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Engineering Solutions Review

	Name	Signed	Date
Project Design Engineer	S Moore	S. Moore	10/03/2023
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Innovation

Are the solutions proposed in this design Innovative?			~~Yes~~/No
~~Why are the solutions proposed in this design regarded as innovative and potentially qualify for RDEC?~~			
Proposed By			
Approved By			

Related Design Output

Document Reference	Description

1. CONTENTS

2. SCOPE

The scope of this note is to assess the potential requirements for groundwater control measures during the construction of the integrated wetlands proposed for the Pont y Felin Combined Sewer Overflow (CSO) scheme. The proposed scheme comprises the construction of a primary and a secondary Nature-Based Solution (NBS) reedbed (constructed wetland), footpaths and decking areas at the surface in addition to upgrades to the existing CSO at the site.

The site is located in Pont-y-Felin, South Wales, circa 200m east of Pont-y-Felin Industrial Estate and comprises an agricultural field bound by treeline. The site is bounded by the river Afon Lwyd to the west, by sports pitches to the north, by residential housing to the east and south.

3. BASIS OF DESIGN

3.1. Standards and Guidance

- CIRIA C750 Groundwater Control: Design and Practice, Second Edition (2016)

3.2. Supporting information

3.2.1. Drawings

- B16789-102503-XX-XX-DR-CA-MM6004
- B16789-102503-01-XX-DR-TA-PN9202

3.2.2. Other Supporting Information

- B16789-102503-XX-XX-RP-GB-GC6703 Pont-y-Felin CSO Geotechnical Ground Investigation Report (Arup, 2022)

4. PROPOSED SCHEME

The proposed scheme will comprise the construction of two NBS reedbeds, a primary and a secondary, and the associated outlet, overflow and screening chambers. B16789-102503-01-XX-DR-TA-PN9202 presents the hydraulic profile across the proposed scheme. A summary of the geometry for the two wetlands is presented below

Primary NBS

- Excavation to be undertaken first and likely to be open of approximately 7 weeks.
- Scenario 1 – Formation level approx. +88.200mAOD (excavation depth 2.6mbgl)
- Scenario 2 - Formation level approx. +88.500mAOD (excavation depth 2.3mbgl)
- Current construction proposal is to excavate the entire basin prior to the installation of the liner and subsequent aggregate installation for the reed bed system.
- Proposed dimensions in plan are 40m X 115m.

Secondary NBS

- To be excavated second and likely to be open approximately 10 weeks. This would commence after the installation of the media stone to the primary NBS (reedbed)
- Scenario 1 – Formation level approx. +87.940mAOD (excavation 2.01-2.81mbgl)
- Scenario 2 - Formation level approx. +88.240mAOD (excavation 1.71-2.51mbgl)
- Current construction proposal is to excavate this basin to full depth prior to the installation of the liner and subsequent planting up.
- Proposed dimensions in plan are 40m X 115m.

5. GROUND CONDITIONS

A Ground Investigation (GI) was commissioned by Arup and was undertaken in August 2022 by Socotec that comprised three boreholes to a maximum depth of 10metres below ground level (mbgl), five trial pits to a maximum depth of 1.9mbgl and three infiltration tests down to 1.2mbgl.. A GI location plan is shown in Figure 1.

Ground conditions are anticipated to comprise limited thickness of Topsoil (up to 0.3m) over cohesive Alluvium to the south and east, and granular Alluvium to the north and west adjacent to the river. The superficial deposits are underlain by a weathered horizon of Mudstone (recovered as clay and gravel) on top of unweathered Mudstone. Made Ground was encountered locally to the east of the site (BH01 and BH02).

Topsoil was recorded as gravelly fine to coarse SAND. Gravel is subangular fine to medium of sandstone/ mudstone/ limestone, often with rootlets.

Made Ground was encountered below topsoil in BH01 and at surface in BH02 and was described as lightly sandy slightly gravelly CLAY and, slightly clayey gravelly fine to coarse SAND becoming slightly silty sandy fine to coarse GRAVEL respectively. Arup report (2016) states that no visual or olfactory evidence of contamination was noted within the Made Ground, however anthropogenic materials such as brick, concrete, glass and ceramics are likely to be associated with general fill/ rubble of unknown origin.

Alluvium was encountered in all boreholes beneath the Topsoil and/or Made Ground and was described either as predominantly cohesive towards the north and east of the site, or as sand and/or gravels to the south and west. It was generally found to become more granular towards the river.

Cohesive alluvial clays were typically described as firm to stiff slightly sandy slightly gravelly CLAY with medium cobble content. Soft clays of 0.4m thickness were encountered at 1.2mbgl within BH01, which indicate the potential of encountering soft clays elsewhere on site. The cohesive Alluvium was recorded to a maximum depth of 2.2mbgl becoming more granular with depth.

Granular Alluvium was typically described as slightly gravelly clayey SAND with high cobble content and medium boulder content and was recorded to a maximum proven depth of 3.0m in BH03.

Raglan Mudstone was recorded only within the three boreholes, initially as weathered comprising clay and gravel, becoming weak to medium weak mudstone at relatively shallow depth. The weathered clay and gravels were present between 2.2m and 5.0mbgl in BH01. The competent bedrock was encountered at depths between 3.0 and 5.7mbgl (+87.82 to +83.71m AOD) within the three boreholes.

Figure 1 GI Location Plan with Proposed Scheme (extract from B16789-102503-XX-XX-RP-GB-GC6703)

In summary, the ground conditions vary laterally across the site, with the formation of the two constructed wetlands lying within the superficial alluvial deposits. The base of the primary NBS will likely be within the cohesive Alluvium with the northern part being partially within the granular Alluvium. The base of the secondary NBS will be largely within the granular Alluvium with the southern part founded within the cohesive Alluvium.

6. GROUNDWATER CONDITIONS

Three rounds of groundwater monitoring were undertaken in the three installed boreholes between August and September 2022 and recorded shallow groundwater levels ranging from 0.85m (+90.05m AOD) to 1.82m bgl (+89.00m AOD) to the north and east of the site and from 0.94m (+88.47m AOD) to 1.82mbgl (+87.59m AOD).

Based on the above, groundwater is likely to be encountered within the two excavations at approximate depth of 1.0m to 1.5mbgl. Furthermore, perched groundwater may be present within the Made Ground at approximately 0.3mbgl. Therefore, appropriate groundwater control measures will be required taking into account the required level of drawdown and the permeability of the materials present at the base of the excavations. Considering the proposed excavation levels of the two basins, maximum drawdown of 1.45 (*i.e. 2.6mbgl (maximum excavation depth) – 0.85mbgl (minimum groundwater depth))* and 1.95m (*i.e. 2.8mbgl (maximum excavation depth) – 0.85mbgl (minimum groundwater depth))* is expected for the primary and secondary NBS respectively.

7. SOIL PERMEABILITY

As part of the GI, three infiltration tests to BRE365 and two variable head tests were undertaken to assess the permeability of the superficial deposits. For all five tests, the infiltration was too slow to allow calculation of infiltration rates and subsequently of soil permeability, thus indicating relatively low permeability superficial deposits (less than $1X10^{-7}$m/s).

Furthermore, Particle Size Distribution (PSD) testing has been carried out on the superficial deposits, indicating high percentage of fines for the granular Alluvium that will result in low permeability and reduced groundwater flow within the deposits. More specifically, the permeability has been assessed for granular Alluvium using Hazen correlation where permeability k is equal to $C*(D_{10})^2$ where C varies between 0.007 and 0.014 (when k is in m/s and D_{10} is in millimetres) and is typically taken as 0.01. Based on this formula and the maximum D_{10} from the available PSD tests (Figure 2), permeability of the alluvial deposits is expected to be less than $1X10^{-7}$m/s.

Considering the material descriptions in the borehole logs and the guidance in CIRIA C750 (table 1.1), a permeability range between $1X10^{-5}$ and $1X10^{-7}$ m/s may be expected for Alluvium.

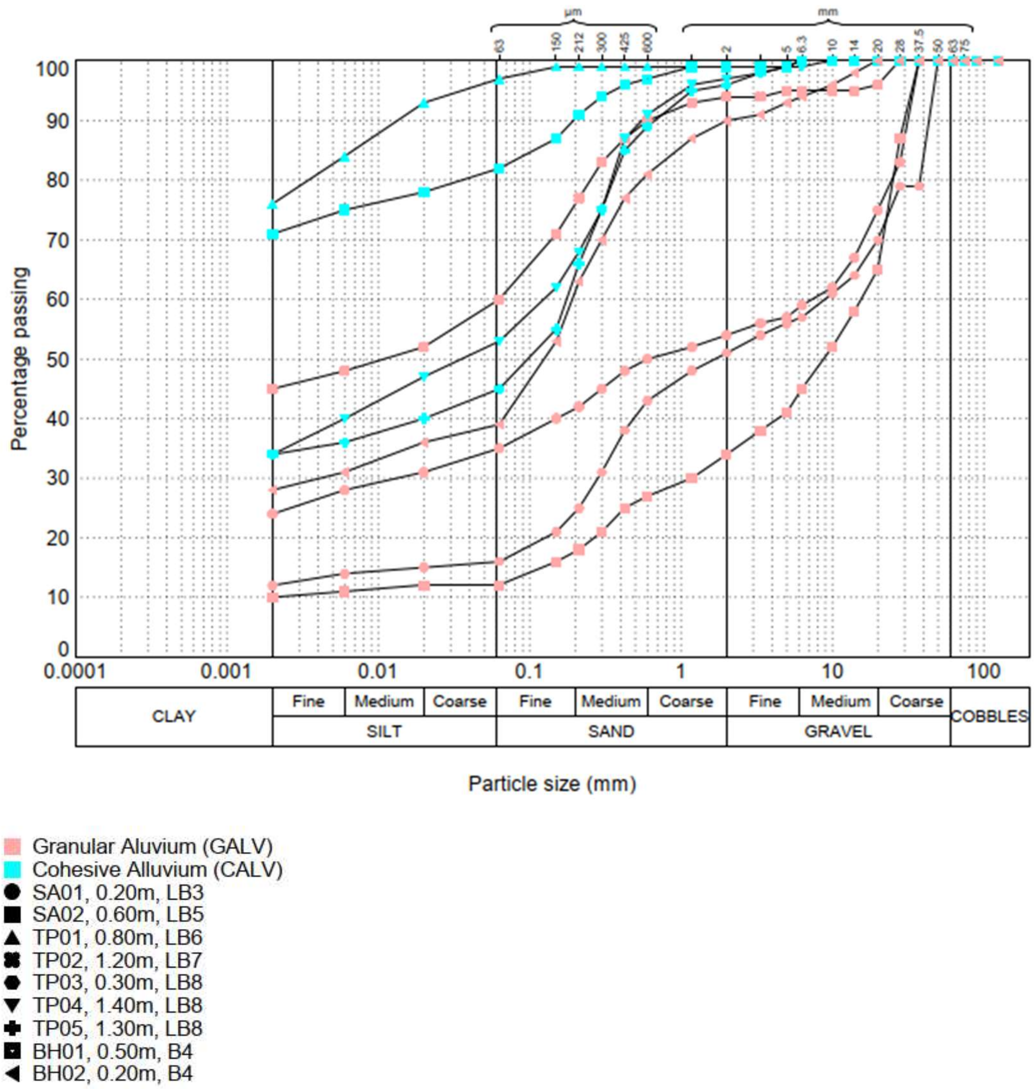

Figure 2 PSD - Alluvium (extract from B16789-102503-XX-XX-RP-GB-GC6703)

8. GROUNDWATER CONTROL

8.1. Groundwater Control Technique

Figures 1.9 and 1.10 in the CIRIA C750 suggest that groundwater control by pumping with or without the use of physical cut-off can be considered as appropriate dewatering measure given the nature of the superficial deposits and anticipated permeability and the relatively small drawdown. Sump pumping or single point well system (1-2m spacing) may be considered.

A filter sump pumping operation with a network of filter drains around the perimeter within each excavation may be appropriate given the conditions summarised in Table 2.1 of CIRIA C750. More specifically, the Alluvial deposits are expected to be well graded sand and gravel or clays typically described as firm to stiff, and comprise an unconfined aquifer. The required drawdown is relatively small (less than 2m) and the surrounding structures, although expected to be on shallow foundations, are likely to be moderately loaded two-storey houses.

Single point well system around each proposed excavation might be a suitable alternative option, allowing for varying ground conditions and permeabilities that are expected to be encountered across the site and in view of the small required drawdown. However, given the relatively shallow depth of bedrock that may impede their installation to a suitable depth, the relatively low permeability of the superficial deposits and the great number of installations required around each excavation (1-2m spacing), their benefit is likely to be limited and thus this option has not been considered further.

Based on the geoenvironmental testing and screening of the groundwater samples undertaken as part of the 2022 GI, all Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAH) and Benzene, Toluene, Ethylbenzene and Xylene (BTEX) compounds were found to be below the screening criteria in all five samples. Two of the samples from the superficial deposits (BH01 and BH02) recorded exceedances for heavy metals Cadmium, Iron and Manganese, with the sample from BH01 having the highest values. Furthermore, two surface water samples were collected from river Afon Lwyd and recorded no heavy metal contamination. Similarly, the deeper groundwater sample from BH03 also recorded no heavy metal exceedances. Given the above, the groundwater quality will need to be considered when selecting a discharge location to dispose of the groundwater.

8.2. Estimated Abstraction Rate

Considering a filter sump pumping as the appropriate groundwater control technique, an estimate of the anticipated flow rate to be discharged has been undertaken assuming a range of anticipated permeabilities and radii of influence (RoI) and on the basis of an unconfined aquifer.

The steady state flow rate, Q, in an unconfined aquifer can be estimated using the Dupuit-Forcheimer equation

$$Q = \frac{\pi k (H^2 - h_w^2)}{\ln[{}^{R_0}/_{r_e}]}$$

Where

k is soil permeability (hydraulic conductivity) taken equal to $1X10^{-5}$ to $1X10^{-7}$ m/s for sensitivity checks

H is the initial piezometric level taken at +90.05m AOD with base of aquifer at top of weathered Mudstone at +86.41m AOD (i.e. 3.64m)

h_w is the target level (in the equivalent well) taken at +87.94m AOD (deepest excavation level between two NBS) with base of aquifer at top of weathered Mudstone at +86.41m AOD (i.e. 1.53m)

R_0 is the radius of influence that depends on the distance to the recharge boundary (which is unknown) and taken equal to 70, 100, 200m for sensitivity checks

r_e is the radius of equivalent well (taken equal to the equivalent radius r_e (=50=(40+115)/π) of each of the NBS basins of 40x115 m dimensions)

The above approach is based on a number of assumptions (infinite areal extent of aquifer, homogeneous isotropic and of uniform thickness aquifer, constant pumping rate and steady state flow, well penetrating full thickness of aquifer, flat initial water table). Furthermore, it is assumed that the construction will be undertaken in a relatively dry period and will be staged (i.e. NBS will be constructed separately).

The resulting abstraction rates were found to vary between 0.2m^3/day and 90m^3/ day as shown in the table below. The were found to be below the exemption limit of 100m^3/day for the anticipated (based on GI data) permeabilities less than 1X10^{-5}m/s. The works will need to comply with the requirements of the small scale dewatering exemption.

Table 1 Estimated Abstraction Rates (Dupuit-Forcheimer)

Estimated Abstraction Rate Q (m^3/day)			
Permeability/ RoI	70m	100m	200m
1X10^{-7} m/s	0.9	0.4	0.2
1X10^{-6} m/s	8.8	4.3	2.1
1X10^{-5} m/s	88.0	42.7	21.3

The aforementioned abstraction rates are likely to be greater by an order of magnitude at the beginning of construction until steady state flow is established.

The drawdown curve can be subsequently determined using the following boundary conditions:

- At distance equal to the RoI, groundwater would be at +90.05m AOD (i.e. maximum recorded groundwater level)
- At the edges of the excavation basis of each NBS, groundwater would be at +87.94m AOD (i.e. minimum proposed excavation level)
- The groundwater level at any distance between the edge of the excavation and the Zone of Influence can be determined using the equation presented above for a given abstraction rate, permeability and RoI.

It has been assumed that no recharge from the adjacent river or any other surface watercourses. This is an assumption at this stage as the depth and the material at the base of the river are unknown. If excavations are in hydraulic continuity with the river, then additional mitigation measures (possibly in the form of physical cut-off) may be required to prevent excessive water ingress, instability of slopes and impact on the watercourse.

Surface water runoff is likely to be significant and will need to be managed on site using a drainage system given the permeability of the superficial deposits and the anticipated low drainage. Code of Construction Practice (CoCP) measures should be incorporated to ensure that surface water is diverted away from any subsurface works.

8.3. Other Considerations

The impact of the dewatering works shall be considered both in terms of hydrogeology and proximity to environmentally-sensitive receptors and neighbouring structures during the proposed construction. Further considerations will need to be made for the permanent design but these lie outside the scope of the present note.

The construction of the reedbeds will be relatively short in duration and therefore any impact due to temporary water abstraction from the secondary aquifers will likely be low. Furthermore, there are no Source Protection Zones (SPZ) in the proximity of the site (within 1km). The nearest surface watercourse is river Afon Lwyd approximately 50m to the west of the site, which discharges into the River Usk, located 10km downstream and considered site of special scientific interest. The main risks to Afon Lwyd are pollution and/ or reduced baseflow during construction. Visual monitoring of the river should be undertaken during the works. Furthermore and as discussed previously, works shall be undertaken on a staged basis and preferably during the dry summer months to reduce groundwater control requirements. Disposal of extracted water will need to allow for the potential presence of heavy metals (for which exceedances were recorded as part of 2022 GI) and any other contaminants. Many construction risks to the water environment can be mitigated through the implementation of good site practice and pollution prevention measures. Reference shall be made to the Environment Agency groundwater collection for further information.

No records for licensed abstractions, consented discharged or unlicensed abstractions (private water supplies) have been obtained. It is recommended that these are requested from Natural Resources Wales (licensed abstractions and discharge consents) and the local authority (private water supplies) within 500m of the site to confirm whether any are in the area that need to be considered further.

9. RECOMMENDATIONS

The use of perimeter filter drains and sump arrangement around each excavation is the preferred method for the control of groundwater for the site and considered the most suitable technique for the proposed site, the anticipated ground conditions (and permeabilities) and the relatively small drawdown requirements (less than 2m). An initial pre-dig to a shallow depth (less than 1m) across the reedbed footprint could be undertaken initially, prior to reaching the final excavation level, in order to better facilitate the installation of the filter drains. Locally installed sump pumps can then be installed within the excavation footprint to lower the groundwater as the excavation progresses. Care should be taken limit the removal of fines within the soil, when using sump pumps.

It is assumed that the construction of the two reedbeds will be undertaken in a staged approach (i.e. the two excavations will not take place concurrently). Furthermore, it is assumed that there will be no direct connectivity with the adjacent Afon Lwyd.

The main risks associated with the dewatering during the construction period comprise the groundwater quality and the contamination potential of the pumped water that will need to be suitable discharged, the impact to neighbouring structures, potential reduced baseflow in Afon Lwyd.