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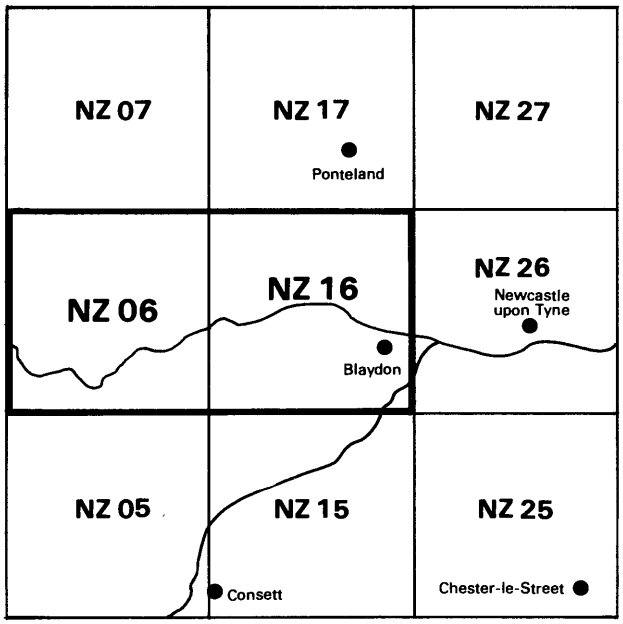

The sand and gravel resources of the country around Blaydon, Tyne and Wear

Description of 1:25 000 resource sheet NZ 06, 16

J. R. A. Giles

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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 co-operation of the Sand and Gravel Association of Great Britain.

This report describes the resources of sand and gravel of the country around Blaydon, Tyne and Wear, shown on the accompanying 1:25 000 resource map NZ 06, 16. The survey was conducted by Mr J. R. A. Giles under the supervision of Mr D. Price, assisted in the drilling and sampling programme by Mr I. Jackson and Mr J. H. Lovell. The work is based on geological surveys, carried out at the scale of 1:10 560 and 1:10 000, by the Institute's Field Staff in 1935–38 and 1976–79. Mr J. D. Burnell, ISO, and Mr C. L. Reeves (Land Agents) have been responsible for negotiating access to land for drilling. The ready co-operation of land owners and tenants in this work is gratefully acknowledged.

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The sand and gravel resources of the country around Blaydon, Tyne and Wear *In pocket*

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The sand and gravel resources of the country around Blaydon, Tyne and Wear

Description of 1:25 000 resource sheet NZ 06, 16

J. R. A. GILES

SUMMARY

The geological maps of the Institute of Geological Sciences, pre-existing borehole information and 69 boreholes drilled for the Industrial Minerals Assessment Unit, form the basis of the assessment of sand and gravel resources around Blaydon, Tyne and Wear.

All deposits in the area which might be potentially workable for sand and gravel have been investigated and a simple statistical method has been used to estimate the volume. The reliability of the volume estimates is given at the asymmetrical 90 per cent probability level.

The 1:25 000 map is divided into 4 resource blocks, containing between 0.9 and 26.3 km^2 of sand and gravel. For each block the geology of the deposit is described and the mineral-bearing area, the mean thicknesses of overburden, mineral and waste, and the mean grading 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.

Bibliographic reference

GILES, J. R. A. 1981 The sand and gravel resources of the country around Blaydon, Tyne and Wear. Description of 1:25 000 resource sheet NZ 06, 16. *Miner. Assess. Rep. Inst. Geol. Sci.*, No. 74.

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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, both the economic and the social factors used to decide whether a deposit may be workable in the future cannot be predicted; they are likely to change with time. Deposits not currently economically workable may be exploited as demand increases, as higher grade or alternative materials become scarce, or as improved processing techniques are applied to them. The improved knowledge of the main physical properties of the resource and their variability which this survey seeks to provide, will add significantly to the factual background against which planning policies can be decided (Archer, 1969; Thurrell, 1971; Harris and others, 1974).

The survey provides information at the 'indicated' and the 'inferred' levels. The indicated level is that "for which tonnage and grade are computed partly from specific measurements, samples or production data and partly from projection for a reasonable distance on 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." At the 'inferred' level "quantitative estimates are based largely on broad knowledge of the geologic character of the deposit . . . there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geologic evidence: this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence." (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 a 0.625 mm BS sieve) should not exceed 40 per cent.
d The deposit must lie within 25 m of the surface, this being taken as the likely maximum working depth under most circumstances. It follows from

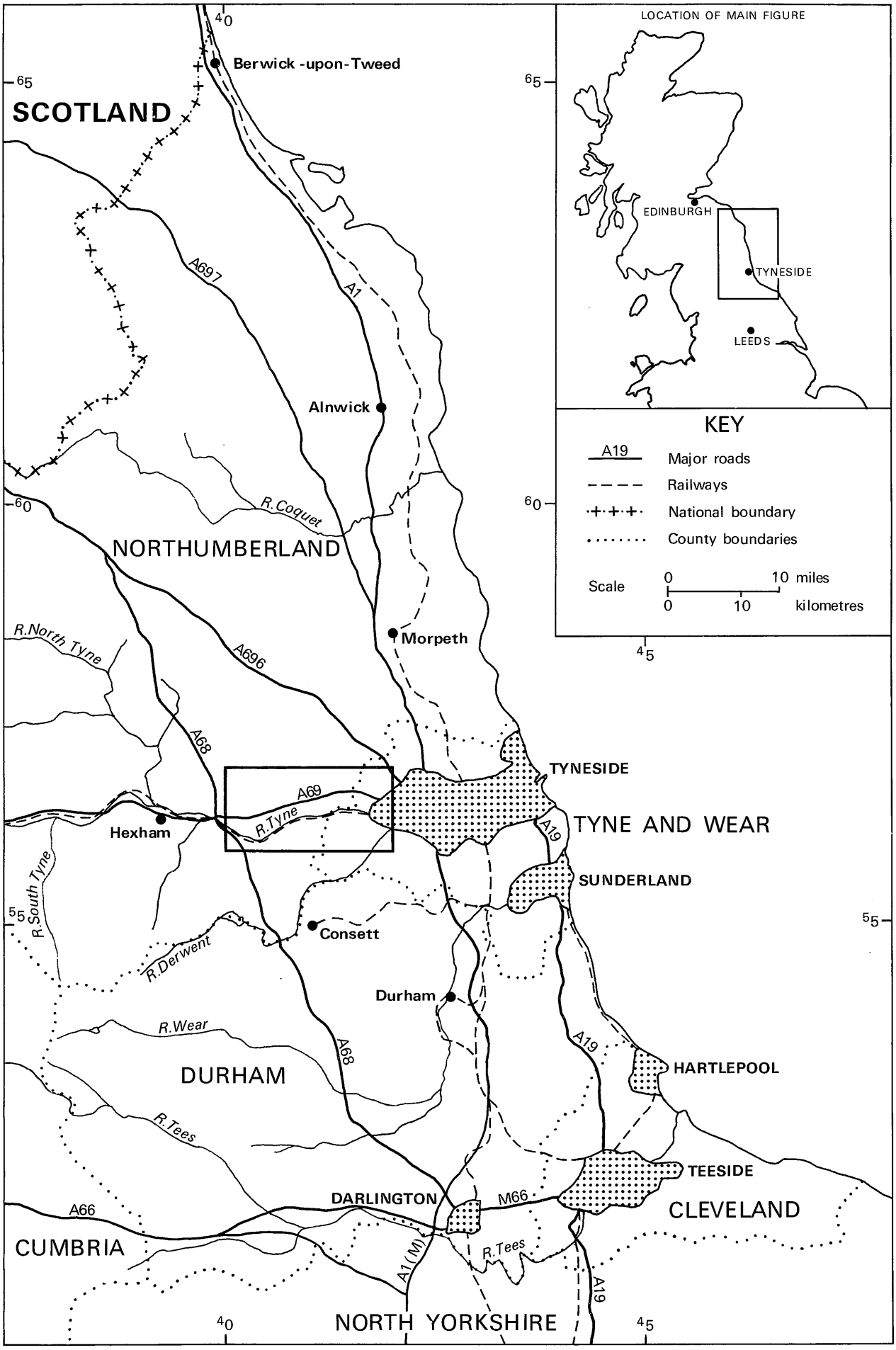

Figure 1 Map showing the location of sheet NZ06, 16.

the second criterion that boreholes are drilled no deeper than 18 m if no sand and gravel has been proved.

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

For the particular needs of assessing sand and gravel resources, a grain-size classification based on the geometric scale $\frac{1}{16}$ mm, $\frac{1}{4}$ mm, 1 mm, 4 mm, 16 mm has been adopted. The boundaries between fines (that is, the clay and silt fractions) and sand, and between sand and gravel grade material, are placed at $\frac{1}{16}$ mm and 4 mm respectively (see Appendix C).

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

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

DESCRIPTION OF THE DISTRICT SHOWN ON SHEET NZ 06, 16

GENERAL

The district shown on sheet NZ 06, 16 lies immediately west of the city of Newcastle upon Tyne, between the village of Riding Mill [019 614] in the west and the town of Blaydon [190 631] in the east. The valley of the River Tyne, the main topographical feature of the district, is incised into uplands which rise to a height of over 200 metres above OD at Kip Hill [0246 6790].

The district is predominantly agricultural, with a mixture of pastoral and arable farming, though residential and industrial areas account for a significant proportion of the landscape, particularly in the east towards Newcastle.

Table 1 List of geological deposits

DRIFT	
Recent and Pleistocene	Peat
	Alluvium
	River Terrace Deposits (Undifferentiated)
	Laminated Clay
	Glacial Sand and Gravel
	Boulder Clay
SOLID	
Carboniferous	Coal Measures (Westphalian)
	Millstone Grit Series (Namurian)

A variety of industrial minerals are being exploited in the district. Sand and gravel is quarried at a number of localities (see Appendix G) and brick clay is exploited near Ryton [1350 6280]. Coal has been won from numerous collieries in the past but only one working mine remains, at Winlaton Mill [1860 6036]. Opencast coal mining has also been prominent in recent years.

GEOLOGY

The geological sequence is summarised in Table 1, in which the deposits are listed as far as possible in order of increasing age. The brief description given below is based in part on *British Regional Geology: Northern England* (Taylor and others, 1971).

SOLID

Carboniferous Carboniferous rocks underlie the whole of the district: Millstone Grit Series (Namurian) strata crop out in the west and are succeeded eastwards by younger Lower and Middle Coal Measures (Westphalian), but they are not shown separately on the resource map.

The *Millstone Grit Series* can be regarded as transitional between the underlying Carboniferous Limestone Series and the succeeding Coal Measures. Its lower, 'Yoredale', facies consists of repetitive sequences of limestone, marine shales and thin sandstones which represent the continuation of the marine–estuarine conditions of the Carboniferous Limestone Series. The upper, arenaceous, facies is characterised by thick coarse-grained sandstones together with fine-grained sandstone, siltstones and mudstones, and minor marine intercalations, and heralds the deltaic lagoon–swamp conditions of the Coal Measures. Both facies contain thin coal seams.

In the *Coal Measures* cyclicity continues to be a feature of the deposits. The 'ideal' cycle consists of marine shale overlain by non-marine shale or mudstone, followed by sandstone, seat earth and coal, though most cycles are incomplete. Sedimentation more or less kept pace with subsidence and marine incursions were of relatively brief duration, so that the succession is predominantly deltaic in character.

DRIFT

Although the North of England was completely covered by ice on several occasions during the Pleistocene, all the glacial deposits of the district are thought to date from the late Devensian cold event, 26 000 to 10 000 years ago, when the north-east of England acted as a receiving area for ice from the west and north (Figure 2). Ice from the Lake District and southern Scotland was diverted across the Northern Pennines, through the Tyne Gap, by the congestion of Scottish, Lake District and Irish Sea ice in the Carlisle district. The eastward flow of ice was of sufficient strength to prevent any Scandinavian ice in the North Sea from impinging upon the coast. As the strength of this flow waned, ice from the Cheviot Hills, being prevented from moving eastwards by the ice in the North Sea, advanced southwards parallel to the present coast.

The eastward-flowing ice was dominant in the district described in this report. Initially it carried Lake District and southern Scottish erratics but picked up large quantities of Carboniferous material as it crossed the Pennines. The advance of the ice was marked

by the deposition of boulder clay over most of the district; on retreat, large amounts of Glacial Sand and Gravel were deposited from melt waters. Erosion and redistribution of the glacial deposits has led to the development of the present topography.

Boulder Clay This is the most extensive of the Pleistocene deposits; it overlies a considerable part of the district, and has been recorded at depth in most boreholes. It is a stiff, sandy to silty, dark grey to brown, stony clay which varies greatly in thickness from a thin veneer on high ground to thicknesses in excess of 18 m on valley flanks. Erratics are mainly of locally-derived Carboniferous rocks and some of them may be very large, for example the Great Limestone erratic that forms Down Hill [0066 6854]. They are shown on the resource map as Great Limestone erratics. Borrowdale Volcanic Group rocks and granites from the Lake District or southern Scotland are also represented.

Glacial Sand and Gravel Extensive spreads of sand, gravel, silt, and clay occur on the flanks of the Tyne Valley and its tributaries and are mapped together as Glacial Sand and Gravel. They show extensive lateral and vertical variation throughout, but two broad types have been recognised.

The first consists of considerable thicknesses of fine-grained, often 'clayey', ripple-bedded sands or silts which infill preglacial valleys or lie on their flanks. They are well exposed on Mosspool Hill, where more than 22.9 m of fine-grained sand occupies the north-western flanks of the preglacial valley of the Blaydon Burn (see Appendix F: Exposure Record 16SE E1). The second type is usually thinner and more gravelly and is generally found in close association with boulder clay, which may occur above, below or within it. In places, the second type overlies the thick fine-grained sands, as for example in the Ryton/Greenside quarries.

Laminated Clay This deposit occupies a limited area around Peepy Farm [037 627], in the valleys of the Clocky Burn and the Stonyverge Burn. It consists of brown, silty, laminated clay with thin fine-grained sand partings.

River Terrace Deposits In places river terrace deposits flank the floodplain of the Tyne Valley and its tributaries. The surfaces of the terraces lie a few metres above the Alluvium, and between 18.0 and 27.0 m above OD. Locally a number of individual terraces are identifiable but their lateral correlation has not been established.

The limited number of boreholes that have been drilled on the terraces reveal sand and gravel, up to a maximum thickness of 7.3 m, beneath thin soil.

Alluvium The alluvial deposits of the Tyne Valley infill channels cut at a time of lower sea level and have been built up to form a floodplain which falls from above 25 m above OD in the west to less than 4 m above OD in the east. They comprise silts, clays, sands and gravels with a maximum proved total thickness of 25 m. The sand and gravel is similar in composition and grading to the river terrace deposits and the Glacial Sand and Gravel and some might be more correctly assigned to them. Alluvium is also associated with smaller streams, depressions and gullies throughout the district.

Peat This deposit occurs in depressions on the upland areas of the district.

COMPOSITION OF THE SAND AND GRAVEL DEPOSITS

The Glacial Sand and Gravel and the fluviatile sediments (river terrace deposits and alluvium) contain potentially workable sand and gravel, which exhibits considerable variation in mechanical composition: the variation is as marked between the formations as within them (see Figures 3 and 4).

Glacial Sand and Gravel In places, deposits mapped as Glacial Sand and Gravel contain proportions of silt and clay which render them not potentially workable. Of those parts which fulfil the requirements for classification as mineral, about 40%, largely in the east of the district, yield less than 5% gravel and consist of mainly 'clayey' to 'very clayey' sand. The remainder range in composition from pebbly

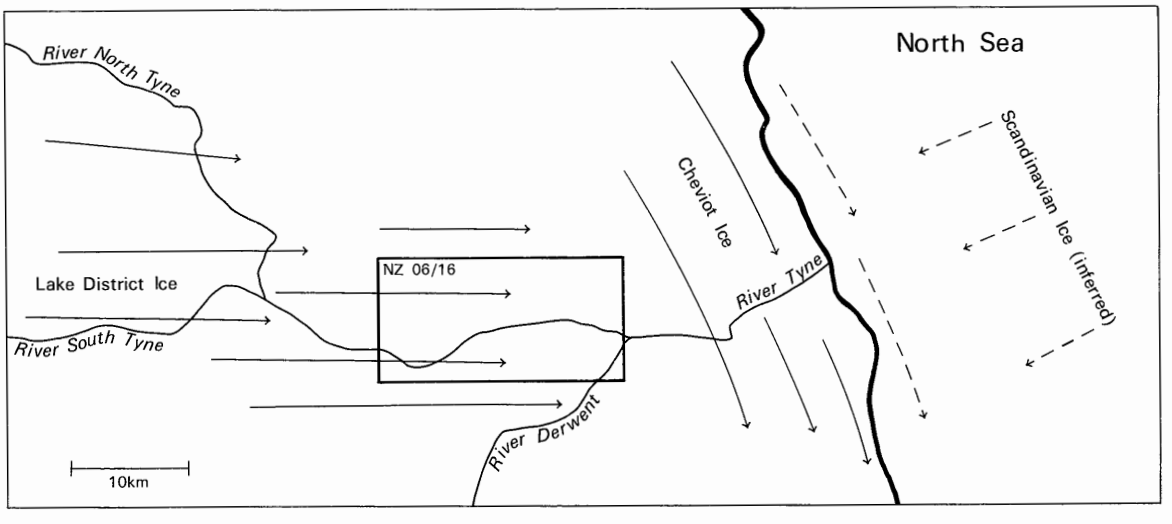

Figure 2 The pattern of late-Devensian ice movement in the areas adjacent to the Tyne Valley.

Table 2 Composition of the gravel (+4 mm) fraction of the mineral-bearing drift deposits in percentages by weight*

The table shows the mean for each deposit and the range of variation

Deposit	Sand-stone	Basic igneous	Vol-canics	Granite	Quartz	Lime-stone	Coal	Iron-stone	Mud-stone
Fluvial Sand and Gravel									
Mean	84	trace	10	1	1	3	trace	1	trace
Maximum	96	1	28	2	2	25	1	3	2
Minimum	69	–	2	–	–	–	–	–	–
Glacial Sand and Gravel									
Mean	86	trace	5	1	trace	4	trace	2	2
Maximum	99	2	13	13	1	29	2	11	20
Minimum	69	–	–	–	–	–	–	–	–

* For description of the methods used, see Note 11, Appendix D.

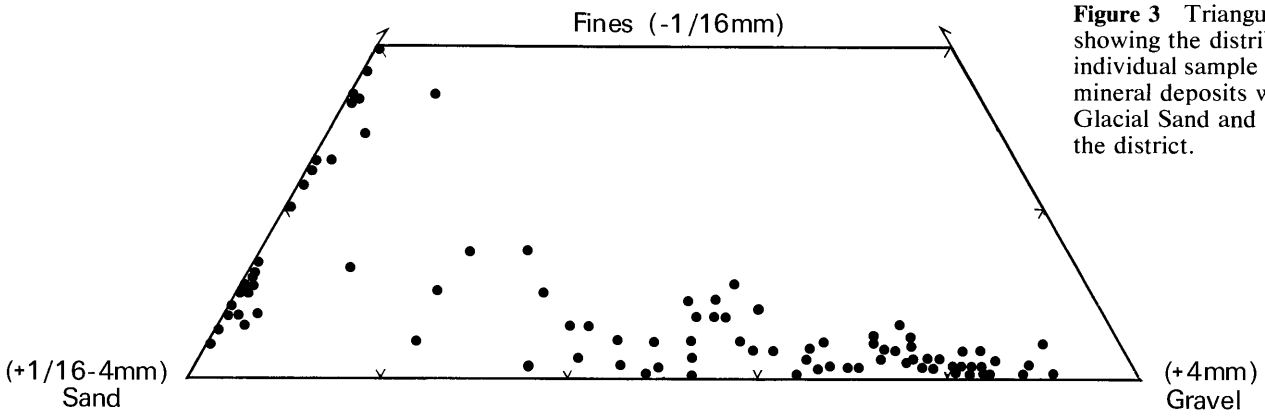

Figure 3 Triangular diagram showing the distribution of individual sample gradings for mineral deposits with the Glacial Sand and Gravel of the district.

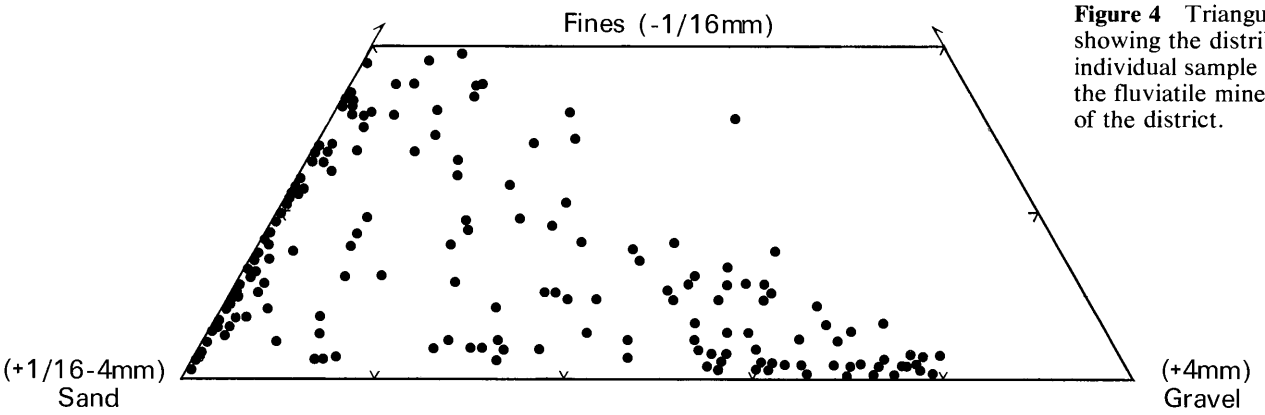

Figure 4 Triangular diagram showing the distribution of individual sample gradings for the fluviatile mineral deposits of the district.

sand to gravel. The mean grading of the glacial mineral as a whole is 23% gravel, 63% sand and 14% fines.

The gravel fraction is predominantly coarse-grained and commonly contains cobbles (up to 31%). The predominant clast lithology is sandstone with subordinate amounts of igneous rocks and limestone (Table 2). Potentially deleterious components such as ironstone, coal and mudstone are generally only present in small proportions (less than 5%) but exceptionally they may exceed 20%. The sand is mainly fine-grained and its major constituent is quartz; lithic fragments reflecting the composition of the gravel fraction are also present, especially in the coarse grade.

Fluviatile Deposits In general it is not possible to distinguish between the alluvial sand and gravel and the terrace deposits in boreholes and they are, therefore, here considered together as fluviatile deposits. In Appendix F deposits classified as 'Alluvium' may include terrace deposits. There is also doubt about the identity of some of the more deeply buried sands; they may, in part at least, be of glacial origin.

The fluviatile deposits, like the glacial sand and gravel, exhibit considerable variation in grading, ranging from 'very clayey' sands to gravels (Figure 4). Their mean grading is 38% gravel, 52% sand and 10% fines. However, deposits classified as sand are found almost exclusively in the lower part of the thickest proved mineral sequences, and the mean grading of

fluvial deposits excluding these sands is 51% gravel, 40% sand and 9% fines which more accurately describes the fluviatile deposits found near the surface.

The gravel fraction is again predominantly coarse-grained and commonly includes cobbles. In lithological composition it is similar to the Glacial Sand and Gravel, but on average contains more volcanics and less deleterious constituents such as coal, ironstone and mudstone (Table 2). The sand fraction is mainly fine-grained and similar in composition to that of the glacial mineral.

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 1:25 000 Outline Edition in grey, on which the topography is shown by contours in green, the geological data in black and the mineral resource information in shades of red.

Geological data The geological boundaries and symbols shown are taken from the geological map of the area, which was surveyed in the years 1935 to 1938 and 1976 to 1979 at the scales of 1:10 560 or 1:10 000; parts are to be resurveyed in the near future and some revision of boundaries may result. 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 survey. However, it is inevitable, particularly with deposits such as those included in the area of sheet NZ 06, 16, that local discrepancies will be revealed as new evidence from boreholes and excavations becomes available.

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

Areas where bedrock crops out, where boreholes indicate the absence of sand and gravel beneath cover, and where sand and gravel beneath cover is interpreted to be not potentially workable, are uncoloured on the map; where appropriate the relevant criterion is noted. In such 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. Areas of unassessed sand and gravel, for example in built-up areas (which are excluded from the survey), are indicated by a red stipple.

For the most part the distribution of categories of deposit is based on the mapped geological boundaries. Where there is a transition from one category to another, which cannot be related to the geological mapping and which could not be accurately delineated during this survey, inferred boundaries have been inserted. Such boundaries are shown by a distinctive symbol which is intended to convey an approximate location within a likely zone of occurrence rather than to represent the breadth of the zone; its size is dictated by cartographic considerations. For the purpose of measuring areas the centreline of the (zig-zag) symbol is used.

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

RESULTS

The results of the assessment are summarised in Table 3. Three of the resource blocks, B, C and D, have been assessed statistically but for the fourth, block A, only an inferred assessment has been attempted. Abstracts of the findings of IMAU boreholes are given in Tables 4, 5 and 6. Graphical representations of the grading information for blocks B, C and D constitute figures 5, 6, 7 and 8.

Some of the drift deposits of this district proved to be very difficult to drill and sample. A number of

Table 3 The statistical assessment of the sand and gravel resources of sheet NZ 06, 16

Resource block	Area		Mean thickness			Volume of mineral					Mean grading percentage			
	Block	Mineral	Overburden	Mineral	Waste		Lower limit*		Upper limit*		Fines	Sand	Gravel	
	km²	km²	m	m	m	$10^6 m^3$	−%	$10^6 m^3$	+%	$10^6 m^3$	$-\frac{1}{16}$mm	$+\frac{1}{16}$ −4mm	+4 −64mm	+64mm
B	31.2	26.3	1.0	6.3	0.6	166	22	129	45	241	10	56	28	6
C	10.7	10.7	1.4	5.8	1.1	62	33	42	90	118	9	57	31	3
D	14.1	11.8	1.2	7.7	0.4	91	20	73	40	128	15	63	19	3
Total	56.0	48.8	1.1	6.5	0.7	319	17	265	27	405				
Inferred assessment of block A, not included above														
A	112.6	0.9	2.5	6.9	–	6	Speculative				1	7	69	23

* Limits at the 90% probability level.

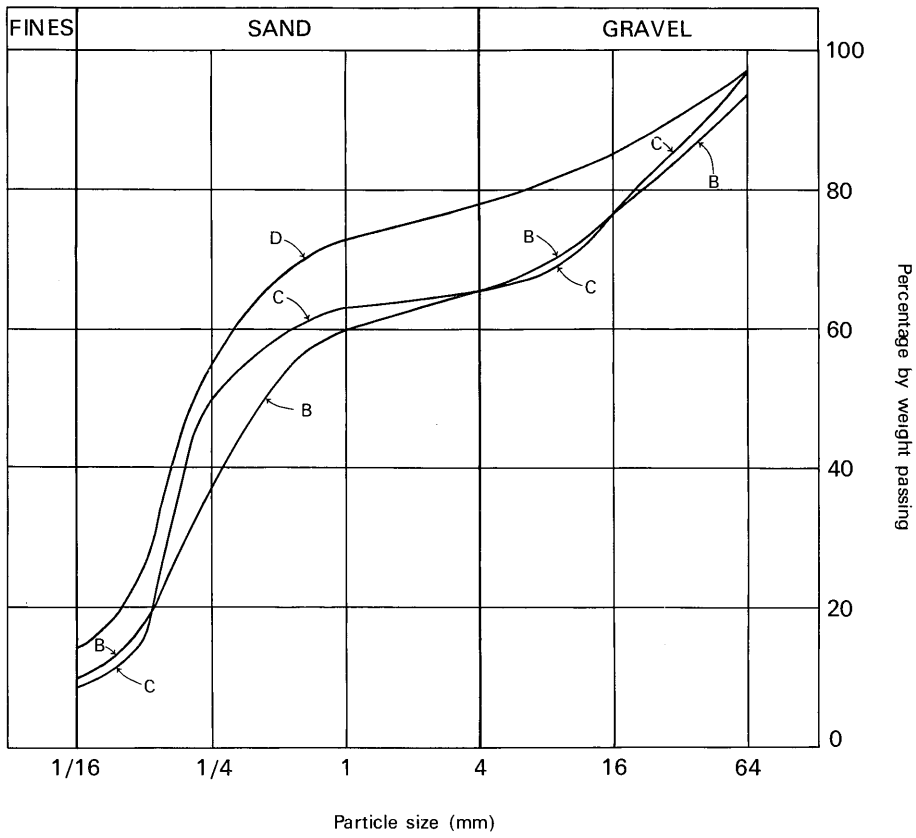

Figure 5 Mean particle-size distribution for the assessed thickness of mineral in resource blocks B, C and D.

boreholes had to be abandoned in mineral without proving the base and others were abandoned in boulder clay before reaching the prescribed depth. As a result the mineral thicknesses derived from these boreholes should be regarded as minima and the estimation of mean thicknesses and volumes is conservative.

Accuracy of results The mineral thicknesses proved by IMAU and commercial boreholes appear to represent a lognormal population rather than the normal distribution that has been assumed in all previous IMAU reports. Means and confidence limits have therefore been calculated using techniques developed for such populations (see Appendix B). Asymmetrical central confidence limits about the mean have been calculated at the 90% probability level rather than at the symmetrical 95% probability level used in previous reports. The lower limits vary from −22 to −30 per cent and the upper limits from +45 to +70 per cent. However, the true values are more likely to be nearer the figures estimated than the limits. Moreover, it is probable that in each block approximately the same percentage limits would apply for the estimate of volume of a very much smaller parcel of ground (say 100 hectares) containing similar sand and gravel deposits if the results from the same number of sample points (as provided by, say, 10 boreholes) were used in the calculation. Thus, if closer limits are needed for the quotation of reserves of part of a block it can be expected that data from more than 10 sample points will be required, even if the area is quite small. This point can be illustrated by considering the whole of the potentially workable sand and gravel in blocks B, C and D. The volume (330 million m^3) can be estimated to a lower limit of −18 per cent and an upper limit of +30 per cent at the 90 per cent probability level, by a calculation based on the data from 196 sample points spread across the 3 resource blocks. However, it must be emphasised that the quoted volume of sand and gravel has no simple relationship with the amount that could be extracted in practice, as no allowance has been made in the calculation for any restraints (such as existing buildings and roads) on the use of the land for mineral working.

Block	Percentage by weight passing					
	$\frac{1}{16}$ mm	$\frac{1}{4}$ mm	1 mm	4 mm	16 mm	64 m
B	10	36	60	66	76	94
C	9	50	63	66	76	97
D	15	55	73	78	85	97

NOTES ON RESOURCE BLOCKS

The three mineral resources, glacial sand and gravel, river terrace deposits and alluvium, have broadly similar characteristics. Individual sample points, however, show that there may be considerable variation in thickness, particle-size analysis and composition and that such variation may be as great within deposits as between them. These variations are such that it would be impractical to attempt to identify them individually or to group them within specific resource blocks. For these reasons the mineral subdivision has been as much geographically based as geologically.

Block A occupies the almost-barren northern half of the district. The valley of the Tyne is arbitrarily divided into two blocks, B and C; block B includes both glacial and fluvial mineral deposits and block C only fluvial. Block D is located on the southern flank of the Tyne Valley and includes 'exposed' glacial sand and gravel. Small areas of mineral sterilised by

Table 4 Data from IMAU boreholes and exposure record used in the assessment of Block B

Borehole	Recorded thickness			Mean grading percentages						
	Mineral m	Overburden m	Waste m	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
06 SW 14	2.3	3.0	–	27	32	23	4	3	7	4
06 SW 15	4.0	9.7	–	35	37	11	3	1	13	–
06 SW 16	2.5	1.0	–	10	22	36	8	9	15	–
06 SW 17	7.4	0.3	0.4	14	33	17	6	10	14	6
06 SW 18	9.8	0.3	6.5	6	31	26	5	9	13	10
06 SW 19	4.2	0.5	–	21	29	8	3	9	19	11
06 SW 20	3.2	1.2	–	8	12	13	8	15	31	13
06 SW 23	18.0	4.0	–	6	22	51	10	7	4	–
06 SW E1	6.4+†	0.1	–	3	5	7	10	15	37	23
06 SE 62	4.0	0.3	1.7	33	36	11	7	6	7	–
06 SE 64	absent	–	–	–	–	–	–	–	–	–
06 SE 68	absent	–	–	–	–	–	–	–	–	–
06 SE 69	10.2	2.4	–	3	12	19	7	19	34	6
06 SE 70	11.1+	0.3	3.7	16	51	26	1	2	4	–
06 SE 74	4.6*	1.2	–	7	27	7	2	11	32	14
06 SE 76	7.0	0.3	–	12	21	21	8	12	22	4
06 SE 78	7.3+	3.2	–	3	11	12	9	15	41	9

* Borehole abandoned before reaching prescribed depth.
† The plus sign indicates that the borehole was abandoned in mineral.

the urban developments of Riding Mill, Ryton and Prudhoe are excluded from the resource blocks.

Block A
This block, with an area of 112.6 km², includes most of the land north of the River Tyne. Numerous inliers of Carboniferous rocks protrude through the glacial drift that covers much of this block. Of the 18 IMAU boreholes that were drilled in this area 13 found no potentially workable sand and gravel, and a further 3 had not encountered sand and gravel before being abandoned at less than their prescribed depth. The general absence of mineral is confirmed by numerous other borehole records.

Of the two IMAU boreholes which proved potentially workable sand and gravel, 16 NW 40 recorded 11.9 m of 'very clayey' sand beneath overburden and 16 NE 91 yielded 1.8 m of gravel beneath overburden. Boreholes adjacent to this latter deposit indicate its lateral extension. A third known mineral deposit on the western margin of the district and north of Aydon Castle was not investigated during the present survey but its westward extension was drilled during the survey of that area (Lovell, 1981).

The volume of potentially workable sand and gravel in the areas indicated as mineral bearing on the resource map is speculatively estimated as 6 million m³.

Block B (Table 4, Figure 6)
Block B follows the Tyne Valley from the western edge of the district to the village of Ovingham [083 639] and includes both glacial and fluvial mineral deposits. The block was assessed using information from 16 IMAU boreholes, one exposure record, and 29 commercial borehole records which are held in confidence by the Institute.

The recorded mineral thicknesses range from 2.3 to 18.0 m, their estimated mean being 6.3 m. Above the mineral up to a maximum of 9.7 m of overburden may occur; but the estimated mean for the overburden is 1.0 m. Occasional waste partings consisting of clays and silts have been recorded, with thicknesses of up to 6.5 m.

The mean grading for the mineral deposits of this block is gravel 34%, sand 56% and fines 10%, though it should be emphasised that there is considerable variation within the block, as is illustrated by the grading curve envelope in Figure 6.

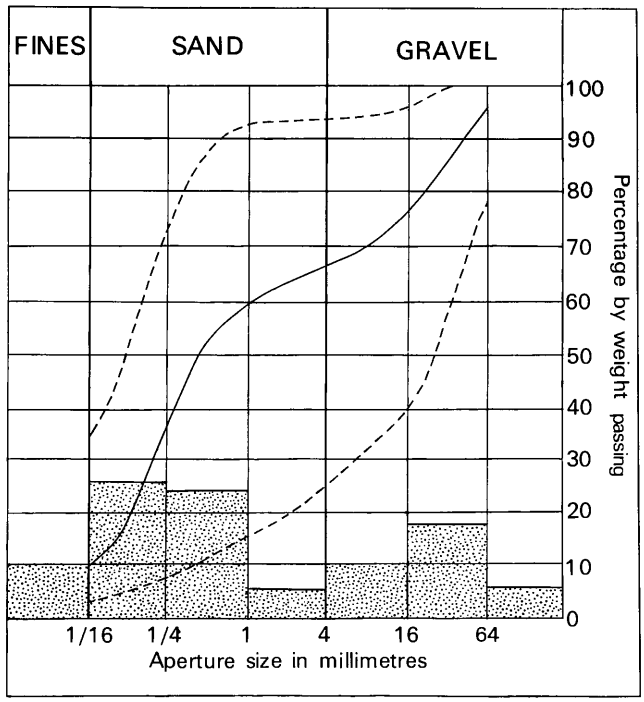

Figure 6 Grading characteristics of the mineral in block B. The continuous line is the cumulative frequency curve of the mean grading of the block as a whole; the broken lines denote the envelope within which the mean grading curves for individual boreholes fall. The mean grading of the block is also shown as a vertical bar graph.

An attempt has been made, in this block, to separate the glacial sand and gravel that is exposed from that which is buried beneath a metre or more of overburden. The information from the IMAU boreholes to the south of the River Tyne indicates that these deposits are on average buried beneath more than one metre of overburden. Commercial data used in conjunction with the IMAU borehole information for the area of this block north of the River Tyne shows that the glacial sand and gravel is almost entirely exposed and is so shown on the accompanying map.

From four quarries, two of which are still active, mineral has been extracted from an area of about 0.5 km^2. The volume remaining is estimated at 166 million m^3 with lower and upper confidence limits (at the 90% probability level) of −22% and +45%.

Block C (Table 5, Figure 7)
Sand and gravel beneath the flood plains of the Tyne, east of Ovingham, and the Derwent constitute the mineral of this block. Although classified as 'Alluvium' on the resource map and in Appendix F it may include terrace deposits and some glacial sand and gravel. The assessment is based on data from 7 IMAU boreholes and 41 confidential commercial borehole records.

The estimated mean thickness for the mineral of this block is 5.8 m, however, thicknesses range widely between 2.9 and 20.0 m. Overburden consisting of soil, silt or clay is also very variable in thickness; up to 8.2 m have been proved, but the estimated mean for the block is only 1.4 m. Clay or silt waste partings of considerable thicknesses were found in three boreholes; the mean thickness of waste in this block is 1.1 m.

The mean grading for the mineral of this block is gravel 34%, sand 57% and fines 9%. There is considerable variation in grade within the block, as can be seen by the width of the envelope about the mean cumulative grading curve in Figure 7. In the three IMAU boreholes of the block that recorded the greatest thickness the lower part of the mineral comprises 'clayey' sand, but if this part is ignored, the mean grading becomes 54% gravel, 38% sand and 8% fines.

The estimated volume of mineral present is 62 million m^3; the lower and upper confidence limits at the 90% probability level are −33% and +90% respectively.

Block D Table 6, Figure 8)
The southern flank of the Tyne Valley, east of the village of Ovingham and around the town of Ryton, is occupied by this block. Mineral consists almost entirely of glacial sand and gravel. The information from 15 IMAU boreholes and one exposure record, together with 94 commercial borehole records held in confidence by the Institute, provided the data used in the assessment of the mineral resources of this block. Recorded mineral thicknesses vary widely from 2.0 m to the maximum of 25.0 m, with an estimated mean of 7.7 m. In the east of the block overburden is uniformly thin, being composed of sandy soil with a mean thickness of 0.7 m. In the west of the block overburden is composed of clay, which may be laminated: it ranges up to 9.0 m in proved thickness with a mean of 2.4 m. The extent of this area of thick over-

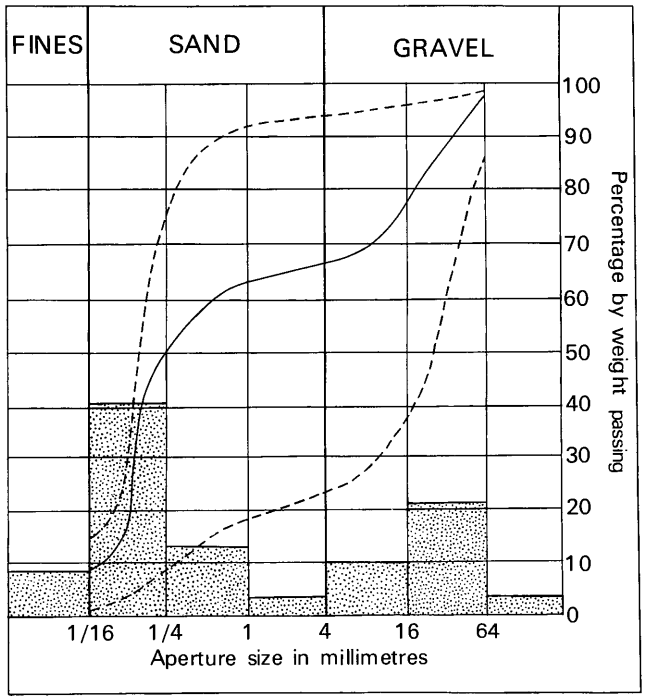

Figure 7 Grading characteristics of the mineral in block C (for explanation see Figure 6).

Table 5 Data from IMAU boreholes used in the assessment of Block C

Borehole	Recorded thickness			Mean grading percentages						
	Mineral	Overburden	Waste	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles
	m	m	m	−$\frac{1}{16}$ mm	+$\frac{1}{16}$–$\frac{1}{4}$ mm	+$\frac{1}{4}$–1 mm	+1–4 mm	+4–16 mm	+16–64 mm	+64 mm
06 SE 71	15.7+†	0.6	8.7	12	63	17	2	2	2	2
16 NW 44	4.0*	3.3	–	1	8	9	5	14	49	14
16 NE 94	20.0	–	–	10	44	12	3	10	20	1
16 SW 207	6.7	1.0	7.0	7	23	22	5	14	27	2
16 SE 224	8.5	1.3	–	6	14	11	5	22	38	4
16 SE 225	18.6+	3.4	3.0	10	42	10	2	11	22	3
16 SE 227	2.9	8.2	–	15	47	4	5	8	20	1

* Borehole abandoned before reaching prescribed depth.
† The plus sign indicates that the borehole was abandoned in mineral.

Table 6 Data from IMAU boreholes and exposure record used in the assessment of Block D

Borehole	Recorded thickness			Mean grading percentages						
	Mineral m	Over-burden m	Waste m	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
06 SE 72	2.4	2.1	–	13	45	7	5	9	14	7
16 SW 206	10.3	9.0	3.6	18	38	10	6	8	18	2
16 SW 208	14.3+†	0.5	10.2	15	51	29	2	2	1	–
16 SW 209	5.9	0.5	1.8	18	39	11	4	7	18	3
16 SW 210	16.4	0.5	–	18	26	33	4	5	10	4
16 SW 211	18.4	6.6	–	26	55	16	1	1	1	–
16 SW 212	15.8	0.1	–	1	7	18	9	18	39	8
16 SW 213	6.2	0.6	–	21	35	16	5	8	9	6
16 SW 214	2.1*	1.7	–	14	43	20	5	9	9	–
16 SW 215	4.0*	0.3	–	2	9	13	11	17	30	18
16 SW 216	3.7	0.9	–	26	39	20	5	6	4	–
16 SW 217	4.3	0.4	–	11	14	17	9	18	28	3
16 SW 220	8.8	0.4	0.6	17	20	12	11	19	16	5
16 SW 226	2.0	0.8	–	4	9	17	12	18	29	11
16 SW 228	2.7	0.5	–	27	64	7	1	1	–	–
16 SE E1	25.0	–	–	10	70	14	2	1	2	1

* Borehole abandoned before reaching prescribed depth.
† The plus sign indicates that the borehole was abandoned in mineral.

burden is not precisely known but the approximate eastern limit, suggested by commercial borehole evidence, is shown on the resource map by an inferred boundary. Clay and silt waste partings were encountered in four boreholes, ranging in thickness between 0.6 and 10.2 m.

The variable nature of the mineral deposits of this district is illustrated by the width of the grading envelope in Figure 8. The mean grading for the block is gravel 22%, sand 63% and fines 15%.

Some 1.8 km^2 of this block has already been worked. The remainder is estimated to contain 91 million m^3 of sand and gravel. The lower and upper confidence limits at the 90% probability level are −20% and +40% respectively. Further information about this block may be obtained from the Ryton/Greenside Quarries Subject Plan (Tyne and Wear County Council, 1978).

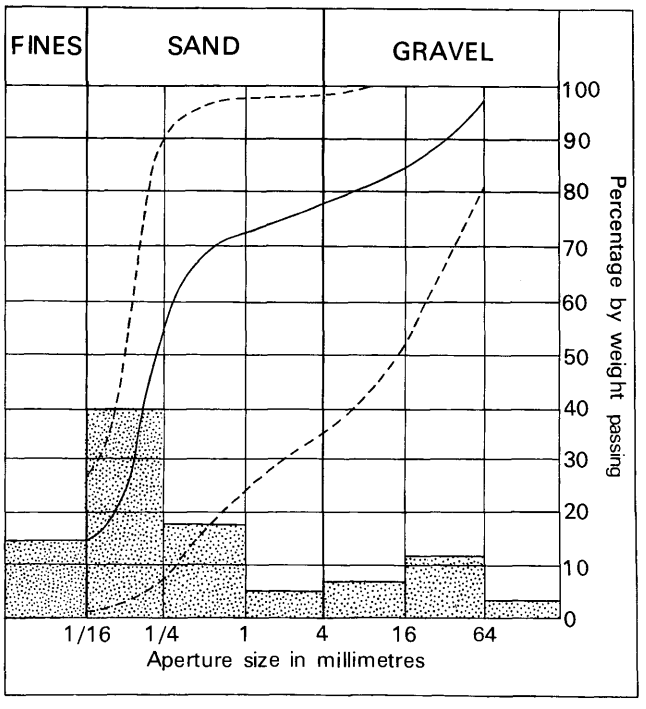

Figure 8 Grading characteristics of the mineral in block D (for explanation see Figure 6).

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 co-operation of sand and gravel operators ensures that boreholes are not drilled where reliable information is already available; although this may be used in the calculations, it is held confidentially by the Institute and cannot be disclosed.

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

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

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

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

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

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

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

APPENDIX B

STATISTICAL PROCEDURE

A statistical assessment is made of an area of mineral greater than 2 km^2, if there is a minimum of five evenly-spaced boreholes in the resource block.

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

Some resource blocks 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.

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

The sampled area in each resource block is coloured pink on the map. Whenever possible calculations relate to the mineral within mapped geological boundaries (which may not necessarily correspond to the limits of deposit). Where the area is not defined by a mapped boundary, that is, where the boundary is inferred, a distinctive symbol is used.

Statistical assessment

The methods used in the calculation are consistent with the amount of data provided by the survey. Asymmetrical confidence limits are calculated for the central 90 per cent confidence interval, that is, there is a 10 per cent or 1 in 10 chance of a result falling outside the stated limits.

The estimated volume (v) of the mineral in a given block is the product of two variables, the estimated area (a) and the estimated mineral thickness (t) calculated from the individual thicknesses at the sample points. The standard error of estimation of v is given by

$$S_v = (S_a{}^2 t^2 + S_t{}^2 a^2 + \rho a t S_a S_t)^{\frac{1}{2}} \quad .$$

If the area a and thickness t are independent, $\rho = 0$. If the errors of measurement of a are very small compared with those of t, $S_a{}^2 \rightarrow 0$ and finally $S_v = aS_t$.

If, therefore, the error of estimation of area is small with respect to that of the true mean thickness, the standard error of the estimated volume will approximate to the product aS_t. Experience suggests that the errors in determining area are small relative to those in thickness. Thus if the confidence limits for the mineral thickness are determined it can be assumed that the approximate confidence limits for volume can be determined easily from this relationship.

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

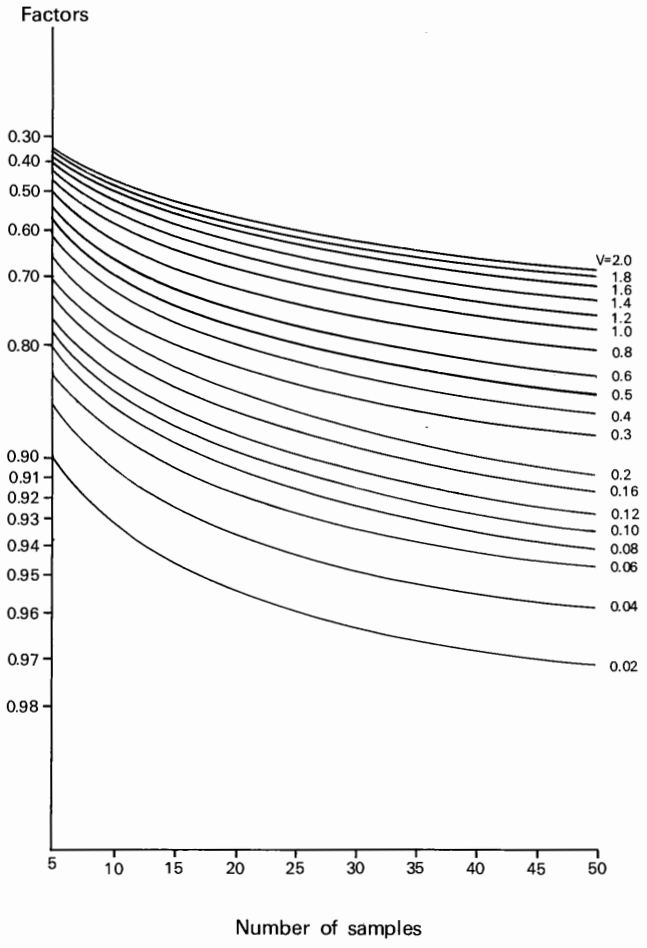

Figure 9 Lower confidence limit factors for a lognormal population.

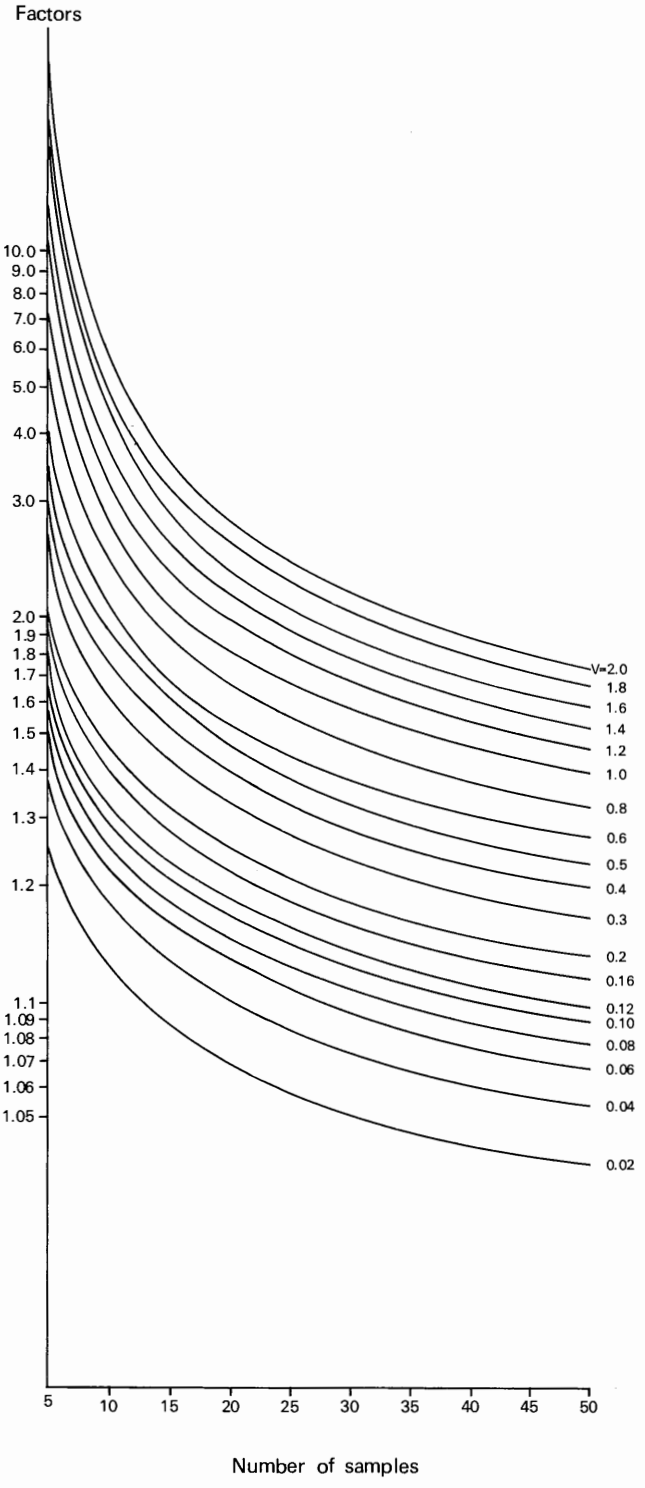

Figure 10 Upper confidence limit factors for a lognormal population.

The number of approximately evenly spaced sample points in the sampled area is n, with weighted thickness measurements $l_1, l_2, \ldots l_n$. A chi-shaped test was used to fit the weighted mineral thicknesses to various statistical distributions. It was demonstrated that the logarithms of the weighted mineral thicknesses $\log_e l_1, \log_e l_2, \ldots \log_e l_n$, approximated to a normal distribution.

With skewed frequency distributions such as the lognormal distribution, the simple arithmetic mean of a small number of observations is an inefficient estimator of the true mean. The true mean (t) is, however, mathematically difficult to estimate. Two workers (Finney, 1941 and Sichel, 1949) independently derived methods for the estimation of the true mean. The work of Sichel is mathematically more tractable and much laborious calculation is avoided by the use of published tables. It has also been frequently used in geological resource estimation.

The mean is found by multiplying the median ($e^{\bar{l}}$) (which is simple to compute) by a tabulated factor (Sichel's t-estimator).

The median is defined as

$$e^{\bar{l}} = \text{antilog}_e \Sigma(\log_e l_1 + \log_e l_2 + \ldots + \log_e l_n)/n \quad .$$

The variance V of the median is

$$V = \Sigma(\log_e \bar{l})^2/n - (\Sigma \log_e \bar{l}/\text{n})^2 \quad .$$

For given values of V and n Sichel's t-estimator ($\gamma_n(V)$) may be read directly from Table 7. The product of this factor and the median gives an estimate of the location of the true mean

$$t = e^{\bar{l}} \gamma_n(V) \quad .$$

The upper and lower confidence limits defining the central 90 per cent confidence interval may be estimated using the two graphs provided, Figures 9 and 10. These graphs have been derived from Sichel's table B (Sichel, 1966). For given values of variance V and sample size n the value for the upper confidence limit may be estimated from Figure 10 and the value for the lower confidence limits estimated from Figure 9.

The application of this procedure to a fictitious area is illustrated in Figures 11 and 12.

Table 7 Factor $\gamma_n(V)$ for estimation of mean of lognormal population (n is the number of samples)

V	$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$	$n=8$	$n=9$	$n=10$	$n=11$	$n=12$	$n=13$	$n=14$	$n=15$	$n=16$	$n=17$	$n=18$	$n=19$	$n=20$	$n=50$	$n=100$	$n=1000$
0.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.02	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
0.04	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.030	1.030
0.06	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
0.08	1.040	1.040	1.040	1.040	1.040	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.041
0.10	1.050	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051	1.051
0.12	1.061	1.061	1.061	1.061	1.061	1.061	1.061	1.061	1.061	1.062	1.062	1.062	1.062	1.062	1.062	1.062	1.062	1.062	1.062	1.062	1.062	1.062
0.14	1.071	1.071	1.071	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072	1.072
0.16	1.081	1.082	1.082	1.082	1.082	1.082	1.082	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083
0.18	1.091	1.092	1.092	1.093	1.093	1.093	1.093	1.093	1.093	1.093	1.094	1.094	1.094	1.094	1.094	1.094	1.094	1.094	1.094	1.094	1.094	1.094
0.20	1.102	1.102	1.103	1.103	1.104	1.104	1.104	1.104	1.104	1.104	1.104	1.104	1.104	1.104	1.104	1.104	1.104	1.105	1.105	1.105	1.105	1.105
0.3	1.154	1.156	1.157	1.158	1.158	1.159	1.159	1.159	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.161	1.161	1.162	1.162
0.4	1.207	1.210	1.212	1.214	1.215	1.216	1.216	1.217	1.217	1.217	1.218	1.218	1.218	1.218	1.219	1.219	1.219	1.219	1.219	1.220	1.221	1.221
0.5	1.260	1.266	1.269	1.272	1.273	1.275	1.276	1.276	1.277	1.278	1.278	1.278	1.279	1.279	1.279	1.280	1.280	1.280	1.280	1.282	1.283	1.284
0.6	1.315	1.323	1.328	1.332	1.334	1.336	1.337	1.338	1.339	1.340	1.341	1.342	1.342	1.343	1.343	1.343	1.344	1.344	1.344	1.348	1.349	1.350
0.7	1.371	1.382	1.389	1.393	1.397	1.399	1.401	1.403	1.404	1.406	1.406	1.407	1.408	1.409	1.409	1.410	1.410	1.411	1.411	1.416	1.417	1.419
0.8	1.427	1.442	1.451	1.457	1.462	1.465	1.468	1.470	1.472	1.473	1.475	1.476	1.477	1.478	1.478	1.479	1.480	1.480	1.481	1.487	1.490	1.492
0.9	1.485	1.503	1.515	1.523	1.529	1.533	1.537	1.540	1.542	1.544	1.546	1.547	1.549	1.550	1.551	1.552	1.552	1.553	1.554	1.562	1.565	1.568
1.0	1.543	1.566	1.580	1.591	1.598	1.604	1.608	1.612	1.615	1.618	1.620	1.622	1.623	1.625	1.626	1.627	1.628	1.629	1.630	1.641	1.645	1.649
1.1	1.602	1.630	1.648	1.661	1.670	1.677	1.682	1.687	1.691	1.694	1.697	1.699	1.701	1.703	1.705	1.706	1.708	1.709	1.710	1.723	1.728	1.733
1.2	1.662	1.696	1.718	1.733	1.744	1.752	1.759	1.765	1.770	1.774	1.777	1.780	1.782	1.785	1.787	1.789	1.790	1.792	1.793	1.810	1.816	1.822
1.3	1.724	1.764	1.789	1.807	1.820	1.831	1.839	1.846	1.851	1.856	1.860	1.864	1.867	1.870	1.872	1.874	1.876	1.878	1.880	1.900	1.908	1.916
1.4	1.786	1.832	1.862	1.884	1.900	1.912	1.922	1.930	1.936	1.942	1.947	1.951	1.955	1.958	1.961	1.964	1.966	1.969	1.971	1.995	2.004	2.014
1.5	1.848	1.903	1.938	1.963	1.981	1.996	2.007	2.017	2.025	2.032	2.037	2.042	2.047	2.051	2.054	2.058	2.060	2.063	2.065	2.095	2.106	2.117
1.6	1.912	1.975	2.015	2.044	2.066	2.082	2.096	2.107	2.116	2.124	2.131	2.137	2.142	2.147	2.151	2.155	2.158	2.161	2.164	2.199	2.212	2.226
1.7	1.977	2.049	2.095	2.128	2.153	2.172	2.188	2.201	2.212	2.221	2.229	2.236	2.242	2.247	2.252	2.256	2.260	2.264	2.267	2.308	2.323	2.340
1.8	2.043	2.124	2.177	2.214	2.243	2.265	2.283	2.298	2.310	2.321	2.330	2.338	2.345	2.352	2.357	2.362	2.367	2.371	2.375	2.422	2.440	2.460
1.9	2.110	2.201	2.260	2.303	2.336	2.361	2.382	2.399	2.413	2.425	2.436	2.445	2.453	2.460	2.467	2.473	2.478	2.483	2.487	2.542	2.563	2.586
2.0	2.178	2.280	2.347	2.395	2.431	2.460	2.484	2.503	2.519	2.533	2.545	2.556	2.565	2.574	2.581	2.588	2.594	2.599	2.604	2.668	2.692	2.718
2.1	2.247	2.360	2.435	2.489	2.530	2.563	2.589	2.611	2.630	2.645	2.659	2.671	2.682	2.691	2.700	2.707	2.714	2.721	2.726	2.800	2.827	2.858
2.2	2.317	2.442	2.526	2.586	2.632	2.669	2.698	2.723	2.744	2.762	2.778	2.791	2.803	2.814	2.824	2.832	2.840	2.847	2.854	2.937	2.969	3.004
2.3	2.388	2.526	2.618	2.686	2.737	2.778	2.811	2.839	2.863	2.883	2.900	2.916	2.929	2.942	2.952	2.962	2.971	2.979	2.987	3.082	3.118	3.158
2.4	2.460	2.612	2.714	2.788	2.846	2.891	2.928	2.959	2.986	3.008	3.028	3.045	3.060	3.074	3.086	3.098	3.108	3.117	3.125	3.233	3.274	3.320
2.5	2.533	2.699	2.812	2.894	2.957	3.008	3.049	3.084	3.113	3.138	3.160	3.180	3.197	3.212	3.226	3.238	3.250	3.260	3.270	3.391	3.438	3.490
2.6	2.607	2.789	2.912	3.003	3.073	3.128	3.174	3.213	3.245	3.274	3.298	3.320	3.339	3.356	3.371	3.385	3.398	3.410	3.420	3.557	3.610	3.669
2.7	2.682	2.880	3.015	3.114	3.191	3.253	3.304	3.346	3.382	3.414	3.441	3.465	3.486	3.505	3.522	3.538	3.552	3.565	3.577	3.730	3.791	3.857
2.8	2.759	2.973	3.120	3.229	3.314	3.382	3.437	3.484	3.524	3.559	3.589	3.616	3.639	3.661	3.680	3.697	3.713	3.727	3.740	3.912	3.980	4.055
2.9	2.836	3.068	3.228	3.347	3.440	3.514	3.576	3.627	3.671	3.710	3.743	3.772	3.799	3.822	3.843	3.862	3.880	3.896	3.911	4.102	4.178	4.263
3.0	2.914	3.166	3.339	3.469	3.570	3.651	3.718	3.775	3.824	3.866	3.902	3.935	3.964	3.990	4.013	4.035	4.054	4.072	4.088	4.301	4.387	4.482
3.1	2.994	3.265	3.453	3.593	3.703	3.792	3.866	3.928	3.981	4.028	4.068	4.104	4.136	4.164	4.190	4.214	4.235	4.255	4.273	4.510		
3.2	3.075	3.366	3.569	3.721	3.841	3.938	4.018	4.086	4.145	4.195	4.240	4.279	4.314	4.346	4.374	4.400	4.424	4.446	4.465	4.728		
3.3	3.157	3.469	3.688	3.853	3.983	4.088	4.176	4.250	4.314	4.369	4.418	4.461	4.500	4.534	4.566	4.594	4.620	4.644	4.666	4.956		
3.4	3.240	3.574	3.810	3.988	4.129	4.243	4.338	4.419	4.489	4.549	4.603	4.650	4.692	4.730	4.764	4.796	4.824	4.850	4.875	5.195		
3.5	3.324	3.682	3.935	4.127	4.279	4.403	4.506	4.594	4.670	4.736	4.794	4.846	4.892	4.933	4.971	5.005	5.037	5.065	5.092	5.445		
3.6	3.409	3.792	4.063	4.270	4.434	4.568	4.680	4.775	4.858	4.929	4.993	5.049	5.099	5.145	5.186	5.223	5.258	5.289	5.318	5.706		
3.7	3.496	3.903	4.194	4.416	4.593	4.738	4.859	4.962	5.052	5.130	5.198	5.260	5.315	5.364	5.409	5.450	5.488	5.522	5.554	5.980		
3.8	3.583	4.017	4.329	4.567	4.757	4.913	5.044	5.156	5.252	5.337	5.412	5.478	5.538	5.592	5.641	5.686	5.726	5.764	5.799	6.266		
3.9	3.672	4.134	4.466	4.721	4.925	5.093	5.234	5.355	5.460	5.552	5.633	5.705	5.770	5.829	5.882	5.930	5.975	6.016	6.054	6.566		
4.0	3.762	4.252	4.607	4.880	5.099	5.279	5.431	5.562	5.675	5.774	5.862	5.940	6.011	6.074	6.132	6.185	6.234	6.278	6.319	6.879		
4.1	3.853	4.373	4.751	5.042	5.277	5.471	5.634	5.775	5.897	6.004	6.099	6.184	6.260	6.329	6.392	6.450	6.502	6.551	6.596			
4.2	3.946	4.496	4.898	5.209	5.460	5.668	5.844	5.995	6.127	6.242	6.345	6.437	6.519	6.594	6.662	6.724	6.781	6.834	6.883			
4.3	4.040	4.622	5.049	5.380	5.649	5.872	6.060	6.223	6.364	6.489	6.599	6.698	6.788	6.869	6.942	7.010	7.072	7.129	7.182			
4.4	4.135	4.750	5.203	5.556	5.843	6.081	6.283	6.458	6.610	6.744	6.863	6.970	7.066	7.154	7.233	7.306	7.373	7.435	7.493			
4.5	4.231	4.881	5.361	5.736	6.042	6.297	6.513	6.700	6.863	7.008	7.136	7.251	7.355	7.449	7.536	7.614	7.687	7.754	7.816			
4.6	4.328	5.014	5.522	5.921	6.247	6.519	6.750	6.950	7.126	7.281	7.419	7.543	7.655	7.756	7.849	7.934	8.013	8.085	8.152			
4.7	4.427	5.149	5.687	6.111	6.457	6.747	6.995	7.209	7.397	7.563	7.711	7.845	7.965	8.075	8.175	8.266	8.351	8.429	8.502			
4.8	4.527	5.288	5.856	6.305	6.674	6.983	7.247	7.476	7.677	7.855	8.014	8.157	8.287	8.405	8.512	8.611	8.703	8.787	8.865			
4.9	4.629	5.428	6.029	6.505	6.896	7.225	7.507	7.751	7.966	8.157	8.328	8.481	8.620	8.747	8.863	8.970	9.068	9.159	9.243			
5.0	4.732	5.572	6.205	6.709	7.124	7.474	7.774	8.036	8.265	8.470	8.652	8.817	8.966	9.102	9.227	9.341	9.447	9.545	9.636			
5.1	4.836	5.718	6.386	6.919	7.359	7.731	8.050	8.329	8.574	8.792	8.988	9.164	9.324	9.470	9.604	9.727	9.841	9.946				
5.2	4.941	5.866	6.570	7.134	7.600	7.995	8.335	8.631	8.893	9.126	9.335	9.524	9.696	9.852	9.996	10.13	10.25					
5.3	5.048	6.018	6.759	7.354	7.847	8.266	8.628	8.944	9.222	9.471	9.695	9.897	10.08	10.25	10.40	10.54						
5.4	5.156	6.172	6.951	7.579	8.102	8.546	8.930	9.265	9.563	9.828	10.07	10.28	10.48	10.66	10.82							
5.5	5.266	6.329	7.148	7.811	8.363	8.833	9.240	9.598	9.914	10.20	10.45	10.68	10.89	11.08								
5.6	5.376	6.489	7.350	8.048	8.631	9.129	9.561	9.940	10.28	10.58	10.85	11.09	11.32									
5.7	5.489	6.652	7.555	8.290	8.906	9.433	9.890	10.29	10.65	10.97	11.26	11.52										
5.8	5.603	6.818	7.766	8.539	9.188	9.745	10.23	10.66	11.04	11.38	11.68											
5.9	5.718	6.987	7.980	8.794	9.478	10.07	10.58	11.03	11.44	11.80												
6.0	5.834	7.159	8.200	9.054	9.776	10.40	10.94	11.42	11.85													

This is Table A from Sichel (1966), the layout slightly amended.

Block calculation 1:25 000 Block } Fictitious

Area
Block: 11.08 km²
Mineral: 8.32 km²

Thickness estimate: measurements in metres
l'_o = overburden thickness l'_m = mineral thickness

Computation of t-*estimator for samples from fictitious resource block*

Sample point	Weighting	Overburden				Mineral				Remarks
	w	l'_o	l_o	$\log_e l_o$	$(\log_e l_o)^2$	l'_m	l_m	$\log_e l_m$	$(\log_e l_m)^2$	
SE 14	1	1.2	1.2	0.1823	0.0332	2.4	2.4	0.8755	0.7665	IMAU boreholes
SE 18	1	0.9	0.9	−0.1054	0.0111	4.8	4.8	1.5686	2.4605	
SE 20	1	0.8	0.8	−0.2231	0.0498	2.8	2.8	1.0296	1.0601	
SE 22	1	0.7	0.7	−0.3567	0.1272	13.2	13.2	2.5802	6.6574	
SE 23	1	0.8	0.8	−0.2231	0.0498	1.5	1.5	0.4055	0.1644	
SE 24	1	1.0	1.0	0.0000	0.0000	4.1	4.1	1.4110	1.9909	
SE 17	½	0.7	0.8	−0.2231	0.0498	2.6	3.2	1.1632	1.3530	
123/45*	½	0.9				3.8				
1	¼	1.0	0.9	−0.1054	0.0111	2.7	3.5	1.2528	1.5695	Close group of four commercial boreholes
2	¼	0.9				3.9				
3	¼	0.9				4.1				
4	¼	0.8				3.4				
Totals	$\Sigma lw = 8$			−1.0545	0.3320			10.2864	16.0223	
Means				−0.1318	0.0415			1.2853	2.0028	

* HydrogeologyUnit record.

Overburden

$e^{\bar{l}o} = \text{antilog}_e(-0.1318)$
$= 0.9$ and

$V = 0.0415 - (-0.1318)^2$
$= 0.02$.

Referring to table with $V = 0.02$ for sample size n = 8, we find that

$\gamma_8(0.02) = 1.010$.

Mean thickness is then

$t = (0.9)(1.010)$
$= 0.9$.

Mineral

$e^{\bar{l}m} = \text{antilog}_e(1.2358)$
$= 3.6$ and

$V = 2.0028 - (1.2358)^2$
$= 0.35$.

Referring to table with $V = 0.3$ and $V = 0.4$, for sample size n = 8, we find that

$\gamma_8 0.3) = 1.159$ and
$\gamma_8(0.4) = 1.216$.

Linear interpolation between these tabulated figures yields
$\gamma_8(0.35) = 1.1825$.

Mean thickness is then

$t = (3.6)(1.1825)$
$= 4.3$.

The estimated volume is a product of the mean thickness of mineral (t), 4.3 m, and the area of the mineral (a), 8.32 km², which yields a volume of 36 million m³.

Confidence limits for the mean of the mineral thickness may be estimated from the two graphs provided, Figures 9 and 10. For sample size $n = 8$ and variance $V = 0.35$ the upper confidence limit factor from Figure 10 is 1.87 and the lower confidence limit factor from Figure 9 is 0.72. Thus the lower 90 per cent confidence limit for the volume of mineral in the fictitious resource block is $(0.72 \times 36) = 26$ million m³ or −28 per cent, whilst the upper 90 per cent confidence limit is $(1.87 \times 36) = 67$ million m or +87 per cent.

Figure 11 Example of resource block assessment: calculation and results.

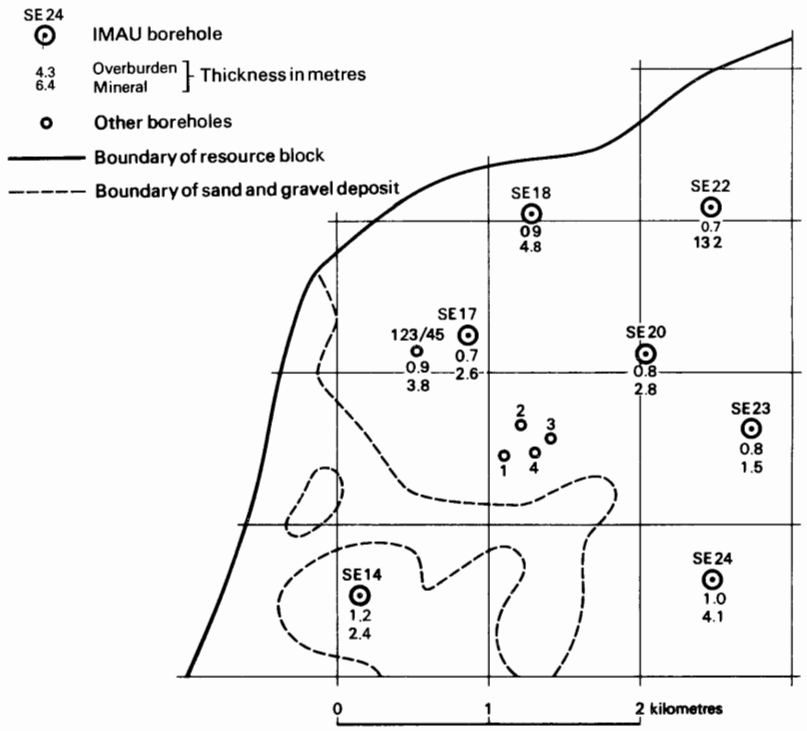

Figure 12 Example of resource block assessment: map of a fictitious block.

APPENDIX C

CLASSIFICATION AND DESCRIPTION OF SAND AND GRAVEL

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

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

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

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

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

Thus it is possible to classify the mineral into one of twelve descriptive categories (see Figure 13). The procedure is as follows:

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

For example, a deposit grading 11 per cent gravel, 70 per cent sand and 19 per cent fines is classified as 'clayey' pebbly sand. This short description is included in the borehole log (see Note 9, Appendix D).

Many differing proposals exist for the classification of the grain size of sediments (Atterberg, 1905; Udden, 1914; Wentworth, 1922; Wentworth, 1935; Allen, 1936; Twenhofel, 1937; Lane and others, 1947). As Archer (1970a, b) has emphasised, there is a pressing need for a simple metric scale acceptable to both scientific and engineering interests, for which the class limit sizes correspond closely with certain marked changes in the natural properties of mineral particles. For example, there is an important change in the degree of cohesion between particles at about the $\frac{1}{16}$ mm size, which approximates to the generally accepted boundary between silt and sand. These and other requirements are met by a system based on Udden's geometric scale and a simplified form of Wentworth's terminology (Table 8), which is used in this Report.

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

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

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

The relative proportions of the rock types present in the gravel fraction are indicated by the use of the words 'and' or 'with'. For example, 'flint and quartz' indicates very approximate equal proportions with neither constituent

accounting for less than about 25 per cent of the whole; 'flint with quartz' indicates that flint is dominant and quartz, the principal accessory rock type, comprises 5 to 25 per cent of the whole. Where the accessory material accounts for less than 5 per cent of the whole, but is still readily apparent, the phrase 'with some' has been used. Rare constituents are referred to as 'trace'.

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

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

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

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

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

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

Table 8 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

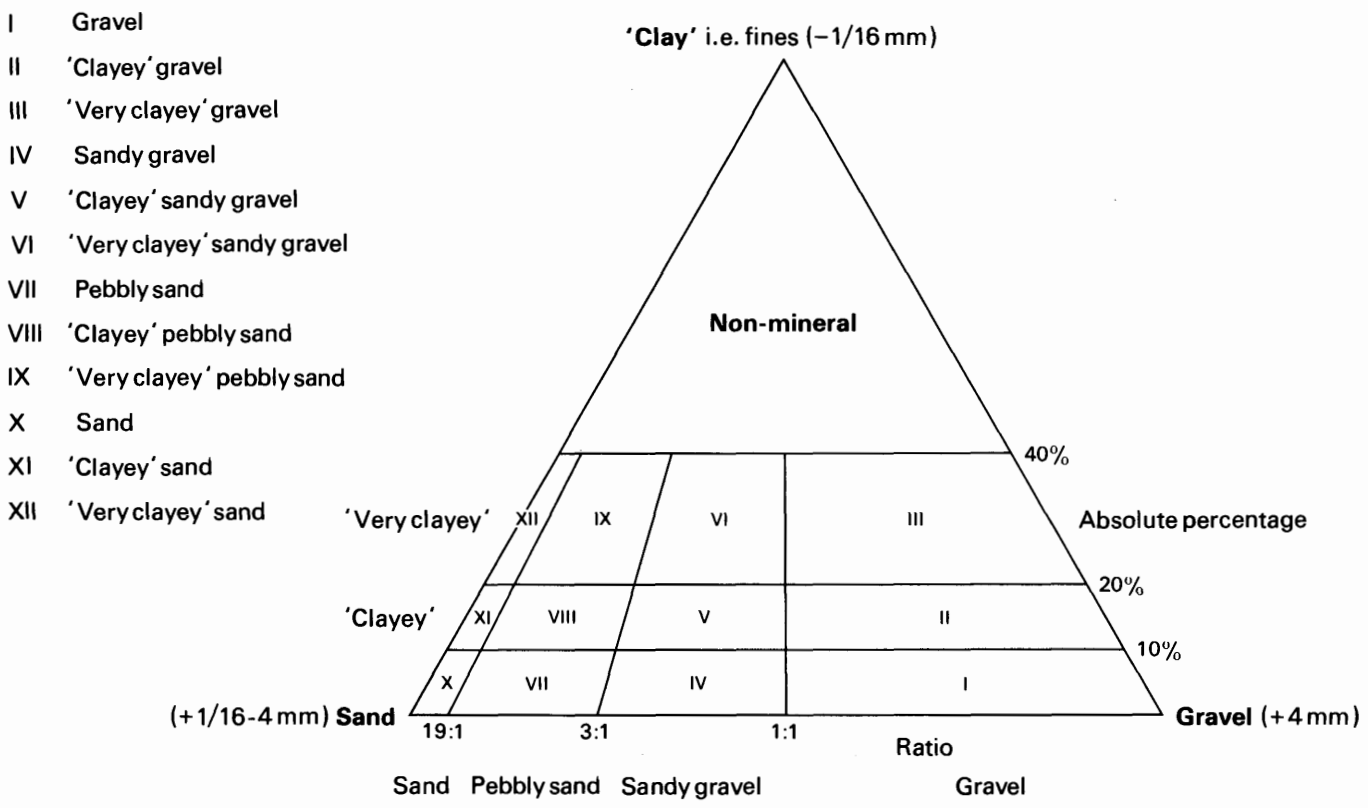

Figure 13 Diagram to show the descriptive categories used in the classification of sand and gravel.

APPENDIX D

EXPLANATION OF THE BOREHOLE RECORDS

NZ 06 SW 18[1] **0330 6159**[2] **Low Shilford**[3] **Block B**

Surface level +25.6 m (+84 ft)[4]
Water struck at +16.5 m[5]
Shell and auger, 250 mm[6]
March 1978

Overburden 0.3 m
Mineral 2.7 m
Waste 6.5 m
Mineral 7.1 m
Bedrock 0.4 m+[8]

LOG

Geological classification	Lithology[9]	Thickness m	Depth m
	Soil	0.3	0.3
River terrace deposits	**a** Gravel Gravel: coarse, subangular to subrounded, sandstone with fine-grained volcanic rocks and some ironstone Sand: medium, subangular to subrounded, quartz with some lithic grains including coal	2.7	3.0
Boulder clay	Clay, sandy and pebbly, grey	6.5	9.5
Glacial sand and gravel	**b** Pebbly sand Gravel: coarse, subangular to subrounded, sandstone with limestone and fine-grained volcanic rocks Sand: fine, subangular to subrounded, quartz with lithic grains including coal	7.1	16.6
Carboniferous	Sandstone, brown	0.4+	17.0

GRADING[10]

	Mean for deposit *percentage*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	5	32	63	0.3–1.3	7	16	15	9	16	29	8
				1.3–2.3	2	5	8	7	21	33	24
				2.3–3.0	8	6	15	15	20	28	8
				Mean	5	9	13	10	19	30	14
b	6	73	21	9.5–10.6	4	14	29	8	18	25	2
				10.6–11.6	9	23	27	5	10	20	6
				11.6–12.6	9	58	33	0	0	0	0
				12.6–14.6	4	37	27	1	1	2	28
				14.6–16.6	7	51	38	2	2	0	0
				Mean	6	39	31	3	5	7	9
a &b	6	62	32	Mean	6	31	26	5	9	13	10

COMPOSITION[11]

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	86	–	11	trace	1	–	trace	2	trace
b	87	–	5	trace	trace	6	1	trace	1

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

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

1 The number of the 1:25 000 sheet on which the borehole lies, here NZ 06.

2 The quarter of the 1:25 000 sheet on which the borehole lies and the number of the borehole in a series for that quarter, here SW 18.

Thus the full number is NZ 06 SW 18. Usually this is abbreviated to 06 SW 18 in the text of the report.

2 National Grid reference
All National Grid references fall in the 100 km square identified by the first two letters of the registration number. Grid references are given to eight figures, accurate to within 10 m.

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

4 Surface level
The surface level at the borehole site is given in metres and feet above Ordnance Datum. Measurements were made in both metres and feet, depending upon the units of the most recent information. Conversions are shown in brackets.

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

6 Type of drill and date of drilling
Type of drilling rig and diameter of casing is shown for each borehole.

7 Overburden, mineral, waste and bedrock
Mineral is sand and gravel which, as part of a deposit, falls within the arbitrary definition of potentially workable material (see page 1). Bedrock is the 'formation', 'country rock' or 'rock head' below which potentially workable sand and gravel will not be found.

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

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

9 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.

10 Grading data
A continuous series of bulk samples is taken throughout the thickness of the sand and gravel. A new sample is normally commenced whenever there is an appreciable lithological change or at every 1 metre 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 are 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 is 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 is made to estimate the grading by comparing the grading and field description of adjacent samples with the sample in question. Such estimates are shown in italics.

11 Composition
Mean lithological compositions are shown when a deposit, within a borehole, contains more than 5% by weight of gravel. Gravel from each grading fraction was randomly selected to form a sample, usually containing over 1000 particles. This sample was then sorted into lithological categories and weight percentages were calculated. The categories recognised were:

Sandstone: fine- to coarse-grained quartzites, arkoses and greywackes.

Fine-grained basic igneous: a durable trace component mostly composed of basalt probably originating from the Whin Sill.

Fine-grained volcanic: chiefly composed of Borrowdale Volcanic group rocks which are greenish-coloured tuffs; some southern Scottish material may also be present.

Granite: a durable minor component composed of alkali-granite, adamellite, and granodiorite.

Quartz: a durable minor component.

Limestone: pale to dark grey Carboniferous limestones, often muddy.

Coal: minor component in fine gravel.

Ironstone: hematite (Fe_2O_3)—minor component in fine gravels.

Mudstone and shale: locally-derived Carboniferous material.

APPENDIX E

LIST OF BOREHOLES AND EXPOSURE RECORDS USED IN THE ASSESSMENT OF RESOURCES

Borehole*	Grid reference
INDUSTRIAL MINERALS ASSESSMENT UNIT BOREHOLES	
NZ 06 NE	
48	0897 6812
49	0998 6771
50	0997 6616
NZ 06 SW	
13	0300 6345
14	0058 6202
15	0347 6239
16	0410 6239
17	0199 6187
18	0330 6159
19	0447 6191
20	0024 6077
21	0134 6001
22	0252 6056
23	0426 6090
NZ 06 SE	
62	0544 6442
63	0689 6482
64	0716 6400
65	0858 6455
66	0981 6498
67	0569 6367
68	0625 6375
69	0735 6305
70	0793 6353
71	0913 6392
72	0987 6335
73	0503 6298
74	0566 6232
75	0722 6228
76	0552 6189
77	0565 6120
78	0655 6169
79	0972 6160
80	0502 6055
NZ 16 NW	
38	1044 6972
39	1235 6986
40	1402 6926
41	1222 6607
42	1401 6624
43	1163 6551
44	1450 6565
NZ 16 NE	
91	1976 6944
92	1566 6843
93	1871 6842
94	1602 6543
NZ 16 SW	
206	1062 6446
207	1222 6495
208	1259 6415
209	1306 6477
210	1493 6493
211	1109 6357
212	1243 6367
213	1460 6344
214	1071 6233
215	1191 6286
216	1274 6286
217	1486 6262
218	1053 6140
219	1209 6171
220	1445 6161
221	1165 6118
NZ 16 SE	
224	1672 6493
225	1787 6421
226	1550 6303
227	1932 6301
228	1517 6132
229	1796 6104
230	1935 6113
231	1635 6022
232	1748 6036
EXPOSURE RECORDS	
NZ 06 SW	
E1	0130 6358
NZ 16 SE	
E1	1574 6255
OTHER BOREHOLES	
06 NW 6; 06 NW 9; 06 NE 4; 06 NE 22; 16 NW 13; 16 NW 28; 16 NE 17; 16 NE 19; 16 NE 22; 16 NE 56; 16 NE 65; 16 NE 80.	

* By sheet quadrant
† Or exposure.

APPENDIX F

INDUSTRIAL MINERALS ASSESSMENT UNIT BOREHOLE AND EXPOSURE RECORDS

NZ 06 NE 48 0897 6812 Bog Plantation **Block A**

Surface level (+125.9 m) +413 ft
Water struck at +125.8 m
Shell and auger, 250 mm
March 1978

Waste 2.8 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made Ground	1.7	1.7
Boulder Clay	Clay, sandy and pebbly, mottled brown	0.6	2.3
	Clay, silty, laminated, grey	0.5	2.8
Carboniferous	Sandstone, micaceous, brown	0.2+	3.0

NZ 06 NE 49 0998 6771 Eppies Hill **Block A**

Surface level (+132.7 m) +435 ft
Water not encountered
Shell and auger, 250 mm
March 1978

Waste 5.7 m
Bedrock 0.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Boulder Clay	Clay, sandy, mottled brown	5.1	5.7
Carboniferous	Mudstone, grey	0.3+	6.0

NZ 06 NE 50 0997 6616 Horsley **Block A**

Surface level +118.1 m (+387 ft)
Water not encountered
Shell and auger, 250 mm
November 1977

Waste 3.2 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Alluvium	Clay, pebbly, mottled brown	0.9	1.4
	Peat with bands of clay	1.8	3.2
Carboniferous	Limestone, fossiliferous, grey	0.1+	3.3

NZ 06 SW 13 0300 6345 Planetreebanks Plantation **Block A**

Surface level +61.6 m (+202 ft)
Water not encountered
Shell and auger, 250 mm
December 1977

Waste 4.9 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, sandy, brown, with pebbles	4.5	4.9
Carboniferous	Sandstone, grey	0.1+	5.0

NZ 06 SW 14 0058 6202 Riding Hills **Block B**

Surface level +107.1 m (+351 ft)
Water not encountered
Shell and auger, 250 mm
March 1978

Overburden 3.0 m
Mineral 2.3 m
Waste 1.6 m
Bedrock 0.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	Clay, sandy and pebbly, grey	2.7	3.0
	'Very clayey' pebbly sand Gravel: coarse, subrounded to well rounded sandstone Sand: fine, subangular to subrounded, quartz and lithic grains	2.3	5.3
Boulder Clay	Clay, pebbly, grey	1.6	6.9
Carboniferous	Sandstone, brown	0.4+	7.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
27	59	14	3.0–4.0	24	32	23	4	4	8	5
			4.0–5.3	29	32	23	4	3	6	3
			Mean	27	32	23	4	3	7	4

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
99	–	1	trace	trace	–	trace	trace	trace

NZ 06 SW 15 0347 6239 Peepy **Block B**

Surface level +41.2 m (+135 ft) Overburden 9.7 m
Water level +31.9 m Mineral 4.0 m
Shell and auger, 250 mm Waste 4.3 m+
March 1978

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial Sand and Gravel	'Very clayey' pebbly sand: medium, subrounded, quartz with lithic grains; some sandstone gravel	0.7	1.3
	Silt, sandy and pebbly, laminated, brown	8.4	9.7
	'Very clayey' pebbly sand: Gravel: coarse, subangular, sandstone with some ironstone Sand: fine, subangular, quartz and lithic grains	4.0	13.7
	Silt, sandy, becoming laminated with increasing depth, brown	4.3+	18.0

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
35	51	14	9.7–11.7	35	37	11	3	1	13	0
			11.7–13.7	*35*	*37*	*11*	*3*	*1*	*13*	*0*
			Mean	35	37	11	3	1	13	0

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
99	–	trace	trace	–	–	trace	1	–

NZ 06 SW 16 0410 6239 Sod Hall **Block B**

Surface level +41.7 m (+137 ft)
Water struck at +39.7 m
Shell and auger, 250 mm
December 1977

Overburden 1.0 m
Mineral 2.5 m
Waste 4.7 m
Bedrock 0.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	Clay, sandy, brown	0.7	1.0
	'Clayey' sandy gravel Gravel: mainly coarse, angular to subrounded, sandstone with some fine-grained volcanic rocks Sand: medium, subangular to subrounded, quartz with some lithic grains including coal	2.5	3.5
Boulder Clay	Clay, silty in upper part becoming sandy with increasing depth, grey	4.7	8.2
Carboniferous	Sandstone, brown	0.5+	8.7

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
10	66	24	1.0–2.0	12	33	33	7	4	11	0
			2.0–3.0	8	17	38	8	11	18	0
			3.0–3.5	10	9	36	12	16	17	0
			Mean	10	22	36	8	9	15	0

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
97	–	3	trace	trace	–	–	trace	trace

NZ 06 SW 17 0199 6187 Styford Park **Block B**

Surface level (+18.9 m) +62 ft
Water struck at +14.9 m
Shell and auger, 250 mm
April 1978

Overburden 0.3 m
Mineral 5.9 m
Waste 0.4 m
Mineral 1.5 m
Waste 0.3 m
Bedrock 1.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	**a** 'Clayey' pebbly sand Gravel: coarse and fine with some cobbles, rounded to well rounded, sandstone with limestone and fine-grained volcanic rocks Sand: fine, subangular to rounded, quartz with some lithic grains including coal	5.9	6.2
	Clay, silty to sandy, pebbly, grey	0.4	6.6
	b Gravel Gravel: coarse, rounded to well rounded, sandstone with limestone and some fine-grained volcanic rocks and mudstone Sand: coarse, subangular to rounded, quartz with some lithic grains including coal	1.5	8.1
	Clay, pebbly, grey	0.3	8.4
Carboniferous	Sandstone, pale grey	1.3+	9.7

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	16	64	20	0.3–2.3	33	58	7	1	1	0	0
				2.3–3.3	15	38	15	4	5	11	12
				3.3–4.3	3	11	15	13	26	27	5
				4.3–5.3	4	30	41	3	3	12	7
				5.3–6.2	8	47	39	3	3	0	0
				Mean	16	40	20	4	7	9	4
b	6	22	72	6.6–8.1	6	5	4	13	23	36	13
a & b	14	56	30	Mean	14	33	17	6	10	14	6

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	78	–	6	trace	1	14	trace	1	trace
b	69	–	4	trace	trace	25	trace	trace	2

NZ 06 SW 18 0330 6159 Low Shilford **Block B**

Surface level +25.6 m (+84 ft)
Water struck at +16.5 m
Shell and auger, 250 mm
March 1978

Overburden 0.3 m
Mineral 2.7 m
Waste 6.5 m
Mineral 7.1 m
Bedrock 0.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
River Terrace Deposits	**a** Gravel Gravel: coarse, subangular to subrounded, sandstone with fine-grained volcanic rocks and some ironstone Sand: medium, subangular to subrounded, quartz with some lithic grains including coal	2.7	3.0
Boulder Clay	Clay, sandy and pebbly, grey	6.5	9.5
Glacial Sand and Gravel	**b** Pebbly sand Gravel: coarse, subangular to subrounded, sandstone with limestone and fine-grained volcanic rocks Sand: fine, subangular to subrounded, quartz with lithic grains including coal	7.1	16.6
Carboniferous	Sandstone, brown	0.4+	17.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	5	32	63	0.3–1.3	7	16	15	9	16	29	8
				1.3–2.3	2	5	8	7	21	33	24
				2.3–3.0	8	6	15	15	20	28	8
				Mean	5	9	13	10	19	30	14
b	6	73	21	9.5–10.6	4	14	29	8	18	25	2
				10.6–11.6	9	23	27	5	10	20	6
				11.6–12.6	9	58	33	0	0	0	0
				12.6–14.6	4	37	27	1	1	2	28
				14.6–16.6	7	51	38	2	2	0	0
				Mean	6	39	31	3	5	7	9
a & b	6	62	32	Mean	6	31	26	5	9	13	10

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	86	–	11	trace	1	–	trace	2	trace
b	87	–	5	trace	trace	6	1	trace	1

NZ 06 SW 19 0447 6191 Bywell Park **Block B**

Surface level +24.5 m (+80 ft)
Water struck at +22.0 m
Shell and auger, 250 mm
April 1978

Overburden 0.5 m
Mineral 4.2 m
Waste 12.5 m
Bedrock 0.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Alluvium	**a** 'Very clayey' pebbly sand Gravel: coarse to cobble, subangular to rounded, sandstone with some fine-grained volcanic rocks Sand: fine, subangular to rounded, quartz with lithic grains	2.0	2.5
	b Gravel: Gravel: coarse, angular to rounded, sandstone with fine-grained volcanic rocks and some granite and ironstone Sand: fine, subangular to well rounded, quartz and lithic grains	2.2	4.7
	Silt, clayey, sandy and pebbly, laminated, dark grey	12.5	17.2
Carboniferous	Sandstone, brown	0.8+	18.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$
a	37	59	4	0.5–1.5	34	44	9	4	2	2	5
				1.5–2.5	40	51	8	1	0	0	0
				Mean	37	48	9	2	1	1	2
b	6	24	70	2.5–3.5	11	20	11	6	17	28	7
				3.5–4.7	2	4	6	4	14	41	29
				Mean	6	11	8	5	16	35	19
a & b	21	40	38	Mean	21	29	8	3	9	19	11

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	96	–	3	trace	trace	–	trace	1	–
b	86	–	11	1	1	trace	trace	1	–

NZ 06 SW 20 0024 6077 Red Hemmels **Block B**

Surface level (+63.1 m) +207 ft
Water struck at +61.9 m
Shell and auger, 250 mm
March 1978

Overburden 1.2 m
Mineral 3.2 m
Waste 11.9 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial Sand and Gravel	Clay, sandy and pebbly, brown	0.6	1.2
	Gravel Gravel: coarse, angular to well rounded, sandstone with some fine-grained volcanic rocks and ironstone Sand: fine and medium, subangular to rounded, quartz and lithic grains	3.2	4.4
Boulder Clay	Clay, silty and pebbly, dark grey	11.9	16.3
Carboniferous	Sandstone, pale grey	0.1 +	16.4

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
8	33	59	1.2–2.2	11	17	17	7	15	22	11
			2.2–3.2	8	8	12	9	21	37	5
			3.2–4.4	6	11	10	8	11	34	20
			Mean	8	12	13	8	15	31	13

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
90	–	5	trace	trace	–	–	5	trace

NZ 06 SW 21 0134 6001 High Plains

Surface level (+135.8 m) +446 ft
Water not encountered
Shell and auger, 200 mm
November 1977

Waste 1.7 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	'Very clayey' sand: fine and medium, subangular to subrounded quartz	0.3	0.6
Boulder Clay	Clay, mottled brown	1.1	1.7
Carboniferous	Sandstone, brown	0.1+	1.8

NZ 06 SW 22 0252 6056 High Shilford

Surface level +103.7 m (+340 ft)
Water not encountered
Shell and auger, 200 mm
November 1977

Waste 1.7 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, mottled brown	1.5	1.7
Carboniferous	Sandstone, brown	0.1+	1.8

NZ 06 SW 23 0426 6090 Shilford East Wood **Block B**

Surface level +68.4 m (+224 ft)
Water struck at +46.4 m
Shell and auger, 200 mm
November 1977

Overburden 4.0 m
Mineral 18.0 m
Waste 1.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Sand and Gravel	Clay, sandy and pebbly, brown	3.8	4.0
	Pebbly sand and sandy gravel Gravel: fine, subangular to subrounded, sandstone with some fine-grained volcanic rocks and limestone Sand: medium, subangular to subrounded, quartz with coal and some other lithic grains	18.0	22.0
Boulder Clay	Clay, sandy and pebbly, brown	1.8+	23.8

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
6	83	11	4.0–5.0	17	28	39	6	8	2	0
			5.0–6.0	7	32	43	7	7	4	0
			6.0–7.0	8	38	46	3	4	1	0
			7.0–8.0	13	51	34	2	0	0	0
			8.0–9.0	8	53	38	1	0	0	0
			9.0–10.0	6	39	53	2	0	0	0
			10.0–11.0	3	15	39	13	16	14	0
			11.0–12.0	2	7	35	24	20	12	0
			12.0–13.0	3	14	42	12	23	6	0
			13.0–14.0	4	22	53	13	6	2	0
			14.0–15.0	4	12	41	17	14	12	0
			15.0–16.0	3	9	36	20	19	13	0
			16.0–17.0	*6*	*17*	*71*	*6*	*0*	*0*	*0*
			17.0–18.0	6	17	71	6	0	0	0
			18.0–19.0	*7*	*17*	*67*	*6*	*1*	*2*	*0*
			19.0–20.0	6	13	68	11	1	1	0
			20.0–21.0	5	9	70	14	2	0	0
			21.0–22.0	1	5	64	18	10	2	0
			Mean	6	22	51	10	7	4	0

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
89	–	3	–	1	4	1	1	1

NZ 06 SE 62 0544 6442 Benlow Hill **Block B**

Surface level (+130.1 m) +427 ft
Water struck at +123.1 m
Shell and auger, 250 mm
April 1978

Overburden 0.3 m
Mineral 3.0 m
Waste 1.7 m
Mineral 1.0 m
Waste 1.0 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	**a** 'Very clayey' pebbly sand Gravel: coarse and fine, rounded, sandstone with ironstone and some shale and fine-grained volcanic rocks Sand: fine, subrounded, quartz and lithic grains	3.0	3.3
Boulder Clay	Clay, silty and pebbly, grey	1.7	5.0
Glacial Sand and Gravel	**b** 'Very clayey' pebbly sand Gravel: coarse and fine, subangular to rounded, sandstone with some ironstone Sand: fine, subrounded, quartz and lithic grains	1.0	6.0
	Silt, sandy and pebbly, brown	1.0	7.0
Carboniferous	Sandstone, brown	0.2+	7.2

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	31	55	14	0.3–1.3	32	37	14	6	5	6	0
				1.3–2.3	34	33	13	6	6	8	0
				2.3–3.3	26	39	13	6	7	9	0
				Mean	31	36	13	6	6	8	0
b	39	51	10	5.0–6.0	39	35	7	9	5	5	0
a & b	33	54	13	Mean	33	36	11	7	6	7	0

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	90	–	2	–	trace	trace	trace	6	2
b	96	–	trace	–	–	trace	trace	3	1

NZ 06 SE 63 0689 6482 Hunter's Hill **Block A**

Surface level +97.6 m (+320 ft)
Water not encountered
Shell and auger, 200 mm
April 1978

Waste 6.9 m
Bedrock 0.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, sandy and pebbly, brown	6.7	6.9
Carboniferous	Sandstone, brown	0.5+	7.4

NZ 06 SE 64 0716 6400 Ovington **Block B**

Surface level +59.4 m (+195 ft)
Water not encountered
Shell and auger, 250 mm
November 1977

Waste 10.3 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Boulder Clay	Clay, sandy and pebbly, dark grey	9.8	10.3
Carboniferous	Sandstone, pale grey	0.1+	10.4

NZ 06 SE 65 0858 6455 Mount Huly **Block A**

Surface level (+56.0 m) +184 ft
Water struck at +50.0 m
Shell and auger, 250 mm
November 1977

Waste 12.5 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, sandy and pebbly, grey	12.0	12.4
	'Clayey' sand: fine and medium, subangular to subrounded, quartz with some coal	0.1	12.5
Carboniferous	Sandstone, yellowish brown	0.1+	12.6

NZ 06 SE 66 0981 6498 Horsley Cottages **Block A**

Surface level +46.7 m (+153 ft)
Water not encountered
Shell and auger, 200 mm
December 1977

Waste 5.1 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Boulder Clay	Clay, silty in upper part, becoming sandy with increasing depth, pebbly, grey	5.0	5.1
Carboniferous	Sandstone, yellowish brown	0.1+	5.2

NZ 06 SE 67 0569 6367 Entry Well **Block A**

Surface level +100.6 m (+330 ft)
Water not encountered
Shell and auger, 200 mm
April 1978

Waste 4.5 m
Bedrock 0.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, sandy and pebbly, brown	4.1	4.5
Carboniferous	Sandstone, brown	0.5+	5.0

NZ 06 SE 68 0625 6375 Ovington Lodge **Block B**

Surface level +71.9 m (+236 ft)
Water struck at +68.5 m
Shell and auger, 250 mm
November 1977

Waste 11.9 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, sandy, pebbly near base, brown	6.5	6.7
	Clay, silty to sandy, grey to dark grey	5.2	11.9
Carboniferous	Sandstone, grey	0.1+	12.0

NZ 06 SE 69 0735 6305 Eltringham House **Block B**

Surface level +7.5 m (+25 ft)
Water struck at +3.0 m
Shell and auger, 250 mm
April 1978

Overburden 2.4 m
Mineral 10.2 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	2.3	2.3
	Soil	0.1	2.4
Alluvium	Gravel Gravel: coarse, angular to subrounded, sandstone with fine-grained volcanic rocks and some limestone and shale Sand: medium, subangular to subrounded, quartz with lithic grains	10.2	12.6
Carboniferous	Sandstone, pale grey	0.2+	12.8

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
3	38	59	2.4–3.0	10	48	18	3	8	13	0
			3.0–4.0	7	14	23	6	21	27	2
			4.0–5.0	3	7	13	5	28	44	0
			5.0–6.0	trace	2	11	3	11	55	18
			6.0–7.0	trace	2	10	4	16	60	8
			7.0–8.0	trace	7	20	9	14	39	11
			8.0–9.0	trace	13	31	8	19	27	2
			9.0–10.0	3	9	20	8	20	34	6
			10.0–11.0	2	13	25	8	19	27	6
			11.0–12.0	4	12	22	11	25	21	5
			12.0–12.6	4	17	20	16	22	17	4
			Mean	3	12	19	7	19	34	6

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
80	–	11	1	trace	5	1	trace	2

NZ 06 SE 70 0793 6353 Field House **Block B**

Surface level +23.7 m (+78 ft)
Water struck at +15.6 m
Shell and auger, 200 mm
November 1977

Overburden 0.3 m
Mineral 4.1 m
Waste 3.7 m
Mineral 7.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	**a** 'Clayey' sand, with gravel between 1.0 m and 2.0 m Gravel: coarse, subangular to subrounded, sandstone with fine-grained volcanic rocks Sand: mainly fine, subangular to subrounded, quartz with lithic grains including coal	4.1	4.4
	Clay, sandy in upper part, becoming silty with depth, grey	3.7	8.1
	b 'Clayey' sand: fine, subangular to subrounded, quartz with some lithic grains including coal	7.0+	15.1
	Borehole abandoned because of rising sand		

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	17	68	15	0.3–1.0	25	54	15	3	1	2	0
				1.0–2.0	1	9	22	7	19	42	0
				2.0–4.0	*21*	*62*	*16*	*1*	*0*	*0*	*0*
				4.0–4.4	21	62	16	1	0	0	0
				Mean	17	48	17	3	5	10	0
b	16	84	0	8.1–10.1	21	37	41	1	0	0	0
				10.1–12.1	17	60	23	0	0	0	0
				12.1–14.1	*13*	*59*	*28*	*0*	*0*	*0*	*0*
				14.1–15.1	10	57	33	0	0	0	0
				Mean	16	53	31	trace	0	0	0
a & b	16	78	6	Mean	16	51	26	1	2	4	0

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	84	–	13	1	1	–	–	1	trace

NZ 06 SE 71 0913 6392 Ovingham Bridge **Block C**

Surface level +9.1 m (+30 ft)
Water level +6.1 m
Shell and auger, 250 mm
February 1978

Overburden 0.6 m
Mineral 4.0 m
Waste 8.7 m
Mineral 11.7 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Clay, silty, laminated, brown	0.3	0.6
	a 'Very clayey' sandy gravel Gravel: fine, coarse and cobble, subangular to rounded, sandstone with fine-grained volcanic rocks Sand: fine, subangular to rounded, quartz with some lithic grains	4.0	4.6
	Clay, silty, laminated; some sandy layers	8.7	13.3
	b Sand 'very clayey' to 'clayey' in upper part: fine, subrounded, quartz with lithic grains including some coal	11.7+	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
a	21	55	24	0.6–1.6	34	61	4	1	0	0	0
				1.6–2.6	29	56	11	4	0	0	0
				2.6–3.4	26	52	14	6	2	0	0
				3.4–4.6	1	4	7	7	27	31	23
				Mean	21	41	9	5	9	8	7
b	9	91	0	13.3–15.0	20	74	6	0	0	0	0
				15.0–16.0	12	79	9	0	0	0	0
				16.0–18.0	11	84	5	0	0	0	0
				18.0–20.0	8	77	15	0	0	0	0
				20.0–22.0	6	61	32	1	0	0	0
				22.0–25.0	4	57	38	1	0	0	0
				Mean	9	70	20	1	0	0	0
a & b	12	82	6	Mean	12	63	17	2	2	2	2

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	81	1	15	1	1	trace	trace	1	trace

NZ 06 SE 72 0987 6335 Broom House **Block D**

Surface level +52.2 m (+171 ft)
Water struck at +46.5 m
Shell and auger, 200 mm
September 1977

Overburden 2.1 m
Mineral 2.4 m
Waste 1.5 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial sand and gravel	Clay, sandy, brown	0.6	1.2
	Silt, micaceous, sandy, olive grey	0.7	1.9
	Clay, sandy, brown; some sand lenses	0.2	2.1
	'Clayey' sandy gravel Gravel: coarse, subangular to subrounded sandstone with angular shale and some ironstone Sand: fine, subangular to subrounded, quartz with lithic grains including coal	2.4	4.5
Boulder Clay	Clay, sandy and pebbly, olive grey	1.5	6.0
Carboniferous	Sandstone, grey	0.1+	6.1

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
13	57	30	2.1–3.0	15	76	6	1	1	1	0
			3.0–3.7	10	43	8	5	14	20	0
			3.7–4.5	15	13	8	9	14	24	17
			Mean	13	45	7	5	9	14	7

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
76	–	1	–	trace	–	trace	3	20

NZ 06 SE 73 0503 6298 Bywell Home Farm **Block A**

Surface level (+82.3 m) +270 ft
Water not encountered
Shell and auger, 200 mm
November 1977

Waste 2.2 m
Bedrock 0.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, sandy and pebbly, brown	1.9	2.2
Carboniferous	Sandstone, yellowish brown	0.5+	2.7

NZ 06 SE 74 0566 6232 Shortwood **Block B**

Surface level +17.7 m (+58 ft)
Water level +13.5 m
Shell and auger, 250 mm
October 1977

Overburden 1.2 m
Mineral 4.6 m
Waste 10.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Alluvium	Clay, sandy and pebbly, brown	1.0	1.2
	Gravel, with 'clayey' pebbly sand between 1.2 m and 2.2 m Gravel: coarse, angular to rounded, sandstone and fine-grained volcanic rocks Sand: fine, subangular to subrounded, quartz with lithic grains	4.6	5.8
Boulder Clay	Clay, pebbly, dark grey	10.0+	15.8
	Borehole abandoned because of inability to penetrate clay		

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
7	36	57	1.2–2.2	13	69	6	2	6	4	0
			2.2–3.2	9	33	5	2	14	37	0
			3.2–4.2	3	7	6	2	11	50	21
			4.2–4.9	4	10	9	3	13	35	26
			4.9–5.8	*4*	*10*	*9*	*3*	*13*	*35*	*26*
			Mean	7	27	7	2	11	32	14

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
70	–	28	trace	1	1	–	trace	trace

NZ 06 SE 75 0722 6228 Lowclose Wood

Surface level +63.2 m (+207 ft)
Water struck at +60.3 m
Shell and auger, 200 mm
October 1977

Waste 10.1 m
Bedrock 0.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, sandy and pebbly, mottled grey	5.5	5.8
Glacial Sand and Gravel	'Clayey' pebbly sand: fine quartz sand with sandstone gravel	1.1	6.9
Boulder Clay	Clay, sandy and pebbly, grey	3.2	10.1
Carboniferous	Sandstone, grey	0.4+	10.5

NZ 06 SE 76 0552 6189 Stocksfield Hall **Block B**

Surface level +21.0 m (+69 ft)
Water struck at +18.0 m
Shell and auger, 250 mm
March 1978

Overburden 0.3 m
Mineral 7.0 m
Waste 13.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
River Terrace Deposits	**a** 'Very clayey' sand: fine, subangular to subrounded, quartz with some lithic grains including coal	2.0	2.3
	b Gravel Gravel: coarse, angular to rounded, sandstone with fine-grained volcanic rocks Sand: medium, subangular to subrounded, quartz with some lithic grains including coal	5.0	7.3
Boulder Clay	Clay, silty, pebbly, grey	13.0+	20.3

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	31	66	3	0.3–1.3	34	56	8	1	1	0	0
				1.3–2.3	29	52	12	3	3	1	0
				Mean	31	54	10	2	2	1	0
b	4	44	52	2.3–3.3	9	11	21	11	20	28	0
				3.3–4.3	4	4	10	17	22	39	4
				4.3–5.3	2	4	22	8	17	35	12
				5.3–6.3	1	7	46	11	9	19	7
				6.3–7.3	4	10	29	10	11	34	2
				Mean	4	7	26	11	16	31	5
a & b	12	50	38	Mean	12	21	21	8	12	22	4

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
b	89	–	8	1	1	–	trace	1	–

NZ 06 SE 77 0565 6120 Stocksfield

Surface level +44.6 m (+146 ft)
Water not encountered
Shell and auger, 250 mm
April 1978

Waste 25.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial Sand and Gravel	Clay, silty, laminated, brown, with bands of silt and 'very clayey' sand	7.6	8.2
	Silt, sandy, brown, and 'very clayey' sand	7.2	15.4
Boulder Clay	Clay, sandy and pebbly, grey	3.3	18.7
Glacial Sand and Gravel	Silt, sandy, brown	1.0	19.7
	'Clayey' sand	5.3+	25.0

NZ 06 SE 78 0655 6169 Merryshield Common **Block B**

Surface level +41.0 m (+135 ft)
Water not encountered
Shell and auger, 250 mm
December 1977

Overburden 3.2 m
Mineral 7.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Sand and Gravel	Clay, sandy, mottled brown and grey	2.7	3.2
	Gravel Gravel: coarse, angular to subrounded, sandstone with fine-grained volcanic rocks and some limestone, granite and fine-grained basic igneous rocks Sand: fine to coarse, subangular to subrounded, quartz with lithic grains including some coal	7.3+	10.5

Borehole abandoned due to obstruction

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
3	32	65	3.2–4.5	4	12	8	13	17	46	0
			4.5–6.0	2	5	6	10	18	41	18
			6.0–8.0	2	8	7	7	14	48	14
			8.0–10.0	4	16	21	7	12	34	6
			10.0–10.5	3	14	19	11	22	31	0
			Mean	3	11	12	9	15	41	9

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
79	2	12	2	1	4	–	trace	trace

NZ 06 SE 79 0972 6160 Prudhoe Moor

Surface level +148.5 m (+487 ft)
Water level not recorded
Shell and auger, 200 mm
October 1977

Waste 14.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, sandy, dark grey, with pebbles and cobbles	13.8+	14.0
	Borehole abandoned because of slow progress		

NZ 06 SE 80 0502 6055 Broomleyhope Wood

Surface level +66.5 m (+218 ft)
Water not encountered
Shell and auger, 250 mm
March 1978

Waste 25.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial Sand and Gravel	Clay, sandy and pebbly, mottled grey	4.6	5.2
	Silt, micaceous, olive grey, with thin bands of 'clayey' and 'very clayey' sand	12.1	17.3
	Gravel, sandy in upper part Gravel: fine and coarse, angular to subrounded, sandstone with limestone and some fine-grained volcanic rocks and ironstone Sand: fine to coarse, subangular to subrounded, quartz with some lithic grains including coal	5.5	22.8
Boulder clay	Clay, sandy and pebbly, brown	2.2+	25.0

NZ 06 SW E1 0130 6358 Styford Lodge **Block B**

Surface level (+74.7 m) +245 ft

Overburden 0.1 m
Mineral 6.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial Sand and Gravel	Gravel Gravel: coarse, subangular to rounded, sandstone with limestone and fine-grained volcanic rocks and some ironstone Sand: coarse, subangular to subrounded, quartz with lithic grains including coal and some mica	6.4+	6.5

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
3	22	75	0.1–2.0	6	8	7	8	12	35	24
			2.0–4.5	1	5	6	12	18	40	18
			4.5–6.5	2	3	7	9	16	35	28
			Mean	3	5	7	10	15	37	23

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
78	–	6	trace	trace	14	trace	2	trace

NZ 16 NW 38 1044 6972 End On **Block A**

Surface level +120.3 m (+395 ft)
Water not encountered
Shell and auger, 250 mm
April 1978

Waste 4.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, dark grey, with pebbles and cobbles	3.8+	4.0
	Borehole abandoned because of obstruction		

NZ 16 NW 39 1235 6986 Pine Dene **Block A**

Surface level +111.2 m (+365 ft)
Water struck at +101.5 m
Shell and auger, 250 mm
March 1978

Waste 9.7 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, pebbly, grey	9.5+	9.7
	Borehole abandoned because of obstruction		

NZ 16 NW 40 1402 6926 Heddon Laws Farm **Block A**

Surface level (+151.1 m) +496 ft
Water not encountered
Shell and auger, 200 mm
March 1978

Overburden 4.3 m
Mineral 11.9 m
Waste 0.8 m
Bedrock 0.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	Clay, sandy and pebbly, brown	4.0	4.3
	'Very clayey' sand: fine, rounded, quartz with lithic grains including some coal	11.9	16.2
	Silt, laminated, pebbly, dark grey	0.8	17.0
Carboniferous	Mudstone, black	0.5+	17.5

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
26	73	1	4.3–5.4	*32*	*54*	*9*	*2*	*2*	*1*	*0*
			5.4–7.4	32	54	9	2	2	1	0
			7.4–9.4	24	66	10	0	0	0	0
			9.4–11.4	28	43	26	3	0	0	0
			11.4–13.4	22	50	27	1	0	0	0
			13.4–16.2	25	36	34	2	3	0	0
			Mean	26	50	21	2	1	trace	0

NZ 16 NW 41 1222 6607 High Close House **Block A**

Surface level (+64.1 m) +210 ft
Water struck at +62.8 m
Shell and auger, 200 mm
December 1977

Waste 5.7 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, sandy and pebbly, grey	5.4	5.7
Carboniferous	Sandstone, brown	0.1+	5.8

NZ 16 NW 42 1401 6624 Heddon Hall **Block A**

Surface level +39.9 m (+131 ft)
Water not encountered
Shell and auger, 250 mm
April 1978

Waste 5.0 m
Bedrock 0.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, sandy and pebbly, brown	4.7	5.0
Carboniferous	Sandstone, yellow	0.4+	5.4

NZ 16 NW 43 1163 6551 Dayhole Dene **Block A**

Surface level (+54.5 m) +179 ft
Water not encountered
Shell and auger, 200 mm
December 1977

Waste 3.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Boulder Clay	Clay, sandy and pebbly, mottled brown	2.7+	3.2
	Borehole abandoned because of obstruction		

NZ 16 NW 44 1450 6565 Heddon Haughs **Block C**

Surface level +5.0 m (+16 ft)
Water struck at +1.7 m
Shell and auger, 250 mm
January 1978

Overburden 3.3 m
Mineral 4.0 m
Waste 5.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Silt, sandy brown	3.0	3.3
	Gravel	4.0	7.3
	Gravel: coarse, angular to subangular, sandstone with fine-grained volcanic rocks and some granite Sand: medium and fine, subangular to subrounded, quartz with some lithic grains including coal		
	Silt, sandy, brown	5.1+	12.4
	Borehole abandoned because of rising silt		

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
1	22	77	3.3–4.3	trace	5	4	3	7	57	24
			4.3–5.3	1	4	18	8	21	36	12
			5.3–7.3	2	11	7	5	14	52	9
			Mean	1	8	9	5	14	49	14

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
89	–	10	1	trace	–	–	trace	trace

NZ 16 NE 91 1976 6944 Woolsington **Block A**

Surface level +66.2 m (+217 ft)
Water struck at +62.8 m
Shell and auger, 200 mm
March 1978

Overburden 3.4 m
Mineral 1.8 m
Waste 8.6 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, micaceous, mottled brown	3.2	3.4
Glacial Sand and Gravel	Gravel Gravel: coarse, angular to subrounded, sandstone with limestone Sand: medium and coarse, subangular to subrounded, quartz with lithic grains	1.8	5.2
Boulder Clay	Clay, sandy and pebbly, grey	8.6	13.8
Carboniferous	Shale, grey	0.2+	14.0

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
1	42	57	3.4–4.4	1	6	20	18	19	24	12
			4.4–5.2	1	8	20	11	16	34	10
			Mean	1	7	20	15	18	28	11

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
69	–	1	–	trace	29	–	1	trace

NZ 16 NE 92 1566 6843 Crescent Farm **Block A**

Surface level +89.7 m (+294 ft)
Water not encountered
Shell and auger, 250 mm
April 1978

Waste 5.6 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Boulder Clay	Clay, sandy and pebbly, mottled brown in top 1.8 m, grey below	5.2	5.6
Carboniferous	Sandstone, brown	0.1+	5.7

NZ 16 NE 93 1871 6842 Whorlton Hall **Block A**

Surface level (+90.5 m) +297 ft
Water not encountered
Shell and auger, 250 mm
March 1977

Waste 2.8 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.7	0.7
Boulder Clay	Clay, sandy, brown, with pebbles and cobbles	2.1	2.8
Carboniferous	Mudstone, brown	0.2+	3.0

NZ 16 NE 94 1602 6543 Newburn Grange **Block C**

Surface level +4.6 m (+15 ft)
Water level +0.6 m
Shell and auger, 250 mm
March 1978

Mineral 20.0 m
Waste 3.5 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Alluvium	**a** Gravel Gravel: coarse, subangular to subrounded, sandstone with fine-grained volcanic rocks and some quartz Sand: medium, rounded to well rounded, quartz and lithic grains including coal	11.0	11.0
	b 'Clayey' sand: fine, rounded, quartz and lithic grains including some coal	9.0	20.0
Boulder Clay	Clay, pebbly, grey	3.5	23.5
Carboniferous	Sandstone, brown	0.3+	23.7

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	7	36	57	0.0–1.0	10	40	15	3	13	19	0
				1.0–2.0	66	8	2	6	13	5	0
				2.0–3.0	2	23	30	5	18	22	0
				3.0–4.0	1	8	19	6	26	40	0
				4.0–5.0	1	8	19	5	24	43	0
				5.0–6.0	trace	7	34	6	9	38	6
				6.0–7.0	1	12	33	5	3	46	0
				7.0–8.0	1	7	7	5	20	43	17
				8.0–9.0	trace	1	3	5	26	65	0
				9.0–10.0	trace	3	9	6	25	51	6
				10.0–11.0	1	32	16	6	17	28	0
				Mean	7	14	17	5	18	36	3
b	13	87	0	11.0–12.0	7	81	7	3	2	0	0
				12.0–14.0	8	83	6	2	1	0	0
				14.0–16.0	9	88	3	0	0	0	0
				16.0–18.0	12	79	8	1	0	0	0
				18.0–20.0	25	69	6	0	0	0	0
				Mean	13	80	6	1	trace	0	0
a & b	10	59	31	Mean	10	44	12	3	10	20	1

COMPOSITION

	Percentages by weight in gravel fraction								
	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	90	1	7	1	1	–	trace	trace	trace

NZ 16 SW 206 **1062 6446** **Hagg Bank** **Block D**

Surface level +36.2 m (+119 ft)
Water not encountered
Shell and auger, 200 mm
September 1977

Overburden 9.0 m
Mineral 3.0 m
Waste 3.6 m
Mineral 7.3 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Sand and Gravel	Clay, sandy in upper part becoming silty with increasing depth, laminated in part, brown	8.8	9.0
	a 'Very clayey' sand: fine, subangular to subrounded quartz with angular to subrounded coal and some mica	3.0	12.0
	Silt, sandy, micaceous, brown	1.2	13.2
Boulder Clay	Clay, sandy and pebbly, brown	2.4	15.6
Glacial Sand and Gravel	**b** 'Clayey' sandy gravel Gravel: coarse, angular to subrounded, sandstone with some fine-grained volcanic rocks, limestone and ironstone Sand: fine, subangular to subrounded, quartz with some lithic grains including coal	7.3	22.9
Carboniferous	Sandstone, yellowish brown	0.2+	23.1

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$
a	27	73	0	9.0–10.0	27	73	0	0	0	0	0
				10.0–11.0	22	77	1	0	0	0	0
				11.0–12.0	33	66	1	0	0	0	0
				Mean	27	72	1	0	0	0	0
b	15	46	39	15.6–16.6	14	23	16	6	16	25	0
				16.6–17.7	16	40	17	7	10	10	0
				17.7–18.3	16	22	12	6	13	19	12
				18.3–19.3	10	16	10	7	16	41	0
				19.3–19.9	32	26	12	5	10	15	0
				19.9–20.9	19	27	13	15	7	19	0
				20.9–21.9	12	20	14	6	7	29	12
				21.9–22.9	5	18	15	7	12	37	6
				Mean	15	24	14	8	11	25	3
a & b	18	54	28	Mean	18	38	10	6	8	18	2

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
b	92	–	3	trace	trace	2	1	2	trace

NZ 16 SW 207 1222 6495 Stephenson's Cottage **Block C**

Surface level +8.6 m (+28 ft)
Water struck at −0.4 m
Shell and auger, 250 mm
January 1978

Overburden 1.0 m
Mineral 1.0 m
Waste 7.0 m
Mineral 5.7 m
Waste 1.2 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Alluvium	Clay, sandy, pebbly, olive grey	0.6	1.0
	a Gravel Gravel: coarse, subangular to subrounded, sandstone with fine-grained volcanic rocks and some ironstone Sand: medium and coarse, subangular to subrounded, quartz with lithic grains	1.0	2.0
	Clay, silty and pebbly, grey	7.0	9.0
	b Sandy gravel Gravel: coarse, angular to subangular, sandstone with some fine-grained volcanic rocks and ironstone Sand: fine and medium, subangular to subrounded, quartz with some lithic grains including coal	5.7	14.7
	Clay, silty, dark grey	1.2	15.9
Carboniferous	Sandstone, pale grey	0.2+	16.1

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	4	40	56	1.0–2.0	4	11	15	14	18	25	13
b	7	52	41	9.0–10.0	6	23	40	4	11	16	0
				10.0–11.0	6	31	31	3	10	19	0
				11.0–13.0	1	12	13	4	19	51	0
				13.0–14.7	15	37	21	5	9	13	0
				Mean	7	25	23	4	13	28	0
a & b	7	50	43	Mean	7	23	22	5	14	27	2

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	85	1	10	trace	1	–	trace	3	trace
b	96	–	2	trace	trace	trace	trace	2	–

NZ 16 SW 208 1259 6415 Castle Hill Farm **Block D**

Surface level +48.0 m (+157 ft)
Water struck at +41.0 m
Shell and auger, 250 mm
April 1978

Overburden 0.5 m
Mineral 9.0 m
Waste 10.2 m
Mineral 5.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Sand and Gravel	**a** 'Clayey' sand, gravelly at top: fine, subangular to subrounded, quartz with some mica, coal and other lithic grains	9.0	9.5
	Silt, sandy, brown	2.8	12.3
	Clay, silty, grey, with bands of silty sand	7.4	19.7
	b 'Clayey' sand: fine, subangular to subrounded, quartz with some mica and lithic grains including coal	5.3+	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
a	18	79	3	0.5–1.5	11	20	38	8	15	8	0
				1.5–2.5	15	51	28	2	3	1	0
				2.5–3.5	22	58	17	3	0	0	0
				3.5–4.5	9	52	38	1	0	0	0
				4.5–5.5	10	41	48	1	0	0	0
				5.5–6.5	8	33	58	1	0	0	0
				6.5–7.5	22	41	36	1	0	0	0
				7.5–8.5	35	61	4	0	0	0	0
				8.5–9.5	26	72	2	0	0	0	0
				Mean	18	47	30	2	2	1	0
b	11	86	3	19.7–20.7	21	74	5	0	0	0	0
				20.7–21.7	10	54	36	0	0	0	0
				21.7–22.7	4	64	31	1	0	0	0
				22.7–23.7	5	45	36	2	3	4	5
				23.7–25.0	14	51	32	1	2	0	0
				Mean	11	57	28	1	1	1	1
a & b	15	82	3	Mean	15	51	29	2	2	1	trace

NZ 16 SW 209 1306 6477 Buildings Farm **Block D**

Surface level +20.4 m (+67 ft)
Water struck at +16.2 m
Shell and auger, 250 mm
February 1978

Overburden 0.5 m
Mineral 4.9 m
Waste 1.8 m
Mineral 1.0 m
Waste 4.7 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Sand and Gravel	**a** 'Very clayey' sandy gravel Gravel: coarse, subrounded to rounded, sandstone with fine-grained volcanic rocks and some ironstone and quartz Sand: fine, subrounded to rounded, quartz with some lithic grains	4.9	5.4
	Silt, pebbly, dark grey	1.8	7.2
	b Gravel Gravel: coarse, angular to well rounded, sandstone with some fine-grained volcanic rocks, ironstone and shale Sand: fine, subrounded to rounded, quartz with some lithic grains	1.0	8.2
Boulder Clay	Clay, sandy, pebbly, olive grey	4.7	12.9
Carboniferous	Siltstone	0.1+	13.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	21	59	20	0.5–0.9	18	37	17	7	13	8	0
				0.9–1.9	23	63	12	2	0	0	0
				1.9–2.9	27	52	17	2	2	0	0
				2.9–4.2	33	58	8	1	0	0	0
				4.2–5.4	1	5	10	8	19	45	12
				Mean	21	43	12	4	5	12	3
b	4	29	67	7.2–8.2	4	16	8	5	14	50	3
a & b	18	54	28	Mean	18	39	11	4	7	18	3

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	89	–	9	trace	1	trace	trace	1	trace
b	90	–	4	trace	trace	trace	trace	5	1

NZ 16 SW 210 1493 6493 Ryton Grange **Block D**

Surface level (+38.0 m) +125 ft
Water not encountered
Shell and auger, 250 mm
March 1978

Overburden 0.5 m
Mineral 16.4 m
Waste 1.5 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Sand and Gravel	**a** 'Very clayey' sand, with scattered thin bands of laminated clayey silt: medium and fine, subangular to subrounded, quartz with some lithic grains and coal	11.0	11.5
	b Gravel, sandy in parts Gravel: coarse, angular to subrounded, sandstone with limestone and some fine-grained volcanic rocks Sand: medium, subangular to subrounded quartz with some lithic grains including coal	5.4	16.9
	Clay, sandy and pebbly, dark grey	1.0	17.9
	'Very clayey' pebbly sand: quartz sand with some sandstone gravel	0.5	18.4
Carboniferous	Sandstone, brown	0.1+	18.5

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	25	73	2	0.5–1.5	38	47	6	2	2	5	0
				1.5–2.5	46	25	25	1	2	1	0
				2.5–8.5	*28*	*28*	*41*	*1*	*1*	*1*	*0*
				8.5–9.5	16	30	52	1	1	0	0
				9.5–10.5	8	40	51	1	0	0	0
				10.5–11.5	2	52	46	0	0	0	0
				Mean	25	33	39	1	1	1	0
b	3	42	55	11.5–12.5	1	7	18	4	3	49	18
				12.5–13.5	trace	7	14	6	18	31	24
				13.5–14.5	2	16	25	11	12	13	21
				14.5–15.5	9	17	26	9	13	26	0
				15.5–16.5	1	13	21	9	18	32	6
				16.5–16.9	3	16	30	15	20	12	4
				Mean	3	12	22	8	13	29	13
a & b	18	63	19	Mean	18	26	33	4	5	10	4

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
b	76	–	3	1	1	18	–	1	trace

NZ 16 SW 211 1109 6357 Eastwoods Farm **Block D**

Surface level +55.4 m (+182 ft)
Water level +39.9 m
Shell and auger, 200 mm
September 1977

Overburden 6.6 m
Mineral 18.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial Sand and Gravel	Clay, sandy and pebbly, mottled brown in upper part becoming grey at 1.9 m	3.3	3.9
	'Clayey' pebbly sand: fine quartz sand with some sandstone pebbles	0.8	4.7
	Clay, silty in upper part becoming sandy with increasing depth, brown	1.9	6.6
	'Very clayey' sand, with 0.5 m 'very clayey' gravel at top: fine, subrounded to rounded, quartz with lithic grains including coal	18.4+	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
26	72	2	6.6–7.1	31	14	8	4	10	33	0
			7.1–9.1	38	61	1	0	0	0	0
			9.1–10.7	35	64	1	0	0	0	0
			10.7–11.9	35	58	1	1	2	3	0
			11.9–13.9	33	67	0	0	0	0	0
			13.9–15.9	15	68	17	0	0	0	0
			15.9–17.5	13	82	5	0	0	0	0
			17.5–19.6	47	43	10	0	0	0	0
			19.6–21.6	20	55	25	0	0	0	0
			21.6–23.6	10	36	47	4	3	0	0
			23.6–25.0	11	29	55	2	2	1	0
			Mean	26	55	16	1	1	1	0

NZ 16 SW 212 1243 6367 The Daniel **Block D**

Surface level +15.5 m (+51 ft)
Water not encountered
Shell and auger, 250 mm
February 1978

Overburden 0.1 m
Mineral 15.8 m
Waste 9.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial Sand and Gravel	Gravel Gravel: coarse, angular to subrounded, sandstone with fine-grained volcanic rocks and some limestone, basic igneous rocks, granite and ironstone Sand: medium, subangular to subrounded, quartz with some lithic grains including coal	15.8	15.9
Boulder Clay	Clay, sandy and pebbly, brown	8.7	24.6
	'Clayey' sand: quartz with some lithic grains including coal	0.4+	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
1	34	65	0.1–2.1	5	14	22	9	21	29	0
			2.1–3.1	1	6	17	8	11	41	16
			3.1–4.1	1	11	24	8	13	33	10
			4.1–5.1	trace	4	9	8	33	46	0
			5.1–6.1	trace	7	11	7	23	52	0
			6.1–7.1	1	5	15	16	24	31	8
			7.1–8.1	1	10	13	3	10	41	22
			8.1–9.1	1	9	19	10	20	21	20
			9.1–10.1	1	5	14	15	25	40	0
			10.1–11.1	1	7	22	10	14	46	0
			11.1–12.1	2	6	28	9	6	42	7
			12.1–13.1	trace	3	24	7	12	39	15
			13.1–14.1	1	2	11	9	22	52	3
			14.1–15.1	trace	3	17	10	15	46	9
			15.1–15.9	1	2	11	15	23	31	17
			Mean	1	7	18	9	18	39	8

The use of a chiselling tool may have resulted in samples not being truly representative of in-situ grading

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
84	1	8	1	trace	5	trace	1	trace

NZ 16 SW 213 1460 6344 Woodside Common **Block D**

Surface level +96.0 m (+315 ft)
Water level +93.0 m
Shell and auger, 250 mm
February 1978

Overburden 0.6 m
Mineral 6.2 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Glacial Sand and Gravel	'Very clayey' sandy gravel Gravel: coarse and fine with cobbles, well rounded, sandstone with shale and some fine-grained volcanic rocks and ironstone Sand: fine, well rounded, quartz with lithic grains including coal	6.2	6.8
Carboniferous	Sandstone, brown	0.2+	7.0

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	$+1-4$	$+4-16$	$+16-64$	$+64$
21	56	23	0.6–1.6	19	51	15	5	7	3	0
			1.6–2.6	27	48	12	2	8	3	0
			2.6–3.8	9	25	13	6	11	22	14
			3.8–5.0	18	36	18	7	8	13	0
			5.0–6.8	28	26	19	4	8	4	11
			Mean	21	35	16	5	8	9	6

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
90	trace	2	trace	trace	trace	trace	2	6

NZ 16 SW 214 1071 6233 Homedale Estate **Block D**

Surface level (+90.5 m) +297 ft
Water struck at +88.8 ft
Shell and auger, 200 mm
September 1977

Overburden 1.7 m
Mineral 2.1 m
Waste 14.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
	Made ground	1.5	1.7
Glacial Sand and Gravel	'Clayey' pebbly sand and 'clayey' sandy gravel Gravel: fine and coarse, angular to rounded, sandstone with some ironstone Sand: fine, subrounded to rounded, quartz with lithic grains including coal	2.1	3.8
	Silt, sandy, micaceous, mottled brown and olive grey	2.3	6.1
Boulder Clay	Clay, sandy, pebbly, grey; 0.3 m of 'very clayey' gravel at 9.0 m	12.0	18.1
	Borehole abandoned because of technical difficulties		

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
14	68	18	1.7–3.0	12	48	23	6	9	2	0
			3.0–3.8	18	34	14	4	10	20	0
			Mean	14	43	20	5	9	9	0

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
97	–	1	–	trace	–	trace	2	trace

NZ 16 SW 215 1191 6286 Bradley Farm **Block D**

Surface level (+57.6 m) +189 ft
Water not encountered
Shell and auger, 250 mm
February 1978

Overburden 0.3 m
Mineral 4.0 m
Waste 3.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	Gravel Gravel: coarse, subangular to subrounded, sandstone with some fine-grained volcanic rocks and coal Sand: medium, subangular to subrounded, quartz with lithic grains including coal	4.0	4.3
Boulder Clay	Clay, sandy, olive grey	3.6+	7.9
	Borehole abandoned because of obstruction		

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
2	33	65	0.3–1.3	6	17	15	11	12	32	7
			1.3–2.3	1	5	9	8	18	42	17
			2.3–3.3	1	5	10	11	13	26	34
			3.3–4.3	2	8	18	16	24	19	13
			Mean	2	9	13	11	17	30	18

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
94	–	4	trace	trace	trace	2	trace	–

NZ 16 SW 216 1274 6286 Willies Well House **Block D**

Surface level (+64.7 m) +212 ft
Water not encountered
Shell and auger, 250 mm
February 1978

Overburden 0.9 m
Mineral 3.7 m
Waste 11.9 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.9	0.9
Glacial Sand and Gravel	'Very clayey' pebbly sand Gravel: fine to coarse, rounded, sandstone with some fine-grained volcanic rocks and ironstone Sand: fine, rounded to subangular, quartz with some lithic grains including coal	3.7	4.6
Boulder Clay	Clay, sandy, dark grey, with sand lenses	11.9	16.5
Carboniferous	Mudstone, dark grey	0.2+	16.7

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
26	64	10	0.9–1.8	16	38	28	8	7	3	0
			1.8–2.8	35	35	19	4	7	0	0
			2.8–3.8	27	47	19	2	2	3	0
			3.8–4.6	23	33	15	6	10	13	0
			Mean	26	39	20	5	6	4	0

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
91	1	3	–	1	trace	1	2	1

NZ 16 SW 217 1486 6262 Ryton Woodside **Block D**

Surface level +125.2 m (+411 ft)
Water struck at +120.5 m
Shell and auger, 200 mm
February 1978

Overburden 0.4 m
Mineral 4.3 m
Bedrock 1.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Glacial Sand and Gravel	'Clayey' gravel Gravel: coarse, rounded to well rounded, sandstone with granite and some fine-grained volcanic rocks, ironstone and shale Sand: medium and fine, rounded, quartz and lithic grains	4.3	4.7
Carboniferous	Sandstone, brown	1.0+	5.7

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
11	40	49	0.4–1.4	9	16	14	9	20	32	0
			1.4–2.4	10	14	22	8	22	24	0
			2.4–3.4	9	11	13	10	14	32	11
			3.4–4.7	15	15	19	11	15	25	0
			Mean	11	14	17	9	18	28	3

The use of a chiselling tool may have resulted in samples not being truly representative of in-situ grading

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
78	1	3	13	trace	1	–	2	2

NZ 16 SW 218 1053 6140 South Park

Surface level (+106.7 m) +350 ft
Water not encountered
Shell and auger, 200 mm
September 1977

Waste 18.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, sandy and pebbly, brown	17.8+	18.0

NZ 16 SW 219 1209 6171 West Kyo Farm

Surface level +161.0 m (+528 ft)
Water not encountered
Shell and auger, 250 mm
February 1978

Overburden 0.4 m
Bedrock 0.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Carboniferous	Sandstone, yellow	0.6+	1.0

NZ 16 SW 220 1445 6161 Reely Mires Farm **Block D**

Surface level +131.8 m (+432 ft)
Water not encountered
Shell and auger, 250 mm
February 1978

Overburden 0.4 m
Mineral 2.3 m
Waste 0.6 m
Mineral 6.5 m
Waste 6.5 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Glacial Sand and Gravel	**a** 'Very clayey' sandy gravel Gravel: fine, rounded, sandstone with ironstone and some fine-grained volcanic rocks Sand: fine, subangular to rounded, quartz and lithic grains	2.3	2.7
	Clay, sandy and pebbly, brown	0.6	3.3
	b 'Clayey' gravel Gravel: fine and coarse, well rounded, sandstone with mudstone and some ironstone and fine-grained volcanic rocks Sand: fine, subangular to subrounded, quartz and lithic grains including coal	6.5	9.8
Boulder Clay	Clay, silty, laminated in part, dark grey; some cobbles	6.5	16.3
Carboniferous	Sandstone, yellowish brown	0.2+	16.5

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	24	47	29	0.4–1.7	21	27	12	10	20	10	0
				1.7–2.7	29	28	9	7	15	12	0
				Mean	24	27	11	9	18	11	0
b	15	41	44	3.3–4.3	32	55	5	2	3	3	0
				4.3–5.3	11	16	13	8	22	30	0
				5.3–6.9	11	12	10	13	25	24	5
				6.9–8.0	16	14	21	15	15	6	13
				8.0–9.0	13	9	13	14	28	23	0
				9.0–9.8	5	7	11	9	15	23	30
				Mean	15	18	12	11	19	18	7
a & b	17	43	40	Mean	17	20	12	11	19	16	5

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	84	–	4	1	trace	–	trace	11	–
b	78	–	3	trace	trace	–	1	5	13

NZ 16 SW 221 1165 6118 Buck's Nook

Surface level +196.3 m (+644 ft)
Water not encountered
Shell and auger, 200 mm
February 1978

Overburden 0.9 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, sandy and pebbly, brown	0.7	0.9
Carboniferous	Sandstone, pale grey	0.1+	1.0

NZ 16 SE 224 1672 6493 Ryton Haugh **Block C**

Surface level +4.6 m (+15 ft)
Water struck at +0.3 m
Shell and auger, 250 mm
April 1978

Overburden 1.3 m
Mineral 8.5 m
Waste 2.5 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	1.3	1.3
Alluvium	**a** 'Very clayey' sand: fine, subrounded, quartz and lithic grains	1.0	2.3
	b Gravel Gravel: coarse, well rounded, sandstone with fine-grained volcanic rocks and some quartz and granite Sand: medium, well rounded, quartz and lithic grains	7.5	9.8
Boulder Clay	Clay, pebbly, dark grey	2.5	12.3
Carboniferous	Sandstone, pale grey	0.2+	12.5

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	26	74	0	1.3–2.3	26	67	7	0	0	0	0
b	3	25	72	2.3–3.3	7	16	18	7	21	30	1
				3.3–4.3	4	9	11	6	22	46	2
				4.3–5.3	4	2	4	2	29	54	5
				5.3–6.3	1	2	5	4	30	56	2
				6.3–7.3	2	4	13	9	23	42	7
				7.3–8.3	2	4	12	7	32	38	5
				8.3–9.8	3	7	18	8	22	37	5
				Mean	3	7	12	6	25	43	4
a & b	6	30	64	Mean	6	14	11	5	22	38	4

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
b	80	–	17	1	2	–	trace	trace	trace

NZ 16 SE 225 1787 6421 Newburn Haughs **Block C**

Surface level +4.9 m (+16 ft)
Water struck at +3.5 m
Shell and auger, 250 mm
April 1978

Overburden 3.4 m
Mineral 2.0 m
Waste 3.0 m
Mineral 16.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	1.4	1.4
Alluvium	Silt, sandy, olive grey	2.0	3.4
	a 'Very clayey' sand: fine, rounded, quartz and lithic grains	2.0	5.4
	Silt, as above	3.0	8.4
	b Gravel, with scattered bands of peat Gravel: coarse, well rounded, sandstone with fine-grained volcanic rocks and some granite, quartz and ironstone Sand: medium, subangular to well rounded, quartz and lithic grains	8.6	17.0
	c 'Clayey' sand: fine, subrounded, quartz and lithic grains including coal	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
a	37	63	0	3.4–5.4	37	55	8	0	0	0	0
b	2	21	77	8.4–9.4	4	8	14	4	14	46	10
				9.4–10.4	3	4	10	3	15	51	14
				10.4–11.4	1	7	10	5	26	42	9
				11.4–12.4	2	7	9	5	20	55	2
				12.4–13.4	1	5	7	5	25	48	9
				13.4–14.4	1	4	6	6	26	49	8
				14.4–15.4	1	5	8	6	25	48	7
				15.4–17.0	3	10	8	6	31	40	2
				Mean	2	7	9	5	23	47	7
c	11	89	0	17.0–19.0	10	80	10	0	0	0	0
				19.0–21.0	13	74	13	0	0	0	0
				21.0–23.0	11	77	12	0	0	0	0
				23.0–25.0	10	74	16	0	0	0	0
				Mean	11	76	13	0	0	0	0
a & b & c	10	54	36	Mean	10	42	10	2	11	22	3

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
b	85	–	11	2	1	–	trace	1	trace

NZ 16 SE 226 1550 6303 Stephen's Hall North Farm **Block D**

Surface level +101.6 m (+333 ft)
Water struck at +96.5 m
Shell and auger, 250 mm
March 1978

Overburden 0.8 m
Mineral 2.0 m
Waste 5.2 m
Bedrock 0.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.8	0.8
Glacial Sand and Gravel	Gravel Gravel: coarse, subangular to subrounded, sandstone with some fine-grained volcanic rock Sand: medium, subangular to subrounded, quartz with lithic grains	2.0	2.8
Boulder Clay	Clay, sandy and pebbly, grey	5.2	8.0
Carboniferous	Sandstone, grey	0.5+	8.5

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
4	38	58	0.8–1.8	5	13	14	11	20	26	11
			1.8–2.8	3	6	19	13	16	33	10
			Mean	4	9	17	12	18	29	11

COMPOSITION

Percentages by weight in gravel fraction

Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
96	–	3	1	trace	trace	trace	trace	trace

NZ 16 SE 227 1932 6301 Blaydon **Block C**

Surface level +3.8 m (+12 ft)
Water level +2.2 m
Shell and auger, 250 mm
March 1978

Overburden 8.2 m
Mineral 2.9 m
Waste 10.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	3.0	3.0
Alluvium	Silt and clay, grey and olive brown with some peat and shelly bands	5.2	8.2
	a 'Very clayey' sand: fine, rounded, quartz with some lithic grains	1.8	10.0
	b Gravel Gravel: coarse, well rounded, sandstone with fine-grained volcanic rocks and some granite Sand: coarse, rounded, quartz and lithic grains	1.1	11.1
	Silt, laminated, micaceous, reddish brown	10.9+	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
a	23	77	0	8.2–10.0	23	73	3	1	0	0	0
b	1	21	78	10.0–11.1	1	4	6	11	21	54	3
a & b	15	56	29	Mean	15	47	4	5	8	20	1

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
b	88	–	7	2	1	trace	trace	1	1

NZ 16 SE 228 1517 6132 Chicken's Wood **Block D**

Surface level +100.7 m (330 ft)
Water struck at +99.2 m
Shell and auger, 250 mm
March 1978

Overburden 0.5 m
Mineral 2.7 m
Waste 10.8 m
Bedrock 0.2 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial Sand and Gravel	'Very clayey' sand: fine, subangular to subrounded, quartz with some lithic grains including coal	2.7	3.2
Boulder Clay	Clay, sandy, grey	8.8	12.0
	Clay, sandy and pebbly, brown	2.0	14.0
Carboniferous	Sandstone, brown	0.2+	14.2

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
27	72	1	0.5–1.5	26	70	2	1	1	0	0
			1.5–2.5	23	61	13	2	1	0	0
			2.5–3.2	34	61	4	1	0	0	0
			Mean	27	64	7	1	1	0	0

NZ 16 SE 229 1796 6104 Winlaton Mill

Surface level +66.5 m (+218 ft)
Water not encountered
Shell and auger, 200 mm
February 1978

Waste 8.1 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, sandy and pebbly, mottled brown in upper part becoming grey with increasing depth	7.9	8.1
Carboniferous	Sandstone, pale brown	0.1+	8.2

NZ 16 SE 230 1935 6113 Damhead Wood

Surface level +51.0 m (+167 ft)
Water struck at +46.9 m
Shell and auger, 200 mm
March 1978

Waste 14.6 m
Bedrock 0.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Boulder Clay	Clay, sandy, pebbly, olive grey to 4.1 m, brown below	14.5	14.6
Carboniferous	Sandstone, yellow	0.4+	15.0

NZ 16 SE 231 1635 6022 Garesfield

Surface level (+139.7 m) +458 ft
Water not encountered
Shell and auger, 200 mm
February 1978

Waste 3.5 m
Bedrock 0.1 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Boulder Clay	Clay, sandy, mottled brown, with bands of laminated silt	0.8	1.1
	Clay, grey	2.4	3.5
Carboniferous	Mudstone, grey	0.1+	3.6

NZ 16 SE 232 1748 6036 Low Thornley

Surface level (+89.3 m) +293 ft
Water struck at +83.8 m
Shell and auger, 200 mm
March 1978

Waste 6.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Boulder Clay	Clay, sandy and pebbly, reddish brown; thin bands of sand	3.8	4.0
	Clay, pebbly, grey, with yellow sandstone boulder at base	2.0+	6.0
	Borehole abandoned because of obstruction		

NZ 16 SE E1 1574 6255 Mosspool Hill **Block D**

Surface level +110.0 m (+361 ft) Mineral 25.0 m

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial Sand and Gravel	**a** 'Clayey' gravel Gravel: coarse, subangular to rounded, sandstone with ironstone and fine-grained volcanic rocks Sand: medium, subangular to subrounded, quartz with lithic grains including coal	2.1	2.1
	b 'Clayey' sand: fine, subangular to subrounded, quartz with lithic grains including coal and mica	22.9+	25.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	11	33	56	0.0–2.1	11	11	15	7	17	31	8
b	10	90	0	2.1–4.0	11	71	18	0	0	0	0
				4.0–6.0	8	76	16	0	0	0	0
				6.0–7.5	6	59	35	0	0	0	0
				7.5–9.0	10	80	8	2	0	0	0
				9.0–11.0	20	63	17	0	0	0	0
				11.0–13.0	*19*	*71*	*10*	*0*	*0*	*0*	*0*
				13.0–15.0	17	79	3	1	0	0	0
				15.0–17.0	10	86	4	0	0	0	0
				17.0–19.0	2	76	22	0	0	0	0
				19.0–21.0	3	89	8	0	0	0	0
				21.0–22.5	6	86	7	1	0	0	0
				22.5–24.0	14	78	8	0	0	0	0
				24.0–25.0	1	53	45	1	0	0	0
				Mean	10	75	14	1	0	0	0
a & b	10	86	4	Mean	10	70	14	2	1	2	1

COMPOSITION

Percentages by weight in gravel fraction

	Sandstone	Basic igneous	Volcanic	Granite	Quartz	Limestone	Coal	Ironstone	Mudstone and shale
a	86	–	6	trace	1	–	–	7	trace

APPENDIX G

List of active and disused workings

Location	*Grid reference*	*Principal deposit worked*
ACTIVE WORKINGS		
NZ 06		
Farnley Haughs	005 632	Alluvium
Styford	014 633	Glacial sand and gravel
NZ 16		
Crawcrook	129 637	Glacial sand and gravel
Path Head	166 635	Glacial sand and gravel
Bewes Hills	166 632	Glacial sand and gravel
Burn Hills	154 620	Glacial sand and gravel
Blaydon	160 627	Glacial sand and gravel
DISUSED WORKINGS		
NZ 06		
Styford	013 623	Glacial sand and gravel
Merry Shield	063 616	Glacial sand and gravel
NZ 16		
Hedgefield	162 644	Glacial sand and gravel
Folly	152 623	Glacial sand and gravel

APPENDIX H

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

m	ft	m	ft	m	ft	m	ft	m	ft
0.1	0.5	6.1	20	12.1	39.5	18.1	59.5	24.1	79
0.2	0.5	6.2	20.5	12.2	40	18.2	59.5	24.2	79.5
0.3	1	6.3	20.5	12.3	40.5	18.3	60	24.3	79.5
0.4	1.5	6.4	21	12.4	40.5	18.4	60.5	24.4	80
0.5	1.5	6.5	21.5	12.5	41	18.5	60.5	24.5	80.5
0.6	2	6.6	21.5	12.6	41.5	18.6	61	24.6	80.5
0.7	2.5	6.7	22	12.7	41.5	18.7	61.5	24.7	81
0.8	2.5	6.8	22.5	12.8	42	18.8	61.5	24.8	81.5
0.9	3	6.9	22.5	12.9	42.5	18.9	62	24.9	81.5
1.0	3.5	7.0	23	13.0	42.5	19.0	62.5	25.0	82
1.1	3.5	7.1	23.5	13.1	43	19.1	62.5	25.1	82.5
1.2	4	7.2	23.5	13.2	43.5	19.2	63	25.2	82.5
1.3	4.5	7.3	24	13.3	43.5	19.3	63.5	25.3	83
1.4	4.5	7.4	24.5	13.4	44	19.4	63.5	25.4	83.5
1.5	5	7.5	24.5	13.5	44.5	19.5	64	25.5	83.5
1.6	5	7.6	25	13.6	44.5	19.6	64.5	25.6	84
1.7	5.5	7.7	25.5	13.7	45	19.7	64.5	25.7	84.5
1.8	6	7.8	25.5	13.8	45.5	19.8	65	25.8	84.5
1.9	6	7.9	26	13.9	45.5	19.9	65.5	25.9	85
2.0	6.5	8.0	26	14.0	46	20.0	65.5	26.0	85.5
2.1	7	8.1	26.5	14.1	46.5	20.1	66	26.1	85.5
2.2	7	8.2	27	14.2	46.5	20.2	66.5	26.2	86
2.3	7.5	8.3	27	14.3	47	20.3	66.5	26.3	86.5
2.4	8	8.4	27.5	14.4	47	20.4	67	26.4	86.5
2.5	8	8.5	28	14.5	47.5	20.5	67.5	26.5	87
2.6	8.5	8.6	28	14.6	48	20.6	67.5	26.6	87.5
2.7	9	8.7	28.5	14.7	48	20.7	68	26.7	87.5
2.8	9	8.8	29	14.8	48.5	20.8	68	26.8	88
2.9	9.5	8.9	29	14.9	49	20.9	68.5	26.9	88.5
3.0	10	9.0	29.5	15.0	49	21.0	69	27.0	88.5
3.1	10	9.1	30	15.1	49.5	21.1	69	27.1	89
3.2	10.5	9.2	30	15.2	50	21.2	69.5	27.2	89
3.3	11	9.3	30.5	15.3	50	21.3	70	27.3	89.5
3.4	11	9.4	31	15.4	50.5	21.4	70	27.4	90
3.5	11.5	9.5	31	15.5	51	21.5	70.5	27.5	90
3.6	12	9.6	31.5	15.6	51	21.6	71	27.6	90.5
3.7	12	9.7	32	15.7	51.5	21.7	71	27.7	91
3.8	12.5	9.8	32	15.8	52	21.8	71.5	27.8	91
3.9	13	9.9	32.5	15.9	52	21.9	72	27.9	91.5
4.0	13	10.0	33	16.0	52.5	22.0	72	28.0	92
4.1	13.5	10.1	33	16.1	53	22.1	72.5	28.1	92
4.2	14	10.2	33.5	16.2	53	22.2	73	28.2	92.5
4.3	14	10.3	34	16.3	53.5	22.3	73	28.3	93
4.4	14.5	10.4	34	16.4	54	22.4	73.5	28.4	93
4.5	15	10.5	34.5	16.5	54	22.5	74	28.5	93.5
4.6	15	10.6	35	16.6	54.5	22.6	74	28.6	94
4.7	15.5	10.7	35	16.7	55	22.7	74.5	28.7	94
4.8	15.5	10.8	35.5	16.8	55	22.8	75	28.8	94.5
4.9	16	10.9	36	16.9	55.5	22.9	75	28.9	95
5.0	16.5	11.0	36	17.0	56	23.0	75.5	29.0	95
5.1	17	11.1	36.5	17.1	56	23.1	76	29.1	95.5
5.2	17	11.2	36.5	17.2	56.5	23.2	76	29.2	96
5.3	17.5	11.3	37	17.3	57	23.3	76.5	29.3	96
5.4	17.5	11.4	37.5	17.4	57	23.4	77	29.4	96.5
5.5	18	11.5	37.5	17.5	57.5	23.5	77	29.5	97
5.6	18.5	11.6	38	17.6	57.5	23.6	77.5	29.6	97
5.7	18.5	11.7	38.5	17.7	58	23.7	78	29.7	97.5
5.8	19	11.8	38.5	17.8	58.5	23.8	78	29.8	98
5.9	19.5	11.9	39	17.9	58.5	23.9	78.5	29.9	98
6.0	19.5	12.0	39.5	18.0	59	24.0	78.5	30.0	98.5

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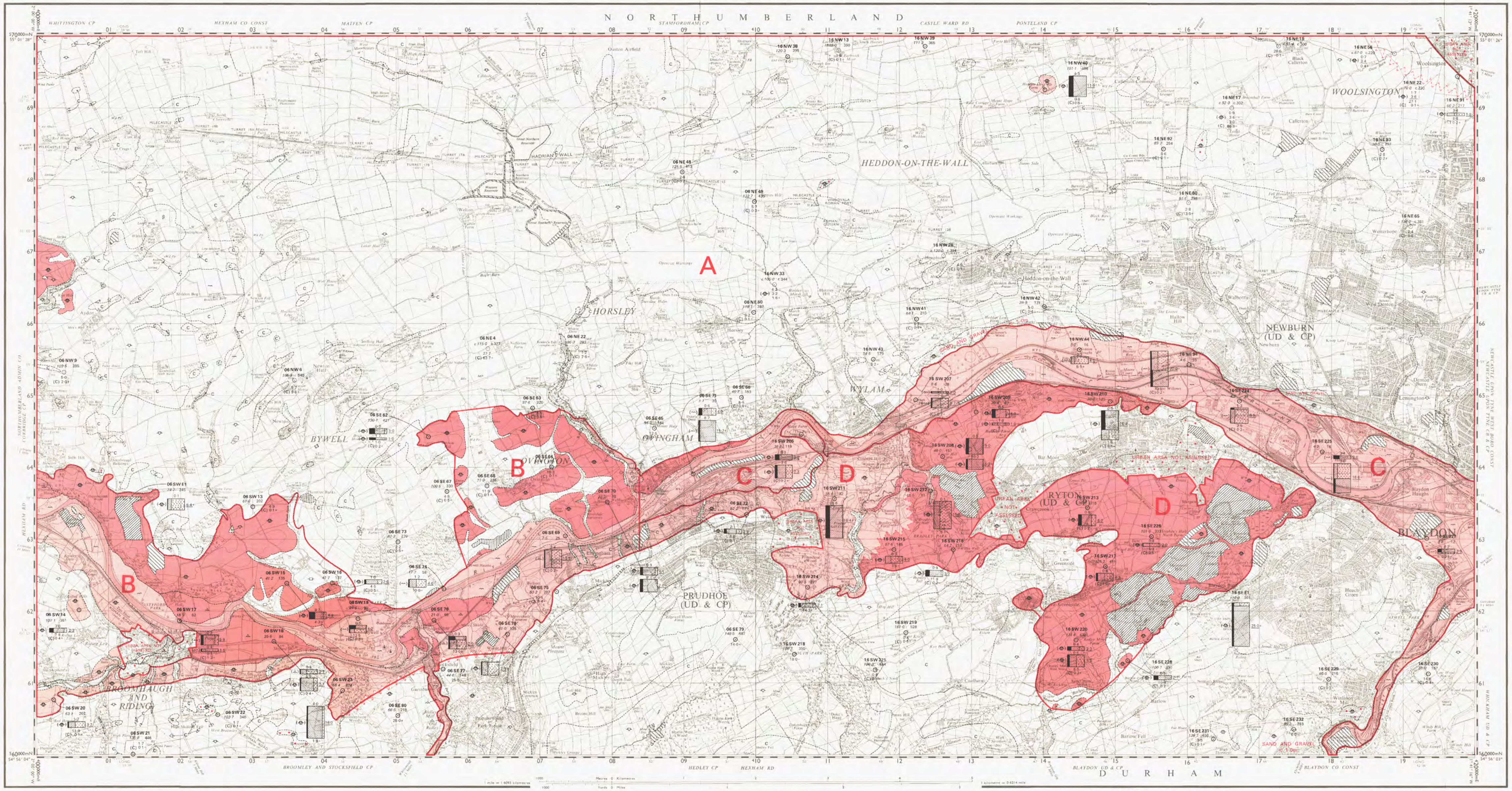
This map should be read in conjunction with the accompanying Report which contains details of the assessment of resources.



EXPLANATION OF SYMBOLS AND ABBREVIATIONS

Landslip L-1

DRIFT

- Peat P-1
- **Alluvium** - sand, gravel, clays and silts A-49
- **River Terrace Deposits (undifferentialed)** - sand and gravel RT-4
- **Laminated Clay** - laminated silty clay LC-4
- **Galcial Sand and Gravel** - sand, gravel, clays and silts GS-53
- **Great Limestone erratics** GE-1
- **Boulder Clay** - stony clay BC-10

RECENT AND PLEISTOCENE

SOLID

- C **Carboniferous Undivided** - sandstone, shale, siltstone, limestone and coal

Areas from which part or all of the sand and gravel has been extracted WO-18

Made Ground excluding restored opencast coal sites MG-5

BOUNDARY LINES

Geological boundary, Drift.

Resource Block boundary

Inferred boundary between recognized categories of deposits

Broken lines denote uncertainty.

BOREHOLE DATA
SITE LOCATIONS

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

Other Boreholes.

I.M.A.U. BOREHOLES

16 SW 207 — Borehole Registration Number
Surface level in metres and feet above O.D. (Newlyn) — 8·6 28
Borehole Site
Overburden — 1·0
Waste — 7·0
Mineral (sand and gravel) — 1·0, 5·7
Geological Classification — (~~)
Waste — 1·2
Bedrock — (C) 0·2+
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 conversions to metres 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. **16 SW 207**. The first numbers and letters refer to the quarter sheet and the second number to the I.G.S. serial number for the quarter. The unique designation for borehole **16 SW 207** is **NZ 16 SW 207**.

Grading Diagrams
Each grading diagram shows the mean particle-size distribution in a distinct deposit of mineral.

Sand, Fines, Gravel
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 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 series.

EXPOSURE RECORDS

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

CATEGORIES OF DEPOSITS

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

Where appropriate on other sheets a category, 'Discontinuous spreads of mineral beneath overburden' is recognised.

RESOURCE BLOCKS

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

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

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

The representation on this map of any other road, track or path is no evidence of the existence of a right of way.

Geological boundaries from surveys principally by W. Anderson and A. Fowler in 1935-8 and D. W. Holliday and G. Richardson in 1976-9. R. Carruthers and B. J. Taylor, District Geologists.

Sand and Gravel Survey by J. R. A. Giles, I. Jackson and J. H. Lovell in 1977-8. R. G. Thurrell, Head, Industrial Minerals Assessment Unit.

1:25 000 Sand and Gravel Resource sheet published 1981.
G. M. Brown, D.Sc., F.R.S., *Director, Institute of Geological Sciences*
(100/81)

Surface heights are to the nearest foot above mean sea level

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.

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Compiled from 1:10 560 scale maps last fully revised 1966-67.
Date of survey 1950-63 with partial revision 1968.
Contours were not surveyed at these dates but were taken from the 1:25 000 Provisional Edition.
Major roads revised 1968.

NY97	NZ07	NZ17	NZ27
13		14	
NY96	NZ06	NZ16	NZ26
19		20	
NY95	NZ05	NZ15	NZ25

Diagram showing the relation of the National Grid 1:25 000 sheets with the New Series One-Inch Geological sheets 14 and 20 and the 1:50 000 Geological sheets 13 and 19.