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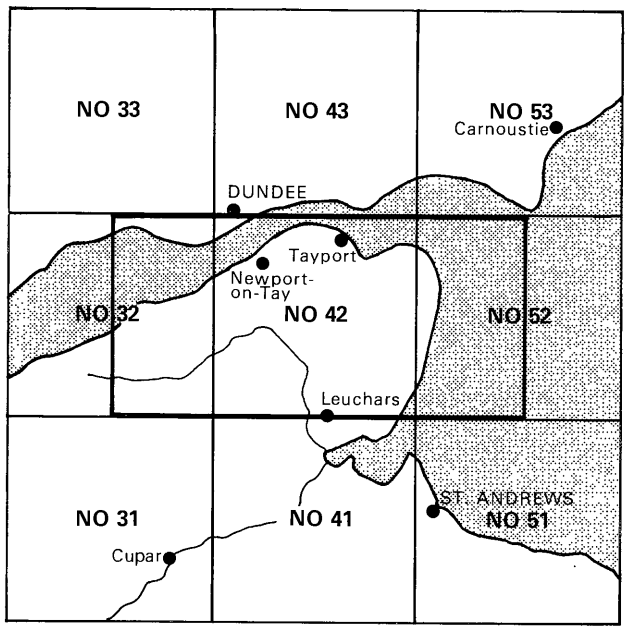

The sand and gravel resources of the country around Newport-on-Tay, Fife Region

Description of 1:25 000 sheet NO 42 and parts of NO 32 and 52

J. L. Laxton and D. L. Ross

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

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

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The asterisk on the cover indicates that parts of sheets adjacent to the one cited are described in this report.

PREFACE

National resources of many industrial minerals may seem so large that stock-taking 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 assessment 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 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. In 1968, following a short feasibility study initiated in 1966 by the Ministry of Land and Natural Resources the Industrial Minerals Assessment Unit (formerly the Mineral Assessment Unit) began systematic surveys which have been extended progressively through central and northern England. Work in Scotland, which began in 1975 in the Darvel area of Strathclyde Region, is being financed by the Department of the Environment, acting through the Scottish Development Department and is being undertaken with the cooperation of the Sand and Gravel Association of Great Britain.

This report describes the resources of sand and gravel of 109.8 km^2 of country around Newport-on-Tay, Fife Region, shown on the accompanying resource map. The survey was conducted by J. L. Laxton and D. L. Ross under the supervision of E. F. P. Nickless, Officer-in-Charge of the sub-unit in Edinburgh. The work is based principally on the revision geological survey at a scale of six inches to one mile of sheets 48E and 49 undertaken between 1962 and 1964 by J. I. Chisholm and M. Armstrong of the North Lowlands Unit.

The section of the report on the geology of the area was prepared by J. L. Laxton and M. A. E. Browne.

J. D. Burnell, ISO, ARICS (Land Agent), has been responsible for negotiating access to land for drilling; the ready cooperation of land owners, tenants and sand and gravel operators is gratefully acknowledged.

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CONTENTS

Plate 1 Quarry [405 250] in moundy glacial sand and gravel to the south-east of Wormit. (D 3057).

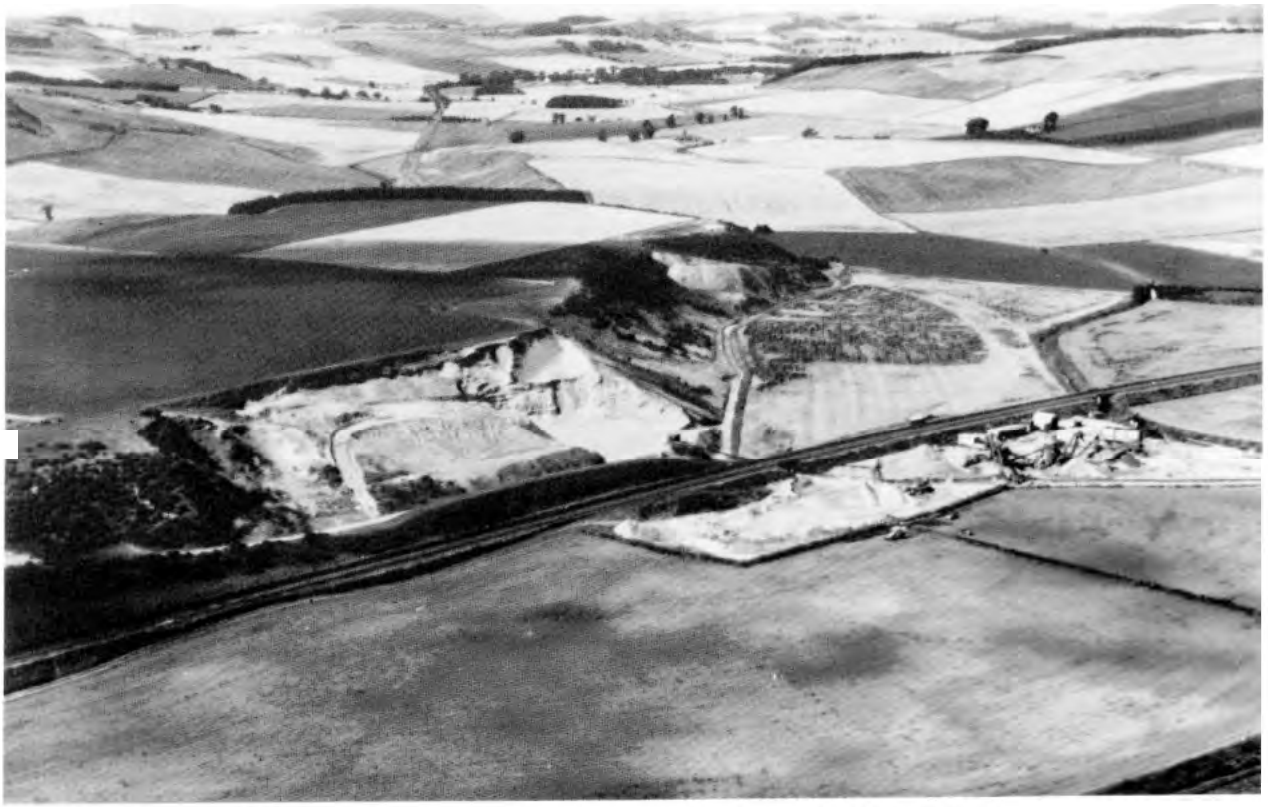

Plate 2 Oblique aerial photograph looking south-west from near North Straiton Pit [419 238] up the valley of the Motray Water. The pit is working the edge of a flat-topped hill of fluvioglacial sand. (D 2031).

The sand and gravel resources of the country around Newport-on-Tay, Fife Region

Description of 1:25 000 sheet NO 42 and parts of NO 32 and 52

J. L. LAXTON and D. L. ROSS

SUMMARY

The geological maps of the Institute of Geological Sciences, fifty-four boreholes and thirty-four shallow pits sunk for the Industrial Minerals Assessment Unit, together with data from eight other boreholes and the inspection of sand and gravel workings, form the basis of the assessment of sand and gravel resources in the Newport-on-Tay area, Fife Region.

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

The 1:25 000 map is divided into five resource blocks, four of which are assessed statistically and contain between 5.2 and 19.2 km^2 of potentially workable sand and gravel. For the fifth resource block inferred assessments are offered for 3.6 km^2 of mineral. The geology of the deposits is described and the mineral-bearing area, the mean thickness of overburden and mineral, and the mean grading are stated. Detailed borehole data are given. The geology and the outlines of the resource blocks, the position of boreholes and shallow pits used in the assessment are shown on the accompanying map.

Bibliographic reference

LAXTON, J. L. and ROSS, D. L. 1981. The sand and gravel resources of the country around Newport-on-Tay, Fife Region. Description of 1:25 000 sheet NO 42 and parts of NO 32 and 52. *Miner. Assess. Rep. Inst. Geol. Sci.*, No. 89.

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

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

The following arbitrary physical criteria have been adopted:

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

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

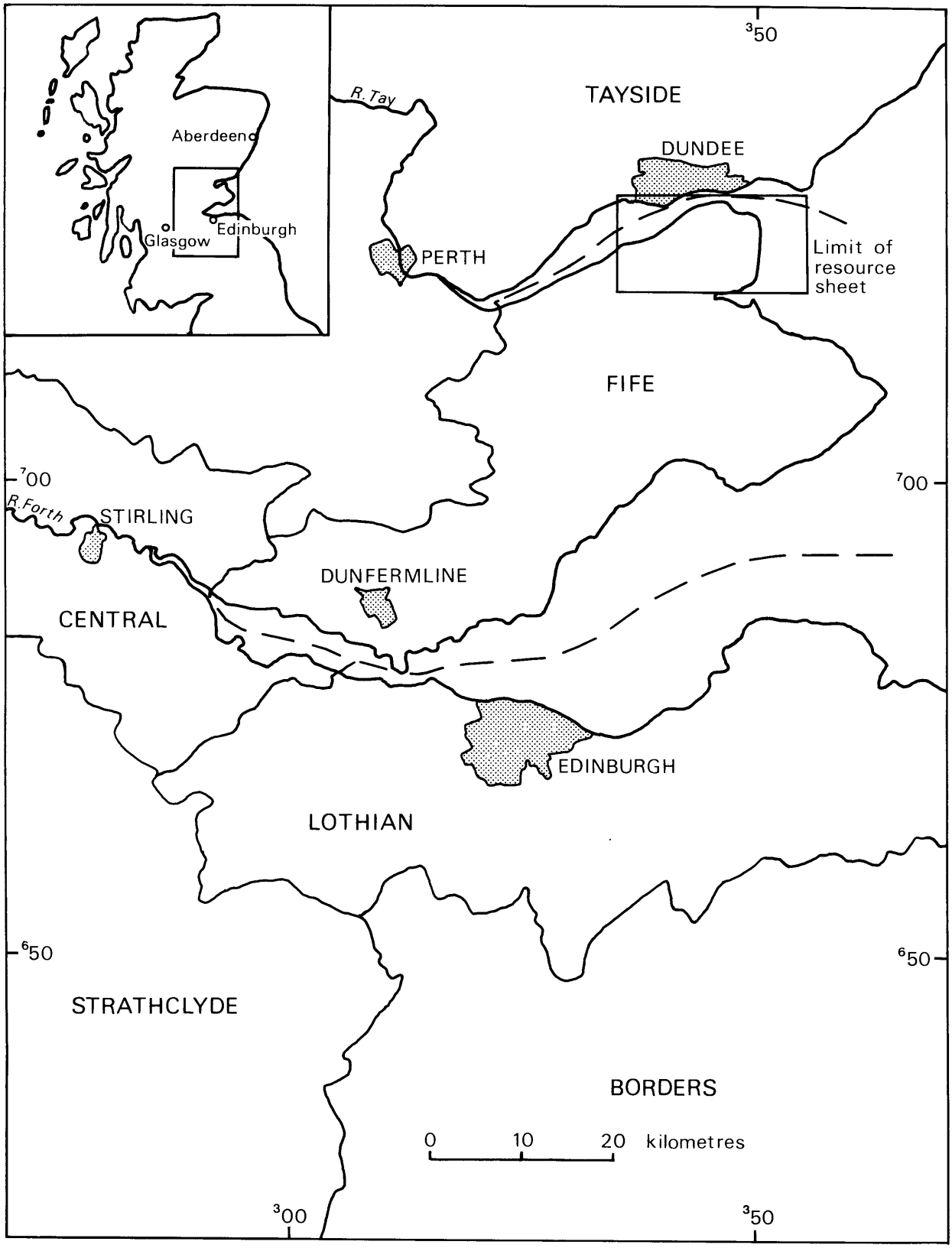


Figure 1 Sketch-map showing the location of the Newport-on-Tay area.

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 RESOURCE SHEET

GENERAL

The survey area, which lies in the extreme north-east of Fife, just south-east of Dundee, is bounded to the north by the Firth of Tay, to the south by the estuary of the River Eden, and to the east by the North Sea (Figure 1). In the east raised beach deposits and blown sand occur, the former supporting rich agricultural land whereas the latter is covered largely by coniferous plantations, the most extensive of which, Tentsmuir Forest, is of about 13 square kilometres. The ground rises to the west where it is either underlain by thick glacial meltwater deposits, which provide good farming land locally worked for aggregate, or has rock close to the surface. The latter gives land rising to 190 m above Ordnance Datum at Lucklaw Hill [419 216] where felsite is quarried for aggregate, but generally the higher ground is used for rough pasture.

The principal watercourse of the area is the Motray Water which flows east-north-east through Kilmany [387 218] to south of West Links Wood [415 248] and then south-east to join the estuary of the River Eden just south of the resource sheet area. The Motray Water has a restricted catchment on account of its position between the Firth of Tay and the River Eden and is no more than a small stream which has been confined for much of its course in an artificial ditch.

The largest town is Newport-on-Tay which, along with Wormit and Tayport also situated on the southern bank of the Firth of Tay, has become a dormitory town for Dundee since the opening of the Tay Road Bridge; Tayport still retains a small working port. The largest village, Leuchars [455 214] is situated adjacent to a major RAF base upon which its economy depends. The Firth of Tay is crossed by both road and rail near Newport-on-Tay. It is not bridged again for about 30 km upstream until Perth, and therefore the main lines of communication from Aberdeen to the south run across the area.

GEOLOGY

The area is mainly included in 1:50 000 Geological Sheet 49 (Arbroath) and partly in Sheet 48E (Cupar), which were originally surveyed at a scale of six inches to one mile by H. H. Howell, J. Geikie and J. Young about 1860 and published in 1884 and 1883 respectively. The area was resurveyed between 1962 and 1964, principally by J. I. Chisholm; the ground north of the Tay was mapped by M. Armstrong. Revised maps at a scale of six inches to one mile covering national grid squares NO 42 and 52 were published between 1972 and 1977. Brief accounts of the sand and gravel resources were given in Anderson (1945) and Browne (1977).

SOLID

Bedrock ranges in age from Lower Devonian lavas, sediments and intrusions to ?late-Carboniferous dykes (Table 1). The strata generally dip to the south-east, the Lower Devonian at about 18°, the Upper Devonian and Lower Carboniferous at 5° to 10°. The generally simple structure is complicated by a series of large, usually normal, faults trending east–west, and, mainly in the north-western part of the area, by a set of smaller north–south faults (Figure 2).

Lower Devonian The lowest exposed 2000 m of the Lower Devonian rocks consist mainly of pyroxene-andesite lavas, generally in flows from 3 to 24 m thick. The lavas are well exposed along the coast between Tayport and Wormit Bay where they are seen to be interbedded with feldspathic sandstones, volcanic conglomerates and some mudstones, the coarser sediments being the products of erosion of the lava flows soon after their formation (Geikie, 1902). Inland, volcanic rocks underlie most of the ground to the west of a line joining Tayport and Balmullo [427 209], and their greater hardness relative to the younger sediments to the east results in a marked break in the topography, the ground in the west being higher with rock at or close to the surface.

The lavas are intruded by a series of broadly contemporaneous igneous rocks, the chief of which in the assessment area are the felsite sheet of Lucklaw Hill [419 216] and the microgranodiorite plug of Forret Hill [332 204]. The uppermost Lower Devonian, which crops out in the east of the assessment area, comprises predominant sandstones with subordinate conglomerate and mudstone beds. Evidence of sporadic volcanic activity is provided by an outcrop of basalt in a disused quarry [4678 2568] and of lava flows in the IGS Morton Lochs borehole [4707 2593].

Severe earth movements, folding and faulting the pre-existing rocks, affected the Midland Valley of Scotland at the end of Lower Devonian time. Within the assessment area the strata were uplifted to form the southern limb of the Ochil Anticline, which was subsequently eroded during the Middle Devonian: Upper Devonian sediments were deposited unconformably on this land surface.

Upper Devonian and Lower Carboniferous Rocks of this age occur in the extreme south-east of the resource sheet area (Figure 2); they are buried by a thick cover of drift and have not been proved in any boreholes. Their presence is inferred from outcrops to the south-west of the resource sheet area where Lower Devonian sediments are unconformably overlain by the more gently dipping younger rocks. The Upper Devonian, comprising mainly yellow sandstones with mudstone

Table 1 Geological classification of deposits

DRIFT	
Recent and Pleistocene	Blown sand
	Peat
	Alluvium of flood plains (or undifferentiated)
	Alluvial cone
	Lake alluvium
	Late-Glacial and modern storm-beach and bar deposits
	Present beach and other intertidal deposits
	Salt march deposits
	Raised beach deposits and associated estuarine alluvium, post-Glacial
	Raised beach deposits and associated estuarine alluvium, late-Glacial
	Marine deposits, late-Glacial
	Hillwash
	Fluvioglacial sand and gravel
	Glacial sand and gravel
	Till
SOLID	
?Late-Carboniferous	Quartz-dolerite dykes
Carboniferous, Lower	Calciferous Sandstone Measures
Devonian	
Upper	Mainly sandstones
Lower	Mainly lavas, some sandstones
Lower (intrusive)	Felsite
	Microgranodiorite
	Basalt and dolerite in sheets

bands and possibly a basal conglomerate, passes conformably up into the Lower Carboniferous Calciferous Sandstone Measures which are predominantly white sandstone with thick bands of grey mudstone, thin limestones and some seatearths. The most recent rocks in the area are dykes possibly of late-Carboniferous age.

DRIFT

The distribution of Quaternary deposits is influenced by the underlying solid rocks. Over north-western and south-western parts of the resource sheet area, where lavas predominate, the drift cover comprises thin and patchy till; the drift is generally thickest over the sedimentary rocks in the east. In the central western area, however, generally encompassed by blocks A and B, bedrock, although volcanic, forms a depression (section II on the map) in which a thick sequence of glacial deposits has accumulated.

Till The deposit, generally a stiff reddish brown clay with clasts up to boulder size, is found at the surface mainly over the higher ground in the west of the resource sheet. At depth the deposit was proved in many boreholes throughout the area, but locally it is absent (boreholes 42 NE 11 and 42 SW 15). Where the full thickness of till was proved it always lies directly on bedrock.

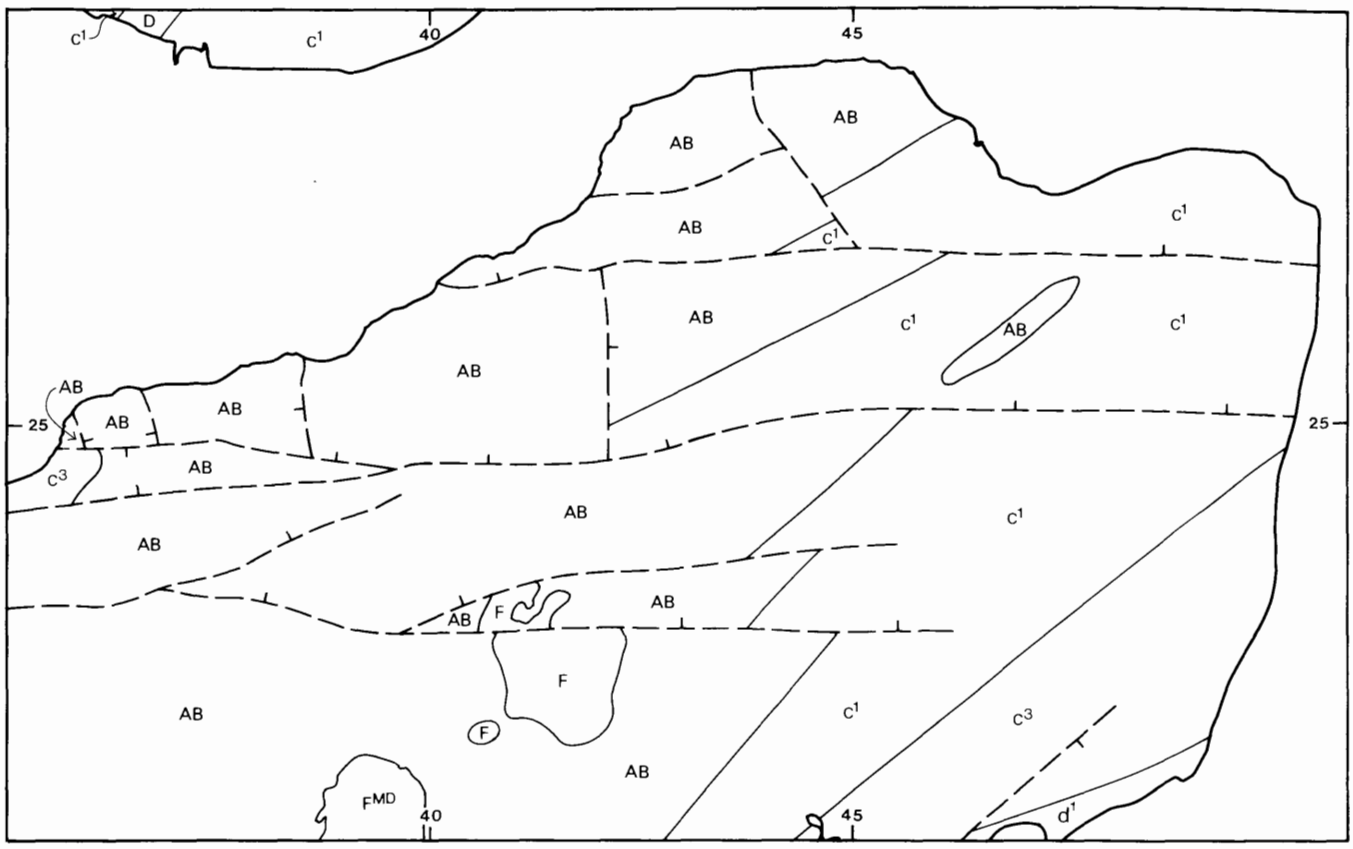
Glacial sand and gravel Within the resource sheet area glacial meltwater deposits can be divided on the basis of landform and composition into glacial and fluvioglacial sand and gravel. The glacial sand and gravel forms a series of steep-sided ridges oriented north-west (Plate 1), which are contained mainly within block A, extending from Wormit to Burnside [4410 2231] in a zone about 2.5 km wide as far as West Links Wood [415 248], narrowing to 1 km south-east of there. Borehole 42 SW 15 shows glacial sand and gravel to underlie the valley of the Motray Water. The deposit over the area as a whole comprises predominant gravel and sandy gravel, often cobbly, with subordinate more sandy bands.

Fluvioglacial sand and gravel Fluvioglacial deposits, generally a fine orange sand, are outlined by the limits of block B. These deposits form the topographically striking steep-sided flat-topped hills of Cowbakie [445 255], Gallow [444 221] and North Straiton [4206 2347] (Plate 2), and similar sands were also proved in boreholes and pits to underlie both the low ground between the hills (for example boreholes 42 SW 13, 14 and pit 42 NW 34) and the late-Glacial raised beach to the north-west of Leuchars. Boreholes which prove a thick sequence of fluvioglacial deposits generally show fining grain size with depth, principally displayed by an increase of fine sand at the expense of medium sand (for example, boreholes 42 SW 8, 11, 22, NW 30 and NE 9) although in borehole 42 SW 11 the deposit grades down into silts. Only boreholes 42 NW 23, SW 13, 14 and 19, marginal to the glacial sand and gravel ridges, prove sequences containing both glacial and fluvioglacial sand and gravel and in all of these the former deposit underlies the latter (see sections I and II on the map).

Late-Glacial marine deposits South-west of Gallow Hill the orange sand is interpreted as passing laterally into laminated red clays and silts (for example from the evidence of pits 42 SW 29, 30, 31, 34, 35, 36, 37, 38) again indicating an extensive area of deposition.

Red laminated clays and silts, apparently identical to those south-west of Gallow Hill, have been proved at or near the surface in the valleys of the Motray Water and Cleughie Burn upstream of Cruivie [4040 2233] (boreholes 32 SE 5, 7, 42 SW 9 and pits 32 SE 10, 11). The red clay also occurs at depth beneath post-Glacial deposits in the east of the resource sheet area, and, in borehole 42 SW 23 it is found beneath fluvioglacial sand. Samples of the red clay from borehole 32 SE 5 have yielded a sparse cold-water marine fauna, and samples from boreholes 42 SE 18 an assemblage typical of the arctic clay of Errol (Davidson, 1932) which the clays resemble lithologically. The deposit, which has been shown to be widespread, both onshore in the Tay and Forth areas, and offshore at least as far north as Aberdeen (Peacock, 1975), is considered to have formed in a marine environment in early late-Glacial times.

Late-Glacial raised beach deposits and associated estuarine alluvium Raised beaches of late-Glacial age extend south from Tayport to Balmullo between the fluvioglacial deposits to the west and post-Glacial deposits to the east. Marine shells (Cullingford, 1972) and estuarine animal burrows have been noted in these sediments. Embayments extend into the glacial



LOWER CARBONIFEROUS

$\dot{d}^1$ Calciferous Sandstone Measures

DEVONIAN

c^3 Upper Devonian

c^1 Lower Devonian

AB Lower Devonian andesite and basalt lavas

INTRUSIVES

F Felsite and felsic acid agglomerate

F^{MD} Microgranodiorite

D Basalt and dolerite in sheets

——— Geological boundary

— ⊥ — Fault, crossmark on downthrow side

Figure 2 Sketch-map showing the solid geology.

deposits, the most extensive being along the northern margin of the glacial sand and gravel ridges. Locally the western limits of the beaches are marked by shoreline features well shown where cut in rock at Craigie Hill [445 244] and in fluvioglacial sand and gravel at Kirkton Wood [4515 2570]. South of Craigie [4535 2425] within the area of late-Glacial marine reworking, boreholes show material indistinguishable from fluvioglacial sand and gravel at the surface (42 SW 13, 14, 23, SE 12 and 13); till is at the surface in boreholes 42 SW 16 and 20. Only north of Craigie were late-Glacial beach deposits identified, boreholes 42 SE 11 and 42 NE 8 proving 1.9 m of 'clayey' sand and 1.0 m of 'very clayey' pebbly sand respectively. Narrow late-Glacial raised beaches of probably equivalent age occur along the coast between Tayport and Balmerino where the rocky ground dips much more steeply towards the sea than it does to the south of Tayport: pit 42 NW 33 proved gravelly beach deposits.

Post-Glacial raised beach deposits and associated estuarine alluvium Within the resource sheet area the post-Glacial beach deposits cover the ground east of a low shoreline feature running south from Tayport to Leuchars, with an embayment extending up the Motray Water valley to Burnside. Deposits proved in boreholes are dominantly shelly sands with subordinate bands of grey, laminated clay and silt, the latter becoming thicker and more numerous with depth. Rare gravel beds occur, often at the base of the post-Glacial (for example, boreholes 42 NE 15, 16, SE 17, 19, 22, 23). The sands and clays accumulated in a nearshore beach and estuarine environment during both the transgressive (rising) and regressive (falling) phases of the marine incursion (Chisholm, 1971);

marine fossils in samples collected during the present survey generally support this environmental interpretation. On the eastern part of the beach flat, however, the deposits have been reworked by the wind to give a thin and patchy cover of blown sand which locally forms dunes up to 12 m in height, generally parallel with the coast, but with a superimposed lineation locally present which is aligned to the south-westerly prevailing winds (Chisholm, 1971).

Alluvium, lake alluvium and peat Alluvium occurs principally in the valley of the Motray Water, where it was proved in boreholes 32 SE 5, 42 SW 9 and 15 to comprise clay, silt or peat of not more than 2.0 m in thickness excluding soil; lake alluvium, considered to be dominantly clay and silt, is found to the south of South Friarton [4320 2514] and near Naughton House [3724 2463]. Small patches of peat occur throughout the area.

Quaternary geological history

Although this part of north-east Fife has been glaciated several times it is thought that no drift deposits are older than the most recent, late-Devensian, ice sheet which extended well east of the present coastline from about 20 000 to 16 000 years ago. The till, which occurs extensively throughout the area lying on bedrock, was deposited by the ice.

When the ice sheet started to decay, it retreated westwards towards the Firth of Tay, and it is thought that the glacial and fluvioglacial deposits were formed at a time when the ice margin was within, or just east of, the resource sheet area. Both the lithology and eskerine landforms of much of the glacial sand and gravel suggest that these deposits were formed by fluvial processes operating in sub-ice tunnels (Rice, 1961). This was probably at a time when the local ice had become stagnant whilst impervious ice still occupied the Tay east of Wormit; the meltwaters of the Tay glacier were diverted through the low ground south-west of Wormit, known in the literature as the Wormit Gap, and provided the sediment supply to the resource sheet area.

Subsequent to the formation of the glacial sand and gravel, with continued down-wasting of the ice, deltaic deposition became dominant. These deposits, the fluvioglacial sand, form the plateaux of Cowbakie, North Straiton and Gallow hills and underlie the valleys between them, where they have probably undergone some subsequent, late-Glacial, marine reworking. South-west of Gallow Hill the upper part of the sands is thought to pass laterally into marine red clays and silts, equivalent to the Arctic Clay of Errol (Davidson, 1932). It is considered that the later parts of the fluvioglacial deposits were laid down in a delta prograding into the sea at about 14 000 to 14 500 years ago when large masses of dead ice still existed within the resource sheet area. The sand was deposited between such ice masses to produce the plateau-like hills with their steep ice-contact slopes. Thinner deposits were laid down on top of the ice and subsequently let down when the ice melted, producing the valley sands (Rice, 1961). Fluvioglacial sand probably also covered some of the eskerine ridges for the former deposit in pit 42 SW 27 is thought to overlie glacial sand and gravel.

Prior to the final south-eastward progradation of the delta sands the sea had penetrated the decaying ice to upstream of Wester Kinear [4006 2272] in the valley of the Motray Water, where marine deposits are found up to a minimum level of 25.3 m above OD. The Quaternary history of the area subsequent to the formation of the delta deposits is principally controlled by the changes in relative sea-level during and after deglaciation. These changes, which began in the early stages of deglaciation, are the product of two interacting factors, the eustatic rise in sea-level due to the increased volume of ocean water as a result of the melting of the ice-sheets, and the isostatic rise of the glacially depressed land due to the removal of the weight of the ice. The net effect of these processes has been a drop in relative sea-level from late-Glacial times to the present day, but there have been temporary reversals; the conspicuous beach and estuarine features were formed at times when the effects of isostasy and eustasy were balanced. On the basis of the correlation of raised beaches in east-central Scotland, that extending from north-west of Leuchars to Tayport is considered by Smith, Sissons and Cullingford (1969) to be the Main Perth Shoreline, the most prominent late-Glacial beach in south-east Scotland; it is thought to have been formed between about 13 000 and 13 500 years ago (Paterson, 1974).

After the formation of the Main Perth Shoreline the late-Glacial sea-level continued to fall until a temporary return to ice age conditions between 11 000 and 10 000 years ago (Loch Lomond Stadial). Subsequent to this, relative sea-level fluctuated from below to somewhat above its present position until it markedly rose during the post-Glacial transgression about 8000 years ago, an episode which culminated about 6500 years ago in the formation of the Main Post-Glacial shoreline of Sissons, Smith and Cullingford (1966). Within the resource sheet area deposits which formed during this episode lie east of the low shoreline feature extending south from Tayport to Leuchars. Between the western limit of the blown sand and the Main Post-Glacial shoreline aerial photographs show a network of estuary channels formed at the acme of the post-Glacial transgression (Chisholm, 1971). Throughout the last 6500 years Tentsmuir Point has continued to grow eastwards, with aeolian action reworking the upper part of the beach sands near the sea.

COMPOSITION OF THE MINERAL DEPOSITS

Graphs showing mean grading characteristics (particle size distributions) for the resources within each geological deposit are presented in Figures 3 to 8 and summarised in Table 2.

The frequency distribution curves for the fluvioglacial sand and gravel, the beach deposits and the blown sand are similar (Figures 4 to 6), with a single mode at a particle size of 0.25 to 0.5 mm, but the amplitude decreases from blown sand through post-Glacial beach deposits to fluvioglacial sand and gravel, suggesting progressive reworking of the earlier sediments.

Glacial sand and gravel and fluvioglacial sand and gravel are distinguished at surface by the distinct landforms they exhibit. In boreholes, however, they are separated on the basis of lithology, the glacial sand and gravel containing abundant gravel whereas the fluvioglacial deposits are predominantly fine orange sand. Where the fluvioglacial sand has been subject to

Table 2 Mean grading of deposits

Deposit	Mean grading percentage						
	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 and boulders +64 mm
Glacial sand and gravel	4	17	21	13	20	20	5
Fluvioglacial sand and gravel	8	62	26	2	1	1	trace
Late-Glacial beach deposits	14	41	27	5	7	6	0
Post-Glacial deposits	10	69	18	1	1	1	0
Blown sand	3	93	4	0	0	0	0
Till	13	24	23	11	15	12	2

later marine reworking, but not changed lithologically, the deposit is classified in the borehole logs as fluvioglacial sand and gravel rather than as beach or marine deposits.

Glacial sand and gravel The deposit is ill-sorted, with poorly developed modes in the medium sand and fine gravel grades, but is laterally relatively homogeneous, as illustrated by the narrow grading envelope (Figure 3). The composition ranges from gravel to sandy gravel, the mean grading being fines 4 per cent, sand 51 per cent and gravel 45 percent (sandy gravel).

The clasts vary from angular to well rounded but generally are subangular to subrounded, with cobbles and boulders up to 30 cm diameter averaging 5 per cent by weight of the deposit. The mean gravel content ranges from 34 per cent in borehole 42 NW 24 to 52 per cent in borehole 42 NW 23.

Sand is generally of fine to medium grade with subordinate coarse: it is angular to subrounded and composed of quartz, feldspar and comminuted rock fragments.

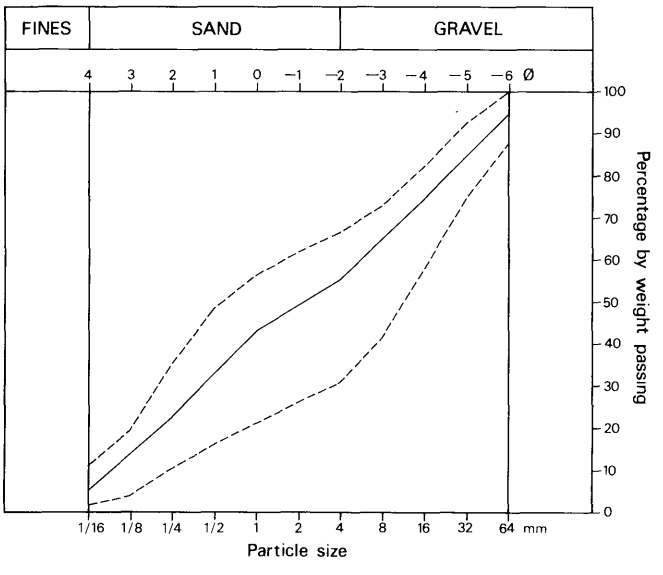


Figure 3 Grading characteristics of resources in the glacial sand and gravel: the continuous line is the cumulative weighted mean; the broken lines denote the envelope containing the cumulative mean grading for each separately identified deposit proved by boreholes to contain less than 40 per cent fines.

Usually fines are disseminated, sandy silt and silty clay seams being rare. The mean fines content of the glacial sand and gravel deposits ranges from 1 per cent in borehole 42 SW 13 to 9 per cent in borehole 42 NW 24.

Fluvioglacial sand and gravel (including that reworked during late-Glacial times) Fluvioglacial sand and gravel is strongly unimodal, peaking in the fine sand grade (Figure 4), and having a mean grading of fines 8 per cent, sand 90 per cent, gravel 2 per cent (sand). Samples from boreholes over much of the deposit fine with depth.

Usually gravel is most abundant in the upper 1 to 2 metres of the deposit, ranging from 0 per cent in boreholes 42 NE 9, 42 SE 13 and in pits 42 SW 26 and 42 SE 30, to 11 per cent in borehole 42 NW 23. Fine gravel predominates over coarse, cobbles and boulders occurring rarely. Pebble shape varies from angular to well rounded, but in general it is subrounded.

The sand fraction is composed of subrounded to subangular grains of quartz and feldspar with less than 2% comprising rock fragments and mica flakes. Coarse sand contains more material that is angular, derived from comminuted rock fragments. With depth, fine

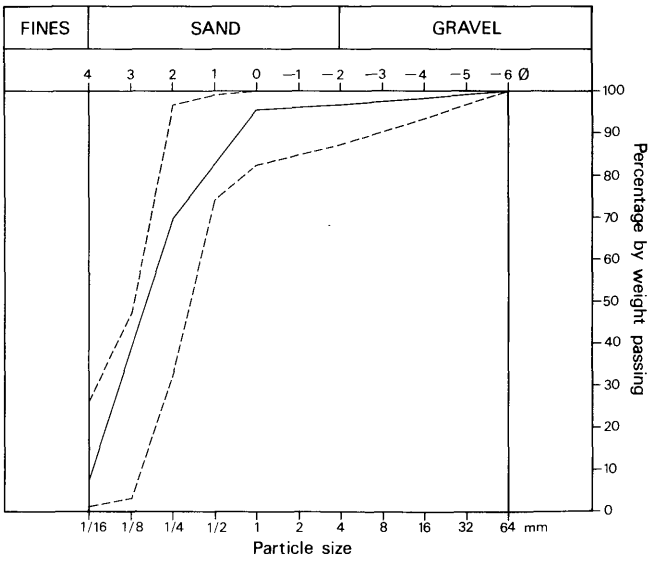


Figure 4 Grading characteristics of resources in the fluvioglacial sand and gravel (for explanation see Figure 3).

sand generally increases at the expense of medium, although the total sand content varies little either within or between deposits ranging from 71 per cent in borehole 42 SW 13 to 99 per cent in pit 42 SE 30.

The fines consist of disseminated silt and seams of silt and clay which in general become more frequent with depth. The mean fines content ranges from 1 per cent in pit 42 SE 30 to 17 per cent in borehole 42 SW 23.

Late-Glacial raised beach deposits and associated estuarine alluvium Late-Glacial raised beach deposits, identified in two boreholes and two pits, have a mean grading of fines 14 per cent, sand 73 per cent, gravel 13 per cent ('clayey' pebbly sand). The mean gravel content ranges from 1 per cent in borehole 42 SE 11 to 32 per cent in pit 42 SW 39 and is poorly sorted with fine and coarse gravel equally abundant (Figure 5); oversize material is rare except in pit 42 NW 33 where cobbles up to 20 cm in diameter were observed. The clasts are angular to well rounded.

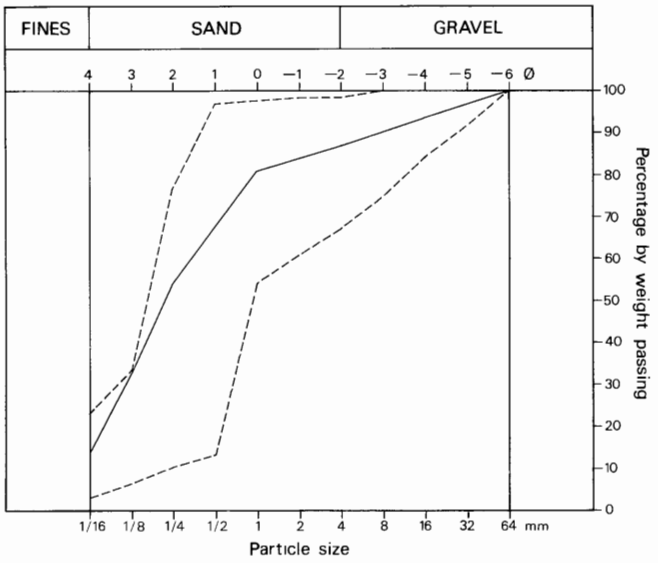


Figure 5 Grading characteristics of resources in the late-Glacial raised beach deposits: the continuous line is the cumulative weighted mean; the broken lines denote the envelope containing the cumulative mean grading for each separately identified deposit proved by boreholes to contain less than 40 per cent fines.

Fine sand predominates over medium grade and coarse is much less abundant: it is angular to subrounded and composed of quartz and rock fragments with some comminuted shell material. The mean sand content ranges from 65 per cent in pit 42 SW 29 to 82 per cent in borehole 42 SE 11.

The fines occur as disseminated silt and clay throughout the deposit and range from 3 per cent in pit 42 SW 39 to 24 per cent in borehole 42 NE 8.

Post-Glacial raised beach deposits and associated estuarine alluvium The mean grading of the post-Glacial raised beach deposits is fines 10 per cent, sand 88 per cent, gravel 2 per cent ('clayey' sand).

Gravel is most common at the base of the deposit in a bed 1 to 2 metres thick, as in boreholes 42 SE 22 and 23. It is fine with some coarse (cobbles and boulders are rare), subangular to well rounded.

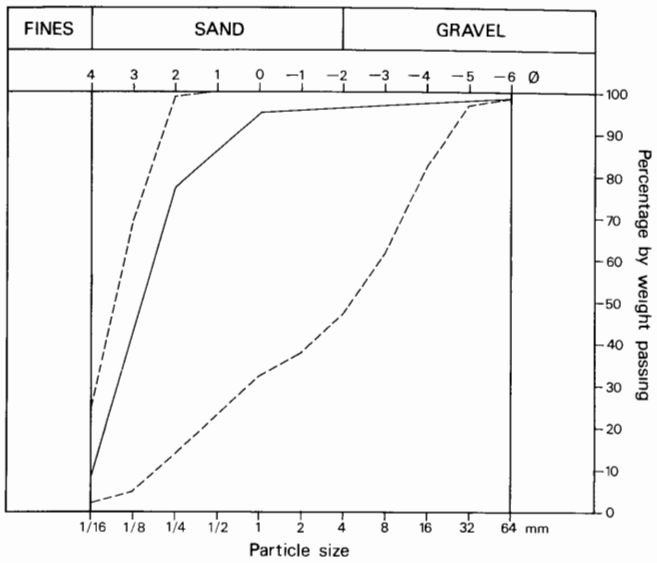


Figure 6 Grading characteristics of resources in the post-Glacial raised beach deposits (for explanation see Figure 5).

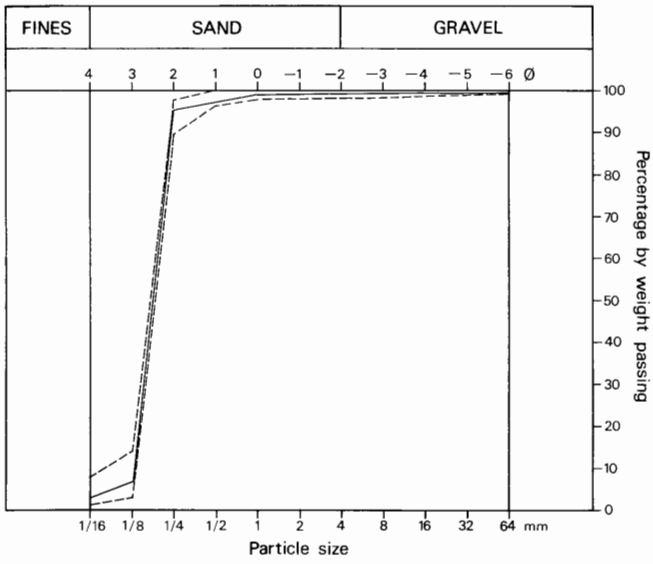


Figure 7 Grading characteristics of resources in the blown sand (for explanation see Figure 5).

Sand is fine with some medium and rare coarse (Figure 6); it is angular to well rounded and often contains much shell debris. The mean sand content ranges from 74 per cent in borehole 42 SE 14 to 95 per cent in borehole 42 SE 21.

The fines which comprise disseminated silt and laminated silt and silty clay tend to increase with depth. The mean fines content ranges from 3 per cent in 42 SE 17 to 26 per cent in 42 SE 14.

Blown sand Blown sand encountered in ten boreholes has a mean grading of fines 3 per cent, sand 97 per cent and gravel 0 per cent (sand).

The sand is fine, with rare medium and coarse (Figure 7). It is generally subangular to subrounded, occasionally angular or well rounded and consists of quartz, feldspar, rock fragments, mica flakes and frequent shell fragments. The mean sand content ranges from 92 per cent in borehole 42 NE 10 to 99 per cent in boreholes 42 NE 13 and 42 SE 19.

The mean fines content, mainly disseminated silt, ranges from 1 per cent in boreholes 42 NE 13, 42 SE 19 and 20 to 8 per cent in borehole 42 NE 10.

Till Till usually is a cohesive clay, varying in colour from reddish brown to grey-green and containing angular to subangular clasts often up to boulder size. Where the deposit is judged potentially workable it has a mean grading of fines 13 per cent, sand 58 per cent, gravel 29 per cent ('clayey' sandy gravel) and exhibits (Figure 8) the lack of sorting typical of a till. Figure 9 shows that the till has a grading curve similar to that of glacial sand and gravel, but generally it is more sandy, suggesting that the glacial sand and gravel was derived from the till, fluvial reworking concentrating the gravel fraction; the fluvioglacial sand and gravel may be derived in part from the residual sand.

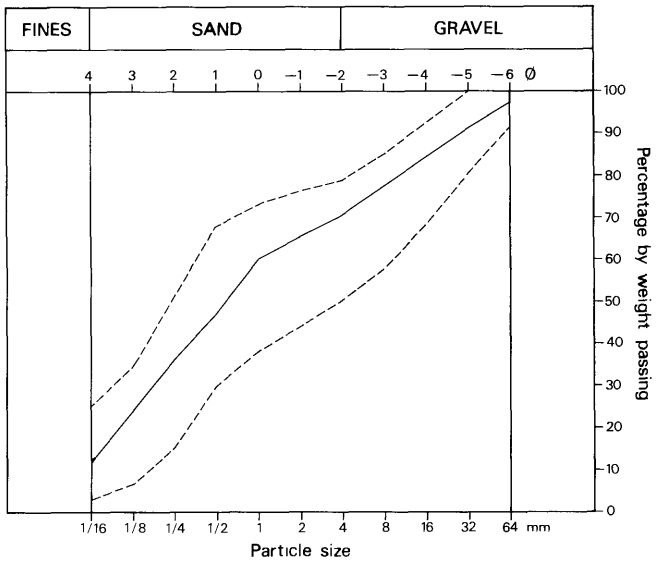


Figure 8 Grading characteristics of potentially workable material in the till (for explanation see Figure 5).

Figure 9 shows that the principal mode of the deposits, except the glacial sand and gravel, lies at 0.25 mm suggesting all the deposits may have been derived one from another.

MECHANICAL AND PHYSICAL PROPERTIES OF THE AGGREGATE

Aggregate impact value (AIV), aggregate impact value residue (AIVR), 10% fines value, relative density (both oven-dried and surface-dried), apparent relative density, water absorption and flakiness index were determined in accordance with BS 812.3 (1975). All the tests were conducted on the 10 to 14 mm fraction obtained by resieving bulk samples after completion of particle size analysis. About 15 kg are required for a complete series of determinations and only glacial sand and gravel was able to provide sufficient material of the required size. By combining up to twenty-one bulk samples (Table 3) the deposit at four borehole sites was examined.

In addition to aggregate testing, pebble counts were carried out on the composite samples in order to compare any variation in lithology with the results of the mechanical and physical testing.

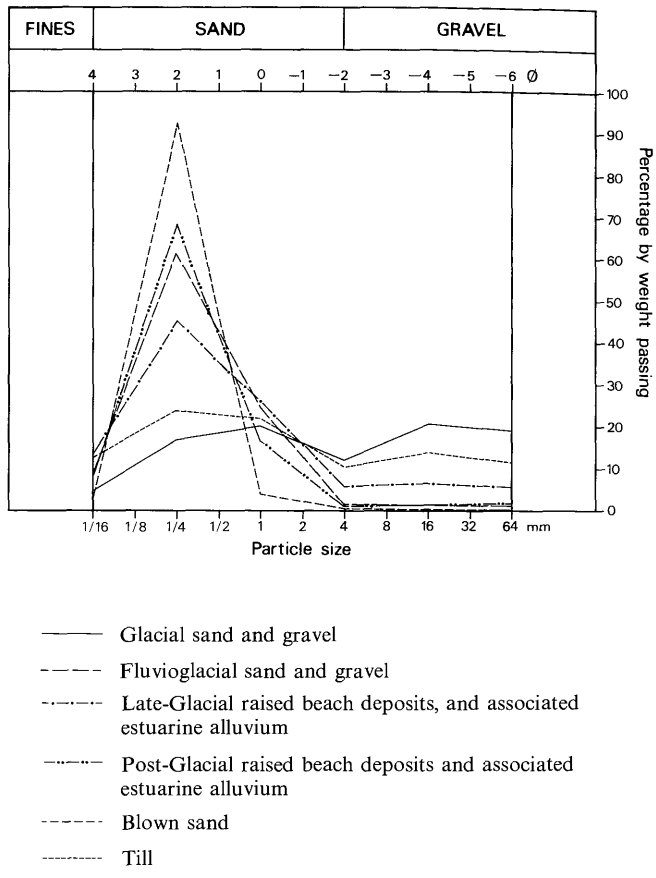


Figure 9 Frequency distribution of the mean grading by deposit.

Composition analysis The classification used is based on the British Standard petrological groups (trade groups) as outlined in BS 812.1: 1975. However, vein quartz is listed both separately and combined with the quartzite trade group in Table 4. Granite, granodiorite, pegmatite, coarse-grained acid gneiss and microgranite are combined to form the granite group.

The compositional analyses are presented in terms of weight per cent and per cent number of clasts. Approximately 275 pebbles are included in each analysis: it is assumed that the 10 to 14 mm size fraction is representative of the material as a whole.

In the resource sheet area pebbles falling in the quartzite, vein quartz, granite, schist and gabbro groups are probably of Highland origin. For the four samples tested the weight per cent falling within these categories ranges from 58.4% to 62.5% and of the categories the quartzite trade group comprising orthoquartzite, metaquartzite and psammite/granulite is the most abundant. These results support the view that the ice from which these deposits were derived came from the north-west.

The basalt and gritstone trade groups, the latter in the samples examined consisting of sandstone, arkose and conglomerate, have a combined weight per cent

Table 3 Source and classification of composite samples

Composite sample number	Borehole from which sample taken	Geological classification	Depth range (m)	Number of samples*
1	42 NW 23	Glacial sand and gravel	0.3–25.0	14
2	42 SW 10	Glacial sand and gravel	0–25.0	21
3	42 SW 15	Glacial sand and gravel	1.7–23.4	18
4	42 SW 18	Glacial sand and gravel	0.4–24.2	20

* The number of samples is less than the total for the depth range owing to the paucity of 10–14 mm material in some samples.

Table 4 Composition analyses (pebble counts) of aggregate test samples expressed as weight per cent (frequency per cent in italics)

Composite sample	1		2		3		4	
Size-range (mm)	10–14		10–14		10–14		10–14	
Number of pebbles counted	239		279		284		278	
Total weight (g)	682		769		770		762	
Quartzite trade group	33.5	*30.9*	34.5	*34.8*	42.8	*40.1*	35.2	*33.5*
Vein quartz	11.0	*11.7*	10.9	*10.0*	8.1	*8.8*	9.7	*9.4*
Basalt trade group	18.6	*20.0*	25.3	*23.3*	21.0	*20.8*	20.7	*21.6*
Granite trade group	13.8	*12.9*	11.3	*11.5*	10.0	*10.2*	10.1	*9.4*
Porphyry trade group	5.6	*6.7*	4.8	*5.4*	5.2	*4.9*	4.6	*5.0*
Gritstone trade group	12.6	*13.4*	11.0	*13.3*	10.6	*12.7*	13.4	*14.4*
Schist trade group	2.5	*1.7*	1.2	*1.1*	0.3	*0.4*	1.4	*1.4*
Gabbro trade group	0.9	*1.3*	0.5	*0.4*	1.3	*1.8*	2.7	*3.2*
Limestone trade group	1.5	*1.7*	0.5	*0.4*	0.3	*0.4*	2.1	*2.1*
Quartzite trade group and vein quartz	44.5	*42.6*	45.4	*44.8*	50.9	*48.9*	44.9	*42.9*

which ranges from 31.2 in sample 1 to 36.3 in sample 2. This material is thought to be of Lower Devonian age and was derived from south of the Highland Boundary Fault: the basalt group dominates over gritstone probably because of its greater resistance to erosion during transport. Minor quantities of porphyry, chiefly felsite, and limestone are also found.

Results of the mechanical testing AIV, AIVR, and 10% fines are tests of the strength of an aggregate. AIV is a relative measure of the resistance of an aggregate to sudden shock or impact, which differs in some aggregates from its resistance to a slowly applied compressive load as indicated by the 10% fines value. AIVR is a measure of the proportion of original-sized material remaining after impact and is thought to be a sensitive reflector of shape influence (Ramsay, Dhir and Spence, 1974) whereas AIV is more dependent on petrography. In clastic sedimentary rocks failure is primarily a function of the strength of the intergranular cement: in igneous rocks it depends on the degree of crystal interlocking, which decreases with increase in the surface area of crystals, therefore being inversely proportional to grain size. Additionally in coarse-grained igneous rocks the strength of individual crystals, a function of twinning, cleavage and microfracture planes becomes important (Ramsay, 1965). Generally, therefore, fine-grained igneous rocks are the strongest, followed by coarse-grained igneous and sedimentary rocks of decreasing induration; weathering will reduce the strength of any rock.

Apart from sample 2, with a value of 23, the AIV results from the present survey (Table 5) are identical with the average for worked gravels of 19 given in

Table 5 Results of mechanical and physical tests (BS 812: 1975)

Composite sample	1	2	3	4
Deposit type	Glacial sand and gravel	Glacial sand and gravel	Glacial sand and gravel	Glacial sand and gravel
AIV (%)	19	23	19	19
AIVR (%)	44	41	45	49
10% fines value (kN)	300	250	290	290
Relative density (oven-dried basis)	2.58	2.54	2.59	2.54
Relative density (surface-dried basis)	2.62	2.59	2.62	2.59
Apparent relative density	2.68	2.67	2.69	2.67
Water absorption (%)	1.5	2.0	1.5	2.0
Flakiness index (%)	8	7	13	10

Edwards (1970). The AIVR and 10% fines results show a similar pattern to that of the AIV suggesting both that the readiness of clasts to break up under impact is independent of their size, and that the samples have the same relative strength to impact and compression. Ramsay (1965) has shown strength to be inversely related to the flakiness index (a measure of the ratio of the short to the intermediate axis) but this does not appear to be so with results from the present survey; sample 2 gives the poorest values for AIV, AIVR and 10% fines, yet it has the lowest flakiness index. However, all the flakiness values obtained from the glacial sand and gravel are considerably lower than the average of 17 for natural aggregates reported by Edwards (1970).

The only way in which sample 2 differs petrographically from the others is in its slightly higher basalt group content (Table 4) but this is unlikely to account for its lower strength, which is probably due to a higher degree of weathering.

The water absorption value of an aggregate is a measure of the amount of water absorbed by the aggregate after 24 hours of immersion, expressed as a percentage of the oven-dried weight. The water absorption value is important because of its broad linear relationship with drying shrinkage, both of the aggregate itself and any concrete manufactured from it. The drying shrinkage in turn is a key factor affecting the stress-carrying and weathering ability of concrete. Measurements have been made of the water absorption of crushed rock aggregates (Edwards 1966, 1970) and attempts made to relate these values to petrography. In very general terms quartz and flint give the lowest absorption, gritstone, mudstone and shale the highest, and the acid igneous rocks have a lower absorption than their more basic counterparts, although weathering is likely to increase the absorption of any rock.

The values obtained from the aggregates tested in this survey range from 1.5 to 2.0 per cent and compare with the average of 1.48 per cent for Scottish gravels listed by Edwards (1970). Sample 2 does not show markedly higher absorption than the other samples, although one might have expected it to if it had undergone a greater degree of weathering. Using the graph drawn by Edwards (1970) linking water absorption with concrete drying shrinkage, the aggregates from the glacial gravels of the resource sheet area have inferred shrinkage values between 0.06 and 0.07 per cent. These values lie mostly in the categories defined by the Building Research Station (Digest 35, 1968) as being suitable, with qualification, for most applications.

It must be emphasised that derived shrinkage values should be interpreted cautiously. For definitive values laboratory testing of concrete blocks made from the aggregates should be undertaken.

The relative density is quoted both on an oven-dried and a saturated surface-dried basis. Values of the former range from 2.54 to 2.59, and have a mean of 2.56: those of the latter range from 2.59 to 2.62 and have a mean of 2.61, the small variation being due to the petrographic homogeneity of the samples. These figures are very close to 2.58, the value given by Edwards (1970) as the mean for worked gravels. Values for apparent relative density vary from 2.67 to 2.69 and reflect the results obtained for the relative densities.

Carbonate analysis Material from boreholes 42 SE 20 and 42 NE 13 was subsampled and the proportion of calcium carbonate (shell material), by weight, determined. A split of about 200 g was taken, washed through a 0.063 mm sieve to remove fines, dried, weighed and placed in a beaker containing an aqueous solution of hydrochloric acid for twenty-four hours, after which time the sample was rewashed, dried, reweighed and the percentage loss in weight calculated.

The results are presented in Table 6. Borehole 42 SE 20 shows an increasing carbonate content to a depth of 11.2 m, the maximum of 6.6 per cent occurring from 10.2 to 11.2 m, with a decrease below that depth. Although there is no obvious correlation with deposit classification this result generally concurs with palaeontological examinations of samples from boreholes 42 SE 23 and 24, which show faunal abundance to decrease below about 11 m. In comparison, values in borehole 42 NE 13 are slightly lower. There is a similar increase in carbonate content to a depth of 11.0 m, the base of the lowest sample, but a marked change where blown sand gives way to beach deposits.

THE MAP

The sand and gravel resource map is folded into the pocket at the end of the report. The base is the

Table 6 Results of carbonate analysis (+0.063 mm sand fraction)

Sample number	Depth (m)	$CaCO_3$ (% by weight)
Borehole 42 SE 20		
BLOWN SAND		
TB 275	0.2–1.2	1.1
TB 276	1.2–2.2	0.6
POST-GLACIAL DEPOSITS		
TB 277	2.2–3.2	0.7
TB 278	3.2–4.2	0.6
TB 279	4.2–5.2	2.0
TB 280	5.2–6.2	2.8
TB 281	6.2–7.2	2.9
TB 282	7.2–8.2	3.8
TB 283	8.2–9.2	3.1
TB 284	9.2–10.2	5.1
TB 285	10.2–11.2	6.6
TB 286	11.2–12.2	4.6
TB 287	13.5–14.5	3.6
TB 288	14.5–15.5	2.4
TB 289	17.5–18.5	3.0
TB 290	18.5–19.5	3.1
Borehole 42 NE 13		
BLOWN SAND		
TAC 1	0.5–1.5	0.7
TAC 2	1.5–2.5	0.4
TAC 3	2.5–3.5	0.7
TAC 4	3.5–4.5	0.8
TAC 5	4.5–5.5	0.8
POST-GLACIAL DEPOSITS		
TAC 6	5.5–6.5	2.2
TAC 7	6.5–7.6	2.0
TAC 8	7.6–8.5	2.0
TAC 9	8.5–9.5	3.9
TAC 10	9.5–10.0	3.4
TAC 11	10.0–11.0	3.8

Ordnance Survey 1:25 000 Outline Edition which together with the contours is printed in grey. The geological lines and symbols are in black. Mineral resource information is in red.

Geological data The geological boundary lines are taken from geological maps surveyed at the scale of 1:10 560; these offer the best interpretation of the available data but, because of the highly variable nature of the deposits, the accuracy of the map will be improved as new evidence from boreholes and excavations becomes available.

Mineral resource information The mineral-bearing ground is divided into resource blocks (see Appendix A) within which the extent of mineral is shown in red, a dark shade being used to identify areas where it is exposed (that is, overburden averages less than 1 m), and a lighter tone areas where it is present in relatively continuous spreads beneath overburden averaging more than 1 m in thickness. The map is left uncoloured where sand and gravel is considered to be generally either absent or not potentially workable, except where this category occurs in small undefinable patches within an area of mineral, for example, in the vicinity of borehole 42 SE 18. Small patches of sand and gravel that have not been assessed, although they may be potentially workable, are indicated by red stipple.

In the main, the boundaries between categories of deposits coincide with geological boundary lines: where a transition between categories occurs that cannot be located in this way an inferred boundary has been drawn. Such boundaries are shown as zigzag lines. The symbol is intended to signify an approximate location within a likely zone of occurrence rather than to represent the breadth of the zone, its size being limited only by cartographic considerations. For the purpose of measuring area the centre-line of the symbol is used.

Borehole data, which include the stratigraphical relations and mean particle-size analysis of the sand and gravel samples collected during the assessment survey, are also shown. Where boreholes prove sand and gravel, but no grading information is available, mineral is depicted by an unfilled grading box.

THE ASSESSMENT

The mineral-bearing ground is divided into four resource blocks for assessment. The positioning of the block boundaries is determined both to provide sufficient sample points on which to base an assessment and to group together deposits of broadly similar origin and composition. As far as possible the block boundaries are determined by geological lines.

Glacial sand and gravel, fluvioglacial sand and gravel, together with the post-Glacial raised beach deposits and associated estuarine alluvium (hereafter, when considered as a whole, referred to as post-Glacial deposits), are the principal components of the potentially workable sand and gravel: the boundaries of blocks A and B generally delimit the areas of occurrence of the glacial and fluvioglacial sand and gravel, and the post-Glacial deposits are considered in blocks C and D. In the north-west and south-west of the resource sheet area the drift cover is thin and mineral occurs as isolated patches; these form block E. The ground to the north of the Firth of Tay includes the southern part of Dundee and has not been assessed.

The statistical procedure adopted for the volumetric assessment of the mineral resources is outlined in Appendix B. A 'statistical' assessment is offered for the resources of blocks A to D. Other more scattered deposits are included in block E: most cover less than one square kilometre each and have insufficient borehole or pit data for statistical assessments to be made. However, in two areas 'inferred' assessments are offered, based on the available sample-point data.

The mineral resources of the sheet are described in the following notes on the resource blocks. Data used in the assessment calculations, together with the results, are given in Tables 8 to 12: a summary of these data is presented in Table 7. Some conclusions are offered, following the block descriptions, regarding the resources most likely to command attention in the short to medium term.

RESULTS

The results of the assessment of resources are summarised in Table 7. More detailed grading and thickness data by block are given in Tables 8 to 12, and presented graphically in Figures 10 to 13 which also show the envelopes within which the gradings fall.

All potentially workable mineral in blocks C and D is either blown sand or post-Glacial raised beach deposits and associated estuarine alluvium: because of the close similarity in grading the two deposits have been assessed as a whole. For blocks A and B, however, as well as an overall statistical assessment, a calculation has been made for the principal mineral component, respectively glacial sand and gravel and fluvioglacial sand and gravel. It is considered that of the total thickness of till penetrated in boreholes the proportion proved to be potentially workable is directly related to the volume of mineral till present in the area, and the deposit has therefore been included in the statistical assessments for the blocks as a whole. Inferred assessments are made for two minor occurrences of sand and gravel in block E.

In calculating the mean thickness of total mineral in each block all boreholes have been considered; a nil thickness is taken for those boreholes which, although not proving potentially workable material, lie within an area where mineral generally occurs. It is not possible to delimit areas where glacial sand and gravel and fluvioglacial sand and gravel are absent in blocks A and B respectively and therefore all boreholes have been used in the statistical assessment of these deposits, nil values being given to those boreholes where the deposit was not proved.

Accuracy of results For the four resource blocks assessed statistically, the accuracy of the results at the symmetrical 95 per cent probability level ranges from 32 to 45 per cent (that is, it is probable that nineteen times out of twenty the true volumes present lie within these limits). However, the real values are more likely to be nearer the median than the limits. Moreover it is probable that roughly the same percentage limits would apply for the estimate of mineral volume within a very much smaller parcel of ground (for example, 100 hectares) containing similar sand and gravel deposits, if the results from the same number of sample points (as provided by, say ten boreholes) were used in the calculation. Thus, if closer limits are needed for the

Table 7 The sand and gravel resources: summary of statistical and inferred assessments

Resource block *Main mineral-bearing deposit*	Number of sample points	Area		Mean thickness		Volume of sand and gravel			Mean grading percentage		
		Block	Mineral	Over-burden	Mineral		Limits at the 95% probability level		Fines	Sand $+\frac{1}{16}$	Gravel
		km^2	km^2	m	m	$m^3 \times 10^6$	± %	$\pm m^3 \times 10^6$	$-\frac{1}{16}$ mm	-4 mm	$+4$ mm
SUMMARY OF STATISTICAL ASSESSMENTS											
A	10	5.5	5.2	0.6	14.6	76	45	34	5	56	39
Glacial sand and gravel	*10*		*5.2*	*2.0*	*12.6*	*65*	*52*	*34*	*4*	*52*	*44*
B	14	15.0	14.9	0.4	15.5	230	32	74	8	87	5
Fluvioglacial sand and gravel	*14*		*14.9*	*0.4*	*14.0*	*209*	*42*	*87*	*8*	*91*	*1*
C	11	15.4	15.4	0.4	9.9	152	36	55	6	91	3
D	11	19.2	19.2	0.3	14.1	271	36	97	7	91	2
Totals	46	55.1	54.6	0.4	13.9	729	–	–	7	82	11
SUMMARY OF INFERRED ASSESSMENTS											
E *Late-Glacial beach deposits north of Craigie*		–	*3.3*	–	*1.5*	*4.8*	–	–	*19*	*78*	*3*
E *Glacial sand and gravel east of Newport-on-Tay*		–	*0.2*	–	*8.1*	*1.7*	–	–	*8*	*58*	*34*
Totals		–	3.6	–	–	6.5	–	–	–	–	–

Notes

1 Limits at the 95 per cent probability level are a measure of the range of thicknesses about the mean. Because of differences in borehole density between blocks it is not justifiable to give limits when volumes of mineral for individual blocks are added.

2 Whereas the best estimate of total volume is the sum of the components, the most accurate assessment of overall mineral thickness is the mean of all borehole data. Consequently, total volume quoted is not the product of area and mean thickness.

3 The term 'sample point' may include a number of closely spaced boreholes which, in the calculations, have been grouped and given a total weighting factor of one. Therefore, the number of sample points used in the assessment of resources may be less than the total number of borehole records available for the block.

4 Figures may not sum to totals shown because of rounding.

quotation of reserves, data from more sample points would be required, even if the area is quite small. However, it must be emphasised that the quoted volumes of sand and gravel have no simple relationship with the amount that could be extracted in practice, as no allowance has been made in the calculations for any restraints (such as existing buildings and roads) on the use of land for mineral working.

NOTES ON THE RESOURCE BLOCKS

Block A

The block boundaries, which have been drawn to encompass the principal occurrence of glacial sand and gravel, namely that between Wormit and Burnside, generally follow the geological lines delimiting the deposit. In the extreme north-west, where fluvioglacial sand and gravel occurs at the surface, borehole 32 NE 20 shows that the deposit lies on till; glacial sand and gravel is absent (Table 8). However, glacial sand and gravel was proved at depth in borehole 42 NW 23 some 600 m to the north-east but there is insufficient evidence to delimit the area over which it is absent. Along its south-eastern margin the block includes alluvium of the Motray Water which is considered, on the basis of borehole 42 SW 15, to be underlain by glacial sand and gravel.

The topography is dominated by sub-parallel ridges trending south-east (Plate I), broken only to the north-west of Crawley Hill [429 237] where the valley of the Motray Water extends over the full width of the block. The ridges comprise glacial sand and gravel, which were proved in seven of the eight IMAU boreholes in the block, 32 NE 20 being the exception, although pit 42 SW 27 proved fine fluvioglacial sand to its base at 2.0 m. Of the total thickness of mineral proved in block A, 83% is glacial sand and gravel. The deposit is relatively homogeneous in composition, both vertically and laterally, grading as clean ill-sorted gravel or sandy gravel, and increasing in thickness from 4.6 m and 6.2 m in boreholes 42 NW 24 and 32 SE 6 respectively, near the margins of the deposit, to more than 25.0 m at borehole 42 SW 10 in the central part of the ridge complex.

The base of the meltwater deposits (that is glacial and fluvioglacial sand and gravel) was proved in all boreholes except 42 NW 23 and 42 SW 10, and apart from 42 SW 15, where glacial sand and gravel rests directly on bedrock, the deposits overlie till (sections I and II on the map). No borehole penetrated the full

Table 8 Block A: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral	Depth of burial	Intervening waste	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 and boulders $+64$ mm	Descriptive category (see the diagram in Appendix C)
	m	m	m								
ALL DEPOSITS											
32 NE 20	5.4	0.2	0.0	12	57	22	5	3	0	1	CS
32 SE 6	6.2	1.5	0.0	4	8	13	12	24	28	11	G
42 NW 23	24.7	0.3	0.0	8	27	23	10	13	15	4	SG
42 NW 24	5.8	0.5	0.0	11	21	21	11	15	18	3	CSG
42 SW 7	6.6	1.3	0.0	3	19	19	11	22	25	1	SG
42 SW 10	25.0	0.0	0.0	5	22	20	13	18	18	4	SG
42 SW 15	21.7	1.7	0.0	3	21	23	12	22	17	2	SG
42 SW 18	24.5	0.4	0.0	3	14	25	15	18	16	9	SG
*Mean	14.6	0.6	0.0	5	22	22	12	17	17	5	SG
GLACIAL SAND AND GRAVEL											
32 NE 20	0.0	–	–	–	–	–	–	–	–	–	–
32 SE 6	6.2	1.5	0.0	4	8	13	12	24	28	11	G
42 NW 23	12.5	12.5	0.0	5	13	17	13	20	24	8	G
42 NW 24	4.6	0.5	0.0	9	23	24	10	15	15	4	SG
42 SW 7	6.6	1.3	0.0	3	19	19	11	22	25	1	SG
42 SW 10	25.0	0.0	0.0	5	22	20	13	18	18	4	SG
42 SW 15	21.7	1.7	0.0	3	21	23	12	22	17	2	SG
42 SW 18	23.0	0.4	0.0	3	14	25	15	18	16	9	SG
*Mean	12.6	2.0	0.0	4	18	21	13	20	19	5	SG

* Mean thickness calculations take account of non-IMAU boreholes not listed here.

Statistical assessment of all deposits

Area of mineral-bearing ground	5.2 km^2
Mean thickness of overburden	0.6 m
Mean thickness of mineral	14.6 m
Estimated volume of mineral	**76 million m^3**

Statistical assessment of glacial sand and gravel

Area of mineral-bearing ground	5.2 km^2
Mean depth below surface	2.0 m
Mean thickness of mineral	12.6 m
Estimated volume of mineral	**65 million m^3**

thickness of till, because it is so stiff, but it is considered everywhere to lie on rock, for boreholes elsewhere in the resource sheet area always show till to be the lowest drift deposit (for example boreholes 42 NW 25, 42 SW 19, 42 SW 11, 15). Further the high consolidation of the deposit suggests it is a basal till and there is no evidence in the area of deposits attributable to an earlier glaciation. Although generally a stiff clay, in boreholes 42 SW 18 and 42 NW 24 the till contains sufficient sand and gravel to be graded as sandy gravel and 'clayey' gravel respectively. There is insufficient evidence to determine the areal extent of potentially workable till but it is thought to be limited; an estimate of the volume based on the thickness penetrated in the boreholes has been included in the overall assessment of mineral volume.

Fluvioglacial sand and gravel, which is most extensive at the surface around Newton Park [398 255], was proved at three data points. In boreholes 32 NE 20 and 42 NW 23 the mean grading is 'clayey' sand and 'clayey' pebbly sand respectively. At the second of these sites the deposit overlies glacial sand and gravel, and this relationship is considered to occur beneath pit 42 SW 27, although here the base of the fluvioglacial sand and gravel was not proved. Fluvioglacial sand and gravel is considered nowhere to be buried by glacial sand and gravel.

The only borehole within the block sited on ground mapped as alluvium, 42 SW 15, proved peat, but upstream, outside the block, boreholes 32 SE 5 and 42 SW 9 showed the deposit to be silt and clay. Nowhere in the resource sheet area is alluvium considered to be potentially workable. Small patches of peat are found throughout the block.

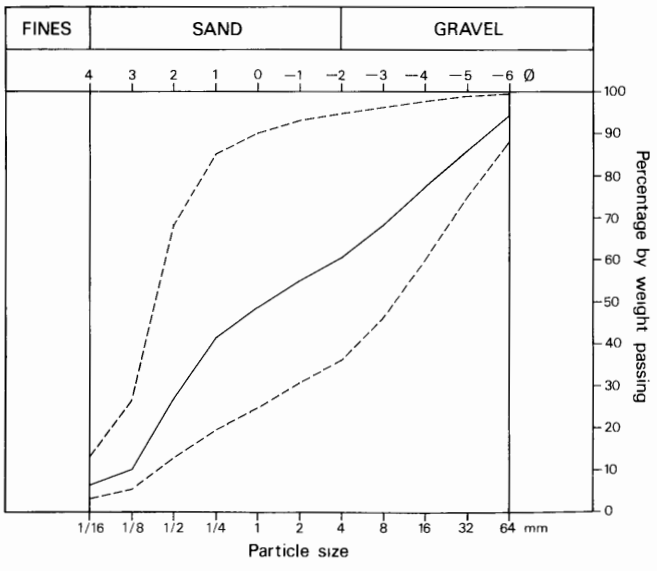


Figure 10 Grading characteristics of resources in block A: the continuous line is the cumulative weighted mean; the broken lines denote the envelope containing the cumulative mean grading for each separately identified deposit proved by boreholes to contain less than 40 per cent fines.

Based on eight IMAU boreholes and three other records, the volume of glacial sand and gravel is assessed at 65 million $m^3 \pm 52$ per cent: the deposit has a mean grading of 4 per cent fines, 52 per cent sand, 44 percent gravel (sandy gravel).

A statistical assessment for the block as a whole (that is, glacial sand and gravel, fluvioglacial sand and gravel and potentially workable till) is 76 million m^3 ± 45 per cent: the mean grading is 5 per cent fines, 56 per cent sand, 39 per cent gravel (sandy gravel) (Figure 10).

Block B

Three discrete areas constitute block B, which delimits the principal deposits of fluvioglacial sand and gravel both at the surface and at depth. Boreholes, pits and exposures, for example 42 SW 14, 23, 42 SE 12, 30 and the sand pits west of Burnside, show material lithologically identical to the fluvioglacial sand which occurs at the surface extensively within areas mapped as late-Glacial raised beach deposits and associated estuarine alluvium, to the south of Craigie, in the vicinity of Leuchars, south of Gallow Hill, and north-west of Southfield [4397 2194] (Table 9).

Much of the fluvioglacial sand and gravel was laid down by meltwaters issuing in a generally south-easterly direction between the bedrock hills of Craigie [445 244] and Straiton [421 223] (section II on the map) but the deposits that form Cowbakie Hill are considered to be a product of meltwater deflected on a more easterly course to the north of Craigie Hill. The area of late-Glacial raised beach and associated estuarine deposits shown on the resource map was formed during a period of marine planation and embayment of the easily eroded fluvioglacial deposits, which were locally reworked but not lithologically changed; sediments identical to the fluvioglacial sand therefore occur at the surface over much of the area mapped as late-Glacial raised beach and associated estuarine deposits (sections I and II). Boreholes 42 SE 14, 17, 18 and 21 in block C, sited on blown sand or post-Glacial deposits and south-east of the

Table 9 Block B: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral	Depth of burial	Intervening waste	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 and boulders $+64$ mm	Descriptive category (see the diagram in Appendix C)
	m	m	m								
ALL DEPOSITS											
42 NW 29	3.9	0.7	0.0	19	61	17	2	1	0	0	CS
42 NW 30	24.4	0.6	0.0	5	57	35	2	1	0	0	S
42 NE 9	24.9	0.1	0.0	9	77	13	1	0	0	0	S
42 SW 8	24.6	0.4	0.0	11	63	23	1	1	1	0	CS
42 SW 11	22.0	0.5	0.0	7	62	27	1	1	2	0	S
42 SW 13	3.8	0.3	2.1	15	37	9	5	14	19	1	CSG
42 SW 14	11.0	0.4	0.4	4	26	29	11	17	11	2	SG
42 SW 17	3.8	0.6	0.0	4	11	49	7	12	16	1	SG
42 SW 19	12.6	0.2	11.0	5	36	24	9	13	11	2	SG
42 SW 21	18.0	0.4	6.6	10	75	14	0	0	1	0	CS
42 SW 22	24.9	0.3	0.0	5	52	40	2	1	0	0	S
42 SW 23	10.0	0.4	3.3	17	72	9	1	1	0	0	CS
42 SE 12	13.7	0.0	0.0	4	72	22	1	1	0	0	S
42 SE 13	19.2	0.3	3.2	9	57	32	1	0	0	0	S
Mean	15.5	0.4	1.9	8	59	26	2	3	2	0	PS
FLUVIOGLACIAL SAND AND GRAVEL											
42 NW 29	3.9	0.7	0.0	19	61	17	2	1	0	0	CS
42 NW 30	24.4	0.6	0.0	5	57	35	2	1	0	0	S
42 NE 9	24.9	0.1	0.0	9	77	13	1	0	0	0	S
42 SW 8	24.6	0.4	0.0	11	63	23	1	1	1	0	CS
42 SW 11	22.0	0.5	0.0	7	62	27	1	1	2	0	S
42 SW 13	2.0	0.3	0.0	27	63	7	1	1	1	0	VCS
42 SW 14	5.0	0.4	0.0	5	44	44	3	3	0	0	S
42 SW 17	0.0	–	–	–	–	–	–	–	–	–	–
42 SW 19	4.0	0.2	0.0	5	58	32	2	2	1	0	S
42 SW 21	18.0	0.4	6.6	10	75	14	0	0	1	0	CS
42 SW 22	24.9	0.3	0.0	5	52	40	2	1	0	0	S
42 SW 23	10.0	0.4	3.3	17	72	9	1	1	0	0	CS
42 SE 12	13.7	0.0	0.0	4	72	22	1	1	0	0	S
42 SE 13	19.2	0.3	3.2	9	57	32	1	0	0	0	S
Mean	14.0	0.4	1.0	8	64	26	1	1	0	0	S

Statistical assessment of all deposits	
Area of mineral-bearing ground	14.9 km^2
Mean thickness of overbur	0.4 m
Mean thickness of mineral	15.5 m
Estimated volume of mineral	**230 million m^3**

Statistical assessment of fluvioglacial sand and gravel	
Area of mineral-bearing ground	14.9 km^2
Mean depth below surface	0.4 m
Mean thickness of mineral	14.0 m
Estimated volume of mineral	**209 million m^3**

main surface occurrences of fluvioglacial deposits, proved late-Glacial marine clay at depth, into which the fluvioglacial sand and gravel is considered to grade laterally (sections I and II). It is thought therefore that the geological line marking the western limit of the post-Glacial deposits approximates to the eastern limit of fluvioglacial sand and gravel, and from south of Milton [4460 2058] to Craigie [4635 2425] it defines the eastern margin of the block.

Boreholes 42 NE 8 and 42 SE 11 in block E, north of Craigie, prove thin late-Glacial raised beach deposits resting on till. The block boundary crossing the late-Glacial raised beach west of Craigie approximates to the limit of occurrence of fluvioglacial sand which is thought to be absent north of here at least as far as Vicarsford [4535 2499], the ground being in the lee of Craigie Hill around which meltwaters were deflected. Between Vicarsford and Lawhouses [4530 2664] fluvioglacial deposits may occur beneath the late-Glacial raised beach deposits but as there is no supporting borehole or pit evidence the eastern margin of block B coincides with the geological boundary to the mapped eastern limit of fluvioglacial sand and gravel, but includes in the block the embayments cut by the late-Glacial sea to the north and south of Cowbakie Hill and the storm bar which partly blocks the mouth of the former inlet at [4525 2620]. Pit 42 NW 34 shows material lithologically identical to the fine fluvioglacial sand at the surface in the northern embayment and although pit 42 NE 17 failed to prove the base of the gravelly storm bar deposits, these are considered to overlie the fine sand.

The northern margin of the block and the southern margin as far east as [4335 2170] generally coincide with the geological boundary separating fluvioglacial sand and gravel from till or rock. East of Balmullo [427 209] pits in block E, for example 42 SW 29, 31, 35 and 38 show, at the surface, late-Glacial marine clay which is interpreted as passing north-eastwards into fluvioglacial sand, as demonstrated by borehole 42 SW 23 and pit 42 SW 33. The boundary of the block hereabout, has been drawn in part along the western margin of the post-Glacial embayment and in part along the geological line separating late-Glacial raised beach deposits and associated estuarine alluvium from late-Glacial marine deposits. The block is split to the north-west of Burnside by the glacial sand and gravel ridges of block A, which trend south-east.

Topographically the block has two distinct landforms, the flat-topped, steep-sided hills, the principal of which are Gallow, Cowbakie and North Straiton (Plate 2) and lower, flat or gently moundy ground found between the hills and beneath the late-Glacial erosion surface. The composition of the sediments, however, is independent of topography, the deposits being laterally homogeneous, predominantly sand or 'clayey' sand, locally with clay or silt beds up to 4.8 m thick as in borehole 42 SW 21; in this report all of these sediments are considered together as fluvioglacial sand and gravel and have been referred to as such in the borehole logs. There is a general downwards fining in the deposit both within the sand and into clay and silt, beds of which become more abundant with depth in boreholes 42 NW 29, 42 SW 8, 11, 13, 14. In boreholes 42 NW 30, 42 SW 8, 11, 19, 22, 23, 42 SE 13, the deposit is gravelly near the surface, a maximum thickness of 6.0 m of pebbly sand being found in 42 SW 11. The topography of the block bears little relation to the form of the bedrock surface (sections I and II) and largely determines the thickness of fluvioglacial deposits which ranges from 4.0 m in borehole 42 SW 19, near the margin of the deposit, to more than 24.0 m in boreholes 42 NW 30, 42 NE 9, 42 SW 8, 11, 21, 22 all of which are sited on the flat-topped hills. Based on fourteen IMAU boreholes, a statistical assessment of the fluvioglacial sand and gravel is 209 million $m^3 \pm 42$ per cent: the deposit has a mean grading of 8 per cent fines, 91 per cent sand, 1 per cent gravel (sand).

All those boreholes not sited on the flat-topped hills established the base of the fluvioglacial deposits; 42 SW 13, 14 and 19 sited close to the glacial sand and gravel ridges of block A, proved at depth the latter deposit, which ranges up to 6.0 m thick in 42 SW 14: in all boreholes it grades as gravel. Borehole 42 SW 17 is anomalous in that it proves, from the surface, 3.8 m of material classified on lithological grounds as glacial sand and gravel, resting on till, although it is sited within an area mapped as fluvioglacial sand and gravel and about 1.2 km from the glacial sand and gravel ridges. The deposit may be the product of local deposition against the proximal side of Craigie Hill.

Where the base of the glacial meltwater deposits was proved it overlies till, although only borehole 42 SW 19 reached the underlying rock. Borehole 42 SW 23 proved 2.2 m of late-Glacial marine clay intervening between fluvioglacial deposits and till. Till is generally a stiff clay but in borehole 42 SW 19 two beds occur which are sufficiently sandy to grade as mineral, although if the thickness of overburden is considered only the lower 5.8 m of pebbly sand classifies as mineral. All potentially workable deposits have been considered in the statistical assessment of the block as a whole. Based on fourteen IMAU boreholes, a volume of 230 million $m^3 \pm 32$ per cent is indicated; the mean grading is 8 per cent fines, 87 per cent sand, 5 per cent gravel (pebbly sand) (Figure 11).

In the west, the block includes the alluvial flat of the Motray Water (Plate 2): although not proved by

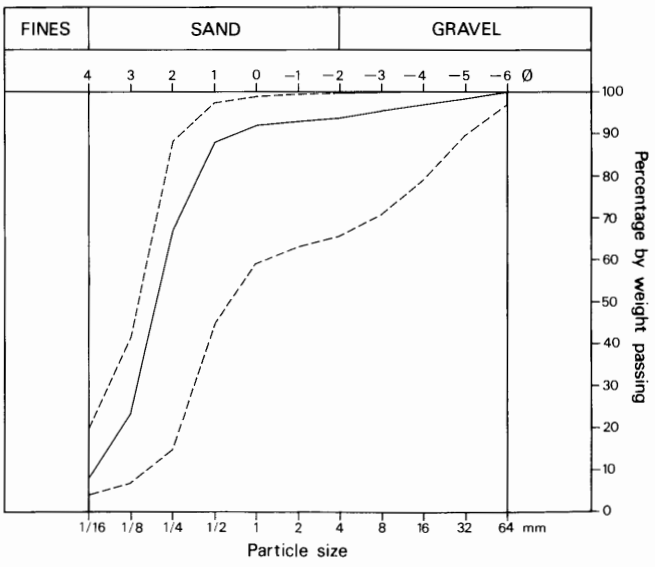


Figure 11 Grading characteristics of resources in block B: the continuous line is the cumulative weighted mean; the broken lines denote the envelope containing the cumulative mean grading for each separately identified deposit proved by boreholes to contain less than 40 per cent fines.

boreholes within the block, evidence from elsewhere suggests that the alluvium is non-mineral. The lake alluvium to the south of South Friarton [4320 2514] is mainly silt. Blown sand has been mapped at surface over much of St Michael's Wood [447 231], although borehole 42 SE 12 proved at the surface material which could not be distinguished from fluvioglacial sand, suggesting the aeolian deposits are very variable and thin.

Block C

Over the eastern part of the resource sheet area post-Glacial raised beach deposits and associated estuarine alluvium or blown sand occur at the surface. This area is divided between blocks C and D: the boundary between them is arbitrary but approximately divides deposits to the south, encompassed by block C, which contain thick clays at depth, from those in the north in which the post-Glacial sediments are predominantly mineral. The western margin of the block follows the geological boundary of the western limit of the post-Glacial raised beach deposits and associated estuarine alluvium, and includes the valley of the Motray Water upstream to Burnside. A patch [446 201] of post-Glacial deposits separated from the main deposit by recent beach material is also included. The block is limited to the east and south by the margin of the resource sheet, or by recent beach deposits, which are not assessed.

The topography of the block which is dominated by post-Glacial beach morphology, is flat and low-lying, ranging from sea-level to about 4.5 m above OD (section II on map). In the east the beach sands have been reworked by the wind to give a cover of blown sand which forms dune ridges up to 12 m in height running generally parallel to the coast but locally with a superimposed lineation aligned to the south-westerly prevailing winds (Chisholm, 1971).

With the exception of small, scattered patches of non-mineral alluvium or peat, post-Glacial deposits or blown sand are found at the surface throughout the block. The post-Glacial deposits generally thicken to the north-east, ranging from 5.7 m at borehole 42 SE 18 to 19.8 m at 42 SE 23: they are generally potentially workable from within 1 m of the surface, a maximum thickness of 18.0 m of mineral being attained in borehole 42 SE 25 (Table 10). The deposit grades in its upper part as sand in all boreholes except 42 SE 14 and 18, the former showing 1.2 m of silt on 5.2 m of 'very clayey' sand, and the latter proving that the entire sequence comprises clay. The surface sand deposit is generally underlain by silt and clay, though in boreholes 42 SE 20 and 24 these lower deposits are interbedded with sand and 'clayey' sand which at the former site are potentially workable, but at the latter are not, owing to an excessive thickness of overburden. However, boreholes 42 SE 17 and 25 prove sand throughout the full thickness drilled, and in borehole 42 SE 22 an upper sand deposit is underlain by 3.0 m of 'very clayey' sand.

Thin pebble beds occur within sand in boreholes 42 SE 17, 20, 21, 22, 24 and 25, but gravel is most common within about 1 m of the base of the post-Glacial deposits where it is present as a lag and ranges in thickness from a 0.2 m parting in borehole 42 SE 25 to 3.3 m of sandy gravel in 42 SE 16; 1.6 m of gravel was encountered in borehole 42 SE 22.

Blown sand is lithologically very similar to the underlying post-Glacial raised beach deposits from which it is derived. It is, however, generally finer grained and contains none of the large shells which are abundant in the beach sediments. A colour change downwards from brown to grey often coincides with a change in these other two factors. Although in part reflecting past or present water levels, the colour change is considered a third criterion on which to distinguish the base of aeolian reworking. The resource

Table 10 Block C: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							Descriptive category (see the diagram in Appendix C)
Borehole	Total mineral m	Depth of burial m	Intervening 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 and boulders $+64$ mm	
ALL DEPOSITS											
42 SE 14	5.2	1.4	0.0	26	74	0	0	0	0	0	VCS
42 SE 16	6.5	0.7	6.6	6	54	21	6	11	2	0	PS
42 SE 17	8.5	0.3	0.0	3	46	42	5	3	1	0	S
42 SE 18	0.0	–	–	–	–	–	–	–	–	–	–
42 SE 20	16.0	0.2	3.3	4	87	7	1	1	0	0	S
42 SE 21	11.5	0.0	0.0	4	80	15	1	0	0	0	S
42 SE 22	9.8	0.0	0.0	11	66	10	4	6	3	0	CPS
42 SE 23	9.8	0.2	0.0	2	82	15	1	0	0	0	S
42 SE 24	10.3	0.2	0.0	6	87	5	1	1	0	0	S
42 SE 25	18.0	0.3	0.0	4	85	8	1	1	1	0	S
*Mean	9.9	0.3	1.0	6	76	13	2	2	1	0	S

* Mean thickness calculations take account of a non-IMAU borehole not listed here.

Statistical assessment of all deposits

Area of mineral-bearing ground	15.4 km^2
Mean thickness of overburden	0.4 m
Mean thickness of mineral	9.9 m
Estimated volume of mineral	**152 million m^3**

map shows blown sand over the eastern part of the block but the deposit was not identified in boreholes 42 SE 22 and 25, and 42 SE 23 penetrated only 0.8 m. Consequently the deposit is probably less extensive than indicated, and its thickness and distribution reflect the dune topography. Although no boreholes were sited on the summits of the highest dunes and the maximum thickness proved was only 3.4 m in 42 SE 21, the mean thickness of 1.35 m, calculated from the six boreholes sites on the mapped extent of the blown sand, is considered to be valid. However, because the blown sand is relatively thin, and is similar in grading to the post-Glacial sediments, the two deposits, which constitute all the potentially workable material in the block, have been assessed together. Based on ten IMAU boreholes and one other record, a volume of 152 million $m^3 \pm 36$ per cent is estimated: the mean grading is 6 per cent fines, 91 per cent sand, 3 per cent gravel (sand) (Figure 12).

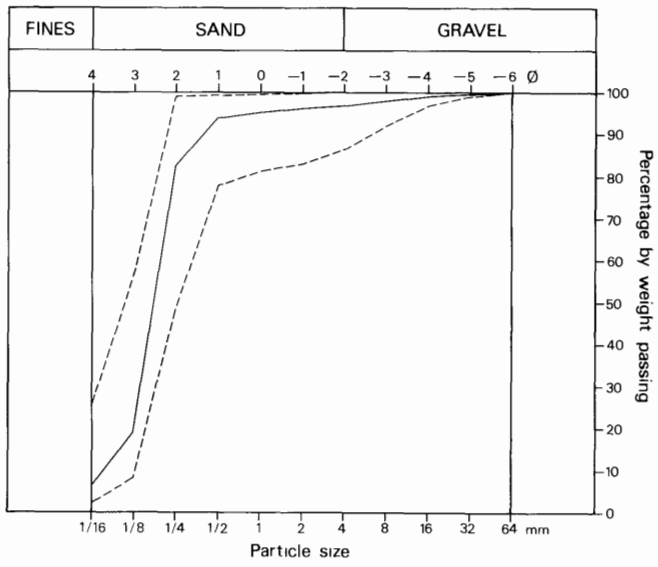


Figure 12 Grading characteristics of resources in block C: the continuous line is the cumulative weighted mean; the broken lines denote the envelope containing the cumulative mean grading for each separately identified deposit proved by boreholes to contain less than 40 per cent fines.

All boreholes proved the base of the post-Glacial deposits and in all but 42 SE 24 (which encountered till) the underlying deposit is late-Glacial marine clay. The late-Glacial marine deposits, although nowhere potentially workable, are thought to grade laterally into fluvioglacial sand near the western margin of the block (section II on map), but there is no information to determine the extent of the latter which, if present within the block, is considered to be volumetrically insignificant. The late-Glacial marine clays range in thickness from 1.6 m in borehole 42 SE 25 to in excess of 12.2 m in 42 SE 14 and 17. Where the full thickness was proved, in boreholes 42 SE 16, 22 and 25, they lie on a stiff, non-mineral till, similar to that proved beneath post-Glacial deposits in borehole 42 SE 24. The till rests on bedrock, although nowhere in the block was this proved. Borehole evidence indicates that the upper surface of the till occurs at higher levels above OD in the north-west and south-east of the block suggesting the existence of a depression trending north-east from around Leuchars. The feature, which was possibly formed by an early outlet of the River Eden in late-Glacial times and subsequently filled by post-Glacial sand and clays, controls the thickness distribution of sand deposits over the block (Figure 14).

Block D

The post-Glacial raised beach deposits and estuarine alluvium north of block C to the Firth of Tay are included in block D. The western limit of post-Glacial deposits or blown sand defines the western margin of the block: the southern boundary is an arbitrary line separating blocks D and C and in the north and east the block extends to the place where present-day beach deposits occur.

Post-Glacial deposits are extensive at the surface in the south-west but have a more restricted outcrop in the north-west. With the exceptions of patches of peat and alluvium, the latter predominantly around Morton Links [46 26], salt marsh deposits near Lundin Bridge [4673 2788], and small bedrock knolls south of Morton [4688 2603], the remainder of the block has blown sand at the surface. Like block C, the topography is generally flat with dune ridges: the east is largely covered by Tentsmuir forest.

Fluvioglacial sands occur to the west of block C whereas to the west of block D till lies beneath a thin cover of late-Glacial raised beach deposits. The fluvioglacial sands were easily eroded by the post-Glacial sea resulting in a much more steeply dipping base to the post-Glacial deposits near their western margin in the south compared to the north. The thickness of post-Glacial deposits in block D ranges from 4.3 m at borehole 42 NE 12, near the western margin, to 22.9 m at 42 NE 16 in the north-east (Table 11). As in block C there is generally an upper deposit which grades as sand, more fine grade material occurring at depth. At borehole 42 NE 10 the upper 2.0 m of the post-Glacial sediments are pebbly as is the whole 4.3 m of the post-Glacial sequence at 42 NE 12, both possibly reflecting a contribution from the reworking of the till to the west. One metre of 'clayey' sand and two metres of clay overlie pebbly sand in borehole 42 SE 15; it is likely these were deposited in tidal channels at the maximum of the post-Glacial transgression (Chisholm, 1971).

Finer-grained post-Glacial deposits occur at depth in all boreholes except 42 NE 12, 15 and 16 in which pebbly sand or sand lies directly on late-Glacial marine deposits. The lower post-Glacial sediments comprise clay, silt, 'very clayey' sand and 'clayey' sand, with sand beds up to 1.7 m thick in borehole 42 SE 19. Clays and silts, which have a maximum thickness of 10.5 m in borehole 42 NE 13, were also proved in boreholes 42 NE 10, 11, SE 15 and 19, all in the western part of the block, where, with the exception of borehole 42 SE 15, they are interbedded with sandier material, the buried deposits grading as mineral. However, in borehole 42 SE 19 the lower deposit is not potentially workable because of excessive overburden.

The potentially workable part of the post-Glacial deposits increases in thickness eastwards from 3.8 m, 4.3 m and 4.5 m in boreholes 42 SE 19, NE 12 and SE 15 respectively to 21.8 m and 22.9 m in boreholes 52 NW 1 and 42 NE 16. The increase is due to both the thickening of the post-Glacial deposits as a whole and to a decrease in the proportion of clays and silts at depth.

Table 11 Block D: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral	Depth of burial	Intervening waste	Fines $-\frac{1}{16}$	Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$	Medium sand $+\frac{1}{4}$	Coarse sand	Fine gravel	Coarse gravel	Cobbles and boulders	Descriptive category (see the diagram in Appendix C)
	m	m	m	mm	mm	−1 mm	+1 −4 mm	+4 −16 mm	+16 −64 mm	+64 mm	
ALL DEPOSITS											
42 NE 10	8.2	0.4	3.6	13	80	5	1	0	1	0	CS
42 NE 11	11.3	0.2	4.0	7	84	9	0	0	0	0	S
42 NE 12	4.3	0.4	0.0	5	54	27	7	6	1	0	PS
42 NE 13	14.0	0.5	10.5	4	91	2	0	1	1	0	S
42 NE 14	22.1	0.0	0.0	14	78	6	0	0	2	0	CS
42 NE 15	21.5	0.2	0.0	4	77	17	1	1	0	0	S
42 NE 16	23.9	0.1	0.0	4	58	35	1	1	1	0	S
42 SE 15	5.5	0.5	2.0	7	45	35	4	3	6	0	PS
42 SE 19	9.9	0.2	0.0	2	92	6	0	0	0	0	S
52 NW1	21.8	0.2	0.0	7	59	33	1	0	0	0	S
*Mean	14.1	0.3	2.0	7	71	19	1	1	1	0	S

* Mean thickness calculations take account of non-IMAU boreholes not listed here.

Statistical assessment of all deposits

Area of mineral-bearing ground	19.2 km^2
Mean thickness of overburden	0.3 m
Mean thickness of mineral	14.1 m
Estimated volume of mineral	**271 million m^3**

Thin gravel partings were found within sand beds at all borehole sites. Boreholes 42 NE 13, 14 and 52 NW 1 failed to prove the full post-Glacial sequence, but of the seven which did a basal gravelly layer was found in 42 NE 15, 16, SE 15 and 19; in 42 SE 19, cobbles up to 11 cm in diameter were recovered. Nowhere are the gravel partings or basal layer thick enough to constitute a separate resource.

Boreholes 42 NE 11, 13, 14, 15, 16, SE 19 and 52 NW 1 were sited on ground mapped as blown sand: all but boreholes 42 NE 11 and 52 NW 1 proved the deposit which ranges up to 6.1 m thick at 42 SE 19. In addition 2.2 m were found at borehole 42 NE 10, just outside the mapped extent of blown sand. The deposit everywhere grades as sand and, based on all eight boreholes, has a mean thickness of 2.8 m, a little higher than in block C, reflecting an increase in the amplitude of dunes within Tentsmuir forest.

Blown sand and post-Glacial deposits constitute the potentially workable material within the block and, as in block C, they are assessed together. Based on ten IMAU and four other IGS boreholes, the volume is estimated at 271 million m^3 ± 36 per cent, the mean grading is 7 per cent fines, 91 per cent sand, 2 per cent gravel (sand) (Figure 13). Table 7 shows that, although the deposits of block D are thicker than those of block C, both the mean gradings and the limits at the 95 per cent probability level are very similar. The latter is a measure of the lateral variability in thickness of the mineral and, considered with the grading, shows the potentially workable material of the two blocks to be part of the same deposit, the sediments in block D representing the continued north-eastward thickening observed to the south.

Five of the seven boreholes which bottomed the post-Glacial sediments proved the deposit to rest on late-Glacial marine clays which, where their full thickness was penetrated, range from 2.1 m in borehole 42 NE 15 to 9.0 m in 42 SE 15. Boreholes 42 NE 10 and 11 show the post-Glacial deposits to be underlain by till and bedrock respectively. Drift thickness is least in the west of the block, bedrock cropping out south of Morton and being proved at depths ranging from 14.3 m to 21.2 m in boreholes 42 NE 11, 12 and SE 15. Rock is overlain by till in boreholes 42 NE 12 and SE 15 and this relationship is also considered to exist at boreholes 42 NE 10 and 15 which terminated in till. The till is generally a stiff clay but in borehole 42 SE 15 the basal 1.2 m contains sufficient clasts to grade as gravel, although it is not mineral because of excessive overburden.

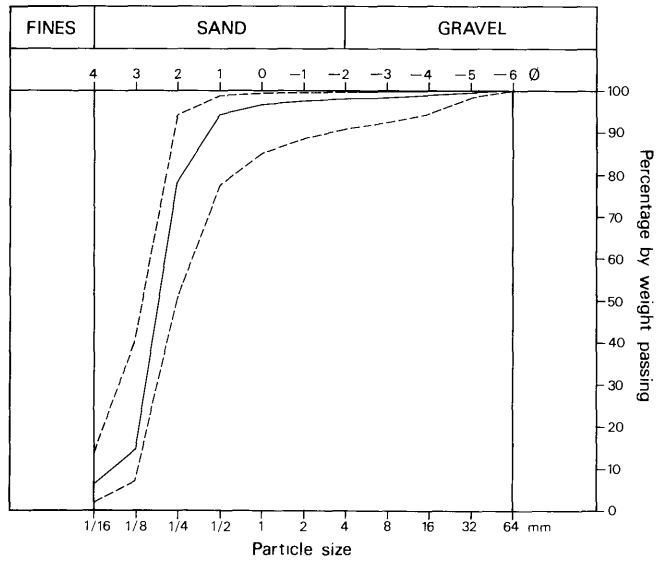


Figure 13 Grading characteristics of resources in block D (for explanation see Figure 12).

Block E

All the ground to the south of the Firth of Tay not embraced by blocks A to D is included in block E. The land surface is generally higher than in the other blocks and rock is exposed, or buried by only a thin cover of till (sections I and II on map): it is dissected in the south-west by the valleys of both the Motray Water and its tributary, the Cleughie Burn, and in the north-west by the Wormit gap.

Till which was found in all boreholes, except 42 NW 27 where rock was proved within 1 m of the surface, ranges in thickness from 0.7 m in borehole 42 NW 25 to 11.2 m in 42 NE 8, the higher values occurring beneath the lower ground both to the east and in the valley of the Motray Water. Compositionally the deposit is generally a stiff clay, locally sandy, but in boreholes 32 SE 7, 42 NW 28 and 42 NE 8 and pit 42 NW 31 it contains sufficient clasts to grade as mineral varying from gravel to 'very clayey' sandy gravel, and having a maximum potentially workable thickness of 8.1 m in borehole 42 NE 8. The deposit in borehole 32 SE 7 grades as gravel but is classified as non-mineral because of the thickness of overburden. Of the total thickness of till penetrated in boreholes, namely 43.6 m, 21 per cent is mineral and, although this is probably representative of the block as a whole, the greater part of the potentially workable material is likely to occur within a restricted but undefined area in the east. There is insufficient information as to its lateral extent to make a volumetric assessment of mineral till.

Small patches of glacial sand and gravel, ranging up to about 0.2 km^2 east of Newport-on-Tay, are found in the northern part of the block, principally between Balmerino [358 247] and Newton [4008 2456], and in the vicinity of Wormit. Only the deposit east of Newport-on-Tay has been investigated, borehole 42 NW 25 proving 8.1 m of sandy gravel similar in composition and lithology to the glacial sand and gravel in block A (Table 12).

An inferred assessment for the deposit is 1.7 million m^3 (Table 7). Similar material was proved within one of the smaller glacial sand and gravel patches by pit 32 SE 9, but as this did not reach the base of the deposit no assessment is possible. Although glacial sand and gravel was not investigated elsewhere in the block the deposit is considered to be homogeneous and formed in an ice-marginal environment. The unassessed glacial sand and gravel is considered to be volumetrically small.

Late-Glacial marine deposits were proved within the valleys of the Motray Water and Cleughie Burn, both at surface on the valley sides (borehole 32 SE 7, pits 32 SE 10 and 11) and beneath the alluvium of the valley bottom (boreholes 32 SE 5 and 42 SW 9). The deposits range in thickness from 1.1 m at pit 32 SE 11 to 13.8 m in borehole 42 SW 9 and generally comprise reddish brown clays, with silt and sand partings, from which foraminifera were recovered in samples from borehole 32 SE 5. Within the clay at borehole 42 SW 9 a 0.3 m bed of gravel was proved. At borehole 32 SE 5 the upper 1.0 m of the late-Glacial marine deposit grades as 'clayey' pebbly sand and is mineral, but 100 m to the north-west pit 32 SE 10 shows the sand to be only 0.4 m thick and potentially workable material is therefore considered to be restricted to the central part of the valley of the Cleughie Burn: there is insufficient information on areal extent for the deposit to be assessed.

South-east of Balmullo, boreholes, 42 SW 16 and 20 and pit 42 SW 32 found till but generally the area is underlain by late-Glacial marine deposits (pits 42 SW 29, 30, 34, 35, 36, 37 and 38) and has been mapped as such; isolated deposits of fine sand, lithologically identical to the fluvioglacial deposits, were proved in pits 42 SW 26 and 31. Although pit 42 SW 26 proved 1.8 m of potentially workable sand, no assessment has been attempted as neither the full depth of the deposit nor its lateral extent is known: the sand is probably an estuarine channel infill and of very restricted extent.

Late-Glacial raised beach deposits are most

Table 12 Block E: Data from sample points and the assessment of resources.

Sample point	Recorded thickness			Mean grading percentage							Descriptive category (see the diagram in Appendix C)
Borehole	Total mineral	Depth of burial	Intervening waste	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 and boulders $+64$ mm	
	m	m	m								
ALL DEPOSITS											
32 SE 5	1.0	1.5	0.0	19	58	12	6	4	1	0	CPS
32 SE 7	0.0	–	–	–	–	–	–	–	–	–	–
42 NW 25	8.1	0.9	0.0	8	27	20	11	15	13	6	SG
42 NW 26	2.0	0.6	0.0	33	48	13	4	1	1	0	VCS
42 NW 27	0.0	–	–	–	–	–	–	–	–	–	–
42 NW 28	1.0	2.2	0.0	13	16	23	24	18	6	0	CSG
42 NE 8	9.1	0.6	0.0	18	25	21	10	13	11	2	CSG
42 SW 9	0.0	–	–	–	–	–	–	–	–	–	–
42 SW 12	0.0	–	–	–	–	–	–	–	–	–	–
42 SW 16	0.0	–	–	–	–	–	–	–	–	–	–
42 SW 20	0.0	–	–	–	–	–	–	–	–	–	–
42 SE 11	1.9	0.6	0.0	17	58	24	0	1	0	0	CS

Inferred assessment of the late-Glacial beach deposits north of Craigie

Area of mineral-bearing ground	3.3 km^2
Mean thickness of mineral	1.5 m
Estimated volume of mineral	**4.8 million m^3**

Inferred assessment of glacial sand and gravel east of Newport-on-Tay

Area of mineral-bearing ground	0.2 km^2
Mean thickness of mineral	8.1 m
Estimated volume of mineral	**1.7 million m^3**

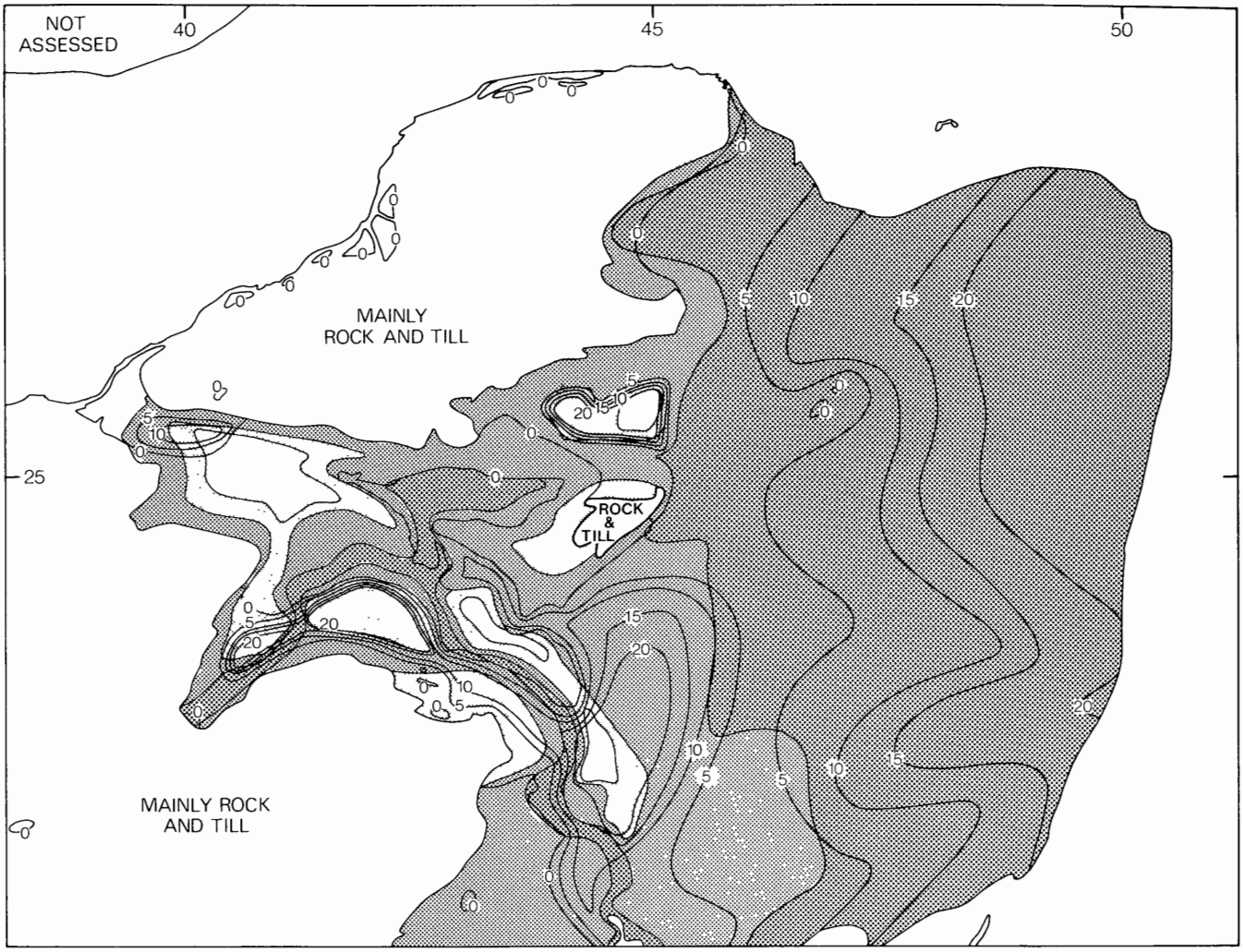
widespread north of Craigie [4535 2425]; they also occur sporadically along the northern coast where they generally form benches about 50 m wide but are more extensively developed around Newport-on-Tay, south-west of Wormit, and at Balmerino.

North of Craigie boreholes 42 NE 8 and 42 SE 11 proved 1.0 m of 'very clayey' pebbly sand and 1.9 m of 'clayey' sand respectively, considered to be late-Glacial raised beach deposits, overlying till. On the basis of these two boreholes the late-Glacial raised beach, throughout its extent from Craigie to Tayport and including two disconnected fragments at [444 273] and [454 284] is considered to be a depositional feature. An inferred assessment for this deposit, with an areal extent of 3.3 km^2, is 4.8 million m^3.

The late-Glacial beach deposits of the north coast were only investigated by pit 42 NW 33 which proved in excess of 1.2 m of gravel. Although the base of the deposit was not reached, the narrow bench morphology of the features, usually cut in rock or till, suggests the sediments are unlikely generally to exceed 2 m in thickness, though 2.4 m of late-Glacial beach deposits, principally gravel, were exposed in a temporary section [3940 2598]. Field evidence indicates that the deposits are predominantly gravelly and all the late-Glacial beaches of the north coast are considered therefore to be underlain by potentially workable material. There are insufficient thickness data to justify an assessment of volume, which is likely, however, to be small. The temporary section [3940 2598], close to the margin of block A, showed that beach deposits overlie red fluvioglacial sand. The latter deposit, although the north-westward continuation of that in block A, has been included in block E and not assessed, as there is no information as to its areal extent beneath the beach deposits. However, as neither the area nor the thickness of buried fluvioglacial sand is considered great, the volume in question is small.

The narrow raised beaches of both post-Glacial and uncertain age are found along the north coast between the Tay Road Bridge and Tayport. The former feature was investigated by pit 42 NW 32 which proved 0.4 m of beach sand although the base of the deposit was not reached. However, it is considered that, although thin, the deposit is mineral but there are insufficient thickness data for a volumetric assessment to be made. In the extreme south-east of the block there are three small patches of post-Glacial deposits; they have not been investigated or assessed but are likely to be thin potentially workable sand.

Borehole 42 NW 26 sited on ground mapped as till in the valley of the Scotscraig Burn proved 2.0 m of 'very clayey' sand on till beneath a gravelly soil. The sand is considered too thick a deposit to be the alluvium of a stream as small as this and to be more likely the product of hillwash, either of recent origin or formed by solifluxion in a periglacial climate after the retreat of ice; it has been classified as hillwash in the borehole log. Although patches of alluvium floor many of the valleys of small streams throughout the block, the only extensive deposit borders the Motray Water and its tributary the Cleughie Burn. Boreholes 32 SE 5 and 42 SW 9 penetrated clay and silt ranging from 0.7 m thick in the former to 2.0 m in the latter; nowhere is alluvium considered potentially workable. Near Naughton House [3724 2463] an area of lake alluvium was investigated by pit 32 SE 8 which proved 1.7 m of clay; a cobble layer was found at the base of the pit but whether this is a basal deposit or interbedded with the clay is not known.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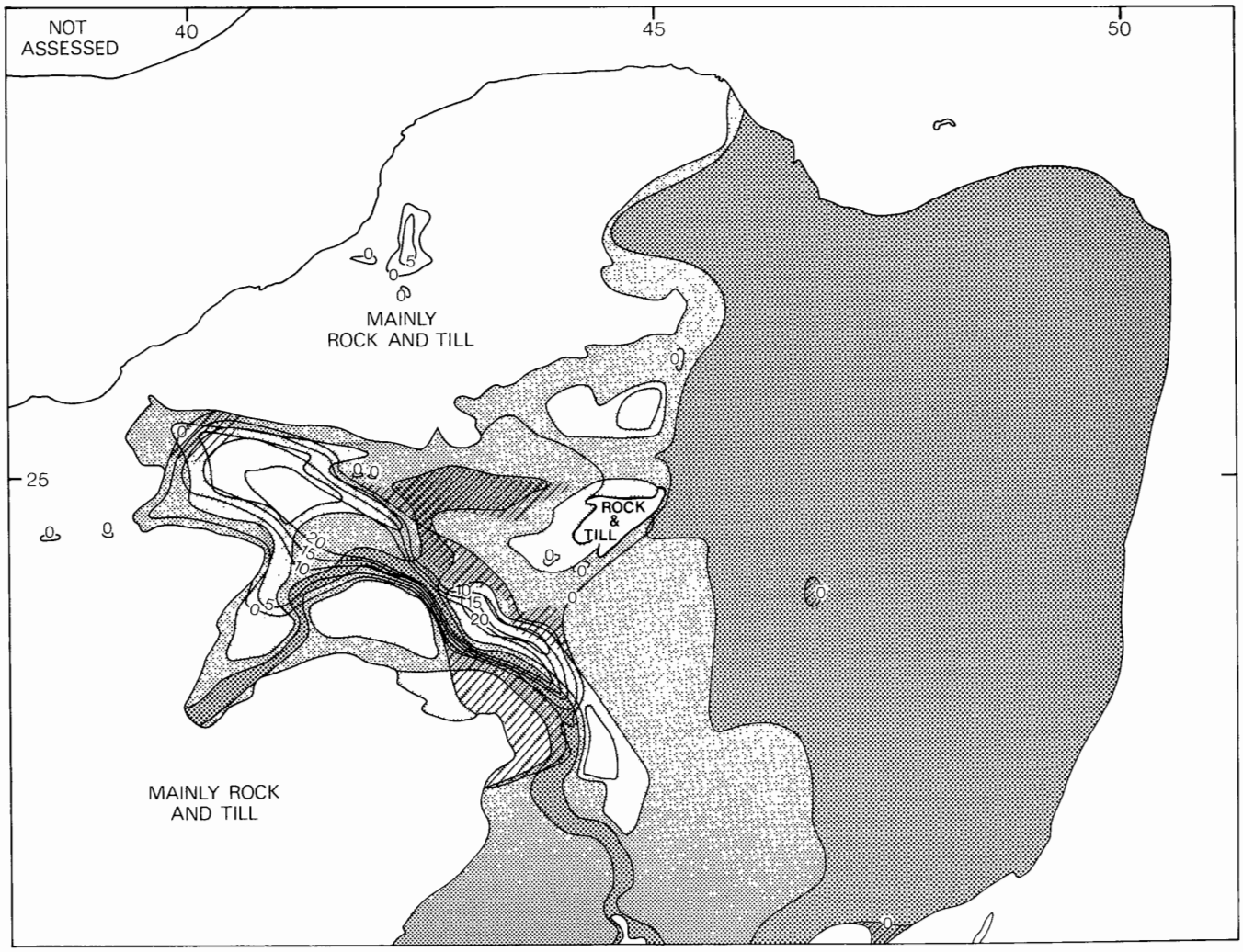
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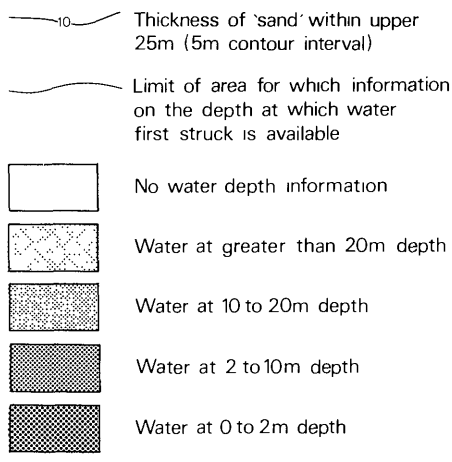


Figure 14 (*opposite, above*) Sand and pebbly sand deposits: thickness isopleths and depth to water in the drift deposits.

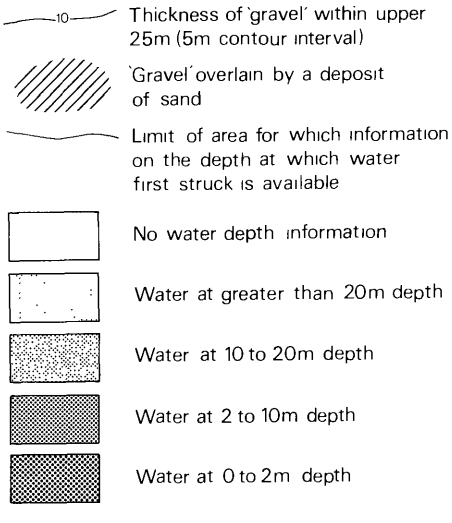


Figure 15 (*opposite, below*) Gravel and sandy gravel deposits: thickness isopleths and depth to water in the drift deposits.

CONCLUSIONS

The sand and gravel resources of the survey area have been described systematically. Statistical volumetric assessments for blocks A to D are given in Table 7 along with the mean grading data for the blocks as a whole. In addition, for blocks A and B, the volume of the most significant deposit within those blocks is estimated. The resources in block E are both much smaller than in the other blocks and occur in discontinuous patches; inferred assessments are offered for the two biggest deposits (Table 7), other occurrences only being briefly described. It must be remembered that the volumes given take no account of present land-use factors which may greatly militate against the exploitation of parts of the resource.

However, two geological factors are important when considering the usefulness of the deposits within the area. The first of these is the ratio of sand to gravel, and Figures 14 and 15 show isopleths on that part of the mineral within 25 m of the surface for which, respectively, the sand to gravel ratio is greater than 3:1, and that for which the sand to gravel ratio is less than 3:1. Figure 14, therefore, shows the thickness of sand or pebbly sand and Figure 15 the thickness of gravel or sandy gravel, independent of fines content, which is generally low and not considered to be a major factor affecting the usefulness of the deposits. The isopleths refer to the total thickness of sand or gravel within 25 m of the surface, and take no account of the relative position of potentially workable material within the drift: however, where sand occurs it is everywhere the uppermost mineral deposit. Gravel, on the other hand, is locally buried by sand and the inferred area over which this occurs is indicated in Figure 15.

The second factor, the depth below surface at which water was first struck in assessment boreholes drilled between June and August 1979, is illustrated in Figures 14 and 15 by tones of stipple. Information on water depth is not given for ground where till or rock occurs at the surface.

Figure 15 shows that block A contains most of the gravel or sandy gravel within the resource sheet area and much of it lies above the water table and might be worked dry; within the survey area the most extensive sand and gravel pits all lie in this block.

The remainder of the resources within the area are predominantly sand, but Figure 14 shows that the deposits of block B are distinct from those of blocks C and D in that the thickest deposits which can be worked dry are in the flat-topped hills within block B. These deposits were being exploited in 1980 by a pit which was being worked back into the steep northern face of North Straiton Hill. Pits, now abandoned, worked the thinner deposit west of Burnside. The sand in blocks C and D is of marine origin and has a high shell content. This factor, together with a water level generally within 2 m of the surface and extensive commercial afforestation, suggests that these resources may be less immediately attractive than those in block B.

A series of mechanical and physical tests was carried out on samples of the gravels of block A. These show the aggregate strength to be about average for gravels for Scotland; the water absorption values range from 1.5 per cent to 2.0 per cent and suggest an inferred concrete drying shrinkage of 0.06 per cent to 0.07 per cent, within the category defined as being suitable, with qualification, for most applications.

APPENDIX A

FIELD AND LABORATORY PROCEDURES

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

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

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

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

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

A continuous series of bulk samples is taken throughout the sand and gravel. Ideally samples are composed exclusively of the whole of the material encountered in the borehole between stated depths. However, care is taken to discard, as far as possible, material which has caved or has been pumped from the bottom of the hole. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel, or at every 1 m (3.3 ft) depth. The samples, each weighing between 25 and 45 kg (55 and 100 lb), are despatched in heavy duty polythene bags to a laboratory for grading. The grading procedure is based on British Standard 1377 (1967). Random checks on the accuracy of the grading are made in the laboratories of the Industrial Minerals Assessment Unit.

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.

APPENDIX B

STATISTICAL PROCEDURE

Statistical assessment

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

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

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

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

4 The above relationship may be transposed such that

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

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

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

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

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

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

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

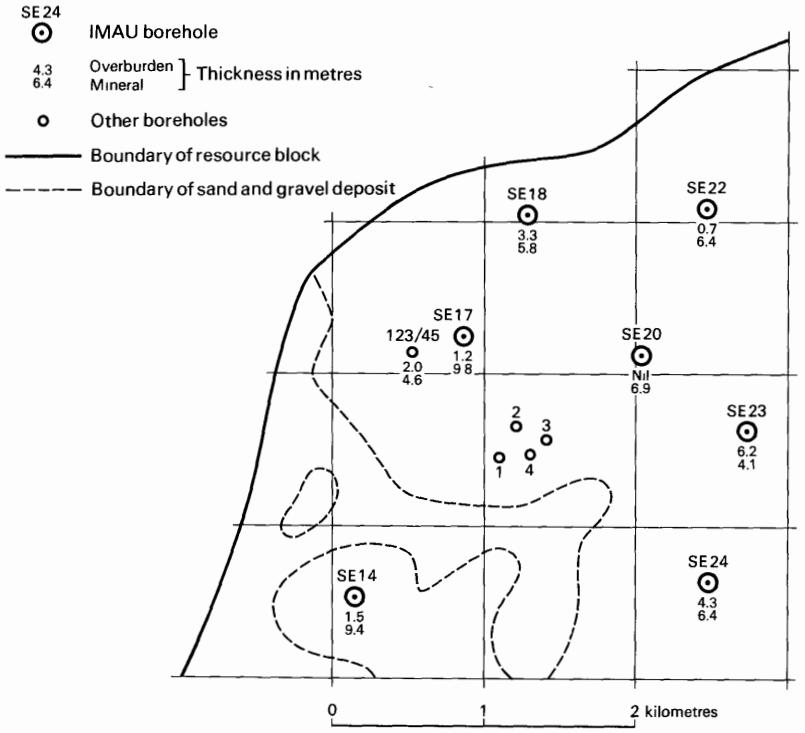
where l_m is any value in the series l_{m_1} to l_{m_n}.

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

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

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

Example of resource block assessment: map of fictitious block, calculation and results.



Block calculation

1:25 000 block: Fictitious

Area
Block: 11.08 km^2
Mineral: 8.32 km^2

Mean thickness
Overburden: 2.5 m
Mineral: 6.5 m

Volume
Overburden: 21 million m^3
Mineral: 54 million m^3

Confidence limits of the estimate of volume at the 95 per cent probability level: ±20 per cent
That is, the volume of mineral (with 95 per cent probability): 54±11 million m^3

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

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

Calculation of confidence limits

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

$\Sigma(wl_m - \overline{wl_m})^2 = 15.82$
$n = 8$
t = 2.365

L_V is calculated as

$$1.05(t/\overline{wl_m})\sqrt{(\Sigma(wl_m - \overline{wl_m})^2/n(n-1)]} \times 100$$
$$= 1.05 \times (2.365/6.5)\sqrt{[15.82/(8 \times 7)]} \times 100$$
$$= 20.3$$
$$\simeq 20 \text{ per cent}$$

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

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

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

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

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

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

and when n is greater than 20, as

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

(weighting factors may be included: see paragraph 15).

11 The application of this procedure to a fictitious area is illustrated.

Inferred assessment

12 If the sampled area of mineral in a resource block is between 0.2 km^2 and 2 km^2 an assessment is inferred, based on geological and topographical information usually supported by the data from one or two boreholes. The volume of mineral is calculated as the product of the area, measured from field data, and the estimated thickness. Confidence limits are not calculated.

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

14 No assessment is attempted for an isolated area of mineral less than 0.2 km^2.

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

APPENDIX C

CLASSIFICATION AND DESCRIPTION OF SAND AND GRAVEL

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

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

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

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

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

Thus it is possible to classify the mineral into one of twelve descriptive categories (see the figure at the end of this Appendix). The procedure is as follows:

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

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

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

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, 1975), 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.

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

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

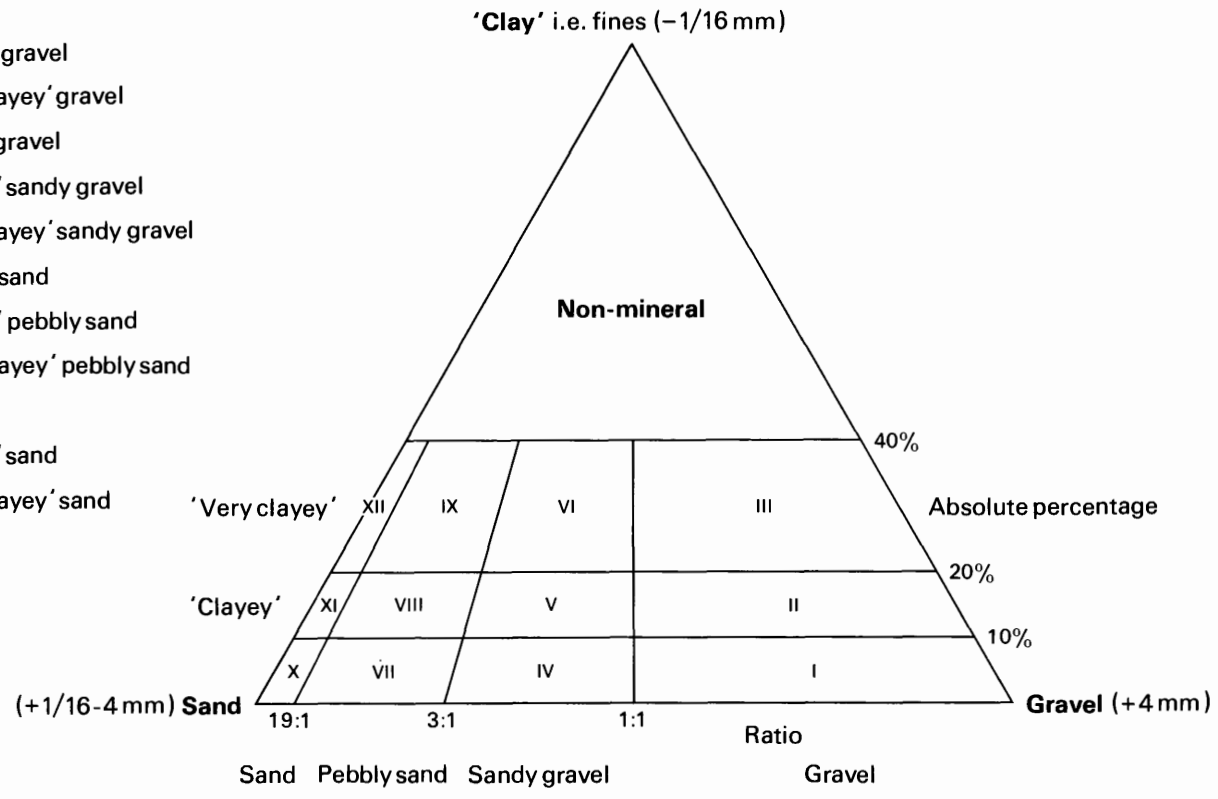


Diagram to show the descriptive categories used in the classification of sand and gravel.

APPENDIX D

EXPLANATION OF THE BOREHOLE RECORDS

Annotated example

NO 42 SW 19[1] 4365 2204[2] Southfield, Leuchars[3] BLOCK B

Surface level + 32.0 m (+ 105 ft)[4]
Water struck at + 14.9 m[5]
250 mm and 200 mm percussion[6]
August 1979

Overburden[7] 0.2 m
Mineral 6.8 m
Waste 11.0 m
Mineral 5.8 m
Waste 0.5 m
Bedrock 0.2 m + [9]

LOG

Geological classification	Lithology	Thickness[8] m	Depth m
	Soil, sandy	0.2	0.2
Fluvioglacial sand and gravel[10]	a Sand[11] Gravel: principally above 1.0 m, fine with coarse, angular to well rounded, quartzite, felsite and sandstone Sand: fine with medium, angular to subangular, quartz, with feldspar and rock fragments, orange-brown Fines: silt, disseminated, and in bands from 2.2 m to 3.2 m	4.0	4.2
Glacial sand and gravel	b Gravel Gravel: coarse with fine and, above 6.0 m, cobbles up to 10 cm diameter, angular to well rounded, quartzite and basalt with red sandstone, felsite, quartz, schist, diorite, tuff and granodiorite Sand: coarse with fine and medium, subrounded to angular, rock fragments and quartz Fines: clay, disseminated, red-brown, locally binding the deposit	2.8	7.0
Till	Clay, very stiff, red-brown, silty and sandy, the latter principally from 11.5 to 13.0 m although sand bands occur below 14.5 m, with angular to well rounded clasts up to 15 cm diameter of basalt with andesite and felsite and, above 11.5 m, quartzite, quartz, and rare gabbro	8.0	15.0
	c 'Very clayey' pebbly sand Gravel: fine with coarse, basalt with andesite and felsite Sand: fine with medium Fines: clay, disseminated, red-brown	1.2	16.2
	Clay, silty with sandy bands and rare clasts of basalt, andesite and felsite	1.8	18.0
	d Pebbly sand Gravel: fine with coarse and, below 20.8 m, cobbles up to 10 cm diameter, angular to rounded, basalt and andesite with quartz, felsite, quartzite and rare volcanic breccia Sand: fine with medium and coarse, angular to subangular with subrounded to rounded, rock fragments with quartz and feldspar Fines: clay, disseminated, red-brown, rare clay-bound lumps recovered. Much of the fines have been lost during drilling	5.8	23.8
	Clay, stiff, red-brown, locally blue-grey, with sandy bands and fine gravel grade clasts of composition as above	0.5	24.3
Lower Devonian	Andesite, poorly developed grain size and colour banding, subhedral feldspar phenocrysts up to 5 mm, pinkish grey, very hard	0.2+	24.5

(continued .....)

GRADING

	Mean for deposit[15] percentages			Depth below surface (m)[12]		percentages[13]							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	5	92	3	0.2	1.0	2	30	46	10	7	5	0	
				1.0	2.2	4	73	21	1	1	0	0	
				2.2	3.2	6	54	40	0	0	0	0	
				3.2	4.2	8	65	25	1	1	0	0	
				Mean		5	58	32	2	2	1	0	
b	7	28	65	4.2	5.3	8	10	9	13	21	29	10	
				5.3	6.0	6	6	6	11	26	35	10	
				6.0	7.0	7	7	7	12	28	39	0	
				Mean		7	8	8	12	25	34	6	
c	28	55	17	15.0	16.2	28	36	14	5	10	7	0	‡[16]
d	5	73	22	18.0	19.0	5	19	20	20	27	9	0	†[14]
				19.0	19.9	6	42	26	8	12	6	0	†
				19.9	20.8	4	38	31	10	9	8	0	†
				20.8	21.8	1	44	20	7	12	6	10	†
				21.8	23.1	8	34	25	14	17	2	0	†
				23.1	23.8	5	29	47	10	8	1	0	†
				Mean		5	34	27	12	15	5	2	
a,b&d	5	69	26	Mean		5	36	24	9	13	11	2	

C

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 or shallow pit is identified by a registration number. This consists of two statements.

1 The number of the 1:25 000 sheet on which the borehole lies, for example NO 42

2 The quarter of the 1:25 000 sheet on which the borehole lies and its number in a series for that quarter, for example SW 19.

Thus the full registration number is NO 42 SW 19.
Usually this is abbreviated to 42 SW 19 in the text.

2 The National Grid reference
All National Grid references in this publication lie within the 100-km square NO. Grid references are given to eight figures, accurate to within 10 m for borehole locations. (In the text, six-figure grid references are used for more approximate locations, for example, for quarries.)

3 Location
The position of the borehole is referred to the nearest named locality on the 1:25 000 base map, usually followed by the name of the parish. The resource block in which it lies is also stated.

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

5 Groundwater conditions
If ground water was present the level at which it was either encountered or statically measured is normally given (in metres above Ordnance Datum).

6 Type of drill and date of drilling
Modified shell and auger rigs were used in this survey. The drilling method, the external diameter of the casing used, and the month and year of completion of the borehole are stated.

7 Overburden, mineral, waste and bedrock
Mineral is sand and gravel which, as part of a deposit, falls within the arbitrary definition of potentially workable material (see p. 1). The summary of mineral thicknesses may include waste partings: the aggregated waste thickness is given in brackets and has been excluded in the assessment of resources. Consequently mineral thicknesses given in Tables 8 to 12 may not correspond precisely with the logs. Bedrock is the 'formation', 'country rock' or 'rock head' below which potentially workable sand and gravel will not be found. Waste is any material other than bedrock or mineral. Where waste occurs between the surface and mineral it is classified as overburden.

8 Thickness and depth
All measurements were made in metres.

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

10 Geological classification
The geological classification is given whenever possible. For economy of space the terms post-Glacial raised beach deposits and estuarine alluvium, and late-Glacial raised beach deposits and estuarine alluvium are abbreviated in the logs. The former is shown as post-Glacial deposits: the latter as late-Glacial beach deposits.

11 Lithological description
When sand and gravel is recorded a general description based on the mean grading characteristics (for details see Appendix C) is followed by more detailed particulars. The description of other rocks is based on visual examination, in the field.

12 Sampling
A continuous series of bulk samples is taken through the thickness of sand and gravel. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel or at every 1 m of depth.

13 Grading results
The results are expressed as per cent by weight retained on British Standard sieves whose aperture sizes are given in millimetres or fractions therefor.

14 Bailed samples
Fully representative sampling of sand and gravel is difficult to achieve, particularly where groundwater levels are high. Comparison between boreholes and adjacent exposures suggests that in borehole samples the proportion of sand may be higher and the proportions of fines and coarse gravel (+16 mm) may be lower. Samples obtained by the bailing technique (that is, from deposits below the water table) are indicated thus:†

15 Mean grading
The grading of the full thickness of the mineral deposit identified in the log is the mean of the individual sample gradings weighted by the thicknesses represented. The classification used is shown in the Table in Appendix C. Where two or more distinct mineral units form continuous sequences, the mean gradings of these are also given under each unit.

16 Samples with less than 40 per cent by weight passing $\frac{1}{16}$ mm, but not considered in the calculation of mean grading, are indicated thus:‡. These samples either are considered non-mineral owing to the amount of overburden or form small parts of sequences regarded as generally unworkable. The same symbol is also used when there are grading data available for samples taken from sites at which the full thickness of mineral was not proved.

APPENDIX E

LIST OF BOREHOLES AND SHALLOW PITS USED IN THE ASSESSMENT OF RESOURCES

Borehole*	Grid reference
1 INDUSTRIAL MINERALS ASSESSMENT UNIT BOREHOLES	
NO 32 NE	
20	3971 2524
NO 32 SE	
5	3819 2126
6	3982 2460
7	3907 2200
NO 42 NW	
23	4026 2542
24	4134 2537
25	4238 2739
26	4369 2799
27	4316 2704
28	4462 2769
29	4480 2635
30	4439 2544
NO 42 NE	
8	4545 2654
9	4500 2582
10	4654 2713
11	4653 2640
12	4617 2579
13	4785 2725
14	4845 2628
15	4870 2512
16	4933 2814
NO 42 SW	
7	4079 2386
8	4090 2324
9	4006 2243
10	4131 2461
11	4160 2352
12	4100 2181
13	4243 2491
14	4293 2410
15	4271 2343
16	4253 2007
17	4399 2466
18	4308 2314
19	4365 2204

Borehole	Grid reference
NO 42 SW	
20	4332 2095
21	4475 2188
22	4422 2186
23	4419 2047
NO 42 SE	
11	4545 2437
12	4501 2371
13	4508 2329
14	4578 2010
15	4628 2482
16	4666 2372
17	4648 2218
18	4654 2083
19	4726 2444
20	4792 2251
21	4709 2166
22	4729 2012
23	4850 2311
24	4838 2143
25	4974 2320
NO 52 NW	
1	5034 2667

Pit*†	Grid reference
2 INDUSTRIAL MINERALS ASSESSMENT UNIT PITS	
NO 32 SE	
8	3761 2449
9	3841 2435
10	3813 2134
11	3953 2198
NO 42 NW	
31	4049 2626
32	4323 2910
33	4325 2904
34	4451 2600
NO 42 NE	
17	4526 2615
NO 42 SW	
24	4291 2364
25	4268 2103
26	4297 2049
27	4341 2336
28	4382 2324
29	4358 2160
30	4337 2130
31	4375 2128
32	4348 2108
33	4392 2078
34	4380 2058
35	4343 2049
36	4402 2014
37	4350 2006
38	4388 2004
39	4461 2429
40	4482 2419
41	4428 2397
42	4403 2349
NO 42 SE	
26	4544 2413
27	4503 2412
28	4513 2408
29	4540 2396
30	4621 2122
31	4664 2120

* By sheet quadrant.
† Shallow pits dug by excavator.

APPENDIX F

INDUSTRIAL MINERALS ASSESSMENT UNIT

BOREHOLE AND SHALLOW PIT RECORDS

NO 32 NE 20 3971 2524 Newton Park, Forgan BLOCK A

Surface level + 40.3 m (+ 132 ft)
Water not struck
250 mm percussion
August 1979

Overburden 0.2 m
Mineral 5.4 m
Waste 2.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	'Clayey' sand Gravel: most abundant below 3.7 m, fine with coarse and cobbles up to 8 cm diameter, subangular to well rounded, red and white sandstones, basalt and quartz with felsite Sand: fine with medium, angular to subrounded, quartz with rock fragments in the coarser fractions Fines: silt, disseminated, orange-brown, with reddish brown clayey silt bands which become grey, thicker, and more numerous below 4.7 m	5.4	5.6
Till	Clay, moderately stiff, brown, sandy near the top, with subangular to well rounded clasts, becoming more angular below 7.0 m, of basalt with quartzite, quartz, felsite, schist, psammite, chert and andesite	2.4+	8.0
	Borehole terminated owing to boulder obstruction		

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages						
Fines	Sand	Gravel			Fines	Sand			Gravel		
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
12	84	4	0.2	1.2	12	57	25	6	0	0	0
			1.2	2.2	10	54	25	7	4	0	0
			2.2	3.7	9	74	13	2	2	0	0
			3.7	4.7	10	39	37	7	6	1	0
			4.7	5.6	22	51	14	3	4	0	6
			Mean		12	57	22	5	3	0	1

NO 32 SE 5 3819 2126 Cleughie Burn, Kilmany BLOCK E

Surface level + 23.6 m (+ 77 ft)
Water struck at +22.3 m
250 mm percussion
August 1979

Overburden 1.5 m
Mineral 1.0 m
Waste 8.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Clay, locally sandy with rare subrounded clasts up to 5 cm diameter of andesite and basalt	0.7	1.0
Peat	Peat, locally clayey	0.5	1.5
Late-Glacial marine deposits	'Clayey' pebbly sand Gravel: fine with coarse up to 3 cm diameter, subangular to subrounded, andesite and basalt with quartz and quartzite and rare schist and sandstone Sand: fine with a little medium and coarse, quartz Fines: silt, disseminated	1.0	2.5
	Clay, stiff, brown, sandy above 3.5 m, sand laminae throughout but becoming rarer with depth	6.9	9.4
Till	Clay, sandy, brown, subangular to angular clasts of andesite with, above 10.3 m, sandstone, quartz, quartzite with rare metamorphic rocks	1.2+	10.6
	Borehole terminated owing to slow progress		

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
19	76	5	1.5	2.5	19	58	12	6	4	1	0	†

NO 32 SE 6 3982 2460 Newton, Forgan BLOCK A

Surface level + 30.2 m (+ 99 ft)
Water struck at + 24.4 m
250 mm percussion
July 1979

Overburden 1.5 m
Mineral 6.2 m
Waste 4.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	1.5	1.5
Glacial sand and gravel	Gravel Gravel: fine and coarse with cobbles, principally above 4.5 m, up to 14 cm diameter, subangular to well rounded, andesite, basalt, dolerite, felsite and quartzite with sandstone, gneiss and schist Sand: fine to coarse, angular to subangular, quartz Fines: silt, disseminated	6.2	7.7
Till	Clay, very stiff, dark grey to greyish brown, with angular to subangular clasts up to 14 cm diameter of andesite with rare quartzite and vein quartz	4.0+	11.7
	Borehole terminated owing to slow progress		

(continued...)

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
4	33	63	1.5	2.5	8	10	11	11	20	26	14	
			2.5	3.5	4	10	16	12	24	17	17	
			3.5	4.5	4	8	12	9	22	18	27	
			4.5	5.5	5	7	15	11	24	31	7	
			5.5	6.5	4	5	14	9	23	41	4	†
			6.5	7.7	2	6	12	17	29	34	0	†
			Mean		4	8	13	12	24	28	11	

NO 32 SE 7 3907 2200 Kilmany BLOCK E

Surface level + 22.2 m (+ 73 ft)
Water struck at + 17.2 m
250 mm percussion
August 1979

Waste 12.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.7	0.7
Late-Glacial marine deposits	Silt and silty clay, laminated, grey-brown to red-brown, with rare sandy partings	3.3	4.0
Till	Clay, brown, sandy, with angular to well rounded clasts up to 20 cm diameter of andesite and basalt with, above 11.5 m, various metamorphic and sedimentary rocks	6.2	10.2
	Gravel Gravel: coarse with fine and cobbles up to 20 cm diameter, angular to subrounded, lavas and various metamorphic rocks with rare sandstone Sand: fine and medium with coarse, angular to subangular, quartz and rock fragments Fines: silt, disseminated, much lost due to washing during drilling	1.8+	12.0
	Borehole terminated owing to slow progress		

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
6	47	47	10.2	11.2	6	21	17	9	12	30	5	†‡

NO 32 SE 8 3761 2449 Naughton House, Balmerino BLOCK E

Surface level + 55.7 m (+ 183 ft)
Water struck at + 53.9 m
Pit
August 1979

Waste 2.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Lake alluvium	Clay, brownish grey, below 1.5 m becomes reddish brown and increasingly well laminated. Sand partings up to 1 cm thick. Ill-sorted fine to coarse gravel with rare cobbles below 2.0 m	1.7+	2.1

NO 32 SE 9 3841 2435 Brownie Wood, Balmerino BLOCK E

Surface level + 75.9 m (+ 249 ft)
Water not struck
Pit
October 1979

Overburden 0.3 m
Mineral 1.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial sand and gravel	Gravel Gravel: fine and coarse, subrounded to well rounded, predominantly quartzite Sand: medium and fine with coarse, angular to subangular, quartz with rock fragments, red-brown Fines: silt, both disseminated and, above 1.1 m, in bands	1.6+	1.9

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
6	45	49	0.3	1.9	6	16	19	10	25	24	0	‡

NO 32 SE 10 3813 2134 Cleughie Burn, Kilmany BLOCK E

Surface level + 25.6 m (+ 84 ft)
Water not struck
Pit
August 1979

Waste 2.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.3	0.3
Late-Glacial marine deposits	Sand, fine to medium, brown	0.4	0.7
	Clay, mottled reddish brown, with rare silt laminae, becomes sandy near base	1.1	1.8
	'Clayey' sand, fine, quartz, grey	0.2+	2.0

NO 32 SE 11 3953 2198 Forret Mill, Logie BLOCK E

Surface level + 18.9 m (+ 62 ft)
Water not struck
Pit
October 1979

Waste 1.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.3	0.3
Late-Glacial marine deposits	Clay, stiff, poorly laminated, reddish brown, rootlet fragments	1.1	1.4
Till	Clay, reddish brown, sandy, with ill-sorted clasts up to 16 cm diameter of lava	0.5+	1.9

NO 42 NW 23 4026 2542 Newton Park, Forgan BLOCK A

Surface level + 43.6 m (+ 143 ft)
Water not struck
250 mm and 200 mm percussion
July 1979

Overburden 0.3 m
Mineral 24.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.3	0.3
Fluvioglacial sand and gravel	a 'Clayey' pebbly sand Gravel: most abundant above 2.7 m, from 5.8 m to 6.8 m, and from 7.8 m to 9.8 m. Fine and coarse with rare cobbles up to 10 cm diameter, angular to well rounded, lavas, quartzite, quartz with gneiss and sandstone Sand: fine with medium, subangular to subrounded, quartz, feldspar and rock fragments with rare iron pyrites, reddish brown Fines: silt, disseminated, and silty clay bands up to 3 cm thick	12.2	12.5
Glacial sand and gravel	b Gravel Gravel: fine and coarse, with cobbles up to 19 cm diameter, subrounded to well rounded, basalt, andesite, quartzite, quartz, red and grey sandstones, diorite and schist Sand: fine to coarse, angular to rounded, red Fines: silt, disseminated	12.5+	25.0

(continued ...)

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages						
	Fines	Sand	Gravel			Fines	Sand			Gravel		
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
a	12	77	11	0.3	1.3	9	21	17	14	19	20	0
				1.3	2.7	20	27	13	8	12	10	0
				2.7	3.8	22	59	14	3	2	0	0
				3.8	4.8	14	49	27	4	4	2	0
				4.8	5.8	19	52	19	4	4	2	0
				5.8	6.8	9	18	41	9	10	13	0
				6.8	7.8	12	53	30	5	0	0	0
				7.8	8.8	3	17	54	12	6	8	0
				8.8	9.8	16	29	35	9	8	3	0
				9.8	10.5	2	22	60	13	2	1	0
				10.5	11.5	5	66	26	3	0	0	0
				11.5	12.5	3	63	34	0	0	0	0
				Mean		12	41	29	7	6	5	0
b	5	43	52	12.5	13.5	5	33	22	7	11	11	11
				13.5	14.7	4	14	20	8	24	30	0
				14.7	15.6	5	11	16	14	31	23	0
				15.6	16.5	10	16	10	10	21	18	15
				16.5	17.5	4	8	12	8	20	36	12
				17.5	18.5	5	6	9	9	22	39	10
				18.5	19.5	4	8	10	10	19	36	13
				19.5	20.4	5	19	24	9	10	21	12
				20.4	21.5	5	16	24	12	20	23	0
				21.5	22.5	4	15	23	12	19	27	0
				22.5	23.5	4	7	18	18	23	8	22
				23.5	25.0	5	5	19	33	22	16	0
				Mean		5	13	17	13	20	24	8
a & b	8	60	32	Mean		8	27	23	10	13	15	4

NO 42 NW 24 4134 2537 St Fort, Forgan BLOCK A

Surface level + 33.2 m (+ 109 ft)
Water not struck
250 mm percussion
August 1979

Overburden 0.5 m
Mineral 5.8 m
Waste 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.5	0.5
Glacial sand and gravel	a Sandy gravel Gravel: fine and coarse, subrounded to well rounded, andesite, basalt, quartz and quartzite with sandstone, schist and gneiss Sand: fine and medium with coarse, angular to subrounded, quartz, feldspar and rock fragments, brown Fines: silt with clay, disseminated	4.6	5.1
Till	b 'Clayey' gravel Gravel: coarse with fine and rare cobbles up to 15 cm diameter, angular to well rounded, andesite, basalt, quartz, quartzite and rare sandstone Sand: fine to coarse, angular to subrounded, quartz, feldspar and rock fragments Fines: silt, disseminated	1.2	6.3
	Clay, stiff, sandy, grey-brown becoming black with depth, angular to subangular clasts up to 10 cm diameter of andesite with rare subrounded quartz and quartzite	0.2+	6.5
	Borehole terminated owing to boulder obstruction		

(continued ...)

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages						
	Fines	Sand	Gravel			Fines	Sand			Gravel		
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
a	9	57	34	0.5	1.3	16	20	12	8	15	18	11
				1.3	2.3	5	31	37	11	12	4	0
				2.3	3.3	13	22	29	10	13	8	5
				3.3	4.3	7	19	17	11	18	24	4
				4.3	5.1	7	22	21	11	17	22	0
				Mean		9	23	24	10	15	15	4
b	15	37	48	5.1	6.3	15	14	11	12	18	30	0
a&b	11	53	36	Mean		11	21	21	11	15	18	3

NO 42 NW 25 4238 2739 Tofts Law, Forgan BLOCK E

Surface level + 57.3 m (+ 188 ft)
Water not struck
250 mm percussion
August 1979

Overburden 0.9 m
Mineral 8.1 m
Waste 0.7 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.9	0.9
Glacial sand and gravel	Sandy gravel Gravel: fine and coarse with cobbles up to 15 cm diameter, subangular to well rounded, andesite with quartzite, basalt, schist, gneiss and sandstone Sand: fine and medium with coarse, subangular to subrounded, quartz with feldspar and rock fragments, reddish brown Fines: silt, disseminated	8.1	9.0
Till	Clay, very stiff, brown becoming black below 9.5 m, sandy, with subangular to subrounded clasts up to 10 cm diameter of lava, sandstone and various metamorphic rocks. Andesite dominant below 9.5 m	0.7	9.7
Lower Devonian	Andesite, greyish black	0.1+	9.8

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages						
	Fines	Sand	Gravel			Fines	Sand			Gravel		
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
	8	58	34	0.9	1.9	10	16	25	14	18	17	0
				1.9	2.9	4	14	27	17	18	16	4
				2.9	3.9	12	21	12	12	15	17	11
				3.9	4.9	14	50	12	5	11	8	0
				4.9	5.9	3	11	25	17	20	14	10
				5.9	6.9	13	34	10	4	11	22	6
				6.9	7.9	4	51	23	9	9	4	0
				7.9	9.0	2	19	27	10	15	9	18
				Mean		8	27	20	11	15	13	6

NO 42 NW 26 4369 2799 Causewayhead, Forgan BLOCK E

Surface level + 52.1 m (+ 171 ft)
Water struck at + 49.1 m
250 mm percussion
August 1979

Overburden 0.6 m
Mineral 2.0 m
Waste 2.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.6	0.6
Hillwash	'Very clayey' sand Gravel: rare fine and coarse up to 2 cm diameter, subangular to subrounded Sand: fine with medium, subangular, quartz, brown Fines: silt, disseminated	2.0	2.6
Till	Clay, very stiff, locally laminated, brown, sandy, with angular to subrounded clasts up to 15 cm diameter predominantly of andesite	2.4+	5.0
	Borehole terminated owing to boulder obstruction		

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages						
Fines	Sand	Gravel			Fines	Sand			Gravel		
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
33	65	2	0.6	1.6	29	46	16	5	1	3	0
			1.6	2.6	36	49	11	3	1	0	0
			Mean		33	48	13	4	1	1	0

NO 42 NW 27 4316 2704 Inverdovat, Forgan BLOCK E

Surface level + 55.7 m (+ 183 ft)
Water not struck
250 mm percussion
July 1979

Waste 0.7 m
Bedrock 0.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.7	0.7
Lower Devonian	Lava, red, highly weathered	0.8+	1.5

NO 42 NW 28 4462 2769 Scotscraig, Ferry Port on Craig BLOCK E

Surface level + 32.8 m (+ 108 ft)
Water struck at + 30.6 m
250 mm percussion
June 1979

Overburden 2.2 m
Mineral 1.0 m
Waste 0.9 m
Bedrock 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.5	0.5
Till	Clay, moderately stiff, grey-brown to brown, with angular to subrounded clasts up to 8 cm diameter of lava with rare quartzite	1.7	2.2
	'Clayey' sandy gravel Gravel: fine with coarse and rare cobbles up to 8 cm diameter, angular to subrounded, lava with rare quartzite Sand: medium and coarse with fine, angular, basalt fragments Fines: silt and clay, disseminated	1.0	3.2
	Clay, very stiff, with a few highly weathered andesite clasts	0.9	4.1
Lower Devonian	Andesite, fine to medium grained, dark grey to black, highly weathered	0.4+	4.5

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
13	63	24	2.2	3.2	13	16	23	24	18	6	0	†

NO 42 NW 29 4480 2635 Kirktonbarns, Forgan BLOCK B

Surface level + 36.1 m (+ 118 ft)
Water not struck
250 mm percussion
June 1979

Overburden 0.7 m
Mineral 3.9 m
Waste 1.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.7	0.7
Fluvioglacial sand and gravel	'Clayey' sand, with clay band from 3.4 m to 4.0 m Gravel: trace of fine Sand: fine with a little medium, angular to subrounded, quartz, feldspar and rock fragments, red Fines: silt, disseminated, with 2 cm thick silt and clay bands at 1.4 m and 2.2 m, and stiff red clay with clasts from 3.4 m to 4.0 m	3.9	4.6
	Clay, laminated above 5.0 m, stiff, red, sandy, with subangular to subrounded clasts of quartzite and basalt up to 6 cm diameter	0.8	5.4
Till	Clay, very stiff, olive-green to grey-green, with angular to subangular clasts up to 10 cm diameter of andesite, basalt and quartzite	0.8+	6.2
	Borehole terminated owing to boulder obstruction		

(continued ...)

Mean for deposit percentages			Depth below surface (m)		percentages						
Fines	Sand	Gravel			Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
19	80	1	0.7	1.7	14	67	17	1	1	0	0
			1.7	2.7	11	57	27	4	1	0	0
			2.7	3.4	30	66	3	1	0	0	0
			3.4	4.0	clay						
			4.0	4.6	26	55	16	2	1	0	0
			Mean		19	61	17	2	1	0	0

NO 42 NW 30 4439 2544 Cowbakie Hill, Leuchars BLOCK B

Surface level + 34.9 m (+ 115 ft)
Water struck at + 15.4 m
250 mm and 200 mm percussion
June 1979

Overburden 0.6 m
Mineral 24.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.6	0.6
Fluvioglacial sand and gravel	Sand Gravel: principally above 1.6 m and from 10.3 m to 11.3 m, fine with coarse, subangular to subrounded, red sandstone, lavas, quartz and quartzite Sand: fine with medium, principally medium above 10.3 m, subangular to well rounded, quartz with rock fragments, feldspar and mica, reddish brown Fines: silt, disseminated, with rare red silt bands up to 1 cm thick most commonly from 15.3 m to 16.3 m	24.4+	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	
5	94	1	0.6	1.6	4	23	44	12	14	3	0	
			1.6	2.6	3	73	21	3	0	0	0	
			2.6	3.6	3	31	62	3	1	0	0	
			3.6	4.6	4	30	64	1	1	0	0	
			4.6	5.6	2	31	61	3	2	1	0	
			5.6	6.6	1	34	65	0	0	0	0	
			6.6	7.6	1	25	74	0	0	0	0	
			7.6	8.6	1	30	69	0	0	0	0	
			8.6	9.6	1	22	73	4	0	0	0	
			9.6	10.3	2	23	64	10	1	0	0	
			10.3	11.3	10	67	13	3	5	2	0	
			11.3	12.3	2	74	23	1	0	0	0	
			12.3	13.3	2	78	20	0	0	0	0	
			13.3	14.3	2	59	39	0	0	0	0	
			14.3	15.3	4	72	22	2	0	0	0	
			15.3	16.3	34	63	3	0	0	0	0	
			16.3	17.3	3	86	9	1	1	0	0	
			17.3	18.3	8	85	7	0	0	0	0	
			18.3	19.3	10	75	15	0	0	0	0	†
			19.3	20.3	4	80	16	0	0	0	0	†
			20.3	21.3	5	74	21	0	0	0	0	†
			21.3	22.3	2	54	44	0	0	0	0	†
			22.3	24.3	3	73	24	0	0	0	0	†
			24.3	25.0	6	88	6	0	0	0	0	†
			Mean		5	57	35	2	1	0	0	

NO 42 NW 31 4049 2626 Wormit Hill, Forgan BLOCK E

Surface level + 80.6 m (+ 264 ft)
Water not struck
Pit
August 1979

Overburden 0.4 m
Mineral 1.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Till	'Very clayey' sandy gravel Gravel: fine with coarse and rare cobbles, subrounded to well rounded, quartzite, psammite, basalt, quartz and red sandstone Sand: fine and medium with coarse, angular, quartz with rock fragments Fines: clay, reddish brown	1.6+	2.0

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
25	56	19	0.4	2.0	25	27	22	7	12	7	0	‡

NO 42 NW 32 4323 2910 Greenside Scalp, Forgan BLOCK E

Surface level + 4.2 m (+ 14 ft)
Water not struck
Pit
August 1979

Overburden 1.7 m
Mineral 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
	Made ground	1.2	1.7
Post-Glacial deposits	Sand Sand: fine and medium, subangular, quartz with rock fragments Fines: trace	0.4+	2.1

NO 42 NW 33 4325 2904 Greenside Scalp, Forgan BLOCK E

Surface level + 15.0 m (+ 49 ft)
Water struck at + 13.0 m
Pit
August 1979

Overburden 0.8 m
Mineral 1.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy and silty	0.8	0.8
Late-Glacial beach deposits	Gravel Gravel: fine, coarse and cobbles up to 20 cm diameter, angular to well rounded, basalt with quartzite, psammite, quartz and rare felsite Sand: fine to coarse, subangular to subrounded, rock fragments with quartz Fines: clay, medium brown, disseminated	1.2+	2.0

NO 42 NW 34 4451 2600 Easter Friarton Cottages, Leuchars BLOCK B

Surface level + 16.0 m (+ 52 ft)
Water struck at + 13.9 m
Pit
August 1979

Overburden 0.9 m
Mineral 1.1 m
Waste 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty and sandy	0.9	0.9
Fluvioglacial sand and gravel	Sand Sand: fine, orange Fines: silt, disseminated	1.1	2.0
	Clay, mottled orange to grey, with rootlets of probable recent origin	0.1+	2.1

NO 42 NE 8 4545 2654 Lawhouses, Forgan BLOCK E

Surface level + 16.0 m (+ 52 ft)
Water struck at + 9.4 m
250 mm and 200 mm percussion
August 1979

Overburden 0.6 m
Mineral 9.1 m
Waste 3.1 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.3	0.3
	Soil, sandy	0.3	0.6
Late-Glacial beach deposits	a 'Very clayey' pebbly sand Gravel: fine and coarse, rounded to angular Sand: fine with medium, quartz with feldspar, rock and a few shell fragments Fines: clay, disseminated, medium brown	1.0	1.6
Till	b 'Very clayey' sandy gravel Gravel: fine and coarse with rare cobbles up to 17 cm diameter, well rounded with rounded and subrounded, quartzite, psammite and basalt with quartz, andesite and red sandstone Sand: fine andmedium with coarse, angular to subangular, quartz with feldspar and rock fragments Fines: clay, disseminated, red-brown becoming brown with depth. Deposit becomes cohesive below 5.6 m.	5.0	6.6
	c Sandy gravel Gravel: fine and coarse with cobbles, becomes finer with depth, angular to well rounded, quartzite, basalt and andesite with felsite, white and red sandstones, quartz, psammite and rare black shale Sand: fine to coarse, angular to subangular, quartz, and rock fragments Fines: clay and silt, red-brown, disseminated. Rare clay-bound lumps suggest much fines has been lost by washing during drilling	3.1	9.7
	Clay, stiff becoming very stiff below 11.5 m, mid-brown becoming greenish grey below 12.0 m, with angular to well rounded clasts of basalt and quartzite with, below 12.0 m, shale, siltstone, fine-grained sandstone and rare limestone	3.1	12.8
Lower Devonian	Volcanic breccia, angular basalt fragments in basaltic matrix. Secondary calcite. Weathered near surface, becoming very hard with depth	0.1+	12.9

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	24	69	7	0.6	1.6	24	49	18	2	3	4	0	
b	26	54	20	1.6	2.6	22	30	23	6	10	9	0	
				2.6	3.6	25	27	22	6	10	10	0	
				3.6	4.7	28	26	22	7	10	7	0	
				4.7	5.6	27	27	19	6	12	9	0	
				5.6	6.6	28	25	17	8	10	12	0	
				Mean		26	27	21	6	11	9	0	
c	3	55	42	6.6	7.7	1	9	18	15	17	27	13	†
				7.7	8.7	2	22	27	13	15	14	7	†
				8.7	9.7	6	11	24	28	28	3	0	†
				Mean		3	14	23	18	20	15	7	
a to c	18	56	26	Mean		18	25	21	10	13	11	2	
b & c	17	55	28	Mean		17	22	22	11	14	12	2	

NO 42 NE 9 4500 2582 Kirkton Wood, Leuchars BLOCK B

Surface level + 33.4 m (+ 110 ft)
Water not struck
250 mm and 200 mm percussion
August 1979

Overburden 0.1 m
Mineral 24.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.1	0.1
Fluvioglacial sand and gravel	Sand Gravel: trace of fine Sand: fine, angular to subangular, quartz, feldspar and rock fragments Fines: silt, disseminated, brown to reddish brown, with red silt bands up to 3 cm thick locally	24.9+	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
9	91	0	0.1	1.1	29	61	7	2	1	0	0
			1.1	2.1	2	36	57	4	1	0	0
			2.1	3.1	5	56	37	1	1	0	0
			3.1	4.1	3	70	26	1	0	0	0
			4.1	5.1	9	82	9	0	0	0	0
			5.1	6.1	3	67	29	1	0	0	0
			6.1	7.1	30	66	4	0	0	0	0
			7.1	8.1	18	73	8	0	0	0	0
			8.1	9.1	14	67	18	1	0	0	0
			9.1	10.1	1	67	28	1	3	0	0
			10.1	11.1	2	82	16	0	0	0	0
			11.1	12.0	3	83	14	0	0	0	0
			12.0	13.0	7	88	5	0	0	0	0
			13.0	14.0	26	73	1	0	0	0	0
			14.0	15.0	6	85	9	0	0	0	0
			15.0	16.0	2	58	40	0	0	0	0
			16.0	17.0	7	90	3	0	0	0	0
			17.0	18.0	3	95	2	0	0	0	0
			18.0	19.0	9	87	2	0	1	1	0
			19.0	20.0	4	90	5	1	0	0	0
			20.0	21.0	20	79	1	0	0	0	0
			21.0	22.0	17	82	1	0	0	0	0
			22.0	23.0	5	91	3	1	0	0	0
			23.0	24.0	6	92	2	0	0	0	0
			24.0	25.0	6	93	1	0	0	0	0
			Mean		9	77	13	1	0	0	0

NO 42 NE 10 4654 2713 Garpit, Ferry Port on Craig BLOCK D

Surface level + 4.9 m (+ 16 ft)
Water struck at + 3.8 m
250 mm and 200 mm percussion
July 1979

Overburden 0.4 m
Mineral 4.2 m
Waste 3.6 m
Mineral 4.0 m
Waste 3.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.4	0.4
Blown sand	a Sand Gravel: trace of coarse below 1.4 m, subrounded to well rounded, quartzite, lava and vein quartz Sand: fine, subangular to subrounded, quartz, feldspar and rock fragments Fines: silt, disseminated	2.2	2.6
Post-Glacial deposits	b Pebbly sand Gravel: mainly above 3.6 m, fine and coarse, subrounded to well rounded Sand: fine with a little medium, subangular to subrounded, quartz, feldspar and rock fragments, with some shell material, dark grey Fines: silt, disseminated, black	2.0	4.6
	Silt, locally laminated, with fine sand stringers, becoming sandier with depth, some shell fragments, plant remains from 7.4 m to 7.8 m	3.6	8.2
	c 'Very clayey' sand Sand: fine, subangular to subrounded, quartz, feldspar, mica and rock fragments, grey Fines: silt, disseminated, decreasing with depth	4.0	12.2
	Silt, both in thin beds and disseminated with sand	0.8	13.0
Till	Clay, stiff, brown, with angular to well rounded clasts up to 5 cm in diameter which increase in number near the base, sandstone, lavas, quartzite and rare gneiss. Some clasts show striations	2.6+	15.6
	Borehole terminated owing to boulder obstruction		

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	8	92	0	0.4	1.4	10	84	6	0	0	0	0	
				1.4	2.6	6	89	3	1	0	1	0	†
				Mean		8	87	4	1	0	0	0	
b	2	93	5	2.6	3.6	0	76	11	3	5	5	0	†
				3.6	4.6	5	78	16	1	0	0	0	†
				Mean		2	77	14	2	3	2	0	
c	21	79	0	8.2	9.2	30	69	1	0	0	0	0	†
				9.2	10.2	26	73	1	0	0	0	0	†
				10.2	11.2	16	83	1	0	0	0	0	†
				11.2	12.2	14	85	1	0	0	0	0	†
				Mean		21	78	1	0	0	0	0	
a to c	13	86	1	Mean		13	80	5	1	0	1	0	
b & c	15	83	2	Mean		15	78	5	0	1	1	0	

NO 42 NE 11 4653 2640 Morton Lochs, Forgan BLOCK D

Surface level + 9.0 m (+ 30 ft)
Water struck at + 7.8 m
250 mm and 200 mm percussion
June 1979

Overburden 0.2 m
Mineral 8.0 m
Waste 4.0 m
Mineral 3.3 m
Bedrock 0.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Post-Glacial deposits	a Sand Gravel: trace, fine and coarse up to 5 cm diameter, subrounded to subangular, quartzite and lava Sand: fine with a little medium, subangular to well rounded, quartz, feldspar and rock fragments with mica. Much shell material below 5.0 m Fines: silt, disseminated. Black organic rich band, 2.5 cm thick, at 5.0 m	8.0	8.2
	Clay, light grey, silty, sandy particularly from 8.8 m to 8.9 m, with rare clasts of sandstone, andesite and basalt, and shell fragments. Plant remains throughout but concentrated in 5 cm bed at 11.0 m	4.0	12.2
	b 'Very clayey' sand Gravel: trace, subrounded to angular, quartz, quartzite and lava Sand: fine, quartz with trace mica, grey Fines: silt, disseminated	3.3	15.5
Lower Devonian	Sandstone, greenish red, weathered	0.5+	16.0

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	1	99	0	0.2	1.2	2	87	11	0	0	0	0	
				1.2	2.2	1	85	14	0	0	0	0	†
				2.2	3.2	1	83	16	0	0	0	0	†
				3.2	4.2	1	91	8	0	0	0	0	†
				4.2	5.2	1	91	8	0	0	0	0	†
				5.2	6.2	1	74	24	1	0	0	0	†
				6.2	7.2	2	92	6	0	0	0	0	†
				7.2	8.2	2	91	7	0	0	0	0	†
				Mean		1	87	12	0	0	0	0	
b	22	78	0	12.2	14.2	22	76	2	0	0	0	0	†
				14.2	15.5	21	74	4	1	0	0	0	†
				Mean		22	75	3	0	0	0	0	
a & b	7	93	0	Mean		7	84	9	0	0	0	0	

NO 42 NE 12 4617 2579 Morton, Forgan BLOCK D

Surface level + 9.3 m (+ 31 ft)
Water struck at + 8.1 m
250 mm and 200 mm percussion
August 1979

Overburden 0.4 m
Mineral 4.3 m
Waste 9.6 m
Bedrock 0.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Post-Glacial deposits	Pebbly sand Gravel: principally above 3.0 m, locally occurs in laminated clay bands, fine with a little coarse and rare cobbles, angular to subangular, red sandstone, basalt and quartz Sand: fine with medium, becoming finer with depth, quartz with rock fragments Fines: silt and clay, medium brown, disseminated and in laminated, often gravelly, bands	4.3	4.7
Late-Glacial marine deposits	Clay, stiff, poorly laminated, micaceous, red-brown, sandy lenses, with, at 5.6 m and below 12.5 m, clasts up to 8.5 cm diameter of basalt with quartzite, quartz, and yellow and white sandstones	8.7	13.4
Till	Clay, stiff, grey, with clasts of grey mudstone with red sandstone	0.9	14.3
Lower Devonian	Mudstone, indurated, grey	0.3+	14.6

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
5	88	7	0.4	1.0	8	27	51	8	5	1	0	
			1.0	2.0	10	15	32	21	18	4	0	†
			2.0	3.0	4	46	41	6	3	0	0	†
			3.0	4.0	1	92	7	0	0	0	0	†
			4.0	4.7	1	90	8	1	0	0	0	†
			Mean		5	54	27	7	6	1	0	

NO 42 NE 13 4785 2725 Shanwell, Ferry Port on Craig BLOCK D

Surface level + 7.2 m (+ 24 ft)
Water struck at + 4.2 m
250 mm and 200 mm percussion
August 1979

Overburden 0.5 m
Mineral 10.5 m
Waste 10.5 m
Mineral 3.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, very sandy	0.5	0.5
Blown sand	a Sand Sand: fine, subrounded to subangular, quartz with feldspar and rock fragments, a little mica below 3.5 m and fine shell fragments below 4.5 m. Light brown becoming grey-brown below 4.5 m Fines: silt, disseminated	5.0	5.5
Post-Glacial deposits	b Sand Gravel: from 7.6 m to 9.0 m a little fine and coarse, subrounded to well rounded, quartzite with basalt Sand: fine, angular to rounded, quartz with rock, feldspar and shell fragments, and a little mica, grey. Carbonaceous material below 9.5 m Fines: silt, disseminated	5.5	11.0
	Silt, poorly laminated, medium grey, sandy in upper part, becoming clayey with depth. Lamelli branch shells throughout. Rare clasts below 20.0 m	10.5	21.5
	c 'Clayey' sand Gravel: above 22.5 m, fine and coarse, subangular, basalt with sandstone Sand: fine, quartz with rock and some shell fragments, brownish grey Fines: silt, disseminated, increasing near the base	3.5+	25.0

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	1	99	0	0.5	1.5	1	98	1	0	0	0	0	
				1.5	2.5	1	97	2	0	0	0	0	
				2.5	3.5	1	94	5	0	0	0	0	
				3.5	4.5	1	94	5	0	0	0	0	†
				4.5	5.5	1	94	5	0	0	0	0	†
				Mean		1	95	4	0	0	0	0	
b	2	96	2	5.5	6.5	0	97	3	0	0	0	0	†
				6.5	7.6	1	93	6	0	0	0	0	†
				7.6	8.5	0	86	8	0	1	5	0	†
				8.5	9.5	3	85	5	1	1	5	0	†
				9.5	10.0	6	92	2	0	0	0	0	†
				10.0	11.0	6	93	1	0	0	0	0	†
				Mean		2	91	5	0	0	2	0	
c	10	86	4	21.5	22.5	7	76	2	2	6	7	0	†
				22.5	23.5	4	94	1	1	0	0	0	†
				23.5	25.0	17	82	1	0	0	0	0	†
				Mean		10	84	1	1	2	2	0	
a to c	4	94	2	Mean		4	91	3	0	1	1	0	
b & c	5	92	3	Mean		5	88	4	0	1	2	0	

NO 42 NE 14 4845 2628 Tentsmuir, Ferry Port on Craig BLOCK D

Surface level + 6.8 m (+ 22 ft) Mineral 22.1 m +
Water struck at + 5.8 m
250 mm and 200 mm percussion
June 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
Blown sand	a Sand Sand: fine, angular to subrounded, quartz, feldspar and rock fragments, orange-brown Fines: silt, disseminated	5.0	5.0
Post-Glacial deposits	b Sand Gravel: from 10.2 m to 11.2 m, coarse with fine and rare cobbles up to 10 cm diameter, lavas, quartzite and rare quartz Sand: fine with a little medium, subangular to subrounded, quartz, feldspar, rock and many shell fragments, grey Fines: silt, disseminated, with rare black bands less than 1 cm thick	7.2	12.2
	c 'Very clayey' sand Gravel: below 20.2 m, coarse with fine and rare cobbles up to 8 cm diameter, subrounded, quartzite, andesite, and basalt Sand: fine, subangular to subrounded, quartz, feldspar, rock and shell fragments. Micaceous below 20.2 m. Grey Fines: silt, disseminated, with rare clay partings up to 1 cm thick	9.9+	22.1
	Borehole terminated owing to technical reasons		

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	4	96	0	0.0	1.0	2	96	2	0	0	0	0	
				1.0	2.0	13	85	2	0	0	0	0	†
				2.0	3.0	1	94	5	0	0	0	0	†
				3.0	4.0	1	92	7	0	0	0	0	†
				4.0	5.0	1	93	6	0	0	0	0	†
				Mean		4	92	4	0	0	0	0	
b	5	93	2	5.0	6.0	12	78	10	0	0	0	0	†
				6.0	7.0	1	80	19	0	0	0	0	†
				7.0	8.0	3	84	13	0	0	0	0	†
				8.0	9.0	3	77	20	0	0	0	0	†
				9.0	10.2	7	81	11	1	0	0	0	†
				10.2	11.2	3	72	11	2	2	10	0	†
				11.2	12.2	8	84	7	1	0	0	0	†
				Mean		5	79	13	1	0	2	0	
c	26	72	2	12.2	14.2	15	82	3	0	0	0	0	†
				14.2	15.2	22	76	2	0	0	0	0	†
				15.2	16.2	25	73	2	0	0	0	0	†
				16.2	17.2	25	73	2	0	0	0	0	†
				17.2	18.2	37	61	2	0	0	0	0	†
				18.2	19.2	31	66	3	0	0	0	0	†
				19.2	20.2	28	66	3	2	1	0	0	†
				20.2	21.2	24	54	3	1	2	16	0	†
				21.2	22.1	38	55	2	1	2	2	0	†
				Mean		26	69	3	0	0	2	0	
a to c	14	84	2	Mean		14	78	6	0	0	2	0	
b & c	17	81	2	Mean		17	74	7	0	0	2	0	

NO 42 NE 15 4870 2512 Tentsmuir, Leuchars BLOCK D

Surface level + 7.4 m (+ 24 ft)
Water struck at + 5.5 m
250 mm and 200 mm percussion
July 1979

Overburden 0.2 m
Mineral 21.5 m
Waste 3.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, very sandy	0.2	0.2
Blown sand	a Sand Sand: fine, subangular to well rounded, quartz with feldspar, rock and mica fragments, light brown to orange-brown Fines: silt, disseminated	3.0	3.2
Post-Glacial deposits	b Sand, with clay band from 12.6 m to 13.3 m Gravel: mainly below 20.0 m, fine with coarse, and a basal layer of cobbles at 21.7 m, subrounded to well rounded, basalt, red sandstone and quartzite, with lamellibranch shells up to 9 cm diameter Sand: fine with medium, well rounded to angular, quartz with feldspar, rock, mica and shell fragments, light brown becoming brownish grey below 6.6 m Fines: silt, disseminated, with thin grey silty clay bands from 9.0 m to 11.8 m and below 20.0 m. Thicker medium grey micaceous clay, with shell and plant fragments, from 12.6 m to 13.3 m. Peat at 11.2 m	18.5	21.7
Late-Glacial marine deposits	Clay, laminated, red	2.1	23.8
Till	Clay, moderately stiff, red-brown, sandy, with ill-sorted subangular to well rounded clasts	1.2+	25.0

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	2	98	0	0.2	1.3	3	93	3	1	0	0	0	
				1.3	2.3	2	97	1	0	0	0	0	†
				2.3	3.2	2	94	4	0	0	0	0	†
				Mean		2	95	3	0	0	0	0	
b	5	94	1	3.2	4.6	1	86	12	0	1	0	0	†
				4.6	5.6	1	92	6	1	0	0	0	†
				5.6	6.6	1	90	9	0	0	0	0	†
				6.6	7.6	1	95	4	0	0	0	0	†
				7.6	8.7	1	95	4	0	0	0	0	†
				8.7	10.1	2	95	3	0	0	0	0	†
				10.1	10.9	2	95	3	0	0	0	0	†
				10.9	11.8	2	92	5	1	0	0	0	†
				11.8	12.6	9	85	4	2	0	0	0	†
				12.6	13.3	clay							
				13.3	14.3	4	47	47	1	1	0	0	†
				14.3	15.3	4	55	39	1	1	0	0	†
				15.3	16.3	4	38	57	1	0	0	0	†
				16.3	17.3	3	32	65	0	0	0	0	†
				17.3	19.0	3	75	22	0	0	0	0	†
				19.0	20.0	7	63	29	1	0	0	0	†
				20.0	21.0	28	53	4	1	7	7	0	†
				21.0	21.7	10	59	23	2	5	1	0	†
				Mean		5	74	20	0	1	0	0	
a & b	4	95	1	Mean		4	77	17	1	1	0	0	

NO 42 NE 16 4933 2814 Tentsmuir Point, Ferry Port on Craig BLOCK D

Surface level + 3.3 m (+ 11 ft)
Water struck at + 1.2 m
250 mm and 200 mm percussion
July 1979

Overburden 0.1 m
Mineral 23.9 m
Waste 1.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.1	0.1
Blown sand	a Sand Sand: fine, angular to subangular, quartz with feldspar, light brown Fines: silt, disseminated	1.0	1.1
Post-Glacial deposits	b Sand Gravel: rare disseminated fine with coarse, with basal, more gravelly, layer below 23.0 m of coarse with fine, subrounded to well rounded, basalt, red and grey sandstones, quartz and quartzite. Some clasts display barnacle epifauna Sand: fine with medium, well rounded to angular, quartz with feldspar, rock and shell material and, below 20.0 m, mica. Carbonaceous material locally. Light brown becoming brownish grey below 5.5 m Fines: silt, disseminated, with thin grey laminated silty clay bands, principally from 9.6 m to 12.5 m	22.9	24.0
Late-Glacial marine deposits	Clay, soft, red-brown	1.1+	25.1

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	3	97	0	0.1	1.1	3	87	9	1	0	0	0	
b	4	94	2	1.1	2.1	1	41	57	1	0	0	0	
				2.1	3.1	1	36	62	1	0	0	0	†
				3.1	4.3	1	54	43	1	1	0	0	†
				4.3	5.5	0	67	30	2	1	0	0	†
				5.5	6.5	1	80	17	2	0	0	0	†
				6.5	7.5	2	79	13	2	1	3	0	†
				7.5	8.5	4	93	3	0	0	0	0	†
				8.5	9.6	5	94	1	0	0	0	0	†
				9.6	10.5	9	89	1	1	0	0	0	†
				10.5	11.4	12	86	1	1	0	0	0	†
				11.4	12.5	10	34	55	1	0	0	0	†
				12.5	13.5	6	41	51	1	1	0	0	†
				13.5	14.7	3	33	55	5	4	0	0	†
				14.7	15.7	2	25	70	2	1	0	0	†
				15.7	16.6	4	28	63	3	2	0	0	†
				16.6	18.0	2	26	69	2	1	0	0	†
				18.0	18.9	3	32	61	3	1	0	0	†
				18.9	20.0	4	31	62	2	1	0	0	†
				20.0	21.0	3	67	29	1	0	0	0	†
				21.0	22.0	5	83	12	0	0	0	0	†
				22.0	23.0	3	90	4	3	0	0	0	†
				23.0	24.0	4	60	11	3	8	14	0	†
				Mean		4	57	36	1	1	1	0	†
a & b	4	94	2	Mean		4	58	35	1	1	1	0	

NO 42 NE 17 4526 2615 Kirktonbarns, Forgan BLOCK B

Surface level + 17.7 m (+ 58 ft)
Water not struck
Pit
August 1979

Overburden 0.4 m
Mineral 1.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy and silty	0.4	0.4
Storm beach and bar deposits	Sand, fine, orange	0.3	0.7
	Sandy gravel, interbedded sand and gravel dipping 8° to the east Gravel: ill-sorted up to cobble grade, well rounded, includes highly weathered clasts Sand: fine to coarse Fines: trace	1.3+	2.0

NO 42 SW 7 4079 2386 Hawkhill, Kilmany BLOCK A

Surface level + 32.9 m (+ 108 ft)
Water not struck
250 mm percussion
July 1979

Overburden 1.3 m
Mineral 6.6 m
Waste 3.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	1.3	1.3
Glacial sand and gravel	Sandy gravel Gravel: abundant below 5.3 m, coarse and fine with rare cobbles up to 10 cm diameter, subangular to well rounded, lavas, various metamorphic rocks and sandstone Sand: fine and medium with coarse, subangular to subrounded, quartz, feldspar and rock fragments, brown Fines: silt, disseminated	6.6	7.9
Till	Clay, stiff, brown, locally sandy, with angular to subangular clasts up to 20 cm diameter of andesite, basalt, quartzite and quartz	3.7+	11.6
	Borehole terminated owing to technical reasons		

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	49	48	1.3	2.3	6	30	30	10	15	9	0
			2.3	3.3	2	29	25	6	15	23	0
			3.3	4.3	2	33	19	7	18	21	0
			4.3	5.3	3	20	18	11	25	23	0
			5.3	6.3	2	7	12	15	30	29	5
			6.3	7.3	2	6	12	16	27	37	0
			7.3	7.9	No data available						
			Mean		3	19	19	11	22	25	1

NO 42 SW 8 4090 2324 Easter Kinnear, Kilmany BLOCK B

Surface level + 37.6 m (+ 123 ft)
Water struck at + 17.1 m
250 mm and 200 mm percussion
July 1979

Overburden 0.4 m
Mineral 24.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.4	0.4
Fluvioglacial sand and gravel	a 'Clayey' sand Gravel: a little fine with coarse, and rare cobbles up to 8 cm diameter, principally above 2.4 m, subangular to well rounded, andesite, basalt, quartzite, schist and gneiss Sand: fine with medium, becoming finer with depth, subangular to subrounded, quartz, feldspar and rock fragments, brown Fines: silt, disseminated and in bands up to 4 cm thick, increasing in abundance with depth. 4 cm thick red clay at 15.3 m	24.6+	25.0

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	11	87	2	0.4	1.4	8	18	20	11	23	20	0	
				1.4	2.4	3	24	61	4	5	3	0	
				2.4	3.4	8	48	41	1	2	0	0	
				3.4	4.4	4	33	57	3	3	0	0	
				4.4	5.4	5	44	49	1	1	0	0	
				5.4	6.4	5	53	40	1	1	0	0	
				6.4	7.4	4	64	32	0	0	0	0	
				7.4	8.4	9	85	6	0	0	0	0	
				8.4	9.4	20	71	9	0	0	0	0	
				9.4	10.4	5	61	34	0	0	0	0	
				10.4	11.4	17	57	26	0	0	0	0	
				11.4	12.4	10	64	25	1	0	0	0	
				12.4	13.4	4	66	30	0	0	0	0	
				13.4	14.4	10	76	14	0	0	0	0	
				14.4	15.4	16	76	8	0	0	0	0	
				15.4	16.4	17	67	16	0	0	0	0	
				16.4	17.4	6	66	28	0	0	0	0	
				17.4	18.4	6	62	32	0	0	0	0	
				18.4	19.4	13	72	15	0	0	0	0	
				19.4	20.4	15	81	4	0	0	0	0	
				20.4	21.4	11	82	7	0	0	0	0	†
				21.4	22.4	14	82	4	0	0	0	0	†
				22.4	25.0	22	76	2	0	0	0	0	†
				Mean		11	63	23	1	1	1	0	†

NO 42 SW 9 4006 2243 Cruivie, Logie BLOCK E

Surface level + 14.5 m (+ 48 ft) Waste 18.0 m +
Water struck at + 13.7 m
250 mm and 200 mm percussion
July 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.7	0.7
Alluvium	Clay, mottled brown	0.8	1.5
	Silt, mottled grey-brown, sandy, with peat and brown clay bands	1.2	2.7
Late-Glacial marine deposits	Clay, stiff, laminated, brown, with sand partings up to 10 cm thick, and rare clasts up to 5 cm diameter	1.8	4.5
	Gravel Gravel: coarse, subangular to well rounded, lavas, quartzite, quartz, sandstone and gneiss Sand: medium and coarse, quartz Fines: silt, disseminated	0.3	4.8
	Clay, poorly laminated, very stiff, red, silty, with sand lenses up to 5 cm thick, principally around 10 m and, at 11.5 m, a subrounded andesite boulder 30 cm in diameter	11.7	16.5
Till	Clay, stiff, reddish brown, with subangular clasts up to 10 cm diameter of andesite, becoming white and with felsite clasts with depth	1.5+	18.0

NO 42 SW 10 4131 2461 West Links Wood, Forgan BLOCK A

Surface level + 33.5 m (+ 110 ft) Mineral 25.0 m +
Water struck at + 14.5 m
250 mm and 200 mm percussion
July 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial sand and gravel	Sandy gravel Gravel: decreasing in abundance with depth, fine and coarse with cobbles and boulders up to 30 cm diameter, subangular to well rounded, dolerite, andesite, basalt, red sandstone, quartzite, quartz and gneiss Sand: fine and medium with coarse, angular to well rounded, quartz, feldspar and rock fragments, red-brown Fines: silt, disseminated, with rare sandy silt bands up to 5 cm thick, principally between 11.0 m and 15.0 m. Brown silty clay at 23.0 m	25.0+	25.0

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
5	55	40	0.0	1.0	9	15	12	7	10	19	28	
			1.0	2.0	12	15	13	13	20	17	10	
			2.0	3.0	8	13	14	16	21	28	0	
			3.0	4.0	6	12	14	13	18	37	0	
			4.0	5.0	4	9	14	17	22	29	5	
			5.0	6.0	4	8	17	15	20	19	17	
			6.0	7.0	4	8	14	12	21	32	9	
			7.0	8.0	3	8	24	14	23	28	0	
			8.0	9.0	3	13	33	15	16	20	0	
			9.0	10.0	6	28	28	7	9	22	0	
			10.0	11.0	5	17	27	7	10	15	19	
			11.0	12.0	13	68	13	1	2	3	0	
			12.0	13.0	5	18	22	13	20	22	0	
			13.0	14.0	3	15	27	8	17	25	5	
			14.0	15.0	5	41	19	10	15	10	0	
			15.0	16.0	8	76	5	1	6	4	0	
			16.0	17.0	5	42	10	7	19	12	5	
			17.0	18.0	3	9	23	19	27	19	0	
			18.0	19.0	4	9	19	15	27	26	0	
			19.0	20.0	2	25	49	15	7	2	0	†
			20.0	21.0	1	17	35	13	15	19	0	†
			21.0	22.0	1	11	20	20	31	11	6	†
			22.0	23.0	3	10	13	26	37	11	0	†
			23.0	24.0	6	23	21	16	16	15	3	†
			24.0	25.0	5	30	25	19	13	8	0	†
			Mean		5	22	20	13	18	18	4	

NO 42 SW 11 4160 2352 North Straiton, Logie BLOCK B

Surface level + 38.2 (+ 125 ft)
Water struck at + 20.2 m
250 mm and 200 mm percussion
August 1979

Overburden 0.5 m
Mineral 22.0 m
Waste 2.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.5	0.5
Fluvioglacial sand and gravel	a Pebbly sand Gravel: most abundant from 1.5 m to 2.5 m, fine and coarse, subangular to subrounded, andesite, basalt, and quartzite with schist, gneiss and sandstone Sand: fine and medium, predominantly fine below 5.5 m, subangular to subrounded, quartz, feldspar and rock fragments, brown to reddish brown Fines: silt, disseminated	6.0	6.5
	b Sand Gravel: fine and coarse from 15.5 m to 17.5 m, subangular to subrounded Sand: fine with medium, angular to subangular, quartz and feldspar with rock fragments, brown to reddish brown Fines: silt, disseminated, most abundant from 18.5 m to 21.5 m, with red silt bands at 11.5 m, 18.0 m and 20.1 m	16.0	22.5
	Silt, with fine quartz sand, and a silty clay band at 23.4 m	2.5+	25.0

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	5	86	9	0.5	1.5	7	46	34	5	6	2	0	
				1.5	2.5	2	21	39	9	11	18	0	
				2.5	3.5	1	27	60	4	5	3	0	
				3.5	4.5	3	44	49	3	1	0	0	
				4.5	5.5	2	48	40	4	3	3	0	
				5.5	6.5	14	70	11	1	2	2	0	
				Mean		5	43	39	4	5	4	0	
b	8	91	1	6.5	7.5	8	68	23	1	0	0	0	
				7.5	8.5	2	48	49	1	0	0	0	
				8.5	9.5	3	70	27	0	0	0	0	
				9.5	10.5	5	80	15	0	0	0	0	
				10.5	11.5	6	82	12	0	0	0	0	
				11.5	12.5	6	71	23	0	0	0	0	
				12.5	13.5	7	79	14	0	0	0	0	
				13.5	14.5	5	83	12	0	0	0	0	
				14.5	15.5	2	60	38	0	0	0	0	
				15.5	16.5	2	35	56	1	2	4	0	
				16.5	17.5	2	50	44	0	1	3	0	
				17.5	18.5	6	80	14	0	0	0	0	
				18.5	19.5	23	70	7	0	0	0	0	†
				19.5	21.5	24	67	9	0	0	0	0	†
				21.5	22.5	7	84	9	0	0	0	0	†
				Mean		8	68	23	0	0	1	0	
a & b	7	90	3	Mean		7	62	27	1	1	2	0	

NO 42 SW 12 4100 2181 Brighouse, Logie BLOCK E

Surface level +109.7 m (+ 360 ft)
Water not struck
250 mm percussion
July 1979

Waste 3.7 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.7	0.7
Till	Clay, stiff, reddish brown, with sand partings, and subangular to subrounded clasts up to 10 cm diameter of lava with red sandstone and various metamorphic rocks	3.0	3.7
Felsite	Felsite, pink, with biotite	0.1+	3.8

NO 42 SW 13 4243 2491 Morendy Wood, Forgan BLOCK B

Surface level + 21.0 m (+ 69 ft)
Water struck at + 19.5 m
250 mm percussion
July 1979

Overburden 0.3 m
Mineral 2.0 m
Waste 2.1 m
Mineral 1.8 m
Waste 1.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.3	0.3
Fluvioglacial sand and gravel	a 'Very clayey' sand Gravel: rare fine and coarse, subangular to subrounded, predominantly lava Sand: fine, subangular to subrounded quartz, feldspar and rock fragments with rare mica, brown Fines: silt, disseminated and in bands	2.0	2.3
	Silt, grey-brown with a little fine, subangular to subrounded, disseminated brown sand	1.7	4.0
	Clay, brown, silty, with subangular to subrounded clasts up to 10 cm diameter of sandstone, lava, and various metamorphic rocks	0.4	4.4
Glacial sand and gravel	b Gravel Gravel: coarse with fine and rare cobbles up to 15 cm diameter, subangular to well rounded, andesite, basalt, quartzite and sandstone with various metamorphic rocks Sand: fine to coarse, subangular to subrounded, quartz Fines: silt, disseminated	1.8	6.2
Till	Clay, stiff, brown, with angular to subangular clasts up to 30 cm diameter of andesite with quartz and quartzite	1.3+	7.5
	Borehole terminated owing to boulder obstruction		

(continued ...)

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	71	2	0.3	1.3	20	63	11	2	3	1	0	
				1.3	2.3	33	62	4	0	0	1	0	†
				Mean		27	63	7	1	1	1	0	
b	1	30	69	4.4	5.4	1	7	11	9	28	44	0	†
				5.4	6.2	2	10	11	12	28	33	4	†
				Mean		1	8	11	11	28	39	2	
a & b	15	51	34	Mean		15	37	9	5	14	19	1	

NO 42 SW 14 4293 2410 Fordelhill, Leuchars BLOCK B

Surface level + 19.9 m (+ 65 ft)
Water struck at 17.6 m
250 mm and 200 mm percussion
August 1979

Overburden 0.4 m
Mineral 5.0 m
Waste 0.4 m
Mineral 6.0 m
Waste 1.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.4	0.4
Fluvioglacial sand and gravel	a Sand Gravel: a little fine with rare coarse, decreasing in abundance with depth, subangular to subrounded, andesite, basalt, quartzite and quartz with gneiss and sandstone Sand: fine and medium, subangular to subrounded, quartz, feldspar, and rock fragments, red-brown Fines: silt, disseminated	5.0	5.4
	Silt, laminated, red, clayey, with 1 mm thick sand partings	0.4	5.8
Glacial sand and gravel	b Gravel Gravel: fine and coarse with cobbles up to 8 cm diameter, subangular to well rounded, andesite, basalt, quartzite and quartz with gneiss, schist and sandstone Sand: medium and coarse with fine, subangular to subrounded, quartz, feldspar and rock fragments Fines: silt, disseminated	6.0	11.8
Till	Clay, brown becoming red with depth, sandy, with angular to subangular clasts of andesite and basalt with various metamorphic rocks	1.8+	13.6
	Borehole terminated owing to slow progress		

(continued ...)

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	5	92	3	0.4	1.4	2	17	60	10	9	2	0	
				1.4	2.4	1	33	58	3	5	0	0	
				2.4	3.4	1	47	50	1	1	0	0	
				3.4	4.4	2	53	44	1	0	0	0	†
				4.4	5.4	18	72	9	0	1	0	0	†
				Mean		5	44	44	3	3	0	0	†
b	4	44	52	5.8	6.8	8	22	26	16	20	8	0	†
				6.8	7.8	5	7	23	15	30	20	0	†
				7.8	8.8	5	16	12	13	25	23	6	†
				8.8	9.8	1	8	6	12	36	32	5	†
				9.8	10.8	1	9	17	25	24	24	0	†
				10.8	11.8	1	4	14	21	34	18	8	†
				Mean		4	11	16	17	28	21	3	
a&b	4	66	30	Mean		4	26	29	11	17	11	2	

NO 42 SW 15 4271 2343 Strathburn, Leuchars BLOCK A

Surface level + 10.7 m (+ 35 ft)
Water struck at + 9.0 m
250 mm and 200 mm percussion
August 1979

Overburden 1.7 m
Mineral 21.7 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.3	0.3
Peat	Peat, black, uncompacted	1.4	1.7
Glacial sand and gravel	Sandy gravel Gravel: increases in abundance below 7.3 m, fine with coarse and rare cobbles up to 15 cm diameter, angular to well rounded, basalt, quartzite, quartz, red and yellow sandstones, grit, andesite, felsite, psammite, and rare conglomerate. Basalt predominant below 22.7 m Sand: fine and medium with coarse, angular to subrounded, quartz and rock fragments Fines: red silt with clay, disseminated, with 15 cm red silt band at 3.4 m and brown clay band at 14.4 m.	21.7	23.4
Lower Devonian	Basalt, fine grained, black, very hard with some chlorite veining	0.1+	23.5

(continued .....)

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	56	41	1.7	3.4	4	16	30	18	18	14	0	†
			3.4	4.3	5	48	34	9	4	0	0	†
			4.3	5.5	4	46	36	4	5	5	0	†
			5.5	6.5	4	38	30	6	13	9	0	†
			6.5	7.3	1	35	29	9	13	13	0	†
			7.3	8.3	2	17	17	7	28	29	0	†
			8.3	9.9	3	32	13	8	28	16	0	†
			9.9	11.7	6	28	10	8	19	25	4	†
			11.7	12.7	2	15	18	10	25	21	9	†
			12.7	13.7	3	9	13	15	35	25	0	†
			13.7	14.7	2	13	17	10	28	30	0	†
			14.7	15.7	3	18	31	18	27	3	0	†
			15.7	16.7	2	18	32	18	22	8	0	†
			16.7	17.7	1	14	24	18	32	11	0	†
			17.7	18.7	1	10	17	14	26	17	15	†
			18.7	19.7	2	13	21	15	23	26	0	†
			19.7	20.7	0	13	23	13	19	32	0	†
			20.7	21.8	3	13	27	17	24	16	0	†
			21.8	22.7	2	10	20	7	28	20	13	†
			22.7	23.4	2	15	20	11	33	19	0	†
			Mean		3	21	23	12	22	17	2	

NO 42 SW 16 4253 2007 Hayston, Leuchars BLOCK E

Surface level + 21.5 m (+71 ft)
Water struck at + 17.8 m
250 mm percussion
August 1979

Waste 3.7 m
Bedrock 1.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.5	0.5
Till	Clay, moderately stiff with a crumbly texture, light brown and grey becoming reddish brown with depth, sandy and silty, with angular to rounded clasts up to 10 cm diameter of quartzite, basalt, sandstone, and red micaceous shale, the latter becoming dominant below 2.5 m	3.2	3.7
Lower Devonian	Shale, red, laminated, soft, with bands of fibrous calcite up to 1 cm thick	1.3+	5.0

NO 42 SW 17 4399 2466 Pickletillem, Leuchars BLOCK B

Surface level + 32.5 m (+ 107 ft)
Water not struck
250 mm percussion
June 1979

Overburden 0.6 m
Mineral 3.8 m
Waste 9.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.6	0.6
Glacial sand and gravel	Sandy gravel Gravel: much less abundant below 2.6 m, fine and coarse with rare cobbles up to 10 cm diameter, subangular to subrounded, red sandstone, lava and various metamorphic rocks Sand: medium with a little fine and coarse, quartz with rock fragments, red Fines: silt, disseminated	3.8	4.4
Till	Clay, red to grey, becoming very stiff with depth, sandy, with subangular to subrounded clasts up to 10 cm diameter of lava with sandstone, quartzite and quartz	9.6+	14.0
	Borehole terminated owing to boulder obstruction.		

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages						
Fines	Sand	Gravel			Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
4	67	29	0.6	1.6	8	14	27	8	14	29	0
			1.6	2.6	3	11	31	9	22	24	0
			2.6	3.6	4	9	75	5	4	3	0
			3.6	4.4	2	8	68	6	6	4	6
			Mean		4	11	49	7	12	16	1

NO 42 SW 18 4308 2314 Strathburn, Leuchars BLOCK A

Surface level + 20.5 (+ 67 ft)
Water struck at + 9.9 m
250 mm and 200 mm percussion
August 1979

Overburden 0.4 m
Mineral 24.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty and sandy	0.4	0.4
Glacial sand and gravel	a Sandy gravel Gravel: most abundant from 2.3 m to 9.4 m and below 17.2 m, fine and coarse with cobbles up to 20 cm diameter, angular to well rounded, basalt, andesite, quartzite, rhyolite, felsite, schist, quartz, and red sandstone with rare granite and conglomerate Sand: medium with coarse and fine, angular to subrounded, quartz, rock fragments and feldspar, reddish brown Fines: silt, disseminated, with bands of medium brown silt and reddish brown laminated clay from 1.3 m to 4.4 m	23.0	23.4
Till	b Sandy gravel Gravel: fine and coarse with cobbles up to 9 cm diameter, angular to well rounded, basalt, quartzite and psammite with red sandstone, andesite, felsite and quartz Sand: medium with fine and coarse, angular to subrounded, rock fragments with quartz and feldspar Fines: clay, disseminated, reddish brown, locally sufficient to bind deposit	1.5+	24.9

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	3	54	43	0.4	1.3	2	32	14	6	11	12	23	
				1.3	2.3	12	62	12	4	6	4	0	
				2.3	3.4	6	18	14	7	16	12	27	
				3.4	4.4	4	8	11	13	16	27	21	
				4.4	5.3	3	6	15	14	17	25	20	
				5.3	6.4	3	7	17	15	23	21	14	
				6.4	7.4	4	10	18	20	28	20	0	
				7.4	8.4	4	11	24	17	20	24	0	
				8.4	9.4	5	6	10	16	25	31	7	
				9.4	10.6	3	39	34	10	7	7	0	
				10.6	11.6	3	34	59	3	1	0	0	†
				11.6	12.4	1	23	25	25	17	9	0	†
				12.4	14.1	1	4	37	27	25	6	0	†
				14.1	15.2	1	9	53	17	6	14	0	†
				15.2	16.2	2	5	36	19	22	16	0	†
				16.2	17.2	1	14	55	10	11	9	0	†
				17.2	18.2	0	2	35	11	16	25	11	†
				18.2	19.1	1	3	16	24	23	21	12	†
				19.1	20.1	0	2	5	21	34	8	30	†
				20.1	21.1	1	2	20	21	28	23	5	†
				21.1	22.1	0	3	15	19	21	26	16	†
				22.1	23.4	2	6	19	11	15	24	23	†
				Mean		3	14	25	15	18	16	9	
b	3	55	42	23.4	24.2	3	15	21	9	21	27	4	†
				24.2	24.9	3	17	37	12	14	10	7	†
				Mean		3	16	29	10	18	19	5	
a&b	3	54	43	Mean		3	14	25	15	18	16	9	

NO 42 SW 19 4365 2204 Southfield, Leuchars BLOCK B

Surface level + 32.0 m (+ 105 ft)
Water struck at + 14.9 m
250 mm and 200 mm percussion
August 1979

Overburden 0.2 m
Mineral 6.8 m
Waste 11.0 m
Mineral 5.8 m
Waste 0.5 m
Bedrock 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.2	0.2
Fluvioglacial sand and gravel	a Sand Gravel: principally above 1.0 m, fine with coarse, angular to well rounded, quartzite, felsite and sandstone Sand: fine with medium, angular to subangular, quartz, with feldspar and rock fragments, orange-brown Fines: silt, disseminated, and in bands from 2.2 m to 3.2 m	4.0	4.2
Glacial sand and gravel	b Gravel Gravel: coarse with fine and, above 6.0 m, cobbles up to 10 cm diameter, angular to well rounded, quartzite and basalt with red sandstone, felsite, quartz, schist, diorite, tuff and granodiorite Sand: coarse with fine and medium, subrounded to angular, rock fragments and quartz Fines: clay, disseminated, red-brown, locally binding the deposit	2.8	7.0
Till	Clay, very stiff, red-brown, silty and sandy, the latter principally from 11.5 to 13.0 m although sand bands occur below 14.5 m, with angular to well rounded clasts up to 15 cm diameter of basalt with andesite and felsite and, above 11.5 m, quartzite, quartz, and rare gabbro	8.0	15.0
	c 'Very clayey' pebbly sand Gravel: fine with coarse, basalt with andesite and felsite Sand: fine with medium Fines: clay, disseminated, red-brown	1.2	16.2
	Clay, silty with sandy bands and rare clasts of basalt, andesite and felsite	1.8	18.0
	d Pebbly sand Gravel: fine with coarse and, below 20.8 m, cobbles up to 10 cm diameter, angular to rounded, basalt and andesite with quartz, felsite, quartzite and rare volcanic breccia Sand: fine with medium and coarse, angular to subangular with subrounded to rounded, rock fragments with quartz and feldspar Fines: clay, disseminated, red-brown, rare clay-bound lumps recovered. Much of the fines have been lost during drilling	5.8	23.8
	Clay, stiff, red-brown, locally blue-grey, with sandy bands and fine gravel grade clasts of composition as above	0.5	24.3
Lower Devonian	Andesite, poorly developed grain size and colour banding, subhedral feldspar phenocrysts up to 5 mm, pinkish grey, very hard	0.2+	24.5

(continued .....)

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	92	3	0.2	1.0	2	30	46	10	7	5	0	
				1.0	2.2	4	73	21	1	1	0	0	
				2.2	3.2	6	54	40	0	0	0	0	
				3.2	4.2	8	65	25	1	1	0	0	
				Mean		5	58	32	2	2	1	0	
b	7	28	65	4.2	5.3	8	10	9	13	21	29	10	
				5.3	6.0	6	6	6	11	26	35	10	
				6.0	7.0	7	7	7	12	28	39	0	
				Mean		7	8	8	12	25	34	6	
c	28	55	17	15.0	16.2	28	36	14	5	10	7	0	‡
d	5	73	22	18.0	19.0	5	19	20	20	27	9	0	†
				19.0	19.9	6	42	26	8	12	6	0	†
				19.9	20.8	4	38	31	10	9	8	0	†
				20.8	21.8	1	44	20	7	12	6	10	†
				21.8	23.1	8	34	25	14	17	2	0	†
				23.1	23.8	5	29	47	10	8	1	0	†
				Mean		5	34	27	12	15	5	2	
a,b&d	5	69	26	Mean		5	36	24	9	13	11	2	

NO 42 SW 20 4332 2095 Burnbrae, Leuchars BLOCK E

Surface level + 33.2 m (+ 109 ft)
Water struck at + 28.7 m
250 mm percussion
July 1979

Waste 8.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.5	0.5
Till	Clay, moderately stiff, red-brown, sandy with angular to rounded clasts up to 14 cm diameter of basalt, which becomes predominant with depth, with felsite, quartzite, psammite, andesite, and schist	7.6+	8.1
	Borehole terminated owing to slow progress		

NO 42 SW 21 4475 2188 Hillpark, Leuchars BLOCK B

Surface level + 22.4 m (+ 73 ft)
Water struck at + 9.2 m
250 mm and 200 mm percussion
August 1979

Overburden 0.4 m
Mineral 1.0 m
Waste 1.8 m
Mineral 13.0 m
Waste 4.8 m
Mineral 4.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.4	0.4
Fluvioglacial sand and gravel	a Sand Gravel: trace fine, subrounded Sand: fine and medium, subangular to subrounded, quartz and feldspar, red Fines: silt, disseminated	1.0	1.4
	Silt, laminated, red, clayey, with sand partings up to 1 cm thick, and rare pebbles	1.8	3.2
	b 'Clayey' sand Sand: fine, angular to subrounded, quartz, brown Fines: silt, brown, disseminated throughout, and in bands above 3.5 m, at 13.0 m, and below 16.0 m	13.0	16.2
	Silt, brown, sandy, with stiff clay bands up to 5 cm thick	4.8	21.0
	c Sand Gravel: principally from 22.0 m to 23.0 m, coarse with fine and rare cobbles up to 10 cm diameter, subrounded, lava, sandstone, and various metamorphic rocks Sand: fine with a little medium, subangular to subrounded, quartz and feldspar Fines: silt, disseminated	4.0+	25.0

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	2	97	1	0.4	1.4	2	47	48	2	1	0	0	
b	12	88	0	3.2	4.2	6	87	6	1	0	0	0	
				4.2	5.2	13	60	27	0	0	0	0	
				5.2	6.2	18	71	11	0	0	0	0	
				6.2	7.2	11	86	3	0	0	0	0	
				7.2	8.2	21	76	2	1	0	0	0	
				8.2	9.2	6	87	7	0	0	0	0	
				9.2	10.2	29	70	1	0	0	0	0	
				10.2	11.2	10	80	10	0	0	0	0	
				11.2	12.2	4	92	4	0	0	0	0	
				12.2	13.2	5	93	2	0	0	0	0	
				13.2	14.2	6	86	8	0	0	0	0	†
				14.2	15.2	5	89	6	0	0	0	0	†
				15.2	16.2	21	75	3	0	1	0	0	†
				Mean		12	81	7	0	0	0	0	
c	5	90	5	21.0	22.0	7	72	21	0	0	0	0	†
				22.0	23.0	8	51	26	0	4	11	0	†
				23.0	24.0	4	62	31	2	1	0	0	†
				24.0	25.0	2	64	29	3	1	1	0	†
				Mean		5	62	27	1	2	3	0	†
a to c	10	89	1	Mean		10	75	14	0	0	1	0	

NO 42 SW 22 4422 2186 Southfield, Leuchars BLOCK B

Surface level + 33.7 m (+ 111 ft)
Water not struck
250 mm and 200 mm percussion
August 1979

Overburden 0.3 m
Mineral 24.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.3	0.3
Fluvioglacial sand and gravel	Sand Gravel: above 6.8 m, a little fine with coarse and, from 1.3 to 2.8 m, rare cobbles up to 9 cm diameter, angular to rounded, quartzite, basalt, and quartz Sand: fine with medium, the latter most abundant above 6.8 m and from 10.0 m to 18.0 m, subangular to subrounded, quartz with rock fragments, orange-brown Fines: silt, disseminated, orange, with bands of brown silt and laminated red clay up to 5 cm thick	24.9+	25.2

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
5	94	1	0.3	1.3	1	22	74	2	1	0	0
			1.3	2.3	4	29	55	7	4	1	0
			2.3	3.5	8	44	37	5	5	1	0
			3.5	4.8	7	35	54	3	1	0	0
			4.8	5.8	6	31	48	6	4	5	0
			5.8	6.8	5	38	50	3	2	2	0
			6.8	8.2	15	77	8	0	0	0	0
			8.2	8.9	9	86	5	0	0	0	0
			8.9	10.0	5	86	9	0	0	0	0
			10.0	11.0	1	48	50	1	0	0	0
			11.0	12.0	1	63	34	2	0	0	0
			12.0	13.0	9	66	24	1	0	0	0
			13.0	14.0	3	33	64	0	0	0	0
			14.0	15.0	3	42	55	0	0	0	0
			15.0	16.0	1	18	79	2	0	0	0
			16.0	17.0	0	22	69	8	1	0	0
			17.0	18.0	2	38	56	4	0	0	0
			18.0	19.0	1	74	25	0	0	0	0
			19.0	20.0	2	67	24	7	0	0	0
			20.0	21.0	2	79	18	1	0	0	0
			21.0	22.0	2	76	22	0	0	0	0
			22.0	23.0	2	70	28	0	0	0	0
			23.0	24.0	9	61	30	0	0	0	0
			24.0	25.2	12	49	38	1	0	0	0
			Mean		5	52	40	2	1	0	0

NO 42 SW 23 4419 2047 Pusk, Leuchars BLOCK B

Surface level + 22.0 m (+ 72 ft)
Water struck at + 12.0 m
250 mm and 200 mm percussion
July 1979

Overburden 0.4 m
Mineral 7.8 m
Waste 3.3 m
Mineral 2.2 m
Waste 5.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.4	0.4
Fluvioglacial sand and gravel	a 'Clayey' sand Gravel: trace of fine with coarse, principally above 3.3 m Sand: fine, with medium above 3.3 m, angular to subrounded, quartz with rock fragments, and mica below 3.3 m, orange-brown Fines: red laminated clay bands above 3.3 m and below 5.4 m, disseminated silt below 2.3 m	7.8	8.2
	Clay, moderately stiff, laminated, silty, red-brown	0.4	8.6
	Silt, sandy, interbedded with red-brown laminated clay, and with fine sand above 10.0 m	2.9	11.5
	b 'Clayey' sand Sand: fine, angular to rounded, quartz with rock fragments, red-brown Fines: silt, disseminated	2.2	13.7
Late-Glacial marine deposits	Clay, laminated, red-brown, silty	2.2	15.9
Till	Clay, very stiff, reddish brown, with ill-sorted angular to well rounded clasts of quartzite, basalt, quartz, felsite and microgranite	3.6+	19.5
	Borehole terminated owing to boulder obstruction		

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	17	82	1	0.4	1.4	10	34	51	3	2	0	0	
				1.4	2.3	18	54	23	3	2	0	0	
				2.3	3.3	20	78	1	0	1	0	0	
				3.3	4.0	35	63	2	0	0	0	0	
				4.0	5.4	25	74	1	0	0	0	0	
				5.4	6.6	8	89	1	0	1	1	0	
				6.6	7.5	10	76	12	2	0	0	0	
				7.5	8.2	13	86	1	0	0	0	0	
				Mean		17	70	11	1	1	0	0	
b	15	85	0	11.5	12.4	12	84	4	0	0	0	0	†
				12.4	13.7	17	81	2	0	0	0	0	†
				Mean		15	82	3	0	0	0	0	
a&b	17	82	1	Mean		17	72	9	1	1	0	0	

NO 42 SW 24 4291 2364 Crawley Hill, Leuchars BLOCK A

Surface level + 41.0 m (+ 135 ft) Overburden 0.3 m
Water not struck Mineral 1.7 m +
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.3	0.3
Glacial sand and gravel	Sandy gravel, interbedded sand and gravel to 1.4 m Gravel: fine and coarse with rare cobbles up to 11 cm diameter, subrounded to well rounded, red sandstone, quartzite, lava and felsite Sand: medium with fine and coarse Fines: silt, disseminated, less abundant below 1.4 m	1.7+	2.0

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	62	37	0.3	2.0	1	12	32	18	20	17	0 ‡

NO 42 SW 25 4268 2103 Balmullo, Leuchars BLOCK E

Surface level + 45.7 m (+ 150 ft) Waste 1.7 m +
Water struck at + 44.0 m
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.3	0.3
Till	Clay, moderately stiff, reddish brown, with angular to well rounded clasts up to 16 cm diameter of lava with sandstone, schist, felsite and quartzite	1.4+	1.7

NO 42 SW 26 4297 2049 Balmullo Farm, Leuchars BLOCK E

Surface level + 28.0 m (+ 92 ft) Overburden 0.3 m
Water not struck Mineral 1.8 m +
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.3	0.3
Fluvioglacial sand and gravel	Sand Sand: fine, subangular, quartz, reddish brown Fines: silt, disseminated, increasing in abundance with depth	1.8+	2.1

(continued .....)

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
9	91	0	0.3	2.1	9	89	2	0	0	0	0	‡

NO 42 SW 27 4341 2336 Strathburn, Leuchars BLOCK A

Surface level + 27.7 m (+ 91 ft)
Water not struck
Pit
October 1979

Overburden 0.3 m
Mineral 1.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.3	0.3
Fluvioglacial sand and gravel	Sand Sand: fine and medium, angular to subangular, quartz with rock fragments, red Fines: silt, disseminated	1.7+	2.0

NO 42 SW 28 4382 2324 Carrick, Leuchars BLOCK A

Surface level + 28.0 m (+ 92 ft)
Water not struck
Pit
October 1979

Overburden 0.3 m
Mineral 1.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, black, humus rich	0.3	0.3
Glacial sand and gravel	Gravel Gravel: fine and coarse with rare cobbles up to 12 cm diameter, including locally derived angular sandstone up to 10 cm diameter, generally subrounded to well rounded, quartzite, sandstone, felsite, lava and schist Sand: medium with coarse and a little fine, angular to subangular, quartz with rock fragments, medium brown becoming greyish brown below 1.0 m Fines: silt, disseminated	1.7+	2.0

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
1	43	56	0.3	2.0	1	5	25	13	31	25	0	‡

NO 42 SW 29 4358 2160 Southfield, Leuchars BLOCK E

Surface level + 15.0 m (+ 49 ft)
Water struck at + 13.1 m
Pit
October 1979

Waste 1.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.3	0.3
Late-Glacial marine deposits	Sand, fine, orange-brown, silty	0.3	0.6
	Clay, poorly laminated, brown, sand, silt, and rarely, gravel partings. Carbonaceous band at 1.4 m, some fragmented rootlets	1.3+	1.9

NO 42 SW 30 4337 2130 Burnbrae, Leuchars BLOCK E

Surface level + 34.0 m (+ 112 ft)
Water not struck
Pit
October 1979

Waste 1.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.4	0.4
Late-Glacial marine deposits	Silt, reddish brown	0.3	0.7
	Clay, stiff, poorly laminated, reddish brown, silt partings, with clasts at the base possibly derived from a lower deposit of till. Scattered rootlets	1.2+	1.9

NO 42 SW 31 4375 2128 Pusk, Leuchars BLOCK E

Surface level + 17.0 m (+ 56 ft)
Water not struck
Pit
October 1979

Waste 2.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.5	0.5
Fluvioglacial sand and gravel	Silt, mottled reddish brown	0.7	1.2
	Sand, fine with medium, angular with subangular, quartz with rock fragments, with rare well rounded pebbles up to 5 cm diameter and a little disseminated silt	0.8	2.0
Till	Clay, soft, reddish-brown, with clasts	0.1+	2.1

NO 42 SW 32 4348 2108 Burnbrae, Leuchars BLOCK E

Surface level + 32.0 m (+ 105 ft) Waste 1.2 m +
Water not struck
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.3	0.3
Till	Clay, stiff, red-brown, with a little coarse sand. Scattered rootlets	0.9+	1.2

NO 42 SW 33 4392 2078 Pusk, Leuchars BLOCK B

Surface level + 29.0 m (+ 95 ft) Overburden 1.0 m
Water not struck Mineral 1.2 m +
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	1.0	1.0
Fluvioglacial sand and gravel	Sand Sand: fine, angular to subangular, quartz with rare rock fragments, red-brown Fines: silt, disseminated	1.2+	2.2

NO 42 SW 34 4380 2058 Pusk, Leuchars BLOCK E

Surface level + 18.0 m (+ 59 ft) Waste 1.5 m +
Water not struck
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.3	0.3
Late-Glacial marine deposits	Silt, medium brown, sandy, with carbonaceous material	0.4	0.7
	Clay, stiff, red-brown, an increasing number of silt partings with depth, scattered rootlets	0.8+	1.5

NO 42 SW 35 4343 2049 Burnbrae, Leuchars BLOCK E

Surface level + 19.0 m (+ 62 ft) Waste 1.9 m +
Water not struck
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.3	0.3
Late-Glacial marine deposits	Clay, stiff, red-brown, laminations becoming more pronounced with depth, 8 cm thick silty sand band at 0.9 m. Scattered rootlets	1.0	1.3
	Sand, fine, angular to subangular, quartz, reddish brown, silty	0.5	1.8
	Clay, red-brown, scattered rootlets	0.1+	1.9

NO 42 SW 36 4402 2014 Balmullo Farm, Leuchars BLOCK E

Surface level + 16.0 m (+ 52 ft) Waste 2.1 m +
Water not struck
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.3	0.3
Late-Glacial marine deposits	Sand, fine, angular, orange-brown, silty	0.6	0.9
	Clay, stiff, poorly laminated, red-brown, with 5 cm thick sand band at 1.1 m. Scattered rootlets	1.2+	2.1

NO 42 SW 37 4350 2006 Pusk, Leuchars BLOCK E

Surface level + 18.0 m (+ 59 ft) Waste 2.0 m +
Water not struck
Pit
October 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.2	0.2
Late-Glacial marine deposits	Clay, stiff, reddish brown, interbedded with red-brown silt partings which become more abundant with depth	1.4	1.6
	Silt, red-brown, with fine sand	0.4+	2.0

NO 42 SW 38 4388 2004 Pusk, Leuchars BLOCK E

Surface level + 22.0 m (+ 72 ft)
Water not struck
Pit
October 1979

Waste 2.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey	0.2	0.2
Late-Glacial marine deposits	Clay, red-brown, laminated in part, interbedded with bands up to 10 cm thick of fine, angular to subrounded, sand, and medium brown silt	2.0+	2.2

NO 42 SW 39 4461 2429 Craigie Hill, Leuchars BLOCK E

Surface level + 19.8 m (+ 65 ft)
Water struck at + 17.7 m
Pit
October 1979

Overburden 0.3 m
Mineral 1.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.3	0.3
Late-Glacial beach deposits	Sandy gravel Gravel: fine and coarse, subangular to well rounded, basalt with quartz, quartzite and felsite Sand: medium with a little coarse and fine, angular to subrounded, quartz with rock fragments, medium brown Fines: silt, disseminated, brown	1.8+	2.1

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
3	65	32	0.3	2.1	3	8	44	13	17	15	0 ‡

NO 42 SW 40 4482 2419 Craigie, Leuchars BLOCK B

Surface level + 15.6 m (+ 51 ft)
Water struck at + 13.5 m
Pit
October 1979

Overburden 0.5 m
Mineral 1.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.5	0.5
Fluvioglacial sand and gravel	Sand Gravel: rare fine, becoming more abundant with depth, subangular to rounded, basalt with quartz. Sand: fine with a little medium, becoming coarser with depth, angular to subrounded, quartz with feldspar and rock fragments Fines: trace	1.6+	2.1

NO 42 SW 41 4428 2397 Craigie Hill, Leuchars BLOCK B

Surface level + 22.5 m (+ 74 ft)
Water not struck
Pit
August 1979

Overburden 0.4 m
Mineral 1.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.4	0.4
Fluvioglacial sand and gravel	Sand Gravel: rare, up to cobble grade, predominantly above 1.0 m, angular to well rounded, andesite, basalt, and various metamorphic rocks Sand: fine to medium, quartz, feldspar and rock fragments, brown Fines: trace	1.8+	2.2

NO 42 SW 42 4403 2349 St Michael's Wood, Leuchars BLOCK B

Surface level + 21.1 m (+ 69 ft)
Water not struck
Pit
August 1979

Overburden 0.3 m
Mineral 1.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, loamy and sandy	0.3	0.3
Fluvioglacial sand and gravel	Pebbly sand Gravel: fine and coarse with very rare cobbles, angular to well rounded Sand: fine to medium with rare coarse, brown Fines: trace	1.9+	2.2

NO 42 SE 11 4545 2437 Craigie, Leuchars BLOCK E

Surface level + 10.8 m (+ 35 ft)
Water struck at + 9.6 m
250 mm percussion
August 1979

Overburden 0.6 m
Mineral 1.9 m
Waste 1.2 m
Bedrock 0.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.6	0.6
Late-Glacial beach deposits	'Clayey' sand Gravel: trace above 1.9 m, occuring in thin laminated clay bands, fine, well rounded Sand: fine with medium, quartz with rock fragments, orange-brown Fines: silt, disseminated, increasing with depth, with stiff red-brown laminated clay bands, mainly above 1.9 m. Trace of peat near 0.6 m	1.9	2.5
Till	Clay, stiff, red-brown, with subangular to well rounded clasts up to 10 cm diameter of basalt with quartzite, felsite and diorite. Below 2.8 m dominantly green sandstone clasts which readily decompose to sand	1.2	3.7
Lower Devonian	Sandstone, medium grained, micaceous, green, highly weathered	0.5+	4.2

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	
17	82	1	0.6	1.9	15	58	25	1	1	0	0	†
			1.9	2.5	21	57	21	0	1	0	0	†
			Mean		17	58	24	0	1	0	0	

NO 42 SE 12 4501 2371 Fordel, Leuchars BLOCK B

Surface level + 13.7 m (+ 45 ft)
Water struck at + 9.9 m
250 mm and 200 mm percussion
June 1979

Mineral 13.7 m
Waste 1.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Sand Gravel: a little from 4.0 m to 6.0 m and below 12.0 m, fine with coarse, sub-rounded, basalt with andesite, quartz, quartzite, felsite, red and grey sandstones and gneiss Sand: fine with medium, angular to subangular, quartz with a few feldspar and rock fragments, orange-brown Fines: silt, disseminated with rare red clay bands up to 1 cm thick. Thicker laminated grey and red-brown clay bands from 6.0 m to 7.0 m	13.7	13.7
Till	Clay, moderately stiff, greyish brown, sandy, with ill-sorted subangular to well rounded clasts up to 10 cm diameter of basalt with andesite, quartz, quartzite, and psammite	1.5+	15.2
	Borehole terminated owing to boulder obstruction		

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
4	95	1	0.0	1.0	1	80	18	1	0	0	0	
			1.0	1.9	1	79	20	0	0	0	0	
			1.9	3.0	2	69	28	1	0	0	0	
			3.0	4.0	4	82	13	1	0	0	0	
			4.0	5.0	4	83	9	3	1	0	0	†
			5.0	6.0	4	68	22	4	2	0	0	†
			6.0	7.0	21	61	17	1	0	0	0	†
			7.0	8.0	1	80	18	1	0	0	0	†
			8.0	9.0	4	88	8	0	0	0	0	†
			9.0	10.0	4	78	17	1	0	0	0	†
			10.0	11.0	2	77	21	0	0	0	0	†
			11.0	12.0	2	71	26	1	0	0	0	†
			12.0	13.0	3	43	49	3	2	0	0	†
			13.0	13.7	3	34	53	5	4	1	0	†
			Mean		4	72	22	1	1	0	0	

NO 42 SE 13 4508 2329 St Michael's Wood, Leuchars BLOCK B

Surface level + 14.4 m (+ 47 ft)
Water struck at + 10.4 m
250 mm and 200 mm percussion
June 1979

Overburden 0.3 m
Mineral 5.5 m
Waste 3.2 m
Mineral 13.7 m
Waste 1.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty	0.3	0.3
Fluvioglacial sand and gravel	a Sand Gravel: trace of fine above 2.3 m Sand: fine with medium, angular to subangular, quartz with rock fragments, orange-red Fines: silt, disseminated, with silty clay bands below 4.0 m	5.5	5.8
	Clay, faintly laminated, red, silty, sand partings, silt and sand increasing with depth	3.2	9.0
	b 'Clayey' sand Gravel: trace of fine below 16.0 m, subangular to subrounded, quartzite, quartz, sandstone, basalt and dolerite Sand: fine with medium, quartz with a few mica and rock fragments, red Fines: silt, disseminated, with rare red clay bands up to 2 cm thick	8.0	17.0
	c Sand Sand: fine and medium, quartz with rock fragments, red Fines: silt, disseminated, with grey clay bands up to 1 cm thick near the base	5.7	22.7
Till	Clay, stiff, greyish brown, sandy, with subangular to well rounded clasts up to 10 cm diameter of andesite, basalt, sandstone, quartz and various metamorphic rocks	1.1+	23.8
	Borehole terminated owing to slow progress		

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
a	8	92	0	0.3	1.3	3	46	48	2	1	0	0	
				1.3	2.3	2	63	32	2	1	0	0	
				2.3	3.3	2	47	50	1	0	0	0	
				3.3	4.0	2	49	39	10	0	0	0	
				4.0	5.0	13	44	42	1	0	0	0	†
				5.0	5.8	24	67	9	0	0	0	0	†
				Mean		8	52	38	2	0	0	0	
b	14	86	0	9.0	10.0	22	70	8	0	0	0	0	†
				10.0	11.0	10	55	34	1	0	0	0	†
				11.0	12.0	22	57	21	0	0	0	0	†
				12.0	13.0	14	67	19	0	0	0	0	†
				13.0	14.0	13	68	19	0	0	0	0	†
				14.0	15.0	13	70	17	0	0	0	0	†
				15.0	16.0	8	68	24	0	0	0	0	†
				16.0	17.0	10	68	20	0	2	0	0	†
				Mean		14	66	20	0	0	0	0	
c	2	98	0	17.0	19.0	3	53	43	1	0	0	0	†
				19.0	20.0	2	54	44	0	0	0	0	†
				20.0	21.0	1	47	52	0	0	0	0	†
				21.0	22.0	1	45	54	0	0	0	0	†
				22.0	22.7	2	64	34	0	0	0	0	†
				Mean		2	52	46	0	0	0	0	
a to c	9	91	0	Mean		9	57	32	1	0	0	0	

NO 42 SE 14 4578 2010 Leuchars Airfield BLOCK C

Surface level + 8.1 m (+ 27 ft)
Water struck at + 5.8 m
250 mm and 200 mm percussion
July 1979

Overburden 1.4 m
Mineral 5.2 m
Waste 15.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Blown sand	Sand Sand: fine to medium, quartz with rock fragments	0.2	0.2
Post-Glacial deposits	Silt, light brown becoming red with depth	1.2	1.4
	'Very clayey' sand Sand: fine, quartz with rock fragments, and rare shell material from 2.3 m to 3.0 m Fines: silt, disseminated, red-brown, with stiff red-brown clay bands up to 0.3 m thick from 3.0 m to 3.9 m	5.2	6.6
	Silt, sand content decreasing with depth, moderately stiff red-brown clay bands at 7.0 m, disseminated clay below 8.0 m	3.4	10.0
Late-Glacial marine deposits	Clay, moderately stiff, laminated, red-brown, slightly silty	12.2+	22.2

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	
26	74	0	1.4	2.3	37	62	0	1	0	0	0	
			2.3	3.0	22	78	0	0	0	0	0	†
			3.0	3.9	33	67	0	0	0	0	0	†
			3.9	4.9	19	81	0	0	0	0	0	†
			4.9	5.9	22	78	0	0	0	0	0	†
			5.9	6.6	20	79	1	0	0	0	0	†
			Mean		26	74	0	0	0	0	0	

NO 42 SE 15 4628 2482 Craigie, Leuchars BLOCK D

Surface level + 8.5 m (+ 28 ft)
Water struck at + 7.0 m
250 mm and 200 mm percussion
June 1979

Overburden 0.5 m
Mineral 1.0 m
Waste 2.0 m
Mineral 4.5 m
Waste 13.2 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.5	0.5
Post-Glacial deposits	a 'Clayey' sand Sand: fine, angular with subangular, quartz, brown becoming grey-brown with depth Fines: silt, brown	1.0	1.5
	Clay, soft, grey, interbedded with brown sand above 2.5 m	2.0	3.5
	b Pebbly sand Gravel: coarse with fine and rare cobbles up to 15 cm diameter, angular to rounded, basalt with felsite, andesite, quartz and quartzite Sand: medium with fine, angular to well rounded, quartz with feldspar and rock fragments Fines: silt, disseminated	3.3	6.8
	c Sand Gravel: rare fine in silt bands below 7.4 m Sand: fine with medium, subangular to well rounded, quartz with feldspar, rock fragments and coal Fines: silt, disseminated, with bands of stiff brown-grey silt below 7.1 m	1.2	8.0
	Clay, moderately stiff, brown-grey, silty in part, sandy laminae, rare well rounded to angular clasts up to 5 cm diameter of basalt. Carbonaceous staining near base	2.0	10.0
Late-Glacial marine deposits	Clay, moderately stiff, grey-brown, increasingly silty, and less stiff, below 17.5 m	9.0	19.0
Till	Clay, sandy, with angular to well rounded clasts up to 8 cm diameter of basalt with felsite, psammite and greenish grey sandstone	1.0	20.0
	d Gravel Gravel: coarse with fine and rare cobbles up to 17 cm diameter, well rounded to angular, basalt with andesite, psammite, quartzite, quartz and feldspar Fines: clay, disseminated	1.2	21.2
Lower Devonian	Sandstone, fine to medium grained, green-grey, including rare subangular clasts up to 1 cm diameter of basalt. Highly indurated	0.1+	21.3

(continued .....)

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	19	80	1	0.5	1.5	19	78	2	0	0	0	0	
b	2	84	14	3.5	4.5	2	24	46	8	13	7	0	†
				4.5	5.5	3	28	57	6	2	4	0	†
				5.5	6.8	1	33	46	4	2	14	0	†
				Mean		2	29	49	6	5	9	0	
c	10	90	0	6.8	7.4	7	59	30	4	0	0	0	†
				7.4	8.0	12	64	21	2	1	0	0	†
				Mean		10	62	25	3	0	0	0	
a to c	7	84	9	Mean		7	45	35	4	3	6	0	
d	3	46	51	20.0	21.3	3	12	25	9	14	37	0	†‡

NO 42 SE 16 4666 2372 Rhynd, Leuchars BLOCK C

Surface level + 8.6 m (+ 28 ft)
Water struck at + 6.8 m
250 mm and 200 mm percussion
June 1979

Overburden 0.7 m
Mineral 3.2 m
Waste 6.6 m
Mineral 3.3 m
Waste 8.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.7	0.7
Post-Glacial deposits	a Sand Sand: fine with a little medium, angular to subangular, quartz with rock fragments, orange becoming grey below 1.8 m Fines: silt, disseminated, with grey clay bands up to 1 cm thick near 1.8 m	3.2	3.9
	Clay, varies from soft to moderately stiff, grey, silty, rare sand laminae, mica with disseminated fine sand below 7.0 m	6.6	10.5
	b Sandy gravel Gravel: fine with coarse, well rounded to subangular, quartz with basalt, felsite, quartzite and andesite Sand: fine with medium, subangular to well rounded, quartz with a little feldspar Fines: clay with silt, disseminated, grey with bands of grey clay up to 20 cm thick between 11.5 m and 12.5 m	3.3	13.8
Late-Glacial marine deposits	Clay, stiff becoming very stiff with depth, grey-brown, rare gastropod shells at 14.0 m	6.4	20.2
Till	Clay, stiff, brown, silty, with subangular to well rounded clasts up to 5 cm diameter of quartz, basalt, volcanic breccia, quartzite, andesite, and white and green-grey sandstones	2.5+	22.7
	Borehole terminated owing to boulder obstruction		

(continued .....)

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	4	96	0	0.7	1.8	3	78	18	1	0	0	0	
				1.8	2.7	6	83	11	0	0	0	0	†
				2.7	3.9	3	81	16	0	0	0	0	†
				Mean		4	81	15	0	0	0	0	
b	9	65	26	10.5	11.5	9	21	18	11	34	7	0	†
				11.5	12.5	8	33	31	11	15	2	0	†
				12.5	13.8	9	30	30	10	16	5	0	†
				Mean		9	28	27	10	21	5	0	
a&b	6	81	13	Mean		6	54	21	6	11	2	0	

NO 42 SE 17 4648 2218 Cast, Leuchars BLOCK C

Surface level + 7.7 m (+ 25 ft)
Water struck at + 5.7 m
250 mm and 200 mm percussion
August 1979

Overburden 0.3 m
Mineral 8.5 m
Waste 12.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.3	0.3
Post-Glacial deposits	Sand Gravel: most abundant from 3.3 m to 4.3 m and below 7.8 m, fine with a little coarse up to 5 cm diameter, subangular to well rounded, andesite, basalt, felsite, quartzite, and sandstone, with schist and gneiss Sand: fine and medium, angular to subrounded, quartz, feldspar and rock fragments with shell material, brown becoming grey below 3.3 m Fines: silt, disseminated, grey, with rare clayey silt bands from 5.6 m to 6.6 m	8.5	8.8
Late-Glacial marine deposits	Clay, grey-brown becoming red-brown below 12.0 m, silty, rare sand lenses up to 1 cm thick, and rare pebbles	12.2+	21.0

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
3	93	4	0.3	1.3	2	86	12	0	0	0	0	
			1.3	2.3	1	59	40	0	0	0	0	
			2.3	3.3	1	43	55	1	0	0	0	†
			3.3	4.3	0	33	58	3	1	5	0	†
			4.3	5.6	2	43	49	4	2	0	0	†
			5.6	6.6	13	57	27	2	1	0	0	†
			6.6	7.8	3	32	57	5	3	0	0	†
			7.8	8.8	1	15	37	26	20	1	0	†
			Mean		3	46	42	5	3	1	0	

NO 42 SE 18 4654 2083 Earlshall, Leuchars BLOCK C

Surface level + 8.6 m (+ 28 ft) Waste 18.0 m +
Water struck at + 2.4 m
250 mm and 200 mm percussion
July 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.2	0.2
	Made ground	0.3	0.5
Post-Glacial deposits	Clay, stiff, grey-green and mottled grey-brown above 2.0 m, grey below becoming grey-red from 4.3 m. Carbonaceous material above 1.5 m and below 4.3 m, sandy band rich in gastropods with lamellibranch shells at 2.5 m	5.7	6.2
Late-Glacial marine deposits	Clay, stiff, red-brown, poorly laminated, silty	11.8+	18.0

NO 42 SE 19 4726 2444 Rhynd, Leuchars BLOCK D

Surface level + 9.9 m (+ 32 ft)
Water struck at + 6.9 m
250 mm and 200 mm percussion
July 1979

Overburden 0.2 m
Mineral 9.9 m
Waste 12.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.2	0.2
Blown sand	a Sand Sand: fine, angular to rounded, quartz with feldspar and rock fragments, light brown becoming grey-brown below 5.3 m Fines: silt, disseminated	6.1	6.3
Post-Glacial deposits	b Sand Sand: fine, angular to well rounded, quartz with rock and shell fragments, medium grey Fines: silt, disseminated, below 9.3 m grey silty clay bands which increase in number and thickness with depth	3.8	10.1
	Clay, soft, laminated, medium grey, becoming stiffer, greenish grey and silty with depth. Thin peat layers below 12.5	3.8	13.9
	Silt, soft, micaceous, medium grey, with shell fragments, sandy near the base	4.1	18.0
	c Sand Gravel: basal layer of basalt clasts up to 11 cm diameter rest on the underlying clay Sand: fine, quartz, with rock and shell fragments and a little mica, brownish grey Fines: silt, disseminated	1.7	19.7
Late-Glacial marine deposits	Clay, soft, laminated, red	2.4+	22.1

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	1	99	0	0.2	1.2	2	95	3	0	0	0	0	
				1.2	2.3	1	96	3	0	0	0	0	
				2.3	3.3	0	96	4	0	0	0	0	
				3.3	4.3	1	90	7	2	0	0	0	†
				4.3	5.3	1	95	4	0	0	0	0	†
				5.3	6.3	1	92	7	0	0	0	0	†
				Mean		1	94	5	0	0	0	0	
b	3	97	0	6.3	7.3	1	90	8	1	0	0	0	†
				7.3	8.3	1	90	9	0	0	0	0	†
				8.3	9.3	2	89	8	1	0	0	0	†
				9.3	10.1	11	80	8	1	0	0	0	†
				Mean		3	88	8	1	0	0	0	
a&b	2	98	0	Mean		2	92	6	0	0	0	0	
c	9	89	2	18.0	18.9	10	77	8	4	1	0	0	†‡
				18.9	19.7	8	75	11	4	2	0	0	†‡
				Mean		9	76	9	4	2	0	0	

NO 42 SE 20 4792 2251 Wards, Leuchars BLOCK C

Surface level + 8.9 m (+ 29 ft)
Water struck at + 7.5 m
250 mm and 200 mm percussion
August 1979

Overburden 0.2 m
Mineral 12.0 m
Waste 1.3 m
Mineral 2.0 m
Waste 2.0 m
Mineral 2.0 m
Waste 5.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.2	0.2
Blown sand	a Sand Gravel: trace fine above 1.2 m Sand: fine, angular to subrounded, quartz with feldspar and rare mica, brown Fines: silt, disseminated	2.0	2.2
Post-Glacial deposits	b Sand Gravel: trace fine below 7.2 m, subrounded, andesite Sand: fine, angular to subrounded, quartz, feldspar and rock fragments with mica, shell material below 4.2 m, grey Fines: silt, disseminated, with rare silt and silty clay bands up to 2 cm thick	10.0	12.2
	Silt, grey, with fine micaceous shelly quartz sand	1.3	13.5
	c 'Clayey' sand Sand: fine with a little medium, quartz with mica and rare shell fragments, grey Fines: silt, disseminated. Band of peat, 5 cm thick, at 15.0 m	2.0	15.5
	Silt, grey, with fine micaceous quartz sand	2.0	17.5
	d Sand Sand: fine with a little medium, quartz and feldspar with rare shell fragments, grey Fines: silt, disseminated	2.0	19.5
	Silt, laminated, grey, clayey, sand partings, with shell material and, principally from 20.3 m to 20.5 m, subangular to well rounded clasts up to 5 cm diameter of andesite and basalt with sandstone, quartzite, schist and gneiss	2.2	21.7
Late-Glacial marine deposits	Clay, soft, brown	2.8+	24.5

(continued .....)

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	1	97	2	0.2	1.2	1	89	6	1	3	0	0	
				1.2	2.2	0	97	3	0	0	0	0	†
				Mean		1	93	4	0	2	0	0	
b	3	97	0	2.2	3.2	0	96	4	0	0	0	0	†
				3.2	4.2	0	94	6	0	0	0	0	†
				4.2	5.2	0	90	10	0	0	0	0	†
				5.2	6.2	0	94	6	0	0	0	0	†
				6.2	7.2	0	96	4	0	0	0	0	†
				7.2	8.2	0	94	5	1	0	0	0	†
				8.2	9.2	2	92	4	1	1	0	0	†
				9.2	10.2	12	81	5	1	1	0	0	†
				10.2	11.2	6	87	3	2	2	0	0	†
				11.2	12.2	9	85	4	1	1	0	0	†
				Mean		3	91	5	1	0	0	0	
c	12	88	0	13.5	14.5	12	79	8	1	0	0	0	†
				14.5	15.5	13	66	20	1	0	0	0	†
				Mean		12	73	14	1	0	0	0	
d	8	92	0	17.5	18.5	11	78	11	0	0	0	0	†
				18.5	19.5	5	80	15	0	0	0	0	†
				Mean		8	79	13	0	0	0	0	
a to d	4	95	1	Mean		4	87	7	1	1	0	0	
b to d	5	95	0	Mean		5	87	7	1	0	0	0	

NO 42 SE 21 4709 2166 Comerton, Leuchars BLOCK C

Surface level + 9.9 m (+ 32 ft)
Water struck at + 8.1 m
250 mm and 200 mm percussion
July 1979

Mineral 11.5 m
Waste 10.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Blown sand	a Sand Sand: fine, quartz with rock fragments and a little mica, brown Fines: silt, disseminated	3.4	3.4
Post-Glacial deposits	b Sand Gravel: trace of fine below 8.5 m Sand: fine with medium, predominantly medium above 4.3 m, quartz with rock fragments and shell material, grey Fines: silt, disseminated, with thin grey silty clay bands from 8.5 m to 9.5 m. Disseminated clay and thicker grey clay bands below 10.5 m as deposit grades into underlying clay	8.1	11.5
	Clay, soft to moderately stiff, light grey, sandy partings near the top, peat at 12.0 m	3.5	15.0
	Silt, grey, with fine sand and rare subangular clasts	2.0	17.0
Late-Glacial marine deposits	Clay, stiff, red, becomes softer and siltier below 18.5 m. Rare angular to subrounded clasts and shell fragments	4.9+	21.9

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	2	98	0	0.0	2.5	2	96	2	0	0	0	0	
				2.5	3.4	2	92	6	0	0	0	0	†
				Mean		2	95	3	0	0	0	0	
b	5	95	0	3.4	4.3	1	3	96	0	0	0	0	†
				4.3	5.3	1	77	22	0	0	0	0	†
				5.3	6.4	3	82	15	0	0	0	0	†
				6.4	7.4	2	91	7	0	0	0	0	†
				7.4	8.5	2	92	6	0	0	0	0	†
				8.5	9.5	2	81	16	1	0	0	0	†
				9.5	10.5	2	90	6	1	1	0	0	†
				10.5	11.5	30	64	4	1	1	0	0	†
				Mean		5	74	20	1	0	0	0	
a&b	4	96	0	Mean		4	80	15	1	0	0	0	

NO 42 SE 22 4729 2012 Ship Hills, Leuchars BLOCK C

Surface level + 3.0 m (+ 10 ft)
Water struck at +2.3 m
250 mm and 200 mm percussion
July 1979

Mineral 9.8 m
Waste 12.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Post-Glacial deposits	a Sand Gravel: a little fine with coarse above 2.3 m, predominantly shell material Sand: fine with a little medium, becoming finer with depth, quartz, rock and shell fragments, with mica below 4.2 m, dark grey Fines: clay, disseminated, grey, with silty clay bands from 1.3 m to 2.3 m. Plant debris from 3.2 m to 4.2 m	5.2	5.2
	b 'Very clayey' sand Gravel: rare fine gravel grade lamellibranch shells from 6.2 m to 7.2 m Sand: fine, quartz with rock and shell fragments and a little mica Fines: silt, disseminated, grey, with rare thin clay bands from 6.2 m to 7.2 m. Plant fragments from 6.2 m to 7.2 m	3.0	8.2
	c Gravel Gravel: fine with coarse up to 5 cm diameter, subangular to well rounded, red and white sandstones, quartz, quartzite, psammite, basalt and andesite Sand: fine to coarse, angular to subangular, quartz and rock fragments with some shell material Fines: silt, disseminated	1.6	9.8
Late-Glacial marine deposits	Clay, stiff, poorly laminated, slightly silty, reddish brown	7.8	17.6
Till	Clay, brown-red, sandy, silty, with subangular to well rounded clasts up to 7 cm diameter of basalt and red and grey sandstones with grey siltstone	4.4+	22.0

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	5	93	2	0.0	1.3	8	57	21	7	6	1	0	
				1.3	2.3	4	80	12	2	1	1	0	†
				2.3	3.2	5	91	3	1	0	0	0	†
				3.2	4.2	4	91	4	1	0	0	0	†
				4.2	5.2	2	90	7	1	0	0	0	†
				Mean		5	80	10	3	2	0	0	
b	25	75	0	5.2	6.2	27	70	2	1	0	0	0	†
				6.2	7.2	32	62	4	1	1	0	0	†
				7.2	8.2	17	77	4	2	0	0	0	†
				Mean		25	70	4	1	0	0	0	
c	3	46	51	8.2	9.8	3	11	19	16	35	16	0	†
a to c	11	80	9	Mean		11	66	10	4	6	3	0	

NO 42 SE 23 4850 2311 Kinshaldy, Leuchars BLOCK C

Surface level + 6.9 m (+ 23 ft)
Water struck at + 5.1 m
250 mm and 200 mm percussion
July 1979

Overburden 0.2 m
Mineral 9.8 m
Waste 12.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Blown sand	a Sand Sand: fine, quartz with rock fragments and mica, medium brown Fines: silt, disseminated	0.8	1.0
Post-Glacial deposits	b Sand Sand: fine with a little medium, dominantly medium above 2.1 m, quartz and rock fragments with mica, shell material below 2.4 m, locally carbonaceous material, brownish grey becoming medium grey below 5.3 m Fines: silt, disseminated	9.0	10.0
	Clay, soft, medium grey, silty, with shell fragments	2.5	12.5
	Silt, slightly cohesive, locally up to 50 per cent sand, with shell fragments and mica	5.5	18.0
	Clay, soft, poorly laminated, grey, sandy and silty	1.8	19.8
	c 'Clayey' pebbly sand Gravel: coarse and cobbles, up to 10 cm diameter, with fine, subangular to well rounded, basalt, felsite, quartz, quartzite and conglomerate Sand: fine, quartz with rock and shell fragments and mica Fines: silt, disseminated	1.0	20.8
Late-Glacial marine deposits	Clay, soft, brownish grey	2.1+	22.9

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	3	97	0	0.2	1.0	3	90	7	0	0	0	0	
b	2	98	0	1.0	2.1	2	4	94	0	0	0	0	
				2.1	3.3	1	87	10	2	0	0	0	†
				3.3	4.3	1	94	5	0	0	0	0	†
				4.3	5.3	2	89	9	0	0	0	0	†
				5.3	6.2	1	97	1	1	0	0	0	†
				6.2	7.2	1	98	1	0	0	0	0	†
				7.2	10.0	3	93	3	1	0	0	0	†
				Mean		2	82	15	1	0	0	0	
a&b	2	98	0	Mean		2	82	15	1	0	0	0	
c	14	68	18	19.8	20.8	14	61	3	4	2	8	8	†‡

NO 42 SE 24 4838 2143 Bigend, Leuchars BLOCK C

Surface level + 7.5 m (+ 25 ft)
Water struck at + 5.5 m
250 mm and 200 mm percussion
July 1979

Overburden 0.2 m
Mineral 10.3 m
Waste 10.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.2	0.2
Blown sand	a Sand Sand: fine, quartz with some mica, brown becoming grey near the base Fines: silt, disseminated	1.9	2.1
Post-Glacial deposits	b Sand Gravel: rare fine below 8.7 m Sand: fine, quartz, with rock and shell fragments and a little mica, grey Fines: silt, disseminated, with grey silty clay bands below 8.7 m grading into the underlying clay	8.4	10.5
	Clay, laminated, medium grey, silty	6.5	17.0
	c 'Clayey' sand Sand: fine, quartz with rock fragments and a little shell and carbonaceous material Fines: silt, disseminated	2.0	19.0
	Clay, moderately stiff, medium grey, lamellibranch shells	0.4	19.4
Till	Clay, moderately stiff, red-brown, sandy, with angular to rounded clasts up to 11 cm diameter of basalt and andesite with diorite, quartz, and quartzite	1.6+	21.0
	Borehole terminated owing to technical reasons		

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	4	96	0	0.2	1.0	6	92	2	0	0	0	0	
				1.0	2.1	2	95	3	0	0	0	0	
				Mean		4	94	2	0	0	0	0	
b	7	92	1	2.1	3.3	1	91	8	0	0	0	0	†
				3.3	4.5	0	95	5	0	0	0	0	†
				4.5	5.5	2	92	5	1	0	0	0	†
				5.5	6.5	2	92	5	1	0	0	0	†
				6.5	7.6	1	97	2	0	0	0	0	†
				7.6	8.7	12	72	11	2	3	0	0	†
				8.7	10.5	21	70	4	3	2	0	0	†
				Mean		7	85	6	1	1	0	0	
a&b	6	93	1	Mean		6	87	5	1	1	0	0	
c	15	85	0	17.0	18.0	16	82	1	1	0	0	0	†‡
				18.0	19.0	14	84	2	0	0	0	0	†‡
				Mean		15	83	2	0	0	0	0	

NO 42 SE 25 4974 2320 Tentsmuir Sands, Leuchars BLOCK C

Surface level + 4.1 m (+ 13 ft)
Water struck at + 2.6 m
250 mm and 200 mm percussion
July 1979

Overburden 0.3 m
Mineral 18.0 m
Waste 4.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Post-Glacial deposits	Sand Gravel: a little fine and coarse above 1.5 m, subrounded to well rounded. From 17.3 m to 17.5 m a little fine and coarse with rare cobbles up to 8 cm diameter in a laminated clay band, subangular to angular, basalt and grey sandstone Sand: fine, and medium below 17.3 m, quartz with rock and shell fragments, carbonaceous material below 7.5 m, micaceous below 15.5 m, grey-brown becoming medium grey below 8.5 m Fines: silt, disseminated, more abundant below 9.5 m, stiff dark grey laminated clay from 17.3 m to 17.5 m, with thinner clay bands below this	18.0	18.0
Late-Glacial marine deposits	Clay, soft, laminated, reddish brown, with lamellibranch shells throughout, and rare clasts near the top	1.6	19.9
Till	Clay, soft and greenish-grey, becoming stiff and grey-green with depth, with ill-sorted angular to well rounded clasts up to 15 cm diameter of basalt with rare dolerite	2.6+	22.5
	Borehole terminated owing to boulder obstruction		

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	4	94	2	0.3	1.5	2	78	5	4	2	9	0	
				1.5	2.5	1	95	3	1	0	0	0	†
				2.5	3.5	1	87	11	1	0	0	0	†
				3.5	4.5	1	89	9	1	0	0	0	†
				4.5	5.3	1	91	7	1	0	0	0	†
				5.3	6.6	1	92	6	1	0	0	0	†
				6.6	7.5	1	95	4	0	0	0	0	†
				7.5	8.5	1	93	2	1	3	0	0	†
				8.5	9.5	3	92	4	1	0	0	0	†
				9.5	10.5	6	88	5	1	0	0	0	†
				10.5	11.5	6	87	6	1	0	0	0	†
				11.5	12.5	6	86	8	0	0	0	0	†
				12.5	13.5	5	89	6	0	0	0	0	†
				13.5	14.5	7	88	5	0	0	0	0	†
				14.5	15.5	9	88	3	0	0	0	0	†
				15.5	16.5	10	89	1	0	0	0	0	†
				16.5	17.3	11	84	4	0	1	0	0	†
				17.3	18.3	9	33	49	1	4	4	0	†
				Mean		4	85	8	1	1	1	0	

NO 42 SE 26 4544 2413 Craigie, Leuchars BLOCK B

Surface level + 10.7 m (+ 35 ft)
Water not struck
Pit
October 1979

Overburden 0.6 m
Mineral 1.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.6	0.6
Fluvioglacial sand and gravel	Sand Sand: fine, angular to subrounded, quartz with feldspar and rock fragments, orange-brown Fines: trace of silt, disseminated	1.5+	2.1

NO 42 SE 27 4503 2412 Craigie, Leuchars BLOCK B

Surface level + 13.8 m (+ 45 ft)
Water struck at + 11.6 m
Pit
October 1979

Overburden 0.7 m
Mineral 1.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty becoming sandy with depth	0.7	0.7
Fluvioglacial sand and gravel	Sand Gravel: trace of coarse, sandstone Sand: fine, subangular to subrounded, quartz with feldspar and rare rock fragments, orange-brown becoming reddish brown with depth Fines: trace	1.5+	2.2

NO 42 SE 28 4513 2408 Craigie, Leuchars BLOCK B

Surface level + 12.6 m (+ 41 ft)
Water not struck
Pit
October 1979

Overburden 0.3 m
Mineral 1.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.3	0.3
Fluvioglacial sand and gravel	Sand Gravel: rare fine with coarse, subangular, basalt with red sandstone Sand: fine, subangular to subrounded, quartz with feldspar and rock fragments, orange-brown Fines: trace	1.7+	2.0

NO 42 SE 29 4540 2396 Fordel, Leuchars BLOCK B

Surface level + 10.5 m (+ 34 ft)
Water struck at + 8.4 m
Pit
October 1979

Overburden 0.3 m
Mineral 1.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.3	0.3
Fluvioglacial sand and gravel	Sand Sand: fine, angular to subrounded, quartz with feldspar and rock fragments, orange-brown Fines: trace	1.8+	2.1

NO 42 SE 30 4621 2122 Earlshall, Leuchars BLOCK B

Surface level + 15.4 m (+ 51 ft)
Water not struck
Pit
October 1979

Overburden 0.7 m
Mineral 1.4 m
Waste 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.7	0.7
Fluvioglacial sand and gravel	Sand Gravel: trace of fine Sand: medium with fine, mainly angular, quartz with rock fragments and feldspar, light brown Fines: silt, disseminated	1.4	2.1
Late-Glacial marine deposits	Clay, moderately stiff, poorly laminated, red, with well rounded coarse gravel and cobble grade clasts of basalt with felsite	0.1+	2.2

GRADING

Mean for deposit percentages			Depth below surface (m)		percentages							
Fines	Sand	Gravel			Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
1	99	0	0.7	2.1	1	33	64	2	0	0	0	‡

NO 42 SE 31 4664 2120 Comerton, Leuchars BLOCK C

Surface level + 8.2 m (+ 27 ft)
Water struck at + 6.2 m
Pit
October 1979

Waste 2.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.4	0.4
Post-Glacial deposits	Clay, soft, light grey with brown mottling, silty, scattered rootlets	1.6+	2.0

NO 52 NW 1 5034 2667 Tentsmuir Sands, Leuchars BLOCK D

Surface level + 3.1 m (+ 10 ft)
Water struck at + 1.9 m
250 mm and 200 mm percussion
July 1979

Overburden 0.2 m
Mineral 21.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Post-Glacial deposits	a Sand Gravel: trace of fine Sand: fine with medium, angular to subrounded, quartz with feldspar, rock and shell fragments, locally micaceous, brown becoming brownish grey below 5.5 m Fines: silt, disseminated, some plant debris	12.3	12.5
	b 'Clayey' sand Sand: fine and medium, angular to subrounded, quartz with feldspar, rock and shell fragments, locally micaceous, brownish grey Fines: silt, disseminated, and grey clay bands which thicken and become more numerous with depth	9.5+	22.0
	Borehole terminated owing to technical reasons		

(continued .....)

GRADING

	Mean for deposit percentages			Depth below surface (m)		percentages							
	Fines	Sand	Gravel			Fines	Sand			Gravel			
						$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$.	+1–4	+4–16	+16–64	+64	
a	2	97	1	0.2	1.2	1	81	17	0	1	0	0	
				1.2	2.2	1	79	20	0	0	0	0	†
				2.2	3.2	0	67	32	1	0	0	0	†
				3.2	4.6	1	73	25	1	0	0	0	†
				4.6	5.5	1	89	8	1	1	0	0	†
				5.5	6.5	1	65	26	6	2	0	0	†
				6.5	7.5	2	68	26	2	2	0	0	†
				7.5	8.5	4	66	26	2	2	0	0	†
				8.5	9.5	5	86	7	1	1	0	0	†
				9.5	10.5	4	62	33	1	0	0	0	†
				10.5	11.5	3	63	33	1	0	0	0	†
				11.5	12.5	3	56	40	1	0	0	0	†
				Mean		2	71	25	1	0	0	0	
b	13	87	0	12.5	13.5	13	64	23	0	0	0	0	†
				13.5	14.5	18	43	37	2	0	0	0	†
				14.5	15.5	11	36	51	2	0	0	0	†
				15.5	16.5	16	27	55	2	0	0	0	†
				16.5	17.5	8	32	58	2	0	0	0	†
				17.5	18.5	7	29	61	3	0	0	0	†
				18.5	19.5	19	33	47	1	0	0	0	†
				19.5	22.0	11	56	33	0	0	0	0	†
				Mean		13	42	44	1	0	0	0	
a&b	7	93	0	Mean		7	59	33	1	0	0	0	

APPENDIX G

LIST OF WORKINGS

In October 1979 five sand and gravel pits were being worked and two had been abandoned: each distinct area of worked ground shown on the resource map is considered as a separate pit.

Location	*Grid reference*	*Deposit worked*
ACTIVE		
Newton Hill	406 248	Glacial sand and gravel
North Straiton (east)	422 244	Glacial sand and gravel
North Straiton (west)	419 238	Fluvioglacial sand and gravel
Strathburn St Michael's (north)	436 232	Glacial sand and gravel
Strathburn St Michael's (south)	437 229	Glacial sand and gravel
DISUSED		
Brackmont Mill (North)	438 225	Fluvioglacial sand and gravel
Brackmont Mill (south)	438 223	Fluvioglacial 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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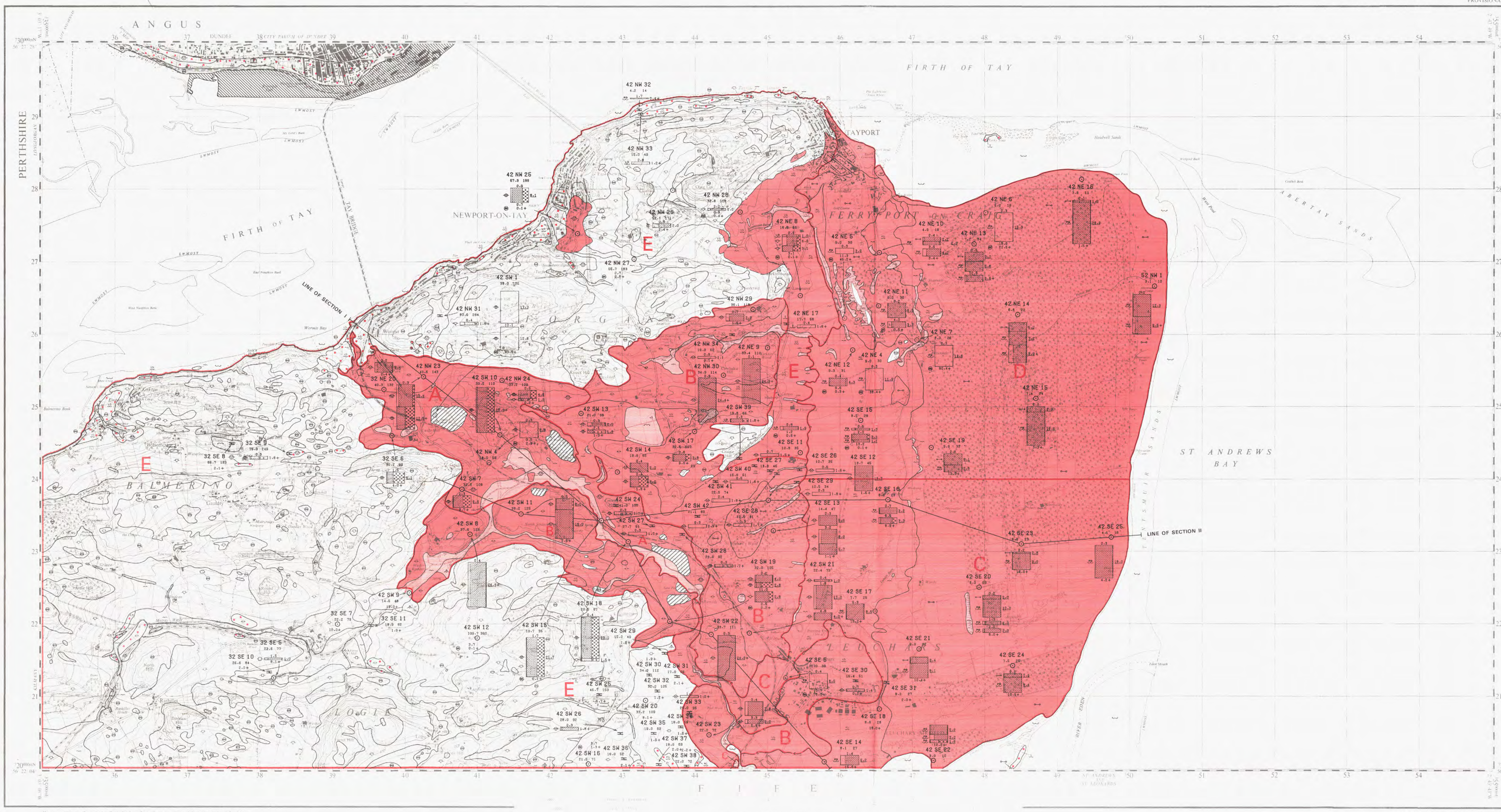
INSTITUTE OF GEOLOGICAL SCIENCES

INDUSTRIAL MINERALS ASSESSMENT UNIT

THE SAND AND GRAVEL RESOURCES OF THE NEWPORT-ON-TAY AREA, FIFE REGION

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

ORDNANCE SURVEY
SHEET NO 42 & Parts of NO 32 & 52
PROVISIONAL EDITION



89

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

EXPLANATION OF SYMBOLS AND ABBREVIATIONS

DRIFT

Recent and Pleistocene

- **Blown sand** – fine sand BS-7
- **Peat** P-1
- **Alluvium of flood plains (or undifferentiated)** – mainly silt and clay A-60
- **Alluvial cone** – fan composed of alluvium AC-2
- **Lake alluvium** – mainly clay LK-2
- **Storm beach and bar deposits, late-Glacial and present day** – mainly sand and gravel ST-2
- **Present beach and other intertidal deposits** PB-3
- **Salt marsh deposits** SMD-1
- **Raised beach deposits, of uncertain age** – mainly sand and gravel RS-4
- **Raised beach deposits and associated estuarine alluvium, post-Glacial** – mainly fine shelly sand with grey clay and silt beds and thin gravelly layers RS-5
- **Raised beach deposits and associated estuarine alluvium, late-Glacial** – fine with medium sand, locally gravelly RS-6
- **Marine deposits, late-Glacial** – red clay with rare local deltaic sand and gravel beds MA-1
- **Hillwash** – 'very clayey'sand (only proved in bore hole 42 NW 26) HW-1
- **Fluvioglacial sand and gravel** – fine red sand with locally thin gravelly beds FL-13
- **Glacial sand and gravel** – generally a poorly sorted sandy gravel deposited beneath ice GS-62
- **Till** – stiff stony clay of various colours, locally sandy TL-11

SOLID

- **Bedrock at or near surface (undifferentiated)** – the west of the resource sheet is underlain mainly by lower Devonian lavas; to the east the overlying lower Old Red Sandstone crops out which, in the extreme south-east of the area, is in turn unconformally overlain by Upper Old Red Sandstone and the Calciferous Sandstone Measures of Carboniferous age
- **Made ground** – man-made and/or natural earth materials deposited on original ground surface or in former quarries MG-3
- **Worked ground (sand and gravel) as at April 1980** WG-3

BOUNDARY LINES

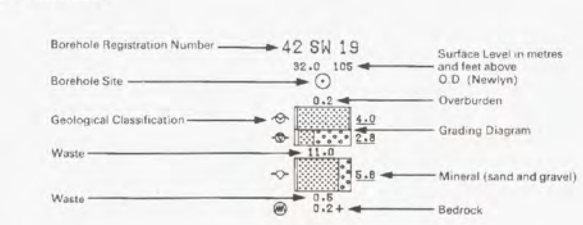
- Geological boundary
- Inferred boundary between categories of deposit
- Resource block boundary
- Feature marking former coastline

BOREHOLE DATA

SITE LOCATIONS

- Industrial Minerals Assessment Unit (I M A U) boreholes
- Other boreholes
- Shallow pits

I M A U BOREHOLES



Note

(i) Figures underlined denote thicknesses used in the assessment of resources

(ii) The + sign indicates that the base of the deposit was not reached

(iii) The geological classification is given only for mineral and bedrock

Registration Number

Each I M A U borehole and pit is identified by a Registration Number e.g. **42 SW 19** The first numbers and letters refer to the quarter sheet and the final figures to the I.G.S. serial numbers for that quarter. The unique designation for borehole **42 SW 19** is **NO 42 SW 19**

Grading Diagrams

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

Sand (+1/16 mm – 4 mm)
Fines (–1/16 mm)
Gravel (+4 mm)

The height of the diagram is proportional to the mineral thickness

The width of the divisions show proportions of **Fines, Sand and Gravel**

OTHER BOREHOLES

The registration and layout of information for other boreholes is the same as for I M A U sample points. However, data may not be as comprehensive, for example, mineral for which grading information is not available is portrayed by an empty grading box the height of which is proportional to the mineral thickness

SHALLOW TRENCHES

The registration and layout of information for shallow trenches is the same as for I M A U sample points. As with other boreholes, mineral for which grading data are not available is portrayed by an empty grading box

CATEGORIES OF DEPOSITS

- **Exposed, potentially workable sand and gravel (mineral)** CAT-E7
- **Continuous or almost continuous spreads of potentially workable sand and gravel beneath overburden** CAT-C4
- **Sand and gravel not assessed** CAT-N1
- **Sand and gravel absent or not potentially workable** CAT-A4

RESOURCE BLOCKS

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

Original geological survey on the six-inch scale by H.H. Howell, J. Geikie and J. Young in 1860. Re-survey by J.I. Chisholm and M. Armstrong between 1962 and 1964. T.R.M. Lawrie and J.R. Earp, District Geologists

Sand and Gravel survey by J.L. Laxton and D.L. Ross in 1979, under the supervision of E.F.P. Nickless. 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, incorporating the Geological Survey of Great Britain, the Museum of Practical Geology and Overseas Geological Surveys.

Borehole Graphics drawn by computer using programs written by J.L. McInnes, Computer Unit, I.G.S., Edinburgh

Data quoted for an individual sample point 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 volume and mean grading of the mineral as a whole in each Resource Block are given in the Report

Diagram showing the relation of this sheet with the National Grid 10km squares and the One Inch New Series Geological Sheets 40, 41, 48, 49

Detailed records may be consulted on application to the Officer-in-Charge, Industrial Minerals Assessment Unit, Institute of Geological Sciences, Murchison House, West Mains Road, Edinburgh EH9 3LA

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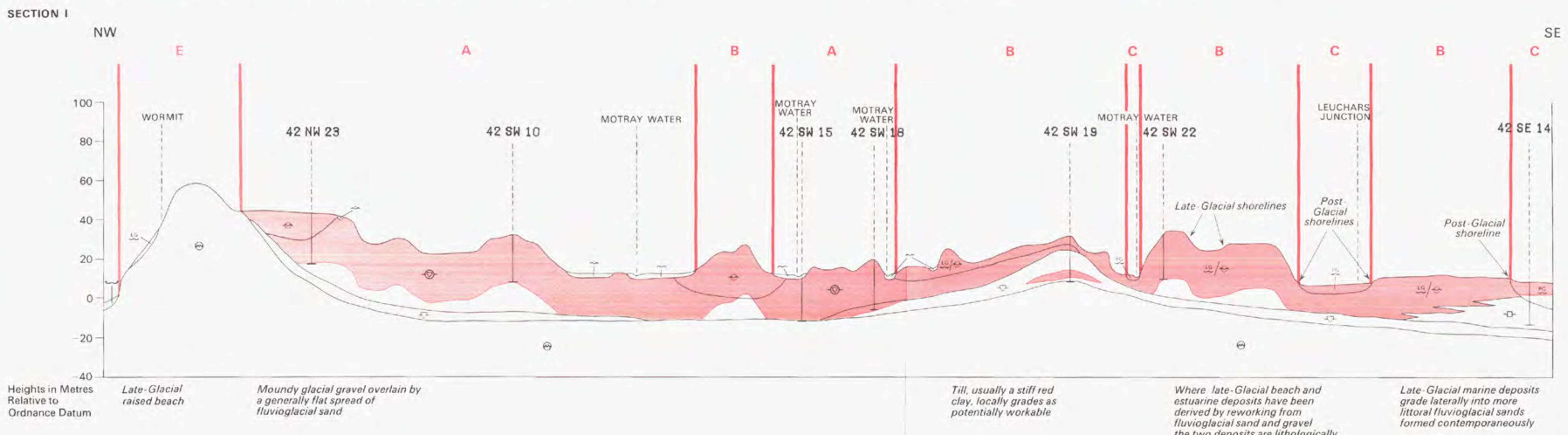
Carto-Graphics (Edinburgh) Limited
Printed by John Bartholomew & Son Ltd., Edinburgh 1981.*

GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS

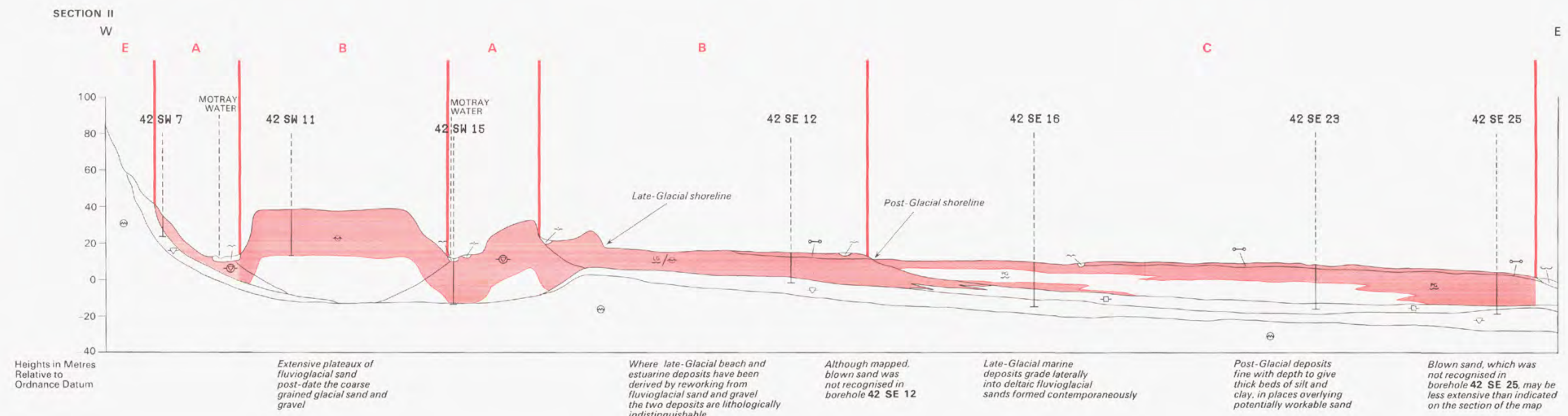
HORIZONTAL SCALE 1:25 000 VERTICAL EXAGGERATION 12.5×

SECTION I



NW
SE
E
A
B
A
B
C
B
C
B
C
WORMIT
42 NW 23
42 SW 10
MOTRAY WATER
MOTRAY WATER
42 SW 15
MOTRAY WATER
42 SW 18
42 SW 19
MOTRAY WATER
42 SW 22
LEUCHARS JUNCTION
42 SE 14
Late-Glacial shorelines
Post-Glacial shorelines
Post-Glacial shoreline
100
80
60
40
20
0
-20
-40
Heights in Metres Relative to Ordnance Datum
Late-Glacial raised beach
Moundy glacial gravel overlain by a generally flat spread of fluvioglacial sand
Till, usually a stiff red clay, locally grades as potentially workable
Where late-Glacial beach and estuarine deposits have been derived by reworking from fluvioglacial sand and gravel the two deposits are lithologically indistinguishable
Late-Glacial marine deposits grade laterally into more littoral fluvioglacial sands formed contemporaneously

SECTION II



W
E
E
A
B
A
B
C
42 SW 7
MOTRAY WATER
42 SW 11
MOTRAY WATER
42 SW 15
42 SE 12
42 SE 16
42 SE 23
42 SE 25
Late-Glacial shoreline
Post-Glacial shoreline
100
80
60
40
20
0
-20
-40
Heights in Metres Relative to Ordnance Datum
Extensive plateaux of fluvioglacial sand post-date the coarse grained glacial sand and gravel
Where late-Glacial beach and estuarine deposits have been derived by reworking from fluvioglacial sand and gravel the two deposits are lithologically indistinguishable
Although mapped, blown sand was not recognised in borehole 42 SE 12
Late-Glacial marine deposits grade laterally into deltaic fluvioglacial sands formed contemporaneously
Post-Glacial deposits fine with depth to give thick beds of silt and clay, in places overlying potentially workable sand
Blown sand, which was not recognised in borehole 42 SE 25, may be less extensive than indicated on the section of the map

KEY TO SECTIONS

- Potentially workable sand and gravel (mineral), exposed or beneath overburden
- Bedrock and waste, including overburden, are uncoloured
- Geological boundary
- Inferred boundary limiting the extent of potentially workable sand and gravel

Otherwise symbols and abbreviations as map legend