DEPARTMENT OF MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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HYDROLOGICAL INVESTIGATIONS IN THE AUSTRALIAN CAPITAL TERRITORY, 1974

by

A.T. Laws

Senior Geologist, Bureau of Mineral Resources
Geology and Geophysics, Canberra A.C.T.

Paper presented at the Meeting on Water Management Research, Canberra, 14-16 May 1974, by permission of the Director, Bureau of Mineral Resources Geology and Geophysics, Canberra, A.C.T.

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CONTENTS

ABSTRACT

Current hydrogeological investigations being carried out by the Engineering Geology and Hydrology Subsection of the Bureau of Mineral Resources, are divided into three categories:

(1) The location of groundwater supplies for farms and small settlements;

(2) Studies of groundwater as it affects engineering structures or gives rise to drainage problems;

(3) Research into aspects of the occurrence of groundwater in crystalline rocks.

A brief description of groundwater occurrence in the ACT is given together with yields and specific capacities. Recharge conditions are described.

Five major investigations concerned with aspects of hydrology are currently in progress. These are:

(1) The ACT observation bore network.

(2) The effect of tunnelling on the groundwater regime, ACT.

(3) Drainage problems in urbanized and nonurbanized areas, ACT.

(4) Consolidation of saturated soils during drainage, ACT.

(5) Leakage from Lake Windemere, Jervis Bay, ACT.

All hydrological data collected during and before these investigations are to be collated to derive a hydrogeological map of the ACT.

INTRODUCTION

The purpose of this paper is to outline current investigations into various aspects of hydrology being carried out by personnel of the Engineering Geology and Hydrology Subsection of the Bureau of Mineral Resources (BMR), to delineate the proposed future program of investigations, and to show how those investigations are related to major engineering projects within the Australian Capital Territory and its environs.

Personnel of the Engineering Geology Subsection (here after referred to as the 'Section') have been studing groundwater within the ACT (including the Jervis Bay Territory) for many years; their studies can be categorized as follows (Burton, 1967):

1. The location of groundwater supplies for farms and small settlements in the ACT;
2. Studies of underground water as it affects engineering structures or gives rise to drainage problems;
3. Research into aspects of the occurrence of water in crystalline rock.

Discussion of the first category has been more than adequately covered in various publications (Burton, 1967; Burton & Wilson, 1959; Burton, 1969) and it is therefore intended to concentrate on the latter two categories in this paper.

GROUNDWATER IN THE ACT

Groundwater in the ACT occurs mainly in joints, fractures, and weathered zones of crystalline rocks; these include volcanics, porphyries, granite, some limestone, and metasediments such as slate and phyllite. A crystalline rock can be defined as one whose component grains havtq crystallized, recrystallized, or compacted to give a dense fabric possessing no significant intergranular porosity (Burton, 1967). Permeability therefore is secondary and confined to the aforementioned features.

Yields from bores in crystalline rocks are generally low and range from less than $0.5 m^3/h$ (100gph) to up to $9 m^3/h$ (1800gph). On rare occasions supplies of $18\text{-}40 m^3/h$ (4-9000gph) have been obtained. The specific capacities of bores range from 27×10^{-3} to 45×10^{-2} $m^3/h/m$ (2-50gph/foot) of drawdown in igneous rocks, from 27×10^{-3} to 27×10^{-2} $m^3/h/m$ (2-20gph/foot) of drawdown in interbedded siltstone and shale, and from 45×10^{-2} to 360×10^{-2} $m^3/h/m$ (50 to 400gph/foot) of drawdown in limestone (Burton, 1967).

Minor aquifers occur as perched lenses in slopewash or scree and in shallow pediplain basins such as Isabella Plains (Laws & Kellett, 1974) and it is invariably these aquifers that are responsible for the major drainage problems within the ACT.

Recharge of groundwater generally begins in autumn as the soil moisture deficiency, created in the summer by evapo-transpiration, is made up by April-May precipitation. Rainfall during the winter months and especially in early spring eventually makes good the deficiency. However, absence of precipitation in autumn and particularly in spring will result in the onset of a period of groundwater drought.

CURRENT INVESTIGATION PROGRAMS

Five major investigation programs are currently being undertaken by the Section. Two are essentially straight forward groundwater investigations, two more are concerned with the applicability of groundwater to major engineering and urban developments, and the fifth is an offshoot of one of the engineering oriented investigations.

A program that has been in operation now for some time is the ACT observation bore network, and it is on this program that a lot of profound work of the late G.M. Burton was based. It has been this network that has enabled many decisions and recommendations concerning groundwater to be made to various government instrumentalities and to private individuals.

In 1971 the study of the effect of tunnelling on the groundwater regime of parts of the ACT was begun. As the ACT develops it has become necessary to use tunnels for transport of sewerage to the various sewerage works within the ACT. The effect of groundwater both during and after tunnelling is of prime importance for the economic operation of tunnelling and waste treatment.

Drainage problems, mentioned earlier, occur in many places in the ACT, both in closely developed areas and in areas that are being developed. In previous years the section has been concerned with the former cases, but lately, with the greater awareness by the town planner of the value of expert geological information and opinion, greater emphasis has been on studies in areas yet to be developed.

As an offshoot of the last investigation the section has recently been looking at the problem of consolidation of the soils in these areas after they have been drained. The study has been concentrated around a particular problem area in Canberra's new satellite town of Tuggeranong, but it is expected that similar investigations will be required in the future in other areas of the ACT.

Finally, a small investigation is being carried out on the groundwater resources of the Jervis Bay area, with particular emphasis on the problem of leakage from Lake Windemere.

THE ACT OBSERVATION BORE NETWORK

The establishment of groundwater observation bores is an essential part of any hydrological study and a sizeable network of bores has been established over the last 15 years (Fig. 1).

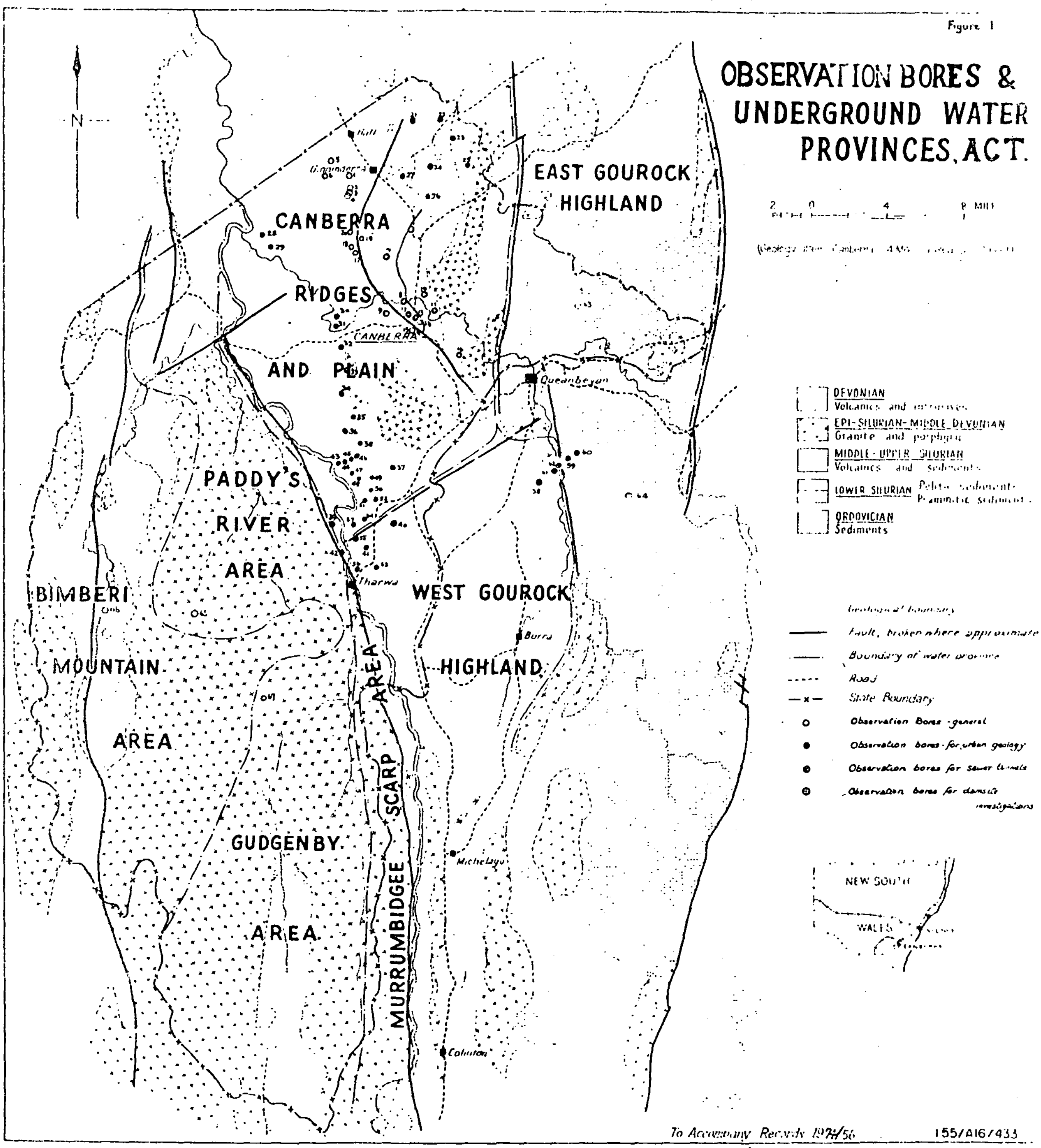
Generally the Section has used BMR drilling rigs whenever possible, but in recent years, with the increase in the development of urban geology, the Section, with the financial aid of other government authorities, has employed contractors to carry out the required drilling. The Section now has a total network of 67 bores that are regularly monitored, generally on a weekly basis (see Table 1).

The original purpose of the establishment of this network was to study fluctuations of the potentiometric surface from season to season. From its beginning in late 1958 the network has expanded to catchments of differing geological, climatological, and vegetation conditions. From providing information on just seasonal fluctuations the network enables the prediction of future fluctuations in particular areas and at particular sites; it provides considerable information in evaluating sites for bores and predicting their depths, and it helps considerably in assessing the safe yields of bores.

Lately observation bores have been established in representative basins to provide groundwater data input to the Representative Basin Model; on the shores of Lakes Burley Griffin and Ginninderra, and the proposed lake at Tuggeranong, to provide information on the effect of the filling of the lakes on the groundwater regime and the prediction and measurement of any leakage from the lakes; and in urban development areas to provide groundwater data prior to development so that the effect of urban development on groundwater can be evaluated.

The measurements of the water levels in the observation bores, together with data on rainfall, evaporation, air temperature, and barometric pressure, are recorded on punched cards. The section operates several computer programs that provide tabulated data and graphs. The hydrographs (Fig. 2) from the observation bores show

Figure 1



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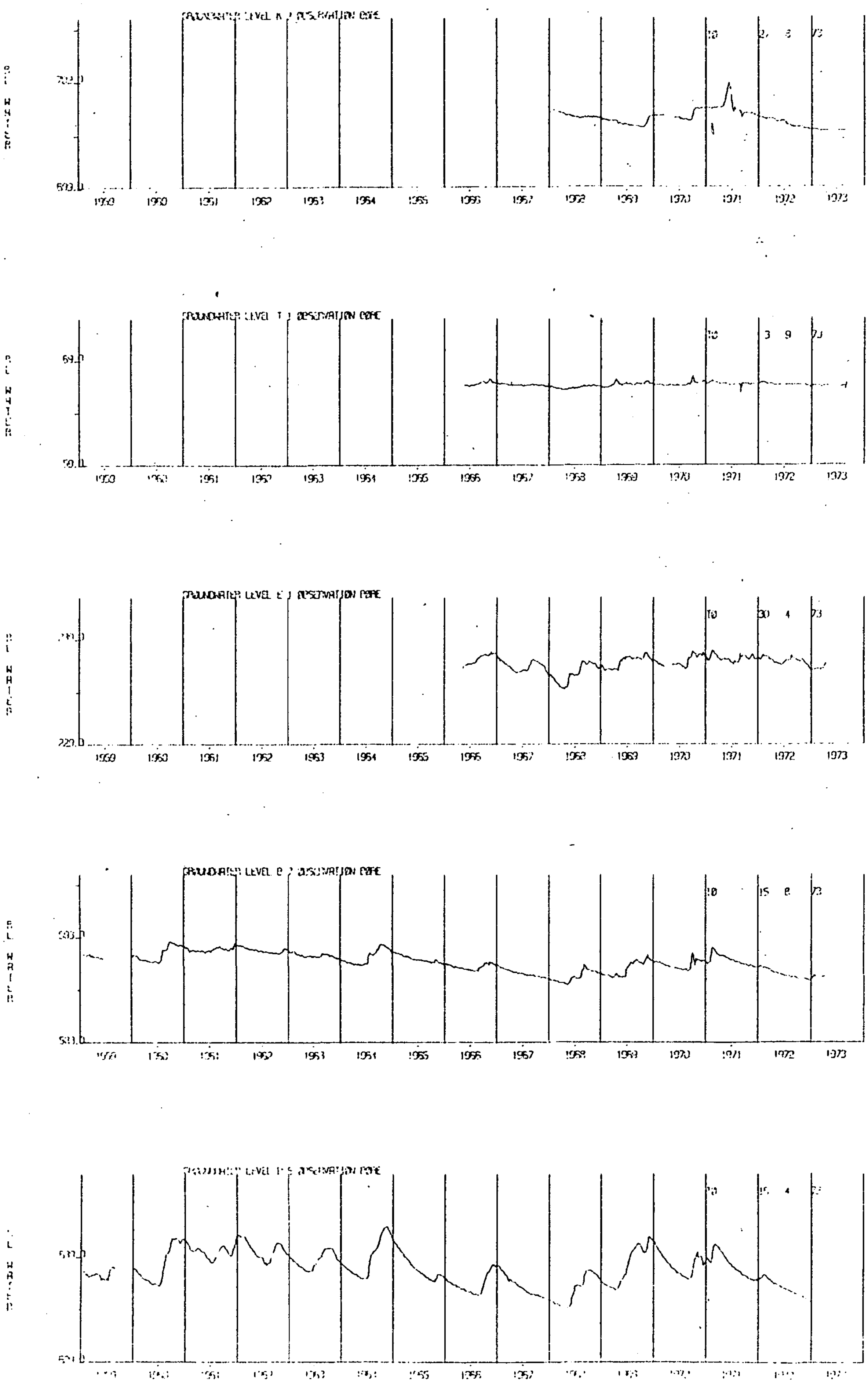
BORE HYDROGRAPHS

Figure 2



clearly the regularity of recharge during the cooler months. Contrasts can also be seen in bores in which the water table is at different levels. In bores where the water table is deep (such as B5, Fig. 2) the movements are obvious and considerable, but in bores where the water table is at shallow depths (such as B7, Fig. 2) the fluctuations due to evaporating water can be delineated and the affect of background 'noise' can be seen.

The Section has recently taken possession of an electric submersible pumping unit; once operable it is planned to make a series of pumping tests on most of the observation bores. From the program of pumping tests it is hoped that detailed conclusions will be drawn on the availability of groundwater in the ACT and that more data will be obtained to further the study of groundwater in crystalline rocks, with particular reference to permeabilities and specific capacities with respect to depth of fracturing.

EFFECT OF TUNNELLING ON THE GROUNDWATER REGIME

In the last four years two major sewerage tunnels have been designed and the construction of both commenced; these tunnels (Fig. 3) have been designed to cope with large quantities of sewerage from the satellite town of Tuggeranong and other areas.

During the course of the design/feasibility investigation, officers of the Section, as a part of the engineering geological study of the routes, paid particular attention to the groundwater hydrology of the area, for it was important that some indication be obtained of the quantities of groundwater that would be likely to flow into the tunnel during construction.

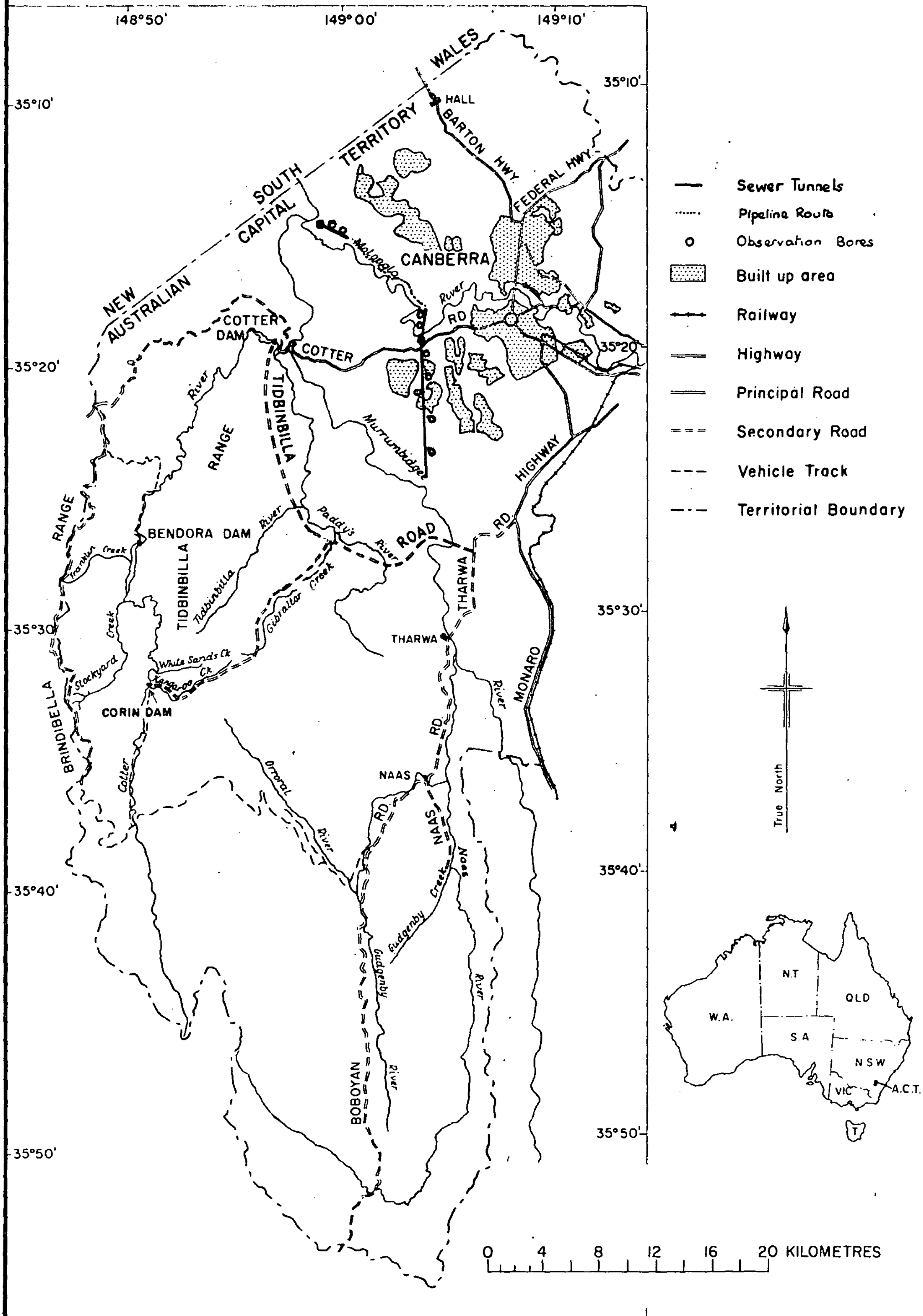
In the initial investigations (Purcell & Simpson, 1973; Purcell, 1974) diamond-drill holes were water-pressure tested and from these results, plus observations on bores in the ACT observation bore network, and with knowledge of rainfall and recharge conditions in the area, it was possible to estimate the total likely amount of groundwater that would flow into the tunnel.

Before tunnel construction started observation bores were drilled close to the tunnel lines (Fig. 3); these have been monitored regularly during the construction period and marked falls in water levels, that can only be attributable to the drainage of the sites by the tunnel, have been noted.

FIGURE 3

SEWER TUNNELS AND OBSERVATION BORES, ACT.

LOCALITY MAP



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Recent recalculations of total groundwater inflows based on measured flows and the monitored water levels have shown that the initial predictions were low by approximately 15 percent and that the new prediction is likely to be very accurate.

In the following months it is intended to continue the regular monitoring of the observation bores so that groundwater inflows can be checked. When the tunnel is constructed, and before it is lined, calculations will be made to ascertain the total effect of the open tunnel on the groundwater regime. During and after lining, monitoring will continue as groundwater levels rise, to check if they return to their pre tunnel condition. Monitoring will serve as an aid in the assessment of leakage of groundwater into the tunnels, for leakage of groundwater into the sewerage will result in increased costs for sewerage treatment.

DRAINAGE PROBLEMS IN URBANIZED AND NON-URBANIZED AREAS

Numerous minor drainage problems have been investigated over the years within the urbanized areas of Canberra. Detailed investigations have been carried out in areas around Red Hill (Noakes, 1958; Wilson, 1959; Wilson & Noakes, 1959, 1963), Ainslie (Wilson, 1959) and in the Woden Valley (Wilson, 1963). In these cases the Section was involved after urbanization and asked to produce remedial recommendations.

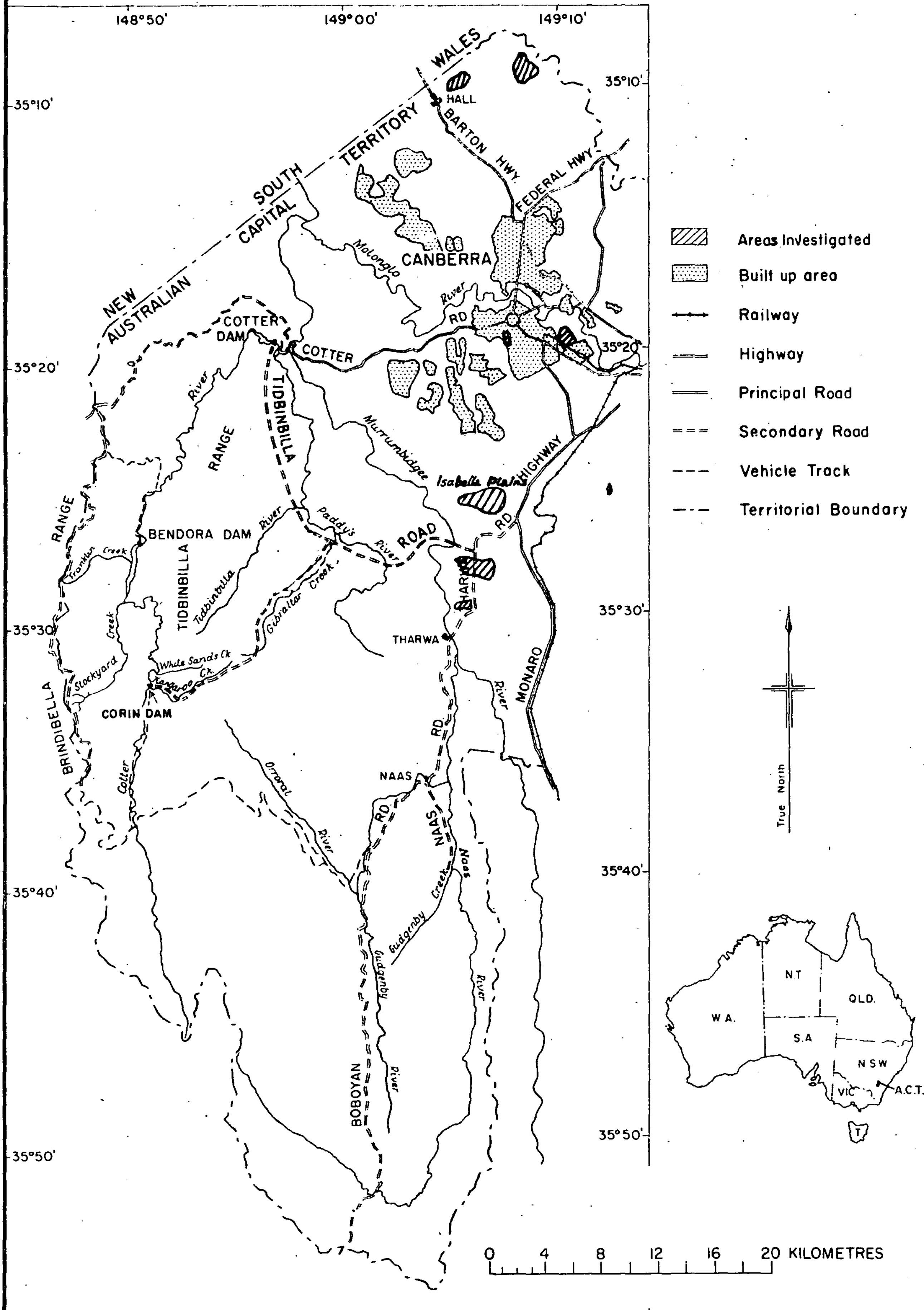
In recent years the town planners of Canberra have become more aware of the value of geological data and advice and the Section has become involved in the investigations of areas requiring drainage prior to any urban constructions of any kind. Such an area exists at Isabella Plains in the proposed town of Tuggeranong (Fig. 4) and the groundwater investigations have been followed up by drainage recommendations (Laws & Kellett, op. cit.). Isabella Plains is a pediplain basin, restricted at the outlet by a rock bar and a permeability barrier, in which interbedded layers of clay, silt, sand, and gravel in a saturated state constitute a complex drainage problem. Detailed investigations were carried out at the predevelopment stage, including detailed drilling of the area, insertion of up to 40 piezometers, and the carrying out of in situ permeability tests. Results of the investigation indicated zones of high horizontal permeabilities and two major drainage channels were located.

Preliminary drainage channels, along the routes recommended by the Section, have been constructed. During installation the Section lost several piezometers, but enough remained to evaluate the effectiveness of the drains. Monitoring of these levels is continuing and so far the channels are working efficiently. By the time development begins on the site the drainage problem will be under control.

FIGURE 4

DRAINAGE PROBLEM AREAS, CANBERRA, ACT

LOCALITY MAP



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This is the first major drainage investigation of this nature undertaken by the Section, but it is clear the Section will be involved in similar work in other areas in the future. The Section is constantly evaluating equipment for such work (drilling, pumping, and monitoring) and studying methods of in situ testing of permeabilities.

CONSOLIDATION OF SATURATED SOILS DURING DRAINAGE

The Section's involvement in soil consolidation has sprung directly from the Isabella Plains investigation. Because of the different rock types present and the thicknesses of aquifers to be dewatered it was obvious that these soils would consolidate and the Section was asked to review the consolidation estimates made by consulting engineers.

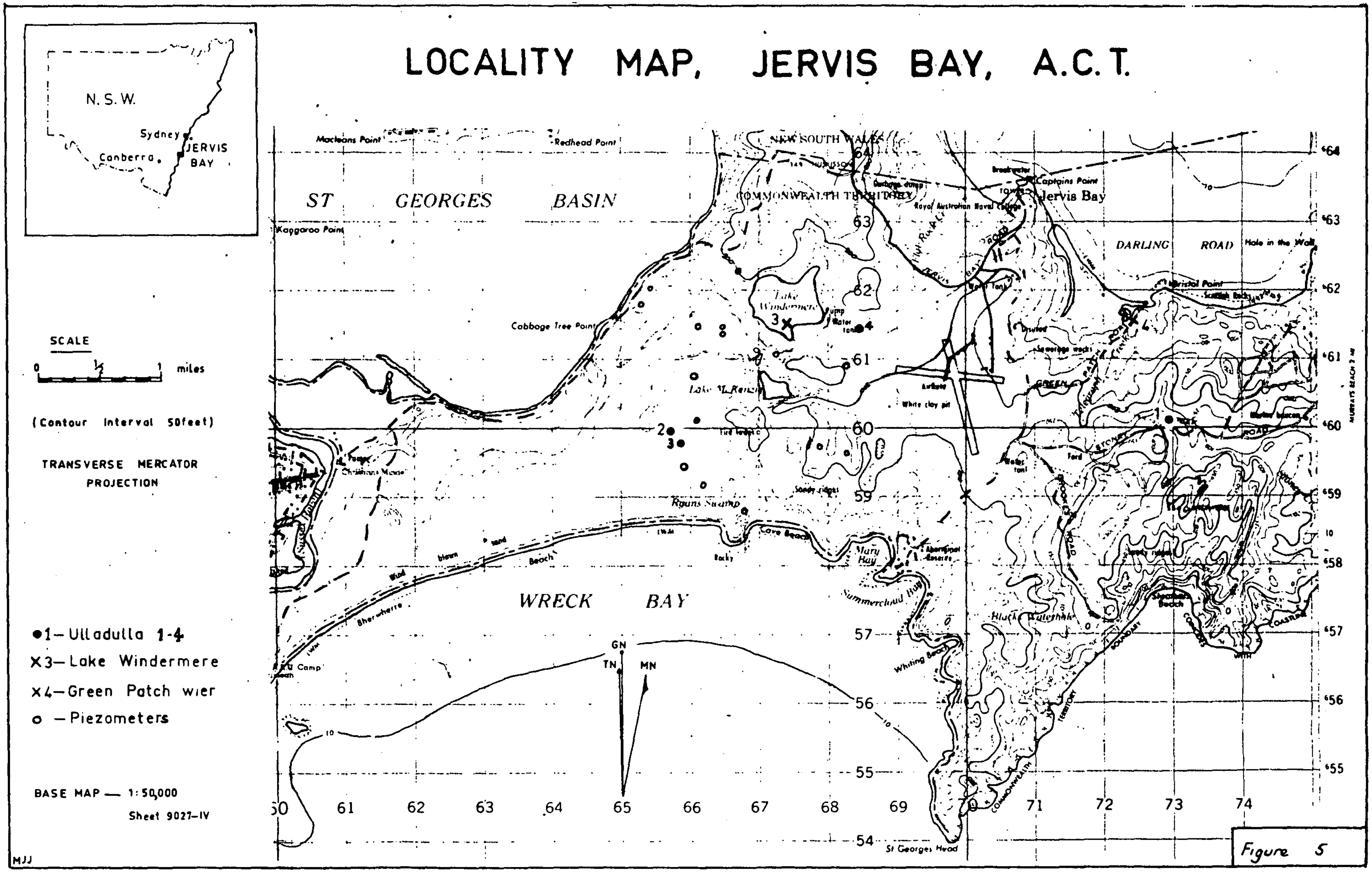
Absolute consolidation and time-ratios of consolidation were calculated according to the Terzaghi theory of one-dimensional primary consolidation i.e. considering vertical drainage only. Expected settlements due to the lowering of the water table during drainage are low because the soils of the plains are over-consolidated; settlements are expected to be a maximum of 15 mm due to dewatering 3 m of clay and a maximum of 50 mm when a 1 m loading of fill is added (Kellett, 1974).

The time for 80 percent of primary consolidation to occur due to dewatering has been calculated at 2 years (average) to 5 years (maximum), and for dewatering and loading at 2 years (assuming double drainage) and 5 years (assuming single drainage).

This has been the Section's first involvement in studies of consolidation, but other areas with similar problems are already under consideration.

LEAKAGE FROM LAKE WINDERMERE, JERVIS, BAY, ACT

Investigations have been carried out at Jervis Bay (Fig. 5) in recent years, into the determination of leakage paths and rates from Lake Windermere. Lake Windermere is an inland freshwater lake that is used for domestic water supply at the Jervis Bay Naval Station. 8 piezometers have been installed and 2 rotary holes drilled. Up to the end of 1973 a leakage path had not been accurately determined, but in April of 1974 additional piezometers were established. Pumping tests will be carried out on them and with the construction of a water table contour map and a flownet it is expected that the leakage path will be accurately determined.



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CONCLUSIONS

Hydrological investigations in the ACT are project-oriented; they are for the most part aimed at providing a hydrological data input into major engineering and urban development projects within the ACT. The effect of groundwater in such engineering projects as tunnels and dams, multi-storey buildings, and major excavations can be considerable and costly. The work carried out by the Engineering Geology and Hydrology Section of the BMR in the field of hydrology is aimed at reducing these effects and in turn reducing capital expenditure.

Research into the development of techniques for the analysis of groundwater problems is continuing. Better methods of determining groundwater inflows into tunnels, better methods of solving major drainage problems, and many other aspects are research projects that have evolved from the section's hydrogeological service to government organizations.

The data gathered over the past 16 years are to be collated later this year for the compilation of a hydrogeological map of the ACT, which will provide the basis for studies in hydrology for many years to come.

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TABLE 1. ACT OBSERVATION BORE DATA

REF. NO.	BORE NAME AND LOCATION	GROUNDWATER PROVINCE	ELEVATION M.A.S.L.	29/3/74 STANDING WATER LEVEL (m)	GAUGING COMMENCED	MAX VARIATION IN LEVELS (m)	APPROX YIELD m^3/h. (where tested)
1	Belconnen B5	Canberra Ridges and Plains	642	Destroyed	Dec 1958	7.5	1.0
2	" B6	" "	592	588.2	Dec 1958	3.5	3.7×10^{-2}
3	" B7	" "	593	589.5	" 1958	4.0	13.8×10^{-2}
4	" B8	" "	592	587.8	" 1958	3.1	1.14
5	" B15	" "	630	599	Jul 1971	7	0.1
6	" B16	" "	591	588	Jul 1971	2.5	2.0
7	Black Mountain B13	" "	615	588.2	Dec 1958	0.4	0.5
8	Hospital C9	" "	561	556.5	Aug 1963	0.25	N.T.
9	Yarralumla C7	" "	563	562.3	Aug 1963	0.6	4.5
10	Reid C4	" "	561	557.8	Aug 1963	0.9	0.3
11	BMR C12	" "	562	560.6	May 1966	0.7	1.6
12	Administration C5	" "	562	557.0	Aug 1963	0.5	0.3
13	Secretariat C6	" "	564	556.2	Aug 1963	4.5	2.1
14	Parliament House C8	" "	565	559.4	Aug 1963	1.9	0.3
15	Canberra Grammar C17	" "	589	596.5	May 1970	1.5	5
16	Fyshwick C13	" "	583	578.4	May 1966	0.7	16.4
17	Lake Ginninderra 4	" "	640	637.7	1973	1.88	0.5
18	" " 3	" "	633	627.3	1973	2.7	1.2
19	" " 2	" "	648	643.0	1.73	1.2	0.5
20	" " 1	" "	625	622.0	1973	1.2	2.2
21	Gungahlin 1	" "	593	590.8	Jul 1973	4.6	3.5
22	" 2	" "	631	Destroyed	" 1973	-	0.1
23	" 3	" "	628	617.2	" 1973	1.3	3.5
24	" 4	" "	645	639.0	" 1973	2.3	3.5
25	" 5	" "	654	629.3	" 1973	1.4	0.6

TABLE 1. (Continued)

REF. NO.	BORE NAME AND LOCATION	GROUNDWATER PROVINCE	ELEVATION M.A.S.L.	29/3/74 STANDING WATER LEVEL (m)	GAUGING COMMENCED	MAX VARIATION IN LEVELS (m)	APPROX YIELD m^3/h. (where tested)
26	Gungahlin 6	Canberra Ridges and Plains	652	644.6	Jul 1973	2.8	18.3
27	" 7	" "	602	597.7	" 1973	1.7	0.7
28	Pine Ridge 2	" "	585	577.9	Oct 1973	1.0	N.T.
29	" " 3	" "	600	583.6	" 1973	0.15	N.T.
30	Ryan Tunnel 2	" "	564	534.2	" 1973	1.9	N.T.
31	" " MV3	" "	581	568.9	" 1973	2.4	N.T.
32	Tuggeranong Tunnel 1	" "	562	Dry	Aug 1972	9.0	N.T.
33	" 2	" "	611	587.8	" 1972	13	N.T.
34	" 3	" "	652	596.7	" 1972	9.8	N.T.
35	" 4	" "	601	594.6	" 1972	4.5	N.T.
36							
37	Tuggeranong TU1	" "	593	Destroyed	Jul 1972	3.1	1.0
38	" TU2	" "	618	616	" 1972	1.1	5.4
39	" TU3	Murrumbidgee Scarp	637	629	" 1972	1.4	5.0
40	" TU4	West Gourock Highland	700	695	" 1972	0.4	2.0
41	" TU5	" "	658	655	" 1972	1.5	3.0
42	" TU6	Murrumbidgee Scarp	647	638	" 1972	2.1	2.0
43	Tuggeranong Town Centre 2	Canberra Ridges and Plains	570	554.2	Sep 1973	1.6	.5
44	" " 9	" "	580	566.7	" 1973	1.1	.7
45	" " 3	" "	572	564.3	" 1973	1.1	.5
46	" " 4	" "	567	561	" 1973	0.96	1.4

TABLE 1. (Continued)

REF. NO.	BORE NAME AND LOCATION	GROUNDWATER PROVINCE	ELEVATION M.A.S.L.	29/3/74 STANDING WATER LEVEL (m)	GAUGING COMMENCED	MAX VARIATION IN LEVELS (m)	APPROX YIELD m^3/h. (where tested)
47	Tuggeranong Town Centre 1	Canberra Ridges and Plains	570	565.8	Sep 1973	5.4	.5
48	" " 10	" "	572	566	" 1973	1.6	.7
49	" " 7	" "	575	573	" 1973	1.9	.5
50	" " 8	" "	580	568.9	" 1973	0.9	.5
51	" " 5	" "	585	583.2	" 1973	1.3	.7
52	" " 6	" "	602	592.3	" 1973	0.4	.2
53	Lanyon 1	West Gourock Highland	658	649	Jul 1973	0.5	1.1
54	" 2	Canberra Ridges and Plains	633	-	" 1973	0.2	4.5
55	" 3	West Gourock Highland	642	632.4	" 1973	0.2	8.1
56	" 4	" "	640	629.9	" 1973	0.6	36.4×10^{-2}
57	" 9	Canberra Ridges and Plains	647	632	" 1973	0.2	2.7
58	Googong 36	West Gourock Highland	666	640.3	Dec 1973	1.3	N.T.
59	" 37	East Gourock Highland	660	648.1	" 1973	8.0	N.T.
60	" 38	" "	701	687.6	" 1973	1.0	N.T.
61	" 39	" "	663	658.9	" 1973	1.4	N.T.
62	" 40	" "	709	679.5	" 1973	0.8	N.T.
63	Kowen 2	" "	711	693	Jan 1968	5.0	0.5
64	" 3	" "	725	714	Jul 1971	1.6	N.T.
65	Corin Dam El	Paddys River Area	1218	1216	Jun 1966	3.5	1.4
66	" " CO2	Bimberi Mountain Area	900	900	Jun 1966	0	N.T.
67	HoneySuckle Ck T1	Gudgenby Area	1056	1049	Jun 1966	1.5	0.5