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Report No. 73/8

ASSESSMENT OF BRITISH SAND AND GRAVEL RESOURCES No. 7

The sand and gravel resources of the country around Layer Breton and Tolleshunt D'Arcy, Essex

Description of 1 : 25 000 resource sheet TL 91 and part of TL 90

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Preface

It has become increasingly clear in recent years that an assessment of resources of many minerals should be undertaken. This is a report of the Mineral Assessment Unit which was set up in May 1968 to undertake such work. It describes and quantifies the resources of sand and gravel of 125.5 km^2 of country around Layer Breton and Tolleshunt D'Arcy shown on the accompanying 1:25 000 resource sheet TL 91 and part of TL 90.

This survey is concerned with assessing sand and gravel resources on a regional scale at the indicated level; the deposits are not outlined completely nor their grade established throughout. The work may be regarded as the application to large areas of methods used commercially for evaluating reserves on small sites. It may also be regarded as an extension of geological mapping by providing information about the thickness and quality of deposits.

The survey was conducted by Mr J.D. Ambrose assisted by Mr N.E. Bradbury as field officer who supervised the drilling and sampling programme, and Mr G.M. Bladon who helped in the preparation of data for this publication. The work is based on a geological survey at the scale of 1:10 560 in 1966-67 by Dr C.R. Bristow (East Anglia and South-East England Field Unit) who has also helped in the geological interpretation.

Mr J.W. Gardner, C.B.E. (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. Special thanks are due to Dr T.L. Thomas of the Royal School of Mines, London, for his advice on methods of resource calculation. Financial support for the survey was provided by the Department of the Environment.

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CONTENTS

ILLUSTRATIONS

TABLES

Summary

The geological maps of the Institute of Geological Sciences, pre-existing borehole information, and seventeen boreholes drilled for the Mineral Assessment Unit form the basis of the assessment of sand and gravel resources in the Layer Breton and Tolleshunt D'Arcy areas of Essex.

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

Two resource blocks, containing 8.9 and 9.1 km^2 of sand and gravel, have been recognised. For each block the mineral-bearing area, the mean thickness of overburden and mineral, and the mean grading are given and the geomorphology and geology of the deposits described.

The position of the boreholes and exposures, the geology and topography and the outlines of the blocks are shown on the accompanying map. Detailed borehole data are given.

Sommaire

Les cartes géologiques de l'Institute of Geological Sciences, les renseignements sur des trous de sonde qui existaient déjà, et dix-sept trous de sonde forés pour le Mineral Assessment Unit, constituent la base de l'évaluation des ressources en sable et en gravier dans les régions de Layer Breton et de Tolleshunt D'Arcy en Essex.

Tous les dépôts qui présentent la possibilité d'exploitation pour le sable et le gravier (mineral) ont été étudiés de point de vue géologique et on s'est servi d'une méthode statistique simple pour en évaluer le cubage. Les évaluations de volume sont tenues d'être à 95 pour cent exactes.

On a reconnu deux blocs de ressources, qui comprennent 8.9 et 9.1 km^2 de sable et de gravier. On donne pour chaque bloc l'étendue mineralisée, l'épaisseur moyenne de recouvrement et de minéral et la gradation moyenne. On décrit aussi la géomorphologie et la géologie des dépôts.

La situation des trous de sonde et des affleurements, la géologie et la topographie, et la configuration des blocs sont montrées sur la carte. Des données detaillées des trous de sonde sont présentées.

Zusammenfassung

Die geologischen Karten von der Institute of Geological Sciences, vorherexistierende Information, und siebzehn Bohrlöcher, die für die Mineral Assessment Unit gebohrt wurden, bilden den Grund für die Einschätzung der Sand- und Schottermittel in den Layer Breton und Tolleshunt D'Arcy Gebieten in Essex.

Man hat im Gebiet alle Ablagerungen, die möglich bearbeitbar für Sand und Schotter (Mineral) sind, geologisch untersucht, und man hat eine einfache Methode benutzt, um das Volumen zu schätzen. Man gibt die Zuverlässigkeit der Volumenschatzungen mit 95 Prozent Vertrauensgrenzwerten.

Man erkannte **zwei** Mittelsblöcke, die 8.9 und 9.1 km^2 von Sand und Schotter einschtiessen.

Man gibt für jeden Block das mineralhaltige Gebiet, die Durchschnitts dicke von Überlastung und Mineral, und die Durchschnitts-klassifizierung. Die Geomorphologie und Geologie der Ablagerungen wurden beschriben.

Man zeigt die Lage von den Bohrlöchern und Aufschlüssen, die Geologie und Topographie und auch die Skizzen von den Blöcken auf der Begleitkarte.

Aus führliche Bohrlöcherdaten werden gegeben.

The sand and gravel resources of the country around Layer Breton and Tolleshunt D'Arcy, Essex

Description of 1 : 25 000 resource sheet TL 91 and part of TL 90

J. D. AMBROSE,[1] BSc

Introduction

AIMS AND LIMITATIONS

National resources of many of the 'bulk' or 'industrial' minerals may seem so large that stocktaking is unnecessary, but the demand for land for all purposes and for minerals is intensifying. In contrast with other developments of land there may be little or no choice of area for the working of minerals and in the case of low-price materials such as sand and gravel transport costs will be an important factor. Whereas the economic benefit of using land for many other purposes can be assessed, hitherto little has been known of the potential value, on a regional scale, of any mineral resources which may be present. An important aim of the work is to improve the factual background against which planning policies can be decided (Archer, 1969; Thurrell, 1971).

Sand and gravel, considered together as naturally occurring aggregate, was selected as the bulk mineral demanding the most urgent attention, particularly 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 Mineral Assessment Unit began systematic surveys on a regional scale in Essex, Suffolk, and Norfolk in May 1968. The work is being supported by the Department of the Environment (which incorporates the former Ministry of Housing and Local Government and the Ministry of Public Building and Works) and is being undertaken with the cooperation of the Sand and Gravel Association of Great Britain (SAGA). The detail is at the 'indicated' level, a term introduced in the United States in connection with the estimation of national mineral resources. The level is that 'for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geological 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' (Anon, 1948, p. 15).

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The survey is therefore concerned not with the estimation of reserves (which can only be assessed in the light of particular or existing economic considerations), but rather with resources, which include deposits not currently exploitable but having a foreseeable use. Clearly, the social and economic criteria used to decide whether a deposit may be workable at some time in the future cannot be rigorously defined. After discussion with the industry, the following arbitrary physical criteria were adopted for this survey:

a. the deposit should average at least 3 ft (0. 9 m) in thickness.

b. the ratio of overburden to sand and gravel should be no more than 3:1.

c. the proportion of fines (that is, particles passing 1/16 mm (approximately No. 200 mesh B. S. sieve)) should not exceed 40 per cent.

Ground below 80 ft (24. 4 m) from the surface is seldom explored, this being taken as the likely maximum working depth under most circumstances. It follows that boreholes are drilled no deeper than 60 ft (18. 3 m) if they are still in overburden.

A deposit of sand and gravel that broadly fulfils the above criteria is considered to be 'potentially workable' and is assessed as 'mineral'. It is recognised that small parts of such a deposit may not satisfy all the requirements.

The volume and chief characteristics of sand and gravel within defined but relatively large areas, referred to as resource blocks, are assessed. Ideally, each resource block contains roughly 10 square kilometres of sand and gravel.

The consequent limitation of the use to which the results can be put must be emphasised. The assessments of quantity and composition apply 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.

It follows that reserves, which are accurately demarcated areas of economically workable mineral, must be proved by the customary detailed exploration undertaken by the industry. However, the information provided about the resource blocks in an area may assist in the selection of the best targets for such commercial exploration and evaluation.

Thus the work can be regarded as the statistically controlled application to large areas of methods similar to those applied by industry to establish the existence of workable reserves on a relatively small site, and also as an extension of conventional geological mapping techniques, which delineate (with varying degrees of accuracy, depending, for example, on the presence of cover) the areal extent of deposits.

PROCEDURE

Trial and error during preliminary studies showed that for the complex and variable glacial deposits of East Anglia and Essex, an absolute minimum of five sample-points evenly distributed across the sand and gravel are needed to provide a worthwhile statistical assessment, but that, ideally, there should be no fewer than ten. Sample-points are any points for which there exists adequate information about the nature and thickness of the deposit and, apart from the holes drilled during the survey, may include exposures and other boreholes. In particular, the cooperation of sand and gravel operators has ensured that boreholes have not been drilled where reliable information was already available. Such data are held confidentially by the Institute and cannot be disclosed, although they may have been used in the calculations.

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 and to provide sufficient sample-points in each block. As far as possible the block boundaries are determined by geological boundaries; for example, wherever practicable 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 establish whether there are 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. Ideally the distribution should be unbiassed with respect to the geology, to ensure that the data obtained are representative of any broad trends in the variation in thickness or grading, as this will govern spot values.

However, because broad trends are independently overlaid by smaller scale variations, characteristically random in form, 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 have been taken into account in siting the holes: at the same time it has been 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. In siting the boreholes and in the subsequent calculations, no account is taken of any factors, for example, roads, villages and areas of high agricultural and landscape value, which might stand in the way of sand and gravel being exploited. The estimate of total volume of sand and gravel therefore bears no simple relationship to the amount that could be extracted in practice.

Ideally 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 100 ft (30 m) at a diameter of about 8 in (200 mm), and 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) and it should be fast. Although uncased continuous flight power augers can meet these requirements in some ground, they fail below the water table, in some clay-free sand and gravel when the mineral does not stay on the flights, or when the borehole caves. On the area covered by this sheet, the German Wirth B1 drill (or B0 modified) was used extensively. With this machine, casing can be advanced at the same time as the hole is being drilled, thus minimising disturbance to the ground, and avoiding contamination and caving. In difficult ground a bailer can be substituted for the auger, although this method suffers from the disadvantage that there is a tendency for the pumping action to draw unwanted material into the hole either from the sides or the bottom. A conventional 'shell and auger' machine has also been used.

A continuous series of bulk samples is taken throughout the thickness of sand and gravel. Ideally, samples are composed exclusively of the whole of the material previously occupying the space defined by the hole's ideal dimensions, as determined by the internal diameter of the casing and the thickness penetrated. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel, or for every 3 ft (0. 9 m) of depth. The samples are despatched in heavy-duty polythene bags to a laboratory for grading. Care is taken to discard, as far as possible, material which has caved, or been pumped from the bottom of a hole. The samples sent for analysis each weigh 60-100 lb (27-45 kg). The grading procedure is based on BS 1377 (Anon., 1967). Random checks are made on the accuracy of the laboratory grading.

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 C. Detailed records may be consulted at the appropriate offices of the Institute, upon application to the Director.

The methods used in estimating the volume of mineral and other statistics for each of the resource blocks are described in Appendix A and the results are quoted on page 8.

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 the area, which was surveyed recently at the scale of 1:10 560. This information was obtained by detailed application of field mapping techniques by the field staff in the Institute's East Anglia and South-East England Unit. Borehole data, which include the stratigraphic relations and mean particle size distribution of the sand and gravel samples collected during the survey, are also shown.

The geological boundaries are regarded as the best interpretation of the information available at the time of survey. However, it is inevitable, particularly with glacial deposits (such as those included in this area) which change rapidly vertically and laterally, that local irregularities or discrepancies will be revealed by some boreholes (for example, at boreholes 91 NW 6 and 91 SW 4). These are taken into account in the assessment of resources.

MINERAL RESOURCE INFORMATION

For assessment purposes the map is divided into areas of mineral and areas where sand and gravel is either not potentially workable or absent. (For definitions of 'mineral' and 'potentially workable' see page 1). The mineral is subdivided into areas where it crops out and areas where it is present in continuous (or almost continuous) spreads beneath overburden. The whole area of exposed sand and gravel as mapped is considered as mineral, although there may be small patches where sand and gravel is absent or not potentially workable.

Beneath overburden mineral may be continuous (or almost continuous) or discontinuous. The recognition of these categories is subjective, depending on the importance attached to the proportion of boreholes which did not find potentially workable sand and gravel and the distribution of barren boreholes within a block. The mineral is described as 'almost continuous' if it is present in 75 per cent or more of the boreholes in a resource block. The 'discontinuous' category has not been recognised on the present sheet.

Areas where bedrock crops out, where boreholes indicate absence of sand and gravel beneath cover, where sand and gravel beneath cover is interpreted to be not potentially workable and areas not assessed, are uncoloured on the map, and where appropriate, the relevant criterion is noted. In such areas it is 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.

The area of exposed sand and gravel is measured from the mapped geological boundary lines. Inferred boundaries have been inserted around areas 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.

Description of sheet TL 91 and part of TL 90

GENERAL

This is a composite sheet covering a total area of 125. 5 km^2 and comprising the whole of 1:25 000 sheet TL 91, and that part of 1:25 000 sheet TL 90 which lies north of the estuary of the River Blackwater. Two sand and gravel-bearing blocks have been outlined, one in the north of 23.3 km^2 containing 8.9 km^2 of mineral, and another in the south of 25.8 km^2 containing 9.1 km^2 of mineral. The remaining 76.4 km^2 of the sheet consists of an undulating area which is mainly exposed London Clay, with a few

Table 1. Geological classification.

Drift (Superficial formations) Recent and Pleistocene		
Alluvium		
River Terrace Deposits	-	First Terrace of River Chelmer
		Second Terrace of River Chelmer
Head		
Chalky Boulder Clay		
Glacial Sand and Gravel		
Solid (Eocene)		
London Clay		

patches of Head and Alluvium, passing southwards and south-eastwards into the flat marshes and creeks bordering the Blackwater Estuary. The only sand and gravel deposits in this area are a few outliers of Glacial Sand and Gravel near Peldon, too small to be assessed in this survey.

TOPOGRAPHY

The estuary of the River Blackwater and its associated creeks and marshes border the area to the south and south-east. To their north and west the land surface rises unevenly to form a low ridge at about 75 ft (22.9 m) to 90 ft (27.4 m) above sea level between Tollesbury and Tolleshunt Major. Further north the undulating land surface rises to a maximum height of over 200 ft (61.0 m) above sea level at the western edge of the area near Harborough Hall [900 187][1]; in the extreme north-west the land is lower.

GEOLOGY

The deposits present are listed in stratigraphical order in Table 1. The Lower London Tertiaries and the Chalk have been proved only in deep boreholes.

London Clay

The London Clay is the only solid formation represented at outcrop in the area, and it forms the bedrock upon which the younger, unconsolidated, drift deposits lie. The drift cover, however, is discontinuous, being mainly confined to the northern and southern parts of the area. When fresh the London Clay is firm and bluish-grey in colour, but the top few feet are commonly weathered to a softer, streaky, brown clay. As the Mineral Assessment Unit boreholes were stopped on reaching London Clay, it is normally the brown, weathered layer which is recorded in the borehole logs.

These logs show that in the north the height of the sub-drift surface of the London Clay decreases to the north and west, so that in borehole 91 NW 7 it is at 147 ft (44.8 m) above O.D., while in 91 NW 1 it is at 48 ft (14.6 m) above O.D. In the south the surface decreases in height southwards, so that in 91 SW 3 it is recorded at 73 ft (22.3 m) above O.D. and in 90 NW 1 at 22 ft (6.7 m) above O.D. Between these two areas, the surface appears to have been at its highest, London Clay being exposed at present at between 150 ft (45.7 m) and 200 ft (61.0 m) above O.D.

Glacial Sand and Gravel

Resting directly on the London Clay, in both the northern and southern areas, are spreads of Glacial Sand and Gravel, but the borehole information has revealed substantial differences in composition and thickness of these deposits in the two areas. In the north the glacial deposits occur in a more or less continuous spread of about 10.0 m mean thickness and contain considerably more sand than gravel. The variation in thickness of these deposits from borehole to borehole can be related inversely to the thickness of the overlying Boulder Clay. In the south the Glacial Sand and Gravel occurs in a discontinuous, patchy spread and its mean thickness in the boreholes is only about 3.5 m although it is considerably more gravelly.

The difference in the mean thickness between the two areas can probably be explained by the fact that in the north much of the sand and gravel has been protected from erosion by the Chalky Boulder Clay cover, whereas in the south the cover consists only of isolated patches of Head which have not afforded the same degree of protection; indeed some of the sand and fines content may have been carried farther afield leaving a higher concentration of gravel in the south.

Chalky Boulder Clay

The Chalky Boulder Clay is brown or greyish-blue in colour and contains fragments of chalk, mainly angular, with a few flint pebbles of varying size. It is sometimes silty and has distinctly gravelly bands in places. It rests

[1] National Grid References in this publication all lie within 100 kilometre square TL (52).

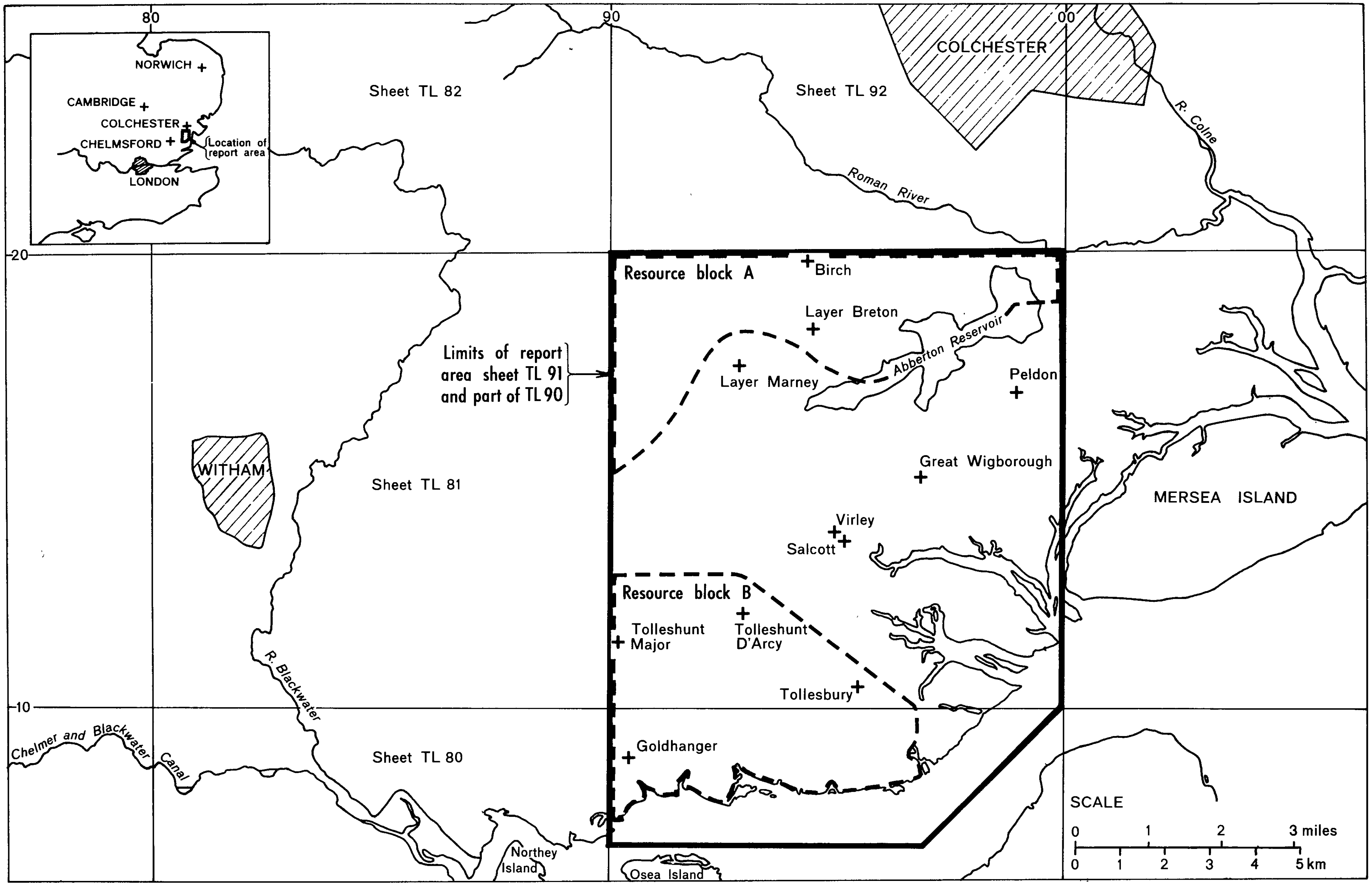


Fig. 1. Sketch map showing the location of sheet TL 91 and part of TL 90 and the position of the resource block boundaries

directly on Glacial Sand and Gravel and cuts down into it so that where the Boulder Clay is thickest the sand and gravel is thinnest (and vice versa). Near Smyth's Green [922 187] the geological map shows the Boulder Clay resting directly on London Clay, the sand and gravel being absent.

Head

Elsewhere the Glacial Sand and Gravel is either exposed or covered by patches of Head, which is usually brown, sometimes silty clay, often containing flint pebbles in varying proportions. While deposits mapped as Head have been recorded overlying Glacial Sand and Gravel in only four boreholes, several other holes have proved similar deposits which are probably too restricted in either thickness or extent to warrant mapping.

River Terrace Deposits

In the extreme south of the area, alongside the Blackwater Estuary, River Terrace deposits occur. These are limited in extent and have not, therefore, been drilled. On an adjoining sheet, TL 80 (Ambrose, 1973) however, similar deposits have been found to contain substantial amounts of gravel and an inferred assessment has been made of these deposits, based on experience gained from that sheet. A remnant of an older terrace occurs in the north-west [900 190]; it is of no economic importance (see Haggard, 1972).

Alluvium

The youngest deposits in the area are the River Alluvium, which occurs flooring the main valleys, and the Marine Alluvium, found bordering the Blackwater Estuary and its associated creeks in the south and east.

COMPOSITION OF THE SAND AND GRAVEL DEPOSITS

Most of the potentially workable sand and gravel is Glacial Sand and Gravel, the mean grading of which, from the borehole evidence, is fines 6 per cent, sand 63 per cent, gravel 31 per cent, but the mean grading for resource block A shows a ratio of sand to gravel of almost 3:1 while in block B they are present in approximately equal proportions. The higher gravel content in block B is accompanied by an increase in the coarseness of the sand; fine sand is rare. In block A, however, there is often as much fine and medium grained sand. The chief constituent of the sand in both blocks is subangular quartz, usually brown or grey-brown, though iron-staining may give rise to a reddish-brown colour.

Fines are normally present but their distribution is very variable both laterally and vertically. For example, in borehole 91 NW 1 there is only a trace of fines throughout the $43\frac{1}{2}$ ft (13.3 m) of mineral, while in borehole 91 NW 3 the top 14 ft (4.3 m) of mineral has a fines content of almost 30 per cent.

The grading figures show vertical and lateral variation from fine to coarse within the gravel fraction in nearly all boreholes. No cobble-size material has been recorded in any of the holes drilled in this area. The pebbles are predominantly subangular to subrounded flints with subordinate subangular to rounded quartz and quartzites.

On this sheet no information is available about the composition of the Terrace Gravels immediately north of the Blackwater Estuary.

RESULTS

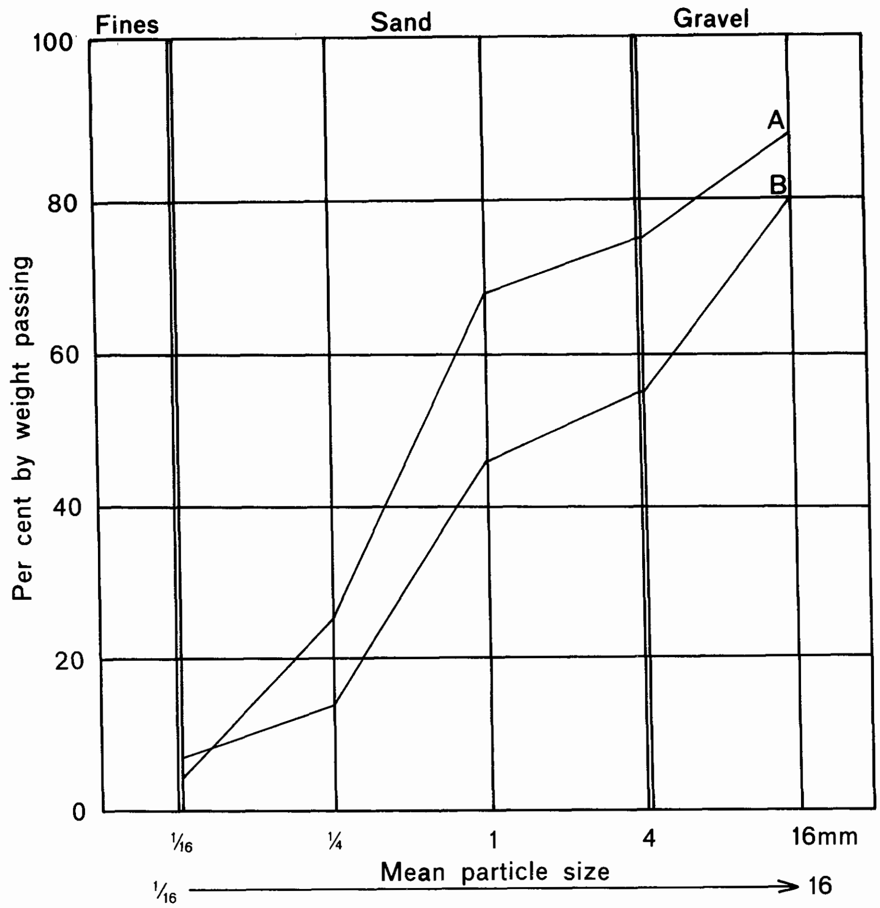
The statistical results are summarised in Table 2. Fuller grading particulars are shown in Fig. 2.

Accuracy of Results

For the two resource blocks A and B on sheet TL 91 and part of TL 90 (excluding the inferred assessment of the River Terrace deposits) the tolerances at the 95 per cent confidence level on the estimate of volume are $\pm$40 and 33 per cent respectively (that is, it is probable that nineteen times out of twenty the true volume present lies within these limits). However, the true values are more likely to be nearer the figure estimated than the limits. Moreover, it is probable that in each block roughly 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 of sample points (as provided by, say, ten boreholes) were used in the calculation. Thus, if closer limits are needed for the quotation of reserves of 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.

It should be noted that in Table 2 confidence limits have not been quoted for the estimate of the combined volume of mineral in resource blocks A and B because the standard deviation for thickness is greater for the combined area than it is for either of the blocks. Thus, the thicknesses of mineral recorded in the boreholes show a smaller variation about the mean in each block than they do about the mean for the combined area of the blocks.

It must again 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



Block	Per cent by weight passing				
	1/16 mm	1/4mm	1mm	4mm	16mm
A	4	25	68	75	88
B	7	14	46	55	80

Fig. 2. Particle size distribution for the assessed thickness of sand and gravel in the resource blocks A and B

Table 2. Sand and gravel resources of the area.

Statistical Assessment of Sand and Gravel Resources.

Block	Area		Mean thickness				Volume of sand and gravel				Mean grading percentages		
	Block	Mineral	Overburden		Mineral				Limits at the 95% confidence level		Fines	Sand	Gravel
	km^2	km^2	m	ft	m	ft	million m^3	million yd^3	$\pm$%	Volume $\pm$ million m^3	-1/16 mm	+1/16 -4 mm	+4 mm
A	23.3	8.9	5.7	$18\frac{3}{4}$	10.1	33	89.9	117.6	40	36.0	4	71	25
B	25.8	9.1	1.4	$4\frac{1}{2}$	3.9	$12\frac{3}{4}$	35.5	46.4	33	11.7	7	48	45
Total		18.0					125.4	164.0					

Inferred Assessment for Terrace Deposits (not included in statistical assessment above).

Part of B		1.2	c.1.3		c.1.8		2.1	2.7	Speculative	Not determined

the land for mineral working.

NOTES ON RESOURCE BLOCKS A AND B

Block A

The mineral in this block is all Glacial Sand and Gravel which is concealed beneath Boulder Clay in the north-west. To the south-east of the main spread there are several patches of mineral, some very small; some, for example, at Layer Breton Heath, are partly concealed by Head. London Clay is exposed in the remainder of the block except where concealed by small areas of Head and Alluvium.

Mineral has been proved in seven of the eight boreholes within this block, the exception being 91 NW 4, where drilling was stopped after proving Boulder Clay to 60 ft (18.3 m). The area in which the mineral is not considered potentially workable because the ratio of overburden to mineral probably exceeds 3:1 extends onto the three adjacent 1:25 000 sheets (TL 81, TL 82, TL 92) and may coincide with an extension in a north-easterly direction of the buried channel known to exist beneath the Blackwater Valley on 1:25 000 sheet TL 81 (Haggard, 1972).

In the remaining seven holes in this block the mineral ranged in thickness from 50 ft (15.2 m) in 91 NW 6 to 6 ft (1.8 m) in 91 NW 7 with a mean thickness of 33 ft (10.1 m) and the thickness of overburden varied from 48 ft (14.6 m) in 91 NW 5 to 5 ft (1.5 m) in 91 NW 3.

General trends in thickness are difficult to determine, but the borehole information suggests that when mineral occurs beneath Boulder Clay there is an inverse relationship between their thicknesses. Thus, in boreholes 91 NW 1 and 91 NW 2, the Boulder Clay is relatively thin but the mineral is thick whereas in borehole 91 NW 5 the overburden is thicker and the mineral is relatively thin. Away from the Boulder Clay outcrop both mineral and overburden thicknesses are variable and no pattern can be discerned.

The mean grading figures for the mineral in the boreholes in this block are fines 4 per cent, sand 71 per cent, gravel 25 per cent. The figures for individual boreholes indicate that the mineral contains a higher percentage of gravel in the north-west than to the south and east where borehole 91 NW 7, for example, contains only 2 per cent gravel. A substantial increase in the content of fines is recorded in the same direction, for example, in 91 NW 3 with 14 per cent fines and 91 NW 7 with 24 per cent although in NE 1 the fines account for only 5 per cent. The sand fraction is consistently between 60 and 70 per cent, except in 91 NE 1 where it rises to 90 per cent.

The volume of mineral within the block,

assessed statistically, is 89.9 million m^3 ± 40 per cent. All limits quoted in this report are calculated at the 95 per cent confidence level.

Block B

Glacial Sand and Gravel constitutes almost all of the potentially workable deposits. It is, however, irregular in thickness, and has a patchy, discontinuous distribution. London Clay is exposed around the margins of the Glacial Sand and Gravel deposits and in inliers within some of the more extensive sand and gravel outcrops, for example, west of Gorwell Hall [944 111]. River deposits representing the first and second terraces of the Rivers Chelmer and Blackwater are present near the northern shores of the Blackwater Estuary. Although they probably contain potentially workable sand and gravel, no statistical assessment has been made for them as they are of limited extent on this sheet. They are a continuation of similar deposits to the west where they are more extensive and have been assessed statistically (Ambrose, 1973). The terraces, the Glacial Sand and Gravel, and the London Clay are covered in parts by Head of varying thickness and extent and by Alluvium along the shores of the estuary and in the larger river valleys. In estimating resources the positions of the boundaries of the mineral beneath cover have been inferred.

Nine Mineral Assessment Unit boreholes, one well record, 241/56 (Davies and Standon Batt 1965), and commercial records have been used in the assessment of this block. Eight of the M.A.U. boreholes proved potentially workable sand and gravel. The exception is 90 NW 2 where 25 ft (7.6 m) of silty and sandy clays rest directly on London Clay, suggesting that mineral is likely to be absent beneath cover in the adjacent valley. The mineral thicknesses proved in the remaining boreholes range from 6 ft (1.8 m) in 91 SW 2 to 24 ft (7.3 m) in 91 SW 6, the mean thickness being $11\frac{1}{2}$ ft (3.5 m). Overburden thicknesses in the boreholes varied from 1 ft (0.3 m) of soil in 91 SW 6 to 15 ft (4.6 m) of clay and 'clayey' gravel in 91 SW 4. No trends in the variation in thickness of either mineral or overburden can be distinguished in the boreholes over the block as a whole.

The mean grading of the mineral in this block is fines 7 per cent, sand 48 per cent, gravel 45 per cent-figures which show that the proportion of gravel is far higher than in block A. However, the distribution of gravel appears to be irregular; in three holes (91 SW 1, 91 SW 4 and 91 SW 5) the gravel content is between 27 and 34 per cent and in one (90 NW 1) it is as high as 62 per cent. In only one hole (91 SW 5) is the content of fines greater than 9 per cent.

The volume of mineral in this block is estimated to be 35.5 million m^3 ± 33 per cent.

The total area over which terrace deposits occur is approximately 1.2 km^2; data from the adjacent 1:25 000 sheet (TL 80) suggests that their mean thickness is likely to be approximately 6 ft (1.8 m), so that the inferred estimate of their total volume is about 2.1 million m^3. Their mean grading to the west on sheet TL 80 is fines 8 per cent, sand 32 per cent, gravel 60 per cent (Ambrose, 1973) and in their continuation into the area here described their grading may be similar.

LIST OF QUARRIES

Known quarries at the time of the survey are listed in Table 3.

Table 3. List of quarries in report area

	Grid Ref.
Working	
Roundbush Corner	928 193
Disused	
Hill Farm, Tolleshunt D'Arcy	922 117

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Appendix A: Assessment Procedure

1. Within a resource block, a statistical assessment is made for a sampled area of mineral greater than 2 km^2 and containing a minimum of five evenly-spaced boreholes.

2. If the sampled area of mineral is between 0.25 and 2 km^2 and contains one or two suitably sited boreholes an inferred assessment is made. An inferred assessment may also be attempted for any area where the deduced mineral content is small and which consequently has not been sampled by boreholes. No specific level of accuracy is claimed for such subjective assessments.

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

Statistical Assessment

4. The simple methods used in the calculations are consistent with the amount of data provided by the survey. Conventional confidence limits (that is, the tolerance on the estimate or the range within which the result falls) are calculated at the two-sided 95 per cent confidence level, that is, there is a $2\frac{1}{2}$ per cent or 1 in 40 chance that the result exceeds the stated upper limit and a corresponding $2\frac{1}{2}$ per cent chance that it is less than the stated lower limit.

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

$$S_V = \sqrt{S_A^2 + S_{\bar{l}}^2} \quad \ldots\ldots\ldots\ldots (1)$$

where S_V, S_A and $S_{\bar{l}}$ are the standard deviations for volume, area and mean thickness, expressed as proportions of V, A and $\bar{l}$, respectively.

6. The above relationship may be transposed such that

$$S_V = S_{\bar{l}} \sqrt{\left[1 + \left(\frac{S_A}{S_{\bar{l}}}\right)^2\right]} \quad \ldots\ldots\ldots\ldots (2)$$

From this it can be seen that as $\left(\frac{S_A}{S_{\bar{l}}}\right)$ tends to 0, S_V tends to $S_{\bar{l}}$. 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.

7. Given that the number of approximately evenly spaced sample points in the sampled area is n, with mineral thickness measurements l_1, l_2, ... l_n, then the best estimate of mean thickness, $\bar{l}$ =

$$\frac{\sum(l_1 + l_2 \ldots l_n)}{n}$$

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, $S_{\bar{l}}$ expressed as a proportion of the mean thickness is given by

$$S_{\bar{l}} = \frac{1}{\bar{l}} \sqrt{\frac{\sum(l - \bar{l})^2}{n\ (n - 1)}}$$ where l is any value in the series l_1 to l_n.

8. The sampled area A 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 a deposit). Generally, therefore, the only error in determining the area is the negligible planimetering error and S_A is 0. Where the area is not defined by a mapped boundary, that is, where the boundary is inferred (and the distinctive symbol is used), experience suggests that S_A is small relative to $S_{\bar{l}}$.

The relationship

$$\frac{S_A}{S_{\bar{l}}} \leqslant \frac{1}{3}$$ is assumed in all cases.

It follows from equation (2) that

$$S_{\bar{l}} \leqslant S_V \leqslant 1.05\, S_{\bar{l}} \quad \ldots\ldots\ldots\ldots (3)$$

9. The two-sided 95 per cent confidence limits, $L_{\bar{l}}$, for the estimate of mean thickness of mineral in the sampled area, for values of n between 5 and 20, may be expressed in absolute units.

$\bar{l} \pm (t \times S_{\bar{l}} \times \bar{l})$,

or as a percentage

$\bar{l} \pm (t \times S_{\bar{l}} \times 100)$ per cent

where t is Student's t at the two-sided 95 per cent confidence level for (n - 1) degrees of freedom and is evaluated by reference to statistical tables. In applying Student's t it is assumed that the measurements are distributed normally.

10. Values of t at the two-sided 95 per cent confidence level for values of n up to 20 are set out below:

BLOCK CALCULATION

1:25 000 Sheet } Fictitious
Block }

Area	**Volume**
Block: 11.08 km^2	Overburden: 21 million m^3
Mineral: 8.32 km^2	Mineral: 38 million m^3
Thickness	95 per cent confidence limits of the estimate of mineral volume
Overburden: 2.5 m	Percentage: ± 53 per cent
Mineral: 4.5 m	Units of volume: ± 20 million m^3

Thickness estimate (l = thickness)
Measurements in metres

Sample point	Weighting w	Overburden lo	Overburden wlo	Mineral lm	Mineral wlm	Remarks
SE 14	1	1.5	1.5	5.2	5.2	MAU Boreholes (SE 14 – SE 17, 123/45)
SE 18	1	3.3	3.3	nil	-	
SE 20	1	nil	-	2.1	2.1	
SE 22	1	0.7	0.7	9.3	9.3	
SE 23	1	6.2	6.2	5.7	5.7	
SE 24	1	4.3	4.3	6.5	6.5	
SE 17	$\frac{1}{2}$	1.2	1.6 (SE 17 and 123/45)	4.2	3.9 (SE 17 and 123/45)	
123/45	$\frac{1}{2}$	2.0		3.6		Hydrogeol. Dept. record
1	$\frac{1}{4}$	2.4	2.5(25)* (1, 2, 4, 5)	3.4	3.6(25)* (1, 2, 4, 5)	Close group of four boreholes (commercial)
2	$\frac{1}{4}$	4.5		0.8		
4	$\frac{1}{4}$	0.4		4.3		
5	$\frac{1}{4}$	2.8		6.0		
Totals	$\sum w = 8$		$\sum wlo = 20.1(25)*$		$\sum wlm = 36.3(25)*$	
Averages			$\bar{l}o = 2.5(16)*$		$\bar{l}m = 4.5(41)*$	

Calculation of Confidence Limits

l	$(l - \bar{l})$	$(l - \bar{l})^2$
5.2	0.7	0.49
nil	4.5	20.25
2.1	2.4	5.76
9.3	4.8	23.04
5.7	1.2	1.44
6.5	2.0	4.00
3.9	0.6	0.36
3.6	0.9	0.81
$\sum l = 36.3\ (25)$ $n = 8$ $\bar{l} = 4.5\ (41)$ $\simeq 4.5$	$\sum(l - \bar{l})^2 = 56.15$	

$n = 8$
$t = 2.365$

$$L_V = 1.05 \frac{t}{\bar{l}} \sqrt{\frac{\sum(l - \bar{l})^2}{n\,(n-1)}} \times 100$$

$$= 1.05 \times \frac{2.365}{4.541} \sqrt{\frac{56.15}{8 \times 7}} \times 100$$

$$= 54.77$$

$$\simeq 55\%$$

* The figures in brackets are additional decimal places used only in the calculation of confidence limits.

Fig. 3. Example of resource block assessment: statement and calculation

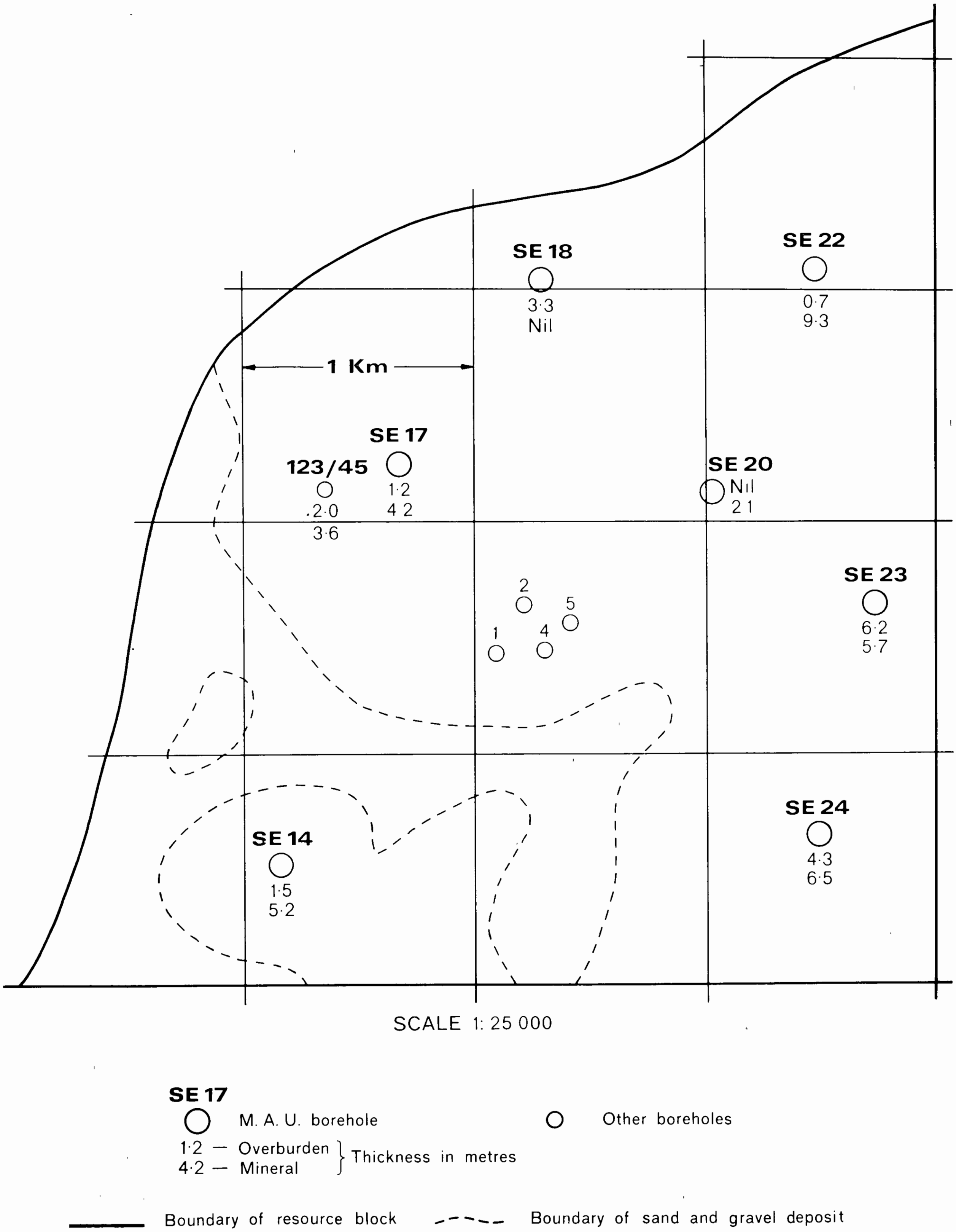


Fig. 4. Example of resource block assessment: map of a fictitious block

n	t	n	t
1	∞	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 Ed. Cambridge University Press, 1962).

The value of t, 1.96, when n is infinity is used when n is greater than 20.

11. In calculating the two-sided 95 per cent confidence limits for volume, L_V, the following inequality corresponding to (3) is applied:

$$L_{\bar{l}} \leqslant L_V \leqslant 1.05 \; L_{\bar{l}}$$

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

$$\frac{1.05 \times t}{\bar{l}} \times \sqrt{\frac{\Sigma(l - \bar{l})^2}{n\ (n - 1)}} \times 100 \text{ per cent}$$

and when n is greater than 20, as

$$\frac{1.05 \times 1.96}{\bar{l}} \times \sqrt{\frac{\Sigma(l - \bar{l})^2}{n\ (n - 1)}} \times 100 \text{ per cent}$$

13. An illustration of the procedures outlined above is given in Figs. 3 and 4, where a volume estimate with confidence limits at the 95 per cent level of confidence is derived from fictitious data.

Inferred Assessments

14. 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 suitably sited boreholes. The volume of mineral is calculated as the product of the sampled area, chosen from interpretation of field data as in the statistical assessment, and the judged average mineral thickness. Confidence limits are not calculated.

15. In some cases in addition to the sampled area of mineral a resource block includes an area left uncoloured on the map, generally based on interpretation of mapping and sample data. On occasions some mineral may be present in such areas and an assessment is made on the basis of the average mineral thickness deduced from exposures and any other evidence available.

Note on Weighting

16. The thickness of a deposit at any point in a sampled area may be governed solely by the position of the point in relation to a broad trend. However, most sand and gravel deposits in addition exhibit a random pattern of local, and sometimes considerable, variation in thickness.

17. Thus, in estimating mean thickness of sand and gravel from a number of data points in a sampled area only the use of simple weighting factors is justified, and the distribution of data points need be only approximately regular. In practice, equal weighting can often be applied to thicknesses at all data points within the sampled area. If, however, there is a distinctly unequal distribution of points, the thicknesses must be weighted to avoid the bias this creates. Weighting factors are determined by first 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.

Appendix B: Classification and Description of Sand and Gravel

The terminology commonly used by geologists when describing sedimentary rocks (Wentworth, 1922) is not entirely satisfactory for the purposes of this Report. For example, Wentworth proposed that a deposit should be described as a 'gravelly sand' when the proportion of sand is greater than that of gravel which must exceed 10 per cent, fines and oversize materials (that is, with diameter greater than 64 mm) being less than 10 per cent. Because deposits containing more than 10 per cent fines (material less than 1/16 mm) are not embraced by this system a modified binary classification based on Willman (1942) has been adopted.

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.

When the fines content exceeds 40 per cent the material is considered to be not 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 and 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

1/16 mm. Thus it has no mineralogical significance and includes particles falling within the size limits of silt. Wherever the term clay does not appear in single quotation marks the normal meaning applies.

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 Fig 5). The procedure is as follows.

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

For example, a deposit grading: gravel, 11 per cent; sand, 70 per cent; fines, 19 per cent is classified as 'clayey' pebbly sand. This short description is included in the borehole log (see Note 10, p.18).

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 1/16 mm size, which approximates to the generally accepted boundary between silt and sand. In this and other respects the system shown in Table 4, used in this report, is satisfactory. It is based on Udden's geometric scale and a simplified form of Wentworth's terminology.

The fairly wide intervals in the scale are consistent with the general level of accuracy of the quantitative assessments of the resource blocks. Three sizes of sand are recognised, fine (−¼ + 1/16 mm), medium (−1 + ¼ mm) and coarse (−4 +1 mm). The boundary at 16 mm distinguishes a range of finer gravel (−16 + 4 mm), often characterised by abundance of worn tough pebbles of vein quartz, from coarser ranges often of notably different average composition. 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, and is presented by the laboratory as logarithmic cumulative curves (see, for example, British Standard 1377:67). In this report the grading is tabulated on the borehole record sheets (Appendix C), the intercepts corresponding with the simple geometric scale 1/16 mm, ¼ 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 for inclusion in Appendix C.

The relative proportions of the rock types present in the gravel fraction are indicated by 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 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 phrase '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.

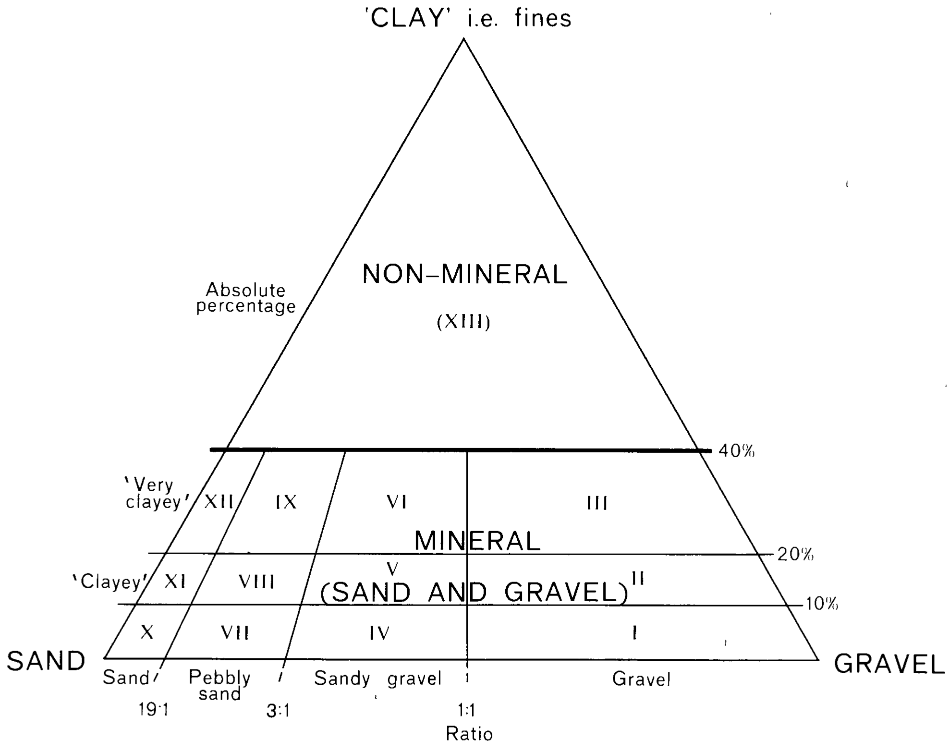
Subrounded: showing considerable wear. The edges and corners are rounded off to smooth curves. Original grain shape is still distinct.

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.

Size limits	Grain size description	Qualification	Primary Classification
	Cobble		Gravel
64 mm	Pebble	Coarse	
16 mm		Fine	
4 mm	Sand	Coarse	Sand
1 mm		Medium	
¼ mm		Fine	
1/16 mm	Fines (silt and clay)		Fines

Table 4. Classification of gravel, sand and fines



I	Gravel	MINERAL
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	

(XIII) NON-MINERAL

Fig. 5. Diagram showing the descriptive categories used in the classification of sand and gravel

Appendix C: Borehole Records

EXPLANATION

Annotated Example of a Borehole Record

TL 91 NW 2[1] 9039 1868[2] Nr Harborough Hall[3]

Surface level (+ 49.4 m) + 162 ft[4]
Water struck at (+ 31.4 m) + 103 ft[5]
Wirth B O, 8 inch diam.,
January 1969[6]

Overburden[7] (6.4 m) 21 ft;
Mineral (14.0 m) 46 ft;
Bedrock (0.9 m +) 3 ft +[8]

		Thickness		Depth[11]	
		(m)	ft	(m)	ft
Boulder Clay[9]	Topsoil and brown chalky clay[10] with chalk fragments up to 60 mm in diameter	(6.4)	21	(6.4)	21
Glacial Sand and Gravel	Sandy Gravel. 'Very clayey' in top 3 ft (0.9 m). Gravelly between 24 ft (7.3 m) and 33 ft (10.1 m), becoming sandy for 14 ft (4.3 m) to 47 ft (14.3 m); gravel content gradually increases below 47 ft (14.3 m) Gravel; fine to coarse, subrounded to subangular flints, with fine subrounded quartz and flints Sand; reddish brown to pale brown subangular; fine to medium in top 3 ft (0.9 m) becoming medium below; mainly fine between 36 ft (11.0 m) and 41 ft (12.5 m)	(14.0)	46	(20.4)	67
London Clay	Weathered brown clay	(0.9 +)	3 +	(21.3)	70

	%	mm	%
Gravel[15]	34	+ 16	14
		− 16 + 4	20
Sand	64	− 4 + 1	6
		− 1 + ¼	39
		− ¼ + 1/16	19
Fines	2	− 1/16	2

Depth below[12] surface (ft)	Percentages[13] Fines	Sand	Gravel
21 − 24	25	62	13
24 − 27	0	46	54
27 − 30	0	40	60
30 − 33	1	53	46
33 − 36	0	83	17
36 − 39	0	92	8
39 − 41	0	94	6
41 − 44	1	76	23
44 − 47	0	82	18
47 − 50	0	68	32
(50 − 53	No grading available)[14]		
53 − 56	1	57	42
56 − 59	2	73	25
59 − 62	0	59	41
62 − 65	2	32	66
65 − 67	0	48	52

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

1. Borehole Registration Number.
Each Mineral Assessment Unit (MAU) 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 91.
2) The quarter of the 1 : 25 000 sheet on which

the borehole lies and its number in a series for that quarter, for example, SE 5.

Thus the full Registration Number is TL 91 SE 5. Usually this is abbreviated to 91 SE 5 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 borehole location is generally referred to the nearest named locality on the 1 : 25 000 base map.

4. Surface Level.
The surface level at the borehole site is given in metres and feet above Ordnance Datum. All measurements were made in feet; approximate conversions to metres are given in brackets.

5. Groundwater Conditions.
Three kinds of entry are made; either, the level at which groundwater was encountered is given in metres and feet above Ordnance Datum; or, where no groundwater was encountered, this is stated; or, where there is no record of the groundwater conditions, this is stated.

6. Type of Drill and Date of Drilling.
Two types of drilling machine have been used in this survey; a Shell and Auger rig and a Wirth (a cased power auger). The type of machine, the external diameter of the casing used, and the month and year of completion of the borehole 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, rock type, country rock or rock-head, below which potentially workable sand and gravel will not be found. In the Norwich area the bedrock is Chalk.

Waste is any material other than bedrock or mineral. Where waste occurs between the surface and a mineral horizon it is classified as overburden.

Thicknesses are given in metres and feet.

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

The borehole log

9. Geological Classification.
A geological classification of the strata encountered in drilling is given whenever possible. (For an explanation of the terms used see p. 4).

10. Lithological Description.
When sand and gravel is recorded, a general description based on the mean grading characteristics is followed by more detailed particulars. (For explanation of conventions see Appendix B). A description of other rock types is based on visual field examination.

11. Depth.
The figures relate to depths from surface to base of the strata recorded on the log.

Grading information

12. Sampling.
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 within the sand and gravel, or for every 3 ft of depth.

13. Grading Results.
The limits are as follows: gravel, +4 mm; sand, -4+1/16 mm; fines, -1/16 mm.

14. Exceptionally the results of the grading of a sample or horizon may not be available. No attempt has been made to estimate the probable grading of such samples, and the grading diagram may not be shown on the map.

15. Mean Grading.
The mean grading for the mineral thickness is the mean of the individual sample gradings, but where the thicknesses of mineral represented by the samples are not constant each grading result is first weighted by its relative thickness.

The results are given for the three main classes, gravel, sand and fines, and for the smaller ranges within these classes.

Since fully representative sampling of sand and gravel is difficult to achieve, particularly where groundwater levels are high, there may be differences between the gradings determined during the survey and the corresponding in-situ grading of the deposit. Comparison with exposures suggests that the proportion of sand in the samples collected from boreholes may be somewhat higher. Conversely the results suggest that the proportion of fines and of +16 mm material may be lower.

Note on metrication

1) All measurements were made in feet. Approximate metric conversions appear in brackets.
2) Metric conversions of measurements of the depth and thickness of beds have been rounded off to the nearest 0.1 m, because quotation to two places of decimals would imply a higher order of accuracy than could be justified by the original figures. To eliminate any discrepancy appearing after metrication between depth as recorded and depth as obtained by summing thicknesses, adjustment has been made where necessary to one or more of the thickness figures. However, the recorded mineral thickness is not adjusted.

LIST OF MINERAL ASSESSMENT UNIT BOREHOLES

Borehole No. (by sheet quadrants)	Grid reference (all fall in 100 km square TL)
TL 91 NW	
1	9013 1968
2	9039 1868
3	9084 1769
4	9121 1965
5	9157 1881
6	9308 1923
7	9485 1877
TL 91 NE	
1	9658 1934
TL 91 SW	
1	9021 1127
2	9121 1035
3	9242 1230
4	9264 1141
5	9433 1171
6	9484 1047
TL 90 NW	
1	9162 0925
2	9359 0949
TL 90 NE	
5	9619 0971

THE RECORDS

TL 91 NW 1 9013 1968 Messing Lodge

Surface level (+ 35.4 m) + 116 ft
Water struck at (+ 27.9 m) + 91½ ft
Shell and Auger, 6 inch diam.,
February 1969

Overburden (7.5 m) 24½ ft;
Mineral (13.2 m) 43½ ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
Boulder Clay	Soil, made ground and firm brown chalky clay to 10 ft (3.0 m), becoming greyish blue, occasionally silty between 10 ft (3.0 m) and 20 ft (6.1 m) and with a compact silt with traces of peat from 14 ft (4.3 m) to 15 ft 6 in (4.7 m). Becoming brown and stony below 20 ft (6.1 m) with a 6 in (0.2 m) lens of clayey sand and gravel at 22 ft (6.7 m) and a 6 in (0.2 m) grey siltstone at 23 ft (7.0 m)	(7.5)	24½	(7.5)	24½
Glacial Sand and Gravel	Sandy Gravel. Pebbly sand in top 24 ft (7.3 m). Increase in gravel content below this at the expense of the sand. Gravel: fine to coarse, subangular to subrounded flints and quartz; large coarse flints, some approaching cobble-size below 63 ft (19.2 m) Sand: brown and reddish brown subangular quartz; medium with fine down to 48 ft (14.6 m); mainly medium below with a medium to coarse zone between 51 ft (15.5 m) and 54 ft (16.5 m)	(13.2)	43½	(20.7)	68
London Clay	Stiff, silty clay; brown for 1 ft (0.3 m) at the top, blue below	(0.9 +)	3 +	(21.6)	71

	%	mm	%
Gravel	29	+ 16	15
		− 16 + 4	14
Sand	70	− 4 + 1	8
		− 1 + ¼	44
		− ¼ + $^1/_{16}$	18
Fines	1	− $^1/_{16}$	1

Depth below surface (ft)	Percentage Fines	Sand	Gravel
24½ – 27	2	77	21
27 – 30	2	88	10
30 – 33	2	92	6
33 – 36	0	93	7
36 – 39	2	92	6
39 – 42	1	86	13
42 – 45	2	92	6
45 – 48	2	93	5
48 – 51	2	48	50
51 – 54	0	55	45
54 – 57	2	62	36
57 – 60	2	52	46
60 – 63	0	52	48
63 – 66	0	32	68
66 – 68	2	26	72

TL 91 NW 2 9039 1868 Nr Harborough Hall

Surface level (+ 49.4 m) + 162 ft
Water struck at (+ 31.4 m) + 103 ft
Wirth B O, 8 inch diam.,
January 1969

Overburden (6.4 m) 21 ft;
Mineral (14.0 m) 46 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
Boulder Clay	Topsoil and brown chalky clay with chalk fragments up to 60 mm in diameter.	(6.4)	21	(6.4)	21
Glacial Sand and Gravel	Sandy Gravel. 'Very clayey' in top 3 ft (0.9 m). Gravelly between 24 ft (7.3 m) and 33 ft (10.1 m), becoming sandy for 14 ft (4.3 m) to 47 ft (14.3 m), gravel content gradually increases below 47 ft (14.3 m) Gravel: fine to coarse, subrounded to subangular flints, with fine subrounded quartz and flints Sand: reddish brown to pale brown subangular; fine to medium in top 3 ft (0.9 m) becoming medium below; mainly fine between 36 ft (11.0 m) and 41 ft (12.5 m)	(14.0)	46	(20.4)	67
London Clay	Weathered brown clay	(0.9 +)	3 +	(21.3)	70

	%	mm	%
Gravel	34	+ 16	14
		− 16 + 4	20
Sand	64	− 4 + 1	6
		− 1 + ¼	39
		− ¼ + $^1/_{16}$	19
Fines	2	− $^1/_{16}$	2

Depth below surface (ft)	Percentage Fines	Sand	Gravel
21 − 24	25	62	13
24 − 27	0	46	54
27 − 30	0	40	60
30 − 33	1	53	46
33 − 36	0	83	17
36 − 39	0	92	8
39 − 41	0	94	6
41 − 44	1	76	23
44 − 47	0	82	18
47 − 50	0	68	32
(50 − 53	No grading available)		
53 − 56	1	57	42
56 − 59	2	73	25
59 − 62	0	59	41
62 − 65	2	32	66
65 − 67	0	48	52

TL 91 NW 3 9084 1769 Haynes Green

Surface level (+ 52.4 m) + 172 ft
Water struck at (+ 49.1 m) + 161 ft
Wirth B O, 8 inch diam.,
February 1969

Overburden (1.5 m) 5 ft;
Mineral (8.9 m) 29 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness (m)	Thickness ft	Depth (m)	Depth ft
Glacial Sand and Gravel	Soil and brown clay	(1.5)	5	(1.5)	5
	'Clayey' Pebbly Sand. The top 14 ft (4.3 m) is 'very clayey'; considerable reduction in fines content below. Gravel more important towards the bottom of the deposit Sand: rust brown becoming grey to greyish brown; fine or fine to medium in top 14 ft (4.3 m) with medium sand dominant below Gravel: fine to coarse subangular to subrounded flints and quartz	(8.9)	29	(10.4)	34
London Clay	Weathered brown clay	(0.9 +)	3 +	(11.3)	37

	%	mm	%
Gravel	18	+ 16	9
		− 16 + 4	9
Sand	68	− 4 + 1	5
		− 1 + ¼	37
		− ¼ + 1/16	26
Fines	14	− 1/16	14

Depth below surface (ft)	Fines	Sand	Gravel
5 − 8	28	64	8
8 − 11	26	61	13
11 − 14	35	61	4
14 − 19	23	62	15
19 − 22	9	73	18
22 − 25	2	70	28
25 − 28	0	92	8
28 − 31	1	64	35
31 − 34	4	59	37

TL 91 NW 4 9121 1965 Disused Airfield, Birch

Surface level (+ 43.3 m) + 142 ft
Water struck at (+ 32.0 m) + 105 ft
Wirth B O, 8 inch diam.,
January 1969

Waste (18.3 m +) 60 ft +

		Thickness (m)	Thickness ft	Depth (m)	Depth ft
Boulder Clay	Soil and brown chalky clay, becoming grey below 23 ft (7.0 m)	(18.3 +)	60 +	(18.3)	60

TL 91 NW 5 9157 1881 Birch Holt

Surface level (+ 45.4 m) + 149 ft
Water struck at (+ 26.2 m) + 86 ft
Wirth B O, 8 inch diam.,
January 1969

Overburden (14.6 m) 48 ft;
Mineral (7.3 m) 24 ft;
Bedrock (1.0 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
Boulder Clay	Soil and brown chalky clay, becoming grey below 20 ft (6.1 m) and containing occasional silty bands and gravel bands	(14.6)	48	(14.6)	48
Glacial Sand and Gravel	Sandy Gravel. Proportion of gravel increasing through the top 9 ft (2.7 m) below this the sand content increases accompanied by decrease in gravel content. Fines content high in the top 3 ft (0.9 m) Gravel: fine to coarse subangular to subrounded flints and quartz, with fine quartzites Sand: brown; subangular, mainly medium, with varying, usually subsidiary, amounts of fine and coarse	(7.3)	24	(21.9)	72
London Clay	Weathered, brown clay	(1.0 +)	3 +	(22.9)	75

	%	mm	%
Gravel	28	+ 16	12
		− 16 + 4	16
Sand	65	− 4 + 1	10
		− 1 + ¼	39
		− ¼ + $\frac{1}{16}$	16
Fines	7	− $\frac{1}{16}$	7

Depth below surface (ft)	Percentages Fines	Sand	Gravel
48 − 51	21	57	22
51 − 54	2	57	41
54 − 57	0	46	54
57 − 60	0	65	35
60 − 63	3	79	18
63 − 66	12	71	17
66 − 69	7	71	22
69 − 72	10	75	15

TL 91 NW 6 9308 1923 Nr Roundbush Corner

Surface level (+ 35.4 m) + 116 ft
Water struck at (+ 26.8 m) + 88 ft
Wirth B O, 8 inch diam.,
July 1969

Overburden (4.0 m) 13 ft;
Mineral (15.2 m) 50 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness (m)	Thickness ft	Depth (m)	Depth ft
? Head	Soil and brown clay	(4.0)	13	(4.0)	13
Glacial Sand and Gravel	Sandy Gravel. Gravel content high at the top; diminishes with increasing depth, becoming irregularly distributed below 30 ft (9.1 m) Gravel: fine to coarse rounded, subrounded and subangular flints, quartzites and some quartz; coarsest in the top 3 ft (0.9 m) Sand: greyish brown to rust brown; mostly medium or fine to medium.	(15.2)	50	(19.2)	63
London Clay	Weathered, brown clay	(0.9 +)	3 +	(20.1)	66

	%	mm	%
Gravel	30	+ 16	15
		− 16 + 4	15
Sand	69	− 4 + 1	7
		− 1 + ¼	50
		− ¼ + 1/16	12
Fines	1	− 1/16	1

Depth below surface (ft)	Percentages Fines	Sand	Gravel
13 − 16	0	18	82
16 − 19	0	28	72
19 − 22	2	45	53
22 − 25	1	76	23
25 − 28	0	68	32
28 − 31	2	89	9
31 − 34	1	99	0
34 − 37	2	98	0
37 − 40	0	94	6
40 − 43	2	68	30
43 − 46	2	90	8
46 − 49	2	60	38
49 − 52	2	44	34
52 − 55	0	96	4
55 − 58	2	84	14
58 − 61	0	70	30
61 − 63	1	45	54

TL 91 NW 7 9485 1877 Layer Breton Heath

Surface level (+ 50.9 m) + 167 ft
Water struck at (+ 46.3 m) + 152 ft
Wirth B O, 8 inch diam.,
July 1969

Overburden (4.3 m) 14 ft;
Mineral (1.8 m) 6 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
Head	Soil and brown clay giving way to grey silty clay at 8 ft (2.4 m)	(4.3)	14	(4.3)	14
Glacial Sand and Gravel	'Very clayey' Sand. Traces of chalk pellets in top 3 ft (0.9 m) Sand: bluish grey, mostly fine with some medium Gravel: Traces only, fine to coarse, rounded to subrounded, flints and quartz	(1.8)	6	(6.1)	20
London Clay	Weathered, brown clay	(0.9 +)	3 +	(7.0)	23

	%	mm	%
Gravel	2	+ 16	1
		− 16 + 4	1
Sand	74	− 4 + 1	3
		− 1 + ¼	26
		− ¼ + $^1/_{16}$	45
Fines	24	− $^1/_{16}$	24

Depth below surface (ft)	Percentages Fines	Sand	Gravel
14 – 17	19	78	3
17 – 20	29	69	2

TL 91 NE 1 9658 1934 Wick Farm

Surface level (+ 41.5 m) + 136 ft
Water struck at (+ 35.1 m) + 115 ft
Wirth B O, 8 inch diam.,
February 1969

Overburden (1.8 m) 6 ft;
Mineral (10.1 m) 33 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness (m)	Thickness ft	Depth (m)	Depth ft
? Head	Soil and brown clay	(1.8)	6	(1.8)	6
Glacial Sand and Gravel	Pebbly Sand. Traces only of gravel except for 12 ft (3.7 m) of 'pebbly sand' between 15 ft (4.6 m) and 27 ft (8.2 m) 'Clayey' bands present between 21 ft (6.4 m) and 24 ft (7.3 m) and for 3 ft (0.9 m) at the bottom of the deposit Sand: fine to medium, subangular, rust brown in top 6 ft (1.8 m);mainly medium, grey to 24 ft (7.3 m); becoming fine to medium, greyish brown below Gravel: fine to coarse subrounded flints and quartz	(10.1)	33	(11.9)	39
London Clay	Brown, weathered clay	(0.9 +)	3 +	(12.8)	42

	%	mm	%
Gravel	5	+ 16	3
		– 16 + 4	2
Sand	90	– 4 + 1	4
		– 1 + ¼	47
		– ¼ + $\frac{1}{16}$	39
Fines	5	– $\frac{1}{16}$	5

Depth below surface (ft)	Percentages Fines	Sand	Gravel
6 – 9	0	100	0
9 – 12	0	97	3
12 – 15	2	96	2
15 – 18	0	92	8
18 – 21	2	87	11
21 – 24	17	68	15
24 – 27	0	94	6
27 – 30	0	100	0
30 – 33	9	88	3
33 – 36	3	94	3
36 – 39	17	80	3

TL 91 SW 1 9021 1127 Gate Farm, Tolleshunt Major

Surface level (+ 28.0 m) + 92 ft
Water struck at (+ 21.0 m) + 69 ft
Wirth B O, 8 inch diam.,
July 1969

Overburden (2.4 m) 8 ft;
Mineral (5.2 m) 17 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
? Head	Soil and brown clay	(2.4)	8	(2.4)	8
Glacial Sand and Gravel	Sandy Gravel. 'Clayey' band between 14 ft (4.3 m) and 17 ft (5.2 m) Gravel: Mostly fine; subangular to subrounded flints and quartz Sand: brown to greyish brown predominantly medium	(5.2)	17	(7.6)	25
London Clay	Blue clay, weathered brown for a few inches below the surface	(0.9 +)	3 +	(8.5)	28

	%	mm	%
Gravel	34	+ 16	12
		− 16 + 4	22
Sand	63	− 4 + 1	8
		− 1 + ¼	50
		− ¼ + 1/16	5
Fines	3	− 1/16	3

Depth below surface (ft)	Percentages		
	Fines	Sand	Gravel
8 − 11	0	70	30
11 − 14	1	47	52
14 − 17	12	65	23
17 − 20	1	69	30
20 − 23	2	57	41
23 − 25	0	72	28

TL 91 SW 2 9121 1035 Manor Farm, Tolleshunt Major

Surface level (+ 14.6 m) + 48 ft
Water struck at (+ 12.8 m) + 42 ft
Wirth B O, 8 inch diam.,
February 1969

Overburden (0.6 m) 2 ft;
Mineral (1.8 m) 6 ft;
Waste (3.4 m) 11 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
Made ground and subsoil		(0.6)	2	(0.6)	2
Glacial Sand and Gravel	Gravel Gravel: fine to coarse becoming coarser downwards; mostly subangular flints with rounded to subrounded quartz Sand: medium; subrounded to subangular	(1.8)	6	(2.4)	8
? London Clay	Brown silty clay	(3.4)	11	(5.8)	19
London Clay	Brown clay	(0.9 +)	3 +	(6.7)	22

	%	mm	%
Gravel	48	+ 16	23
		− 16 + 4	25
Sand	45	− 4 + 1	8
		− 1 + ¼	32
		− ¼ + 1/16	5
Fines	7	− 1/16	7

Depth below surface (ft)	Percentages Fines	Sand	Gravel
2 – 5	6	52	42
5 – 8	8	38	54

TL 91 SW 3 9242 1230 Grout's Farm, Tolleshunt D'Arcy

Surface level (+ 29.0 m) + 95 ft
Water struck at (+ 25.6 m) + 84 ft
Wirth B O, 8 inch diam.,
February 1969

Overburden (1.8 m) 6 ft;
Mineral (4.9 m) 16 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
Head	Soil and brown silty clay	(1.8)	6	(1.8)	6
Glacial Sand and Gravel	Gravel. 'Clayey' in the top 4 ft (1.2 m), the fines content decreasing below. Most gravelly in the bottom 6 ft (1.8 m) of the deposit Gravel: subangular to subrounded flints, quartzites and quartz; mostly fine in the top half of the deposit, becoming coarser downwards. Sand: greyish brown to brown; mainly medium	(4.9)	16	(6.7)	22
London Clay	Brown, weathered clay	(0.9 +)	3 +	(7.6)	25

	%	mm	%
Gravel	53	+ 16	24
		− 16 + 4	29
Sand	38	− 4 + 1	7
		− 1 + ¼	26
		− ¼ + 1/16	5
Fines	9	− 1/16	9

Depth below surface (ft)	Percentages Fines	Sand	Gravel
6 – 8	16	42	42
8 – 10	11	39	50
10 – 13	9	39	52
13 – 16	10	53	37
16 – 19	3	29	68
19 – 22	4	28	68

TL 91 SW 4 — 9264 1141 — Wild Fowl Farm, Tolleshunt D'Arcy

Surface level (+ 26.8 m) + 88 ft
Water struck at (+ 24.4 m) + 80 ft
Wirth B O, 8 inch diam.,
July 1969

Overburden (4.6 m) 15 ft;
Mineral (3.6 m) 12 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
? Head	Soil and brown clay	(4.0)	13	(4.0)	13
Glacial Sand and Gravel	'Very clayey' gravel	(0.6)	2	(4.6)	15
	Sandy Gravel. 'Clayey' in the top 3 ft (0.9 m). Very sandy between 18 ft (5.5 m) and 21 ft (6.4 m) Gravel: fine to coarse; mostly coarse in the top 3 ft (0.9 m), and mostly fine below; subangular to subrounded flints Sand: rust brown; fine with medium in the top 3 ft (0.9 m), mainly medium below	(3.6)	12	(8.2)	27
London Clay	Blue clay, weathered brown in parts.	(0.9 +)	3 +	(9.1)	30

	%	mm	%
Gravel	27	+ 16	10
		− 16 + 4	17
Sand	66	− 4 + 1	10
		− 1 + ¼	36
		− ¼ + $\frac{1}{16}$	20
Fines	7	− $\frac{1}{16}$	7

Depth below surface (ft)	Percentages		
	Fines	Sand	Gravel
15 – 18	16	41	43
18 – 21	4	86	10
21 – 24	1	64	35
24 – 27	7	71	22

TL 91 SW 5   9433 1171   Guisnes Court, Tollesbury

Surface level (+ 25.3 m) + 83 ft
Water struck at (+ 21.3 m) + 70 ft
Wirth B O, 8 inch diam.,
February 1969

Overburden (0.9 m) 3 ft;
Mineral (2.5 m) 8 ft;
Waste (3.6 m) 12 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
	Soil	(0.9)	3	(0.9)	3
Glacial Sand and Gravel	'Very Clayey' Sandy Gravel. 'Very clayey' below the top 2 ft (0.6 m). Gravel: mostly fine; subangular to subrounded flints, quartzites and quartz. Sand: greyish brown; medium to coarse in the top 2 ft (0.6 m), medium below	(2.5)	8	(3.4)	11
? London Clay	Brown, silty clay	(3.6)	12	(7.0)	23
London Clay	Brown, weathered clay	(0.9 +)	3 +	(7.9)	26

	%	mm	%
Gravel	27	+ 16	9
		− 16 + 4	18
Sand	49	− 4 + 1	15
		− 1 + ¼	32
		− ¼ + $\frac{1}{16}$	2
Fines	24	− $\frac{1}{16}$	24

Depth below surface (ft)	Percentages Fines	Sand	Gravel
3 − 5	10	57	33
5 − 8	31	48	21
8 − 11	30	44	26

TL 91 SW 6 9484 1047 Nr Garland's Farm, Tollesbury

Surface level (+ 24.1 m) + 79 ft
Water struck at (+ 22.6 m) + 74 ft
Wirth B O, 8 inch diam.,
February 1969

Overburden (0.3 m) 1 ft;
Mineral (7.3 m) 24 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
	Soil	(0.3)	1	(0.3)	1
Glacial Sand and Gravel	Gravel. Very sandy in top 3 ft (0.9 m) Gravel: fine and coarse; subangular flints and subordinate subrounded quartz Sand: brown, medium, subangular	(7.3)	24	(7.6)	25
London Clay	Brown, weathered clay	(0.9 +)	3 +	(8.5)	28

	%	mm	%
Gravel	52	+ 16	24
		− 16 + 4	28
Sand	41	− 4 + 1	7
		− 1 + ¼	29
		− ¼ + 1/16	5
Fines	7	− 1/16	7

Depth below surface (ft)	Percentages Fines	Sand	Gravel
1 − 4	9	60	31
4 − 7	8	39	53
7 − 16	7	38	55
16 − 19	5	35	60
19 − 22	6	36	58
22 − 25	6	47	47

TL 90 NW 1 9162 0925 Longwick Farm, Tolleshunt Major.

Surface level (+ 11.0 m) + 36 ft
Ground water conditions not recorded
Wirth B O, 8 inch diam.,
February 1969

Overburden (1.2 m) 4 ft;
Mineral (3.1 m) 10 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
Head	Soil and clay with gravel	(1.2)	4	(1.2)	4
Glacial Sand and Gravel	Gravel. Becomes increasingly sandy and less gravelly with depth Gravel: fine to coarse down to 10 ft (3.0 m), mainly fine below; subangular flints and subrounded and rounded quartz and quartzites Sand: brown, mainly medium with coarse and a trace of fine; subangular to subrounded	(3.1)	10	(4.3)	14
London Clay	Brown clay	(0.9 +)	3 +	(5.2)	17

	%	mm	%
Gravel	62	+ 16	29
		− 16 + 4	33
Sand	36	− 4 + 1	9
		− 1 + ¼	24
		− ¼ + $^1/_{16}$	3
Fines	2	− $^1/_{16}$	2

Depth below surface (ft)	Percentages Fines	Sand	Gravel
4 − 7	0	30	70
7 − 10	7	31	62
10 − 13	0	44	56
13 − 14	0	47	53

TL 90 NW 2 9359 0949 The Wycke, Tolleshunt D'Arcy

Surface level (+ 10.1 m) + 33 ft
Water not struck
Wirth B O, 8 inch diam.,
February 1969

Waste (7.6 m) 25 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness		Depth	
		(m)	ft	(m)	ft
Head	Soil and silty clay	(2.7)	9	(2.7)	9
? London Clay	Brown sandy clay	(4.9)	16	(7.6)	25
London Clay	Brown clay	(0.9 +)	3 +	(8.5)	28

TL 90 NE 5 9619 0971 nr Mell House, Tollesbury

Surface level (+ 18.0 m) + 59 ft
Water struck at (+ 15.8 m) + 52 ft
Wirth B O, 8 inch diam.,
February 1969

Overburden (2.4 m) 8 ft;
Mineral (3.7 m) 12 ft;
Bedrock (0.9 m +) 3 ft +

		Thickness (m)	Thickness ft	Depth (m)	Depth ft
Glacial Sand and Gravel	Soil and brown clay with gravel	(2.4)	8	(2.4)	8
	Gravel. 'Clayey' in top 3 ft (0.9 m); Gravel: fine and coarse, mainly rounded to subrounded quartzites with occasional subrounded to subangular flints, and rounded to subrounded quartz becoming common below 17 ft (5.2 m) Sand: brown; mainly medium, subangular and subrounded down to 17 ft (5.2 m); mostly fine to medium below	(3.7)	12	(6.1)	20
London Clay	Brown clay	(0.9 +)	3 +	(7.0)	23

	%	mm	%
Gravel	55	+ 16	28
		− 16 + 4	27
Sand	40	− 4 + 1	10
		− 1 + ¼	21
		− ¼ + $\frac{1}{16}$	9
Fines	5	− $\frac{1}{16}$	5

Depth below surface (ft)	Percentages Fines	Sand	Gravel
8 − 11	12	35	53
11 − 14	0	43	57
14 − 17	7	40	53
17 − 20	0	42	58

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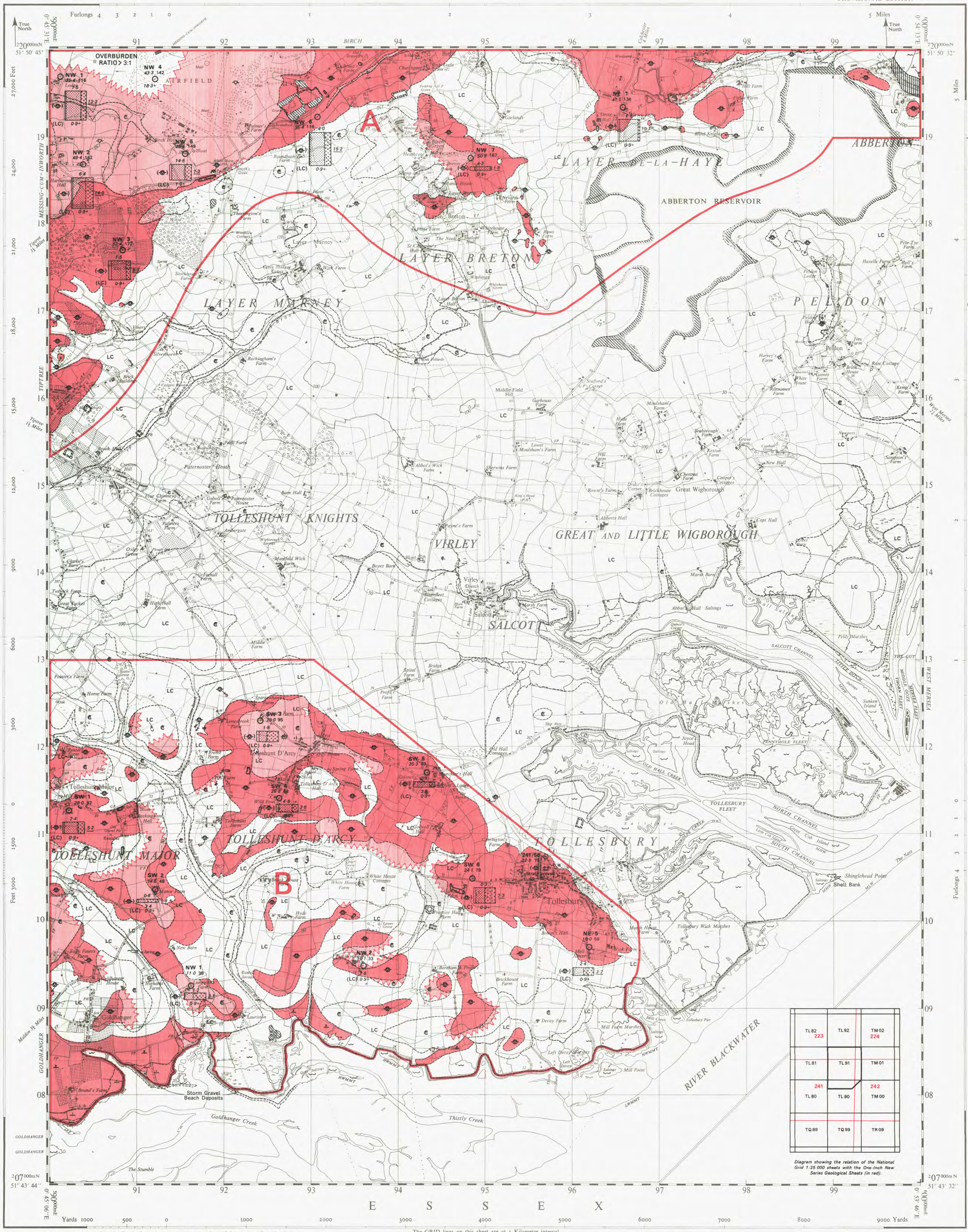
INSTITUTE OF GEOLOGICAL SCIENCES

MINERAL ASSESSMENT UNIT

THE SAND & GRAVEL RESOURCES OF SHEET TL 91 & part of SHEET TL 90
(LAYER BRETON AND TOLLESHUNT D'ARCY, ESSEX)

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

ORDNANCE SURVEY
SHEET TL91 & Pt TL90
PROVISIONAL EDITION



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

7

EXPLANATION OF SYMBOLS AND ABBREVIATIONS

DRIFT

TF-1 **Tidal Flat Deposits** – present day sand and mud flats.

ME-1 **Marine or Estuarine Alluvium** – marine clays and silts.

A-1 **Alluvium** – brown clays and silts, often sandy.

1T-4 **1st Terrace**, 2T-2 **2nd Terrace**, 5T-1 **5th Terrace** — **River gravels of the River Blackwater** – mainly gravels and sandy gravels.

H-8 **Head** – brown clay with silts and pebbles.

BC-9 **Boulder Clay** – brown or grey-blue clay with chalk and flints.

GS-15 **Glacial Sand and Gravel** – gravels and sandy gravels.

RECENT AND PLEISTOCENE

SOLID

LC **London Clay** – firm, blue-grey clay, weathering brown. EOCENE

The Lower London Tertiaries and the Chalk have been proved in deep boreholes.

MG-2 **Made Ground**

L-1 **Landslip**

BOUNDARY LINES

Geological boundary, Drift.

Inferred boundary between categories of deposits recognised.

Resource Block boundary.

BOREHOLE DATA

SITE LOCATIONS

Mineral Assessment Unit (M.A.U.) Boreholes.

Other Boreholes.

M.A.U. BOREHOLES

Borehole Registration Number → SW 2

14·6 48 ← Surface level in metres and feet above O. D. (Newlyn)

Borehole site

Geological Classification (LC)

Grading Diagram.

0·6 ← Overburden

1·8 ← Mineral (sand and gravel)

3·4 ← Waste

0·9+ ← Bedrock

Note:
(1) Figures underlined denote thicknesses used in the assessment of resources.
(2) The + sign indicates that the base of the deposit was not reached.
(3) The figures in *italics* are the conversions to metres of measurements recorded in feet.
(4) The Geological Classification is given only for mineral and bedrock.

Borehole Registration Number

Each M.A.U. borehole is identified by a registration number e.g. SW 2. The letters refer to the relevant standard quarter sheet and the figures to the I.G.S. serial number for that quarter. The unique designation for borehole SW 2 is TL 91 SW 2.

Grading Diagrams

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

Sand ($+\frac{1}{16}$–4 mm)
Fines ($-\frac{1}{16}$ mm)
Gravel (+4 mm)

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

OTHER BOREHOLES

The layout of information is the same as for M.A.U. boreholes, though data available may not be as comprehensive. They are registered in the same series, except for records in the Hydrogeological Department, for example, 241/56 signifies Hydrogeological Department borehole number 56 on New Series One-Inch Geological Sheet 241.

EXPOSURE RECORDS

Information from the inspection of exposures is shown 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 sand and gravel as mapped and assessed. CAT-E4

Continuous, or almost continuous spreads of mineral beneath overburden. CAT-C1

Sand and gravel either not potentially workable (see Report) or absent. CAT-A2

Where appropriate on other sheets a fourth category, 'Discontinuous spreads of sand and gravel beneath overburden' is recognised.

RESOURCE BLOCKS

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

Detailed records may be consulted on application to the Director at the appropriate offices of the Institute of Geological Sciences.

Made and printed for the Institute of Geological Sciences by the Director General of the Ordnance Survey

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

The GRID lines on this sheet are at 1 Kilometre interval.
Heights are in feet above Mean Sea Level at Newlyn.

1 square inch on this map represents 99·639 acres on the ground.

Compiled from 6'' sheets last fully revised 1920-21
Other partial systematic revision 1938-53 has been incorporated.
Major roads revised 1965.

Geological lines from a Six-Inch survey in 1966-67 by C. R. Bristow.
S. C. A. Holmes, District Geologist.
Included in One-Inch Geological Sheets 223, 224, 241, 242.

Sand and Gravel survey by John D. Ambrose and N. E. Bradbury in 1969.
R. G. Thurrell, Head, Mineral Assessment Unit.

1:25 000 Sand and Gravel Resource Sheet published 1973.
Sir Kingsley Dunham D.Sc., F.R.S., *Director, Institute of Geological Sciences, incorporating the Geological Survey of Great Britain, the Museum of Practical Geology, and Overseas Geological Surveys.*
2050/73

Data quoted for an individual borehole refer strictly to that site from which 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.