COMMONWEALTH OF AUSTRALIA

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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Record 1971/132

GEOLOGICAL EVALUATION OF THE PROPOSED BELCONNEN REFUSE DISPOSAL AREA, CANBERRA CITY DISTRICT, A.C.T.

By

P.H. Vanden Broek

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PLATE

1. Geology of the proposed refuse disposal area, Belconnen, A.C.T.

SUMMARY

The proposed refuse disposal area near the Canberra Suburb of Holt is intended to service the Belconnen area, which may have an eventual population of 120,000. The disposal area occupies 185 acres of a mildly eroded, perched basin; the basin has eroded in to an area that was once a Tertiary peneplain.

Highly weathered+ to fresh volcanic and sedimentary rocks underlie the area; they are mostly covered by a thick veneer of soil*; outcrops are rare. The soil mantle is composed mostly of the products of extensive residual weathering that took place in the Tertiary. A thin topsoil layer is underlain by a thick layer of clay; the clay layer is underlain by completely weathered volcanic rock or moderately weathered sedimentary rock. Completely weathered volcanic rock can normally be easily excavated and is classified as soil.

Eight seismic traverses were done to find the depths to bedrock in selected areas. Velocities corresponding to various soil and rock layers were determined. Soil with a seismic velocity of less than 3000 ft/sec.** can be excavated without much trouble. Soils with a seismic velocity of 3000-5000 ft/sec. can be excavated by ripping.

Augering showed that over most of the site 1 or 2 feet of topsoil is underlain by 5 to 10 feet of clay, which may in turn be underlain by completely weathered volcanic rock or moderately weathered sedimentary rock.

Groundwater occurs in unconfined and confined aquifers in the lower parts of the area; the unconfined groundwater produces areas of seepage after heavy rain, and the confined groundwater produces springs where leakage through the overlying impermeable layer occurs. The confined groundwater could be a problem if suitable precautions are not taken.

+ Definitions of weathering terms are given in Appendix 1.

* The terms 'soil' and 'rock' are used in the engineering sense in this report. 'Soil is a natural aggregate of mineral grains that can be separated by such gentle mechanical means as agitation in water. Rock on the other hand is a natural aggregate of minerals connected by strong and permanent forces' (Terzaghi & Peck, 1967). Rock cannot normally be excavated by manual methods alone.

** The Bureau commenced conversion to the metric system of units in 1970. British units are used in this report but metric equivalents are shown where appropriate; a table of conversion factors is given in Appendix 2.

Refuse disposal areas can pollute groundwater unless they are hydrologically safe or can be made hydrologically protective. The proposed area is not hydrologically safe and therefore should be made hydrologically protective. This involves lining the bottom and sides of trenches excavated with the clay that is found at the site.

From groundwater considerations the area should be worked by trenching and filling downhill, the sides of each trench sloping less than two in one. The problems of erosion and scouring during heavy rainfall, however, must be considered. By sloping the sides of each trench, two adjacent trenches leave a triangular soil channel for groundwater movement.

The depths to which trenches can be excavated will vary but an average of 20 feet in areas of completely weathered volcanic rock is indicated by seismic and augering results. A trench width of 150 feet would give a width after clay lining of 60 feet at the bottom of the 20-foot-deep trench. Although this is much wider than at present used at Pialligo it would mean less clay lining of trench sides. The completely weathered volcanic rock that is excavated and surplus after filling can probably be used as graval pavement and may be saleable.

The disposal area would service a population of 120,000 for at least 20 years; also it may be possible to rework the site.

INTRODUCTION

In December 1970, the National Capital Development Commission (NCDC) requested the Bureau of Mineral Resources (BMR) to report on the suitability of a proposed refuse disposal area at 'Belconnen' (Block 105, Canberra City District), 1 mile (1.6 km) west of the suburb of Holt, A.C.T. (Fig. 1). The area is divided into four sites, designated A, B, C and D (Plate 1).

The investigation, between February and May 1971, was carried out in two stages: (1) detailed surface geological mapping, and (2) subsurface investigations, consisting of augering and seismic refraction traverses. A base map for the investigation was compiled from a colour air-photo (Run 6, 9680, CAC/C12) and a topographic 'P' Series map, drawn by the Department of the Interior.

In all, eight seismic traverses, totalling 1760 feet, were carried out by P.J. Hill and G. Pettifer of the BMR's Engineering Geophysics Group.

Augering was carried out using equipment for recovering undisturbed samples; the sampler recovers a core sample and provides an accurate record of soil layering. Thirty-five auger holes, totalling 350 feet, were sunk.

PHYSIOGRAPHY

The area occupies 185 acres of rolling* to undulating+ terrain at present used for grazing. The land surface is a remnant of an old Tertiary peneplain (Van Dijk, 1965); it averages 1850 feet above sea level and is covered by a thick soil mantle. The area has been partly eroded to form a basin.

The area drains to the southwest along two small creeks; the creeks join and run to the Murrumbidgee River, 1 mile (1.5 km) away. The creek is increasingly dissected as it approaches the river.

The physiography of the land around Belconnen has been controlled primarily by the Murrumbidgee River. The river has a large alpine catchment with excellent run-off; consequently it has cut deeply into the old peneplain, as is at present 400 feet (125 m) below it.

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* Rolling = short, moderately steep slopes.

+ Undulating = long, gentle slopes.

Local tributaries have far smaller catchments; therefore run-off is much less and the strength of the surface rock influences the rate of erosion. Only immediately adjoining the Murrumbidgee River have the tributaries managed to incise short deep valleys into fresh rock. Away from the river fresh rock has formed an impenetrable barrier to incision and determined a high local base level. As a result erosion has progressed, laterally rather than vertically, as a series of small branching perched basins spreading back into the old weathered zone of the peneplain. The basins that form the headwaters to the tributaries are surrounded by thick almost undissected remnants of the old peneplain.

Areas undergoing active erosion are shown on Figure 2; all rock outcrops border these areas. An erosion gully exposes rock at one locality (Plate 1).

GEOLOGY

General

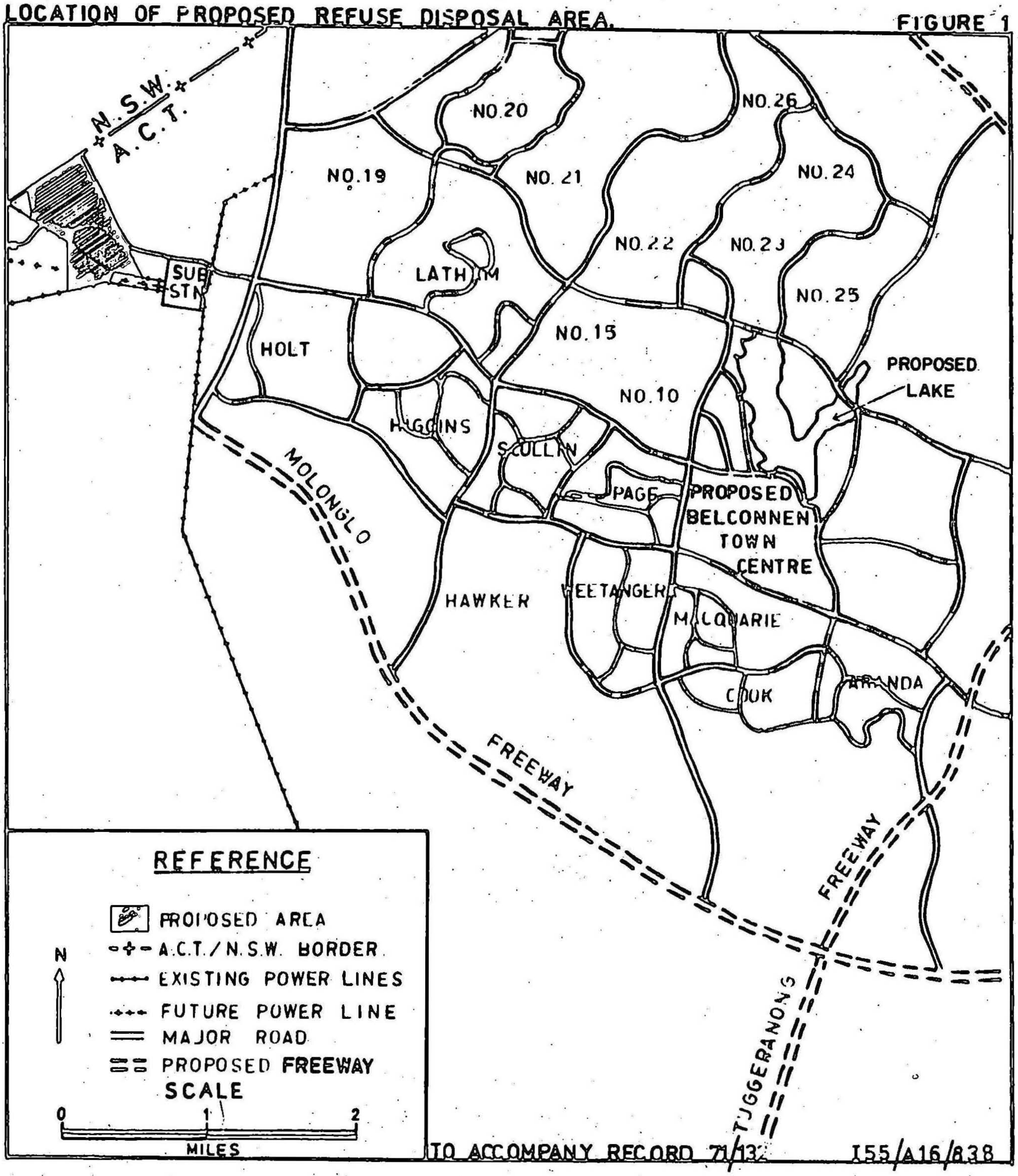
There are few rock outcrops within the area (Plate 1). Those that occur are slightly to moderatly weathered; they include both volcanic and sedimentary rocks.

The volcanic rocks include welded tuffs and lava flows; and the sedimentary rocks are sandstone, siltstone, and mudstone. Geological boundaries between the rock types could not be established because of the scarcity of outcrops; the structure in the sediments could not be defined. The rocks are thought to belong to the Deakin Volcanics (G.A.M. Henderson - pers. comm) of Upper Silurian age.

Volcanic rocks

Rhyodacite welded tuff: Rhyodacite welded tuff is found in the central part of Site A (Plate 1), as one large and two small outcrops of hard grey boulders. The tuff consists of white and pale green plagioclase, and transparent quartz phenocrysts set in a dark grey groundmass of devitrified volcanic glass. Thin section (No. 71360001) is described in Appendix 3.

LOCATION OF PROPOSED REFUSE DISPOSAL AREA. FIGURE 1



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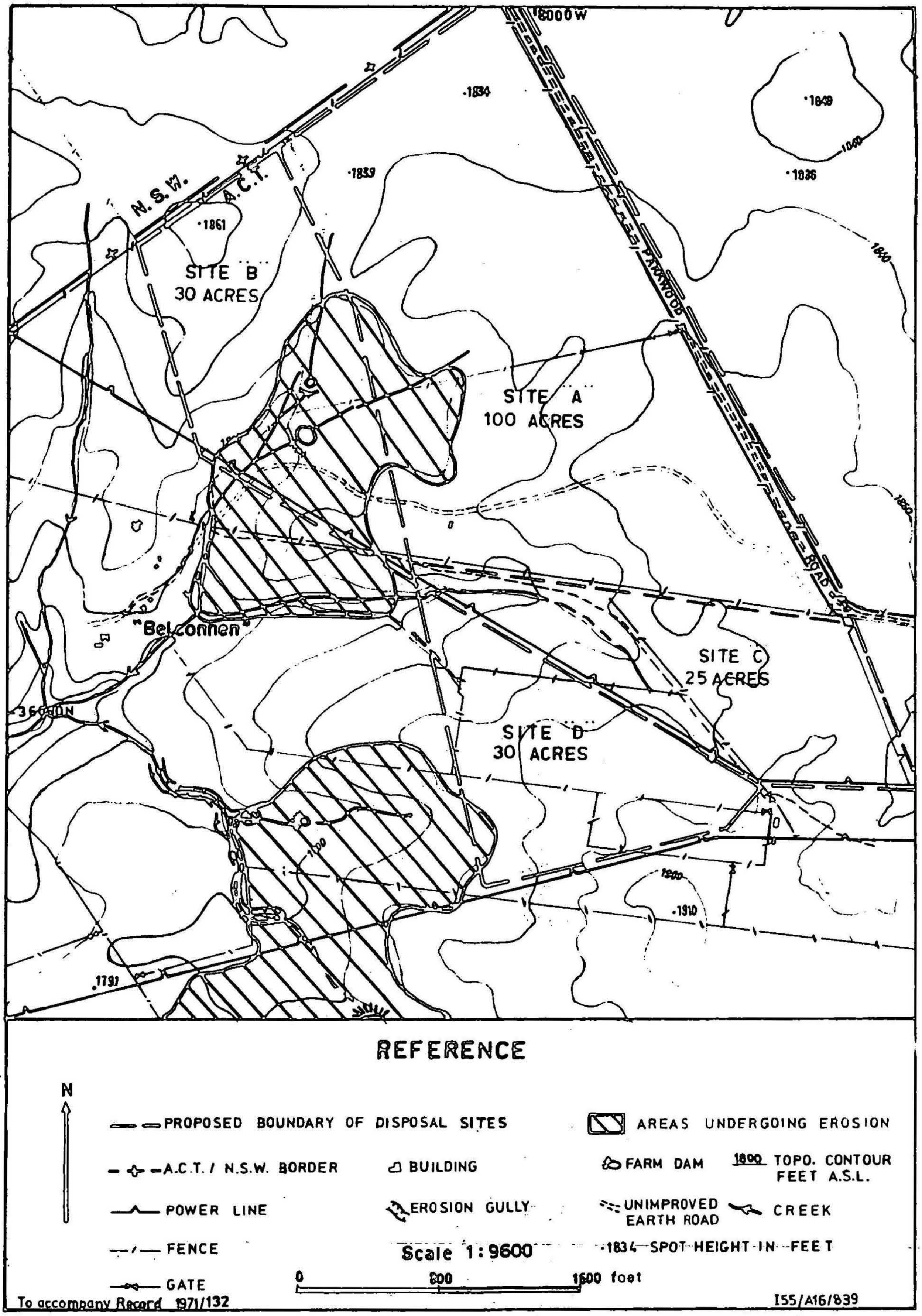
BELCONNEN REFUSE DISPOSAL AREA; AREAS UNDERGOING EROSION. FIGURE 2



Rhyodacite lava: Porphyritic rhyodacite lava occurs in the central part of Site D (Plate 1); it is light grey and forms outcrops of moderately weathered boulders. The rock consists of white plagioclase, transparent quartz, and dark green altered biotite phenocrysts set in a light pink or pale green cryptocrystalline groundmass. Two thin sections (Nos. 71360006, 71360007) are described in Appendix 3.

Sedimentary rocks

Sedimentary rocks crop out level with the soil surface. They occur partly at the southern tip of Site B (Plate 1) where they have been partly excavated for road material. Three types of sedimentary rocks are present: sandstone, siltstone, and mudstone; each is described below. The sediments are tuffaceous and poorly sorted; they appear to have been derived from volcanic rocks. The mudstone contains limestone lenses in which shelly fossils occur. The shelly limestone indicates that the sediments were deposited in a shallow marine environment. Other sediments, including micaceous sandstone, tuffaceous sandstone, silicified dsasandstone, and mudstone were found in Auger Holes 14, 28, 29, 30, 31, and 33 (Plate 1).

Tuffaceous sandstone: This is a hard, yellow and black speckled, tuffaceous sandstone. It has poorly sorted, angular, sand-sized, quartz, plagioclase, biotite and opaque particles, set in a matrix of devitrifed volcanic glass and sericite. A thin section (No. 71360002) is described in Appendix 3.

Tuffaceous siltstone: The tuffaceous siltstone is hard yellow-green and brown speckled and has a conchoidal fracture. It has poorly sorted, angular, sand-sized quartz, plagioclase, biotite and opaque particles, set in a matrix of devitrified volcanic glass and sericite. A thin section (No. 71360003) is described in Appendix 3.

Tuffaceous mudstone: This is a hard, grey-green mudstone with a blocky to angular fracture. It has a few scattered grains of quartz, plagioclase, biotite, muscovite and carbonate, in a matrix of devitrified volcanic glass and sericite. The mudstone is also described in the appendix (Thin section No. 71360004).

Rounded or oval yellow-coated limestone lenses (about 3-5 inches (7.5-12.5 cm) in diameter) occur throughout the mudstone. The limestone lenses are made up of crystals of calcite and grains of an amorphous carbonate in a matrix of fine-grained carbonate mudstone. Some of the calcite has recrystallized from carbonate but some also replaces shell fragments. About 50 lb of the limestone lenses were submitted for palaeontological determination.

SUBSURFACE INVESTIGATIONS

Seismic traverses

The eight seismic traverses (Fig. 3) were carried out by P.J. Hill and G. Pettifer to assist in ascertaining depths to solid rock*, and seismic velocities of the soil and rock layers. The traverses give an indication of maximum excavatable depths at various places within the area. The results of the traverses are shown on Figures 4 and 5, and Table 1 shows the correlation between the seismic velocity ranges and the nature of the corresponding layers determined by augering.

TABLE 1

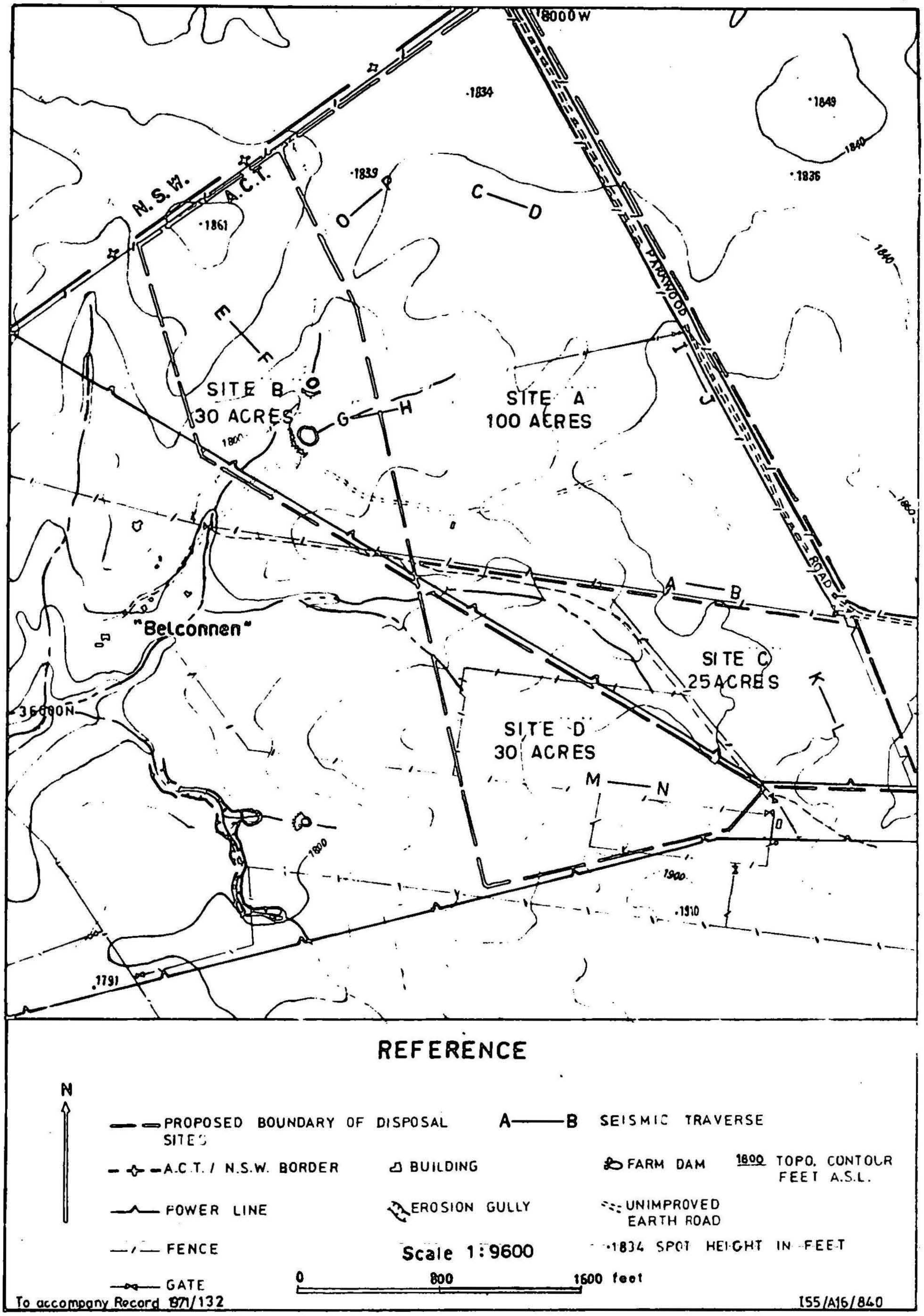
Correlation of seismic velocity
with soil or rock type

Velocity range (ft/sec)	Layer
1000-2200	Topsoil, clay
2500-4200	Completely weathered rock
5000-6200	Highly weathered rock
7400-9800	Mudstone, sandstone or moderately weathered volcanics

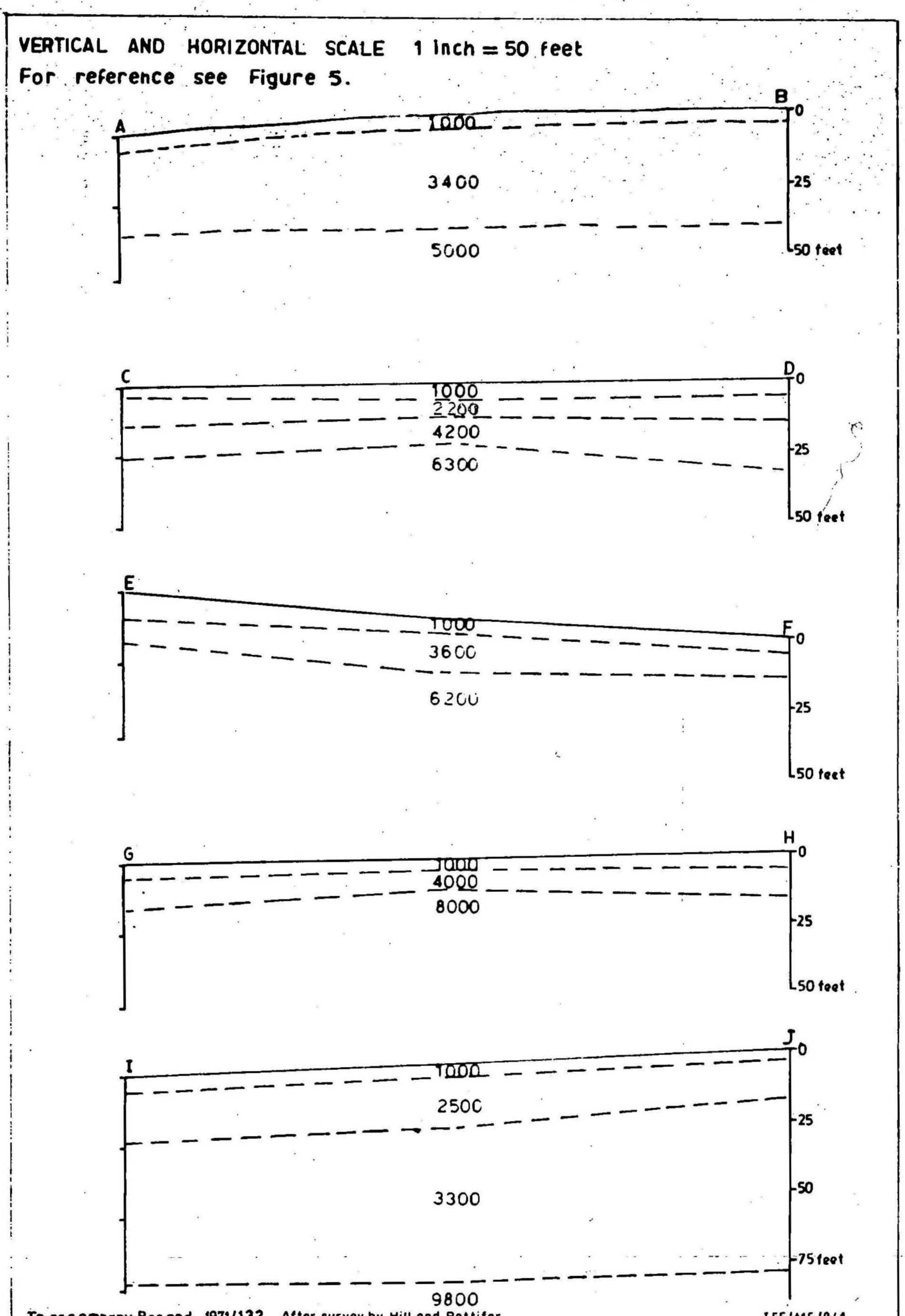
Subsequent augering on the seismic traverses showed that material with a seismic velocity of up to 3000 ft/sec was quite soft; augering became more difficult in materials with a seismic velocity of over 4000 ft/sec. Material with a seismic velocity of 5000 ft/sec or more is considered to be solid rock.

* Solid rock is defined as rock that is either very difficult or too hard to rip.

BELCONNEN REFUSE DISPOSAL AREA; LOCATION OF SEISMIC TRAVERSES. FIGURE 3



SEISMIC CROSS-SECTIONS A-B, C-D, E-F, G-H, AND I-J. FIGURE 4.



To accompany Record 1971/132 After survey by Hill and Pettifer

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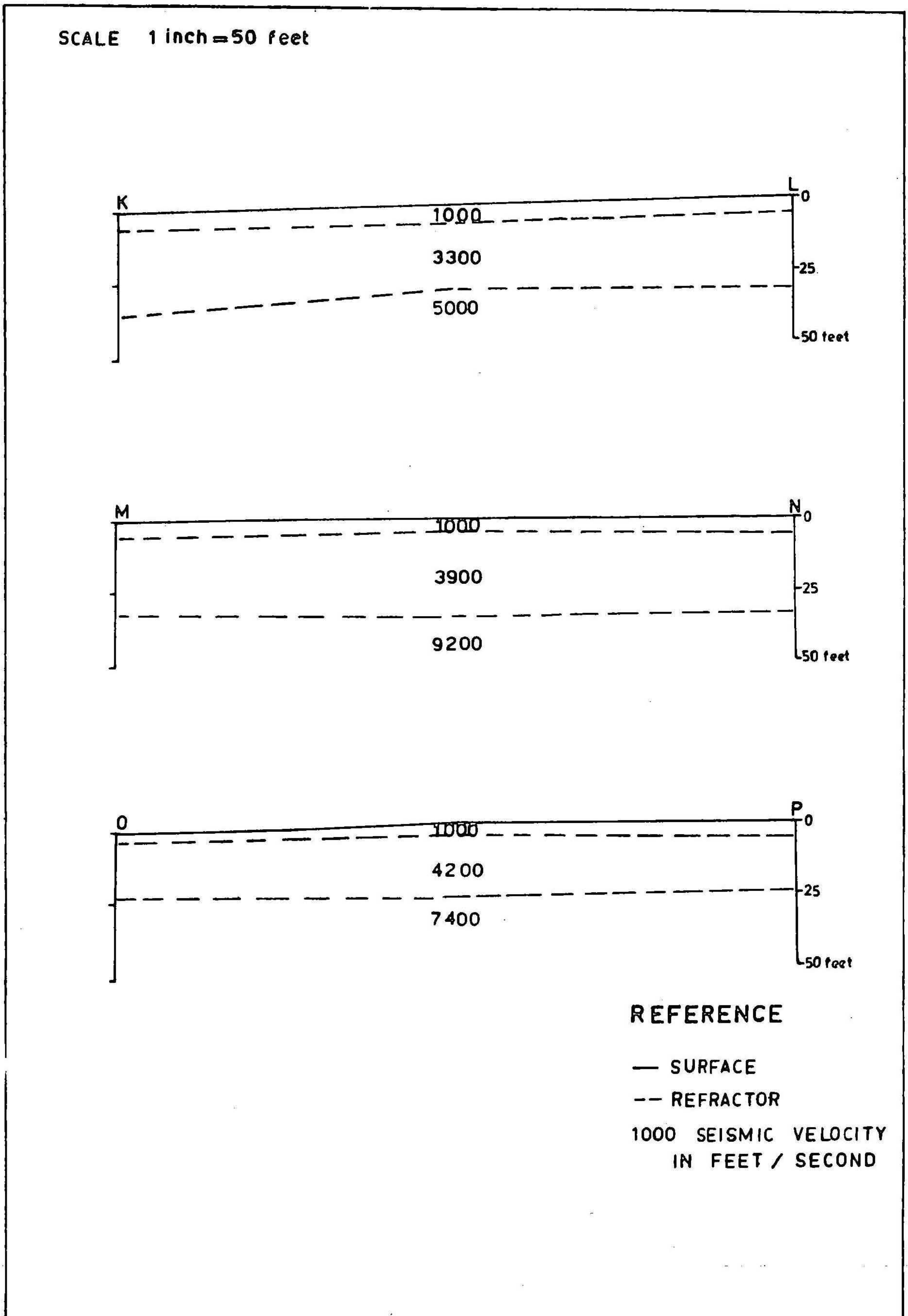
SEISMIC CROSS-SECTIONS K-L, M-N, AND O-P. FIGURE 5



To accompany Record 1971/132 After survey by Hill and Pettifer I55/A16/842

Augering

The location of the 35 auger holes sunk in May are shown on Figure 6. The holes indicate the types and thickness of soil likely to be encountered in the area. Detailed written logs of individual holes are given in Appendix 4, and diagrammatic logs are shown on Plate 1.

In most auger holes 1 or 2 feet of grey or dark grey topsoil* is underlain by 5-10 feet of plastic clay, which in turn is underlain by completely weathered volcanic rock or slightly weathered sedimentary rock. Where completely weathered volcanic rock was found to extend deeply no attempt was made to auger deeper than 12 feet (3.6 metres) because seismic results indicate complete weathering may be as deep as 60 feet (18 metres) in some places (see Traverse I - J, Fig. 4).

The ease with which a 4-in (9.1 cm) hand-auger hole can be sunk into soil is a good indication of how easily it can be excavated by ripping; the point of refusal is usually the maximum depth to which the soil can be ripped. It should be noted that ease of augering depends considerably on the moisture content of the soil. The moisture content at the time of the Bureau's augering was representative of what can be expected for most of the life of the landfill area.

A hand-auger hole was put down in the centre of Seismic Traverse I - J. It was found that, after augering down through topsoil, clay, and completely weathered rock to a depth of 14 feet (4.2 metres), augering became easier, the completely weathered rock became softer, and the hole could be continued to 17 feet (5.1 metres). Auger extensions were not available to continue the hole, but it can be concluded from the results that it is possible to excavate to at least 17 feet at this location using a bulldozer.

ENGINEERING GEOLOGY

Soil

There are three soil types in the area; topsoil, clay, and completely weathered volcanic rock. The clay and weathered rock are remnants of an old weathering period (Tertiary time) described in more

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* Topsoil: All soils forming the A horizon, including both organic and leached layers.

detail by Van Dijk (1965) and later in this report. Soil-forming processes have not modified the clay and weathered volcanic rock very much since their formation in the Tertiary. The clay type and colour do not depend on the underlying rock type.

Topsoil: A layer of topsoil 1-2 feet (0.3 - 0.6 metres) thick occurs over the whole area. It is a medium grey coloured, sandy silt, rich in decomposed organic material and very porous. The soil has been derived from wind blown sand and silt (loess) and shows only slight variations in thickness.

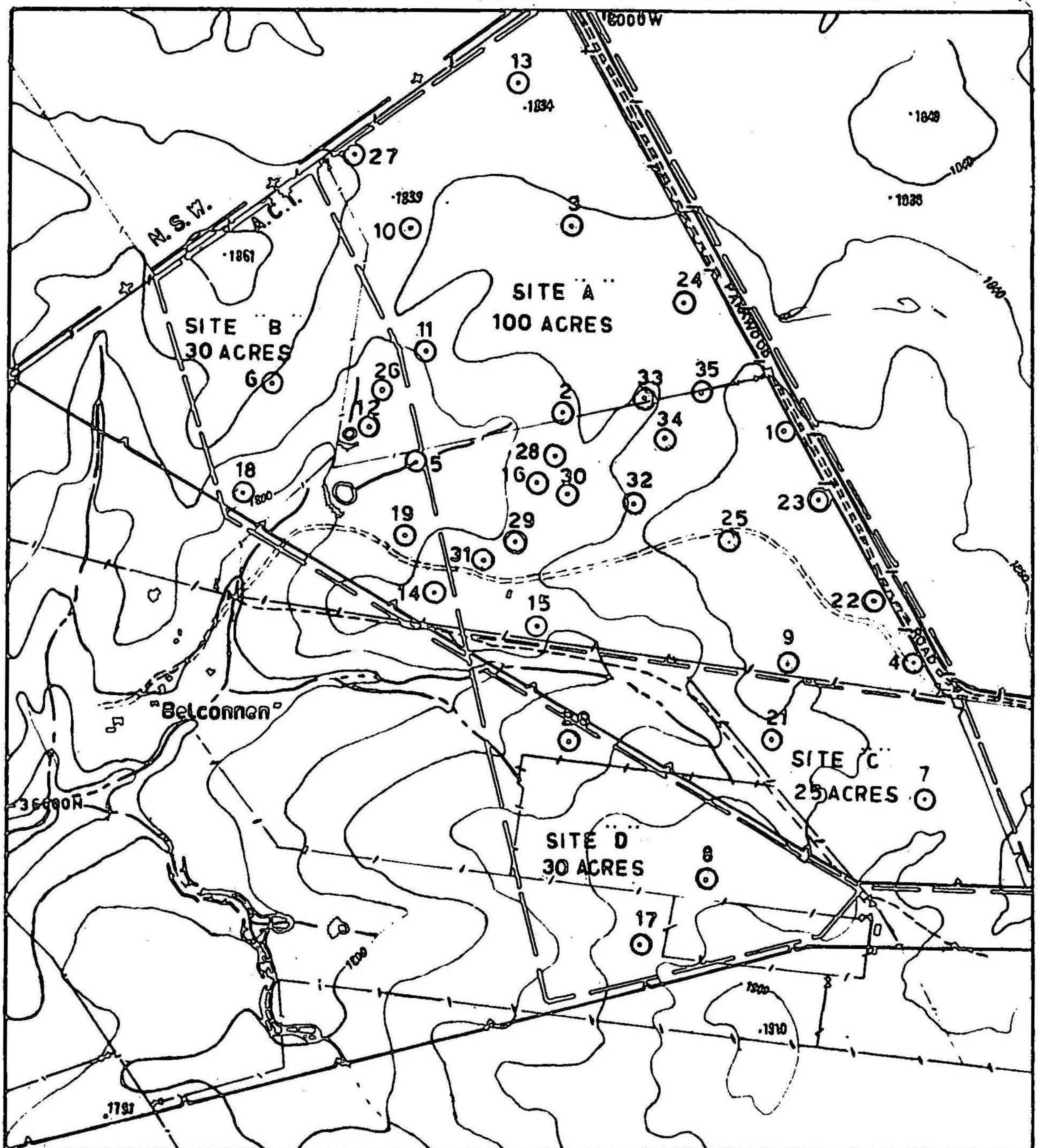
Clay: A uniform layer of clay, 1-10 feet (0.3 - 3.0 metres) thick occurs immediately below the topsoil over almost the whole area. It is an orange, red or yellow, massive, fat clay developed in situ from the underlying weathered rock. Where underlain by completely weathered rock, the lower few feet of clay is often yellow-grey mottled or grey; this results from water fluctuations beneath the clay acting on the interface between the clay and the completely weathered rock (gleyed effect).

The clay is thickest where it overlies completely weathered volcanic rock and where less erosion has taken place. It is much thinner, or is absent, where it overlies unweathered sedimentary rocks. The clay layer is thought to represent the upper basal layer of an older, thicker soil profile because the thickness it attains (11 feet in holes 13 and 18) could only have been formed in a much thicker soil profile, the upper part of which has since been removed.

Completely weathered volcanic rock: Completely weathered volcanic rock occurs over a large area immediately below the clay layer. It retains the fabric of the original rock but the rock has been completely discoloured and chemically broken down to a much softer aggregate of particles. The thickness of this soft, yellow-brown decomposed rock ranges from 3 to 60 feet (0.9 to 18 metres). It is thought to be the basal part of an older, thicker soil profile.

Testing to date indicates that the completely weathered volcanic rock, as found in this area, would be classified under the Department of Works' specifications for road materials being as 'suitable for gravel pavement'. The 'gravel' contains some clay binder and usually has a plasticity index of 8-12. Gravel pavement material is used extensively for the construction of rural roads and shoulders of sealed roads, and for bedding and backfilling pipelines; it is also used as a pavement in home driveways, tennis courts, and for paving recreation areas. Some gravel from the disposal area could probably be used for these purposes.

BELCONNEN REFUSE DISPOSAL AREA; LOCATION OF AUGER HOLES. FIGURE 6



REFERENCE

N

PROPOSED BOUNDARY OF DISPOSAL SITES

A.C.T. / N.S.W. BORDER

POWER LINE

FENCE

GATE

BUILDING

EROSION GULLY

13 AUGER HOLE.

FARM DAM

1800 TOPO. CONTOUR FEET A.S.L.

UNIMPROVED EARTH ROAD

·1834 SPOT HEIGHT IN FEET

Scale 1:9600

0 800 1600 foot

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Antecedent weathering

As early as the Tertiary period, deep and thorough chemical weathering of the surface volcanic rocks occurred while the area was a peneplain with little physiographic relief (Van Dijk, 1965). Downward percolating meteoric water caused complete chemical weathering to water-table level. Volcanic rocks in the region were very susceptible to the prolonged chemical weathering and as physical erosion was very slow a thick weathered soil mantle developed.

The deeply weathered peneplain was subsequently uplifted to a plateau and streams flowing westward eroded down through the weathered profile in areas adjacent to the Murrumbidgee River until they reached the lowest level of complete chemical weathering. The resistance of the underlying fresher volcanic rock to stream erosion then formed a temporary stable high base level. Areas upstream of this stable high base level have consequently a slower rate of erosion than they would have had if the level of the Murrumbidgee River was directly controlling the rate of erosion.

Groundwater

Groundwater conditions within the area are of two types: groundwater in unconfined ('surficial' - Van Dijk) aquifers and groundwater in confined aquifers (Van Dijk, 1959).

Unconfined aquifers: Unconfined aquifers result from a permeable surface layer overlying a less permeable horizon.

Within the area, porous sandy topsoil becomes saturated in places during periods of heavy rain; downward percolation is prevented by an impermeable clay subsoil. Lateral water movement through the aquifer may lead to temporary waterlogging where the gradient of the aquifer lessens without an increase in thickness, or where the cross-sectional area or permeability of the aquifer decreases along a uniform gradient. Areas of waterlogging are shown in Figure 7.

Confined aquifers: Confined aquifers are formed in some of the areas where a permeable layer is overlain by an impermeable layer.

A sample of completely weathered volcanic rock from the area, tested by the BMR's Petroleum Technology Section, has a permeability of 0.34 millidarcies or an apparent fluid flow velocity (K) of 8.7×10^{-4} centimetres/second (cm/sec), which is moderately permeable (Peck, Hanson, & Thornburn, 1963); the overlying clay sample, as tested, is impermeable. Yellow-grey and grey-mottled clay overlying the completely weathered volcanic rock results from cationic exchange and indicates prolonged water contact from below.

Where leakage through the overlying clay occurs in the lower parts of the area, springs develop which may persist throughout the year. Springs also occur close to the boundary between the sedimentary and volcanic rocks.

It is thought that the unweathered sedimentary rocks form a permeability barrier to subsurface water movement and this causes the water to rise to the surface (Fig. 7). Springs reach their maximum water flow some days after periods of heavy rain. The location and diagrammatic cross-section of a spring caused by a permeability barrier close to the boundary between the sedimentary rocks and the completely weathered volcanic rocks is shown on Figure 7.

The confined groundwater could be a problem if suitable precautions, described in 'Working the site', are not taken.

Diagrammatic cross-sections

Eight diagrammatic cross-sections (Figures 8, 9, and 10) have been constructed from geological seismic traverses, and auger hole data; the cross-sections indicate soil conditions likely to occur when working the area (Figs. 9 and 10).

Notes on refuse disposal

The term refuse includes all solid wastes; food waste is referred to as garbage, and rubbish includes everything else. Garbage is a major source of pollution because it putrifies, whereas much rubbish is a problem because it does not decompose. Methods available to dispose of refuse include landfill, incineration, composting, open-dumping, and open-burning. Of these only landfill can be operated efficiently without causing pollution.

To operate a landfill area a soil thickness of about 50 feet* is desirable (Williams & Wallace, 1970). Refuse is dumped into a trench or hollow and compacted. At the end of each day the refuse is covered with 6 inches of soil. When each trench is filled at least 2 feet of soil is spread over the compacted layers.

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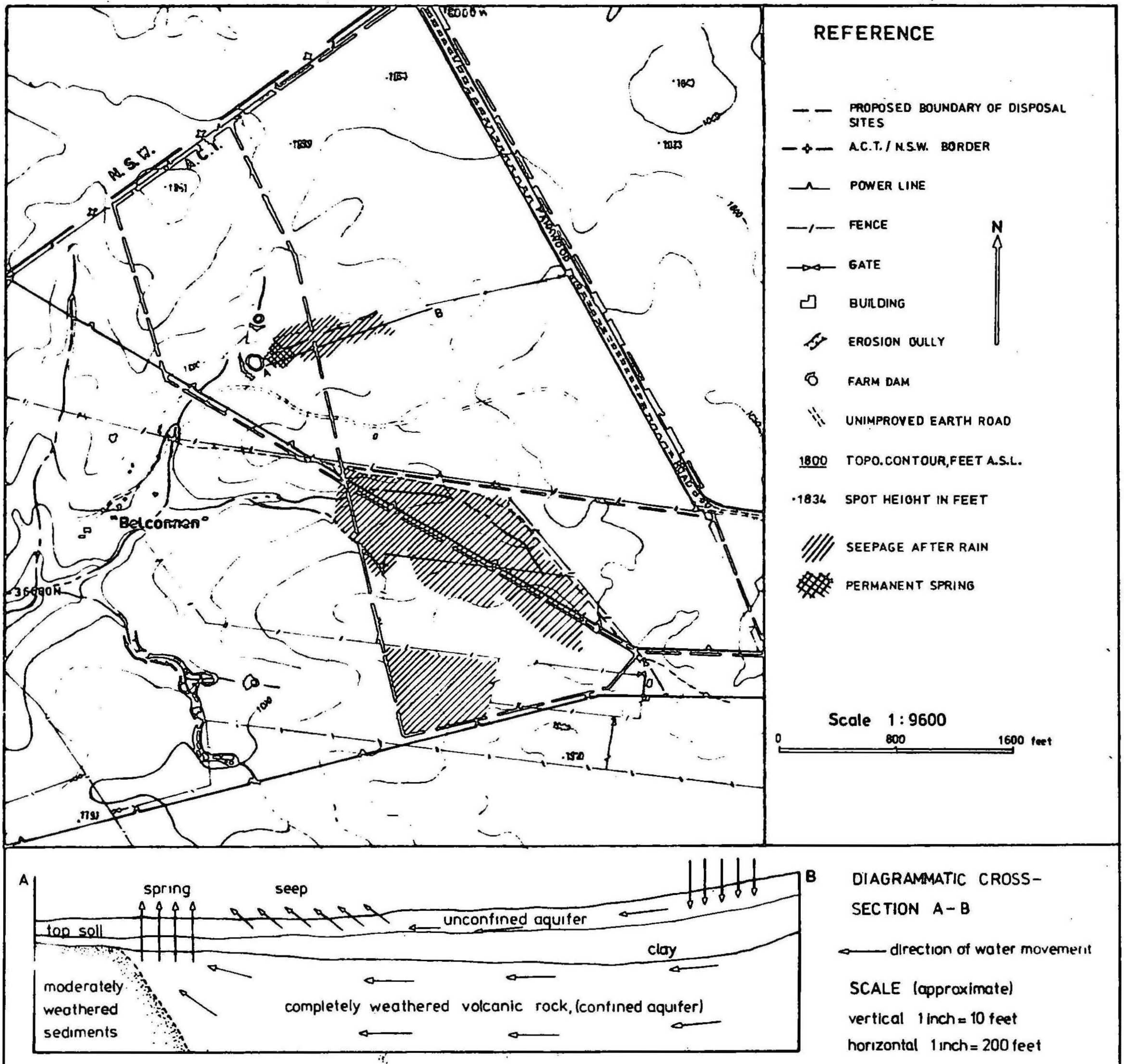
* Current practice at the Pillagio landfill indicates that a soil depth of 6 - 18 feet can be worked efficiently.

BELCONNEN REFUSE DISPOSAL AREA; LOCATION OF SPRINGS AND SEEPS. FIGURE 7



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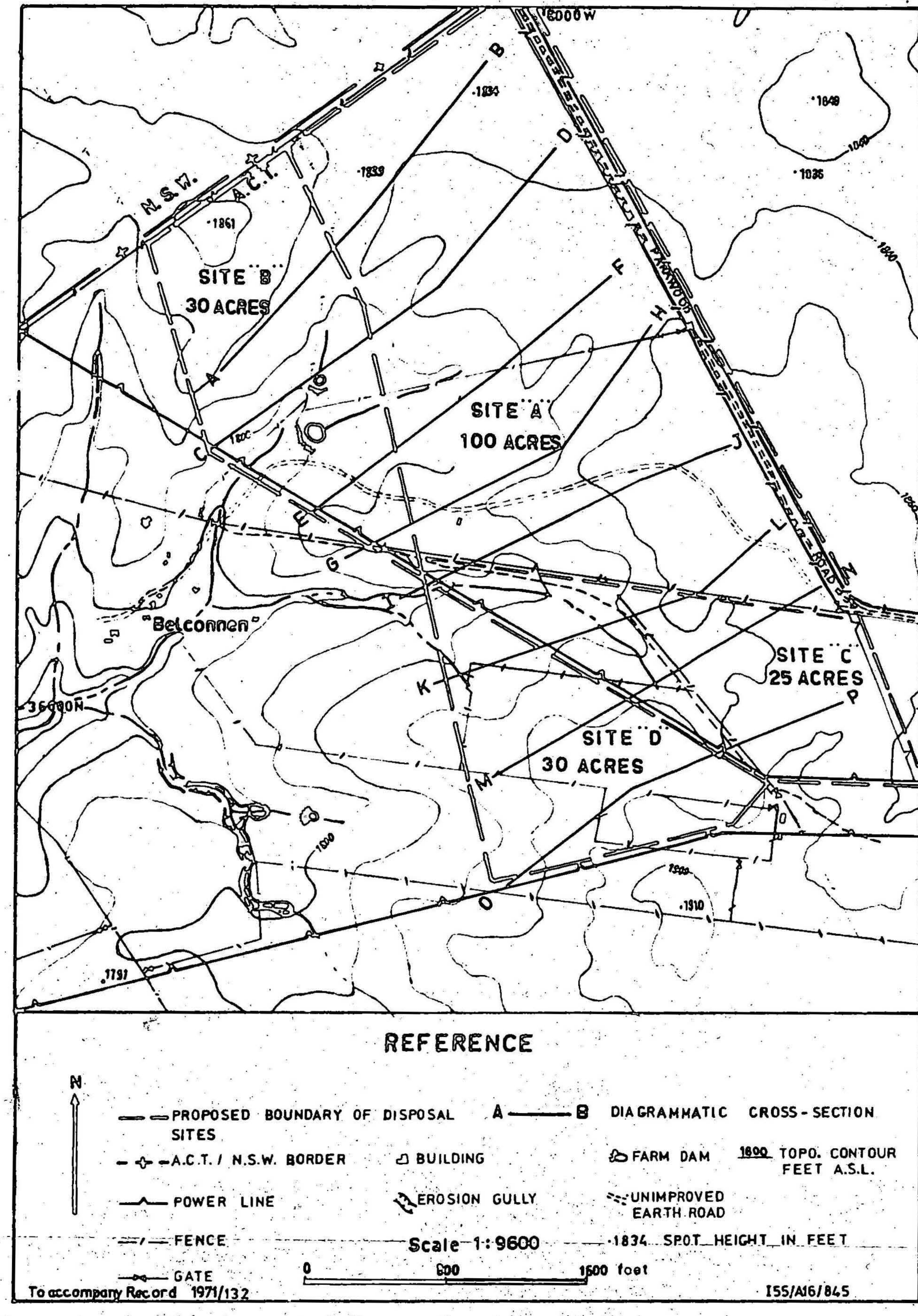
BELCONNEN REFUSE DISPOSAL AREA; LOCATION OF CROSS-SECTIONS. FIGURE 8



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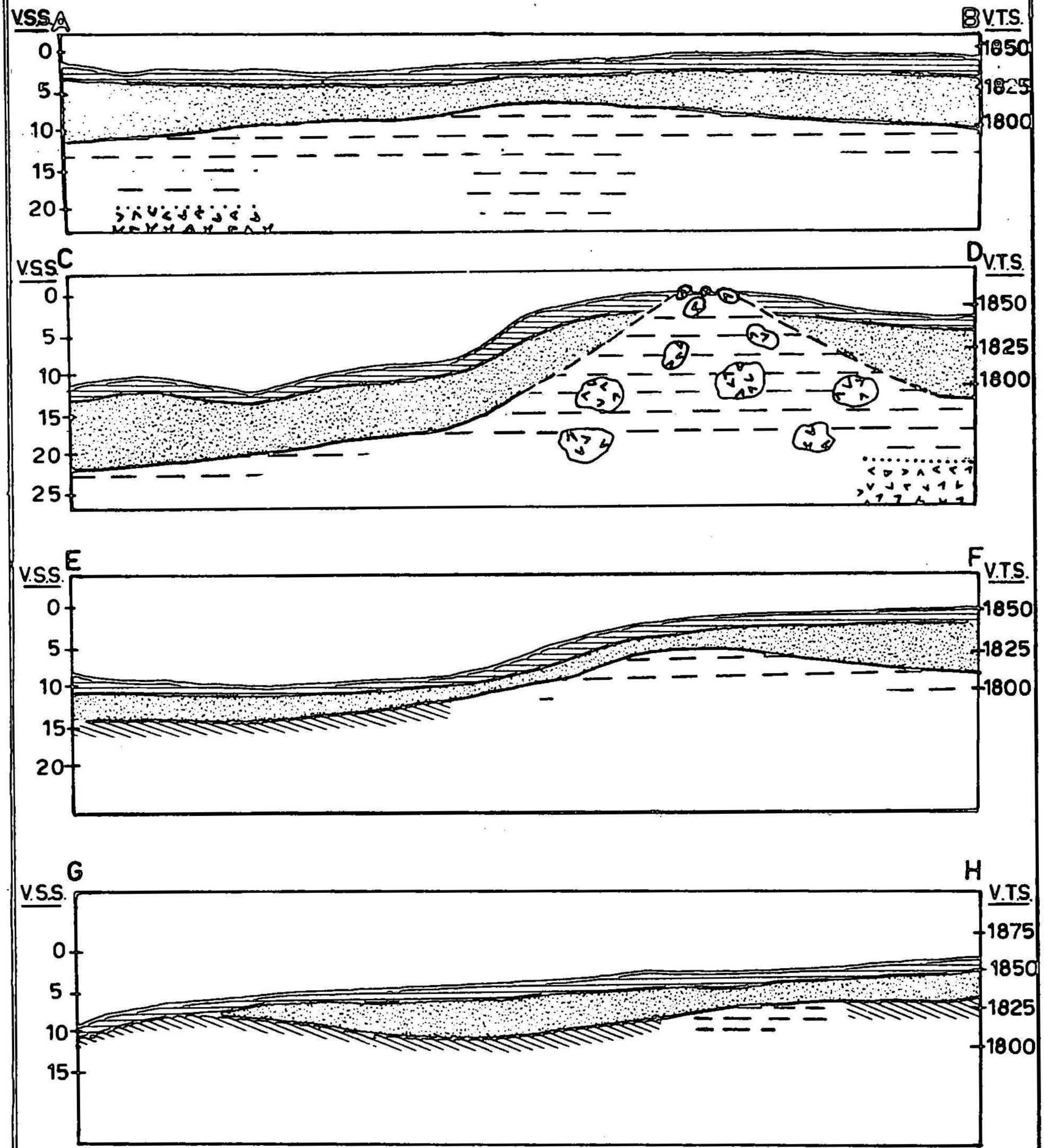
DIAGRAMMATIC CROSS-SECTIONS; A–B , C–D , E–F , G–H. FIGURE 9

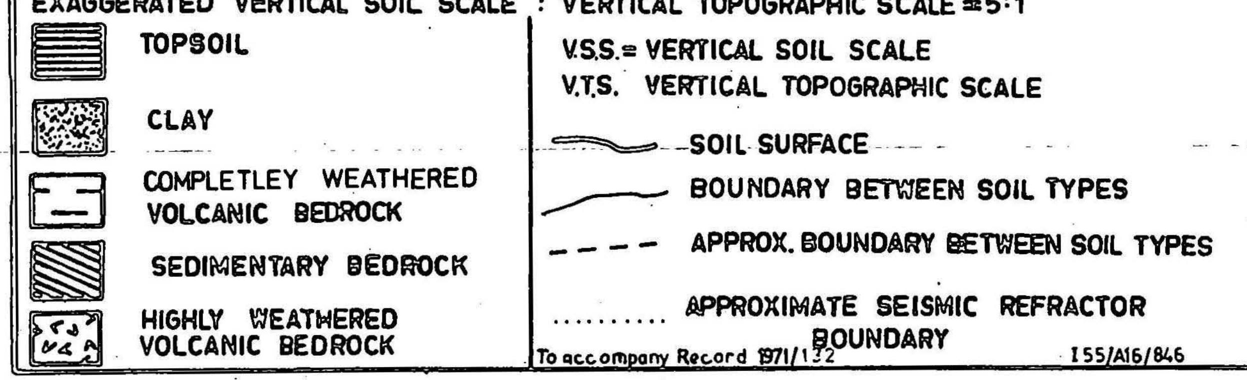


REFERENCE

HORIZONTAL SCALE 1 inch = 400 feet

VERTICAL TOPOGRAPHIC SCALE : HORIZONTAL TOPOGRAPHIC SCALE = 4 : 1

EXAGGERATED VERTICAL SOIL SCALE : VERTICAL TOPOGRAPHIC SCALE = 5 : 1



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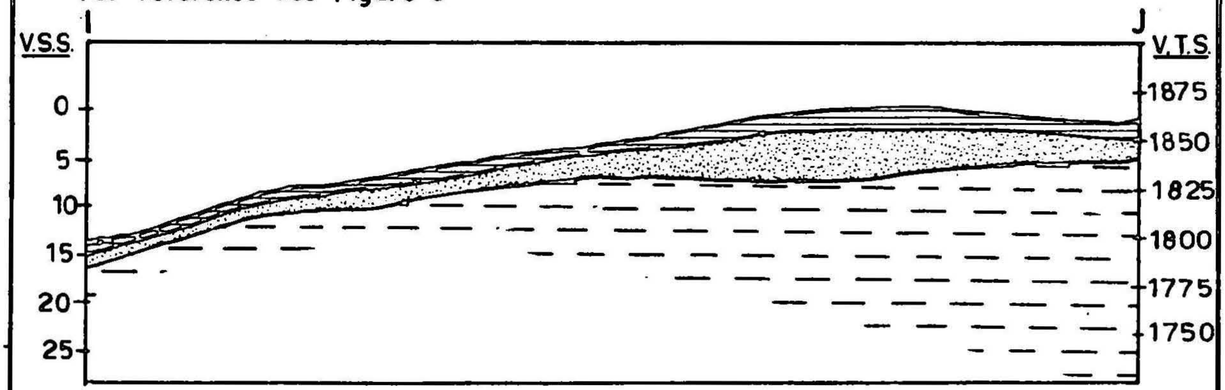
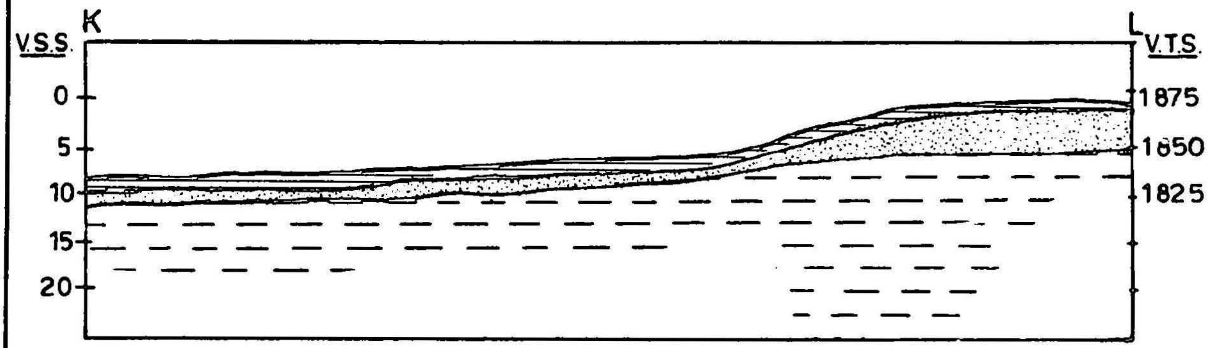
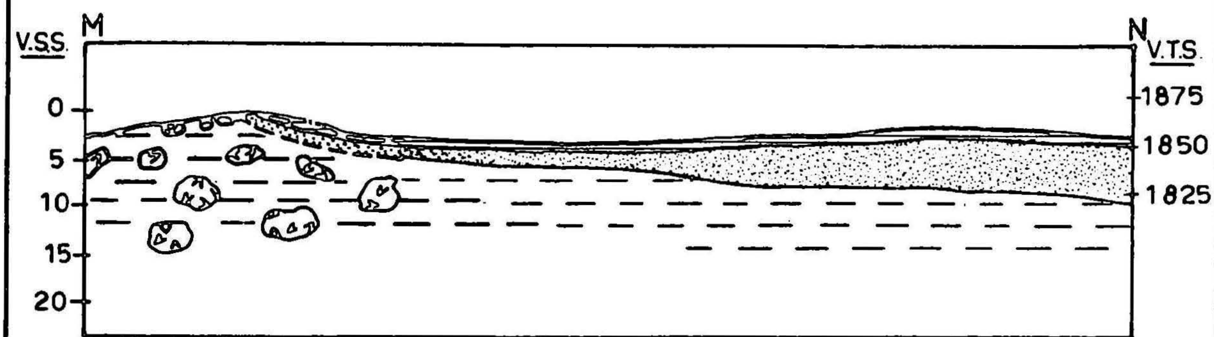
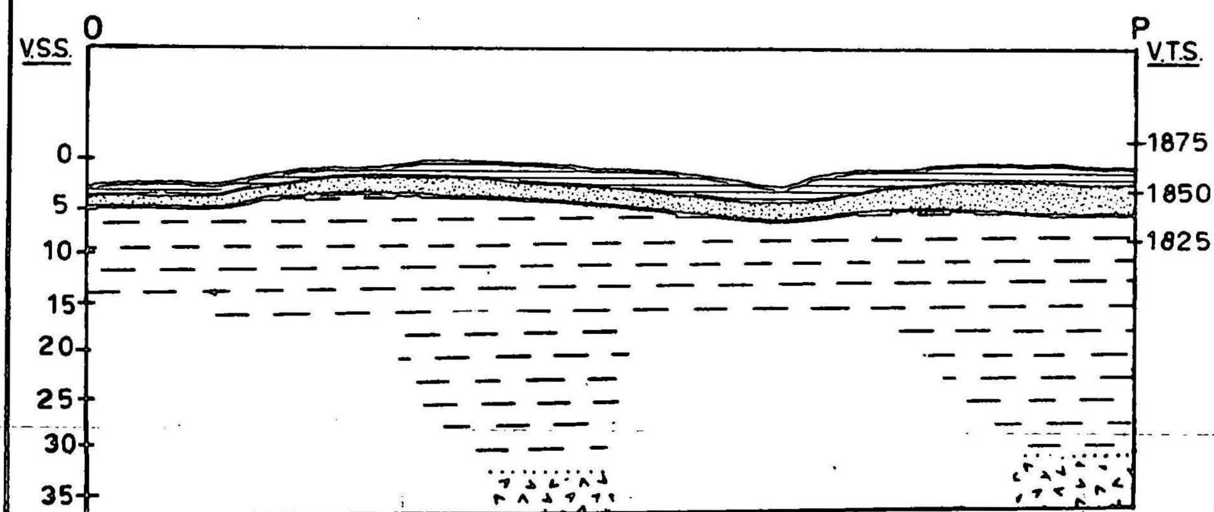
DIAGRAMMATIC CROSS-SECTIONS; I–J, K–L, M–N, O–P. FIGURE 10

For reference see Figure 9









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The time taken for refuse to decompose and stabilize in landfills depends on moisture conditions. Decomposition is rapid when refuse has a moisture content of 40 - 80 percent. Refuse that may take 3 to 5 years to decompose in a warm humid environment (Williams & Wallace, 1970) will take more than 30 years to decompose in a temperate well-drained one.

Leaching liquid from a landfill contains dissolved pollutants such as organic matter, chlorides, sulphates and carbonates of sodium, potassium and calcium, and traces of ammonium, cyanide and arsenic compounds. Self-purification of the leached liquid by percolation through adjacent soil material is mainly by adsorption and biological activity. Purification from organic matter is complete but removal of some organic compounds and inorganic chemical salts is not as effective. A continual polluting source such as a landfill, will eventually, given sufficient time, exhaust the adsorptive capacity of the soil and contamination of groundwater commences. Springs supported by the groundwater may in turn pollute the surface streams. Hence a landfill area must be hydrologically safe.

Hydrologically safe sites are generally those that occur above the water table in fine-grained unconsolidated clays and silts. Movement of contaminants is such that they could not affect useful groundwater or surface water resources. If such a site is not available than a hydrologically protective site must be used. The establishment of a protective site involves the installation of a clay liner 1 to 2 feet thick on the bottom and sides of each excavated trench. Clay is usually impermeable or can react with leachate to become impermeable; ionic exchange between the clay minerals and the leachate minimizes the risk of pollution. Covering of filled trenches with a clay layer has been tried but this does not allow gases (nitrogen, carbon dioxide and methane), generated by anaerobic processes, to escape.

Re-use of landfill areas is possible where other sites cannot be found. Stabilized and inert material is removed and new refuse buried; this may create problems of odour, and increase in volume. Completed landfills have been successfully converted to parks, sportsfields, parking areas and campuses.

Working the site

The proposed site will be the main refuse disposal area for Belconnen, a 'Town' with an eventual population of 120,000, a Town Centre, Government Offices, and possibly a minor industrial area. Refuse likely to be generated by Belconnen is detailed in Tables 2 and 3 (L.T.F.A., 1970).

TABLE 2. Composition of Refuse in Canberra

Composition	Percentage
Domestic refuse	41
Trade waste	17
Parks and Gardens rubbish	16.8
Householders and miscellaneous trades	9.3
Builders refuse	6.4
Wet garbage	3.4
Government waste paper	3.2
Public litter	2.0
Street sweepings	0.4
Miscellaneous	0.3
Total	99.8
Grease traps	300,000 gallons
Sump oil	?

TABLE 3. Generation of Refuse in Canberra

Population	Refuse (Tons)		Refuse (cub. yds.)	
	Daily	Annually	Daily	Annually
25,000	25	9,100	187	68,200
50,000	50	18,250	394	136,400
100,000	100	36,500	788	272,800

The site is not a hydrologically safe area and therefore measures should be taken to make it hydrologically protective.

This suggests that it should be worked by trenching and filling downhill - the sides of trenches sloping less than two in one. If a downhill method of working is chosen consideration should be given to controlling infiltration to within optimum conditions for decomposition in completed areas. Care should be taken to avoid spillage of excess infiltration at the downhill end of each trench.

The bottom and sides of each trench should be clay-lined to make it hydrologically protective, and to allow all-weather working on the site. The problems of erosion and scouring during heavy rainfall, however, must be considered. An alternative to complete clay lining is to line the sides of the trench with clay, and to compact loose completely weathered bedrock on the bottom of the trench. By sloping the sides of each trench two adjacent trenches leave a triangular soil channel for groundwater movement (Fig. 11).

The depth to which trenches can be excavated will vary but an average of 20 feet in completely weathered volcanic rock is indicated by seismic results. A trench width of 150 feet would give a width of 66 feet at the bottom of a 20-foot - deep trench. This is wider than at present used at Pialligo but would mean less clay lining of trench sides. There may be problems covering the refuse daily if spread over such a large area.

Surplus excavated soil should be stockpiled in areas where a thin soil cover is indicated; some of the completely weathered volcanic rock appears suitable, from testing to date, for use in pavements etc. as a plastic gravel and probably could be sold and removed from the area. Stockpiled clay may become unworkable if allowed to dry or if it becomes too wet and sticky. Some topsoil for the final cover over the landfill may have to be imported.

The recommended size, shape, and orientation of trenches in the landfill area are shown on Figure 11. Servicing a population of 120,000, the landfill would have a minimum life of 20 years. Reworking of the site may be difficult as some of the refuse may not decompose; also it may not be possible to make the site hydrologically protective again. Use of plastic sheeting may be an economically feasible way of protecting the site should reworking become necessary.

CONCLUSIONS

(1) The area is located in a perched basin which is undergoing mild erosion.

(2) Sedimentary and volcanic rocks occur in the area; the volcanic rocks are mostly deeply weathered, the sedimentary rocks only slightly.

(3) Seismic results indicate considerable thickness (as much as 60 feet) of excavatable completely weathered volcanic rock; and thin soil overlying sedimentary rocks.

(4) Augering confirmed that the site has sufficient thickness of soil for refuse disposal.

(5) Contamination of groundwater and subsequently surface water by the landfill could occur if precautions are not taken.

(6) Working the area by trenching, downhill, should be considered in view of the problem of pollution.

(7) By sloping the sides of each trench, two adjacent trenches would leave a triangular channel for groundwater movement.

(8) Servicing a population of 120,000 the site would have a minimum life of 20 years.

(9) Reworking the site would be possible if the refuse had decomposed completely, and if the site can be preserved as a hydrologically protective one.

(10) The completely weathered volcanic rock may be usable as gravel pavement.

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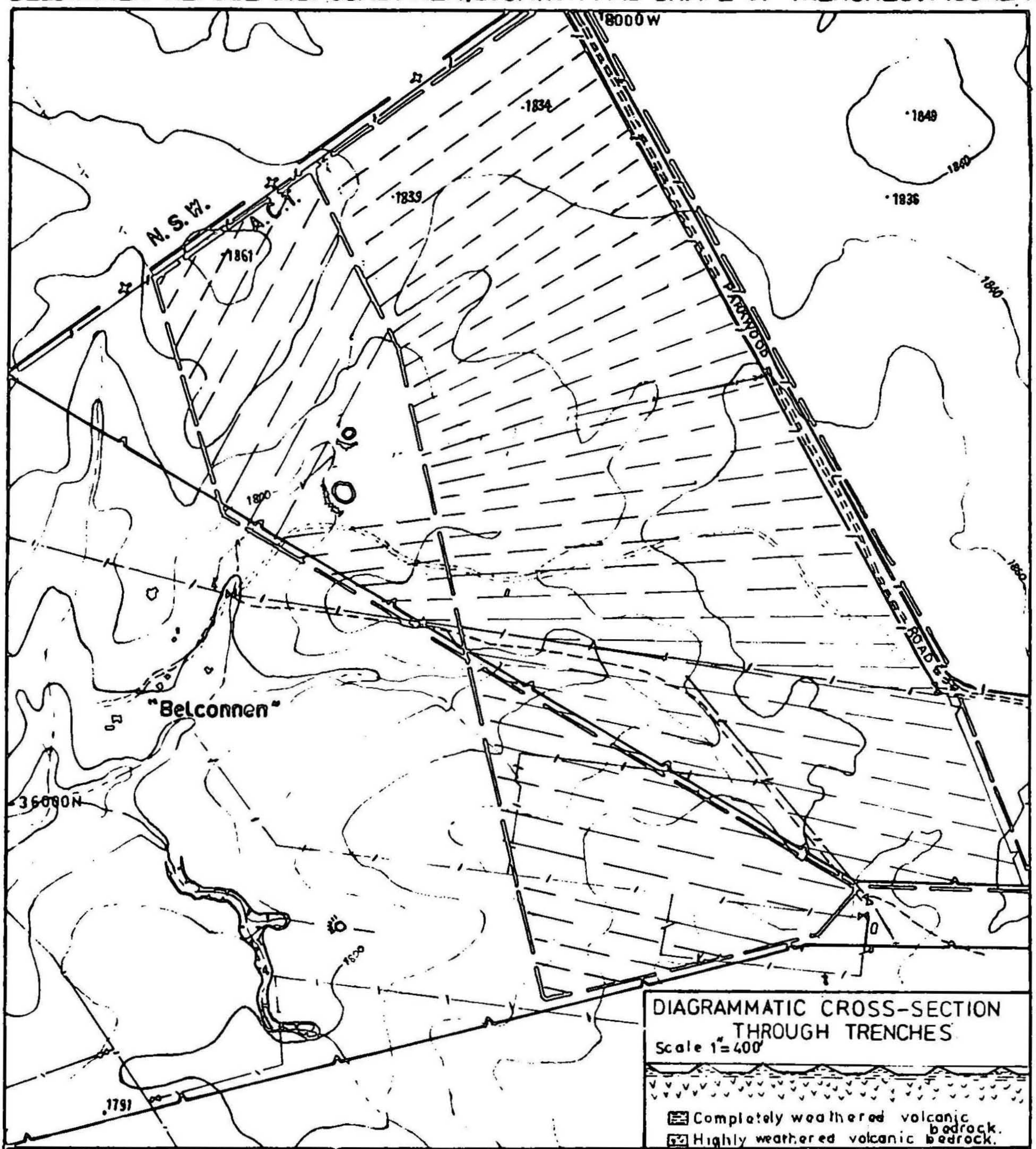
BELCONNEN REFUSE DISPOSAL AREA; LOCATION AND SHAPE OF TRENCHES. FIGURE 11



REFERENCE

N

- PROPOSED BOUNDARY OF DISPOSAL SITES
- TRENCH
- A.C.T. / N.S.W. BORDER
- BUILDING
- FARM DAM
- 1800 TOPO. CONTOUR FEET A.S.L.
- POWER LINE
- EROSION GULLY
- UNIMPROVED EARTH ROAD
- FENCE
- •1834 SPOT HEIGHT IN FEET
- GATE

Scale 1:9600

0 800 1600 feet

To accompany Record 1971/132

I55/A16/848

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APPENDIX 1

WEATHERING - DEFINITION OF TERMS

FRESH	Rock shows no discoloration or loss of strength.
SLIGHTLY WEATHERED	Rock is slightly discoloured but not noticeably weakened; a 2-inch diameter drill core cannot usually be broken by hand across the rock fabric.
MODERATELY WEATHERED	Rock is discoloured and noticeably weakened, but a 2-inch drill core cannot usually be broken by hand across the rock fabric; ripping by bulldozer not possible.
HIGHLY WEATHERED	Rock is usually discoloured and weakened to such an extent that a 2-inch drill core can readily be broken by hand across the rock fabric. Wet strength generally lower than dry strength; ripping with bulldozer may be possible along joint planes.
COMPLETELY WEATHERED	Rock is discoloured and entirely broken down to an aggregate of particles that has the mechanical property of a soil; the original fabric of the rock is mostly preserved. The properties of the soil depend on the composition of the parent rock; easily ripped by a bulldozer.

APPENDIX 2

CONVERSION FACTORS - BRITISH TO METRIC UNITS

Quantity	Imperial Unit	Metric Unit	Conversion Factors (Approximate): Imperial to Metric Units	Metric to Imperial Units
LENGTH	inch (in)	millimetre (mm) or centimetre (cm)	1 in = 25.4 mm	1 cm = 0.394 in
	foot (ft)	centimetre or metre (m)	1 ft = 30.5 cm	1 m = 3.28 ft
	yard (yd)	metre (m)	1 yd = 0.914 m	1m = 1.09 yd
	mile	kilometre (km)	1 mile = 1.61 km	1 km = 0.621 mile
MASS	ounce (oz)	gram (g)	1 oz = 28.3 g	1 g = 0.0353 oz
	pound (lb)	gram (g) or kilogram (kg)	1 lb = 454 g	1 kg = 2.20 lb
	ton	tonne (t)	1 ton = 1.02 tonne	1 tonne = 0.984 ton
AREA	square inch (in^2)	square centimetre (cm^2)	1 in^2 = 6.45 cm^2	1 cm^2 = 0.155 in^2
	square foot (ft^2)	square centimetre (cm^2) or square metre (m^2)	1 ft^2 = 929 cm^2	1 m^2 = 10.8 ft^2
	square yard (yd^2)	square metre (m^2)	1 yd^2 = 0.836 m^2	1 m^2 = 1.20 yd^2
	acre (ac)	hectare (ha)	1 ac = 0.405 ha	1 ha = 2.47 ac
VOLUME	cubic inch (in^3)	cubic centimetre (cm^3)	1 in^3 = 16.4 cm^3	1 cm^3 = 0.0610 in^3
	cubic foot (ft^3)	cubic decimetre (dm^3) or cubic metre (m^3)	1 ft^3 = 28.3 dm^3	1 m^3 = 35.3 ft^3
	cubic yard (yd^3)	cubic metre (m^3)	1 yd^3 = 0.765 m^3	1 m^3 = 1.31 yd^3
	bushel (bus)	cubic metre (m^3)	1 bus = 0.0364 m^3	1 m^3 = 27.5 bus
VOLUME (fluids)	fluid ounce (fl oz)	mililitre (ml)	1 fl oz = 28.4 ml	1 ml = 0.0352 fl oz
	pint (pt)	mililitre (ml) or litre (l)	1 pint = 568 ml	1 litre = 1.76 pint
	gallon (gal)	litre (l) or cubic metre (m^3)	1 gal = 4.55 litre	1 m^3 = 220 gallons
FORCE	pound-force (lbf)	newton (N)	1lbf = 4.45 N	1 N = 0.225 lbf
PRESSURE	pound per square inch (psi)	kilopascal (kPa)	1 psi = 6.89 kPa	1 kPa = 0.145 psi
VELOCITY	mile per hour (mph)	kilometre per hour (km/h)	1 mph = 1.61 km/h	1 km/h = 0.621 mph
TEMPERATURE	Fahrenheit temp (°F)	Celsius temp (°C)	$°C = \frac{5}{9}(°F - 32)$	$°F = 9 \times \frac{°C}{5} + 32$
DENSITY	pound per cubic inch (lb/in^3)	gram per cubic centimetre (g/cm^3) = tonne per cubic metre (t/m^3)	1 lb/in^3 = 27.7 t/m^3	1 t/m^3 = 0.0361 lb/in^3
	ton per cubic yard	tonne per cubic metre	1 ton/yd^3 = 1.33 t/m^3	1 t/m^3 = 0.752 ton/yd^3
ENERGY	British thermal unit (Btu)	kilojoule (kJ)	1 Btu = 1.06 kJ	1 kJ = 0.948 Btu
	therm	megajoule (MJ)	1 therm = 106 MJ	1 MJ = 9.48 x 10^{-3} therm
POWER	horsepower (hp)	kilowatt (kW)	1 hp = 0.76 kW	1 kW = 1.34 hp

REFERENCE: "Metric conversion for Australia". METRIC CONVERSION BOARD. Aust. Govt. Publ. Serv. Canberra. 1971.

APPENDIX 3

PETROGRAPHIC DESCRIPTION OF ROCK TYPES

ROCK NAME: Rhyodacite welded tuff.

Registered No: 71360001 Co-ordinates: W8600, N38300

Hand Specimen: A massive fine-grained, dark grey, porphyritic, crystal vitric tuff containing phenocrysts of plagioclase and quartz.

Thin Section:

Optical estimate of constituents

Phenocrysts:	Approx. Percentage	Size Range (mm)	Average (mm)
Quartz	20	1.5 - 0.1	0.5
Orthoclase	5	0.5 - 0.25	0.3
Plagioclase	5	1.0 - 0.1	0.3
Biotite	5	1.0 - 0.1	0.3

Groundmass: Devitrified glass consisting of equal amounts of quartz and potash feldspar. Secondary calcite, amorphous carbonate, muscovite, epidote and quartz are present. Iron oxides replace biotite.

Description

Quartz: Occurs as rounded, corroded phenocrysts, typically embayed and which have smooth outlines. Quartz also occurs as angular clastic fragments; all quartz shows straight extinction.

Orthoclase: Occurs as rounded and corroded phenocrysts, kaolinised; and not very abundant.

Plagioclase: Crystals show albite twinning and remnant zoning; composition is An_{34-40} (andesine).

Biotite: Ragged, elongated, bent phenocrysts showing wavy extinction and strong pleochroism, pale grey-brick red; generally it is an orange-brown colour.

Groundmass: Devitrified glass displays a eutaxitic texture and contains small angular fragments of quartz and feldspar.

Comments: The groundmass and clastic fragments in the section indicate it is a pyroclastic volcanic rock, probably a welded tuff.

ROCK NAME: Tuffaceous sandstone.

Registered No: 71360002 Co-ordinates: W9100 N37100

Hand Specimen: A yellow-brown fine-grained tuffaceous sandstone, speckled in appearance.

Thin Section:

Optical estimate of constituents.

Crystals	Approx. percentage	Size range (mm)	Average (mm)
Quartz	15	0.25 - 0.01	0.1
Potash feldspar	2	0.25 - 0.05	0.1
Plagioclase	2	0.25 - 0.05	0.1
Biotite	minor	0.25 - 0.01	0.1

Matrix: Mostly devitrified glass consisting of quartz and potash feldspar but also some sericite, also contains some reconstituted quartz and opaques distributed throughout the matrix.

Description

Quartz: The dominant mineral in the section and occurs as angular, poorly sorted, fragments randomly orientated; all grains show straight extinction.

Plagioclase: Angular to sub-rounded grains of andesine (An_{34}) show albite twinning.

Biotite: Ragged, strongly pleochroic, light grey-yellow-brown, grains are surrounded by iron oxides.

Comments: The section consists of poorly sorted, angular, fine-grained, quartz, feldspar and biotite crystals in a matrix of devitrified glass and sericite.

ROCK NAME: Tuffaceous siltstone.

Registered No: 71360003 Co-ordinates: W9100, N37100

Hand Specimen: Yellow-brown, fine-grained speckled tuff or tuffaceous siltstone.

Thin Section:

Optical estimate of constituents

Crystals:	Approx. Percentage	Size Range (mm)	Average (mm)
Quartz	15	0.2 - 0.005	0.025
Plagioclase	2	0.25 - 0.005	0.025
Biotite	minor		0.05
Muscovite	minor		0.05
Accessories:			
Opaques	2		
Zircon	trace		

Rock Fragments: minor - uniformly distributed throughout the section.

Matrix: comprises more than sixty percent of the section.

Description

Quartz: Occurs as angular to sub-rounded grains, poorly sorted, occasionally showing undulose extinction.

Plagioclase: Is sub-ordinate to quartz and is andesine (An_{30}) in composition.

Biotite: Not very abundant, strongly pleochroic, colourless to brown.

Opaques: Iron oxides uniformly disseminated throughout the section.

Matrix: Mostly made up of silica with lesser amounts of potash feldspar and sericite.

Comments: The section consists of poorly sorted, angular silt-sized fragments of quartz, plagioclase, biotite, muscovite and opaques set in a very fine matrix of quartz, potash feldspar and sericite.

ROCK NAME: Mudstone.

Registered No: 71360004 Co-ordinates: W9100, N37100

Hand Specimen: Angular, blocky dark grey-brown mudstone.

Thin Section:

Optical estimate of constituents

Crystals:	Approx. Percentage	Size Range (mm)
Quartz	a few scattered grains	up to 0.2
Plagioclase	minor	0.5
Amorphous carbonate	a few grains	up to 0.25
Biotite	minor	up to 0.15
Muscovite	a few grains	up to 0.15
Opaques	3	0.03 - 0.003
Matrix:		
Quartz	50	
Sericite	30	
Potash Feldspar	20	

Description

Quartz: A few angular fragments.

Biotite: A few ragged, pleochroic, grey to yellow-brown grains.

Carbonate: Rounded grains, some enclosing rock fragments.

Opaques: Uniformly disseminated iron oxides.

Matrix: Consists of devitried volcanic glass and sericite.

Comments: Section consists of a few angular grains of quartz, carbonate, feldspar, mica and opaques in a very fine-grained matrix of quartz, potash feldspar and sericite.

ROCK NAME: Limestone

Registered No: 71360005 Co-ordinates: W9100, N37100

Hand Specimen: A lens of hard, fine-grained, medium grey limestone which has a yellow surface coating.

Thin Section:

Optical estimate of constituents

Crystals:	Approx. Percentage	Size Range (mm)	Average (mm)
Calcite	20 - 30	0.35 - 0.1	0.2
Amorphous carbonate	60 - 70	0.35 - 0.1	0.2
Quartz	minor	0.1 - 0.02	0.04
Opaques	scattered throughout	0.1 - 0.001	0.005

Description

Calcite: Recrystallized from carbonate by strain and forms aggregates of crystal clusters; some have replaced shell fragments.

Groundmass: Consists of fine-grained carbonate.

Comments: Largely made up of shell fragments and amorphous carbonate; it is most likely a detrital limestone.

ROCK NAME: Rhyodacite porphyry.

Registered No: 71360006 Co-ordinates: W7900, N35700

Hand Specimen: A moderately weathered, medium-grained, light grey-pink porphyritic crystal tuff, containing phenocrysts of plagioclase, quartz and altered biotite in a light pink groundmass.

Thin Section:

Optical estimate of constituents

Phenocrysts:	Approx. Percentage	Size Range (mm)	Average (mm)
Quartz	25	5.0 - 0.1	1.0
Plagioclase	10	2.0 - 0.1	1.0
Orthoclase	10	2.0 - 0.1	1.0
Biotite	10	2.0 - 0.3	0.75
Apatite	accessory		0.75
Groundmass:			
Quartz	20		0.025
Potash feldspar	20		0.025
Secondary chlorite	minor		

Description

Quartz: Mostly rounded and embayed, shows straight extinction; some crystals show hexagonal outlines of β -quartz.

Orthoclase: Cloudy and partly altered to kaolinite, shows carlsbad twinning in some crystals.

Plagioclase: Some crystals show combined carlsbad-albite twinning; composition ranges from oligoclase to andesine (An_{25}).

Biotite: Mostly altered to chlorite and epidote but still displays the outlines and cleavage of biotite.

Chlorite: Replaces biotite and occurs in both fibrous and radiating habits and is pleochroic; pale green-neutral.

<u>Groundmass</u>: A cryptocrystalline mosaic of quartz and potash feldspar makes up the entire groundmass.

<u>Comments</u>: The section consists of large phenocrysts of quartz, orthoclase, plagioclase, and altered biotite set in a cryptocrystalline groundmass of quartz and potash feldspar; the texture of the section suggests the rock may have been a lava flow.

ROCK NAME: Rhyodacite porphyry.

Registered No: 71360007 Co-ordinates: W8100, N35700

Hand Specimen: A moderately weathered, medium-grained, pale green porphyritic crystal tuff, containing phenocrysts of plagioclase, quartz, biotite in a light green-grey matrix.

Thin Section:

Optical estimate of constituents

Phenocrysts:	Approx. Percentage	Size Range (mm)	Average (mm)
Quartz	25	4.0 - 0.4	0.2
Orthoclase	10	2.0 - 0.25	0.5
Plagioclase	10	2.5 - 0.5	1.0
Biotite	10	1.0 - 0.25	0.5
Groundmass:			
Quartz	20		0.05
Potash feldspar	20		0.05

Description

Quartz: Mostly rounded and embayed, shows straight extinction; some crystals show hexagonal outlines of β -quartz.

Orthoclase: Rounded subhedral to anhedral grains, clouded, and fairly altered.

Plagioclase: Crystals anhedral, fairly altered, and andesine (An_{31}) in composition.

Biotite: Mostly altered to chlorite and epidote.

Groundmass: A cryptocrystalline mosaic of quartz and potash feldspar makes up th e entire groundmass.

Comments: The section consists of large phenocrysts of quartz, orthoclase, plagioclase, and altered biotite set in a cryptocrystalline groundmass of quartz and potash feldspar. The texture of the section suggests the rock may have been a lava flow.

APPENDIX 4

LOGS OF AUGER HOLES

Hole 1:	0-1 Feet	Medium dark brown topsoil.
	1-4 "	Yellow-orange plastic clay.
	4-8 "	Mottled grey-yellow clay.
	8-15½ "	Completely weathered volcanic rock. Hole discontinued.
Hole 2:	0-1 Feet	Brown topsoil.
	1-2 "	Yellow-orange Clay.
	2-6 "	Completely weathered volcanic rock. Augering very slow and difficult.
Hole 3:	0-1 Feet	Dark brown and light grey topsoil.
	1-5½ "	Yellow-brown heavy plastic clay.
	5½-9 "	Mottled grey clay (iron oxide mottles).
	9-12 "	Completely weathered volcanic rock. Hole discontinued.
Hole 4:	0-1 Feet	Brown-grey topsoil.
	1-6 "	Yellow-orange clay.
	6-12 "	Completely weathered volcanic rock.
Hole 5:	0-1 Feet	Brown-grey topsoil.
	1-7 "	Heavy plastic yellow-orange clay. Auger hit hard rock.
Hole 6:	0-1 Feet	Topsoil.
	1-3 "	Dark red clay.
	3-8 "	Plastic yellow clay.
	8-12 "	Completely weathered volcanic rock. Hole discontinued.

Hole 7:	**0-1 Feet**	**Grey-brown topsoil.**
	1-1½ "	**Orange clay.**
	1½-4½ "	**Yellow clay.**
	4½-12 "	**Completely weathered volcanic rock. Hole discontinued.**
Hole 8:	**0-1 Feet**	**Grey-brown topsoil.**
	1-2½ "	**Red clay.**
	2½-9 "	**Completely weathered volcanic rock.**
Hole 9:	**0-1 Feet**	**Grey-brown topsoil.**
	1-4 "	**Yellow-orange clay.**
	4-12 "	**Completely weathered volcanic rock. Hole discontinued.**
Hole 10:	**0-1 Feet**	**Grey-brown topsoil.**
	1-4½ "	**Yellow clay.**
	4½-9 "	**Completely weathered volcanic rock. Hole discontinued.**
Hole 11:	**0-1 Feet**	**Grey-brown topsoil.**
	1-7½ "	**Yellow clay.**
	7½-9 "	**Completely weathered volcanic rock. Hole discontinued.**
Hole 12:	**0-1 Feet**	**Grey-brown topsoil.**
	1-5 "	**Yellow clay.**
	5-7 "	**Soft mudstone.**
Hole 13:	**0-1 Feet**	**Grey-brown topsoil.**
	1-8 "	**Yellow clay.**
	8-13 "	**Completely weathered volcanic rock. Hole discontinued.**
Hole 14:	**0-2 Feet**	**Grey topsoil.**
	2 "	**Mudstone.**

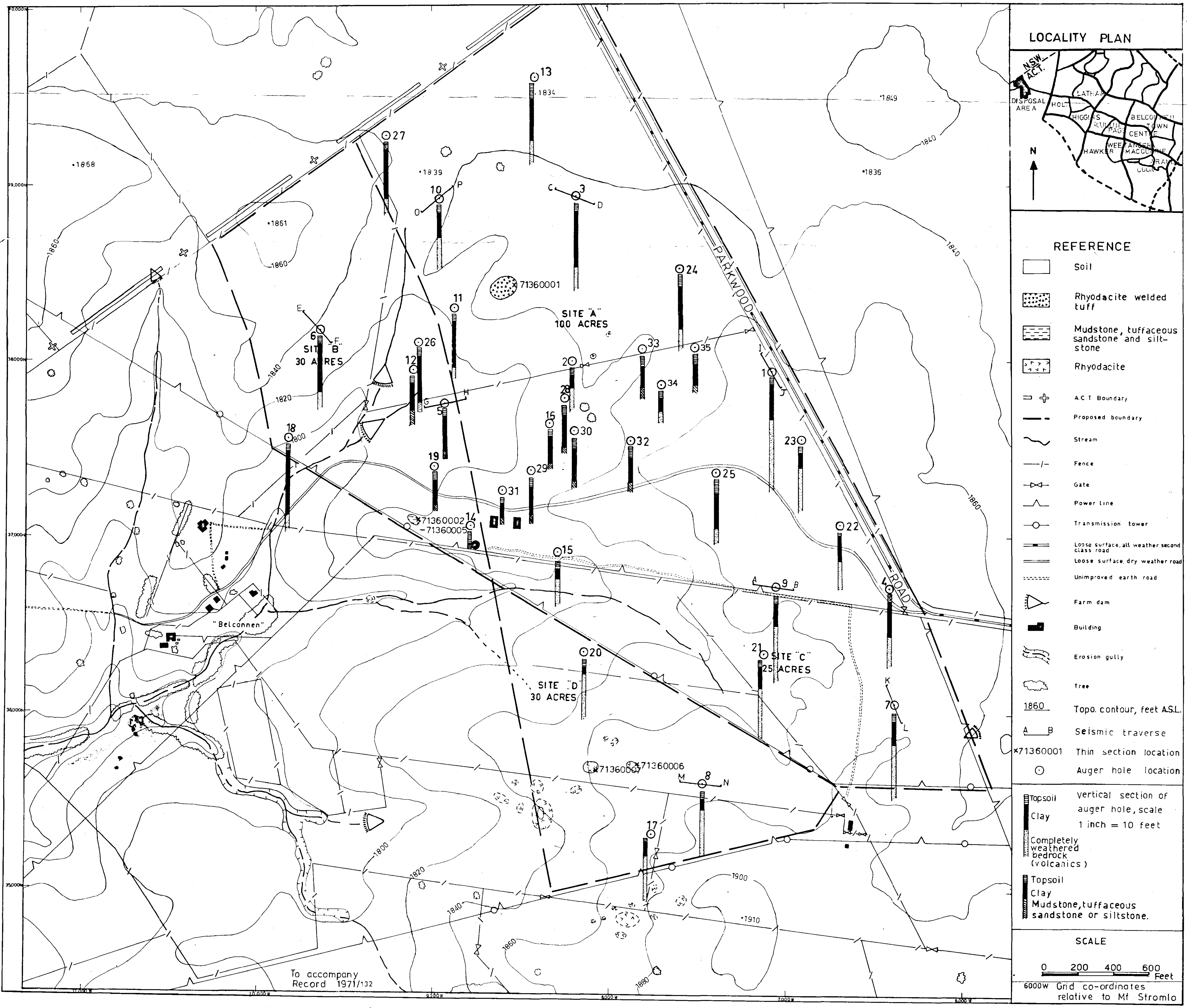
Hole 15:	0-1 Feet	Grey topsoil.
	1-2½ "	Red clay.
	2½-6 "	Completely weathered volcanic rock. Hole discontinued.
Hole 16:	0-1 Feet	Grey topsoil.
	1-5 "	Yellow clay.
	5 "	Rock.
Hole 17:	0-½ Feet	Grey topsoil.
	½-2½ "	Red clay loam.
	2½-8½ "	Completely weathered volcanic rock. Hole discontinued.
Hole 18:	0-1 Feet	Grey Topsoil.
	1-5 "	Red clay.
	5-14 "	Completely weathered volcanic rock. Hole discontinued.
Hole 19:	0-1 Feet	Grey topsoil.
	1-1½ "	Red clay.
	1½-4½ "	Yellow-grey clay.
	4½ "	Mudstone.
Hole 20:	0-1 Feet	Grey topsoil.
	1-2 "	Red clay.
	2-8 "	Completely weathered volcanic rock. Hole discontinued.
Hole 21:	0-½ Feet	Grey topsoil.
	½-2 "	Sandy alluvium.
	2-4 "	Yellow clay.
	4-13 "	Completely weathered volcanic rock. Hole discontinued.

Hole 22:	0-½ Feet	Grey topsoil.
	½-4 "	Yellow clay.
	4-10 "	Completely weathered volcanic rock. Hole discontinued.
Hole 23:	0-1 Feet	Grey topsoil.
	1-3 "	Red clay.
	3-9 "	Completely weathered volcanic rock.
Hole 24:	0-1½ Feet	Grey topsoil.
	1½-7½ "	Yellow clay.
	7½-12 "	Completely weathered volcanic rock. Hole discontinued.
Hole 25:	0-2 Feet	Grey topsoil.
	2-7 "	Yellow and red clay.
	7-9 "	Completely weathered volcanic rock. Hole discontinued.
Hole 26:	0-1 Feet	Grey topsoil.
	1-4 "	Orange-yellow clay.
	4-7½ "	Grey and orange mottled clay.
	7½-9 "	Completely weathered volcanic rock. Hole discontinued.
Hole 27:	0-1 Feet	Grey topsoil.
	1-4 "	Orange-yellow clay.
	4-7½ "	Orange-grey mottled clay.
	7½-10 "	Grey clay.
	10-22 "	Completely weathered volcanic rock. Hole discontinued.
Hole 28:	0-1½ Feet	Grey topsoil.
	1½-4½ "	Orange-yellow clay.
	4½ "	Mudstone.

Hole 29:	0-1½ Feet	Grey-brown topsoil.
	1½-5 "	Orange-yellow clay.
	5 "	Silicified sandstone.
Hole 30:	0-1½ Feet	Grey topsoil.
	1½-4½ "	Orange-yellow clay.
	4½ "	Mudstone.
Hole 31:	0-1 Feet	Grey topsoil.
	1-3 "	Orange-yellow clay.
	3 "	Micaceous sandstone.
Hole 32:	0-1½ Feet	Grey topsoil.
	1½-5 "	Sandy clay.
	5 "	Rock.
Hole 33:	0-1½ Feet	Grey topsoil.
	1½-4½ "	Orange-yellow clay.
	4½-6 "	Soft micaceous sandstone.
Hole 34:	0-1 Feet	Grey topsoil.
	1-3 "	Orange-yellow clay.
	3-4½ "	Rock.
Hole 35:	0-1½ Feet	Grey topsoil.
	1½-4½ "	Orange-yellow clay.
	4½ "	Rock.

GEOLOGY OF THE PROPOSED REFUSE DISPOSAL AREA, BELCONNEN, A.C.T.

PLATE 1



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