Gloucestershire Emerging New Minerals Plan
Hydrogeological Assessment - Redpool's Farm
Gloucestershire County Council

31 March 2016
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## Executive summary

### Project Outline

Gloucestershire County Council is preparing a new county-wide Minerals Local Plan to replace its 2003 plan. Consideration is being given allocating several sand and gravel sites throughout the county. Before any decisions are taken hydrogeological impact assessments are being conducted. Presently Atkins Ltd has been commissioned to assess the effect of potential quarry expansions of limestone (crushed rock) workings in the Cotswolds and Forest of Dean and the development of a new sand and gravel quarry in the Severn Vale area.

### Site Overview

The site option at Redpool’s Farm consists of a single 32 ha parcel of flat agricultural land where sand and gravel extraction is proposed. The site is located in the Severn Vale area adjacent to the county boundary with Worcestershire, approximately 2 km north of Tewkesbury.

### Geology

The site is underlain by superficial deposits of the Second (Worcester) and Fourth (Kidderminster) River Severn Terrace Deposits, composed of sands and gravels.

The Tewkesbury Fault bisects the site in the east. To the west the bedrock is Mercia Mudstone Group, Triassic massive, red-brown silty mudstones and in the east Blue Lias Formation, Jurassic interbedded limestone, mudstone and siltstones.

### Hydrology / Hydrogeology

The site is bounded in the north west by Ripple Brook and in the west by Mythe Brook, both tributaries of the River Severn which flows north to south c. 450 m west of the site. Several drains are present onsite and in the surrounding area, additionally a number of ponds/lakes are present within 1 km of the site. The western area of the site is designated as an Environment Agency Flood Zone 2 and 3.

The superficial deposits and Blue Lias Formation are both classified as Secondary A aquifers, capable of providing water supplies at a local scale. The Mercia Mudstone Group is classified as a Secondary B aquifer, which has the potential to store and yield limited groundwater due to localised features.

### Land Designations

No source protection zones are located within 1 km of the site boundary. Three Key Wildlife Sites and Four Local Wildlife Sites are located within 1 km of the site boundary.

### Impact Appraisal

The main risk of quarrying onsite is related to flooding (Significant), assuming that during/post quarrying, open areas will be backfilled with low permeability inert material. As a result effects are likely to be ‘Significant’ to both the superficial deposits, Ripple Brook and Mythe Brook in the absence of any mitigation measures. Low significant impacts are expected to be felt in other onsite surface water features (drains) and the nearby Local Wildlife Site.

### Mitigation Measures

It is considered that the potential impacts could be mitigated by good design including the use of Sustainable Drainage Systems and including measures to maintain groundwater connectivity.

### Site Investigation and monitoring recommendations

It is recommended that a programme of site monitoring be carried out; monthly monitoring of groundwater levels for a period of at least 12 months prior to quarrying works, which should continue through the operation phase. Monitoring during the aftercare period should also be continued to demonstrate that any mitigation measures included are effective. Locations should be agreed with the Mineral
Planning Authority in advance if possible and should ensure that there is adequate spatial coverage to understand groundwater flow around the sites. Collaboration with other proposed minerals sites in the area may be required. Precipitation data can be collected from the Environment Agency/Met Office to supplement this. Water quality should also be monitored to determine any potential contamination, focusing on the Ripple Brook and Mythe Brook. The monitoring routine can follow the same as that for groundwater levels.

<table>
<thead>
<tr>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The site is bounded by Ripple Brook and Mythe Brook which will likely be affected during the quarrying works. If mitigation measures are properly implemented, the watercourses should only be slightly adversely affected following the restoration of the site. Backfilling of the site using low permeability material will inhibit groundwater flow in the area and result in lower groundwater levels.</td>
</tr>
</tbody>
</table>
1. Introduction

1.1. Background
Gloucestershire County Council (herein referred to as “the County Council”) is the Mineral Local Planning Authority (MPA) for the entirety of Gloucestershire. The County Council is preparing a new county-wide Minerals Local Plan to replace its previously adopted minerals local plan, which has been in place since 2003.

As part of this work, Atkins has been commissioned by the County Council to undertake a review of previous hydrological studies and undertake a hydrogeological assessment concerning a number of potential mineral extraction sites across the Cotswolds, Forest of Dean and Severn Vale mineral resource areas. These sites are described by the Council as ‘site options’ and are currently under consideration for inclusion within the new county wide minerals local plan.

Atkins has completed hydrogeological impact assessments to cover each of the 6 extraction site options under consideration for inclusion within a new county wide minerals local plan. This equates to 5 quarries to extract crushed rock (limestone) and one for sand and gravels (see Figure 1 for the site option locations).

This report provides an appraisal and utilisation of existing local evidence, much of which has been provided by the County Council. This includes water resources information that has been submitted to accompany mineral planning applications, which are either likely to have an influence or encompass the areas identified as site options, and technical work in support of other environmental strategies, plans and proposals.

1.2. Policy and legislative context
This initial hydrogeological assessment will be carried out line with the statutory and non-statutory guidance set out in the national, regional and local plans below:

**EU Legislation:**
- Water Framework Directive (WFD)\(^1\)

**UK legislation:**
- Town and Country Planning Act 1990 (as amended)
- The Environmental Permitting (England and Wales) Regulations 2010 (as amended)

**National policy:**
- Groundwater Protection: Policy and Practice (GP3)\(^3\)
- Catchment Flood Management Plans
- The National Planning Policy Framework (NPPF)\(^4\) published in March 2012
- The Planning Practice Guidance to the NPPF\(^5\).

**Local policy:**
- Gloucestershire Waste Core Strategy\(^6\)
- Gloucestershire Revised Minerals and Waste Development Scheme (MWDS)\(^7\)

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2. Assessment method

2.1. WFD WebTAG methodology

Assessment criteria have been used based on the methodology for appraising the impact of projects (plan level appraisal) set out in the Department for Transport's (DfT) Transport Analysis Guidance (TAG) Unit A3 Environmental Impact Appraisal and the specific guidance for the water environment sub-objective set out in TAG Unit 10.2 (10.2.12 Impact Appraisal). Although this methodology has been developed for the assessment of road and bridge projects it can be used to assess the impacts of other developments such as the proposed mineral extraction sites.

The methodology takes into account the importance of the feature (Table 2-1), magnitude of the likely impact (Table 2-2) and significance of predicted effects on the water environment.

The severity of a specific potential effect is then derived by considering both the importance (or sensitivity) of the feature and the magnitude of the impact (impacts must be quantified where possible, also estimating the change from the baseline conditions and the range of uncertainty). The significance of the impacts must be identified. This has been addressed in the derivation of significance of potential effects matrix shown in Table 2-3 which gives the significance of effect as a function of the sensitivity of the receptor and magnitude of impact.

Table 2-1 Importance of water feature or resource

<table>
<thead>
<tr>
<th>Importance</th>
<th>Criteria</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>Feature with a high quality and rarity, regional or national scale and limited potential for substitution.</td>
<td>Aquifer providing potable water to a large population (Groundwater). Important fish population (Surface water). Floodplain or defence protecting more than 100 residential properties (Flood Risk).</td>
</tr>
<tr>
<td>High</td>
<td>Feature with a high quality and rarity, local scale and limited potential for substitution. Feature with a medium quality and rarity, regional or national scale and limited potential for substitution.</td>
<td>WFD “High” status water body (Surface water). Aquifer providing potable water to a small population (Groundwater). Notable fish population (Surface water). Floodplain or defence protecting up to 10 industrial premises (Flood risk).</td>
</tr>
<tr>
<td>Medium</td>
<td>Feature with a medium quality and rarity, local scale and limited potential for substitution. Feature with a low quality and rarity, regional or national scale and limited potential for substitution.</td>
<td>WFD “Good” status water body (Surface water). Aquifer providing abstraction water for agricultural or industrial use (Groundwater). Floodplain or defence protecting up to 10 industrial premises (Flood risk).</td>
</tr>
<tr>
<td>Low</td>
<td>Feature with a low quality and rarity, local scale and limited potential for substitution.</td>
<td>WFD “Less than good” status (Surface water). Unproductive strata (Groundwater). Floodplain with limited existing development (Flood risk).</td>
</tr>
</tbody>
</table>


## Table 2-2  Magnitude of potential impacts

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Criteria</th>
<th>Example</th>
</tr>
</thead>
</table>
| Large Adverse        | Results in loss of feature                    | • Loss of important fishery.  
• Change in WFD classification of river reach.  
• Compromise employment source.  
• Loss of flood storage/increased flood risk.  
• Pollution of potable source of abstraction. |
| Moderate Adverse     | Results in adverse impact on integrity of feature or loss of part of feature. | • Loss in productivity of a fishery.  
• Contribution of a significant proportion of the effluent in the receiving river, but deemed insufficient to change its’ WFD classification.  
• Reduction in the economic value of the feature. |
| Slight Adverse       | Results in minor adverse impact on feature.   | • Measurable changes in feature, but of limited size and/or proportion.                                                                 |
| Negligible           | Results in an impact on feature but of insufficient magnitude to affect use/integrity. | • Discharges to watercourse but no significant loss in quality, fishery productivity or biodiversity.  
• No significant impact on the economic value of the feature.  
• No increase in flood risk.                           |
| Slight beneficial    | Results in minor beneficial impact on feature or a reduced risk of adverse effect occurring. | • Measurable changes in feature, but of limited size and/or proportion.                                                                 |
| Moderate beneficial  | Results in moderate improvement of feature     | • Enhanced productivity of a fishery.  
• Reduction in a significant proportion of the effluent in a receiving river, but not sufficient to change its WFD classification.  
• Moderate reduction in flood risk.                     |
| Large beneficial     | Results in major improvement of feature        | • Removal of major existing polluting discharge to a watercourse.                                                                         |
• Major reduction in flood risk.

Table 2-3  Significance of impacts

<table>
<thead>
<tr>
<th>Magnitude of potential impact</th>
<th>Importance / Sensitivity of attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very high</td>
</tr>
<tr>
<td>Large Adverse</td>
<td>Very Significant</td>
</tr>
<tr>
<td>Moderate Adverse</td>
<td>Highly Significant</td>
</tr>
<tr>
<td>Slight Adverse</td>
<td>Significant</td>
</tr>
<tr>
<td>Negligible</td>
<td>Low Significance</td>
</tr>
</tbody>
</table>

In applying this methodology to both construction and operational stages, significant effects would be those of low significance or above. If an adverse significant effect is identified then potential mitigation measures have been developed to reduce or mitigate this effect. When beneficial impacts are identified, then opportunities for further environmental enhancement can be considered.
3. Baseline conditions

3.1. Site option
The site option is located in the Severn Vale area adjacent to the county boundary with Worcestershire, approximately 2 km north of Tewkesbury, 1 km south west of Twyning. The site area is located at National Grid Reference location 388300, 235936 and covers approximately 32 ha agricultural land. An overview plan of the site option is provided in Figure 2.

The site is bounded to the north by Pukrup golf course and Ripple Brook (which forms the county boundary), to the east the site is restricted by the A38 and an agricultural nursery. The southern boundary is with Twyning Farm and the site extends approximately 200 m west of the Mythe Brook. The surrounding land is relatively flat and is part of the River Severn floodplain, land use is dominated by agricultural land with sporadic settlements.

There is no history of mineral workings at the site. Planning permission for extraction of sand and gravel with restoration to agriculture has encountered historical refusal and is currently under review by Gloucestershire County Council for land at Page’s Lane immediately east of the site. The closest properties to the site option are Fairfield, within the north east corner of the site option, Far End and the agricultural nursery adjacent to the eastern boundary and Twyning Farm c. 200 m to the south. The villages of Pukrup, Shuthonger and Church End all lie within a 1 km radius of the site.

3.2. Surface water and drainage
The surface water bodies within 1 km of the site, and their associated flood zones are presented on Figure 3 and details of the main rivers, watercourses and drains are presented within Table 3-1.

3.2.1. Main rivers
The River Severn is located 445 m to the west of the site option boundary, and the River Avon is located 1,450 m to the east; both rivers are flowing north to south. The Mythe Brook flows north to south on the western boundary of the site option and the Ripple Brook flows along the northern site boundary.

3.2.2. Ordinary watercourses (Lead local flood authority (GCC))
The site option is located on the River Severn floodplain and Ripple and Mythe Brook floodplains, several drains are present within the site option and in the surrounding area which drain into the main rivers. Only those drains which intersect the site have been included within Table 3-1. It is possible that some agricultural drainage ditches are not shown.

3.2.3. Lakes and ponds
There are no lakes or ponds on site, however several are indicated within 1 km of the site option on OS and satellite mapping. The locations of these ponds are presented within Table 3-1.

The Page’s Lane Hydrogeological Impact Assessment suggests that Walmer Pool is fed by both groundwater and a pool in the northwest of Hillview Nurseries. The pond 20 m north of the site within the golf course grounds is likely to be spring-fed from the superficial deposits.

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### 3.2.4. Water Framework Directive status

**Table 3-1**  Surface water bodies within 1 km of the site option

<table>
<thead>
<tr>
<th>Water body name / ID</th>
<th>Location (NGR)</th>
<th>Hydromorphological status</th>
<th>Current ecological quality (Certainty)</th>
<th>Current chemical quality (Certainty)</th>
<th>Value/Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Severn (confluence of River Teme to confluence of River Avon) GB109054039760</td>
<td>445 m west of Site (387210, 235646)</td>
<td>Heavily Modified</td>
<td>Moderate (very certain)</td>
<td>Good (no information available)</td>
<td>Medium</td>
</tr>
<tr>
<td>Ripple Brook (including Mythe Brook) GB109054039730</td>
<td>Within site boundary (387910, 235964)</td>
<td>Not designated</td>
<td>Moderate (very certain)</td>
<td>Good (no information available)</td>
<td>Medium</td>
</tr>
<tr>
<td>Unnamed brook/ditch</td>
<td>Within site boundary (387823, 235861)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Unnamed brook/ditch</td>
<td>Within site boundary (388542, 235844)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Pond/Lake</td>
<td>20 m north of Site (388397, 236250)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Pond/Lake</td>
<td>145 m north of Site (388397, 236250)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Walmer Pool</td>
<td>210 m north of site (388821, 236466)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Hillview Fishing Lakes</td>
<td>300 m north east of Site (389003, 236505)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Lake</td>
<td>307 m north west of Site (387598, 236153)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Pond/Lake</td>
<td>529 m east of Site (389390, 236235)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Ripple Lake</td>
<td>578 m north west of Site (387308, 236263)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Pond/Lake</td>
<td>663 m east of Site (389521, 236212)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Lake</td>
<td>820 m north west of Site (387910, 234814)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
<tr>
<td>Lake</td>
<td>815 m south of site (387883, 234849)</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Not designated</td>
<td>Low</td>
</tr>
</tbody>
</table>

3.3. **Flood risk**

This section summarises the relevant data on flooding that is available for the site option.

3.3.1. **Surface water flooding**

The majority of the site is recorded as not at risk of surface water flooding\(^\text{11}\). Surface water flooding is highlighted in line with the Ripple Brook and Mythe Brook in the north and west of the site and along the northern and southern boundaries. Risk of surface water flooding in these locations is from events with annual probabilities of occurrence up to 3.3%\(^\text{11}\).

3.3.2. **River flooding**

Figure 3 shows the locations of Flood Zones across the site and surrounding area. The western half of the site and area to the west within Flood Zones 2 and 3\(^\text{12}\). An Environment Agency earth embankment is installed as a flood defences along the western bank of the Mythe Brook.

3.3.3. **Groundwater flooding**

No information on the probability of groundwater flooding occurring is available, however information on the areas susceptible to groundwater flooding has been provided by the Environment Agency\(^\text{13}\). As indicated on Figure 4, in the west, greater than 75% of each 1 km grid square is susceptible to groundwater flooding and in the east 50-75% is susceptible to groundwater flooding.

The data should not be interpreted as identifying areas where groundwater is actually likely to flow or pond, thus causing flooding, and does not give any indication of the probability of frequency that flooding may occur.

3.3.4. **Sewer flooding**

As the site option is in a relatively rural area and it is unlikely that significant discharges to sewers will be required, sewer flooding has not been considered.

3.4. **Geology**

This section provides a summary of the geology that underlies the site option. The geological units that are present beneath the site are listed within Table 3-2. The Tewkesbury Fault bisects the site in the east, at the contact between the Mercia Mudstone Group and Blue Lias Formation. Plans showing the superficial geology and bedrock geology underlying the site option are provided within Figure 5a and 5b respectively\(^\text{14}\).

Borehole SO83NE203 at Pukrup Hall Hotel\(^\text{15}\), on the northern boundary of the site option (388400, 236200) logs sand and gravels from 0.5 – 7 mbgl overlying Mercia Mudstone, similarly borehole SO83NE204 at Hillview Nurseries (389050, 236540) records sand and gravel from 1 – 7 mbgl\(^\text{16}\). Trial pitting as part of the impact assessment\(^\text{17}\) for the proposed Page’s Lane sand and gravel pit, immediately east of the A38, indicates the base of the gravels to be 4-5 mbgl. The elevation of the contact between the sands and

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\(^{13}\) Environment Agency, 2015. Areas susceptible to Groundwater Flooding [GIS shapefile].


\(^{15}\) BGS borehole scan SO83NE203 available at http://scans.bgs.ac.uk/so_bscans/boreholes/271980/images/14801447.html Accessed 19 February 2016

\(^{16}\) BGS borehole scan SO83NE204 available at http://scans.bgs.ac.uk/so_bscans/boreholes/271981/images/14801451.html Accessed on 22 February 2016

The superficial deposits are classified as a Secondary A aquifer by the Environment Agency and are comprised of sands and gravels. Secondary A aquifers are typically 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. The Environment Agency classifies the Blue Lias Formation (interbedded limestone, mudstone and siltstone) as a Secondary A aquifer and the Mercia Mudstone Group (massive red-brown silty mudstone) as a Secondary B aquifer. Secondary B aquifers are typically lower permeability layers which may store and yield limited amounts of groundwater due to localised features.

The Environment Agency considers the superficial deposits to be Highly Vulnerable (Secondary A aquifer) to pollution. Easily able to transmit pollution to groundwater; such areas are typically characterised by high leaching soils. The bedrock is not classified with respect to pollution vulnerability.

Limited hydrogeological information is available regarding the aquifer properties beneath the site or within close proximity of the site. As such the transmissivity, porosity, yield and hydraulic conductivity of the aquifer is not known. Therefore it is recommended that a full hydrogeological assessment of the aquifer beneath the site is conducted prior to the start of the mineral extraction operations in order to fully evaluate the potential risks of the operations at the site.

The Page’s Lane hydrogeological impact assessment reports estimated permeabilities for the superficial deposits (Fourth (Kidderminster) Terrace of River Severn) using particle size distribution (PSD) curves. The

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range in estimated permeability using the Hazen (1892)\textsuperscript{19}, Kozeny-Carmen (1927)\textsuperscript{19} and Breyer (1964)\textsuperscript{19} analysis is $5.3 \times 10^{-5}$ to $5.6 \times 10^{-4}$ m/s with an average of $2.3 \times 10^{-4}$ m/s. The investigation notes that the spatial limit of the sand and gravels reduces their potential as a water resource. The sand and gravels are cased out of the Hillview Nurseries borehole\textsuperscript{16} and water is abstracted from the underlying Blue Lias, confirming the previous statement.

Limited pumping test data is available from the Hillview Nurseries borehole\textsuperscript{16,17}; assuming the borehole penetrates the entire aquifer (thickness of 59 m) permeability is estimated at $8.8 \times 10^{-7}$ m/s. At the contact with the sands and gravels above, the hydrogeological impact assessment\textsuperscript{17} concludes that the Blue Lias is dominated by clay, and can be considered an aquitard.

No local information is available on the Mercia Mudstone Group.

### 3.5.3. Groundwater elevation and fluctuations

As part of the Page’s Lane investigation\textsuperscript{17}, ten piezometers were installed in the River Terrace Deposits (Fourth (Kidderminster) Terrace of River Severn) east of the A38, extending towards Hillview fishing lakes. Groundwater levels are shown to exhibit a north to south increasing trend and there is some evidence of perched groundwater. Given the relatively small vertical extent of the sands and gravels groundwater flow is assumed to be influenced by the topography of the contact with the underlying Blue Lias, and flows northwards across the site. Average range in levels across all piezometers is 1.4 m, however range is greater in the south of the site. There is evidence of a significant seasonal change in volume of water stored within the aquifer.

Groundwater flow within the superficial deposits (Fourth (Kidderminster) Terrace of River Severn) at Page’s Lane is estimated at an average of 1.1 l/s based on the most likely aquifer properties on site (average saturated thickness 1.1 m, permeability $2.0 \times 10^{-4}$, hydraulic gradient $1.1 \times 10^{-2}$).

#### Table 3-3 Summary of groundwater conditions from borehole data closest to Redpool’s Farm

<table>
<thead>
<tr>
<th>Borehole ID</th>
<th>Rest water levels (mbgl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGS SO83NE203</td>
<td>2.21</td>
</tr>
<tr>
<td>WMBH1</td>
<td>0.2 – 2.7</td>
</tr>
<tr>
<td>WMBH2</td>
<td>0.1 – 2</td>
</tr>
<tr>
<td>WMBH5</td>
<td>1.4 – 2.7</td>
</tr>
<tr>
<td>WMBH6</td>
<td>2.2 – 3.3</td>
</tr>
</tbody>
</table>

### 3.5.4. Monitoring locations and groundwater flow

The Centre of Ecology and Hydrology (CEH) have a number of surface water monitoring points throughout the UK\textsuperscript{20}. One of which is located approximately 7 km downstream on the River Severn at Deerhurst. The BGS monitors groundwater throughout the UK and stores it on a publically available database, the UK Hydrometric Register, the nearest borehole monitoring the Mercia Mudstone Group is located approximately 26 km to the south west at Stores Cottage. The available monitoring stations are summarised in Table 3-4.

#### Table 3-4 Summary of surface and groundwater monitoring stations

<table>
<thead>
<tr>
<th>Surface/groundwater monitoring station</th>
<th>Grid reference</th>
<th>Area covered (km$^2$)</th>
<th>Mean flow (m$^3$/s)</th>
<th>Groundwater level L$^{95}$ (mAOD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface: 54110 – Severn at Deerhurst</td>
<td>SO86703010</td>
<td>9877</td>
<td>95.5</td>
<td>-</td>
</tr>
<tr>
<td>Ground: SO71/18 – Stores Cottage</td>
<td>SO71701970</td>
<td>-</td>
<td>-</td>
<td>65.27</td>
</tr>
</tbody>
</table>


\textsuperscript{20} Centre For Hydrology and Ecology & British Geological Survey. 2008. UK Hydrometric Register
3.5.5. **Water Framework Directive status**
The WFD status of groundwater bodies is determined using quantitative and quality components and is measured as being either Good or Poor. The Mercia Mudstone Group and Blue Lias Formation beneath the site option is contained within the Severn Vale/Secondary Combined Groundwater Body.\(^{21}\)

<table>
<thead>
<tr>
<th>Waterbody name (ID)</th>
<th>Current quantitative quality (Certainty)</th>
<th>Current chemical quality (Certainty)</th>
<th>Overall risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severn Vale/Secondary Combined (GB40902G204900)</td>
<td>Good (No information available)</td>
<td>Good (No information available)</td>
<td>Probably at risk</td>
</tr>
</tbody>
</table>

### 3.6. Land designations
This section summarises the relevant protected areas and historic land uses within 1 km of the site option.

#### 3.6.1. Source protection zones
No Source Protection Zones are located within 1 km of the site option boundary.

#### 3.6.2. Historical land use and pollution incidents
No pollution incidents are reported within 1 km of the site according to Environment Agency mapping.\(^{22}\) A single historical landfill is located within 1 km; Twyning Pit landfill at Church End Farm, east of the A38 (former mineral workings). No information is available from the EA regarding the type of waste or date of closure. BGS mapping indicates that extensive site investigation has been undertaken on the site as a large number of confidential boreholes are present both onsite and in the surrounding area.

#### 3.6.3. Protected areas
The site option is located within a SSSI Impact Risk Zone, however no SSSI are located within 1 km of the site boundary.\(^{23}\) Three Gloucestershire County Council (GCC) Key Wildlife Sites and four Worcestershire County Council (WCC) Local Wildlife Sites are located within 1 km of the site boundary, as presented on Figure 6.

#### 3.6.4. Abstractions
There are no abstractions onsite. Licensed and un-licensed (private) abstractions within 1 km of the site option are summarised in Table 3-6 below. The groundwater abstraction at Hillview Nurseries is known to be abstracting from the Blue Lias Formation underlying the sands and gravels; this formation is hydraulically isolated from the superficial deposits by a known low permeability horizon at the contact.\(^{17}\)

No abstraction information was made available by the Malvern Hills District Council (Worcestershire) in the reporting timeframe.

---

## Table 3-6  Type and number of surface water and groundwater abstractions within 1 km of the site option

<table>
<thead>
<tr>
<th>Source</th>
<th>Location</th>
<th>Purpose</th>
<th>Max annual abstraction (m³/year)</th>
<th>Maximum daily abstraction / volume (m³/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater Midlands Region</td>
<td>400m north east of site</td>
<td>Industrial, commercial and public services</td>
<td>5000</td>
<td>25</td>
</tr>
<tr>
<td>Surface Water Midlands Region</td>
<td>Immediately north of site</td>
<td>Agriculture</td>
<td>13636</td>
<td>13636</td>
</tr>
<tr>
<td>Groundwater Midlands Region</td>
<td>1 km south of site</td>
<td>Private abstraction</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

4. Hydrogeological and hydrological risk assessment

4.1. Review of activities proposed and potential impacts

It is proposed that the GCC allocate several sites throughout the county for further mineral extraction and expansion. One of the sites which is being considered sand and gravel extraction is located at Redpool’s Farm. This study aims to carry out a hydrogeological assessment of the site area and examine the risks posed by any future development to specific receptors and the pathways that may cause this risk to affect receptors within the boundary of the proposed development area. For the purposes of this assessment it has been assumed that work has taken place and the quarried areas have been backfilled with clay, therefore this is an assessment of the worst case scenario.

The proposed activities at the site and across all site options involve mineral extraction within the parcel. The mineral resource of interest at Redpool’s Farm are the sands and gravels of the Severn and Avon River Terrace Deposits which are present across the site.

The most significant potential impacts are focused on flooding (Table 4-2). The likely restoration of the site using low permeability inert infill will present a barrier to groundwater flow, resulting in an elevated risk of groundwater flooding. Surface run-off will be increased due to the reduction in permeability of subsurface deposits. Additionally, half of the site is designated as an Environment Agency Flood Zone 2 and 3; as a result the potential risk (and subsequent effects) can be magnified. There is further potential of river flooding during and following elevated periods of precipitation.

4.2. Receptors

A summary of the receptors for the site option at Redpool’s Farm is presented in Table 4-1.

<table>
<thead>
<tr>
<th>Controlled waters</th>
<th>Sensitive land use</th>
<th>Flood risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-site surface water features</td>
<td>Key wildlife sites</td>
<td>Fairfield</td>
</tr>
<tr>
<td>Ripple Brook</td>
<td>Local Wildlife Sites</td>
<td>Twyning Farm</td>
</tr>
<tr>
<td>Mythe Brook</td>
<td></td>
<td></td>
</tr>
<tr>
<td>River Severn</td>
<td>Lakes/Ponds</td>
<td>Pakrup golf course</td>
</tr>
<tr>
<td>Secondary A aquifer (superficial deposits)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary A aquifer (Blue Lias Formation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary B aquifer (Mercia Mudstone Group)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3. Identification of pathways

There are three main pathways which will be affected by any change in flow paths:

- Groundwater;
- Surface water (overland flow); and
- Fluvial (river) water pathways

The Ripple Brook is a direct pathway which runs along the north western site boundary and the Mythe Brook bounds the site in the west. Fluvial water is therefore the most immediate and likely pathway. The groundwater pathway also lies within the Secondary A aquifer within the superficial deposits, meaning the
aquifer may be an indirect pathway (as well as a receptor) as it transmits groundwater across the site. This is likely to vary as a function of the aquifer properties.

Surface water pathways (overland flow) represent another potential pathway and may pose a more significant problem in the western part of the site where there is a Low-High risk of flooding from surface water. This is only likely to be of significance during periods of high precipitation when the ground on site has become saturated, allowing excess precipitation to flow onto the ground and remain there.

4.4. Appraisal of magnitude of impact on receptors

The significance of any effect on the identified receptors is likely to vary depending on a number of factors, such as the sensitivity of the relevant waters, the current conditions within the site and the magnitude of any impact. There are a number of potential issues that could arise from the development, most notably changes in the groundwater levels underlying the site. It is believed Mythe and Ripple Brooks are in hydraulic continuity with the groundwater in the superficial deposits, and hence any impacts on groundwater levels as a result of quarry dewatering are likely to affect local streams and their ecology.

Such impacts have been displayed have been displayed in Table 4-2. This section uses the criteria set out in Section 2 to assess the impact, magnitude and significance of any change on the receptors, due to mineral extraction work, within the site area. It must be noted that this table details possible effects that could occur in the absence of appropriate mitigation. It is expected that applicants will complete detailed assessment and develop appropriate mitigation measures. It is likely therefore that the impacts of any particular scheme would not approach those detailed.
### Table 4-2  Appraisal of Magnitude of Impact on Receptors

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Importance</th>
<th>Impact</th>
<th>Magnitude</th>
<th>Significance</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-site surface water features</td>
<td>Low</td>
<td>Re-alignment of drainage channels may be required. Increase in volume of suspended solids into the river which can smother benthic organisms and eggs and increase turbidity. Diversion of water away from rivers as a result of dewatering or infilling.</td>
<td>Large Adverse: Loss of channels within the site may be required to facilitate extraction. De-watering processes during quarrying may result in a decrease in water levels to the Ripple Brook and Mythe Brook. During quarrying there will likely be an increase in suspended sediment present in the water from the site. If this is discharged straight into the Brooks it could cause an adverse impact on water quality.</td>
<td>Large Adverse: Potential loss of the drainage channels due to workings. Reduction in base flow to perimeter ditches due to use in inert fill for restoration</td>
<td>Low Significance</td>
</tr>
<tr>
<td>Lakes/Ponds</td>
<td>Low</td>
<td>Increase or decrease in water levels due to groundwater diversion and dewatering. Increase in suspended solids present in ponds.</td>
<td>Moderate Adverse: Dewatering to facilitate mineral extraction may reduce the flow of water feeding these features. Water which still reaches the ponds is likely to have a high suspended solids content, impacting on water quality.</td>
<td>Moderate Adverse: The use of inert fill may introduce barriers to groundwater flow and therefore may affect the level of water in the lakes.</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Secondary A aquifer (superficial deposits)</td>
<td>Medium</td>
<td>Dewatering and diversion of groundwater from this area of the aquifer. Decrease in water quality.</td>
<td>Large Adverse: De-watering activities from quarrying is likely to result in a decrease of water levels in the aquifer surrounding any quarrying activities. Pollution of the aquifer from chemicals used during quarrying may decrease water quality in the aquifer. Any alteration to the quality or lowering of the groundwater table could significantly impact the spring-fed</td>
<td>Moderate Adverse: Restoration with inert fill could introduce contamination into the aquifer if appropriate acceptance criteria are not utilised. Inert fill is likely to be of lower permeability than the natural materials and therefore create a reduction in groundwater flow and storage. Any alteration to the quality or lowering of the groundwater table could</td>
<td>Significant</td>
</tr>
<tr>
<td>Receptor</td>
<td>Importance</td>
<td>Impact</td>
<td>Magnitude During operation</td>
<td>Magnitude After restoration</td>
<td>Significance</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>--------</td>
<td>----------------------------</td>
<td>----------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Secondary A aquifer (Blue Lias Formation)</td>
<td>Medium</td>
<td>Dewatering and diversion of groundwater from this area of the aquifer. Decrease in water quality.</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>De-watering activities and pollution from chemicals used during quarrying are unlikely to result in a decrease of water levels or introduce contamination into the Blue Lias Formation due to the known clay dominated aquitard-like properties at the contact with the overlying superficial deposits. No impact is expected to be felt by nearby groundwater abstractions.</td>
<td>Restoration with inert fill is unlikely to result in introduction of contamination to the aquifer due to the known clay dominated aquitard-like properties at the contact with the overlying superficial deposits. Reduction aquifer recharge due to low permeability inert fill is expected to be negligible due to the low permeability of the aquifer and the relatively small site option area overlying the Blue Lias. No impact is expected to be felt by nearby groundwater abstractions.</td>
<td></td>
</tr>
<tr>
<td>Secondary B aquifer (Mercia Mudstone Group)</td>
<td>Low</td>
<td>Dewatering and diversion of groundwater from this area of the aquifer. Decrease in water quality.</td>
<td>Slight Adverse</td>
<td>Slight Adverse</td>
<td>Insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>De-watering activities and pollution from chemicals used during quarrying are unlikely to result in a considerable decrease of water levels or introduce significant contamination into the Mercia Mudstone Group due to the low permeability of the formation.</td>
<td>Restoration with inert fill is unlikely to result in introduction of significant contamination to the aquifer due to the low permeability of the formation. Reduction in aquifer recharge due to low permeability inert fill is expected to be negligible due to the low permeability of the aquifer and the relatively small site option area overlying the Mercia Mudstone.</td>
<td></td>
</tr>
<tr>
<td>Ripple Brook and Mythe Brook</td>
<td>Medium</td>
<td>Increase in volume of suspended solids into the river which can smother benthic organisms and eggs. Changes to base flow</td>
<td>Large Adverse</td>
<td>Moderate Adverse</td>
<td>Significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>De-watering activities during operations may result in diversion of water from the Ripple and Mythe Brooks as groundwater flow paths are interrupted.</td>
<td>Due to their close proximity to the site option it is likely that restoration with low permeability inert fill is likely to reduce baseflow contribution to the two brooks. This reduction is unlikely to be</td>
<td></td>
</tr>
<tr>
<td>Receptor</td>
<td>Importance</td>
<td>Impact</td>
<td>Magnitude During operation</td>
<td>After restoration</td>
<td>Significance</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>--------</td>
<td>----------------------------</td>
<td>-------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>River Severn</td>
<td>Medium</td>
<td>Increase in volume of suspended solids into the river which can smother benthic organisms and eggs. Changes to base flow as a result of dewatering and/or inert infill.</td>
<td><strong>Negligible</strong> De-watering activities during operations are not expected to reduce baseflow to the River Severn as the Ripple and Mythe Brooks are present between the site option and River Severn. The quarrying process will result in a greater volume of suspended sediments being present in the water of the River Severn tributaries (Ripple and Mythe Brooks), however it is expected that these will settle or filter out before they reach the River Severn.</td>
<td><strong>Negligible</strong> Due to the considerable distance from the site and the presence of two surface watercourses between the River Severn and the site it is unlikely that any impact will be observed.</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Mythe Railway KWS, Mythe Composite Site (lakes and reservoirs) KWS and Brokeridge Common KWS</td>
<td>Low</td>
<td>Increase in volume of suspended solids or change in water quality can impact sensitive aquatic wildlife. Changes in groundwater levels and/or quality can impact sensitive vegetation.</td>
<td><strong>Slight Adverse</strong> GCC Key Wildlife sites are designated areas with a rich diversity of habitats that provide refuges and corridors for wildlife across Gloucestershire. Some of which may contain plant species sensitive to groundwater levels, or aquatic life sensitive to changes in water quality. Use of chemicals and dewatering during quarry operations have the potential to result in decreased groundwater levels and reduced water quality at the KWS, however due to their distance from the site option it is likely to have only a small impact, if any.</td>
<td><strong>Slight Adverse</strong> Due to the distance from the site option it is unlikely that any KWS will be affected by the works after they are complete.</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Ripple Brook LWS, Ripple</td>
<td>Medium</td>
<td>Changes to water</td>
<td><strong>Moderate Adverse</strong></td>
<td><strong>Moderate Adverse</strong></td>
<td>Low</td>
</tr>
<tr>
<td>Receptor</td>
<td>Importance</td>
<td>Impact</td>
<td>Magnitude</td>
<td>Significance</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------</td>
<td>------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Lake and The Knapps LWS, Ripple Meadow LWS and River Severn LWS</td>
<td></td>
<td>availability. Discharge of polluted water</td>
<td>WCC Local Wildlife Site are designated as areas of county-level importance or greater for their flora and fauna. Any potential change in hydrological conditions could potentially impact on integrity of the site. The proximity to the LWS to the site option suggests a potential for adverse impact as a result of quarry dewatering operations and use of chemicals.</td>
<td>The proximity of the LWS to the site option indicates the possibility that restoration using low permeability inert fill cause a negative impact due to localised changes in groundwater flow direction. This will need to be confirmed during the details work to support any application.</td>
<td></td>
</tr>
<tr>
<td>Flood Risk</td>
<td>High</td>
<td>Increased risk of flooding from rivers, surface water and groundwater</td>
<td><strong>Moderate Adverse</strong> Dewatering is likely to be required and discharge of this water may give rise to an increased risk of flooding if the capacity of the receiving waterbody is exceeded. Any stockpiling of materials within areas susceptible to surface water flooding may increase the risk of flooding off site due to a reduction in flood plain storage.</td>
<td><strong>Moderate Adverse</strong> The backfilling of the mineral working with lower permeability material is likely to increase the amount of runoff from the site following a rainfall event and may therefore increase the risk of flooding. The lower permeability materials are likely to block the migration of groundwater through the site and therefore water levels may rise upstream of the site. This may give rise to an increased risk of groundwater flooding locally.</td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.5. Mitigation measures

It is recognised that the proposed mineral extraction activities could, absent any mitigation, have various adverse impacts upon the water environment. However, it is anticipated that potential operators would, as part of their applications undertake detailed site investigations and monitoring and provide a more detailed assessment of the impacts. Where a development is an EIA development this would be presented in the relevant chapter of the Environmental Statement as well as within a flood risk assessment compatible with the requirements of the NPPF. For non-EIA developments it is still expected that the effects of the development on the water environment, with particular attention to flood risk, will be properly considered and documented. Where necessary it is expected that mitigation measures will be detailed within the application to reduce the impacts to acceptable levels.

Mitigation measures to reduce the impact of dewatering are likely to include some or all of:

- Subdivision of the working area into smaller cells to reduce the active perimeter;
- Use of sheet piles or compacted clay walls to minimise groundwater inflow and limit impact of this dewatering on any sensitive receptors; and
- Control of dewatering volumes, and if necessary suspension of pumping during storm event, to ensure receiving waters have appropriate capacity for the flow.

Mitigation measures to reduce impact on water quality are likely to include some or all of:

- Use of bunded tanks and drip trays to prevent spillages;
- Use of settlement (silt) ponds or proprietary equipment to reduce the silt content of discharged water;
- Compliance with quality limits set by the Environment Agency; and
- Use of inert materials only for restoration.

Measures to minimise the impact of flood risk are likely to include some or all of:

- Placing buildings, stockpiles and other infrastructure outside the flood plain and outside areas at risk if surface water flooding where ever possible;
- Where storage within a flood risk areas is required, place it at as low a risk as possible, which will commonly be as close to the edge of the zone as possible;
- Restore the sites to existing ground level and no higher so as not to impact upon flood plain storage;
- Provide flow balancing using sustainable drainage systems such that the greenfield (pre-development) rate of runoff is not exceeded in line with current SuDS guidance; and
- Provide safe pathways for groundwater to move around or through the infilled site such the groundwater levels do not rise above the pre-development levels.

4.6. Residual effects

If mitigation measures are implemented with the addition of a stringent monitoring programme, the residual effects of the mineral extraction activities at Redpool’s Farm should be negligible.
5. Site investigation and monitoring

It is recommended that the following parameters be monitored before, during and after quarry operations:

- **Groundwater levels** – Monthly monitoring for a period of 12 months prior to quarrying during operation (at a higher frequency if required) and during the aftercare and management period. Locations should be identified to provide good coverage of the proposed site, taking into account the need to understand groundwater/surface water interaction and should as far as possible be located so that they can function for the whole of the period required.
- **Precipitation** – Data can be collected from Environment Agency or Meteorological Office at the same times, and for the same period, as groundwater levels are recorded.
- **Water Quality** – pH, dissolved oxygen, Biochemical Oxygen Demand (BOD), conductivity, ammonia, nitrates, suspended solids and other relevant chemical parameters should be measured to ensure Mythe Brook, Ripple Brook and River Severn are not contaminated.
6. Conclusions

6.1. Overall
The site at Redpool's Farm has been identified as one of six potential sites for mineral extraction within the proposed Gloucestershire County Council Minerals Plan. This report provides a hydrogeological impact assessment for the proposed works, using existing information and baseline conditions at the site and a review of the aforementioned works has been carried out. The key conclusions are outline below:

- The main risk of concern is an elevated flooding risk (assuming backfilling using low permeability material)
- Ripple and Mythe Brooks running directly along the north western and western boundaries of the site option respectively have the potential to suffer the most significant impact onsite as a result of the works. Any changes in the groundwater flow from quarrying onsite will have a direct repercussion on the watercourses.
- The sand and gravel superficial deposits (Secondary A aquifer) beneath the site represents a key pathway for any effects.
- All quarrying works within the site option will require environmental monitoring. Groundwater level monitoring has been recommended prior to, during and post operations in addition to precipitation and water quality monitoring.
- Mitigation measures implemented during operations can reduce the significance of any negative residual impacts.

6.2. Operation
Mineral extraction presents a series of risks to water quality, water resources and flood risk. However, subject to appropriate design, especially with regard to storage and stockpiles, and the inclusion of appropriate mitigation measures it is likely that any impacts can be reduced to acceptable levels.

Depth of quarrying must be limited to the extent of the superficial deposits and not extend down into the bedrock below to prevent quarry activities impacting on the aquifers beneath. Dewatering activities could impact the brooks that form the boundary of the site and careful consideration of the effect of such changes on water resources and habitats will be required during the application process.

6.3. Restoration
It is proposed that the site be restored to agriculture using inert fill. This restoration has the potential to increase flood risk, by increasing surface water runoff and damming groundwater flow paths.

Mitigation measures to manage these highlighted risks are available and the council should ensure that well designed mitigation is included in any applications that are submitted.