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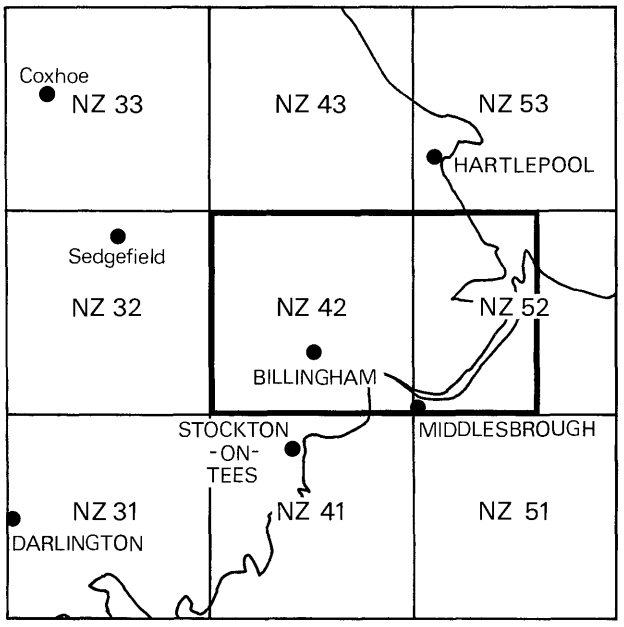

The sand and gravel resources of the country north and west of Billingham, Cleveland

Description of 1:25 000 sheets NZ 42 and part of NZ 52

J. W. C. James

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The first twelve reports on the assessment of British sand and gravel resources appeared in the Report Series of the Institute of Geological Sciences as a subseries. Report No. 13 and subsequent reports appear as Mineral Assessment Reports of the Institute.

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

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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 the country north and west of Billingham, Cleveland, shown on the accompanying 1:25 000 resource map NZ 42 and part of NZ 52. The survey was conducted by Mr J. W. C. James assisted in the drilling and sampling programme by Mr D. A. Abraham. The work is based on six-inch scale geological surveys by D. B. Smith in 1963-69 and G. D. Gaunt in 1954-56, published in part on New Series one-inch geological sheet 27 (Durham).

Mr T. D. Hillyard (PSA, Land Agent) was responsible for negotiating access to land for drilling. The ready cooperation of landowners and tenants in this work is gratefully acknowledged.

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SUMMARY

The geological maps of the Institute of Geological Sciences, pre-existing borehole information, and 70 boreholes drilled for the Industrial Minerals Assessment Unit form the basis of the assessment of the sand and gravel resources of the country north and west of Billingham, Cleveland.

All the deposits in the district that 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 mineral-bearing ground is divided into two resource blocks, containing 12.5 and 10.6 km^2 of potentially workable sand and gravel. For each block the geology of the deposits is described, and the mineral-bearing area, the mean thickness of overburden and mineral and the mean gradings are stated. Detailed borehole data are also given. The geology, the position of the boreholes and the outlines of the resource blocks are shown on the accompanying map.

Notes

Each borehole registered with the Institute is identified by a four-element code (e.g. NZ 42 NW 32). The first two elements define the 10-km square (of the National Grid) in which the borehole is situated; the third element defines a quadrant of that square, and the fourth is the accession number of the borehole. In the text of the report the letters NZ are normally omitted.

All National Grid references in this publication lie within the 100-km square NZ unless otherwise stated. Grid references may be given to eight figures, accurate to within 10 m, and four- or six-figures for more extensive locations.

Bibliographical reference

JAMES, J. W. C. 1982. The sand and gravel resources of the country north and west of Billingham, Cleveland: description of 1:25 000 sheet NZ 42 and part of NZ 52. **Miner. Assess. Rep. Inst. Geol. Sci.**, No. 99.

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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, neither the economic nor the social factors used to decide whether a deposit may be workable in the future can 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, 1981; Harris and others, 1974).

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

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

a The deposit should average at least 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 B.S. sieve, about 1/16 mm) should not exceed 40 per cent.
d The deposit should lie within 25 m of the surface, this being taken as the likely maximum working depth under most circumstances. It follows from the second criterion that boreholes are drilled no deeper than 18 m if no sand and gravel has been proved.

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

Pre-Pleistocene rocks, which are usually consolidated and devoid of potentially workable sand and gravel, are referred to as 'bedrock'; 'waste' is any material other than bedrock or mineral; 'overburden' is waste that occurs between the surface and an underlying body of mineral.

For the particular needs of assessing sand and gravel resources, a grain-size classification based on the geometric scale 1/16 mm, ¼ mm, 1 mm, 4 mm, 16 mm, 64 mm has been adopted. The boundaries between fines (that is, the clay and silt fractions) and sand, and between sand and gravel material, are placed at 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

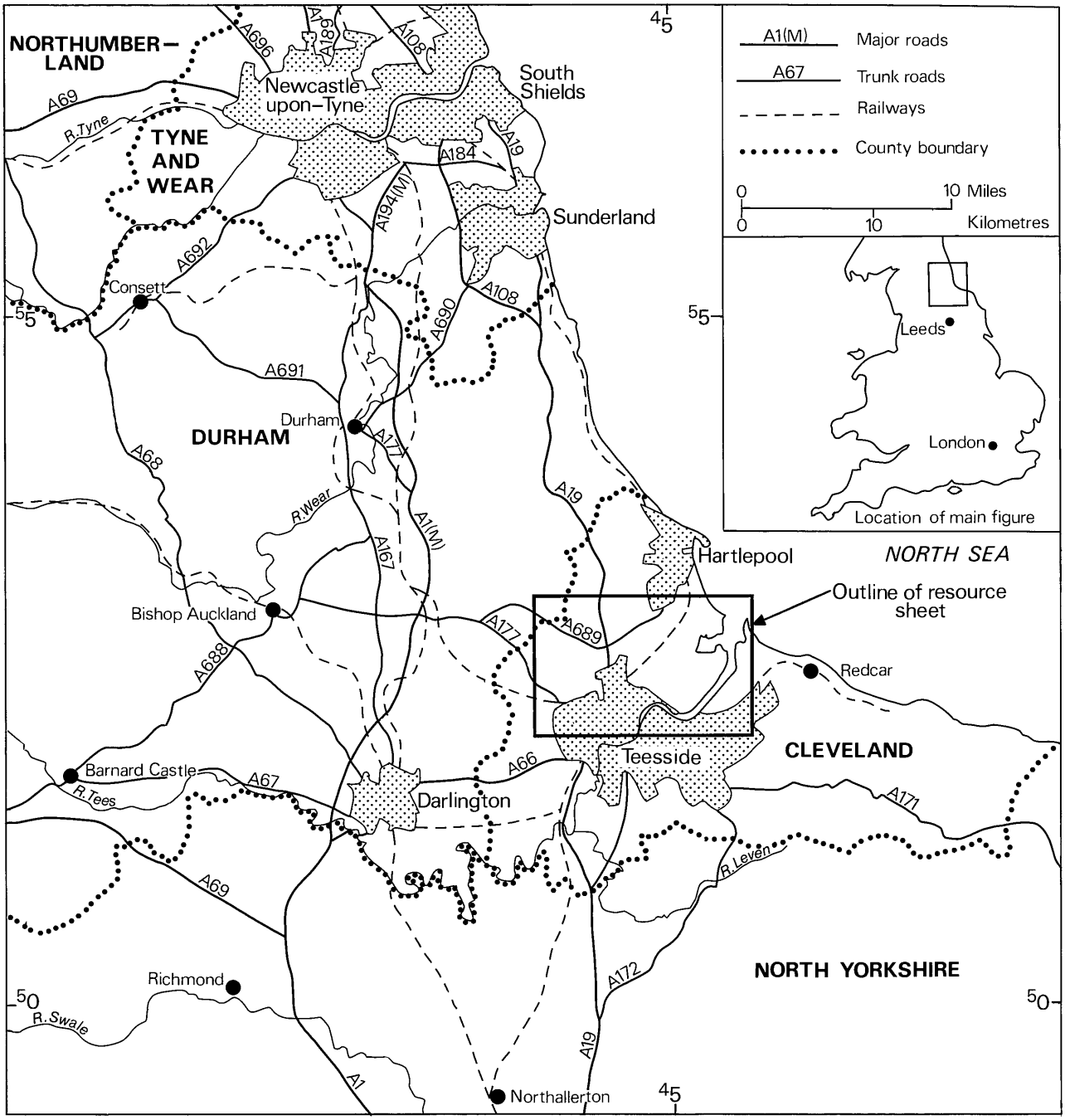

Figure 1 Sketch-map showing the location of the district.

approximately 10 km^2 of sand and gravel. No account is taken of any factors, for example roads, villages or land of 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 mineral in parts of a block, except in the immediate vicinity of the actual sample points.

DESCRIPTION OF THE DISTRICT

GENERAL

From the mouth of the Tees (Figure 1) the land forms a plain which rises to the west, gently at first but then more steeply, to attain a height of over 96 m above OD in the north-west corner of the district. Within the higher ground, Billingham and Close becks and their tributaries have incised relatively deep valleys; they drain ultimately into the River Tees.

Ever since the Industrial Revolution the Tees has been a focus for heavy engineering, shipbuilding, steel making, and chemicals manufacture, originally based on local salt and anhydrite. These activities continue but have been eclipsed by the development of the petrochemical industry, with major works at Billingham and new plant allied to a North Sea oil pipeline on Seal Sands. A nuclear power station is under construction at Graythorp, south of West Hartlepool. Outside the urban and industrial areas most of the land is given over to agriculture.

GEOLOGY

The drift deposits of the area and the 'solid' formations which crop out beneath them are listed in Table 1 and described briefly below. Further details may be found in the Northern England regional guide (Taylor and others, 1971), The geology of Durham County (Smith 1970, p. 66) and, for the northernmost part, in the Durham and West Hartlepool memoir (Smith and Francis, 1967).

Table 1 Stratigraphy.

DRIFT	
Recent and **Pleistocene**	Blown Sand
	Peat
	Lacustrine Alluvium
	Alluvium and Alluvial Fan
	Marine or Estuarine Alluvium
	Head
	Glacial Sand and Gravel
	Laminated Clay
	Boulder Clay (Till) and Glacial Drift, undifferentiated
SOLID	
Jurassic	Lias
Trias and **Permian**	Rhaetic
	Mercia Mudstone Group (Keuper Marl)
	Sherwood Sandstone Group (Bunter Sandstone)
	Permian Upper Marls
	Upper Magnesian Limestone (Seaham Formation)
	Permian Middle Marls
	Middle Magnesian Limestone

Solid

Beneath the district, the Carboniferous land surface was very uneven, with the relief approaching 250 m. This resulted in great variation in thickness and lithology of the unconformably overlying Permian sediments, up to, and in places including, the Upper Magnesian Limestone.

The Middle Magnesian Limestone, the oldest formation to crop out beneath drift, comprises white to pale grey, mainly oolitic dolomite with scattered bivalves, and with secondary anhydrite at depth. Above are the Permian Middle Marls, red and grey mudstones and siltstones with nodular and bedded anhydrite or their residues at many levels; they pass locally into continental breccias, and are collapse-brecciated where the interbedded evaporites have been dissolved.

The Upper Magnesian Limestone comprises thinly bedded fine-grained dolomite with scattered bivalves and abundant **Calcinema permiana.** It is overlain by the Permian Upper Marls which consist of reddish brown mudstone and siltstone with thin red sandstones. At their base is the Billingham Main Anhydrite or its residue, one of the resources on which the Teesside chemical industry was originally based; where present it is generally 4.5 m to 7.6 m thick but it thins gradually to the west. Halite, commonly about 35 m thick, overlies the anhydrite in a narrow coastal strip from Greatham southwards but thins out rapidly towards the west.

By gradual increase in sand content the Permian Upper Marls pass diachronously upwards into the Sherwood Sandstone Group (Bunter Sandstone), a soft red sandstone with subordinate beds of red mudstone and siltstone. It is unconformably overlain by the Mercia Mudstone Group (Keuper Marl) which comprises a thin sandy basal bed succeeded by purple, green, red and grey mudstones and siltstones with traces of evaporites in the lower part.

The Mercia Mudstone is succeeded at a marked colour and lithology boundary by the Rhaetic, which consists of dark grey or black shaly mudstones overlain by pale grey or green, finely laminated, soft mudstones. The Rhaetic marks the initiation of the marine transgression that continued into the Lias. Only the lower part of the latter is found in the district; it comprises soft grey partly micaceous shales with some beds of fine sandstone and thin limestones and many calcareous and sideritic concretions.

Drift

Drift shrouds almost the whole of the district, solid rocks having been recorded at surface only at North Burn [463 274] (Smith, 1965, p. 58). None of the 70 widely scattered boreholes drilled for the assessment proved the base of the drift even though the majority of them reached depths of from 18 m to 25 m. The thickest recorded drift cover is found in the north-west corner of the district where 67.1 m of boulder clay rests on Permian strata.

Glacial deposits constitute the major part of the drift and most, if not all, of these are the product of the last, Devensian, glaciation. The preponderance within the glacial deposits of Carboniferous and Permian material indicates that ice moved across these strata before entering the district. Lesser numbers of farther-travelled erratics from the Lake District, Scotland and the Cheviots are also found, indicating a more distant source of ice. This and other evidence has been cited to postulate major ice sheets flowing into the Tees Lowlands over Stainmore to the west, and from the Cheviots and Southern Scotland to the north. These were supplemented by more local ice from the eastern slopes of the Pennines (Taylor and others 1971, p. 85-89).

The apparent homogeneity of the boulder clay (till) found in this survey makes any stratigraphic subdivision difficult, bearing in mind that no systematic research has yet been undertaken on stone content or mineralogy. Further, the fact that IMAU boreholes did not reach bedrock means that the conclusions reached are generally valid only for the top 18-25 m of the drift.

However, in places there does appear to be evidence for some order in the glacial drift sequence. For example, south of Billingham Beck [450 234] there is an extensive deposit of glacial sand and gravel which is overlain by a boulder clay up to at least 16.5 m thick and underlain by boulder clay which may exceed 9.0 m in thickness. Neither boulder clay is constant in thickness or elevation.

North of Billingham Beck, in ground above 35 m to 40 m OD, the crude consistency of this sequence is lost in a more heterogeneous mixture of boulder clay, laminated clay, silt, sand and gravel. Beneath lower ground to the east, which extends to the sea at Tees Bay, some boreholes, particularly those east of Greatham [493 275], reveal an irregular threefold division but primarily with laminated clays and silts sandwiched between boulder clay. As yet there is insufficient evidence to show that correlation of these crude sequences is possible across the district.

Boulder Clay (Till) This, the predominant glacial deposit, consists of generally brown, massive, partly silty, stony clay. Erratics are usually less than 6 mm in diameter although larger pebbles and cobbles are also present; they are mainly of Permian limestone and dolomite and Carboniferous sandstone and limestone, but also include mudstone, siltstone, quartz, coal, greywacke and red Permo-Triassic sandstone and, less commonly, porphyries, lavas and granites from the Cheviots, Scotland and the Lake District.

The boulder clay is in many places interbedded with beds of sand, silt and silty clay up to about 10 m thick, pebbly sands and gravels up to 1.5 m thick, and stoneless, generally laminated clays up to 10.6 m thick. Commonly these cannot be mapped readily; they are designated 'Glacial Drift, undifferentiated' and included within the boulder clay outcrop. They are classified as such in Appendix E of this report where to do otherwise would involve excessive subdivision of the abridged borehole logs.

Glacial Sand and Gravel The relationship of the Glacial Sand and Gravel to the other elements of the drift sequence is complex, both vertically through the succession and laterally across the district. It is generally subordinate to boulder clay (till) but in some

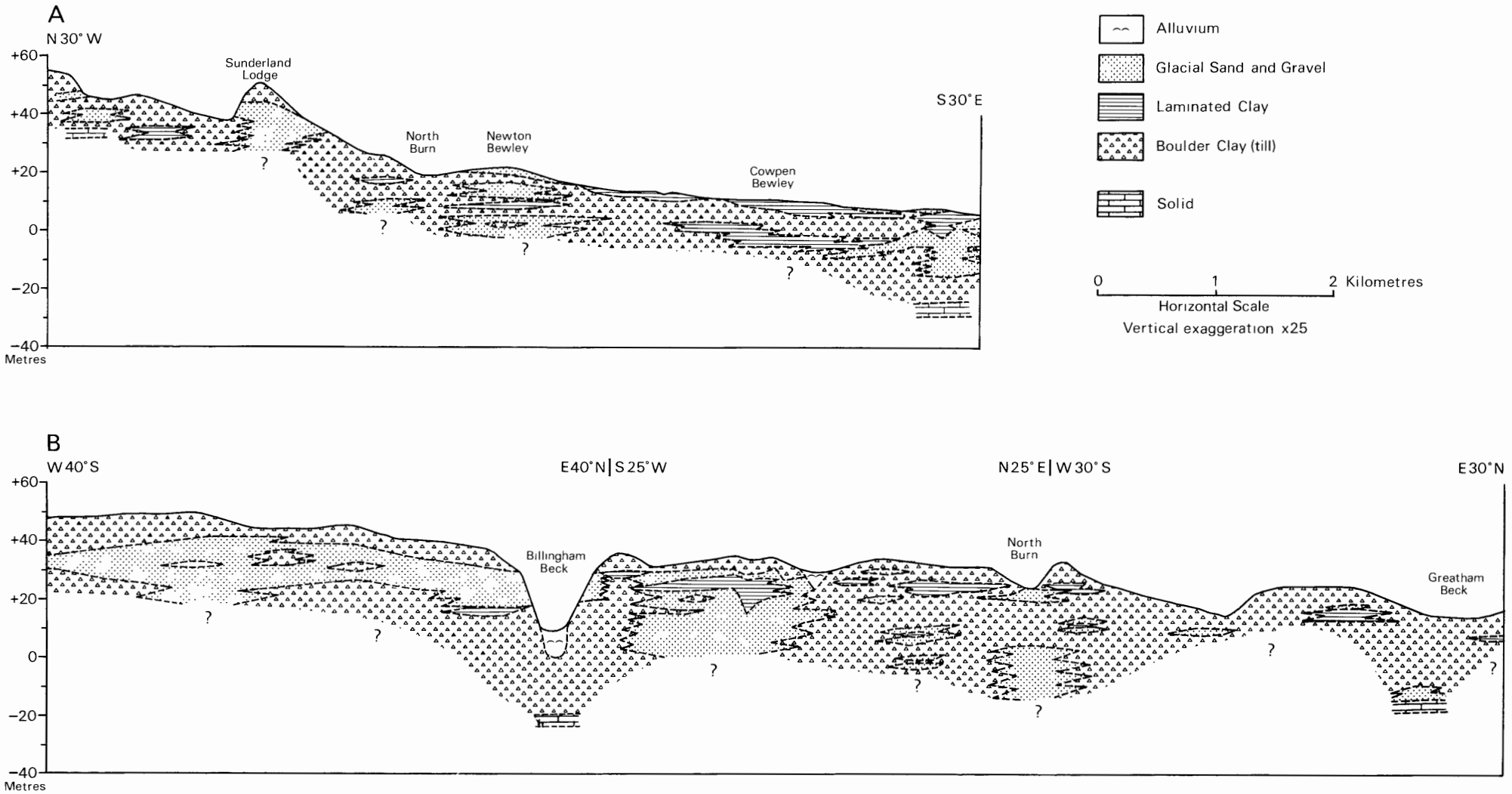

Figure 2 Schematic cross-sections across the district.

areas forms a significant part of the succession. It ranges from small lenses less than 0.5 m thick within the boulder clay to relatively extensive spreads more than 25 m thick (as at IMAU boreholes 42 NE 96 and 97), but the thicker sequences often contain beds of silt and clay.

Outcrops of Glacial Sand and Gravel range from those of less than a hectare to the large expanse, approximately a kilometre wide, which stretches southwards from Newton Bewley [466 267] to Billingham Beck.

On the higher ground north of Billingham Beck in the western half of the district numerous thin continuous outcrops are mapped along valley sides and follow the contours round hillsides. They might be thought to suggest the presence of an extensive spread of glacial sand and gravel beneath boulder clay but IMAU boreholes have not shown this to be the case.

South of Billingham Beck in the south-west corner of the district, borehole evidence suggests an extensive, although not completely continuous, spread of Glacial Sand and Gravel mainly underlying boulder clay (see Figure 2, section B). It crops out in the urban area around Norton [444 220] and appears to extend northeastwards across Billingham Beck to beyond Newton Bewley. In many places the deposit passes both laterally and vertically into laminated clays and silts, as in boreholes 42 SW 36 and SW 43.

Elsewhere in the district thick sequences of Glacial Sand and Gravel are found only in isolated boreholes. Some are associated with hilly features such as at Sunderland Lodge (see Figure 2, Section A), while others show no such association.

Over half the Glacial Sand and Gravel found in IMAU boreholes consists of brown to reddish brown 'very clayey' and 'clayey' sand, and it is sand which is generally found at surface (for definitions of terms, see Appendix C). Varying amounts of gravel were proven at depth, but only in three boreholes (42 NW 27, NE 96 and SW 36) was the fraction found throughout any considerable thickness. The composition of the Glacial Sand and Gravel is more fully described under 'Composition of the Sand and Gravel Deposits' (below).

Laminated Clay Laminated clays are found both interbedded with boulder clay and Glacial Sand and Gravel and overlying them. The youngest of them occupy a large part of the lower Tees plain and crop out around Billingham and Cowpen Bewley [481 248], as well as beneath made ground south of the river. They are generally reddish brown but are grey in places. They are silty and contain laminae of fine-grained micaceous quartz sand with some coal debris. Thin stony clays may also be present.

The clays were particularly well developed in IMAU boreholes around Cowpen Bewley (Figure 3), where the majority of IMAU boreholes found them to be up to 5.0 m thick at or near the surface. Laminated clays are also present in the underlying boulder clay; they range from 0.2 to 5.4 m in thickness and in elevation from 3 m above OD to 15 m below OD. In some boreholes these latter clays are associated with silts, sands and silty clays, and together, they are from 3.4 m to 17.0 m thick.

In IMAU boreholes the younger clays have not been found above 13.1 m OD in this area, although Agar (1954) suggested that the sands at the surface between Newton Bewley and Norton, at a higher level (Figure 2, section A), might have been deposited contemporaneously. Boreholes within this latter area have found laminated clays within sands lying beneath boulder clay. They are 2.0 to 12.0 m thick and generally lie at about 20 to 25 m above OD, but they were found at 5 m above OD south of Norton. Although at a higher elevation than the laminated clays within the boulder clay around Cowpen Bewley, they may have formed penecontemporaneously with them.

The variability in altitude and thickness of the laminated clays of the district and their close association with silts and sands indicates a heterogeneous depositional environment, probably with many ponds and lakes being formed across the district at different times during the glacial period, as well as the large late- to post-glacial lake, in which were deposited the younger laminated clays that are found at the surface in the lower Tees plain.

Head Solifluction deposits have accumulated on the sides and floors of many valleys, and in small patches on slopes and depressions within the boulder clay terrain of the higher western part of the district. They generally consist of stony clay.

Marine or Estuarine Alluvium A strip of marine or estuarine alluvium up to nearly 3 km wide occupies the coastal area south of Seaton Carew and the ground immediately west of Seal Sands. It comprises grey to brown silt and clay with beds of peat in places, and includes sparingly scattered recent marine shell fragments. It has been proved to be up to 12 m thick.

Alluvium The major valleys are floored with alluvium as are many of their tributaries. Some of the latter extend small fans into the larger valleys. Alluvium is also found in small depressions on boulder clay. The deposits are diverse in character, being mainly of silt and clay with some peat and bands of sand and gravel.

Lacustrine Alluvium Small flat areas of lacustrine alluvium mark the site of lakes which may range from Recent to Late-Glacial in age. They consist generally of micaceous clay, silt and sand.

Peat Within the district, surface peat is only found 1 km south of Thorpe Thewles [400 219], where it partially fills an alluvial hollow. However, peat has been encountered by a number of boreholes sunk into marine, estuarine and freshwater alluvium and it is exposed in the beds of several streams. It is commonly less than a metre thick, although 6.6 m of peaty clay was recorded in IMAU borehole 42 NE 105.

Blown Sand A belt of blown sand stretches southeastwards from Seaton Carew, reaching a width of about 400 m at North Gare Breakwater. It largely comprises a stable ridge on the western side with an active dune ridge to the east (Smith and Francis, 1967, p. 250). Boreholes have shown the sand to be up to 7.0 m thick on Seaton Carew golf course. Ridges of blown sand are also found on the eastern side of Teesmouth.

COMPOSITION OF THE SAND AND GRAVEL DEPOSITS

Within the district, potentially workable sand and gravel exists in the Glacial Sand and Gravel, alluvium, blown sand and beach sand, although the last-named has not been included in this assessment.

Glacial Sand and Gravel The mineral of this deposit has a mean grading of fines 16 per cent, sand 73 per cent and gravel 11 per cent. It ranges in composition from 'very clayey' sand to gravel, but the latter is uncommon.

The sand consists of fine- to medium-grained, subangular to rounded quartz with subordinate sandstone, limestone, dolomite and some quartzite and coal. The gravel fraction, when present, is fine and coarse with a few cobbles in places, and comprises subangular to rounded dolomite, sandstone and limestone with igneous rocks and some quartzite, silicified limestone and mudstone.

Alluvium Only one assessment borehole, 42 SW 33, out of six drilled into alluvium proved mineral. It had a mean grading of fines 3 per cent, sand 48 per cent and gravel 49 per cent. The sand fraction is predominantly coarse- to medium-grained and comprises subrounded to rounded sandstone, dolomite and limestone with subordinate

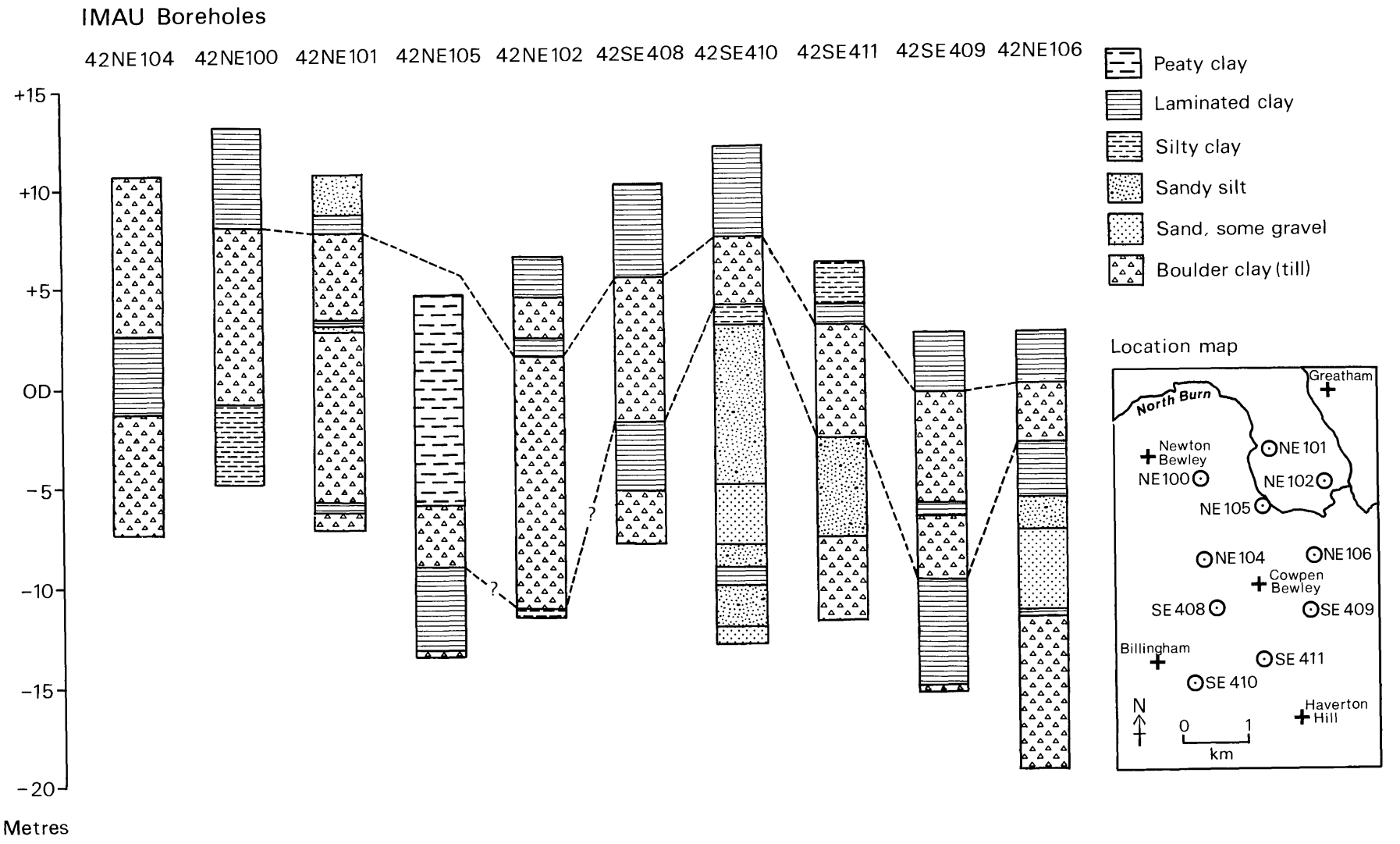

Figure 3 Comparative sections of IMAU boreholes in a part of the Lower Tees plain.

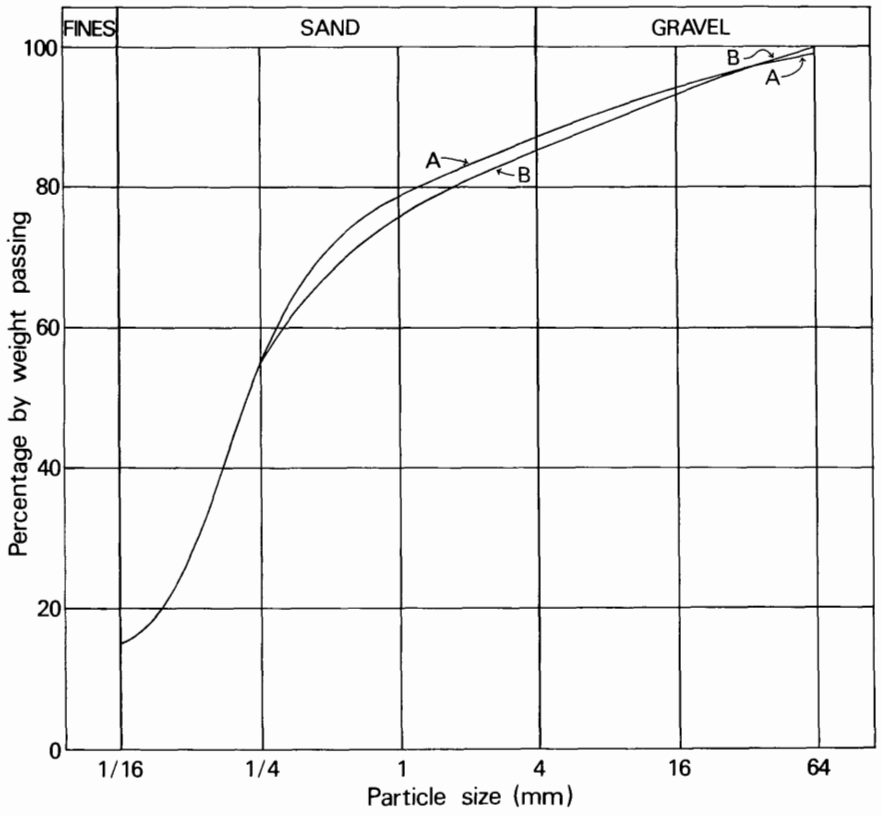

Figure 4 Mean particle-size distributions for the mineral in resource blocks A and B, based on data from IMAU boreholes

Block	Percentages by weight						
	$-\frac{1}{16}$ mm	$+\frac{1}{16}$ mm $-\frac{1}{4}$ mm	$+\frac{1}{4}$ mm -1 mm	+1 mm -4 mm	+4 mm -16 mm	+16 mm -64 mm	+64 mm
A	15	40	24	8	7	5	1
B	15	40	21	9	8	7	trace

quartz and igneous rocks and some quartzite, silicified limestone and mudstone. The gravel is fine and coarse with some cobbles, and consists of similar material to the sand fraction but with only a minor proportion of quartz and the addition of some soft red sandstone and a trace of ironstone.

Blown Sand No IMAU borehole penetrated this deposit and therefore no comprehensive information is available as to its composition and grade. At the surface it consists generally of fine- and medium-grained sand.

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, on which the topography is shown by contours in grey, the geological data in black and the mineral resource information in shades of red.

Geological data The geological boundary lines, symbols, etc., shown are taken from the geological map of this area, which was surveyed recently at the scale of 1:10 560. This information was obtained by detailed application of field mapping techniques by Drs. D. B. Smith and G. D. Gaunt. Borehole data, which include the stratigraphic relations, thicknesses and mean particle size distribution of the sand and gravel samples collected during the assessment survey, are also shown.

The geological boundaries are the best interpretation of the information available at the time of field mapping. However, this assessment survey indicates that the Glacial Sand and Gravel may not, in places, be as extensive beneath boulder clay as suggested by the geological boundaries, nor where mapped as an outcrop is the Glacial Sand and Gravel always as close to the surface as indicated (as for example at boreholes 42 NE 99 and NE 102). These factors are taken into account in the assessment of resources. It is inevitable, particularly with drift deposits which change rapidly vertically and laterally, that further local irregularities or discrepancies will be revealed by future borings and excavations.

Mineral resource information For assessment purposes, the area is divided into resource blocks (see Appendix A) which are subdivided into areas where mineral is 'exposed', areas where mineral is present beneath overburden, and areas where sand and gravel is absent or not potentially workable. The mineral is identified as 'exposed' where the overburden, commonly consisting only of soil and subsoil, averages less than 1.0 m in thickness. Areas where bedrock outcrops, where boreholes indicate absence of sand and gravel beneath cover, and where sand and gravel beneath cover is interpreted to be not potentially workable are uncoloured on the Map. In such areas it has been assumed that mineral is absent except in infrequent and relatively minor patches which can neither be outlined nor assessed quantitatively in the context of this survey.

Table 2 The sand and gravel resources of sheet NZ 42 and part of NZ 52: statistical assessment.

Block	Area		Mean thickness			Volume of sand and gravel			Mean grading percentage		
	Block	Mineral	Overburden	Mineral	Waste		Limits at the 95% probability level		Fines $-\frac{1}{16}$ mm	Sand $+\frac{1}{16}$ -4 mm	Gravel +4 mm
	km^2	km^2	m	m	m	$m^3 \times 10^6$	± %	± $m^3 \times 10^6$			
A	12.7	12.5	6.9	6.8	5.9	85	50	43	15	72	13
B	65.0	10.6	4.7	9.5	6.7	101	31	31	15	70	15
A + B	77.7	23.1	5.8	8.1	6.3	186	26	48	15	71	14

Where possible, the limits of the different categories of deposits are based on the mapped geological boundaries. Where there is a transition from one category to another which is independent of the geological lines and which could not be accurately delineated during this survey, inferred boundaries have been inserted. Such boundaries are shown by a distinctive symbol. The symbol is intended to convey an approximate location within a likely zone of occurrence, rather than to represent the breadth of the zone, its size being limited only by cartographic considerations. For the purpose of measuring area the centre-line of the symbol is used.

RESULTS

The statistical results are summarised in Table 2. Fuller grading particulars are shown in Figures 4, 5 and 6 and Tables 3 and 4; the cumulative grading curves are based on up to 11 data points.

For the two resource blocks, A and B, the accuracy of the results at the symmetrical 95 per cent probability level (that is, on average nineteen out of every twenty sets of limits constructed in this way contain the true value for the volume of mineral) is 50 per cent and 31 per cent respectively (Appendix B). However, the true values are more likely to be nearer the figures estimated than either of the limits. Moreover, it is probable that approximately the same percentage limits would apply for the estimate of volume of a very much smaller parcel of ground (say, 100 hectares) containing similar sand and gravel deposits if the results from the same number of sample points were used in the calculation. Thus, if closer limits are needed for the quotation of reserves of part of a block, it can be expected that data from more points will be required, even if the area is quite small. This point can be illustrated by considering the whole of the potentially workable sand and gravel on this sheet. The volume (186 million m^3) can be estimated to limits of ± 26 per cent at the 95 per cent probability level, by a calculation based on the data from 27 sample points spread across the two resource blocks.

However, it must be emphasised that the quoted volume of sand and gravel bears no simple relationship to the amount that could be extracted in practice, as no allowance has been made in the calculations for any restraints (such as existing buildings and roads) on the use of land for mineral working.

NOTES ON THE RESOURCE BLOCKS

Urban and industrial development accounts for 42 per cent of the land area shown on the resource sheet. The remainder is divided into two resource blocks. Block A occupies the south-west corner of the district; the mineral within it is either exposed at the surface or is apparently almost continuous beneath overburden. The remaining assessed area comprises Block B, of which only a small part is deemed to contain potentially workable sand and gravel.

Block A (Figure 5, Table 3)

The mineral of this block comprises glacial sand and gravel which is exposed in valley sides but is for the most part overlain by boulder clay, together with alluvial sand and gravel in the valley of Billingham Beck. The assessment is based on eleven IMAU boreholes and fourteen others. Five boreholes, including IMAU boreholes 42 SW 41 and SW 43, found no mineral; the area of barren ground cannot be delimited but the 'nil' values of all these boreholes have been taken into account in assessing the resources.

The glacial mineral is generally a 'very clayey' or 'clayey' sand with some pebbly horizons. Gravel is found in significant amounts only at borehole site 42 SW 47. Proved thicknesses range up to 13.5 m, though boreholes 42 SW 45 and 47 did not bottom the deposit. Borehole 42 SW 33, sunk into the alluvium of Billingham Beck, found more than 21.0 m of gravel. The estimated volume of mineral in the block is 85 million m^3 ± 43 million m^3.

The glacial mineral is largely covered by boulder clay overburden, up to 16.5 m of which has been proved by boreholes. The alluvial mineral in borehole 42 SW 33 lay beneath 4.0 m of soil, clay, silt and peat.

Waste was encountered within mineral in only four boreholes and varied from 1.3 m to 9.1 m in thickness, with a mean of 3.9 m.

Block B (Figure 6, Table 4)

The potentially workable sand and gravel includes some blown sand but for the most part consists of glacial sand and gravel. The latter is commonly concealed beneath boulder clay and, therefore, is of uncertain extent but its presence is postulated in seven discrete areas ranging from 0.3 to 5.6 km^2. The remainder of the block is thought to be generally covered by clays and silts exceeding 18.0 m in thickness; some sand and gravel may be present but is believed to be not potentially workable because it is too thin, too deeply buried or too limited in extent.

The largest postulated area of glacial mineral lies around and to the south-west of Newton Bewley. Although the geological map shows 'exposed' Glacial Sand and Gravel over much of the area, boreholes have shown that silts and clays, up to 5.0 m thick occur at surface over a large part of the outcrop. Mineral ranges up to 19.0 m in proved thickness. It consists of 'very clayey' sand with sequences of 'clayey' sandy gravel and 'very clayey' pebbly sand. However, of the 28 boreholes used in the assessment of this area, five proved to be barren.

North of Newton Bewley, near Sunderland Lodge (Figure 2, Section A), five boreholes have proved potentially workable sand and gravel and, on the basis of these and the mapped outcrop, the presence of 2.1 km^2 of mineral is inferred. One IMAU borehole, 42 NW 27, found 12.6 m of gravel, but in the other, 42 NE 90, gravel has a more restricted development.

In the rest of the block five IMAU boreholes found significant thicknesses of glacial sand and gravel and suggest the presence of mineral in five small discrete areas. Proved thicknesses range up to 19.3 m, but only near Claxton [481 278] and Seaton Grange [512 298] is gravel present in appreciable amounts.

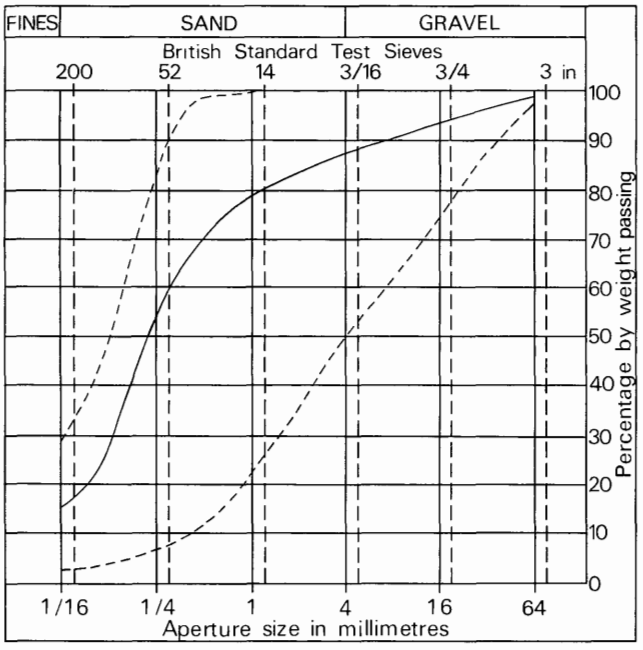

Figure 5 Grading characteristics of the mineral in block A: the continuous line represents the mean grading of the block; the broken lines denote the envelope within which the mean grading curves for individual gradings fall.

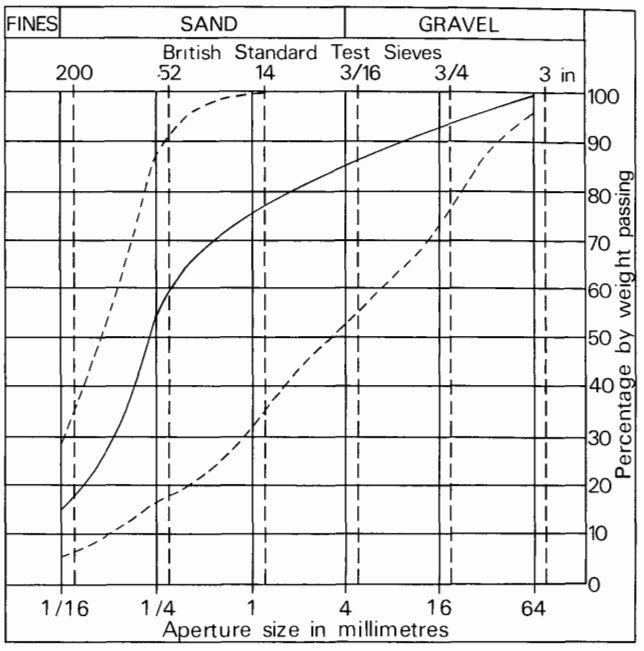

Figure 6 Grading characteristics of the mineral in block B: the continuous line represents the mean grading of the block; the broken lines denote the envelope within which the mean grading curves for individual gradings fall.

Table 3 Block A: data from IMAU boreholes.

Borehole	Recorded thickness (m)			Mean grading percentage						
	Mineral	Over-burden	Waste within mineral	Fines $-\frac{1}{16}$ mm	Fine sand $+\frac{1}{16}-\frac{1}{4}$ mm	Medium sand $+\frac{1}{4}$ -1 mm	Coarse sand +1 -4 mm	Fine gravel +4 -16 mm	Coarse gravel +16 -64 mm	Cobbles +64 mm
42 SW 32	9.5	14.9		24	60	16	trace	trace	0	0
42 SW 33	21.0+	4.0		3	4	17	27	24	23	2
42 SW 38	8.0	8.0		21	59	19	1	trace	0	0
42 SW 39	13.5	7.0		14	55	29	1	1	trace	0
42 SW 41	absent									
42 SW 42	10.4	6.3	1.3	29	54	12	2	2	1	0
42 SW 43	absent									
42 SW 44	4.8	13.7		12	25	62	1	trace	0	0
42 SW 45	8.7+	16.3		14	62	24	trace	0	0	0
42 SW 46	2.0	4.4		20	49	30	1	trace	0	0
42 SW 47	13.4	8.4	3.2	16	36	31	9	7	1	0

+ The plus sign indicates that the full thickness of mineral was not proved in the borehole.

Table 4 Block B: data from IMAU boreholes.

Borehole	Recorded thickness (m)			Mean grading percentage						
	Mineral	Over-burden	Waste within mineral	Fines $-\frac{1}{16}$ mm	Fine sand $+\frac{1}{16}-\frac{1}{4}$ mm	Medium sand $+\frac{1}{4}$ -1 mm	Coarse sand +1 -4 mm	Fine gravel +4 -16 mm	Coarse gravel +16 -64 mm	Cobbles +64 mm
42 SW 25	14.7+	10.3		24	64	11	1	trace	trace	0
42 NW 27	12.6+	12.4		8	12	18	15	22	24	1
42 NW 32	14.3+	8.0	2.7	12	55	22	4	5	2	trace
42 NE 90	16.6+	6.8	1.6	20	49	21	5	4	1	0
42 NE 96	14.9+	2.4	7.7	9	7	15	24	19	23	3
42 NE 97	19.3	0.6	1.7	13	48	35	3	1	trace	0
42 NE 98	nil									
42 NE 99	5.6	4.4		27	50	8	5	4	6	0
42 NE 103	3.6	5.0		24	52	24	trace	0	0	0
42 SW 36	12.3	7.6	2.5	16	16	25	14	16	13	0
42 SW 37	2.0	5.0		29	54	13	2	1	1	0
42 SE 407	13.9	0.3	6.0	15	37	29	12	6	1	0
52 NW 178	7.8+	17.2		9	49	18	12	8	4	trace

+ The plus sign indicates that the full thickness of mineral was not proved in the borehole.

Four non-IMAU boreholes at Seaton Sands [530 290] proved blown sand up to 7.0 m thick. In two of the boreholes glacial sand and gravel was also found, separated from the blown sand by grey silt.

The estimated volume of mineral within the block is 101 million $m^3 \pm 31$ million m^3. The mean grading of the glacial mineral is 15 per cent fines, 70 per cent sand and 15 per cent gravel; no grading data are available for the blown sand.

The mineral is generally concealed beneath overburden which ranges up to the maximum of 18 m (see p. 1). Waste within mineral varies from 1.5 m to 12.0 m, with a mean for the mineral-bearing areas of 5.3 m.

NOTES ON THE SAND AND GRAVEL WORKINGS OF THE AREA

Table 5 gives brief details of the larger workings of the area. There are a number of very small disused sand and gravel pits in the higher ground of the district, generally on slopes and valley sides where Glacial Sand and Gravel crops out, e.g. along Billingham Beck. They are too small to be shown as 'areas worked for sand and gravel' on the resource map, although many of them are indicated on the Ordnance Survey base-map.

Table 5 List of active and disused workings.

Location	Grid Reference	Principal deposit worked
ACTIVE WORKINGS		
North Gare Foreshore	539 272	Modern beach sands
Off North Gare Sands (Harbour dredging)	55 28	Marine and estuarine sands
DISUSED WORKINGS		
Thorpe Thewles	40 23	Glacial Sand and Gravel
Wynyard Road, Grindon	414 247	Glacial Sand and Gravel
White House Farm, Norton	427 227	Glacial Sand and Gravel
Wolviston	460 261	Glacial Sand and Gravel
Claxton Quarry, Greatham	481 278	Glacial Sand and Gravel
Gravel Hole Farm, Norton	440 230	Glacial Sand and Gravel
Low Middlefield Farm	417 239	Glacial Sand and Gravel.

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APPENDIX A

FIELD AND LABORATORY PROCEDURES

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

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

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

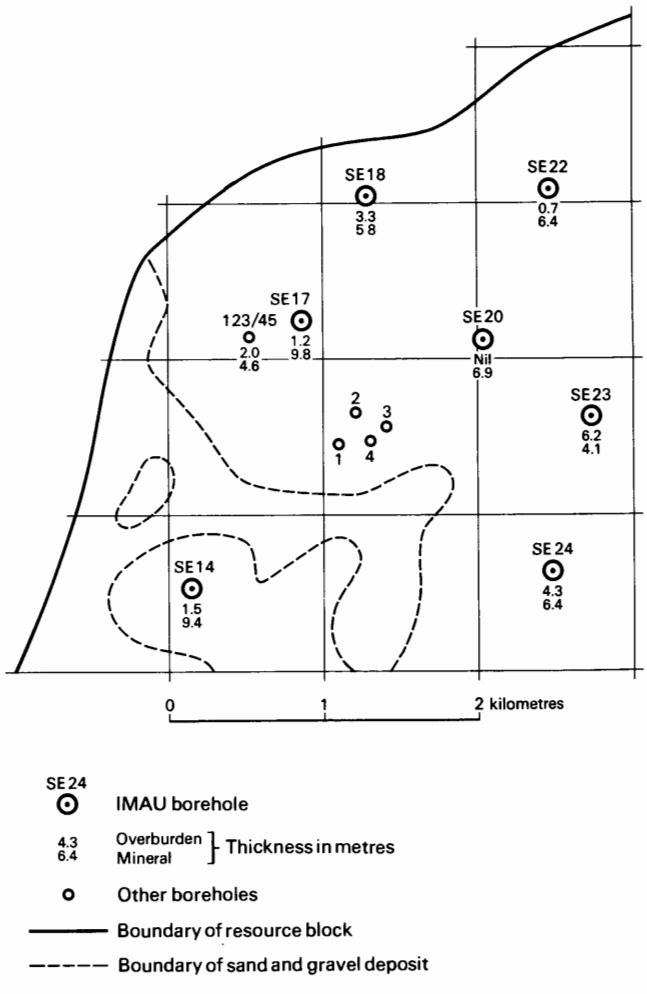
The drilling machine employed should be capable of providing a continuous sample representative of all unconsolidated deposits, so that the in-situ grading can be determined, if necessary, to a depth of 30 m (100 ft) at a diameter of about 200 mm (8 in), beneath different types of overburden. It should be reliable, quiet, mobile and relatively small (so that it can be moved to sites of difficult access). Shell and auger rigs have proved to be almost ideal.

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

A continuous series of bulk samples is taken throughout the sand and gravel. Ideally samples are composed exclusively of the whole of the material encountered in the borehole between stated depths. However, care is taken to discard, as far as possible, material which has caved or has been pumped from the bottom of the hole. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel, or at every 1 m (3.3 ft) depth. The samples, each weighing between 25 and 45 kg (55 and 100 lb), are despatched in heavy-duty polythene bags to a laboratory for grading. The grading procedure is based on B.S. 1337 (British Standards Institution, 1967). Random checks of the accuracy of the grading are made in the Institute's laboratories.

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

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



Example of resource block assessment: map of a fictitious block

APPENDIX B

STATISTICAL PROCEDURE

Statistical assessment

1 A statistical assessment is made of an area of mineral greater than 2 km^2, if there are at least 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 (Hull, 1981). Conventional symmetrical confidence limits are calculated for the 95 per cent probability level, that is, on average nineteen out of every twenty sets of limits constructed in this way contain the true value for the volume of mineral.

3 The volume estimate (V) for the mineral in a given block is the product of 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 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 $S_{\bar{l}_m}$, expressed as a proportion of the mean thickness, is given by

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

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

6 The sampled area in each resource block is coloured pink on the map. Wherever possible, calculations relate to the mineral within mapped geological boundaries (which may not necessarily correspond to the limits of a 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 $S_A / S_{\bar{l}_m} \leqq 0.\dot{3}$ is assumed in all cases. It follows from Equation [2] that

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

7 The limits on the estimate of mean thickness of mineral, $L_{\bar{l}_m}$, may be expressed in absolute units

$\pm (t/\sqrt{n}) \times S_{\bar{l}_m}$ or as a percentage

$\pm (t/\sqrt{n}) \times S_{\bar{l}_m} \times (100/\bar{l}_m)$ per cent, where t is Student's t at the 95 per cent probability level for $(n-1)$ degrees of freedom, evaluated by reference to statistical tables. (In applying Student's t it is assumed that the measurements are distributed normally).

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 in *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:

$$L_{\bar{l}_m} \leqq L_V \leqq 1.05\ L_{\bar{l}_m}.$$

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 the accompanying Figure and example of a block calculation.

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 on the basis of 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 needs to 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 with the zone as the weighting factor.

Block calculation

Scale: 1:25 000
Block: Fictitious

Area
Block: 11.08 km²
Mineral: 8.32 km²

Mean thickness
Overburden: 2.5 m
Mineral: 6.5 m

Volume
Overburden: 21 million m³
Mineral: 54 million m³

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

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

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

Calculation of confidence limits

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

$\Sigma(wl_m - \overline{wl}_m)^2 = 15.82$

$n = 8$

$t = 2.365$

L_V is calculated as

$1.05\ (t/\overline{wl}_m)\ \sqrt{[\Sigma(wl_m - \overline{wl}_m)^2/\ n(n-1)]} \times 100$

$= 1.05 \times (2.365/6.5)\ \sqrt{[15.82/(8 \times 7)]} \times 100$

$= 20.3$

$\simeq 20$ per cent.

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 (< $\frac{1}{16}$ mm) and coarser than pebbles (> 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 considered to be not potentially workable and falls outside the definition of mineral. Deposits which contain 40 per cent fines or less are classified primarily on the ratio of sand to gravel 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 the accompanying Figure). The procedure is as follows:

1 Classify according to the ratio of sand to gravel.
2 Describe the 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 Appendix D)

Many differing proposals have been made 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 (see the accompanying table), which is used in the Report.

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

The size distribution of borehole samples is determined by sieve analysis, which is presented by the laboratory as logarithmic cumulative curves (see, for example, British Standards Institution, 1967). In this report the grading is tabulated on the borehole record sheets (Appendix E), 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 roughly 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 constitutents are referred to as 'trace'.

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

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

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

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

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

Well rounded: not 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.

Classification of gravel, sand and fines

Size limits	Grain-size description	Qualification	Primary classification
	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

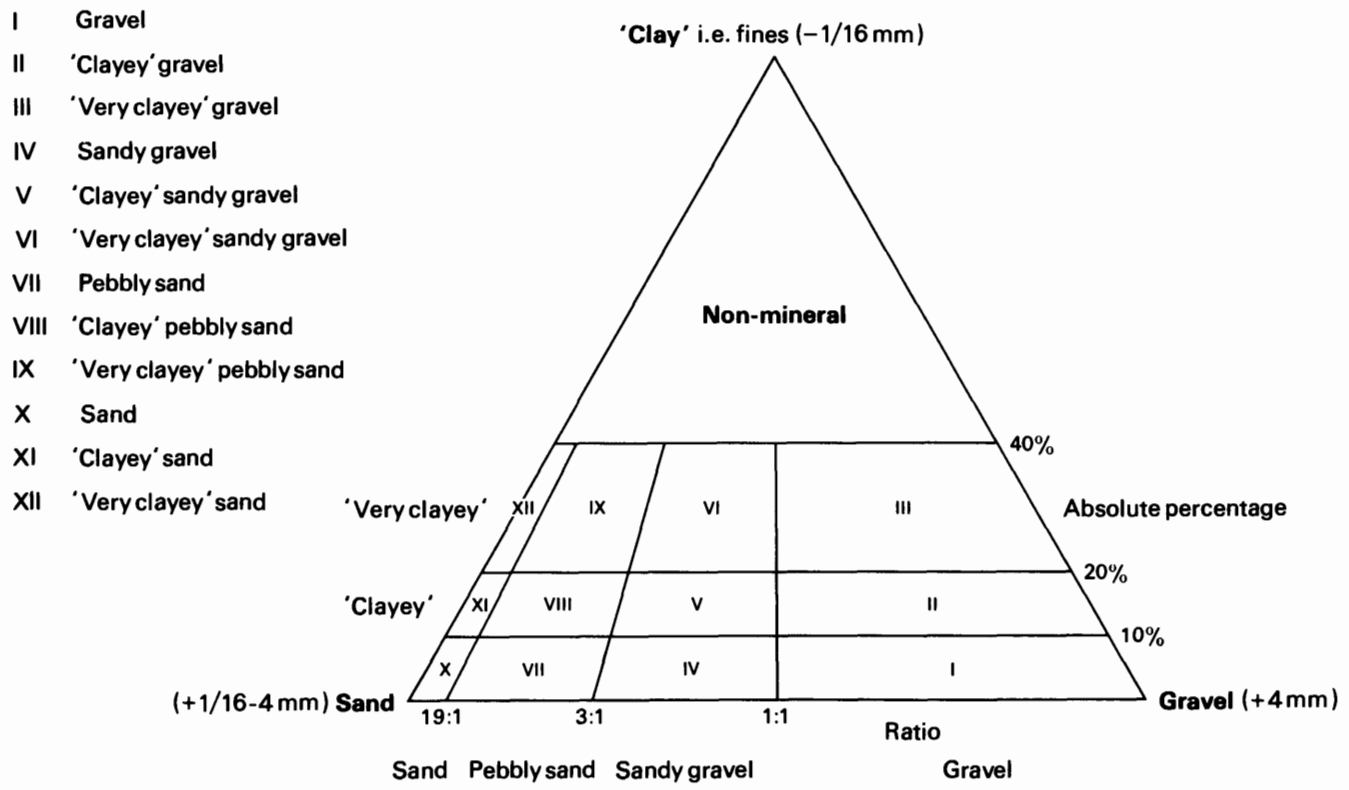


Diagram showing the descriptive categories used in the classification of sand and gravel

APPENDIX D
EXPLANATION OF THE BOREHOLE RECORDS

Annotated fictitious example

CK 66 NW 5 **6191 6962** **Northfields**[1] **Block B**

Surface level (+49.7 m) + 163 ft[2]
Water struck at +45.9 m[3]
October 1977[4]

Overburden[5] 2.8 m
Mineral 5.4 m
Waste 1.1 m
Mineral 1.4 m
Bedrock 0.7 m+[6]

LOG

Geological classification	Lithology[7]	Thickness m	Depth m
	Soil	0.2	0.2
Alluvium	Clay, silty, dark brown	2.6	2.8
River Terrace Deposits	**a** Gravel Gravel: fine to coarse, with cobbles towards base, angular to rounded, flint and limestone with ironstone and some quartz and chalk Sand: medium with coarse and some fine, quartz and limestone	5.4	8.2
Boulder Clay	Clay, sandy and pebbly, red-brown	1.1	9.3
Glacial Sand and Gravel	**b** Sand, 'clayey' in part: fine, subangular to rounded, quartz with some coal	1.4	10.7
Lias	Mudstone, blue-grey, fossiliferous	0.7+	11.4

GRADING[8]

	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 mm
a	5	46	49	2.8-3.8	20	14	62	2	2		
				3.8-4.8	2	2	12	18	42	24	
				4.8-5.8	1	3	24	13	35	24	
				5.8-6.8	0	4	21	20	26	29	
				6.8-8.2	4	3	23	10	23	30	7
				Mean	5	5	28	13	25	22	2
b	5	95	0	9.3-10.3	3	73	23	1			
				10.3-10.7	9	85	5	1			
				Mean	5	77	17	1			
a+b	5	56	39	Mean	5	20	26	10	20	17	2

COMPOSITION[9]

Depth below surface (m)	Percentages by weight in gravel fraction				
	Flint	Quartz	Limestone	Chalk	Ironstone
3.8-4.8	41	5	50	1	3
4.8-5.8	39	3	45	5	8
5.8-6.8	45	2	42	5	6
6.8-8.2	19	6	61	3	11
Mean	35	4	51	3	7

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

1 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 the borehole lies is stated.

2 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.

3 Groundwater conditions
If groundwater was present, the level at which it was encountered or the level at which it stood on the completion of drilling is normally given (in metres relative to Ordnance Datum)

4 Type of drill and date of drilling
Unless otherwise stated the borehole was drilled by a shell and auger rig using 152-mm diameter casing. The month and year of completion of drilling are stated.

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

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

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

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

For each bulk sample the percentages of fines ($-\frac{1}{16}$ mm), fine sand ($+\frac{1}{16}-\frac{1}{4}$ mm), medium sand ($+\frac{1}{4}-1$ mm), coarse sand (+1-4 mm), fine gravel (+4-16 mm), coarse gravel (+16 -64 mm), and cobble gravel (+64 mm) are stated.

The mean grading of groups of samples making up an identified mineral horizon is also given in detail and in summary. Where more than one horizon is recognised the mean grading for the whole of the mineral in the borehole may be given. Where necessary, in calculating mean gradings, data for individual samples are weighted by the thickness represented. If, exceptionally, grading results are not available for a sample, an attempt may be made to estimate the grading by comparing the grading and field descriptions of adjacent samples with the sample in question. Such estimates are shown in square brackets.

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

9 Composition
Details of the composition of selected samples or groups of samples may be given.

APPENDIX E

INDUSTRIAL MINERALS ASSESSMENT UNIT BOREHOLE RECORDS

NZ 42 NW 18 4170 2984 Embleton Farm, Embleton Block B

Surface level (+77.7 m) +255 ft
Water level +73.0 m
September 1975

Waste	18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, grey and brown generally silty with stones, poorly laminated in top and bottom metre	17.6+	18.0

NZ 42 NW 19 4339 2939 Close House, Elwick Hall Block B

Surface level (+68.3 m) +224 ft
Water level +64.9 m
November 1975

Overburden	3.0 m
Mineral	1.6 m
Waste	1.6 m
Mineral	1.2 m
Waste	12.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown, massive, stony; 0.2 m of sandy gravel at 2.6 m	2.7	3.0
Glacial Sand and Gravel	**a** 'Clayey' pebbly sand Gravel: fine to coarse; Magnesian Limestone, sandstone and limestone Sand: fine to medium, subangular to subrounded; quartz, Magnesian Limestone, sandstone and limestone with some tabular coal.	1.6	4.6
Boulder Clay	Clay, brown, massive and stony	1.6	6.2
Glacial Sand and Gravel	**b** 'Clayey' sandy gravel Gravel: fine to coarse; Magnesian Limestone, limestone and sandstone Sand: fine to medium, subangular to subrounded; Magnesian Limestone, quartz, limestone and sandstone with some coal and trace of red sandstone	1.2	7.4
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but with sand laminae and generally stoneless from 14.4 m to 17.8 m; 1.0 m sandy gravel at 9.8 m and thin sands at 12.0 m and 13.0 m	12.6+	20.0

GRADING

	Mean for deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$ mm
a	10	73	17	3.0-4.0	10	35	36	6	5	8	0
				4.0-4.6	12	26	28	10	11	13	0
				Mean	10	32	33	8	7	10	0
b	16	45	39	6.2-7.4	16	15	17	13	21	18	0
a+b	13	60	27	Mean	13	24	27	9	14	13	0

NZ 42 NW 20 **4083 2899** **Middle Swainston Farm** **Block B**

Surface level (+83.2 m) +273 ft
Water level +79.7 m
August 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Boulder Clay	Clay, stony, mainly red-brown to 8.3 m grey and micaceous below, sandy from 4.9 m to 5.9 m	17.4+	18.0

NZ 42 NW 21 **4231 2887** **Low Swainston Farm** **Block B**

Surface level (+68.9 m) +226 ft
Water level +56.0 m
September 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Boulder Clay	Clay, dark brown, stony, part silty; thin coarse sand partings near top	17.4+	18.0

NZ 42 NW 22 **4474 2914** **Gunners Vale** **Block B**

Surface level (+45.1 m) +148 ft
Water not encountered
September 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Boulder Clay	Clay, brown to grey-brown, stony; scattered thin sands	10.8	11.3
Glacial Drift undifferentiated	Clay, green-grey, stoneless; silt laminations and thin bands of stony clay	4.3	15.6
Boulder Clay	Clay, brown, massive, stony	2.4+	18.0

NZ 42 NW 23 **4034 2778** **Cockpit** **Block B**

Surface level (+73.8 m) +242 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Drift undifferentiated	Clay, red-brown, generally laminated and with few stones to 5.6 m, massive and stony below	6.2	6.4
	Silt, grey-brown, slightly micaceous; laminations of very fine quartz sand	1.6	8.0
Boulder Clay	Clay, brown, stony - especially above 12.0 m, mainly massive but poorly laminated at top	10.0+	18.0

NZ 42 NW 24 **4125 2817** **Middle Swainston Plantation** **Block B**

Surface level (+70.1 m) +230 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Drift, undifferentiated	Clay, red-brown, stony to 4.0 m, poorly laminated below	9.9	10.2
	Clay, brown, generally massive and stony but poorly laminated in part; 0.2 m sandy silt at 11.8 m	7.8+	18.0

NZ 42 NW 25 **4297 2787** **Low Newton Hanzard Farm** **Block B**

Surface level (+60.7 m) +199 ft
Water not encountered
September 1975

Overburden 10.3 m
Mineral 14.7 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.7	0.7
Glacial Drift, undifferentiated	Clay, brown, mainly silty and stony, sandy towards base	9.6	10.3
Glacial Sand and Gravel	'Very clayey' sand, brown: fine, subrounded; quartz with some lithic grains including coal; few pebbles near top	14.7+	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 mm
24	76	trace	10.3-11.4	26	39	33	1	1	0	0
			11.4-12.4	36	48	13	2	1	0	0
			12.4-13.4	29	56	11	2	1	1	0
			13.4-14.4	32	66	2	trace	0	0	0
			14.4-15.4	23	58	18	1	trace	0	0
			15.4-16.4	13	70	17	trace	0	0	0
			16.4-17.4	33	63	3	1	0	0	0
			17.4-18.4	31	67	2	trace	0	0	0
			18.4-19.4	24	63	13	trace	0	0	0
			19.4-20.4	11	71	18	trace	0	0	0
			20.4-21.4	18	74	7	1	trace	0	0
			21.4-22.4	16	78	6	trace	0	0	0
			22.4-23.4	39	58	3	trace	0	0	0
			23.4-25.0	16	75	9	trace	0	0	0
			Mean	24	64	11	1	trace	trace	0

NZ 42 NW 26 **4346 2830** **Red Gap Cottage** **Block B**

Surface level (+57.6 m) +189 ft
Water level +54.7 m
September 1975

Waste 25.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.8	0.8
Glacial Drift, undifferentiated	Silt and clay, brown, partly sandy, stony near top	7.3	8.1
Boulder Clay	Clay, brown and grey, stony	6.4	14.5
Glacial Sand and Gravel	'Very clayey' sand, yellow-brown: fine with medium quartz; sporadic pebbles	1.0	15.5
	Sandy silt, yellow-brown	1.2	16.7
	'Clayey' sand, yellow-brown: fine quartz	2.0	18.7
	Sandy silt, yellow-brown to grey, micaceous; 0.9 m laminated silty clay at 21.2 m	6.3+	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 mm
22	75	3	14.5-15.5	22	57	16	2	2	1	0
18	82	0	16.7-17.7	16	77	7	trace	0	0	0
			17.7-18.7	21	73	6	trace	0	0	0
			Mean	18	75	7	trace	0	0	0

NZ 42 NW 27 **4457 2805** **High Burntoft** **Block B**

Surface level (+52.4 m) +172 ft
Water not encountered
September 1975

Overburden 12.4 m
Mineral 12.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial Drift undifferentiated	Clay, red-brown; mainly poorly laminated with some stones from 4.0 m to 10.2 m, elsewhere massive and stony	11.8	12.4
Glacial Sand and Gravel	Gravel with 'very clayey' sand at top Gravel: fine to coarse; limestone and sandstone with dolomite, igneous rocks, some quartzite, quartz, silicified limestone and trace of mudstone and ironstone Sand: fine to coarse, quartz with lithic grains as gravel including coal	12.6+	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 mm
8	45	47	12.4-13.8	26	51	20	1	1	1	0
			13.8-14.8	6	7	12	11	24	38	2
			14.8-15.8	5	9	23	14	24	25	0
			15.8-16.8	4	5	11	14	28	33	5
			16.8-17.8	5	8	13	19	24	31	0
			17.8-18.8	6	8	13	16	26	31	0
			18.8-19.8	7	6	13	19	25	30	0
			19.8-20.8	8	9	22	15	21	25	0
			20.8-21.8	7	7	26	13	22	23	2
			21.8-22.8	7	8	24	17	25	19	0
			22.8-23.8	6	5	13	19	34	23	0
			23.8-25.0	8	6	21	23	22	20	0
			Mean	8	12	18	15	22	24	1

COMPOSITION

Depth below surface (m)	percentages by weight in gravel fraction							
	Sandstone	Limestone	Dolomite	Igneous rock	Quartzite/ Quartz	Silicified limestone	Mudstone	Ironstone
14.8-15.8	24	49	14	6	3	3	1	trace
18.8-19.8	34	37	18	8	1	2	trace	0
22.8-23.8	29	47	16	5	2	1	0	0

NZ 42 NW 28 **4051 2693** **The Racecourse, Wynyard Park** **Block B**

Surface level (+68.6 m) +225 ft
Water not encountered
November 1975

Waste 20.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Drift, undifferentiated	Clay, red-brown, stony, mainly massive but poorly laminated to 5.0 m and in part from 9.0 m to 12.5 m; some fine sand lenses below 12.5 m and 0.2 m 'clayey' pebbly sand at 17.6 m	19.8+	20.0

NZ 42 NW 29 **4161 2724** **Salter Houses** **Block B**

Surface level (+59.4 m) +195 ft
Water level +48.0 m
August 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Drift, undifferentiated	Clay, red-brown, part stony, part silty; some laminations to 12.1 m, 0.6 m sandy silt band at 12.7 m	17.5+	18.0

NZ 42 NW 30 **4369 2727** **Woodside Farm** **Block B**

Surface level (+51.5 m) +169 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, brown, laminated and sandy in part; some stones	17.6+	18.0

NZ 42 NW 31 **4055 2604** **Woodend Farm** **Block B**

Surface level (+65.5 m) +215 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown, mainly massive and stony but poorly laminated in parts below 9.5 m	17.7+	18.0

NZ 42 NW 32 **4171 2625** **Wynyard Park** **Block B**

Surface level (+60.0 m) +197 ft
Water not encountered
November 1975

Overburden	8.0 m
Mineral	2.3 m
Waste	2.7 m
Mineral	12.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Drift, undifferentiated	Clay, brown; some stones to 6.9 m, 0.4 m of sandy and silty micaceous laminae at 7.3 m, poorly laminated to base	7.7	8.0
Glacial Sand and Gravel	**a** Sandy gravel, 'clayey' at top Gravel: fine with coarse; sandstone and limestone with dolomite and igneous rocks, some quartzite, quartz, silicifed limestone, mudstone and trace of ironstone Sand: fine to coarse, subangular to subrounded; grains as gravel	2.3	10.3
Boulder Clay	Clay, brown, massive and stony	2.7	13.0
Glacial Sand and Gravel	**b** Sand, grey: fine to medium; quartz with Magnesian Limestone and Carboniferous rocks including some coal	4.0	17.0
	c 'Clayey' sand, grey: fine as above; thin silt bands at 21.0 m	8.0+	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 mm
a	8	54	38	8.0-9.0	16	22	20	16	20	6	0
				9.0-10.3	2	11	18	22	28	17	2
				Mean	8	16	19	19	24	13	1
b	7	91	2	13.0-14.0	10	38	45	3	4	trace	0
				14.0-15.0	4	38	54	3	1	0	0
				15.0-16.0	6	34	57	2	1	0	0
				16.0-17.0	8	44	44	3	1	0	0
				Mean	7	39	50	2	2	0	0
c	16	83	1	17.0-18.0	14	53	28	3	2	0	0
				18.0-19.0	17	74	7	1	1	0	0
				19.0-20.0	16	73	8	1	trace	2	0
				20.0-21.0	23	74	3	trace	trace	0	0
				21.0-22.0	16	79	5	trace	0	0	0
				22.0-23.0	14	79	6	1	0	0	0
				23.0-24.0	15	80	5	trace	0	0	0
				24.0-25.0	16	80	4	trace	0	0	0
				Mean	16	75	8	trace	1	trace	0
b+c	13	86	1	Mean	13	62	22	2	1	trace	0
a+b+c	12	81	7	Mean	12	55	22	4	5	2	trace

COMPOSITION

Depth below surface (m)	percentages by weight in gravel fraction							
	Sandstone	Limestone	Dolomite	Igneous rock	Quartzite/ Quartz	Silicified limestone	Mudstone	Ironstone
8.0-10.3	38	39	11	6	2	2	2	trace

NZ 42 NW 33 **4258 2672** **Kennel Hill Plantation** **Block B**

Surface level (+50.0 m) +164 ft
Water level not recorded
October 1975

Waste 25.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown to grey, massive, stony, poorly laminated at top	6.7	7.0
Glacial Sand and Gravel	Gravel: mainly coarse sand and fine to coarse pebbles of of Magnesian Limestone and Carboniferous rocks	1.5	8.5
Boulder Clay	Clay, brown, massive and stony; 0.6 m 'very clayey' pebbly sand at 11.4 m	9.3	17.8
Glacial Drift, undifferentiated	Sandy silt, brown, laminated and micaceous with some fine coal detritus; massive at base, 'clayey' sandy gravel from 18.0 m to 18.7 m	7.2+	25.0

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$ mm
8	41	51	7.0-8.5	8	6	8	27	36	15	

NZ 42 NW 34 **4340 2656** **Whinny Moor Cottage** **Block B**

Surface level (+53.3 m) +175 ft
Water not encountered
September 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, brown and grey, stony, silty and sandy in part; some silt laminae from 16.4 m to 17.6 m	17.6+	18.0

NZ 42 NW 35 **4430 2687** **Annigate House** **Block B**

Surface level (+41.1 m) +135 ft
Water not encountered
November 1975

Waste 22.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, brown and grey, stony; thin bands of medium quartz sand towards base	7.2	7.4
Glacial Sand and Gravel	'Very clayey' sand, yellow-brown: fine to medium; quartz with some quartzite and coal	2.2	9.6
Glacial Drift, undifferentiated	Clay, brown, with some stones, silty and sandy in part, partly laminated; very clayey sand and thin silt bands from 17.6 m to 18.6 m	12.4+	22.0

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 mm
20	79	1	7.4-8.4	23	38	31	6	2	0	0
			8.4-9.6	18	31	46	5	trace	0	0
			Mean	20	35	39	5	1	0	0
23	72	5	17.6-18.6	23	40	23	9	4	1	0

NZ 42 NW 36 **4261 2543** **Warren Cottages** **Block B**

Surface level (+53.9 m) +177 ft
Water not encountered
November 1975

Waste 18.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown, stony, generally massive but laminated in part	18.0+	18.3

NZ 42 NW 37 **4345 2519** **Warren Farm** **Block B**

Surface level (+37.8 m) +124 ft
Water not encountered
September 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, brown, massive, slightly micaceous; some stones	9.0	9.4
Glacial Drift, undifferentiated	Clay, brown, poorly to well laminated; sporadic stones from 12.4 m to 13.4 m	5.0	14.4
	Clay, brown to grey, micaceous, with some stones; slightly laminated and stoneless from 16.4 m to 17.2 m	3.6+	18.0

NZ 42 NE 86 **4675 2977** **Brierton** **Block B**

Surface level (+39.9 m) +131 ft
Water not encountered
October 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Boulder Clay	Clay, brown, stony	17.5+	18.0

NZ 42 NE 87 **4757 2972** **Brierton** **Block B**

Surface level (+20.1 m) +66 ft
Water not encountered
December 1975

Waste 25.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	1.2	1.2
Alluvium	Clayey, peaty gravel	0.7	1.9
Boulder Clay	Clay, red-brown to cream, mainly massive and stony, silty in part	9.7	11.6
Glacial Sand and Gravel	Sandy silt, grey-brown, laminated; 1.3 m 'very clayey' sand at 13.4 m	3.6	15.2
	'Clayey' pebbly sand with gravel at base Gravel: pebbles and cobbles of Magnesian Limestone, Carboniferous sandstone and red sandstone Sand: fine; quartz with some coal	3.3	18.5
Boulder Clay	Clay, brown, massive, stony, slightly silty; some red sand lenses	6.5+	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 mm
22	78	trace	12.1-13.4	22	73	3	2	trace	0	0
17	71	12	15.2-16.2	20	72	7	1	0	0	0
			16.2-17.2	17	75	6	1	trace	1	0
			17.2-18.5	14	48	5	2	2	29	0
			Mean	17	64	6	1	1	11	0

NZ 42 NE 88 **4682 2901** **West Pasture** **Block B**

Surface level (+34.1 m) +112 ft
Water not encountered
December 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown and grey, stony, mainly massive but laminated from 9.4 m to 12.0 m and 16.8 m to 18.0 m; 0.2 m sandy gravel at 9.2 m	17.7+	18.0

NZ 42 NE 89 **4853 2916** **Greatham Beck, Owton Manor** **Block B**

Surface level (+15.8 m) +52 ft
Water not encountered
December 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Alluvium on Glacial Drift, undifferentiated	Clay, grey-brown, poorly laminated; some stones	3.8	4.0
	Clay, grey-brown, plastic and stoneless, with very fine micaceous quartz and coal laminae from 8.0 m to 9.0 m	7.8	11.8
	Clay, brown to red-brown, poorly laminated to massive, stony	6.2+	18.0

NZ 42 NE 90 **4533 2842** **Low Burn Toft** **Block B**

Surface level (+52.4 m) +172 ft
Water not encountered
September 1975

Overburden	6.8 m
Mineral	1.0 m
Waste	0.2 m
Mineral	10.6 m
Waste	1.4 m
Mineral	5.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Drift, undifferentiated	Clay, red-brown, varies from stony and massive to silty with laminae of fine micaceous quartz and coal sand; bands of medium to coarse sand at 5.6 m	6.3	6.8
Glacial Sand and Gravel	**a** 'Clayey' sandy gravel Gravel: fine to coarse, subangular to subrounded sandstone, limestone and Magnesian Limestone Sand: fine to medium, subangular; quartz with lithic grains as in gravel	1.0	7.8

Boulder Clay	Clay, grey-brown, massive and stony	0.2	8.0
Glacial Sand and Gravel	**b** 'Clayey' pebbly sand on 'very clayey' sand Gravel: fine, subangular to subrounded sandstone limestone and Magnesian Limestone Sand: fine to medium, quartz and Magnesian Limestone with Carboniferous lithic grains including some tabular coal	10.6	18.6
Glacial Drift, undifferentiated	Sandy silty clay, brown; bands and laminae of 'clayey' sand, silt and clay	1.4	20.0
Glacial Sand and Gravel	**c** 'Very clayey' sand, brown: fine; quartz with coal and other Carboniferous lithic grains	5.0+	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 mm
a	18	52	30	6.8-7.8	18	19	25	8	14	16	0
b	19	76	5	8.0-9.0	19	22	27	12	13	7	0
				9.0-10.0	10	32	46	8	4	trace	0
				10.0-11.0	12	47	35	5	1	0	0
				11.0-12.0	11	25	46	11	6	1	0
				12.0-13.0	11	16	43	20	10	trace	0
				13.0-14.0	13	30	36	15	5	1	0
				14.0-15.0	14	52	28	5	1	0	0
				15.0-16.0	21	61	16	2	trace	0	0
				15.0-17.0	31	61	8	trace	0	0	0
				17.0-18.6	35	62	3	trace	0	0	0
				Mean	19	42	27	7	4	1	0
c	22	77	1	20.0-21.0	25	69	6	trace	0	0	0
				21.0-22.0	24	71	5	trace	trace	0	0
				22.0-23.0	20	67	11	1	1	trace	0
				23.0-24.0	20	70	7	2	1	trace	0
				24.0-25.0	23	68	9	trace	trace	0	0
				Mean	22	69	8	trace	1	0	0
a+b+c	20	75	5	Mean	20	49	21	5	4	1	0

NZ 42 NE 91 **4728 2852** **Springwell House Farm** **Block B**

Surface level (+24.7 m) +81 ft
Water level +19.7 m
December 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown, stony, massive	5.8	6.1
Glacial Drift, undifferentiated	Clay, brown, mainly stoneless and laminated but stony and poorly laminated to massive from 12.0 m to 14.0 m and 17.0 m to base; 0.1 m gravel at 6.2 m	11.9+	18.0

NZ 42 NE 92 **4936 2836** **Greatham Villa** **Block B**

Surface level (+19.2 m) +63 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but poorly laminated in part from 4.0 m to 11.7 m and stoneless and laminated from 12.0 m to 14.8 m	17.5+	18.0

NZ 42 NE 93 **4552 2725** **Stob House Farm** **Block B**

Surface level (+28.0 m) +92 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, brown, massive; some stones	3.6	4.0
Glacial Drift, undifferentiated	Clay, brown, well to poorly laminated and generaly stoneless	10.6	14.6
	Sandy silt, brown; silty clay from 16.2 m to 17.0 m	3.4+	18.0

NZ 42 NE 94 **4632 2784** **Low Burn Toft** **Block B**

Surface level (+17.7 m) +58 ft
Water not encountered
October 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Drift, undifferentiated	Clay, brown, poorly to well laminated with 0.8 m sandy silt at 7.6 m	9.5	9.8
Boulder Clay	Clay, brown, massive and stony; some thin sandy lenses towards base	8.2+	18.0

NZ 42 NE 95 **4731 2732** **Claxton House** **Block B**

Surface level (+16.2 m) +53 ft
Water level +4.2 m
September 1975

Waste 25.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Drift, undifferentiated	Clay, brown, mainly massive but poorly laminated from 2.0 m to 4.0 m, stony towards base	5.5	6.0
	Sandy silt, brown; 0.3 m massive stony clay at 8.1 m and 1.0 m 'very clayey' sand at 15.0 m	10.7	16.7
Glacial Sand and Gravel	'Very clayey' sand, red-brown: fine; quartz and lithic grains including some coal	4.3	21.0
Boulder Clay	Clay, grey-brown, massive, stony; 0.2 m gravel at 23.8 m	4.0+	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 mm
32	68	0	14.0-15.0	32	66	2	trace	0	0	0
22	78	0	16.7-18.0	20	78	2	trace	0	0	0
			18.0-19.0	23	74	3	trace	0	0	0
			19.0-20.0	24	64	10	2	trace	0	0
			20.0-21.0	22	71	6	1	0	0	0
			Mean	22	72	5	1	0	0	0

NZ 42 NE 96 **4818 2781** **Dalton Back Lane** **Block B**

Surface level (+22.6 m) +74 ft
Water level + 1.6 m
November 1975

Overburden	2.4 m
Mineral	1.5 m
Waste	5.1 m
Mineral	3.9 m
Waste	1.1 m
Mineral	2.2 m
Waste	1.5 m
Mineral	7.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.8	0.8
Glacial Sand and Gravel	Silty clay, red-brown, micaceous, with very fine quartz sand and some stones	1.6	2.4
	a 'Clayey' gravel Gravel: coarse to fine; dolomite with limestone, sandstone and some quartzite, igneous rocks and silicified limestone Sand: fine to coarse; grains as gravel with quartz and rare red sandstone	1.5	3.9
	Sandy silt, red-brown, poorly laminated to massive; thin clay partings and lenses of sand; 0.8 m gravel at 7.3 m	5.1	9.0

b 'Clayey' gravel Gravel: coarse to fine; dolomite with limestone, sandstone and some igneous rocks, silicified limestone, quartzite and trace of mudstone Sand: coarse to fine; grains as gravel but with quartz	3.9	12.9
Silty clay, red-brown, poorly laminated to massive	1.1	14.0
c Gravel Gravel: fine to coarse; dolomite and limestone with sandstone and some igneous rocks, silicified limestone, quartzite and traces of mudstone and ironstone Sand: coarse to fine; grains as gravel but with quartz	2.2	16.2
Clay, brown, massive to poorly laminated; sporadic stones	1.5	17.7
d Sandy gravel, 'clayey' in part Gravel: fine to coarse; dolomite and sandstone with limestone and some igneous rocks, silicified limestone, quartzite and trace of mudstone; much red sandstone towards base Sand: coarse to medium; grains as gravel with quartz	7.3+	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 mm
a	11	30	59	2.4-3.9	11	6	10	14	19	36	4
b	10	32	58	9.0-10.0	7	7	12	11	16	38	9
				10.0-11.0	no recovery						
				11.0-12.0	12	6	6	15	16	43	2
				12.0-12.9	13	8	12	19	17	25	6
				Mean	10	7	10	15	16	37	5
c	8	45	47	14.0-15.0	9	6	6	17	32	30	0
				15.0-16.2	8	10	14	33	25	10	0
				Mean	8	8	11	26	28	19	0
d	9	57	34	17.7-18.7	5	4	12	23	17	39	0
				18.7-20.0	6	5	15	23	27	19	5
				20.0-21.0	10	7	32	44	5	2	0
				21.0-22.0	9	7	23	43	14	4	0
				22.0-23.4	13	9	23	31	15	9	0
				23.4-25.0	9	10	19	25	18	19	0
				Mean	9	7	20	30	18	15	1
a to d	9	46	45	Mean	9	7	15	24	19	23	3

COMPOSITION

Depth below surface (m)	percentages by weight in gravel fraction							
	Sandstone	Limestone	Dolomite	Igneous rock	Quartzite/ Quartz	Silicified limestone	Mudstone	Ironstone
2.4-3.9	12	18	57	5	5	3	0	0
11.0-12.0	9	20	62	6	1	2	trace	0
14.0-15.0	18	28	45	5	2	2	trace	trace
17.7-18.7	11	21	58	5	1	4	trace	trace
22.0-23.4	35	21	31	7	2	4	trace	0

Surface level (+20.1 m) +66 ft
Water not encountered
October 1975

Overburden	0.6 m
Mineral	2.8 m
Waste	1.3 m
Mineral	15.5 m
Waste	0.4 m
Mineral	1.0 m
Waste	3.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial Sand and Gravel	**a** 'Clayey' sand: fine, subangular to subrounded; quartz with tabular coal and some Carboniferous and Magnesian Limestone; some pebbles	2.8	3.4
	Clay, red-brown, silty at top, stony towards base	1.3	4.7
	b 'Clayey' sand: fine to medium; as above; 0.2 m laminated silty clay at 13.6 m; trace of pebbles	15.5	20.2
	Sandy silt, red-brown to grey	0.4	20.6
	c 'Very clayey' sand: fine; quartz with tabular coal and and Carboniferous and Magnesian Limestone rocks	1.0	21.6
	Sandy silt, red-brown, with bands of partly stony laminated silty clay and 'very clayey' sand	3.4+	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 mm
a	13	85	2	0.6-2.0	14	61	22	2	1	0	0
				2.0-3.4	12	73	10	1	1	3	0
				Mean	13	67	16	2	1	1	0
b	13	87	trace	4.7-6.0	19	61	20	trace	trace	0	0
				6.0-7.0	10	67	23	trace	0	0	0
				7.0-8.0	12	58	30	trace	0	0	0
				8.0-9.0	10	51	39	trace	trace	0	0
				9.0-10.0	11	49	39	1	trace	0	0
				10.0-11.0	12	35	50	3	trace	0	0
				11.0-12.0	11	41	46	2	0	0	0
				12.0-13.4	9	20	71	trace	0	0	0
				13.4-13.6	Clay band						
				13.6-14.6	13	24	55	8	trace	0	0
				14.6-15.6	17	48	31	4	0	0	0
				15.6-16.6	14	61	21	4	trace	0	0
				16.6-17.6	11	39	33	11	6	0	0
				17.6-18.6	8	44	38	8	2	0	0
				18.6-20.2	10	42	44	4	trace	0	0
				Mean*	13	45	39	3	trace	0	0
c	29	71	trace	20.6-21.6	29	58	12	1	trace	0	0
a+b+c	13	86	1	Mean*	13	48	35	3	1	trace	0

* Assuming ungraded clay comprises 100% fines

NZ 42 NE 98 **4538 2619** **Wolviston** **Block B**

Surface level (+30.8 m) +101 ft
Water not encountered
December 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Drift, undifferentiated	Clay, brown, mainly massive to poorly laminated and stony but stoneless and laminated from 5.8 m to 8.3 m, silty towards base	17.7+	18.0

NZ 42 NE 99 **4636 2662** **Blue Bells, Newton Bewley** **Block B**

Surface level (+21.6 m) +71 ft
Water level +15.5 m
October 1975

Overburden 4.4 m
Mineral 5.6 m
Waste 15.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Sand and Gravel	Sandy silt, brown with quartz sand and some coal detritus	1.5	1.7
Boulder Clay	Clay, brown, stony, mainly massive but poorly laminated at top	2.7	4.4
Glacial Sand and Gravel	'Very clayey' pebbly sand with gravel at top Gravel: fine to coarse; limestone, sandstone and Magnesian Limestone Sand: fine; quartz with coal and other Carboniferous lithic grains Fines: sandy silt and clay bands	5.6	10.0
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but laminated and generally stoneless from 11.6 m to 14.0 m; 0.5 m sandy gravel band at 14.5 m and 1.1 m pebbly sand at base	7.6	17.6
	Sandy silt, red-brown, slightly micaceous; band of brown stony clay at 19.8 m and pebbly sand from 21.9 m to base	5.8	23.4
	Clay, brown, mainly laminated, stoneless in parts; massive and stony at base	1.6+	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 mm
27	63	10	4.4-5.4	6	9	11	21	22	31	0
			5.4-6.4	19	68	7	3	trace	3	0
			6.4-7.4	39	58	3	trace	trace	0	0
			7.4-8.4	31	60	8	1	0	0	0
			8.4-10.0	36	53	10	1	0	0	0
			Mean	27	50	8	5	4	6	0
17	61	22	16.6-17.6	17	24	23	14	2	20	0
9	72	19	21.9-23.4	9	14	44	14	5	14	0

NZ 42 NE 100 **4731 2634** **Manor House Farm** **Block B**

Surface level (+13.1 m) +43 ft
Water not encountered
October 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Laminated Clay	Clay, brown, laminated	4.6	5.0
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but poorly lamianted in part, silty	13.0+	18.0

NZ 42 NE 101 **4831 2680** **Field House, Greatham** **Block B**

Surface level (+10.7 m) +35 ft
Water not encountered
October 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Laminated Clay	Sandy silt and thin laminated clays, grey to grey-brown micaceous	2.5	3.0
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but poorly laminated in parts; thin bands of silt, laminated clay and sand at 7.8 m and 16.5 m	15.0+	18.0

NZ 42 NE 102 **4918 2631** **Greatham Viaduct** **Block B**

Surface level (+6.4 m) +21 ft
Water not encountered
October 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.9	0.9
Laminated Clay	Clay, red-brown to grey-brown, laminated to 2.0 m and at base; grey, massive and plastic in part, with some stones	5.1	6.0
Boulder Clay	Clay, brown, massive, stoneless in part; sandy and silty from 17.6 m to base	12.0+	18.0

NZ 42 NE 103 **4602 2574** **Marsh House (Demolished)** **Block B**

Surface level (+19.2 m) +63 ft
Water level +14.2 m
September 1975

Overburden 5.0 m
Mineral 3.6 m
Waste 11.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Glacial Sand and Gravel	Silty clay, red-brown, poorly laminated	2.6	3.0
	Sandy silt, red-brown, slightly micaceous	2.0	5.0
	'Very clayey' sand, red-brown: fine with medium; quartz and Carboniferous rocks with Magnesian Limestone and coal	3.6	8.6
Glacial Drift, undifferentiated	Silt and Clay: alternating bands of silt, sandy silt and clay, mainly laminated, partly stony	11.4+	20.0

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16 -1/4	+1/4 -1	+1 -4	+4 -16	+16 -64	+64 mm
24	76	0	5.0-6.0	15	45	40	trace	0	0	0
			6.0-7.0	23	47	30	trace	0	0	0
			7.0-8.6	29	60	11	trace	0	0	0
			Mean	24	52	24	trace	0	0	0

NZ 42 NE 104 **4734 2514** **Calfclose Bridge** **Block B**

Surface level (+10.7 m) +35 ft
Water not encountered
December 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Drift, undifferentiated	Clay, brown, mainly poorly laminated to massive, generally stony, but well laminated from 8.0 m to 12.0 m with rare stones	17.8+	18.0

NZ 42 NE 105 **4828 2594** **Cloff Bridge** **Block B**

Surface level (+4.6 m) +15 ft
Water level +0.1 m
October 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.7	0.7
Alluvium	Clay, grey, plastic; fine quartz sand lenses	3.3	4.0
	Peaty clay, black and grey, silty	6.6	10.6
Glacial Drift, undifferentiated	Clay, brown, silty; mainly massive and stony but laminated and stoneless from 15.0 m to 17.8 m	7.4+	18.0

NZ 42 NE 106 **4902 2518** **Cowpen Bewley** **Block B**

Surface level (+2.4 m) +8 ft
Water Struck at -11.6 m
October 1975

Overburden 10.0 m
Mineral 3.8 m
Waste 8.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Laminated Clay	Clay, red-brown, laminated	2.3	2.6
Glacial Drift, undifferentiated	Clay, brown, mainly massive to poorly laminated but well laminated in parts, stony to 5.5 m	5.6	8.2
	Silt, red-brown, sandy; poor laminae of fine coal	1.8	10.0
Glacial Sand and Gravel	'Clayey' sand, red-brown: fine to medium, subangular to subrounded; quartz with coal and some Carboniferous and Magnesian Limestone fragments	3.8	13.8
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but laminated and stoneless in top 0.5 m; 0.1 m sand at 20.6 m	8.2+	22.0

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 mm
18	82	trace	10.0-11.0	33	51	16	trace	0	0	0
			11.0-12.0	16	41	41	2	trace	0	0
			12.0-13.0	12	50	38	trace	0	0	0
			13.0-13.8	9	52	39	0	0	0	0
			Mean	18	48	33	1	trace	0	0

NZ 42 SW 32 **4026 2399** **Thorpe Thewles Station** **Block A**

Surface level (+46.3 m) +152 ft
Water not encountered
November 1975

Overburden 14.9 m
Mineral 9.5 m
Waste 0.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Boulder Clay	Clay, red-brown, stony; silty at top	9.5	10.0
	Silt, sandy, red-brown; grey clay laminae and lenses at top	4.9	14.9
Glacial Sand and Gravel	'Very clayey' sand, red-brown: fine, subangular to rounded; quartz with coal and a little mica; 0.1 m sandy silt at 21.2 m	9.5	24.4
Boulder Clay	Clay, grey, massive, stony	0.6+	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 mm
24	76	trace	14.9-15.9	30	63	7	trace	0	0	0
			15.9-16.9	24	72	4	trace	0	0	0
			16.9-17.9	18	73	9	0	0	0	0
			17.9-18.9	11	83	6	trace	0	0	0
			18.9-19.9	20	75	5	0	0	0	0
			19.9-20.9	26	63	11	0	0	0	0
			20.9-21.9	32	38	29	1	trace	0	0
			21.9-22.9	22	37	39	2	trace	0	0
			22.9-24.4	29	45	26	trace	0	0	0
			Mean	24	60	16	trace	trace	0	0

NZ 42 SW 33 **4118 2445** **Grindon** **Block A**

Surface level (+22.6 m) +74 ft
Water level +18.6 m
December 1975

Overburden 4.0 m
Mineral 21.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Clay and silt, brown to grey, shelly at top, stony towards base; 0.3 m peat at 2.0 m	3.7	4.0
	Gravel Gravel: fine to coarse, subrounded to rounded; sandstone, dolomite and limestone with igneous rocks and some quartzite, silicified limestone, mudstone and soft red sandstone, and trace of ironstone Sand: coarse to medium; lithic fragments as in gravel, with quartz	21.0+	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 mm
3	48	49	4.0-5.0	5	7	10	15	29	34	0
			5.0-6.0	4	3	16	26	20	29	2
			6.0-7.0	2	2	20	31	14	28	3
			7.0-8.0	3	5	27	27	16	17	5
			8.0-9.0	1	3	10	22	29	32	3
			9.0-10.0	2	3	11	20	32	28	4
			10.0-11.0	2	4	11	17	27	33	6
			11.0-12.0	2	2	18	31	18	25	4
			12.0-13.0	2	2	14	21	24	32	5
			13.0-14.0	4	3	14	40	28	11	0
			14.0-15.0	3	4	14	28	26	23	2
			15.0-16.0	4	3	13	33	30	16	1
			16.0-17.0	3	5	17	28	22	19	6
			17.0-18.0	5	3	26	27	21	17	1
			18.0-19.0	1	1	22	38	20	18	0
			19.0-20.0	2	1	24	31	22	16	4
			20.0-21.0	4	4	17	28	24	23	0
			21.0-22.0	3	2	14	30	26	25	0
			22.0-23.0	2	3	15	26	27	25	2
			23.0-24.0	4	4	16	25	26	23	2
			24.0-25.0	3	10	26	30	20	9	2
			Mean	3	4	17	27	24	23	2

COMPOSITION

Depth below surface (m)	percentages by weight in gravel fraction							
	Sandstone	Limestone	Dolomite	Igneous rock	Quartzite/ Quartz	Silicified limestone	Mudstone	Ironstone
4.0-5.0	33	24	24	16	trace	2	1	trace
9.0-10.0	23	29	27	8	4	8	1	0
14.0-15.0	32	26	25	11	1	3	2	0
19.0-20.0	25	10	43	13	1	1	7	0
24.0-25.0	49	20	18	8	2	2	1	trace

NZ 42 SW 34 **4250 2474** **Bottle Hill** **Block B**

Surface level (+49.7 m) +163 ft
Water level +45.1 m
September 1975

Waste 22.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Drift, undifferentiated	Clay, brown, massive, stony, sandy in parts, 0.1 m coarse gravel at 5.3 m and 0.3 m 'very clayey' sand at 7.8 m	8.3	8.6
Glacial Sand and Gravel	'Very clayey' sand, yellow-brown: fine to medium quartz	2.8	11.4
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but laminated and stoneless from 13.0 m to 15.6 m; 0.6 m 'very clayey' sand at 12.4 m	10.6+	22.0

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$ mm	
22	77	1	8.6-11.4	22	43	32	2	1	0	0	

NZ 42 SW 35 **4353 2401** **Viewly Hill** **Block B**

Surface level (+36.6 m) +120 ft
Water not encountered
December 1975

Waste	18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Drift, undifferentiated	Clay, brown, massive to laminated, stony in part; some silty horizons, 0.3 m 'very clayey' sand at 7.5 m	17.7+	18.0

NZ 42 SW 36 **4417 2468** **White House Farm** **Block B**

Surface level (+33.8 m) +111 ft
Water not encountered
November 1975

Overburden	7.6 m
Mineral	11.3 m
Waste	2.5 m
Mineral	1.0 m
Waste	2.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but poorly laminated in part, silty at base; 1.1 m sandy silt at 5.2 m	7.4	7.6
Glacial Sand and Gravel	**a** 'Very clayey' pebbly sand: medium to fine, subangular to subrounded; quartz with some quartzite; some sandstone and quartzite pebbles	2.1	9.7
	b 'Clayey' sandy gravel, 'very clayey' at base Gravel: fine to coarse, subangular to subrounded; sandstone, limestone and dolomite with igneous rocks and some quartzite, silicified limestone, and traces of mudstone and ironstone Sand: medium to coarse, subangular to subrounded; quartz with quartzite and some sandstone and limestone Fines: mainly brown to grey but black and peaty at 14.0 m	9.2	18.9
	Silt and clay, brown, sandy and micaceous	2.5	21.4
	c 'Very clayey' sand: fine; quartz with some mica	1.0	22.4
	Sandy silt	2.6+	25.0

GRADING

	Mean for deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					-1/16	+1/16 -1/4	+1/4 -1	+1 -4	+4 -16	+16 -64	+64 mm
a	25	71	4	7.6-8.6	28	18	46	6	2	0	0
				8.6-9.7	22	33	30	9	6	0	0
				Mean	25	26	37	8	4	0	0
b	11	54	35	9.7-10.7	11	14	23	29	15	8	0
				10.7-11.7	10	18	21	12	12	27	0
				11.7-12.7	8	8	29	20	12	23	0
				12.7-13.8	7	6	25	23	22	17	0
				13.8-14.8	13	10	47	16	9	5	0
				14.8-15.9	6	5	32	10	21	26	0
				15.9-17.0	9	8	36	11	15	21	0
				17.0-18.0	5	5	26	11	32	21	0
				18.0-18.9	30	8	32	7	13	10	0
				Mean	11	9	30	15	17	18	0
a+b	13	58	29	Mean	13	12	32	14	14	15	0
c	37	63	0	21.4-22.4	37	62	1	0	0	0	0
a+b+c	16	55	29	Mean	16	16	25	14	16	13	0

COMPOSITION

Depth below surface (m)	percentages by weight in gravel fraction							
	Sandstone	Limestone	Dolomite	Igneous rock	Quartzite/ Quartz	Silicified limestone	Mudstone	Ironstone
9.7-10.7	40	27	17	10	3	2	1	trace
12.7-13.8	21	22	40	9	4	4	trace	0
14.8-15.9	23	33	31	5	2	5	1	0
18.0-18.9	27	38	18	10	2	5	trace	trace

NZ 42 SW 37 **4474 2395** **Northfield House** **Block B**

Surface level (+23.8 m) +78 ft
Water level +22.3 m
November 1975

Overburden 5.0 m
Mineral 2.0 m
Waste 17.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	1.1	1.1
Alluvium	Clay, grey-black, peaty and micaceous, sandy in part; 0.1 m peat at 3.6 m	3.9	5.0
Glacial Sand and Gravel	'Very clayey' sand, yellow-brown: fine quartz	2.0	7.0
Glacial Drift, undifferentiated	Clay, brown, poorly laminated, micaceous	12.8	19.8
	'Clayey' sand, brown: fine with medium quartz; traces of limestone pebbles	3.7	23.5
	Clay, grey and brown; some silty lenses	1.0+	24.5

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16 -1/4	+1/4 -1	+1 -4	+4 -16	+16 -64	+64 mm
29	69	2	5.0-7.0	29	54	13	2	1	1	0
11	89	trace	19.8-20.8	13	81	6	trace	trace	0	0
			20.8-21.8	11	64	24	1	trace	0	0
			21.8-23.5	10	50	37	3	trace	0	0
			Mean	11	62	25	2	trace	0	0

NZ 42 SW 38 **4166 2336** **Low Middlefield Farm** **Block A**

Surface level (+50.3 m) +165 ft
Water not encountered
November 1975

Overburden	8.0 m
Mineral	8.0 m
Waste	9.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony, silty in parts; 0.6 m micaceous silt and 'very clayey' sand at 6.1 m	7.8	8.0
Glacial Sand and Gravel	'Very clayey' sand, grey to brown: mainly fine; quartz with some quartzite	8.0	16.0
Glacial Drift, undifferentiated	Clay, grey and brown, silty, partly laminated; stony towards base	9.0+	25.0

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16 -1/4	+1/4 -1	+1 -4	+4 -16	+16 -64	+64 mm
21	79	trace	8.0-9.0	17	38	39	5	1	0	0
			9.0-10.0	15	44	39	2	trace	0	0
			10.0-11.0	13	54	32	1	0	0	0
			11.0-12.0	10	65	25	trace	0	0	0
			12.0-13.0	21	72	7	trace	0	0	0
			13.0-14.1	28	69	3	0	0	0	0
			14.1-15.1	29	70	1	0	0	0	0
			15.1-16.0	32	64	4	0	0	0	0
			Mean	21	59	19	1	trace	0	0

NZ 42 SW 39 **4282 2315** **Brookdale Farm** **Block A**

Surface level (+36.9 m) +121 ft
Water level not recorded
November 1975

Overburden 7.0 m
Mineral 13.5 m
Waste 4.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Boulder Clay	Clay, grey-brown, massive, stony, silty in part	6.4	7.0
Glacial Sand and Gravel	**a** 'Very clayey' sand Sand: fine, subrounded to rounded quartz Fines: yellow-brown micaceous clay	2.6	9.6
	b Sand, pebbly in upper part, yellow and grey: medium; quartz with quartzite and some coal	5.0	14.6
	c 'Clayey' sand, light brown: fine; quartz with some coal	5.9	20.5
Glacial Drift, undifferentiated	Clay, grey and brown, slightly micaceous, stony towards base; fine sand laminae	4.5+	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 mm
a	35	65	trace	7.0-8.0	39	58	3	trace	0	0	0
				8.0-9.6	33	60	7	trace	0	0	0
				Mean	35	59	6	trace	0	0	0
b	6	91	3	9.6-10.6	5	26	55	11	3	trace	0
				10.6-11.6	7	14	65	5	6	3	0
				11.6-12.6	8	31	58	2	1	trace	0
				12.6-13.6	5	23	71	1	trace	0	0
				13.6-14.6	5	18	76	1	0	0	0
				Mean	6	22	65	4	2	1	0
c	12	88	0	14.6-15.6	10	76	14	trace	0	0	0
				15.6-16.6	11	83	6	0	0	0	0
				16.6-17.6	10	84	6	0	0	0	0
				17.6-18.6	14	80	6	trace	0	0	0
				18.6-20.5	14	78	8	trace	0	0	0
				Mean	12	80	8	trace	0	0	0
a+b+c	14	85	1	Mean	14	55	29	1	1	trace	0

NZ 42 SW 40 **4375 2315** **Newclose Farm** **Block B**

Surface level (+7.9 m) +26 ft
Water struck at +3.2 m
November 1975

Waste 20.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Alluvium on Glacial Drift, undifferentiated	Clay, red-brown to grey, silty; band of 'very clayey' sand from 3.2 m to 4.2 m and fine to coarse gravel from 4.7 m to 5.7 m	5.5	5.7
	Clay, brown and grey, stony; partly silty and sandy	14.3+	20.0

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$ mm
22	78	trace	3.2-4.2	22	52	26	trace	trace	0	0
4	24	72	4.7-5.7	4	5	10	9	29	43	0

NZ 42 SW 41 **4073 2252** **Middlefield Farm** **Block A**

Surface level (+40.5 m) +133 ft
Water not encountered
November 1975

Waste 20.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown and yellow, stony, massive	8.3	8.6
Glacial Drift, undifferentiated	Clay, brown and grey, mainly stony, silty and sandy in part; 1.2 m laminated micaceous silt at 9.8 m and 1.4 m 'very clayey' sand at 19.0 m	11.4+	20.0

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$ mm
20	80	0	17.6-19.0	20	52	28	trace	0	0	0

NZ 42 SW 42 **4187 2260** **Howden Hall** **Block A**

Surface level (+44.8 m) +147 ft
Water not encountered
October 1975

Overburden	6.3 m
Mineral	7.0 m
Waste	1.3 m
Mineral	3.4 m
Waste	6.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, massive and stony	6.0	6.3
Glacial Sand and Gravel	**a** 'Very clayey' sand, red-brown: fine, subrounded to subangular; quartz with some lithic grains including coal	7.0	13.3
Boulder Clay	Clay, brown, generally massive, silty in part	1.3	14.6
Glacial Sand and Gravel	**b** 'Very clayey' pebbly sand, grey-brown Gravel: fine to coarse, subrounded to subangular; limestone and sandstone Sand: fine and medium, subrounded to subangular; quartz with some Magnesian Limestone	3.4	18.0
Boulder Clay	Clay, grey, massive, part silty	6.0+	24.0

GRADING

	Mean for deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$ mm
a	30	70	trace	6.3-8.3	37	61	1	1	trace	0	0
				8.3-10.3	30	63	6	1	0	0	0
				10.3-12.3	26	70	4	trace	trace	0	0
				12.3-13.3	28	68	4	trace	0	0	0
				Mean	30	66	4	trace	trace	0	0
b	25	67	8	14.6-15.6	36	50	14	trace	trace	0	0
				15.6-16.6	18	28	35	8	8	3	0
				16.6-18.0	22	23	36	7	8	4	0
				Mean	25	33	29	5	5	3	0
a+b	29	68	3	Mean	29	54	12	2	2	1	0

NZ 42 SW 43 **4330 2256** **Hornleys Farm** **Block A**

Surface level (+31.4 m) +103 ft
Water not encountered
November 1975

Waste	18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	1.0	1.0
Glacial Drift, undifferentiated	Clay, brown, mainly massive and stony but well laminated and sandy from 6.6 m to 14.6 m and poorly laminated in places elsewhere; 0.6 m fine 'very clayey' quartz sand at 6.6 m	17.0+	18.0

NZ 42 SW 44 **4012 2058** **Carlton Farm** **Block A**

Surface level (+48.8 m) +160 ft
Water not encountered
October 1975

Overburden 13.7 m
Mineral 4.8 m
Waste 5.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Boulder Clay	Clay, brown, stony, sandy at base; silty laminae in parts	13.2	13.7
Glacial Sand and Gravel	'Clayey' sand, brown: mainly medium, subangular to subrounded; quartz with some lithic fragments including coal	4.8	18.5
Boulder Clay	Clay, brown, massive, with some stones	5.5+	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 mm
12	88	trace	13.7-14.7	18	50	31	1	0	0	0
			14.7-15.7	12	18	69	1	trace	0	0
			15.7-16.7	11	14	74	1	trace	0	0
			16.7-17.7	8	21	71	trace	trace	0	0
			17.7-18.5	9	21	68	1	1	0	0
			Mean	12	25	62	1	trace	0	0

NZ 42 SW 45 **4128 2124** **Norton** **Block A**

Surface level (+41.5 m) +136 ft
Water level not recorded
October 1975

Overburden 16.3 m
Mineral 8.7 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Boulder Clay	Clay, brown, silty in part, mainly massive but poorly laminated at 7.5 m	16.2	16.3
Glacial Sand and Gravel	'Clayey' sand, 'very clayey' at base, brown: mainly fine, subrounded to rounded; quartz with some Magnesian Limestone and coal	8.7+	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 mm
14	86	0	16.3-17.3	12	56	32	trace	0	0	0
			17.3-19.3	12	56	32	trace	0	0	0
			19.3-20.3	8	55	37	trace	0	0	0
			20.3-21.3	7	59	33	1	0	0	0
			21.3-22.3	9	60	29	2	0	0	0
			22.3-23.3	19	72	9	trace	0	0	0
			23.3-25.0	23	72	5	trace	0	0	0
			Mean	14	62	24	trace	0	0	0

NZ 42 SW 46 **4248 2037** **Hardwick Dene Farm** **Block A**

Surface level (+23.5 m) +77 ft
Water level not recorded
November 1975

Overburden	4.4 m
Mineral	2.0 m
Waste	13.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown to grey, silty	4.1	4.4
Glacial Sand and Gravel	'Very clayey' sand Sand: fine to medium; quartz with lithic grains Fines: thin partings of brown and grey clay	2.0	6.4
Glacial Drift, undifferentiated	Clay, grey, very silty, laminated in places; some pebbles, 0.9 m silt at base	5.9	12.3
	Silt, clayey, brown; some fine coal detritus, 0.7 m red-brown to grey clay with silt partings at 13.0 m	7.7+	20.0

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$ mm
20	80	trace	4.4-5.4	21	56	22	1	trace	0	0
			5.4-6.4	20	40	38	2	trace	0	0
			Mean	20	49	30	1	trace	0	0

NZ 42 SW 47 **4074 2169** **Carlton** **Block A**

Surface level (+50.6 m) +166 ft
Water struck at +39.6 m
September 1976

Overburden	8.4 m
Mineral	8.3 m
Waste	2.2 m
Mineral	1.5 m
Waste	1.0 m
Mineral	3.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, silty, brown to red-brown, generally massive, stony	8.1	8.4
Glacial Sand and Gravel	a 'Clayey' pebbly sand with silty clay partings at 9.6 m and 13.3 m Gravel: fine with some coarse, subangular to rounded; sandstone, dolomite and limestone with some igneous rock, quartzite, silicified limestone, red sandstone, quartz and mudstone Sand: mainly medium, subangular to subrounded; quartz with some limestone, sandstone and coal Fines: brown silty clay	8.3	16.7
Glacial Drift, undifferentiated	Silty clay, red-brown; some silty and sandy laminae, 0.4 m clayey gravel at 17.2 m	2.2	18.9

Glacial Sand and Gravel	**b** 'Very clayey' sand Sand: fine to medium, quartz with some coal Fines: some brown clay partings and some silty clay towards base	1.5	20.4
	Clay, brown, with sand and silt laminae and some fine coal bands, some stones	1.0	21.4
	c 'Very clayey' sand with scattered silty clay bands near top: fine quartz with some coal	3.6+	25.0

GRADING

	Mean for deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$ mm
a	11	77	12	8.4-9.4	10	69	21	trace	0	0	
				9.4-9.6	clay band						
				9.6-10.6	17	53	28	2	trace	0	0
				10.6-11.6	9	20	55	10	6	0	0
				11.6-12.6	7	14	58	12	9	0	0
				12.6-13.2	3	4	42	22	26	3	0
				13.2-13.3	clay band						
				13.3-14.3	3	5	34	27	26	5	0
				14.3-15.3	2	3	38	25	31	1	0
				15.3-16.3	5	18	62	12	3	0	0
				16.3-16.7	6	18	53	23	0	0	0
				Mean*	11	23	41	13	11	1	0
b	29	71	trace	18.9-20.4	29	39	30	2	trace	0	0
c	23	77	trace	21.4-22.4	32	59	8	1	0	0	0
				22.4-23.4	23	53	21	1	2	0	0
				23.4-25.0	18	77	5	trace	trace	0	0
				Mean	23	66	10	1	trace	0	0
a+b+c	16	76	8	Mean*	16	36	31	9	7	1	0

* Assuming ungraded clay comprises 100% fines

NZ 42 SE 407 4537 2478 **Cowbridge Beck** **Block B**

Surface level (+28.3 m) +93 ft
Water not encountered
October 1975

Overburden	0.3 m
Mineral	1.0 m
Waste	3.0 m
Mineral	1.7 m
Waste	3.0 m
Mineral	11.2 m
Waste	1.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	**a** 'Very clayey' sand, brown to grey: fine with medium; quartz with coal, Carboniferous sandstone, limestone and Magnesian Limestone	1.0	1.3
	Sandy silt, red-brown	3.0	4.3
	b 'Very clayey' sand: fine; as above	1.7	6.0
	Sandy silt, red-brown with clay bands up to 0.1 m thick	3.0	9.0

	c 'Clayey' sand, 'very clayey' at top and near base Sand: fine to medium, subangular to subrounded; quartz with sandstone, limestone, coal and some Magnesian Limestone Fines: mainly brown to red-brown but grey-black from 11.0 m to 12.8 m	5.8	14.8
	d Pebbly sand Gravel: fine with some coarse; sandstone, dolomite and limestone with igneous rock, some silicified limestone and quartz and trace of mudstone Sand: medium to coarse, subangular to subrounded; quartz with sandstone, limestone, dolomite and coal	5.4	20.2
Boulder Clay	Clay, brown, massive and stony; 0.1 m clayey silt at top	1.3+	21.5

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 mm
a	22	76	2	0.3-1.3	22	49	24	3	2	0	0
b	34	66	0	4.3-5.3	36	63	1	trace	0	0	0
				5.3-6.0	31	67	2	trace	trace	0	0
				Mean	34	64	2	trace	0	0	0
c	18	82	trace	9.0-10.0	26	67	7	0	0	0	0
				10.0-11.0	9	53	38	trace	0	0	0
				11.0-12.0	15	34	48	3	trace	0	0
				12.0-12.8	13	36	46	5	trace	0	0
				12.8-13.8	26	68	6	trace	0	0	0
				13.8-14.8	18	57	22	2	1	0	0
				Mean	18	53	27	2	trace	0	0
d	5	76	19	14.8-15.8	7	19	29	22	17	6	0
				15.8-16.8	4	6	40	37	11	2	0
				16.8-17.8	6	5	33	32	17	7	0
				17.8-18.8	3	1	36	40	14	6	0
				18.8-20.2	6	7	51	22	12	2	0
				Mean	5	7	39	30	15	4	0
c+d	12	79	9	Mean	12	31	33	15	7	2	0
a+b+c+d	15	78	7	Mean	15	37	29	12	6	1	0

COMPOSITION

Depth below surface (m)	percentages by weight in gravel fraction							
	Sandstone	Limestone	Dolomite	Igneous rock	Quartzite/ Quartz	Silicified limestone	Mudstone	Ironstone
15.8-16.8	35	24	28	8	2	3	trace	0
17.8-18.8	33	28	28	8	1	2	trace	0

NZ 42 SE 408 **4753 2441** **Cowpen Lane** **Block B**

Surface level (+10.1 m) +33 ft
Water not encountered
October 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Laminated Clay	Clay, red-brown to grey, laminated	4.4	4.7
Boulder Clay	Clay, brown, mainly massive and stony	7.3	12.0
Laminated Clay	Clay, brown, laminated generally stoneless	3.4	15.4
Boulder Clay	Clay, brown to grey-brown, massive and stony	2.6+	18.0

NZ 42 SE 409 **4897 2437** **Fore Marsh** **Block B**

Surface level (+2.4 m) +8 ft
Water not encountered
October 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Estuarine Alluvium and Laminated Clay	Clay, brown, laminated	2.6+	3.0
Boulder Clay	Clay, brown, stony,mainly massive but poorly laminated from 8.6 m to 9.2 m and 10.6 m to 11.6 m	9.3	12.3
Glacial Drift, undifferentiated	Clay, brown, laminated and relatively stoneless to 17.7 m; green-grey, massive and stony at base	5.7+	18.0

NZ 42 SE 410 **4722 2327** **Greenwood Road, Billingham** **Block B**

Surface level (+11.9 m) +39 ft
Water not encountered
October 1975

Waste 25.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Laminated Clay	Clay, brown, with fine sand laminae	4.2	4.6
Boulder Clay	Clay, brown, massive and stony	3.4	8.0
Glacial Sand and Gravel	Sandy silt, red-brown; clayey to 9.0 m	9.0	17.0
	'Very clayey' sand, red-brown: fine; quartz with coal and some Magnesian Limestone and Carboniferous rocks	3.0	20.0
	Sandy silt, red-brown, with 0.9 m laminated clay at 22.1 m and 0.9 m 'clayey' gravel at base	5.0+	25.0

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				−1/16	+1/16 −1/4	+1/4 −1	+1 −4	+4 −16	+16 −64	+64 mm
31	69	0	17.0-18.0	34	64	2	trace	0	0	0
			18.0-19.0	33	64	3	0	0	0	0
			19.0-20.0	27	72	1	0	0	0	0
			Mean	31	67	2	0	0	0	0
13	40	47	24.1-25.0	13	20	10	10	25	22	0

NZ 42 SE 411 4822 2365 **Bewley Road, Cowpen Bewley** **Block B**

Surface level (+6.1 m) +20 ft
Water level +1.8 m
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Laminated Clay	Clay, brown, silty, micaceous, laminated at base; some stones	3.0	3.2
Boulder Clay	Clay, brown, mainly massive and stony but poorly laminated in part	5.6	8.8
Glacial Sand and Gravel	Sandy silt, grey-green; fine sand laminae near top	5.0	13.8
Boulder Clay	Clay, brown, massive and stony, with bands of sandy silt at base	4.2+	18.0

NZ 52 NW 177 5030 2931 **Stockton Road, Hartlepool** **Block B**

Surface level (+15.8 m) +52 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Drift, undifferentiated	Sandy silt, brown and grey, poorly laminated and slightly micaceous	1.4	1.6
	Clay, brown, massive, stony; 0.3 m grey laminated sandy silt at 5.8 m	6.6	8.2
	Silt and silty clay with irregular silty laminae at top, scattered stones	2.6	10.8
	Clay, brown to green-grey, mainly massive and stony but with scattered laminae below 14.6 m	7.2+	18.0

NZ 52 NW 178 5119 2981 Seaton Grange (demolished) Block B

Surface level (+7.6 m) +25 ft
Water level -10.4 m
December 1975

Overburden 17.2 m
Mineral 7.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Drift, undifferentiated	Clay, red-brown to grey-brown, mainly massive and stony but laminated and stoneless below 4.6 m	6.1	6.3
Glacial Sand and Gravel	Sandy silt, grey-brown to red-brown, massive; 0.5 m sandy gravel at base	8.4	14.7
	Silty clay, grey-brown, laminated and slightly micaceous	2.5	17.2
	a Sandy gravel Gravel: fine to coarse, subangular to subrounded; dolomite with sandstone, limestone and igneous rocks, and some silicified limestone, quartz and mudstone Sand: fine to coarse, subangular to subrounded; dolomite, sandstone and limestone with quartz and coal	1.8	19.0
	b Pebbly sand with 0.2 m brown laminated clay at 21.2 m Gravel: fine, subangular to subrounded; dolomite, sandstone and limestone Sand: fine with medium to coarse; quartz with coal and some other lithic fragments	6.0+	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 mm
a	4	66	30	17.2-18.2	3	8	25	30	20	14	0
				18.2-19.0	5	30	26	14	7	15	3
				Mean	4	18	25	23	14	15	1
b	10	83	7	19.0-20.0	6	58	28	6	1	1	0
				20.0-21.0	5	73	20	2	trace	0	0
				21.0-21.2	Clay band						
				21.2-22.0	6	51	10	23	10	0	0
				22.0-23.0	9	64	14	9	4	0	0
				23.0-24.0	8	66	15	7	4	0	0
				24.0-25.0	5	50	11	12	18	4	0
				Mean*	10	58	16	9	6	1	0
a+b	9	79	12	Mean*	9	49	18	12	8	4	trace

* Assuming ungraded clay comprises 100% fines

COMPOSITION

Depth below surface (m)	percentages by weight in gravel fraction							
	Sandstone	Limestone	Dolomite	Igneous rock	Quartzite/ Quartz	Silicified limestone	Mudstone	Ironstone
17.2-19.0	19	19	43	15	1	2	1	0

NZ 52 NW 179 **5215 2922** **Cricket Ground, Seaton Carew** **Block B**

Surface level (+5.2 m) +17 ft
Water not encountered
December 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, red-brown, mainly massive and stony but stoneless from 15.6 m to 16.2 m; some fine quartz sand lenses, 0.3 m sandy silt at 13.4 m	17.7+	18.0

NZ 52 NW 180 **5136 2903** **Brenda Road, Seaton Carew** **Block B**

Surface level (+7.6 m) +25 ft
Water level +3.6 m
January 1976

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown, stony, mainly massive but laminated from 9.8 m to 12.3 m	17.7+	18.0

NZ 52 NW 181 **5278 2889** **Golf Links, Seaton Carew** **Block B**

Surface level (+1.8 m) +6 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Estuarine Alluvium	Clay, grey-green, silty; 0.2 m peat at 2.0 m and peaty towards base	2.7	2.9
Boulder Clay	Clay, brown, mainly massive and stony but includes silty laminae from 10.8 m to 12.0 m	15.1+	18.0

NZ 52 NW 182 **5212 2827** **Hunter House** **Block B**

Surface level (+3.7 m) +12 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, brown, mainly massive and stony but laminated and stoneless from 11.7 m to 12.8 m and stoneless at base	17.8+	18.0

NZ 52 NW 183 **5127 2766** **Graythorp** **Block B**

Surface level (+9.1 m) +30 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown, massive, stony, silty at top	12.1	12.4
Glacial Drift, undifferentiated	Clay, grey-brown, red-brown, laminated, slightly silty, stony towards base; 0.6 m sandy silt at 15.8 m	5.6+	18.0

NZ 52 NW 184 **5012 2715** **Thorn Tree Lane, Greatham** **Block B**

Surface level (+15.2 m) +50 ft
Water not encountered
November 1975

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, brown, massive, stony	10.7	11.0
Glacial Drift, undifferentiated	Clay, grey-brown, mainly laminated and relatively stoneless but below 15.4 m includes bands of massive stony clay	7.0+	18.0

Other boreholes

NZ 42 NW 2, 3, 4, 5, 6, 12, 14, 15, 17, 38/59, 38/60.

NZ 42 NE 1, 3, 4, 5, 36, 38, 43, 55, 68, 69, 70, 71, 74, 75/10, 75/11, 75/12, 75/20, 75/23, 75/29, 82.

NZ 42 SW 1, 2, 20, 21a, b, c, 25, 26, 27, 30, 31a, b, c, 48/32, 48/33, 48/44A, 48/45, 48/47, 48/48A, 48/48R, 48/49, 48/53, 48/54, 48/55, 48/56, 48/57A, 48/58A.

NZ 42 SE 229, 230, 234.

NZ 52 NW 1a, b, c, d, e, f, g, u, j, k, l, m, n, p, q, r, s, 85, 86, 87, 90, 102.

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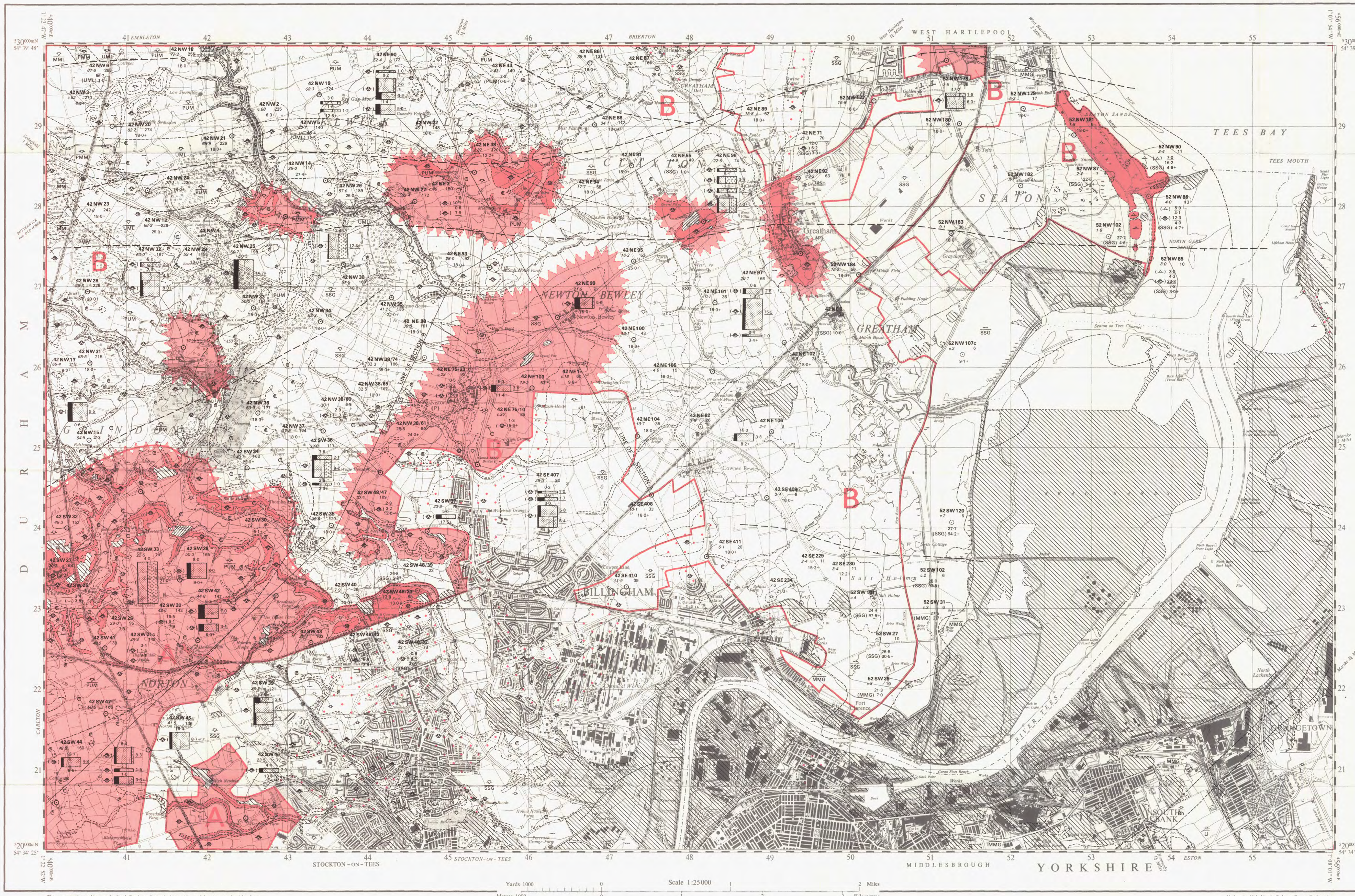
INSTITUTE OF GEOLOGICAL SCIENCES

INDUSTRIAL MINERALS ASSESSMENT UNIT

THE SAND & GRAVEL RESOURCES OF SHEET NZ42 & part of SHEET NZ52 (BILLINGHAM, CLEVELAND)

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

ORDNANCE SURVEY
SHEET NZ42 & Pt NZ52
PROVISIONAL EDITION



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

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

Geological lines from six-inch surveys by D. B. Smith in 1963-69, and G. D. Gaunt in 1954-56. (The solid lines shown here are provisional) W. Anderson, A. W. Woodland and E. H. Francis, District Geologists.

Sand and Gravel Survey by J. W. C. James and D. A. Abraham in 1975. R. G. Thurrell, Head, Industrial Minerals Assessment Unit.

1:25 000 Sand and Gravel Resource Sheet published 1982. G. M. Brown, D.Sc., F.R.S., Director, Institute of Geological Sciences incorporating Geological Survey of Great Britain, the Museum of Practical Geology and Overseas Geological Surveys. 1100.82

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 1913-39. Other partial systematic revision 1938-53 has been incorporated. Major roads revised 1963-72.

Made and published by the Ordnance Survey, Southampton.

Diagram showing the relation of the National Grid 1:25 000 sheets with the One-inch Geological Sheets 27, 33 and 34

THE SAND & GRAVEL RESOURCES OF SHEET NZ42 & part of SHEET NZ52 (BILLINGHAM, CLEVELAND)

99 Mineral Assessment Report 99

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

EXPLANATION OF SYMBOLS AND ABBREVIATIONS

Landslip L-1

DRIFT

RECENT AND PLEISTOCENE

- **Blown Sand** BS-6
- **Peat** P-1
- **Lacustrine Alluvium** -clay, silt and sand LA-6
- **Alluvium and Alluvial Fan** -silt and sand with gravel and some peat A-62
- **Marine or Estuarine Alluvium** -silt and clay with scattered bivalve shells ME-11
- **Head** -heterogeneous colluvium, mainly of stony clay H-39
- **Glacial Sand and Gravel** -'clayey' to 'very clayey' sand with some beds of stony and laminated clay, and scattered bands of gravel GS-67
- **Laminated Clay** -red-brown silt and silty clay with beds of sand and stony clay LC-7
- **Boulder Clay (Till) and Glacial Drift, undifferentiated** -brown stony clay with some bands of silt, sand, gravel and laminated clay BC-36

SOLID

JURASSIC

- Li **Lias** -soft grey shales with thin limestones, beds of fine sandstone and calcareous and sideritic concretions

PERMIAN AND TRIAS

- Rh **Rhaetic** -grey, black and green, shaly or soft mudstones
- MMG **Mercia Mudstone Group (Keuper Marl)** -green, red, purple and grey mudstone and siltstone with traces of evaporites in the lower part
- SSG **Sherwood Sandstone Group (Bunter Sandstone)** -soft red sandstone with subordinate beds of red mudstone and siltstone
- PUM **Permian Upper Marls** -red-brown mudstone and siltstone with thin red sandstone, and the Billingham Main Anhydrite or its residue at base
- UML **Upper Magnesian Limestone (Seaham Formation)** -grey thinly bedded fine-grained dolomite
- PMM **Permian Middle Marls** -red and grey mudstone and siltstone with anhydrite or its residue at many levels. Passes locally into breccia
- MML **Middle Magnesian Limestone** -white to pale grey mainly oolitic dolomite

Made Ground MG-2

Areas worked for Sand and Gravel WO-20

BOUNDARY LINES

- Geological boundary, Drift.
- Geological boundary, Solid.
- Fault, crossmark indicates downthrow side.
- Resource Block boundary.
- Inferred boundary between recognised categories of deposits.

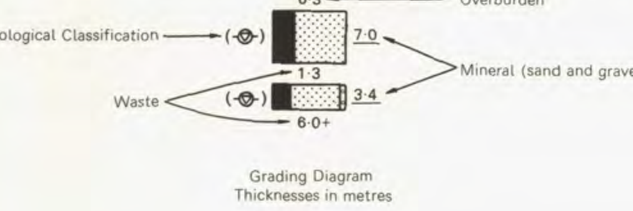
Broken line denotes uncertainty.

BOREHOLE DATA

SITE LOCATIONS

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

I.M.A.U. BOREHOLES



Grading Diagram
Thicknesses in metres

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 metric conversions of 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. **42 SW 42.** The first number and letters refer to the quarter sheet and the second number to the I.G.S. serial number for that quarter. The unique designation for borehole **42 SW 42** is **NZ 42 SW 42.**

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 show the proportions of **Fines, Sand** and **Gravel** but small amounts of gravel may be omitted or exaggerated.

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.

CATEGORIES OF DEPOSITS

- **Exposed mineral, assessed.** CAT-E2
- **Continuous or almost continuous spreads of mineral beneath overburden.** CAT-C1
- **Sand and gravel either not potentially workable (see Report) or absent.** CAT-A2
- **Sand and gravel not assessed.** CAT-N1

RESOURCE BLOCKS

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

Horizontal sections showing the general relations of the drift deposits along the lines shown constitute Figure 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.

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