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Mick George Limited

Report No. K0438-BLP-ENV-R-001
March 2023

Watlington Quarry Oak Field Extension

Hydrogeological Impact Assessment (HIA)

MICK GEORGE

BYRNELOOBY
AN ayesa COMPANY

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1 Introduction

1.1 Background and Risk Assessment Objectives

ByrneLooby (BL) has prepared this Hydrogeological Impact Assessment (HIA) for the extension to the Watlington Quarry site into the Oak Field area to support the application for a planning permission. This HIA is in response to the Environment Agency's comments on the planning application (FUL/2021/0007) in which concerns were made regarding the consideration of the impacts of the proposed dewatering. The Environment Agency specifically highlight the impacts on the Spring Pit Pond to the north of the site, as well as the lakes filling past quarrying voids to the east of the site that are used for abstractions for spray irrigation licences.

The HIA considers the impacts of the proposed works, namely the dewatering of the superficial Tottenhill Gravel Member to enable the dry extraction of sand and gravel mineral at Watlington Quarry. It will also consider the wider impacts on the surrounding surface water features and the regional Principal Aquifer of the Sandringham Sands to the east. The impact on water quality from the proposed operations has also been taken into account. If imported inert wastes are utilised in the restoration the requirement and specification for any pollution prevention measures will be confirmed in a future Environmental Permit application.

The water availability at the site for the superficial deposits is outlined in the Environment Agency's abstraction licencing strategy for North West Norfolk[1]. It states the following:

"Localised areas of sand and gravel (secondary aquifer) can be found in the North West Norfolk ALS area. Where these overlie principal aquifers the licensing policy for the underlying principal aquifer GWMU will apply. Where they lie within areas classed as 'unproductive strata' they will be treated on a case by case basis but are more likely to follow the surface water strategy for the catchment subject to local conditions and impacts."

Mick George are proposing to excavate and remove an estimated 748,000 tonnes of sands, gravels and 300,000 tonnes of clay on the land identified in Figure 1 (MIN206). The site will require the importation of inert material in order to restore the site back to appropriate levels upon completion of the quarrying operations. It is expected that some 800,000 m3 of material will be required to restore the site to a level that approximates with existing ground level.

2 Baseline Conditions

2.1 Site Setting

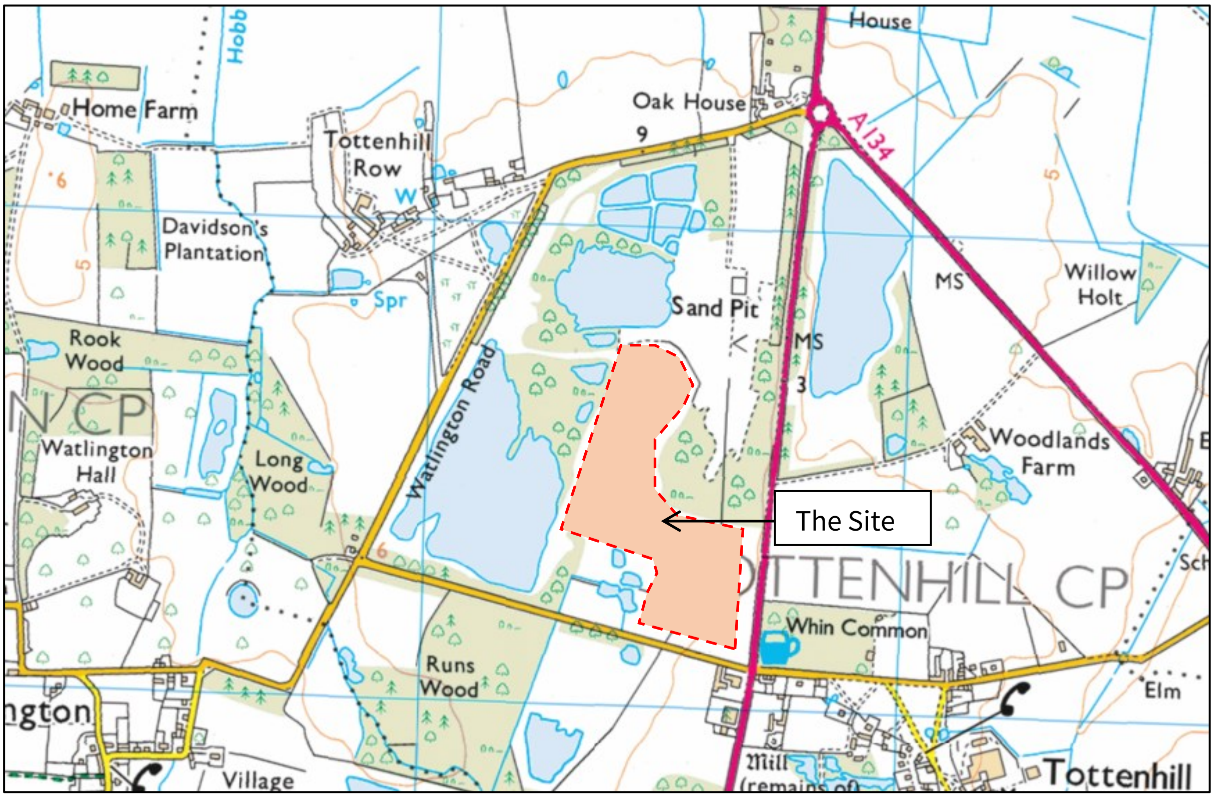
The proposed site (hereinafter known as "the site") for the Watlington Quarry extension is 10.5 hectares, located at Watlington Quarry, between Tottenhill Row and Woodlands Farm. The site is

[1] Environment Agency 2017, North West Norfolk abstraction licensing strategy. 227_10_SD01 version 7

situated approximately 6.4km to the south of King's Lynn in Norfolk at National Grid Reference TF 634 115 (Figure 1). The land is classified as Grade 3 in the Agricultural Land Classification scheme.

The site is adjacent to a previously quarried site, now a pond and the current extraction area MIN76 which are both located to the west of the site. Ponds and silt lagoons around the perimeter of the site are the restored legacy from these on-going processes and are being used as an integral component of the sand and gravel process. The current processing plant will be used which is to the north of the site.

Figure 1 Site Location and Extraction Area



Watlington and the surrounding area is formed by a rise in topography towards the south above a historically reclaimed fenland where the ground rises from approximately 2mAOD up to 12mAOD. This rise is formed by the presence of the Sandringham Sands and Chalk outcrops which were not previously eroded by the fluvioglacial network which deposited the Tottenhill Gravels. The site area itself is at 10.9-8.2AOD in the north and central sections and then falls towards the south of the site to 7.5-8.5AOD with the exception of the south-east corner which rises again form 9.0-10.8AOD.

2.2 Geology

The geology at the site is based on BGS GeoIndex, BGS (1995) and RMC (1991) site investigations. The geological sequence in the vicinity of the site comprises;

Superficial Sediments

- Alluvium (within the former fenland areas)
- Tottenhill Gravel Member

- Nar Valley Clay and Nar Valley Freshwater Beds

Bedrock

- Kimmeridge Clay

The site's geology comprises Tottenhill Gravels overlying Kimmeridge Clay (Drawing 10312-001-01 and 10312-002-01). There is alluvium to the west of the site near the Spring Pit. To the south and east of the site, the Tottenhill Gravels and Nar Valley Deposits give way to Glacial Till to the south and the Sandringham Sand Formation in the east.

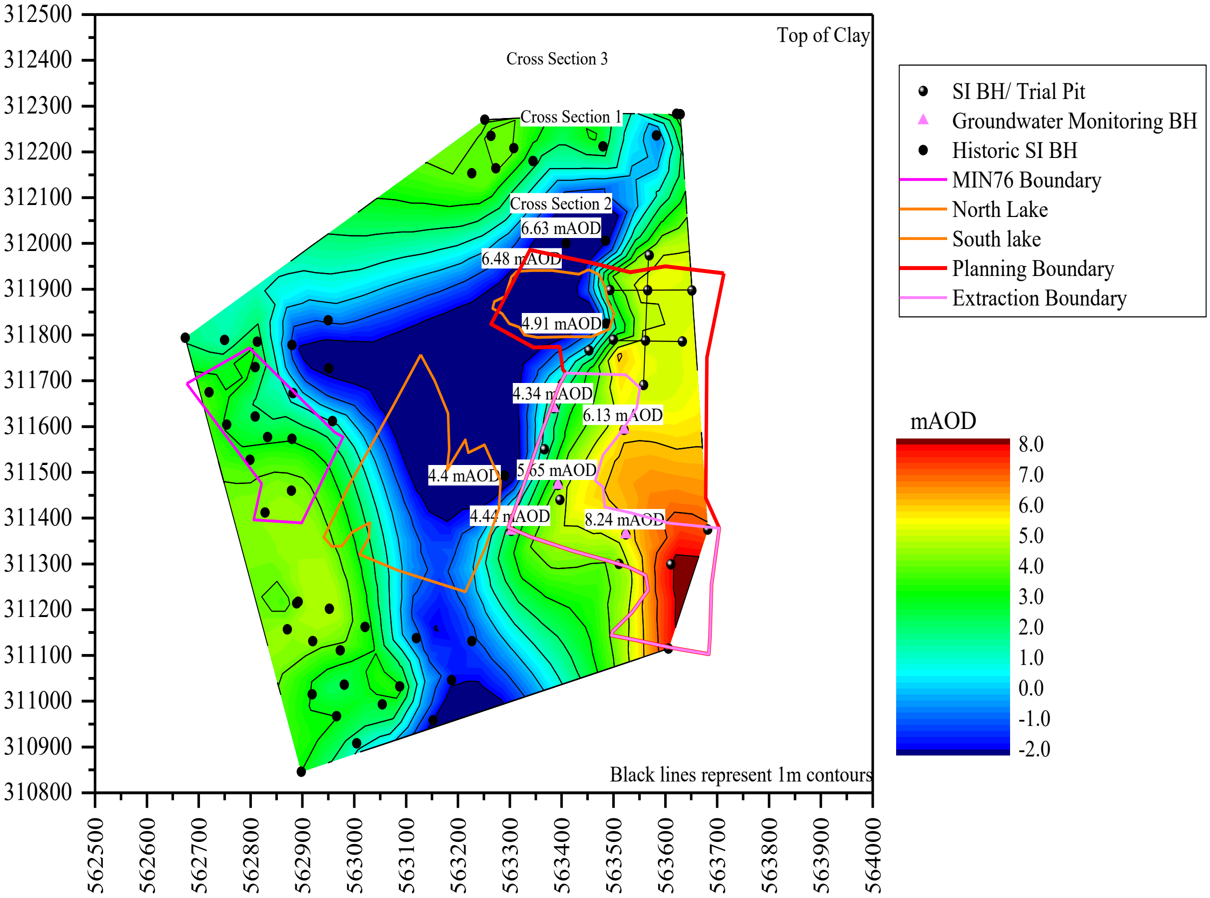
The Tottenhill Gravels as well as the underlying Kimmeridge Clay comprise the mineral formations to be quarried, the extracted clay will be used to supply local flood defence networks, lining of lagoons and capping of landfill sites. The British Geological Survey describes the Tottenhill Gravel Member as a complex sequence of sands and gravels, dominated by flint. In the Tottenhill area, the Tottenhill Gravel Member unconformably overlies silts and clays of the Nar Valley Clay and the Nar Valley Freshwater Beds.

There is a sharp lithological change between the Tottenhill Gravels and the Nar Valley Formations. These comprise a succession of fluvial and marine deposits including salt marsh, peat, clay, silt and sand deposits. The Nar Valley Clay and Nar Valley Freshwater Beds are encountered sporadically across the site, but have not been identified at the extension area.

There is an equally sharp lithological change between the Tottenhill Gravels and the Kimmeridge Clay Formation. The Kimmeridge Clay Formation comprises dark brown-grey to black, organic rich, fissile mudstone with occasional hard, thin carbonate-cemented horizons.

There is a regional south easterly dip in the bedrock in which the surface of the Kimmeridge Clay would be expected to outcrop at approximately 10mAOD; however, the surface of the Kimmeridge Clay has been modified by fluvial erosion and the deposition of the Tottenhill Gravels. However, the Kimmeridge Clay does outcrop above the fenland in the order of 3 - 5mAOD.

Figure 2 Interpolated Kimmeridge Clay Surface within the Application Area



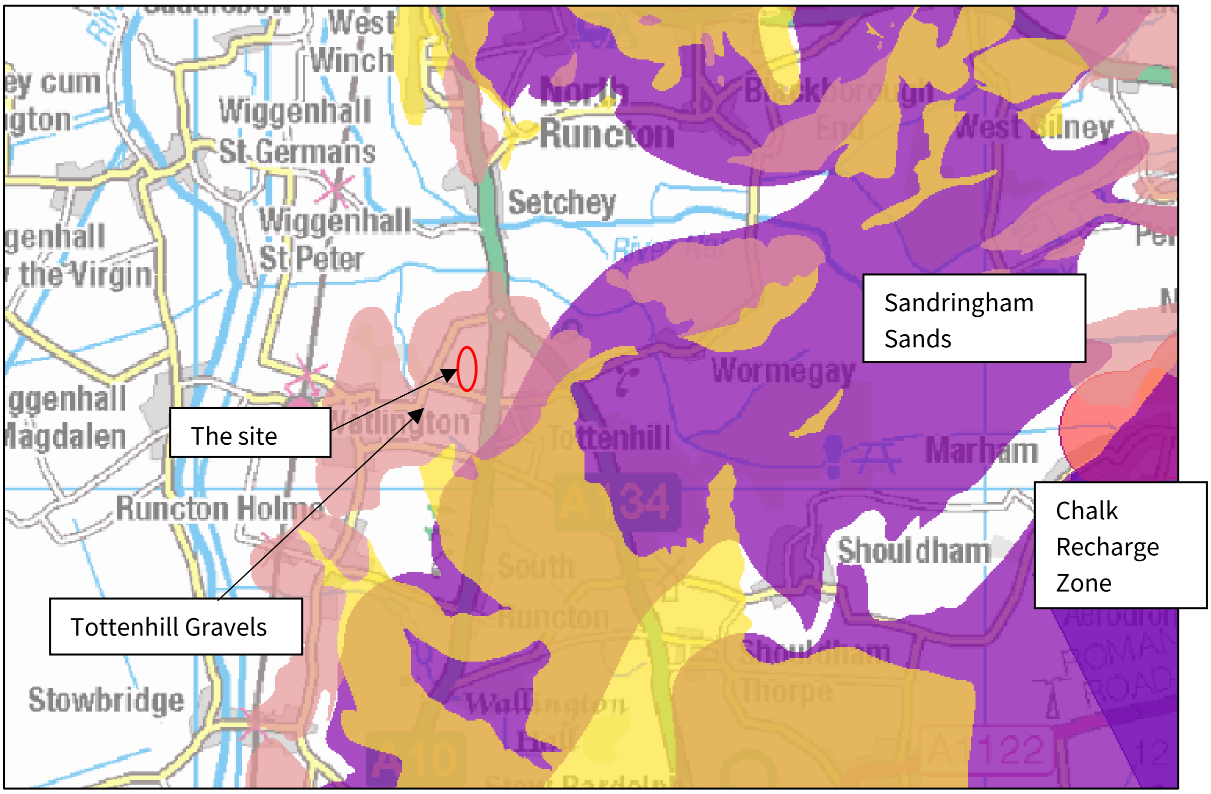
Due to its long history as a sand and gravel resource Watlington Quarry has been subjected to extensive ground investigation in the past. The information these investigations have provided has been collated and the surface of the Kimmeridge Clay has been interpolated (Figure 2). This clearly shows a fluvio-glacial channel incised into the clay surface in the area of the quarry.

Site investigations have identified a rise in the Kimmeridge clay surface in the south east corner of the proposed excavation site. Adjacent to the valley feature resulting from fluvio-glacial processes immediately to the west of the site. The elevated clay surface is potentially home to a localised depression which gives rise to deeper depth of saturated mineral and higher groundwater levels as water is channelled down to the valley feature. These depressions in the surface of the Kimmeridge Clay are associated with localised thickening of the superficial deposits and may require groundwater management and dewatering as depths reach 2m in the south-easterly area around BH1.

2.3 Hydrogeology

The Kimmeridge Clay and the Nar Valley sediments to the north of the site are classified as Unproductive Strata.

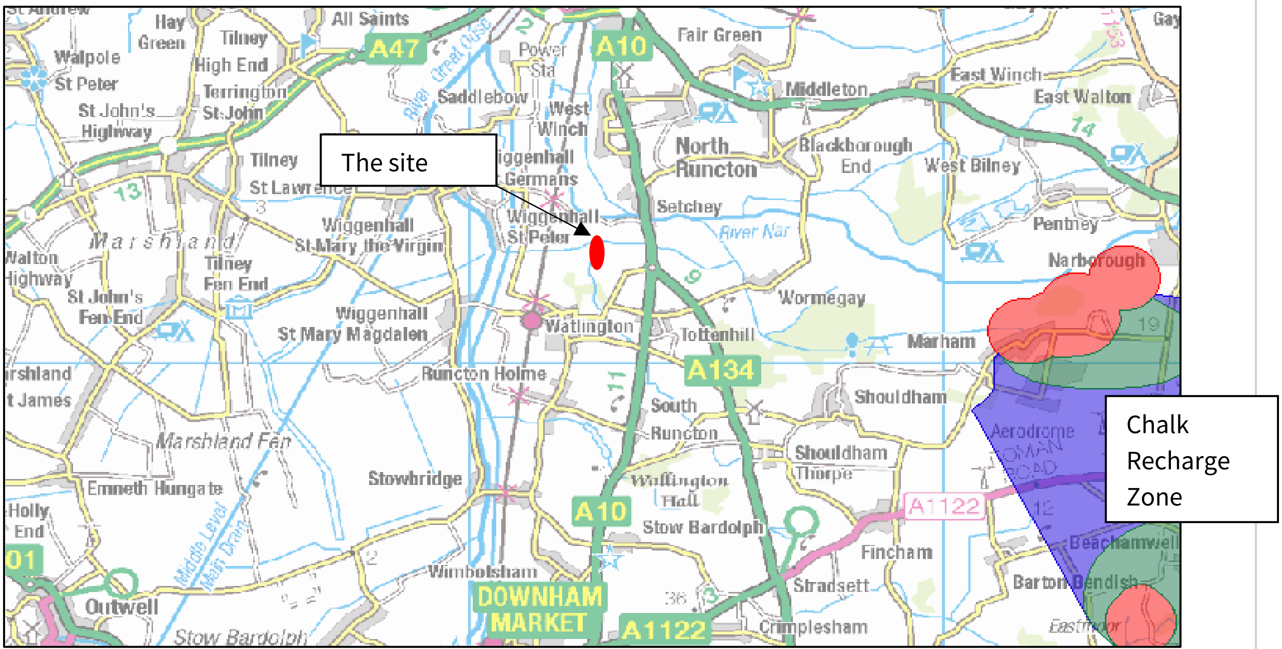
Figure 3 Superficial and Bedrock Aquifer Status



Key: Principal Secondary A Secondary B Secondary (undifferentiated) Unproductive

The Tottenhill Gravels and the Sandringham Sands Formation are classified as Secondary A and Principal Aquifers respectively (Figure 3). The site is not located within a source protection zone (SPZ), the closest of which is associated with the West Melbury Marly chalk abstraction some 8.8km to the east at Narborough. These abstraction points are physically and hydrogeologically separate from the gravel deposits (Figure 4).

Figure 4 Groundwater Source Protection Zones



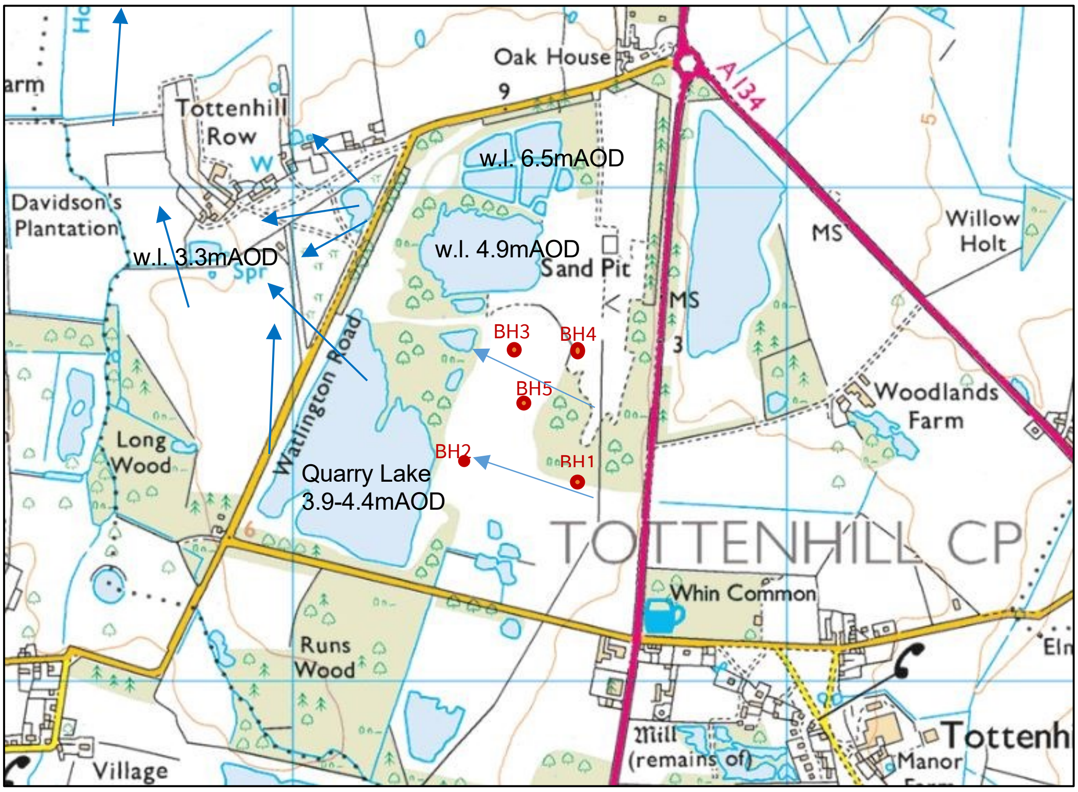
Inner zone (Zone 1) Outer zone (Zone 2) Total catchment (Zone 3)

Groundwater discharges to a series of spring lines where the Kimmeridge Clay surface outcrops at the surface, such as the spring at Spring Pit close to Tottenhill Row. This spring discharges via a series of ponds and ditches to Hobbs Drain.

Groundwater within the Nar Valley Formation and Alluvium is within the fenland area, where the water level is artificially managed to near ground level.

The site hydrogeology is controlled by topography, the Kimmeridge Clay surface and artificial ponds associated with quarrying activities with recharge directly to the site and from the south/southeast. There is a hydraulic gradient from southeast to northwest, towards Spring Pit and possibly to the North of Oak House (Figure 5 and Figure 6). Locally the groundwater flow is controlled by the elevation and shape of the Kimmeridge Clay.

Figure 5 Groundwater Flow Direction and Surface Pond Elevation



For the natural and unbunded ponds the water level will come to an equilibrium in continuity with the surrounding groundwater system in the Tottenhill Gravels. This can be seen with the quarry lake level being very similar to the groundwater levels in borehole BH2, which is adjacent to the quarry lake.

There is a small amount seasonal variation in groundwater levels, in the range of 50cm or so, as shown by Figure 6, with the highest groundwater levels in March as would be expected after winter recharge of groundwater. BH1 has the highest groundwater levels and is located where the clay surface is higher. Data for the depth of saturated zone was taken in March and July of 2017 as these were the annual minimum and maximum of groundwater level. The seasonal variations in depth of saturated zone (Figure 7 and Figure 8) are also minor as these are directly influenced by the top of the Kimmeridge clay surface so groundwater is confined to the sands and gravels above.

Figure 6 Groundwater Levels mAOD

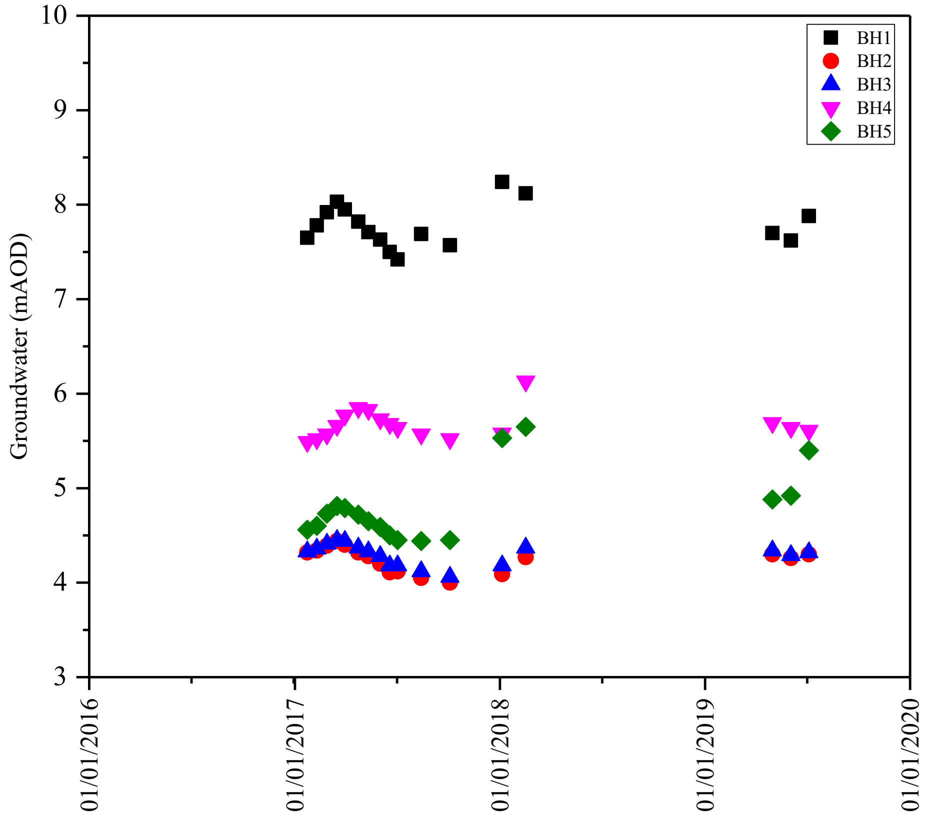


Figure 7 Depth of Saturated Zone March 2017

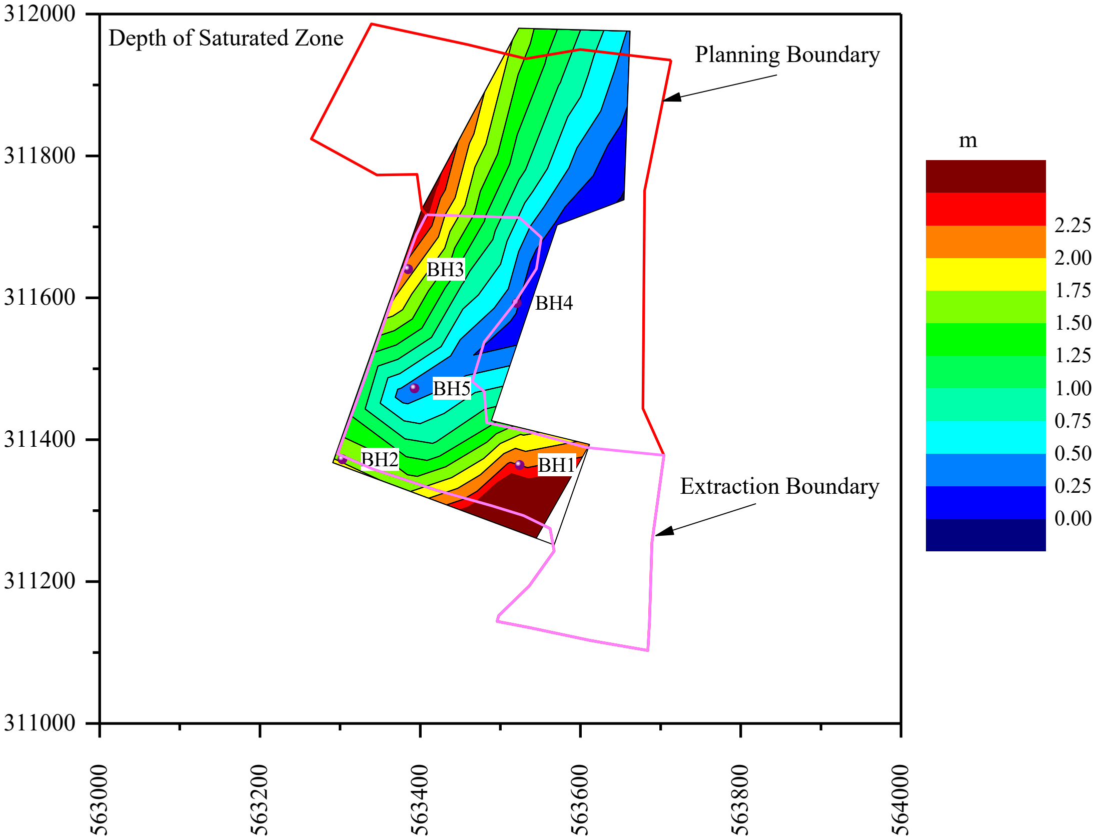
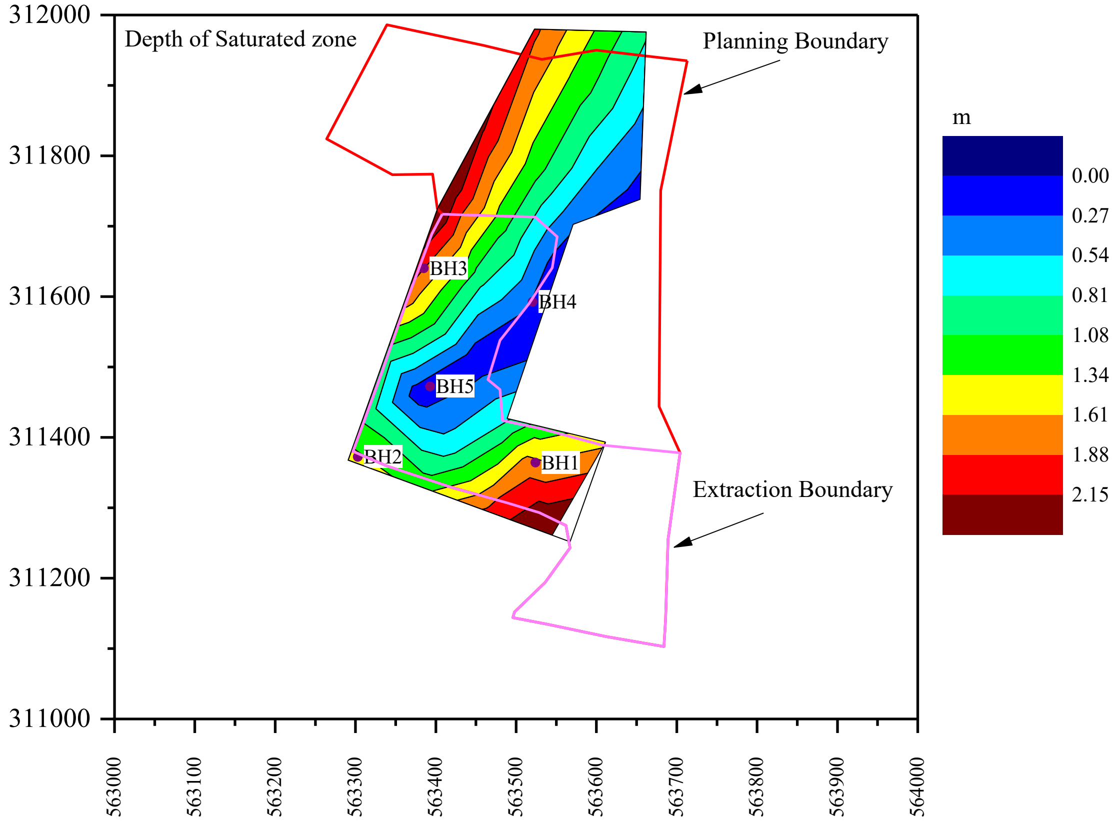


Figure 8 Depth of Saturated Zone July 2017



Although the overall groundwater flow across the site is from the south/southeast to the north/northwest, there may be some localised variations due to the presence of small, localised depressions within the surface of the Kimmeridge Clay. Borehole BH1 shows a greater saturated thickness than BH4 or BH5 (Figure 7 and Figure 8), suggesting groundwater flow does not move directly from BH1 to either BH4 or BH5, but potentially more towards the west or southwest first, then back in line with the general groundwater flow for the area.

The excavation itself will not affect the groundwater levels or flow. As dewatering is required then, without any mitigation, groundwater levels and flow would be expected to be changed, especially to the west and northwest of the proposed working area. Water levels in the adjacent pond to the west of the proposed excavation at 3.9-4.4mAOD are consistent with the groundwater levels within borehole BH2, showing that the pond is most likely in continuity with the groundwater.

Groundwater recharge around the south-eastern and southern sides of the proposed excavation can therefore be readily intercepted to prevent it entering the excavations into the Tottenhill Sands. This water would then be diverted around the existing lagoons as per the current practices without any significant change to the flow patterns thereby maintaining the same recharge to any down-gradient springs and ponds.

2.4 Chemical Status

The groundwater in the Tottenhill Sands under the proposed excavation is a calcium bicarbonate solution with secondary calcium sulphate, consistent with expectations for the site setting and host geology (Table 1). Heavy metals and metalloids are negligible and typically below detection limits. Concentrations are below both Drinking Water and Environmental Quality Standards.

There is only one substance in excess of EQS and DWS, namely the agricultural fertilizer ammonium, which can be derived from both manure and artificial additions.

The mineral extraction process is not expected to discernibly change groundwater quality as the only component in the groundwater is the clay and silt fraction of the host geology through which the groundwater is already in equilibrium with. Given that the clay and silts are already derived from the host ground, then any suspended solids returned to the ground will not affect groundwater quality.

In the event that groundwater management is required, any significant impact is limited to the west and northwest of the site in the zone where the base of the Kimmeridge Clay is depressed (Figure 2).

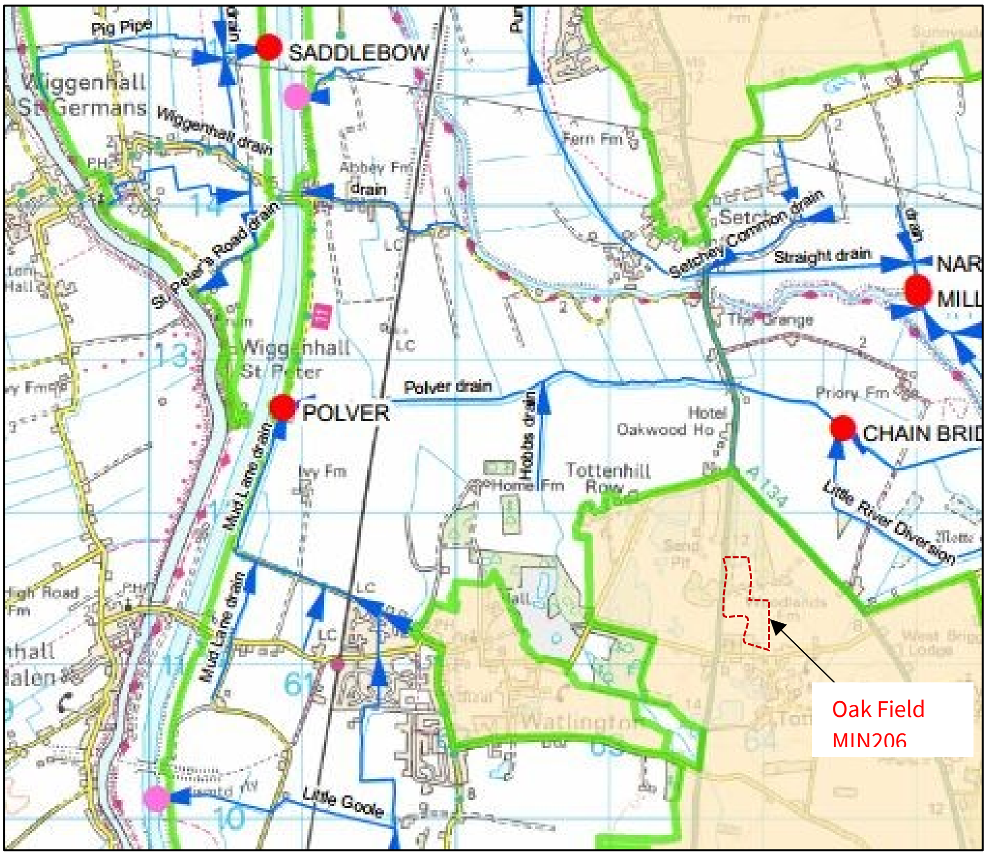
Table 1 Groundwater Quality (May 2019)

Parameter	Units	BH 1	BH 2	BH 3	BH 4	BH 5
pH		8.3	7.8	Dry at 4.34mAOD	7.5	8.0
Electrical Conductivity	µS/cm	540	730		530	700
Ammoniacal-N	mg/l	4.4	4.0		4.0	15
Calcium	mg/l	100	110		75	89
Magnesium	mg/l	5	5		3	6
Sodium	mg/l	15	16		13	19
Potassium	mg/l	3	3		3	9
Chloride	mg/l	9	47		10	23
Sulphate	mg/l	34	76		49	61
Alkalinity	mg/l	200	120		130	350
Iron	µg/l	130	110		94	140
Manganese	µg/l	<1	3		4	7
Zinc	µg/l	<1	3		<1	<1
Cadmium	µg/l	<0.08	<0.08		<0.08	<0.08
Chromium	µg/l	<1	<1		<1	<1
Copper	µg/l	4	3		<1	3
Nickel	µg/l	<1	2		<1	<1
Lead	µg/l	<1	<1		<1	<1
Selenium	µg/l	2	<1		<1	1
Mercury	µg/l	<0.01	<0.01		<0.01	<0.01

2.5 Hydrology

The site is located 1.4km south of the River Nar within the River Nar valley, an area of low-lying drained land at an elevation of 2 to 3m AOD. The surface water features and groundwater elevation are controlled by the artificial drainage channels which all ultimately drain to the Polver Drain, via Hobbs Drain to the north. The site itself and the low-lying area surrounding the site and around the ridge falls within the Inland Drainage Board (IDB) area of the East of Ouse, Polver and Nar IDB, as shown on Figure 9.

Figure 9 East of Ouse, Polver and NAR IDB District Plan



Green Line - IDB Drainage Board area boundaries

Hobb's Drain is located approximately 400m northwest of the site and drains a substantial catchment to the west of the site and is set in a shallow valley. Hobb's Drain flows northwards to join the Polver Drain which, in turn, flows eastwards to join with the River Great Ouse.

There are a number of small and large ponds hydrogeologically cross-gradient and down-gradient of the restored quarry (Figure 5). The adjacent ponds/lakes to the northeast, north and west of the site are either used within the washing process or are just voids from previous extractions many of which are under the control of the operator.

3 Proposed Works

3.1 Dewatering Logistics

The proposal is the extract the full thickness of the Tottenhill Gravel Member sands and gravels at the Oak Field site, as well as 300,000 tonnes of the underlying Kimmeridge Clay. Groundwater has been shown to be present within the sands and gravels, perched upon the very low permeability Kimmeridge Clay. The excavation work, and associated dewatering, will be conducted in a phased approach, and as such on part of the site will be an open excavation at any one time.

Groundwater elevations for the Tottenhill Gravels are in the order of 0 – 2.6m above the top of the Kimmeridge Clay in the proposed operational area, with the thickest saturated zones being in the southeast and northwest corners of the area. This is due the surface elevation of the Kimmeridge Clay rising in the centre, east and northeast of the working area, thus channelling the groundwater to the northwest, southwest, and southeast. Dewatering is therefore expected in these areas of the proposed excavations for the operator to work the mineral dry.

Calculations are required to delineate a radius of influence of the dewatering and the required pumping rate to achieve the necessary depth of dewatering.

3.2 Radius of Influence of Dewatering

An estimation of the sphere of influence of a dewatering sump can be gained using the same methodologies used for the 2015 (MIN75) and the previous applications. The Construction Industry Research and Information Association Report number 113, 'Control of groundwater for temporary works' provides a methodology for calculating the radius of influence of a drawdown curve during dewatering, as shown in Equation 1:

$$R = Ch\sqrt{k} \qquad \text{(Equation 1)}$$

Where: R = Radius of influence

C = dimensionless factor for type of excavation (3,000 for radial flow to pumped wells)

h = depth of dewatering (2.4-2.6m)

k = hydraulic conductivity of 5x10-4m/s for a Sand and Gravel

For a drawdown depth of 2.6m (equivalent to the maximum depth to the top of Kimmeridge Clay with the plot area), the dewatering sphere of influence extends approximately 160 - 175m from the dewatering centre:

$$R = 2.6m * \sqrt{(5x10\text{-}4m/s)} * 3{,}000 = 175m \qquad \text{(Equation 1)}$$

3.3 Associated Abstraction Rates

An estimated abstraction rate can be derived assuming a zone of influence of 175m using the Dupuit-Forchheimer Equation (Equation 2).

$$Q = \pi k \,(H2 – hw2) / \ln (Ro / rw) \qquad \text{(Equation 2)}$$

Where: Q = abstraction rate in m3/s
k = hydraulic conductivity (5x10-4m/s)
H = hydraulic head of the original water table (2.6mAOD)
hw = hydraulic head at maximum dewatering (0mAOD)
Ro = radius of influence of point source (175m)
rw = equivalent radius of the well (m, as per Equation 3)

To obtain an equivalent radius of the well (rw) can be calculated from:

$$rw = \sqrt{(ab / \pi)} \qquad \text{(Equation 3)}$$

Where: a = length of excavation in area where dewatering is expected (370m)

b = width of excavation in area where dewatering is expected (150m)

$$rw = \sqrt{(370 \times 150 / \pi)} \qquad \text{(Equation 3)}$$

The expected maximum abstraction rate for the northeast section of the site is therefore:

$$Q = \pi \times 5\times10^{-4} \times (6.76 - 0) / \ln(175/133) \qquad \text{(Equation 2)}$$

Q = $0.0386m^3/s$
38.6L/s
$139m^3/hr$

It should be noted that this peak sustained abstraction rate of 38.6L/s is likely to be a significant over-estimation as it is based on the conservative assumption that the maximum groundwater depth observed during monitoring is present across the whole site. The monitoring data clearly indicates that saturated zone thicknesses across the site are much thinner than the maximum thickness. There will be little groundwater recharge due to the limited radius of recharge, at 175m. In all likelihood there will be no recharge from the east and north, with the majority of recharge coming from either up-gradient groundwater to the south, or from the lake directly to the west.

It is therefore expected that the majority of groundwater management will only be required whilst working the sands and gravels to the northwest, southwest and southeast of the proposed excavation.

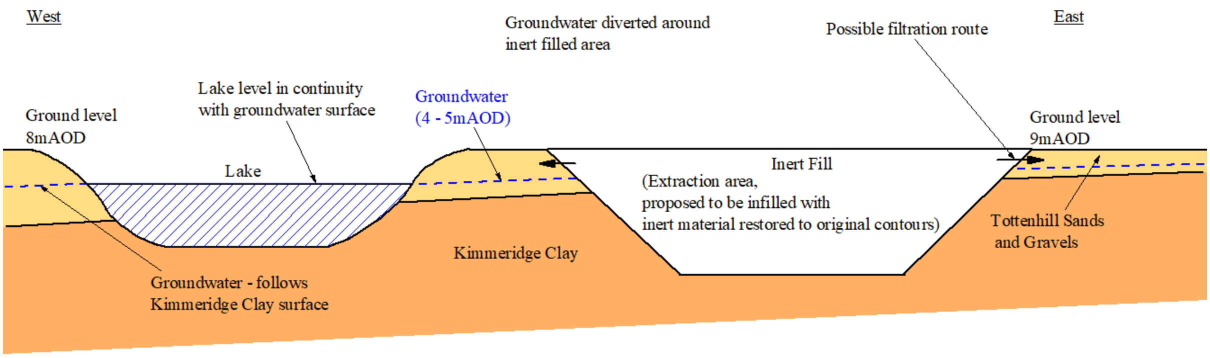
4 Conceptual Site Model

Groundwater is derived from rainfall falling on to permeable soils and strata both on the site and land up-gradient of the site. The groundwater flows across the surface of the Kimmeridge Clay within a shallow saturated horizon at the base of the Tottenhill Gravels. This flow is from the south towards the north with a component of radial flow in a westerly direction due to localised variations in the erosion surface of the Kimmeridge Clay, and ultimately discharges via a spring line where the Kimmeridge Clay surface outcrops at the point it intersects the topography. This water then enters the artificially drained fenland area.

Groundwater is artificially diverted around the restored quarry, but is otherwise unhindered in its recharge to the lower level surface water features as illustrated within Figure 10. There is therefore minimal, if any interruption in the recharge to the various springs and surface water features.

The sand and gravels extracted will be processed as the same mineral types already managed by the facility and these works will not increase the processing throughput of the plant. Consequently, there is no change in the environmental risk. Excavation of the clay will be undertaken as a dry working and this will be stockpiled for reuse or sale and does not constituent an environmental risk.

Figure 10 Schematic Conceptual Cross-Section



5 Receptors

5.1 Hydrological and Hydrogeological Receptors

There are a number of potential hydrological receptors, namely the off-site ponds, springs, and streams which enter the Nar Valley artificially managed fenlands. Ponds and surface water features to the south of Watlington Road are expected to be unaffected by the proposed scheme as they are generally up-gradient of the dewatering.

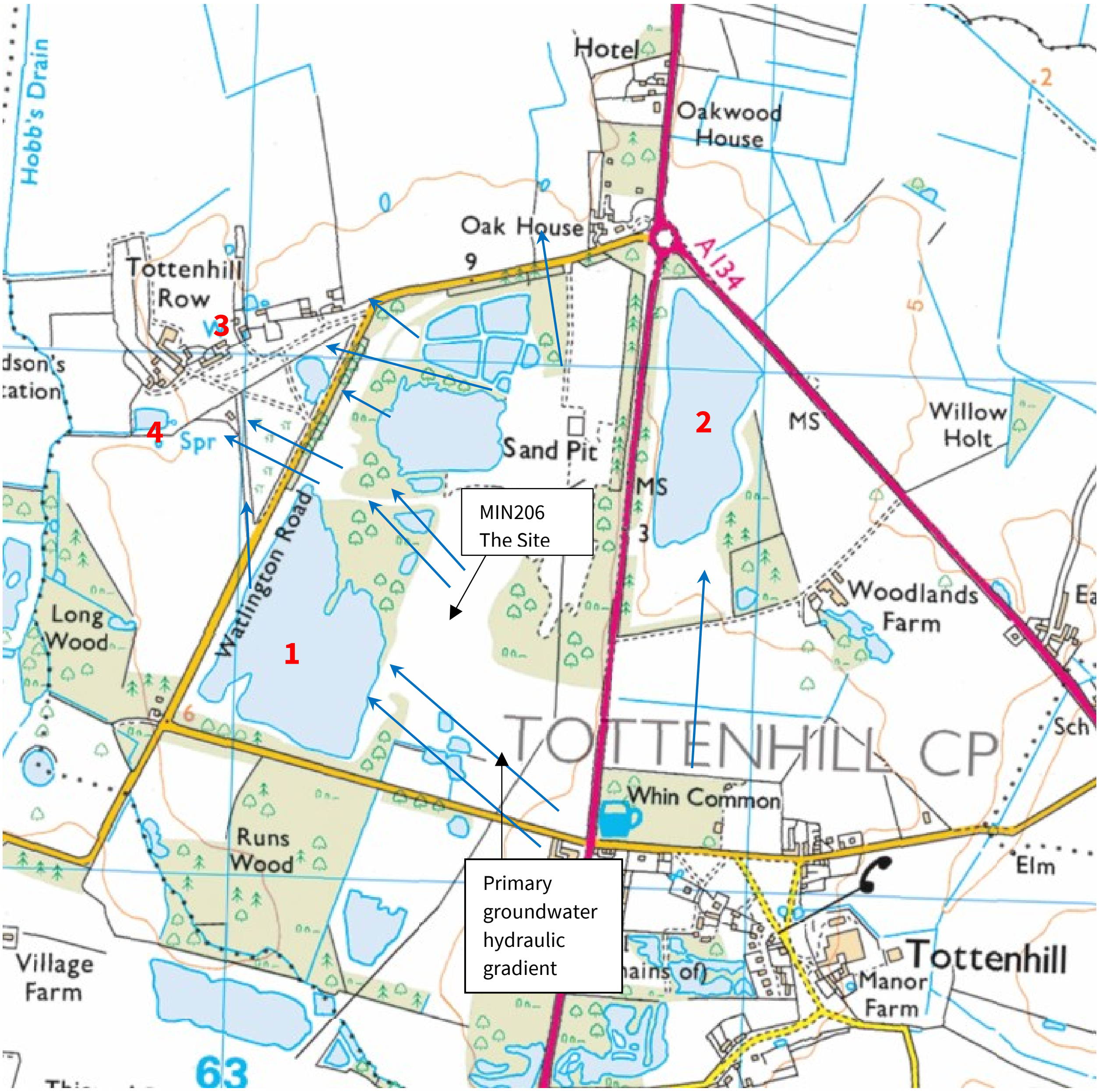
There are therefore four potential receptors (as identified in Figure 11), namely:

1) the large pond adjacent to the proposed extension, approximately 10m to the west of the proposed excavation
2) the pond 235m to the east of the proposed extension, on the east side of the A10 (Lynn Road)
3) the well on Tottenhill Row approximately 550m northwest of the proposed extension, and
4) the pond and spring line 570m to the north of the proposed lagoon across Watlington Road (Spring Pit pond).

Receptor 1 is the closest receptor to the dewatering, and adjacent to the area of the site with the thickest saturated zone within the sands and gravels. The maximum thickness of saturated sands and gravels in the borehole nearest receptor 1 (BH2) is 1.65m, therefore the amount of dewatering will be less at this area than where the greater saturated zone thicknesses are observed (BH1 and

BH3). Therefore, this receptor is considered, the most at risk from water loss due to the dewatering activities.

Figure 11 Groundwater Receptors and Groundwater Flow Direction



(Numbers in red refer to hydrogeologically down-gradient receptors)

Receptor 2 is located across the A10 and is considered to be across-gradient, as well as being in the same direction as borehole BH4, which has an incredibly thin saturated zone. Although this receptor is located outside of the calculated zone of influence of the dewatering, at ~235m from the site, due to assumptions made within the calculations it is prudent to consider the potential for a limited hydraulic impact from the dewatering,

Receptors 3 and 4 are located well outside the calculated zone of influence, however they are considered directly down-gradient of the proposed works. The current excavation operations are located closer to receptors 3 and 4, therefore the proposed dewatering activities at the Oak Field extension area are not considered to have any greater impact than that which is currently occurring. Additionally, the presence of the large ponds/lake between the receptors and the proposed mineral extraction will act as buffers to any impact from dewatering down-gradient from the dewatering.

5.2 Groundwater Abstractions

A Groundsure report[2] identified two groundwater abstractions not belonging to the operator within 500m of the perimeter of the Oak Field extension site. Both are spray irrigation licences. The first is located in the lake immediate to the west of the site, identified as receptor 1, whilst the second groundwater abstraction licence is located in the lake to the east of the A10, identified as receptor 2.

The historic well identified at Meadow Farm, Tottenhill Row (Receptor 3) on Ordnance Survey mapping (*e.g.* Figure 1) is not registered with the Environment Agency or the Borough Council however it can still be considered within the assessment as it is not known .

5.3 Surface Water Abstraction

There is one medium surface water abstraction point located within 1km of the site to the east-northeast. The next closest three are some 1.5km – 2.1km to northeast of the proposed site. The more distant surface water abstractions within the area are located 2.2-3km away from the site to the west north west and south-southwest. The eastern point is from a surface water drain in the alluvium below the Tottenhill gravels, and the southern from a pond constructed into the Kimmeridge Clay. There is no hydrogeological connection between theses abstraction points and the proposed area. The north-eastern surface water abstraction is from the Plover Drain and therefore will be unaffected by any groundwater management as any water would be returned to this system upstream of the abstraction.

The Borough Council of King's Lynn & West Norfolk, report one private abstraction point registered within a 3.5km radius of the extraction area. This is from the River Nar and provides the supply for a single dwelling and is located 3km to the north-west of the site at Nar Hideaway, Saddlebow, King's Lynn, Norfolk, PE34 3AP, E: 561598 N: 315364. This abstraction is to the north of the Plover Drain and is not affected by the proposed development.

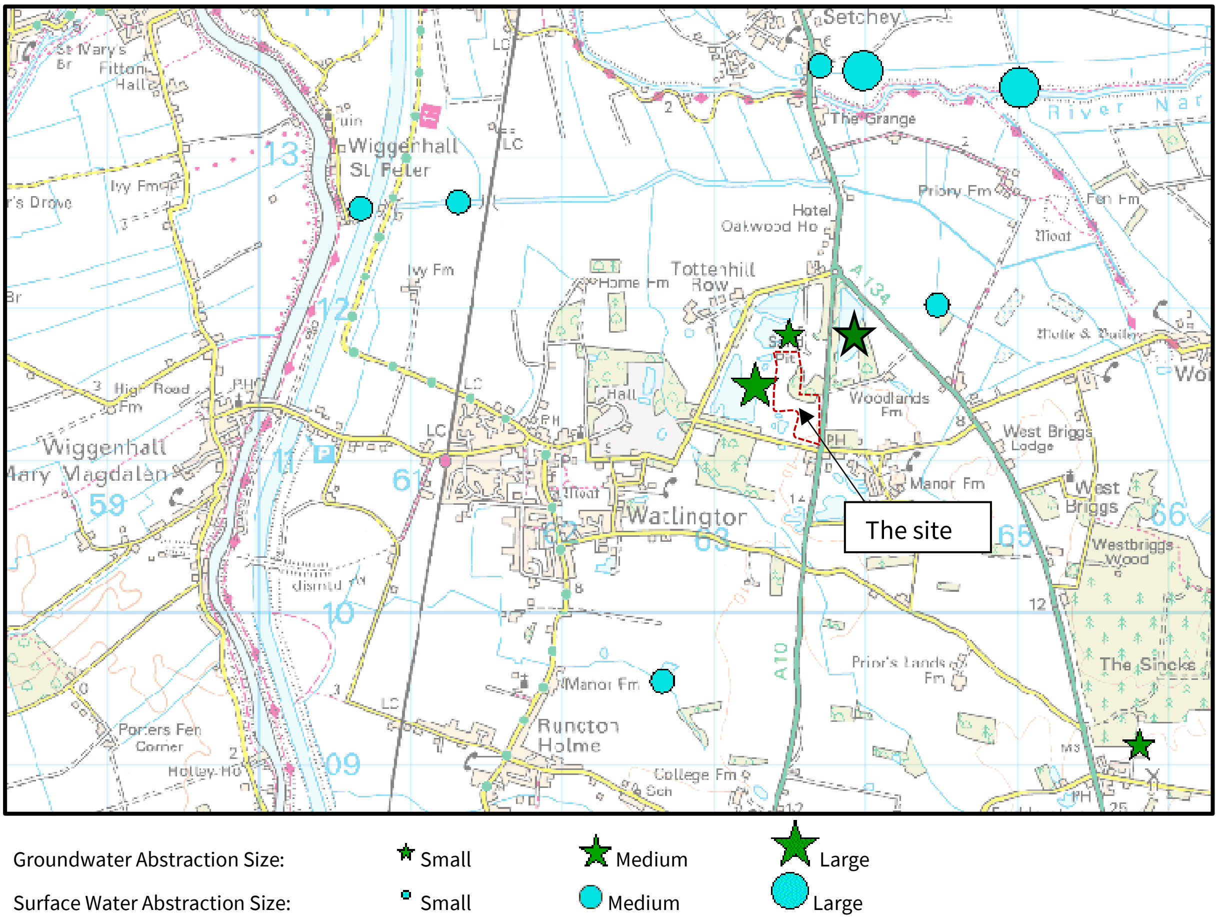
5.4 Receptors Summary

There are four receptors identified that could be impacted by the dewatering of the groundwater within the sands and gravels at Watlington Quarry's Oak Field extension site. The primary receptor is the lake immediately to the west of the Oak Field extension site (Receptor 1), as it is the closest receptor, is in the area with the deepest saturated thickness of sands and gravels, and has a spray irrigation abstraction licence associated with it. Receptor 2 also has a spray irrigation licence associated with it, however it is located outside of or at the far extent of the radius of influence of the dewatering as well as being cross-gradient to the site.

[2] Groundsure 2023, Enviro+Geo Insight: Watlington Quarry Oak Field Extension. Reference GS-9417633

Receptors 3 and 4 are located over 500m from the site, beyond the large lake to the west and the lakes/ponds onsite to the north. There are however directly down-gradient of the site. All licenced abstractions are shown in Figure 12 below.

Figure 12 Abstraction licences



6 Water Quality

6.1 Excavation Operations

Whilst the mineral is being extracted, there is only one potential impact on water quality namely fuel leakages from vehicles and machinery. However, as the works will utilise the existing quarrying machinery there is no change to the pollution risk. Consequently, the existing management practices, such as the provision of spill kits is already in place.

Suspended solids could be considered as a pollution risk, however, the operation of the dewatering process will include silt traps and other measures to mitigate the discharge of suspended solids.

6.2 Restoration Operations

The proposed backfilling and restoration of the resultant void created by mineral extraction shall be with site derived inert material and imported inert waste. Pollution control measures, including the necessity for any engineered lining system will be derived from specific risk assessments that will support any future Environmental Permit Application.

It is proposed that the site will be restored to approximately the pre-development level to allow the return to productive use of the land using imported inert material which may include the use of inert wastes. The material used to complete the restoration may represent a source of substances of concern that could cause elevated levels within the groundwater system. Consequently, to ascertain the level of risk posed by these materials it is necessary to understand the potential leachable substances that could be present within the imported inert fill and the likely make up of any leachates.

These leaching and total component criteria given in the Landfill Directive are set maximums for waste during testing, therefore it is highly unlikely that these concentrations will be realised for the bulk of the waste. Hence any assessment should accept that the average concentration would be substantially less. Furthermore, leaching tests performed within a laboratory are highly aggressive and will mobilise substantially more than would be available following *in-situ* leaching within any inert fill. However, it is likely that the total amount leached is representative of the total amount available of the most mobile substances over the entire '*potentially polluting*' lifespan of the site.

Leachate quality generated from inert materials can be categorised into a series of sub-groups, namely:

- Matrix salts including Na, K, Ca, Mg, Cl, SO4, alkalinity which are non-toxic, but could be at concentrations which could increase salinity levels above typical terrestrial water drinking water standards (DWS) or Environmental Quality Standards (EQS).
- Primary products from degrading organic matter, including ammonium, BOD, COD and TOC. Of these ammoniacal-N is toxic at high concentrations and elevated BOD can cause eutrophication in surface water bodies; however, elevated BOD is a short-term hydrolysis product which is only produced in significant quantities during the period taken for a microbial population to develop. Following a relatively short microbial growth phase the residual dissolved organic matter is usually biologically inert.
- The redox sensitive metals Fe and Mn, which are common metals insoluble under oxidising and reducing conditions, but soluble under anoxic (iron and manganese reducing) conditions.
- Metals, including Cd and Hg, which could be present at trace concentrations and other metals including Cr, Cu, Ni, Zn and Pb form the largest potential component of persistent pollutants within wastes.
- Hazardous and non-hazardous organic compounds.

The primary organic content is expected to be present as a minor component and primarily as a soil organic matter which cannot be distinguished visually or as vegetation derived cellulose or other similarly slowly degrading types. Any acceptance procedures for inert fill controlled by an Environmental Permit or via a CL:AIRE Definition of Waste Code of Practice Protocol Management

Plan will also exclude green and food wastes as well as visually identified oil or contaminated materials.

Consequently, given that the proposed waste types are unlikely to contain a significant or rapidly degradable organic content, elevated ammoniacal-N and BOD is not expected to be associated with the inert fill. Similarly, solvents, refined petroleum products or other chemical spillages will be excluded from the site. With regards to metals and metalloids ByrneLooby have compiled a leachate source term from a combination of reviewing leachate data from hazardous soil landfill sites over a 10-year period as well as other leaching data (Table 2). Given that the acceptance procedures for inert fill will specifically exclude hazardous soils, then this leachate source is considered to be highly conservative and above the maximum concentration range which could be expected for the proposed inert fill whether classified as waste or otherwise. The data is presented solely as an example of the limited real-world leachability of substances from worst-case waste soils which consequently produce leachate of limited concern. By extrapolation leachate produced by inert fill will have levels lower than those indicated below.

Table 2 Hazardous Soil Leachate Source Study

Chemical	Sample Count	Units	Leachate concentration			DWS	MRV
			Minimum	Average	Maximum		
Hazardous Metals							
Cadmium	161	µg/l	0.025	0.29	6.7	5	0.1
Mercury	153	µg/l	0.005	0.037	0.3	1	0.01
Non-hazardous Metals & Metalloids							
Arsenic	154	µg/l	0.4	4.9	25	10	
Lead	59	µg/l	0.2	1.8	10	10	
Chromium	60	µg/l	0.25	3.1	14	50	
Copper	58	µg/l	0.5	6.2	21	2,000	
Nickel	60	µg/l	1.5	8.1	22	20	
Zinc	60	µg/l	1	45	1,600	5,000	
Organic							
PAH	15	µg/l	<1.7	n/a	<34	0.1	
Matrix Components							
Sulphate	193	mg/l	38	485	1,300	250	
Ammoniacal-N	214	mg/l	0.01	2.5	16.9	0.39	

It is noted that the majority of the metals and metalloids are expected to be below DWS at source, although maximum cadmium concentrations were determined to approximate to the 5 µg/l DWS (at 6.7 µg/l). Given that this waste source is derived from hazardous soils, then it is considered as highly conservative compared to an inert source where negligible cadmium would be present.

There are therefore two primary potential leachable components within inert materials, namely an increase in chloride or sulphate which causes an increase in an otherwise low salinity water resource to above EQS or DWS standards. However this will be limited as sulphate producing wastes will be excluded if wastes are used in the quarry restoration scheme.

6.3 Risk Assessment

The conceptual model indicates that rain which falls on the site will infiltrate through the in-situ subsoils and top soils used as restoration at the site. The water that infiltrates through these soils will reach the layer of imported inert materials.

The water that mixes with the inert materials / waste may cause leaching of substances within the infill material forming a leachate. Protection of the Tottenhill Gravels aquifer and the requirements of any pollution control engineering measures shall be determined by risk assessments prepared for any permit application.

Section 6.2 discusses the potential leachate quality produced and concludes that sulphate and chloride are the most likely substances to be leached associated with the material to be used, however as they, especially sulphates, are controlled by the acceptance criteria it is unlikely that a significant producing source will be formed. It has also been noted in research undertaken by ByrneLooby discussed above that metals do not particularly leach, even from hazardous waste sources, therefore it is unlikely that any will be produced in concentrations greater than the respective DWS or EQS limits. Ultimately any leachate leaving the waste mass will contain very low concentrations of substances of environmental concern. This situation will only be improved if engineered pollution control measures are required.

In that event that leached substances percolate through the placed fill they would enter the remaining Tottenhill Gravels. If this was to occur any leachable components could disperse laterally in the groundwater towards the identified receptors in Section 5.

As the fill will be of a lower permeability than the surrounding sand and gravel, groundwater present will flow around the site within the gravels. Mixing with groundwater will occur in/under and around the site causing dilution of any migrating leachate. Further dispersion will occur as the substances migrate to the north and northwest.

As the Tottenhill Gravels will be completely removed at the site, there will be no unsaturated zone beneath as the restored site will sit directly on the Kimmeridge Clay. Therefore, any dispersion of leachate will be laterally into the surrounding sands and gravels. The large ponds to the north and west of site are the closest receptors, however the large volumes of water should allow for greater dilution, making the risk to these receptors negligible.

7 Impacts Assessment

7.1 Dewatering of the Tottenhill Gravels

Groundwater elevations for the Tottenhill Gravels are in the order of 0 – 2.6m above the top of the Kimmeridge Clay in the proposed operational area, with the thickest saturated zones being in the southeast and northwest corners of the area. This is due the surface elevation of the Kimmeridge Clay rising in the centre, east and northeast of the working area, thus channelling the groundwater to the northwest, southwest, and southeast. Dewatering is therefore expected in these areas of the proposed excavations for the operator to work the mineral dry.

The dewatering is expected to impact the pond 10-15m directly to the west of the site (Receptor 1), potentially lowering the pond level by up to 1.65m. As the extraction of the sands and gravels will utilise the full thickness of the strata, the excavation will dig down to the Kimmeridge Clay beneath. The excavated Kimmeridge clay will be utilised for use as the geological barrier for the inert landfill once excavation has been completed, in accordance with the Environment Agency's landfill permit requirements. The presence of the clay barrier will restrict any further impact of the dewatering on the pond and wider environment between the emplacement of the barrier and the completion of filling of the void space with inert fill. In addition, dewatering water can be pumped into the pond to ensure the water level remains at a satisfactory level and allows the spray irrigation abstraction to continue unhindered before the clay barrier can be emplaced.

Receptor 2 is calculated to be outside of the zone of influence of the dewatering (or at the very limit of it), and cross-gradient of the site, therefore the impacts on the lake and the associated spray irrigation abstraction licence are considered likely to be negligible. Receptors 3 and 4 are located far outside the calculated zone of influence, however they are located down-gradient of the site and therefore there is the potential for a slight decrease in groundwater volume flowing towards these receptors as it is removed from the aquifer upgradient of the receptors.

7.2 Water Quality

During the dewatering and excavation operations, the utilisation of the appropriate pollution control measures currently being used at the site, coupled with silt traps to remove suspended solids, will render the risk of groundwater contamination at the site negligible. The discharge of the dewatering water to any of the groundwater fed water features identified as receptors will have no material change in water quality as it will be the same water that would have naturally supported those features.

After restoration of the site, the primary water quality risk is posed by leachate from the inert waste fill used for the restoration entering the groundwater. Due to the composition of the inert fill and lack of putrescible material, the main substances of concern will be chloride and sulphate. It is considered that the volume of groundwater in the surrounding sands and gravels, coupled with the large volumes of the water within the lake to the west, lake to the northeast and the numerous ponds and lakes onsite to the north, that sufficient dilution is available to render the risk to the receptors negligible.

8 Monitoring Programme

Whilst the likelihood of any impact on local receptors from the groundwater management is considered to be low, it is proposed that water level monitoring be conducted at the lake to the west (receptor 1), the lake to the north-east (receptor 2), as well as water level monitoring continuing at Spring Pit pond (receptor 4). This will establish an understanding of baseline seasonal water levels within these features. It is understood that the operator will not have access to the private well at Meadow Farm (receptor 3) if it still exists. However, as Spring Pit pond is located very close to the well, at a similar distance and direction from the dewatering, any impact on the well will be also be identifiable at the Spring Pit pond. Therefore, monitoring at Spring Pit pond will cover both receptors.

Water level monitoring will be carried out weekly, as per the Environment Agency's statement, prior to the dewatering activities and throughout the period the dewatering is performed. Following the cessation of dewatering, water level monitoring will be carried out monthly until quarrying operations are completed. Baseline conditions will be established through a period of weekly monitoring during September (groundwater low) which will continue prior to dewatering activities taking place. This baseline data will be presented to the Environment Agency prior to the commencement of dewatering.

9 Data Management and Action Plan

Water level monitoring will be assessed for significant decreases outside the expected background seasonal variation where this is available. Pumping volumes (m^3/day) will also be recorded for data interpretation purposes. Following the collection of water level data the following action plan will be used:

9.1 Action Plan

1. Is the water level above or in accordance with baseline/ background conditions? If yes, continue with weekly monitoring. If no, continue to step 2.
2. Is there a general decreasing trend or significant water level reduction identifiable within the recent data? If no, continue with weekly monitoring. If yes, notify the relevant competent manager and continue to step 3.
3. The cause of the fall in water level will be considered having regard to
    a. weather data (has there been a period of low precipitation or warmth in comparison to when baseline conditions were observed?);
    b. pumping records (has there been an increase in pumping volumes from the site?); and
    c. any additional outside influences which could be affecting water levels.

Where it is identified that there are no outside influences and there has not been a significant change in weather conditions water level monitoring should be increased to twice weekly.

Where two consecutive measurements demonstrate a continued fall in the water level dewatering will be temporarily halted to determine whether the cause of the water level drop is related to the quarrying activities. An investigation into the cause and significance of the water level reduction will be carried out.

Where two repeat measurements demonstrate a stabilisation or increase in the water level monitoring visits will resume in accordance with the routine weekly monitoring schedule.

4. Monitoring data will be made available to the Environment Agency on a quarterly basis for assessment. Where it is identified that dewatering activities are having an impact on the receptors, the Operator will notify the Environment Agency immediately. An investigation into the cause and significance of the water level reduction will be carried out. Dewatering will be temporarily halted until the investigation has concluded.

If the conclusion of the investigation indicates that the dewatering is the cause of the impacts, then a mitigation plan will be implemented.

9.2 Mitigation Measures

The primary method of mitigation available would be the discharge of sufficient dewatering water to compensate for the loss of water at the receptor in question. As the groundwater quality for the dewatering water will be same as the receiving water body (due to the waterbodies being groundwater fed from the same aquifer) then, assuming best practices are observed for pollution prevention within the quarry, there will be no impact on the water quality at the receiving receptors upon discharge of the dewatering water to mitigate the loss of water from dewatering.

10 Conclusions

The operator proposes to extract the entire thickness of sands and gravels of the Tottenhill Gravel Member at the Oak Field extension site of Watlington Quarry, along with 300,000 tonnes of the underlying Kimmeridge Clay. The excavation will be a dry working, with dewatering of groundwater within the sands and gravels required to achieve this. The excavation works will be conducted in a phases approach, therefore only one part of the quarry will be an open excavation at any one time.

Groundwater monitoring indicates that groundwater is flowing from southeast to northwest, and that the saturated thickness of the sands and gravels is greatest in the northwest, southwest and southeast portions of the site. The topography of the upper surface of the underlying Kimmeridge Clay creates a small valley feature running southeast to northwest, with the clay rising highest (and therefore thinnest sands and gravels) in the northeast.

There are four receptors identified that are hydraulically linked to the groundwater within the site, and as such can be considered at risk from the dewatering of the sands and gravels. The primary receptor is the lake ~10m to the west of the site, which also has an associated spray irrigation licence. The lake to the northeast is the receptor of least concern due to the thin saturated thickness of the sands and gravels at that side of the site, combined with the location being cross-gradient from the site. There are two receptors (Spring Pit pond and a private well on Tottenhill Row) which although over 500m from the site, are considered down-gradient of the dewatering. The presence of the large bodies of water filling old quarry voids providing buffering between the dewatering and these two receptors means that risk of impact from the dewatering is also considered to be very low.

The calculated radius of influence for the dewatering is 175m, with a total hourly abstraction rate of 139m^3/hr calculated to be required to achieve the necessary dewatering. The only receptor located within the radius of influence is the pond immediately to the west, however due to the uncertainties inherent within the calculations the pond 235m to the northeast may fall just within the very edge of the radius of influence.

Weekly monitoring of three of the receptors (lake to the west, lake to the northeast and Spring Pit pond 570m to the northwest) is required prior to dewatering beginning to establish a baseline water level within each receptor. The weekly monitoring will continue throughout the period of dewatering to monitor the impacts of the dewatering and to provide comparison with the baseline data.

An action plan has been designed once any changes are observed at the receptors, to establish whether the changes are natural seasonal variations, or whether they are likely due to a result of the dewatering. Should it be concluded the impacts are from dewatering, mitigation measures are proposed to counteract the impacts. The primary mitigation measure is the discharge of the dewatering water to the impacted receptor as to compensate for the volume of water lost due to the dewatering. The quality of the dewatering water will be the same as the water quality at the receptors as they are fed by the same groundwater, therefore there will be no risks from the discharge for mitigation measures.

It is concluded that the potential for impact from dewatering is considered very low for all receptors except for the lake to the west. However, the use of best practice pollution prevention and control within the quarry will ensure that any impacts can be mitigated against and protect the receptor.

The restoration of the site using site-won material will not pose a pollution risk to groundwater receptors; however the use of imported inert fill for restoration may require the engineering of pollution prevention measures. The assessment of inert fill leachate production and the local hydrogeology indicates the risk for the receptors from leachate from the imported inert fill will be very low.

In summary, with suitable mitigation measures there is not expected to be a discernible impact on groundwater and surface resources with respect to the quantity of recharge and the quality of the groundwater.

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www.ayesa.com/en/

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