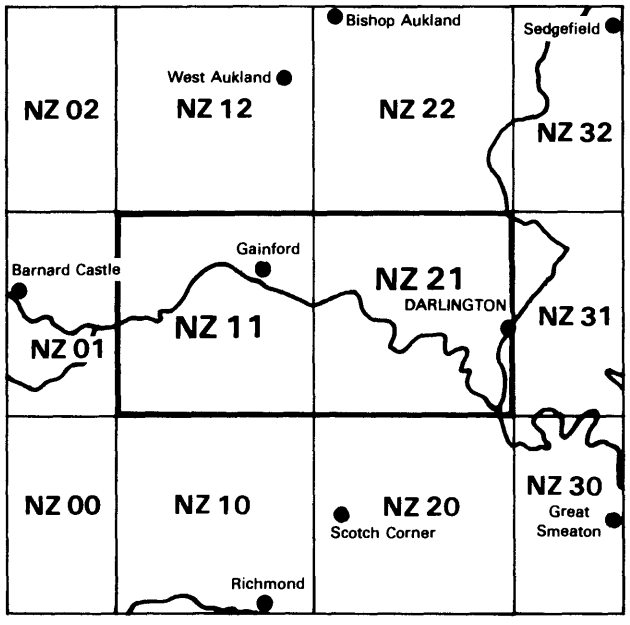
INSTITUTE OF GEOLOGICAL SCIENCES

Natural Environment Research Council

Mineral Assessment Report 40



The sand and gravel resources of the country west of Darlington, County Durham

Description of 1:25 000 resource sheet NZ 11 and 21

A. Smith

ISBN 0 11 884086 X

London Her Majesty's Stationery Office 1979

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 for 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 sand and gravel resources of an area west of Darlington, County Durham, particularly those in the valley of the River Tees, as shown on the accompanying 1:25 000 resource map NZ 11 and 21. The survey was conducted by Mr A. Smith, assisted in the drilling and sampling programme by Messrs J. R. Gozzard, K. Chell and A. Halker. The work, which was controlled from the sub-unit in Leeds (J. H. Hull, Officer-in-Charge), is based on six-inch geological surveys carried out in 1871–1879 and 1960–1973 and published in one-inch New-Series Geological Sheet 32 (Barnard Castle) and 1:50 000 Sheet 33 (Stockton). The geological lines now presented at the 1:25 000 scale incorporate minor revisions resulting from the present work.

Mr T. D. Hillyard (Land Agent, Property Services Agency) has been responsible for negotiating access to land for drilling. The ready cooperation of land owners, tenants and gravel companies in this work is gratefully acknowledged.

Austin W. Woodland
Director

Institute of Geological Sciences
Exhibition Road
London SW7 2DE

20 *October* 1978

CONTENTS

The sand and gravel resources of the country west of Darlington, County Durham

Description of 1:25 000 resource sheet NZ 11 and 21

A. SMITH

SUMMARY

The geological maps of the Institute of Geological Sciences, pre-existing borehole information, exposures and 41 boreholes drilled for the Industrial Minerals Assessment Unit, form the basis of the assessment of sand and gravel resources of an area in North Yorkshire and County Durham, west of Darlington.

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 three resource blocks containing respectively 5.3, 9.2 and 9.9 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, mineral and waste 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.

Bibliographical reference

SMITH, A. 1979. The sand and gravel resources of the country west of Darlington, County Durham: description of 1:25 000 resource sheet NZ 11 and 21. *Miner. Assess. Rep. Inst. Geol. Sci.*, No. 40.

Note

All National Grid references in this report fall within 100-km square NZ and are given in the form [142 162]

Author

A. Smith, 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 geological evidence. The sites available for inspection, measurement, and sampling are too widely spaced to permit the mineral bodies to be out-lined 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 1 m 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 must 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.

If a deposit of sand and gravel broadly meets these criteria, it 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 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

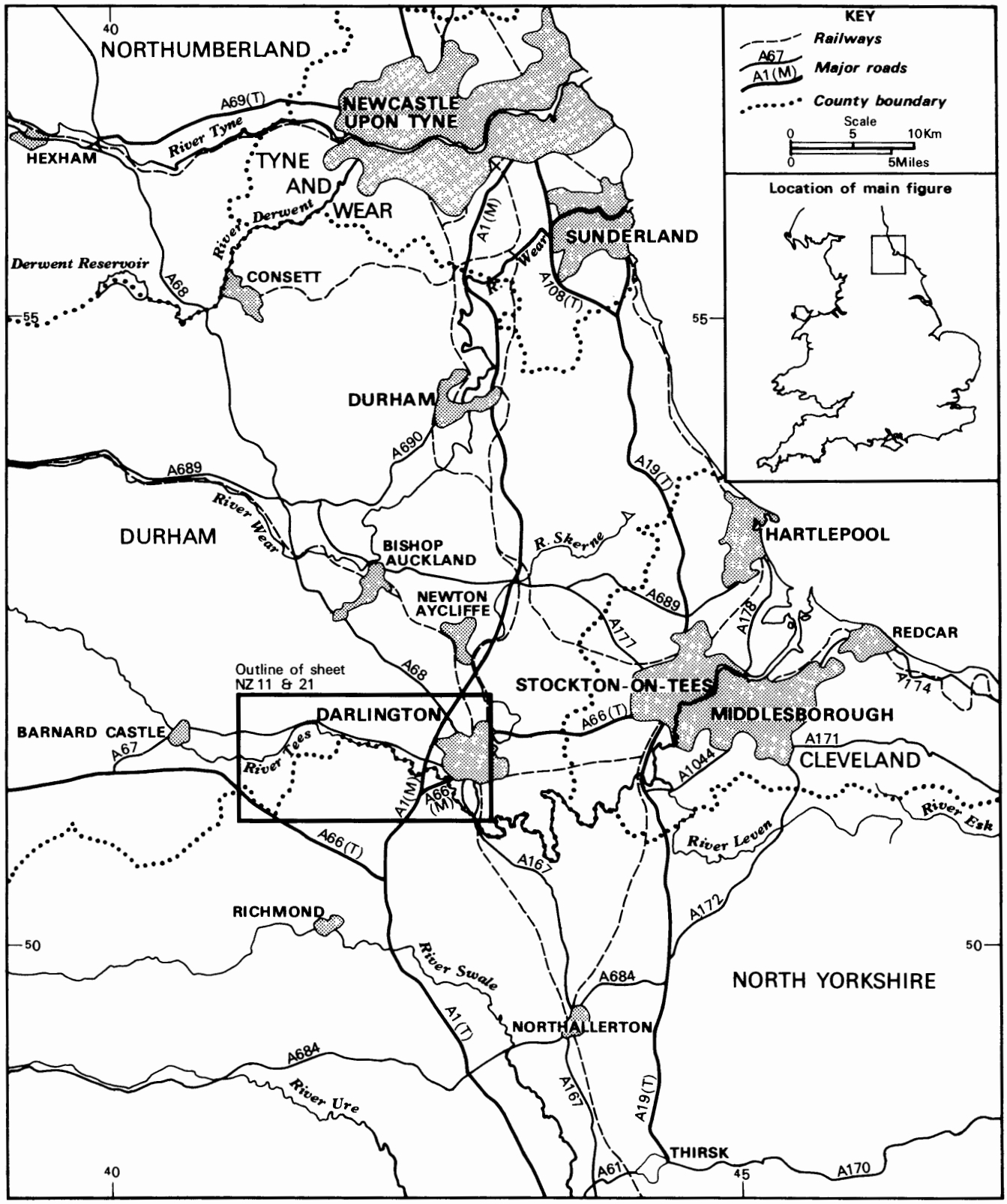


Figure 1 Map showing the location of sheet NZ 11 and 21

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.

DESCRIPTION OF THE RESOURCE SHEET

GENERAL

The area lies to the west of Darlington, in parts of Durham and North Yorkshire (Figure 1). It is a mixed farming region with the town providing a focus for light industry. Sand and gravel extraction from the valley of the River Tees provides aggregate mainly for the Stockton–Middlesbrough conurbation, about 30 km to the east, which is undergoing rapid industrial development (Newton, 1971).

The area is of moderate relief, falling from about 600 ft (180 m) above OD west of Cleatlam in the north-west of the sheet, to about 100 ft (30 m) above OD south of Darlington. The River Tees enters the area in a gorge, but downstream of Winston Bridge [142 162] the valley gradually broadens out into a floodplain up to 1.5 km wide. Elsewhere, the topography is hummocky because of glacial and postglacial modification of an area of diverse solid geology.

GEOLOGY

The geological sequence is summarised in Table 1, where deposits are listed as far as possible in order of increasing age. The relationship between deposits is illustrated in Figure 2. The lines of section are shown on the accompanying resource map. A fuller account of the geology of the central and western areas is given in the Barnard Castle memoir (Mills and Hull, 1976).

Table 1 Geological sequence

	Landslip
	Foundered ground
DRIFT	
Recent and Pleistocene	Peat
	Alluvium
	River Terrace Deposits
	Post-Glacial Lake Deposits
	Fluvioglacial and Older River deposits
	Glacial Sand and Gravel
	Morainic Drift
	Laminated Clay
	Boulder Clay and Undifferentiated Drift
SOLID	
Permo-Triassic	Sherwood Sandstone Group ('Bunter' Sandstone)
	Permian, undivided
Carboniferous	Millstone Grit Series, undivided
	Carboniferous Limestone Series, undivided

SOLID

Carboniferous Limestone Series (Viséan): These beds occur in the south-west of the area, where, however, they are mainly covered with drift. The strata at crop are up to 150 m thick and consist of shallow-water limestones, shales and sandstone in repeated sequences (cyclothems). Dips are generally low and mainly towards the north.

Millstone Grit Series (Namurian): These rocks occupy much of the area and are generally drift-covered; like the underlying rocks they have variable northerly dips. They attain a thickness of 530 m. Lithologically, they may be subdivided into a lower sequence similar to that of the Viséan and an upper more arenaceous division. Around Cleasby the strata are reddened, probably by ferric oxide. A thin coal seam has been worked opencast at two localities [123 160; 131 160] south-west of Winston.

Permian: Permian rocks, up to about 130 m thick with gentle easterly dips, occupy the eastern part of the area, where they rest unconformably on older rocks. They consist of Lower, Middle and Upper Magnesian limestones together with Permian Middle and Upper marls, all deposited in the Zechstein Sea. They are mostly covered with drift and do not form marked topographical features. However, excellent exposures occur in cliffs along the River Tees between Piercebridge and High Coniscliffe [226 154], where the Lower and Middle Magnesian limestones consist of soft, buff-yellow dolomite and dolomitic limestones. These limestones are good aquifers and may yield artesian water when penetrated.

Triassic: Sherwood Sandstone Group ('Bunter' Sandstone) is exposed only in the bed of the River Tees [290 101] in the extreme south-east of the area. Elsewhere, it has been proved in boreholes beneath thick drift.

DRIFT

The distribution, age and correlation of the Pleistocene deposits in north-eastern England has long been of interest (Trotter, 1929a; Penny, 1964; Francis, 1970). Such deposits cover much of the area of sheets NZ 11 and 21, and probably represent one glacial episode of Late Devensian age, namely the last period of ice advance (Mills and Hull, 1976). Locally, this is recognised as Stainmore ice (Dwerryhouse, 1902; Trotter, 1929b) which entered the area from the west and held back Upper Teesdale ice to the north and Swaledale–Tan Hill ice to the south; it brought with it Lake District erratics, including distinctive Shap Granite pebbles.

Boulder Clay: Most of the area is covered by Boulder Clay, which generally ranges from 1.5 to 6 m in thickness but thickens to between 14 and 18 m east of Thornton Hall [237 170], Hall Moor [241 157] and Cleasby [252 130]. Although the deposit is very variable locally, its lithology changes regionally from stiff, dark grey, stony clay in the west to softer, red-brown clay with fewer stones in the east. Most of the pebbles were derived locally and include Carboniferous limestones, sandstones and basaltic rocks. However, some Lake District erratics are found including Borrowdale Volcanic Series rocks, Shap Granite, Palaeozoic greywackes, Brockram conglomerates and soft, red Permo-Triassic sandstones.

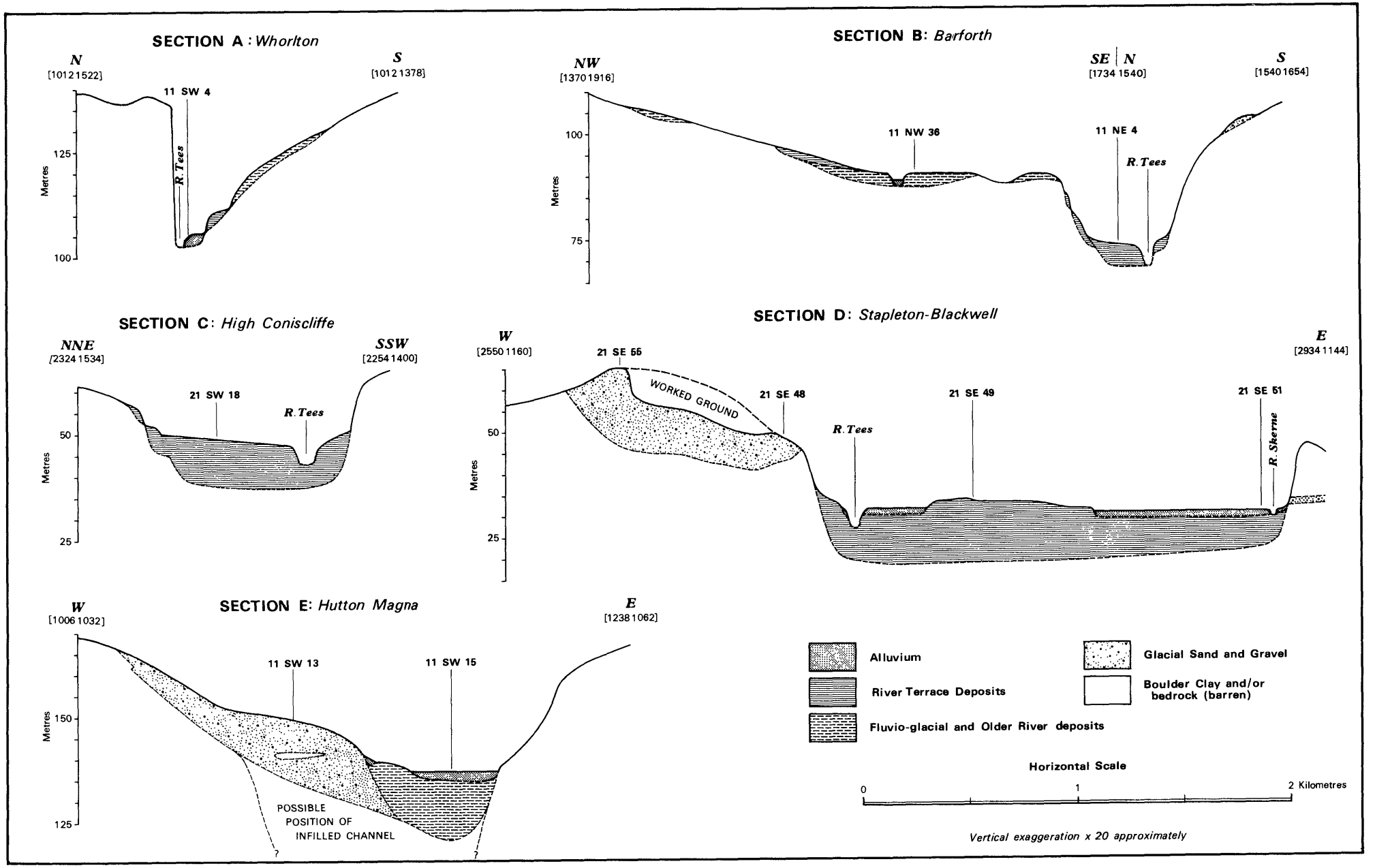
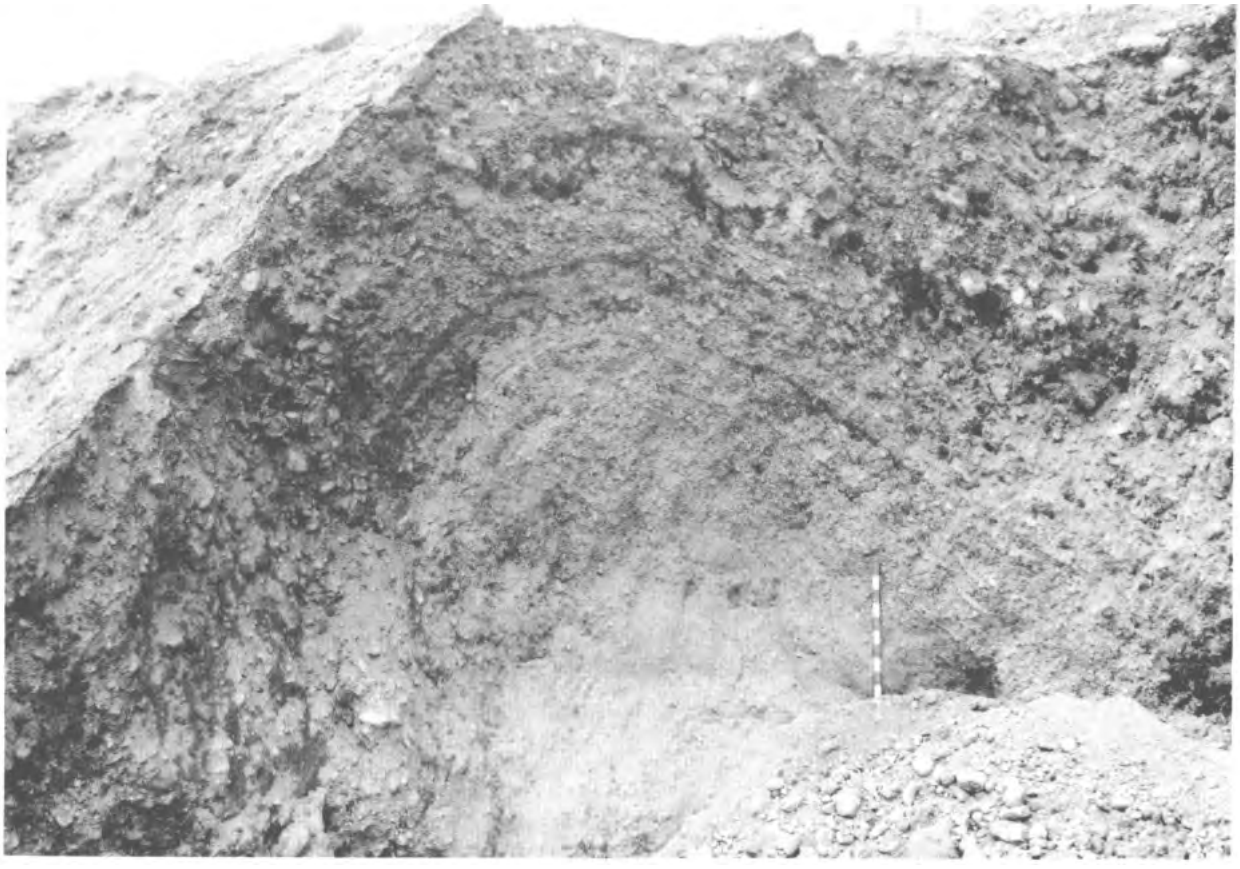


Figure 2 Schematic horizontal sections in the district (the lines of the sections are shown on the resource map)



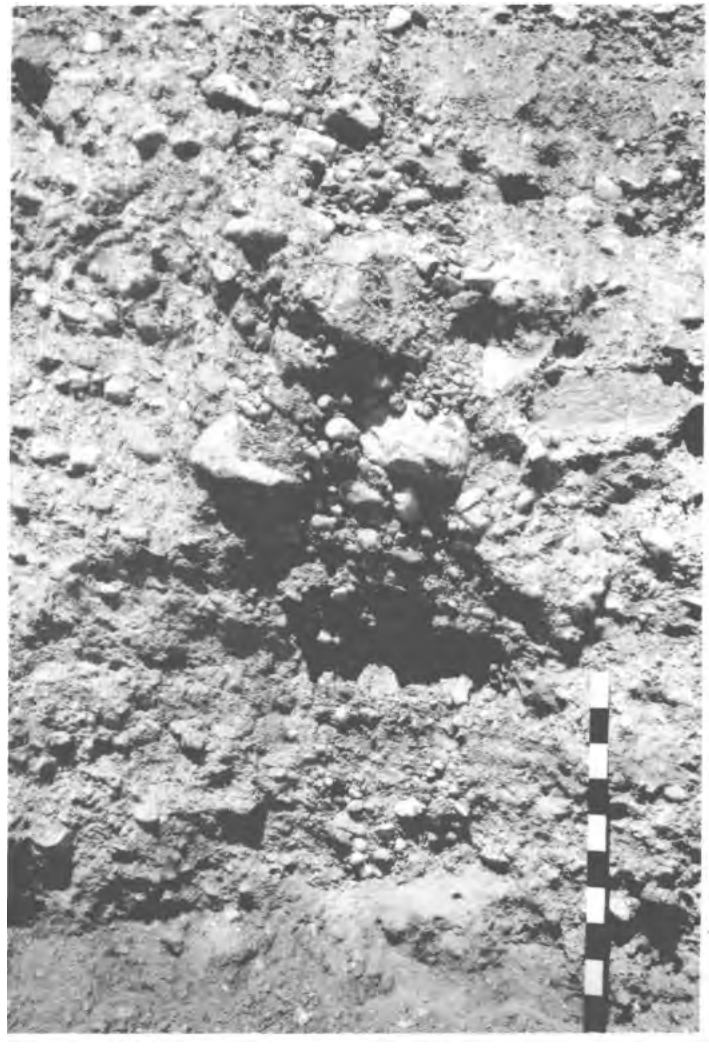


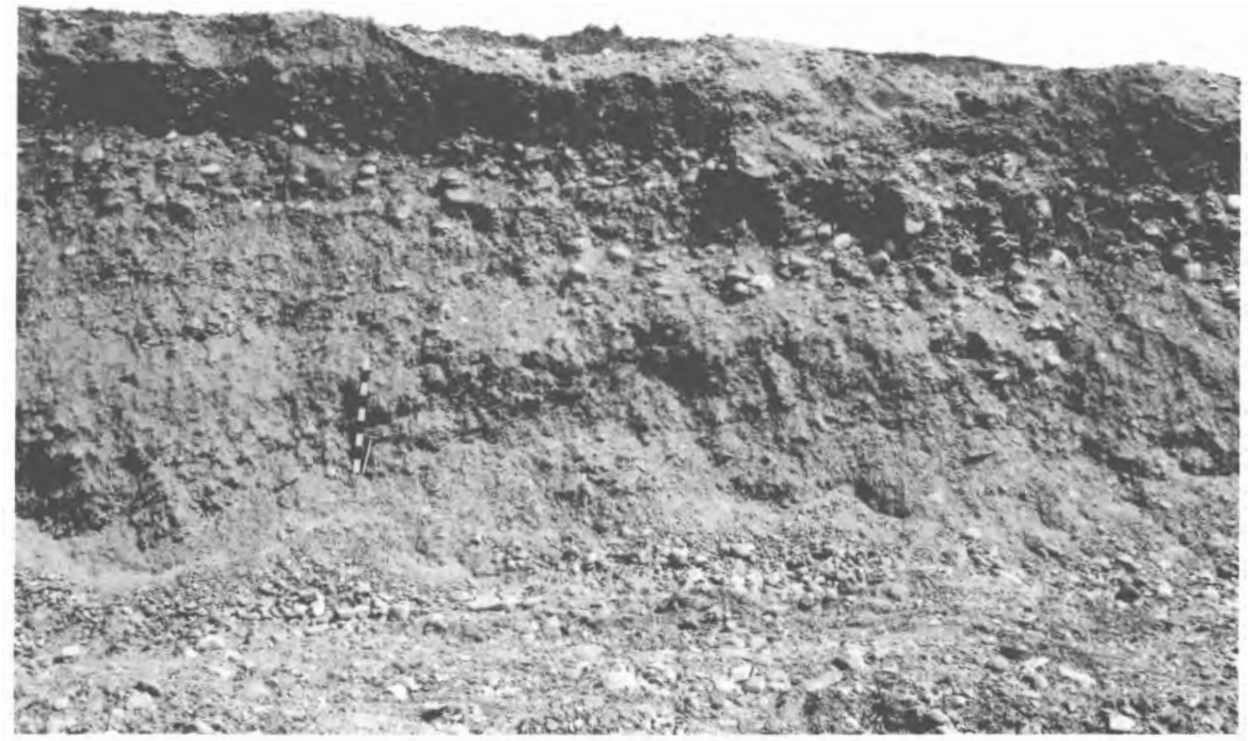
Plate 1 Glacial Sand and Gravel at Stapleton Quarry [261 116]

General view of the working face (*above*). The folded bedding is highlighted by the alternation of sandy and pebbly layers

Detail of the deposit (*right*) shows the considerable size range of the subrounded gravel

One division of the scale bar in both photographs equals 10 cm

Photographs by K. Thornton



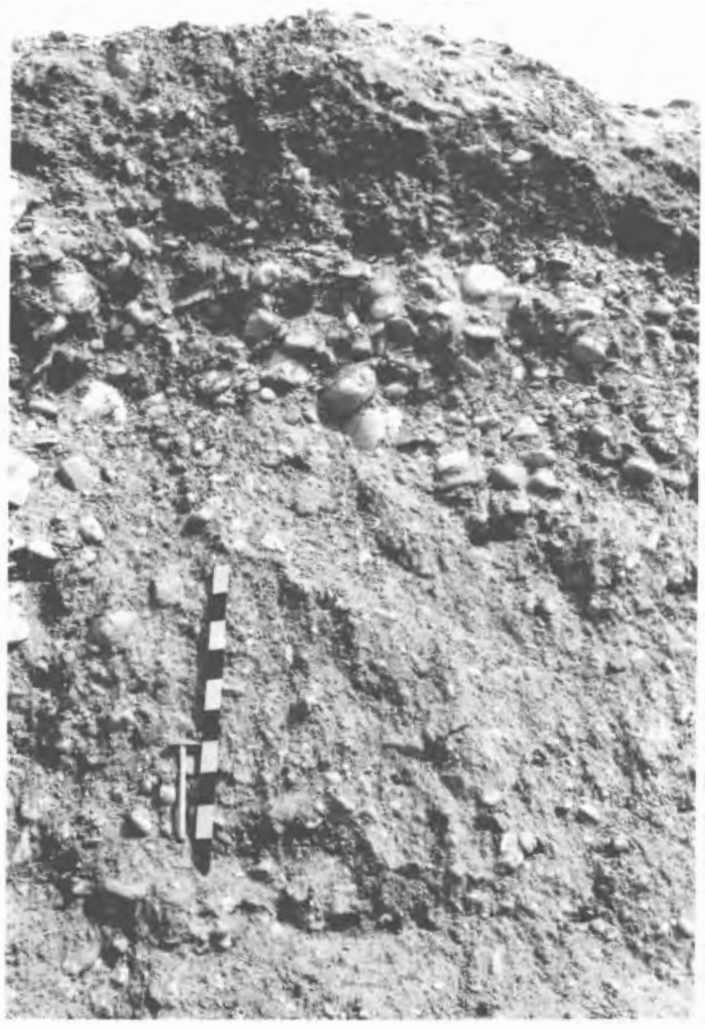


Plate 2 River Terrace Deposit at Piercebridge New Quarry [217 154]

General view of the working face (*above*). The cleanly washed, closely packed gravel (forming the prominent ledge in shadow at the top left) overlies a coarse gravel with cobbles, especially at the top, in a sandy matrix

Detail of the deposit (*left*) shows the wide size range and rounded gravel: compare Plate 1

One division of the scale bar in both photographs equals 10 cm

Photographs by K. Thornton

Laminated Clay: These deposits, extensive enough to be mapped only in the eastern part of the area, were probably laid down in glacial lakes. Laminated Clay was proved in some boreholes, for example 21 SE 44 near Stapleton.

Morainic Drift: Deposits mapped as Morainic Drift form a discontinuous hummocky belt running north-west from Darlington, and have been classed as 'kame moraine' (Mills and Hull, 1976). They consist mainly of stony clay locally with sand, as in borehole 21 SE 41 in Darlington.

Glacial Sand and Gravel: These deposits are found mainly around Newsham [110 100] and to the south of Darlington, but smaller outcrops occur throughout the area. Averaging 7.0 m but up to 16.2 m in thickness, deposits vary from sand or gravel or both, through clayey admixtures to clay with or without stones. In boreholes and cuttings for the A1(M) trunk road (Figure 1), Glacial Sand and Gravel was proved which is thought to form irregular layers and lenses up to about 1.0 m thick within boulder clay. Locally, for example near Aldbrough [202 124] and Stapleton [264 116], these deposits form prominent mounds and ridges.

Fluvioglacial and Older River deposits: **Fluvioglacial deposits were formed by ice meltwaters, whereas the Older** River Deposits were formed penecontemporaneously in an extra-glacial river system demonstrably older than that of the present day. No attempt has been made to separate these deposits on the map. They occur throughout the area with an average thickness of 6.4 m, though exceptionally borehole 11 SW 18 proved them to be at least 12.5 m thick.

Fluvioglacial Sand and Gravel, comprising lenses and layers of silt and sand intermixed with poorly sorted gravels, was formerly exposed [1999 1579] at Piercebridge beneath river terrace gravels.

Older River Deposits are best developed along the valley of the River Tees between Whorlton [100 147] and Wycliff Grange [110 142] where they form a terrace about 20 m above present river level.

Post-Glacial Lake Deposits: These deposits occur in small patches throughout the area and probably represent the infilling by clay, silt and peat of shallow lakes in depressions on the boulder clay surface. As such they are thin, probably averaging less than 2 m in thickness.

River Terrace Deposits: River Terrace Deposits are well developed along the valley of the River Tees, up to four having been mapped below Winston. They consist of sand and gravel with cobbles, boulders and silt and clay lenses. There is no systematic change in composition or grading from high to low-level terraces. The combined deposits average 5.5 m in thickness but up to 14.4 m have been proved. The first and second terraces are the most extensive and best developed, with an average thickness of 6.0 m. In boreholes it has not been possible to distinguish River Terrace from Fluvioglacial deposits and some so-called terrace gravels may be fluvioglacial in origin.

Near Ovington [133 153], well above present river level, a thin gravel forming an Undifferentiated River Terrace Deposit rests on bedrock. Small terrace deposits also occur along misfit tributaries of the River Tees, for example Aldbrough Beck [182 129].

Alluvium: Alluvium is found along the River Tees, notably near Holmes House [222 151] and downstream from Low Coniscliffe where it consists of sand and silt with some pebbles, overlying gravels with interbedded silts and clays; together they average 4.3 m in thickness and are proved up to 14.4 m. In the higher parts of the valley, above Piercebridge, alluvium often consists of boulder gravel resting on bedrock.

An extensive area of alluvium north and east of Newsham [110 100] marks a former course of the River Tees when it flowed to the south-east. A reversal of drainage resulted in the removal or burial of older river deposits by silt, for example that proved in borehole 11 SW 15. Many other smaller streams, for example Langley, Cocker and Caldwell–Aldbrough–Clough Becks have narrow alluvial tracts of thin clays, silts, and sands.

Peat: Whilst most peat infills small shallow depressions on the Boulder Clay surface, a more extensive deposit west south-west of Hutton Magna [126 126] appears to have formed in a depression on the flood plain.

Foundered ground: Several small areas of foundered ground have been mapped in the east. Some are associated with water-filled depressions and are thought to have been caused by solution of gypsum in the underlying Permian strata with subsequent collapse (Land and Smith, in preparation).

Landslip: Landslips are found along the River Tees at Osmond Croft [130 150], Manfield [230 139], [233 136], and Monk End Wood [276 106].

COMPOSITION OF THE SAND AND GRAVEL

The potentially workable sand and gravel deposits in the district consist of Glacial Sand and Gravel, Fluvioglacial and Older River deposits, River Terrace Deposits and Alluvium. Patches of these deposits which occur away from the River Tees are too small to justify assessment and are not considered further (see Appendix B, paragraph 14).

Glacial Sand and Gravel: The deposits assessed have a mean grading of fines 8, sand 43 and gravel 49 per cent respectively for borehole samples. However, the deposits are variable and lithologies range from sand to gravel, locally with fines contents over 20 per cent which qualify for the designation 'very clayey' (Figure 10). By comparison, the mean grading of fines 11, sand 40 and gravel 49 per cent respectively from exposures in Stapleton Quarry (Section E 21 SE 2) [263 116], suggests that reasonably representative samples were obtained by the larger-diameter drilling employed during the latter part of the survey; even so, field observations show the deposits to include up to 5 per cent of boulders which could not be adequately sampled by the equipment used (Appendix A).

The gravel fraction is typically coarse, with cobbles and boulders (Plate 1). It consists mainly of subangular to rounded Carboniferous sandstone and limestone pebbles, with subordinate subangular chert and silicified limestone, well-rounded basic igneous and Borrowdale Volcanic Series rocks, dolomite and dolomitised limestone, subrounded siltstones and mudstones, ironstones, quartzite and a trace of quartz. Locally, composition varies slightly, for example the Stapleton section (E 21 SE 2) contains more dolomitic limestone, reflecting its position above Permian bedrock, more quartzite and igneous rocks, but less sandstone and silicified limestone. The sand fraction, though dominantly fine grained, includes much medium and coarse material. The composition of the

coarse fraction is similar to the gravel, but quartz and quartzite grains become more common in the finer grades.

Fluvioglacial and Older River deposits: The potentially workable parts of these deposits are 'clayey' gravels on average, with a mean grading of fines 16, sand 40 and gravel 44 per cent respectively, but they range in composition from sands to gravels and are locally 'very clayey'. The gravel is coarse with pebbles and cobbles consisting mainly of rounded Carboniferous sandstone and subordinate limestone, basic igneous and Borrowdale Volcanic Series rocks, together with some minor constituents similar to those found in the Glacial Sand and Gravel. The sand fractions are also similar in grading and composition to the Glacial Sand and Gravel.

Alluvium and River Terrace Deposits: Borehole samples from these deposits have a mean grading of fines 9, sand 41 and gravel 50 per cent respectively. In contrast, the mean grading of samples from exposures in the terraces near Cleasby (E 21 SE 1) and Piercebridge (E 21 NW 1; Plate 2) is fines 3, sand 18 and gravel 79 per cent respectively. The difference in grade may reflect genuine compositional variability within the deposits or be due to poor recovery from the gravel fraction when relatively small diameter boreholes were drilled in the early part of the survey (Appendix A); both reasons are thought to contribute to the disparity. Thus in drilled samples the sand fractions are enhanced by cominuted gravel, amounting to a maximum increase of 30 per cent by weight, whereas the fines fractions sampled in exposures are thought to be naturally less than elsewhere.

The gravel fractions consist mainly of coarse, rounded to well-rounded Carboniferous sandstone pebbles and subordinate limestone, basic igneous and Borrowdale Volcanic Series rocks and quartzite, together with minor constituents including sporadic traces of coal and pyrite. Exceptionally, the Undifferentiated River Terrace Deposits mapped upstream from Ovington [130 147] and proved in borehole 11 SW 4 and section E 11 NW 1 contain only minor amounts of limestone. The broad similarity in composition to the Glacial Sand and Gravel suggests that these fluvial gravels are to some extent reworked glacial deposits, washed clean and more rounded.

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 boundaries are based on six-inch geological surveys carried out between 1871–1879 and 1960–1973 which were published, in part, on New Series Geological Sheet 32 (Barnard Castle). A narrow strip of country down the eastern margin is included in the Stockton (33) Sheet which is in preparation at the 1:50 000 scale. The resource map now presented at the 1:25 000 scale incorporates minor amendments resulting from the sand and gravel survey. The geological lines for solid rocks have been simplified so that only major subdivisions are shown. Similarly for the Drift, 'Fluvioglacial Sand and Gravel plus Older River Gravel' and 'Fluvioglacial Terrace, Undifferentiated and Older River Gravel Terrace, Undifferentiated' have been grouped into one category, namely Fluvioglacial and Older River deposits. Peat and Hill Peat are combined into Peat.

The geological boundaries are the best interpretation of the information available at the time of the resource survey. It is inevitable, however, that discrepancies will be revealed by new boreholes and excavations because of the variability of superficial deposits.

Borehole data, which include the stratigraphical relations, thickness and mean particle size analysis of the sand and gravel samples collected during the assessment are also shown.

Mineral resource information: For assessment purposes, the map is divided into areas of mineral and areas where sand and gravel are not assessed, not potentially workable or absent (for definitions of 'mineral' and 'potentially workable', see page 1). A further distinction is made between mineral at the surface or beneath a thin soil cover and that beneath overburden more than one metre thick, on average. Within areas of mineral there may be small patches of overburden insufficiently well known to be mapped, for example around borehole 11 SW 12 which

Table 2 Mineral resources of the area

Resource block	Area		Mean thickness			Volume of mineral			Mean grading percentage		
	Block	Mineral	Overburden	Mineral	Waste		Limits at the 95 per cent confidence level		Fines	Sand	Gravel
						Million	±%	±Vol. million	$-\frac{1}{16}$ mm	$+\frac{1}{16}$ -4 mm	$+4$ mm
	km^2	km^2	m	m	m	m^3		m^3			
A	11.0	9.2	1.1	3.8	0.3	35	36	13	8	37	55
B	12.8	9.9	1.2	5.5	1.4	54	21	11	8	40	52
C	6.9	5.3	2.7	5.0	0.7	27	47	13	10	41	49
	18.5	Urban area of Darlington									
	150.8	Barren areas									
Sheet total	200.0	24.4	1.5	4.6	0.8	112	17	19	8	40	52

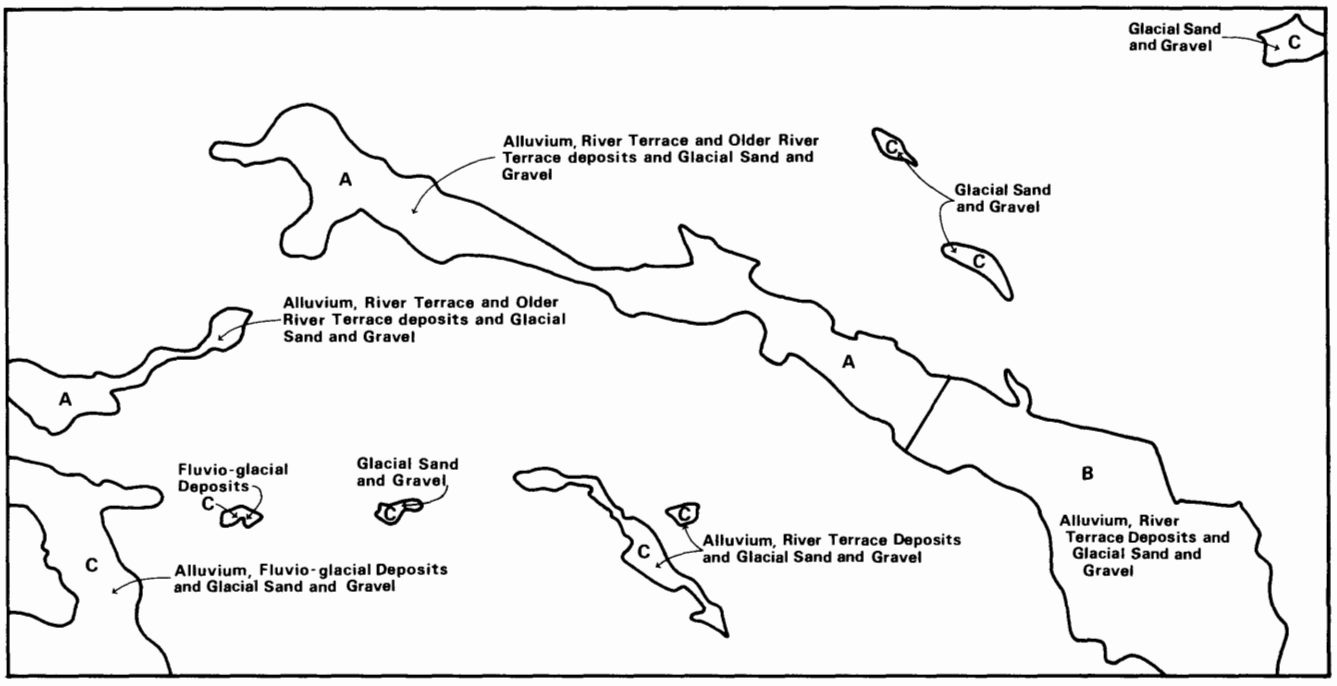


Figure 3 Relationship of drift deposits to resource block boundaries

proved 1.4 m of overburden. Additionally, there may be other small areas where sand and gravel is absent or not potentially workable, for example around borehole 11 NE 11 where the terrace consists of waste material.

Non-mineral areas including bedrock, superficial deposits and sand and gravel not potentially workable are left uncoloured on the map. Unassessed areas of sand and gravel, for example within the urban area of Darlington, are stippled red.

For the most part, distribution of categories of deposits is based on the mapped geological boundaries. Where there is a transition from one category to another which cannot be related to the geological lines and which could not be accurately delineated during this survey, inferred boundaries have been inserted. These are shown by a distinctive symbol intended to convey an approximate location within a likely zone of occurrence rather than to represent the breadth of the zone; its width is limited by cartographic considerations. For the purpose of measuring areas the centre line of the symbol is used.

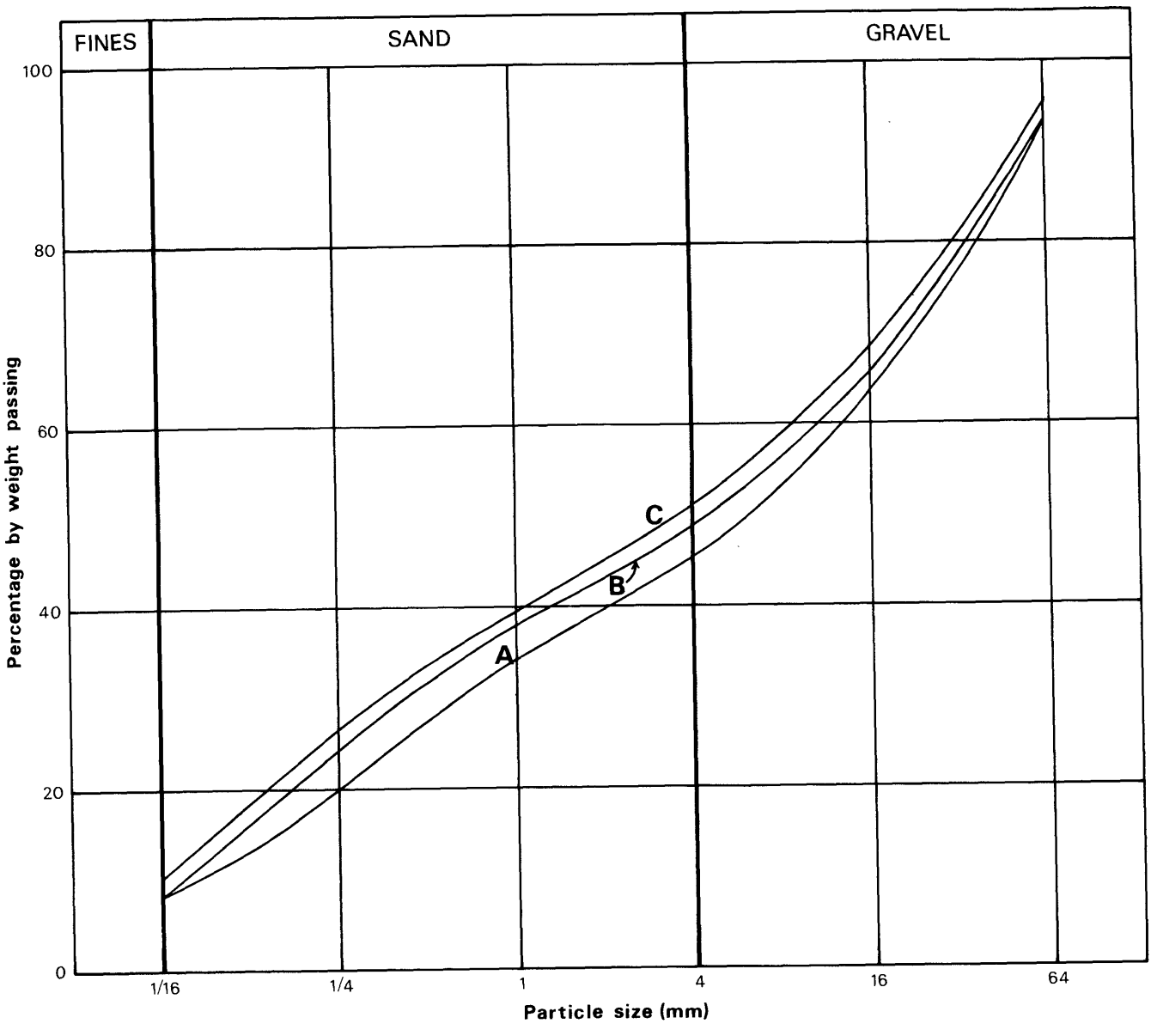
RESULTS

The results are summarised in Table 2. Fuller grading particulars are shown in Figure 4 and the mean grading and grading envelope for each resource block are given in Figures 5 to 7.

Accuracy of results: For the three resource blocks the accuracy of results at the symmetrical 95 per cent probability level ranges from 21 to 47 per cent. The true values are more likely to be nearer the figures estimated than the limits. Closer limits can be achieved by using more sample points in the calculations, as for example in Block B where additional boreholes were used. It follows that for the quotation of reserves a larger number of sample points would be required even in a small area. This point can be illustrated by considering the whole of the potentially workable sand and gravel in the resource blocks A to C on this sheet. The volume (112 million cubic metres can be estimated to limits of ± 17 per cent at the 95 per cent probability level by a calculation based on data from 120 sample points spread across the resource blocks. It must be emphasised that the quoted volume of sand and gravel has no simple relationship to the amount that could be extracted in practise 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.

NOTES ON RESOURCE BLOCKS

The choice of resource block boundaries reflects the geographical distribution of the mineral-bearing deposits (Figure 3). Blocks A and B include all the fluvial deposits along the valley of the River Tees together with adjacent fluvioglacial and glacial deposits, the division between these blocks being arbitrary. All current sand and gravel extraction is within these blocks. Block C includes representatives of every drift deposit which is located outside the Tees Valley. The built-up area of Darlington sterilises Glacial Sand and Gravel and fluvial deposits, which, together with many small patches of sand and gravel elsewhere, have not been assessed.



Block	Percentage by weight passing					
	$\frac{1}{16}$ mm	$\frac{1}{4}$ mm	1 mm	4 mm	16 mm	64 mm
A	8	20	34	45	63	93
B	8	24	38	48	65	93
C	10	26	39	51	68	95

Figure 4 Particle size distribution of the mineral in blocks A, B and C

Table 3 Block A: data from IMAU boreholes and sections

Section or borehole	Recorded thickness			Mean grading percentage						
	Over-burden	Mineral	Waste within mineral	Fines $-\frac{1}{16}$	Fine sand $+\frac{1}{16}-\frac{1}{4}$	Medium sand $+\frac{1}{4}-1$	Coarse sand $+1-4$	Fine gravel $+4-16$	Coarse gravel $+16-64$	Cobble gravel $+64$
	m	m	m	mm	mm	mm	mm	mm	mm	mm
E 11 NW 1	0.5	1.0	0.0	19	19	14	7	7	25	9
11 NW 35	–	absent	–	–	–	–	–	–	–	–
11 NW 36	2.2	3,7	0.0	12	9	10	15	20	23	11
11 NW 37	1.0	2.0	0.0	13	12	13	7	11	29	15
11 NE 4	1.1	3.9	0.0	12	19	16	16	17	14	6
11 NE 7	1.0	4.0	0.0	9	14	10	8	15	44	0
11 NE 8	0.6	10.9	3.5	9	10	18	16	21	21	5
11 NE 10	1.5	3.4	0.0	4	18	15	12	13	30	8
11 NE 11	–	absent	–	–	–	–	–	–	–	–
11 SW 4	0.5	1.5	0.0	22	32	14	4	9	14	5
11 SW 5	0.7	4.6	0.0	13	15	10	6	15	40	1
E 21 NW 1	0.5	7.0	0.0	3	4	7	6	18	42	20
21 NW 12	0.3	5.1	0.0	4	10	18	12	15	35	6
21 NW 13	1.2	1.8	0.0	19	26	18	12	8	17	0
21 NW 14	1.3	4.5	0.0	8	12	15	10	15	32	8
21 SW 18	1.4	9.1	0.0	3	10	18	13	20	31	5
21 SW 19	1.3	1.8	0.0	21	25	19	15	14	6	0

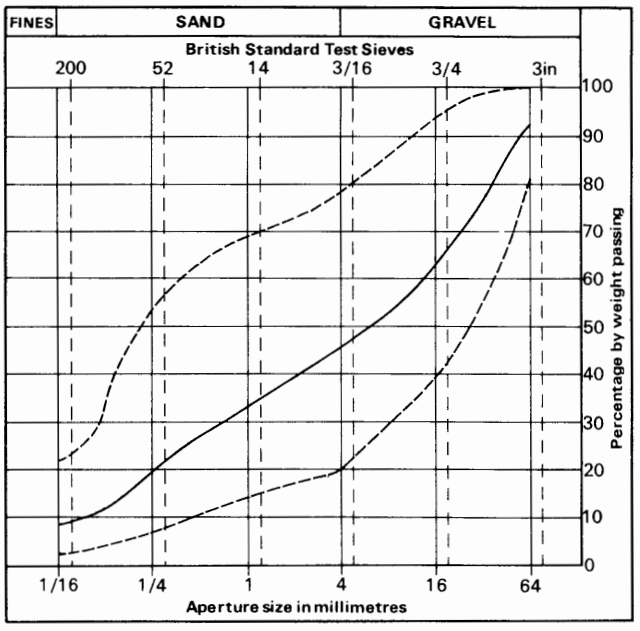


Figure 5 Particle size distribution of the mineral in Block A. The continuous line represents the weighted mean grading of the block; the broken lines denote the envelope within which the mean grading curves for individual boreholes and sections fall

Block A

Block A consists of deposits in the valley of the River Tees in the western part of the area and includes Alluvium, River Terrace, Fluvioglacial and Older River deposits, together with Glacial Sand and Gravel. Although boreholes 11 NW 35 and 11 NE 11 proved non-mineral (the fines exceeded 40 per cent), elsewhere mineral thicknesses range from 1.0 m to 10.9 m in assessment boreholes (Table 3); the mean thickness of the mineral is 3.8 m when data from other (non-IMAU) boreholes are included. The mean gravel content ranges from 20 to 59 per cent in boreholes 21 SW 19 and 11 NE 7 respectively but exceptionally up to 80 per cent was recorded in section E 21 NW 1. Mean fines content varies from 3 to 22 per cent.

The estimated volume of mineral in the block is $35 \pm 13 \times 10^6$ m^3, the mineral having a mean grading of 8 per cent fines, 37 per cent sand and 55 per cent gravel. Of this total, mineral with an estimated volume of 0.6×10^6 m^3 occurs in a narrow gorge between Wycliffe [114 144] and Ovington [136 155] and, because of the poor access, would probably be difficult to extract. Additionally, sand and gravel has already been extracted from an area of 0.6 km^2 near Piercebridge and is currently worked there [217 154] from terrace deposits.

Overburden, consisting mainly of soil with some clay, is generally thin; the boreholes prove a mean thickness of 1.1 m. Waste within mineral was proved only in borehole 11 NE 8, where 3.5 m is recorded.

Table 4 Block B: data from IMAU boreholes and sections

Section or borehole	Recorded thickness			Mean grading percentage						
	Over-burden	Mineral	Waste within mineral	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobble gravel
	m	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}-\frac{1}{4}$ mm	$+\frac{1}{4}-1$ mm	$+1-4$ mm	$+4-16$ mm	$+16-64$ mm	$+64$ mm
21 SW 21	0.8	6.8	1.3	9	12	18	14	21	25	1
E 21 SE 1	1.5	5.0	0.0	2	4	10	6	14	37	27
E 21 SE 2	0.4	7.0	0.0	11	15	14	11	16	20	13
21 SE 42	0.4	5.4	0.0	16	17	11	9	17	30	0
21 SE 43	1.3	1.8	0.0	5	15	17	13	17	33	0
21 SE 44	1.4	4.1	0.0	4	12	16	8	15	36	9
21 SE 45	2.7	4.6	4.8	22	59	4	3	6	6	0
21 SE 48	0.3	5.7	0.0	4	14	16	20	20	22	4
21 SE 49	0.7	6.4	2.9	6	7	12	7	21	41	6
21 SE 50	1.1	4.3	0.5	6	13	18	7	15	37	4
21 SE 55	2.0	13.3	0.0	4	17	14	12	19	24	10

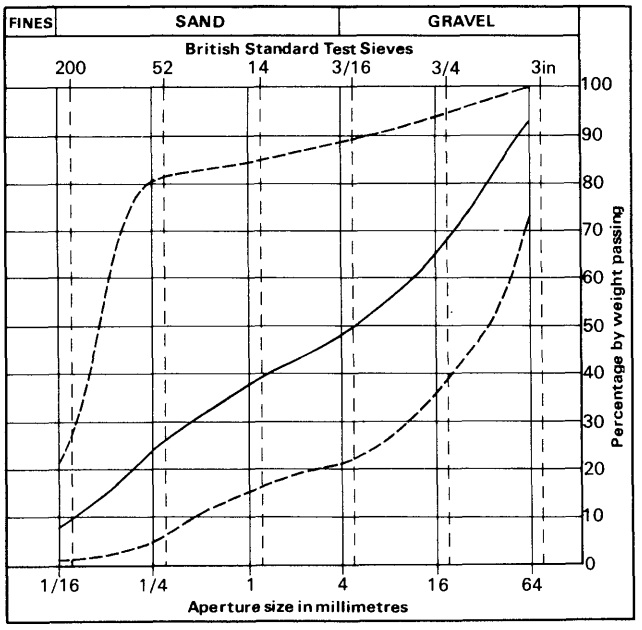


Figure 6 Particle size distribution of the mineral in Block B. The continuous line represents the weighted mean grading of the block; the broken lines denote the envelope within which the mean grading curves for individual boreholes and sections fall

Block B

This block includes deposits found in the valley of the River Tees in the eastern part of the area, comprising Alluvium, River Terrace Deposits, Fluvioglacial and Older River deposits, and Glacial Sand and Gravel. Recorded mineral thicknesses range from 1.1 to 16.2 m, with a mean thickness of 5.5 m. The mean gravel content ranges from 12 to 68 per cent in boreholes 21 SE 45 and 21 SE 49 respectively, but 78 per cent is recorded in section E 21 SE 1 (Table 4). The mean fines content varies from 2 to 22 per cent.

The estimated volume of mineral in the block is $54 \pm 11 \times 10^6$ m^3 with a mean grading of 8 per cent fines, 40 per cent sand and 52 per cent gravel. Sand and gravel has already been extracted from an area of 0.9 km^2 and is currently worked in fluvial deposits at localities [252 135; 270 129] along the River Tees and in glacial deposits [261 117] near Stapleton.

Overburden is mainly thin; the mean thickness calculated from borehole data is 1.2 m, individual readings ranging up to 10.7 m in a non-IMAU borehole. It consists mainly of soil, with alluvial and glacial clays locally. Waste within mineral, which occurs in four IMAU boreholes, has a mean thickness of 1.4 m, but ranges up to 5.5. m in another borehole.

Table 5 Block C: data from IMAU boreholes

Borehole	Recorded thickness			Mean grading percentage						
	Over-burden	Mineral	Waste within mineral	Fines $-\frac{1}{16}$	Fine sand $+\frac{1}{16}-\frac{1}{4}$	Medium sand $+\frac{1}{4}-1$	Coarse sand $+1-4$	Fine gravel $+4-16$	Coarse gravel $+16-64$	Cobble gravel $+64$
	m	m	m	mm	mm	mm	mm	mm	mm	mm
11 SW 6	–	absent	–	–	–	–	–	–	–	–
11 SW 13	1.4	9.7	1.1	11	12	9	15	21	29	3
11 SW 15	4.6	2.0	0.0	28	70	2	0	0	0	0
11 SW 18	0.4	8.1	4.0	8	15	10	7	21	34	5
11 SW 19	0.5	6.5	2.0	13	11	8	11	15	24	18
11 SE 8	1.5	2.0	0.0	7	8	14	18	15	33	5
21 NW 11	7.1	4.9	0.0	4	14	26	11	15	27	3
21 NE 36	3.9	2.0	0.0	24	39	34	3	0	0	0
21 SW 22	4.8	6.7	0.0	2	11	15	16	24	32	0

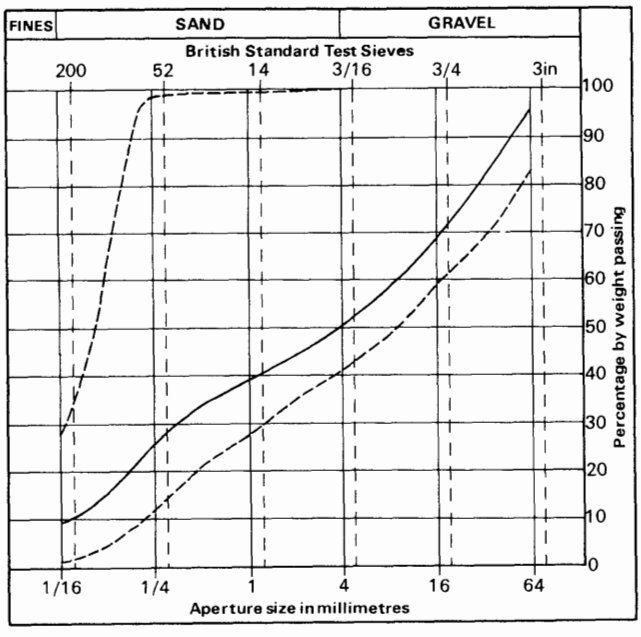


Figure 7 Particle size distribution of the mineral in Block C. The continuous line represents the weighted mean grading of the block; the broken lines denote the envelope within which the mean grading curves for individual boreholes and sections fall

Block C

The mineral included in this block is located well away from the River Tees in the north-eastern and south-western parts of the resource sheet. It consists of Glacial Sand and Gravel around Newsham [110 100], but elsewhere of Alluvium, River Terrace Deposits and Fluvioglacial and Older River deposits. Mineral thicknesses range from 2.0 m (recorded from three IMAU boreholes) to over 9.7 m in borehole 11 SW 13 (which had to be abandoned for technical reasons before the base of the deposit was proved), giving a mean thickness of 5.0 m. The mean gravel content in the boreholes, ranges from 45 to 60 per cent (Table 5), but gravel is absent in boreholes 11 SW 15 and 21 NE 36. The mean fines content ranges from 2 to 28 per cent.

The estimated volume of mineral in the block is 27 ± 13 × 10^6 m^3 with a mean grading percentage of 10:41:49 for fines, sand and gravel respectively.

Overburden has a mean thickness of 2.7 m, ranging up to 7.1 m in borehole 21 NW 11 and comprises soil, silt or Boulder Clay. Waste within mineral is found in only three boreholes (Table 5). Borehole 11 SW 6 proved sand and gravel in the Alluvium too thin to qualify as mineral, and accordingly the deposits in the vicinity are separated by an inferred boundary from similar deposits to the south-east which are mineral-bearing.

Boreholes 11 SW 16, 11 SW 17, 11 SW 10 and 11 SE 10 proved waste material and are therefore excluded from the resource block.

Five IMAU boreholes were sited beside the B6279 road, extending south-eastwards from Denton [215 186] to Coniscliffe Grange [251 158], to investigate a possible buried glacial channel of Cocker Beck. Two, 21 NW 8 and 21 NW 9, proved Permian Magnesian Limestone bedrock at 2.0 and 1.4 m respectively. Borehole 21 NW 10 proved waste to 12.6 m on bedrock, whereas boreholes 21 NW 11 and 21 NE 36 found mineral beneath overburden. On the evidence from these and other non-IMAU boreholes an area of mineral has been delineated by an inferred boundary.

APPENDIX A

FIELD AND LABORATORY PROCEDURES

Experience has shown that a minimum of five sample-points, evenly distributed across a sand and gravel deposit, are needed to provide a worthwhile statistical assessment, and 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 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, usually about 10 km^2 in size, with sufficient sample points in each block to meet the aims of the survey. Where possible, block boundaries are determined by geological boundaries, but otherwise, subdivisions are arbitrary and may be unrelated to the geology.

Prior to the drilling by IMAU a survey 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. 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 position of roads and farms) may reflect particular geological conditions, and hence bias the drilling results.

The principal area of study was the valley of the River Tees and other potentially workable deposits. Large areas away from the River Tees, considered to be barren of mineral on the basis of borehole records and mapping, were not drilled.

The survey commenced using a 152-mm diameter percussion drill. When used on the deposits in the valley, some difficulty was experienced in penetrating the coarse gravels and in recovering representative samples; occasionally no sample was recovered, usually because of a boulder at the base of the casing being driven down through the deposit. Many boreholes were abandoned in boulder clay before reaching 25 m because of slow penetration. Drilling problems included equipment and casing jamming in the hole, and damage by boulders. Within the outcrop of the Carboniferous only shale could be identified with certainty as bedrock because sandstone or limestone fragments could indicate either bedrock or a boulder impeding progress.

With the cooperation of gravel companies, experimental drilling was carried out adjacent to quarries at Piercebridge and Stapleton in boulder gravels, the most difficult deposit to drill. This experience initiated a second phase of drilling using a 254-mm percussion rig which successfully obtained complete and more representative borehole samples at the more difficult sites.

Wherever possible, deposits above the water table were drilled dry, but in gravels a small amount of water was added as necessary to facilitate drilling and sampling. Below the water table the use of a bailer resulted in the probable loss of some of the fine fraction, the pumping action drawing unwanted material, especially sand, into the hole from the sides or bottom.

In general, 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 (3.3 ft) depth. In the event of excessively large samples being taken a representative sub-sample is obtained by cone and quartering in the field. The samples, each weighing up to 100 kg, are despatched in heavy-duty polythene bags to a laboratory for grading. The grading procedure is based on BS 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 elsewhere (Appendix F).

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

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

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

4 The above relationship may be transposed such that

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

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, $\bar{l}_m$, is given by

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

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

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

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

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

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% 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		$\bar{l}_o = 2.5$		$\bar{l}_m = 6.5$		

Calculation of confidence limits

l_m	$(l_m - \bar{l}_m)$	$(l_m - \bar{l}_m)^2$
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

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

L_V is calculated as

$1.05\ (t/\bar{l}_m)\sqrt{[\Sigma(l_m - \bar{l}_m)^2/n(n-1)]} \times 100$
$= 1.05 \times (2.365/6.5)\sqrt{[15.82/(8 \times 7)]} \times 100$
$= 20.3$
$\simeq 20$ per cent.

Figure 8 Example of resource block assessment: calculation and results

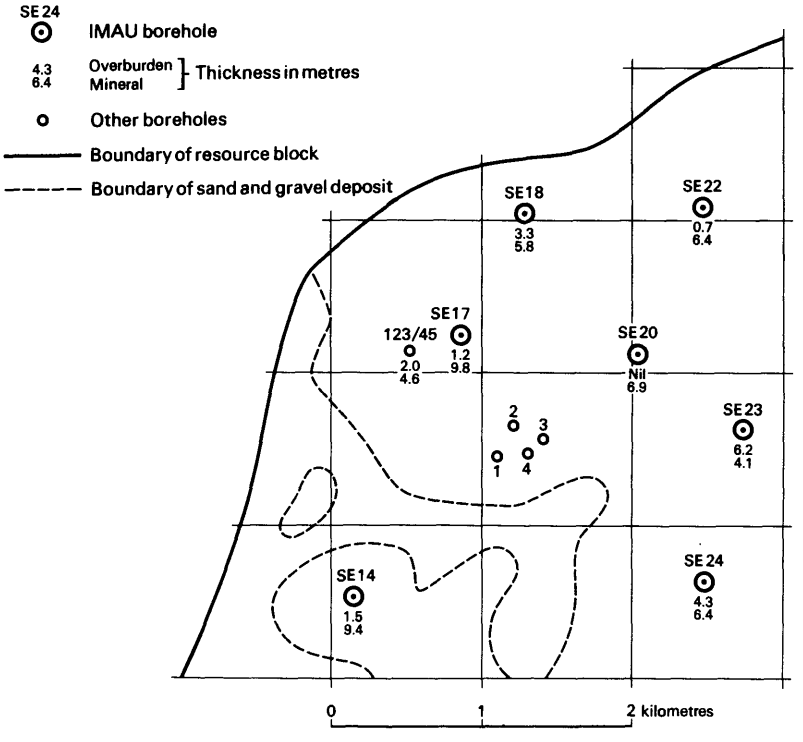


Figure 9 Example of resource block assessment: map of a fictitious block

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).

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 8 and 9.

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 10). 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 11, 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 6), 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 ($-\frac{1}{4}$ $+\frac{1}{16}$ mm), medium (-1 $+\frac{1}{4}$ 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 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. 'Boulder' describes stones greater than 256 mm.

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 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: shows 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 6 Classification of gravel, sand and fines

Size limits	Grain size description	Qualification	Primary classification
	Boulder		
256 mm –			
	Cobble		
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

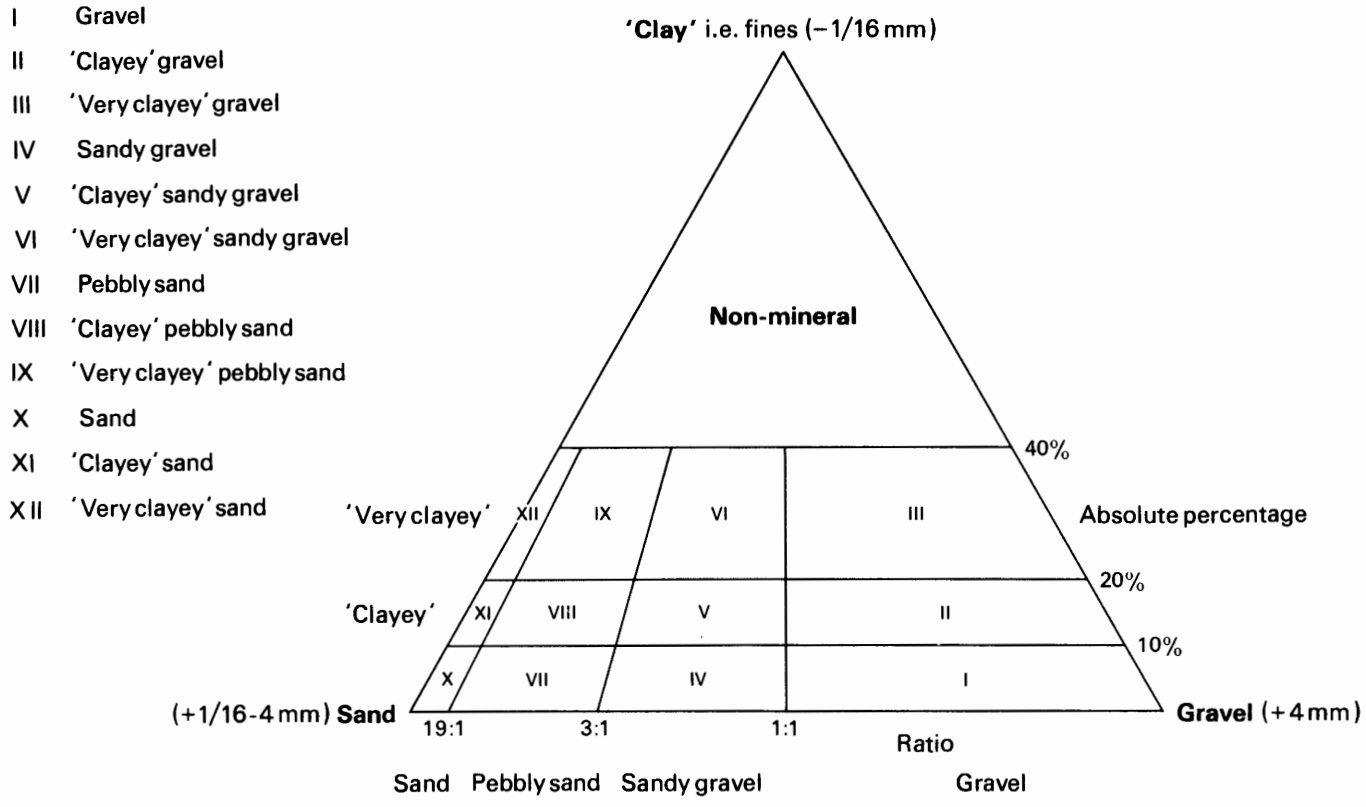


Figure 10 Diagram showing the descriptive categories used in the classification of sand and gravel

APPENDIX D

EXPLANATION OF BOREHOLE AND SECTION RECORDS

Annotated example

NZ11 SW 5[1] **1098 1421**[2] **Wycliffe Grange**[3] **Block A**

Surface level (+120.1 m)+394 ft[4]
Water level +118.1 m[5]
152-mm percussion[6]
January 1975

Overburden[7] 0.7 m[8]
Mineral 4.6 m
Waste 0.6 m
Bedrock 0.6 m+[9]

Log

Geological classification[10]	*Lithology*[11]	*Thickness* m	*Depth* m
	Soil	0.7	0.7
Older River Deposit	**a** 'Clayey' gravel, sandy at top, less clay at base Gravel: coarse, subangular to subrounded sandstone with basaltic rocks and quartzite, some chert, mudstone and ironstone and a trace of quartz Sand: medium, subangular quartz and quartzite with some dark grains	4.6	5.3
Boulder Clay	Sandy clay, grey-brown	0.6	5.9
Millstone Grit Series	Shale, grey, fossiliferous	0.6+	6.5

Grading

	Mean for deposit[15] *percentages*			Depth below[12] surface (m)	*percentages*[13]						
	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	13	31	56	0.7–1.7	*20*	*24*	*14*	*5*	*11*	*26*[14]	
				1.7–2.7	13	24	15	4	10	34	
				2.7–3.7	17	16	7	4	13	43	
				3.7–4.7*	3	2	6	10	28	51	
				4.7–5.3	9	6	10	9	15	44	7
				Mean	13	15	10	6	15	40	1

* Poor recovery

Composition[16]

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Sandstone	Ironstone
3.7–4.7	75	—	9	trace	13	—	1	1	1

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, either NZ 11 or NZ 21.
2 The quarter of the 1:25 000 sheet on which the the borehole lies and the number of the borehole in a series for that quarter, for example SW 5.

Thus the full Registration Number is NZ 11 SW 5. Usually this abbreviated to 11 SW 5 in the text. Collected sections are numbered similarly in a series of their own with the prefix E.

2 The National Grid reference
All National Grid references in this publication lie within the 100-km square NZ unless otherwise stated. Grid references are given to eight figures, accurate to within 10 m for borehole locations. (In the text, four and six-figured 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 where applicable.

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
Four kinds of entry are made: the record indicates the level at which groundwater stood on completion of drilling, in metres above OD; level struck; water not encountered; that no record obtained.

6 Type of drill and date of drilling
The type of drilling machine, the external diameter of the casing used and the month and year of completion of the borehole are stated.

7 Mineral, waste, bedrock and overburden
Mineral is sand and gravel which, as part of the 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 Thickness and depth
All measurements were made in metres to the nearest 0.1 m.

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

10 Geological classification
The geological classification (p. 3) is given whenever possible.

11 Lithological description
When sand and gravel is recorded a general description based on the mean 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.

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 at every 1 m of depth.

13 Grading results
The limits are as follows: gravel, +4 mm; sand, $+\frac{1}{16}-4$ mm: fines, $-\frac{1}{16}$ mm.

14 If, exceptionally, no sample was recovered, an attempt is made to give grading information based on field observations and comparison with the grading for adjacent samples. Such estimates are shown *in italics*. Other related notes may be shown by an asterisk.

15. Mean grading for deposit
The grading of each mineral deposit identified in the log is the mean of the individual sample gradings weighted by the thicknesses represented, if these vary. The classification used is shown in Table 6. The largest size fraction sampled was cobble (+64 −256 mm) although boulders (+256 mm) occur.

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 proportions of fines and coarse gravel (+16 mm) may be lower.

16 Composition
A selection of gravel samples was analysed. The categories recognised were:

Sandstone Generally medium grained, moderately well cemented, typical Carboniferous 'Millstone Grit'.

Limestone Carboniferous, varying from pure pale coloured carbonate to dark muddy limestones, fossiliferous, very durable.

Quartzite A durable but subordinate component.

Quartz A durable trace component in fine gravel fraction.

Igneous Two main components:

a basaltic Cleveland Dyke or Whin Sill type;
b Borrowdale Volcanic Series rocks, generally green-coloured acidic tuff or agglomerate.

Both are mechanically resistant.

Dolomite Including dolomitic rocks from the Magnesian limestones, also traces of dolomitised Carboniferous limestones. All are mechanically weak.

Chert and silicified limestone; durable, subordinate amounts.

Siltstone Including mudstone; mechanically weak rocks, of comparable strength to soft Permo-Triassic sandstones.

Ironstone Hematite (Fe_2O_3)

Others Minor amounts of coal and pyrite (FeS_2).

Trace in the columns of figures means less than 0.5 per cent (0.5 and above rounds up to 1).

APPENDIX E

LIST OF BOREHOLES AND SECTIONS USED IN THE ASSESSMENT OF RESOURCES

Borehole number*	Grid reference†		Page
IMAU BOREHOLES			
11 NW 35	1352	1783	21
36	1468	1797	22
37	1477	1679	23
11 NE 4	1538	1734	24
7	1684	1674	24
8	1764	1654	25
10	1710	1648	26
11	1963	1610	26
11 SW 4	1011	1467	27
5	1098	1421	28
6	1032	1278	28
10	1425	1217	29
13	1095	1046	29
15	1174	1046	30
16	1154	1229	30
17	1232	1251	30
18	1144	1122	31
19	1103	1076	32
11 SE 8	1813	1297	33
10	1535	1231	33
COLLECTED SECTIONS			
E 11 NW 1	1311	1504	21
IMAU BOREHOLES			
21 NW 8	2158	1861	34
9	2256	1767	35
10	2355	1701	35
11	2433	1646	36
12	2061	1595	37
13	2166	1558	38
14	2217	1504	38
21 NE 36	2511	1581	39
21 SW 18	2295	1479	40
19	2328	1421	41
21	2432	1354	42
22	2067	1092	43
21 SE 41	2714	1438	46
42	2538	1347	47
43	2638	1335	48
44	2630	1271	49
45	2782	1247	50
48	2680	1154	51
49	2768	1138	52
50	2833	1062	53
55	2604	1166	55
COLLECTED SECTIONS			
E 21 NW 1	2169	1533	34
E 21 SE 1	2511	1336	44
E 21 SE 2	2632	1165	45

* By sheet quadrant.
† All fall in 10-km square NZ.

OTHER BOREHOLE RECORDS ON OPEN IGS FILES

NZ 11 NW 2; 3 and 5
NZ 21 NW 1; 7a, b, c, d
NZ 21 NE 12; 17p
NZ 21 SW 10; 12g, h
NZ 21 SE 2a, b; 3a, b, c, d; 4; 17; 18; 19; 20; 37; 51a, b, c, d, g, h

CONFIDENTIAL RECORDS

Gravel companies in the area have supplied a large number of borehole records, of which many have been used in the assessment. All these records are held in confidence.

APPENDIX F

INDUSTRIAL MINERALS ASSESSMENT UNIT
BOREHOLE AND SECTION RECORDS

E 11 NW 1 1311 1504 Osmond Croft Natural Section **Block A**

Surface level (c+91.4 m) c+300 ft
February 1975

Overburden 0.5 m
Mineral 1.0 m
Bedrock 2.0 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.5	0.5
River Terrace Deposits	'Clayey' gravel Gravel: coarse rounded sandstone with basalt, some rotted sandstone, shale, mudstone, ironstone and quartzite, and traces of limestone, quartz and chert Sand: medium sandstone with some igneous lithic fragments and quartzite and traces as above	1.0	1.5
Millstone Grit Series	Shale with sandstone bands	2.0+	3.5

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
19	40	41	0.5–1.5	19	19	14	7	7	25	9

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
0.5–1.5	66	trace	3	trace	24	—	trace	5	1

NZ 11 NW 35 1352 1783 Westholme **Block A**

Surface level (+106.1 m)+348 ft
Water level +101.6 m
152-mm percussion
January 1975

Waste 14.2 m
Bedrock 0.3 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.6	0.6
Older River Deposit	Sandy clay, firm dark brown, iron stained, with cobbles and pebbles of weathered sandstone and quartzite	2.0	2.6
Boulder Clay	Clay, dark brown, with sandstone and quartzite pebbles	5.0	7.6
	Laminated clay, pebble free, dark brown, with fine sand layers	0.9	8.5
	'Very clayey' sand; fine quartz, with some mica and coal	1.8	10.3
	Laminated clay, grey	0.3	10.6
	Clay, dark grey, with sandstone pebbles	3.6	14.2
Millstone Grit Series	Shale, dark blue-grey, with thin sandstone bands	0.3+	14.5

NZ 11 NW 36 1468 1797 Primrose Hill **Block A**

Surface level (+94.5 m)+310 ft
Water level +91.5 m
152-mm percussion
January 1975

Overburden 2.2 m
Mineral 3.7 m
Waste 7.6 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.2	0.2
Older River Deposit	Sandy clay, brown, iron stained, with sandstone pebbles	2.0	2.2
	'Clayey' gravel with some cobbles Gravel: coarse, angular to subrounded sandstone with basaltic rocks, limestone and ironstone, some quartzite and dolomitised limestone and traces of quartz, chert and pyroclastic rocks Sand: poorly sorted subangular quartz and quartzite with some sandstone and igneous rock Fines: brown clay matrix at base	3.7	5.9
Boulder Clay	Silty and sandy pebbly clay, grey-black to brown, with Carboniferous limestone boulder at 6.7 m *Borehole abandoned, penetration very slow*	7.6+	13.5

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
12	34	54	2.2–3.2	14	10	10	9	17	25	15
			3.2–4.2	7	10	8	10	20	21	24
			4.2–5.2	2	8	12	28	24	26	
			5.2–5.9	31	9	8	11	21	20	
			Mean	12	9	10	15	20	23	11

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
3.2–5.9	66	8	3	trace	17	1	trace	—	5

NZ 11 NW 37 1477 1679 Hedgeholme **Block A**

Surface level (+83.8 m)+275 ft
Water level +78.8 m
152-mm percussion
December 1974

Overburden 1.0 m
Mineral 2.0 m
Waste 0.5 m
Bedrock 2.0 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.0	1.0
Second River Terrace	'Clayey' gravel Gravel: coarse, subrounded sandstone with some limestone and basalt Sand: mainly fine and medium quartz with limestone, dark igneous fragments and sandstone Fines: brown clay matrix	2.0	3.0
Boulder Clay	Clay, iron stained, sandy, with sandstone pebbles	0.5	3.5
Millstone Grit Series	Sandstone, fissile, micaceous	0.5	4.0
	Shale, dark grey, calcareous, with thin sandstone bands	1.5+	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
13	32	55	1.0–2.0	16	11	10	7	13	33	10
			2.0–3.0	11	13	17	6	10	24	19
			Mean	13	12	13	7	11	29	15

NZ 11 NE 4 1538 1734 West Tees Bridge **Block A**

Surface level (+75.9 m)+249 ft
Water struck +70.9 m
152-mm percussion
November 1974

Overburden 1.1 m
Mineral 3.9 m
Waste 7.2 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.1	1.1
First River Terrace	**a** 'Very clayey' sand Sand: fine quartz and quartzite	0.9	2.0
	b *Obstruction, assumed to be boulder within mineral as below; no recovery*	1.0	3.0
	Gravel with some cobbles, sandy at base Gravel: poorly sorted well rounded sandstone with rounded basalt, occasional volcanic rock and traces of quartz and chert Sand: coarse quartz and quartzite with sandstone and basalt and occasional volcanic rock	2.0	5.0
Boulder Clay	Pebbly silty clay	6.8	11.8
	Sandstone boulder *Borehole abandoned, boulder obstruction*	0.4+	12.2

Grading

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$
a	32	66	2	1.1–2.0	32	51	12	3	2		
b	7	46	47	2.0–3.0	*7*	*9*	*17*	*20*	*22*	*18*	*7*
				3.0–4.0	8	10	9	12	22	24	15
				4.0–5.0	5	8	25	28	22	12	
				Mean	7	9	17	20	22	18	7
a+b	12	51	37	Mean	12	19	16	16	17	14	6

NZ 11 NE 7 1684 1674 Gainford **Block A**

Surface level (+72.8 m)+239 ft
Water level not recorded
152-mm percussion
January 1975

Overburden 1.0 m
Mineral 4.0 m
Waste 3.7 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.0	1.0
First River Terrace	Gravel Gravel: coarse, subangular sandstone and quartzite Sand: mainly fine and medium, quartz and quartzite with some sandstone	4.0	5.0
Boulder Clay	Silty clay, black, with pebbles of sandstone, quartzite and volcanic rocks	3.7+	8.7

Grading

Mean for deposit *percentages*			Depth below surface (m)	*percentages*					
Fines	Sand	Gravel		Fines	Sand			Gravel	
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$
9	32	59	1.0–5.0*	9	14	10	**8**	**15**	**44**

* Composite sample

NZ 11 NE 8 1764 1654 Gainford **Block A**

Surface level (+69.5 m) +228 ft
Water level not recorded
152-mm percussion
January 1975

Overburden 0.6 m
Mineral 6.9 m
Waste 3.5 m
Mineral 4.0 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.6	0.6
First River Terrace	**a** 'Clayey' gravel, sandy towards base Gravel: coarse, with some cobbles, subangular to subrounded sandstone with limestone and basaltic rocks, some ironstone and quartzite and traces of chert and pyroclastic rocks Sand: medium, quartz and sandstone with some volcanic fragments	6.9	7.5
	Sandy silt, dark brown to black	3.5	11.0
First River Terrace?	**b** Gravel Gravel: fine to coarse, subangular to subrounded quartz and sandstone Sand: coarse, quartz and sandstone with some volcanic fragments	2.8	13.8
	c Pebbly sand Gravel: subrounded volcanic rocks and sandstone Sand: as above	1.2+	15.0
	Hole abandoned, boulder obstruction		

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	12	48	40	0.6–5.0	12	11	13	14	20	30	
				5.0–7.5	11	12	36	19	18	4	
				Mean	12	11	21	16	19	21	
b	5	21	74	11.0–13.8	5	7	4	10	28	27	19
c	4	79	17	13.8–15.0	4	13	33	33	10	7	
b+c	5	39	56	Mean	5	9	13	17	22	21	13
a+b+c	9	44	47	Mean	9	10	18	16	21	21	5

Composition

Depth below surface (m)	**Percentage by weight in gravel fraction**								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
0.6–5.0	66	21	2	—	8	—	trace	—	3

NZ 11 NE 10 1710 1648 Gainford **Block A**

Surface level (+68.3 m) +224 ft
Water level +65.3 m
152-mm percussion
December 1974

Overburden 1.5 m
Mineral 3.4 m
Bedrock 0.3 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.5	1.5
Alluvium	Gravel, sandy at base Gravel: coarse, rounded sandstone with rounded dolerite and some pyroclastic fragments Sand: fine, quartz and quartzite with sandstone and some dark grains	3.4	4.9
Millstone Grit Series	Shale, dark grey with thin sandstone bands	0.3+	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
4	45	51	1.5–2.5	4	13	13	11	12	28	19
			2.5–3.5	3	17	15	11	13	32	9
			3.5–4.5*	4	21	13	10	15	37	
			4.5–4.9*	8	25	23	19	14	11	
			Mean	4	18	15	12	13	30	8

* Poor recovery

NZ 11 NE 11 1963 1610 Whitecross **Block A**

Surface level (+38.1 m) +125 ft
Water level not recorded
152-mm percussion
January 1975

Waste 7.0 m
Bedrock 6.0 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.3	1.3
Third River Terrace	Sandy clay, orange-brown with some sandstone, quartzite and volcanic pebbles	1.5	2.8
	Sandy silt	0.8	3.6
Boulder Clay	Clay, dark brown, with quartzite and sandstone pebbles	1.0	4.6
	Clay, red brown, with lenses of grey-blue silt	2.4	7.0
Millstone Grit Series	Shale, black	6.0+	13.0

NZ 11 SW 4 **1011 1467** **West Thorpe** **Block A**

Surface level (+108.8 m) +357 ft
Water level +106.5 m
152-mm percussion
January 1975

Overburden 0.5m
Mineral 1.5 m
Bedrock 0.5 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.5	0.5
River Terrace Undifferentiated	'Very clayey' pebbly sand on 'clayey' gravel Gravel: coarse with some cobbles, subrounded sandstone with quartzite, ironstone and basaltic rocks, some mudstone and limestone and traces of quartz and coal Sand: fine, quartz and quartzite with coarse angular sandstone and some dark grains	1.5	2.0
Millstone Grit Series	Sandstone	0.2	2.2
	Shale, dark grey, fossiliferous, with thin sandstone bands	0.3+	2.5

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
22	50	28	0.5–1.5	28	39	16	4	6	7	
			1.5–2.0	12	18	9	4	15	27	15
			Mean	22	32	14	4	9	14	5

Composition

Depth below surface (m)	Percentage by weight in gravel fraction									
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone	Coal
0.5–1.5	60	1	11	trace	17	—	2	3	6	trace

NZ 11 SW 5 1098 1421 Wycliffe Grange **Block A**

Surface level (+120.1 m) +394 ft
Water level +118.1 m
152-mm percussion
January 1975

Overburden 0.7 m
Mineral 4.6 m
Waste 0.6 m
Bedrock 0.6 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.7	0.7
Older River Deposit	'Clayey' gravel, sandy at top, less clay at base Gravel: coarse, subangular to subrounded sandstone with basaltic rocks and quartzite, some chert, mudstone and ironstone and a trace of quartz Sand: medium, subangular quartz and quartzite with some dark grains	4.6	5.3
Boulder Clay	Sandy clay, grey-brown	0.6	5.9
Millstone Grit Series	Shale, grey, fossiliferous	0.6+	6.5

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
13	31	56	0.7–1.7	20	24	14	5	11	26	
			1.7–2.7	13	24	15	4	10	34	
			2.7–3.7	17	16	7	4	13	43	
			3.7–4.7	3	2	6	10	28	51	
			4.7–5.3	9	6	10	9	15	44	7
			Mean	13	15	10	6	15	40	1

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
3.7–4.7	75	—	9	trace	13	—	1	1	1

NZ 11 SW 6 1032 1278 Greta Bridge **Block C**

Surface level (+129.5 m) +425 ft
Water level +129.0 m
152-mm percussion
November 1974

Waste 9.5 m
Bedrock 0.1 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.2	1.2
Alluvium	'Very clayey' gravel Gravel: coarse subangular to subrounded sandstone with limestone and some chert and trace of dark igneous rock Sand: fine, quartz and quartzite with coarse dark igneous fragments and some chert and limestone	0.9	2.1
Boulder Clay	Clay, blue grey, with sandstone cobbles	0.4	2.5
	Silty sandy clay, grey brown, with sandstone pebbles, gravel and boulders	6.0	8.5
	'Clayey' gravel Gravel: coarse, angular to rounded limestone and sandstone with some quartzite and occasional pyroclastic rocks Sand: coarse angular sandstone and limestone fragments	1.0	9.5
Carboniferous Limestone Series	Limestone, dark grey, crinoidal	0.1+	9.6

NZ 11 SW 10 1425 1217 White House

Surface level (+125.3 m) +411 ft
Water level +119.3 m
152-mm percussion
November 1974

Waste 6.2 m
Bedrock 0.2 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.3	0.3
Alluvium	Sandy clay, grey-brown iron stained, firm, with sandstone, quartzite, dark igneous rocks and occasional limestone pebbles	3.2	3.5
Boulder Clay	Silty clay with pebbles, blue-grey with infrequent sand and silt laminae	2.7	6.2
Millstone Grit Series	Sandstone, grey, iron stained	0.2+	6.4

NZ 11 SW 13 1095 1046 Newsham **Block C**

Surface level (+150.6 m)+494 ft
Water struck +144.6 m
152-mm percussion
October 1974

Overburden 1.4 m
Mineral 5.6 m
Waste 1.1 m
Mineral 4.1 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.4	1.4
Glacial Sand and Gravel	**a** 'Clayey' gravel Gravel: fine and coarse with some cobbles, rounded sandstone with some limestone and trace of coal Sand: poorly sorted quartz and quartzite with sandstone and some chert and limestone	5.6	7.0
Boulder Clay	Silty clay, firm dark blue-grey pebbly and sandy	1.1	8.1
Glacial Sand and Gravel	**b** Gravel, 'clayey' at top, sandy at base Gravel: fine and coarse, with some cobbles, subangular to well rounded sandstone with rounded limestone and some dark igneous and pyroclastic rocks Sand: poorly sorted, angular sandstone, dark igneous fragments and chert with some quartzite *Borehole abandoned, penetration very difficult*	4.1+	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	+64
a	14	33	53	1.4–2.4	14	12	6	17	21	30	
				2.4–3.4	10	11	6	8	24	33	8
				3.4–4.4	16	13	7	11	28	25	
				4.4–5.4	16	12	8	13	21	30	
				5.4–6.4	13	15	10	9	19	26	8
				6.4–7.0	21	19	11	13	16	20	
				Mean	14	13	8	12	22	28	3
b	6	40	54	8.1–9.1	15	15	5	6	17	25	17
				9.1–10.1	4	5	8	18	27	38	
				10.1–11.1	4	11	11	23	25	26	
				11.1–12.2	3	10	14	30	15	28	
				Mean	6	10	10	20	21	29	4
a+b	11	36	53	Mean	11	12	9	15	22	28	3

NZ 11 SW 15 1174 1046 Newsham **Block C**

Surface level (+139.6 m)+458 ft
Water level +136.6 m
152-mm percussion
November 1974

Overburden 4.6 m
Mineral 2.0 m
Waste 9.6 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.2	0.2
Alluvium	Sandy clay, rusty brown	1.4	1.6
	Silty clay, blue-grey, with sandy laminae and some sandstone pebbles	3.0	4.6
Older River Deposit	'Very clayey' sand Sand: fine, quartz and quartzite with dark lithic grains Fines: grey, some occasional silt bands	2.0	6.6
	Sandy silt, grey, with some fine sand *Borehole abandoned, penetration very slow*	9.6+	16.2

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
28	72	0	4.6–5.6	30	69	1				
			5.6–6.6	26	72	2				
			Mean	28	70	2				

NZ 11 SW 16 1154 1229 Hutton Magna

Surface level (+131.4 m)+431 ft
Water struck +129.4 m
203 and 254-mm percussion
January 1976

Waste 18.0 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.0	1.0
Boulder Clay	Laminated clay, soft blue-grey, silty, with occasional pebbles	1.0	2.0
	Silty stony clay, firm grey-black, with sandstone pebbles, cobbles and boulders	11.9	13.9
	'Very clayey' gravel: fine angular limestone and sandstone in a firm sandy clay matrix	1.0	14.9
	Stony sandy clay: fine to coarse sandstone, limestone and quartzite in a firm brown iron stained matrix	1.9	16.8
	Silty stony clay, firm grey-black	1.2+	18.0

NZ 11 SW 17 1232 1251 Hutton Magna

Surface level (+128.6 m)+422 ft
Water level +127.3 m
254-mm percussion
January 1976

Waste 3.3 m
Bedrock 0.2 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.6	0.6
Boulder Clay	Silty clay, brown, iron stained, with some fine sand laminations and occasional sandstone pebbles, traces of coal and soft red sandstone	2.7	3.3
Millstone Grit Series	Limestone, dark grey, massive, crinoidal	0.2+	3.5

NZ 11 SW 18 1144 1122 Smallways Bridge **Block C**

Surface level (+140.2 m)+460 ft
Water struck +134.2 m
203 and 254-mm percussion
January 1976

Overburden 0.4 m
Mineral 1.0 m
Waste 4.0 m
Mineral 7.1 m
Waste 12.5 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.4	0.4
Glacial Sand and Gravel	**a** 'Clayey' gravel Gravel: coarse subangular to subrounded sandstone with some limestone, chert, mudstone, ironstone and basaltic rock, and a trace of quartzite Sand: fine and medium subangular quartz, sandstone and quartzite Fines: brown, iron stained clay	1.0	1.4
Boulder Clay	Stony clay, firm dark brown, silty, with sandstone, limestone and igneous lithic fragments	4.0	5.4
Glacial Sand and Gravel	**b** Gravel, sandy in parts, 'very clayey' sand at base Gravel: coarse, fine in parts, subangular to subrounded sandstone with limestone, chert and silicified limestone, some quartzite and shale and traces of quartz, dolomitised limestone, ironstone and basaltic rocks Sand: fine to coarse, sandstone, quartz fragments; trace of coal at base	7.1	12.5
Fluvioglacial Deposit	Silt, dark grey-black, laminated, with fine sand partings and fine 'very clayey' to 'clayey' sand bands at 15.5–16.5, 18.5–20.5 and 22.5–23.5	12.5+	25.0

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
a	14	36	50	0.4–1.4	14	16	10	10	18	25	7
b	7	32	61	5.4–6.4	9	9	8	8	16	38	12
				6.4–7.4	8	11	8	12	24	37	
				7.4–8.4	2	6	9	8	27	44	4
				8.4–9.0	7	33	26	7	13	9	5
				9.0–10.0	3	7	7	7	29	37	10
				10.0–11.0	2	11	6	3	20	53	5
				11.0–11.8	2	10	7	7	29	43	2
				11.8–12.5	28	53	18	1			
				Mean	7	15	10	7	21	35	5
a+b	8	32	60	Mean	8	15	10	7	21	34	5

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
0.4–1.4	86	5	trace	—	4	—	3	1	1
5.4–6.4	58	33	1	—	1	—	4	2	1
7.4–8.4	62	18	2	—	—	—	14	3	1
9.0–10.0	68	14	trace	trace	—	trace	14	3	trace
11.0–11.8	66	17	trace	—	—	trace	13	4	—

NZ 11 SW 19 **1103 1076** **Newsham** **Block C**

Surface level (+146.3 m)+480 ft
Water level +141.1 m
203 and 254-mm percussion
December 1975

Overburden 0.5 m
Mineral 1.0 m
Waste 2.0 m
Mineral 5.5 m
Waste 9.5 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.5	0.5
Glacial Sand and Gravel	**a** 'Very clayey' sandy gravel with cobbles Gravel: coarse sandstone and limestone with some fine quartzite, siltstone and mudstone Sand: fine sandstone and limestone with quartzite Fines: moderately stiff brown clay matrix	1.0	1.5
Boulder Clay	Stony clay, brown, with contained sand and pebbles as above	2.0	3.5
Glacial Sand and Gravel	**b** Gravel, sandy at base Gravel: cobbles and coarse sandstone and limestone with chert and silicified limestone, some siltstone and ironstone and traces of quartzite, quartz, dolomitised limestone and igneous rocks Sand: poorly sorted quartz and quartzite with limestone and sandstone	5.5	9.0
Boulder Clay	Stony clay, dark grey-black, firm, silty with sandstone and limestone pebbles, cobbles and boulders *Stopped on boulder*	9.5+	18.5

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
a	32	40	28	0.5–1.5	32	22	10	8	12	16	
b	9	29	62	3.5–4.5	9	10	6	9	12	32	22
				4.5–5.5	10	11	7	7	14	29	22
				5.5–6.5	10	8	5	8	12	27	30
				6.5–7.5	15	10	8	7	14	23	23
				7.5–8.5	5	5	8	23	23	21	15
				8.5–9.0	7	11	19	22	27	11	3
				Mean	9	9	8	12	16	25	21
a+b	13	30	57	Mean	13	11	8	11	16	24	17

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
4.5–5.5	53	34	trace	—	—	—	11	2	trace
6.5–7.5	44	42	trace	—	trace	—	12	1	1
8.5–9.0	49	28	—	trace	2	trace	11	4	6

NZ 11 SE 8 1813 1297 Carlton Grange **Block C**

Surface level (+98.5 m)+323 ft
Water level at surface
152-mm percussion
December 1974

Overburden 1.5 m
Mineral 2.0 m
Waste 4.5 m
Bedrock 1.3 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.5	0.5
Alluvium	Sandy clay, firm, blue-grey, with weathered sandstone pebbles	1.0	1.5
	Gravel Gravel: coarse, angular to rounded sandstone and limestone Sand: coarse, subangular quartz, sandstone and limestone	2.0	3.5
Boulder Clay	Sandy clay, soft, blue-grey with sandstone and quartzite pebbles	0.9	4.4
	Gravel Gravel: coarse sandstone and limestone pebbles with coarse quartz, limestone and sandstone sand	0.6	5.0
	Clay, blue-grey, with sandstone pebbles	3.0	8.0
Millstone Grit Series	Shale, iron-stained grey, fossiliferous, top weathered to clay	1.3+	9.3

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
7	40	53	1.5–2.5	10	8	14	19	17	32	
			2.5–3.5	5	7	14	18	13	34	9
			Mean	7	8	14	18	15	33	5

NZ 11 SE 10 1535 1231 Layton Fields

Surface level (+117.7 m)+386 ft
Water level +107.7 m
152-mm percussion
November 1974

Waste 12.2 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.5	0.5
Boulder Clay	Sandy and silty clay, grey and brown, with sandstone and limestone pebbles	11.5	12.0
	Calcareous shale boulder *Borehole abandoned, boulder obstruction*	0.2+	12.2

E 21 NW 1 2169 1533 Piercebridge Quarry Section **Block A**

Surface level (c+56.4 m) c+185 ft
December 1974

Overburden 0.5 m
Mineral 7.0 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.5	0.5
Second River Terrace	Gravel, 'clayey' from 0.5–1.5 m Gravel: coarse with cobbles and sporadic boulders of subrounded sandstone and limestone with coarse subrounded to rounded volcanic and basic igneous rocks, and quartzite with some mudstone and ironstone, and traces of dolomite, chert and quartz Sand: medium angular to subangular quartz and quartzite with coarse subangular sandstone fragments, subrounded limestone and chert fragments with some volcanics and traces of rotted basic igneous rocks *Section complete on quarry floor near base of deposit resting on Magnesian Limestone bedrock*	7.0+	7.5

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
3	17	80	0.5–1.5	11	6	7	2	10	53	11
			1.5–2.5	3	3	10	10	18	31	25
			2.5–3.5	2	4	7	6	18	50	13
			3.5–4.5	2	1	4	4	34	40	15
			4.5–5.5	3	3	8	8	16	36	26
			5.5–6.5	2	3	4	3	14	53	21
			6.5–7.5	2	5	13	7	17	28	28
			Mean	3	4	7	6	18	42	20

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
0.5–1.5	62	8	12	trace	15	1	1	trace	trace
1.5–2.5	48	28	5	trace	16	trace	1	trace	1
2.5–3.5	51	28	7	trace	10	trace	1	1	1
3.5–4.5	39	38	3	trace	10	—	trace	6	3
4.5–5.5	45	35	3	trace	13	1	1	1	1
5.5–6.5	60	19	6	trace	8	2	1	3	1
6.5–7.5	34	28	2	trace	14	3	1	14	4

NZ 21 NW 8 2158 1861 Denton

Surface level (+80.8 m)+265 ft
Water not encountered
152-mm percussion
January 1975

Waste 2.0 m
Bedrock 0.1 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.7	0.7
Boulder Clay	Clay, dark brown, with red and yellow lenses; some sandstone, quartzite and coal pebbles	1.3	2.0
Permian	Dolomitic limestone, yellow powdery	0.1+	2.1

NZ 21 NW 9 2256 1767 Ulnaby Hall

Surface level (+68.6 m)+225 ft
Water not encountered
152-mm percussion
October 1974

Waste 1.4 m
Bedrock

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.9	0.9
Boulder Clay	Silty sandy clay with iron staining	0.5	1.4
Permian	Dolomitic limestone, yellow, powdery	2.0+	3.4

NZ 21 NW 10 2355 1701 Thornton Hall

Surface level (+60.4 m)+198 ft
Water level not recorded
152-mm percussion
January 1975

Waste 12.6 m
Bedrock 0.1 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.5	0.5
Boulder Clay	Silty clay, dark brown, with sandstone, quartzite, mudstone, coal and limestone fragments	4.5	5.0
	Sandy clay, dark brown, with thin sand and orange clay layers	1.0	6.0
	Sand, medium subangular to subrounded quartz with thin detrital coal layers	0.9	6.9
	Sandy silt, laminated, dark brown, micaceous	3.5	10.4
	Gravel, coarse sandstone and dolomite with medium quartz and dolomite sand	2.2	12.6
Permian	Dolomitic limestone	0.1+	12.7

NZ 21 NW 11 2433 1646 Thornton Hall **Block C**

Surface level (+57.9 m) +190 ft
Water level +52.9 m
152-mm percussion
October 1974

Overburden 7.1 m
Mineral 4.9 m
Waste 12.4 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.4	0.4
Boulder Clay	Sandy and silty clay, yellow to dark brown, with sandstone, quartzite, coal, dolomite, mudstone and dolerite pebbles	6.7	7.1
Glacial Sand and Gravel	Sandy gravel and gravel Gravel: coarse, mainly subrounded sandstone and limestone with chert and silicified limestone and some dolerite, agglomerate, ironstone, quartz, quartzite, dolomite, breccia and conglomerate; angular to subrounded dolomite common at top Sand: medium, quartz, quartzite and sandstone with limestone and some chert, dolomite, igneous rocks and coal	4.9	12.0
Boulder Clay	Silty clay, firm dark brown, with sandstone, limestone and dolomite boulders and cobbles, quartzite and igneous pebbles and some coal	12.4+	24.4

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	+64
4	52	44	7.1–8.1	4	8	18	10	17	43	
			8.1–9.1	2	12	30	10	18	24	4
			9.1–10.1	4	22	32	5	10	27	
			10.1–11.1	7	12	14	15	23	21	8
			11.1–12.0	2	20	34	18	7	19	
			Mean	4	14	26	11	15	27	3

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
7.1–8.1	28	26	1	1	6	26	11	—	1

NZ 21 NW 12 **2061 1595** **Piercebridge** **Block A**

Surface level (+60.4 m) +198 ft
Water level +56.4 m
152-mm percussion
November 1974

Overburden 0.3 m
Mineral 5.1 m
Waste 2.6 m
Bedrock 0.2 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.3	0.3
Second River Terrace	Gravel Gravel: coarse, with some cobbles, rounded sandstone Sand: medium, quartz, quartzite and sandstone	1.0	1.3
	Obstruction, assumed to be boulder within mineral; no recovery	1.0	2.3
	Gravel Gravel: coarse, with some cobbles, angular to rounded sandstone with limestone and dolomitic limestone, pyroclastic rocks, some quartzite, chert and ironstone, and a trace of quartz Sand: medium, quartz and quartzite with sandstone with some limestone, dark igneous and volcanic fragments	3.1	5.4
Boulder Clay	Silty clay, dark grey to brown and red, with sandstone, mudstone and limestone pebbles	2.6	8.0
Permian	Dolomitic limestone, yellow clayey	0.2+	8.2

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
4	40	56	0.3–1.3	6	9	12	6	14	28	25
			1.3–2.3	*4*	*11*	*18*	*12*	*15*	*36*	*4*
			2.3–3.3	5	10	18	17	21	29	
			3.3–4.3	2	12	22	15	11	38	
			4.3–5.4	5	9	17	11	14	44	
			Mean	4	10	18	12	15	35	6

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
3.3–4.3	59	17	4	trace	9	8	2	—	1

NZ 21 NW 13 2166 1558 Piercebridge **Block A**

Surface level (+52.7 m) +173 ft
Water level +49.7 m
152-mm percussion
December 1974

Overburden 1.2 m
Mineral 1.8 m
Waste 0.2 m
Bedrock 1.3 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.2	1.2
First River Terrace	'Clayey' to 'very clayey' sandy gravel Gravel: coarse, subrounded sandstone and quartzite with dolomite and limestone Sand: medium, quartz, quartzite and sandstone with igneous rocks	1.8	3.0
	Sandy clay, grey-brown	0.2	3.2
Permian	Dolomitic limestone	1.3+	4.5

Grading

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$
19	56	25	1.2–2.2*	15	27	19	12	9	18	
			2.2–3.0*	25	25	16	12	7	15	
			Mean	19	26	18	12	8	17	

* Poor recovery

NZ 21 NW 14 2217 1504 High Coniscliffe **Block A**

Surface level (+51.5 m) +169 ft
Water level not recorded
152-mm percussion
December 1974

Overburden 1.3 m
Mineral 4.5 m
Bedrock 1.0 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil on red-brown clay	1.3	1.3
Alluvium	Gravel, 'clayey' at base Gravel: coarse, subrounded to rounded sandstone and limestone with some dark igneous rocks Sand: medium, quartzite, quartz and sandstone with igneous rock fragments	4.5	5.8
Permian	Dolomitic limestone, coarse, friable, yellow	1.0+	6.8

Grading

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$
8	37	55	1.3–2.3	7	11	18	12	20	32	
			2.3–3.3*	6	14	15	8	14	43	
			3.3–4.3*	6	16	17	8	4	25	24
			4.3–5.3	6	9	12	10	25	31	7
			5.3–5.8	18	10	10	12	11	29	10
			Mean	8	12	15	10	15	32	8

* Poor recovery

NZ 21 NE 36 2511 1581 Coniscliffe Grange **Block C**

Surface level (+50.3 m) +165 ft
Water level +47.0 m
152-mm percussion
September 1974

Overburden 3.9 m
Mineral 2.0 m
Waste 11.4 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.4	0.4
Alluvium on Boulder Clay	Sandy clay and silt, blue-grey, with ironstained sand laminae	3.5	3.9
Glacial Sand and Gravel	'Very clayey' sand Sand: fine quartz and quartzite with some coal	2.0	5.9
Boulder Clay	Silty pebbly clay with 'clayey' sand and gravel partings	11.1	17.0
	Limestone boulder *Borehole abandoned, boulder obstruction*	0.3+	17.3

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
24	76	0	3.9–4.9	31	39	26	3	1		
			4.9–5.9	17	38	42	3			
			Mean	24	39	34	3			

NZ.21 SW 18 2295 1479 High Coniscliffe **Block A**

Surface level (+49.4 m) +162 ft
Water struck +41.4 m
152-mm percussion
October 1974

Overburden 1.4 m
Mineral 9.1 m
Waste 10.0 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.4	1.4
First River Terrace	Gravel Gravel: coarse with some cobbles, subangular to subrounded sandstone and limestone with basaltic rocks, some quartzite, silicified limestone and mudstone with traces of quartz, dolomite and ironstone Sand: medium, quartz, sandstone and dark igneous rock fragments with some dolomite near base	9.1	10.5
Boulder Clay?	Clayey silt, firm, red, with only occasional dolomite, siltstone and sandstone pebbles *Borehole abandoned, penetration very slow*	10.0+	20.5

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
3	41	56	1.4–2.4	7	10	13	11	19	28	12
			2.4–3.4	8	26	24	19	13	2	8
			3.4–4.4	4	9	14	18	26	18	11
			4.4–5.4	1	7	16	7	19	50	
			5.4–6.4	2	8	21	12	24	33	
			6.4–7.4	1	6	19	12	18	38	6
			7.4–8.4	1	5	15	10	26	37	6
			8.4–9.4	1	7	22	18	23	29	
			9.4–10.5	2	10	13	13	15	39	8
			Mean	3	10	18	13	20	31	5

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
4.4–5.4	42	40	6	trace	10	trace	1	1	trace

NZ 21 SW 19 2328 1421 Manfield **Block A**

Surface level (+47.5 m) +156 ft
Water level not recorded
152-mm percussion
December 1974

Overburden 1.3 m
Mineral 1.8 m
Waste 5.9 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.2	1.2
Second River Terrace	Clay, dull grey	0.1	1.3
	'Very clayey' sandy gravel Gravel: fine, subangular to subrounded, dolerite, sandstone and limestone Sand: fine, quartz and quartzite with sandstone	1.8	3.1
Boulder Clay	Clay, brown and grey, with limestone, quartz and dolerite cobbles *Borehole abandoned, penetration very slow*	5.9+	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	+64
21	59	20	1.3–2.3*	18	26	20	14	17	5	
			2.3–3.1*	21	24	18	15	10	8	
			Mean	21	25	19	15	14	6	

* Poor recovery

NZ 21 SW 21 **2432 1354** **Low Coniscliffe** **Block B**

Surface level (+42.7 m) +140 ft
Water level not recorded
152-mm percussion
October 1974

Overburden 0.8 m
Mineral 2.8 m
Waste 0.2 m
Mineral 1.4 m
Waste 1.1 m
Mineral 2.6 m
Waste 12.1 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.8	0.8
First River Terrace	**a** Gravel, 'clayey' and sandy in part Gravel: fine and coarse, angular to subrounded sandstone and subangular to well rounded limestone with basaltic rocks, some quartzite, chert and ironstone and traces of quartz and mudstone Sand: medium, quartz and coarse sandstone and limestone	2.8	3.6
	Clayey silt, soft, grey	0.2	3.8
First River Terrace?	**b** Gravel, sandy at base Gravel: as above Sand: as above with trace of coal	1.4	5.2
	Silty clay, dark brown, with sandstone and quartzite pebbles	1.1	6.3
	c 'Clayey' gravel Gravel: fine and coarse angular to subrounded sandstone and limestone, with basaltic rocks, dolomite and chert with some quartzite, mudstone, soft red sandstone, ironstone and pyrite Sand: coarse, quartz, sandstone and limestone	2.6	8.9
Boulder Clay?	Silty clay with sandstone and quartzite pebbles	1.4	10.3
	'Very clayey' sandy gravel, basically as above	0.7	11.0
	Clayey silt, grey, firm, laminated, with some sandstone, limestone and igneous pebbles and cobbles	9.5	20.5
	Sandy gravel *Borehole abandoned, penetration very slow*	0.5+	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	+64
a	10	45	45	0.8–1.8	15	15	22	7	12	21	8
				1.8–2.8	6	11	23	14	22	24	
				2.8–3.6	8	9	20	13	22	28	
				Mean	10	12	22	11	18	24	3
b	3	46	51	3.8–4.8	1	11	19	15	23	31	
				4.8–5.2	8	13	21	14	17	27	
				Mean	3	12	19	15	21	30	
c	13	42	45	6.3–7.3	21	14	13	13	20	19	
				7.3–8.3	5	7	15	25	26	22	
				8.3–8.9	11	13	14	12	25	25	
				Mean	13	11	14	17	24	21	
a+b+c	9	45	46	Mean	9	12	19	14	21	24	1

Composition

Depth below surface (m)	Percentage by weight in gravel fraction									
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone	Pyrite
2.8–3.6	53	33	4	trace	7	—	2	trace	1	—
7.3–8.3	42	26	3	—	11	5	6	3	3	1

NZ 21 SW 22 2067 1092 Aldbrough **Block C**

Surface level (+80.5 m) +264 ft
Water level not recorded
152-mm percussion
December 1974

Overburden 4.8 m
Mineral 6.7 m
?Bedrock 0.1 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.9	0.9
Alluvium	Sandy pebbly clay, 0.2 m peat at c1.5 m	1.9	2.8
Boulder Clay	Clay, blue-grey	2.0	4.8
Glacial Sand and Gravel?	Gravel Gravel: fine, subangular to rounded limestone, sandstone and quartzite Sand: coarse, sandstone, quartz and quartzite with limestone	6.7	11.5
Millstone Grit Series?	Sandstone, coarse grey-brown *Penetration very difficult. Assumed to be bedrock*	0.1+	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	+64
2	42	56	4.8–5.8	1	13	14	14	22	36	
			5.8–6.8	1	10	18	18	35	18	
			6.8–7.8	2	9	20	20	28	21	
			7.8–8.8	1	12	12	21	30	24	
			8.8–9.8	2	7	12	9	21	49	
			9.8–10.8	2	6	16	18	15	43	
			10.8–11.5	2	19	17	13	19	30	
			Mean	2	11	15	16	24	32	

E 21 SE 1 2511 1336 Cleasby Quarry Section **Block B**

Surface level (c+38.1 m) c+125 ft
December 1974

Overburden 1.5 m
Mineral 5.0 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.5	1.5
First River Terrace	Gravel	5.0+	6.5

Gravel: coarse, with cobbles and occasional boulder of well rounded sandstone with subrounded quartzite, rounded limestone and pyroclastic fragments, some chert and traces of ironstone, mudstone, dolomite and quartz
Sand: medium with a coarse angular lithic fraction, similar in composition to gravel
Section completed at quarry floor near base of deposit just above boulder clay surface

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	20	78	1.5–2.5	1	4	10	3	12	39	31
			2.5–3.5	1	4	10	2	9	39	35
			3.5–4.5	1	3	8	12	13	21	42
			4.5–5.5	2	8	13	6	20	39	12
			5.5–6.5	3	3	10	6	17	49	12
			Mean	2	4	10	6	14	37	27

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
1.5–2.5	48	14	27	trace	9	—	1	trace	1
2.5–3.5	53	4	27	trace	9	trace	5	1	trace
4.5–5.5	52	10	17	1	10	trace	8	1	1
5.5–6.5	47	21	15	trace	12	—	3	1	1

E 21 SE 2 2632 1165 Stapleton Quarry Section **Block B**

Surface level (c+61.0 m) c+200 ft
December 1974

Overburden 0.4 m
Mineral 7.0 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.4	0.4
Glacial Sand and Gravel	'Very clayey' gravel and gravel Gravel: coarse with cobbles and boulders of angular to subrounded sandstone and limestone with dolomitised limestone and quartzite, some chert, basic igneous and volcanic rocks, ironstone and siltstone Sand: fine and medium with composition similar to gravel *Section complete at quarry floor near base of deposit just above a large glacial raft of Carboniferous shale*	7.0+	7.4

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	+64
11	40	49	0.4–1.4	23	24	10	5	8	12	18
			1.4–2.4	28	18	8	5	10	16	15
			2.4–3.4	5	13	17	13	17	24	11
			3.4–4.4	9	12	18	16	19	21	5
			4.4–5.4	4	12	15	14	22	25	8
			5.4–6.4	4	11	14	12	18	17	24
			6.4–7.4	5	18	14	11	20	25	7
			Mean	11	15	14	11	16	20	13

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
0.4–1.4	70	18	3	trace	6	trace	trace	1	1
2.4–3.4	50	20	2	trace	3	18	3	trace	3
4.4–5.4	37	33	3	trace	5	9	7	1	5
6.4–7.4	35	30	6	trace	8	11	7	1	2

NZ 21 SE 41 2714 1438 Hummersknott **Within urban area: not included in resource block**

Surface level (+57.6 m) +189 ft
Water level +44.2 m
152-mm percussion
September 1974

Overburden 1.5 m
Mineral 4.8 m
Waste 6.9 m
Mineral 3.1 m
Waste 0.3 m
Mineral 6.0 m
Waste 1.8 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.3	0.3
Morainic Drift	Pebbly clay, orange-brown to red, with sandstone, coal and siltstone pebbles	1.2	1.5
	a Sand, 'clayey' at top Sand: fine, quartz with traces of dark rock fragments and coal	4.8	6.3
	Silty pebbly clay, with two 0.5 m 'clayey' sand partings	6.9	13.2
	b Sand, pebbly at top, 'clayey' at base Gravel: fine, rounded quartzite and well rounded dolomite Sand: medium, quartz and quartzite with some dark igneous, coal, volcanic and chert fragments	3.1	16.3
	Silty pebbly clay, as above	**0.3**	**16.6**
	c 'Very clayey' sand, pebbly in upper part Gravel: fine subrounded sandstone and quartzite with limestone Sand: fine quartz and quartzite with some dark igneous, coal, volcanic and chert fragments	6.0	22.6
	Sandy silty clay, red	1.8+	24.4

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	+64
a	10	90	0	1.5–2.5	18	66	16				
				2.5–3.5	13	66	20	1			
				3.5–4.5	6	64	30				
				4.5–5.5	4	68	26	1	1		
				5.5–6.3	7	78	14	1			
				Mean	10	68	22	trace			
b	7	89	4	13.2–14.2	4	44	41	3	6	2	
				14.2–15.2	3	31	60	4	1	1	
				15.2–16.3	12	27	53	4	3	1	
				Mean	7	34	51	4	3	1	
c	24	72	4	16.6–17.6	17	31	38	5	2	7	
				17.6–18.6	24	31	33	6	5	1	
				18.6–19.6	22	30	33	8	6	1	
				19.6–20.6	22	40	32	4	2		
				20.6–21.6	23	41	29	4	3		
				21.6–22.6	33	38	23	4	2		
				Mean	24	35	32	5	3	1	
a+b+c	15	82	3	Mean	15	46	33	3	2	1	

NZ 21 SE 42 2538 1347 Cleasby **Block B**

Surface level (+39.9 m) +131 ft
Water level not recorded
152-mm percussion
January 1975

Overburden 0.4 m
Mineral 5.4 m
Waste 7.5 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.4	0.4
Second River Terrace	'Clayey' gravel, 'very clayey' at top Gravel: coarse, subrounded, sandstone with some limestone, quartzite and dark igneous rock fragments Sand: fine, quartz and quartzite with sandstone, some limestone and igneous rock	5.4	5.8
Boulder Clay	Clay, dark brown, with some pebbles	2.5	8.3
	'Clayey' sand	0.2	8.5
	Sandy clay, red-brown, with some pebbles of quartz, volcanic rock and sandstone	1.0	9.5
	Obstruction, no recovery, assumed to be boulder within clay	1.5	11.0
	Gravel, coarse sandstone with volcanic rock, quartzite and limestone	0.5	11.5
	Clay with pebbles *Borehole abandoned, boulder obstruction*	1.8+	13.3

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
16	37	47	0.4–1.4	29	17	9	5	10	30	
			1.4–3.4	15	18	12	10	19	26	
			3.4–5.4	14	17	13	10	18	28	
			5.4–5.8*	3	3	4	7	26	57	
			Mean	16	17	11	9	17	30	

* Poor recovery

NZ 21 SE 43 2638 1335 Hummersknott **Block B**

Surface level (+38.1 m) +125 ft
Water level +29.6 m
152-mm percussion
October 1974

Overburden 1.3 m
Mineral 1.8 m
Waste 21.3 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.3	1.3
Alluvium	Gravel, sandy at base Gravel: coarse, subangular to subrounded sandstone with some rounded dolerite and quartzite and traces of subangular to subrounded quartz Sand: fine and medium sandstone with some dark igneous fragments, quartz and quartzite	1.8	3.1
Boulder Clay	Silty clay with sandstone and quartzite pebbles	4.6	7.7
	Silt, grey laminated	1.0	8.7
	Silty clay, grey at top then brown, with sandstone, dolomite, dark igneous and limestone pebbles	15.7+	24.4

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	+64
5	45	50	1.3–2.3	7	9	11	8	17	48	
			2.3–3.1	2	24	24	19	17	14	
			Mean	5	15	17	13	17	33	

NZ 21 SE 44 2630 1271 Stapleton **Block B**

Surface level (+35.7 m) +117 ft
Water level +33.7 m
152-mm percussion
November 1974

Overburden 1.4 m
Mineral 4.1 m
Waste 9.0 m+

Log

Geological Classification	*Lithology*	*Thickness* m	*Depth* m
Alluvium	Soil on sandy peaty clay	1.4	1.4
	Gravel, 'clayey' and sandy at top Gravel: coarse, angular to rounded sandstone and limestone with subrounded basaltic rocks and quartzite, some chert, mudstonënstone and traces of quartz, dolomite and pyroclastic rocks knd: medium, sandstone, quartz and quartzite with some dark igneous fragments	4.1	5.5
Boulder Clay	Silty clay, blue-grey, mainly laminated, pebbly at base	6.3	11.8
	'Very clayey' pebbly sand	1.4	13.2
	Silty clay with pebbles	0.7	13.9
	Sandy gravel *Borehole abandoned, unable to get casing down*	0.6+	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	+64
4	36	60	1.4–2.4	13	24	17	10	9	19	8
			2.4–3.4	1	6	9	11	22	51	
			3.4–4.4	2	13	16	6	12	33	18
			4.4–5.5	1	6	19	6	16	41	11
			Mean	4	12	16	8	15	36	9

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
4.4–5.5	51	29	5	trace	10	trace	3	1	1

NZ 21 SE 45 2782 1247 Blackwell **Block B**

Surface level (+41.5 m) +136 ft
Water level +40.6 m
152-mm percussion
September 1974

Overburden 2.7 m
Mineral 1.0 m
Waste 1.8 m
Mineral 1.0 m
Waste 2.0 m
Mineral 1.0 m
Waste 1.0 m
Mineral 1.6 m
Waste 11.9 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.7	0.7
Glacial Sand and Gravel	Sandy clay, rusty brown, with sandstone and some dark igneous pebbles	2.0	2.7
	a Gravel, with thin red silt band Gravel: fine, rounded sandstone and quartzite with subangular chert, subrounded limestone and igneous rock, rounded quartz and traces of well rounded dolomite Sand: medium, quartz and quartzite with igneous rock and some chert	1.0	3.7
	Clay, firm, red-brown, with quartzite boulder and sandstone and dolomite cobbles	1.8	5.5
	b 'Clayey' sand Sand: fine, quartz with dark igneous fragments	1.0	6.5
	Sandy silt	2.0	8.5
	c 'Very clayey' sand Sand: as above	1.0	9.5
	Sandy silt	1.0	10.5
	d 'Very clayey' sand, as above	1.6	12.1
	Sandy silt and silty clay, firm, brown, with pebbles of sandstone, quartzite, limestone and some dolomite, mudstone and coal	11.9+	24.0

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
a	9	39	52	2.7–3.7	9	9	15	15	28	24	
b	15	85	0	5.5–6.5	15	84	1				
c	36	64	0	8.5–9.5	36	63	1				
d	26	74	0	10.5–11.5	28	71	1				
				11.5–12.1	24	75	1				
				Mean	26	73	1				
a+b+ c+d	23	66	11	Mean	23	59	4	3	6	5	

NZ 21 SE 48 2680 1154 Stapleton Manor **Block B**

Surface level (+48.5 m) +159 ft
Water struck +38.7 m
152-mm percussion
December 1974

Overburden 0.3 m
Mineral 5.7 m
Waste 12.5 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.3	0.3
Glacial Sand and Gravel	Sandy gravel and gravel, 'clayey' at top Gravel: coarse, angular to subrounded, sandstone and limestone with dolomite, chert and silicified limestone, ironstone and basaltic rocks, some quartzite and traces of quartz and siltstone Sand: coarse, quartz and quartzite with sandstone and some limestone and dark igneous rock	5.7	6.0
Boulder Clay	Clay, blue-grey, laminated in parts, with sandstone, quartzite, dolomite and mudstone pebbles	3.8	9.8
Glacial Sand and Gravel	'Clayey' gravel, coarse, subangular sandstone with some dolomite and limestone gravel and fine sand	1.0	10.8
Boulder Clay	Clay, grey-brown, with sandstone, limestone, dark igneous and dolomite pebbles	3.0	13.8
	Silty clay, grey-brown to red, laminated to 16.9 m, pebbly below *Borehole abandoned, penetration very slow*	4.7+	18.5

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	50	46	0.3–1.3	11	14	19	15	17	18	6
			1.3–2.3	3	12	19	22	21	18	5
			2.3–3.3	3	13	22	19	19	24	
			3.3–4.3	1	13	13	25	24	24	
			4.3–5.3	2	12	13	22	24	27	
			5.3–6.0	7	22	9	11	14	20	17
			Mean	4	14	16	20	20	22	4

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
2.3–3.3	38	36	2	trace	6	6	7	trace	5

NZ 21 SE 49 2768 1138 Nags Head Farm **Block B**

Surface level (+32.9 m) +108 ft
Water level +29.9 m
152-mm percussion
September 1974

Overburden 0.7 m
Mineral 5.4 m
Waste 2.9 m
Mineral 1.0 m
Waste 1.5 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.5	0.5
First River Terrace	Clay, brown, with sandstone and coal fragments	0.2	0.7
	a Gravel Gravel: coarse, subangular sandstone and limestone with subrounded basaltic rocks and quartzite, some dolomite, chert and ironstone and traces of quartz, siltstone and coal Sand: medium, quartz, quartzite and sandstone with traces of dark igneous rock fragments	5.4	6.1
	Clay, brown to grey, laminated	1.0	7.1
	Clayey silt, grey	1.9	9.0
First River Terrace?	**b** 'Clayey' gravel Gravel: coarse subangular sandstone with limestone and basaltic rocks, some quartzite, dolomite and chert and a trace of ironstone Sand: as above but fine and with traces of dolomite	1.0	10.0
	Silt, grey-brown, with quartzite and igneous rocks and some limestone pebbles *Borehole abandoned, penetration very slow*	1.5+	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	+64
a	5	29	66	0.7–1.7	9	6	10	6	13	40	16
				1.7–2.7	6	8	9	5	15	35	22
				2.7–3.7	8	10	13	9	23	37	
				3.7–4.7	1	8	17	13	28	33	
				4.7–5.7	3	5	13	7	30	42	
				5.7–6.1	1	7	27	6	9	42	8
				Mean	5	7	14	8	21	38	7
b	11	15	74	9.0–10.0	11	7	2	6	19	55	
a+b	6	27	67	Mean	6	7	12	8	21	40	6

Composition

Depth below surface (m)	Percentages by weight in gravel fraction									
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone	Coal
0.7–2.7	57	18	10	trace	10	2	2	1	—	trace
3.7–4.7	39	35	7	trace	15	trace	2	—	2	—
9.0–10.0	62	23	3	—	7	2	3	—	trace	—

NZ 21 SE 50 2833 1062 Oxen-le-Fields **Block B**

Surface level (+31.1 m) +102 ft
Water level +26.1 m
152-mm percussion
September 1974

Overburden 1.1 m
Mineral 2.1 m
Waste 0.1 m
Mineral 1.2 m
Waste 0.4 m
Mineral 1.0 m
Waste 8.5 m+

Log

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	1.1	1.1
Alluvium	**a** Sand: medium, quartz with traces of dark igneous rock fragments	0.7	1.8
	b Gravel Gravel: coarse, subrounded sandstone and limestone with angular to rounded quartzite, chert and basaltic rock, some dolomite and traces of quartz, mudstone and ironstone Sand: medium quartz with traces of dark igneous rock fragments	1.4	3.2
	Silty clay, dark brown	0.1	3.3
	c Gravel Gravel: as above but with more basaltic rock Sand: as above but coarse	1.2	4.5
	Silty clay, red-brown, with sandstone pebbles	0.4	4.9
	d 'Clayey' gravel Gravel: basically similar to above 1.4–3.2 m Sand: fine quartz with traces of dark igneous rocks	1.0	5.9
Boulder Clay?	Silt, grey-brown, clayey	2.1	8.0
	Silty sandy clay, red-brown, with boulders and pebbles of sandstone, chert, limestone, dolerite, mudstone, dolomite, volcanic and igneous rock fragments	6.3	14.3
	Gravel? coarse rounded dolerite, basalt and subrounded sandstone with some dolomite and limestone, and trace of iron pyrites *Hole abandoned. Casing stuck at 13.5 m, gravel blowing up hole, unable to penetrate*	0.1+	14.4

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	+64
a	4	96	0	1.1–1.8	4	40	55	1			
b	2	33	65	1.8–2.8	2	12	17	8	20	41	
				2.8–3.2	1	5	12	8	16	43	15
				Mean	2	10	15	8	19	42	4
a+b	2	55	43	Mean	2	20	29	6	12	28	3
c	3	22	75	3.3–4.0	4	6	10	10	18	45	7
				4.0–4.5	3	4	6	6	18	53	10
				Mean	3	5	8	9	18	49	8
d	15	21	64	4.9–5.9	15	9	6	6	14	50	
a+b+ c+d	6	37	57	Mean	6	13	18	6	14	39	4

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
1.8–2.8	68	11	7	trace	6	—	6	1	1
2.8–3.2	63	16	5	trace	10	2	4	trace	trace
4.0–4.5	51	16	4	1	26	trace	1	1	—
4.9–5.9	69	22	2	trace	6	—	—	1	—

NZ 21 SE 55 2604 1166 Stapleton **Block B**

Surface level (+65.5 m) +215 ft
Water not encountered
Dando 250 and 41-cm Piling rig
May 1975

Overburden 2.0 m
Mineral 13.3 m+

Log*

Geological classification	*Lithology*	*Thickness* m	*Depth* m
	Soil	0.2	0.2
Glacial Sand and Gravel	Clay with stones	1.8	2.0
	a Gravel Gravel: cobbles, boulders and coarse gravel of angular to subrounded sandstone and limestone with dolomitic limestone, chert and silicified limestone, basaltic rocks, some quartzite, quartz and ironstone and a trace of mudstone Sand: coarse limestone and sandstone with quartz, quartzite and volcanics and some dark igneous rocks and dolomite	11.8	13.8
	b Sand, fine quartz and quartzite with some coal	1.5+	15.3

* Composite log of two experimental boreholes

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	3	38	59	2.0–3.0	11	16	14	8	13	21	17
				3.0–4.0	3	8	10	10	23	31	15
				4.0–5.0	2	5	6	16	20	26	25
				5.0–6.0	2	5	16	11	27	33	6
				6.0–7.0	2	8	18	15	20	23	14
				7.0–8.0	2	9	10	9	21	34	15
				8.0–9.0	2	6	10	17	26	25	14
				9.0–10.0	3	9	21	15	19	18	15
				10.0–11.0	2	12	21	23	23	19	
				11.0–12.0	2	10	14	12	23	39	
				12.0–13.0	3	10	18	14	20	28	7
				13.0–13.8	9	20	15	10	18	26	2
				Mean	3	10	14	14	21	27	11
b	14	86	0	13.8–15.3	14	75	9	2			
a+b	5	43	52	Mean	5	17	14	12	19	24	9

Composition

Depth below surface (m)	Percentages by weight in gravel fraction								
	Sandstone	Limestone	Quartzite	Quartz	Igneous	Dolomite	Chert	Siltstone	Ironstone
2.0–3.0	34	37	trace	trace	7	13	6	trace	2
4.0–5.0	35	24	3	trace	5	20	9	1	3
6.0–7.0	49	19	1	trace	10	9	8	trace	3
8.0–9.0	33	28	4	trace	9	11	8	1	6
10.0–11.0	51	24	3	1	4	11	5	trace	1
12.0–13.0	41	23	4	2	5	13	9	trace	3

APPENDIX G

LIST OF WORKINGS

In 1976 sand and gravel was being worked at four localities:

Alluvial gravels and terrace deposits of the River Tees floodplain.
Piercebridge (Cliffe) [217 154]
Cleasby [252 135]
Blackwell [270 129]
Glacial sand and gravel
Stapleton [261 117]

All are worked dry but may require pumping to be kept free of water. The gravel is excavated, washed, and the coarse pebbles, cobbles and boulders crushed to provide a variety of angular gravel grades and coarse sand. Much of the finer material is used for backfilling.

Worked out quarries are found at:

Piercebridge [200 157]
Low Coniscliffe [240 137]
Cleasby [259 126]

Minor disused sand and gravel pits are found at:

Osmond Croft [129 156]
Sough Hill [168 140]
Hillhouse Hill [183 182]
Wood House [195 154]
Mowden [267 157]
Whiley Hill [275 198]
Hill Banks [295 192]

APPENDIX H

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	47.5	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

REFERENCES

ALLEN, V. T. 1936. Terminology of medium-grained sediments. *Rep. Natl Res. Counc. Washington 1935–36. App. 1, Rep. Comm. Sedimentation*, pp. 18–47.

ANON. 1970. Metrication: two opposing views. *Quarry Managers' J.*, Vol. 54, No. 6, p. 230.

ARCHER, A. A. 1969. Background and problems of an assessment of sand and gravel resources in the United Kingdom. *Proc. 9th Commonw. Min. Metall. Congr., 1969.* Vol. 2. Mining and petroleum geology, pp. 495–508. (London: The Institution of Mining and Metallurgy.)

— 1970a. Standardisation of the size classification of naturally occurring particules. *Géotechnique*, Vol. 20, pp. 103–107.

— 1970b. Making the most of metrication. *Quarry Managers' J.*, Vol. 54, No. 6, pp. 223–227.

ATTERBERG, A. 1905. Die Rationelle Klassifikation der Sande und Kiese. *Chem. Z.*, Vol. 29, pp. 195–198.

BRITISH STANDARD 1377. 1967. *Methods of testing soils for civil engineering purposes.* (London: British Standards Institution.)

BUREAU OF MINES AND GEOLOGICAL SURVEY. 1948. *Mineral Resources of the United States.* (Washington D.C.: Public Affairs Press.) pp. 14–17.

DWERRYHOUSE, A. R. 1902. The glaciation of Teesdale, Weardale and the Tyne Valley, and their tributary valleys. *Q. J. Geol. Soc. London*, Vol. 58, No. 3, pp. 572–608.

FRANCIS, E. A. 1970. The Quaternary *in* Geology of Durham County, JOHNSON, G. A. L. (Editor). *Trans. Nat. Hist. Soc. Northumberland*, Vol. 41, pp. 134–152.

HARRIS, P. M., THURRELL, R. G., HEALING, R. A. and ARCHER, A. A. 1974. Aggregates in Britain. *Proc. R. Soc.*, Ser. A, Vol. 339, pp. 329–353.

LAND, D. H., and SMITH, D. B. *In preparation.* Geology of the country around Stockton. *Mem. Geol. Surv. G. B.*, Sheet 33.

LANE, E. W. and others. 1974. Report of the sub-committee on sediment terminology. *Trans. Am. Geophys. Union*, Vol. 28, pp. 936–938.

MILLS, D. A. C. and HULL, J. H. 1976. Geology of the country around Barnard Castle. *Mem. Geol. Surv. G. B.*, **Sheet 32.**

NEWTON, M. 1971. The sand and gravel industry in north east England. *Res. Ser. Dep. of Geogr. Univ. Newcastle-upon-Tyne*, No. 7.

PENNY, L. F. 1964. A review of the last glaciation in Great Britain. *Proc. Yorkshire Geol. Soc.*, Vol. 34, pp. 387–411.

PETTIJOHN, F. J. 1957. *Sedimentary rocks.* 2nd Edition (London: Harper and Row).

THURRELL, R. G. 1971. The assessment of mineral resources with particular reference to sand and gravel. *Quarry Managers' J.*, Vol. 55, pp. 19–25.

TROTTER, F. M. 1929a. The Tertiary uplift and resultant drainage of the Alston Block and adjacent areas. *Proc. Yorkshire Geol. Soc.*, Vol. 21, pp. 161–180.

— 1929b. On the glaciation of eastern Edenside, Alston Block and the Carlisle plain. *Q. J. Geol. Soc. London*, Vol. 85, pp. 549–612.

TWENHOFEL, W. H. 1937. Terminology of the fine-grained mechanical sediments. *Rep. Natl Res. Counc. Washington, 1936–37. App. 1, Rep. Comm. Sedimentation*, pp. 81–104.

UDDEN, J. A. 1914. Mechanical composition of clastic sediments. *Bull. Geol. Soc. Am.*, Vol. 25, pp. 655–744.

WENTWORTH, C. K. 1922. A scale of grade and class terms for clastic sediments. *J. Geol.*, Vol. 30, pp. 377–392.

— 1935. The terminology of coarse sediments. *Bull. Natl Res. Counc. Washington*, No. 98, pp. 225–246.

WILLMAN, H. B. 1942. Geology and mineral resources of the Marseilles, Ottowa and Stretar quadrangles. *Bull. Illinois State Geol. Surv.*, No. 66, pp. 343–344.

The following reports of the Institute relate particularly to bulk mineral resources

Reports of the Institute of Geological Sciences

Assessment of British Sand and Gravel Resources

1 The sand and gravel resources of the country south-east of Norwich, Norfolk: Resource sheet TG 20. E. F. P. Nickless.
Report 71/20 ISBN 0 11 880216 £1.15

2 The sand and gravel resources of the country around Witham, Essex: Resource sheet TL 81. H. J. E. Haggard.
Report 72/6 ISBN 0 11 880588 6 £1.20

3 The sand and gravel resources of the area south and west of Woodbridge, Suffolk: Resource sheet TM 24.
R. Allender and S. E. Hollyer.
Report 72/9 ISBN 0 11 880596 7 £1.70

4 The sand and gravel resources of the country around Maldon, Essex: Resource sheet TL 80. J. D. Ambrose.
Report 73/1 ISBN 0 11 880600 9 £1.20

5 The sand and gravel resources of the country around Hethersett, Norfolk: Resource sheet TG 10. E. F. P. Nickless.
Report 73/4 ISBN 0 11 880606 8 £1.60.

6 The sand and gravel resources of the country around Terling, Essex: Resource sheet TL 71. C. H. Eaton.
Report 73/5 ISBN 0 11 880608 4 £1.20

7 The sand and gravel resources of the country around Layer Breton and Tolleshunt D'Arcy, Essex: Resource sheet TL 91 and part of TL 90. J. D. Ambrose.
Report 73/8 ISBN 0 11 990614 9 £1.30

8 The sand and gravel resources of the country around Shotley and Felixstowe, Suffolk: Resource sheet TM 23.
R. Allender and S. E. Hollyer.
Report 73/13 ISBN 0 11 880625 4 £1.60

9 The sand and gravel resources of the country around Attlebridge, Norfolk: Resource sheet TG 11. E. F. P. Nickless.
Report 73/15 ISBN 0 11 880658 0 £1.85

10 The sand and gravel resources of the country west of Colchester, Essex: Resource sheet TL 92. J. D. Ambrose.
Report 74/6 ISBN 0 11 880671 8 £1.45

11 The sand and gravel resources of the country around Tattingstone, Suffolk: Resource sheet TM 13.
S. E. Hollyer.
Report 74/9 ISBN 0 11 880675 0 £1.95

12 The sand and gravel resources of the country around Gerrards Cross, Buckinghamshire: Resource sheets SU 99, TQ 08 and TQ 09. H. C. Squirrell.
Report 74/14 ISBN 0 11 880710 2 £2.20

Mineral Assessment Reports

13 The sand and gravel resources of the country east of Chelmsford, Essex: Resource sheet TL 70. M. R. Clarke.
ISBN 0 11 880744 7 £3.50

14 The sand and gravel resources of the country east of Colchester, Essex: Resource sheet TM 02. J. D. Ambrose.
ISBN 0 11 880745 5 £3.25

15 The sand and gravel resources of the country around Newton on Trent, Lincolnshire: Resource sheet SK 87.
D. Price.
ISBN 0 11 880746 3 £3.00

16 The sand and gravel resources of the country around Braintree, Essex: Resource sheet TL 72. M. R. Clarke.
ISBN 0 11 880747 1 £3.50

17 The sand and gravel resources of the country around Besthorpe, Nottinghamshire: Resource sheet SK 86, part SK 76. J. R. Gozzard.
ISBN 0 11 880748 X £3.00

18 The sand and gravel resources of the Thames Valley, the country around Cricklade, Wiltshire: Resource sheet SU 09, 19, parts SP 00, 10. P. R. Robson.
ISBN 0 11 880749 8 £3.00

19 The sand and gravel resources of the country south of Gainsborough, Lincolnshire: Resource sheet SK 88, part SK 78. J. H. Lovell.
ISBN 0 11 880750 1 £2.50

20 The sand and gravel resources of the country east of Newark-upon-Trent, Nottinghamshire: Resource sheet SK 85. J. R. Gozzard.
ISBN 0 11 880751 X £2.75

21 The sand and gravel resources of the Thames and Kennet Valleys, the country around Pangbourne, Berkshire: Resource sheet SU 67. H. C. Squirrell.
ISBN 0 11 880752 8 £3.25

22 The sand and gravel resources of the country north-west of Scunthorpe, Humberside: Resource sheet SE 81.
J. W. C. James.
ISBN 0 11 880753 6 £3.00

23 The sand and gravel resources of the Thames Valley, the country between Lechlade and Standlake: Resource sheet SP 30, parts SP 20, SU 29, 39. P. Robson.
ISBN 0 11 881252 1 £7.25

24 The sand and gravel resources of the country around Aldermaston, Berkshire: Parts of Resource sheet SU 56, parts 66. H. C. Squirrell.
ISBN 0 11 881253 X £5.00

25 The celestite resources of the area north-east of Bristol: Resource sheet ST 68, parts ST 59, 69, 79, 58, 78, 68, 77. E. F. P. Nickless, S. J. Booth and P. N. Mosley.
ISBN 0 11 881262 9 £5.00

26 The limestone and dolomite resources of the country around Monyash, Derbyshire: Resource sheet SK 16.
F. C. Cox and D. McC Bridge.
ISBN 0 11 881263 7 £7.00

27 The sand and gravel resources of the country west and south of Lincoln, Lincolnshire: Resource sheet SK 95, 96, 97. I. Jackson.
ISBN 0 11 884003 7 £6.00

28 The sand and gravel resources of the country around Eynsham, Oxfordshire: Resource sheet SP 40, part SP 41. W. J. R. Harries.
ISBN 0 11 884012 6 £3.00

29 The sand and gravel resources of the country south-west of Scunthorpe, Humberside: Resource sheet SE 80.
J. H. Lovell.
ISBN 0 11 884013 4 £3.50

30 Procedure for the assessment of limestone resources. F. C. Cox, D. McC Bridge and J. H. Hull.
ISBN 0 11 884030 4 £1.25

31 The sand and gravel resources of the country west of Newark upon Trent, Nottinghamshire. Resource sheet SK 75. D. Price and P. J. Rogers.
ISBN 0 11 884031 2 £3.50.

32 The sand and gravel resources of the country around Sonning and Henley. Resource sheet SU 77, 78.
H. C. Squirrell.
ISBN 0 11 884032 0 £5.25

33 The sand and gravel resources of the country north of Gainsborough. Resource sheet SK 89. J. Gozzard and D. Price.
ISBN 0 11 884033 9 £4.50.

34 The sand and gravel resources of the Dengie Peninsula, Essex: Resource sheet TL 90, etc. M. B. Simmons.
ISBN 0 11 884081 9 £7.50

35 The sand and gravel resources of the country around Darvel: Resource Sheet NS54, 63, etc. E. F. P. Nickless, A. M. Aitken and A. A. McMillan.
ISBN 0 11 884082 7 £7.00

36 The sand and gravel resources of the country around Southend-on-Sea, Essex: Resource sheets TQ 78/79 etc. S. E. Hollyer and M. B. Simmons.
ISBN 0 11 884083 5 £7.50

37 The sand and gravel resources of the country around Bawtry, South Yorkshire: Resource sheet SK 69. A. R. Clayton.
ISBN 0 11 884053 3 £5.75

38 The sand and gravel resources of the country around Abingdon, Oxfordshire: Resource sheet SU 49, 59, SP 40, 50. C. E. Corser.
ISBN 0 11 884084 5 £5.50

39 The sand and gravel resources of the Blackwater Valley (Aldershot) area: Resource sheet SU 85, 86, parts SU 84, 94, 95, 96. M. R. Clarke, A. J. Dixon and M. Kubala.
ISBN 0 11 884085 1 £7.00

40 The sand and gravel resources of the country west of Darlington, County Durham: Resource sheet NZ 11, 21. A. Smith.
ISBN 0 11 884086 X £4.75

Reports of the Institute of Geological Sciences

Other Reports

69/9 Sand and gravel resources of the inner Moray Firth. A. L. Harris and J. D. Peacock.
ISBN 0 11 880106 6 35p

70/4 Sands and gravels of the southern counties of Scotland. G. A. Goodlet.
ISBN 0 11 880105 8 90p

72/8 The use and resources of moulding sand in Northern Ireland. R. A. Old.
ISBN 0 11 881594 0 30p

73/9 The superficial deposits of the Firth of Clyde and its sea lochs. C. E. Deegan, R. Kirby, I. Rae and R. Floyd.
ISBN 0 11 880617 3 95p

77/1 Sources of aggregate in Northern Ireland (2nd edition). I. B. Cameron.
ISBN 0 11 881279 3 70p

77/2 Sand and gravel resources of the Grampian Region. J. D. Peacock and others.
ISBN 0 11 881282 3 80p

77/5 Sand and gravel resources of the Fife Region. M. A. E. Browne.
ISBN 0 11 884004 5 60p

77/6 Sand and gravel resources of the Tayside Region. I. B. Paterson.
ISBN 0 11 884008 8 £1.40

77/8 Sand and gravel resources of the Strathclyde Region. I. B. Cameron and others.
ISBN 0 11 884028 2 £2.50

77/9 Sand and gravel resources of the Central Region. Scotland. M. A. E. Browne.
ISBN 0 11 884016 9 £1.35

77/19 Sand and gravel resources of the Borders Region, Scotland. A. D. McAdam.
ISBN 0 11 884025 8 £1.00

77/22 Sand and gravel resources of the Dumfries and Galloway Region of Scotland. I. B. Cameron.
ISBN 0 11 884025 8 £1.20

78/1 Sand and gravels of the Lothian Region of Scotland. A. D. McAdam.
ISBN 0 11 884042 8 £1.00

Typeset for the Institute of Geological Sciences by Seel House Press Group, Merseyside.

Printed in England for Her Majesty's Stationery Office by Commercial Colour Press, London E7. **Dd.595766 K8 9/79**

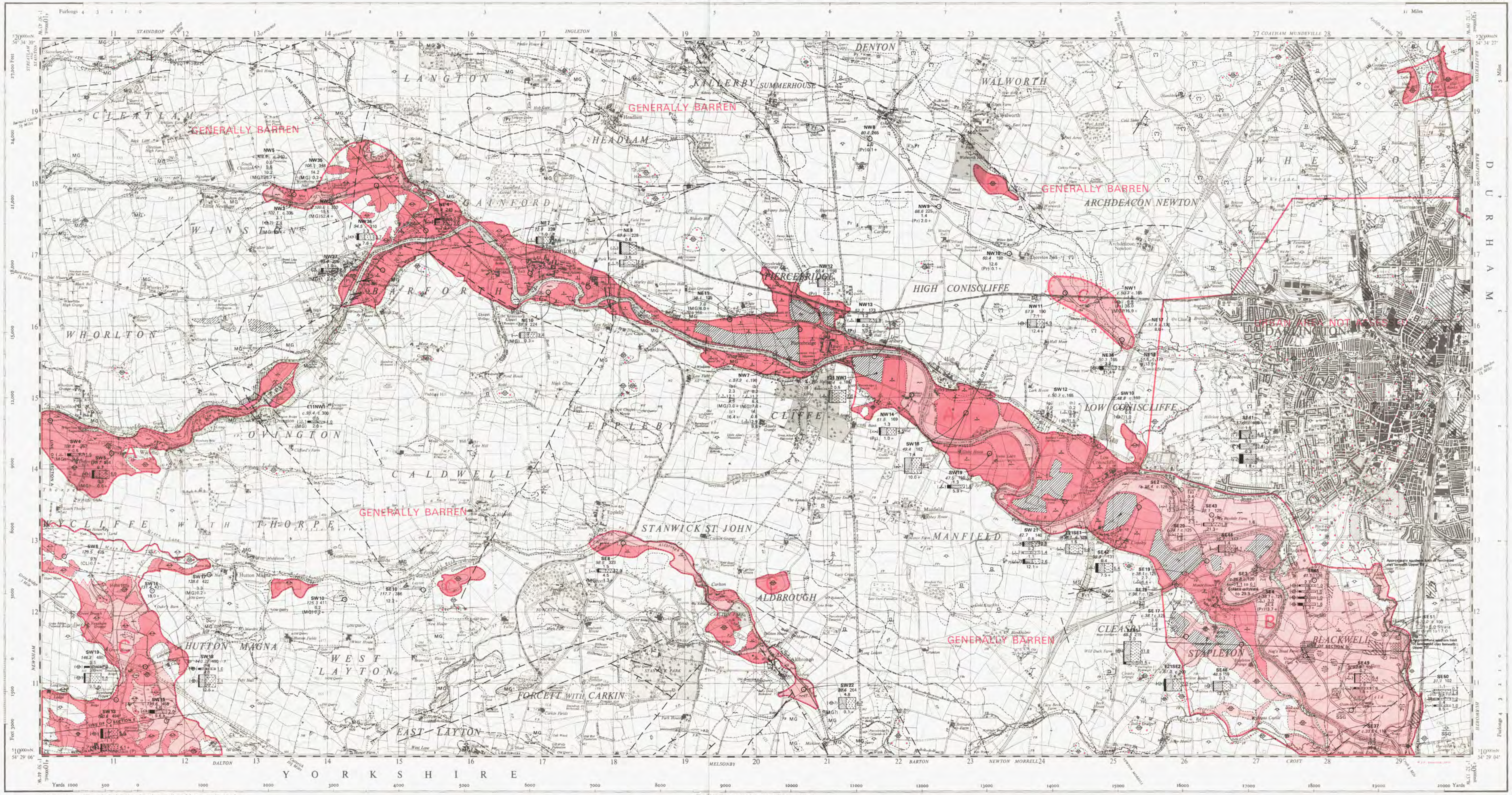
INSTITUTE OF GEOLOGICAL SCIENCES

INDUSTRIAL MINERALS ASSESSMENT UNIT

THE SAND & GRAVEL RESOURCES OF SHEET NZ 11 & NZ 21 (WEST OF DARLINGTON, Co. DURHAM)

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

ORDNANCE SURVEY SHEET NZ11 & NZ21 PROVISIONAL EDITION



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

Original geological survey on the six-inch scale by H.H.Howell, W.Gunn and A.G.Cameron in 1871 to 1879.

Resurveyed on the six-inch scale by D.A.C.Mills, J.H.Hull and D.H.Land in 1960-1973; A.W.Woodland, E.H.Francis and B.J.Taylor, District Geologists.
Included in One-Inch Geological Sheet 32 and 1:50000 Geological Sheet 33. Partially revised by J.H.Hull and A.Smith in 1976.

Sand and Gravel Survey by A.Smith, J.R.Gozzard, K.Chell and A.Halker in 1974-1976 under the supervision of D.Price and B.J.Taylor.
R.G.Thurrell, Head, Industrial Minerals Assessment Unit.

1:25000 Sand and Gravel Resource Sheet published 1978.
Austin W. Woodland, C.B.E., Director, Institute of Geological Sciences, incorporating the Geological Survey of Great Britain, the Museum of Practical Geology and Overseas Geological Surveys.
1100/79

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.

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.

Compiled from 6" sheets last fully revised 1912-19.
Other partial systematic revision 1938-51 has been incorporated.
Some major roads revised 1965.

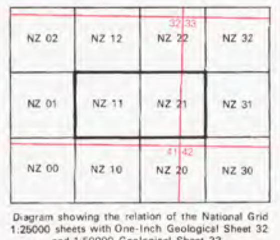


Diagram showing the relation of the National Grid 1:25000 sheets with One-Inch Geological Sheet 32 and 1:50000 Geological Sheet 33.

THE SAND & GRAVEL RESOURCES OF SHEETS NZ11 & NZ21 (WEST DARLINGTON, CO. DURHAM)

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

40

EXPLANATION OF SYMBOLS AND ABBREVIATIONS.

- **Landslip** L-1
- **Foundered ground** F-1

DRIFT (RECENT AND PLEISTOCENE)

- **Peat** P-1
- **Alluvium**-clays, silts, sand and gravel. A-17
- **River Terrace Deposits, Undifferentiated**-sand and gravel with some silt and clay. RT-10
- **River Terrace Deposits, First to Fourth**-sand and gravel with some silt and clay. RT-11
- **Post-Glacial Lake Deposits**-clay, silt and peat. PO-1
- **Fluvio-glacial and Older River Deposits**-sand and gravel with some clay. FL-1
- **Glacial Sand and Gravel**-sand and gravel with some clay. GS-24
- **Morainic Drift**-stony clay with sand and gravel locally. MD-1
- **Laminated Clay**-pebble-free clay. LC-1
- **Boulder Clay and Undifferentiated Drift**-clay and stony clay with silt, sand and gravel locally. BC-14

SOLID

- SSG **Sherwood Sandstone Group ('Bunter' Sandstone)**-red quartzitic sandstone. (PERMO-TRIASSIC)
- Pr **Permian, undivided**-including dolomitic limestones and marls. (PERMO-TRIASSIC)
- MG **Millstone Grit Series, undivided**-including sandstones, shales and limestones. (CARBONIFEROUS)
- CL **Carboniferous Limestone Series, undivided**-including limestones with sandstones and shales. (CARBONIFEROUS)

- **Made Ground** MG-2
- **Worked-out area of sand and gravel.** WO-9
- **Worked-out opencast area of coal** WO-14

BOUNDARY LINES

- Geological boundary, Drift.
- Geological boundary, Solid.
- Fault, crossmark indicates downthrow side.
- Limit of laminated clay beneath Upper Till.
- Inferred boundary between recognised categories of deposits.
- Resource Block boundary.

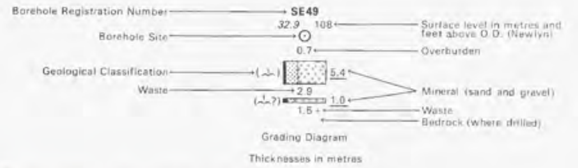
Broken lines denote uncertainty.

BOREHOLE DATA

SITE LOCATIONS

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

I.M.A.U. BOREHOLES



Note:
(i) Figures underlined denote thicknesses used in the assessment of resources.
(ii) The + sign indicates that the base of the deposit was not reached.
(iii) The figures in *italics* are the metric conversions of the measurements recorded in feet.
(iv) 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, e.g. **SE49** The letters refer to the quarter sheet and the figures to the I.G.S. serial number for that quarter. The unique designation for borehole **SE49** is **NZ21 SE49**.

Grading Diagrams

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

Sand (+1/16-4mm) — Fines (1/16mm) — Gravel (+4mm)

The height of the diagram is proportional to the mineral thickness.
The widths of the divisions shown 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 river and quarry sections is shown in the same way as for boreholes but it is located by an asterisk thus. * They are registered in their own series and have prefix E.

CATEGORIES OF DEPOSITS

- **Exposed mineral** CAT-E6
- **Continuous or almost continuous spreads of mineral beneath overburden.** CAT-C2
- **Sand and gravel either not potentially workable (see Report) or absent.** CAT-A2
- **Sand and gravel not assessed.** CAT-N1

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

RESOURCE BLOCKS

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

Horizontal sections across the district showing the general relations of the mineral-bearing drift deposits along lines of section A-E on this map are shown in Fig.2 of the Report.

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

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