APPENDIX 5

DOVE'S NEST FARM - HYDROGEOLOGICAL ECOLOGICAL MONITORING RHDHV006 DNF TECHNICAL NOTE

Technical Note

HaskoningDHV UK Ltd.
Industry & Buildings

To:	Richard Izatt-Lowry
From:	Wendy Johnston
Date:	21 December 2016
Copy:	Claire Smith and Robert Staniland
Our reference:	RHDHV TN002 Rev 2
Classification:	Open

Subject: **Hydrogeologically Supported Terrestrial Ecosystems and Ecological Monitoring for the Phase 2 Works at Dove's Nest Farm Mine Site**

Introduction

This document has been produced to provide:

- Details on the habitats and associated species within Ugglebarnby Moor that are considered to be hydrogeologically supported; and
- Clarification of the ecological monitoring protocol that should be implemented for this site in respect of the Phase 2 site preparatory works.

This document covers the ecological (botanical) aspects only and has been prepared to support the Hydrogeological Risk Assessment work undertaken to date by FWS Consultants Ltd. Therefore this document should be read in conjunction with the following documents.

- Ugglebarnby Moor Supplementary Vegetation Mapping and Analysis (Paul Chester and Associates, 2013);
- Dove's Nest Mine Site: Groundwater and Vegetation Environmental Monitoring Scheme, November 2013;
- Hydrogeological Risk Assessment of the Mine site Development at the Dove's Nest Site, North Yorkshire (1433MineOR024E) (FWS Consultants Ltd, 2014);
- Proposed Mine head Baseline Ecology Survey (Paul Chester and Associates, 2014); and
- Hydrogeological Baseline Report for the Dove's Nest Mine site, North Yorkshire 2012 to 2016 (1975OR01) (FWS Consultants Ltd, 2016).

Habitats within the North York Moors Special Area of Conservation

The Dove's Nest Farm site (DNF) is located adjacent to the North York Moors Special Area of Conservation (SAC) and Special Protection Area (SPA), which includes Sneaton Low Moor and Ugglebarnby Moor. These areas of the North York Moors SAC predominantly comprise dry heath habitats with occasional wetter heath sections (Paul Chester & Associates, 2013). Patches of acid grassland are also present. To the west of DNF is Ugglebarnby Moor, which comprises a dense band of trees and shrubs as well as a mosaic of wider habitat with patches of gorse, scattered self-established birch and Scots pine. Further to the west the habitat becomes more open with scattered trees and a mosaic of wet heath and purple moor-grass dominated mire (Paul Chester & Associates, 2013).

Ugglebarnby Moor was subject to further and more detailed botanical surveys in 2013; these were subsequently updated in 2014. Detailed botanical quadrat surveys were undertaken in 2014 (in accordance with the National Vegetation Classification (NVC) methodology) following discussions and agreements with Natural England. **Figure 1** shows the National Vegetation Classification (NVC) vegetation map generated from this survey. Full details of these surveys and their findings are provided in the *Proposed Minehead Baseline Ecology Survey report* (Paul Chester & Associates, 2014) and the *Ugglebarnby Moor: Supplementary Vegetation Mapping and Analysis* (Paul Chester & Associates, 2013).

The 2013 and 2014 botanical surveys identified almost 200 species of vascular plants, all common or relatively common species. No nationally rare, nationally scarce, or regionally rare species were recorded.

The 2013 vegetation mapping exercise concluded that the communities recorded within Ugglebarnby Moor **do not** represent groundwater dependent moor communities. The habitat types of Ugglebarnby Moor are either associated with dry/well drained habitats (i.e. bracken, gorse, dry heath, neutral grasslands, blackthorn scrub etc.) or, where wetter, the species are associated with soil type/topography (wet heath, purple moor-grass mire etc.). They are more typically associated with surface fed habitats (i.e. with shallow root systems) and with free draining ground or lower lying damper ground, where the soils are predicted to be damper primarily as a result of topographical influences (Paul Chester & Associates, 2014). It was concluded (Paul Chester & Associates 2014) that the recorded "Dry Heath" vegetation communities are **not hydrogeologically supported**.

In relation to the "Wet Heath" areas, the 2014 NVC botanical surveys (Paul Chester & Associates, 2014) concluded that while the areas of wet heath and blanket bog habitats may be impacted by alteration to the groundwater flow, other factors indicate that this was not the case. It was concluded that the species recorded **do not** make up groundwater dependent moor plant communities as a result of the nature of the superficial soils present (predominantly cohesive and of low permeability with only local sand / silt lenses); and general movement of water downslope through these habitats, with central open sections.

The 2014 NVC botanical surveys (Paul Chester & Associates, 2014) concluded that the only location where hydrogeologically supported habitats have been identified is in the "Spring Flush" area adjacent to Lousy Hill Lane, as shown by the white and blue lines in **Figure 1** below. The following water dependent species, indicative of the habitat of interest, have been recorded during the surveys to date:

- purple moor grass;
- deer grass;
- cross leaved heath;
- sharp flowered rush; and
- bog mosses.

Royal HaskoningDHV

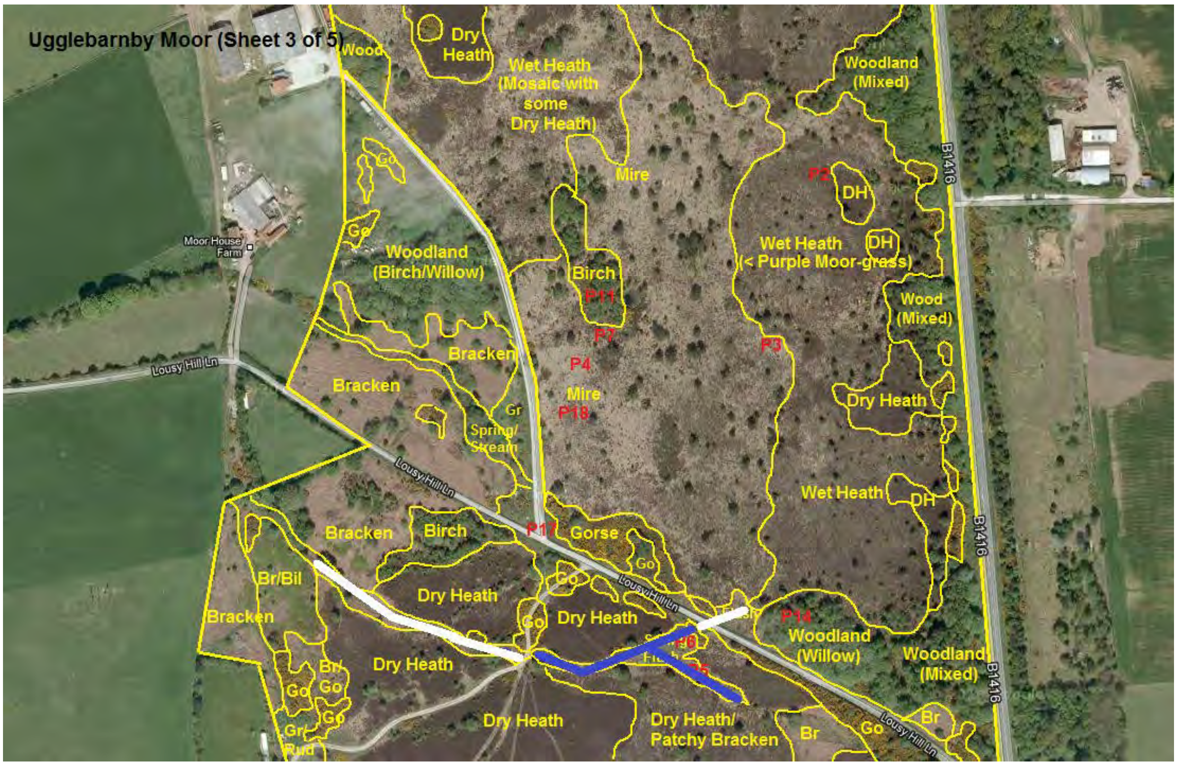


Figure 1– Location of spring/flush hydrogeologically dependent habitats adjacent to Lousy Lane (denoted by the white and blue lines)

The findings of these surveys were used to inform the Environmental Statement and the Supplementary Environmental Information Report, and accompanied the planning application. All of this information was reviewed by Natural England, during determination of the planning application. It was agreed that the botanical species recorded in the Spring Flush supported a conclusion that this is the only area of habitat in Ugglebarnby Moor and Sneaton Low Moor that should be considered as hydrogeologically supported.

Ecological Monitoring For the Phase 2 Site Preparatory Works

An ecological monitoring strategy for the mine site development was proposed in *Dove's Nest Farm Mine Site: Groundwater and Vegetation Environmental Monitoring, November 2013*. This document was submitted to, and approved by, Natural England.

As part of the Phase 2 works, the following ecological monitoring programme should be implemented to ensure that no adverse impact occurs during this phase of works, or to enable remedial measures to be adopted if required and when changes in specific ecological conditions (triggers) are identified.

Objectives of Monitoring

The objective of the ecological monitoring is to determine whether the Phase 2 works at Dove's Nest Farm are impacting the groundwater dependant flora (see below) in the Spring Flush area (i.e. Lousy Lane). Any changes in the habitat or its botanical composition in this area should be compared to the groundwater levels recorded during this phase. A conclusion can then be drawn as to whether the changes in the botanical composition are as result of the Phase 2 works.

Scope of Monitoring

The key indicator species to be monitored in the Spring Flush area are:

- purple moor grass;
- deer grass;
- cross leaved heath;
- sharp flowered rush; and
- bog mosses.

The monitoring should not be limited to these key indicator species and the presence of all botanical species, and changes in their populations, should be recorded.

Location of monitoring points

The survey area should be the two areas (i.e. the white and blue lines) adjacent to Lousy Lane, as shown on **Figure 1**. A series of ten fixed monitoring locations for quadrat sampling should be identified on site during the first baseline sampling visit. These locations should be identified by the use of GPS and photographs and used for all future sampling. The areas for sampling should be selected based on those areas where habitats show more diversity, although some areas of lesser diversity should also be selected

Monitoring Frequency

The window for NVC surveys is April to September with the optimal time for monitoring being July – September when the plants are in bloom. All NVC monitoring should be undertaken in accordance with the NVC methodology set out in guidance (Rodwell, 2006). The preconstruction, baseline monitoring should be undertaken immediately prior to the start of the construction works in April 2017 with a further survey being undertaken in August or September 2017. Future surveys should be undertaken annually in August or September, with an additional survey being undertaken every two years during the sub-optimal period (October - March); this will capture habitat diversity in periods when the ground is likely to be more saturated.

Assessment Trigger Values

The results of the annual and twice yearly sampling should be compared against the trigger values and, where trigger values are reached, the reasons for these changes should be assessed. Where required, contingency actions should be identified and agreed with Natural England.

The habitat trigger values which should promote investigations and the potential contingency action are:

Change in NVC class – the quadrats will allow the detailed definition of NVC class(es) for each habitat type and location. A change in NVC class will indicate a change in assemblage sufficient to cause a change in vegetation, thereby impacting the interest of the site;

Change in percentage cover (loss of 5%) of the key indicator species – the quadrats will allow the definition of percentage cover. Should coverage of the key indicator species drop by 5% or more, this will trigger a review of the significance of the change in the context of the wider habitat conditions (to allow isolation of the construction impact);

Colonisation by new species – the ability of different species to colonise within a quadrat will indicate a different niche or water availability has arisen and should trigger a review of the significance and consequence of the change;

Change in water discharge - the flow in summer (witnessed in nearby becks) is classed as low and it is conceivable that these do dry out. The concern is that the volume of water discharged will drop. A 10%

change in discharge volume should trigger a review of the groundwater conditions and general pluvial conditions at the time. In contrast, it is also conceivable that some locations might receive increased volumes of water so that should also be addressed in the same way (monthly inspections and the monitoring of flow at spring locations).

Conclusion

Surveys undertaken to date indicate that although the botanical species identified in the Spring Flush could be groundwater dependant, the Phase 2 works will have no discernible impact on this habitat or its species. However, as a precautionary measure, the technical note recommends suitable monitoring to confirm that botanical species and their associated habitat are not impacted by these works.

APPENDIX 6

ARUP TECHNICAL NOTE : SUMMARY OF DEEP SALINE INJECTION WELL (REF. YP-P2-REP-003 JANUARY 2015)

York Potash Ltd.

Dove's Nest Farm Minehead

Feasibility Study for Dove's Nest Site Recharge Borehole

YP-P2-Rep-003

Rev 3 | 26 January 2015

Job number 234376

Ove Arup & Partners Ltd
Admiral House Rose Wharf
78 East Street
Leeds LS9 8EE
United Kingdom
www.arup.com

ARUP

Document Verification

ARUP

Job title		Dove's Nest Farm Minehead		**Job number** 234376	
Document title		Feasibility Study for Dove's Nest Site Recharge Borehole		**File reference**	
Document ref		YP-P2-Rep-003			
Revision	**Date**	**Filename**	YPL_Recharge_well_design_report_Draft_2_Rev2_CRT.docx		
Draft 1	14 May 2014	**Description**	First draft		
			Prepared by	Checked by	Approved by
		Name	Charlene Timmen/Gerd Cachandt/Michael Chendorain	Gerd Cachandt/Michael Chendorain	Andrew Hornung
		Signature			
Issue	16 May 2014	**Filename**	YPL_Recharge_well_design_report_Issue Rev 0.docx		
		Description			
			Prepared by	Checked by	Approved by
		Name	Charlene Timmen	Gerd Cachandt / Michael Chendorain	Andrew Hornung
		Signature			
Rev 1	31 Jul 2014	**Filename**	YP-P2-Rep-003 Recharge Borehole Feasibility Report 20140731 Rev 1.docx		
		Description	General update to reflect scheme development		
			Prepared by	Checked by	Approved by
		Name	Charlene Timmen	Andrew Hornung	Andrew Hornung
		Signature			
Rev 2	12 Sept 2014	**Filename**	YP-P2-Rep-003 Recharge Borehole Feasibility Report 20140731 Rev 2.docx		
		Description	General update to reflect programme schedule		
			Prepared by	Checked by	Approved by
		Name	Charlene Timmen	Andrew Hornung	Alastair Gordon
		Signature			

Issue Document Verification with Document ✓

Job title		Dove's Nest Farm Minehead		Job number 234376
Document title		Feasibility Study for Dove's Nest Site Recharge Borehole		**File reference**
Document ref		YP-P2-Rep-003		

Revision	Date	Filename	YP-P2-Rep-003 Recharge Borehole Feasibility Report 20150119 Rev 3.docx		
Rev 3	26 Jan 2015		Revise the flow data following change in treatment strategy for wastewater from MTS		
			Prepared by	Checked by	Approved by
		Name	Charlene Timmen	Andrew Hornung	Alastair Gordon
		Signature			

Issue Document Verification with Document ✓

Contents

			Page
Executive Summary			**3**
1	**Introduction**		**6**
	1.1	Background	6
	1.2	Objectives	6
2	**Wastewater Disposal Options Appraisal**		**7**
	2.1	Source of wastewater	7
	2.2	Initial identification of disposal options	7
	2.3	Option 1: On-site treatment and discharge to watercourse or ground	8
	2.4	Option 2: Off-site treatment at WWTW via new sewer	9
	2.5	Option 3: Off-site disposal to sea outfall	10
	2.6	Option 4: Tankering to off-site disposal facility	11
	2.7	Option 5: Deep wastewater recharge borehole	12
3	**Procedure to Develop a Deep Recharge Borehole**		**14**
	3.1	Typical recharge borehole development process	14
	3.2	Recharge borehole primary considerations	17
	3.3	Recharge borehole secondary considerations	17
4	**Target Aquifer Assessment**		**18**
	4.1	Hydrogeological review of Dove's Nest Site	18
	4.2	Target aquifer considerations	20
	4.3	Recommended target aquifer	21
	4.4	Regional characteristics of the Sherwood Sandstone	21
	4.5	Local characteristics of the Sherwood Sandstone	22
5	**Potential Wastewater Volumes and Quality**		**23**
	5.1	Wastewater volumes during construction	23
	5.2	Wastewater volumes during operation	23
	5.3	Wastewater quality	23
6	**Recharge Borehole and Wastewater Quality Regulation**		**27**
	6.1	Permits and consents	27
	6.2	Relevant EA policy and position statements	27
	6.3	Wastewater discharge quality criteria	28
	6.4	Initial review of hazardous substances in wastewater	32
	6.5	Naturally Occurring Radioactive Material (NORM)	36

7 Sherwood Sandstone Baseline Characterisation 38

8 Recharge Borehole Design 39

8.1 Design standards 39
8.2 Components of a recharge borehole 39
8.3 Hydrogeological conceptual site model and potential environmental impacts 41
8.4 Recharge borehole outline design 43
8.5 Recharge borehole construction 46

9 Conclusions and recommendations 49

9.1 Summary 49
9.2 Saline wastewater disposal options assessment 49
9.3 Wastewater quality and hazardous substances 50

References

Executive Summary

This report provides an assessment of the feasibility and outline design of a deep recharge borehole at the Dove's Nest minehead site. The following conclusions and recommendations summarise the critical points associated with the proposed scheme to dispose of wastewater during the construction phase. Water ingress from the tunnel and associated intermediate sites has not been included in this assessment as all water generated from those activities will be transported and treated at Wilton.

General Conclusions

There is a need to dispose of wastewater generated during construction of York Potash Ltd.'s (YPL's) proposed mine at Dove's Nest, North Yorkshire. The environmental impacts resulting from the discharge of wastewater, some of which will be highly saline, can be significant and options available for disposal are limited. A review of potential options for wastewater disposal at the site has identified a deep recharge borehole (also referred to as a recharge well or injection borehole) as the preferred solution.

This report describes the need for, a proposed outline design of, and the sequence of stages of investigation, feasibility and construction to develop a recharge borehole at Dove's Nest site.

A review of possible target aquifers has concluded that the confined Triassic Sherwood Sandstone (TSS) underlying the site at depth appears to be the best available target for wastewater discharge. Because of its high transmissivity, naturally highly saline water quality and isolation from other aquifers and receptors in the area, injection into the TSS aquifer is considered feasible from a technical, environmental and regulatory perspective. However, additional evaluations are required to better understand the hydraulics and chemistry of the TSS aquifer.

Two options were considered for constructing the recharge borehole. The first was a retrofit of an existing exploratory borehole at Mortar Hall, borehole SM7. This option was rejected, the primary reasons were that the 5 ½" casing through the target aquifer is too small a diameter to meet the requirements of the injection well. Also, the casing through the target aquifer is grouted, meaning the surrounding rock may have fractures that have been cemented and therefore of a very low permeability. Finally, this option would require a 2km pipeline from Dove's Nest to the borehole.

It is therefore considered that construction of a new recharge borehole at Dove's Nest site is the most feasible option. The capacity of this well would be 1000m^3/day to accommodate the "worst case" wastewater generation of 750m^3/day during the construction phase.

Given the depth and remoteness of the proposed recharge zone from environmental receptors, a lack of practical alternatives and the fact that the TSS is not used as a groundwater resource in the area (due to its salinity and inaccessibility), it is believed that the Environment Agency (EA) will not object to a proposal for a deep recharge borehole provided it is designed, constructed and

operated within constraints set by the EA. The key constraints regarding quality noted by the EA are:

- that injected wastewater quality must cause no deterioration in groundwater quality in the TSS and the discharge should not cause there to be any more onerous treatment required to make the Sherwood Sandstone 'suitable for use';
- there should be no discharge of additional hazardous substances other than those naturally occurring in the Sherwood Sandstone.

Because of the unusual nature of the proposal, the EA will likely apply conditions such as a requirement to monitor the water quality within the near surface freshwater aquifers. These requirements should be established at the earliest possible opportunity. Currently, the EA does not have any technical standards and design detail requirements for recharge boreholes. Consequently, discussions with the EA are underway, minutes and actions from these discussions are included within the Appendix to this report.

Drilling and testing any large well in the TSS involves other issues such as the disposal of drilling wastes, the potential for pollution of upper aquifers during drilling and the potential to impact water sensitive features at surface. However these issues are common to any drilling activity and can be effectively managed and mitigated.

Feasibility of injection into Sherwood Sandstone

The TSS aquifer in the vicinity of the Dove's Nest site appears to be a suitable target formation because:

- The aquifer has high porosity, moderate to high hydraulic conductivity, good formation thickness and resulting moderate to high transmissivity. The aquifer properties are favourable for the injection and storage of large quantities of discharge waters.
- The base of the TSS lies on the effectively impermeable Roxby Formation (formerly referred to as Upper Permian Marl) and is capped by the overlying Mercia Mudstone Group, an aquiclude which fully confines it. The geometry of the TSS aquifer is thus favourable for injection.
- The TSS is naturally saline beneath the Dove's Nest site and will also be the source of a significant proportion of the wastewater, thus injected wastewater quality can be treated to be of similar or better quality.

There are some residual uncertainties relating to the feasibility of injection into the TSS which should be investigated further. Given the lack of direct knowledge of the formation in the area, exploratory or pilot scale drilling and testing would be prudent. This testing could potentially be carried out within the existing Mortar Hall borehole (SM7). Key uncertainties include:

- Need to better understand distribution of hydraulic conductivity within the TSS and whether it is dominated by fracture or inter-granular matrix flow;
- With high natural Total Dissolved Solids, there is a need to understand potential chemical interactions between the native water, discharge water and formation rocks.

Proposed construction schedule

The current schedule assumes that the construction of the recharge borehole will occur within a period between month 1 and month 4, and following EA permitting, will be fully operational by month 7. There will be a period where the recharge borehole is not operational at the start of construction of the headframe chambers (between between month 6 and month 7). Wastewater generated during this time would be from the upper "freshwater" (Moor Grit and Scarborough Formation aquifers). Maximum water ingress during this period has been calculated to be approximately 100m^3/day, which would be tankered off site for disposal.

Recommendations

A detailed feasibility study is necessary. It should include consideration of the following issues:

- Hydrogeological conditions and aquifer properties of the TSS;
- Waste effluent volumes and quality (and changes over time);
- Geochemical analysis of TSS groundwater;
- Environmental impact including a detailed Hydrogeological Risk Assessment;
- Infrastructure and treatment needs;
- Outline design, costs and development/testing plan.

1 Introduction

1.1 Background

There is a need to dispose of wastewater generated during shaft sinking, mine construction and, to a lesser extent during operation of the York Potash Ltd. (YPL) proposed mine at Dove's Nest North Yorkshire. A significant proportion of the wastewater generated will comprise groundwater from the Triassic Sherwood Sandstone aquifer which has been identified as hyper-saline beneath the site.

The environmental impacts resulting from the discharge of highly saline wastewater can be significant and options available are limited. Disposal of water with potentially large volumes of high total dissolved solids (TDS) is not acceptable to either local surface water or sewer systems. Treatment technologies such as evaporation exist, however these are complex, result in solid waste generation and have very high operating costs.

This report presents a review of the potential disposal options and key considerations for the preferred option of a recharge borehole into the underlying confined Triassic Sherwood Sandstone aquifer (TSS) at YPL's Dove's Nest minehead site including:

- Environmental and regulatory considerations;
- Hydrogeological review for the potential and feasibility of deep injection;
- Waste volumes and quality generated for deep injection; and,
- Injection well design and construction.

1.2 Objectives

The objectives of this report are:

- To provide a high level assessment to evaluate options for non-domestic wastewater disposal at Dove's Nest mine head site.
- To undertake a preliminary feasibility study for a recharge borehole considering technical, environmental and regulatory issues.

2 Wastewater Disposal Options Appraisal

An integrated water management strategy has been developed to ensure that treatment flows, quantities and routes are compatible with the aim of minimising potable water demand during the construction phase at the Dove's Nest site. The Integrated Water Management Strategy report (REP-P2-WSD-003) provides an assessment of how much of the non-domestic wastewater generated by site activities can be recycled for use on site to minimise water consumption during the construction phase, and identifies that there will be a requirement to dispose of surplus wastewater.

2.1 Source of wastewater

Wastewater collected during development of the mine arises from the following activities:

- Drilling for grouting in advance of excavations for headworks;
- Groundwater ingress into headworks structures;
- Drilling for grouting in advance of excavations in the production service and MTS shafts;
- Drilling for blasting in advance of excavations in the production, service and MTS shafts;
- Groundwater ingress from the highly saline TSS during construction of the production and service shafts middle section;
- Drilling for blasting in the MTS shaft bottom inset TBM launch section;
- Groundwater ingress from mudstone during tunnel construction; and,
- Leachate from temporary storage area for non-hazardous non-inert waste.

The original source of the water determines its chemistry, such as:

- Seepage or drilling returns from shallow aquifers (fresh groundwater);
- Seepage or drilling returns from intermediate level aquifers (acidic and iron rich groundwater);
- Seepage or drilling returns from deep aquifers (saline groundwater); and,
- Recycled water introduced into the mine for construction activities (drilling, grounding, cement mixing and subsequently lost (mixed groundwater types).

The TSS aquifer is by far the thickest and most transmissive aquifer unit intersected. Consequently it will be the largest single source of groundwater during shaft sinking. The groundwater within the TSS beneath the site is known to be hyper-saline and this therefore exerts a strong influence on the treatment and disposal options that can be considered.

2.2 Initial identification of disposal options

Table 1 lists the possible options for the management of saline wastewater generated at the Dove's Nest site i.e. is an unconstrained list that does not consider factors such as cost, practicality, environmental impacts or sustainability. This initial list of options has been reviewed at a high level for major flaws or "showstoppers" in the following sections, before shortlisting the more practical or realistic options that can then be taken forward for further consideration.

Table 1: Overview of management options for saline wastewater

Ref.	Option	Description
1.	On-site treatment	On site wastewater treatment works which discharges treated effluent to either Sneatonthorpe Beck or shallow groundwater and generates a solid waste that can be sold on or disposed of to landfill
2.	Off-site treatment	Gravity or pumped sewer to nearest WwTW (Whitby) for treatment and discharge via existing outfall to sea
3.	Off-site disposal	Dedicated gravity or pumped sewer to new dedicated sea outfall, no treatment required
4.	Tankering	Storage on site and disposal by collection by tankers for off-site disposal at a licenced waste management site or consented sea outfall.
5.	Deep wastewater recharge borehole	On site wastewater recharge borehole to return the saline water back to the deep confined saline aquifers which generated much of the wastewater.

2.3 Option 1: On-site treatment and discharge to watercourse or ground

2.3.1 Assumptions

- An on-site water treatment works could be designed to treat the saline wastewater and discharge the treated effluent to Sneatonthorpe Beck (or possibly to shallow groundwater).
- Given the very high salinity such a works would need to be multistage and include components such as membrane or Reverse Osmosis to create a high quality permeate suitable for disposal to local surface water or groundwater.
- Water quality will need to meet Environment Agency (EA) quality standards for discharge to surface watercourse or local groundwater (which are in close hydraulic continuity and will essentially be treated as having the same characteristics).
- A solid waste composed predominantly of sodium and potassium chloride will be generated. This will need to be stored for later removal off site.

2.3.2 Option benefits

- Contained within the minehead site – giving YPL complete control of process and potential impacts.
- Well understood technologies, easy to regulate and consent.

2.3.3 Option risks

- Treatment by evaporation (ponds or mechanical evaporators) is not considered feasible given the large land requirements and unfavourable climate.
- The potential variations in water quality and quantity over time make design and operation of a reliable treatment plant very complex.

- The highly saline wastewater would require very extensive and expensive treatment, in both capital and operating costs, before the treated water is suitable quality for disposal to local water bodies.
- Power costs are expected to be very high. Carbon costs also likely to be high.
- Although an onsite HiPAF package treatment plant is the preferred option for managing domestic foul sewerage from the Dove's Nest site, because of the high volumes and extreme chemistry it will not be possible to combine the saline wastewater and domestic foul water streams.
- The capacity of local surface water course (Sneatonthorpe Beck) to receive additional discharge is considered to be limited. A flow up to 750m^3/day is the anticipated volume of treated saline water which will be much larger than existing flows and there is a possible risk of deterioration of the water body. As such the discharge may not be permitted by the Environment Agency.
- There will be an on-going requirement to store, and dispose of a solid salt waste.
- This option may need an EIA.

2.3.4 Initial option assessment

Given the uncertainty of design requirements; the projected high costs both in CAPEX and OPEX and potentially significant environmental impacts to local water courses the on-site treatment option does not appear to be realistic or practical. It therefore has not been taken forward for further assessment.

2.4 Option 2: Off-site treatment at WWTW via new sewer

2.4.1 Assumptions

- This option involves collecting and storing saline water at the minehead prior to discharging it via a gravity sewer for treatment and final disposal at an existing wastewater treatment works.
- The most likely option for this would be Whitby WwTW operated by Yorkshire Water which has a sea outfall some 8.2km to the north of the minehead site.
- It should be noted that there is currently no foul sewer in the vicinity of the minehead site, the nearest being located at Sneaton about 2.9km to the north.
- Previous communications with Yorkshire Water (Report REP-P2-FD-001) indicated that there are significant capacity constraints within the local sewer networks, the existing sewerage pumping station at Ruswarp. In addition YW have confirmed that Whitby WwTW is currently operating close to capacity.
- On behalf of YW, Arup completed a process review on Whitby WwTW in February 2014 (Ref: REP/01-12-08). The review showed that the treatment works already suffers from saline ingress at high tide. As the WwTW currently only get saline at high tide it is believed there would be a lot of resistance to receiving an extra water source which has high salt content. The biology has time to recover between tides but that would not be the case for a continual discharge (particularly at times of low flows where the saline discharge would be an additional 50% of the DWF). It is unlikely that the

flows would be sufficiently balanced and the high salinity is likely to have a significant impact on the biology and performance of the WwtW.

2.4.2 Initial option assessment

- Whitby WwTW is fundamentally unsuited to treating significant volumes saline wastewater. The high salinity will have a significant impact on the performance of the current process.
- A complete redesign and rebuilding of the WwTW and associated sewer network and pumping stations would be required to accommodate the high flows of saline water.
- As a result the direct transfer of flows from Dove's Nest Mine to Whitby is not considered a realistic option. This option is not been taken forward for further assessment.

2.5 Option 3: Off-site disposal to sea outfall

2.5.1 Assumptions

- Although the saline wastewater is highly saturated (~4 to 6 times the concentration of natural seawater) the breakdown of the total dissolved solids (TDS) is very similar to the composition of seawater. Chemical impacts on natural seawater are likely to be low and direct disposal to sea is a possibility. It should be noted that such an arrangement already operates at the Cleveland Potash mine at Boulby located about 15km to the northwest.
- A purpose built pipeline and sea outfall structure would be required.
- A dedicated long sea outfall could be located at Whitby (approx. 7.0km to the north), Maw Wyke Hole (approx. 6.0km to the north) or at Robins Hood Bay (approx. 6.5km to the north).
- The pipeline would need to be 150mm to 225mm in diameter and could mainly follow public highways.
- Given the relative elevation of the Dove's Nest minehead site it is assumed that a gravity pipeline would be used to reduce infrastructure requirements, and on-going maintenance and energy costs. However a detailed topographical survey would be needed to confirm whether a gravity option is viable.
- Geotechnical surveys, marine habitat surveys, bathymetric survey and characterisation of environmental sensitivity would be required.

2.5.2 Option benefits

- Seawater may have the capacity to receive and disperse the saline wastes without significant disturbing local ecology; and,
- Robust and simple solution.

2.5.3 Option risks

- The environmental impacts will depend upon the source of the wastewaters, any pre-treatment and the discharge system and need a detailed feasibility study and EIA for full characterisation.
- Complex baseline monitoring would be required; including marine habitat surveys, bathymetric surveys and characterisation of environmental sensitivity.
- Although the route of the pipeline could mainly follow public highways, it would be necessary to cross some private land. This could give rise to access problems during construction, land ownership issues and restricted on-going access for maintenance.
- The pipeline route would be entirely within the national park, and would have an environmental impact particularly during construction.
- High cliffs along this section of the Yorkshire coast restrict the possible location of a new sea outfall to the coastal developments of Whitby, Maw Wyke Hole or at Robins Hood Bay; all of which are very scenic and popular tourist attractions, and very crowded. Construction could be disruptive to local roads and businesses consequently obtaining planning permissions may be difficult.
- Some of the pipeline route would be along roads that would be used to access the Dove's Nest site, introducing potential conflict between off-site construction activities and deliveries during the site preparation phase. This could result in unacceptable impacts on the local highway network and delays to the construction programme.
- Buildability may be an issue; the pipeline and outfall would extend across a number of sites. Multiple interfaces need to be managed including traffic management and existing buried utilities. The construction programme is likely to have unacceptably long timeframe for delivery of a suitable solution.

2.5.4 Initial option assessment

Because of the significant number of uncertainties, programme constraints and potential impacts both to land and sea, the construction of a dedicated sea outfall from the minehead site is not considered to be a realistic option. As a result this option is not been taken forward for further assessment.

2.6 Option 4: Tankering to off-site disposal facility

2.6.1 Assumptions

- The wastewater could be taken to a commercial wastewater treatment facility suitable for reception of the highly saline water.
- This implies an outfall into marine or estuarine water or a large WwTW capable of diluting the saline wastewater sufficiently.
- A specific reception facility has not yet been identified, although it is believed that are several potentially suitable treatment works at Teeside (e.g. Middlesborough, Redcar or Hartlepool).

2.6.2 Option benefits

- Wastes will be managed in a transparent and environmentally appropriate way.
- Likely to be readily available.

2.6.3 Option risks

- The amount of tankering required would be significant during the peak periods and the impact would need to be considered along with other traffic movements generated by the development.
- High financial and carbon cost of road transport.

2.6.4 Initial option assessment

Tankering the waste saline waters off site is considered feasible. However the environmental (road, traffic, noise, dust, carbon) and financial costs of this option could be significant and need to be taken forward for more detailed appraisal.

2.7 Option 5: Deep wastewater recharge borehole

2.7.1 Assumptions

- The bulk of the saline wastewater will be derived from the Sherwood Sandstone aquifer, therefore it would make sense to return the water back to the formation from whence it came.
- A deep recharge borehole will be subject to obtaining an environmental permit from the Environment Agency. Discussions of regulatory aspects are at an early stage (minutes of meetings in the Appendix). The permit will specify achievable conditions for recharge into the deep aquifer.
- Some variation in water quality is acceptable, but there can be no discharge of "priority" hazardous substances. Pre-treatment will therefore be required to remove hazardous substances and also to limit risk of clogging by suspended solids/ precipitates/biofilms.
- The Triassic Sherwood Sandstone (TSS) aquifer is a suitable "target" formation. It has the high effective porosity and permeability and a good formation thickness required for the injection of wastewater. In addition it is naturally highly saline and is fully confined both above and below by thick impermeable marl formations. At a depth of over 700m the Sherwood sandstone aquifer is completely isolated from any near surface environmental feature.

2.7.2 Option benefits

- The possibility of wider environmental impacts are effectively minimized by returning the wastewater to where is first came from;
- Minimal land area required, no additional impact on the National Park or third parties;
- An operationally simple and robust solution; and,

- Is likely to be a viable option in terms of cost (both financial and carbon) and programme.

2.7.3 Option risks

- Subsurface disposal of wastewater is practised worldwide although is not that common in the UK. The regulatory agencies will need to be convinced of the effectiveness of the technology and the risk management measures;
- Target formation is deep and not well understood, additional assessment of the hydraulics and chemistry of the injection process will be required.
- Drilling and testing of a large well involves other issues such as the disposal of drilling wastes, the risk of polluting upper aquifers during drilling and potential to impact water sensitive features at surface. However these issues have been managed successfully by YPL in the past.

2.7.4 Initial option assessment

Although there are some uncertainties associated with deep injection of saline wastewater, the technology is well proven and effective. The TSS target formation is considered suitable, being highly confined but of high transmissivity. Deep injection appears to have some significant advantages over all other options. This option is therefore taken forward for more detailed appraisal.

The following sections of this report outline the feasibility and design of a deep recharge borehole to accept wastewater from the Dove's Nest minehead site.

3 Procedure to Develop a Deep Recharge Borehole

Deep recharge boreholes are technology for disposing of treated or untreated wastewater into geological formations. The prevention of contaminant migration into potable aquifers or reaching sensitive receptors is an essential part of the design process. A typical recharge borehole consists of a series of concentric pipes, which may extend hundreds of metres down from the surface level into non-potable (often highly saline), permeable injection 'target' zones.

3.1 Typical recharge borehole development process

A typical injection well scheme will develop through the following stages and phases. It should be noted that there are several points at which the success of the scheme will need review as illustrated in Figures 1 and 2:

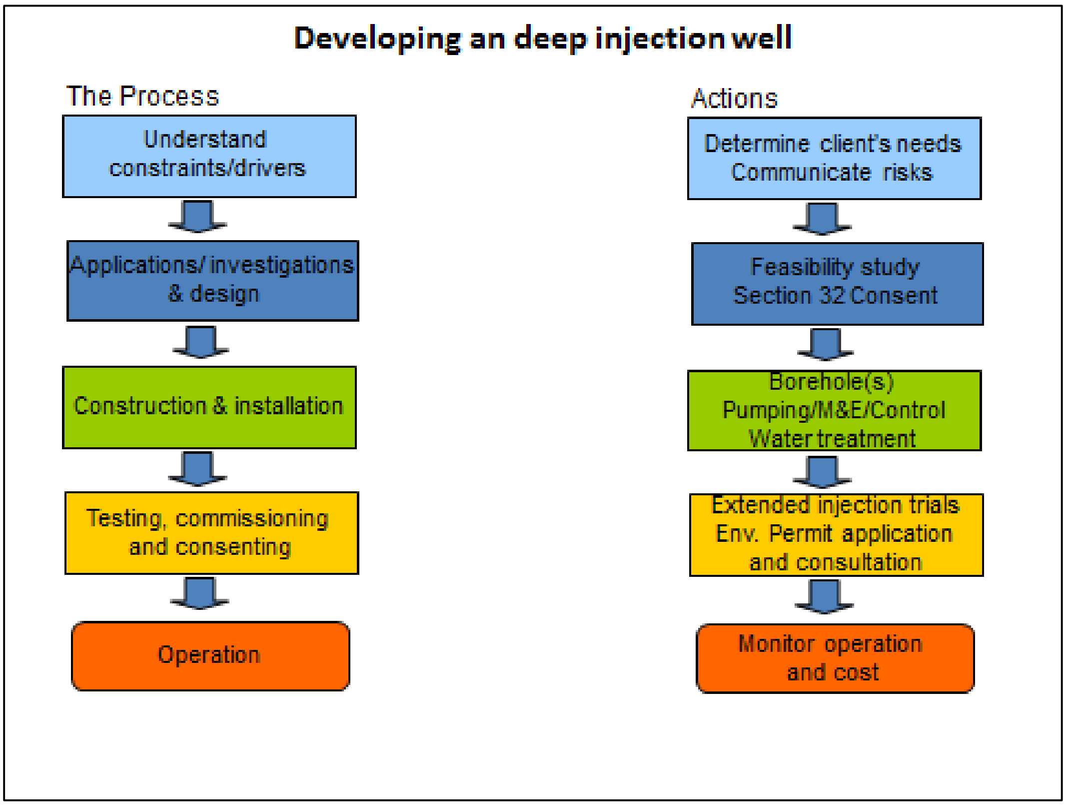
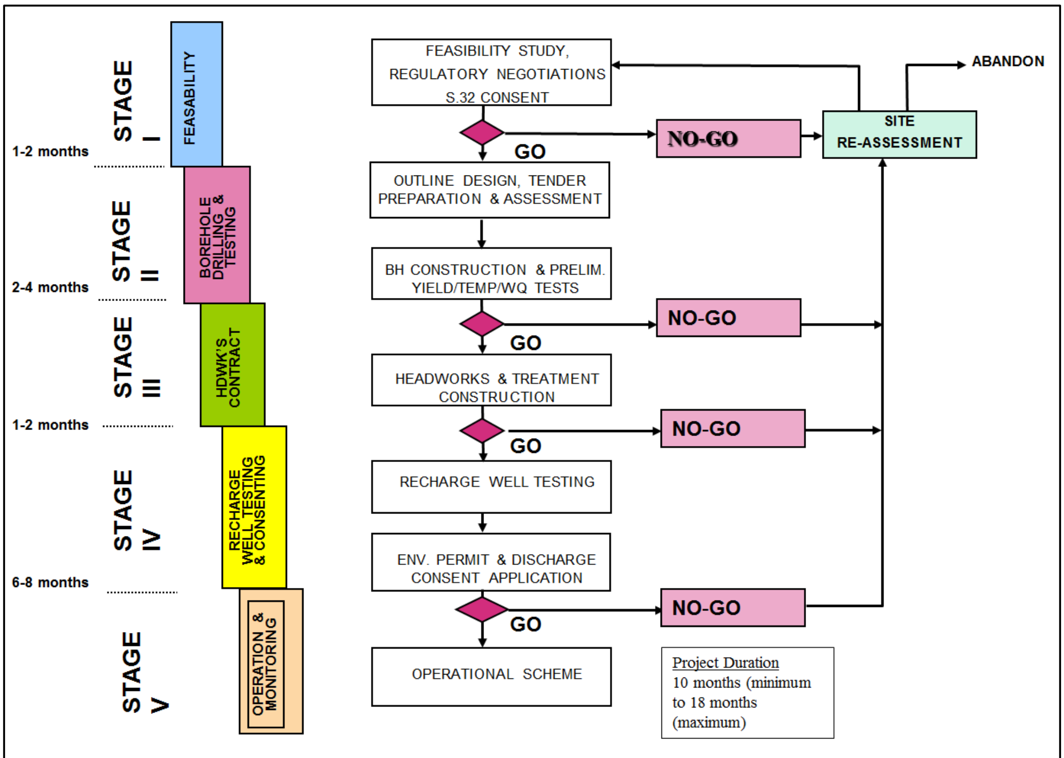


Figure 1: Injection well (recharge borehole) development process



Phased Approach to deep injection well schemes

Figure 2: Phased approach to injection well (recharge borehole) development

3.1.1 Stage 1: Detailed feasibility study

This phase includes all planning, investigation and feasibility activities required to develop a concept design & costs required to drill and test a single recharge borehole and associated monitoring facilities at the minehead site as follows:

- Completion of detailed hydrogeological investigations and additional desk study of available data to confirm design assumptions;
- Preliminary concept design study and report for discussion with regulators and other stake-holders;
- Complete risk assessment and initial cost estimates for YPL;
- Liaison with regulators such as the EA; and,
- Application for S.32 consent to drill and test a borehole.

The duration for this stage would be 4 to 6 weeks.

3.1.2 Stage 2: Final design, regulatory permits & tendering

Stage 2 would include the following:

- Completion of a detailed design;
- Technical specification & tender preparation;

- Completion of environmental investigations including preparation of supporting statement for Section 32 consent application and water features survey (but not full licence application);
- Environmental Impact Assessment (EIA) / Hydrogeological Impact Assessment (HIA) to support planning application;
- Numerical groundwater modelling of long term operational strategy & environmental impacts may be necessary to support design and the HIA;
- Development and testing of a long term monitoring programme;
- Final confirmation of requirements from the EA; and,
- Preparation of detailed designs, plans, specifications and drawings to take forwards to the final tender documents.

This stage will require 3 months to obtain a S.32 consent from the EA. Planning permission for the borehole will be required and it is proposed that the borehole be included in the planning application for the mine.

3.1.3 Stage 3: Recharge borehole drilling and testing

This phase includes all activities required to drill, construct, test and commission a single recharge borehole and then connect it to the deep wastewater disposal system. It is divided into two stages the second of which is dependent upon the successful drilling and testing of the recharge borehole.

Stage 3A:

- Borehole and headworks tender assessment and selection of contractor;
- Site preparation, excavation and land grading as required;
- Drilling recharge borehole; and,
- Testing and analysis of recharge borehole. If successful then proceed with Stage 3B.

The stage 3A duration (including drilling and testing) will take 2 months (presumed to occur during month 1 or month 2 of the programme, following the award of planning permission).

Stage 3B:

If recharge borehole testing is successful, the tender will be let for the headwork contract which will include:

- Construction of transmission facilities: pipeline connection to Wastewater Treatment Works (WwTW);
- Installation of additional observation (monitoring) wells (if required by the EA);
- Installation of control and metering facilities; and,
- Construction headworks buildings and landscaping.

In addition site & asset maintenance will be required (assumed to be performed by the operator).

3.1.4 Stage 4: Testing, commissioning and regulatory permits

If the recharge borehole is successful then the WwTW will need to be commissioned and trials undertaken to test and optimise recharge borehole performance.

Upon successful completion of these activities, it is anticipated that the borehole would be available for use in month 7.

3.2 Recharge borehole primary considerations

Deep well disposal of saline fluids into a confined highly permeable aquifer is considered a relatively safe and reliable technology and is used widely. However, the success of a deep recharge borehole will depend on a number of primary factors:

- Presence of a suitable aquifer for wastewater disposal;
- Quantity and quality of the effluent to be discharged; and
- Willingness of regulators to consent the discharge and to agree to the operation of a recharge borehole.

3.3 Recharge borehole secondary considerations

Other considerations that are important in determining the success of an injection scheme are listed below. However, the success of an injection well scheme is not necessarily dependent on these factors at this stage and can be considered at a later stage of feasibility.

- Risk based management plan;
- Pre-treatment of injectant;
- Availability of land for pre-treatment, temporary storage and the injection well headworks;
- Monitoring and sampling; and,
- Maintenance and contingency plans.

These issues are discussed in the following sections.

4 Target Aquifer Assessment

4.1 Hydrogeological review of Dove's Nest Site

Identifying a suitable aquifer for wastewater disposal is the primary requirement for a deep recharge borehole disposal method. There must be an aquifer present with sufficient hydraulic conductivity to accept the required injection volume and there must be adequate containment to prevent unacceptable environmental impacts, such as a confining unit above the injection aquifer to prevent upward movement of water into freshwater aquifers.

Hydrogeological deep injection is most effective in confined aquifers with moderate to high effective porosity and high transmissivity. A transmissivity of about $100m^2/d$ is probably the minimum transmissivity required for effective injection.

There are a number of aquifer units beneath the Dove's Nest minehead site. Table 2 summarizes the aquifer properties from both the January 2014, FWS Factual Geotechnical Report for the Shafts at the Dove's Nest Minehead, North Yorkshire (FWS-b, 2014), and the FWS, 2013, The baseline geology and hydrogeology of the Dove's nest site, North Yorkshire (FWS-a, 2013) and updated with the FWS, 2014, Hydrogeological Baseline Report of the Dove's Nest Site, North Yorkshire (FWS-d, 2014).

Table 2**:** Summary of aquifers present beneath the Dove's Nest site.

Aquifer Units		Approximate top Elevation (mOD)	Average Thickness (m)	Inferred Groundwater Surface (mAOD)	Water Quality	Design Permeability (m/s)	Approximate Bulk Transmissivity (m2/day)
Moor Grit Formation		204	9	variable between 196 - 202	Fresh	7.2x10-6 (bulk matrix sandstone)	6
Scarborough Formation		185	9	185 to 187	Fresh	2.9x10-5	57
Cloughton Formation		180	31	180 to 191	Fresh	3.7x10-5	99
Saltwick Formation		147	50	140 to 150	Fresh	1.4x10-6	7
Cleveland Ironstone		30	22	No significant groundwater anticipated	Acidic, Sulphatic Fe rich	Estimates unavailable, considered to be impermeable by FWS	
Staithes Sandstones		5	50	No significant groundwater anticipated	Acidic, Sulphatic Fe rich	Estimates unavailable, considered to be impermeable by FWS	
Sherwood Sandstone Formation (TSS)	Upper Bunter	-604	97	Potentiometric surface at approximately -40	Saline/Brine	7.3x10-5	612
	Middle Shale		38.6				243
	Middle Bunter		104.8				661
Brotherton Formation		-1160	48	No data available	Saline/Brine	1.2x10-6 to 2.2x10-11	5 to 9x10-5
Source: FWS (2013/2014)							

Notes.

Transmissivity (T) is a measure of the rate which groundwater flows horizontally through an aquifer. Transmissivity is calculated as the product of the horizontal hydraulic conductivity (m/day) and aquifer thickness (m) and is defined in units of m^2/day.

Lowest values taken from FWS report design permeability to calculate "worst case" transmissivity and permeability.

4.2 Target aquifer considerations

Table 3 describes the suitability of each aquifer unit described in Section 4.1 in terms of potential for injection of saline wastewater from the Dove's Nest mine shaft.

Table 3: Possible target aquifers beneath the Dove's Nest site

Aquifer Units	Potential for target aquifer	Discussion
Moor Grit Formation	No	The uppermost Moor Grit and Scarborough Formations are not acceptable aquifers because they are unconfined and in close hydraulic continuity with local surface water features such as springs and private water supplies.
Scarborough	No	The uppermost Moor Grit and Scarborough Formations are not acceptable aquifers because they are unconfined and in close hydraulic continuity with local surface water features such as springs and private water supplies.
Cloughton Formation	No	The uppermost Jurassic aquifers are all fairly shallow and contain fresh or moderately good quality water of fairly recent origin. The Environment Agency would consider the injection of saline water into these aquifers as a deterioration of their natural status and would be very unlikely to permit such activities.
Saltwick Formation	No	The uppermost Jurassic aquifers are all fairly shallow and contain fresh or moderately good quality water of fairly recent origin. The Environment Agency would consider the injection of saline water into these aquifers as a deterioration of their natural status and would be very unlikely to permit such activities.
Cleveland Ironstone	No	The uppermost Jurassic aquifers are all fairly shallow and contain fresh or moderately good quality water of fairly recent origin. The Environment Agency would consider the injection of saline water into these aquifers as a deterioration of their natural status and would be very unlikely to permit such activities.
Staithes Sandstones	No	The uppermost Jurassic aquifers are all fairly shallow and contain fresh or moderately good quality water of fairly recent origin. The Environment Agency would consider the injection of saline water into these aquifers as a deterioration of their natural status and would be very unlikely to permit such activities.
Sherwood Sandstone Formation (TSS)	Yes	The deeper Triassic Sherwood Sandstone is highly confined and isolated from the surface. The unit is thought to be naturally saline and both could make an effective target aquifer. The favourable hydraulic conductivity of the TSS means that low pressure injection techniques can be used. The high transmissivity and porosity means that the formation is capable of receiving and storing large volumes of injected wastewater. The TSS aquifer is divided into three units; the Upper Bunter Sandstone, Middle Shale and the Middle Bunter Sandstone.
Brotherton Formation	No	The deeper Permian Brotherton Limestone is highly confined and isolated from the surface. The unit is thought to be naturally saline and could make an effective target aquifer. The formation occurs at a depth of about 1200m to 1400m at the minehead, at least 600m deeper than the Sherwood Sandstone, and has much lower T and smaller storage potential than the TSS and is therefore not considered further.

4.3 Recommended target aquifer

Only the Cloughton and Sherwood Sandstone aquifers stand out as being sufficiently transmissive to be suitable for injection. The transmissivity values provided in Table 3 for the TSS[1] indicate that the TSS is the largest and most permeable aquifer of all the aquifers present beneath the site.

Based on the characterisation work compiled by FWS, the recommended target aquifer beneath the Dove's Nest site is the Sherwood Sandstone which occurs at a depth 814m below ground level with an approximate total thickness of 240m (FWS-b, 2014 and FWS-d, 2014).

4.4 Regional characteristics of the Sherwood Sandstone

The Triassic Sherwood Sandstone Group is a thick sequence of red sandstones and marls laid down in continental desert conditions as fluvial and lake marginal deposits, sandwiched between the underlying marine Roxby Formation (Upper Permian Marls) and the overlying lacustrine Mercia Mudstones. The TSS forms a regionally important aquifer in the shallower outcrop area to the west of the site where it typically consists of reddish medium to fine grained sandstones (Malvia, R.G. &Missimer, T. 2012). The deposit becomes progressively softer, muddier and less porous northwards and loses some of its ability to hold and yield water (Malvia, R.G. &Missimer, T. 2012). Across Yorkshire, the sandstone unit generally ranges between 200 to 400m (BGS, 1997) with an approximate total thickness of 240m in the minehead area as reported in the FWS Factual Geotechnical Report (FWS-b, 2014).

Additional information about the TSS in the area is available in the BGS aquifer properties manual, their regional memoir and from their investigations into the geothermal energy potential in the Lincolnshire deep basin dating back to the 1980's (BGS, 1997, BGS, 1980, and Downing R.A. & Gray D.A. 1996). In summary:

- In Yorkshire and Northumbria there is apparently less water circulation with depth (as indicated by poor quality water at depth); this may suggest a general decrease in fracture frequency with depth;
- The absence of sedimentary compaction and relatively high porosity of the sandstones suggest that while they were initially cemented, much of the primary cementation has subsequently been dissolved. A variety of cements are now found, for example Anhydrite ($CaSO_4$) is found deep in north-east England at Cleethorpes.
- Groundwater in the confined part of the aquifer is generally much older and has a more evolved chemistry. The presence of evaporates such as gypsum and anhydrite alters the chemistry of any water recharging through the overlying Mercia Mudstone Group and contributes to the salinity of the confined aquifer.

[1] The TSS design permeability of $7.3x10^{-5}$ m/s is based on the lowest result from Modular Formation Dynamics Tester (MDT) measurements at borehole SM-11 (SRK, 2013).

4.5 Local characteristics of the Sherwood Sandstone

The Hydrogeological Baseline Report (FWS-d, 2014) and Factual Geotechnical Report (FWS-b, 2014), collate much of the information available about the TSS beneath the minehead site and included a summary of logging and testing data from two deep exploration boreholes. In summary:

- The TSS is described as comprising many individual sandstone members, separated by impermeable mudstone beds, with a porosity of between 20 and 25%, and a hydraulic conductivity range of 1.1×10^{-4} to 7.3×10^{-5} m/s (based on site-specific measurements made as part of geophysical investigations of borehole SM11 from 609.4mBOD to 863mBOD;
- Observations at Newton House Plantation (BH SM6) showed a potentiometric surface for the TSS aquifer of approximately -40mOD (about 560m above the top of the TSS) which indicates that the aquifer is confined with high hydrostatic pressure;
- Water samples collected from the formation had high TDS with up to 16% NaCl and 4% sulphate, a pH range of 6.4 to 6.6 and a temperature range of 33°C to 34.4°C; and,
- Major saline inflows were encountered at the Boulby Mine between 762 and 730mbgl, which was believed to be a result of open joints. It was noted that elsewhere joints are usually filled with anhydrite or gypsum and are tight. Analysis of the inflows gave TDS concentrations between 202,000 mg/l and 209,000mg/l (20.2 & 20.9% respectively), mainly chloride and sulphate.

5 Potential Wastewater Volumes and Quality

5.1 Wastewater volumes during construction

Estimates of the quantity of non-domestic wastewater expected to be generated by mining activities have been made using information provided in a wide range of sources, as summarised in Dove's Nest Non-Domestic Wastewater Management Strategy (Report Ref: REP-P2-NDWW-001). Figure 3 below, extracted from that report, show that a maximum groundwater flow of approximately 750m^3/day could be expected. It should be noted that these figures are conservative "worst case" estimates, which include inflows into the MTS tunnel from the section between Dove's Nest site to Lady Cross Plantation intermediate shaft which could, theoretically be tankered to Dove's Nest, although this does not form YPL's proposal.

A conservative design maximum of 1000m^3/day has been adopted. Wastewater that will be injected into the TSS would be from activities at the Dove's Nest site only and not from the MTS and associated intermediate shafts.

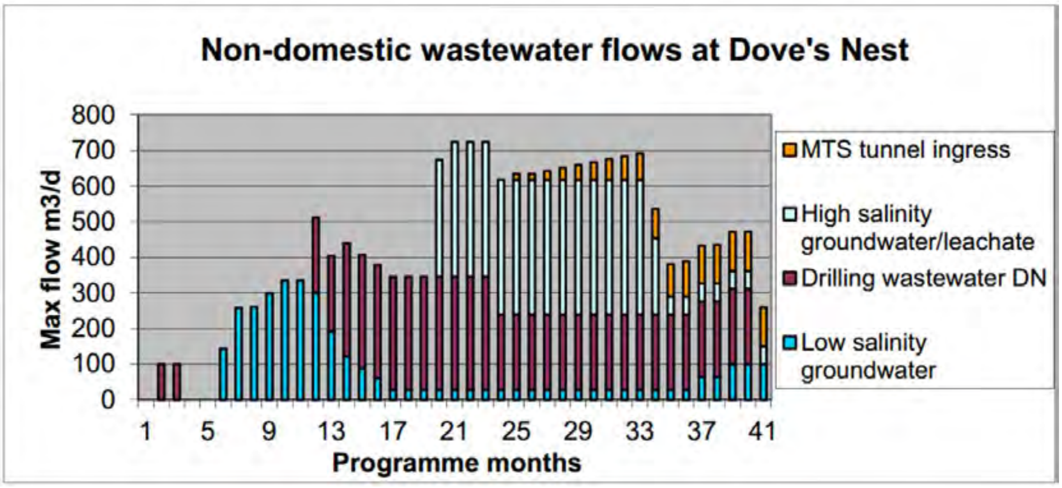


Figure 3: Assumed sources and estimated volumes of non-domestic wastewater

5.2 Wastewater volumes during operation

Water ingress during long-term operation is expected to be much less than during the construction phase. The treatment facility and recharge well would still be on-site, and being designed for the volume of water expected during the construction phase would have the capacity to accept the volumes encountered during long-term operation, if necessary. However, this is not YPL's proposal, and it is intended that non-domestic wastewater arising during operation will be conveyed via a pipeline within the MTS tunnel to Wilton.

5.3 Wastewater quality

The wastewater that is proposed to be recharged will be derived from groundwater from a mix of the following sources produced by the construction works:

- Several shallow fresh water aquifers - the Ravenscar group aquifers (e.g. Moor Grit, Scarborough, Cloughton & Saltwick Fms);

- Intermediate level groundwater – acidic and ferruginous groundwater principally from Cleveland & Staithes Fm;
- Deep saline groundwater – Sherwood Sandstone & possibly Permian Brotherton Formation.

The main groundwater bearing units are illustrated in Figure 4.

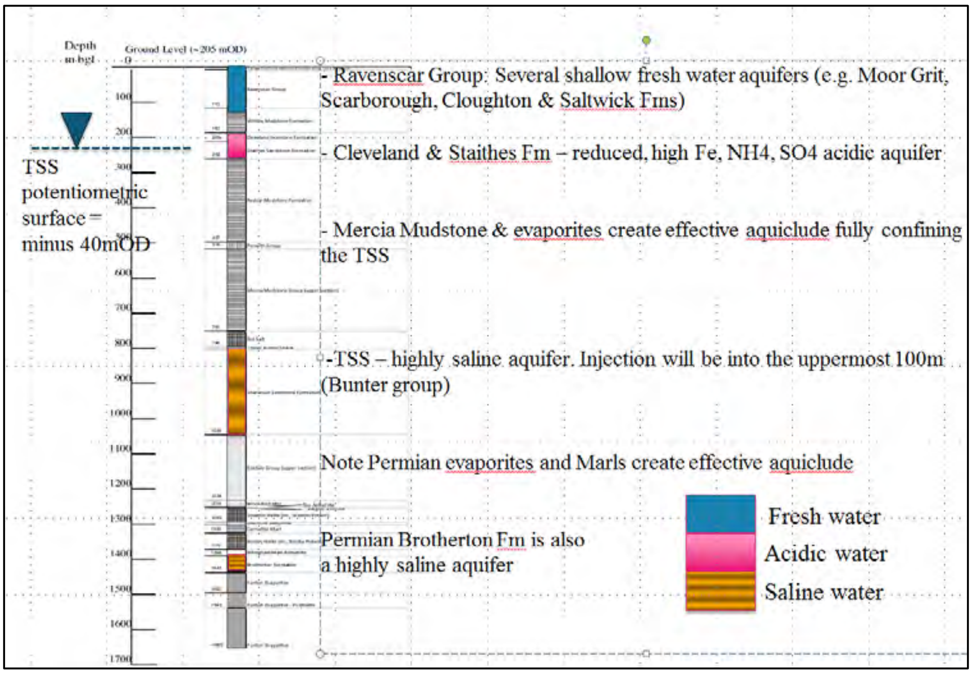


Figure 4: Summary of main groundwater-bearing units

The lower permeability units (e.g Mercia Mudstone, Whitby, Penarth Group) between the permeable units identified above may also contribute to the wastewater. Although the volume of wastewater generated by these aquiclude units is likely to be relatively low, the quality of the discharge may be significant due to the possible presence of naturally occurring hydrocarbons (see discussion of 'hazardous substances').

In addition to sources of natural groundwater there is also potential for water entering the construction works to be contaminated by anthropogenic additives such as drilling mud, construction materials and plant fuels/lubricants, although these anthropogenic sources are likely to be very small in volume compared to that released by groundwater bearing formations such as Sherwood Sandstone. The composition of non-natural components of wastewater is uncertain at this stage although they may include hazardous substances (e.g. mineral oil).

The quality of groundwater likely to arise during construction and dewatering of below ground structures at the Dove's Nest site has been described (FWS-c, 2014) as follows:

> *'The chemistry for groundwater from the Ravenscar Group (Moor Grit, Scarborough Formation, Cloughton Formation and Saltwick Formation) is described generically as "Freshwater".*
>
> *The chemistry for groundwater derived from the Sherwood Sandstone (the target aquifer) is based on two chemical analyses of water collected by Schlumberger from borehole SM14 (the North Shaft) at depths of*

836.5mBGL (-633.4mOD) and 100.3mBGL (-792.2mOD). Historical references note layering of the Sherwood Sandstone aquifer, with total NaCl saturation within the lowest sections of the sandstone. Schlumberger samples had temperatures of between 33 and 34.4 °C. Groundwater at this temperature, when it reaches the surface, will become supersaturated in salts, leading to their precipitation in the water treatment lagoon/settling pond leaving a solid residue for disposal. We have assumed any groundwater from the [underlying] *Brotherton Formation will be of a similar chemical composition as the Sherwood Sandstone groundwater.*

We have assumed that groundwater derived from pyritic units (the Whitby Mudstone, Cleveland Ironstone, and parts of the Redcar Mudstone) will have a lower (more acidic) pH, contain higher levels of iron and potentially be more sulphatic.

We have assumed any groundwater derived from the Penarth Group (Rheatic) will be acidic (due to the presence of pyrite) and may also contain (natural) hydrocarbons.

We have assumed the groundwater derived from the Mercia Mudstone Group will be saline and contain elevated levels of sulphate and chloride (from dissolution of anhydrite, gypsum and halite), becoming progressively more enriched in sulphates/halides with depth especially in the vicinity of the Rot Salt.'

Water quality data has been reviewed in some detail in the Non-Domestic Wastewater Management Strategy (Arup, 2014 Ref: REP-P2-NDWW-01) which reports:

A number of water quality issues have been examined in detail and the key points include:

- **Iron:** The presence of significant quantities of ferric ions would require treatment such as pH correction and precipitation to reduce to acceptable values.
- **Hardness:** Hard water occurs in some strata but is unlikely to lead to precipitates in cold water.
- **Salinity:** Water from Sherwood Sandstone has shown concentrations about 6 times higher than seawater. High salinity is unacceptable in surface water and many re-use situations, and can be very costly to remove both in capital and operational costs. About 2% dilution with low salinity water is required to prevent precipitation and operational problems
- **Ammonia:** The highest ammonia levels reported in the shallow groundwater are well above what would be acceptable in surface water although average values are within norm. Additional treatment would be required if further sampling confirms this to be a risk.
- **Nitrate:** The use of explosives can lead to contamination of drilling water with nitrate. Conditions of discharge to surface water are likely to include maximum nitrate concentration. If treatment is required, this would involve complex and expensive ion exchange giving rise to an aqueous concentrate for disposal. However, good construction practice can minimise such contamination and no specific treatment is proposed.

- **Oil:** Estimates of a maximum 10 litres per 100m^3 relating to oil leakage from machinery have been made by YPL. YPL has also advised that drilling additives will not be used. On this basis the estimates of potential oil contamination appear to be high and may require more sophisticated removal than skimming alone. This will require further investigation.

The regulatory criteria that the wastewater must achieve prior to recharge are discussed in detail in the following section, including consideration of 'hazardous substances' (as defined by the Water Framework Directive/Groundwater Daughter Directive) and NORM (naturally occurring radioactive material).

6 Recharge Borehole and Wastewater Quality Regulation

6.1 Permits and consents

A deep recharge borehole would require the approval of the Environment Agency through a number of consents and permits.

Under Section 32 of the Water Resources Act consent would be required to drill and test pump the well. Obtaining this consent requires a 'water features survey' to be completed by the applicant comprising a desk study and walkover to identify any water features that may be appropriate to monitor during the test pumping.

An abstraction licence would not be required for operation of the recharge borehole as there is no intention to abstract groundwater.

Discussions with the Environment Agency (EA) have commenced to establish the regulatory requirements affiliated with construction and operation of a deep recharge borehole at the Dove's Nest site. Minutes and actions from these meetings are included within the Appendix to this report.

The Environment Agency has indicated the wastewater disposal via a recharge borehole would be regulated as a 'groundwater activity' under Schedule 22 of the Environmental Permitting Regulations. A 'radioactive substances' environmental permit may also be required, depending on the presence of naturally occurring radioactive material (NORM) in wastewater. NORM is discussed further in section 6.5.

6.2 Relevant EA policy and position statements

The following statements are taken from the EA Groundwater Protection: Principles and Practice (GP3) document (EA, August 2013 Version 1.1):

G1 – Direct inputs into groundwater

"We will only agree to the direct input of non-hazardous pollutants into groundwater if all of the following apply:"

- It will not result in pollution of groundwater;
- There are clear and overriding reasons why the discharge cannot reasonably be made indirect; and,
- There is adequate evidence to show that the increased pollution risk from direct inputs will be mitigated.

G9 – Use of deep infiltration systems for surface water and effluent disposal

"We will only agree to the use of deep pit based systems (including boreholes or other structures that bypass the soil layers) for surface water or effluent disposal if the developer can show that all of the following apply:

- There are no other feasible disposal options such as shallow infiltration systems (for surface water) or drainage fields/mounds (for effluents) that can be operated in accordance with current British Standards;

- The system is no deeper than is required to obtain sufficient soakage;
- Pollution control measures are in place;
- Risk assessment demonstrates that no unacceptable discharge to groundwater will take place, in particular that inputs of hazardous substances to groundwater will be prevented; and,
- There are sufficient mitigating factors or measures to compensate for the increased risk arising from the use of deep structures."

6.3 Wastewater discharge quality criteria

6.3.1 Groundwater Daughter Directive, Water Framework Directive and Environmental Permitting Regulations 2010

Historically, the European Groundwater Directive (80/68/EC)[2] has ensured protection of groundwater and specifically prevented the entry of defined List I substances and prevented pollution by List II substances. This directive has been replaced by the Water Framework Directive (2000/60/EC)[3] (referred to as WFD) and the Groundwater Daughter Directive (2006/118/EC) (referred to as GWDD).

The GWDD, implemented in England and Wales by the Environmental Permitting (England & Wales) Regulations 2010[4] (EPR), is similar in its requirements to the original Groundwater Directive in that the entry of 'hazardous substances' into groundwater should be prevented and the entry of 'non-hazardous pollutants' should be limited to prevent pollution or significant or sustained upward trends in pollutant concentrations in groundwater. 'Hazardous substance' and 'non-hazardous pollutant' are defined in the Water Framework Directive and Groundwater Daughter Directive and discussed further in the document Environmental Permitting Guidance: Groundwater Activities[5] (and summarised below).

The EPR also replace those parts of the Water Resources Act 1991 that relate to the regulation of discharges to controlled waters (including groundwater). Under the EPR, a 'groundwater activity' refers to inputs of pollutants to groundwater.

Naturally occurring formation fluids are also potentially contaminating and their entry into groundwater as a consequence of anthropogenic activity is also subject to these requirements.

---

[2] European Parliament and Council, 1980. European Council Directive of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances (80/68/EEC) (OJ L 20, 26.1.1980, p. 43)
[3] European Parliament and Council, 2000. Water Framework Directive. Ref. 2000/60/EC. 72pp.
[4] Environmental Protection (England and Wales), 2010. The Environmental Permitting (England and Wales) Regulations (2010). Ref. SI 675. 211pp.
[5] Department for Environment, Food and Rural Affairs (Defra), 2010. Environmental Permitting: Environmental Permitting Guidance for Groundwater Activities. For the Environmental Permitting (England and Wales) Regulations 2010. Defra, London, UK. 43pp.

6.3.2 Definition of 'Groundwater'

'Groundwater' is defined in European and domestic legislation as 'all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil'.

DEFRA/EA consider groundwater to be present in all geological formations except where permeability is very low 'for example, in very low permeability strata such as clays, evaporites and dense crystalline rocks it may not be possible to define a zone of saturation because the water is bound to the rock or is relatively immobile[5]. The definition of groundwater is not dependent on quality or the potential for future use as a resource or interaction with surface water.

Therefore 'groundwater' in accordance with the legal definition is present in the Sherwood Sandstone beneath the site and in other permeable units (e.g. Cleveland and Staithes Formation), as well as fresh water groundwater units in the Ravenscar Formation.

6.3.3 Hazardous substances and non-hazardous pollutants

As noted above, the WFD/GWDD, and the EPR, require entry of hazardous substances to groundwater to be prevented and entry of non-hazardous pollutants to be limited.

A hazardous substance is defined in Schedule 22 paragraph 4(1) of EPR 2010 as 'any substance or group of substances that are toxic, persistent and liable to bio-accumulate. This includes in particular the following when they are toxic, persistent and liable to bio-accumulate:

- organohalogen compounds and substances which may form such compounds in the aquatic environment;
- organophosphorous compounds;
- organotin compounds;
- substances and preparations, or the breakdown products of such, which have been proved to possess carcinogenic or mutagenic properties or properties which may affect steroidogenic, thyroid, reproduction or other endocrine-related functions in or via the aquatic environment;
- persistent hydrocarbons, and persistent and bioaccumulable organic toxic substances;
- cyanides;
- metals (in particular, cadmium and mercury) and their compounds;
- arsenic and its compounds;
- biocides and plant protection products.'[4]

The UK is required under the GWDD to publish a list of substances it considers hazardous and this list is determined by the Joint Agencies Groundwater Directive Advisory Group (JAGDAG) of which the EA is a member. Based on preliminary determination by JAGDAG, all former List 1 substances are hazardous substances (http://www.wfduk.org/substance-classifications-and-public-consultation-results). This includes cadmium, benzene, toluene, ethylbenzene and xylenes and many polycyclic aromatic hydrocarbons (PAHs).

The list of hazardous substances is still being developed as JAGDAG or others apply the defined methodology to substances to determine their classification. In

2012 JAGDAG assessed a further 20 substances in accordance with the methodology and proposed lead, antimony, nickel, chromium VI, selenium, arsenic, boron and a number of other substances as hazardous to groundwater (http://www.wfduk.org/substance-classifications-and-public-consultation-results).

All substances liable to cause pollution that are not considered hazardous are deemed non-hazardous pollutants. The non-hazardous list of pollutants does not simply replace the old List II but is wider. For example, nitrate is now classed as a non-hazardous pollutant whereas before it was not included in either List I or List II.

6.3.4 Direct and indirect input

Schedule 22 of EPR also makes the distinction between direct and indirect inputs to groundwater. 'Direct input' into groundwater is defined as 'the introduction of a pollutant to groundwater without percolation through soil or subsoil'. The proposed wastewater injection is therefore a 'direct input'.

Direct input of hazardous substances to groundwater is not permitted by regulation unless it satisfies certain specific criteria (see exclusions section below).

Direct input of non-hazardous pollutants into groundwater is only acceptable if all of the following apply:

- it will not result in pollution of groundwater;
- there are clear and overriding reasons why the discharge cannot reasonably be made indirect;
- there is adequate evidence to show that the increased pollution risk from direct inputs will be mitigated [6].

6.3.5 Exclusions and exceptions

If hazardous substances are present in the proposed wastewater injection a number of regulatory options may be available in principle, but would require justification and regulators agreement, namely 'permanently unsuitable for use', 'discernibility' and 'de minimis':

- Permanently unsuitable for use - Schedule 22 paragraphs 8(a) and 8(c) of EPR 2010 note that provided it does not compromise the objectives set out in Article 4 of the Water Framework Directive, the EA may grant a permit for the injection of water containing hazardous substances from mining activities – but only where the strata have been determined as permanently unsuitable. EPR 2010 states that the geological formation must for natural reasons be permanently unsuitable for other purposes and the EA GP3 document[6] identifies the requirements to demonstrate the groundwater meets the 'definition of permanently unsuitable'. While the Sherwood Sandstone at depth beneath the site appears a strong candidate for such status the EA has

[6] Environment Agency (EA), 2013. Groundwater protection: Principles and practice (GP3). August 2013 Version 1.1. EA, Bristol, UK

not previously designated any groundwater permanently unsuitable (that we are aware of).

- Discernibility - The definition of 'prevent' relating to input of hazardous substances is linked to discernibility[5]. Input of hazardous substances is considered by the regulators to have been prevented if there is no discernible concentration in the discharge and there are no discernible concentrations of hazardous substances attributable to the discharge in the groundwater immediately down-gradient of the discharge zone. The EA takes the view that a substance would be discernible if its concentration at a defined point exceeds:
    - the natural background quality of the groundwater, or
    - a minimum reporting value (MRV), usually the limit of quantification or other value prescribed by legislation; (whichever has the highest concentration.) 5
- De minimis - Under EPR 2010 there are certain exclusions whereby a discharge or activity is not classed as a groundwater activity and therefore an environmental permit is not required. Schedule 22 paragraph 3(3), may be relevant to the proposed wastewater injection, and excludes an input of a pollutant into groundwater 'of a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater.' This is commonly referred to as the 'de minimis' exclusion. This exclusion has previously been applied to recirculation back into the same strata of water abstracted at natural background quality and unaltered, but may not be accepted by the EA where injection is into a different geological formation.

6.3.6 EA approach to assessment criteria

At a meeting with the EA on 16 July 2014 the regulatory approach to hazardous substances was discussed. The EA had previously indicated (email J Senior to A Irving dated 8 July 2014) that an environmental permit application could be made under Schedule 22 Part 8(a) of the EPR. Part 8(a) states the regulator may grant a permit for:

(a) the injection of water containing substances resulting from the operations for exploration and extraction of hydrocarbons or mining activities, and injection of water for technical reasons, into geological formations from which hydrocarbons or other substances have been extracted or into geological formations which for natural reasons are permanently unsuitable for other purposes, provided that the injection does not contain substances other than those resulting from the above operations,

The EA indicated they would not define the receiving groundwater as 'permanently unsuitable for use' and a permit could be granted if it met the following criteria:

- No deterioration in quality in the receiving groundwater (i.e. injected water must contain lower concentrations of hazardous substances than naturally present in Sherwood Sandstone) and the discharge should not cause there to be any more onerous treatment required to make the Sherwood Sandstone groundwater 'suitable for use';
- No discharge of additional hazardous substances other than those naturally occurring in the Sherwood Sandstone (i.e. no hazardous substances from mine

operations, drilling fluids, or naturally occurring hydrocarbons not already present in Sherwood Sandstone groundwater).

To meet these criteria further characterisation of hazardous substances naturally occurring in Sherwood Sandstone groundwater will be required. Data is available for metals but not hydrocarbons. This will only be available when the injection well is drilled, although supporting evidence from other wells (such as onshore hydrocarbon wells) may also be available.

6.4 Initial review of hazardous substances in wastewater

This section provides an initial review of available groundwater quality data to assess the possible hazardous substances present and inform the scope of further data gathering.

6.4.1 Shallow groundwater (Ravenscar Group)

FWS Hydrogeological Baseline Report (reference FWSC1433MineOR15A/June 2014) includes laboratory analysis of groundwater from twenty site boreholes into the Ravenscar Group. These boreholes have enabled sampling and analysis of approximately 250 samples of groundwater from the Moor Grit, Scarborough, Cloughton, and Saltwick Formations.

This data has been reviewed to identify any hazardous substances, summarised below.

Table 4: Summary of hazardous substances analyses of Ravenscar Group groundwater

Substance	UK DWS	Units	Comments
Arsenic	10	ug/l	1 sample exceeded drinking water standard, 11ug/l reported for HG4 (Cloughton Formation) on one occasion. All other samples typically <1ug/l.
Cadmium	5	ug/l	All samples below drinking water standard, typically <0.5ug/l. Max 0.76ug/l in BH3A (Scarborough Formation)
Hexavalent Chromium		ug/l	All samples below detection limit of 10ug/l.
Lead	25	ug/l	All samples below drinking water standard, typically <0.5ug/l. Max 11ug/l in BH3A (Scarborough Formation)
Mercury	1	ug/l	All samples below drinking water standard, typically <0.01ug/l. Max 0.25ug/l in HG7 (Cloughton Formation)
Selenium	10	ug/l	Not analysed
Antimony	5	ug/l	Not analysed
Boron	1000	ug/l	All samples below drinking water standard, typically <20ug/l. Max 540ug/l in HG3 (Moor Grit)
Petroleum hydrocarbons (TPHCWG banding and ali/aro split)		ug/l	Nearly all samples below detection limit (0.01ug/l TPH). 17 samples (out of 250) show results greater than detection limit. Max 50ug/l in HG10 (Cloughton Formation) but below detection in subsequent samples. No boreholes show

Substance	UK DWS	Unit s	Comments
			consistently elevated results and conclude no significant results relevant to this initial review of hazardous substances.
Polycyclic Aromatic Hydrocarbons, PAH (16 speciated plus total)		ug/l	Nearly all samples below detection limit (0.2ug/l total PAH). 11 samples (out of 250) show results greater than detection limit. Max 6.2ug/l in HG6A (Cloughton Formation) but below detection in subsequent samples. No boreholes show consistently elevated results and conclude no significant results relevant to this initial review of hazardous substances.
Benzene, Toluene, Ethylbenzene and Xylenes, BTEX (speciated)		ug/l	Nearly all samples below detection limit (1ug/l). 7 samples (out of 250) show results greater than detection limit for benzene (all on same sample round, Max 21ug/l in HG5A (Cloughton Formation)) and no detections in subsequent samples. No boreholes show consistently elevated results and conclude no significant results relevant to this initial review of hazardous substances.

Note: Source of data FWS Hydrogeological Baseline Report (reference FWSC1433MineOR15A/June 2014) NS = not scheduled, DWS = UK drinking water standard

The hazardous substances arsenic, cadmium, lead, mercury, boron and certain hydrocarbons are present above detection limits, however only one analysis (out of 250) indicated a (marginal) exceedance of the drinking water standard.

Therefore the review of available shallow groundwater data does not indicate the presence of hazardous substances relevant to this assessment.

6.4.2 Intermediate groundwater (Cleveland Ironstone, Staithes Sandstone, Redcar Mudstone)

Available groundwater quality data collected during the on-going ground investigation for the mineral transport tunnel has been reviewed. Five analyses have been provided and the results for identified hazardous substances are summarised in Table 5. It should be noted that these boreholes are remote from the Dove's Nest site.

Table 5: Summary of hazardous substances analyses from ground investigation (April/May 2014)

Borehole			**BH01**	**BH01**	**BH02**	**BH02**	**BH04**
Formation			**Redcar Mudstone**	**Redcar Mudstone**	**Cleveland Ironstone**	**Staithes Sandstone**	**Redcar Mudstone**
Sampling Date			**09/05/14**	**09/05/14**	**30/04/14**	**30/04/14**	**22/05/14**
Sampling Method			**Standpipe**	**Standpipe**	**Grab**	**Grab**	**Grab**
Test	**UK DWS**	**Unit**					
Metals (dissolved)							
Arsenic	10	ug/l	8.4	2.1	**87**	**84**	1.2
Cadmium	5	ug/l	0.04	< 0.03	< 0.03	< 0.03	< 0.03
Hexavalent Chromium		ug/l	< 10	< 10	< 10	< 10	< 10
Lead	25	ug/l	0.16	0.37	< 0.09	0.11	0.40
Mercury	1	ug/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Selenium	10	ug/l	2.4	0.92	NS	NS	< 0.25
Antimony	5	ug/l	NS	NS	NS	NS	NS
Boron	1000	ug/l	NS	NS	NS	NS	NS
Petroleum Hydrocarbons							
C5-C10 Gasoline Range Organics (GRO)		ug/l	**320**	**260**	NS	NS	**3.1**
EPH (C10-C40)		ug/l	**31**	**58**	NS	NS	**240**
Benzene		ug/l	NS	NS	< 1.0	< 1.0	NS
Toluene		ug/l	NS	NS	< 1.0	< 1.0	NS
Ethylbenzene		ug/l	NS	NS	< 1.0	< 1.0	NS
Xylene		ug/l	NS	NS	< 1.0	< 1.0	NS
PAHs		ug/l	NS	NS	All below detection	All below detection	NS
VOCs		ug/l	All below detection	All below detection	NS	NS	All below detection

Note: Source of data Arup tabular update of water quality results 16/6/2014. NS = not scheduled, DWS = UK drinking water standard

This data suggests the hazardous substances arsenic, cadmium, lead, selenium and certain hydrocarbons are present above detection limits. Only arsenic exceeds the drinking water standard and only in samples from Cleveland Ironstone and Staithes Sandstone.

The C5-C10 GRO detections in BH01 (Redcar Mudstone) should be investigated further as this suggests either possible naturally occurring hydrocarbons or groundwater contamination from an anthropogenic source.

6.4.3 Deep groundwater (Sherwood Sandstone, Brotherton Formation)

The Sherwood Sandstone is expected to be the main source of wastewater produced by inflow during shaft construction and therefore the potential for hazardous substances to be present in the wastewater must be considered.

Available data relating to groundwater in the Sherwood Sandstone at the site has been reviewed and the occurrence of hazardous substances summarised in Table 6, taken from FWS report (reference FWSC1433MineOR15A/June 2014) 'Chemical sampling of the Sherwood Sandstone by SRK'.

Table 6: Summary of hazardous substances analyses from Sherwood Sandstone samples

		Borehole/sample ref	**SM11/ serial no 387**	**SM11/ serial no 108**
		Formation	**Sherwood Sandstone (633.4mBOD)**	**Sherwood Sandstone (797.2mBOD)**
		Sampling Date	06/02/2013	06/02/2013
Test	**UK DWS**	**Units**		
Arsenic, Dissolved	10	ug/l	NS	**52.1**
Cadmium, Dissolved	5	ug/l	**1580**	**194.1**
Hexavalent Chromium		ug/l	NS	NS
Lead, Dissolved	25	ug/l	**24**	**77**
Mercury, Dissolved	1	ug/l	<0.1	<0.1
Selenium, Dissolved	10	ug/l	NS	**80.3**
Boron	1000	ug/l	NS	NS
Antimony	5	ug/l	NS	NS

Note: Source of data FWS Hydrogeological Baseline Report (reference FWSC1433MineOR15A/June 2014) NS = not scheduled, DWS = UK drinking water standard

This data indicates that arsenic, cadmium, lead and selenium are present in Sherwood Sandstone groundwater at concentrations exceeding drinking water standards. Concentrations are significantly higher than observed in shallow groundwater.

The hazardous substances boron and antimony may be present in deep groundwater, however these parameters have not been analysed. Similarly no hydrocarbon data is available, although naturally occurring hydrocarbons may be present in the Sherwood Sandstone.

No analyses of groundwater samples from the Brotherton Formation at the site are available. Considering the hydrogeological setting, it is reasonable to assume groundwater in the Brotherton Formation will be highly saline and contain similarly elevated hazardous substances to the Sherwood Sandstone.

6.4.4 Summary of hazardous substances identified

- The Sherwood Sandstone, the proposed injection zone, contains naturally occurring hazardous substances (arsenic, cadmium, lead and selenium) at concentrations greatly exceeding drinking water standard.
- Intermediate groundwater (Cleveland Ironstone and Staithes Sandstone and Redcar Mudstone) contains lower concentrations of the same hazardous substances.
- Shallow groundwater contains no significant hazardous substances.

Therefore the concentration of hazardous substances (metals) in the injected wastewater is likely to be lower than background concentrations in the receiving groundwater.

The possible presence of naturally occurring hydrocarbons in wastewater needs further assessment. PAHs and BTEX are 'hazardous substances' that could be present in groundwater from Redcar Mudstone, Penarth Group, Whitby and Brotherton Formations that may not be present in Sherwood Sandstone.

6.5 Naturally Occurring Radioactive Material (NORM)

Shale deposits, and other rocks, such as granite, naturally contain low levels of radioactivity as a result of the mineralogy of their formation. Naturally Occurring Radioactive Materials (NORM) is the term used to describe materials which naturally contain radioactive isotopes and where human activities may increase exposure to these materials. The EA noted assessment of the possible presence of NORM in wastewater would be required at the EA meeting on 12 June 2014 and followed this up with more detailed discussion on 16 July 2014.

The ways in which NORM could enter the wastewater stream are:

- Incorporation of mineral particulates from NORM-containing rock within the wastewater e.g. fines from drilling; and
- Groundwater containing dissolved radioisotopes (from rock).

The oil and gas industry routinely manages occupational health risks associated with NORM during drilling and production, and is regulated by the HSE. The recently published NORM Waste Strategy Consultation (DECC, 2014) reports 12,000,000m^3 of liquid NORM waste is generated and safely managed by the UK onshore oil and gas industry each year, mainly be re-injection into the hydrocarbon reservoir.

It is understood no analyses of NORM content of groundwater or rock samples at Dove's Nest has been undertaken.

If wastewater contained NORM at levels that exceed 1 Becquerel per litre (>1Bq/l) it could be defined as radioactive waste in accordance the Environmental Permitting Regulations 2010 (as amended) (DEFRA, 2010) and a radioactive substances permit may be required. However potash mining is not a specified NORM-listed activity (under the EPR 2010), unlike onshore hydrocarbons, however it may fall under a 'catch-all' category and a response is currently awaited from the EA regarding whether a permit would be required if >1Bq/l is encountered.

If a radioactive substances environmental permit is required it can be applied for in parallel or after the groundwater activity permit, so long as it is in place before injection commences. The EA indicated a radioactive substances permit for injection of wastewater has recently been issued for an onshore hydrocarbon production site near Pickering. The EA agreed to provide a copy of the permit application for information.

The EA also noted that the potential for pipework scale exceeding radioactive waste solids threshold should be considered in the wastewater treatment design.

7 Sherwood Sandstone Baseline Characterisation

The Sherwood Sandstone has been identified as the preferred injection zone or 'target aquifer' and the EA indicated the injection should cause no deterioration in quality, as discussed above. Therefore characterisation of Sherwood Sandstone groundwater quality is required to define the baseline, considering also non-hazardous pollutants (as well as hazardous substances discussed above).

Regarding Sherwood Sandstone groundwater quality the FWS report states:

Based on published information, the groundwater encountered during the sinking of the shaft at Boulby Mine indicated Total Dissolved Solid (TDS) concentrations of between 202,000 and 209,000 mg/l, composed predominantly of chloride (118,000 to 121,000 mg/l) and sulphate (3,100 to 4,770 mg/l, with much lower levels of bicarbonate (101 to 153 mg/l) (Ref. 41).

Based on site-specific measurements made by FWSC during drilling of SM6 (Ref. 36), the groundwater in the Sherwood Sandstone was found to have the following concentration ranges: Calcium 880 to 1800 mg/l; Iron 22 to 210 mg/l; Magnesium 250 to 630 mg/l; Manganese 290 to 630 mg/l; Potassium 11,000 to 18,000 mg/l; Sodium 65,000 to 110,000 mg/l; Chloride 130,000 to 180,000 mg/l, Sulphate 3,000 to 5,600 mg/l; Total Dissolved Solids 210,000 to 320,000 mg/l; Electrical Conductivity 176 to 260 mS/cm. These data are given in Appendix 9.

Site specific measurements were made on two groundwater samples by Schlumberger on exploration borehole SM11 (Ref. 21). The formation waters sampled had a pH range of 6.4 to 6.6, low levels of trace metals, 16% Na, 3,440 to 4,030 mg/l sulphate, 0.2 to 0.3% potassium, 1,450 to 1,630 mg/l calcium, alkalinity (as $CaCO_3$) ranging from 74.9 to 88.8 mg/l and 6.1 to 13.7 mg/l total iron.

Note that the SM6 analysis is unreliable due to the influence of drilling fluids. However the FWS data summarised above is sufficient to confirm groundwater in the Sherwood Sandstone is highly saline.

Available data suggests the Sherwood Sandstone is highly saline and poorer quality than groundwater from shallow and intermediate groundwater-bearing units. As noted in Sections 6.4.3 and 6.4.4 The Sherwood Sandstone, the proposed injection zone, contains naturally occurring hazardous substances (arsenic, cadmium, lead and selenium) at concentrations greatly exceeding drinking water standard, an exceeding the concentrations that will be present in the wastewater derived from the other aquifer units.

This supports the justification that no deterioration will be caused by the injection of wastewater, although it is noted that the data available on deep water quality is limited.

8 Recharge Borehole Design

8.1 Design standards

The UK has no commonly accepted standards or guidelines for the design of recharge boreholes. It is, therefore, necessary to look elsewhere, for example to the United States, where deep wastewater injection is widely used.

The United States Environmental Protection Agency (USEPA) has defined six classes of recharge boreholes for different settings. Class I wells are used for the injection of municipal and industrial wastes beneath underground sources of drinking water, are the most technologically sophisticated, and considered to provide the highest level of protective measures. Class II wells are used for the injection of fluids associated with oil and gas production, excluding hydraulic fracturing and Class III wells are used for the injection of fluids used in mineral solution mining beneath underground sources of drinking water and can be of simpler construction.

Table 7: US EPA recharge borehole classification

Class	Use
Class I	Inject hazardous wastes, industrial non-hazardous liquids, or municipal wastewater beneath the lowermost United States Drinking Water standard (USDW).
Class II	Inject brines and other fluids associated with oil and gas production, and hydrocarbons for storage.
Class III	Inject fluids associated with solution mining of minerals below lowermost USDW.
Class IV	Inject hazardous or radioactive wastes into or above USDWs. These wells are banned unless authorized under a federal or state groundwater remediation project.
Class V	All injection wells included in Classes I-IV. In general, Class V wells inject non-hazardous fluids into or above USDW's and are typically shallow, on-site disposal systems. However, there are some deep Class V wells that inject below USDW's.
Class VI	Inject Carbon Dioxide (CO2) for long term storage, also known as Geologic Sequestration of CO2.

Evaluation as to the class of well required to meet regulatory consent will be determined during detailed design, however it is expected that Class II or Class III would be appropriate.

8.2 Components of a recharge borehole

Recharge boreholes consist of a drilled hole and one or more concentric lengths (strings) of pipe, called casing or tubing depending upon its diameter. Construction methods are adapted from oilfield technology. Because the recharge borehole will pass through freshwater aquifers ensuring well integrity to prevent potential contamination of these aquifers is essential.

8.2.1 Surface or conductor casing

The surface or conductor casing is the first casing installed in the well and extends below the base of any underground sources of drinking water. It is cemented back to the surface to prevent cross contamination. The purpose of the conductor casing is to stabilise the top of the borehole, to seal off the shallower aquifers, and to avoid aquifer contamination with surface water. More than one string of conductor casing may be required.

Cementing is the introduction, usually from the bottom up, of cement. The cement protects the casing from corrosion and seals the well annulus (between casing and formation or between inner and outer casing strings). Good quality cementing is essential to ensure well integrity.

8.2.2 Long-string or injection casing

Directly inside the surface casing is a long-string casing that extends to and sometimes into the injection zone. This casing is cemented all the way back to the surface in order to seal off the injected waste from the formations above the injection zone back to the surface. The casing provides a seal between the wastes in the injection zone and the upper formations.

Based on the US EPA underground injection control UIC guidance (there are no comparable regulations or guidance in the UK) the maximum down-hole velocity of the injected fluid should be less than 3.0m/s. Using an assumed injection rate of 1000m^3/day, an internal casing diameter of 150mm will result in an acceptable down-hole velocity of 0.7m/s.

8.2.3 Injection zone

The wastewater flows through the injection tubing inside the long string casing either through perforations in the long-string or in the open hole below the bottom of the long string.

If the degree of cementation of the TSS injection zone is poor then the injection zone may need to be supported by a well-screen and gravel pack, the size of gravel pack and well screen will be determined during detailed design. The need for a screen and gravel pack would result in an increase to the overall drilled diameter of the hole.

Given the uncertainty in the geology and hydraulics of the injection zone, it is assumed that the injection zone will extend the whole length of the Upper Bunter Sandstone within the TSS, an approximate thickness of 100m, as identified in the FWS Factual Geotechnical Report (FWS-b, 2014).

8.2.4 Tubing and packer

Tubing is the smallest diameter pipe in the well. It is installed inside the long string casing and carries the wastewater from the surface to the injection zone. It is usually constructed from corrosion resistant steel or fibreglass reinforced plastic (FRP).

In some instances, the space between the long string casing and the injection tube is filled with an inert, pressurized fluid, and is sealed at the bottom by a removable packer to prevent injected wastewater from backing up into the annulus. A wellhead seals the gap between the tubing and the long-string casing to the top of the tubing. The need for a fluid filled annular space (between tubing and casing) will be evaluated during detailed design.

8.3 Hydrogeological conceptual site model and potential environmental impacts

Figure 5 overleaf shows the conceptual model for the recharge borehole at the Dove's Nest site relative to the anticipated stratigraphy. The conceptual understanding of the site is inferred from "Hydrogeological Baseline Report of the Dove's Nest Site, North Yorkshire" (FWS-d, 2014). Figure 5 shows that the geology at the Dove's Nest site is adequate to support an injection well. The target TSS aquifer is fully confined with around 500 metres separating the top of the TSS from the bottom of the deepest freshwater aquifer (the Saltwick Formation) and 144 metres separating the top of the TSS potentiometric surface from the bottom of the Saltwick Formation. Therefore there is no hydraulic connection between the TSS and shallow aquifer units.

Near-surface groundwater-bearing units in the vicinity of the site are known to be in continuity with watercourses and springs within the North Yorkshire Moors National Park, therefore it is important to ensure no contamination will occur as a result of the recharge borehole.

Table 7 summarises the EA classification for the near surface, good quality groundwater units.

Table 7: EA aquifer classification

Aquifer	EA aquifer classification
Moor Grit Member	Secondary A
Scarborough Formation	Secondary A
Cloughton Formation	Secondary A
Saltwick Formation	Secondary A

A Secondary A aquifer is defined by the EA as:

"Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers."

The design of the recharge borehole will need to demonstrate well integrity through multiple barriers, such as cemented casing to protect potential groundwater receptors.

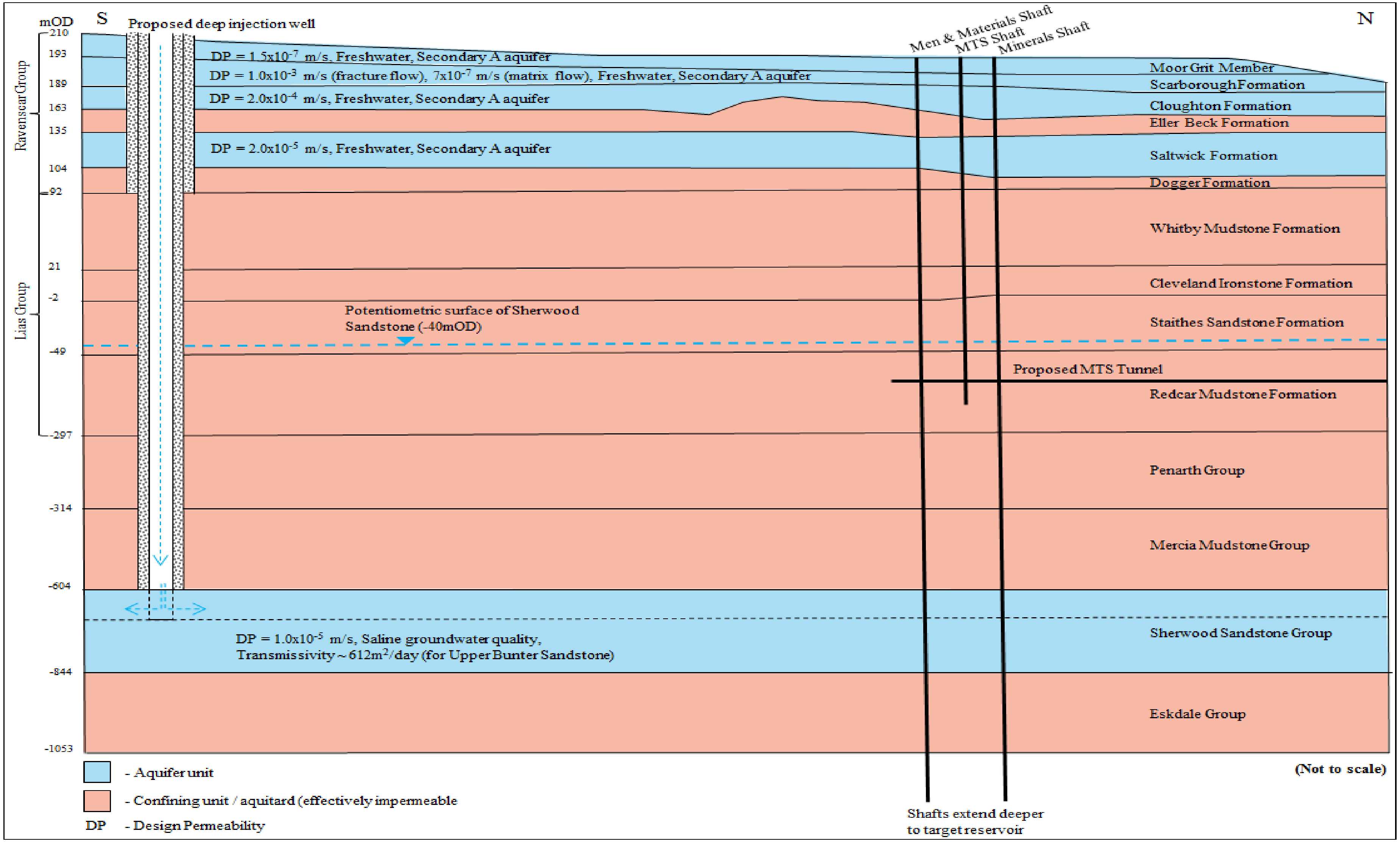


Figure 5: Hydrogeological conceptual model of a recharge borehole at Dove's Nest site

8.4 Recharge borehole outline design

Two options have been considered for provision of a recharge borehole:

- A new recharge borehole within the site
- Retrofit the current Mortar Hall borehole (SM7) (YPL, 2012) which is approximately 2km from the Dove's Nest site.

These options are considered within this section.

It is assumed for both options, that prior to deep injection wastewater treatment will be required to achieve regulatory requirements (no deterioration of Sherwood Sandstone groundwater quality) and technical criteria for borehole performance (low particulates, precipitation considerations). Particulate matter will need to be removed to a low level by settlement, followed by filtration, so as not to block the recharge infiltration zone. The treatment for hydrocarbons, both naturally occurring and plant leakages, will need consideration, (Arup, 2014a).

It should be noted that the EA may specify that additional monitoring wells should be constructed in freshwater aquifers above the injection zone to assure that groundwater quality does not deteriorate.

8.4.1 Proposed construction schedule

The current schedule assumes that the construction of the recharge borehole would occur within a period between month 1 and month 4, and following EA consent, be brought into full operation in month 7, before wastewater generation becomes significant.

Thus there will be a period where the recharge well is not operation at the start of construction of the headframe chambers and ventilation shafts (month 6 and month 7). Wastewater generated during this time would be from the upper "freshwater" (Moor Grit and Scarborough aquifers). From Figure 3, water ingress is not expected to exceed 100m^3/day during this period. It is assumed that during this time water will be tankered off site.

Currently, the recharge borehole is assumed to only be functional during the construction phase (5 years) and mothballed after 5 years. Should it be brought back into use, the deep recharge borehole would require maintenance at least every 5 years.

8.4.2 Recharge borehole option 1: Retrofit of Mortar Hall Borehole (SM7)

The Mortar Hall borehole (SM7) was drilled as an exploratory hole for the shafts at Dove's Nest and completed on 18 August 2012. This borehole was drilled to a depth of 1607.9m with the following sequence of casing installed as detailed in the YPL SM7, Mortar Hall Well Completion Report (YPL, 2012):

- 18 5/8" steel conductor pipe: to a depth of 4.6mbgl (Devensian glacial till drift)
- 10 3/4" steel casing: to a depth of 123.67mbgl (base of Ravenscar Group and Dogger Formation)

- 7 5/8" steel casing: to a depth of 624.02mbgl (base of Mercia Mudstone Group)
- 5 ½" steel casing: 1205.7mbgl (base of Eskdale Group)
- From 1205.7mbgl to the base of the borehole is open hole/coring.

Testing conducted in this borehole included:

- Gyro
- HNGS (Spectral Gamma Ray Log)
- SSLT (Sonic Log – Compressional and Shear DT)
- Ultrasonic Borehole Image Log (1210-1530 meters below rotary table (mbRT))
- Nuclear (Density, Porosity, Natural Gamma Ray Log)
- 1 dry and 1 wet cutting samples were recovered every 5m during drilling and coring operations
- Continuous gas monitoring.

The well is fully cased and cemented through the freshwater aquifers of the Ravenscar Group ensuring the protection of these aquifers. Also, the casing through the target aquifer is grouted, meaning the surrounding rock may have fractures that have been cemented and therefore of a very low permeability.

The borehole was left in a state of temporary suspension. The uncased bottom section of the borehole was cemented up to 998mbRT (approx. 50m within the 5 ½" casing string and the approximate base of the Sherwood Sandstone), before a final cement cap was pumped to seal the top of the well, the base of the top cement plug was set at approximately 198mbRT (approximate base of the Staithes Sandstone) (Barrie, 2014).

In order to make this borehole suitable for recharge of wastewater the following primary actions would be required:

- Drilling through the upper cement cap
- Perforation of the 5 ½" steel casing through the Sherwood Sandstone
- Review and reinterpretation of construction and testing reports
- Construction of a transport system for wastewater from Dove's Nest to the injection well (approximately 2km distance).

There are a number of factors associated with the existing borehole that are considered to render it unsuitable for use as a recharge borehole for the development:

- The casing through the target aquifer is grouted, meaning the surrounding rock may have fractures that have been cemented and therefore of a very low permeability which would compromise the effectiveness of the borehole.
- The 5 ½" casing through the target aquifer is too small a diameter to meet the requirements of the recharge borehole.

Rehabilitation of the existing borehole has therefore been discounted.

8.4.3 Recharge borehole option 2: New recharge borehole at Dove's Nest

Table 8 provides a preliminary overview of recharge borehole components. The details of well construction will be developed during the detailed design phase. Table 8: Recharge borehole design parameters

Table 8: Recharge borehole design parameters

Component	Approximate Elevation (mOD)	Size – diameter (mm)	Comments
Surface casing	Ground surface to 92	≥450	To below base of the lowest freshwater aquifer – the base of the Ravenscar Group
Injection casing	92 to -604	250 – 350	150mm if open hole, ≥200mm if screen & formation stabiliser required
Open hole injection zone	-604 to -701	250	Through Upper Bunter Sandstone unit
Injection tubing	-604	6 5/8" nominal diameter	May need downhole flow control valve

Choice of materials for the linings will depend upon the required asset life.

If an extended asset life is required (beyond 5 years), the recharge borehole should be lined with either stainless steel or fibreglass reinforced plastic (FRP).

Because the potentiometric surface of TSS aquifer is approximately 250mbgl, wastewater cascading down the tubing may cause operational problems (such as precipitation, air entrapment & encrustation). Thus a down-hole flow control valve will be required.

8.4.4 Minimum requirements for deep recharge borehole design

Figure 6 shows the proposed preliminary schematic for a deep recharge borehole for wastewater disposal at the Dove's Nest site. This is intended to give indicative construction details. Final details will be dependent upon regulatory consent criteria, further investigation, and detailed design.

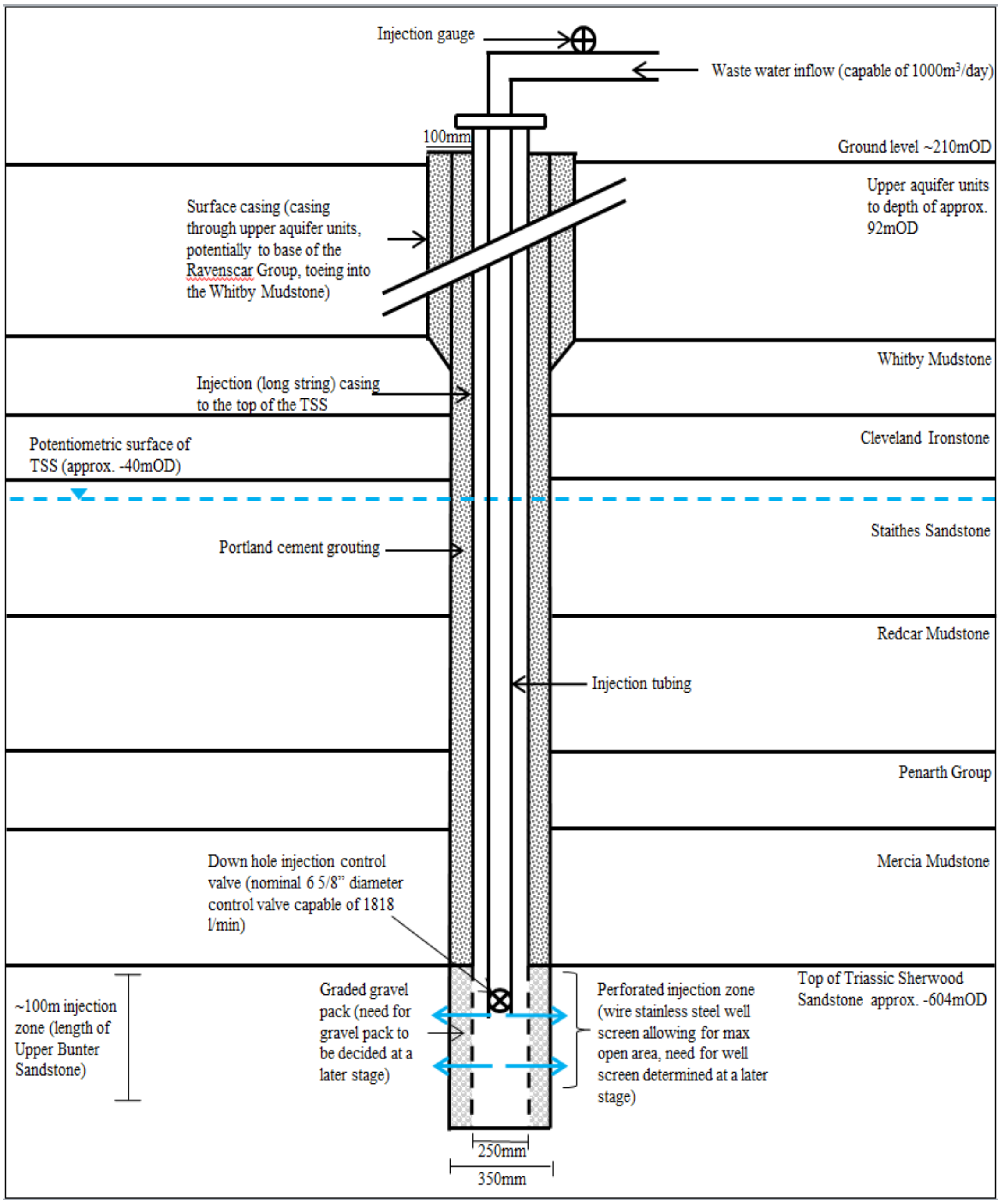


Figure 6: Schematic drawing of deep saline injection well at Dove's Nest site

8.5 Recharge borehole construction

8.5.1 Drilling

Deep recharge boreholes are generally constructed by the same rotary drilling methods used for onshore oil and gas exploration wells. Prior to drilling, access to the well site is established by construction of an access road including adequate area around the well site is developed to accommodate the drilling rig and associated equipment. Also, during preparation of the site for well construction, provision of a water supply for displacement fluids during drilling and cementing is generally necessary. During rotary drilling, the hole is kept full of fluid as the drilling progresses. Pumps maintain circulation of drilling fluid down the inside of the drill pipe, through the bit, and up the outside of the drill pipe to the surface.

8.5.2 Aquifer protection

While drilling through freshwater aquifers, operators should take precautions to assure that no contaminants are introduced into these zones. Under certain conditions, operators may wish to use air in place of drilling fluids to drill in shallow depths to reduce the likelihood of contaminating freshwater aquifers. As much as technically practicable and feasible, the hole should be drilled under laminar flow conditions, with appropriate fluid loss control, and minimising hole washouts. Further prevention of contamination will occur by ensuring surface casing and cementing of casing across any freshwater aquifers. The casing will be keyed into the Whitby Mudstone to effectively case off shallow freshwater aquifers.

8.5.3 Drilling fluid/mud selection

In some cases, air may be used near surface in place of drilling fluids to avoid contamination of freshwater aquifers. Due to the depth of this well and expected high pressure heads (such as in the Sherwood Sandstone) it is likely that appropriately weighted drilling mud will be required. While drilling, it is important to have a great enough mud weight to balance the expected pressure head in the hole. It is likely that a bentonite or polymer based mud will be used during drilling.

8.5.4 Cement volume

The volume of cement pumped must be "of a volume equivalent to at least 120% of the volume calculated necessary to fill the annular space between the hole and casing and between casing strings to the surface of the ground." (Texas Commission on Environmental Quality, 1995). The following provides a preliminary estimate of cement volume required:

- Total diameter of hole = 350mm
- Approximate length of long string casing below surface casing = 696m
- Internal volume of long string casing = $(0.125\text{m})^2 \times \pi \times 696\text{m} = 34.16\text{m}^3$
- Total diameter of hole including surface casing = 450mm
- Approximate length of surface casing = 118m
- Volume of a column = $\text{radius}^2 \times \pi \times \text{Length}$
- Estimated volume of cement for injection well = $(0.175\text{m}^2 \times \pi \times 696\text{m}) + (0.225\text{m}^2 \times \pi \times 118\text{m}) - 34.16\text{m}^3 = 51.57\text{m}^3 \times 120\%$ = **62m^3 of cement**

8.5.5 Water supply requirements

An adequate volume of water will need to be maintained on site during well construction. Uses of water include well drilling and flushing, adequate supply for mixing of the cement. It is assumed that 24 hour drilling will take place with approximately 30m of drilling progress per day. The maximum diameter of the hole is 450mm. In addition, 2 times the well volume has been assumed to account for water required during casing installation. Thus the estimated daily volume of water required on site is:

- Volume of water = $(0.225m^2 \times \pi \times 30m) \times 2$ = **$4.8m^3$/day (4771 l/day)**

This value assumes that water will be fully recirculated during construction. It should also be assumed that disposal of this volume of water will need to be accounted for and will need to be transported off site in tankers. There is significant uncertainty associated with these assumptions and a greater daily water supply may be required. Advice from contractors will be requested.

9 Conclusions and recommendations

9.1 Summary

This report considers five options for disposal of wastewater derived principally from groundwater during construction of the mine facilities at the Dove's Nest site. Disposal of wastewater via a recharge borehole has been identified at the preferred approach.

The potential suitability of geological units beneath the site as the target disposal aquifer have been considered and the Sherwood Sandstone, a deep saline groundwater unit beneath the site, has been identified as the most suitable.

Two options for recharge borehole have been considered. Firstly use of an existing deep borehole at Mortar Hall 2km from the Dove's Nest site, and secondly construction of a new deep recharge borehole at the Dove's Nest site. Of these, construction of a new borehole is the preferred option.

The EA are the lead regulator relating to recharge borehole construction and operation. A groundwater activity Environmental Permit will be required and a radioactive substances Environmental Permit may be necessary depending on the wastewater quality. A Water Resources Act Section 32 consent to drill and test pump the well will also be required. On-going dialogue with the EA will be necessary as the scheme develops.

9.2 Saline wastewater disposal options assessment

Five options for management of saline to manage saline wastewater have been assessed.

The options for on-site treatment and disposal to surface water, sewer transfer to existing off-site treatment works or for direct off-site disposal to a sea outfall all have fundamental constraints or risks. It is therefore recommended that these options are not considered further.

Two options appear feasible: a deep recharge borehole at the Dove's Nest site and tankering off-site to a suitable treatment facility.

The bulk of the saline wastewater will be derived from the Sherwood Sandstone. Deep disposal via an 800m deep recharge borehole back to the Sherwood Sandstone is considered to be the most practical, viable and sustainable method of wastewater management and is therefore recommended as the preferred option. It is considered that the potential wider environmental impacts can be effectively minimized by returning the wastewater back to the same formation.

There remain some technical and regulatory risks associated with the deep recharge well option, and an alternative "Plan B" is required in case the recharge borehole cannot be realised. The most suitable alternative option appears to be tankering to an off-site treatment and disposal facility. It is therefore recommended that the wider impacts associated with tankering the wastewater to a suitable treatment facility should also be assessed.

Additional feasibility study of both options is required and further development of technical design. Whole life costs (expressed as Net Present Costs) and evaluation of sustainability (using EA carbon calculator) may be required to fully establish which of these two solutions is optimal.

9.3 Wastewater quality and hazardous substances

Given the depth and remoteness of the proposed recharge zone from environmental receptors, a lack of practical alternatives and the fact that the TSS is not used as a groundwater resource in the area (due to its salinity and inaccessibility), it is believed that the Environment Agency (EA) will not object to a proposal for a deep recharge borehole provided it is designed, constructed and operated within constraints set by the EA in a 'groundwater activity' environmental permit. However several key constraints regarding quality have been noted by the EA as follows:

- that injected wastewater quality must cause no deterioration in groundwater quality in the TSS and the discharge should not cause there to be any more onerous treatment required to make the Sherwood Sandstone groundwater 'suitable for use';
- there should be no discharge of additional 'hazardous substances' (as defined by the Water Framework Directive/Groundwater Daughter Directive) other than those naturally occurring in the Sherwood Sandstone.

An assessment of the possible presence of hazardous substances in the wastewater identified the following:

- Hazardous substances (arsenic, cadmium, lead, selenium) are present in groundwater in the Sherwood Sandstone and in lower concentrations in intermediate groundwater (Redcar Mudstone, Cleveland Ironstone, Staithes Sandstone).
- Naturally occurring hydrocarbons (containing hazardous substances PAHs and BTEX) may be present in intermediate and deep groundwater however available analytical data is inadequate to make this assessment.

The EA requested assessment of the possible presence of naturally occurring radioactive material (NORM) in wastewater. No groundwater samples have been analysed for NORM and no assessment of geological strata NORM content has yet to been undertaken. A 'radioactive substances environmental permit' for the management and disposal of radioactive waste may be required and will be confirmed by the EA.

The following actions are recommended:

- Collate all available data relating to naturally occurring hydrocarbons in the TSS and in other formations that may contribute to the wastewater;
- Review the environmental permit and application documents for Third Energy site at Ebberston near Pickering where injection of wastewater has recently been permitted;
- Identify as far as possible any non-natural hazardous substances that may be present in wastewater, such as from drilling fluids, plant and grouting;
- Continue ongoing dialogue with the EA regarding permit applications and consent requirements.

References

[1] Arup. 2014a. Deep Groundwater Management Design Basis Report. RE-P2-GWN-001, Draft 3.

[2] Arup. 2014b. *MTS: Preliminary Estimate of Groundwater Ingress*. Revision 2, prepared by Arup, dated 8 May 2014

[3] Barrie, J. 2014. Email to Arup, 18/02/2014.

[4] BGS. 1980. *British Regional Geology, Eastern England from the Tees to the Wash*. 2nd Edition

[5] BGS. 1997. *The physical properties of major aquifers in England and Wales*. Technical Report WD/97/34

[6] Downing R.A. & Gray D.A. 1986. *Geothermal resources of the United Kindom*. Journal of the Geological Society, London. Vol 143, pp. 499-507

[7] Environment Agency, 2014. *Groundwater protection policy (GP3)* [Online]. [Accessed 09/05/2014]. Available from: https://www.gov.uk/government/publications/groundwater-protection-principles-and-practice-gp3

[8] FWS-a. 2013. *The baseline geology and hydrogeology of the Dove's nest site, North Yorkshire.* Ref: 1433/01A/April 2013.

[9] FWS-b, 2014. *Factual Geotechnical Report for the Shafts at the Dove's Nest Minehead, North Yorkshire*. Final Draft 1433-01

[10] FWS-c. 2014. *1433 Mine O R Groundwater ingress preliminary report*. February 2014

[11] FWS-d. 2014. *Hydrogeological Baseline Report of the Dove's Nest Site, North Yorkshire*. Draft 1433MineOR15/April 2014

[12] Malvia, R.G, T. Missimer 2012. *Managed Aquifer Recharge. Arid Lan ds Water Evaluation and Management*. Environmental Science and Engineering. P p 559-630

[13] Malvia R.G.& Walker C.W. 1998. *Hydrogeology of deep-well disposal of liquid wastes in southwestern Floriday, USA*. Hydrogeology Journal. Vol. 6, pp 538 – 548.

[14] Schlumberger Water Services. 2009. *Water supply development, aquifer storage and concentrate disposal for membrane water treatment facilities*. 2nd Edition

[15] Texas Commission on Environmental Quality. 1995. *Class I injection well construction standards of Title 30*. Texas Administrative Code (TAC), Section §331.62.

[16] Toprak wastewater engineering. 2014. *Deep well injection*. [Online]. [Accessed 09/05/2014]. Available from: http://web.deu.edu.tr/atiksu/ana58/deepwell.html

[17] United Sates Environmental Protection Agency. 2014. Technical information, forms and sample documents. [Online]. [Accessed 09/05/2014]. Available from: http://www.epa.gov/region5/water/uic/techdocs.htm

[18] York Potash Ltd. 2012. *SM7 Mortar Hall Well Completion Report*. Draft

Appendix: EA meeting minutes and actions

Project title		**Job number**	
Meeting name and number	Injection well regulatory aspects	**File reference**	
Location	Lateral House	**Time and date** 10:00 26 January 2015	
Purpose of meeting			
Present	Gerd Cachandt James Senior Arnold John	Jenny Lightfoot Ruth Buckley	
Apologies			
Circulation	Those present Gerd Cachandt Chris Williams Andrew Hornung Dom Ainger Alastair Gordon		

Action

1. Naturally occurring radioactive material (NORM) in wastewater

Arnold John, EA radioactive substances specialist, commented on the implications of wastewater potentially exceeding 1Bq/l, the aqueous threshold for radioactive waste.

Potash mining is not a specified NORM-listed activity, unlike onshore hydrocarbons, however it may fall under the category or 'any other'. If it does then the EA may require a 'radioactive substances environmental permit' for the management and disposal of radioactive waste. AJ to confirm.

EA – Arnold John

AJ notes the radioactive substances env permitting process for this type of material is not particularly onerous. It can be done in parallel or after the groundwater activity permit, so long as it is in place before injection commences. AJ indicated a rad subs permit for injection of wastewater has recently been issued for Knapton Generating Station (Third Energy onshore hydrocarbon production site, near Pickering) and AJ will send a copy of the permit for information.

EA – Arnold John

AJ also noted that the potential for pipework scale exceeding radioactive waste solids threshold should be considered in the wastewater treatment design.

AJ will provide: suggested parameters and methods for wastewater analysis; confirmation of whether the EA would require a rad subs permit; and a copy of the Knapton permit and application docs.

EA – Arnold John

2. Water Framework Directive: hazardous substances in wastewater

JL presented the available info on haz subs in wastewater. Ruth Buckley/James Senior discussed the EA's approach to permitting. JS had previously noted (email J Senior to A Irving 8 July 2014) that an env permit application could be made under Schedule 22 Part 8(a) of the EPR. Part 8(a) states the regulator may grant a permit for:

(a) the injection of water containing substances resulting from the operations for exploration and extraction of hydrocarbons or mining activities, and injection of water for technical reasons, into geological formations from which hydrocarbons or other substances have been extracted or into geological formations which for natural reasons are permanently unsuitable for other purposes, provided that the injection does not contain substances other than those resulting from the above operations,

JL noted that this seems to suggest that the receiving Sherwood Sandstone groundwater would need to be defined as 'permanently unsuitable for use' for any haz subs to be discharged (as it is not 're-injection' due to water from other formations and possible drilling/construction haz subs).

JS/RB noted the EA would not define the receiving groundwater as 'permanently unsuitable for use' (this has not been done by the EA for any groundwater) however they do not consider this to be necessary. RB and JS noted a permit could be granted if it met the following criteria:

- No deterioration in quality in the receiving groundwater (ie injected water must contain lower concentrations of haz subs than naturally present in Sherwood Sandstone) and the discharge

		Action
	should not cause there to be any more onerous treatment required to make the Sherwood Sandstone 'suitable for use'; • No discharge of additional haz substances other than those naturally occurring in the Sherwood Sandstone (ie no haz substances from mine operations, drilling fluids, or naturally occurring hydrocarbons not already present in Sherwood Sandstone).	
	RB/JS note to meet these criteria further characterisation of haz subs naturally occurring in Sherwood Sandstone will be required. Data is available for metals but not hydrocarbons. This will only be available when injection well is drilled, although supporting evidence from other wells (eg Third Energy see below) may also be available. Arup to collate all available evidence such as DECC End of Well Records for the Third Energy hydrocarbon wells, BGS boreholes, geophysical logs.	Arup – JL/GC
	Also need to assess naturally occurring hydrocarbons in Redcar Mudstone, Whitby Formation and other potentially contributing formations and estimate concentration in injection water. If no naturally occurring hydrocarbons in Sherwood Sandstone then will need to treat to 'de minimis' before injection.	Arup/YP Arup/YP
	Also need to assess haz subs concentrations from drilling/construction activities. If greater than 'de minimis' in injection water and not naturally occurring in Sherwood Sandstone then treatment will be necessary.	
	RB/JS noted a groundwater activity permit has recently been granted for reinjection to Sherwood Sandstone at Third Energy Knapton/Ebberston and will forward details/copy of permit (same site as the one referred to by AJ above with a rad subs env permit).	EA – James Senior
	JL to send a summary of our understanding to EA so they can confirm (in writing) the approach is correct and if adhered to will lead to a permit.	Arup - JL
3.	**Section 32 consent**	
	EA noted an abstraction licence would not be required for operation but a S32 consent would be required to drill and test pump.	
	GC asked whether reinjection in the form of push-pull hydraulic tests could be undertaken during testing of injection well – EA will confirm whether this can be done without an env permit.	EA – James Senior
	During drilling and testing and for the permit, EA would want monitoring of shallow groundwater (including baseline monitoring) but would not require any deeper gw monitoring.	
	Natural England will be a consultee on the S32 consent.	
	GC noted intention to submit S32 application in next 2 weeks.	