Wangford Quarry
Limekiln Farm Extension
Hydrogeological Risk Assessment

Final Report
July 2018

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This report describes work commissioned by Chris Pointer, on behalf of CEMEX UK Operations Ltd, by an e-mail dated 19th January 2018. Brendon McFadden, Alice Davis and Susan Wagstaff of JBA Consulting carried out this work.

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Purpose

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1 Introduction

1.1 Project Description
CEMEX UK Operations Limited propose to extend their existing workings at Wangford Quarry, Suffolk. JBA Consulting have been appointed to undertake a hydrogeological risk assessment (HRA) and flood risk assessment (FRA) for the proposed extension site which is known as Limekiln Farm. This report forms the HRA.

Quarrying operations and restoration involve many activities that may affect the hydrogeological or hydrological environment. These activities have been identified, their potential effects assessed, and appropriate mitigating measures outlined.

1.2 Methodology

1.2.1 Description of the Baseline Environment
A baseline description of the local environment was formed through:

- A desktop study of relevant information (see References);
- Consultation with the relevant bodies;
- A site walkover.

The site visit was carried out by JBA Consulting on 21 March 2018 and included:

- Walkover of the proposed extension area;
- Identification of water features;
- Viewing of landfill operations.

1.2.2 Assessment of Impacts
On completion of the baseline description, the following process was undertaken to assess the significance of environmental effects:

- Identification of activities related to the operation and restoration with potential environmental effects;
- Identification of mitigation measures; and
- Assessment of residual effects after taking mitigation measures into account.

The significance of the residual environmental impacts was evaluated using Table 1-1 and Table 1-2 taking three factors into account.

1) Sensitivity of the receiving environment:
- Not sensitive – Low environmental importance;
- Sensitive – Moderate importance, e.g. licenced water supplies;
- Very Sensitive – High importance, e.g. ecologically designated, public water supplies.

2) The potential magnitude (scale or duration) of the effect:
- Negligible – No perceptible change;
- Low – Detectable but non-material change;
- Medium – Material but non-fundamental change;
- High – Fundamental change.

3) The likelihood of that effect occurring after mitigation.
Table 1-1 Potential Significance (Sensitivity v Magnitude)

<table>
<thead>
<tr>
<th>Receiving Environment Sensitivity</th>
<th>Potential Magnitude</th>
<th>Not sensitive</th>
<th>Sensitive</th>
<th>Very Sensitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Not significant</td>
<td>Not significant</td>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Not significant</td>
<td>Minor</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Minor</td>
<td>Moderate</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Minor</td>
<td>Moderate</td>
<td>Major</td>
<td></td>
</tr>
</tbody>
</table>

Table 1-2 Residual Significance (Significance v Likelihood after Mitigation)

<table>
<thead>
<tr>
<th>Likelihood after mitigation</th>
<th>Sensitivity v Magnitude</th>
<th>Unlikely</th>
<th>Possible</th>
<th>Likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Significant</td>
<td>Not significant</td>
<td>Not significant</td>
<td>Not significant</td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>Not significant</td>
<td>Minor</td>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Not significant</td>
<td>Minor</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Major</td>
<td>Minor</td>
<td>Moderate</td>
<td>Major</td>
<td></td>
</tr>
</tbody>
</table>

An example of calculating the significance is a Sensitive environment with a Medium magnitude impact has Moderate Potential Significance. After mitigation the likelihood is Possible, so it has Minor Residual Significance.
2 Proposed Works

The planning application boundary includes the fields containing the proposed area of extraction, an access track, and an area of land within the current extraction site which will be used temporarily until the end of Phase 1 for mineral screening. Throughout this report, the fields containing the proposed area of extraction are referred to as the "site". These fields which fall within the planning application boundary have an area of ~22ha, with the actual footprint of extraction covering an area of ~13.5ha. The total area of the planning application boundary, including the access track and land within the current extraction site is 25.44ha. There are proposed to be six phases of extraction at the Limekiln Farm extraction site. The phasing plans are provided in Appendix A.

Suitably coarse material will be removed from Limekiln Farm and taken to the existing processing plant at Wangford Quarry. The planning application boundary includes a strip of land which will be used to track material from the Limekiln Farm extraction site to the existing processing plant. It also includes an area of the current quarry which will be used to accommodate the overburden from Phase 1 of the Limekiln Farm site. The area in the current quarry will be restored largely as per the current restoration scheme.

Quarrying activities will involve vegetation and soil removal and storage, heavy machinery activity, use of the existing processing plant, mineral storage, and increased traffic flow and human activity. Working shall not be undertaken less than 1m above the highest water table which is equivalent to an elevation of 2.5 mAOD on a level with the top of the site; no workings will be undertaken below the water table and no dewatering will take place. A Flood Risk Assessment has also been prepared to assess the effects of the proposed quarrying on Flood Risk (JBA, 2018). Fuel storage and vehicle maintenance will not be undertaken in the extension area. Likewise, no wastewaters will be generated in the extension area - facilities in the existing quarry shall continue to be used. Potable water for domestic use will continue to be supplied to existing infrastructure via a mains supply.

It is proposed to restore the site to a combination of agricultural land (which is the present usage) and nature conservation habitats. Finished elevations of the excavation will be between 2.5 and 2.9 mAOD with the final land profile leaving a hollow (above the water table). This means that there will be generally significantly more than 1m unsaturated zone to the north - probably a minimum of around 1.4m at the north and around 1.8m at the south of the site. Some sorting of mineral will be undertaken at Limekiln Farm, with fine sands unsuitable for processing being used to regrade the final site and form the sloping sides of the hollow. No material will be imported to the site for restoration.
3 Existing Environment

3.1 Topography, climate and land use

The approximate centre of the extension is at National Grid Reference (NGR) 647680, 277620 with the site boundary shown in Map 1. The site is located 1km south of Wangford, Suffolk and the fields containing the extraction area are approximately 22ha in size (area of proposed extraction ~13.5ha). The total area of the planning application boundary, including the access track and land within the current extraction site is 25.44ha.

3.1.1 Topography and land use

The topography of the main extraction site is fairly flat to slightly undulating (see Map 2 and Photograph 6-1), with the highest elevation in the west and the lowest in the east. The maximum elevation is approximately 14.5mAOD (above Ordnance Datum) in the northwest of the site, sloping down to ~8.5mAOD in the south-east. There is a topographical depression (hollow) in the north of the site associated with a historical sand/gravel pit. The base of the hollow was dry, with no evidence of water ponding in this area. The land use of the main extraction site, on the day of the site visit, was arable.

The current workings at Wangford are west of the Limekiln Farm extension site. The mineral extracted is currently used for concrete aggregate and as sharp sand. As well as containing the main area of proposed extraction, the planning application boundary also encompasses a small area which stretches from the southwestern corner of the proposed extraction site to the existing Wangford Quarry. This strip of land will comprise a track for transporting mineral from the Limekiln Farm extension site to the processing plant in the existing quarry.

Wangford landfill site (no longer active) lies approximately 35m to the west of the proposed Limekiln extraction site. The Minsmere-Walberswick Heath & Marshes SSSI, SPA & Ramsar lies ~348m to the south of the proposed extraction site, with arable farmland and Halesworth Road lying between the two (Photograph 6-2).

No dewatering has ever taken place as part of the quarrying activities at Wangford; all workings are dry and located a minimum of 1m above highest water table. The same conditions will be applied to extraction at the Limekiln Farm extension site.

3.1.2 Climate

The Flood Estimation Handbook (FEH) CD-ROM includes long-term average rainfall data for catchments in the UK. For the smallest catchment containing the site, the Standard Annual Average Rainfall (SAAR) is 590 mm/yr for the period 1961-1990 and 582 mm/yr for the period 1941-1970 (CEH, 2009).
3.2 Geology

A summary of the local geology is given in Table 3-1 and illustrated in Map 3 and Map 4.

### Table 3-1 Summary of geology underlying the site

<table>
<thead>
<tr>
<th>Age</th>
<th>Group</th>
<th>Formation / Member</th>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Superficial Deposits</td>
<td>Lowestoft Formation - Diamicton Till</td>
<td>Soft to firm sandy clay</td>
<td>0 - 2.2m *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lowestoft Formation - Sand and gravel</td>
<td>Fine to coarse sand and gravel</td>
<td>~15m *</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crag Group</td>
<td>A suite of shallow-water marine and estuarine sands, gravels, silts and clays deposited on the southwest flank of the North Sea Basin.</td>
<td>~ 50m **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Palaeogene Thames Group</td>
<td>Silty clay/mudstone, sandy silts and sandy clayey silts of marine origin.</td>
<td>~ 50m **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lambeth Group</td>
<td>Ormesby Clay Formation</td>
<td>~ 20 m **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The Ormesby Clay is variably glauconitic, partly calcareous clay, commonly silty at the base, with a basal gravel bed. The gravelly bed is typically between 0.1 and 0.2m thick, comprising unworn green-coated flints in a matrix of bright green, glauconitic-rich sand or sandy silt. The mudstone is intensively bioturbated, blocky and poorly bedded. It is mostly pale grey to dark greenish grey but also includes a bed of red-grey mudstone and thin bands of grey-green mudstone.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cretaceous Chalk Group</td>
<td>Chalk, with or without flint and discrete limestone, marl (calcareous mudstone), sponge, calcarenite, phosphatic, hardground and fossil-rich beds.</td>
<td>~400 - 560m ***</td>
</tr>
</tbody>
</table>

**Sources:**

* Borehole Log Records (CEMEX, 2017)
**BGS Geological Survey of England and Wales 1:63,360/1:50,000 geological map series, 176 (Lowestoft)
***BGS Lexicon

3.2.1 Superficial (drift) geology

The extension site is underlain by the Lowestoft Formation which is Pleistocene in age and forms an extensive sheet of chalky till, together with outwash sands and gravels, silts and clays in East Anglia. The sands and gravels form lenses within more extensive sandy-clay tills. The majority of the site is mapped as being underlain by a sand and gravel dominated unit of the Lowestoft Formation. The north-western corner of the site is mapped as being underlain by a till dominated unit but there is no extraction planned for this area (it is outside the phasing plan).

A small area in the south-east of the site (extraction phase 4) is mapped as being free from drift.

Borehole logs (Appendix C) show that the area to the north and north-west of the extraction area is overlain by a soft to firm sandy/stoney/chalky clay layer, up to 3.2m thick. Beneath this layer and overlaying the majority of the rest of the site is a varying mixture of sand and gravel strata.
3.2.2 Bedrock geology

The Crag Group underlies the Lowestoft Formation and forms a suite of shallow-water marine and estuarine sands, gravels, silts and clays. The sands are characteristically dark green from glauconite, but weather bright orange with haematite 'iron pans'. The gravels in the lower part of the group are almost entirely composed of flint. Those higher in the group include up to 10% of quartzite from the Midlands, igneous rocks from Wales, and chert from the Upper Greensand of southeast England.

Underlying the Crag Group is the Thames Group (formerly known as the London Clay Group), which comprises silty clay/mudstone, sandy silts and sandy clayey silts of marine origin. This is underlain by The Ormesby Clay Formation, which comprises grey clay bedrock lying unconformably on the Chalk Group.

The Chalk Group underlies these and is defined as chalk with or without flint and discrete limestone, marl (calcareous mudstone), sponge, calcarenite, phosphatic, hardground and fossil-rich beds. The Chalk Group is approximately 400m thick in the Norfolk area to the north of the site, varying based on the extent of erosion.

3.2.3 Soils

Soils in the area are classified by the Soils Survey of England and Wales as belonging to the Newport 4 Soil Association, which comprises well drained sandy soils. This was confirmed during the site visit, where soils were observed to be very sandy and containing a high proportion of flint gravel (Photograph 6-3). The soils also contained an element of clay, leading to some ponding of water at the surface where soils were compacted in tyre tracks. Borehole logs for exploratory holes completed on site (Cemex, 2017) show soils are generally sandy with stones.

3.3 Surface water hydrology

There are no watercourses present within the site boundary. Wangford Landfill site lies approximately 35m to the west of the site boundary and is mapped as being surrounded by a small drainage ditch on its northern and eastern boundaries (it was not possible to observe this ditch when the site was visited on 21st March 2018).

Approximately 360m to the south of the site lies a wetland named Wolsey Creek Marsh. The Marsh contains a number of ditches and extensive reedbeds and is impounded by a large embankment which separates the marsh from Wolsey's Creek, a tidal watercourse contained within an area of mudflat (Photograph 6-4). The upstream end of Wolsey's Creek is defined by a slice gate on Wolsey Bridge (Photograph 6-5), which also forms the downstream limit of the River Wang. Upstream of the sluice gate the Hen Reed Beds lie on the left bank of the River Wang and the Norman Gwatkin Marsh on the right. Wolsey's Creek discharges to the River Blyth Estuary. These three wetlands (Wolsey Creek Marsh, Hen Reed Beds and Norman Gwatkin Marsh) all belong to the Minsmere-Walberswick Heath & Marshes nature area.

Additional water features within 1 km of the main extraction site include:

- A small pond containing reeds adjacent to the unnamed road at Limekiln Farm (Photograph 6-6).
  - Channels have been cut into this pond allowing road drainage to drain to the pond. On the day of the site visit the pond held only a small quantity of water. Groundwater monitoring in nearby boreholes shows the groundwater table to be significantly lower than the pond bed, meaning this pond is unlikely to be groundwater fed, and may be behaving as a soakaway.
• A small pond adjacent to Mardle Road ~500m to the northwest of the site (Photograph 6-7).
  o This pond is located in an area mapped as being underlain by Lowestoft till. Water may be perched above groundwater here as it is a local hollow, with a low permeability bed.
• Four ponds related to a historical quarry ~500m to the east of the site (it was not possible to access these ponds on the day of the site visit).
  o LIDAR data suggests the excavations here may have been in excess of 10m deep. As this area is mapped as being free from drift, the bed of the ponds are considered to lie within the Crag Group, meaning that the water level in the ponds is likely to be an expression of groundwater.

3.3.1 Water level monitoring
Suffolk Wildlife Trust have been monitoring water levels across the three wetlands, Hen Reed Beds, Norman Gwatkin Marsh and Wolsey Creek Marsh since September 2000. The water levels have been monitored using gauge boards, with one installed in each of the wetlands and readings taken weekly, their approximate locations are shown on Map 5. Historically these readings have been used to show the relative changes in water level over time, but following the surveying of the gaugeboards by CEMEX, it has been possible to reduce these levels to Ordnance Datum. This data is available up until the summer of 2016 and is presented in Figure 3-1.

Figure 3-1 Water levels monitored by Suffolk Wildlife Trust

3.4 Catchment descriptors
The FEH gives the Standard Percentage Runoff (SPR) for the catchment containing the site as 22%. The SPR is the percentage of rainfall responsible for the short-term increase in river flow during and/or following a rainfall event (Boorman et al., 1995). 22% is a relatively low SPR suggesting only around one fifth of rainfall rapidly reaching a watercourse.

The Baseflow Index (BFI) for the smallest catchment containing the site is 0.81. The BFI is the total proportion of streamflow made up of baseflow (mostly groundwater input), suggesting that most of the streamflow in the vicinity of the site is made up of baseflow.
3.5 Hydrogeology

3.5.1 Aquifer Classification

The sands and gravels of the Lowestoft Formation and Crag Group have been classified by the EA as a ‘Secondary A’ aquifer - 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 till dominated units of the Lowestoft Formation are classified as a Secondary Undifferentiated aquifer, a designation which is assigned in cases where it has not been possible to attributed either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristic of the rock type.

3.5.2 Aquifer Properties

The Lowestoft Formation and Crag Group are in hydraulic continuity, the boundary between the two being often undistinguishable lithologically. The deposits are permeable having high storage capacity (porosity) and are prone to groundwater fluctuations of between 1 and 2m a year (IGS, 1981). Data from monitoring boreholes to the southwest of the site suggest that seasonal groundwater fluctuations in the vicinity of the current quarry are less than this, with seasonal fluctuations generally between 0.15 and 0.55m (CEMEX, 2013).

There is limited hydrogeological information available for the Thames Group and Ormesby Clay Formation; however, it is known that they have a confining effect on the underlying chalk (EA, 2000). They are not aquifers and are likely to act as aquitards. This means that, due to the poor hydraulic conductivity of the beds and their thickness of up to 70m, there is no effective hydraulic connection between the Chalk Group and the Lowestoft Formation and Crag Group.

The chalk bedrock underlying the whole region is classified as an extensive and highly productive aquifer in which flow is dominantly through fissures and other discontinuities (IGS, 1977). It is for this reason that the EA has classified it as a ‘Principal’ aquifer. Good borehole yields may be between 330 and 980m³/d, and chemically the water is hard but generally good quality (EA, 1997).

Soakaway testing

In February 2018 CEMEX provided results from soakaway tests performed in three trial pits across the footprint of the Limekiln Farm Extension site. The location of the trial pits (TP4, TP5, and TP6) are indicated on Map 5 and a summary of the results is given in Table 3-2. Each of the trial pits was excavated to a depth of 1.2m. The maximum depth of soil recorded in the trial pit locations was 0.4m, with each of the soakaway tests performed within the mineral. One test was performed in each of TP4 and TP6, with two tests performed in TP5. BRE Digest 365 outlines the methodology for soakaway testing and states that the soil infiltration rate (f) should be calculated from the time taken for the water level to fall from 75% to 25% effective storage depth in the trial pit. Given the length of time taken to perform the tests, it was not possible to continue the tests until the 25% level was reached. Each test was performed for a minimum of 2 hours, with the data extrapolated beyond this point. As the data has been extrapolated, a sensitivity analysis has been performed giving the results ±10%. The actual result, should the test have been completed would likely fall somewhere within this range. Calculated soil infiltration rates fall within the range of 0.27 - 1.27 m/d.

Table 3-2 Results of soakaway testing

<table>
<thead>
<tr>
<th>Test Pit</th>
<th>NGR</th>
<th>Test f (m/d)</th>
<th>Mean f (m/d)</th>
<th>Sensitivity analysis f (m/d) 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+10%</td>
</tr>
<tr>
<td>TP-4</td>
<td>647337 277653</td>
<td>0.58</td>
<td></td>
<td>0.64</td>
</tr>
<tr>
<td>TP-5</td>
<td>647766 277466</td>
<td>1.16</td>
<td>1.03</td>
<td>1.27</td>
</tr>
</tbody>
</table>

2018s0106_Wangford_LKF_FINAL 100718.docx
Published values of hydraulic conductivity in literature for fine sand, or silt, clay, and mixtures of sand silt and clay give ranges of 0.001 to 1 m/d (Brassington, 2007). All of the trial pits penetrated deposits dominated by sand and gravel, a clay component was also noted in the upper ground profile in TP4 and TP5.

3.5.3 Monitoring Boreholes

Six boreholes (W07-W12) for groundwater monitoring were installed across the Limekiln site in November 2017 (Map 5), with groundwater levels first measured on 20 December 2017. There have been three rounds of dip measurements taken at all boreholes on-site to date, in December 2017, January 2018 and February 2018 (see Figure 3-2).

Groundwater levels have not exceeded 1.5 mAOD; the highest groundwater level recorded was 1.484 mAOD at W07 on 16th Jan 2018, to the north-west of the site. The lowest levels were observed in the south/south-east of the site at locations W10 and 11 (lowest at 0.3mAOD).

Groundwater levels have been monitored at a location close to the proposed extension site (south-west) at W03 (Map 5), for the original Wangford quarry site since 2002. These groundwater levels are shown in Figure 3-3 and display a typical range of 0.6 to 1.4mAOD.

![Dipped groundwater levels at Limekiln Farm extension site](image_url)
Workings on site will be limited to an elevation equivalent to 1m above the highest water table. As the highest water level recorded close to the site is around 1.5 mAOD (W07 - 16 January 2018), and this water level has not been exceeded in the long-term records at W03 (when the incorrect reading is omitted), workings will be limited to 1m above this level, at 2.5 mAOD.

3.5.4 Groundwater Flow

Groundwater levels measured in January 2018 have been used to create a groundwater contour map at the water table, Figure 3-4. These contours indicate that groundwater flow is in an approximate south-easterly direction, towards the River Blyth (Section 3.6.2).
3.5.5 Groundwater Vulnerability

Groundwater vulnerability mapping produced by the EA suggests that where the Lowestoft Formation is present the groundwater has a medium to high vulnerability to contamination. In areas free from drift, like the south-eastern corner of the extension area, the groundwater has medium to low vulnerability.

Groundwater close to the surface (0 to 10m bgl) in an unconfined sand and gravel aquifer is vulnerable to pollution.

The underlying chalk aquifer is not vulnerable due to the considerable thickness of overburden, including the confining Thames Group and Ormesby Clay Formation directly overlying it.

3.6 Water Abstractions and Discharges

Water abstractions and discharges are mapped on Map 5.

3.6.1 Quarry Abstractions

CEMEX currently have two EA abstraction licences, one for groundwater and one for surface water. The groundwater licence allows for 605m$^3$/d to be abstracted for gravel washing via 20 wellpoints (only one borehole is present) up to 10.7m in depth. The maximum abstraction permissible per year is 105,000m$^3$. The surface water licence allows 1,189m$^3$/d to be
abstracted from Marsh Drain for gravel washing. The maximum abstraction per year is 30,000m$^3$.

Water is abstracted from a groundwater fed lagoon in the west of the existing site for use in the mineral processing plant after which it is returned to this lagoon via a silt lagoon system.

The groundwater abstraction lies within the Catchment Abstraction Management Strategy (CAMS) Groundwater Management Unit: East Suffolk - Confined Chalk. These units are used by the EA to manage groundwater resources. The confined chalk has a status of no water available for licencing (EA, 2017). The quarry borehole is not deep enough to abstract water from the chalk aquifer and there are no plans to drill a borehole that is capable of doing this.

The surface water abstraction lies within the East Suffolk CAMS within the North Suffolk Group. Assessment Point, AP2, is located on the River Wang at Wangford Gauging Station (EA 2017). For assessment point 2 there is no water available for licensing at Q95, and water is available at Q70, and Q50. This means that for new licences: water is only available during periods of median and higher flows. The EA may consider applications for groundwater abstractions on a case by case basis depending on scale and impact on surface water.

3.6.2 Other Licensed Abstractions

The EA holds records of all licensed water abstractions and were contacted to provide details of those located within 2km of the site boundary.

3.6.2.1 Public water supply

Two Essex & Suffolk Water abstraction boreholes lie within 2km of the extension area: Alder Carr, and Quay Lane. Alder Carr lies approximately 280m to the southeast, with the Quay Lane abstraction lying approximately 550m to the east. The Quay Lane borehole is no longer used for public water supply (last used mid-October 1999), though Alder Carr supplies water to Southwold and the surrounding area.

The Alder Carr abstraction well is 5.9m deep, abstracting from the Crag, with a maximum pumped output of 18.9l/s. Water is abstracted all year, with further details given in Table 3-3. Approximate locations of the abstractions are indicated on Map 5. The source protection zones associated with the abstractions are discussed in Section 3.6.4.

3.6.2.2 Private abstractions

There are nine licenced water abstractions (non-public water supply) within 2km of the extension site (including the quarry abstractions), details are given in Table 3-3. Only one of these is located down hydraulic-gradient of the site. It is a groundwater supply located approximately 595m to the southeast of the site and is used for general farming and domestic purposes.
Table 3-3 Groundwater and surface water abstractions within 2km of the extension (2018)

<table>
<thead>
<tr>
<th>Type of licence</th>
<th>Location (NGR)</th>
<th>Distance and direction from site</th>
<th>Use</th>
<th>Max daily abstraction (m³)</th>
<th>Max annual abstraction (m³)</th>
<th>Hydraulic connection to site?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater (Alder Carr)</td>
<td>648000 277180</td>
<td>280m southeast</td>
<td>Public water supply</td>
<td>1630</td>
<td>450000</td>
<td>Yes - located down-hydraulic gradient</td>
</tr>
<tr>
<td>Groundwater (Quay Lane)</td>
<td>648560 277400</td>
<td>550m east</td>
<td>No longer in use</td>
<td>No longer in use</td>
<td>No longer in use</td>
<td>No longer in use</td>
</tr>
<tr>
<td>Surface water</td>
<td>646700 276900</td>
<td>840m southwest</td>
<td>Make up/top up water</td>
<td>1189</td>
<td>30000</td>
<td>No - located on the far side of the R. Wang</td>
</tr>
<tr>
<td>Surface water</td>
<td>646540 278600</td>
<td>1,245m northwest</td>
<td>Spray irrigation direct</td>
<td>327</td>
<td>14700</td>
<td>No - Located near the R. Wang upstream</td>
</tr>
<tr>
<td>Surface water</td>
<td>646450 277650</td>
<td>840m west</td>
<td>Mineral washing</td>
<td>1189</td>
<td>30000</td>
<td>No - Located near the R. Wang upstream</td>
</tr>
<tr>
<td>Groundwater</td>
<td>648950 279000</td>
<td>1,530m northeast</td>
<td>General farming and domestic</td>
<td>20</td>
<td>5600</td>
<td>No - located up-hydraulic gradient</td>
</tr>
<tr>
<td>Groundwater</td>
<td>648400 277100</td>
<td>595m southeast</td>
<td>General farming and domestic</td>
<td>20</td>
<td>5000</td>
<td>Yes - located down-hydraulic gradient</td>
</tr>
<tr>
<td>Groundwater</td>
<td>646400 277700</td>
<td>900m west</td>
<td>Mineral washing</td>
<td>605</td>
<td>105000</td>
<td>No - located up-hydraulic gradient</td>
</tr>
<tr>
<td>Groundwater</td>
<td>646680 278040</td>
<td>760m northeast</td>
<td>General farming and domestic</td>
<td>20</td>
<td>800</td>
<td>No - located up-hydraulic gradient</td>
</tr>
<tr>
<td>Groundwater</td>
<td>646890 278720</td>
<td>1,065m northeast</td>
<td>Spray irrigation direct</td>
<td>218</td>
<td>14000</td>
<td>No - located up-hydraulic gradient</td>
</tr>
<tr>
<td>Groundwater</td>
<td>646100 276400</td>
<td>1,620m southwest</td>
<td>Spray irrigation direct</td>
<td>910</td>
<td>5545</td>
<td>No - located on the far side of the R. Wang</td>
</tr>
</tbody>
</table>

3.6.3 Private water supplies (non-licensed)
Suffolk Coastal and Waveney District Council were contacted as part of this study and confirmed that there are no private water supplies located within 2km of the site.

3.6.4 Source Protection Zones
Groundwater Source Protection Zones (SPZs) are defined by the Environment Agency to protect groundwater in proximity to groundwater abstractions used for drinking water supply or food production. SPZs are available to view online using the EA’s “What’s in your backyard?” mapping viewer, which presently shows the site to lie partly within an SPZ1, SPZ2 and SPZ3.

SPZ1 is the inner zone and is defined as the 50-day travel time from any point below the water table to the source. All groundwater abstractions intended for human consumption or food production have an SPZ1 with a minimum radius of 50m. SPZ2 is the outer zone and is defined by the 400-day travel time from a point below the water table, in some cases depending on the volume abstracted, a default SPZ2 with a minimum radius of 250m applies. SPZ3 is the total catchment zone and is defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source.
As part of this study the EA were contacted in 2018 and asked to provide further information on the mapped SPZs. They advised that the existing SPZs were no longer valid and that they would be updated in 2018.

At present the east of the site lies within a circular SPZ1 which has a 750m radius and appears to be associated with Essex and Suffolk Water's abstraction at Quay Lane. The EA have advised that the abstraction regime in the area has changed, and that when the updated SPZ mapping is updated this SPZ1 will no longer exist. Essex and Suffolk Water have confirmed that there has been no abstraction from the Quay Lane borehole since mid-October 1999.

At present, the southern half of the site lies within a SPZ2 and SPZ3 which appear to be associated with Essex and Suffolk Water's abstraction at Alder Carr. The EA have advised that the abstraction regime in the area has changed and that the SPZs associated with this abstraction are due to be remodelled in the coming year. The newly modelled SPZ is anticipated to be orientated to the north-northwest and have a smaller SPZ2 (the SPZ2 was previously defined as 25% of the capture zone). This means that the majority of the site (if not the entirety) will lie within the SPZ3, with some of the southeast of the site potentially lying within SPZ2.

Alder Carr's SPZ3 presently has a strong north-westerly trend, and the EA have advised that this will be updated to be a north-north-westerly trend, with a slightly shorter tail than is presently mapped, suggesting that groundwater flow is towards the south-southeast. It is understood that Alder Carr abstracts from the Crag Group.

For the purpose of this risk assessment, we will consider the SPZs as the EA have advised that they will appear following the remodelling. We will also adopt the precautionary principle, assuming that the entirety of the Limekiln Farm site lies within the SPZ3 and that a proportion of the southeast of the site lies within the SPZ2 (which once the SPZs are re-modelled may or may not be the case).

The EA Position Statement N8 - Physical disturbance to aquifers in SPZ1 (The Environment Agency's approach to groundwater protection, 2018) states: 'Within SPZ 1, the Environment Agency will normally object in principle to any planning application for a development that may physically disturb an aquifer' (Environment Agency, 2017). Though part of the site lies within an existing SPZ1, the EA have advised that this SPZ1 is now redundant and will no longer exist once the SPZ mapping has been updated. Therefore, it is considered that Position Statement N8 will not apply to the proposed extraction at Limekiln Farm, as no such restriction applies to activities within SPZ2 or SPZ3.

The EA Position Statement N11 (EA, 2018) - Protection of resources and the environment from changes to aquifer conditions states: "For any proposal that would physically disturb aquifers, lower groundwater levels, or impede or intercept groundwater flow, the Environment Agency will seek to achieve equivalent protection for water resources and the related groundwater-dependent environment as if the effect were caused by a licensable abstraction." However, given that the site is not proposed to intersect the water table there should be minimal impact on the functioning of the aquifer.

### 3.6.5 Licensed Discharges

There is one licenced discharge in the vicinity of the site located 1.4km to the northwest and associated with a sewage works.

The quarry does not currently directly discharge any process water to the ground or to the surface water environment and does not anticipate doing so for the foreseeable future. All waters generated on site due to wheel washing and grading are directed to the settlement lagoons in the west of the main Wangford Quarry site. The settlement lagoons are in series and partially supplied by a spring which discharges into the upper lagoon - this maintains the water level throughout the year.
3.7 Sites of interest

3.7.1 Ecologically designated sites

The Minsmere-Walberswick Heath & Marshes, of which Wolsey Creek Marsh is part, lies to the south of the proposed extension. This has a patchwork of designations including SSSI, SPA, SAC and Ramsar, a summary of which is shown in Table 3-4 and Map 6. All site information has been taken from the Joint Nature Conservation Committee (JNCC) website www.natureonthemap.org.uk/. None of the designations state that the sites are groundwater dependant.

Table 3-4 Environmentally Sensitive Sites

<table>
<thead>
<tr>
<th>Designation</th>
<th>Site Code</th>
<th>Description</th>
<th>Condition</th>
<th>Minimum distance from extension site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minsmere-Walberswick Heath &amp; Marshes SSSI</td>
<td>1001860</td>
<td>Fen, marsh, swamp - lowland.</td>
<td>54.90% Favourable 40.58% Unfavourable</td>
<td>348m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Recovering 3.38% Unfavourable - No change</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.28% Unfavourable - declining</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.50% Partially destroyed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.36% Destroyed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minsmere-Walberswick SPA</td>
<td>UK9009101</td>
<td>Heath, woodland, marsh, mudflats.</td>
<td></td>
<td>348m</td>
</tr>
<tr>
<td>Minsmere-Walberswick Heath &amp; Marshes SAC</td>
<td>UK0012809</td>
<td>Annex I habitats: annual vegetation of drift lines and European dry heaths.</td>
<td></td>
<td>1,645m</td>
</tr>
<tr>
<td>Minsmere-Walberswick Ramsar</td>
<td>UK11044</td>
<td>Largest continuous stand of reedbeds in England and Wales. Contains Annex II Species Vertigo angustior.</td>
<td></td>
<td>348m</td>
</tr>
</tbody>
</table>

The groundwater of the Lowestoft Formation and Crag Group will be in connection with the surface waters of the marshes. The surface water levels within the Minsmere-Walberswick Heath & Marshes are controlled by the EA and Suffolk Wildlife Trust using a series of sluice gates. These activities may therefore impact groundwater flow beneath the extension site, depending upon what water level is maintained. It is likely that part of the natural regional discharge of groundwater is to the surface waters to the south of the site. However, some of this may also be to the River Wang and the Blyth Estuary. Water levels in the tidal River Blyth are monitored by the EA at Blythburgh and indicate that water levels in the estuary fall to around -0.5mAOD, which is lower than water levels in Wolsey’s Creek of around -0.3 to -0.4 mAOD.

The existing quarry and proposed extension also lie within the Suffolk Coast and Heaths Area of Outstanding Natural Beauty. This designation protects heathland, reed beds, salt-marsh and mud-flats.
3.7.2 Wangford Landfill Site

Wangford Landfill Site, managed by Viridor Ltd., lies adjacent to current mineral workings, west of the proposed Limekiln Farm extension (Map 6). The landfill is fully lined and was used for municipal waste, commercial and industrial waste (excluding liquids and asbestos) since the early 1990s (P. Fenton, 2010, pers. comm. 17 June). A windrow composting facility is contained within specific phases and landfill gas electricity generation equipment is also installed on site (SCC, 2006). Information on the Viridor website (https://blog.viridor.co.uk/2015/04/10/viridor-landfill-closures-confirmed/ uploaded 10/04/15, accessed 29/01/2018) indicates that the site closed to waste acceptance on 31st March 2015 and underwent a period of restoration completed in 2016.

Observations of the landfill site during the site visit (21 March 2018) found the site to be covered in boreholes for the collection of landfill gas and not yet fully restored (Photograph 6-8).

A historical landfill site named Wangford No.1 lies adjacent to the site managed by Viridor, approximately 410m to the northwest of the proposed extraction site at Limekiln Farm. Wangford No.1 landfill site was an unlined landfill used for the disposal of household, commercial and industrial waste. Leachate from the landfill site is known to be entering groundwater beneath the site (Local Environment Agency Plan - East Suffolk, June 1997). Limited groundwater chemical data obtained from the network of boreholes on and around the site have been provided by CEMEX. This data has been examined as part of this investigation and there is no evidence to suggest that groundwater beneath the Limekiln Farm site is currently being impacted by contaminant leachate from the landfill.

If landfill leachate were migrating beneath the site, ammoniacal nitrogen concentrations would be expected to be highest closest to the landfill site. Unfortunately, ammoniacal nitrogen was only recorded within three monitoring wells around the Lime Kiln Farm site; W07, W11, and W12. W07 and W12 are not located immediately downgradient of the landfill site so are unlikely to display evidence of contamination from the landfill, a concentration of 0.11 mg/l was recorded in W11 at the south of the Lime Kiln Farm site. A concentration of 0.11mg/l is not particularly high, however it is important to note that this based upon a single set of data. Water chemistry data is also available from a number of monitoring boreholes within the current quarry which is closer to the landfill site. Ammoniacal nitrogen concentrations of ~1-1.5 mg/l have been recorded on a number of occasions within W01 (~70m from the landfill site). On one occasion a value of 2.5mg/l was recorded in W03. These values could be indicative of landfill leachate, and it is possible that landfill leachate could migrate beneath the site in the future.
4 Conceptual Model

4.1 Existing Environment

The Environment Agency defines a conceptual model as "a description of how a hydrogeological system is believed to behave" and its development as "an iterative or cyclical process of development and testing in which new observations are used to evaluate and improve the model." (Environment Agency, 2002, p.4.1-2). In this assessment, the conceptual model also considers the relevant sources, pathways and receptors which are key to this assessment.

Based on analysis of the information described above, Figure 4-1 summarises the hydrogeological conceptual model of the proposed Wangford Limekiln Quarry.

Figure 4-1 Conceptual Model (vertical scale highly exaggerated)

The main features of the conceptual model are as follows:

- The main extension site covers an area of 22ha with extraction proposed over ~13.5ha, to the east of the existing CEMEX Wangford Quarry.
- The topography of the extension falls from 14.5mAOD in the northwest to 8.5mAOD in the south-east.
- The soils are well drained and sandy.
- The extension site will be excavated for sands and gravels from the unconsolidated Lowestoft Formation and Crag Group. In the region, these can be up to 20m and 50m thick respectively.
- The Thames Group (~50m thick) and Ormesby Clay Formation (~20m thick) are clay-rich deposits underlying the sands and gravels.
- Chalk bedrock underlies the whole region.
- Recharge rates to the Lowestoft Formation and Crag Group are high due to the high permeability of the soils and near surface sediments.
- Runoff flows are very small.
- The Lowestoft Formation and Crag Group are considered to be in hydraulic continuity.
- Groundwater flow within the shallow aquifer (Lowestoft Formation) and the Crag Group both appear to be in a south-easterly direction.
• Groundwater of the Chalk Group is not hydraulically connected to the Lowestoft Formation or Crag Group due to the low permeability and thickness of the intervening Thames Group and Ormesby Clay Formations.
• The groundwater beneath the site is vulnerable to contamination.
• Water is abstracted from a groundwater fed lagoon in the west of the existing quarry at Wangford for use in the mineral processing plant after which it is returned to this lagoon via a silt lagoon system. CEMEX currently hold two Environment Agency abstraction licences, one for groundwater and one for surface water.
• No workings at Wangford Quarry are currently undertaken below the water table, and no dewatering takes place. Extraction at Limekiln Farm will continue to be limited to a minimum of 1m above the highest water table, meaning extraction will be undertaken to a minimum elevation of 2.5 mAOD.
• Including Wangford Quarry itself, there are ten licenced groundwater abstractions (non-public water supply) within 2km of the extension.
• The public supplies abstract from the Lowestoft Formation and/or Crag Group; it has been assumed that this is also the case for the other licenced groundwater abstractions, as the Crag Group underlies the entirety of the study area.
• There are no private water supplies located within 2km of the site.
• Though the extension site is currently mapped as presently lying within groundwater SPZs associated with two public water supplies, the EA have given more up to date information suggesting most of the site will lie within an SPZ3 with potentially some of the site (south-west) lying within an SPZ2. The assessment has been undertaken on this assumption.
• Groundwater discharges locally to Wolsey’s Creek, Walberswick Heath & Marshes, and the Blyth Estuary and public water abstraction borehole at Alder Carr. The level of discharge may be indirectly controlled by the sluices (which regulate the surface water levels in the Marshes) and abstraction rates at Alder Carr.
• Minsmere-Walberswick Heath & Marshes are described as being supported by rainfall and spring discharges, they will most likely receive groundwater from the Lowestoft Formation and the Crag to the north (up-gradient). Overall control is likely to be the sluices locally and sea level more distantly.
• There are no surface water courses within the site boundary. There is one pond to the south of the extraction site at Limekiln Farm, though this appears to be a soakaway which takes road drainage and is perched above groundwater levels. The nearest watercourse to the site is the ditch surrounding Wangford Landfill site to the west.
5 Assessment of Impacts

5.1 Source-Pathway-Receptor
An impact can only occur if all three elements of the Source-Pathway-Receptor model are present. The sources are detailed in Section 5.2 below and the receptors are detailed in Section 5.3. The pathway between the source and the receptor is the unsaturated or saturated zones within the subsurface and any connection to the surface.

Mitigation measures are recommended in Section 5.3.2.1, these aim to remove the source or, in circumstances when this is not possible, remove the pathway before a receptor is impacted. Impacts during the working life of a quarry are temporary, while those post-restoration are permanent. This has been taken into account during the assessment.

5.2 Potential Impacts

Construction and Operation
It has been assumed that, due to the area being a quarry extension (as opposed to a new quarry) construction activities (stripping of topsoil and creation of bunds) will be a continuation of the existing operational activities.

During operation of the site, the recharge to groundwater may increase as there will be no vegetation on the site. The active use of machinery on site once soils have been stripped may result in increased risk of contamination from vehicle oils/fuels. It is anticipated that the extraction works will last around 11 years.

Restored Scenario
With the exception of landscaping, there will be no significant site works during the restoration phase. During the restored scenario the presence of soil on site will reduce the contamination risk. The presence of vegetation on site is likely to result in recharge of a similar magnitude as at present, especially if restoration is to be to the same land use as at present, which is currently arable. There could be some limited changes to recharge if the restoration vegetation is to nature conservation.

Following restoration, machinery used on site for arable farming will be the same as used at present. Agricultural chemical usage will be similar to that at present (possibly less if the restoration includes nature conservation areas), but the vulnerability of the aquifer will be slightly higher, and attenuation may be lower due to a thinner unsaturated zone. However, most attenuation is likely to be in the more organic rich soil zone. Restoration to nature conservation could result in lower contamination risk due to less usage of agricultural inputs and potentially fewer vehicle movements on site. Overall the situation of the site following restoration will be very similar to that at present. Restoration to nature conservation would be lower risk than agriculture, but both may be higher risk than the current situation due to the thinner unsaturated zone.

5.2.1 Groundwater Impacts
The potential impacts identified for the groundwater environment are:

- Modification of groundwater resources available for supply in the local area (including reduction/increase in recharge);
- Alteration of groundwater flow paths;
- Change in groundwater quality;
- Increased groundwater vulnerability.

The principal mechanisms which could lead to these potential impacts are:

- Construction/operational phase:
- Compaction of sediment - reduces the permeability resulting in reduced groundwater recharge and increased surface runoff;
- Stripping of soil - increases groundwater vulnerability by decreasing the unsaturated zone thickness;
- Storage of soil - increases the potential for soil erosion and sediment-laden runoff leaving the site;
- Mineral extraction - increases the groundwater vulnerability by decreasing the unsaturated thickness and potentially increases groundwater recharge as a void is created with limited runoff;
- Ponding of surface waters - increases the potential for contamination to enter groundwater and increase surface water runoff or recharge depending upon local topography;
- Vehicle use and refuelling during the excavation - increases the possibility of hydrocarbon contamination due to leaks and spills.

- Restored scenario:
  - The unsaturated zone thickness will be permanently reduced;
  - Ponding of surface waters - increases the potential for contamination to enter groundwater and increase surface water runoff or recharge depending upon local topography;
  - Vehicle use and refuelling - will be similar to the current arrangement (i.e. agricultural use), so the risk of hydrocarbon contamination due to leaks and spills will be similar to present baseline conditions.

Though water chemistry data suggests that leachate contaminant is unlikely to be passing beneath the Limekiln Farm extension site presently (based on a limited data set), the fact that it may do so in the future cannot be ignored. However, given that all extraction will be from the unsaturated zone, works on site are unlikely to impact any future migration of landfill contaminants within the subsurface.

5.2.2 Surface Water Impacts
There will be no impacts to surface waters on site as there are no surface waters on site.

There will be no impacts to surface waters off-site, as the works on site will not change the surface water environment off site.

5.3 Potential Receptors
The following potential receptors have been identified:
- Licenced water supplies (non-public water supply);
- Public licenced water supplies - Alder Carr;
- Private water supplies (if present);
- Minsmere-Walberswick Heath & Marshes SSSI;
- Minsmere-Walberswick Heath & Marshes SPA and Ramsar.

5.3.1 Potential impacts on water supplies

5.3.1.1 Increased risk of contamination
The extraction will increase groundwater vulnerability by decreasing the unsaturated zone thickness. This may increase the risk of any contamination at the surface within the extension site reaching water supplies. The water supply most at risk is the Alder Carr abstraction as it is located closest to the site, down-hydraulic gradient from the site, and is used for public water supply. All but one of the other identified water supplies are located up-gradient of the extension site or are hydraulically separated. The other abstraction located down-gradient of
the extension is used for general farming and domestic use, this abstraction has a small increased risk.

The majority of the site will lie within SPZ3 with some potentially lying in SPZ2, defined as the total catchment and 400-day travel time areas respectively. This suggests that any contamination entering the aquifer at the Limekiln Farm site would take over 400-days to reach the Alder Carr abstraction during which time it would be subject to attenuation within the aquifer. The slow migration of contamination through a sand and gravel aquifer with significant storage provides the time for remediation prior to the contamination leaving the site.

5.3.1.2 Alterations to the recharge pattern
Creating a void in the surface topography may increase total amount of recharge to ground as there will be little to no run-off from within the confines of the excavation. The time it takes for infiltration at the surface to reach the groundwater table could also be reduced given the removal of part of the unsaturated zone and subsequent reduction in travel time. During construction and operation (prior to restoration) when there is no vegetation on site, there may be enhanced recharge as vegetation limits recharge during the growing season.

The replacement of soils on the surface during restoration could play a part in reducing the rate of infiltration. It is proposed to reconstruct the upper ground profile using reject material which is typically fine sand, and this may reduce the rate of infiltration from the present situation, however the total amount of recharge will not change from the present situation.

There may be a greater amount of recharge during the excavation phase, as there will be no vegetation present in the void. However, following restoration to either arable or nature conservation uses the presence of vegetation may result in recharge rates similar to those prior to excavation.

5.3.2 Potential impacts on Minsmere-Walbersick Heath and Marshes

5.3.2.1 Increased risk of contamination
Groundwater flow is likely to naturally discharge to Wolsey Creek Marsh as it is located down the hydraulic gradient from the site. The removal of part of the unsaturated zone will increase groundwater vulnerability hence the potential contamination risk to the marshes may be increased. Given the proposed use of the site, sources of contamination are limited to oils and fuels from vehicles and machinery used on site.

There may be increased vehicle and machinery usage on site during the excavation phase to facilitate mineral excavation. However, following restoration to arable or nature conservation vehicle usage on site is likely to be similar to that as at present. It is noted that to the south of the site there is a pond at Limekiln Farm which appears to accept road drainage which potentially drains to the underlying groundwater aquifer, acting as a soakaway. This road drainage is potentially a more significant source of contamination than the activities on site and is closer to Minsmere-Walberswick Heath and Marshes.

5.3.2.2 Alterations to the recharge pattern
Recharge volumes could be increased during the construction/operation stage as the vegetation (which limits recharge during the growing season) will be removed. The rate of recharge could be increased due to the removal of part of the unsaturated zone, but could also potentially be decreased by the placement of reject fines at the surface (Section 5.3.1.2).

Given the fact that water levels within the marshes are controlled by sluice gates, and that the ultimate recharge volume and rate of recharge are unlikely to change significantly, the impacts of any alteration to the recharge volume or rate of recharge on site is likely to have negligible impact on the marshes.

5.4 Mitigation Measures
Mitigation measures either reduce the likelihood of an event’s occurrence or reduce the magnitude of its consequences. Proposed mitigation measures are detailed in the following sections.
Pollution prevention – Environmental protection equipment will be inspected a minimum of once a week in line with CEMEX inspection protocol and enforced by the Quarry Manager. Pollution prevention strategies on site will comply with guidelines for pollution prevention produced jointly by DEFRA and the EA (www.gov.uk). Pollution Prevention Guidelines (PPGs) produced jointly by the EA, the Scottish Environment Protection Agency and the Environment and Heritage of Northern Ireland have now been revoked but may also provide best practice guidance. Measures to prevent chemical pollution will include:

- Storage – chemical, fuel and oil stores will be not be sited in the extension site.
- Vehicles and refuelling – standing machinery will have drip trays placed underneath to prevent pollution by oil/fuel leaks. Where practicable, refuelling of vehicles and machinery will be carried out on an impermeable and contained surface in one designated area well away from any watercourse, drainage channel and outside of the extension area.
- Maintenance – only emergency maintenance to plant will be carried out in the extension. This should preferably be carried out on an impermeable surface in one designated area well away from any watercourse or drainage channel. However, it is recognised that broken-down vehicles may require maintenance at the point of breakdown.
- Toilet facilities – no on-site toilet facilities will be installed in the extension.
- Contingency Plans – an up-to-date drainage plan will be maintained, hazards identified and a contingency plan drawn up. Appropriate spill kits or absorbent materials will be held on site in the event of leaks, spills or run-off from fire-fighting.

Modification of groundwater levels – all workings will remain at least 1m above the highest water table, ensuring that there is no requirement for dewatering. Once the quarry is restored with sand and topsoil, the total amount of recharge is not likely to be significantly different to that under the present conditions. Infiltrating water may, however, recharge the groundwater quicker due to a thinner unsaturated zone, or recharge the aquifer slower due to the presence of a lower permeability upper ground profile; it is unlikely this will have any significant effect on groundwater levels beneath the site or in the vicinity of the marshes. The seasonal groundwater level variation is recorded as being fairly small to the south-west of the site in the location of the current quarry. This is because the site has sediments with a high available storage (specific yield/drainable porosity). The proximity of the site to the estuary (sea level provides a lower limit for groundwater levels) and the managed reed beds (artificially maintained water levels) also limits the groundwater level variation.

Impediments to surface water flows causing ponding – There are currently no surface water features on site. After restoration, surface water runoff from the site will be minimal due to the topography and high permeability of the surface sediments.

Compaction of sediment – Land surrounding the immediate quarry area will be fenced off, bunded or otherwise demarcated, to prevent inadvertent intrusion from heavy plant.

5.5 Residual Impacts

Residual impacts (impacts remaining after mitigation) are summarised in Table 5-1 for both operational and restoration phases. Assuming that the proposed mitigation measures are adopted, and that best practice is followed, the quarry extension is assessed as having no significant impact on any of the identified receptors.

The impact on the Public Water Supply of Alder Carr and the general farming abstraction to the east is limited in terms of flow and level as excavations will be limited to 1m above the highest water table. The mineral extraction is not thought to have significant short-term impacts on recharge during construction and operation, which will last around 11 years (though recharge could be higher and more rapid given the absence of vegetation), and long-term recharge rates following restoration are likely to be similar to those at present. The distance to the water table will be reduced, but the placement of fines at the surface may reduce infiltration rates. Given the limited potential for contamination during excavation and use of a PPP the risk of water quality impacts is also low.
The borehole and surface water licenced abstractions to the south/west of the River Wang are not likely to be impacted by the activities on site due to the River Wang forming a hydraulic boundary. Surface and groundwater abstractions located to the north and west of the extension are up hydraulic gradient of the site. Hence, they are not likely to be impacted by the activities on site. Though information of private water supplies was not provided by the council, the fact that the change to recharge pattern is limited, and the risk of pollution following mitigation measures is limited, it is unlikely that any private water supplies present in the locality will be negatively impacted by excavation at Limekiln Farm.

Minsmere-Walberswick Heath & Marshes SSSI and Minsmere-Walberswick Heath & Marshes SPA and Ramsar are located down hydraulic gradient of the site in the superficial deposits. However, the likely limited impact on the recharge and quality of groundwater means that the impact on the marshes is not likely to be significant. There is potentially migration of historical contamination from the landfill site up-gradient of the site, beneath the site, to the marshes down-gradient. This is unlikely to be significantly changed following the mineral excavation, as the excavation will not reach the water table. The removal of some of the unsaturated zone during excavation may result in small changes to recharge during excavation, however these are likely to be limited. Potentially during excavation recharge could be higher due to removal of soil and vegetation with bare ground allowing higher infiltration (due to lower evapotranspiration). This would provide further dilution of any contamination with rainwater. However, the effect is likely to be limited. Following restoration and re-vegetation the situation would be similar to that at present.
### Table 5-1 Summary of Hydrogeological Receptors and the Significance of Potential Impacts during the Operational Phase and Restored Scenario

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Sensitivity</th>
<th>Potential Impact</th>
<th>Magnitude</th>
<th>Potential Significance</th>
<th>Likelihood after Mitigation</th>
<th>Residual Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Licenced Water Supplies</strong></td>
<td>Sensitive</td>
<td>Groundwater level and flow</td>
<td>Negligible</td>
<td>Not significant</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groundwater contamination</td>
<td>High</td>
<td>Moderate</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
<tr>
<td><strong>Public Licenced Water Supply (Alder Carr)</strong></td>
<td>Very Sensitive</td>
<td>Groundwater level and flow</td>
<td>Negligible</td>
<td>Minor</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groundwater contamination (during operation)</td>
<td>High</td>
<td>Major</td>
<td>Unlikely</td>
<td>Minor</td>
</tr>
<tr>
<td><strong>Private Water Supplies</strong></td>
<td>Sensitive</td>
<td>Groundwater level and flow</td>
<td>Negligible</td>
<td>Not significant</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groundwater contamination</td>
<td>High</td>
<td>Moderate</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
<tr>
<td><strong>Minsmere-Walberswick Heath &amp; Marshes SSSI</strong></td>
<td>Very Sensitive</td>
<td>Groundwater level and flow</td>
<td>Negligible</td>
<td>Minor</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groundwater contamination</td>
<td>Medium</td>
<td>Moderate</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
<tr>
<td><strong>Minsmere-Walberswick Heath &amp; Marshes SPA and Ramsar</strong></td>
<td>Very Sensitive</td>
<td>Groundwater level and flow</td>
<td>Negligible</td>
<td>Moderate</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groundwater contamination</td>
<td>Medium</td>
<td>Minor</td>
<td>Unlikely</td>
<td>Not significant</td>
</tr>
</tbody>
</table>
6 Conclusions

Quarrying involves activities that have the potential to affect the hydrogeological environment of the area. These activities have been identified and an assessment of their potential effects made.

The operational phase potentially poses the greatest risk to the groundwater regime because it will involve constant earthworks and frequent vehicle movements. There will also be minimal vegetation and no soil within the excavation area.

The main potential impacts to the hydrogeological environment are: alteration of recharge pattern, reduction in groundwater quality and increased groundwater vulnerability.

Groundwater receptors in the area are the licenced water supplies, Alder Carr public water supply, Minsmere-Walberswick Heath & Marshes SSSI and Minsmere-Walberswick Heath & Marshes SPA and Ramsar Site.

Proposed mitigation measures include the use of a Pollution Prevention Plan and the limitation of all workings to at least 1m above the highest water table.

With the proposed mitigation measures in place it is considered that the quarry extension will have no significant impact on the majority of the identified receptors and could have a potentially minor impact on the public water supply at Alder Carr with regards to groundwater contamination during operation. There would be no significant long-term impact following restoration.
Appendices

A  Phasing Plans
Phase 1
Years of Production = 1 year
Cumulative Years of Production = 1 year

The remaining 32,000m³ of stripped overburden materials from the Phase 1 working area shall be used to restore the existing Wangford Quarry extraction area.

3,000m³ of stripped soils and 14,000m³ of stripped overburden materials from the 'Phase 1' working area shall be used to create a series of 2m and 3m high bunds along the site perimeter to provide visual screening.

All 'dry screening' of excavated mineral shall be undertaken in the existing Wangford Quarry excavation until the end of Phase 1 at which time there will be sufficient space to accommodate the excavation and dry screening operations.

The remaining 32,000m³ of stripped overburden materials from the Phase 1 working area shall be used to restore the existing Wangford Quarry extraction area.
At the end of Phase 1 the mobile 'dry screening' plant shall be relocated from Wangford Quarry to the base of the Lime Kiln Farm working area where it shall remain for the life of the quarry development.

Once sufficient space has been created in the Phase 1 working area, 38,000m³ of fine sand materials produced in the screening of the Phase 1 mineral shall be relocated to the west of the working area as part of the site's ongoing restoration.
The remaining 2,000m³ of stripped soils and 19,000m³ of stripped overburden from the Phase 2 working area shall be used to restore the Phase 1 working area in accordance with the site's restoration design.

1,000m³ of stripped soils and 9,000m³ of stripped overburden materials from the Phase 2 working area shall be used to complete the site's 2m high screening bund.

49,000m³ of fine sand materials produced during the 'dry screening' of the Phase 2 mineral deposit shall be used to backfill the Phase 1 and Phase 2 working areas.
4,000m³ of stripped soils and 16,000m³ of
stripped overburden materials from the Phase 3
working area shall be used to restore the Phase 2
working area in accordance with the site’s
restoration design.

73,000m³ of fine sand materials
produced during the 'dry screening' of the Phase 3
mineral deposit shall be used to
backfill the Phase 2 and Phase 3
working areas.
69,000m³ of fine sand materials produced during the ‘dry screening’ of the Phase 4 mineral deposit shall be used to backfill the Phase 3 and Phase 4 working areas.

3,000m³ of stripped soils and 6,000m³ of stripped overburden materials from the Phase 4 working area shall be used to restore the Phase 2 working area in accordance with the site’s restoration design.

64,000m³ of fine sand materials produced during the ‘dry screening’ of the Phase 4 mineral deposit shall be used to backfill the Phase 3 and Phase 4 working areas.
The northern quarry faces shall be developed to their final face positions to release additional restoration materials before being restored with fine sand, overburden and soil materials.
66,000m³ of fine sand materials produced during the 'dry screening' of the Phase 5 mineral deposit shall be used to backfill the Phase 4 and Phase 5 working areas.

5,000m³ of stripped soils and 35,000m³ of stripped overburden materials from the Phase 5 working area shall be used to restore the Phase 4 and Phase 5 working areas in accordance with the site’s restoration design.

Phase 5
Years of Production = 2 years
Cumulative Years of Production = 8 3/4 years

Lime Kiln Farm Extension
Proposed Method of Working
End of Phase 5

Legend
- Planning Application Boundary
- Limit of Extraction
- Removal of Overburden
- Removal of Sand and Gravel
- Areas Awaiting Restoration
- Fine Sand Backfill Awaiting Restoration
- Final Restoration Areas
- Screening Bunds / Edge Protection
- Temporary Quarry Access Routes
- Direction of Quarry Development
The northern quarry faces shall be developed to their final face positions to release additional restoration materials before being backfilled with fine sand and restored with overburden and soil materials.
56,000m³ of fine sand materials produced during the ‘dry screening’ of the Phase 6 mineral deposit shall be used to backfill the Phase 5 and Phase 6 working areas.

4,000m³ of stripped soils and 63,000m³ of stripped overburden materials from the Phase 6 working area shall be used to restore the Phase 5 and Phase 6 working areas in accordance with the site’s restoration design.
Stripped soils and overburden materials comprising the site’s screening bunds shall be removed and used to restore the remainder of the quarry in accordance with the site’s restoration plan.