	1.41E-02

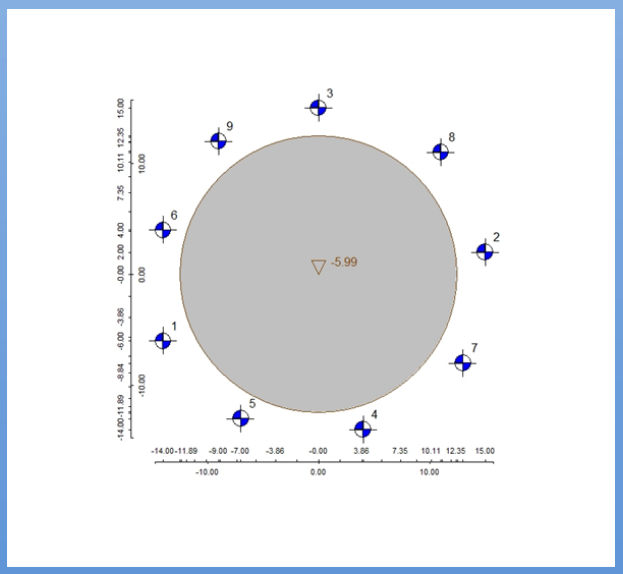
Dewatering Design Assessment

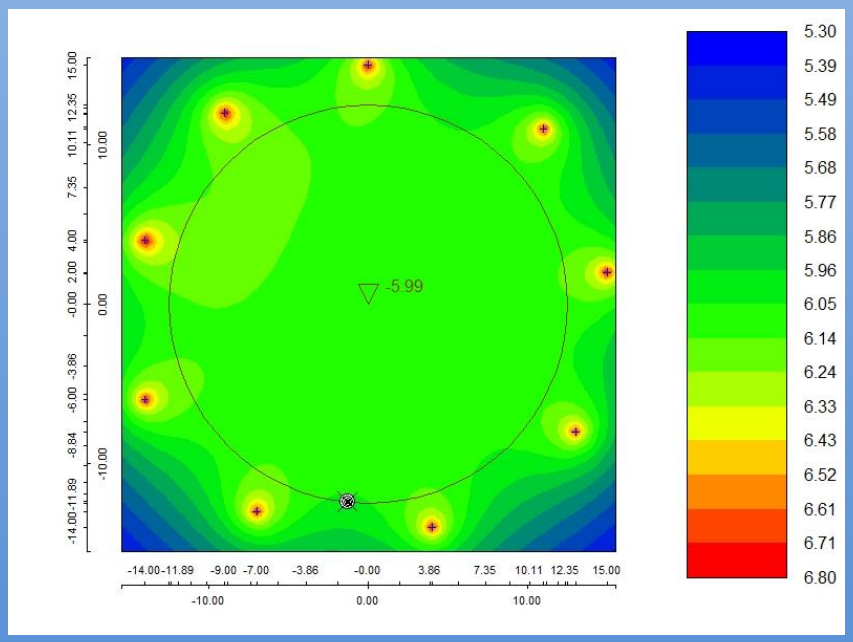
Analyicical Assessment – Duplit Method: Equilivant Well Analyisis

- Unconfined Aquifer with Saturated Aquifer Thickness (H) = 7.5m
- Maximum Drawdown (hw) = 3.1m
- Radius of Influence (Ro)& Boundary Condition: 220m distance to adjacent lake
- Permeability Range: 1.8 x 10-3m/sec to 2.3 x 10-4 m/sec

Source	Permeability (m/s)	Total Flow (l/s)	Well Yield (l/s)	Number of Wells
TP503 (1.5m) - Kozeny Carmen	2.80E-03	127.449	11.67	11
TP503 (1.5m) - Slitcher	1.24E-03	62.672	7.733	8
TP503 (1.5m) - Terzaghi	1.79E-03	86.181	9.331	9
Geomean of above	1.84E-03	88.274	9.46	9
Dolgarrog Pump Test	2.33E-04	15.242	3.366	9
			Average number of wells	8
	Average of Flow and Well Yield	75.9636	8.312	9







Stuart We Services Ltd

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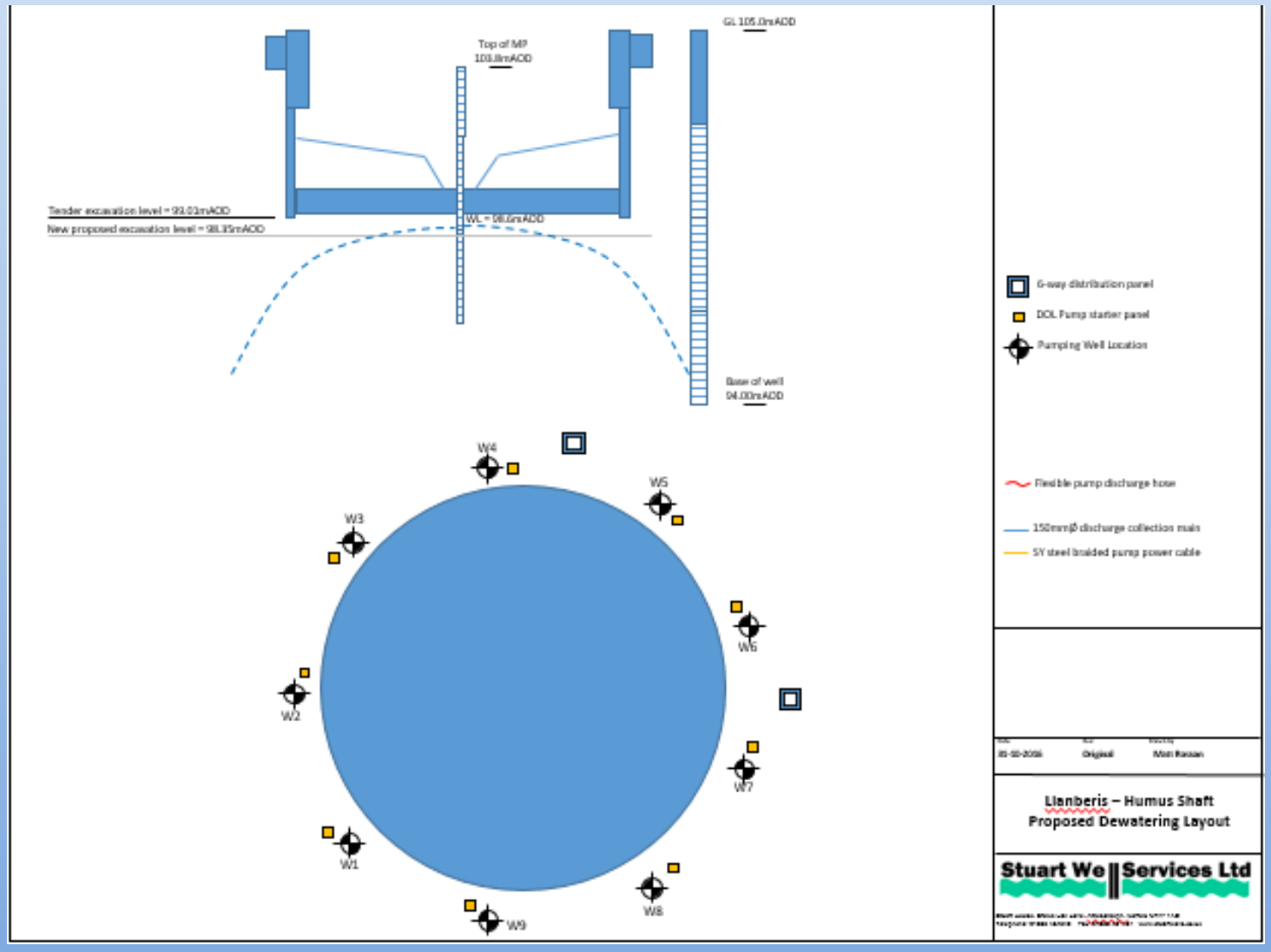
Dewatering Proposals

- Dewatering Wells: 9no
- Well Depth: 11.0m
- Finish Drilling Diameter: nominal 300mm
- Drilling Method: Cable Percussive
- Well Liner: 225mm x 209mm uPVC – 1mm slot
- Filtration: 2-5mm silica sand
- Monitoring Well: 1no. within centre of shaft
- Pumping: 415V 7.5 kW submersible borehole pumps (15 lts/sec)

Borehole pumps suspended on 63mm Ø riser to a wellhead assembly. In turn the wells are connected 4no x 150mm Ø collection mains discharging via v-notch tank then to a collection MH with a 200mm Ø polybauer discharge line to river, with flotation strainer within the river



To mitigate environmental concerns with discharging into the river. Phased pumping was proposed to control the impact of flow and water quality with discharge samples taken and analysed during each phase, prior to starting the next phase.

Phase 1 – Initial commissioning of 9no BH pumps to discharge maximum 40 lts/sec until discharge water quality confirmed

Phase 2 – Upon acceptance of water quality to increase the total discharge flow from the 9no dewatering wells in incremental increases of a maximum 20 lts/sec per day with a maximum increase of 5 lts/sec at any stage. Increasing to maximum flow with continuous pumping to enable construction of the shaft.

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Site Operation & Performance
The 9no wells dewatering wells and internal monitoring points were drilled and installed over a 2 week period 1st November to 14th November 2016.

During this period dewatering wells were developed and BH pumps installed. The system was commissioned with phased pumping undertaken over a 1 week period from the 16th November 2016

Dewatering was operational and the shaft successful completed over a 6 week period

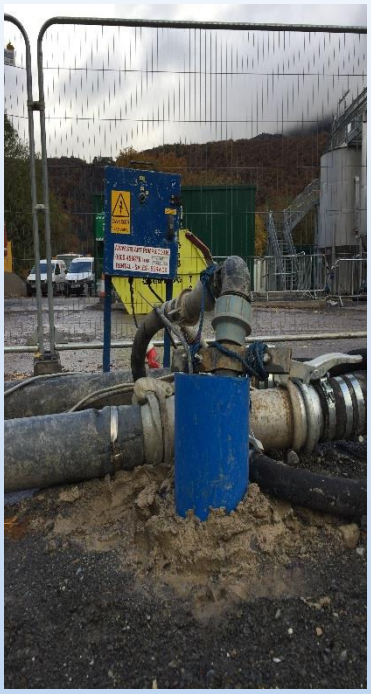

Table showing groundwater flow and level data over phased pumping period.

				Pumping Wells								
Date	Time	Flowrate lts/s	MP1	W1	W2	W3	W4	W5	W6	W7	W8	W9
16-Nov-16	08:00	0.0	0.33	2.14	1.90	1.84	1.97	1.96	2.10	2.22	2.20	2.05
17-Nov-16	08:00	0.0	0.34	2.13	1.88	1.84	1.98	1.97	2.10	2.24	2.20	2.06
17-Nov-16	17:00	40.0	2.30									
18-Nov-16	08:00	40.0	2.98									
18-Nov-16	11:30	60.0	3.53									
21-Nov-16	09:00	60.0	4.52									
21-Nov-16	18:30	70.0	5.01									
22-Nov-16	09:00	70.4	5.05	7.28	7.15	9.24	9.10	9.78	7.40	8.70	9.60	6.29
23-Nov-16	18:00	71.0	5.13									
24-Nov-16	08:30	70.0	5.19									

Video showing discharge arrangement – **please click**
(power-point format only)

Customer Feedback

Stuart Wells provided everything we required to dewater the HST shaft at Llanberis including invaluable ECI, smooth installation and fault free operation.

David Atkinson
Director – AE Yates Trenchless Solutions Limited