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GEOLOGICAL EVALUATION OF TERRAIN FOR URBAN AND REGIONAL DEVELOPMENT IN THE AUSTRALIAN CAPITAL TERRITORY

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SUMMARY

Geological evaluation has for many years been integrated into the planning of urban and regional development for Canberra and its satellite towns in the Australian Capital Territory. In proposed new development areas geological constraints are evaluated from preliminary mapping, geophysics, and drilling, with the production of thematic maps at 1:25 000 scale of geology, soils and foundation conditions, hydrology, and resources. Mapping and investigation of key areas, such as town centres or places with foundation problems, are carried out at large scales. More detailed project investigations are undertaken where necessary for the design of hydraulic services, transportation routes, and engineering structures. The engineering geological data is eventually consolidated into urban geology maps to be published at 1:10 000 scale.

More efficient planning of development has resulted from the early identification of geological constraints. These constraints include groundwater seepage problems in the colluvial mantle at the foot of hillslopes, and differential weathering of bedrock which creates local difficulties for excavation and foundations. Another consideration is the control of pollution of groundwater and surface water; and landfill areas for refuse disposal must be carefully sited. The supply of construction materials such as brick clay, sand, gravel, and crushed rock has to be considered before the alienation of land for other uses, and the quality of the residential environment has to be balanced against the requirements of the construction industry.

INTRODUCTION

> '.... The federal capital should be a beautiful city, occupying a commanding position with extensive views ....'
>
> H. Mahon, Australian Minister of Home Affairs, 1908.

The agreement to construct an Australian national capital was made at the time of the federation of the Australian States in 1901. Several years later, in 1909, a site was selected (Fig. 1) in the state of New South Wales to become the Australian Capital Territory. The Territory occupies 2350 km^2, of which more than half is hilly to mountainous forested country used mainly for water catchment and recreation purposes.

The basic design for Canberra, the national capital in the ACT, was prepared by the American architect Walter Burley Griffin in 1912. Griffin made topography the dominant element in the design, using the surrounding hills and mountain ranges as a scenic background for the city. The city is on a plain about 600 m above sea level, and the surrounding hills rise about 200 m above the plain, with more distant ranges rising to 1900 m. Griffin's design incorporated many public buildings and other National Capital functions and has generally been adhered to, although modified in detail. Construction began in 1913 and proceeded slowly until 1957, when the population was 36 000. In the last twenty years the population has grown to 210 000 and the annual growth rate is about 5 percent. As Canberra has grown its basic design has been developed to incorporate a series of new satellite towns (Fig. 2).

Canberra was the first of Australia's planned growth centres and is at present the only large urban development project apart from the State capitals; it is also Australia's largest inland city. Canberra is the only Australian city where the government has retained ownership of land. This has permitted long range planning to be undertaken and development to be programmed without the conflicting interests of traditional private ownership and the quality of the urban environment that have developed in other Australian cities.

Since 1957, the planning and development of Canberra have been the responsibility of the National Capital Development Commission, whose current planning strategy (NCDC, 1970) envisages the city growing as a

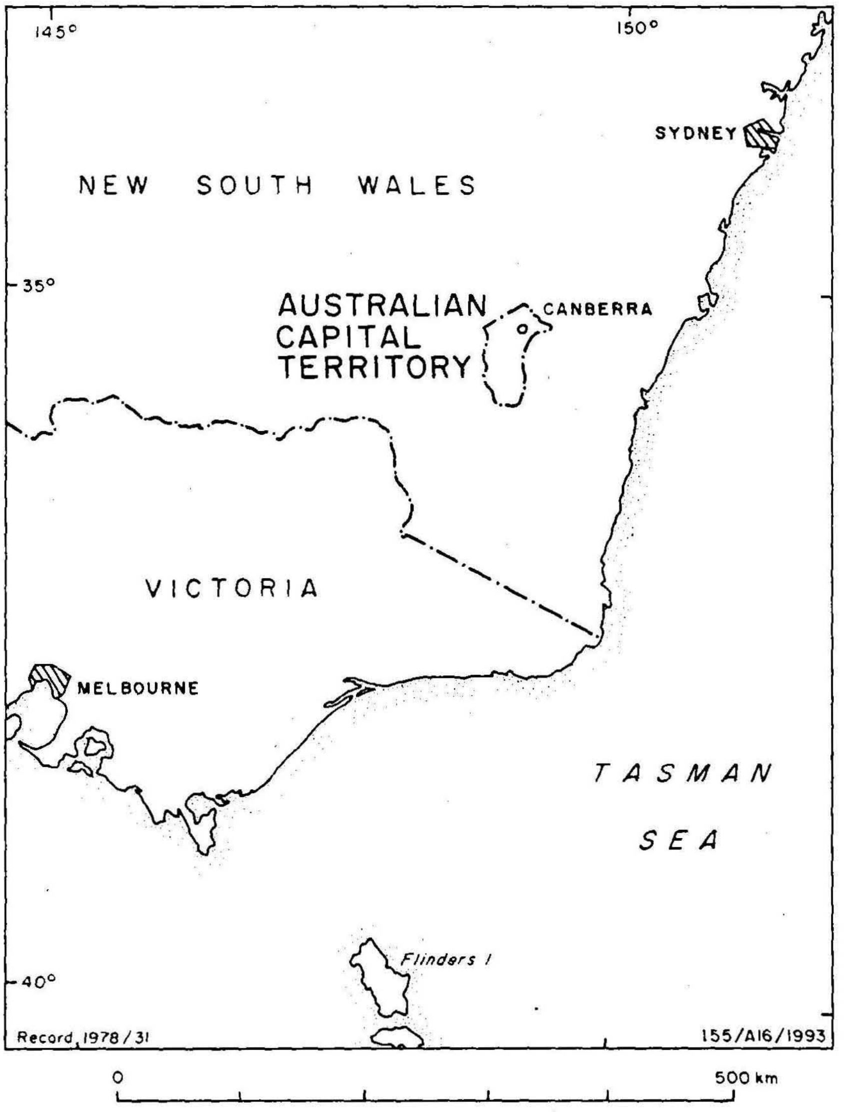

Fig. 1 Location map

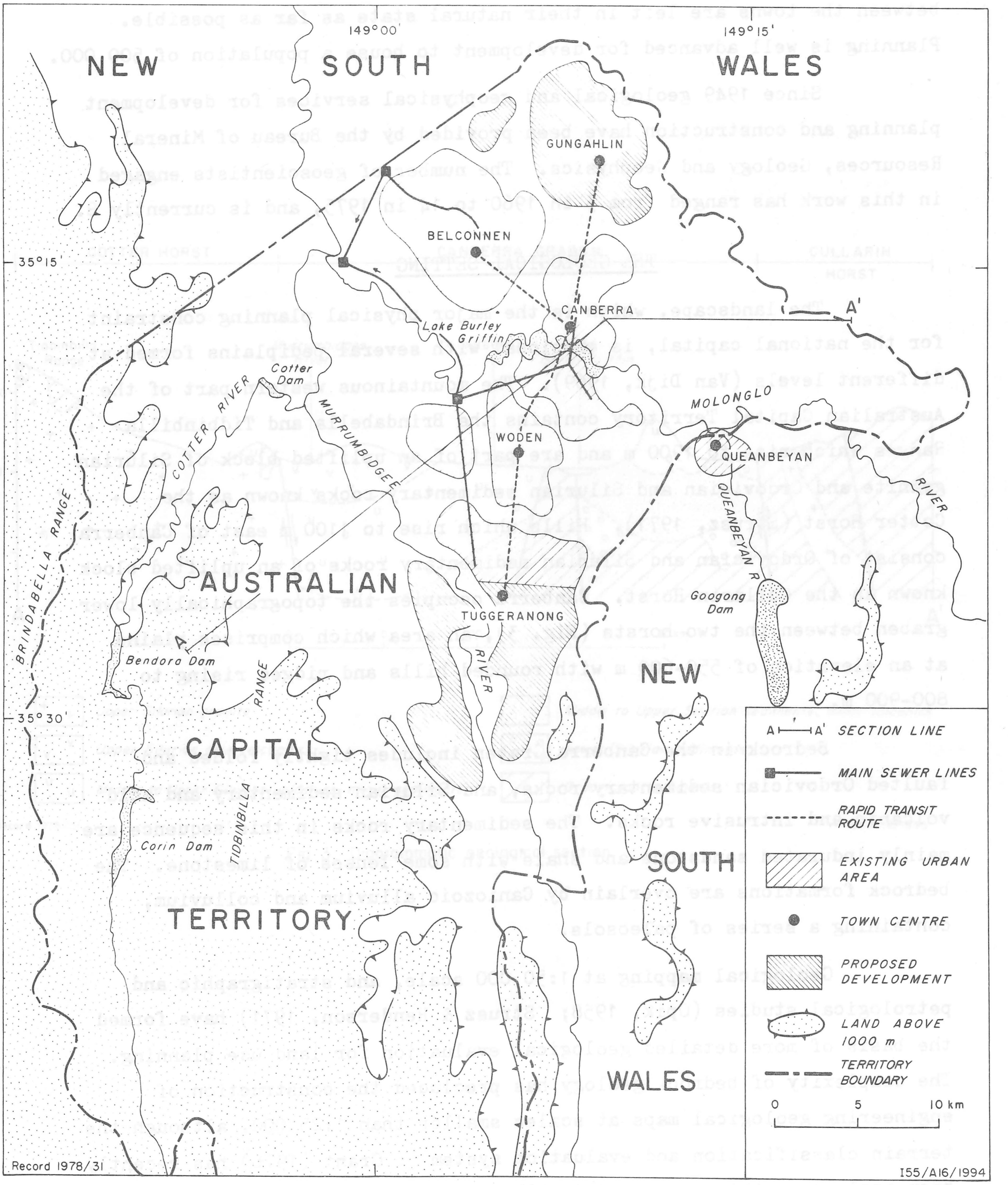

Fig. 2 The Australian Capital Territory

series of new towns extending in a Y shape from inner Canberra (Fig. 2) along gently sloping valleys or undulating country. The hills and ridges between the towns are left in their natural state as far as possible. Planning is well advanced for development to house a population of 500 000.

Since 1949 geological and geophysical services for development planning and construction have been provided by the Bureau of Mineral Resources, Geology and Geophysics. The number of geoscientists engaged in this work has ranged from 3 in 1960 to 14 in 1975, and is currently 8.

THE GEOLOGICAL SETTING

The landscape, which is the major physical planning constraint for the national capital, is erosional with several pediplains formed at different levels (Van Dijk, 1969). The mountainous western part of the Australian Capital Territory contains the Brindabella and Tidbinbilla Ranges which rise to 1900 m and are part of an uplifted block of Silurian granite and Ordovician and Silurian sedimentary rocks known as the Cotter Horst (Strusz, 1971). Hills which rise to 1100 m east of Canberra consist of Ordovician and Silurian sedimentary rocks of an uplifted block known as the Cullarin Horst. Canberra occupies the topographically lower graben between the two horsts (Fig. 3), an area which comprises plains at an elevation of 550-600 m with rounded hills and ridges rising to 800-900 m.

Bedrock in the Canberra Graben includes tightly folded and faulted Ordovician sedimentary rocks, and Silurian sedimentary and acid volcanic and intrusive rocks. The sedimentary rocks in this sequence are mainly indurated sandstone and shale with some lenses of limestone. The bedrock formations are overlain by Caniozoic alluvium and colluvium, containing a series of paleosols.

Geological mapping at 1:50 000 scale, and stratigraphic and petrological studies (Opik, 1958; Strusz & Henderson, 1971) have formed the basis of more detailed geological evaluation for land use planning. The complexity of bedrock geology has precluded the construction of engineering geological maps at scales smaller than 1:25 000, although the terrain classification and evaluation system of Grant (1976) has recently been applied to this area, and is illustrated by a map at 1:100 000 scale.

GEOLOGICAL EVALUATION OF TERRAIN

The geological evaluation of terrain for urban and regional development in the ACT takes place at several stages in development, and

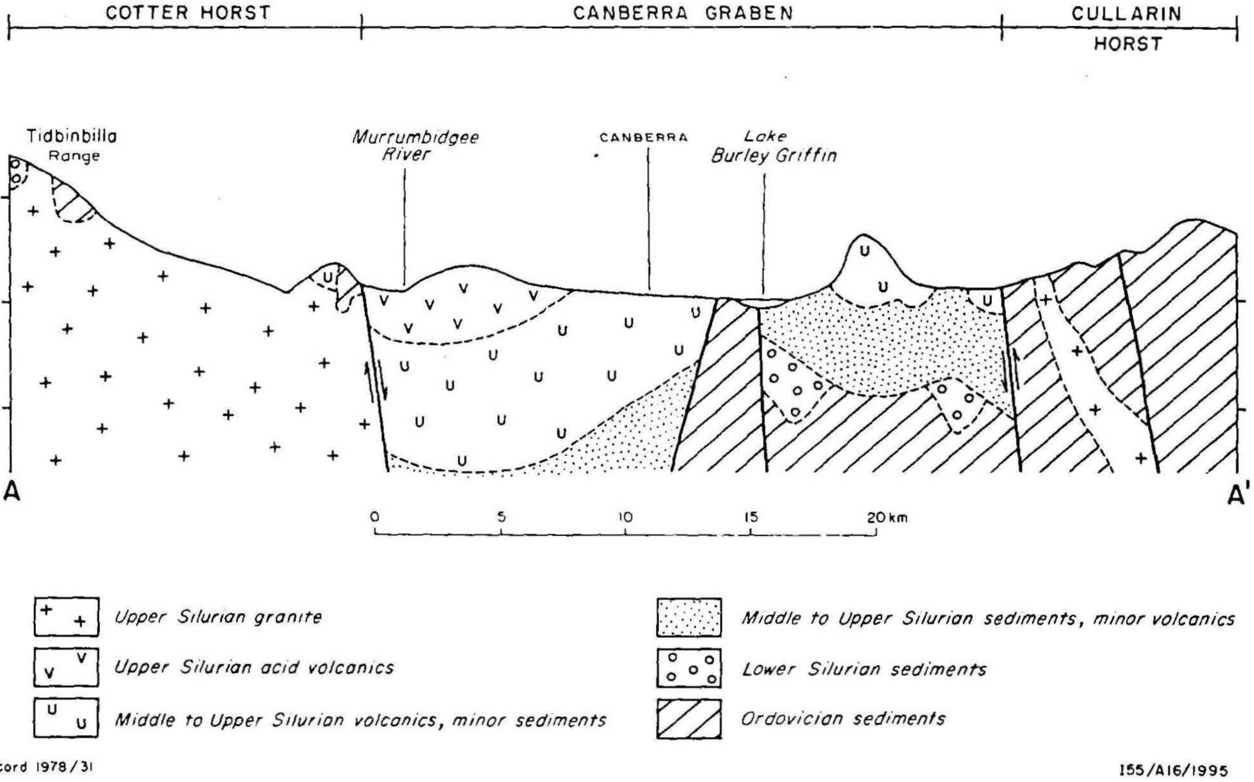

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Fig. 3 Diagrammatic geological section

information is presented at various appropriate scales. The general relation between the stages of urban planning and the associated geotechnical investigations is shown in Table 1. Results are presented on base maps at the same scale as those used for development planning.

TABLE 1

STAGES OF PLANNING AND ASSOCIATED GEOTECHNICAL ACTIVITIES

Stage of planning	Geotechnical activities
Data collection and analysis	Preliminary geological, hydrological and soils survey of new town area
Land use plan	Maps of geotechnical constraints
Preferred structure plan	Detailed geological and geophysical investigations of problem areas
Development plan	Geological investigations of town centre and individual suburbs
Feasibility and design of major elements - roads, water, sewerage	Geological and geophysical investigations for engineering projects
Contract specifications	Geotechnical information in tender documents

Geology for new town planning

In the initial stages of planning the new towns of Tuggeranong and Gungahlin (Fig. 2), geology and soils were mapped using colour airphotos at 1:25 000 scale. The investigation work included power augering in key areas to determine soil profiles and weathering characteristics and, in some places, seismic traverses for additional subsurface information. The results were presented to the planners as a series of 1:25 000 thematic maps covering geology, soils, foundation and excavation conditions, hydrogeology, geomorphology, and extractive resources. An additional map presented all the geological constraints to development in a form readily adaptable to the planning process (Hohnen, 1974; Jacobson, Vanden Broek & Kellett, 1976).

Investigations of problem areas

Following the preliminary survey of a new town area, additional information may be required for problem areas that have been identified, such as groundwater seepage areas, lenses of cavernous limestone, areas of difficult excavation with hard rock close to the surface, or areas containing valuable resources. Investigations of these areas may require detailed geological mapping, drilling, geophysics, and soils and aquifer testing. Mapping is generally done at scales of 1:10 000 or 1:5 000. The results are used in the consideration of development options for the preferred structure plan of the town.

Detailed investigations for planning

Also, at this stage, detailed geotechnical investigations are undertaken of certain areas where evaluation is required for planning. such as proposed town centres where geological constraints on siting large buildings must be identified, and areas zoned for industrial use. Additional investigations of particular suburbs may also be required before a development plan is formulated. Base maps at 1:5 000 or 1:2 500 are used for this work, which might require detailed geological mapping, geophysics, and drilling - depending on the nature of the investigation.

Project investigations

At a later stage, although in some cases concurrently, engineering geological investigations are undertaken for specific development projects such as sewer tunnels, water supply dams and pipe lines, highways and sanitary landfill sites. Major engineering works have included the main sewer system (Fig. 2) construction of which has involved about 30 km of hard rock tunnelling; most sewerage is piped to a large water treatment plant on the Molonglo River. Large water supply dams have been constructed on the Cotter River and Queanbeyan River.

Table 2 shows the relation between the major geological investigations undertaken during the early development of the new town of Tuggeranong. Before the land servicing contracts are let, additional detailed geological investigations of suburbs may be carried out for the excavation of services in problem areas. Site investigations for individual large buildings are generally done by consulting firms, but in many areas a preliminary geological survey is made to ensure the suitability of the area for the proposed construction.

Geological records

The basic geological documentation that has been adopted for Canberra is the 1:10 000 engineering geological map series. These maps are being compiled initially for the older, developed areas where development proceeded without geological appraisal and where geotechnical data from construction projects have been recorded. The first completed map in this series is now being published (Henderson, in prep.) and several others are in an advanced stage of compilation. An index system of recording all reference material including geotechnical data, such as logs of excavations and drillholes, has been developed using the 1:10 000 map series. It is anticipated that the 1:10 000 engineering geology maps

TABLE 2.

TUGGERANONG: GEOLOGICAL INVESTIGATIONS AND DEVELOPMENT

DRAINAGE PROBLEM, ISABELLA PLAINS

Investigation Dewatering

DRAINAGE PROBLEM, LANYON

Investigation

TOWN CENTRE

Geotechnical survey Building site investigations, damsite, etc.

MAIN TRUNK SEWER

Tunnel investigation Construction

OTHER TRUNK SEWERS

Route investigations Construction

LANDFILL SITES

Appraisal Site investigations

WATER PIPELINES

Route investigations Construction

WATER RESERVOIRS

Site investigations

HIGHWAYS

Route evaluations, bridge sites, etc.

1971	1972	1973	1974	1975	1976	1977	1978
General planning		Land servicing began	First inhabitants	Detailed planning and engineering investigations		Population 15 000	

will provide geotechnical data appropriate for redevelopment of Canberra's inner suburbs.

COST EFFECTIVENESS OF GEOTECHNICAL INVESTIGATIONS

Substantial cost benefits are achieved by properly conceived geological studies applied to development planning. Table 3 shows that planning investigations that identify geological constraints result in considerably more efficient use of available funds. Some older areas of Canberra developed without geological appraisal have suffered drainage and foundation problems necessitating expensive remedial works. These additional costs can be avoided if sufficient geotechnical data are available at the planning stage to enable buildings to be located better.

TERRAIN AS A DEVELOPMENT CONSTRAINT

The terrain of the ACT is a primary development constraint. In general, only the land east of the Murrumbidgee River (800 km^2) is suitable for urban development. Most of the higher land to the west of the Murrumbidgee River (1550 km) has slopes which are too steep or rocky to be economically developed. Consequently future urban growth is likely to extend beyond the border of the Australian Capital Territory to the north and east.

GEOLOGICAL CONSTRAINTS TO DEVELOPMENT

Examples of geological constraints to development in the ACT include groundwater seepage problems associated with a high potentiometric surface; building foundations in structurally complex and differentially weathered rocks including cavernous limestone; limited areas suitable for sanitary landfill sites; and the distribution of construction materials that will necessitate longer hauls and consequently higher charges.

TABLE 3.

COST EFFECTIVENESS OF GEOTECHNICAL INVESTIGATIONS

Scale of investigation	Approximate investment ($A)	Approximate cost of investigation ($A)	Cost effectiveness
New town	1000-2000 million	100 000	Identifying major constraints permits a more efficient use of the funds available, by more efficient planning
Town centre	200-400 million	30 000	Identifying poor or difficult foundation conditions such as fault zones or cavernous limestone could save several millions of dollars by relocating buildings to better sites
Individual suburbs	30-50 million	10 000	Identifying a drainage problem or the areas of difficult excavation conditions can save up to $1 million, if the geotechnical data are made available to contractors and the construction industry develops confidence in geological advice
Individual large building	10-20 million	50 000	$0.5-1.0 million saved on remedial foundation works if alternative sites are available
Sewerage tunnel several kilometres	10 million	100 000	$1-2 million reduction in tender prices can be expected if the contractors have confidence in the geotechnical reports provided for tenderers

Groundwater seepage problems

Perched aquifers commonly occur in colluvium on hillslopes and in shallow pediplain basins, and give rise to groundwater seepages that affect residential development. More difficult problems are encountered where groundwater in the underlying fractured rock aquifer has a high potentiometric surface and discharges into the overlying materials (Fig. 4). The potentiometric surface at one location in South Canberra is consistently 3 m above ground level, and roads in this area require constant maintenance and frequent rebuilding. Where these conditions were not recognised in the older parts of Canberra the only effective remedial measure has been the regular pumping of groundwater from bores in the underlying fractured-rock aquifer (Hohnen, 1977) In the new town of Tuggeranong, hydrogeological investigations at the planning stage identified three major drainage problem areas totalling 15^2km . In one of these areas, Isabella Plains, the problem was solved by constructing deep drainage channels and dewatering the ground before the suburb could be developed. In the Lanyon area, a computer model has been developed for calculating optimum drain spacing from hydraulic and meteorological parameters, and is expected to provide less costly and more efficient drainage works for an affected area of 6 km^2.

A network of groundwater observation bores is maintained to provide information on, among other things, the effects of groundwater seepages on urban development.

Building foundations

The main problems in siting large buildings in Canberra are: the high potentiometric surface in places; the lenses of limestone,

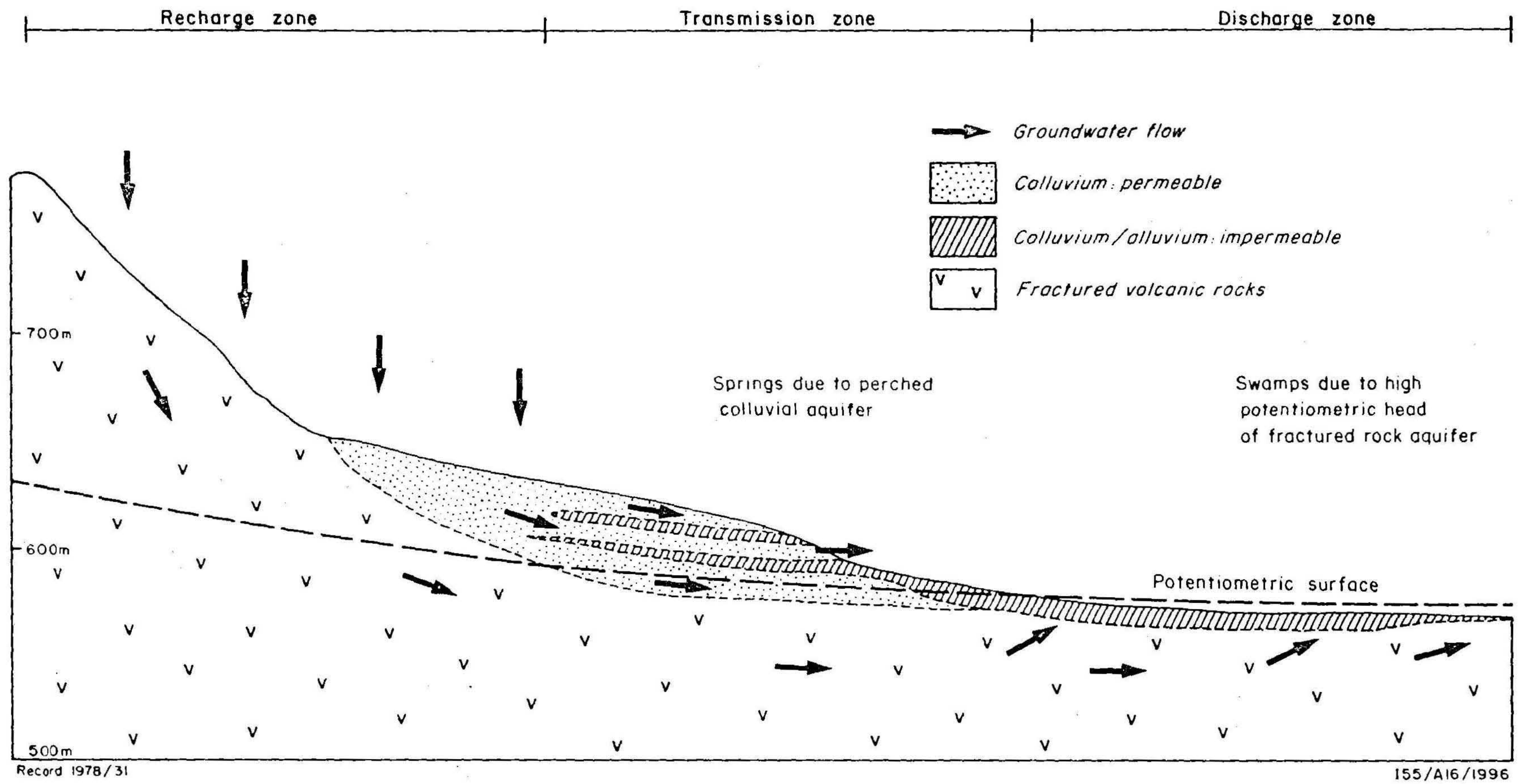

Fig. 4 Groundwater seepage problems affecting urban development

much of it cavernous; and deep, irregular weathering associated with many faulted and sheared zones. In all cases detailed foundation investigations are required for the foundation design of major buildings.

A recent investigation of a site for a major office building in Canberra City delineated a zone of highly to extremely weathered rock to a depth of 75 m associated with a 200 m wide fault zone (Fig. 5). Problems encountered in the design of the building were concerned with differential settlement of pad footings and the assessment of expenditure on pile and raft foundations. The building was resited outside the fault zone where more uniform foundation conditions prevail.

Expensive raft or piled foundations have bad to be constructed for large buildings on limestone where the problems encountered were not foreseen, or did not become evident until the construction stage.

Because of the complexity of the bedrock geology, geological investigations are now done of areas where large buildings are planned, before the final allocation of sites.

Water pollution and waste disposal

Canberra is situated in an inland hydrological system and extraordinary measures have been taken to safeguard water quality. The waters of the Murrumbidgee River downstream of the ACT are intensively used for domestic supply and irrigation. Consequently all sewerage is carried to treatment plants and only high-quality treated effluent is discharged back into the river. Mine workings at Captains Flat, on the Molonglo River 60 km upstream from Canberra, have been rehabilitated at considerable cost to stop zinc pollution of the river water that enters Lake Burley Griffin. The civil engineering works for the comprehensive sewerage system and pollution control projects have required considerable geological support.

Recently, pollution of groundwater by refined petroleum products has occurred in Canberra city (Fig. 5), and investigations are in progress to assess the extent of pollution and the remedial measures.

The disposal of solid waste is by sanitary landfill, and good landfill sites with respect to geological criteria for excavation conditions and pollution control are not common in this region (Wilson, 1975). The evaluation of the sites requires drilling and seismic traverses. The largest operating landfill site was developed intthe 1960s and monitoring has indicated a groundwater pollution plume extending for 400 m. Recently developed sites have been carefully designed for pollution control and

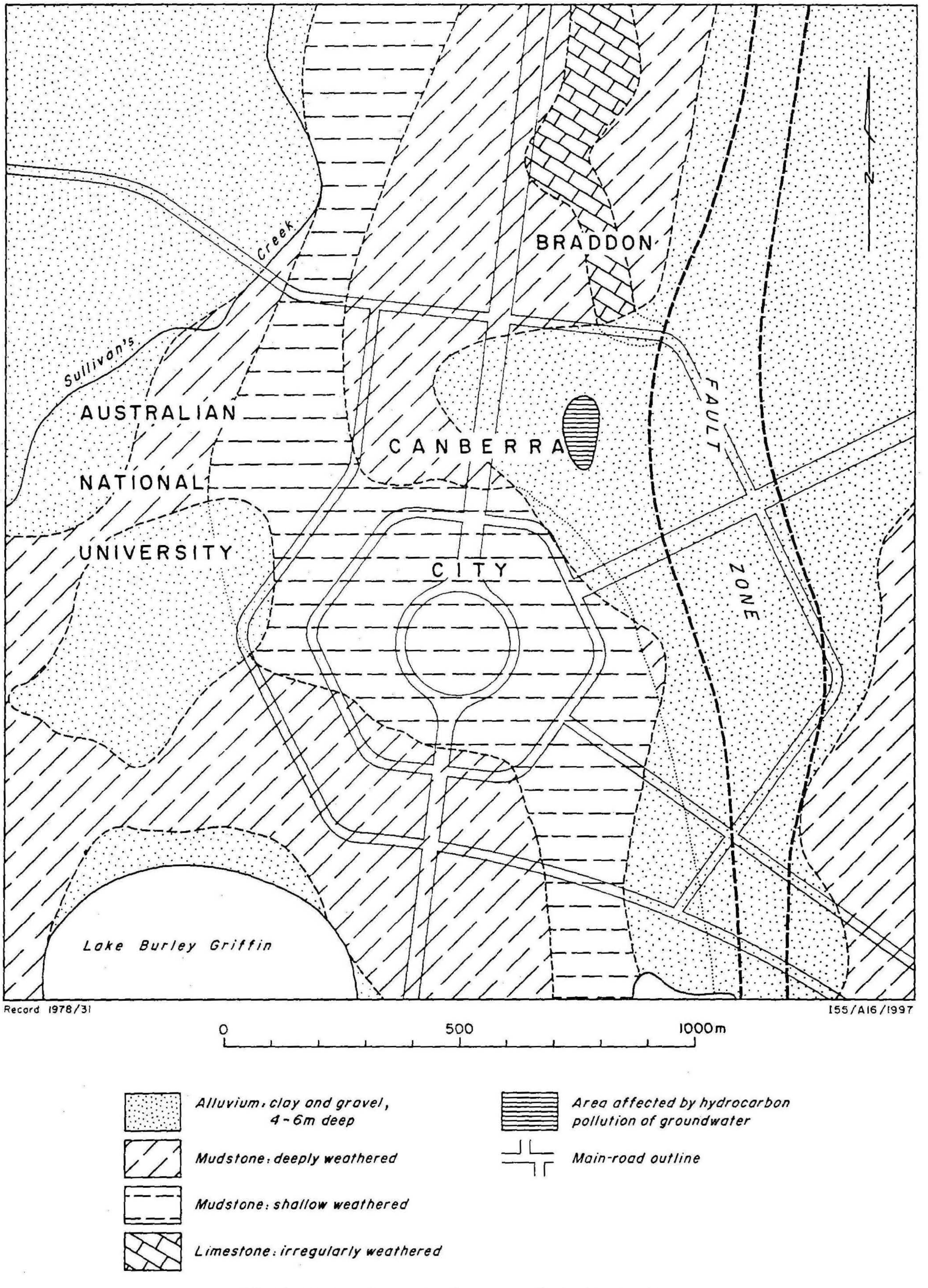

Fig. 5 Engineering geological map of Canberra City

completely filled sites are to be reclaimed for industrial use. The lack of compaction in the older landfill sites has restricted the planning options for redevelopment.

Construction materials

The geological evaluation is also concerned with the identification of materials suitable for construction purposes. Competition for land use commonly arises when valuable resources are located on land designated for purposes other than extractive industry. Materials discovered in the course of geological mapping are brick shale, which is common in Gungahlin, and alluvial and windblown sand deposits in Tuggeranong. Multiple land use planning should be practised so that mining of a material may be permitted provided that the land will be left suitable for other uses.

The quarrying of materials close to urban residential areas is considered undesirable, yet has to be balanced against the cost of long haulages from distant sources of materials. For instance, in Canberra there are valuable, undeveloped, alluvial sand deposits at the east end of Lake Burley Griffin; the alternative sources of sand range in distance to about 50 km from Canberra and exploiting them means an increased cost to the consumer and the deterioration of country roads because of the traffic of heavy trucks.

CONCLUSIONS

Properly conceived and applied geological studies have proved important to urban and regional planning in the ACT. More efficient planning and substantial cost benefits can be achieved by the early identification of geological constraints at the feasibility, design, and construction phases of urban development and of the associated major engineering projects.

ACKNOWLEDGEMENTS

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