ARCADIS Design & Consultancy for natural and built assets

CHALK MINE STABILISATION PROJECT
HIGHBARNS, HEMEL HEMPSTEAD

Treatment Report

Report No 00013-UA000857-TR-01

DECEMBER 2015

Incorporating

EC HARRIS BUILT ASSET CONSULTANCY

Hyder

CONTACTS

ROGER BARSBY
Technical Director – Geotechnics and Tunnelling
Approver

Signature……..

Date: 17 December 2015

dd +44 (0)148 3803156
m +44 (0)774 8188683
e roger.barsby@arcadis.com

Arcadis.
The Surrey Research Park
Medawar Road, Guildford
Surrey, GU2 7AR
United Kingdom

ANDREW HOPE
Senior Geotechnical Engineer
Geotechnics and Tunnelling
Checker

Signature……..

Date: 17 December 2015

dd +44 (0)203 3014 9247
e andrew.hope@arcadis.com

Arcadis.
The Surrey Research Park
Medawar Road, Guildford
Surrey, GU2 7AR
United Kingdom

ALEX BLAKE
Senior Geotechnical Engineer
Geotechnics and Tunnelling
Author

Signature……..

Date: 17 December 2015

dd +44 (0)1483 803168
m +44 (0)7809 594523
e alex.blake@arcadis.com

Arcadis.
The Surrey Research Park
Medawar Road, Guildford
Surrey, GU2 7AR
United Kingdom

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APPENDICES

1 INTRODUCTION

1.1 Scheme Details

Dacorum Borough Council (DBC) has undertaken the treatment of abandoned chalk mines identified beneath houses, roads, areas of public open space, some garages and a small car park located within the vicinity of the junction of Highbarns, Pond Road and East Green in Hemel Hempstead, Hertfordshire. These works have been funded under the Land Stabilisation Programme (LSP), administered by the Homes and Communiites Agency (HCA).

Dacorum Borough Council appointed Arcadis Consulting (UK) Limited (formerly Hyder Consulting (UK) Limited) in September 2009 to manage the investigation and stabilisation of these mine workings including the design and supervision of the treatment works.

1.2 Scope of Report

This report summarises the work undertaken to stabilise the interpreted chalk mine at Highbarns in accordance with Hyder's proposal dated July 2010 (Highbarns Chalk Mines Project, Hemel Hempstead: Project Management, Design, Supervision and Validation of Mine Treatment Scheme Proposal, reference XGD0236), in the format as subsequently agreed with DBC.

The report provides:

- a summary of the treatment works undertaken;
- evidence that the works have been effective in stabilising mine related disturbed ground and;
- details of any residual risks that remain.

Full records of the treatment works (the Contractor's Factual Report) and an electronic 3-D mine model are provided as appendices.

This report addresses the treatment of chalk mines beneath the site only. Other issues, such as pre-existing problems with buildings or the nature of deposits overlying the chalk stratum, may exist.

Details of any remedial works to properties following treatment are outside the scope of this report.

This report addresses the risks to property associated with the current site use. Further assessment and advice will be required for changes in site use, intensification of use or re-development.

This report is a considered professional opinion. It is not a warranty or guarantee as regards the works undertaken, and no liability can be accepted except to the extent of any failure to exercise reasonable skill, care and diligence in the provision of services under the Terms of Appointment. This report does not in any way increase liability beyond that agreed under the Terms of Appointment. This report is not a certificate of design of construction as defined in The Building Act 1984 and The Building (Approved Inspectors, etc.) Regulations.

2 SOURCES OF INFORMATION

2.1 Ground Investigation Reports

- Geotechnology (2010), Microgravity Survey Report, Highbarns, Hemel Hempstead. Report Number 926r1v1d0310, March 2010. Geotechnology, Neath.
- Hyder Consulting (2010), Highbarns Chalk Mines Project Geophysical Survey Report No 0002-LN01292-GD-02-0, June 2010.
- Hyder Consulting (2011), Highbarns Chalk Mines Project, Cavity Autoscanning Laser System (CAL-S) Survey Report No 0005-UA000857-GDR-01-0, June 2011.
- Hyder Consulting (2012), Highbarns Chalk Mines Project, Interpretive Ground Investigation Report No 0010-UA000857-GDR-01, September 2012.
- Inspectahire (2012) CALS and CCTV Inspection of Voids report no 6658, Issue 02, August 2012.
- Peter Brett Associates (2008), Interpretative Geotechnical Report – Phase 1 No 20247/0043/Int01/rev2, July 2008.
- Soil Engineering (2012), Report on a Ground Investigation at Highbarns, Hemel Hempstead, Volumes One and Two (Project No: TB6279, Document No. D01), August 2012.

Relevant information from the ground investigations completed prior to the treatment works is included in the electronic mine model for the site (see Appendix B).

2.2 Design and Feasibility Documentation

- Hyder Consulting (2010a), Highbarns Chalk Mines Project Feasibility Study Report, No 0004-LN01292-GD-01-0, July 2010.
- Hyder Consulting (2010b), Highbarns Chalk Mines Project Geotechnical Assessment Report, No 0004-LN01292-GD-01-0, February 2010.
- Hyder Consulting (2012), Highbarns, Hemel Hempstead, Chalk Mine Stabilisation Project, Specification for Site Works, No 0007-UA000857-GDR-01, September 2012.

The specification for the mine treatment works is included in electronic format as Appendix D.

2.3 Mine Model

- Hyder Consulting (UK) Limited: Highbarns Chalk Mine Model, 2014.

An electronic version of the post-completion version of the mine model in RocWare Rockworks v7 is included in electronic format as Appendix C.

2.4 Contractor's Reports

- BAM Ritchies: Highbarns Sectional Validation Reports ref. BBK704U, VR-001 to 010. March 2015.

An electronic version of the contractor's factual reports for mine treatment works containing the factual version of the mine model is included as Appendix E.

3 SITE DETAILS

3.1 Site Description

The Site (defined by the Derelict Land Clearance Order site boundary) is located approximately 2.5km to the south-east of Hemel Hempstead town centre, within a residential area known as Nash Mills. The treatment site and immediate surrounding area includes forty-three houses, a low rise block of flats, some areas of public open space, a small car park and some blocks of garages located around the junction of Highbarns, Pond Road and East Green. The approximate National Grid Reference for the centre of the site is 507088 204921.A Site location plan is provided as Figure 1. The approximate plan area of the Site considered during investigations and treatment works is approximated 2.0 hectares. The site layout is shown on Figure 2.

The centre of the site lies at an approximate elevation of 100m above Ordnance Datum but slopes downhill to the south-east, south and west towards the valley of the River Gade. The semi-detached and terraced houses that cover most of the site are mainly privately owned with eleven houses and two flats owned by Dacorum Borough Council.

3.2 Ground Conditions

3.2.1 Summary of ground conditions

A summary of the interpreted ground conditions is presented in table 1 below:

Unit	Description from available boreholes	Comment
Made Ground	The made ground generally consists of brown slightly sandy gravelly clay. Gravel sized fragments are angular to rounded, fine to coarse of glass, asphalt, metal, clinker, tile, concrete, flint, chalk, china, plastics, brick and charcoal. Sand sized fragments range from fine to coarse. Occasional sub-angular to sub-rounded brick, concrete, chalk and flint cobbles.	The thickness of the made ground ranges up to 3.85m. In BH09 made ground was recorded to a depth of 10.3m indicating a shaft. Assumed to be related to levelling parts of the site for construction of the current houses and roads
Clay-with- flints	Generally consists of firm brown slightly sandy slightly gravelly clay. Gravel is angular to rounded fine to coarse of flint and occasionally chalk. Sand is fine to coarse. Rare to frequent angular to sub-angular flint and chalk cobbles.	Occurs throughout most of the area investigated. The thickness of the deposits ranges between 0.29m to 9.60m and generally increases in a downhill direction to the south.

Unit	Description from available boreholes	Comment
Lewes Nodular Chalk	Chalk generally recovered as light brownish white gravelly sandy SILT with occasional pockets of brown clay. Gravel is very weak to weak, low to medium density, white with rare to occasional black specks and frequent light to heavily brown staining, sub-angular to sub-rounded fine to coarse chalk, frequent to occasional dark grey rimmed sub-angular flint. (typically grade Dm and locally Dc). (SPT N blow counts range from <5 to >50)	The top of the chalk was encountered at depths ranging between 0.48m and 10.80m. In places the chalk surface appears to be highly weathered to up to 10m depth suggesting dissolution features. Includes mine workings (voids and collapsed ground). Locally includes foamed concrete and grout where previously treated.

Table 1: Interpreted Ground Conditions

3.2.2 Distribution of deposits

The layer of Made Ground that caps the site generally ranges in thickness between 0.1m and 1.45m, with localised thickening recorded in just two areas, namely to a depth of 3.85m beneath the pavement adjacent to No. 5 Highbarns and in the area of public open space adjacent to No. 24 Highbarns where 10.3m of made ground appears to represent a backfilled mine shaft.

Across almost the entire site the Made Ground rests on the Clay-with-flints (the few exceptions being where the made ground rests directly on the Chalk) which extends to depths of between 0.48m and 10.8m with a thickness range of between 0.29m and 9.6m. The Clay-with-flints is generally thicker beneath the southern side of Highbarns where it ranges between 0.84m and 9.6m with many boreholes indicating a thickness in excess of 3m. The Clay-with-flints is generally thinner beneath the northern side of Highbarns where its thickness ranges between 0.29m and 1.57m, although it thickens near No. 1 Pond Road to 3.3m, with the majority of boreholes showing these deposits to have a thickness of less than 1m in this area.

This indicates that the depth to chalk rock head generally increases from the northern side of Highbarns where it ranges from 0.4m to 2.2m (only extending to 4.5m near No. 1 Pond Road) to the southern side of Highbarns where the depth to the chalk surface ranges from 1.2m to 10.8m.

Investigations to date have indicated that the site is underlain by galleried chalk mine workings with original mine heights and spans typically ranging between approximately 2m and 4m. Larger void heights and spans are possibly a result of void migration or the location of chambers associated with mine junctions. Depths to original roof levels are between 11.5m to 18.5m beneath existing ground level while the original floor of the mine lies at depths of between approximately 13.9m and 25.0m. An interpretation of the distribution of probable chalk mine workings encountered is shown in Figure 3. The condition of the workings suggest widespread collapses have occurred within the mine while some sections are likely to be infilled with backfill material.

3.2.3 Groundwater

The groundwater level within the Chalk has been recorded throughout the mine stabilisation works in six monitoring wells (BHGW01 to BHGW06). The range of groundwater depth recorded in the monitoring wells was between 16.08m and 29.81m.

No unusual groundwater observations were recorded during the treatment works.

4 STABILISATION WORKS

4.1 Design Basis

The scope of the mine stabilisation design is limited to addressing the risk of subsidence and settlement of structures due to historic chalk mining within the DLCO boundary. Other factors that might affect the stability/condition of properties are considered outside the scope of the stabilisation works.

Given that the ground investigations indicated that significant areas of the mine workings had collapsed, and that it was unsafe to enter open areas of mine workings, a surface based approach to treatment was preferred.

4.2 Validation Procedure Adopted

At Highbarns, to give the highest level of confidence, a multi-faceted validation process was adopted which had been successfully used for the validation of the Briars Lane chalk mine treatment works in Hatfield. This included validation probing, but also incorporated an integrated review of treatment data against a 3-D model of the mine workings. This approach was undertaken continuously during the works to allow additional treatment or validation to be undertaken if any anomalous results were detected.

During the ground investigation, extensive super heavy dynamic probing (DP) was undertaken to identify voids and collapsed ground. A close correlation was found between DP blow values of less than 3 per 100mm penetration and the presence of workings. It was concluded that comparison between pre and post treatment dynamic probe holes would allow an objective assessment of the effectiveness of the treatment. Blow counts greater than 3 per 100mm were determined to represent an acceptably treated mine, based on the results of the pre-treatment surveys. To allow manageable assessment of the data the site was divided into 14 No. discrete treatment areas (see Figure 2).

The validation procedure employed during the works comprised the following:

- A review of drilling and borehole CCTV records to confirm the absence of any large voids missed by previous investigations which may require bulk infilling
- Confirmation that grout/infill volumes are in excess of the hole volume thereby demonstrating that small voids are being infilled and/or compaction of poor ground is occurring
- Comparison of actual grout/infill volumes in areas where poor ground was anticipated via use of the mine model.
- A review of the vertical distribution of grout/infill volumes within the mine model to confirm treatment of anticipated mine features
- A comparison between post-treatment dynamic probing data and pre-treatment data to confirm that areas of weak mined ground have been improved

Pre and post treatment dynamic probing data was screened to identify blow counts above or below the threshold value of 3 per 100mm. This data was then compared within the mine model. In most cases a clear improvement could be identified following compaction grouting, confirming that treatment of collapsed workings was occurring. Probe data results were also cross-checked against other treatment data.

4.3 Treatment Areas

A summary for each Treatment Area (numbered TA001 to TA0014) is presented in Figure 2, Appendix A adopting the numbering system of the contractor's Sectional Validation Reports, which were numbered VR01 to VR010 (see Appendix E).

- Treatment Area 1: Nos. 2-8 Pond Road
- Treatment Area 2: Nos. 10-14 Pond Road
- Treatment Area 3: Nos 5-15 Highbarns
- Treatment Area 4: Nos. 8-12 Highbarns
- Treatment Area 5: Nos. 14-24 Highbarns
- Treatment Area 6: Nos. 30-34 Highbarns
- Treatment Area 7: Nos. 25-27 East Green
- Treatment Area 8: Nos. 28-30 East Green
- Treatment Area 9: Nos. 5-11 Pond Road
- Treatment Area 10: Meadow Road and Highbarns Junction
- Treatment Area 11: Nos. 2-8 Meadow Road
- Treatment Area 12: Nos. 1-3 Pond Road
- Treatment Area 13: Pond, Highbarns and East Green Roads

4.4 Treatment Method

The original construction method, extent of treatment, and quality control and validation procedures are set out in detail within the Feasibility Report (Hyder, 2010c) and the Project Specification for Site Works (Hyder, 2012b).

The following sections describe the methods used in the works and any departures from the original construction method that were necessary in the completion of the treatment works and also indicates where there were limitations with the drilling and grouting process encountered during the works.

4.4.1 Records

Full records of all works undertaken were maintained. Much of this was real time electronic data used to control the works. Data collected at the site and provided in the Contractor's Factual Report (Appendix E and F) included:

- Grout batching records
- Grout test data
- Drilling records
- Continuous grout injection pressure and flow rate data
- Validation probing data

Grouting data and validation probing data was assessed using RocWare Rockworks v7 software to provide a 3-D assessment of treatment and enable comparison with pre-treatment investigation and validation data. This information and the resultant 3-D mine model is provided as Appendix C.

4.4.2 Drilling

Uncased auger drilling was utilised during the works at a nominal 150mm diameter. A highly abrasion resistant "Bulldog Head" bit type was utilised to address wear from flints. Holes were generally dry and stable during the works, though some re-drilling was required, particularly following periods of heavy rainfall, if the area had been heavily trafficked following drilling or the hole had been left open for several days due to high grout volumes at the preceding hole. Inclined holes were generally drilled using a hollow stem auger system. Chalk recovered was highly disturbed by the

drilling becoming putty but provided sufficient information to assess the strata encountered.

During drilling the depth of chalk, the presence of any major voids, solution features and any grout encountered was established. Borehole CCTV (predominantly using a small drainage camera) was undertaken immediately following drilling in most holes. This was sufficient to confirm the presence of large voids but for smaller voids the smearing of chalk along the borehole made observation difficult. Where there was evidence of significant voids being encountered during the grouting operations any further holes required were also surveyed by CCTV. Where major voids were encountered a more sophisticated downhole camera was used in an attempt to obtain void sizes and orientation.

4.4.3 Bulk infilling

Bulk infilling was carried out through dedicated boreholes which were located to intersect known voids. The bulk infill material used was a cement based grout with high flow characteristics. The grout was delivered to site by standard concrete trucks where it was pumped through a P11 pump (or through a holding agitator if required) to the bulk infill treatment holes.

The grout mix used for bulk infilling had a limestone to cement ratio of 7:1 using CEM I 52.5N with a water: solids ratio of 0.45.

Grout flow was typically in the range of 200mm to 400mm and this was a stiffer mix than specified to allow the same grout mix to be used for both compaction grouting as well as bulk infilling to provide BAM Ritchies with the flexibility to cope with variable conditions within the mine without the need to change mixes. Evidence of grout migration between boreholes demonstrated that even a flow of 200mm was still adequate for successful treatment of the mine workings.

The results of cube crushing tests indicate the 28 day strength to generally be in excess of the required 1MPa.

4.4.4 Compaction grouting

BAM Ritchies has developed a grout mix for use in treating chalk mines based on their experience on a previous scheme at Briars Lane in Hatfield and at other sites. This mix has proven flexibility to readily treat ground requiring bulk infilling or compaction grouting. For previous contracts BAM Ritchies have stated that they have used a limestone to cement ratio of 5.6:1 using CEM II 32.5N Portland Cement.

An initial grouting trial was carried out at the Highbarns site which showed that a grout with the limestone to cement ratio previously used by BAM Ritches was over hydrating the mix resulting in a grout that was difficult to pump at the required pressures.

Following the initial grout trial, BAM Ritchies changed the grout mix to a 7:1 limestone to cement ratio using CEM I 52.5N and all the production grout (including bulk infill grout) used at Highbarns was produced at this ratio. The limestone filler had a grading with 99.97% passing a 2mm sieve and the grout had a water to solids ratio of 0.45 by mass of material. The cement content was equivalent to 156kg/m^3.

Grout was batched off site for BAM Ritchies by a single sub-contract supplier, Hanson. The constituent materials were discharged into standard concrete trucks and mixed by rotating drum during transit. The primary mixing process relied on the shearing action of the internal screw blades within the agitating drum. Materials were loaded into the truck using a pre-programmed weigh batch system, allowing for a highly repeatable grout mix.

Grout was discharged at site by the concrete trucks where it was pumped through a P11 pump (secondary mixing) directly to the treatment area or through a holding agitator if required. The secondary pumping process provided further agitation and mixing to the grout to produce a fully homogenous mix.

Grout was tested on site for bleed, flow, specific gravity and temperature using standard testing apparatus. Material was initially sampled at the point of discharge, not at the point of injection which has affected some of the test results (see BAM Ritchies' appended Grouting Summary Report).

Grout cubes were tested for their compressive strength off site at 7, 14 and 28 days and BAM also tested many samples at 56 days. Cubes were made in pairs with a total of eight per day.

During the initial grout trial the preliminary grout cube test results achieved 2MPa at 7 days and 4 MPa at 28 days confirming that the reduction in cement content had no impact on the strength of the grout being injected into the ground.

Bleed measured at two hours was in the range of 0-1%. The grouting trial confirmed that there was negligible increase in bleed after two hours.

Grouting was carried out using an ascending stage method via a 100mm internal diameter delivery hose. The delivery hose was lowered down the hole using a portable tripod winch to the required treatment level. An air packer was then inflated to seal the borehole at the top of the grout stage. Once the air packer was inflated grouting commenced until one of the termination criteria was reached. The packer was then fully deflated and lifted using a purpose made lifting strop integral with the delivery hose to the level of the next grouting stage.

Grouting stage lengths of 2m were utilised although in some areas where various difficulties were encountered increased stage lengths were necessary

Monitoring of grout flow and pressure was carried out using electronic measuring equipment supplied by Jean Lutz Limited. The monitoring allowed the grout pressure and flow data to be viewed and recorded for each stage to allow real time control of the grouting process. The data was downloaded at the end of each day to allow post processing using Jean Lutz software to create a graphical presentation of the grout flow and pressure for each grout stage.

The termination criteria applied to each grout stage were as follows;

- Maximum pressure reached
  1. 500kPa (5 Bar) between 5 and 10m depth
  2. 1000kPa (10 Bar) below 10m depth
- Grout appeared at ground surface indicating flow through near surface broken ground or around the packer.
- Ground surface movement was recorded.

4.5 Shaft treatment

Four potential shafts were identified during the pre-treatment ground investigations by low dynamic probe blow counts from ground level to mine depths (at all four locations), by a greater thickness of made ground (at one location) and by void migration (at one location). These shafts appeared to be only some 2m in diameter. All the shafts appeared to have been backfilled with material of similar strength to the surrounding ground.

No significant degradable material (such as wood) was encountered during drilling of these shafts. Each shaft location was treated by a combination of bulk infilling and compaction grouting.

4.6 Validation testing

The validation process undertaken involved continuous assessment of all treatment data. Specific validation testing carried out included:

- super heavy dynamic probe holes (DPSH) to compare pre and post treatment blow counts and to locate areas where blow counts remained below a threshold of 3 for 100mm (set following the initial investigations)
- additional grouting was undertaken where validation testing proved that grouting had not been completed successfully with subsequent additional validation probe holes.

4.7 Monitoring

Given the potential uncertainties in mine behaviour, monitoring was undertaken at all properties where mine treatment was undertaken and included the following:

- regular precise levelling
- daily visual inspections
- monitoring of groundwater levels and monthly groundwater chemical analysis
- hazardous gas monitoring during drilling

During the course of works, there was no evidence of building movements exceeding the agreed monitoring levels that required emergency procedures to be implemented No hazardous gasses were detected during drilling and no significant impacts on groundwater levels or quality recorded.

4.8 As Built Information

The Project Specification for the Works is included in Appendix D. The anticipated and actual scope of the treatment works are summarise in the Table 2 below.

Table 2: Proposed and actual treatment quantities

Item	Proposed quantity	Actual quantity
Grout holes	836 No.	942 No.
Bulk grout infill volume	1398m^3	1604.1m^3
Compaction grout volume	1291m^3	7894.8m^3
Validation Dynamic probes	160 No.	1123 No.

The as built details for the locations of the drilled and grouted holes are presented in the Factual Report for the treatment works (BAM Ritchies, 2015).

4.9 Reinstatement

In addition to the repair of any avoidable damage, reinstatement at the site undertaken by the treatment works contractor included:

- topping up of all grout holes
- replacement of topsoil
- application of tarmac to affected areas

5 MINEWORKINGS INTERPRETATION AND TREATMENT

5.1 Revised Mine Layout

The extent of the mine workings at the site, as determined following the pre-treatment ground investigations, has been reviewed in the light of the additional information gained during the mine stabilisation works. This information has been derived from the following sources;

- grout hole drilling records (recording disturbed ground and voids)
- grouting records (recording volume of grout injected with depth)
- validation probing (recording zones of low blow counts)
- CCTV surveys (recording images of mine workings)

The interpreted mine layout, along with a summary of grout takes and recorded areas of voids and disturbed ground are also shown in the Arcadis individual treatment area reports contained in Appendix B. Whilst the method of boring grout holes (open hole auguring) allowed only basic logging of the soils encountered this was sufficient to allow disturbed ground and voids to be recorded. In addition, it was possible to identify grout in the drilling arisings in areas where treatment had previously been carried out adjacent.

During the works the data obtained from the above sources was reviewed in conjunction with the pre-treatment data to provide refinement in the interpreted mine layout. This process was carried out using the three dimensional Rockworks model developed through the course of the works and allowed the relationship between all data to be studied giving a high degree of confidence in the completeness of the treatment.

Following the interpretation of the site data a number of refinements have been made to the original mine model. The key modifications made are;

- The original 'T-section' mine workings were modified to a single mine gallery, re-aligned and extended principally along Nos. 6-8 Meadow Road. Further investigation carried out during Phase 2 works identified additional mine workings along the front and rear gardens at Nos. 2 and 4 Meadow Road before extending towards the Meadow Road / Highbarns junction. Extension of mine workings beneath the northern side of Highbarns between No. 1 Pond Road and the junction of Highbarns and Meadow Road.
- extension of mine workings beneath No. 8 Pond Road (and outside the Derelict Land Clearance Order site boundary beneath Nos. 10 and 12 Pond Road)
- extension of mine workings beneath the rear garden of No. 2 Pond Road.
- possible connection identified between the mine workings beneath Nos. 7 and 9 Highbarns.
- extension of mine workings beneath No. 15 Highbarns.
- additional mine workings beneath No. 30 Highbarns connecting the workings in the rear garden of the property to the mine workings in the central area.
- Mine workings extended beneath Nos. 25 and 26 East Green.
- extension of the mine workings beneath the rear gardens of Nos. 20 and 22 Highbarns to the lock-up garages beside East Green.
- extension of the mine workings beneath the rear garden of No. 14 Highbarns to the front gardens of Nos. 12 and 14 Highbarns. These mines are connected to the workings beneath the junction of Meadow Road and Highbarns (which also extend

into the front garden of No. 10 Pond Road) and will be discussed in a separate validation report following treatment of this road junction).

Full details of the treatment completed for each treatment area, including outputs from the Rockworks model, are presented in Appendix C. In general, the site works have confirmed that the mine workings form a single network of interconnected galleries on a single level with the majority of the mine having a similar layout as the interpreted mine layout based on the findings of the pre-treatment ground investigations, the exceptions being the extensions to mine passageways as listed above. In general, the mine workings were encountered between depths of 11.5m and 21m. The deepest confirmed working using CCTV was identified beneath the rear gardens of Nos. 6 Meadow Road/No. 3 Pond Road in grout hole CGV050 at a depth of 21m.

The revised mine layout is shown in Figure 3, Appendix A.

5.2 Mine Treatment

The initial phase of mine treatment involved the bulk infilling of known voids with grout. The location of the bulk infill holes are shown in BAM Ritchies' sectional Validation rRports (BAM, 2015) and contained in appendix E. Although the pre-treatment ground investigations had indicated that the mine workings consisted predominantly of open voids at the centre of the site with the majority of the mine galleries radiating out from this centre appearing to be either partially or fully collapsed or infilled with backfill material, it was anticipated that some additional isolated voids would be encountered that had not been intercepted by the exploratory holes.

Further areas of suspected open mine workings were identified either during drilling of grout holes, during CCTV surveys of grout holes or where high grout takes were experienced in a single injection stage. In all cases following bulk infilling, further compaction grouting in adjacent holes and validation probing were carried out to confirm that the mine workings had been treated.

More commonly across the site, disturbed ground only was recorded (i.e. with no large voids). In these areas it was interpreted that either partial or full collapse of the mine workings had occurred resulting in disturbance of the ground for some distance above the original workings (but not necessarily extending to ground surface) or the mine workings had been infilled with backfill material. In these areas grout volumes were generally less discrete due to the widespread disturbed nature of the ground. Treatment of these areas was carried out using compaction grouting alone with the high grout pressures both consolidating loose materials and infilling any small remaining voids.

5.3 Drainage

Pre-treatment surveys indicated that the drainage was in a generally poor condition, revealing cracked pipework and blocked drainage gullies. The extent to which this condition was related to its construction, their maintenance, poor superficial ground conditions causing settlement or mine related ground movements is not known.

Drainage surveys were conducted during and following the works and these confirmed that there was no significant deterioration in the drainage condition as a result of the works.

Soakaways exist at the site adjacent to some houses (for rainwater run-off). The effectiveness of these is unknown and soakaways over collapsed ground could exacerbate the potential for settlement. The most significant risk associated with these relates to any soakaways close to houses.

6 CONCLUSIONS

From the investigations and treatment work undertaken and the subsequent validation testing it can be reasonably concluded that;

- based upon the evidence, all mined ground encountered has been treated and that compaction and consolidation of collapsed voids and mine shafts has taken place;
- as a result of the above assessment, significant risk from chalk mine workings within the treatment area has reduced to an acceptably low level following treatment;
- there is no evidence of any adverse impacts on groundwater quality beneath the site as a consequence of the work;
- there is no evidence of any significant movement or other adverse effects on buildings or infrastructure during the works; and
- the risks from further untreated workings in the treatment area is considered to be no higher than elsewhere in Hemel Hempstead.

The grouting work undertaken has only targeted the treatment of mined ground for the current site use and building layout. It is still the responsibility of the land owner to seek appropriate design advice prior to future development.

Dacorum Borough Council Building Control should be informed if any evidence of mine workings (such as shafts, voids or collapsed ground) is found during any future works undertaken as part of redevelopment.

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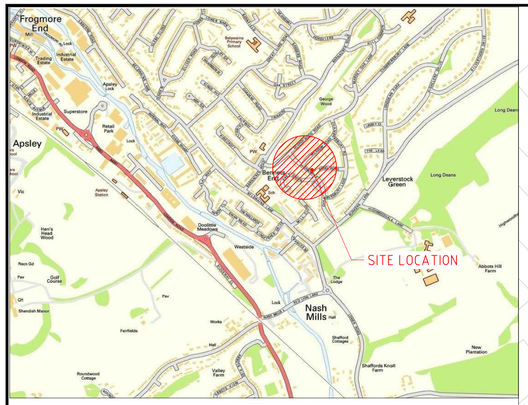
APPENDIX A

Drawing GDD-020-UA4004620: Site Location Plan

Drawing GDD-021-UA4004620: Treatment Area Plan

Drawing GDD-022-UA4004620: Interpreted Mine Layout



SITE MAP

NTS

SITE LOCATION PLAN

SCALE 1:400

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS NOTED OTHERWISE.
2. ALL LEVELS IN METRES UNLESS NOTED OTHERWISE.

LEGEND	
PATTERN	DETAIL
	DERELICT LAND CLEARANCE ORDER BOUNDARY

Rev	Date	Auth	Description	Ckd	Apprd
A01	15.10.15	AB	FIRST ISSUE	AH	RB

Client

DACORUM BOROUGH COUNCIL

ARCADIS Design & Consultancy for natural and built assets
10 Medawar Road, The Surrey Research Park, Guildford, Surrey, GU2 7AR
Tel: +44 (0)1483 803071, www.arcadis.com

Project:

HIGHBARNS
CHALK MINE STABILISATION PROJECT

Drawing status:

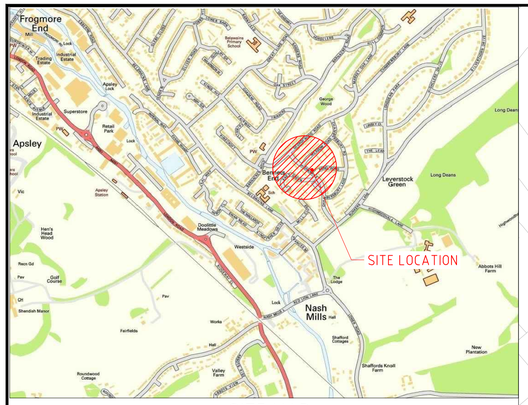
PRELIMINARY

Drawing title:

SITE LOCATION PLAN

Drawn by:	Date:	Author:	Date:
D.MORE	15.10.15	A.BLAKE	15.10.15
Checker:	Date:	Approver:	Date:
A.HOPE	15.10.15	R.BARSBY	15.10.15

Scale:	Sheet No.:
AS SHOWN ON DRAWING	01
Drawing No:	Revision:
HBS-020-UA000857	A01



SITE MAP

NTS

TREATMENT AREA PLAN

SCALE 1:400

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS NOTED OTHERWISE.
2. ALL LEVELS IN METRES UNLESS NOTED OTHERWISE.

LEGEND	
PATTERN	DETAIL
	TREATMENT AREA BOUNDARY
	DERELICT LAND CLEARANCE ORDER BOUNDARY

Rev	Date	Auth	Description	Ckd	Apprd
A01	15.10.15	AB	FIRST ISSUE	AH	RB

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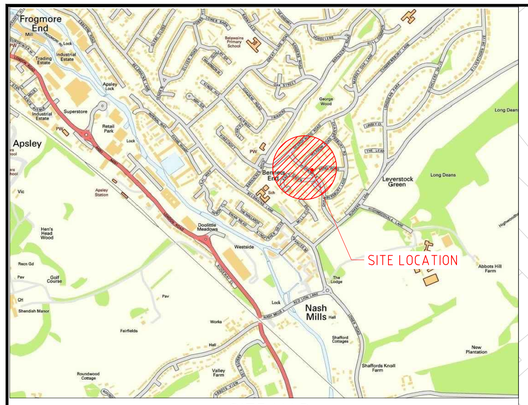
TREATMENT AREA PLAN

Drawn by:	Date:	Author:	Date:
D.MORE	15.10.15	A.BLAKE	15.10.15
Checker:	Date:	Approver:	Date:
A.HOPE	15.10.15	R.BARSBY	15.10.15

Scale:	Sheet No.:
AS SHOWN ON DRAWING	01
Drawing No:	Revision:
HBS-021-UA000857	A01



SITE MAP

NTS

INTERPRETED MINE LAYOUT

SCALE 1:400

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS NOTED OTHERWISE.
2. ALL LEVELS IN METRES UNLESS NOTED OTHERWISE.
3. VOIDS IDENTIFIED BY LASER SURVEYS UNDERTAKEN IN 2008 AND REMEDIATED IN 2008 ARE BASED ON PETER BRETT ASSOCIATES (2008), INTERPRETATIVE GEOTECHNICAL REPORT- PHASE 1, NO 20247/0043/INT01/REV2, JULY 2008.
4. VOIDS IDENTIFIED BY LASER SURVEYS UNDERTAKEN IN 2012 ARE BASED ON INSPECTAHIRE (2012), CALS AND CCTV INSPECTION OF VOIDS REPORT NO 6658, ISSUE 02, AUGUST 2012.

LEGEND	
PATTERN	DETAIL
	DERELICT LAND CLEARANCE ORDER BOUNDARY
	INTERPRETED MINE EXTENTS FOLLOWING TREATMENT
	VOIDS IDENTIFIED BY LASER SURVEYS UNDERTAKEN IN 2012 (SEE NOTE 4)
	VOIDS IDENTIFIED BY LASER SURVEYS UNDERTAKEN IN 2008 AND REMEDIATED IN 2008 (SEE NOTE 3)
	INTERPRETED SHAFT LOCATION FOLLOWING TREATMENT
	COLLAPSED GROUND RECORDED DURING TREATMENT

Rev	Date	Auth	Description	Ckd	Apprd
A01	15.10.15	AB	FIRST ISSUE	AH	RB

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ARCADIS Design & Consultancy for natural and built assets
10 Medawar Road, The Surrey Research Park, Guildford, Surrey, GU2 7AR
Tel: +44 (0)1483 803071, www.arcadis.com

Project:

HIGHBARNS
CHALK MINE STABILISATION PROJECT

Drawing status:

PRELIMINARY

Drawing title:

INTERPRETED MINE LAYOUT

Drawn by:	Date:	Author:	Date:
D.MORE	15.10.15	A.BLAKE	15.10.15
Checker:	Date:	Approver:	Date:
A.HOPE	15.10.15	R.BARSBY	15.10.15

Scale:	Sheet No.:
AS SHOWN ON DRAWING	01
Drawing No:	Revision:
HBS-022-UA000857	A01

APPENDIX B

Treatment Areas Reports TAR0001 to TAR0012

APPENDIX C

Rockworks Mine Model (Issued on CD)

APPENDIX D

Specification for Site Works (Issued on CD)

APPENDIX E

BAM Ritchies' Factual Report (Issued on CD)

APPENDIX F

BAM Ritchies' Summary Report of Grout Testing (Issued on CD)

Arcadis Consulting (UK) Limited

The Surrey Research Park
10 Medawar Road
Guildford
GU2 7AR
United Kingdom

T: +44 (0)1483 803 000

arcadis.com