Hafren Water

# Investigation of the hydrology and hydrogeology in the vicinity of Wakerley Quarry, Northamptonshire

**FINAL**
**May 2007**

**Report prepared for**:


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# 1 INTRODUCTION

## 1.1 Background

An area containing commercially exploitable limestone has been identified in the vicinity of Wakerley, Northamptonshire. The site is within the landholding of the Burghley Estate.

The mineral is to be used primarily as a general aggregate for local building/civil engineering works. Some crushed lime may be produced, and possibly blocks to be used for walling and general construction, depending on the size of material extracted.

Part of the site has the benefit of a phase 1 "active consent" dating from November 1962, issued for the extraction of ironstone and overlying minerals. A mineral review application was submitted to Northamptonshire County Council in October 1997. Half of the original 1962 permission will be surrendered and the other half is included within the current Planning Application (see ***Figure 1***).

The estimated reserve is around 11.25 million tonnes, and at a rate of 250,000 tonnes per annum the estimated life of the quarry will be some 45 years.

## 1.2 Location

The Extraction Area is located approximately 1 km to the south of Wakerley Village at its nearest point, and some 7 km to the east of the town of Uppingham in Northamptonshire. The A43 road is located approximately 1.5 km to the southeast of the site, at its nearest point. The Extraction Area is centred around National Grid Reference (NGR) SP 946 982 and the area to be surrendered is situated immediately to its north. The locations of the Extraction Area and surrendered area are shown on ***Figure 1***.

## 1.3 Scope of study

The investigation comprised the following sections:

- Baseline data collection
  Data was collated from various sources to enable the definition of current, baseline conditions

- Site visits and water features survey
  Site visits were undertaken to identify and characterise water features within the quarry and its immediate vicinity, to assess the geology within the quarry and to determine the relative elevations of the quarry and surrounding area.

- Calculation of water ingress volumes
  The volumes of water which may be generated within the quarry void were calculated to enable the potential impact of the quarry extension upon the water regime to be determined.

- Identification of potential impacts upon the water environment
  The effects which may result from the proposed quarry extension have been identified together with mitigation measures, where required.

- Assessment and reporting

The findings of the investigation, including the definition of baseline conditions and potential impacts and mitigation measures, are included within this report.

## 1.4 Data sources

The following data sources were used in this investigation:

British Geological Survey (BGS)
- 1:50,000 scale geological map: Sheet 157, Stamford (1978)
- Well records
- Publication: Petrology of the Northampton Sand Ironstone Formation, HMSO, 1949
- Publication: Memoirs of the Geological Survey of Great Britain, Rutland, 1875

Environment Agency (EA)
- Long-term average rainfall data
- Licensed abstractions
- Water quality data

Ordnance Survey maps (OS)
- Explorer Sheet 234, Rutland Water, 1:25,000 scale

Natural England (formerly English Nature)
- Details of conservation areas within a 2 km radius of the centre of the site

East Northamptonshire Council
- Details of unlicensed abstractions within a 1.5 km radius of the centre of the site

Consultants' reports
- Geological investigation – Limestone Reserve Assessment, D K Symes Associates, November 2000
- Ecological assessment – 2005 EcoTech ecological consultancy

# 2 BASELINE DATA

## 2.1 Landform

The Extraction Area is situated close to the summit of a hill, which rises to an elevation of 101metres Above Ordnance Datum (mAOD). Ground elevations decrease steadily northwards to the River Welland, which is situated at an elevation of 35-40 mAOD and some 800 m from the northern site boundary. Ground elevations decrease more gradually to the east and south of the summit of the site. Several small valleys are incised into the raised area in which the Extraction Area is situated, some of which are associated with streams.

Within the Extraction Area ground elevations range between some 80–101 mAOD. The highest elevations occur in the western extremity of the site and decrease northeastwards, in the direction of Wakerley Village.

Limestone was formerly extracted to the southwest of the Extraction Area and a naturally restored area of grassland now occupies the former working area. Ironstone was also historically worked extensively in the region, modifying the local landform markedly. The closest such workings to the Extraction Area is situated immediately adjacent to the northwest of the proposed extraction area. A larger area of ironstone extraction was located some 800 m from the western boundary of the site. The locations of the former limestone and ironstone workings are shown on ***Figure 1***.

The majority of the Extraction Area was utilised as an airfield (RAF Spanhoe) during the 2nd World War. Engineering works associated with the construction of the airfield are likely to have included levelling and the provision of additional drainage. Both of these will have affected the pre-existing, natural landform and drainage characteristics of the site.

The area to the south and east of the Extraction Area comprises laterally extensive woodland, the largest contiguous area to the east of the site being known as Wakerley Great Wood.

## 2.2 Watercourses

The Extraction Area is situated within the catchment of the River Welland, which rises near Market Harborough in Leicestershire and flows in a northeasterly direction in the vicinity of the quarry. It flows eastwards through Stamford, approximately 11 km northeast of Wakerley, and discharges into the Wash at Fosdyke Bridge. Water features described within the report are shown on ***Figure 2***.

The nearest watercourse to the site is an eastwards flowing stream located approximately 400 m to the south of the proposed quarry. The stream rises within Wakerley Great Wood and flows towards Laxton Hall.

## 2.3 Springs and seepages

Several springs/seepages have been identified within 1 km of the boundary of the Extraction Area and were investigated during a site visit on 22nd June 2006. Two issues are located some 400 m to the northeast of the site and to the south of Wakerley Village. (NGR SP 953 993). They occur at an elevation of approximately 55 mAOD and converge to flow northwards towards Wakerley Village. The springs were dry at the time of the site visit after a period of dry weather.

An Issue is indicated approximately 1 km to the north of the western extremity of the Extraction Area (NGR SP 937 987) at an elevation of approximately 50 mAOD. When investigated, this feature was found to consist of three pipes: two of approximately 150 mm diameter and one some 250 mm diameter. Water was flowing from each of the pipes at the time of the site visit into a large ditch which runs northwards to the River Welland. The greatest quantity of water was seen to emerge from the largest diameter pipe. The total flow from the three pipes was estimated as approximately 1-2 l/s.

A further pipe was found some 200 m further south, adjacent to a track and at an elevation of approximately 60mAOD. This emerged from the side of the neighbouring field to the west which is at a slightly higher elevation. The flow from the pipe, which was a steady trickle, appeared to infiltrate into the ground before re-emerging on the track to the east, at a lower elevation.

Four issues occur at elevations of between 40 and 50 mAOD closer to the River Welland and some 800m to the north of the central section of the Extraction Area. All Issues and springs discussed within the report are shown on ***Figure 2.***

Additional seepages, not shown on the published OS map, were identified during a water features survey. These seepages appeared well-established as the associated vegetation was representative of a frequently wet area. All issues were flowing at the time of the site visit. The small watercourses flowing from the springs averaged some 0.5 m wide and 1-3 cm deep (see ***Figure 2***). A drain, considered likely to be sourced from a seepage, is located c500 m to the northeast of the issues described above (NGR SP 941 991) at an elevation of approximately 50 mAOD.

## 2.4 Surface water quality

Water quality of the River Welland is measured by the Environment Agency at a sampling point near the Wakerley/ Barrowden Road bridge (NGR SP 956 998).

This sampling point is situated some 700 m to the north of the Extraction Area boundary. Details of the water quality in this reach of the River Welland (from Harringworth, NGR SP 922 977 to Duddington, NGR SK 984 010) are summarised in Table 2.4 below.

| Criteria | Year of classification | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GQA grades: | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 |
| Chemical | B | C | B | B | B | C | B | B | B | B | B | C | B | B | B | B | B | A | B | B |
| Biological | | | | | | C | C | C | B | B | B | C | B | B | A | B | | B | A | A |
| Phosphate | | | | | | 6 | | | | | 5 | | | | | 5 | 5 | 5 | 5 | 5 |
| Nitrate | | | | | | | | | | | | | | | | 5 | 4 | 4 | 4 | 4 |

Table 2.4: Water quality

The chemical GQA indicates 'fairly good' (C) to 'very good' (A) water quality over the last 20 years of available data and biological water quality also ranges from 'fairly good' to 'very good', with improved biological water quality ratings in most recent years. Phosphate levels in this stretch of the river have been classified as 'very high' (5) since 1995 and nitrate levels rated 'moderate' (4) since 2001.

## 2.5 Rainfall

Long-term average (LTA) monthly rainfall data were obtained from the Environment Agency (EA) for the closest gauging station to the site. The gauging station (EA ref: Seaton Mill) is located at NGR SP 908 976, which is some 3 km to the west of the site. The LTA monthly data are summarised below:

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 52 | 40 | 47 | 52 | 49 | 49 | 48 | 60 | 48 | 48 | 54 | 56 |

Table 2.5: Long-term average monthly rainfall data (mm)

The LTA annual rainfall is thus 603 mm.

## 2.6 Waterbodies

Several small waterbodies are located within a 1.5 km radius of the Extraction Area at the locations shown on ***Figure 2***.

The closest such feature to the Extraction Area is a small pool within the site boundary, situated at NGR SP 948 980. A shallow pond is present in the lowest elevations of former mineral extraction located to the southwest of the Extraction Area (see ***Photosheet 1***) at NGR SP 937 970. The elevation of the water is approximately 90 mAOD. The clayey, impermeable nature of the base of the feature, and its shallow depth, are such that it is considered to represent surface water: the first site visit was made after a period of prolonged rainfall and the pool was reduced to around a quarter of the size at the time of the second site visit (after a prolonged dry period).

A marshy area with small pools is shown on the OS map (Explorer Sheet 234) to the north of Wakerley Village, immediately adjacent to the River Welland.

It is noted that an elongate waterbody indicated on the OS 1:25,000 scale map to the southwest of the Extraction Area does not now exist. The feature is man-made and is considered highly likely to have been associated with water management during extraction of ironstone which historically occurred immediately to its west. The ironstone is considered likely to have been situated partially beneath the watertable therefore provisions would have been required to pump water off-site.

## 2.7 Ecology

Details of designated sites of ecological interest have been identified using information from Natural England (formerly English Nature). A Site of Special Scientific Interest (SSSI) known as Wakerley Spinney is situated approximately 600m to the east of the Extraction Area, at its nearest point. The locations of these sites are shown on ***Figure 2***. The SSSI site is sub-divided into two areas and further details are provided in Table 2.7 below.

| | Unit ID | Area | Habitat | Condition |
|---|---|---|---|---|
| Unit 1 | 1000157 | 4.02 Ha | Broadleaved, mixed and yew woodland – lowland | Favourable |
| Unit 2 | 1000158 | 0.32 Ha | Calcareous grassland – lowland | Unfavourable: recovering |

Table 2.7: Wakerley Spinney SSSI

## 2.8 Landfilling

One landfill site (Wakerley Landfill) was identified by the Environment Agency within a 2 km radius of the Extraction Area. It is located some 1.7 km to the northeast of the site and is now closed. The Agency holds no records of the waste type deposited at the site.

## 2.9 Geology

### 2.9.1 Regional

The regional solid geology comprises a vertically extensive sequence of sedimentary deposits of Jurassic Age. A summary of these strata is shown below:

| | |
|---|---|
| Great Oolite Series | Oxford Clay<br>Kellaways Sand<br>Kellaways Clay<br>Cornbrash<br>Blisworth Limestone (3-8 m)<br>Upper Estuarine Series (9-12 m)<br>Basal Ironstone bed |
| Inferior Oolite Series | Upper Lincolnshire Limestone (0-15 m)<br>*Crossi* Bed<br>Lower Lincolnshire Limestone (0-17 m)<br>Lower Estuarine Series (0-5 m)<br>Northampton Sand / Ironstone (0-7 m) |
| Upper Lias | Clay (46–65 m) |

Oxford Clay is the most recent of the Jurassic strata present in the region and occurs some 2.5 km to the east of the Extraction Area. The Great and Inferior Oolite Series constitute the majority of the solid geology to the east of the Extraction Area, whereas the Upper Lias Clay predominates to its west.

The BGS map indicates that the regional dip of strata is east-southeastwards and is very shallow to sub-horizontal. The sub-horizontal dip of all the strata is such that the distribution of formations at outcrop and sub-crop is governed largely by elevation: Lias Clay occurring at lower elevations in valley bottoms whereas the limestone sequence occurs at higher elevations in the east.

The Great and Inferior Oolite Series outcrop extensively on higher ground within the region. Exposures of Northampton Sand occur at higher elevations to the west of this line and have historically been worked for iron ore manufacture. The closest such workings occur immediately to the north and west of the disused Spanhoe Quarry, where an area of over 0.5 $km^2$ is shown on the geological map (Sheet 157) as having been worked.

The Lincolnshire Limestone comprises the economic mineral at the proposed Wakerley Quarry.

Superficial deposits are generally sparse within the region. The most laterally persistent superficial deposit is Boulder Clay which occurs on the highest sections of interfluve areas. The regional geology is shown on ***Figure 3***, which is extracted from BGS sheets 157 and 143.

### 2.9.2 Local

Details of the local geology are well known from published and unpublished data sources, logs of mineral evaluation boreholes and observations of nearby exposures in the quarry to the west of the Extraction Area.

Geological logs of waterwells situated on the southeastern edge of the Extraction Area (NGR SP 948 975, BGS ref SP99/16) and some 700 m to the south of the quarry (NGR SP 946 967, BGS ref SP99/17) penetrated much of the Great Oolite and all of the Lower Oolite Series. A summary of the logs are given below and are included in their entirety in ***Appendix 1***. Locations are shown on ***Figure 2***.

| SP99/16 | Thickness (m) | Depth to base (m) |
|---|---|---|
| Soil | 0.3 | 0.3 |
| Boulder Clay | 5.8 | 6.1 |
| Boulder Stone | 0.9 | 7.0 |
| Light Grey and Yellow Stone | 3.0 | 10.1 |
| Soft Limestone | 0.6 | 10.7 |
| Hard Limestone | 1.2 | 11.9 |
| Medium Limestone | 4.3 | 16.2 |
| Yellow Sand (running) | 0.6 | 16.8 |
| Hard and Soft Limestone | 7.0 | 23.8 |
| Grey Sand – Friable | 0.6 | 24.4 |
| Estuarine Clay | 1.8 | 26.2 |
| Ironstone | 5.5 | 31.7 |
| Lias Clay | 3.0 | 34.7 |

Table 2.9.2a: Summary of geological log SP99/16 (Spanhoe Airfield)

| SP99/17 | Thickness (m) | Depth to base (m) |
|---|---|---|
| Drift | 1.52 | 1.52 |
| Great Limestone | 0.91 | 2.43 |
| Upper Estuarine Series | 12.19 | 14.62 |
| Lincolnshire Limestone (undivided) | 10.97 | 25.59 |
| Lower Estuarine Series | 3.66 | 29.25 |
| Northamptonshire Sand | 4.87 | 34.12 |
| Upper Lias Clay | >0.6 | >34.72 |

Table 2.9.2b: Summary of geological log SP99/17 (Town Wood Farm)

The Lincolnshire Limestone is described within the drill log for SP99/17 as comprising alternating bands of 'hard', 'medium' and 'soft' limestone. This limestone unit is some 11 m thick and overlies the Lower Estuarine Series. The latter comprises a mixture of black sandy clay (0.61 m), grey sand (2.13 m), ganister (0.3 m) and black estuarine clay (0.61 m).

The Northampton Sand underlies the Inferior Oolite Series and between 4.9 and 5.5m was encountered within the boreholes. The laterally and vertically extensive Upper Lias Clay was reached at the base of each waterwell.

Mineral evaluation boreholes were drilled in the area by British Steel (now Corus) prior to 1997 to determine limestone resources within the area consented under the original permission of 1962 and of adjoining land to the south (the disused Spanhoe Airfield). A further programme of mineral evaluation drilling was undertaken by consultants DK Symes Associates in 2000 on behalf of Burghley Estate to assess the quality and thickness of the limestone. Drilling was undertaken in September 2000, and comprised 22 vertical airflush rotary cored boreholes.

In the report produced by DK Symes Associates the Extraction Area is sub-divided into 3 areas, as shown on ***Figure 4***. The Lincolnshire Limestone was recorded at outcrop over the majority of the 1962 permitted area. This is underlain by up to 5 m of fine sands, silts and mudstones of the Lower Estuarine Series, which in turn overlies the Northampton Sand. Representative borehole logs are included as ***Appendix 2***. Detailed information on the nature of the overburden occurring to the south of the surrendered area was not required therefore the boreholes were drilled open-hole to the top of the Limestone. The following interpretation was made:

| | Thickness (m) | Description |
|---|---|---|
| Boulder Clay | 0–6.70 (BH S15) | Grey-green clay, chalky in part with some flints. Apart from localised areas it is restricted to the downthrow side of the Spanhoe Fault. |
| Upper Estuarine Series | Up to 6 | Lies conformably on the Lincolnshire Limestone. Consists of grey, yellow/brown, brown/red silty clays with a thin, nodular ironstone bed at the base. |
| Lincolnshire Limestone | Up to 14.5 | Generally medium-bedded and thinly bedded. Four main limestone types have been identified, occurring in bands of a few cm to several m in thickness. These are:<br>a) Sandy fissile limestones of Collyweston slate type<br>b) Fine-grained limestone<br>c) Oolith/pellet limestone<br>d) Medium to course grained oolites |
| Lower Estuarine Series (LES) | Up to 5 | Comprises fine sands, silts and mudstones. Underlain by weak sandstones, limestones and ironstone of the Northampton Sands. |

Table 2.9.2c: Summary of geological logs from boreholes drilled in September 2000

In the western, central section of the Extraction Area up to 6 m of sands and clays of the Upper Estuarine Series rest unconformably above the Lincolnshire Limestone. The mineral is overlain by a cover of Boulder Clay which attains a maximum proven thickness of 6.7 m. The Upper and Lower Lincolnshire Limestone rarely exceed a combined thickness of 12.2 m within the Extraction Area.

The area is affected locally by several faults, the largest of which is known as the Spanhoe Fault. This trends broadly WSW to ENE and its location is shown on the geological map included in ***Figure 3***. The fault has a downthrow of 4-5 m to the southeast. Other faults exist within the Extraction Area, both parallel to the Spanhoe Fault and with trends SW to NE. The locations of the faults are shown on ***Figure 4***. A consequence of the faulting is that the base of the deposit is inclined: in the northern section of the Extraction Area the effective dip of the limestone is northwards, towards the valley of the River Welland. The inclination of the base of the deposit, based upon cross-section K-E (see ***Figures 4*** and ***5)*** is some 1:30 (ie 0.03). To the south of the Spanhoe Fault the inclination is south eastwards, at an average trend of approximately 1:40 (0.025). The relatively steep inclination of the base of the deposit has implications for groundwater flow, which are discussed in following sections of the report.

Superficial deposits

Within the Extraction Area Boulder Clay is predominantly confined to land situated at the highest elevations and to the south of the Spanhoe Fault. The clay thickens to the east-southeast locally, due to a combination of the southeasterly downthrowing of faults, regional dip and topography.

The thickness of overburden (ie soils and Boulder Clay) varies greatly within the Extraction Area. Overburden ranges from 0 to 2.5 m in the surrendered area to the north (marked red on ***Figure 4***); from 0 to 4.3 m in the yellow area, and from around 1 m in the west to around 11.5 m in the east of the green area.

## 2.10 Hydrogeology

### 2.10.1 Regional

The Lincolnshire Limestone is laterally extensive within the region and forms an aquifer that can store and transmit significant volumes of groundwater. The Lincolnshire Limestone comprises the most significant component of the aquifer system which is situated above the vertically extensive Lias Clay Formation. The physical characteristics of the Lias Clay are such that it restricts vertical groundwater flow hence it forms the base to the active groundwater system in the vicinity of the Extraction Area. The Environment Agency has classified the formations that occur within the region in relation to their aquifer properties, as summarised below.

| Formation | Flow mechanism | Geological classification |
|---|---|---|
| Lincolnshire Limestone | Fissure | Major Aquifer |
| Lower Estuarine Series | Varied | Non-aquifer |
| Northampton Sand | Varied | Minor Aquifer |
| Lias | Varied | Non-aquifer |

Table 2.10.1: Environment Agency classification of aquifers

### 2.10.2 Local

The results of mineral evaluation drilling do not include records of water strikes, and groundwater level monitoring has not been undertaken. Information on groundwater elevations within the Lincolnshire Limestone in the vicinity of the site is therefore based upon records of geological logs from the BGS, observations made during site visits on 14th March and 22nd June 2006 and discussions with personnel with experience of the operations at the former Shotley Quarry, which is situated to the south of the Extraction Area.

The BGS hold records for two boreholes in the vicinity of the Extraction Area (***Figure 2***), located on its southeast boundary (SP99/16) and approximately 700 m to the south (SP99/17). Rest water levels were recorded as follows:

| Borehole | Date of drilling | Rest Water Level (m below | Estimated borehole | Estimated rest water level |
|---|---|---|---|---|

| | | ground level) | elevation (mAOD) | elevation (mAOD) |
|---|---|---|---|---|
| SP99/16 | 1941-2 | 23 | 99 | 76 |
| SP99/17 | 1943 | 20.4 | 98 | 78 |

Table 2.10.2: Rest water levels

The close proximity of borehole SP99/16 to the extraction boundary is such that the groundwater level recorded within it is taken to represent that which occurs beneath the Extraction Area ie approximately 76 mAOD.

The seepages/springs discussed in Section 2.3 all occur at the boundary between the base of the Northampton Sand and the underlying Lias Clay. The seepages represent groundwater discharge from the aquifer system which is partially situated beneath the Extraction Area. It can be assumed, due to the occurrence of springs at the geological contact, that the watertable lies relatively near the base of the Northampton Sand.

There are no instances of seepage from the exposed limestone faces of Shotley Quarry, to the south of the Extraction Area and the settlement lagoons from the former ironstone workings were also dry at the time of both site visits. Discussions with personnel who worked at the former quarry stated that water and its management was never a significant issue in the operation of the site.

### 2.10.3 Conceptual hydrogeology

Within the region the Lincolnshire Limestone and underlying Northampton Sand comprise an aquifer system which is situated overlying the Lias Clay. The clay forms the base of the active groundwater system within the Extraction Area and its immediate surroundings.

Two significant geological controls exist upon the water environment in the vicinity of the Extraction Area:

a) variability in the elevation of the base of the aquifer caused by the sub-parallel series of faults. The inclined nature of the base of the mineral is considered to be a key control on groundwater distribution: Its flow will be governed principally by the geometry of the base of the Northampton Sand.

b) The presence of a significant thickness of Boulder Clay over much of the Extraction Area, which is assumed to have low hydraulic conductivity, will limit the volume of rainfall recharge which can enter the aquifer system within the limestone sequence.

The total volume of water within the groundwater system in the vicinity of the Extraction Area is consequently considered to be relatively small.

The base of the active groundwater system is defined by the upper surface of the Liassic Clay, which forms an aquiclude. The upper limit of the aquifer is assumed to occur within the limestone itself or within the Northampton Sand, thus groundwater can be assumed to be unconfined. The lateral boundaries of the limestone aquifer are defined by the limits of the limestone itself. The northern and western limits of the limestone aquifer thus both occur some 800 m from the boundaries of the Extraction Area.

The watertable is considered to be within the Northampton Sand or near the base of the limestone, with a limited saturated thickness as the seepages to the north of the Extraction Area all occur at the contact between the Northampton Sand and the Lias Clay. There is no evidence of wet ground or seepages at elevations above this contact. The total volume of groundwater within the limestone is therefore considered likely to be relatively small due to the limited area of potential recharge: The presence of Boulder Clay over much of the Extraction Area is likely to preclude the majority of rainfall entering the limestone.

### 2.10.4 Water abstractions

Details of unlicensed and licensed water abstractions have been obtained from East Northamptonshire County Council and the Environment Agency respectively. There are no recorded unlicensed surface water or groundwater abstractions within a 1.5 km radius of the site and no licensed abstractions within a 2 km radius. The nearest public water supply borehole is located to the North of Barnack, some 13 km to the northeast of the proposed extraction area and the Source Protection Zone (SPZ) III, the Total Catchment, of this borehole is located some 3 km to the north of the proposed extraction area (***Figure 6***).

# 3 PROPOSED DEVELOPMENT, RESTORATION and WATER MANAGEMENT

## 3.1 Development

It is proposed to extract limestone from part of the original permitted extraction area of 1962 and land to the south, in the area of the disused Spanhoe Airfield. Part of the original permitted area has been surrendered to provide a cordon to screen the workings. It is proposed that mineral extraction will now take place in the area marked in yellow on the location plan (***Figure 1***).

The mineral will be processed using portable/mobile crushing and screening equipment. The equipment will be sited within the quarry void and re-located as required to suit the various phases of quarry development.

Mineral extraction will commence in the southeastern section of the site and progress broadly clockwise in 5 phases. The proposed phase boundaries are shown on ***Figure 7.*** Extraction will be undertaken to the base of the mineral over the majority of the site. The base of the workings will be inclined eastwards with lowest elevations in the north (c 72 mAOD) and east (c 80 mAOD) of the site.

The quarry will be restored progressively utilising material solely derived from with the site. A landform will be created which is below that of the current contours. The majority of the site will be returned to agriculture, however tree planting will be undertaken to increase the ecological interest of the site. The proposed restoration is shown in ***Figure 8***.

## 3.2 Proposed water management

The water management which will be undertaken during and after mineral extraction will differ. During extraction active management (ie pumping) can be undertaken, if required, to ensure that access is always available, when required, to the working faces. Conversely, after the completion of restoration it will be necessary to manage water passively. The difference in criteria is such that the two phases of water management are discussed separately below.

### 3.2.1 During mineral extraction

The relationship between the lowest elevation of mineral extraction and that of the estimated watertable, based on BGS data, is such that the great majority of the mineral is considered likely to be unsaturated. Based on the BGS watertable elevation of 76 mAOD, the saturated thickness of limestone within borehole SP99/16 (adjacent to the southeastern boundary) is approximately 3 m and within borehole SP99/17 (700 m to the south) it is some 5.5 m. Based on the elevations of the proposed depth of quarrying the only section of the entire development which, it is considered, will be situated beneath the watertable is within Phase 5. The maximum depth of sub-watertable working is anticipated to be restricted to some 1 m (ie floor level of 75mAOD and groundwater level of 76 mAOD). The total area in which this is predicted to occur is small, being some 4 hectares.

The volume of groundwater which will enter the quarry void is anticipated to be small due to the extremely limited depth of sub-watertable working. However, it may be necessary to pump water from the lowest sections of the quarry void to permit access to the quarry faces, particularly after periods of high rainfall and in the winter months when the watertable is anticipated to be at its highest. In addition to groundwater ingress water accumulating within the quarry void will also be derived from rainfall. In the majority of the quarry this is not anticipated to be a problem as the quarry floor is situated above the watertable and will thus be free-draining. However, in the central section of Phase 5 drainage by vertical percolation will not be possible as the quarry floor is situated beneath the watertable. A requirement may thus exist, during the working of mineral beneath 76 mAOD, to remove water from the lowest levels of the quarry void. The volume of rainfall ingress under average and peak conditions has been calculated to permit an assessment to be made of water management requirements.

Average rainfall
The total area of Phase 5 is some 40, 000 m$^2$. Under worst case conditions all of the rainfall would collect in the lowest section of Phase 5 and require discharge. The volumes that may require discharge as a s result of rainfall accumulation are given below:

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly rainfall (mm) | 52 | 40 | 47 | 52 | 49 | 49 | 48 | 60 | 48 | 48 | 54 | 56 |
| Monthly total (m$^3$) | 2080 | 1600 | 1880 | 2012 | 1960 | 1960 | 1960 | 2400 | 1960 | 1960 | 2160 | 2240 |
| Equivalent continuous rate (l/sec) | 0.8 | 0.7 | 0.7 | 0.8 | 0.75 | 0.75 | 0.75 | 0.9 | 0.75 | 0.75 | 0.8 | 0.8 |

Table 3.2.1: Monthly and instantaneous rainfall ingress in Phase 5

The volumes of water which require removal from the quarry void under average conditions are small. The water could be disposed of either by conveying it to sumps excavated into the floor of Phase 5 or to surface, via a long, perforated pipe, on to restored land to its west or unworked ground adjacent to the phase. The naturally free-draining nature of the northern section of the Extraction Area, as evidenced by the absence of ditches, is such that it is anticipated that pumped water could readily infiltrate into the underlying strata.

Peak rainfall
The volume of water generated during storm events would be significantly greater than the average volumes discussed above. An estimate of the volume of water derived during storm events has been made utilising the Rational Formula. The method has been used to determine peak flow rates and total water volumes. The Rational Formula is of the form:

$$Q = 2.78\ Aki$$

Where Q = peak flow (l/sec)
A = rainfall catchment area (m$^2$)
k = run-off co-efficient
i = rainfall intensity for the storm

Storm events with return frequencies of between 2 and 100 years have been used, together with site-specific rainfall intensity data calculated using methods given within the Flood Estimation Handbook. The rainfall intensity data, for storms with durations from 30 minutes to 24 hours, are included in ***Appendix 3***.

The volume of water accumulating within the floor of the quarry void, assuming different pumped discharge rates, has been calculated. For example, if pumping was maintained at 75 l/second the maximum volume of residual water accumulation in the quarry void would be some 4,525 m$^3$. This could all be removed from the void within 24 hours if pumping was maintained at the same rate. A spreadsheet showing the results is included as ***Appendix 4***.

It is not proposed to discharge water off-site at any stage of working. Maintenance of water within the boundary of the site will be achieved by disposal to surface in restored or unworked sections of the site, as discussed above. The use of infiltration ditches and areas of stripped ground will ensure that all pumped water can be recharged in close proximity to its source which will serve to minimise any impact on the nearby water environment. It will only be necessary to undertake active water management during mineral extraction within Phase 5. All other phases of working will be above the watertable and are anticipated to be free-draining. In the event of prolonged periods of wet weather resulting in localised ponding, these waters will be managed by pumping and discharge to other areas within the site boundary.

### 3.2.2 After the completion of restoration

The placement of overburden material will be such that the lowest elevations of the restoration are situated above the watertable therefore resulting in a predominantly dry restoration. Provision has been incorporated into the restoration design to allow the passive drainage of each area by gravity flow to engineered low-points (see ***figure 8***)

A clay-lined pond will be created in the central section of Phase 5 to provide additional ecological interest to the site.

# 4 POTENTIAL IMPACTS and MITIGATION MEASURES

## 4.1 Background

The understanding of the water environment in the vicinity of the Extraction Area which has been derived from the investigation has permitted the identification of potential impacts which may arise from the proposed development. These are discussed in turn below, together with mitigation measures, where appropriate.

## 4.2 Potential impacts

### 4.2.1 Water abstractions

The Environment Agency and East Northamptonshire Council were approached to determined whether licensed and unlicensed water abstractions were present within a 2km radius of the Extraction Area. The organisations confirmed that they held no records of such abstractions.

### 4.2.2 Groundwater flow

The great majority of proposed mineral extraction will be undertaken above the watertable, thus there will be no significant impact upon the watertable or groundwater flow. The removal of a section of the unsaturated zone of the Lincolnshire Limestone aquifer will reduce attenuation of rainfall recharge and thereby modify the existing aquifer characteristics. However, the relatively small area in which this will occur, in relation to that of the whole aquifer, is such that discernible impact is not predicted.

### 4.2.3 Springs/seepages

Several springs/seepages have been identified to the north of the Extraction Area. They occur at the point where more permeable aquifer strata are in contact with the underlying Lias Clay. The great majority of the Extraction Area is situated above the watertable. It is considered that the most significant element of the local groundwater system is the Northampton Sand, which has significantly greater potential to store and transmit groundwater than the limestone. The Northampton Sand will not be affected by the proposed mineral extraction therefore it is considered that impact will not occur upon the springs/seepages. Consequently specific mitigation measures are not proposed.

### 4.2.4 Water quality

In the unlikely event that a spillage of pollutants was to occur on the quarry floor the material would be contained and disposed of in accordance with current best practice. The provision of ‘spill kits’ at strategic locations within the quarry, maintaining the awareness of personnel of the need to contain spills and on-going vigilance will ensure that the potential for pollution incidents to occur is extremely limited.

### 4.2.5 Ecology

The Extraction Area does not contain any water-supported features of ecological interest. It is considered that the area of woodland to the south and east of the Extraction Area is not supported by groundwater as the ground surface is situated some 20-25 m above the local watertable. The absence of discharge of water off-site during the limited phase of sub-watertable working is such that impact upon the external water environment is considered to be highly unlikely. Due to the low perceived level of risk to water-supported ecological features specific mitigation measures are not proposed.

# 5 SUMMARY

5.1 Part of the Wakerley site has the benefit of a phase 1 “active consent” dating from November 1962 issued for the extraction of ironstone and overlying minerals. Half of the original 1962 Permitted Area will be surrendered and the other half is included within the current Planning Application.

5.2 The Extraction Area is located approximately 1 km to the south of Wakerley Village at its nearest point, and some 7 km to the east of the town of Uppingham in Northamptonshire.

5.3 The Extraction Area is situated close to the summit of a hill of low relief, which rises to an elevation of 101 mAOD. Ground elevations decrease steadily northwards to the River Welland, which is situated at an elevation of 35-40 mAOD and some 800 m from the northern site boundary. Ground elevations decrease more gradually to the east and south of the summit of the hill.

5.4 The Extraction Area is situated within the catchment of the River Welland, which rises near Market Harborough in Leicestershire and flows in a northeasterly direction in the vicinity of the quarry. The nearest watercourse to the site is an eastwards flowing stream located approximately 400 m to the south of the proposed quarry. The stream rises within Wakerley Great Wood and flows towards Laxton Hall.

5.5 Seepages/springs occur at three locations to the north of the Extraction Area. They generally occur at elevations of between 50 and 55 mAOD, at the contact between the Northampton Sand and the underlying Lias Clay.

5.6 The regional solid geology comprises a vertically extensive sequence of sedimentary deposits that are of Jurassic Age. Superficial deposits are generally sparse within the region. The most laterally persistent superficial deposit is Boulder Clay which occurs on the highest sections of interfluve areas. The Lincolnshire Limestone comprises the economic mineral at the proposed Wakerley Quarry.

5.7 Within the region the Lincolnshire Limestone forms an aquifer which can store and transmit significant volumes of groundwater. Within the Extraction Area and its immediate vicinity the Lincolnshire Limestone comprises one component of an aquifer system which also includes the underlying Northampton Sand.

5.8 The limestone is present in areas of elevated relief. Boulder Clay overlies the limestone in the areas of highest relief in the vicinity of the site, limiting recharge of the limestone. The saturated thickness of the aquifer is considered to be relatively small due to the occurrence of springs at the contact between the Northampton Sand and the Liassic Clay and the absence of saturated ground or springs above this level.

5.9 There are no recorded unlicensed surface water or groundwater abstractions within a 1.5 km radius of the site and no licensed abstractions within a 2 km radius. The nearest public water supply borehole is located to the North of Barnack, some 13 km to the northeast of the proposed extraction area and the Source Protection Zone (SPZ) III of this borehole is located some 3 km to the north of the proposed extraction area.

5.10 The watertable elevation in the vicinity of the Extraction Area is estimated to be some some 76 mAOD. The maximum proposed depth of mineral extraction is such that the great majority of the site is situated above the watertable, therefore the mineral will be predominantly unsaturated. However, the northernmost section of the site (ie Phase 5) is to be worked to 75 mAOD, consequently some of the mineral will be worked sub-watertable.

5.11 A requirement will exist to remove water from the quarry void when working in the northern section of Phase 5. It is proposed to manage water pumped from the quarry void by disposal to surface entirely within the site boundary. There will therefore be no requirement for off-site discharge.

5.12 After cessation of mineral extraction and the completion of the restoration water management will be passive. The site will be free-draining with a waterbody in the northernmost section of the site.

## 6 CONCLUSIONS

6.1 The understanding of the water environment within the Extraction Area and its vicinity which has been gained from this study has demonstrated that the total volumes of surface water and groundwater within the Extraction Area and its vicinity are small: The mineral comprises the upper part of an aquifer system which has a very limited saturated thickness and lateral extent and which is perched above a significant thickness of clay deposits.

6.2 The great majority of the mineral is situated above the watertable, hence the extant regime will be largely unaffected directly by the proposed development. A limited amount of sub-watertable working will be undertaken in the northernmost section of the Extraction Area.

6.3 It is not proposed to discharge water derived from with the quarry void within the site boundary. Water will be pumped from the floor of the quarry to unworked or restored sections within the confines of the Extraction Area. The use of recharge ditches / trenches and, possibly, larger areas of ground from which overburden has been removed, will promote the infiltration of water to the underlying strata. The retention of water generated from the workings within the confines of the site boundary has been proposed specifically to minimise the potential for impact upon the water environment in the vicinity of the site.

6.4 After the cessation of mineral extraction active water-management will cease. The majority of the restored area will be free-draining with several soakaways incorporated into the restoration to facilitate the ability of rainfall-derived water to enter underground strata.

6.5 The understanding of the water environment in the vicinity of the Extraction Area which has been gained from the study has allowed the identification of potential impacts which may occur upon it as a result of the proposed development. The relatively small volumes of both surface water and groundwater which will be affected by the proposed quarry, and the absence of water-supported features of ecological interest or water abstractions, are such that specific mitigation measures are not proposed.