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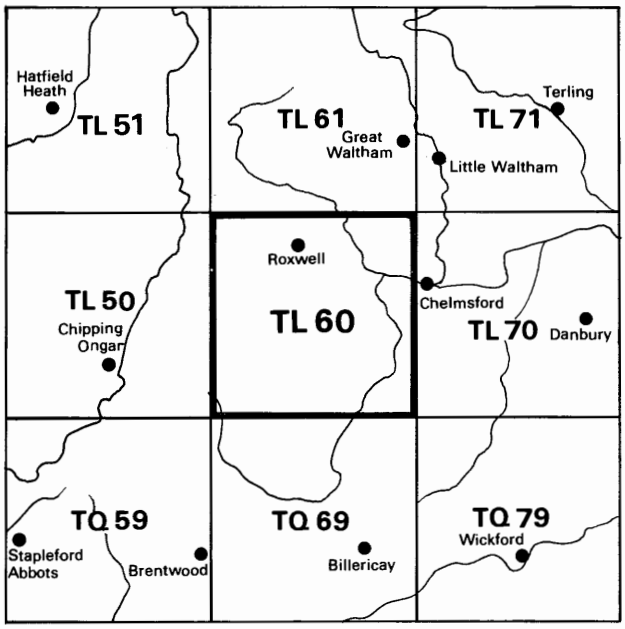

The sand and gravel resources of the country west of Chelmsford, Essex

Description of 1 : 25 000 resource sheet TL 60

P. M. Hopson

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The first twelve reports on the assessment of British sand and gravel resources appeared in the Report series of the Institute of Geological Sciences as a subseries. Report 13 and subsequent reports appear as Mineral Assessment Reports of the Institute.

Details of published reports appear at the end of this Report.

Any enquiries concerning this report may be addressed to Head, Industrial Minerals Assessment Unit, Institute of Geological Sciences, Keyworth, Nottingham NG12 5GG.

PREFACE

National resources of many industrial minerals may seem so large that stocktaking appears unnecessary, but the demand for minerals and land for all purposes is intensifying and it has become increasingly clear in recent years that regional assessments of the resources of these minerals should be undertaken. The publication of information about the quantity and quality of deposits over large areas is intended to provide a comprehensive factual background against which planning decisions can be made.

Sand and gravel, considered together as naturally occurring aggregate, was selected as the bulk mineral demanding the most urgent attention, initially in the south-east of England, where about half the national output is won and very few sources of alternative aggregates are available. Following a short feasibility project, initiated in 1966 by the Ministry of Land and Natural Resources, the Industrial Minerals Assessment Unit (formerly the Mineral Assessment Unit) began systematic surveys in 1968. The work is now being financed by the Department of the Environment and is being undertaken with the cooperation of the Sand and Gravel Association of Great Britain.

This report describes the resources of sand and gravel of 100 km^2 of the country west of Chelmsford, Essex, shown on the accompanying 1:25 000 resource sheet TL 60. The survey was conducted by Mr P. M. Hopson, assisted by Mr R. J. Marks and Mr D. W. Murray during the drilling and sampling programme. Mr Hopson compiled the report. The work is based on a geological survey at the 1:10 560 scale by Mr R. D. Lake and Mr R. A. Ellison in 1969 and 1977. Mr J. D. Burnell, ISO, (Land Agent) has been responsible for negotiating access to land for drilling. The ready cooperation of land owners and tenants in this work is gratefully acknowledged.

G. M. Brown
Director

Institute of Geological Sciences
Exhibition Road
London SW7 2DE

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SUMMARY

The geological maps of the Institute of Geological Sciences, pre-existing borehole information and 42 boreholes drilled for the Industrial Minerals Assessment Unit form the basis of the assessment of the sand and gravel resources of the country west of Chelmsford.

All deposits in the area which might be potentially workable for sand and gravel have been investigated and a simple statistical method has been used to estimate the volume. The reliability of the volume estimates is given at the symmetrical 95 per cent probability level.

The 1:25 000 map is divided into 3 resource blocks containing between 2.1 and 10.5 km^2 of potentially workable sand and gravel. For the blocks assessed statistically the geology of the deposits is described and the mineral-bearing area, the mean thickness of overburden and mineral, and the mean grading of the mineral are stated. Detailed borehole data are given. The geology, the position of the boreholes and the outlines of the resource blocks are shown on the accompanying map.

Bibliographic reference
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Note
All National Grid references in this report lie in the 1:25 000 sheet TL 60

Author
P. M. Hopson, BSc.
Institute of Geological Sciences
Keyworth, Nottingham NG12 5GG

INTRODUCTION

The survey is concerned with the estimation of resources, which include deposits that are not currently exploitable but have a foreseeable use, rather than reserves, which can only be assessed in the light of current, locally prevailing, economic considerations. Clearly, both the economic and the social factors used to decide whether a deposit may be workable in the future cannot be predicted; they are likely to change with time. Deposits not currently economically workable may be exploited as demand increases, as higher grade or alternative materials become scarce, or as improved processing techniques are applied to them. The improved knowledge of the main physical properties of the resource and their variability which this survey seeks to provide, will add significantly to the factual background against which planning policies can be decided (Archer, 1969; Thurrell, 1971; Harris and others, 1974).

The survey provides information at the 'indicated' level "for which tonnage and grade are computed partly from specific measurements, samples or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout" (Bureau of Mines and Geological Survey, 1948, p. 15).

It follows that the whereabouts of reserves must still be established and their size and quality proved by the customary detailed exploration and evaluation undertaken by the industry. However, the information provided by this survey should assist in the selection of the best targets for such further work. The following arbitrary physical criteria have been adopted:

a The deposit should average at least one metre in thickness.
b The ratio of overburden to sand and gravel should be no more than 3:1.
c The proportion of fines (particles passing the No. 240 mesh BS sieve, about $\frac{1}{16}$ mm) should not exceed 40 per cent.
d The deposit should lie within 25 m of the surface, this being taken as the likely maximum working depth under most circumstances. It follows from the second criterion that boreholes are drilled no deeper than 18 m if no sand and gravel has been proved.

A deposit of sand and gravel which broadly meets these criteria is regarded as 'potentially workable' and is described and assessed as 'mineral' in this report. As the assessment is at the indicated level, parts of such a deposit may not satisfy all the criteria.

For the particular needs of assessing sand and gravel resources, a grain-size classification based on the

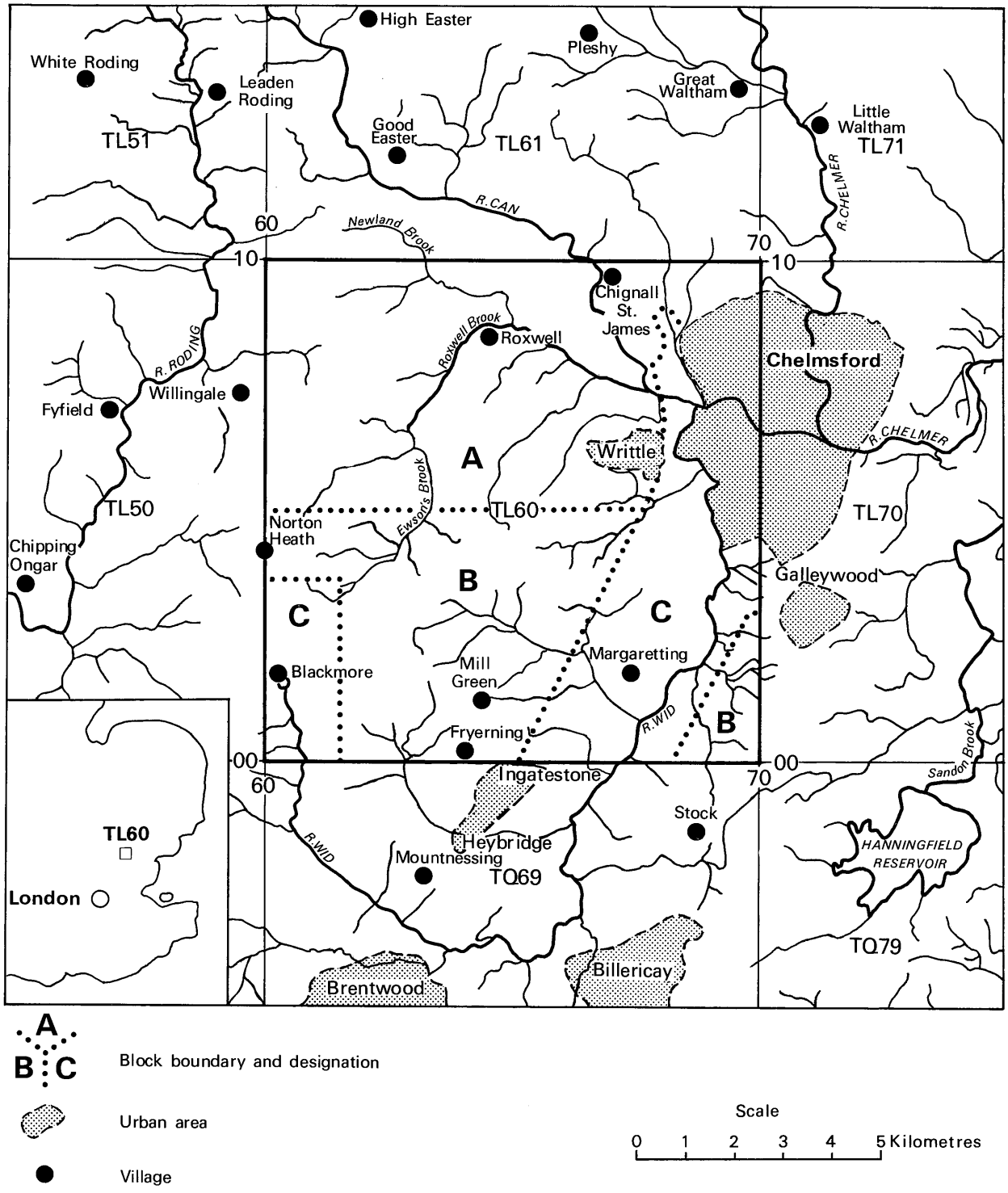

Figure 1 Sketch map of the location of sheet TL 60, showing the resource block boundaries.

geometric scale $\frac{1}{16}$ mm, $\frac{1}{4}$ mm, 1 mm, 4 mm, 16 mm has been adopted. The boundaries between fines (that is, the clay and silt fractions) and sand, and between sand and gravel grade material, are placed at $\frac{1}{16}$ mm and 4 mm respectively (see Appendix C).

The volume and other characteristics are assessed within resource blocks, each of which, ideally, contains approximately 10 km^2 of sand and gravel. No account is taken of any factors, for example, roads, villages and high agricultural or landscape value, which might stand in the way of sand and gravel being exploited, although towns are excluded. The estimated total volume therefore bears no simple relationship to the amount that could be extracted in practice.

It must be emphasised that the assessment applies to the resource block as a whole. Valid conclusions cannot be drawn about the mineral in parts of a block, except in the immediate vicinity of the actual sample points.

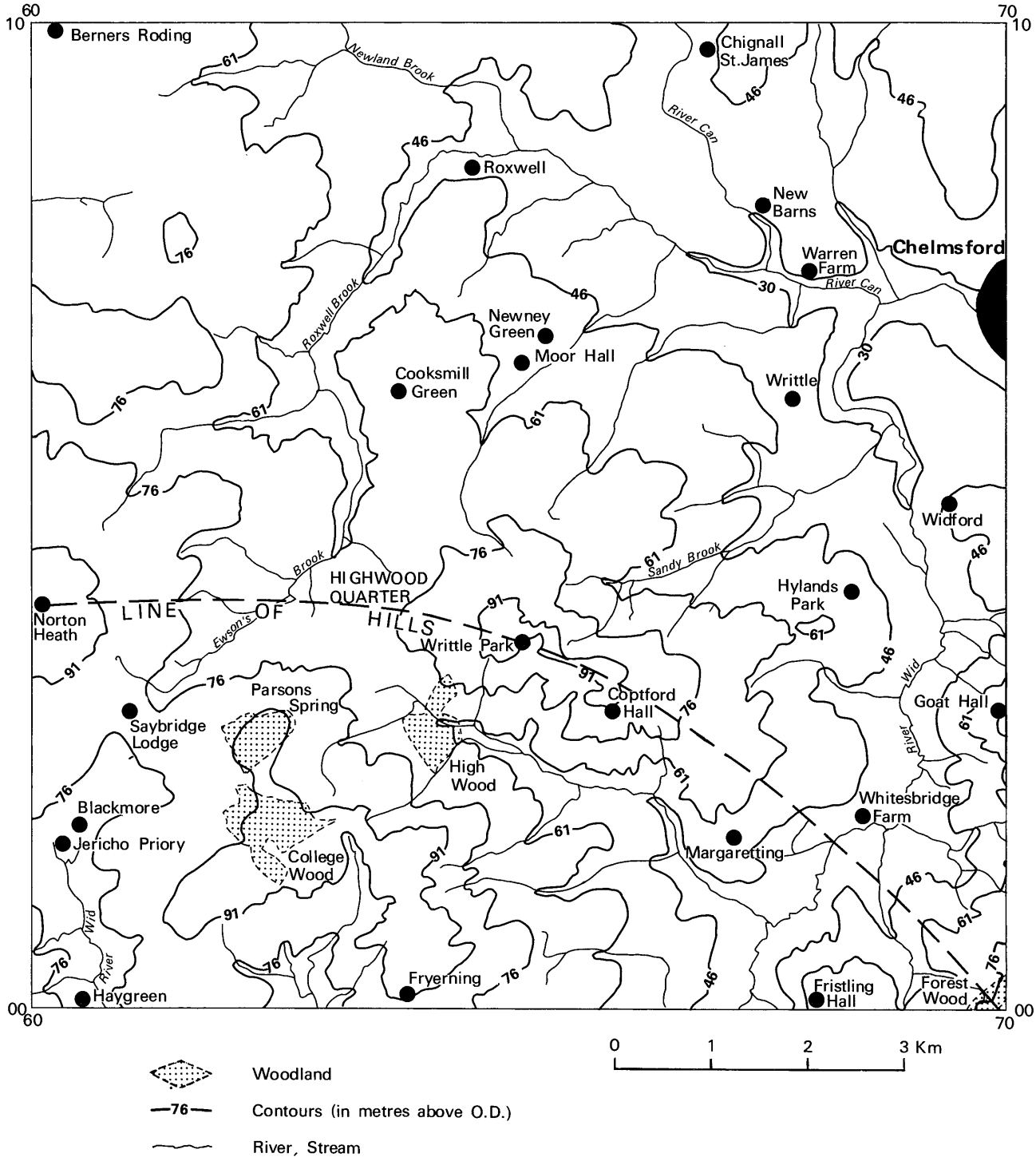

Figure 2 Sketch map of the topography of the country west of Chelmsford, showing the places mentioned in the text.

DESCRIPTION OF THE RESOURCE SHEET

GENERAL

The resource sheet covers an area of 100 km^2 to the west of Chelmsford, the county town of Essex (Figure 1). Chelmsford situated 48 km north-east of central London, is the centre for a large commuting population, and with Writtle, a small dormitory town to the west, covers an area of 7.5 km^2 on the eastern margin of the sheet. The remainder of the district is largely rural and the major industry is mixed farming, which includes some forestry on the higher ground towards the south. However, some light industries are located in the urban area of Chelmsford.

Essex has long been a source of aggregate and this sheet area, although only containing 17.6 km^2 of mineral-bearing ground, covers the western margin of a highly productive area centred to the east of Chelmsford.

TOPOGRAPHY

The area is dominated to the south by a line of hills, the remnants of a dissected upland, which extends from Norton Heath [602 043] in the west to Stock [TQ 688 986] in the south-east (Figures 1 and 2). These hills, which rise to 98 m above Ordnance Datum, are broken by two gaps. In the west at Saybridge Lodge [610 030], between Norton Heath and Blackmore [605 018], Ewson's Brook cuts a broad shallow depression trending north-eastwards, and in the east the River Wid, flowing in a narrow deep valley, cuts through these

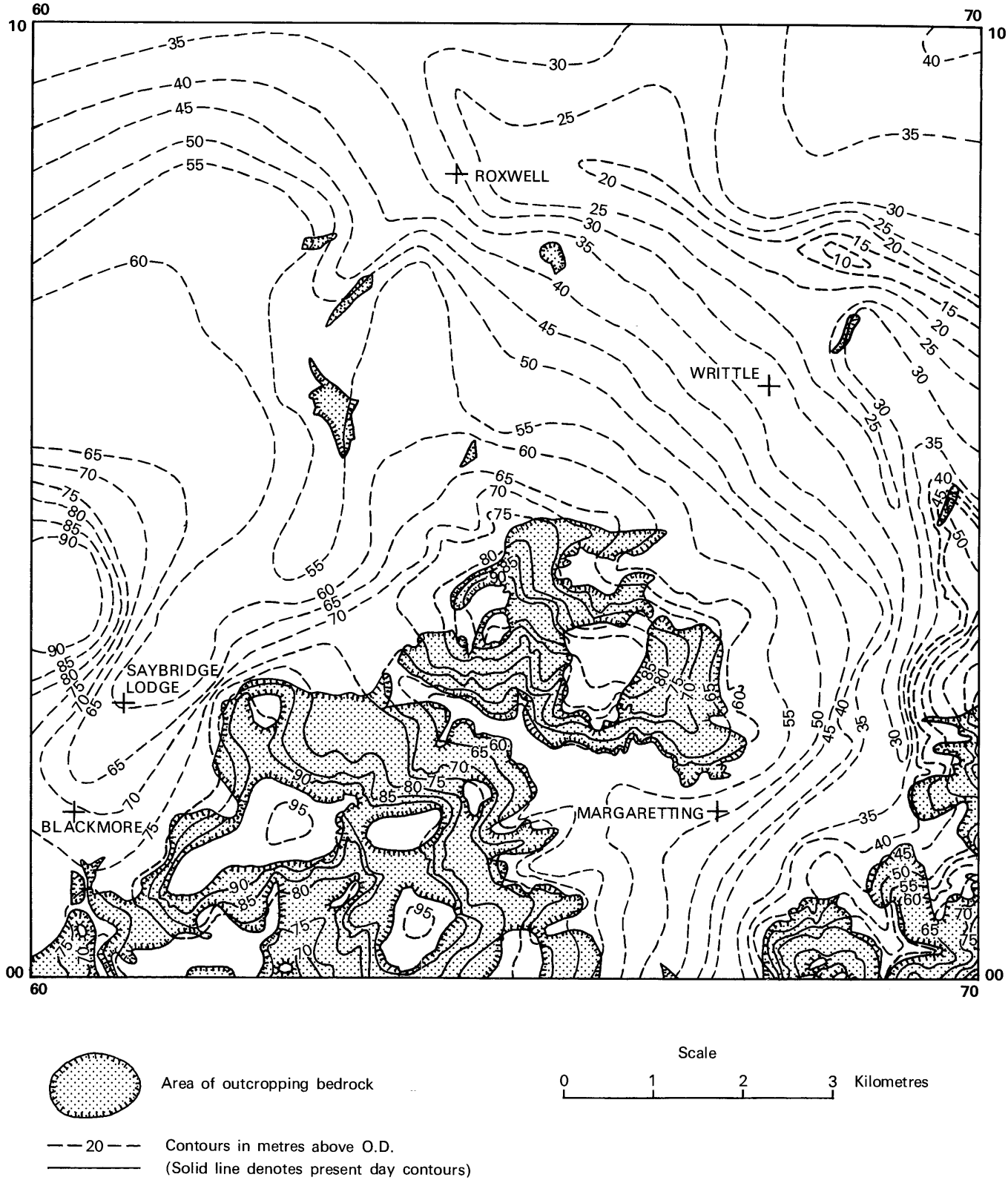

Figure 3 Contour map of the bedrock surface.

hills south-east of Margaretting [671 017]. The River Wid rises at Jericho Priory [603 016], Blackmore, and flows south leaving the sheet area at Hay Green [650 000] (Figure 1). It then flows south-eastwards south of Mountnessing [TQ 632 976] before turning north-east and re-entering the sheet area near Fristling Hall [680 000]. Thence it flows northwards from Whitesbridge Farm [684 019] to its confluence with the River Can east of Warren Farm [680 074] (Figure 2).

North of these hills the ground falls gently towards the north-east and is dissected by numerous streams. Ewson's and Newland Brooks are tributaries of the Roxwell Brook which flows north from near Ewson's Bridge [633 050] to Roxwell [645 084] and then east to join the River Can.

The River Can flows south-east from Chignall St James [670 096] turning to the east at its confluence [675 074] with Roxwell Brook. After being joined by the River Wid it flows east through Chelmsford to its confluence with the Chelmer.

In the north-west, near Spains Hall [603 064] the ground rises to 80 m above Ordnance Datum at the

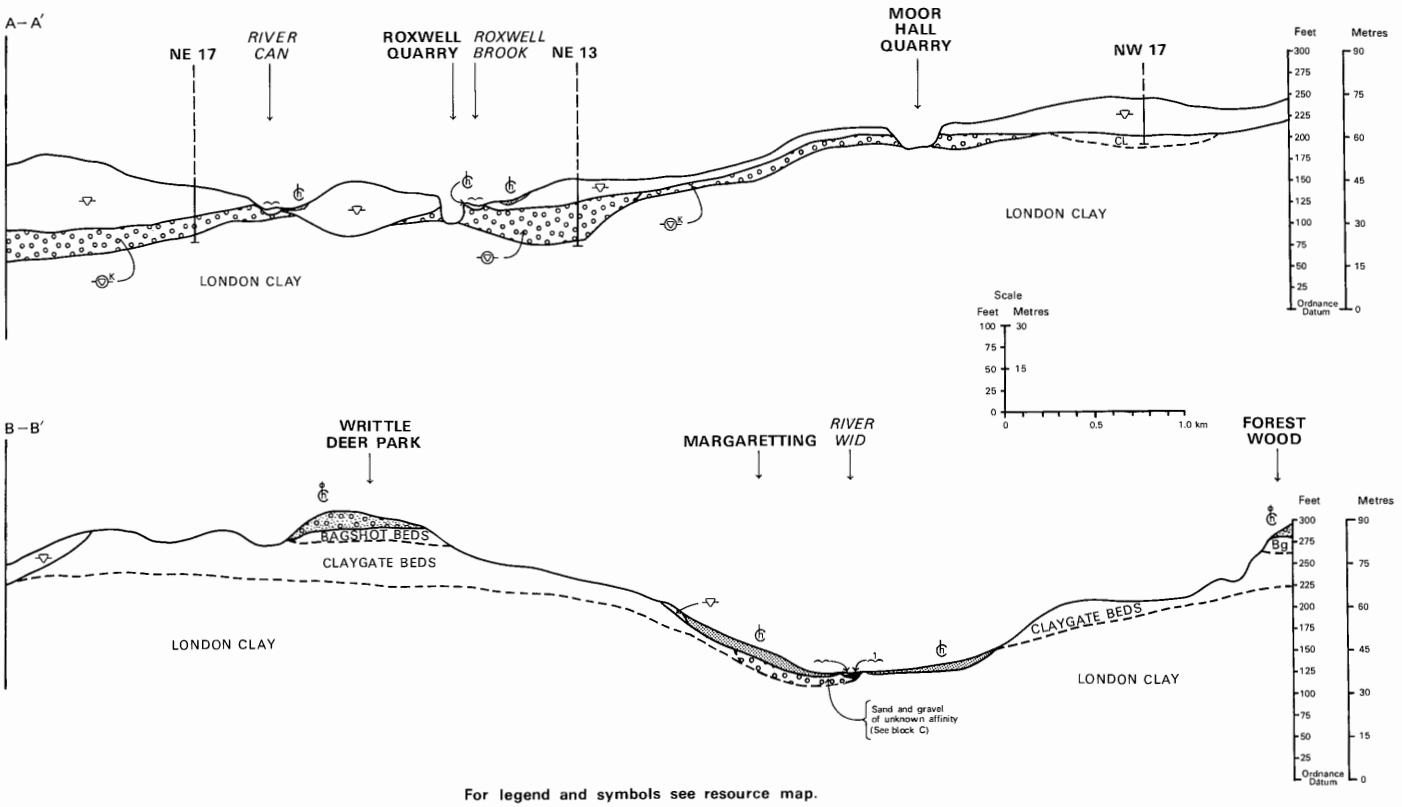

Figure 4 Sketch section showing the general relationships of the drift and bedrocks.

southern margin of the Boulder Clay sheet that extends over most of the northern part of this district.

GEOLOGY

This district may be divided into two areas of contrasting geological characteristics, lying respectively north and south of the line of hills mentioned above (Figure 2).

The northern area is a boulder-clay plain with infrequent and small patches of Kesgrave Sands and Gravels and small inliers of London Clay; to the south large outcrops of London Clay, Claygate Beds and Bagshot Beds are capped on the higher ground by patches of Older Head and in the valleys by Head (Figures 2 and 4). This general pattern is modified in the gap at Saybridge Lodge [610 030] where Boulder Clay and Glacial Sand and Gravel predominate, and in the valleys of the Rivers Wid, Can and Roxwell Brook where Alluvium and Head deposits occur.

The Upper Chalk, Thanet Beds and Woolwich and Reading Beds are encountered only in deep boreholes beneath a considerable thickness of London Clay and will not be discussed further in this report.

A list of the formations that crop out in the area of the resource sheet is given in Table 1.

SOLID FORMATIONS

London Clay

The London Clay crops out as small inliers surrounded by the overlying Boulder Clay in the valley of Roxwell Brook and in the vicinity of Newney Green [651 069]; it forms more extensive outcrops around Blackmore and High Woods [63 02].

The London Clay consists predominantly of silty clay or clayey silt but at both the top and bottom of the formation it includes a fine sand. Characteristically at the top of the formation on alternation of sand and clay lithologies occurs, with the sand concentrated within fine laminae and thin seams separated by silty clay.

The boundary between the London Clay and the overlying Claygate Beds is gradational, but during mapping the lowest significant sandy horizon recognis-

Table 1 List of the formations that crop out in the area of the resource sheet

Recent and **Pleistocene**	
Peat	Dark brown or black vegetable matter with varying amounts of silt and sand
Alluvium	Clayey silt and silty fine sand with some thin gravel seams, yellowish brown
First Terrace	Gravel and sandy gravel, yellowish brown
Head	Silty sandy clay with some flint pebbles, medium brown
Glacial Silts	Laminated silt and fine sand with some gastropod debris and peat seams, yellowish grey
Boulder Clay	Silty clay with flint and chalk pebbles and some fine sand, dark bluish grey, weathering to ochre brown
Glacial Sand and Gravel	Gravel with some thin pebbly silty boulder clay seams
Kesgrave Sands and Gravels	Sandy gravel with some thin silty clay seams, yellowish brown and orange-brown
Older Head	'Very clayey' well rounded flint gravel, yellowish brown and orange-brown
Eocene	
Bagshot Beds	Fine and medium sand with subordinate thin clay seams, yellowish brown and orange-brown
Claygate Beds	Fine sandy clay and silt, laminated, pale yellowish brown
London Clay	Dark bluish grey silty clay with some fine sand

able in the field was used as the boundary. Throughout the London Clay, pockets or lenses of drab olive-green glauconitic fine and medium sand may occur.

The colour of the London Clay varies from dark olive-green to dark bluish grey when fresh, but on weathering the clay is usually brown with orange-brown mottling. Pyrite occurs throughout the deposit both as disseminated particles and as nodules. The reaction between the weathering products of pyrite and calcium carbonate present in the clay leads to the formation of scattered selenite (gypsum) crystals. Calcareous concretions (septarian nodules) occur at some levels within the clay; they are characteristically veined with calcite and often contain well preserved molluscan shells.

Claygate Beds

The passage beds which were deposited during the transitional period of gradual shallowing from the deeper-water conditions that prevailed during the deposition of the London Clay to the shallower-water conditions in which the Bagshot Beds were laid down, are called the Claygate Beds. They are a series of alternations of evenly-bedded and laminated sand, silt and clay. In the lower part of the sequence, near the junction with the London Clay, clay and silt seams predominate over thin partings of white sand, while in the upper part the sandy beds increase to the virtual exclusion of the clay. The Claygate Beds pass without a clear demarcation line into the overlying Bagshot Beds.

The sand is predominantly fine grained and yellow or pale yellow, whilst the clay and silt are white, pale grey or more commonly lilac grey.

Results from IGS stratigraphical boreholes at Stock, Hadleigh, Hockley and Westley Heights (Cratchley and others, 1975) have shown that three broad subdivisions of the Claygate Beds can be recognised: the lowest division is a micaceous glauconitic sand overlain by silty clay. The middle division is of finely laminated micaceous glauconitic fine-grained sand overlain by silty clay and clayey silt interlaminated with fine sand. The uppermost division consists of interbedded fine-grained sands and silts with subordinate clay lenses and wisps. These divisions cannot generally be recognised in IMAU boreholes since insufficient thicknesses of bedrock have been penetrated, but in borehole SE 83 [6558 0298] the middle and lower divisions are distinguishable.

Bagshot Beds

The Bagshot Beds are marine in origin and only their lower part is present in the area covered by this resource sheet. This consists of fine and medium slightly micaceous sands (about 13 m was proved in the IGS borehole at Stock), often laminated and cross-bedded with subordinate beds of lilac and light grey clay. The overlying clay and silt group, with pebble beds, is not seen in this area.

The sands range in colour from almost white to orange-brown but are generally pale brown and often contain black carbonaceous flecks. Subordinate beds of clay and silt are lilac or light grey in colour.

The base of the deposit lies generally at about 91 m above Ordnance Datum and the Bagshot Beds cap the highest ground around Writtle Park [649 036], Coptford Hall [659 030], College Wood [62 01], High Woods, Goat Hall [699 030] and Forest Wood [698 001].

Since in south-east Essex the top of the Bagshot Beds has been removed by post-Eocene erosion, the full original thickness is not known in this district.

DRIFT DEPOSITS

Older Head

This deposit is found in numerous small outcrops capping the high ground on the southern half of the sheet. The gravel fraction is predominantly (90 per cent) of rounded to well rounded flint set in a 'clayey' or 'very clayey' sand matrix. In some areas a pebbly sand is developed at the base, notably at Writtle Park and Parsons Spring [62 01], 1.5 km south-west of Highwood. A further variation from the normal lithology was proved in borehole SW 27 [6222 0149] and Exposure SW E1 [6234 0170] at College Wood, where the composition was highly variable, with much smaller amounts of well rounded flint and greater amounts of angular flint, quartzite, quartz and sandstone.

The origin and age of the Older Head deposit are not known with certainty but they are generally considered to be early Pleistocene in age. Prestwich (1890, p. 164) grouped these deposits with the Warley Gravels, found to the south of this sheet, and called them the Brentwood Group. He considered them to be 'little else than Bagshot Shingle, more or less disturbed, mixed with a few subangular flints, quartzite and quartz'.

The Older Head is probably a solifluxion deposit formed from the Bagshot Pebble beds mixed in varying proportions with high level gravels such as the Plateau Gravels of the Epping ridge, south-west of this sheet.

Kesgrave Sands and Gravels

This deposit, the principal occurrence of mineral on the sheet area, is limited in outcrop but has been proved to be more extensive under the boulder-clay cover. It occurs exclusively in the north where small outcrops are seen in the valleys of the River Can and Roxwell Brook. The gravels comprising the deposit have no limestone material and a high proportion (30 per cent) of quartz and quartzite. They were formerly thought to be outwash gravels, deposited in front of an advancing Pleistocene (Anglian) ice sheet. More recently, however, they have been considered to be periglacial (Beestonian) proto-Thames fluvial gravels, deposited in a braided-stream environment (Rose and Allen, 1977).

The Kesgrave Sands and Gravels thin towards the south where Boulder Clay rests directly on bedrock (Figure 4) as shown in boreholes NW 17 [6393 0519] and NE 16 [6516 0564].

Glacial Sand and Gravel

The Glacial Sand and Gravel, locally called 'Hussick', is more widely distributed, but often thinner than Kesgrave Sands and Gravels, being found both north and south of the hills capped by Bagshot Beds. It is a proximal outwash gravel closely associated with and intercalated within the Boulder Clay, and always rests on the older Kesgrave Sands and Gravels where the latter are present, for example, in borehole NW 15 [6303 0742]. The gravels found infilling the incised buried valley of the River Can/Roxwell Brook (Figure 3) are of this chalk-rich type, and have been recorded, for example, in boreholes NE 13 [6501 0814] and NE 24 [6835 0759].

Boulder Clay
Boulder Clay covers most of the northern half of this sheet and extends southwards in two lobes at Hylands Park [685 042] and in the col at Saybridge Lodge. A number of small patches are also found in the vicinity of Margaretting and Fryerning [638 002] in the south.

It consists of dark bluish grey silty sandy clay containing many pebbles of various sizes and rock-types; despite its name boulders are rare. The clay matrix is derived mainly from the pyrite-rich dark bluish grey and black Lias, Oxford, Ampthill, Kimmeridge and Gault clays, over which the ice moved on its journey south. The pebbles, constituting up to 40 per cent of the deposit, are predominantly of chalk with flint (both angular and well rounded) and some quartzite, quartz and black shale and a trace of fossil debris.

Weathering greatly affects the appearance of the Boulder Clay; generally the upper three or four metres have been leached of chalk and the pyritous clay matrix has been oxidised to produce a colour of brown or ochre. The base of this deposit, particularly where it rests directly on bedrock, becomes sandy and often very pebbly (but free of chalk), for example in borehole NW 12 [6183 0617].

Glacial Silts
Glacial Silts have been found in only two limited areas in this sheet area: in the north-east, half a kilometre east of New Barn [675 081], and in the south in the vicinity of Saybridge Lodge. In the north they crop out on the western flank of the valley of a tributary stream of the River Can and have been proved to the east beneath head deposits in borehole NE 24. They typically consist of laminated pale yellowish brown clayey silty fine sand and fine sandy silt with, high in the sequence, seams of dark brown peat and comminuted gastropod debris. Usually, a 'Clayey' gravel with disseminated carbonaceous material overlies the sand and silt, the organic matter indicating that the lake persisted into the subsequent warmer climatic period. In the south the Glacial Silts crop out around Saybridge Lodge and pass under Boulder Clay to the north-east; here they consist of silty chalky fine-grained sand, interlaminated with fine sandy silt, as proved in boreholes SW 16 [6099 0291] and SW 17 [6135 0319].

Head
This solifluxion deposit covers large areas in the vicinity of Writtle; it is also widespread in the valley of the River Wid, and in most of the other river valleys where it flanks the Alluvium. It is a heterogeneous deposit, whose lithology varies widely from silty clay through sandy pebbly silty clay to sandy gravel seams. These are thin and not considered potentially workable. Though up to 7.9 m of Head has been proved, for example, in borehole SE 89 [6981 0415], it is generally about two or three metres thick.

In the vicinity of Margaretting the Head masks gravel, probably of fluvial origin, which, for simplicity, has been classified with the Head on the map.

First Terrace
Only one small area of river terrace deposits, classified as First Terrace, has been mapped on the sheet area; it is south of Whitesbridge Farm [684 020] and is thought to be mineral, although no borehole information is available.

Alluvium
Alluvium, of silty sandy clay lithology, forms sinuous belts that closely follow the present-day streams. The Alluvium masks sandy gravel of fluvial origin in the valley of the River Wid.

Peat
This deposit occurs only in the valley of Roxwell Brook south-east of Patience Bridge [633 071]. It consists of decomposed vegetable matter mixed with silty sandy clay.

COMPOSITION OF THE SAND AND GRAVEL

Six formations contain potentially workable sand and gravel deposits: Older Head, Kesgrave Sands and Gravels, Glacial Sand and Gravel, Glacial Silts, First Terrace and the fluvial gravels associated with the River Wid.

For the purpose of this report, the Glacial Silts and River Wid deposits have been considered with the Glacial Sand and Gravel. For the small area of First Terrace, no grading or compositional data are available, and although the First Terrace sands and gravels are considered to be potentially workable they will not be considered further in this section.

Although the Claygate Beds and Bagshot Beds would qualify as mineral under a rigid interpretation of the IMAU criteria they are considered not to be potentially workable owing to the fineness of their sand, the included deleterious accessory minerals (particularly iron oxides) and their clayey nature.

Older Head
The Older Head consists of well rounded pebbles packed in a stiff matrix of sandy silty, often waxy, clay. At its top in most boreholes up to 0.8 m of loose pebbles in a subsoil have been found. It grades as a 'clayey' gravel; locally, however, as in borehole SW 26 [6238 0275], 'clayey' pebbly sands and 'clayey' sands, similar in lithology to the Claygate Beds, are found at the base. The mean grading for the deposit is fines 17 per cent, sand 40 per cent and gravel 43 per cent. The sand is medium with fine and some coarse grade (rarely exceeding 7 per cent) and is composed of angular flint with subrounded and rounded quartz. The gravel is coarse and fine with a trace of cobbles and consists, predominantly, of well rounded flint (67 per cent) with angular flint (25 per cent) and some subrounded fine-grade quartz and quartzite with a trace of sandstone, igneous and metamorphic rocks. In the coarse gravel grade, well rounded flint constitutes up to 90 per cent of the deposit and only trace amounts of other rock types occur. In contrast, the Older Head mapped at College Wood shows a greater percentage of quartz and quartzite and a preponderance of angular (50 per cent) over well rounded (24 per cent) flint. This composition may be the result of post-depositional solifluxion and admixture with glacial material.

Kesgrave Sands and Gravels
This formation contains the principal deposits of potentially workable mineral in the district: it has a mean grading of fines 6 per cent, sand 50 per cent and gravel 44 per cent, giving an overall classification of sandy gravel; only two boreholes proved mineral with more than 10 per cent fines.

The sand is predominantly of medium grade with some coarse and fine material and is composed of

subrounded quartz with some angular flint. In the coarse sand grade, angular flint and quartz are of equal proportions.

The gravel fraction is fine with coarse material: cobble grade was found in only one borehole. The gravel is predominantly angular flint (50 per cent) with well rounded flint (24 per cent) and with some subrounded quartz, quartzite and subangular sandstone with a trace of igneous and metamorphic material. (For the usage of 'with' and 'and' in this context, see Appendix C.)

Glacial Sand and Gravel

The Glacial Sand and Gravel, which is present in blocks A and C, has a mean grading of fines 7 per cent, sand 45 per cent and gravel 48 per cent (including 1 per cent of cobble grade), giving an overall classification of gravel.

The sand is predominantly medium with coarse and some fine grades and is composed principally of subrounded quartz and angular flint with traces of ironstone, chalk and limestone.

The gravel fraction is fine with coarse and a trace of cobble grade, and is predominantly angular flint (53 per cent) with rounded flint (16 per cent) and subrounded to rounded chalk (13 per cent) with some rounded to subrounded quartz, quartzite and subangular sandstone and characteristically (in trace amounts) limestone, ironstone, phosphatic nodules, pyrite, red chalk and fossil debris.

In the valley of the River Wid, the Head and Alluvium cover sand and gravel deposits whose affinity is not known. Only two IMAU boreholes were drilled into these deposits and they proved sandy gravel and gravel respectively, giving a mean grading of fines 9 per cent, sand 47 per cent and gravel 44 per cent including 1 per cent of cobble grade. Borehole SE 88 [6842 0195] proved mineral with a composition akin to the Glacial Sand and Gravel, while in borehole SE 85 [6662 0086] material with a composition intermediate between that of Older Head and Glacial Sand and Gravel was proved, suggesting reworking and admixture of these deposits. The latter borehole also contains 10 per cent of well rounded 'jasperised' flints derived from the Warley Gravels to the south (Dines, 1925 p. 23).

The Glacial Silts, in the vicinity of Warren Farm, also contain some potentially workable very chalky 'clayey' gravel resembling the Glacial Sand and Gravel. They rest on lacustrine peats and silts and Boulder Clay.

THE MAP

The sand and gravel resource map is folded into the pocket at the end of this report. The base map is the Ordnance Survey 1:25 000 Outline Edition in grey, on which the topography is shown by contours in green, the geological data in black and the mineral resource information in shades of red.

Geological data The geological boundary lines, symbols, etc., shown are taken from the geological map of this area recently surveyed at the scale of 1:10 560. This information was obtained by detailed application of field mapping techniques by the field staff of the Institute's East Anglia and South-Eastern England Unit. Borehole data, which include the stratigraphic relations, thicknesses and mean particle size distribution of the sand and gravel samples collected during the assessment, are also shown.

The geological boundaries are regarded as the best interpretation of the information available at the time of the survey. However, it is inevitable, particularly with deposits (such as those represented in this area) which change rapidly vertically and laterally, that local irregularities or discrepancies will be revealed by some boreholes (as, for example, at borehole SE 84). These are taken into account in the assessment of the resources (see Appendix B).

Mineral resource information The mineral-bearing ground is subdivided into resource blocks (see Appendix A). Within a resource block the mineral is subdivided into areas where it is exposed, that is where overburden averages less than 1 m in thickness, and areas where it is present in continuous spreads beneath overburden. The 'almost continuous' or 'discontinuous' mineral categories have not been recognised in this area.

Areas where bedrock crops out, where boreholes indicate absence of sand and gravel beneath cover and where sand and gravel beneath cover is interpreted to be not potentially workable, are uncoloured on the map; where appropriate the relevant criterion is noted. In such cases it has been assumed that mineral is absent except in infrequent and relatively minor patches which can neither be outlined nor assessed quantitatively in the context of this survey. Areas of unassessed sand and gravel, for example in built-up areas, are indicated by a red stipple.

The area of the sand and gravel is measured, where possible, from the mapped geological boundary lines. The whole of this area is considered as mineral, although it may include small areas where sand and gravel is not present or is not potentially workable. Inferred boundaries have been inserted where sand and gravel beneath cover is interpreted to be not potentially workable or absent. Such boundaries (for which a distinctive symbol is used) are drawn primarily for the purpose of volume estimation. The symbol is intended to convey an approximate location within a likely zone of occurrence rather than to represent the breadth of the zone, its size being limited only by cartographic considerations. For the purpose of measuring areas the centre-line of the symbol is used.

Worked areas and made ground The approximate extent of known sand and gravel workings to July 1979 are shown on the map; active and disused workings are indicated, together with areas which have been returned to agricultural use and areas partly backfilled with waste from the sand and gravel industry. Workings which have been filled with mixed waste or refuse are shown as 'made ground'.

RESULTS

The statistical results are summarised in Table 2. Fuller grading particulars are shown in Figure 5 and Tables 3, 4 and 5.

Accuracy of results For the three resource blocks A, B and C the accuracy of the results at the 95 per cent probability level ranges from 32 to 48 per cent (that is, it is probable that 19 times out of 20 the true volumes lie within the given limits of the mean). However, the true values are more likely to be nearer the figures estimated than the limits. Moreover, it is probable that in each block approximately the same percentage limits would apply for the estimate of volume of a very much smaller parcel of ground (say 200 acres) containing similar sand and gravel deposits, if the results from the same number

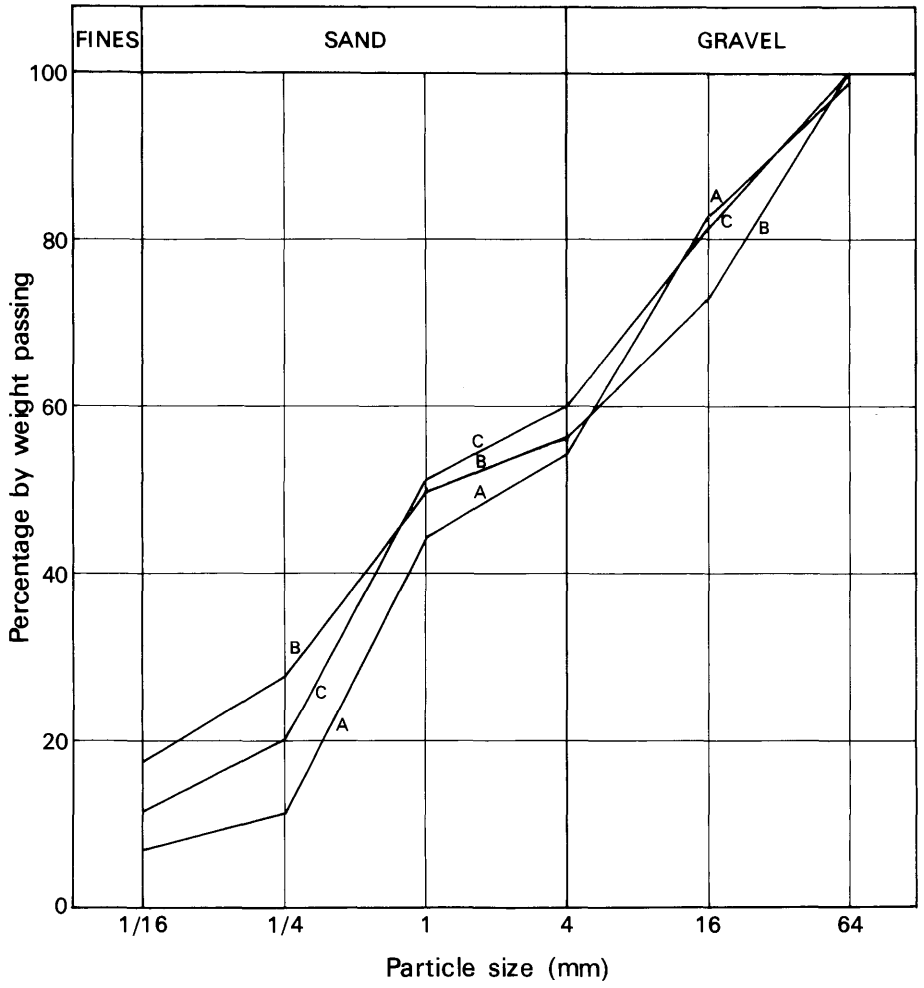

Figure 5 Particle size distribution for the assessed thickness of mineral in resource blocks A, B and C.

Resource Block	Percentage by weight passing					
	1/16mm	1/4mm	1mm	4mm	16mm	64mm
A	6	11	44	54	81	100
B	17	28	50	56	73	100
C	11	20	51	60	82	99

of sample points (as provided by, say, ten boreholes) were used in the calculation. Thus, if closer limits are needed for the quotation of the reserves in part of a block, it can be expected that data from more than ten sample points will be required, even if the area is quite small. This point can be illustrated by considering the whole of the potentially workable sand and gravel on this sheet. The total volume (66.9 million m^3) can be estimated to limits of ±23 per cent at the 95 per cent probability level, by a calculation based on the data from eighty-eight sample points spread across the three resource blocks. However, it must be emphasised that the quoted volume of sand and gravel has no simple relationship with the amount that could be extracted in practice, as no allowance has been made in the calculations for any restraints (such as existing buildings and roads) on the use of land for mineral working.

Table 2 The sand and gravel resources of sheet TL 60

Block	Area		Mean thickness		Volume of mineral			Mean grading percentages					
	Block	Mineral	Overburden	Mineral		Limits at the 95% confidence level		Fines	Sand			Gravel	
	km^2	km^2	m	m	$10^6 m^3$	± %	± Volume $10^6 m^3$	$-\frac{1}{16}$ mm	$+\frac{1}{16}-\frac{1}{4}$ mm	$+\frac{1}{4}-1$ mm	+1–4 mm	+4–16 mm	+16 mm
A	40.1	10.5	5.7	4.9	51.5	33	17	6	5	33	10	27	19
B	29.6	2.1	0.4	3.0	6.3	32	2	17	11	22	6	17	27
C	23.8	5.0	2.3	2.7	13.5	48	7	11	9	31	9	22	18
Total (A,B,C)	92.5	17.6	3.5	3.8	66.9	23	15	9	7	30	9	24	21

NOTES ON THE RESOURCE BLOCKS

The area of sheet TL 60 (excluding the urban areas of Writtle and Chelmsford) has been divided into three resource blocks: Block A in the north contains the principal deposits of Kesgrave Sands and Gravels, and some Glacial Sand and gravel. Block B the Older Head and Block C the remaining mineral deposits proved during the survey.

Block A

This block covers 40.1 km^2, of which 10.5 km^2 is mineral-bearing; it extends over the northern half of the sheet with the exception of the urban areas of Writtle and Chelmsford, and a small area of Block C immediately to the west of Chelmsford.

Much of the sand and gravel within the rural area is concealed beneath Boulder Clay with only limited outcrops in the valleys of the Roxwell Brook and River Can. The overburden within the mineral area ranges in thickness from 1.1 m in borehole NW 19 [6490 0648] to 10.4 m in borehole NW 11 [6181 0731] (Table 3) and has a mean thickness of 5.7 m. The Boulder Clay becomes excessively thick outside the mineral area, and the underlying Kesgrave Sands and Gravels and Glacial Sand and Gravel thin out against the hills in the south-west and south (Figure 4).

Table 3 Data from IMAU boreholes: Block A

Borehole No.	Recorded thickness		Mean grading percentage					
	Mineral	Overburden	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel
	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$–$\frac{1}{4}$ mm	$+\frac{1}{4}$–1 mm	+1–4 mm	+4–16 mm	+16 mm
NW 8	absent	–	–	–	–	–	–	–
NW 9	absent	–	–	–	–	–	–	–
NW 10	6.6	5.4	14	5	45	6	19	11
NW 11	3.8	10.4	1	1	20	17	37	24
NW 12	absent	–	–	–	–	–	–	–
NW 13	1.6*	12.9	1	3	23	11	46	16
NW 14	2.8	9.1	1	3	31	8	31	26
NW 15	3.2†	4.5	2	1	58	14	18	7
NW 16	4.7	6.6	6	3	30	9	26	26
NW 17	absent	–	–	–	–	–	–	–
NW 18	2.5	2.1	4	3	17	15	37	24
NW 19	4.7	1.1	13	13	32	7	20	15
NE 12	absent	–	–	–	–	–	–	–
NE 13	14.0‡	1.4	6	4	26	14	29	21
NE 14	3.2	5.7	3	3	18	14	36	26
NE 15	absent	–	–	–	–	–	–	–
NE 16	absent	–	–	–	–	–	–	–
NE 17	3.7	9.4	3	5	33	9	28	22
NE 18	absent	–	–	–	–	–	–	–
NE 19	0.7*	1.3	4	3	30	8	31	24
NE 20	absent	–	–	–	–	–	–	–
NE 21	5.9	5.4	2	4	38	10	29	17
NE 22	absent	–	–	–	–	–	–	–
NE 23	7.1	1.9	6	6	49	6	19	14

* Sand and gravel that does not satisfy the criteria of 'mineral'.
† Excluding 2.2-m waste parting.
‡ Excluding 4.3-m waste parting.

Table 4 Data from IMAU boreholes: Block B

Borehole No.	Recorded thickness		Mean grading percentage					
	Mineral	Overburden	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel
	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$–$\frac{1}{4}$ mm	$+\frac{1}{4}$–1 mm	+1–4 mm	+4–16 mm	+16 mm
SW 23	3.1	0.2	12	4	25	6	15	38
SW 26	3.9*	1.0	20	8	39	5	11	17
SW 27	4.7	0.1	10	3	20	10	31	26
SW 28	3.5	0.1	14	8	17	5	16	40
SW 29	4.6	0.1	24	15	26	4	13	18
SW E1	2.3+	0.5	16	3	7	7	25	42
SE 83	2.4	0.1	22	18	20	3	12	25
SE 84	absent	–	–	–	–	–	–	–
SE 90	1.2	0.3	29	63	3	2	1	2
SE 91	absent	–	–	–	–	–	–	–

* Excluding 2.3-m waste parting.

Table 5 Data from IMAU boreholes: Block C

Borehole No.	Recorded thickness		Mean grading percentage					
	Mineral	Overburden	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel
	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$–$\frac{1}{4}$ mm	$+\frac{1}{4}$–1 mm	+1–4 mm	+2–16 mm	+16 mm
NE 24	6.1*	1.4	14	14	32	8	18	14
NE 25	absent	–	–	–	–	–	–	–
SW 24	1.2	2.0	2	3	22	10	29	34
SW 25	absent	–	–	–	–	–	–	–
SE 85	3.3	0.1	9	5	32	8	25	21
SE 86	absent	–	–	–	–	–	–	–
SE 87	absent	–	–	–	–	–	–	–
SE 88	1.2	2.7	8	6	31	17	28	10
SE 89	absent	–	–	–	–	–	–	–

* Excluding 5.6-m waste parting.

The mineral ranges in thickness from 2.5 m in borehole NW 18 [6428 0738] to a total of 14.0 m in borehole NE 13 [6501 0814] and has a mean thickness of 4.9 m. The great thickness of sand and gravel in borehole NE 13 represents an infill of chalky Glacial Sand and Gravel in the deeply cut buried channel of the 'proto' Can (Figure 4).

The mean grading for the block is fines 6 per cent, sand 48 per cent and gravel (including a trace of cobble grade) 46 per cent (Table 2 and Figure 5). The estimated total volume of mineral is 51.5 ± 17 million m^3.

Block B

This block, which is divided into two areas by the valley of the River Wid, covers 29.6 km^2 of ground around Highwood and to the south-east of Margaretting; of this area, only 2.1 km^2 is mineral-bearing.

Much of the mineral is exposed with only small areas concealed beneath Head around College Wood, Norton Heath and Fryerning. The overburden ranges in thickness from 0.1 m, for example in borehole SE 83 [6558 0298], to 1.0 m in borehole SW 26 [6238 0275] and has a mean thickness of 0.4 m (Table 4).

Borehole SE 91 [6997 0005] in the extreme south-east of the sheet was drilled into the edge of an Older Head deposit. It proved no potentially workable sand and gravel.

The mineral has a mean thickness of 3.0 m and ranges in thickness from 1.2 m in borehole SE 90 [6983 0282] to 4.7 m in borehole SW 27 [6222 0149]. The block contains an estimated total volume of 6.3 ± 2 million m^3 of mineral: its mean grading is fines 17 per cent, sand 39 per cent and gravel (including a trace of cobble grade) 44 per cent (Table 2).

Block C

This block, containing all the remaining glacial, together some fluvial mineral deposits, covers an area of 23.8 km^2, of which 5.0 km^2 is mineral-bearing. The overburden, consisting of Alluvium, Head, Boulder Clay and Glacial Silts, ranges in thickness from 0.1 m in borehole SE 85 [6662 0086] to 5.0 m in borehole SE 50 [6842 0251] and has a mean thickness of 2.3 m (Table 5). The mean recorded thickness of the mineral is 2.7 m and ranges from 6.1 m in borehole NE 24 [6835 0759] to 1.2 m in, for example, borehole SE 88 [6835 0195] (Table 2).

The total volume of mineral in the block is estimated at 13.5±7 million m^3: its mean grading is fines 11 per cent, sand 49 per cent and gravel 40 per cent, including 1 per cent of cobble grade.

NOTES ON THE SAND AND GRAVEL WORKINGS OF THE AREA

Sand and gravel has been worked from both the Kesgrave Sands and Gravels and Older Head deposits of the district (see table 6). To date workings cover an area of 74 hectares and an estimated 3.5 million m^3 has been removed. Of this total only about 0.3 million m^3 has been won from the Older Head. The Older Head workings have been abandoned since the turn of the century. They were worked for hoggin, on a local basis, to provide hardcore for tracks and roads. These hand-dug pits have not been reclaimed and they are now heavily overgrown or flooded.

The Kesgrave Sands and Gravels pit at Chignall St James and the Glacial Sand and Gravel Pits at Roxwell are being or have been reclaimed and the working face at Chignall is now north of the sheet margin.

Table 6 List of active and disused workings

Location and Grid Reference	Deposit worked
Active workings	
Chignall St James [662 100]	Kesgrave Sands and Gravels
Moor Hall 1 [656 065]	Kesgrave Sands and Gravels
Moor Hall 2 [648 065]	Kesgrave Sands and Gravels
Main disused workings	
Roxwell 1 [657 085]	Glacial Sand and Gravel
Roxwell 2 [664 081]	Glacial Sand and Gravel
Norton Heath [603 043]	Older Head
Parsons Spring [624 027]	Older Head
College Wood [623 015]	Older Head
Writtle Deer Park [654 029]	Older Head

APPENDIX A

FIELD AND LABORATORY PROCEDURES

Trial and error during initial studies of the complex and variable glacial deposits of East Anglia and Essex showed that an absolute minimum of five sample points evenly distributed across the sand and gravel are needed to provide a worthwhile statistical assessment, but that, where possible, there should be not less than ten. Sample points are any points for which adequate information exists about the nature and thickness of the deposit and may include boreholes other than those drilled during the survey and exposures. In particular, the cooperation of sand and gravel operators ensures that boreholes are not drilled where reliable information is already available; although this may be used in the calculations, it is held confidentially by the Institute and cannot be disclosed.

The mineral shown on each 1:25 000 sheet is divided into resource blocks. The arbitrary size selected, 10 km^2, is a compromise to meet the aims of the survey by providing sufficient sample points in each block. As far as possible the block boundaries are determined by geological boundaries so that, for example, glacial and river terrace gravels are separated. Otherwise division is by arbitrary lines, which may bear no relationship to the geology. The blocks are drawn provisionally before drilling begins.

A reconnaissance of the ground is carried out to record any exposures and inquiries are made to ascertain what borehole information is available. Borehole sites are then selected to provide an even pattern of sample points at a density of approximately one per square kilometre. However, because broad trends are independently overlain by smaller scale characteristically random variations, it is unnecessary to adhere to a square grid pattern. Thus such factors as ease of access and the need to minimise disturbance to land and the public are taken into account in siting the holes; at the same time it is necessary to guard against the possibility that ease of access (that is, the positions of roads and farms) may reflect particular geological conditions, which may bias the drilling results.

The drilling machine employed should be capable of providing a continuous sample representative of all unconsolidated deposits, so that the in-situ grading can be determined, if necessary, to a depth of 30 m at a diameter of about 200 mm, beneath different types of overburden. It should be reliable, quiet, mobile and relatively small (so that it can be moved to sites of difficult access). Shell and auger rigs have proved to be almost ideal.

The rigs are modified to enable deposits above the water table to be drilled 'dry', instead of with water added to facilitate the drilling, to minimise the amount of material drawn in from outside the limits of the hole. The samples thus obtained are representative of the in-situ grading, and satisfy one of the most important aims of the survey. Below the water table the rigs are used conventionally, although this may result in the loss of some of the fines fraction and the pumping action of the bailer tends to draw unwanted material into the hole from the sides or the bottom.

A continuous series of bulk samples is taken throughout the sand and gravel. Ideally samples are composed exclusively of the whole of the material encountered in the borehole between stated depths. However, care is taken to discard, as far as possible, material which has caved or has been pumped from the bottom of the hole. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel, or at every 1 m depth. The samples, each weighing between 25 and 45 kg, are despatched in heavy duty polythene bags to a laboratory for grading. The grading procedure is based on British Standard 1377 (1967). Random checks on the accuracy of the grading are made in the Institute's laboratories.

All data, including mean grading analysis figures calculated for the total thickness of the mineral, are entered on standard record sheets, abbreviated copies of which are reproduced in Appendix F.

Detailed records may be consulted at the appropriate offices of the Institute, upon application to the Head, Industrial Minerals Assessment Unit.

APPENDIX B

STATISTICAL PROCEDURE

Statistical assessment

1 A statistical assessment is made of an area of mineral greater than 2 km^2, if there is a minimum of five evenly spaced boreholes in the resource block (for smaller areas see paragraph 12 below).

2 The simple methods used in the calculations are consistent with the amount of data provided by the survey. Conventional symmetrical confidence limits are calculated for the 95 per cent probability level, that is, there is a 5 per cent or one in twenty chance of a result falling outside the stated limits.

3 The volume estimate (V) for the mineral in a given block is the product of the two variables, the sampled areas (A) and the mean thickness ($\bar{l}_m$) calculated from the individual thicknesses at the sample points. The standard deviations for these variables are related such that

$$S_V = \sqrt{(S_A^2 + S_{\bar{l}_m}^2)} \quad . \qquad [1]$$

4 The above relationship may be transposed such that

$$S_V = S_{\bar{l}_m}\sqrt{(1 + S_A^2/S_{\bar{l}_m}^2)} \quad . \qquad [2]$$

From this it can be seen that as $S_A^2/S_{\bar{l}_m}^2$ tends to 0, S_V tends to $S_{\bar{l}_m}$.

If, therefore, the standard deviation for area is small with respect to that for mean thickness, the standard deviation for volume approximates to that for mean thickness.

5 Given that the number of approximately evenly spaced sample points in the sampled area is n with mineral thickness measurements $l_{m_1}, l_{m_2}, \ldots l_{m_n}$, then the best estimate of mean thickness, l_m, is given by

$$\Sigma(l_{m_1} + l_{m_2} \ldots l_{m_n})/n \quad .$$

For groups of closely spaced boreholes a discretionary weighting factor may be applied to avoid bias (see note on weighting below). The standard deviation for mean thickness $S_{\bar{l}_m}$, expressed as a proportion of the mean thickness, is given by

$$S_{\bar{l}_m} = (1/\bar{l}_m)\sqrt{[\Sigma(l_m - \bar{l}_m)^2/(n-1)]}$$

where l_m is any value in the series l_{m_1} to l_{m_n}.

6 The sampled area in each resource block is coloured pink on the map. Wherever possible, calculations relate to the mineral within mapped geological boundaries (which may not necessarily correspond to the limits of deposit). Where the area is not defined by a mapped boundary, that is, where the boundary is inferred, a distinctive symbol is used. Experience suggests that the errors in determining area are small relative to those in thickness. The relationship $S_A/S_{\bar{l}_m} \leq \frac{1}{3}$ is assumed in all cases. It follows from equation [2] that

$$S_{\bar{l}_m} \leq S_V \leq 1.05\, S_{\bar{l}_m} \quad . \qquad [3]$$

7 The limits on the estimate of mean thickness of mineral, $L_{\bar{l}_m}$, may be expressed in absolute units $\pm(t/\sqrt{n}) \times S_{\bar{l}_m}$ or as a percentage $\pm(t/\sqrt{n}) \times S_{\bar{l}_m} \times (100/\bar{l}_m)$ per cent, where t is Student's t at the 95 per cent probability level for $(n-1)$ degrees of freedom, evaluated by reference to statistical tables. (In applying Student's t it is assumed that the measurements are distributed normally.)

Block calculation 1:25 000 Block Fictitious

Area
Block: 11.08 km²
Mineral: 8.32 km²

Mean thickness
Overburden: 2.5 m
Mineral: 6.5 m

Volume
Overburden: 21 million m³
Mineral: 54 million m³

Confidence limits of the estimate of mineral volume at the 95 per cent probability level: ±20 per cent
That is, the volume of mineral (with 95 per cent probability): 54 ± 11 million m³

Thickness estimate measurements in metres
l_o = overburden thickness l_m = mineral thickness

Sample point	Weighting w	Overburden l_o	Overburden wl_o	Mineral l_m	Mineral wl_m	Remarks
SE 14	1	1.5	1.5	9.4	9.4	IMAU boreholes
SE 18	1	3.3	3.3	5.8	5.8	
SE 20	1	nil	–	6.9	6.9	
SE 22	1	0.7	0.7	6.4	6.4	
SE 23	1	6.2	6.2	4.1	4.1	
SE 24	1	4.3	4.3	6.4	6.4	
SE 17	½	1.2	1.6	9.8	7.2	Hydrogeology Unit record
123/45	½	2.0		4.6		
1	¼	2.7	2.6	7.3	5.8	Close group of four boreholes (commercial)
2	¼	4.5		3.2		
3	¼	0.4		6.8		
4	¼	2.8		5.9		
Totals	$\Sigma w = 8$	$\Sigma wl_o = 20.2$		$\Sigma wl_m = 52.0$		
Means		$w\bar{l}_o = 2.5$		$w\bar{l}_m = 6.5$		

Calculation of confidence limits

wl_m	$\lvert(wl_m - w\bar{l}_m)\rvert$	$(wl_m - w\bar{l}_m)^2$
9.4	2.9	8.41
5.8	0.7	0.49
6.9	0.4	0.16
6.4	0.1	0.01
4.1	2.4	5.76
6.4	0.1	0.01
7.2	0.7	0.49
5.8	0.7	0.49

$\Sigma(wl_m - w\bar{l}_m)^2 = 15.82$
$n = 8$
t = 2.365

L_V is calculated as

$t/w\bar{L}_m$

$1.05(t/w\bar{l}_m)\sqrt{(\Sigma(wl_m - w\bar{l}_m)^2/n(n-1)]} \times 100$
$= 1.05 \times (2.365/6.5)\sqrt{[15.82/(8\times7)]} \times 100$
$= 20.3$
$\simeq 20$ per cent

Figure 6 Example of resource block assessment: calculation and results.

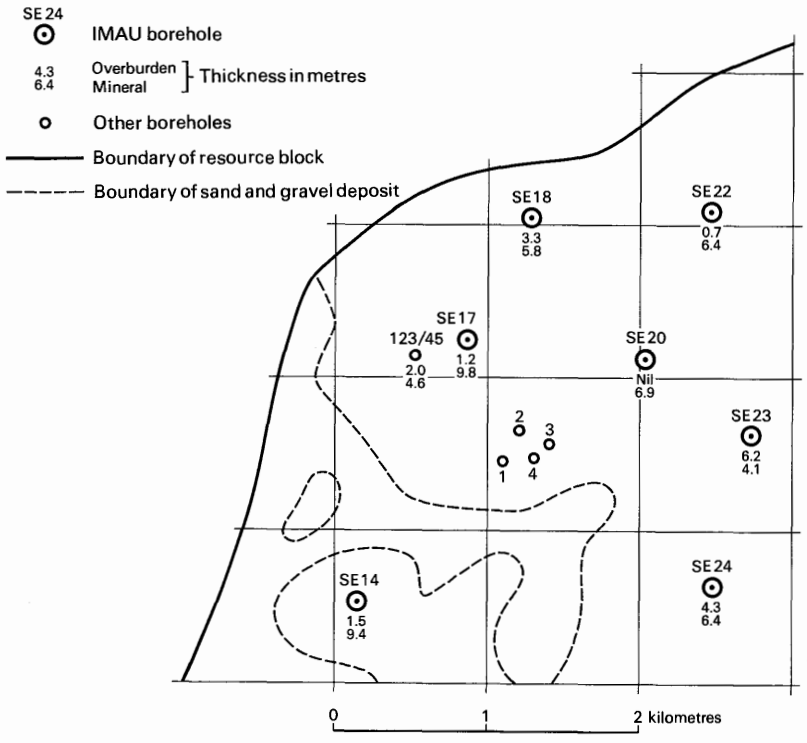

Figure 7 Example of resource block assessment: map of a fictitious block.

8 Values of t at the 95 per cent probability level for values of n up to 20 are as follows:

n	t	n	t
1	infinity	11	2.228
2	12.706	12	2.201
3	4.303	13	2.179
4	3.182	14	2.160
5	2.776	15	2.145
6	2.571	16	2.131
7	2.447	17	2.120
8	2.365	18	2.110
9	2.306	19	2.101
10	2.262	20	2.093

(from table 12, Biometrika Tables for Statisticians, Volume 1, Second Edition, Cambridge University Press, 1962). When n is greater than 20, 1.96 is used (the value of t when n is infinity).

9 In calculating confidence limits for volume, L_V, the following inequality corresponding to equation [3] is applied: $L_{\bar{l}_m} \leq L_V \leq 1.05\, L_{\bar{l}_m}$.

10 In summary, for values of n between 5 and 20, L_V is calculated as

$$[(1.05 \times t)/\bar{l}_m] \times [\sqrt{\Sigma(l_m - \bar{l}_m)^2/n(n-1)}] \times 100$$

per cent, and when n is greater than 20, as

$$[(1.05 \times 1.96)/\bar{l}_m] \times [\sqrt{\Sigma(l_m - \bar{l}_m)^2/n(n-1)}] \times 100$$

per cent.

11 The application of this procedure to a fictitious area is illustrated in Figures 6 and 7.

Inferred assessment

12 If the sampled area of mineral in a resource block is between 0.25 km^2 and 2 km^2 an assessment is inferred, based on geological and topographical information usually supported by the data from one or two boreholes. The volume of mineral is calculated as the product of the area, measured from field data, and the estimated thickness. Confidence limits are not calculated.

13 In some cases a resource block may include an area left uncoloured on the map, within which mineral (as defined) is interpreted to be generally absent. If there is reason to believe that some mineral may be present, an inferred assessment may be made.

14 No assessment is attempted for an isolated area of mineral less than 0.25 km^2.

15 *Note on weighting* The thickness of a deposit at any point may be governed solely by the position of the point in relation to a broad trend. However, most sand and gravel deposits also exhibit a random pattern of local, and sometimes considerable, variation in thickness. Thus the distribution of sample points need be only approximately regular and in estimating the mean thickness only simple weighting is necessary. In practice, equal weighting can often be applied to thicknesses at all sample points. If, however, there is a distinctly unequal distribution of points, bias is avoided by dividing the sampled area into broad zones, to each of which a value roughly proportional to its area is assigned. This value is then shared between the data points within the zone as the weighting factor.

APPENDIX C

CLASSIFICATION AND DESCRIPTION OF SAND AND GRAVEL

For the purposes of assessing resources of sand and gravel a classification should take account of economically important characteristics of the deposit, in particular the absolute content of fines and the ratio of sand to gravel.

The terminology commonly used by geologists when describing sedimentary rocks (Wentworth, 1922) is not entirely satisfactory for this purpose. For example, Wentworth proposed that a deposit should be described as a 'gravelly sand' when it contains more sand than gravel and there is at least 10 per cent of gravel, provided that there is less than 10 per cent of material finer than sand (less than $\frac{1}{16}$ mm) and coarser than pebbles (more than 64 mm in diameter). Because deposits containing more than 10 per cent fines are not embraced by this system a modified binary classification based on Willman (1942) has been adopted.

When the fines content exceeds 40 per cent the material is not considered to be potentially workable and falls outside the definition of mineral. Deposits which contain 40 per cent fines or less are classified primarily on the ratio of sand to gravel but qualified in the light of the fines content, as follows: less than 10 per cent fines—no qualification; 10 per cent or more but less than 20 per cent fines—'clayey'; 20 to 40 per cent fines—'very clayey'.

The term 'clay' (as written, with single quote marks) is used to describe all material passing $\frac{1}{16}$ mm. Thus it has no mineralogical significance and includes particles falling within the size range of silt. The normal meaning applies to the term clay where it does not appear in single quotation marks.

The ratio of sand to gravel defines the boundaries between sand, pebbly sand, sandy gravel and gravel (at 19:1, 3:1 and 1:1).

Thus it is possible to classify the mineral into one of twelve descriptive categories (see Figure 8). The procedure is as follows:

1 Classify according to ratio of sand to gravel.
2 Describe fines.

For example, a deposit grading 11 per cent gravel, 70 per cent sand and 19 per cent fines is classified as 'clayey' pebbly sand. This short description is included in the borehole log (see Note 10, Appendix D).

Many differing proposals exist for the classification of the grain size of sediments (Atterberg, 1905; Udden, 1914; Wentworth, 1922; Wentworth, 1935; Allen, 1936; Twenhofel, 1937; Lane and others, 1947). As Archer (1970a, b) has emphasised, there is a pressing need for a simple metric scale acceptable to both scientific and engineering interests, for which the class limit sizes correspond closely with certain marked changes in the natural properties of mineral particles. For example, there is an important change in the degree of cohesion between particles at about the $\frac{1}{16}$-mm size, which approximates to the generally accepted boundary between silt and sand. These and other requirements are met by a system based on Udden's geometric scale and a simplified form of Wentworth's terminology (Table 7), which is used in this Report.

The fairly wide intervals in the scale are consistent with the general level of accuracy of the qualitative assessments of the resource blocks. Three sizes of sand are recognised, fine ($+\frac{1}{16}$–$\frac{1}{4}$ mm), medium ($+\frac{1}{4}$–1 mm) and coarse (+1–4 mm). The boundary at 16 mm distinguishes a range of finer gravel (+4–16 mm), often characterised by abundance of worn tough pebbles of vein quartz, from larger pebbles often of notably different materials. The boundary at 64 mm distinguishes pebbles from cobbles. The term 'gravel' is used loosely to denote both pebble-sized and cobble-sized material.

The size distribution of borehole samples is determined by sieve analysis, which is presented by the laboratory as

logarithmic cumulative curves (see, for example, British Standard 1377: 1967). In this report the grading is tabulated on the borehole record sheets (Appendix F), the intercepts corresponding with the simple geometric scale $\frac{1}{16}$ mm, $\frac{1}{4}$ mm, 1 mm, 4 mm, 16 mm and so on as required. Original sample grading curves are available for reference at the appropriate office of the Institute.

Each bulk sample is described, subjectively, by a geologist at the borehole site. Being based on visual examination, the description of the grading is inexact, the accuracy depending on the experience of the observer. The descriptions recorded are modified, as necessary, when the laboratory results become available.

The relative proportions of the rock types present in the gravel fraction are indicated by the use of the words 'and' or 'with'. For example, 'flint and quartz' indicates very approximate equal proportions with neither constituent accounting for less than about 25 per cent of the whole; 'flint with quartz' indicates that flint is dominant and quartz, the principal accessory rock type, comprises 5 to 25 per cent of the whole. Where the accessory material accounts for less than 5 per cent of the whole, but is still readily apparent, the phase 'with some' has been used. Rare constituents are referred to as 'trace'.

The terms used in the field to describe the degree of rounding of particles, which is concerned with the sharpness of the edges and corners of a clastic fragment and not the shape (after Pettijohn, 1957), are as follows.

Angular: showing little or no evidence of wear; sharp edges and corners.

Subangular: showing definite effects of wear. Fragments still have their original form but edges and corners begin to be rounded off.

Subrounded: showing considerable wear. The edges and corners are rounded off to smooth curves. Original grain shape is still distinct.

Rounded: original faces almost completely destroyed, but some comparatively flat surfaces may still remain. All original edges and corners have been smoothed off to rather broad curves. Original shape is still apparent.

Well-rounded: no original faces, edges or corners left. The entire surface consists of broad curves; flat areas are absent. The original shape is suggested by the present form of the grain.

Table 7 Classification of gravel, sand and fines

Size limits	Grain size description	Qualification	Primary classification
64 mm –			
		Coarse	Gravel
16 mm –	Pebble		
		Fine	
4 mm –			
		Coarse	
1 mm –			
	Sand	Medium	Sand
$\frac{1}{4}$ mm –			
		Fine	
$\frac{1}{16}$ mm –			
	Fines (silt and clay)		Fines

I Gravel
II 'Clayey' gravel
III 'Very clayey' gravel
IV Sandy gravel
V 'Clayey' sandy gravel
VI 'Very clayey' sandy gravel
VII Pebbly sand
VIII 'Clayey' pebbly sand
IX 'Very clayey' pebbly sand
X Sand
XI 'Clayey' sand
XII 'Very clayey' sand

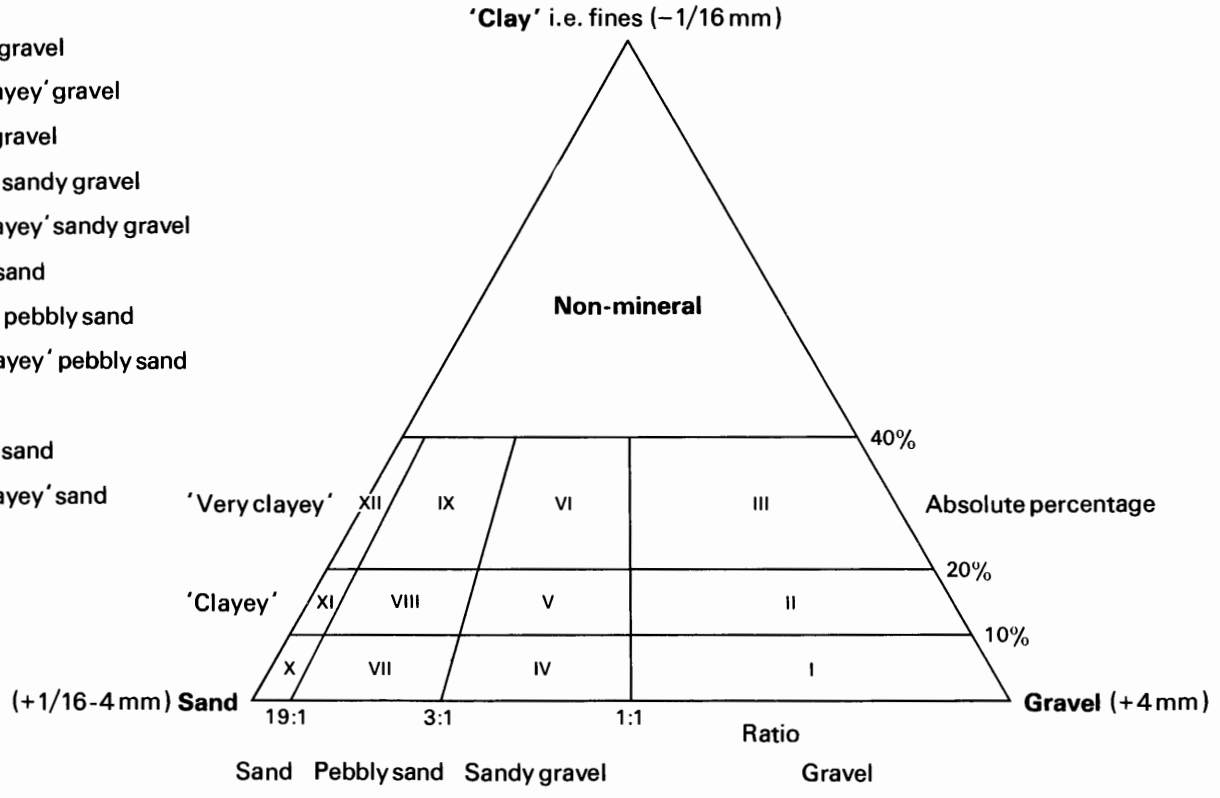

Figure 8 Diagram to show the descriptive categories used in the classification of sand and gravel.

APPENDIX D

EXPLANATION OF THE BOREHOLE RECORDS

TL 60 NE 13[1] **6501 0814**[2] **Roper's Farm, Roxwell**[3] **Block A**

Surface level +44.4 m[4]
Water struck at +39.7 m[5]
Percussion, 152 mm diameter
November 1978[6]

Overburden[7] 1.4 m
Mineral 1.2 m
Waste 4.3 m
Mineral 12.8 m
Bedrock 0.2 m+[8]

LOG

Geological classification[9]	Lithology[10]	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, sandy with pebbles of flint and quartz, pale brown soft	0.3	0.5
	Clay, silty, sandy with pebbles of flint and chalk and a trace of quartz, pale yellow brown, firm	0.9	1.4
Glacial Sand and Gravel	**a** 'Very clayey' gravel Gravel: fine with coarse, angular flint with well rounded chalk and flint, with some subrounded to rounded quartzite, quartz and sandstone, with a trace of limestone, igneous, metamorphic, fossil debris, phosphatic nodules and ironstone Sand: medium and coarse with some fine, predominantly subrounded quartz with coarse and medium angular flint and rounded chalk, yellow brown	1.2	2.6
Boulder Clay	Clay, very sandy, silty with a 'very clayey' sandy chalk gravel between 2.8 and 2.9 m, yellow brown soft	3.4	6.0
	Clay, silty, sandy with pebbles of flint and chalk and many thin sandy silt seams, grey, soft	0.9	6.9
Glacial Sand and Gravel	**b** Gravel: with two thin seams of chalky, flinty, silty brown clay developed between 17.3 and 17.7 m and 19.1 and 19.2 m Gravel: fine with coarse and a trace of cobble grade towards base, angular flint with well rounded chalk and flint with some subrounded to rounded quartzite, quartz and sandstone with a trace of limestone, igneous, metamorphic, fossil debris, phosphatic nodules and ironstone. Chalk content decreases towards base Sand: medium with coarse with some fine predominantly subrounded quartz with coarse and medium angular flint and well rounded chalk, pale brown	12.8	19.7
London Clay	Clay, silty, becomes waxy dark grey brown	0.2+	19.9

GRADING[11]

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
a	20	37	43	1.4–2.6	20	6	18	13	27	16	0
b	5	44	57	6.9–7.9*	6	6	29	15	26	18	0
				7.9–8.9*	3	6	34	16	27	12	0
				8.9–9.9*	5	4	35	14	29	13	0
				9.9–10.9*	3	4	30	13	32	18	0
				10.9–11.9*	4	4	35	11	26	20	0
				11.9–12.9*	5	3	26	15	35	26	0
				12.9–13.9*	5	3	19	14	31	26	2
				13.9–14.9*	6	3	18	19	32	22	0
				14.9–15.9*	3	2	19	14	27	33	2
				15.9–17.3*	4	1	34	15	29	14	3
				17.7–19.1*	6	3	24	16	32	16	3
				19.2–19.7*	4	3	11	9	31	43	0
				Mean	5	3	27	14	30	20	1
a+b	6	44	50	Mean	6	4	26	14	29	20	1

COMPOSITION[12]

Depth below surface (m)	*Percentage by weight in 4–64 mm fraction* Quartz	Quartz-ite	Sand-stone	Angular flint	Well rounded flint	Chalk	Lime-stone	Igneous and meta-morphic	Fossil debris	Iron-stone	Phos-phatic nodules	Others
1.4–2.6 } 6.9–19.7	4	5	4	55	13	16	1	1	1	trace	trace	trace

The numbered paragraphs below correspond with the annotations given on the specimen record.

1 Borehole Registration Number
Each Industrial Minerals Assessment Unit (IMAU) borehole is identified by a Registration Number. This consists of two statements.

1 The number of the 1:25 000 sheet on which the borehole lies, for example TL 60

2 The quarter of the 1:25 000 sheet on which the borehole lies and the number of the borehole in a series for that quarter, for example NE 13

Thus the full Registration Number is TL 60 NE 13
Usually this is abbreviated to NE 13 in the text.

2 The National Grid reference
All National Grid references in this publication lie within the 100 km square TL unless otherwise stated. Grid references are given to eight figures, accurate to within 10 m for borehole locations. (In the text, six-figure grid references are used for more approximate locations, for example, for farms.)

3 Location
The position of the borehole is generally referred to the nearest named locality on the 1:25 000 base map and the resource block in which it lies is stated.

4 Surface level
The surface level at the borehole site is given in metres above Ordnance Datum. All measurements were made in metres.

5 Groundwater conditions
If groundwater was present the level at which it was encountered is normally given (in metres above Ordnance Datum).

6 Type of drill and date of drilling
Unless otherwise stated, all boreholes were drilled by a shell and auger rig using 6-inch casing. The month and year of completion of the hole are stated.

7 Overburden, Mineral, Waste and Bedrock
Mineral is sand and gravel which, as part of a deposit, falls within the arbitrary definition of potentially workable material (see p. 1). Bedrock is the 'formation', 'country rock' or 'rock head' below which potentially workable sand and gravel will not be found. Waste is any material other than bedrock or mineral. Where waste occurs between the surface and mineral it is classified as overburden.

8 The plus sign (+) indicates that the base of the deposit was not reached during drilling.

9 Geological classification
The geological classification is given whenever possible.

10 Lithological description
When sand and gravel is recorded a general description based on the grading characteristics (for details see Appendix C) is followed by more detailed particulars. The description of other rocks is based on visual examination, in the field. Where more than one mineral deposit is recognised, each is designated by a letter, e.g. a, b, etc.

11 Grading data
A continuous series of bulk samples is taken throughout the thickness of sand and gravel. A new sample is commenced whenever there is an appreciable lithological change or at every 1 m of depth.

For each bulk sample the percentages of fines ($-\frac{1}{16}$ mm), fine sand ($+\frac{1}{16}-\frac{1}{4}$ mm), medium sand ($+\frac{1}{4}$–1 mm), coarse sand (+1–4 mm), fine gravel (+4–16 mm) and coarse gravel (+16 mm) are stated. The mean grading of groups of samples making up an identified mineral horizon are also given in detail and, to the left, in summary. Where more than one horizon is recognised the mean grading for the whole of the mineral in the borehole is also given. Where necessary in calculating the mean grading, data for individual samples are weighted by the thickness represented.

Fully representative sampling of sand and gravel is difficult to achieve, particularly where groundwater levels are high. Comparison between boreholes and adjacent exposures suggests that in borehole samples the proportion of sand may be higher and the proportion of fines and coarse gravel may be lower.

12 Composition
Details of the composition of the gravel fraction of selected samples or grouped samples may be given. Where appropriate the calculated weighted mean composition of grouped samples may be indicated. An asterisk * means that samples were obtained from below the water table using a baling technique.

APPENDIX E

LIST OF IMAU BOREHOLES USED IN THE ASSESSMENT OF RESOURCES

Borehole number	Grid reference*	Block
NW 8	6031 0704	A
9	6023 0559	A
10	6175 0843	A
11	6181 0731	A
12	6183 0617	A
13	6271 0952	A
14	6369 0884	A
15	6303 0742	A
16	6349 0636	A
17	6393 0519	A
18	6428 0738	A
19	6490 0648	A
NE 12	6534 0988	A
13	6501 0814	A
14	6548 0694	A
15	6598 0601	A
16	6516 0564	A
17	6677 0938	A
18	6621 0862	A
19	6638 0742	A
20	6622 0518	A
21	6758 0952	A
22	6743 0816	A
23	6866 0940	A
24	6835 0759	C
25	6817 0548	C
SW 23	6014 0452	B
24	6018 0295	C
25	6132 0128	C
26	6238 0275	B
27	6222 0149	B
28	6385 0026	B
29	6483 0362	B
E1†	6234 0170	B
SE 83	6558 0298	B
84	6632 0358	B
85	6662 0086	C
86	6810 0410	C
87	6877 0376	C
88	6842 0195	C
89	6981 0415	C
90	6983 0282	B
91	6997 0005	B

* All grid references fall within the 100-km square TL.
† Exposure reference number.

APPENDIX F

INDUSTRIAL MINERALS ASSESSMENT UNIT BOREHOLE RECORDS

TL 60 NW 8 6031 0704 Spains Wood, Willingale **Block A**

Surface level +75.8 m
Water not struck
Percussion 152 mm diameter
November 1978

Waste 13.9 m
Bedrock 0.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Boulder Clay	Clay, with flint pebbles, pale brown	0.3	0.6
	Clay, silty, with pebbles of flint, quartz, quartzite and some chalk, light brown mottled grey becoming darker with depth	4.3	4.9
	Clay, silty, with pebbles of flint, quartz and chalk, dark grey, stiff	8.1	13.0
	Clay, silty, with pebbles of flint and quartz, dark brown	0.9	13.9
London Clay	Clay, silty, fine sandy, micaceous, brown-grey	0.5+	14.4

TL 60 NW 9 6023 0559 Hulkes Farm, Willingale **Block A**

Surface level +79.5 m
Water not struck
Percussion 152 mm diameter
December 1978

Waste 16.8 m
Bedrock 0.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with flint pebbles, pale brown mottled grey	0.4	0.6
	Clay, silty, sandy, with pebbles of flint, quartz and chalk, dark brown mottled dark grey	3.4	4.0
	Clay, silty, with pebbles of chalk, flint and quartz, dark grey with some brown mottling	11.9	15.9
	Clay, silty, increasingly pebbly with depth predominantly flint and quartz, dark brown	0.9	16.8
London Clay	Clay, very silty, micaceous, dark grey brown with abundant pyritised remains	0.9+	17.7

TL 60 NW 10 6175 0843 Bushey Heys Spring, Roxwell **Block A**

Surface level +68.0 m
Water struck at +61.4 m
Percussion 152 mm diameter
November 1978

Overburden 5.4 m
Mineral 6.6 m
Bedrock 0.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
Boulder Clay	Clay, silty, light brown soft	0.3	0.3
	Clay, silty, with pebbles of chalk, flint and quartz, light brown mottled grey becoming darker with depth	1.9	2.2
	Clay, silty, with chalk and flint pebbles, dark grey	3.0	5.2
	Clay, very sandy, silty, with flint pebbles, orange brown	0.2	5.4
Kesgrave Sands and Gravels	'Clayey' sandy gravel, 'very clayey' pebbly sand between 8.3 m and 11.6 m with fine clay laminae Gravel: fine and coarse, with a trace of cobble grade at base, predominantly angular and well rounded flint, with rounded quartz and quartzite, with some sandstone, and a trace of igneous and metamorphic material Sand: medium with some coarse and fine grade, predominantly subrounded quartz with coarse angular flint, orange brown	6.6	12.0
London Clay	Clay, silty, faintly laminated, micaceous, rusty brown	0.3	12.3
	Clay, silty, micaceous, dark blue-grey, firm	0.3+	12.6

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
14	56	30	5.4–6.4	14	7	44	6	21	8	0
			6.4–7.4*	2	3	37	10	34	14	0
			7.4–8.3*	4	2	22	15	37	20	0
			8.3–11.6*	21	7	57	2	7	6	0
			11.6–12.0*	3	3	26	9	31	25	3
			Mean	14	5	45	6	19	11	0

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphics
5.4–12.0	16	12	4	46	21	1

TL 60 NW 11 6181 0731 Sandpit Wood, Willingale **Block A**

Surface level +72.1 m
Water struck at +60.5 m
Percussion 152 mm diameter
November 1978

Overburden 10.4 m
Mineral 3.8 m
Bedrock 0.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
	Subsoil, sandy, silty clay, with chalk and flint pebbles, pale brown	0.6	0.7
Boulder Clay	Clay, silty, with a seam of putty chalk 5 cm thick at 0.9 m, pale brown	0.3	1.0
	Clay, silty, chalky, pebbly, pale brown mottled blue grey becoming dark blue grey with depth	3.1	4.1
	Clay, silty, with pebbles of chalk and flint and some cobble grade flint, dark grey	3.6	7.7
	Clay, silty, sandy, with flint and a few chalk pebbles, blue grey	1.8	9.5
	Clay, very fine sandy, pebbly, yellow brown	0.9	10.4
Kesgrave Sands and Gravels	Gravel: Gravel: fine with coarse, angular and well-rounded flint, with rounded quartz and quartzite, with some sandstone and igneous and metamorphic material Sand: medium and coarse and a trace of fine, predominantly angular flint and rounded quartz, pale brown	3.8	14.2
London Clay	Clay, silty, faintly laminated, micaceous, blue-grey with a brown tinge	0.3+	14.5

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
1	38	61	10.4–11.4	0	1	17	16	40	26
			11.4–12.4*	2	3	33	13	31	18
			12.4–13.4*	0	0	15	22	37	26
			13.4–14.2*	2	0	15	18	38	27
			Mean	1	1	20	17	37	24

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*						
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic	Others
10.4–14.2	16	13	5	36	27	3	trace

TL 60 NW 12 6183 0617 Rolls Farm, Willingale **Block A**

Surface level +71.5 m
Water not struck
Percussion 152 mm diameter
November 1978

Waste 9.5 m
Bedrock 4.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, sandy, with flint and chalk pebbles and rare quartz, pale brown mottled grey, firm	1.6	1.8
	Clay, very silty, with flint, chalk and quartz pebbles. Thin sand seams throughout, some flint and limestone cobbles, dark grey with a brown tinge, stiff	6.7	8.5
	Clay, very pebbly and sandy, with silt, many pebbles of rounded flint, quartz, quartzite and sandstone, brown, firm	1.0	9.5
? London Clay	'Clayey' sand: medium and fine with a trace of coarse, very rare rounded flint pebbles, fines predominantly silt with some clay. Some thin seams of clear fine white sand throughout, yellow brown	4.5+	14.0

TL 60 NW 13 6271 0952 Mountneys, Roxwell **Block A**

Surface level +52.1 m
Water struck at +40.6 m
Percussion 152 mm diameter
November 1978

Waste 14.5 m
Bedrock 0.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Boulder Clay	Clay, silty, with chalk and flint pebbles, pale brown mottled orange brown	2.1	2.4
	Clay, silty, with chalk pebbles, dark grey mottled orange brown	0.6	3.0
	Chalk, putty, creamy-white	0.4	3.4
	Clay, silty, with pebbles of chalk flint and quartz, dark grey with rare brown mottling, become sandy towards base	8.4	11.8
	Clay and gravel seams, alternation of pale brown very chalky flint gravel and dark grey chalky silty clay	1.1	12.9
Glacial Sand and Gravel	Gravel: becoming sandy towards base Gravel: fine with some coarse, predominantly angular and well rounded flint, with rounded quartz, and some subrounded quartzite and sandstone, with a trace of limestone, igneous, metamorphic, chalk, pyrite and fossil debris Sand: medium with coarse and some fine, predominantly rounded quartz with angular coarse flint and chalk, brown, with some thin clay partings	1.6	14.5
London Clay	Clay, silty, fine sandy, micaceous, dark grey, firm	0.4+	14.9

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
1	37	62	12.9–13.9*	1	2	13	11	57	16
			13.9–14.5*	2	6	39	11	25	17
			Mean	1	3	23	11	46	16

COMPOSITION

Depth below surface	*Percentage by weight in* 4–64 *mm fraction*										
	Quartz	Quartz-ite	Sand-stone	Angular flint	Well rounded flint	Chalk	Lime-stone	Igneous and meta-morphic	Pyrite	Fossil debris	Others
12.9–14.5	13	6	4	40	30	1	2	2	1	1	trace

TL 60 NW 14 6369 0884 Cooley Spring, Roxwell **Block A**

Surface level +48.3 m
Water struck at +39.2 m
Percussion 152 mm diameter
November 1978

Waste 11.9 m
Bedrock 1.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Boulder Clay	Clay, silty, with some fine sand, with pebbles of flint quartz and sandstone, and roollets, yellow brown, soft	0.3	0.6
	Clay, silty, with flint and quartz and some chalk pebbles, yellow brown becoming mottled grey	2.1	2.7
	Clay, silty, with flint, quartz and chalk pebbles up to cobble grade. With thin sand seams from 6.1 m. Stiff becoming soft at base, dark blue grey with a brown tinge	6.4	9.1
Kesgrave Sand and Gravels	Gravel: Gravel: fine and coarse, predominantly angular with some well rounded flint with some rounded to subrounded quartz, quartzite and sandstone, and a trace of igneous and metamorphic material Sand: medium with some coarse and fine predominantly rounded quartz with some coarse angular flint, yellow brown	2.8	11.9
London Clay	Clay, silty, waxy, with some comminuted shale debris and pyrite nodules, brown	1.8+	13.7

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
1	42	57	9.1–10.1	1	4	29	6	35	25
			10.1–11.1	1	5	41	10	34	9
			11.1–11.9	2	1	20	7	23	47
			Mean	1	3	31	8	31	26

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*						
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic	Others
9.1–11.9	7	7	2	55	28	1	trace

TL 60 NW 15 6303 0742 Tye Hall, Roxwell **Block A**

Surface level +56.0 m
Water struck at +51.9 m
Percussion 152 mm diameter
November 1978

Waste 9.9 m
Bedrock 1.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with flint and some chalk pebbles, brown	0.6	0.8
	Clay, silty, with flint quartz and chalk pebbles, and some carbonaceous patches, pale yellow brown mottled pale grey becoming darker with depth	2.6	3.4
	Clay, silty, with flint and chalk pebbles, dark grey mottled orange brown	0.6	4.0
	Clay, sandy, silty, with some chalk pebbles, dark grey	0.5	4.5
Glacial Sand and Gravel	**a** Very clayey sandy gravel: Gravel: fine and coarse, angular with well rounded flint, with some subrounded to rounded chalk, sandstone, limestone, quartz and quartzite, and a trace of pyrite, fossil debris, igneous, metamorphic and ironstone Sand: medium with coarse and fine, predominantly rounded quartz, with angular corase flint, and medium and coarse well rounded chalk, pale brown	0.9	5.4
Boulder Clay	Clay, silty, with chalk and flint pebbles, dark grey	2.1	7.5
	Clay, silty, with flint and quartz pebbles, orange brown	0.1	7.6
Kesgrave Sands and Gravels	**b** Sandy gravel: with some thin pebbly clay seams Gravel: fine with coarse, angular flint, with well rounded flint and rounded quartz and quartzite, with some sandstone and igneous and metamorphic material Sand: medium with coarse and a trace of fine, predominantly rounded quartz, with some coarse angular flint	2.3	9.9
London Clay	Clay, silty, micaceous, orange brown	0.6	10.5
	Clay, silty, micaceous, dark grey	1.0+	11.5

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
	Fines	Sand	Gravel		Fines	Sand			Gravel	
					$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
a	22	52	26	4.5–5.4*	22	10	34	8	13	13
b	2	73	25	7.6–8.6	4	2	58	10	18	8
				8.6–9.6	0	1	60	19	17	3
				9.6–9.9	3	1	50	14	19	13
				Mean	2	1	58	14	18	7

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*											
	Quartz	Quartz-ite	Sand-stone	Angular flint	Well rounded flint	Chalk	Lime-stone	Igneous and meta-morphic	Fossil debris	Iron-stone	Pyrite	Others
4.5–5.4	5	3	7	42	23	9	6	1	1	1	1	1
7.6–9.9	11	8	4	57	17	0	0	2	0	0	0	1

TL 60 NW 16 **6349 0636** **Blows Farm, Roxwell** **Block A**

Surface level +66.7 m
Water struck at +62.6 m
Percussion 152 mm diameter
November 1978

Overburden 6.6 m
Mineral 4.7 m
Bedrock 0.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Boulder Clay	Clay, silty, sandy, with pebbles of flint and a trace of chalk, mid brown, soft	0.3	0.6
	Clay, silty, with pebbles of chalk and flint, with a trace of quartz, brown mottled grey, firm	1.4	2.0
	Clay, silty, with pebbles of flint and chalk, grey-brown, stiff	1.9	3.9
	Clay, sandy, silty, with flints, orange brown	0.1	4.0
	Sand, silty, clayey, with flint and chalk pebbles, pale, yellow brown, soft	0.3	4.3
	Clay, very sandy, silty, with pebbles of flint, quartz and chalk, mid-brown, soft	0.7	5.0
	Clay, silty, with pebbles of flint, quartz and chalk, pale grey brown, soft	1.4	6.4
	Clay, very sandy, silty, with pebbles of flint and quartz, pale orange brown, soft	0.2	6.6
Kesgrave Sands and Gravels	Gravel: 'clayey' between 9.6 and 10.6 Gravel: fine and coarse, angular flint with rounded quartzite, well rounded flint and rounded quartz, with some sandstone and igneous and metamorphics Sand: medium with coarse with some fine, predominantly rounded quartz, with coarse angular flint, pale brown becoming yellow brown	4.7	11.3
London Clay	Clay, silty, mottled and streaked brown and orange brown, soft	0.3	11.6
	Clay, silty, with pockets of dark olive green silty fine sand, dark blue grey	0.6+	12.2

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
6	42	52	6.6–7.6*	6	6	40	7	19	22
			7.6–8.6*	3	2	28	11	28	28
			8.6–9.6*	1	2	15	11	37	34
			9.6–10.6*	14	2	24	7	26	27
			10.6–11.3*	3	4	49	10	19	15
			Mean	6	3	30	9	26	26

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*						
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic	Others
6.6–11.3	13	17	5	45	16	4	trace

TL 60 NW 17 6393 0519 Hawkin Smiths Farm, Highwood **Block A**

Surface level +73.,7 m
Water struck at +64.8 m and +64.2 m
Percussion 152 mm diameter
November 1978

Waste 12.0 m
Bedrock 3.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Boulder Clay	Clay, silty, sandy, with chalk pellets, pale brown, soft	0.3	0.6
	Clay, silty, sandy, with pebbles of chalk and flint, pale brown, firm	0.4	1.0
	Clay, silty, with chalk and flint pebbles, brown mottled, pale grey, firm	2.5	3.5
	Clay, silty, with pebbles of chalk flint and quartz, grey, hard	5.4	8.9
	Sandy gravel, predominantly quartz and flint rounded fine and coarse gravel, with rounded fine and medium quartz sand, some angular coarse flint sand, grey brown	0.3	9.2
	Clay, silty, with chalk pellets and pebbles of flint and quartz, becomes very silty and pebbly from 10.2 m, dark grey, firm. Thin sandy gravel seams at 9.5 m	1.7	10.9
	Clay, silty, with chalk pellets and pebbles of flint and quartz, dark brown, firm	0.2	11.1
	Clay, silty and sandy, with a trace of flint and quartz, brown, firm	0.9	12.0
? London Clay	Clay, silty, and fine silty sands, with faint laminations becoming well laminated with depth. Clay partings are waxy and sands contain mica. Mid brown with yellow brown partings	3.6+	15.6

TL 60 NW 18 6428 0738 Greenlane Farm, Roxwell **Block A**

Surface level +55.3 m
Water struck at +53.2
Percussion 152 mm diameter
November 1978

Overburden 2.1 m
Mineral 2.5 m
Bedrock 0.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.3	0.3
Boulder clay	Clay, very silty, with pebbles of flint and quartz, yellow brown, firm	0.5	0.8
	Clay, silty, with pebbles of flint, quartz and chalk, yellow brown mottled grey, firm	0.8	1.6
	Clay, silty, with pebbles of flint and chalk, dark blue grey, soft	0.5	2.1
Glacial Sand and Gravel	Gravel: Gravel: fine and coarse with a trace of cobble, angular with well rounded flint, with some rounded quartzite, quartz and sandstone, with a trace of chalk, igneous metamorphic and fossil debris Sand: medium and coarse with some fine, predominantly rounded quartz, with some coarse and medium angular flint, and a trace of chalk, yellow brown	2.5	4.6
London Clay	Clay, silty, waxy, brown, soft	0.1	4.7
	Clay, very silty, fine sandy, dark grey	0.8+	5.5

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
4	35	61	2.1–3.1*	5	2	14	11	40	28	0
			3.1–4.1*	3	2	16	22	38	17	2
			4.1–4.6*	3	6	25	10	32	24	0
			Mean	4	3	17	15	37	23	1

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*							
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Chalk	Igneous and metamorphic	Fossil debris
2.1–4.6	8	9	4	49	27	2	1	trace

TL 60 NW 19 6490 0648 Moor Hall, Writtle **Block A**

Surface level +56.1 m
Water struck at +52.3 m
Percussion 152 mm diameter
December 1978

Overburden 1.1 m
Mineral 4.7 m
Bedrock 1.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with a trace of flint pebbles, pale orange brown	0.3	0.5
	Clay, very sandy, silty, with pebbles of flint, orange brown	0.6	1.1
Kesgrave Sands and Gravels	**a** 'Very clayey' pebbly sand: gravelly in the uppermost 1.0 m Gravel: fine with coarse, predominantly angular and well rounded flint, with some rounded quartz, quartzite and sandstone, and a trace of igneous and metamorphic Sand: medium with fine with some coarse, predominantly subrounded to rounded quartz, orange brown banded yellow and orange	2.7	3.8
	b Gravel: Gravel: fine and coarse, predominantly angular and well rounded flint, with some rounded quartz, quartzite and sandstone, and a trace of igneous and metamorphic Sand: medium with some coarse and fine, predominantly subrounded quartz, with some coarse angular flint, yellow brown	2.0	5.8
London Clay	Clay, silty, orange brown	0.5	6.3
	Clay, silty, micaceous, blue grey, firm	0.7+	7.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
	Fines	Sand	Gravel		Fines	Sand			Gravel	
					$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
a	22	62	16	1.1–2.1	22	6	18	11	30	13
				2.1–3.1	23	33	42	2	0	0
				3.1–3.8	21	22	55	2	0	0
				Mean	22	20	37	5	11	5
b	2	38	60	3.8–4.8*	2	3	28	8	31	28
				4.8–5.8*	2	3	23	11	31	30
				Mean	2	3	26	9	31	29
a+b	13	52	35	Mean	13	13	32	7	20	15

COMPOSITION

Depth below surface (m)	*Percentage by weight in 4–64 mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
1.1–5.8	9	7	3	46	34	1

TL 60 NE 12 6534 0988 Boyton Hall, Roxwell **Block A**

Surface level +53.1 m
Water struck at +35.5 m
Percussion 152 mm diameter
November 1978

Waste 18.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with flint pebbles, pale yellow brown, firm	0.5	0.7
	Clay, silty, with flint and chalk pebbles, pale brown mottled orange brown	3.7	4.4
	Putty chalk, cream, soft	0.6	5.0
	Clay, silty, with pebbles of chalk and flint, pale brown mottled orange brown becomes dark brown mottled grey	3.4	8.4
	Clay, silty, very chalky, with flint pebbles, dark grey mottled orange brown	4.8	13.2
	Clay, silty, with pebbles of chalk and flint, dark grey	4.4	17.6
	Interbedded medium to fine very silty chalky sand with silty clay containing chalk pellets, dark grey	1.0+	18.6

TL 60 NE 13 6501 0814 Ropers Farm, Roxwell **Block A**

Surface level +44.4 m
Water struck at +39.7 m
Percussion 152 mm diameter
November 1978

Overburden 1.4 m
Mineral 1.2 m
Waste 4.3 m
Mineral 12.8 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, sandy, with pebbles of flint and quartz, pale brown, soft	0.3	0.5
	Clay, silty, sandy, with pebbles of flint and chalk and a trace of quartz, pale yellow brown, firm	0.9	1.4
Glacial Sand and Gravel	**a** 'Very clayey' gravel Gravel: fine with coarse, angular flint, with well rounded chalk and flint, with some subrounded to rounded quartzite, quartz and sandstone, with a trace of limestone, igneous, metamorphic, fossil debris, phosphatic nodules and ironstone Sand: medium and coarse with some fine, predominantly subrounded quartz, with coarse and medium angular flint and rounded chalk, yellow brown	1.2	2.6
Boulder Clay	Clay, very sandy, silty, with a 'very clayey' sandy chalk gravel between 2.8 and 2.9 m, yellow brown, soft	3.4	6.0
	Clay, silty, sandy, with pebbles of flint and chalk, and many thin sandy silt seams, grey, soft	0.9	6.9
Glacial Sand and Gravel	**b** Gravel: with two thin seams of chalky, flinty, silty, brown clay developed between 17.3 and 17.7 m and 19.1 and 19.2 m Gravel: fine with coarse and a trace of cobble grade towards base, angular flint, with well rounded chalk and flint, with some subrounded to rounded quartzite, quartz and sandstone, with a trace of limestone, igneous, metamorphic, fossil debris, phosphatic nodules and ironstone. Chalk content decreases towards base Sand: medium with coarse with some fine, predominantly subrounded quartz, with coarse and medium angular flint and well rounded chalk, pale brown	12.8	19.7
London Clay	Clay, silty, becomes waxy, dark grey brown	0.2+	19.9

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
a	20	37	43	1.4–2.6	20	6	18	13	27	16	–
b	5	44	51	6.9–7.9*	6	6	29	15	26	18	0
				7.9–8.9*	3	6	34	16	27	12	0
				8.9–9.9*	5	4	35	14	29	13	0
				9.9–10.9*	3	4	30	13	32	18	0
				10.9–11.9*	4	4	35	11	26	20	0
				11.9–12.9*	5	3	26	15	35	26	0
				12.9–13.9*	5	3	19	14	31	26	2
				13.9–14.9*	6	3	18	19	32	22	0
				14.9–15.9*	3	2	19	14	27	33	2
				15.9–17.3*	4	1	34	15	29	14	3
				17.7–19.1*	6	3	24	16	32	16	3
				19.2–19.7*	4	3	11	9	31	42	0
	5	44	51	Mean	5	3	27	14	30	20	1
a+b	6	44	50	Mean	6	4	26	14	29	20	1

COMPOSITION

Depth below surface (m)	*Percentage by weight in 4–64 mm fraction*											
	Quartz	Quartz-ite	Sand-stone	Angular flint	Well rounded flint	Chalk	Lime-stone	Igneous and meta-morphic	Fossil debris	Iron stone	Phos-phatic nodules	Others
1.4–2.6 } 6.9–19.7 }	4	5	4	55	13	16	1	1	1	trace	trace	trace

TL 60 NE 14 6548 0694 Newney Hall, Writtle **Block A**

Surface level +51.4 m
Water struck at +44.1 m
Percussion 152 mm diameter
November 1978

Overburden 5.7 m
Mineral 3.2 m
Bedrock 0.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.5	0.5
Boulder Clay	Clay, silty, with flint pebbles, brown	0.6	1.1
	Clay, silty, with pebbles of chalk and flint, pale brown mottled orange brown becoming dark brown mottled pale grey	3.1	4.2
	Clay, silty, sandy, increasingly pebbly with depth with flint, and decreasingly chalk	1.5	5.7
Kesgrave Sands and Gravels	Gravel: with some thin silty clay seams in uppermost 1.6 m Gravel: fine and coarse, angular flint, with well rounded flint, with some rounded quartz, quartzite and sandstone, with a trace of igneous and metamorphic Sand: medium and coarse with some fine, predominantly subrounded quartz, and some coarse angular flint, orange brown	3.2	8.9
London Clay	Clay, silty, micaceous, with laminations, orange brown	0.5	9.4
	Clay, silty, micaceous, laminated, blue grey, firm	0.4+	9.8

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
3	35	62	5.7–6.5	8	5	25	13	32	17
			6.5–7.3	5	4	20	16	37	18
			7.3–8.3*	0	2	15	12	37	34
			8.3–8.9*	0	2	9	17	38	34
			Mean	3	3	18	14	36	26

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
5.7–8.9	8	8	5	55	23	1

TL 60 NE 15 6598 0601 Bush Farm, Writtle **Block A**

Surface level +53.6 m
Water not struck
Percussion 152 mm diameter
November 1978

Waste 1.4 m
Bedrock 4.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Head	Clay, silty, sandy, with a trace of fine angular flint pebbles	1.1	1.4
London Clay	Clay, silty, with race nodules, purplish brown mottled pale blue grey streaked orange	3.6	5.0
	Clay, silty, brown becoming dark olive grey, stiff	1.2+	6.2

TL 60 NE 16 6516 0564 Little Moor Hall, Writtle **Block A**

Surface level +65.7 m
Water not struck
Percussion 152 mm diameter
November 1978

Waste 8.1 m
Bedrock 1.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, with pebbles of flint, pale yellow brown	0.4	0.6
	Clay, silty, with chalk and some flint pebbles, pale yellow brown mottled orange brown	0.9	1.5
	Clay, very sandy, silty, with some flint pebbles, orange brown	0.1	1.6
	Clay, silty, with pebbles of chalk and flint, brown becoming grey mottled orange brown	1.8	3.4
	Clay, silty, with chalk and some flint pebbles, dark blue grey	3.8	7.2
	Clay, silty, with chalk and some flint pebbles, dark grey brown	0.5	7.7
	Clay, silty, with a trace of chalk pebbles and some flint, dark grey brown	0.4	8.1
London Clay	Clay, silty, micaceous, becoming waxy, dark orange brown becoming grey	1.2	9.3
	Clay, silty, micaceous, dark blue grey	0.6+	9.9

TL 60 NE 17 6677 0938 Chignall St James, Chignall **Block A**

Surface level +41.2 m
Water struck at +31.8 m
Percussion 152 mm diameter
November 1978

Overburden 9.4 m
Mineral 3.7 m
Bedrock 0.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with pebbles of chalk and flint, dark brown mottled yellow brown becomes mottled grey with depth	4.2	4.4
	Clay, silty, with pebbles of chalk and some flint, dark grey	3.0	7.4
	Clay, silty with pebbles of flint and a trace of quartzite, dark grey, soft	2.0	9.4
Kesgrave Sands and Gravels	Gravel:	3.7	13.1
	Gravel: fine and coarse with a trace of cobble, angular flint with well rounded flint, and some quartz, quartzite and sandstone, with a trace of igneous and metamorphic		
	Sand: medium with some coarse and fine, predominantly subrounded quartz sand, with some angular coarse flint, orange brown		
London Clay	Clay, silty, micaceous, orange brown becoming grey and blue grey with depth	0.8+	13.9

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
3	47	50	9.4–10.4*	3	7	48	7	24	11	0
			10.4–11.4*	1	5	31	8	30	25	0
			11.4–12.4*	6	4	30	10	27	21	2
			12.4–13.1*	1	3	21	14	32	29	0
			Mean	3	5	33	9	28	21	1

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
9.4–10.4	8	6	2	58	26	trace

TL 60 NE 18 6621 0862 Blackwall Bridge, Roxwell **Block A**

Surface level +43.5 m
Water seepage at +42.5 m
Percussion 152 mm diameter
November 1978

Waste 18.9 m
Bedrock 1.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, sandy, with some thin discrete sand seams, with pebbles of chalk and flint, pale yellow brown, soft	3.3	3.5
	Clay, silty, with pebbles of chalk and flint with some quartz, red mudstone and black shale, pale grey brown becoming blue grey, firm becoming stiff	14.0	17.5
	Clay, silty, with pebbles of chalk and rounded quartz and flint with some angular flint, dark brown, firm	1.4	18.9
London Clay	Clay, silty, dark brown, firm becoming waxy and fissured	1.6+	20.5

TL 60 NE 19 6638 0742 Reeds Farm, Writtle **Block A**

Surface level +34.5 m
Water struck at +33.1 m
Percussion 152 mm diameter
November 1978

Waste 2.0 m
Bedrock 1.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Head	Clay, silty, with some flint and quartz pebbles, brown	1.0	1.3
Kesgrave Sands and Gravels	Gravel Gravel: fine and coarse, angular with well rounded flint, with some rounded quartzite and quartz, with a trace of sandstone, igneous and metamorphic Sand: medium with some coarse and fine, predominantly subrounded quartz, with some coarse angular flint, brown	0.7	2.0
London Clay	Clay, silty, brown	0.6	2.6
	Clay, silty, olive grey	0.7+	3.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
4	41	55	1.3–2.0*	4	3	30	8	31	24

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
1.3–2.0	4	9	1	66	20	trace

TL 60 NE 20 6622 0518 Halfway House, Writtle **Block A**

Surface level +65.6 m
Water not struck
Percussion 152 mm diameter
November 1978

Waste 6.5 m
Bedrock 0.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with some pebbles of flint, pale orange grey mottled orange brown	0.5	0.7
	Clay, silty, with pebbles of chalk and flint, pale yellow grey mottled orange brown, becomes stiff	3.6	4.3
	Clay, silty, with some pebbles of flint, dark grey	2.2	6.5
London Clay	Clay, silty, with fine sandy laminations, micaceous, with pyritised remains, waxy purple grey	0.8+	7.3

TL 60 NE 21 6758 0952 Britton Hall, Chignall **Block A**

Surface level +42.0 m
Water struck at +34.9 m
Percussion 152 mm diameter
November 1978

Overburden 5.4 m
Mineral 5.9 m
Bedrock 0.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with flint pebbles, dark brown	0.2	0.4
	Clay, silty, with chalk and flint pebbles, orange brown mottled dark grey with depth	3.6	4.0
	Clay, silty, with chalk and flint pebbles, waxy, blue grey, stiff	1.4	5.4
Kesgrave Sands and Gravels	Sandy gravel: Gravel: fine with coarse and a trace of cobble from 9.4 m, angular with well rounded flint, with some rounded to subrounded quartz, quartzite and sandstone, with a trace of igneous and metamorphic Sand: medium with coarse and some fine, predominantly subrounded quartz, with some angular coarse flint, orange yellow becoming yellow brown	5.9	11.3
London Clay	Clay, silty, micaceous, dark grey brown, stiff	0.3+	11.6

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
2	52	46	5.4–6.4	6	6	31	12	30	15
			6.4–7.4*	2	2	68	8	14	6
			7.4–8.4*	0	3	22	14	37	24
			8.4–9.4*	1	4	44	7	21	23
			9.4–10.4*	1	4	33	11	35	16
			10.4–11.3*	0	4	27	12	38	19
			Mean	2	4	38	10	29	17

COMPOSITION

Depth below surface (m)	*Percentage by weight in 4–64 mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
5.4–11.3	10	7	3	51	28	1

TL 60 NE 22 6743 0816 New Barn, Writtle **Block A**

Surface level +35.3 m
Water level +34.3 m
Percussion 152 mm diameter
November 1978

Waste 3.7 m
Bedrock 4.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with fine angular flint pebbles, rootlets at top, orange brown becoming paler with depth	1.5	1.7
	Clay, silty, with pebbles of flint and quartz, dark brown	2.0	3.7
London Clay	Clay, silty, micaceous, orange brown mottled vivid blue	1.0	4.7
	Clay, silty, fissured, dark blue grey	3.3+	8.0

TL 60 NE 23 6866 0940 Blue House, Chignall **Block A**

Surface level +44.4 m
Water struck at +38.4 m
Percussion 152 mm diameter
November 1978

Overburden 1.9 m
Mineral 7.1 m
Bedrock 1.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, sandy, silty, with flint pebbles, dark brown becoming orange brown	1.3	1.5
	Clay, silty, with pebbles of chalk and flint, pale orange brown	0.2	1.7
	Clay, very sandy with flint pebbles, brown	0.2	1.9
Kesgrave Sands and Gravels	**a** Pebbly sand: with thin silty clay seams between 3.9 and 4.9 m Gravel: fine with coarse, angular flint, with well rounded flint and quartz, with some rounded quartzite and subrounded sandstone, with a trace of igneous and metamorphic Sand: medium with some fine and coarse, predominantly subrounded quartz, with a trace of angular coarse flint, orange brown	4.0	5.9
	b Gravel: Gravel: fine and coarse, angular and well rounded flint, with rounded quartz and quartzite, with some subrounded sandstone, and a trace of igneous and metamorphic Sand: medium with coarse and some fine, predominantly subrounded quartz, with angular coarse flint, yellow brown	3.1	9.0
London Clay	Clay, silty, micaceous, with some carbonaceous speckling, pale orange brown with orange very silty seams	0.8	9.8
	Clay, silty, micaceous, waxy, blue grey	0.2+	10.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
	Fines	Sand	Gravel		Fines	Sand			Gravel	
					$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
a	8	80	12	1.9–2.9	6	7	69	3	10	5
				2.9–3.9	6	10	64	3	11	6
				3.9–4.9	11	14	66	4	3	2
				4.9–5.9	7	7	69	4	10	3
				Mean	8	9	67	4	8	4
b	4	37	59	5.9–6.9*	2	3	24	8	30	33
				6.9–7.9*	9	2	17	12	36	25
				7.9–9.0*	1	1	33	10	32	23
				Mean	4	2	25	10	32	27
a+b	6	61	33	Mean	6	6	49	6	19	14

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
1.9–5.9	9	5	4	65	16	1
5.9–9.0	9	9	2	45	34	1

TL 60 NE 24 6835 0759 Warren House, Writtle **Block C**

Surface level +33.3 m
Water struck at +25.8 m and +23.8 m
Percussion 152 mm diameter
November 1978

Overburden 1.4 m
Mineral 2.6 m
Waste 5.6 m
Mineral 3.5 m
Waste 7.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.4	0.4
Head	Clay, silty, flint pebbles abundant with depth	0.4	0.8
	Clay, very sandy, silty with pebbles of flint and quartz, with some carbonaceous material, orange brown	0.6	1.4
Glacial Silts	**a** 'Clayey' gravel with disseminated carbonaceous material Gravel: fine with coarse, angular with well rounded flint, with some rounded to subrounded quartz, quartzite and sandstone, with a trace of igneous and metamorphic Sand: medium and coarse with some fine, predominantly subrounded quartz and angular flint, dark brown	2.6	4.0
	Peat, silty, clayey, with abundant shell debris, dark brown and black	1.0	5.0
	Clay, pale yellow grey, soft	0.1	5.1
	Clay, silty, sandy, with many chalk pellets and gastropod shells, grey	0.4	5.5
	Peat, silty, very shelly, greenish, with a thin seam of shell debris at 6.1 m	1.5	7.0
	Peat, silty, sandy, shelly, blue grey, with a thin seam of shell debris at 7.5 m	0.6	7.6
Boulder Clay	Clay, very silty, with pebbles of flint, chalk and quartz, dark blue grey	2.0	9.6
Glacial Sand and Gravel	**b** 'Clayey' pebbly sand: with a seam of pebbly orange brown clay between 12.5 and 12.6 Gravel: fine and coarse, angular flint, with well rounded chalk, with some subangular sandstone, well rounded flint and subrounded limestone, and a trace of quartz, quartzite, igneous, metamorphic, fossils, phosphatic nodules and ironstone Sand: medium with fine and some coarse, predominantly subrounded quartz, with well rounded chalk, grey becoming orange brown	3.5	13.1
Boulder Clay	Clay, silty, very chalky, becoming dark brown with depth	0.3	13.4
	Clay, silty, with pebbles of chalk and flint and some thin seams of silty sand, dark blue grey	7.6+	21.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
	Fines	Sand	Gravel		Fines	Sand			Gravel	
					$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
a	13	39	48	1.4–2.4	18	5	23	11	27	16
				2.4–3.5	12	5	23	9	29	22
				3.5–4.0	7	4	20	16	35	18
				Mean	13	5	23	11	29	19
b	14	66	20	9.6–10.6*	10	19	61	6	4	0
				10.6–11.6*	20	24	40	6	9	1
				11.6–12.5*	14	26	26	7	13	14
				12.6–13.1*	12	11	18	6	14	39
				Mean	14	21	39	6	10	10
a+b	14	54	32	Mean	14	14	32	8	18	14

COMPOSITION

Depth below surface (m)	*Percentage by weight in 4–64 mm fraction*											
	Quartz	Quartz-ite	Sand-stone	Angular flint	Well rounded flint	Chalk	Lime-sone	Igneous and meta-morphic	Fossil debris	Phosphatic nodules	Iron-stone	Others
1.4–4.0	4	4	4	63	25	0	0	1	0	0	0	trace
9.6–13.1	1	1	8	58	4	21	4	1	1	1	trace	1

TL 60 NE 25 **6817 0548** **Writtle Lodge, Writtle** **Block C**

Surface level +38.7 m
Water struck at +33.5 m
Percussion 152 mm diameter
December 1978

Waste 6.0 m
Bedrock 2.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Head	Clay, silty, sandy, with some flint pebbles, pale orange brown, firm	0.5	0.7
Boulder Clay	Clay, silty, sandy, with some flint and chalk pebbles, pale brown firm	1.1	1.8
	Clay, silty, sandy, with pebbles of flint and chalk, pale brown mottled grey, stiff	1.7	3.5
	Clay, silty, fine sandy, with chalk and flint pebbles, dark grey	1.7	5.2
	Silt, sandy, clayey, with some sand sized chalk pellets, dark grey	0.2	5.4
	Clay, silty, sandy, with chalk and flint pebbles, dark grey	0.6	6.0
London Clay	Clay, silty, micaceous, with calcareous race nodules, dark grey brown	2.6+	8.6

TL 60 SW 23 6014 0452 Norton Heath, Norton Mandeville **Block B**

Surface level +94.3 m
Water not struck
Percussion 152 mm diameter
November 1978

Overburden 0.2 m
Mineral 3.1 m
Bedrock 1.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Older Head	'Clayey' gravel: becomes more 'clayey' and less pebbly with depth, gravel closely packed in clay matrix Gravel: coarse with fine, predominantly well rounded black, brown, grey blue and red with some angular brown flint, with a trace of quartz, quartzite, igneous, metamorphic and sandstone Sand: medium with some coarse and fine, predominantly rounded quartz and angular flint, yellow brown mottled and streaked orange brown	3.1	3.3
Claygate Beds	Sand, fine with medium, very silty, with seams of clayey white fine sand, yellow brown	1.1+	4.4

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
12	35	53	0.2–1.2	9	2	10	5	18	56
			1.2–2.2	10	3	19	8	19	41
			2.2–3.3	16	7	44	4	10	19
			Mean	12	4	25	6	15	38

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
0.2–3.3	trace	trace	trace	19	81	trace

TL 60 SW 24 6018 0295 1 km South of Norton Heath, High Ongar **Block C**

Surface level +81.3 m
Water struck at +79.3 m
Percussion 152 mm diameter
November 1978

Overburden 2.0 m
Mineral 1.2 m
Waste 1.3 m
Bedrock 0.7 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, very sandy, silty, with pebbles of angular flint and rounded quartz, dark yellow brown, soft	0.3	0.5
	Clay, silty, sandy, with pebbles of chalk and flint with some quartz, yellow brown mottled grey becoming dark brown mottled pale blue, firm	1.5	2.0
Glacial Sand and Gravel	Gravel: 'clayey' in uppermost 0.1 m Gravel: coarse and fine with a trace of cobble, angular and well rounded flint, with subrounded quartzite, with some rounded quartz and subangular sandstone, with a trace of igneous, metamorphic, chalk and ironstone Sand: medium with coarse and some fine, predominantly angular flint, with rounded to subrounded quartz, yellow brown	1.2	3.2
Boulder Clay	Clay, silty, with chalk pellets and pebbles and a trace of flint, dark blue grey, firm	0.6	3.8
	Clay, silty, sandy, with rounded and angular flint pebbles and some chalk pellets, dark brown	0.7	4.5
? London Clay	Sand, fine, very clayey and silty, with rare well rounded flint pebbles at top, faintly laminated with fine white sand seams, dark green brown	0.7+	5.2

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
2	35	63	2.0–3.2	2	3	22	10	29	33	1

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*							
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Chalk	Igneous and metamorphic	Ironstone
2.0–3.2	5	12	2	42	39	trace	trace	trace

TL 60 SW 25 6132 0128 Fryerning Wood, Fryerning and Ingatestone **Block C**

Surface level +84.7 m
Water not struck
Percussion 152 mm diameter
November 1978

Waste 5.6 m
Bedrock 0.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Boulder Clay	Clay, silty, sandy, with angular flint pebbles, pale brown, soft	0.7	1.0
	Clay, silty, fine sandy, with angular flint and rounded chalk pebbles, pale brown mottled grey, firm	2.2	3.2
	Very clayey sandy gravel Gravel: fine and coarse, angular and well rounded flint, with some rounded quartz, and a trace of chalk Sand: fine and medium with some coarse, predominantly subrounded quartz, with some angular flint, yellow brown	0.3	3.5
	Clay, very sandy, silty, with pebbles of flint and chalk, brown, firm	0.5	4.0
	Clay, silty, with pebbles of flint and chalk with a trace of quartz, dark grey, firm	1.6	5.6
? Claygate Beds	Clay, silty, with some comminuted shell debris, dark blue grey, firm	0.4+	6.0

TL 60 SW 26 6238 0275 Parsons Spring, Highwood **Block B**

Surface level +93.9 m
Water struck at +87.3 m
Percussion 152 mm diameter
December 1978

Overburden 1.0 m
Mineral 2.8 m
Waste 2.3 m
Mineral 1.1 m
Bedrock 1.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.4	0.4
Older Head	Clay, very silty, sandy, pebbly, pale yellow brown	0.6	1.0
	a 'Very clayey' sandy gravel: becomes less pebbly with depth Gravel: coarse and fine, well rounded with some angular flint, with a trace of quartz, quartzite, sandstone, chalk, limestone, igneous, metamorphic and ironstone Sand: medium with some fine and coarse, predominantly subrounded quartz and angular flint, orange brown	2.8	3.8
	Silt, very sandy, with some well rounded flints and a trace of quartz, orange brown streaked white becoming red mottled white and purple	2.3	6.1
	b 'Clayey' pebbly sand, with some thin discrete clay beams Gravel: coarse with fine, well rounded with some angular flint, with a trace of quartz, quartzite sandstone, chalk, limestone, igneous metamorphic and ironstone Sand: medium with some coarse and fine, predominantly angular flint and quartz	1.1	7.2
Claygate Beds	Salt, sandy, orange brown	1.8+	9.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
	Fines	Sand	Gravel		Fines	Sand			Gravel	
					$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
a	21	48	31	1.0–2.0	24	9	27	5	13	23
				2.0–3.0	18	7	26	6	20	23
				3.0–3.8	22	7	57	2	5	7
				Mean	21	8	35	5	13	18
b	16	68	16	6.1–6.9*	16	7	54	7	4	12
				6.9–7.2*	No grading data available					
a+b	20	52	28	Mean	20	8	39	5	11	17

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*								
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Chalk	Limestone	Igneous and metamorphic	Ironstone
1.0–3.8 6.1–7.2	1	1	trace	16	82	trace	trace	trace	trace

TL 60 SW 27 6222 0149 Bell Grove, Fryerning and Ingatestone Block B

Surface level +97.6 m
Water not struck
Percussion 152 mm diameter
November 1978

Overburden 0.1 m
Mineral 4.7 m
Bedrock 1.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
Older Head	'Clayey' gravel Gravel: fine and coarse, angular with well rounded flint, with some rounded quartzite, quartz and subrounded sandstone, with a trace of igneous and metamorphic Sand: medium with coarse and some fine, predominantly angular flint with subrounded quartz, orange brown	4.7	4.8
Claygate Beds	Clay, very silty, fine sandy, brown mottled pale brown, soft	0.4	5.2
	Interlaminated very clayey silt and silty fine sand, with a waxy red and grey mottled clay, packed with well rounded flints at 5.5 m, yellow brown, brown and white	1.1+	6.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
10	33	57	0.1–1.1	14	2	18	11	28	27
			1.1–2.1	7	4	32	7	27	23
			2.1–3.1	9	4	15	11	32	29
			3.1–4.1	11	4	14	13	34	24
			4.1–4.8	8	3	24	10	35	20
			Mean	10	3	20	10	31	26

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
0.1–4.8	9	12	3	54	21	1

TL 60 SW 28 6385 0026 Fryerning Hall, Ingatestone and Fryerning **Block B**

Surface level +97.7 m
Water not struck
Percussion 152 mm diameter
December 1978

Overburden 0.1 m
Mineral 3.5 m
Bedrock 0.7 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
Older Head	'Clayey' gravel: becoming less clayey with depth Gravel: coarse with some fine, well rounded with some angular flint, with a trace of quartz, quartzite and sandstone Sand: medium with fine and coarse, predominantly subangular quartz, with some angular flint, brown becoming orange brown mottled green	3.5	3.6
Claygate Beds	Silt, clayey, fine sandy, micaceous, pale orange brown and yellow brown streaked pale green white	0.7+	4.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
14	30	56	0.1–0.6	19	7	12	3	12	47
			0.6–1.6	17	7	16	3	10	47
			1.6–2.6	13	11	21	5	18	32
			2.6–3.6	8	8	17	7	22	39
			Mean	14	8	17	5	16	40

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Others
0.1–3.6	1	1	trace	6	92	trace

TL 60 SW 29 6483 0362 Writtle Park House, Highwood **Block B**

Surface level +93.8 m
Water not struck
Percussion 152 mm diameter
November/December 1978

Overburden 0.1 m
Mineral 4.6 m
Bedrock 2.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
Older Head	**a** 'Very clayey' gravel Gravel: coarse with fine, well rounded with some angular flint, with a trace of quartz, quartzite, sandstone, igneous and metamorphic Sand: medium with fine and coarse, predominantly subangular quartz, with a trace of angular flint, grey brown mottled orange brown	3.1	3.2
	b 'Very clayey' sand, faintly laminated Gravel: a trace of fine well rounded flint Sand: medium and fine with a trace of coarse, predominantly subangular quartz, yellow brown	1.5	4.7
? Bagshot Beds	Silt, clayey, fine sandy, well laminated, with seams of well rounded flint pebbles, yellow brown and pale grey	2.3+	7.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
	Fines	Sand	Gravel		Fines	Sand			Gravel	
					$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
a	25	29	46	0.1–0.8	21	9	20	4	18	28
				0.8–1.8	44	5	8	3	16	24
				1.8–2.8	15	3	21	8	27	27
				2.8–3.2	12	5	38	3	11	31
				Mean	25	5	19	5	19	27
b	23	77	0	3.2–4.2	19	25	54	2	0	0
				4.2–4.7	30	54	13	2	1	0
				Mean	23	35	40	2	0	0
a+b	24	45	31	Mean	24	15	26	4	13	18

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*						
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic	Others
0.1–3.2	1	1	trace	15	83	trace	trace
3.2–4.7	Insufficient material						

TL 60 SW E1 6234 0170 College Wood, Ingatestone and Fryerning **Block B**

Surface level C. +95.0 m
Water not struck
Exposure
January 1979

Overburden 0.5 m
Mineral 2.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
Older Head	Clay, silty, sandy, with pebbles of well rounded and angular flint, many rootlets, dark brown	0.4	0.5
	'Clayey' gravel Gravel: coarse and fine with some cobble grade, angular with well rounded flint, with some rounded quartz, quartzite and sandstone, and a trace of igneous and metamorphic Sand: medium and coarse with some fine, predominantly angular flint, with rounded quartz, orange brown mottled grey brown, red and yellow brown	2.3+	2.8

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
16	17	67	0.5–1.5	18	1	5	5	25	43	3
			1.5–2.8	14	4	9	8	26	36	3
			Mean	16	3	7	7	25	39	3

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
0.5–2.8	12	8	5	47	27	1

TL 60 SE 83 6558 0298 Writtle Park Wood, Highwood **Block B**

Surface level +88.1 m
Water struck at +81.1 m
Percussion 152 mm diameter
November 1978

Overburden 0.1
Mineral 2.4 m
Bedrock 9.7 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
Older Head	'Very clayey' sandy gravel Gravel: coarse with fine, well rounded with some angular flint, with a trace of quartz, sandstone and quartzite Sand: medium and fine with some coarse, predominantly subangular quartz, with a trace of angular flint, pale brown	2.4	2.5
Claygate Beds	Sand, fine, very silty, clayey, dark orange brown	0.1	2.6
	Interlaminated silty fine sand and sandy silts and clay, clay highly coloured with red, brown and pale grey, yellow brown, white and pale yellow, micaceous	1.6	4.2
	Sand, fine, silty, micaceous, laminated, pale yellow brown	0.2	4.4
	Sand, fine, silty, micaceous, some faint laminations, pale green brown	1.6	6.0
	Clay, silty, waxy, with thin seams of pale pinkish brown silt, dark pinkish brown, with ochre brown pockets	1.0	7.0
	Sand, fine, silty, with some dark green mineral grains, pale green brown	3.1	10.1
	Silt, fine sandy, with more clayey seams, laminated yellow brown, ochre brown and pale yellow brown	1.5	11.6
	Clay, silty, sandy, with oxidised pyrite nodules, orange brown	0.2	11.8
	Clay, silty, with some pyrite nodules, dark blue grey	0.4+	12.2

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
22	41	37	0.1–0.8	19	15	16	3	20	27
			0.8–1.8	28	20	24	3	8	17
			1.8–2.5	18	17	17	3	11	34
			Mean	22	18	20	3	12	25

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*				
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint
0.1–2.5	1	trace	1	10	88

TL 60 SE 84 6632 0358 Bakers Wood, Margaretting **Block B**

Surface level +82.6 m
Water not struck
Percussion 152 mm diameter
December 1978

Waste 2.1 m
Bedrock 3.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Older Head	Clay, very silty, sandy, with some rounded flints, pale grey and orange brown	1.8	2.1
(?) Bagshot Beds	Silt, fine sandy, with thin clay seams, micaceous, orange brown	2.3	4.4
(?) Claygate Beds	Clay, silty, micaceous, blue grey	1.6+	6.0

TL 60 SE 85 6662 0086 Canterburys, Margaretting **Block C**

Surface level +53.3 m
Water struck at +51.3 m
Percussion 152 mm diameter
December 1978

Overburden 0.1 m
Mineral 3.3 m
Bedrock 0.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
Head	Gravel: clayey in uppermost 1.6 m Gravel: fine and coarse with a trace of cobble, well rounded red, black and brown and angular flint, with some rounded quartz and quartzite, with a trace of sandstone, igneous and metamorphic Sand: medium with coarse and fine, predominantly subangular quartz, with some angular flint, brown	3.3	3.4
(?) Claygate Beds	Clay, silty, with oxidised pyrite nodules, brown mottled orange brown	0.5	3.9
	Clay, silty, micaceous, with pyrite nodules, drab olive green	0.4+	4.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
9	45	46	0.1–0.6	16	4	12	9	29	26	4
			0.6–1.7	11	4	17	8	30	30	0
			1.7–2.7*	5	7	43	7	24	14	0
			2.7–3.4*	5	7	54	9	16	9	0
			Mean	9	5	32	8	25	20	1

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
0.1–3.4	8	5	1	40	46*	trace

* Including 10% 'jasperised' flint.

TL 60 SE 86 6810 0410 Home Farm, Writtle **Block C**

Surface level +57.6 m
Water not struck
Percussion 152 mm diameter
December 1978

Waste 7.7 m
Bedrock 0.7 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Boulder Clay	Clay, silty, with fine patinated white flint pebbles, yellow brown, firm	0.4	0.6
	Clay, silty, with pebbles of chalk and flint with a trace of quartz, yellow brown mottled grey becomes dark brown mottled blue grey, stiff	2.7	3.3
	Clay, silty, with some thin sand seams, with pebbles of rounded flint and quartz with some angular flints and calcareous nodules	2.5	5.8
	Clay, silty, with many pebbles of well rounded flint, becomes micaceous and less pebbly from 7.0 m, dark grey brown, firm	1.9	7.7
London Clay	Clay, silty, fine sandy, with pyrite nodules and pockets of olive green fine sand, drab olive green, firm	0.7+	8.4

TL 60 SE 87 6877 0376 Elm Farm, Margaretting **Block C**

Surface level +45.2 m
Water not struck
Percussion 152 mm diameter
December 1978

Waste 1.5 m
Bedrock 4.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Head	Clay, sandy, very pebbly, mid brown	0.7	0.9
	Clay, silty, sandy, with some flint pebbles, pale brown mottled orange brown	0.6	1.5
London Clay	Clay, silty, fine sandy, brown mottled orange brown	2.0	3.5
	Septarian nodule, calcareous mudstone, pale grey	0.1	3.6
	Clay, silty, fine sandy, with mica, pyrite nodules and worm burrowed claystone, brown mottled grey becomes dark grey	2.3+	5.9

TL 60 SE 88 6842 0195 Whitesbridge Farm, Margaretting **Block C**

Surface level +38.1 m
Water struck at +35.4 m
Percussion 152 mm diameter
December 1978

Overburden 2.7 m
Mineral 1.2 m
Bedrock 0.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.1	0.1
Head	Clay, silty, sandy, with some angular flint pebbles, pale yellow brown, firm	1.3	1.4
	Clay, silty, very sandy, with black carbonaceous pockets, yellow brown mottled pale grey	1.3	2.7
	Sandy gravel: Gravel: fine with coarse and some cobble, angular with well rounded flint, with some rounded quartz and quartzite, and a trace of igneous, metamorphic and sandstone Sand: medium with coarse with some fine, predominantly rounded quartz, and coarse and medium angular flint, yellow brown	1.2	3.9
London Clay	Clay, silty, brown mottled orange brown	0.5	4.4
	Clay, silty, fine sandy, with pockets of olive green fine sand, drab olive grey	0.3+	4.7

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
8	54	38	2.7–3.9*	8	6	31	17	28	8	2

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*					
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic
2.7–3.9	5	4	trace	61	29	1

TL 60 SE 89 6981 0415 Moulsham Thrift Wood, Chelmsford **Block C**

Surface level +55.2 m
Water struck at +47.5 m
Percussion 152 mm diameter
December 1978

Waste 7.9 m
Bedrock 0.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Head	Clay, very silty, sandy with pebbles of angular and rounded flint and some quartz, brown, firm	0.6	0.8
	Clay, silty, with pebbles of white patinated angular flint and rounded quartz, pale orange brown mottled grey brown and red brown along fissures, very hard	6.2	7.0
	Clay, silty, sandy, with pebbles of flint, quartz and quartzite, dark grey brown, firm	0.7	7.7
	Clay, very sandy, pebbly, brown	0.2	7.9
London Clay	Clay, silty, fine sandy, mucaceous, brown mottled yellow brown, soft	0.3	8.2
	Clay, silty, fine sandy, micaceous, with pockets of olive green fine sand, drab olive grey	0.3+	8.5

TL 60 SE 90 6983 0282 Goat Hall, Chelmsford **Block B**

Surface level +70.8 m
Water not struck
Percussion 152 mm diameter
December 1978

Overburden 0.3 m
Mineral 1.2 m
Bedrock 1.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.3	0.3
Older Head	'Very clayey' sand Gravel: coarse and fine, well rounded with angular flint, with some rounded quartz and sandstone Sand: fine with a trace of medium and coarse, predominantly subangular quartz, pale yellow grey	1.2	1.5
Claygate Beds	Sand, very fine, silty, clayey, micaceous, yellow brown mottled grey green and white	1.8+	3.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64
29	68	3	0.3–1.5	29	63	3	2	1	2

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*			
	Quartz	Sandstone	Angular flint	Well rounded flint
0.3–1.5	3	2	26	69

TL 60 SE 91 6997 0005 Forest Wood, Stock **Block B**

Surface level +88.3 m
Water not struck
Percussion 152 mm diameter
December 1978

Waste 1.4 m
Bedrock 1.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Topsoil	0.2	0.2
Older Head	Very clayey gravel: Gravel: fine and coarse, well rounded flint, with some angular flint and rounded quartz, with a trace of ironstone, quartzite, sandstone, igneous and metamorphic Sand: medium with some fine and coarse, predominantly subrounded quartz, pale brown	0.6	0.8
	Clay, silty, yellow brown, mottled orange brown and grey green	0.2	1.0
	'Clayey' pebbly sand: pebbly at base only Gravel: cobbles with coarse and fine, well rounded flint, with some angular flint and rounded quartz Sand: medium with fine and some coarse, finely laminated, subangular quartz, orange brown and white	0.4	1.4
? Bagshot Beds	Clay, very silty and sandy, yellow brown mottled pale grey, with fine brown angular iron nodules, lilac tinge in parts	1.6+	3.0

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}$–$\frac{1}{4}$	$+\frac{1}{4}$–1	+1–4	+4–16	+16–64	+64
25	43	32	0.2–0.8	29	5	21	5	22	18	–
			1.0–1.4	18	17	42	3	2	4	14
			Mean	25	10	29	4	14	12	6

COMPOSITION

Depth below surface (m)	*Percentage by weight in* 4–64 *mm fraction*						
	Quartz	Quartzite	Sandstone	Angular flint	Well rounded flint	Igneous and metamorphic	Ironstone
0.2–0.8 1.0–1.4	2	trace	trace	9	88	trace	1

APPENDIX G

CONVERSION TABLE, METRES TO FEET (to nearest 0.5 ft)

m	ft	m	ft	m	ft	m	ft	m	ft
0.1	0.5	6.1	20	12.1	39.5	18.1	59.5	24.1	79
0.2	0.5	6.2	20.5	12.2	40	18.2	59.5	24.2	79.5
0.3	1	6.3	20.5	12.3	40.5	18.3	60	24.3	79.5
0.4	1.5	6.4	21	12.4	40.5	18.4	60.5	24.4	80
0.5	1.5	6.5	21.5	12.5	41	18.5	60.5	24.5	80.5
0.6	2	6.6	21.5	12.6	41.5	18.6	61	24.6	80.5
0.7	2.5	6.7	22	12.7	41.5	18.7	61.5	24.7	81
0.8	2.5	6.8	22.5	12.8	42	18.8	61.5	24.8	81.5
0.9	3	6.9	22.5	12.9	42.5	18.9	62	24.9	81.5
1.0	3.5	7.0	23	13.0	42.5	19.0	62.5	25.0	82
1.1	3.5	7.1	23.5	13.1	43	19.1	62.5	25.1	82.5
1.2	4	7.2	23.5	13.2	43.5	19.2	63	25.2	82.5
1.3	4.5	7.3	24	13.3	43.5	19.3	63.5	25.3	83
1.4	4.5	7.4	24.5	13.4	44	19.4	63.5	25.4	83.5
1.5	5	7.5	24.5	13.5	44.5	19.5	64	25.5	83.5
1.6	5	7.6	25	13.6	44.5	19.6	64.5	25.6	84
1.7	5.5	7.7	25.5	13.7	45	19.7	64.5	25.7	84.5
1.8	6	7.8	25.5	13.8	45.5	19.8	65	25.8	84.5
1.9	6	7.9	26	13.9	45.5	19.9	65.5	25.9	85
2.0	6.5	8.0	26	14.0	46	20.0	65.5	26.0	85.5
2.1	7	8.1	26.5	14.1	46.5	20.1	66	26.1	85.5
2.2	7	8.2	27	14.2	46.5	20.2	66.5	26.2	86
2.3	7.5	8.3	27	14.3	47	20.3	66.5	26.3	86.5
2.4	8	8.4	27.5	14.4	47	20.4	67	26.4	86.5
2.5	8	8.5	28	14.5	47	20.5	67.5	26.5	87
2.6	8.5	8.6	28	14.6	48	20.6	67.5	26.6	87.5
2.7	9	8.7	28.5	14.7	48	20.7	68	26.7	87.5
2.8	9	8.8	29	14.8	48.5	20.8	68	26.8	88
2.9	9.5	8.9	29	14.9	49	20.9	68.5	26.9	88.5
3.0	10	9.0	29.5	15.0	49	21.0	69	27.0	88.5
3.1	10	9.1	30	15.1	49.5	21.1	69	27.1	89
3.2	10.5	9.2	30	15.2	50	21.2	69.5	27.2	89
3.3	11	9.3	30.5	15.3	50	21.3	70	27.3	89.5
3.4	11	9.4	31	15.4	50.5	21.4	70	27.4	90
3.5	11.5	9.5	31	15.5	51	21.5	70.5	27.5	90
3.6	12	9.6	31.5	15.6	51	21.6	71	27.6	90.5
3.7	12	9.7	32	15.7	51.5	21.7	71	27.7	91
3.8	12.5	9.8	32	15.8	52	21.8	71.5	27.8	91
3.9	13	9.9	32.5	15.9	52	21.9	72	27.9	91.5
4.0	13	10.0	33	16.0	52.5	22.0	72	28.0	92
4.1	13.5	10.1	33	16.1	53	22.1	72.5	28.1	92
4.2	14	10.2	33.5	16.2	53	22.2	73	28.2	92.5
4.3	14	10.3	34	16.3	53.5	22.3	73	28.3	93
4.4	14.5	10.4	34	16.4	54	22.4	73.5	28.4	93
4.5	15	10.5	34.5	16.5	54	22.5	74	28.5	93.5
4.6	15	10.6	35	16.6	54.5	22.6	74	28.6	94
4.7	15.5	10.7	35	16.7	55	22.7	74.5	28.7	94
4.8	15.5	10.8	35.5	16.8	55	22.8	75	28.8	94.5
4.9	16	10.9	36	16.9	55.5	22.9	75	28.9	95
5.0	16.5	11.0	36	17.0	56	23.0	75.5	29.0	95
5.1	17	11.1	36.5	17.1	56	23.1	76	29.1	95.5
5.2	17	11.2	36.5	17.2	56.5	23.2	76	29.2	96
5.3	17.5	11.3	37	17.3	57	23.3	76.5	29.3	96
5.4	17.5	11.4	37.5	17.4	57	23.4	77	29.4	96.5
5.5	18	11.5	37.5	17.5	57.5	23.5	77	29.5	97
5.6	18.5	11.6	38	17.6	57.5	23.6	77.5	29.6	97
5.7	18.5	11.7	38.5	17.7	58	23.7	78	29.7	97.5
5.8	19	11.8	38.5	17.8	58.5	23.8	78	29.8	98
5.9	19.5	11.9	39	17.9	58.5	23.9	78.5	29.9	98
6.0	19.5	12.0	39.5	18.0	59	24.0	78.5	30.0	98.5

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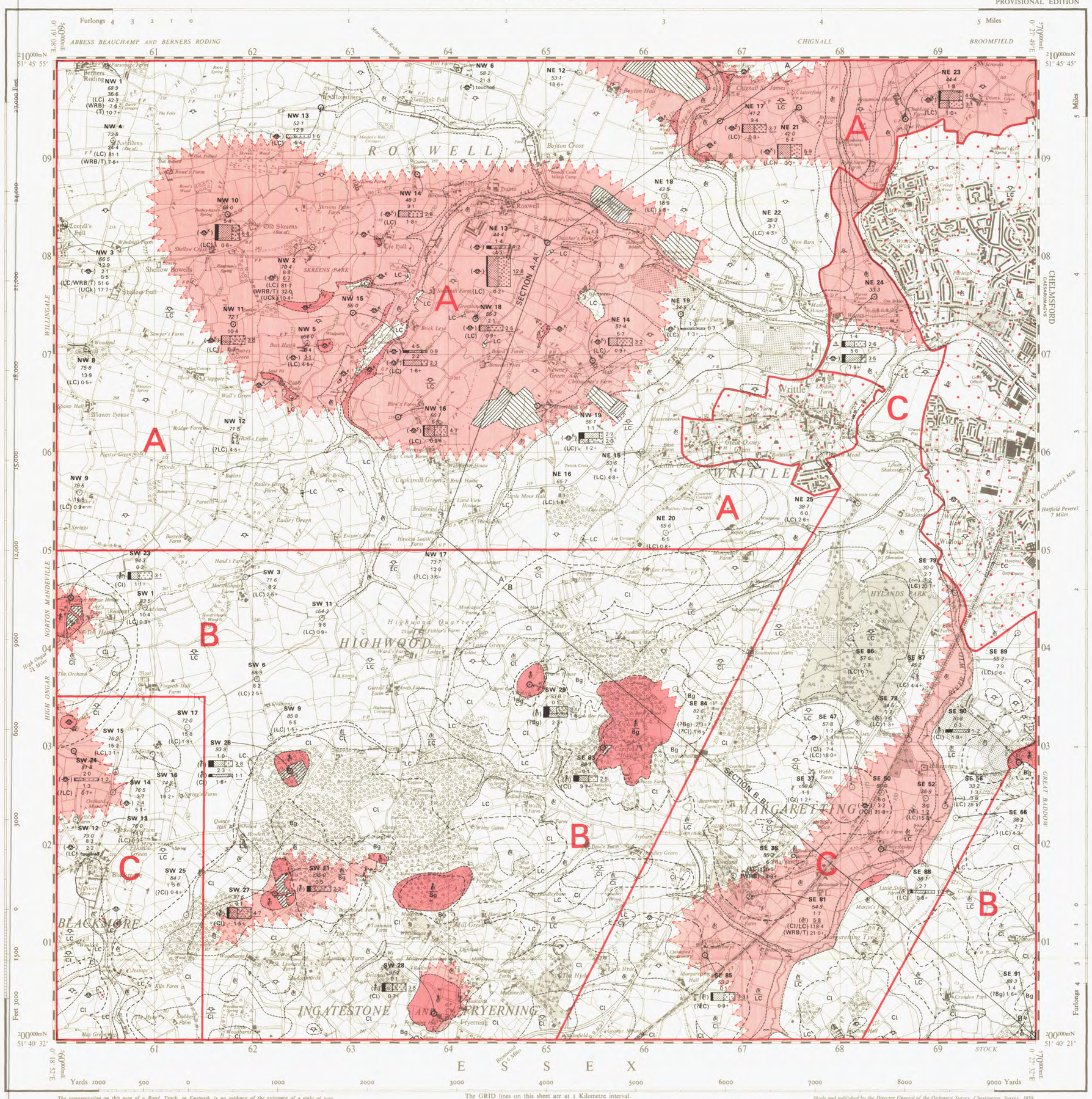
INSTITUTE OF GEOLOGICAL SCIENCES

INDUSTRIAL MINERALS ASSESSMENT UNIT

THE SAND AND GRAVEL RESOURCES OF THE COUNTRY WEST OF CHELMSFORD

Scale 1:25 000 or about 2½ Inches to 1 Mile

ORDNANCE SURVEY
SHEET TL60
PROVISIONAL EDITION



The representation on this map of a Road, Track, or Footpath, is no evidence of the existence of a right of way.

Geological lines from six-inch surveys by R. D. Lake and R. A. Ellison, in 1969-77.
S. C. A. Holmes and W. A. Read, District Geologists.
Sand and Gravel Survey by P. M. Hopson, D. W. Murray and R. J. Marks in 1978.
R. G. Thurrell, Head, Industrial Minerals Assessment Unit.

1:25 000 Sand and Gravel Resource Sheet published 1980.
G. M. Brown, D.Sc., F.R.S., Director, Institute of Geological Sciences.
1100/80

The GRID lines on this sheet are at 1 Kilometre interval.
Heights are in feet above Mean Sea Level at Newlyn.
Contours values are in feet.
1 square inch on this map represents 99·639 acres on the ground.

Compiled from 6" sheets last fully revised 1915-19.
Other partial systematic revision 1938-55 has been incorporated.
Major roads revised 1961.

Made and published by the Director General of the Ordnance Survey, Chessington, Surrey, 1958.
Reprinted with minor changes 1962.

Data quoted for an individual borehole refer strictly to that site: reliable conclusions cannot be drawn about the thickness and grading elsewhere in the deposit, particularly in material as variable as sand and gravel. However, estimates of the volume and mean grading of the mineral as a whole in each Resource Block are given in the Report.

TL 51	TL 61	TL 71
TL 50	TL 60	TL 70
	240	241
	257	258
TQ 59	TQ 69	TQ 79

Diagram showing the relation of the National Grid 1:25 000 sheets with the One-Inch Geological sheet 240 and 1:50 000 Geological sheets 241, 257 and 258.

THE SAND AND GRAVEL RESOURCES OF THE COUNTRY WEST OF CHELMSFORD

This map should be read in conjunction with the accompanying Report which contains details of the assessment of resources.

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EXPLANATION OF SYMBOLS AND ABBREVIATIONS

DRIFT

	Peat - vegetable matter with some silt and fine sand, dark brown or black. P-6	RECENT AND PLEISTOCENE
	Alluvium - clayey silt and silty fine sand with some thin gravel seams, yellowish brown. A-44	
	First Terrace - gravel and sandy gravel, yellowish brown. 1T-26	
	Head - silty sandy clay with some flint pebbles, medium brown. H-28	
	Glacial Silts - laminated silt and fine sand with some gastropod debris and peat seams, yellowish grey. GSI-2	
	Boulder Clay - silty clay with some fine sand containing flint and chalk pebbles, dark bluish grey. BC-23	
	Glacial Sand and Gravel - gravel with some thin pebbly silty boulder clay seams. GS-46	
	Kesgrave Sands and Gravels - sandy gravel with some thin silty clay seams, yellow brown. K-1	
	Older Head - clayey well rounded flint gravel, yellow or orange brown. OH-1	

SOLID

Bg	**Bagshot Beds** - fine and medium sand with subordinate thin lilac clay seams, yellowish brown and pale orange brown.	EOCENE
Cl	**Claygate Beds** - fine sandy clay and silt interlaminated with fine sand, pale yellowish brown.	
LC	**London Clay** - silty clay with some fine sand, dark bluish grey.	
WRB	**Woolwich and Reading Beds**	PALEOCENE
T	**Thanet Beds**	
UCk	**Upper Chalk**	CRETACEOUS

Strata proved in boreholes only

BOUNDARY LINES

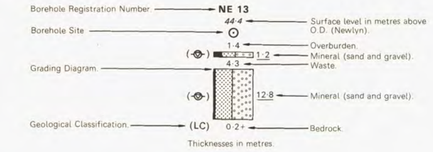
- Geological boundary, Drift.
- Geological boundary, Solid.
- Resource block boundary.
- Inferred boundary between categories of deposits. Broken lines denote uncertainty.
- **Made Ground** MG-2
- **Worked-out area** WO-11

BOREHOLE DATA

SITE LOCATIONS

- ⊙ Industrial Minerals Assessment Unit (I.M.A.U.) Boreholes.
- ⊙ Other Boreholes
- * Pits

I.M.A.U. BOREHOLES



Note:
(i) Figures underlined denote thickness used in the assessment of resources.
(ii) The + sign indicates that the base of the deposit was not reached.
(iii) The Geological Classification is given only for mineral and bedrock.

Borehole Registration Number

Each I.M.A.U. borehole is identified by a Registration Number, eg NE 13. The first letters refer to the quarter sheet, and the figures to the I.G.S. serial number for that quarter. The unique designation for borehole NE 13 is TL60NE 13.

Grading Diagrams

Each grading diagram shows the mean particle size distribution of a distinct deposit of mineral.

The height of the diagram is proportional to the mineral thickness.
The widths of the divisions show the proportions of **Fines** **Sand** and **Gravel**.

OTHER BOREHOLES

The layout of information is the same as for I.M.A.U. boreholes, although data available may not be as comprehensive. They are registered in the same series.

EXPOSURE RECORDS

Information from the inspection of exposures is given in the same way as for boreholes, but they are located by an asterisk, thus * Reference number and details of thickness are shown.

CATEGORIES OF DEPOSITS

- **Exposed Mineral.** CAT-E6
- **Continuous or almost continuous spreads of mineral beneath overburden.** CAT-C1
- **Sand and Gravel not assessed.** CAT-N1
- **Sand and Gravel either not potentially workable (see Report) or absent.** CAT-A2

RESOURCE BLOCKS

For the purpose of assessment the mineral is divided into Resource blocks (see Report). Each is designated by a letter.

Detailed records may be consulted on application to the Head, Industrial Minerals Assessment Unit, Institute of Geological Sciences Nottingham NG12 5GG.

Horizontal sections showing the general relations of the drift deposits along the lines shown, constitute figure 4 of the report.

Made and published by the Director General of the Ordnance Survey, Southampton, for the Institute of Geological Sciences.